Catchers of the Light

Short Edition

The Forgotten Lives of the Men and Women who First Photographed the Heavens

Their True Tales of Adventure, Adversity & Triumph

Stefan Hughes

Foreword

The magnificence of the *'Catchers of the Light'* has burst across my sensibilities and enthralled me. I don't know the background of how Stefan Hughes devoted what has obviously been many years of research and writing; I merely know that the book's website* is an astonishingly varied, interesting, and important resource, that provides fundamental information about an astonishingly wide range of individuals who are important not only to the history of astronomical photography, but also to astronomy in general. It is also fun to read through, whilst at the same time looking at the many pictures that are to be found there.

Although I have seen both the electronic '*flip book*' and pdf versions, I still think it was important that the book be published in print, and I am very glad to know that it has now appeared. I had previously chosen to review the e-book versions for the newsletter of the Historical Astronomy Division of the American Astronomical Society, which I chair; and I am pleased that Dr. Hughes has asked me to contribute the foreword to the printed edition of his book.

I have my own interests in astronomical photography and in some of the photographers or astronomers featured here, and I can vouch for the accuracy of those things about which I am knowledgeable--and so I extrapolate to vouch for the overall quality of the work.

So many of the people featured are familiar names to me, and it is a delight to be able to read about them and to see relevant photographs in Hughes's book. Everyone knows about Louis Daguerre (and I will be on the rue Daguerre near l'Observatoire de Paris soon as I write this, when I am awarded the Prix Jules Janssen of the Société Astronomique de France) but fewer know about his predecessor Nicéphore Niépce, who was equally important in the early evolution of photography.

These early pioneers immediately saw the importance of the '*newfangled*' Daguerreotype process to astronomy, in being able to provide a permanent view of the Moon. I've been privileged to visit the house in Hastings-on-Hudson, New York of the '*First Astrophotographer'* - John William Draper, and to see the stack of (still disorganized) photographs held there.

As for the Solar Physicist - Pierre Jules César Janssen, whose life story is beautifully presented in a new biography by Françoise Launay of l'Observatoire Paris (with an English translation by Storm Dunlop), quite aside from my new prize I've been reading about his role and that of his contemporaries - the well-known Sir Joseph Norman Lockyer and the more obscure Norman Pogson in the discovery of helium - made during the first application of the spectroscope to a solar eclipse back in 1868 (in India for Janssen and Pogson; and after the eclipse back in England by Lockyer). The new book - *'The Story of Helium and the Birth of Astrophysics'* by Biman B. Nath tells their dramatic stories and places them in the context of scientific and photographic advances.

I've been collaborating with the art-historian Roberta J. M. Olson since the run-up to Halley's Comet's 1985-6 apparition. In carrying out research for our book, with support from the Getty Research Fund, about comets in British Art, we discovered that the first comet photograph (that of Donat's Comet of 1858) was taken - not through the Harvard *'Great Refractor'* as previously thought by the Harvard College Observatory Astronomer, George Phillips Bond (its Director from 1859 to 1865) and the Boston Daguerreotypist, John Adams Whipple; but by an unknown English portrait artist, William Usherwood of Walton-on-the-Hill, Surrey. Usherwood used a portrait camera with a much lower f/number than the refractor's, so he was able to image the tail that Bond couldn't, but even more galling he also beat Bond by imaging the Comet the night before!

We couldn't find out much about him, and I even spent time in the Harvard archives looking at the bottom of folders to see if the copy plate that Usherwood sent Bond was there (no images survive, though descriptions do). Usherwood was so obscure that even his location had been ambiguous, with several English similar place names (Walton Heath, Walton Common, Walton-on-Thames, Walton-on-the-Hill etc.). I was reduced about twenty years ago to placing a query in a letter-to-the-editor in the magazine New Scientist. One of the several replies panned out, and my wife and I even paid what must have been the first-ever Usherwood pilgrimage. We found little of historic interest there, though. (Our findings appeared not only in our book *'Fire in the Sky:Comets and Meteors, the Decisive Centuries, in British Art and Science'*, but also in an article we did, together with the Harvard plate-librarian/astronomer Martha Hazen, in the Journal for the History of Astronomy).

Imagine my surprise, then, when I looked up Usherwood in Hughes's ebook and discovered a treasure-trove of interesting material. Somehow (and he did have the advantage of the internet) Hughes tracked down his listing in census reports, found records of his marriage (including his 60th wedding anniversary announcement), and even showed a picture of his grave. How did Hughes find time to do such wonderful research and to find such information and such photographs for not only Usherwood but also the many dozens of others who contributed to the development of astronomical photography? I am in awe!

I am so glad that Hughes's - *'Catchers of the Light'* now exists in printed form, and I hope it finds its way to all scientific libraries and those interested in photography. The volumes could even be bedside table reading--an episode at a time. It is a pleasure to see so many interesting figures in the history of astronomy and in the history of photography brought to a wide audience.

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* *www.catchersofthelight.com/shop*

Catchers of the Light

Volume 1 - Catching Space

Origins, Moon, Sun, Solar System & Deep Space

The Forgotten Lives of the Men and Women who First Photographed the Heavens

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Catchers of the Light

Every day our eyes catch the light of our memories – time spent with family, the journey to work, a special holiday, a beautiful sunset or a dark starlit night. Each image captured is a picture drawn in light – a photograph: only to be lost in our minds or forever forgotten. Nearly two hundred years ago a small group of amateur scientists achieved what had eluded mankind for centuries – the ability to capture a permanent record of an image seen by their own eyes – a moment in time frozen onto a surface. They had discovered Photography. They were the '*Catchers of the Light*'.

Stefan Hughes
Banana Grove Observatory
Paphos, Cyprus
July 2013

Sarah Williams (1837-1868) was an English poet born in Marylebone, London of a Welsh father, Robert Williams (c1807-1868) and an English mother, Louisa Ware (c1811-1886). During her short life she made a successful career as a poet, writer and journalist under her pen name of '*Sadie*'. She died of cancer on the 25th of April 1868 at her home at No. 95 Queen's Crescent, Kentish Town, London, following failed surgery. Later that year a volume of her poems entitled *'Twilight Hours: A Legacy of Verse'* was published by her friend Alexander Strahan. It was edited by her former teacher, Edward Hayes Plumptre (1821-1891), the Dean of Wells cathedral. However perhaps her finest poem was *'The Old Astronomer'*, which tells the story of a dying astronomer giving advice and solace to his sorrowful young pupil. In its verses are the famous words used by many an astronomer as their epitaph; and is also a fitting tribute to our 'Catchers':

"Though my soul may set in darkness, it will rise in perfect light; I have loved the stars too fondly to be fearful of the night."

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The Old Astronomer to His Pupil

Reach me down my Tycho Brahe, I would know him when we meet,
When I share my later science, sitting humbly at his feet;
He may know the law of all things, yet be ignorant of how
We are working to completion, working on from then to now.

Pray remember that I leave you all my theory complete,
Lacking only certain data for your adding, as is meet,
And remember men will scorn it, ‘tis original and true,
And the obloquy of newness may fall bitterly on you.

But, my pupil, as my pupil you have learned the worth of scorn,
You have laughed with me at pity, we have joyed to be forlorn,
What for us are all distractions of men’s fellowship and smiles;
What for us the Goddess Pleasure with her meretricious smiles.

You may tell that German College that their honour comes too late,
But they must not waste repentance on the grizzly savant’s fate.
Though my soul may set in darkness, it will rise in perfect light;
I have loved the stars too fondly to be fearful of the night.

What, my boy, you are not weeping? You should save your eyes for sight;
You will need them, mine observer, yet for many another night.
I leave none but you, my pupil, unto whom my plans are known.
You “have none but me,” you murmur, and I “leave you quite alone”?

Well then, kiss me, -- since my mother left her blessing on my brow,
There has been a something wanting in my nature until now;
I can dimly comprehend it, -- that I might have been more kind,
Might have cherished you more wisely, as the one I leave behind.

I “have never failed in kindness”? No, we lived too high for strife,
Calmest coldness was the error which has crept into our life;
But your spirit is untainted, I can dedicate you still
To the service of our science: you will further it? you will!

There are certain calculations I should like to make with you,
To be sure that your deductions will be logical and true;
And remember, “Patience, Patience,” is the watchword of a sage,
Not to-day nor yet to-morrow can complete a perfect age.

I have sown, like Tycho Brahe, that a greater man may reap;
But if none should do my reaping, ‘twill disturb me in my sleep
So be careful and be faithful, though, like me, you leave no name;
See, my boy, that nothing turn you to the mere pursuit of fame.

I must say Good-bye, my pupil, for I cannot longer speak;
Draw the curtain back for Venus, ere my vision grows too weak:
It is strange the pearly planet should look red as fiery Mars,
God will mercifully guide me on my way amongst the stars.

Sarah Williams (1837-1868), English Poet

Short Edition

Preface

I was twelve years old when I first looked up at the stars and wondered.

From atop the hill high above my house I used to look up night after night under dark skies and dreamed of all the wonderful photographs I had seen in my books - of other galaxies far beyond our own Milky Way, of glowing clouds of gas, clusters containing stars far too many to count, and the mystical dark clouds through which no stars could shine.

Images of the *'Great Andromeda Spiral'*, the '*Great Orion Nebula*' and the *'Great Hercules Cluster'* and the most iconic of them all – the '*Horsehead*' filled my soul as I lay beneath the stars all those years ago.

I used to think that the people who made all this possible were famous scientists – household names. They had to be - after all they had captured in these magnificent photographs the true nature of our universe. Yet the truth is so very different.

How many of you have heard of a clockmaker called William Cranch Bond; a doctor named Henry Draper; the brothers Paul and Prosper Henry; the priest Angelo Secchi; the '*wedding & baby*' photographer, William Usherwood; or the housemaid Williamina Fleming? These were the true pioneers of Astrophotography - whose names have long been forgotten and confined to the closed pages of history.

Although it is over forty years since I first stood upon that hill, it is only now that I am able to repay them for what they gave to me. I can think of no better way than to tell the story of their lives; not in the language of a scientist but in ordinary words; befitting these ordinary people who did such extraordinary things.

I stood upon that silent hill

And stared into the sky until

My eyes were blind with stars and still

I stared into the sky

The Song of Honour

Ralph Hodgson (1871-1962), English Poet

About the Book

This Book is a *'Family History'* of Astrophotography, and tells the story of the lives and achievements of the great pioneers of Astrophotography*.

It is not meant to be an academic treatise of their work; this is best left to papers written for eminent scientific journals and societies.

It is however about the events that shaped them and their immediate families; where they were born, who their parents were, where they went to school, who they married, the telescopes they owned, the astronomical photographs they took, their successes and failures; and the legacy they left to the modern world.

Each chapter of the Book is devoted to a particular Astrophotographer(s) and includes '*Snippet Panels*' and Notes, which contain background information on subjects and people relating to their life and the sources of information used in telling their story.

The Book has been further divided into nine self contained parts, each devoted to a particular aspect of the history of astrophotography and the pioneers who contributed to it. Each part ends with a '*Summary*' chapter which brings together the '*threads*' discussed in the chapters on the individual pioneers.

The parts cover every aspect of the subject from the early photographers; the first astronomical photographs of the Moon, Sun and Planets; Deep Space Astrophotography of stars, cluster, nebulae and galaxies; Astronomical Spectroscopy; Photographic Sky Surveys; the development of the Astrograph (Photographic Telescope); and ending with role of the amateur in Astrophotography and the coming of the modern digital age.

A number of Appendices are included which contain more detailed information on topics such as the chemistry of photographic processes, telescope optical systems, and the Charge Coupled Device (CCD). A timeline summarizing the historical development of Astrophotography is also to be found as an Appendix, as is an '*A List*' of 109 of the most important astronomical photographs, and a number of simple but useful formulas used in Astrophotography.

A Glossary of Terms used in the book is included in an Appendix. Finally, a '*Family Pedigree*' for each Astrophotographer is provided for those interested in conducting further research and as a reference aid when reading the chapters related to them.

The reader can choose which part to read either in sequence, in the order that takes their interest or any chapter of their choosing. They will lose nothing no matter how they read the book or in what order.

Furthermore the book can be used at a number of levels; either as a biography of the lives of the pioneers of astrophotography, a source of reference for a student or researcher; and finally as a technical compendium on the historical development of photographic equipment, processes, technologies and techniques, that are relevant to Astrophotography.

* The term Astrophotography was probably first used in 1858 by Thomas Sutton in his Dictionary of Photography, in which he wrote - *"Astro-Photography: A convenient name for the application of photography to the delineation of solar spots, the moon's disc, the planets and constellations."*

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Gratitude

During the course of the seven years it has taken me to research, write and publish the '*Catchers of the Light'*, I have been helped by many individuals and organizations. In the main this assistance has been confined to the provision of information, documents and photographs; and for this I am especially grateful. Acknowledgement of this valuable assistance has been included in the appropriate chapter(s) of the Book.

However in a number of cases this assistance has been of such importance and magnitude that without it, this Book would never have been started let alone finished; and to these individuals and organizations I extend my eternal gratitude and respect.

Firstly, I wish to mention the late Sir Patrick Moore, for without the inspiration I found in his many books and his famous long lived BBC TV programme - '*The Sky at Night*', I would never have aspired to become an Astronomer.

Next I should like to refer to the important role played by the staff and fellow students in the Department of Astronomy at the University of Leicester, during the eight happy years I spent successively as undergraduate, postgraduate and finally as a post doctoral research fellow. Here I found a warmth of friendship and companionship that has not been surpassed in all the years that have followed.

It is a great testament to Professor Jack Meadows and his staff at the time that many of the students they so ably taught are still to this day employed as professional Astronomers in Universities, Observatories and other Institutions across the Globe. It is to them that I owe all the astronomical knowledge and expertise required to write the '*Catchers*'.

Today there are many thousands of amateur Astrophotographers in almost every country of the world, who on a nightly basis take images of the heavens that would be the envy of our '*Catchers of the Light'*. Without their efforts and the invaluable advice and encouragement given to me by many of them, I could never have taken the astronomical images I did. Thanks also to those who supplied the equipment and software I used - the Adobe Corporation, the Celestron Corporation, Cyanogen (MAXIM DL), Losmandy, the Meade Corporation, OPTEC, Pier Tech, the Santa Barbara Imaging Group, Software Bisque (SkyX) and William Optics.

Without the Internet and Google, it would have been impossible for me to have conducted the vast amount of research needed to complete the monumental task I set myself. In the days before the world wide web, it would have required me to visit individuals, record repositories, libraries, observatories and other institutions in over fifty countries of the world. Special thanks goes in particular to the SAO/NASA Astrophysics Data System for providing me access to many of the astronomical articles used in this Book.

Finally I should like to express my immense thanks and the great debt I owe to my wife Patricia Flint Hughes, not only for her invaluable advice, her proof reading skills and considerable moral support, but also for the years of seeing me either glued to an iMac screen, or with my head in book, or my eyes gazing up at the heavens, without criticism or complaint, except when she felt it was time for me to rest and recuperate from the many thousands of hours of exertion, necessary to finish this magnum opus of Astronomy.

In memory of Professor Andre Deprit (1926-2006), who taught me the language of Mathematics

How to Become a Great Astrophotographer

"What makes a man great? A man may be great in his aims, or in his achievements, or in both, but I think that a man is truly great who makes the world his debtor... who does something for the world which the world needs and which nobody before him has done or known how to do."

Lt. Commander Rupert Thomas Gould RN, – *'John Harrison and his Timekeepers'*

A question that is often asked is - How do you become a '*Great Astrophotographer*'?

Before I answer, the question should be clarified. Does the phrase '*Great Astrophotographer'*, mean how do you take great images? Or does it really mean a Great Astrophotographer, i.e. someone who fits Rupert Gould's definition.

If it is the former, then the words: enthusiasm, dedication, perseverance, love of computers, patience, technical knowledge, practical ability, willingness to learn, choose the right equipment and so on, all come to mind.

However, if the questioner means the latter, then the answer becomes much more difficult to give.

So, here is the advice that I believe some of the great pioneers of Astrophotography would give on how to become a '*truly great*' Astrophotographer:

Be the First: John William Draper (1811-1882); he was to first person to successfully photograph an astronomical object, when he imaged the Moon in 1840 with a Daguerreotype Camera attached to a '*homemade*' telescope. Louis Daguerre had taken an earlier but unsuccessful blurred photograph of the Moon.

Don't Give up your Day Job: Edward Emerson Barnard (1857-1923); for over 17 years he worked as a photographer's Assistant in Nashville, Tennessee before becoming a staff astronomer at the Vanderbilt University Observatory. He was to later become one of the greatest observational astronomers of all time, as well as being famous for his magnificent wide field photographs of the Milky Way and the catalogue of Dark Nebulae which bears his name.

Give up your Day Job: Lewis Morris Rutherfurd (1816-1892); he started out life as a lawyer but decided to give up a career at the '*Bar*' to concentrate on science and in particular astronomy. He later became one of the pioneers of astronomical spectroscopy and took in 1865 photographs of the Moon which were the best of the day, and remained unsurpassed until the later work of Puiseux and Loewy.

Find a Good Wife (or Husband): William Huggins (1824-1910) the father of spectroscopy married Margaret Lindsay Murray in 1875, and for the next 35 years she became her husband's assistant, co-worker and inspiration. It was Huggins who carried out pioneering work in our understanding of the physical nature of nebulae, discovering that some were made up of gas whilst others were made up of stars.

Form a Society: James Edward Keeler (1857-1900) formed the Maybury Astronomical Society in his home town in Florida in 1875. In 1898 he was appointed Director of the Lick Observatory, where he began photographing Deep Space Objects with the 36-inch Crossley Reflector. Even today these photographs remain some of the finest images ever taken.

Change Your Career: George Willis Ritchey (1864-1945); in 1919 he was fired from Mount Wilson Observatory in a dispute with its then director George Ellery Hale over the usefulness of his telescope design (the Ritchey-Chretien optical system). For the next five years he eked out a living on his Orange Grove in Azusa, California. The Ritchey-Chretien design forms the basis of the optical system used in many of today's '*super*' telescopes including the Hubble Space Telescope.

Win an '*Oscar*': Henri Chretien (1879-1956); in 1954 he became the only astronomer ever to win a Hollywood Oscar for his invention of '*Cinemascope*', a type of projection system used in many a Blockbuster movie. He is famous today along with George Willis Ritchey, for the optical system which bears their name. Initially, it was difficult to test and expensive to make, but recently affordable RC systems have become available, giving ordinary amateurs the benefits of its wide flat field.

Learn from Others: Henry Draper (1837-1882); in 1857 he visited the estate of William Parsons, the 3rd Earl of Rosse, at Birr Castle, Ireland; where he saw the Earl's 'Leviathan' a - 72-inch speculum metal Reflecting Telescope. On his return to America, he began to construct mirrors using techniques learned from his visit. On the 30th September 1880, Henry Draper took the first ever photograph of a Deep Space Object when he imaged the Great Orion Nebula (M42).

Give it a Name: John Herschel (1792-1871); was the person who in 1839 coined the term Photography from the Latin, meaning literally *'writing with light'*. He was also instrumental in making advances in photographic processes, as well as completing the work began by his father William and his Aunt Caroline in cataloging DSOs in the southern hemisphere.

Inspire Others: William Parsons (1800-1867); almost single handed created the 72-inch Reflector known as the '*Leviathan of Parsonstown*', which was for nearly three quarters of a century the largest telescope in the world. He inspired others to do great things with his enthusiasm, hard work and ingenuity, including the likes of Henry Draper and Johann Louis Emil Dreyer, the compiler of the NGC/IC.

Invent Something Special: Pierre Jules César Janssen (1842-1907); in 1874 he constructed his *'revolver photographique*', a special camera which was capable of taking a sequence of photographs. In one hour it could take up to 100 photographs. He used this remarkable camera on a trip to Japan, to observe the transit of Venus which took place that year. This was the very first astronomical webcam!

Become Master of Your Trade: John Adams Whipple (1822-1891); was one of the earliest professional photographers, being the first to import the chemicals required for the Daguerreotype process, as well as a pioneer of night time photography. He became so much of an expert that William Cranch Bond recruited him as a technician to work with him at the Harvard College Observatory where he became an early pioneer of astrophotography.

Good Equipment is Not Essential, but it Helps; William Cranch Bond (1789-1859); when he was young, although he had no telescope he used to prepare himself for an observing session by climbing down a well in order to adapt his eyes to the dark. He later became the first Director of the Harvard College Observatory, and used a 2.75-inch Refractor (which was at that time the only telescope available to him) to observe in the October of 1846 the newly discovered planet Neptune.

Collaborate with Other: The Henry Brothers; Pierre Paul (1848-1905) and Mathieu Prosper (1849-1903) Henry were two brothers who worked together all their lives at the Paris Observatory. It was remarked at the time that they were inseparable, and that their work was a joint effort with no brother dominating the work of the other. They were responsible for taking the first successful photographs of the Planets when they imaged Jupiter and Saturn the years 1885-86; as well as the design and construction of some of the finest telescopes ever made, including the great 33-inch Refractor at Meudon, near Paris.

Never Let Adversity Stop You: George Phillips Bond (1825-1865); was responsible for taking the first ever photograph of a Double Star when he imaged Mizar and its companion Alcor in 1857. He also suggested in 1858 that photography could be used to measure stellar magnitudes, i.e. photometry. In an eleven month period ending on 29th January 1859, George Bond suffered the tragic deaths of his youngest daughter, his wife and his father.

A Physical Handicap is Not an Excuse: Bernhard Voldemar Schmidt (1879-1935); was probably the finest optician who ever lived. When he was 15 years old he had to have his right hand amputated when one of his experiments with Gunpowder went wrong. In 1930 he designed the first ever practical optical system which possessed a wide angle flat field. No telescope of this design, which became known as the Schmidt Camera was built in his lifetime. In the September of 1936 an 18-inch Schmidt Camera was completed at the Mount Palomar Observatory in California, less than a year after his death. The Schmidt design was later used in many amateur telescopes and in the Kepler Space Telescope, which in 2011 discovered two '*Earth*' like planets orbiting another star.

Education is Not Essential: Milton Lasell Humason (1891-1972); was responsible for carrying out much of the photographic and spectroscopic work from which Edwin Hubble derived the first distances of galaxies and which enabled him to formulate the famous law, which now bears his name. Humason was a man who had no PhD or education of any significance whatsoever, and who began working at Mount Wilson Observatory as a janitor.

‘The Purpose of History’

“History is the witness that testifies to the passing of time; it illuminates reality, vitalizes memory, provides guidance in daily life and brings us tidings of antiquity”

Marcus Tullius Cicero (106 BC – 43 BC) from his speech ‘*Pro Publio Sestio*’

'The Rules of History'

(As adopted in the writing the *'Catchers of the Light'*)

"It is the first and fundamental law of history that it should neither dare to say anything that is false, nor fear to say anything that is true, nor give any just suspicion either of favour or disaffection; that, in the relation of things, the Writer should observe the order of time, and add also the description of places; that in all great and memorable transactions he should first explain the counsels, then the acts, lastly the events; that in the counsels he should interpose his own judgment on the merit of them; in the acts he should relate not only what was done, but how it was done; in the events he should show what share chance, or rashness, or prudence had in them; that in regard to persons he should describe not only their particular actions, but the lives and characters of all those who bear an eminent part in the story."

***Marcus Tullius Cicero* (106 BC – 43 BC)**

From his speech 'Pro Publio Sestio'

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Acknowledgement for the help given by companies, individuals, institutions, libraries, observatories, organizations, record offices, web sites in the use of - text extracts from original sources, genealogical information, photographs, maps, drawings and illustrations is given in the appropriate chapter(s) of this Book.

Short Edition

Part I

Firstlight

The Origins of Astrophotography

Possibly the 'first' ever photograph attributed to Thomas Wedgwood, c1800

"In 1851 Scott Archer and Dr. Diamond introduced the collodion process in practical form, and this finally prepared the way for such a worker as Mr. De La Rue; for the introduction of the collodion process was an event in photography second only in importance to the discovery by Daguerre in 1839." **Lady Margaret Lindsay Murray Huggins (1848-1915).**

I. Origins of Astrophotography

The earliest origins of Astrophotography are intrinsically linked to the development of the photographic process as introduced by Louis Daguerre (1787-1851) in 1839; for it was with his Daguerreotype method that the first successful photographs of astronomical objects were obtained during the 1840s and early 1850s.

The other early photographic process, the Calotype of William Henry Fox Talbot (1800-1877) was little used in astronomical photography, partly because of the patent restrictions placed on its application, but mainly due to its lack of sensitivity when compared to its competitor the Daguerreotype.

However by the mid 1850's onwards both had been replaced by newer and more light sensitive chemically based photographic processes. In 1851 the sculptor and chemist, Frederick Scott Archer (1814-1857) published his '*wet collodion*' method; its introduction marked a major step forward in the development of photography. Not only was it more sensitive than processes of Daguerre and Fox Talbot, it also incorporated the advantages each had over the other.

Wet collodion photographs possessed the same fine detail as exhibited by the Daguerreotype; and like the Calotype multiple positive copies could be obtained from a negative image. The method was not perfect and required a certain amount of chemical aptitude in the use of several potentially dangerous substances including Potassium Cyanide and Bichloride of Mercury. In addition wet collodion plates had to be developed within 15 minutes or so after exposure before the collodion solution dried and therefore required the use of a portable darkroom when taking images '*in the field*'.

The *'wet collodion'* process became widely used in astronomical photography from 1851 onwards, a number of pioneers used it to take images of the sun, moon, planets and stars. George Phillips Bond, John Adams Whipple and James Wallace Black used it to in 1857, obtain images of stars as faint as the sixth magnitude. The following year, in 1858, William Usherwood, a miniature artist from Walton-on-the-Hill. Surrey, England, used the wet collodion method to take the first successful image of a Comet.

In 1864 the Collodio-Bromide process was published by William Blanchard Bolton (1848-1899) and Benjamin Jones Sayce (1837-1895). In their '*dry collodion*' process a ready-made emulsion of Collodion and Silver Bromide was poured directly onto the glass plate The prepared plates can be kept for some time before deterioration sets. It was unfortunately less light sensitive than the wet collodion process and was never used in astronomical photography.

In 1871 by Richard Leach Maddox's (1816-1902) proposed the use of the Gelatino-Bromide '*dry*' photographic plate. It was this process which marked the greatest advance in the development of astronomical photography, even more so than the introduction of Archer's wet collodion method. The increased sensitivity of the '*dry*' plate over Archer's 'wet' process enabled the first images of Deep Space Objects (DSOs), so called because they are only found in the deep recesses of the universe, far beyond the confines of our own insignificant Solar System.

The '*dry*' plate technology was only slowly accepted by both astronomers and photographers in general. It was not until the introduction of '*mass produced*' dry plates from 1877 onwards that the gelatino-bromide method began to replace the collodion processes.

Only in 1880 did the New York Doctor, Henry Draper with the aid of a '*dry*' photographic plate obtain the first image of a DSO - when he imaged the '*Great Orion*' nebula (M42) on the 30th of September that year.

The coming decades saw the development of photographic emulsions sensitive to all parts of the visible and beyond; for both glass plates and the celluloid film (following its introduction in 1889).

In 1906 Charles Edward Kenneth Mees, when working for Wratten & Wainwright, produced the very first true panchromatic photographic plate, i.e. sensitive to all colours including '*deep red*'.

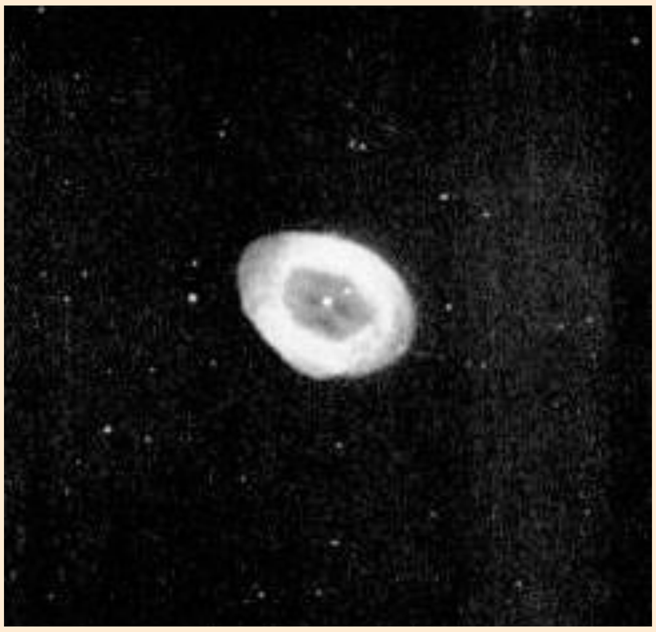
Following Mees' move to KODAK in 1907 to head their research laboratory at Rochester, New York, the company introduced a range of photographic emulsions particularly suited for astronomical use, most notably the KODAK 103a series and latterly the black and white Tech Pan and the colour Ektachrome films.

In 1969 came the greatest technological leap (so far) in astronomical photography with the invention of the Charge Coupled Device or CCD, by Willard Sterling Boyle and George Elwood Smith. Although originally designed for use as a form of solid state memory device, its application as an imaging device was developed by others and in particular Michael Francis Tompsett, who filed the first CCD imaging patent in 1971.

The digital imaging cameras developed in the 1970s and 1980s by the likes of Fairchild Imaging and KODAK were introduced into astronomy in 1979 at the Kitt Peak Observatory in Arizona. The first usable and affordable CCD cameras for the amateur astronomer were introduced in the 1990s by firms such as Celestron and the Santa Barbara Imaging Group.

The modern CCD camera and the introduction of fast Personal Computers, when coupled with the availability of high quality optical telescopes has revolutionized amateur Astrophotography during the last decade or so.

"It is somewhat difficult to lay down any precise instructions for the successful development of astronomical photographs. Much might be written, and pages of various formula; given; but after all, experience, and extreme, almost antiseptic, cleanliness are the chief aids to success; and those readers who have successfully followed the methods of ordinary photography are not likely to make many mistakes. It must be borne in mind that our object in astrophotography is to produce negatives of extreme sharpness and accuracy of detail, and any method which would tend to produce the slightest effect which has no objective existence must be carefully avoided."



M57 'Ring' Nebula, John Charles Duncan, 1935, 100-inch Reflector

I.1

‘The Showman and the Inventor’

Louis Jacques Mandé Daguerre

Born: 18th November 1787, Cormeilles en Parisis, Val d’Oise, France

Died: 10th July 1851, Bry-sur-Marne, near Paris, France

Joseph Nicéphore Niépce

Born: 7th March 1765, Chalon sur Saône, Saone-et-Loire, Bourgogne France

Died: 5th July 1833, Saint-Loup-de-Varennes, Saône-et-Loire, France

On the 7th of January 1839, members of the French *Académie des Sciences* were shown images that would provide Astronomy with the means to unlock the very secrets of creation. What they saw was the work of a Parisian showman, named Louis Jacques Mandé Daguerre, who had relied heavily on the earlier efforts of his now dead partner, the inventor, Joseph Nicéphore Niépce. In 1839 Daguerre attempted to photograph the Moon and failed. Astrophotography was about to be born.

I.1.1 Failure

On the 7th of January 1839, members of the French Académie des Sciences were shown examples of Photography, an invention that would forever change the study of astronomy [1]. The astonishingly precise pictures they saw were the work of Louis Jacques Mandé Daguerre - a Romantic painter and printmaker; most famous until then as the proprietor of the Diorama, a popular Parisian spectacle featuring theatrical painting and lighting effects. Each Daguerreotype (as Daguerre dubbed his invention) was a one of a kind image on a highly polished, silver-plated sheet of copper. It was the Polaroid of the day.

Louis Jacques Mandé Daguerre (1787-1851) made no significant contributions to Astrophotography with the exception of his failed attempt to produce the first photograph of the Moon; which unfortunately has not survived [2].

“La préparation sur laquelle M. Daguerre opère, est un réactif beaucoup plus sensible à l’action de la lumière que tous ceux dont on s’était servi jusqu’ici. Jamais les rayons de la lune, nous ne disons pas à l’état naturel, mais condensés au foyer de la plus grande lentille, au foyer du plus large miroir réfléchissant, n’avaient produit d’effet physique perceptible. Les lames de plaqué préparés par M. Daguerre, blanchissent au contraire tel point sous l’action de ces mêmes rayons et des opérations qui lui succèdent, qu’il est permis d’espérer qu’on pourra faire des cartes photographiques de notre satellite.”

“The process of M. Daguerre is much more sensitive to the action of light than those which had been used so far. Never before has natural moonlight produced any perceptible physical effect, even when magnified with the largest lens, or focused by the biggest reflective mirror. The plates prepared by Mr. Daguerre, bleach on the contrary the surface under the action of these same rays and it is hoped when he is successful with his experiments, one will be able to make photographic charts of our satellite.”

François Arago 1839, Perpetual Secretary, French Académie des Sciences.

However, as one of the great pioneers of early Photography, and without doubt its finest publicist, it was felt only right that the first chapter of this book should be devoted to him. A more important reason for his inclusion is that the very first astronomical photographs taken during the 1840s were Daguerreotypes and not the Calotypes of his arch Nemesis – William Henry Fox Talbot [3].

The name Joseph Nicéphore Niépce is unknown today by all, with the exception of a few photographic aficionados. Yet it was Nicéphore Niépce who took the first true Photograph some thirteen years before Arago made his historic announcement to the world, extolling the images of Louis Daguerre. However in recent years there have been efforts by Photographic Historians to redress the balance in Niépce’s favour.

How did it come about that the name of Daguerre is engraved so deeply in the pages of history, and that of Niépce has been so effectively erased from it? We will now tell the story of how this distortion of history came about: and it is only right that it should be done:

“ It is the first and fundamental law of history that it should neither dare to say anything that is false, nor fear to say anything that is true, nor give any just suspicion either of favour or disaffection; that, in the relation of things, the Writer should observe the order of time, and add also the description of places; that in all great and memorable transactions he should first explain the counsels, then the acts, lastly the events; that in the counsels he should interpose his own judgment on the merit of them; in the acts he should relate not only what was done, but how it was done; in the events he should show what sheer chance, or rashness, or prudence had in them; that in regard to persons he should describe not only their particular actions, but the lives and characters of all those who bear an eminent part in the story.”

Marcus Tullius Cicero (106 BC – 43 BC), Roman Philosopher, Orator and Statesman.

I.1.2 Cormeilles-en-Parisis

Louis Jacques Mandé Daguerre was born on the 18th November 1787 in the French Commune of Cormeilles-en-Parisis, Val d’Oise, some ten miles to the North West of Paris [4]. He was the eldest of the two children born to Louis Jacques Daguerre (c1761-), a clerk in the Finance Ministry and his wife Anne Antoinette Hauterre (1767-). His younger sister, Marie Antoinette Eulalie was born some four years later on the 11th of September 1791.

From a very early age Louis Daguerre wanted to be a painter and nothing else. His father like parents of every generation wanted what they thought was best for their children, and decided that his son should take up an honorable profession. So when he was very young his parents apprenticed him to an architect. As is often the case with children, Daguerre's parents made the mistake of not realizing that their son was an individual not to be moulded into what they wanted, but who would become what he wanted to be.

After much opposition his father reluctantly gave in to Louis Daguerre's ambition to be a painter, and apprenticed him at the age of sixteen to a new master, Monsieur Degotis, the principal set designer of the Paris Opera. This was a perfect compromise to the two apparently immovable and dichotomous opinions of father and son. The father was happy that there was a certain Architectural element to the work, whilst the son felt he could still achieve his ambition to be a Painter, and after a suitable interval perhaps drop the Architecture completely!

For the next fifteen years Louis Daguerre worked as a set designer at the Paris Opera, nine of which was spent as assistant to the Opera's scenic painter, Pierre Prevost (1764-1823), helping him with his famous panoramic paintings of the cities of Rome, Naples and London[5]. During which time he acquired a reputation as a talented artist. In 1814 he exhibited his work at the Paris Salon and later worked as an independent stage designer, away from the rigorous confines of the Opera. However, for Daguerre this kind of work was not enough.

As an artist he was always very interested in reflection and the effects of light on objects, and was therefore keen to incorporate them into his theatrical work, as an integral part of a much greater spectacle. His ambition was realized when he formed a partnership on the 25th of April 1821 with one Charles Marie Bouton (1781-1853) [6].

Louis Jacques Mandé Daguerre (1787-1851) was born the only son of Louis Jacques Daguerre (1761-), a local finance official and his wife Ann Antoinette Hauterre (1766-) on the 18th of November 1787 in the town of Cormeilles-en-Parisis. As a young boy he wished to become an artist much against the wishes of his parents who wanted for him a safe career in a respectable profession like his father. As a compromise he was apprenticed to the principal set designer of the Paris Opera.

It was in this way that Louis Daguerre became involved with the art of the Panorama and Diorama, both popular forms of entertainment in early 19th century Paris. Not satisfied with the fleeting nature of these art media, he wished to create a more permanent way of representing the effect of light on architecture, nature and life. The efforts of the inventor, Joseph Nicéphore Niépce to create a permanent image of an object on metal, seemed the answer to his needs. A collaboration between the showman and the inventor began, which ultimately led to Photography.

Rear of the House in Cormeilles en Parisis where L. J. M. Daguerre was born

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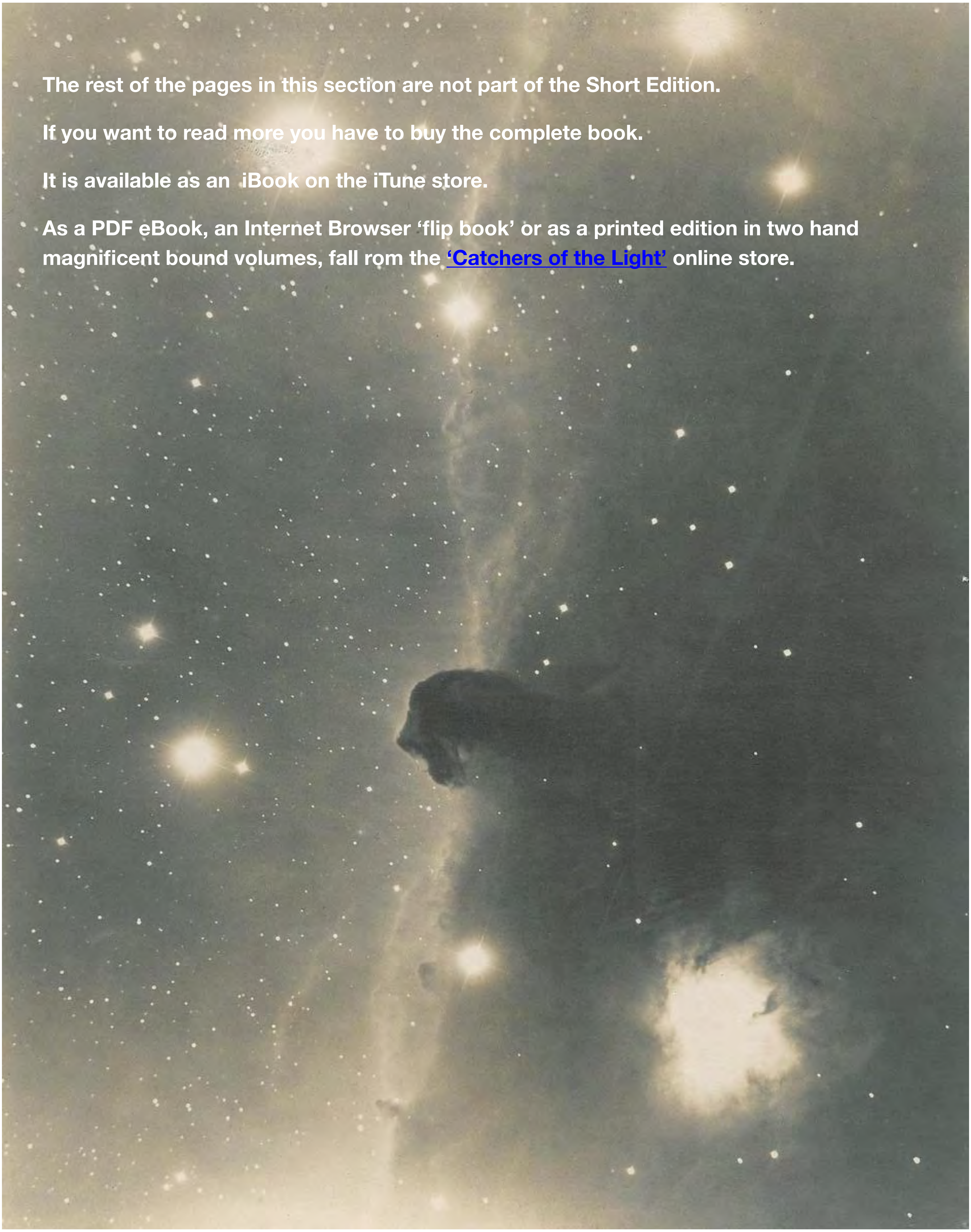


Short Edition

I.2

'The Chemist'

Frederick Scott Archer

Born: 30th August 1814; Hertford, Hertfordshire, England

Died: 1st May 1857; Bloomsbury, London, England

Frederick Scott Archer was a great pioneer whose invention of the wet collodion process, published in 1851 revolutionized the Science of Photography; but who nevertheless died largely unrecognized and in virtual poverty. It was his process which brought photography within the reach of the ordinary man, and also enabled astronomers to capture images of the heavens only hinted at by the earlier Daguerreotypes.

I.2.1 Unrecognized

Frederick Scott Archer (FSA) was without doubt one of the great pioneers of early photography, whose name should without doubt stand near to, if not alongside the likes of Joseph Nicéphore, Niépce, Louis Daguerre and William Henry Fox Talbot.

The publication of his discovery in 1851 of the so called wet collodion process revolutionized photography, making it easier to obtain images with exposures of a few seconds only, and which also enabled multiple positive copies to be quickly made from the same glass negative plate; unlike the Daguerreotype process which produced a one off positive image on a silvered copper plate which could not be readily replicated. The Wet Collodion Plate was the preferred photographic process from its introduction in the early 1850s until the advent of the mass produced Dry Gelatin Plate in the late 1870s and early 1880s.

The importance of Archer's work to Photography was recognized by Lady Margaret Huggins, when in her 1889 obituary of the great pioneering Astrophotographer Warren De La Rue she wrote of the Collodion Process [1]:

"In 1851 Scott Archer and Dr. Diamond introduced the collodion process in practical form, and this finally prepared the way for such a worker as Mr. De La Rue; for the introduction of the collodion process was an event in photography second only in importance to the discovery by Daguerre in 1839."

Yet at the time of his death in 1857, although well respected by his photographic colleagues, he was largely unrecognized by the rest of the public at large; certainly unrewarded and definitely in impoverished circumstances. Even today he is not as well known as the other early photographic pioneers. The 150th Anniversary of his death in 2007 came and went largely unnoticed by the world, despite ample opportunity in the years since his death for historians to reassess his contribution to the development of photography.

I.2.2 Frederick Scott Archer of Hertford

It is generally believed that Frederick Scott Archer was born in Bishops Stortford, Hertfordshire around 1813; the son of a Butcher [2].

However there is no extant or primary documentary or indeed any other reliable evidence to support this view. It has just been '*passed off*' as being the '*truth*'.

The 1841 Census record relating to Frederick Scott Archer states somewhat confusingly that he was born in Scotland [3]; whilst the 1851 Census states that he was born in Hertford, Hertfordshire around 1814 [4]. The family headstone in Kensal Green Cemetery adds weight to the theory that he actually came from Hertford, stating that his father was [5]:

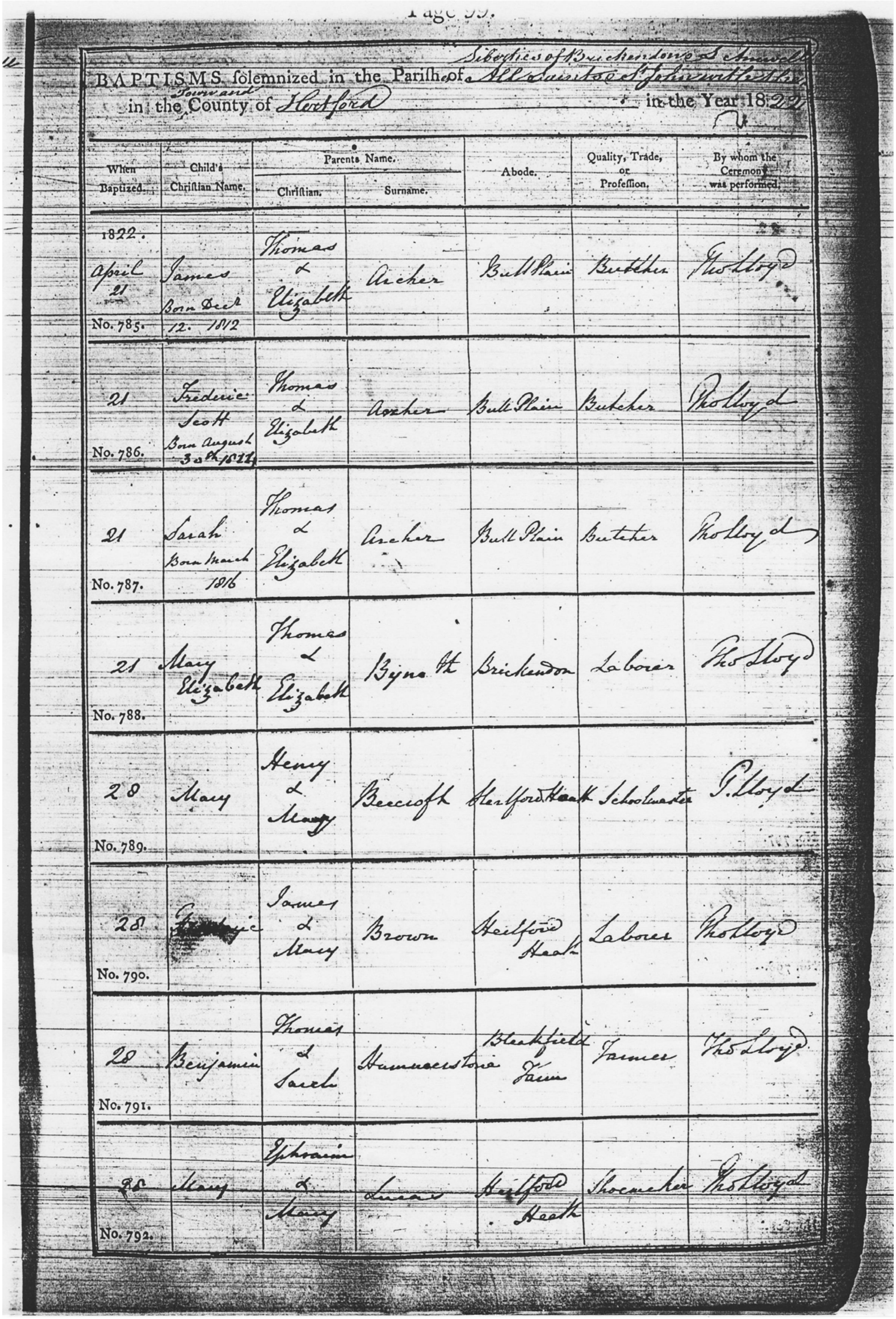
'THOs ARCHER FORMERLY of HERTFORD ...'.

No record of a Thomas Archer butcher of Bishops Stortford can be found in the surviving documents of the Hertfordshire Archive and Local Studies Office (HALSO), at Hertford. However records relating to Thomas Archer, Butcher of Hertford and his ancestors are to be found in abundance at the HALSO.

Furthermore, Frederick Scott Archer, his brother James and his sister Sarah were all baptized in All Saints Church, Hertford on the same day – 21st April 1822 [6]. In his monumental work on British Sculptors, Rupert Gunnis gives the true year of Archer's Birth as 1814 [24].

The only certain connection of Frederick Scott Archer to Bishops Stortford is that his wife Frances Garrett Machin was born there, the daughter of Nathaniel Smith Machin, an auctioneer of Bishops Stortford and No. 26 King Street, Covent Garden, London [7].

Even the date of his death is often given incorrectly as 2nd May 1857; his death certificate clearly shows he died a day earlier on the 1st May 1857 [8].



Page 99.

BAPTISMS solemnized in the Parish of All Saints & St John with the Liberties of Brickendon & St Andrew in the Town and County of Hertford in the Year 1822

When Baptized.	Child's Christian Name.	Parents Name. Christian.	Parents Name. Surname.	Abode.	Quality, Trade, or Profession.	By whom the Ceremony was performed.
1822. April 21 No. 785.	James Born Decr 12. 1812	Thomas & Elizabeth	Archer	Bull Plain	Butcher	Tho Lloyd
21 No. 786.	Frederic Scott Born August 30th 1813	Thomas & Elizabeth	Archer	Bull Plain	Butcher	Tho Lloyd
21 No. 787.	Sarah Born March 1816	Thomas & Elizabeth	Archer	Bull Plain	Butcher	Tho Lloyd
21 No. 788.	Mary Elizabeth	Thomas & Elizabeth	Bynoth	Brickendon	Laborer	Tho Lloyd
28 No. 789.	Mary	Henry & Mary	Beecroft	Hertford Heath	Schoolmaster	T. Lloyd
28 No. 790.	Frederic	James & Mary	Brown	Hertford Heath	Laborer	Tho Lloyd
28 No. 791.	Benjamin	Thomas & Sarah	Hammerstone	Bleakfield Farm	Farmer	Tho Lloyd
28 No. 792.	Mary	Ephraim & Mary	Lucas	Hertford Heath	Shoemaker	Tho Lloyd

Frederick Scott Archer's Baptism Entry at All Saints Church, Hertford, 21st April 1822

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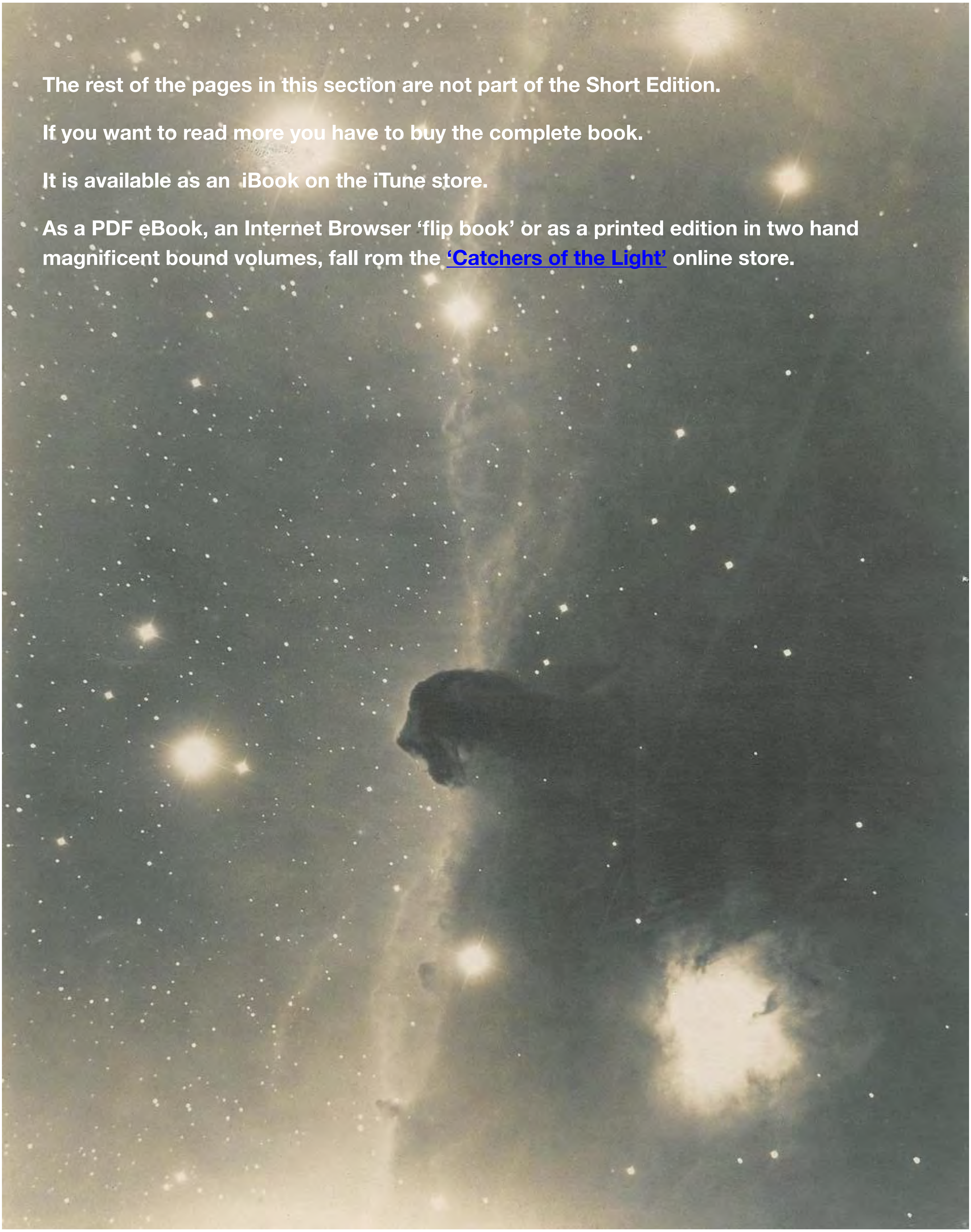


I.3

‘The Medical Man’

Richard Leach Maddox

Born: 4th August [or 4th May] 1816, Bath, Somerset, England

Died: 11th May 1902, Portswood, near Southampton, Hampshire, England

In 1871, Richard Leach Maddox first published the use of Gelatino-Bromide to the create Dry Photographic Plates. It was this process which began the next revolution in Astrophotography. Its increased sensitivity over that of the Collodion process meant that images of Deep Space Objects (DSOs) could be obtained for the very first time, by pioneers such as Henry Draper, Isaac Roberts, William Edward Wilson, James Edward Keeler and others. It was later found out that many of these objects lie at distances millions of light years beyond the boundaries of our own insignificant ‘*Milky Way*’ star system.

I.3.1 Gelatino-Bromide

During the whole history of Astrophotography, only three chemically based photographic processes have ever been used to any degree – the Daguerreotype, the Wet Collodion and the Gelatino-Bromide. Each in turn has spurred the development of astronomical photography forward and enabled astronomers to image fainter and more distant objects in space. Of the three the Gelatino-Bromide process was by far the most important of them all. Only the invention in 1969 of the CCD (Charge Coupled Device) had a greater impact on the use of photography for astronomical research.

On the 30th of September 1880 the New York Doctor, Henry Draper using a Gelatino-Bromide ‘Dry Plate’ imaged the ‘*Great Orion Nebula*’ (M42) [1]. This was the first photograph of any Deep Space Object (DSO) ever taken. It marked one of the great milestones in Astrophotography.

The earliest published account of the use of gelatine and silver bromide in photography was a paper published in the 8th September 1871 Issue of the British Journal of Photography, by Dr. Richard Leach Maddox (1816-1902), the son of a Tea Dealer from Bath, Somerset, England [2].

He later wrote modestly of his invention in a letter to the photographer William Jerome Harrison (1845-1908) [3], [4]:

“…The world has been benefited, and I have been honoured with a gold medal and diploma by the Jurors’ Committee of the Inventions Exhibition. Do not for one moment suppose I ignore the work of other hands perfecting the gelatino-bromide process, and thus giving it its worldwide value in all departments of photography, especially that far reaching one of its adaptation to astronomical research. I am only too thankful to feel that I have been merely the stepping-stone upon which others have safely put their feet…”

Do not be fooled by this modesty, we as Astrophotographers owe much to Richard Leach Maddox, of whom remarkably little is known. Let us now tell his story and that of the Gelatino-Bromide process.

I.3.2 Teatime at Bath

The name Maddox has its roots in the ancient Welsh male given name Matoc, a diminutive of ‘mad’ meaning ‘*fortunate*’ or ‘*good*’, which survives in the modern Welsh personal name of Madog. It is from this ancient land of Wales, that Richard Leach Maddox’s family came.

His father Walter Vaughan Maddox (1775-1857) was the eldest of the five children, (four sons and a daughter) born to Richard Maddox, a carpenter and his wife Jane (née Morris) from Welshpool (Y Trallwng) in the ancient Welsh County of Montgomeryshire (now Powys) [5]. As a young man, Walter Vaughan Maddox left the Welsh Marches, which had been the home of his ancestors for centuries, to seek better prospects in London.

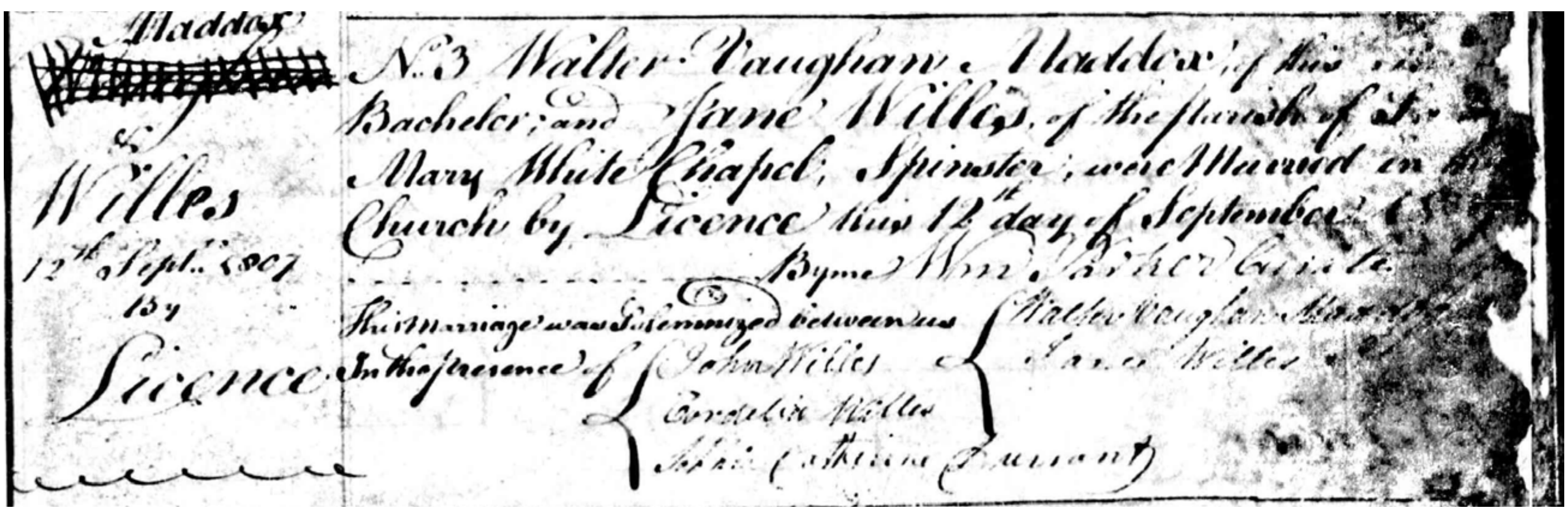
By the time of his marriage to Jane Willes (c1786-1818), a spinster from the parish of St. Mary’s Whitechapel on the 12th September 1807, we find Walter Vaughan, living in the area of St. Luke’s, Old Street, Middlesex [6]. Their first child, Jane Maddox (1811-1883) was born in Middlesex (probably St. Lukes) on the 17th of July 1811, a year later we find the Maddox family living in Bath in Somerset, probably at No. 8 Charles Street, having given birth to a son, William Willes Maddox (1812-1853) on the 23rd of August 1812 [7], [8].

Three years later on the 4th of August 1816 (according to the usual sources), their third child, Richard Leach Maddox was born at Charles Street, Bath [9]. He was baptized at St. Mary’s Chapel, Walcot on the 26th of June 1818. His baptismal entry states that he was born on the 4th of May 1816, and not the 4th of August as is commonly believed. This discrepancy has to be taken seriously as its source represents the earliest and only contemporary record of his birth that has been found to date.

This was to be their last child, for Jane Maddox died in the New Year of 1818. She was buried on the 7th January 1818, at St. Swithin’s church, in the parish of Walcot, now part of Bath [10]. In the years following his wife’s death, Walter Vaughan became a wealthy grocer and tea dealer in Bath, with his premises at No. 8 Charles Street. By the time of the 1841 Census, we find him living with his daughter Jane and two female servants at his private residence at Acacia Villa, Sion Hill, Bath – in one of the town’s most ‘*up market*’ areas [11]. Richard Leach Maddox was in 1841, not living at home, but at Burton Street in the St. Pancras District of London, giving his occupation as a man of Independent means [12].

Welshpool (Y Trallwng), Montgomeryshire, c1901

The small town of Welshpool in the ancient county of Montgomeryshire (now Powys) was the home of the Maddox family for centuries. it was only Richard Leach Maddox's father, Walter Vaughan Maddox who broke with this tradition and left to join the 'enemy' in England. Welshpool known in Welsh as Y Trallwng, is a town in Powys, Wales, 4 miles (6 km) from the Wales-England border. The town is low-lying on the River Severn; the Welsh language name Y Trallwng literally meaning *'the marshy or sinking land*'. In English it was initially known as Pool but its name was changed to Welshpool in 1835 to distinguish it from the English town of Poole. Today it still a quiet town of a few thousand people (6,269 as of 2001).


Maddox
& Willes
12th Sept. 1807
by Licence

No. 3 Walter Vaughan Maddox of this [illegible]
Bachelor; and Jane Willes of the Parish of St
Mary White Chapel, Spinster; were Married in this
Church by Licence this 12th day of September [illegible]
By me Wm. Parker Curate
This marriage was solemnized between us Walter Vaughan Maddox
Jane Willes
In the presence of John Willes
Cordelia Willes
Sophia Catherine Durant

Walter Vaughan Maddox Marriage St. Luke, Old Street, Middlesex, 1807

Walter Vaughan Maddox (1775-1857), the father of Richard Leach Maddox was married to Jane Willes of Whitechapel, in the Parish Church of St. Luke's, Old Street, London on the 12th of September 1807. St Luke is an historic Anglican church building in the London Borough of Islington. The church was closed by the Church of England Diocese of London in 1964 after subsidence made it unsafe and it lay empty. The roof was removed two years later for safety reasons and the shell became a dramatic ruin for 40 years, overgrown with trees, despite being a Grade I listed building. After many years of neglect, it eventually became a music centre operated by the London Symphony Orchestra, now known as LSO St Luke's.

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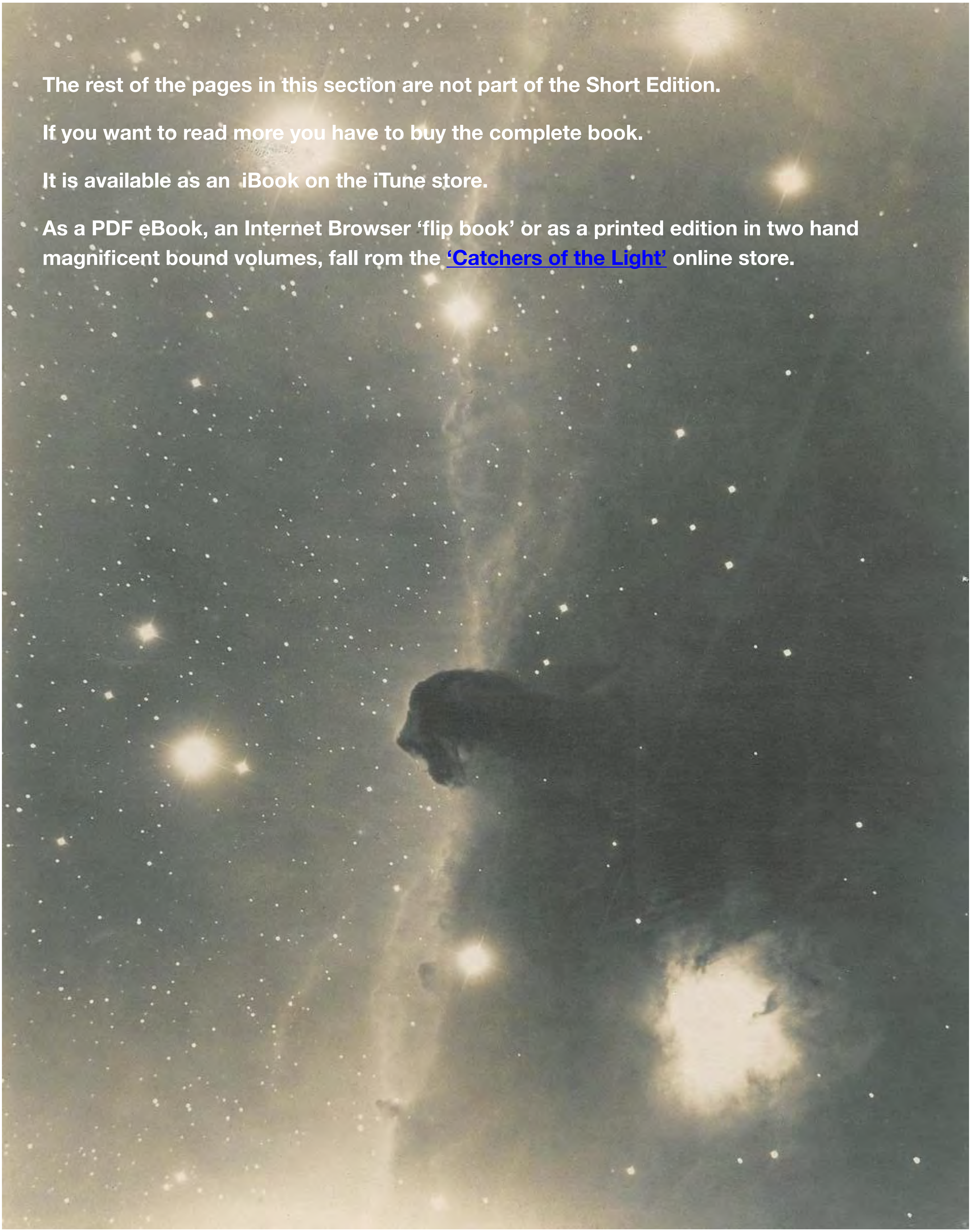


I.4

'Plates of Chips'

Astronomical Photographic Processes

Wratten & Wainwright Photographic Products

Only four main photographic processes and technologies have been used by astronomers to any great extent during the whole History of Astrophotography – the Daguerreotype, the Wet Collodion, the '*Dry*' Gelatino-Bromide and the CCD; the celluloid film was rarely used, except by amateurs.

I.4.1 Processes and Technologies

The emergence of Astrophotography from the new Art of Photography in the 1840s is one of the most important milestones in the History of Astronomy. It is that which bridges the gap between the previously subjective and speculative observations of the eye and the solid scientific theories of modern Astrophysics.

Although photographs had been taken of the Moon and Sun as early as the 1840s, such images revealed nothing that could not as easily be seen by eye or through a small telescope. The famous photograph of the *'Great Orion'* nebula' (M42) taken Henry Draper's in 1880 changed everything. With his use of the Gelatino-Bromide or '*dry*' photographic plate, Astrophotography was for the very first time able to capture objects and details far fainter than the eye could see, even if the eye was at the eyepiece of the largest of telescopes.

However in the early days of Astrophotography, its greatest advantage was something quite different – it gave for the first time a truly accurate and incontrovertible record of an observation. Photographic Astrometry was used to measure star positions directly off a plate rather than being obtained by hand from painstaking and time consuming visual observations. Details of nebulae and galaxies became the same for everyone rather than dependent on the eye of the observer. The subjectivity of human vision was replaced with the objectivity of a repeatable photograph. It is important to consider how the various photographic processes used in astrophotography developed, what were their advantages and disadvantages, what problems were met, how they were overcome and who solved them. Only four main photographic processes and technologies have been used by astronomers to any great degree during the whole History of Astrophotography [1]:

- Daguerreotype; introduced by Louis Jacques Mandé Daguerre in 1839;
- Frederick Scott Archer's wet collodion first published in 1851;
- Dry Gelatino-Bromide Plates; which became widely available from the early 1880s onwards;
- CCD (Charge Coupled Devices) which form the technological heart of the modern digital camera.

It is interesting to note that the Calotype Process of William Henry Fox Talbot was almost never used in Astrophotography, with only three reference having being found in the literature relating to its use in Astronomy.

The plastic film was rarely used by professional observatories, and was almost solely the province of the amateur astronomer, but even this has now largely given way to the CCD following the introduction of high quality affordable digital cameras and dedicated astronomical imagers over the last ten years or so.

I.4.2 Daguerreotype

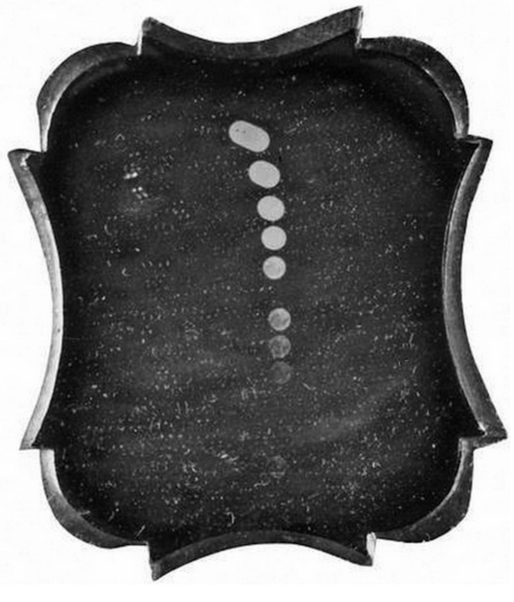
The first photographs ever taken of celestial objects were taken with one of the earliest practical methods of photography, the Daguerreotype process, invented by the French showman Louis Jacques Mandé Daguerre (1787-1851) and introduced to the world in 1839. The Daguerreotype process was complex, expensive, and difficult, requiring the use of silver-coated copper plates, iodine solutions, and vaporized magnesium.

For astronomical use Daguerreotypes were far from ideal. There was no easy way to make duplicate photographs, and by modern standards they had very low sensitivity. John William Draper's first Daguerreotype of the moon required a 20 minute exposure, an achievement made even more remarkable by the lack of a clockwork motor drive on the instrument he used. However, Draper's photograph revealed the immense potential of photography for scientific study. But the lack of sensitivity hindered its widespread use. It would be a further ten years before a Daguerreotype image was taken of any object beyond the solar system when a photograph of the star Alpha Lyra (Vega) was taken on the 17th July 1850 by George Phillips Bond (1825-1865) of the Harvard College Observatory and the Boston, Daguerreotypist John Adams Whipple [2].

Indeed very few Daguerreotypes of the Astronomical Objects were taken and even less have survived to the present day. With the introduction of Frederick Scott Archer's wet collodion process in 1851, the Daguerreotype was abandoned and replaced as the preferred process for Astrophotography.

Date	Photographer	Object	Notes
1839	Louis Jacques Mandé Daguerre	Moon	Imperfect Image, destroyed by fire when Daguerre's studio went up in flames in 1839
1839	John William Draper	Moon	Imperfect Image
1840	John William Draper	Moon	First successful Image of the Moon
1842	Gian Alessandro Majocchi	Partial Solar Eclipse	First photograph of a partial eclipse of the sun taken on the 8th of July 1842 from Milan.
1842	Alexandre Edmond Becquerel	Solar Spectrum	Earliest Image of the Solar Spectrum taken on the 13th of June 1842.
1842	John William Draper	Solar Spectrum	Photograph of the Solar Spectrum dated the 27th July 1842.
1843	Armand Hippolyte Fizeau & Jean Bernhard Foucault	Sun	Obtain coin sized images of the Sun from as early as August 1843.
1844-1845	Armand Hippolyte Fizeau & Jean Bernhard Foucault	Sun	Only surviving large scale example dated 2nd April 1845 of a series of photographs of the Sun taken by them in the period 1844-1845.
1849	Samuel D. Humphreys	Moon	Taken on 1st September 1849, when the nearly full Moon appeared over the town of Canandaigua, New York.
1849	William Cranch Bond & John Adams Whipple	Moon	Took a series of lunar daguerreotypes using the 'Great Harvard Refractor' with 40 second exposures during the period 1849 to 1852.
1851	George Phillips Bond & John Adams Whipple	Vega	Taken on 17th July 1850 using the 15-inch '*Great Harvard Refractor*'.
1851	Berkowski	Total Solar Eclipse	First Daguerreotype of a total eclipse of the Sun obtained, recording the inner corona and several prominences on 28th July 1851.
1854	William and Frederick Langenheim	Annular Solar Eclipse	The Langenheim brothers obtain eight Daguerreotypes on 26th May 1854.
1854	Marcus A. Root, John Campbell & Elias Loomis	Annular Solar Eclipse	26th May 1854 from Campbell's Observatory in New York.
1854	William Bartlett & Victor Prevost	Annular Solar Eclipse	26th May 1854 from West Point, New York.
1854	Stephen Alexander & Edward H. Olds	Annular Solar Eclipse	26th May 1854 from Ogdensburg, New York.

Known Daguerreotypes of Astronomical Subjects (1839–1854)



The earliest known but imperfect image of the Moon was a Daguerreotype taken by John William Draper in 1839. The image clearly shows the Moon, but is spoiled by a number of unwanted photographic artefacts. Draper persevered and in the following year obtained the first successful photograph of our nearest astronomical neighbour. His pioneering photograph of the Moon entitled John William Draper to be called the '*First Astrophotographer*'.

In about 1840, he turned his attention to the Sun and created another milestone in Astrophotography when he obtained one of the first photographs of the Fraunhofer lines in the solar spectrum. After these triumphs he abandoned Astrophotography to pursue his many other interests in fields as diverse as medicine and the History of the American Civil War.

Daguerreotypes of the Moon, Samuel D. Humphreys, 1849

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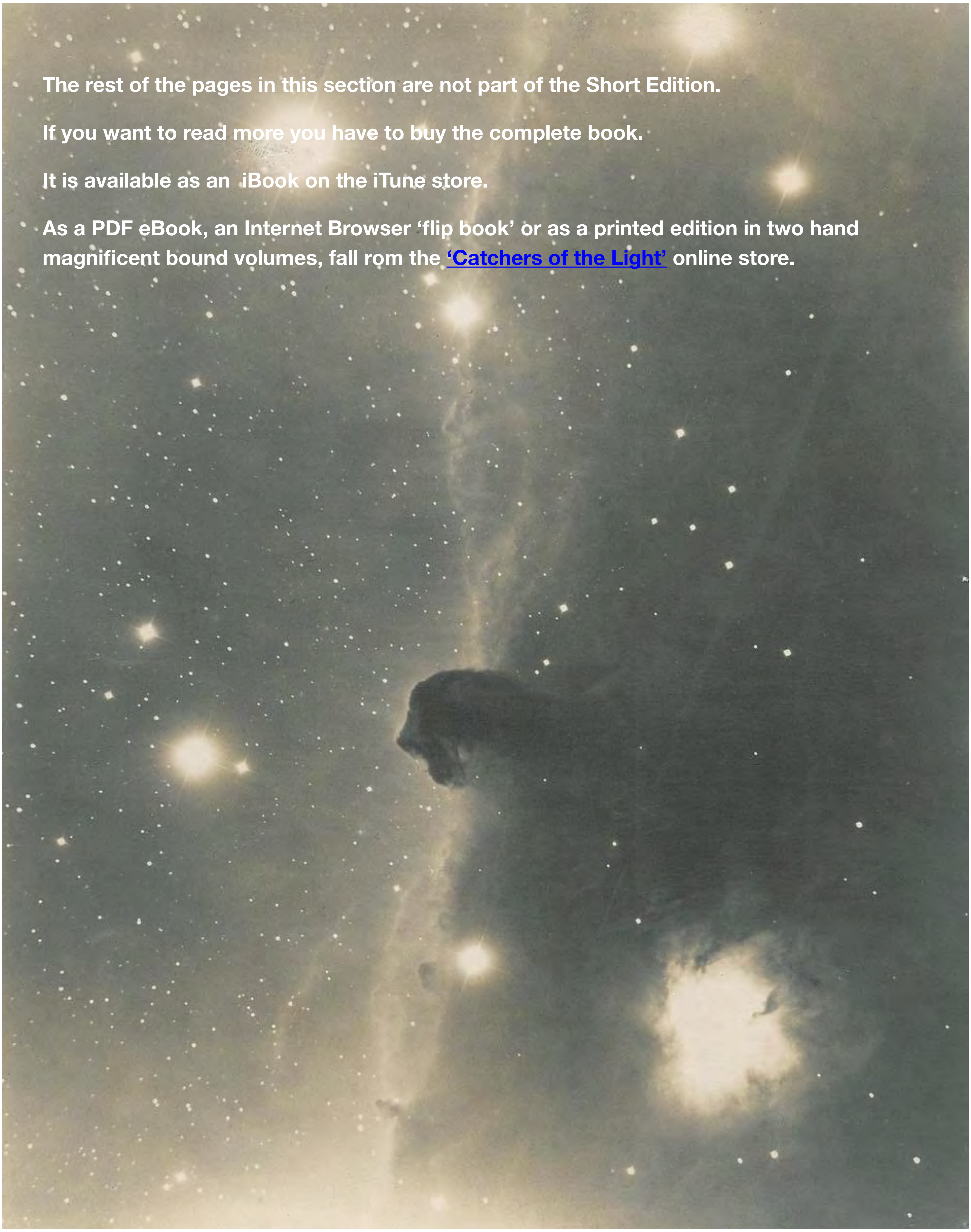


Short Edition

Part II

Moonlight

Lunar Astrophotography

Copernicus Crater, George Willis Ritchey, c1910

"A portion of the figure was very distinct," declared the minutes of the meeting, "but owing to the motion of the Moon, the greater part was confused. The time occupied was twenty minutes, and the size of the figure was about one inch in diameter. Daguerre had attempted the same thing but did not succeed. This is the first time that anything like a distinct representation of the moon's surface has been obtained." Contemporary Description of John William Draper's first Moon Photograph of 1840

II. Lunar Astrophotography

The first attempt at photographing an astronomical object was made by Louis Daguerre (1787-1851) in 1839 when he tried to image the Moon, but his efforts were met with failure. The following year, John William Draper (1811-1882), a Professor of Chemistry at New York University obtained the first successful image of the Moon, and in doing so earned himself title of the '*First Astrophotographer'*.

It was not until the 18th of December 1849 that the next photograph of the Moon was obtained by the Boston Daguerreotypist, John Adams Whipple (1822-1891), using the 15 inch 'Great Refractor' at Harvard College Observatory. Two years later in 1851 he took a series of Lunar Daguerreotypes which became prize winning exhibits at the Great Exhibition held that year at the Crystal Palace, London.

In the years that followed a number of astronomers including Warren De La Rue (1815-1889), Lewis Morris Rutherfurd (1816-1892) and Henry Draper (1837-1882)took photographs of the Moon of ever increasing quality and in much greater detail.

In 1852, De La Rue takes first wet collodion Images of the Moon with his 13 inch Reflector from his Observatory in Canonbury, Middlesex, which shows its surface in increased detail. Six years later he obtains the the first stereoscopic images of the moon from his new observatory at Cranford, Middlesex.

In 1863, Henry Draper begins taking photographs of the Moon with his 15 inch Reflector constructed by himself. These photographs were at the time the finest ever taken, until the work of Lewis Morris Rutherfurd two years later.

In 1865, the New York amateur scientist, Lewis Morris Rutherfurd, obtains excellent images of the Moon using a specially corrected photographic 11.25-inch (290mm) lens. His images were for many years the best ever taken, until the work of Pickering, Loewy and Puiseux.

During the 1890s and 1900s images of the Moon were taken of sufficiently high quality and detail to form the basis of the earliest Photographic Atlases of the Moon.

In 1897, Edward Singleton Holden begins issuing in serial form the Lick Observatory Atlas of the Moon compiled by Ladislaus Weinek from photographs obtained at the Lick and Paris Observatories. Only 19 sheets of reproduced photographs out of the 60 originally intended were ever published; of low resolution and poor quality.

In 1903 the Harvard astronomer, William Henry Pickering (1858-1939) became the first to publish a complete photographic atlas of the Moon with the appearance of his: *'The Moon – A summary of the Existing Knowledge of our Satellite with a Complete Photographic Atlas'.*

His photographs were taken in an eight month period from 31st December 1900 to 31st August 1901 from Mandeville, Jamaica using a horizontal refractor of 12-inch aperture and 135 feet focal length. Pickering divided his atlas into sixteen areas, with a photographs taken of each area but under five differing illuminations.

Although the photographs he obtained were not of the highest, the fact that the same features were imaged during differing lunar phases was a very useful feature of the atlas. It is well known that lunar feature under differing illumination 'take on' very differing aspects and are often difficult to identify without photographic help.

However the first true photographic atlas of the Moon was the work of Moritz Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928) of the Paris Observatory. In 1894 they took the first photograph of the Moon using the Observatory's 23.6-inch Equatorial Coudé Refractor that would be included in their monumental *L'Atlas Photographique De La Lune* published in 1910.

Their work was published in twelve parts from 1896 to 1910. Each part relates to a specific area of the moon, and contains high quality photographs of the region, as well as a description of the major lunar features, craters, mare, mountain ranges etc present. A general index of features was also published as the thirteenth part of the atlas.

The photographs of Loewy and Puiseux were to remain unsurpassed in quality for the next fifty years until those taken by the Lunar Orbiter Probes in the 1960s, although Francis Gladheim Pease came very close with his images of 1919, taken with the 100-inch Hooker Telescope at Mount Wilson.

In 1964, the Lunar Orbiter program was initiated, as a series of five unmanned lunar orbiter missions launched by the United States from 1966 through 1967. All five of the Lunar Orbiter missions were successful, and 99 percent of the Moon was mapped from photographs taken with a resolution of 60 metres or better.

The first three missions were dedicated to imaging 20 potential manned lunar landing sites, selected based on Earth-based observations. These were flown at low inclination orbits.

The fourth and fifth missions were devoted to broader scientific objectives and were flown in high-altitude polar orbits. Lunar Orbiter 4 photographed the entire nearside and 9 percent% of the far side, and Lunar Orbiter 5 completed the far side coverage and acquired medium (20 m) and high (2 m) resolution images of 36 pre-selected areas.

In 1971 the images obtained from the Lunar Orbiters were used to create LOPAM – the Lunar Orbiter Photographic Atlas of the Moon compiled by David E. Bowker and J. Kenrick Hughes. This work is now considered to be the definitive reference manual on the global photographic coverage of the Moon.

“As the image of the Moon photographed with telescopes of the dimensions usually found in the hands of amateurs is small, even if amplifying lenses are used, the chief desideratum is to get a negative of extreme sharpness, which will admit of considerable subsequent enlargement.”

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

Collodion Image of the Moon, John Dilwyn Llewelyn & Thereza Llewelyn, c1857

II.1

‘The First Astrophotographer’

John William Draper

Born: 5th May 1811, St. Helens, Merseyside, Lancashire, England

Died: 4th January 1882, Hastings-on-Hudson, Westchester, New York, USA

John William Draper is generally recognized as the father of photographic portraiture as well as being the ‘*First Astrophotographer*’. In 1840, he was the first person to successfully image an astronomical body, when he obtained a Daguerreotype photograph of the Moon.

II.1.1 Ambition

John William Draper knew from a very early age that he wanted to become a scientist; yet he became much more than he could ever have imagined. Not only did he realize his ambition of a career in Science, but he also became one of the great pioneers of the new Art of Photography and the very *'First Astrophotographer'* [1].

In early 1840 John William Draper obtained a clear Daguerreotype image of the Moon. It was the first time anybody had ever successfully obtained a photograph of any astronomical object. It was the beginning of Astrophotography and the first evidence that photography could be of great value as a serious tool for scientific study.

To understand how John William Draper, the son of an itinerant English preacher grew up to become an American citizen and one of the 'Photographic Greats'; we must start as always at the beginning - not in New York State where he spent most of his life but in the town of St. Helens, Lancashire, England, in the early years of the nineteenth Century when its King was mad, its Regent was little better and a new world across the Atlantic Ocean was beckoning to many.

II.1.2 St. Helens

John William Draper was born on the 5th May 1811 [2] in the then small Lancashire town of St. Helens [3], ten miles from the port of Liverpool. He was born into a family of Methodists. His father John Christopher Draper was an itinerant Preacher who moved from chapel to chapel in the hope of eking out a living [4]. The geographical ministrations of Draper, the father can be closely followed by the birth of his four children, who were born in four different locations, reflecting where he happened to be preaching at the time.

His eldest daughter Dorothy Catherine was born in Newcastle-upon-Tyne in 1807, his second daughter Elizabeth Johnson was born two years later in Penrith, Cumberland, John William in St. Helens in 1811, and his youngest daughter, Sarah Ripley in Lincoln, Lincolnshire in 1813.

At the time of John's birth the family was living in St. Helens, where his father was a preacher at the Methodist Chapel on Tontine Street. He was baptized the following month at the Tontine Street Chapel by his father's friend, the well known Methodist Preacher Jabez Bunting (1779-1853) who conducted the service held there on the 23rd of June.

The early education of John Draper was in the main done at his home by private tutors, a result of the family's meagre income, but at the age of eleven he was sent to a public school at Woodhouse Grove in neighbouring Yorkshire, run by the Wesleyan Methodist Church. At Woodhouse School John Draper was a model pupil; hard working, well behaved, attentive and inquisitive in all his studies, whether it was Mathematics or Classics. In recognition of his efforts he was chosen in 1824 to deliver the customary address from the school to the Wesleyan conference, which met that year at Leeds.

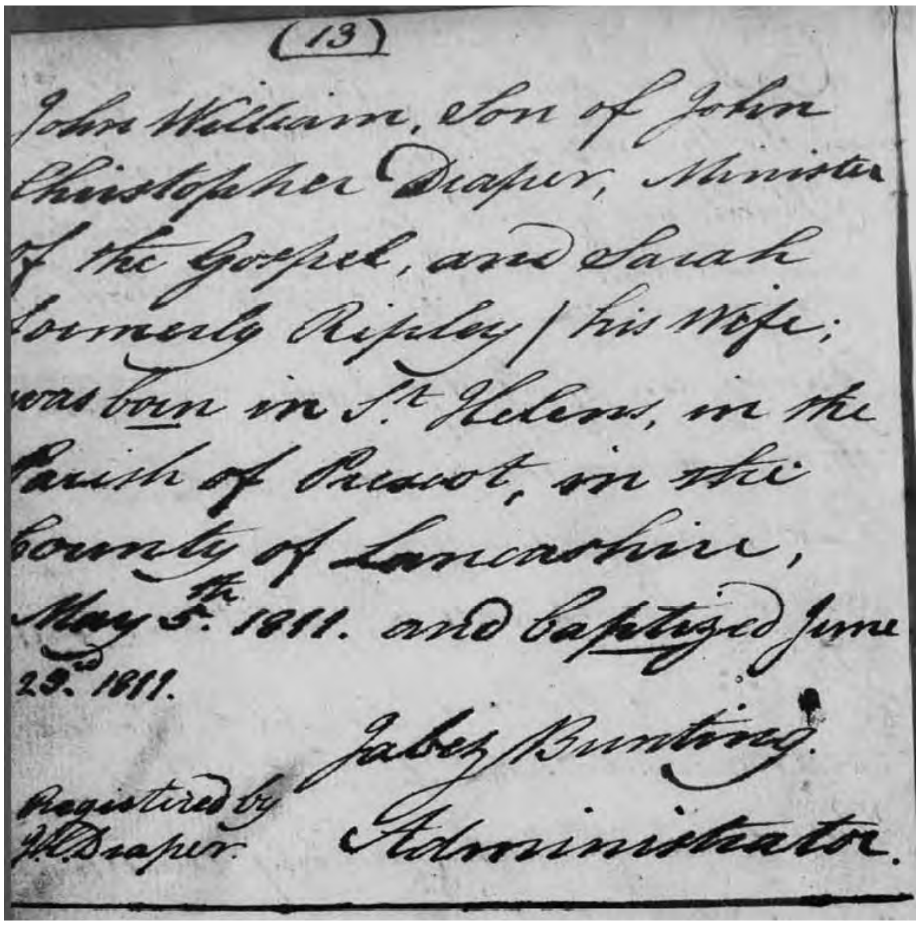
This was his first effort at public speaking and he was good at it – something he never forgot and which he was called upon many times to do in his later life. Not long afterwards he left the Woodhouse Grove school and returned home, to continue his studies, as before, under private tutors. It is known that John W. Draper was interested in Astronomy from an early and was the proud owner of a Gregorian Reflector which he often used to make observations and to find his way around the night sky. He was also passionate about science in general and loved to experiment with chemicals at home whenever he could, parents permitting!

It was therefore not surprising that in 1829, Draper then aged 18 enrolled as a student of Chemistry at the newly founded University College, University of London. Here he came under the care and influential of the much respected chemist Dr. Edward Turner [5]. For the next three years he spent his time in the fruitful study, investigation and analysis of all branches of Chemistry- inorganic, organic and physical all under Turner's expert guidance. Whilst studying for his degree, John Draper took lodgings with a friend of his father, a Mrs Mary Barker in Minster Sheppey in Kent.

It was here in 1830 that a met her niece and ward, Miss Antonia Coetana Pereira Gardner; whose father was private physician to Emperor Don Pedro Primeiro of Brazil [6]. The following year they were married on the 13th September 1831 at the Parish church of St. Mary & St. Sexburga, having obtained a marriage license the day before [7].

During the course of his studies his father died [8] and for whatever reason was unable to finish his course and did not graduate. This was a life changing event for the family who decided following the death of the Reverend John Christopher Draper, that they would seek a new life in the former British Colony of America.

Before the War of Independence several of Draper's ancestors on his mother's side had come to America and had settled in Virginia, founding a small Wesleyan colony. Subsequently others of members of the family had crossed the ocean and joined the colony. Urged by these relatives and accompanied by his mother and his three sisters Dorothy, Sarah and Elizabeth; John W. Draper and his new wife Antonia, all sailed for America in 1832.



(13)
John William, Son of John
Christopher Draper, Minister
of the Gospel, and Sarah
formerly Ripley / his Wife;
was born in St Helens, in the
Parish of Prescot, in the
County of Lancashire,
May 5th 1811. and baptized June
23. 1811.
Jabez Bunting
Registered by
J.W. Draper Administrator.

The baptismal entry for John William Draper dated 23rd June 1811 provides a good deal of useful biographical information, of the utmost value in tracing his family history. In particular it gives the date and place of his birth, the names of his parents, his mother's maiden name, the occupation of his father, John Christopher Draper as a 'Minister of the Gospel'. The maiden name of his mother, Sarah Ripley is useful in finding the date and place of the marriage of John William Draper's parents. Such detailed information pre-dates the General Registration of Births for England and Wales by over twenty five years. It was only in 1837 that it became a statutory requirement for such records to be kept.

It should also be noted that the name of Jabez Bunting is clearly shown to be the minister who officiated at the baptism.

Register Entry of the Birth of John William Draper on 5th May 1811, in St. Helens

The baptism in 1811 of John William Draper, the son of John Christopher Draper and his wife Sarah (née Ripley) was performed by Jabez Bunting (1779–1858), one of the most well known and charismatic of all English Wesleyan preachers.

He was born of humble parentage in Manchester, Lancashire, England. He received his education at Manchester Grammar School, and at the age of nineteen began to preach. It was only in 1803 that he was received into full Connexion and became a fully ordained minister. He continued to minister for upwards of fifty-seven years in Manchester, Sheffield, Leeds, Liverpool, London and elsewhere. Bunting was a popular preacher, and an effective platform speaker; in 1818 he was given the degree of M.A. by the University of Aberdeen, and in 1834 that of DD by Wesleyan University of Middletown, Connecticut, United States. He died in 1858 and was interred in Wesley's Chapel, London.

Jabez Bunting, a Wesleyan Theologian, who baptized John William Draper

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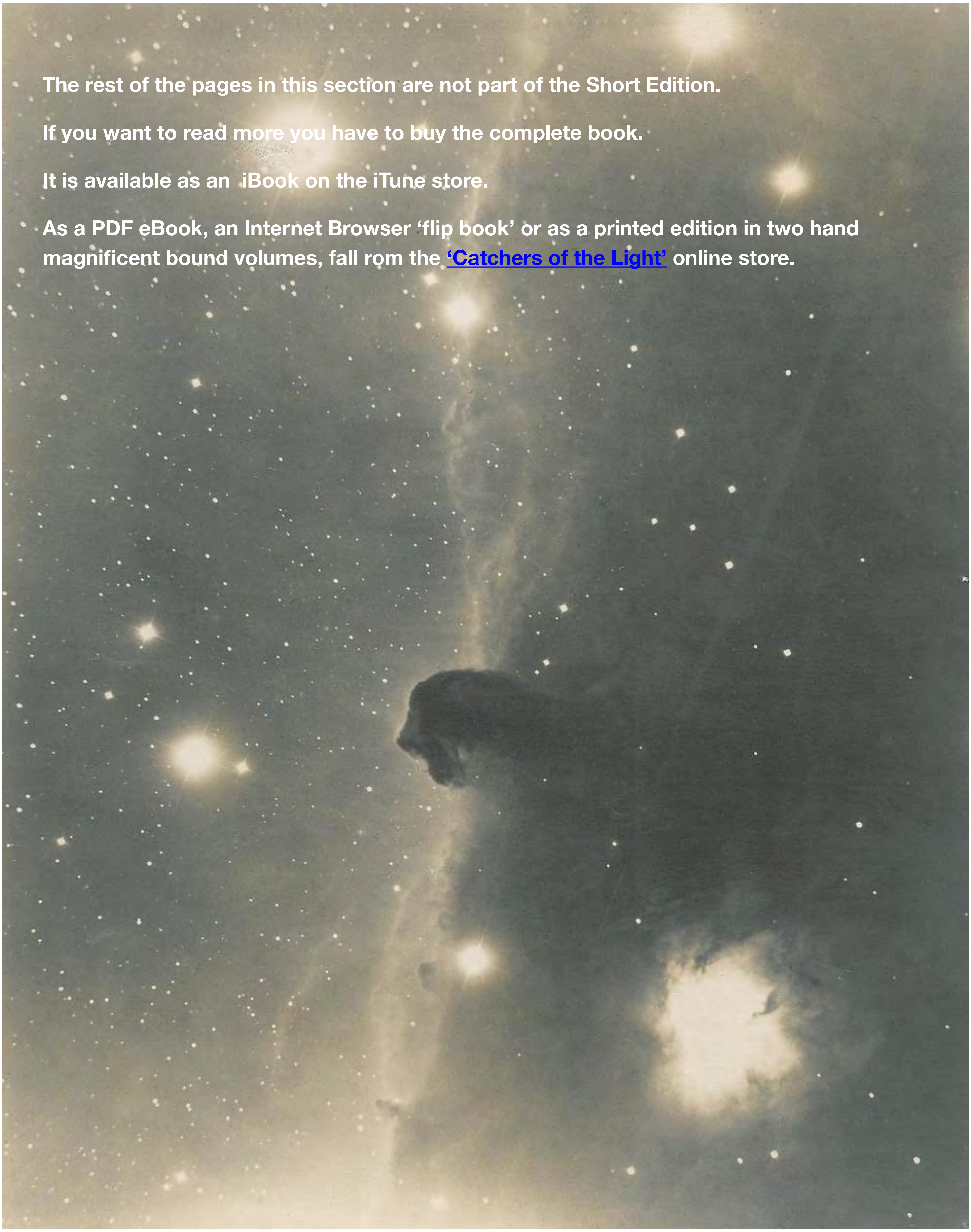

II.2

'The Celestial Mechanics'

Moritz (Maurice) Loewy

Born: 15th April 1833, Vienna, Austria

Died: 15th October 1907, Paris, France

Pierre Henri Puiseux

Born: 20th July 1855; Paris, France

Died: 28th September 1928; Paris, France


Moritz (Maurice) Loewy and Pierre Henri Puiseux both started their careers as Mathematicians; but ended up working together to do their finest work – the '*Atlas Photographique de La Lune'*. In its pages are some of the finest images of the Moon ever taken which were not surpassed until over half a century later, when in the 1960s the Lunar Orbiter Probes compiled a new photographic atlas of the Moon, known as LOPAM.

II.2.1 Persecution & Mountaineering

Moritz (Maurice) Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928) were brought up in two different worlds – one in Vienna, where Jews like Loewy and his family lived in perpetual fear; whilst Puiseux knew only of the peace of the mountains and the elegance of Mathematics. Yet these two men from these two very different backgrounds worked together at the Paris Observatory in the years from 1894 until 1910 to create one of the most wonderful Atlases ever produced.

The Atlas of Loewy and Puiseux, was not one of our Earth; yet it pictured a world that had seas, which you could not swim in; It had mountains too, but unlike the one's Puiseux climbed, they had no snow; It saw no rain or clouds but had features called the Mare Imbrium (Sea of Rains) and the Mare Nubium (Sea of Clouds). Loewy and Puiseux took over 6000 photographs for their Atlas, choosing only the best 82 for the published version. Their Atlas also included text to accompany the photographs, which described in detail the most interesting of the features that were to be seen in its pages.

It was not an Atlas in the usual sense of the word, but a Photographic Atlas of the Moon – known as *'L'Atlas Photographique de La Lune', 'Publie par L'Observatoire de Paris, Execute Par M.M. Loewy et M.P. Puiseux'*

Since its publication in its completed form in 1910, it remained for over fifty years the finest photographic atlas of the Moon. It was only in the 1960s with the launch of the USA's Lunar Orbiter probes that an Atlas of the Moon was created that bettered it.

Sadly, the work of Loewy and Puiseux is all but forgotten, and copies of their great Atlas are to be found in only a handful of libraries and institutions across the world [1]. Occasionally individual photographs come up for sale at auction and even rarer a complete edition [2].

II.2.2 Celestial Mechanics

Moritz Loewy was born on the 15th April 1833 in Vienna, Austria of Jewish parents, Leopold Loewy and his wife Caroline Herzel, both natives of neighbouring Slovakia. At that time there was considerable Anti-Semitism in the Austrian-Hungarian Empire. A fact which ironically shaped the rest of Loewy's life for the better, especially in respect of his career.

He was educated at the Polytechnic School and University of Vienna, and received his astronomical training under its director Karl Von Littrow (1811-1877) at the Imperial Vienna Observatory where he was employed as an assistant [3]. His original area of interest was celestial mechanics. In 1857 he computed the orbit of the newly discovered asteroid Leda, other similar calculation followed including that of Comet Donati [4].

He later escaped the persecution of his home city when he took up an appointment at the Paris Observatory, where he could work in peace and be what he wanted to be - an astronomer.

Pierre Henri Puiseux was born the 20th July 1855 in Paris, France, the son of the mathematician Victor Puiseux (1820-1883) [5] and his wife Laure Louise Fabronie Jannet (1830-1858), who brought him up to love science and the mountains.

From an early age Puiseux loved mountaineering and climbed many of the peaks in the French Alps and outside its borders. He even succeeded in climbing Mont Blanc alone. During his ascents he studied the Geology of the Rocks he came across. It is not surprising that he became one of the greatest photographers of the Moon – a body renowned for its mountainous landscapes.

He was later to make some of the earliest scientific investigations into the Geology of the Moon based on his knowledge of the mountains he climbed, the rocks he studied and the Lunar photographs he took.

His education began at the Ecole Normale Superieure and was completed when he began work at the Paris Observatory in 1885. It was here that he worked as assistant to Loewy. In the early years of his career he like became interested in author's own former specialism of celestial mechanics [6], and in particular tidal friction and the secular acceleration of the Moon [7].

Urbain Jean Joseph Le Verrier and Victor Alexandre Puiseux were two great French Mathematicians who specialised in the field of Celestial Mechanics. They were largely responsible for the career paths of Moritz Loewy and Pierre Henri Puiseux. It was Le Verrier who offered Loewy a position at the Paris Observatory and thus escape the Anti Semitism of his native Vienna; whilst Puiseux encouraged his son to pursue his interest in mathematics, geology and mountaineering.

Urbain Jean Joseph Le Verrier (Left) & Victor Alexandre Puiseux (Right)

II.2.3 'The Paris Observatory'

In August 1860, an event occurred which changed his life forever and for the better. It was an invitation from the great mathematician Urbain Le Verrier (1811-1877). Le Verrier together with John Couch Adams (1819-1892) had gained eternal fame when they had independently predicted the orbit of the planet Neptune, which had ultimately led to its discovery in the September of 1846.

At that time Le Verrier was Director of the Paris Observatory, so the offer of a job at one of the world's leading astronomical institutions, was an opportunity Loewy could not possibly turn down. It was also a wise career move, since at that time Jews were not permitted to rise to high office in Austrian-Hungarian institutions.

Immediately on arriving in Paris he changed his name from Moritz to the safer form of Maurice, and it was as Maurice Loewy that he was known for the remainder of his life. In the years following 1861 the initials M. L. were to be found frequently in the observation reports of the Paris Observatory. He quickly became at home in Paris, and in 1864 he became a naturalized French Citizen, even serving on the city's ramparts during the Franco-Prussian war of 1870.

His interest in the orbits of minor planets and comets continued, in particular he made some improved calculations of the orbit of the asteroid Eugenia allowing for planetary perturbations [8]. In 1872 he published a paper on a new method for the calculation of the orbits of minor planets, which with the aid of accompanying tables greatly simplified their computation.

Both Moritz Loewy and Pierre Henri Puiseux began their careers in astronomy in the field of celestial mechanics - an extremely difficult subject requiring great skill and a good knowledge of all branches of mathematics. They later became involved in more practical aspects of astronomy with the design of the '*Equatorial Coudé*' refractor; which they used to great effect in their monumental work - the '*Atlas Photographique de la Lune*'.

Maurice Loewy (Left) & Pierre Henri Puiseux (right)

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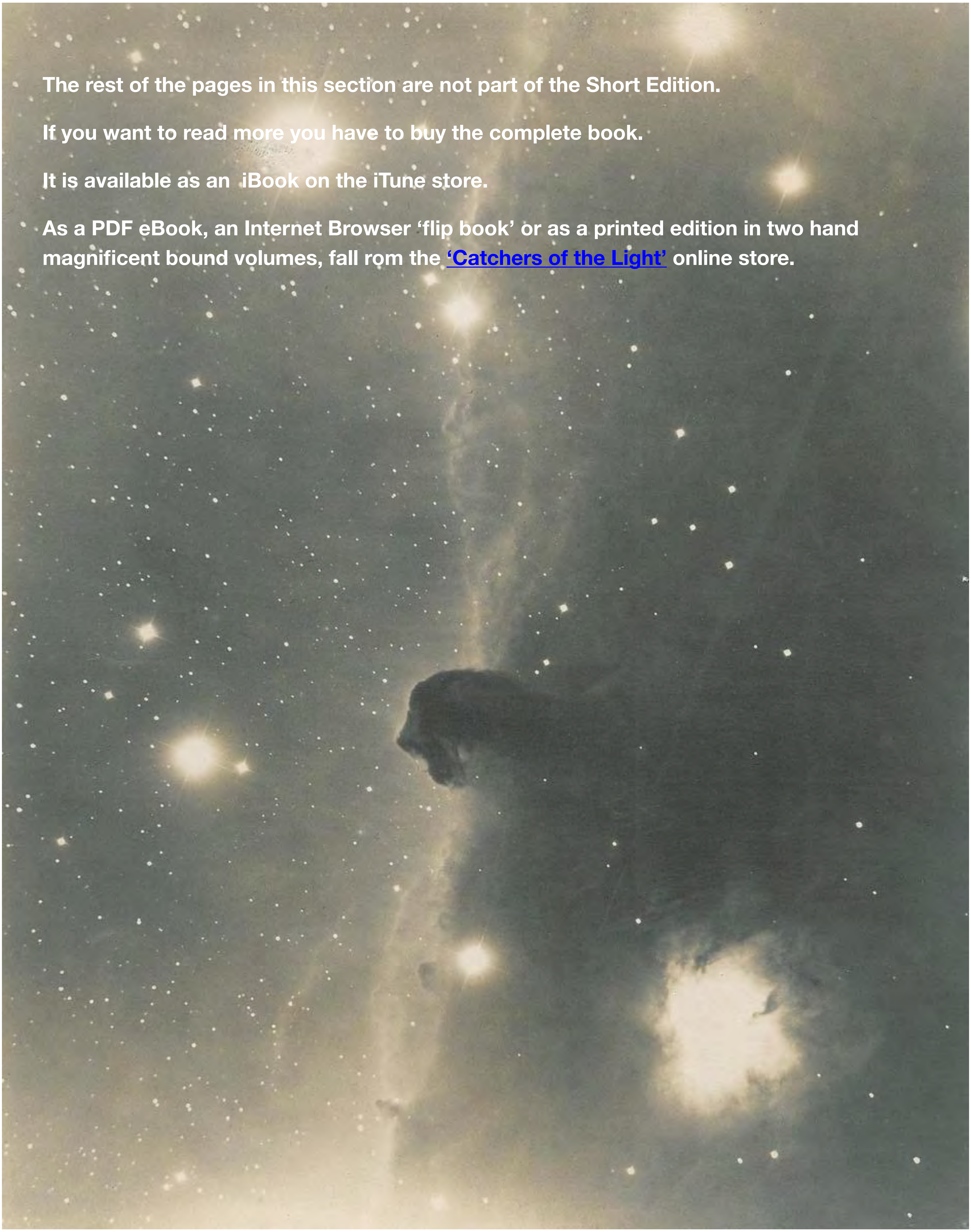

II.3

‘The Lunatic’

William Henry Pickering

Born: the 15th February 1858, Beacon Hill, Boston, Massachusetts, USA

Died: 16th January 1938, Mandeville, Jamaica

William Henry Pickering was the younger brother of Edward Charles Pickering and a great pioneer of Astrophotography in his own right; producing in 1903 the first ever complete Photographic Atlas of the Moon, seven years before Loewy and Puiseux completed the publication of their *‘Atlas Photographique de la Lune’* in its entirety.

II.3.1 Footsteps

William Henry Pickering (1858-1938) followed in the footsteps of his elder brother, Edward Charles Pickering (1846-1919), and became a great astronomer. It was in fact William Henry who introduced his more famous sibling to astronomical photography and set him on his path which led to some of the most important work ever carried out in the new science of Astrophysics [1].

In contrast, William Henry's work led him to nearer and more traditional areas of study – the Sun, Moon and Planets; and not the distant stars; about which man knew so very little, a situation Edward Charles Pickering was determined to alter. Although, he lived in the shadow of his illustrious brother, William Henry made his own mark in Astrophotography.

In 1903 he published the very first complete Photographic Atlas of the Moon, which contained images of our nearest astronomical neighbour of a quality somewhat short of the great heights reached by Maurice Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928); who not only had the resources of the Paris Observatory to call upon, but a telescope which far surpassed anything available to Pickering [2].

II.3.2 Harvard

William Henry Pickering was born on the 15th February 1858 at the family's ancestral home on Beacon Hill, Boston, Massachusetts, United States, the third and last child of Edward Pickering (1807-1876) and Charlotte Daniel Hammond (1819-1901). His elder brother Edward Charles Pickering was for over forty years, the Director of the Harvard College Observatory and one of the world's greatest ever astronomers.

After completing his school and college studies in Boston and Cambridge, W. H. Pickering went onto study Physics at the Massachusetts Institute of Technology; where he graduated in 1879. He was then appointed as an assistant then later an instructor in MIT's Department of Physics. He held this position until 1887 when he joined the staff at the Harvard College Observatory (HCO) as an assistant astronomer. In the June of 1889 he was appointed Assistant Professor of Astronomy from September 1st that year. He remained as an Assistant Professor at the HCO until his retirement in 1924.

II.3.3 Investigations

Prior to joining the HCO, W. H. Pickering had been collaborating with his brother in an *'Investigation in Stellar Photography'* [3]. These experiments which had begun in 1882 had looked into the use of the newer Gelatino-Bromide or '*Dry*' Photographic Plates in three areas of stellar astronomy; namely the brightness of stars, the construction of sky charts and the imaging of stellar spectra.

E. C. Pickering in the published report of these investigations acknowledged the contributions made his brother [4]:

"The experiments to be described below were mainly conducted by the aid of an appropriation made in June, 1885, from the Bache Fund, of the National Academy of Sciences. Numerous preliminary experiments had been made with a grant from the Rumford Fund of the American Academy. My attention was directed to stellar photography in 1882, by Mr. W. H. Pickering. Many of the preliminary experiments were made by him, and his advice was followed regarding the photographic processes to be employed. In the later work, he has rendered important aid by his advice, and by making many auxiliary experiments in his photographic laboratory at the Massachusetts Institute of Technology."

The help given to E. C. Pickering by his brother was without question a major factor in setting him on the path to success in every aspect of his future career in Astrophysics; for photography was the key tool used in the studies that made him famous. By 1883 it was clear that W. H. Pickering had become an accomplished Astrophotographer [5]:

"On February 21, 1883, a photograph of Orion was obtained by Mr. W. H. Pickering with a small Voigtländer camera and without clockwork. Although the aperture was only 1.6 in. and the focus 5.2 in., trails were obtained of stars as faint as the fifth magnitude. Still better results were obtained with a Voigtländer No. 4 lens (Series B), having an aperture of 2 inches and a focal length of 7 inches."

W. H. Pickering continued with his investigations into astronomical photography at the HCO in the years 1887 to 1891, with particular emphasis placed on the determination of the magnitudes of stars in the vicinity of the Orion Nebula [6].

I.3.4 Travels

Following his early work on stellar photography W. H. Pickering began to concentrate on observing the Sun, Moon and Planets. During the course of this work he travelled far and wide to carry out his observations – to the southern and western United States, Hawaii, the Azores, Europe, Chile and Peru.

Rather surprisingly, William Henry Pickering turned his back on photography as the best way to study the bodies of our solar system, preferring to use visual methods whenever he could. He did not abandon its use entirely, but could certainly have made more use of it during the course of his work. Why should he have done this? The reasons are several, not only scientific, but often as not are concerned with the strained relationship he had with his elder brother Edward Charles Pickering.

E. C. Pickering was the '*doyen*' of American Astronomy in the late nineteenth century, hard working, ambitious and totally charming – and arguably the greatest astronomer of his age. He was involved in large scale investigations into the workings of stars – often requiring years of painstaking effort by a team of people. W. H. Pickering considered his elder brother somewhat narrow minded; whilst he himself preferred to use his inquisitive mind on what he saw as the ever changing faces of the planets, and in particular Mars.

Esther Pickering Harland (1889-1988), his daughter once said [7]:

"My father didn't want to feel dependent at all on Uncle Edward, and he'd sometimes branch out into things that Uncle Edward didn't just think were what he wanted at the observatory."

In 1888, W. H. Pickering using Harvard's 13-inch Boyden Refractor took some of the earliest photographs of Mars. However, the location of the telescope at the Cambridge, Massachusetts site was far from ideal, so the two Pickering brothers began a search for suitable 'station' in a more southerly location with a better climate than the main HCO site.

A number of sites were tested including Pike's Peak in Colorado. In the end it was Wilson's Peak (Mount Wilson) in California that was chosen [8]. In 1889 under W. H. Pickering's supervision the 13-inch Boyden Refractor was moved from Cambridge to Wilson's Peak, arriving there on the 2nd of April that year.

In the November 1890 issue of the Journal of the British Astronomical Association, an account was given by A. Stanley Williams of a series of Photographs of the Planet Mars taken by Pickering in the April of 1890 from Wilson's Peak, California [9]:

"Besides the eye observations above referred to, a series of photographs of Mars were obtained with a 13-inch telescope stationed on Wilson's Peak, California (6,200 feet above the level of the sea), which appear to have been remarkably successful. Not only were distinct and identifiable spots and markings well shown on the photographs, but an important result of a different nature was also obtained from them. The white polar spot, or snow cap, on the south varies, it is well known, in size from time to time, being largest towards the end of the Martian winter, and smallest near the end of the summer.

The photographs taken on two successive nights (April 9 and 10), and at times when the same part of the planet was presented to the Earth, showed a marked increase in the size of this white spot in the short interval of only about 24 hours. According to Prof. Pickering, the visible area affected by the change amounts to as much as 2,500,000 square miles (or somewhat, less than the area of the United States), though being near the limb the change is not so conspicuous as might be supposed.

The probable explanation of the change is that between the 9th and 10th April a fall of snow occur- red over an area of about 2,500,000 square miles; or else that there was an extensive formation of cloud, or even mist, over the area in question."

The Harvard College Observatory (HCO) appointed its astronomer, Solon Irving Bailey (1854-1931) to find a site for a new observatory in the southern hemisphere, even further south than Wilson's Peak. The goal of the new observatory would be to perform stellar photometry, photographic surveys of the sky and stellar spectroscopy on stars not visible from the HCO's northern latitude. In 1890, Bailey established the Boyden Station near Arequipa, Peru.

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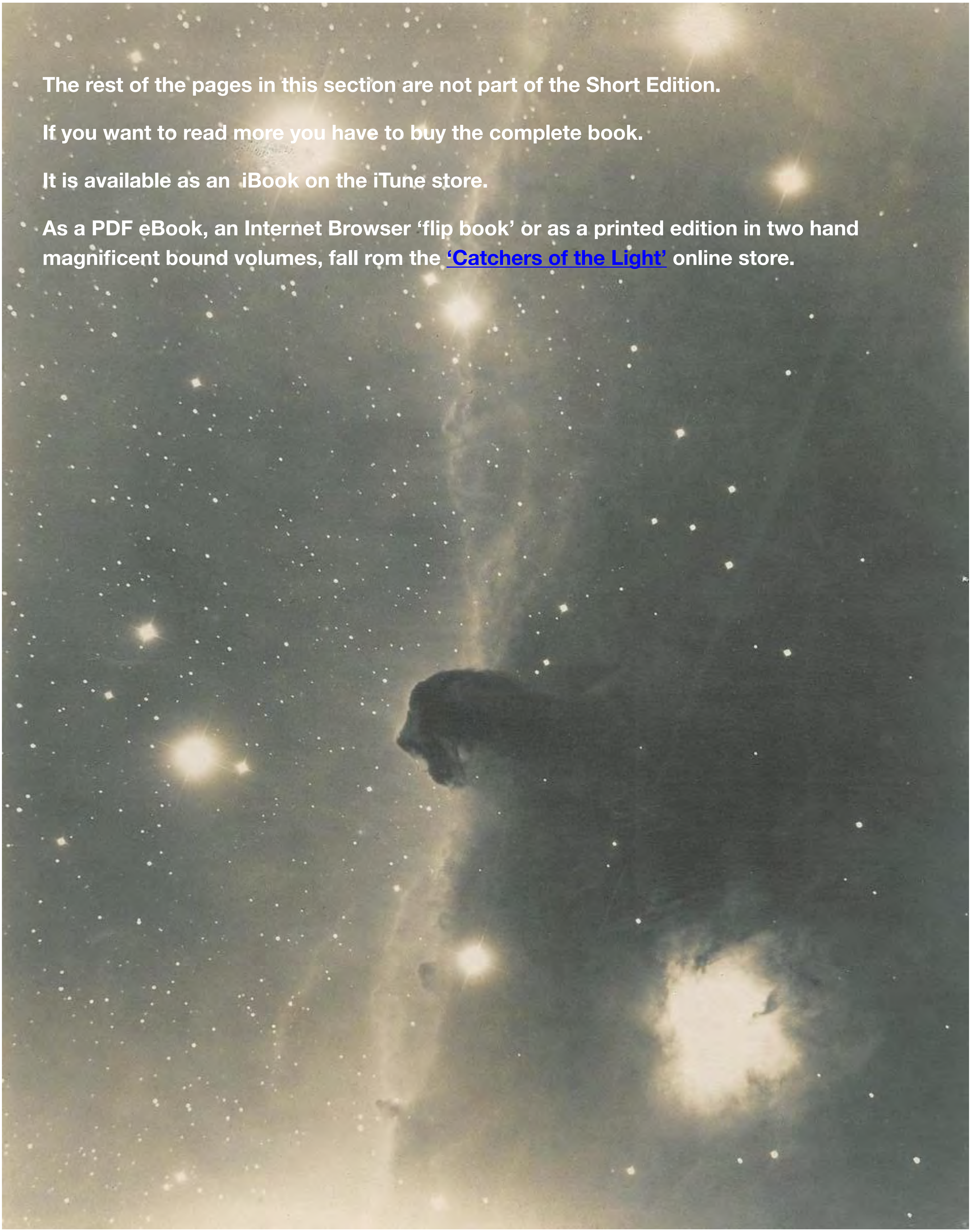


II.4

‘LOPAM’

Lunar Photographic Atlases

The history of Lunar Photography has a long tradition beginning in 1839 with Louis Daguerre’s failed attempt, followed a year later by the first successful image of John William Draper; and continuing with the pioneering photographs of Warren De La Rue and Lewis Morris Rutherfurd. Only in 1903 did the first complete and detailed photographic atlas appear; that of William Henry Pickering. Seven years later the magnificent *‘Atlas Photographique De La Lune’* by Maurice Loewy and Pierre Henri Puiseux was published. It was to be fifty years before the Lunar Orbiter probes of the 1960s obtained images of greater quality.

II.4.1 Early Lunar Maps

Ever since man first looked up at the sky and seen the Moon, he has tried to draw it.

The first serious attempts at naming the features of our Moon as seen through a telescope were made by Michel Florent van Langren (1598-1675) in 1645 [1]. His work is considered to be the first true map of the Moon, as it portrayed the various Maria (seas), Craters, Mountain Peaks and Ranges.

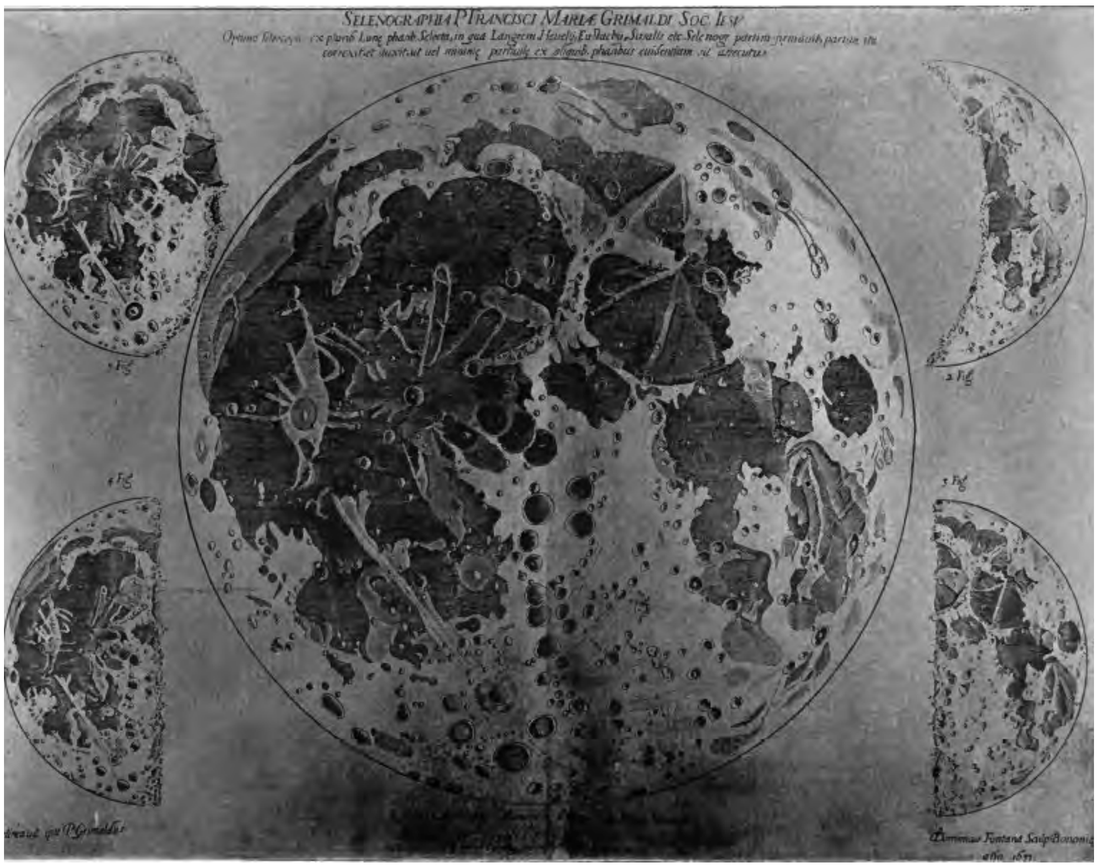
The modern scheme of lunar nomenclature was devised by Giambattista Riccioli (1598-1671), a Jesuit priest and scholar who lived in northern Italy. His *'Almagestum Novum'* was published in 1651 as a defence of the Catholic views during the Counter Reformation. However the only significant aspect of the work to survive to the present period is Riccioli's system of lunar nomenclature.

The lunar illustrations in the Almagestum Novum were drawn by a fellow Jesuit teacher by the name of Francesco Grimaldi (1618-1663). The nomenclature was devised based on a subdivision of the visible lunar surface into octants, numbered in the Roman style from I through VIII. Octant I formed the northwest section, and subsequent octants proceeded in a clockwise direction aligned with the compass directions. Thus the Octant VI lay to the south, and included the well known Clavius and Tycho craters.

In 1749, the German Mathematician, Tobias Mayer (1723-1762) [2], while working for the Homann Company of Cartographers, produced a map of the moon measuring seven and a half inches in diameter. It was the first map of the moon which used accurately measured positions of the craters. In fact Mayer measured the positions of 24 craters, which he included in the map, using a micrometer to obtain an accuracy of 1' in latitude and longitude.

However, the greatest Map of Moon in the pre-photographic era was that of Wilhelm Beer(1797-1850) and Johann Heinrich Von Madler (1794-1874) known as the *'Mappa Selongraphica'* published in four parts between 1834 and 1836. This was followed in 1837 by their publication of a description of the Moon (Der Mond). These two works were the best descriptions of the Moon for many decades, and were not superseded until Johann Friedrich Julius Schmidt's (1825-1884) map in the 1870s.

In the years following the start of the 19th century experiments were being carried out by of Thomas Wedgwood (1771-1805) , Joseph Nicéphore Niépce (1765-1833), William Henry Fox Talbot (1800-1877) and Louis Jacques Mandé Daguerre (1787-1851), into a method of permanently capturing images of objects through the action of light on chemically treated surfaces [3]. Lunar Astrophotography was about to be born.

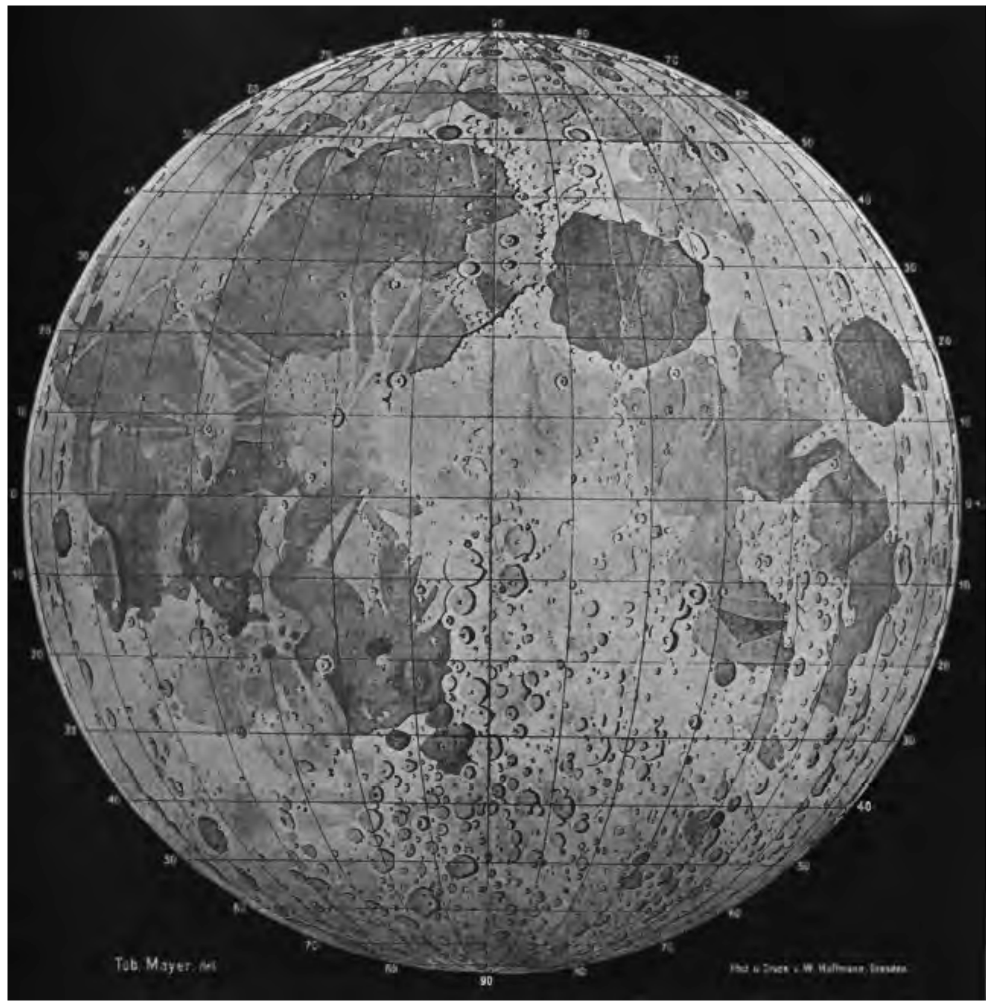


Giovanni Battista Riccioli, was born on the 17th April 1598 in Ferrara, Italy. He devoted his career to the study of astronomy, often working with Francesco Maria Grimaldi. In 1651 he wrote the important work Almagestum Novum. Despite his stated opposition to Copernican heliocentric theory he named a prominent lunar crater after him, and other important craters were named after other proponents of the theory, e.g. Kepler and Galileo Much of the nomenclature of lunar features still in use today is due to him and Grimaldi. He died in Bologna, on 25th June 1671.

Riccioli's Map of the Moon, 1651

Tobias Mayer (1723–1762) was a self taught German astronomer and mathematician, famous for his studies of the Moon. He was born at Marbach, in Württemberg, and brought up at Esslingen in abject poverty. In 1746, he entered J. B. Homann’s cartographic establishment at Nuremberg. Here he introduced many improvements in map making, and gained a scientific reputation which led in 1751 to his election to the chair of economy and mathematics at the University of Göttingen.

In 1754 he became director of the observatory, where he worked until his death in 1762. But his fame rests chiefly on his lunar tables of 1755 which were sufficiently accurate to determine the moon’s position to 5”, and consequently the longitude at sea to about half a degree.



Mayer’s Map of the Moon, 1775

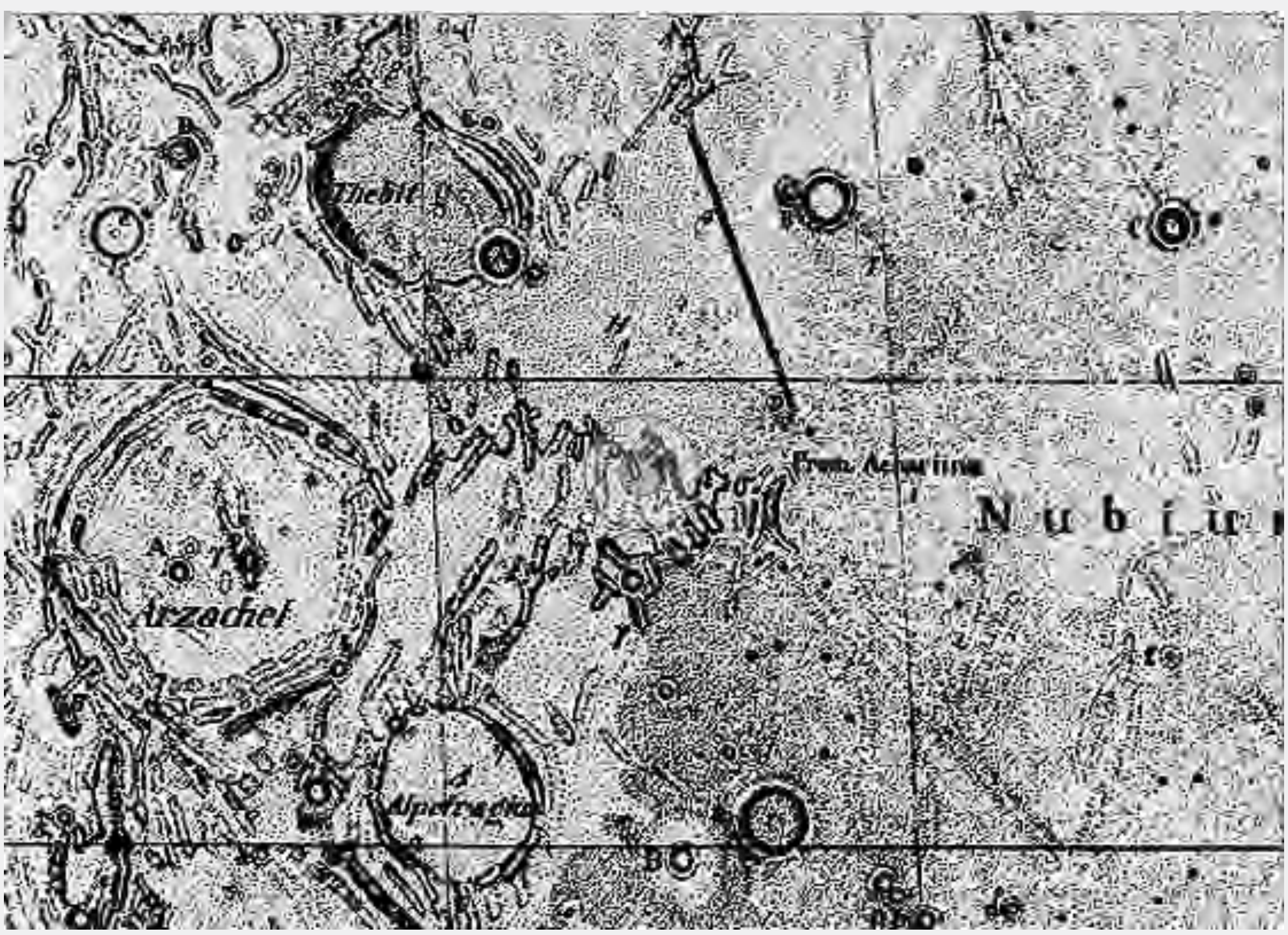
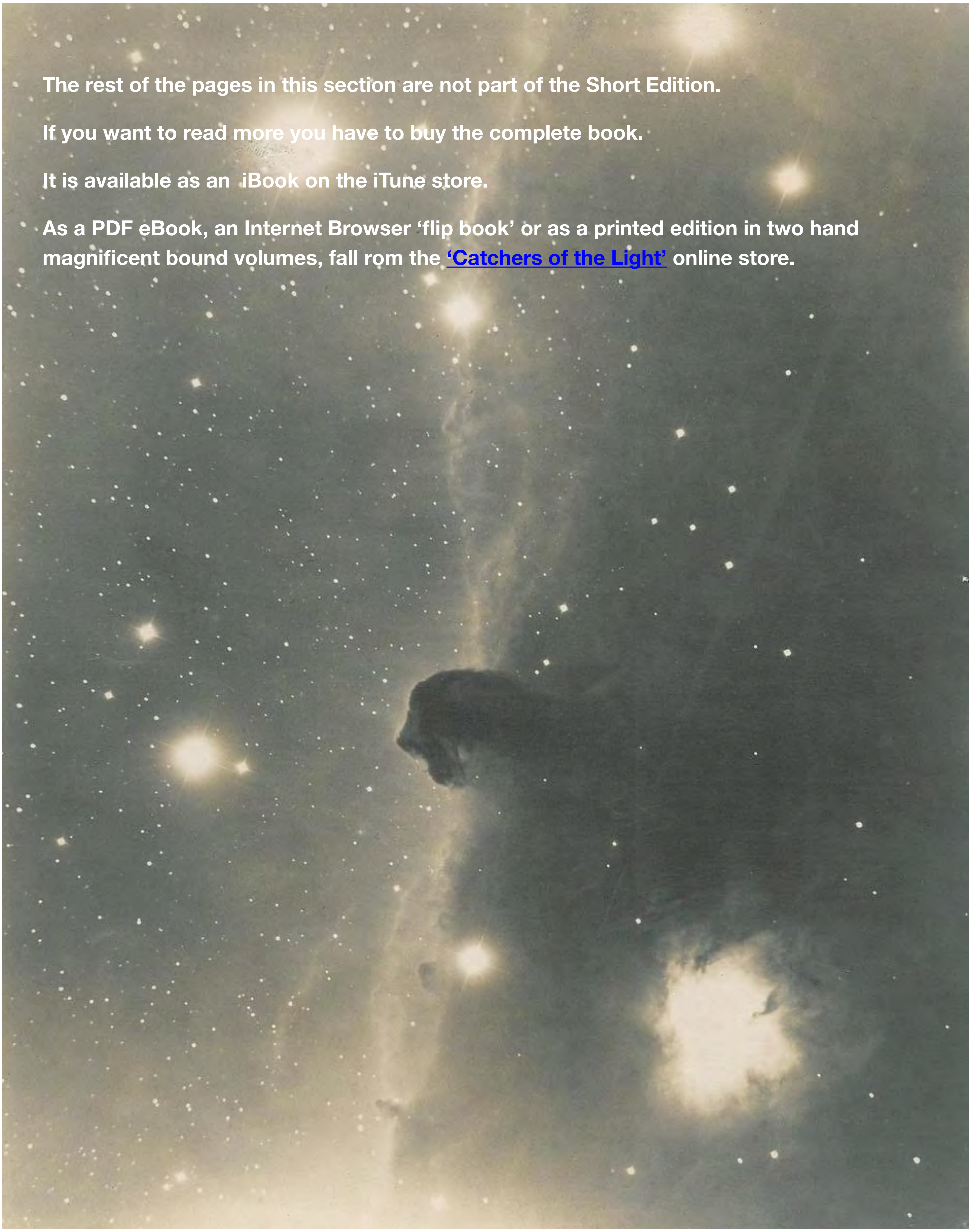


Chart from Beer & Madler’s Map of the Moon, 1837

Wilhelm Wolff Beer (4th January 1797 – 27th March 1850) was a banker and astronomer from Berlin, Prussia. Together with Johan Heinrich Madler (29th 1794 – 14th March 1874) he produced the first exact map of the Moon, Mappa Selenographica, published in four volumes in 1834–1836. In 1837 their description of the Moon (Der Mond) was published. In 1829 Beer decided to set up a private observatory with a 3.75-inch (95mm) refractor telescope made by Joseph von Fraunhofer, where Mädler was employed as his assistant. It was with this modest instrument that they produced their Mappa Selenographica.



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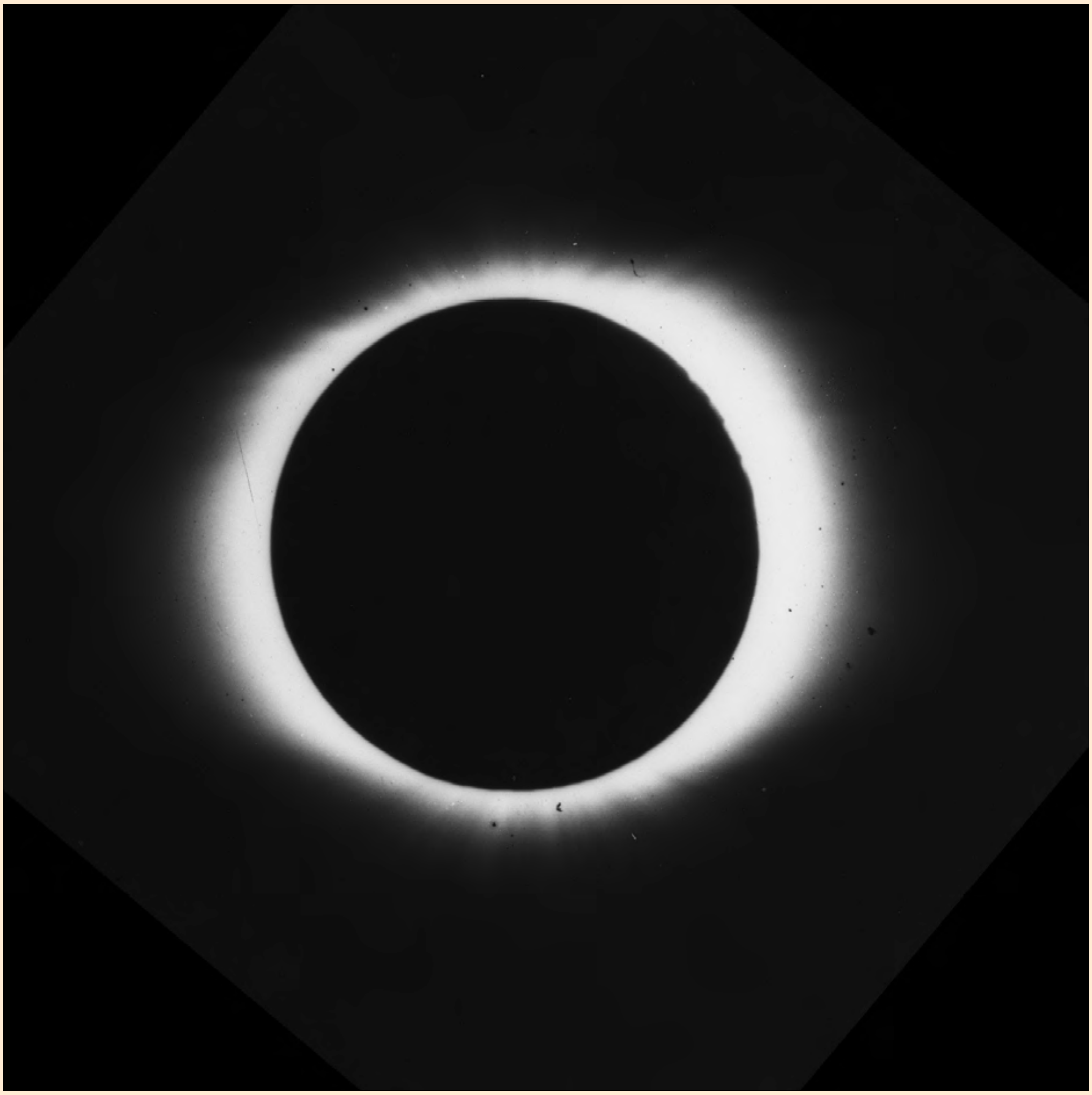
Part III

Sunlight

Solar Astrophotography



Total Eclipse of the Sun, William Harkness, 29th of July, 1878, Creston, Wyoming, USA

“Curse the man who invented helium! Curse Pierre Jules César Janssen!” - Principal Skinner from an Episode of the Simpsons TV Series, speaking of the man who in 1868 was the first to discover a chemical element on another world - in the atmosphere of our Sun.

III. Solar Astrophotography

Having successfully imaged the Moon - the brightest object in the night sky, the pioneers of Astrophotography naturally turned their focus to the Sun - the brightest object of them all.

The earliest extant large scale image of the Sun's surface dates from the 2nd of April 1845 and was taken by the two French physicists, Armand Hippolyte Louis Fizeau (1819-1896) and Jean Bernhard Leon Foucault (1819-1868) from the Paris Observatory. However it is known that by the August of 1843, they had obtained '*coin*' size images of the sun's face which clearly showed the presence of spots.

The first attempt to image an Eclipse of the Sun was made by the Italian physicist Gian Alessandro Majocchi from Milan on the 8th of July 1842, but he only succeeded in obtaining Daguerreotype photographs of the moments before and after totality. He also attempted to photograph the sun during Totality but his image unfortunately showed nothing. His photographs have not survived.

The first truly successful photograph of a Total Eclipse had to wait a further nine years before being taken. This meritorious event occurred on the 28th July 1851 when a Daguerreotypist named Berkowski from Konigsberg in East Prussia (now Kaliningrad, Russia) succeeded in capturing the moment of Totality. His photograph recorded the inner corona and several prominences. His first name is not known.

Over the course of the following decades astronomers and the Governments of their countries mounted many Eclipse expeditions to the far flung corners of their empires Their sole aim was to photograph the fleeting moments of totality. Most notably was the 1860 expedition to the village of Rivabellosa in Northern Spain, when on the 18th of July, Warren De La Rue (1815-1889) obtains two wet collodion photographs of totality using the Kew Photoheliograph. The Kew Photoheliograph was the first telescope specifically built to photograph the Sun.

The construction of the first Photoheliograph sparked an explosion in the construction of others of its kind, particularly by the English scientific instrument maker, John Henry Dallmeyer. In the 1870s an extraordinary breed of solar photographic cameras known as '*Revolvers*' began to appear. These remarkable instruments so called because of their apparent similarity in operation to the gun of the same name were an early forerunner of the Cine camera in that they took repeated images in quick succession to each other.

The most famous of these '*Repeating Photographic Devices*' were those constructed for the French solar physicist, Pierre Jules César Janssen (1824-1907). His device the '*Revolver Photographique'* was built to capture the transit of the planet Venus across the face of the Sun, due to take place on the 9th of December 1874.

Other similar devices were constructed by Dallmeyer for use by a number of British expeditions sent to the four corners of the world to do the same thing. At that time Transits of Venus provided a rare opportunity for determining the Earth-Sun distance. This was in the days before radar and space probes. A remarkable fact regarding these expeditions is that as far as it known, despite thousands of '*Revolver*' photographs being taken, not a single one has survived to this day.

In 1890 the solar physicist, George Ellery Hale (1868-1938) invented an instrument known as the Spectroheliograph, which was able to take photographs of the Sun at a single wavelength of light. With the aid of the Spectroheliograph, the red solar prominences, could for the very first time be photographed without the need for a total eclipse of the Sun.

The American astronomer, David Peck Todd (1855-1939) was without doubt the most unluckiest of people when it came to photographing a Total Solar Eclipse and in particular capturing the sun's '*pearly necklace*' known as the Corona. During the years 1887 to 1901, in the course of four separate eclipse expeditions, he failed to take a single image using his purpose built automated repeating photographic machines. In each instance he was '*clouded out*'. Only at the fifth attempt did he succeed during an eclipse expedition to Tripoli in Libya in 1905.

In 1914, Todd made another attempt to photograph a Total Eclipse with his new and improved automated equipment. However it ended in total and absolute failure. Not only did his equipment not arrive in Russia for the 21st of August, the date of the eclipse; but even worse the Danish scientist Dr. Nils Viktor Emmanuel Nordenmark (1867-1962) from his observing site at Solleftea in Sweden succeeded in taking the very first cine film of a total eclipse of the Sun. Todd's equipment had now been rendered 'out of date' by the onset of the modern movie age!

In 1930 even the need for a total solar eclipse of the sun to photograph the pearly white corona was rendered obsolete; with the invention of the Coronagraph by the French astronomer, Bernard Lyot (1897-1952). The Lyot Coronagraph, with the aid of a series of baffles and diaphragms removes the unwanted stray light, but at the same time keeps that which is required, and in doing so makes it possible to image only the edge of the solar disc and not its bright photosphere.

From the 1960s onwards with the coming of the space age, a number of satellites and probes have been used to study and image the Sun, including the hugely successful Solar and Heliospheric Observatory or SOHO for short. Following its launch in 1995 SOHO has sent back to us the most spectacular photographs ever taken of our Sun.

"In photographing the Sun through a telescope at the primary focus, as already mentioned the aperture should be stopped down to an equivalent of about f/64...: Slow lantern plates will be found best, and they must be carefully backed. Some form of fairly rapid shutter will be required. M. L. Rudeaux recommends a wide sheet of blackened card- board, with a slit about 1 1/3 ins. wide, which can be moved rapidly in front of the object glass. As the Sun's direct rays are very penetrating, it is well to cover up the dark slide and carrier during exposure with a focussing cloth or piece of dark calico."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

Partial Solar Eclipse, 1854, Langenheim Brothers

III.1

‘The ‘c’ Men’

Armand Hippolyte Fizeau

Born: 23rd September 1819, Paris, France

Died: 18th September 1896, Ferte-sous-Jouarre, Seine-et-Marne, France

Jean Bernhard Leon Foucault

Born 18th September 1819, Paris, France

Died 11th February 1868, Paris, France

Armand Hippolyte Fizeau and Jean Bernhard Leon Foucault were two of the greatest physicists of the nineteenth century. Their improvements to the photographic process and the development of terrestrial methods for the determination of a more accurate value for the speed of light, paved the wave for many advances in all branches of science. Together they obtained the first successful images of the Sun’s surface showing clearly the presence of sunspots.

III.1.1 Solar Photography

Although it was to America that the spoils of victory went in the race to take the first successful astronomical photograph, it was to France and Louis Jacques Mandé Daguerre (1787-1851), that John William Draper (1811-1882) owed the technical means by which he obtained his famous 1840 image of the Moon [1]. It was also to France that we owe the next major advance in Astrophotography, and the Solar Photography of Armand Hippolyte Louis Fizeau (1819-1896) and Jean Bernhard Leon Foucault (1819-1868).

The Moon and the Sun are by far the two brightest objects in the sky, with Sunlight dominating the daylight hours and Moonlight ruling over the hours of darkness. As John W. Draper had captured the image of the Moon, it was only natural that the Sun should be the next focus of attention in the new field of celestial photography. So it was to the Sun that Fizeau and Foucault applied their combined photographic expertise during the period 1843 to 1845.

According to the then Director of the Paris Observatory, François Jean Dominique Arago (1786-1853), the two Physicists took during this period a series of Daguerreotype images of the Sun, which were the first to successfully capture the face of our star [2]. Fortunately, one of these images has survived, dated the 2nd of April 1845 and shows clearly the presence of sunspots on its surface; and as such is one of the most important astronomical photographs ever taken.

Today the names of Fizeau and Foucault are not known for their photographic achievements, but as two of the greatest physicists of the nineteenth century. In particular, they were the first scientists to measure the speed of light by terrestrially based measurements and not through astronomical observation. Although they began working together at Arago's suggestion in 1845, they parted company after a few years and began to work independently of each other.

In 1849 Fizeau obtain a value for the speed of light '*c*', of 195,615 miles (315,000 km) per second - a number slightly higher (by about five percent) than that obtained by astronomical means, but certainly far more accurate than any previous terrestrial method had yielded. The modern figure for the speed of light is approximately 186,000 miles (299,700 km) per second [3].

A year later in the April of 1850 his former partner, Foucault had developed his own means of measurement and showed that light travels slower in water than in air. This was in accordance with what the wave theory of light predicted, but contradicted the predictions of Newton's corpuscular theory. Foucault is also better known today for his '*Pendulum*' experiment which demonstrated the daily rotation of the Earth on its axis; and as a telescope maker of some note.

The lives and careers of Fizeau and Foucault are so entwined that it is impossible to tell the story of one without telling that of the other. After all, they were born within five days of each other in Paris; they attended the same school; they both had intended to follow a career in medicine; they were experts in the use of the newly invented Daguerreotype photographic process; and they also worked together at the Paris Observatory.

They were for many years like twin brothers, until they fell out over the matter of '*c*', but not before they had written themselves into history as two of the great pioneers of Astrophotography.

III.1.2 Medicine

Armand Hippolyte Louis Fizeau was born in Paris on the 23rd September 1819, the second son of Louis Aime Fizeau (1775-1864) and his wife, Beatrice Marie Petel [4]. His father held the chair of Pathology at the Paris Faculty of Medicine, a position which brought the family both social prominence and wealth. Louis Fizeau came from a long line of doctors and it was expected that his son would follow in the family tradition. Intending to join his father in the field of medicine, the young Fizeau enrolled at the prestigious College Stanislas in Paris [5].

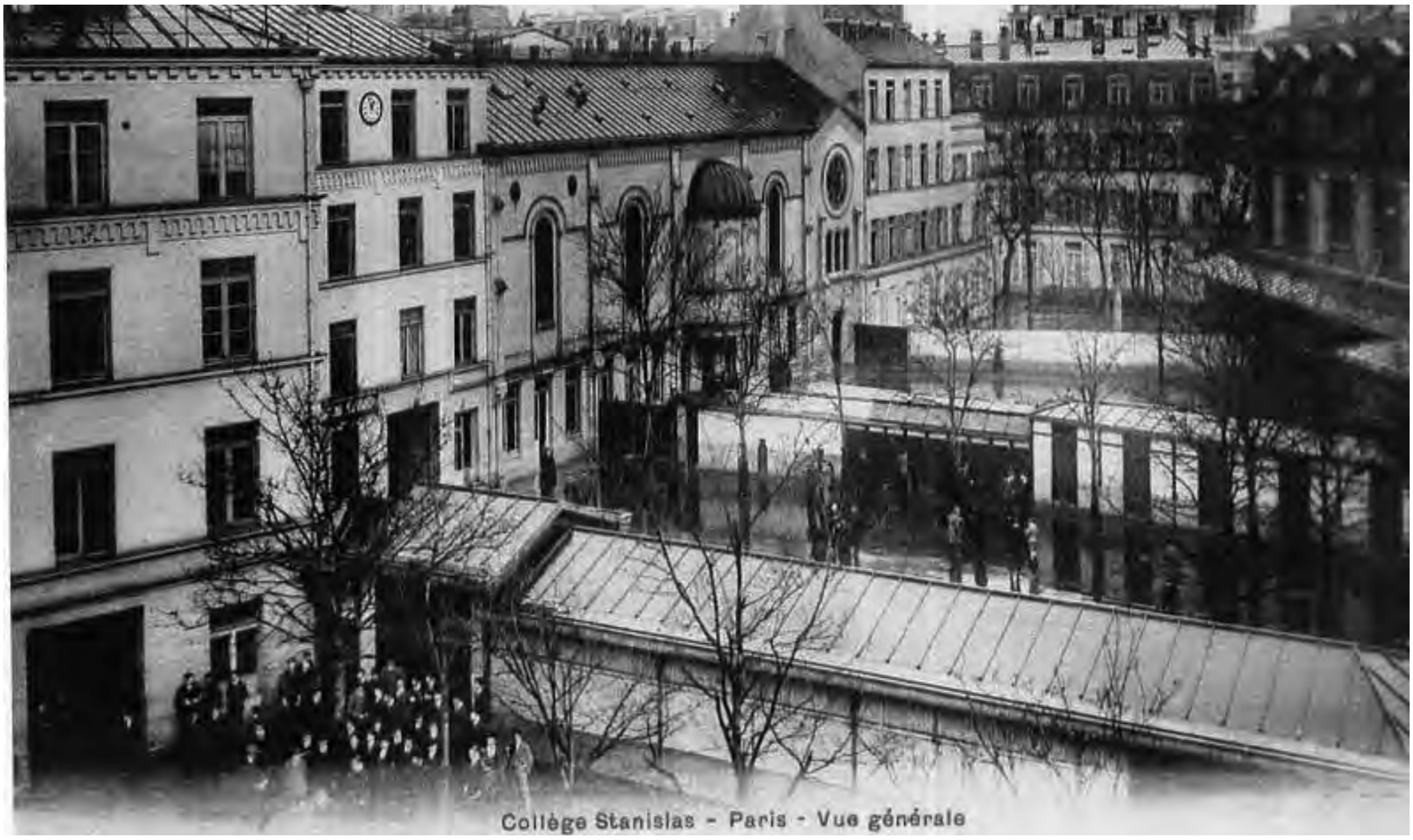
In 1840 Fizeau entered the Paris Medical School. However, he suffered severe migraines and decided to give up medicine. He spent a while travelling during which time he regained his health and began preparing for a career change away from medicine. He began attending the lectures at the Paris Observatory given by the renowned astronomer and physicist François Jean Dominique Arago (1786-1853). He also enrolled in a course on Optics at the Collège de France given by Henri Victor Regnault (1810-1878) and before long Fizeau had ended up studying Physics full time at the College. Arago and Regnault recognized Fizeau's potential and encouraged him towards a career in Experimental Physics – which he duly did.

Only a matter of five days and a few hundred metres separated the birth of Fizeau and Jean Bernhard Leon Foucault, who was born in Paris on the 18th September 1819; the eldest child and only son of the publisher, Jean Leon Fortune Foucault (1784-1839) and his wife, Aimee Nicole Le Petit (1793-1880) [6]. When Foucault was young, his father retired due to ill health, and the family moved to Nantes, where they owned property. His father's poor health left him virtually fatherless and had to be brought up by his mother, who decided that they would return to Paris, so from the age of ten Foucault lived with his mother in a rather fine house on the junction of Rue de Vangirard and Rue d'Assas. The house is still there today and is marked by a commemorative plaque. His father eventually died in 1839, an event which greatly affected the deeply sensitive Foucault [7].

Although Foucault's mother could not give her son back his father, she could ensure that he received a good education, and sent him to the Collège Stanislas; but like many a young boy, he did not make the most of the opportunities afforded to him. His teachers described him as lazy, he did not submit work on time, and his mother was forced to employ tutors to educate him at home. Foucault did, however, become a friend of one of the students at the Collège Stanislas, namely one - Armand Hippolyte Louis Fizeau.

If academic work was not to Foucault's liking, he did however, begin to show other talents. As a teenager he constructed toys and machines, some of which were really highly sophisticated, and included a steam engine and a telegraph. His skill with his hands suggested to his mother that he would make a fine surgeon. In 1839 following his graduation from high school, he enrolled as a student like Fizeau, at the Paris medical school. At first all well and his tutor, Professor Alfred François Donné (1801-1878), was very pleased with his progress. However, on his first spell of hospital experience he saw some blood and fainted.

After trying to overcome his blood phobia, he realized that he would never be able to finish his studies and become a doctor. Donné, however, wanted him to continue using his talents to help medical science in a way that did not involve him coming in contact with ill people, so he employed him as his assistant.



College Stanislas, Paris

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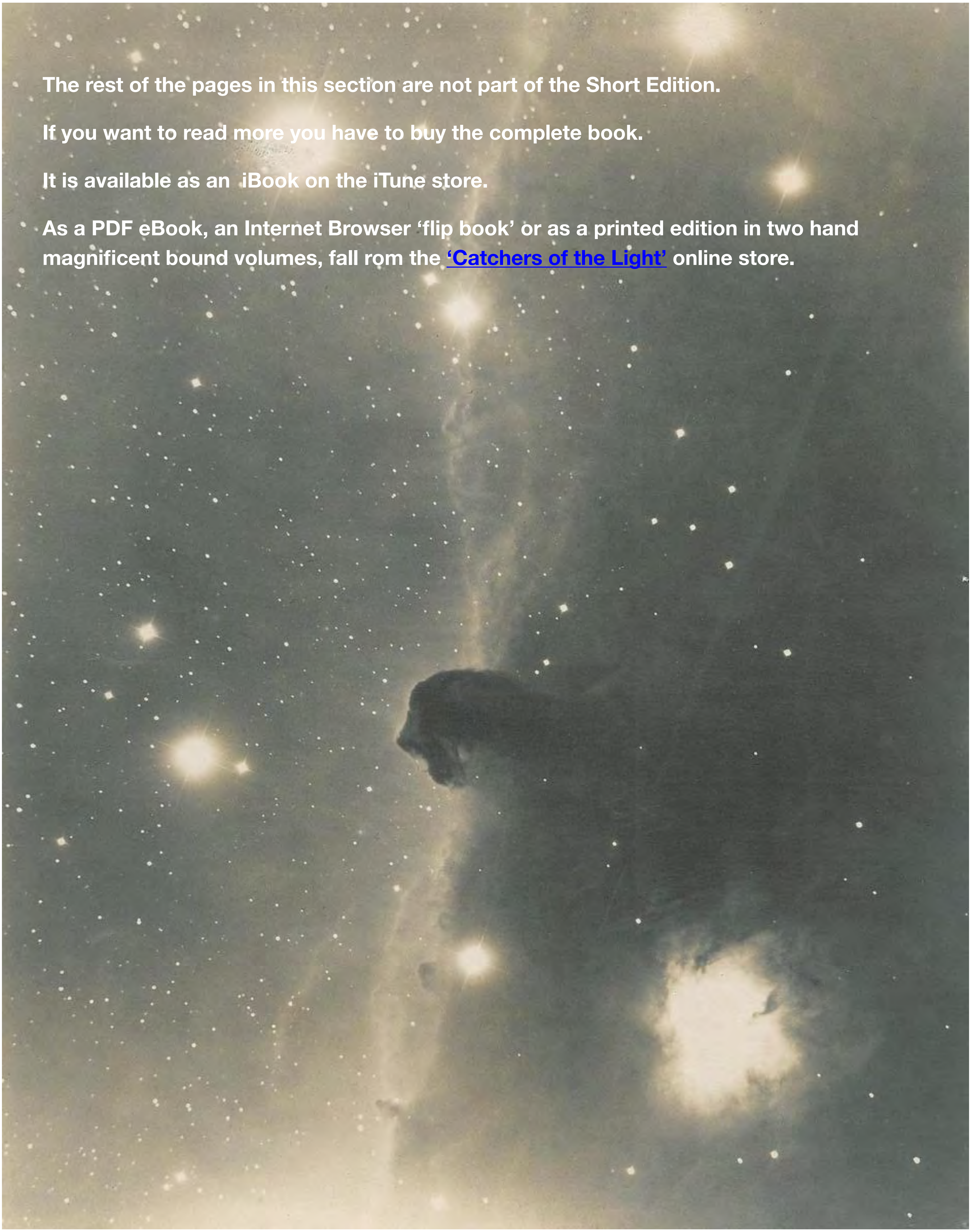


III.2

'The Stationery Man'

Warren De La Rue

Born: 18th January 1815, St. Peters Port, Guernsey, Channel Islands

Died: 19th April 1889, Portland Place, London, England

The Channel Islander, Warren De La Rue was the *'Foremost Celestial Photographer'* of his adopted country, England; who did his finest work in the years before the likes of Henry Draper, Isaac Roberts, Andrew Ainslie Common and Edward Emerson Barnard made their own great contributions. In 1857 he produced the design for the Kew Photoheliograph, the first telescope specifically built to photograph the Sun. In 1860 it was taken by De La Rue, to Northern Spain to successfully photograph the Solar Corona during the total eclipse which took place on the 18th of July that year.

III.2.1 Collodion

Warren De La Rue was England's first Astrophotographer. In 1851 during the '*Great Exhibition*' held at the Crystal Palace in London, he saw Daguerreotypes of the Moon by the Boston Daguerreotypist, John Adams Whipple (1822-1891). The sight of these images of our nearest celestial neighbour was a turning point in his life, so much so that they inspired him to devote all his energies to replicate and improve upon them.

One year later he had done just that, as Lady Margaret Huggins later wrote [1]:

"In 1852 Mr. De La Rue, working in his little garden at Canonbury with a 13-inch reflector and availing himself of the Collodion process, succeeded in obtaining a really excellent picture of the Moon; and to him therefore belongs the credit of first employing the Collodion process in celestial photography, as well as that of obtaining the first very valuable success in lunar photography."

In the years which followed he was to do even better, ultimately becoming England's *'Foremost Celestial Photographer'*. All of this was made possible by the wealth gained from the family's Stationery business, which gave De La Rue both the means and the time to achieve the great goal he had set.

It was however his work on the construction and subsequent use of the *'Kew Photoheliograph'* – the first telescope built specifically to image the Sun - where his greatest legacy is to be found.

III.2.2 Shoreditch

Warren De La Rue was born on the 18th of January 1815 in St. Peters Port, on the Channel Island of Guernsey; the first child of Thomas De La Rue a printer & publisher; and his wife Jane Warren; a native of the village of Bishops Nympton in Devonshire, England [2].

In about 1818 when Warren was barely three years old Thomas De La Rue moved with his family to England and set up home at No. 45 Crown Street, in the Shoreditch area of Middlesex, on the outskirts of London's square mile. He obviously felt that better prospects awaited him amongst the teeming streets of London's metropolis and he was right. His first business was not in printing but in the manufacture of '*Leghorn*' straw hats [3].

The young Warren De La Rue grew up in Shoreditch with his younger brothers and sisters. His parents gave birth to ten children in all, of whom only six survived into adulthood [4]. It was not long before Warren was sent abroad for his education at the Collège Sainte Barbe, Paris [5]; his father taking the view that his son would receive better tuition if it was French and not English.

Whilst Warren was at school his father's business activities went from strength to strength. Thomas De La Rue gave up the straw hat manufacturing business; and in 1830 together with Samuel Cornish and William Rock he founded a business of playing card makers, hot pressers and enamelers. De La Rue's was the first company to print playing cards, and it received a Royal Patent to do so in 1831. The following year the company printed its first deck of cards.

Thomas De La Rue's first occupation on coming to England from Guernsey was not as a printer or publisher, but as a Leghorn Hat manufacturer with premises at No. 45 Crown Street, in the Shoreditch district of Middlesex. A Leghorn is a featherweight, open-weave hat made of specially cultured and woven wheat fibre, shipped from the port of Leghorn (Livorno), Italy, whence it gets its name. The finer, upper portion of the wheat stalk is plaited into Leghorn braid. This straw hat is light, durable, clear and bright in colour. It was a style of hat especially popular amongst ladies of the late Georgian and Victorian eras. The fashion for such hats lasted until the end of the nineteenth century, when new styles and materials appeared.

Leghorn Straw Hat

Thomas De La Rue Playing Cards & Royal Warrant of William IV, 1831

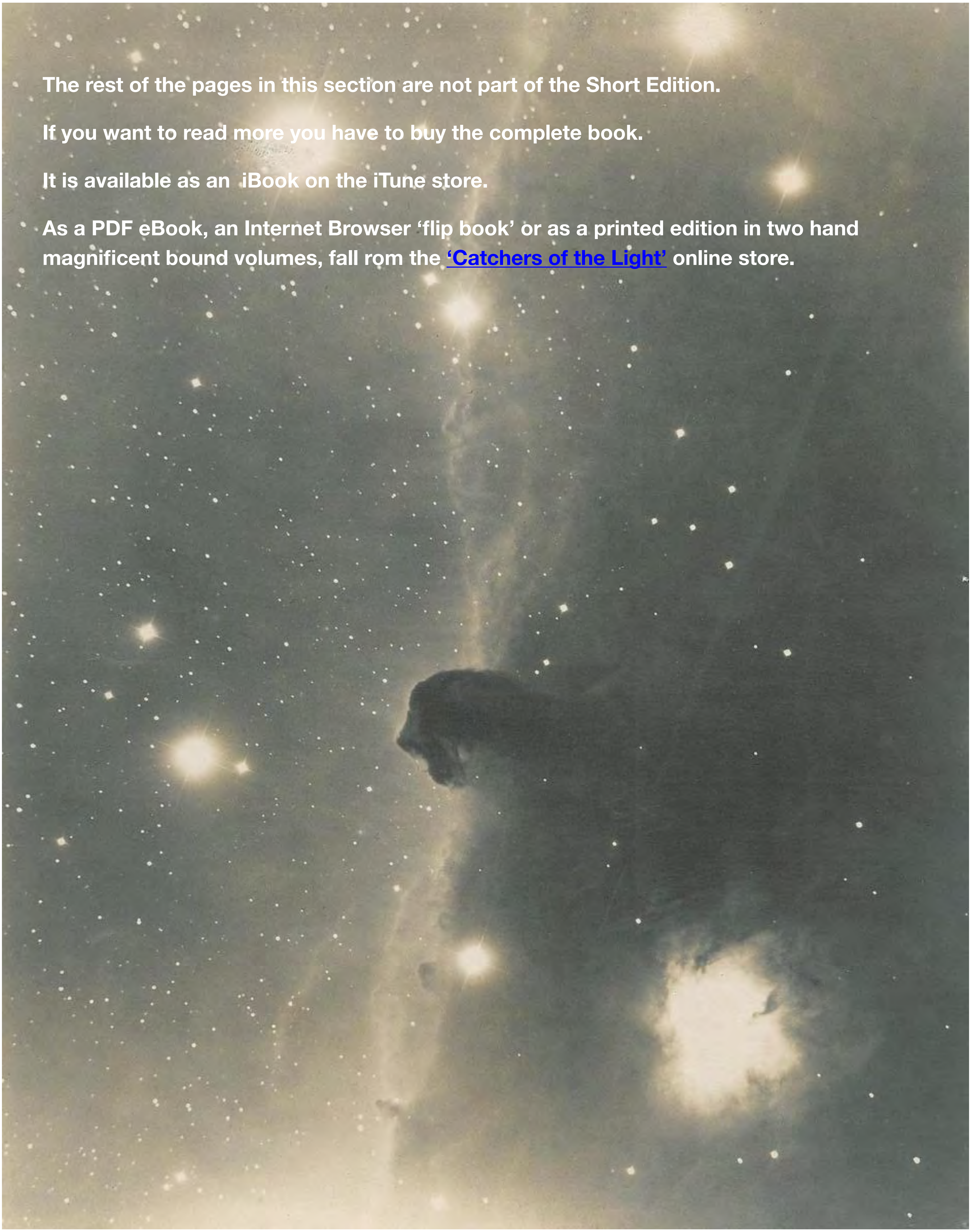
III.2.3 Bunhill Row

In 1833, Thomas De La Rue and his partners rented premises at 110 Bunhill Row, London where they established a wholesale and fancy stationers business [6]. From this small beginning, the De La Rue family would eventually build a great company which is still in existence to this day.

By the time of the 1841 Census Warren De La Rue was married and actively employed in his father's business at Bunhill Row. He had married Georgiana Bowles, a native of Guernsey at the Parish church of Saint Luke's, Old Street, Middlesex on the 17th of February 1840 [7], and was living at nearby Artillery Row, giving his occupation as a Card Manufacturer [8].

From an early age Warren De La Rue showed remarkable aptitude for anything mechanical or electrical, despite having received no known training in these areas [9]. He stayed a number of years in Paris before returning to help run his father's business activities. When he was just 21 Warren wrote his first scientific paper dated the 15th of September 1836, entitled *'On Voltaic Electricity and on the Effects of a Battery charged with Sulphate of Copper'*, which was published in the December 1836 edition of the Philosophical Magazine.

Thomas De La Rue & Co., 110 Bunhill Row, London, c 1833 & 1940



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III.3

'The Elemental Man'

Pierre Jules César Janssen

Born: 22nd February 1824, Paris, France

Died: 23rd December 1907, Meudon, France

Pierre Jules César Janssen used photography to study the Sun and was therefore one of the founders of Solar Physics. In 1868, during an expedition to India to witness a Total Eclipse of the Sun, Janssen noticed the presence of an unknown line in the yellow part of the solar spectrum at a wavelength of 587.4 nm; which was later found to be produced by a new and as yet undiscovered element – now known as Helium. This was the first chemical element to be discovered on another world.

III.3.1 'The Simpsons'

In an episode of the well known American cartoon series, the Simpsons, Principal Skinner, the head of Springfield School is seen to raise his fist and utter the words: *"Curse the man who invented helium! Curse Pierre Jules César Janssen!"* [1].

In 1868, over a hundred and thirty years earlier, the French scientist and astronomer, Pierre Jules César Janssen (1824-1907) had travelled to India to witness a Total Eclipse of the Sun, which was due to take place on the 18th of August that year. During the expedition he noticed the presence of an unknown line in the yellow part of the solar spectrum having a wavelength of 587.4 nm, which was totally unfamiliar to him:

"The bright yellow line was actually located very close to D [sodium], but it belonged to refrangible rays more than D. My subsequent studies on the Sun show the accuracy of what I say here."

However, the line was also noticed on the 20th October 1868 by the eminent English scientist, Sir Joseph Norman Lockyer (1836-1920) who in 1870 concluded that this was due to an unknown chemical element, which was later to become known as helium after the Greek God of the Sun – Helios [2]. This was a momentous observation as it led to discovery of the very first chemical element to be found on another world. Although, Janssen's observation of the chemical element Helium made him famous, it was not the only significant contribution he made to science.

In 1862 Janssen had established an observatory in the Montmartre district of Paris, where he carried out investigations into the Solar Spectrum. He believed that some of the dark absorption lines in its spectrum did not emanate from the Sun itself, but were caused by the earth's atmosphere. These became known as the Telluric Lines, a name given to them by Janssen.

On the 19th of August 1868, a day after the total eclipse, Janssen made a discovery which had a major impact on Solar Physics. He found a method of utilizing the Fraunhofer '*C*' Emission Line, also known as *'Hydrogen Alpha'* by which he could observe the spectra of Solar Prominences without the need for a Total Solar Eclipse. The same method was independently discovered somewhat later by his friend, Lockyer. The French Academy of Sciences struck a medal bearing the effigies of the two scientists to commemorate the achievement. A '*Hydrogen Alpha*' filter is still used today by the modern day Astrophotographer to obtain images of the Sun's surface, its prominences and flares. For this we have to thank Janssen and Lockyer.

In 1874 Janssen went to Japan to observe the transit of Venus, and in order to witness the exact moment of the planet's contact with the sun's limb, he had developed a special camera he called the *'Revolver Photographique*'. This remarkable instrument was able to take a rapid series of photographs with very short exposures showing Venus's approach towards the limb of the sun. It was the very first webcam!

However, it was his *'L'Atlas de Photographies Solaires'*, published in 1904, which earned Jules Pierre César Janssen his right to be called one of the great pioneers of Astrophotography and one of the founders of modern Solar Physics. This remarkable work contains some 6,000 photographs of the Sun taken in the years 1876 to 1903 from the newly established Meudon Observatory, near Paris; which was later to be known as the Paris Astrophysical Observatory.

III.3.2 Bank Clerk to Explorer

Pierre Jules César Janssen was born in Paris, France on the 22nd February 1824, the only child of Antoine César Janssen (1760-1860) and Pauline Marie Le Moyne (1789-?) [3]. His father was a well known clarinettist and his mother the daughter of the architect, Paul Guillaume Le Moyne [4]. His father made a good living from music and was well known in Paris as a designer of clarinets who made a number of important contributions to its development as an instrument [5].

At an early age as a result of carelessness by a nurse Janssen suffered an accident which rendered him lame for the rest of his life. He was a boy of many talents, demonstrated initially through painting and drawing. When he was sixteen he became a clerk at a bank and worked there for about seven years; spending his spare time studying mathematics. A subject he found so fascinating that he decided to give up a career in banking for one in science, something he clearly found more interesting!

He entered the College Bonaparte (now the College Royal de Bourbon) and around 1850 was awarded a Bachelor of Science Degree. He continued his studies at the Sorbonne where attended lectures given by some of the finest mathematicians of the age, including Augustin Louis Cauchy (1789-1857) and Urbain Jean Joseph Le Verrier (1811-1877). In 1852 he was awarded the degree of Licentiate of Mathematical Sciences and at a later date one in the Physical Sciences.

For the next decade Jules Janssen, as he preferred to be called, moved from job to job, not finding one to suit his particular tastes and interests. He had a brief spell as a computer at the Paris Observatory working under Le Verrier, who was at the time it's Director. This was followed by two years as an assistant Professor of Mathematics at the Lycée Charlemagne. He found such work was not for him, so he began to travel and seek new adventures abroad. In 1856 he went on a tour of Turkey, Egypt and Asia Minor, followed in 1857-58 by an expedition to Peru to determine the position of the magnetic equator, accompanied by two assistants, the brothers Alfred (1836-1921) and Ernest Grandidier (1833-1912). He became seriously ill with malaria during the course of the expedition and very nearly died, returning to Europe in the July of 1858 to recover [6].

The '*Simpsons*' is one of the most famous cartoon series of all time. It tells the story of a dysfunctional American family headed by the '*rotund*' Homer, his wife Marge (with the very blue hair), their irksome son Bart, their '*perfect*' daughter Lisa and baby Maddy (who never seems to grow up).

It has been said that the average American family more resembles the Simpsons than it does the Waltons.

"Curse the man who invented helium! Curse Pierre Jules César Janssen!" - Principal Skinner from an Episode of the Simpsons TV Series

The College de Sorbonne is largely synonymous with the Historic University of Paris and its successor institutions. It was closed during the French Revolution, but reopened its doors in 1808 on the orders of the Emperor Napoleon Bonaparte. Jules Janssen attended the University of Paris, and in 1852 received his licence ès sciences. During his time at the College de Sorbonne he was tutored by some of the finest mathematicians of the age, including Urbain Le Verrier and Augustin Louis Cauchy.

College de Sorbonne, Paris

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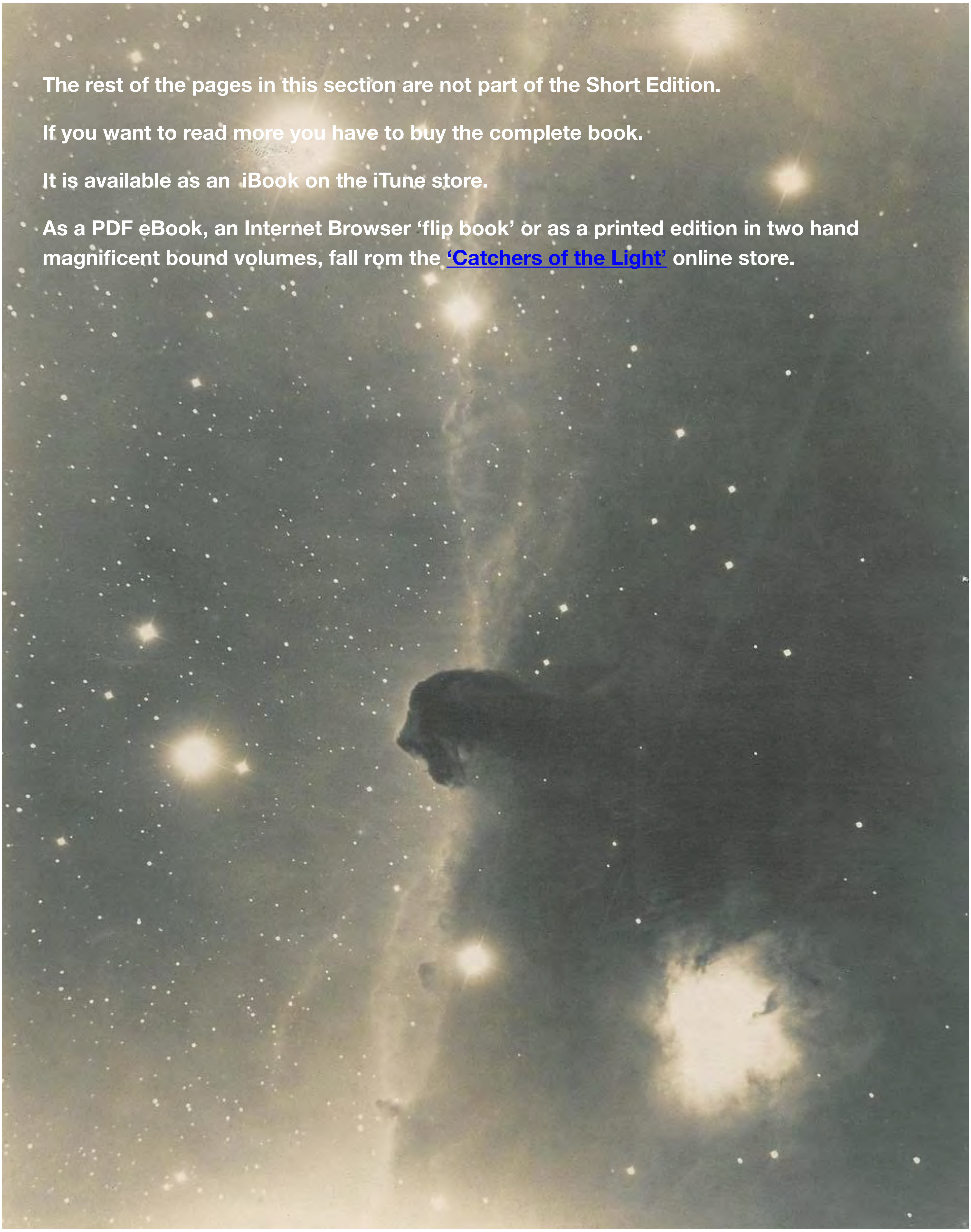
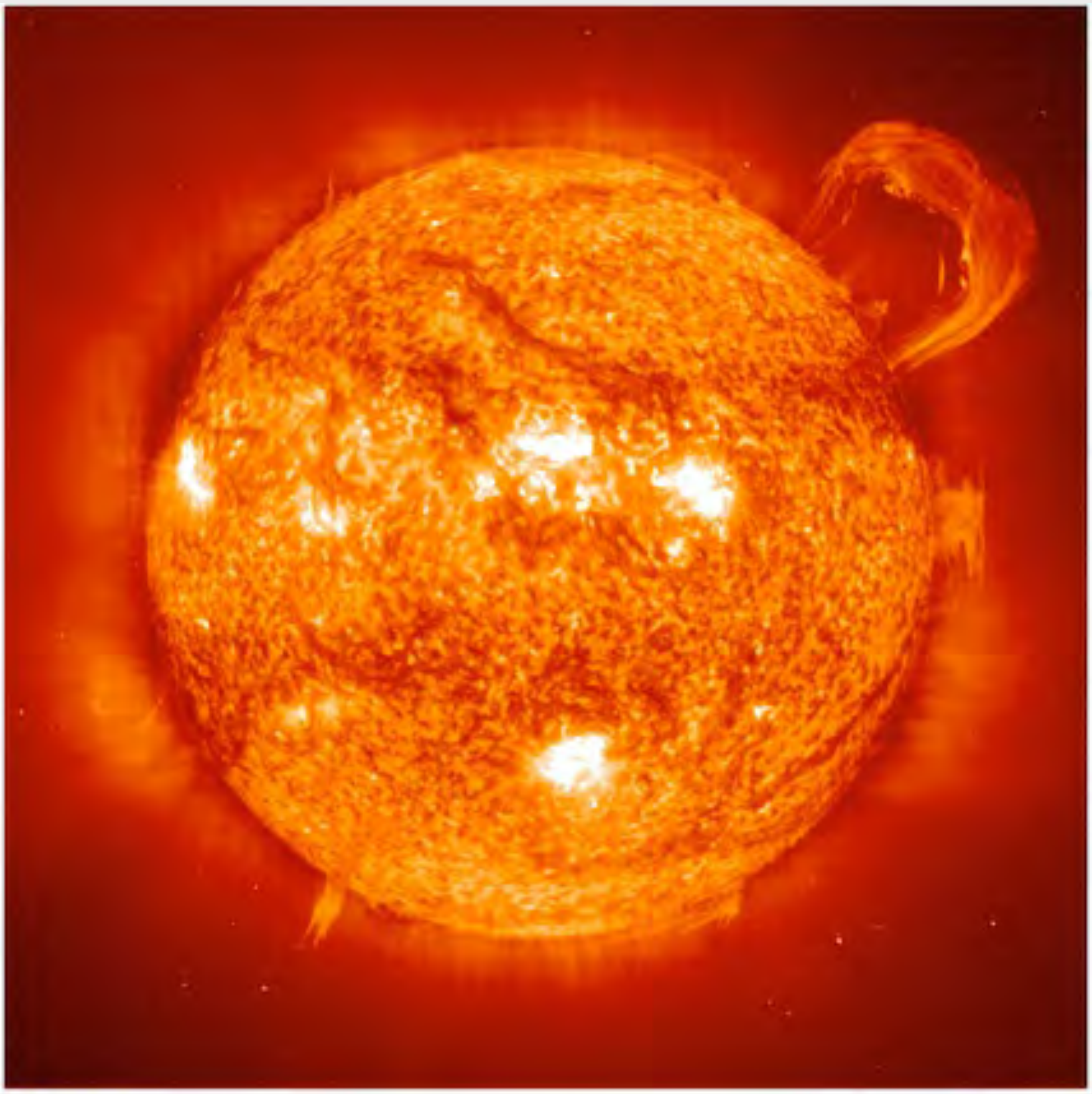


Short Edition

III.4

‘SOHO’

Solar Photographic Surveys



Ever since 1843, when Hippolyte Fizeau and Leon Foucault began taking the first images of the Sun, photography has been an important tool in helping man to understand the physics of our star. In the years since, many telescopes both on the ground and in space have been trained on its surface. With each passing generation we begin to understand more about the complex processes which make our Sun shine; and which ultimately supports all life on Earth.

III.4.1 Our Sun

Our Sun is the brightest object in the Heavens and the nearest star. It lies at a distance of only 92.95 million miles (149.6 million km) from the Earth – a mere stone's throw in the scale of cosmic measurement. It is not surprising that man from the very moment he opened his eyes to world around him - has observed it, studied it and even worshipped it as a God.

The Sun has never been an easy object to observe whether it be visually, telescopically, photographically or spectroscopically. It has the power to blind and cause damage to any form of instrumentation used to study it. Nevertheless this has not stopped man from devising mechanisms of ever increasing sophistication and incredible ingenuity in his attempts to understand the great processes which enable an object of 864,938 miles (1,391,980 km) across and weighing 1.99 x 10^{30} kg to *'shine'* for billions of years.

It must be remembered that our sun and every other star in the universe are nothing more than controlled nuclear bombs. If the cause of *'ban the bomb'* is taken to its literal conclusion, we and any other life that may be found in the cosmos would not exist. It is unfortunate that mankind neither understands the physics or the morals behind the nuclear processes which make stars '*shine*'; and as such does not to deserve the right to possess the knowledge to build such instruments of mass destruction, when in better hands it could be used for so much good.

The first attempts by man at observing the Sun were done visually; official records of naked eye sightings of sunspots in China go back as far as 28 BC and certainly as long ago as 364 BC [1]. It is also possible that the Greek Philosopher Anaxagoras observed a sunspot as early as 467 BC. However, the earliest attempts at viewing the sun in a scientific manner were made through the telescope by Galileo and Thomas Harriot around the end of 1610 [2]. Since that time a number of astronomers began to make extensive observations of the Sun, notably Christopher Scheiner (1573-1650), Pierre Gassendi (1592-1655), Johannes Hevelius (1611-1687) and Giovanni Battista Riccioli (1598-1671).

It was only after the introduction of the Daguerreotype photographic process in 1839 that the next major advance in the study of the sun became possible. In the August of 1843, the French Physicists, Hippolyte Fizeau (1819-1896) and Leon Foucault (1819-1868) took the very first images of the 'spotted' face of the Sun [3]. Although their first Daguerreotype photographs were only 13mm across, about the size of a small coin, they were large enough to show the presence of sunspots. They later produced larger images about 9cm across of which only one has survived, dated the 2nd of April 1845. The work of Fizeau and Foucault marked the beginning of Solar Photography.

In the years that followed improvements were made not only in the photographic processes used, but in the observing techniques adopted and more importantly in the instruments used. In 1860 Warren De La Rue (1815-1889) used Frederick Scott Archer's Collodion process to image an eclipse of the Sun from Rivabelossa in Spain, with the aid of the Kew Photoheliograph – the very first telescope specifically designed for Solar Photography. At the eclipse of 1878 the Gelatino-Bromide '*dry*' Plate was used for first time. The introduction of the '*dry*' plate was the second most important technological advance in the entire history of Astrophotography, being only surpassed by the use of the CCD chip in the 1980s [4].

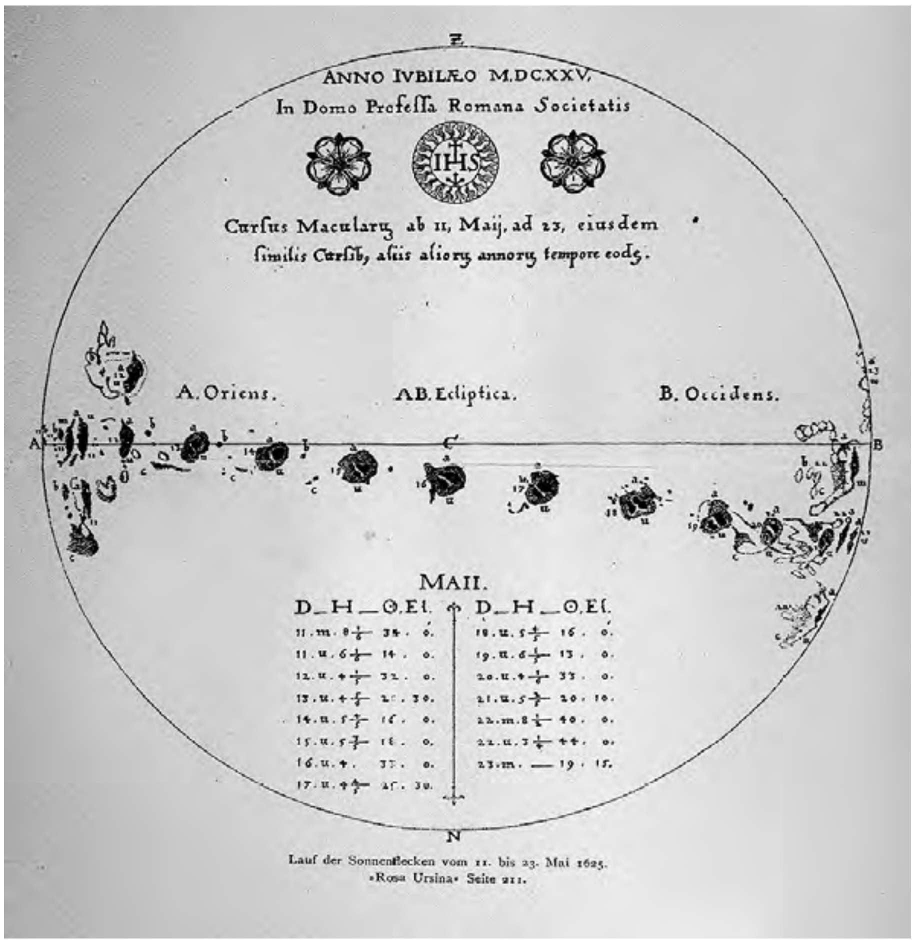
Although Jules Janssen (1824-1907) and Norman Lockyer (1836-1921) had discovered in 1868, a method of observing the solar prominences spectroscopically without the need for a total eclipse, it was not later that an instrument was designed which could photograph them without the need for an eclipse at all. In 1890, George Ellery Hale (1868-1938) invented the remarkable instrument known as the Spectroheliograph, which revolutionized Solar Photography. The importance of the Spectroheliograph lay in its ability to photograph the Sun in the light of a single wavelength, usually that of a chemical element present in its atmosphere, and in particular that of Hydrogen Alpha in the red end of the solar spectrum at 656.28 nm. With this remarkable instrument the red solar prominences could be photographed at will. The French astronomer, Heri Alexandre Deslandres (1853-1948) had developed a similar device somewhat later than Hale's.

Following his invention of the Spectroheliograph, Hale proceeded to build the first Solar Telescopes which made use of a movable mirror known as a Coelostat and to which was attached to a Spectroheliograph. This telescope was destroyed by fire shortly after its completion and was soon replaced in 1903 by the Snow Telescope. The telescope was moved in 1904 from its original location at the Yerkes Observatory, Williams Bay, Wisconsin, to its new home on Mount Wilson in California. The Snow telescope was the first telescope of the new Mount Wilson Solar Observatory, which now houses two other solar telescopes.

The pearly white necklace known as the Corona, that surrounds the Sun's photosphere was up until 1930 only visible during a total eclipse of the Sun. That year a device was developed by the French astronomer Bernard Lyot which did away the need for a total solar eclipse and could image them at anytime.

The launch of the Pioneer 5 space probe on the 11th of March 1960 heralded a new era in the study of the Sun. Although designed to study the interplanetary space between the orbits of Earth and Venus, it did however collect valuable data on the particles emitted by Solar Flares. It was followed by a number of other Solar missions, the most important of which was SOHO (Solar and Heliospheric Observatory); launched in 1995 this orbiting solar satellite has sent back to Earth some truly amazing images of the Sun.

The development of Solar Photography can be divided into three distinct parts – the imaging of the Sun's surface (section III.3), the photography of solar eclipses (section III.4) and the equipment used obtain the images (sections III3.5 to III3.8). Each of these is discussed in detail in the indicated sections of this Chapter.



Sunspots were first observed through the telescope by Galileo and Thomas Harriot around the end of 1610. However it was the German, Jesuit Priest and astronomer Christopher Scheiner (1573-1650) who made the first detailed set of sunspot observations. His observations were made during the period from 21st October 1611 to the June of 1627. He published over 70 drawings, from perhaps 900 observations; several '*observation days*' were often included within a single drawing.

He used Refractors of different dimensions, as well as various observational methods: pinhole projection, small mirror projection, and eyepiece projection, The whereabouts of his original drawings is unknown. In 1630 he published '*Rosa Ursina*', which became the standard work on sunspots for more than a century.

III.4.2 Pre-Photographic Drawings

The precursor to Solar Photography, were the drawings of the Sun's surface or Photosphere made by a legion of astronomers from Galileo onwards.

The scientific study of the Sun and its spots began in Europe, shortly after the introduction of the telescope into astronomy, by Galileo in 1609. Although there is still some doubt as to when and by whom the first telescopic observations of the Sun were made; we can say with a fair degree of certainty that it was either Galileo or Thomas Harriot, around the end of 1610.

Shortly afterwards David Fabricius (1564-1617) and his eldest son Johannes (1587-1616), and Christoph Scheiner made observations of sunspots in the March of 1611. Johannes Fabricius was the first to publish observations on sunspots. His book, entitled *'De Maculis in Sole Observatis'* - 'On the Spots Observed in the Sun', appeared in the autumn of 1611, but it remained unknown to the other observers for some time.

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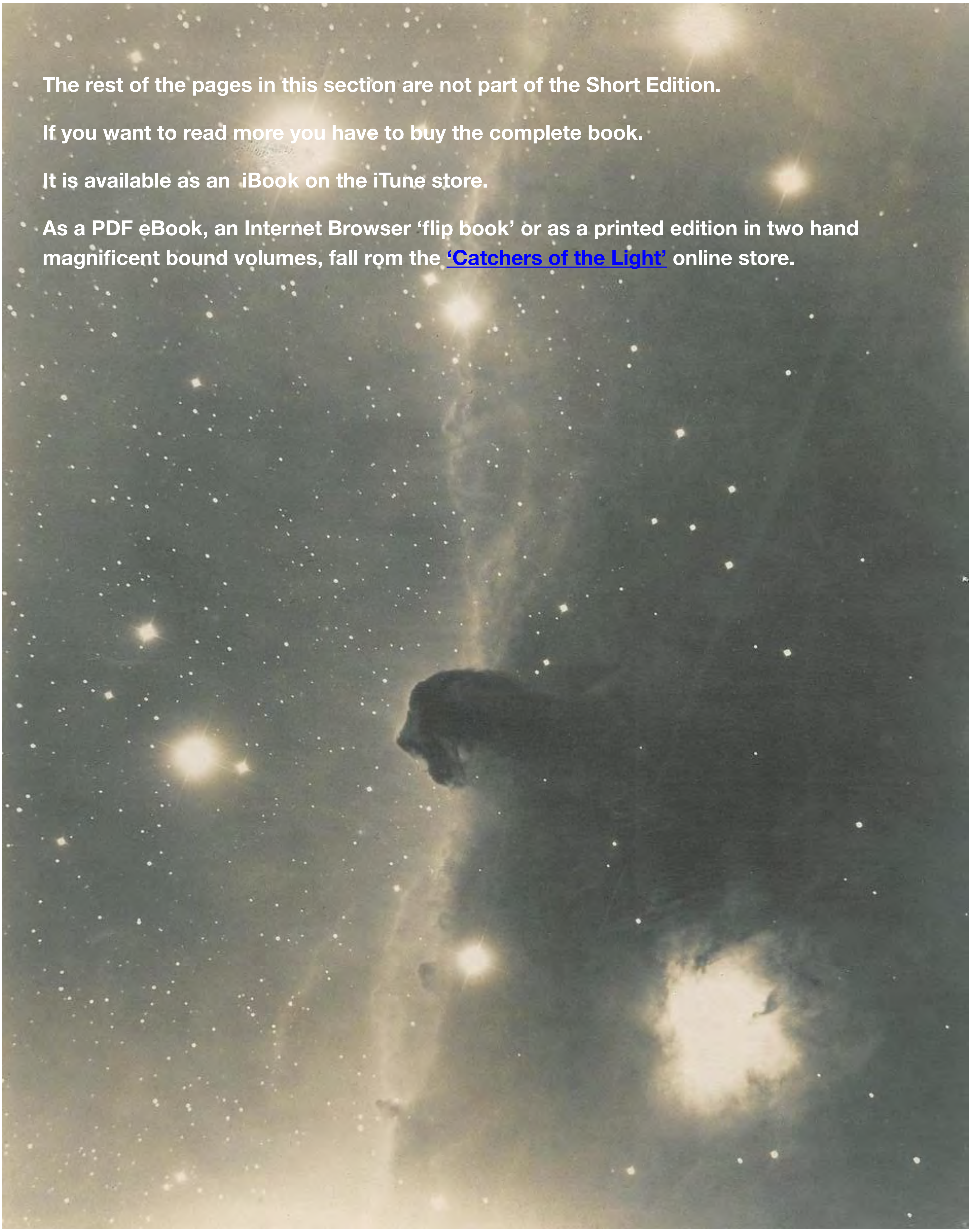
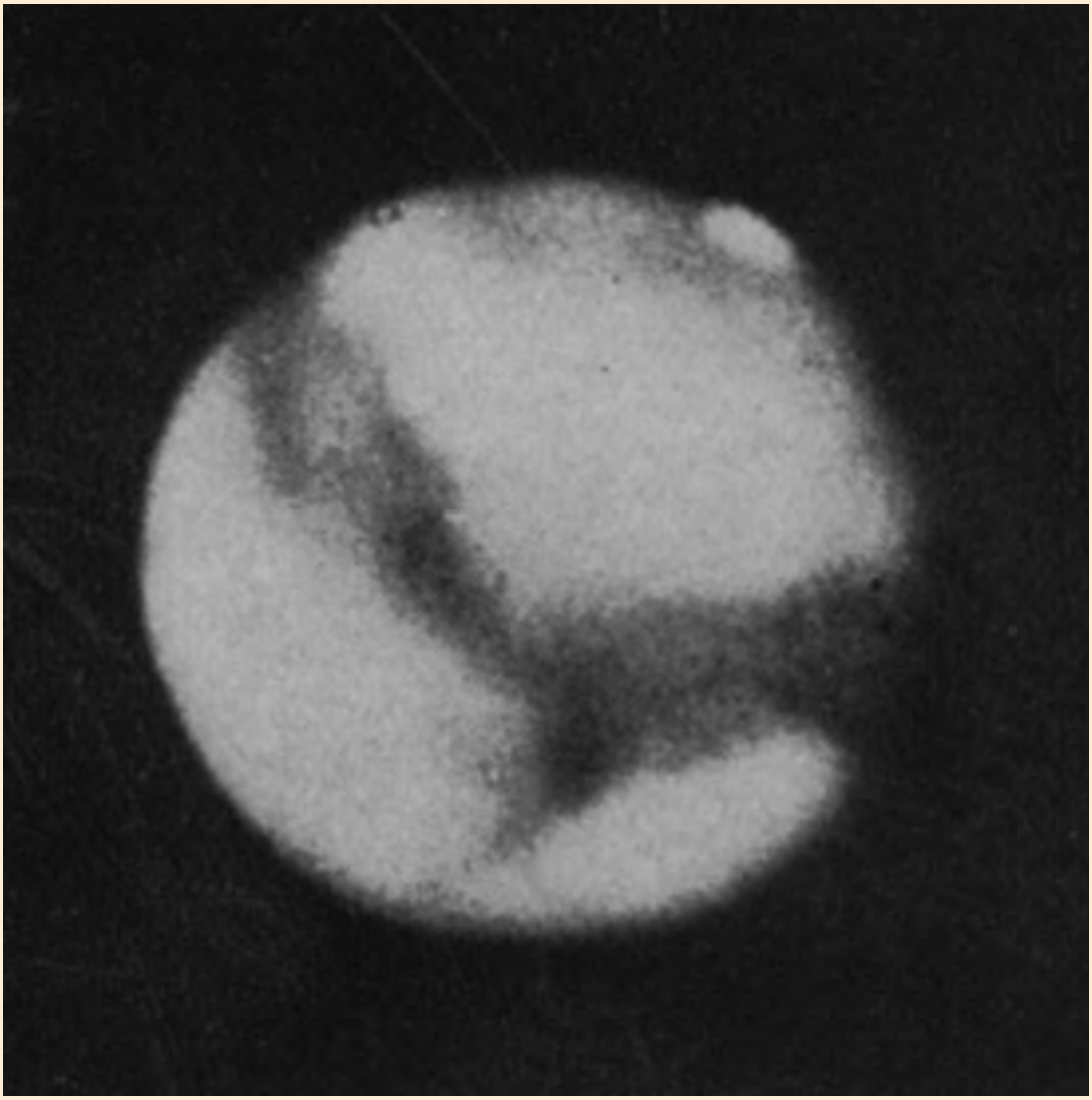


Part IV

Planets & Comets

Solar System Astrophotography



The Planet Mars, 60-inch Reflector, Mount Wilson, 1909, George Ellery Hale

"The only recorded photograph is one taken by Mr. Usherwood on Walton Common with a stationary camera furnished with a portrait lens of short focus.... We must content ourselves with noting the fact that Mr. Usherwood's was the first photograph taken of a comet." Edward Herbert Grove-Hills (1864-1922)

IV. Solar System Astrophotography

The successful imaging of the diverse set of objects contained in our Solar System represented the biggest challenge to date for the pioneers of nineteenth century Astrophotography. The earliest attempts by John Adams Whipple (1822-1891) carried out in 1851 and 1857, at photographing a planet, even one the size of Jupiter met with what can at best be described as limited failure. The images obtained of Jupiter were so small as to require a magnifying glass to discern its familiar zones and belts.

Other attempts by Warren De La Rue (1815-1889) who captured both Jupiter and Saturn in 1857 and Andrew Ainslie Common (1841-1903) with Jupiter alone in 1879 met with similar failure due to the size of the images obtained, which were only a millimetre or less across.

It was not until 1858 that the first success came in photographing a body contained within our Solar System and even then it was not a planet, but ironically a much more difficult target - a Comet. On the 27th of September 1858, William Usherwood (1821-1915), a *'wedding and baby'* photographer from Walton-on-the-Hill, Surrey, England imaged Donati's Comet - head, tail and all using his jobbing portrait camera. This was a day before a failed attempt was made by George Phillips Bond, using the *'Great Refractor'* at the Harvard College Observatory.

Only in 1885-1886 did astronomers succeed in obtaining a large scale image of a planet. This was achieved by the two brothers Pierre Paul Henry (1848-1905) and Mathieu Prosper Henry (1849-1904) when they used a 33 cm (13 inch) photographic refractor at the Paris Observatory to image both Jupiter and Saturn. Their success was due to the use of a refractor of large focal ratio f10.4 and an enlarging lens of magnification x11.

This event took place a full five years after Henry Draper had obtained his iconic photograph of the '*Great Nebula*' in Orion - an object whose light took not minutes to reach us as is the case with a planet, but over 1300 years. The early years of Solar System Astrophotography were proving much more difficult than anyone could possibly have imagined.

However further success came on the 22nd of December 1891 when the then German amateur, Maximilian Franz Joseph Cornelius Wolf (1863-1932), discovered asteroid No. 323 '*Brucia*' from his observatory at Heidelberg. It was the first asteroid to be discovered photographically.

Not so successful were attempts by astronomers to photograph the Red planet, Mars. The story of these attempts represent without doubt the nadir or in more modern phraseology - the '*pits*' of nineteenth Astrophotography. Not until the Martian images of Carl Otto Lampland and Earl Carl Slipher taken during the first decade of the twentieth century were the first detailed photographs obtained of the planet.

In the November of 1885 that most transient of phenomena, the meteor or shooting star was seen for the first time as trail some 7mm long on a photographic plate taken by Ladislaus Weinek (1848-1913), the Director of the Klementium Observatory in Prague.

The German Otto Rudolf Martin Brendel (1862-1939) during an expedition to Bossekop in northern Norway with Otto Baschin in the winter of 1891-1892 to study the Northern Lights imaged this most beautiful of all of nature's splendours. His photographs obtained in the January and February represented the first ever successful images of an Aurora.

The cloud shrouded planet Venus proved elusive in showing anything other than a blank face when observed visually or by photography. Only in the March of 1921, did an amateur from Salt Lake City, Utah, named Alfred Rordame (1862-1931) obtain a photograph using his 16-inch Mellish reflector, which showed for the very first time markings in its atmosphere.

The so called ‘*Green Flash*’ seen as the sun rises or sets, is however the most elusive of all nature’s phenomena. A person can look for it their whole lifetime and never see it. I have looked almost every day for over ten years and still not glimpsed even a speck of green. It took until the September of 1925 before the French astronomer, Lucien Rudaux (1874-1947) obtained the first photograph of it, albeit in black and white.

Ironically the last planet to be photographed was our own world - the Earth; when a camera aboard a captured ‘*German*’ V2 Rocket; obtained on the 24th October 1946, the first ever photograph of our planet from Space.

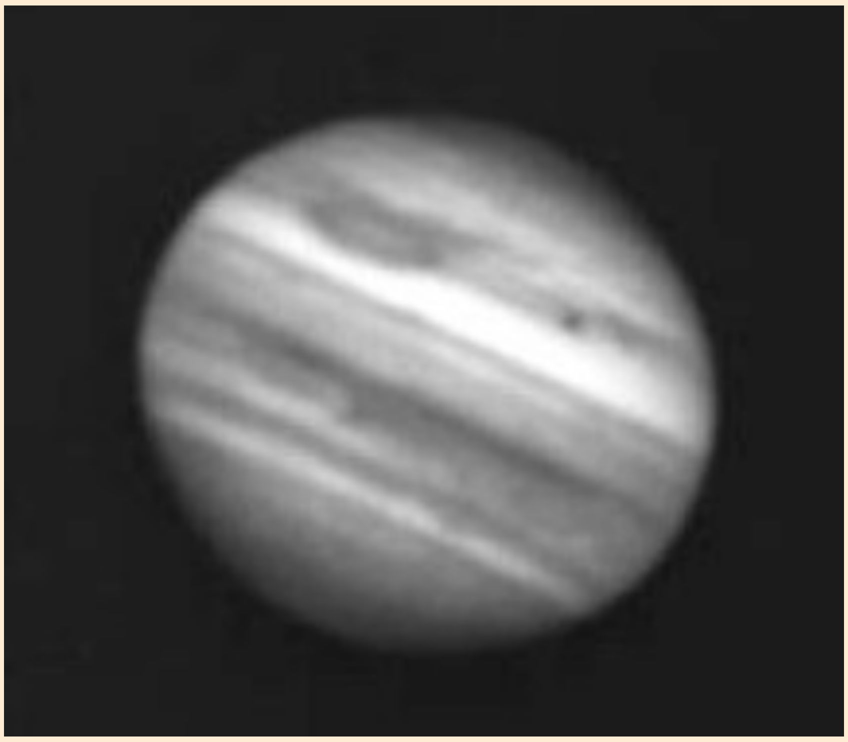
The arrival of the age of the space probe in the 1960s marked the beginning of a new phase in Solar System Astrophotography. In 1964, the Mariner 4 spacecraft returned the first pictures of the Martian surface. They showed a cratered, seemingly dead world which largely changed the opinion of the scientific community on whether life existed on Mars, from a ‘*maybe*’ to a ‘*probably not’* vote.

Over the course of the decades which followed space probes went to fiery furnace world of the innermost planet, Mercury; landed on inhospitable toxic surface of Venus, roved around the red planet and travelled to the great gas giants of Jupiter and Saturn, then onto the ice giants that are Uranus and Neptune. A probe is even on its way now as I write these words to the now demoted ninth planet - Pluto and is due to arrive at the dwarf planet in the July of 2015.

The images returned to Earth by these probes (and not forgetting the Hubble Space Telescope) represent the finest and most detailed ever captured of the planets, asteroids, comets and natural satellites that make up our Solar System.

“The Planets - Very little useful work is possible with amateur equipment, and under the best circumstances the results will be far inferior to these obtained by visual observation even with a very small telescope...Unless a long focal length is available, the image of a planet is so very small and faint, that when sufficiently enlarged, the grain of the plate is so pronounced as to blot out all detail.”

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.



Jupiter & its ‘Red Spot’, William Hammond Wright, 1927, 36-inch Refractor

IV.1

'The American Pioneer'

John Adams Whipple

Born: 10th September 1822; Grafton, Massachusetts, USA

John Adams Whipple not only made significant contributions to the development of early photography, he was also one of the great pioneers of Astrophotography. It is likely that he was the first person to successfully image a planet, when he obtained Daguerreotype images of Jupiter in 1851. His planetary images preceded those of the Henry Brothers by over thirty years. Sadly the photographic plates have not survived.

IV.1.1 Forgotten Pioneer

Today the name of John Adams Whipple (1822-1891) is largely forgotten; his work is confined to the past like that of so many other early pioneers of photography [1]. Yet in his day he was celebrated for his achievements not only in being one of the first Americans to practice Photography, but to use this new '*art form*' for scientific purposes [2]:

"In looking back upon this early period in the history of photography, we find it claiming the attention of our most learned scientists as an aid to the study of the sciences, particularly in astronomy and terrestrial phenomena, anatomy and diseases, and proved of great aid in their study.

The most notable practical Daguerreians, who devoted most of their time in investigating photography as an aid to science and the fine arts, and gave the most practically valuable results, were Messrs. Whipple and Black, of Boston, who spent much time and money in their experiments. They accomplished feats in telescopic photography that were a marvel at that time, and which gained for them a high reputation throughout the scientific world.

We are indebted to them largely for the position that photography took in its application to scientific investigation, particularly after the discovery of the collodion film."

The work of John Adams Whipple was seen by the general public at the very first '*World's Fair*' held in 1851 at the Crystal Palace, London; where he exhibited prize winning Daguerreotype photographs of the Moon. He was one of only a small number of Americans to exhibit photographs at the Exhibition and one of the three to be awarded a medal [3].

Over a ten year period, John Adams Whipple collaborated with William Cranch Bond and his son George Phillips Bond, the first two Directors of the Harvard College Observatory in the earliest investigations into Stellar Astrophotography [4]:

"About seven years since (July 17, 1850,) Mr. WHIPPLE obtained daguerreotype impressions from the image of alpha Lyrae formed in the focus of the great equatorial …"

In 1851, he took some Daguerreotype images of the planet Jupiter which purportedly showed its famous *'belts'.* If this is so then he was the first person to photograph a planet [5].

He was one of the truly great pioneers of Astrophotography.

IV.1.2 Daguerreotypist

The small town of Grafton in Massachusetts had been the home of the Whipple family since before its incorporation in 1735 [6]. John Adams Whipple was born there on the 10th of September 1822, the eldest of the five children of Jonathan Whipple (1795-1850) a Gum Copal worker [7], and his wife Melinda Grout (1799-1863).

From an early age he loved to study and was more interested in learning than in toys and other indulgences common to boys of his age. Chemistry was his overriding passion and it was to this subject he devoted all of his energies, effort and money. It was said that his parents were displeased with what they considered gross profligacy, when the young Whipple began to spend all his pocket money on chemical experiments.

This did not deter him. So when the Daguerreotype photographic process was introduced into America in the years 1839 to 1840 it was only natural that he should be fascinated by the '*chemistry'* of it. He made his first daguerreotype in the winter of 1840, using a sun-glass for a lens, a candle box for a camera, and the handle of a silver spoon as a substitute for a plate.

At the age of eighteen, John Adams Whipple realized that Grafton held nothing for him. If he was going to progress in life and pursue a career in chemistry - it was not going to happen in Grafton; so he left to seek his fortune in the city of Boston. As is often the case in life it is chance events that change a person's life, and not deliberate planning or actions – so was it with John Adams Whipple. One day shortly after his arrival in Boston, he happened to be visiting a philosophical instrument maker; there he met a gentleman who was trying to find Iodine Chloride [8] (as you do!). He had searched everywhere in the city without success, no one seemed to know anything about it.

Whipple seeing an opportunity to create an impression and show off his knowledge of chemistry, immediately offered to make him some – much to the gentleman's surprise. He had been made an offer he could not refuse. In a few hours it was prepared and delivered. Through this stroke of luck, Whipple's years of study and dedication had finally earned him money, rather than costing him money. It was not long before he began to manufacture and supply all the chemicals for the ever increasing number of Daguerreian '*artists*' who needed them. Unfortunately his health began to suffer from the effects of the fumes of the toxic chemicals, so he decided to concentrate on Photography itself.

In 1843 he took up the camera and photography as a profession, at first working alone and then, two years later in partnership with Albert Litch, a fellow Boston Daguerreotypist. He now devoted all of his time to creating Daguerreotype miniatures; and with his great knowledge of the chemicals used he always created portraits for his clients of such excellence which anyone would be proud to own - and inevitably '*show off'* to their family and friends. Very soon the name of Whipple was associated with all that was excellent in the Daguerreian Art. His partnership with Litch was short lived, and only lasted until about 1847 when Litch left to pursue his '*own thing*' – which always meant going into business with others that never lasted [9]. The reason for the breakup of his partnership with Whipple is explained by the following which appeared in the Boston Medical Journal for 1869 [10]:

> **EXTRA-LARYNGEAL OPERATION FOR THE REMOVAL OF GROWTHS UPON THE VOCAL CHORDS.**
>
> By E. Cutter, M.D., Boston.
>
> The patient, Mr. Albert Litch, of Cambridgeport, was born in 1814; he is a large, well-developed, muscular man, of dark complexion and nervous temperament, and has enjoyed excellent health during most of his life. There has been no cancer in the family, except in the case of a paternal aunt who died at the age of 80. His mother is still living, aged 79; his father was a strong man, and died of ague. He was engaged with Mr. John A. Whipple in introducing photography in the United States, and in 1846 he was injured by overturning a large jar of bromine upon his face and hands, the vapor from which strangled him and almost deprived him of life. Since then he has been actively engaged in mercantile pursuits. He attributes his subsequent laryngeal affection to the inveterate smoking of tobacco, which he used to buy by the barrel for his own use. He "supposes that he has colored more pipes than any man in Boston."

Albert Litch (1814-1893) was a partner in John Adams Whipple's photographic business from 1845 until 1847. In 1846 Litch nearly lost his life in an accident at Whipple's Studio at No. 96 Washington Street, Boston, when he overturned a large jar of Bromine on his face and hands. The first commercial use of Bromine, besides some minor medical applications, was its use in creating daguerreotypes. In 1840 it was discovered that bromine had some advantages over the previously used iodine vapour to create the light sensitive silver halide layer used for daguerreotype. After his accident Litch took up '*mercantile pursuits'*, and was for a number of years involved in the leather and shoe business. On September 26, 1867 Albert Litch was operated on in Boston, for the removal of a tumour in his throat. Although initially successful, it was later reported in 1869, that there were signs of the tumour returning.

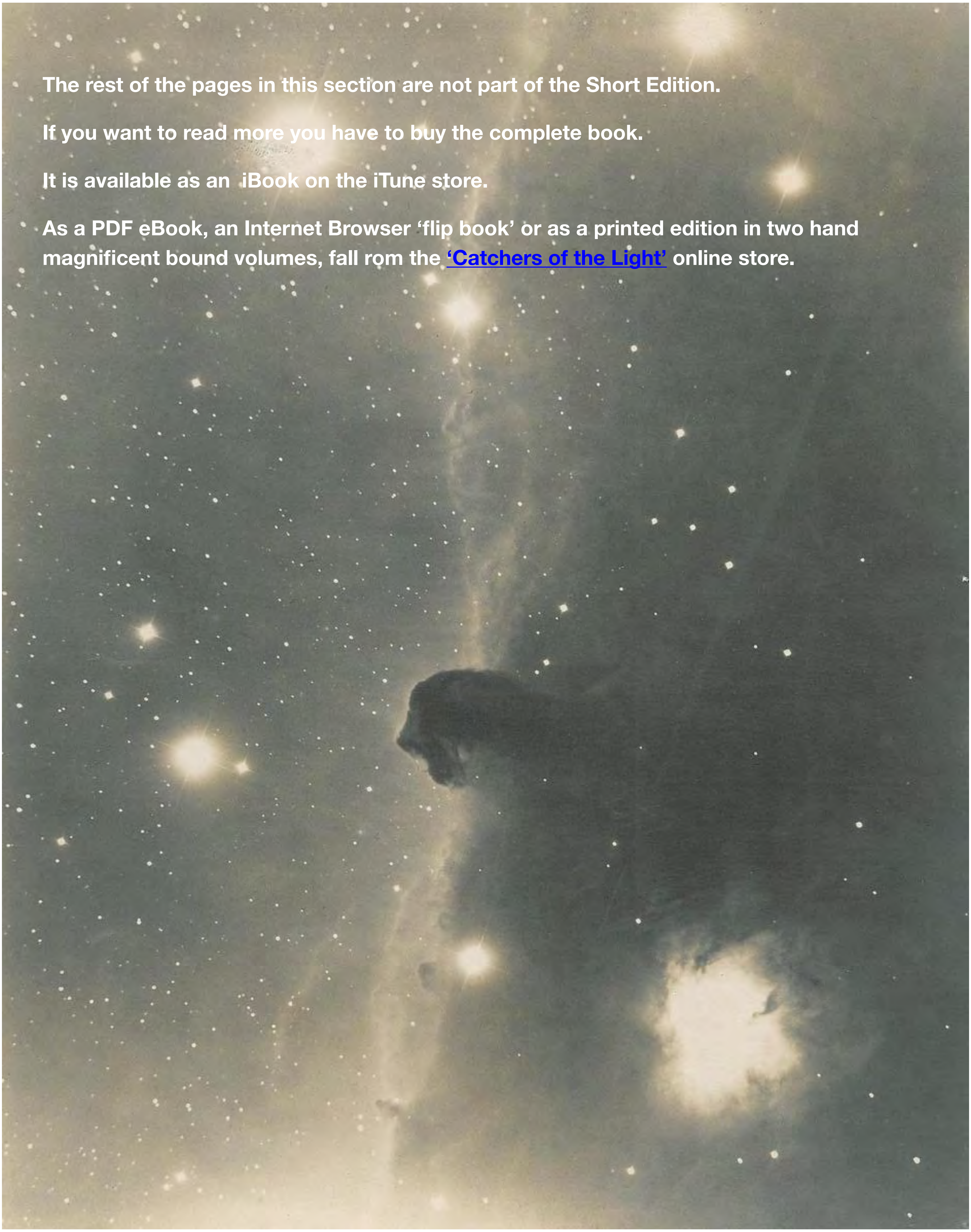
There is current medical evidence to link high quantities of Bromine to Thyroid Cancer. Litch thought his problem was due to the '*inveterate smoking of tobacco'*. He died at South Hampton, New Hampshire on the 24th of May 1893.

Albert Litch, Boston Medical Journal of 1869

Whipple's business on the other hand was thriving; he was able to take on William B. Jones [11] as an assistant in 1849 and open up photographic premises at No. 96 Washington Street, Boston, which are described in his advertisements of the day as an *'extensive establishment'*; and also maintain a house at Bowdoin Place in nearby Cambridge.

The creation of the Daguerreotype Plates, i.e. the preparation of the silver surface to receive the photographic image, was time consuming and required a great deal of manual effort. Whipple thought long and hard on how to overcome this obvious drain on his resources, until an idea occurred to him, *"Why not apply power to this as well as other branches of business?"*

A small steam engine was purchased, and put in operation with complete success. Only one person was required to attend the machinery, and any number of plates could be prepared at the shortest notice, with more uniformity than doing by hand; for the larger plates it was found to be almost indispensable. Not only was the steam used to create his pictures, but it heated his premises in the winter, and cooled them in the summer by means of an ingeniously constructed fan!



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IV.2

‘The Comet Man’

William Usherwood

Born: 31st August 1821, Marylebone, Middlesex, England

Died: 4th November 1915, Dorking, Surrey, England

William Usherwood, a miniature artist and commercial photographer from Walton-on-the-Hill, Surrey, England, took the first ever photograph of a comet when he captured Donati’s comet from nearby Walton Heath, Surrey on the 27th September 1858, beating George Phillips Bond of Harvard College Observatory by a night! Unfortunately, the photograph taken by Usherwood has been lost.

IV.2.1 Comet

In the late summer of 1858 a '*Great Comet*' [1] appeared which was so bright it could easily be seen in broad daylight; people were awed by it, artists painted it and the great astronomers of the day tried to photograph it. The famous Astrophotographer, Warren De La Rue attempted to capture it and failed. George Phillips Bond (1825-1865), the son of the Director of the Harvard College Observatory, even succeeded in photographing it on the 28th of September of that year. However he would later find out that he was beaten to it – by a single day, and therefore lost his claim of being the first person ever to photograph a Comet.

So which of the great observatories with their large telescopes claimed this remarkable feat as theirs: Greenwich, Berlin, Paris or St. Petersburg? And who was the astronomer whose name would live forever in the annals of the History of Photography - Sir George Airy, the Astronomer Royal; or Johann Galle, the discoverer of the Planet Neptune; or Giovanni Battista Donati (1826-1873) [2], the comet's discoverer? It was none of them!

The honour went in fact to - William Usherwood (1821-1915), an unknown miniature artist and commercial photographer from Walton-on-the-Hill, Surrey, England. Yet his name like the object he photographed shone brightly for a while, before disappearing into the dark depths of space and time. So why did William Usherwood, with the aid of the camera he used for photographing babies and weddings succeed; whilst Bond with the *'Great Harvard Refractor'* [3] at his disposal only managed a photograph of the comet, which he himself admitted was poor and a day too late?

Let us now tell William Usherwood's story, which begins not on Walton Common [4] where he captured the light of an object which man had not seen since the time before Rome ruled the known world; or at Dorking where he lived for a good part of life, but in the streets of the old parish of St. Marylebone in the old county of Middlesex, where he was born.

William Turner (1789-1862), an English painter who specialised in watercolour landscapes. He was a contemporary of the famous artist, Joseph Mallord William Turner (1775-1851) and his style was not dissimilar. He is often known as William Turner of Oxford to distinguish him from his better known namesake. Many of Turner's paintings depicted the countryside around Oxford. He sailed the seas as a pirate and spent his leisure time on his pirate ship painting!

Donati's Comet painted by William Turner (1789 – 1862) of Oxford

IV.2 St. Marylebone

William Usherwood was born on the 31st of August 1821 in the parish of St. Marylebone [5], then in the City of Westminster; but which is now lost in the urban sprawl of the London Metropolis. His father was John Hughes Usherwood (1797-1870), a skilled artisan who earned his living in the manufacture of wallpaper as a paper stainer [6]. With wife Mary Lacey (c1800-1842) they bore six children, five of whom survived into adulthood; William being the second born.

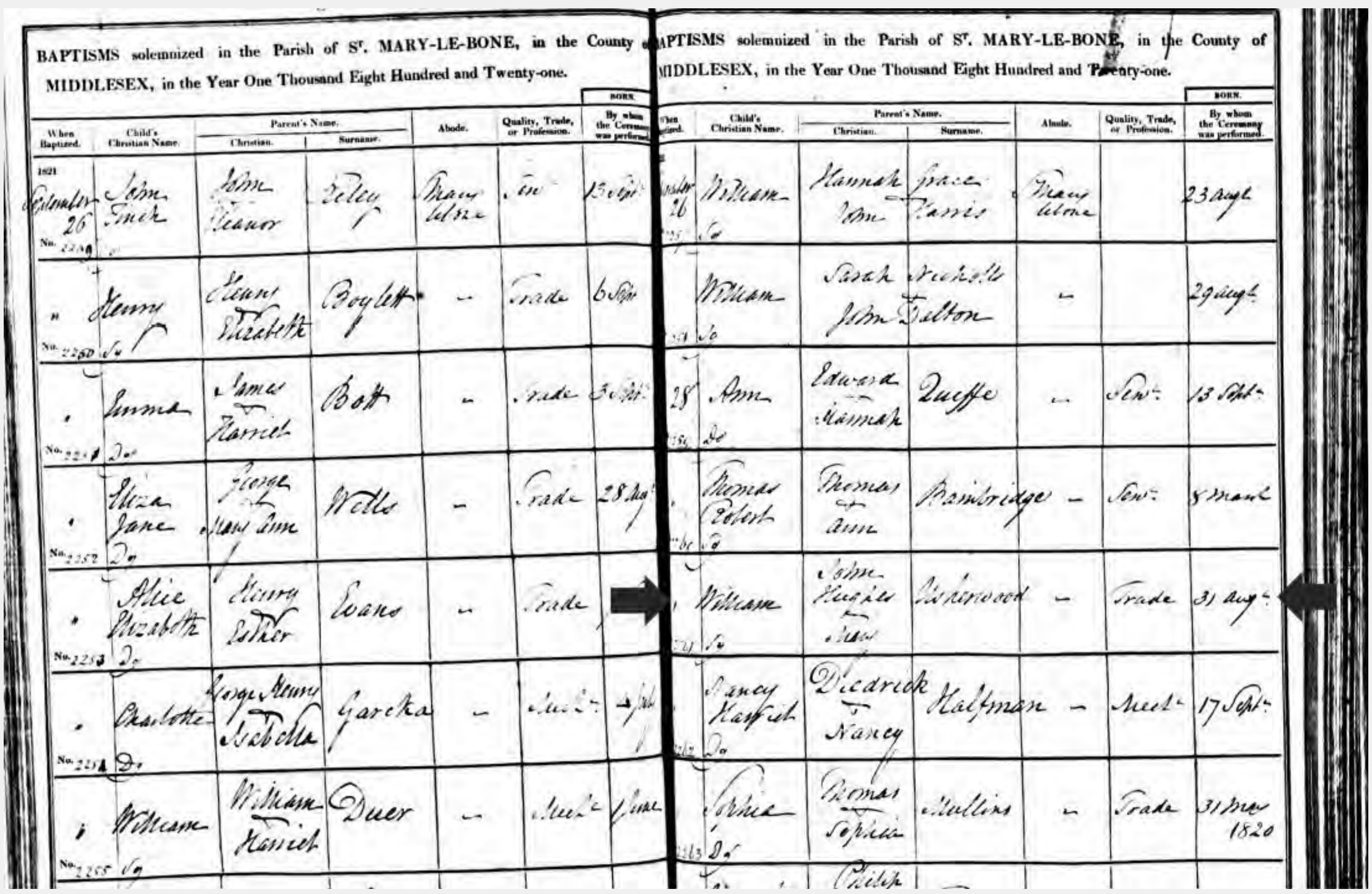
Very little is known of his early life or education. The first record of him after is birth is when he appears as a 17 year old in the 1841 Census living in Islington in the household of John Ashley, a Workhouse Relieving Office, his wife Matilda and their son Edward, a Cabinet Maker.

He appears to have had no occupation. He gives his age as 17 when in fact he was 19 [7]. The giving of false and misleading information is something William Usherwood did throughout his life. In future Census returns he never gave the same information twice and always gave a wrong age which varied from one decade to the next.

At the time of the 1851 Census he gave his age as 28 years old (incorrect) and was to be found residing at No. 95 Mary Street, near London's Regents Park; and employed as a Portrait and Miniature Painter, born in Middlesex [8]. This was the first clue to the direction in life William Usherwood was to take and the career he would follow. It is quite likely that William's choice of career was influenced to some extent by his father. The work of a Paper Stainer required a fair degree of artistic flair and know how to create the patterns on the wallpapers of the early decades of the nineteenth Century.

During the early 1850s Photography was still a very new art form. It had only been just over a decade since François Arago first revealed to the world the remarkable work of Louis Daguerre [9]. As a consequence the number of people employed as full time professional photographers was small - but growing rapidly. Many others like William Usherwood would later change from being artists or sculptors to the new media of Photography.

On the 25th of October 1853 the then 32 year old (correct age!) portrait and miniature painter married Amelia Ann Westbrook (c1829-1917), the daughter of James Westbrook, a Coach Painter [10]. Shortly after his marriage William Usherwood moved to Walton Heath (Common), near to the village of Walton-on-the-Hill in Surrey. At Walton-on-the-Hill, William Usherwood set up in business as a Miniature Painter. For the next few years William worked at his trade, began to learn the new art of photography, and to bring up a large family [11]. As the summer of 1858 approached William Usherwood's destiny and Donati's Comet awaited him.



BAPTISMS solemnized in the Parish of St. MARY-LE-BONE, in the County of MIDDLESEX, in the Year One Thousand Eight Hundred and Twenty-one.

When Baptized.	Child's Christian Name.	Parent's Name. Christian.	Parent's Name. Surname.	Abode.	Quality, Trade, or Profession.	Born. By whom the Ceremony was performed.
1821 September 26 No. 2249	John Finch	John Eleanor	Petley	Mary le bone	[illegible]	13 Sept
" No. 2250	Henry Do	Henry Elizabeth	Boylett	—	Trade	6 Sept
" No. 2251	Emma Do	James Harriet	Bott	—	Trade	3 Sept
" No. 2252	Eliza Jane Do	George Mary Ann	Wells	—	Trade	28 Aug
" No. 2253	Alice Elizabeth Do	Henry Esther	Evans	—	Trade	
" No. 2254	Charlotte Do	George Henry Isabella	Garcka	—	Mech.	4 July
" No. 2255	William Do	William Harriet	Duer	—	Mech.	1 June

BAPTISMS solemnized in the Parish of St. MARY-LE-BONE, in the County of MIDDLESEX, in the Year One Thousand Eight Hundred and Twenty-one.

When Baptized.	Child's Christian Name.	Parent's Name. Christian.	Parent's Name. Surname.	Abode.	Quality, Trade, or Profession.	Born. By whom the Ceremony was performed.
September 26	William Do	Hannah John	Grace Parris	Mary le bone		23 Aug
	William Do	Sarah John	Nicholls Dalton	—		29 Aug
28	Ann Do	Edward Hannah	Quiffe	—	Serv.	13 Sept
"	Thomas Robert Do	Thomas Ann	Bainbridge	—	Serv.	8 March
"	William Do	John Hughes Mary	Usherwood	—	Trade	31 Aug
"	Nancy Harriet Do	Dicarick Nancy	Halfman	—	Mech.	17 Sept
	Sophia Do	Thomas Sophia	Mullins	—	Trade	31 May 1820
		Philip				

William Usherwood's Baptism Entry St. Marylebone, 28th September 1821

William Usherwood was renowned for giving false or misleading information to authorities concerning his place and date of birth. In the Census records for the decades from 1851 to 1911 he made it a point of providing the enumerators with differing dates and locations. However his baptism entry in the register of St. Marylebone Church reveals that he was born on the 31st August 1821 in Marylebone, London to John Hughes Usherwood and his wife Mary (née Lacey). It was the one time he was in no position to lie to those who wished to pry into his private life!

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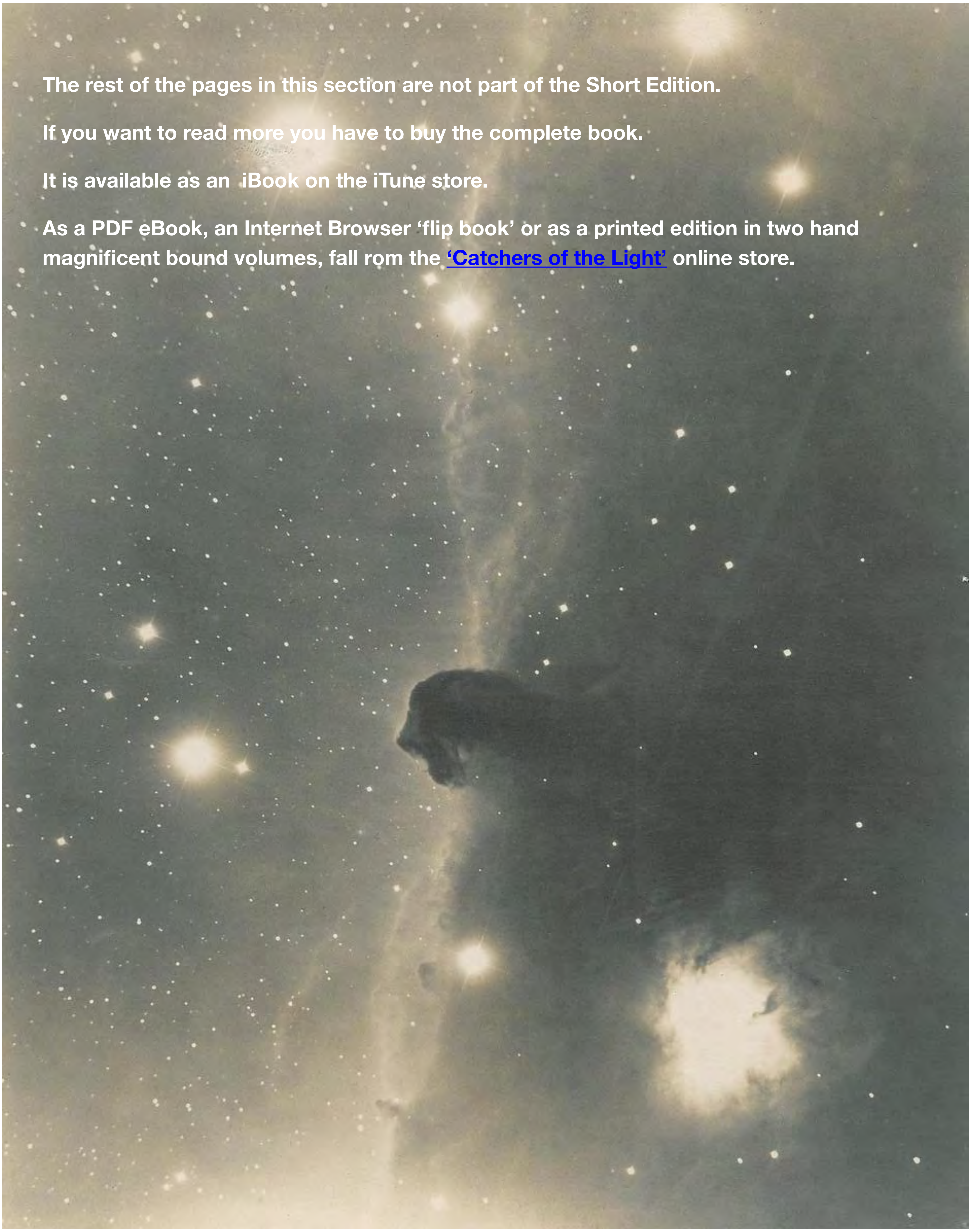


IV.3

'The Inseparable Brothers'

Pierre Paul Henry

Born: 21st August 1848, Nancy, Meurthe-et-Moselle, Lorraine, France

Died: 4th January 1905, Montrouge, Paris, France

Mathieu Prosper Henry

Born: 10th December 1849, Nancy, Meurthe-et-Moselle, Lorraine, France

Died: 25th July 1903; Pralognan, Rhône-Alpes, France

The Henry Brothers – Pierre Paul and Mathieu Prosper, were inseparable all throughout their lives. Together they grew up to be two of the greatest Astrophotographers of all time and were the first to take truly successful photographs of the Planets. They also created some of the finest telescopes ever made, which were without doubt the equal of those of the legendary Alvan Clark & Sons. Their pioneering experiments in using photography to create star charts was a major contributory factor in persuading Rear Admiral Amédée Mouchez to inaugurate the ill fated '*Carte du Ciel'* project.

IV.3.1 Inseparable

Pierre Paul Henry (1848-1905) and his younger brother Mathieu Prosper Henry (1849-1903), lived in the world as though they were just a single person. Everything they did in life, they did together; they went to the same school, they both trained as opticians, they both left to live in Paris, they both became astronomers and both got jobs at the Paris Observatory – where they both worked together.

Pierre Jean Octave Callandreau (1852–1904), a colleague of theirs at the Paris Observatory wrote of them [1]:

“So united was their friendship and collaboration that at the Observatory we seemed to see but one person; so forgetful were they of giving prominence to their respective merits that it is impossible to decide what may belong to each of their common work.”

Together their achievements made them famous the world over, and in France they could do no wrong:

- They took the first successful photographs of the Planets when they imaged Jupiter and Saturn in 1886;
- They provided the optics for the first example of Maurice Loewy’s (1833-1907) Equatorial Coudé Refractor - a new and radical telescope design;
- They took magnificent photographs of stars down to the below the 15th magnitude, which convinced the Observatory’s Director Contre-Amiral Amédée Ernest Barthélémy Mouchez (1821-1892) that a complete photographic survey of the heavens was technically possible;
- At the end of their lives they constructed with the Parisian engineer Paul Gautier (1842-1909) large refracting telescopes for the Nice and Meudon Observatories, which rivaled those built by Alvan Clark & Sons of Cambridge, Massachusetts, USA.

It was a team of one that the inseparable brothers became two of the truly great pioneers of Astrophotography.

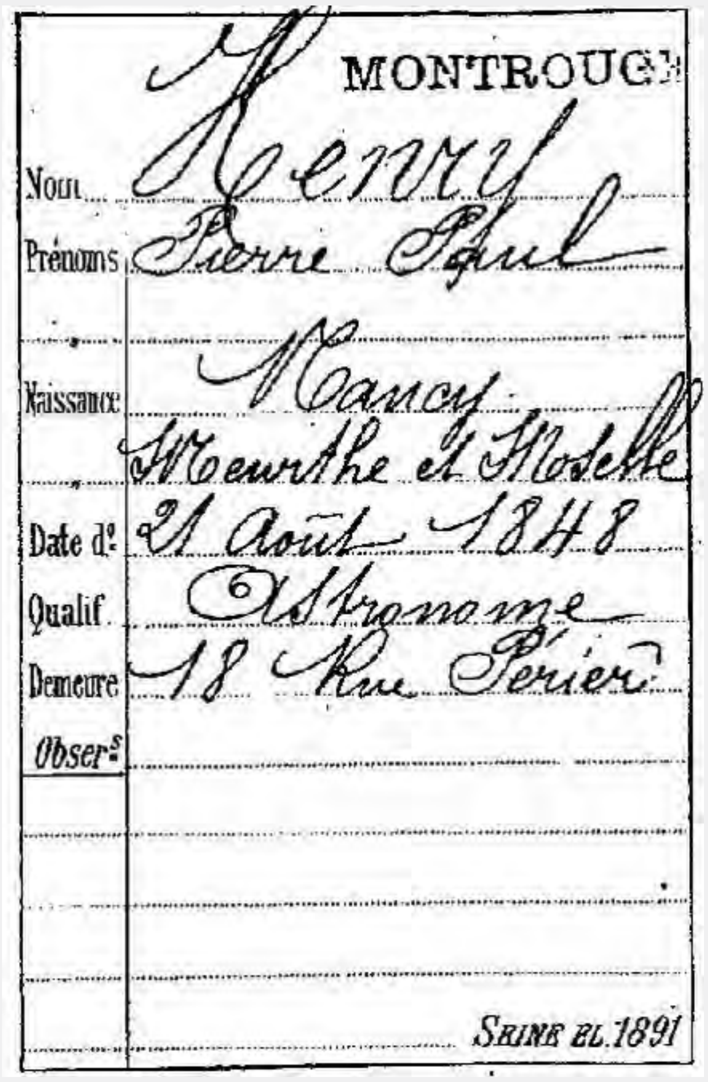
IV.3.2 Opticians

Although the brothers were known throughout their lives as Paul and Prosper Henry – these were not the names given to them at birth by their parents. The elder brother Paul was born Pierre Paul Henry on the 21st of August, 1848 at Nancy, Meurthe-et-Moselle, Lorraine, France to Claude Henri Henry and his wife Marie Madeleine Josephine Pretot. Prosper Henry was born Mathieu Prosper Henry a year later on the 10th of December, 1849.

Little is known of their early life save that they came from a modest family, and were educated at a local Catholic School. They began their careers as opticians working in their home town of Nancy. In 1864 they came to Paris, and began work at the Paris Observatory in the Department of Meteorology, Paul in 1864 and Prosper a year later [2].

In 1868 they were promoted to assistants by Urbain Jean Joseph Le Verrier (1811-1877), the then Director of the Observatory. On the retirement of Le Verrier in 1871, Charles Delaunay (1816-1872) succeeded him as Director. Le Verrier’s retirement was only temporary, and he later returned as Director for a second term following the tragic death of Delaunay in a boating accident, near Cherbourg in 1872.

In their lodgings in the Paris suburb of Neuilly-sur-Seine, the Henry Brothers succeeded in making a 12 inch mirror and began to use the telescope to complete the ecliptic chart begun by Jean Chacornac (1823-1873), but which at that time remained incomplete. When this was brought to Delaunay’s knowledge, he immediately recognized the Henry Brothers talent for optics and transferred them from the meteorological to the astronomical side of the Observatory. On the 1st of July 1871 he put them in charge of the ‘*Equatorial du Jardin*’ [3].



MONTROUGE

Nom Henry

Prénoms Pierre Paul

Naissance Nancy

Meurthe et Moselle

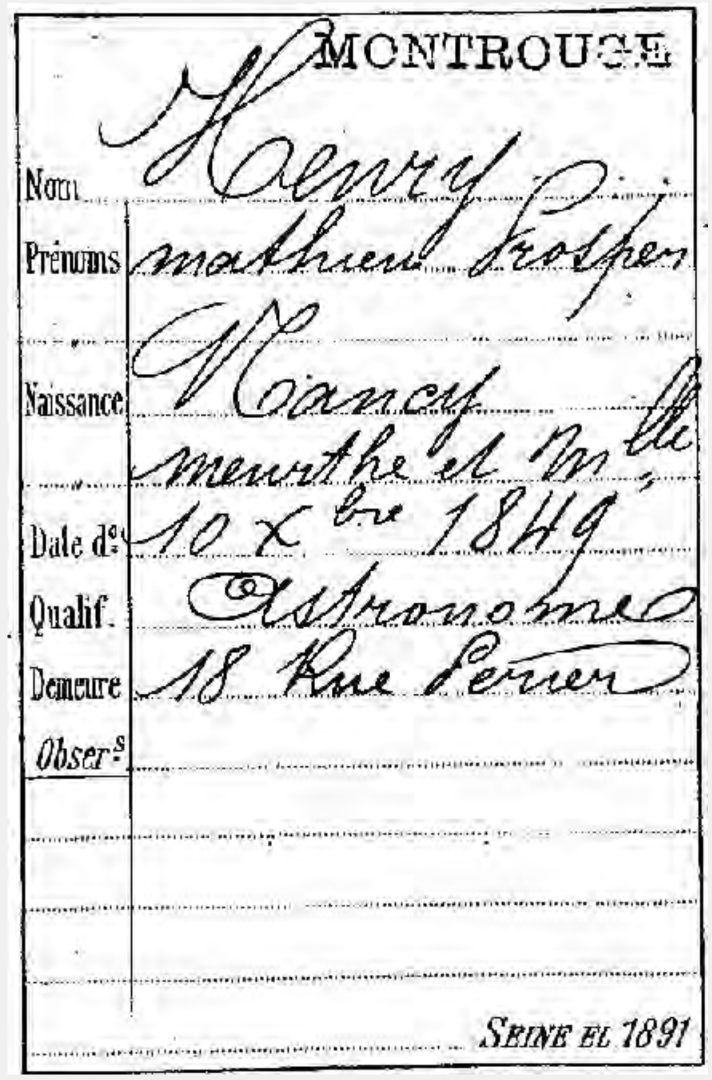
Date d° 21 Août 1848

Qualif. Astronome

Demeure 18 Rue Périer

Obsers

SEINE EL.1891



MONTROUGE

Nom Henry

Prénoms mathieu Prosper

Naissance Nancy

meurthe et Mlle

Date d° 10 Xbre 1849

Qualif. Astronome

Demeure 18 Rue Perier

Obsers

SEINE EL 1891

1891 Electoral Register for Henry Brothers, Montrouge, Paris

The above two documents are the entries for Paul (left) and Prosper (right) Henry, extracted from the 1891 Paris Electoral Register. In particular it gives not only their date and place of birth, but their names as Pierre Paul and Mathieu Prosper as given to them by their parents Claude Henri Henry and Marie Madeleine Josephine Pretot.

V.3.3 Astronomers

In 1871 the Henry Brothers began the task of completing Jean Chacornac's charts of the Ecliptic, begun in 1852 [4]. In all there were 108 charts each 13" square covering a 5^{o} field of view and containing stars down to the thirteenth magnitude. Chacornac had only completed thirty six of the charts and had mapped about 60,000 stars, leaving a further 72 charts still to be done. The purpose of the chart was to help in the discovery of minor planets.

As the region of the charts approached the Milky Way, the Henry Brothers became alarmed at the large number of stars made visual observations almost impossible even for observers of their skill and experience. Typically a chart would consist of between 1500 to 1800 stars, but near to the Milky Way this number increased tenfold. However, it occurred to them that if they were to take photographs, the problem would be solved. They then began experimenting with photography as a means to speed up the process. It was to be pivotal moment in their lives – they were about to become Astrophotographers. To this end they made their first Astrograph - one with an object-glass of six and a half inches aperture, and seven feet focal length, achromatized for photographic rays.

By 1884 the Henry Brothers had completed sixteen charts using one of the 10" (0.25m) '*Equatorial du Jardin*' Refractors, showing 36,000 stars in total, and nearly finished four more with 15,000 stars [5]. The annual reports of the Director of the Paris Observatory show the progress of the work, and give an idea of the arduous toil and the perseverance of the two brothers. In the course of their work they discovered no less than fourteen minor planets, the first of these, Liberatrix (125), being discovered in September 1872 [6].

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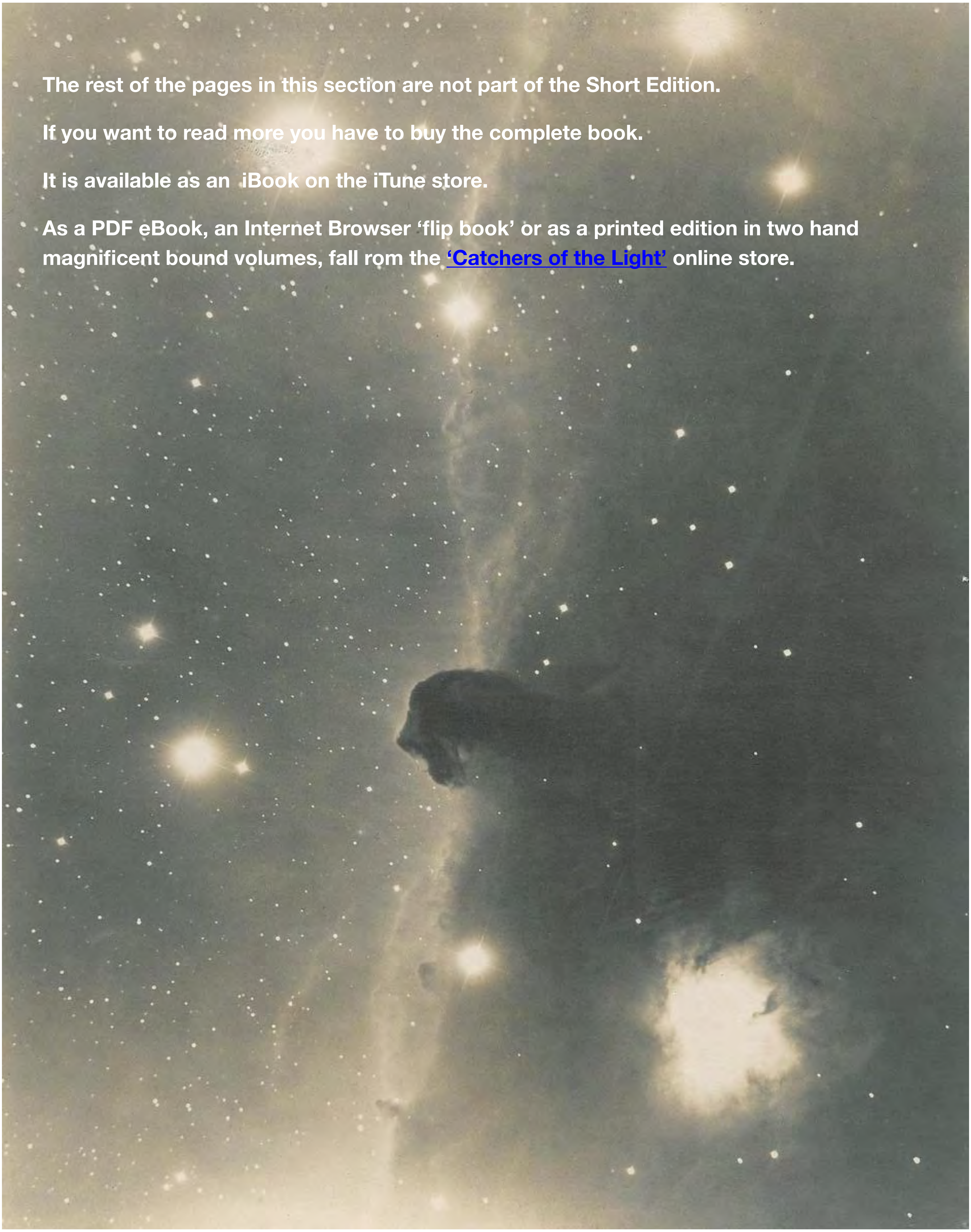


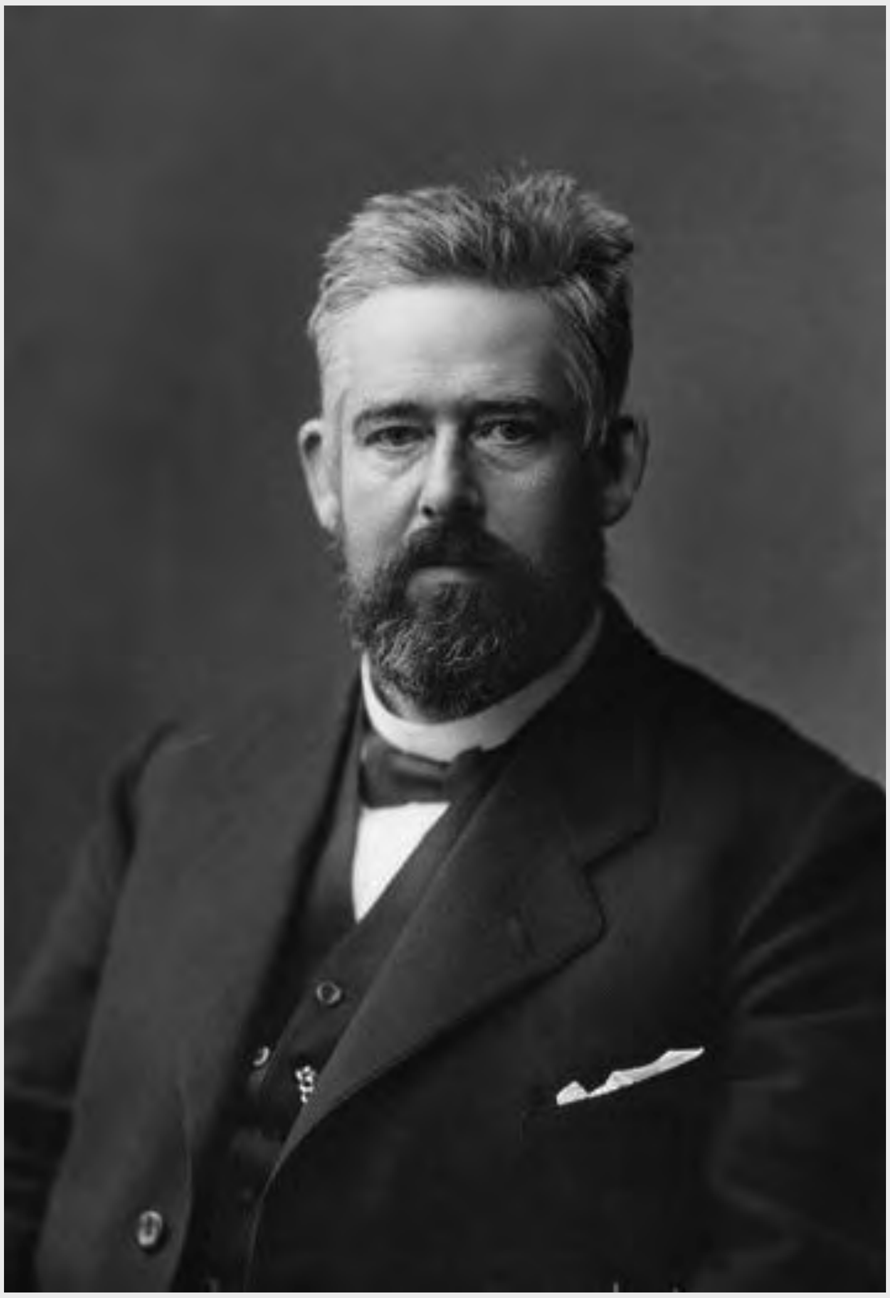
IV.4

‘The Verminator’

Maximilian Franz Joseph Cornelius Wolf

Born: 21st June 1863; Heidelberg, Baden-Württemberg, Germany

Died: 3rd October 1932; Heidelberg, Baden-Württemberg, Germany



Max Wolf was the first person to discover an Asteroid by means of Photography when in 1891, he imaged No. 323 Brucia; which he named after Catherine Wolfe Bruce who later funded the construction of the 16-inch Double Astrograph at the Landessternwarte Heidelberg-Königstuhl. Later, Wolf helped Carl Pulfrich of the optical firm of Carl Zeiss Jena in the development of the Stereo Comparator, a device used as an aid to the discovery of asteroids and supernovae.

IV.4.1 'Vermin of the Sky'

Max Wolf (1863-1932) was given a name so German, it told everyone who met him, that this was a person who would make something of himself. Although, Maximilian Franz Joseph Cornelius Wolf was his birth name, he preferred wisely from an early age, to be called just Max Wolf. Despite spending nearly all of his life in his native town of Heidelberg, he grew up to be one of the great pioneers of Astrophotography and a respected Astronomers of his time.

It was in the field of *'vermin'* that Max Wolf first made his name known to astronomers, not the creatures with long tails and fleas which plagued Europe, during the *'Black Death'*, but the lumps of rock and iron that litter the space between the orbits of the planets Mars and Jupiter.

On the 1st of January 1801, the Italian astronomer and Catholic priest, Guiseppe Piazzi (1746-1826) discovered the first '*vermin'* when he observed the asteroid [1] or minor planet Ceres, an event which was greeted with great interest by the popular press of the time [2]:

"An important circumstance in Astronomy has just occurred, no less than the Discovery of ANOTHER NEW PLANET!!! This celestial phenomenon moves between the orbit of Mars and Jupiter, and is an intermediate Planet between them. It was discovered by M. PIAZZI, an Italian Astronomer, on the 1st of January, 1801. He concealed the discovery, to preserve all the honour and observations to himself, till after six weeks close watching, he fell ill.

It will not be in a situation, with regard to the Sun, to be observed again, till a month or two hence. It is but a small Planet, ranking only as a star of the eighth magnitude, and therefore not visible to the naked eye. Its motion is nearly parallel to the ecliptic, at present about 4½ to the north of it, and nearly entering the sign Leo. The distance from the Sun is about 2½ times that of the earth, and the periodical time nearly four years and two months.—other particulars shall be given in our next..."

A second asteroid Pallas was discovered on the 28th of March 1802 by Heinrich Wilhelm Olbers (1758-1840). In the years that followed more and more of these bodies had been discovered. By 1850 there were ten and by 1891 their numbers had risen to over three hundred. They had become the *'Vermin of the Sky'*, a somewhat derogatory and unfair phrase first used by the Austrian astronomer, Edmund Weiss (1837-1917) [3].

On the 22nd of December 1891 Maximilian Franz Joseph Cornelius Wolf had lived up to his name and discovered Vermin No. 323 which he called '*Brucia*'. What was so remarkable about this discovery was that Wolf had found it on a Photographic Plate and not through the eyepiece of a telescope [4]. More photographic discoveries followed and during the period 1891 to 1894 he had discovered a total of 21 [5].

A new age of *'Vermin'* study had been begun by Wolf, in which these bodies once seen as *'pests'* became more like *'pets'* to astronomers, who now realized that asteroids could hold vital clues to man's understanding of the origin of our Solar System and the Earth itself [6].

However, it was his work on the development of the Stereo-comparator, a device that allowed the operator to view two photographic plates simultaneously, and to determine if any objects had moved in the two images, was perhaps his greatest legacy to astronomy. It was a device which revolutionized the discovery of not only asteroids by photographic means, but virtually automated the detection of supernovae. Today, software has largely replaced the need for optical stereo-comparators, and their successor the blink-comparator.

In the field of Astrophotography, Max Wolf, took images of many of the most well known *'nebulae'* in the heavens, Even to this day his images are amongst the finest ever seen. He also used photography to discover over 1100 Deep Space Objects (DSOs) now included in Dreyer's Index catalogue (IC) [7].

The modern Astrophotographer owes Wolf a great debt, for it was he who first imaged a number of the more challenging targets including the *'Cocoon'* Nebula (Sh2-125) and its associated open cluster IC 5146, in Cygnus and the *'Cave'* Nebula (VdB 152) in Cepheus.

IV.4.2 Indulgence

Maximilian Franz Joseph Cornelius Wolf was born at Heidelberg, Baden-Württemberg, Germany, on the 21st of June 1863, the son Dr. Franz Wolf (1827-1894), a general practitioner and medical officer, and his wife Elise, nee Helwerth (1840-1927) [8].

Max Wolf became interested in astronomy like many before and even more since - by just looking up at the night sky and wondering. He was however more fortunate than most because of the encouragement of his father, who had a pocket to match. His father indulged the young Wolf, by erecting for him a well equipped observatory next to the family home. It was of such a size that nobody who saw it, could fail to be awed by its magnificence.

When Max Wolf was young he once said [9]:

“I can’t imagine becoming anything other than an astronomer, except maybe a physicist”

In 1884 Wolf made his first astronomical discovery, when on the 17th of September that year he observed the short period comet Comet 14P/Wolf [10]. This was the beginning of his long and illustrious career in astronomy.

Like any sensible would be professional astronomer, Max Wolf wisely decided to concentrate his studies at the University of Heidelberg, on mathematics and physics, the two most important subjects needed by anyone wishing to pursue such a career. Only after completing his first and post graduate degrees did Wolf’s attention switch to astronomical research.

In 1888, at the age of twenty five he was awarded his PhD in Mathematical Astronomy from the University of Heidelberg, working under the direction Leo Konigsberger (1837-1921). His Doctoral Dissertation was entitled – *‘Die Differentialgleichung der mittleren Anomalie’* [The Differential Equations of the Mean Anomaly]. The next two years were spent on post graduate studies in Stockholm, with the Finnish-Swedish astronomer, Hugo Gylden (1841-1896).

In 1890 he returned to his home town of Heidelberg where he took up the position of *‘privat-dozent’* [11]in at the University, where he gave lectures on astronomy, meteorology and geophysics. From this time onwards his star rose rapidly in the astronomical firmament and it was not long before he had the respect of his peers, both at home and abroad.

Meanwhile, Wolf continued to conduct research at his private observatory. In 1890, on his return from Sweden he began to use wide-field photography to search for asteroids. At that time, most professional astronomers were using refractors of long focal length for photography, adapting their methods only to the extent of moving plate holders to achieve better *‘photographic’* focus. The field of view with such instruments covered only a few square degrees of sky and was totally unsuited to *‘vermin’* hunting.

After early experiments with smaller instruments, Wolf acquired in the February of 1892, a photographic camera with a 6-inch doublet portrait lens, which gave a huge field of view measuring some 12°x 8° [12].

In 1895 Wolf added a second identical lens which was mounted side by side with the first to form a 6-inch Double Astrograph.

By 1893 Wolf was well-known for his photography of meteors, comets, asteroids, and nebulae. He had shown that the famous *‘Great Orion’* nebula (M42) was much larger than previously believed. In the constellation of Cygnus, he was the first to photograph the large emission nebula, NGC 7000, which he named the *‘Amerika Nebel’,* on account of its close resemblance to the North American continent. His great friend the American astronomer, Edward Emerson Barnard, suggested that Wolf should add the *‘North’* to the original name.

Many other photographic discoveries were to follow during the course of the coming decades, including a massive 1124 DSOs included Dreyer’s NGC/IC, more than any other observer, apart from the French astronomer, Stephane Javelle (1864-1917), who had over 1400 [13]; and of course the Herschels, William and John had even more, 2415 and 1646 respectively.

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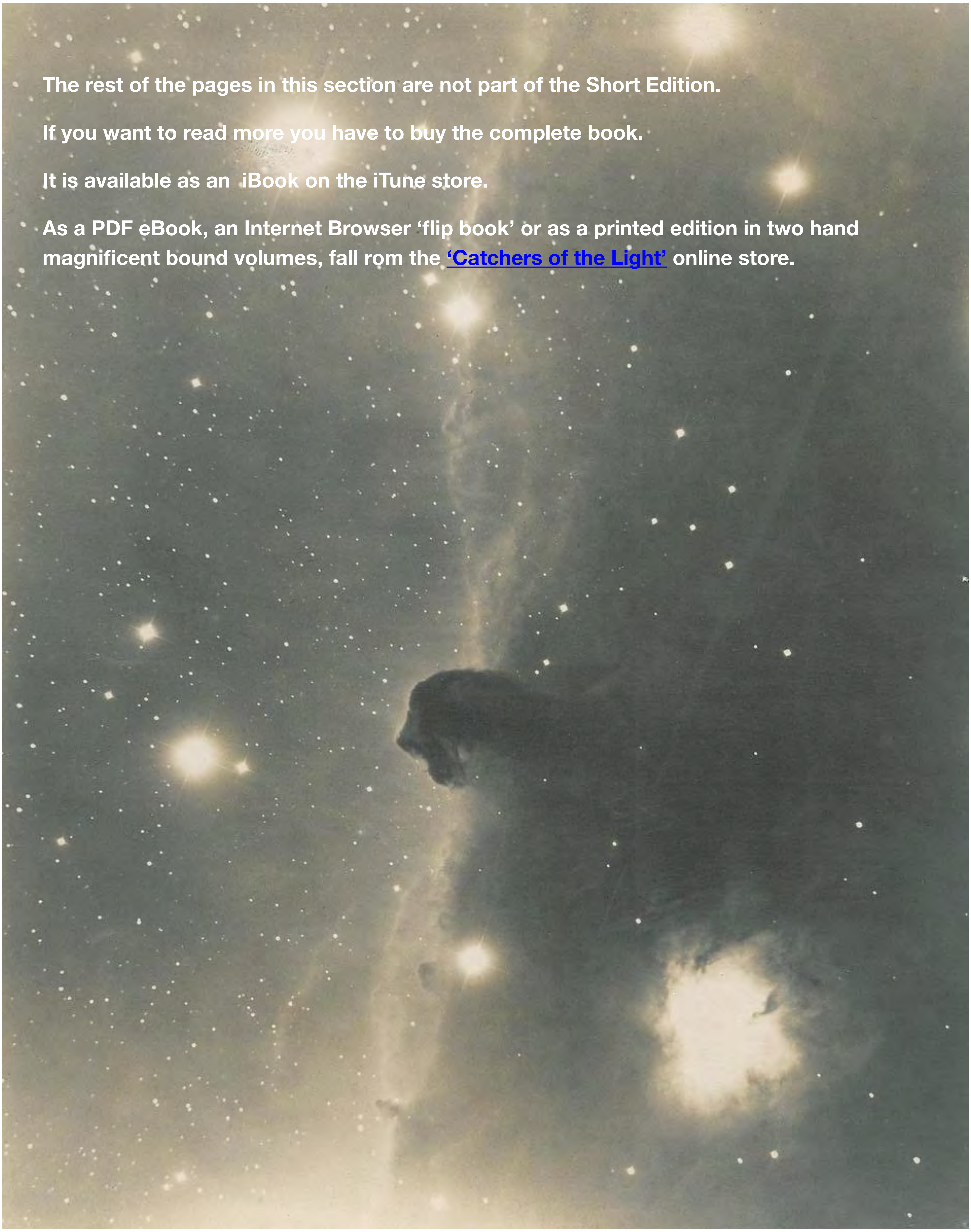

Short Edition

IV.5

‘Wandering Stars’

Imaging the Solar System

‘The Great Comet of 1882’, Anonymous Photographer, 28th October 1882

Imaging the very diverse astronomical objects to be found in our Solar System has proved to be a great challenge, ever since 1839 when Louis Daguerre failed to take a successful photograph of the Moon. It was not until 1885 that the first truly successful images of Planets were obtained by the Henry Brothers; and as late as 1946 before our own Earth was first photographed from space. Today, high quality images of Planets, Natural Satellites, Comets, Meteors and Asteroids are common place, following the advent of the Digital Camera, Space Probes and the Hubble Telescope.

IV.5.1 'Wandering Stars'

Imaging the many diverse bodies which are to be found in our solar system has proved to be a great challenge to the Astrophotographer, and in many ways even more so than capturing the incalculable number of *'faint fuzzies'* known as Deep Space Objects or DSOs, that lie in the depth of space amongst the stars. With the exception of the Moon and the Sun which were the first two objects to be successfully imaged during the early days of Astrophotography, the other members of our near space environment were not so easy.

After the early successes with the Sun and Moon it was only natural that the early pioneers of Astrophotography should try and image the planets . The five planets, Mercury, Venus, Mars, Jupiter and Saturn have been known to man since antiquity, and many ancient cultures have commented on the fact that they were not fixed but *'wandered'* between the stars. In fact the name planet comes from the Greek word πλανήτης, planētēs, meaning *'wanderer'*.

The planets were initially seen as easy targets by the early devotees of the new science of astronomical photography. They were bright and in the case of Mars, Jupiter and Saturn were visible for months on end often appearing high in the sky. Mercury and Venus were somewhat more difficult due to their close proximity to the Sun and could only be seen well in either the early morning or the early evening. Jupiter and Saturn being the two planets with the largest angular size were not surprisingly attempted first.

It soon became obvious that obtaining a successful photograph of a Planet would be no easy matter, if an image measuring more than a millimetre was required. During the 1850s there were a number of attempts to image Jupiter, notably by Warren de La Rue (1815-1889) [1] and John Adams Whipple (1822-1891) [2], but all required a magnifying glass to see clearly its belts and zones. It was not until 1885 that the Henry brothers Paul (1848-1905) and Prosper (1849-1903) obtained the first *'large'* photographs of Jupiter and Saturn that true success could be claimed [3].

In the chronological sequence of successful Solar System Imaging, the next object to be *'captured'* after the Moon and Sun was not a planet, but a Comet. It used to be thought that the first successful image of a Comet was obtained by the French solar physicist Pierre Jules César Janssen (1824-1907) in 1881, but in fact it was a *'jobbing'* babies and wedding Photographer from Walton-on-the-Hill, Surrey, England, named William Usherwood (1821-1915) who beat him by over twenty years when he photographed Comet Donati, including both the head and tail, in 1858 [4].

The other planets of the solar system proved even more difficult than Jupiter and Saturn. In the case of Mars, its smaller average angular size and infrequent close approaches to the Earth meant that it was not until the images of the Red Planet taken by William Henry Pickering (1858-1938) in 1890, that any surface features were visible at all on a photographic plate.

The cloud shrouded face of Venus was an even bigger challenge to the Astrophotographer; only in 1921 did an amateur astronomer from Salt Lake City, Utah named Alfred Rordame (1863-1931) obtain images which showed any visible features. Surprisingly the last planet to be imaged successfully was in fact the Earth itself when in 1946 a 'German' V2 rocket now in the hands of the Americans photographed our *'Home'* from space.

However the most difficult of all the bodies of the Solar System to image were the fleeting *'shooting stars'* or meteors that briefly flash across the night sky as they are consumed in fire as they enter the Earth's atmosphere. It was left to the Hungarian astronomer Ladislaus Weinek (1848-1913) to capture one of these ephemeral objects in 1885 from the Klementium Observatory in Prague, Czechoslovakia.

An Aurora is the astronomical equivalent of a firework show and is without doubt one of the most beautiful spectacles to be seen either in heaven or on Earth. It was not until 1892 that the first successful photograph of an Aurora was obtained, by the German astronomer, Otto Rudolf Martin Brendel (1862-1939) from Bossekop in Norway.

It was only with the coming of the age of the Digital Camera, Space Probes and the Hubble Space telescope, from the 1960s onwards, that truly high quality images of all the objects to be found in our Solar System, large and small, bright and faint, permanent or fleeting were taken by both amateur and professional astronomers.

The Bayeux Tapestry was commissioned in around 1070 by Bishop Odo, half-brother to William of Normandy in celebration of the great victory over the Anglo-Saxons led by King Harold at Hastings, Sussex, England. In one tableau of the tapestry is a scene in which Halley's Comet is shown with a number of onlookers pointing to it in the sky. This is one of many examples to be found in paintings, drawings, tapestries, wood carvings and the like depicting the various bodies of the Solar System, before the age of photography. In fact for many years after its introduction, the media of drawing was preferred to photography by many astronomers and is still so even today.

Halley's Comet as depicted in the Bayeux Tapestry, 1070

IV.5.2 Pre-Photographic Drawings

Ever since man learnt the art of drawing he has recorded what he has seen in the sky. The earliest form of art dates from the Paleolithic age (circa 2.6 million BC – 10000 BC), when man created realistic representation of various forms of wildlife, which were important to him as objects to hunt and ultimately for his survival from day to day. Especially common are paintings of horses and the great bison (wisent) that once roamed the steppes of Europe, although mammoths, woolly Rhinoceroses, and other long extinct animals and fauna also appear in Cave paintings.

However it was only during the later Neolithic age (c 10000-4500 BC) that man began recording his perceptions of celestial objects through paintings and petroglyph (incised images in rock). This *'rock art'* represents an objective record of man's never ending interest in the heavens. Among the most common astronomical petroglyph are those typically interpreted as images of the Sun. Included here are simple images featuring a circular disc from which 'rays' emanate in all directions; and this certainly is how one might expect our distant ancestors to have depicted the sun.

Even as Art grew more sophisticated and used different types of media – parchment, paper, and canvas, celestial phenomena still remained a common theme; even Halley's Comet appeared in a section of the famous Bayeux tapestry. It was only following the invention of the telescope that the drawing of astronomical objects took on a more scientific interpretation, rather than a religious or artistic one. The earliest drawing of an astronomical object as seen through a telescope was by made by the English astronomer and mathematician, Thomas Harriot (c1560-1621) when he produced a sketch of the Moon in the July of 1609.

In the years which followed the invention of the telescope and up until to the advent of photography and beyond, drawing has proved to be an invaluable tool in recording images of the various objects in the Solar System as seen by the observer at a particular date and time. Although the first successful astronomical photograph was taken in 1840 it was to be several decades before the photographic image even began to remotely replace the need for a drawing. A point made very clear by Warren De La Rue in 1857, when he wrote [5]:

"The photographs of Jupiter and Saturn now submitted to the Society give promise that as the art advances it will prove to be of great service; at the same time it will be seen that they are very far from depicting the details which are represented in hand drawings of the planets, and indeed for such minute objects a long time will probably elapse before photography supersedes the pencil."

A drawing was seen for many years, by both professional and amateur alike to be easier, cheaper, quicker and more accurate than a photograph. It was a fact which could not be denied even by the most ardent supporter of celestial photography. Despite living in the age of the Digital camera and the astronomical CCD, many modern day amateur astronomers still prefer a drawing to a photograph when recording their observations.

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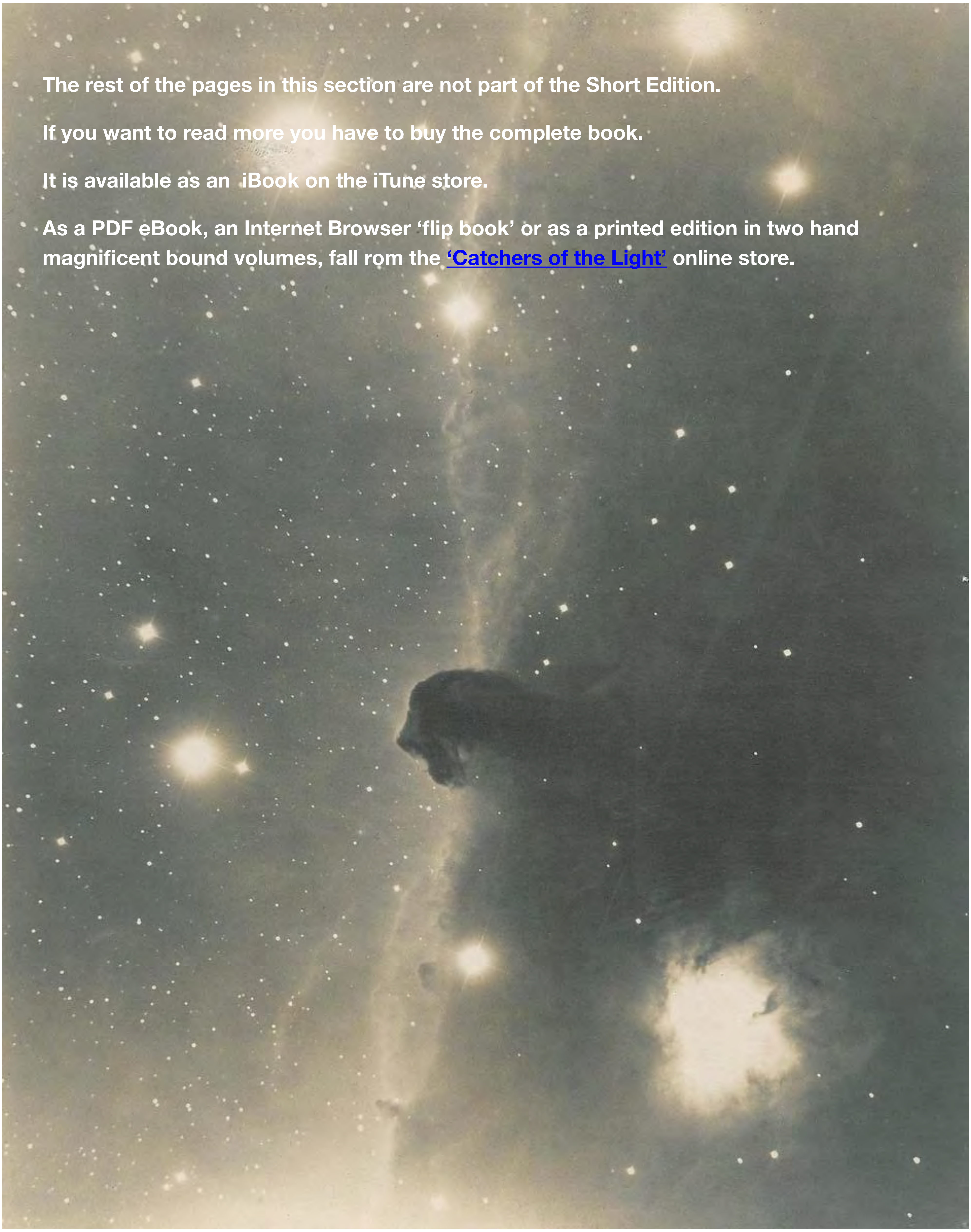


Short Edition

Part V

Starlight

Deep Space Astrophotography

‘*Edge On*’ Galaxy NGC 4565 in Coma Berenices, George Willis Ritchey, 1910

“But from these lesser lights my telescope constantly swung back to the Milky Way, again to gaze on the ‘broad and ample road where dust is stars. So enraptured was I with these glimpses of the Creator’s works that I heeded not the cold nor the loneliness of the night.” Edward Emerson Barnard (1857-1923)

V. Deep Space Astrophotography

Many a modern Astrophotographer having '*cut his baby imaging teeth*' on the Moon and Sun, has experienced an irresistible urge to '*have a go*' at Stellar Photography, perhaps even before attempting a planet or two.

So it was with the early pioneers, when on the evening of the 17th of July 1850, John Adams Whipple (1822-1891) and George Phillips Bond (1825-1865), obtained the very first photograph of a star, that of Alpha Lyrae, Vega, using the 15-inch (38cm) Harvard refractor. Its image was captured on a Daguerreotype plate with a 100 second exposure. The second magnitude star Castor (alpha Geminorum) was also photographed and represented the faintest star imaged at that time. Only in the following year of 1851, did Whipple '*have a go*' at the planet Jupiter.

Seven years later, G.P. Bond assisted by Whipple and his partner James Wallace Black began using the more sensitive wet collodion process to carry out further experiments in stellar photography. On the 27th of April 1857 they obtained a photograph of the double star Mizar (zeta Ursa Majoris) and its fourth magnitude companion Alcor (80 UMa) They also took images of the double-double star epsilon Lyrae and in doing so capture a star of the sixth magnitude, the faintest imaged at that time.

Bond and Whipple's work on stellar photography was continued by the New York amateur scientist Lewis Morris Rutherfurd (1816-1892). During the years from 1858 to 1877, Rutherfurd took 664 collodion photographic plates of star groups and open clusters, including 54 of the Pleiades (1865-1874) and 23 of the Praesepe (M44) cluster (1865-1877). The faintest stars which appeared on his plates were of magnitude 9 at best. Rutherfurd's images were obtained with an 11.25-inch 'photographically corrected' refractor - it was the very first Astrograph.

Benjamin Apthorp Gould (1824-1896), the very first astronomer to be awarded a Doctorate in that subject, continued where Rutherfurd had left off. In a ten year period from 1872 to 1882, he and his assistants at the National Observatory of the Argentine at Cordoba took photographs of many of the well known open clusters visible from the southern hemisphere. He was also one of the first to make use of the increased sensitivity of the '*dry*' photographic plate and managed to obtain images of stars as faint as the tenth magnitude.

The 30th of September 1880 marked one of the greatest milestones in the history of Astrophotography. On that date, Dr. Henry Draper (1837-1882), the son of the '*First Astrophotographer*', John William Draper (1811-1882), using an 11.25-inch Alvan Clark photographic refractor obtained the very first photograph of a '*Deep Space Object'*, when he imaged the '*Great Orion'* Nebula (M42). His photograph taken with a '*dry*' photographic plate and an exposure of 51 minutes became that night one of the most famous ever; and marked the beginning of Deep Space Astrophotography.

Henry Draper died two years later and was unable to continue the great work he had started in the field of Deep Space Astrophotography save to take two improved images of M42. His mantle was taken up by others, including Andrew Ainslie Common (1841-1903) and Isaac Roberts (1829-1904). Common was awarded the Gold Medal of the Royal Astronomical Society of London in 1884 for his astronomical photographs and in particular his image of the '*Great Orion*' nebula taken on the 28th of February, the previous year.

Isaac Roberts was one of the most prolific of all Astrophotographers, taking over two thousand photographic plates. It was his images of well known Deep Space Objects that were the first to show what many of them actually looked like.

During the latter part of the nineteenth and early twentieth century, the finest images of Deep Space Objects were obtained by four astronomers in particular - James Edward Keeler (1857-1900) and his assistant Charles Dillon Perrine at the Lick Observatory, using a 36-inch reflector made by Andrew Ainslie Common; George Willis Ritchey (1864-1945) using the 24-inch reflector of the Yerkes Observatory and later the 60-inch Mount Wilson reflector; and the little known Irish amateur William Edward Wilson (1851-1908), using a 24-inch reflector at his Observatory at Daramona.

In the field of '*wide*' Astrophotography Edward Emerson Barnard (1857-1923) and his friend Maximilian Franz Joseph Cornelius Wolf (1863-1932) imaged supreme. During the years 1892 to 1895, Barnard obtained a series of magnificent images of Milky Way starfield and nebulae using the Lick Observatory's Crocker Astrograph. He followed this up with his '*Atlas of Selected Regions of the Milky Way*', published posthumously in 1927. The photographs contained in this great work were obtained with Bruce 'Triple' Astrograph of the Yerkes Observatory, many of which were actually taken from when the telescope was temporarily situated on Mount Wilson in California in 1904-1905.

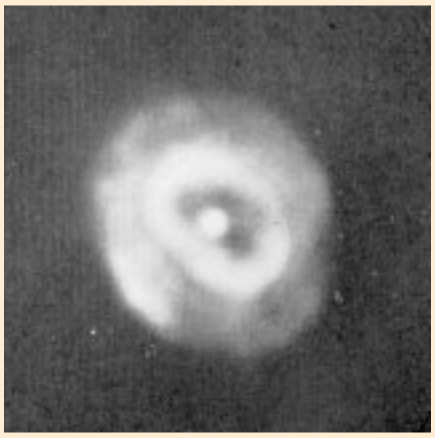
Max Wolf at Heidelberg used his 6-inch Double Astrograph from 1891 and then later from 1900 the Observatory's 16-inch Bruce Double Astrograph to take many magnificent photographs of Nebulae and regions of the Milky Way. It was he who independently discovered the '*Horsehead'* nebula on a plate taken in 1891, thirteen years after Williamina Fleming first saw it. Wolf also named the famous emission nebula NGC 7000 after the American (North) continent.

It was to be a further three decades again before the photographs of Keeler, Ritchey, Wilson, Barnard and Wolf were surpassed in quality by the images of Marcel De Kerolyr (1873-1969), taken in the years from 1929 to 1934, using in the main the 80cm reflector of the Astrophotographic station of the Paris Observatory at Forcalquier, France.

"Stellar Photography - Here we are dealing with conditions entirely different...with objects often far beyond the limit of visibility to the unaided eye, and in the case of faint stars and nebulae, often away out of reach of average telescopes.

For this class of work the ordinary visual form of telescope, whether reflector or refractor, as used by amateurs, is entirely unsuitable, and unless the worker has a good clock-driven stand, and is prepared to mount a reflector of focal aperture between f/4 and f/5 it is advisable to stick to doublet lenses."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.



'Blue Snowball' Planetary Nebula, NGC 7662, Francis Gladheim Pease, 1911, 60-inch Reflector

V.1

‘The Bonds of Harvard’

William Cranch Bond

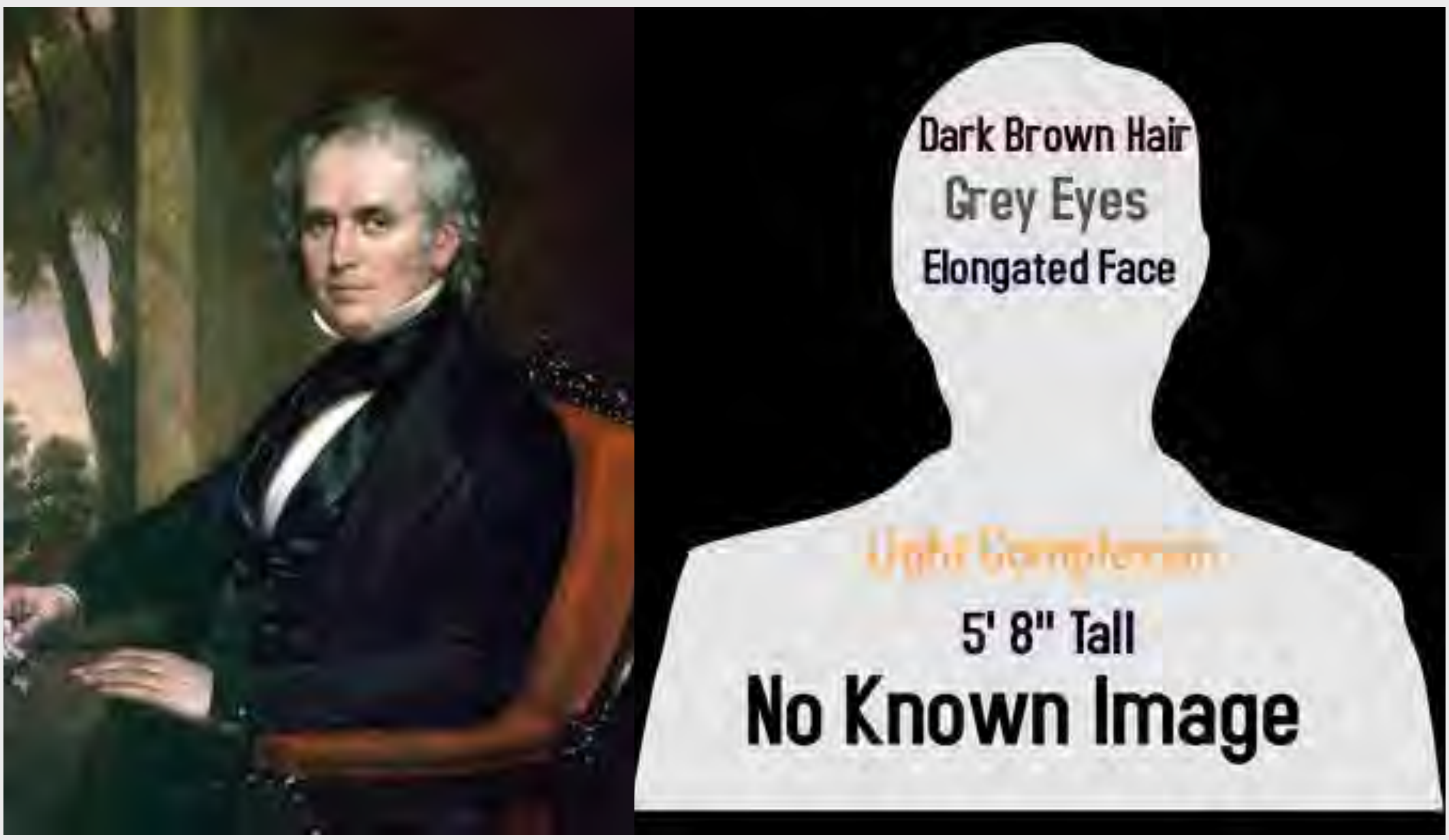
Born: 9th September 1789; Cumberland, Portland, Maine, USA

Died: 29th January 1859; Cambridge, Middlesex, Massachusetts, USA

George Phillips Bond

Born: 20th May, 1825; Dorchester, Suffolk, Massachusetts, USA

Died: 17th February, 1865; Cambridge, Massachusetts, USA



William Cranch Bond and his son George Phillips Bond were the first two Directors of the Harvard College Observatory, who with the help of John Adams Whipple and his partner James Wallace Black, took the first photographs of stars; work which marked the beginnings of Deep Space Astrophotography; and which helped pave the way for others like Henry Draper to follow. It was at Harvard under the Bonds’ direction that the first systematic experiments were carried out into the then new field of celestial photography.

V.1.1 Father & Son

William Cranch Bond (1789-1859) and his son George Phillips Bond (1825-1865) were the first two Directors of the Harvard College Observatory in Cambridge, Massachusetts, USA [1], [2], [3]. It was at this venerable institution that the very first extended investigations into astronomical photography were carried out by the Bonds in the years 1847 to 1857. During this period with the assistance of the Boston Photographers, John Adams Whipple and James Wallace Black, the Bonds obtained a series of remarkable images of the Moon, the Sun and some of the brighter stars.

Whipple's Daguerreotypes of the Moon were in every respect superior to John William Draper's first lunar image of ten years previous. For the very first time the features of the Moon – its craters, seas, mountains and valleys could be seen in great detail, other than through the eyepiece of a telescope. Not only that, they were a permanent record of something which could be marveled at by the public at large – the likes of which very few had seen. In 1851 Whipple's images of the Moon were taken by G. P. Bond to Europe and displayed at the '*Great Exhibition*' held that year in the Crystal Palace, Hyde Park, London for all to see.

However, it was their work in early stellar photography which captured the imagination of the scientific world, as reported by G. P Bond to the '*Annual of Scientific Discovery*' for 1851 [4]:

"Mr. Bond of the Cambridge Observatory has recently succeeded in obtaining a Daguerreotype picture of the star alpha Lyra in the space of about 30 seconds, the image being transmitted through the great refractor, used without the eye-glass. …Yet such are the facts, and it follows that the ray of light which made the first impression on our Daguerreotype plates took its departure from the star more than twenty years ago, long before Daguerre had conceived his invention'..."

Although, J. W. Draper took the first known photograph of an astronomical object when he imaged the Moon in 1840, it is the Bonds who can be considered to be the father and son of Astrophotography. It was they who realized the importance that photography held as a vital tool for astronomical research, and did everything in their power to advance its development.

Let us now tell the story of the Bonds of Harvard in their own words and in those of their family and friends.

V.1.2 'The New World'

The Bonds' story begins not in America but in the '*Old World'* of Plymouth, England. William Cranch Bond's Grandfather, Thomas Bond (1705-1782) was a native of that town, where he practiced as a surgeon and apothecary. He was reputably descended from an ancient family of Bond who had held estates in Brendon in the Parish of St. Dominic, Cornwall, since the time of the Norman Conquest in 1066 [5]. In 1750, Thomas Bond, married Thomasin Phillips of Bideford in the church of St. Andrew's, Plymouth on the 30th of September that year. Together they had four sons, only one of which had children of their own – William Bond (1754-1844), the father of William Cranch Bond.

It was William Bond who emigrated to America and to a life in the *'New World'*. This important decision arose as a result of his marriage in 1777 to Hannah Cranch, a member of a staunch *'Non Conformist'* family from the nearby market town of Kingsbridge. It was Hannah's uncle Richard Cranch who urged the Bond's to emigrate to America, he himself having left the restricted confines of Kingsbridge to *'make good'* in Massachusetts in the May of 1746 [6].

Among the papers found after the death of W. C. Bond was a manuscript which contained valuable information on the Bond family history, and the circumstances of his father's emigration to America [7]:

"After a previous visit to this country in 1784, my father [WILLIAM, son of THOMAS] settled in Falmouth, Casco Bay [now Portland], in May, 1786, bringing with him his wife and two children, THOMAZINE and THOMAS. The brig John in which they came had been chartered by my father for that and commercial purposes."

This manuscript is interesting in that the Bonds, William and Hannah in fact gave birth to two William Cranch Bonds, the first in 1781 in Plymouth, but he died when still an infant, and a second, born in America, who went onto become the first Director the Harvard College Observatory [8].

William Bond, his wife Hannah and their two children Thamazine Elizabeth (1778-1864) and Thomas (1783-?), arrived in Boston in the May of 1786, and settled in Falmouth (now Portland), Maine. Once there they found life far from easy. At first he set up a business shipping lumber, but this venture proved unsuccessful. His situation was not helped financially by the birth of two more children, Hannah Cranch Bond, born on the 13th April 1787 and William Cranch Bond, born on the 9th of September 1789.

So in 1790 he and his wife and by then four children moved back to Boston. Here he began trading as a silversmith and watch and clockmaker; skills he had learned in London in his youth. In 1793 he established the firm of William Bond & Sons, and began to import clocks and watches from England. It took time to build up a business, and his family had a long, hard struggle with poverty.

The Bonds of Harvard were descended from an ancient family with its roots in the English county of Cornwall. They later settled in neighbouring Devon, where Thomas Bond, the grandfather of William Cranch Bond was a respected Apothecary in the town of Plymouth, who married Thomasin Phillips, a native of Bideford, in St. Andrew's Church, Plymouth, on the 30th of September 1750.

15th Century Church of St. Andrew's, Plymouth

The Cranch side of the Bond family hailed from the small market town of Kingsbridge, in the county of Devon. It is in fact a combination of two parishes, Kingsbridge and Dodbrooke; with an even older neighbour, Churchstow which boasts the mother church of St. Mary for both parishes.

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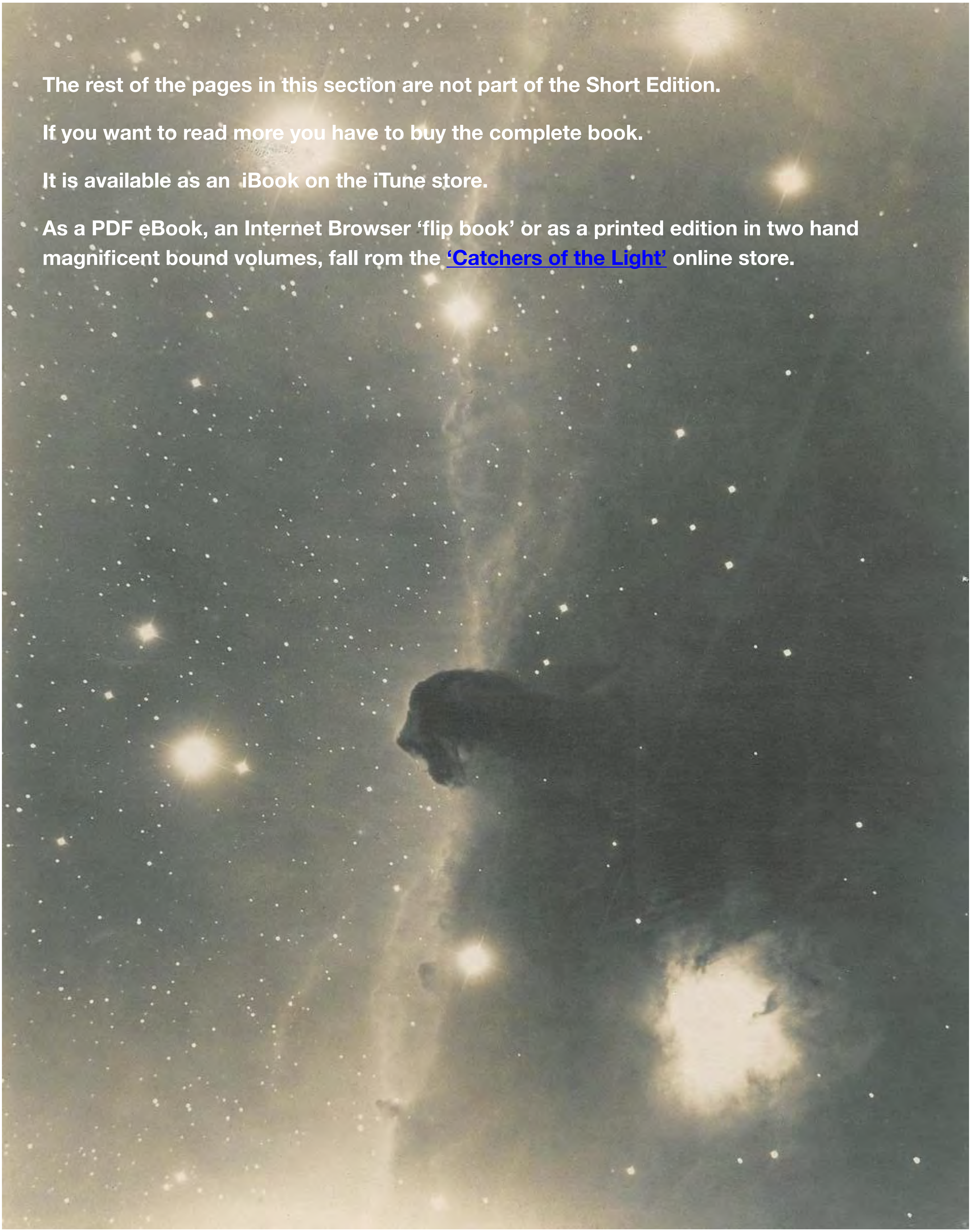

V.2

'Our Man in Cordoba'

Benjamin Apthorp Gould

Born: 27th September 1824, Boston, Suffolk, Massachusetts, USA

Died: 26th November 1896 Cambridge, Middlesex, Massachusetts, USA

Benjamin Apthorp Gould was an Astronomer of the *'old school'* who believed in the importance of measurement and position, preferring it to the then new science of Astrophysics. He along with his mentor Lewis Morris Rutherfurd pioneered the development of Photographic Astrometry. In the years 1872 to 1882, during his time as the first Director of the *Observatorio Astronómico de Córdoba*, Argentina, Gould and his assistants photographed and measured the brightest stars in many of the most well known Open Clusters in the Southern Hemisphere.

V.2.1 Clusters

Benjamin Apthorp Gould (1824-1896) was an astronomer who believed in the old ways. He wished to measure the positions of stars and thus continue with the work begun by the great pioneers of stellar cartography; amongst whose ranks is included the likes of Johann Bayer (1572-1625), John Flamsteed (1646-1719) and Nicolas Lacaille (1713-1762) [1]. Although he was of the old school Gould did not dwell in the past by using antiquated methods and equipment. He was keen to make use of photography to measure stellar positions and together with his mentor Lewis Morris Rutherfurd, founded the branch of astronomy now known as Photographic Astrometry [2].

Like the modern astronomer, Gould was prepared to travel to the ends of the Earth to carry out his observations. As a young PhD student I was always envious of my postgraduate friends who were observational astronomers. They would go off to exotic locations on mountain tops or in deserts in far off lands to use some great telescope of the world, while I would find myself in library or a computer room, peering at some paper containing what my friends jokingly called *'nasty sums'*. So it was in 1870 that Benjamin Apthorp Gould left the familiarity and safety of Cambridge, Massachusetts for the Argentine to become the first Director of the *Observatorio Astronómico de Córdoba*, Argentina [3]:

"…Gould sailed for the Argentine, via Europe, to execute, the projects which had been taking shape in his mind since 1865. Narrowly escaping entanglement in the Franco-Prussian War of 1870, he arrived at Buenos Aires as the southern winter was changing into spring and found his destination still far away. Proceeding by boat up the La Plata to Rosario, and thence northwestward by a newly constructed railway across the pampas, he found in Cordoba, the site chosen for his work, a medieval Spanish city of 30,000 people, set down in the new world but perpetuating in it the life and ideas of a bygone time. Capable of supporting life in a primitive but fairly comfortable fashion, the place was almost wholly devoid of accessories for a scientific establishment. Mechanical facilities of every kind, light, power, machinery, and skilled labor were almost unknown, and local assistance was of small avail save for the aid given by one or two Cordobans who had been educated in Europe."

During a ten year period at Cordoba, from the summer of 1872 until the winter of 1882, Gould and his assistants took hundreds of photographs of 35 of the most well known Open Star Clusters visible from the Southern hemisphere; including the *Butterfly Cluster'* (M6), *Ptolemy's Cluster'* (M7) and the *'Jewel Box'* Cluster (Kappa Crucis) [4]. The two famous Northern Hemisphere Clusters the *'Pleiades'* (M45) and the *'Praesepe*' (M44), were also photographed.

Using these photographs Gould obtained accurate measurements of the positions of their brightest members, down to about magnitude 10.5. This mammoth effort marked the true beginning of Photographic Astrometry, and paved the way for the even greater challenge of using photography to map the entire sky, but that as they say is another story [5].

He was also responsible for the production of the Great Star Catalogue, known as the Uranometria Argentina, for which he was ultimately awarded the Gold Medal of the Royal Astronomical Society in 1883, some four years after its completion [6], [7]. In it Gould assigned 'numerical designations' to the brightest stars within 100 degrees of the South Celestial Pole (i.e. from Declinations of +10º to -90º), in a manner similar to which John Flamsteed had done earlier for the Northern Hemisphere [8].

Benjamin Apthorp Gould's journey to the Argentine was from a professional viewpoint one of great achievements and a tremendous pride gained from the many honours bestowed upon him by his peers; but personally it was to be full of tragedies from which he would never recover and which haunted him even until the very day he died.

V.2.2 Boston & Harvard

Researching the personal life of Benjamin Apthorp Gould has not been an easy task. In his case there is a distinct (but not total) lack of the usual biographical sources required by the Genealogist in piecing together a person's life; namely family papers, letters from friends and loved ones, the entries of a daily diary and not forgetting the goldmine of information to be found in the family photographic album. It is not even possible to turn to the other biographies for help, his only biographer of note, George C. Comstock bitterly complains of the problems he faced in his memoir on Gould [9]:

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Benjamin Apthorp Gould had a long association with the Boston Latin School. His father, Benjamin Apthorp Gould, senior (1857-1859) was headmaster of the school for a number of years, Gould himself was not only educated at the school, but also worked there as a teacher after his graduation from Harvard University in 1844. The Boston Latin School was founded on the 23rd of April 1635, in Boston, Massachusetts. It is both the first public school and the oldest existing school in the United States.

The Public Latin School was a bastion for educating the sons of the Boston elite, resulting in the school claiming many prominent Bostonians as alumni, including his wife Mary Apthorp Quincy's father, grandfather and great grandfather. Its curriculum followed that of the 18th century Latin school movement, which held that the classics was the basis of an educated mind. Over the years the school has been housed in six separate buildings, the first built in 1635. The present building on Avenue Louis Pasteur, dates from 1922. It was not until 1972 that the school admitted its first coeducational class. Today it has about 2400 pupils.

Benjamin Peirce (1809-1880) was Professor of Mathematics and Astronomy at Harvard University during the time Benjamin Apthorp Gould was a student (1841-1844). It was Peirce who introduced Gould to Science and away from the Classical education he had been pursuing. Benjamin Peirce taught at Harvard for some 50 years, being appointed a tutor in 1829, then as Professor of Mathematics from 1831 and in 1842 he added Professor of Astronomy. to his portfolio. In his time at Harvard he made contributions to celestial mechanics, statistics, number theory, algebra, and the philosophy of mathematics. In addition, he was instrumental in the development of Harvard's science curriculum, and served as the college's librarian. From 1867 until 1874, he served as the director of the U.S. Coast Survey.

He remained a Harvard Professor until the very day he died. He remained a lifelong friend of Gould's and supported him during the infamous *'Dudley Observatory Controversy'* of 1858-1859 He married Sarah Hunt Mills, the daughter of U.S. Senator Elijah Hunt Mills. Peirce and his wife had four sons and one daughter. He died on the 6th of October 1880 in Cambridge, Massachusetts, at the age of 71.

Benjamin Peirce (1809-1880)

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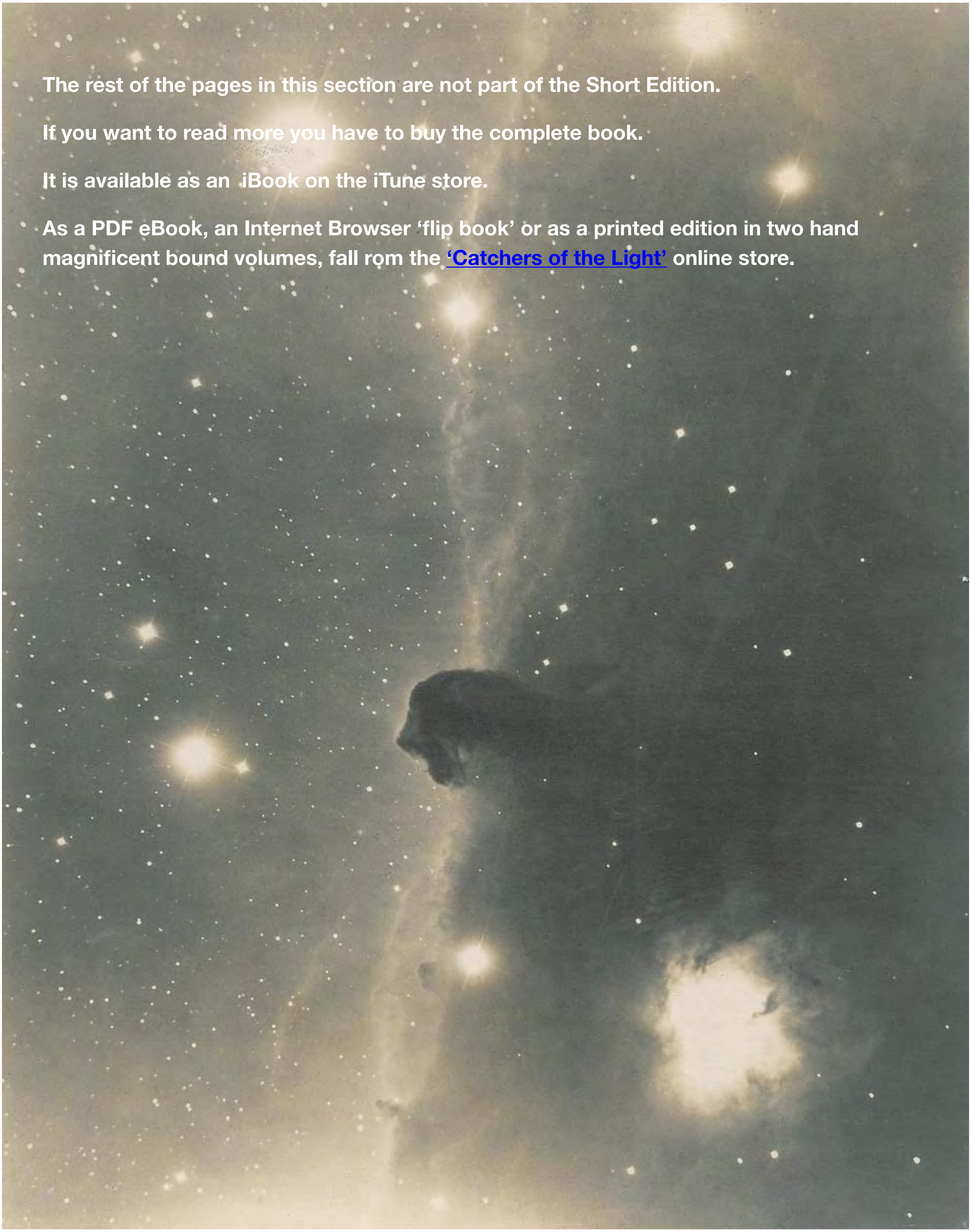


V.3

‘Nebula Man’

Henry Draper

Born: 7th March 1837, Prince Edward County, Virginia, USA

Died: 20th November 1882; New York, USA

On the 30th of September 1880, the New York Doctor, Henry Draper used a Gelatino-Bromide Dry Photographic Plate and his 11-inch Alvan Clark Refractor to take his iconic image of the ‘*Great Orion’* Nebula (M42). It is now one of the most famous and important photographs of all time. In doing so he became the first person to successfully image a Nebula. At this moment *Deep Space Astrophotography* was truly born.

V.3.1 Nebula

Henry Draper was destined from an early age to become a Medical Doctor like his father had before him. However, his father John William Draper had been no ordinary man. In 1840 when Henry was just three years old his father took a photograph which had astounded the world – it was of the Moon and the first ever permanent image of an astronomical body [1]. It was inevitable that one of his children at least should follow their father into the Astrophotography *'Hall of Fame'.* Henry Draper was such a child.

Henry Draper began like every other '*newbie*' Astrophotographer - by taking images of the Moon. His photographs of the Moon were a little bit different – they were at the time amongst the finest ever taken; and brought him in 1864 to the attention of George Phillips Bond, the then Director of the Harvard Observatory and America's leading authority on Astrophotography,

In a letter dated the 15th of November 1864, G. P. Bond gave the young Henry Draper great encouragement to continue with his promising efforts [2]:

"Through the kindness of Mr. Folsom, I have received, in perfect condition, the magnificent photograph of the moon, with the accompanying memoir, which you have presented to the observatory. Please accept my best thanks for this fine specimen of your successful labors in celestial photography. You seem to have surrounded yourself with advantages quite unrivaled. Chief among them, I should reckon that of joining to your own knowledge of the theory of the chemical process involved, the fruit of your father's long experience and profound researches…"

Henry Draper did just that - with a photograph, that like his father's forty years earlier was of such importance that it astounded the world; and which subsequently became one of the most famous photographs ever taken.

In the early morning of the 30th September 1880, the New York Doctor, Henry Draper MD from his Observatory at Hastings-on-Hudson, New York, took a photograph of the '*Great Orion Nebula'* (M42), an object whose light had taken over 1300 years to reach him [3].

The light which formed the image on Draper's photographic plate had started its journey, when the Prophet Mohammed was spreading the word of Islam and Ancient Rome was no longer ruled by Emperors, but by Barbarian tribes. It was an event that marked one of the greatest milestones in the history of Astrophotography.

Let us now tell the story of Henry Draper: Doctor, Civil War Surgeon, Astronomer and Photographer – one of the truly great pioneers of Astrophotography. We begin our narrative not in New York or the township of Hastings-on-Hudson, but in Prince Edward County, Virginia, where Henry Draper was born.

V.3.2 Prince Edward County

Henry Draper was born on the 7th March 1837 in Prince Edward County Virginia, United States, the son John William Draper (1811-1882) and Antonia Coetana de Paiva Pereira Gardner (1815-1870) [4]. He was born into a medical family; his father was a well known Doctor, Chemist, Botanist and a Professor at New York University and his mother was the daughter of the personal physician to an Emperor of Brazil.

In 1839 John William Draper who had been a Professor of Chemistry at the nearby Sidney Hampton College was offered the Chair of Chemistry in the undergraduate department of the University of New York. So when he was just two years old, Henry Draper found himself uprooted from the peace and tranquility of Prince Edward County into the hustle and bustle of the metropolis of New York.

Not long after his arrival, Henry Draper entered the primary school, which was at that time was connected with the University, from which he passed into the preparatory school. From the early age of thirteen onwards, he began to assist his father with his photographic work, including the taking of Daguerreotype photographs through a microscope. He quickly became hooked on photography and had already chosen the path he would follow in life. Meanwhile his formal education continued apace. At the young age of fifteen Henry Draper became an undergraduate student at New York University, where he proved himself to be a conscientious and gifted scholar.

On the advice of his father, however, and partly on account of his not very vigorous constitution, he did not complete his bachelor's degree, but left the course at the end of his second year and entered the department of medicine, when he was seventeen years old. In 1857 he graduated from the New York School of Medicine at the age of just twenty; which meant that he was unable to receive his degree or practice medicine until he became twenty one. Henry Draper decided to do what many a modern day student still does – he elected to have a *'gap'* year.

V.3.3 Parsonstown

On the 11th of July 1857, Henry Draper and his elder brother John Christopher Draper, (1835-1885), also a Doctor, applied to the New York authorities for Passports; which were issued to them two days later [5]. Shortly afterwards the two brothers left the Port of New York bound for a year long trip Europe, partly for a rest but also to meet eminent scientists of the day and to acquaint themselves on the research being carried out by them.

In the August of 1857 Henry Draper attended the annual meeting of the British Association for the Advancement of Science held that year in Dublin, Ireland from the 26th of August until the 2nd of September. This meeting was to change his life forever. Also attending that meeting was William Parsons (1800-1867), 3rd Earl of Rosse, who had constructed at his estate in Parsonstown a 72-inch Reflecting Telescope [6]. At that time it was the largest telescope in the world, and remained so until 1917 when the 100-inch Hooker Telescope at Mount Wilson, California came into operation.

At the end of the meeting Lord Rosse invited Henry Draper and others back to his estate at Birr Castle, to view his great telescope, known as the *'Leviathan of Parsonstown'.* Henry Draper saw the workings of the telescope and the workshop used to grind and maintain the mirrors (a second main mirror was used when the first was being re-polished). It was here that he found inspiration for his work on astrophotography, and was determined to construct his own telescope, though not on such a grand a scale as the one at Parsonstown [7]:

"In the summer of 1857, I visited Lord Rosse's great reflector, at Parsons town, and, in addition to an inspection of the machinery for grinding and polishing, had an opportunity of seeing several celestial objects through it. On returning home, in 1858, I determined to construct a similar, though smaller instrument; which, however, should be larger than any in America, and be especially adapted for photography. Accordingly, in September of that year, a 15-inch speculum was cast, and a machine to work it made. In 1860, the observatory was built, by the village carpenter, from my own designs, at my father's country scat, and the telescope with its metal speculum mounted. This latter was, however, soon after abandoned and silvered glass adopted."

After his *'Gap'* year in Europe, he qualified as Doctor in 1858 and wrote his graduation dissertation, *'On Changes of Blood Cells in the Spleen',* which was later published in the New York Journal of Medicine' [8]:

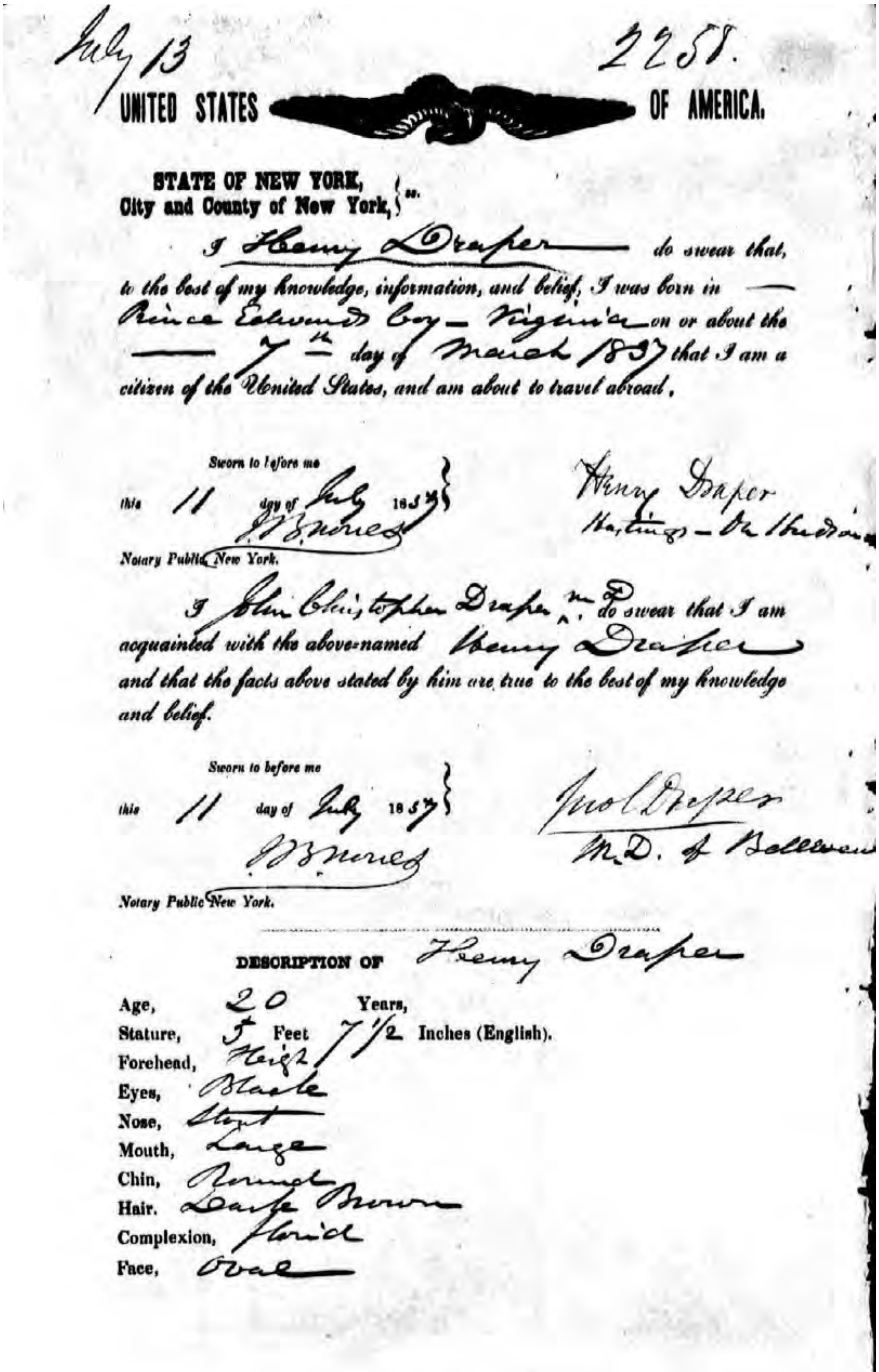
"The researches of Mr. Gray, Professor Kolliker, Dr. Sanders, and others, show that the spleen consists of an exterior iibro-muscular coat, from the internal surface of which bands project in every direction. The divisions to which these bands give rise, are filled by—1st, splenic corpuscles; 2d, parenchyma; 3d, blood-vessels and lymphatics.

The splenic or malpighian corpuscles are made up exteriorly of a prolongation of the sheath of their artery (for. they are arranged upon the artery like grapes upon a stalk), containing, 1st, very minute cells, with nuclei; 2d, free nuclei; 3d, according to Dr. Sanders, bright golden-colored cells; 4th, an intercellular plasma: and 5th, the arterial twig."

I am not sure what all that means, apart from making me realize that Henry Draper was a very clever man.

Whilst in Europe Henry Draper was appointed *'in absentia'* to the medical staff of Bellevue Hospital, New York. A position he took up after his return and did so for the next eighteen months. Henry Draper's medical career was as meteoric as it was distinguished. In 1860, at the young age of twenty-three, he was elected Professor of Natural Science in the Undergraduate Department of the University of New York, and only two years later, he was appointed Professor of Physiology in the Medical Department; being made at the same time Dean of the Faculty. He retained his connection with the New York University Medical School until 1873.

Subsequently he held the chair of Analytical Chemistry in the Academic Department of the University, and upon the death of his father, on the 4th of January 1882, he was chosen to succeed him as Professor of Chemistry, a position which he held, however, only until the close of the academic year. He then severed entirely his connection with the University, but sadly by the end of November that year he was dead.



July 13 2258.

UNITED STATES OF AMERICA.

STATE OF NEW YORK,
City and County of New York, } ss.

I Henry Draper do swear that, to the best of my knowledge, information, and belief, I was born in Prince Edwards Co. — Virginia on or about the — 7th day of March 1837 that I am a citizen of the United States, and am about to travel abroad.

Sworn to before me
this 11 day of July 1857 } Henry Draper
Hastings — On Hudson
J. B. Nones
Notary Public New York.

I John Christopher Draper M.D. do swear that I am acquainted with the above-named Henry Draper and that the facts above stated by him are true to the best of my knowledge and belief.

Sworn to before me
this 11 day of July 1857 } Jno C Draper
M.D. of Bellevue
J. B. Nones
Notary Public New York.

DESCRIPTION OF Henry Draper

Age, 20 Years,
Stature, 5 Feet 7 1/2 Inches (English).
Forehead, High
Eyes, Black
Nose, Straight
Mouth, Large
Chin, Round
Hair, Dark Brown
Complexion, Florid
Face, Oval

Official documents are a valuable source of information for the family historian, but they seldom tell the whole story. On the left is Henry Draper's passport application made on the 11th of July 1857. Although it gives useful facts about his physical characteristics it does not say why he needed a passport or where he was going. Fortunately we have other sources which tell us all of this. Henry Draper had passed his examinations to become a Doctor, but because he was only twenty he could not graduate.

So it was in the July of 1857 he embarked on a trip to Europe. Whilst in Dublin, Ireland he met William Parson, the 3rd Earl of Rosse, who invited him back to his Estate at Birr Castle. It was to be a life changing event for the young Henry Draper.

For on his visit to Birr he saw the Earl's great *'six-feet'* telescope. This inspired him to construct a more modest 15-inch instrument. This marked the beginning of his astronomical career.

Henry Draper Passport Application, 13th July 1857

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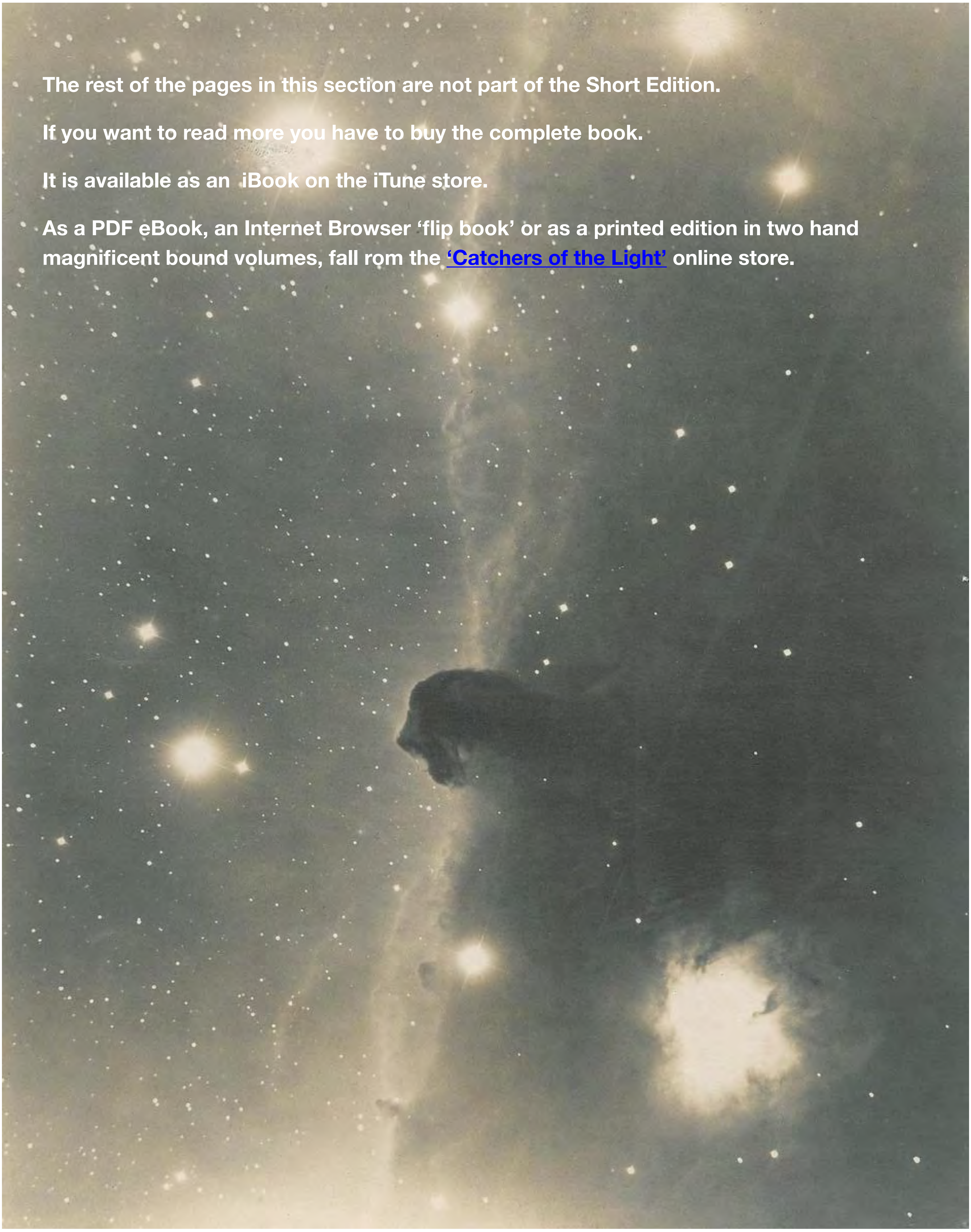


Short Edition

V.4

‘The Welshman’

Isaac Roberts

Born: 21st January 1829, Groes, Denbighshire, Wales

Died: 17th July 1904; Crowborough, Sussex, England

Isaac Roberts was one of the great pioneers of Deep Space Astrophotography. His images of objects such as the ‘*Great Andromeda Spiral*’ and the ‘*Pinwheel*’ Galaxy in Triangulum are even to this day masterpieces, which many a modern imager would be proud to have taken. It was Roberts who showed for the very first time what many of these objects truly looked like. He took at least 2485 photographic plates during the years 1883 to 1904.

V.4.1 Roots

Isaac Roberts was a Welshman all his life even though he spent the majority of it in England. He both spoke and wrote the language of his birth fluently. His family were also Welsh through and through, They had farmed the land around Denbigh for as long as anyone could remember. Yet Isaac Roberts was destined not to be a farmer like his father and his father before him. Instead he was to become one of the greatest pioneers of Astrophotography, whose images of the heavens astounded the world [1].

On the 30th of September 1880, the New York Doctor, Henry Draper (1837-1882) obtained a photograph of the '*Great Orion'* Nebula (M42) and in doing so became the first person to successfully image a Deep Space Object (DSO). However despite the magnificence of this great achievement the nature of these '*nebulae*' remained elusive and even their true appearance was in many cases unknown, appearing as mere smudges in the eyepieces of every telescope irrespective of its size.

From 1883 onwards until his death in 1904, Isaac Roberts began taking photographs of almost every well known Deep Space Object visible from his observing locations. In many cases he was the first person to image a particular object and as such it was his eyes which saw the fainter and more elusive of them as they truly are, ahead of any other person who had ever lived. His list of '*firsts*' is truly impressive and includes such famous objects as - *'Great Andromeda Spiral*' (M31), '*Dumbbell Nebula*' (M27), '*Bode's Galaxy*' (M81) and '*Sombrero Hat Galaxy*' (M104).

On the monument erected to his memory by his widow, Dorothea Klumpke (1861-1942) in Flaybrick Cemetery, Merseyside, England can be seen engravings of two of his favourite DSOs - the '*California*' nebula (NGC 1499) and the '*Great Andromeda Spiral*' (M31). At the time of his death in 1904, Roberts was aware that certain nebulae like NGC 1499 were made up of glowing gas whilst spiral nebulae such as M31 were composed of stars.

However, what he did not know was that many of the 'nebulae' he captured were in fact separate *'Island Universes*' lying millions of light years beyond the boundaries of our own Milky Way star system. It was Robert's images of DSOs that were to be of great assistance in the long process which would ultimately lead to the understanding of their nature. This was Isaac Roberts' legacy to Astronomy and was left to those who followed him, most notable of which would include the great Edwin Powell Hubble (1889-1953).

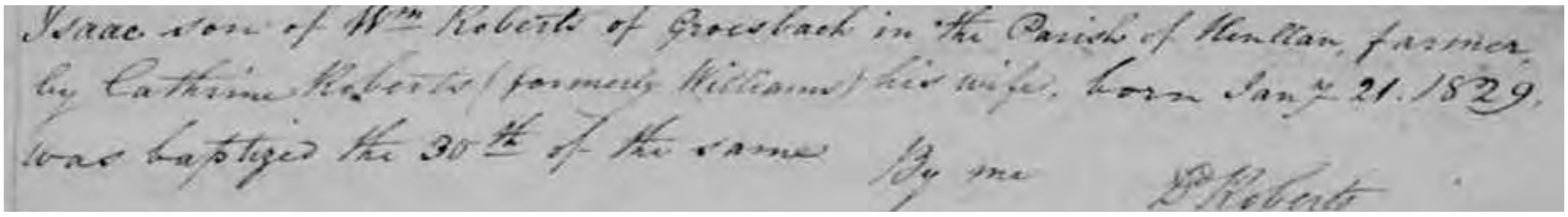
Let us now tell the story of his life which began amid the sheep, choirs and sermons of the Vale of Clwyd, Northern Wales in the years just before Queen Victoria ascended the throne.

V.4.2 Groes

Isaac Roberts was born on the 21st January 1829 [2] in the tiny village of Groes a few miles from the market town of Denbigh, Denbighshire, Wales, the son of a local farmer William Roberts (c1799-?) and his wife Catherine Williams (c1806-?). A few days later on the 30th of January his christening took place at the Swan Lane Chapel, Chapel Street in Denbigh, where successive generations of the Roberts and Williams families' children had gone before [3].

In the early decades of the nineteenth century many people in the villages surrounding Denbigh earned their living from farming the sheep and cows which grazed in the luscious pastures of the Vale of Clwyd, made green by a never ending season of rain, followed by more rain. The sheer drudgery was only broken on Sundays when a trip to the local chapel was for many the highlight of their week – a chance to meet friends and family, to have chat and to sing. This never ending cycle of sheep and sermons took place week in week out and continued from one generation to the next.

Then rumours were heard of a better life '*over the water*' in the burgeoning port of Liverpool; where employment was guaranteed and where people could perhaps make something of themselves and actually be somebody. For Isaac Roberts and his parents it was time to move on. Sometime around 1836 before Isaac Robert's childhood had ended, the whole Roberts family moved to Liverpool.


Isaac son of Wm Roberts of Groesbach in the Parish of Henllan, farmer
by Cathrine Roberts (formerly Williams) his wife, born Jany 21. 1829,
was baptized the 30th of the same By me D Roberts

Isaac Roberts Baptism, 30th January 1829

The document above is an extract from the baptism register of the Swan Lane Chapel, Denbigh, Denbighshire; which states that Isaac Roberts son of William Roberts and his wife Catherine Williams was born on the 21st of January 1829 and baptised on the 30th of the same month. Other biographies and obituaries give his date of birth as the 27th of January 1829.

Isaac Roberts was brought up in the small farming community of Groes, Denbighshire, Wales. He was the eldest son of William Roberts, a farmer and his wife Catherine Williams; who had in all seven children, two boys and five girls: Jane (1825-), Phoebe (1827-1905), Isaac (1829-1904), Elizabeth (1831-), Sophia (1833-), Alicia (c1838-) and William (c1842-).

Like many a Welshmen he was a devout chapel goer and often used to sing in his native tongue whenever he got the chance. Isaac Roberts left no children by either of his two marriages, so his second wife the astronomer Dorothea Klumpke, inherited all his astronomical effects and a considerable fortune. The capital of his estate would ultimately go to the Universities of Liverpool and Wales (at Bangor and Cardiff) for the provision of student scholarships.

The village of Groes sits nearby the beautiful Vale of Clwyd (Welsh: Dyffryn Clwyd). The Vale extends south-south west from the coast of the Irish Sea for some 20 miles (about 30 km) forming a triangle of low ground bounded on its eastern side by the well-defined scarp of the Clwydian Range and to the west by numerous low hills.

It has been the subject of a number of Landscapes by romantic artists of the nineteenth century, including David Cox (1783-1859).

Vale of Clwyd by David Cox, 1849

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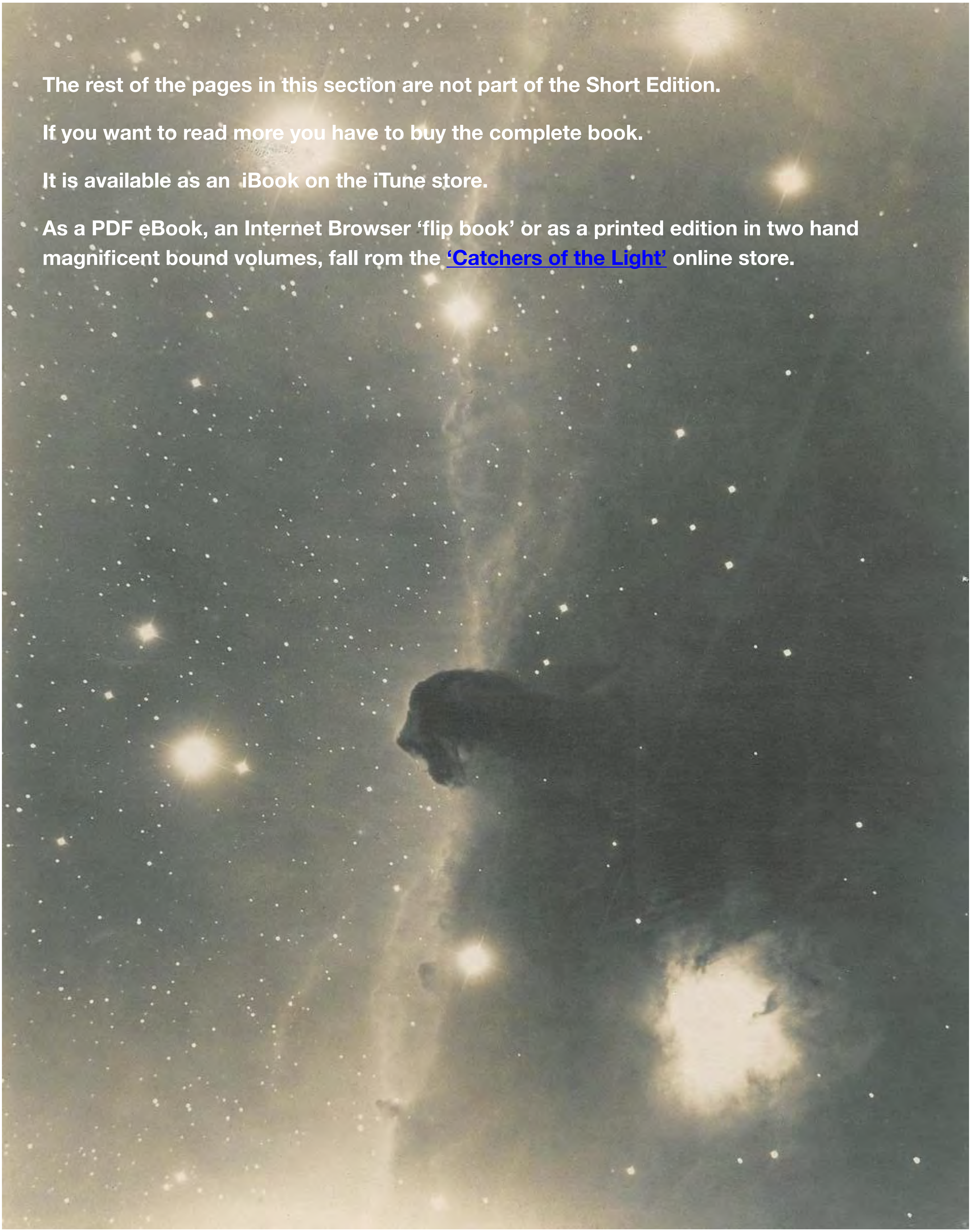

Short Edition

V.5

‘The Man from Daramona’

William Edward Wilson

Born: 19th July 1851, Greenisland, County Antrim, Northern Ireland

Died: 6th March 1908, Daramona House, Streete, County Westmeath, Ireland

William Edward Wilson was one of the greatest Deep Space Astrophotographers of his day; as well as a scientist who made valuable contributions in the field of Astrophysics. His *‘wide field’* photograph of the *‘Great Orion’* Nebula (M42) and the *‘Running Man’* Nebula NGC 1977 is still to this day one of the finest astronomical images ever taken.

V.5.1 Recognized

The name William Edward Wilson is largely unknown today, but in his day he was recognized as one of the greatest Astrophotographers of his age, as well as an amateur astronomer of some note.

Although he had no formal education he was still able to carry out scientific research of the highest quality.

He was one of the first to measure the temperature of the surface of our Sun; and his value of just over 6500ºC compares reasonably well with today's accepted figure of around 5505ºC.

On the 11th of April 1895 Wilson together with George Fitzgerald and George Minchin made the first photometric determination of the brightness of stars. They obtained results for four first magnitude stars - Deneb (Alpha Cygni), Arcturus (Alpha Bootis), Vega (Alpha Lyrae) and Regulus (Alpha Leonis).

His wide field photographs taken in the 1890s of well known Deep Space Objects (DSOs) such as the *'Great Orion Nebula'* (M42) and the *'Pinwheel'* Galaxy (M33) in the constellation of Triangulum, were the finest of the day. At the time, only the images taken by the professional astronomers, James Edward Keeler and Charles Dillon Perrine at the Lick Observatory could be compared to those of Wilson [1].

Today his photographs, although they were taken over a century ago are still amongst the finest images of astronomical objects ever captured, whether on plate, film or CCD.

John Wilson (1826-1906) - William Edward Wilson's father

V.5.2 Daramona

William Edward Wilson was born on the 19th of July 1851 at Greenisland, County Antrim, Northern Ireland [2], the only son of John Wilson and Frances Wilson Nangle [3]. His father was an educated man, a graduate of Trinity College, Dublin, who knew the importance of learning. This together with his father's considerable means and influence gave young William Edward Wilson a *'head start'* in life [4].

In about 1855 the Wilson family moved to their new home – Daramona House, in the village of Streete, County Westmeath, Ireland [5]. Their new home was not so much a house but more of a mansion; some idea of its size can be gauged from the details provided by John Wilson in the 1901 Irish Census. The entry for Daramona House stated that it had 30 rooms occupied by the six members of the family, a Governess, a Cook, a Children's Maid, a Kitchen Maid, a Parlour Maid, a House Maid and a Laundress. There were also a further 27 Offices and Farm Buildings attached to the property [6].

It was at Daramona House that William Edward Wilson grew up and lived for the remainder of his life. As a child he had three younger sisters – Elizabeth Dupre (1852-1927), Matilda Dorothea (1856-1939) and Beatrice Frances (1862-1899), but it was to Science that he lavished the majority of his affection. From an early age William Edward Wilson's health was delicate and so he had to be educated at home. This education was all he ever received, and he did not attend any school or university. His father was a man of some intelligence, and it was he who had the greatest influence on the young William.

When young he acquired a great liking for Astronomy. This was to become not only his hobby, but also his career, albeit unpaid.

Daramona House, Streete, County Westmeath, Ireland, c1900

V.5.3 Algeria

William Edward Wilson's first recorded venture in Astronomy was as a member of an expedition to Oran in Algeria to witness the total eclipse of the sun which occurred there on the 22nd of December 1870 [7]. This trip could not have failed to influence the young nineteen year old, for amongst those who journeyed to the witness the eclipse were some of the finest astronomers of the day, notably William Huggins (1824-1910), the English Spectroscopist and the French Solar Physicist, Pierre Jules César Janssen (1824-1907). In later life the study of the Sun and the measurement of Stellar Magnitudes were to become two of his most important areas of research, in which he made significant contributions. Huggins, Janssen and Wilson himself were all to take up astronomical photography at various points in their lives; and become three of its greatest pioneers.

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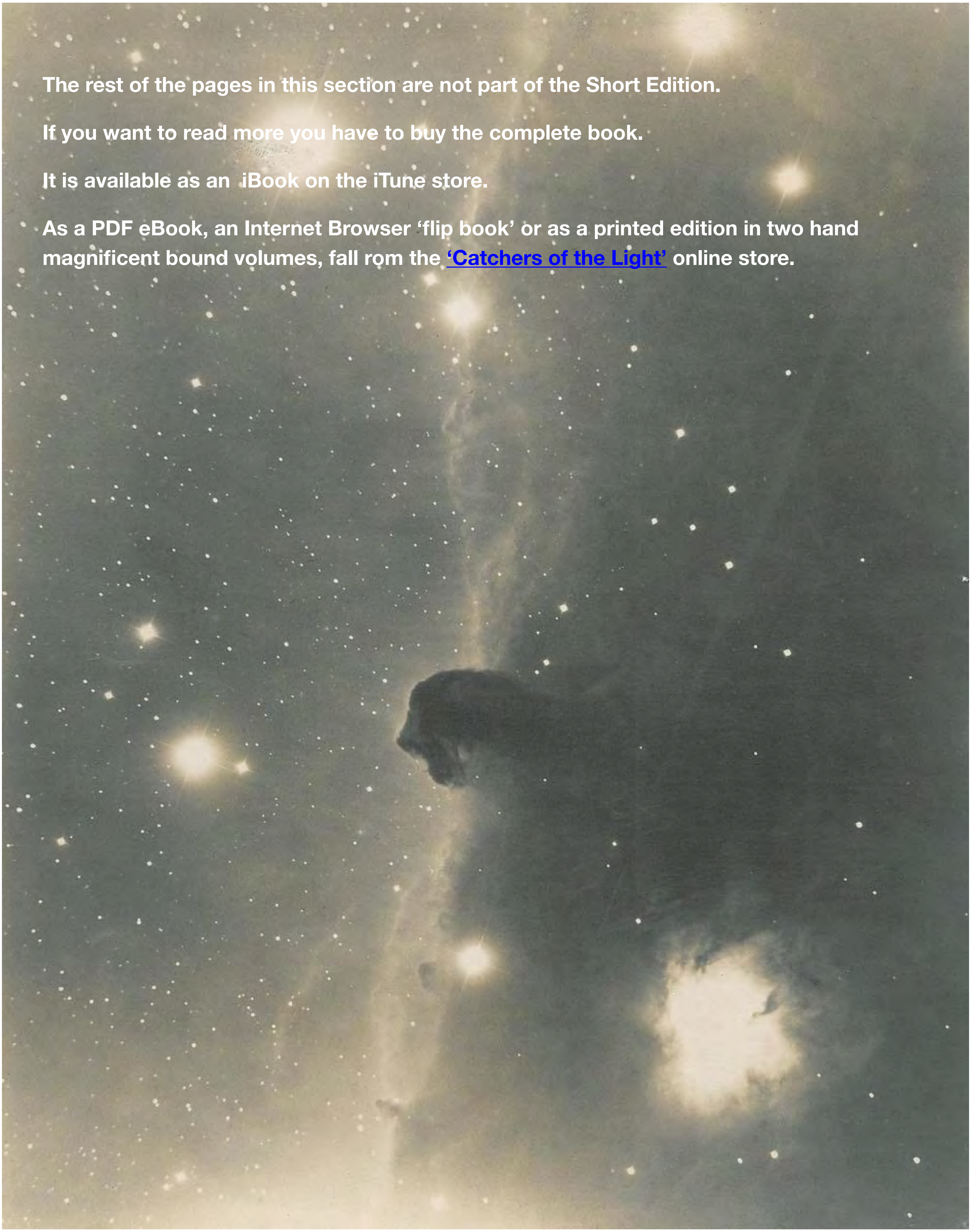

V.6

‘The Mirror Man’

James Edward Keeler

Born: 10th September 1857; La Salle, Illinois, USA

Died: 12th August 1900; San Francisco, California, USA

During the latter part of his career James Edward Keeler used the 36-inch Crossley Reflector at the Lick Observatory, California, USA to demonstrate the great potential large silvered mirrored reflectors had in the conduct of astrophysical research. The wonderful images produced by James Edward Keeler with this telescope are a great testament to his all too brief life.

V.6.1 Mirrors

James Edward Keeler (1857-1901) was one of the first professional astronomers to recognize the great contribution large silvered mirrored reflecting telescopes could make in man's never ending quest to understand the nature, structure and origin of the universe, in which he is just a mere speck of dust in the enormity that surrounds him [1].

Astronomy in the nineteenth century was dominated by the refractor. It was the age when the great observatories of the world competed to own the telescope with the largest objective lens. In 1847 the largest refractor had an aperture of just 15-inches, with the observatories at Harvard College, in Cambridge, Massachusetts and the Imperial Russian Observatory at Pulkovo, near St. Petersburg each owning instruments that jointly held the then title of world's biggest telescope.

The years that followed saw refractors of ever increasing size being constructed, with no observatory holding the title of *'world's largest'* for more than a few years at a time. By the end of the century there were six refractors with apertures of 30-inches or more: the 30-inch at Pulkovo (1885); the 30.3-inch at Nice (1886); the 31.5-inch at Potsdam (1899); the 32.7-inch at Meudon (1891); the 36-inch at Lick (1888); and the 40-inch at Yerkes (1897. Of these '*Great Refractors*' only those at Pulkovo, Nice and Lick were briefly entitled to call itself the *'world's largest'*; the two at Meudon and Potsdam never could. Even the massive 40-inch at Yerkes briefly lost its seemingly '*permanent*' crown in 1900, to the ill-fated 49.2-inch 'Paris Exhibition' telescope [2].

Unbeknown to the astronomical establishment of the time an alternative type of telescope - which they had completely ignored and frequently scorned, was preparing to hammer the *'nails into the coffins'* of the precious but ageing dinosaurs which were their *'Great Refractors'*. These once fine instruments had dominated the world of astronomy for nearly three centuries, ever since the time of Galileo, but were now reluctant to move into a new world born of photography and one to be dominated by a new species of telescopes.

The alternative in question was the silvered mirrored reflecting telescope, which for the whole of the nineteenth century was largely left in the hands of a dedicated but nevertheless competent body of amateur astronomers. Even James Edward Keeler who was to become one of the reflector's greatest supporters was until the last few years of his life totally ignorant of the capabilities of such telescopes.

In 1898, Keeler was appointed the Director of the Lick Observatory atop Mount Hamilton in California, with it came a telescope which was unknown, untried and mistrusted – a 36-inch silvered mirrored reflector, the gift of a carpet tycoon from Halifax, England, named Edward Crossley. In the two years which were left to him, James Edward Keeler, learnt to trust his new charge, to repair and modify it, and in doing so turned what was a '*Trojan Horse*' into the beginnings of a new age - the era of the reflector.

With the 36-inch '*Crossley*' reflector, James Edward Keeler and his assistant Charles Dillon Perrine (1867-1951) took a series of photographs of Deep Space Objects (DSOs), which even in the age of the CCD chip are still arguably some of the finest ever taken.

V.6.2 La Salle

James Edward Keeler was born on the 10th September 1857 at La Salle, Illinois, United States, the third of four children born to William Frederick Keeler (1821-1886), a partner in the local iron works and his wife, Anna Eliza Dutton (1824-1901), the daughter of Henry Dutton (1796-1869), a former Governor of Connecticut [3], [4]. The Keeler's second child, Minnie (1854-1857) had died in 1857 when she was only three, less than four months before Eddie Keeler, as the future astronomer preferred to be called, was born. His other two siblings, Henry Dutton Keeler (1847-1877) and Elizabeth Elliott Keeler (1860-?) survived into adulthood [5].

His parents had named their second son after his father's two dead brothers. In the March 1849, William Frederick Keeler left his wife and their young son Henry Dutton, aged 2 at their home in Bridgeport, Connecticut to travel to the nearby port of New Haven to board a ship bound for San Francisco and the Gold fields of California [6].

Accompanying on his quest for easy riches were his two younger brothers James (-1849) and Edward (-1850), and 57 other *'forty-niners'.* All of them had invested $300 in the California & New Haven Stock Company, with the aim of finding Gold [7]. The Company had charted the Bark, *'Anna Reynolds'* for their expedition complete with crew, a cook and his wife; and three dogs who it seems fought a lot much to the annoyance of the passengers.

On the 12th of March 1849, the Anna Reynolds left New Haven, two days late, not that it mattered much as the voyage ending up taking 255 days, and not arriving in San Francisco until the 22nd of November that year. By the time the sixty '*forty-niners*' arrived in California, they had by all accounts had enough. James Keeler kept a detailed diary of their on board adventures, as well as making a number of drawing depicting the voyage [8]. During the eight months at sea they had to contend with sea sickness, a leaky ship, heavy storms, little or no food as the cook and his wife, who only catered for themselves; and of course - the three pesky dogs.

All was not bad as they kept themselves amused in varying pastimes, mention is made of classes in arithmetic, geometry and surveying; regular Sunday religious services were held, whilst others played backgammon and checkers; the really keen amongst them made Gold washing machines for use on their rich claims and the desperate braided hats. James Keeler even published an '*on board*' magazine called appropriately the *'Golden Budget'*. About a month or so before they arrived in San Francisco, a calamity struck the ship, of which James Keeler records [9]:

"It was between the hours of 3 & 4 in the morning as I lay in my Bunk fast asleep and dreaming that the ship had sprung a leak and the men were hard at work at the pumps when I was aroused by a heavy shook and a crash. I sprung from my Berth all was confusion and ... on deck and cries of she is going down keep her away hard down the wheel Brace round the head yards. My first thought was we was on the rocks but that could not be possible out here in mid ocean the next was we was run down by a vessel.

Then I recollected the Bark we exchanged signals with yesterday. I hurried on my clothes and ran upon deck and saw the vessel alongside a smashing in our Bulworks every lurch she made. We got spars and tried to get her off but her head gear got afoul of one anchor one of our seamen jumped aboard of her and with a knife cut her jib stays and other rigging and in a few minutes we fell off clear from her. She tore our Flying jib and topsail and tore all to pieces. Stove in our Bulworks from the Bow to gangway on starboard side carried away the sprittail and flying jib guy fore topmast stay jib stay the fore shroud breaking the chain plates into tore our starboard anchor off the bone with the cathead. The anchor hung alongside for a few minutes and stove in the other vessel. Bow above water line.

They got off with only the loss of their head gear such as flying jib boom jib boom bob stays...no damage done to either vessel below water line had there been much wind at the time we both must have gone down instantly but as it happened there was but a light air.. .some on Board were much frightened the French passengers uttered invectives on the other vessel...and one of them went so far as to shake his fist at her and say by Dam. She stood off a few miles and we both hove to till morning."

Their time in California did not however live up to their great expectations of quick money and loose women. The Company set about finding a claim but met with little success, and by the March of 1850 it wound up, the men having decided they could not work together. They each received $50 to help set up on their own and $20 worth of provisions [10]. It was a financial disaster. The Keeler brothers stayed for a while but even this was cut short by the death of Edward Keeler. It seems that James Keeler for some reason rejoined the Anna Reynolds on its voyage to the Sandwich Islands (Hawaii). He died en-route. William Frederick Keeler made his way back to home via China on the Clipper ship the *'Samuel Russell'*; no richer but a lot poorer for the loss of his two brothers [11], [12].

On arriving back in America, William Frederick Keeler moved his family to a plot of land he had bought in 1846 in the town of La Salle, Illinois, near to the shore of Lake Michigan and its bigger neighbour, Chicago [13]. It was here that the Keeler's three other children were born, two sisters and a brother to Henry Dutton Keeler, who had been born in Bridgeport, Connecticut. By 1853 William Frederick Keeler had set himself up in business as a watchmaker, but by the time Eddie was born he had become a senior partner in Keeler, Bennigin & Co. a local Iron Works, which traded as the *'La Salle Iron Works'*, and made all kinds of steam engines and general machinery [14].

The life of Eddie's father was anything but boring. If his adventures aboard the Anna Reynolds and the Gold fields of California were not enough for him, then the onset of the American Civil War gave him plenty more.


First Street, La Salle, Illinois (Then and Now)

The *'Anna Reynolds'* was a sailing bark of 197 tons, built in 1838 in Lewiston, Delaware. After her voyage to San Francisco with the three Keeler brothers onboard, she later traded with the Sandwich Islands (Hawaii). The wooden three- masted bark was a common sight in the port of San Francisco in the 1850s.

The ship was chartered by the California & New Haven Joint Stock Company, of which William Frederick Keeler and his two younger brothers, Edward and James, were shareholders. They each paid some $300 with the view of earning a fortune as a *'forty-niner'* in the Gold fields of California. Only William Frederick Keeler returned home alive, after taking a long way round via China.

Bark 'Anna Reynolds', c1850

The *'Samuel Russell'* was a clipper ship built in 1847 by Brown & Bell of New York for its owners A. A. Low & Brother, of New York, for the lucrative China trade. William Frederick Keeler, '*Eddie'* Keeler's father, joined this ship at San Francisco in the May of 1850 and returned with her on the 29th of October 1850 from Whampoa (Huangpu, Guangzhou, China) on its 89 day journey to New York, following his adventures in the Californian Gold fields, as one of the celebrated '*forty-niners*'. At the time the '*Samuel Russell*' was captained by his old school friend Charles Porter Low (1824-1913).


Clipper Ship, 'Samuel Russell', c1850 and its Master: Captain Charles Porter Low

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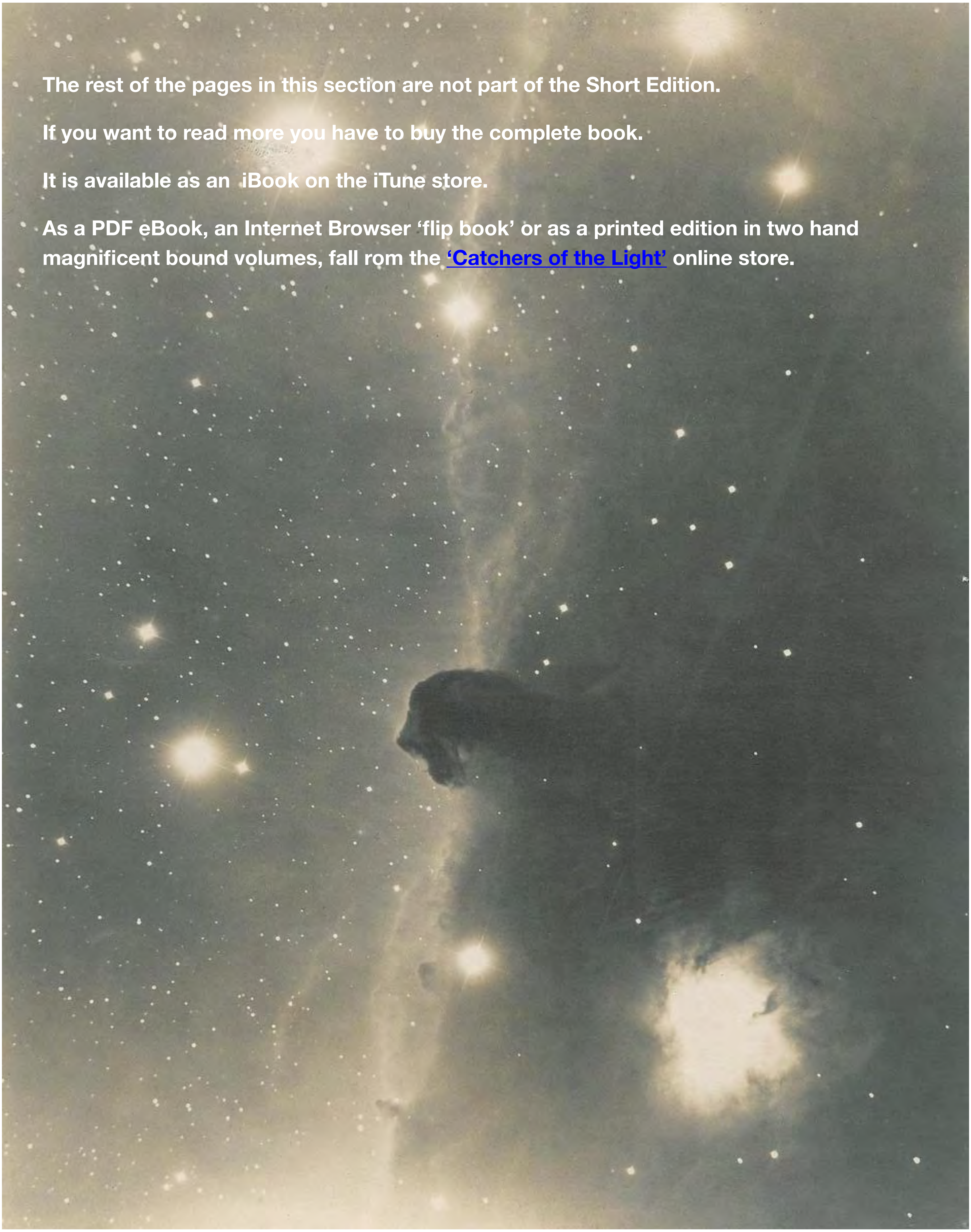

V. 7

'The Photographer's Assistant'

Edward Emerson Barnard

Born: 16th December 1857, Nashville, Tennessee, USA

Died: 6th February 1923, Williams Bay, Wisconsin, USA

Edward Emerson Barnard was one of the greatest observational astronomers of all time. Despite having virtually no formal education, his enthusiasm and his knowledge of the night sky enabled him to become a staff astronomer at both the Lick and Yerkes Observatories. It was from these '*Great*' Observatories that he took some of the finest '*wide field'* images ever captured of our universe.

V.7.1 Vega

Edward Emerson Barnard (1857-1923) had an inauspicious start to life. He was brought up in the '*Deep South*' of the United States, amid the poverty, disease and death of the American Civil War [1]. His father had died before he was born and from an early age he needed to work to support his family, thus sacrificing even the slim chance he might have had of receiving any form of uninterrupted education whatsoever. Yet despite all of this he grew up to become one of the greatest astronomers of his age and the earliest pioneer of '*wide field*' Astrophotography.

It was not surprising that the young Barnard developed a high degree of self reliance, a great capacity for hard work and a tenacity to persevere no matter what life had to throw at him. Before he was even nine years, he had begun work as a photographer's assistant, and for the next seventeen years he remained with the same photographic studio learning the business of photography; a trade which was to prove invaluable in later life, when he turned his attention to imaging the heavens.

As a young boy he acquired a great interest in astronomy long before he had ever owned or even used a telescope. He was often to be found after dark , lying on his back in an old wagon looking up at the stars. On summer evenings he later recalled, after dusk had fallen, a bright white star shone high above his home. It was a sight which fascinated him and for some unknown reason it always remained his special star. He never forgot this star, only years later did he learn that it was called Vega [2].

In 1881, Barnard discovered the first of the sixteen comets that now bear his name, a number greater than that of the legendary French '*comet ferret*' Charles Messier, who could only manage a measly thirteen [3]. His Comet discoveries gained him attention of the astronomical community, who would now remember his name both during his lifetime and in the decades which followed; even today day he is still revered amongst amateur and professional astronomers alike.

In his professional career which lasted forty years from his first appointment at Nashville's Vanderbilt University Observatory in 1883, until his death in 1923 at the Yerkes Observatory, Wisconsin, E. E. Barnard never forgot his astronomical roots. For it was the thrill of comets and the wonders of the Milky Way which were to become the '*targets*' for the magnificent images which even now over a century later are only rarely bettered.

Edward Emerson Barnard (1857-1923) had a traumatic childhood. He found it difficult and painful to speak of events which occurred decades earlier. He was later to recall that they were '*so sad and bitter that even now I cannot look back to it without a shudder*'. Not only had his father died before he was born, the young Barnard had to witness at first hand the horrors, deprivation and disease which was the American Civil War, a conflict which was once described as a '*hellish way to settle a disagreement.*' If all of this was not enough, he nearly died in the great cholera epidemic which swept Nashville in 1866. The disease which was little understood at that time, went onto to kill upwards of 1,000 Nashville's citizens. This was nothing new as the disease had also ravaged the town in 1849, 1850 and 1854. It is a credit to E. E. Barnard that through his tenacity, perseverance and strength of will, given only two months formal education and the traumas experienced from birth, that he should have even managed to survive, let alone became a great and famous astronomer.

Edward Emerson Barnard, Photographer's Assistant, aged 9

V.7.2 Nashville

Edward Emerson Barnard was born on the 16th December 1857 amongst the slums of the southern American town of Nashville, Tennessee, the youngest of the two sons of Reuben Barnard (?-1857) and his wife, Elizabeth Jane Haywood (1815-1884) [4]. From the very moment of his birth, life was hard. His father had died in Cincinnati, Ohio, before he was born. Soon after her husband's death, the then pregnant Elizabeth Barnard left Cincinnati with E. E. Barnard's elder brother Charles (1854-1924) and moved to Nashville, Tennessee.

Why his mother chose Nashville is not known. Although she was a native of the neighbouring state of Kentucky, there were no known relatives in Nashville or the nearby area. So it seems she came alone and without any relations or friends to a strange town in search of work, possibly as a maker of wax flowers, an art at which she was particularly skilled. Whatever the reason for coming to Nashville, her life and that of her two young children would not be easy.

When E. E. Barnard was not even four years old, life for him and his family; and the whole of America got even worse. Fort Sumter in Charleston Harbour, South Carolina had been attacked by forces loyal to the Confederate South; and so began the American Civil War on the 12th of April 1861 [5]. It was a war that ruined the South and was particularly felt in Nashville which ended up in the thick of it. For it was at Nashville that the Confederate Army made its final gamble in the hope of victory and lost.

In the June of 1861, Tennessee joined the other southern states and became part of the Confederacy. It was not a wise decision, for by the 18th of February the following year, Nashville was under the control General Ulysses S. Grant of the Union Army, and would remain so right up until the end of the war. Nashville was cut off from its southern friends; and the Union did nothing to alleviate its misery, but instead only added to its privation [6]. The Barnard family was forever on the borderline between hunger, starvation and death.

At the end of 1864 the war was not going well for the forces of the Confederacy. In the November of that year the Army of Tennessee made a last ditch effort to gain a victory over the Federals. The Confederate General John B. Hood led the Army of Tennessee out of Alabama toward Nashville in an effort to cut off the Union's supply line. But the conditions were not good, severe bad weather had frozen the ground and their rations were almost completely gone. One soldier who marched from Atlanta to Nashville later described the long walk he and his comrades had to endure: '*Our shoes were worn out and our feet were torn and bleeding . . . the snow was on the ground and there was no food'*. But they nevertheless made the journey.

Unfortunately for these weary Confederate soldiers, the Union army was waiting for them in Nashville. For almost two weeks, both sides waited in the ice brought by the freezing rain, this only delayed the inevitable clash between the two opposing armies. As soon as the weather cleared, the fighting began on the 15th of December 1864. Less than 48 hours later, the Confederate troops were in full retreat, defeated and demoralized [7]. It was the beginning of the end of the war for the south; but for E. E. Emerson Barnard the cessation of hostilities gave him scant respite, before life's next lot of woes hit the young boy.

At least he, his mother and his brother had survived a conflict in which upwards of 600,000 soldiers died and an unknown number of civilian deaths, possibly as high as 100,000 [8]. The year after the war ended, when the Union Army still ran Nashville, a great cholera epidemic swept the town during 1866, claiming several hundred lives and very nearly E. E. Barnard's as well [9].

From an early age E. E. Barnard's fondest memories were of the heavens, but even these were tinged with the horror of the conflict which ruined the South in the years 1861 to 1865: *"When 1 was very small I saw a comet; and I have a vague remembrance that the neighbours spoke of this comet as having something to do with the terrible war that was then desolating the South."* He used to look up at the stars from the back of an old wagon. Among the stars he recalled *'a very bright one, which during the summer months shone directly overhead in the early hours of the evening.'* Only years later would he learn its name. Vega is a very special star for '*wannabe*' astronomers. I too a century later, used to spend hours looking at this star through my telescope at its captivating blue-white colour, wondering what it would be like to go there; and did it have any orbiting planets. Perhaps it should be called the '*Astrophotographer's Star'*.

In 1806, the town of Nashville was made a city. On the 7th of October 1843 it was selected as the permanent state capital of Tennessee. Several towns across Tennessee were nominated; all received votes, but Nashville and Charlotte were the top contenders. Nashville in the end won by a single vote. The Tennessee State Capitol building (right) was constructed over a period of ten years from 1845 to 1855. It was designed by the Philadelphia architect William Strickland, and modelled along the lines of a Greek Ionic temple. It housed both the State Legislature and the Governor’s office. Following the outbreak of the Civil War in 1861, President Abraham Lincoln appointed future President Andrew Johnson as the Military Governor of Tennessee. He set up offices in the Nashville state capitol building. Confederate uprisings and guerrilla attacks continued sporadically in the city. On the 16th of December 1864, the Battle of Nashville ended all hopes of a ‘*Reb*’ victory.

View of Nashville Capital Building, by J. H. Stavoren Studio, c1864

Battle of Nashville – Union Army Camp, December 1864

The Battle of Nashville was a major American Civil War battle which took place at Nashville, Tennessee on the 15th to the 16th of December 1864, between the Union Army under the command of Maj. Gen. George H. Thomas and the Confederate Army under the command of Gen. John Bell Hood. The battle centred around an area to the south of the Union Fort Negley, which was located approximately two miles (three km) south of the town. It was a disaster for the South and the Confederate Army of Tennessee, which suffered losses of 1,500 killed and 4,500 wounded. The Union casualties were only 387 killed, 2,558 wounded and 112 missing or captured! It was one of the largest victories ever achieved by the Union Army during the war. It effectively ended any hopes the South had of victory.

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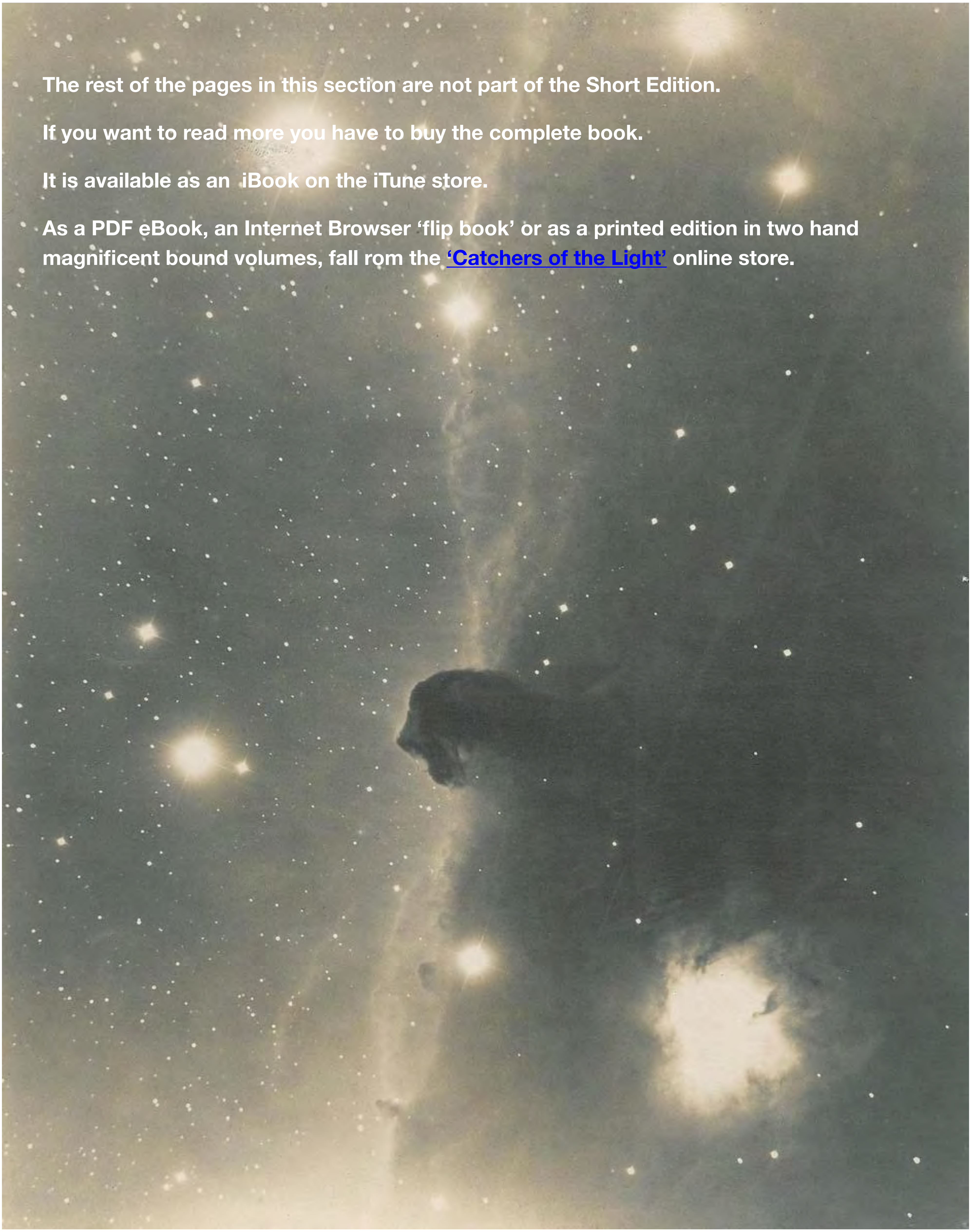


Short Edition

V.8

'The Astronomer's Maid'

Williamina Paton Stevens Fleming

Born: 15th May 1857, Dundee, Angus (Forfarshire), Scotland

Died: 21st May 1911, Boston, Suffolk, Massachusetts, USA

Williamina Paton Stevens Fleming will always be remembered by Astrophotographers for her discovery in 1888 of the *'Horsehead'* Nebula, probably the most famous and iconic of all astronomical objects in the heavens. A remarkable achievement, considering that she had begun her astronomical career as the housekeeper of Edward Charles Pickering, the then Director of the Harvard College Observatory.

V.8.1 Icon

Williamina Paton Stevens Fleming never took a photograph of an astronomical object; indeed there is no evidence to suggest that she took a photograph of anything. Yet her place in the history of astrophotography is assured - because of a discovery she made – one for which modern Astrophotographers should both revere and revile her, for in almost equal measure.

For in 1888 she found on a photographic plate an object which is without doubt the most iconic and beautiful of all astronomical objects ever to be seen by human eyes – the famous '*Horsehead*' Nebula. Let us now tell her story, which is one any author of fiction would be proud to write - of how a housemaid with no scientific training or qualifications became one of the world's a greatest astronomers.

Her life begins not in the hallowed halls of Harvard College where she worked or amongst the stars of Orion where her '*Horsehead*' lies, but in the streets of the ancient Scottish city of Dundee.

The iconic '*Horsehead'* Nebula is one of the most difficult and elusive of all Deep Space Objects (DSOs) an amateur astronomer is ever likely to try and see. Many have likened it to the '*Grim Reaper*' saying it will be the death of them before they set eyes on it!

For the Astrophotographer - it is the '*Holy Grail*' of objects; to obtain a good image of this object is seen as the pinnacle of achievement for modern day imager. Photographs of it taken by the Hubble Space Telescope and before it by the 200-inch at Mount Palomar have inspired many to pursue astronomy as a hobby or even a career.

The 'Horsehead' Nebula (B33)

V.8.2 Dundee

Williamina Paton Stevens first saw the world at half past five in the early evening of the 15th May 1857 from her mother's bedroom above a shop at number 86 Nethergate, Dundee [1]. She was born into a working class family, who if fate had been kinder would have been very wealthy indeed. Her father was Robert Stevens, a carver and guilder who was also an early pioneer of photography in the city. Her mother Mary Walker was a descendent of the ancient Scottish Clan, known as the *'fighting Grahams'* of Claverhouse.

According to family legend, Williamina's Great-Great Grandmother lived in the Dower House (Doune Castle) at Stirling, but because of a lack of a legitimate male heir her fortune passed to another branch of the family. Her great grandfather had previously eloped with, and later married the Dowager's daughter. In 1809 she gave birth to a son, John Walker (Williamina's Grandfather) by which time the inheritance had been lost. On the day he was born - the 16th January 1809, John Walker was made an orphan – his father, a Captain in the 79th Highland Regiment was killed at the Battle of Corunna, Spain, within earshot of his newborn son's first cries! [2]

Very little is known of her early life in Dundee apart from the fact that she belonged to a large extended family. She had six brothers and two sisters. As in any mid Victorian family infant mortality was high; her brother Richard had died aged four, some 4 months before she was born; and three other brothers Andrew, Alexander and Fox had died when she was young [3]. The year 1864 was a very bad year for the Steven's family, not only did Williamina lose two of her brothers - but at 11 o'clock on the morning of the 19th of March her father Robert Stevens had a heart attack and died [4]. He was 39 years old.

The early death of her father when Williamina was not even seven years old meant that it was highly unlikely that he was able to teach her about his passion for photography, which is ironic given that her future claim to fame as a female astronomer was by conducting painstaking examination and measurements of photographic plates. However she may have seen enough of her father's work to unknowingly acquire skills that helped her later in life. Whatever the truth it is clear that she was an able scholar, becoming a pupil teacher when she was 14. The income from which must have helped her family which had lost its main breadwinner seven years earlier.

The career path that Williamina took for a young girl growing up in mid nineteenth century Dundee was somewhat unusual. At that time a large proportion of people in the city were employed in its many Jute Mills and Marmalade factories. In the 1860s Dundee was the centre of the world Jute trade, having acquired this claim to fame in 1833, when Jute fibre was spun mechanically there for the first time [5]. It was also the home of Marmalade, where the factory James Keiller & Co., being the founder of this most British of breakfast traditions [6]. Both industries were no places for people with ambition or dreams. Williamina did not suffer such a fate. Her destiny lay across the Atlantic Ocean and the Harvard College Observatory.

Williamina Paton Stevens Fleming was born on the 15th May 1857 at 86 Nethergate, Dundee, the fifth child of Robert Stevens and his wife Mary (née Walker). Of her nine siblings four died in infancy, and four others Robert, John, Charles and Joanna, emigrated to America to live in Cambridge, Massachusetts.

Only her elder sister Mary Anderson Stevens stayed in Dundee. Eventually her mother Mary Walker also joined them, and died there in 1910, the year before the premature death of Williamina herself.

Nethergate Dundee, Birthplace of Williamina Paton Stevens Fleming

V.8.3 Abandonment

In everyone's life there is at least one event which is so important that it determines their entire future - for good or bad. The 26th May 1877 was Williamina Steven's. On that day at the United Presbyterian Church on Paradise Road, Dundee she married James Orr Fleming [7]. Shortly afterwards her biographers state that the '*happy*' couple emigrated in the December of 1878 to Boston, Massachusetts in search of a new life, away from the cold depressing streets of Dundee; where most people could only look forward to a life of hard work in a Jute or Marmalade factory.

Once in Boston, James Fleming abandoned his new bride when she was pregnant with their child. Desperate to survive and to look after her baby soon to be born, she sought employment and found it as a housemaid at the home of the astronomer, Professor Edward Charles Pickering (1846-1919) - the Director of the Harvard College Observatory. Now in all the accounts of her life up until now her husband James Fleming was the '*baddy*'. Any good historian will tell you never believe what you read until you have done the (proper) research! So let us now find out what really happened to Williamina after her marriage to James Orr Fleming.

James Orr Fleming was a native of Paisley Abbey (near Glasgow), Lanarkshire having being born there on the 2nd July 1841 to a merchant draper, Archibald Fleming and his wife Agnes (née Orr). At the time of his marriage to Williamina he was a man '*on the up*'. He was a widower who had a career as a Bank Accountant. He had previously married Isabella Brown Barr in 1866, but she had died from consumption three years later in 1869 aged 22 [8], [9]. They had a daughter Nancy Brown Fleming born in 1867.

Unfortunately no official passenger records have survived which follow their emigration to Boston, or whether James Fleming even went with her.

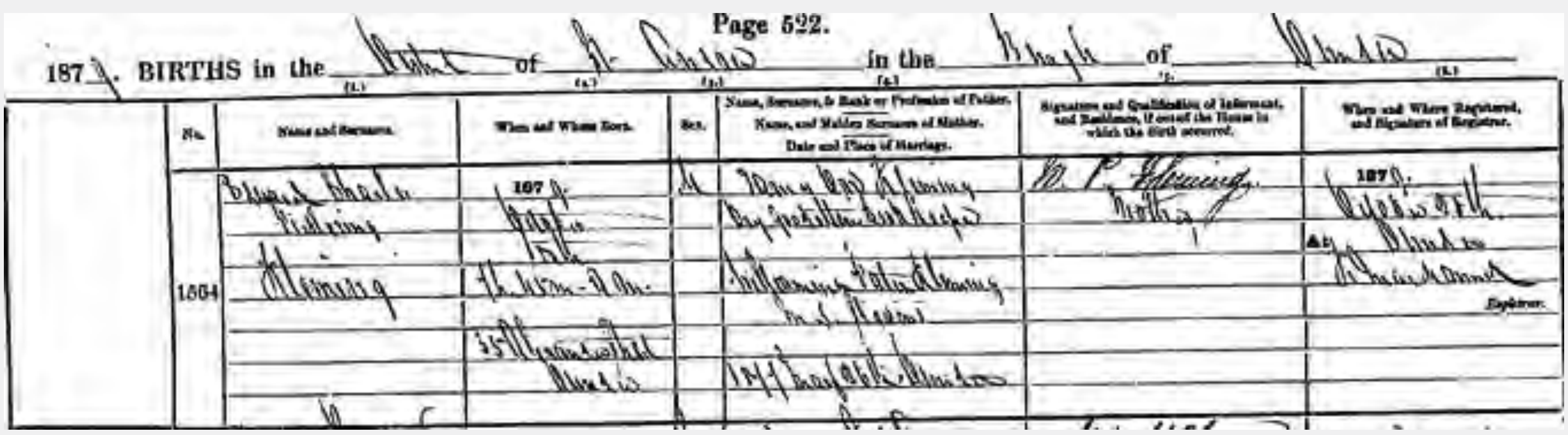
However, the United Stated Census for 1910 [10] records that Williamina first immigrated to Boston in the year 1879. Although the earlier 1900 US Census [11] contradicts this and states that she first arrived in America in 1884. However the consensus of evidence points to 1879 as being the actual year of her arrival in Boston [12].

The 1900 US Census also states that by the time it was taken in the June of 1900, Williamina was a widow and that James Orr Fleming was dead. The last known whereabouts of James Orr Fleming was in fact in 1900, where we find him living in Manhattan, New York, with his third wife, Annie Moore and their four children[44]. Following the alleged abandonment by her husband, Williamina did not remain in Boston, but returned to Dundee to her family to have her child. On the 6th October 1879 her son Edward Charles Pickering Fleming was born at 35 Alexander Street, the home of her mother [13], [14].

It was here that she remained until sometime after the 3rd April 1881[15] when Williamina boarded a steamer again at Glasgow to return to her new found life in Boston, Massachusetts.

The yearning to go back must have been very strong as was her affection for her new employer, Professor Edward Charles Pickering. The fact that she had named her son after him is evidence of this. Some researchers might suggest something a little more than affection, and which might explain why her husband left her - but this is nothing more than pure speculation! Whatever the truth is, she returned alone to Boston to take up employment as a *'female computer'* at the Harvard College Observatory where Pickering was the Director. Her son who was less than two years old at the time was left in the care of his grandmother Mary Stevens and his great grandmother Mary Walker.

It would be a further six years before mother and son would see each other again. Fortunately the official records which tell the story of their reunion have survived. On the 10th September 1887 Edward Fleming who was then nearly eight years old boarded the Montreal Ocean Steamship SS Prussian [16] at Glasgow Docks bound for the port of Boston. Accompanying the young Edward were his grandmother Mary Stevens (Williamina's mother) and his cousins Andrew and Joanna Stevens [17]. None were ever to see the land of their birth again.


Page 522.
1879. BIRTHS in the ... of ... in the ... of ...

No.	Name and Surname.	When and Where Born.	Sex.	Name, Surname, & Rank or Profession of Father. Name, and Maiden Surname of Mother. Date and Place of Marriage.	Signature and Qualification of Informant, and Residence, if out of the House in which the Birth occurred.	When and Where Registered, and Signature of Registrar.
1604	[illegible]	1879. [illegible]	[illegible]	[illegible]	[illegible]	1879. [illegible] Registrar.

Edward Charles Pickering Fleming's Birth Certificate 1879

V.8.4 Pickering's Woman

On her return from Dundee in 1881 Williamina Fleming took up a position at the Harvard College Observatory [18] under the supervision of its Director Edward Charles Pickering as a *'female computer'* – the less charitable of researchers often refer to them as *'Pickering's Women'* or even *'Pickering's Harem'*.

These computers were hired to do the tedious examination and measuring of astronomical photographic plates and the resulting calculations relating to the positions and brightness of stars. Pickering could hire female computers as unpaid volunteers or for a fraction of the price of men, and he observed that the women he hired were actually more capable of the laborious and detailed work than many of their male counterparts.

The exact circumstances of how she shifted her career from being Pickering's Housekeeper to gaining employment at Harvard College are not entirely clear. One version is that Pickering one day declared his frustration at the ineptitude of a male colleague by saying his maid could do better; whilst another says Pickering offered her a part-time position as a copyist and computer at the Observatory because he was '*struck by her obviously superior education and intelligence'.* It proved to be a right decision for both of them.

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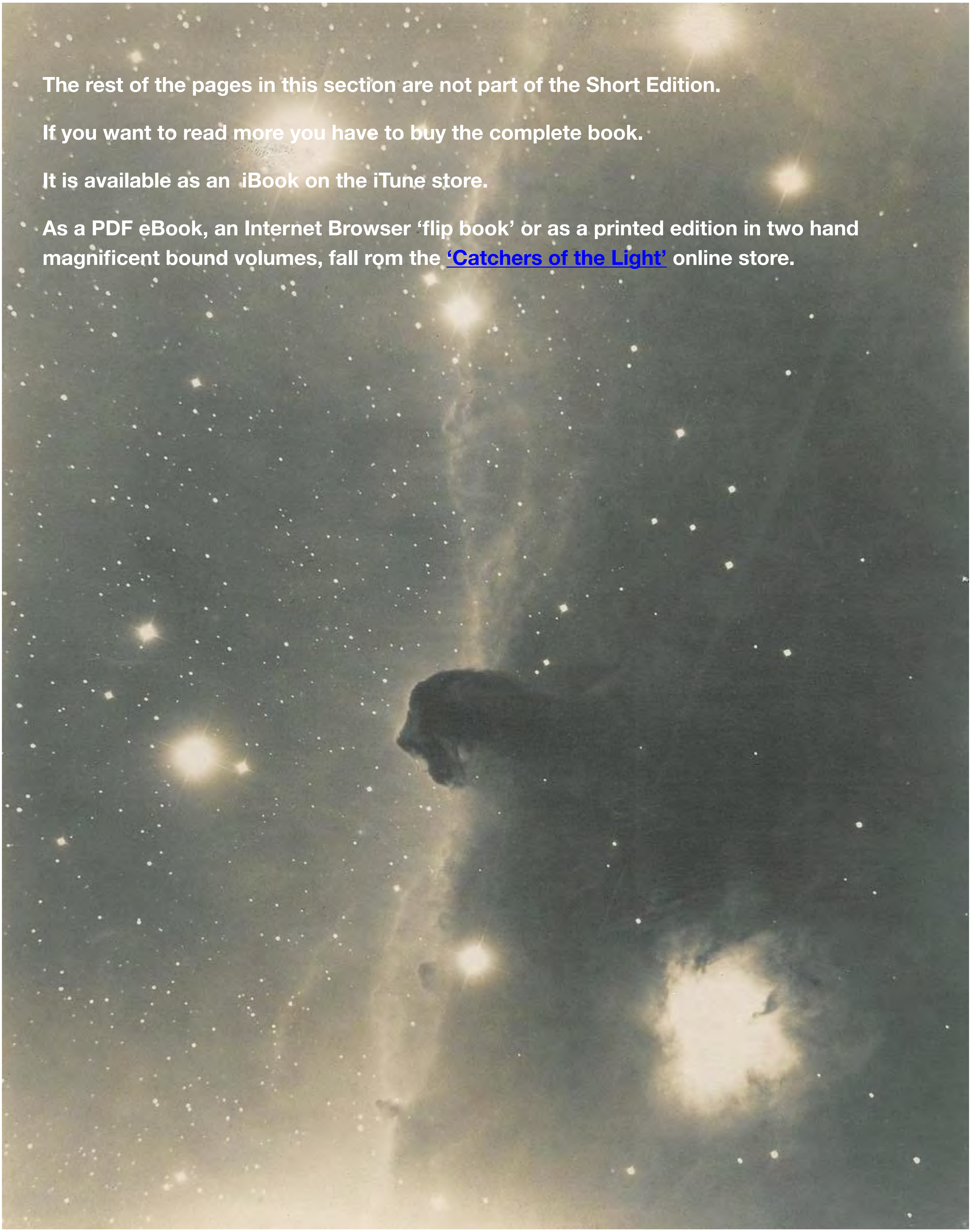


V.9

‘Nebulae’

Photographing DSOs

‘Horsehead’ Nebula in Orion, 13th November 1920, 100-inch Reflector, Mount Wilson, John Charles Duncan

The ‘Holy Grail’ of Astrophotography during the nineteenth century was to image successfully the controversial objects known as ‘nebulae’. It was not until the 30th of September 1880, that the New York Doctor, Henry Draper captured the ‘Cup of Christ’ when he photographed the ‘Great Orion’ Nebula, one of the most famous of all objects in the Kingdom of Heaven. The age of photographing Deep Space Objects (DSOs) had begun.

V.9.1 Deep Space

To image successfully one of the almost incalculable number of objects known as ‘*nebulae*’ that often appeared as mere smudges on the glass of a telescope’s eyepiece, was seen as the ultimate challenge to the early pioneers of Astrophotography. However it was not until 1880, over forty years after François Arago’s historic announcement to the world of the Daguerreotype photographic process that a New York Doctor, Henry Draper succeeded in imaging a Deep Space Object (DSOs). Even then the object of his success was the ‘*Great Orion’* Nebula (M42), one of the brightest and largest of all DSOs.

During the first half of the nineteenth century there took place a great religious and scientific debate centred around the what was known as the ‘*Nebular Hypothesis*’ [1]. Its supporters including Sir John Herschel, maintained that many of the ‘nebulae’ which could not be resolved into individual stars were composed of gas; whilst its protractors such as Dr. Thomas Romney Robinson believed they could all be resolved into stars given a telescope of sufficient size [2].

Photography was seen as the key to solving the morphology of the ‘*nebulae*’; were they all made up entirely of stars, or just clouds of gas, or a mixture of both stars and gas [3]. Astronomers made use of photography in two distinct ways – firstly by directly imaging the objects themselves, and secondly by capturing their spectra. The combination of the two techniques, ultimately led to a solution of the nebulae controversy. The answer they found was that all three of the possible solutions were in fact correct in certain instances. However it was not until the 1920s that the problem was entirely solved through the work of Edwin Hubble and Milton Humason, when many ‘*nebulae*’ were in fact ‘*Island Universes*’ lying millions of light years beyond the boundaries of our own ‘*Milky Way*’ [4].

As with any new area of scientific research the early pioneers of Astrophotography began with the basics and imaged single stars, then they progressed to capture fainter stars and once this had been achieved they went onto to photograph star clusters. This is exactly the same ‘*right of passage*’ that many a modern amateur Astrophotographer goes through when learning how to image DSOs. Only when he/she has mastered these fundamentals should they progress to try their hand at the ‘*nebulae*’.

Although there were reports as early as 1842 that Daguerreotypes had been obtained by Italian astronomers in Rome of stars, it was not until 1850 that a ‘*bona fide*’ photograph of a star was actually obtained by George Phillips Bond and John Adams Whipple using the 15-inch ‘*Great Harvard Refractor*’. The earlier ‘*Roman*’ images proved to be nothing more than fakes and were in fact photographs of drawings!

The Daguerreotype process used by Bond and Whipple could only capture stars as faint as the second magnitude. It was not until the introduction of Frederick Scott Archer’s more sensitive wet collodion process in 1851 that imaging fainter stars became possible. It was again G.P. Bond and Whipple, together with his partner James Wallace Black who succeeded in imaging fainter stars in 1857, when they captured stars of the sixth magnitude.

The earliest known photograph of a star cluster was obtained three years later in 1860 by Warren De La Rue from his observatory at Cranford, Middlesex. In the years that followed the collodion process was used by Lewis Morris Rutherfurd from New York and Benjamin Apthorp Gould from Cordoba in Argentina, to image fainter stars in more and more open clusters.

The year 1880 marked one of the greatest milestones in the history of Astrophotography, when Henry Draper (1837-1882), the son of the ‘*First Astrophotographer’*, John William Draper (1811-1882) captured the ‘*Holy Grail’* – a nebula, albeit the large and bright ‘*Great Orion*’ nebula (M42). It was only the increased sensitivity of Richard Leach Maddox’s Gelatino-Bromide ‘*dry*’ Plate process which enabled Draper to succeed where others have failed and in some cases cheated in their attempts.

In 1888 the German Astrophysicist, Herman Carl Vogel (1841-1907) sent the equivalent of a supernova explosion through the observatory domes of the astronomical establishment, when he claimed that photographs of ‘*nebulae*’ taken with modest instruments were superior to drawings made at the eyepiece of even the largest of telescopes.

Deep Space Astrophotography had come of age.

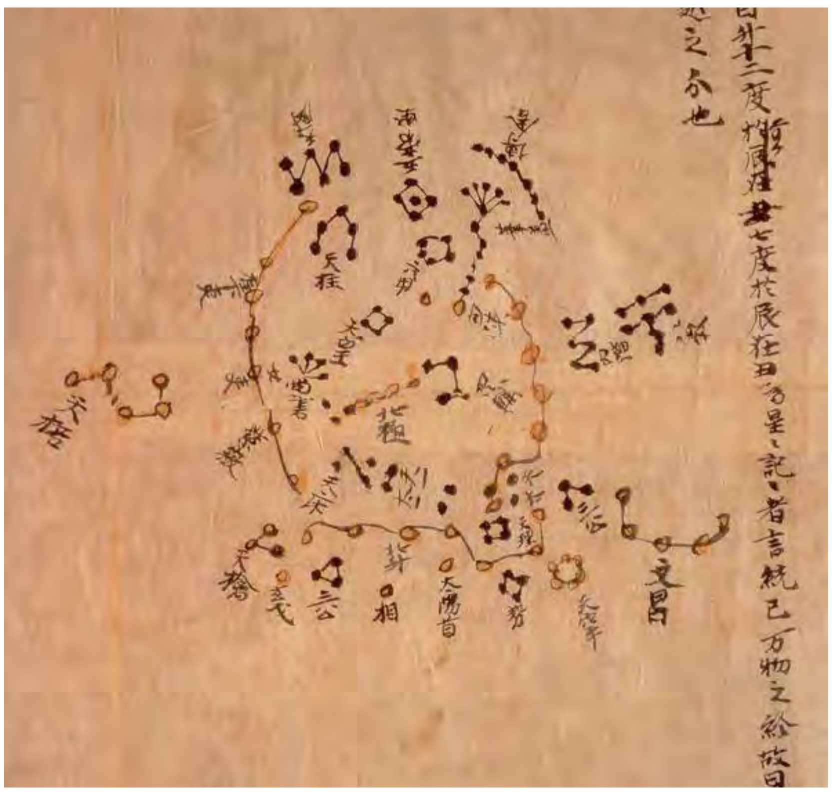
DSO	Composition	Description	Examples
Asterism	Stars	Stars that form a pattern, but which are physically unrelated and separated by large distances. The 88 Constellations are all asterisms.	‘*The Big Dipper*’, ‘*Coathanger*’, ‘*Square of Pegasus*’
Dark Nebula	Stars	A type of interstellar cloud that is so dense that it obscures the light from a background emission or reflection nebula or that it blocks out background stars. The extinction of the light is caused by interstellar dust grains located in the coldest, densest parts of larger molecular clouds.	‘*Horsehead*’ Nebula in Orion, ‘*Snake*’ Nebula in Ophiuchus, ‘*Coalsack*’ Nebula (Crux)
Emission Nebula	Gas	A cloud of ionized gas emitting light of various colours. The most common source of ionization is high-energy photons emitted from a nearby hot star. Among the several different types of emission nebulae are H II regions, in which star formation is taking place and young, massive stars are the source of the ionizing photons.	M42 ‘*Orion Nebula*’, M8 ‘*Lagoon*’, NGC 7000 ‘*North American*’, ‘*Rosette*’ Nebula in Monoceros
Galaxy	Gas & Stars	A star system like our own ‘*Milky Way*’ composed of billions of stars, as well open clusters, globular clusters and gaseous nebulae, both bright and dark. They lie outside the boundaries of our ‘Island Universe’.	M31 in Andromeda, M51 ‘*Whirlpool*’ in Canes Venatici, M81 ‘*Bode*’ in Ursa Major, M104 ‘*Sombrero*’ in Virgo.
Galaxy Cluster	Gas & Stars	A large compact collection of Galaxies, typically between 50 and 1000 in number.	Virgo Cluster, Fornax Cluster, Hercules Cluster
Galaxy Group	Gas & Stars	A small compact collection of Galaxies typically less than 50 in number.	‘*Stephan’s Quintet*’ in Pegasus
Globular Cluster	Stars	A globular cluster is a spherical collection of hundreds of thousands of stars that orbits a galactic core as a satellite. Globular clusters are very tightly bound by gravity, which gives them their spherical shapes. They have relatively high stellar densities toward their centres.	M13 in Hercules, M56 in Lyra, Omega Centauri in Centaurus, 47 Tucanae in Tucana
Open Cluster	Stars	A group of up to several thousand stars, but typically only a few tens to a few hundred, that are loosely bound to each other by mutual gravitational attraction. They can become disrupted by close encounters with other clusters and clouds of gas.	M45 ‘*Pleiades*’ in Taurus, M44 ‘*Beehive*’ in Cancer, ‘*Double Cluster*’ in Perseus, ‘*Jewel Box*’ in Crux
Planetary Nebula	Gas	An emission nebula consisting of an expanding glowing shell of ionized gas ejected from a Red Giant star’s outer atmosphere during the last stages of its life. Their name originated with their first discovery in the 18th century because of their similarity in appearance to giant planets when viewed through small optical telescopes.	M27 ‘*Dumbbell*’ in Vulpecula, M57 ‘*Ring*’ in Lyra, M76 ‘*Little Dumbbell*’in Perseus, M97 ‘*Owl*’ in Ursa Major
Reflection Nebula	Gas	Clouds of dust which are simply reflecting the light of a nearby star or stars. The energy from the nearby star, or stars, is insufficient to ionize the gas of the nebula to create an emission nebula, but is enough to give sufficient scattering to make the dust visible.	‘*Running Man*’ in Orion, ‘*Witch’s Head*’ in Eridanus
Supernova Remnant	Gas	Structure resulting from the explosion of a star in a supernova. The supernova remnant is bounded by an expanding shock wave, and consists of ejected material expanding from the explosion, and the interstellar material it sweeps up along the way.	‘*Crab*’ in Taurus, ‘*Veil*’ Nebula in Cygnus

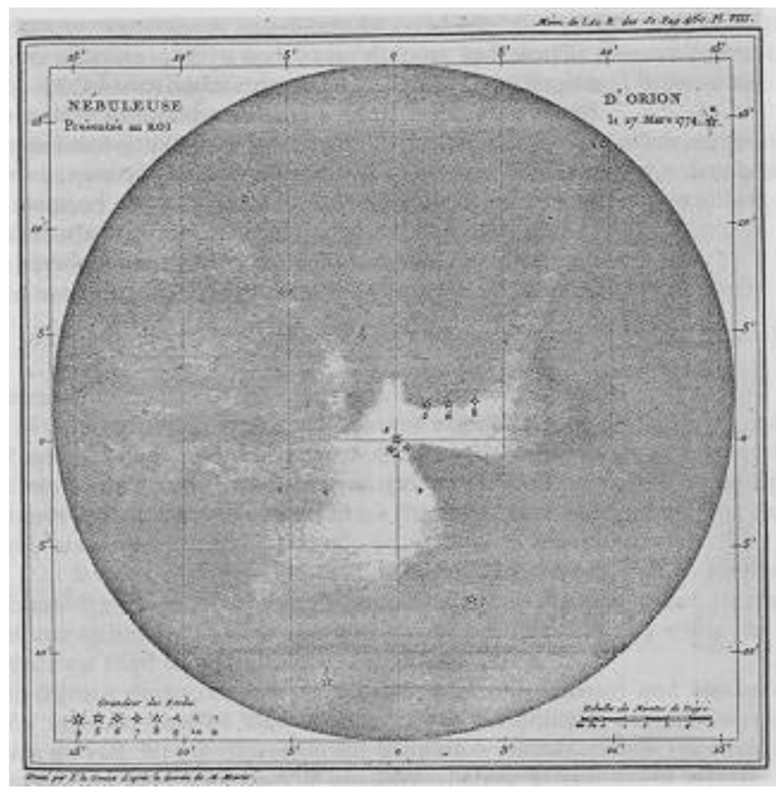
The first serious attempt at classifying Deep Space Objects (DSOs) was made by Sir William Herschel, the discoverer of the planet Uranus and published in his three catalogues: Catalogue of One Thousand New Nebulae and Clusters of Stars (1786), a Catalogue of a Second Thousand New Nebulae and Clusters of Stars (1789) and a Catalogue of 500 New Nebulae nebulous Stars, planetary Nebulae, and Clusters of Stars; with Remarks on the Construction of the Heavens (1802). See note [3].

The year 1908 was especially important for Astrophotography, in that year came the publication of James Edward Keeler's posthumous photographs of nebulae taken with the 36-inch Crossley of the Lick Observatory [15] and the completion of the largest operational telescope in the world – the 60-inch reflector atop Mount Wilson [16]. These two events marked the moment when astronomers not only admitted that photography of nebulae was essential to the future of astronomical research, but that work would be done with large silvered mirrored reflecting telescopes and not with the great refractors.

The earliest known drawings made by man of the heavens can be found amongst the '*ice age*' paintings in a cave at Lascaux, France. The map, which is thought to date back 16,500 years, shows three bright stars known today as the Summer Triangle, Vega, Altair and Deneb. A map of the Pleiades star cluster in Taurus has also been found among the Lascaux frescoes. Another pattern of stars, drawn 14,000 years ago, has been identified in a Spanish Cave.

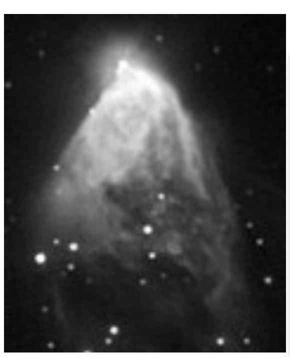
'Ice Age Star Map', from a Cave at Lascaux, France, circa 14,500 BC



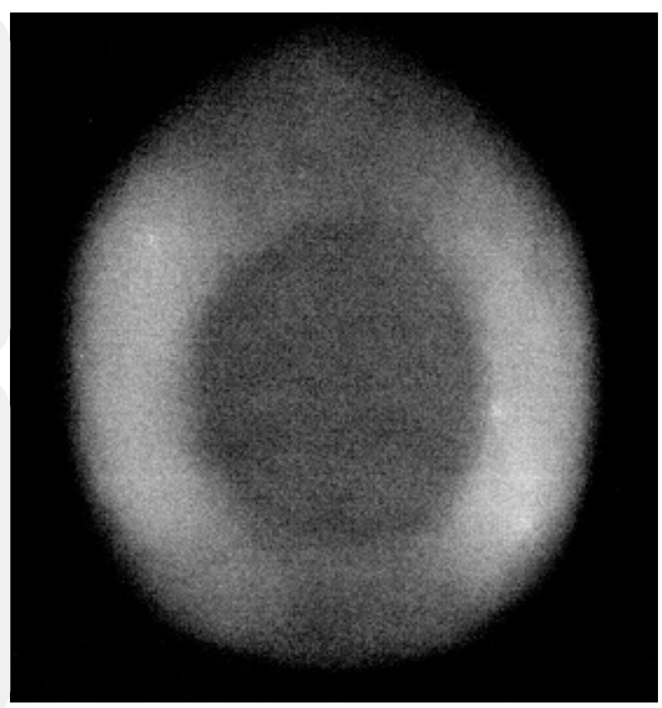


Chinese Dunhuang Star Chart, c700 AD (left); Messier, 'Great Orion' Nebula, 1769 (right)

The drawing featured bottom right is of the '*Ring*' nebula in Lyra made in 1874 with the Harvard Observatory's 15-inch refractor. It does not show its central 15th magnitude star. It was however seen on a photograph taken in 1886 by the Hungarian Eugen Von Gothard with a 10-inch reflector!



The images to the left show NGC 2261, a reflection nebula in Monoceros. The image above is of a drawing made in 1850 by William Parsons using his 72-inch reflector at Birr Castle, Ireland. To the bottom left is a modern CCD image. Parsons was the first person to show the true form of nebulae.



NGC 2261, Monoceros (left); Ring Nebula, Lyra, drawn in 1874 (right)

The famous *Pleiades* or *'Seven Sisters'* in the constellation of Taurus was the first open star cluster to be photographed. This honour fell to the English amateur astronomer, Warren De La Rue (1815-1889) who imaged it in 1860 using a '*wide field*' portrait lens camera attached to the clockwork driven Equatorial Mount of his 13-inch Reflector. It was necessary to use such a camera as the Pleiades (M45) is a large open cluster covering an area of sky of some 110' x 110', or nearly four square degrees.

Two years earlier De La Rue had tried to image Donati's Comet which had a tail of some 10^o to 20^o with his 13-inch reflector, and failed. His telescope had too small a field of view and lacked the necessary sensitivity.

The 'Pleiades' in Taurus (M45), Isaac Roberts, 1888

The famous Praesepe (M44) or '*Beehive*' open star cluster in Cancer was the second to be successfully photographed. During the period 1865 to 1877, Lewis Morris Rutherfurd took 23 images of this cluster from his observatory in the centre of New York City, which even then was experiencing an increasing problem with both traffic vibration and light pollution. The photograph of M44 shown here (right) was taken in 1888 by Isaac Roberts from his observatory at Maghull, near Liverpool. It was not long before light pollution from the busy port of Liverpool caused him to move his observatory in 1890, this time to a dark site at Crowborough in Sussex on top of a cliff overlooking the sea. He called his new home appropriately '*Starfield*'.

His observatory and its 20-inch Grubb reflector have been preserved and are to be found on the roof at the Science Museum in South Kensington, London.

Praesepe Open Cluster in Cancer, Isaac Roberts, 20-inch Reflector, 1888

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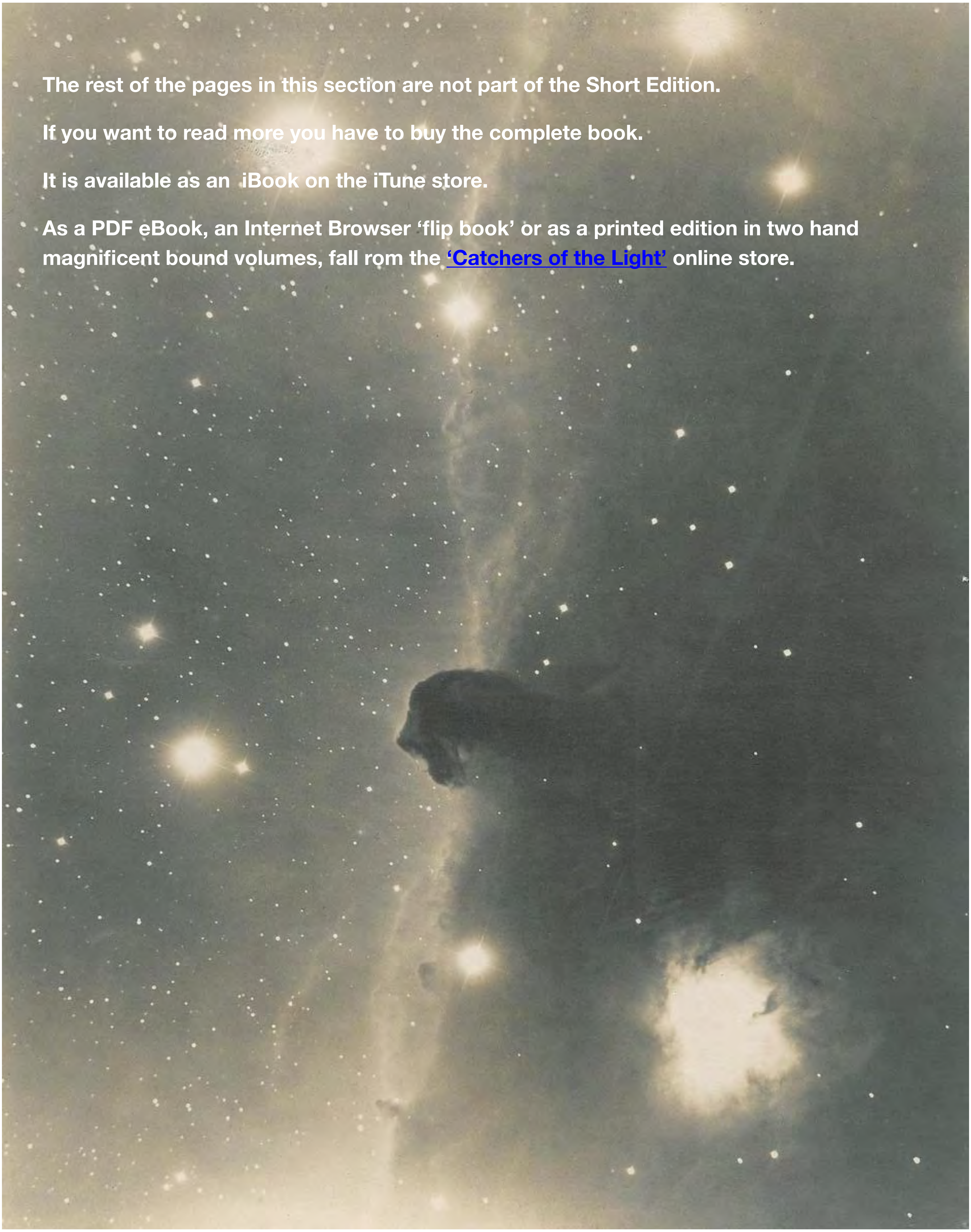

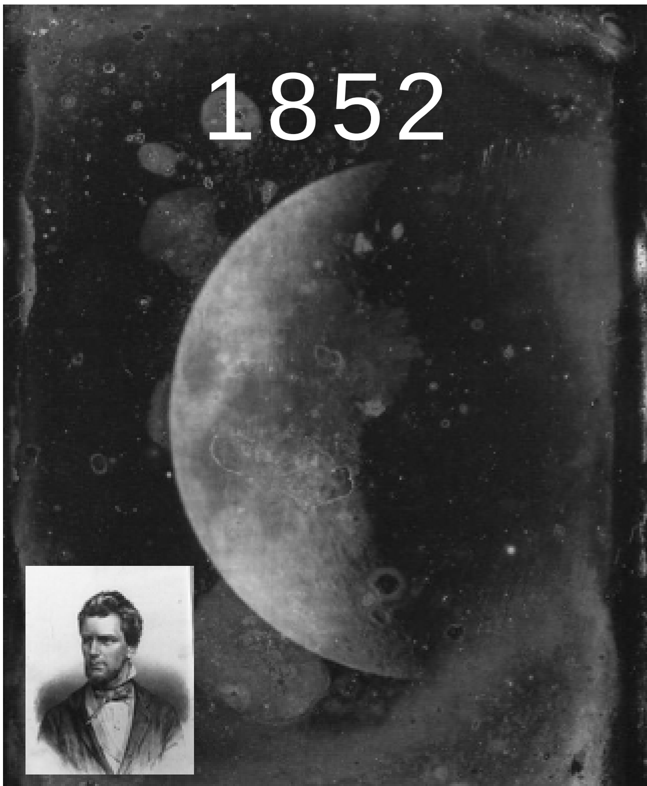

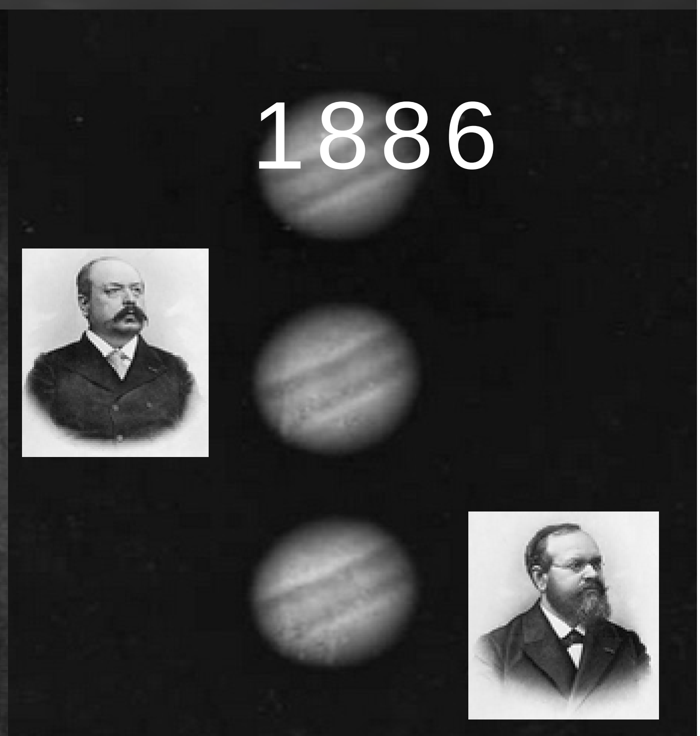

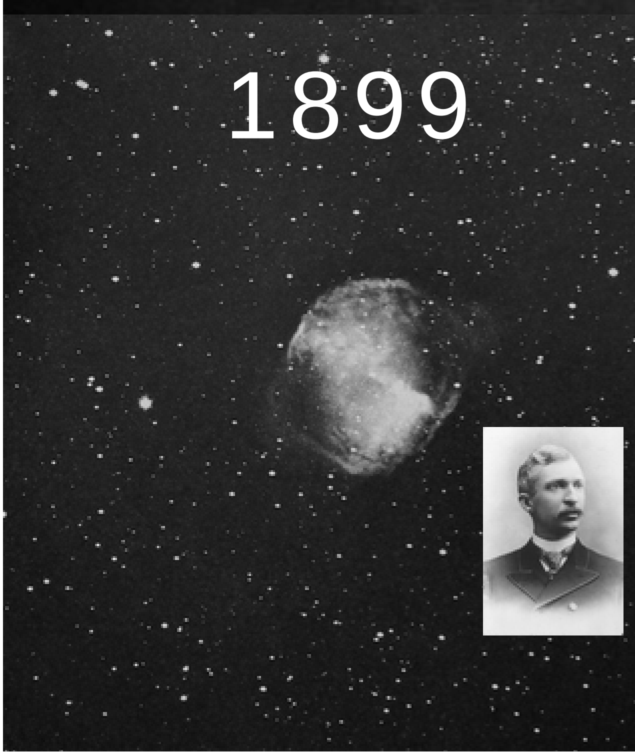

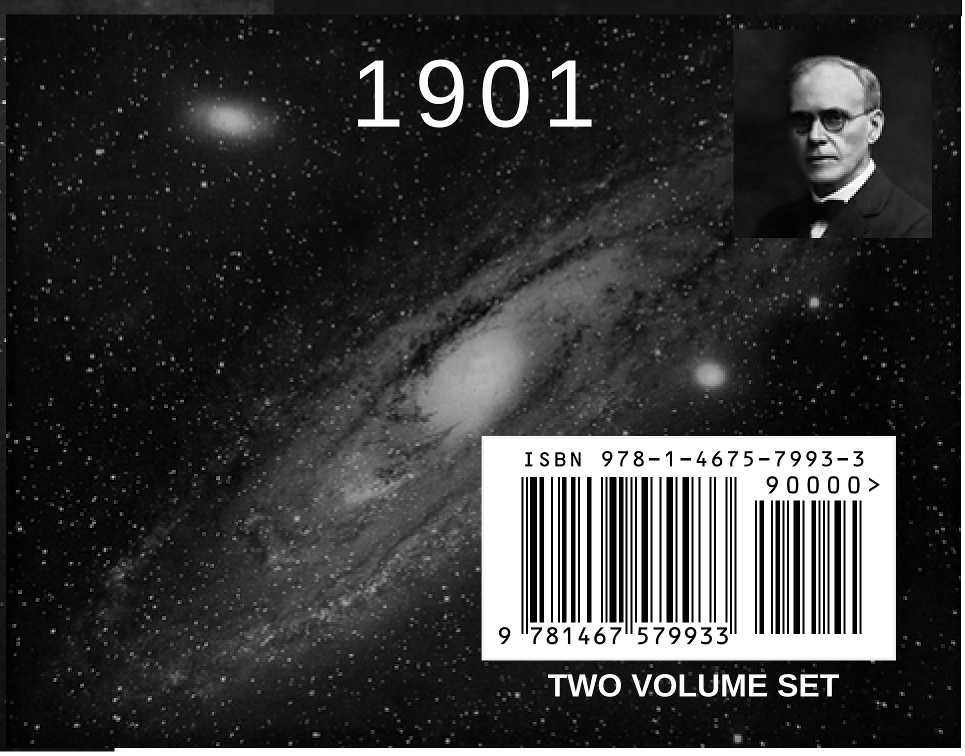

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TWO VOLUME SET

Catchers of the Light

Volume 2 - Imaging Space

Spectra, Surveys, Telescopes, Digital & Appendices

The Forgotten Lives of the Men and Women who First Photographed the Heavens

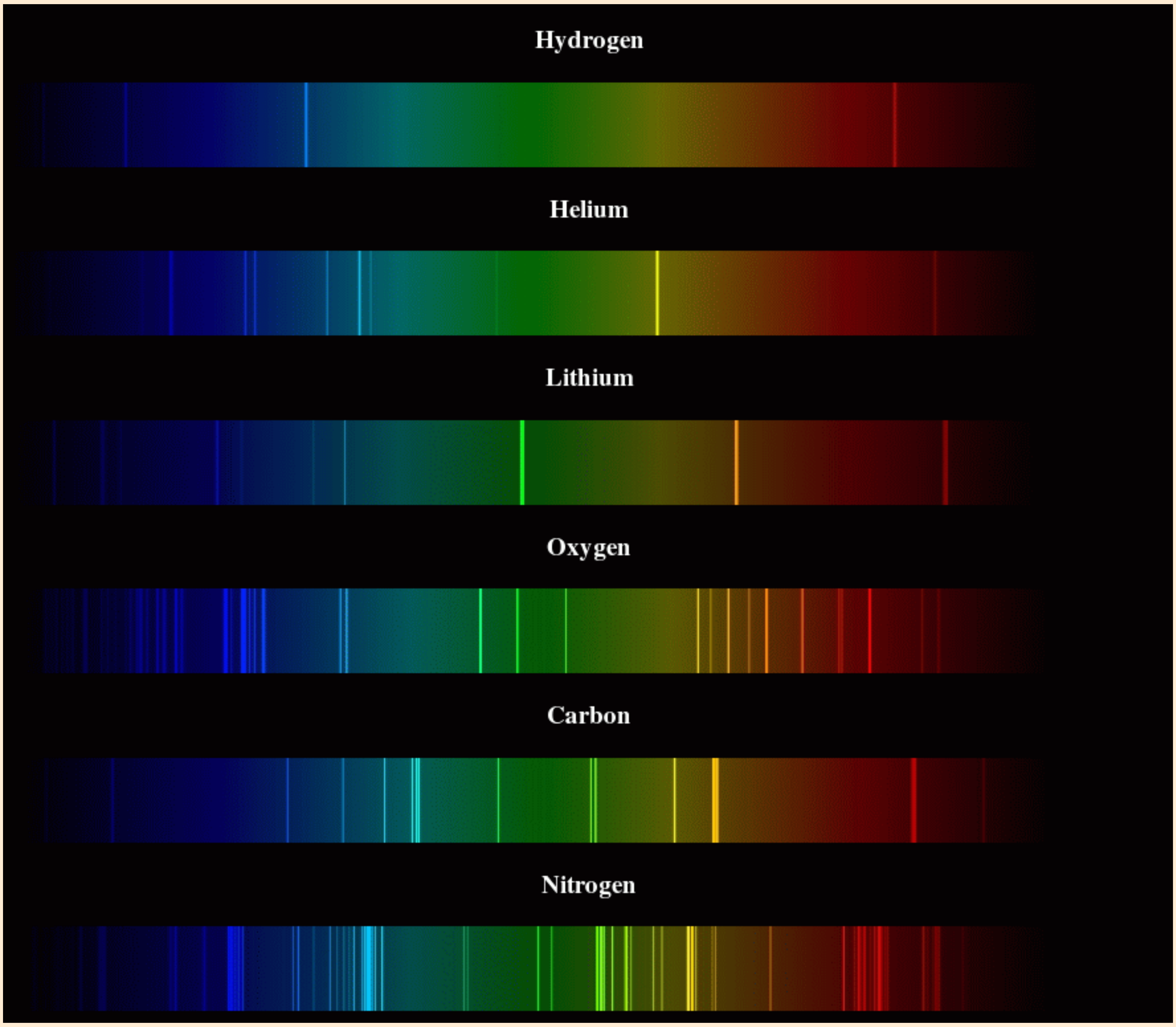
Their True Tales of Adventure, Adversity & Triumph

Stefan Hughes

Part VI

Spectra

Photographic Astronomical Spectroscopy



Emission Line Spectra for Important Chemical Elements found in the Universe

"One important object of this original spectroscopic investigation of the light of the stars and other celestial bodies, namely to discover whether the same chemical elements as those of our earth are present throughout the universe, was most satisfactorily settled in the affirmative; a common chemistry, it was shown, exists throughout the universe." Sir William Huggins (1824-1910)

VI. Photographic Astronomical Spectroscopy

The single most important use of Photography in astronomical research is in the field of Astronomical Spectroscopy. It proved to be an invaluable tool not only for the study of the composition and origins of Stars, Nebulae and Galaxies, but more importantly, it was used to measure Galactic Redshifts; and was therefore able to put a '*yardstick*' on the size of our universe.

For over thirty years after John William Draper took his photograph of the Moon in 1840, the use of spectroscopy for astronomical research was done by visual observation and hand made drawings. Only in 1872 did his son, Henry Draper photograph for the first time the spectrum of a star, when he imaged Vega (Alpha Lyrae), using a 28-inch (72 cm) reflector and a quartz prism.

However by this date Astronomical Spectroscopy had been put on a firm scientific footing by others, and in particular most notably: Lewis Morris Rutherfurd (1816-1892), William Huggins (1824-1915) and the Jesuit Priest Pietro Angelo Secchi (1818-1878).

In 1862 Rutherfurd had published a paper in the American Journal of Science on the spectra of the moon, planets and stars. This was the first paper published on the subject since those of Bunsen and Kirchhoff, and continued the work begun by Joseph Von Fraunhofer in 1814. It included the first attempt at classifying stars based on their spectra. Two years earlier, the Italian astronomer Giovanni Battista Donati, had begun a series of observations on the spectra of the '*fixed stars*', the results of which he published in 1862. The chief feature of Donati's classification was his separation of the various stars according to their colours.

Secchi had begun work on classifying the spectra of stars based on their spectra in 1863. Three years later he had created three types now known as Secchi classes. He added a fourth the so called carbon stars in 1868. A fifth was added in 1877. Even as late as the 1890s a number of astronomers were still using his system.

Huggins who has been called the father of astronomical spectroscopy was not so much interested in the classification of stellar spectra but in determining whether a common set of chemical elements existed in the universe as they did on our Earth.

He began studying the spectra of the 'fixed stars' with this aim in mind with the chemist and neighbour William Allen Miller. In 1863 they published a paper entitled '*On the lines in the Spectra of Some Fixed Stars*'. This was followed by other papers on the spectra of various stars, which showed that each contained a selection of lines also visible in the Solar Spectrum. That same year they tried to photograph the spectra of the star Sirius, but failed.

A year later in 1864, Huggins made one of his greatest discoveries when he recorded the spectra of '*Cat's Eye Nebula'* (NGC 6543), a bright Planetary Nebula in Draco. Instead of a series of spectral lines he found only a single bright Emission line. He concluded that this was due to gas, thus proving that certain 'nebulae' were in fact gaseous and not made up of individual stars.

In 1882 Edward Charles Pickering, the Director of the Harvard College Observatory began a programme of astronomical spectroscopy using objective prisms. This type of setup enabled up to 200 stellar spectra to be captured on a single photographic plate. This work was continued under the auspices of the Henry Draper Memorial, a fund set up by the widow of Henry Draper to honour his work in the field of astronomical spectroscopy.

In 1890 the Draper Catalogue of Stellar Spectra is published by Edward Charles Pickering, which contains the photographic spectra of 10,351 stars, nearly all of them north of 25° south declination.

In this work the spectrum of each star was classified according to a scheme developed by Williamina Fleming (1857-1911). In her system known as the '*Draper Classification*', the letters A to Q (omitting J) were used to classify stellar spectra.

Fleming's system was later modified by Annie Jump Cannon into the familiar Harvard Classification based on the spectral types: O, B, A, F, G, K and M, arranged according to the surface temperatures of the stars, such that those of Class O (blue-white stars) were the hottest and those of Class M (red stars) the coolest.

In 1943 a new system was introduced by the astronomers William Wilson Morgan (1906-1994) and Philip Childs Keenan (1908-2000), together with their photographic assistant, Edith M. Kellman (1911-2007).

The MKK system named after its authors, differed from that of Harvard's in that it was a two dimensional system based on both temperature and luminosity, whilst the Harvard classification was based on surface temperature only. The MKK system was revised in 1953 and renamed the MK or Morgan-Keenan classification. This system is currently the accepted method for the classification of stellar spectra.

Perhaps the greatest and most widely known use of astronomical photographic spectroscopy is as a '*yardstick*' for measuring the size of the Universe. At Mount Wilson in the late 1920s, Edwin Powell Hubble (1889-1953) and Milton Lasell Humason (1891-1972) began a programme of work aimed at extending Hubble's own measurements of galaxy distances based on Shapley's Cepheid period-luminosity data and using Slipher's galactic redshift measurements.

During the course of this work they discovered that there existed a roughly linear relationship now known as Hubble's Law, between the distance of a galaxy and the value of its recessional redshift velocity. Although they were not the first to suspect that a relationship existed between '*redshifts*' in a the spectra of external galaxies and distance, it was Hubble and Humason in 1929, who quantified it in mathematical form, drew a graph of it and proved conclusively of its existence by observational means.

"No reference has been made to the use of the prismatic camera or grating spectrograph, as these are beyond the limits of an elementary treatise."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

Spectroscope, c1875, Adam Hilger, London

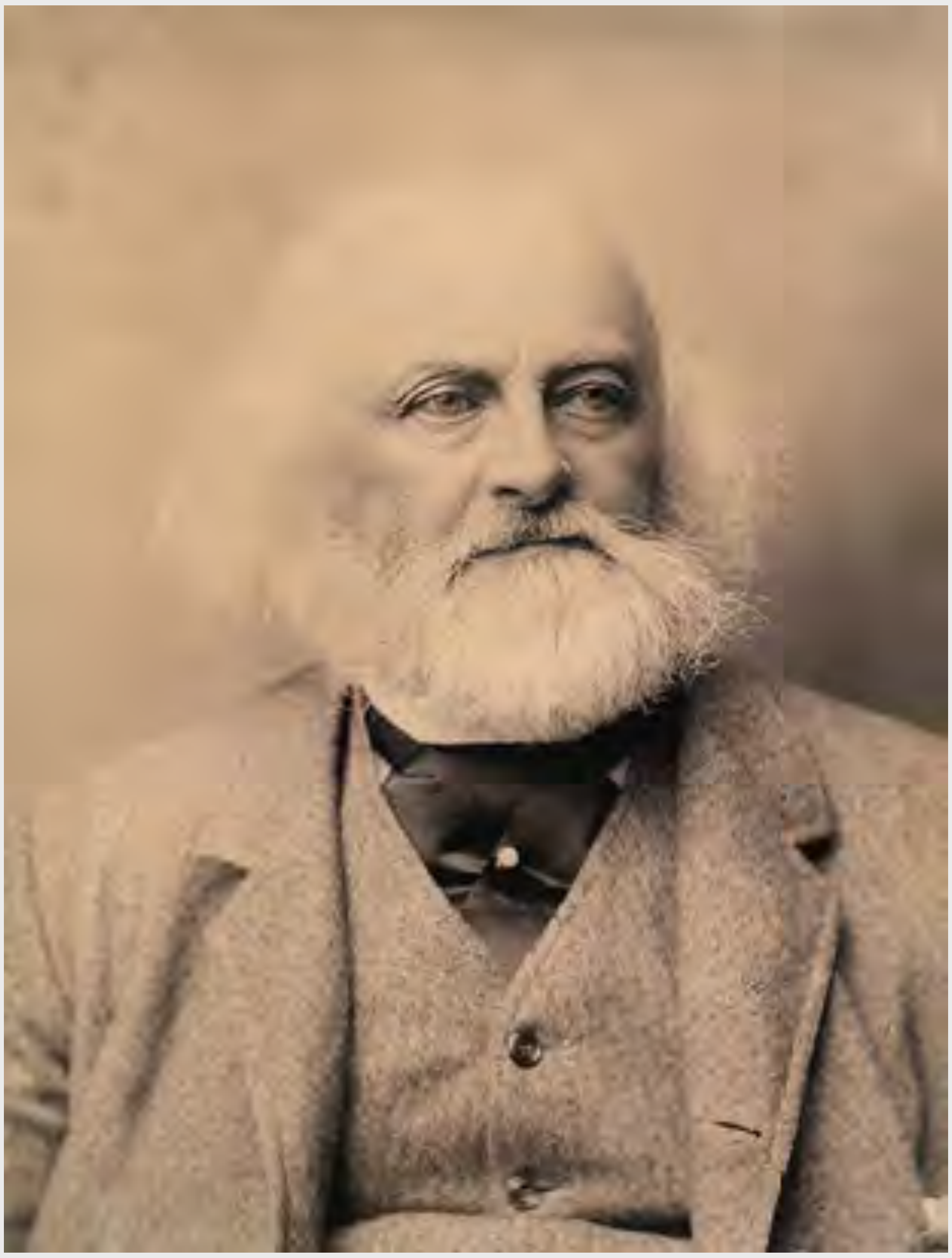
VI.1

'The Lawyer'

Lewis Morris Rutherfurd

Born: 25th November 1816, Morrisania, Bronx, New York, USA

Died: 30th May 1892, '*Tranquility*', Allamuchy, Warren, New Jersey, USA



Lewis Morris Rutherfurd although coming from an unlikely legal background and having received no formal scientific education, made contributions to Astronomical Spectroscopy that were truly ground breaking; and which were the envy of many professional scientists. He was also the first person to build a telescope suitable for photographic use only. With this instrument he took photographs of the Moon, which were for over twenty years unequalled in their quality.

V1.1.1 An Unlikely Scientist

Lewis Morris Rutherfurd (1816-1892) was at first sight an unlikely candidate for a great amateur scientist and even less so as one of the pioneers of Astrophotography, yet that is exactly what he became. Born into a family whose male members had been lawyers for as long as America had been a Nation, it seemed that he too would be another Rutherfurd destined for a life at the Bar [1].

Then something happened which changed his life – he found science. He realized much to the horror of his parents, that micrometers, telescopes and diffraction gratings were infinitely more interesting than serving affidavits and drawing up deeds.

Sometime around 1850 he broke the family tradition which had lasted for three generations; and gave up the law to devote all of his effort, time and money to science. It was not long before he and others realized that not only did he enjoy it but he was also rather good at it.

In the January of 1863 Rutherfurd published a paper in the American Journal of Science on the spectra of the Moon, Planets and Stars. This was the first paper published on the subject of spectral analysis since that of Robert Bunsen and Gustav Kirchhoff, written some four years previously [2]. It included the very first attempt at classifying stars based on their spectra [3].

The paper was a milestone in the new science of Astrophysics, and greatly extended the work of Joseph Von Fraunhofer done nearly half a century earlier; and even went beyond the more recent findings of Kirchhoff and Bunsen [4]. Rutherfurd's stellar classification work was later expanded upon by the Jesuit priest Pietro Angelo Secchi in 1867, and further advanced by others including Williamina Fleming, Antonia Maury and Annie Jump Cannon during the 1890s [5].

A year later In 1864, he made one of the greatest technical advances in the entire history of Astrophotography when he succeeded in constructing an 11.25-inch objective lens suitable for photographic use. This event marked the birth of the '*Photographic Refractor*' or Astrograph.

With his new Astrograph the very first of its kind, Rutherfurd was able to take images of the Moon whose quality was not to be surpassed for over twenty years; but more importantly for Deep Space Astrophotography – he was able to image stars as faint as the ninth magnitude.

In the 1860s, Rutherfurd took a series of Photographs of a number of the most well known open clusters in the heavens. This was the first time that this had been done and was in fact the logical continuation of the work done on Stellar Photography by the Bonds of Harvard and the Boston Photographers, John Adams Whipple and James Wallace Black during the 1850s [6].

However, the work of Rutherfurd in which he was later assisted by Benjamin Apthorp Gould (1824-1896), was particularly important in that not only the images of the stars were captured on the Photographic Plate, but their positions in the sky were also measured directly from the plates. This was the beginning of Photographic Astrometry.

Let us now tell the story of Lewis Morris Rutherfurd, the onetime lawyer who changed his life by catching the light of the moon, planets and stars.

VI.1.2 'The Law'

Lewis Morris Rutherfurd was born on the 25th November 1816 in Morrisania, New York into a privileged and influential family, the fourth of the five children of Robert Walter Rutherfurd (1788-1852) and his wife Sabina Elliot Morris (1789-1857). His paternal grandfather was the well known US Senator John Rutherfurd (1760-1840) and his maternal great grandfather, Lewis Morris (1726-1798) one of the signatories on the American Declaration of Independence [7].

It was not surprising that Lewis Morris Rutherfurd was expected to begin life's journey as a lawyer. His father was a lawyer and his grandfather John Rutherfurd was a lawyer. It was only his great grandfather Walter Rutherfurd (1723-1810) who was not a lawyer.

He was Scottish soldier sent out by King George II to fight in the American Revolution against the French. In the October of 1777, a year after the declaration of Independence, Major Walter Rutherfurd was held hostage in New Jersey by the Governor as a suspected English sympathizer and worse still - for refusing to swear an Oath of Allegiance to the American Flag. He eventually gave in, resigned his commission and became a New York citizen, where he died in 1804! [8]

Lewis Morris Rutherfurd attended Williams College, Massachusetts where graduated in 1834, and then practiced law with William Henry Seward (1801-1872) of Auburn, New York and then with George Wood in New York City. He was admitted to the bar in 1837, and continued working as a partner first in the firm of Peter Augustus Jay (1776-1843), and then afterwards with Hamilton Fish (1808-1893). Everything was just as his family expected. He had found positions through their influence with some of the finest law firms and most influential individuals in the country. Both Seward and Fish were to become Governors of New York, US Senators and US Secretaries of State. However in fact all was not as well with Rutherfurd when it came to spending a lifetime at the Legal Bar. All of this meant nothing to Rutherfurd he wanted to become a scientist, as his biographer the astronomer, Dr. Benjamin Apthorp Gould (1824-1896) later recorded [9]:

“While an undergraduate his inborn tastes for physical research and mechanical contrivance manifested themselves in a conspicuous degree, and he acted as assistant to the professor of physics and astronomy, preparing the experiments and constructing apparatus…

But, from the first, astronomy had for him a higher charm than legal studies, and after fortunate circumstances relieved him from the necessity of seeking pecuniary gain, he devoted himself more and more to scientific study.”

Robert Walter Rutherfurd (1788-1852) was the third of the eight children born to Senator John Rutherfurd (1760-1840) and his wife Helena Magdalena Morris (1762-1840). He too like his father trained as a lawyer, and it was expected that his Lewis Morris Rutherfurd would like his father and grandfather before him enter the legal profession. This he did for a while, working the practices of some of the most influential and powerful men in America. However the lure and love of science and in particular astronomy got the better of him. In 1845 he purchase his first telescope a 4-inch achromatic refractor from Henry Fitz (1808-1863).

This was the beginning of a lifelong friendship and collaboration between the two men, who worked together on the construction of the very first telescope suitable for Photographic use - an 11.25-inch refractor. With this telescope Rutherfurd took some of the finest photographs of the Moon and was the first to image many well known northern hemisphere open clusters.

Robert Walter Rutherfurd (1788-1852)

Lewis Morris Rutherfurd’s grandfather, John Rutherfurd was an American politician, land surveyor and lawyer. He was born in 1760 in New York City. John attended the College of New Jersey (now Princeton University) and studied law. He practiced law in New York City for several years, and then moved to the Rutherfurd ancestral home known as ‘*Tranquility*’ in New Jersey following his marriage to Helena Magdalena Morris in 1787. They had eight children. He entered politics, serving in the New Jersey General Assembly from 1788 to 1790. He was then elected as a Federalist to the United States Senate from New Jersey and served in the Senate from 1791 to 1798. He was re-elected in 1796 but resigned in December 1798, for reasons that are unclear. He died in 1840 at Bergen, New Jersey, and his wife died shortly afterwards.

Sen. John Rutherfurd (1760-1840)

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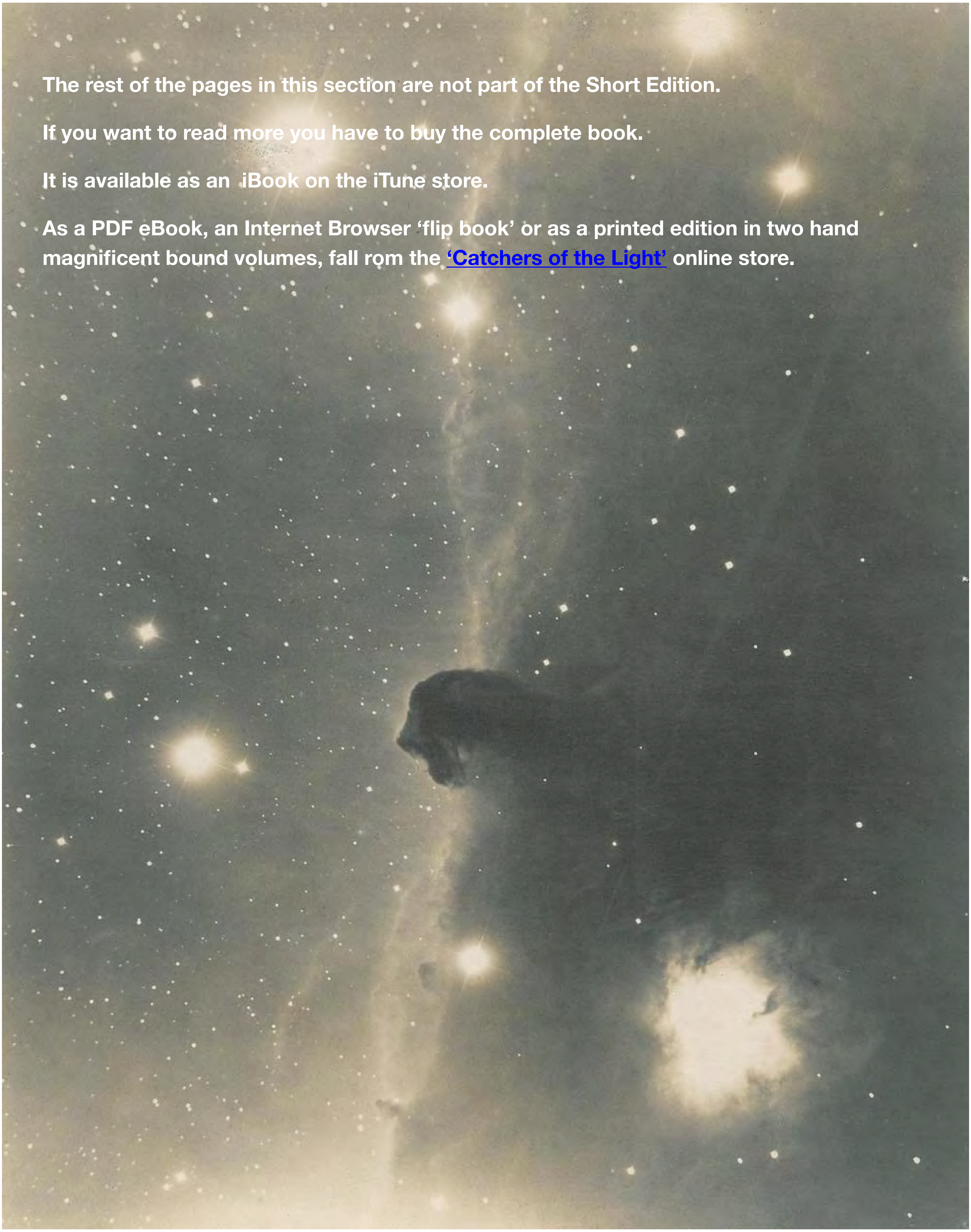

Short Edition

VI.2

‘God’s Astronomer’

Father Pietro Angelo Secchi

Born: 29th June 1818, Reggio Emilia, Emilia-Romagna, Italy

Died: 26th February 1878, Rome, Lazio, Italy

Father Pietro Angelo Secchi was a Jesuit Priest and a pioneer of astronomical spectroscopy. The work for which he is best remembered is his Spectral Classification System; which ultimately led to the Harvard Classification of Stellar Spectra developed by Williamina Fleming, Antonia Maury and Annie Jump Cannon in the 1890s and early 1900s.

VI.2.1 ‘The Kingdom of Heaven’

The Roman Catholic Church has always kept a close eye on the heavens, but even more so, on the astronomers who studied it [1]:

“I, Galileo, being in my seventieth year, being a prisoner and on my knees, and before your Eminences, having before my eyes the Holy Gospel, which I touch with my hands, abjure, curse, and detest the error and the heresy of the movement of the earth.”

In these words the Italian astronomer Galileo Galilei (1564-1642) had recanted his belief that the Earth revolved around the Sun, and that the Earth was indeed the centre of the Kingdom of Heaven. It was the year 1633 and nothing could move the Catholic Church away from the view that God’s Universe was perfect and without flaws. The Earth did not move; there were no spots on the surface of the Sun or craters on the Moon; and almost certainly no dark lines could be seen emanating from the stars. Galileo renouncing what he knew to be true in his heart, was exiled to his villa at Arcetri near Florence in 1634, where he spent the remainder of his life under house arrest.

In 1818 there was born a man who in later life would see all of these things, including the dark absorption lines in the spectra of stars. What is remarkable is that his name was Father Pietro Angelo Secchi, a Jesuit Priest; and firm believer in both his church, and a heaven based on science, not on what his religion wanted it to be.

In 1877 Secchi published the results of his great study of 4000 fixed stars, in which he argued that all stars could be classified according their chemical nature as exhibited by the various dark absorption lines found in their spectra. Furthermore this classification could be achieved by using only five spectral types. These later became known as ‘*Secchi Classes*’.

The pioneering work of Secchi in the Spectral Classification of Stars, ultimately led to the Harvard Observatory’s Classification as developed by Williamina Fleming, Antonia Maury and Annie Jump Cannon in the 1890s and early 1900s [2]. This in turn formed the basis of the currently accepted Morgan-Keenan system.

The accurate classification of stars according to the characteristics of their spectra was the start needed by others to begin the process of understanding their structure and evolution, from the moment of their birth amongst vast clouds of gas and dust, to an end which produces white dwarfs, neutron stars and black holes - bodies as strange as they are unbelievable.

Father Secchi lived a contented life within the embrace of his venerated Catholic Church and his beloved Pope, but at the same time conducting astronomical research into the very nature of a ‘*flawed*’ universe. Yet two centuries earlier this very same research would have condemned him to exile or even death.

How could this be? How did Pietro Angelo Secchi on his death in 1878 enter the ‘*Kingdom of Heaven*’ with the full blessing of the Holy Catholic Church, as both Jesuit and Astronomer?

VI.2.2 Jesuit

Pietro Angelo Secchi was born on the 18th of June 1818 at Reggio Emilia in the Northern Italian region of Emilia-Romagna, the son of a joiner, Antonio Secchi and his wife Luise Belgieri [3]. He began his education with his mother, who by all accounts was a practical middle-class woman, and apart from the usual lessons for a boy destined for life as one of ‘*God’s Marines*’ she also taught her son the arts of sewing and knitting.

After studying for several years in the Gymnasium kept by the Jesuits in his native town, Secchi in his sixteenth year entered the Jesuit Order at Rome on the 3rd of November 1833. The Jesuits were a male religious order bound by almost fanatical loyalty the Roman Catholic Church and its Pope. It had been founded in 1534 by Ignatius of Loyola (1491-1556) and six other young men, including Saint Francis Xavier (1506-1552) and the Blessed Pierre Favre (1506-1546) [4]. In 1540 the Jesuit Order was ratified by Pope Paul III.

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The Jesuit Order or the Society of Jesus, known colloquially as '*God's Soldiers*' professed vows of poverty, chastity, and later obedience, including a special vow of obedience to the Pope. Rule 13 of Ignatius' Rules for '*Thinking with the Church'* went so far as to say [5]:

"That we may be altogether of the same mind and in conformity… if [the Church] shall have defined anything to be black which to our eyes appears to be white; we ought in like manner to pronounce it to be black"

The order was bound to obey its set of rules known as the *'Formula of the Institute of the Society of Jesus'*, whose opening lines read [6]:

"Whoever desires to serve as a soldier of God beneath the banner of the Cross in our Society, which we desire to be designated by the Name of Jesus, and to serve the Lord alone and the Church, his spouse, under the Roman Pontiff, the Vicar of Christ on earth, should, after a solemn vow of perpetual chastity, poverty and obedience, keep what follows in mind. He is a member of a Society founded chiefly for this purpose: to strive especially for the defence and propagation of the faith and for the progress of souls in Christian life and doctrine, by means of public preaching, lectures and any other ministration whatsoever of the Word of God, and further by means of retreats, the education of children and unlettered persons in Christianity, and the spiritual consolation of Christ's faithful through hearing confessions and administering the other sacraments. Moreover, he should show himself ready to reconcile the estranged, compassionately assist and serve those who are in prisons or hospitals, and indeed, to perform any other works of charity, according to what will seem expedient for the glory of God and the common good"

For the next six years Secchi applied himself diligently to learning; taking courses not only in Latin, and Theology, but also studying Philosophy and Humanism. During his time at the Jesuit's Collegio Romano, he had exhibited an extraordinary talent for the natural sciences, which led to his appointment in 1839 as one of its tutors in Mathematics and Physics. Two years later he became a Professor of Physics at the Jesuit College at Loreto, Ancona in 1841.

In the autumn of 1844 Secchi returned to the Collegio Romano and began an intensive course of theological studies under several of its most distinguished teachers, including Carlo Passaglia (1812-1887), Professor of Mathematics, Philosophy and Theology; Giovanni Perrone (1794-1876), Professor of Theology; Frances Xavier Patrizi (1797-1881), Professor of Sacred Scripture and Hebrew; and Antonio Ballerini (1805-1881), Professor of Moral Theology.

On the 12th of September 1847, he was ordained a priest and became Father Pietro Angelo Secchi – Jesuit and Scientist.

The town of Reggio Emilia in the northern Italian Province of the same name, was the birthplace of Pietro Angelo Secchi, the son of Antonio Secchi, a cabinet maker and his wife Luise Belgieri. Reggio Emilia is the main commune (municipality) of the Province of Reggio Emilia and one of the eight which form the Region of Emilia-Romagna. The town is also referred to by its official name of Reggio nell Emilia. The inhabitants of Reggio nell Emilia (called Reggiani) usually call their town by the simple name of Reggio. In some ancient maps the town is also named Reggio di Lombardia. At the time of Secchi's birth, Reggio was under the rule of Francis IV (Joseph Charles Ambrose Stanislaus), Duke of Modena and the son of Archduke Ferdinand of Austria.

Francis was hated for his bloody and tyrannical rule in which he suppressed all attempts to introduce democracy during his reign, especially following a major revolt which took place in 1830. In 1860 Reggio became part of the new unified Italy, something which was to cause Secchi much unhappiness in his future life as a Jesuit devoted to both God, church and Pope. At the age of 15 Angelo Secchi left Reggio for Rome on a road which would make him '*God's Astronomer*'.

House in Reggio, Emilia, Birthplace of Pietro Angelo Secchi (1818-1878)

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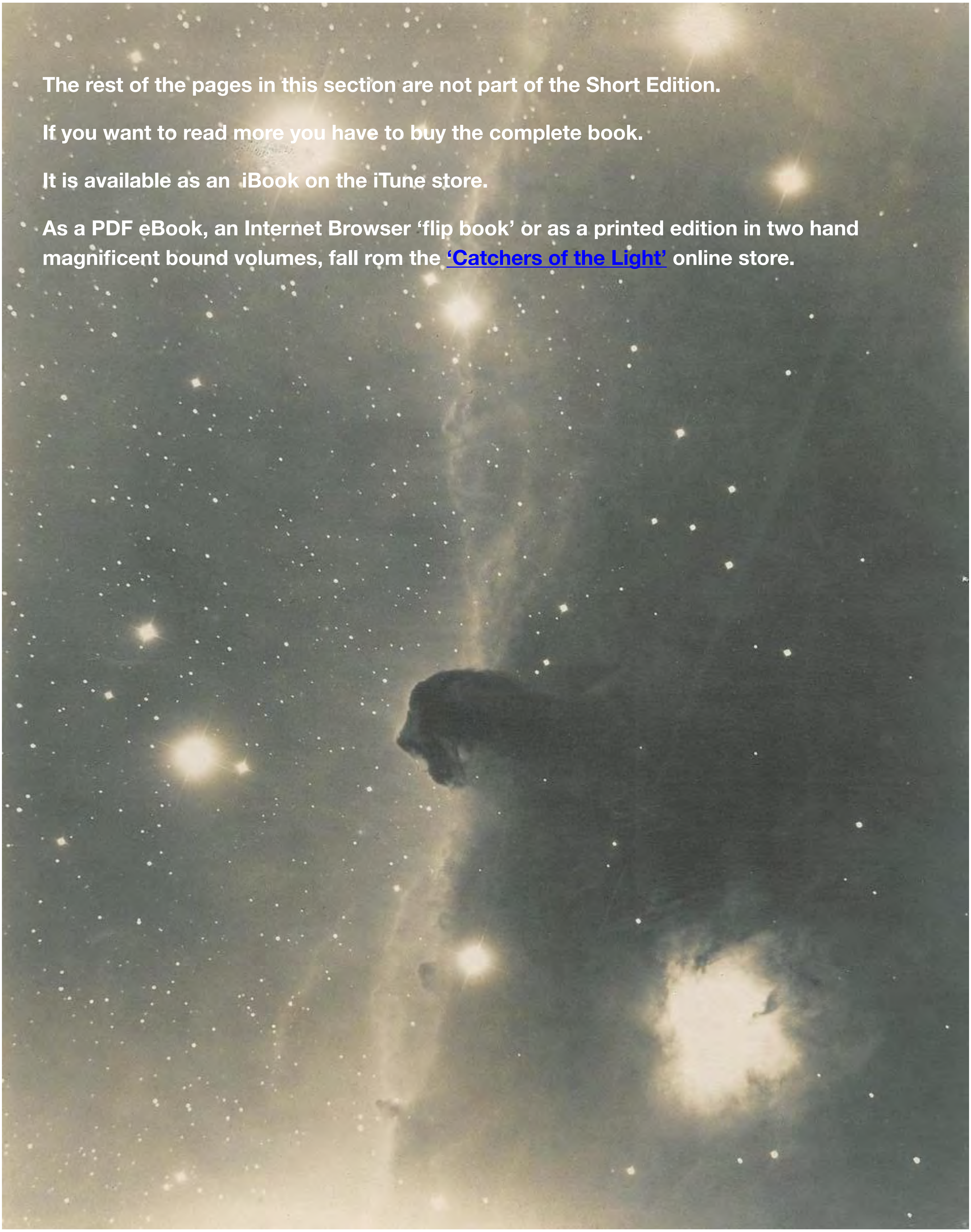


VI.3

'The Devoted Couple'

William Huggins

Born: 7th February 1824, Cornhill, London, England

Died: 12th May 1910; Brixton, London, England

Lady Margaret Lindsay Murray

Born: 14th August 1848, Dublin, Ireland

Died: 24th March 1915, Chelsea, Middlesex, England

Sir William Huggins was a one of the founders of modern Astrophysics. He and his wife Margaret Lindsay Murray conducted some of the earliest research into the spectra of stars, and contributed greatly to our knowledge of the physical structure of the universe based on a common set of chemical elements.

VI.3.1 ‘The Father & Mother of Astronomical Spectroscopy’

The nineteenth Century was a period of great change for Astronomy, not only the in the type of research which was undertaken, but also in the manner in which such investigations were carried out. In the short space of these one hundred years more was learnt about our universe and the diversity of the objects it contained than in all the millennia which had gone before.

For the very first time man began to glimpse the sheer size of what he saw when he looked up at the night sky from the Earth; a planet which he now realized was nothing more than a speck of dust in the cosmic scheme of things. How must Friedrich Wilhelm Bessel (1784-1846) have felt in 1838 when he calculated the distance to the star 61 Cygni to be an incredible 10.4 light years away – or to put it in terrestrial distances, a staggering 98,391,159,596,914,840.32 km [1]? , which is the equivalent of travelling 2,455,175,535,793 times round the Earth’s Equator in a plane! Such distances are in truth beyond our comprehension. Tremendous though the achievement of Bessel was, it was only the beginning. At that time nobody had any idea of what a star really was, or what it was made up of; and they certainly knew even less about the many objects known as ‘*nebulae*’ which astronomers were beginning to find in ever increasing numbers as faint ‘smudges’ in the eyepieces of their telescopes.

All of this was about to change in the early 1800s with the birth of the new branch of Astronomy known as Astrophysics; which was concerned, not with position and measurement of the old days, but with the very make up and workings of the universe itself. The cuStørmers who patronized the London premises of William Thomas Huggins, silk mercer and linen draper, during the middle years of the nineteenth century, may well have been served by his young son William Huggins (1824-1910); little knowing that they had met someone who would soon begin to add pieces to a jigsaw puzzle, which when complete would explain the very nature of the universe in which they shopped.

In the years following the publication of his first scientific paper in 1856, Sir William Huggins, as he was later to become, carried out some of the very earliest investigations into Astronomical Spectroscopy in which he hoped to *‘discover whether the same chemical elements as those of our earth are present throughout the universe…’* At the time of his death in 1910 he was in a position to write that it ‘*was most satisfactorily settled in the affirmative; a common chemistry, it was shown, exists throughout the universe.’*

It has been said that Sir William Huggins was the ‘*Father of Astronomical Spectroscopy’*, but if this so then his wife Lady Margaret Lindsay Murray (1848-1915) was its mother. In the years following their marriage in 1875, she was not only his wife, but a friend, an assistant, a photographer and a co-worker. It was Margaret Lindsay Murray who introduced photography as an integral and necessary element of their 35 years of devotion to each other and to their work.

VI.3.2 Shop Assistant

William Huggins lived in a world which for him anyway, was filled with privilege and laden with opportunity, so much so that he could concentrate in the main on what he wanted to do; and not be inconvenienced by having to earn a living. Although it has to be said, that during his lifetime he worked extremely hard, not through conventional employment, but laboured in astronomical research, for his own pleasure and without payment.

William Huggins was born a ‘*true*’ Londoner on the 24th February 1824, at the premises of his parents’ drapery shop in Gracechurch Street, in the parish of St. Peter’s, Cornhill, in London’s ‘*square mile*’ within the sound of the bells of the church of St. Mary Le Bow [2], [3], [4], [5]. He was the only child of William Thomas Huggins (1779-1856), a wealthy silk merchant and his wife Lucy Miller (c1786-1868). Like many other shopkeepers of their time, the Huggins family lived in the building that housed their business, as did their assistants and servants. At the time of the 1841 Census, the business of William Thomas Huggins was thriving, and profitable enough to maintain four servants [6].

William’s parents were Congregationalists and as Nonconformists they did not belong to the official Church of England [7]. At the time members of such minority religious groups were still discriminated against, especially if they were to apply for a governmental position. They were therefore more than usually aware of the need for their son William to be well educated if he were to have a successful career. Before the age of 10, William was sent to a small school in Great Winchester Street for a short time. He also took extra lessons in classics and mathematics from a clergyman, as well as attending lectures in the ‘*Adelaide Gallery*’, a sort of precursor to a modern technical school.

When the City of London School opened in January 1837, William Huggins was one of its first pupils [8]. It was an enlightened institution, offering a curriculum similar to a present-day academically orientated high school. However, his time there was brought to an end by an attack of smallpox, after which his parents took him away, fearing further infectious diseases. Following his removal from the City of London School, his education was continued at home under the supervision of private tutors. Under their tutelage,

William Huggins became particularly good at languages, supposedly being fluent in French, German, and Italian as well as Spanish, Swedish, and Hebrew. Music was not neglected, he had violin lessons and possibly learnt how to play the piano as well.

According to his biographers, Mills and Brooke it was William Huggins' intention to eventually continue his studies at Cambridge University [9]. This at the time would have been difficult for any but practicing members of the Church of England to gain admission to the old English Universities of Cambridge and Oxford. In order to enter the halls of these hallowed institutions, William Huggins would have had to have repudiated the religion of his birth and joined the official church.

When he was about 15 years old, William Huggins was introduced to the new '*art*' of photography, when his mother brought him to Paris. It was in Paris that the astronomer and politician, Francois Arago had recently revealed to the world the invention of the Daguerreotype photographic process, named after its originator, Louis Jacques Mandé Daguerre (1787-1851) [10]. It was whilst in Paris that he obtained the necessary equipment and chemicals for making Daguerreotypes.

At this time the young William Huggins was already an active amateur scientist, building his own apparatus for chemistry, optics, physics, electricity, and photography. For a time he remained undecided as to which branch of science he should concentrate on, so he conducted extensive experiments in a number of areas, including chemistry, physics and biology. At first he seems to have been most interested in microscopy and plant, physiology. However after much thought he finally decided on Astronomy, a decision which not only dictated the rest of his life but which also influenced the lives of many others.

When he was 18 years old he bought his first telescope in 1842 for £15. This was then an enormous amount of money to be spent on a hobby, considering that an unskilled labourer would have to work for a year before he could afford one for himself. The London smog which clung to its many tall buildings were far from being an ideal setting for astronomical observations. However, William Huggins would have to wait fourteen years before he could look at the night sky from a dark, pollution free location, but for now he would have to be content with using his telescope from the roof of his home or through an open window.

It is not known if William Huggins gave up his Nonconformist roots for the sake of a University education; because just at the time when he would have to have made this important decision, his father became seriously ill. However, it is known that he did not adopt the strict Calvinistic ideas of the Falcon Square Congregational Church, to which the family then belonged [11]. In later life his wife was to describe him somewhat interestingly as a '*Christian unattached*'; perhaps he might well have adopted the Church of England if '*push came to shove*'.

To complicate matters further, the drapery business then needed close attention because they suspected that their foreman was stealing from them. William had to give up any idea of studying at Cambridge. Instead, he was forced to take over the shop. So by the time of the 1851 Census, we find William Huggins as an assistant in his father's shop at No. 97 Gracechurch Street, London [12]. Although living and now working in London he still had sufficient time to pursue his interests in microscopy and astronomy. In 1852 he joined the Royal Microscopical Society, which was followed two years later, by his election as a Fellow of the Royal Astronomical Society on the 12th of April 1854. These prestigious societies were in fact dominated by amateurs, at least in membership numbers, during the nineteenth century. Indeed much of the '*quality*' scientific research of the time was carried out by talented and wealthy amateurs like William Huggins.

As any good Victorian Christian should and did, William '*denied himself idle amusements'* and seems to have had a circle of rather serious friends. However, the pursuit of business and Christian values was interspersed with holidays on the continent, which he enjoyed with these friends. Although the heyday of the '*Grand Tour*' had long gone, we do know of two extensive trips made by William Huggins in the years 1850 and 1854.

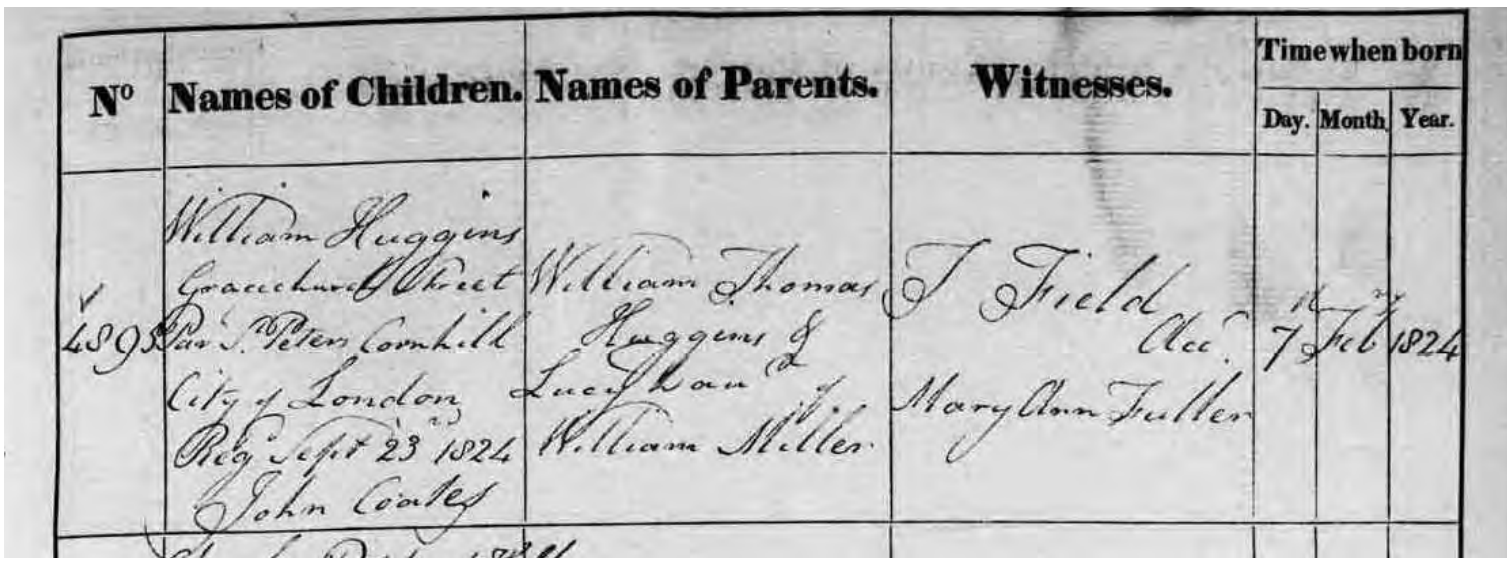
The earlier of the two trips was to Belgium, Germany and Switzerland. William Huggins was like every other Englishman of his day and travelled with a rather superior attitude towards all foreigners. He referred rather critically in his travel diary to the German habit of smoking, as something [13]:

'...which has called down upon the devoted nation the sarcasm and rebuke of every English traveller, as a selfish and disgusting habit, which sacrifices another's comfort to the gratification of one's own prurient appetite'.

His later travels in 1854 were to Paris, the Loire, and the Pyrenees. At the age of 30 William Huggins was very much a bachelor unused to the pleasures of the flesh. Of Eaux Bonnes, near Pau, he remarked [14]:

'It is a very fashionable bathing place and much renowned for diseases of various kinds, especially those of the skin. Even celibacy, says our witty guide book, is often cured here. I very much doubt whether the remedy is not found much worse to bear than the disease itself'.

He was also somewhat disinclined to appreciate the bouquet of the grape [15]: *'The little relish I have for wine is certainly not fostered by being told how the labourers wash their hands and feet, and … but I forbear.'*



Nº	Names of Children.	Names of Parents.	Witnesses.	Time when born Day.	Month.	Year.
4893	William Huggins Gracechurch Street Par. S. Peters Cornhill City of London Reg. Sept 23 1824 John Coates	William Thomas Huggins & Lucy Ann d. of William Miller	T. Field Acc. Mary Ann Fuller	7	Feb	1824

William Huggins' Birth Record Entry at Dr. William's Library, London

The Pinners Hall Meeting House in New Broad Street, London, was established in the early 1800s as a place of worship for Congregationalist. As William Huggins' parents were Congregationalists who lived just a few hundred metres from Pinners Hall, it was only natural that he should be baptised there. The ceremony took place on the 24 August 1824, and was recorded by Samuel Nichols in the Register Book of Pinners Hall. A record of William Huggins' birth is also to be found (see above) in the archives of the Dr. Williams Library, London. Dr. Daniel Williams (1643-1716) was a Presbyterian minister who collected a large number of books and manuscripts, which he bequeathed to public use. The library opened in 1729 in Red Cross Street, London.

The General Register of Births, as the baptismal register was called, originated with a group of Protestant dissenting ministers of the Three Denominations (Baptist, Congregational, Presbyterian). It began to collect details of births of dissenting children, as so many nonconformist ministers failed to keep registers. Arrangements were made with Dr. Williams' Library for the librarian to receive and record the information. The keeping of records began on the 1st of January 1743.

Pinners Hall Meeting House, c1815

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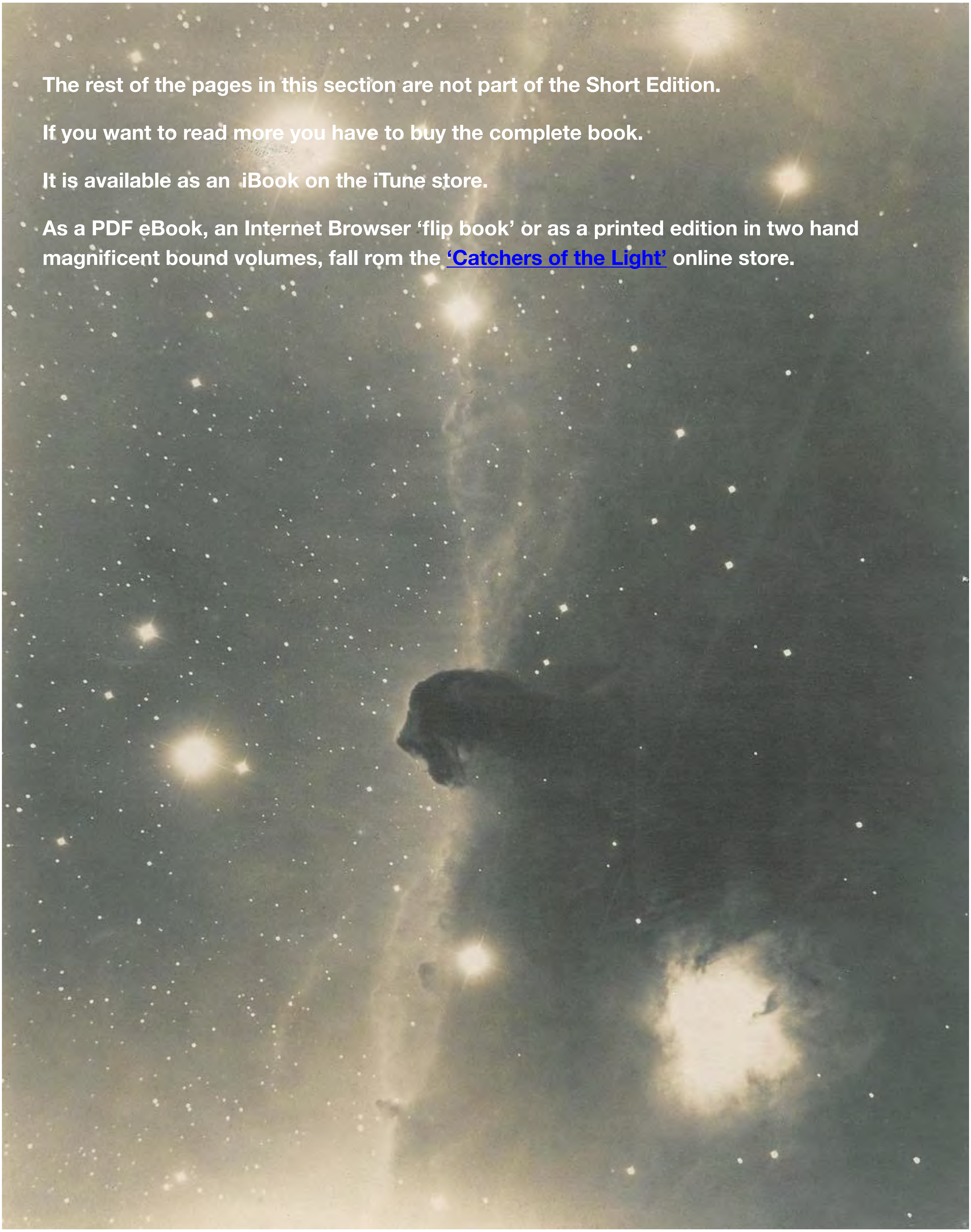

VI.4

'The Ladies' Man'

Edward Charles Pickering

Born: 19th July 1846, Boston, Suffolk, Massachusetts, USA

Died: 3rd February 1919, Cambridge, Middlesex, Massachusetts, USA

Edward Charles Pickering had three great talents; one was the ability to inspire himself to do great things; the second to recognize the potential in women, to become great astronomers; and lastly to persuade wealthy philanthropists to part with their money to finance his research. With these talents and the women he employed, some of the finest astronomical research ever carried out, was done under his supervision at Harvard College Observatory during the forty two years he was its Director.

VI.4.1 Astrophysics

Edward Charles Pickering (1846-1919) was one of the new breed of Astronomers that began to appear in the USA during the last decades of the nineteenth century. Unlike many of his European counterparts, he was not interested in the old Astronomy of measurement and position. He did not want to know where a star was in the sky; but to know the answers to more '*important*' questions like: how bright it was; why were some stars intrinsically brighter or dimmer than others; and why some stars were orange and others were white.

He was above all else an Astrophysicist who wanted to use the science of physics to understand the stars. Throughout his career he used photography in an attempt to answer the many questions that burned in him - like the stars he wanted to understand. During his time as Director of the Harvard College Observatory which lasted longer than any other that have held this illustrious office, he and his female staff of Astronomers carried out fundamental Astrophysical research into the measurement of stellar magnitudes, the classification of stellar spectra and the size of the Universe itself.

With his great personal charm Edward Charles Pickering had the knack of obtaining grants of large sums of money to pursue his research and in particular to construct some of the finest examples of Photographic Refractors (Astrographs), notably the 8-inch Bache and 24-inch Bruce Telescopes.

VI.4.2 Beacon Hill

Edward Charles Pickering was born on the 19th July 19 1846 at Mount Vernon Street, in the fashionably chic area of Beacon Hill in Boston, Suffolk, Massachusetts, USA [1]; into an affluent and well to do family. He was the second of the three children of the lawyer, Edward Pickering (1807-1876) and his wife Charlotte Daniel Hammond (1819-1901). His younger brother, William Henry Pickering (1858-1938), was also a famous Astronomer and Astrophotographer [2]. His elder sister Ellen Pickering (1842-1861) had died before she had reached the age of twenty [3].

Unlike his father, his grandfather and his great grandfather before him, he chose not to become a lawyer, but a scientist [4], [5]. For five years he attended the Latin School in Boston, where he acquired a great loathing for the Classics. This antipathy towards Latin and the other '*dead*' languages turned him in the opposite direction - towards Science. He entered the Lawrence Scientific School of Harvard to study Civil Engineering and graduated from there in 1865. Here he remained for the next two years as a teacher of mathematics. When only twenty one he became the Thayer Professor of Physics at the Massachusetts Institute of Technology, a position he held for the next ten years; during which time his methods revolutionized the teaching of the subject.

Edward Charles Pickering (1846-1919), his younger brother William Henry Pickering (1858-1938) and his elder sister Ellen Pickering (1842-1861) were born '*of a Salem family known and honoured since revolutionary days'*. Their parents were Edward Pickering (1807-1876), a well to do lawyer and his wife Charlotte Hammond (1819-1901). As young children they were brought up in the middle class area of Mount Vernon Street, Beacon Hill - one of the best and elitist parts of the city of Boston.

Even today, Beacon Hill is regarded as one of the most desirable and expensive neighbourhoods in Boston. Mount Vernon Street: has even been dubbed as *'The finest address in all America'*.

Mount Vernon Street, Beacon Hill, Boston, circa 1870

Edward Charles Pickering became interested in Astrophotography through his younger brother William Henry Pickering. Astrophotography became of paramount importance to him in the development of the new science of Astrophysics. In his 1920 Obituary to Pickering, the English astronomer Herbert Hall Turner, a one time critic of his, expressed as much: *"To estimate the importance of his initiative, we must go back to the beginning of his work —in Miss Cannon's words, to the eve of the greatest revolution this ancient science (of astronomy) had known since the days when Galileo constructed his rude telescope'..It was a revolution foreseen by G. P. Bond from afar ...'Any considerable improvement in the sensitiveness of the present photographic processes will revolutionise practical astronomy'. it was not till nearly two more decades had elapsed that the dry-plate brought the improvement he anticipated... In 1882 Pickering, one of his successors, revivified the method at Harvard and played a leading part in the revolution Bond had foretold."*

Edward Charles Pickering as a Young Man

VI.4.3 Harvard College Observatory

E. C. Pickering's rise in the scientific hierarchy was meteoric, although tempered with a considerable degree of luck. In 1876 Charles William Eliot (1834-1926) the President of Harvard appointed Pickering as Professor of Astronomy and Director of the Harvard College Observatory (HCO), a post he held from the 1st February 1877 held until his death on the 3rd February 1919.

The early years of the HCO had been graced by two great Directors, William Cranch Bond and his son George Phillips Bond who together with the Boston Photographer, John Adams Whipple had given birth to Stellar Photography [6]. However, following the death of its third Director, Joseph Winlock (1826-1875) in 1875 the HCO did not appoint his successor for over a year, the position was seen by several worthy candidate as unattractive. Simon Newcomb (1835-1909), the Professor of Astronomy at the United States Naval Observatory, was one such candidate. He later wrote of the reasons why he had rejected Eliot's offer of the Directorship [7]:

"{The observatory} was poor in means, meagre in instrumental outfit and wanting in working assistants; I think the latter did not number more than three or four, with perhaps a few other temporary employees. There seemed little prospect of doing much."

Eliot's appointment of Pickering was not well received in a number of quarters; in fact he seemed to have had no other logical alternative. His decision later proved to be the wisest choice that Harvard could possibly have ever made.

So on the 1st February 1877 Edward Charles Pickering with his wife Elizabeth Wadsworth Sparks (1849-1906) moved into the HCO Director's residence on Observatory Hill in Cambridge, Massachusetts with an annual salary of $3400 and a lot of work to do - if the comments of Simon Newcomb were anything to go by! During the next 42 years Pickering embarked on three great programmes of research at the HCO which lasted throughout his Directorship until the very day he died – Stellar Photometry, Stellar Photography and Stellar Spectroscopy. Astrophysics had arrived at the Harvard College Observatory!

It was during the course of this work that Pickering's ability to manage such huge astronomical projects came to the forefront. He knew instinctively what had to be done and the answers to the multitude of questions that came to mind. What type of equipment should be used? Where in the world should it be situated so as to get the best possible results from it? Who will make the observations? Who will be used to reduce the data from the observations? How long will it take and how much will it cost? And so on.

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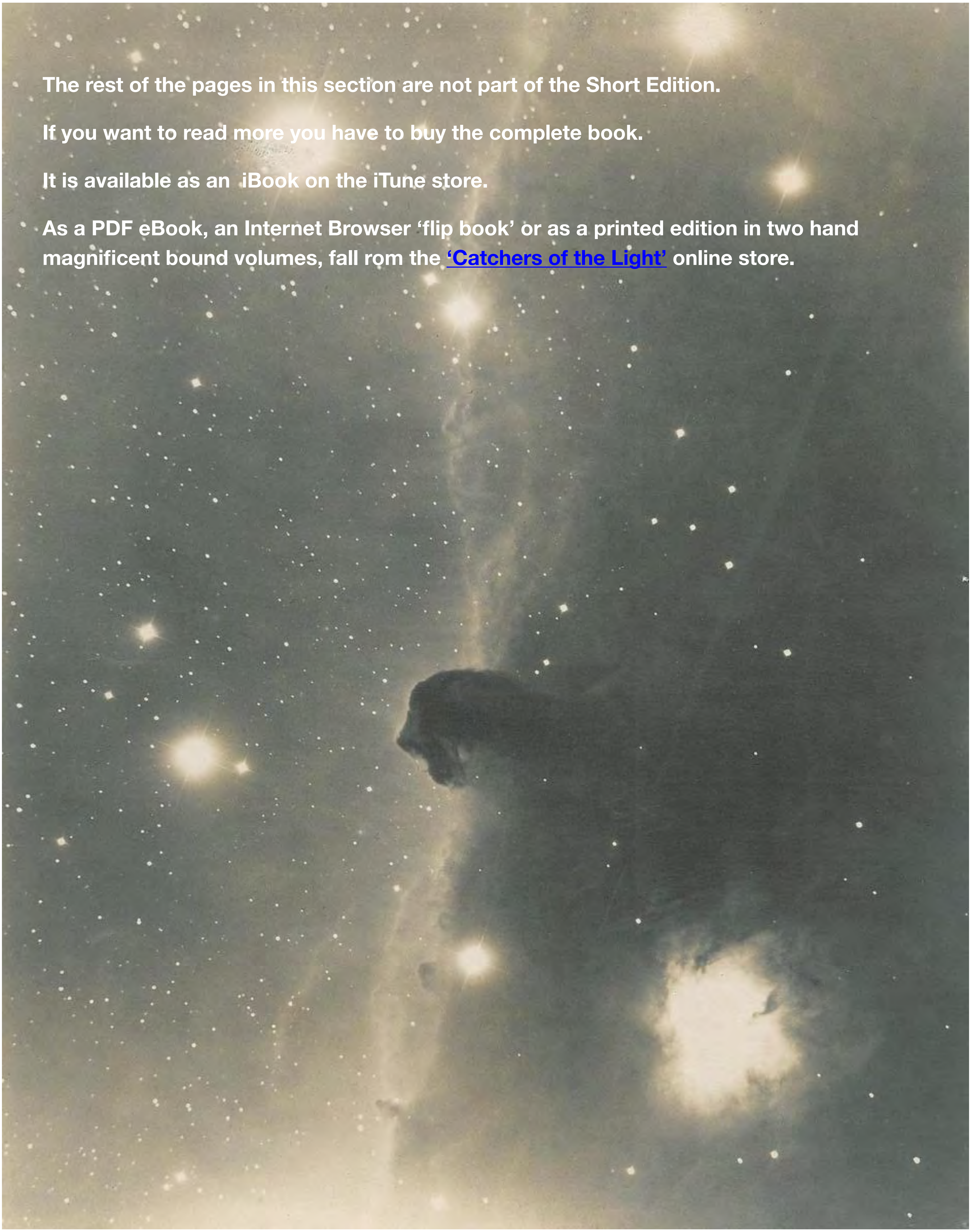

Short Edition

VI.5

'The Rainbow Men'

Hermann Carl Vogel

Born: 3rd April 1841, Leipzig, Germany

Died: 13th August 1907, Potsdam, Germany

Wilhelm Oswald Lohse

Born: : 13th February 1845, Leipzig, Germany

Died:14th May 1915, Potsdam, Germany

Julius Scheiner

Born: 25th November 1858, Cologne, Germany

Died: 20th December 1913, Potsdam, Germany

Hermann Carl Vogel

Wilhelm Oswald Lohse

Julius Scheiner

Hermann Carl Vogel, Wilhelm Oswald Lohse and Julius Scheiner were three of the great pioneers of Astronomical Photographic Spectroscopy. They made significant contributions to the then new science of Astrophysics. It was Vogel who first realized that photographs taken with modest telescopes were the equal of visual observations made with even the largest of telescopes. Lohse was the Chemist who worked with Vogel all his life, providing his friend with the technology to photograph the '*rainbows of the stars*.' And it was Scheiner who proved conclusively through photographic spectroscopy that the '*Great Andromeda Nebula'* was in fact an *'Island Universe'* made up of individual stars.

VI.5.1 'The Fatherland' of Astrophysics

Germany can be considered to be the fatherland of the '*New Astronomy*' now known as Astrophysics. Throughout the whole of the nineteenth century there was a gradual shift away from the '*Old Astronomy*' of measurement and position towards one based on understanding the nature, structure, composition and origin of the Universe. Such a change was slow at first, but as the century progressed it gradually accelerated until it became the principal area of research in a number of institutions, most notably in Germany and later in America.

Hermann Carl Vogel (1841-1907) and Wilhelm Oswald Lohse (1845-1915) were friends from school and University days. Later they became master and assistant at the Bothkamp Observatory, a private institution, near Kiel - the very first set up specifically to study the physics of the universe. It was here that they learned their trade as astronomers of the new school; and from there they would eventually become two of the greatest disciples of the emerging science of Astrophysics.

Together and individually they used photography to capture the spectra of the sun and its planets, and those of stars, nebulae and galaxies, so that they might understand their physical nature and chemical composition. Their efforts in the field of Photographic Astronomical Spectroscopy led to some of the most significant contributions ever made to the development Astrophysics during the age in which they lived.

Lohse constructed one of the first purpose built Astronomical Photographic Cameras. In the years 1879 to 1889 he used this camera to take a total of 217 photographic plates of the moon, planets, stars, clusters, nebulae and galaxies. His camera was described and cited in many works of the time, and proved to be a useful instrument in the development of many new photographic techniques. However his greatest claim to fame in the annals of the History of Astrophotography was the series of photographs he took of the planet Jupiter in the years 1878 to 1881, which clearly showed the '*Red Spot, two Equatorial Belts, and the North Polar Zone'*. These images predated those of the Henry brothers by three years.

Vogel also did his bit in promoting Astrophotography. In 1888 he published a paper on the usefulness of photography for depicting accurately the shape and structure of the nebulae. It was his view that photographs obtained with only modest equipment could show details which were absent or only slightly visible to an observer using even the largest of telescopes.

The remarkable and sometimes controversial research carried out by Vogel and Lohse during the latter decades of the nineteenth century enabled other astronomers to build upon what they had found; and to add further pieces to the complex jigsaw puzzle which would when complete show the true nature of the universe in which we live.

VI.5.2 Leipzig

Hermann Carl Vogel [1] was born on the 3rd of April 1841 in Leipzig, Germany, the sixth child of Johann Carl Christoph Vogel, a well known theologian, educationalist and school principal of a Leipzig Gymnasium (Secondary School) [2].

From a very early age, the young Hermann Vogel was surrounded by some of the finest scientists of the nineteenth century. Listed amongst his father's friends were the naturalist, Alexander Von Humboldt (1769-1859), the geographer, Carl Ritter (1779-1859) and the physicist Robert Bunsen (1811-1889). It was Robert Bunsen, who along with Joseph Von Fraunhofer (1787-1826) and Gustav Robert Kirchhoff (1824-1887) founded the science of Spectroscopy [3]. So it was not in the least surprising that Vogel himself was later inspired to continue their pioneering efforts in this new branch of Physics.

Herman Vogel's elder brother Eduard (1829-1856) [4], who later became an astronomer and African explorer, was a friend of Heinrich Louis D'Arrest (1822-1875), the '*Observer*' of the Leipzig Observatory [5]. Through this friendship Hermann Vogel came into contact with astronomy while still young. The die was cast Hermann Carl Vogel would become an Astronomer.

After graduating from his father's Leipzig Gymnasium, Vogel entered the Dresden Polytechnic School in 1860. However before he completed his training both his parents died, leaving him seriously in debt.

He managed to support himself by doing odd jobs, supplemented by some financial help from his older brothers. Eventually Vogel was able to return to Leipzig and in 1863 he began studying physics at the city's University.

Two years into his studies he became an assistant at the University's Observatory then under the Directorship of Karl Christian Bruhns (1830-1881). Vogel's remarkable mechanical skills and ingenuity proved invaluable in maintaining and operating the Observatory's equipment.

At the time, the Leipzig Observatory was participating in the *'Astronomische Gesellschaft'* project, the aim of which was to determine the positions of all stars down to the ninth magnitude [6]. At Bruhns's suggestion Vogel agreed to conduct observations of nebulae in the zone +9°30' to 15°30', the area which had been assigned to the Leipzig observatory. This work formed the basis of Vogel's Doctoral Thesis, which was completed in 1868; the subject of his thesis being the micrometrical determination of the positions of star clusters and nebulae [7].

In 1866 while Vogel was a student at Leipzig, a new Privat-dozent (unpaid researcher/lecturer) was appointed by the name of Dr. Johann Karl Fredrich Zöllner (1834-1882). Although only seven years older than Vogel, Zöllner became a mentor to the young student; and it was he who steered Vogel in the direction of Astrophysics and especially astronomical spectroscopy. Zöllner's most important work in stellar photometry was carried out whilst Vogel was working on his doctorate, i.e. during the years 1867 to 1870. At this time, Zöllner proposed his ingenious design for a reversible spectroscope with which he sought to demonstrate the existence of Doppler shifts in the spectra of stars; the very same field of study in which Vogel was later to make his mark.

At about the time Vogel was appointed to his position as a second assistant astronomer (i.e. general dogsbody) at the Leipzig Observatory, he met up with an old friend from his school days, Wilhelm Oswald Lohse. Lohse like Vogel was a native of Leipzig, but had not the good fortune to have a father with influential friends, but nevertheless had attained great academic distinction.

Lohse had gained his PhD in Chemistry at the very young age of just twenty; most students only gain such a higher degree when they are some four of five years older. His friend Vogel had not yet earned his first degree, although he was nearly four years older than Lohse. Vogel did not gain his doctorate from the University of Jena until 1868, when he was twenty seven. Lohse after gaining his Doctorate left the sheltered world of academia to earn his living working in the chemical industry; and spent a number of years working for companies specializing in gas and fertilizers! However it was not long before his friend Vogel made him an offer which he could not refuse.

Eduard Vogel (1829 - 1856) was Hermann Carl Vogel's elder brother. It was through his influence that Hermann was introduced to astronomy at an early age. Eduard had studied mathematics, botany and astronomy at Leipzig and later at Berlin with the noted astronomer, Johann Franz Encke. In 1851, he was engaged as assistant astronomer to John Russell Hind, the Director of George Bishop's private observatory in London. On the 20th of February Eduard Vogel join a British Expedition in North Africa tasked with finding suitable trade routes in the region. After a series of adventures in which Vogel did not ingratiate himself with the locals found himself in the February of 1856 in Wara, the capital of Ouddai. (Chad).

Vogel's odd habit of existing almost solely on eggs and writing with a pencil rather than the expected ink was of concern to the local Sultan's advisors who had advised the Sultan to kill him '*just in case*' He was eventually beaten to death with iron tipped clubs after further offending the Sultan by climbing the sacred and forbidden Mount Treya.

Eduard Vogel (1829-1856)

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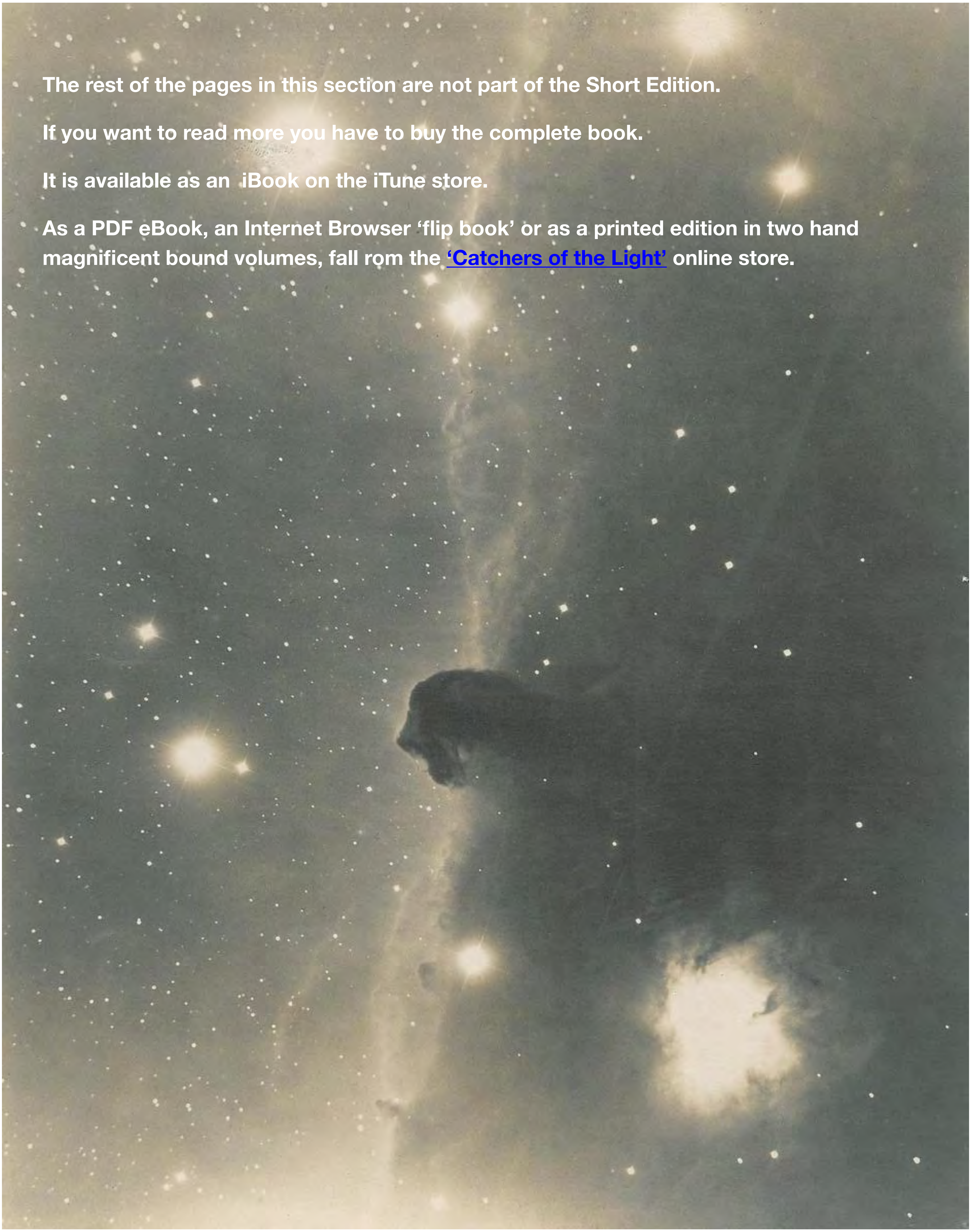

VI.6

'The Yardstick Men'

Edwin Powell Hubble

Born: 20th November 1889, Marshfield, Missouri, USA

Died: 28th September 1953, San Marino, California, USA

Milton Lasell Humason

Born: 19th August 1891, Dodge Center, Minnesota, USA

Died: 18th June 1972, Mendocino, California, USA

Edwin Powell Hubble and Milton Lasell Humason were two of the greatest astronomers of the twentieth century. Edwin Hubble will always be remembered for the Law which bears his name; and more importantly for his pioneering efforts to put a '*yardstick*' to the true size of the universe. Milton Humason worked closely with Hubble on the determination of the distances of galaxies; despite having started his career as a *'mule skinner'* and later as a janitor at the Mount Wilson Observatory.

VI.6.1 Measuring the Universe

Edwin Powell Hubble (1889-1953) was without doubt one of the greatest astronomers who ever lived. Anybody with even a passing interest in the night sky will have seen the magnificent images taken by the great space telescope which now bears his name. Not so many will know why he was granted such an honour, or how as a young boy born into a working class family from an ordinary small Midwestern American town, he should now be its most famous citizen.

Marshfield, Missouri is to all intents and purposes – '*Hubble Town*'. As soon as you enter Marshfield off of the famous route 66 highway you know who was born here. There are signs for East and West Hubble Drive. The town's elementary school is named the 'Edwin P. Hubble Elementary School'. Outside of the town's courthouse you might expect to see a statue of a former mayor or a famous judge – not in Marshfield – you have a replica of the Hubble Space Telescope to greet you!

What was it that Hubble did - to make him so famous? When you hear astronomers say this Galaxy was so many million light years away and that Galaxy is the most distant ever discovered – you have Edwin Powell Hubble to thank. Until the pioneering work of Hubble in the 1920s, nobody had any real idea of how big the universe was. It was not even known whether certain '*nebulae'* now known as Galaxies were within the confines of our own Milky Way or did they lay way beyond its boundaries as individual '*Island Universes*'.

Hubble was the first person to put a '*yardstick*' to the size of the Universe by determining that Galaxies were in fact separate star systems lying at distances far beyond our Milky Way, whose light had left their boundaries long before man had even walked on the Earth.

In order to tell the real story of Edwin Powell Hubble, it is also necessary to include that of Milton Lasell Humason (1891-1972). Like Hubble, Milton Lasell Humason was born into a working class family from a small Midwestern American town. Unlike Marshfield - Dodge Center, Minnesota - the birthplace of Milton Lasell Humason has no School, Drive or Space Telescope to remember him by. Yet in truth Humason also deserves his share of recognition, in respect of the monumental discoveries now so often attributed solely to Edwin Powell Hubble.

The mid-western American town of Marshfield, Missouri, possesses a most unusual centrepiece - a replica of the Hubble Space Telescope, in memory of its most famous '*son*' - Edwin Powell Hubble. This is a fitting monument to all who wish to pay tribute to the man who with his colleague Milton Lasell Humason, were responsible for determining the true '*distance scale of the universe*'. For there is no known grave of this great pioneer of Astrophysics, who with Humason used the powerful tool of photography to answer fundamental questions on man's insignificant place in the cosmos.

Replica of Hubble Space Telescope, Marshfield, Missouri

VI.6.2 Marshfield ... Dodge Center

Edwin Powell Hubble was born on the 29th November 1889 at Marshfield, Missouri, [1] the third of the eight children of John Powell Hubble (1835-1913), an insurance agent and his wife Virginia Lee James (1867-1934) [2]. At the time Marshfield was a typical '*frontier*' town, which in the Webster County History for the year of Edwin Hubble's birth is described as [3]:

"…[Marshfield] the county seat of Webster County is situated on the St. Louis & San Francisco Railroad, 212 miles from St. Louis. This town, with a population of 1,000, is located on the summit of the Ozark Range, as eligible and beautiful a site as any in Missouri; is 1,505 feet above the sea level, 1,081 feet above Si Louis, 223 feet above Lebanon, its neighboring town on the east, and 142 feet above Springfield, its neighboring town on the west. It is therefore the highest point in Missouri, except Cedar Gap, in Wright County, and among the most beautiful and pleasant of residence places. The population in June, 1880, was 815, but a few months before the number of inhabitants was over 1,000, which is now a little under the true number of residents."

The dramatic drop in the population referred to above was the result of a devastating tornado that swept over the town of Marshfield in the April of 1880, in which many died and others just left their flattened homes, never to return.

The Hubble (or Hubbell) family had their American origins with Richard Hubbell (1626-1699) who came from Ribbesford, Worcestershire, England sometime around 1631-1639 and put down his roots in the area of Fairfield, Connecticut. From there the family gradually moved westwards via the states of New York, Virginia to Missouri and finally to California where Edwin Powell Hubble's life truly began and ends [4].

John Powell Hubble had qualified as a lawyer in Saint Louis, Missouri and had moved to Marshfield with his parents, Martin Jones Hubble (1835-1920) and Mary Jane Powell (1840-1918) in around 1881 and began practicing law there, after his admission to the Bar in March 1882 [5]. However after a couple of years his eyesight became badly affected so he went into the same business as his father – Insurance. At the time Martin Jones Hubble was the Missouri State Superintendent for the Farm Department of the Home Insurance Company of New York, and was extremely experienced in this line of work having been in practice in Saint Louis previously [6].

It seemed that every male member of the family was being forced to become first a lawyer and then an insurance agent. For by the time of Edwin P. Hubble's birth, his father, his grandfather and two of his three, uncles Levi Jones Hubble (1866-1931) and Joel William Hubble (1868-1933) were all Insurance Agents in nearby Springfield (home of the Simpsons?) [7]. The tradition in the law was started by Martin Jones Hubble who was the Clerk to the Greene County Court in Springfield at the start of the American Civil War [8].

His father's third brother, Marshall Washington Hubble (1862-1916) had escaped the fate of his three brothers by working firstly on a ranch in Highwood, Montana as a cook and then later as a miner in Webb City, Missouri, which at the time was the world's largest area for the mining of lead and zinc [9]. It should be pointed out that these two places are about as far from insurance as you can get, Highwood, Montana is in one of the least densely populated areas of America with only 40 persons per square mile as of 2000; whilst in and around Webb City in the early 1900s there were over 700 mines, where men could escape from almost anything, there was no health insurance here, only the daily threat of cave ins and the hope of a quick end.

It was evident that the career of Edwin Powell Hubble had been mapped out even before he was born – first he must qualify as a lawyer and then go into Insurance. His two brothers Henry James Hubble (1885-1961) and William Martin Hubble (1892-1941), also insured their escape and went into careers as a Broker (Insurance?); and the Manager of a Creamery respectively [10]. Of his five sisters, four survived into adult and managed to avoid insurance (well almost!), Lucy Lee Wasson (1887-1980), Helen Mary Hubble Lane (1898-1991), Emma Jane Francis (1902-?) and Elizabeth (Betsy) Hubble (1905-2002) [11]. The fifth sister Virginia (1894-1896) died when she was just two years old [12].

It was into this predetermined policy that Edwin Powell Hubble was born. Fortunately, despite the loss of a few more insurance policies, the understanding of the universe came first when Edwin Hubble decided on his chosen career.

History often reports the '*truth*' from the viewpoint of the victorious and the revered, and in doing so has like gravity the power to bend space and time. Such has been the case with Edwin Powell Hubble. Although nothing can take away his great achievements; much of what he did and reported to have done, was in fact the work of others. Galactic '*redshifts*' were not discovered by Hubble but by Vesto Slipher. Similarly, Hubble's Law was formulated together with Humason. A fact acknowledged by Powell himself.

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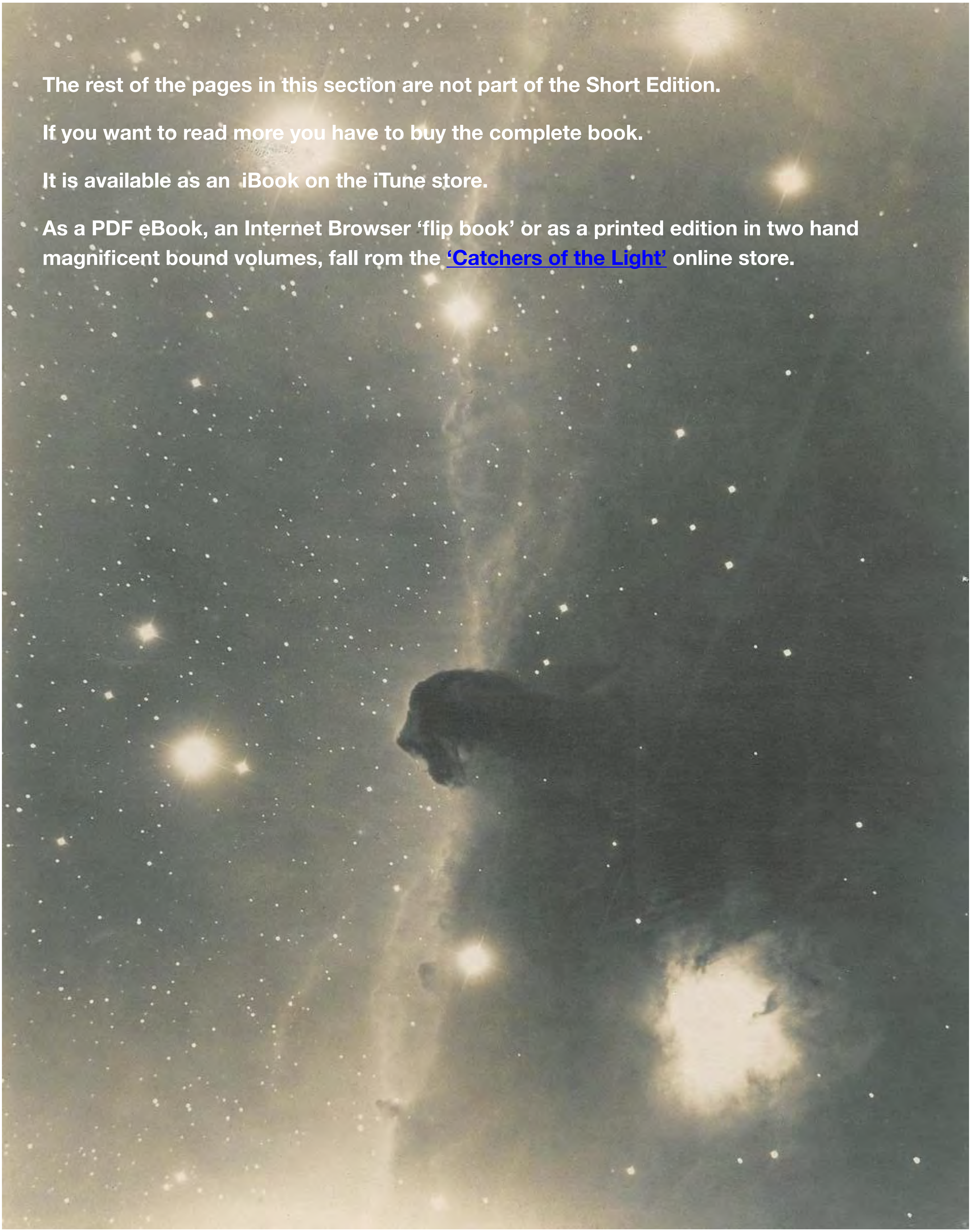
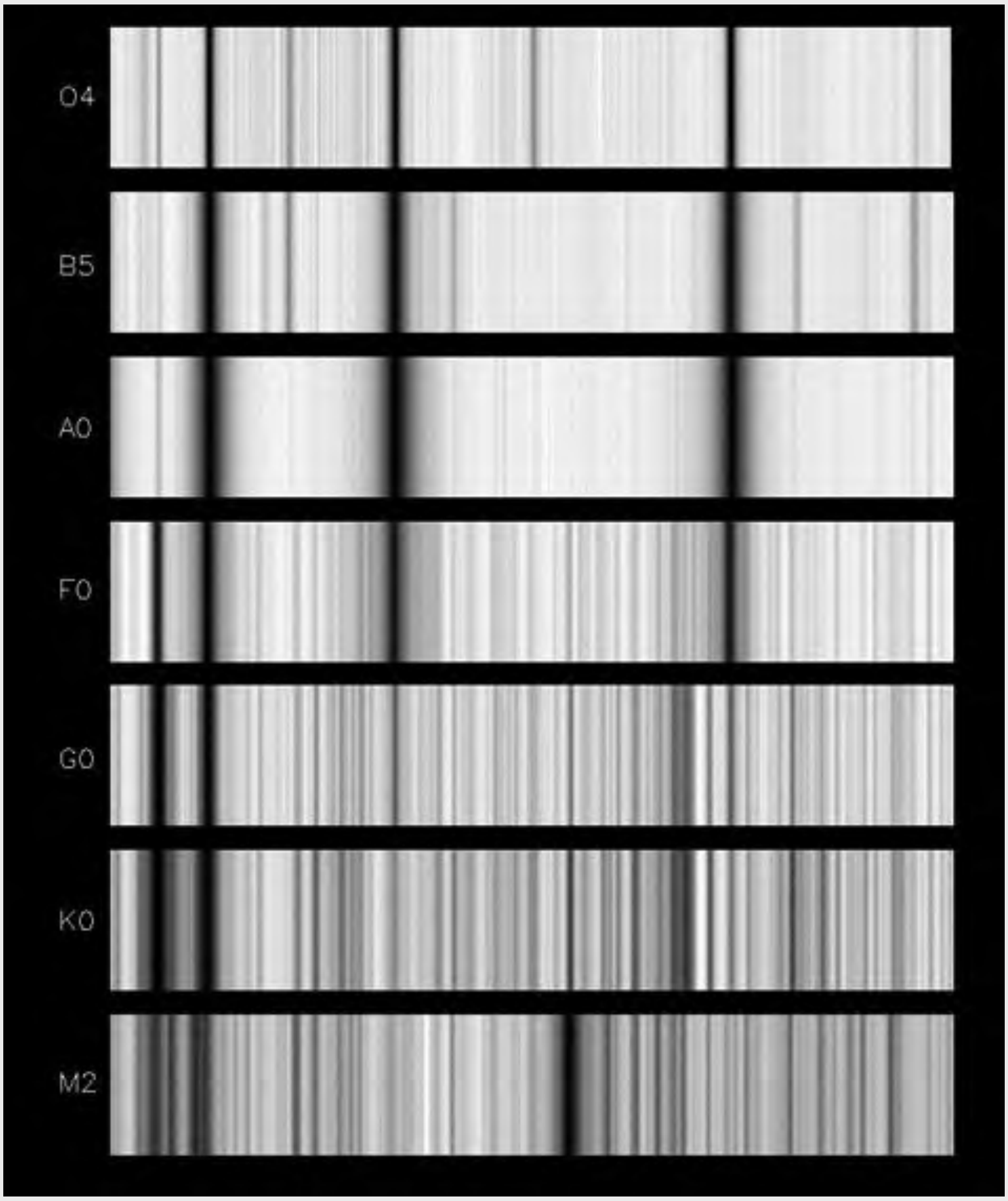


VI.7

‘Rainbows of Heaven’

Imaging Astronomical Spectra



Harvard Spectral Classification of Stars

Capturing the spectra of celestial bodies is the single most important use of Photography in Astronomical Research. It proved to be an invaluable tool for the study of the composition and origins of stars, nebulae and galaxies. More important still it was used to measure Extra-Galactic ‘*redshifts*’; and was therefore able to put a ‘*yardstick*’ on the size of our Universe.

VI.7.1 'Catching the Rainbow'

'One important object of this original spectroscopic investigation of the light of the stars and other celestial bodies, namely to discover whether the same chemical elements as those of our earth are present throughout the universe, was most satisfactorily settled in the affirmative; a common chemistry, it was shown, exists throughout the universe.'
William Huggins

A rainbow is one of the most beautiful of all nature's sights. It also gave man one of his first clues in the long road to understanding the complex structure of the Universe. A rainbow is an example of a continuous spectrum – i.e. one that shows light at all wavelengths, both visible and invisible. Such a spectrum is typified by the seven colours of the rainbow – Red, Orange, Yellow, Green, Blue, Indigo and Violet, first described in 1671 by Sir Isaac Newton. These seven colours only represent the visible portion of the continuous spectrum.

In 1800, the German-English astronomer Sir William Herschel (1738-1822) first showed that the continuous spectrum was composed of 'light' which invisible – when he detected the rise in temperature of a thermometer beyond the red part of the spectrum – the infrared. This was followed in 1801, with the discovery of the ultraviolet part of the spectrum by the German physicist Johann Wilhelm Ritter (1776-1810). We now know that sunlight has a continuous spectrum; made of an electromagnetic radiation of all wavelengths from those of the longest – radio, through microwaves, the near infrared, visible, ultraviolet, x-rays and to the shortest – gamma rays. All hot '*blackbodies*' such as the Sun produce a continuous spectrum.

A second type of spectra is to be found in the Universe – discrete spectra, i.e. ones that produce energy at only certain wavelengths. Discrete spectra in turn are classified further into two distinct types - emission line spectra, consisting of one or more bright lines; and absorption line spectra made up of dark lines in an otherwise continuous spectrum.

It is these types of Spectra – continuous and discrete which provide the fundamental clues as to structure of our Universe. Continuous spectra are indicative of Stars and Star Systems like our own Milky Way; whilst the Discrete Spectra are indicative of Gaseous Nebulae. It was only with the introduction of the science of Astronomical Spectroscopy in the early years of the nineteenth century, that man had his first glimpse into the true nature of the Universe in which he lived.

The use of Photography to capture the spectra of stars and nebulae from the 1870s onwards by the likes of Henry Draper (1837-1882), William Huggins (1824-1910), Hermann Carl Vogel (1841-1907) and Julius Scheiner (1858-1913), enabled a permanent and measurable record to be obtained, from which their composition in terms of the fundamental chemical elements of nature, such as Hydrogen, Oxygen and Nitrogen was determined.

The discovery of displacements in the position of the absorption lines in the spectra of stars and nebulae caused by the '*Doppler Effect*', provided astronomers with values for their radial motions in space. During the 1920s Edwin Hubble and his assistant Milton Humason measured the redshifts in the photographic spectra of Galaxies to determine their radial velocities. From these measurements they found that they were in fact receding away from us at very high speeds; such that the further away they were the faster they were travelling. This settled a long running argument as to whether these star systems were part of our own Milky Way or situated outside of its boundaries. Hubble and Humason showed conclusively that they lay millions of light years beyond our Galaxy.

VI.7.2 Wollaston's Forgotten Lines

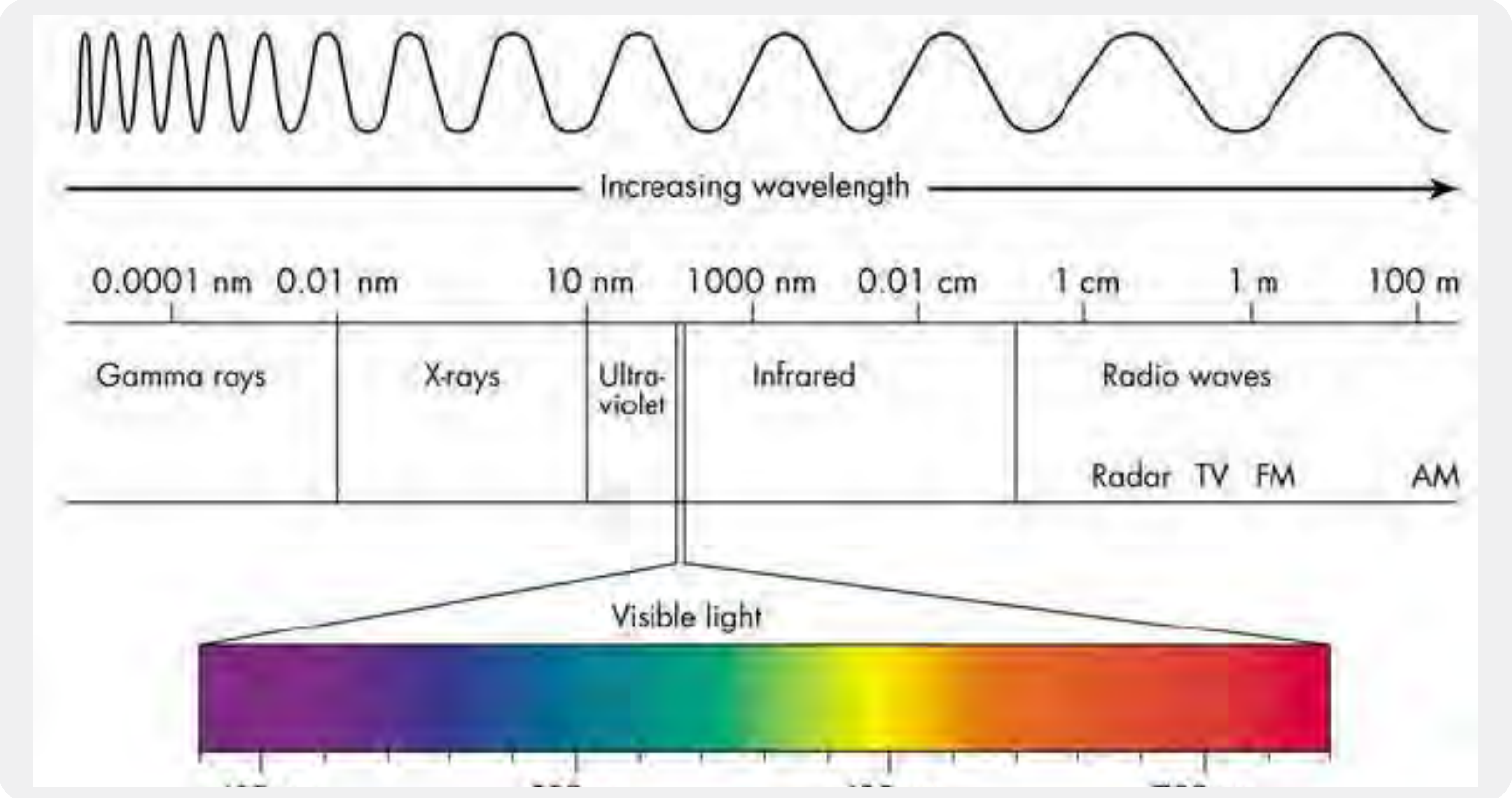
In 1802 the chemist and mineralogist William Hyde Wollaston (1766-1828) [1] was the first person to observe the dark lines in the solar spectrum, now known as absorption lines [2]. These he incorrectly interpreted as gaps separating the colours of the sun's continuous spectrum.

Then, in 1814 the German optician, Joseph Von Fraunhofer (1787-1826) [3] while working at a military and surveying instruments firm rediscovered the lines, when he was calibrating the optical properties of glass. He immediately discounted Wollaston's colour boundary interpretation. He observed a continuous colour change across the whole spectrum and saw no colour discontinuities at the dark absorption lines.

He later discovered dark lines in the spectra of stars and noted that some of the lines in stars were absent in the sun and vice versa. This clearly indicated that not all of the lines were of terrestrial origin. To his credit he did not '*spoil*' his findings with false interpretations and confined himself to highly accurate empirical observations. Herschel considered that the Fraunhofer lines could either be caused by absorption in a cool gas in the earth's or in the sun's atmosphere. In 1817, Fraunhofer published his findings on the dark lines in the spectra of the sun, planets and stars [4],[5]:

"The spectra of the light of Mars and Venus contain the same fixed lines as the sunlight, and these lie in exactly the same position, — at least the D, E, b and F lines do, whose relative position could be accurately determined. I was unable to perceive any lines in the orange and yellow of the spectrum of the light of Sirius, but a very strong band could be recognized in the green, as well as two other strong bands in the blue which appeared to have no resemblance to any of the lines in the spectra of the planets. We determined their positions with the micrometer. Castor gives a spectrum similar to that of Sirius, and in spite of the faintness of the light I was able to measure the line in the green and found it to be in precisely the same position as for Sirius. The bands in the blue could be recognized, but were too faint to permit a determination of their position. In the spectrum of Pollux I saw numerous but faint lines, resembling those of Venus. I saw the D line very well, and it occupied precisely the same position as in the spectrum of the planets. Capella gives a spectrum showing the same lines at D and b as the sunlight. The spectrum of Betelgeuse contains numerous fixed lines which seemed distinct when the air was steady. Although the spectrum does not at the first glance seem to have any similarity with that of Venus, yet there occur in it lines at exactly the same places with the D and b lines of the solar spectrum. A few lines could be recognized with difficulty in the spectrum of Procyon, but they were not distinct enough so that their position could be determined with certainty. I think I could see a line in the orange near the place of D."

In 1836, Sir David Brewster (1781-1868) found that certain lines had strengths that varied with the sun's elevation and with the seasons [6]. He correctly ascribed these '*atmospheric lines*' as originating in the terrestrial atmosphere. Remarkably, he failed to take into account Fraunhofer's observational evidence as described by him for the solar origin of many of these absorption lines. Later, in 1859 the solar origin of most of the Fraunhofer lines was established by the work of Robert Bunsen (1811-1899) and Gustav Kirchhoff (1824-1887). In 1860 Sir David Brewster and John Hall Gladstone (1827-1902) had demonstrated the existence of '*atmospheric bands*' in the solar spectrum which originated in the Earth's atmosphere [7]. The work of Pierre Jules Cesar Janssen (1824-1907) on the so called '*Telluric* Lines' established beyond all doubt in 1866 that most of these absorption lines are produced by water vapour in the Earth's atmosphere [8].

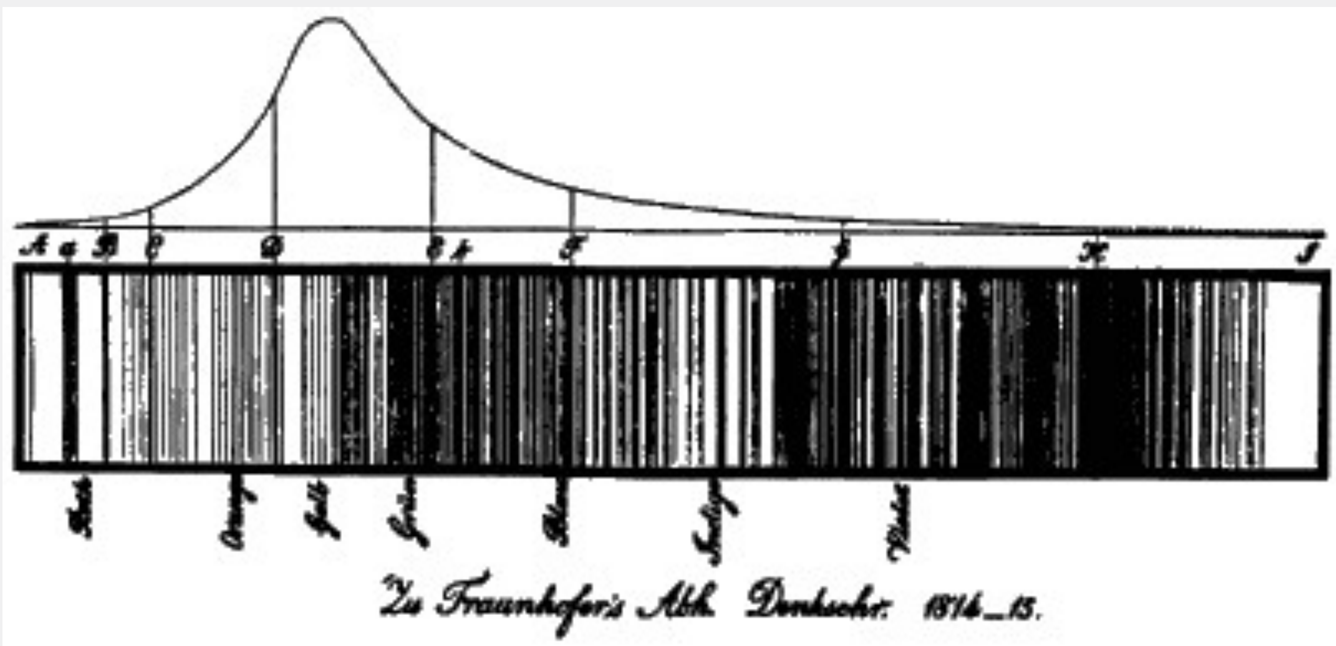


Electromagnetic Spectrum

William Hyde Wollaston (1766-1828) was in 1802 the first to see the dark lines in the solar spectrum which are now known as Fraunhofer Lines. He unfortunately interpreted them incorrectly as being just gaps separating the colours of the '*rainbow*'. He is chiefly remembered today for the discovery of two chemical elements and the denial of the existence of a third. Wollaston became wealthy by developing the first method for processing platinum ore in practical quantities, and in the process of testing the method he discovered the elements palladium (symbol Pd) in 1803 and rhodium (symbol Rh) in 1803.

In 1802, Anders Gustav Ekeberg discovered Tantalum, however, Wollaston declared it was identical with Niobium (then known as Columbium). As a result the existence of Columbium was temporarily denied. Later in 1846, Heinrich Rose proved hat Columbium and Tantalum were indeed different elements and he renamed Columbium, Niobium. Confused?

William Hyde Wollaston (1766-1828)



Fraunhofer's Lines in the Solar Spectrum, 1814-1815

In 1814 Joseph Von Fraunhofer (1787-1826) rediscovered '*Wollaston's Forgotten Lines'*, using an instrument known as a Spectroscope (left). This essentially simple device consisted of a prism on a rotating table, with a microscope through which the spectrum of the light source can be seen. By rotating the prism different parts of the spectrum can be seen. A scale of wavelengths is marked on the table, which can be read with the aid of a simple micrometer.

With this ingenious device Fraunhofer also observed the spectra of Mars and Venus and a number of the brightest stars. The design of the spectroscope remained largely unaltered for well over half a century.

Joseph von Fraunhofer's Spectroscope, c1814

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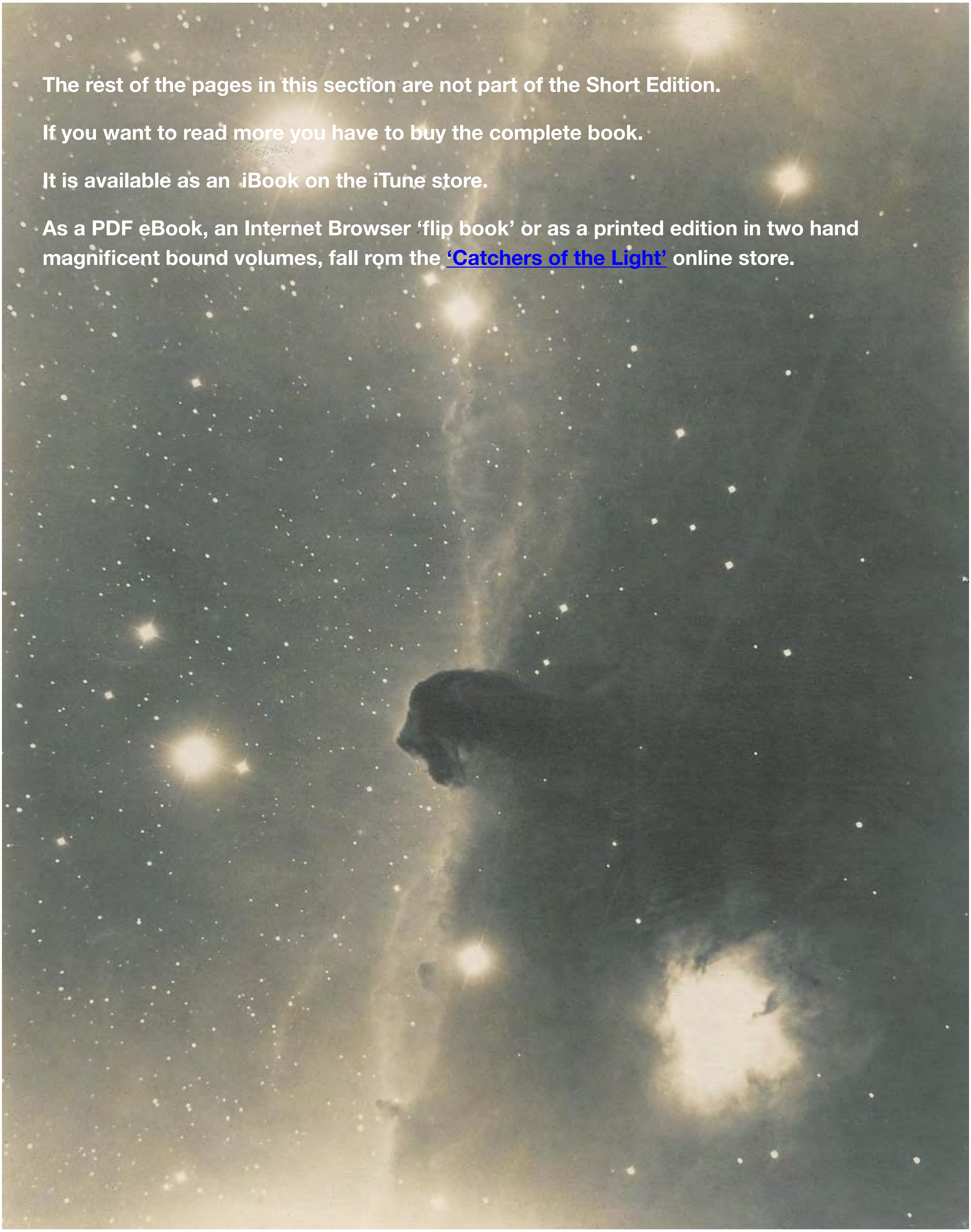
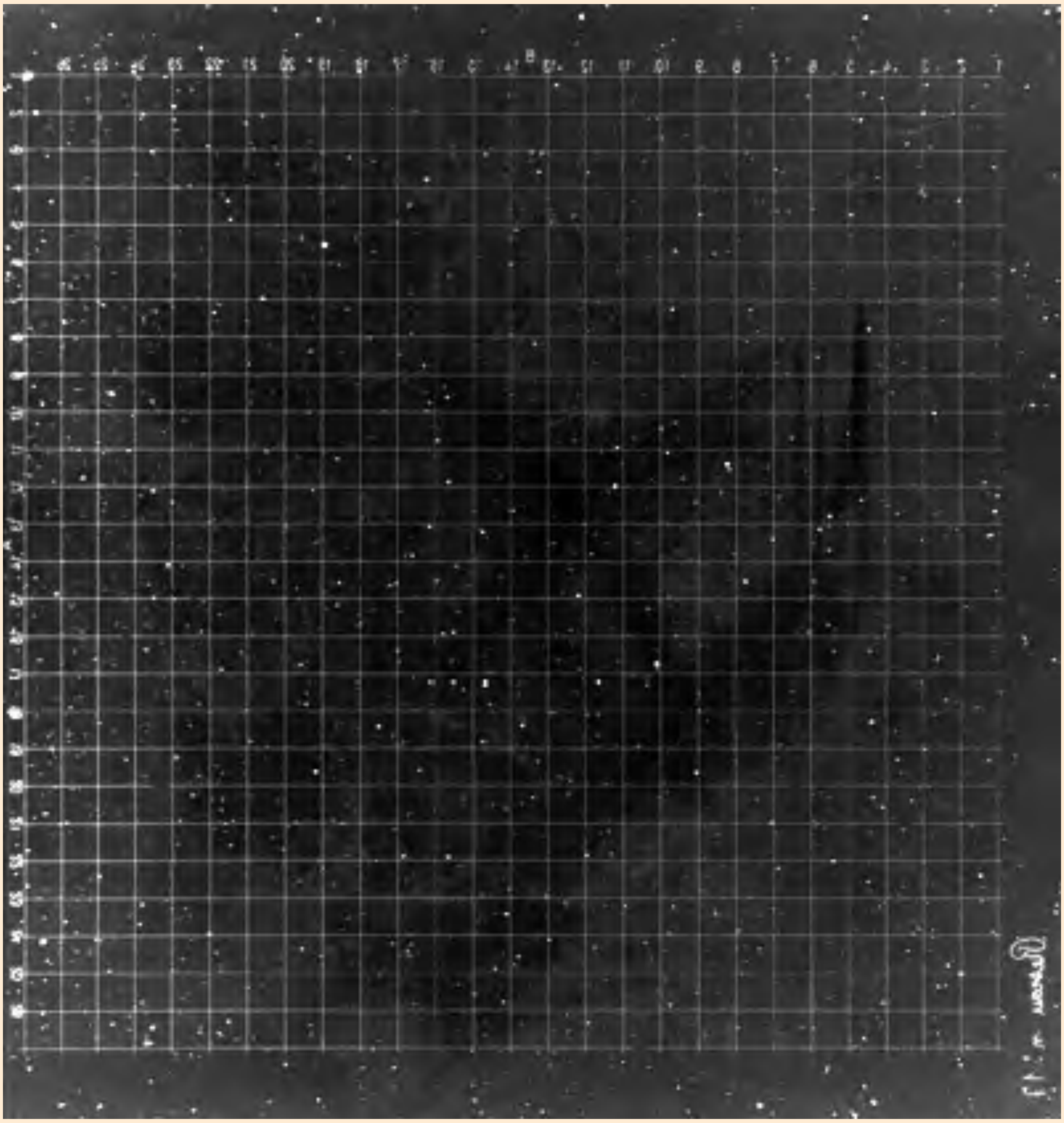


Part VII

Les Cartes du Ciel

Photographic Sky Surveys



***'Carte du Ciel'* Plate, Royal Greenwich Observatory**

" ...to catalogue the stars on each plate, to measure them for the purpose only of getting their places written down, would be the most utter waste of time, labour, and money that it could enter the mind of man to conceive." Andrew Ainslie Common (1841-1903) & Herbert Hall Turner (1861-1930)

VII. Photographic Sky Surveys

The story of the photographic mapping of the heavens is a woeful tale of failed attempts, over ambitious aims and misuse of valuable resources; and above all the wasted decades of effort on a project that was years ahead of its time and as a consequence lacked the necessary technology to succeed. In the end all became well with the introduction of the modern digital computer, searchable databases, mass storage devices and astrometric satellites.

It was not long after the first photographs of stars were obtained in the 1850s that astronomers such as George Phillips Bond and Lewis Morris Rutherfurd began thinking about mapping the stars with the aid of a camera. The operative word here is ‘thinking’. At that time the currently preferred wet collodion process could only obtain impressions of stars down to magnitude nine at best.

It was only following the introduction of mass produced Gelatino-Bromide ‘*Dry*’ photographic plates in the late 1870s and early 1880s, which were capable of obtaining well defined images of stars as faint as the 15th magnitude that the technology had matured sufficiently enough for an adventurous pioneer to be able to make such an attempt.

During the period May to December 1885, the English amateur Isaac Roberts (1829-1904) had taken a number of images with his 20-inch Reflector of regions of the sky 2 x 1.5 degrees in area. His aim was to complete a photograph sky chart of that part of the heavens visible from his observing location, near Liverpool, England. He shortly afterwards abandoned what soon became clear a task that was best left to professional observatories with their far greater resources.

The history of Photographic Sky Charts began well with the successful completion of the Cape Photographic Durchmusterung, a joint project between the Cape of Good Hope Observatory, South Africa and the University of Groningen. It was published between 1896 and 1900 and listed the positions and magnitudes for 454,875 stars down to about magnitude 10.2 in the Southern Hemisphere for Declinations from -18S to -90S.

In the April of 1887 a congress was held in Paris at the instigation of Ernest Amédée Barthélémy Mouchez (1821-1892), Director of the Paris Observatory with a view to encourage the cooperation of overseas observatories in the production of a photographic chart of the entire sky - a ‘*Carte du Ciel*’ (CDC). It was attended by 58 astronomers representing observatories and institutions from 19 countries.

At the end of the Congress the delegates agreed in principle to photograph, catalogue and map the positions of millions of stars as faint as the 11th magnitude and ultimately to extend this to those of the 14th magnitude. It was a project doomed to fail from the very outset. Sadly, despite the best will in the world and lots of promises the work was dogged by delays and problems. The zones allocated to several observatories had to be given to others, as they had failed to even begin the work or were not able carry on because of political unrest or war.

In 1900 the zones originally assigned to La Plata Observatory, Argentina were given to Cordoba, Argentina; whilst the zones originally assigned to the Rio de Janeiro Observatory, Brazil were given to Perth, Australia. In 1909, Hyderabad, India was assigned part of the zones originally to be done by Santiago Observatory, Chile; and in 1920 it was assigned the remainder of those originally given to Santiago.

Following the end of the First World War the Potsdam observatory announced it could not continue with the project. Its zones were reassigned to Uccle, Belgium, Hyderabad and Oxford. An allied bomb in the Second World War destroyed virtually all of the 1226 plates taken at Potsdam. Only 406 plates were ever measured.

The project was a complete and utter shambles. In 1970 at the International Astronomical Union's 14th General Assembly held in Brighton, England, it was finally acknowledged that after an interval of more than eighty years after its inception, the *Carte du Ciel* enterprise remained unachieved.

The Astrographic Catalogue part of the '*Carte du Ciel*' project, containing stellar positions and magnitude down to the eleventh, were published between 1902 to 1964, and resulted in 254 printed volumes of printed data. The more ambitious Carte du Ciel Charts for stars down to magnitude 14, were never completed and only one Observatory, Greenwich ever published them.

On the 11th November 1949 whilst the '*Carte du Ciel'* was struggling along in its final death throes, the technology which it so badly needed began to appear. On a mountain in San Diego County, California, 5570 feet (1700 metres) high, a telescope undreamed of in Ernest Mouchez's day opened its '*eyes*' to the night sky. It was about to expose the first plate in the modern era of photographic sky surveys.

A year previously, the 48-inch Schmidt Telescope (now known as the Samuel Oschin Telescope) at the Mount Palomar Observatory was completed after nearly ten years in the making. It was not really a telescope at all, but a camera, for it was built from the outset with no provision for an eyepiece.

It was at the time the ultimate Astrograph. The Schmidt optical design enabled photographs to be taken of the sky which were completely '*flat*' with no distortion of the star images at the edges; which meant the whole of the plate could be used and not just the inner part as was the case with the CDC plates.

The Samuel Oschin telescope was put almost immediately to good use in 1949, when it began work on the National Geographic Society sponsored – Palomar Observatory Sky Survey (NGS-POSS I). It was completed in 1958, less than ten years after it began – a feat which was meant to be achieved by the CDC.

Not satisfied with this great success, a Second Palomar Observatory Sky Survey (POSS-II) was performed in the 1980s and 1990s that made use of better, '*faster*' dry plate technology and an upgraded telescope.

In 1994 a digital photographic atlas of the entire sky in both hemispheres was completed, known as DSS I. For the northern sky, the Palomar Observatory Sky Surveys provided almost all of the source data. For the southern sky, images taken by the UK Schmidt Telescope at Anglo-Australian Observatory, were used. The publication of a digital version of these photographic collections has subsequently become known as the First Generation DSS.

In 1996, a more highly compressed version of the DSS was published by the Astronomical Society of the Pacific under the name '*RealSky*'. RealSky is searchable and includes software, which can be used to display any part of the sky up to one degree square, or find Deep Sky Objects (DSOs) which are included in the New General Catalogue (NGC).

Ten years later in 2006, the Second Generation DSS II was finished, and distributed on CDROM to partner institutions. Generally, the data are available through the websites of the partner institutions.

The vast amount of effort invested in the '*Carte du Ciel'* project looked for many years to have been a total and utter waste of time, only serving to keep busy those tasked with cleaning the dust that gathered on the tons of printed tomes it produced. But all is now forgiven, because this near century old star positional data has found itself to be of use, somewhat ironically in today's world of satellites and digital computers - the very technology it lacked to succeed.

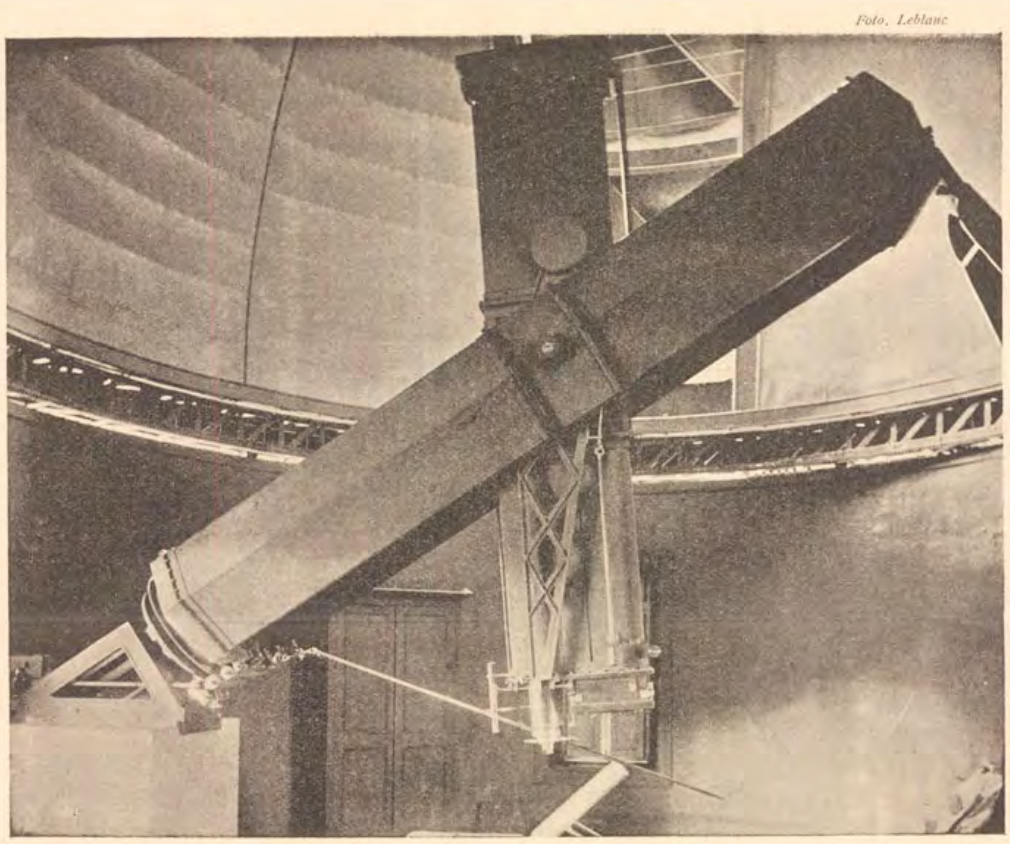
The European Space Agency's (ESA) *Hipparcos* space astrometry satellite launched in 1989 was tasked with the job of creating a '*Carte du Ciel*' for the twenty-first century. As part of the mission it was found possible to combine old data from the '*Carte du Ciel'* project with Hipparcos measurements to enable highly accurate proper motions to be derived for some 2.5 million stars.

In 2013 ESA plans to launch HIPPARCOS's successor, *GAIA* – Global Astrometric Interferometer for Astrophysics. It derives its name from the Greek Goddess of Nature Gaia. Its capabilities go way beyond what HIPPARCOS achieved.

"It will often happen that when a picture is taken of a portion of the heavens with which the worker is unfamiliar, identification of the principal stars on the plate is exceedingly difficult. Photographic and visual magnitudes differ very considerably; the scale, too, is smaller than a naked-eye view, and 20 minutes exposure on the crowded portions of the Milky Way on a good night will secure thousands of star images, the result of which is often absolutely bewildering.

A reversed image..is also confusing when comparing with an atlas, or portrait lens photographs. A good plan is to put a mark on the edge of the plate which, when in position, will be at the top side of the camera. Then with a good star atlas...the principal stars can soon be identified from the central star on which the telescope was guided. Some practice may be needed, but generally, after a little concentration, the whole group or constellation seems to jump into view, and the proper S. and N. points can be marked on the edge of the plate."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.



'Carte du Ciel Astrograph, Santiago Observatory, Chile

Short Edition

VII.1

'The Visionary Man'

Ernest Amédée Barthélémy Mouchez

Born: 24th August 1821, Madrid, Spain

Died: 29th June 1892, Wissous, Seine et Oise, France

Rear Admiral Ernest Amédée Barthélémy Mouchez was a man of vision who recognized the role of photography as an important tool to chart the heavens. To this end he instigated the ill fated and over ambitious Carte du Ciel project. His faith in the Carte du Ciel was ultimately rewarded when data from the project was successfully used in conjunction with that obtained from the HIPPARCOS Astrometric Satellite.

VII.1.1 Ahead of His Time

"Gentlemen: In the name of the Paris Observatory I also welcome the eminent men of science who have graciously accepted our invitation to this international congress, where will be decided the execution of a work of the first importance for the future of astronomy.

I tender my profound thanks for the cordial readiness with which you consented to come at our call, which proves the great interest you all feel in this new branch of science, astronomical photography, which, by your recent labours, has made such admirable and rapid progress.

It has now become a wonderful and potent auxiliary, the great value of which one could not overestimate. By its aid —since a document can be secured in an hour's time for which a year's work would have been required by the old methods— the slow and laborious processes of astronomical observations will be changed. There will, perhaps, be some weak resistance, some obscure regret, as is inevitably produced by every great progress, but which will soon vanish before the brilliant light of success, as a half-century ago the old stage-coaches disappeared before the triumph of the locomotive.

It is, therefore, a great honour for our old national observatory, in the course of the progresses it also has realized, to receive the first assembly, where this (for astronomical science) new era is about to be inaugurated.

It will be a glorious and never-to-be-forgotten date in its history, as will be likewise memorable the grand work which we wish to leave as a legacy to future generations—a work which we might define as an inventory, as exact and as complete as possible, of the visible universe at the close of the nineteenth century.

E. MOUCHEZ,

Le Contre-Amiral, Directeur de l'Observatoire"

The above words were spoken by Ernest Amédée Barthélémy Mouchez (1821–1892) at the opening of the '*Congres Astrophotographique*' held in Paris from the 16th to the 25th of April 1887 [1].

His vision of a *Carte du Ciel* (literally - Map of the Sky) never came true in his lifetime. History has written a different ending to that predicted by Ernest Mouchez – one of problems, delays, acrimony, over ambition, failure and ultimate redemption.

Whatever is written of Ernest Mouchez concerning the *Carte du Ciel*, nobody can deny that he was a Visionary; who tried to do something that at the time was impossible from the outset, but which today is taken for granted – a Complete Photographic Chart of the Heavens.

VII.1.2 Navy

Ernest Amédée Barthélémy Mouchez's [2] was born in Madrid, Spain on 24th August 1821 the eldest of the three children of Jacques Barthélémy Mouchez (c1783-c1849), and his wife Louise Cecile Bazin (1798-1868) [3]. He was educated at the Lycée St. Louis in Paris and then at Versailles. At the age of sixteen he entered the Naval School at Brest to train as a Naval Officer. He was gazetted a Midshipman in 1839, became an Ensign in 1843 [4], promoted to Lieutenant six years later and made a full Captain in 1861. He remained a seaman all his life and distinguished himself many times in a vocation he was born to.

At this time in France's history the country was in a state of relative peace with the world. As there were no wars to fight the work of Mouchez was largely confined to research and exploration. His first major task as a career Naval Officer was to conduct hydrographic surveys in Korea, China and South America. He spent the years from 1856 to 1861 surveying the coast of Paraguay and Brazil; and similar length of time surveying the Algerian coastline [5], [6], [7], [8]. In all he produced nearly 150 maps. His maps of Algeria came in very useful some seventy years later during the Second World War, when they were the only maps of the country available to allied troops in their struggle against the Axes forces of Italy and Germany.

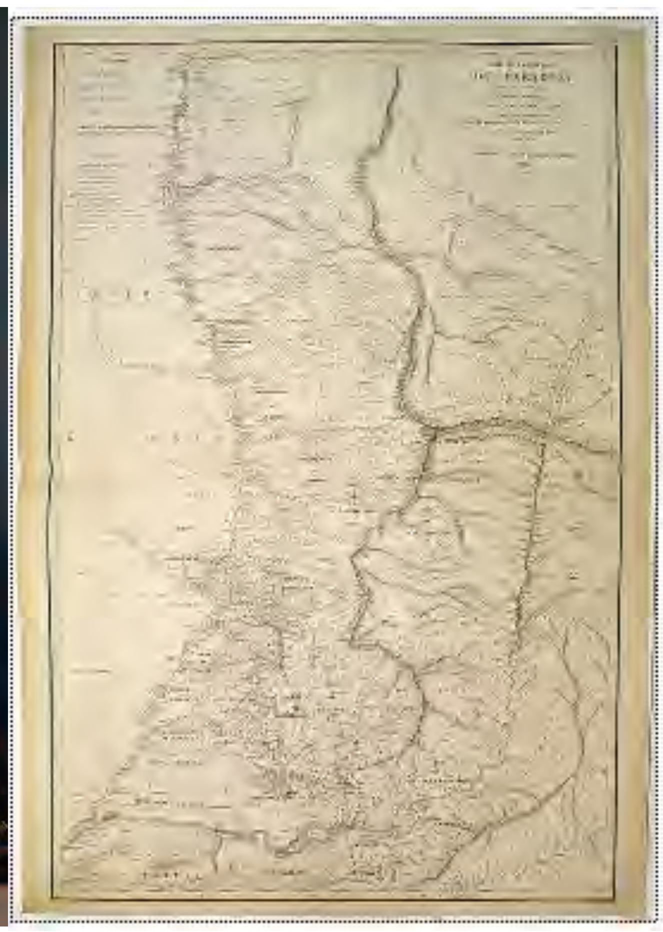
Early on in life, Ernest Mouchez gained a passion for surveying and measurement, particularly with regard to the accurate determination of longitude at sea. He made improvements to the theodolite and meridian telescope adapting them for use at sea, which resulted in the reduction in errors in longitude from 30 arc seconds down to 3 arc seconds, a remarkable order of magnitude improvement.

In 1868 after attaining the rank of post-captain he embarked on a survey of the Algerian Coast. This work was interrupted in 1870 by the Franco-Prussian war during which Mouchez was called upon to take part in a heroic defence of the port of Le Havre. After the end of the war he returned to complete the surveying work in Algeria, which came to a successful end in 1873.

Ernest Mouchez's father, Jacques Barthélémy Mouchez was wig maker and perfumer to King Ferdinand VII of Spain and in this capacity he spent a number of years living at the Royal Court in Madrid.

It was here that he that he married his second wife, Louise Cecile Bazin on the 17th of October 1820. His first wife, Sophie Transom (c1769-1819) had died the year before his marriage to Ernest Mouchez's mother.

Jacques Barthélémy Mouchez and his wife Louise Cecile Bazin



King Ferdinand VII of Spain was ruler of his country on two occasions. His first reign was short and only lasted a few months from the 19th of March to the 6th of May of 1808, following his father's abdication in favour of the Emperor Napoleon.

He regained his throne on the 11th of December 1813 and ruled until his death on the 29th of September 1833. Some historians argue that he was not the son of King Charles IV, Manuel Godoy, the Prime Minister and Queen's lover, his mother, Maria Luisa of Parma.

King Ferdinand VII of Spain (1784-1833); Mouchez Map of Paraguay, 1862

As a Genealogical aside, Ernest Mouchez's step sister, Thérèse Sophie Madeleine Mouchez (1814-1879), the daughter of Jacques Barthélémy Mouchez by his first wife, Sophie Transom (c1796-1819), married André Pascal Filat (c1806-c1846)), and their third daughter Maria Carlota Fernande Filat (c1843-c1931), later married Ernest Mouchez in about 1862. So in fact Ernest Mouchez's wife was in reality his half-niece.

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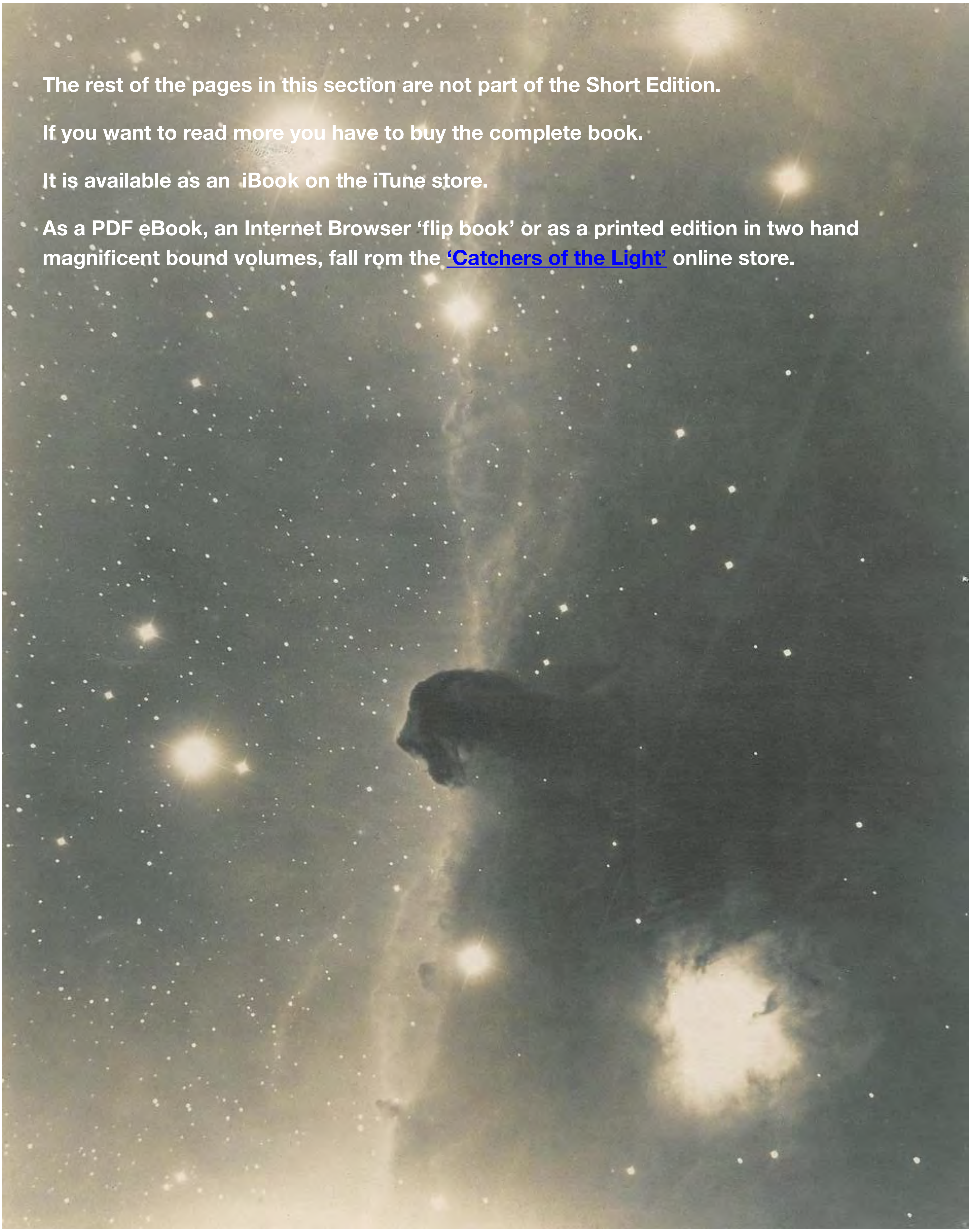


VII.2

‘The Surveyor’

Sir David Gill

Born: 12th June 1843, Aberdeen, Scotland

Died: 24th January 1914, Kensington, London, England

Sir David Gill was one of the great astronomers of the late nineteenth century, and was universally recognized as such. He made significant contributions to many areas of astronomy, including the measurement of the sun’s distance and the completion of a successful photographic survey of stars in the southern hemisphere, known as the Cape Photographic Durchmusterung or CPD, which listed the positions and magnitudes for 454,875 stars down to about magnitude 10.2 in the Southern Hemisphere.

VII.2.1 Surveyor

David Gill was a surveyor not of buildings or land but of the heavens.

Although originally destined to become a clock maker like his father, fate chose otherwise. Ironically it was through clocks that David Gill became interested in Astronomy, a hobby which would eventually lead to a career that lasted fifty years, during which time he was to become one of the great astronomers of his age.

All throughout his astronomical career David Gill was involved in measuring and surveying.

At first it was a desire to set up an accurate time service for his native city of Aberdeen. Then he began to make plans to measure the distance of nearby stars. This was followed shortly by an expedition to Ascension Island to determine the distance of the planet Mars and by implication the distance of the Sun from the Earth.

However it was his great photographic survey of the stars in the southern hemisphere – the '*Cape Photographic Durchmusterung*' that became his greatest legacy to Astrophotography and Astronomy in general [1].

VII.2.2 Aberdeen

David Gill was born on the 12th June 1843 at No. 48 Skene Terrace, Aberdeen, Scotland; the first of five surviving children born to David Gill (1789-1878), a clock maker and his wife Margaret Mitchell (1809-1870) [2], [3].

His father, David Gill, ran the clock and watch making business at No. 13 Queen Street, Aberdeen, and later at No. 78 Union Street; which his father Peter Gill had set up some sixty or so years earlier [4]. Under David Gill's father, the business became more of a wholesale clock dealer, rather than a maker of clocks and watches; where David Gill (senior) acted as his own travelling salesman.

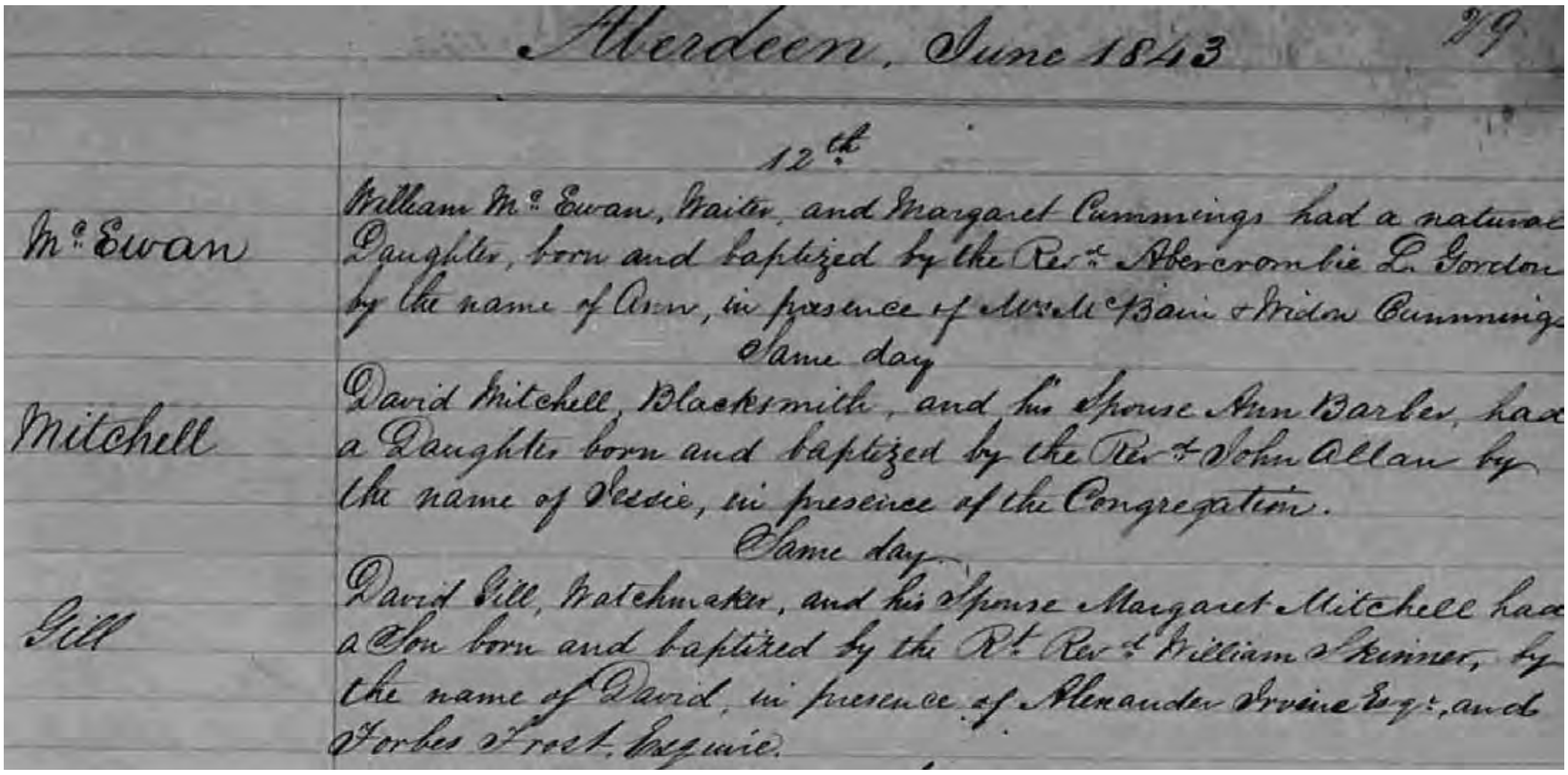
David Gill, junior began his education at the Bellevue Academy, in Aberdeen. As a young student he did not exhibit any specific talent or precocity, which would indicate someone destined to do great things. Although he was particularly proud of a card bearing the following words, awarded when he was twelve years old: *"Certificate of Superior Proficiency in Elocution, awarded by Competition to Master David Gill—" Emeritus "and Prizeman of a former session." Bellevue Academy, Sept. 25th, 1855.* This was one of the few souvenirs of his childhood that David Gill kept.

In 1857 at the age of fourteen he was sent to the Dollar Academy in Clackmannanshire to complete his secondary education [5]. It was here that David Gill was first introduced to Science. Whilst at the Dollar Academy, he boarded with one of its teachers, Dr. James Lindsay (c1823-), a man interested in those things David Gill would in later life find most useful – mathematics, physics and chemistry [6]. In 1909 David Gill returned to the Dollar Academy after an absence of more than fifty years to present the prizes at the school's open day. After speaking of his experiences at the school he said [7]:

"The Chairman had told them that he had been a very successful man, but he wanted to tell them that if he had been in some small degree successful, the man that put that capacity into him was a Dollar man, the late Dr. Lindsay."

In 1858 David Gill enrolled as a private student at Marischal College, Aberdeen. Two years later in 1860, it amalgamated with Kings College, Aberdeen to form the University of Aberdeen. The term private student referred to those who wished to attend lectures but who chose not to sit for a degree. Whilst at Marischal he attended the lectures in Natural Philosophy (Physics) given by the great James Clerk Maxwell [8]. He was to say later in life that it was James Clerk Maxwell's '*teachings which influenced the whole of my future life*'. James Clerk Maxwell also held David Gill in high regard and wrote the following testimonial on his former student, sometime around 1868 [9]:

"Mr. David Gill was one of my ablest students in Marischal College, Aberdeen. He was even then devising methods for the experimental determination of physical quantities."


Aberdeen, June 1843 79

12th

McEwan — William McEwan, Waiter, and Margaret Cummings had a natural Daughter, born and baptized by the Revd. Abercrombie L. Gordon by the name of Ann, in presence of Mrs. McBain & Widow Cummings.

Same day

Mitchell — David Mitchell, Blacksmith, and his Spouse Ann Barber, had a Daughter born and baptized by the Revd. John Allan by the name of Deedie, in presence of the Congregation.

Same day

Gill — David Gill, Watchmaker, and his Spouse Margaret Mitchell had a Son born and baptized by the Rt. Revd. William Skinner, by the name of David, in presence of Alexander Irvine Esqr., and Forbes Frost Esquire.

Birth & Baptism of David Gill, 12th June 1843

David Gill was born on the 12th June 1843 at the family home at No. 48 Skene Terrace, Aberdeen. He was baptised that same day in Aberdeen by the Right Reverend William Skinner in the presence of Alexander Irvine Esq., and Forbes Frost Esq. For a number of years David's father operated his successful clock making business from No. 78 Union Street, which served as both workshop and home. The first floor was used for business and the upper storeys for the family's accommodation. David Gill's birthplace still survives to this day.

Birthplace of Sir David Gill – No. 48 Skene Terrace, Aberdeen

When David Gill was about fourteen he attended the Dollar Academy of which he wrote: *"... and came under the inspiring influence of Dr. Lindsay at whose house I boarded. His teaching filled me with the love of Mathematics, Physics and Chemistry."*

The school was originally known as '*The Dollar Institution';* and until the introduction of compulsory Scottish primary education in 1887, provided free education for local children who could not afford to pay. Those who could afford it, paid fees based on a '*sliding scale*".

The Dollar Academy in the Nineteenth Century

David Gill senior, the father of Sir David Gill, Her Majesty's Astronomer at the Cape of Good Hope Observatory was like his father Peter Gill (1757-1850) before him, a maker of high quality clocks and watches in Aberdeen, Scotland. He married Margaret Mitchell (1809-1870), a native of Foveran, Aberdeenshire on the 20th of November 1838 in Aberdeen. Together they had four sons and a daughter, of whom David Gill was the eldest. David Gill, senior, died on the 6th of April 1878 at Blairythan, Aberdeen and is buried along with his wife in the small cemetery in Foveran.

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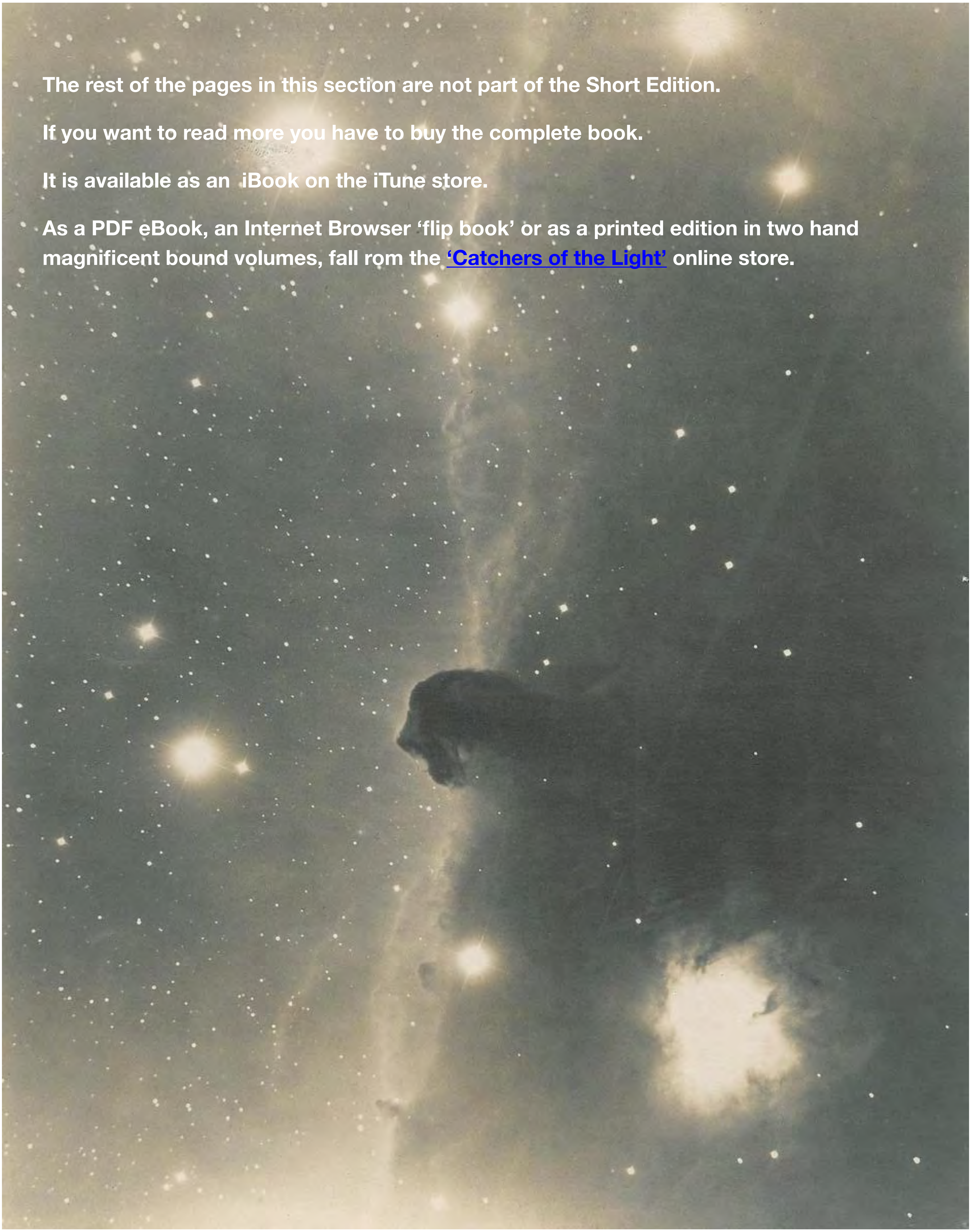
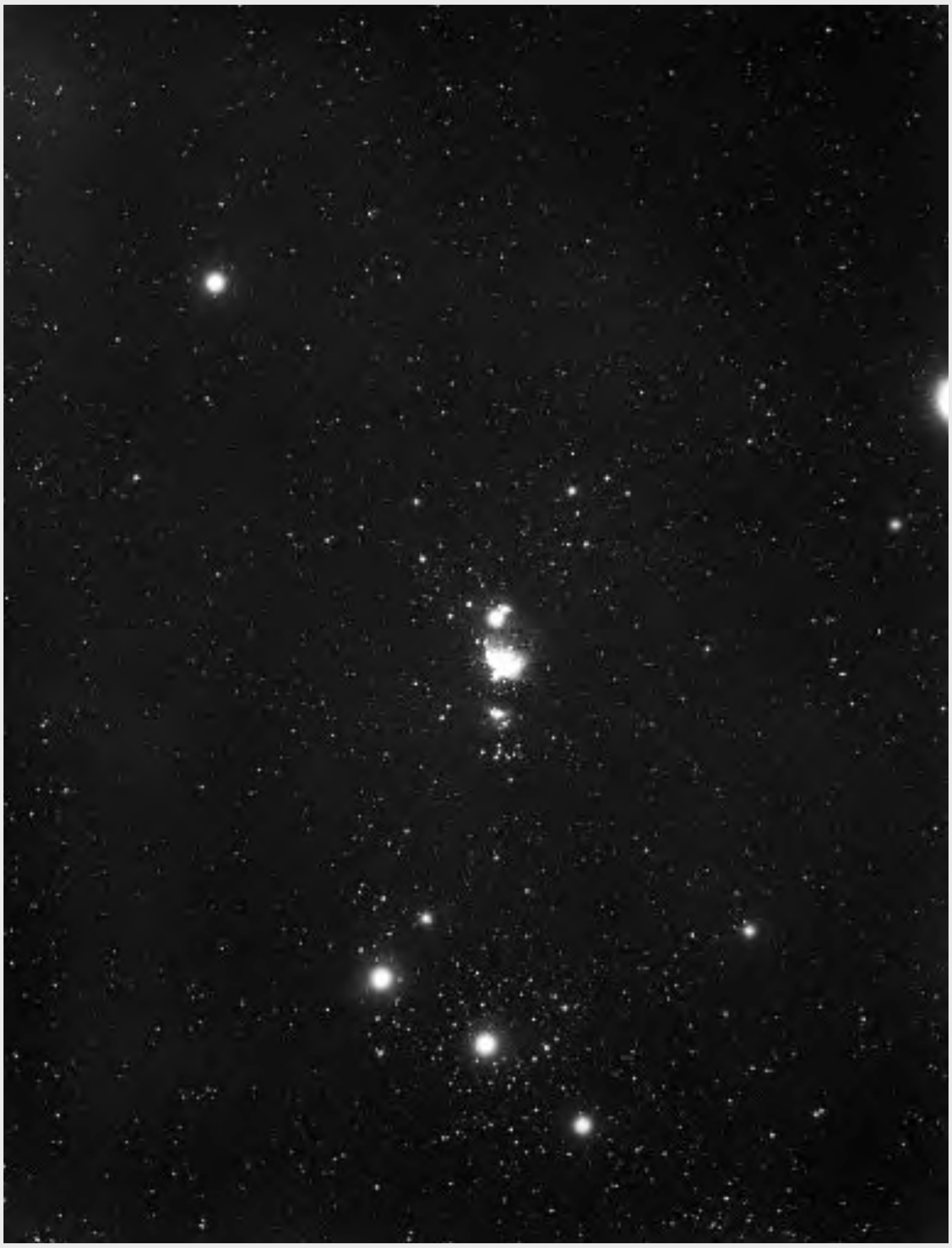


Short Edition

VII.3

'HIPPARCOS'

Mapping the Heavens



Part of the Constellation of Orion, Sydney Astrograph, 1890

Photographic Sky Surveys are a blessing to the modern astronomer, but this was not always so. The laudable but ultimately doomed '*Carte du Ciel'* project took years longer than planned and used up valuable observatory resources that many argued could have been better spent. However, it was to triumph in the end when its century old data was to provide valuable input into the HIPPARCOS Satellite Astrometry Project.

VII.3.1 Early Star Charts

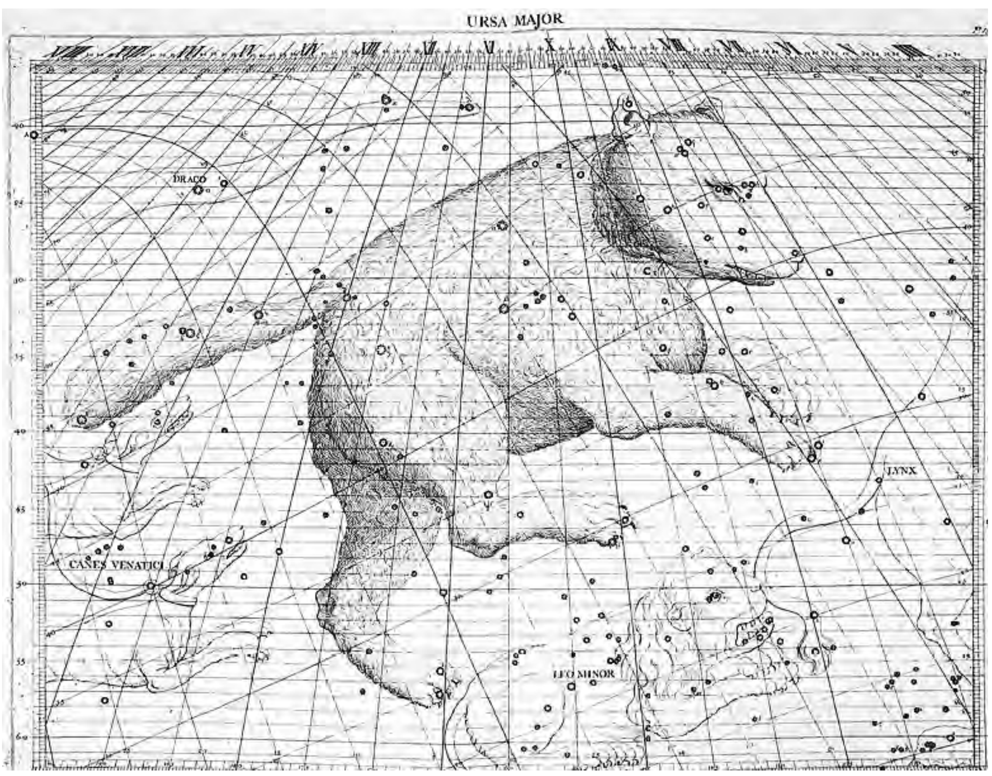
Although charts of the stars had been produced in antiquity [1], it was during the Golden Age of European celestial cartography that star charts as we know and understand them came into being. This was a period which spanned roughly the years 1600 to 1800 and was driven by technological advances in both astronomical observation and printing techniques.

In the course of these two hundred years, four major star atlases were produced; the ‘*Uranometria*’ of Johann Bayer (1603); the ‘*Firmamentum Sobiescianum sive Uranographia*’ of Johannes Hevelius (1690); John Flamsteed’s ‘*Atlas Coelestis*’ (1729); and the ‘*Uranographia*’ of Johann Elert Bode (1801). It was in the pages of these beautiful maps that the 88 constellations as we know them were first depicted in their entirety. During this period of stellar cartography, the Bayer and Flamsteed notations for the brightest of the stars were also introduced.

Such Atlases were works of art in which visual beauty coincided with astronomical content. It was only in the nineteenth century that accurate star catalogue were produced which plotted the positions and brightness of tens or hundreds of thousands of stars. The most famous of these was the Bonner Durchmusterung (Bonn Survey) or simply the BD.

The BD was produced by the three German astronomers, Friedrich Wilhelm August Argelander (1799-1875), Adalbert Krüger (1832-1896) and Eduard Schönfeld (1828-1891). This monumental work was published between the years 1852 and 1859; and which gave the positions and brightness of more than 324,000 stars, although it did not cover much of the southern half of the sky. The accompanying charts, published in 1863, were the most complete and accurate made until that time. This was the last star map to be published without the use of photography.

With the advent of Astrophotography in the 1840s, the production of star charts would never be the same – stellar cartography was entering a new era; and in the way subsequent events were to unfold, it would not be plain imaging, nor would their production be as easy as was envisaged by their creators.



John Flamsteed (1646-1719), the first Astronomer Royal of England, presided over the building of the Greenwich Observatory. His “*British Catalogue*” of stars, finally published in 1725, six years after death, brought stellar astronomy to a new level. His star atlas, published four years after the catalogue, but in development for over twenty years, was based on his new and more accurate observations. That fact, coupled with its impressive size (it was the largest that had ever been published), immediately vaulted Flamsteed into the select ranks of the Great Stellar Cartographers.

Ursa Major (‘Great Bear’) from Flamsteed’s ‘Atlas Coelestis’ of 1729

VII.3.2 Ideas & Attempts

It would not too be long after George Phillips Bond and John Adams Whipple took the first photograph of a star on the 17th July 1850, that the question arose as to whether photography could be used to create star charts; and thus replace the lengthy and tedious process of visual observations; where the positions of stars were measured as they cross the meridian as seen by an observer using a transit telescope.

Seven years later, G. P. Bond, was to write a letter to a friend in which he discussed likely advances in astronomical photography [2]:

"... Could another step in advance be taken equal to that gained since 1850, the consequences could not fail of being of incalculable importance in astronomy. The same object Alpha Lyrae, which in 1850 required 100 seconds to impart its image to the plate, and even then imperfectly, is now photographed instantaneously with a symmetrical disc fit for exact micrometer measurement. We then were confined to a dozen or two of the brightest stars whereas now we take all that are visible to the naked eye. Even from week to week we can distinguish decided progress. ... At present the chief object of attention must be to improve the sensitiveness of the plates, to which I am assured by high authorities in chemistry there is scarcely any limit to be put in point of theory. Suppose we are able finally to obtain pictures of seventh magnitude stars."

He then went onto discuss the effect of using telescopes at high altitude and increasing the size of the telescopes currently available [3]:

"...This would increase the brightness of the stellar images, say eightfold, and we should be able then to photograph all the stars to the tenth and eleventh magnitude inclusive. There is nothing then so extravagant in predicting a future application of photography to stellar astronomy on a most magnificent scale."

In 1864 Lewis Morris Rutherfurd succeeded in constructing the first telescope specifically designed for photographic use. It consisted of an 11.25-inch photographic objective fitted into the OTA of existing refractor. On the evening of the 6th of March 1865 Rutherfurd obtained with his new instrument the finest photograph ever obtained of the Moon. He reported his results in the American Journal of Science in May of that year [4]:

"Since the completion of the photographic objective but one night has occurred (March 6) with a fine atmosphere, and on that occasion the instrument was occupied with the moon, so that as yet I have not tested its powers upon the close double stars, 2″ being the nearest pair it has been tried upon. This distance is quite manageable provided the stars are of nearly equal magnitude. The power to obtain images of the ninth-magnitude stars with so moderate an aperture promises to develop and increase the application of photography to the mapping of the sidereal heavens and in some measure to realize the hopes which have so long been deferred and disappointed.

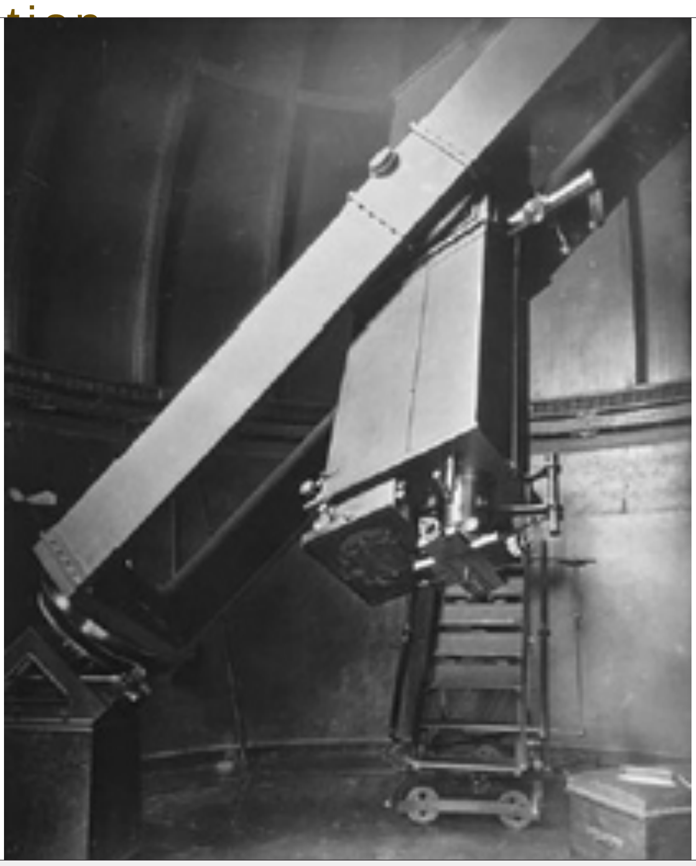
It would not be difficult to arrange a camera-box capable of exposing a surface sufficient to obtain a map of two degrees square, and with instruments of large aperture we may hope to reach much smaller stars than I have yet taken. There is also every probability that the chemistry of photography will be very much improved and more sensitive methods devised."

The statements made by George Phillips Bond and Lewis Morris Rutherfurd were to prove uncannily accurate in the coming decades of the nineteenth century. As yet, these were only ideas; nobody had yet the confidence or the technology to attempt to actually produce a photographic sky chart. Although Warren De La Rue (1815-1889) had in 1860 made the first tentative steps at imaging wide fields and whole constellations using a portrait lens attached to his telescope mount [5]:

"The next subject to which I have to call your attention is the photographic depiction of groups of stars—for example, such as form a constellation like Orion,—in other words, the mapping down the stars by means of photography... The fixed stars depict themselves with great rapidity on a collodion plate; and I have experienced no difficulty in obtaining pictures of the Pleiades by a moderate exposure even in the focus of my telescope; they would be fixed much more rapidly by a portrait-camera. The difficulty in star mapping does not consist in the difficulty of fixing the images of stars, but in finding the images when they are imprinted; for they are no bigger than the specks common to the best collodion..."

With the introduction of mass produced Gelatino-Bromide '*dry*' photographic plates in the early 1880s, capable of obtaining well defined images of stars as faint as the 15th magnitude; the technology had matured sufficiently enough for an adventurous pioneer to be able to make such an attempt. In the January of 1886, Isaac Roberts published a paper in the Monthly Notices of the Royal Astronomical Society entitled '*Photographic Maps of the Stars'* [6]. In it he cites the proposal made by Ernest Mouchez, the Director of the Paris Observatory to create a '*Carte du Ciel*' published in the MNRAS the previous November [7].

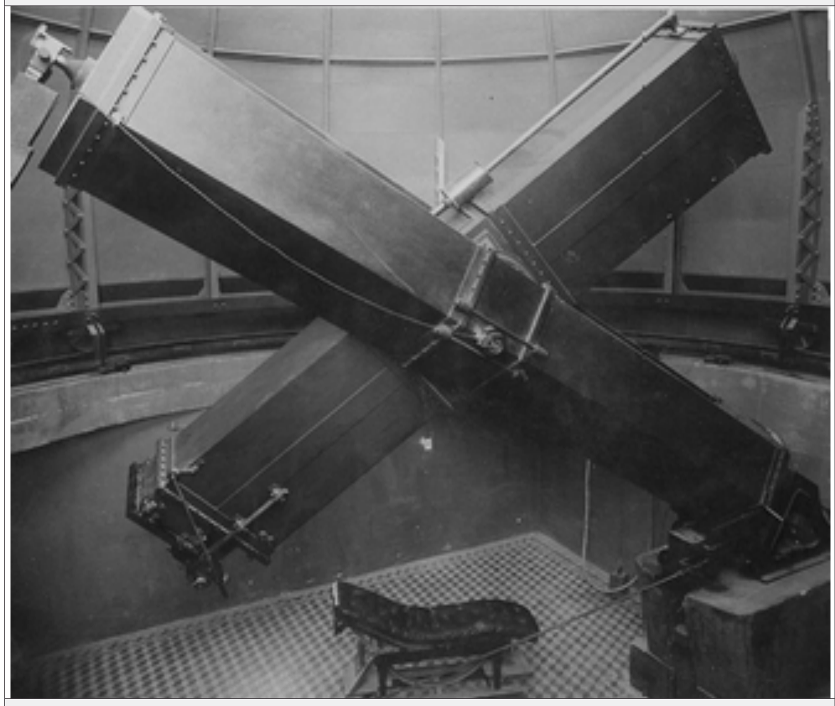
Algiers (Algeria) - Henry Brothers



Bordeaux (France) - Henry Brothers

Cape (South Africa) - Howard Grubb

Catania (Italy) - Henry Brothers



Cordoba (Argentina) - Henry Brothers

Greenwich (England) - Howard Grubb

'Carte du Ciel' Astrographs

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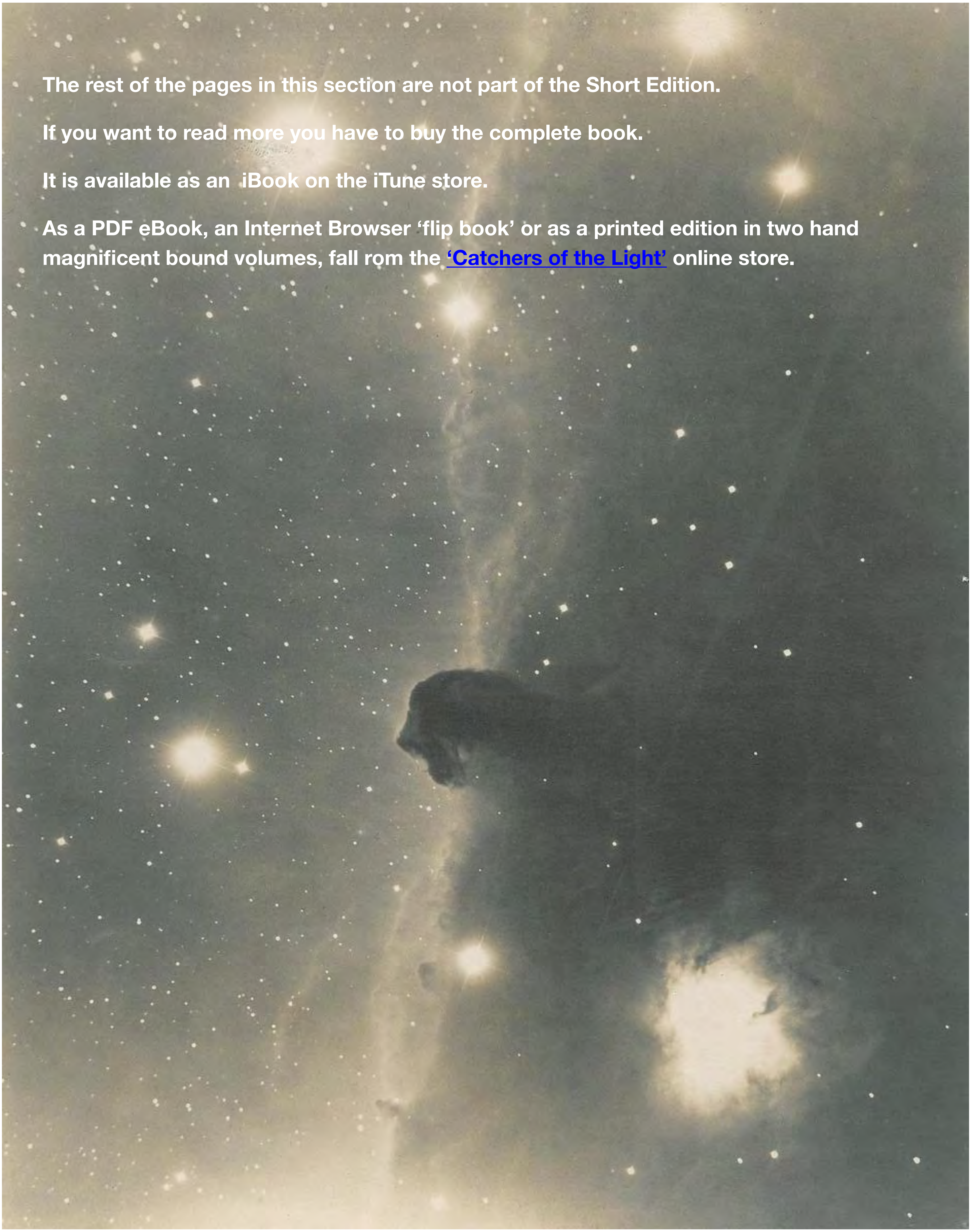


Short Edition

Part VIII

Astrograph

Photographic Telescopes

Greenwich Observatory Astrograph, built by Sir Howard Grubb, c1891

“In this paper Dr. Vogel expresses an opinion that the photographs of Herr von Gothard taken with this comparatively small instrument show results which far surpass any obtained by eye observation with the largest telescope.” Andrew Ainslie Common (1841-1903)

VIII. Photographic Telescopes

In the early years of astronomical photograph pioneers like John William Draper, Warren De La Rue and the Bonds of Harvard, William Cranch and his son George Phillips used whatever equipment they had, no matter whether it was suitable or not.

Only in 1864 did the New York amateur scientist, Lewis Morris Rutherfurd create the first Astrograph - a telescope designed specifically with photography in mind. It would be many years before photographic refractors became used in a professional observatory.

At that time the '*Great Observatories*' were more interested in claiming the title of owner of the 'largest' telescope rather than caring about whether it was the best or even less whether it was photographically corrected'. This '*blinkered*' attitude effectively meant who had the biggest '*Great Refractor*'. Its rival - the reflector was considered the instrument of amateurs and cranks, despite it having achieved great success in the hands of Sir William Herschel and his son Sir John Herschel.

Those who held the purse strings often did not care about science but only their egos; and astronomers were often only too glad to receive the gift of a '*Great Refractor*'; and besides many even up to the end of the nineteenth century were not convinced of the advantages of photography over visual observations.

As a consequence the nineteenth century was the age of the 'Great Refractor', many examples of which sprang up across the North American Continent and Europe, with every few years an even bigger one would appear under the Dome of this observatory or another, until it was supplanted by one elsewhere; 15-inch (1839), 18.5-inch (1862), 24.5-inch (1869), 26-inch (1873), 30-inch (1885), 30.3-inch (1887), 36-inch (1888), 40-inch (1897). It was a case of aperture fever bordering on scientific insanity. However there appeared a few voices of reason in the astronomical community who supported either the reflector which was better by design suited to photography, or the photographic refractor.

William Parsons, the 3rd Earl of Rosse (1800-1868) at his estate in Parsonstown (now Birr) built a series of '*Great Reflectors*', culminating in the completion of his 72-inch '*Leviathan*' in 1845. Using this instrument Parsons saw details in the objects known as '*nebulae*' which the refractors could not see. In particular he observed that several exhibited a '*spiral*' nature. Such nebulae were later to be found separate '*Island Universes*' lying millions of light years beyond the boundaries of our own Milky Way star system.

Edward Charles Pickering, the Director of the Harvard College Observatory, went against the norm of his fellow observatory heads - and believed in small photographic refractors as the best way forward for the new science of Astrophysics. In 1885 Pickering obtained $2000 from a grant provided by the Bache Fund of the American National Academy of Sciences for the purchase an 8-inch Photographic Refractor.

It was with this instrument that his younger brother William Henry Pickering took a photographic plate on the 6th of February 1888, on which Williamina Fleming found the dark nebula known as the '*Horsehead*' - probably the most iconic of the all the wonders to be seen in the heavens. Furthermore he used this Astrograph and others to carry out useful science in the areas of stellar spectroscopy and photographic sky surveys.

With the instigation of the ill-fated ‘*Carte du Ciel*’ photographic sky mapping project in 1887, the appearance and use of photographic refractors bred like clones across the globe from Greenwich, to Paris, to Rome, to North Africa, to Australia and to South America; all made to the same specification based on a 13-inch aperture.

The first nails in the coffins of the ‘*Great Refractors*’ had begun to appear. In 1898 the nails had begun to be hammered into the coffins when, James Edward Keeler and his assistant Charles Dillon Perrine began taking photographs with a 36-inch reflector of many well known Deep Space Objects. The images they obtained were of such magnificence that they made even the most skeptical of astronomers believe that the new era of the large silvered mirrored reflector had begun and the age of the ‘*Great Refractor*’ had come to an end.

So it proved to be when in 1908 a 60-inch reflector appeared atop Mount Wilson in California, followed nine years later by an even bigger one of 100-inch aperture next to it. Following the 1900 Paris exhibition when a refractor of 49-inch aperture made a final bow before being scrapped, no more ‘*Great Refractors’* were built, save the 30-inch Thaw photographic refractor completed for the Allegheny Observatory, Pittsburgh in 1914. In the years that followed many new ‘*Great Reflectors*’ appeared under the domes of the world’s observatories, whose designs were based on high quality optics, entirely suited to astronomical photography. Telescopes using the Schmidt and Ritchey-Chretien optical systems also began to slowly displace the conventional Newtonian/Cassegrain designs as adopted by the 200-inch Hale reflector on Mount Palomar.

On the 24th of April 1990 the ultimate Astrograph - the Hubble Space Telescope was launched into orbit above the Earth and with it a new chapter in the history of Astrophotography was opened.

“In ordinary photography, the lenses used are designed for the purpose, and have usually all necessary information as to focal length and focal aperture engraved on the lens mount. An operator has only to focus the image on the ground glass, set an indicator to the ‘stop’ required, consult an exposure table for the light-factor appropriate to the hour and month, and then he can go ahead.

But in ‘telescopic’ photography the conditions are quite different. The instrument is not designed for the purpose, and in refractors the actinic rays come to a different focus from the visual rays, so that the ground glass requires suitable adjustment. Focal lengths and apertures have to be determined, and suitable stops manufactured, by the photographer himself,and except for solar photographs, ordinary exposure tables in their usual form are useless. Fortunately, however, all the necessary information can be ascertained without difficulty..”

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

40-inch Yerkes Refractor

VIII.1

‘The Leviathan Man’

William Parsons, 3rd Earl of Rosse

Born: 17th June 1800; York, Yorkshire, England

Died: 31st October 1867, Seapoint, Monkstown, Dublin, Ireland

William Parsons was the *‘Great Telescope’* Builder, whose 72-inch Reflector was for almost three quarters of a century the largest telescope in the world. He did something no one else had done before or since - create almost single handedly a telescope of such a size and use it to *‘afford us some insight into the construction of the material universe’.* He made drawings of Deep Space Objects (DSOs) which showed for the very first time what many of them truly looked like. It was he who first discovered with his ‘*Leviathan of Parsonstown*’ the ‘*Spiral*’ nature of certain nebulae.

VIII.1.1 ‘Great Telescopes’

William Parsons (1800-1867), the 3rd Earl of Rosse was born into an age when wealthy amateur scientists could and did make great contributions to our understanding of the universe in which we live.

He was the first of the great telescope builders who created almost single handedly a series of speculum metal mirrored reflectors of ever increasing size; beginning with a 6-inch in 1826, followed by a 15-inch in 1830, then soon afterwards by a 24-inch, which was then superseded in 1839 by a 36-inch; and finally in 1845 construction was completed on his famous 72-inch telescope - the ‘*Leviathan of Parsonstown*’. This telescope was to remain the largest telescope in the world for over 70 years until 1917 when it was ‘*overtaken*’ by the 100-inch Hooker Reflector at the Mount Wilson Observatory in California, USA.

Although William Parsons never used any of his telescopes to take photographs of the Deep Space Objects (DSOs) he observed, he nevertheless made vital discoveries regarding their structure. His drawings of DSOs made by him and his assistants at Birr Castle during the period 1845 to 1867, showed for the very first time accurate representations of their true appearance, later to be confirmed by the photographs of Isaac Roberts (1829-1904), William Edward Wilson (1851-1908), James Edward Keeler (1857-1900) and others.

Above all else, William Parsons demonstrated the great potential reflecting telescopes had in the future conduct of astronomical research. An opinion that was later to be proved correct. The age of telescope building at Birr in the years 1826 to 1845 marked the onset of the ‘*death*’ of the ‘*Great Refractor*’. However it was to be others who caused ‘*its*’ death; Andrew Ainslie Common dealt ‘*it*’ the fatal blow, and it was James Edward Keeler who put the nails in ‘*its*’ coffin [1].

In 1845 William Parsons began using his 72-inch Reflector and during the course of his observations noticed that a number of the bright ‘*nebulae*’ exhibited a definite spiral structure to them. The 3rd Earl of Rosse’s discovery of the spiral nature of certain nebulae helped fuel the flames of a long standing argument between himself and another great astronomer of the time – Sir John Herschel. Rosse believed that all ‘*nebulae*’ were made up of individual stars, a fact which would become evident if telescopes of sufficient size were available to observe them; on the other hand Herschel believed that not all nebulae are ‘*resolvable*’ and some of them are made up of clouds of gas which collapse to form stars.

History has subsequently shown that both were right and both were wrong in equal measures! Certain nebulae are in fact made up of clouds of gas, some of which are even ‘*star forming nurseries*’; whilst others including Rosse’s ‘spirals’ were in fact external galaxies made up of individual stars, much resembling our own Milky Way; but situated millions of light years beyond the boundaries of our own ‘*Island Universe*’.

VIII.1.2 Lord Oxmantown

William Parsons [2] was born on the 17th June 1800, in York, England. An event which was recorded for posterity in the following announcement that appeared in the York Courant for Monday 23rd June 1800 [3]:

“*On Tuesday evening [17th June] the Lady of Sir Lawrence Parsons Bart., of Parsons Town, M.P. for King’s County, Ireland, was safely delivered of a son and heir, at their lodgings in this city.”*

It is not known where their lodgings were in York, or why they were there. Presumably they were in England to escape the Irish Rebellion of 1798, in which a number of magistrates were murdered in Queens (Laois) and Kings (Offaly) Counties, and also at Cork and Kildare. As a result a number of the Irish Gentry fled to England in fear of their lives [4].

At the age of seven, William Parsons inherited the title of Lord Oxmantown, following the death on the 20th of April 1807 of Laurence Harman Parsons (1749-1807), the 1st Earl of Rosse; his father Sir Laurence Parsons, then Baron Oxmantown became the 2nd Earl of Rosse.

He received his preparatory education at home from a private tutor, but in 1818 he entered University College, Dublin. A year later he left to continue his studies at Magdalene College Oxford, where he received a 1st Class Honours Degree in Mathematics in 1822.

In 1821 when he was Lord Oxmantown, William Parsons entered the world of politics when he was elected as one of the two Members of Parliament for Kings County, Ireland [5]:

"Crown Office, August 11, 1821.
MEMBER returned to serve in this present PARLIAMENT.

***King's 'County**.*
The Honourable William Parsons, commonly called Lord Oxmantown, in the room of William Parsons, Esq. who has accepted the office of a Judge of the Insolvent Court in Ireland."

In the March of that same year, it was reported that a '*conspiracy*' had been uncovered to assassinate both him and his father because of their efforts to preserve the tranquility of King's County; and that a '*party of military and constables*' had been sent, with orders to protect them. Even in 1821, Irish politics was a dangerous game to be involved with. William Parsons remained in politics until 1834 when he gave up his seat.

On the 24th of February 1841 his father Laurence Parsons, the 2nd Earl of Rosse died at his home in Brunswick Square, Brighton, Sussex. William inherited his father's title and became the 3rd Earl of Rosse and also took possession of his Estates at Parsonstown in Kings County, Ireland [6]. At that time Irish Peers had no seat in the House of Lords, which enabled him to pursue full time his passion for all things scientific, and especially astronomy.

Laurence Parsons (1758-1841), 2nd Earl of Rosse was born at Birr Castle, Parsonstown, Kings County, Ireland on the 21st of May 1758, the eldest child of William Parsons (1731-1791), 4th Baronet of Birr. He inherited his title on the death in 1807 of his half-brother Laurence Harman Parsons, 1st Earl of Rosse. The 2nd Earl was descended from an ancient English family. In 1620 his distant ancestor Sir Laurence Parsons was granted 1277 acres of Land at Birr Castle by King James I of England. Since that time Birr Castle has been in the possession of the Parsons family, the Earls of Rosse. The present incumbent is William Clere Brendan Parsons (1936-), the 7th Earl of Rosse, who has been active in preserving not only Birr Castle and its magnificent grounds, but its Astronomical Heritage, and especially the 72-inch Telescope of William Parsons, 3rd Earl of Rosse.

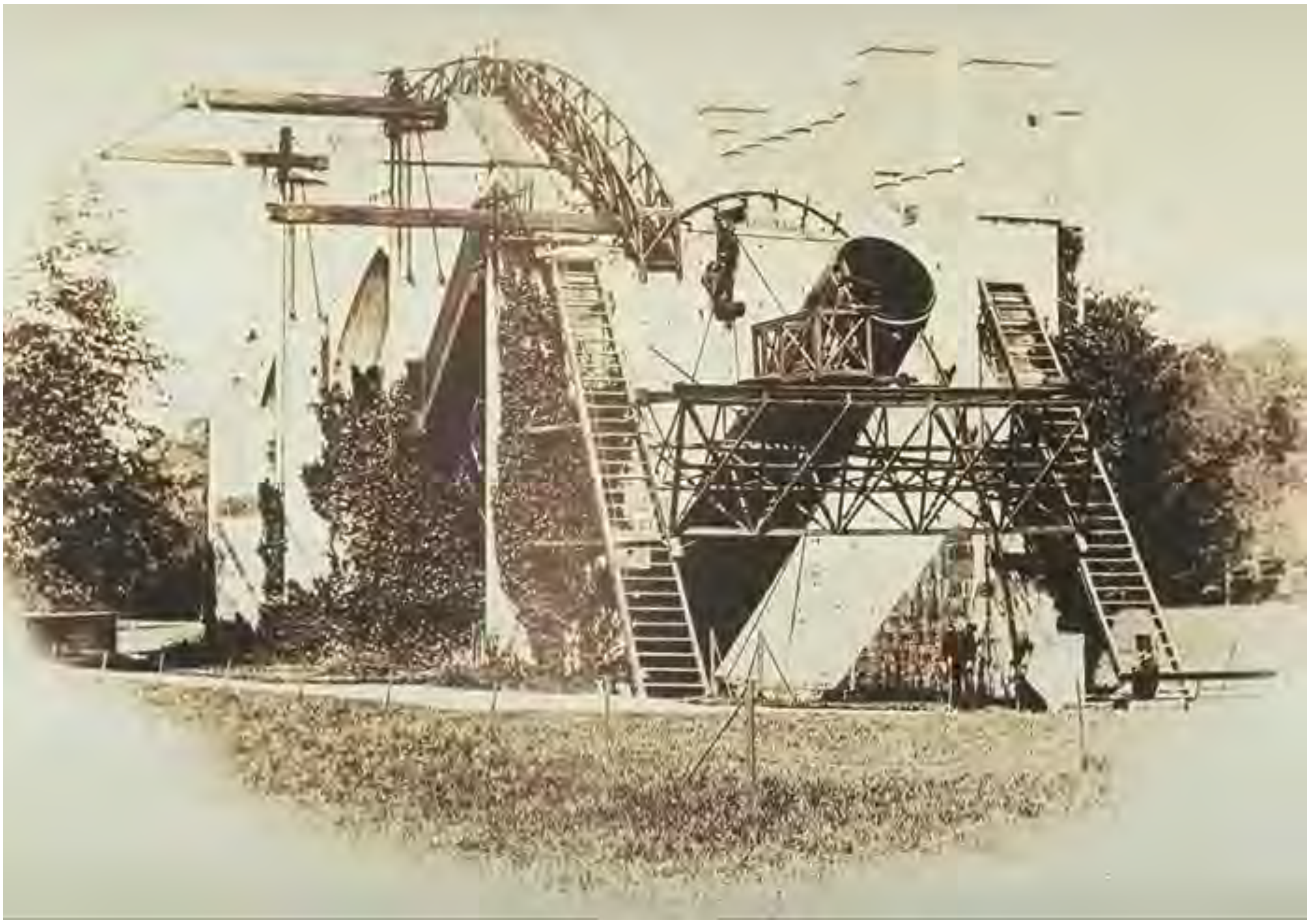
Lawrence Parsons, 2nd Earl of Rosse (1758-1841)

VIII.1.3 Mary Field of Heaton Hall

William Parsons when he was Lord Oxmantown married Mary Field a Yorkshire heiress, on the 14th of April 1836 at the parish church of St. George's Hanover Square, Middlesex [7]. The financial security from this marriage, as well as the ownership of Birr Castle (which his parents granted him before they left Ireland to live in Brighton, England) allowed him to realize his scientific ambitions and plans.

Mary Field (1813-1885) was the eldest daughter of John Wilmer Field, Lord of the Manors of Heaton, Shipley and Upper Helmsley in Yorkshire. She along with her younger sister Delia (1815-1873) were coheiresses to their father's considerable fortune and estates. The ancestral home of the Field family was Heaton Hall in the then small village of Heaton, situated some two miles from the industrial town of Bradford, of which it is now a part.

Heaton Hall in its day was an impressive and large mansion, built around 1660 by John Field, a great-great uncle of John Wilmer Field. The house complete with a large park, numerous farms and parks, amounting to some 880 acres. Sadly it is no more, having being pulled down sometime shortly before 1939, making way for the St. Bede's School, which had moved to Heaton Hall in 1919. The old Hall, proved to be an unsatisfactory building as the number of pupils continued to grow and the new school was opened in 1939.



'Leviathan of Parsonstown' - 72-inch Reflector, Birr Castle, by W. Lawrence

Nebulae were a great problem to the nineteenth century astronomer and it was only following the construction of the '*Leviathan of Parsonstown*' that any real light was shone on resolving the issues they presented to William Parsons and his '*peers*'. The contribution of the '*six-foot*' telescope in this regard and the problems posed by the '*nebulae*' was eloquently summed up the in the obituary to William Parsons, which appeared in the Monthly Notices of the Royal Astronomical Society for 1868 [42]:

"We have seen how it has with certainty resolved certain of the nebulae, and how, for a while, till spectrum analysis arose to arrest the conclusions it tempted, it threatened to disprove the existence of such things as nebulae at all by bringing all the objects so called within the domain of star-clusters; and we have seen how it has in this same class of bodies revealed a structure and arrangement more wonderful and inexplicable than anything which had hitherto been known to exist—we allude to the spiral conformation in all its varying conditions; we have seen, too, how it has necessitated some modifications in our previous ideas regarding planetary nebulae, by breaking up the symmetric outlines that gave them their distinctive name."

The '*spectrum analysis'* referred to, was the work done by William Huggins at his Observatory at Tulse Hill, Brixton, London. In a momentous paper written by him in 1864 entitled 'On the Spectra of Some of the Nebulae', which appeared in the Proceedings of the Royal Society of London, Huggins revealed his conclusions that not all nebulae were resolvable into stars, but some were in fact composed of gas:

"The riddle of the nebula; was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas. Stars after the order of our own sun, and of the brighter stars, would give a different spectrum; the light of this nebula had clearly been emitted by a luminous gas. With an excess of caution, at the moment I did not venture to go further than to point out that we had here to do with bodies of an order quite different from that of the stars."

The nebulae which caused the greatest controversy were those not capable (at the time) of being resolved into stars. The resolution of the *'Great Orion Nebula*' by William Parsons caused an unwarranted and indeed false leap of faith that all other nebulae were capable of resolution. The discovery of the '*Spirals*' added a further class of objects to what was rapidly becoming a very complex cosmos – which in honesty was far beyond the boundaries of their limited scientific knowledge. In a paper published in 1861 [57], William Parsons illustrated his 'new cosmos' with a series of drawings of DSOs made by his assistants, Mr. Bindon Blood Stoney, Mr. R. J. Mitchell and Mr. S. Hunter [58]. It must be remembered that it has only been a few years earlier that astronomers of Parsons' time had found out just how far away the stars were – whose distances are measured in *'light years*' and not mere miles or kilometres. Apart from this and that stars were other Suns summed up the totality of their knowledge. They had no idea how hot stars were, or what made them '*shine*' or what they were made of; so to begin to understand what '*Spirals*' were was something of an impossibility at the time.

The true understanding of their nature was not to be known until over fifty years after the death of William Parsons, with the pioneering work of Edwin Hubble in the 1920s, who showed that they were separate '*Island Universes'* far beyond the boundaries of our own '*Milky Way*' [60].

The famous drawing by William Parsons, the 3rd Earl of Rosse' of the '*Whirlpool'* nebula, M51 in the constellation of the Hunting Dogs, was the very first occasion on which a spiral form was recognized in a '*nebula*'. The drawing was made in April 1845, and circulated at the June meeting of the British Association for the Advancement of Science.

It was not until 1923 with the discovery of a Cepheid variable star in the '*Great Andromeda Spiral'* by Edwin Powell Hubble, that their distances first became known.

Drawing of 'Whirlpool Galaxy' (M51), William Parsons

The '*face on'* Spiral Galaxy known as the '*Whirlpool*' or M51 is justly one of the most famous and beautiful of the incalculable number of '*nebulae*' in the heavens. Its fame began when observations of it made by William Parsons, 3rd Earl of Rosse, at Birr Castle in 1845, which established its '*Spiral*' nature.

More recently the wonderful images of it captured by both amateur CCD cameras and by the Hubble Space Telescope have brought it back into the spotlight once more.

'Whirlpool Galaxy' (M51), Canes Venatici

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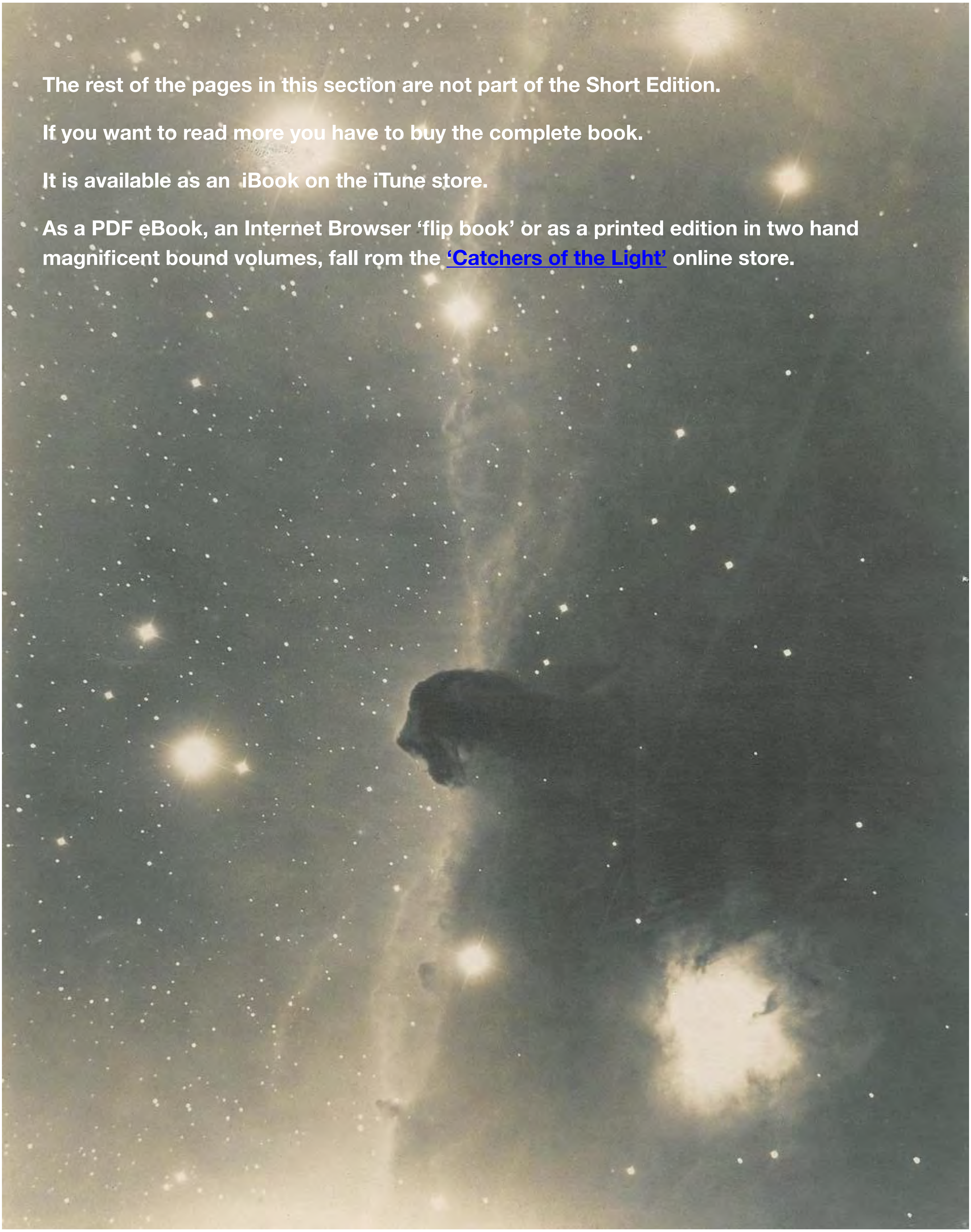


VIII.2

‘The Miller’

Andrew Ainslie Common

Born: 7th August 1841, Newcastle-upon-Tyne, Northumberland, England

Died: 2nd June 1903, Ealing, Middlesex, England

Andrew Ainslie Common was a pioneer in the construction of large silvered mirrored telescopes. He showed the potential of such instruments to photograph the heavens provided they were accurately driven and situated in a suitable observing location. Two of his telescopes are still in operation today, the 36-inch *‘Crossley’* reflector at the Lick Observatory in California and the 60-inch *‘Rockefeller’* reflector at the Boyden Observatory, Bloemfontein, South Africa.

VIII.2.1 Procedures & Techniques

Andrew Ainslie Common was without doubt one of the great pioneers of Astrophotography. His chief claim to fame lies, not particularly because of the photographs he took, but in the techniques and procedures he used to capture them, and even more importantly in the telescopes he constructed and designed specifically for Deep Space Astrophotography.

He believed that the telescopes of the future should be silvered mirrored reflectors and not the *'Great Refractors'* which at that time, were to be found under the domes all the '*Great Observatories*' of the world. Furthermore, if they were to be of any use to astronomers, they should be on a stable platform of '*such, a construction of mounting as to give the greatest mount of steadiness with the least amount of motion*'; provided with a '*Driving clock. Circles to find or identify an object and motions taken to eye end*' and most important of all '*a suitable locality for the erection of the telescope'.*

His start in life was one borne of fear apprehension; whether from the real possibility of an early death from the cholera which plagued the streets where he lived; or the prospect of financial hardship brought on by his father's insolvency. As a consequence of the early death of his father when he was barely thirteen years old, his education was cut short and he was sent out into the world to earn a living as a Miller at his uncle's flour mill in Gayton, Norfolk. It was here that he became '*a strong man in all senses, and liked trying himself to the limit'* in both physique and in character, learning be never afraid of hardship or the thought of hard work.

His legacy lives on today for two of the great reflecting telescopes he constructed over a century ago are still in use and are helping us to understand the universe in which Andrew Common first gazed upon so long ago. Let us now turn the pages of history back over 150 years to a world far different from the one fate decreed Andrew Ainslie Common would follow.

VIII.2.2 Newcastle-upon-Tyne

Andrew Ainslie Common was born on the 7th August 1841 [1] in Oxford Street [2], in the parish of St. Andrew's, Newcastle-upon-Tyne, the second of the three children born to Thomas Common (1810-1851), a surgeon of that city, and his wife Mary Hall (1806-1873) [3]. The area of Newcastle where Andrew Common was born was at the time a new residential area on the outskirts of the city. The empty spaces around his home were soon to disappear as the city's population rapidly expanded in the coming years [4]; as is evident from a map of 1843 which shows the ominous presence of land allocated for new buildings. It maybe thought that Andrew was immune from the poverty, disease and deprivation that many tens of thousands in the city were accustomed to. This was far from being the case, indeed the opposite was true.

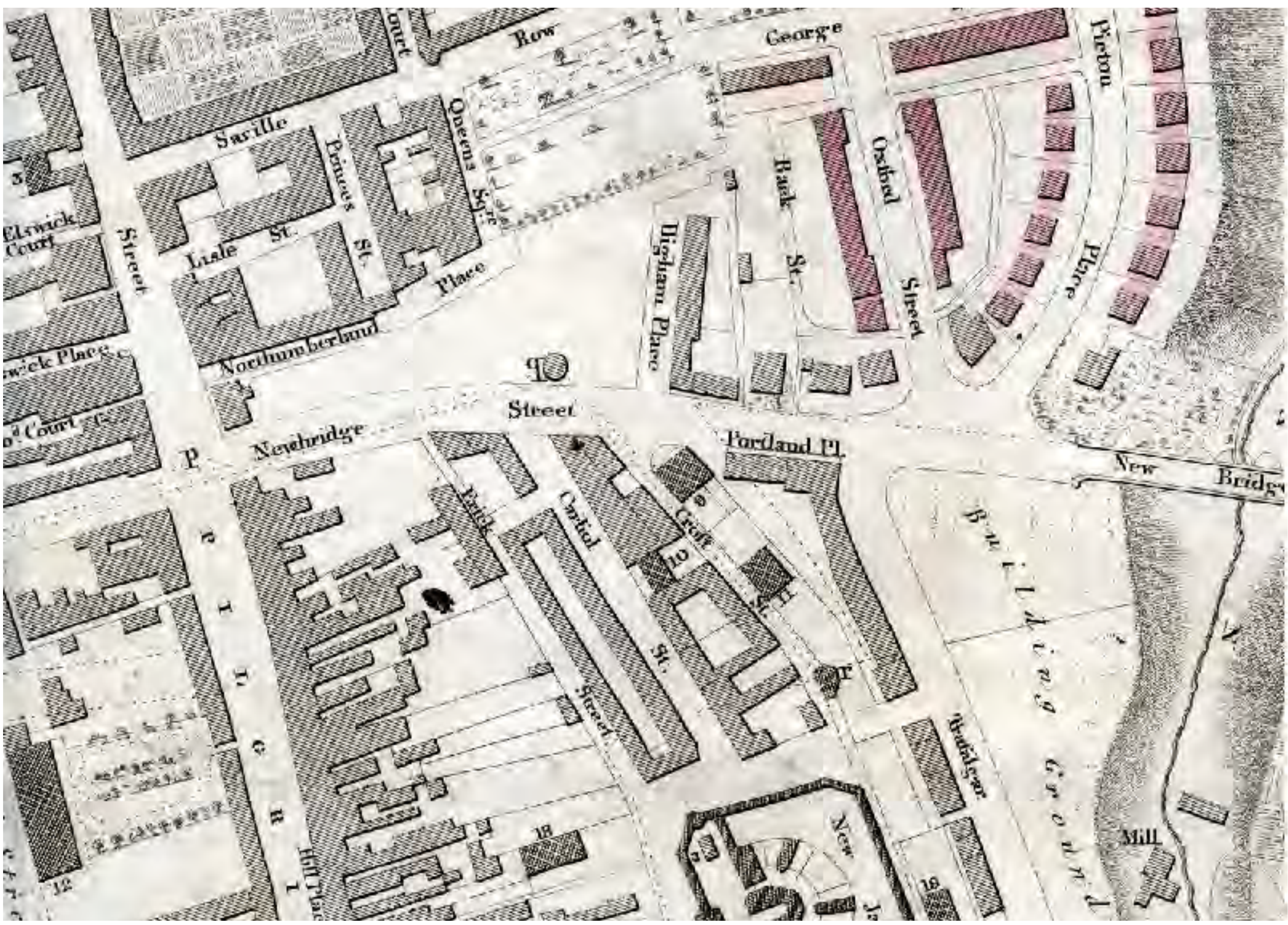
His father, Thomas Common was a respected and well known surgeon in the North of England, being one of the early pioneers in the field of eye cataract surgery. He had qualified as a Surgeon and Apothecary, becoming a member of the Royal College of Surgeons in 1832, at the age of just 22. He subsequently trained other Apprentice Surgeons who later would make great contributions to helping the poor, the sick and needy in the city. The most well known of his students was Dr. Charles John Gibb (1824-1916), the House Surgeon at the Newcastle Infirmary [5]

As a young boy growing up in Newcastle with his brother John Freeland Fergus (1839-1916) and his sister Mary Jane (1844-1912), young Andrew was always aware of the fragility of life. His father's profession must have been a constant reminder to him of this hard lesson. The city of Newcastle had during the period 1831 to 1853 suffered a number of cholera epidemics caused by poor sanitation and the presence of much slum housing [6].

In 1842, the year following Andrew's birth his father was appointed the resident surgeon at the nearby Gateshead Dispensary [7]. The Gateshead Dispensary was established in 1832 as a direct consequence of the cholera epidemic of the previous year. Its purpose was to provide free medical care to those unable to pay for it – the poor and the deprived [8]. As is always the way it was too little too late - the cholera outbreak of 1831 had already killed 306 people. It had taken this shock treatment for the '*great and the good*' of Gateshead to be stirred into action!

"All Saints Church [Newcastle] is situated on the brow of a steep bank, on the south side of Silver-street, at the foot of Pilgrim-street. It was erected on 1796, at a cost of £27,000, on the site of the former church of All Saints, which was erected previous to the year 1284, but the precise date is not known. It is an elliptical structure of 86 feet by 72, and in the Grecian Style of architecture, the spire having an elevation of 202 feet. This elegant edifice is constructed of freestone, and the pews are all formed of mahogany... The register commences in 1600." From History, Topography, and Directory of Northumberland, Whellan, 1855.

All Saints, Newcastle was the parish church of Thomas Common and his family. It is where Andrew Ainslie Common was baptised in 1841, his elder brother John Freeland Fergus in 1839 and his younger sister Mary Jane in 1844. His father was also baptised at All Saints in 1810 and in 1836 he married Mary Hall there; who herself had been brought up as a Scottish Presbyterian. She was baptised not in All Saints, but at the High Bridge Meeting Hall, High Bridge, Newcastle in 1806, as were all her other eight brothers and sisters.



Oxford Street, Newcastle-upon-Tyne, 1843 (highlighted)

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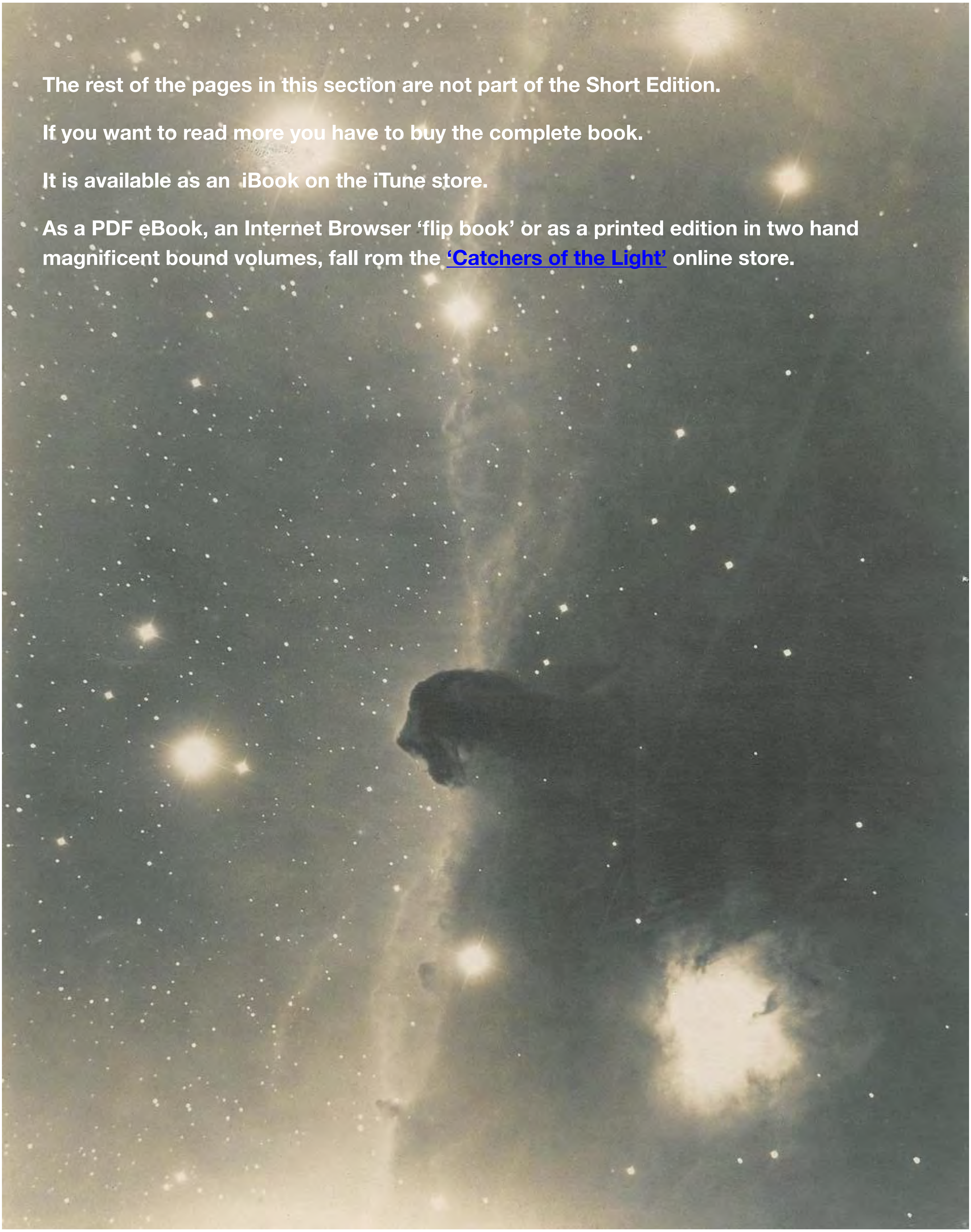


VIII.3

'The Visionaries'

George Willis Ritchey

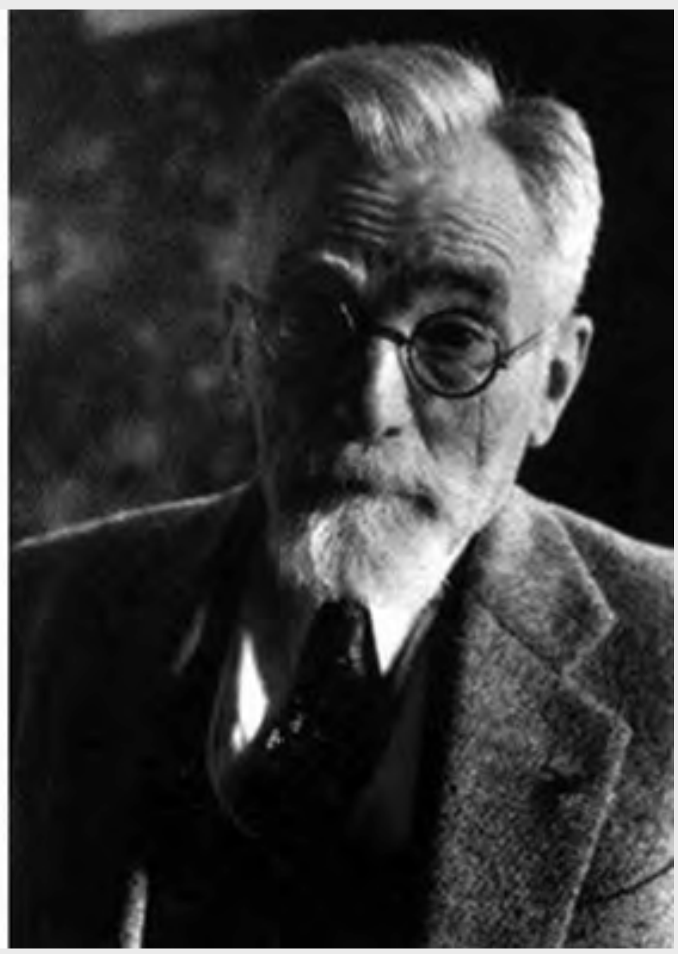
Born: 31st December 1864, Tuppers Plains, Ohio, USA

Died: 4th November 1945, Azusa, California, USA

Henri Chretien

Born: 1st February 1879, Paris France

Died: 6th February 1956, Washington DC, USA



George Willis Ritchey was not only one of the greatest designers of Telescope Optical Systems, but more importantly he was a visionary whose ideas were too radical for the age in which he lived. It was his collaboration with the French optician Henri Chretien that led to the optical design which now bears their name and which is the basis of almost all of today's new breed of '*super telescopes*'.

VIII.3.1 Visionaries

On the 13th of December 1908 atop a mountain in southern California a '*Great*' telescope opened its dome to see the night sky for the very first time. Not only was this a memorable occasion for those who had constructed it, but it also marked the end of one era in Astronomy and the beginning of another.

For three centuries ever since the days of Galileo the refracting telescope had dominated astronomical research in almost every observatory across the globe. Its rival the mirrored reflector was looked upon with scorn and contempt by the astronomical establishment. They saw it as the instrument of amateurs and cranks, and not fit to be given dome space in their Great Observatories.

Now the age of the glass lens and the refractor was gone, and the new age of the large silvered mirrored reflector had arrived; for the telescope that saw its firstlight in 1908, at the summit of Mount Wilson, over 5700 feet above sea level, was such an instrument. It had a mirror of 60-inches aperture, which at the time, made it the largest operational telescope in the world. The man who had ground, polished and nurtured the mirror was George Willis Ritchey (1864-1945) [1].

He was born the son of a cabinet maker of Irish emigrant stock, in a small Ohio settlement whose name few have heard and not many more have lived in. Yet despite these humble beginnings and probably because of them, he grew up to become not only a great optician and telescope designer, but also an outstanding Astrophotographer whose images of Deep Space Objects (DSOs) were the finest of their day

His images of such iconic objects as the as Great Spiral Galaxies in Andromeda (M31),Canes Venatici (M51), Ursa Major (M101) and Triangulum (M33) were of the most incredible quality and greatly improved upon those taken earlier by the likes of Andrew Ainslie Common, Isaac Robert, James Edward Keeler and William Edward Wilson.

In 1910 in collaboration with the French optician, Henri Chretien (1879-1956) [2] they designed the now famous Ritchey-Chretien optical system affectionately known as the RC. It was this design that brought George Willis Ritchey and the Mount Wilson Observatory's Director, George Ellery Hale into conflict. Ritchey believed he should at least have been allowed to make a prototype of the new design, but Hale was adamant it was too new and too different to waste precious time on. Any telescope he had anything to do with would be constructed using traditional designs only.

In 1919 Hale fired Ritchey, but not before he had finished work on the mirror for his new 100-inch Hooker reflector. A deeply hurt and disillusioned Ritchey left the mountain, never to return. Left to ponder what might have been, he scratched a living growing oranges, lemons and avocados.

In 1928 Ritchey wrote of his dreams for the future of telescope design [3]:

"This is the incomparable exploration - the effort to bring the resources of the Universe to the service of mankind. This series of telescopes, by revealing to all men, graphically, by means of exquisite photographs, a Universe of which the Earth, the Sun and the Milky Way are but an infinitesimal part, will bring to the world a greater Renaissance, a better Reformation, a broader science, a more inspiring education, a nobler civilization. This is the Great Adventure. These telescopes will reveal such mysteries and such riches of the Universe as it has not entered the heart of man to conceive. The heavens will declare anew the Glory of God."

On the 24th of April 1990 an event took place which proved Ritchey right and Hale wrong. The words spoken by George Willis Ritchey over sixty years earlier, eloquently described the work that the Hubble Space Telescope launched that day was soon to perform, but especially so - as it was his optical and Chretien's design which made it all possible.

Ritchey and Chretien were visionaries ahead of their time, often vilified and ignored by the astronomical establishment for their '*new curves'* optical design. Today in space and in an ever increasing number of backyards and gardens across the world these two men's names are remembered for the '*new breed*' of telescope that has changed and is still changing our understanding of the universe in which we live.

Hubble Space Telescope Image of the Spiral Galaxy M101 in Ursa Major

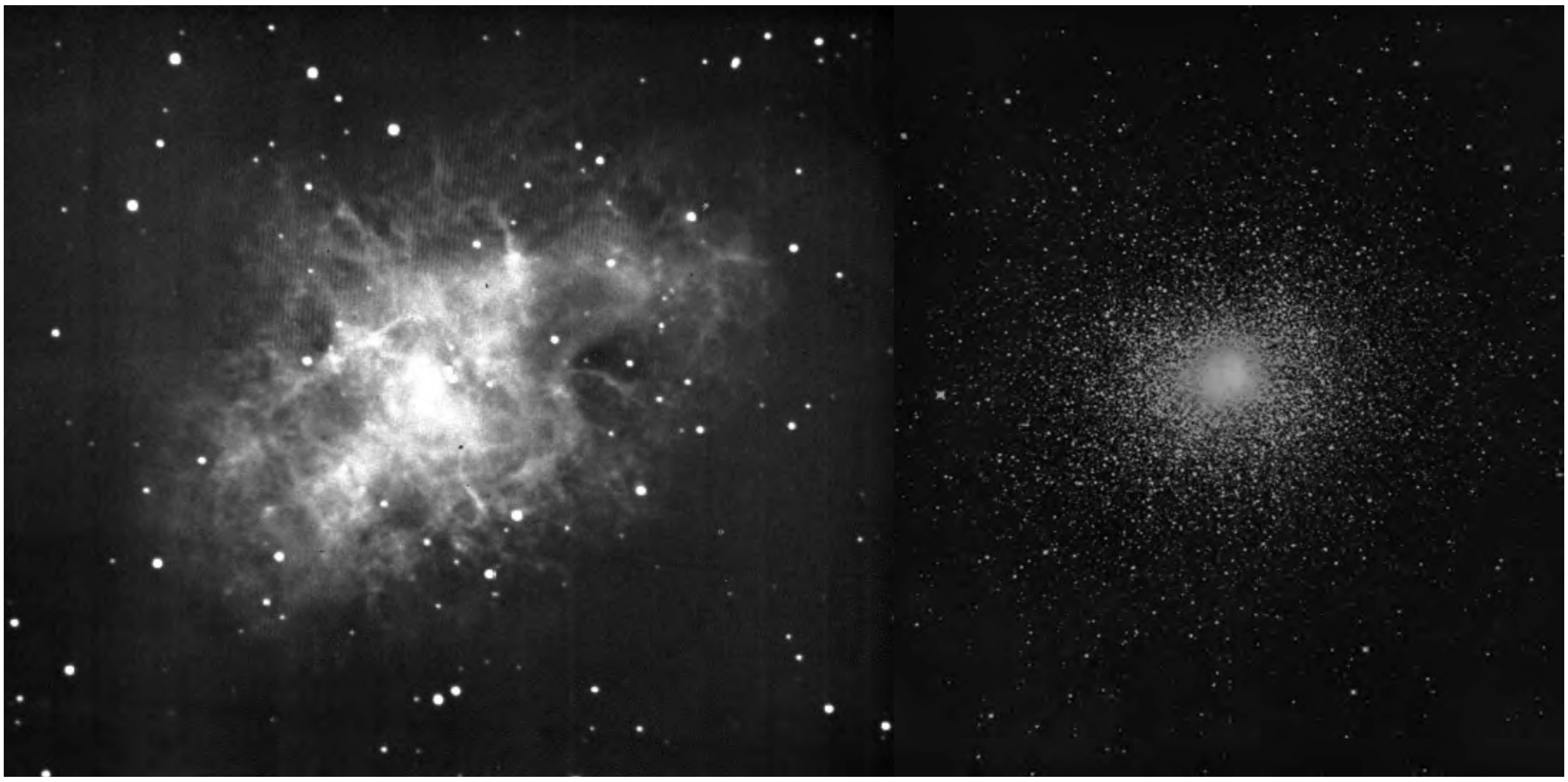
Since its launch in 1990 the Hubble Space Telescope (HST) has taken the finest images ever captured of the magnificent objects to be found in abundance in the farthest corners of our Universe. The Great '*Pinwheel*' Galaxy M101 in the constellation of Ursa Major (above) was also photographed in 1910 by George Willis Ritchey using the then new, but '*conventional*' 60-inch Mount Wilson reflector. It was his design and that of the French Optician, Henri Chretien first developed in 1910 at Mount Wilson that forms the basis for the optics used onboard the HST.

VIII.3.2 'The American Wake'

Nineteenth century Ireland was for the vast majority of its people a place of poverty, disease, famine and no hope. At the time the dominant industry of the country was agriculture, where large areas of their then '*United Land*' was under the despotic control of wealthy English aristocrats, many choosing to remain in England in their great houses, far away from the misery they caused. Much of their land was rented to small farmers who through a lack of capital, tilled it with antiquated implements and grew crops using outdated methods.

The average wage for a farm labourer in Ireland in the 1850s was no more than £3 a month. This was only a fifth of what could be obtained in America and those without land began to seriously consider moving across the Atlantic Ocean to the New World. In 1816 around 6,000 left Ireland for America. Within two years this figure had doubled and continued to increase until it reached its peak in the years following the Great Potato Famine which began in the autumn of 1845.

Those who bravely pursued this path did so only because they knew their future in Ireland would only be more poverty, more disease, and more English oppression. America became their dream. Early immigrant letters described it as a land of plenty and urged others to follow them through this '*Golden Door*'. Their letters were read at events organized specifically to encourage more to join them in this wonderful new country. They left in their tens of thousands with hundreds of thousands soon to follow.



‘Crab Nebula’ (M1), Taurus, (left); ‘Great Hercules Cluster (M13); 60-inch Reflector

Whirlpool’ Galaxy in Canes Venatici (M51); M101 Spiral Galaxy, Ursa Major

“The method of focusing and refocusing finally adopted is by means of the “knife-edge” used in testing optical surfaces. An extremely thin sharp edge, like that of a hollow-ground razor, is moved across the cone of light from a star, near the plane of the focus; the eye, without an eyepiece, is placed just outside the focus, so that the cone of light is received through the pupil and the entire surface of the mirror is seen illuminated. If the plane of the knife-edge is inside the plane of the focus, the illuminated mirror will be seen to darken first on the same side as that from which the knife-edge advances across the cone; if the knife-edge is outside the plane of focus, the mirror will be seen to darken first on the side opposite that from which the knife-edge advances; when the knife-edge is exactly in the plane of the focus, the mirror will be seen to darken uniformly all over.” George Willis Ritchey, 1910.

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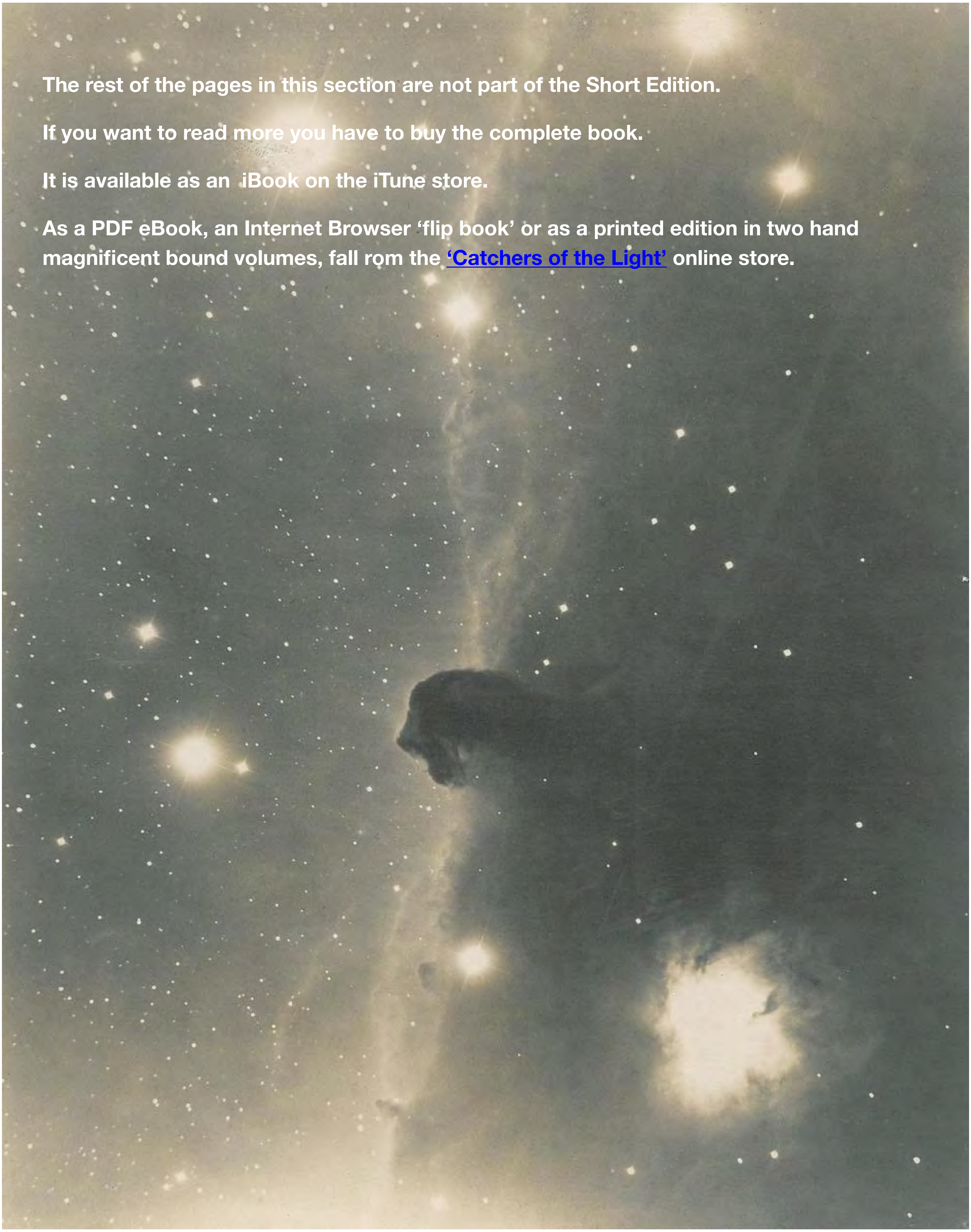


VIII.4

'The Optician'

Bernhard Voldemar Schmidt

Bernhard Voldemar Schmidt was without doubt one of the greatest opticians of all time. Almost every amateur has seen or used a telescope which owes its design to Schmidt's invention. The concept of Schmidt's design is simple, and in many ways too simple, something which may have contributed to the lateness of its invention. It is a design which could easily have been made 200 years earlier and not left until the twentieth century. Nevertheless since its introduction in 1930 it has proved to be one of the finest telescope optical systems ever created.

VIII.4.1 … Newton … Fraunhofer … Schmidt

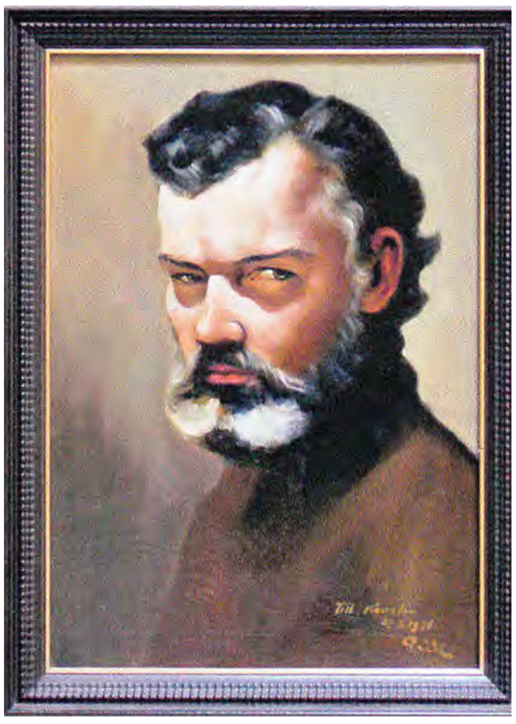
In tens of thousands of backyards, gardens, rooftops and amateur observatories all around the world, can be found a telescope whose origin lay in the brain and left hand of an Estonian optician named Bernhard Voldemar Schmidt (1879-1935). In his lifetime he remained largely unrecognized by the astronomical community, so much so that whilst he lived no telescope of his design was ever built by anybody other than himself.

Yet in 1936, less than a year after his death an 18-inch telescope made to his design was completed at the Mount Palomar Observatory [1]. It was a telescope that was to revolutionize both amateur and professional astronomy for decades to come. Of this genius, his fellow Estonian, the astronomer Ernst Julius Opik (1893-1985), wrote [2]:

"Perhaps the greatest advance—it could be called a revolution—in astronomical optics since Newton's time took place in 1930, when a one-handed invalid from Estonia, who went to Germany to work in optics, constructed at Hamburg Observatory a photographic telescope of a new type. This man was Bernhard Schmidt. Photographic cameras all over the world, based on his invention, are called 'Schmidt', sometimes 'schmidt cameras' without a capital letter."

The Schmidt Camera was an optical system of pure genius and simplicity. It had a wide field of view [of around 16 square degrees in his prototype] which not only gave high definition and sharpness across the whole of the photographic plate, its '*fast*' focal ratio also enabled faint detail to be seen with much shorter exposures than those required by conventional telescopes. It was in effect the perfect Astrograph, which could be manufactured with minimal extra cost when compared to the enormous benefits it offered. By creating the Schmidtspiegel or Schmidt reflector, Bernhard Schmidt became one of the greatest opticians the world has ever known, in stature equal to the likes of Hans Lippershey, Isaac Newton and Joseph Von Fraunhofer. Although statements as laudable as those given by Opik and the many others made after his death are entirely true, the reality for Schmidt during his life was very different.

For Bernhard Voldemar Schmidt it was a never ending physical and mental battle to get his optical designs recognized; in which his only companions were the ones so often befriended by geniuses – those of frustration, disappointment and loneliness.



Erik Schmidt (1925-), the nephew of Bernhard Schmidt, has done much to promote the life and work of his uncle. His biography of *'Optical Illusions' The Life Story of Bernhard Schmidt, the Great Stellar Optician of the Twentieth Century'*, provides an accurate and fascinating account of Schmidt's life and work. Unfortunately it is now difficult to obtain, but without doubt deserves a much wider circulation than it has received so far. The book has in fact formed the basis of several more recent accounts of Bernhard Schmidt. He has also appeared as himself in the documentary film Vastutuulesaal (Sailing against the Wind) about the Estonian conductor Tõnu Kaljuste and his crazy idea of building an opera house on Bernhard Schmidt's family estate on Naissaar; an island, which at that time had no regular ferry line, no electricity and only one permanent resident. In the summer of 2006, the Nargen Opera House was completed and the first performances took place on the land which Bernhard Schmidt used to play as a boy and often tried to blow up.

Erik Schmidt (1925-)

VIII.4.2 Naissaar Island … Photography … Gunpowder

Much of what we know of Bernhard Schmidt's childhood comes from information supplied by his younger brother August as told years later to his son Erik Schmidt [3]. August Schmidt, in his account of his brother's life, provides a fascinating insight into what made Bernhard Schmidt different from the norm, and more importantly gives valuable clues as to how he became the great optician, he undoubtedly was [4]:

"Maybe his life was nothing out of the ordinary. And maybe his childhood was similar to that of many another boy in the village. But, looking at it from the perspective of years, it becomes as fascinating as any life story could be ...I will try to narrate about his childhood—as much as I know. I was born in the same house, and so was my father. He is Bernhard's younger brother August. They grew up together. What I tell is what my father has told me. Only, he is not very talkative. Neither was Bernhard . . ."

Bernhard Voldemar Schmidt was born on the 30th March 1879 at '*Jaani's Place*' on the small island of Naissaar, off the coast of Tallinn, Estonia. He was the first of the five children of Carl Constantin Schmidt (1852-1889) and his wife Maria Helene ChristineRosen (1860-1930) [5]. The Schmidt family like the majority of the island's other inhabitants were Estonian Swedes, who at the time were subject to the rule of the Russian Tsars.

Carl Schmidt, although born on Naissaar was educated at a German School on the mainland in Reval (the German name for modern Tallinn). He earned his living off the sea as did all the inhabitants of Naissaar, by fishing and acting as a '*pilot*' for ships to Tallinn. Life was tough and Bernard Schmidt's parents brought the family up as best they could. One of the best things Carl Schmidt did for his children was to teach them German. From an early age, Bernhard and his four siblings were trilingual in the Estonian of his country; Swedish which was taught at the island's small school; and in German which was the only language spoken at home. The ability to speak German was to prove very useful to Bernhard Schmidt in later life.

Bernhard had two brothers and two sisters; Wilhelm Schmidt (1880-1883) died when he was less than three years old. The remaining three August Fredrik Schmidt (1883-1974), Olga Schmidt Wallenius (1885-1931) and Bertha Regina Schmidt Blees (1888-1938), all lived full lives [6].

In his early years Bernhard Schmidt was a typical, lively, adventurous and inquisitive youngster, although somewhat shy and reserved in the company of other children, but as Erik Schmidt relates, he was [7]:

"…always busy with something interesting…When other boys played with small bark boats, Bernhard made himself one that was jet-driven. He bored a hole into the boat, filled it with homemade gunpowder, ignited it, and the boat started speeding around, to everybody's great wonder. Of course, he gave the demonstration for just a few chosen friends."

Carl Constantin Schmidt died on the 16th of November 1889, when Bernhard was just ten years old. From then on, life became even harder for the Schmidt family and Bernhard in particular, with his mother now having the sole responsibility of bringing up four young children aged, ten, six, four and one.

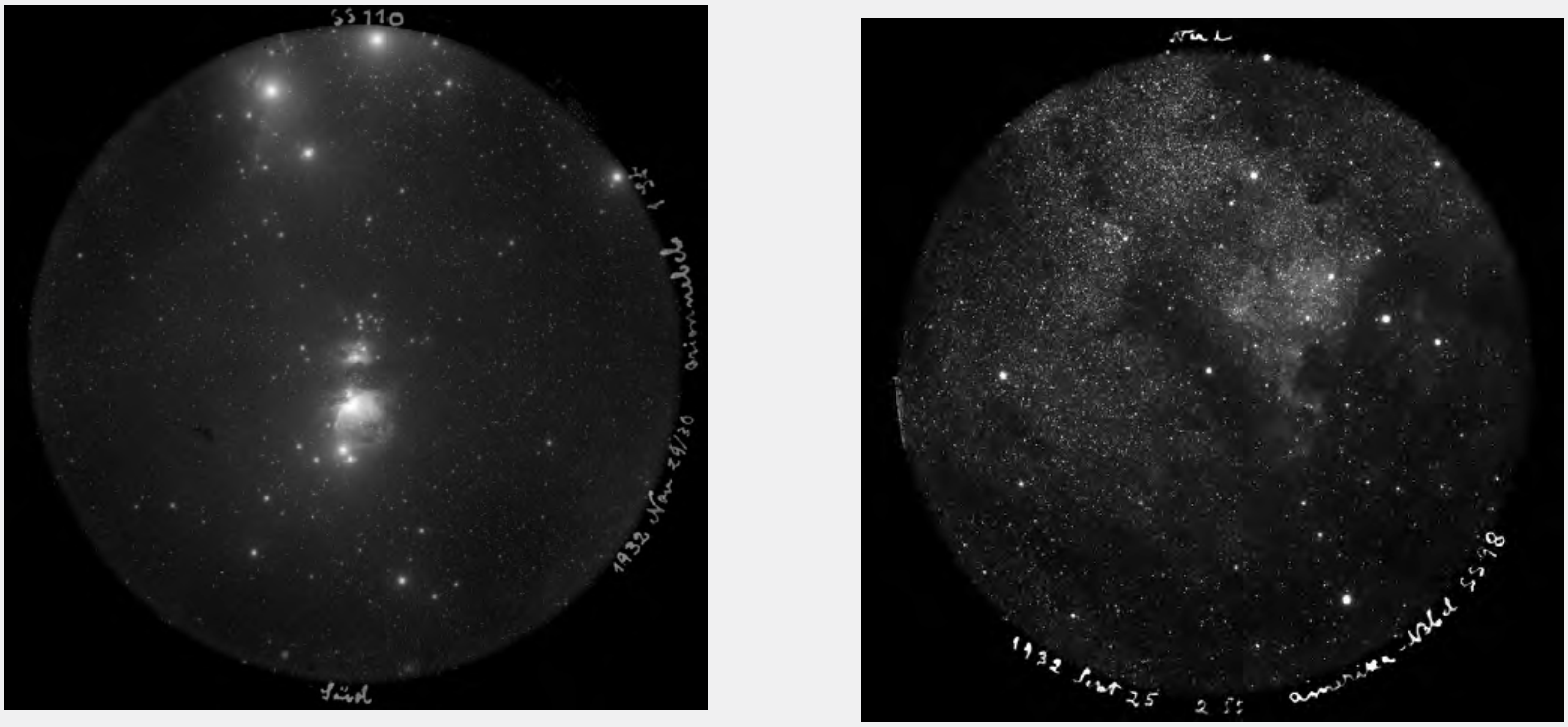
In many ways the young Bernhard Schmidt, despite his outwardly quiet personality was someone who nevertheless possessed a devilish and often dangerous side to his character. In 1893, this trait in his personality reached its peak and marked the beginning of the end of Bernhard Schmidt's youth [8]:

"One autumn day Bernhard had got hold of a catapult. All boys probably do. But Bernhard used embers as projectiles. That was fascinating! Just like shooting stars! He and August were shooting in the yard, and went later into the kitchen. There was a hearth with a huge, straight chimney. Bernhard shot upwards into the deep black hole. He even let his younger brother August have a try. But then they got bored, and found something else to do. About half an hour later, there was banging on the windows, and neighbours shouting that the house was on fire. The whole house burns! The embers had fallen upon the thatched roof, and it was all in flames. Now the villagers tried to save the adjoining buildings. The animals were let out. Furniture and other things were carried out of the house. The roof and attic burned down before the fire was stopped. August and Bernhard were sent to next-door relatives and watched awe-stricken as their home burned. Yet the neighbours came to the stricken family's aid. They laid a new roof and repaired the house, and after Christmas it was ready to be moved into again."

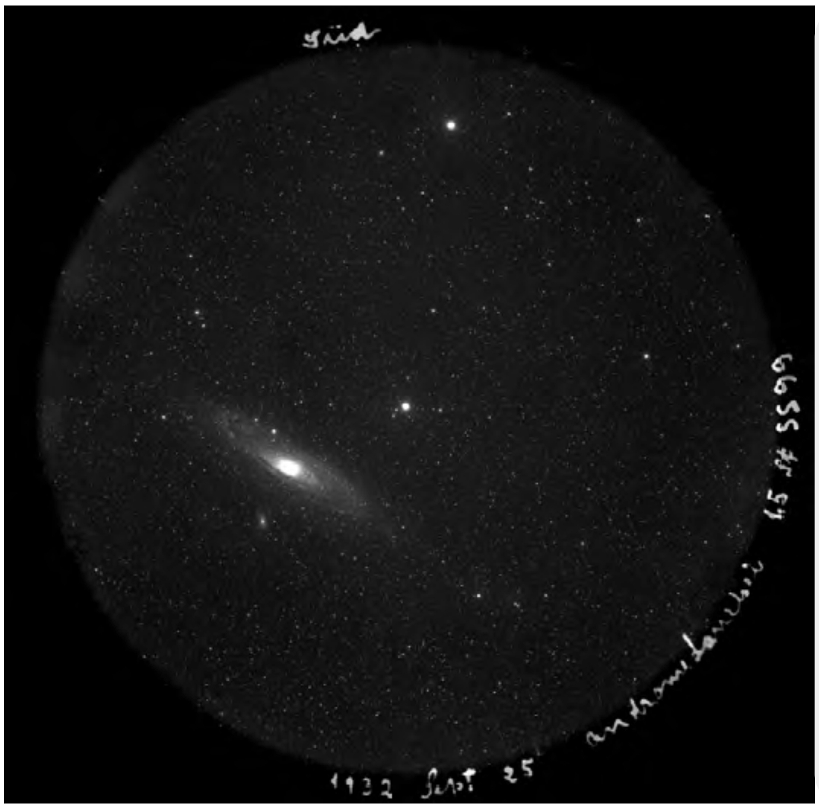
However despite all of these adventures they gave no clue as to the genius which Bernard Schmidt exhibited in later life; which enabled him produce a telescope design of such importance that almost every modern amateur and professional astronomer has heard of, and many of them used. The first sign that he was anything other than ordinary was when he built his own camera and took up photography [9]:

In 1930 when Bernhard Schmidt completed the first Schmidtspiegel he did like many a modern eager amateur with a new telescope, tested it out on terrestrial targets, before pointing it up at the night sky. Two of the known objects he chose for his '*firstlight*' images was a tombstone in a cemetery adjoining the Bergedorf Observatory and the nearby '*Wentorfer Mühle'*, a windmill some 3km distant. Following these successful images the Schmidtspiegel, Schmidt began taking wide field images of astronomical objects.

Wentorfer Mill, Bergedorf, c1932



Schmidtspiegel, 1932: 'Great Orion Nebula' (left); NGC 7000 (right)



For his '*firstlight*' astronomical images, Bernhard Schmidt chose a number famous DSOs, including the '*Great Orion Nebula*' (M42) and its surrounding area; the '*North American Nebula*' (NGC 7000) in the constellation of Cygnus, the Swan; and the '*Great Andromeda Spiral*'. (M31) All three of these objects are large '*wide field*' targets, ideally suited to the capabilities of the Schmidtspiegel's 16 degree field of View. In particular, NGC 7000 and M31 are very large objects, each covering several square degrees of sky.

Although there were at the time a number of Astrographs capable of imaging wide-field objects such as these, they had fields of view which were badly distorted towards their edges, and as a consequence only at best some 70% of the image was usable. However, with the Schmidtspiegel, its field of view was '*flat*' to the very edge.

'Great Andromeda Spiral' (M31), Bernhard Schmidt, 1932

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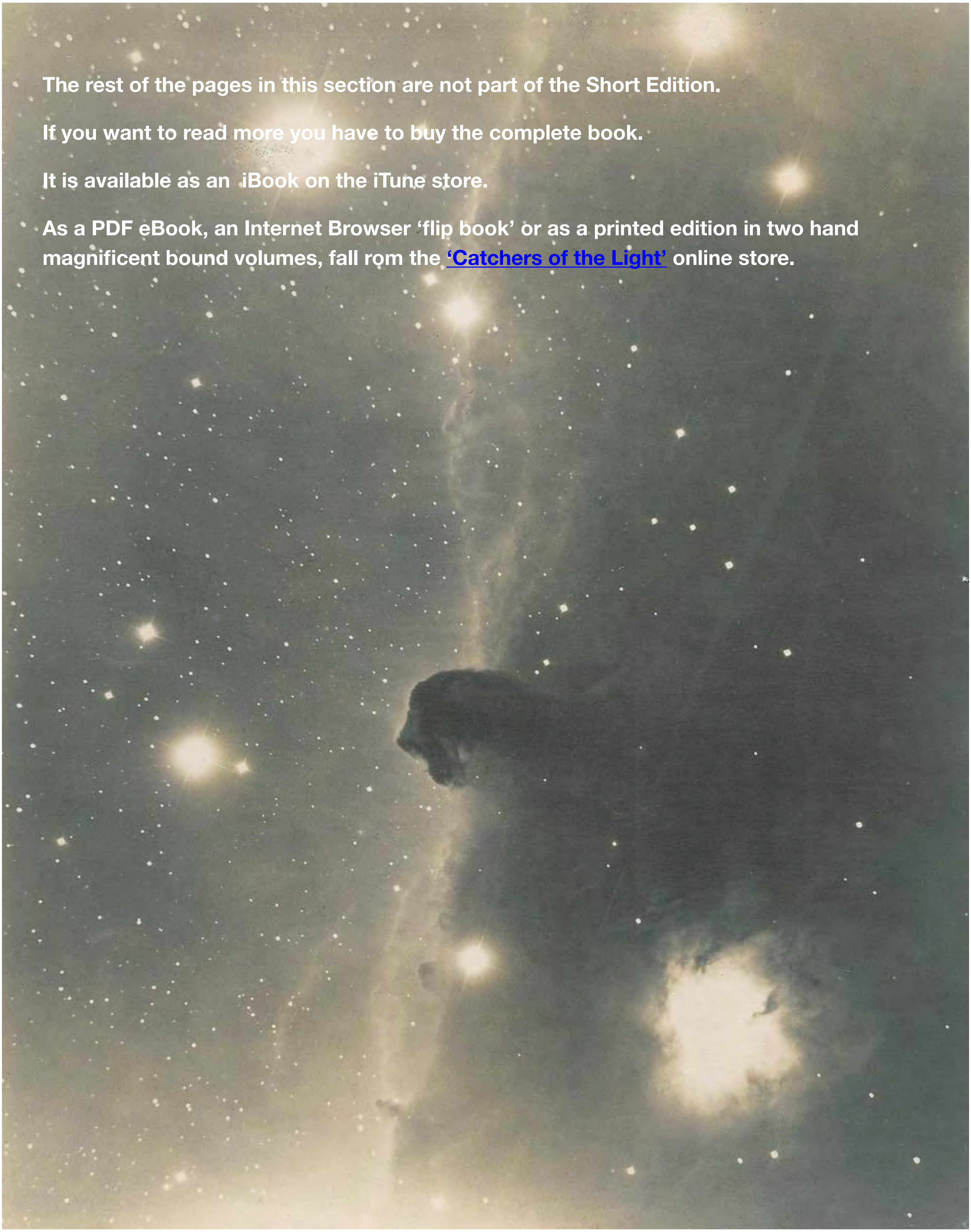


VIII.5

‘HUBBLE, BUBBLE, TOIL & TROUBLE’

Telescopes in Astrophotography

13-inch Astrograph of the Sydney Observatory, New South Wales, Australia

The role of the telescope in the history of Astrophotography has been instrumental to its development from the first primitive images taken by early pioneers such as John William Draper and the Bonds of Harvard to the stunning images captured by the Hubble Space Telescope. At first the *‘Great Refractor’* dominated and were present under the Domes of all the major Observatories; but by the end of the nineteenth century, the era of the large silvered mirrored reflector had begun. These telescopes were constructed from the very outset with Astronomical Photography in mind and form the basis for today’s breed of ‘*Super Telescopes*’.

VIII.5.1 'In the Beginning'

In the early days of Astrophotography little or no attention was given to the many factors which are now known to be essential if a successful image of an astronomical object is to be obtained. The early pioneers such as John William Draper and the Bonds of Harvard were just happy to have taken a photograph which gave a fair representation of their chosen target whether it be the Moon, the Sun or the brighter stars.

It must be remembered that as in any new branch of Art or Science, the early pioneers were the '*shock troops*' so casualties and failures were to be expected. In the 1840s and early 1850s little was known or understood about Photography let alone its interface with a Telescope. It was therefore not surprising that the first Astrophotographers used whatever equipment they had to hand and gave no thought to whether it was the right telescope design to use or that they were using it in the '*correct*' way [1].

As a consequence the earliest astronomical photographs were obtained with a variety of telescope optical systems, for example:

John William Draper's Lunar Photographs of 1839-1840 used a Heliostat which focused the moon's rays onto a Daguerreotype Plate using a 6-inch mirror and a 3-inch lens; his primitive camera being made from a discarded cigar box!;

George Phillips Bond and John Adams Whipple used the 15-inch '*Great Harvard Refractor*' with a Daguerreotype Camera attached at the prime focus to obtain on the 17th July 1850 the first photograph of a star, the bluish first magnitude star Vega (Alpha Lyrae);

William Usherwood captured the first successful photograph of a Comet on the 27th September 1858 with an ordinary portrait camera normally used for weddings and babies!

It was only the later pioneers who recognized, understood and acted on the importance of matching the design of the telescope with the photographic process and the object being imaged [2]:

That the point of focus of a refracting telescope was different when looking through it visually from that when using it with a photographic plate; and that for reflecting telescope designs this was not an issue;

The stability of the telescope mount fitted with a clockwork or electric motor capable of accurately tracking the motion of the stars caused by the diurnal rotation of the Earth;

Making use of telescope designs suited to the type of astronomical object being photographed, e.g. one with a field of view which matches that of the target;

Well balanced optics free from flexure;

An optical tube assembly (OTA) which minimizes the effect of atmospheric turbulence within its interior;

A suitable '*dark site*' location with optimal chance of good seeing and transparency.

A number of large telescopes both refractors and reflectors were constructed during the early decades of Astrophotography which failed to recognize the importance of Photography to the future of Astronomical Research and as a result were designed to be entirely unsuitable for successfully capturing images of the heavens.

It would not be until the early decades of the twentieth century that it would be the norm for new telescopes to be designed with both photographic and visual use in mind. More recently even the visual capability of a telescope was not considered important and as a result many OTAs were built for photographic use only.

Today, the latest breed of '*super telescopes'* are purely photographic and looking through them is something that is just not done - the modern astronomer relies entirely on computers controlling not only the telescope but a whole range of auxiliary scientific instrumentation attached to the OTA.

VIII.5.2 'The Age of the Refractor'

The years which followed the first astronomical photographs of the 1840s and 1850s until the end of the nineteenth century was the '*age of the refractor'*; when this telescope design ruled supreme amongst the '*Great Observatories*' of the world. The use of large reflecting telescopes was relegated to wealthy amateurs such as William Parsons [3], the 3rd Earl of Rosse, and William Lassell, the brewing tycoon [4].

It was a common perception amongst the astronomical community of the day, that those who built silvered mirrored reflectors, and especially the astronomers who advocated their superiority over the glass lens of the refractor, were considered at best misguided individuals or worse still - cranks of the first magnitude.

Furthermore, the great potential photography offered to astronomy was slow to be taken up by the Directors of the Great Observatories. Little attention and even less effort was given by them to the study of the astronomical photographic process, or the photographic design of their equipment or the use of photography in their observing programmes.

There were few exceptions to this, notably William Cranch Bond (1789-1859) and his son George Phillips Bond (1825-1865), the first two Directors of the Harvard College Observatory [5]; and Francoise Jean Dominique Arago (1786-1853), the Director of the Paris Observatory [6].

When John William Draper took his first photograph of the Moon the largest Refractor in existence was the 15-inch Refractor at Pulkovo. Ten years later its twin the 15-inch '*Great Harvard Refractor'* was used by George Phillips Bond and John Adams Whipple to take the first photograph of a star. Over the next half century refractor building continued in America and Europe at almost breathtaking speed – observatories competing to claim the title of '*world's largest refracto*r'. It was '*aperture fever'* in its most virulent strain.

During the last two decades of the nineteenth century, the tide of refractor building in America culminated in the erection of the great, but purely visual 36-inch Lick and 40-inch Yerkes refractors. The European observatories were more forward looking and found room for new and larger instruments which were both visual and, whenever possible, photographic. Even as late as the 1880s large refractors were still being built which were designed solely for visual use, such as the 26.8-inch at Vienna and the 30-inch at Pulkovo [7].

Several methods were employed to make one mounting serve both visual and photographic purposes, including [8]:

1.**Twin Tubes**; when funding permitted, twin lenses and tubes were adopted; the 33-inch visual and 24.4--inch photographic twin telescope at Meudon is the largest and heaviest of this type;

2.**Interchangeable Objectives**; a less satisfactory alternative was to supply a single tube with two interchangeable objectives, one photographic and one visual, The Henry brothers furnished the 23.6--inch Equatorial Coudé at the Paris Observatory with two such alternative object-glasses;

3.**Correcting Lens**; or to place '*correcting*' lens into the OTA in addition to the visual objective; for example a 33-inch correcting lens was made for the 36-inch Lick refractor, although it was rarely used;

4.**Reversible Objective;** a fourth arrangement, a rare one, was to design the objective so that the front lens could be reversed. This was used unsuccessfully in the 28-inch Grubb refractor at Greenwich;

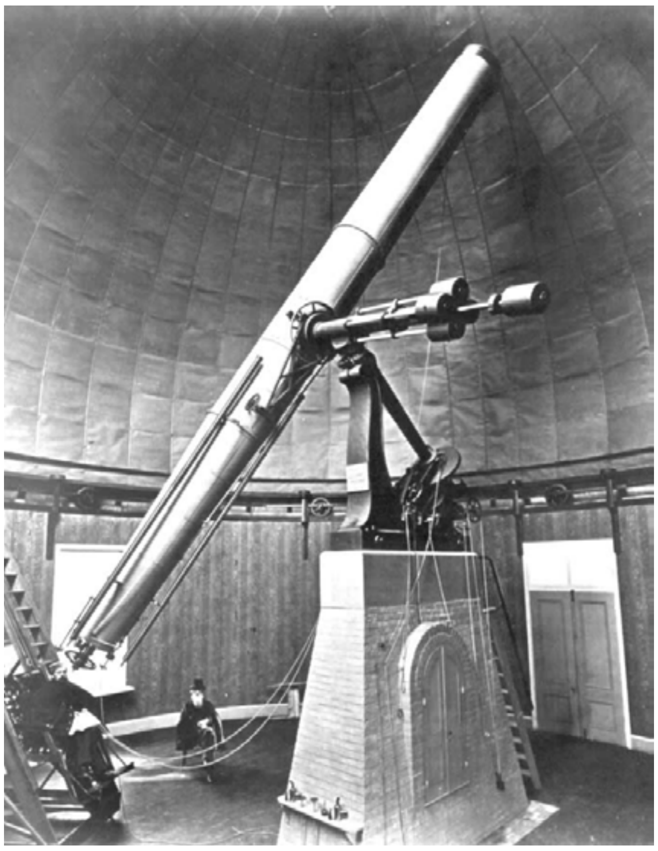
5.**Photographic-Visual**; when a corrector lens is used to transform a purely photographic refractor to one suitable for visual observations; Brashear's 30-inch Thaw photographic refractor at the Allegheny Observatory is of this type, here a 12-inch visual corrector is inserted near the middle of the length of the tube.

The introduction of visual isochromatic (yellow), orthochromatic (except red) and panchromatic (all colours) dry plates in the late 1890s and early 1900s made it possible for a visual refractor to be used photographically merely by the addition of a yellow filter.

This was the case with the 40-inch Yerkes Refractor which was an instrument designed for visual use, but could be easily converted for photography by this simple solution, as described by George Willis Ritchey [9]:

"The photographic attachment consists of a double-slide plate-carrier for guiding, on which is supported the plate-holder containing a yellow color-screen or ray-filter very nearly in contact with a yellow-sensitive (Cramer instantaneous isochromatic) plate. The yellow screen freely transmits to the sensitive plate the sharp and intense yellow or visual image produced by the visual objective, and effectually excludes from the plate the blue and other wave-lengths of light which are not included in the visual image, and which would entirely destroy the sharpness of the photographs.

Two very fine 8 X 10-inch yellow screens, one of slightly stronger tint than the other, were obtained after some experimenting. Each screen consists of two thin plates of glass, ground and polished approximately flat; one of these is coated with a film of collodion of a delicate yellow tint. After the collodion film is dry it is flowed with Canada balsam, and the second thin plate, which serves as a cover-glass, is put on. The two plates are bound together with adhesive tape. The screens are brilliantly transparent. When in use one of the screens is placed in the plate-holder directly in front of the yellow sensitive plate. Screen and plate are separated only by the thickness of the binding tape around the edges of the former."



24.5-inch Newall Refractor (left); 26-inch Refractor, USNO, Washington (right)

18-inch Dearborn Observatory Refractor, 1903

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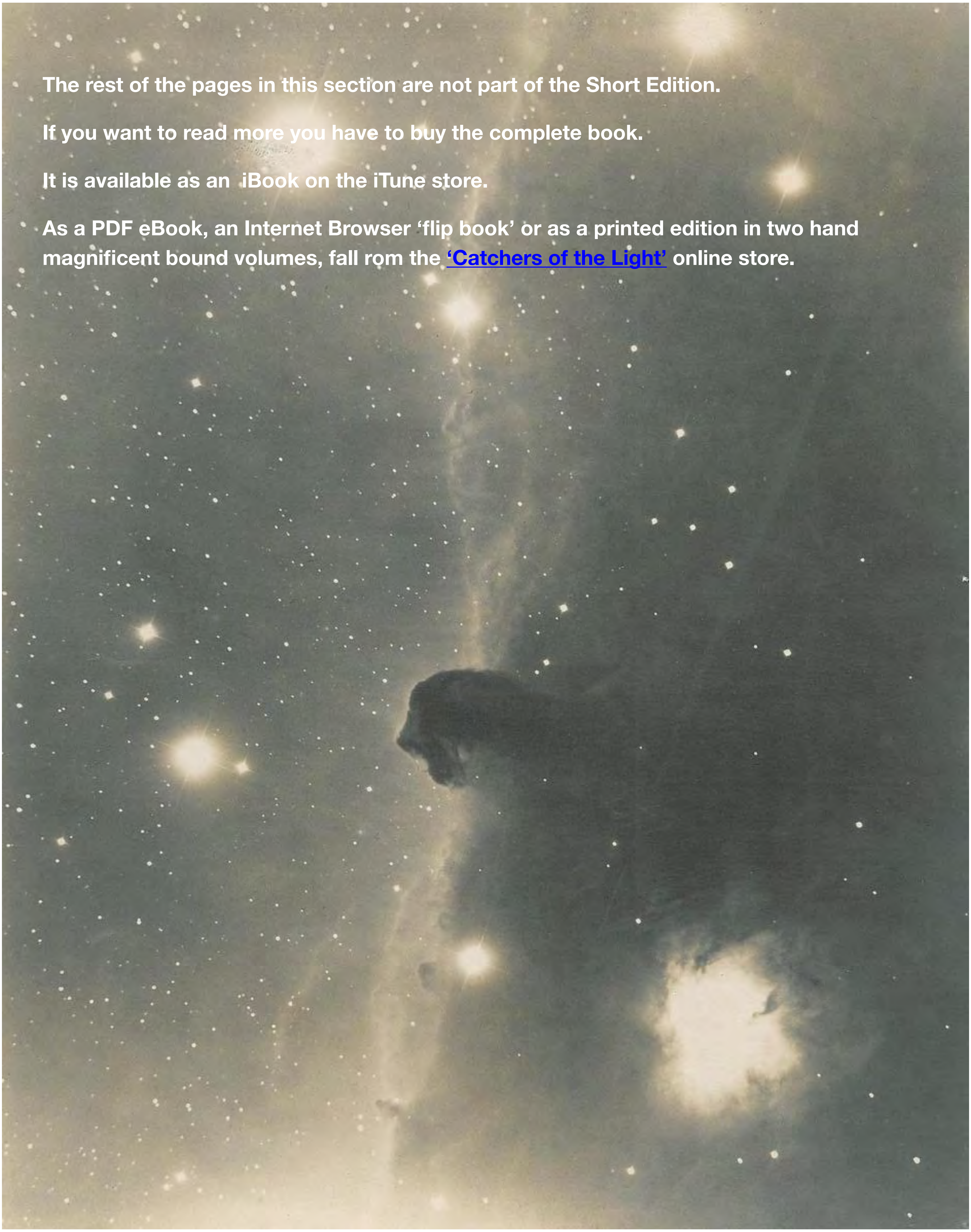


Short Edition

Part IX

Amateur

The Modern Digital Age

Modern *'Very Amateur'* CCD Image of the 'Crab' Nebula in Taurus taken with an SBIG ST 2000XM/XCM CCD and an 11-inch NextStar SCT

The CCD Chip has revolutionized modern Astrophotography beyond all recognition from the seemingly crude attempts made by the early pioneers of the 19th century to the magnificent coloured images of the modern digital camera. As to what will happen in the next two centuries of Astrophotography is anybody's guess, but whatever happens, nothing can take away the work of those described in these pages.

They were the 'Catchers of the Light'.

IX. Amateur

The modern amateur Astrophotographer using only modest equipment to obtain images better than larger but outdated telescopes first appeared the persona of Eugen Von Gothard, a wealthy and talented scientist from Hereny in Hungary.

On the 1st of September 1886, Von Gothard took a photograph of the famous '*Ring*' nebula (M57) in the constellation of Lyra using a '*mass produced*' 10.25-inch reflector made by John Browning of London. His photograph clearly showed its faint 15th magnitude central star, a feat only possible visually by instruments much larger than his.

This photograph heralded the rise of the amateur in astronomical photography, who not only took high quality images, but ones which of scientific importance, all with the aid of affordable instruments with apertures of sizes bordering on the small.

The appearance of Von Gothard's photographs caused a supernova like effect on the astronomical community. Herman Carl Vogel, the Director of the Potsdam Observatory went so far as to express the opinion that the *'photographs of Herr von Gothard's taken with this comparatively small instrument show results which far surpass any obtained by eye observation with the largest telescope*'.

In the years to come Von Gothard was joined by other equally remarkable amateurs, like Alfred Rordame, a violinist from Salt Lake City, Utah, who photographed in 1921 features in the cloudy atmosphere of the planet Venus; or another violinist, the elusive Marcel De Kerolyr (1873-1969) who took during the years from 1929 to 1934 perhaps the finest pre-digital images of Deep Space Objects.

De Kerolyr's 1932 wide field image of the region surrounding the iconic '*Horsehead*' nebula in Orion, obtained with an 80cm telescope is perhaps the leading contender for the title of '*Greatest Astronomical Photograph'* of all time.

However, the greatest advance of the amateur in Astrophotography came in the years which followed the invention of the Charge Coupled Device or CCD in 1969. In 1974 the first digital image of an astronomical object - the Full Moon was obtained with an 8-inch reflector and a CCD chip possessing a resolution of only 10,000 pixels.

In the 1990s the first amateur astronomical CCD cameras began to appear. These relatively primitive devices had pixel resolutions measured in the 100,000s, but nevertheless could be linked to a personal computer for image acquisition and processing functions.

The coming of the twenty-first century saw even greater advances in amateur CCD technology, when the first budget cameras were introduced alongside research quality megapixel models for those with deeper pockets.

This seed change in CCD technology coupled with the availability of high quality telescopes of Schmidt-Cassegrain design, sturdy computer controlled mounts fitted with accurate GOTO/Tracking DC Servo motors brought about a revolution that changed the practice of Astrophotography beyond all recognition.

The introduction of Personal computers with fast processor chips and large storage discs from the late 1990s onwards; which when used with sophisticated image acquisition and image processing software provided the amateur with additional and much needed essential resources.

The modern amateur possessed of only modest equipment of the kind previously described, is now able to take images of the Moon, Planets, Comets, Star Clusters Nebulae and every other kind of object to be found in the heavens with a quality that the early pioneers of astronomical photography probably had never even dreamt was possible. The magnificence of these images was beyond even their pioneering comprehension and imagination.

What is even more remarkable is that these images are regularly taken on a daily basis, not by just one or two amateurs but thousands in every corner of the world. The images they capture are infinitely superior to those obtained in the 1970s by the '*Great Reflectors*' atop the mountains of California using conventional photographic emulsion based glass plates, at a time when the '*firstlight*' of a photon hit a CCD chip.

"The average amateur photographer doubtless takes a passing interest in the beauties of the night sky, and nearly every amateur astronomer of my acquaintance is a dabbler in photography. Many seem to be deterred from combining the two hobbies by the impression that nothing can be done without very elaborate and costly apparatus, an impression which the perusal of the average astronomical textbook does little to remove.

*Yet photographs of comets, the Milky Way, etc., from which valuable scientific results have been deduced, have been secured with simple and inexpensive apparatus of a portable character. One of our greatest living astronomers, Professor G. E. Hale, states, '**The results of amateur observations may not only be useful—they may equal, or even surpass, the best products of the largest institutions**'."*

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

M78 in Orion - Gordon Haynes (2015)

IX.1

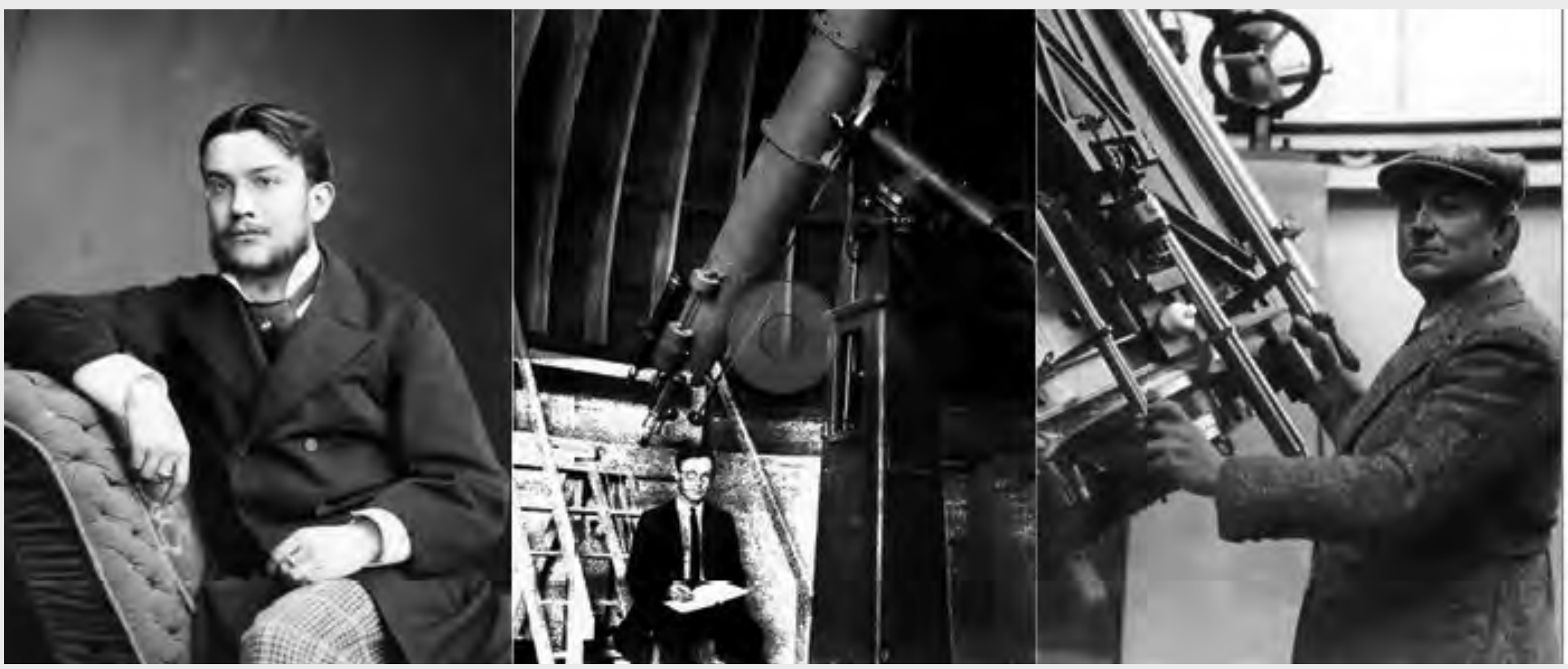
‘Lord of the Ring Nebula’

The Pioneers of Amateur Astrophotography

Eugen Von Gothard: Born 31st May 1857, Herény, Vas, Hungary
Died 29th May 1909, Herény, Vas, Hungary

Alfred Rordame: Born 8th of June 1862, Oslo, Norway.
Died: 30th November 1931, Salt Lake City, Utah, USA

Marcel De Kérolyr: Born 1873. Died 1969



On the 1st of September 1886, a Hungarian amateur astronomer named Eugen Von Gothard using a *‘mass produced’* **10 inch reflecting telescope photographed for the first time the central star of the famous *‘Ring Nebula’* (M57) in the constellation of Lyra. This photograph heralded the rise of the amateur in Astrophotography. Prior to this date *‘celestial photography’* was the sole province of the wealthy or the professional astronomer who owned or had access to large and expensive custom made telescopes. He was the first true pioneer of amateur Astrophotography. Following him were the likes of Alfred Rordame, who was the first person to photograph features on the cloud shrouded planet Venus; and Marcel de Kérolyr, whose photographs were the equal if not better than all who came before him and many of those who followed him.**

IX.1.1 Rise of the Amateur

The average modern amateur Astrophotographer owns a modest telescope, either a refractor with an aperture of between 3-inches (7.5 cm) and 6-inches (15 cm) or a reflector/catadioptric with an aperture of typically 6-inches to 12-inches (30cm). However, the early pioneers of Astrophotography were either wealthy amateurs or professional astronomers who used telescopes with apertures considerably larger than the average modern imager.

From the 1880s onwards a new breed of Astrophotographer began to appear, who with the aid of telescopes of moderate size, took photographs of astronomical objects which showed detail that even the '*Great Refractors*' of the age were hard pressed to see. This as you can imagine was a revelation that the astronomical establishment found hard to swallow, but nevertheless it sent a clear message which echoed around the Domes of their Great Observatories, which said: when you build a new telescope ensure that has a photographic capability and not one designed solely for visual use!

The evidence for this assertion was clear for all to see at the time. Wealthy amateurs such as Andrew Ainslie Common and Isaac Roberts were regularly exhibiting their astronomical photographs at meetings of the Royal Astronomical Society during the 1880s onwards [1]. However, what really shocked the astronomical community was that their efforts were taken with mirrored reflecting telescopes, albeit with large apertures ranging from the 20-inch of Roberts to 36-inch of Common.

In the last two decades of the nineteenth century the *'Great Refractor'* ruled supreme under the domes of the world's elite Observatories, at Lick and Yerkes in America, at Pulkovo in Russia, at Meudon and Nice in France and at Greenwich in England [2]. No mirrored telescope was ever considered good enough to be given dome space by the Directors of these venerable institutions. Even when Carpet Tycoon, Edward Crossley donated, Andrew Ainslie Common's 36-inch reflector to the Lick Observatory in 1895, it was only politely accepted by its Director, Edward Singleton Holden, but never used during his tenure of office [3[.

However what rooted the world's astronomical elite to their eyepiece and which shook the very foundations of their astronomy, was a photograph taken by a Hungarian amateur named Eugen (Jeno) Von Gothard (1857-1909). On the 1st of September 1886, he obtained a photograph of the famous planetary nebula in the constellation of Lyra known as the '*Ring*' Nebula (M57). It was a remarkable photograph not only for the fact it was the first ever taken of this beautiful 's*moke ring*' in space, but more importantly it showed its 15th magnitude central star.

The significance of this was not lost on all who saw or read about Von Gothard's photograph. This star at that time could only be seen under the best conditions with only the largest of telescopes, but for it to stand out like a tiny bright torch amid the black velvet of the night sky and be revealed so easily by a mere 10-inch mirrored telescope must have caused many a missed heart beat of Observatory Directors across the world.

Eugen Von Gothard's epic photograph heralded the rise of the ordinary amateur Astrophotographer. He was the first of his kind, and was soon to be followed by others; few at first but in the coming decades more and more appeared. These amateurs obtained photographs which were not only of exceptional quality but more importantly produced scientific results of importance to their professional '*betters*'. Alfred Rordame (1863-1931) and Marcel De Kérolyr (1873-1969) were two other members of this pioneering breed of amateur Astrophotographers.

It was Rordame an amateur from Salt Lake City, Utah,who obtained in 1921, photographs of the planet Venus, which for the first time showed conspicuous features on its cloud shrouded disc, using only a 9-inch refractor and a 16-inch reflector. This was six years before Frank Elmore Ross (1874-1960) obtained similar images with the '*Great*' 60-inch and 100-inch reflectors atop Mount Wilson in California.

De Kérolyr was a self-trained French amateur, who in the 1930s took some of the finest astronomical images ever captured of such iconic objects as the '*Horsehead*' Nebula (B33) in Orion and the '*Whirlpool*' Galaxy (M51) in Canes Venatici, with telescopes much smaller than used by many of his professional colleagues.

Today, their names have long been forgotten, but in the pages that follow they will live again and each will be given the chance to tell their incredible stories.

IX.1.2 Eugen Von Gothard (1857-1909)

Eugen '*Jeno*' Von Gothard was born on the 31st of May 1857 in the village of Herény, near Steinamanger, Hungary, the eldest son of the wealthy land owner Stephan Von Gothard. From an early age Jeno exhibited a great interest in physics, which he inherited from his father; who had been in turn inspired by his father Francis von Gothard. Jeno's grandfather was a lifelong devotee of scientific experiments, which he conducted avidly for some fifty years from 1780 to 1830. It was therefore, no surprise that through the enthusiastic encouragement of their father, Jeno and his younger brothers Alexander (1859-1939) and Stephen (1869-1948) would devote their lives to scientific research.

Jeno's secondary education began at the gymnasium at Szombathely, where he avidly studied physics and anything mechanical. He carried out experiments with steam engines and electric motors in a small laboratory which his father had provided for him. In 1875 at the age of eighteen, he left the gymnasium for Vienna, to continue his studies in the Department of Mechanical Engineering at the Politechnische Hochschule. During his time at Vienna he attended lectures on Astronomy given by Professor Wilhelm Robert Tinter.

After completing his studies in 1879 he travelled abroad for a year or so before returning to his estate at Herény, with the intention of setting up his own Physics Laboratory. However he changed his plans, partly because of his now awakened interest in Astronomy and also because of the influence of his friend, the astronomer, Dr. Nicolaus Von Konkoly (1842-1916). Jeno decided instead to add an Astronomical slant to his proposed Physics Laboratory and so it came about that on the 20th of October 1881, the first observations were made at the newly inaugurated Herény Astrophysical Observatory.

Within a year of seeing '*firstlight*', Jeno Von Gothard's Observatory was making useful scientific contributions and in 1884 it published its first report on the work carried out during its first two years of operation. In 1884, '*Science*' magazine published a review of the Herény Astrophysical Observatory's first report, in which it provides a detailed description of the observatory, its equipment, personnel and research activities [4]:

"The astrophysical observatory of Herény has recently issued its first volume of publications, prefaced by the director, von Gothard, with a graceful tribute to his friend, the well-known Dr. von Konkoly.

The observatory is situated on the estate of Herény, near Steinamanger, in the western part of Hungary. The main building was finished in 1881, and is of two stories, with a tower for the equatorial at one corner: a smaller building receives the transit instrument. The rooms are all admirably planned and arranged to promote the comfort and efficiency of the observers. In the upper story we find an office, a room for the director, and a large, well-appointed physical laboratory. On the ground-floor there are, besides two smaller rooms, a chemical laboratory fitted with many conveniences, and a workshop. The workshop, a feature in which most of our observatories are deficient, is supplied with tools intended not only for making minor repairs, but for constructing many valuable pieces of apparatus; and what is even more valuable, as it is unusual, the director and his assistants appear to be skilful mechanics.

The principal instrument of the observatory is a Newtonian reflector by Browning, of ten and one-fourth inches aperture, which is provided with a very complete outfit of photographic and spectroscopic accessories. A little portable transit of about an inch aperture, the object-glass of which is by Fraunhofer, and the mounting by Reichenbach, is used for determining time. There are two astronomical clocks by Freitag, a set of meteorological instruments, and a large collection of subsidiary physical apparatus. The library, though still small, is steadily increasing.

The director of the observatory, Eugen von Gothard, is assisted by his brothers, Alexander and Stefan von Gothard, and by Josef Molnar. The observations in the present volume are, for the most part, upon the spectra of the fixed stars. In 1881 and 1882 the spectra and colours of nearly three hundred fixed stars were examined, and the stars classified according to Vogel's types. Spectroscopic observations, and observations of a generally descriptive nature, were also made of Wells's comet, the great comet of 1882, and Barnard's comet.


The two younger brothers of Eugen Van Gothard, Alexander (1859-193) and Stephen (1869-1948) were also two talented scientists who helped him with his work at the Herény Astrophysical Observatory. While Eugen concentrated on Astrophotography and Spectroscopy, Alexander made visual observations of the planets Mars and Jupiter, and made a number of fine drawings of them. Stephen collected meteorological Data for use by his brothers in their work.

Alexander Van Gothard (1859-1939); Stephen Von Gothard (1869-1948)

Baron Dr Nicolaus Konkoly (1842-1916) was a major influence on the life of the Von Gothard brothers and in particular Eugen. He advised Eugen to set up an Astrophysical Institution at Herény and provided it with some instruments from his own Observatory. Konkoly had acquired an interest in science at an early age and from 1858 to 1860 he studied Astronomy and Physics at Pest (now Budapest). He then continued his studies in Berlin under Johann Franz Encke, Heinrich Wilhelm Dove and Heinrich Gustav Magnus.

In 1871 he began astronomical observations from the balcony of his castle at Ogyalla. He later built his own private observatory in 1874 and expanded it in 1879, complete with three magnificent domes. From his Observatory he began in 1874 a programme of astronomical research in Spectroscopy, Photometry, Photography and Solar Physics. He became well known at the time for his 1876 and 1887 catalogues of stellar spectra. He also made extensive photographic observations of the Sun, from 1872 to 1916.

Miklós Konkoly Thege (1842-1916)

John Browning (c1833-1925) was born in Welling, Kent around 1833 and became one of the leading scientific instrument makers of his time. His clients included the Royal Observatory at Greenwich and the Kew. Observatory. His Trade Card pronounced that he was ‘*Optical & Physical Instrument Maker to Her Majesty’s Government*’.

He was also responsible for making a number of Spectroscopes for the astronomer Sir Norman Lockyer. Following the death of his father William Browning in 1862, he inherited the family business of Spencer, Browning & Rust at No. 111 Minories, London (near Tower Hill) and its factory at No. 6 Vine Street; which he had in fact been running since about 1856. He later in the 1870s had premises at various addresses in the Strand and a factory in Southampton Street, London. Sometime after 1901 he retired from business and moved to Cheltenham in Gloucestershire, where he died in 1925.

John Browning (c1833-1925), London Scientific Instrument Maker

IX.1.3 Alfred Rordame (1863-1931)

Alfred Rordame (1863-1931) arrived in America in about 1880 [14]. He had been born on the 8th of June 1862 in Akershus, near Oslo, Norway, the son of Jacob Rordame and his wife Karoline Simmonsen [15]. The first mention of him in official records is on the 4th of June 1880, when he is recorded in the US Census as living in the mining town of Eureka, Nevada and working as a violinist [16].

It is highly likely that he worked at one of the '*hotels*', brothels or lodging houses built to support the town's bulging population of some 10,000, swollen by the thousands of miners who had arrived following the discovery of large seams of lead and silver in '*them there hills*' [17]. The population of Eureka reached a peak in 1878 and after then went into a steady decline as the mining seams dried up as did the wealth it brought.

By 1884 Alfred Rordame had left Eureka to live in the Mormon stronghold of Salt Lake City (SLC), Utah, where he remained for the rest of his life. Several generations of Rordame have since been born in Brigham Young's city and many still live there up until the present day [18]. Once settled in SLC he took up his violin again and began to play for the local Symphony Orchestra and take up again his interest in astronomy, which he had acquired prior to coming to America.

In an article he wrote in 1912, he recalls how first became interested in Astronomy, as well as commenting on the sad state of the world , a century ago. His words I have to admit are as true today as they were then [19]:

"In school, as a little boy, I had my first introduction to astronomy, when the old fashioned geography in use in those days was placed in my hands. The preface contained a short description of the solar system and the earth as a planet. It opened a vista of grandeur to my youthful mind that has grown with the years, until the contemplation of the universe has, by the aid of the telescope, come to be a source of intense pleasure, as well as affording a means of refuge from all the sordid cares and vexations of ordinary life. I hold that it is a duty we owe to our families as well as to ourselves, to try to beautify our lives as much as possible. As a nation, we are continually grubbing in the dirt of politics and business instead of exercising the esthetic qualities of our minds; the qualities by which we are enabled to look out upon nature, and by which alone we are distinguished from the other animals."

On the evening of the 8th of July 1893, Alfred Rordame was returning home after performing in a concert, when he noticed an unknown object in the obscure constellation of the Lynx [20]. What he saw turned out to be a new comet, now known as C/1893 N1 Rordame- Quénisset. He at once reported his discovery to the Warner Observatory in Rochester, New York, and within a day or two the news had been communicated to astronomers throughout the world. The comet had been discovered independently about the same time by the French astronomer, Ferdinand Quénisset (1872–1951), whose name it now shares with that of Rordame. It had also been seen previously as a '*hazy star*'; and in the preceding June it had been observed by an amateur astronomer, who mistook it for an already known comet!

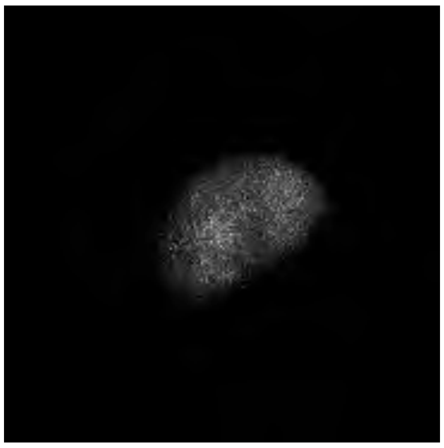
Sometime around 1910, Alfred Rordame began taking Astronomical photographs with a variety of telescopes and portrait cameras. In 1911 he described the results he had obtained with his simple equipment [21]:

"Perhaps the majority of students of astronomy are of the opinion that, in order to make photographs of the heavens, the very finest of apparatus must be used. While it is conceded that of two cameras, the one specially made for celestial photography by eminent opticians will produce the best results, yet good pictures can be made with ordinary portrait lenses, which nowadays may very often be purchased for a trifle at some of the older photographic studios throughout the country. The apparatus I have used in celestial photography is of the simplest possible construction, consisting of a square box of wood, painted black outside as well as inside, to which the lens, a Darlot of 3 inches aperture and of ten inches focus, is securely fastened. This box is made in two sections, one sliding within the other, making it adjustable for focusing."

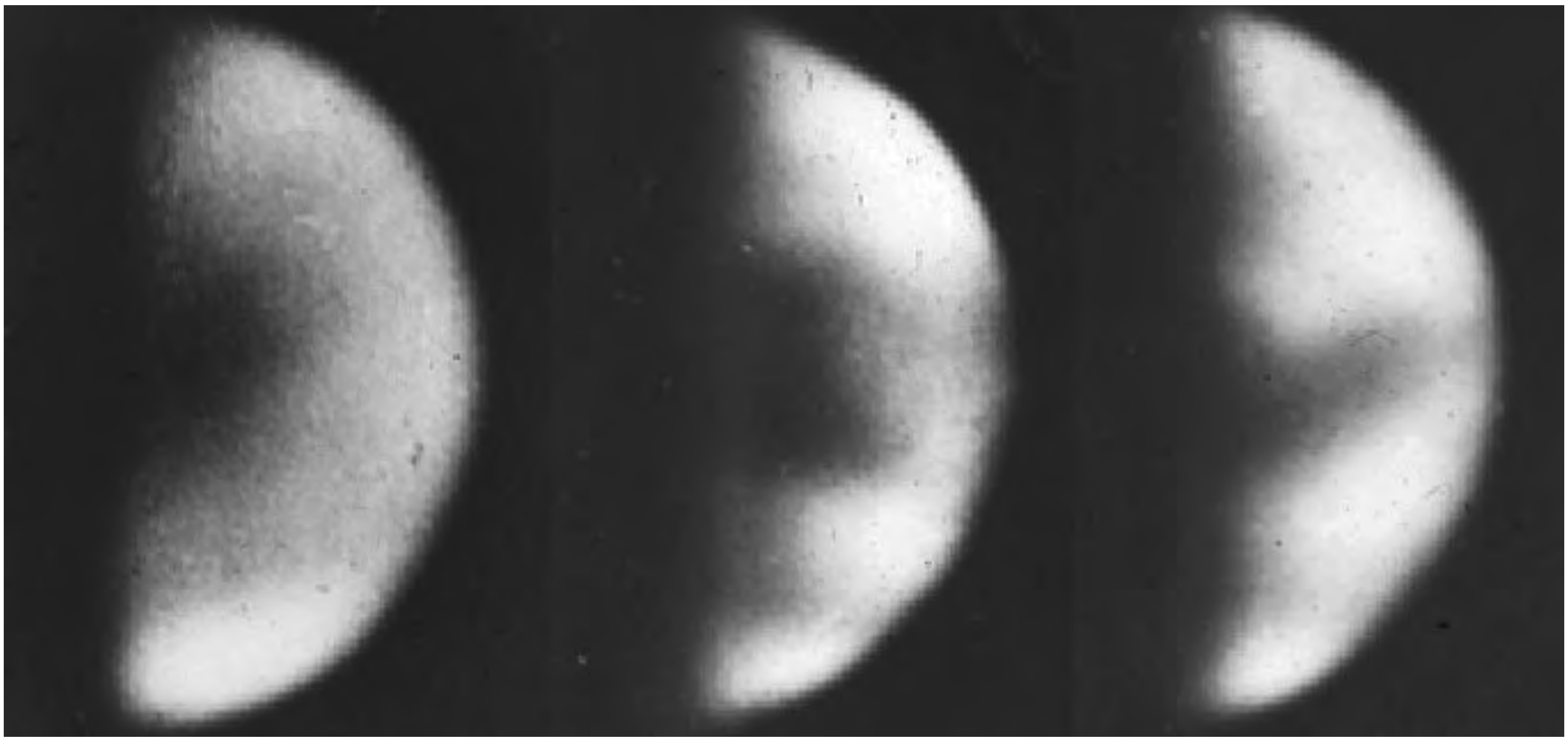
He then went onto describe his method of '*focusing*', the mount used and the photographic process adopted [22]:

"It is no use trying to focus on the stars; the best way is to expose several plates, until the star trails show as the finest lines. Most portrait lenses are lacking in a flat field, and it becomes necessary to compromise on the roundness of the field and focus sharply at a little distance from the center; this will tend to make it sharpen all over, at the expense of the center...

Alfred Rordame was one of the most prolific observers of the planet Venus who ever lived: *"I have observed Venus daily, when visible and not obscured by clouds, for a period of nearly 20 years, with telescopes varying in aperture from 4 inches to 16 inches. In that time I have made thousands of sketches; but the majority of them show only the phase, with perhaps brilliant spots at the horns of the crescent and a shaded terminator. On less than fifty occasions have I seen decided and unmistakable markings and on six occasions only has a positive movement of the spots been observed."* He was also the first to photographs in the March of 1921 markings in a cloudy atmosphere.



Venus, 9-inch Alvan Clark Refractor, Alfred Rordame, 17th July 1921



Venus in Ultraviolet Light, Frank Elmore Ross, Mount Wilson Observatory, 1927

Alfred Rordame (1862-1931) was one of the most astounding amateur astronomers of his age who used photography to obtain results, which were professional in their quality. He wrote a number of exceptional articles which were published by the Astronomical Society of the Pacific of which he was a long standing member. On his death the society published the following obituary (which included some minor errors):

"Alfred Rordame, known for his discovery of a comet in 1893 and for his work as an amateur astronomer, died suddenly from a heart attack on November 30 at his home in Salt Lake City. Mr. Rordame was born in Oslo, Norway, in 1862, where he studied music and at the same time showed a lively interest in astronomy. At the age of twenty he came to the United States and settled in Salt Lake City, Utah, where he played for a time in the symphony orchestra. It was when returning one evening from a concert that he discovered with the unaided eye the comet which has since borne his name. He was a member of the Astronomical Society of the Pacific and of the British and French Astronomical Societies."

He was also a talented violinist and musician, qualities which have been passed down the generations to his great grandson, Alfred Rordame IV, but above all he was a free thinker who cared much about Astronomy, Life and the Universe.

"Our own insignificance becomes painfully manifest upon contemplation of this fact; and further, that the earth is absolutely invisible to an inhabitant of a planet, should it exist, revolving around Alpha Centauri. And yet, mankind stew and worry about their own little affairs, and are ready to kill one another for a difference of opinion. In the Great Universe the earth is unknown and the sun itself is merely one of the innumerable small luminous points helping to make up the misty radiance we call the Milky Way."

Alfred Rordame, 10th October 1912, Salt Lake City.

IX.1.4 Marcel de Kérolyr (1873-1969)

Almost nothing is known of the life of Marcel Bonnemain De Kérolyr (1873-1969), with one single most important exception, and that is – he was without question, one of the greatest Astrophotographers of all time.

Much of the little we do know, we owe to the late Pasteur Andre Richardot, founder of the Sabarat Observatory in Daumazan-sur-Arize, France [29]. We do not know for certain when Marcel De Kérolyr was born According to Richardot, he died in 1969 in a nursing home on the Cote D'Azur, France, but of this we too cannot be certain.

A search of the usual Genealogical sources reveals nothing of him or his family. The International Genealogical Index does not have a single entry for the surname De Kérolyr or Kérolyr, nor do any of the large Internet family history databases. Marcel De Kérolyr is a shadowy figure as ghostly and as difficult to capture as the nebulae he photographed. He does however, show himself through his work and his photographs. We unfortunately have to be content with this alone.

Marcel Bonnemain de Kérolyr was born in 1873, neither the location nor even the country of his birth are known to us. In his younger days he earned his living as a talented professional violinist. He married a singer and acted as an accompanist to his wife. Together they toured Europe in a carefree period before the First World War, even giving a recital before Tsar Nicholas II and the Tsarina Alexandra Feodorovna Romanova, before their unfortunate, but not unexpected demise on the 17th July 1918.

Between tours the De Kérolyrs, lived in a mansion on the celebrated '*Promenade des Anglais*' at Nice, where they lived the 'good life', often entertaining friends and celebrities. On the night of the 14th of September 1927, when leaving their home, they witnessed directly in front of them, the tragic death of the notorious American dancer Isadora Duncan (1877-1927). According to her obituary in the New York Times [30]:

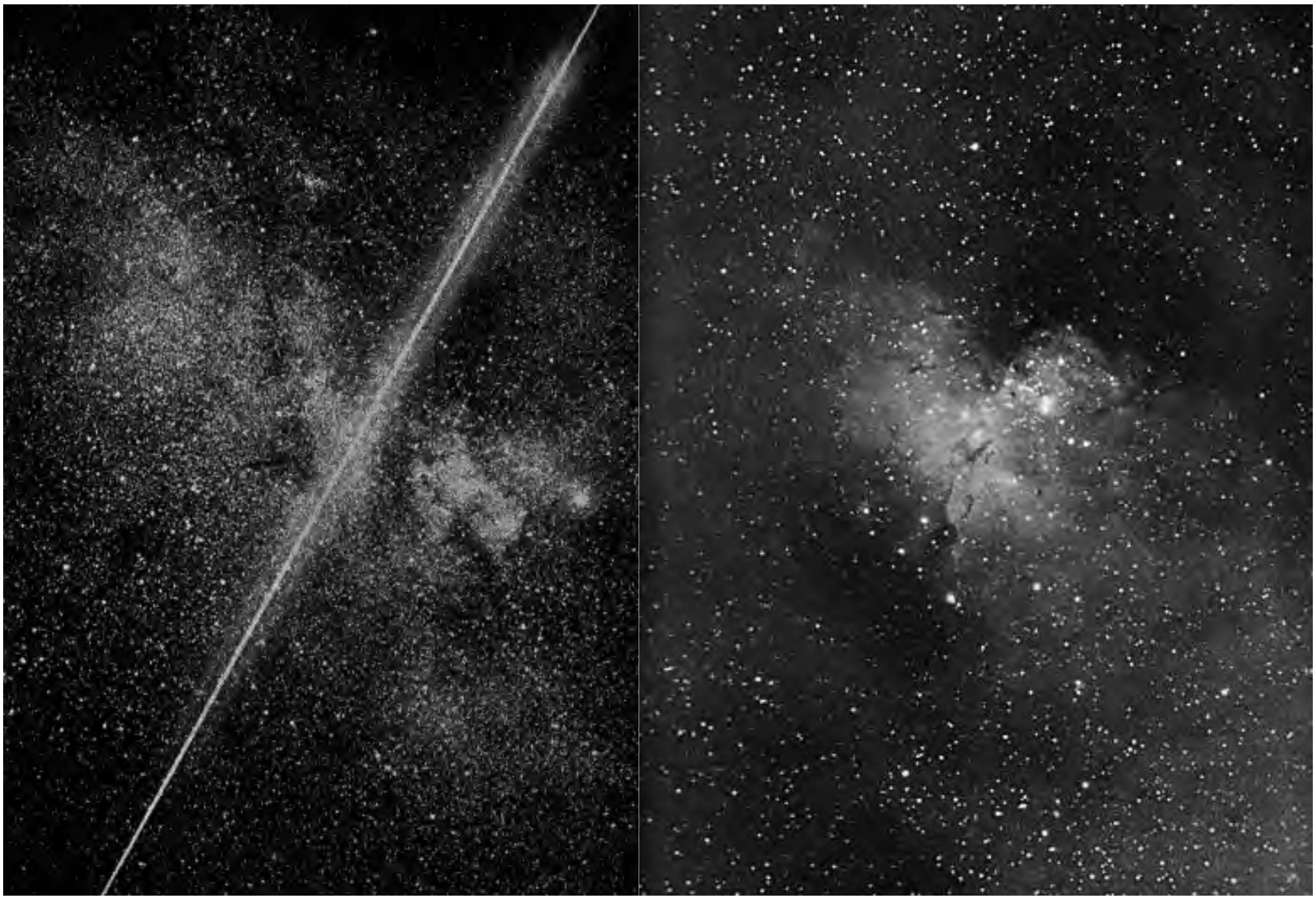
"*Isadora Duncan, the American dancer, tonight met a tragic death at Nice on the Riviera. According to dispatches from Nice, Miss Duncan was hurled in an extraordinary manner from an open automobile in which she was riding and instantly killed by the force of her fall to the stone pavement*."

However, the cause her death was in reality her fondness for flowing scarves. On the night of her death she had been a passenger in the Amilcar automobile of a handsome French-Italian mechanic named Benoît Falchetto, whom she had nicknamed Buggatti (sic). As they drove off the large silk scarf draped around her neck became entangled around one of the vehicle's open spoke wheels and rear axle. It was reported at the time that her head was nearly ripped off her neck by the sudden jolt as she was catapulted out of the car.

The death of Isadora Duncan marked the beginning of a difficult time for the Kérolyrs. Madame De Kérolyr lost her voice, and was also found to be suffering from chronic anaemia. They could no longer tour or give recitals, there were to be no more fees. For them the '*good life*' had ended. Somehow, they managed to survive by selling their furniture and pictures, and Madame De Kérolyr's jewelry. Marcel De Kérolyr became profoundly depressed and even considered suicide at one point.

It appears that Marcel De Kérolyr had by the late 1920s acquired an interest in Astronomy. He had already visited the Nice Observatory and seen its '*Great Refractor'* 77cm (30.3-inch), but his enquiring mind wanted more. He later met up with an amateur astronomer named Georges Raymond, who convinced him that he should devote the rest of his life to astronomy, and in particular to astronomical photography. So it was that with a few objective lenses he had acquired, Kérolyr went in search of an optician and together they built his first telescope. At his home in Nice he also had built, a small *'Astrophotographic Installation*'.

Sometime around the October of 1927, the Kérolyrs managed to scrape together enough money to buy a house at Digne in the Alpes de Haute Provence. It was an excellent location for an observatory with its then almost perfect atmospheric transparency. This was in the days before the world was cursed by the ubiquitous and totally unnecessary neon light. Here Marcel De Kérolyr built what became known as the *'Astrophotographic Station at La Haute Provenance*'. It was not long in operation before its existence was brought to the attention of the astronomical community.



Fireball in Cygnus, 13th Aug 1928; ‘Eagle Nebula in Serpens Caput

Pleiades Nebulosity, 80cm Reflector, Marcel de Kérolyr, 1932

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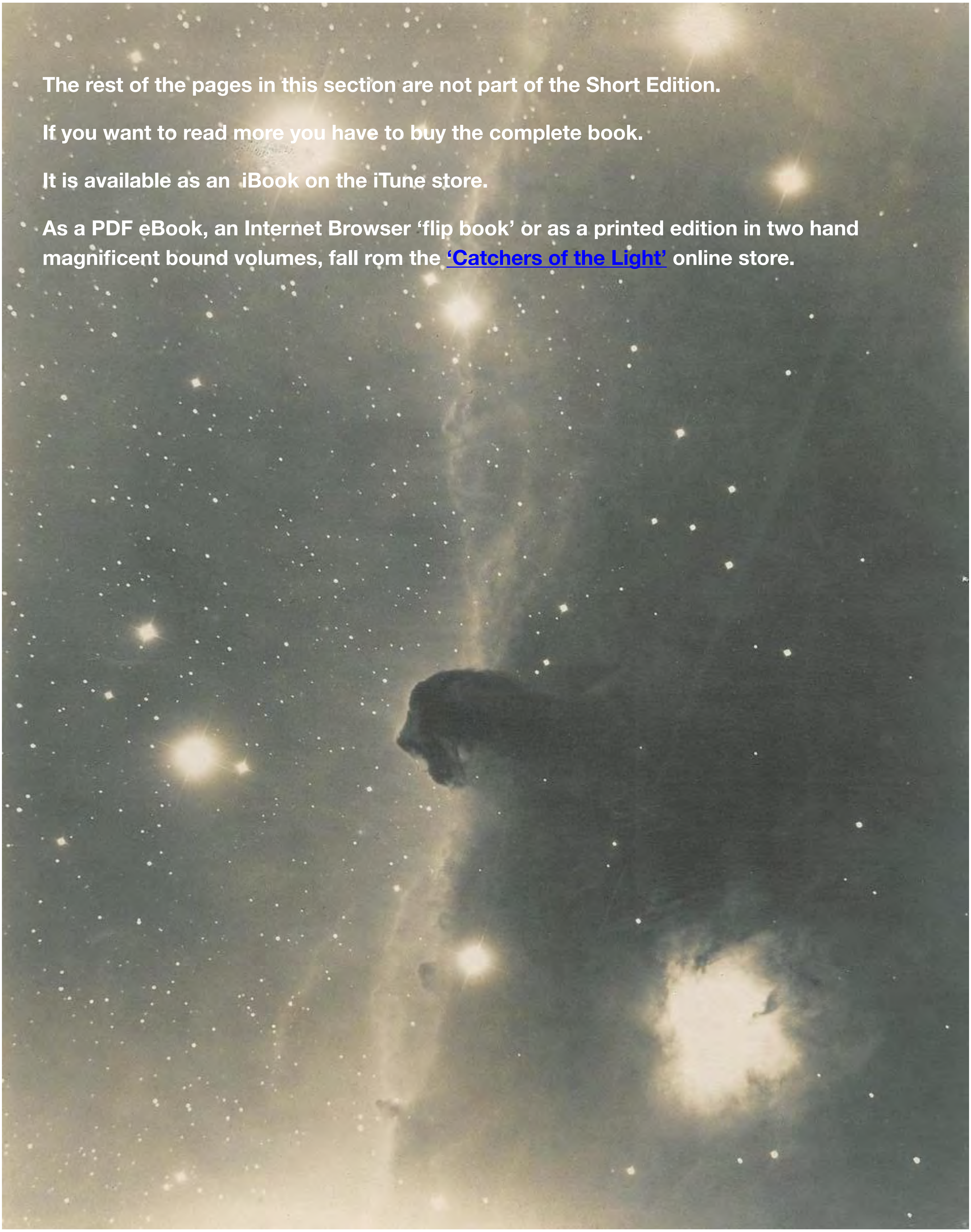

IX.2

‘The Horse’s Head’

Modern Astrophotography

Modern CCD Image of the Horse Head Nebula taken in Hydrogen Alpha Light
©Theodore Arampatzoglou, Athens, 2009

In 1969 Willard Sterling Boyle and George Elwood Smith at the AT&T Bell Laboratories invented the Charge Coupled Device, otherwise known as the CCD; and with it was born the age of Digital Astrophotography. Today many amateur astronomers possessing only modest equipment costing just a few thousand dollars, are regularly capturing images of the heavens, far superior to the photographic plates taken four decades ago by the great reflectors atop the mountains of southern California - in the days when the CCD chip saw the *‘firstlight’* of a photon.

The 'Horsehead' Nebula

Ah, to softly slip behind the scene
One clear and snow-draped, silent winter night,
To pierce the density which seems to screen,
Obstruct the splendor of that cosmic light,
To pass beyond that dark and mystic cloud
Which looms like portal in a garden wall,
The ancient loveliness within to shroud,—
How it one's fancy does inspire, enthrall.
In that great starlit garden of the sky
Where light eternal dwells in calm repose
Who knows what beauty there might greet the eye,
What undreamed truth a brief glimpse there disclose
As strange as thought, to thought there is no space,
At will, one's thoughts the universe may embrace.

Lisa Odland, 1940

IX.2.1 'The Grim Reaper's Horse'

As a young boy the night sky was a place of wonder and excitement where I could escape from the cares of everyday life and travel in my mind to worlds beyond imagination. On top of a hill at the back of my house I used to lie for hours under an ink black canopy lit by the faint glow of almost countless fireflies across which a milky white stream spilled from horizon to horizon. With my telescope I saw even more wonders – the pox marked surface of the Moon littered with craters and *'seas',* the belts and spots of Jupiter, the rings of Saturn and the crescent of a cloud shrouded Venus.

All of these sights palled into insignificance when I first saw the photographs in my books of the wonders to be found in the deep recesses of space – the glowing clouds gas, the swirling arms of distant *'Island Universes'* and the glowing spheres of densely packed stars. But of all the wonders to be found amongst these pages, one stood out above any other. It was an image which showed what I can only describe as the head of a black horse, one born out of myth and legend that rose from darkness of hell into the light of heaven. This was my first sight of the most iconic and famous of all Deep Space Objects (DSOs) – a dark nebula known as the *'Horsehead'* [1].

It is now over forty years since I first saw this object which dictated the course of my life. It is without doubt the most difficult of all DSOs any amateur is ever likely attempt to see or image; so much so that some morbid astronomers have dubbed it the *'Grim Reaper'* likening it to one of the four horsemen of the Apocalypse known as '*Death*'. Such a macabre name arose because many an amateur has been heard to speak in jest the words - *'Looking for the Horsehead nebula will be the death of me'.* I, like the great observational astronomer, Stephen O'Meara think, B33 to give it its correct astronomical catalogue designation, is in reality the *'Grim Reaper's'* black steed, which he rides for all eternity, gathering the souls of the dead in his never ending journey across time and space [2].

Even when I was young I was never so naïve as to believe I could possibly see the '*Horsehead*' with my puny 6-inch telescope, given that in the 1960s, only the *'Great Reflectors'* atop the Californian Mountains could capture its true magnificence. This sad realization tempered my view of the wonders of the heavens; and would eventually steer me into a career in mathematical astronomy, far away from the night sky of my youth. Yet, I longed for the day when I could see for myself the head of the *'Grim Reaper's'* mighty stallion, with a telescope I could afford; and the not just remember the image I saw in my books, now, so long ago [3].

In 2006 my wish came true when I saw the '*Horse's Head*'- not through an eyepiece but with the eyes of a CCD Chip, projected onto a computer screen. Although the image was grainy and of very poor quality it was nevertheless there – in front of me, I had waited forty years for such a moment. Over the course of the next few years I have improved upon my first capture of this most personal of all of treasured memories.

Today I am able to access my Observatory's computer from my iPhone wherever I might be in the world. I can set up an *'imaging run'* to begin at a particular time, at which point my telescope will automatically slew to B33 at RA. 5h 40m 59s and Dec. -2º 27' 30"S. The CCD camera will then proceed to take a predefined series of images of the '*Horsehead*'. Finally the telescope will slew back to its '*Home*' position. If the weather is bad, the in-built meteorological station will notify the telescope not to even bother to wake up, or shut the Observatory down if rain threatens during the imaging sequence.

In this last chapter I will relate how it became possible for the modern amateur to capture the Horse of the '*Grim Reaper'* and in doing so continue the work begun so many years before, by the men and women you have come to know as the *'Catchers of the Light'*.

'Horsehead', SBIG STL11000M, 4-inch WO FLT 110 Refractor, 2010

The dark nebula in the constellation of Orion known as the '*Horsehead*' is considered the *'Holy Grail'* of Astrophotography. To capture its image on plate, film or CCD chip, no matter how badly is often considered to be the transition from a '*Greenhorn*' imager to the status of someone who has been awarded his/her astronomical imaging spurs. Most of us who have captured the '*Horsehead*' will never forget the moment its black mane appeared on the computer screen or in the quiet of the darkroom. This event marks one of the '*good times*' in the career of an Astrophotographer. Once captured we then go the next step and obtain the '*perfect*' image of the *'Horsehead'* in full colour, and begin comparing it to all the other great images of it that are now being regularly taken by the modern amateur. The quality of these images are truly stunning given that they are the betters of any taken only twenty or so years ago by the great reflectors atop mountains or in the deserts of the world. This fact is made even more remarkable that their equipment did not cost millions of dollars but just a few thousands in many cases. The '*Horsehead*' or Barnard 33 as it is known in the catalogues is to be found about half a degree south of the bright white star Alnitak, the left-most star of the three which make up the Hunter's belt. I liken its appearance as that of the Grim Reaper's mighty black stallion riding up out of the darkness of hell into the light of heaven lit by the *'Rays of God'*. Perhaps one day man will travel across the vast distances of space to see this celestial wonder, which stands some 1500 light years away from us. Until then we have to make do with its image, first captured in 1888 on a photographic plate taken at the Harvard College Observatory.

The ‘*Grim Reaper’* is the black-cloaked, scythe-wielding personification of death often seen riding a black horse. In the Christian religion he is often associated with one of the four horsemen of the Apocalypse. The true origin of the Grim Reaper can be traced back to before the birth of Christ. He was known as Cronus to the Greeks and Saturn to the Romans. However the Grim Reaper as he is depicted today comes directly to us from the Middle Ages and the rat infested period known as the Black Death. According to William Bramley in his book the *‘Gods of Eden’*:

“In Brandenburg, Germany, there appeared fifteen men with fearful faces and long scythes, with which they cut the oats, so that the swish could be heard at great distance, but the oats remained standing. The visit of these men was followed immediately by a severe outbreak of plague in Brandenburg... It is from these reports that people created the popular image of death as a skeleton, a demon, a man in a black robe carrying a scythe.” To the Astrophotographer it is the black horse’s head that is of interest, for it represents the greatest imaging challenge they are ever likely to face. If successful they will treasure the image of the ‘*Horsehead*’ - that many have often said ‘*will be the death of me*’.

IX.2.2 Capturing the Horse

The ‘*Horsehead*’ is not only personal to me. It is the *‘Bête Noire’* of the Astrophotographer. Many an amateur astronomer having seen the light and transferred his attention from visual observations to photography yearns for the day when he can obtain a half decent image of this most difficult of all DSOs. He knows from what he read and what his friends have told him that such a quest will not be easy.

It will test not only his skill, patience and perseverance; but also that of his equipment – the quality of his telescope’s optics; the accuracy of its mount to find and track the ‘*steed*’ across the sky; the light gathering power of his camera to grab its dark mane; and finally the ability of the image processing software to turn raw noisy digital frames into a single image of awesome magnificence.

The fact that an amateur astronomer of today, possessing only modest equipment is able to take a digital image of the ‘*Horsehead*’ of a quality far superior to the photographs taken forty or even twenty years ago by the *‘Great Reflectors’* atop the mountain peaks of California, is without doubt one of the greatest miracles of modern technology. Let us now tell the story of how this came about through the eyes of the Grim Reaper’s Horse and those who first saw its likeness on plate, film and computer screen.

To do so we have to use the power of the word to travel back through time and space to the Harvard College Observatory (HCO) in Cambridge, Massachusetts and the night of the 6th February 1888. On that night, the HCOs latest telescope an 8-inch Photographic Refractor was being tested before being shipped the following year to Mount Harvard in Peru, where it would begin work in earnest on obtaining photographic spectra of southern stars [4].

The imager responsible for taking what would eventually become one of the most famous photographic plates in the history of Astronomy was William Henry Pickering, the younger brother of the HCOs then Director Edward Charles Pickering. When John Louis Emil Dreyer was compiling the first of the two Index Catalogues to his New General Catalogue, the list of objects then discovered at the HCO, were all attributed simply to ‘*Pickering*’, without distinguishing between the two brothers.

E. C. Pickering in a paper entitled – *‘Detection of New Nebulae by Photography’,* published in the Annals of the Harvard College Observatory for 1890, describes Plate B2312 and the objects it contains, and the role of his assistant, Williamina Fleming in the discovery of the ‘*Horsehead*’ [5]:

Appendices

Astrophotography Resources

M3 Globular Cluster in Canes Venatici ; George W. Ritchey 1910, 60-inch Reflector

I must say Good-bye, my pupil, for I cannot longer speak;
Draw the curtain back for Venus, ere my vision grows too weak:
It is strange the pearly planet should look red as fiery Mars,
God will mercifully guide me on my way amongst the stars.

Appendix A

Astrophotography Timeline

This Appendix gives a summary of the main events that took place in the historical development of Astrophotography.

Events are included covering the period from 1800 up to the present day (as of 2013), beginning with the '*sun pictures*' of Thomas Wedgwood right through to age of the space telescope and the digital camera.

For each event, the following information is given:

- Date of the Event;
- Name of the Pioneer(s) associated with the Event;
- Type of Event; e.g.:

  - Astrograph;
  - Deep Space;
  - Lunar;
  - Photographic;
  - Sky Survey;
  - Solar;
  - Solar System;
  - Spectroscopy;
  - Terrestrial;

- Description of the Event including its significance in the History of Astrophotography.

Date	Name/Event Type	Event
1800	**Thomas Wedgwood** *Photographic*	Thomas Wedgwood (1771-1805); produces *'sun pictures'* by placing opaque objects on leather treated with silver nitrate. The resulting images deteriorated rapidly.
1802	**William Hyde Wollaston** *Spectroscopy*	William Hyde Wollaston (1766-1828) was the first person to observe the dark lines in the Solar Spectrum, now known as absorption lines; which he incorrectly interpreted as gaps separating the colours of the sun.
1804	**Thomas Wedgwood** *Photographic*	Thomas Wedgwood; in 2008 one of the major historians of early British photography, Dr Larry J Schaaf, has suggested at length that a surviving photogenic drawing of a leaf (formerly attributed to William Fox Talbot) could in fact be by Thomas Wedgwood, and might date from 1804 or 1805. If this can be confirmed, then Wedgwood had succeeded in obtaining a permanent '*fixed'* image, something which he had previously believed not to have done.
1814	**Joseph Von Fraunhofer** *Spectroscopy*	Joseph Von Fraunhofer (1787-1826) rediscovered the absorption lines in the Solar Spectrum, whilst calibrating the optical properties of glass, when working at a military and surveying instruments firm.
1816	**Joseph Nicéphore Niépce** *Photographic*	Joseph Nicéphore Niépce (1765-1833) combines the camera obscura with photosensitive paper.
1825	**Joseph Nicéphore Niépce** *Photographic*	In 2002, an earlier surviving photograph which had been taken by Niépce was found in a French photograph collection. The photograph was found to have been taken in 1825, and it was an image of an engraving of a young boy leading a horse into a stable. The photograph itself later sold for 450,000 Euros at an auction to the French National Library.
1826	**Joseph Nicéphore Niépce** *Photographic*	Produces the first permanent image (Heliograph) using a camera obscura and white bitumen. It shows a view out of a window over roof tops at his family chateau at Le Gras, France. Prior to 2002 it was thought to be the oldest surviving photograph.
1829	**Joseph Nicéphore Niépce & Louis Jacques Mandé Daguerre** *Photographic*	Joseph Niépce & Louis Daguerre (1787-1851) sign a ten year agreement to work in partnership developing their new recording medium.
1834	**William Henry Fox Talbot** *Photographic*	William Henry Fox Talbot (1800-1877); creates permanent (negative) images using paper soaked in silver chloride and fixed with a salt solution. Talbot created positive images by contact printing onto another sheet of paper. Talbot's *'The Pencil of Nature'*, published in six instalments between 1844 and 1846 was the first book to be illustrated entirely with photographs.

The rest of the pages in this section are not part of the Short Edition.

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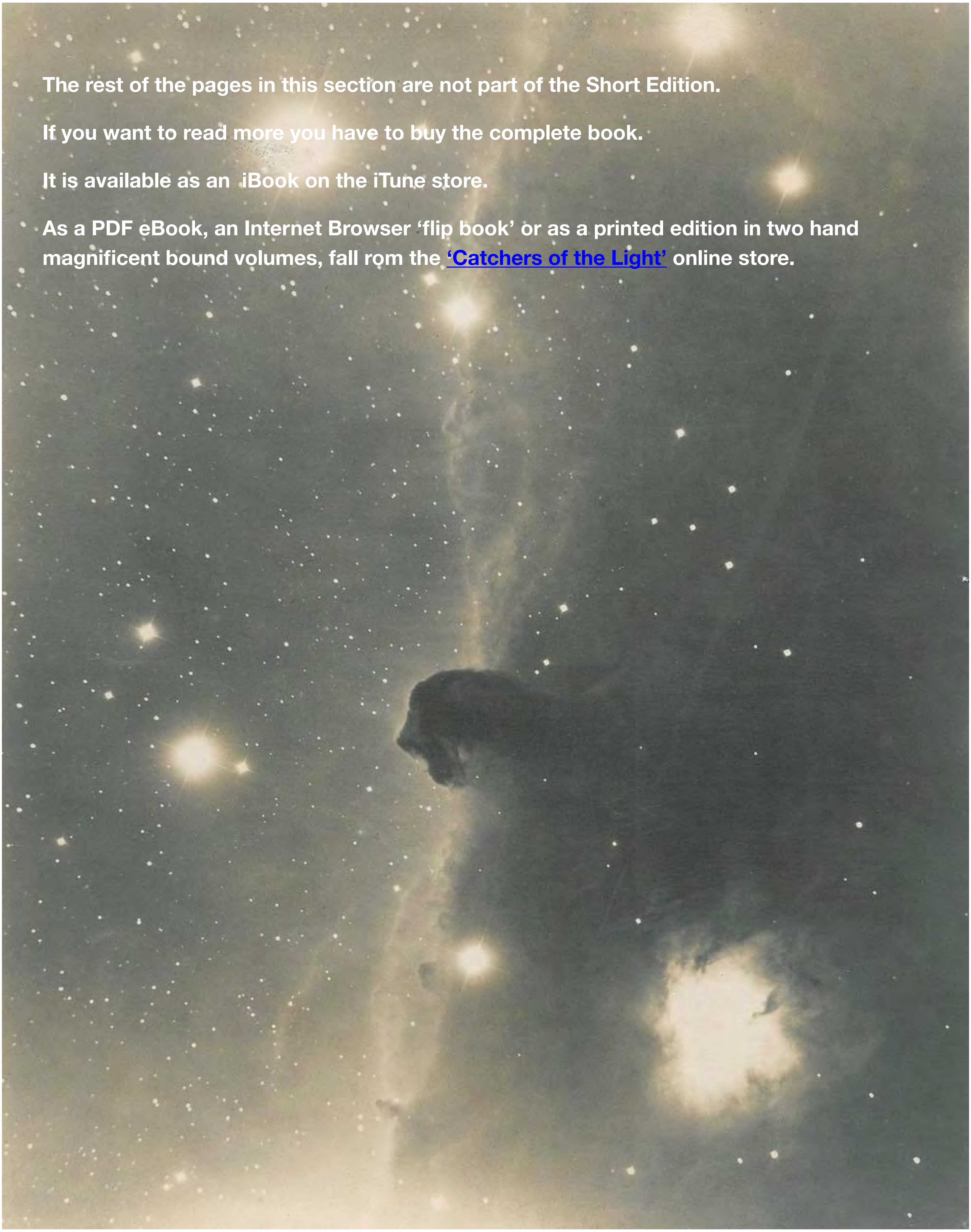


Appendix B

109 Important Astronomical Photographs

This Appendix contains a list of 109 Astronomical Objects and Telescopes which were important to the historical development of Astrophotography. I have called it the ‘*A*’ List.

For each object the following information is given:

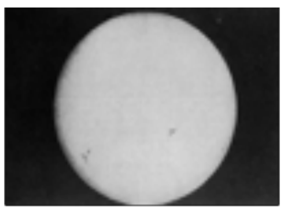
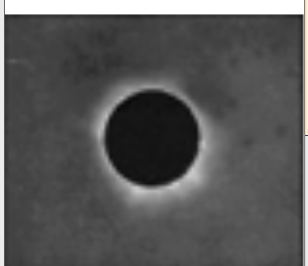
- ‘*A*’ List Number, e.g. A32, indicating B33, the ‘*Horsehead*’ Nebula in Orion;
- Photograph of Object, whenever possible the earliest known is shown, if not it is indicated by an ‘*’ to the left of the image;
- Object Name, i.e. Usual catalogue name, e.g B33 for Barnard’s Dark Nebula No. 33;
- Common Name, e.g. ‘*Horsehead*’ Nebula;
- Date of the earliest known photograph of the object, e.g. 1888;
- Name of Pioneer(s) associated with the photograph, e.g. Williamina Fleming;
- Constellation in which object is located (if applicable), e.g. Orion;
- Type of Object, e.g. Deep Space Object (DSO), Lunar, Solar, Solar System, Terrestrial
- Right Ascension (RA) and Declination (Dec.) of the Object;
- Magnitude and Angular Size of the Object;
- Whether the Object is visible at Night (☻), during Daylight (☺) or both (☺☻);
- Whether the Object is visible in the Northern (N), Southern (S) or Both (N S);
- Degree of Difficulty in Imaging the Object on a scale of 1 to 5 with 1: Simple, 2: Easy, 3: Difficult, 4: Very Difficult, 5: Exceptionally Difficult
- Notes associated with the object.

The last 11 objects in my list are telescopes. I have included them because these remarkable instruments were used to obtain the images seen throughout the pages of this book, and without them the work of the pioneers who used or built them would have not have existed.

The choice of objects is my own, and I am sure I have left out a number of others which could have been included with some justification.

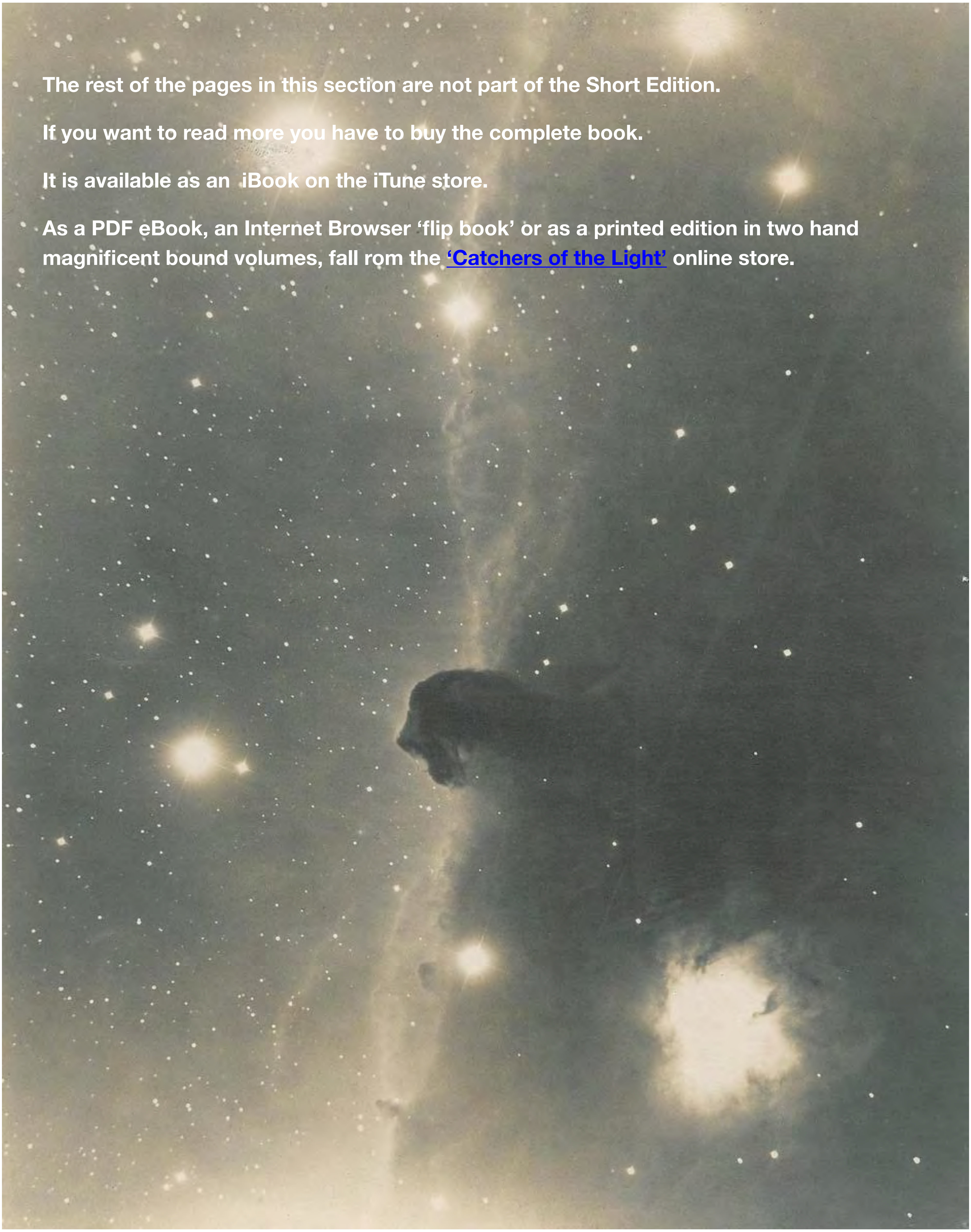
The ‘*challenge*’ for the modern Astrophotographer is to capture all of them using the technical equipment available to him or her. Even with today’s ‘*GO TO*’ telescopes, Digital SLRs and Astronomical CCD Cameras it will not be easy.

But when you have done so - reflect on this; if you found it hard then what must it have been like for the early pioneers who went before you?

<table>
<tr><th>No.</th><th>Image</th><th>Name</th><th>Common Name</th><th>Date/Pioneer</th><th>Constellation</th><th>Type</th><th>RA/Dec</th><th>Mag.</th><th>Size</th><th>☺ ☻</th></tr>
<tr><td rowspan="3">A1</td><td rowspan="3"></td><td rowspan="2">Full Moon</td><td rowspan="2">-</td><td>1840</td><td rowspan="2">Zodiacal</td><td rowspan="2">Lunar</td><td rowspan="2">-</td><td rowspan="2">-12.74</td><td rowspan="2">29.3’
34.1’</td><td rowspan="2">☺
☻</td></tr>
<tr><td>John William Draper</td></tr>
<tr><td colspan="6">In the March of 1840, Dr John William Draper took the first photograph of an astronomical object when he imaged the Moon. In doing so he became the ‘First Astrophotographer’. The Moon should be the first target for any budding Astrophotographer to image.</td><td colspan="2">1</td><td></td></tr>
<tr><td rowspan="3">A2</td><td rowspan="3"></td><td rowspan="2">Partial Solar Eclipse</td><td rowspan="2">-</td><td>1842</td><td rowspan="2">Zodiacal</td><td rowspan="2">Solar</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">☺</td></tr>
<tr><td>Gian Majocchi</td></tr>
<tr><td colspan="6">The first photographs of a Partial solar eclipse were obtained by the Italian astronomer, Gian Alessandro Majocchi from Milan on the 8th of July 1842. The three photograph he obtained have not survived. The image shown here is by William & Frederick Langenheim taken on the 26th May 1854.</td><td colspan="2">3</td><td></td></tr>
<tr><td rowspan="3">A3</td><td rowspan="3"></td><td rowspan="2">Solar Photosphere</td><td rowspan="2">-</td><td>1845</td><td rowspan="2">Zodiacal</td><td rowspan="2">Solar</td><td rowspan="2">-</td><td rowspan="2">-26.74</td><td rowspan="2">31.6’
32.7’</td><td rowspan="2">☺</td></tr>
<tr><td>Hippolyte Fizeau & Leon Foucault</td></tr>
<tr><td colspan="6">During the period 1843 to 1845, Hippolyte Fizeau and Leon Foucault had obtained Daguerreotypes of the Solar Photosphere from the Paris Observatory. Only one detailed large scale image has survived that taken on the 2nd of April 1845. It clearly shows the presence of sunspots on the sun’s surface.</td><td colspan="2">3</td><td></td></tr>
<tr><td rowspan="3">A4</td><td rowspan="3"></td><td rowspan="2">Total Solar Eclipse</td><td rowspan="2">-</td><td>1851</td><td rowspan="2">Zodiacal</td><td rowspan="2">Solar</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">31.6’
32.7’</td><td rowspan="2">☺</td></tr>
<tr><td>M. Berkowski</td></tr>
<tr><td colspan="6">The first photograph of a Total eclipse of the sun was obtained on the 28th of July at Konigsberg (now Kaliningrad, Russia) by a local Daguerreotypist named Berkowski (his first name is not known), using a small telescope of 2.4 inch aperture attached to the 6 inch Heliometer of the Konigsberg Observatory.</td><td colspan="2">4</td><td></td></tr>
<tr><td rowspan="3">A5</td><td rowspan="3"></td><td rowspan="2">Alpha Lyrae</td><td rowspan="2">Vega</td><td>1850</td><td rowspan="2">Lyra</td><td rowspan="2">DSO Star</td><td rowspan="2">18h 36m 56s

+38º 47’ 01”</td><td rowspan="2">0.03</td><td rowspan="2">-</td><td rowspan="2">☻</td></tr>
<tr><td>George P. Bond & John A. Whipple</td></tr>
<tr><td colspan="6">On the 17th of July 1850 George Phillips Bond, assisted by Boston the Daguerreotypists John Adams Whipple and James Wallace Black took the first ever photograph of a star when they imaged Vega (Alpha Lyrae), using the 15-inch ‘Great Harvard’ Refractor. The image shown here is by Edward Barnard and dates from 1895.</td><td colspan="2">1</td><td></td></tr>
<tr><td rowspan="3">A6</td><td rowspan="3"></td><td rowspan="2">Zeta & 80 Ursa Majoris</td><td rowspan="2">Mizar & Alcor</td><td>1857</td><td rowspan="2">Ursa Major</td><td rowspan="2">DSO Stars</td><td rowspan="2">13h 23m 55s

+54º 55’ 31”</td><td rowspan="2">2.23
3.99</td><td rowspan="2">-</td><td rowspan="2">☻</td></tr>
<tr><td>George P. Bond</td></tr>
<tr><td colspan="6">On the 27th of April 1857, G. P. Bond using the Harvard 15-inch refractor, with the assistance of John A. Whipple and James Wallace Black obtained the first photograph of a double star - Mizar and its companion Alcor.</td><td colspan="2">1</td><td></td></tr>
</table>



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Appendix C

Chemistry of Photographic Processes

C.1 Overview

Only three chemically based photographic processes were used by Astronomers to any great extent – the Daguerreotype, the Collodion and the Gelatino-Bromide. The Calotype process was very rarely used in Astronomy and only three references to its application have been found in the literature.

A detailed description of the chemistry involved in these four processes is given below, together with an outline of a number of variants which were used during the period 1839 and onwards.

C.2 Daguerreotype

The Daguerreotype [1] is a direct positive process in which a silvered copper plate is made sensitive to light by fuming in iodine vapour. After exposure the latent image is made visible by the fumes of warmed mercury.

The image in a Daguerreotype is formed by the amalgam, or alloy, of mercury and silver. Mercury vapour from a pool of heated mercury is used to develop the plate that consists of a copper plate with a thin coating of silver rolled in contact that has previously been sensitized to light with iodine vapour so as to form silver iodide crystals on the silver surface of the plate.

Exposure times were later reduced by using bromine to form silver bromide crystals, and by replacing the Chevalier lenses with much larger, faster lenses designed by Joseph Petzval.

The image is formed on the surface of the silver plate that looks like a mirror. It can easily be rubbed off with the fingers and will oxidize in the air, so from the outset daguerreotypes were mounted in sealed cases or frames with a glass cover.

When viewing the Daguerreotype, a dark surface is reflected into the mirrored silver surface, and the reproduction of detail in sharp photographs is very good, partly because of the perfectly flat surface.

Although daguerreotypes are unique images, they could be copied by re-daguerreotyping the original.

Invented by Louis Jacques Mandé Daguerre (1787-1851), it was revealed to the public on the 19th of August 1839, and remained immensely popular throughout the 1850s, and was especially used by professional portrait photographers.

C.3 Calotype

The Calotype [2] is a photographic process for making negatives on paper in which the latent image is made visible by chemical development. The process was announced to the public by William Henry Fox Talbot on the 10th of June 1841.

The sensitive element of a Calotype is silver iodide. With exposure to light, silver iodide decomposes to silver leaving iodine as a free element. Excess silver iodide is washed away after oxidizing the pure silver with an application of gallo-nitrate (a solution of silver nitrate, acetic, and gallic acids). As silver oxide is black, the resulting image is visible. Potassium bromide then is used to stabilize the silver oxide.

Silver chloride is sometimes favoured over silver iodide because it is less sensitive to temperature. During long exposures in direct sunlight the temperature on the paper can be quite high (see C.6.21 Salted Paper).

The Calotype created a negative image on the silver iodide from which positives could be printed (onto silver chloride paper). This made the Calotype superior in one aspect to the daguerreotype which only made one positive image (whereby it was difficult to get multiple copies).

The essentials of the process remained at the core of numerous variants introduced over the next twenty five years.

Strictly speaking, the Calotype refers to the process for making a camera negative, but is often mistakenly used to identify prints.

Talbotype, was an alternative name for the Calotype process and most frequently used by Talbot's friends and supporters, though never by Talbot himself.

C.4 Collodion

Collodion is a flammable, syrupy solution of pyroxylin (aka '*nitrocellulose*', '*cellulose nitrate*', '*flash paper*', and '*gun cotton*') in ether and alcohol. There are two basic types; flexible and non-flexible. The flexible type is often used as a surgical dressing or to hold dressings in place. When painted on the skin, collodion dries to form a flexible cellulose film. While it is initially colorless, it discolors over time. Non-flexible collodion is often used in theatrical make-up.

In 1851, the English sculptor and photographer, Frederick Scott Archer (1814–1857) discovered that collodion could be used as an alternative to egg white (albumen) on glass plates [3]. This also reduced the exposure time when making the image. This became known as the *'wet plate collodion'* or '*wet collodion'* method or *'wet collodion'* process.

Collodion was also grain less and colourless, and allowed for one of the first high quality duplication processes, also known as negatives. This process also produced positives, the Ambrotype and the Tintype (also known as '*ferrotype*').

The process required great skill and included the following steps:

- Clean the glass plate (extremely well)
- In the light, pour "*salted*" (iodide/bromide) collodion onto the glass plate, tilting it so it reaches each corner. The excess is poured back into the bottle.
- Take the plate into a darkroom or orange tent (the plate is only sensitive to blue light) and immerse the plate in a silver nitrate sensitizing bath (for 3–5 minutes)
- Lift the plate out of the bath, drain and wipe the back and load it into a dark slide (UK terminology) or plate holder (US terminology)
- Load the plate holder into the camera, withdraw the dark slide and expose the plate (can range from less than a second to several minutes)
- Develop the plate (using a ferrous sulfate based developer)
- Fix the plate (with potassium cyanide or sodium thiosulfate [hypo])

All of this was done in a matter of minutes and some of the steps in (red) safelight conditions, which meant that the photographer had to carry the chemicals and a portable darkroom with him wherever he went. After these steps the plate needed rinsing in fresh water. Finally, the plate was dried and varnished using a varnish made from sandarac (resin from the cypress-like tree Tetraclinis articulata), alcohol and lavender oil.

Dark tents to be used outdoors consisted of a small tent that was tied around the photographer's waist. Otherwise a wheelbarrow or a horse and covered wagon were used.

C.5 Gelatino-Bromide

From the 1850s until the mid-1870s photographers used glass plates coated with collodion, the collodion being wet or dry.

Then experiments began, making the emulsion coating with gelatin, so creating gelatino-bromide emulsion plates.

Gelatine had the advantage of being fluid when warm and a jelly when cold [4].

In 1875 a photographer who described himself as an '*Amateur'* gave the following account of how to prepare Gelatino-Bromide Plates:

"To make 1 ounce of emulsion ...

1. Soak 15 grains of Nelson's patent opaque gelatin in a 2 ounce bottle of water for several hours.

2. Pour off the water and add 2 drachms of distilled water and 18 grains of bromide of potassium.

3. Place the bottle in hot water until the contents are dissolved

While doing this…

4. Dissolve 25 grains of nitrate of silver in 2 drachms of distilled water.

Then take all into the darkroom, and...

5. Add the silver to the bromised gelatine gradually, shaking well between each addition.

6. Add 1 or 2 drachms of methylated spirit.

7. Add sufficient water to make up the quantity to 1 ounce.

Allow it to rest until the next day

8. Dialyse for 4 or 5 hours (following Mr King's directions)

To coat the plate...

The plates should be coated as soon as possible (though in cold weather, the emulsion may keep good for 2 weeks).

1. Clean the plates well, particularly at the edges.

2. Guide the emulsion over the plates with a glass rod.

3. Place the plates on a level dry shelf to dry, covered by a board about 1 inch above, to protect them from falling dust.

The plates should have dried by the next day, and "present a beautiful glossy and transparent appearance like opal glass.

Develop, Fix, Intensify

After exposing the plates they should be laid in a tray of water for a minute or two to soften the film.

1. Develop in a strong alkaline developer alone.

2. Fix the plate.

Washing details before and after fixing are not given, except as below. If the plate needs to be intensified

3. Immerse the plate in a solution of bichromate of mercury until the picture appears distinctly as a positive by reflected light.

4. Wash

5. Apply ordinary alkaline developer without the bromide.

Any shade from rich brown to jet black may be obtained.*"*

Our '*Amateur*' claimed to have tried almost every modification that he could think of, including the addition of an iodide and a chloride and an excess of silver with aqua regia, added both before and after dialysing the emulsion.

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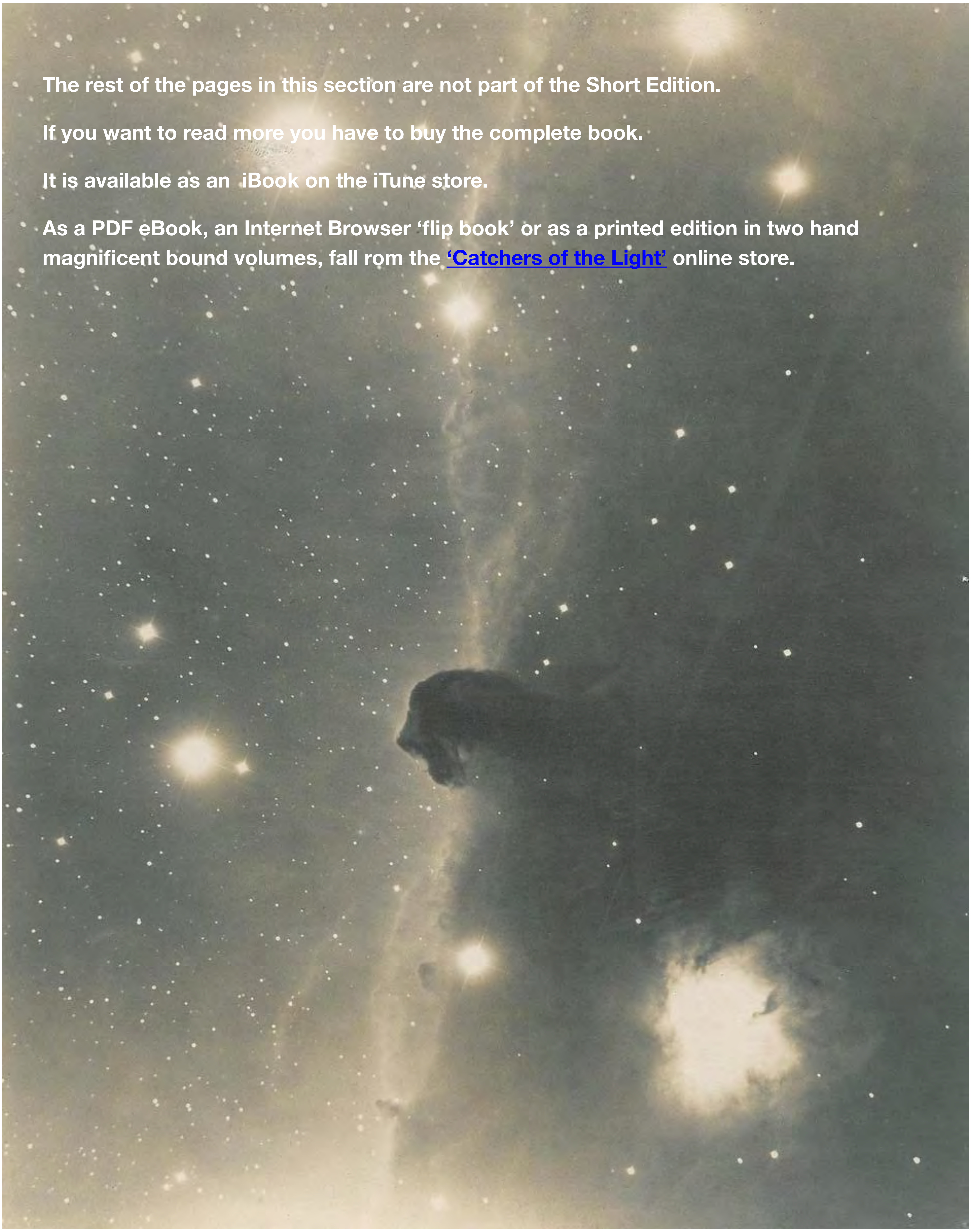


Appendix D

Telescope Optical Systems

D.1 Overview

A number of designs of Telescope Optical Systems were used over the last century and a half by Astronomers to take photographs of the Moon, Sun, Planets and Deep Sky Objects (DSOs).

This Appendix describes them in terms of their optical design, including their advantages and disadvantages relating to their usefulness in Astrophotography.

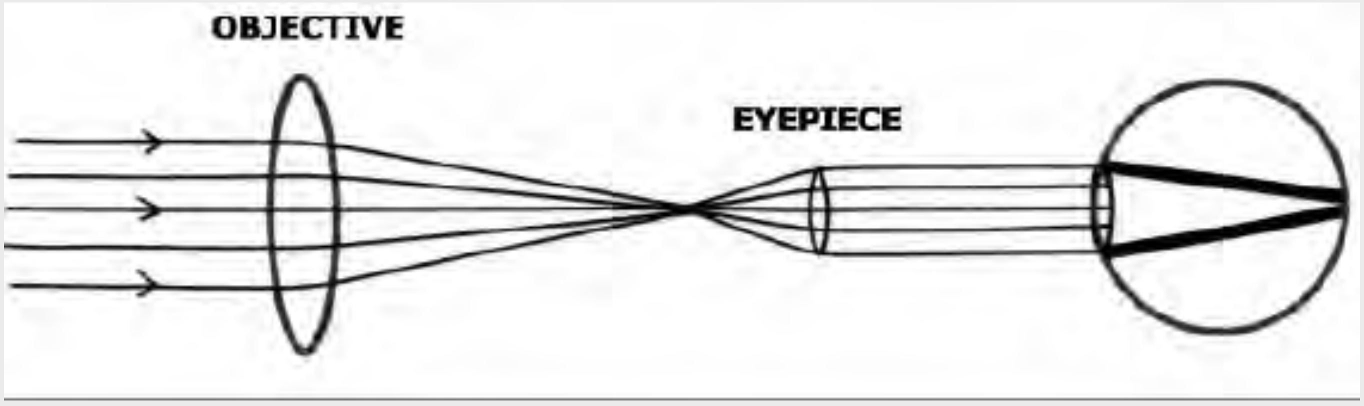
D.2 Refractors

The Refracting Telescope or simply the Refractor is a Dioptric system, i.e. one which uses only lenses.

Refractors were the earliest type of optical telescope. The first practical refracting telescopes appeared in the Netherlands in about 1608, and were credited to three individuals, Hans Lippershey and Zacharias Janssen, spectacle-makers in Middelburg, and Jacob Metius of Alkmaar also known as Jacob Adriaanszoon. The Italian Scientist Galileo Galilei, happened to be in Venice around May 1609, and heard of this remarkable invention and constructed a version of his own. Galileo then communicated the details of *'his invention'* to the public, and presented the instrument itself to the Doge Leonardo Donato, sitting in full council.

All refracting telescopes use the same principles. The combination of an objective lens and some type of eyepiece is used to gather more light than the human eye could collect on its own, focus it, and present the viewer with a brighter, clearer, and magnified virtual image.

D.2.1 Simple Refractor



Simple Refractor Optical System

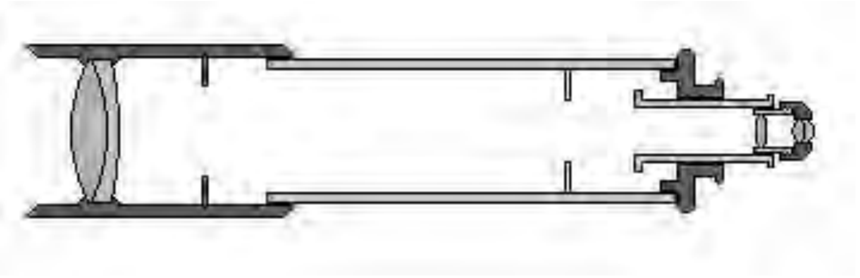
Refractors have been criticized for their relatively high-degree of residual chromatic and spherical aberration. This affects shorter focal lengths more than longer ones.

In very large apertures, there is also a problem of lens sagging, a result of gravity deforming glass. Since a lens can only be held in place by its edge, the centre of a large lens sags due to gravity, distorting image it produces. The largest practical lens size in a refracting telescope is around 1 meter.

There is a further problem of glass defects, striae or small air bubbles trapped within the glass. In addition, glass is opaque to certain wavelengths, and even visible light is dimmed by reflection and absorption when it crosses the air-glass interfaces and passes through the glass itself. Most of these problems are avoided or diminished by using reflecting telescopes, which can be made in far larger apertures.

D.2.2 Achromatic Refractor

The Achromatic refracting lens was invented in 1733 by an English barrister named Chester Moore Hall although it was independently invented and patented by John Dollond around 1758. The design overcame the need for very long focal lengths in refracting telescopes by using an objective made of two pieces of glass with different dispersion, '*crown*' and *flint*' glass, to limit the effects of chromatic and spherical aberration. Each side of each piece is ground and polished, and then the two pieces are assembled together.



Achromatic Refractor Optical System

Achromatic lenses are corrected to bring two wavelengths (typically red and blue) into focus in the same plane. The era of the Great refractors in the 19th century saw large achromatic lenses culminating with largest achromatic refractor ever built, the Great Paris Exhibition Telescope of 1900 – which had an objective of 49 inches in diameter. This was the work of the Parisian engineer, Paul Gautier (1842-1909).

D.2.3 Photographic Refractor

The normal achromatic objective of a refractor is totally unsuitable for photographic use. When we look through a telescope; our eyes use mainly light in the yellow part of the spectrum. The early photographic plates in use at the end of the nineteenth century were in the main sensitive to light in the blue-violet parts of the spectrum. At that time a lens could not be constructed which focuses light in all parts of the spectrum in the same plane; consequently if a telescope were to be used for photography a second photographic objective had to be constructed. It was the American Lawyer, Lewis Morris Rutherfurd who constructed the first photographic refractor in 1864. It was only with the introduction of widely available yellow sensitive isochromatic photographic plates at the beginning of the twentieth century that enabled the simple use of a yellow filter to cut out the blue-violet light and therefore allowing a purely visual refractor to be used photographically.

D.2.4 Equatorial Coudé Refractor

The Equatorial Coudé (Elbow) Refractor was designed by French astronomer Maurice Loewy (1833-1907); this compound telescope used a main lens in conjunction with two mirrors. As this arrangement allowed the eyepiece to remain stationary, the observer could work in a separate heated room while the telescope was open to the sky. It also had greater stability and could measure larger angles than a conventional equatorial. When not in use, the telescope was protected by a large moveable shed which was simpler and cheaper to produce than a conventional observatory dome.

Equatorial Coudé at Lyon Observatory: Then and Now

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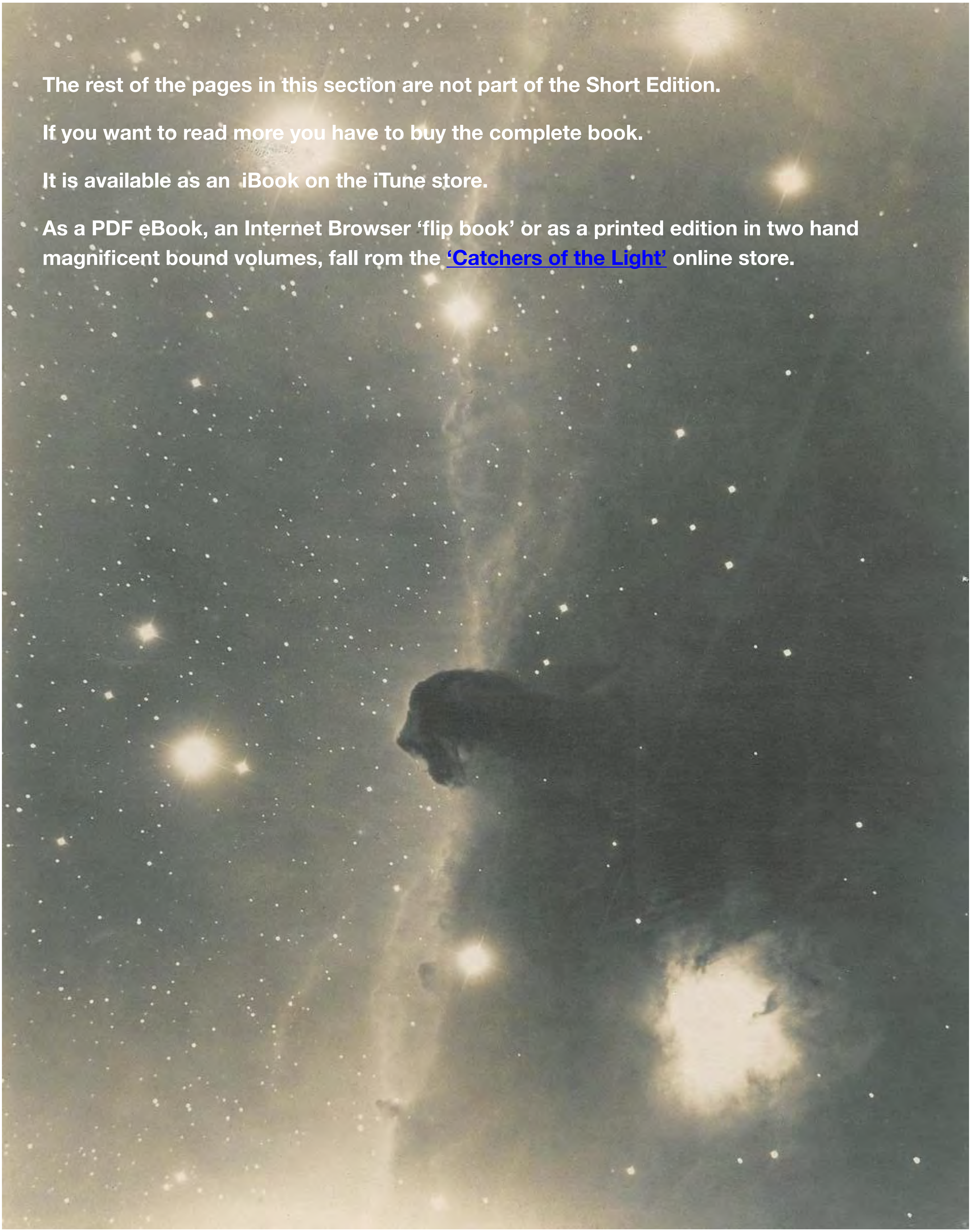


Appendix E

Charge Coupled Devices

E.1 Overview

It is no exaggeration to say that the invention of the Charge Coupled Device in 1969 by Willard Sterling Boyle and George Elwood Smith at the AT&T Bell Laboratories, is up to the present time, the single most important ever made in the History of Astrophotography; even greater than the Daguerreotype, Collodion or Gelatino-Bromide processes.

Why? How can I say this without suffering the *'slings and arrows'* of an Army of Photographic Historians?

To answer this, I will just show you three photographs, taken with 4 inch, 8 inch and 200 inch telescopes; only one used a CCD, the other two used 'dry' photographic plates; the photographs were taken in 1888, 1951 and 2009; the cost of the equipment used in today's money ranged from a few thousand dollars up to tens of millions of dollars.

Can you guess which image is which? The answer is at the end of this Appendix. I trust I have justified my bold claim?

A	B	C
		
Date?	**Date?**	**Date?**
Technology?	**Technology?**	**Technology?**
Cost?	**Cost?**	**Cost?**

E.2 Basic Operation

Although not discernible to the naked eye, the CCD chip is basically an array of small sensors, called pixels. In the latest CCD chips used by amateur Astrophotographers, there are several million of these sensors.

You can think of each pixel like a *'bucket'* that collects light. The bucket collects light, just like rain collects in a rain gauge, for the time the sensor is exposed to the light. However, like a rain gauge it can overflow if too much rain falls, so can the sensor overflow in a CCD imager should the pixels be exposed to light for too long.

When the CCD imager is connected to a telescope, the image of the object being looked at is projected onto the CCD chip. As will be the case with most images, there will be bright areas (stars, emission nebulae) and dark areas (barren sky or dark nebulae); the sensors will collect light in proportion to how much light is falling on them. At the end of the exposure some pixels will be quite full while others may be nearly empty.

During an exposure, the light falling onto the CCD chip makes its way into the thousands or millions of pixels (buckets) on the chip. These buckets keep filling up with light until the exposure ends. The next step is to take the contents of the buckets and convert it to a digital word so that the computer can work with it (the initial signal in the pixel is an analogue signal).

The exact process varies from camera to camera, but the basic process is as follows:

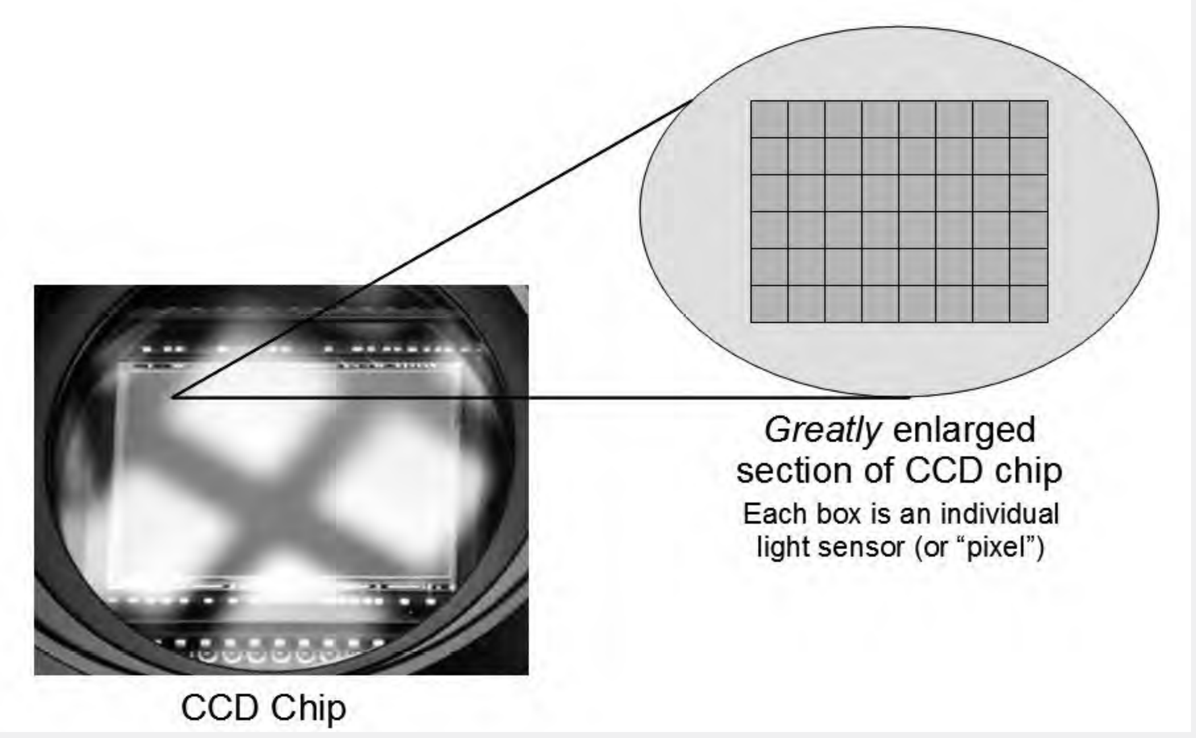
1. The signal in each pixel of the camera is applied (one by one) to a circuit called an Analogue-to-Digital Converter. This device converts the analog signal into a digital value (number) that represents the level of the signal in a particular pixel;

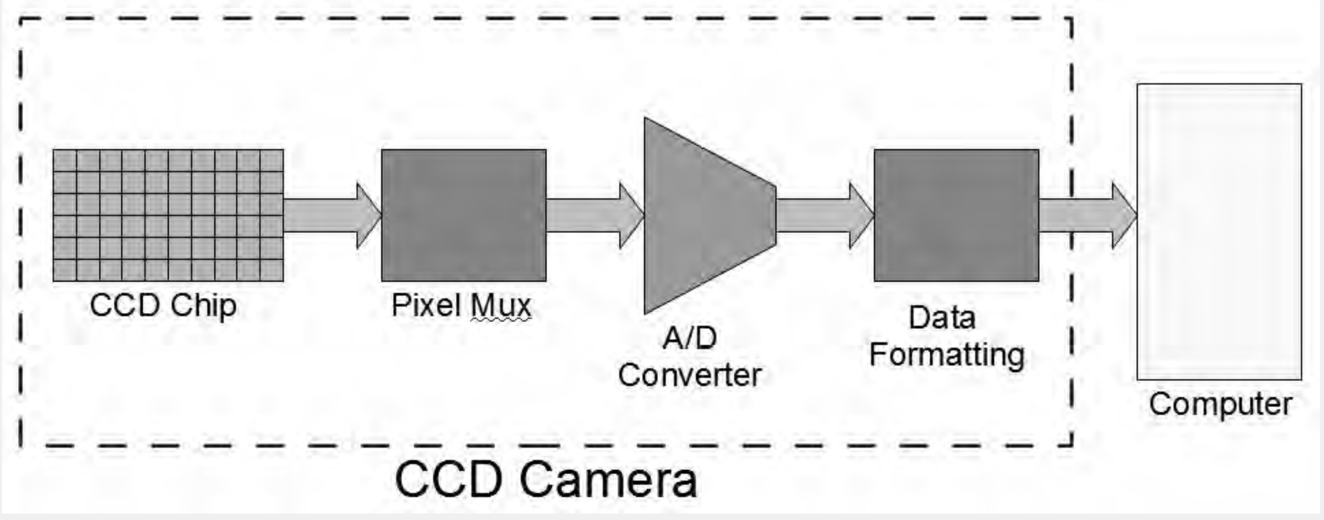
2. Then, each pixel value (again this could be millions of them) are then typically read out of the camera and sent to a computer where they are arranged in an image format and saved off as a file.

3. A device called a Pixel Multiplexer is the device arranges for each '*bucket*' on the CCD chip to have its signal (amount of light gathered) applied to the A/D Converter (Analogue to Digital). The A/D Converter takes the signal from the Pixel Multiplexer and converts it into a digital value;

4. This value is then passed on to the Data Formatting function. In this function the data may be arranged into a file and held in memory while it awaits download to the host computer. Note that with most modern CCD cameras a computer is required.

5. All cameras come with software that has to be installed on the computer, this software is used to control the camera and it also usually handles other things like downloading the images, basic processing, etc.





Components of a CCD Camera

In order to obtain the beautiful images of DSOs seen in books, magazines and the internet it is necessary when using an ACCD to capture a number of single raw images with exposures lasting several minutes, using Clear (Luminosity), Red, Green and Blue Filters placed in front of the CCD Chip. These are then calibrated (i.e. removal of noise and other unwanted artefacts), aligned and combined into a single beautiful colour image.

Single CCD Calibrated Image – M101 Spiral Galaxy in Ursa Major

E.3 Astrophotography CCDs

E.3.1 Types of CCD

Three basic types of CCD Cameras are used in modern Astrophotography, the specialist Astronomical CCD (ACCD), the Digital Single Lens Reflex (DSLR) camera and the Webcam. Each type has its own advantages and disadvantages.

Remember the saying ‘horses for courses’, the same is true of astrophotography.

There are many types of telescopes, mounts, cameras and accessories that can be used in astrophotography, but not all are suitable for every circumstance.

Some equipment is best suited to DSO astrophotography, but is equally totally unsuitable for Solar System Imaging.

For example, I would never dream of using my SBIG STL 11000 ACCD to image a Lunar Crater, nor would I ever use my Lumenera webcam to photograph the *‘Horsehead*’ Nebula.

It is absolutely vital that you are able to determine which equipment and equally importantly which combination of equipment is right for a particular type of astrophotography or specific target.

If you are a beginner don’t go out and buy an expensive SBIG or FLI ACCD and expect to get amazing results; don’t run before you can walk. Begin with a cheap webcam and image the moon and planets. When you feel more confident and want to branch out into DSO astrophotography buy a DSLR which you can use for terrestrial photography or a basic ACCD like a Meade DSI.

For Experienced Astrophotographer who really wants to capture those stunning wide field shots you see then you will have to invest more heavily in both time and money in an expensive ACCD; also the purchase of a high quality stable pier and mount cannot be over emphasized. High quality mounts are made by Losmandy and Software Bisque.

E.3.2 Specialist Astronomical CCD (ACCD) Cameras

An ACCD is ideally suited to Deep Space Astrophotography and in particular fainter objects; they can be cooled to reduce system noise either by thermoelectric coolers and/or water cooling.

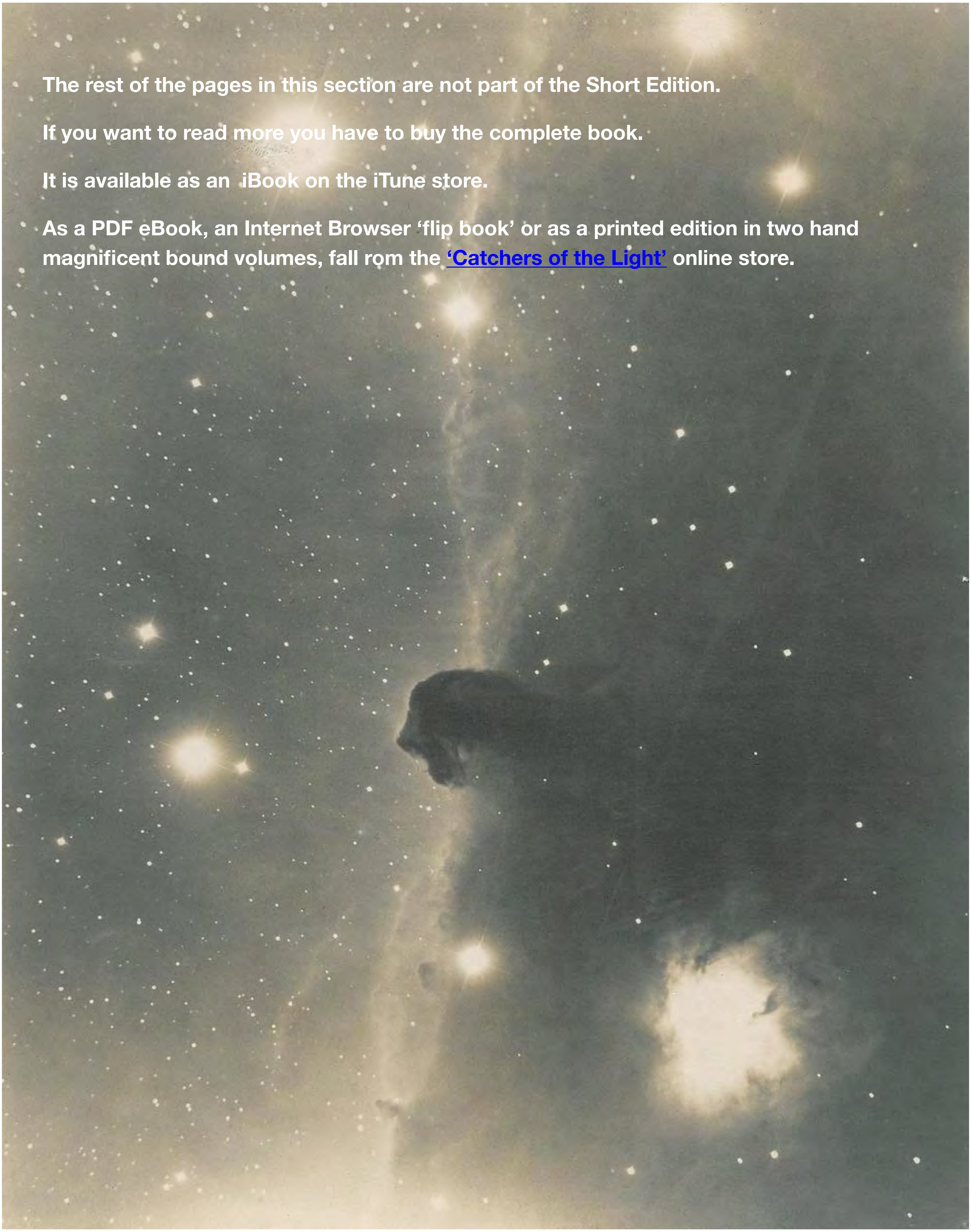
A large format ACCD (i.e. those with large 35mm size chips) are needed to capture large faint nebulae, e.g. ‘*Horsehead*’ or ‘*Witches Head*’ or large bright galaxies such as M31 and M33.

The rest of the pages in this section are not part of the Short Edition.

If you want to read more you have to buy the complete book.

It is available as an iBook on the iTune store.

As a PDF eBook, an Internet Browser ‘flip book’ or as a printed edition in two hand magnificent bound volumes, fall rom the [‘Catchers of the Light’] online store.



Appendix F

Useful Astrophotography Formulas

F.1 Overview

A list of simple mathematical formulas are given in this Appendix, which the reader may find useful in relation to the content of this book, and help him better understand some of the more technically difficult areas.

Sample calculations based on the 8 inch (20cm) Bache Telescope which has a focal length of 44.8 inches (118.8cm) and used photographic plates of 8 inches (20cm) by 10 inches (25cm) are used to illustrate the formulas.

F.2 Telescopes

F.2.1 Focal Ratio

The focal ratio (f) of a telescope is a measure of the '*speed*' of the instrument to capture images of astronomical objects in terms of exposure times on photographic plates or on a CCD chip.

A '*fast*' telescope is one with a small focal ratio of around f5 or less, whilst a '*slow*' telescope has an focal ratio of f10 or higher.

If A is the aperture of the telescope's mirror or objective lens and F is its focal length, then:

Focal Ratio (f) = F/A

So the Focal Ratio of the Bache Telescope is = 44.8/8 = 5.6 or f5.6, i.e. it is a '*fast*' telescope.

F.2.2 Eyepiece Magnification

If F is the focal length of the telescope and E the focal length of the eyepiece, then the magnification of the telescope using this eyepiece (M) is given by:

Magnification (M) = F/E

So if the Bache Telescope is fitted with a Plössl eyepiece of focal length 0.5 inches, the magnification obtained will be = 44.8/0.5 = x85.6

F.2.3 Eyepiece Field of View

The True field of view of an eyepiece (FOV) in degrees is given by the formula:

FOV = AFOV*E/F or AFOV/M

where AFOV is the Apparent Field of View of the eyepiece, M is the magnification of the eyepiece, E is the focal length of the eyepiece and F is the focal length of the telescope.

The field stop is a metal ring inside of the eyepiece barrel that limits the field size. It is projected by the eyepiece so that it appears as a circle out in space when you look through the eyepiece. The angular diameter of this circle is called the apparent field of view (AFOV) and is a fixed property for each eyepiece design. For example, Plössl eyepieces have an AFOV of 50°, Radians have 60°, Panoptics have 68°, Naglers have 82° and Ethos eyepieces have 100°.

So if the 0.5 inch focal length Plössl eyepiece of the Bache Telescope has an apparent field of view of 50º, its true field of view is given by:

FOV = 50*0.5/44.8 = 50/85.6 = 0.584º

F.3 Photographic Plates

F.3.1 Image Scale

The Image Scale (R) in degrees per inch (or cm) of a photographic plate/telescope combination can be calculated from the simple formula:

R = 57.296/F

where F is the focal length of the telescope.

In the case of the Bache Telescope R = 57.296/44.8 = 1.27^o per inch the equivalent of 0.5^o per cm, or as Edward Charles Pickering reported 2cm per degree.

F.3.2 Field of View (FOV)

The Horizontal Field of View (H), in degrees of a photographic plate/telescope combination can be calculated from the simple formula:

H= 57.296 x h/ F

where h = Horizontal Width of the Photographic Plate and F = focal length of the telescope.

The corresponding Vertical field of view (V) is given by:

V= 57.296 x v/ F

where v = Vertical Height of the Photographic Plate and F = focal length of the telescope.

In the case of the Bache Telescope we have:

H= 57.296*8/44.8 = 10.23^o

and

V= 57.296*10/44.8 = 12.79^0

F.4 Charge Coupled Devices (CCDs)

In the case of CCDs they consist of a rectangular array of pixels, with each pixel having a size usually measured in microns (i.e. one millionth of a metre).

It is also possible in some CCD cameras to '*Bin*' images where groups of 1x1 (Binning 1), 2x2 (Binning 2) or 3x3 (Binning 3) etc, are used in exposures to reduce the resolution of the final image.

So if we were able to attach a CCD say an SBIG STL 11000M, which has a pixel size of 9 microns, a binning capability of up to x5, and an size of 4008 (h) x 2672 (v) corresponding to a chip size of 36.1mm x 24mm.

F.4.1 Image Scale

The image scale or resolution (R) usually measured in arc seconds(") per pixel is given by:

R = 206.23*p*b/F

where p is the pixel size (in microns), b the binning (i.e. 1, 2, 3 etc) and F is the focal length of the telescope in mm.

So if we were use the SBIG STL 11000M, and a binning of 1 , the Resolution will be R = 206.23*9*1/(44.8*25.4) = 1.63"/ pixel.

The experienced Astrophotographer will realize that this is not an ideal combination and can only be used with a binning of 2, when the resolution will increase to 3.26. The reason for this is that except under ideal conditions the effects of the atmosphere can cause errors of between 1" and 2".

In fact the Bache telescope has too long a focal length and is therefore not an ideal choice for use with a modern CCD even with those having a large format chip; as the resulting image scale is too small to obtain high quality images, except when binning is used, given normal levels of ‘*seeing*’. Such a telescope needs to be located where the Harvard college Observatory actually used it - at Arequipa in Peru.

F.4.2 Field of View

The Horizontal field of view (H), in arc minutes (‘) of a photographic plate/telescope combination can be calculated from the simple formula:

H= 3.437 x p*h/ F

where p is the pixel size in microns, h is the horizontal array size of the chip in numbers of pixels and F is the focal length of the telescope in mm.

The corresponding formula for the Vertical field of view (V) is:

V= 3.437 x p*v/ F

where v is the vertical array size in pixels.

So using our STL1000M on the Bache Telescope we would have Horizontal and Vertical fields of view of:

H = 3.437*4008*9/(44.8*25.4) = 109.0’

V = 3.437*2672*9/(44.8*25.4) = 72.6’

F.5 Square Degrees

A square degree is a non-SI unit measure of solid angle. It is denoted in various ways, including deg^2, sq.deg. and $(°)^2$. Just as degrees are used to measure parts of a circle, square degrees are used to measure parts of a sphere. Analogous to one degree being equal to π /180 radians, a square degree is equal to $(\pi /180)^2$ or about 1/3283 steradian.

F.5.1 Total Number of Square Degrees

The number of square degrees S, in a whole sphere is given by the formula:

$S = 4* \pi(180/ \pi)^2 = 129600/ \pi = 41,253\ deg^2$

F.5.2 Area of Constellations

The total area of the 88 constellations in the sky is equal to this figure of 41,253 deg^2.

For example the area of the constellation Orion is 594.12 deg^2, whilst that of Hydra (Sea Serpent), the largest is 1302.84 deg^2.

F.5.3 Angular Area of the Moon

For example, observed from the surface of the Earth, the Moon has a diameter of approximately 0.5°, so it covers a solid angle of approximately 0.20 deg^o, which is 4.8×10^{-6} of the total sky sphere.

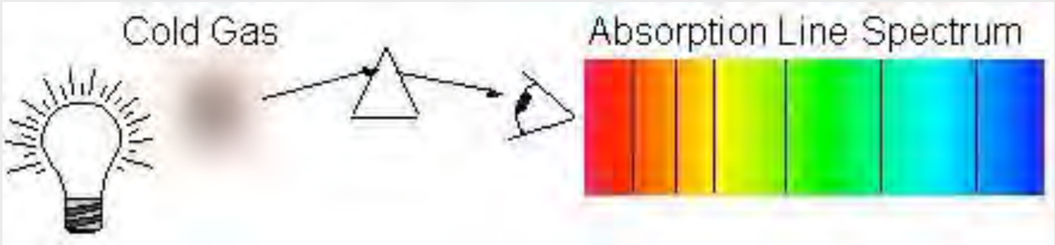
Appendix G

A Brief Glossary of Terms

In order to provide a complete definition of all the terms used in the '*Catchers of the Light*' would require another book of the same size! This I do not propose to do. However, I have compiled this *'short'* **Glossary of Terms** to help those readers with a general educational background to understand the more important and relevant of the many tens of thousands to be found in the vast literature relating to astronomy, Astrophysics, photography and optics etc.

A:

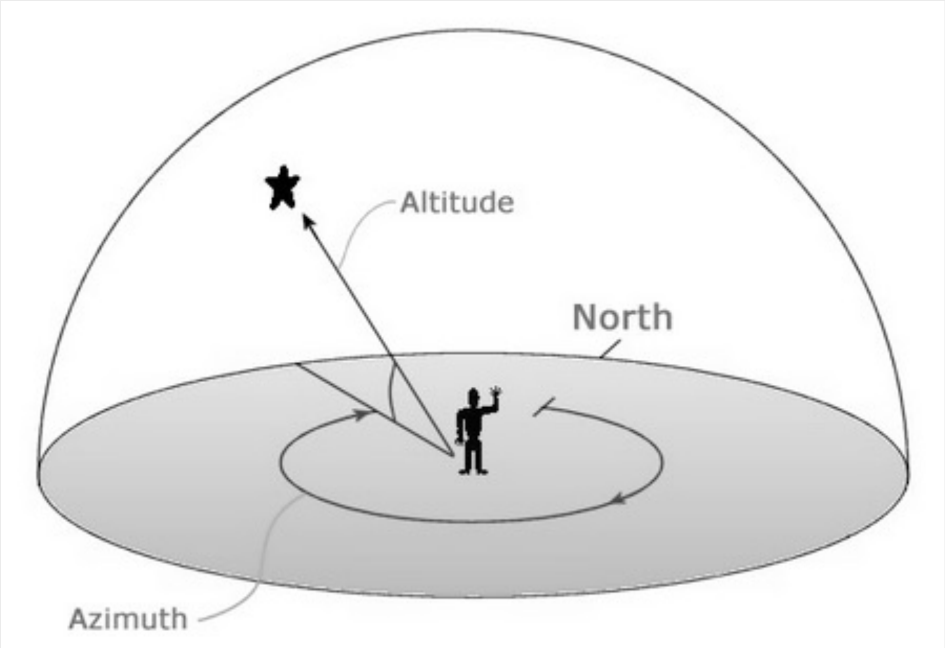
Absorption Line: A dark line in the spectra of astronomical bodies caused by the absorption of light at a particular wavelength due to the presence of a chemical element, which also can produce a bright emission line at the same wavelength.



Achromatic: The term literally means without colour and is used in the context of telescope design. In particular an achromatic refractor is one whose objective is made of two lenses made from differing types of glass to reduce the effect of chromatic aberration (see section D.2.2 of Appendix D)

Astrograph: A telescope specifically designed for the sole purpose of astrophotography, it can be either a refractor, reflector or catadioptric system.

Altitude: Is used to describe the location of an object in the sky as viewed from a particular location at a particular time. The altitude is the distance an object appears to be above the horizon. The angle is measured up from the closest point on the horizon.



Astrometry: A branch of astronomy that involves precise measurements of the positions and movements of stars and other celestial bodies.

Astronomical Spectroscopy: A branch of astronomy that studies the spectra of astronomical objects - stars, planets, galaxies, nebulae and supernovae in order to obtain information about them, such as structure, composition and distance.

Azimuth: Is used to describe the location of an object in the sky as viewed from a particular location at a particular time. The azimuth of an object is the angular distance along the horizon to the location of the object. By convention, azimuth is measured from north towards the east along the horizon.

B:

Black Body: Is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. It is also an ideal emitter: it emits as much or more energy at every frequency than any other body at the same temperature. In astronomy, the radiation from stars and planets is sometimes characterized in terms of an effective temperature, the temperature of a black body that would emit the same total flux of electromagnetic energy.

Bolide: A type of extremely bright **fireball**. The word bolide comes from the Greek βολίς (bolis) which can mean a missile or to flash. The term is generally applied to fireballs which reach magnitude −14 or brighter. It may also be used to mean a fireball which creates audible sounds.

C:

Calotype: A photographic process for making negatives on paper in which the latent image is made visible by chemical development (see section C.4 of Appendix C). It was developed by William Henry Fox Talbot and was announced to the public on the 10th of June 1841.

Carte du Ciel: The name given to the ill-fated project to make a complete photographic survey of the sky. The name from the French means *'map of the sky'* (see section VII.3.5 of chapter V.3).

Cassegrain Telescope: A type of reflecting telescope. A Cassegrain reflector is a combination of a primary concave mirror and a secondary convex mirror, often used in optical telescopes and radio antennas.

Catadioptric: An optical system in which refraction and reflection are combined, usually via lenses (dioptrics) and curved mirrors (catoptrics).

Catoptric: An optical system which only contains mirrors.

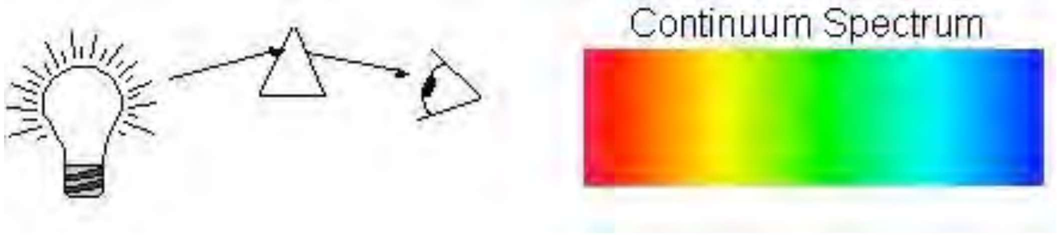
CCD: See **Charge Coupled Device**.

Celestial Mechanics: A branch of astronomy dealing the dynamic motion of astronomical bodies according to Newton's inverse square law of gravity.

Charge Coupled Device: A solid state device invented in 1969 by Willard Sterling Boyle and George Elwood Smith of the AT&T Laboratories. Originally it was intended to be an alternative form of computer memory , but was developed by Michael Francis Tompsett and others into an Imaging device (see section IX.2.5 of Chapter IX.2).

Collodion: A flammable, syrupy solution of pyroxylin (aka *'nitrocellulose'*, *'cellulose nitrate'*, *'flash paper'*, and *'gun cotton'*) in ether and alcohol; or name of the photographic process introduced by Frederick Scott Archer in 1851 (see section C.4 of Appendix C).

Continuous Spectrum: A spectrum apparently having all wavelengths over a comparatively wide range, usually characteristic of solids and other substances at high temperatures. In astronomy, the presence of a continuous spectrum in a 'nebulae' indicates that is made up of stars as is the case with extragalactic nebulae otherwise known as galaxies, which are 'Island Universes' similar to our own *'Milky Way'.*



Corona: See **Solar Corona**.

Coronagraph*:* A device developed in 1950 by the French astronomer, Bernard Lyot, to photograph the **Solar Corona** without an eclipse (see section III.4.4 of Chapter III.4).

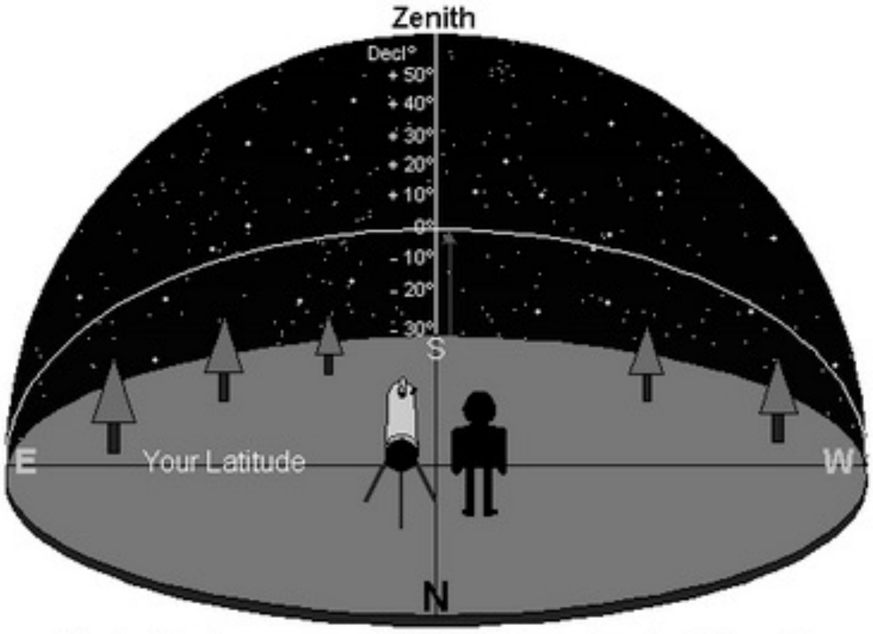
Crater: The word crater adopted by Galileo is from the Latin word for cup. Evidence collected during the Apollo Project and from unmanned spacecraft of the same period proved conclusively that meteoric impact, or impact by asteroids for larger craters, was the origin of almost all lunar craters, and by implication, most craters on other bodies as well.

D:

Daguerreotype: A direct positive process in which a silvered copper plate is made sensitive to light by fuming in iodine vapour. After exposure the latent image is made visible by the fumes of warmed mercury (see section C.2 of Appendix C). It was invented by Louis Jacques Mande Daguerre (1787-1851), and was revealed to the public on the 19th of August 1839.

Dioptric: An optical system which only contains lenses.

Declination: It is one of the two coordinates of an equatorial coordinate system, the other being either **right ascension** or hour angle. Declination in astronomy is comparable to geographic latitude, but projected onto the celestial sphere. Declination is measured in degrees north and south of the celestial equator. Points north of the celestial equator have positive declinations, while those to the south have negative declinations.



Declination is measured + (northerly) and - (southerly) from 0°

Dry Plate: A photographic process introduced in 1871 by Richard Leach Maddox (1816-1902), who proposed the use of an emulsion of gelatin and silver bromide on a glass plate. Its use in astronomy revolutionized Astrophotography and enabled the imaging of Deep Space Objects (DSOs) for the first time.

DSLR: Digital Single Lens Reflex. Refers to a type of digital camera that typically uses a mirror and prism system (hence *'reflex',* from the mirror's reflection) that permits the photographer to view through the lens and hence see exactly what will be captured, as opposed to a viewfinder cameras where the image could be significantly different from what will be captured.

DSO: Deep Space Object or Deep Sky Object, refers to astronomical bodies found outside of the boundary of our Solar System, i.e. stars, clusters, nebulae, galaxies and supernova.

Dwarf Planet: Is defined by the International Astronomical Union (IAU), as a celestial body in direct orbit of the Sun that is massive enough that its shape is controlled by gravitational rather than mechanical forces (and thus an ellipsoid in shape), but has not cleared its neighboring region of other object. Pluto once the ninth planet of the Solar System in became in 2006 a dwarf planet along with the asteroid Ceres and the **Kuiper Belt** objects Haumea, Makemake, and Eris.

Durchmusterung: From the German meaning *'survey'*.

Short Edition

Appendix H

Astrophotographers Family Pedigrees

This Appendix contains a Family Pedigree for each Astrophotographer featured in the Book, when known.

In order to save space only the direct male line is included.

The Genealogical information presented here, is not intended to be complete and definitive.

A person can and often does spend a lifetime researching their own family's history, to do so for forty seven individuals included here, would be an impossibility.

In a small number of cases very little information is known regarding the ancestry of certain Astrophotographers and as such no pedigree is provided.

This unfortunately has proved to be the case for Wilhelm Oswald Lohse and Marcel De Kerolyr. For Eugen (Jeno) Von Gothard only a sketchy pedigree has been included.

For each Astrophotographer the following information is given (when known) for every generation through the male line from the earliest known ancestor up to recent times:

•Date and Place of Birth;

•Date and Place of Marriage(s);

•Name of Spouse(s); Date and Place of their Birth, Death and Burial;

•Names of Children; Date and Place of their Birth, Marriage, Death and Burial;

•Date and Place of Death;

•Date and Place of Burial.

Although William Henry Fox Talbot (1800-1877) has no specific chapter devoted to him, nevertheless a Pedigree has been included, for this important pioneer of early photography.

In addition for each Pedigree the principal sources used to compile them have also been included.

Accompanying the Pedigrees are a number of '*snippet panels*' and photographs/illustrations. These have been added so as to make the Appendix more interesting, in what otherwise is a somewhat '*dull read*'. They contain further information related to the '*Catchers*', but not included in main text for lack of space.

The following Abbreviations have been used: **b** [birth], **c** [christened/baptised], **m** [married], **d** [died], **bu** [buried].

Armand Hippolyte Louis Fizeau was one of the early pioneers of photography, who took some of the first Daguerreotype images in the 1840s, mainly of architectural scenes in Paris. The photograph shown here was taken in 1840 of the Roman Catholic Church of St. Sulphice, Paris. The present church was founded in 1646 by the parish priest Jean-Jacques Olier (1608–1657), on the site of an earlier 13th century Romanesque church. Its construction took about 140 years, and by 1732 the church was mostly completed.

St. Sulphice Church, Paris, France, Hippolyte Fizeau, Daguerreotype of 1840

Jacob RORDAME
+ **Karoline SIMMONSEN**
- 1 **Alfred RORDAME** b. 8 Jun 1862 Akershus, Norway
  d. 30 Nov 1931 Salt Lake City, Salt Lake, Utah, USA
  bu. 2 Dec 1931 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
  + **Gertrude Alice BUCKERIDGE** b. 29 Dec 1870 Theale, Berkshire, England
  m. 3 May 1890 Salt Lake City, Salt Lake, Utah, USA
  d. 24 Oct 1957 Salt Lake City, Salt Lake, Utah, USA
  bu. 28 Oct 1957 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
  - 1 **John C. RORDAME** b. 12 Feb 1891 Salt Lake City, Salt Lake, Utah, USA
    d. 12 Feb 1891 Salt Lake City, Salt Lake, Utah, USA
    bu. 14 Feb 1891 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
  - 2 **Alfred Arthur Walter Goltered RORDAME** b. 23 Feb 1903 Salt Lake City, Salt Lake, Utah, USA
    d. 31 Jul 1940 Pocatello, Bannock, Idaho, USA
    bu. 4 Aug 1940 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
    + **Mildred DERRICOTT** b. 20 Jul 1908 Liberty, Bear Lake, Idaho, USA
    m. 30 Mar 1933 Farmington, Davis, Utah, USA
    d. 10 Jan 2000
    - 1 **Alfred RORDAME** b. 11 Jun 1938 Salt Lake City, Salt Lake, Utah, USA
      + (---) (---)
      - 1 **Alfred RORDAME** b. abt 1955 Salt Lake City, Salt Lake, Utah, USA
      - 2 **Andrew Rocky RORDAME**
      - 3 **Holly Ramona RORDAME**
      - 4 **Tammy Sue RORDAME**
  - 3 **Judith Frances Caroline RORDAME** b. 11 Jan 1892 Salt Lake City, Salt Lake, Utah, USA
    d. 26 Nov 1984 Salt Lake City, Salt Lake, Utah, USA
    + **Archibald Fitzgerald McALLISTER** b. 14 May 1886 Salt Lake City, Salt Lake, Utah, USA
    m. 29 Sep 1892 Salt Lake City, Salt Lake, Utah, USA
    d. 30 Dec 1969 Salt Lake City, Salt Lake, Utah, USA
  - 4 **Beatrice Alice RORDAME** b. 10 Apr 1894 Salt Lake City, Salt Lake, Utah, USA
    d. 5 Dec 1991 Salt Lake City, Salt Lake, Utah, USA
    + **Percy James PARSONS** b. abt 1890
    m. 3 Jan 1912 Salt Lake City, Salt Lake, Utah, USA
  - 5 **(---) RORDAME** b. 1 Nov 1896 Salt Lake City, Salt Lake, Utah, USA
  - 6 **Gertrude Elsie Eugene RORDAME** b. 1 Dec 1897 Salt Lake City, Salt Lake, Utah, USA
    d. 9 Mar 1975
    + **Orlan Russell WILLIAMS** m. 27 Apr 1922 Salt Lake City, Salt Lake, Utah, USA
  - 7 **Kenneth Ralph RORDAME** b. 14 Oct 1907 Salt Lake City, Salt Lake, Utah, USA
    d. 7 Dec 1912 Salt Lake City, Salt Lake, Utah, USA
    bu. 9 Dec 1912 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA

1 2 3 4 5

Sources:

The following principal sources were used in the compilation of the Family Pedigree for Alfred Rordame:

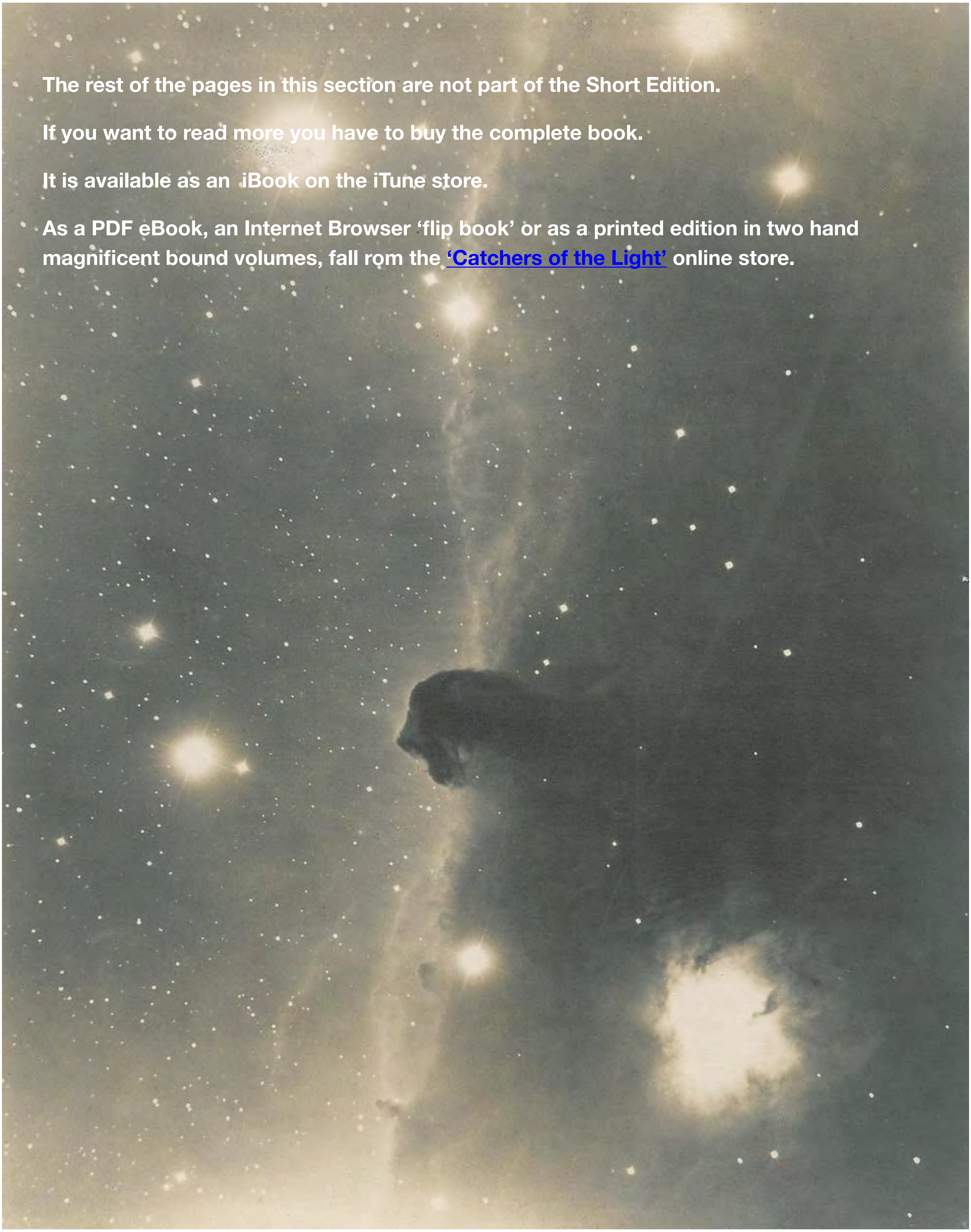
1. Alfred Rordame I Birth; Norway Baptisms 1634-1927, Film No. : 446237, Piece No.: 89169;
2. Birth, Marriage and Death Certificates, General Register Office of England and Wales;
3. USA Census 1880-1940, Available at Ancestry.com;
4. Utah, County Marriages, 1887-1937; https://familysearch.org;
5. Utah, Salt Lake County Death Records, 1908-1949; https://familysearch.org;
6. Utah, Deaths and Burials, 1888-1946; https://familysearch.org;
7. Utah Death Certificates, 1904-1956; https://familysearch.org;
8. Monumental Inscriptions, Mount Olivet Cemetery, Salt Lake City, Utah;

The rest of the pages in this section are not part of the Short Edition.

If you want to read more you have to buy the complete book.

It is available as an iBook on the iTune store.

As a PDF eBook, an Internet Browser ‘flip book’ or as a printed edition in two hand magnificent bound volumes, fall rom the [‘Catchers of the Light’] online store.



List of Abbreviations

ADC: Analogue to Digital Converter.

Alt: Altitude.

AJ: Astronomical Journal

AN: Astronomische Nachrichten.

ApJ: Astrophysical Journal.

AReg: Astronomical Register

AU: Astronomical Unit

Az: Azimuth.

bhp: brake horse power.

CCD: Charge Coupled Device.

CDC: Carte du Ciel.

cm: Centimetre.

CPD: Cape Photographic Durchmusterung

Dec: Declination.

DSLR: Digital Single Lens Reflex

ESA: European Space Agency.

f: Focal Ratio.

FL: Focal Length.

FSA: Frederick Scott Archer.

HCO: Harvard College Observatory.

HM: Her/His Majesty's

HST: Hubble Space Telescope.

JBAA: Journal of the British Astronomical Association.

JHA: Journal of the History of Astronomy

JRASC: Journal of the Royal Astronomical Society of Canada.

JWST: James Webb Space Telescope.

ly: Light Year.

km: Kilometre.

m: metre.

MNRAS: Monthly Notices of the Royal Astronomical Society of London.

mps: miles per second.

NASA: National Aeronautics and Space Administration;

nm: nano-metre.

OTA: Optical Tube Assembly.

PASP: Publications of the Astronomical Society of the Pacific.

Phil. Trans. Roy. Soc.: Philosophical Transactions of the Royal Society of London.

Proc. Roy. Soc: Proceedings of the Royal Society of London.

RA: Right Ascension.

RC: Ritchey-Chretien.

SAO: Smithsonian Astrophysical Observatory

SCT: Schmidt Cassegrain Telescope.

SLR: Single Lens Reflex.

USCS: United States Coast Survey.

USNO: United States Naval Observatory

Lacock Abbey, Wiltshire, Ancestral Home of William Henry Fox Talbot

The Author

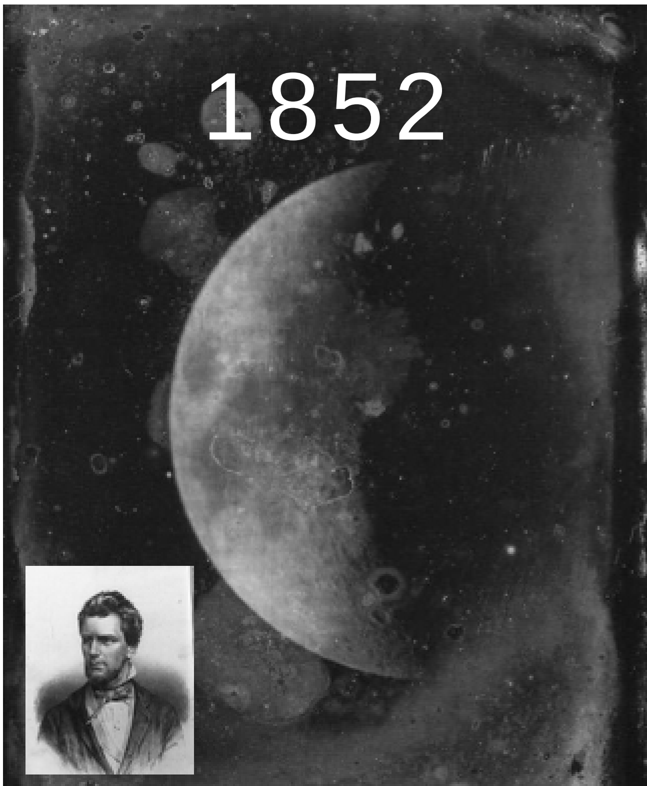
Stefan Hughes began his career as a professional astronomer, gaining a 1st Class Honours degree in Astronomy from the University of Leicester in 1974 and his PhD four years later on the '***Resonance Orbits of Artificial Satellites due to Lunisolar Perturbations***', which was published as a series of papers in the Proceedings of the Royal Society of London.

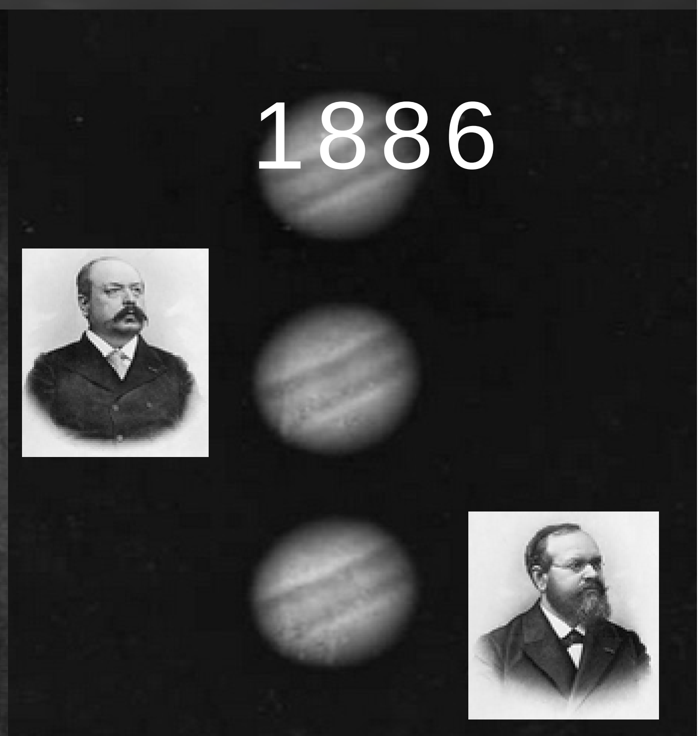
After graduating he became a Research fellow in Astronomy, followed by a spell as as a lecturer, firstly in the Department of Engineering at Warwick University and then in Applied Mathematics at Queen Mary College, University of London. Then came a ten year long career as an IT Consultant, working on large technology infrastructure projects for an international software house.

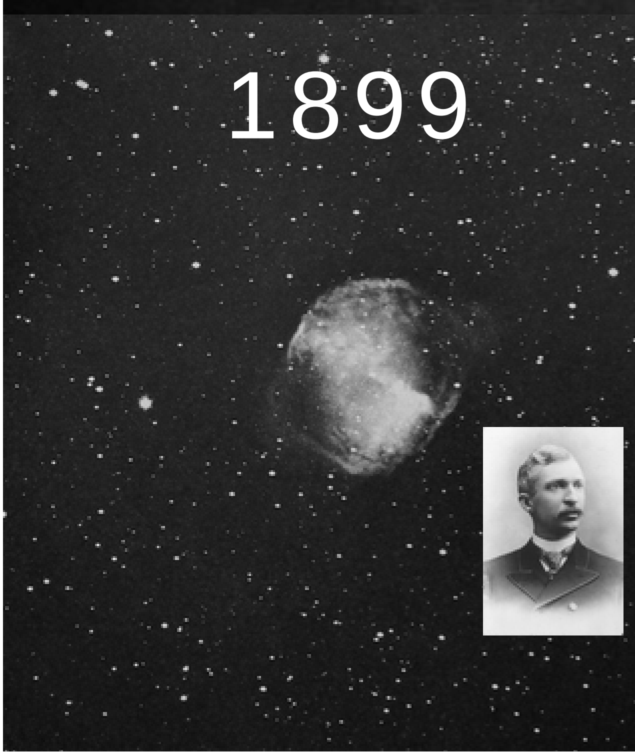
In '***mid life'*** he spent several years retraining as a Genealogist, Record Agent and Architectural Historian, which he practiced for a number of years before moving to the Mediterranean island of Cyprus.

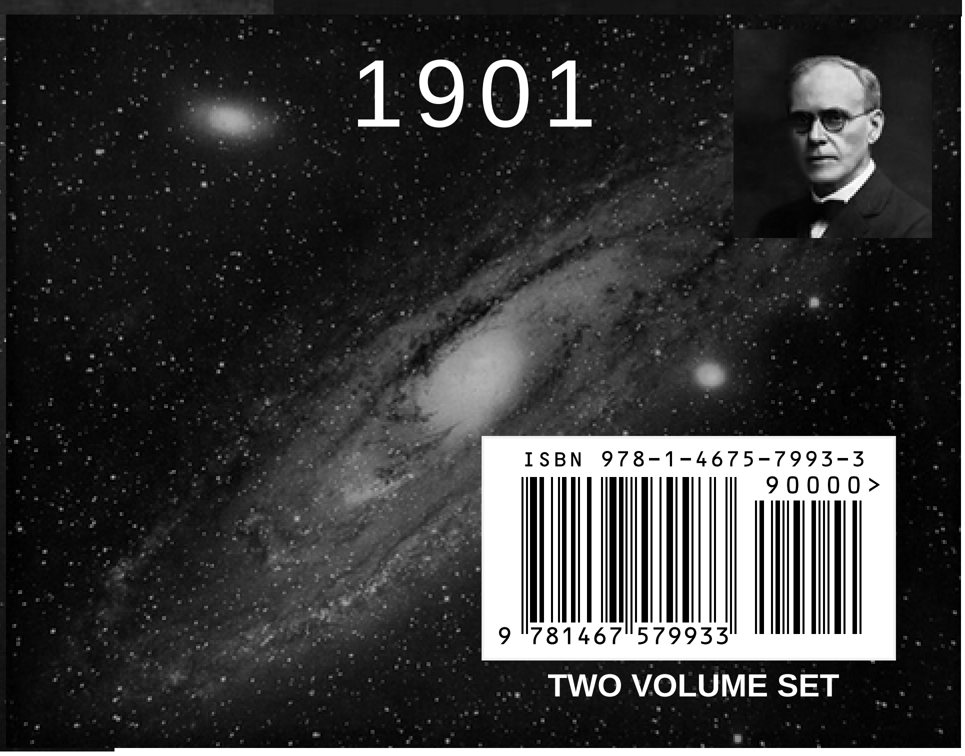
During his time working as an Architectural Historian and Genealogist, he was a regular contributor to Family History and Period Property Magazines.

For the past ten years he has been imaging the heavens, as well as researching and writing the '***Catchers of the Light'*** - *'Featuring the Forgotten Lives of the Men and Women Who First Photographed the Heavens'*.









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