African Skies

Cieux Africains

Working Group on Space Sciences in Africa
Groupe de Travail sur les Sciences de l'Espace en Afrique

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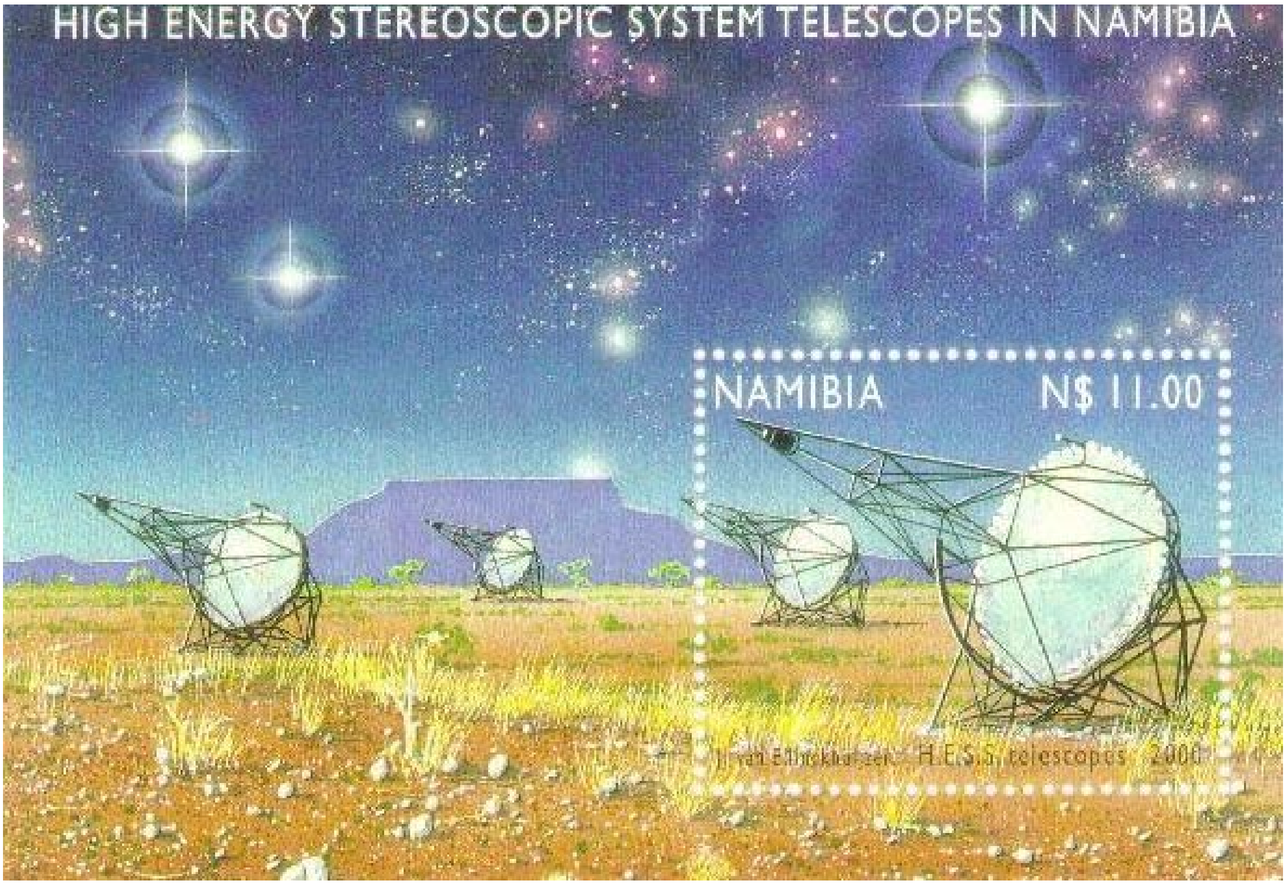

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The Working Group on Space Sciences in Africa

The Working Group on Space Sciences in Africa is an international, non-governmental organization founded by African delegates at the 6th United Nations/European Space Agency Workshop on Basic Space Science held in Bonn on 9–13 September 1996. The scientific scope of the Working Group's activities is defined to encompass: (a) astronomy and astrophysics, (b) solar-terrestrial interaction and its influence on terrestrial climate, (c) planetary and atmospheric studies, and (d) the origin of life and exobiology.

The Working Groups seeks to promote the development of the space sciences in Africa by initiating and coordinating various capacity-building programmes throughout the region. These programmes fall into a broad spectrum ranging from the promotion of basic scientific literacy in the space sciences to the support of international research projects. The Working Group also promotes international cooperation among African space scientists and acts as a forum for the exchange of ideas and information through its publications, outreach programmes, workshops, and scientific meetings.

The Working Group receives financial support from foundations and institutes committed to its objectives. One of its principal forms of support, however, is the time contributed freely by individual scientists.

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Editorial

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La diffusion de notre journal s'étend de plus en plus; le présent numéro est tiré à 1100 exemplaires.

En collaboration avec des collègues européens et japonais, les scientifiques africains ouvrent de nouveaux champs de recherche, en Namibie avec HESS pour l'étude des rayons gamma (astronomie des hautes énergies), ou bien en Afrique du Sud au SAAO avec IRSF pour l'étude des Nuages de Magellan (en infrarouge).

Pour faciliter la formation en astrophysique de nombreux étudiants du continent, l'Afrique du Sud a ouvert une université par correspondance qui dispense un BSc en Astronomie. Les travaux pratiques sont effectués avec des télescopes sud-africains; des projets dans des niches scientifiques adaptées sont préparés.

Plusieurs astrophysiciens africains ont proposé des projets de Laboratoire d'Astrophysique à leur gouvernement avec la construction d'un Observatoire National pour l'éducation et la recherche coordonnée entre plusieurs pays. Certains projets nationaux semblent aboutir, d'autres, hélas, paraissent être oubliés dans un cabinet ministériel, attristant et démotivant nos collègues qui se sont fortement investis. Souhaitons-leur toutefois quelques succès pour qu'ils gardent espoir dans l'avenir astrophysique et spatial de leur pays.

Dans ce numéro d'AS/CA, deux articles sur le statut des Sciences de l'Espace retiennent plus particulièrement l'attention:

- l'un nous vient de collègues de l'Université du Nigéria à Nsukka. Comme scientifiques, d'abord, ils montrent comment les Sciences de l'Espace stimulent le dévelop–pement des nouvelles technologies, comment elles sont un catalyseur pour la jeunesse, comment elles forment les outils du développement économique et de la culture moderne. En tant que responsables universitaires, ensuite, ils définissent les causes du sous-développement en Afrique et proposent des remèdes.
- l'autre article nous vient de l'Université Mbarara de l'Ouganda. Notre collègue universitaire y fait état d'une enquête sur l'impact des Sciences de l'Espace au sein de l'Université. Les conclusions et les recommandations déduites de cette enquête sont édifiantes. Les besoins et les solutions y sont clairement exprimés.

Ces deux documents rédigés par des membres de l'élite scientifique africaine sont des appels solennels aux gouvernements africains en faveur des Sciences de l'Espace, clefs actuelles indispensables du développement scientifique, technique et industriel de l'Afrique. Puissent-ils être entendus par les gouvernements africains qui n'ont pas encore entrepris de réflexions sur les Sciences de l'Espace. Le destin de l'Afrique est aussi entre les mains des Africains eux-mêmes. De plus en plus de pays le montrent aujourd'hui. C'est une grande espérance vers le progrès et la paix.

Our Newsletter is becoming more widely circulated, with 1100 copies of this issue being printed.

In collaboration with their European and Japanese colleagues, African space scientists are opening new fields of research in Namibia with HESS to study gamma-rays (high-energy astronomy) and in South Africa at SAAO with the IRSF for infrared studies of the Magellanic Clouds.

To facilitate training in astrophysics amongst students on the continent, the University of South Africa offers a BSc in astronomy as a correspondence course. Training includes the use of South African telescopes in certain scientific niche areas.

Several African astrophysicists have proposed to their governments projects on an astrophysical laboratory with the construction of a National Observatory for education and research coordinated between several countries. Some national projects are on the way to success. Unfortunately, others seem to be forgotten by some ministerial offices. This is depressing and demotivating for our colleagues who are involved in these projects.

In this issue of AS/CA, we draw attention to two articles concerning the status of the space sciences in Africa:

- the first comes from colleagues at the University of Nigeria at Nsukka. As scientists, they show how the space sciences stimulate the development of new technologies, how they are a catalyst for the youth, how they form the tools of economic development and modern culture. As university representatives, they define the causes of the under-development in Africa and suggest some remedies.
- the second comes from Mbarara University in Uganda. Our university colleague discusses a survey on the impact of the space sciences at that University. The conclusions and recommendations drawn from this survey are enlightening. Needs and solutions are clearly expressed.

These two articles, written by members of the African scientific elite, are solemn calls to African governments in favour of the space sciences to present the keys necessary for the scientific, technical and industrial development of Africa. We can only hope that they will be heard by African governments who have not yet considered the importance of the space sciences. Africa's destiny is in the hands of Africans themselves. A growing number of African countries recognise this. It is a great step towards progress and peace.

NEWS / NOUVELLES

IAU General Assembly

The 24th General Assembly of the International Astronomical Union, held in Manchester from 6–18 August 2000, was attended by a record number of African Space Scientists. There were 14 IAU members and 4 invited participants from Algeria (2), Egypt (3), South Africa (11), Zambia (1) and Zimbabwe (1). During the Special Session on Astronomy for Developing Countries, the session chairman, Prof Alan Batten, attributed this growth in African participation to our Working Group.

In spite of the promising (modest) growth in the number of African participants, there is still a very serious dearth of African members of the IAU. The advent of large-scale facilities such as SALT, HESS and the World Space Observatory, coupled to increasing internet access, presents unprecedented opportunities for the sustainable development of space science in Africa. This should lead to a steady growth in the numbers of African participants at future IAU general assemblies.

Fig. 1: Photograph of the 1.13-km diameter Pretoria Saltpan impact crater (also known as the Tswaing Crater) in South Africa. At Tswaing, a major museum is being developed, with the aim of providing the several million people living in the region around this site with multidisciplinary natural science and environmental education. View towards the west.

African Impact Cratering Research Group Founded

The importance of impact cratering (by asteroids, comets, and large meteorites) and the potential danger that it represents to mankind has, in recent years, been widely publicised and debated. Most recently, the British parliament held a debate dedicated to this issue and resolved that more efforts had to be made to detect potentially earth-orbit crossing asteroids and comets. American and British projects, such as Spaceguard, have already been highly successful in identifying a large number of previously unknown Near-Earth Asteroids and other, possible, threats. NASA's Shoemaker-NEAR (Near-Earth-AsteroidRendezvous) mission has already provided an enormous amount of previously unknown information about the nature of asteroids, and will continue to do so until the mission comes to an end in 2001. The international impact cratering community has made major efforts to arrange for a deep-drilling program into one of the world's largest impact structures, the 65 million year old Chicxulub impact structure off the Yucatan peninsula in Mexico. And European and African (from Ghana and South Africa) scientists are working towards a drilling investigation of the 10 km wide, complex meteorite crater Bosumtwi in Ghana.

To date, 19 impact structures are known from Africa. Most of them are located in Saharan Africa and were discovered in the course of oil exploration around the mid-20th century. Others are known from southern Africa, and in part have been known for many decades but were hotly debated as being of impact or some other geological origin. Much work on these structures has been carried out over the past 20 years at the University of the Witwatersrand (Wits) in Johannesburg. In 1999 many new impact cratering related results were presented at the 62nd Annual meeting of the Meteoritical Society in Johannesburg, Gauteng, the "city of gold". On that occasion, the first dedicated African Impact Cratering Research Group (ICRG), founded shortly before by Wits University, was presented to the international community. Since then, workers at the Wits Geology Department, the Hugh Allsopp Isotope Laboratory, and at the University of the North West – collectively forming the ICRG, have been tremendously active. More than 20 research articles, partially in close collaboration with researchers in Europe and the United States, have been published. The group continued work on the world's largest known impact structure, the Vredefort Structure which incorporates the gold-rich Witwatersrand basin, Bosumtwi in Ghana, and the 70 km-wide impact structure Morokweng in North-West Province of South Africa. Following a first report at the Meteoritical Society conference by geologists from Botswana of an interesting crater structure in the eastern part of that country, the 2.5 km-wide Kgagodi impact crater was confirmed and presented to the planetological community at the 2000 Meteoritical Society conference in Chicago. The Kgagodi impact crater has the potential to provide a significant, rather long palaeoenviron–mental record, should it be possible to drill into this structure in its center and to obtain a complete drill core through the sedimentological crater fill. This is a very important prospect for the international global change programme.

The ICRG successfully presented a proposal to participate in the

Chicxulub drilling project and now hopes that this multi-national investigation will be successfully started. In July 2000, the 4th Snowbird Conference, titled "Impacts and Beyond…." took place in Vienna, and the ICRG team participated with three delegates, who presented talks on the African impact cratering record and the South African sections across the Permian-Triassic boundary, which demarcates the time at 250 million years ago, when by far most lifeforms became extinct in a relatively short time. It is hotly debated whether this mass extinction, like that at the Cretaceous-Tertiary Boundary at 65 million years ago, could be the result of a catastrophic impact event as well. Experimental work towards the understanding of shock metamorphic microdeformation in the very resistant (to weathering and metamorphism, for example) mineral zircon has also been conducted, in collaboration with Austrian and German scientists. Clearly, the impact cratering community – and the ICRG workers – deal with a multidisciplinary subject, involving astronomy and earth science disciplines such as sedimentology, geochemistry, mineralogy, and palaeontology, *inter alia*.

Besides being busy with these and a few other projects, the ICRG is engaged in meteorite research. Meteorites, in South Africa, are strictly protected by the government, and permits are required even to study them. The ICRG has obtained the only permit yet issued in South Africa granting permission to "*damage* meteorites for the purpose of their proper identification and classification". "Damage" here, of course, means that small samples may be extracted for mineralogical or geochemical analysis. It is therefore possible to contact the ICRG with any find which may be thought to represent a meteorite and request to have the specimen identified. So far, a number of "meteo-wrongs" have been studied, but in due course the "real McCoy" (meteo-rights) will appear. There must be thousands of meteorites lying on the surface of the African continent – at least some of which will be of great scientific and educational value and still have the potential to make major contributions to our understanding of the formation and evolution of the Solar System.

The ICRG is dedicated to state-of-the-art research on impact crater structures and meteorites, but not only within the South African context. Collaboration with other countries in Africa is encouraged and desirable, and the members of the research group look forward to contacts (address details are given below) from all parts of Africa. Many analytical facilities are available to the ICRG, but should it not be possible to assist with analytical work in South Africa, contacts with all other parts of the world do exist. It is also possible to assist with setting up direct research links between African and overseas researchers.

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Groundbreaking Ceremony for Africa's Giant Eye

On 1 September 2000, international and local partner and scientists, as well as other dignitaries attended the ground-breaking ceremony to mark the official start of construction of the Southern African Large Telescope (SALT) at the South African Astronomical Observatory (SAAO), near Sutherland in the Northern Cape.

Funding partners from five countries joined Dr Ben Ngubane, South Africa's Minister of Arts, Culture, Science and Technology in digging into the rock-hard soil where SALT will be built over the next four years. Germany, New Zealand, the UK, Poland and the USA are all committed to supporting Africa's quest for a giant eye to the universe. The international representatives described SALT as a bold step into the future and wished South Africa every success with the construction phase lying ahead.

"It is with great national pride that we stand here today to witness the turning of the sod of what will be the most powerful telescope – not only on the continent of Africa, but in the entire southern hemisphere," said Minister Ben Ngubane. "Such a telescope will provide a focus for the development of basic sciences on the African continent," he said.

"The new telescope will have two primary objectives – to do cutting-edge physics, and to change the fortunes of the country," said Dr Khotso Mokhele, President of the National Research Foundation (NRF). The NRF is the official South African SALT partner, with funding provided by the Department of Arts, Culture, Science and Technology (DACST).

Minister Ngubane expressed the hope that SALT would be a significant catalyst in producing more black post-graduate students in science and engineering. The great economic and educational benefits expected from the project were emphasised throughout the day.

The local community of Sutherland is positioning itself to become a popular tourism and science destination. Earlier in the day, a twinning agreement was signed between Sutherland and Fort Davis in Texas, USA. Fort Davis is home to the Hobby-Eberley Telescope, which pioneered the design being used in SALT.

Fig. 2: Digging in – Dr Ben Ngubane, South Africa's Minister of Arts, Culture, Science and Technology and Mr Manne Dipico, Premier of South Africa's Northern Cape Province, where Sutherland is situated.

Exactly the right thing, at the right time and in the right place. That was the overwhelming feeling at the groundbreaking ceremony.

Western Cape, South Africa becomes Space Junkyard

On April 27, mysterious glowing objects began falling out of the Western Cape sky. The largest fell on a farm about 37 km NE of the centre of Cape Town, only 13 km from the centre of the suburb of Durbanville. Another landed about 70 km further ESE at Lemoenpoort (100 km ENE of Cape Town and 25 km south of the town of Worcester). A third hit the ground another 24 km further ESE, near the town of Robertson. The story about the Lemoenpoort "space ball" broke first, with 15-year old Theodore Solomons telling how a "glowing hot" ball "came out of nowhere, straight at me. It didn't come from straight above, but at an angle. Then I ran away and I heard something like two gunshots when the ball hit the ground only meters away, but it didn't make much of a dent". It was still too hot to touch half an hour later, when farmer Pieter Viljoen arrived. Labourers in his vineyards had told him about a shining ball that hit the ground 50 m from where they were working, and as soon as it was cool enough he loaded the mysterious intruder into his bakkie (pickup truck) for storage in his barn. It eventually ended up being investigated by the Department of Civil Aviation at Cape Town International Airport, who soon realized this was not part of any known aircraft.

Chris Koen at SAAO found himself fielding media calls the next day, with the media apparently reasoning that astronomers ought to know about things that come from the sky. After a hasty consultation with retired SAAO astronomer and satellite tracking hobbyist Greg Roberts, Chris was able to suggest various bits of orbital debris that might conceivably have come down to earth that day.

But the story didn't die, as over the weekend newspapers began reporting the landing of a much bigger, oblong object on Buurmanskraal, Philip Scher's farm, near Durbanville. Neighbour Lampies Lampbrecht heard "a sort of crack and then an explosion", and some of his farm workers saw the glowing "ball" land on Scher's farm a short distance away. Lampbrecht said it looked like a 3000-litre water tank. Monday, 1 May, was a holiday, but SAAO's Dave Laney found himself rousted out of bed by media calls about this latest rusty intruder from outer space, which early reports said had fallen a day after the first "space ball". A bit of hasty web research showed that a suspiciously similar object had fallen near Georgetown, Texas on January 22, 1997 – a propellant tank from the second stage of a Delta II rocket. A team of e-tv reporters who arrived for an interview later in the day looked at the web page picture and immediately identified the Durbanville "spaceball" as almost identical to the Texas object, in size, shape and appearance. Alan Pickup in Edinburgh quickly posted an analysis giving the likely culprit as the Delta II second stage rocket from the launch of a GPS satellite in March 1996.

Fig. 4: This close-up of the propellant tank in Fig. 3 shows an impact site from a micro-meteorite. The crater is 2 mm across.

Fig. 3: A propellant tank from the second stage of a Delta II rocket, found on the farm Buurmanskraal, near Cape Town. *Photograph by courtesy of Die Burger.*

It was predicted to decay around the time when eyewitnesses reported the various falling objects (between 1300 and 1330 UTC), and it was over the Cape at the right time. New interviews by reporters established that all objects had in fact fallen on the same day at roughly the same time.

On May 3, a report previously buried in a local newspaper reached Cape Town. The Afrikaans newspaper "Die Burger" reported that Bertie Nel, manager of Le Grande Chasseur wine cellar near Robertson, had heard a noise "like a helicopter", then looked up to see a glowing object apparently 150 m up and falling fast. About a second later it had made a dent in the yard of Wouter de Wet some 200 m away, splashing hot metal as it landed. A piece of what looked like rubber appeared to be melting in the heat. This was the "thrust chamber" (exhaust nozzle), "about as large as a 20-litre drum" It hit the ground at 1530 SAST on April 27, farthest east along the track of the orbiting rocket stage and presumably last to land.

Reports and pictures matched what would be expected if these were bits of a Delta II second stage, but it was time for a personal view. The first close encounter was at the Kraaifontein police station's vehicle pound, where Case Rijsdijk and Dave Laney of SAAO photographed the main propellant tank. Captain Jane Cohen was more than willing to deliver it to SAAO for safekeeping the next day. Sightseers kept arriving to see the "space ball", and the vehicle pound offered no protection from rain. The Robertson police were just as happy to give up the exhaust nozzle, providing

Case drove out to fetch it. It took a bit more persuasion to get the civil aviation authorities to give up the Worcester object, which proved to be one of the pressurisation spheres mounted around the base of a Delta II second stage. After a short stay in SAAO's mechanical workshop, the objects went on display in Cape Town's new MTN ScienCentre.

Nobody was hurt by the falls in the U.S. or South Africa, though a bit of "gauze" hit a woman in Oklahoma. So far the only "sky is falling" casualty is a Cuban cow hit by another piece of American space hardware years ago. The propellant tank definitely took some hits in orbit before falling on South Africa, however. Photographs show a number of micrometeorite pits from small bits of debris. Even a fleck of paint can make a surprisingly large dent when travelling at 30 000 km/h.

Infrared facility in Karoo to probe nearby galaxies

Japanese and South African astronomers are about to start putting together a clearer, sharper picture of the two nearest galaxies to our own (the Magellanic Clouds) and of the central regions of our own Milky Way galaxy. These will be the main targets of surveys with the new InfraRed Survey Facility (IRSF), officially opening on Wednesday 15 November 2000.

The IRSF is the seventh telescope on the South African Astronomical Observatory (SAAO) observing site near Sutherland in the Northern Cape, and the second largest there, with a mirror 1.4-metres in diameter.

"Japan and South Africa have long been partners in building and using infrared cameras for astronomy. This international partnership resulted in the new computerised, hi-tech facility at Sutherland, ushering in an exciting new era for infrared astronomy," says Dr Khotso Mokhele, President of the National Research Foundation (NRF). Mokhele officially opened the facility with Prof Shuji Sato, Principal Investigator and Head of the Infrared Group at Nagoya University, Japan.

"We can't see infrared radiation, but we may feel it as heat. At these wavelengths we can 'see' through dust clouds to regions otherwise hidden from our view," explains Dr Bob Stobie, Director of the South African Astronomical Observatory (SAAO). "Infrared light is also ideal for studying cool stars that radiate most of their energy at wavelengths too long for the eye to see," he says.

To date, collaboration between Japanese and South African astronomers for infrared observations has mainly involved the 0.75-metre telescope at the SAAO's Sutherland site and a small 0.4-m telescope at the SAAO in Cape Town.

The total construction cost of the IRSF is about R18 million (US $2.25 million). The SAAO is responsible for the building (R1.1 million), infrastructure and continuing support. Major funding came from the Japanese Ministry of Education. Nagoya University in Japan built the infrared camera (SIRIUS) at a cost of R7 million. University staff worked with an optical company at Kyoto to build the telescope (R10 million), using Russian optics.

In each infrared survey exposure at Sutherland, an area of the sky (a square about one quarter as wide as the full moon) will be recorded in three different infrared wavebands simultaneously. Previous infrared surveys have covered large areas of sky, while the Sutherland project will record fainter objects, in images four times as sharp.

10th UN/ESA Workshop

The 10th UN/ESA Workshop on Basic Space Science, titled "Exploring the Universe – Sky Surveys, Space Exploration, and Space Technologies," will be hosted by the University of Mauritius from 25 to 29 June 2001.

In 1900, the United Nations, in cooperation with the European Space Agency, initiated the organization of annual Workshops on Basic Space Science as part of the Programme on Space Applications of the United Nations Office for Outer Space Affairs. These Workshops, focusing on planetary exploration and astronomy, have been held in India (1991) and Sri Lanka (1995) for Asia and the Pacific, Costa Rica (1992) and Honduras (1997) for Central America, Colombia (1992) for South America, Nigeria (1993) for Africa, Egypt (1994) and Jordan (1999) for Western Asia, and Germany (1996) and France (2000) for Europe.

This Workshop is the 10th in the series of UN/ESA Workshops on Basic Space Science and will be oriented to the opportunities for developing countries to participate in world space observations and in the utilization of space technologies. Efforts will focus on sky surveys, breakthroughs in space science/technology and the studies of the universe. Emphasis will be placed on data manipulation techniques (including data reduction, archiving, retrieval, etc) and multi-wavelength analysis.

The programme of the Workshop will comprise:

- Sky Surveys
- From Solar/Planetary Systems to Galactic/Extragalactic Systems
- Data Manipulation, Databases and Multi-wavelength Analysis
- Education and Networking of Telescopes, with special reference to the southern hemisphere
- Utilization of Space Science & Technologies and their benefits to society

During the Workshop, additional working group sessions will be held to develop future activities related to these topics. As part of the Workshop visits to the Mauritius Radio Telescope and the National Remote Sensing Centre/INSAT TeleTracking Station will be organized for interested participants.

Updated information about the Workshop series can be obtained via the World-Wide-Web at http://www.seas.columbia.edu/~ah297/un-esa/.

Indication of Interest deadline is 1 May 2001

HESS – An Array of Gamma Ray Telescopes in Namibia

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Abstract. Several European institutions have successfully pioneered the principle of stereoscopic observation of gamma-ray induced air showers as a technique to do very high energy astronomy with the HEGRA instrument on the island of La Palma. Following the success of HEGRA, a next generation instrument, called HESS (High Energy Stereoscopic System), is currently under construction in the Khomas Highland of Namibia.

Sommaire. Plusieurs institutions européennes ont réussi à mettre au point le principe de l'observation stéréoscopique des gerbes produites dans l'atmosphère terrestre par les photons induits par les rayons gamma comme technique appliquée à l'astronomie des très hautes énergies avec l'instrument HEGRA sur l'Ile de La Palma aux Canaries. A la suite du succès d'HEGRA, un instrument de nouvelle génération, appelé HESS (Système Stéréoscopique à Haute Energie), est actuellement en construction dans l'Highland Khomas en Namibie.

Introduction

In March 1997 the Max Planck Institute for Nuclear Physics in Heidelberg (MPIK[1]), Germany, published a Letter of Intent[1] in which they proposed the establishment of a ground-based large stereoscopic system of medium-size Imaging Atmospheric Čerenkov Telescopes (IACTs) for very high energy (VHE) γ-ray (gamma-ray) astronomy. The name suggested for this project was HESS, which is an acronym that stands for High Energy Stereoscopic System. The name was chosen to honour Viktor Hess, the discoverer of comic radiation.

This array of atmospheric Čerenkov detectors is intended to replace the older HEGRA (High Energy Gamma Ray Astronomy) project that is currently running on the island of La Palma in the Canary islands. As in the case of the HEGRA project, which is a collaboration involving MPIK and other institutions in Europe (University of Hamburg; University of Kiel; Complutense University of Madrid; Max Planck Institute for Physics, Munich; BUGH Wuppertal; Yerevan Physics Institute), HESS was from the onset also intended to be a collaboration, but on a larger scale yet.

The HEGRA project successfully proved the concept of stereoscopic observation of air showers produced by γ-ray photons entering the atmosphere from space. The ability to observe these showers with several telescopes at various viewing angles enabled the HEGRA instrument to determine the shower axis accurately, thus ensuring good angular resolution (0.1°) of the direction of motion of the incident γ-ray photon. The stereo–scopic technique also enabled HEGRA to discriminate efficiently between γ-ray induced showers and showers induced by the nucleonic component of cosmic rays. An efficient triggering scheme also ensured a high degree of background suppression. This resulted in a low detection threshold in photon energy (500 GeV). Also, by using the redundant experimental data provided by several telescopes, researchers were able to calculate reliable energy spectra for γ-ray sources in space[3]. For 1 TeV photons the HEGRA instrument can detect an energy flux as low as $f_E(> 1\ \text{TeV}) = 10^{-12}$ erg/(cm^{2}s), where $f_E = E\, dF\gamma/d\ln E = E^2\, dF\gamma/dE$.

The HESS array is being designed to be approximately one order of magnitude more sensitive than its predecessor, HEGRA.

Site

In choosing the site for the HESS array, the following requirements had to be met: a documented optical quality of the atmosphere above the site, as high above sea-level as possible, and no extreme weather conditions. Also, a site in the southern hemisphere is desirable for viewing the galactic centre and also to complement similar experiments in the northern hemisphere (like the VERITAS project proposed in the United States). Australia was eliminated from the choice due to the existence of the CANGAROO and the proposed CANGAROO II projects by the Japanese and Australians. South America was disregarded because of logistical reasons.

This left southern Africa, with two possible sites: Sutherland in the Karoo in South Africa and the Gamsberg in the Khomas Highland of Namibia. Both these sites were also in contest for the SALT telescope and although Sutherland was chosen for this, the Gamsberg was identified as one of the best sites in the world.

Due to logistical reasons it was decided to situate HESS on a farm in the Gamsberg region, and not on the mountain itself. This farm (23°20'S, 15°50'E) is located about 100 km from Windhoek, the capital of Namibia. Although the site is not on the Gamsberg, it is still about 1800 m above sea-level, the same height as the highest point on the Sutherland site.

Science requirements for the HESS array

As the name suggests, stereoscopic observation capabilities will also be a key feature of the HESS array. This will provide the instrument with capabilities similar to that of the HEGRA instrument: good angular resolution per shower producing photon, good energy resolution and hadron suppression, a low energy threshold and the ability to measure reliable energy spectra.

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[1] German: Max-Planck-Institut für Kernphysik

The proposed system will be able to detect γ-rays above a threshold photon-energy of about 40 GeV. However, due to the effect of the geomagnetic field on the charged secondary particles that produce the Čerenkov light flashes in the upper atmosphere, the operational threshold of the HESS instrument will have to be limited to photon energies above 100 GeV to ensure acceptable spatial resolution of the incident γ-ray photons (about 0.1° per photon).

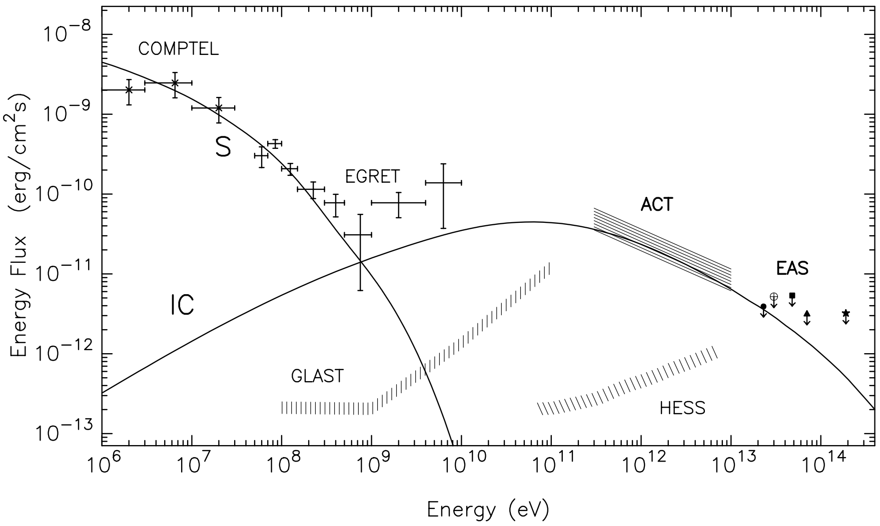

Fig 1. Sensitivity of the IACT array in its final stage relative to the flux from the Crab Nebula as measured by the COMPTEL and EGRET experiments on the Gamma-Ray Observatory (GRO) satellite. Shown on this graph are the inverse Compton (IC) and synchroton (S) contributions to the Crab spectrum. Also indicated are the sensitivity levels of other ACTs. From the HESS Letter of Intent[1].

Each IACT will have a field of view of about 5°. This generously large field of view will enable the mapping of extended γ-ray sources like supernova remnants (SNRs) and giant molecular clouds (GMCs).

A single IACT has the sensitivity to detect γ-ray sources with intensities of about 20% of that of the Crab Nebula source, a frequently used standard. In stereoscopic mode the HESS array will be able to detect sources at a few percent of the Crab source, i.e., a new population of "milli-Crab" sources will be available for discovery. For 1 TeV photons the minimum detectable energy flux for the array will be in the order of f_E(> 1 TeV) = 10^{-13} erg/ (cm^2 s) for observation over 100 h (see Figure 1). This implies a flux sensitivity, *F*γ(> 100 GeV) of 10^{-12} photons/ (cm^{2}s) in 100 h.

Technical Specifications of the HESS array

The HESS telescope will be constructed in two phases. In Phase I, four telescopes will be erected in a square formation approximately 100 m apart. It is expected that the first of these will be tested late during 2001 or early 2002. All four of the Phase I telescopes should be opera–tional late in 2002 or early 2003.

During Phase II, the number of telescopes will be increased to 16 units, possibly making HESS the largest VHE array in the world. A possible lay-out of a 4-by-4 array is conceived. Also during Phase II an optical monitoring telescope (ATOM – Automatic Telescope for Optical Monitoring) will be erected and will be slaved to the HESS array for multiwavelength observations. In addition, a LIDAR (Light Detection and Ranging – an instrument that uses a laser beam to probe the atmosphere) and other instruments to monitor atmospheric conditions above the site will be installed either late in Phase I or early in Phase II.

For each individual telescope a segmented Davies-Cotton reflector (a spherical reflector) with a total area of 80 m^2 and a focal length of 15 m will be used.

Each reflector will be made up of 300 circular aluminised glass mirror tiles, each with a diameter of 60 cm. A quartz coating protects the reflective layer. Two companies, COMPAS in the Czech Republic and GALACTICA in Armenia, are currently manu–facturing the mirrors. Each of the individual mirror tiles will be automatically adjustable, using two actuators with a Hall effect sensor. The mirrors will be adjustable to a precision of 40 μm, corresponding to 1 mrad. The automatic mirror alignment procedure will use a CCD camera on the telescope camera lid, observing images of stars to do the calibration.

A 500-kg, 1.4-m diameter camera will be placed at the focus of this reflector. The whole structure will be supported by a space-frame to ensure stiffness and proper alignment. The mounting will be of the alt-azimuth type with freedom to move a full 360° in azimuth and from -30° to +180° in altitude. This freedom to have negative altitude settings will be used for camera maintenance and installation, as well as being the inactive position of the telescope. The alt-azimuth wheel friction drive will allow for positioning with a precision of 0.01°. The maximum drive speed will be 100° per minute.

The heart of the IACT is the imaging camera at the focus of the reflector. This camera will contain 960 so-called "smartpixels" (a single PMT with all the necessary electronics integrated in as a single replaceable unit), each with 0.16° field of view, arranged in a more or less circular way.

Each of these smartpixels contains a hexagonal Winston cone, a photo-multiplier tube (PMT) with bialkali photocathodes and the relevant electronics. The high voltages for the PMTs are produced by cards con–taining a DC–DC converter at the back of the PMT. Also a large part of the triggering electronics, analogue signal storage and other electronics is situated either in the smartpixel or in the camera housing. This provides short paths for the fast analogue signals to allow short gate times in order to minimise the night sky background noise. The triggering is done by a first level trigger in each smartpixel, with a second level topo–logical trigger in the camera housing itself. Depending on the conditions, the threshold for a single pixel is 3 to 5 photoelectrons. A third level global trigger is activated if a minimal number of telescopes have triggered within a short coincidence interval.

Astrophysical Objectives of HESS

With the HESS instrument physicists can observe various objects and processes that form part of the non-thermal universe, i.e., matter and radiation with an energy distribution that has power-law energy spectra as opposed to Maxwellian distributions. For the projected sensitivity of $F\gamma(> 100 \text{ GeV}) = 10^{-12}$ photons/ (cm^{2}s) for the instrument, there should exist many potential sources of VHE γ-rays.

Perhaps one of the most pressing and long-standing problems that may be addressed with the HESS instrument is that of the origin of Cosmic Rays (CRs). Even now, more than 3 decades after the proposal of the theory of diffusive shock acceleration of charged particles in astrophysical shocks, the question of the sources of cosmic rays is not yet settled. Observations in the TeV spectrum may help to identify specific sources where cosmic rays are being accelerated. The prime candidates are Supernova Remnants (SNRs). Detection of γ rays from SNRs in the range of 100 GeV to 10 TeV will confirm that shock acceleration does indeed produce VHE particles at SNRs. In fact, γ-rays have been detected from SN 1006 by the CANGAROO IACT. γ rays produced by SNRs should be a combination of those produced by the nucleonic component and those produced by the leptonic component of CRs. The latter are produced by inverse Compton (IC) scattering on the ambient photon field and the first by π^0 (which decays into γ rays) production through the interaction between CR nucleons and the Inter–stellar Medium (ISM).

This means that the γ fluxes from low density regions of the Galaxy should be dominated by photons produced by the leptonic component of CRs and those SNRs in high density regions should be dominated by photons produced by the hadronic component. At least 10 SNRs in the Sedov phase should be detectable by the instrument.

Another way to search for CR accelerators is by searching for Giant Molecular Clouds (GMCs) that are luminous in the TeV region. Among other possibilities, this could indicate the presence of an accelerator of high energy CR nucleons inside or near the GMC.

Another problem is the presence of TeV electrons in spectra measured at earth. Due to synchrotron and inverse Compton energy losses, the lifetime of electrons at these energies is very short. This implies that there must be (an) accelerator(s) nearby (within 100 pc). Prime candidates for electron accelerators are pulsar driven nebulae (Plerions). Electrons can be accelerated by the pulsar itself or at the pulsar wind termination shock in the nebula. These processes should also be visible in the TeV region due to inverse Compton and synchrotron self Compton processes.

Fig 2. A photo montage showing the mechanical structure, space-frames and reflectors of the telescopes in their proper positions on the farm Gölschau.

Another problem is that of the very high energy (VHE) component of CRs of extragalactic origin. Shock acceleration cannot account for the acceleration of CRs up to energies $E \geq 10^{20}$ eV. Some theorists suggest that they may be the decay products of some massive particles from earlier epochs. These are sometimes called topological defects (TDs) like cosmic strings, monopoles, etc. that formed in a symmetry breaking phase transition in the very early universe. The possible collapse of these TDs may be just visible at the lower limit of the IACT's threshold energy.

Other sources to be searched for and known sources to be studied are accreting neutron stars and stellar black holes and the newly discovered superluminal objects, or microquasars discovered in our Galaxy. These are thought to be scaled down versions of Active Galactic Nuclei (AGNs) that are found in other galaxies. The centre of our own Galaxy also may hold surprises that can be detected in the TeV region, such as a large black hole.

Outside our own Galaxy, one of the most important classes of objects to be studied is AGNs. Already, two BL Lac (blazars) objects (Mrk501 and Mrk421) have been discovered to be sources of TeV γ rays. The synchronous flaring in the keV (X-ray) region and the TeV (γ-ray) energy regions supports the theory that both of these components are produced by synchrotron and synchrotron self Compton processes by the same relativistic electrons in jets ejected from a central object (possibly a giant black hole) in these galaxies. The IACT array should be able to detect several of these blazars. Other AGN class objects, like radio-loud galaxies and optically violent variable quasars, also produce VHE γ rays, and should also be detectable above 100 GeV. In addition to this, VHE radiation is also expected from AGNs without jet-like features, like Seyfert galaxies.

Additionally, VHE studies of rich clusters of galaxies should be informative about galaxy formation in the early universe.

From the field of observational cosmology, the observation of pair halos is of interest. Theory suggests that γ rays from UHE (Ultra High Energy) sources can be scattered on the 2.7 K microwave, infra-red or optical Diffuse Extragalactic Back–ground Radiation (DEBRA) fields. The photon-photon reactions then produce a cascade, and if the magnetic field near (within a few Mpc) the UHE γ-ray source is large enough, the electron/ positron pairs in the cascades will be isotropised. These electrons will then produce observable VHE γ-ray photons through inverse Compton scattering on the 2.7 K microwave DEBRA field. The discovery and mapping of these pair halos that are of distinct extragalactic origin will enable HESS researchers to determine several things.

Firstly, observing pair halos at different redshifts (different distances) will tell us something about the time evolution of the DEBRA fields. Secondly, comparison of the characteristic physical sizes of such pair halos with their redshift-distance relation (Hubble's law), will give us direct information on source distances without resorting to a distance-ladder technique.

Also of cosmological interest is the issue of γ rays from dark matter, especially from massive relic particles produced in the very early universe, such as WIMPs (Weakly Interacting Massive Particles). A specific experiment in this regard was suggested at a HESS workshop in December 1999, concerning the decay of neutralinos in the Galactic halo. Theoretical models can predict the difference in the VHE energy spectra from the Galactic halo with and without neutralino decay. By measuring the energy spectrum of VHE radiation from the galactic halo, HESS should be able to provide clues in this regard.

The above discussion broadly illustrates only *some* of the possibilities of HESS science. It must be stressed that there may be many more possi–bilities that cannot be discussed here and/or that the author is not aware of, nor capable of discussing at this stage.

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Studying the Atmosphere Over Africa using Astronomical Data: I – Extinction Measurements

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Abstract. The article highlights the potential uses of astronomical extinction measurements in the study of the transport and concentration of aerosols, which in turn have an effect on the global radiation balance, as well as cloud formation. Some examples of cases where astronomical extinction measurements have facilitated atmospheric research in Africa are presented, these being (a) the properties of Saharan dust and its transportation to the Canary Islands; (b) the Pinatubo ash-cloud and its evolution; (c) the brown haze in Cape Town; and (d) the passage of pyrogenic aerosol clouds over Sutherland.

Sommaire. L'article met l'accent sur les utilisations potentielles des mesures de l'extinction astronomique dans l'étude du transport et de la concentration des aérosols qui, à leur tour, ont un effet sur le bilan global des radiations comme sur la formation des nuages. Quelques exemples de cas où les mesures d'extinction astronomique ont facilité la recherche atmosphérique en Afrique, sont présentés: (a) les propriétés de la poussière du Sahara et son transport vers les Iles des Canaries, (b) le nuage de cendres du Pinatubo et son évolution, (c) la brume foncée à Cape Town, et (d) le passage des nuages d'aérosols pyrogéniques au-dessus du Sutherland en Afrique du Sud.

Introduction

Cross-disciplinary research projects offer the opportunity for creating numerically stronger and thus more effective research teams at otherwise relatively isolated institutions, making such projects an attractive proposition for many African science research centers and faculties. In the case of scientists with an interest in astronomy, there are a lot of often unrecognised possibilities for collaborative research with atmospheric scientists. Examples of such overlapping research fields are:

(a) *Atmospheric transmission:* Atmospheric extinction measurements, which are regularly made by astronomers engaged in all-sky photometry, can be used to determine the concentration, transportation and typical particle size of atmospheric aerosols.

(b) *Diffuse radiation*: Night-sky brightness depends on, amongst other things, aerosol absorption and reflection properties, altitude, azimuth and lunar position. The theory for deriving night sky intensity has been developed and applied by several authors[3,7]. By fitting these models to the night sky measurements (often recorded during routine astronomical observations) it is possible to determine parameters such as aerosol concentration and reflectivity.

(c) *Airglow*: Sky comparison spectra recorded during spectroscopic observing programmes contain usually unutilised information about atmospheric molecular absorption and fluorescence lines.

(d) *Atmospheric micro-turbulence:* Astronomical "seeing" is the apparent size of an intrinsically point-like image of a star after passage of the wavefront through the atmosphere. "Seeing" measurements are frequently recorded in astronomical work, either explicitly during site testing operations, or as a by-product of imaging observations, or even when estimates are recorded in observing logbooks. "Seeing" is indicative of the degree of atmospheric instability and can be compared with meteorological and topographic data to investigate micro-turbulence.

(e) *Cloud formation studies*: Despite the astronomers' understandable preoccupation with clouds, almost no attempts have been made to use astronomical instruments and facilities for the study of the reflectivity, transmissivity, polarisation and growth of clouds. It is conceivable that such studies could be carried out with astronomical data recorded during partly cloudy conditions. It is an area of study that awaits development.

The current paper will focus on the first–mentioned topic – atmospheric extinction.

Aerosols and their effect on optical radiation

Aerosols may be defined as particles suspended in the atmosphere, and the term is generally used to denote units larger than molecules. Aerosol diameters typically range from about 10^{-4} to 100 μm.

Apart from their use as tracers in atmospheric circulation studies, aerosols have more recently been recognised as important contributors to weather phenomena and climate change. This is partly due to their role as nuclei on which water droplets can grow, and also partly because of their effect on the global radiation balance.

Three processes determine the concentration and particle size distribution of an aerosol ensemble:

1. The injection of aerosol into the atmosphere from ground level through a variety of mechanisms described below;
2. The growth of particles through the coalescing of smaller particles;
3. The deposition of airborne particles on the ground through precipitation.

The composition, shape, size and refractive properties of aerosol particles are often determined by their mode of generation. It is convenient to categorise aerosols accordingly:

(a) *Volcanic ash*: Propelled skywards in the course of volcanic eruptions, these sulphur-rich aerosols are occasionally lifted as high as the stratosphere, where they have typical lifetimes of several years, much longer than their tropospheric counterparts. Recent such events include the eruptions of Agung (1963), El Chichon (1982) and Pinatubo (1991). Characteristically, the aerosols get dissipated throughout the stratosphere within a few months. The particles then coalesce until they become too large to be supported and fall to the ground.

(b) *Pyrogenic aerosols*: These are in essence the smoke from forest and savannah fires. High concentrations of these aerosols are usually recorded over sub-Saharan Africa during and just after the dry season.

(c) *Wind-born sand and dust*: Such aerosols are usually generated in arid regions and tend to be rich in silicates. Significant generation of dust also occurs in wetter areas following the ploughing season or even through traffic on dirt roads.

(d) *Maritime aerosols*: These result from the uplifting of sea spray through wind. These particles characteristically have high abundances of sodium chloride. Though prevalent over the oceans, these aerosols can be transported far inland.

(e) *Biogenic emissions*: Biogenic processes are more commonly responsible for trace gas generation, which may contribute to the formation of aerosols. They also produce airborne microscopic organisms such as pollen.

(f) *Industrial and other anthropogenic emissions:* Aerosols originating in this fashion include the emissions from coal-burning power stations, dust generated by open-cast mining operations and domestic wood and coal burning.

Aerosols contribute to the attenuation of incoming starlight, which in turn implies that their concentration may be estimated by measuring the degree of extinction in the atmosphere. Extinction in the wavelength range 350–800 nm may be due to Rayleigh scattering, stratospheric ozone or aerosols,

$$k_\lambda = k_{\lambda,Rayleigh} + k_{\lambda,ozone} + k_{\lambda,aer}$$

where k is the standard astronomical extinction coefficient, defined as

$$k = 2.5\,(\log Intensity_{above\ atmosphere} - \log Intensity_{on\ ground})$$

for a star at the zenith.

The Rayleigh extinction is almost constant at any particular location and altitude, while ozone only affects specific parts of the spectrum. Outside these spectral regions any variations in the extinction are thus due to changes in the aerosol concentration or characteristics.

Extinction by aerosols is largely the result of Mie scattering, and its dependence on wavelength may be described by the following relation[4]:

$$\log k_{\lambda,aer} \propto -\alpha \log \lambda.$$

The coefficient α ranges from 0 for very large particles to 4 for very small particles.

Examples of cases where astronomical extinction measurements facilitated atmospheric research in Africa

Properties of Saharan dust and its transportation to the Canary Islands

Saharan dust is occasionally transported as far as the Canary Islands in the northern hemisphere summer months. It manifests itself as an almost fog-like haze at the various astronomical sites on the archipelago, such as the Roque de los Muchachos observatory on La Palma. Through the measurement of the extinction during such events it has been possible to not only monitor the passage and density of the dust clouds, but also to determine the colour dependence of the aerosol opacity (and hence particle size distribution) of Saharan dust. Stickland *et al* (1987) found that the aerosol opacity at La Palma is independent of wave-length to a good approximation[9]. This confirmed the theoretical work of several authors[10], who showed that the refractive properties of typical Saharan dust grains are expected to be colour-neutral. Kidger[5] and Andrews & Williams[1] found a small wavelength dependence on the extinction coefficients in the infrared and optical regimes respectively, which is likely to be the result of mixing of the type of grains modelled by Whittet, Bode & Murdin with smaller particles[10].

The Pinatubo ash-cloud and its evolution

The volcanic eruption of Mount Pinatubo in the Philippines in 1991 injected huge quantities of volcanic ash into the stratosphere. Within a couple of months these volcanic aerosols became distributed around the globe. The development of the volcanic ash clouds over the South African Astronomical Observatory in Sutherland can be traced by plotting the measured extinction coefficients[6]. The study showed that enhanced aerosol concentrations persisted for several years. It also illustrated the patchy nature of the stratospheric ash clouds.

Figure 1 shows the volcanic ash extinction coefficients calculated by Kilkenny as a function of wavelength for two high-extinction events following the eruption. These were

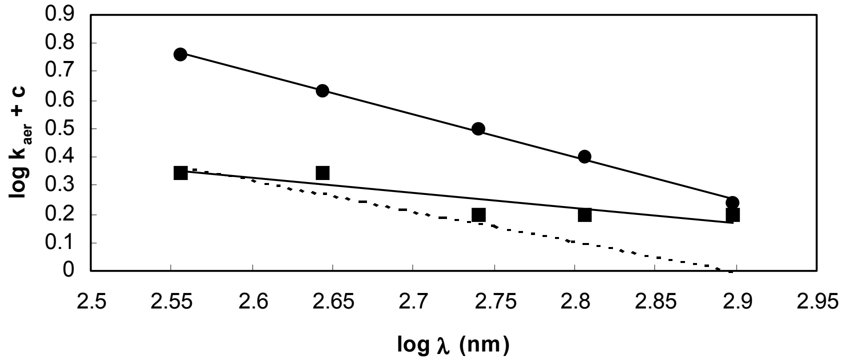

Fig. 1. log $k_{\lambda,aer}$ vs log λ graph for the nights 10–11 September 1991 (top) and 26–27 September 1992 (bottom). The dashed line represents an α-value of 1.08, the result expected from Mie theory.

obtained by subtracting the Sutherland "normal" (*i.e.* pre-Pinatubo clear day) values from the measured extinction coefficients. Note that the value of α (*i.e.* the slope of the graph) is much smaller on 26 September 1992 than on 10 September 1991. This illustrates the change in the particle size distribution in the intervening period – the smaller particles that had dominated the distribution soon after the eruption had coalesced into bigger units a year later.

The brown haze in Cape Town

Where telescopes equipped with photometers exist in urban areas, the extinction measurements may be utilised to study pollutants. The city with the largest available extinction value database in Africa is probably Cape Town, as a result of the extensive standard star work by Cousins at the South African Astronomical Observatory head–quarters. Cousins has described extinction coefficient behaviour as a function of meteorological con–ditions[2]. He has been able to detect maritime aerosols and the "brown haze", which is caused by domestic fires in the Cape Flats. Future measurements of the extinction at the site will provide the opportunity to monitor the severity of brown haze-type pollution as a result of further urbanisation and electrification.

Passage of pyrogenic aerosol clouds over Sutherland

During the winter months an anti-cyclonic air circulation pattern frequently develops over southern Africa.

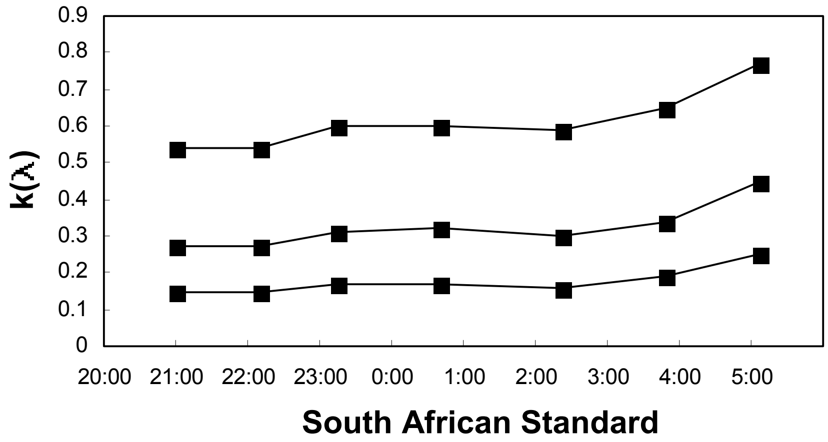

Fig. 2. Variations in the total k_U, k_B and k_V extinction coefficients (from top to bottom) during the night 29–30 September 1997.

The late winter months are a period of intense woodland burning in the belt just to the south of the Intertropical Convergence Zone, centred on Zambia and including neighbouring countries.

The pyrogenic aerosols thus placed into circulation are frequently transported southward and form layers of haze over the subcontinent, occasionally moving as far south as Sutherland. On the night of 29–30 September 1997, an aerosol cloud passed over Sutherland observatory, and the extinction was measured regularly throughout the night. Brownish haze was spotted above the horizons at dawn, making it unlikely that the aerosols were locally generated dust.

Figure 2 illustrates the change of the U, B and V-band extinction co–efficients during the course of the night. The 23h00 arrival time of the aerosol cloud and its intensification just before dawn can clearly be seen on the graph. Such events can be interpreted in conjunction with meteorological data to estimate the generation and trans–port of the aerosols.

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The Case for Atmospheric Physics & Space Exploration in Nigeria

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Abstract. Capability in basic space science is an essential component for economic development in the 21st century. Yet, African countries in particular are completely passive to the development of basic space science. This article examines the problems facing the development of space science in Nigeria and presents arguments for why a nation such as Nigeria should invest in research on basic space science.

Sommaire. La compétence en science spatiale fondamentale est un composant essentiel du développement économique au 21^{ième} siècle. Cependant les pays africains, en particulier, sont complètement passifs envers le développement des sciences spatiales fondamentales. Cet article examine les problèmes auxquels le développement des sciences spatiales se heurte au Nigéria, et présente les raisons pour lesquelles une nation telle le Nigéria devrait investir dans la recherche spatiale.

Introduction

Atmospheric physics and space exploration are part of basic space science, which also includes astronomy. The basic feature of all space science is that the sky is the laboratory where physical laws and theories are applied, tested and refined for a wide range of physical conditions which can be unattainable on earth. In basic space science, we are interested in studying our environment at the largest possible scale. This may lead to the discovery of new physical laws and stimulate the development of new technologies.

The techniques employed in the study of atmospheric physics and space exploration are common in all branches of basic space science, especially astronomy (which is the mother of all sciences). These include: ground-based optical and radio telescopes, space telescopes, remote sensing from ground and space, communication satellites, measurements from balloons and satellite platforms, phased-radar techniques and modern infrared detectors.

Space science in general, and astronomy in particular, is now widely seen as a major growth point in basic physical science and therefore plays an indispensable role in the development of science throughout the world.

It is known from studies in advanced countries that contact with space science at an early age excites young minds and acts as a catalyst in encouraging students to follow careers in science and technology. Space science can be used to teach physical principles at all levels, providing young graduates with exciting applications of physical principles and training at postgraduate levels where projects of real scientific value are coupled with the development of a wide range of scientific and engineering skills.

Why should a nation like Nigeria invest in research in atmospheric physics and space exploration?

Initially, people study astronomy because of its fascination and challenges. Even today any creative person should be anxious to understand the universe and our role in it.

Apart from this, we note that throughout history observations of the sky have led to the discoveries that have had major impact on people. Observations of motion of planets have led to the understanding of gravity and forces governing motion. Other examples of discoveries which resulted from research in atmospheric physics and space exploration includes the discovery of cosmic radio waves, satellite communication, modern receivers and detectors.

Space science helps tremendously in raising the general level of scientific awareness of people and draws young minds towards careers in physical sciences and associated areas of technology. Countries that see science as an essential part of their future wealth and well-being, participate actively in the development of space science. Any modern observatory requires not only space scientists but skilled engineers and technicians in electronics, optics, mechanics, computers and software in order to function. It requires advanced industrial capabilities and precision engineering to set up telescopes for ground-based observations as well as for satellite observations. Industrial capabilities acquired through the fabrication of equipment used by space scientists could prove invaluable to companies developing hi-tech products.

Space technology provides mankind with the potential tools for economic development and extends man's cultural horizon. The technologies associated with space science and nuclear science determine the economic and military power of nation. Any country without these potentials is classified as under-developed. Development does not mean the ability to purchase ready-made products of space technology such as satellites, cellular phones, fax machines and aeroplanes. Development is the unfolding of peoples' imaginations and liberation to begin to assert authority and self-reliance in carrying out human activities. There is currently real danger that a few countries monopolize the development of space technology. This has led to a continued inequality and widening of the huge technological gap between advanced countries and underdeveloped countries. South Africa, India, China, Indonesia, Brazil and others have been making frantic efforts to join the space club. This has resulted recently in the attainment of a high level of technological development in these countries. On the other hand, African countries in particular are completely passive to the development of basic space science. This no doubt is responsible for our poor level of technological development.

Basic space science has been linked to the development of radio and satellite communication, television, telex, faxes, telephone, electronic mail, accurate weather forecasts, aeroplanes, remote-sensing techniques and many others. The launching in 1957 by the U.S.S.R. of the first artificial man-made satellite (the Sputnik), started a major revolution in space science. Being able to place a man or satellite at such a great height from the earth opened up a chain of new technologies. A platform in space can be used either for looking outwards or downwards to earth. The first has revolutionalized research in astronomy. The second pertains to such areas as geophysics, atmospheric physics, space communication, earth resource survey, meteorology, navigation, education, commerce, national security, etc.

Efforts to explain with our present laws of physics the physical behaviour of several astrophysical objects such as pulsars, neutron stars, binary stars, black holes, quasars and others, have not been fully successful. This makes one think that new physical laws are yet to be discovered with the aid of space investigations. The huge cosmic ray energies of up to ~10^{20} eV cannot be produced in man-made laboratories on earth, and will not be in the foreseeable future. Presently we can probably attain ~10^{9} eV. The end of the twentieth century has seen major developments in space research throughout the world. Currently, with the development of astronomy from space (in gamma-rays, x-rays, UV, visible, infrared, and in sub-mm regions) there are large-scale building programs for large ground-based telescopes.

We can thus say that among the many discoveries of tomorrow, perhaps new forms of energy or something revolutionary will undoubtedly emanate from the current intensive research in basic space science. Space science is therefore a huge investment in our future.

Some contributions of atmospheric physics & space exploration

Modern space science contributes to areas of more immediate practicality: training in industry, medicine, defense and computers.

A Training

Our economy depends on our ability to compete technologically with other nations. Because of its broad appeal, space science (especially astronomy) is often the science that initially arouses the scientific interest of people who eventually specialize in other technical disciplines. Seventy percent of American universities currently offer degrees in astronomy. Forty percent of students who attain higher degrees in astronomy eventually take jobs in industry.

B Industry

(a) The corporation, Milltech, whose founders are radio astronomers, currently build the millimeter components largely used for the communications industry.
(b) The National Radio Astronomy Observatory in the United States has improved now-noise receivers, some of which have given rise to commercial products.
(c) Computer programs used to control telescopes, and to make maps from interferometers have found wide application in industry.
(d) Efforts to produce ever better emulsions for astronomical purposes led to the discovery of gold sensitization by Kodak.
(e) The infrared emulsions developed for astronomers have proved useful in aerial reconnaissance and more recently in remote-sensing of the earth's surface.

C Medicine

Space science and medicine share the problem of imaging the inaccessible. Some of the image-reconstruction techniques of radio astronomy are now used in medicine including CAT scans, magnetic-resonance imaging, and positron emission tomography.

C Defense

Advanced countries employ persons with degrees in astronomy for scientific defense work. Progress in military technology, from World War II radar technology to present-day infrared detectors, is coupled to a nation's astronomical capabilities.

C Computers

Computers play an indispensable role in both theoretical and observational astronomy. Powerful and sophisticated computer programs are an indispensable tool for acquiring and analyzing radiation from violent, complicated astrophysical environments. Computers are used for controlling the operation of telescopes, acquisition of data, and analysis. Software engineering has become as important as mechanical, optical and electronic engineering in astronomy. High-performance computing has become necessary to make full use of many space observations.

Problems facing space science in Nigeria

A number of problems have contributed to the very slow pace in the growth of basic space science in Nigeria. One of the major problems is the lack of recognition of the importance of space science by policy makers. The perception is that space science is not only unaffordable, but that it also has no immediate value. It is, however, obvious that economic development based on the application of technologies imported from industrialized countries without any attention to science and research has been the bane of most underdeveloped nations.

Another serious problem militating against the development of space science in Nigeria is the absence of reliable communications systems e.g. telephones, fax machines and electronic mail in Nigerian Universities. The use of computers in scientific research is yet to become popular.

Furthermore, the non-existence of a science culture in Nigeria is another major setback in the development of space research in Nigeria. There is a need to establish a space research center to co-ordinate current efforts in our universities and to popularize science in the country.

First Visibility of the Lunar Crescent

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Abstract. Astronomical observatories are often asked to predict the visibility of the young crescent moon by communities (especially Islamic and Karaite) which use traditional lunar calendars. The SAAO has provided such information for many years, but the early 1990s were a watershed of sorts. Astronomical visibility factors in those years created an unusually severe bias against visibility of the Ramadaan and Shawwall crescents from the southern half of the continent, relative to North Africa and the Mideast (to an extent not seen since the 1860s!). The perplexity caused by the resulting delay in sightings ultimately led to a much greater level of communication between astronomers and the crescent-watching community. The SAAO began collecting, systematizing, and propagating the astronomical information available on the crescent visibility issue, the current results of which are summarized here.

Sommaire. Les communauté (spécialement islamiques et karaïtes) qui utilisent les calendriers lunaires traditionnels, demandent souvent aux observatoires astronomiques de prédire le moment où le croissant de lune naissant devient visible. Depuis de nombreuses années le SAAO fournit cette information, mais les années 1990 furent une sorte de tournant. Dans ces années-là les facteurs de visibilité astronomiques créèrent une déviation exceptionnellement grave par rapport à la visibilité des croissants du Ramadan et du Shawal sur la moitié sud du continent relative à l'Afrique du Nord et au Moyen-Orient (dans une mesure jamais atteinte depuis les années 1860!). La perplexité due au retard qui en résulta dans la vision du nouveau croissant, conduisit finalement à renforcer la communication entre les astronomes et la communauté des observateurs du croissant. Le SAAO commença à collecter, systématiser et diffuser l'information astronomique disponible sur la question de la visibilité du croissant dont nous résumons ici les résultats actuels.

Introduction to Young Crescents

First we review a few basics. Because of the Earth's motion around the sun, the sun appears to move along a path through the sky called the *ecliptic*. The sun's position on this path (measured from the point where it crosses the equator moving north) is the sun's *celestial longitude*. Each new astronomical lunar month (lunation) begins at the moment when the center of the moon has the same celestial longitude as the center of the sun, from the perspective of the center of the Earth, i.e. the moment when the moon "passes" the sun. This is the moment of astronomical *new moon*, and it occurs at the same instant everywhere since it does not depend in any way on the viewer's perspective.

At this time the moon is always invisible from the Earth. When the moon first becomes visible again (always more, usually much more, than half a day after astronomical new moon), observers see a young crescent moon. Note that usually the moon does not have the same celestial latitude as the sun, but instead passes above or below it, so there is no eclipse. The kind of crescent considered here is typically much younger, fainter, narrower, and shorter than the bright arc which comes to most people's minds when they recall an occasion of having noticed the crescent. Sadly, much of the world's population is not privileged to enjoy the amazing sight of the thinnest, shortest crescents because of poor air transparency due to dust, haze, humidity, pollution, chronic cloudiness, and other hindrances to observing the celestial sky.

SAAO Crescent Visibility Program

The SAAO effort to clarify this issue for the public has been threefold. Firstly information has been collected and presented on our Lunar Crescent Visibility homepage on the Internet. Secondly critical observations have been carried out when possible. Lastly an annual brochure of visibility predictions for South Africa and, for comparative purposes, locations in the Middle East has been made available to visitors and by post.

The SAAO crescent visibility homepage (*http://www.saao.ac.za/ sky/ vishome.html*) contains a database of all credible, critical observations which we were able to obtain from the literature, the Internet and our own efforts. The website has our annual visibility predictions, based upon the SAAO visibility criteria, that are founded on the observations in the database. The website also has links to related ones, two of which it would be remiss not to mention at this point. One is the Mooncalc program (*http://www.starlight.demon.co.uk/mooncalc*) by Monzur Ahmed which is extremely useful for all information relating to the predicted state and appearance of the moon, and is probably unsurpassed in its graphical depiction of the start of lunar months across the globe. The other site is the Islamic Crescents' Observation Project (*http://www.jas.org.jo/icop.html*), a global project organized by the Arab Union for Astronomy and Space Science and the Jordanian Astronomical Society to gather information about actual crescent observations at the start of each lunar month, and about the official first day in different countries.

Our crescent observations are normally undertaken at Signal Hill, Cape Town, (long 18.41, lat –33.92, alt 350m) which is easily accessible, borders directly on the South Atlantic, and enjoys a sea horizon for the entire annual azimuth range of the setting moon. The usual optical device is a pair of 20×80 binoculars (3.5° field) attached to an alt-az mount made by SAAO technician W.P. Koorts (*http://www.saao.ac.za/~wpk*), which is marked off in degrees. The pointing is calibrated on several convenient local landmarks, the sun, and any brighter planets available in the twilight. Signal Hill is an excellent location for spotting the most difficult crescents, and precise pointing with a very stable mounting contributes to the con–

fidence in assessing the most challenging cases.

SAAO Crescent Visibility Database

The database at our website has been compiled in an effort to muster all sufficiently useful obser–vations bearing on the issue of the visibility of the crescent. Below is cited a sample entry to give an idea of the information tabulated for each event. This includes a critical attribute, the visibility judgment, in terms of the following basic scheme:

A: Seen with the naked eye
B: Seen with the naked eye, but remarked or inferred as being very near the limit of feasibility
C: Not seen with the naked eye, but with binoculars
D: Not seen with the naked eye or binoculars, but with a telescope
E: Not seen with the naked eye, no optical aid mentioned
F: Not seen even with optical aid.

The database order is chronological. For brevity it is limited to crescents within a restricted altitude range relative to the setting sun, which excludes all relatively trivial sighting events. Multiple observers at the same event and nearly the same location are condensed to one entry based on the most successful credible outcome to save space. For further minor details see the website.

The basic sources for the "historical" sightings are the compilations by Schaefer (1988), Schaefer *et al.* (1993), Doggett and Schaefer (1994), Ilyas (1994), and Schaefer (1996). The numerical quantities in the database were rederived with the Interactive Computer Ephemeris (ICE) program supplied by the US Naval Observatory Almanac Office. A sample line from the data base is:

date	place(person)	long	lat	alt(m)
1999 07 13	Signal Hill	18.41	–33.92	350

zone	vis	set(rise)	dalt	daz	lag	arcl	%ill
+2	F	15:54:04	5.4	2.4	36	7.8	0.5

time4	dalt4	daz4	new moon
16:10:53	2.6	2.3	13 02 24

The following abbreviations are used in the database, and some of the terms are used below:

long: longitude of site
lat: latitude of site
alt: altitude of site in meters (not always available)
zone: time zone
vis: visibility judgment from A–F scheme
set: time of sunset (or sunrise if parenthesized)
dalt: apparent altitude of the lower limb of the moon (with topocentric parallax and refraction corrections), at moment of sunset (or sunrise)
daz: moon azimuth minus sun azimuth, at moment of sunset (or sunrise)
lag: moonset(to nearest minute) minus sunset(to nearest minute), or analogously for moonrise and sunrise
arcl: arc of light, the angle subtended at the center of the Earth by the center of the moon and the center of the sun
%ill: fraction of the lunar disk which is illuminated
time4: time when center of the sun is at 4° below the horizon, which is reasonably close to the twilight time of optimum (though transient) visibility of the most difficult crescents
dalt4: dalt at time4
daz4: daz at time4
new moon: time of nearest new moon by day, hour, and minute (UT)

Lunar Crescent Visibility

The great advantage of a quantitative online database of this sort is its utility for judging the likelihood of visibility of any future crescent based upon the record of past experience. The study and synthesis of crescent visibility criteria has been much advanced by recent work (Schaefer (1993), Ilyas (1994), Loewinger (1995), McPartlan (1996), Yallop (1997), and Fatoohi *et al.* (1998,1999)), wherein may be found references to the earlier literature. At least a brief sketch of the factors involved is necessary for com–prehending the results below.

It is clear that the chance for visibility of the crescent increases with the growth of the so-called arc of light, viz. the angular separation of the sun and moon. As the sun-moon angle increases, so does the thickness or diametric extent of the crescent. Also the circumferential extent grows to the complete 180 degree arc, and the surface brightness of the crescent increases with the illumination angle. Visibility is also promoted by the apparent diameter being enhanced, as near perigee.

The visibility of the crescent is clearly *decreased* by atmospheric extinction, viz. the effect of the opaqueness of the air through which we see the moon. This is due to the molecular nature of air and worsened by haze, humidity, pollution, etc. Within the last degree or two of finally setting, the moon lies behind a "wall of obscuration" because its light must penetrate such a large column of air that only a small fraction can reach the observer, typically a percent for the cleanest air to a percent of a percent or less for hazier conditions.

To perceive the local bright patch due to the crescent against the glowing, often colorful and mottled, twilight sky, that patch must have a sufficient brightness and shape contrast with its surroundings. Hence the crescent is easier to see (a) later in the twilight, at a given altitude, (b) higher or farther sideways from the sunset point, at a given time, and (c) through air layers which are cleaner and less mottled (typically higher than a few degrees altitude) regardless. The visibility of the crescent for a nearly borderline case would just cross the threshold of possibility some 15–20 minutes into the twilight as the sky brightness decays exponentially, and remain possible until a few minutes before setting when the crescent is pre–maturely "extinguished" by atmo–spheric extinction, or lost in confusion with haze mottling in the last 1–2 degrees of altitude. The naked-eye impression during such time is of a very small brightening of elongated but otherwise rather indistinct shape. In an optical device such an extreme crescent is a short (90° or less), needle-thin arc, little brighter than its surrounds, giving a subjective impression of "sitting on" rather than "shining out" from the glow of the sky.

It is clear that the astronomical factors governing the visibility will be those that specify, firstly, the path that the moon takes in ascending out of the sun's glare, and, secondly, the speed with which the moon moves along this path. The first set of factors concerns the angle which the ecliptic makes with the horizon for a given location and season and the displacement of the moon north or south of the ecliptic due to the 5.15° tilt of the moon's orbital plane. The second set of factors concerns the moon's angular speed on the sky (which is greatest near perigee) and the relative lateness of sunset depending on longitude and season, which directly affects the age of the moon at local sunset. Clearly, the older the moon, the more vertical its celestial path upwards from the local western horizon, and the faster the moon is moving on that path, the more likely it is that a young crescent will be visible. For each lunation (cycle of lunar phases), there will be a point on the Earth's surface where the crescent is vertically above the sun at sunset, and where the angular distance from the sun, etc. is just sufficient at sunset so that the crescent is marginally visible. That will be the eastern-most point of visibility. Observers at the same latitude but farther west (assuming ideal atmo–spheric conditions) will find it progressively easier to see the crescent, as the moon will have moved farther from the sun by the time their location reaches the sunset line. North or south of the latitude of first visibility, the moon (for a given longitude) will lie closer to the local sunset horizon because from these places the moon will not appear directly above the sun. The event of first visibility for each latitude will consequently occur along a quasi-parabolic curve on the globe, with visibility occurring farther west as the latitude is farther north or south of the optimum.

Crescent Visibility Criteria

Since antiquity, astronomers and crescent observers have tried to find simple parameters which can be used to predict crescent visibility, usually by looking for a clear separation between occasions when the moon was visible and when it was not. A totally clear separation, how–ever, is impossible even with an ideal parameter set: observers and con–ditions are both highly variable quantities.

Observers are by no means equally likely to look at the right spot at the right time, with the same visual acuity and properly aimed and focused equipment. Assuming good, properly corrected, eyesight, there are still factors like preparedness, experience, and having got various "teething troubles" out of the way beforehand, that can make a difference.

It is also clear that one must subdivide the visibility criteria into subcases for naked-eye and optically-aided viewing, since magnifying the crescent enhances its visibility. This is supported by the record ages for young crescents at the time of sighting: 15.4 hours with naked eye, 12.7 hours with binoculars, and 12.2 hours with a telescope. That specified, one has to accept that there will be some inter-observer scatter due to eyesight, experience, and scruple of objectivity. It will be hard to reduce this inhomogeneity entirely, but sometimes there are clues about the weight to attach to significantly discrepant results.

The sensitive dependence upon atmospheric transparency is a second source of inhomogeneity in the outcome of attempted crescent sightings. Places with more cloud cover, heat and humidity, heavy urbanization and industry, biomass burning, soil and wind conditions conducive to dust and haze, etc. will be at a perennial disadvantage. How–ever, excellent conditions would be stochastically possible at a poor site, e.g. after the air is cleaned by a rainstorm, just as the best sites are not immune to appalling conditions. An observing location at high elevation generally improves the prospect of good transparency, but not inevitably so (e.g. botanical aerosols in the Great Smoky Mountains). The best one can hope for is that local weather and air transparency conditions are described by crescent observers in sufficient detail for others who would later make use of their findings.

One of the commonly used parameters related to crescent visibility, the "age of the moon" (i.e. the interval as sunset or time of sighting since the instant of new moon) serves to illustrate the third class of problem. It correlates with visibility very imperfectly due to celestial factors which are not adequately taken into account when an overly simplistic parameter is taken as a visibility index. In some circum–stances it will be possible to see a moon 16 hours old, in others impossible to see a moon 36 hours old. Relying on the "age" alone leaves out other important factors such as the direction of the moon's celestial path away from the western horizon, the moon's angular speed along that path, and the size differential due to variable Earth-moon distance.

(Some prefer to reckon the age from the moment of *topocentric* new moon: when the celestial longitudes of the sun and moon are equal from the perspective of a particular observing site. Although this may vary by as much as two hours from geocentric new moon, the distinction is essentially irrelevant for the predicting of visibility. The reason is that the Earth's rotation and the lunar motion ensure a very different topocentric geometry hours later at the moment of attempted sighting, and it is at that moment that the dependence of visibility on topocentric effects is best taken into account.)

The variable angular speed of the moon can be allowed for by using the arc of light for an index instead of the age, but the angle of the moon's celestial ascent out of the sunset glare remains a decisive but overlooked variable. A relatively large, bright crescent can elude detection if the season, latitude and inclination of the lunar orbit prescribe a very low and shallow path of ascent from the western horizon.

The time delay between sunset and moonset (hereafter moonset lag) is a parameter that would seem to be an index of both the stage of growth of the crescent and the available grace period for the twilight to fade. The moonset lag may have usefulness when restricted to low latitude, but it is prone to inconsistencies when it can coincide with either a large arc of light observed at high latitude or a small arc of light observed at low latitude.

The apparent altitude and azimuth separation of the sun and moon at sunset, or at a slightly later time nearer to that for optimum visibility, is a two-parameter index of visibility. Some–times the so-called arc of vision is used instead of the apparent altitude. The arc of vision is essentially the projection of the arc of light *perpendicular* to the local horizon direction, and thus resembles the apparent altitude except that it dispenses with topocentric parallax and refraction, and that the angle is taken between the sun and moon centers, not the horizon and moon's lower-limb. From these differences the arc of vision is typically 1½° degrees larger than the crescent altitude at sunset, dalt, with a typical scatter of about ½° due mostly to the variation of topocentric parallax with latitude.

Schaefer (1990) has modelled crescent visibility by a computer program built upon parametric equations from first principles for the physical processes upon which visibility is contingent. Proprietary software and an accurate atmospheric extinction factor are required for each event so modelled.

Predicting Visibility from the Moon's Altitude and Azimuth

The SAAO database permits one to test the usefulness of some of the visibility criteria available. Figures 1–3 address various aspects of using the moon's altitude and azimuth (relative to the sun) as parameters for predicting its visibility or invisibility. In these graphs, the x-axis gives the difference in azimuth (i.e. compass angle) from the sunset point to a point on the horizon directly below the moon's position at sunset, always converted to a positive number, since the moon's being right or left of the sun should be immaterial for visibility. The y-axis gives the apparent altitude above the horizon of the moon's lower limb at sunset. Successful sightings by naked eye observers (class A) are represented by large filled circles; a few filled circles crossed by a short horizontal line represent marginal sightings (class B). Large open circles represent cases where the crescent was visible through telescopes or binoculars, but not visible to the naked eye (class C). A short horizontal line crossing the open circle denotes visibility in a telescope only (class D) and not in binoculars nor by naked eye. Large 3-pointed delta symbols show the locations of crescents which were invisible both with optical aid and with the naked eye (class F). Small deltas represent unsuccessful sightings by naked eye observers without optical

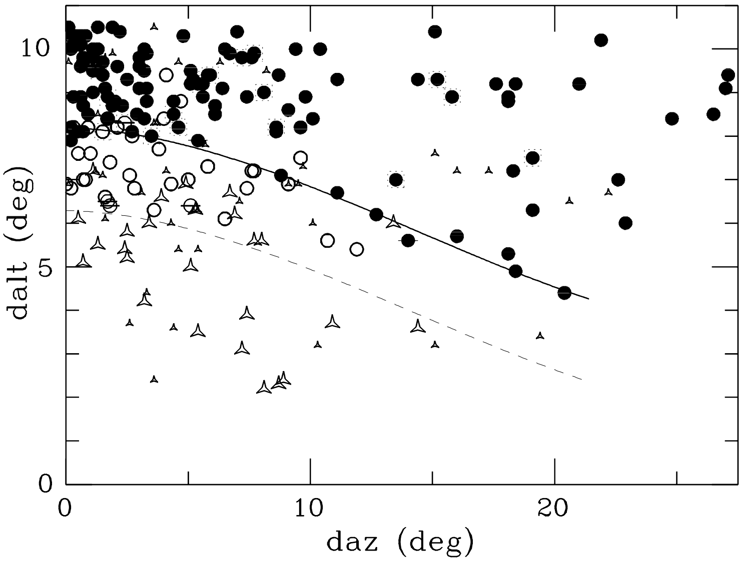

Fig.1: The circles are sightings by naked-eye (filled) or optical device (open), while the pointed symbols are non-sightings; finer distinctions are explained in the text.

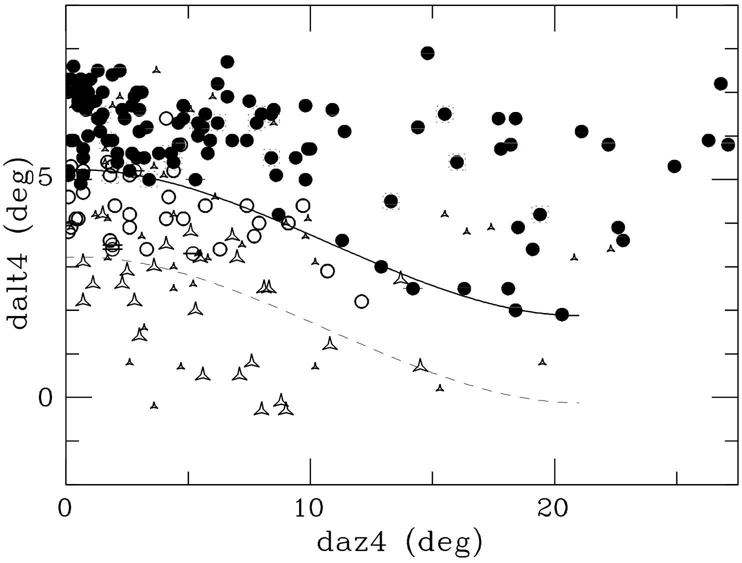

Fig.2: As Fig. 1, but the positions are plotted corresponding to the time when the sun is 4 degrees below the horizon, closer to the time of maximum probability of sighting.

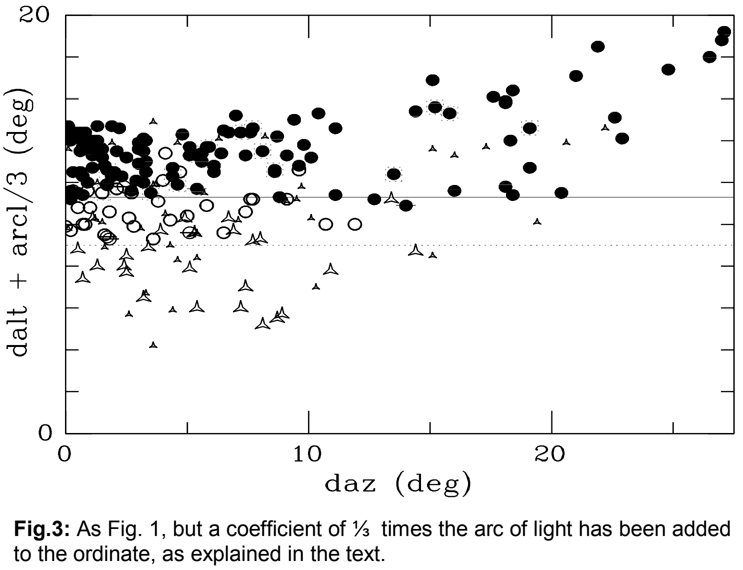

Fig.3: As Fig. 1, but a coefficient of ⅓ times the arc of light has been added to the ordinate, as explained in the text.

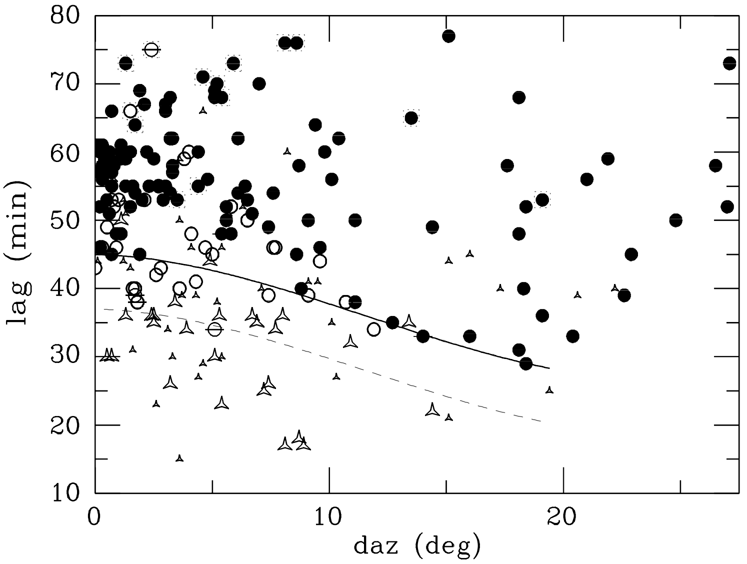

Fig.4: As Fig. 1, but the ordinate is the time lag between sunset and moonset (or moonrise and sunrise).

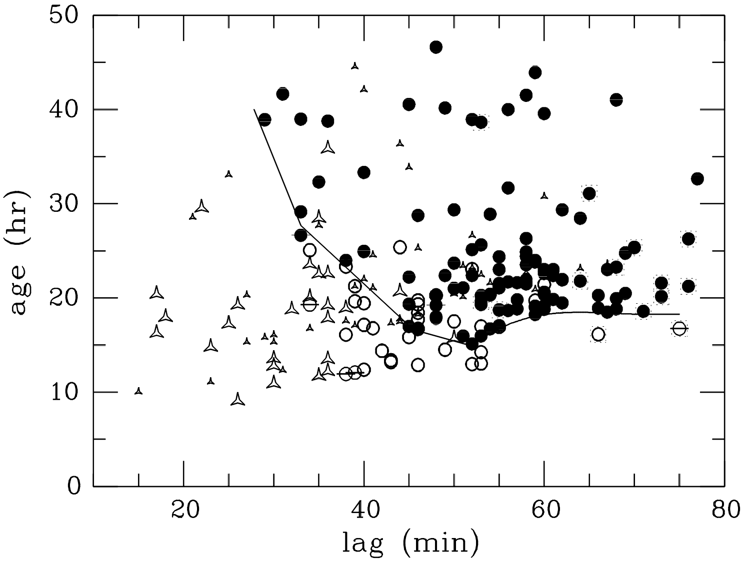

Fig.5: As Fig. 1, but the abscissa is the time lag between sunset and moonset and the ordinate is the time lag between new moon and sunset, thus the moon's age.

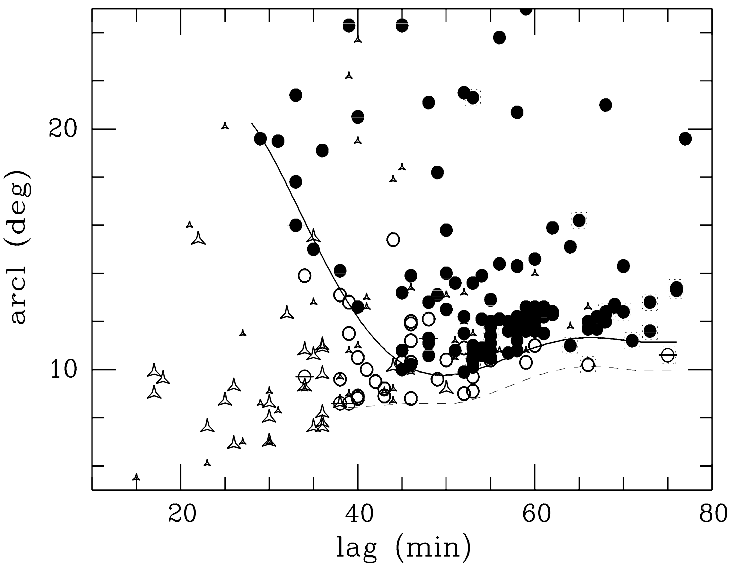

Fig.6: As Fig. 5, but the ordinate is the arc of light, as explained in the text.

aid (class E, not as stringent at class F). Events at high latitude, taken here as at least 45° from the equator, are distinguished by a halo of small dots around the point. Note that the sightings and non-sightings are not implied to occur at the instant of sunset, but are attempted throughout (and typically only successful at a later stage during) the fading twilight. In the intervening interval the moon's offset from the sun has scarcely altered, except possibly in summer at high latitude (see below).

The solid curve is our attempt to delineate a boundary below which visual sighting is *improbable*, even given ideal viewing conditions (cloudless, clear air, skilled observers, etc.) We have used this curve, shifted to include even the most extreme optically-aided sighting, to generate the dotted line "best guess" boundary below which even optically-assisted sighting from the surface of the Earth would be *impossible*. Clearly, more observations will be needed so that these lines can be more precisely and confidently defined, especially at large azimuth differences. More sighting attempts at *large* azimuth differences, in general from higher latitudes, are very much needed.

These lines are intentionally optimistic, taking account of all apparently reliable sighting and in practice visibility could be much worse. However, we consider that the important factor for verifying a lunar calendar is not what the average outcome would be for a random observer at an average, frequently turbid, site. What is more germane is what is would be marginally achievable by objective, seasoned observers at an excellent site, but taking into account the vagaries of the weather.

One worry with the altitude-azimuth-at-sunset parameterization is that observers at high latitude in the summer would gain an advantage from the exceptionally long delays possible between sunset and moonset. The latitude would then enter as a "third parameter" potentially obscuring the criterion. One would then expect an improvement in the separation between visible and invisible cases by using the altitude and azimuth difference at a time better corresponding to that typical of marginal sightings. As this refinement is a small effect, a complicated estimate of the time seems unnecessary, and we have adopted the time when the sun center has a depression of 4° below the horizon as fiducial.

Figure 2 shows the altitude difference versus the azimuth difference at the time of 4° solar depression. No apparent advantage for visibility discrimination can be seen in this diagram over Figure 1 at this stage. It may be expected that high latitude data with very large azimuth differences will in time produce a clearer prediction in terms of this second approach.

Figure 3 is another modification arising from Figure 1, taking advantage of the fact that at a larger arc of light, the moon is both brighter and necessarily located at an azimuth of a dimmer sky brightness than near the sun. The increase of the arc of light can then compensate for a decrease of altitude difference, and by experiment a factor of 3 seems to allow the effects to cancel over a considerable range of azimuth difference. Keeping the limitations of the data in mind, it appears nonetheless possible to make a reasonably sound inference about the past or prospective visibility of a particular crescent observation by reference to the guidelines in Figures 1–3.

Predicting Visibility from the Time Lag between Sunset and Moonset

Figures 4–6 address various aspects of using the time delay between sunset and moonset (moonset lag) as a parameter for predicting crescent visibility or otherwise. Figure 4 is most analogous to Figures 1–3 since it uses the same parameter for the x-axis, but plots the moonset lag on the y-axis. Although superficially similar in appearance, there is not as clean a separation of outcomes in Figure 4 because a relatively large moonset lag *can* be compatible with a low crescent altitude at sunset even at middle-latitude sites. One might imagine that the scatter in this plot will only worsen with more data from high latitude where both extremes would be encountered – large moonset lag at low altitude, and large arc of light at low moonset lag.

The public tends to guess at the visibility based on the two most readily available indices, namely the moon's age and the moonset lag. Figure 5 illustrates why neither of these in itself is a satisfactory parameter on which to base a visibility prediction. Even quite old moons can be invisible if their altitude or travel-direction towards the horizon is such that they set quickly after sunset (short lag). Even crescents with a long moonset lag can be invisible if their travel-direction towards the horizon is very gradual, as is the case at high latitudes. Interestingly, the combination of both numbers, usually requiring no more than a good newspaper, can yield at least a not-unreasonable guess. It will not be very precise for a lag below 45 minutes, as in this regime the neglect of other decisive factors becomes a more serious problem.

Figure 6 gives an improvement of the preceding by using the arc of light for the y-axis. In the light of the variation of the Earth-moon distance, the arc of light should correlate better with the total brightness of the crescent and its angular separation from the sun (still subjected to variable topocentric parallax), than the age alone. It shows a promising degree of discrimination between outcomes.

Summary of Criterion Lines

Table 1 gives the numerical values of the lines shown in 1–4. If the crescent moon lies below the upper y-value figure for a given x-value (i.e. the upper curve), then a sighting is *improbable*, by which we mean that seeing the crescent without a telescope or binoculars is *exceedingly unlikely*. Sighting the moon with optical aid may be possible if the crescent is near the upper figure, but glimpsing it *visually* should be right at the extreme edge of perception if at all feasible. If the crescent lies nearer the lower y-value figure (i.e. the lower curve), sighting the moon *would be exceedingly unlikely* even with optical aid. Crescent moons falling below the lower limit are considered to be genuinely *impossible* to see even with optical aid, because of their intrinsic lack of contrast with the surrounding sky brightness.

Table 2 gives the numerical values for the solid line shown in Figures 5–6, below which visual sighting would be improbable.

The Annual and Long-Term Cycle between North-African/Mideast and Southern African Visibility

Some of the factors affecting lunar crescent visibility are seasonal, and therefore affect northern and southern hemisphere observers oppositely. The seasonal effect arises from the fact that the moon's path makes a much more favourable angle to the western horizon in spring than in autumn. A smaller effect is the changing time of sunset, depending on latitude. The result is to favour southern observers during September and October and northern observers during March and April, barring other considerations.

The position of the moon in its orbit can also favour either northern or southern hemisphere observers since, while a young crescent, the moon can be as much as 5° north or south of the ecliptic. For example in 2000 the moon is farthest north of the ecliptic for the young crescent on September 28 (favouring northern observers), and furthest south of its "average path" at sunset for the April 5 young crescent (favouring southern observers).

These two effects (seasonal and moon-orbit), can cause a one-day difference between the dates when northern and southern observers *even at nearly the same longitude, and at comparable distance from the equator,* are enabled to sight the crescent moon, especially when their effects act in concert. In 2000 the two effects are about six months "out of synch," and tending to oppose and cancel. Hence the 2000 dates of first visibility tend to agree very well between Southern Africa and Northern Africa/Mideast. The supposition of similar crescent visibility conditions holding for most lunar calendar observers in a restricted longitude zone has been invoked by Ilyas (1994) to suggest a compromise three-longitude-zone global lunar calendar, as a start toward a Unified World Islamic Calendar, in place of the proliferation of lunar calendars occurring under the present multi-domain system. Unfortunately the quasi-parabolic shape of the line of first visibility, together with the strong but intermittent north-south visibility differences, causes the actual visibility dates to differ with latitude within an Ilyas zone as markedly as they would differ from one longitude zone to its neighbor.

To clarify the north-south effect we have calculated a parameter we dub the North-South Advantage (NSA). It is the altitude difference of the crescent moon as seen by an observer from latitude +30° minus that as seen by an observer from latitude –30°, for a crescent with an ecliptic longitude of 12° greater than that of the setting sun, a very typical configuration for sightings. The seasonal and moon-orbit effects just discussed can obviously cause changing advantages amounting to many degrees of crescent altitude as perceived from north or south of the equator, which when large enough will inevitably affect lunar calendar synchrony. A positive NSA favours the north, a negative one the south, and a zero NSA means equal accessibility of the crescent to both.

Figure 7 illustrates the effect by show–ing the NSA for an 240-year period. The horizontal axis shows the day of the year and the vertical axis the NSA *lined off in divisions of 10°*. Notice that the NSA varies strongly with the season for several years, followed by several more years where the variation is much reduced. This shows the consequence of the moon-orbit effect alternately enhancing and then canceling the underlying seasonal effect, in the rhythm of the 18.61 year regression of the lunar orbit node. Societal interest in the Ramadaan and Shawwall crescents being what it is, we plot the latter as vertical arrows in the diagram. One notes immediately that many decades go by with little advantage to either hemisphere in sighting the crescent for this particular lunar month and its predecessor. Thus

Table 1. Numerical values of the criterion lines in Figures 1–4

x=daz or daz4 (deg)	y=dalt (deg)		y=dalt4 (deg)		y=dalt+arcl/3 (deg)		y=lag (min)	
0.0	8.19	6.29	5.22	3.22	11.3	9.0	45.00	36.99
0.5	8.18	6.28	5.22	3.22	11.3	9.0	44.93	36.92
1.0	8.16	6.26	5.22	3.22	11.3	9.0	44.82	36.81
1.5	8.14	6.24	5.20	3.20	11.3	9.0	44.67	36.66
2.0	8.10	6.20	5.17	3.17	11.3	9.0	44.48	36.47
2.5	8.06	6.16	5.13	3.13	11.3	9.0	44.26	36.24
3.0	8.02	6.12	5.09	3.09	11.3	9.0	43.99	35.98
3.5	7.96	6.06	5.03	3.03	11.3	9.0	43.70	35.69
4.0	7.91	6.01	4.96	2.96	11.3	9.0	43.37	35.36
4.5	7.84	5.94	4.89	2.89	11.3	9.0	43.02	35.01
5.0	7.77	5.87	4.81	2.81	11.3	9.0	42.64	34.62
5.5	7.70	5.80	4.72	2.72	11.3	9.0	42.23	34.22
6.0	7.62	5.72	4.63	2.63	11.3	9.0	41.80	33.79
6.5	7.53	5.63	4.53	2.53	11.3	9.0	41.35	33.33
7.0	7.44	5.54	4.43	2.43	11.3	9.0	40.87	32.86
7.5	7.35	5.45	4.32	2.32	11.3	9.0	40.38	32.37
8.0	7.26	5.36	4.21	2.21	11.3	9.0	39.88	31.86
8.5	7.16	5.26	4.09	2.09	11.3	9.0	39.36	31.34
9.0	7.05	5.15	3.97	1.97	11.3	9.0	38.83	30.81
9.5	6.95	5.05	3.85	1.85	11.3	9.0	38.28	30.27
10.0	6.84	4.94	3.73	1.73	11.3	9.0	37.73	29.72
10.5	6.73	4.83	3.61	1.61	11.3	9.0	37.18	29.16
11.0	6.61	4.71	3.49	1.49	11.3	9.0	36.62	28.60
11.5	6.50	4.60	3.36	1.36	11.3	9.0	36.05	28.04
12.0	6.38	4.48	3.24	1.24	11.3	9.0	35.49	27.47
12.5	6.26	4.36	3.12	1.12	11.3	9.0	34.92	26.91
13.0	6.15	4.25	3.00	1.00	11.3	9.0	34.36	26.35
13.5	6.03	4.13	2.89	0.89	11.3	9.0	33.81	25.80
14.0	5.91	4.01	2.78	0.78	11.3	9.0	33.26	25.25
14.5	5.79	3.89	2.67	0.67	11.3	9.0	32.72	24.71
15.0	5.67	3.77	2.57	0.57	11.3	9.0	32.20	24.18
15.5	5.55	3.65	2.47	0.47	11.3	9.0	31.68	23.67
16.0	5.43	3.53	2.37	0.37	11.3	9.0	31.18	23.17
16.5	5.31	3.41	2.29	0.29	11.3	9.0	30.70	22.68
17.0	5.19	3.29	2.21	0.21	11.3	9.0	30.23	22.22
17.5	5.08	3.18	2.13	0.13	11.3	9.0	29.79	21.77
18.0	4.96	3.06	2.07	0.07	11.3	9.0	29.36	21.35
18.5	4.85	2.95	2.01	0.01	11.3	9.0	28.97	20.95
19.0	4.74	2.84	1.96	-0.04	11.3	9.0	28.59	20.58
19.5	4.64	2.74	1.93	-0.07	11.3	9.0		
20.0	4.53	2.63	1.90	-0.10	11.3	9.0		
20.5	4.43	2.53	1.88	-0.12	11.3	9.0		
21.0	4.33	2.43	1.88	-0.12	11.3	9.0		

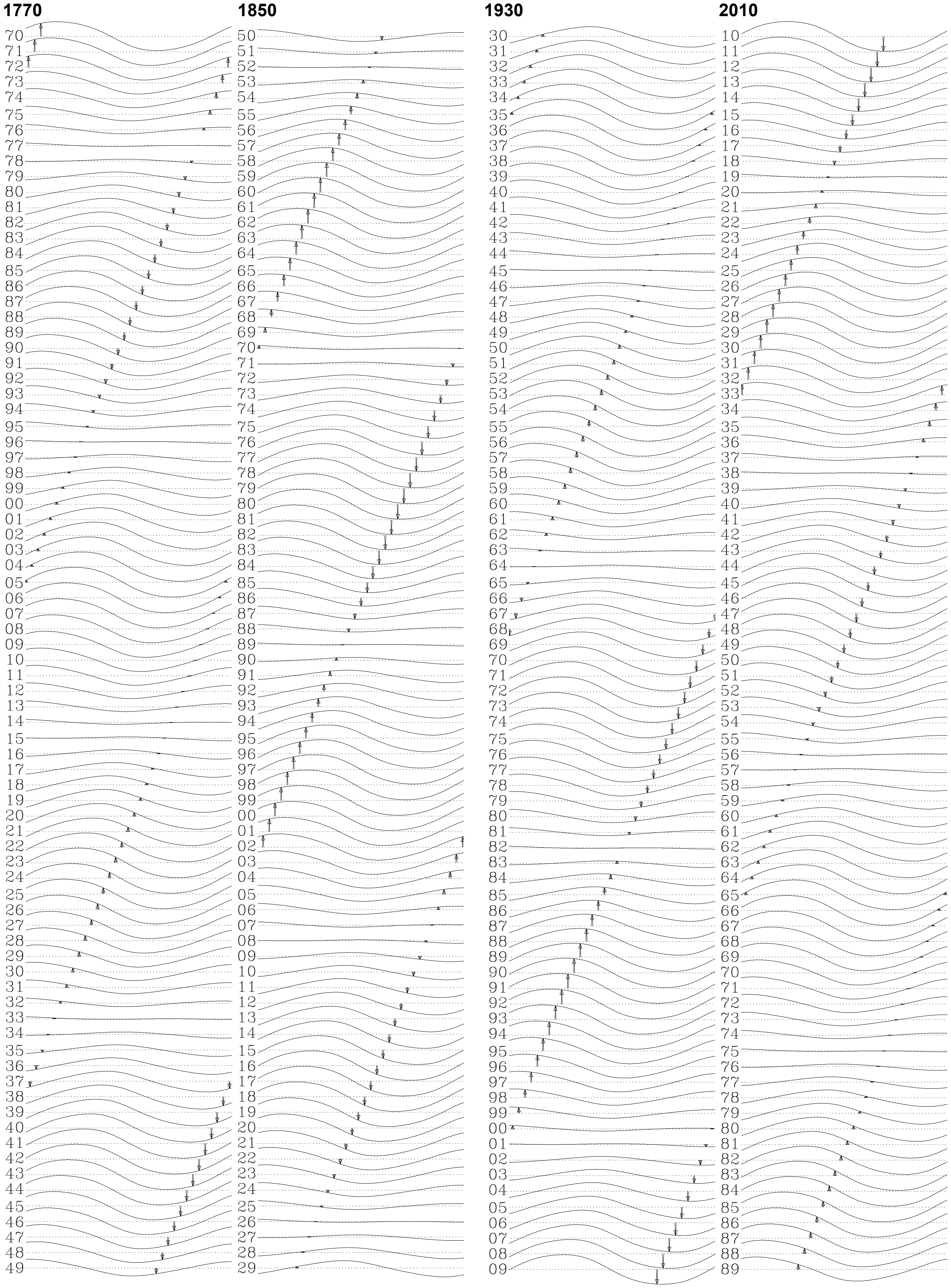

Fig.7: The North-South Advantage from 1770 to 2089 shown as solid lines during the course of each year, with each vertical division corresponding to an NSA of 10°. A long up-arrow signifies an extreme northern advantage, southern disadvantage, in viewing the Shawwall crescent, such as recurs in two spells within each 130 year cycle (see circa 1860, 1900, 1990 and 2030).

Table 2. Numerical values for the solid line shown in Figures 5–6

x=lag (min)	y=age (hr)	y=arcl (deg)	x=lag (min)	y=age (hr)	y=arcl (deg)
28	39.53	20.26	52	14.90	9.87
30	34.80	19.08	54	16.21	10.08
32	30.07	17.66	56	17.17	10.35
34	26.81	16.16	58	17.82	10.64
36	25.04	14.68	60	18.22	10.92
38	23.26	13.33	62	18.42	11.13
40	21.49	12.17	64	18.47	11.27
42	19.72	11.23	66	18.43	11.33
44	17.94	10.53	68	18.35	11.30
46	16.48	10.06	70	18.28	11.22
48	15.95	9.82	72	18.28	11.15
50	15.43	9.77	74	18.27	11.15

the extreme and in recent memory unprecedented *disadvantage* accruing to southern Ramadaan/Shawwall obser–vers in the early 1990s occasioned some understandable perplexity and controversy. A compensating, extreme southern advantage will appear from about 2005 onwards.

One has to look back to the 1860s to find a comparable southern handicap, 130 years before the early 1990s occurrence. The overall cycle has a periodicity of 130 years or 7 lunar nodal regression cycles. The pattern appears to be one of 4 nodal cycles with no large NSA followed by three of which two show a large NSA, hence: N N N N Y N Y, where Y or N denote the presence or absence of a large one-sided NSA in a given nodal cycle. Thisaccounts for the gap of 38 years between the large NSA years around 1992 and 2030, and the gaps back to the corresponding NSA peaks 130 years before.

Conclusions

We have discussed the empirical data on lunar crescent visibility and find prediction criteria that are quite satisfactory to explain the past record of credible, critical obser–vations, and in the process we have examined a wide range of possible parameters and their merits and short–comings as predictors.

A novel realization has been the extremely large and time-variable visibility advantage that can tem–porarily hold sway from north to south across our continent. The southern delays in sighting the Ramadaan and Shawwall crescents in the early 90s furnished a case in point of this occasionally dominant effect, which should be borne in mind by crescent watching communities that compare with results originating far to their north or south.

The Internet and computer-controlled telescopes have opened up the field for new rapid progress, but careful and objective observing, with depen–dable pointing, is as indispensable as ever. Some apparent needs remain: attracting the engagement of skilled observers at higher latitudes, and pursuing the rather unspectacular task of providing high quality *negative* sightings when occasions warrant.

While better observing and com–munication technology, and a more global and objective approach are contributing to a more realistic concept of the conditions for visibility and invisibility, the long-standing problem of erroneous sightings remains. On the encouraging side, we have been gratified by the widespread, substantial compatibility of the results achieved by different observers at different locations, *in good conditions*.

The sobering lesson that we have taken away from this work is the lack of due skepticism *in poor conditions* (indeed a reluctance to recognize bad observing conditions for what they are) which handicaps the search for the actual boundaries of true visibility. A frank account of the relevant weather conditions to accompany all sighting reports would provide an important check on this tendency.

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Astronomy at the University of South Africa

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Abstract. Unisa is the largest correspondence university in Africa and the only South African university currently offering a BSc in Astronomy. The astronomy modules can be included in any standard BSc Physics programme. Besides using the radio and optical telescopes at HartRAO and SAAO, Unisa also has its own Observatory on the main campus equipped with modern instrumentation for training students and doing niche research projects.

Sommaire. Unisa est la plus importante université d'enseignement par correspondance en Afrique et la seule université d'Afrique du Sud qui forme des licenciés ès sciences (BSc) en Astronomie. Les modules d'astronomie peuvent être inclus dans tout programme standard de Physique pour BSc. En plus d'utiliser les télescopes radio et optiques à HartRAO et SAAO, Unisa a aussi sur le campus principal son propre Observatoire équipé d'une instrumentation moderne pour la formation des étudiants et pour mener à bien des projets de recherche dans des niches scientifiques modernes.

UNISA

The University of South Africa (Unisa) is a correspondence university offering internationally recognised certificate, diploma and degree courses up to doctoral level in a wide range of subjects to approximately 120,000 registered students from all over the world. The main campus is situated on a ridge overlooking the capital city of Pretoria.

Students must submit assignments regularly so their progress can be monitored. Examinations are written at more than 450 conveniently located centres all over the world. The students on-line service enables students who have access to the internet to communicate with their lecturers and fellow students electronically. It also provides access to the extensive library catalogue.

Research and community participation are part of the mission of Unisa. For many years various departments have participated in community-based projects, often as an integral part of the University's teaching and research endeavours. More information is available on the University's web page at: *http://www.unisa.ac.za*.

Astronomy Programme

Degrees in astronomy are offered through the Department of Mathematics, Applied Mathematics & Astronomy in the Faculty of Science. However, students do not have to register for a degree to do these courses. Individual courses may be taken purely out of interest for non-degree purposes.

Fig. 1: The Unisa Observatory.
Inset: Celeston 14-inch telescope at Unisa.

Students from other universities in South Africa may obtain credit towards their degree for any astronomy modules they pass at Unisa. The undergraduate astronomy modules are designed in such a way that they can be incorporated into any standard physics BSc degree.

A BSc is made up of 30 modules, of which no more than 14 modules may be taken from 1st-year courses and at least 8 modules from 3rd-year courses. To major in astronomy, the 9 astronomy modules listed below must be included in the curriculum together with some prerequisite maths and physics modules. Suitable electives make up the balance of 30 modules.

The practical modules AST255 and AST355 include a two-week session at the Unisa Observatory in June or July.

All modules use study guides prepared in the Department. Study material, tutorial letters and assignments are mailed to registered students; some material is available electronically.

Facilities

The Unisa Observatory, situated on the main campus, is a modern well-equipped facility housing a computer-controlled 14-inch telescope mounted on a fixed pillar. The Observatory is used primarily to train astronomy students using its state-of-the-art instrumentation.

Viewing evenings at the Observatory give members of the public an opportunity to look at some of the splendours of the night sky, and stimulates an awareness of science and technology in disadvantaged communities.

Instrumentation for the telescope includes a spectrograph, a photometer, a CCD and a 35-mm SLR camera. Research is possible for certain niche projects using this equipment. Some images taken with the CCD can be seen on the Observatory webpage at: *http://astro.unisa.ac.za/~uniobs.*

The Department has a number of powerful linux workstations on which astronomical software has been installed for analysing data collected at South Africa's two national astronomical facilities:

- the 26-m radio telescope of the Hartebeesthoek Radio Astronomy Observatory (HartRAO), and
- the optical telescopes of the South African Astronomical Observatory (SAAO).

Staff in the Astronomy Department regularly get observing time at these observatories, in addition to which they have a 5% share of observing time on the Automatic Photoelectric Telescope at SAAO.

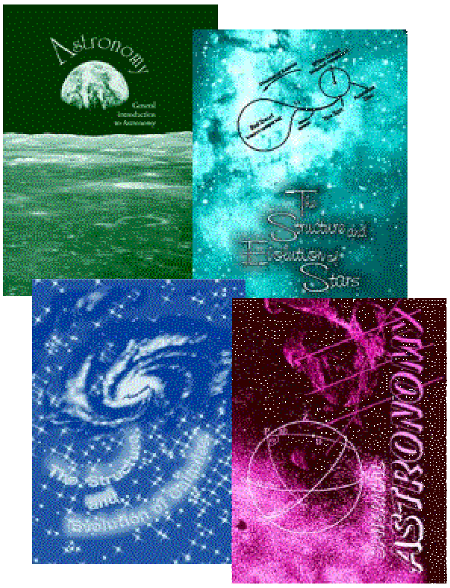

Fig 2. Unisa astronomy handbooks.

UNISA Astronomy Courses

- [AST-131] A General Introduction to Astronomy
- [AST-134] Spherical Astronomy
- [AST-251] The Structure and Evolution of Stars
- [AST-252] The Structure and Evolution of Galaxies
- [AST-255] Astronomy Practical I
- [AST-355] Astronomy Practical II
- [AST-361] Radiative Mechanisms80
- [AST-362] Radiative Transfer
- [Ast-363] Observational Techniques

The Peoples' Attitudes on Space Science: A Case Study at Mbarara University of Science and Technology in South-Western Uganda

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Abstract. A public survey to establish the space-interested group in Uganda has never been done before. This paper gives the proportion of the space-interested group from a section of the informed sector of Ugandan society. The results are based on the answers to questionnaires and oral questions from 623 respondents from Mbarara University of Science and Technology. Nearly 90% of the respondents were space-attentive, while 72% of the space-attentives favour research geared towards development of civilian and scientific purposes. The survey has outlined the way forward to promote the development of basic space science in Uganda.

Sommaire. Il n'avait jamais été mené auparavant d'enquête publique pour mettre en évidence l'intérêt potentiel du spatial en Ouganda. Cet article donne le pourcentage de personnes intéressées venant d'une section d'un « secteur informé » de la société ougandaise. Les résultats sont basés sur les réponses à des questionnaires et à des questions orales soumis à 623 personnes de l'Université des Sciences et de la Technologie de Mbarara. Presque 90% des personnes interrogées sont attentives au spatial, alors que 72% de ces dernières privilégient une recherche visant au développement d'objectifs civils et scientifiques. L'enquête a ébauché les recommendations pour promouvoir le développement de la science spatiale fondamentale en Ouganda.

Introduction

Research in space science and space exploration is one of the crucial areas that requires time and resources to achieve tangible results and it is undoubtedly clear that the study of space science is vital for the survival and well-being of humans, as it helps to regulate our activities, preserve our environment and develop the right perspectives about our solar system and the Universe as a whole[2].

Several nations besides the traditional space-faring ones have made major inputs in terms of time and resources in broadening the spheres of space science, both in our immediate and remote environments. However, more efforts and contributions are required globally to boost the pursuance of space science.

In Uganda, space science has never occupied any conspicuous course structure in the national curriculum at any levels, which I think is a representation of a missed opportunity. Further, the national budget over the years has had no vote designated particularly for space science research. However, the Government makes available some research grants to government-owned higher institutions of learning. These may not be sufficiently adequate to run empirical research efforts towards space exploration, therefore posing an impasse to the design and management of ambitious projects which may involve sophisticated equipment and methodology.

The United Nations and the European Space Agency, together with the efforts of many institutions established for space research and exploration, have made and continue to make further efforts in the direction of developing space science. Nevertheless, many have not benefited from these efforts, whereas a good percentage may be interested in contributing directly or indirectly to the expansion of our knowledge on space.

This survey was therefore conducted to ascertain the percentage of interested people from a section of the "informed sector" of Ugandan society and their perceived focus in developing this subject. It further sought to identify peoples' attitudes towards the on-going efforts in furthering space science and space exploration.

While all the respondents in this survey did not constitute a scientific sample, they did provide valuable information about the attitudes of an informed sector of the public on space science and exploration.

Table 1. Table of survey respondents.

POSITION	F/Sc-ED	F/MED	FDS
FIRST-YEAR STUDENTS	54	62	42
SECOND-YEAR STUDENTS	53	55	31
THIRD-YEAR STUDENTS	24	64	4
FOURTH-YEAR STUDENTS	–	52	–
FIFTH-YEAR STUDENTS	–	54	–
POST-GRADUATE DIPLOMA STUDENTS	–	–	16
GRADUATE STUDENTS (MSc)	6	10	–
PhD STUDENTS	–	2	–
ACADEMIC STAFF	17	29	16
NON-ACADEMIC STAFF	3	16	13

Key: F/Sc-ED = Faculty of Science with Education
F/MED = Faculty of Medicine
FDS = Faculty of Development Studies

Method

The survey was conducted by administering questionnaires and oral interviews to a randomly-sampled total number of 623 university students and staff. Out of the total, 84.91% (refer to Table 1 below) were students of different academic levels; 9.95% of the sample space was constituted of the academic staff, while 5.14% was constituted of non-academic staff.

Results

This survey targeted mostly university students who are considered as the epicentre of future scientific development in space science. This sample constituted part of the informed sector of the public.

Analysis of the survey results showed that 89.73% (559 respondents) of the sample supported the unconditional continuity of all the on-going space projects world-wide.

Of the 89.73% "space-attentives", 71.91% (402 respondents) support space programmes mainly geared towards development of civilian and scientific purposes (refer to Figure 1 below).

9.15% (57 respondents) believe that space exploration ventures into the "unknown" and that these are very exorbitant projects with little or no immediate physical benefit to the human race, and that they are a waste of time and resources. They further believe that such resources should be diverted to projects which are tailored to address and mitigate immediate threats in the environmental and health sectors. The percentages may not add to 100% due to "no-response" answers and rounding of figures.

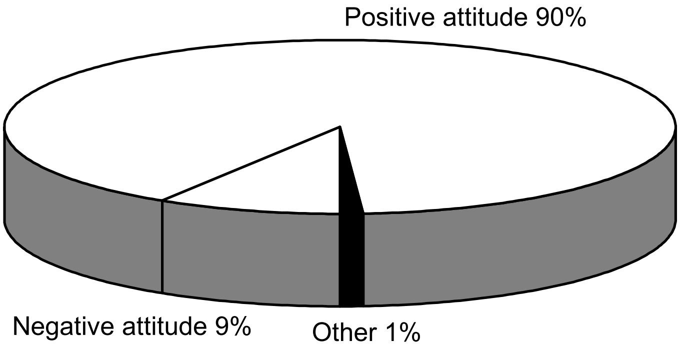

Fig.1. Attitudes on the space sciences at Mbarara University.

Conclusion

The results of the survey above clearly indicate that most of the respondents were "space-attentive" and this proportion is oriented towards continued research in space science and exploration inclined to benefit civilian and scientific purposes.

Recommendations

The following suggestions could possibly improve the status of space science in Uganda.

1. Explicit inclusion of basic space science in the curriculum at all levels of education in Uganda. This will introduce the empirical concepts of basic space science at the early stages of education.
2. The media should be involved in disseminating the current issues in space science. Regular television programs, radio talk shows, film shows, access to the internet and e-mail facilities, and popular columns in the press should be run to expose new ideas developed in the space sciences.
3. Encourage astronomical societies and clubs in schools. This will instill interest and encourage exchange of diverse ideas among students.
4. Visits to space centres and exposure to facilities used in space research is yet another interest-inspiring activity.
5. Visits by space experts with a lot of experience on the benefits and new breakthroughs in space science should be encouraged.
6. Inter-university and/or inter-college co-operation should be established in respect of student exchange programmes. This will stimulate the exchange of ideas and establish a common front in space research.

Acknowledgement

I am very grateful to Dr. Ngaka Willy of Makerere University and Dr. Fred Nuwaha for their valuable contri–butions towards the success of this paper. I am indebted to Mr. Julius Bunny Lejju of the Biology Depart–ment of Mbarara University for his valuable criticism in preparing this paper. This survey was supported by Mbarara University of Science and Technology, and I am grateful for the help and assistance offered by the university community towards the realisation of this paper.

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Advice to Contributors

The purpose of this publication is to provide a forum for communication among space scientists in Africa. In addition to recording the activities of the Working Group, *African Skies/Cieux Africains* features articles on current research developments in the space sciences in Africa as well as educational material intended for general readers and science educators. Contributions relevant to these themes will be considered for publication in *African Skies/Cieux Africains*. Shorter communications will be considered for publication in the *News, Letters* or *Announcements* sections of *African Skies/Cieux Africains*.

The official languages of *African Skies/Cieux Africains* are English and French. Contributions in either of these languages are acceptable. Authors fluent in both these languages are encouraged also to provide a translated one-page summary of their contribution. Papers in Arabic are also acceptable provided that (i) they are accompanied by a summary in one of the two official languages and (ii) a camera-ready copy of the Arabic text is submitted.

Papers should preferably be submitted as normal ASCII files. Authors who do not have access to word processing equipment are encouraged to submit typed or handwritten manuscripts to the Editor for typesetting.

Line drawings and photographs may be submitted for publications. Where possible, electronic copies of illustrations should also be submitted. Line drawings submitted electronically should preferably be in PostScript format. Photographs or other images should be scanned at the highest possible resolution to produce greyscale images in a common graphics image format.

Contributions may be submitted by post, fax, or electronic mail, to the address inside the front cover.

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