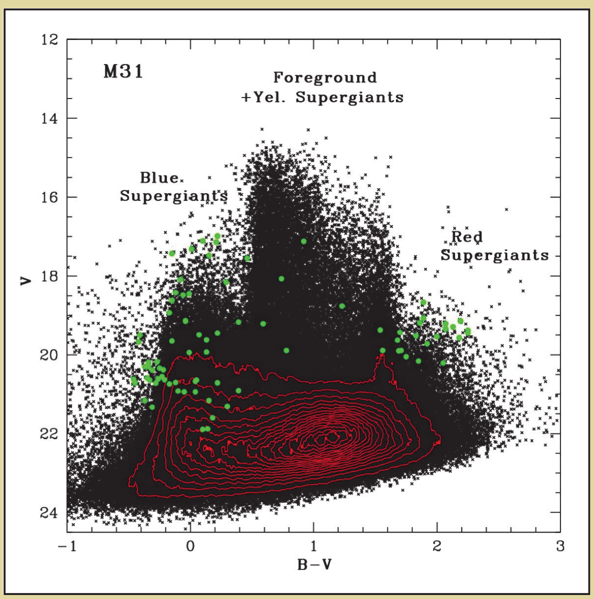
THE LOWELL
Observer
THE QUARTERLY NEWSLETTER OF LOWELL OBSERVATORY ISSUE 80 FALL 2008

Filling in the Yellow Void: A Census of Yellow Supergiants in M31

By Phil Massey (Lowell Observatory) and Maria Drout (University of Iowa)

When we look at a neighboring galaxy (such as M31, the Andromeda Galaxy) with a large telescope, we see stars – LOTS of stars! The bluest stars are massive, luminous super-giants. But, for the yellow and red stars, what we see is a mixture of M31 supergiants plus foreground stars within our own galaxy. It is very hard to distinguish these two: a yellow star could be a dwarf like our own sun, located maybe 3,000 parcsecs (10,000 light years) away in our own galaxy, or it could be a massive yellow supergiant 65,000 times more luminous, and located in the Andromeda Galaxy, at a distance of 760,000 parsecs (2.5 million light-years). Either would have the same brightness (about 17th magnitude) and colors.



A plot of the apparent visual magnitude V against the color index B-V for stars seen towards M31. Most of the hot, blue stars on the left side of the diagram are bona fide members of M31. About half of the cool, red stars on the right are also members. But in the middle, where the intermediate-temperature, yellow stars are found, the numbers are dominated by foreground stars within our own Galaxy.

The color-magnitude diagram shown here underscores the problem. Stars over on the left side, where we expect to find the blue supergiants, we can be pretty sure are all members of the Andromeda Galaxy. This is because there are no intrinsi-cally faint blue stars in our own galaxy that we could get confused with. On the extreme right, where we would expect to find the red supergiants, we actually find about a 50-50 mixture of foreground stars and bona fide red supergiants. But in the middle, in the yellow part of the color-magnitude, the situation is a seemingly hopeless mess: most of the stars are going to be foreground.

Why do we care if we know which stars are actual M31 members? The number of these stars proves to be a *very* sensitive test of stellar evolution theory, as the lifetimes are so short. As a massive star evolves from very high temperatures to cooler temperatures, it spends about 90 percent of its life on its main-sequence, converting hydrogen into helium and not changing its physical properties very much. After the star has used up all of the hydrogen in its core, it begins to convert helium to carbon, providing an additional energy source. During this helium burning stage profound changes take place within the star, and the star could become a red supergiant, and/or a Wolf-Rayet star depending upon its mass. These advanced stages of evolution are not well understood.

Massive stars don't live very long (a few million years, a mere cosmic eye blink by most standards) and this advanced evolutionary stage is short-lived indeed, about 100,000 to 500,000 years. Consider that this is comparable to the time it takes for a photon to make its way from the core of the sun to the surface, and you can begin to appreciate the difficulty in doing the calculations of what is actually going on in a star over this short an interval. For the yellow (F- and G-type) supergiants, the situation is even worse: a massive star simply *sprints* through this stage! For instance, consider a star with 15 times the mass of the sun. It spends 7 million years as an OB star, and about 700,000 years as a red supergiant. But in between the two it becomes an F- and G-type supergiant, spending about 2,500 years in this cameo.

In the Milky Way, obtaining an accurate census of the yellow supergiants is nigh on to impossible, as we don't know the distances to stars directly beyond about 100 parsecs. Is that yellow star a supergiant member of that cluster? Or is it a foreground (or background?) star. Only a few dozen of these yellow supergiants are known in our own Milky Way, compared to about a thousand blue supergiants, underscoring how rare they are. This scarcity is the "yellow void" referred to in the title.

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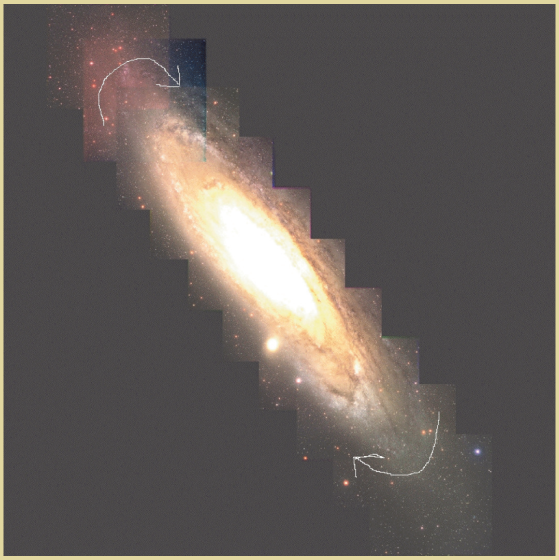


M31 is moving towards the sun at -300 km/sec, and in addition, the galaxy is rotating at 250 km/sec. So, a star in the south-west corner (lower right) will have a radial velocity of -550 km/sec, allowing easy separation from foreground stars, which have nearly zero radial velocities.

But, back to M31. In M31 we do have an observational way to separate the wheat from the chaff—the yellow supergiants from foreground stars—and that is through measuring the radial velocities of the stars. M31 is barreling towards us at -300 km/sec (about -670,000 miles/hr), where the minus sign serves as a reminder that the velocity is towards us. (Truth be told: most of this apparent motion is actually due to the sun's motion around the center of the Milky Way.) On top of that, the galaxy is rotating at 250 km/sec (560,000 miles/hr). So, a star seen in the southeast part of the galaxy, where the rotation is towards us, will have a radial velocity of about -550 km/sec. On average, a foreground star will have almost NO velocity relative to the sun. Given that one can measure the radial velocities of stars to within a few km/sec without breaking into a sweat, this would seem an observationally sweet project. The only rub is that there are about several thousand stars of the right colors and magnitude to be yellow supergiants in M31. Of course, we expect that the vast majority of these are foreground stars, but without taking spectra of these in order to measure the radial velocities, we can't tell.

Enter the MMT

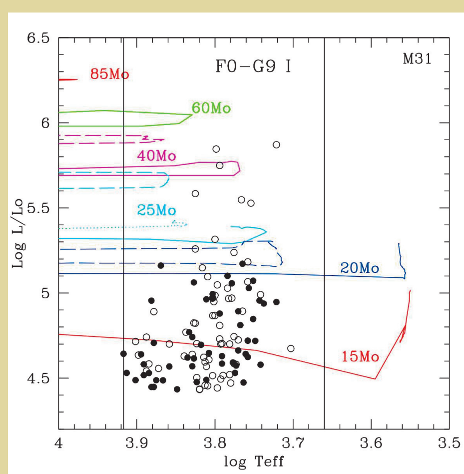
Fortunately with modern instruments, taking spectra of many thousands of objects is no longer in the realm of fantasy. Sitting on Mt. Hopkins, south of Tucson, is the mighty MMT 6.5-m telescope. One of its many instruments is Hectospec, a spectrograph fed by 300 fibers which can be moved to specified coordinates in a 1 degree field of view. In October 2007 we managed to obtain spectra of 3,000 stars in just a couple of nights of observing.

It sounds like a lot of work to analyze 3,000 stars...and it is! Fortunately, I had one of the best-ever summer students this year, Maria Drout from the University of Iowa, who came to Lowell through the Research Experiences for Undergraduates (REU) program run through the National Science Foundation. Maria not only was able to separate the wheat from the chaff, but also carried the analysis to the point of drafting a paper for the Astrophysical Journal! We are now working on cleaning up a few of the details. (I'll note in passing that her analysis was made easier and more pleasant thanks to a new 24" iMac purchased with a grant from the Mt. Cuba Astronomical Foundation.)

Summer student Maria Drout is shown the inner workings of the spectrograph. The fancy head gear is to keep the area clean. *(Photo by Phil Massey)*

So What Did We Find?

Of the 3,000 stars, 56 (1.8%) turned out to be "definite" yellow supergiants, and another 71 (2.4%) "probable" members. Talk about a few needles in a haystack! Thus, the foreground contamination was larger than we guessed, somewhere between 95.8% and 98.2%. But even more interesting than this is the issue of which stars turned out to be yellow supergiants, and where they fall on a Hertzprung-Russell diagram (plot of luminosity against temperature).



The Hertzprung-Russell (H-R) diagram is the stellar astronomer's best friend, allowing us to compare the physical properties (luminosity versus temperature) of stars with evolutionary models. Here the black dots are the certain yellow supergiants in M31. The open circles are "probably" yellow supergiants. The colored lines show various flavors of evolutionary tracks; i.e., a star with 15 times the mass of the sun should follow the red line at the bottom as it evolves from hotter temperatures (left) to cooler temperatures (right). The foray through the yellow supergiant (F0-G9 I) regime is *very* fast, taking only a few thousand years.

But, what is so astonishing about this diagram is the number of the yellow supergiants as a function of luminosity. Nearly all of the stars we found have masses of 20 solar masses or less—they are found below the line labeled 20Mo. Between the 15Mo and 20Mo tracks we count about 47 stars. Between the 25Mo and the 40Mo we count an additional 5, all of which are "probable" and not certain. That ratio is about 9.4.

Yet, current evolutionary theory predicts that there should be *far* more yellow supergiants of higher mass than lower mass. The lifetime in the yellow supergiant stage is only a few thousand years for a star with 15-20 times the mass of the sun, while current theory predicts a lifetime of 50,000 years for a higher mass 25-40 Mo yellow supergiant. So, rather than the ratio being 9.4, the expected ratio is 0.08 (even taking into account that fewer high mass stars get born each year than lower mass stars.) This discrepancy of a factor of 100 is something we are now trying to sort out with our good friends and colleagues who do these complicated theoretical calculations.

What's Next?

The obvious next step is to extend this work to the yellow supergiants of other galaxies. The evolutionary calculations are very sensitive to mass loss, the amount of material a massive star loses due to radiation pressure. This mass loss is in turn dependent upon the "metallicity" of the parent galaxy—how many carbon atoms, say, that there are for every hydrogen atom. So, we will be applying for observing time in the Southern Hemisphere on similar instruments to carry this work to the Magellanic Clouds.

Bike to Work Week 2008— The Lowell Riders Win Again

Ken Lane, Absolute Bikes; Susan Hueftle, Bike to Work Week Coordinator for Flagstaff Biking Organization; Linden Lane, Absolute Bikes; Jenean Perelstein, "Merk", Big Brothers/Big Sisters of Flagstaff; and Melinda Linzey, Lowell Observatory. The new Breezer bike in the picture was donated to Big Brothers/Big Sisters of Flagstaff by BTWW winners, Lowell Observatory.

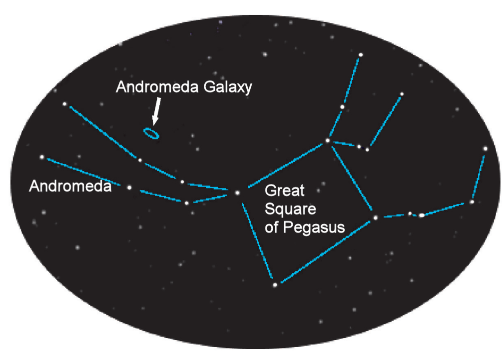
REU Students At Lowell Observatory Summer 2008

Lowell Observatory was host to three Research Experience for Undergraduate students this summer. From left to right: Malanka Riabokin, University of Wisconsin, worked with astronomer Deidre Hunter on star formation in dwarf galaxies. Rachel Spreng, Rowan University, worked with astronomer Lisa Prato doing photometry on young T Tauri stars. Maria Drout, University of Iowa, worked with astronomer Phil Massey conducting a census of F and G supergiants in M31 (see cover story).

Fall Sky Highlight

The Andromeda Galaxy, also known as M31, is a spiral galaxy physically larger, but less massive, than our Milky Way Galaxy. The Andromeda is the largest member of the Local Group, a cluster of about 30 galaxies that are gravitationally attracted to one another. At a distance of 2.5 million light-years, it is the most distant object easily seen with the unaided eye.

To find the Andromeda Galaxy, first look for the Great Square of Pegasus. In October, look toward the eastern skies just after sunset; as we move into November and December, you will look nearly overhead. You will see four stars that, if connected by imaginary lines, form a square. The square will be tipped and standing on one of its corners; it resembles the outline of a baseball diamond. Using this analogy, look at the star representing third base. Extending to its left is a collection of six paired stars that resembles a cornucopia. These stars are the brighter members of the constellation Andromeda and loosely form three pairs, with each pair further apart, thus forming the V-shape of the cornucopia. Just above and to the right of the second pair is the Andromeda Galaxy, appearing as a faint, fuzzy dot. Though with the unaided eye it may appear very small, it in fact takes up a part of the sky nearly four times wider than the moon.



New Percival Lowell Society Members Janet and Bill Tifft

By Rusty Tweed

When Bill and Janet Tifft began outlining their estate plan several years ago, their first concern was to provide for their children and grandchildren. They realized that it would be better to provide assistance while the children were young adults and generally in greater financial need. Handling personal family matters sooner rather than later also provided greater freedom to explore a "broader goal that might benefit society and extend our goals beyond our lifetimes," Bill explained.

The Tiffts established a Trust as their primary estate mechanism to provide them flexibility; it provides protection of assets and incorporates long-range provisions for distribution — such as educational support for grandchildren, and the ability to use residual balances for charitable purposes. "We were well organized in advance, and had a good idea of what we wanted to do in establishing a Trust. A knowledgeable attorney was an essential part of the process."

Bill and Janet chose to name Lowell Observatory as a beneficiary in their Trust primarily because Bill became very attached to Lowell during his time here as an astronomer from 1961 to 1964. He remembers, in particular, how gracious and understanding the Observatory was when he and his first wife Carol were faced with challenging personal circumstances that required him to spend more time at home with his first two children — his son who was born in Flagstaff, and his daughter who was an infant when Bill arrived in Flagstaff. "I owe Lowell a tremendous debt of gratitude for its understanding and help during a stressful part of my life. Lowell was very supportive; the 'family' aspect of Lowell was extremely valuable and much appreciated."

Bill also especially remembers the extraordinary skies at Lowell's research site, Anderson Mesa. He was fortunate to have lots of time on the Perkins Telescope where his data on the brighter galaxies in the Virgo Cluster provided an important extension of his original doctoral work on the colors of galaxies. This study would later redirect his career. "For my work, the quality of the sky had to be consistently good since each galaxy would require a couple of hours of telescope time. The Lowell site was an extraordinarily good area for doing photometry due to the fantastic atmospheric conditions. It was photometric heaven."

While at Lowell Bill developed an interest in NASA's manned space program, which ultimately led him to take a position at the University of Arizona; he left Flagstaff in 1964 'with great regret' to move to Tucson with his two children. In 1965 he was selected as one of 16 finalists for the first scientist astronaut program; ultimately his application was declined due to a minor medical condition. He continued to develop a space astronomy program at the UA until returning to extragalactic research in the early 1970s. The key to that final transition was finding an unexpected link between the Lowell photometry and nuclear and redshift properties of galaxies. That link would prove to be critical in defining his future career dedicated to the study of the nature of galaxies, time, and the cosmic redshift.

Bill met and married Janet, a widow pursuing her Masters degree in art education, in 1965 and they raised a his, hers, and ours family of six children in Tucson. "Reconnecting to Lowell was like fulfilling a dream for us." explained Janet. As a watercolor artist, teacher and tutor for 30 years, Janet had a desire to experience the natural beauty that surrounds the Lowell campus. The thought of moving to Flagstaff in retirement did occur to them but their roots were firmly planted in Tucson, where they will continue to reside while occasionally visiting Mars Hill.

"I believe in Bill's commitment to Lowell because of the emphasis on research and education there. He always felt loyalty, love and concern for Lowell," Janet explained. Bill continued that "Lowell has a very broad-minded approach to scientific research; if you see something strange, you should try to explain it — it ought to be pursued. It is extremely important to preserve private institutions like Lowell that value intellectual freedom and at the same time maintain a high level of respect for people on a personal level."

We are very appreciative of the Tiffts' commitment to helping ensure the long-term success and future financial stability of Lowell Observatory through their new membership in the Percival Lowell Society. We thank them for their generosity and support, and for sharing their story. Please use the enclosed envelope to request information about planned giving, the Percival Lowell Society, or to make a charitable gift to the Observatory.

Plan early for the Holiday Season. Use the enclosed envelope to buy gift memberships with the Friends of Lowell Observatory for friends and family!

Lowell Board Members Honored

Drew Barringer, President of the Lowell Observatory Advisory Board, and Carolyn Shoemaker, Lowell Observatory Advisory Board member, were named Fellows of the Meteoritical Society during its Annual Meeting in Matsue, Japan this summer. This honor is bestowed on individuals who have distinguished themselves in meteoritics or in closely allied fields. Drew also received the 2008 Service Award, which honors members who have advanced the goals of the Society to promote research and education in meteoritics and planetary science. The Barringer family are long-time stewards of the natural landmark Meteor Crater in northern Arizona and Carolyn Shoemaker holds the record for the most comet discoveries. Congratulations to both of you!

Carolyn Shoemaker and Drew Barringer in the Lowell Observatory Library

Hendricks Center for Planetary Studies

During Lowell Observatory's summer 2008 Advisory Board meeting, there was a special presentation. The Hendricks Center for Planetary Studies was dedicated in honor of John and Maureen Hendricks and family to help recognize their generous support of Lowell's Discovery Channel Telescope. From left to right: Maureen Hendricks, Bob Millis, Bill Putnam, and John Hendricks.

Ask an Astronomer!

What is parallax?

Parallax is an optical effect caused when you observe a close object against a more distant object (or objects) and then shift your viewpoint. The nearer object appears to move while the distant object appears to remain mostly stationary.

The easiest way to see this is to hold up your finger a few inches in front of your nose and look at something far away. Close one eye and then the other. Your finger appears to move back and forth while the distant object stays put. It turns out if you know the distance between the two viewpoints (called the baseline), then from the shift, you can measure the distance to the closer object.

Astronomers realized that this effect could be used to measure the distance to nearby stars. In this case the more distant stars would be the background and the baseline would be the diameter of the Earth's orbit (2 x 93,000,000 miles or 186,000,000 miles). Basically, you measure where your target star is relative to the background stars today. Then you wait six months until the Earth has gone halfway around the sun and do it again. The star will shift, and the amount of the shift can be used to calculate the distance to the star.

Unfortunately, the closest stars are so far away that even with a 186,000,000 mile baseline, the shift of the star due to parallax is *tiny* and very difficult to measure. Although astronomers tried, it was not until 1837 when the first parallax of a star was actually measured. The measured shift was 0.3 arc-seconds. This shift is about the width of a soccer ball as seen from 100 miles away, and this was from a star only 10 light years away, one of the closest stars.

This question was asked by Sharon Clarke, who teaches at Mill Creek Middle School in Kent, Washington and answered by Lowell Observatory astronomer Larry Wasserman. If you have a question, e-mail him at lhw@lowell.edu

New Pre- and Postdoctoral Students Join Lowell Observatory Staff

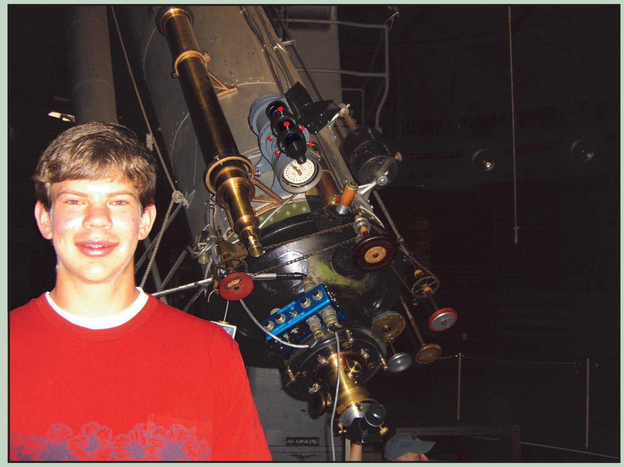
This summer saw the arrival of a new pre-doctoral student and post-doctoral student. Matthew Knight earned a B.S. in Physics from the University of Virginia and a Ph.D. in Astronomy from the University of Maryland. For his thesis he studied the sungrazing comets observed by the SOHO satellite. He observed comets in the optical and infrared, including 9P/Tempel1 during the Deep Impact encounter, and 73P/Schwassmann-Wachmann 3. At Lowell he is working with Dr. Dave Schleicher studying gas and dust coma morphologies in comets, including 6P/d'Arrest and 96PMachholz 1.

Matthew Knight, Postdoctoral Student

Christopher Crockett is a third year graduate student from the UCLA and the third student to join the Predoctoral Fellowship Program. He will be splitting his time between working with Dr. Lisa Prato on a radial velocity survey on brown dwarfs and giant planets around young stars, and assisting in the instrumentation lab under the guidance of Dr. Ted Dunham on instrumentation for the 42-inch Hall Telescope and the Discovery Channel Telescope. In addition, Chris will be working with teachers on the reservations to bring astronomy to the classrooms of 5th to 8th grade students as part of the Navajo-Hopi Outreach Program.

Christopher Crockett, Predoctoral Student

Discovery Channel Young Scientist



Karl Sorensen won a trip to Lowell Observatory in August for his participation in the 2007 Discovery Channel Young Scientist Challenge. Karl entered the competition with his science fair project on the easiest, most cost efficient way of anesthetizing fish. He met with Director Bob Millis, Discovery Channel Telescope Project Manager Byron Smith, and several astronomers on the staff during his visit.

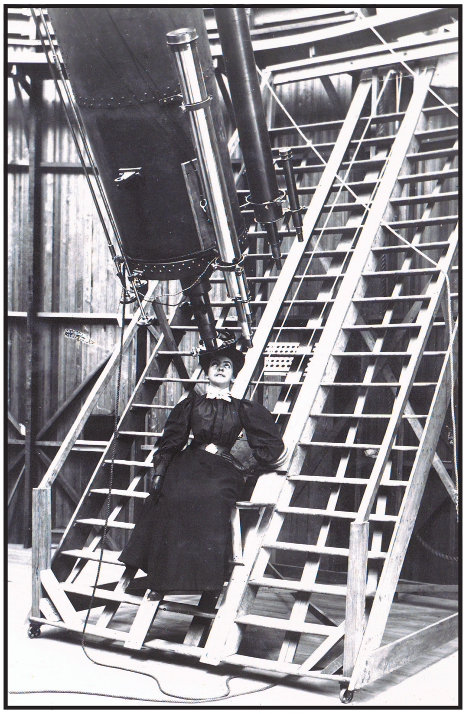
Wrexie Louise Leonard: Take a Letter, Take a Look

By Jan Millsapps

So much about Wrexie Louise Leonard, Percival Lowell's assistant from soon after he established Lowell Observatory in 1894 until his death twenty-two years later, will never be known. An article published by J. M. Hollis in the Griffith Observer (January 1992) describes her as "the enigmatic Wrexie," while a 1935 biography written by Lowell's brother Abbott Lawrence Lowell does not mention her at all.

We will never know, for instance, whether the "real estate man who lives on the Hill" that she wrote of meeting while visiting Boston in April 1895 was Percival Lowell, although it's certainly possible. He was not yet known as an astronomer and he was engaged in real estate activities around that time, including the purchase of his home on Boston's Beacon Hill. What we do know is that by the end of that year, Lou, as she was known then, had been hired as Lowell's assistant and was traveling with him through northern Africa in search of a suitable site to build a new observatory dedicated to the study of Mars and other planets.

The next summer finds her in Flagstaff, outfitted head to toe in Victorian finery, seated on the viewing platform, her eye to the eyepiece of the 24" Clark telescope at Lowell's newly established observatory. Although this photo from the Lowell archives may have been posed, the Observatory's historical logbooks are authentic. "W.L.L." was an early and frequent observer of the cosmos. Dating from 1895, her drawings of Mars and Venus share pages with those by "P.L." and others, verifying that Wrexie Louise Leonard was a woman routinely looking through the big telescope at Lowell Observatory — at least half a century before women were allowed to do this.*



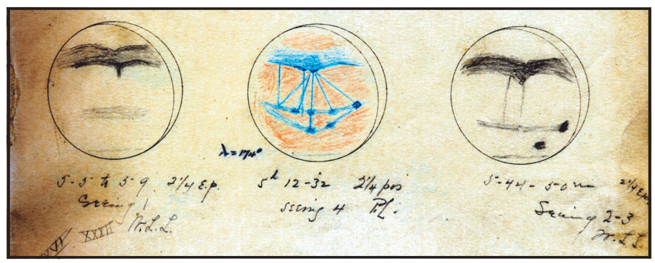
Wrexie Louise Leonard at the Clark Telescope circa 1897.

Wrexie worked as Percival Lowell's secretary for the next two decades; she ordered his cigars, edited his manuscripts, and shared his dedication to astronomy. However, details of her life remain sketchy. In most biographies of Percival Lowell she is described as a competent and intelligent secretary, one who, according to former Lowell Observatory Director John Hall (in a letter dated 4-13-71), "had the knack of conveying in subtle form…the spirit in which Lowell asked her to write..." Appropriately, the one remaining artifact related to Wrexie's position at Lowell Observatory is the Hammond typewriter, on which she must have typed hundreds of letters.

We can confidently say that Wrexie Leonard adored her boss; she kept a photo of him on her desk, defended him against astronomical naysayers and stayed mostly by his side during his prolonged breakdown and recovery from 1897 to 1901. Most historians acknowledge their association was intimate as well as professional; some cite as evidence the "not-so-secret" passage running beneath the rooms in the Baronial Mansion where Wrexie and Percival lived during their Flagstaff sojourns. Moreover, Lowell's wife Constance fired Wrexie within hours of his death in 1916, although in her later years, Percival's brother A. Lawrence Lowell contributed to her support.

For Lowell biographers, the story of Wrexie as a dedicated and possibly lovestruck secretary goes no further; yet records indicate that her association with Lowell and his observatory afforded her opportunities considered rare and remarkable for her gender. While women of her era, even when educated in astronomy, could only work as "computers" who studied photographic plates made by male astronomers, Wrexie's front line observations under the dome set her apart as someone with an unabashed enthusiasm for astronomy ("Many times the seeing was so good that in my excitement," she writes, "I forgot to take notes…") and also as someone increasingly serious about her planetary observations.

Not only did she study Mars, but also Mercury, Venus and Jupiter. On June 1, 1904, she was admitted to the *Societé Astronomique de France*, an unusual and significant honor for a woman. When she published her Mars drawings in Popular Astronomy (Vol. XV, No. 7, 1907), she took great care in preparing her materials, writing to the engraver creating prints from her drawings, "You know how I like a soft finish – not harsh." Her visuals are accompanied by detailed notes about Mars during opposition years 1901, 1903 and 1905, in which she describes its terminator line, polar ice caps, "Mr. Lowell's newly discovered canal," and a "queer birthmark effect."



The contrast on this sketch from the 1897 logbook for the 24-inch Clark refractor has been digitally enhanced to clearly show the signatures of Wrexie Louise Leonard and Percival Lowell. They both observed the planet Mars on the night of January 22nd.

While there is no definitive statement on record to show whether Wrexie considered herself more a serious astronomer or a fortunate bystander, "This lady," says her great niece Helen Klauk (in e-mail of 6/03/08 to J. Millsaps), "was way ahead of her time." Perhaps because of her gender, the world failed to take notice; at the time of her death in 1937 Wrexie was described (in J.M. Hollis e-mail of 6/22/90 to M.L. Evans) as a "retired secretary in real estate." If so, the record might be amended to state that her "real estate" ventures included not only Mars Hill, but Mars itself and worlds beyond.

*"The History of Women in Astronomy," Sally Stephens
http://astro.berkeley.edu/~gmarcy/women/history.html

Jan Millsapps, Ph.D., by Wrexie's Hammond typewriter, visited Lowell Observatory this past summer to research a historical novel she is writing, "Corrective Lenses," in which Wrexie Leonard is a character who keeps a secret journal of her astronomical observations. For more information, visit the web site: http://darkskycity.com

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2008 Public Program Fall Special Events

October *Regular public hours: daytime 9 AM-5 PM; M/W/F/Sat nights 5:30 PM-9;30 PM*

Wed 1 **Flagstaff Night** *(regular evening hours)*
Tonight at 7 PM, Lowell Educator Tim Rodriquez will give an indoor presentation about archaeoastronomy. Telescope viewing will also be available. Flagstaff residents (must show valid drivers license or utility bill) pay only half price for entrance into our regular evening programs.

Sun 12 **Autumn Star Fest** (*regular evening hours)*
Celebrate autumn with a Star Fest. This event will feature indoor programs and numerous telescopes set up for viewing throughout the Lowell campus.

Mon 20 **Orionid Meteor Shower** (*regular evening hours)*
Indoor programs will focus on meteor showers such as the upcoming Orionids. Telescope viewing of various celestial objects is included in the evening's activities.

November *Regular public hours: daytime noon-5 PM; M/W/F/Sat nights 5:30 PM-9:30 PM*

Wed 5 **Flagstaff Night** *(regular evening hours)*
Flagstaff residents (must show valid drivers license or utility bill) pay only half price for entrance into our regular evening programs.

Sun 9 **Veteran's Weekend Star Fest** (*regular evening hours)*
This special event will feature indoor programs and numerous telescopes set up for viewing throughout the Lowell campus.

Tues 11 **School's Out & Kids Are Free** (*9 AM to 5 PM)*
Lowell Observatory will be open for kids' activities throughout the day. Complete our self-guided scavenger hunt of the exhibit hall and outdoor exhibits and receive a prize. Children must be accompanied by an adult or responsible guardian.

26, 28, 29 **Thanksgiving Star Fest** *(regular evening hours)*
This event will feature indoor programs and numerous telescopes set up for viewing throughout the Lowell campus.

28, 29 **Thanksgiving Weekend Celebration** (9 AM to 5 PM)
Extended daytime hours with indoor programs and special tours including stops at the Pluto Telescope dome.

December *(Regular public hours same as above)*

1, 3, 5, 6, 8, 10, 12, 15, 17, 19, 20, 22
Holiday Skies Program *(regular evening hours)*
Our 7 PM presentation discusses the mythology and science of the winter sky, including a discussion of the Star of Bethlehem. Telescope viewing and other indoor programs will also be available.

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