THE LOWELL
Observer
THE QUARTERLY NEWSLETTER OF LOWELL OBSERVATORY ISSUE 85 WINTER 2009

Comet Lulin Zooms By
By Matthew Knight

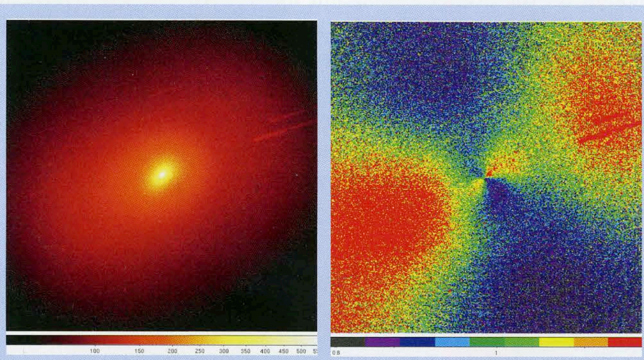

Figure 1: Raw (left) and enhanced (right) images of Comet Lulin on March 2, 2009 in a CN filter with different false color stretches to show detail. The nucleus is at the center in both images. In the raw image, white is the brightest area, and black is the darkest. In the enhanced image, red is the brightest area and blue is the darkest. Notice that the comet looks elongated from the bottom left to top right in the raw image. In the enhanced image there are two jets extending from the nucleus, one to the bottom left and the other to the top right. The diagonal lines near the right edge are stars that were trailed during the exposure. The circular rings in the images are artifacts of the enhancement. The field of view in each image is ~150,000 km at the comet.

There are very few things that astronomers study where they only have one chance, and Comet C/2007 N3 (Lulin) was one. Lulin originated in the Oort Cloud, thousands of times farther from the sun than the Earth. Given a small gravitational tug by a passing star or perhaps a Pluto-like object, it was nudged out of its slow orbit at the edge of the solar system into an orbit that brought it near Earth. As Lulin zoomed past us in early 2009, we had a few months to observe it before it receded back to the fringes of the solar system, from where it won't return for millions of years, if at all. Fortunately, Lowell astronomer Dave Schleicher and I were prepared to make the most of this fleeting appearance. Here is the story of how we studied it.

Lulin was discovered in July 2007 on images obtained at Lulin Observatory in Taiwan. At the time it was a faint (magnitude ~19) object beyond the orbit of Jupiter. It gained brightness steadily as it approached the sun, but due to the geometry of its orbit, was unobservable from Earth in late 2008. Although Lulin reached its closest distance to the sun in January 2009, it actually appeared brightest in late February when it was closest to Earth. At this time it was briefly visible with the naked eye, and I had the rare opportunity to see a comet with my eye at the same time that I was studying it using a telescope!

Lulin orbits the sun almost in the plane of Earth's orbit, but in the opposite direction as the Earth. Therefore, it was moving extremely fast when it passed Earth, and we had a limited time in which to study it. Our observations began in January 2009, when Lulin was visible for a few hours just before sunrise. Interestingly, while it looked relatively similar for three hours of a given night, it looked very different on the next night. On the third night it looked more like the first night than the second, and on the fourth night it looked closer to the second night. We surmised that the nucleus rotated with a period somewhat shorter than 48 hours, and planned our February observations to try to determine the rotation period.

Lulin was very well placed for observing in late February, appearing brighter than in January and being up all night. We monitored it regularly using a CN filter. This filter isolates a narrow range of light that is due to emission by cyanogen (CN), a bright gas that is commonly seen in the coma of comets. As a comet nucleus is heated by sunlight, ice that has been frozen since the formation of the solar system sublimates, turning instantly from a solid into a gas. Typically much of the surface is covered by inactive rubble and gas only escapes from a small portion. Far from the comet, this escaping gas looks like a beam, called a jet. By using a filter that isolates the gas, we can extrapolate where the gas originated on the surface. As the nucleus rotates, we can watch how the jet moves and infer how fast the nucleus is rotating, the orientation of the rotation axis, and where the jet is located.

As with most science, this is easier said than done! Because CN is actually the "daughter" product of HCN gas that escaped from the interior and quickly split into H and CN, CN gas appears smeared out, and CN jets are difficult to see. In the left panel of Figure 1, a CN image is shown where the comet appears elongated (bottom left to top right). To see the jets more clearly, we enhance the images to show areas that are brighter than average. This enhancement (right panel of Figure 1) reveals two jets, one in each direction of the *(continued on page 2)*

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elongation in the unenhanced image (red is brighter in these images, blue is fainter).

By enhancing each image, we isolated the jets and watched their motion during our extensive February run. At the start of the third night, the jets looked identical to the end of the first night (about 42 hours earlier). The start of the fourth night looked identical to the end of the second night, and so on. Since the features were repeating every ~ 42 hours, we suspected this was the rotation period (this also agreed nicely with our estimate from January). However, the same phenomenon could be seen if the period was 1/2 as long (21 hours), 1/3 (14 hours), 1/4 (10.5 hours), etc. This effect is called aliasing. Since our observations spanned about 10 hours per night over seven consecutive nights, we were able to rule out all of these aliases by comparing images that should have been identical for a given alias, but were not. Thus, the only possible period was 42 hours.

As further confirmation that the comet rotates in a 42-hour "day," we constructed a sequence of images obtained over several nights that were phased to the order in which they occurred in the rotation cycle. Four images spaced evenly apart in phase are shown in Figure 2. Using more images with a smaller time step between them, we made a movie (http://www.lowell.edu/users/knight/research/lulin.html) that clearly shows two side-on gas jets, each rotating such that it produces a corkscrew appearance.

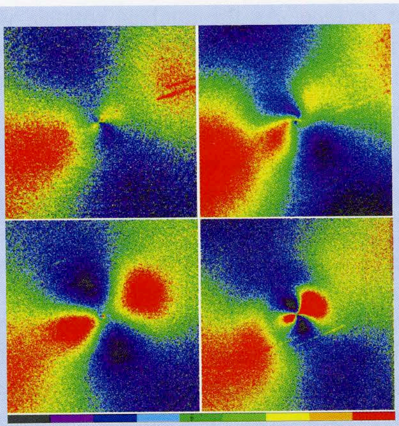


Figure 2: Enhanced CN images showing the rotation in late February and early March. The sequence goes in a clockwise direction. Red is the brightest area and blue is the darkest. The nucleus is at the center in all images. The streaked lines are stars that trailed during the exposure. The field of view in each image is ~150,000 km at the comet.

With the rotation period pinned down, we set out to determine the orientation of the nucleus' spin axis (i.e. the poles) and the location of the jets on its surface. This is challenging because we are using 2-D images where everything looks like it is in the plane of the sky to determine a 3-D model of the nucleus. But, there were some useful constraints provided by the high quality of the January and February data. Since the jet on the left always stayed on the left and the jet on the right always stayed on the right, we deduced that each jet was near a pole and that the pole was tilted by about 90° so that the comet's equator was perpendicular to the plane of its orbit. The result is that the comet appears to be rolling along its orbit rather than spinning like a top as the Earth does.

To better visualize this, we developed a 3-D computer model that reproduced the corkscrew structure seen in both January and February, and predicted how the comet would look during March, April, and May. Due to the extreme tilt of its axis, Lulin experiences more severe seasons than on the Earth (which is tilted by only 23.5°). Our computer model predicted that between January and March, the seasons should change on the comet as the sun moved from being overhead for one hemisphere to being overhead for the other hemisphere. Specifically, the hemisphere on the right would go from late summer to early winter while the hemisphere on the left would go from late winter to early summer. Since the activity of a comet is due to heating from the sun, more gas should be seen coming from the hemisphere that is in summer. This is just what we saw!

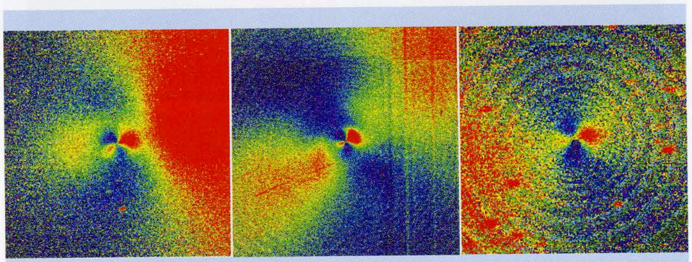


Figure 3: Enhanced CN images from January (left), February (middle), and March (right). Colors are as in Figures 1 and 2, and the nucleus is at the center in all images. The circular rings and horizontal and vertical lines are artifacts of the enhancement. The bulk of the brightness far from the comet (red) is on the right in January, on both sides in February, and on the left in March. This is evidence of the changing seasons on the comet. The field of view in each image is ~150,000 km at the comet.

Figure 3 shows enhanced images from January, February, and March. In January, most of the gas far from the nucleus (the red) was on the right, when this side was in summer and the left side was in winter. In February, the sun was near the comet's equator (spring on the left and fall on the right), and the gas was seen in roughly equal amounts on both the left and right sides of the nucleus. By March, the sun was in the left hemisphere (summer), and the majority of the gas is seen in the left half of the image since the right half was in winter. The comet was much fainter in April and May, but confirmed this seasonal change. Note that because of the highly elongated shape of the comet's orbit, its seasons are not of equal length and the side that is currently in winter will not have summer again until its next orbit in over a million years!

So that brings you up to date on our effort to understand Comet Lulin. We learned that it has a "day" lasting about 42 hours, has a pole that is tilted so far that it seems to roll along its orbit, and has a gas jet near each of its poles. There are still some things that we hope to learn about Lulin, such as how can a jet remain active even when it's not getting sunlight (the jet on the right is still active even though it is in winter)? But Lulin is already too faint to be studied further, and will be zooming past Jupiter about the time you read this. We had one chance to study it and, continuing a long tradition of comet observations at Lowell Observatory, we made the most of it.

New Engineering Challenges for Heather Marshall

Heather Marshall, mechanical engineer on the Discovery Channel Telescope since October, 2005, oversaw the design and construction of the DCT dome and served in the capacity of facility site manager. She recently accepted an exciting new position as Enclosure Manager with the Advanced Technology Solar Telescope (ATST) project, which is funded through the National Science Foundation and managed by the National Solar Observatory and the Association of Universities for Research in Astronomy. The ATST will be located atop Haleakala on the island of Maui, and will have a 4-meter main mirror and the latest in computer and optical technologies. During her tenure at Lowell Observatory, Heather met and subsequently married Charlie White, son of Lowell adjunct astronomer Nat White, who she met while playing volleyball after hours on the Mars Hill campus. We offer her our best wishes in her new position and will miss a valued member of the Lowell Family.

VIP Donors Enjoy Special Event

Members of Lowell Observatory at the Pluto Society level and higher were invited to a special evening on Mars Hill to meet our new director, Eileen Friel. The event was sponsored by BEC Southwest, the general contractor on the Discovery Channel Telescope (DCT). Astronomer Jeff Hall provided an update on the DCT, while DCT Engineers Alex Venetiou and Bill DeGroff demonstrated how the DCT's prototype actuators work. One hundred sixty actuators will be used to control the shape of the DCT mirror and are currently being assembled in Lowell's instrument shop on Mars Hill. Next year we are planning several tours at the DCT site in Happy Jack for small groups of Lowell members at the Pluto Society level and higher.

Jerry McGlothlin, Superintendent of Buildings and Grounds, Retires After 26 Years

Jerry McGlothlin was hired in July, 1982, as assistant groundskeeper. By 1986, he had moved into one of the historic homes on Mars Hill, where he raised his family. During his tenure, he helped build the five-car garage across the street from the John M. Wolff machine shop, as well as one of the newer houses on Mars Hill. He also jacked up the old Lampland dome, replaced the crumbling foundation with new concrete, put in new electrical and plumbing, and used the space as a greenhouse and pottery studio. Jerry's annual holiday ceramic show was always highly anticipated and well attended. Over the years, Jerry had many assistants including Andy and Charlie White, sons of adjunct astronomer Nat White, and Landon Inge, son of longtime Lowell bookkeeper Mimi Inge. After the Steele Visitor Center was completed in 1994, Jerry upgraded the landscaping around it, giving particular attention to the flower gardens. His plantings were appreciated as much by the staff as by the many visitors to the Observatory. Jerry, and his wife Susan, have retired to Sedona, where he has opened a new pottery studio.

Construction Progress on the Mars Hill Titan Monitor

By Henry Roe

The Titan Monitor is a new autonomous robotic small telescope that we are building on Mars Hill. The Mt. Cuba Astronomical Foundation has generously funded the construction of this project. The Titan Monitor will be a 0.5-m (20-inch) infrared-optimized telescope that will provide a continuous measure of the total cloud coverage on Saturn's moon Titan. This facility will play a key role in my work studying Titan's weather. When Titan is not available in the sky, the facility will be used for several other infrared projects. Here we show the construction of the building and dome in the fall of 2009. The mount and telescope are on-site and will be installed in December 2009. By spring 2010 we expect to have the facility observing autonomously every clear night.

Fig. 1: The central pier to support the telescope includes a 4'x4'x4' cube of concrete sitting directly on bedrock. Each of the four building piers extends down to bedrock as well.

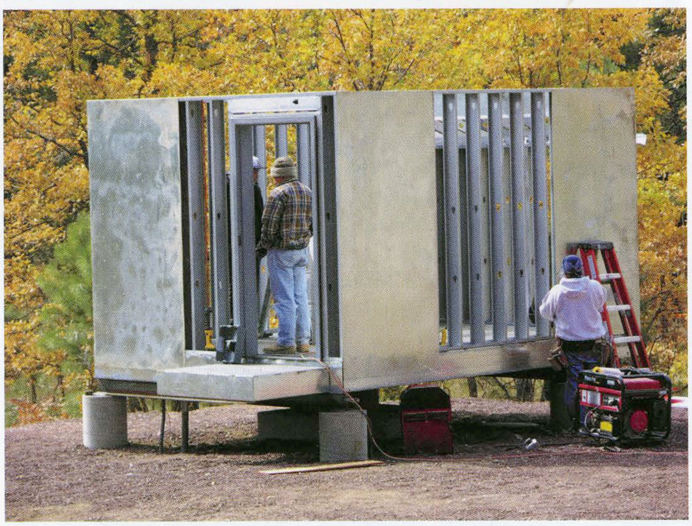


Fig. 2: The metal building is constructed by a crew from Loven Contracting, Inc.

Fig. 3: The building is mostly complete and ready for installation of the fiberglass dome.

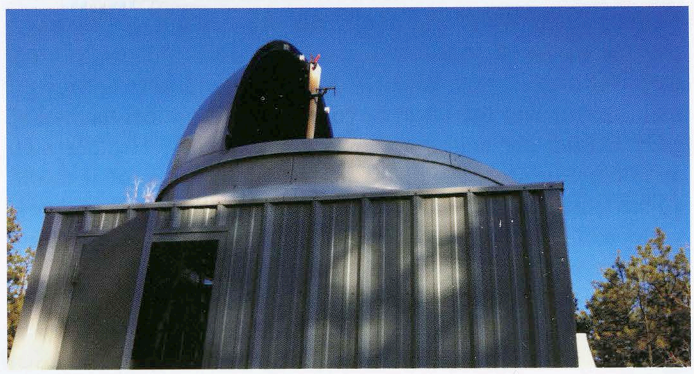


Fig. 4: The first two segments of the dome are attached and braced with a temporary jig.

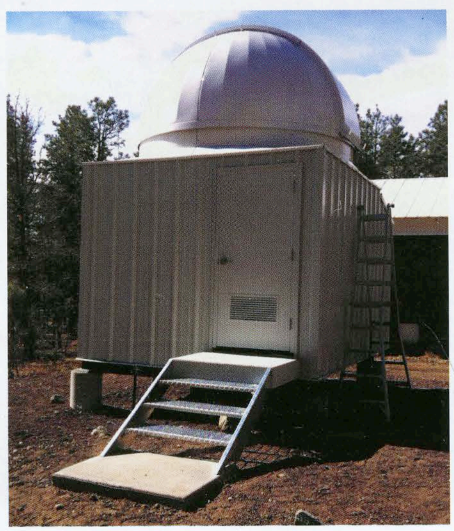
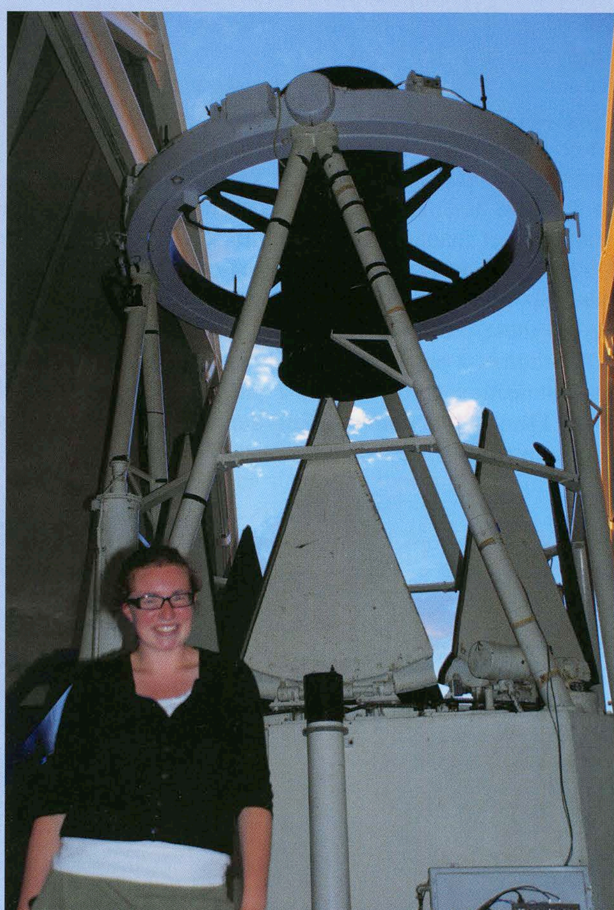


Fig. 5: The nearly completed building and dome. As of press time the dome was fully operational and hand-rails had been added to the steps.

My Second Summer at Lowell Observatory

By Kathryn Neugent, Wellesley College

I first arrived at Lowell Observatory two winters ago as astronomer Henry Roe's Research Experiences for Undergraduates (REU) Field Camp student. The REU program is sponsored by the National Science Foundation and is based at Northern Arizona University in Flagstaff. After a wonderful and memorable month, it seemed only natural to find an acceptable reason to return. So luckily, Dr. Phil Massey chose me as his student this past summer. The research forced me to journey away from my planetary roots and compare two spectral modeling programs and their resulting fits using Phil's plethora of O-Star data. While the results were very interesting, they represent only a small fraction of what I took away from my summer experience.



Kathryn Neugent, summer 2009 Research Experiences for Undergraduates student, standing in front of the 2.1-m telescope at Kitt Peak before a night of observing.

More importantly, I learned valuable life lessons while working at Lowell. For example, when using FORTRAN 77 it is best to keep a line of code under 72 characters long. Or, if food (or really, anything) appears on the Hendrick's Center for Planetary Studies table, it will be long gone before you do a double take. Additionally, when prompted to type <CR>, one probably shouldn't type the actual letter C and then R. While soaking in this important information, I also engaged in Lowell's fabulous culture through volleyball games, science teas, and tours of the Anderson Mesa site.

As a Wellesley College student I've spent almost every clear night observing asteroid light curves against the brightly lit skies of Boston. So, when Phil asked me if I wanted to accompany him on an observing run down to Kitt Peak I was ecstatic. I loved learning about spectroscopy by changing the 2.1-meter's grating, looking at Saturn through the 91-inch and taking stunning astrophotography images against a completely dark sky. It didn't matter to me (though, I'm sure it mattered to Phil) that we failed to acquire any useful data that night thanks to a light haze.

I was lucky enough to repeat this experience a few weeks ago with Phil at the MMT and at Kitt Peak (except this time we actually collected something USEFUL). Ideally, I'll be looking at some of this data when I, once again, return to Lowell this spring as Phil's research assistant. After so many amazing experiences at Lowell Observatory, I just can't help coming back for another round.

Discovery Channel Telescope Exhibit

The Discovery Channel Telescope has significantly altered nearly every aspect of Observatory operations, including our interaction with the public. We are in the process of refocusing programming and exhibits to address DCT and research in general. One component of this change is a new DCT exhibit in the Steele Visitor Center lobby, made possible by the GeoFund and the Flagstaff Community Foundation. Conceptualized and designed by Michael Chabin, this display compares the diameter of the DCT primary mirror to Galileo's first telescope, the Clark 24-inch refractor, and the Perkins 72-inch. This stunning visual demonstration is a first step towards visitors' understanding of the scale and breadth of DCT. Display cases housing DCT components, informational posters, and DCT content in the hourly daytime tours result in a better comprehension by visitors of the DCT and what it will allow our astronomers to do.

Discovery Channel Telescope Update: Lowell Observatory Then and Now

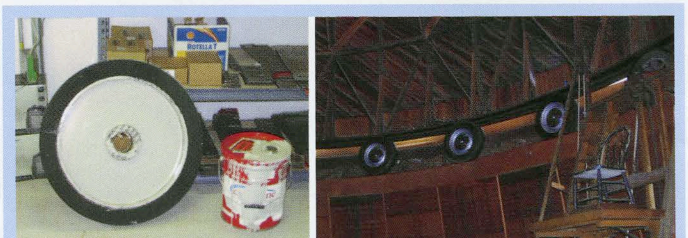
By Jeff Hall

I visited the Discovery Channel Telescope site near Happy Jack, Arizona in early November to discuss the best way to provide temporary lodging for staff and engineers on site as they assemble the telescope in 2010. It was energizing to be discussing such an advanced stage of the project, and a pleasure to work with the very helpful folks from the U. S. Forest Service, which administers the special use permit for the DCT site.

The facility is done, and the observing floor of the dome is an impressively cavernous space with a heavy-duty bridge crane for moving massive telescope parts, a futuristic-looking personnel lift, and four powerful motors that rotate the dome. One of these motors is at lower left in the picture below. In the white housing below the motor is a drive wheel, which lies horizontally and is mounted against a huge steel ring at the base of the dome. The motors turn the drive wheels, exerting torque on the steel ring sufficient to rotate the dome.

The well-ventilated DCT dome, with personnel lift (at right, sporting copious hydraulics) and motor (blue with white drive wheel housing, lower left).

On the dome's mezzanine level below the observing floor are numerous spare parts, including a spare drive wheel. The new DCT drive wheels have, in their general aspect, a striking similarity to the old tires that support and drive the rotation of Percival Lowell's Clark telescope dome here on Mars Hill.



A spare DCT drive wheel (left) and the dome of the Alvan Clark refractor on Mars Hill, with drive wheels and Percival Lowell's observing chair.

These wheels unify Lowell then and now: leading research drives this institution, and the Clark and the DCT are the essential assets that span more than a century of discovery. Vesto M. Slipher's observations of the first galactic redshifts were made in 1912 with the Clark telescope, often requiring multiple nights for a single observation; this was painstaking work. Soon our astronomers Phil Massey, Henry Roe, Lisa Prato, Deidre Hunter, and others will begin collecting new research data with the DCT. Through our partnership with Discovery Communications, our researchers will continue to carry out unique research programs, with the public visibility that remains a Lowell trademark.

As of this writing, the DCT primary mirror is finished, awaiting transport to Happy Jack from Tucson. Test assembly of the mount is underway in Texas and beginning in December, parts of the mirror support structure and mount will begin arriving in Flagstaff and at Happy Jack for assembly and testing. Milestones are coming quickly, thanks to the fine team we have assembled to build the facility under the guidance of project manager Byron Smith. Our 2010 newsletters will have many interesting pictures of everything coming together.

As all these parts fall into place, it's hard not to stand in the DCT dome, a place with much research promise, and not feel a connection to the Clark, a place with much research history. Thanks for your ongoing support of our endeavors and for joining us in new discoveries.

The new Discovery Channel Telescope dome (left), alongside the historic Clark Telescope dome.

Lowell Hosts Second Solar Analogs Workshop

By Jeff Hall

Workshop participants at the 2009 *Solar Analogs II* workshop held at Lowell.

The sun has been quite the enigma lately, as the present solar minimum has dragged on far beyond expectations. Initial predictions of the strength of the upcoming solar cycle indicated it would begin in 2007, but those had to be revised as 2007 passed, and 2008...Only now, in late 2009, does there seem to be clear signs that the new solar activity cycle is beginning to gather steam.

It was therefore a particularly appropriate time to host *Solar Analogs II* this past September 20-23 as this year's annual Lowell Observatory Fall Workshop. Wes Lockwood, Brian Skiff, and I hosted *Solar Analogs* in 1997, one solar cycle ago, and the scientific goal of that meeting was to examine the data available at that time and determine which stars, if any, were truly good stellar equivalents of the sun.

We care about that because we have only a narrow glimpse into the sun's lifetime: 400 years of sunspot numbers and just 30 years of measurements from space, above the complicating effects of Earth's atmosphere. Thirty years out of a ten billion year lifetime isn't much; it's like observing a person for several seconds out of 80 years. Scattered about our celestial neighborhood, however, are stars similar to the Sun that we can use to infer the broader behavior the Sun might exhibit over thousands of years.

Solar Analogs II demonstrated the progress we have made in 11 years. We have a fairly good idea which bright stars we can use as good solar analogs and which ones we can't. Now we're much more interested in understanding their detailed behavior, the nature and origin of their activity cycles (or lack thereof), and their effects on the nearby planets. These topics formed the basis of many of the talks.

Extrasolar planets in particular were the subject of a number of talks, which is quite timely. With the *Kepler* spacecraft beginning observations, we will soon begin to discover Earth-mass planets around distant, faint solar analogs. Such planets would be good candidates for harboring some form of life, and understanding the activity and variability of their host stars (observations we cannot make right now but which would be possible, say, with a certain 4-meter telescope not far from Lowell) is essential to placing bounds on the likely planetary conditions.

As with any good meeting, some questions were answered and many were raised. For example, we know that the Sun's total brightness is a bit higher at solar maximum and a bit lower at solar minimum. This variation in solar brightness has demonstrable effects on Earth's climate; while it appears insufficient to explain the rapid warming since 1970, it can have significant regional effects on temperature and rainfall. However, recent satellite data reveal that in certain parts of the solar spectrum, the sun's brightness is *anticorrelated* with its activity level...and one of these parts of the spectrum is just the one we've been using to measure stellar brightness variations! This is a proverbial bombshell, and may force us to rethink how we view the variations of stars. We left the meeting with some action items to further explore the issue, and the result also suggests a number of new observational programs for the longer term.

Scientists traveled to Lowell from not just the USA but from France, Germany, Brazil, Italy, Sweden, Finland, and Algeria to take part in the conference. We were delighted to welcome colleagues from so far and wide, and to reconnect and talk science.

VISIT LOWELL'S GIFT SHOP FOR UNIQUE HOLIDAY GIFTS!

We have astronomy-themed books, toys, DVDs, CDs, clothing, binoculars, gift memberships for the Friends of Lowell program, and more.

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Lowell Observatory 1400 W. Mars Hill Road Flagstaff AZ 86001 928-774-3358
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2009-2010 Public Program Winter Special Events

December 26, 27, 28, 29, 30, 31
Winter Holiday Celebration *(9 a.m. to 5 p.m.)*
Lowell Observatory will extend our daytime hours and offer indoor programs and special tours.

26, 27, 28, 29, 30 **Holiday Star Fest** *(regular evening hours 5:30–3:30 p.m.)*
Lowell Observatory will celebrate the holidays with a Star Fest. Numerous telescopes will be set up for viewing, weather permitting.

Closed December 24–25, evening December 31, January 1

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

Wed 6 **Flagstaff Night** *(regular evening hours)*
Lowell Astronomer Deidre Hunter will give a presentation at 7:00 p.m. about her exciting research with dwarf galaxies. Telescope viewing will also be available throughout the evening. Flagstaff residents (must show valid drivers license or utility bill) pay only half price for entrance into our regular evening programs.

Sun 17 **MLK Star Fest** *(regular evening hours)*
This special event will feature indoor programs and numerous telescopes set up for viewing. The Orion Nebula will be featured.

Mon 18 **School's Out and Kids are Free** *(9 a.m. to 5 p.m.)*
Lowell Observatory will be open for kids' activities throughout the day. Activities include science demonstrations, telescope viewing of the sun, tours, and multimedia presentations. Children must be accompanied by an adult or responsible guardian.

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

Wed 3 **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 14 **Winterfest Star Fest** *(regular evening hours)*
This special event will feature indoor programs and numerous telescopes set up for viewing. The Orion Nebula will be featured.

Mon 15 **School's Out and Kids are Free** *(9 a.m. to 5 p.m.)*
Lowell Observatory will be open for kids' activities throughout the day. Activities include science demonstrations, telescope viewing of the Sun, tours, and multimedia presentations. Children must be accompanied by an adult or responsible guardian.

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