THE LOWELL
Observer
THE QUARTERLY NEWSLETTER OF LOWELL OBSERVATORY ISSUE 79 SUMMER 2008

A Comet Tuttle Odyssey
By Dave Schleicher

Comets are always in motion. I'm sure you are aware that comets, like the planets, orbit the Sun. The nucleus or core of a comet, composed of ice and dirt, also rotates around an axis, and the axis is tilted with respect to the comet's orbit. In the case of the Earth, the tilt of 23.5° is sufficient to cause our seasons. The amount of sunlight received at a particular location (such as Flagstaff) varies as the Earth travels along its orbit about the Sun. For planets and comets, seasons will be more extreme when the axis is tilted at a larger angle. Moreover, in the case of a comet, the gas and dust released from the nucleus, which forms the coma and tail, originates from only a few locations on the comet's surface. Therefore, the amount of ice which is vaporized and the corresponding amount of material released depends very strongly on whether a particular "source region" is experiencing winter, summer, or a transition between these extremes.

The problem is that without a close flyby, of a (very expensive) spacecraft, we can't directly map the surface or even see the nucleus rotate on its axis. My work, and that of my colleagues, comes into the picture here. A portion of my research is to try to infer basic physical properties of comet nuclei based on a variety of different observations. For instance, by measuring the amount of gas and dust in a comet's coma as a function of time, we can determine whether the total rate of vaporization is the same or different as the comet approaches and recedes from the Sun on its elliptical orbit; if different, we deduce that a significant change in the seasons must be taking place and therefore that the nucleus must have a significant tilt of its axis. If there is not too much dust in the coma, we can sometimes measure the amount of sunlight reflected by the nucleus. This value can go up and down as the comet rotates: if the shape of the nucleus is elongated, as is usually the case, then more light is reflected when the nucleus is face-on to the observer than when it is end-on. The degree of the change in reflected light helps us to constrain the shape of the nucleus, while the time it takes for these brightness variations to repeat (over and over again) can yield the rotation period. Finally, the comae of many comets exhibit outward flowing streams of material called jets that curve due to rotation and change appearance as the comet moves with respect to the Earth. Such jets of material originate from the individual source regions described previously. By looking for jets and examining their shape and motion as the comet rotates and moves along its orbit, we can learn how fast the nucleus rotates on its axis. More importantly, we can sometimes determine both the size of the tilt and the direction that the axis is pointing, and also infer the size and location of the source region(s). In a few cases, we can use both the morphology and the brightness variation techniques, and we hope they yield answers that agree with each other!

Comet Tuttle passing the M33 galaxy on December 30, 2007. The comet is blue-green in color due to the light emitted by diatomic carbon molecules, one of the gas species in a comet's coma; usually, comets look white or even somewhat pink as their dust reflects all colors of the spectrum. Tuttle has very little dust, and the light emitted by C_2 molecules dominates the visible portion of the spectrum. *(Photograph courtesy and copyrighted by Mike Broussard. Visit his website for more information on how the image was created at http://www.cajunastro.com/tuttle)*

This past winter (in Flagstaff), Comet 8P/Tuttle provided an excellent target for such investigations. When last observed in 1980 (before the age of CCD cameras), Bob Millis of Lowell Observatory (and now its Director) determined that the comet released little dust from its surface as compared to the amount of gas, making it a candidate for detecting light from its nucleus. With no images of the comet obtained in 1980, however, we went into this current apparition having no clue as to whether morphology studies would be worthwhile, as some comets do not exhibit jets and others exhibit overlapping jets which are difficult to disentangle.

Comet Tuttle's orbit takes it from barely past the orbit of the Earth out to the distance of Saturn and back again. The orbit is also highly inclined, such that Tuttle approaches the Sun from far to the north, passes through the plane of the solar system near closest approach, and then recedes in the south. In fact, our observations of *(continued on page 2)*

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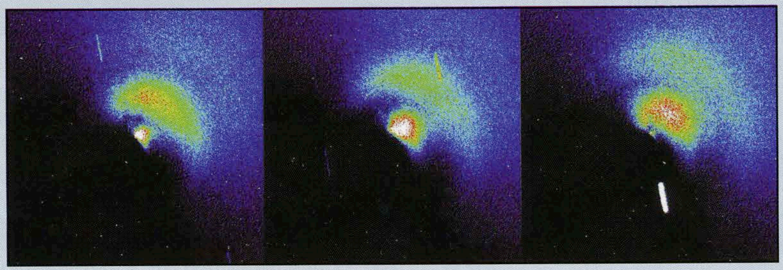
Tuttle began in November when it passed within 1° of Polaris, the North Star. The observations continued from Lowell until mid-January when the comet was too far south to be seen from Flagstaff. In this interval, I obtained photometric measurements of the outgassing of the comet. My former post-doc, Laura Woodney of CSU San Bernardino, and I also obtained images to be used both for monitoring the brightness of the nucleus and to look for and monitor any jets that might exist. As we had suspected, based on the 1980 data, Comet Tuttle's nucleus was indeed detectable, but preliminary analysis indicates that the brightness variations caused by rotation are fairly small. The images will require much more extensive data reduction before a rotation period can be determined using this method.

In contrast, our hopes of discovering simple jet morphology were answered: a single, strong gas jet was detected on our first night after applying a simple enhancement to each image. The shape of the jet was that of an incomplete spiral, caused by the rotation of the nucleus coupled with the vaporization from the source region turning on and off as the source experienced day and night. Even better, we could watch the jet move outward from hour to hour and, after just two nights of observations, we were able to determine that the jet morphology repeated every 5.7 hours (see the figure this page).



The gas jet in the coma of Comet Tuttle. These false-color images of the ultraviolet light emitted by cyanogen (CN) molecules have been enhanced to remove the bulk fall-off in brightness from the center of the comet to the edge, thereby emphasizing the location and outward motion of the jet. Images were taken on December 31, 2007 and are two hours apart. Two rotational cycles of the jet are easily seen in each image.

By the time the comet had disappeared to the south in mid-January, we had obtained nine nights of images, and the jet morphology was consistent with Tuttle's nucleus having a 5.73-hour rotation period. This period is now somewhat controversial. Other researchers bounced radar off of the nucleus using the Arecibo radio telescope in Puerto Rico to measure how the shape of the nucleus varies with rotation, and they derived a period of 11.4 hours, twice our own value. We suspect they may have made a possible erroneous assumption in their analysis, yielding too long a period. For now, all researchers agree that every 23 hours the comet is back where it started, and the question is whether the comet rotated two, three, or four times in each 23-hour interval. In any case, we will discuss the various data sets at an international meeting to be held in Baltimore later this summer.

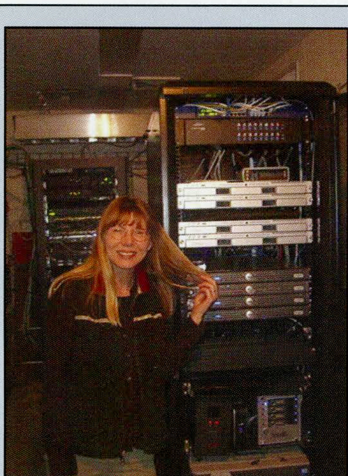
Knowing that Comet Tuttle would be unobservable from Lowell after mid-January, I had long planned to follow the comet south, and I did just that, hopping a series of planes to fly to Perth, Australia, at the end of January. Why Perth? First, there is an observatory there. In many respects, Perth Observatory is a sister institution of Lowell — it was founded in 1896, only two years after Lowell Observatory, it has a research program, and it also has a major public outreach program. Second, its largest telescope, installed in 1971 with a 24" diameter mirror, is owned by Lowell Observatory. (A larger telescope, 40" in diameter, is currently being refurbished at Lowell and will be installed at Perth later this year.) In addition, Lowell astronomers have had many successful collaborations with Perth astronomers in the past four decades; this was my fourth trip to Perth in the last 15 years. Being a returning visitor, I readily acclimated: using the AC rather than the heat in the control room (it was summer in the southern hemisphere), becoming comfortable driving on the "wrong" side of the road, and watching out for "roo" (kangaroo) rather than for elk on the road going home late at night after observing. However, I still could not get used to having Orion stand on his head!

My goals for the observations from Perth were simple extensions of those from Flagstaff: First, monitor the shape and motion of the jet, since as the comet passed close by the Earth over an interval of a few months, we observed the jet from ever-changing viewing geometries. The Perth images have not yet been processed, so I don't know what we may have detected. Second, obtain photometry to measure the rate of outgassing. This yielded a surprising result — the comet was vaporizing at a much higher rate than it had when it was at the same distance from the Sun during its approach. This was confirmed two months later, by additional data obtained by Arie Verveer, a colleague at Perth Observatory. The reason this was a surprise is that a very preliminary model of the nucleus and the jet, which I had created in January in an attempt to reproduce the Lowell images, suggested that the source of the jet is located midway between the equator and the pole of the nucleus. The source region was experiencing "summer," with the Sun high in its sky as the comet was inbound. The model also predicted that following closest approach to the Sun, the motion of the comet coupled with the orientation of the rotation axis would cause the Sun to appear to rapidly change hemispheres, causing "winter" to quickly set in. This, in turn, would result in ice vaporizing at a much lower rate. So, before my own move from winter to summer (Flagstaff to Perth), I predicted that the rate of outgassing would decrease with time, not increase as we ultimately observed.

Why was my prediction wrong? I cannot rule out that my preliminary model was simply incorrect, and that the location of the source region and the orientation of the rotation axis are quite different from the model solution. I'll be investigating this possibility in the months ahead. Another possibility is the model is correct but that one or more other (and larger) source regions exist on the other hemisphere of the nucleus. These would have been experiencing winter when the comet was inbound and were therefore inactive, but then "turned on" as the comet moved along its orbit and the Sun's apparent motion caused the change in seasons. Fortunately, the images I obtained from Perth may permit us to test this possibility; if this scenario is true, then these outbound images should show one or more new jets appearing as the original jet faded from view. I certainly hope that we can ultimately derive an overall, self-consistent model of Comet Tuttle from our observations, because it will be 27 years before another Tuttle odyssey can take place!

Mary Demuth's Hair Dryer (or The Greening of the Observatory Datacenter)

By Padraig Houlahan



Mary DeMuth, standing next to her "hair dryer."

This year, Lowell Observatory entered the brave new world of datacenter management problems when it added a new computer rack containing eight new servers to its small datacenter. The tipping point came when the back wall of the room reached a temperature in the upper 90s and an emergency shutdown system was triggered to protect the computers from overheating. (Computers and electronics don't fare well under such conditions since there is an increased risk of static electricity, causing disk damage.)

Part of the problem is associated with the trend to host an ever increasing number of servers in high density rack mounted arrays. Racks are desirable because they provide a compact, stable, and protected environment so the risk of inadvertent damage to dangling power chords and network cables is reduced. Newer servers can run at much hotter temperatures and they will heat up the ambient air to greater temperatures — in fact four of our new ones output air that is so hot, that one of our staffers, Mary DeMuth, declared it would make a great hair dryer!

When we looked into these heating issues we found our air conditioner was operating at the limits of its capacity and it was only January! Worse, after installing some temperature probes, we found the supply air from the air conditioner was much hotter than the chilly outside air. It was time to learn about air-conditioning systems.

AC systems usually operate on a mostly closed cycle, where the AC unit accepts return air to its input. This makes sense in most places (e.g. Phoenix) since return air can be colder than the blistering outdoor temperatures. However, it didn't make sense for a hot computer room in Flagstaff, where the outside temperature is generally cold for most of the year. The solution we found was to add a device to the AC unit called an 'economizer.' This device can be programmed to mix in outside air so the AC compressor doesn't have to work to cool the hot return air from the datacenter. To handle peak summer temperatures, a secondary AC unit was also installed. Our expectation is that the economizer will increase the efficiency of the main AC unit for most of the year, and the secondary unit will help in the hotter summer afternoons.

In dollars and cents, we calculated that an older heavy-duty server was drawing about nine amps of current, which is about a kilowatt of power. Since each kilowatt costs about 10 cents per hour, the old server required almost $900 per year of electricity to operate and at least this much again to cool – a sobering statistic which prompted the Observatory to buy a $1500 replacement that uses less than a quarter of the power and should pay for itself within a year. (It is worth noting, when we turned off the older server, the temperature in the datacenter dropped by six degrees!) The lesson we learned is there are considerable cost savings to be realized through paying attention to computer energy consumption and this "green" approach is very much a part of our future.

Glass Plate Cleaners Hard at Work

Thanks to a generous grant from the Arizona Historical Records Advisory Board and the Raymond Educational Foundation, the Observatory's historical glass plate collection is being cleaned and re-housed in new four-flap archival enclosures and acid-free boxes. Bee Valvo (at left), photo curator at Northern Arizona University, provided instruction and assistance to Lowell Observatory library intern Lauren DeMuth (at back), and librarian Antoinette Beiser.

Summer Sky Highlight: The Constellation Scorpius

Photo: Ralph Nye Historic Observatory

Edward Emerson Barnard wrote in 1905, "The region of Rho Ophiuchi is one of the most extraordinary in the sky." This image shows a spectacular five by eight degree field of view near Antares, located just below center in the photograph, the brightest star in the summer constellation of Scorpius. The image also features two star clusters: a larger one, M4 at the right of Antares, and a small cluster, NGC 6144, immediately above and to the right of Antares. Rho Ophiuchi is the blue reflection nebulae directly above NGC 6144.

Photographed from a northern Arizona dark sky location by accomplished amateur astro-photographer and Lowell Observatory Director of Technical Services, Ralph Nye, the image was taken through a six-inch restored Petzval lens built around 1850. The 60 minute hand-guided exposure brings out color that would have awed the lens maker, as color photography was not invented until 1861. Think of the working conditions of opticians during this time. He probably rode a horse to work, hand-ground and polished all four of the optical components of the Petzval lens (comprised of eight surfaces), and then hoped this would ensure the black and white film plates focused correctly. Who would have thought that 150 years later, this optical system would be used to produce color astro-photographs using modern film?

2007 Institutional Supporters of Lowell Observatory

Lowell Observatory greatly appreciates the following organizations that provided support in 2007:

Discovery Communications, Silver Spring, MD
John M. Wolff Foundation, Scottsdale, AZ
Honeywell International, Inc., Phoenix, AZ
Cascade Foundation, Rockport, ME
Mt. Cuba Astronomical Foundation, Greenville, DE
City of Flagstaff / Flagstaff Cultural Partners, Flagstaff, AZ
APS, Flagstaff/Phoenix, AZ
The Wells Fargo Foundation, Flagstaff, AZ
The Don Nierling Memorial Foundation, Phoenix, AZ
Bank of America, Flagstaff, AZ
Barringer Crater Company, Flagstaff, AZ
International Society for Optical Engineering, Bellingham, WA
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Arizona State Library, Archives and Public Records, Phoenix, AZ
AV Domotics, Sedona, AZ
The Raymond Educational Foundation, Flagstaff, AZ
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*Matching Gifts Program: We encourage Friends of Lowell to ask their employers if they provide matching gifts to the organizations their employees support.

STATEMENT OF FINANCIAL POSITION

December 31, 2007

ASSETS

Current Assets	
Cash & Cash Equivalents	$ 663,335
Restricted Cash	444,619
Certificates of Deposit	305,182
Research grants receivable	392,486
Contributions receivable	3,231,595
Inventory and other assets	241,422
Total Current Assets	$ 5,278,639
Contributions receivable, net of current	5,280,521
Investments, unrestricted	907,074
Investments, restricted	41,863,780
Collection item	400,000
Property, plant and equipment, net	17,928,073
Total Assets	$ 71,658,087

LIABILITIES AND NET ASSETS

Current Liabilities	
Accounts payable	$ 191,701
Accrued vacation , employee related expenses	200,416
Accrued liabilities	161,456
Deferred research grant revenue	86,146
Total Current Liabilities	$ 639,719
Net Assets	
Unrestricted	$27,511,234
Temporarily Restricted	1,671,403
Permanently Restricted	41,835,731
Total Net Assets	$71,018,368
Total Liabilities and Net Assets	$71,658,087

The audited financial statements include a restatement of net assets for a prior year. A copy is available upon request.

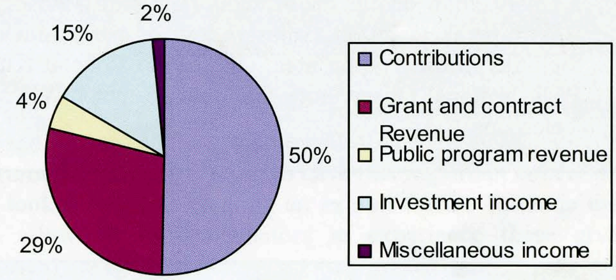
STATEMENT OF ACTIVITIES

December 31, 2007

REVENUE AND OTHER SUPPORT

Contributions	$ 5,422,016
Grant & Contracts	3,080,417
Public Programs	468,005
Investment gain	1,617,438
Miscellaneous Income	187,072
TOTAL SUPPORT & REVENUE	$10,774,948

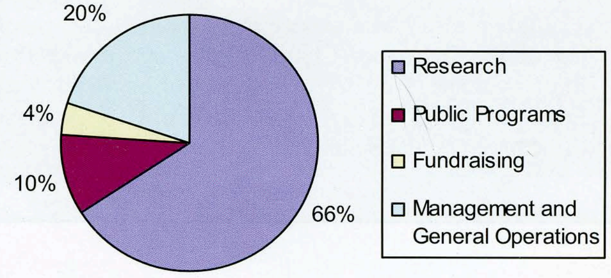
Sources of Revenue



EXPENSES

Research	$3,467,314
Public Programs	537,609
Fundraising	213,670
Management & General	1,049,034
TOTAL EXPENSES	$5,267,627

Expenses by Category



Tucson-area Tour Made by Lowell Supporters

Photo courtesy Ed Post

Several members of the Lowell Observatory staff met a small group of our major supporters and Advisory Board members for an exclusive tour of astronomical facilities in the Tucson area. One of the stops at Kitt Peak National Observatory was the 3.5-meter WIYN Telescope.

The group also had a chance to learn about the polishing of the Discovery Channel Telescope mirror from Marty Valente, Director of the Optical Fabrication and Engineering Facility at the University of Arizona's College of Optical Sciences.

Celebrating 50 Years of Dark Skies

By Wes Lockwood

On April 15, 2008, Lowell Observatory hosted a gathering of civic leaders, astronomers, and dark sky advocates to commemorate the 50th anniversary of the world's first dark sky ordinance. Mayor Joe Donaldson proclaimed April 15 Dark Sky Protection Day and the observatories presented the City of Flagstaff with a framed poster showing the cloud-capped San Francisco Peaks against the starry background of the rising summer Milky Way.

The story begins in early 1958, just as Lowell was reaching an agreement to relocate Ohio's Perkins Observatory 69-inch reflector, then America's 5th largest, to a site on Anderson Mesa 15 miles from Mars Hill. The Naval Observatory's 40-inch Ritchey-Chrétien reflector, located west of Flagstaff, was moved in 1955 from the bright sky of Washington D.C. Lowell's Dr. Harold Johnson noted that a Phoenix gas station chain, with a location in Flagstaff, had begun advertising in the valley with bright moving searchlights. He became alarmed about the potential danger to Flagstaff's pristine dark skies. Johnson knew that an advertising searchlight in Flagstaff would disrupt observations as far away as Anderson Mesa.

Photo courtesy Dan and Cindy Duriscoe

Several letters exchanged in March 1958 between Johnson and incoming Lowell Director John Hall, then at the U.S. Naval Observatory in Washington, described what happened next. Lowell Acting Director E. C. Slipher brought the matter to the attention of the Chamber of Commerce and then to the City Council. Within 30 days of declaring an emergency, the Council enacted Ordinance 440 prohibiting searchlights and imposing a stiff fine for violation.

The City of Flagstaff and Coconino County have subsequently updated lighting codes several times over the past 50 years and now have what are widely regarded as the world's most effective dark sky protection codes. From a single thwarted searchlight a half century ago, thanks to community support and wise governance, Flagstaff retains the title of the world's first and only designated International Dark Sky City.

Historical Chronometers and Sextants Donated to Lowell Observatory

By Kevin Schindler

As a young boy growing up in the Netherlands, Edward van Amerongen developed quite an interest in astronomy. During his teenage years, high school was not available due to his country's preoccupation with World War II. So, Ed had a lot of time on his hands. To keep busy, he built his own telescope and set it up on the rooftops of the Amstel Brewery, learning the same night skies as fellow Dutchmen Christiaan Huygens, Gerard Kuiper, and Jan van Oort.

After the war ended, Ed moved to the United States where he dreamed of studying astronomy, but practicality directed him elsewhere. After earning a Bachelor's Degree in architecture from Tulane University, and an MBA from the University of Chicago, he and his brother started their own company, Great Lakes Architects & Engineers, Ltd. (They would have preferred to use their family name, but nobody seemed to be able to pronounce it correctly.) The company had many large clients, specializing in the construction of production plants and distribution centers for the pharmaceutical industry. Ed is also an author, a lecturer on construction and engineering-related topics, and the holder of 12 patents for medical devices.

Ed traveled extensively for his work, and often visited local museums. During a series of trips to England in the 1960s, he came across several historical instruments that spoke to his passion for science and technology. One was a high precision brass sextant with associated eye pieces, brass fasteners and handle, wooden carrying case, and the original certificate of calibration by the Kew Observatory dated March, 1912. Other instruments included two beautiful marine chronometers, both in brass-bound wooden boxes and still containing original keys. Over a several year period, Ed purchased these exquisite items and took great pride in their preservation.

Nearing his 80th birthday, Ed decided to look for a permanent home for these treasured artifacts. At about the same time, he traveled to Phoenix to visit one of his two sons. While in Arizona, he and his wife, Anne, decided to visit Flagstaff to reconnect with an old classmate. Ed also wanted to visit the observatory built by Percival Lowell, a name he knew since childhood.

He was immediately taken by the welcome he received from the Lowell staff, particularly MaryAnn Mayrand, who introduced the van Amerongens to the history and current research of the Observatory. Ed was especially intrigued by the Zeiss Blink Comparator and other historical instruments in the Rotunda Library Museum. Exhilarated by this visit, he returned home and researched the Observatory. He realized Lowell was the ideal place for his collection, knowing the staff would properly care for and display the items.

The marine chronometers on the left are precise timekeeping devices used in determining longitude by incorporating celestial navigation. The sextant on the right is used to measure, among other things, latitude, by determining the altitude of the sun or other celestial objects.

After corresponding with Observatory director Bob Millis, Ed and Anne returned to Lowell to officially donate the instruments. We are thrilled to have this important collection, and look forward to creating an exhibit for the Rotunda that will allow all of our visitors to experience these great historical tools.

Photo courtesy Anne van Amerongen

Lowell Observatory Director Bob Millis examines one of two chronometers donated by Edward van Amerongen (left) to be used in an exhibit of historical instruments.

OBSERVATORY LOWELL

THE LOWELL **Observer**

THE QUARTERLY NEWSLETTER OF LOWELL OBSERVATORY ISSUE 78 SPRING 2008

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2008 Public Program Summer Special Events

July *Regular public hours: daytime 9 AM–5 PM; M/T/W/T/F/Sat nights 5:30 PM–10:00 PM*

Wed 2 **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 6 **Independence Star Fest** (*regular evening hours)* — Lowell Observatory will celebrate the holiday weekend with a special Sunday Star Fest. This event will feature indoor programs and numerous telescopes set up for viewing throughout the Lowell campus.

Sun 20 **Summer Star Fest** (*regular evening hours)* — Tonight at 7 PM, guest speaker and astronomy book author Klaus Brasch will give an indoor presentation, *The Search for Extraterrestrial Intelligence.* In addition to this presentation, we will feature numerous telescopes set up for viewing throughout the Lowell campus

August *Regular public hours: daytime 9 AM–5 PM; M/T/W/T/F/Sat nights 5:30 PM–10:00 PM*

Sun 3 **Dog Days Star Fest** (*regular evening hours)* — Tonight at 7 PM, guest speaker, scientist and writer Joan Horvath, will give a presentation about her new book, *What Scientists Actually Do.* This special event will also feature indoor programs and telescopes set up for outdoor viewing.

Wed 6 **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.

Mon 11 **Perseid Meteor Shower** (*regular evening hours)* — Indoor programs will focus on meteor showers such as the upcoming Perseids. Telescope viewing of various celestial objects is included in the evening's activities.

Sun 31 **Labor Day Star Fest** (*regular evening hours)* — Tonight at 7 PM, guest speaker, Sasha Karcz will give an indoor presentation, *Radioactivity and You.* This program will cover types of radiation, where they come from, and how we can use them. Also, telescopes will be set up to view Jupiter, the featured object.

September *Regular public hours: daytime 9 AM–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 28 **Festival of Science Open House** *regular evening hours)* — Visitors admitted free of charge this evening. Events feature Space Theatre programs, access to the historic Rotunda Library Museum, and telescopes set up for viewing throughout the campus.

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