

THE LOWELL OBSERVER

EXPANDING OUR UNIVERSE

The quarterly newsletter of Lowell Observatory

Issue 102

Winter 2015



To search for Wolf-Rayet stars, Phil Massey and Kathryn Neugent traveled to Las Campanas Observatory in the southern Atacama Desert of Chile. This facility is operated by the Carnegie Institution of Science and includes the 1-meter Swope Telescope, pictured here, which Massey and Neugent used for their search.

Searching for Wolf-Rayet Stars in the Magellanic Clouds

by Phil Massey

Last year, Research Associate Kathryn Neugent and I were privileged to attend an international conference on massive stars on the Island of Rhodes in Greece. One day we had lunch with our good friend and collaborator Nidia Morrell, an astronomer at Las Campanas Observatory in Chile, and by the end of the meal we had agreed to do something that was, in many ways, completely crazy: we were going to survey the Small and Large Magellanic Clouds for Wolf-Rayet stars. Let me explain.

In 1814 the German physicist Joseph von Fraunhofer passed sunlight through a prism and noticed dark bands in the resulting spectrum. These dark features were due to various chemical elements in the outer layers of the sun absorbing those particular wavelengths. Most stars — nearly all — show such absorption bands. Fifty-three years later, however, two French astronomers, Charles Wolf and Georges Rayet, were examining the spectra of stars using a visual spectrometer on a 40-cm (16-in) telescope, and

chanced upon three stars (all within a degree of each other in the constellation Cygnus) that instead showed bright emission bands rather than absorption. Today we understand that these enigmatic Wolf-Rayet (WR) stars are in the final stages of massive star evolution. Their bright emission lines are formed in an outflowing stellar wind, driven by the intense radiation pressure from their high luminosities.

There are two types of Wolf-Rayet stars: those belonging to the nitrogen sequence (WN-type) and those belonging to the carbon sequence (WC-type). As a massive star evolves, it will convert hydrogen to helium in its core, creating nitrogen as a byproduct. Once the hydrogen is used up, it will begin to

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William Lowell Putnam III (1924-2014)

William Lowell Putnam III ("Bill"), died on December 20, 2014 at the age of 90. Grandnephew of Percival Lowell, he served as Sole Trustee at Lowell Observatory for 26 years after a groundbreaking career in broadcasting. Bill was also a decorated World War II veteran, world-renowned alpinist, and author of a score of books. See the special Bill Putnam edition of *The Lowell Observer* (Issue 99) for more information about his fascinating life. Thank you, Bill, for your leadership and friendship.

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Director's Update

by Jeffrey Hall

I hope you enjoy this first issue of the *Observer* for 2015 – the “Year of Pluto.” You’ll be hearing a lot from us about Pluto this year as we approach the July New Horizons flyby of the little world Clyde Tombaugh discovered 85 years ago here on Mars Hill. But that will only be the tip of the proverbial iceberg; as New Horizons goes hurtling into space beyond Pluto, we’re going to bring you a story that likewise has additional – but related – threads.

Lowell astronomers study not just Pluto but the full span of our solar system from the brutally cold and dark Kuiper Belt all the way inward to the Sun.

More than a century after Percival Lowell postulated the existence of “Planet X,” we are still very much in the business of finding and characterizing worlds, now that technology has advanced to the point we can detect them around other stars.

We explore the nature of stars themselves, since they affect the worlds orbiting them, and we explore galaxies, the reservoirs of gas and dust from which stars form and evolve.

From Pluto to its faraway analogs are many questions unanswered. One thing we do know, however, is that exoplanets are everywhere out there, and we wonder if Earth-sized ones in the right place around the right star harbor some life, any life, whatever form it might take. It’s one of humanity’s monumental questions, and it’s a privilege to live in a time when we can look across trillions of miles of space for worlds that might have glimmers of the answer.

We look forward to sharing all our discoveries in this and upcoming years with you about Pluto – and beyond. 📧



Trustee's Update

by W. Lowell Putnam

Throughout this issue and the year ahead you will be hearing about the New Horizons mission and the research work our astronomers are doing, not only within our Solar system but also across the Universe. We are also addressing very real issues here on Earth as well.

Dark Sky protection, particularly here in Northern Arizona, remains a critical foundation for our work, and makes looking out at night so very beautiful. Flagstaff is the only population center I have been in where you can see the Milky Way from downtown. That is worth protecting, not only for the existing economic benefit and investment that

has been made, but for the future investments, many of which are underway. For the past 10 years (and for the next five at least) the observatories in Flagstaff have invested more than \$5 million dollars/year in capital projects.

We are continuing to work on getting the Cherenkov Telescope Array northern hemisphere site here in Arizona. That would represent another \$20 million/year in construction. Astronomy is big business in our area and it relies on clear and dark night skies.

We also benefit from a vibrant community and want to ensure that Flagstaff continues to be a wonderful place to live and work. So we are committed to working with our friends and neighbors on new ways to develop and grow that can add appropriate light where it is needed without damaging the extraordinary “seeing” we all treasure.

My best wishes to all of you for 2015! 📧

#YearOfPluto

2015 has been dubbed the Year Of Pluto. For more info about this year’s special programming see page 7.

Alan Stern at the Orpheum

2015’s #YearOfPluto is set to kick off with a bang with Dr. Alan Stern at the Orpheum Theater in Flagstaff, AZ on February 21. Dr. Stern is a planetary scientist, space program executive, aerospace consultant and author. He is also the Principal Investigator of NASA’s \$727M New Horizons mission that will fly past Pluto in July. We will host a VIP meet & greet at 6 p.m., followed by general admission at 7 p.m. For more information or to purchase tickets email Hannah Graves at hgraves@lowell.edu or call (928) 255-5059.



Pictured above is an artist concept of New Horizons (NASA/JHUAPL/SwRI).

Video Observing for the Public

by Bill McDonald

For the last five years Lowell's evening program has occasionally included live video observing. Using a video camera designed to augment observing, we have been able to show visitors a wide range of celestial objects: detailed views of galaxies, emission and planetary nebula in full color, globular clusters, comets, supernovae remnants, even current supernovae. Until this year the system has been operated by volunteers, but beginning this spring Lowell's paid outreach staff has begun to run the system, increasing the number of nights that the video system is used.

Group observing has several distinct advantages. Because the operator does not have to guide each individual, he can spend his time talking about the objects that are being observed, providing a much deeper insight into the significance of the object on screen. Everyone gets to see a well-focused object. This observing technique is ideal for visually and physically handicapped visitors. We've found that we get lots of good questions and good interaction with visitors.

We regularly engage in conversations about black holes, dark matter and energy, element formation, stellar evolution,




Bill McDonald has volunteered in the Public Program for years, driving to Flagstaff from his home in Prescott. He is a longtime amateur astronomer, active in the Prescott Astronomy Club and enthusiastic about sharing his passion for astronomy with the general public. Bill has been the driving force behind Lowell's video observing demonstrations, which are quite popular with visitors.

the big bang and expanding universe (Vesto Slipher gets lots of credit), comets, asteroids, the structure of the Milky Way and more. It turns out that the format encourages visitors to bring up issues that they've been thinking about.

Over time we've begun to incorporate other material into our programs. We often begin long before dark, displaying, for example, an animation of the motions of stars around the Milky Way's central black hole. We sometimes use live observing sessions from the East Coast. After dark we can inject relevant

materials into observing conversations.

If we mention that there are 200 billion galaxies in the visible universe, we're often asked how we could possibly know that. We can bring up the Hubble Ultra Deep Field and explain how it was taken and how it suggests a galaxy density. These options are particularly useful on cloudy nights.

The live video observing format provides a unique opportunity to engage visitors with the wonders of modern astronomy. 

Galactic Disks Workshop

From October 5-9, Deidre Hunter hosted 67 scientists from around the world at a workshop, The Formation and Evolution of Exponential Disks in Galaxies. The stars in both spiral and dwarf galaxies are generally found to be organized in exponential disks. This workshop addressed fundamental questions about these disks, including formation, evolution and behavior.



WOLF-RAYET continued from page 1

convert helium into carbon and oxygen. The star becomes layered like an onion, and as stellar winds remove the hydrogen-rich outer layers, the star is “peeled down” to first form a WN-type WR, and then later, a WC-type.

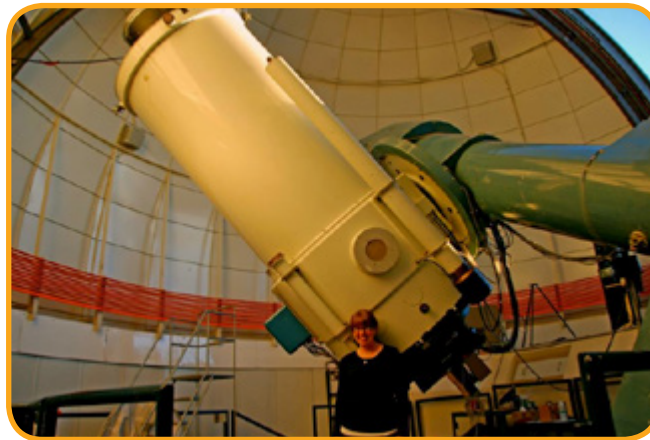
Modern stellar evolutionary theory predicts that there should be relatively more WNs than WCs in galaxies where there are fewer metals (such as the Magellanic Clouds and M33) and more WCs than WNs in galaxies where there are more metals (such as the Milky Way and M31, the Andromeda Galaxy). Kathryn and I surveyed all of M33 and M31 for Wolf-Rayet stars a few years ago, finding that there were more WCs compared to WNs than theory predicted in M31, but relatively good agreement in M33. This wasn’t a complete surprise, as our colleagues in Geneva who make stellar evolutionary models suspected there would be problems at high metallicities. However, what was surprising was that the numbers for the Magellanic Clouds were off too – the relative number of WC and WN types were too high there as well.

The problem is that WCs are relatively easy to find compared to WNs – their emission lines are nearly 10 times stronger. For M31 and M33 we had used a special technique of taking images through interference filters that isolated particular emission lines as well in a continuum region (i.e., one free of emission lines). We then used an “image subtraction” technique to separate the continuum image from the emission-line image, resulting in WR stars “popping out.” (We would still have to take spectra to confirm that these were WR stars as other things would pop out as well.)

We realized that we had to use this technique on the Magellanic Clouds. This was going to be a really difficult project though, as the Magellanic Clouds are huge in angular extent because they are so close to us – a mere 50-60 thousand parsecs (160-200 thousand light years) away. Using the 1-meter Swope Telescope with its nice large field of view, we estimated it would take around 900 fields to cover these galaxies. Realistically we were looking at a three-to-five-year-long project.

This project was risky. Many astronomers thought that we already knew the WR content of the Magellanic Clouds

Phil Massey settles in at the control room of the 1.0-meter Swope Telescope. This instrument was built in 1971 by Boller and Chivens — the same maker as Lowell’s 16-inch McAllister public telescope — and was the first telescope used at the Cerro Las Campanas Observatory. It is named after former Carnegie astronomer Henrietta Swope.



Kathryn Neugent stands in front of the Swope Telescope. Kathryn is a Senior Web Security Specialist at the National Renewable Energy Lab in Golden, Colorado. She began collaborating with Phil Massey as an REU (Research Experience for Undergraduates) summer student in 2009. Later that year she became a Lowell Research Assistant and has served in this role since.

well enough – there are 12 in the SMC, and about 130 in the LMC. Certainly that’s what I thought a few years back. But, then one night Nidia, Kathryn, and I were taking spectra of stars in a dense OB association in the LMC and came across a WO-type WR. WO-types are like WCs but have very strong oxygen lines. They are very rare – only one other one had previously been known in the LMC. The star has very strong lines but had never been discovered in previous searches. So, what else was missing? Still, it was entirely possible that we would spend a lot of our time and resources and have nothing to show for it. (I’ll note that long observing runs in Chile are expensive, and we had not budgeted for this, but Lowell Observatory’s research support fund was able to help cover this thanks to generous donations by Mr. Michael Beckage and Mr. Donald Trantow).

We spent nine nights on our initial run in September 2013 turning up a few dozen WR candidates. Spectroscopy with the 6.5-meter Magellan Telescope confirmed that nine of these were newly found WRs! (Whew! Remember it was entirely possible that we would find nothing). Of these nine, eight of them were

WNs, so we were right – the statistics were incorrectly biased. The other one turned out to be yet another WO star – so we have now tripled the number of known WOs in the LMC. What was even more interesting, though, was that six of these WNs were unlike any WNs ever seen – they not only have the emission lines of a WN star but also the absorption spectrum of an O3 star, the hottest and most luminous star known. We realized almost immediately, though, that these aren’t binary stars – for one thing, the stars are too faint, fainter even than what an O3 star would be by itself. With the help of our collaborator John Hillier (University of Pittsburgh) we were able to model the spectrum of the star with a single set of parameters, further supporting the notion that this is but one star.

We now have time on Hubble Space Telescope to follow up these discoveries, with one program aimed at the WO stars, and another at these new, weird WN/O3 hybrids. We also had a couple more observing runs recently. We’ve already found three more candidates, and have barely begun to analyze the data. What new things will we find? Stay tuned! 🍷

Lowell Sightings at the DPS Meeting in Tucson

Several Lowell astronomers and support staff attended the 46th Annual Meeting of the Division of Planetary Sciences this past November.

(Top) At one of the poster sessions about comets, astronomer Dave Schleicher caught up with several current and past students and collaborators. From left to right, Matthew Knight, Assistant Research Scientist at Lowell; Susan Lederer, Optical Measurements Lead Scientist in the Orbital Debris Program Office (ODPO) at Johnson Space Center; Laura Woodney, Assistant Professor in the Department of Physics at California State University, San Bernardino; Allison Bair, Lowell Research Assistant.



(Middle) Heidi Hammel, Executive Vice President of the Association of Universities for Research in Astronomy (AURA), stands with Lowell astronomer Stephen Levine.



(Bottom) Part of the New Horizons management team stopped by the Lowell booth at DPS. Pictured here (left to right) are Lowell Curator Samantha Thompson; Alan Stern, New Horizons Principal Investigator; Alice Bowman, New Horizons Mission Operations Manager; Hal Weaver, New Horizons Project Scientist; Kevin Schindler, Lowell's Communication Manager.



KJZZ Expo

Thanks to the support of Lowell Advisory Board member John Radway, Educator Erik Lehmkuhl (pictured here) and Communication Manager Kevin Schindler attended the KJZZ Travel and Discovery Expo this past November. Lehmkuhl and Schindler spoke with attendees from Phoenix and beyond, sharing information about visiting Lowell.

This issue of *The Lowell Observer*, as well as past issues, can be found on our website at:

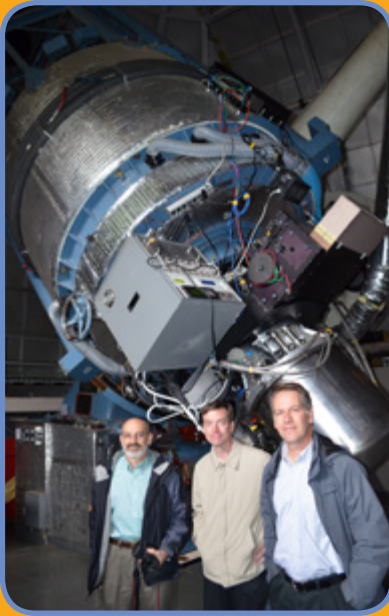
lowell.edu/about_observer.php



Gerard took workshop participants on a tour of the Navy Precision Optical Interferometer (NPOI), including the control room, pictured here. (Image: Chris Estrada)

2014 Speckle Workshop

Gerard van Belle hosted the 2014 Lowell Speckle Interferometry Workshop on Mars Hill from October 3-5. This meeting covered the technique of "speckle interferometry", which allows modest-to-large-sized telescopes get around the diluting effects of the atmosphere and recover their full spatial resolution potential. Twenty attendees, from both the academic and amateur communities, discussed the particulars of the technique and participated in on-sky speckle observing with both home-brew and professional equipment, including hands-on experience with the DSSI speckle camera on the DCT. Details (including PDFs of the presentations) are available online at: <http://www2.lowell.edu/workshops/speckle2014>



Touring Anderson Mesa and DCT

Lowell Director Jeffrey Hall (center) and astronomer Gerard van Belle (right) recently gave a tour of the Anderson Mesa and Discovery Channel Telescope facilities to Rick Fienberg, the AAS's Press Officer and Director of Communications. Here, the trio stands in front of the Perkins Telescope at Anderson Mesa.

Recent Publications

The Observer now includes this listing of recent publications by our scientists so you can keep up with their latest research.

Transiting Exoplanet Survey Satellite (TESS). *Proceedings of the SPIE*, Volume 9143, id. 914320. Ricker, George R.; Winn, Joshua N.; Vanderspek, Roland; Latham, David W.; Bakos, Gáspár. Á.; Bean, Jacob L.; Berta-Thompson, Zachory K.; Brown, Timothy M.; Buchhave, Lars; Butler, Nathaniel R.; Butler, R. Paul; Chaplin, William J.; Charbonneau, David; Christensen-Dalsgaard, Jørgen; Clampin, Mark; Deming, Drake; Doty, John; De Lee, Nathan; Dressing, Courtney; **Dunham, E. W.**; Endl, Michael; Fressin, Francois; Ge, Jian; Henning, Thomas; Holman, Matthew J.; Howard, Andrew W.; Ida, Shigeru; Jenkins, Jon; Jernigan, Garrett; Johnson, John A.; Kaltenegger, Lisa; Kawai, Nobuyuki; Kjeldsen, Hans; Laughlin, Gregory; Levine, Alan M.; Lin, Douglas; Lissauer, Jack J.; MacQueen, Phillip; Marcy, Geoffrey; McCullough, P. R.; Morton, Timothy D.; Narita, Norio; Paegert, Martin; Palle, Enric; Pepe, Francesco; Pepper, Joshua; Quirrenbach,

American Astronomical Society (AAS) Meeting



In early January, staff attended the AAS meeting in Seattle, WA. (Left) Lowell astronomer Deidre Hunter won the prestigious Education Award for her work with Lowell's Navajo-Hopi program. (Right) Director Jeffrey Hall and Communication and Marketing Associate Josh Bangle were on hand to man the Lowell table.

Andreas; Rinehart, S. A.; Sasselov, Dimitar; Sato, Bun'ei; Seager, Sara; Sozzetti, Alessandro; Stassun, Keivan G.; Sullivan, Peter; Szentgyorgyi, Andrew; Torres, Guillermo; Udry, Stephane; Villaseñor, Joel (2014).

Warm ice giant GJ 3470b - II. Revised planetary and stellar parameters from optical to near-infrared transit photometry. *Monthly Notices of the Royal Astronomical Society*, Volume 443, Issue 2, p.1810-1820. Biddle, Lauren I.; Pearson, Kyle A.; Crossfield, Ian J. M.; Fulton, Benjamin J.; Ciceri, Simona; Eastman, Jason; Barman, Travis; Mann, Andrew W.; Henry, Gregory W.; Howard, Andrew W.; Williamson, Michael H.; Sinukoff, Evan; Dragomir, Diana; Vican, Laura; Mancini, Luigi; Southworth, John; Greenberg, Adam; Turner, Jake D.; Thompson, Robert; Taylor, Brian W.; Levine, Stephen E.; Webber, Matthew W. (2014).

Two B's, or Not Two B's? An NPOI Survey of Massive Stars. De Rosa, R. J.; Patience, J.; Zavala, R. T.; **Prato, L.**; Marois, C.; Thomas, S. *Resolving The Future Of Astronomy With Long-Baseline Interferometry*. Proceedings of a conference held 28-31 March 2011, at New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA. ASP Conference Series, Vol. 487. San Francisco: Astronomical Society of the Pacific, p.251. Edited by Michelle J. Creech-Eakman, Joyce A. Guzik, and Robert E. Stencel. (2014).

HAZMAT. I. The Evolution of Far-UV and Near-UV Emission from Early M Stars. *The Astronomical Journal*, Volume 148, Issue 4, article id. 64. Shkolnik, Evgenya L.; Barman, Travis S. (2014).

Secular orbital evolution of planetary systems and the dearth of close-in planets around fast rotators. *Monthly Notices of the Royal Astronomical Society*, Volume 443, Issue 2, p.1451-1462. Lanza, A. F.; Shkolnik, E. L. (2014).

Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) - 2009 January through 2009 June. *The Minor Planet Bulletin*. Bulletin of the Minor Planets Section of the Association of Lunar and Planetary Observers, Vol. 41, no. 4, pp. 2860300. Koehn, Bruce W.; **Bowell, Edward G.**; Skiff, Brian A.; Sanborn, Jason J.; McLelland, Kyle P.; Pravec, Petr; Warner, Brian D. (2014).

Dwarf Diameters. *Resolving the Future Of Astronomy With Long-Baseline Interferometry*. Proceedings of a conference held 28-31 March 2011, at New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA. Edited by Michelle J. Creech-Eakman, Joyce A. Guzik, and Robert E. Stencel. ASP Conference Series, Vol. 487. San Francisco: Astronomical Society of the Pacific. Boyajian, T.; Braun, K. v.; **van Belle, G. T.**; McAlister, H. A.; Brummelaar, T. T.; Ciardi, D. R.; Lopez-Morales, M.; Ridgway, S.; Sturmman, L.; Sturmman, J.; and 3 coauthors (2014).

Long Baseline Interferometric Observations of Asteroids: Physical Characterization of Binary Systems. *Resolving The Future Of Astronomy With Long-Baseline Interferometry*. Proceedings of a conference held 28-31 March 2011, at New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA. Edited by Michelle J. Creech-Eakman, Joyce A. Guzik, and Robert E. Stencel. ASP Conference Series, Vol. 487. San Francisco: Astronomical Society of the Pacific, p. 217. Delbo, M.; Tanga, P.; **van Belle, G.**; Matter, A.; Carry, B.; Creech-Eakman, M. J. (2014).

De-biased Populations of Kuiper Belt Objects from the Deep Ecliptic Survey. *The Astronomical Journal*, Volume 148, Issue 3, article id. 55. Adams, E. R.; Gulbis, A. A. S.; Elliot, J. L.; Benecchi, S. D.; Buie, M. W.; Trilling, D. E.; **Wasserman, L. H.** (2014).



Science on a Sphere Exhibit

On January 10, 2015, Lowell Observatory's Steele Visitor Center opened Science on a Sphere, a room-sized, global display system that uses computers and video projectors to display planetary data onto a six-foot diameter sphere, analogous to a giant animated globe. Images of atmospheric storms, ocean movements and land masses of a planet can be shown on the sphere, explaining complex environmental processes in ways that are intuitive and captivating. We will be working closely with NASA to bring unique Lowell Observatory images to this system. We hope to feature Percival Lowell's Mars maps and updated photos of Pluto as New Horizons gets closer to its target.

ARRIVALS

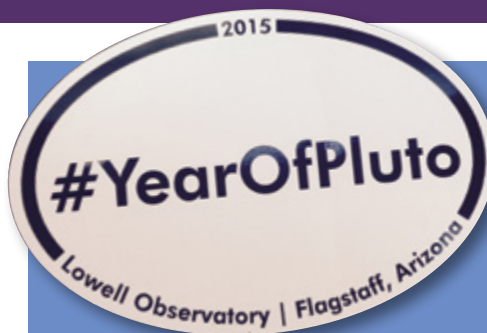
- Stephanie Bewley - Controller
- Skyler Coombs - Curatorial Intern
- Jacob Gannon - NPOI Observer
- Hannah Graves - Development Assistant
- Brandon Porter - Accountant
- Michael Sarkosky - NPOI Observer
- Stephen Zawicki - NPOI Observer

Public Program Educators

- Hannah Brower
- Jim Cole
- Kelly Ferguson
- Angela Lexvold
- Justin Ringle
- Justin Toller

POSITION CHANGES

- Joshua Bangle - Communication and Marketing Associate
- Sarah Conant - Creative Specialist
- Kevin Schindler - Content Specialist



2015 | Year of Pluto

NASA's New Horizons spacecraft is currently on the final leg of its journey to Pluto, which was discovered at Lowell Observatory by in 1930 by Clyde Tombaugh. Throughout the year Lowell will present special programming to celebrate this monumental event and will incorporate the hashtag #YearOfPluto on social media.

2015 #YEAROFPLUTO SPECIAL EVENTS

FEBRUARY 21 **New Horizons Principal Investigator Dr. Alan Stern at the Orpheum**
6pm VIP Meet & Greet,
7pm General Admission
Contact (928) 255-5059 or
hgraves@lowell.edu for info.

MARCH 13 **Pluto Exhibit Grand Opening**
Pluto at 85: From Discovery to New Horizons
This new exhibit will answer your questions about Pluto, from why we were searching for a planet, to what it means to be a "planet" and what we might find when we arrive.

APRIL 4 **Featured Speaker Dr. Gerard van Belle**
The Pluto Vote: One Astronomer's Personal Story
The 2006 vote on the planetary status of Pluto has had a long-lasting reverberation throughout astronomy. Dr. van Belle's own accidental involvement in this has its own amusing story, which he will recount along the way to re-examining a question: What is a planet, and why do we care?

MAY 2 **Pluto Discovery Walking Tour**
Follow in the footsteps of Clyde Tombaugh, visiting several sites at Lowell and in downtown Flagstaff where Tombaugh went the day he discovered Pluto. Limited space; for information call (928) 255-5059.

JUNE 13 **Lowell Observatory's Annual Gala**
Celebrate Pluto and Beyond at our 4th Annual Gala.

JULY 14 **NASA New Horizons Pluto Encounter**
New Horizons will make its closest approach to Pluto.

AUGUST **Featured Speaker**
More info TBA

SEPTEMBER **Festival of Science**
Lowell will host several hands-on activities during the 10-day Festival, which runs from September 18-27.

For more special event info visit
www.lowell.edu/visit_events.php



Friends of Lowell - The Spahns

by Antoinette Beiser

John and Linda Spahn have visited Flagstaff every summer since the early 1980s to take a break from the hot Las Vegas weather. A viewing session through the historic Clark Telescope inspired them to buy a telescope of their own. They also became two of the first members of our Friends of Lowell program. Several years later they accidentally wandered into a higher-level Friends appreciation event. Director Bob Millis made them feel so welcome they decided upgrading their membership was the way to go! Since then they have not only helped support the observatory financially but have also volunteered in the Lowell Archives. They helped process Dr. Millis's papers, have tagged, inventoried, and described a variety of historic astronomical instruments, cataloged the fabulous Bob Bruner rare Mars book and new meteorite collections, and organized and cataloged V.M. Slipher's spectra plate collection. We are so happy and grateful they decided to formally include Lowell Observatory in their estate plan three years ago. They admire the observatory and its mission of research and outreach and we certainly admire and are very thankful for their loyalty and support in so many ways throughout the years.

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The Lowell Observer is published quarterly by Lowell Observatory
1400 West Mars Hill Road, Flagstaff, AZ 86001 • www.lowell.edu
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Layout and Production Design by Sarah Conant
Contents Copyright 2015 by Lowell Observatory ISSN 1054-0059

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