FALL . QUARTER / SEPTEMBER . 2016

REFLECTIONS

THE UNIVERSE EXPANDED HERE

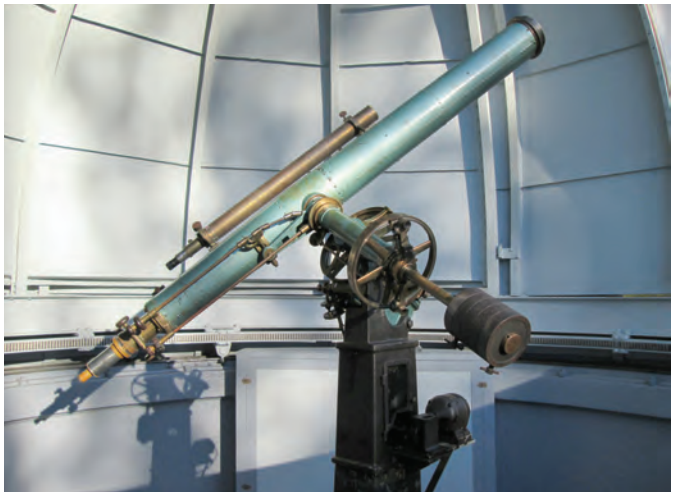
Perfect Planets

Using Mount Wilson's 6-inch Refractor

by **DR. THOMAS J. SPIROCK** (ASTROPHOTOGRAPHY) *and* **JOHN W. BRIGGS** (TEXT)

Mount Wilson Observatory has been described as the best site in the continental United States for nighttime astronomical "seeing," a term describing the sharpness of images as limited by atmospheric turbulence near and above a telescope. This was the finding of the Naval Postgraduate School's Professor Don Walters, a specialist in astronomical site characterization who recorded extensive data at many sites in the 1990s. Even experienced observers returning to Mount Wilson can be caught off-guard by the quality of the local seeing. One might say it must be experienced to be believed!

In June 2016, Tom Spirock joined John Briggs at Mount Wilson during John's visit to finish various adjustments to the recently reactivated 6-inch refractor built by Warner & Swasey in 1914. The small but celebrated telescope had been in storage for several years until 2015, when it was returned to its original dome by Briggs and Mount Wilson staff. Preparing for the June visit, John regaled Tom with stories of local seeing. At the same time, Tom was becoming increasingly familiar with modern "lucky imaging" planetary photography technique and image processing using the 13-inch Schupmann refractor at Stellafane near Springfield, Vermont. The unusual Schupmann optical design, with its unobstructed and color-free features, had been memorably described as the "most mathematically perfect" telescope by the great 20th-century optical designer, James G. Baker [1]. Tom's results from the 13-inch had been very encouraging. But neither he nor John thought they would be easily improved without access to a much larger telescope.



JOHN BRIGGS

MOUNT WILSON'S 6-inch refractor, recently refurbished and returned to its original dome.

While visiting Mount Wilson is always a pleasure, it was especially so for John. The June timing gave him a chance to see Mount Wilson's

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ANNOUNCEMENTS

Mount Wilson Observatory Is Open to Visitors

Weather and roads permitting, Mount Wilson Observatory is anticipated to be open to the public every day for the season. Come on up to the mountain to enjoy the beautiful weather and uplifting surroundings! The Cosmic Café is open Saturdays and Sundays, 10 A.M. to 5 P.M., offering a variety of fresh-made sandwiches and other treats to visitors. At the café you may purchase a National Forest Adventure Pass and tickets for the weekend walking tours. The Cosmic Café is located in the Pavilion overlooking the large parking lot at the entrance to the Observatory. We will see you at the top!

VISIT THE OBSERVATORY
WELCOME VISITORS

ABOUT US

The Mount Wilson Institute operates Mount Wilson Observatory on behalf of the Carnegie Institution for Science. Mount Wilson Institute is dedicated to preserving the Observatory for scientific research and fostering public appreciation of the historic cultural heritage of the Observatory. *Reflections* is published quarterly by the Mount Wilson Institute.

INFORMATION

For information about the Observatory, including status, activities, tours, and reserving 60-inch and 100-inch telescope time, visit our website — *www.mtwilson.edu.*

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For the use of historical photographs of Mount Wilson, we thank the Observatories of the Carnegie Institution for Science, the Huntington Library, Don Nicholson, and other sources as noted.

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PAGE ONE BANNER PHOTOGRAPHS

X-rays stream off the Sun in this composite of observations by NASA's Nuclear Spectroscopic Telescope Array and Solar Dynamics Observatory. (Inset) Edwin Hubble at the Newtonian focus of the 100-inch Hooker telescope on Mount Wilson, circa 1923.

NEWS + NOTES

EDUCATIONAL OUTREACH PROGRAM LAUNCHED

Mount Wilson Observatory, together with Carnegie Observatories, is running a program that brings groups of children to the Observatory for both daytime and nighttime visits, inaugurated at the (inspired) request of Magnolia Schools, a California-based chain of charter schools emphasizing STEM education.

Between February and June 2016, groups of 6th- to 11th-grade students from schools throughout Southern California came to the Observatory to learn the concepts enumerated in the current California school science standards — solar magnetism, Earth's place in the Milky Way, spectroscopy and stellar evolution, the existence of other galaxies, redshift and the expanding universe, the Big Bang — at the very instruments that uncovered them. And in August the Observatory hosted over 50 science teachers at a training seminar to demonstrate the field trips.

MWI Board member Dan Kohne is spearheading the program for Mount Wilson Observatory in collaboration with Dr. Cynthia Hunt of Carnegie Observatories. Typically, school visits begin with an introductory talk by Dr. Hunt in the Mount Wilson auditorium and include stops at the 150-foot solar tower (with demonstration by Steve Padilla), the Snow solar telescope, and the 60- and 100-inch telescopes.

Mount Wilson Observatory is working to expand this program in the coming months, with a training presentation for teachers planned in October. Watch for more about this exciting new initiative in the December *Reflections*!

CARNEGIE ARCHIVAL PHOTOS PRESENTED

Dr. Cynthia Hunt of Carnegie Observatories gives an interesting and informative presentation on SpacePod. Carnegie Observatories is the repository of many original photographic plates taken by astronomers at the Mount Wilson Observatory, among others. Dr. Hunt describes the history and significance of the archival material at Carnegie, which includes work produced by notable astronomers Edwin Hubble and Milton Humason. *www.listentospacepod.com/episodes/2016/8/28/episode-60-data-you-can-see-touch-and-lick-with-dr-hunt*

MOUNT WILSON SPEAKER'S BUREAU

A Speaker's Bureau has been established to facilitate setting up educational talks on Mount Wilson Observatory's history for service clubs, schools, neighborhood organizations, astronomy clubs, and other appropriate groups. To engage a speaker, contact Don Nicholson at *dnich@alumni.caltech.edu*. There is no charge for this service.

FOMWO Membership

All are invited to join the Friends of Mount Wilson Observatory. The Observatory receives no continuing state or federal support. You can help ensure the continued operation of this science heritage site with your tax-deductible gift. FOMWO offers a variety of membership levels and benefits. For information on how to become a FOMWO member, visit www.mtwilson.edu. The Observatory welcomes donations and volunteer efforts of all kinds, and we thank you.

MOUNT WILSON OBSERVATORY

CUREA 2016

The 2016 Consortium for Undergraduate Research and Education in Astronomy (CUREA) summer program was held June 19–July 2, 2016 at Mount Wilson Observatory. According to Mike Simmons, one of the volunteer instructors, it "was a really amazing group, all great students, and really international — two USA, two India, one each Spain, Italy, UK, Namibia, and Indonesia."

The intensive two-week course uses historic and modern facilities at Mount Wilson. Students also enjoy pre-arranged tours of local astronomical sites.

CUREA director Paula Turner of Kenyon College, Gambier, Ohio, provided descriptions of the projects undertaken by the 2016 students.

SARA MARTIN

CUREA GROUP at the 16-inch telescope dome on Mount Wilson.

Elba Alonso Monsalve, from Spain, used photometric techniques on remote telescopes in Chile and the US to record the rotation curve of asteroid 10259 Osipurvyurij, a previously unmeasured asteroid. She is preparing her results for possible publication.

Ankush Banerjee, from India, used slitless spectroscopy on the 16-inch LX200 telescope to measure the redshift of quasar 3C273, finding a value within 10 percent of the accepted value.

Flavia Cicala, from Italy, used a low-resolution slit spectrometer on the 16-inch LX200 telescope to measure the spectra of stars from a variety of spectral classes, analyzing her data by fitting Planck curves to each smoothed spectrum to determine the star's surface temperature.

Richa Fitria, from Indonesia, used filtered photometry on the 16-inch LX200 telescope to plot the HR diagrams for two open clusters, M11 and NGC 6633, finding results in excellent agreement with published HR diagrams for those clusters.

Sam Frederick, from Davidson College in North Carolina, used the same low-resolution slit spectrometer on the 16-inch LX200 telescope to measure the spectrum from planetary nebula M57 (the Ring Nebula). From his data, he calculated the electron temperature of the fluorescing gas comprising the nebula, arriving at a result within 11 percent of the accepted value.

Prashansa Gupta, from India, used filtered photometry on the 16-inch LX200 telescope to measure the transit of an extrasolar planet in the system HAT-P37. In addition to producing a light curve in good agreement with published results, she also discovered another variable star in the field of view of her images and plans to follow up on this object, which does not appear to be listed in catalogs of known variable stars.

Rob Johnstone, from Namibia, who conducts educational outreach using astronomy in Namibia and operates a business taking interested parties to do dark-sky observing there as well, followed up on observations of an unusual solar event that he and two other students imaged using the Observatory's Lunt H-alpha telescope and a DSLR camera. The eruptive event they observed consisted of four separate events, which he followed up using images from the Solar Dynamics Observatory (SDO), available on-line. He is preparing his observations for possible publication.

Seth Miller, from Penn State University (Mont Alto campus), assisted with Johnstone's observations but pursued a separate project making engineering improvements to the matched pair of Mortimer solar telescopes with narrowband H-alpha filters (one scope and filter donated to CUREA by former instructor Jim LoPresto, the other on loan from current instructor Sara Martin of La Crescenta, California).

Mark Till, from Great Britain, used the low-resolution slit spectrometer on the 16-inch LX200 telescope to measure the integrated spectrum across the core of globular cluster M92, detecting hydrogen-line absorption in the combined spectra from the cluster.

CUREA 2017 will run Sunday, June 18, through Saturday, July 1, 2017. Applications will open in early January. Applicants must be 18 years or older by June 18 to participate. Visit *www.curea.org* for information.

Perfect Planets — continued from page 1

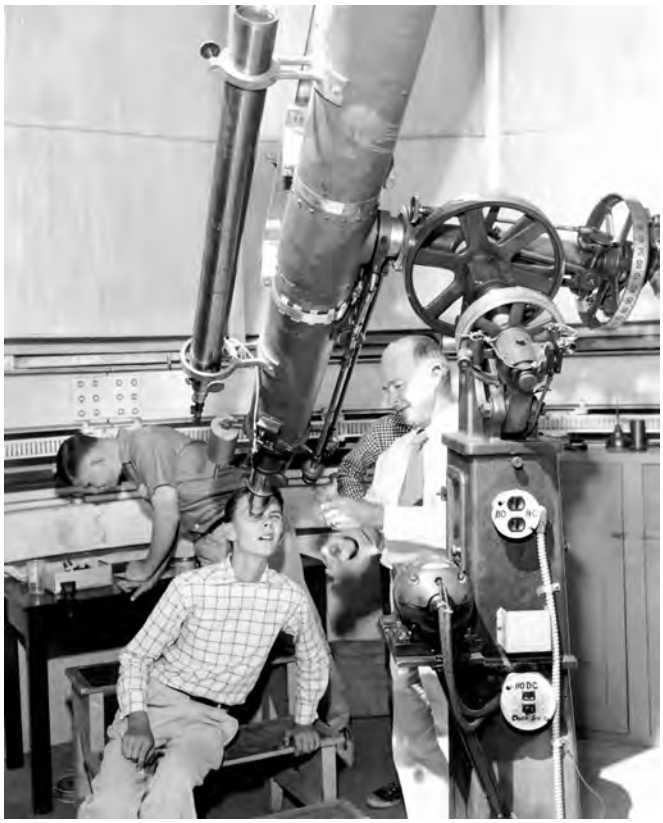
annual Consortium for Undergraduate Research and Education in Astronomy (CUREA) summer program in action. John spoke regarding the remarkable series of solar telescopes built by George Ellery Hale, and he facilitated a visit by Dr. Leif Svaalgard of Stanford University's Wilcox Solar Observatory. Dr. Svaalgard spoke to CUREA on a current collaboration to better calibrate 18th-century sunspot records by observing the Sun with reproduction instruments.

The reactivated 6-inch allowed spontaneous demonstrations for passing CUREA students, both day and night. Daytime views included the bright star Sirius during polar alignment tracking tests as well as the planet Mercury. Evening views included Jupiter, Mars, and Saturn, and a demonstration by Tom of the video technique that gathers thousands of short-exposure frames for selection, alignment, and addition into a single high-resolution image. Memorable views included binary stars under high power in very good seeing; the most impressive was Izar (epsilon Boötis). The Latin nickname *Pulcherrima*, meaning "the most beautiful," was applied to the pair by the early Russian double-star specialist F. G. Wilhelm Struve. Demonstrations as simple as this — showing clear Airy disks, diffraction rings, and thus a dramatization before one's eyes of the wave-nature of light — are ideal for students. And of course, for anyone!

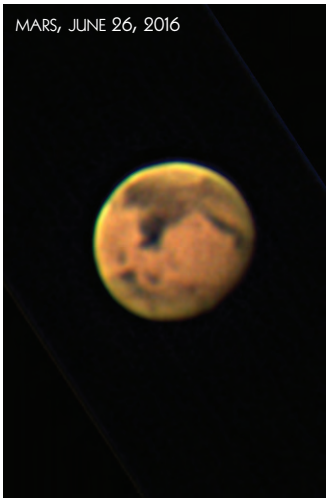
With the 6-inch objective lens newly cleaned and collimated, there was no question of its excellent performance. Collimation involves adjusting the tilt of the lens assembly relative to the position of the eyepiece at the back of the telescope. This is a simple empirical procedure. Unexpectedly for John, testing collimation led to a view that remains his most vivid memory from the whole visit. Daytime "artificial stars" are formed by sunlight glinting off any shiny curved surface that is some distance from a telescope. One morning in early sunlight, the dome of the nearby 150-foot solar tower seemed fertile territory for artificial stars. As it proved, a subtle, rolling texture in fresh glossy paint at the top of the tower allowed a seeming thousand brilliant artificial stars in a single high-power view through the 6-inch — something like looking into the heart of an amazing globular star cluster, all the stars diffraction-limited, and each shining at maybe an apparent magnitude equal to Venus!

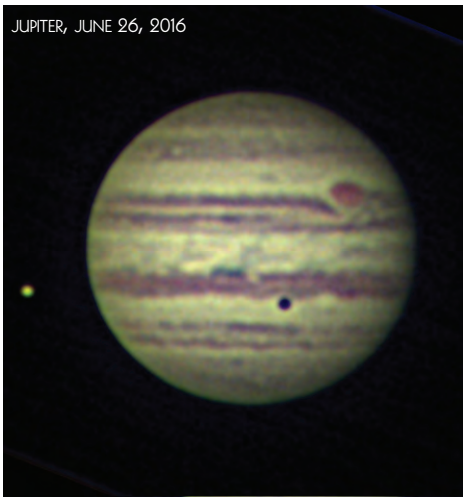
Of the several days available at the site for Tom and John, the first few offered poor seeing by the standards of Mount Wilson. CUREA had scheduled the 60-inch one of these nights, but sadly, the visual images were among the worst with that telescope in collective memory! However, on the evening of Saturday, June 25, the excellent summertime seeing at Mount Wilson returned. Tom was now familiar with the idiosyncrasies of the 102-year-old Warner & Swasey and its weight drive. To our great surprise, his results imaging Mars and Saturn with the 6-inch Brashear achromatic objective were immediately and obviously his best ever, even given previous experience using the 13-inch Schupmann with the same camera equipment and processing, back in Vermont trying approximately monthly over the course of a year.

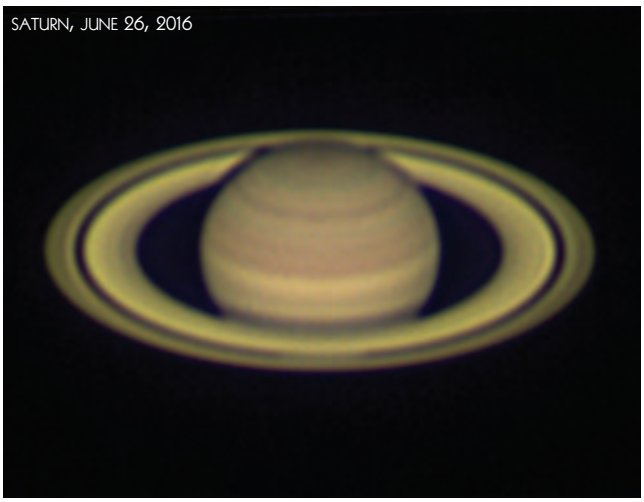
We were thus reminded of James G. Baker's work in 1963 — that while the Schupmann design is very good and generally neglected, other telescope designs can compete with it to allow viewing extremely low-contrast features. And of more immediate import to us, our experience with excellent Mount Wilson seeing was renewed,



THE MOUNT WILSON 6-INCH TELESCOPE has inspired staff, students, and visitors since its 1914 installation. Shown here is staff astronomer Joe Hickox with visiting students, circa 1953. The youngster at the eyepiece is Jack Harvey, who grew to become a leading solar physicist at National Solar Observatory and recipient of the George Ellery Hale Prize of the American Astronomical Society. (Image courtesy of Dr. John W. Harvey and the collection of The Astronomical Lyceum, Magdalena, New Mexico.)







Near-perfect seeing allows surprising excellence in modern planetary imaging, even when using a small non-apochromatic refractor. — J. Briggs

and we were especially glad the small telescope allowed such a good demonstration for visiting students who had been unlucky in their timing with the 60-inch.

The images reproduced here were recorded with the f/15 Brashear achromat, a flint-forward design following Charles S. Hastings, using also a 2× Barlow lens. The camera was a ZWO ASI120MC with 3.5-micron pixels ($199), sampling 0.16 arc-second per pixel.

Mars was recorded June 26, 2016, 08:39 Universal Time, aligned and stacked with Autostakkert! shareware, using the best 30 percent of 15,376 images, each exposed 6 milliseconds. Gain = 100; drizzle = 3.0×. Noise reduction and sharpening were performed using RegiStax6 shareware. The central meridian of Mars is 310 degrees.

Jupiter was recorded the same evening, 04:33 UT, aligned and stacked with Autostakkert!, using the best 30 percent of 3,157 images, each exposed 20 milliseconds. Gain = 100; drizzle = 1.5×. Noise reduction and sharpening were performed using RegiStax6. Jupiter's central meridian in System I was 59 degrees; in System II, 178 degrees.

Saturn was recorded, again on the same evening, 09:44 UT, aligned and stacked with Autostakkert!, using the best 30 percent of 9,095 images, each exposed 100 milliseconds. Gain = 100; drizzle = 1.5×. Noise reduction and sharpening were performed using RegiStax6. Saturn's central meridian in System I was 31 degrees; in System III, 72 degrees. All image processing and reduction was done by Thomas J. Spirock.

Whatever may be the ultimate telescope for low-contrast planetary imaging, it was most gratifying to see such impressive results from the old but revered 6-inch telescope. It was tempting to conclude that the results were at the limit of what might be possible using a 6-inch achromat. It was also most gratifying being able to share the experience with CUREA — CUREA being such a wonderful program for students of all ages.

Reference

[1] Baker, James G. (1963) Planetary Telescopes, *Applied Optics*, February 1963, Vol. 2, No. 2. pp. 111–129.

About the Authors

John W. Briggs was a staff observer for Mount Wilson's HK Project and a founding instructor in the CUREA program. His recent article regarding the Mount Wilson 6-inch and its logbook appeared in the September 2015 issue of *Reflections*. Dr. Thomas J. Spirock completed his graduate studies at New Jersey Institute of Technology building a digital vector magnetograph for Big Bear Solar Observatory. Both are members of the Springfield Telescope Makers, the organization responsible for the well-known annual Stellafane Convention in Vermont.

CHARA Array Update

by **THEO TEN BRUMMELAAR**

Things have been moving ahead over the last year for the Center for High Angular Resolution Astronomy (CHARA) Array. The ongoing upgrade of our telescope systems with the addition of adaptive optics (AO), as described in the June 2016 *Reflections*, recently passed a milestone as we formally entered into an agreement with the French electro-optical company ALPAO for the design and construction of the deformable mirrors required to complete the AO system. This contract came at the end of a year-long exploration of potential vendors around the world. These mirrors must be built to order, as no off-the-shelf components of this type exist. We expect the delivery of the first of these mirrors in the spring of 2017 and first tests of a full AO system in the early summer.

Besides our internal AO program, our collaborators have made great progress. Dr. Stephan Kraus of the University of Exeter in the United Kingdom recently obtained funding from the European Research Council to upgrade one of our beam combiners called MIRC — the Michigan Infra-Red Combiner. MIRC, originally built by Dr. John Monnier and his team at the University of Michigan, is capable of combining all six CHARA telescopes at once, and is responsible for almost all the images made by the CHARA Array. This upgrade, dubbed MIRCx, includes a change in the optics of the beam combiner, but more importantly, the installation of a new infrared camera system that is able to detect light much fainter than is currently possible. We hope that MIRCx will allow us to observe many more, and fainter, objects.

THE COMPONENTS of the MIRC imaging beam.

In parallel with the MIRCx project, Dr. Monnier has also obtained funding to build an entirely new beam combiner to complement MIRCx called MYSTIC (Michigan Young Star Imager at CHARA).

ROBERT STENCEL, UNIVERSITY OF DENVER

ONE OF THE CHARA ARRAY telescopes on Mount Wilson. The Array is operated by Georgia State University.

Using the same camera technology as MIRCx, MYSTIC will open up new bands in the infrared spectrum for observations at the CHARA Array. Our French collaborators at the University of Nice, led by Dr. Denis Mourard, are also hard at work designing a new visible-light six-way beam combiner system for the Array.

Finally, we are now able to announce that our most recent proposal to the National Science Foundation was successful, and that we will begin a new era of open observing time at the CHARA Array. This program, funded through the Mid-Scale Innovations Program of the National Science Foundation, will allow us to give more observing time at the CHARA Array for anyone who wishes to use it. This time, up to 75 nights per year, will be open to anyone in the world, and will be awarded based on observing proposals submitted to an independent Time Allocation Committee run by the National Optical Astronomical Observatory in Tucson, Arizona. Our hope is that this will help start a new era for CHARA, and the field of interferometry in general, and bring a broad range of astronomers to Mount Wilson — as this funding includes travel support for visiting scientists. It will also allow us to hire more staff, including another Array operator, another assistant for Larry Webster (our site manager), a laboratory technician, and two new scientists who will manage the observing program and interact with the visiting scientists.

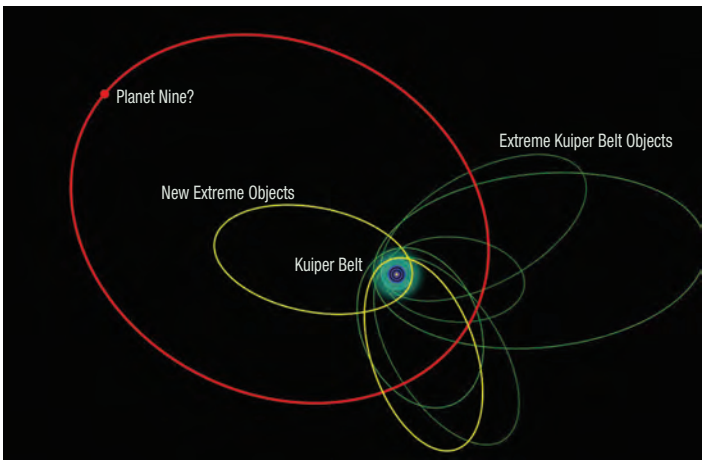
Theo ten Brummelaar is Director of the CHARA Array. Visit the website at *chara.gsu.edu* or link from the *www.mtwilson.edu* website for more information.

Seeking Planet Nine

The Carnegie Institution for Science announced on August 29, 2016, that Scott Sheppard of Carnegie and Chadwick Trujillo of Northern Arizona University had observed several never-before-seen objects at extreme distances from the Sun in our solar system. In 2014, the two scientists announced that they had found an object with the most distant orbit ever observed, a possible dwarf planet far beyond Pluto. This body was temporarily designated 2012 VP113.

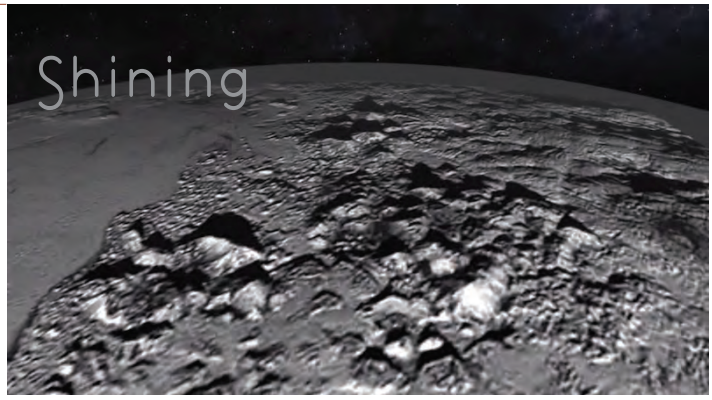
When Sheppard and Trujillo announced the discovery, they noted that the small number of known extreme trans-Neptunian objects all cluster with similar orbital angles. They predicted the existence of a planet at more than 200 times Earth's distance from the Sun and five times more distant than Pluto that shepherds the smaller objects into similar types of orbits. In 2016, Caltech scientists Mike Brown and Konstantin Batygin announced they had found evidence for a planet roughly 10 times as massive as Earth with a perihelion of 200 astronomical units, based on their analysis of the orbits of several distant objects. Nicknamed Planet Nine, this object might take 10,000 years to orbit the Sun.

Sheppard and Trujillo have found 50 previously unknown objects, but most have orbits too close to Neptune to be useful in determining the existence of Planet Nine. Only about five of the extreme trans-Neptunian objects display orbits that would help locate the mysterious giant planet. Sheppard states "greater numbers...must be found to fully determine the structure of our outer solar system." Sheppard, Trujillo, and David Tholen of the University of Hawaii are conducting the largest, deepest survey for objects beyond Neptune and the Kuiper belt.



ORBITS OF NEW AND KNOWN EXTREMELY DISTANT OBJECTS. The clustering of most of their orbits indicates that they are likely influenced by something massive and very distant: the proposed Planet Nine. ROBIN DIENEL

In addition to the Carnegie Institution for Science press release of August 29, 2016, Amina Khan's excellent article in the *Los Angeles Times* (September 2, on-line) was also a source for this summary.



by **BOB EKLUND**

So effortlessly
Our sycamore tree reflects
This morning's sunlight.
On distant Pluto
These same sunbeams illumine
The icy mountains.
Just being a light
Shining on things near and far:
What a lovely task!

Derived from an animation created from images taken during NASA's New Horizons spacecraft closest approach to Pluto on July 14, 2015, the image shows the dwarf planet's Norgay Montes (Norgay Mountains) and Sputnik Planum (Sputnik Plain).

This poem first appeared in the Astronomers Without Borders AstroPoetry Blog — *astronomerswithoutborders.org/awb-programs/arts-and-culture/astropoetry.html*

METEOR MANIA

Dr. Lance Benner of JPL provided the following report on observing the Perseids while on vacation in Maine: "I was out from about 23:15-01:10 on the night of August 11–12 when the rates were expected to peak. I was impressed by the numbers I saw. I did four 10-minute counts and tallied 47 meteors. That's a pretty good rate for about 3–4 hours before the peak. If one includes the others that I saw before I did the 10-minute counts, then I probably saw a total of at least 70."

Your *Reflections* editor reports seeing only one meteor (something of an accident, since it was early in the evening, viewing from an Altadena patio), but it was spectacularly bright and carved a splendid, blazing path through the sky.

— M. Morgan

MOUNT WILSON
OBSERVATORY

Mount Wilson Institute
P. O. Box 94146
Pasadena, CA 91109

VISIT THE OBSERVATORY
≈ THIS FALL ≈

WELCOME, VISITORS!

OBSERVATORY STATUS

Welcome hikers, bikers, star-gazers, visitors of all interests! The Observatory and Skyline Park are open from 10:00 A.M. to 5:00 P.M. daily through the season, weather permitting. The Cosmic Café at the Pavilion, offering fresh-made sandwiches and Observatory memorabilia, is open Saturdays and Sundays from 10:00 A.M. to 5:00 P.M. You may purchase a National Forest Adventure Pass at the Café for parking.

DOCENT-LED WALKING TOURS

Two-hour weekend tours of the Observatory are held on Saturdays and Sundays at 1:00 P.M. Meet at the Cosmic Café at the Pavilion to buy a ticket. Guests on these tours are admitted to the telescope floor right beneath the historic 100-inch telescope.

SPECIAL GROUP TOURS

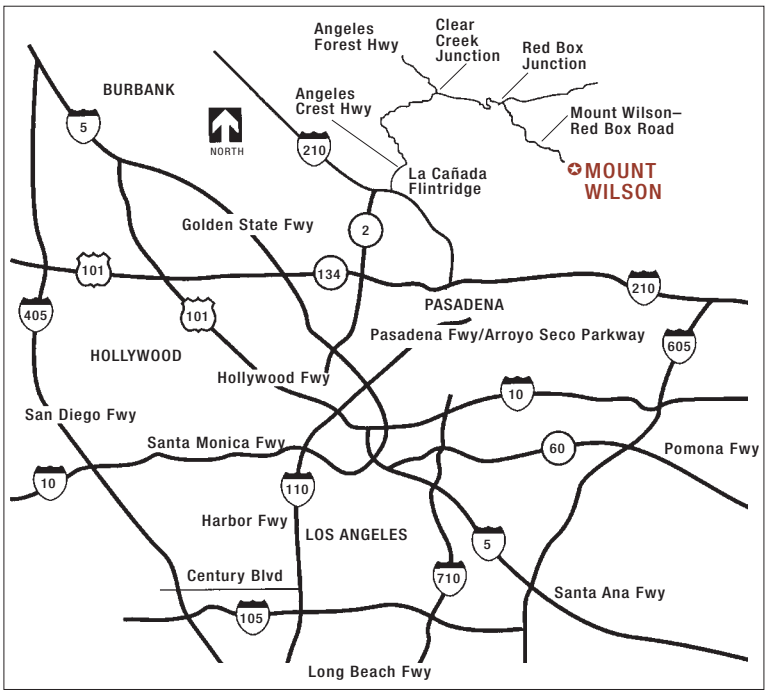
Group daytime tours are available. Reservations are required and a modest fee is charged. Groups can also place orders in advance for box lunches from the Cosmic Café. For information, please visit *www.mtwilson.edu*.

LOOK THROUGH THE TELESCOPES

Mount Wilson's 60-inch telescope and 100-inch telescope provide incredible views of some of the most beautiful objects in the night sky. For details on scheduling a viewing session, see *www.mtwilson.edu*.

PARKING AT THE OBSERVATORY

The U.S. Forest Service requires those parking within the Angeles National Forest and the National Monument (including the Observatory) to display a National Forest Adventure Pass. For information, visit *www.fs.usda.gov/angeles/*. Display of a National Parks Senior Pass or Golden Age Passport is also acceptable.

HOW TO GET TO MOUNT WILSON OBSERVATORY

From the 210 freeway, follow Angeles Crest Highway (State Highway 2 north) from La Cañada Flintridge to the Mount Wilson–Red Box Road; turn right, go 5 miles to the Observatory gate marked Skyline Park, and park in the lot below the Pavilion. Visit the Cosmic Café at the Pavilion, or walk in on the Observatory access road (far left side of parking lot) about 1/4 mile to the Observatory area. The Museum is opposite the 150-foot solar tower.