SkyWAAtch

Dumbbell Nebula

Olivier Prache provided this image of the Dumbbell Nebula (M27) in Vulpecula. Olivier employed a 12.5” Hyperion astrograph with an ML16803 camera. The image represents 11 hours of exposure (10 minute subs, all unguided).

M27 is one of the finest planetary nebula in the night sky. It lies at a distance of about 1300 light-years. The nebula formed as a Sun-like star, late in its evolution, shed its outer layers and formed a white dwarf.

In This Issue . . .

Events for October

WAA October Lecture

"Formation and Growth of Galaxies over Cosmic Time."
Friday October 7th, 7:30pm
Leinhard Lecture Hall,
Pace University, Pleasantville, NY

Dr. Bruce Elmegreen, whose research deals with interstellar gas with a focus on star formation in gaseous nebulae and large-scale structure of spiral galaxies, will speak on the formation and growth of galaxies. Dr. Elmegreen joined IBM in 1984 after holding a faculty position at Columbia University. He received his Ph.D. at Princeton University under the guidance of Lyman Spitzer, Jr., and was a Junior Fellow at Harvard University. He was raised in Milwaukee and attended the University of Wisconsin in Madison as an undergraduate. He has written over 300 scientific articles and given 200 invited talks at international conferences. Directions and Map

Upcoming Lectures

Pace University, Pleasantville, NY

On November 4th, Dr. Kenneth Kremmer will speak on rocket technology.

Starway to Heaven

Saturday October 22nd, Dusk.
Ward Pound Ridge Reservation,
Cross River, NY

This is our scheduled Starway to Heaven observing date for October, weather permitting. Free and open to the public. The rain/cloud date is October 29th. **Important Note**: By attending our star parties you are subject to our rules and expectations as described here. Directions and Map.

New Members. . .

Antelmo Villarreal - West Harrison
Jeffrey Lichtman - Briarcliff Manor
Cat Hannan - Rye
Stephanie Hurwitz - Scarsdale

Renewing Members. . .

Thomas Boustead - White Plains
George & Susan Lewis - Mamaroneck
Leandro Bento - Mohegan Lake
Josh & Mary Ann Knight - Mohegan Lake
Eileen Fanfarillo - Irvington

At a recent Starway to Heaven Claudia Parrington modeled astronomy themed footwear (Cassiopeia is also the WAA logo).

Wanted Assistant Editor

The WAA newsletter (the SkyWaatch) is seeking an Assistant Editor. If you can help, please let us know. Your participation in editing, compositing and proofreading tasks or submitting articles or images, will be much appreciated. Email Tom at waa-newsletter@westchestersastronomers.org

WAA Apparel

Charlie Gibson will be bringing WAA apparel for sale to WAA meetings. Items include:

- Hat ($15)
- Polos ($15)
- Tee shirts ($12)

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA website.

Westchester
Amateur Astronomers

ALMANAC
For October 2016 by Bob Kelly

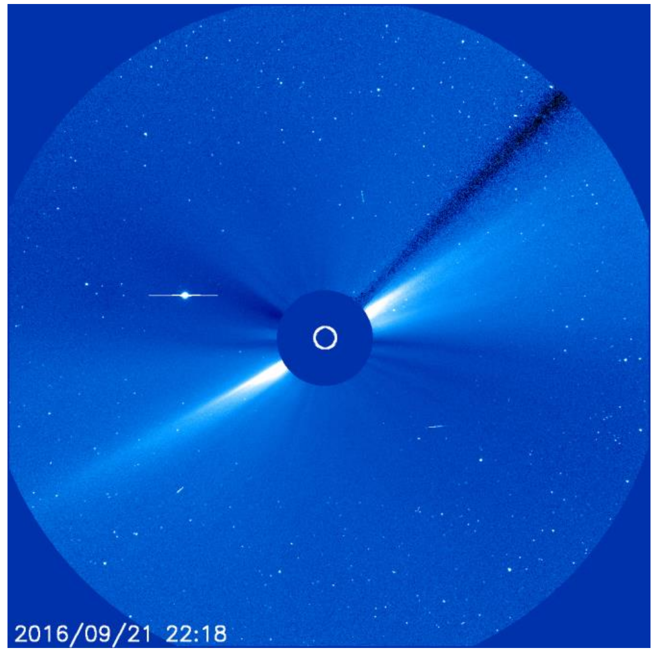
The Moon gets in the way in a spectacular fashion on the night of the 19th/20th, as the bright star (magnitude +0.9) Aldebaran is hidden by the Moon from 1:45 to 2:50am for our neck of the woods. The Moon will be 86 percent lit that night, so we'll need telescopes to pick out the tiny reddish spark of a star going behind the bright limb of the Moon. The reappearance will be on the slim dark limb – try not to blink and miss the instant of return! If you are out earlier in the evening, use high power to catch some of the dimmer stars in the Hyades cluster disappear and reappear from behind the Moon.

Let's continue with the other bright stuff. Can you regularly find Venus, low in the western sky after sunset? No rush. Venus will be hanging out after sunset well into next year.

Mercury gives you a reason to observe before some of the latest sunrises of the year, if you have a good view of the eastern horizon. Through the middle of October, the Northern Hemisphere gets the best views of Mercury. Mercury starts off October as the closest planet to Earth, but still only about 6.6 arc seconds wide. Mercury appears to shrink as it heads out behind the Sun.

Next, Mars takes the crown as closest planet to Earth for a while, but it's only 8 arc seconds wide when you see it low in the west. Telescopes show little but Mars' gibbous shape as 15 percent of Mars is in the dark from our point of view. Venus starts its turn as closest to Earth before the month ends. It'll be the closest major planet to Earth through mid-December. For now it'll be 12 arc seconds wide and about the same phase as Mars. Saturn hangs 15 degrees or less above the horizon off to the left of where the Sun sets and down and to the right of Mars. Not much larger than Venus from our point of view, but still dramatic with its rings tilted 26½ degrees from edge-on toward us. Get your camera out on the evening of the 28th, when Saturn, Venus and Antares reprise the line up of Mars, Saturn and Antares last month. After that, Saturn and Antares get lower in the western haze as the month ends, with Antares appearing to sink faster as Saturn slowly drifts eastward. During the first week of the month, Mars looks cute as a cherry on top of the Sagittarian teapot.

Jupiter pops up in the morning sky, exiting the SOHO C3 camera's view (as seen here in late September) around the 6th.



The Saturn-like "Ring" is an artifact caused by Jupiter's brightness overwhelming the detector and photon energy spilling into adjacent pixels.

Jupiter, already at 30.7 arc seconds wide and magnitude minus 1.7, soars past smaller 5.4 arc second, magnitude minus 1.1 Mercury around the 11th and 12th. The Moon and Jupiter make a pretty pair a degree and a half apart before sunrise on the 28th. Leaving the morning sky, Mercury makes the scene in C3 for the second half of October.

It continues to be a good couple of months for Uranus and Neptune in the evening sky. We make our closest approach to Uranus around the 15th. Shining at magnitude +5.7 Uranus can be found in any optical instrument, but a telescope is best for seeing it as a disk and seeing it is definitely not star-like.

Dwarf planet Ceres, aka asteroid 1Ceres is at its brightest (+7.4) in Cetus. It's much easier to find than the next closest dwarf planet, Pluto. The Dawn spacecraft continues its exploration of Ceres as it loops around the dwarf planet. Minor planet 4Vesta, which was previously reconnoitered by the Dawn spacecraft, is at magnitude +7½ in Cancer, highest in the morning sky. Do any of our telescopes make these small objects look like a dot, instead of a point of light like all the stars in their part of the sky? If you catch one of them, let everyone know by posting a comment on our facebook page. Asteroids 2 and 3 are harder to find with minor planet 2Pallas at magnitude +9.8 in Aquarius and 3Juno at 11th magnitude in Libra.

The International Space Station is visible in the evening sky through the 20th. Watch the Chinese space station (uncrewed and not sending telemetry data) mornings in early October and evenings for the rest of the month.

The Chinese space station will fall out of orbit, perhaps in the second half of 2017. The OTV-4 US Air Force space plane has been in orbit since May 2015. We didn't see it go over at our last star party – maybe you will have better luck spotting it in the evening sky around mid-month.

Sunset on Halloween evening is at 6pm, well after the end of the school day thanks to Daylight Time, which ends on November 6th. Then, morning sunrises 'fall' back from 7:35 to 6:35am, so October is a good month for morning astronomy! By the end of October, Mars sets at 9:35pm EST for the rest of the year (thanks to Sky and Telescope's graphic Skygazer's Almanac for the visual!).

Some Thoughts on a Few Supermoons

Bob Kelly

What was all the fuss about the September Full Moon? Yes, on September 16th the Moon was the Full and the Full Moon closest to the equinox, thus it was titled 'Harvest Moon'. A Harvest Moon is special because its rises less than 40 minutes later each night, which makes it more useful for extra light when fall harvesting goes into overtime. But it wasn't the largest Full Moon of the year. October's Full Moon will be closer and November's the closest. I'm hard pressed to see the difference when looking at the Moon. People who watch the tides will notice; with larger than normal tidal ranges from the 17th though the 20th. All this is brought to you by this month's lunar perigee of 357,681km occurring only 20 hours after Full Moon.

Speaking of Full Moons, our astronomical entertainment for last month's Town of Bedford overnight campout included the one-day-past-full Moon. We and our guests (or were we the guests?) noted the flat look of the lunar terrain in the areas where the Sun was high in the lunar sky. But being a day past Full Moon, we could see a bit of the rough texture of the craters and mountains on the edge of the Moon where sunset was occurring. It dramatically showed the difference between the low and high-Sun angles and which would be better if you wanted to land your spaceship safely on the Moon. After the blazing light of the Full Moon in an eight-inch telescope, it's hard to believe the Moon reflects only 12 percent of incoming sunlight

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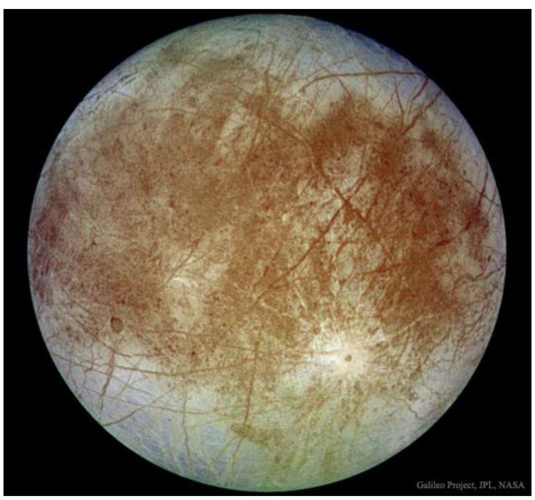


Water World?

Recent images from the Hubble Space Telescope indicates that plumes of water vapor sometimes emanate from Jupiter's ice-crusted moon, Europa -- plumes that might bring microscopic sea life to the surface. Europa, roughly the size of Earth's Moon, is pictured here in natural color as photographed in 1996 by the now-defunct Jupiter-orbiting Galileo spacecraft.

Credit: APOD

Image Credit: Galileo Project, JPL, NASA

Building the Hale Telescope
Larry Faltz

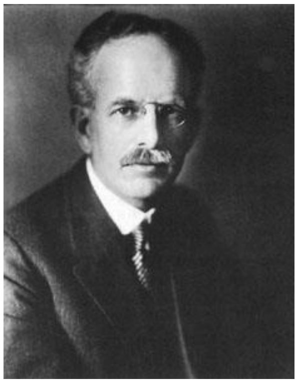
Until 1923, the Milky Way was the entire universe. The exact nature of objects we now know to be distant galaxies was completely unknown. As I noted in the June SkyWAAtch, "spiral nebulas" were most commonly thought to be solar systems in evolution, although in the 18th century Emanuel Swedenborg, Thomas Wright and Immanuel Kant independently proposed that there could be distant island universes made up of stars. Kant correctly deduced that the Milky Way was a flattened disk. Counting stars, William and Caroline Herschel showed that our galaxy was indeed flattened but erroneously deduced that the Sun was near its center. In the first decade of the 20th century, Jacobus Kapteyn estimated that our galaxy was about 8.5 kiloparsecs across 1.7 kiloparsecs at its thickest point (1 parsec=3.26 light years), using measurements of stellar parallax and magnitude. He did not account for as-yet unknown interstellar dust that reduces the brightness of more distant stars, and so his distances were too low. He also wrongly placed the Sun in the center of the galaxy.

Using the 60-inch reflector at the Mt. Wilson Observatory, Harlow Shapley, just out of graduate school at Princeton, measured the distances to globular clusters by observing Cepheid variables and RR Lyrae stars, which can be used as "standard candles" as shown by the remarkable Henrietta Swan Leavitt. Shapley correctly deduced that the globulars were distributed in a sphere around the center of the galaxy, publishing his work in 1914. His calculation of the galaxy's extent was much larger than Kapteyn's, about 100 kiloparsecs across. He didn't account for dust either, and we now think the actual diameter is on the order of 50 kiloparsecs. Shapley correctly concluded that the Sun was not in the center of the galaxy, although there too he was misled by not factoring in the dust, and he put our star closer to galactic center than it actually is.

On April 26, 1920, Shapley participated in what is known in astronomical circles as the "Great Debate" over the nature of spiral nebulas. The debate was sponsored by the National Academy of Sciences and took place in Washington DC at the Smithsonian Institution. Shapley took the traditional position that the spirals were within the Milky Way, while his opponent, Lick Observatory's Heber Curtis, argued that they were separate "island universes." Curtis was the discoverer of M87's jet, among his many contributions to astronomy.

Three years later Edwin Hubble showed that the spirals were distant Milky Ways in their own right by finding and measuring Cepheid variables in the Andromeda nebula with the 100-inch Hooker telescope at Mt. Wilson, which saw first light in 1917. Even before Hubble's second great discovery, the 1929 finding that the galaxies were receding with velocities proportional to their distance, George Ellery Hale, builder of Yerkes and Mt. Wilson, was dreaming of a larger instrument to investigate the distant realm of the galaxies.

Francis Pease was an astronomer who worked closely with Hale at Yerkes and Mt. Wilson. He designed the 100-inch Hooker telescope. In 1920, Pease and Albert Michelson (of the 1887 Michelson-Morley experiment that ruled out the existence of the ether, for which he won the Nobel Prize in 1907) measured the diameter of Betelgeuse with an interferometer of Michelson's design on the 100-inch. By 1925, Pease was showing visitors to Mt. Wilson drawings and a model of a 300-inch instrument. Ultimately, it was decided that going from 100 inches to 300 inches was too great a leap for the engineering and construction resources of the day, so Hale and Pease settled for a diameter of 200 inches, still an order of magnitude greater in difficulty compared to the 100-inch even if physically only twice as large. Hale, ever enthusiastic to build another "largest in the world" telescope (his motto was "Make no small plans. Dream no small dreams."), began to raise funds in earnest in 1928 by soliciting the Rockefeller Foundation. Although Mt. Wilson was owned and operated by the Carnegie Institution, they didn't have enough money for a project that was estimated to cost the then-astronomical sum of $6 million. The telescope was to be built and operated under the auspices of the California Institute of Technology, with a support re-


George Ellery Hale

lationship to the more-established and richly staffed Mt. Wilson. This arrangement was useful, but was also a source of tension throughout the building of the 200-inch. A good bit of politics and personalities were in play during this and later stages of the project.

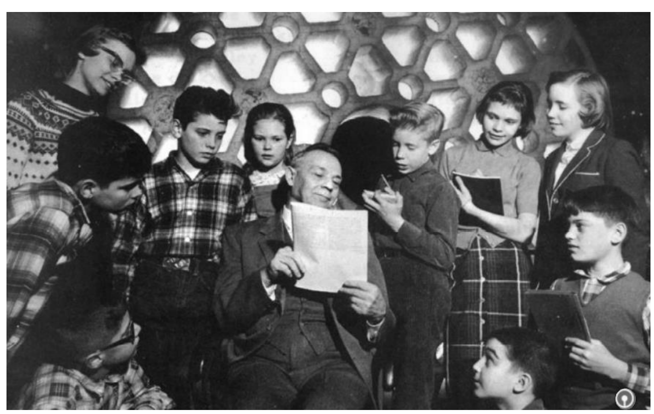
Hale assembled a design team that included Pease and the multi-talented amateur astronomer, telescope maker, artist, architect, surveyor and polar explorer Russell Porter. Pease handled the optics while Porter had overall design responsibility for the telescope itself, including the dome and site plan. The aesthetics of the Hale telescope, so dramatically different from any other astronomical instrument, are a reflection of Porter's artistic sensibilities. Many other astronomers, engineers and constructors were of course involved throughout the project, each providing special expertise, but all were working in *terra nova*, encountering problems that had never arisen with previous instruments. They borrowed extensively from other industries. For example, the scope owes much to the design, manufacture and control of battleship gun turrets. Throughout the project the team encountered and overcame obstacles never faced before. Even its human resources management broke new ground.

The first task was to see whether a 200-inch mirror could even be made. No glass object this large had ever been cast. To minimize thermal effects that would vary the mirror's figure as the observing session wore on, it was decided to make the mirror from fused quartz. Quartz and glass are both made of silicon dioxide, but quartz is purer and has a more regular crystal structure. General Electric was contracted to make the mirror blank. The idea of a ribbed-back design, so prominent on the 200-inch mirror, belongs to GE's Elihu Thompson. Thompson was a British-born inventor whose company, the Thompson-Houston Electric Company, merged with Thomas Edison's corporation to form General Electric in 1892. Thompson held over 700 patents. Among many honors, he was offered but turned down the presidency of MIT. An amateur astronomer, he took an interest in the mirror-making process and realized that by casting the back of the mirror in the form of a honeycomb, weight would be reduced while still maintaining rigidity, and the pockets could serve as mounting locations. Mirror production started in December 1928.

Elihu Thompson

The process of making fused quartz blanks involves applying quartz powder in a furnace that is heated to over 3,000° F by an oxygen/hydrogen mixture. GE's first casting was an 11-inch mirror. This went well, although the blank was not figured and therefore the behavior of the fused quartz in the optical shop was not tested. Scaling up for a larger mirror meant enlarging the ovens, and larger ovens meant more heat and greater working distance for the laborers who had to apply the quartz powder and ensure proper mixing. A 22" blank was a disaster, and repeat experiments with new 11" disks ran into a variety of problems: bubbles, internal striae, iron contamination and an uneven surface that damaged the figuring instruments. GE's last attempt was a 60-inch blank that cracked upon cooling.

GE had sought vast publicity in advance of the (presumed) success of their efforts, and so it was no secret that the project was failing. The efforts ultimately cost three years of work and more than 10% of the project's budget. George McCauley, a physicist who was Chief Scientist of Corning Glass Works' Optical Glass Division, heard of GE's woes. In 1915, Corning had invented Pyrex, a borosilicate glass with improved thermal stability for home and kitchen use. But by 1931, with the Depression in full swing, Corning was looking for new markets so that their workers wouldn't have to be laid off as sales of household glass products plummeted. McCauley thought he could make a 200-inch blank at the Corning factory although it would require the construction of new furnaces and new casting techniques, which he designed. Hale gave up on GE and Corning got the job.



George McCauley with "Junior Curators" at the Corning Museum in a 1959 photograph

Casting large glass objects is more complex than just making a mold and pouring in the molten glass. When the object is going to be as massive as the 200-inch blank, special problems arise. There is no way to melt that amount of glass all at once in a furnace, at least not in the 1930's (Roger Angel at the University of Arizona has now overcome that problem with his rotating oven technique for 8-meter class mirrors). Small amounts of glass had to be poured into the mold on top of existing glass to build up the blank. Asbestos-clad workers used large ladles on tracks to take a dollop of molten glass, swing it around, open a door in the furnace and layer it on top of the blank. This was difficult, fatiguing work. The temperatures were enormous and the noise from the burners deafening. While this technique solves some problems, it can create others: inhomogeneity of the glass layers, stresses, and bubbles. Contaminants such as iron from the metallic parts of the apparatus can infect the growing blank.

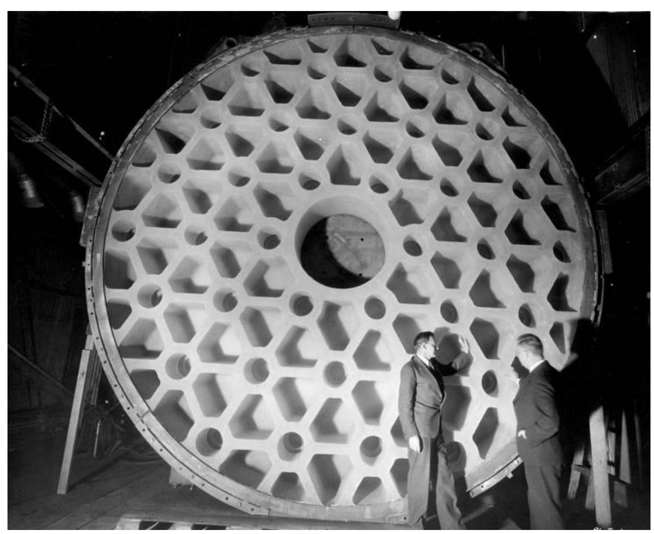
Workers at Corning ladling glass into the oven of the 200-inch mirror

In March 1933, after producing some smaller blanks, McCauley was able to produce a 120-inch blank that was ground flat for testing purposes. With that success, Corning built an even larger oven and a 200-inch blank was attempted.

Another view of glass being ladled into the furnace

The March 25, 1934 pouring was a public event with national newspaper and radio coverage. The popular and influential radio newsman Lowell Thomas had provided breathless reporting of the coming event and spoke of the Hale telescope in superlatives: heaviest, largest, most costly, seeing farthest. He commented that it was "the greatest item of interest to the civilized world in 25 years, not excluding the World War." Tickets to the casting were sold and thousands passed through the Corning works during the day-long pouring. However, the attempt was a failure. Steel bolts holding insulating firebricks on the bottom of the giant mold melted, allowing the bricks to float up into the mirror. They rose to the top and ruined the surface. This mirror is still an impressive object, and is on display at the Corning Museum of Glass.

The furnace was redesigned and rebuilt and a second attempt was scheduled. Unsure of the outcome, McCauley insisted that the public and press not be invited. The pouring was done essentially in secret on Sunday, December 2, 1934. This appeared to be successful, and the mirror was allowed to sit in the annealing oven while electronic heating elements controlled by large, oil-cooled transformers managed the temperature, which had to drop by exactly 0.8° C per day for ten months. Large glass objects have to be annealed: they need to cool at defined rates to avoid internal stresses and cracks. McCauley checked the disk every single day during the annealing process.

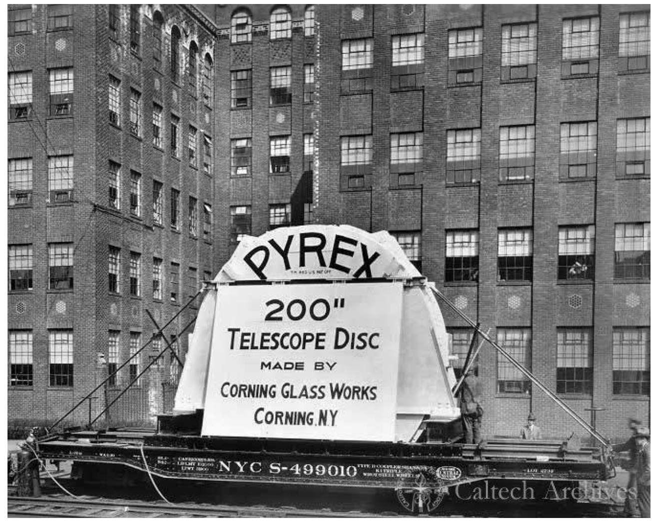


George McCauley and John Hostetter, head of the Optical Glass Division, examine the 200" disk at Corning, 1936

But the drama was not over. In July, torrential rains deluged the Chemung Valley and the river overflowed its banks. The Corning factory began to fill with water, threatening the electrical controllers and transformers that kept the annealing oven working. With every Corning worker called to the task, sandbags, bricks and concrete were laid to try to keep the water from entering the transformer area. When this was unsuccessful and the water was creeping up the sides of the devices threatening to destroy them, McCauley had crews use jackhammers to open a hole in the thick concrete ceiling above the oven. One of the transformers was hoisted to safety and reconnected, and the annealing process was saved.

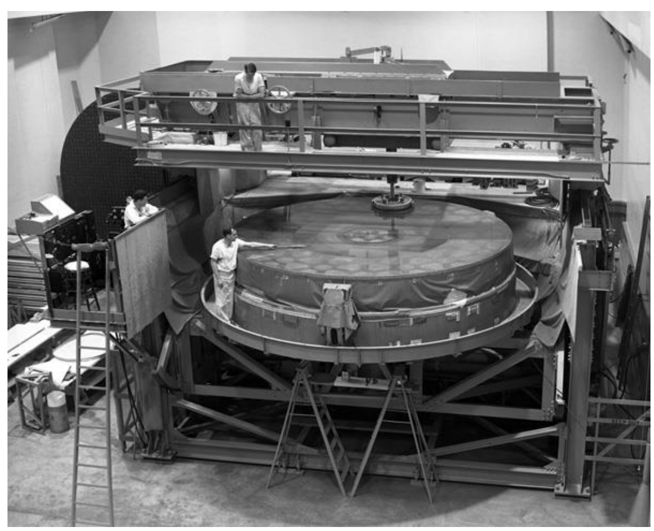
Lifting the crated blank onto a railway car, March 25, 1936

Finally ready, the 14½-ton mirror blank was crated (the Chemung again overflowing its banks just as the moving operation began) and traveled by train across the United States. This was another complicated logistical problem because of the cargo's size and delicacy. A special rail car with smaller wheels and a sunken deck carried the disc vertically. It was too wide to be mounted horizontally. It still towered 18 feet above the rail bed, too high for many underpasses. The train traveled a serpentine path across the country on tracks of 4 different railroad companies. Even with meticulous planning, several unexpected detours were required to get past bridges that were lower than originally documented. The trip was a national event: people lined the tracks to see the miracle of science and engineering pass by. The journey took 16 days with the train never going faster than 25 miles an hour, and then only traveling in daylight. From the terminus in East Pasadena it was moved by truck to the Caltech optical shop, where it was to be figured into an f/3.3 parabola under the direction of Marcus Brown, better known as "Brownie." The figuring and polishing, which had to be accurate to 2/1,000,000 of an inch, was a meticulous and difficult process that began in 1936 and was essentially finished only in 1947 (interrupted for 3 years by World War II, which took workers away from the project). As good as it finally was, figuring by hand continued even after the mirror was mounted on the telescope at Palomar.



The crated blank loaded on its special railway car at the Corning factory.

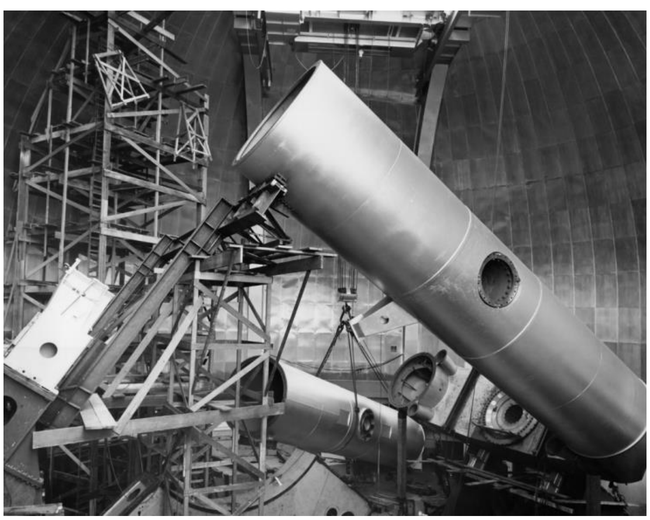
While all of this was going on, the telescope designers were trying to come up with a mounting that could handle the weight and stress of the large mirror while still tracking with pinpoint accuracy and without any vibrations or flexure that would destroy the collimation or ruin images.



Polishing in the Caltech optical shop

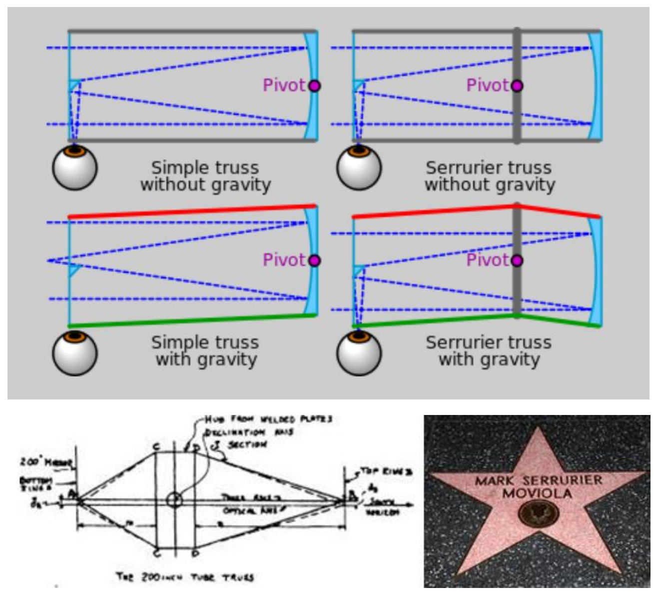
Although Pease's initial concept was for a fork mount like the 60-inch at Mt. Wilson, it was realized that the pressure on the bearings at the bottom of the telescope would be too great. Russell Porter's split horseshoe design had the rigidity of a yoke but allowed access to the entire sky, unlike the 100-inch Hooker with its pure English yoke. The scope's ground-breaking oil bearings were designed by a Westinghouse engineer who was new to telescope design, Rein Kroon. He was able to demonstrate that a thin layer of oil could support the weight of the telescope with much less friction than roller bearings. He convinced all the nay-sayers, including Pease. As a result, slewing of the 530-ton telescope in the polar axis is accomplished by one 3-horsepower motor and in declination by a 1-horsepower motor. Tracking is done by a separate 1-horsepower motor, which in 2014 replaced the original $^{1}/_{12}$ horsepower motor. The scope is essentially in perfect balance (by the way, that's a message for all amateurs: balance your scopes properly and they will slew and track much more accurately).

To minimize the weight of the mount while still providing maximum stiffness, many of its components, including the giant horseshoe upper polar bearing and the yoke struts, were welded rather than riveted. Much of the manufacturing took place at Westinghouse's South Philadelphia plant; Westinghouse had been one of the contractors for the Hoover Dam (constructed 1931-1936) and had experience welding large, complex structures for that project. The sections of the struts and horseshoe were transported by ship, train and truck to Mt. Palomar and welded into their final configuration on site.



The Hale mount under construction

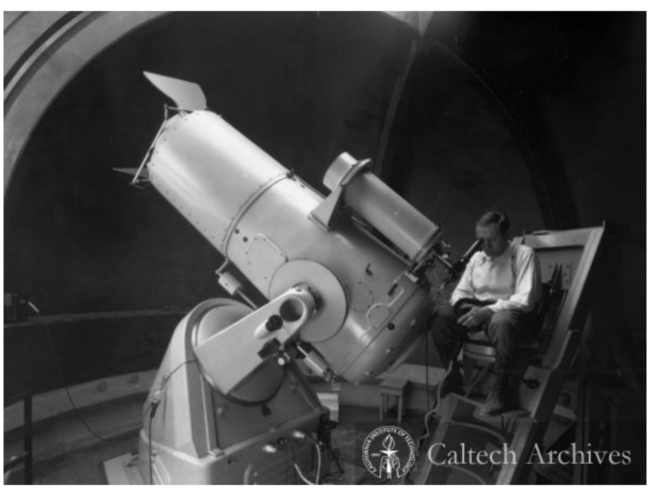
The mirror's enormous weight posed a problem for the design of the supporting tube. Even the strongest steel would flex a tiny amount under the uneven weight distribution of the tube and the resulting misalignment would decollimate the optics and destroy the image. Engineer Mark Serrurier figured out what was later called the "Serrurier truss," a system of support members that would create an equal amount of tube flexion above and below the declination pivot at any altitude of the tube, keeping the center of the mirror parallel and precisely aligned with the center of the secondary. This system is now used in all large telescope designs, as well as in smaller telescopes such as the 12-24" open-tube Dall-Kirkham astrographs made by PlaneWave and others for the amateur market, although the actual amount of flexion is nil in these instruments. Serrurier's father invented the Moviola film editing machine in 1924, and after World War II Serrurier took over the business. In 1979 he received an Academy Award for Technical Achievement and a star on the Hollywood Walk of Fame.



The Serrurier truss system, Serrurier's original drawing and his star on Hollywood Boulevard.

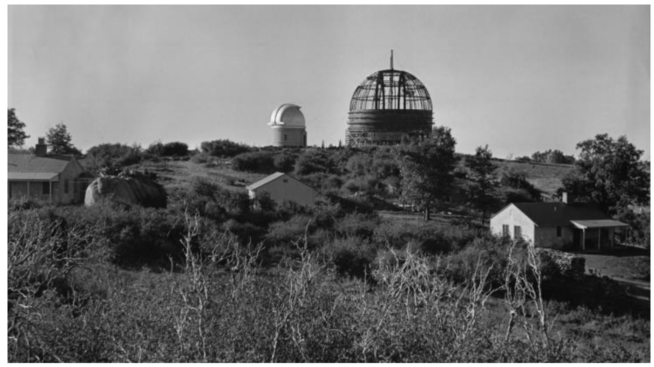
Another problem for the mount was the control mechanism that would be needed to precisely command the movements of the instrument. The complicated system would have to account for irregularities in the Earth's rotation caused by our planet not being exactly spherical and by gravitational effects from the Moon's slightly elliptical and inclined orbit, as well compensating for atmospheric refraction as the telescope's position varies in altitude. Caltech physicist and researcher Sinclair Smith, an expert in electronic detectors and controls, designed an ingenious but complex system to control both the telescope and the dome, making use of a "phantom telescope" that lives in a cabinet near the Coudé focus room (see my article in last month's Sky*WAA*tch). Smith's work was tragically interrupted when he developed cancer and died in 1938 at the age of 39. Edward Poitras completed the design.

Hale had strong views about the new observatory's location. He recognized that light pollution from urban development in Los Angeles was rapidly deteriorating the value of Mt. Wilson as a deep-sky observatory. Sites throughout the southwest and even northern Mexico were proposed. A southern hemisphere location was suggested by Harlow Shapley, who had left Mt. Wilson in 1921 to become the head of the Harvard College Observatory, which operated a telescope in Peru. Hale knew that a modern observatory couldn't be too remote from its optical, engineering and academic supports. The seeing in candidate locations was assessed with 6-inch refractors designed by Russell Porter. By 1934, the site selection committee settled on Mt. Palomar, far enough away from Pasadena and San Diego to be dark (and presumed to remain dark forever), but reachable from Pasadena by decent roads in a few hours. A relatively primitive road to the mountaintop already existed, called the Nathan Harrison Grade. It had been hacked out of the mountain by Harrison, a slave who came to the area as a miner in 1848. He lived on the mountain year-round, dying in 1920 at age 107. This rough road was on the west side of the mountain, providing access to several hotels that operated each summer. It was eventually replaced by the South Grade Road, the current route to the observatory and the road that the mirror traveled when finally brought to the site.



Fritz Zwicky at the 18-inch Schmidt

Once the mirror arrived in Pasadena, construction on the mountain began. The first instrument to become operational was an 18-inch Schmidt astrograph, now decommissioned and on display in the Greenway Visitor's Center at the observatory. This telescope was suggested by Fritz Zwicky, designed by Russell Porter and engineered by Caltech optician John Anderson, control genius Sinclair Smith and engineer Albert Brower. The actual field of view at the focus of this f/2 telescope is 8.75 degrees. As in all Schmidt astrographs, the detector is not an eyepiece but a piece of film cut to size (in this case 6 inches in diameter) and applied to a curved film holder since the focal plane of this optical design is not flat.



The observatory with the 200-inch dome under construction and the 18-inch Schmidt dome to its left.

World War II slowed down construction but after the war, the project finally came together. Hale and Pease both died in 1938 and others took on the management of the venture. While the work on the mounting and dome was essentially completed in 1939, the mirror didn't arrive until 1947. The "Big Eye" left the Caltech optical shop on November 18, 1947 in a truck convoy, arriving on the mountain the next day. Three large diesel trucks, one in front and two behind, were required to get the mirror safely up the South Grade Road. It rained heavily during the ascent.

The mirror on its way to the mountain, Nov. 18, 1947

It took nearly two years of further development and testing to ready the telescope for astronomical use. Even after installation the mirror required additional polishing when some areas were found to be slightly off. Thirty-six mirror mountings, complex mechanical counterweighted mechanisms situated in the hollows of the honeycombed back, were complemented by 12 equally complex edge-support compensators to eliminate astigmatism that resulted from mirror flexion at different telescope positions. The final corrective adaptation was installed in 1949 when four cheap fisherman's scales were fitted to supports on the back of the mirror to add just a few pounds of tension. They are apparently still there.

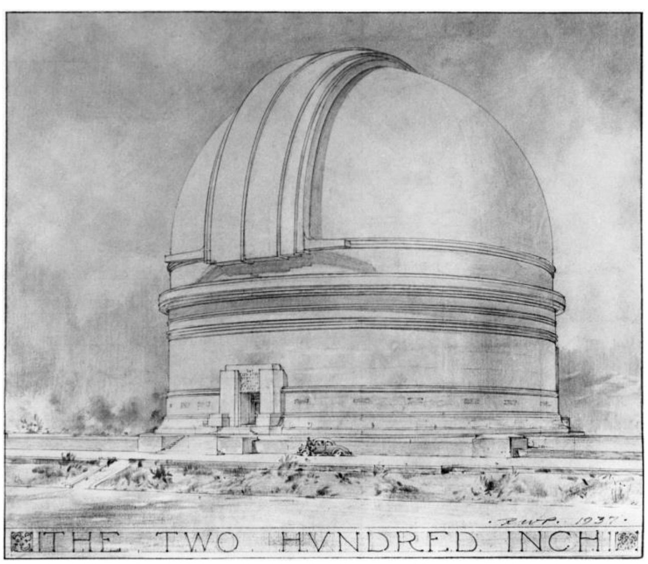
Dedication ceremony, June 3, 1948

First light was on December 22, 1947. The images were not very good, and further adjustments were required. One of the problems was vibration in the mount, which was caused by Kroon's oil bearings being *too* good. Some friction had to be added to damp out vibrations from the drive motors. Testing, adjustments and modification occurred throughout 1948. A dedication ceremony took place on June 3, 1948, with many invited guests, including Hale's widow Evelina. Vannevar Bush, head of the Office of Scientific Research and Development during World War II and initiator of the Manhattan Project, gave the keynote speech. During his talk a lark flew into the dome through its open shutters and most of the audience reportedly watched the bird circle high above the telescope. Bush announced, as most people expected, that the telescope would be named in honor of George Ellery Hale.

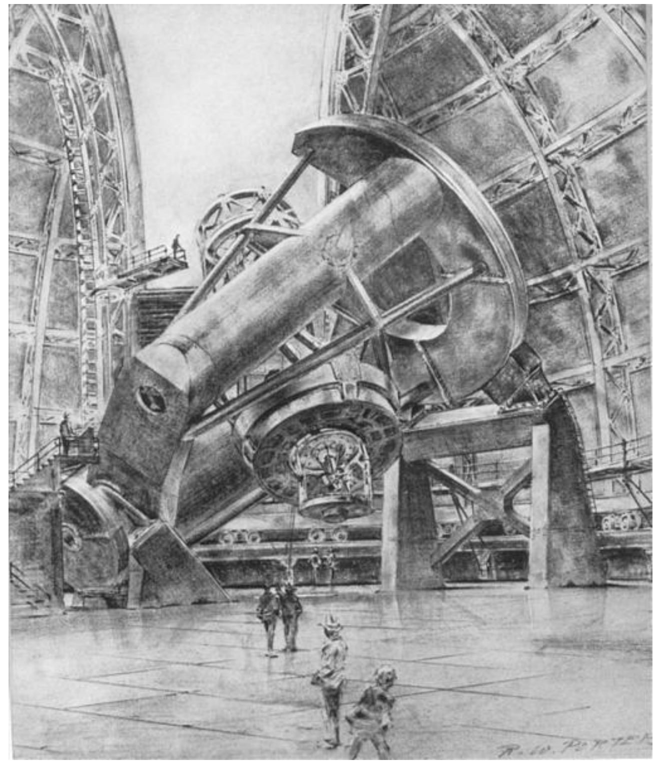
On the night of January 26, 1949, Edwin Hubble was given the honor of making the first image with the new telescope. He rode up to the primary focus cage and put a glass plate in the holder. The telescope slewed to NGC 2261 in Monoceros, now known as "Hubble's Variable Nebula". When the plates were developed in the darkroom inside the dome below the telescope level, Hubble was satisfied. He later commented that "exposure of five or ten minutes" could record stars that the 100-inch Hooker couldn't see in an entire night. Figuring of the mirror, sometimes involving single strokes with a thumb and the polishing mineral barnesite, continued until November 1949, when Ike Bowen, the observatory's first director, declared the mirror officially finished and the 200-inch Hale telescope became an official astronomical research instrument. It is still productive today.

First image from the Hale Telescope

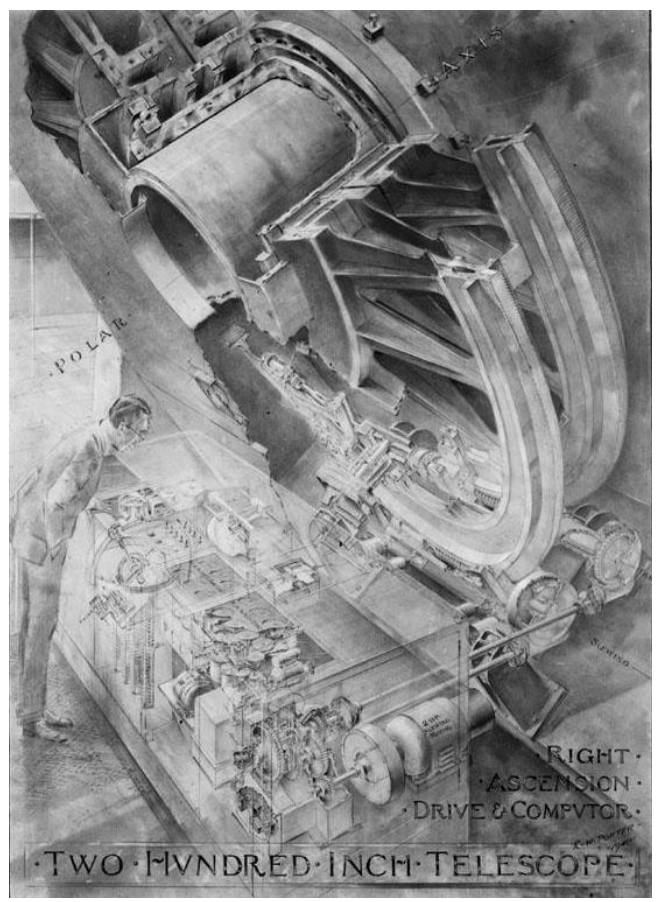
The full story of the building of the Hale Telescope is much more dramatic than this brief sketch can capture, and there are countless worthy details, remarkable personalities and twists and turns to the story than I've related here. I learned about them from a remarkable book that is an absolute "must-read" for anyone interested in astronomical history, *The Perfect Machine* by Ronald Florence, published in 1993. I found this book serendipitously the day after Elyse and I visited the telescope with JPL astronomer Charles Lawrence, as described in my SkyWAAtch article last month. We had decided to spend what promised to be a beautiful sunny spring day at the glorious Huntington Library and Gardens in San Marino, the town just east of Pasadena. We arrived dutifully 10 am, the time we expected it to open. However, that day opening was delayed until noon. So to kill two hours, we did what we usually do when we need to fill a hiatus in an urban area: we hunted for a used bookstore. Pasadena, being a university town, should have a good one and sure enough we found Book Alley, on Colorado Boulevard a few blocks east of the city's upscale downtown. The science and astronomy section was well-stocked. I had to exert enormous self-control to keep my selections from potentially overloading our baggage weight limit on the return flight. So among the large number of titles I wanted but had to pass up was a first edition of Fred Hoyle's 1950 *The Nature of the Universe*, with its creatively wrong exposition of the steady-state theory. I did take home a biography of Edwin Hubble as well as Michael Shermer's *Why People Believe Weird Things*. But the jewel was a fresh paperback copy of Florence's book, which cost me just $6. It's a tremendously detailed and perceptive work, and through 400 pages it never flags. My copy is inscribed "Paul Dimotakis April 2003" and, as is my practice when the opportunity arises, I tried to find out something about the prior owner. In this case, it was pretty easy. Dimotakis is the John K. Northrop Professor of Aeronautics and Professor of Applied Physics at Caltech and the Chief Technologist at the Jet Propulsion Laboratory. He must have culled his library at some point, and I'm sure he was just too busy to think he could ever get to *The Perfect Machine*. I shall have to write him and recommend it, maybe even send my (I mean his) now slightly dog-eared copy back to him. Amazon has plenty of copies, including a version for Kindle, so don't pass up the opportunity to read the compelling story of one of the greatest scientific instruments of all time. ■



Porter's drawing of the dome

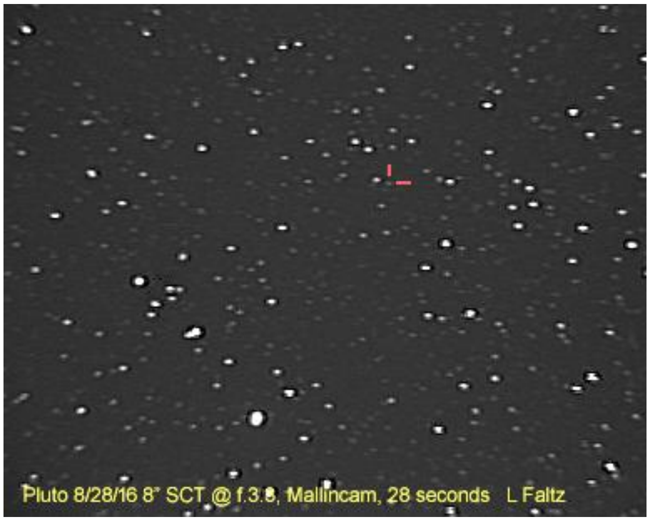


The view from the eastern side of the telescope



Porter's cutaway drawing of the lower polar bearing

More on Viewing Pluto
Larry Faltz



Following up on the publication of the above photo in last month's SkyWAAtch, I thought I'd relate the story about how this image came about. Until late August, I had never considered looking for Pluto. Its faintness (magnitude 14.2 now) makes it an unreachable visual object, just at the theoretical magnitude limit of my biggest scope (8 inches), but put beyond it by my slightly cataracted, incompletely dilatable senior citizen eyes and our light-polluted WPR skies. (There's a good limiting magnitude calculator on the Internet). Even for young people with perfect eyesight it would be hard to distinguish visually from the background stars. To do so, you would have to keep moving from scope to star map and back again, and your dark adaptation would not keep up. But with all the spectacular news over the past year from the New Horizons mission, it occurred to me to give it a try with my Mallincam. In 2010, John Paladini and I found and imaged the Twin Quasar in Ursa Major, QSO 0957-561 A/B, a 16.7 magnitude object (although we didn't resolve it because of the focal length we were using) so I figured 14.2 magnitude Pluto shouldn't be that hard, especially since I upgraded to the Mallincam Xterminator, which has a more sensitive Sony imaging chip than the Mallincam I had been using before.

This year, Pluto is travelling through the constellation Sagittarius, smack dab in the center of the Milky Way. To be able to pick it out, I made finder maps with Cartes du Ciel, one of them with the approximate field of view of the camera, 46x34 arc-minutes, just a little larger than the full moon. One nice feature of the camera is that you can flip the camera's output vertically or horizontally to orient the video image exactly like the real sky (and the star map) and not have it image-reversed as if viewed with an eyepiece. I could get more magnification by taking out the focal reducers that are in the optical train, but if the field is smaller it's harder to recognize star patterns for orientation and the amount of light delivered to the sensor drops substantially. An f/10 telescope operating at f/5 will deliver 4 times the amount of light to the focal plane at ½ the magnification and 4 times the field area. Increasing exposure time to compensate runs the risk of field rotation since the scope is on an alt-az mount.

The August 27th Starway to Heaven star party was blessed with good weather and reasonably clear skies until well after 11 pm. There were quite a few scopes and many visitors. I aligned Locutis, my 8" Celestron CPC800 dressed up in full mufti for video display with two screens, two computers and four power supplies, dew heaters and wireless scope control. I selected Pluto as the go-to target and the telescope slewed to the position. There were a large number of stars on the video display. Somewhere in there was the planet, hopefully bright enough to be seen. I located Pluto within a couple of minutes. It was, as expected, a tiny dot, just off the northwest side of UCAC4-344-176359, a 13.07 magnitude star.

As small and undistinguished as it was on the screen, Pluto seemed to be a hit of the evening for many of the attendees who came over to look when the buzz went through the field that it was on screen.

I tried to make some video captures, but perhaps due to a microscopic black hole that temporarily occupied a critical area of my grey matter, I messed up the capture software and no images were saved. When I found that out Sunday morning, after the profanity ceased I resolved to try again that evening. Elyse and I went back up to WPR after dinner and I set up Locutis with, one screen and one computer, with just Pluto as the target. This time, I made sure to verify that the captures had been saved.

The purpose of making a capture of a Mallincam video image is to produce a record the event, not to create an artistic astrophoto. The Mallincam is not really an astro-imaging camera. It's based on a relatively mundane security camera chassis modified for long exposures and given the latest video sensors and unique video amplification circuitry. Sensitivity and rapid image transfer are substantially achieved by a small number (0.38 megapixels) of large pixels, 82.3 square microns each. It has an advantage over DSLRs or true astro-imaging cameras in that it has a buffer that displays the prior image while a new one is being acquired. Its low-light performance is assisted by Peltier (thermoelectric) cooling to reduce noise from the device's internal electronics. The video-USB converter I use, typical of those available on the market, is a weak link. It has relatively poor low-light performance. It does well pulling bright images off of a television, but for astronomical images the captures lose some fidelity and contrast. Nevertheless, a little post-processing can make up partially for the deficiencies. I thought the screen image was superior to the capture, even with processing.

The image shown is a single frame, captured for 28 seconds, without any additional in-camera amplification. I darkened the background and cropped the image with Photoshop. The field of view is 25x20 arcminutes (0.42x0.33 degrees), about the same as you would get with a 52-degree Plossl eyepiece at 125x.

One of the challenges observing Pluto this year is that it's low in the sky: its altitude was 27° 17' when I made the capture. The airmass at that elevation is 2.2, meaning that the photons travelled through more than twice as much air than if it had been at the zenith, with more than twice the thermal currents and atmospheric particulates to degrade the image. The average optical extinction is about 0.3 magnitudes per unit of airmass in our area. Also, Pluto's azimuth of 184° 29' took the line of sight from WPR over the light dome of Greenwich, Connecticut and then the center of Nassau County (Glen Cove, Mineola, Garden City, Rockville Center, Oceanside and Long Beach). But the camera can cut through that mess pretty well, and Photoshop can remove some of the background glow.

On Sunday night, the planet had moved 40" to the west of its position Saturday, and was now on the right side of UCAC4-344-176359. Since I had failed to make a capture on Saturday, I will have to rely on fellow WAA'ers who viewed it with me to testify that indeed it was to the upper left of the star Saturday. I recalled the signed affidavits by friends of Joseph Smith who claimed that they had actually seen (and some had handled) the golden tablets of the Book of Mormon. The testimonials, given in 1829, were needed because the angel Moroni told Smith he could not keep the divine pages. Or so they said.

Paul Alimena, WAA's Vice President for Membership, was probably the only person Saturday night who was seeing Pluto for the second time. He and WAA member Rick Bria, who operates the telescope at the Stamford Observatory, viewed the planet a few years ago with the observatory's fine 22-inch instrument. Paul will attest to Pluto's position on Saturday. I trust him…he's my dentist.

Pluto is moving away from the inner solar system. It's now 32.52 astronomical units from the Sun. Each year it will be just a little lower in the sky at culmination and a little further away. Its brightness won't change much: 10 years from now it will be in Capricorn, 34.7 AU distant, magnitude 14.5, 25° above the horizon at culmination in late August 2026. We should be able to demonstrate it at future late-summer star parties. It's about the most excitement you can have with one single pixel on a video screen.

So now for the question everyone asks any time the word "Pluto" is mentioned: Is it a planet? The answer is, I don't know and actually no one else knows, although most people seem to want it to be one. The classification of natural phenomena by human beings is by definition arbitrary, approximate and usually temporary, merely models of reality that allow us to control and extend scientific discourse. It's not absolute truth, but a registration point around which we can formulate our thoughts, even if we disagree. As more is discovered about bodies that circulate around stars, the classification of "planets" will evolve, just as new discoveries in biology, medicine, chemistry, geology and all the other sciences influence the classification of their subject matter. My own feeling is that *all* planets require an adjective modifier, one that gives some information about what they really are: rocky, gaseous, icy, etc. Size is less important.

At NEAF in April 2016, I attended Alan Stern's talk on the New Horizons mission. Before discussing the remarkable results from the Pluto fly-by, Stern got exercised about the newly announced prediction by Caltech astronomer Mike Brown that a large, distant body might be influencing the orbits of Kuiper Belt objects. Brown referred to this theoretical object as the Ninth Planet. With Clyde Tombaugh's elderly son and daughter in the audience, Stern got red-faced when he rebuked Brown for having "insulted" the memory of Tombaugh. Then Stern showed that wonderfully detailed image of Pluto from New Horizons, heart-shaped Tombaugh Regio prominently visible in its center, and said, "This looks like a planet to me." The audience burst into cheers. *Vox populi, vox dei.*