SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

November 2019

The Orion Nebula

On a cold night in February, Arthur Rotfeld captured this excellent image of M42, M43 and, on the left, Sharpless 279, better known as the Running Man Nebula (composed of NGC 1973, NGC 1975, NGC 1977 and the open cluster NGC 1981). Explore Scientific 80 mm apochromatic refractor, Orion Skyview Pro go-to mount, Canon Rebel T6i ISO 800, 90 second exposure edited with MacPhoto. Also see this month's Research Highlight on page 14.

WAA November Meeting

Friday, November 1st at 7:30 pm

Lienhard Hall, 3rd floor
Pace University, Pleasantville, NY

Christopher Clavius & the Gregorian Calendar

Paul R. Mueller, S.J., Ph.D.
Superior of the Jesuit Community and Vice Director, Vatican Observatory, Castel Gandolfo, Italy, and Tucson, Arizona

In this year marking the 480th anniversary of the birth of Christopher Clavius, S.J., it seems appropriate to focus on his life and legacy. That legacy ranges from the Gregorian calendar, which is the calendar that we all use today, to the Stanley Kubrick film *2001: A Space Odyssey*. It ranges from popular textbooks to worldwide curricular reform. And it ranges from the history of science in China to the Vatican Observatory, which Pope Gregory XIII established in 1580 to help confirm and refine astronomical observations made in support of Clavius' reform of the calendar. Paul Mueller, S.J. will explore Clavius' life and work in their early and modern contexts and illuminate his enduring legacy for modern science, religion, and culture.

Pre-lecture socializing with fellow WAA members and guests begins at 7:00 pm!

New Member

Pavithra Harsha	Pleasantville

Renewing Members

Bill Caspe	Scarsdale
Parikshit Gogte	Chappaqua
John Higbee	Alexandria, VA
Bob Kelly	Ardsley
Matthew Leone	Fishkill
Robert Lewis	Sleepy Hollow
Emmanouil Makrakis	Scarsdale
William Newell	Mt. Vernon
James Steck	Mahopac
Cathleen Walker	Greenwich

WAA December Meeting

Friday, December 6th at 7:30 pm

Lienhard Hall, 3rd floor
Pace University, Pleasantville, NY

The History of Glass: The Power Behind Discovery

Alan Witzgall
Senior Optician, ESCO Optics

Alan is an active member and officer of several amateur astronomy societies in New Jersey. In his professional life, he is a Senior Optician for ESCO Optics of Oak Ridge, NJ. His career in optics started with building telescopes in his basement during his high school and college years. In 1977, one of them, a 10-inch reflector, took first award at Stellafane, the birthplace of the amateur telescope-making hobby in America.

Mr. Witzgall has been "pushing glass" for a living for over 40 years, and will speak on how his favorite material has built the modern world and opened up all sciences and technologies.

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

Starway to Heaven

Ward Pound Ridge Reservation,
Cross River, NY

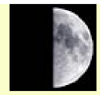
The last regular star party of the year is scheduled for Saturday, November 23rd, with a rain/cloud date of November 30th. Dress for the cold! Formal star parties will resume in March 2020.

For directions and link to Google Maps, click http://bit.ly/waastarparty.

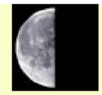
Also In This Issue

ALMANAC For November 2019

Bob Kelly, WAA VP for Field Events


1Q
11/4


Full
11/12


3Q
11/19


New
11/26

Saturn and Jupiter are joined by Venus in the evening sky. Venus is very low in the sky, despite moving further east from the Sun this month. If you draw a line with your mind connecting Venus, Jupiter and Saturn, you'll see how shallow the ecliptic, the apparent path of the planets, is in our northern hemisphere skies. Venus sails less than 10 degrees from the horizon by dusk all month, even when 25 degrees away from the Sun. Don't worry: we'll be seeing Venus in the evening sky through next June. Guy Ottewell's blog shows Venus's loop across the evening sky: (https://www.universalworkshop.com/2019/10/14/venus-from-now-to-next-june/. Jupiter-set goes from 7 pm Eastern Standard Time on the 8th to 6 pm by the end of the month. Saturn follows half an hour later.

Venus scoots under Jupiter, closest on the 22nd. The two brightest planets (from Earthlings' point of view) being so low and so close in the sky will startle quite a few people who chance upon them. Compare Venus and Jupiter in a telescope. Venus is vastly brighter, but one-third the width of Jupiter.

Mercury photobombs our Sun as seen from Earth from 7:35 am to 1:04 pm EST on Monday the 11th, a Federal holiday. See our Larry Faltz's article on page 6 for the excitement, history and essential caution and warning statements.

Then, as if burned by the Sun, Mercury races into the morning sky, reaching 20 degrees east of the Sun by the 28th. Compare the colors of Mars and nearby Spica low in the southeast in the pre-dawn sky. They are closest around the 10th. The Moon points the way to Mars and Mercury on the 24th and 25th. Mercury never gets up to Mars's altitude above the horizon.

Traveling for Thanksgiving? Bring your host the gift of showing them the crescent Moon low in the southwest, appearing to hover over three bright planets (from left to right) Saturn, Venus and Jupiter. See the graphic for a map.

Will it be dark enough to see Sagittarius before it dives into your neighbors' houses?

If you are traveling westward by aircraft just after sunset, watch for Venus low in the southwest, its setting prolonged by your rapid westward travel offsetting some of the speed of the Earth's rotation.

Ice giants Uranus and Neptune are out there floating amid the lesser lights of Aries and Aquarius, respectively. Follow the upper-right side of the Square of Pegasus down to Neptune and the lower-right side of the Square to Uranus. It's a bit of a trip, so finder charts are useful when you approach their neighborhoods. Once you get there, these blue brothers are definitely non-stellar in a telescope.

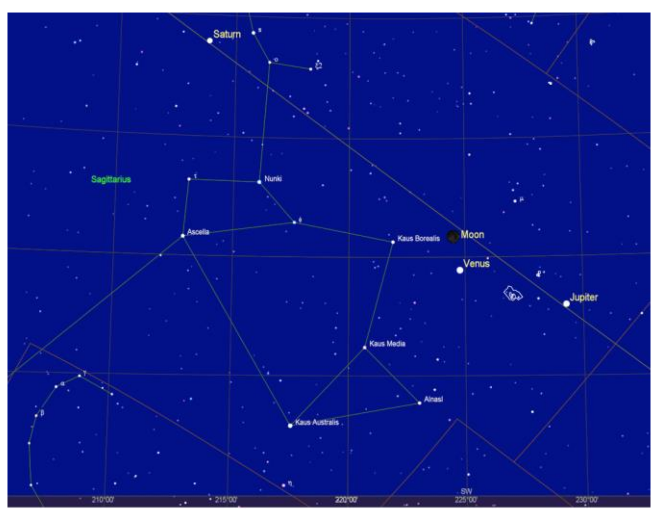
The Leonid meteors peak about and after midnight on the 17th/18th. The waning gibbous Moon is up, so it's a washout for the dozen or so meteors an hour. Leonids were a legend in their day.

Pluto and Saturn are hidden by the Moon twice this month, and Jupiter once. None of these invisibility events are visible from USA.

The Big Dipper swings as low as it can go in the evening sky as we end the month. This past month, just before dawn, I could see it in the northeastern sky, framed by my storm door window, doing a handstand on its handle. Since it never sets at our latitude, you can look for it evenings and mornings.

Sunrise jumps from 7:26 am to 6:28 am because of the "fall back" to standard time on the 3rd. The Sun still rises after I get up in the morning, so the time change doesn't help me to get out of bed but now I won't see the stars when I get up.

The International Space Station is visible mornings through the 14th and in the evening starting on the 20th.



Member Profile: Cat (Catalina) Hannon

Home town: Peekskill, NY

How did you get interested in astronomy? My mother was interested in astronomy and the space race, and kept her children informed as well as repeatedly taking us to planetariums – her enthusiasm was highly infectious. My father's job moved us all over the world during my childhood so we got the chance to observe the European and North American skies as well as South American ones although only with binoculars on a very amateurish level.

Do you recall the first time you looked through a telescope? What did you see? I was probably around 10 or 11 years old. One of the neighborhood children got a beginner's telescope and I remember looking at the Moon.

What's your favorite object(s) to view? The Moon, planets and constellations (especially in the winter sky.)

What kind of equipment do you have? Orion 09007 SpaceProbe 130ST Equatorial Reflector Telescope, Celestron - 70mm Travel Scope – Portable Refractor Telescope

What kind of equipment would you like to get that you don't have? I am too new at this so I honestly don't know yet.

Have you taken any trips or vacations dedicated to astronomy? Not yet but I always have my favorite (and sharp) Celestron 71198 Cometron 7x50 Binoculars in the car, ready to observe. I stopped the car while driving home just the night before I wrote this to jump out and look at the (orange) Moon. The travel scope also comes on weekend trips in case I get a chance to view.

Are there areas of current astronomical research that particularly interest you? Pluto, exoplanets, future missions to the moon and Mars, planetary defense –the Tunguska anniversary falls on my birthday!!

Do you have any favorite personal astronomical experiences you'd like to relate? These are still early days for me but looking though the various of telescopes of fellow WAA members is always thrilling. When I come to star parties, I never know what I am going to see that night.

What do you do in "real life"? I am the Research Librarian for Historic Hudson Valley. My fields are history and librarianship, and I take care of and work with old and contemporary books, manuscripts, maps, etc., dealing with the history of my museum's historic houses and the last four hundred years in the Hudson Valley, as well as assisting staff and outside researchers with projects, inquiries, fellowships, grants, and much, much more.

Have you read any books about astronomy that you'd like to recommend? I have no background in science bur I do read books on astronomy for people at my "level." Since my field is history, though, here are some which combined both disciplines, and that I greatly enjoyed, some of them more than once:

- *Chasing Venus: The Race To Measure the Heavens* (Andrea Wulf)
- *The Day the World Discovered the Sun: The Extraordinary Story of Scientific Adventure and the Race to Track the Transit of Venus* (Mark Anderson)
- *The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy* (Emily Winterburn)

- *America's First Great Eclipse: How Scientists, Tourists, and the Rocky Mountain Eclipse of 1878 Changed Astronomy Forever* (Steve Ruskin)
- *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race* (Margot Lee Shetterly)
- *Chasing New Horizons: Inside the Epic First Mission to Pluto* (Alan Stern and David Grinspoon)

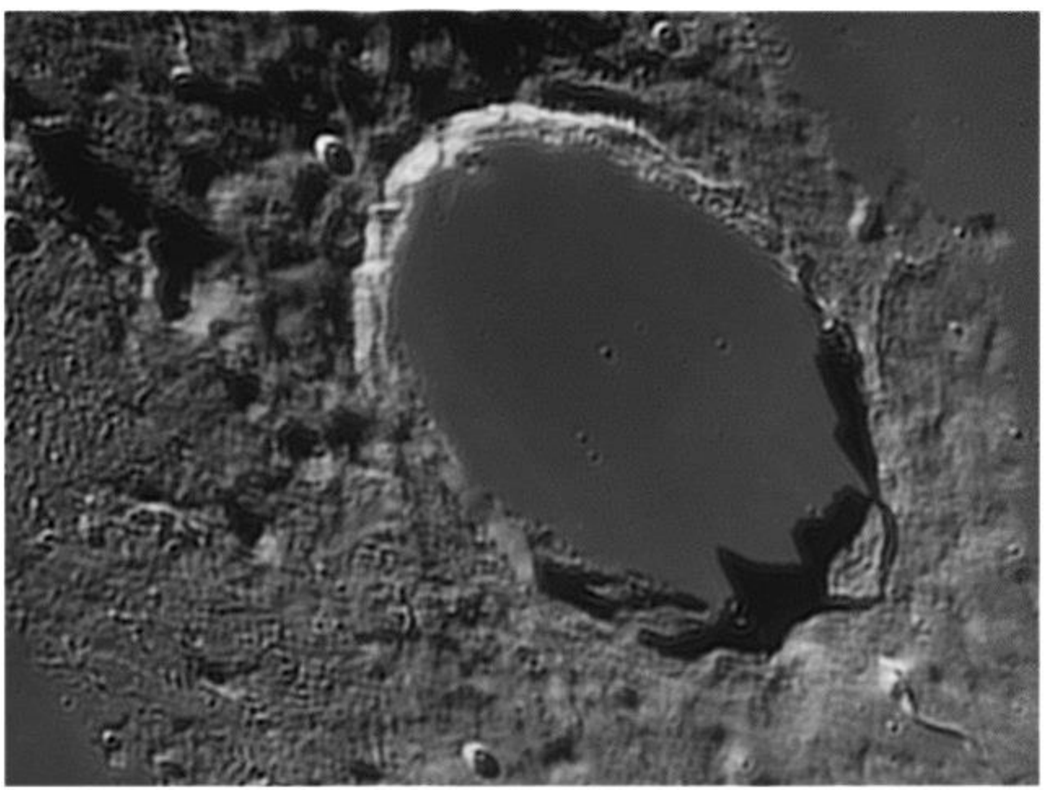
This last book blends science with recent history and the nightmares of writing grants, something which, working in a museum, is all too familiar to me!

How did you get involved in WAA? Instead of taking courses in astronomy, I wanted hands-on experiences with knowledgeable people, and found a group that also allowed me to observe using different kinds of telescopes and hear about many different of projects and topics through discussions and the lecture series.

What WAA activities do you participate in? Star parties, outreach events, the lectures at Pace and related events that are promoted by WAA, and the annual picnic.

Provide any other information you think would be interesting to your fellow club members, and don't be bashful! Although I have had a passion for history all of my life and have a special interest in the 16th, 17th and 18th centuries' history of astronomy, I feel that astronomy itself is the ultimate experience in living history. I like to know when light left particular stars, and then remember the historical events associated with that time period. I am an avid "needleworker" (knitting, sewing, quilting, rug hooking, stitching) and have used celestial inspiration for some of my work - a knitted solar system, miniature galactic objects as well as a cross-stitched chart of the phases of the moon. I also love 1950-60s science fiction movies, and will admit to being a Trekkie.

Plato by John Paladini



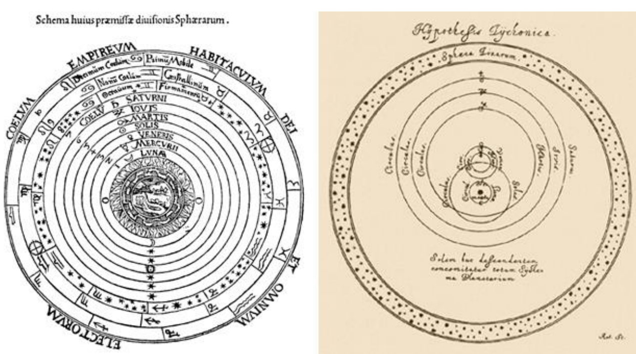
John Paladini captured this lovely image of Plato on September 21st. from his driveway in Mahopac He used a Celestron 9.25-inch SCT, a 2x Barlow to give f/20 and a ZWO ASI120MM planetary camera. He stacked 200 frames with Registax.

The crater is actually round, its ovoid appearance the result of it being at lunar latitude 51.39 degrees. The lava-filled crater is 101 km in diameter. There are a few young craters pockmarking the interior. The walls are up to 2 km high. The crater is estimated to be 3.8 billion years old, forming just after the large Mare Imbrium to its south.

The Transit of Mercury

Larry Faltz

This month's transit of Mercury on Monday, November 11, 2019, will be the last one until November 13, 2032 and the 53rd viewed by astronomers. Mercury transits occur about 13 times a century, in early May and early November when the orientation of the planet's orbit relative to the ecliptic, the plane of the Earth's orbit around the Sun, creates a syzygy (a word that every writer wants to use!) It's an event worth seeing if only because of its historical importance. Unlike the much rarer transit of Venus, of which only 7 have been observed, transits of Mercury didn't have much value for determining the astronomical unit, as proposed by Edmund Halley. Mercury is just too small: timing the exact moment that its edge crosses the Sun's limb is much more difficult than for Venus, which is hard enough because of the "black drop" effect. Because Mercury is never more than 27 degrees from the Sun, it cannot be observed without the Earth's atmosphere having a substantial impact on image quality. For most apparitions, the planet is close to the horizon, where refraction can substantially displace it from its true position. At least during the transits it can be measured against the Sun's disk, whose position can be reasonably well tied down and whose orbit is precisely defined.



(L) Ptolemaic System. Peter Apian, *Cosmographia*, 1524. (R) Tychonic System. Johannes Hevelius, *Selenographia*, 1647

The Chaldeans had astronomical tables that tracked the planet. They knew that it could be in the morning sky or the evening sky, but was always close to the Sun. In the Aristotelian/Ptolemaic geocentric plan of the heavens, Mercury was outside of the Moon and interior to both Venus and the Sun. When the geocentric system was overthrown by Copernicus, it moved into its rightful place as the innermost planet. Copernicus himself never saw it, complaining about both his latitude and observing conditions in *De Revolutionibus* (Book V, Section 30).

> The ancients have directed us to this method of examining the movement of this planet, but they were favored by a clearer atmosphere at a place where the Nile—so they say—does not give out vapors as the Vistula does among us. For nature is rare; and furthermore on account of the great obliquity of the sphere it is less frequently possible to see Mercury, as its rising does not fall within our vision at its greatest distance from the Sun when it is in Aries or Pisces, and its setting in Virgo and Libra is not visible; and it is not apparent in Cancer or Gemini at evening or early morning, and never at night, except when the Sun has receded through the greater part of Leo. On this account of the planet has made us take many detours and undergo much labor in order to examine its wanderings. On this account we have borrowed three positions from those which have been carefully observed at Nuremburg.

Copernicus knew that Mercury would pass in front of and behind the Sun periodically although his tables were not refined enough to make specific predictions. The three "borrowed" observations were compared to rough data in the *Almagest* and the Alphonsine Tables (1483), the latter compiled in Spain from Islamic sources and some local observations in Toledo. In addition, Copernicus assumed that the movements of all the planets were circular, and he made his calculations on the basis of epicycles and eccentrics.

Fortunately for scientific astronomy, in 1576 King Frederick II of Denmark granted the astronomer Tycho Brahe title to the island of Hven and funding to set up an observatory, which Brahe christened "Uraniborg." This gift was the result of Brahe's fame after his observations of the Supernova of 1572. His status as a nobleman didn't hurt. Using the Moon as a reference point, Brahe established via parallax measurements that the "new star" was not sublunary but resided among the other stars. Thus the sphere of the stars was changeable, a concept alien to 2000 years of astronomical thinking, which held that anything transient in the heavens must be interior to the orbit of the Moon. At Hven, Brahe was able to refine stellar positions as close as one minute of arc using (pre-telescopic) instruments of surpassingly high quality.

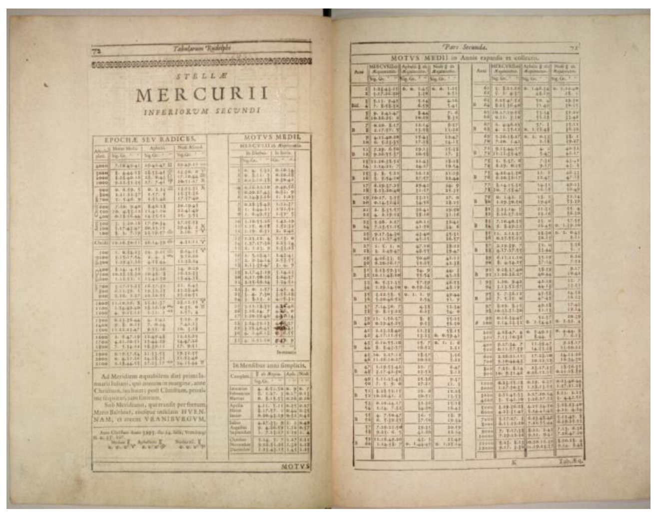
Uraniborg was a center of astronomical observation and research. Brahe trained many younger astronomers, the most well-known among them Christian

Longomontanus. King Frederick died in 1588 and was replaced by his son, crowned King Christian IV at the age of 11. Support in the Danish court for the sometimes difficult Brahe waned and the peasants on Hven became unruly, perhaps egged on by Brahe's political enemies. Brahe abandoned Denmark in 1597, taking some of his instruments and all his data. In 1600 he became the official court astronomer to the inquisitive and cultured Holy Roman Emperor Rudolf II, in Prague. An observatory was constructed at Benátky nad Jizerou, a town about 35 km from Prague in what is now the Czech Republic.

The young mathematician Johannes Kepler joined Brahe in Prague just a few months after Brahe's arrival. Almost immediately, in 1601, Brahe died, apparently from urinary obstruction and a "burst bladder." Kepler took over as imperial mathematician, inheriting Brahe's data with the specific charge of publishing more accurate astronomic tables.

Erasmus Reinhold had published the Prutenic Tables in 1551. They were the first planetary ephemerides based on Copernicus' heliocentric design of the solar system. While important astronomically, their main impact on history was that Aloysius Lilius and Christopher Clavius used them as the basis for the reformation of the calendar. The Julian calendar was replaced in 1582 by the Gregorian calendar we use today. The Prutenic Tables also helped spread Copernicus' heliocentric vision throughout Europe. Nevertheless, there was still resistance to heliocentrism even among sophisticated astronomers. Tycho's system, published in 1588, had Mercury and Venus orbiting the Sun but still held the Earth at the center of the universe. It seemed to work fairly well, and absent better data its predictions were competitive with Copernicus. On his deathbed, Tycho apparently expressed the hope that Kepler would base the forthcoming tables on Tycho's own system. Kepler, however, was a confirmed Copernican. As his first achievement, Kepler used Tycho's data to work out the orbit of Mars, finding in 1609 that it was an ellipse. This was one of the most momentous accomplishments in astronomical history, rivalling Galileo and setting this stage for Newton.

Kepler published his planetary tables, the Rudolphine Tables (named in Rudolf II's memory), in 1627. The creation of these ephemerides required a vast commitment of time and energy to perform prodigious numbers of arithmetic and trigonometric calculations. Fortunately, logarithms had just been invented and that helped somewhat, but it took many hours to do a calculation that our planetarium programs, like Cartes du Ciel or SkySafari, do in the background in an instant.



There is a scanned copy of the Rudolphine Tables on the internet.[1] It's a lengthy work in Latin with a lot of explanatory text that Kepler included to justify his methods and calculations.

Among the most immediate impacts was that the tables could be used to the predict transits of Mercury and Venus. In 1629, Kepler published a pamphlet *De raris mirisque Anni 1631* (On the rare and wonderful Year 1631) that included an *admonitio ad astronomos* (warning to astronomers) of a transit of Mercury in 1631 and transits of Venus in 1631 and 1761. Kepler died in 1630 and so was not able to observe the 1631 events. Three astronomers viewed the Mercury transit on November 7, 1631, the most notable being Pierre Gassendi. The passage of the tiny disc across the Sun

[1] https://www.ub.uni-kiel.de/digiport/bis1800/Arch3_436.html

provided the first real exacting test for the planetary tables. Gassendi found that the transit occurred ahead of the computed time by 4 hours 49 minutes and 30 seconds, which was actually not bad, all things considered. Kepler's computations for the predicted position of the planet were off by just 13 minutes in longitude and 1 minute 5 seconds in latitude, while the Ptolemaic and Prutenic tables were off by 5 degrees.

Galileo had observed Mercury but his telescope was not able to resolve its disk. Gassendi was surprised at the small size of the planet, just 1/196 the diameter of the Sun's disk. It wasn't until 1639 that the Jesuit astronomer Giovanni Zupi observed that Mercury had phases, and thus it had to revolve around the Sun.

A 1644 transit was apparently not observed. The transit of November 3, 1651, was seen by English astronomer Jeremy Shakerly, who viewed it from Surat, India. The more famous astronomers Christiaan Huygens (from London) and Johannes Hevelius (from Gdansk) observed the next transit on May 3, 1661. By then, Kepler's tables had been slightly corrected and "came near the truth, and failed not many minutes" as noted by a contemporary writer.

Planetary tables became increasingly accurate. Newton's theory of gravity, combined with the complete acceptance of the Copernican model by the end of the 17th century, provided a framework upon which calculations could be made. Advances in telescope design and manufacture and better clocks allowed astronomers to plot ever more accurate positions. But in spite of this progress, errors surrounding the Mercury transits were significant and sometimes rather dramatic. In 1707, the French polymath Philippe de La Hire was off by one entire day in his prediction of the transit. In 1753, Edmund Halley was off by several hours. In 1786, Jérôme Lalande was off by 53 minutes of arc in the location of the planet (almost twice the solar diameter). In 1802, a widely observed transit, William Herschel among the viewers, was many minutes off of the predicted time.

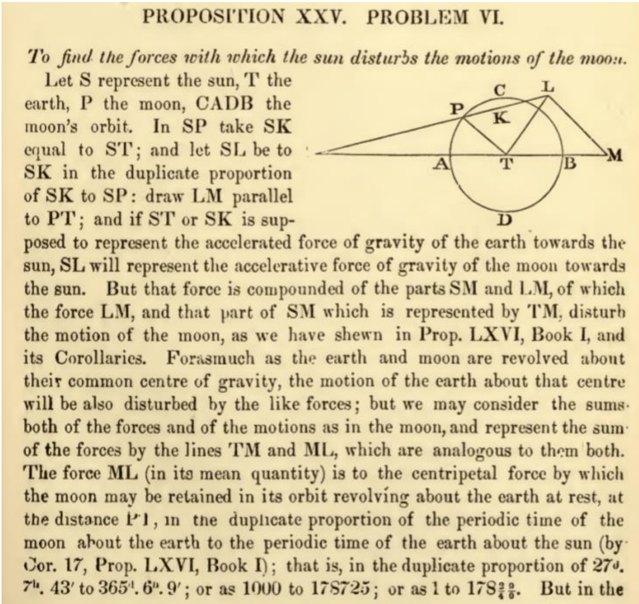
Meanwhile, transits of Venus, of which there had only been four between the publication of the Rudolphine Tables and the end of the 18th century, were more accurately predicted. The 1631 transit, as previously mentioned, was not looked for. Kepler's prediction for 1639 was that the planet would just miss transiting the Sun, but Jeremiah Horrocks, a young English astronomer, had been making observations and corrections to Kepler's tables and found that a transit would occur on November 4. The young Horrocks was a self-taught mathematical and astronomical genius. He was the first person to prove that the Moon followed an elliptical orbit. The march of progress in astronomy was undoubtedly slowed because of his death at the young age of 23.

Horrocks predicted that the transit of Venus would occur at 3:00 pm. He started observing the Sun the day before, just in case. Nothing was seen on the 3rd, and on the 4th the sky was cloudy until about 3:15 pm, when the Sun became visible and Venus had already entered the solar disk. According to NASA's catalog of Venus transits, first contact occurred at 14:47 UT and second contact at 15:15. We can't be exactly sure of how Horrocks set his clock, but it seems likely that his prediction was fairly spot-on within the expected theoretical limits of the day.

The 1761 and 1769 transits of Venus are the stuff of legend, as recounted in Andrea Wulf's *Chasing Venus*, a best seller published just before the 2012 transit. The predicted ingress and egress were reasonably accurate for both 18th century events. Venus's orbit was well described, but why was Mercury's so resistant to accurate predictions?

Throughout the 17th and 18th centuries, until the development of spectroscopy, the most important activity in astronomy was astrometry: making ever more accurate observations of the positions and brightness of stars and planets. After the publication of the *Principia* in 1687 Newton's formulation of gravity could be used to check and refine the accuracy of planetary orbits.

It has been known since the time of the Babylonians that the movements of the Moon seemed to be irregular and she was not always where she was expected to be. The variations seemed to be periodic. The Moon's perturbations are summarized under the rubric of "lunar theory." Formulas for the main anomalies were found so that reasonable lunar positions could be predicted even in ancient times. Hipparchos measured the annual precession of the lunar perihelion, which he calculated takes 8.88 years to make a full cycle, correct within just 0.34%. The Antikythera mechanism, an ancient calculating device made no later than 100 BC, accurately corrects for this phenomenon. The youthful Jeremiah Horrocks was interested lunar theory and developed tables of lunar motion that were accurate to 10 minutes of arc. However, the reason for these anomalies was unknown until Newton, who realized that the mass of the Sun would have a significant gravitational influence on the Earth-Moon system.


PROPOSITION XXV. PROBLEM VI.

To find the forces with which the sun disturbs the motions of the moon.

Let S represent the sun, T the earth, P the moon, CADB the moon's orbit. In SP take SK equal to ST; and let SL be to SK in the duplicate proportion of SK to SP: draw LM parallel to PT; and if ST or SK is supposed to represent the accelerated force of gravity of the earth towards the sun, SL will represent the accelerative force of gravity of the moon towards the sun. But that force is compounded of the parts SM and LM, of which the force LM, and that part of SM which is represented by TM, disturb the motion of the moon, as we have shewn in Prop. LXVI, Book I, and its Corollaries. Forasmuch as the earth and moon are revolved about their common centre of gravity, the motion of the earth about that centre will be also disturbed by the like forces; but we may consider the sums both of the forces and of the motions as in the moon, and represent the sum of the forces by the lines TM and ML, which are analogous to them both. The force ML (in its mean quantity) is to the centripetal force by which the moon may be retained in its orbit revolving about the earth at rest, at the distance PT, in the duplicate proportion of the periodic time of the moon about the earth to the periodic time of the earth about the sun (by Cor. 17, Prop. LXVI, Book I); that is, in the duplicate proportion of 27d. 7h. 43′ to 365d. 6h. 9′; or as 1000 to 178725; or as 1 to 178$\frac{29}{40}$. But in the

From Newton's Principia, Book 3, 1st American Edition, 1846

Newton took up the problem of lunar theory in the *Principia*. He recognized that the Sun's gravitation would distort the lunar orbit, but he was unable to account for all of its effects. After the publication of his masterwork he spent another 7 years on the problem but gave up in frustration. The challenge is not simple. Even if the Earth and the Moon were the only bodies in the Solar System, the Moon's orbit would still not be a perfect ellipse because the Earth is not a perfect sphere: there is oblateness caused by the tides as well as movement of the Earth's crust under the gravitational influence of the Moon. Then you add the substantial gravitational influence of the Sun, which can vary when the Earth is at apogee or perigee and when the Moon is in different locations in its orbit.

It was not until 1749 that Alexis-Claude Clairault figured out all of the terms that needed to be calculated to get a reasonable solution for lunar theory. The problem had also been attacked by the great Swiss mathematician Leonard Euler, whose answer was basically that there must be a slight deviation of the range of Newtonian gravity from $1/r^2$. (If this sounds familiar, it is similar to the mantra of those astronomers who support MOND—Modified Newtonian Dynamics—as a substitute for dark matter to explain the unusual rotation of galaxies). The power of Newtonian gravity was further proved when Clairault accurately predicted the perihelion of the 1759 return of Halley's Comet, the orbit of which was perturbed by relatively close passes by Jupiter and Saturn.

It was known to Kepler and Horrocks that Jupiter and Saturn had deviations in their own motions, and Edmund Halley had made corrections in his 1695 tables for these planets to account for them. Jupiter received an acceleration of 0° 57' per thousand years, and Saturn a retardation of 2° 19'. The orbits of Jupiter and Saturn were solved explicitly in 1784 by Pierre-Simon Laplace. Laplace wrote "the law of universal gravitation…represents all the celestial phenomena even in their minutest details." But he also noted that "The rigorous solution to this problem surpasses the actual powers of analysis, and we are obliged to have recourse to approximations." This is the famous "n-body problem," and it has only been explicitly solved for n=2. Solutions for n>2 require iterative approximations, which in the days before digital computers meant exhausting arithmetic and trigonometric calculations stretching into the thousands of hours.

William Herschel, the Hanoverian musician working in Bath, England, spent his nights systematically observing and charting the heavens. On March 13, 1781, he discovered a new object that after some months of further observations by him and others was determined to be a planet beyond the orbit of Saturn. He wanted to call it *Georgium Sidus* (the Georgian Star, after King George III). The name "Herschel" was proposed by Lalande and even "Neptune" was suggested. German astronomer Johann Elert Bode offered "Uranus." There being no IAU to control astronomic nomenclature, the various names competed for quite a few years until "Uranus" won the day. As Uranus was studied (including recovering positions from observations made prior to Herschel), its orbit appeared to have deviations. The French astronomer Alexis Bouvard published tables for Uranus in 1821, but observations in the next decade continued to show aberrations from its expected position, and astronomers began to suspect that there was perturbing a planet even more distant in the solar system.

Two mathematicians took up the problem: John Couch Adams (Britain) and Urbain Le Verrier (France). To determine the position of the unknown planet, they would have to apply Newtonian mechanics not only to Uranus but to the other large Solar System bodies: Jupiter, Saturn and the Sun.

The race between Adams and Le Verrier is the stuff of astronomical legend, full of grit, genius and lost opportunities. Suffice it to say that Adams got a solution first but only showed it to George Airy, the Astronomer Royal, who asked Cambridge Observatory director James Challis to look for the object. Challis failed to find it (he actually saw it twice but did not recognize it as a planet). Meanwhile, Le Verrier independently found a solution and asked Johann Galle to look for it with the refractor of the Berlin Observatory. He found it on September 23, 1846, the very night he received Le Verrier's letter, just 1 degree from its predicted position and 12 degrees from the location suggested by Adams. While both Le Verrier and Adams are given credit for the calculation, it seems to me that 12 degrees is too wild a pitch to claim victory. So the honor does belong to Le Verrier, in spite of his personal reputation. The Director of the Paris Observatory, he was a relentless, grim and driven man, acknowledged as brilliant but hard to work for. It was once said of him that "although he is not the most despicable man in France, he is the most despised."

The prediction and discovery of Neptune was an affirmation of the dominance of Newtonian mechanics in the affairs of astronomy. Newton ruled everything. So, what was going on with Mercury?

By 1843, Le Verrier had spent 3 years completing new tables for Mercury, applying Newtonian mechanics as thoroughly as possible. He published a paper, "Détermination nouvelle de l'orbite de Mecurie et de ses perturbations" that year, followed by a book, *Théorie du Mouvement de Mercurie*. He predicted a transit on May 8, 1845 that would be fully visible from North America. Ormsby Mitchel observed the event with the 11-inch Merz refractor at the Cincinnati Observatory. Mercury crossed the Sun's limb 16 seconds late, although at the exactly predicted position. While Mitchel was elated, Le Verrier was disappointed. The error was too great, meaning something was wrong with the orbital calculations. Some element of the gravitational relationships among the Solar System bodies had not been properly accounted for. Le Verrier was baffled. He stopped publication of the Mercury tables, and would only go back to the problem after his interlude with Neptune and solving the orbits of two new comets, among other projects.

In 1859, Le Verrier began a project to work out with new detail and accuracy the motion of each planet in the Solar System. For Mercury, he had a bunch of transit circle observations and data on contact points for 14 transits of Mercury. He relied primarily on the transits because they were much more accurate than the transit circle observations, which were obtained at low planetary altitudes. He painstakingly worked out the influence of all the other planets on the precession of the perihelion of Mercury (employing an army of human "computers") and found the following impacts (in terms as seconds of arc per century):

Venus	280.6″
Earth	83.6″
Mars	2.6″
Jupiter	152.6″
Saturn	7.2″
Uranus	0.1″
Total	526.7″

To accurately account for the transit observations, Le Verrier found he would have to add 38" of arc per century (the modern value is 43") to the precession of Mercury's perihelion, but he had no Newtonian reason to do so. Given his triumph with the prediction of Neptune using pure Newtonian mechanics, Le Verrier could only suppose that there was another Solar System object interior to Mercury whose gravitational influence resulted in the planet's extra motion. Thus began an intense search for the planet Vulcan, about which I will write next month.

Observing the 2019 Transit of Mercury

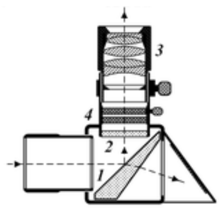
This year's transit will be fully visible from our area.

First contact	7:34:43 am
Second contact	7:36:24 am
Mercury closest to center of Sun	10:19:46 am
Third contact	1:03:13 pm
Fourth contact	1:04:54 pm

The chances of a clear sky are unpredictable until right before the event, typical of our New York weather. Historical weather records show that November 11th has been clear about 38% of the time, mostly clear 10%, partly cloudy 9%, mostly cloudy 10% and completely cloudy 33%. So the chances of seeing some or all of the transit are good, but not great. The 2016 transit had perfectly clear skies, but the prior one in 2006 was completely clouded out.

Mercury will be just 9.9" in diameter, while the Sun is 32' 18.6" in diameter, a ratio of 1:195.8. The planet will not be visible to the naked eye, so forget about finding those eclipse glasses you put somewhere after the 2017 solar eclipse. If you want to see the transit, you'll need a telescope and proper filtration. **Never look at the Sun without proper filtration!**

The best white light views of the Sun are seen with Herschel wedges. These devices substitute for a diagonal. The full energy of the Sun enters the scope. A trapezoidal prism in the wedge deflects most of it harmlessly out the back. About 4.6% is reflected and passes through a neutral density filter (and sometimes a variable polarizer) into the eyepiece. Herschel wedges can only be used with refractors. They cost around $300 and are made by Lunt, Baader and Meade and come in 1.25” and 2” formats.



Herschel Wedge

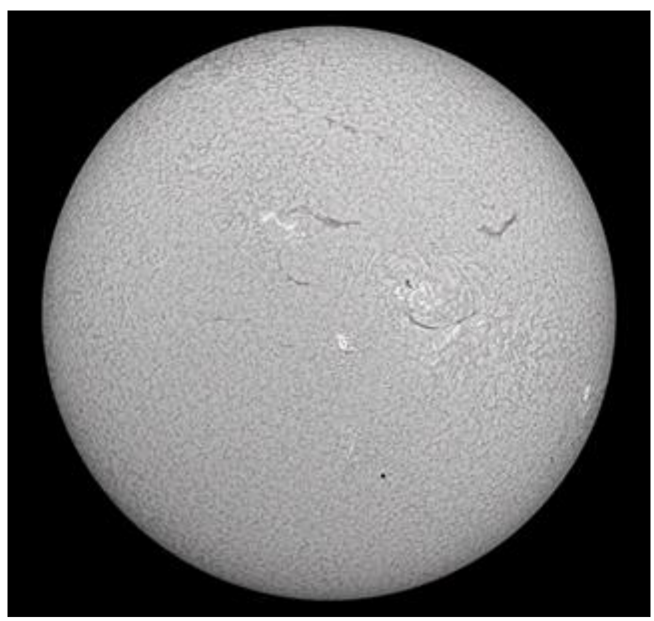
1. Prism
2. Neutral density filter
3. Eyepiece
4. Variable density polarizing filter

If having all the Sun’s energy falling on your optics makes you nervous (it does to me), then you must use a Baader aluminized mylar filter or a Thousand Oaks glass filter. These can be purchased in a size to fit any scope. They attach to the front of the scope with nylon set screws. They are physically secure (check the Baader for pinholes before mounting it), but using the “belt and suspender” concept I also use a couple of pieces of tape to secure the filter. I like the steel grey color of the Baader much better than the yellow hue of the Thousand Oaks, but *chacun à son goût*.

To image, use the prime focus technique with the correct T-adaptor for your camera, and remember that the size of the Sun’s image on the camera’s sensor will be your scope’s focal length multiplied by 0.009. So an 80 mm f/7 refractor, with a focal length of 560 mm, will give a 5 mm solar image. If you want to increase it, use a Barlow or a longer FL refractor. Don’t forget the magnification factor if your camera doesn’t have a “full frame” (36x24 mm) sensor. A useful tool is the free Windows program *CCDcalc*, www.newastro.com/book_new/camera_app.html.

Another way to view or image the transit is to use a hydrogen alpha telescope. This makes the background more interesting for sure. When photographing through an Hα scope you’ll have to keep the diagonal in the optical train, since it has a special blocking filter that shouldn’t be bypassed. A cell phone can do the trick quite nicely in “afocal” mode, but it helps to have one of those jigs that hold the phone in the right spot. Imaging with Hα scopes sometimes results in a phenomenon called “Newton’s rings.” These are wavy lines of greater and lesser brightness caused by reflections off of two parallel surfaces. The Fabry-Pérot etalons at the heart of Hα scopes make this problem almost inevitable, but some camera sensors are more prone to it than others. With my 60 mm Lunt scope, a QHY 5L-II camera shows far more intense rings than a very similar Celestron Skyris 445. I can’t use the Canon T3i DSLR with the Lunt at all. Daystar makes a device that can tilt the camera slightly to reduce or eliminate the rings, but it might challenge the focus. You can only work this out with trial and error. Finally, you’ll likely need to convert your Hα image to black and white, or at least fiddle with the color. Monochrome cameras work best for Hα imaging.

May 9, 2016 transit in white light with Baader filter, Stellarvue SVR-105 f/7 triplet, Canon T3i with T-adapter, 1/3200 sec, ISO 200, true color, cropped but not manipulated (LF)



May 9, 2016 transit in hydrogen alpha. Lunt 60 mm Hα scope, Celestron Skyris 445 monochrome camera, best 100 of 400 frames, Autostakkaert!2, wavelets in Registax 6.1 (LF)

Images by Members

M17 by Gary Miller

Gary acquired this image of M17 in August at Ward Pound with his usual set-up, an Explore Scientific 127 mm refractor on a Celestron AVX mount and a DSLR. Although dramatic in images, M17, also known as the “Swan” or “Omega” nebula, is very rewarding for visual observation even in modest telescopes. It’s in Sagittarius, so you’ll have to wait for next summer in order to see it.

Rick Bria captured these images on July 25th at Mary Aloysia Hardey Observatory in Greenwich. He used a Televue TV-85 with 2X Barlow, QHY-290c camera, and processed in AS!3, Registax 6 and Photoshop. Europa is the Jovian moon seen on the lower left. These are spectacularly clear and detailed images, especially considering that the planets were low in the sky (~25 degrees) and that Rick recorded just 30 seconds of data for each image.

Magellanic and Earthly Clouds from Rapa Nui by Larry Faltz

There is always a substantial amount of cloudiness over Rapa Nui (Easter Island) in the southern winter. July is the rainiest month in that isolated mid-Pacific island and this past July was no exception. Larry got up at 5:00 am to on July 6th to try to catch the rising Magellanic Clouds. They were only intermittently visible through large patches of rapidly moving thick and thin clouds. Exposures of 25-30 seconds were inevitably ruined as clouds crossed the field. Finally, just as the sky was starting to lighten about 7:00 am, there was a moderately clear window for a shot, with swirling clouds only hugging the border of the field. Clouds are visible on the lower left, just beyond the star Canopus (the second brightest star in the sky, not visible from Westchester) and on the lower right. The Large Magellanic Cloud is in the center and the Small Magellanic Cloud on the upper right. Tripod-mounted Canon T3i, Canon EF-S 18-135 IS lens at 20 mm (35 mm equivalent focal length 36 mm), f/3.5, 25 seconds, ISO 6400, cropped around 15%. The field is about 50 degrees across. The brightest star to the upper right of the SMC is actually the magnificent globular cluster 47 Tucanae.

Transit of Mercury Viewing at Rye Playland

Charles Fulco, known to many WAA'ers as an astronomy educator and outreach enthusiast, will be holding an observing event at Rye Playland on Monday, November 11th. Charles writes "Join us this November 11th between 7 am and 1 pm at Playland Boardwalk in Rye, NY, as the planet Mercury transits the Sun. Back in the day, transits of Mercury, and especially Venus, were used to estimate the distances between the Sun and planets. Now, although we know these distances quite accurately, transits are still interesting phenomena to observe. With students off from school that day, I'd like to ask parents to bring them by for a look through our telescopes (which are properly fitted with safe filters, of course). Coffee, donuts and solar glasses will be provided!"

Scopes will be set up near the miniature golf course at Playland. Reach Charles at saros61@gmail.com.

Research Highlight of the Month

Runaway Young Stars near the Orion Nebula

Aidan McBride and Marina Kounkel, Western Washington University, arXiv:1908.07550

Abstract: The star forming region of the Orion Nebula (ONC) is ideal to study the stellar dynamics of young stars in a clustered environment. Using Gaia DR2 we search for the pre-main sequence stars with unusually high proper motions that may be representative of a dynamical ejection from unstable young triple systems or other close three-body encounters. We identify twenty-six candidate stars that are likely to have had such an encounter in the last 1 Myr. Nine of these stars could be traced back to the densest central-most region of the ONC, the Trapezium, while five others have likely interactions with other OB-type stars in the cluster. Seven stars originate from other nearby populations within the Orion Complex that coincidentally scattered towards the ONC. A definitive point of origin cannot be identified for the remaining sources. These observations shed light on the frequency of the ejection events in young clusters.

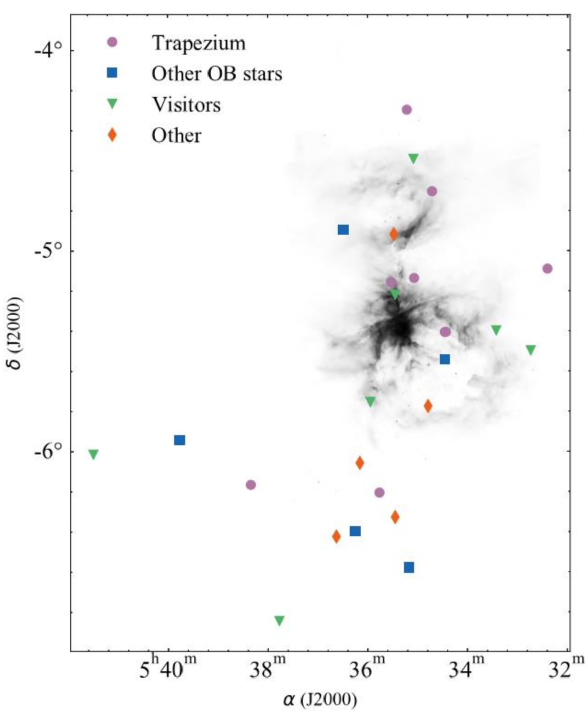


Figure 3. Distribution of the high proper motion sources (colored according to their apparent point of origin), projected against the Spitzer 8µm background

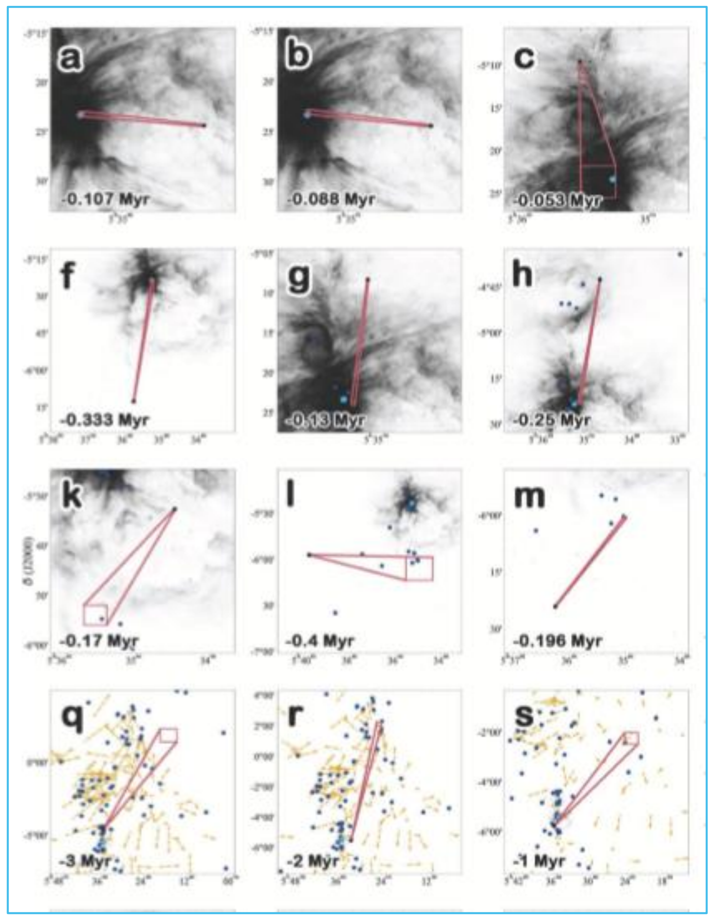


Figure 4 (excerpt). The apparent path of the high proper motion sources projected back in time over the course of the period shown in the bottom left corner of each image. The cone shows the uncertainty in the path. The sources are projected against the Spitzer µm background for a reference of their position

The Orion Nebula is not only birthing new stars, but it seems to be flinging some of them out of the nest! This is one of many interesting papers coming out on nearly a daily basis using data from the 2nd data release of the European Space Agency's Gaia satellite. For more about the Orion Nebula, read the February 2016 SkyWAAtch.—LF.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Celestron 8" SCT on Advanced VX mount	Purchased in 2016. Equatorial mount, portable power supply, polar scope, AC adapter, manual, new condition.	$1200	Santian Vataj spvataj@hotmail.com
Celestron CPC800 8" SCT (alt-az mount)	Like-new condition, perfect optics. Starizona Hyperstar-ready secondary (allows interchangeable conversion to 8" f/2 astrograph if you get a Hyperstar and wedge). Additional accessories: see August 2018 newsletter for details. Donated to WAA.	$1000	WAA ads@westchesterastronomers.org
Explore Scientific Twilight I Mount	Manual Alt/Az, capacity 18 lb. Steel tripod. Excellent condition. Used fewer than 10 times. Great for grab-and-go viewing. Owner upgrading to an EQ mount.	$110	Eugene Lewis genelew1@gmail.com
Celestron StarSense autoalign	Brand-new condition in original packaging. Accurate auto-alignment. Works with all recent Celestron telescopes (fork mount or GEM). See info on Celestron web site. Complete with hand control, cable, both mount brackets. Printed documentation. List $359. Donated to WAA.	$175	WAA ads@westchesterastronomers.org
Meade 395 90 mm achromatic refractor	Long-tube refractor, f/11 (focal length 1000 mm). Straight-through finder. Rings but no dovetail. 1.25" rack-and-pinion focuser. No eyepiece. Excellent condition. A "planet killer." Donated to WAA.	$100	WAA ads@westchesterastronomers.org

Want to list something for sale in the next issue of the WAA newsletter? Send the description and asking price to ads@westchesterastronomers.org. Member submissions only. Please submit only serious and useful astronomy equipment. WAA reserves the right not to list items we think are not of value to members.

Buying and selling items is at your own risk. WAA is not responsible for the satisfaction of the buyer or seller. Commercial listings are not accepted. Items must be the property of the member or WAA. WAA takes no responsibility for the condition or value of the item or accuracy of any description. We expect, but cannot guarantee, that descriptions are accurate. Items are subject to prior sale. WAA is not a party to any sale unless the equipment belongs to WAA (and will be so identified). Sales of WAA equipment are final. Caveat emptor!

Steve Gould waiting for sunset at Ward Pound, 2013

WAA Members: Contribute to the Newsletter!
Send articles, photos, or observations to
waa-newsletter@westchesterastronomers.org

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