SkyWAAtch

Triangulum Galaxy

Gary Miller provided this image of M33, the Triangulum galaxy. Taken at ward Pound Ridge, Gary employed an ES 127mm triplet refractor and Canon T7i camera mounted on a Celestron CG5. He stacked 42 30-second exposures in DeepSkyStacker (darks subtracted) and then processed the image in Photoshop.

M33 is about three (3) million light years distant and is the third largest member of the Local Group. Seen face-on, this spiral galaxy is about 50,000 light years in diameter. Interactions between M33 and its nearby neighbor, the Andromeda galaxy, is an ongoing area of research.

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Events for May

WAA May Lecture

"Uncertainties in Core Collapse Supernova Simulations"
Friday May 4th, 7:30pm
Lienhard Hall, Pace University, Pleasantville, NY

The identification of type Ia supernovae is an important tool for determining distance in astronomy as the consistent peak brightness of this phenomena provides a useful standard candle for measurements. Our speaker for May will be Fr. John Cunningham of Fordham University who will speak on Uncertainties in Core Collapse Supernova Simulations and the Impact on Type Ia Supernovae Sample Purities.

Father Cunningham is an Associate Professor in the Department of Physics & Engineering Science at Fordham University. He holds a Ph.D. in physics from the University of Notre Dame. Free and open to the public. Directions and Map.

Upcoming Lectures

Leinhard Lecture Hall
Pace University, Pleasantville, NY

Our speaker on June 1st will be Alex Teachey. His talk is tentatively entitled "Kepler's Hidden Gems: In Search of Exomoons." Free and open to the public.

Starway to Heaven

Saturday May 12th, Dusk.
Ward Pound Ridge Reservation, Cross River, NY

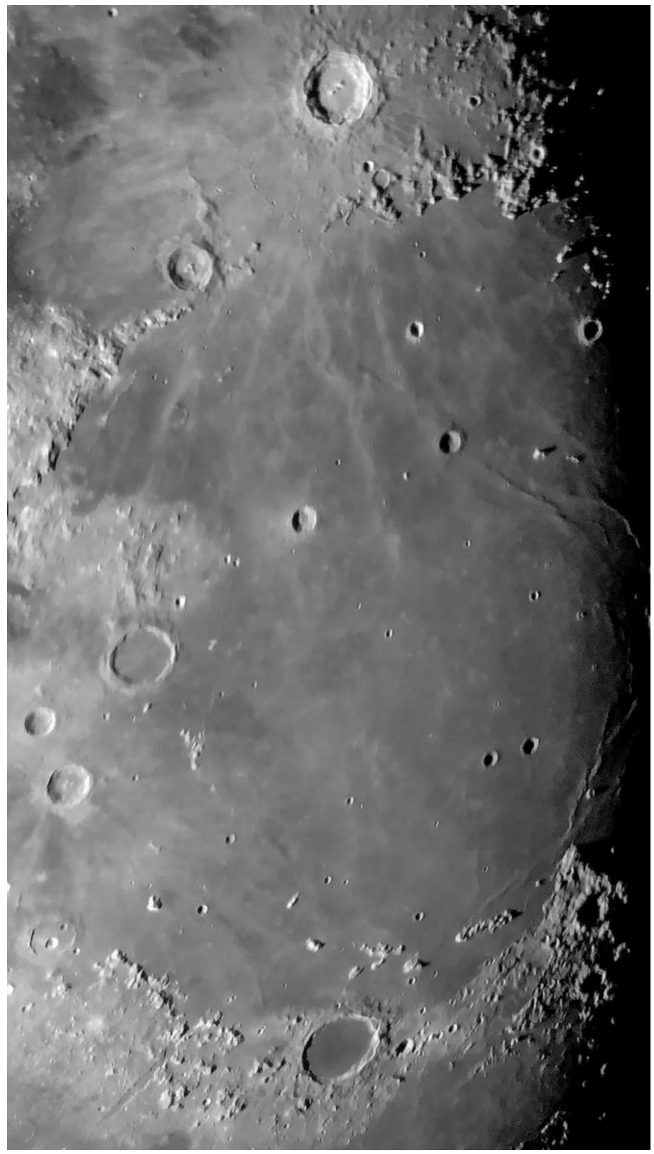
This is our scheduled Starway to Heaven observing date for May, weather permitting. Free and open to the public. The rain/cloud date is May 19th. **Important Note**: By attending our star parties you are subject to our rules and expectations as described here. Directions and Map.

New Members. . . .

Joel Szklarski - New Rochelle
Abdul Mirza - Flushing
Alan Struth - Irvington
Robbins Gottlock - Sleepy Hollow
Alan Young - Tarrytown
Arthur Rotfeld - White Plains

Renewing Members. . .

Emily Dean - Pelham
Tom & Lisa Cohn - Bedford Corners
Everett Dickson - White Plains
Pierre-Yves Sonke - Tarrytown
Lawrence C Bassett - Thornwood
Red Scully - Cortlandt Manor
Lisa Walker - Thornwood
Arumugam Manoharan - Yonkers
Jeffrey Jacobs - Rye
Kevin Lillis - Yorktown Heights
Jimmy Gondek and Jennifer Jukich - Jefferson Valley
Neil Roth - Somers
Jonathan Williams - New Rochelle
James Peale - Bronxville
Jim Cobb - Tarrytown
Anthony Sarro - Scarsdale

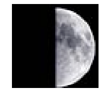


Gary Miller took this lunar image at Ward Pound Ridge with a cellphone through his 10" dobsonian (using a Tele-vue FoneMate) and an 8mm Ethos eyepiece (150x magnification; lightly processed in Adobe Lightroom). Crater Copernicus is at the top; crater Plato at the bottom.

ALMANAC
For May 2018 by Bob Kelly


May 8


May 15


May 22


May 29

Jupiter is a treat in any telescope at any time of night as it peaks at magnitude -2.5 and 44 arcseconds wide. Its four brightest moons are visible with any optical aid, even (steadily held) binoculars. All this is thanks to our opposition with Jupiter on May 8th when Jupiter is directly opposite from the Sun in our sky. Make your own estimate of the hue and brightness of the Great Red Spot. It's best when it is near the middle of the planet's disk, about every other evening or so.

Jupiter's four brightest moons have visual magnitudes ranging from magnitude +4.6 to +5.7. If they weren't in the glare of giant Jupiter, they would be visible to the unaided eye. Can you tell which of Jupiter's four brightest moons are which? Charts are available on many web sites and in astronomy magazines. But, with larger telescopes, Jupiter's moons show subtle differences. Io is redder; it and Io and Europa are the smallest of the four. Their apparent sizes range from 1.0 to 1.7 arcseconds. Compare that with 2 to 3 arcseconds wide for Uranus and Neptune. Some observers with large telescopes and good skies will be able to show us some patterns on these distant worlds. My favorite site to see the latest shots from the planetary paparazzi is ALPO-Japan. As Jupiter, Saturn, and Mars approach opposition, the photos will get better and better.

Mars is highest in the sky by sunrise, but even then, it sits low in the southern sky. Its apparent size increases by one third in May. By the end of the month, the southern polar cap starts tilting a bit toward us and is still substantial as spring begins in Mars's southern hemisphere. The white polar cap against the reddish Martian dust may have enough contrast to show up in smaller telescopes next month.

Saturn tops the teapot portion of Sagittarius, low in the south at dawn. Saturn's rings are still tilted wide open, rewarding the early morning observer. Its largest moon, Titan, at magnitude +8.4, is readily visible in telescopes. Iapetus, at magnitude +11, passes south of the planet on the 23rd. The two-faced moon is on its way toward showing its more reflective side, peaking in brightness to the west of Saturn in mid-June.

While you are in northern Sagittarius, check out minor planet 4 Vesta at magnitude +6. Look for a finder chart with both Saturn and Vesta at sites like Naked-EyePlanet. Open cluster M18 is just north of Vesta's location.

The rising time for Jupiter and Saturn rapidly moves earlier in May, but Mars's nightly arrival moves earlier at a more leisurely pace. At the end of the month, Saturn will be rising by 11 P.M. EDT, but Mars, which was so close to Saturn in early April, will not rise until after midnight EDT. The Moon hangs as if lounging in a hammock between them on the 5th.

Venus dazzles in the western sky for two and a half hours after sunset through June. Get out there just after dark in early May to see Venus positioned near the Hyades open star cluster and their honorary member, bright Aldebaran. Best views of Venus, in the telescope, are during early twilight. Or, even during daytime, if you can find Venus when it's highest in the sky in the early afternoon. Remember to keep the Sun behind a solid, opaque object! Our evil twin planet is just starting to look a bit out of round, almost as gibbous as Mars (and nearly the same apparent size).

Mercury is farthest out from the Sun in the morning sky early in the month. It's even harder to see than usual, rising less than an hour before the Sun.

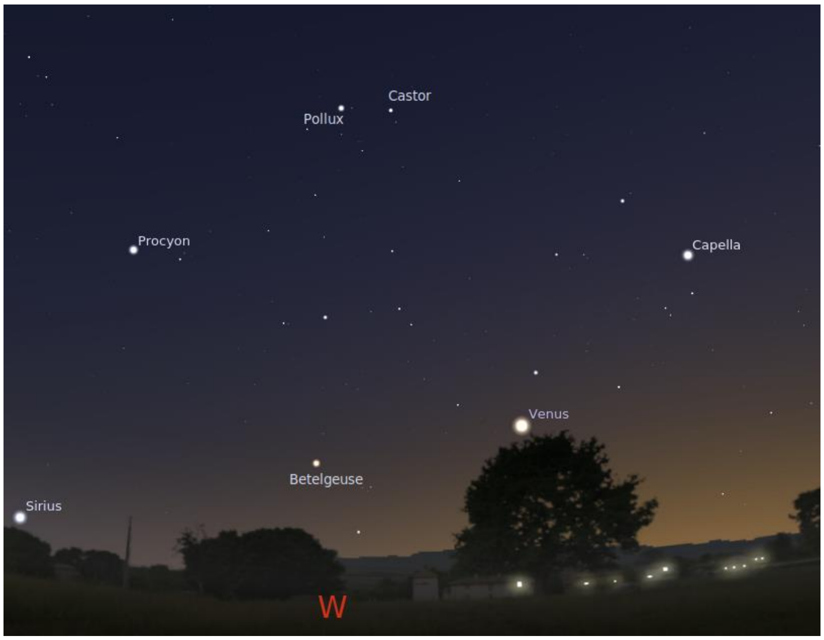
The Eta Aquariid meteors give a strong show for southern hemisphere observers. However, if you are up early on the 6th, be on the watch for a few long-path meteors streaking across the eastern sky from right to left. Since the radiant is near the horizon at dawn, the resulting meteors at our latitude skip sideways across the top of our atmosphere. The gibbous Moon will be out that morning, making it harder to see these grains from Comet Halley. While you are out, compare the Moon and Mars, just four moon-widths apart.

The International Space Station is visible for a few minutes of each 93-minute-long orbit after midnight for much of the month. During the last third of the month, our out-of-this-world human outpost is visible in the evening skies, as well. Check NASA or Heavens-Above for updated times and directions to look.

In The Naked Eye Sky
For May 2018: The Triangle and the Arch
by Scott Levine

A few weeks ago, I sat outside watching Venus set behind the hills across the river, and got talking to a neighbor. In his words, he "forgot to bring the dog" on his walk. It was a gorgeous night, and it reminded me that soon the weather will change just enough, and will people start to come out of hibernation. The neighborhood will come alive again.

While we chatted, we got talking about the stars overhead. He's a casual fan. His big naked-eye favorite this time of year is, more or less, the **Spring Triangle**. That's the broad stretch of sky with **Regulus** (α Leo), **Arcturus** (α Boo), and **Spica** (α Vir) at its corners. Some people like to trade **Denebola** (β Leo), the reddish double star that form's the lion's tail, for Regulus. It makes for a cozier and more compact triangle.



There are plenty of deep-sky objects in that part of the sky. The **Leo Triplet** (spiral galaxies **M65**, **M66**, and **NGC 3628**) is about half-way between Regulus and Denebola, and the Virgo cluster is… in Virgo, far behind Spica. To the naked eye, though, the Triangle is a bit underwhelming. Still, the old mnemonics that have you use the Big Dipper to find the Triangle's stars are still fun and interesting enough at the end of a long day. "Arc to Arcturus; Spike to Spica; and Reach to Regulus," are great and helpful, especially when you're just starting out.

For my sky-watching dime, I told my friend, I prefer to look toward the west. Over there was the pentagon-shaped outline of Auriga, with Orion waiting behind it, almost like a catcher crouching behind the galaxy's biggest home plate.

Ever since the **Winter Circle** popped over the rooftops toward the east last fall, it's been a great sight, inching across the sky. This past winter, I realized that one of my favorite things about the skies are the three days each month we get to watch the Moon cross the Circle. May is the last chance we'll have until the weather cools again.

By late April or Early May, time has shrunk and subdued the Circle. Those old winter stars have taken on new life as an elegant and stately arch. Only **Sirius** (α CMa), **Procyon** (α CMi) **Pollux** (β Gem), **Castor** (α Gem) and **Capella** (α Aur) are still above the horizon by mid-evening. This time around, **Venus** is in Taurus just under the arch, not far from **Betelgeuse** (α Ori).

As the stars popped into view in the glowing twilight after sunset, my friend told me he'd never seen it that way before. It was strange to see them out of context, far from where he's used to them, high in the sky on a dark and cold January night. In these long dusks, the arch looks like the gateway to summer. It's calling us toward cannonball contests, hot dogs and good things to come. It's a great way to end the story that started last Halloween when those stars were sneaking into the nights' eastern skies.

Watching the skies can very easily be a solitary one, but it's always great when someone, with or without a dog, comes along to talk about it. I hope you'll take a look this month.

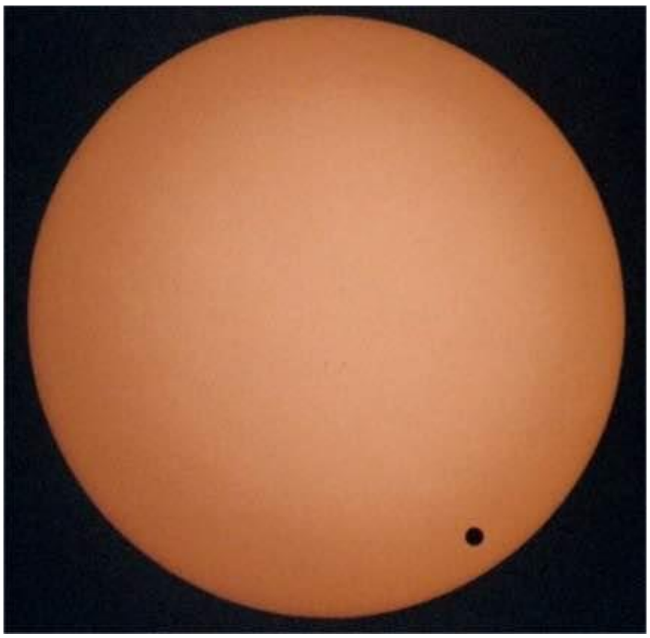
Westchester Amateur Astronomers

Imaging an Exoplanet from Greenwich, Connecticut

Rick Bria

Recently, ground and space-based observations have discovered thousands of planets orbiting distant stars. These planets are beyond our solar system and are called extrasolar planets, or exoplanets.

Most exoplanets are discovered using the transit method. When a planet passes in front of (transits) a distant star, the light of that star is dimmed slightly. Measuring transits can reveal information about the exoplanet and its orbit. Follow-up observations of newly discovered exoplanets are needed to refine existing data.

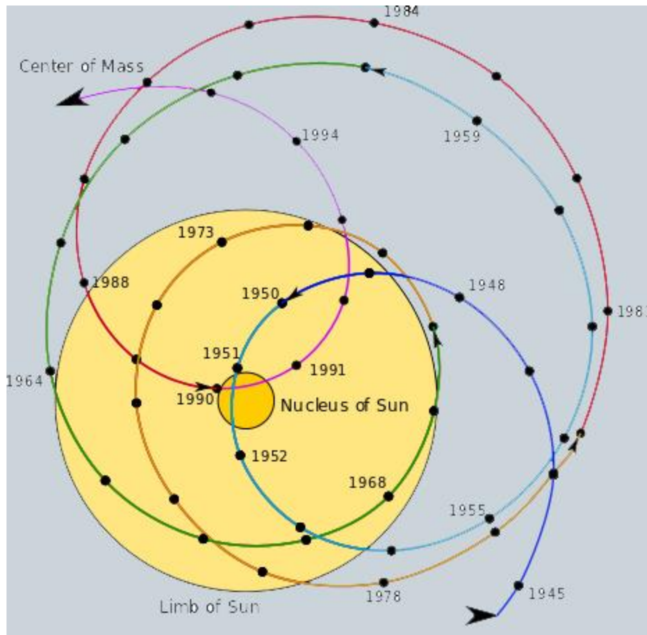


The Transit of Venus, June 8, 2004

This is a picture I took of Venus transiting the Sun in 2004. The black dot is the silhouette of Venus passing in front of the Sun. Venus is blocking a small portion of the Sun's light. This is analogous of what is happening during an exoplanet transit.

We successfully recorded the transit of exoplanet WASP-39b using the 16” Schmidt-Cassegrain telescope at the Mary Aloysia Hardey Observatory in Greenwich on May 16, 2017. Operating the telescope at f/6.7, our SBIG11k camera captured 360 33-second exposures of the exoplanet's host star throughout the night. We compared the host star’s brightness to three nearby comparison stars in the image field.

The resulting transit data was processed in AstroImageJ (AIJ) software to produce the graph on the next page. The Y axis is brightness and the X axis is time. The time standard used for exoplanet work is Barycentric Julian Date/Barycentric Dynamical Time (BJD_TDB).



The location of the barycenter of the solar system

BJD_TDB is referenced to the gravitational barycenter of the Solar System. The barycenter moves as the planets orbit the Sun. It can vary as much as 8 seconds from the Sun's center. Until I attempted this exoplanet transit, I had never heard of BJD_TDB. It took me nearly a year to finally master AstroImageJ, but it was worth it. It is a powerful but complicated program for stellar photometry. One huge advantage is that it’s free. I also got a lot of help by taking an online course by AAVSO’s Dennis Conti and attending his workshops at NEAIC.

The black circles in the graph on the next page represent the raw brightness (relative flux) of the host star. The blue circles and blue line represent a statistical fit of the transit event processed in AIJ software. Both data sets show an undeniable dip in brightness as WASP-39b passed in front of the target star (T1) during the transit. The brightness drop during the transit was 2 percent. The green dots represent the brightness of the three nearby comparison stars. Their brightnesses remain constant, proving the target star dimmed from an exoplanet transit.

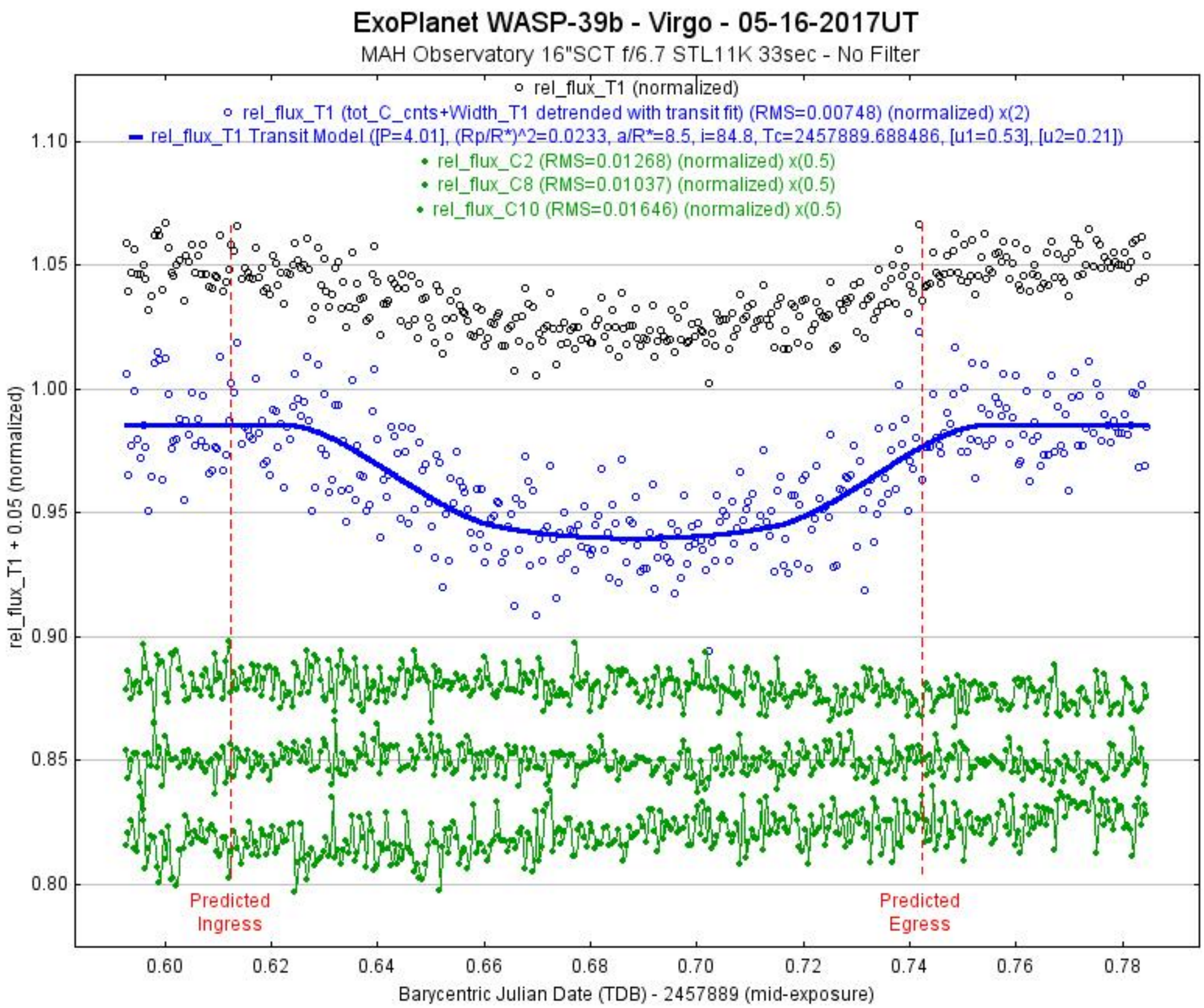
WASP-39b is an exoplanet 33% larger than Jupiter. It orbits a 12th magnitude star 700 light years away in the constellation Virgo. WASP-39b orbits very close to its host star, and so its surface temperature is very high, 1200 degrees C or more. Despite that, water vapor has been detected in its atmosphere. Because of its proximity to the host star, its year is only four days long. This type of exoplanet is called a “Hot Jupiter”. WASP-39b took 168 minutes to transit its host star.

If you told me a few years ago I could record an exoplanet transit, I would have said you were crazy!

As of April 1, 2018, there were 3,758 confirmed exoplanets in 2,808 stellar systems. More than a third of these were discovered by the Kepler space telescope, which detected transits while observing about 150,000 stars on the border of the constellations Cygnus and Lyra.

We may soon hear of many more exoplanet discoveries. NASA successfully launched the Transiting Exoplanet Survey Satellite (TESS) on a SpaceX Falcon 9 rocket on April 18th. TESS will use the transit method to search nearly the entire sky for exoplanets.

Good luck TESS!



Some Thoughts About Black Holes

Larry Faltz

It wasn't that long ago that black holes were merely theoretical objects. The prediction that a gravitational field can be strong enough to prevent the emission of light comes directly from Einstein's equations of General Relativity, although English astronomer and clergyman John Michell, musing on the implications of Newton's theory of gravitation, made such a prediction in 1784, as did Pierre-Simon Laplace independently a decade later. General Relativity is described mathematically by a set of 10 differential equations that are notoriously difficult to solve. They can be schematically represented in the simple equation $G_{\mu\nu}=8\pi GT_{\mu\nu}/c^4$, basically stating that the curvature of space (the "Einstein tensor" G, combining the Ricci tensor R and the metric tensor *g*, both needed to describe space) is determined by the mass-energy that's present (T). As a result, mass moves in space along geodesics (the shortest distance between two points). All the details of the calculations are subsumed in those two innocent-looking Greek subscripts μ and ν, which must be expanded into the 10 differential equations needed to calculate solutions that describe actual phenomena in the universe.

Albert Einstein published General Relativity in November 1915, and as is well known, within a few weeks Karl Schwarzschild, an astronomer and mathematician serving in the German Army on the Russian front in World War I, derived an exact solution for a single spherical non-rotating mass. He showed this could result in a region of space with a gravitational potential so great that the escape velocity at its surface was equal to the speed of light. Einstein was impressed by this result since he had been only able to find approximate solutions to his own equations. He wrote to Schwarzschild, "I have read your paper with the utmost interest. I had not expected that one could formulate the exact solution of the problem in such a simple way. I liked very much your mathematical treatment of the subject. Next Thursday I shall present the work to the Academy with a few words of explanation." Schwarzschild, unfortunately, had come down with a rare and at that time untreatable skin disease, pemphigus, which was the probable cause of his death in May 1916 at the age of 42.

Karl Schwarzschild

The Schwarzschild metric, as the solution is known, is a model that describes the gravitational field outside of any non-rotating, non-charged spherical mass. It can be used to approximate the field around a slowly rotating astronomical object such as a planet since the density of matter and the speed of rotation is negligible compared to relativistic situations where the objects are highly condensed and General Relativity substantially deviates from Newtonian gravity. Its exact solution can be used to model the behavior of matter in extreme gravitational environments. For the curious, here's what it looks like:

$$c^2\,d\tau^2 = \left(1-\frac{r_s}{r}\right)c^2\,dt^2 - \left(1-\frac{r_s}{r}\right)^{-1}dr^2 - r^2\left(d\theta^2+\sin^2\theta\,d\varphi^2\right)$$

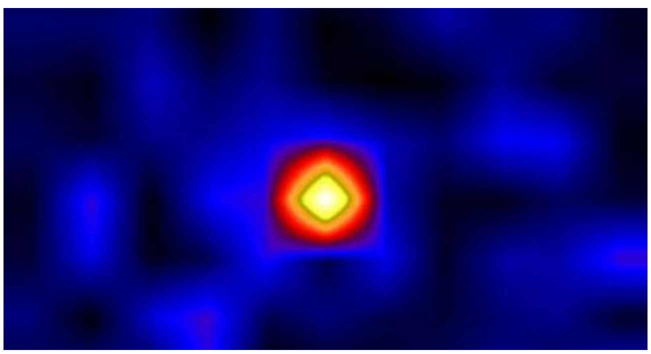
It fundamentally describes how time passes for an object moving along a geodesic.

In 1931, Subrahmanyan Chandrasekhar, on route from India to a post-doctoral position at Cambridge University, spent his shipboard time reading Arthur Eddington's book *The Internal Constitution of Stars*. Chandrasekhar decided to calculate the upper limit of mass for a white dwarf. He found that above 1.4 solar masses the mechanism for preventing gravitational contraction, electron degeneracy pressure related to the Pauli Exclusion Principle, was inadequate to prevent further collapse. This was only partially true: we now know that stars just above that limit will collapse into a stable neutron star, unknown in 1931, since neutrons were unknown and only discovered a year later. In 1939, J. Robert Oppenheimer, whose contributions as a theoretical physicist were dwarfed by his later management of the Manhattan Project, showed that in the presence of just a little more matter the collapse into a singularity could not be stopped. This amount of matter, known as the Tolman-Oppenheimer-Volkoff limit, is now know to be about 2.17 solar masses.

Subrahmanyan Chandrasekhar

There are probably no non-rotating black holes in the universe, but the Schwarzschild metric is useful for understanding many of the peculiarities of spacetime proximate to a black hole. The equations of General Relativity for a rotating black hole, which are much more complicated, weren't solved until 1963. These are called Kerr black holes after New Zealand mathematician Roy Kerr, who was at the University of Texas at the time he found the solution.

Many astronomers and physicists had hoped that some mechanism could be found to prevent total gravitational collapse into a point of infinite density. It was unseemly: nature and mathematics abhor singularities, places where there are no physical dimensions and solutions to equations can take on any value. [I suppose that's why Microsoft Excel adds the exclamation point to its division-by-zero error (#DIV/0!).] By the mid-1960's interest in General Relativity had been rekindled with growing academic interest in the subject. For an interesting history of the theory with a focus on the personalities evolved, read *The Perfect Theory* by Pedro Ferreira (Mariner Books, 2014). The potential reality of black holes was no longer challenged and some of the more peculiar predictions coming out of the math were not viewed with terror.



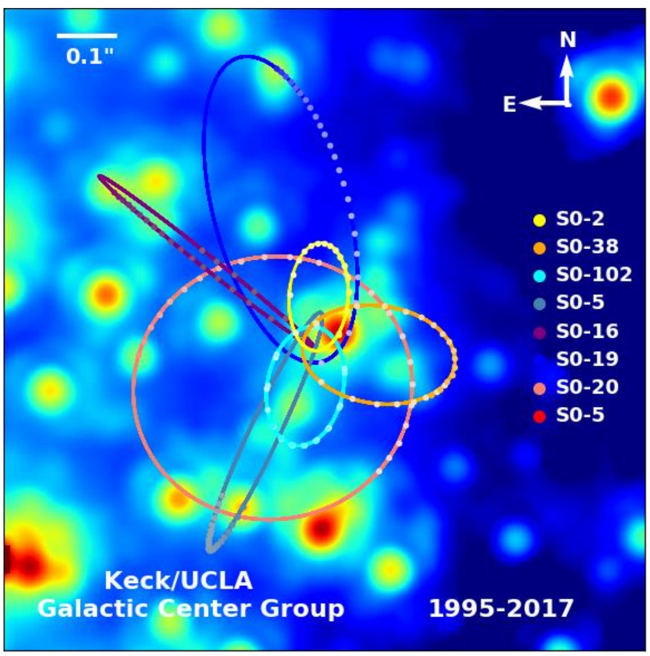
X-ray image of Cygnus X-1 by the HERO (High-Energy Replicated Optics) telescope. NASA

Since black holes are black, how can we detect them? The first object that met potential criteria for being a black hole was the X-ray object Cygnus X-1. It was detected by the earliest suborbital rocket-borne X-ray observatories in the mid 1960's. The X-rays presumably come from hot, dense matter circulating in an accretion disk around the black hole outside of its event horizon, which is the orbit at which the escape velocity is equal to the speed of light. Because Cygnus X-1 was found to be a binary system with a blue giant star (visual magnitude 8.95) orbiting an unseen companion, the mass of the companion could be calculated, assuming the blue giant is a typical member of its stellar class. The result was an object that we now calculate to weigh 14.8 solar masses. In 1970 the Uhuru satellite discovered rapid fluctuations in the X-ray signal, indicating that the object had to be quite small, smaller than a star would be with that mass. Variability on the order of 1 millisecond has been detected, relating to the infall of matter from the blue giant onto the accretion disk of the black hole, which it orbits at a distance of only 0.2 astronomical units. Subsequent observations, including the discovery of many similar objects and the detection of axial radio jets that could only have their origin in a spinning object of vast mass, have made it certain that black holes exist.

Remarkably, the late Stephen Hawking was a skeptic in spite of his contributions to the theory of black hole thermodynamics. In 1974, Hawking bet gravitation expert (and *Interstellar* advisor) Kip Thorne that Cygnus X-1 was not a black hole. The bet read as follows:

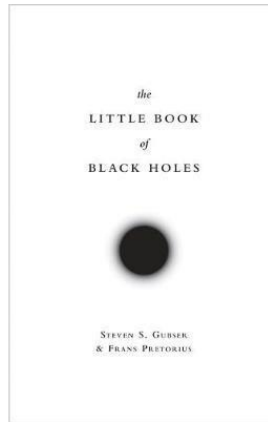
> Whereas Stephen Hawking has such a large investment in General Relativity and black holes and desires an insurance policy, and whereas Kip Thorne likes to live dangerously without an insurance policy, therefore be it resolved that Stephen Hawking bets 1 year's subscription to Penthouse as against Kip Thorne's wager of a 4-year subscription to Private Eye that Cygnus X-1 does not contain a black hole of mass above the Chandrasekhar limit.

In 1990, Hawking conceded the wager, apparently by breaking to Thorne's office at the California Institute of Technology (assisted by his nurses and attendants) and affixing his thumbprint to Thorne's copy of the bet. Hawking was notorious for making and losing scientific bets. In 2000, he bet University of Michigan physicist Gordon Kane $100 that the Higgs boson would never be found. He famously lost a bet to John Preskill, the Richard P. Feynman Professor of Theoretical Physics at Caltech, regarding black hole information loss, the prize being a baseball encyclopedia. The story of the controversy surrounding what is known as the "information paradox," whether information is lost to the universe when it falls into a black hole, is told in Leonard Susskind's excellent book, *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics* (Little, Brown, 2008). In this extensive and interesting volume, Susskind reveals that in 1980 Hawking had bet physicist Don Page, who was a graduate student of Hawking's, that "in quantum gravity, the evolution of a pure initial state [composed entirely of regular field configurations on complete, asymptotically flat hypersurfaces] can be given in general only by an S-matrix to a mixed final state and not always by an S-matrix to a pure final state." Page bet that there would be a pure final state, but whatever that physics gibberish actually means, Hawking conceded the bet in 2007, again affixing his thumbprint to the original contract. Hawking also had bet Canadian theoretical physicist Neil Turok that cosmic inflation existed and claimed publicly in a BBC interview that he won when the BICEP2 data was first released (see "Pardon My Dust" in the May 2015 SkyWAAtch). The discovery of polarization in the cosmic microwave background due to gravitational waves that permeated the universe at the end of the inflationary era 10^{-32} seconds after the Big Bang was later retracted and attributed to scattering by galactic dust, so Hawking was premature in his claim. Turok is invested in a cyclic universe theory, which does not predict primordial gravitational waves (see Steinhardt and Turok's *The Endless Universe*, published in 2007). Primordial gravitational waves are distinct from those emitted by a black hole merger, as seen by LIGO. The primordial waves would not be detectable by that instrument.



Orbits of stars around Sagittarius A*, the 4 million solar-mass black hole at the center of the Milky Way galaxy. There's a lot of information at http://www.astro.ucla.edu/~ghezgroup/gc/?.

A number of additional observations are consistent with black holes and in fact can only be explained by them. The energy output of quasars, for example, only makes sense if the radiation is emitted by the accretion disk surrounding a supermassive black hole. The jet of M87 is similarly explainable only by a supermassive black hole at the center of the galaxy. The orbits of the stars at the center of our galaxy, determined by serial observations with the Keck telescope in Hawaii, clearly have a common focus located at a point that does not contain a visible object.

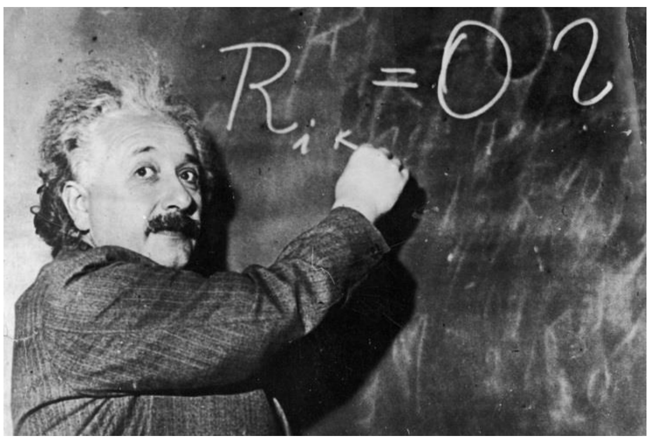


There are quite a number of decent books about General Relativity and black holes but one just published has much to recommend it. *The Little Book of Black Holes*, by Princeton physics professors Steven Gubser and Frans Pretorious (Princeton University Press, 2017, $19.95) is part of the Science Essentials series, whose goal is to "bring science to a general audience. The series provides the foundation for a better understanding of the scientific and technical advances changing our world," notes the publisher. Topics are primarily in the realm of the physical sciences but biology and even neuroscience are included.

The book is efficient: in 7 chapters and less than 200 small-format pages, it provides clear explanations of Special and General Relativity, presents the dynamics of Schwarzschild black holes and spinning black holes, describes real black holes in our universe and what happens when they collide, and discusses black hole thermodynamics and information theory. The level of information is hardly trivial. In the chapter on Special Relativity, for example, the authors discuss the Lorentz transformation and Minkowski space-time and even make a geometric derivation of $E=mc^2$.

The most fascinating parts of the book are descriptions of how the environment around a black hole influences the motion of objects and the experiences of observers both close to and distant from the event horizon (and even inside of it!). One of Oppenheimer's contributions in the late 1930'was the demonstration that an observer close to the collapsing object wouldn't notice anything unusual until they reached the singularity, and would experience the passing of time in an ordinary way. A distant observer on the other hand would see his colleague becoming increasingly redshifted over an infinite amount of time, never reaching the singularity, which in any case is not visible because it is shielded by the event horizon. Gubser and Pretorius have you travel around both Schwarzschild and Kerr black holes to explain how the gravitational field affects spacetime, modifies your trajectory and alters your perceptions.

In the chapter on Black Holes in the Universe, Gubser and Pretorius make the interesting point that the mathematics (and thus the modelling calculations) of black hole collisions takes on an extremely simple form. Because the total energy density of matter (recalling $E=mc^2$) outside of a black hole is negligible compared to the rest energy of the black holes themselves, we can ignore the stress-energy tensor of the equation of General Relativity given at the beginning of this article. Thus, if $T_{\mu\nu}=0$, then the solution to the field equations of General Relativity becomes the rather simple $G_{\mu\nu}=0$! There's even a famous picture of Einstein writing an analogous form of the equation on the blackboard (making the Ricci tensor equal to 0).



Einstein solving the equation for a black hole in the absence of surrounding matter.

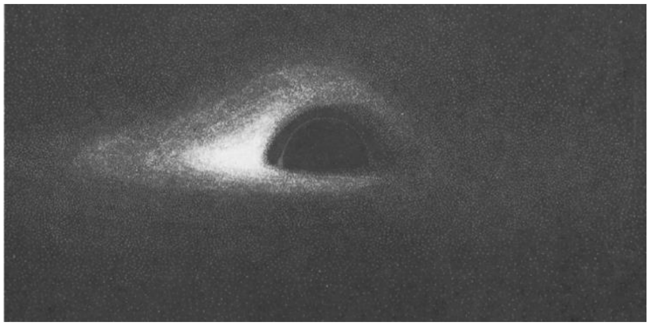
Gubser and Pretorius give excellent, efficient explanations of the LIGO black hole merger detection and describe Hawking radiation and black hole thermodynamics in an understandable way. They even address the possibility of wormholes. Overall, as an introduction to black holes, I think this highly focused book is better than some other excellent tomes. Kip Thorne's epic 1994 book *Black Holes & Time Warps: Einstein's Outrageous Legacy* (W.W. Norton) is comprehensive and extremely informative, but at over 550 pages it's not an efficient read. I'd stay away from *The Science of Interstellar*, Thorne's 2014 justification of the plot of the movie of the same name, which focuses too much on the movie and the highly speculative, mathematically unproven elements of the wormhole and tesseract (the interior of the black hole into which the protagonist falls). As some of you may recall, I hated the movie and reported my objections in detail in my article in the January 2015 SkyWAAtch. You can get a quick bite of Thorne's approach in a talk he gave on January 5, 2018 at the Keck headquarters in Hawaii, posted on the Keck Observatory web site. Keck sponsors an excellent public lecture series, presented in the town of Waimea on the Big Island. They cover a wide variety of astronomy topics. They are recorded and archived on the Keck web site at http://www.keckobservatory.org/recent/type/video.

Barnard professor Janna Levin describes the search for gravitational waves with LIGO in *Black Hole Blues* (Knopf, 2016). She focuses (like Ferreira's history of General Relativity) on the personalities of the scientists involved, starting with Joseph Weber, who claimed to have detected gravitational waves in 1969 using a thick bar of aluminum, and going on to Rainer Weiss, Kip Thorne, Barry Barish and Ronald Drever, the most prominent of the individuals who developed LIGO. Drever would probably have won the 2017 Nobel (with Weiss and Thorne) in place of Barish had he not passed away in early 2017 (Nobels can only be given to living recipients). It's an interesting and chatty book: Levin delights in reporting her interactions with the scientists. I think it suffers a little from having been finished just before the LIGO announcement in early 2016, the detection being added as an Epilogue. In any case, the interested and perhaps time-pressed amateur astronomer probably wants a more rigorous and objective review of the topic, and for this Gubser and Pretorius fill the bill perfectly.

We can "see" black holes indirectly through the detection mechanisms already mentioned: X-ray detectors, star orbits, quasar measurements. But could we really "see" one and make out its boundaries?

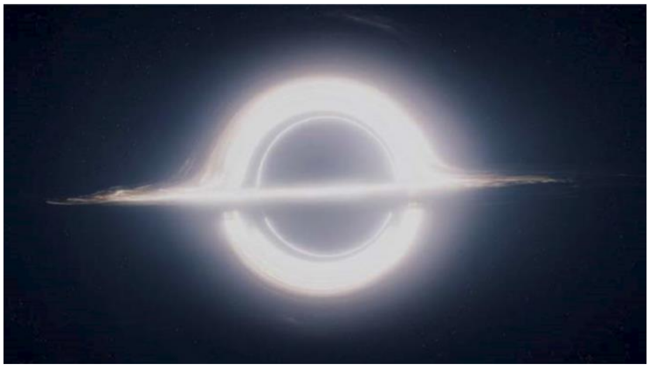
The first simulated image of a black hole, based on the mathematics of the Schwarzschild metric, was made by Jean-Pierre Luminet. In 1978, he performed an accurate numerical simulation using the IBM 7040 computer of the Paris-Meudon Observatory. The 7040 was a refrigerator-sized, transistor-based mainframe computer made in the early 1960's. An incredible technological wonder when it debuted in 1963, by 1978 it was already obsolete, and by way of comparison your Apple iPhone exceeds its processing capability by a factor of over 100 million! Even a USB thumb drive has more processing power. The data was inputted via punch cards (if you've ever worked with punch cards, as I have, you will know what a torture that was), and processing would have taken many hours. There was no video output. Lument writes:

Without a computer visualization tool, I had to create the final image by hand from the digital data. For this I drew directly on negative image paper with black India ink, placing dots densely where the simulation showed more light. Next, I took the negative of my negative to get the positive, the black points become white and the white background becoming black.



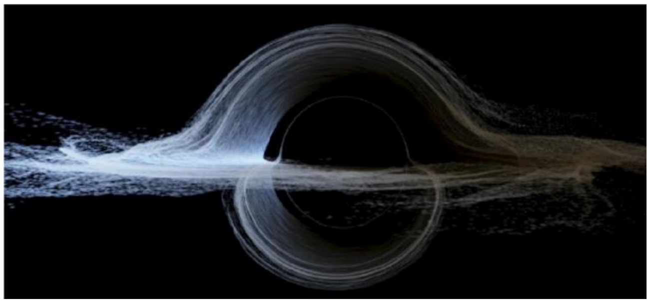
Simulated photograph by Luminet of a black hole with a thin accretion disk seen from 10° above the disk's plane

We are more familiar with the image of the black hole "Gargantua" from the movie *Interstellar*. The event horizon is intersected by the foreground part of the accretion disk, and light from the disk behind the object is spread out circumferentially as it is bent by the black hole's gravitation, appearing as a halo.



Gargantua, the Kerr black hole and its accretion disk as seen from the disk's plane in *Interstellar*

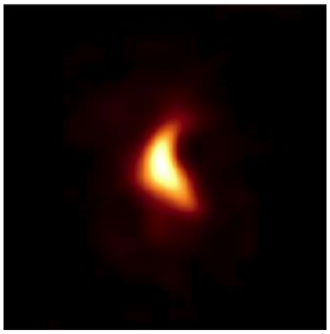
It turns out that this image is not scientifically correct. The movie's director, Christopher Nolan, didn't like the look of the more accurate rendering as originally calculated and visualized by Kip Thorne. Nolan insisted that the object appear symmetrical. Because of the speed of rotation of the accretion disk, a more correct depiction would have the approaching light rays blue-shifted and brightened and the receding rays red-shifted and attenuated.



Kip Thorne's more accurate visualization of a Kerr black hole

The Event Horizon Telescope, an array of radio telescopes across the globe, is attempting to image Sagittarius A* through interferometry. The project, in operation since 2006, has finally gathered enough data and may produce the first image of a black hole sometime this year. It would be a black area partially surrounded by distorted light from the accretion disk. The challenge for the EHT is to resolve an object that is thought to be 25 million kilometers wide but 26,000 light years distant. Its angular diameter is estimated to be only 50 microarcseconds. This is the diameter of an apple on the Moon as seen from Earth. The EHT is also trying to image the supermassive black hole in M87, which is a thousand times more massive than Sgr A*. M87's 7 billion solar mass black hole has a diameter of perhaps 36 billion kilometers (about 0.25 astronomical units). At a distance of 53.5 million light years, it should subtend the same angle from our vantage point as Sgr A* and thus be detectable. It's unlikely that we could directly image a stellar mass black hole in the Milky Way. There are none close enough: the nearest is the binary X-ray source A0620-00, which is 3,500 light years distant and estimated to be 40 kilometers in diameter, giving an angular diameter of around 20 nanoarcseconds by my calculation. We wouldn't want stellar mass black holes to be close, anyway, given their prodigious emission of X-rays.

Many of the peculiar and fascinating properties of black holes remain in the province of mathematics, not likely to be physically experienced by anyone but nevertheless true, and you can appreciate those wonders by reading *The Little Book of Black Holes*. ■



Simulation of what Sgr A* might look like in the Event Horizon Telescope

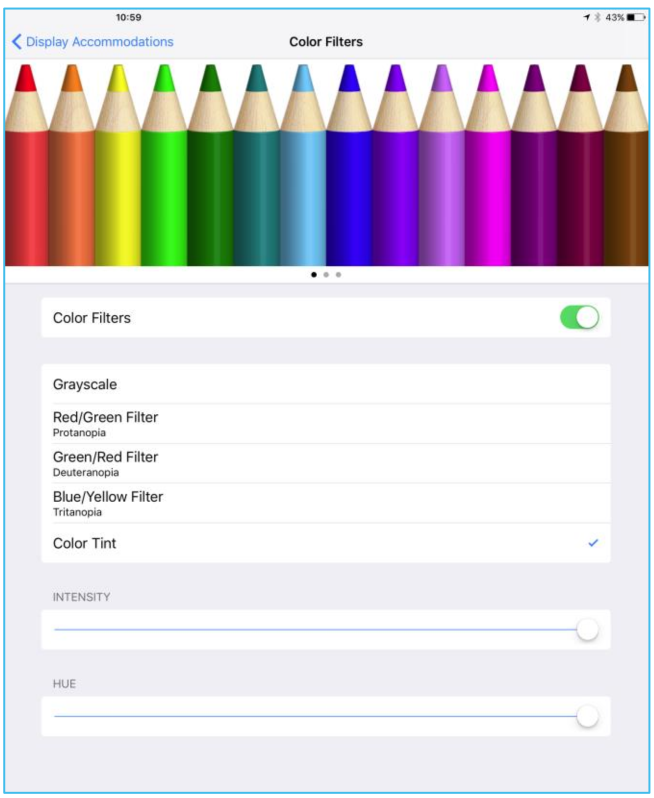
Red Screen Overlay for iOS Devices

Do you get embarrassed when you turn on your iPhone at a star party and the bright screen attacks your dark adaptation (or worse, your neighbor's)?

There's a simple way to change the screen so that it has a red cast, as if you had a piece of Rubylith placed over it. This can be done using controls native to iOS, and it's simple to turn the effect on and off. Here's how.

Go to Settings, click on General and then Accessibility.

Choose Display Accommodations and then Color Filters. You will see a row of colored pencils across the top. Click the Color Filters switch to on (green), then select Color Tint. Scroll down to the two sliders and move them all the way to the right. The display will turn deep red. Click the Color Filters switch off. The display will return to its usual color.



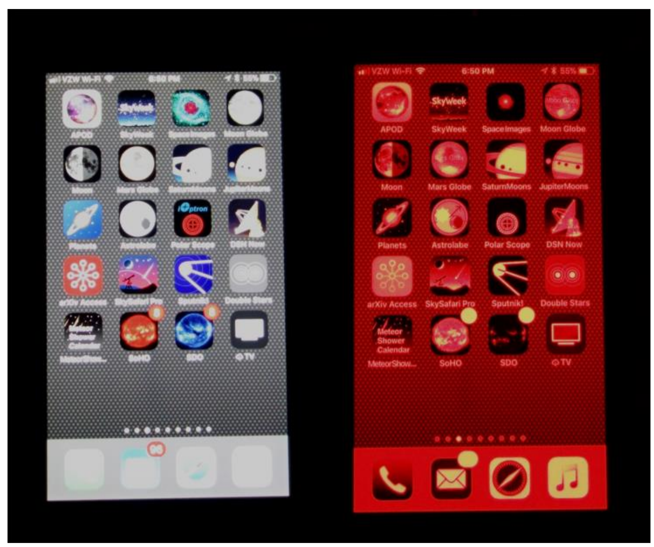
Click "< Display Accommodations" at the top left to go back, then click "< Accessibility" go back to the Accessibility screen. Scroll all the way down to Accessibility Shortcut and click it. Select Color Filters and a check will appear next to it. Then exit out of the Settings app.

Now, when you triple-click the Home button on your iPhone, the display will turn deep red. Triple click again and you are back to the usual display.

You won't need this for apps such as SkySafari, which has its own night setting (in fact, you can't see the SkySafari controls at the bottom of the screen if this red effect is on), but it's useful for lots of other software. It works from any screen you happen to be on.

This works for all iOS devices (iPhones, iPads, iPods). We don't know whether there's something similar for Android. If you know of one, send it along.

This trick came to us from Bruce Berger of the Amateur Telescope Makers of Boston.



Now, if you have to send a message or look at your calendar or do something else on your iPhone or iPod at a star party, you won't be a source of light pollution.

The Moon's Northern Region

The Moon's North Pole is situated near the line of bright cliffs marking the edge of the crater Peary, where the terminator merges with the sharp eastern limb of the moon in this image made on March 26, 2018. The image extends down to the northeast edge of the Mare Imbrium and the recognizable lava-filled crater Plato. The Alpine Valley is the cut in the Montes Alpes. The swath of nearly crater-free lava between the Alps and the highlands near the pole is the Mare Frigoris. 127 mm Maksutov, QHY-5L-II camera, red filter, best 25%, of 3036 frames, each 3.297 ms in duration. Processed in Autostakkert!2, Registax 6.1 and Photoshop Elements.

--Larry Faltz

Whirlpool Galaxy

M51, the Whirlpool Galaxy, is an obvious favorite for astrophotographers. Mauri Rosenthal used this target to confirm the performance of a new lens picked up at NEAF. "Usually new equipment brings 3 weeks of rain but I'll take this stroke of good luck" noted Mauri after compiling 90 minutes of useful exposure time in the same weekend. He used a Borg 71FL scope with a ZWO ASI1600MC camera mounted on an iOptron CubePro 8200 mount, and processed the image with PixInsight. "This lens delivers a lot of detail in a very lightweight form, which allows me to use an inexpensive portable mount for deep sky work typically associated with more substantial equipment." Any shortcomings of the mount are obviated by shooting 15 second subs, stacked live with SharpCap. The two galaxies interacting to form such a beguiling shape are about 25 million light years away and the main galaxy is said to be about one third the size of our Milky Way.

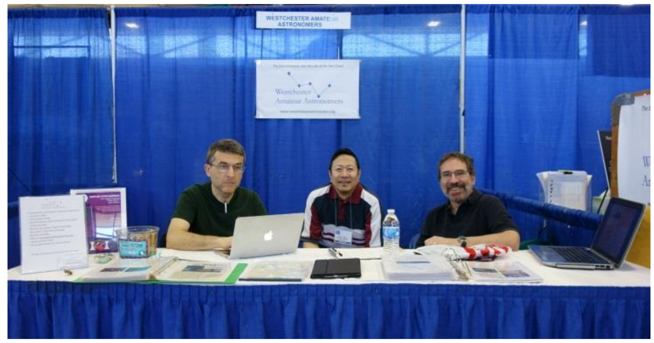
-- Mauri Rosenthal

NEAF 2018

There was a plethora of scopes, cameras and many new high-tech devices at this year's NEAF.

Front (L-R): Angie Virsinger, Mike Cefola, Charlie Gibson. Rear (L-R): Josh Knight, Mike Virsinger, Darryl Ciucci, Woody Umanoff

Mike Lomsky and Rich Steeves



Matt Leone, Peter Young, Mauri Rosenthal

WAA member John Higbee (Alexandria, VA) next to his newly-restored early 1960's Spacek 6-inch f/15 refractor at the Classic Telescope booth

The largest scope at NEAF this year. It won't fit in your Fiat 500!

Thanks to official booth staffers Mike Cefola, Darryl Ciucci, Brian Dugan, Larry Faltz, Charlie Gibson, Bob Kelly, Josh Knight, Matt Leone, Scott Levine, Mike Lomsky, Pat Mahon, Olivier Prache, Dede Raver, Mauri Rosenthal, Karen Seiter, Richard Steeves, Woody Umanoff and Peter Young, and the many other club members who stopped by and spent time supporting the club.

Member & Club Equipment for Sale
May 2018

Item	Description	Asking price	Name/Email
Celestron 8" SCT on Advanced VX mount	Purchased in 2016. Equatorial mount, potable power supply, polar scope, AC adaptor, manual, new condition.	$1450	Santian Vataj spvataj@hotmail.com
Televue 2X Powermate	PMT-2200. 2" version, with 2"-1¼" eyepiece adaptor. 4 elements, 48mm filter thread. Al Nagler's improvement on the Barlow. Big, weighs 22 oz. New condition. In polypropylene bolt case. Link.	$175	Larry Faltz lfaltzmd@gmail.com
ADM VCW Counterweight system	Clamping plate for a V series dovetail. 5" long ½" thick threaded rod for counterweights. Original ADM 3.5 lb counterweight plus a second weight. New condition. Lists at $55. Link.	$35	WAA ads@westchesterastronomers.org
Celestron Ultima-LX 5 mm eyepiece Celestron Ultima-LX 8 mm eyepiece	70° FOV, fits 2" and 1¼". 16mm eye relief. 28 mm clear aperture eye lens. 8 elements. Rubber coated bodies. Ergonometric contours. Extendable twist-up eyeguards. Takes 1¼" filters. These are large, impressive eyepieces, no longer in production! New condition.	$50 each	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.	$200	WAA ads@westchesterastronomers.org
Interfit 487 large rolling storage bag	39½x22x16" fabric-sided standing gear bag with rollers, Velcro compartments. Excellent condition. Donated to WAA.	$25	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 only submit serous 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. 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*!