SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

March 2022

The Pleiades Up Close by Rick Bria

The core of the Pleiades. The four brightest stars are, clockwise from left, Alcyone, Maia, Electra and Merope. Fourteen-inch PlaneWave telescope at Mary Aloysia Hardey Observatory, Sacred Heart School, Greenwich.

WAA March Meeting

Friday, March 11 at 7:30 pm

On-line via Zoom

Comets, Asteroids and Near-Earth Objects

Steve Bellavia
Brookhaven National Labs & Suffolk Community College

Steve will discuss comets, asteroids and Near Earth Objects that have been discovered in the last several years, including visitors from other star systems as well as close neighbors that pose potential hazards, crossing Earth's orbit every several years.

Steven Bellavia is an amateur astronomer and telescope maker. He is an aerospace engineer who worked for Grumman Aerospace with the Thermodynamics Group of the Space Division. He performed the analysis, design and fabrication of the micro-gravity liquid droplet radiator that flew on Space Shuttle mission STS-029. Steve has been at Brookhaven National Laboratory since 1992 and was the principal mechanical engineer for the camera on the Vera Rubin (formerly called the Large Synoptic Survey Telescope, LSST).

Steve is an assistant adjunct professor of astronomy and physics at Suffolk County Community College and the Astronomy Education and Outreach Coordinator at the Custer Institute and Observatory in Southold, New York.

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WAA April Meeting

Friday, April 8 at 7:30 pm

On-line via Zoom

The Amazing Variability of the T Tauri Stars

F.M. Walter
Stony Brook University

Starway to Heaven

Ward Pound Ridge Reservation, Cross River, NY

March 5 (no make-up date)
March 26 (rain/cloud date April 2)

Call: **1-877-456-5778** for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA web site www.westchesterastronomers.org.

New Members

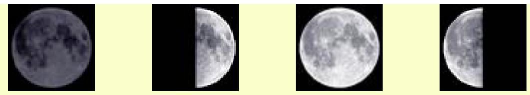
Joya Colon-Berezin	White Plains
Wellington Veras	Hartsdale

Renewing Members

Steven Bellavia	Mattituck
Darryl Ciucci	Greenwich
Tom & Lisa Cohn	Bedford Corners
Matthew Dugan	White Plains
Wayne Forrest	Briarcliff Manor
Patricia, Jon and Frank Gelardo	Mamaroneck
Peter Germann	Katonah
Jinny Gerstle	West Harrison
Jonathan Gold	Newcastle
Emmanouil Makrakis	Scarsdale
John Markowitz	Ossining
Geoffrey McFadden	Stamford
Hans Minnich	Mahopac
William Newell	Mt. Vernon
John Pasquale	Bedford
Albert Sayers	Pelham
OliverWayne and Elizabeth Scott	Cliffside Park
Kathleen Thrane	Greenwich
Joseph Willsen	Yonkers
Lori Wood	Yonkers
Albert Ysaguirre	White Plains

ALMANAC For March 2022

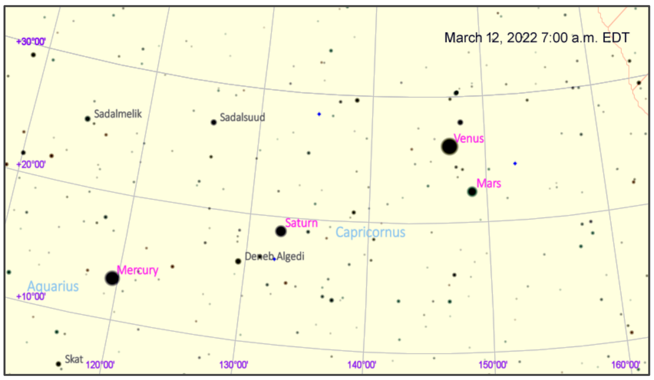
Bob Kelly, WAA VP for Field Events



New 3/2 | 1Q 3/10 | Full 3/18 | 3Q 3/25

Blazing Venus Hovers in the Dawn Sky

Venus maxes out at 47 degrees from the Sun at greatest western elongation on the 20th. This beacon of brightness, now at magnitude -4.7, stays just ahead of the Sun in the morning sky until conjunction with the Sun in October. Venus has a socially distanced conjunction with **Mars**. They're closest on the 12th, four degrees apart.



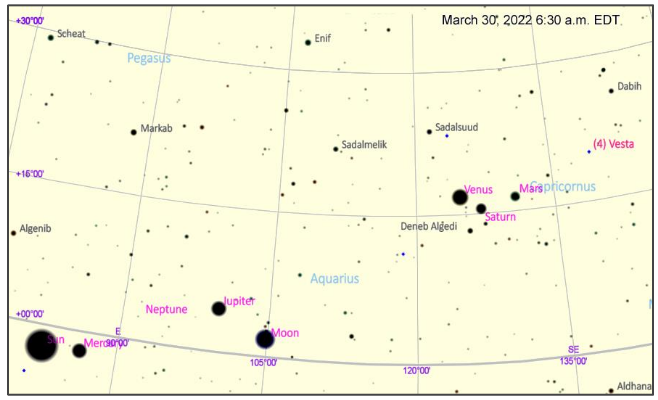
Jostling for Position in the Morning Sky

Venus and Mars start out the month waiting for company only 10 degrees above the horizon an hour before sunrise. They leave the tea party in Sagittarius, moving into Capricornus, which has a high opinion of itself as the Goat. **Saturn** is moving out from the Sun's glare. On the 2nd, the sixth planet passes **Mercury**, which is leaving the morning sky, very low above the horizon. Venus, Mars and Saturn get their act together to make a nice trio on the 28th that just might fit in one view through a pair of wide-field binoculars. The Moon spends several days well off to the right of the planet party starting on the 26th.

Jupiter will also come out of the glare after solar conjunction on the 5th. You might catch it low in the morning sky on the 30th. That day, the Moon comes to visit only 39 hours before it's new.

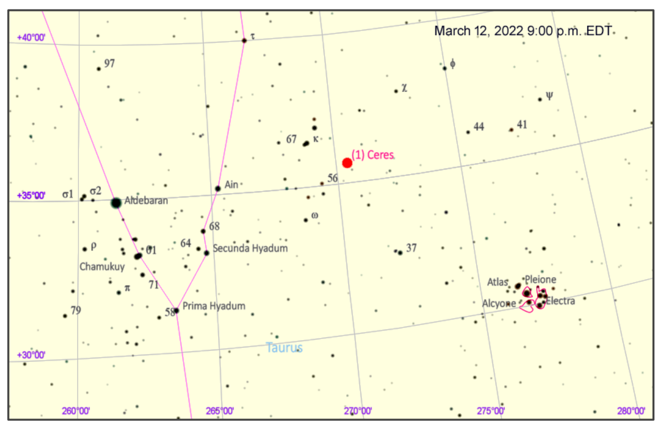
The shallow slope of the ecliptic is why our morning planets don't get much altitude. They are easier to see in the southern hemisphere where the ecliptic is almost perpendicular to the horizon.

Uranus and Neptune aren't visible this month.



Asteroid Trap

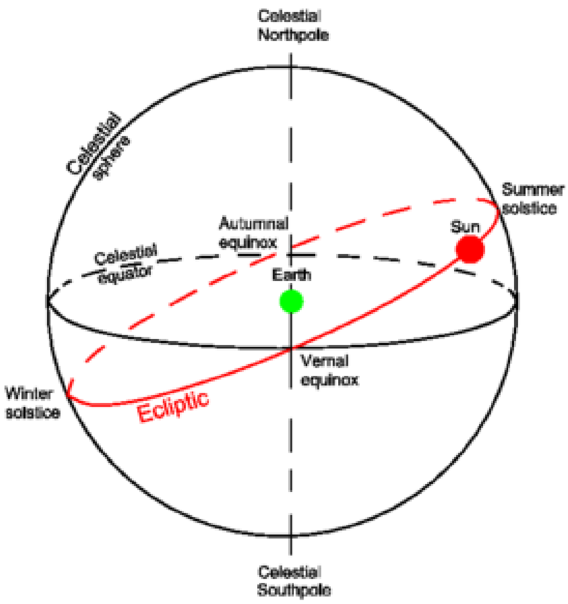
The minor planet **4 Vesta** is the brightest of object in the Asteroid Belt this month. If you want to find Vesta, it's hanging out near Mars (see the map above). You'll need to be up and out before astronomical twilight begins to see this 8.1-magnitude speck in binoculars or a telescope. It'll move to the upper right as the month goes on, heading toward opposition in August when it will reach magnitude 5.9.



The largest asteroid, dwarf planet **1 Ceres**, may be easier to find, even at magnitude 8.9. This is because it's in a darker part of the evening sky, hanging out between the Hyades and Pleiades clusters.

Spring Time

The coming of Daylight Time gives us more light during the commute home. And, a more convenient time for viewing morning planets! [But we have to start our evening observing an hour later!-Ed.]



We ”spring forward” at 2 a.m. local time on Sunday, March 13th. Sunrise jumps from 6:11 a.m. to 7:10 a.m., with the start of astronomical twilight going from 4:40 a.m. to 5:38 a.m. It’ll make it easier to get up to see the morning planet parade out your eastern window.

The Vernal (spring) equinox for the northern hemisphere occurs at 10:33 a.m. EDT on the 20th. An equinox occurs when the Sun is at the exact point at which the ecliptic crosses the celestial equator, moving northwards in the spring and to southwards in the fall.

Hiding Behind a Bright Moon

The Moon will occult some brighter stars this month. About 7:50 p.m. on March 15th, **Eta Leonis** will appear to slide behind the Moon. It’ll be a struggle to see this magnitude 3.5 star, near the end of twilight and so close (by definition) to the almost full Moon.

On the 18th, just about 11:51 p.m., **Porrima** (Gamma Virginis) will disappear behind the 99-percent-lit Moon. Even at magnitude 2.8, this also may be hard to see. It will pop out at 12:46 a.m. Get out in advance of the event to see if you can spot Porrima at all in the Moon’s glare.

The start of the Moon-Eta Leonis occultation, 7:51:23 EDT. The Moon is 94% illuminated, but the occultation starts on the narrow shadowed side. (made with Cartes du Ciel)

More Moon

The Moon is closest to us for March on the 23rd, near the last quarter phase, and is visible low in the south during the morning.

Hope for Auroras

Increasing solar activity may give us aurora. If you have a solar filter for your telescope, you’ll find sunspots showing up regularly now for your viewing pleasure.

International Space Station

The ISS is predicted to be visible in the morning twilight through the 13th and in the evening twilight starting on the 15th.

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

Editor: Larry Faltz
Assistant Editor: Scott Levine
Almanac Editor: Bob Kelly
Editor Emeritus: Tom Boustead

Member Profile: Eli Goldfine

Home town: Larchmont

Family: I live with my parents, my sister, Nina, and my cat, River.

How did you get interested in astronomy? Do you recall the first time you looked through a telescope? What did you see? I got interested in astronomy the first time I looked through a telescope. I was three years old at the time, and lived on the Upper East Side of Manhattan. My dad had taken me to a Manhattan moon observing night with the American Astronomical Society. I still remember that night, even though it was six years ago. I was fascinated by that view and I got very interested in astronomy after that.

What's your favorite object(s) to view? My favorite objects to view are the objects from the Messier catalog, particularly M31 (the Andromeda galaxy), M13 (the Hercules cluster), M92 (NGC 6341 in Hercules), and M27 (the Dumbbell nebula). I also really enjoy looking at Jupiter and Saturn. I can see those much better with my equipment.

What kind of equipment do you have? I have a Celestron NexStar 4SE, a 25-mm eyepiece, a Star-Pointer FinderScope, and a Celestron 12V PowerTank. I have a Canon Rebel XSI camera, T-adapter, and T-ring for astrophotography. Although I have attempted to do the photography, it has not worked yet.

What kind of equipment would you like to get that you don't have? I would like a bigger aperture telescope because the one I have now is only four inches. I would also like an eyepiece that would give more magnification; the only one I have now is the one that came with the telescope, which is 25 mm (magnification 53x). I would also like a Celestron StarSense AutoAlign, which can, as its name suggests, auto align the telescope so you do not have to use the finder scope to align the telescope to the sky.

Have you taken any trips or vacations dedicated to astronomy? Tell us about them. Not yet, but I would like to go to a town in upstate New York called Copake Falls (my cousins have a house there), to be closer to the totality path of the Great American Eclipse in 2024. I have done some astronomy on previous trips (some to Copake Falls), but no trips have been dedicated to astronomy.

Are there areas of current astronomical research that particularly interest you? I am very interested in the research that the James Webb Space Telescope is going to do, and, in fact, I am writing this only a couple hours after watching the launch. The JWST cost $10 billion dollars over 20 years, and the efforts of hundreds of people. This telescope will let astronomers, other scientists, and even the general public to look back in time to the beginning of the universe. One day I would like to study these photos (assuming the telescope works) as a professional astronomer.

Do you have any favorite personal astronomical experiences you'd like to relate? I have a few. For the first one, I am going to refer again to that first time I looked through a telescope when I was three years old. The second time was at the June 2021 WAA Star Party. I never thought I could see something so sophisticated with my relatively small NexStar telescope. It was M13. It only looked like a green smudge, but I was still really excited I could see anything at all. The third took place in my front yard when I got a great, very detailed view of Jupiter, and then of Saturn.

Have you read any books about astronomy that you'd like to recommend? I strongly recommend Mike Massimino's *Spaceman*. I read the young readers edition, but I am sure that the adult version is also excellent. It is a veteran astronaut's autobiography. He traveled on STS109 and STS125, and was committed to becoming an astronaut since he was six years old. The book focuses on the obstacles he overcame to fulfill his dream. This book is my favorite, but I would also suggest *Endurance* by Scott Kelly, *American Moonshot* by Douglas Brinkley, and *Brief Answers to the Big Questions* by Stephen Hawking.

How did you get involved in WAA? I was researching the Great Conjunction in December 2020 and I found out about WAA. The Conjunction was clouded over, but I am certainly glad I found WAA.

What WAA activities do you participate in? Mostly the star parties. Unfortunately I have only been to two of them (by coincidence two of them fell on the days my dad spent the day in bed after his Covid shots), but I hope to be able to go to more in 2022. I also really enjoyed observing the 5 a.m. partial solar eclipse on June 10, 2021 with WAA.

Besides your interest in astronomy, what other avocations do you have? I enjoy cartooning, drawing, writing, reading, math (especially the division algorithm and stoichiometry), playing piano, and tasting different cuisines (my favorites are Mexican, Indian, Korean, and Ethiopian). My favorite food is beans, and I like to cook bean stews, cassoulets, beans and rice dishes, and many other dishes.

Provide any other information you think would be interesting to your fellow club members, and don't be bashful! Last academic year (2020-21), My parents decided to homeschool me due to the pandemic. Meanwhile, my 4 year-old sister was doing remote at a private Hebrew nursery school. A month or two into the year, her teachers decided to teach an astronomy unit. My sister had told them that I was interested in astronomy, so they sent me an email asking if I wanted to come into their zoom for ten minutes and conduct a small lecture about space and astronomy. I said yes. I was excited to take advantage of the opportunity. During the Zoom, I showed the 4-year olds the order of the planets using a small model of the solar system I got for my birthday when I was six. After that, I talked a little about Mercury, the planet they were studying that week. For this I used a small globe of Mercury. I pointed to one of the craters. "Does anyone know what these are called?" I think I did get the right answer from one of them. Surprisingly, all of my sister's classmates were really involved in the discussion. Then I asked if anyone had any questions. I got one that I think was very intelligent for a four-year old. He was excited about the MARS2020 mission. He asked, "Do scientists build the rovers that are on Mars?" "Yes," I said. "You're right. There are thousands of people all around the country that worked on that." I thought that was the end of it, but strangely enough, the teachers asked me to come into their Zoom every week so I could teach the class more about the stars, planets, and space exploration. So after that I spent a reasonable amount of time finding models, images and ideas to make concepts less confusing. This lasted their whole space unit (practically the whole year), and I never once missed a week. My lecture series ended with a concluding talk about the Hubble Space Telescope. It was a very fun experience, and I would definitely do it again. ■

Editor's note: I did very little editing of Eli's profile! I did advise Eli to plan to get into the path of totality in 2024. The Sun in West Copake will only be 90% eclipsed.

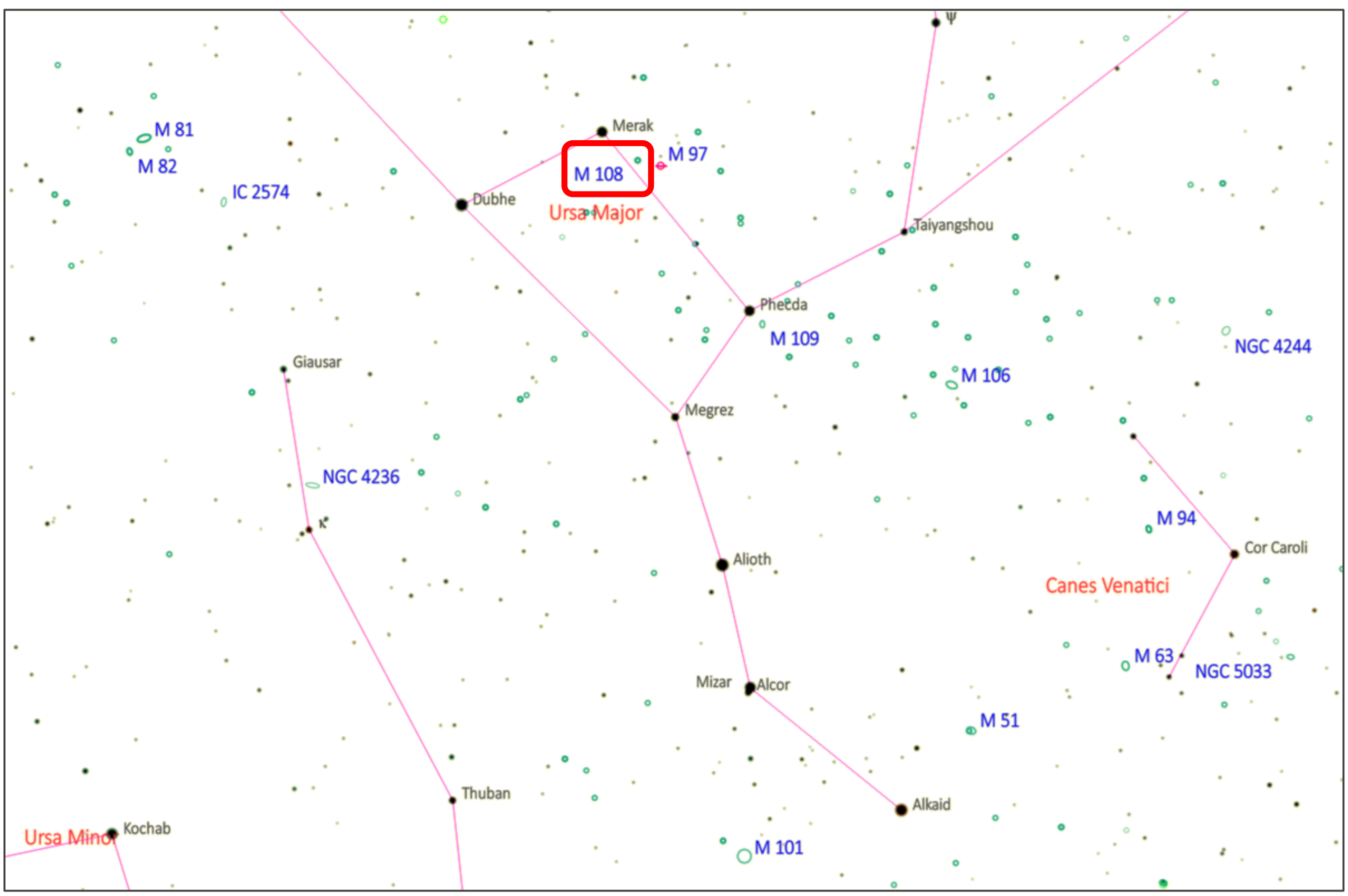
See Xavier Jubier's site for much more information on the 2024 eclipse. https://is.gd/TSE2024.

Deep Sky Object of the Month:

Messier 108	
Constellation	Ursa Major
Object type	Galaxy
Right Ascension J2000	11h 11m 31s
Declination J2000	+55d 33m 11s
Magnitude	10.7
Size	8.7 x 2.2 arc minutes
Distance	45.9 million LY
NGC designation	3556
Discovery	Pierre Mechain 1781

Sometimes called the "Surfboard Galaxy," M108 is a barred spiral galaxy pitched 75 degrees to our line of sight. It has a small supermassive black hole at its core weighing 24 million solar masses. The total mass of the galaxy is about 125 billion solar masses. About 300 globular clusters surrounding it have been identified, although the exact number is still unclear.

Visibility for M108			
10:00 pm EST/EDT	3/1	3/15	3/31
Altitude	46° 34'	46° 56'	38° 04'
Azimuth	62° 07'	61° 26'	69° 33'



Astronomy 101: Eye Relief

Larry Faltz

Like most beginning amateur astronomers, my initial understanding of how telescopes were constructed and used was pretty rudimentary, growing as much by trial and error as anything else. I had read Sam Brown's *All About Telescopes* but it takes hands-on learning to really know the details. I learned about eye relief (henceforth ER) the hard way. Wanting something with higher power and wider field for my then-new 5-inch orange-tube Celestron SCT, I saw an ad for an 8-mm "wide-field Konig" eyepiece from University Optics, one of the big mail-order firms in the pre-Internet days. Sadly, they closed their doors in 2017 after more than 55 years supplying amateurs with mirror-building kits, scope and mount hardware, finders and eyepieces.

The Japanese-made Konig promised 65 degrees of field, a lot better than the 43-degree 10-mm and 25-mm Orthoscopics that came with the C5 (although you can't beat Orthos for sharpness). The first time I put it in the scope, I had to squash my cornea right up to the surface of the lens to get the whole field on to my retina. It wasn't much fun. I never did use it much. It was only afterwards that I learned about the importance of ER and its dependent on focal length among different eyepiece designs.

Eye relief is formally defined as the distance the eye must be from the last lens surface of the eyepiece in order to view the entire field. It's only one of the factors one needs to consider when choosing an eyepiece. While focal length, directly related to magnification by the formula M=telescope FL/eyepiece FL, is usually the primary consideration, apparent field of view, special glasses, coatings, weight, and cost also need to be considered. Some factors that aren't usually listed are field curvature, contrast, internal reflection suppression, and even image color. Astronomy web sites such as CloudyNights carry heated discussions about the quality and performance of various eyepieces. Some brands, designs and even specific focal lengths have partisans with the rabidity shown in support of a European soccer team.

Older eyepiece designs generally have poor ER, particularly at shorter focal lengths, preventing you from seeing the entire field. Fortunately, archaic designs like Hugenians, Kellners and Ramsdens are no longer marketed by reputable vendors. ER in short focal-length 4-element Orthoscopics, is low, but they can be useful for planetary observing where you don't necessarily care about the outer parts of the field. They are particularly prized by owners of large (six to nine- inch) refractors. My Meade Research-Grade 7-mm does fine work on Mars in my 8" CPC, but my 4-mm Ortho is only useful for collimating my SCT, which is the sole reason I bought it. Telescopes today, when they come with eyepieces, are usually supplied with Plössls, also a four-element design but with a wider field of view than Orthos. Again, ER is less with shorter focal lengths, fairly similar to the Orthos.

The ER fall-off with shorter focal-lengths can be illustrated with data for some Televue Plössl eyepieces.

Focal length (mm)	Field of View (degrees)	Eye Relief (mm)
40	43	28
25	50	17
15	50	10
8	50	6

There are new multi-element designs with excellent ER and wider fields of view at all focal lengths. For example, Televue 62-degree DeLite and 72-degree Delos line all have 20 mm of ER at every focal length, even down to 3 millimeters. Televue Nagler T6 82-degree eyepieces have 12 degrees of ER and the 100-degree Ethos eyepieces all have 15-degrees of ER. Many other high-quality makers now offer long-ER designs at many focal lengths, and unlike the old days the ER is always listed in the description of the eyepiece. A Barlow lens or Televue Powermate increases magnification without reducing ER, so that's another way of gaining magnification.

Glasses-wearers will need at least 15 millimeters of ER. For people with astigmatism, wearing glasses while observing may be necessary, but if your astigmatism isn't that bad, try to observe without them. Another alternative, although at a cost, is the Televue DIOPTRX™ line of astigmatism-compensating lenses, which attach to the top of some Televue eyepieces and can be rotated to the correct axis. They range from 0.25 to 3.5 diopters. You are of course locked-in to Televue's eyepiece line, which can be a little more expensive than competing brands, but they are among the best. ■

Fast Optical Systems Robin Stuart

In the October 2021 SkyWAAtch, p.13, Olivier Prache gave a comprehensive review of his Celestron 8″ f/2 RASA astrograph, along with a number of fine images that displayed its impressive capabilities. His article prompted me to revisit my own understanding of the advantages of fast optical systems that was largely formed in the days when astrophotography was carried out with photographic emulsions—film—and examine whether these ideas still apply in an age of digital detectors.

As a teenager longingly reading books on astrophotography, I learned that in order to capture comets or diffuse nebulas you needed fast optics - meaning a system with a small f-ratio. This requirement however apparently didn't apply to stars. Another message was also clear. Fast optical systems needed mirrors with deep curves that were beyond the ability of most amateur telescope makers (ATMs) to grind and figure. In addition they were very sensitive to optical aberrations and collimation errors. Manufactured systems, if they existed at all, were prohibitively expensive. Given this sad reality I mentally filed the information and thought not much more about it.

Reciprocity Failure

A key advantage touted for fast optics was that they produced brighter images that required shorter exposures and were therefore less prone to the effects of the dreaded of *reciprocity failure*. With its grandiose and esoteric title it was bound to strike fear into the heart of any aspiring astrophotographer!

For short exposures, the density of an image in the photographic emulsion, denoted E, is proportional to the light intensity, I, times the exposure time, t, or $E \sim I \times t$. If the light intensity is reduced, the same image density can be achieved by increasing the exposure time by the corresponding factor. Unfortunately at low light intensities requiring exposures of longer than about 30 seconds, this reciprocal relationship between intensity and exposure time breaks down and the effective film speed slows down considerably. In photographic film, the light sensitive pixels are tiny grains of silver halide suspended in a gelatin emulsion. When a photon strikes the grain it produces a silver atom within the larger silver halide crystal. This situation is unstable however and the silver atom may revert to its original state unless sufficient light is received to produce enough silver atoms to trigger the conversion of the entire crystal to metallic silver.

Reciprocity failure could be mitigated to some degree by *hypersensitization*. There were several methods of doing this. Gas hypersensitization involved bathing the film in mixtures of hydrogen and nitrogen or even mercury vapor before exposure. The film might also be baked for an extended period during the procedure. The aim of the nitrogen and heating was to drive out oxygen and water vapor from the photographic emulsion and increase the stability of the latent silver atoms. Hydrogen seeds the silver halide crystals with stable silver atoms that catalyze the conversion of the entire crystal. Articles on film hypersensitization can be found in *Sky & Telescope* from 1970 until 1995. Lumicon sold hypersensitized film and gas hypersensitization kits.

Lumicon advertisement for gas hypersensitization kits from *Sky & Telescope*, January 1997, p.93.

An alternative to gas hypersensitization was to chill the film to very low temperatures. This extends the life of the unstable single silver atoms allowing more time for enough of them to accumulate to trigger the conversion of the whole silver halide crystal. In the Amateur Scientist column of its December 1973 issue, *Scientific American* described how to construct a cooled camera in which the film was sandwiched between a thick plug of clear plastic facing the telescope and crushed dry ice (solid CO_2) behind. The plastic plug provided enough thermal insulation that the exposure could be completed before the chill of the dry ice reached its far side causing dew to form.

Now that CCD and CMOS detectors have replaced film, reciprocity failure is thankfully a thing of the past. So, do my preconceptions, formed long ago, concerning the unique advantages offered by fast optical systems still hold true?

Imaging Systems

The amount of light (the number of photons) that an optical system gathers depends only on the aperture. The image scale at focal plane, measured in, say, arc minutes per millimeter, depends only on the system's (effective) focal length. The brightness of the image at the focal plane, or irradiance[1], measured in say watts per square centimeter (W/cm^2) therefore depends only on the ratio of the aperture to the focal length – the f-ratio. These key properties are summarized in the table below

Property	Proportional to
Light gathering power	Aperture^2
Image Size	Focal Length
Image Area	Focal Length^2
Image Brightness	f-ratio^2

It follows that both a 6-inch aperture f/2 and a 6-inch aperture f/4 system gather the same amount of light. The f/2 system with its shorter focal length however produces an image that is ½ the linear size, and therefore occupies ¼ of the area, compared to that of the f/4 system. Since the light in the f/2 system is concentrated into a ¼ the area it is 4 times as bright as it would be at f/4 and is therefore 4 times as fast. This argument does not apply to point sources such as stars as they are unresolved and their size on the image plane are doesn't depend on the focal length[2]. Their brightness then only depends on the aperture.

A 6-inch f/2 system and a 3-inch f/2 system both produce images that are equally bright at the focal plane but the image scale, image size and resolution of the 3 inch are half that of the 6 inch.

Digital detectors responding linearly over a wide range dynamic range can compensate for low light intensity by longer exposure times. Digital images can be stacked by the tens or hundreds, which is impossible with film. They offer a tremendous range of processing options that are not available in the dark room. Can digital processing take the place of the advantages traditionally associated with fast optics?

Digital Binning

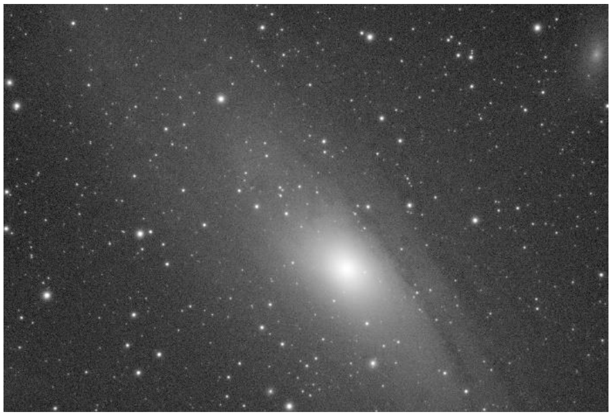
With digital detectors it is possible to combine the signals from a group of pixels and treat them as if they were a single larger pixel. The process is known as binning and can be done in post processing or within the camera itself. In 2×2 binning, the signal or count of photoelectrons from 2×2 square groups of four pixels are combined by either adding them up or averaging. The resulting image will then have half the number of pixels on a side compared to the original, and thus the image will have a quarter the total number of pixels in the camera. Binning can also be done using larger groups of pixels. For a given digital detector and exposure time, an image taken with a 6-inch aperture f/4 system employing 2×2 additive binning will be just as bright and have same size and scale as an image taken with a 6-inch aperture f/2 system. The f/2 system will have twice the field of view. In addition, since the read noise associated the sum of n pixels scales as $\sqrt{n}$ it will be twice as large for the binned pixels as for the unbinned pixels.

The images on page 11 show M31 in Andromeda through a 70-mm aperture Televue Pronto equipped with a 0.8× focal reducer, yielding an effective focal length of 384 mm at f/5.5. All the images were taken with a Meade LPI-G monochrome camera that has the option to perform *additive* or *average* binning. The former was used here. The images were all stretched using the default *Screen Transfer Function* in *PixInsight*. The unbinned exposure time was 300 seconds and for an $n \times n$ binned image it was 300/n^2 seconds. All exposures show very similar image density. In the 4×4 binned image the telescope was operating at an effective f/1.4!

The main difference between the image produced by an actual fast f-ratio optical system and one simulated by binning is the field of view. To match the field of view of a real physical f/1.4 system by digital binning images from the f/5.5 system would require that 16 subimages to be stitched together into a mosaic, requiring a total exposure time of 300 seconds, which is the same as the exposure time for the original un-

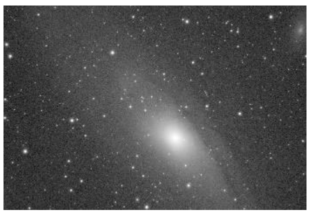
[1] *Irradiance* is the total power per unit area over the entire electromagnetic spectrum. *Illuminance* is the same as irradiance but restricted to visible wavelengths.

[2] In principle the size of a star's Airy disk in the image plane is proportional to the focal length but in practice it is normally overwhelmed by the effects of seeing and pixel size.



300 seconds exposure
No binning, 3040×2048 pixel image
Effective f/5.5

75 seconds exposure for comparison
No binning, 3040×2048 pixel image
Effective f/5.5



75 seconds exposure
2×2 binning
1520×1024 pixel image
Effective f/2.7

33.3 seconds
3×3 binning
1012×682 pixels
Effective f/1.8

18.75 seconds
4×4 binning 760×512 pixels
Effective f/1.4

18.75 seconds exposure at left enlarged for comparison with the unbinned exposures above

binned image and far longer than the 18.75 seconds required for the physical f/1.4 system.

It should be noted that digital binning works nicely for monochrome cameras with or without filters but is not so straightforward for one-shot color (OSC) cameras.

Conclusion

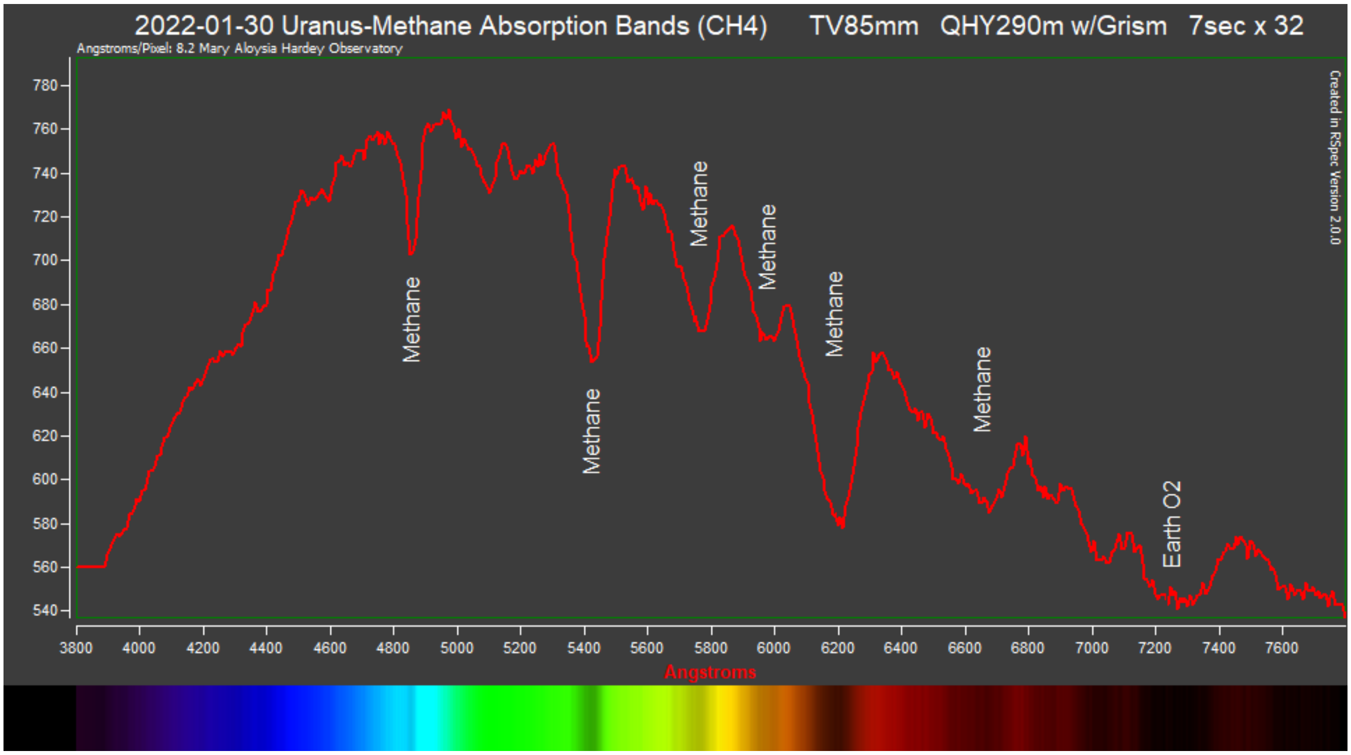
In an age of digital detectors the principle advantage offered by fast optical systems is in the time needed to produce an image. If imaging and processing time is not a constraint then the output of a fast optical system of a given aperture can be matched by a system with the same aperture and longer focal length. The longer focal length system will also show finer detail as each pixel covers a smaller number of arc seconds.

When time is a critical factor, fast optical systems still shine! These situations include making sky surveys or maybe capturing the faint but changing knots in a cometary tail. For the amateur astronomer the time constraints might also be driven by the access available to a dark sky site, the frequency of clear skies or life in general.

■

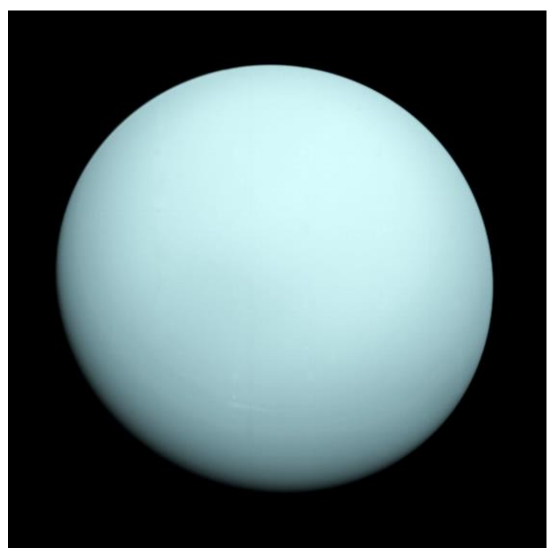
Editor's note: As Robin notes, stars are "point sources" because their angular diameter is beyond the resolving power of film or digital sensors. However, early astrophotographers noticed that brighter stars looked bigger than fainter stars. The light from bright stars scatters in the emulsion of photographic film, a process known as "halation." The difference in sizes was used as an early objective measure of stellar magnitude. See "Measuring Starlight" in the September 2021 SkyWAAtch.

The Spectrum of Uranus — Rick Bria



Rick writes:

The planet Uranus looks blue-green in the Voyager 2 picture from NASA. It is similar in color to Earth, but that is where the similarity ends. Uranus looks blue-green due to methane. Less than 3% of its atmosphere is methane, but that is enough to give it its color, which is also its hue when seen in a medium size telescope.



Full spectrum sunlight is filtered by the methane in the atmosphere of Uranus. Red is absorbed and blue-green is reflected.

Spectroscopy reveals wide absorption bands at multiple wavelengths from methane. This spectrum of Uranus was taken at the Mary Aloysia Hardey Observatory at the Sacred Heart School in Greenwich. Absorption bands of methane and Earth 0_2 are labeled.

It is interesting to think that sunlight took 2 hours and 40 minutes to travel from the Sun to Uranus. Just the blue-green wavelengths were reflected back. Blue-green light then took more than 2 hours more for the return trip to Earth. As that blue-green light passed through the Earth's atmosphere and was recorded in our camera, wavelengths near 7200 angstroms were absorbed from oxygen and water vapor (Earth 0_2). The spectrum graphically displays the story of the sunlight's journey.

Editor's note: Like spectra of individual atoms, molecular spectra depend on the quantized energy transitions of electrons, but these electrons are the ones involved in bonds between the atoms, the so-called valence electrons. As the bonds stretch, bend and wiggle, the electrons gain or lose energy. Since there are many vibrational modes, molecular spectra can be very complex and the bands are often broader than the sharp energy levels in atomic spectra.

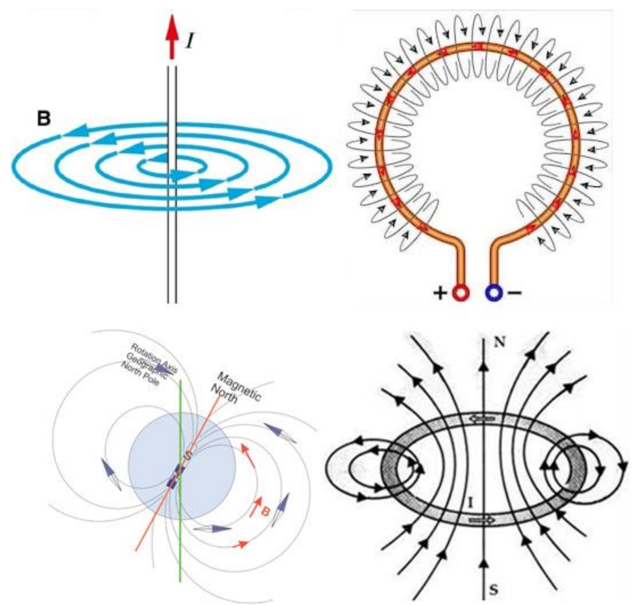
The Magnetic Universe

Larry Faltz

Most students are introduced to physics in grade-school by playing with two bar magnets. Students feel their opposite poles attract, and then that peculiar and baffling feeling as their like poles resist. Then, inevitably the teacher puts one under a sheet of paper and sprinkles iron filings on top, showing the magnetic field. Shortly thereafter, the relationship between electric current and magnetism is demonstrated by watching a compass needle change direction when placed near a wire carrying an electric current. Maybe a crude electromagnet is demonstrated. At least, that how it was at P.S. 96 back in the late 1950s. It's a bit of a jump from that point to Maxwell's Equations, but even without a formal introduction to physics everyone knows a magnet will stick to the refrigerator but not to your skin, no matter what some anti-vaxxers have claimed.

One of the most important concepts in physics is that of fields. In fact, everything in the universe is actually a field, even matter. It seems odd to think that material objects are just data at points in space, but it seems to be true. A clear explanation is provided in a 2017 lecture[1] at the Royal Institution by Cambridge theoretical physicist David Tong, a presentation at the Royal Institution's lecture series that was begun by Michael Faraday himself. It's a basic introduction delightfully presented and I highly recommend it.

The magnetic field is generated by the motion of electrons. A bar magnet, or its bent analog the horseshoe magnet, is simply a rod of iron whose component atoms are oriented so that the spin of their electrons is more or less the same direction. Spin should really be in quotes because electrons don't actually spin, but since they have a property called angular momentum[2] we might as well think of them as spinning. Naturally occurring lodestones, known since antiquity, contain crystals of magnetite, $Fe^{2+}(Fe^{3+})_2(O^{2-})_4$. This compound contains both ferrous (2+) and ferric (3+) iron, a somewhat unusual pairing. Magnetites probably formed in an intermediate oxygen environment.[3] Iron is the main but not the only atom that can be magnetic. Nickel, cobalt and some rare earth metals can also form magnets. Artificial magnets are made nowadays by exposing these materials to a strong magnetic field, although in ancient times iron bars could be magnetized by hammering them, which forces the iron atoms to align enough to create a weak magnetic field. Disrupting the orientation of the electron spins by heating beyond the "Curie temperature" (a characteristic of each atomic species, discovered by Pierre Curie) will cause the material to lose its magnetism. For iron, this temperature is 1,043 Kelvin.



Clockwise from upper left: A current *I* in a wire creates a concentric magnetic field **B**. When the wire is curved, the field rotates and forms an electromagnet. A circulating current, as in the Earth's outer core, generates a magnetic field that establishes a north and south pole, with lines of force emanating from it. The Earth thus acts like a bar magnet, all from circulating electric charges.

The scientific revolution really began with William Gilbert's magnetic experiments, culminating in the publication of *De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure (On the*

[1] https://www.youtube.com/watch?v=zNVQfWC_evg

[2] From two sources: orbital motion around the nucleus and their inherent individual "spin." The latter property is utilized to detect 21-cm hydrogen line in deep space. See the January 2016 SkyWAAtch, p. 8.

[3] When an atom loses an electron, it becomes more positive. This is "oxidation"; the reverse process is "reduction." A very useful mnemonic I learned in 10th grade chemistry is "LEO GR" for "loss [of] electron=oxidation, gain=reduction.

Magnet and Magnetic Bodies, and on the Great Magnet the Earth) in 1600. Lodestones had been known since antiquity and compasses were in use from around the beginning of the second millennium, first in China and then in the West. How magnets worked was a complete mystery. Aristotle wrote that ""Thales [of Miletus, who lived 200 years before Aristotle], judging by what they report, seems to have believed that the soul was something which produces motion, inasmuch as he said that the magnet has a soul because it moves iron." When mystical explanations of natural phenomena were no longer blindly accepted, magnetism, like light and electricity, would yield its secrets to human intelligence and curiosity.

Gilbert was the first great experimentalist. He made a model of the Earth called a terella, and with it showed that the Earth itself was magnetic. Prior to Gilbert, the common belief was that there was a lodestone at the North Pole to which other lodestones were attracted. Once Gilbert showed that the Earth itself was magnetic, this property was invoked to explain the Earth's spin, its orientation in space, and the motions of the planets. Other than Aristotle's "First Mover," the actual mechanism of celestial motion had no physical cause. Eudoxus' epicycles and Ptolemy's deferents and eccentrics were merely mathematical devices and everyone knew they were not real. With magnetism came evidence that "action at a distance," a concept that had up to then only been mythical, could actually occur.

Kepler, a dedicated heliocentrist, thought the Sun emitted magnetic impulses that whipped the planets around in their orbits. Galileo was supportive of this idea. Jesuit astronomers, looking to oppose heliocentrism, claimed that a magnetic Earth had to be the center of the universe, magnetism acting to pull everything towards it. Some felt that magnetism wasn't strong enough because if the Earth was magnetic then the Moon, thought to be made of ferrous material, would come crashing down on our heads. There was no real way to test Kepler's hypothesis, and anyway later in the 17th century Newton's *Principia* replaced magnetism with gravity, a concept still incorporating the mysterious "action at a distance" but built on a mathematically substantial foundation that quickly won acceptance. The commonly experienced "action at a distance" property of magnetism, at least at the local scale of the lodestone and compass, may have softened human reason enough so that it could accept the "action at a distance" property of gravity.

In the late 18th century, experiments began to close in on the relationship between magnetism and electricity, finally yielding to the wonderful experiments, commencing in the early 1820s, of Michael Faraday at the Royal Institution in London. Faraday, a completely self-taught genius, showed how moving electric currents could generate magnetic fields and how moving magnetic fields could generate electric currents, leading to the invention of the electromagnet and the electric generator. Faraday was so important that his laboratory, in the basement of the Royal Institution in central London just off Piccadilly, has been kept exactly as it was in the 1830s, his first electromagnet proudly on display.

Faraday's first electromagnet, on display at the Royal Institution (LF, 2013)

James Clerk Maxwell formally inaugurated the concept of fields and established the theoretical and mathematical relationships between electric and magnetic fields with his four famous (and somewhat inscrutable) equations, publishing his work in 1861 and 1862. Besides relating the fields to each other, the equations require that electromagnetic waves propagate at the speed of light. A corollary is that they can do so in a vacuum, that is, they don't need an "ether." Twenty years later, the existence of the ether, long a tenet of astronomy, was disproved.

The Earth is a gigantic electromagnet. Liquid iron in the outer core circulates, heated from below by the inner core and flowing under the influence of the Earth's rotation. The movement of its constituent electrons creates the field. The field lines extend from the poles of the axis of the outer core's rotation, forming a 3-dimensional magnetic torus. Its axis is tilted about 11 degrees from the Earth's rotational axis. Physicists and geologists still debate the tilt's origin.[4] The field strength is fairly weak. The intensity on the Earth's surface is 0.5 Gauss ($5x10^{-5}$ Tesla). It takes a superconducting electromagnet in an MRI machine to do significant magnetic damage, although small magnets can wipe the magnetic strip on your credit card without much difficulty. Early MRI's had a field strength of about 0.5 Tesla and new ones in common use routinely are 3-Tesla units. There are 7- to 11-Tesla research MRIs that can visualize individual neurons in the brain. I've seen the images. These are very strong magnetic fields, and metallic objects can be pulled into the machine or out of the patient with devastating consequences. Ultra-meticulous precautions are taken to exclude anything metallic within range of the magnet, either inside the patient or in equipment that may be needed for medical purposes or emergencies.

The magnetic field is a vector field: it has both strength and direction. A compass or iron filings on a sheet of paper over the magnet are the simplest types of magnetometers, devices which measure the direction and/or strength of the field. What direction would a compass point to at the exact point of the north magnetic pole? The field lines point straight down, and so would the compass. Compasses aren't helpful for finding one's direction in the far north or south (unless you're looking for the magnetic pole itself!) Modern magnetometers use a variety of sophisticated techniques to measure the direction and strength of a magnetic field.

Spacecraft are commonly outfitted with magnetometers. They provide a read-out of the local magnetic field, which will change along the probe's trajectory and thus provide details about objects and charges in the area. A fluxgate magnetometer was aboard Pioneer 1, which was launched on October 11, 1958. It was designed to reach the Moon, but premature shutdown of the main rocket engine caused to reach an altitude of only 71,000 miles. Nevertheless, it confirmed the existence of the Van Allen radiation belts, which had been discovered by the radiation detector on Explorer 1, and made other useful measurements of the Earth's magnetic environment. Voyagers 1 and 2 made remarkable measurements of the magnetic fields around the outer planets. Magnetometers of various designs, becoming more capable, reliable and accurate, have been nearly ubiquitous on subsequent spacecraft.

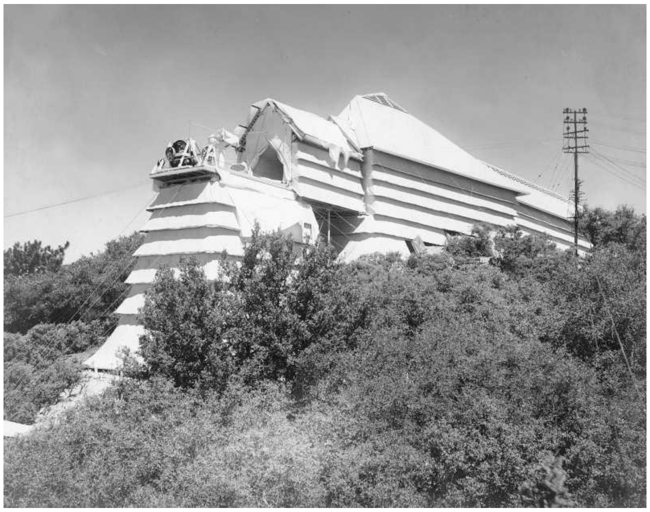
But how might we detect magnetism if we can't see its effect on a physical object like a compass needle or the detector of a magnetometer? Half a century before Pioneer 1, George Ellery Hale discovered magnetism in the Sun, whose composition was as yet known.[5] Hale, the great telescope impresario, was by training and interest a solar astronomer. He invented the spectroheliograph while still an undergraduate at MIT. When he moved to Mt. Wilson, he built three solar telescopes. The first was the Snow telescope, the largest solar telescope in the world on its completion in 1905 until 1908, when he built 60-foot and later the 150-foot (1910) tower telescopes. All three of these instruments are still operational at the observatory, although not used for formal research.

The Snow telescope's used a flat coelostat mirror mounted on the ground, feeding the light beam to a 24-inch f/30 mirror which projected the image horizontally into the observing shed. Using the Snow, Hale determined that sunspots were cooler than the surrounding solar surface. The 60-foot tower telescope had the advantage of better resolution because

[4] If you are setting up your telescope and use a compass to roughly align it to the north pole, be sure to correct for the north magnetic pole's offset. From WAA's observing site at Ward Pound Ridge, magnetic north on your compass is actually 12° 58' west of true north (in February 2022, moving east by 3' per year), not an insignificant deviation. There are a number of apps available that can make the correction; a simple one I use is "Compass Map Barometer" for iOS. A magnetic deviation calculator is at https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml?.

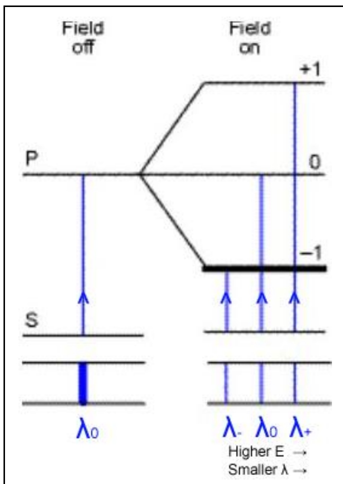
[5] See "How Stars Produce Energy" in the June 2021 SkyWAAtch.

the mirror was much less subject to heat distortion from the ground. With this instrument, in 1908 Hale found Zeeman splitting of spectral lines.



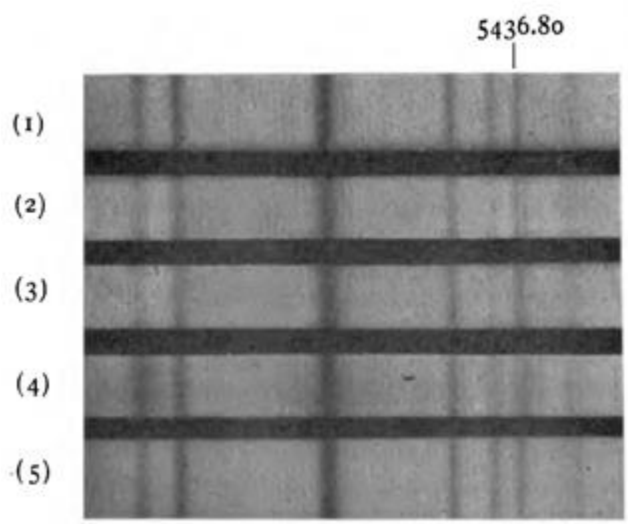
The Snow solar telescope at Mt. Wilson (Mt. Wilson Observatory)

The 150-foot (L) and 60-foot (R) tower solar telescopes at Mt. Wilson. The dome of the 100” telescope is on the left (LF, 2016)



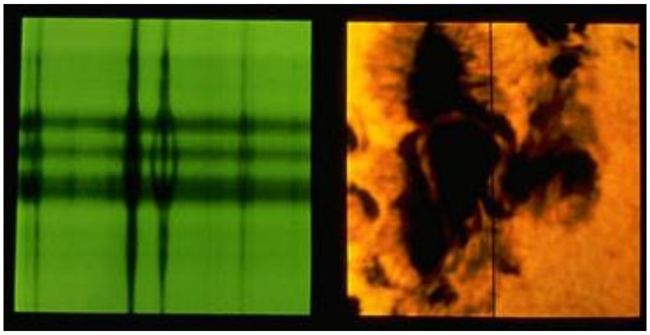
The Zeeman effect. An electron in the solar chromosphere at energy level P will absorb a photon with sufficient energy to jump to a more energetic orbital P. An absorption line will be seen in the spectra at the wavelength λ_0=hc/E where h is Planck’s constant and c is the speed of light. Interaction of the atom with the magnetic field slightly raises and lowers the energy of P. This is manifest as absorption lines in the solar spectrum at slightly different wavelengths (λ_- λ_0 λ_+).

The Zeeman effect was discovered in 1896 by Dutch physicist Pieter Zeeman, who was awarded the 1902 Nobel Prize for this work. Zeeman discovered this effect before the electron was discovered, but we have a clear picture now of how the phenomenon works. Electrons in atoms behave as if they were orbiting the nucleus (the Bohr model of the atom) although quantum mechanics tells us they are not actually doing that: they occupy “orbitals” at different energy levels. Each orbital is associated with a specific amount of orbital angular momentum. An electron can change orbitals by absorbing or emitting photons of a specific wavelength, *E= hv* (where *h* is Planck’s constant and *v* is the frequency, related to the wavelength *λ* by *λ=c/v*), detected as a spectral line. The background radiation from the Sun is a continuous output of photons of many wavelengths. A lower energy electron can absorb energy and jump to the higher level. In a magnetic field, the higher-energy electron orbitals each gain or lose a small amount of energy, determined by certain quantum details of angular momentum and their orientation in the field. The absorbed electrons have slightly different energies, resulting in splitting of the absorption line. This results in splitting of the spectral line. From the amount of splitting, the strength of the solar magnetic field can be calculated.



Hale’s spectrum of sunspots (#2, 3, 4) compared to the regular solar photosphere (#1, 5). Note the distinct broadening of the 5436.80 angstrom line of titanium in spectra 2 and 4. Hale, GE, On the Probable Existence of a Magnetic Field in Sun-Spots, *Astrophysical Journal*, 1908: 28: 315-343.

The Sun is a rapidly rotating ball of plasma, and the magnetic field is markedly different from that of the sedate Earth. Magnetic lines continually interact with the plasma, which circulates in the convective zone. The magnetic field is strongest in sunspots. There, the magnetic pressure increases while the surrounding atmospheric pressure decreases. This lowers the local temperature because the concentrated magnetic field inhibits the flow of hot, new gas from the Sun's interior to the surface. The stronger field strength is what results in the Zeeman effect. Sunspots are still hot, about 4600 K compared to the solar surface of 5780 K. They look black in the telescope, but that’s because of the contrast of the rest of the Sun. If the whole Sun was covered with sunspots, it would appear deep red. Magnetic field lines can leap from the surface and carry hot plasma into space (coronal mass ejections). But the Earth’s magnetism protects us from the magnetic aggression of the Sun as the charged particles flung from the Sun encounter the Earth’s field and are redirected to the poles.

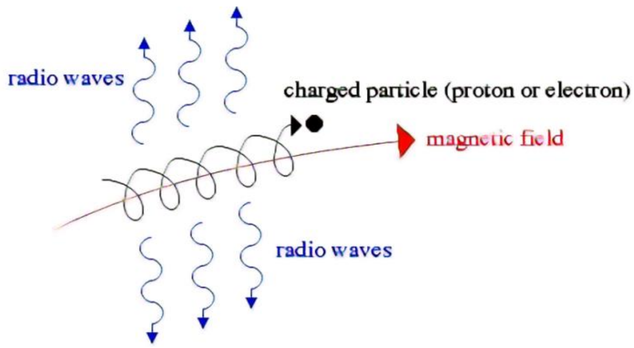


A clearer example of the Zeeman effect, showing splitting as the spectrograph slit moves across a sunspot (National Optical Astronomy Observatory).

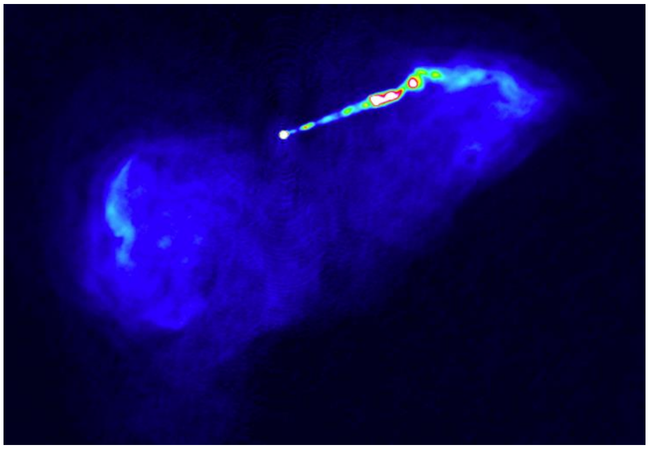
Mercury, like Earth, has a circulating molten iron outer core that generates its magnetic field, albeit 100 times weaker than ours. Venus rotates too slowly to have a magnetic field, although some magnetism is generated when its ionosphere interacts with the solar wind. Mars probably cooled too quickly and solidified its core. It only has some residual crustal magnetism. The outer planets have strong magnetic fields. Those of Jupiter and Saturn have been well studied by the Galileo and Cassini missions, respectively. Jupiter’s field is particularly large and intense, the product of the rapid rotation of liquid hydrogen in its outer core. The field strength at Jupiter’s equator is 4.17 Gauss. Saturn also has liquid hydrogen outer core and like Jupiter rotates rapidly. Both Uranus and Neptune have offset magnetic fields that may be generated by currents in salty oceans in the planets’ interiors. The Sun’s magnetosphere interacts with those of the other planets. It extends out to the heliopause, the place where the Sun yields its influence to interstellar space.

All stars generate magnetic fields that, like the Sun’s, influence their local solar systems. Among stars, the strongest fields are found in magnetars, a form of neutron star. Neutron stars form from the collapse of stars weighing 5-20 solar masses. The resulting neutron star weighs about 1.4-5 solar masses but have a diameter of just 12 miles, so they are extraordinarily dense. A sugar cube of neutron star material weighs some 100 million tons. They rotate rapidly, magnetars somewhat slower (once every 2-10 seconds) than their less magnetic pulsar siblings (1-10 times a second). The surface field strength of a magnetar is 10^9-10^{11} Tesla. As the progenitor star collapses, an extremely dense proton-rich superconducting fluid creates a magnetohydrodynamic dynamo inside the magnetar. Even though a neutron star is made of primarily neutrons and not individual protons and electrons, in magnetars enough charged particles remain and circulate at such a rapid rate that an intense field is created. The power of the magnetic field is so great that it generates gamma rays and X-rays, which differentiates a magnetar from other neutron stars, including pulsars. Magnetars have a short life span, depleting their magnetic fields in perhaps 10,000 years, but they put on a great show while they last.

In magnetars and pulsars, charged particles spiral in the magnetic axis of rotation, forming beams that go many parsecs into space and generate synchrotron radiation detectable in the radio band. Rotating supermassive black holes at the center of active galactic nuclei produce even more intense matter jets that emit copious amounts of synchrotron radiation.

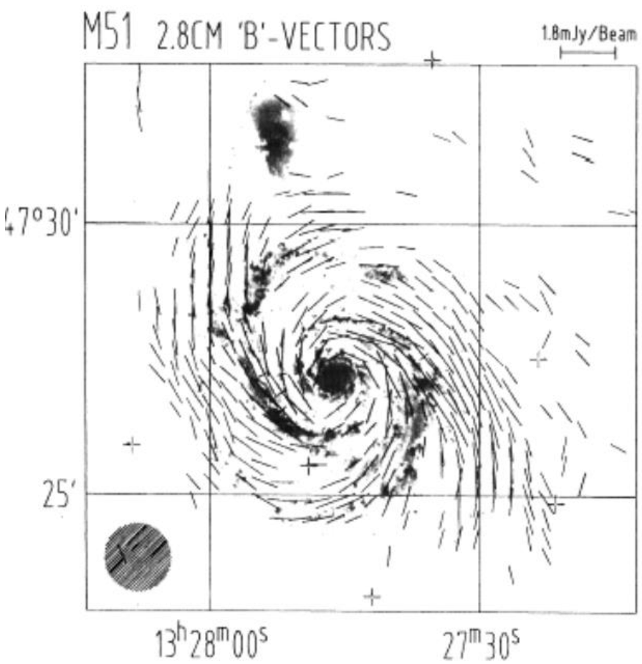


Synchrotron radiation is emitted when charged particles spiral around magnetic field lines..



Jansky VLA image of the center of Messier 87, showing its jet, formed by charged particles spiraling at relativistic speeds in an intense magnetic field, emitting synchrotron radiation. (NRAO)

Synchrotron radiation can be used to map out the magnetic fields of distant galaxies as well as objects in the Milky Way.

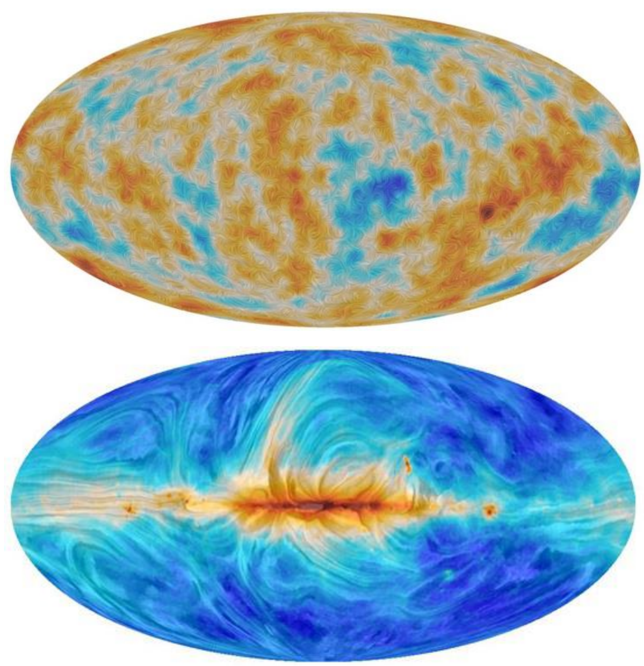


Magnetic field vectors in M51 (Neininger, N. et. al., The Magnetic Field of M 51, The cosmic dynamo: *Proceedings of the 157th Symposium of the International Astronomical Union*, 1992)

The Milky Way is filled with charged particles and is also rotating, so it should not be surprising that it has its own magnetic field, but it is extremely weak, about $5x10^{-11}$ Tesla ($5x10^{-7}$ Gauss). That's a millionth the intensity of the Earth's field but it's enough to alter the course of cosmic rays, adding to the difficulty of pinpointing their origin. How could we detect our galaxy's weak magnetic field? What can be coupled to the galactic magnetic field that would give us a useful signal?

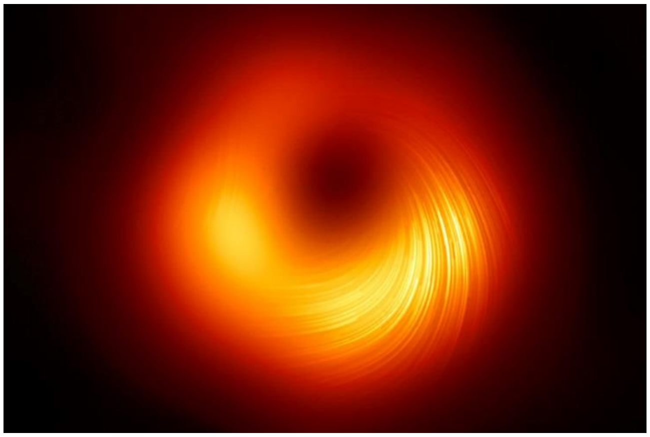
Interstellar dust particles created in supernova explosions are made of microscopic grains that contain small amounts of iron. These grains line up along the galaxy's magnetic field lines, just like iron filings on the paper above a bar magnet. When photons pass through these dust particles, the light becomes polarized in proportion to the field strength, and that allows the field to be detected and mapped. This phenomenon is called "directional extinction."

Not only can starlight be polarized, but even the photons of the cosmic microwave background can respond to the magnetic field. A small proportion of CMB photons, around 10%, were polarized by interactions with electrons at the "surface of last scattering," when the CMB formed 13.8 billion years ago. This process is known as Thomson scattering. These "E mode" polarizations can be seen as small squiggles overlying the familiar temperature variations in the CMB image below. CMB photons passing through the universe can be further polarized by dust grains oriented by the galactic magnetic field. These polarizations have also been detected by the Planck mission.



Top: E-mode Thomson polarization of the CMB (enlarge for clarity). Bottom: Polarization of the CMB by dust grains in the Milky Way (Planck)

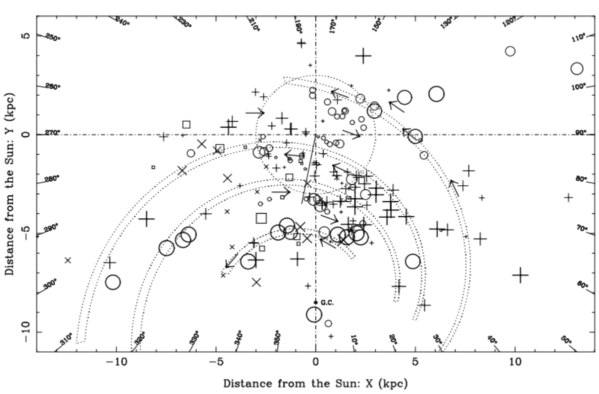
These foreground polarizations are what confused astronomers at the South Pole Telescope, who reported detecting "B mode" polarization in the CMB that would have been evidence for cosmic inflation. The polarizations were simply the result of intervening Milky Way dust particles.



Magnetic field lines of the accretion disc surrounding the black hole at the center of M87 (EHT)

You would also expect the rapidly rotating accretion disks around black holes to generate a significant magnetic field that would polarize the emission from the disk. The Event Horizon Telescope, which imaged the supermassive object at the center of Messier 87, detected that polarization. The intense magnetic field may connect the black hole with the accretion disk.

A magnetic field can further rotate the plane of polarization of already polarized light, a discovery made by Faraday in 1845. Faraday rotation of pulsar radiation by magnetic fields along the line of sight has helped to map out the magnetic field in several arms of the Milky Way galaxy.



Beck, R, Galactic and Extragalactic Magnetic Fields, *Space Science Reviews*, 99: 243-260 (2001).

Do the magnetic fields in the Milky Way contribute to the organization and evolution of the galaxy, or are they simply just there?

Current theories of star formation now include the magnetic environment in molecular clouds, in addition to the cloud's composition, temperature and density and the pressure from nearby supernova explosions. Using the 500-meter FAST radiotelescope in China, an international team of astronomers based at the National Astronomical Observatories of the Chinese Academy of Sciences detected splitting in hydrogen using the HINSA technique (HI Narrow Self-Absorption).[6] This method observes the spectra of hydrogen atoms that are cooled through collisions with hydrogen molecules (H_2).The frequency shift of the normal Zeeman effect in hydrogen is on the order of a few billionths of the intrinsic frequencies of the spectral lines, but the HINSA technique offers a significant increase in detectability. A field strength of $3.8 \pm 0.3 \times 10^{-6}$ Gauss, about 7 million times weaker than the field strength at the surface of the Earth, was measured in L1544, part of the Taurus molecular cloud.[7] This is about ten times stronger than the field strength of the Milky Way itself. The cold gas of L1544 has a coherent magnetic structure, encompassing both the cloud's core and its envelope. The authors cleverly use radiation from two quasars positioned in the cloud (but at cosmological distances behind it) in their analysis. A strong magnetic field would prevent the cloud from collapsing against gravity, but it must eventually do so in order for star formation to occur. This happens when the field becomes "supercritical," which appear s to be happening in the outer part of the cloud, the 'envelope," and not in the core as was previously suspected.

Compared to the sedate gravitational field, which changes smoothly in response to mass in the universe, the magnetic field can easily be pitched into complete chaos. We can thank the Sun's field for sending us just enough charged particles to create auroras, but we'll have to hope we don't have another "Carrington Event," when the flux is so great that the Earth's magnetic field is overwhelmed. The particles create their own magnetic fields and induce destructive currents that destroy electronics. Magnetism and electricity are an inseparable pair. ■

[6] Ching, T-C, Li, D, Heiles, C, et. al., Early transition to magnetic supercriticality in star formation, *Nature* (2022) 601:49-52, published Jan. 6, 2022.

[7] See Steve Bellavia's image of part of the Taurus cloud on the cover of the February 2022 SkyWAAtch.

Images by Members

The North American Nebula with the Hubble Palette by Tony Bonaviso

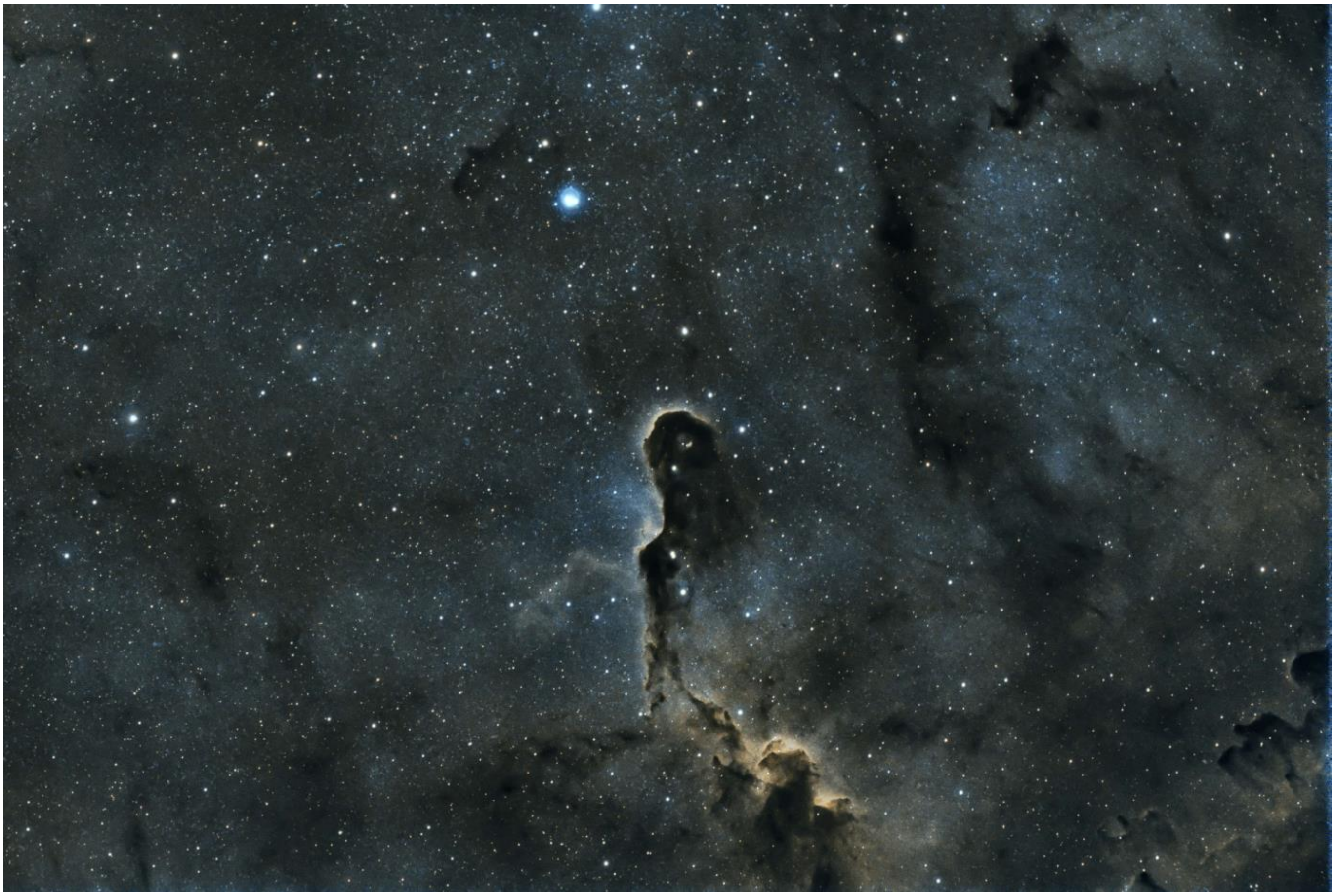
The sky is full of unwanted light, mixing with and obscuring faint objects that imagers are interested in. The old sodium and mercury vapor streetlamps emitted light in specific spectral bands that could be filtered out, but they are now pretty much gone, replaced by broad-spectrum LED's. When the Moon is high in the sky, it's reflecting broad-spectrum sunlight. All of this emission reduces contrast and obscures detail.

If we just wanted to look at stars, it would be less of a problem, because they too have broad-spectrum emission. But glowing gas in nebulas radiates at specific wavelengths, and to bring out detail it's best to filter out the wavelengths that they don't produce. The wavelengths that are of greatest interest are atomic hydrogen (H-alpha, 656.28 nm), doubly-ionized oxygen (OIII, 500.7 nm) and singly-ionized sulfur (SII, a doublet at 671.6 and 673.1 nm). Imagers with color sensors often use a narrow-band filter that passes Hα and OIII, while imagers using monochrome cameras can use individual filters, with even tighter bandpasses, for each spectral line.

The Hubble palette maps the three bands of interest to distinctly different colors. Since the Hα and SII bands are fairly close in the red, the Hubble imagers decided to make Hα green, keeping SII red, and making OIII a deeper blue than the blue-green of 500.7. These separations bring out details of structure and intensity that are unavailable with true-color imaging, even with narrow-band filters.

Tony made this image with a color camera and a single dual-bandpass (Hα/OIII) filter, and then used PixInsight to re-map the colors to create a Hubble palette image. The very powerful software is capable of isolating different wavelengths in a single image, extracting and transforming them at the user's command.

IC 1396, The Elephant's Trunk (Hubble Palette) by Gary Miller



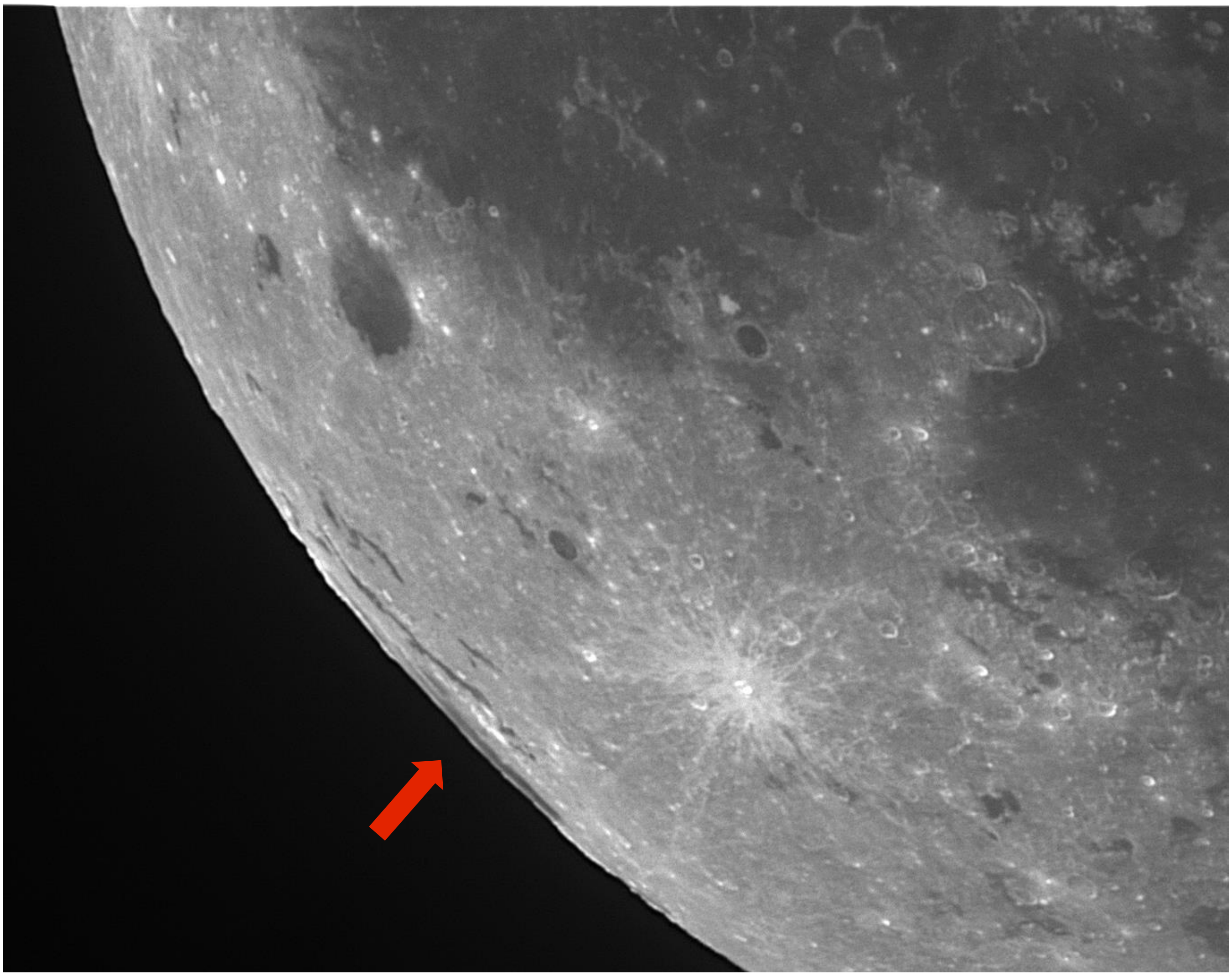
Gary used the PixInsight technique mentioned on the previous page to turn a color image of the Elephant's Trunk into a Hubble palette image. Digital image processing affords the opportunity to separate wavelengths in a single image electronically. Gary said that "the steps are easy. Basically, run channel extraction, delete blue channel, combine red with green channels, then run LRGB combination using red for luminance and red channels, the combined red + green image as the blue channel and the green as green."

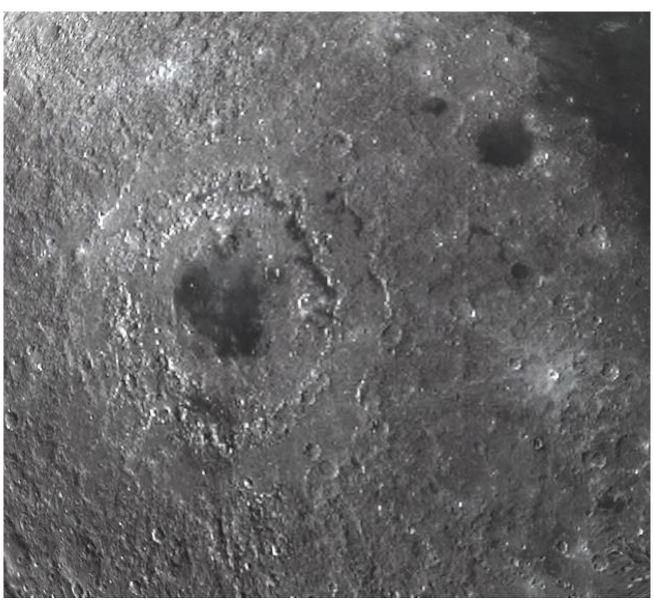
In any case, imagers can use the relative intensities in the various wavelength bands to reconstruct the image in whatever colors they wish.

The main imaging camera on the Hubble Space Telescope is a Wide Field Camera. The earlier Wide Field Camera II had 48 filters. Its successor, the WFC III, was installed in 2009. It has two sensors, one for UV and optical wavelengths (200-1000 nm) that uses 62 filters, and another sensor for the near infrared (800-1700 nm) which uses 15 filters. Images are obtained in various wavelengths for scientific purposes, but when images are made for public consumption they use either a "true-color" RGB palette or the Hubble palette, whose colors were chosen primarily for aesthetic reasons. It's actually better for perception when there's a lot of hydrogen around because the human eye is most sensitive around in the green, around 550 nm, and visual intensity rapidly falls off in the red and deep blue. So making the hydrogen green rather than red provides a lot of signal for our eyes and allows us to see more detail.

For more information on the Elephant's Trunk and its surrounding nebula, see the December 2021 SkyWAAtch, page 24, which also has Jordan Webber's fine true-color image of the nebula.

Mare Orientalis by John Paladini





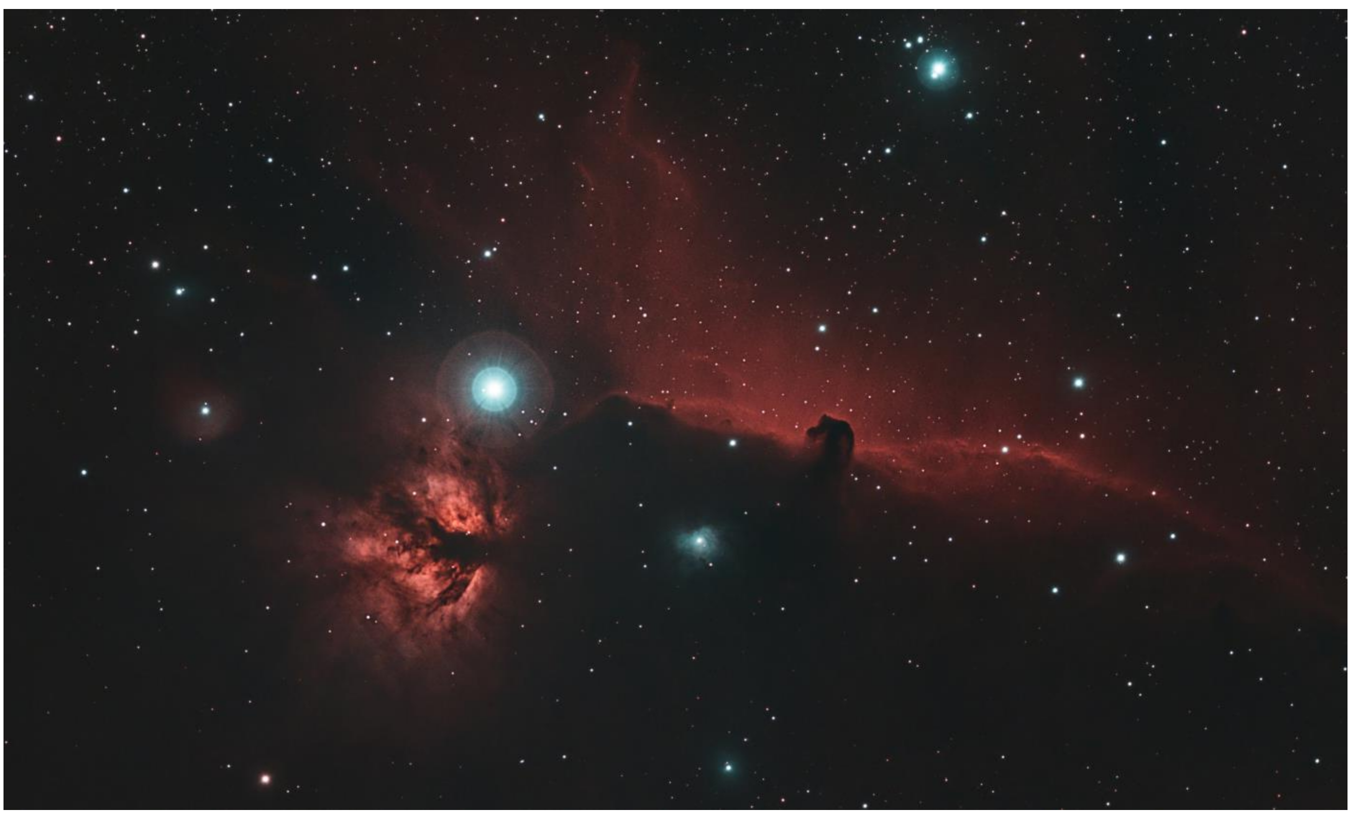
A favorable lunar libration brought the Mare Orientalis (red arrow) into view on the Moon's southwestern limb on January 23. John used an old Edmund 3-inch f/15 refractor, ASI290MM camera, stacking 100 frames.

The crater Byrgius, with its ray structure, and the flat plain Grimaldi will orient you to the face-on image on the left, copied from NASA's 3D model of the Moon, https://solarsystem.nasa.gov/resources/2366/earths-moon-3d-model/.

The feature is named "Orientalis" because this side of the Moon is "east" in the sky. Once the Moon became a landing site, the cardinal directions were reoriented by the IAU to a surface perspective. Mare Orientalis is considered to be the most recent giant impact feature on the Moon's surface. It is 300 km in diameter.

Two Nebulas in Orion with RASA-8 Astrograph by Olivier Prache

Messier 42 and 43 and NGC 1973 (the “Running Man” nebula)



The Flame Nebula (NGC 2023), O9 star Alnitak and the Horsehead Nebula (Barnard 33)
Olivier made these images from his home observatory in Pleasantville.

The Bubble Nebula by Rick Bria

Rick writes:

This image was taken at the Mary Aloysia Hardey Observatory through hydrogen alpha and oxygen III filters with our STX camera and CDK14 telescope. Four minute guided exposures were stacked and processed in PixInsight.

The Bubble Nebula (NGC 7635) is a gaseous star forming region 65 light years across and 7200 light years distant. Hot, young stars have formed from the collapse of this nebula. The stellar winds from one very hot star has blown a bubble within the gas cloud. That star is 45 times more massive and much hotter than our Sun. It is the star above and left of center within the bubble.

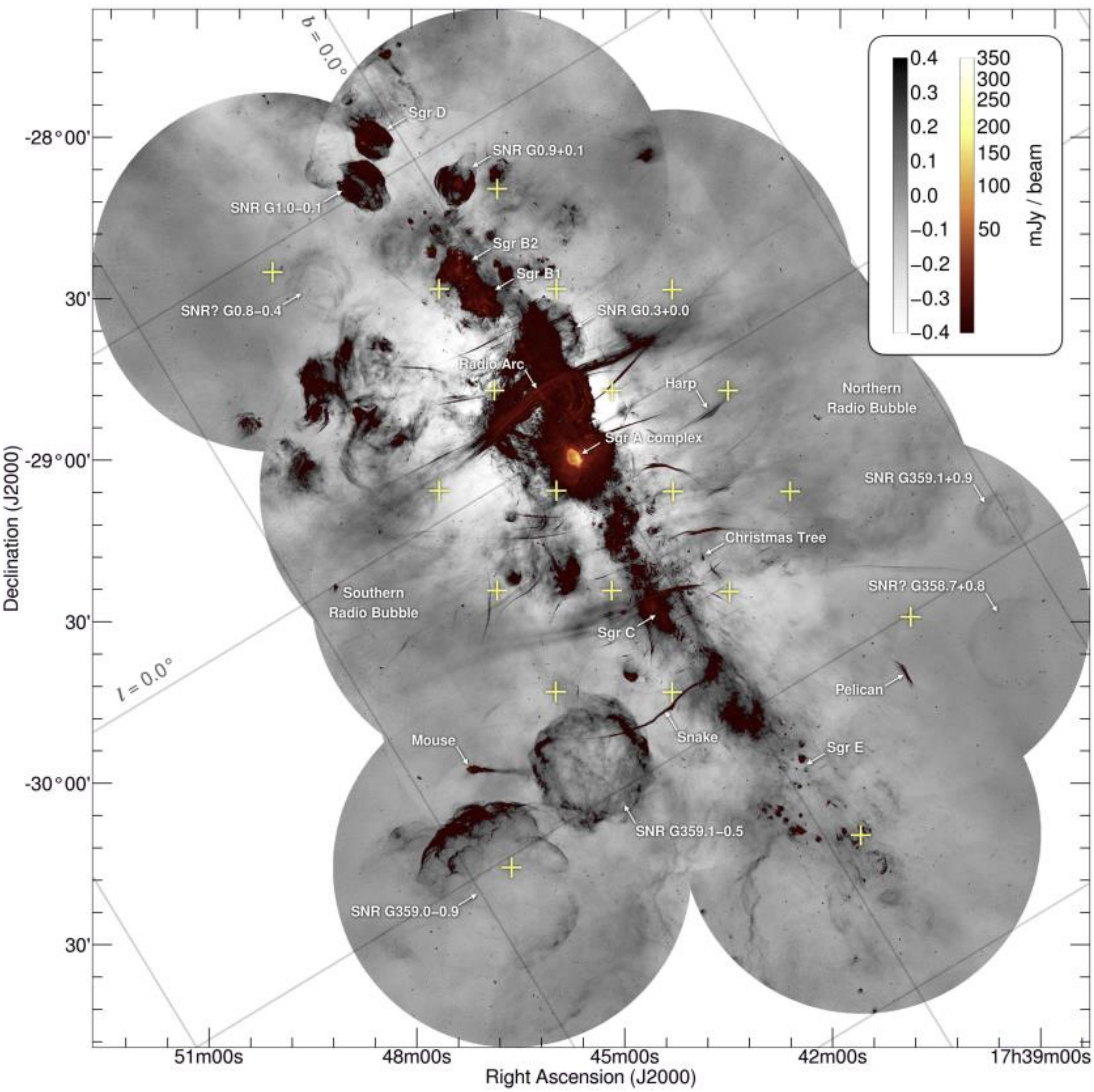
The stellar winds from this extremely hot star stream out at about 1,100 miles per second. This fast stellar wind is composed mostly of electrons and protons. It collides and pushes against the surrounding nebula, compressing the gas to form a bubble 7 light years (42 trillion miles) across.

It is thought that colliding gases within a nebula can trigger more star formation. From Earth nebulae like the Bubble appear static and serene. It is easy to forget that everything in our galaxy is moving. It is various forms of movement that cause star formation.

Research Highlight of the Month

Heywood, I, et. al. (101 authors), The 1.28 GHz MeerKAT Galactic Center Mosaic, accepted for publication in the Astronomical Journal, https://arxiv.org/pdf/2201.10541.pdf (posted January 25, 2022).

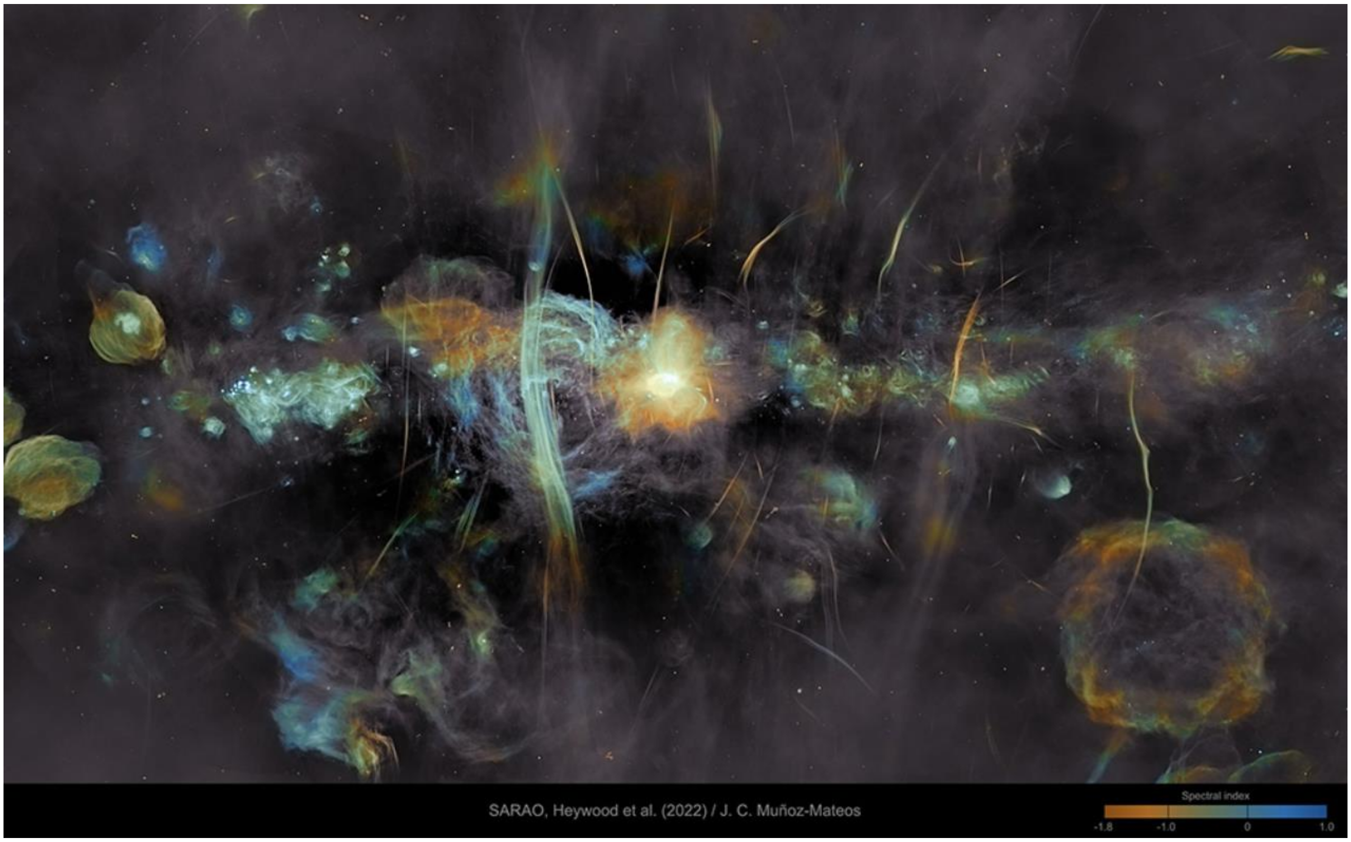
You may have seen the consumer version of this figure, without labels, which was released with great fanfare at the end of January. It shows radio emissions from the center of our galaxy, with a plethora of peculiar radio filaments that may be generated when energetic cosmic rays (charged particles) interact with the intense local magnetic field. The radiation was picked up by the MeerKAT telescope, an array of 64 dishes in South Africa operated by the South African Radio Astronomy Observatory, which is a facility of the National Research Foundation, an agency of the Department of Science and Innovation.



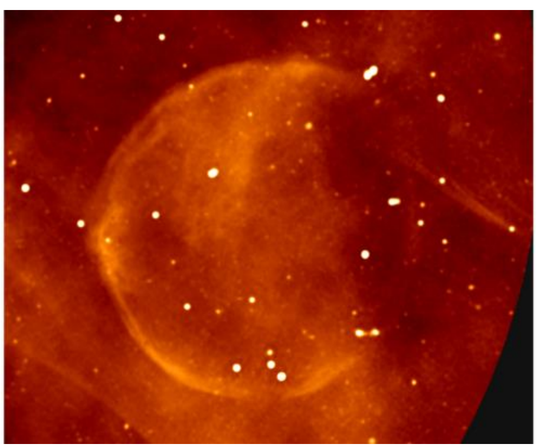
The full MeerKAT total intensity mosaic (Figure 1 from Heywood, et. al.) The inset shows the signal intensity.

The full image covers 6.5 square degrees with a resolution of 4 arcseconds. Twenty “pointings” of the array were used, totaling 144 hours of integration time.

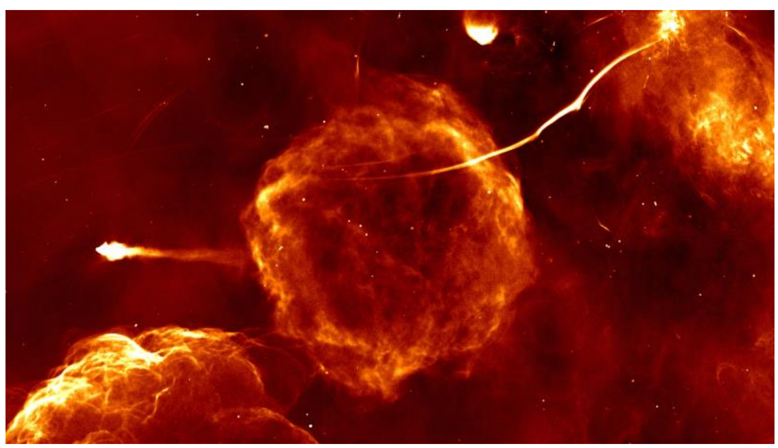
The image abounds in supernova remnants, some of which were not previously known. Many pulsars are seen. The black hole at the center of the Milky Way, SgrA*, emits a large amount of radiation.



The image above is colorized to reflect spectral index (the flux of radiation dependent on the frequency). The spectral index helps distinguish thermal emission from synchrotron emission.



A newly-discovered supernova remnant. Note the object on the right, thought to be a rapidly moving object leaving a trailing wake, a kind of super-comet.



Supernova remnant G359.1-0.5. On the left is “the Mouse,” a runaway pulsar possibly formed and ejected by the supernova. To the upper right is one of the longest radio filaments, known as ‘the Snake’.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
NEW LISTING Orion 6” f/8 Dobsonian	Orion XT6 SkyQuest Dob with 1.25" focuser, 25-mm Plössl eyepiece, and reflex sight finder. Essentially new condition, perfect optics. A terrific first or even only telescope. Lists at $429.99 on the Orion site. Includes an Orion LaserMate Deluxe II Telescope Laser Collimator. Donated to WAA.	$250	WAA ads@westchesterastronomers.org
NEW LISTING Orion 1.25" Premium Telescope Accessory Kit	Brand new condition, may never have been used. Five Plössl eyepieces (40-mm, 17-mm, 10-mm, 7.5-mm, and 6.3-mm), 2X Barlow, 5 color filters for planetary viewing and a 13% neutral density Moon filter. Lists at $219.99 on the Orion site. Donated to WAA.	$125	WAA ads@westchesterastronomers.org
Celestron Nexstar 8i telescope	8” Schmidt-Cassegrain go-to scope on single arm alt-az mount. Excellent optics and mechanics, mild tube blemishes. Hand control, dew shield, tripod, diagonal, 40-mm Celestron Plossl eyepiece.	$495	Jeffrey Jacobs jacobsfilm@gmail.com
Stellarvue 90-mm triplet telescope	90 mm f/7 triplet refractor, aluminum tube, 2½-inch focuser, clam shell mounting ring with standard Vixen dovetail, soft case. Excellent condition.	$400	Thomas Boustead bousteadtom@gmail.com
Meade 390 refractor telescope	90-mm f/11 doublet refractor in very good condition with several eyepieces, Barlow, aluminum tripod, accessory tray, straight-through finder. The alt-az mount head is very solid. An image of the mount head is here. Proprietary Meade interface between tube rings and mount (two thumb screws). Slow-motions with flexible stalks. A few minor blemishes on the tube. A great lunar/planetary scope.	$100	WAA ads@westchesterastronomers.org
Celestron Cometron telescope	Small, lightweight 114 mm f/4 reflector. Red dot finder, 25 mm eyepiece. Dovetail. A starter scope for a smart child. No tripod (use a camera tripod). Excellent condition.	$50	WAA ads@westchesterastronomers.org
ADM R100 Tube Rings	Pair of 100 mm adjustable rings with large Delrin-tipped thumb screws. Fits tubes 70-90 mm. You supply the dovetail bar. Like new condition, no scratches. See them on the ADS site at https://tinyurl.com/ADM-R100. List $80.	$50	Larry Faltz lfaltzmd@gmail.com
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 offer only serious and useful astronomy equipment. WAA reserves the right not to list items we think are not of value to members.			
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