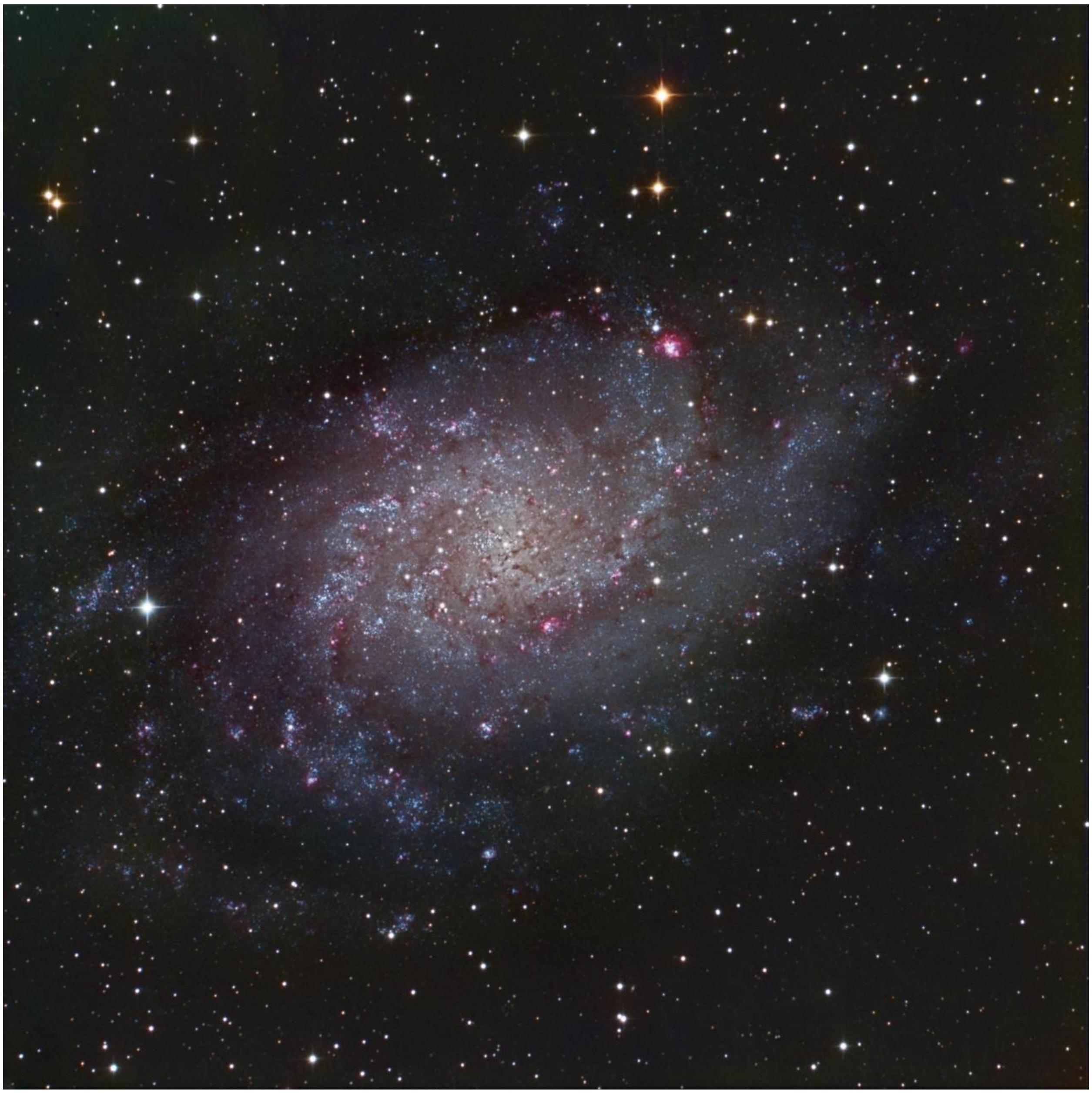
SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

February 2023



Messier 33, the Triangulum Galaxy, by Olivier Prache

Celestron RASA 8 astrograph, from Pleasantville, NY

Our club meetings are held at the David Pecker Conference Room, Willcox Hall, Pace University, Pleasantville, NY, or on-line via Zoom (the link is on our web site, www.westchesterastronomers.org).

WAA February Meeting

Friday, February 10 at 7:30 pm

How Are Orbits Determined?

Dan Platt, PhD
IBM Watson Research Labs &
Westchester Amateur Astronomers

When I was young, my family had a book on the history of astronomy. Its discussion of how Gauss determined the orbit of Ceres from the sparse measurements Piazzi had obtained fascinated me. Later, my interests in math and physics led me to celestial mechanics and methods for computing orbits, so I added to my bucket list the goal of doing an orbit calculation from scratch. Now, after many years, I decided to take the question seriously and complete these calculations. The first thing I realized is that there is a lot to it. I needed to understand coordinate systems. I will present a short history of those systems and of the precision required for these orbit methods to work. The second goal was to find how much measurement precision we need today to determine orbital elements. I wanted to see whether commercial telescopes have the precision required to permit us to compute orbits. My approach was first to check my code output for known orbits from Stellarium, then to add noise to the "observed" angular measurements, and then see whether I could still compute a reasonable orbit. That will give a standard check if our commercially available scopes can deliver the required precision. As an aside, I'll tell you just what Tycho Brahe's fight was about that made his nose famous (and other history). – Dan Platt

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

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

WAA March Meeting

Friday, March 10 at 7:30 pm

Artificial Intelligence and its use in Astronomy

Marwan Gebran, PhD
Chair of Physics, St. Mary's College, Note Dame, IN

Starway to Heaven

Meadow Picnic Area Parking Lot, Ward Pound Ridge Reservation, Cross River

March 18 (rain/cloud date March 25)

New Members

Cathy Carapella	Eastchester
William Duncumb	London, UK
Richard Greco	Tuckahoe
Tony Irvin	Beyton, Suffolk, UK

Renewing Members

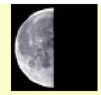
Winston Archer	Yonkers
Steven Bellavia	Mattituck
Rick Bria	Greenwich, CT
David Butler	Mohegan Lake
Brian Carroll	Ossining
Gregory Estevez Borrelly	Yonkers
Carlton Gebauer	Granite Springs
Patricia, Jon and Frank Gelardo	Mamaroneck
Jinny Gerstle	Lexington
Parikshit Gogte	Chappaqua
Richard Link	Ardsley
Geoffrey McFadden	Stamford, CT
Bob Quigley	Eastchester
Robert Rehrey	Yonkers
David & Lisa Sadowsky	Larchmont
Anthony Sarro	Brooklyn
Cathleen Walker	Greenwich, CT
Joseph Willsen	Yonkers

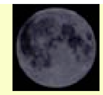
Also In This Issue

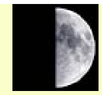
ALMANAC For February 2023
Bob Kelly, WAA VP of Field Events


Bob Kelly


Full 2/5

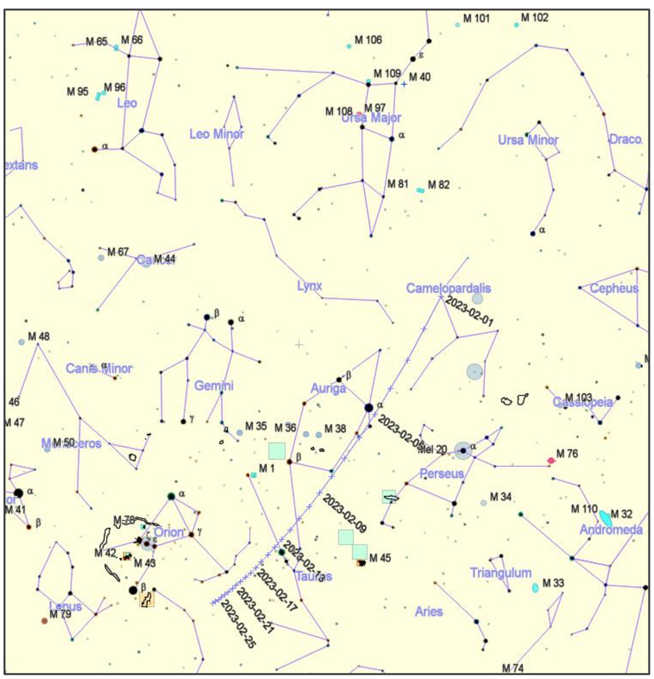

3Q 2/13


New 2/20


1Q 2/27

Comets

How's our comet doing? **Comet C/2022 E3**, reported to be visible in binoculars last month, should still be near its brightest early this month. It will be closest to Earth, 27 million miles away, on the 2nd. As the month progresses, E3 becomes visible in the evening sky, passing by **Mars** on the 10th. The gibbous **Moon** around that date will make the comet harder to see, even if it is easier to locate. This interloper from the deepest depths of the solar system sets after midnight. It was last in our inner solar system 47,000 years ago. Its orbit appears to have been modified enough by the gravity of the major planets to steer E3 out of the solar system after this pass, never to return. See page 23 for images of the comet in January by WAA members Steve Bellavia and John Paladini.



Path of Comet C/2022 E3 ZTF in February 2023

A brighter comet comes along, plunging to within 18 million miles of the Sun, on January 31st. **Comet 96P/Machholz** is too close to the Sun for us to see when it peaks at magnitude +2. We should be able to watch it as it passes through the Solar & Heliospheric Observatory's C3 camera view through February 2nd.

The Planets

Speaking of bright! **Venus** is at magnitude -3.9 and sets after the end of evening twilight so it will be visible low in the west at sunset. **Jupiter** follows the path of **Saturn** into the evening twilight. By the end of the month, Jupiter sets with Venus just before 8:30 p.m. EST. They are closest on the 28th, the two brightest planets making a great pairing in twilight. They'll be even closer on March 1st, just 31 arcminutes apart just after sunset.

Saturn is gone! It'll be back in the morning sky starting in March. Conjunction with the Sun occurs on the 16th.

Mercury rises during morning twilight, starting off at magnitude zero, and getting a tad brighter, but it will be lower in the dawn sky.

Mars' brightness falls through zero magnitude this month. It's only 9 arc seconds wide, appearing as large (or small) as the lunar crater Gardner. Gardner is a crater on the northern edge of the Sea of Tranquility, and may be part of the largest volcanic dome on the Moon. The area is best viewed on the 25th and the 26th.

In other lunar news, the new Moon on the 20th occurs only 22 hours from the time of perigee. Not as close together as last month, but be on alert for higher than normal tides for a few days after the 19th.

Mars and the Moon make another close pass at each other overnight on the 27th/28th.

Constellations

Orion, with its three star belt, stands up high in the southern sky about 8 p.m. this month. It gives us a good starting point for exploring the winter skies. **Betelgeuse**, **Rigel**, the three stars of Orion's Belt (from left to right **Alnitak**, **Alnilam**, and **Mintaka**) and the **Orion Nebula** are located in what Earthlings call the Orion Arm of the galaxy. Our solar system seems to be on the inner edge of the Orion Arm, giving us a good view of Orion's highlights. The Milky Way isn't as dense here it is near Sagittarius, since we are looking out in the direction of the Galaxy's edge.

The **Big Dipper** is standing on its handle in the evening at this time of year. The **Little Dipper** is hanging as if **Polaris** were a thumbtack on the bulletin board. **Cassiopeia** looks like an 'M' high in the northwest (or a 'W' if you stand on your head-Ed.).

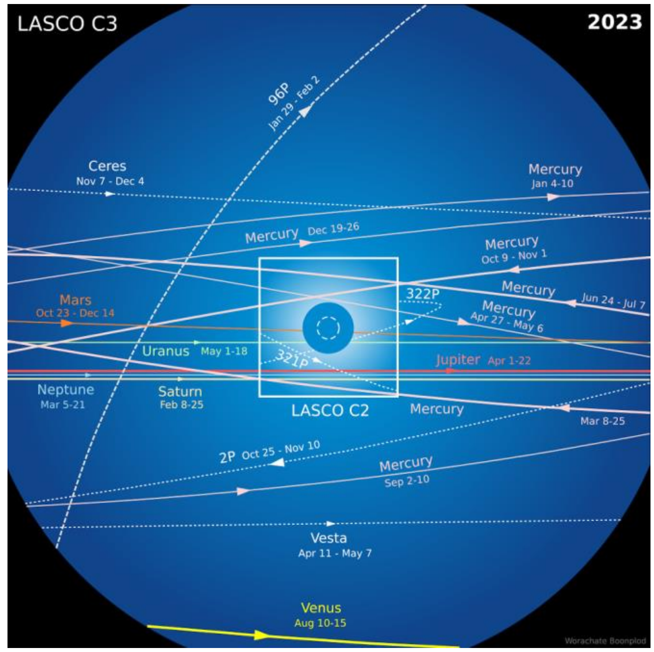
Other observing options

Space station visibility in our twilight skies include the **International Space Station** in the evenings through the 6th and mornings starting on the 15th. **Tiangong** will be visible in the mornings from the 13th until the end of February.

No significant meteor showers until the Lyrids in April.

Solar activity has been increasing, and with it the chance for a solar flare impacting the Earth's magnetic field and maybe pushing the auroral belt southward toward our latitude sometime soon. One can hope.

Planets can often be seen in the LASCO C3 camera field of the NOAA's Space Weather Prediction Center. You can find the most recent 24-hour animation at https://www.swpc.noaa.gov/products/lasco-coronagraph. Below is a chart of the passages of solar system objects through the field for 2023.



Light Pollution is Getting Worse Faster than We Thought

Data on light pollution has been gathered recently by satellites, particularly the Visible Infrared Imagining Radiometer Suite (VIIRS) aboard the Suomi NPP satellite, operated by NOAA. An annual increase of 2% was expected to be an underestimate because VIIRS is not sensitive at the blue end of the spectrum. So VIIRS data did not accurately reflect the impact of the increased use of LEDs for outdoor lighting, a trend that is now a decade old. Blue light scatters more than other wavelengths and has a disproportionate effect on sky glow, reducing the contrast needed to see faint objects. In addition, it has more negative biologic effects than other wavelengths.

The best sensor to study the impact of artificial light at night would be the human eye. The January 20, 2023 issue of *Science*, the journal of the American Association for the Advancement of Science, reports the results of the *Globe at Night* project, in which ordinary citizens periodically recorded the faintest stars they could see, determining the *Naked Eye Limiting Magnitude* (NELM). Based on the results of 51,351 observations from around the world over a ten-year period, light pollution has been increasing at an annual rate of 6.5% in Europe and 10.4% in North America. World-wide, the average increase is 9.6%.

The authors write, "The visibility of stars is deteriorating rapidly, despite (or perhaps because of) the introduction of LEDs in outdoor lighting applications. Existing lighting policies are not preventing increases in skyglow, at least on continental and global scales." John Barentine, a dark-sky researcher and advocate, noted that "You put together cheap lighting and fear of the dark … and people are not choosing preservation of darkness." We need to do more to make the public aware of light pollution! WAA will be developing a more robust action plan in collaboration with the International Dark-Sky Association. See the December 2022 SkyWAAtch, page 7.

You can read science writer Joshua Sokol's commentary on the article at https://www.science.org/content/article/light-pollution-drowning-starry-night-sky-faster-thought, and the article itself, which appears to be freely available, at https://www.science.org/doi/10.1126/science.abq7781.

Deep Sky Object of the Month: NGC 2244

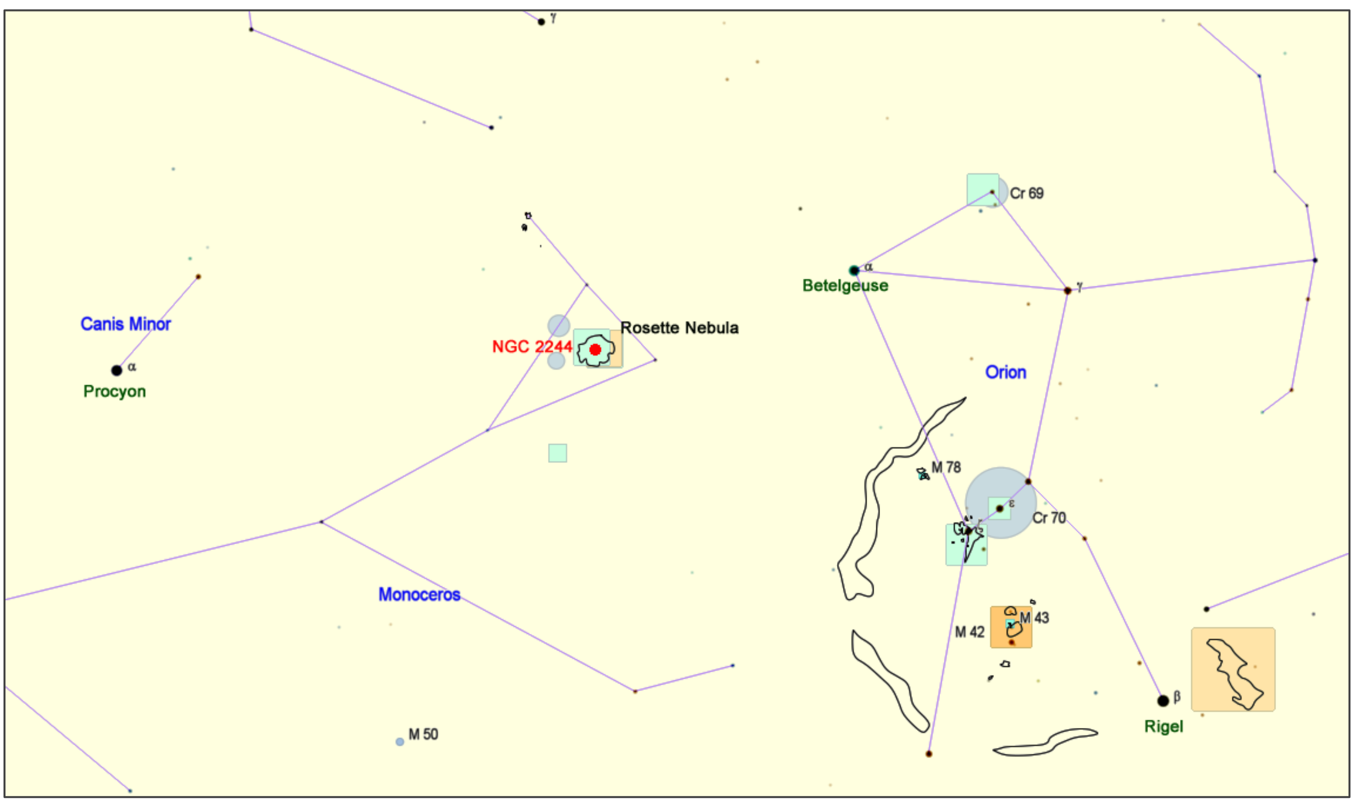
NGC 2244	
Constellation	Monoceros
Object type	Open Cluster
Right Ascension J2000	06h 31m 54s
Declination J2000	+04° 57′ 00″
Magnitude	4.8
Size	24 arcminutes
Distance	4700 LY
Other designation	Caldwell 50
Discovery	W. Herschel, 1784

NGC 2244 is the main open cluster in the Rosette Nebula, which has three NGC listings for its glowing gas: 2237, 2238 and 2246. While the Rosette is faint and needs very dark skies to be detected visually, the cluster is bright and easy to find. O'Meara even claims it can be a naked-eye object. NGC 2244 formed about the same time as the Trapezium stars in the Orion nebula, less than one million years ago. The brightest star is 12 Monocerotis, a foreground K0 star only 560 light years from us, so not a member of the cluster. The center of the Rosette is cleared by stellar winds from large (50 $M_\odot$) O-type stars HD 46223 and HD 46150.

Visibility for NGC 2244

2200 EST	2/1/23	2/15/23	2/28/23
Altitude	52° 45′	49° 26′	43° 36′
Azimuth	188° 00′	209° 20′	225° 54′

Surrounding the Rosette are some less dramatic open clusters, including NGC 2252 (mag 7.7) on its northeast edge and several in the Collinder catalog (Cr 97, 104, 106 and 107).



Another Movie Telescope

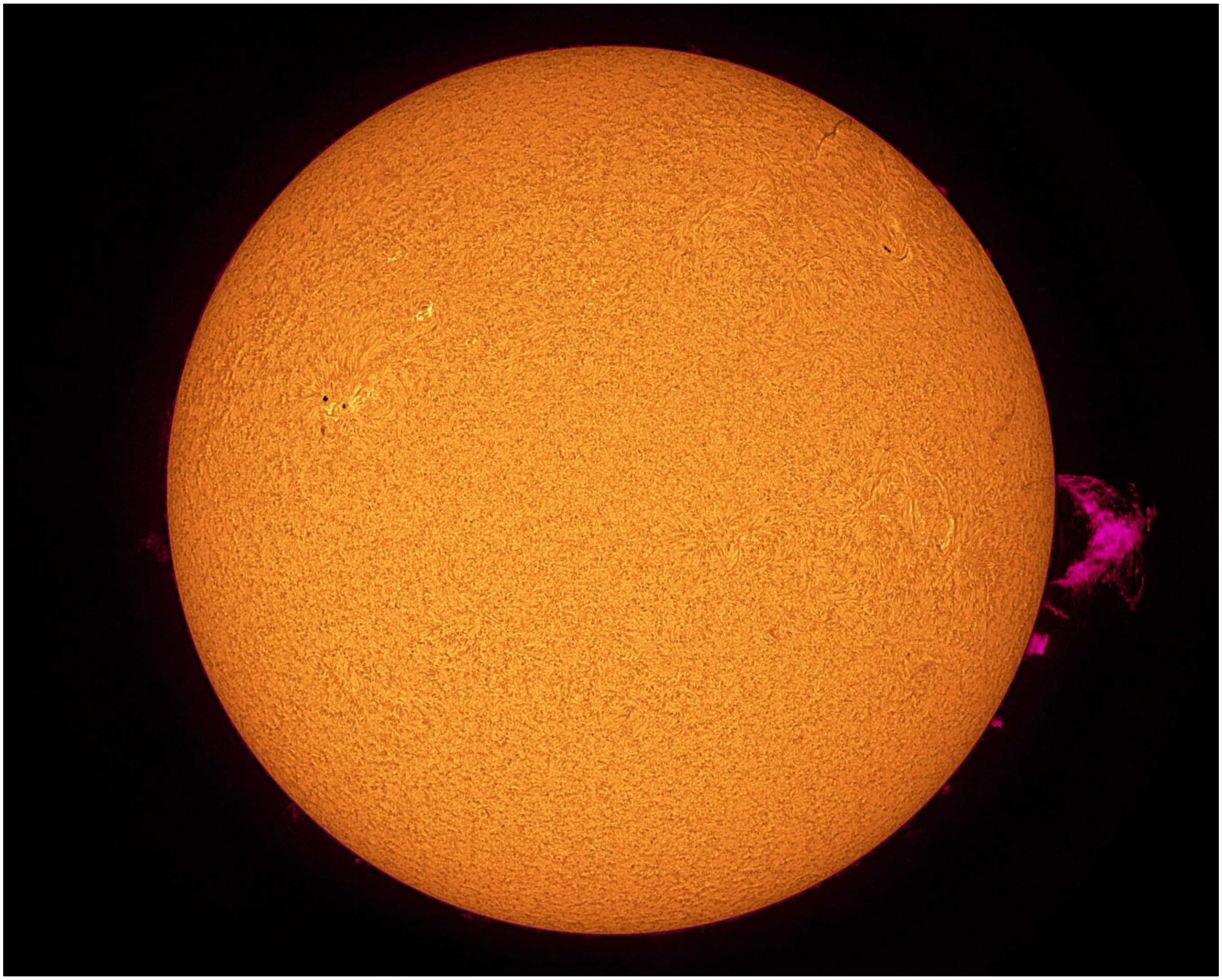
The great English actor Michael Redgrave plays Burgomil Trebitsch, the proprietor of a run-down junk shop in Brussels in the rarely seen Orson Welles film *Mr. Arkadin* (sometimes referred to by its alternative title *Confidential Report*). The film, written, directed and starring Welles, was shot in Europe in 1954 using the camera techniques he pioneered in *Citizen Kane* and used so effectively in *The Third Man* and *A Touch of Evil*. Welles plays a European businessman and arms dealer whose background is mysterious. Oddly, he hires Guy Van Stratten (Robert Arden), a small-time American smuggler, to investigate his past under the pretext that he has no recollection of his early years. The actual reason is, of course, something else. Van Stratten tracks down some of Arkadin's pre-war associates and learns the truth. The plot is complicated by his interest in Arkadin's daughter, who is played by Welles' last wife, Italian actress Paola Mori. Welles delayed editing the film, and it was taken out of his hands. There are several different film versions. Although Welles never approved any of them, the one in current circulation is apparently most faithful to Welles's ideas. Welles said *Mr. Arkadin* was his "greatest disaster," but like most of his works it has some remarkable moments, this scene being one of them.

In his one scene in the film, Redgrave, as the odd Trebitsch, prattles nearly incoherently about the broken spyglass, trying to avoid giving any information of value to Van Stratten while still looking to get money from him.

Prolific on stage and screen, Michael Redgrave was knighted in 1959. He was the father of actresses Vanessa and Lynn Redgrave. Of all his roles, our favorite is his turn as Jack Worthing in the 1952 version of Oscar Wilde's *The Importance of Being Earnest*, which deserves to be seen not only for his fine performance, but for the utterly spectacular Edith Evans as Lady Bracknell.

A Lesson in Solar Imaging

Robin Stuart



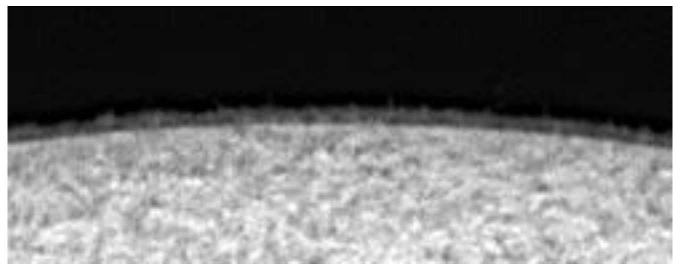
In first few days of August 2022, the Sun's limb was decorated with a giant prominence which I was able to observe and capture on the morning of the 4th. The image above is a stack 100 subframes taken through a TeleVue Pronto equipped with a Coronado Hα filter using a Meade LPI-G video camera.

At the time several smaller prominences were also visible. Some of these were considerably brighter than the colossus but they were still about five to eight times dimmer than the face of the Sun. Typically when imaging the Sun in Hα I take the naïve approach of making separate video sequences with exposure times determined by adjusting the histogram for the Sun's disk, the bright prominences and in this case the larger, relatively faint, one. Then I use Autostakkaert!3 to select and stack the best images from each sequence. The results are sharpened with RegiStax and stretched to enhance the visibility of fainter elements. I make careful measurements of the images and manually construct masks that allow the three images to be stitched together for the final result. Ugh! Is there a quicker, more streamlined way of doing things?

There are several difficulties or disadvantages to doing things as described. Prominences and features on the Sun's surface are constantly changing. Images taken several minutes apart may be sufficiently different that they cannot be stacked together to yield a single improved image. Taking video sequences with different exposures for different features creates a temporal patchwork and not a snapshot of the Sun at a single moment in time. Increasing the exposure time in a sequence to capture fainter features means more moments of good and bad seeing are lumped together potentially degrading the images. Is there anything that can be done to mitigate these issues?

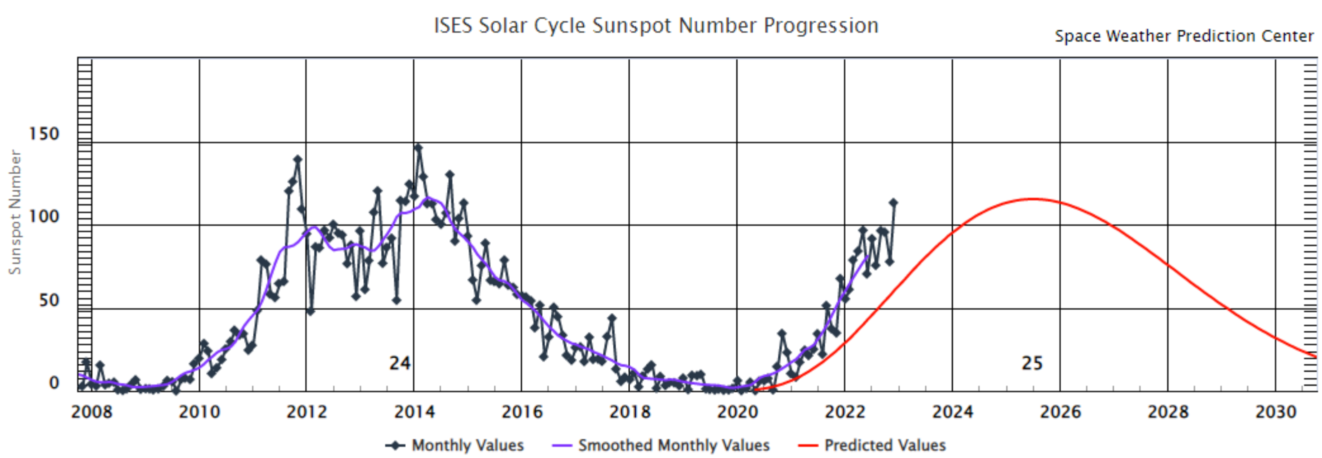
As it turns out, much of what I was doing was completely unnecessary. In principle, 100 subframes can be added together or *integrated* to produce an effective exposure of 100 times that of the individual frames[1] that should be sufficient to reveal even the faintest details. My videos are stored in AVI format, which are 8-bit images. This means that their pixels can take 2^8 possible values, ranging from 0 to 255. Simply adding together 100 images would, however, saturate brighter pixels on the Sun's disk. After some experimentation and investigation, I discovered that AutoStakkaert!3 automatically represents 8-bit images internally as 16-bit images with 2^{16} possible pixel values ranging from 0 to 65,535. In this way there is plenty of dynamic range available to accumulate the signal from the fainter pixels without saturating the brighter ones.

In the resulting High Dynamic Range (HDR) image of the Sun there two quite distinct brightness regimes. A section of the image, after wavelet sharpening with RegiStax, is shown in the next column. Note that there is a distinct smooth border where the brightness suddenly drops. This is the boundary between the photosphere or visible surface of the Sun and the chromosphere which we see as the pink-purple domain of the prominences during a total solar eclipse. The fact that the transition is sharp and distinct means that the two regions can be easily and cleanly separated using a *range mask* in PixInsight or other image processing application. They can then be worked on separately and enhanced as desired before finally being recombined using the same range mask.



[In the email that accompanied this article, Robin wrote "I played with adding a globe of the Earth for size comparison but it's only 17 pixels in diameter and practically invisible. The two endpoints of the arc of the prominence are 165,000 km apart!"—Ed.]

Editor's note: Solar activity has been higher than initially predicted for cycle 25. It's a good time to view the Sun, provided you take proper precautions. See https://www.swpc.noaa.gov/products/solar-cycle-progression.



[1] In practice each exposure introduces some read noise to the final image so that the sum of *N* exposures is not precisely the same as a single exposure *N* times as long. In the summed image the signal is increased by a factor N but the combined read noise only increases by a factor of $\sqrt{N}$ so that the SNR is nevertheless increased by a factor $\sqrt{N}$.

Are Globular Clusters The Same or Different?

Larry Faltz

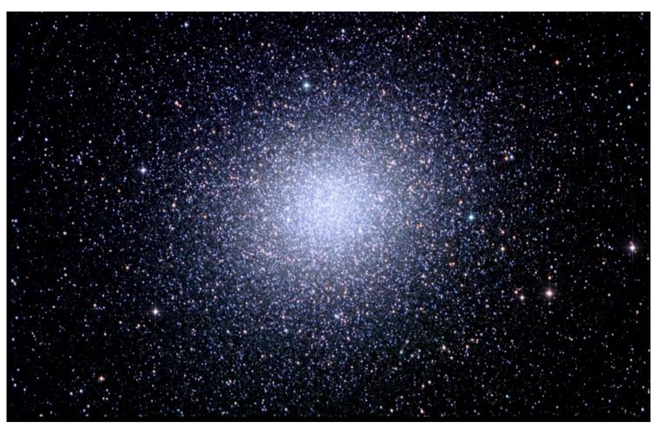
Globular clusters M15 (L) and M2 (R). 6-inch f/5 reflector, ASI183MC camera, ZWO AM5 mount, stack of ten 10-seconds images

Same or different? It's a learning game for the youngest children, yet it's a fundamental question for astrophysics, in fact for science in general, starting with Aristotle's attempts to organize nature.

Globular clusters (GCs) pose an astronomical same-or-different problem. Some people feel "if you've seen one, you've seen them all." For the average observer, some are brighter than others, or larger, or have somewhat more concentrated centers, or different details in their outer starry envelope, but does that make them different enough to call each visually "unique?" Is a calico cat different than a tabby, or do we hew to the old adage "In the night, all cats are grey?" What about two leopards? From a distance they all look the same, yet no two share the exact same pattern of spots, something that can be easily revealed by a very close-up examination (at your own risk). How important to our viewing pleasure is the exact pattern of stars of one globular cluster or another? It's a question that comes to mind each time I look at them during an observing session. Each observer will have to make his or her own decision, and *de gustibus non disputandem est*. As we shall see, behind this same-or-different conundrum lies some remarkable cosmic mysteries. GCs play unique roles in astronomy and astrophysics.

There's one thing that can't be denied: in a good telescope under a dark sky, a bright globular cluster is a magnificent object. The description "diamonds on velvet" is surely overused, but it's truly apt. The first time I looked at Messier 13 with just an 80-mm refractor at a dark sky site in the Colorado Rockies at 8,650 feet elevation, the sight was thrilling. And seeing Omega Centauri and 47 Tucanae through a 28-inch reflector in the Atacama desert in Chile was beyond mind-blowing. The brighter GCs are nice to look at in any telescope. Dark skies always improve the view.

There are 89 GCs brighter than magnitude +10.0, but 17 are never above the horizon from Westchester and another 10 are never above 10 degrees. As always, aperture rules, so if the WAA 20-inch Obsession is on the field at a star party, be sure to observe at least one globular cluster through it.



Omega Centauri (NGC 5139)

Globular clusters are arguably the most perplexing objects in the optically observable sky. Their origin is mysterious, their distribution peculiar, their evolution still unclear. GCs surrounding most galaxies may be the oldest light-emitting objects in the universe. Many were formed at the same time as the galaxies they accompany, and some maybe even earlier. If the conditions for their formation were unique to the composition of the nascent universe, how is it that globular clusters are forming today in places like the Large and Small Magellanic Clouds and the peculiar interacting galaxies known as “The Antennae” (see image on page 11). Does the same-or-different paradigm include the possibility that very different initial conditions, when applied at different cosmic epochs, can result in what appears, at least to the eye, as the same object?

In the mid-1600s, the great Polish astronomer Johannes Hevelius and the lesser-known German observer Abraham Ihle noted nebulosity in a very faint star-like object that was later catalogued as Messier 22 in Sagittarius. The exact priority is debated, although in his 1771 and 1784 catalogues Messier cites Ihle as the discoverer. Omega Centauri, the largest and most beautiful GC, was known since ancient times. It appeared to be a 3rd magnitude star and was given the omega appellation in Bayer’s *Uranometria*. Edmund Halley, observing with a small telescope during his star-hunting sojourn at St. Helena (1676-78), found it to be a nebula. It wasn’t resolved as a globular cluster until John Herschel studied it in the 1830s from South Africa. Twenty-nine of the Messier objects are GCs; there are 39 additional ones in William Herschel’s catalogues. We know now that there are over 150 GCs surrounding the Milky Way, with more likely to be discovered, a task for the JWST. The Andromeda Galaxy (M31) has over 500, while the gigantic elliptical galaxy M87 is said to be surrounded by over 13,000. The Large Magellanic Cloud has about 60 GC’s. Only the smallest dwarf galaxies lack a cloak of GCs.

Globular clusters are agglomerations of roughly between 10^4 and 10^6 stars. A typical GC of 10^5 solar masses will have a half-light radius (the distance from the core containing half the total luminosity of the cluster) of less than 10 parsecs (32.6 light years). The average stellar density in a GC is 0.4 stars per cubic parsec, but the density increases towards the core, where it may be as high as 1,000 stars per cubic parsec. The density of space surrounding the Sun, for comparison, is only 0.1 star per cubic parsec. Stars in the center of a GC may be only one-third of a light-year apart.

Harlow Shapley determined that GCs are distributed in a spherical shell around the Milky Way by examining the RR Lyrae stars in GCs to determine distance. These data also showed that that the Sun was not at the center of the galaxy. Here’s a figure and caption from his 1918 paper:

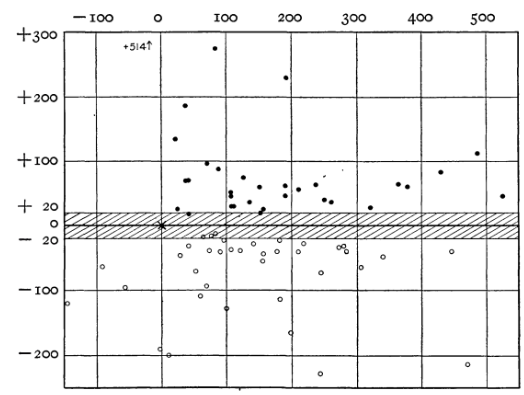


FIG. 4.—Projection of the positions of globular clusters on a plane perpendicular to the Galaxy, illustrating (1) the absence of clusters from the mid-galactic region, (2) their symmetrical arrangement with respect to the Galaxy, (3) the eccentric position of the sun (the cross) with respect to the center of the system of clusters. The ordinates are distances from the galactic plane, $R \sin\beta$; the abscissae are projected distances in the direction of the center, $R \cos\beta \cos(\lambda - 325°)$. The unit of distance is 100 parsecs; the side of a square is accordingly 10,000 parsecs. On this scale the actual diameter of the clusters is about one-fifth the diameter of the circles and dots. The cluster N.G.C. 4147 is outside the boundary of the diagram, as indicated by the arrow.

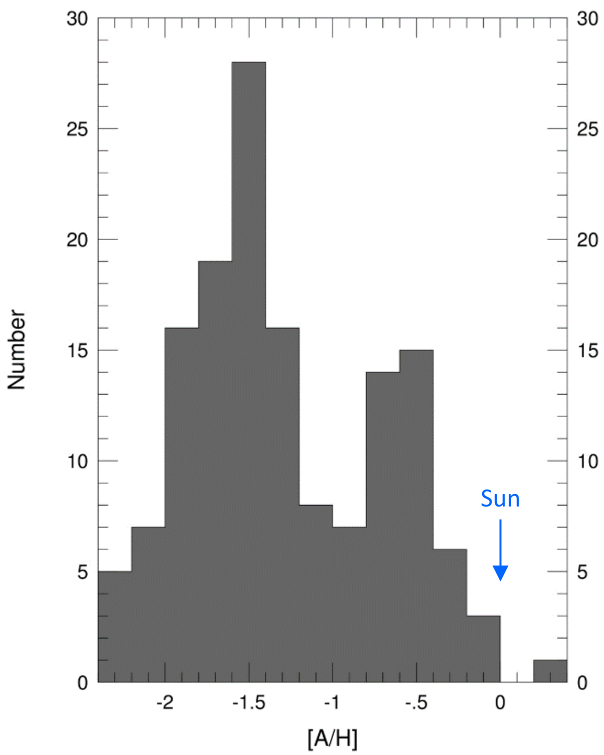
Shapley, H, Studies based on the colors and magnitudes in stellar clusters. VI. On the determination of the distances of globular clusters. *Astrophysical Journal* 48, 89-124 (1918).

This distribution of GCs inevitably led to the concept of a “galactic halo,” a spherical region surrounding the galaxy that has been shown to contain not only globular clusters but also streams of tidally displaced stars, regions of gas, and of course dark matter.

Stars in globular clusters are older than those in our local galactic neighborhood. We know this from their metal content (a metal in astronomy is any element heavier than helium) as determined by spectroscopy. Metallicity, by convention, is expressed as a ratio of iron to hydrogen, [Fe/H], in a logarithmic format, normalized to the Sun. Our star has a metallicity of zero.

Metallicity works as a determinant of age because stellar evolution causes the number of iron nuclei to increase over time, while the amount of hydrogen in the universe is constant. The oldest stars, so-called Population III, formed from the primordial material of the Big Bang a few hundred thousand years after the

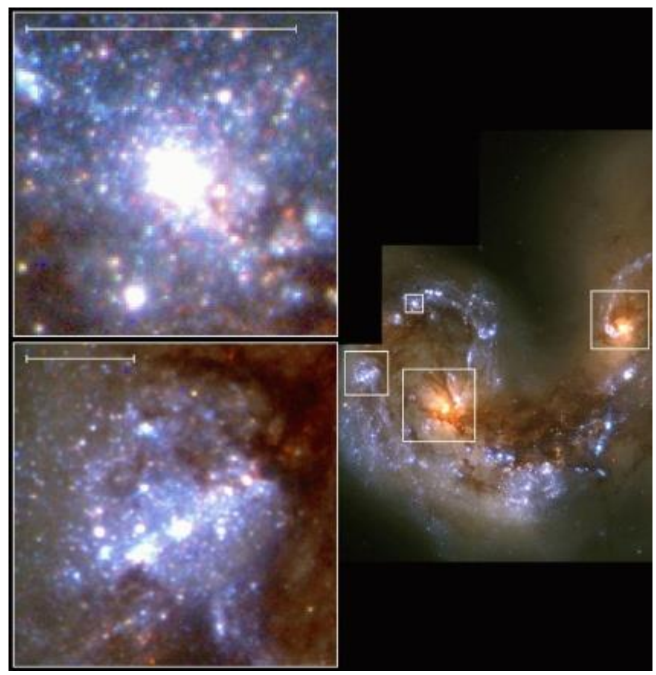
Cosmic Microwave Background radiation was emitted. This gas was essentially all hydrogen and helium, with a trivial amount of lithium. If the JWST manages to see a Population III star, it should have a vanishingly small metallicity. Stars forming in the next generation, Population II, will be made of hydrogen, helium and a bit of the dust and chemical products of those first generation of stars spewed into the interstellar medium by solar winds, planetary nebula ejections and supernova explosions. The stars in GCs surrounding mature galaxies are Population II, older than Population I stars like the Sun, with an order of magnitude or two lower metallicity.



Metallicity of Milky Way globular clusters. Smith, GH, The Metal Contents of Milky Way Globular Clusters, *PASP* **112** 12-17 (2000)

Globular clusters are found surrounding nearly all galaxies, whether spiral or elliptical, including dwarf galaxies. They are even seen surrounding small galaxies whose rotational rates suggest an absence of dark matter. There must be a relationship between GC formation and galaxy formation. Which came first? Perhaps the two processes are mutually dependent. As Samuel Butler famously wrote, "A chicken is only an egg's way of making another egg."

Since stars form from collapsing hydrogen gas, if globular clusters form solely in this manner, why didn't the collapsing gas form one gigantic star, or even a black hole? There is a difference in the behavior of collapsing gas when it contains different amounts of metals and is at different temperatures. The earliest stars, Population III, were made of primal cosmic material, hydrogen and helium in a ratio of 3:1. They were most likely immensely large, hot and short-lived, going supernova in some tens of millions of years or less. Then the hydrodynamic properties of the newly metal-enriched gas, buffeted by supernova impacts, would have allowed GCs to form, containing new Population II stars.



Newly formed superclusters in the merging Antennae Galaxies

In 1968, P.J.E. Peebles and R.H. Dicke from Princeton, fresh on the heels of their explanation of the cosmic microwave background radiation, proposed that GCs form before galaxies.[2]

> We argue that the globular clusters may have originated as gravitationally bound gas clouds before the galaxies formed. This idea follows from the primeval-fireball picture, which suggests that the first bound systems to have formed in the expanding Universe were gas clouds with mass and shape quite similar to the globular star

[2] Peebles, PJE, Dicke, RH, Origin of the Globular Star Clusters, *ApJ* 1968, 154:891-908

> clusters…. The galaxies would have formed as clusters of these clouds (plus debris from clouds)

Over time, Peebles and Dicke's simple (and influential) explanation had to be modified as galaxies and their environments were observed with newer and more sophisticated instruments. One version of this proposal is that thermally unstable haloes of hot gas surrounding already-forming early galaxies (what we see now as high-redshift objects) condensed into GCs under the influence of the nascent but still very immature galaxy, and not the other way around, meaning that galaxies and GCs formed interactively. Even this explanation has some weaknesses: most low-mass galaxies, which probably never had hot haloes, have GCs. Another theory suggests GCs result from galaxy mergers, which were frequent in the older ($z \geq 3$), smaller universe. But some low-mass GC-containing galaxies may never have been involved in mergers. Newly formed globular clusters have been seen in recent galaxy mergers, but whether the formation mechanism is "the same or different" considering the very different cosmic conditions a billion years after the Big Bang isn't known.

Another proposal is that GCs may have formed in dark matter haloes before reionization, a process that is estimated to have been completed around z=6-7. However, dark matter, which should have been evident from rotational data, has not been detected in the outskirts of GCs. An even more exotic idea is that GCs form along cosmic string loops. Cosmic strings are (theoretical) one-dimensional topological defects in space-time that arise in a large class of particle physics models beyond the Standard Model.

> The accretion of matter about string loops starts as soon as loops are created, i.e. much earlier than the time of reionization. Hence, our mechanism offers an explanation for why the globular clusters are the oldest components of a galaxy. The string loops are initially distributed throughout the region which eventually falls in to form the galaxy and will hence end up in the galactic halo rather than the disk.[3]

Cosmic strings have been proposed to solve several cosmological problems, but as yet there is no evidence for their existence.

It has also been theorized that GCs are merely the cores of dwarf galaxies that have been tidally disrupted by their larger neighbors during the frequent galactic mergers in the early universe. No special formation mechanism would then be required. This explanation is often cited for Omega Centauri, the largest and brightest GC, and it has also been suggested for Messier 56, but there is insufficient evidence from the chemical nature of the GCs to support it as a general mechanism. Many Milky Way globular clusters, including Omega Centauri, have retrograde orbits around the galaxy's center, strong evidence for capture during mergers (but not a mechanism for initial formation). There is evidence from HST and large ground-based telescopes, and most recently a vast amount of data from Gaia, that our galaxy has been tidally interacting with many smaller galaxies over its lifetime. This seems to be a common feature of all large galaxies. The big fish eat the smaller fish.

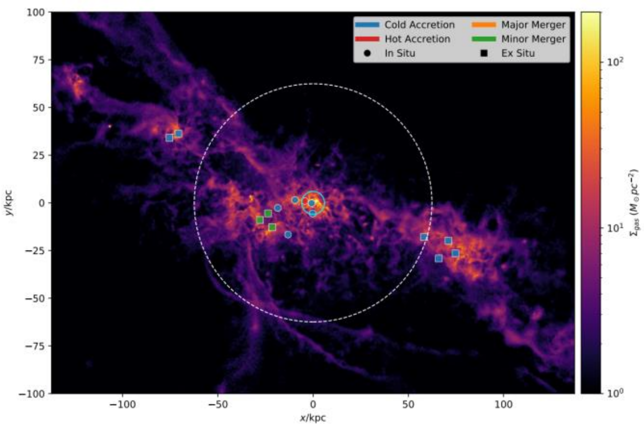
The history of galaxy formation and evolution in the giant elliptical galaxy Messier 87 was traced by looking in detail at its surrounding corona of globular clusters. The colors and velocities of 737 of its 13,000 GCs were measured by Strader, et. al.,[4] who proposed that M87 is still being actively assembled from mergers with smaller galaxies in the Virgo cluster.

As for GC sphericity, dynamic models suggest that globular clusters were more elliptical in their early stages, but then became increasingly spherical over much shorter times than the similar "relaxation" process in the much larger elliptical galaxies.

As inferred from the chemical composition of their stars, most GCs we examine today appear to have formed close to the peak of general cosmic star formation in galaxies (z=2-3), not earlier. Early galaxies (seen as they were about 12 billion years ago) are too small and faint for their GCs to be accurately identified. Simulations are capable of showing globular clusters forming along with galaxies. The goal is to compare the fully-evolved simulation with observations of galaxy structure and GC distribution. The better the match, the more likely that the simulation reflects reality.

[3] Barton, A, Brandenburger, R, Lin, L, Cosmic Strings and the Origin of Globular Clusters, Journal of Cosmology and Astroparticle Physics, 2015;

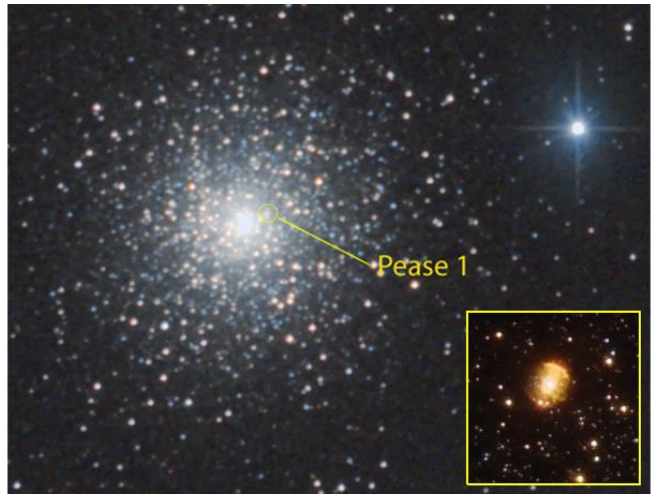
[4] Strader, J, et. al., Wide-field Precision Kinematics of the M87 Globular Cluster System, *ApJ Suppl* 197:33-82 (2011)



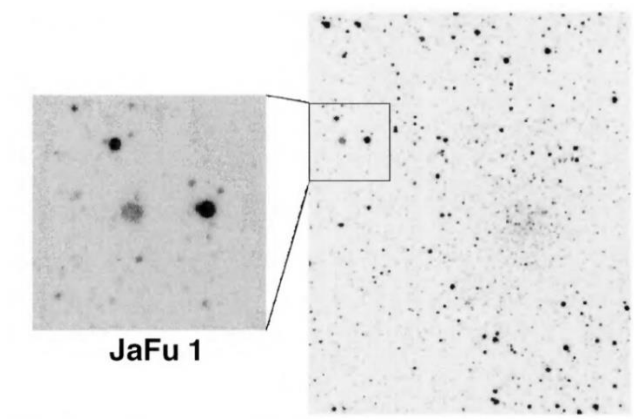
A figure from the E-MOSAICS simulation, showing the location of nascent globular clusters at z=2.5.

The-E-MOSAICS simulation, led by Dutch astronomer J M Diederik Kruijssen of the University of Heidelberg, has successfully modeled GC formation, predicting that "most GCs formed initially in turbulent, high-redshift discs, with a small fraction formed during [later] mergers."[5] When younger galaxies merge, their gas mixes at high-temperature, density and turbulence, mimicking conditions in early galaxies and thus causing a second round of GC formation. The recent JWST images of Stephan's Quartet show this phenomenon in the near-universe, but the simulations identify GC formation at redshifts greater than 2.5, consistent with earlier theory.

Even if the stars in a GC formed at approximately the same time, they would not all be the same size, and so they will progress along the main sequence of the Hertzsprung-Russell [H-R] diagram at different rates as they consume their fuel. It should be expected that some of the more massive stars in the clusters will have reached the end of their lives in the current epoch, and they will have become white dwarfs (throwing out material in their planetary nebula phase) or perhaps neutron stars or black holes. [6] Planetary nebulas have been detected in at least four GCs (Messier 15, Messier 22, NGC 6441 and Palomar 6).



Messier 22 and Planetary Nebula Pease 1 (HST)



Planetary nebula JaFu 1 in Palomar 6[7]

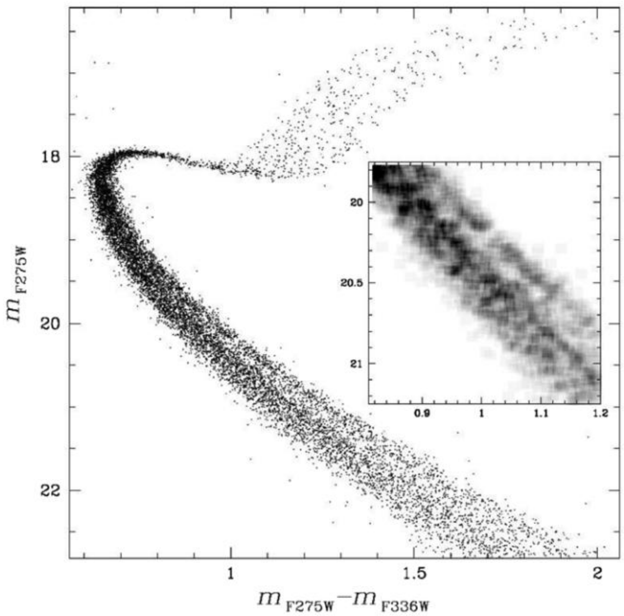
There is now general agreement that multiple populations of stars can be found in most GCs, the evidence being in the details of the H-R plots. For example, data from the Hubble Space Telescope, published in 2013,[8] shows heterogeneity in the distribution of stars in NGC 6752 (Caldwell 93 in the southern constellation Pavo, nicknamed the Great Peacock Globular). The stellar populations appear randomly distributed within the cluster. Studies of young clusters suggest that a second round of new star formation does not occur until after the first two billion years of a cluster's life.

[5] Keller, B., et. al., Where Did the Globular Clusters of the Milky Way Form? Insights from the E-MOSAICS Simulations, *Monthly Notices of the Royal Astronomical Society*, 495: 4248-4267 (2020)

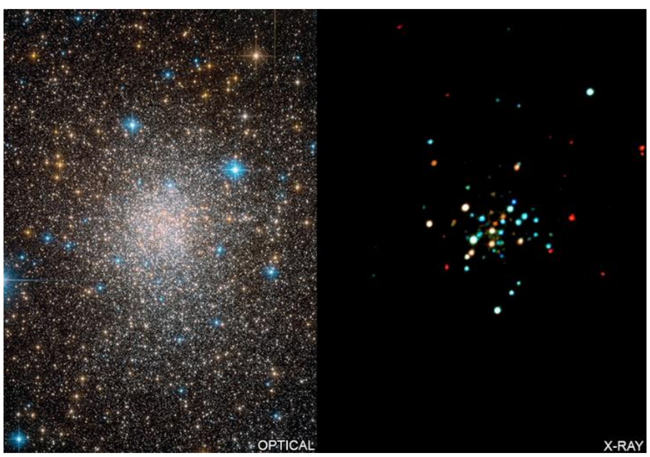
[6] A supernova has been invoked for the formation of at least one young globular cluster in the Large Magellanic Cloud (Tsujimoto, T, Bekki, K, First Evidence of Globular Cluster Formation from the Ejecta of Prompt Type Ia Supernovae, *Astrophysical Journal Letters*, 751:35-40 (2012)

[7] (Jacoby, GH, et. al., Planetary Nebulae in the Globular Cluster PAL 6 and NGC 6441, *Astronomical Journal* 114: 2611-2625 (1997)

[8] Milone, AP, et. al., A WFC3/HST View of the Three Stellar Populations in the Globular Cluster NGC 6752, *ApJ* 2013



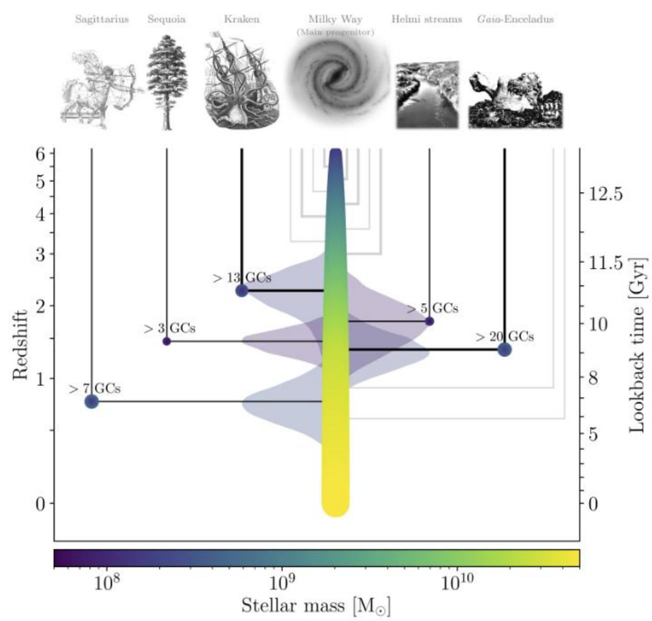
Color-magnitude diagram of stars in NGC 6752 (Milone, et. al.) showing multiple populations of stars on the main sequence and the horizontal branch.



Terzan 5 Optical (L) and Chandra X-ray (R) images showing X-ray sources.

More evidence of stellar evolution in GCs comes from the detection of X-ray binaries. The cores of some GCs are potent sources of X-ray luminosity. Very hot, young, massive stars might have X-ray emission, but a more likely explanation for the X-rays is that one of the stars in a binary system has evolved, collapsing into a neutron star. This dense stellar remnant pulls matter from its companion. The hydrogen-rich material falling onto the surface of the neutron star undergoes thermonuclear detonation, a potent source of X-radiation. In addition, there is evidence for the presence of stellar-mass black holes in GCs, but not a supermassive black hole as an organizing object in the cluster's center. One study suggested that a quarter of all globular clusters hosts least one black hole.

While the exact mechanism for GC formation is still not settled, the ages, metallicity, locations and velocities of Milky Way globular clusters can be used to extrapolate our galaxy's formation history. Kruijssen and his colleagues[9] used a neural network to train the E-MOSIACS simulation with actual data on Milky Way globular clusters. They were able to reconstruct a plausible merger history for the galaxy, showing the contributions of at least five other galaxies, the last one merging about seven billion years ago. Our galaxy started out with a mass of about 10^8 Mʘ and grew to its current size, just under 10^{11} Mʘ by these periodic mergers. It is still accreting mass due to the absorption of small satellite galaxies and the associated intergalactic gas that remains in its halo.



Merger history of the Milky Way (Kruijssen et. al.)

You can decide for yourself whether GCs are observationally the same-or-different, exciting or boring. We've learned a lot about them and they are critically important to our understanding of the formation and evolution of galaxies, especially our own. They still harbor mysteries. ■

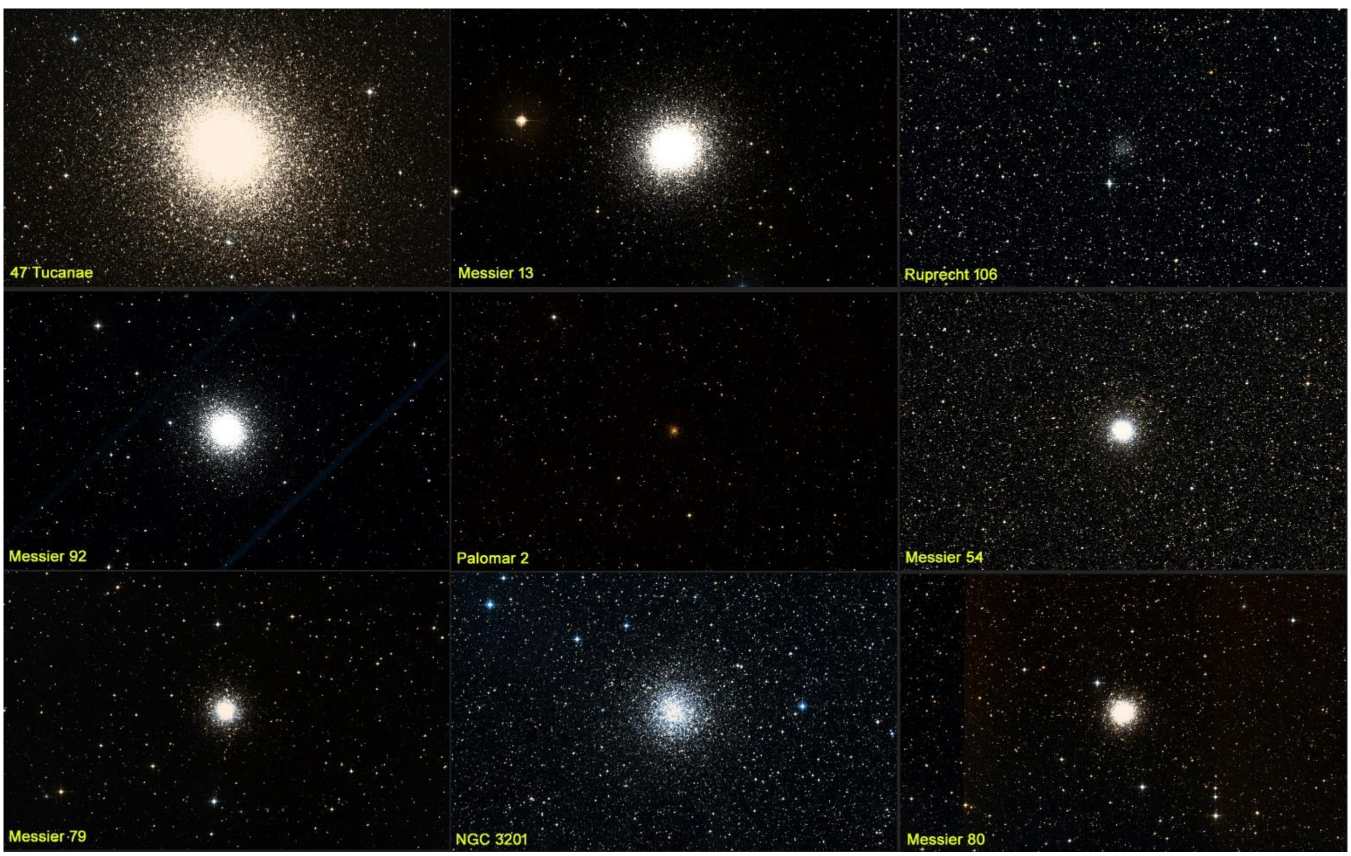
[9] Kruijssen, JMD, et. al., Kraken reveals itself – the merger history of the Milky Way reconstructed with the E-MOSAICS simulations, *Monthly Notices of the Royal Astronomical Society*, 498: 2472-2491 (2020)

The Twenty Brightest Globular Clusters

NGC	Messier or other designation	Constellation	Magnitude	Visible from Westchester?
NGC 5139	Omega Centauri	Centaurus	3.7	No
NGC 104	47 Tucanae	Tucana	4.0	No
NGC 6656	M22	Sagittarius	5.1	Yes
NGC 6752	Pavo Globular	Pavo	5.4	No
NGC 6397		Ara	5.7	No
NGC 5904	M5	Serpens	5.8	Yes
NGC 6121	M4	Scorpius	5.9	Yes
NGC 6205	M13, Great Cluster in Hercules	Hercules	5.9	Yes
NGC 2808		Carina	6.3	No
NGC 5272	M3	Canes Venatici	6.4	Yes
NGC 7078	M15	Pegasus	6.4	Yes
NGC 6341	M92	Hercules	6.5	Yes
NGC 7089	M2	Aquarius	6.5	Yes
NGC 6218	M12	Ophiuchus	6.6	Yes
NGC 6266	M62	Ophiuchus	6.6	Yes
NGC 362		Tucana	6.6	No
NGC 6254	M10	Ophiuchus	6.6	Yes
NGC 6541		Corona Australis	6.6	No
NGC 3201		Vela	6.8	No
NGC 6626	M28	Sagittarius	6.9	Yes

A Gallery of Globular Clusters

Selected globular clusters at the same scale. Digital Sky Survey images downloaded from CDS via the Aladin web site. Each field is 48’ 49” across.



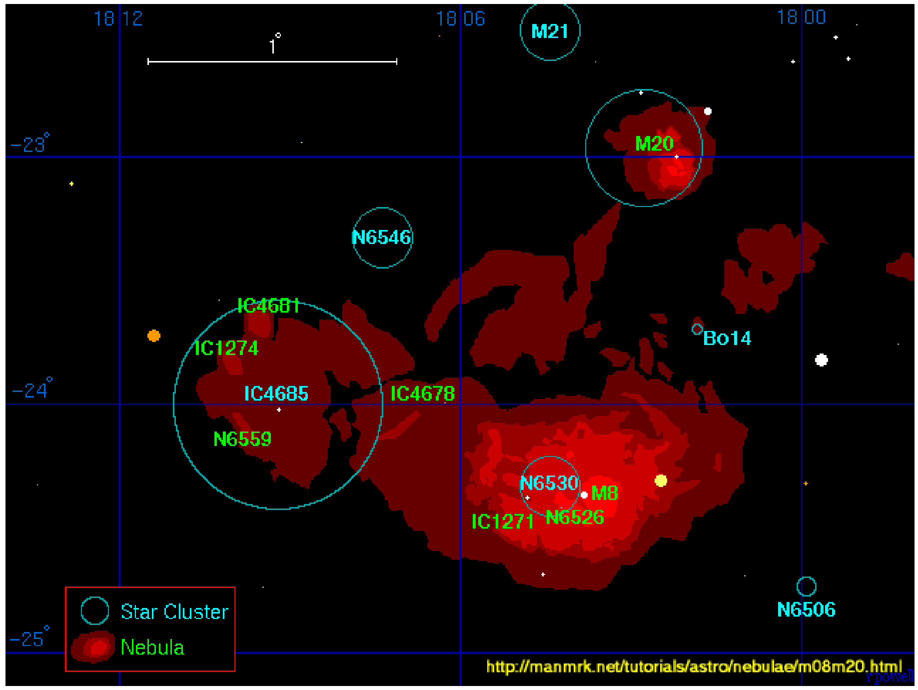
Images by Members

Glories of Sagittarius by Gary Miller

As we shiver in the cold of February, Gary's image reminds us of warm observing nights in August.

A star-forming complex of hot gas, dust and young stars, the magnitude 4.6 Lagoon Nebula (M8) is a naked-eye object in dark skies (but not in Westchester). Its light is spread over the area of three full Moons, so only the bright central area can be seen without optical aid. Even in a small telescope, we can see complex areas of gas and dust, with a prominent central dust lane separating the brightest area of glowing gas from the star cluster NGC 6530 embedded in its own nebulosity. A degree and a half to the northeast is a fainter complex of star clusters and gas composed of the emission/reflection nebula NGC 6559 (LBN 29) and the smaller IC 4685, with two additional knots of gas catalogued as IC 1274 (LBN 33) and IC 4681. The stars in this region are collected in the open cluster Collinder 367, although sometimes the cluster is labeled IC 4685, as in the map on page 17.

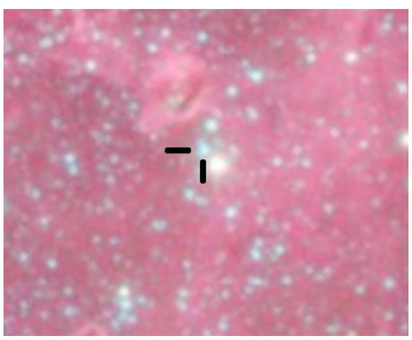
Messier's entry in his 1784 catalog states "A cluster of stars that appears in the form of a nebula when looking at it with an ordinary three-foot telescope; but with an excellent instrument only a large quantity of small stars is noticed." (You can have too much magnification!) Guillame LeGentil reported the nebula in 1747, which Messier acknowledges, but Burnham tells us that it was recorded as a "nebulosum" by Flamsteed as early as 1680. The appellation "Lagoon" was first applied by the Irish astronomer and writer Agnes Clerke, in her *System of the Stars* (1890). The main dust lane was catalogued as B88 by E.E. Barnard in 1919.



A degree and a half to the north of M8 is the Trifid Nebula, which has a reflection component that appears blue in images. It's a bit dimmer than M8, at magnitude 6.3. Its prominent dust lanes give it a clover-like appearance. Half a degree to its north is the open cluster Messier 21, slightly brighter at magnitude 5.9.

The area with M21 at the top and M20 at the bottom marks the area known as "Webb's Cross," so named by the British clergyman and amateur astronomer Thomas William Webb, whose *Celestial Objects for Common Telescopes*, published in 1859, was *the* observing handbook for nearly a century, although it had plenty of competitors. The nebula itself was christened "Trifid" by John Herschel.

Messier 8 is energized by several hot stars. Including 9 Sagittarii (mag 5.97, O4V), Herschel 36 (mag 9.0, O7V, a spectroscopic binary) and possibly some hidden stars behind the dust.



The energizing star of the Trifid appears to be the triple star HD 164492 (listed as mag 6.8, O7.5V), also known as HN 40 or GC 24537. It's seen on the left in a Spitzer infrared image. The Simbad database described this star as a "young stellar object." These are young stars with a good bit of infrared radiation coming from their cooler circumstellar envelope of gas and dust. They have not completed their contraction; as they mature, the IR component of their spectra decreases. Herbig-Haro objects and proplyds would fall into this category.

Stephen James O'Meara, in *Deep Sky Companions: The Messier Objects*, notes that "the dark channel (of M8) is so prominent at low power that it must be the most dramatic example of dark nebulosity in any deep-sky object visible in small telescopes." He recommends using moderate power and averted vision to bring out the dark dust clouds in the Lagoon and in the Trifid as well. The main problem for observers or imagers is the low declination of this area of the sky. From Westchester, the highest the Lagoon Nebula ever gets is about 24 degrees. Since its in the south (declination -24° 22') it is bathed in the intense New York City skyglow in that direction. We often use a moderate visual "light pollution reduction filter" at the eyepiece, such as a good old Lumicon Deep Sky filter. Modern dual-band filters filters work well for imaging, especially if you want to preserve the reflection nebula component of M20.

The distances to these nebulas are not precisely known. The NED (NASA/IPAC Extragalactic Database) doesn't give distances for many Milky Way objects. The currently accepted distance for M8 is 5,200 light years, and the same for M20, while cluster M21 is given as 4,350 light years.

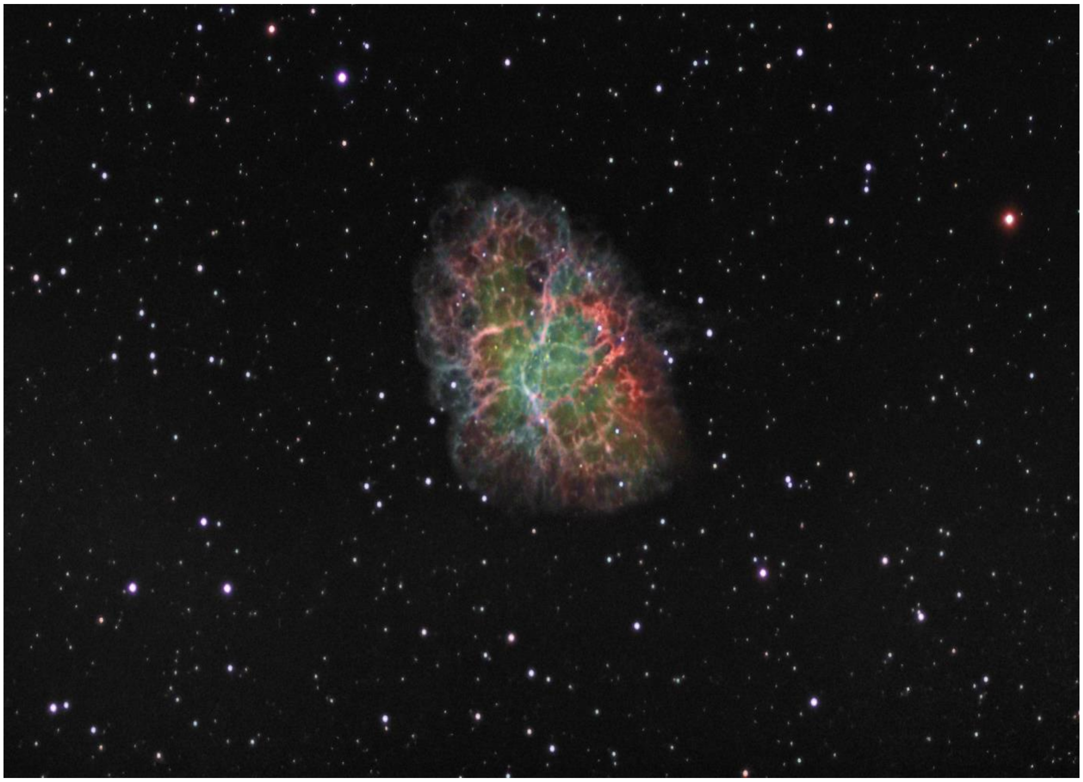
Gary made this image at Ward Pound Ridge Reservation in July 2022. William Optics GT71G refractor with 0.8x reducer/corrector, Radian Triad Filter; ZWO asi2600 MC Pro. The field of view is 4 x 2.7 degrees. The Radian Triad has fairly narrow bandpasses (narrower than the Optolong L-eNhance)-in the Hα, Hβ and OIII bands. It's a filter for seriously commited imagers: the 1.25" version lists for $375.

More Images from the Arizona desert by Arthur Miller (see the December 2022 SkyWAAtch, p. 17)

IC 2169 is a rarely imaged reflection nebula in Monoceros. It's not described in any of Stephen James O'Meara's *Deep Sky Companion* books, nor in Sue French's *Deep Sky Wonders*, nor in Phil Harrington's *Cosmic Challenge*.

Messier 43 and 43

The Orion Nebula is one of the most photographed celestial objects, always enticing to imagers who are fond of bringing out detail and color saturation in the swirling gas and dust.



Messier 1

The Crab Nebula in Taurus is what's left of the supernova of 1054.

Galaxies in Eridanus. The spiral on the right edge is NGC 1723, mag 12.7. The three middle galaxies, all mag 13.0, are NGC 1728, 1725, and 1721 (top to bottom), forming VV 669 in the Vorontsov-Velyaminov catalog of interacting galaxies (http://www.sai.msu.su/sn/vv/). In the upper left corner is the edge-on spiral galaxy PGC 016507, mag 15. A dozen smaller, fainter galaxies are also visible. The field is 22.6 x 14.5 arcminutes.

The Owl Cluster by Rick Bria

NGC 457, the Owl Cluster is also known as the ET Cluster, presumably because the two bright stars look like ET's bulgy eyes. It also is sometimes called the Dragonfly Cluster or the Kachina Doll Cluster. In addition, it is catalogued as Caldwell 13, Melotte 7 and Collinder 12. This bright (mag 6.4) group of stars is 7,900 light years distant in Cassiopeia. The stars forming the eyes are Phi Cassiopeiae (mag 5, spectral type F0) and HD 7902 (mag 7, spectral type B5).

Rick made this image on October 27, 2022 at Mary Aloysia Hardey Observatory in Greenwich. PlaneWave CDK 14 telescope, STX camera, stack of 33 15-second images.

Remembrance of Jupiter by Steve Bellavia

Low in the west at sunset in February, Jupiter will finally leave the evening sky in March. In September 2022, Steve caught this shadow transit of Europa when the planet was at about 40 degrees elevation. The high albedo of ice-covered Europa reveals the planet as a bright dot, with its shadow heading towards the Red Spot.

Steve made this image at the Custer Institute in Southold, Long Island, on September 14, 2022 around midnight. He used a Celestron 6-inch SCT operating at 3,000 mm focal length (2X Barlow), ZWO ASI 290MC camera, and Astronomik L-2 UV/IR blocking filter, all on a SkyWatcher EQ6-Pro mount. Seeing was estimated at 3/10. He captured 20 millisecond frames at 44 FPS with SharpCap. He processed the image with AstroSurface.

Shadow Transits of Jupiter Visible from Westchester, February 2023

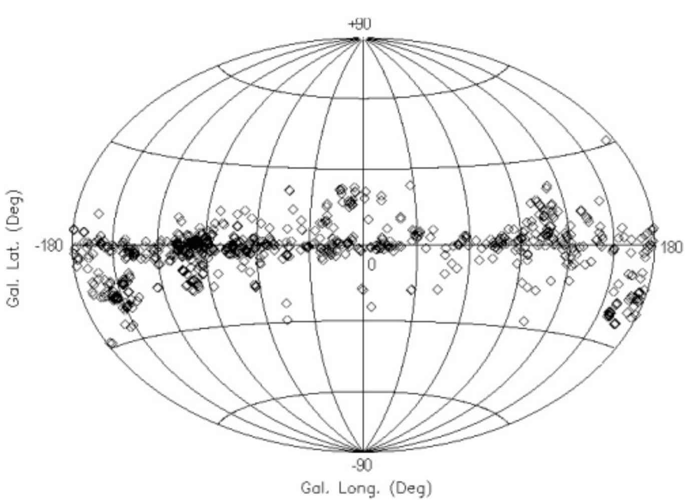
As Jupiter sinks in the western sky heading towards conjunction with the Sun on April 12, only two shadow transits in February will be reasonably observable after sunset. The planet needs to be above 25 degrees altitude at any time during the transit after sunset to make our list. Then it’s goodbye for observable transits until later in the year.

Date	Moon	Ingress		Egress		Sunset	Nautical Twilight ends
		Time	Alt (Deg)	Time	Alt (Deg)		
2/6	Europa	16:45	45	19:11	24	17:17	18:18
2/10	Io	17:02	42	19:14	21	17:22	18:23

The Ghost Nebula by Steve Bellavia

This image was made over two nights in September in two different locations: StarHaven in Livingston Manor in the Catskills and Orient Point in Long Island. Technical details are at https://www.astrobin.com/ajw4bq/C/.

The Ghost Nebula is a reflection nebula in the constellation Cepheus, catalogued as Sh2-136 and VdB 141 but not appearing in the NGC or IC catalogues. It should not be confused with several other nebulas that have been given the "Ghost" appellation: the "Little Ghost Nebula" (NGC 6369) in Ophiuchus, the "Ghost Head Nebula" (NGC 2080) in Dorado (properly a nebula within the Large Magellanic Cloud) or the "Ghost of Cassiopeia" (IC 63).



The brightest part of the nebula contains the star BD+67 1300, thought to be a binary system early in its formation The core of the right side of the nebula, containing a faint comet-shaped feature within a dark area, is a Bok globule. The Ghost is 1,470 light years distant. Reflection nebulas are composed primarily of dust. They are generally near or intermingled with clouds of hydrogen in which new stars are forming, distributed near the plane of the Milky Way (except those clearly in the Large or Small Magellanic clouds), as can be seen in this diagram, taken from Magakian, T. Yu, Merged Catalog of Reflection Nebulae, *A&A*, 399: 141-145 (2003), https://www.aanda.org/articles/aa/pdf/2003/07/aa3212.pdf.

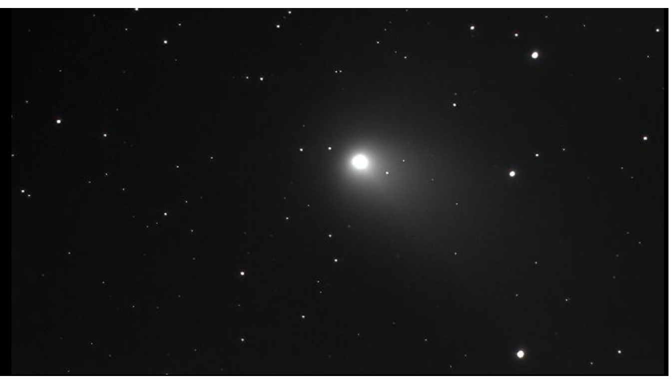
Comet C/2022 E3 ZTF

This relatively bright comet achieved perihelion on January 12th and will be closest to Earth on February 1st, possibly reaching 5th magnitude. Steve Bellavia and John Paladini imaged it in January.

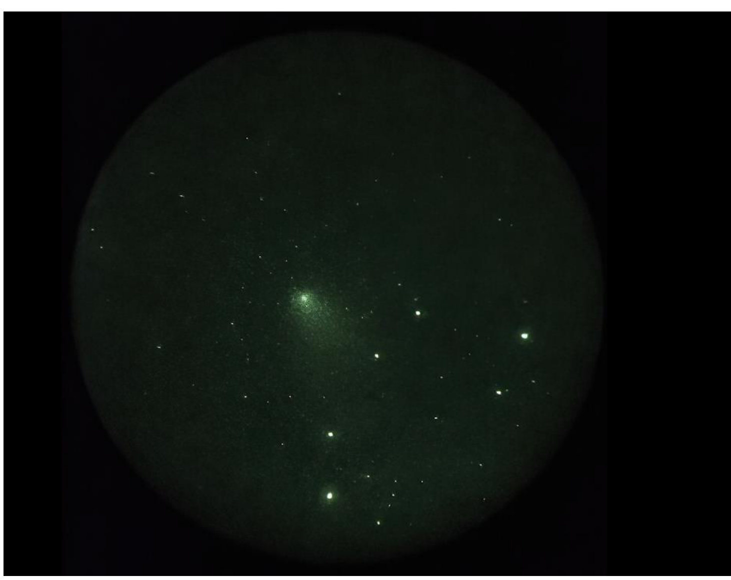
Steve Bellavia, January 8 (through the trees)

Steve Bellavia, January 8

John Paladini, January 17, tracking the comet



John Paladini, January 17, tracking the stars



John Paladini, January 17, Image intensifier

Steve Bellavia, January 16

Research Highlight of the Month

Vallée, Jacques P, Kinematic Structure of the Milky Way Galaxy, Near the Spiral Arm Tangents, *International Journal of Astronomy and Astrophysics,* 12, 382-392. doi: 10.4236/ijaa.2022.124022.

The pitch angle of a spiral is defined as the angle between the tangent of the spiral and the tangent of a circle with its center at the same location as the origin of the spiral. This is a measurement that can be applied to a spiral galaxy, and it can be used to characterize the structure of the Milky Way. Our galaxy's arms can't be visualized from the outside, and they overlap when we look in any particular direction. To decide where an object is in our galaxy, various tracers can be used: age, motion and chemical composition of stars (much enriched by Gaia data), radiation from Hi, HII, CII or NII atoms, thermal electrons, radio masers, and other quantities determined with Earth- and space-based telescopes. These measurements can be used to test various theories and populate models of spiral arm formation and evolution.

The components of the spiral arms don't all move at the same rate. The movements are influenced by gas pressure, gravity and magnetic fields, and perhaps local concentrations of dark matter. In previous publications, Vallée, an astrophysicist working at Herzberg Astronomy and Astrophysics, National Research Council of Canada, provided maps and models for spiral arm distance, pitch angle and rotational velocity. In this publication, he checked the predictions of density wave theory, in which gas enters a spiral arm at a supersonic velocity, creates a shock and later leaves the arm at a subsonic velocity. In density waves, the actual spiral arm structure itself moves at a different rate than its stellar and gas components.

Gas and stars rotate around the galaxy at 233 km/s, but move away from the shock front at the inner side of a spiral arm at 81.5 km/s. With the Sun located (and remaining) 8.15 kpc from the center of the galaxy, we would be expected to move from one spiral arm to the next in about 160 million years. The linear pattern speed of the density wave is 152 km/s. Interestingly, the time of 160 million years is also close to the mean time between major biologic extinctions on Earth. So among the various theories for Earth's periodic biologic catastrophes, we may have to add the trauma of the density wave of a galactic arm passing over us.

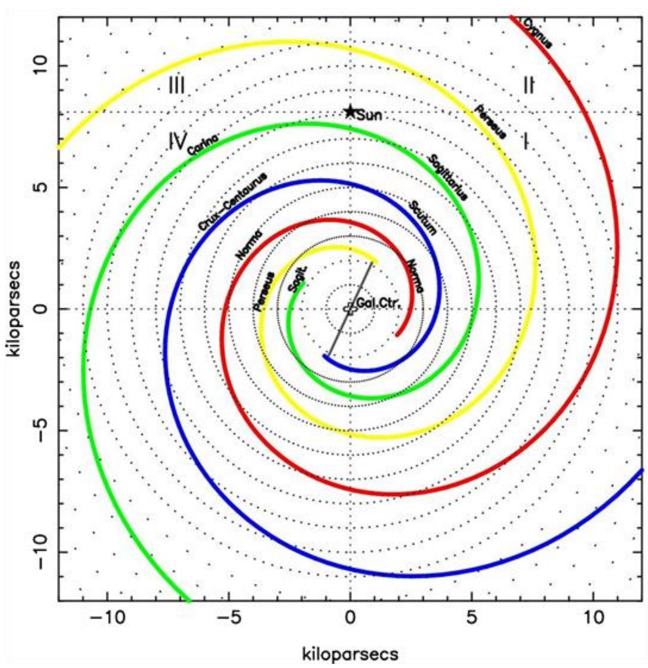


Fig. 1: The galactic disk, viewed from above. The galactic quadrants are plotted relative to the position of the Sun, which is 8.15 kpc from the galactic center.

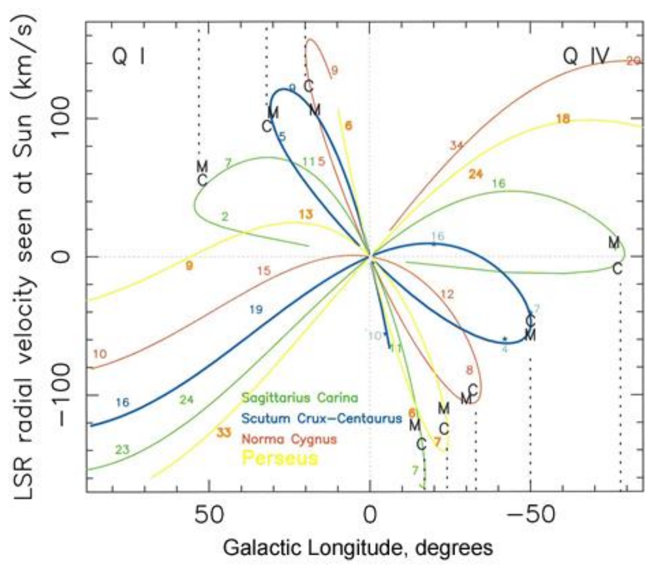


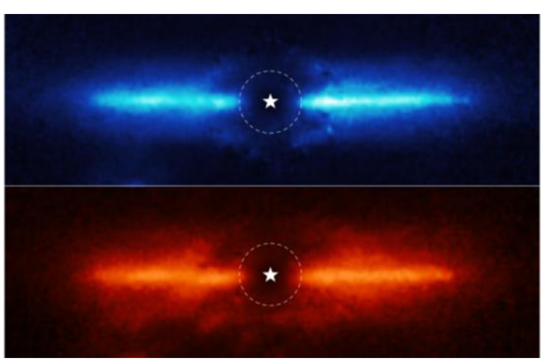
Fig 2: The radial velocity of each spiral arm. The numbers near each arm are the actual distance from the Sun. The dashed lines show the arm tangents. M and C are the positions of the origin of radio masers or broad diffuse CO lines, respectively.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Televue Big Barlow	2" Barlow. 1.25" eyepiece adapter, 48 mm filter threads, captive lock screws, brass compression ring, full multicoating on the high quality optics. Weight 0.75 lb.	Best offer	Peter Rothstein peterrothstein01@gmail.com
Telrad finder	Excellent condition, with removable base.	Best offer	Peter Rothstein peterrothstein01@gmail.com
Celestron 127mm Maksutov-Cassegrain	f/11.8. Celestron's version of this compact, high-performing telescope. Great lunar/planetary scope. Excellent optical and cosmetic condition. Well cared for. OTA only. Image here.	$400 or best offer	Manish Jadhav manish.jadhav@gmail.com
Orion Short Tube 80mm refractor	2-element achromat f/5.0. Metal tube rings and dovetail for Vixen saddle. A classic travel scope. Excellent optical condition, and very good cosmetic condition. Diagonal and a 25mm Celestron eyepiece included. Image here.	$200 Or best offer	Manish Jadhav manish.jadhav@gmail.com
Celestron Cometron telescope	Small, lightweight 114 mm f/4 reflector. Red dot finder, 25 mm eyepiece. Dovetail bar. A starter scope for a smart, interested child. No tripod: use a camera tripod. Excellent condition.	$50	WAA Ads@westchesterastronomers.org
Meade 8" SCT LX-80	Go-to mount, tripod. Tube wrapped in Reflectix for faster cooling. See https://is.gd/16F0Tv.	$600	Greg Borrelly gregborrelly@gmail.com
Celestron SE mount	No optical tube. Go-to alt-az mount and tripod. Can carry 12 lb payload or tube up to 17". Upgradeable hand control.	$300	Greg Borrelly gregborrelly@gmail.com
Celestron Binoviewer	Use both eyes with your telescope. Original case, with two 18-mm eye pieces.	$180	Greg Borrelly gregborrelly@gmail.com

Want to list something for sale in the next issue of the WAA newsletter? Send the description and asking price to waa-newsletter@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.

Buying or selling items is at your own risk. WAA is not responsible for the satisfaction of the buyer or seller. Commercial listings are not accepted. Items must be the property of the member or WAA. WAA takes no responsibility for the condition or value of the item, or for the accuracy of any description. We expect but cannot guarantee that descriptions are accurate. Items 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!*



These two **JWST Near-Infrared Camera (NIRCam) images** are of the dusty debris disk around AU Mic, a red dwarf star located 32 light-years away in the southern constellation Microscopium. NIRCam's coronagraph blocked the star. Its location is marked by a white, graphical star at the center of each image. The region blocked by the coronagraph is shown by the dashed circle. Blue image, filter F356W (3.2-4.0 µ), Red image: filter F444W (4.0-5.0 µ)

Credits: NASA, ESA, CSA, and K. Lawson (Goddard Space Flight Center). Image processing: A. Pagan (STScI)