SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

June 2023

The Owl Nebula (M97) and the Surfboard Galaxy (M108) by Steve Bellavia

Although most planetary nebulas are found near the plane of the Milky Way, Messier 97 is in the galaxy-rich region of Ursa Major. The 11.6-magnitude Owl, so called because of its two "eyes," has a reasonable surface brightness and can be glimpsed in 8-inch telescopes, especially with a good filter that increases contrast by preferentially passing the forbidden oxygen line of 500.7 nm and the hydrogen alpha line at 656.28 nm. Just 48 arcminutes to the northwest lies the magnitude 10.7 galaxy M108. It's 14,000 times further away than the Owl. The brightest star between them is HD 97455, magnitude 7.44, spectral class F5V. Technical details at https://www.astrobin.com/1xf4nv/. More on planetary nebulas in the October 2015 SkyWAAtch, p. 6. The June DSO of the Month is also a planetary nebula. See page 5.

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 June Meeting

Friday, June 9, 2023 at 7:30 pm

Searching for New Physics in the Universe's Oldest Light

J. Colin Hill, PhD
Department of Physics, Columbia University

What do we know about our universe, and how do we know it? Dr. Hill will discuss recent and ongoing work focused on attempts to resolve a potential discrepancy among measurements of the current cosmic expansion rate (the "Hubble constant"). This discrepancy could potentially be resolved via the introduction of new physics into our cosmological model around the time of "recombination", the moment when photons in the cosmic microwave background (CMB) last scattered in the primordial plasma, a few hundred thousand years after the Big Bang.

The latest CMB data from the Atacama Cosmology Telescope (ACT) and studies of Supernova Refsdal will be presented. Forthcoming CMB measurements from ACT and the Simons Observatory will definitively detect or exclude these scenarios.

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

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WAA September Meeting

Friday, September 8, 2023 at 7:30 pm

Members' Night

WAA Members

It's one of our most popular events. WAA members will make short presentations on a variety of topics of interest to their colleagues. Contact Pat Mahon, WAA VP for Programs, at waa-programs@westchesterastronomers.org if you wish to be included on the program.

There are no meetings in July and August, but star parties are scheduled.

Starway to Heaven

Ward Pound Ridge Reservation, Cross River, NY

June 10 (Rain/cloud date June 17)

New Members

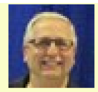
Daniel Assumma	Armonk
Christopher Auletta	White Plains
Maria Chelliah	Chappaqua
Joyce Dow	White Plains
Jake Sablosky	Chappaqua

Renewing Members

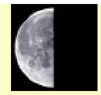
Paul Alimena	Rye
Richard Austin	Milford
John Benfatti	Bronx
Kenneth Creary	White Plains
Barry Feinberg	Croton on Hudson
Jeffrey Jacobs	Rye
Arthur Miller	New Rochelle
John Paladini	Mahopac
Charles Pevsner	Riverside
Daniel Platt	Putnam Valley
Daniel Rosenthal	New York
Michael Sheridan	Mt. Kisco
Francesca Varga	Pleasantville

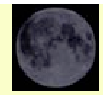
ALMANAC For June 2023

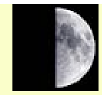
Bob Kelly, WAA VP of Field Events


Bob Kelly

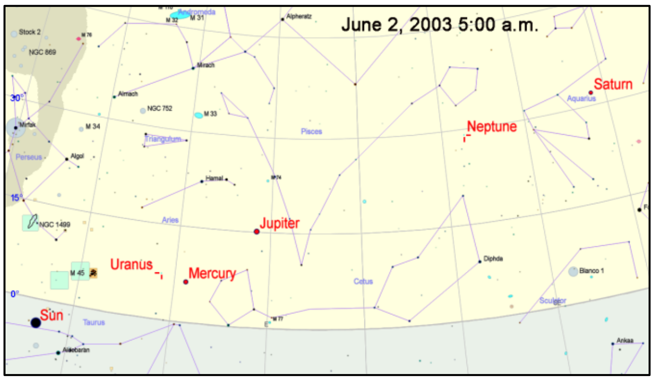

Full 6/3


3Q 6/10


New 6/18


1Q 6/26

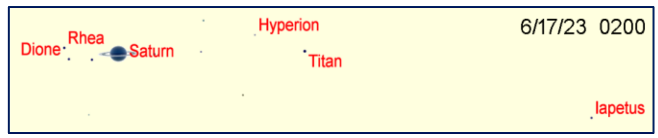
Saturn rises at 1:15 a.m. on June 1 and before midnight by the last week of the month. **Jupiter** follows, but keeps its distance, about two hours behind, lower in the pre-dawn sky.



Find a good app to follow Jupiter's four Galilean moons as they dance near and across Jupiter's disk. There are several shadow transits this month. A rarer double shadow transit of Io and Europa will begin on the 11th at 3:47 a.m. and last about an hour. The planet will be low in the east. Jupiter's **Great Red Spot** has shrunk and faded a bit over the last century but is now back to being quite intensely red. Apps will also give you dates when the GRS is best seen, centered in the southern hemisphere of the planet's disk. Good views will be an hour before dawn on the 11th and the 23rd. Watching the movement of the GRS gives a good illustration of the speed of Jupiter's 9-hour 55-minute rotation period. You'll need at least a three-inch telescope to get a good view of the GRS.

Double shadow transit of Jupiter, Nov 2, 2022 (LF)

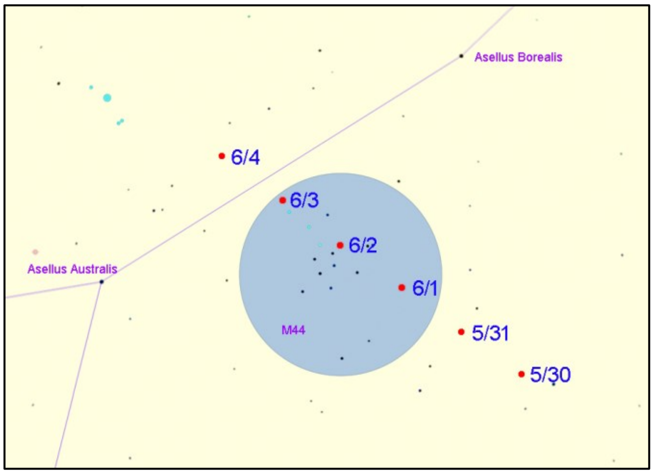
Saturn, of course, has lots to see, even though the butterscotch disk looks small in most of our telescopes. Saturn's rings are tilted 7.3 degrees to our line of sight in June, the narrowest the rings will appear this year, but still magnificent in almost any telescope. Saturn's brightest moon is **Titan**, at magnitude +8. For the latter two-thirds of June, two-faced **Iapetus** is 12 ring-diameters west of Saturn, brightening to magnitude +10. Titan slides almost half-way between Iapetus and Saturn on the16-17th, which makes it easier to find Iapetus in a telescope.



Mercury tries to join the club of the giant planets, but it's so low in northern hemisphere skies it's hard to spot even as it gets brighter. Look well to the lower left of Saturn and Jupiter.

Dominating the evening sky, **Venus** will get a bit brighter and slimmer as it starts to fall toward the twilight after its greatest elongation from the Sun on June 3rd. Venus'-set time moves up to 10:45 p.m. by the end of June. Catch it in the bright sky to see the phase better. We get 45% more Venus by the end of June! The crescent phase of Venus will be easier to discern as it appears larger in our sky. As it swings around the Sun in our direction to get closer to us, it appears larger and a bit brighter.

Venus appears to be trying to catch **Mars**. Mars is playing hard-to-get as it moves eastward against the stars, leaving Gemini far behind and heading toward Regulus in Leo. Mars is a steady, red-tinted light, bright, but at magnitude +1.6, 100 times dimmer than Venus' magnitude -4.5. We'll get to see how close they get until they both tumble into the glare of the Sun in August. The Moon slides by, above the pair on the 21st. Mars becomes a big brother to the bees of **M44** (the Beehive Cluster) on the 2nd. It's a photo opportunity via zoom lens or wide-field telescope.



Mars crossing the Beehive Cluster (positions at 9 p.m.).

The **Moon** approaches Jupiter on the 13th, passing by on the 14th. Mercury and the Moon are side-by-side, but hard to see in the morning twilight, on the 17th.

The **International Space Station** runs out the string of evening sky appearances on the 1st. We don't see it again from here until the 24th, when the ISS appears in the dawn sky.

Solar activity has been increasing. We could get a peek at the aurora borealis, although with only five hours of true darkness this month, opportunites for viewing the diffuse northern lights are limited. Get as dark a location as possible. They can be visible as a gray cloud, with colors only apparent in photographs, due to the lack of sensitivity of our eyes to dim, diffuse colors. Check the University of Fairbanks web site at https://www.gi.alaska.edu/monitors/aurora-forecast to see if aurora are predicted to be visible this far south on any given night.

What time is sunrise this month? That's easy to remember! The **Sun** rises at 5:25 a.m. EDT on the 1st and the 29th. The earliest sunrise is on the 14th at 5:22 a.m. If someone asks anytime in June, say 5:23 and you'll be good enough for the whole month. Sunset time covers a bit more range. We start the month at 8:20 p.m. and the Sun stays out later each night, until the latest sunset, at 8:31 p.m. on the 27th. The solstice occurs with the Sun furthest north at 10:58 a.m. on June 21st. After that, the days start to shorten.

Watch for bright star **Vega** and its constellation Lyra soaring higher in the eastern sky, heralding the arc of our Milky Way which will stretch across the sky during Summer. Can you make out the entire Summer Triangle (Vega, Deneb and Altair)?

There are no major meteor showers in June. ■

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
Proofreader: Elyse Faltz
Editor Emeritus: Tom Boustead

Don't forget to RSVP for the

WAA Annual Member's Picnic
June 17th 12:00 noon to 4:00 p.m.

Pavilion #1, Croton Point Park, Croton-on-Hudson, New York

Food, fun and friendship. Bring your family or a friend. It's an annual benefit of membership in WAA.

Please RSVP to Eva Andersen by June 10th by sending an email or text with your name(s), contact phone number and food allergies or avoidances. Email: andefam55@gmail.com, cell: 845-803-4949. We need a head count so we know how much food to prepare!

Deep Sky Object of the Month: The Turtle Nebula

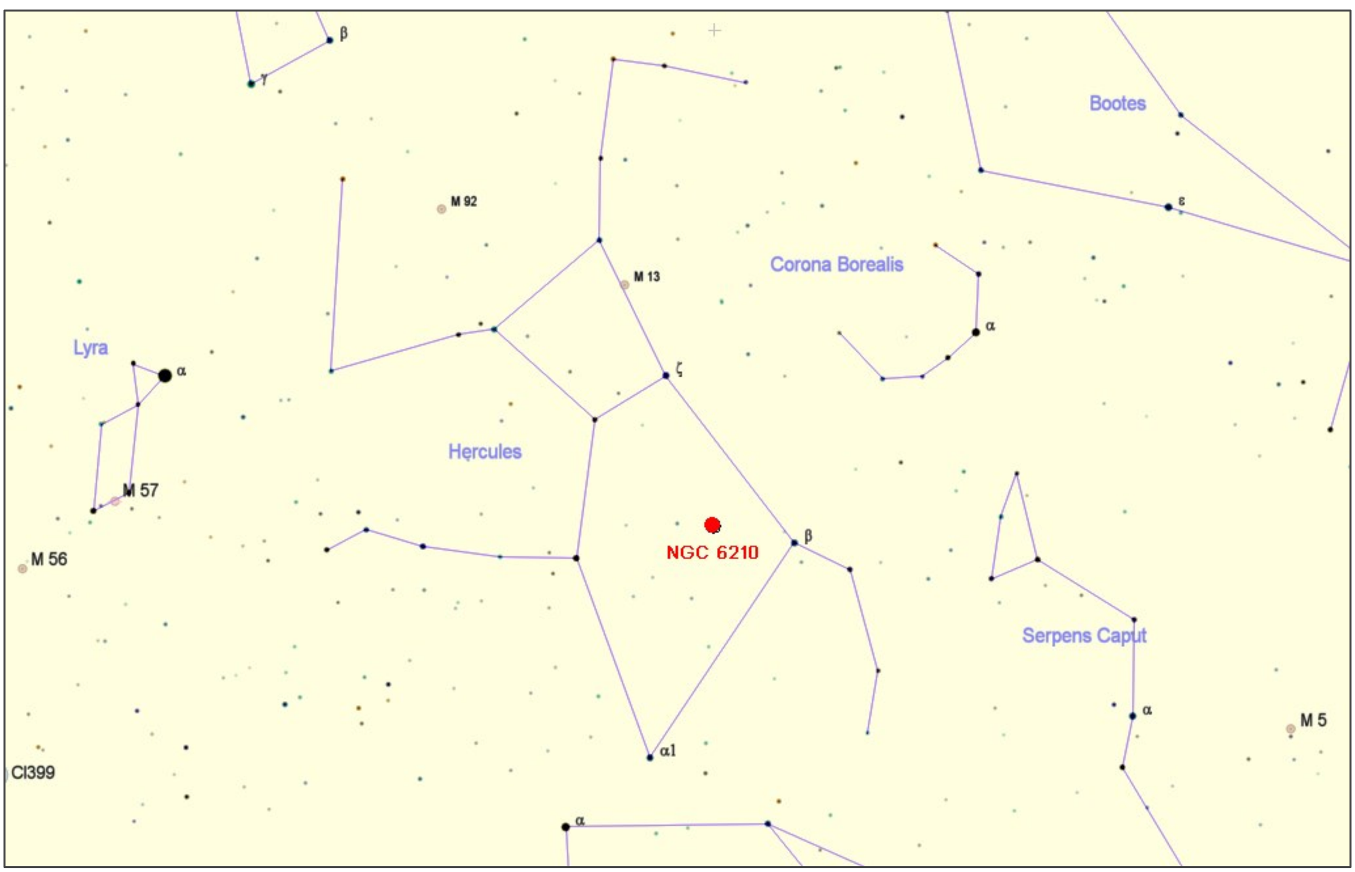
Constellation	Hercules
Object type	Planetary Nebula
Right Ascension J2000	16h 44’ 29.5”
Declination J2000	+23° 47’ 59.2”
Magnitude	+9.0
Size	18 arcseconds
Distance	5,400 LY
NGC designation	NGC 6210
Other designation	PN G043.1+37.7
Discovery	Struve, 1825

This small but compact planetary should be visible in most telescopes as a slightly fuzzy blue star. Magnification will show its breadth, as large as Saturn’s disk when the planet is at opposition. Wilhelm Struve first noticed it as a non-stellar object using the famous 9.6-inch f/17.6 Dorpat refractor made by Joseph von Frauenhofer in 1824.

The Hubble Space Telescope image of the Turtle is at https://esahubble.org/images/potw1026a/.

Visibility for NGC 6210			
2200 EST	6/1/23	6/15/23	6/30/23
Altitude	48° 39’	58° 23’	67° 16’
Azimuth	101° 36’	115° 15’	137° 59’

Astrophotographers who can image at high magnification might give this object a try.



Another Movie Telescope

A brass refractor looks out to the Pacific Ocean from an elegant mid-20th century seaside house in Malibu, while George Clooney, playing the famous but somewhat brainless movie star Baird Whitlock, sits in a Roman military costume, martini in hand. He had been sedated and then kidnapped off the set of a *Quo Vadis*-like Bible epic by a cadre of disgruntled Communist scriptwriters. Upon awakening, the credulous Whitlock is easily convinced by the writers to embrace Marxism, although he clearly doesn't understand it at all.

Hail, Caesar!, a Coen brothers film from 2016, is an homage to, and send-up of, studio films and film stars of the early 1950's. At the same time, it explores internal conflicts in the life of the protagonist, Eddie Mannix, played brilliantly by Josh Brolin. Among his jobs at the studio, Mannix (who was a real person) is a "fixer," who quietly and efficiently disposes of the indiscretions of the studio's stars. His devout but flawed Catholicism is an important element in his quest to understand himself.

Mannix has been offered the presidency of Lockheed with a ten-year contract and a promise of wealth and a much easier day-to-day life, but he is psychologically tethered to the studio and to the actors and actresses to whom he feels a very personal, if usually unrequited, obligation. When Whitlock is finally rescued, he tries to explain the Marxist dialectic to Mannix, who angrily sets him straight with a short but terrific speech that reveals the core of his entire being and depicts filmmaking as a communal organization that Karl Marx himself might have promoted. Rounding out the symbolism for our understanding of Mannix, the scene that Whitlock then goes off to shoot is the Crucifixion, the empty set of which Mannix visits at the close of the film.

All of the characters, archetypes really, are wonderfully drawn, among them the Communist philosopher Herbert Marcuse (who was also a real person), to whom the screenwriters appeal for doctrinaire clarification, and who spouts incomprehensible Marxist gibberish in return.

Joel and Ethan Coen are known for their off-beat, humorous-serious movies. Their most well-known films are *The Big Lebowski*, *Fargo* and *O Brother, Where Are Thou?* but among their works *Hail, Caesar!* has become our favorite. It's often hilarious, just abstract enough to be both real and not real, and loving and cynical, at the same time. Ultimately, it's a surprisingly profound story about generosity of the spirit, without seeming to be so.

Coma Cluster Galaxies Everywhere … All at Once Robin Stuart

The image above shows the Coma Cluster of galaxies that lies 321 million light years away in Coma Berenices. It is a stack of 21×10 minute subframes for a total 3½ hour exposure with a ZWO ASI2600MC camera through a TeleVue NP127 in the morning hours of 25 March, 2023. The field of view is 2.04°×1.36°.

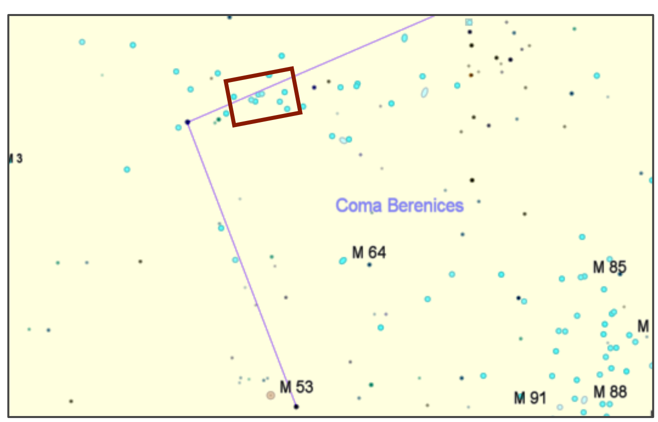
Prominent at the center are the two supergiant elliptical galaxies, NGC 4889 (left) and NGC 4874. The magnitude 7.6 foreground star HD 112887 appears with similar brightness above NGC 4874.

NGC 4889 is probably the largest and most massive galaxy within a radius of 100 megaparsecs of the Milky Way. It harbors the largest known supermassive black hole at an estimated at 21 billion solar masses or 5,200 times that of Sagittarius A*, the black hole that dwells at the heart of our own galaxy.

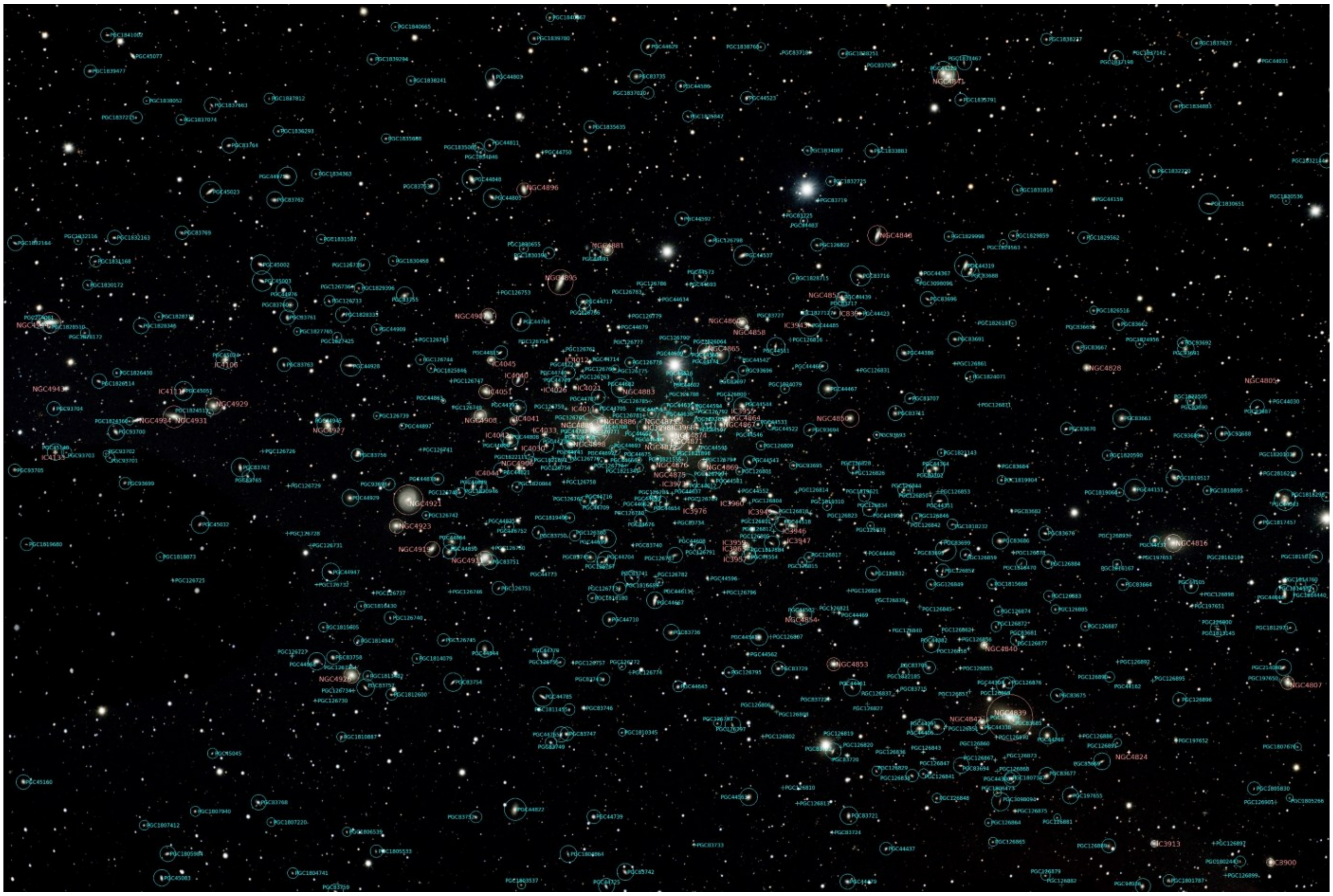
Both NGC 4889 and NGC 4874 are surrounded by impressive entourages of globular clusters, hosting an estimated 15,800 and 18,700 respectively.

The largest spiral galaxy in the cluster, NGC 4921, is seen face-on, left of center in the image.

The Coma Cluster was one of the first places where gravitational anomalies suggested the existence of *dark matter* which is now thought to make up 90% of the cluster's mass. It was Fritz Zwicky who, in 1933, showed that the constituent galaxies were moving too fast be held together by the matter in the visible galaxies alone.



Field from astrometry.net. Map from Cartes du Ciel.



At six times further away than the Virgo Cluster (see the September 2022 SkyWAAtch, page 27), the Coma Cluster is much less visually striking. However when PixInsight's Script > Render > AnnotateImage function is applied to the image file, around 700 galaxies are identified in the image and the staggering extent of the cluster becomes clear. Further exploration of the image with the aid of CDS (https://cds.unistra.fr//) shows it to be strewn with a myriad of unlabeled galaxies. Some of these form obvious associations whose common reddish tinge suggests that they are clusters in their own right lying far beyond the Coma Cluster. Although difficult to pin down an exact value for the limiting magnitude, objects of at least visual magnitude 21 are clearly discernible.

Editor's Note:

The redoubtable, curmudgeonly Fritz Zwicky, one of the most colorful characters in 20th century astronomy, published "Die Rotverschiebung von extragalaktischen Nebeln" (The Redshift of Extragalactic Nebulae) in *Helvetica Physica Acta*, Vol. 6, p. 110-127 (1933). Zwicky measured the velocity dispersion of seven Coma cluster galaxies as part of a study on the origin and properties of the red shift, the role that intervening matter might play, and the possible origin of cosmic rays. Hubble's discovery of the distance-velocity relationship was just four years old and still controversial (and in a sense may still be today, what with the "Hubble tension"). An English translation of the paper appeared in 2017 (https://arxiv.org/ftp/arxiv/papers/1711/1711.01693.pdf).

Using the virial theorem, which states that the kinetic energy of a rotating mass at equilibrium is equal to (minus) one-half of the potential energy, and deriving a mass for the cluster of 1.6 x 10^{45} grams from the luminous material, Zwicky noted that, "In order to obtain, as observed, a medium-sized Doppler effect of 1000 km/s or more, the average density in the Coma system would have to be at least 400 times greater than that derived on the basis of observations of luminous matter…. If this should be verified, it would lead to the surprising result that dark matter (*dunkle Materie*) exists in much greater density than luminous matter." ■

The "How Lucky am I" Astronomy Trip Report

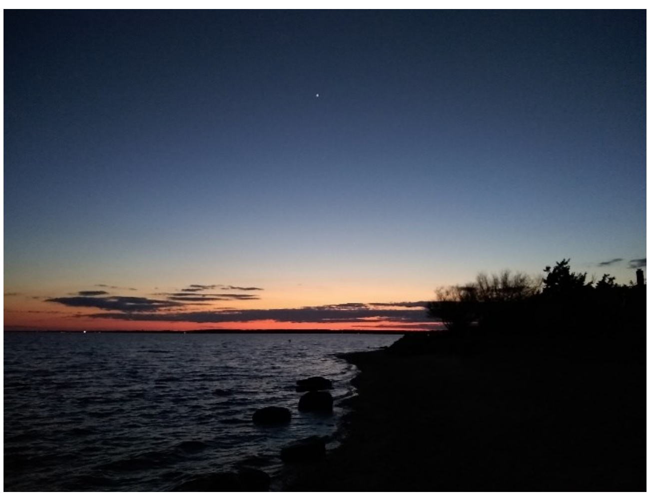
Steve Bellavia

While driving home, approaching the end of another astronomy trip, it occurred to me how lucky I have been to be able to do these things. I have done many of these trips, but only now did I decide to start naming them. So this one is called the "How Lucky am I" trip.

The first part of "the trip" on Saturday evening March 18 was only 20 minutes away from my home, to Orient Point, where I wanted to see if getting Sh2-308, the Dolphin Nebula, was even possible, especially so late in the season, with it being low in the sky and already past the meridian before astronomical twilight ends.

I found a nice south-facing beach. It was windy, clouds came and went (mostly in front of my target), and there was some light pollution towards the southwest, the glow of the town of Greenport.

I got to watch a gorgeous sunset, Venus, and listen to the sound of the waves hitting the beach... How lucky am I?



When I got home, I quickly processed the 57 minutes of usable data and could easily see the Dolphin!

I was to give a talk at SUNY New Paltz the following Tuesday, so I checked the forecast and made a last-minute reservation at the Cold Spring Lodge for Monday and Tuesday, only 52 miles from New Paltz.

I set a record for ease of getting there. I averaged a mile-a-minute the whole way, (and 31.3 mpg) and only stepped on the brake pedal to stop for lunch at the elegant Sloatsburg Travel Plaza. A very unhealthy but delicious burger, fries and a coke, and back on the road, viewing snow-covered mountains in the distance, which always gets me excited.

I arrived with plenty of time to set up and then go out to a steak dinner at Peekamoose Restaurant.

And then it was a race against the sidereal clock. I polar aligned, swung over to my target, re-focused and started imaging in twilight. I had to make sure there were no opportunities for gremlins, at least until the Dolphin set into the trees and mountains. And I got lucky. I got almost 2 hours of uninterrupted useful data to complement the 57 minutes I got from Orient Point. I was in bed before midnight.

Tuesday was very relaxing. After breakfast at the Phoenicia Diner, I spent the morning tweaking the slides for my talk, and in the early afternoon, I walked to the very back of the Lodge property, which is on the Esopus River. I sat in my little chair, where the air felt cool, but the Sun felt so warm. I call that "perfect weather." I then meditated for a while, listening to the water flowing by the river. By "meditate" I mean I had a beer and dozed on and off.

I then put on my shirt and tie and headed to New Paltz, with the sun setting and more gorgeous mountain views along the drive.

The talk went very well, and then I was given a tour by Eric Myers of New-Paltz-Henge in the Coykendall science building. It catches the sun at both solstices and equinoxes. So cool! Eric is a former BNL scientist and now physics professor at SUNY. I then had a nice dinner with most of the attendees of the talk, with great conversations, and was back to my room by midnight.

Wednesday was an easy drive home. I saw an ambulance that I mused must have been owned by an anti-astronomer, or at least not concerned about preserving night-vision. A sign on the ambulance read “This vehicle does not turn on red lights.”

When I got home, I processed all my data and was pleasantly surprised that the Dolphin allowed me to capture him in my digital net. Technical information is at https://www.astrobin.com/xwx833/.

Here is the full set of photos from the trip: https://is.gd/stevetrip.

How lucky am I?

Steve’s image of Sh2-308, the Dolphin Head Nebula, in Canis Major. The nebula is an HII region surrounding Wolf–Rayet star EZ Canis Majoris (HD 50896, the star in the center of the nebula, mag 6.6). It is in the brief, pre-supernova phase of its stellar evolution. The distance to this nebula is not clear; estimates range from 1,875 to 5,870 light years. The bright star near the edge of the nebula is Omicron Canis Majoris, a red giant magnitude 3.87. The field is 1.89° across; distance between the two stars is 15 arcminutes. The Dolphin Head is about the diameter of the full Moon!

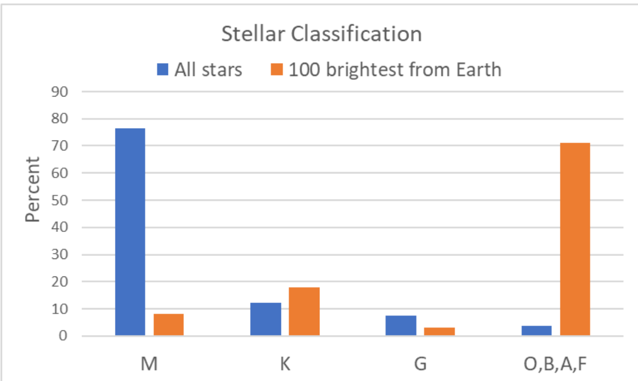
Steve Bellavia is a member of several astronomy clubs including WAA. He is a prolific astrophotographer and shares his images with WAA, other local clubs and on-line. He is active at the Custer Institute in Southold on Long Island’s North Fork. See a few more of his images in this issue, on the cover and on pages 18, 19 and 27.

Stars Come in All Sizes, But Mostly Small

Larry Faltz

The points of light we see in the sky on a clear, dark night (both adjectives rarely applying to Westchester, but nevertheless our fervent hope each evening) are not representative of the actual population of stars.

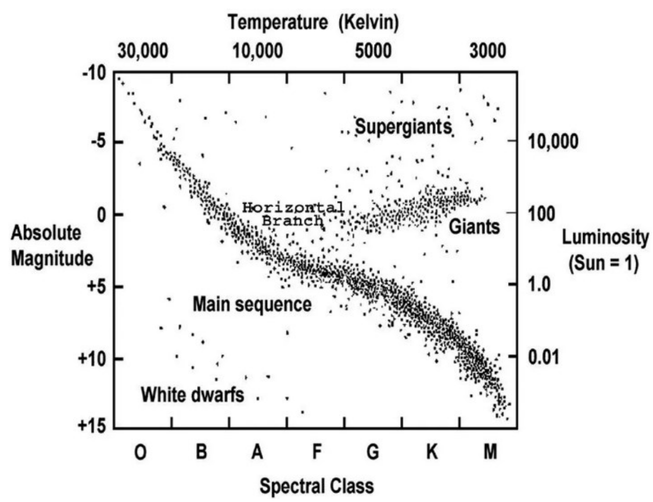
We see mostly bright, young stars that are larger and younger than the Sun. The galaxy is filled, however, with faint, small old stars. I made a graph of the 100 visually brightest (lowest visual magnitude) stars in the SAO catalog and compared their distribution to a general telescopic survey of stellar classes.



The initial system for stellar classification was proposed by Secchi in Rome in 1866. It was amplified and refined by the painstaking work of the "computers" of the Harvard Observatory. finally resulting in the famous OBAFGKM classification and the Henry Draper Catalog. O stars are the hottest, bluest, youngest and most massive stars, while M stars are the coolest, reddest, oldest and least massive. Recent detection of brown dwarfs by infrared astronomy has extended the classification to L, T and Y. These dwarfs may not fuse hydrogen, but they are still products of star formation (as distinguished from planetary formation around a nascent star). The Morgan–Keenan (MK) system, now in common use, is an extension of the Harvard system with more subdivisions and modifiers. It includes characters that add details about the star's composition and its rank among its peers. For example, a star like Vega, initially just class A, is now A0Va.This tells us it is in the hottest group of stars within class A (the "0"), that it's on the main sequence (V) and the "a" higher luminosity with the class.

A typical red dwarf, which we can take as representative of the vast majority of stars in the galaxy, is Proxima Centauri, the star closest to the Sun. It's just 12% as massive as the Sun. It is class M5.5Ve: cool, on the main sequence, and with emission lines ("e") in its spectrum. Even though it's close, it shines at just visual magnitude 11.

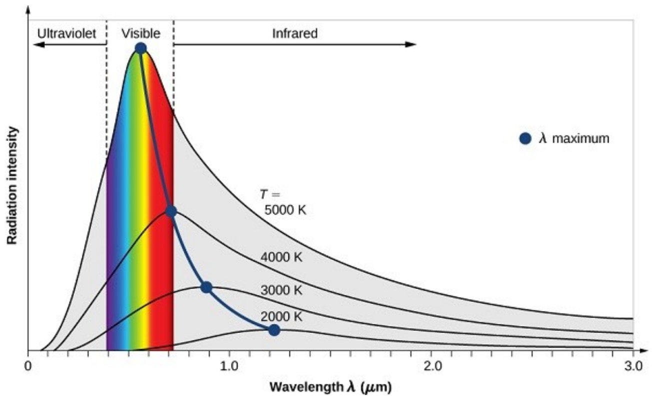
On the other hand, the red stars that we can see with the naked eye are all older giant stars. For example, Betelgeuse (M1) and Antares (M1.5) are more than 16 and 12 times more massive the Sun, respectively. Their surfaces are cool, but that's because they are large stars that started out very hot but then underwent expansion in the later stages of their lives. A very bloated star with a large surface area can still radiate a large amount of energy while having a cool surface. The amount of energy per unit surface area may be low, but the surface area is huge. If Betelgeuse were our star, its surface would extend past the orbit of Saturn and we'd be deep inside of it, a rather unpleasant thought. Its surface area is more than a million times greater than the Sun's. Its energy output is about 125,000 times that of the Sun, so radiation per unit surface area is one eighth as great. Its surface, at about 3,200 K, is cooler than the Sun, whose photosphere is nominally 5,777 K.



The Hertzsprung-Russell diagram (Chandra X-Ray Observatory)

The relationship between luminosity (a star's energy output) and color (spectral class) is shown in the Hertzsprung-Russell diagram. The HR-diagram was first plotted by Ejnar Hertzsprung in 1911 and discovered independently by Henry Norris Russell, Jr. in 1913. From it we can understand any star's life history in broad terms. To appreciate it fully, we need to go over some basic concepts: color, magnitude, absolute magnitude, distance, and luminosity.

Color and Temperature



Blackbody radiation spectral intensities imposed on the visible spectrum (LibreTexts Chemistry)

A star's color is a direct reflection of the temperature at its surface. Stars are close to being "blackbodies," which are perfect emitters or absorbers of energy. The radiation profile of a blackbody has a peak that depends only on its temperature, and not at all on its composition. Hotter bodies radiate more short-wavelength (UV and blue) photons and cool bodies radiate more long-wavelength (red and infrared) photons. Wien's Displacement Law is a simple equation that states that that the peak wavelength is inversely proportional to the temperature,

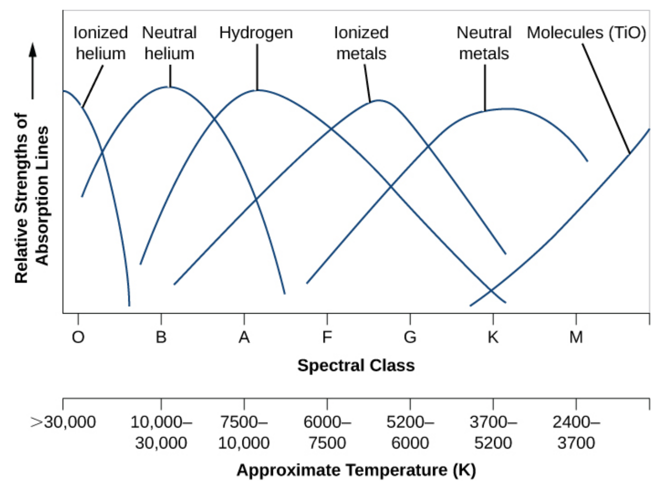
$$\lambda_{peak} = \frac{b}{T}$$

where *b* is Wien's displacement constant, equal to 2.897771955...×10^{-3} m·K, and temperature is in Kelvin. The Kelvins cancel out, so the result gives a length, which is what we want.

Kirchoff's Laws of Spectroscopy

- A luminous solid, liquid, or dense gas emits light of all wavelengths.
- A low density, hot gas seen against a cooler background emits a BRIGHT LINE or EMISSION LINE spectrum.
- A low density, cool gas in front of a hotter source of a continuous spectrum creates a DARK LINE or ABSORPTION LINE spectrum.

The OBAFGKM classification was initially determined by detecting absorption lines in stellar spectra on black-and-white photographic plates (see an example on page 17). The lines are due to absorption of the thermal radiation by specific elements and molecules in the stellar atmosphere. At different temperatures, absorption lines from identifiable chemical species become visible since they ionize at different temperatures. There is a nice on-line demonstration of how this works at https://is.gd/abslines.



Absorption line strengths (OpenStax CNX)

Multiple stellar spectra generally appeared on each plate, and the Harvard "computers" had to scrutinize each one and make exacting measurements. The first Draper catalog had stellar classifications for about 10,000 stars. It was primarily the work of Williamina Fleming, whom we encountered during our review of the history of the Horsehead Nebula in the April 2023 SkyWAAtch, page 6. The main Henry Draper catalog, published between 1918 and 1924, was based on a refined classification system worked out by Annie Jump Cannon. It contained 225,000 stars. Cannon added another 46,850 before her death in 1941. Read Dava Sobel's book *The Glass Universe* for the full story on this incredible undertaking.

Magnitude

Magnitude, more properly relative magnitude, is simply the star's brightness as we perceive it. We usually use V (visual) magnitudes for stars, but magnitudes can be determined in various sub-regions of the electromagnetic spectrum. We often see infrared magnitudes for distant galaxies whose light is shifted to longer wavelengths, which is one reason the JWST was designed as an infrared telescope. A magnitude can't tell us too much about the star's actual energy output unless we know its distance, although the magnitude difference measured with two standardized filters (generally B and V) can make a reasonable estimate of the star's color and thus a rough estimate of its surface temperature. Magnitude is a dimensionless number, with lower (including negative) values meaning brighter objects.

Absolute magnitude is how bright the star would appear if it was exactly 10 parsecs (32.6 light years) from Earth. To determine absolute magnitude, the star's distance must be known.

Magnitude and absolute magnitude are logarithmic functions and are more fully discussed in "Measuring Starlight: Magnitudes, Film and Filters" in the September 2021 SkyWAAtch, page 8.

Distance

The distance to a star is most accurately measured using parallax, the observation at opposite sides of the Earth's orbit of a star's position against the background of far more distant stars in the Milky Way. Although attempts were made to find stellar parallax in the 18th century, equipment simply wasn't good enough. By the 1830s, advances in metallurgy, optics and manufacturing made telescopes and micrometer eyepieces much more precise instruments. The first accurate stellar distance was found by Thomas Henderson, who measured the parallax of Alpha Centauri from South Africa in 1832. It was known that Alpha Centauri had a large proper motion, so it was assumed it was also close to the Sun. Henderson's distance result was about 25% too small, but not bad for a first attempt based on a parallax angle of just three-quarters of an arcsecond.[1] Henderson didn't publish his results right away. Friedrich Georg Wilhelm von Struve published the distance to Vega in 1837 and Friedrich Bessel measured the parallax of 61 Cygni a year later. (Bessel is frequently cited as the first person to measure parallax, but this isn't correct.)[2] By the end of the 19th century, distances of about 60 stars were known. This changed dramatically with observations by larger 20th century telescopes and then by space telescopes. We now have accurate parallaxes from Gaia for about 1.3 billion stars.

Luminosity

Luminosity is the total electromagnetic energy output of a star at all wavelengths. It does not include the energy of stellar neutrinos that are generated during fusion. Neutrinos carry only about 2% of stellar energy output unless the star goes supernova, in which case they dominate the energy flux. Luminosity and absolute magnitude are fairly closely correlated, and H-R diagrams can be found with either one on the ordinate, and often both, as seen on page 11.

When a star is formed, no matter its mass, nuclear fusion begins and it enters the "main sequence" on the H-R diagram. The main sequence is a narrow band. Stars are relatively simple. They get all their energy at the beginning of their lives from the proton-proton chain reaction (see "How Stars Produce Energy" in the June 2021 SkyWAAtch, p. 10 for details). The initial position on the HR diagram is dependent on the star's mass, as reflected by its temperature and luminosity. As the star consumes hydrogen, it gets slightly hotter and more luminous, moving slightly to the left and up on the main sequence. Eventually the star stops fusing hydrogen and burns helium in its core. It has swelled and ejected some of its mass, becoming a red giant or even a supergiant. It leaves the main sequence along the horizontal or "red giant" branch. Ultimately, a star less than 8 $M_\odot$ will shed most of its mass and become a white dwarf. It's initially very hot but has much lower luminosity because it no longer makes photons as a product of nuclear fusion. It sits in the lower left corner of the H-R diagram, emitting thermal photons over time spans of trillions of years, slowly cooling towards the CMB temperature (which itself will decrease over cosmic time).

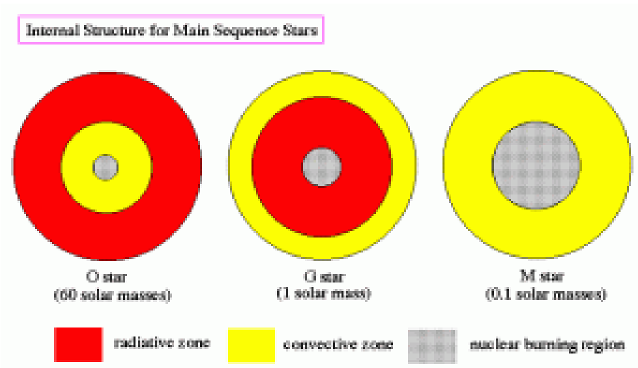
Why do small stars live longer?

As illustrated in the chart on page 11, more than three quarters of stars in the galaxy are class M, almost all of them small stars with feeble energy output but long lifetimes. In spite of their small size, their

[1] Think about the last time you saw Neptune in a telescope at high power. The planet was probably 2.5 arcseconds across. A tiny dot in a telescope at 300X. Now imagine effectively determining a relative displacement of less than a third of the planet's diameter. Using your eyes!

[2] Von Struve's paper is at https://articles.adsabs.harvard.edu/pdf/1837AN.....14..249S, but it will only make sense if you read Latin.

leisurely consumption of hydrogen fuel means their tanks won't be empty for trillions of years. At this time there are no stars in the universe below 0.8 solar masses that have evolved to become white dwarfs.



University of Oregon

You might think it peculiar that the smaller stars have longer lifetimes. You would think their fuel supply would be used up in a cosmic instant compared to enormously larger stars, but the opposite is the case.

A class G star like the Sun has a small, dense, hot core in which all the nuclear reactions take place, surrounded by a substantial radiative zone where the photons bounce around heating the proton-electron plasma. This in turn is surrounded by a convective zone in which heat is transferred to the surface by gross movement of the ionized gas. After about 12% of the star's hydrogen is consumed, helium burning takes over, the star moves on to the horizontal branch and eventually the star becomes unstable. The larger the star, the faster the transitions.

Small class K or M stars have a different internal structure that favors the near-complete consumption of hydrogen. The zone of hydrogen fusion is large, with constant circulation of the convective zone providing more fuel to sustain the nuclear reactions. Small stars may never get hot enough to fuse helium, like stars of class G or larger. In a sense they leave much less hydrogen on the table at the end of their lives. In trillions of years, when red dwarfs finally use up their fuel, the larger ones (>0.25 $M_{\odot}$) will become "small giants" in a sense, occupying a zone of the H-R diagram that currently has nothing in it, off the right edge of the current diagram. Very small class M stars may directly evolve to an equivalent of the white dwarf stage.

Very large, hot stars have their convective zone interior to the radiative zone. They use up their fuel quickly because their hotter core temperatures permit the much more efficient triple-alpha process to dominate the thermonuclear chemistry. If large enough, they will collapse in a supernova explosion to become a neutron star or black hole.

There are 317 luminous stars of class M or more massive. 85 brown dwarfs and 20 white dwarfs within 10 parsecs (32 light years) of the Sun, as well as 77 exoplanets (as of 2021).[3] The smallest mass of a star powered by hydrogen fusion is estimated to be about 0.075 $M_{\odot}$. These stars will have an absolute magnitude of less than +14. Faint, small, cool, but there are a lot of them: 78% of the luminous stars in the 10 pc sample are class M.

Star Formation

Stars form from the collapse of masses of gas and dust. Can we know anything about the formation process by looking at stars today? A survey of a group of stars in a defined volume of space, whether around the Sun, in an open cluster like the Pleiades, in globular clusters, or even in distant galaxies[4] can give the distribution, at the present time,[5] of star masses and luminosities across the potential mass range (0.075 to about 100-150 $M_{\odot}$.) The time stars of a given mass spend on the main sequence is a fairly well-established estimate. It can be used to derive the mass distribution of stars during a given star formation event by extrapolation backwards in time. The result is the Initial Mass Function (IMF).

The IMF takes the form of a simple differential equation with a negative exponent. It is a hyperbolic curve, as shown in the plot on page 15. Don't be fooled by the straight line: the axes are logarithmic, and a hyperbolic curve looks like a straight line in that projection. Australian astronomer Edwin Salpeter first proposed an equation for the IMF in 1955, based on a survey of stars in the solar neighborhood with

[3] Reylé, C, et. al., The 10 parsec sample in the Gaia era, *Astronomy & Astrophysics*, 2021, 650: A201

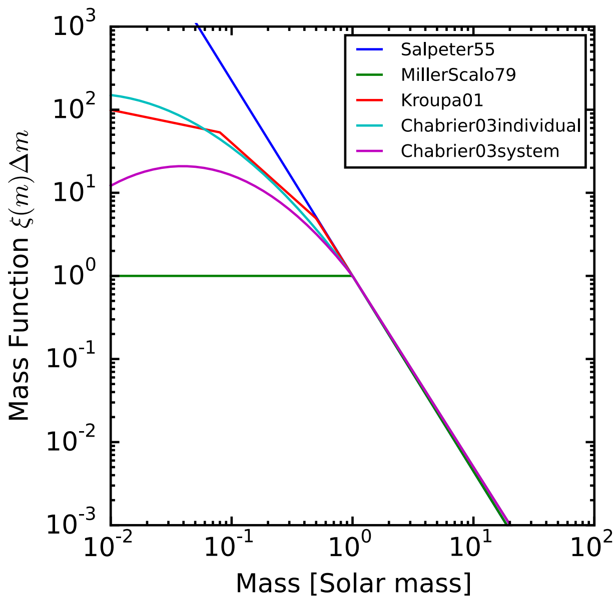
[4] By examining globular clusters around nearer galaxies like M31 or by extrapolating from integrated values of brightness, color and perhaps mass of an entire distant galaxy.

[5] For galaxies, at the lookback time based on the red shift.

absolute magnitudes of -4.5 to +13.5. The IMF equation takes the basic form

$$\mathcal{E}(m)\Delta m \propto m^{-\alpha}$$

where $\varepsilon(m)\Delta m$ is the number of stars in the mass range m to $m+dm$ (that is, an infinitesimal increment, as differential equations require). It gives us a star count by mass. Salpeter found the exponent to be -2.35. Many other astronomers have looked at stellar populations in open and globular clusters and have derived equations with slightly different exponents as well as variations of the linearity of the mass curve. For stars as large or larger than the Sun, -2.35 seems to be correct. The bigger the star, the fewer of them form in an episode of star formation.



Initial mass function plots (graph by Johannes Buchner)

The abstract of Salpeter's paper reads,

> The hypothesis is made that stars move off the main sequence after burning about 10 *(sic)* per cent of their hydrogen mass and that stars have been created at a uniform rate in the solar neighborhood for the last five billion years. Using this hypothesis and the observed luminosity function, the rate of star creation as a function of stellar mass is calculated. The total number and mass of stars which have moved off the main sequence is found to be comparable with the total number of white dwarfs and with the total mass of all fainter main-sequence stars, respectively.[6]

Smaller stars prevail during star formation. As the cluster in which they form ages, these stars persist while larger, shorter-lived stars evolve and eventually become either white dwarfs (>90%), neutron stars or black holes. Chemical elements made by nucleosynthesis are recirculated into the interstellar medium when a star nears the end of its life (as planetary nebula mass ejections or via intense stellar winds). Heavier compounds and other isotopes are injected into the ISM by supernova explosions, or as we've learned recently, via binary neutron star mergers. They are mixed into new clouds of gas and dust to be part of the next cluster of new stars. But long-lived red and brown dwarfs effectively lock up the gas from which they are formed. It will be trillions of years before they reach an unstable state.

All stars form from cool molecular gas. The gas needs to be at a temperature low enough for gravitational forces to become stronger than the kinetic energy of the gas (which provides thermal pressure). The conditions for this to occur were worked out by the British physicist James Jeans and is called the Jeans Instability. The process is dependent on the density and pressure of the gas, which are related to the temperature by the ideal gas law (also known as the equation of state) $pV=nRT$, where p density, V the volume, n is amount of the substance in moles[7], R is the gas constant, (8.31446261815324 $\mathrm{J{\cdot}K^{-1}{\cdot}mol^{-1}}$), and T is the temperature in Kelvin.

Composition of gas in the protostellar nebula also affects the rate of collapse. The cooling effect of carbon monoxide (CO) and ionized carbon (C+), which are present in many molecular clouds, is stronger than that of molecular hydrogen (H_2), so clouds enriched in CO and C+ will condense faster.

Astronomers wonder whether there is a universal equation for the initial mass function, applicable to all local conditions, metallicity and other factors. This would be similar in form to Salpeter's equation, an

[6] Salpeter, EE, The Luminosity Function and Stellar Evolution, *Astrophysical Journal*, 1955; 121:161-167

[7] Recall that one mole of an element or compound is the mass of Avogadro's number of particles (6.02214076×10^{23}) or, easier to understand, its atomic or molecular weight in grams.

empirical formula derived from observations and applicable to any star-forming event.

However, it is thought that in the earliest round of star formation after the "dark era" of cosmic history (after the cosmic microwave background was emitted), many, if not most, newborn stars were quite large, perhaps 100 $M_\odot$. Once this first generation, called Population III, lived their short lives, they went supernova and created shock waves that compressed and heated gas and dust, spewing metals (anything heavier than H and He) into the interstellar medium for the next round of stellar synthesis. It is more than possible that the exponent α in the IMF equation in the Population III era was different than it was in more recent cosmic eras. That is, while there is always an IMF of some sort, it is not necessarily "universal." A recent paper in *Nature* looked at the spectra of 93,000 M-class stars within 300 parsecs of the solar system and found "unambiguous evidence of a variable IMF that depends on both metallicity and stellar age."[8] Additional terms would have to be added to an IMF equation in that case.

The galaxy itself has a metallicity gradient: stars more distant from the galactic center have, in general, lower metallicity, and tend to be hotter than equivalent mass stars with higher metallicity. In any formulation of an IMF from observations, extinction from interstellar gas and dust has to be taken into account. For open clusters, some members may have been flung out by gravitational effects or supernova explosions, moving away as fast a 50 km/second, and so they may not be recognized as members of the cluster, the data sample thus being incomplete.

Some astronomers working on star formation propose that the curve for distribution of masses is not a smooth function (examine the Kroup01 curve in the IMF plot on page 15). The number of very low mass stars certainly drops off below 0.1 $M_\odot$ and the curve may not be smooth between 0.1 and 1.0 $M_\odot$. It is not clear yet if this is a sampling problem or if distinct physical processes come into play at specific mass ranges.

Star formation is also modulated by specific collapse mechanisms, which may operate under distinct circumstances and environments. *Competitive accretion* is a process where seed stars accrete mass, competing for available cool gas, but at some point stop gaining mass, a transition likely related to temperature and pressure even before fusion starts. This scenario is more likely in the absence of turbulence in the cloud. In *turbulent fragmentation*, shock waves stir the gas, creating a broad range of local density distributions from which stars can form. This does not explain the variance in IMF slopes on the low end of the mass range, as shown in the figure on page 15. A *bottom-up* scenario has individual clouds within the larger mass of gas, each with its own local star formation rate, dependent on local concentrations of H_2, CO and C+ as the primary drivers of cooling.

An interesting application of the IMF calculation was given in a recent paper on evidence for a supernova in the Sun's neighborhood at the time the solar system formed. This paper is summarized in the Research Finding of the Month in this issue (page 28).

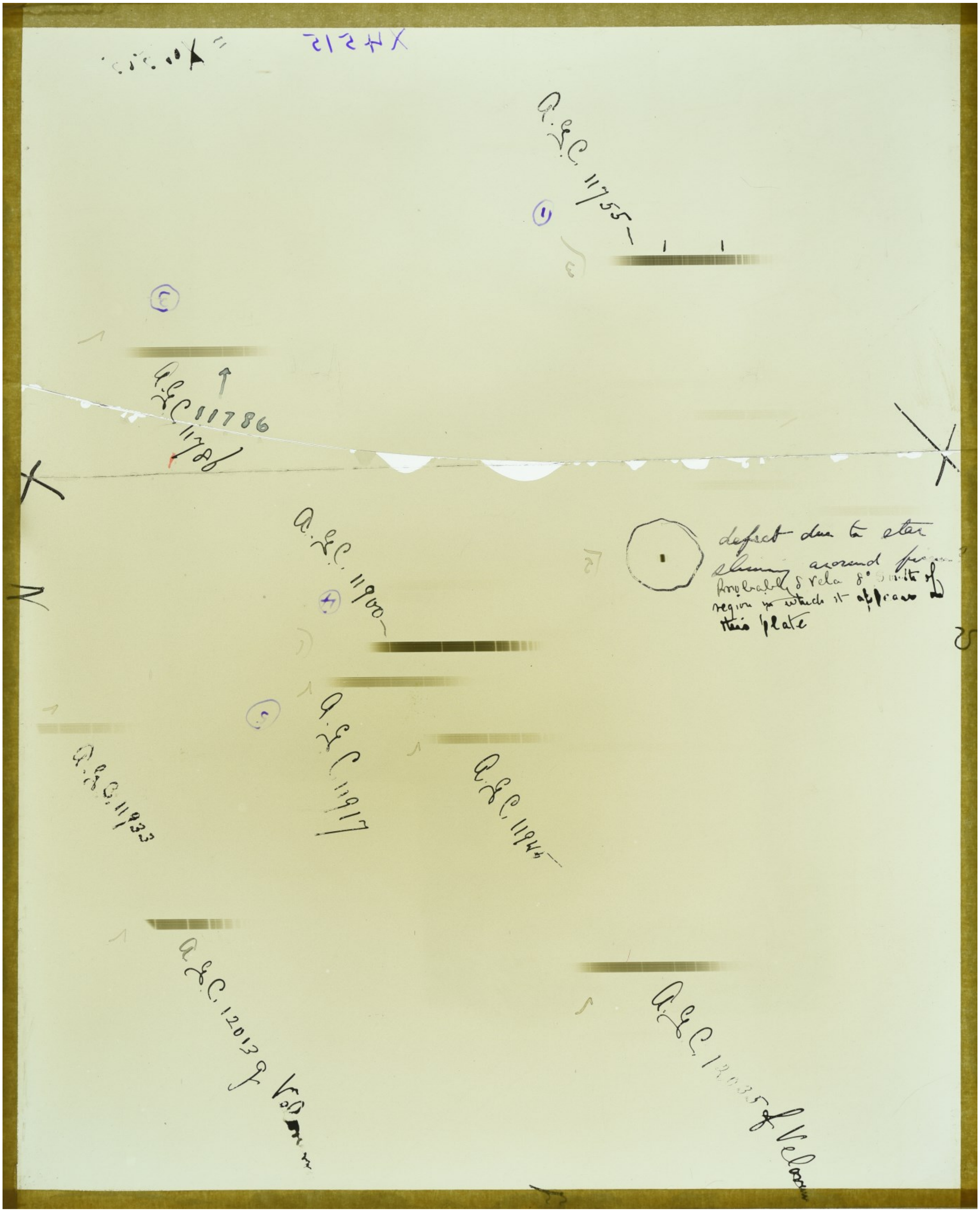
In a recent review,[9] Australian astronomer Andrew Hopkins notes

> There are few areas of astrophysics as emotionally charged as the argument over whether the IMF is 'universal,' that is, the same unchanging distribution regardless of environment and over the entirety of cosmic history. With conflicting lines of evidence and apparently inconsistent conclusions, emotional attachments to a particular viewpoint, as opposed to evidence-based conclusions, easily develop and can strongly influence discussion in person and also in published work. Such an environment by itself makes work in this area challenging and can limit the depth or scope of investigations and interpretation, independent of any actual observational limitations.

The IMF will continue to be a rich source of controversy, with more data undoubtedly spawning even more (hopefully friendly) conflict, although it sounds like at some meeting or other, astronomers might even have gotten a little nasty about it! ■

[8] Li, JL., et. al., Stellar initial mass function varies with metallicity and time, *Nature* 2023; 623: 460-462.

[9] Hopkins, AH, The Dawes Review 8: Measuring the Stellar Initial Mass Function, *Publications of the Astronomical Society of Australia*, 2018, 35, e039, 39 pages.



Spectrographic plate X04515 (Wolbach Collection, Harvard University)

Images by Members

Here are some recent images by the prolific **Steve Bellavia** that we didn't have room to publish over the past few months.

Steve posts most of his images on astrobin.com, providing detailed technical information with each high-resolution image. The links are provided in the captions. His image of M97 and M108 is on this month's cover, the rarely seen Dolphin Head Nebula is on page 10, and his image of the recent M101 supernova is on page 27.

Messier 100, galaxy in Coma Berenices. It's a magnitude 9.3 spiral some 55 million light years from us.

https://www.astrobin.com/n8chmv/

Strottner-Dreschler 1 (PN-G 185.1-00.9), is a newly discovered planetary nebula in Taurus. In 2020, Steve was the second person to image this small, faint object, just months after it was discovered. This is a January 2023 image.

https://www.astrobin.com/g7vb8c/

The **Rosette Nebula** in Monoceros

Caldwell 49, SH 2-275, and several NGC numbers

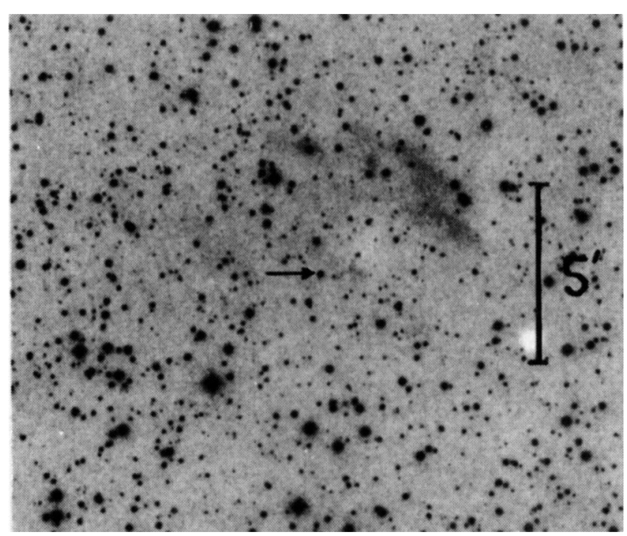
https://www.astro-bin.com/bracsa/

IC1283/1284, NGC 6589/6590, SH2-237, Ced 157d in Sagittarius

https://www.astro-bin.com/sagfkz/

Dengel-Hartl 5 in Cepheus by Gary Miller

Also catalogued as PK 111+11.1, Dengel-Hartl 5 (DeHt5) is an ancient planetary nebula. It was discovered to be a planetary in 1979 on a survey of the Palomar Sky Survey plates (Dengel, J, Hartl, H, Weinberger, R, A search for planetary nebulae on the "POSS", *Astronomy and Astrophysics*, 1980; 85: 356-358). The discovery image, below, shows the central star (arrowed). This object had first been noticed in 1965 by Lynd. It was characterized as a reflection nebula, LBN 538. The central star is a white dwarf, WD 2218+706, V-band magnitude 15.495. This object appears to be one of the nearest planetary nebulas, estimated to be 400-500 parsecs distant. It has a radius of about 0.5 parsecs.



The expansion velocity of DeHt5 was reported by Weinberger (*Astronomy and Astrophysics*, 1989, S78: 301-324). The OIII and NII spectra show a rate of 10 km/sec while the HI (neutral hydrogen) is expanding at 2 km/sec, although this value is considered less reliable. With an estimated age of 70,000 years, the nebula might be described as "senescent." It is losing structure and its gases are dispersing into the interstellar medium.

The field in Gary's image is 47.9 x 35.9 arcminutes.

Messier 17 by Rick Bria

The nebula was discovered in 1746 by the Swiss astronomer Philippe Loys de Chéseaux. Known by a variety of names, Messier 17 is an easy and familiar object in club telescopes during summer observing nights. It's been called the Swan, the Omega, the Checkmark, the Lobster and even the Horseshoe Nebula, an appellation created by the British astronomer Admiral William Henry Smyth in his influential two-volume, 1,000-page *A Cycle of Celestial Objects for the use of Naval, Military, and Private Astronomers* (1844), a digitized copy of which is online (https://is.gd/smyth1844). On page 416 of volume 2, Smyth describes and draws the nebula (shown below).

> In my telescope [a 5.9-inch refractor, f/17.2] charged with a moderate eye-piece, this curious nebula is well seen, though not to the extent of convolution figured by Sir John Herschel. A magnificent, arched, and irresolvable luminosity occupies more than one third of the area, in a splendid group of stars…. They are principally from the 9th to the 12th magnitudes, reaching more or less all over the field….

In a very dark sky M17 might be visible to the naked eye since its magnitude is given as 6.0. Rick made this image at the June Hill Observatory several years ago using a Televue NP-101 telescope and a Canon 60D DSLR camera. The exposure was 12 minutes. This field is 80.8 x 53.9 arcminutes; south is up.

Progress in astrophotography is illustrated by Rick's more recent image of M17 on the next page.

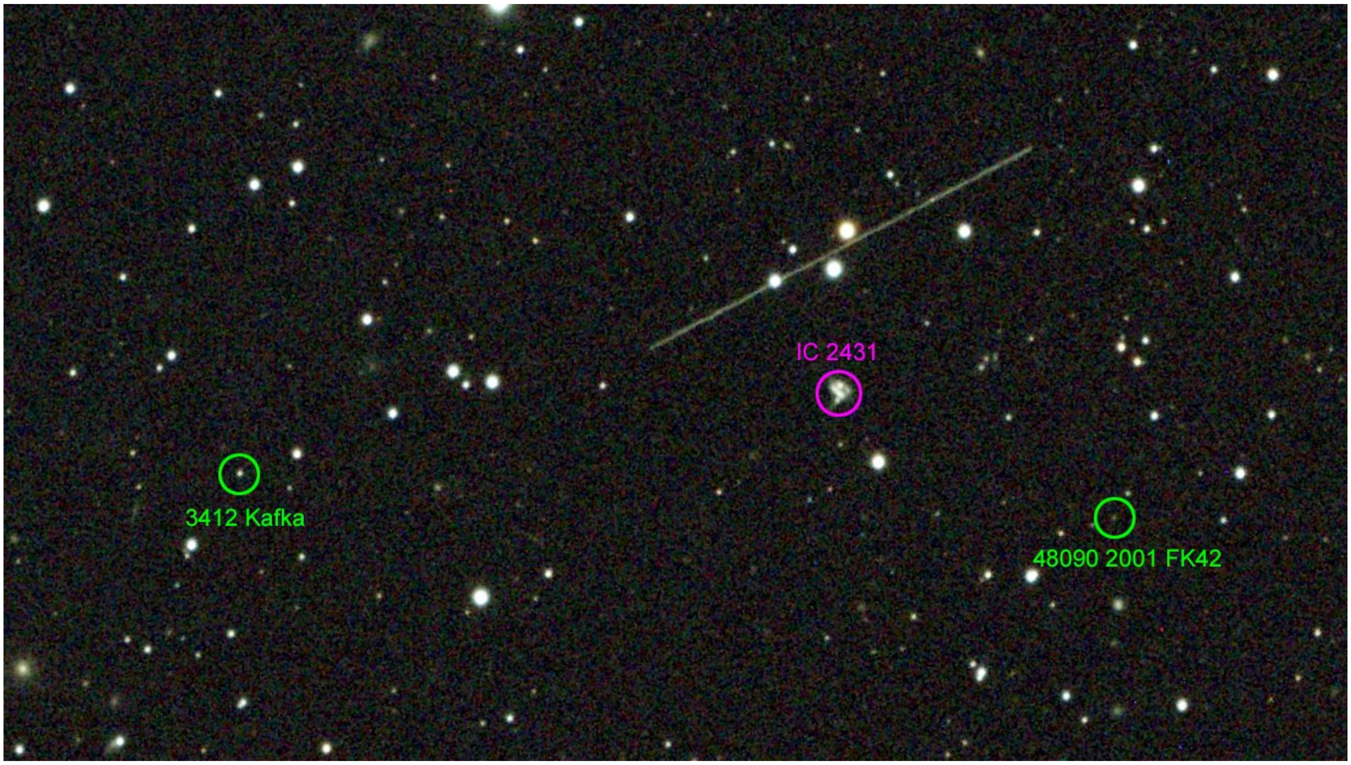
Messier 17, Again, by Rick Bria

Using the CDK-14 astrograph, the main telescope at the Mary Aloysia Hardey Observatory at the Sacred Heart School in Greenwich, and imaging through filters with a monochrome STX16803 camera, Rick made this deep image of the nebula in the summer of 2022. The Swan is swamped by nebulosity recorded during 132 minutes of exposure with 12 times the aperture and a more sensitive camera than in the image on page 21, where only a hint of the surround gas is seen. Such is progress in astrophotography in just a short time.

The field is 48.1 x 46.4 arcminutes; south is up.

In his book *The Messier Objects*, Stephen James O'Meara suggests that the gap between the two areas of nebulosity is due to a foreground dust cloud, with the stars seen in it closer to us than the nebula.

The Crowded Skies: Asteroid 2023 DZ by Robin Stuart



Asteroid 2023 DZ_2 was discovered on 27 February 2023 while inbound to its closest approach to Earth of 175,000 km on 25 March 2023 at 19:52 UTC, when it would be within half the average distance between the Earth and the Moon. The asteroid's size was estimated to be 40–90 meters across. This is somewhat larger than the object that produced the 1908 *Tunguska Event* (50–60 meters). Had it been on a collision course, 2023 DZ_2 would have struck the Earth at around 13.4 km/s compared Tunguska's 27 km/s. JPL's Center for Near Earth Object Studies (https://archive.ph/A0Fdz) estimated that it was packing a little over ⅓ the punch of Tunguska.

On the evening of 24 March at 20:48 EDT from Eustis, Maine, I captured 2023 DZ_2 as an 8.49 arcminute streak in the constellation of Cancer. It was 19.4 hours before its closest approach. At the time, it was magnitude 14, streaking across the sky at 46′ 37″ per hour. It was 550,000 km distant, just less than 1½ times the average distance to the Moon.

The image is a single 10 minute exposure with a ZWO ASI2600MC camera through a TeleVue NP127. The field is 26.7′×15.0′ cropped from the full frame of image of 2.04°×1.36°.

Intrigued by the strange, coiled object below the asteroid's trail, I applied PixInsight's *Script > Render > AnnotateImage* function, which labelled it as IC 2431. The object can be seen more clearly in the IR/visible/UV composite view (below) released by the Hubble Space Telescope in February 2022. Although partially obscured by a dense dust cloud at the center, it shows the roiling merger of a triplet of galaxies experiencing strong tidal distortions and enhanced star formation.

Along with IC 2431, the PixInsight script flagged an additional 8 asteroids with magnitudes ranging from 16.97 to 18.96 in the full frame. Two of them, 3412 Kafka at magnitude 16.97 and 48090 2001 FK42 at magnitude 18.92, can be seen in the cropped image.

RS

NGC 2903 in Leo by Olivier Prache

The beautiful barred spiral galaxy NGC 2903 is a 9.0-magnitude member of the Virgo supercluster. The northern spiral arm has a brighter luminous area that J.E.L. Dreyer awarded a separate identifying number (2905) in his *New General Catalog*. The galaxy is about 12x5 arcminutes in extent. Olivier made this image with his 8-inch Celestron RASA f/2 astrograph. The field is 47.5 x 48.7 arcminutes; north is up.

There are three faint galaxies in the image. Triangulate the colored markers to find them. Green is UGC 5086 (*z*=0.001721), blue is LEDA 1648681 (*z*=0.034219), and red is LEDA 1647510 (*z*=0.05135). UGC 5086 is a dwarf companion to NGC 2903 (*z*= 0.0018596); the other two are far more distant.

Shadow Transit of Jupiter, January 2, 2023 by John Paladini

Among his many telescopes, John owns a 7-inch f/15 Maksutov. The central obstruction is only 28%, compared with 34% in a Schmidt-Cassegrain. Maks are considered superior planetary telescopes compared to equivalent-sized or even slightly larger SCTs, rivalling apochromatic telescopes. The Mak design employs spherical surfaces that are easier to make than parabolas or hyperbolas. It is very well-corrected and free of coma. However, the thick corrector plate means that the scope takes a long time to reach ambient temperature to eliminate thermals in the closed tube. That's one of the reasons there are few large Maks. The 22" Mak at the old Stamford Observatory (now relocated to New Mexico), which may have been the second largest in the world, was often criticized for being unable to reach ambient temperature during an observing session.

Meade used to make a fork-mounted 7" Mak. The optical tube was longer than the fork arms, so it couldn't be folded all the way down, making it clumsy to store or carry. It was also heavy because it had a 15-lb ring-shaped weight in the rear mirror cell to balance the tube on the fork. Celestron makes a 7" f/15 Mak optical tube. It doesn't need the rear cell weight since it can be balanced by sliding along the mounting dovetail on a GEM or alt-az mount. John's scope, branded by Orion, is similar, if not identical, to the current Celestron product, both probably coming from the same Chinese factory.

John's image shows the sharp shadow of Io; the satellite itself is the white round patch just inside the left limb overlying the South Equatorial Belt. Like we said, Maks are good planetary telescopes!

The Moon and Venus on April 23 by Larry Faltz

Venus and the Moon were 5° 12’ apart at 8:40 p.m. on Sunday, April 22. A band of heavy rain had passed through Westchester just half an hour earlier. The sky cleared, with wonderful transparency. I made this shot from my street in Larchmont, using a tripod-mounted Canon T3i with a Canon EF 75-300 zoom at its lowest setting. The multiplication factor of 1.6 (because the T3i has an APC-sized sensor but the EF lens is made for a full-frame sensor) gave an effective focal length of 120 mm. Exposed at ISO 1600, 1/30 sec, f/4.

The Moon was 16% illuminated, shining at magnitude -8.02. Venus was in a gibbous phase, 69.3% illuminated, shining at magnitude -4.1. The two orbs had been just 28 arcminutes apart at 7:40 a.m. on the morning of the 22nd, but they were below the horizon (and in daytime), and so impossible to observe even if weather had permitted.

My 5” Mak, also taken out for the evening, showed wonderful detail on the lunar crescent. Detail on the earthshine-illuminated lunar disc was quite evident.

Typically, after a rapidly moving rainstorm there is excellent transparency, but at the expense of suboptimal seeing, with the atmosphere still turbulent behind the passing front. Venus bounced around a lot in the scope.

LF

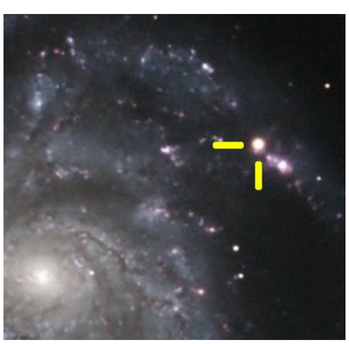
Supernova SN 2023ixf in M101 by Steve Bellavia

A type II (core collapse) supernova was spotted on May 19th by veteran Japanese supernova hunter Koichi Itagaki, who has discovered nearly 100 supernovas. It was initially magnitude 14.9 but brightened to 11.1 by May 21st.

Steve Bellavia had imaged M101 on April 19th and we were going to show that on page 18 with some of his other images, but on May 22nd he sent a new image showing the supernova, so we thought to show them together.

Within hours, many amateurs had posted images on CloudyNights and other sites, and uploaded magnitude estimations to the AAVSO site. A spectrum can be found at https://www.wis-tns.org/object/2023ixf.

Type II supernovas fade at a slow rate, just 0.008 magnitudes per day, so this supernova should be visible throughout June, perhaps longer.



We don't like to deface the original images with tick marks (sometimes we put markers outside the image for triangulation, as on page 24), so we magnified a portion of Steve's image and marked SN 2023ixf on that in case you are having trouble finding it on the full image. South is up in these images. See Steve's animated gif comparison at https://www.astrobin.com/mbulfj/.

More Supernova Images and Imagers

Rick Bria's labeled image, 14-inch CDK

Gary Miller

Jordan Webber

Larry Faltz's scope

David Parmet

Larry's image with 105-mm triplet refractor

Four of us were at Ward Pound Ridge on May 25th to shoot the supernova. Smoke from Canadian wildfires had been thick overhead in Westchester earlier in the week, impacting Rick Bria's 5/23 image. Rain during the day on 5/24 cleared out much of the smoke, and we had far better transparency on the 25th. My image was a stack of just eight 120-second subs, no darks or flats. I did it to prove to myself that I could capture the SN with my new EAA setup. LF

Here are two more images from our pop-up star party on the evening of May 25th.The images are rotated and cropped a little from the originally submitted files so that the supernova is relatively in the same position as the two images on the previous page.

North is approximately up in these images. The scales are slightly different. Refer to Rick Bria's similarly oriented image on page 28 if you need to identify the supernova.

Jordan Webber

Gary Miller

Gary added some data from the night of May 26th, putting an Optolong L-eNhance filter in the light path to bring out the HII regions.

Research Highlight of the Month

Arakawa, S, Kokubo, E, Number of stars in the Sun's birth cluster revisited, *Astronomy & Astrophysics* 2023; 670: A105. https://www.aanda.org/articles/aa/pdf/2023/02/aa44743-22.pdf

Abstract

The Sun is thought to have been formed within a star cluster. The coexistence of ^{26}Al-rich and ^{26}Al-poor calcium–aluminum-rich inclusions indicates that a direct injection of ^{26}Al-rich materials from a nearby core-collapse supernova would be expected to occur in the first 10^5 years of the existence of the Solar System. Therefore, at least one core-collapse supernova ought to occur within the duration of star formation in the Sun's birth cluster. Here, we revisit the number of stars in the Sun's birth cluster from the point of view of the probability of experiencing at least one core-collapse supernova within the finite duration of star formation within the birth cluster. We find that the number of stars in the birth cluster may be significantly greater than that previously considered, depending on the duration of star formation.

It should be obvious that supernovas contributed their products to local star formation: how else can we account for all the elements that are found on Earth? The Milky Way was already six billion years old when the Sun formed, and the local environment was swirling with gas and dust, buffeted by supernova shock waves and stellar winds from Wolf-Rayet stars. Gould's Belt, if it is an actual structure in the local Milky Way (see "Unbuckling Gould's Belt" in the June 2020 SkyWAAtch) provides a scenario of this process, although its stars are much younger than the Sun. Evidence for supernova explosions can come from the isotopic composition of primitive solar system bodies (primarily asteroids and meteorites). Short-lived radionuclides, copiously formed in supernovas, would decay and their presence and concentration can be reconstructed from excess amounts of daughter isotopes. In particular, the chemistry of core-collapse supernovas (CCSN) in the 20-60 Mʘ range correlates with the content of ^{26}Al and ^{60}Fe.

The coexistence of ^{26}Al-rich and ^{26}Al-poor calcium-and-aluminum-rich inclusions (CAIs, the oldest solid particles in the Solar system) would serve as evidence of the direct injection of ^{26}Al-enriched dust grains by a CCSN into the solar nebula during the relatively brief epoch of CAI formation, 4.567 billion years ago. It is known that the duration of CAI formation is $\leq 10^5$ years. This is a tenth of the duration of star formation in a cluster, and previous work has shown that at least one CCSN should occur during that time.

From the statistics of cluster formation and the accepted duration of star-formation events, utilizing the initial mass function (see page 14) to estimate the masses of stars forming in a cluster the authors propose that a plausible number of stars in the Sun's birth cluster would be around 2,000. If the duration of star formation is shorter, the number of the Sun's siblings could be as high as 20,000. In any case these numbers are larger than previous estimates, which suggested a birth cluster of about 500 stars.

The authors also note that previous studies have suggested that the misalignment between the Sun's equator and the ecliptic plane (7.25 degrees) and the sharp truncation of the Kuiper Belt could be explained by a nearby CCSN event.

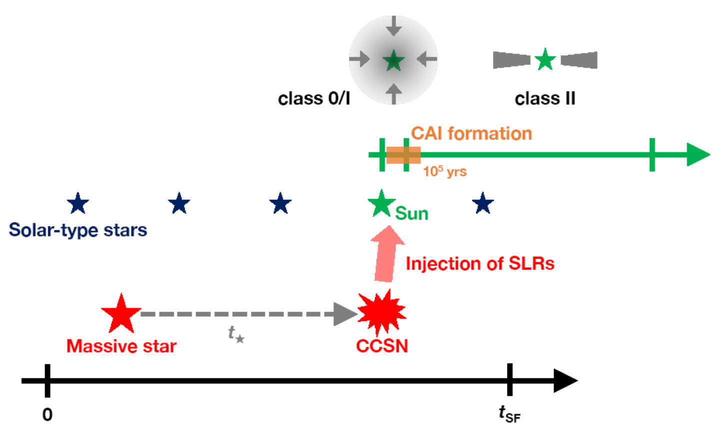


Fig. 1. Schematic of the direct injection of short-lived radioisotopes (SLRs) into the early Solar System within the birth cluster. Massive stars born in the cluster would trigger CCSN explosions when they finished their lifetime, $t_\star$. To explain the coexistence of ^{26}Al-rich and ^{26}Al-poor CAIs in the early Solar System, a direct injection of SLR-rich dust grains from a CCSN should occur during CAI formation in the Solar System. A necessary condition for Solar System formation is that at least one CCSN occurs in the birth cluster within the duration of star formation, tSF.

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NEW LISTING Nagler Type 1 9mm Eyepiece	82 degree apparent field of view. 12.4-mm eye relief. The original Nagler design. Fits both 1¼-inch and 2-inch focusers. 7 lens elements. A fabled eyepiece. Like new condition, in the original box. A current Type 6 Nagler, essentially the same optics, costs $335. Image here. Donated to WAA.	$200	WAA ads@westchesterastronomers.org
Orion Starblast 6-inch reflector	Orion's famous 6-inch f/5 table-top Dobsonian. reflector. 1¼" focuser. All original with red-dot finder, 25-mm and 10-mm Orion Plössl eyepieces, hex wrenches, tube rings, mount, bolts, manual. Optics are pristine; tube has a couple of very minor blemishes. Orion's image is here. A new one is $449.	$325	Larry Faltz lfaltzmd@gmail.com
NEW LISTING Orion Glass Solar Filter for 6" telescope	A glass (not mylar) solar filter with maximum inside diameter 193 mm. Perfect for 6" f/5 or f/8 reflector. New condition with original documentation. New mylar filters of this size list for $150.	$100	Larry Faltz lfaltzmd@gmail.com
Eyepiece holder for Dobsonian	Anodized aluminum. Bolts onto side of rocker box. Very solid. Holds three 2" and two 1½" eyepieces. Made by Astrozap. Similar ones are sold by ScopeStuff for $32. See picture here.	$15	Larry Faltz lfaltzmd@gmail.com
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 $89.	$50	Larry Faltz lfaltzmd@gmail.com
NEW LISTING Tiltall photo/spotting scope tripod	TE Original Series solid aluminum tripod with 3-way head, center stalk. Very solid. 3-section legs. Height range 28.5"-74". Can carry up to 44 lbs. Folded length 29.6". Weighs 6 lbs. Carry bag. Image here. List $199.50. Donated to WAA.	$100	WAA ads@westchesterastronomers.org
RUBYLITH Screens	I have two 1/8" thick rubylith screens for placing over a laptop or tablet screen. Sizes are 14½x9" (for 17" diagonal 16:9 laptop) and 10½ x 7" for a large tablet. Includes strong rubber retainers. I don't need them anymore. First come, first served.	Free	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 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.			
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Look Up in the Sky - It's a Bird

Theresa Summer

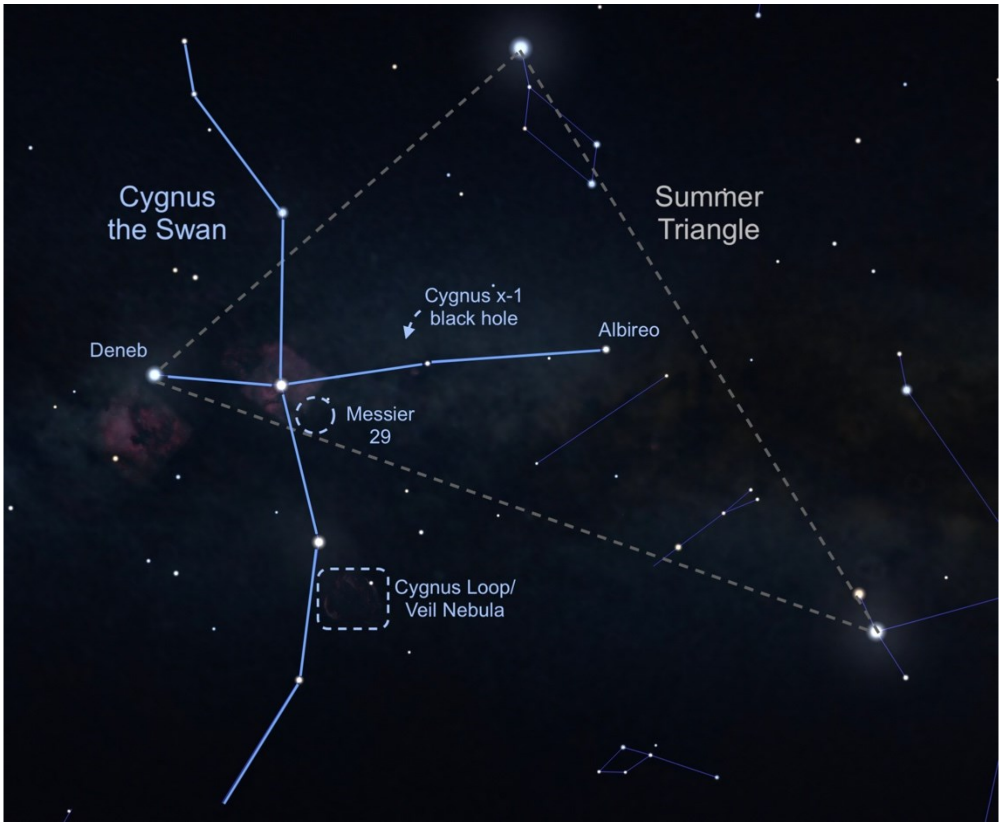
Bird constellations abound in the night sky, including **Cygnus**, the majestic swan. Easy to find with its dazzling stars, it is one of the few constellations that look like its namesake and it is full of treasures. Visible in the Northern Hemisphere all summer long, there's so much to see and even some things that can't be seen. To locate Cygnus, start with the brightest star, **Deneb**, also the northeastern most and dimmest star of the Summer Triangle. The Summer Triangle is made up of three bright stars from three different constellations – read more about it in the September 2022 issue of Night Sky Notes. "Deneb" is an Arabic word meaning the tail. Then travel into the triangle until you see the star **Albireo**, sometimes called the "beak star" in the center of the summer triangle. Stretching out perpendicular from this line are two stars that mark the crossbar, or the wings, and there are also faint stars that extend the swan's wings.

From light-polluted skies, you may only see the brightest stars, sometimes called the Northern Cross. In a darker sky, the line of stars marking the neck of the swan travels along the band of the **Milky Way**. A pair of binoculars will resolve many stars along that path, including a sparkling open cluster of stars designated **Messier 29**, found just south of the swan's torso star. This grouping of young stars may appear to have a reddish hue due to nearby excited gas.

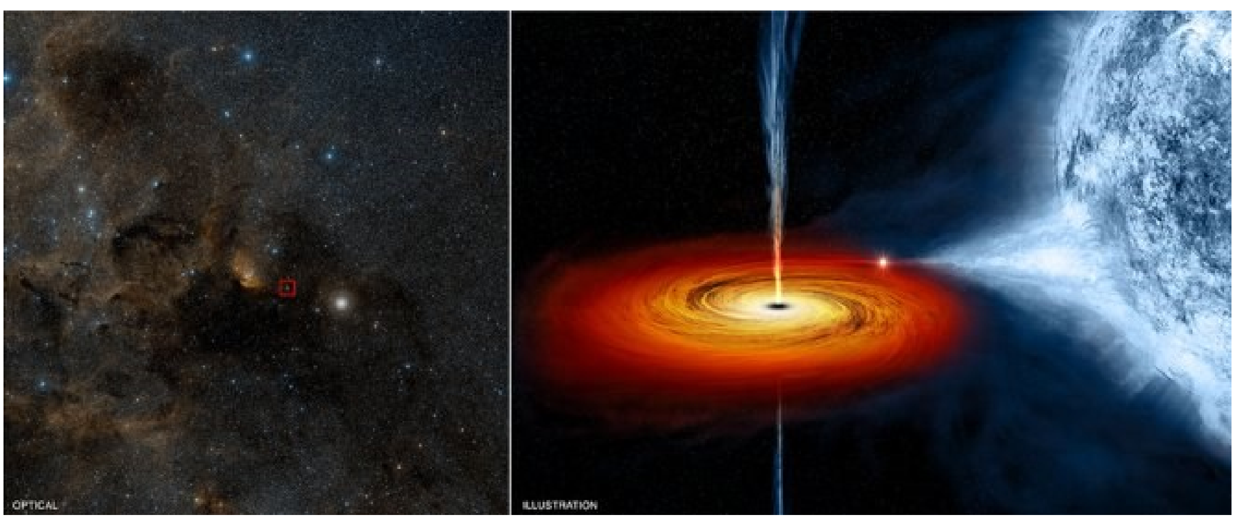
Let's go deeper. While the bright beak star Albireo is easy to pick out, a telescope will let its true beauty shine! Like a jewel box in the sky, magnification shows a beautiful visual double star, with a vivid gold star and a brilliant blue star in the same field of view. There's another marvel to be seen with a telescope or strong binoculars – the Cygnus Loop. Sometimes known as the **Veil Nebula**, you can find this supernova remnant (the gassy leftovers blown off of a large dying star) directly above the final two stars of the swan's eastern wing. It will look like a faint ring of illuminated gas about three degrees across (six times the diameter of the Moon).

Speaking of long-dead stars, astronomers have detected a high-energy X-ray source in Cygnus that we can't see with our eyes or backyard telescopes, but that is detectable by NASA's Chandra X-ray Observatory. Discovered in 1971 during a rocket flight, Cygnus X-1 is the first X-ray source to be widely accepted as a black hole. This black hole is the final stage of a giant star's life, with a mass of about 20 Suns. Cygnus X-1 is spinning at a phenomenal rate – more than 800 times a second – while devouring a nearby star. Astronomically speaking, this black hole is in our neighborhood, 6,070 light years away. But it poses no threat to us, just offers a new way to study the universe.

Check out the beautiful bird in your sky this evening, and you will be delighted to add Cygnus to your go-to summer viewing list. Find out NASA's latest methods for studying black holes at www.nasa.gov/black-holes.



Look up after sunset during summer months to find Cygnus! Along the swan's neck find the band of our Milky Way Galaxy. Use a telescope to resolve the colorful stars of Albireo or search out the open cluster of stars in Messier 29. Image created with assistance from Stellarium: stellarium.org



While the black hole Cygnus X-1 is invisible with even the most powerful Optical telescope, in X-ray, it shines brightly. On the left is the optical view of that region with the location of Cygnus X-1 shown in the red box as taken by the Digitized Sky Survey. On the right is an artist's conception of the black hole pulling material from its massive blue companion star. (Credit: NASA/CXC chandra.harvard.edu/photo/2011/cygx1/)