SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

July 2023

Messier 101, the Pinwheel Galaxy in Ursa Major by Rick Bria

14-inch CDK scope, SBIG 16803 camera, total of 9 hours 20 minutes through RGB & Hα filters. PixInsight. Rick made this image before Supernova SSN 2023ixf appeared. See the June 2023 SkyWAAtch for SN images.

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 September Meeting

Friday, September 8 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. Subjects such as new equipment, techniques, astronomical travel, astro-photography or anything else you think would be of interest to your fellow club members are welcome. If you are interested in making a presentation, please contact Pat Mahon, WAA VP for Programs, at waa-programs@westchesterastronomers.org.

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

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

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

Also In This Issue

WAA October Meeting

Friday, October 13 at 7:30 pm

Space Volcanoes

Caitlin Ahrens, PhD
NASA/Goddard Space Flight Center

There are no meetings in July and August.

The WAA picnic has been rescheduled to Sept. 17.

Starway to Heaven

Meadow Picnic Area parking lot, Ward Pound Ridge Reservation, Cross River, NY

Saturday, July 15 (Sunset 8:29 p.m.)
Rain/cloud make-up date July 22 (Sunset 8:23 p.m.)

WAA members can view at Ward Pound Ridge on any night, with advance notification to the park. Call (914) 864-7317 in advance and be sure to bring your ID card (sent as an attachment to the acknowledgement your membership or renewal).

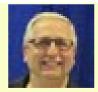
New Members

Ramon Blandino	Yorktown Heights
Kristine Cochran	Pleasantville
Peter Desimini	Tarrytown
Gavin George	Bedford
Daniel Karpel	Mt. Kisco
John Lanzetta	Tarrytown
Kelli McCourt	Stamford, CT
Alison Ng	Brewster
Peter Spenser	New Rochelle

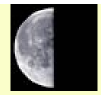
Renewing Members

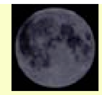
Eric & Katherine Baumgartner	Redding, CT
Brian Blaufeux	Larchmont
Andrzej Cichon	Port Chester
Marcy Cohen	Croton on Hudson
Mitchell Feller	Cortlandt Manor
Al Ferrari	Yonkers
John & Maryann Fusco	Yonkers
Daniel Intrilligator	Cortlandt Manor
Jordan Solomon	Pleasantville

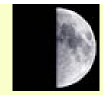
ALMANAC for July 2023
Bob Kelly, WAA VP of Field Events


Bob Kelly

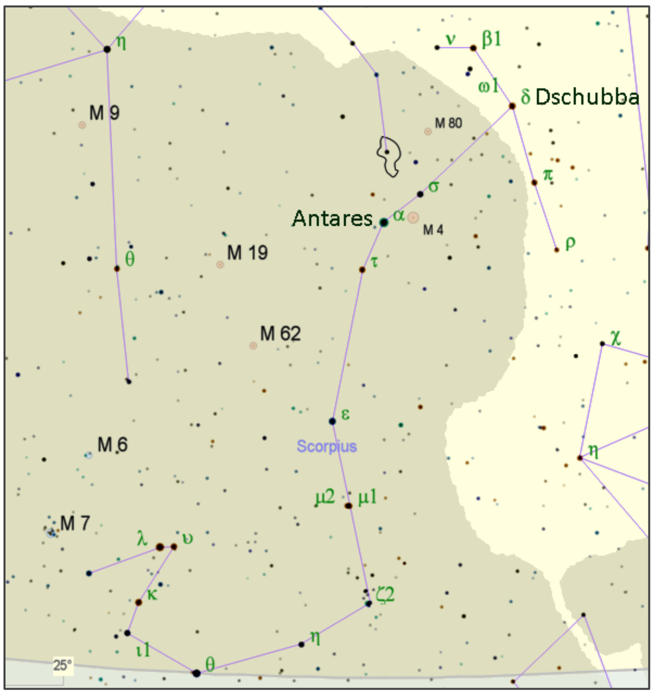

Full Jul 3


3Q Jul9


New Jul 17


1Q Jul 25

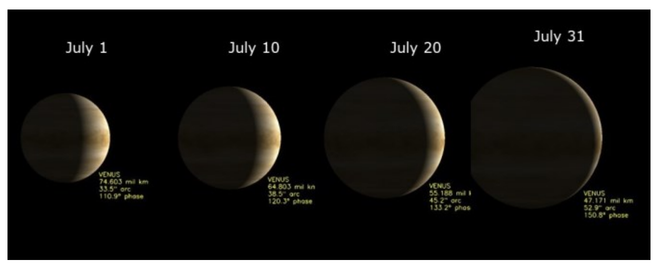
This month, **Scorpius** stands up on his stinger low in the evening's southern sky. He's known for his distinctive vertical row of three stars like buttons on a shirt, with reddish Antares as a logo on the Scorpion's right pocket (left from our point of view). Compare the middle of the three stars, **Delta Scorpii**, also known as Dschubba, with its two neighbors. A variable binary star, It doubled in brightness in 2011 and may still be a bit brighter than its friends.



Higher in the sky, **Vega**, in its constellation Lyra, precedes the Northern Cross (Cygnus) and is the apex of the Summer Triangle (**Vega**, **Deneb and Altair**). The **Milky Way** flows through it. How far south can you follow the Milky Way? If some areas look blank, like bays or lakes in the Milky Way, remind yourself you are "seeing" clouds of interstellar dust blocking the light from more distant members of our galaxy. This view is especially good from dark locations and in the first half of the month when the Moon is otherwise occupied.

Regulus (Alpha Leonis) gets friendly with inner solar system planets as **Mars**, **Venus**, and **Mercury** move into **Leo** while the Lion drops into the evening twilight. Venus starts the month falling 4 degrees short of meeting with Mars, still a beautiful sight. Mars gets the first dance with the alpha star in Leo, closest together on the 10th; good because Mars is the faintest of the evening planets. See map on page 4.

Once again, Venus doesn't quite get to the meet-up, sailing below first magnitude Regulus as the month ends. As if to show it how it's done, Mercury jumps up and gets the alpha star's attention. Regulus and Mercury are only bit more than a Moon's width apart on the 28th. You'll need binoculars to see Regulus and its passing close friends in the twilight's last gleaming, even with Venus pointing the way. Mercury's trip to the evening sky is better viewed in the Southern Hemisphere (we've heard that a lot this year). Mercury-set time is about 80 minutes after sunset in the second half of the month. That's still well before the evening twilight ends. Mercury will be near quadrature and thus visible as a half-lit sphere. You'll need a reasonable telescope to see the 6.5 arcsecond disc.



Venus in July 2023

Venus is worth watching. This steady sight in the evening sky will quickly get closer to the horizon. By month's end, Venus is only seven degrees higher than the Sun in the sky, only visible because it's 20 degrees to the left of the Sun. In July, Venus' phase thins, while Venus' visible size gets larger. The greatest illuminated extent, the combination of largest angular size and thickest remaining crescent, occurs on the 7th. The crescent may be discernable even in binoculars. Lean them on a fence or other sturdy object for the best view. Look early, even in daytime, to resolve the crescent, as Venus is so bright, it may look like a dazzling beacon with no shape in the dark sky. But be careful not to look at the Sun!

Find a location with a clear view of the western horizon on the 20th, when the thin **Moon** will prance through the front legs of Leo, with the Moon, Regulus and Mars above Venus and Mercury to the right of Venus. Bring binoculars or a wide-field telescope and get there early after sunset, since Venus will set by 9:30 p.m. EDT.

Saturn-rise moves to the end of astronomical twilight by the 20th, but that's still late in the evening at 10:15 p.m. EDT. Even then, it doesn't get to its highest point in the sky until 3:15 a.m. At any time of night it's fun to view the ringed planet through a telescope. The rings' tilt widens from 7 ½ to 8 degrees wide in July, but will decrease towards the next ring plane crossing on March 23, 2025.

Jupiter is getting higher in the pre-twilight morning sky in July. It'll be August before it rises before midnight Daylight Time.

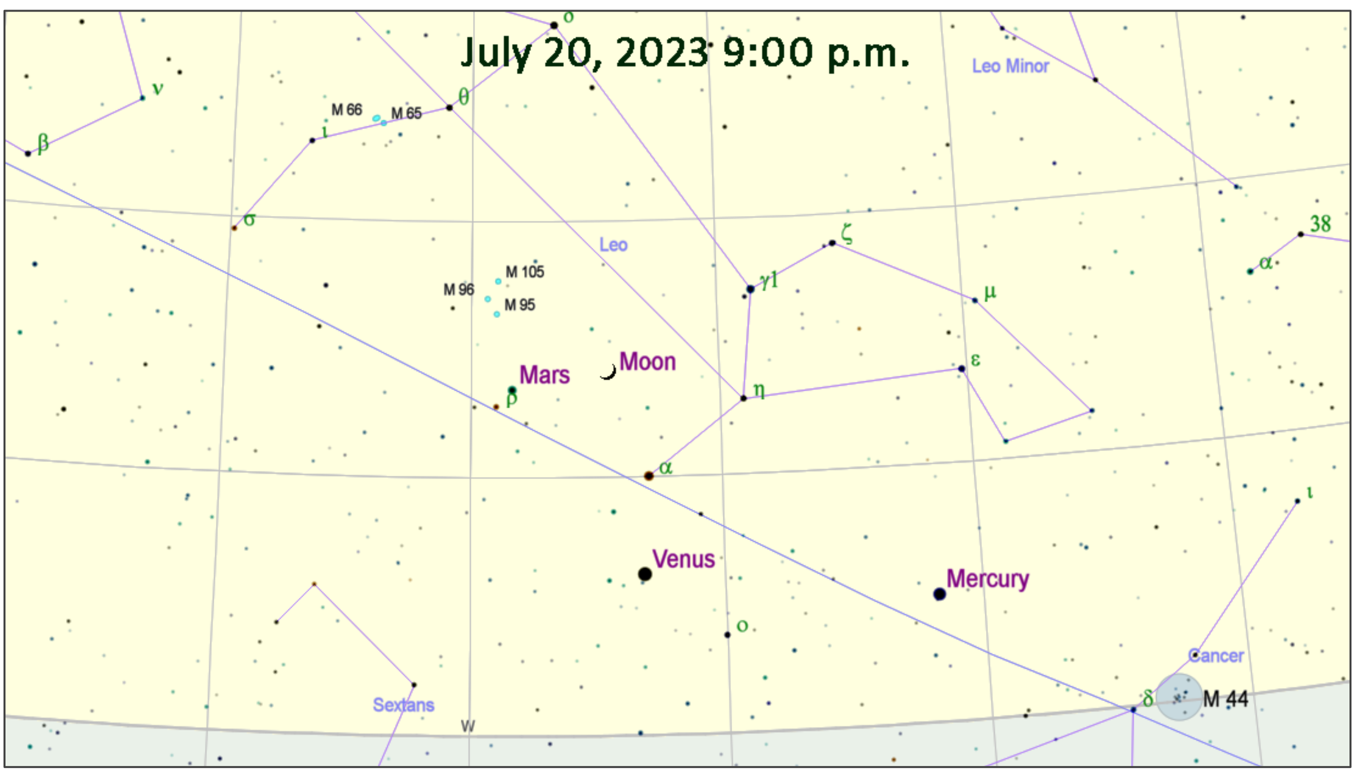
M44, the Beehive Cluster, makes a beautiful scene with the Sun in late July and early August, a sight only visible in the Solar and Heliospheric Observatory's C3 imager. You can see the latest image at https://soho.nascom.nasa.gov/data/realtime/c3/1024/latest.jpg, and there's also a nice SOHO app for your phone. In the first week of July, Mercury will be seen as a very bright object in the C3's view since it passes through superior conjunction with the Sun on the 1st. The inner-most planet will be fully lit behind the Sun from our point of view. But it's not a telescopic object for us.

Auroras have sometimes been visible at our latitude this year. It's still hard to see them with the short nighttime combined with their often being low on the northern horizon. Watch for alerts of enhanced solar wind (a Kp index of 6 or more) and check out the aurora forecast maps from the University of Alaska Fairbanks at https://www.gi.alaska.edu/monitors/aurora-forecast. There are also aurora alert apps for your phone.

From the 11th through the 14th, we'll have another set of nights when the Inte**rnational Space Station** is predicted to be visible in our area every 93 minutes during the night. Go to https://heavens-above.com and enter your location for the latest predictions. There are apps for ISS passes as well!

No great meteor showers this month, at least for the northern skies.

Earth's elliptical orbit reaches its aphelion point, when Earth is farthest from the Sun, at 4:06 p.m. EDT on the 6th. The center of the Sun will be exactly 94,506,364 miles away.



EZ3D

Robin Stuart

Some of the first 3D photographs of astronomical objects that I ever saw appeared in *Sky & Telescope* in the 1980's. These were presented as free fusion pairs. One example showed an ethereal comet floating serenely in front of a starry field. It was produced by taking 2 exposures separated by enough time that the comet's position had changed appreciably against the background stars. The two printed images were then painstakingly rotated and aligned to produce the final 3D effect.

Nowadays the same result can be obtained much more quickly and easily from a single image. My previous SkyWAAtch articles on 3D imagery (October 2019 SkyWAAtch, p. 8, July 2021 SkyWAAtch, P. 15) made use of custom Mathematica code to manipulate the surfaces of the Moon and planets. Nothing that complicated is needed in this case.

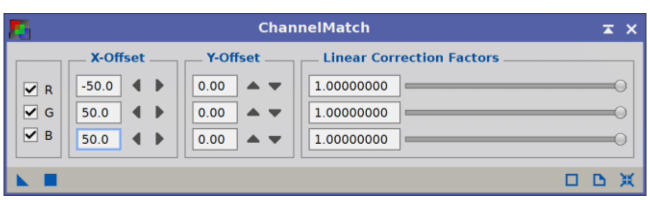
It has become a common practice in image processing to separate the stars from the nebulosity and process them separately. This can be achieved using the free software Starnet that is available as a PixInsight plugin or standalone program (https://www.starnetastro.com/).

Alternatively, StarXTerminator is available as a plugin for PixInsight or Photoshop (https://www.rc-astro.com/StarXTerminator/).

Making a Red-Cyan Anaglyph

Suppose separate images have been obtained for the comet and stars.

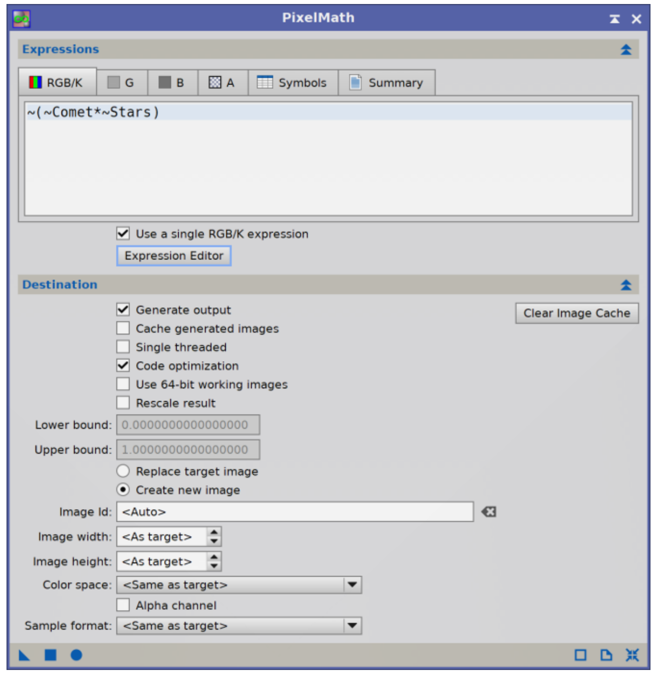
1. Open the *Comet* and *Stars* files in PixInsight.
2. Apply the *ChannelMatch* process, as shown below, three times to *Stars*



3. Apply the *PixelMath* operation

   `~(~Comet*~Stars)`

as shown in the dialog box in the next column.



4. Crop 150 pixels from the left and right edges
5. Save the resulting image.

The *ChannelMatch* process is intended to adjust the relative positions of the red, green and blue layers to correct for atmospheric dispersion. Its maximum offset is limited to 100 pixels which is why it needs to be applied multiple times. The end result of step 2 is that the red images of individual stars are separated from their green and blue images by 300 pixels.

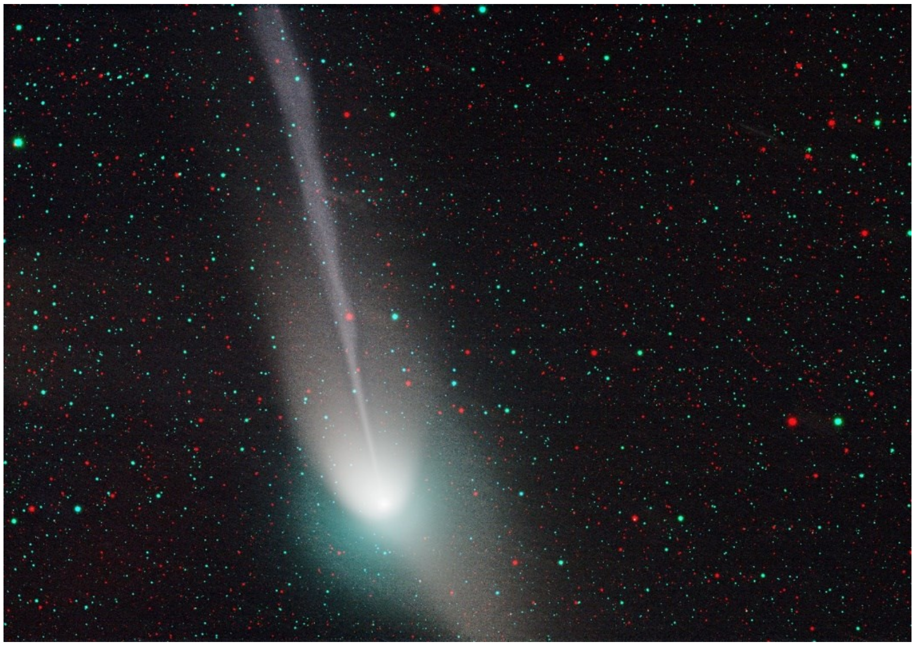
Depending on the resolution and desired 3D image depth, the size of the offsets used in *ChannelMatch* may need to be adjusted. The present case the original image is 6428×4176 pixels.

Free fusion pairs

In this case two images need to be produced

1. Apply *ChannelMatch* 3 times to *Stars* with X-Offsets of the R, G and B layers all set to 50.0 and combine this with *Comet* using *PixelMath* as in step 3 above. This image is placed on the right for parallel viewing and on the left for cross-eyed viewing.
2. Apply *ChannelMatch* 3 times to *Stars* with X-Offsets of the R, G and B layers all set to -50.0 and combine this with *Comet* using *PixelMath* as in step 3 above.

Red-Cyan Anaglyph



Free Fusion Parallel Viewing

Free Fusion Cross-Eyed Viewing

The original images of Comet C/2022 E3 (ZTF). appeared in the May 2023 SkyWAAtch p.11.

Another Movie Telescope

Using an 8-inch Newtonian with a peculiar eyepiece extender device, Nicholas Cage is showing Saturn to his son in a scene near the beginning of the 2008 movie *Knowing*. (It's not just a Barlow: the connection to the focuser seems to work like a ball joint). Alas, this moment of astronomical bliss is followed by revelations, cataclysms, aliens, invisible angels and the complete destruction of the planet Earth. *Knowing* is a potpourri of a horror flick, a disaster flick, a Biblical flick, a Dan Brown novel, *Childhood's End* and *When Worlds Collide*. It's the kind of movie I expect would appeal to people who believe that the Flood happened and are now hoping for the Rapture.

I was chagrined by the use of the *Allegretto* from Beethoven's Seventh Symphony to accompany the obliteration of Boston by the solar flare that wipes out all life on Earth. Richard Wagner called the Seventh Symphony "the apotheosis of the dance." Hollywood thinks it's achieving irony or pathos by accompany scenes of horror with relatively calm classical music (exception: *Apocalypse Now*). I would have chosen something more honestly fitting to destruction: the ending of Wagner's *Gotterdammerung*, the crazy loud music that accompanies an army of the dead in Arnold Schönberg's 1911 oratorio *Gurrelieder,*, the threnody at the end of Act 2 Scene 3 of Györgi Ligeti's wonderfully nutty 1977 opera *Le Grande Macabre* or, fitting directly with the film's apocalyptic theme, the "Weltuntergang"("The End of the World") from Franz Schmidt's 1938 oratorio *The Book of the Seven Seals*. No problem destroying Boston or the entire Earth: just give it the musical kick it deserves.

I seem to recall that eyepiece extenders, really 1-power transfer telescopes, had once been commercially available to help wheelchair-bound individuals view through eyepieces. I couldn't find any references to them on-line. The 60-inch and 100-inch telescopes at Mt. Wilson have custom-made transfer scopes to allow people to view at each instrument's otherwise unreachable Cassegrain focus. I think the device attached to the reflector might just be a prop, chosen to keep Cage and his grim expression facing the camera during the scene (there's a lot of grim throughout this film). But it's a nice idea for outreach. Anyone willing to try making one?

Thanks to Howard Fink for pointing out this scene.

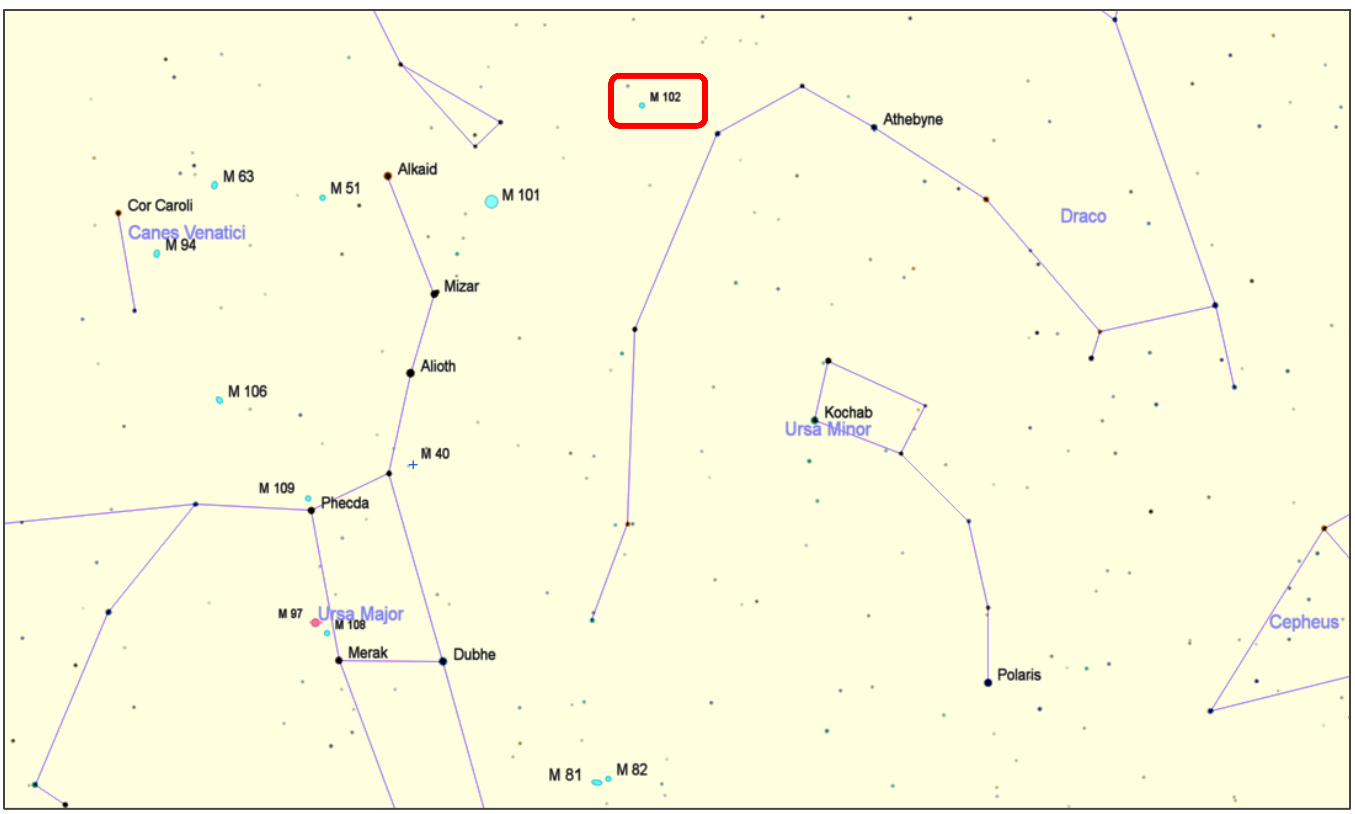
Deep Sky Object of the Month: Messier 102?

Messier 102/NGC 5866	
Constellation	Draco
Object type	Lenticular Galaxy
Right Ascension J2000	15h 06m 29.5s
Declination J2000	+55° 45' 48"
Magnitude	9.9
Size	6.5' x 3.1'
Distance	50 million LY
Discovery	Méchain 1781

Is there really a Messier 102? Méchain retracted the observation in 1783 believing it was a duplicate observation of M101 (NGC 5457). Others have suggested that what Méchain had seen in 1781 was NGC 5866, which is some 9 degrees east of M101. Herschel saw this object on May 5, 1787 (catalogued as I 215). The NASA/IPAC Extragalactic Database (NED) lists M102 as NGC 5457, which is M101, but many other sources designate M102 as NGC 5866. This confusion is why the number of Messier objects is often given as 109, even though there's an M110. By listing 109 Caldwell objects, Sir Patrick Moore obviously didn't believe there's an M102. Do you?

Visibility for Messier 102			
2200 EDT	7/1/23	7/15/23	7/31/24
Altitude	75° 02'	69° 45'	61° 33'
Azimuth	339° 41'	320° 33'	312° 14'

NGC 5866 is viewed edge-on and is sometimes called the "Spindle Galaxy", but there's another Spindle Galaxy, NGC 3115 in Sextans. NGC 5866 is a Seyfert galaxy.



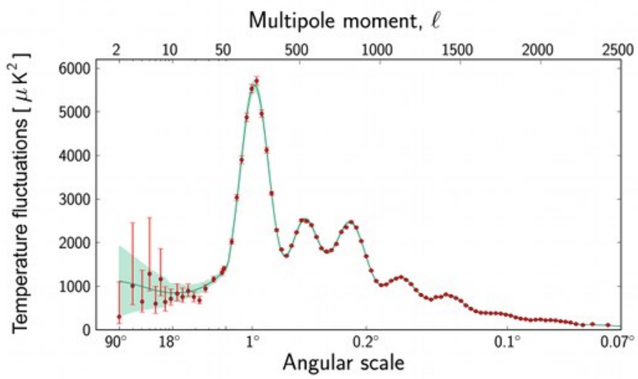
Is the Search for Dark Matter Getting Brighter? Larry Faltz

Yesterday, upon the stair,
I met a man who wasn't there
He wasn't there again today
I wish, I wish he'd go away...[1]

The idea that there is dark matter, a substance with mass that we can't see, used to be astonishing. We've heard enough about it now that it just seems perplexing.[2] Even though there's more than five times as much of it as "regular" matter (the stuff made of protons, neutrons, electrons and neutrinos), we've failed to identify what dark matter actually is. Meanwhile, all sorts of astronomical and physics progress has been achieved in areas that were utterly mysterious not long ago (think of the Higgs boson, exoplanets, cosmic microwave background, cosmic web and gravitational waves, to name a few). One might cavil that we are blind to what we cannot see!

There are five lines[3] of evidence that show that dark matter is a major component of our universe.

- *Cluster rotation*: In the 1930s, Fritz Zwicky showed that galaxy clusters rotated faster than would be predicted from their matter content (as determined by their brightness).
- *Galaxy rotation*: In the 1970s, Vera Rubin showed that the rotation rate of the outer parts of individual galaxies was too rapid to be explained by their matter content.
- *Gravitational lensing*: The amount of mass required to explain the displacement of background galaxies by foreground galaxy clusters (and the amount of brightening of those background galaxies) is greater than can be explained by the cluster galaxies' matter content.
- *CMB periodicity*: The anisotropy pattern (the angular periodicity of temperature fluctuations) in the cosmic microwave background would be different than what was detected if there was more or less than the postulated amount of dark matter. Since DM has no (or extremely little) electromagnetic interaction to oppose gravitational collapse, it doesn't build up radiation pressure and can start forming structure sooner after the Big Bang than regular matter, affecting the CMB.



CMB Angular Power Spectrum (Planck)

- *Cosmic structure*: The observed distribution of gas, galaxies and galaxy clusters in the current universe is consistent with the presence of dark matter and its earlier effect on structure formation.

Dark matter interacts primarily, if not solely, by gravity. Many theoretical models have been proposed for its composition.

- WIMPs (Weakly interacting massive particles). These would be slow-moving, heavy fundamental particles that form halos in which the galaxies and clusters sit. Extension of the Standard Model of particle physics have been tweaked to include such particles, primarily under the rubric of supersymmetry.
- MACHOs (Massive compact halo objects). Perhaps there's a lot of normal matter we just don't see hanging around the outskirts of galaxies. This could take the form of brown dwarfs, black holes, exotic dark objects, or heavy neutrinos. There seems to be almost no evidence for these objects and the MACHO solution to the dark matter problem apparently has few proponents anymore.
- Axions. A large number of very light particles could account for the missing mass. The particles

[1] From *Antigonish* by William Hughes Mearns (1899)
[2] Astonishment is more fun than perplexity.
[3] In the early 1930s, Jan Oort noticed that some stars in the galactic plane were moving so quickly that they should escape the galaxy. He proposed that there might be missing mass, but then qualified his guess by noting that much of the light from the galactic center is obscured and the velocity results could thus be in error. We can give him credit for the idea of invisible mass, but not for finding actual evidence, because he hedged his bet.

are generated by symmetries in Quantum Chromodynamics (QCD), the theory of the strong nuclear force. They are also found in string theory,

- There are some wild theories involving extra dimensions or bizarre particles called Q-balls, WIMPzillas, branons, and GIMPs.

There is no requirement for dark matter to be only one type of particle or entity, perhaps analogous to matter, which is a mixture of hadrons and leptons. The ΛCDM cosmological model doesn't prescribe the exact nature of dark matter, assuming only that it does not move at relativistic velocity (*i.e.*, "cold").

Although the evidence for dark matter seems strong, there are a few observations that weaken the case, particularly for WIMPs. DM predicts more dwarf galaxies than are seen, called the "missing satellite problem." Dwarf galaxies are more often aligned in the plane of host galaxy than DM would predict, since the dark matter is presumed to form a spherical "halo" around galaxies rather than a plane that would create a preferred gravitational orientation of the dwarfs. Most simulations suggest dark matter should create a "cusp" within dwarf galaxies, where the matter density increases dramatically towards the center, but this is not seen. Dark matter cannot also fit as cleanly as astronomers would like with the Tully-Fisher Law,[4] which states that the brightness of galaxies is correlated with their rotational velocities.

The primary alternative to dark matter is some form of modified gravity, where the gravitational field over large distances does not scale as $1/r^2$ but by some small incremental variance, with a length scales dependence. Mordechai Milgrom, in 1983, proposed Modified Newtonian Dynamics (MOND) but since then many modified gravity theories have been offered. A modified gravity theory has to account for the fact that at sub-cosmic scales, gravity clearly does scale at exactly $1/r^2$, otherwise the Apollo astronauts would have missed the Moon and who knows where Jupiter might be today. The simplest MOND theory modifies the force equation $F=ma$ with a new constant, a_0, an acceleration term that marks the scale in which MOND operates (Milgrom sets a_0 as 1.2×10^{-10} m/s^2) and an interpolation function $\mu(x)$ that seems totally arbitrary but is needed to make things work. At first glance, the modified gravity theories have the quality of being designed *ad hoc* merely to expunge the possibility of dark matter but there are versions that purport to be complete and consistent theories of gravitation and relativity.

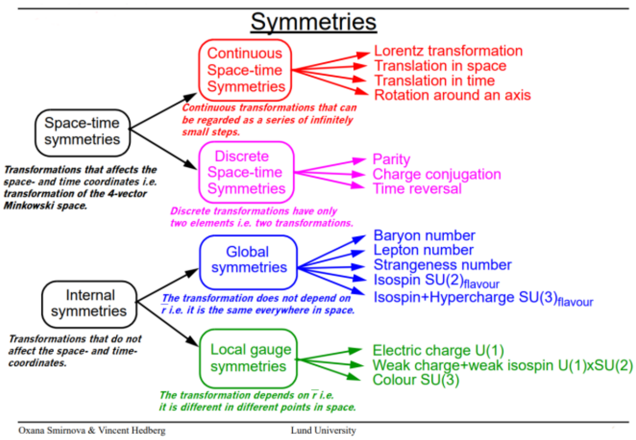
For a long time, it was expected that WIMPS would be found and would account for all of dark matter's effects. Extensions of the Standard Model readily predict them as partners of the particles we've already found in our universe. They should have masses that begin around 100 MeV, which would be in the range of the Large Hadron Collider at CERN. Detecting WIMPS depends on them having at least some, albeit very rare, interaction with normal matter through the weak force, the force involved in radioactive beta decay (the conversion of a neutron into a proton, an electron and an antineutrino). Many experiments have searched for these particles, but only an upper limit for a possible interaction ("cross section") can be claimed. Each succeeding experiment seems to make the upper limit of the cross-section smaller and smaller. It might go to zero, which means either we can never detect WIMPS or they don't exist.

As experiments to detect massive dark matter particles continue to come up with null results, interest in axions has increased. One of the attractive aspects of axions is that they were originally proposed not to solve the dark matter problem at all, but to address a well-defined, fundamental problem in particle physics. Having a single particle solve two problems at the same time would show our universe to be attractively parsimonious (an attribute one might question, given the ungainly number of particles and arbitrary constants required by the Standard Model in the first place). To see the behavior of the universe at the largest scales, we have to look at the smallest.

There are three credos, for want of a better word, around which the cosmos is organized: general relativity, quantum mechanics and symmetry. We hear a lot about the first two when discussing cosmology and astrophysics, but not much about symmetry, although as a general concept it's more understandable. We inherently know what we mean when we say something is symmetrical. We're used to looking in a mirror, after all. But there are more kinds of symmetry, distinguishable by where, how and on what in the universe they operate, and all according to cer-

[4] See "Determining Galactic Distances" in the March 2021 SkyWAAtch, p. 13.

tain rules of transformation. Among its many manifestations, symmetry operates in particle physics to organize and distinguish quarks and gluons. Principles of symmetry led to the prediction, and then experimental confirmation, of quarks and their masses.



The conservation of energy is a consequence of the symmetry of time reversal: all fundamental processes in physics are valid (theoretically and mathematically) if time is run backwards even though we can't run time backwards in reality. The conservation of momentum is a consequence of the fact that a physical process is the same wherever it takes place, as long as velocity is constant. Conservation of angular momentum comes from the fact that a physical process rotated in space will be unchanged. In particle physics, there are conserved quantities such as baryon number, lepton number and strangeness number, among others.

A critical question is whether a process is invariant under a symmetry operation. Parity "invariance" means that the mirror image of a process would give the same results (since we are dealing with three dimensions in the real world, we really mean the axes *x*, *y* and *z* are replaced with *-x*, *-y* and *-z*). Charge invariance means if we exchange charges, the process is unchanged (for example, the positively charged proton and the negatively charged antiproton have opposite charge and magnetic moment, but exactly the same mass, to 11 decimal places), and time invariance means basically means that the laws of physics don't change over time. Quantum field theories, [5] which are an accurate way to describe the universe in spite of their mathematical complexity, are invariant under the combined CPT operations, that is, making all three transformations at the same time. Is it possible that, in spite of combined CPT invariance, the individual transformations are not invariant?

In 1957, Wu discovered that the weak interaction violated P symmetry by observing the decay of ^{60}Co in a magnetic field. However, it was believed that the combined charge-parity symmetry, known as CP, was not violated. In 1964, Cronin and Fitch reported their measurements at Brookhaven of the decay of the K meson, which is a bound state of a strange quark with either an up or a down quark (or their antiquarks). Analysis of the decay products showed that CP symmetry <u>was</u> violated.

The equations of quantum chromodynamics (QCD) predict that CP violation should occur in processes mediated by the strong force, just like in the weak interaction, yet these violations have never been found. This is termed the "strong CP problem." The equations for QCD contain an angle, $\bar{\Theta}$, which can take on any value between 0 and 2π (0 to 360 degrees). It is an arbitrary parameter of the Standard Model, one that is "put in by hand" and can only be determined by experiment. Unless it is very close to zero, QCD requires that the neutron should have a large and detectable electric dipole moment. The neutron has no electrical dipole moment. The value of $\bar{\Theta}$ must be less than 5×10^{-11}. What makes it so arbitrarily close to zero? Is something missing?

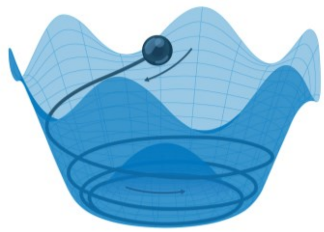
To solve this problem, in 1977 Peccei and Quinn suggested that $\bar{\Theta}$ was not just an angle, but a field (it is said they "promoted it" to a field). They did this by adding a new symmetry to the universe.[6] In quantum field-theory-speak, $\bar{\Theta}$ is proportional to the value of a new scalar field,[7] a(t, x) that has a value everywhere in space. The value a = 0 is energetically favorable, so $\bar{\Theta}$ tends towards zero. The field never quite reaches exactly zero, however. Quantum uncertainty and all that.

[5] See Cambridge theoretical physicist David Tong's excellent 2017 lecture at the Royal Institution on the basics of quantum field theory at https://is.gd/tongfields.

[6] That is, they added terms to the equations of QCD that describe a new symmetry but don't change its other predictions or symmetries. There are several formulations of the axion that result from this new symmetry.

[7] An example of a scalar field is temperature. It has a value everywhere in space, but no direction. A vector field like the gravitational field, it has a value and a direction.

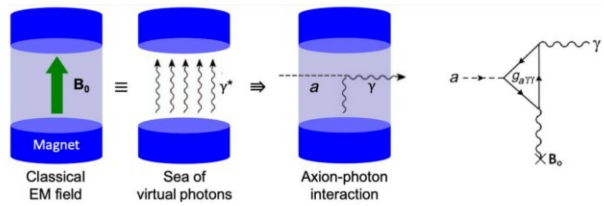
The field would have had a high energy in the early universe that weakened through symmetry breaking as the universe expanded. The oscillations of the field around its minimum value would generate a population of very low mass particles throughout the universe. These quanta of the field are the axions themselves, named by Frank Wilczek after the laundry detergent because they "cleaned up" the strong CP problem.[8]


Decay of the axion field after the Big Bang. From an on-line talk by Frank Wilczek.

Among the properties of axions that emerge from the mathematics of the theory is that they can couple to gluons and photons. In the presence of a background magnetic field, the axion field mixes with photons and injects energy into the electromagnetic field.[9]

Experiments to detect axions are underway. Many of these experiments depend on the prediction that axions will generate photons in a strong magnetic field, although even under the most optimistic scenarios the coupling is extremely weak. The ADMX experiment at the University of Washington is an "axion haloscope" that seeks to generate microwave photons from axions in the Milky Way's halo in the presence of a strong magnetic field. The apparatus is cooled to below 4.2 K. If the resonant frequency of the device matches the axion mass, about a yoctowatt (10^{-24} watts) of power will be generated. Sensitive amplifiers might be able to detect this nearly infinitesimal increase.

ADMX is only one of a number of ongoing and proposed experiments. There is even one named ABRACADABRA (A Broadband/Resonant Approach to Cosmic Axion Detection with an Amplifying B-field Ring Apparatus). Each experiment can only search for axions in a certain mass range. The axion mass is certainly far lower than the neutrino mass (~ 0.8 eV) and is likely to be less than 10^{-12} eV, maybe much less.



Principle of axion detection. A classical strong magnetic field generates a sea of virtual photons with which axions interact, generating real photons. The corresponding Feynman diagram is also shown. From Semertzidis, YK, Axion dark matter: How to see it?, *Sci Adv*. 2022; 8: eabm9928.

The Sun should be a potent source of axions. X-rays generated by fusion would scatter off electrons in the intense solar magnetic field, creating axions.

But what does this have to do with astronomy? If dark matter is made of very light axions rather than massive WIMPs, would this have any observable effects that astronomers could detect?

In 1924, during the fertile period when quantum mechanics was developing, Louis de Broglie proposed that matter behaves as waves and waves as matter, the so-called wave-particle duality. That explains how electrons can exhibit interference in the famous two-slit experiment, for example. De Broglie proposed that a "matter wave" would have a wavelength based on its momentum,

$$\lambda = \frac{h}{p}$$

Where *h* is Planck's constant (6.626×10^{-34} J Hz^{-1}) and *p* the momentum in kg-m sec^{-1}.[10]

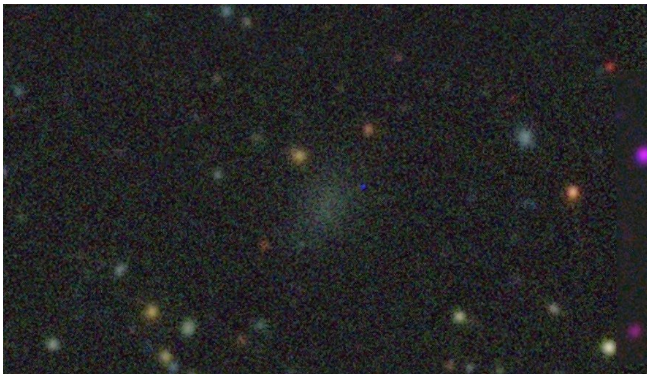
Because the mass (and therefore the momentum) of axions is so low, they can behave like waves with characteristic interference (think of the way LIGO detects gravitational waves). There are several potentially discernible consequences of this behavior, as shown by simulations. The dark matter halos would tend towards lower masses due to quantum pressure. The core of the halo would be a soliton, a standing wave that remains in place. The self-interfering

8 The late Steven Weinberg wanted to call them "higgslets" but that was deemed even more facetious than "axions."

9 QCD is extremely complicated and mathematically arcane. Theories seeking to account for dark matter and the solution to other outstanding problems propose all manner of new symmetries, fields and particles. For a review that is somewhat technical but can give you a good idea of how the axion fits into the general schema of QCD and dark matter, see Chadha-Day, et. al., Axion dark matter: What is it and why now?, *Sci. Adv*. 8, eabj3618 (2022). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8865781/

10 A 95 mph fastball has a wavelength of 3×10^{-35} meters, around the Planck length.

waves modulate the local dark matter density. The count and distribution of local dwarf galaxies would be consistent with observations. Previous studies had shown that dark matter halos composed of wave-like DM would address the "missing satellite problem" and the "cusp" problem. Evidence for a soliton had been suggested by the flat stellar velocity dispersion of the ultra-diffuse dwarf galaxy DF44. There are possibly observable effects on stellar lifespans and black hole rotation.

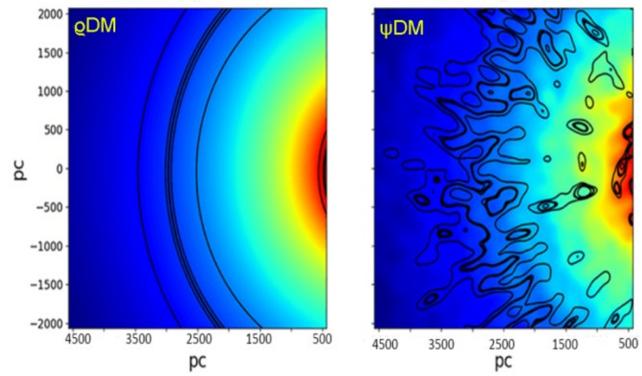


DF44, a low surface brightness galaxy in the Coma Cluster, The field is 2.24 arcminutes across. The image from CDS, made with the Dark Energy Camera on the 4-meter Victor Blanco telescope at Cerro Tololo in Chile. See the July 2017 SkyWAAtch, p. 4, for more about this observatory.

Invisible dark matter is substantially responsible for gravitational lensing by galaxy clusters. A new study[11] led by graduate student Alfred Amruth of the University of Hong Kong examined the differences between axion dark matter, termed *ψ*DM, and WIMP dark matter, termed *ϱ*DM, on the geometry of gravitationally lensed quasars.

Because waves can reinforce or cancel, it might be possible to detect density fluctuations at the axion's de Broglie wavelength scale by viewing the exact positions of gravitationally lensed background quasars. *ϱ*DM would create smoothly varying density profiles, while *ψ*DM would not, because of interference.

The chaotic lensing environment surrounding a galaxy in a *ψ*DM halo could create positional anomalies of the background object on the order of 10 milliarcseconds. This is beyond the reach of optical instruments, even the HST or JWST, but radio telescopes using Very Long Baseline interferometry (VLBI) might have sufficient resolution. Previous observations via VLBI showed evidence for such positional anomalies in three faint, distant gravitationally lensed objects.



Isomagnification profiles ("lensing halos") for *ϱ*DM (left) and *ψ*DM (right) for a simulation of a point source behind a massive galaxy (forming an Einstein ring). From Amruth, et. al.,

Amruth and colleagues specifically studied the gravitationally lensed object HS 0810+2554.

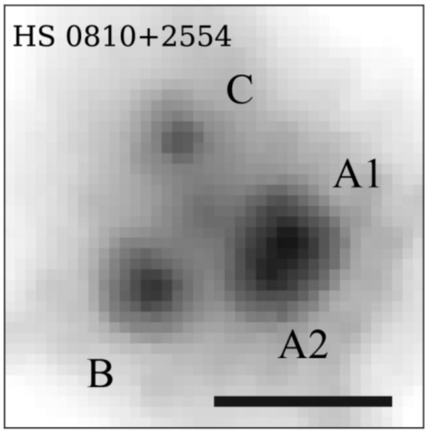
The object in the center is HS 0810+2554, in the constellation Cancer. The field of view is 3.92 arcminutes across. SDSS image.

The four optically detectable components of HS 0810+2554 are accompanied by a pair of radio jets, detected by the European VBLI Network. The authors found that for an axion mass of 10^{-22} eV,[12] models of lensing based on the presence of *ψ*DM accounted for the observed positions of the lensed images and jets better than *ϱ*DM. They note that "perturbations in the positions of the quadruply lensed images introduced by fluctuations in the surface mass density of the model *ψ*DM lens can bring the model-predicted positions to good agreement with the observed positions." The intensity of the jets is also

[11] Amruth A, et. al., Einstein rings modulated by wavelike dark matter from anomalies in gravitationally lensed images, *Nature Astronomy*, published on line April 20, 2023. https://is.gd/AmruthAxionDM

[12] More than 27 orders of magnitude less than an electron.

more consistent with *ψ*DM than *ϱ*DM. The authors note that, “By contrast, this system continues to pose a challenge for ϱDM: future efforts incorporating triaxial DM halos or baryonic structures with morphologies different from the DM halo, along with subhalos, may be required to assess whether current lensing anomalies can be reconciled using ϱDM lens models.”



Hubble Space Telescope image of HS 0810+2554. The bar is 1 arcsecond. The four images of the background quasar are marked. The lensing galaxy is vaguely seen in the center.

These models and observations don’t yet prove that dark matter is made of axions. The results are intriguing but need verification. The authors conclude,

> The increasing astrophysical evidence for ultralight bosons with rest-mass energies of the order of 10^{-22} eV has propelled axions—a class of particles well motivated by theories of new physics—to the forefront as a candidate for cold dark matter (CDM). New observational consequences of ψDM continue to be evaluated and subjected to astrophysical tests. Laboratory experiments to detect DM axions continue, and new experiments are being proposed and developed. Laboratory experiments designed to detect WIMPs at sensitivities reaching the neutrino floor (as imposed by cosmic, terrestrial and man-made neutrinos), slated for this decade, will provide a critical reckoning for the class of new physics that predicts WIMPs—and with it the viability of these particles as candidates for CDM. Crucially, determining whether ϱDM or ψDM better reproduces astrophysical observations will tilt the balance towards one of the two corresponding classes of theories for new physics.

A firm discovery of either the axion or the WIMP will be difficult. If one comes, the Nobel Prize comes soon after. ■

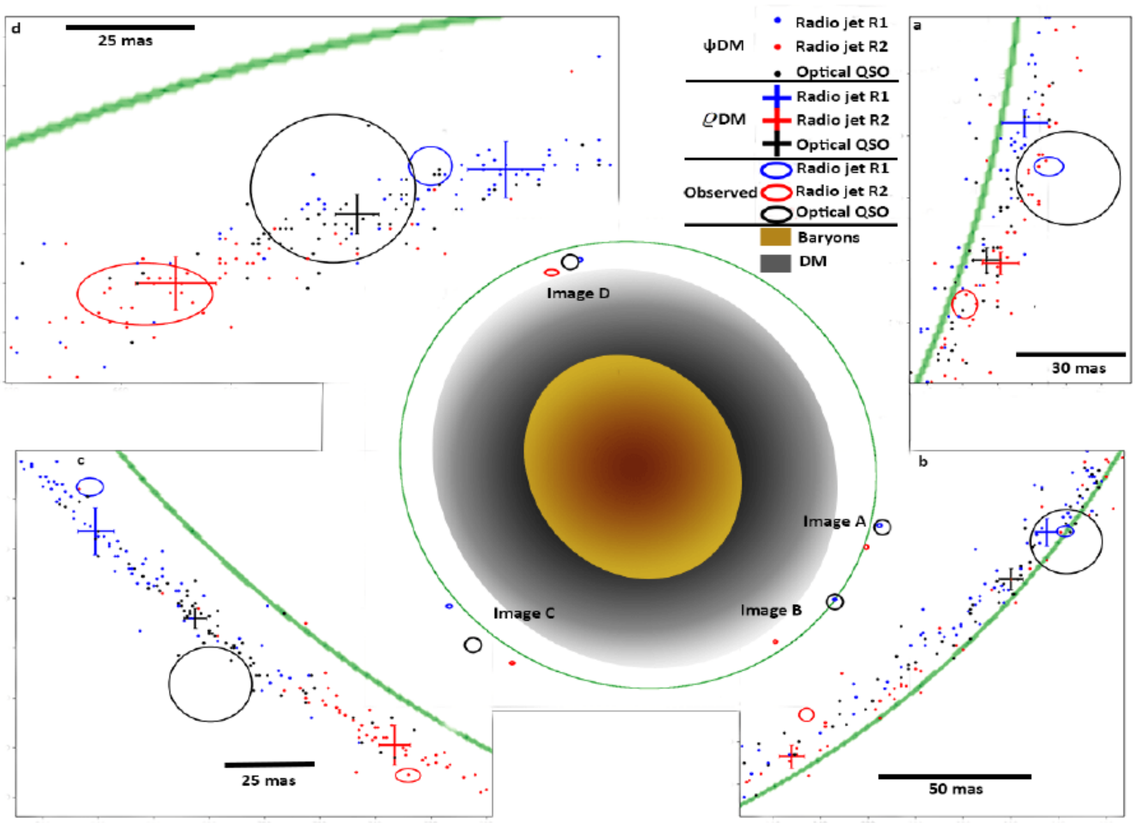


Fig. 4 from Amruth, et.al,: showing the model and observed positions of the optical and radio images. The authors changed the lensed image labels from the HST image, above. HST A1→Image A, HST A2→Image B, HST B→Image C and HST C→Image D.

Images by WAA Members

NGC 2403 by Steve Bellavia

NGC2403 (Caldwell 7) is a somewhat large (21.9' x 12.3') and bright (mag 8.9) spiral galaxy. It's the most well-known object in the faint constellation Camelopardalis, the giraffe. It is visible in binoculars in a dark sky. It was missed by Messier, first observed by William Herschel in 1788, and included in Sir Patrick Moore's Caldwell catalog as #7. It was "DSO of the Month" in the February 2021 SkyWAAtch. A finder map can be found there.

NGC 2403 is an outlying member of the M81 Group, approximately 8 million light-years distant from the solar system. Like the Triangulum Galaxy, M33, it has many H II regions where star formation is occurring. These are evident in the image as reddish knots, made prominent by the use of a narrowband H-alpha filter.

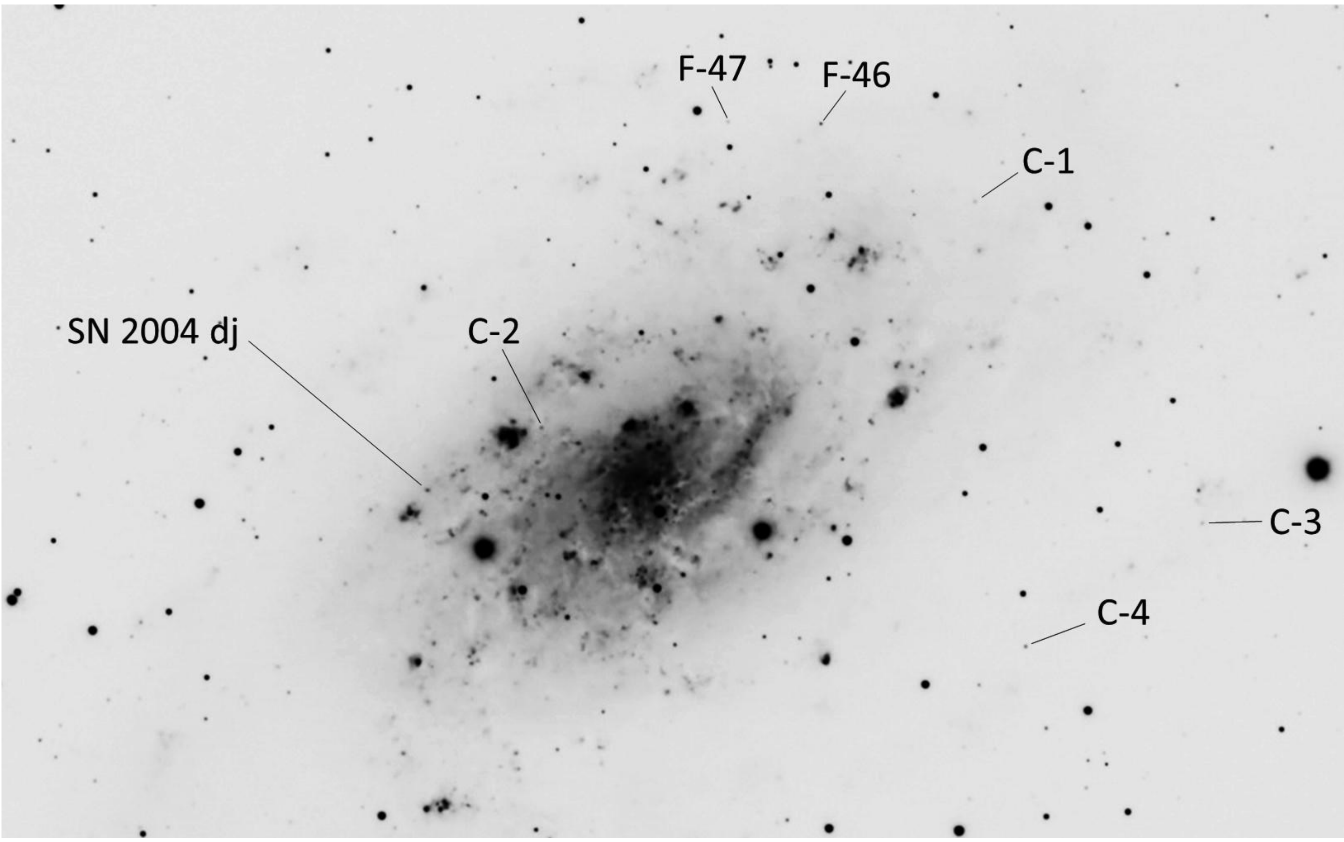
Steve gives extensive technical information at https://www.astrobin.com/2r2d7r/.

The study of this galaxy was instrumental in determining the first reasonably accurate value of the Hubble Constant. In a review celebrating the 50th anniversary of the 200-inch Hale telescope at Mt. Palomar, noted astronomer Allan Sandage wrote,

> The long collaboration between G.A. Tammann and the writer began in 1963, starting with the analysis of the 200-inch plates of NGC 2403. By 1968 Tammann had obtained light curves for 17 Cepheids in NGC 2403, with periods between 87 and 20 days, and light curves based on a photoelectric sequence that had been set up in the field of the galaxy. The distance modulus was $(m - M)_0 = 27.56$, based on the Cepheid calibration of the period-luminosity relation.

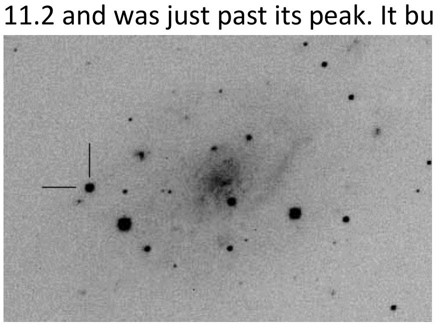
The result was a major shock at the time because of its implied consequences for the revision of Hubble's "remote" distance scale, and therefore for the value of the Hubble constant. As late as 1950, Hubble's distance modulus for NGC 2403 was (m - M) = 24.0 (D = 0.6 Mpc). If we were right that the modulus was (m - M)o = 27.56 (D = 3.2 Mpc), then even at the very local distance of NGC 2403, Hubble's distance scale would be too small by a factor of five. This was much larger than Baade's original factor of two, as well as the final factor of three from Baade & Swope (1963). Therefore, by 1965 it was clear that a much larger attack on the distance scale was necessary than had been anticipated in 1948. The program was expanded into what ultimately became the series of ten papers called "Steps Toward the Hubble Constant."

The entire article, first published in the *Annual Review of Astronomy and Astrophysics*, can be found on the Caltech web site at https://is.gd/sandage50.



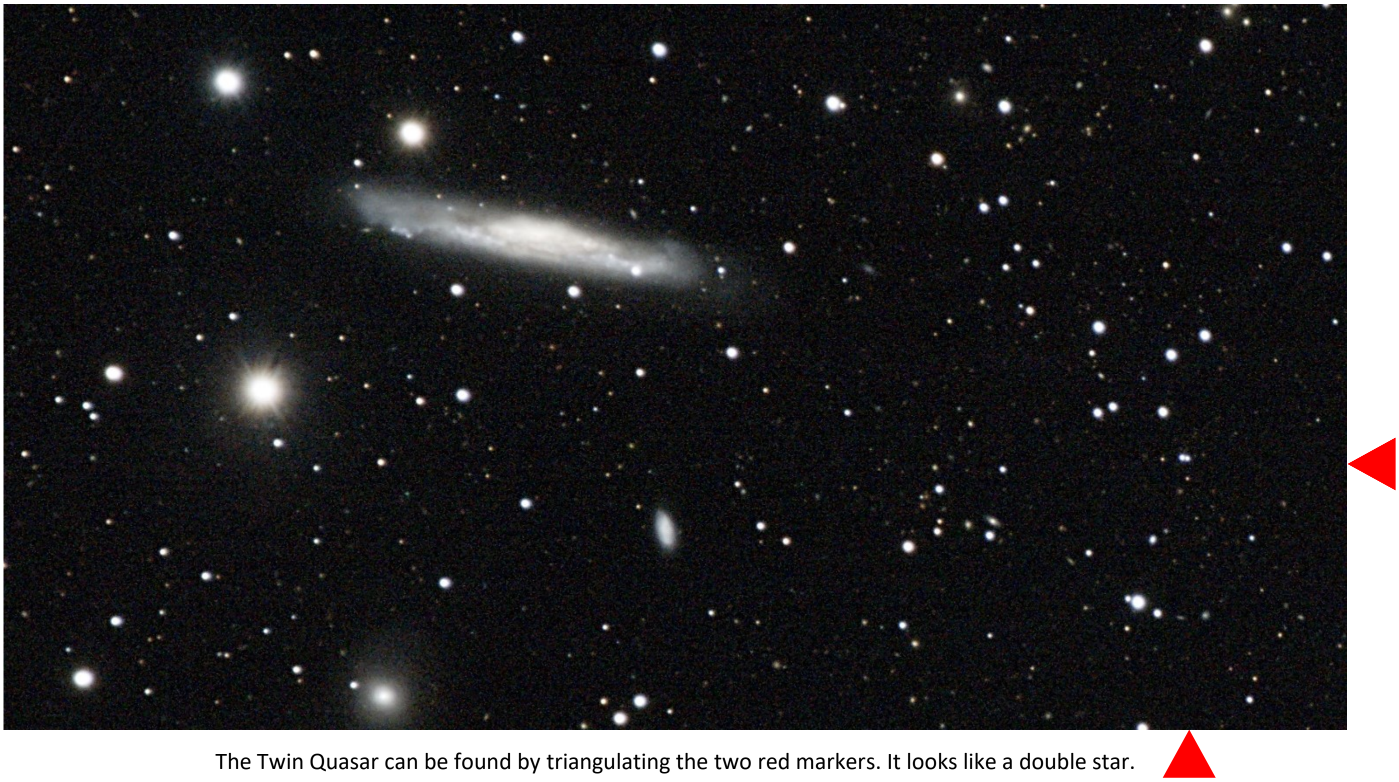
Steve enlarged the galaxy image and found half a dozen of its globular clusters. He presents it as a negative B/W image, which makes the faint gas and stars more easily visible. One of the clusters once hosted a supernova.

Supernova SN 2004dj was discovered on the night of July 31, 2004 by Japanese amateur astronomer Koichi Itagaki (who also discovered SN 2023ixf; see the June 2023 SkyWAAtch, p. 27-29). At the time it was magnitude 11.2 and was just past its peak. It burst in a globular cluster that Allan Sandage had first noticed in 1984. At it's discovery, SN 2004dj was the brightest supernova since the famous SN 1987A in the Large Magellanic Cloud. It was a type II (core collapse) supernova of type II-P, which means it had a long period where its brightness decayed very slowly (P for "plateau"). It took 800 days for it to fade below the optical flux of the underlying globular cluster Sandage 96. In a Type II-P supernova, the explosive shock wave ionizes the star's outer envelope, slowing the release of photons as they interact with charged particles. The cluster was extensively studied after the event. The supernova's progenitor star is thought to have had a mass of 12 to 20 Mo. The paper is at https://is.gd/sandage96.



Koichi Itagaki's discovery image of SN 2004dj. Now we only see the globular cluster in which SN 2004dj was located.

Seeing Double: The Twin Quasar by Robin Stuart



The Twin Quasar can be found by triangulating the two red markers. It looks like a double star.

Robin writes:

Following a suggestion by SkyWAAtch's esteemed editor, from Eustis, Maine in early April I turned my TeleVue NP127, equipped with a 2× Powermate and a ZWO ASI2600MC camera, toward Ursa Major, and began taking 10 minute exposures of the *Twin Quasar*, QSO 0957+561A/B. This object appears as two star-like bodies of magnitude 16.5 and 16.7 separated by 5.7 arc seconds. Other club members have successfully imaged it with larger instruments (see the May 2020 SkyWAAtch, p. 20). The Dawes limit for my telescope is 0.91 arc seconds. This is, of course, an ideal value and in long duration exposures the resolution may be degraded by atmospheric seeing. As the first image materialized on my laptop screen it was clear that the pair was cleanly split.

In 1979 it was noticed that two quasars were unusually close and that their redshifts (z = 1.41, corresponding to a lookback time of over 9 billion years) and their spectra were remarkably similar. This raised the possibility that the twins were not separate objects but rather a double image of single quasar magnified and split due to gravitational lensing by a massive foreground body. In 1936, long before the discovery of the first quasar, Einstein examined gravitational lensing of stars as a prediction of General Relativity but concluded that "there is no hope of observing this phenomenon directly." In the case of the Twin Quasar, the lensing body is a giant elliptical galaxy, YGKOW G1, and other galaxies in its associated cluster.

The image above is a cropped detail of the camera's field. I identified and labeled the objects in the full image on page 18 using PixInsight's image annotation functionality. The Twin Quasar is circled at the center of the image and shown enlarged in the inset. There are 22 other quasars, brighter than 20th magnitude, also visible within the field of view. These are labeled in yellow with their designation and visual magnitude. Redshifts range from z = 0.64 (6.0 billion light years) for SDSS J10007+5613 to z = 2.96 (11.5 billion light years) for SDSS J10015+5541. One of the brightest, SDSS J10033+5623, at magnitude 17.27 has redshift z = 2.11. It is astonishing to think that photons emitted by this quasar when the Universe was just 3 billion years old travelled for 10.4 billion years before striking my camera's sensor. This is well over twice the age of the solar system itself. Try to wrap your head around that!

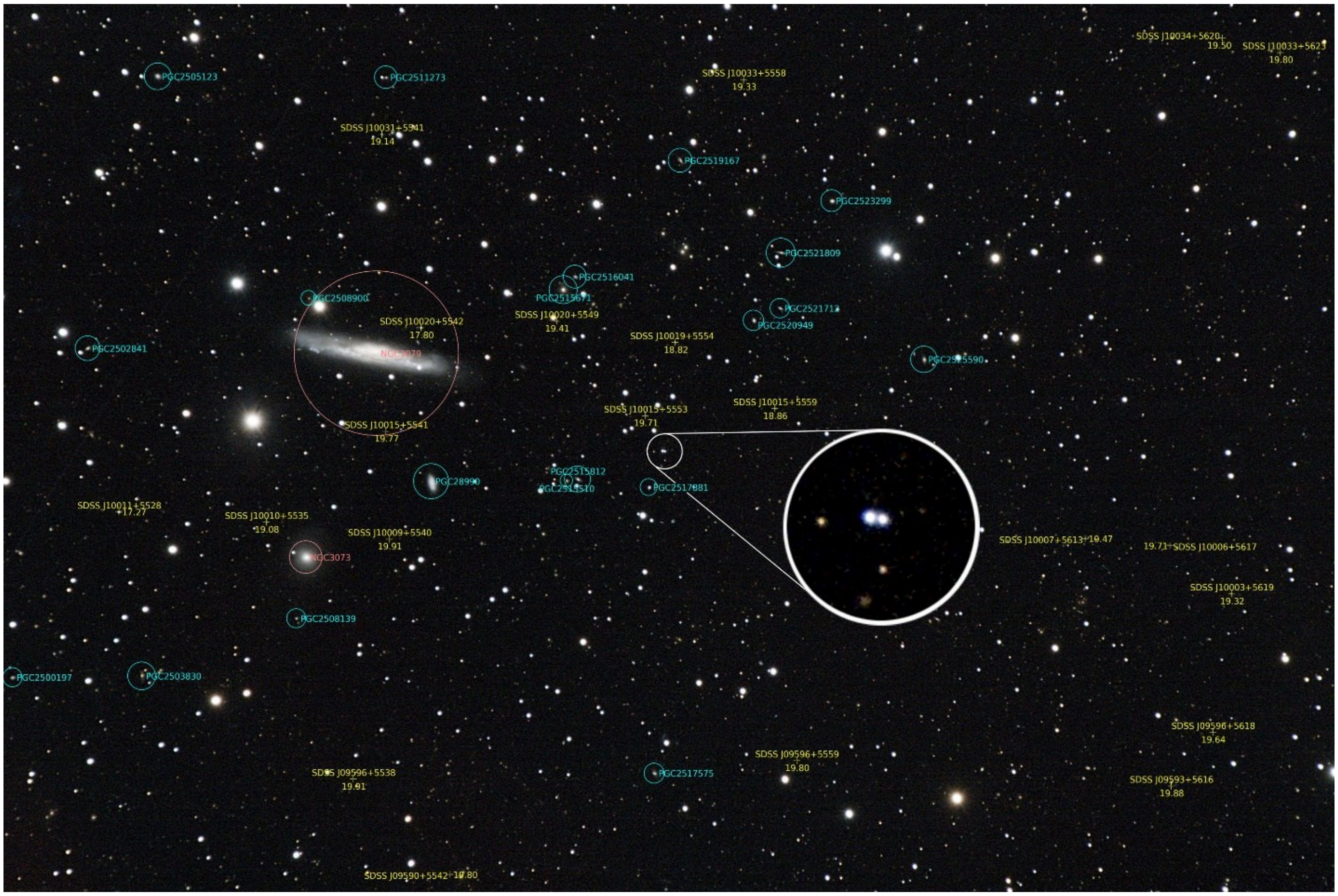


Image Capture and Processing

Over the course of 3 nights, a total of 35 ten-minute subframes (5 hours, 50 minutes total integration time) were made. On one of those nights, when the seeing was relatively poor, I recorded 16 images. The inclusion of that set of subframes in the final stacked image reduces the noise and increases the limiting magnitude but the Twin Quasar is split less cleanly and the crispness of the dust lanes in the large galaxy, NGC 3079, is reduced. In the main image all 35 subframes were stacked but in the inset only the best 19 (3 hours 10 minutes total) were used.

As noted, objects in the image were labeled using the PixInsight *Render>AnnotateImage* script. Quasars are not part of the standard installation but are easily added by creating a tab-delimited text file and linking it as a Custom Catalog (see https://is.gd/pixinst). This approach would also provide a simpler way to identify the globular clusters in Messier 31 than the custom Mathematica coding I used for the image in the January 2023 SkyWAAtch, p.6.

Quasar positions from the Sloan Digital Sky Survey (SDSS) can be downloaded from the CDS Portal at https://is.gd/SDSSquasars. Visual magnitudes, V, are not available in the dataset but, as explained in the Gaia Data Release Documentation (available at https://is.gd/gaiadataexplanation section 5.3.7, Table 5.9), they can be calculated from the Gaia G, G_{BP} and G_{RP} magnitudes using the formula,

$$V = G + 0.01760 + 0.006860\,(G_{BP} - G_{RP}) + 0.1732\,(G_{BP} - G_{RP})^2.$$

The SDSS designations for quasars are constructed from their right ascension and declination to arcsecond accuracy and are too long to be practical as labels in images. For that reason, the shorter naming convention adopted in the earlier catalog of Quasars and Active Nuclei https://cdsarc.cds.unistra.fr/viz-bin/cat/VII/248 by Véron-Cetty and Véron was used in the image. ■

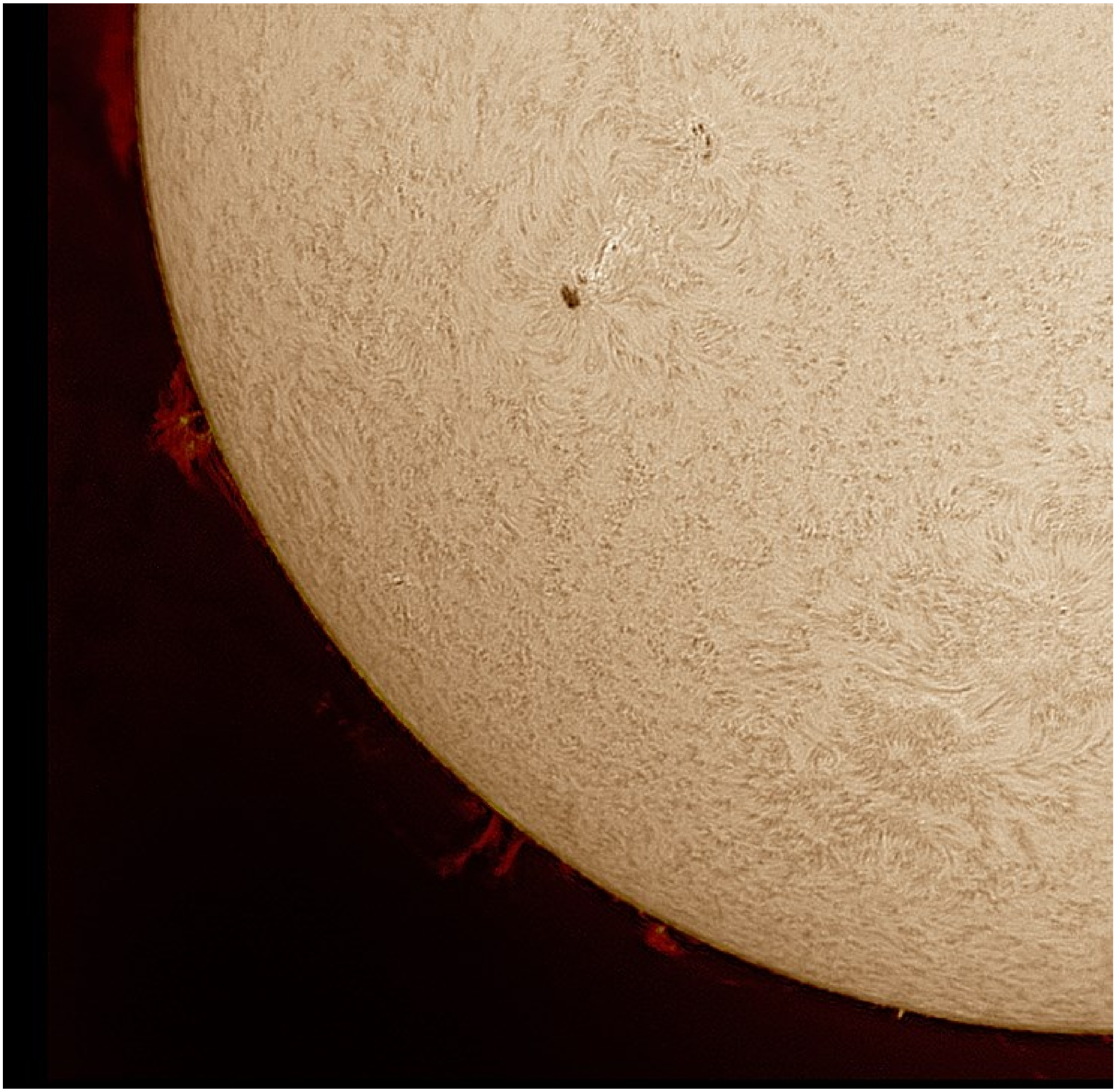
Einstein's paper on lensing is at https://www.science.org/doi/10.1126/science.84.2188.506. The idea of lensing was actually proposed by R.W. Mandl, as Einstein notes. Mandl's story is fascinating: see https://is.gd/rwmandl.

North American Nebula by David Parmet

David celebrated his new equipment by heading out to the Cherry Springs Star Party. His light-weight set-up consists of a ZWO ASI533 camera, Redcat 51 f/4.9 telescope, Star Adventurer GTi mount, and ASIAIR Plus. The image is 20 guided frames of 180 seconds (3 minutes) each, dithered, stacked and all calibration frames (15 each) were applied. Astrometry.net tells us that this image is 2.6 x 2.6 degrees, centered at RA 20h 59m 23.745s, Dec +44° 21' 33.493". The resolution in the original image is 3.12 arcseconds per pixel.

David commented, "I actually like the square format [of the ASI533]. I used to shoot film on a Hasselblad so it's somewhat like returning home for me. Just substitute PixInsight for the darkroom." As someone who learned photography with a square format (6x6 cm negative) Rolleiflex twin-lens reflex camera, your editor feels the same way and also just acquired a 533.

The H-alpha Sun on April 20, 2023 by Rick Bria



Rick used the 80-mm Lunt hydrogen-alpha telescope at the Mary Aloysia Hardey Observatory to take this image of the Sun's chromosphere using a monochrome ASI 290 camera. The color was added in post-processing. Numerous prominences are seen on the Sun's limb, and a sunspot pair is seen on the Sun's face.

The hydrogen-alpha absorption line at 656.281 nm shows the Sun's chromosphere, the 2,000-3,000 mile thick layer just above the solar "surface" (the photosphere, which is the layer that emits the Sun's thermal radiation that we see as the "white light" spectrum). The temperature in the chromosphere is cooler than the photosphere at their boundary, but then rises to as high as 35,000 K before transitioning to the corona. The chromosphere is also about one ten-thousandth as dense as the photosphere. Prominences, properly solar filaments, arise in the photosphere and pass through the chromosphere into the lower corona.

Messier 13 by Olivier Prache

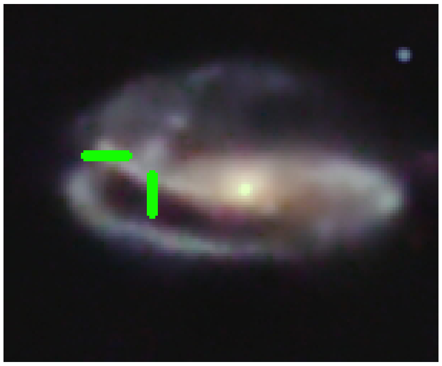
Although M13 is the most famous and frequently viewed globular cluster in the northern sky, it's only the fourth brightest (after M22, M4 and M5). The southern hemisphere has the two brightest globulars (Omega Centauri and 47 Tucanae) and two others brighter than M13 (NGC 6752 and NGC 6379). The small galaxy found by triangulating the red makers is IC 4617, a Seyfert 2 galaxy with a red shift of 0.036, g magnitude 15.59. Galaxy NGC 6702 (mag 11.6), which can be glimpsed in moderate-sized telescopes, is just beyond the top of the image. The field is 49 arcminutes on each side. More in globular clusters in the February 2023 SkyWAAtch, page 9.

Olivier made this image with a 12.5-inch Hyperion RC astrograph; 5.5 hours of exposure through LRGB filters.

The Tadpole Galaxy by Steve Bellavia

The Tadpole, catalogued as Arp 188, UGC 10214 or VV 29 is a gravitationally disrupted spiral galaxy in the constellation Draco. About 100 million years ago Arp 188 interacted with a smaller galaxy, creating a tidal stream of stars that is now some 280,000 light years in length, as well as provoking a vast amount of new star formation. The Tadpole's faint tail of stars is seen to the right of the galaxy. The smaller galaxy passed behind the Tadpole and is still faintly visible, as seen in the enlargement below. Steve made this image on May 18 at Cherry Springs. The field of view is 17.9 x 11.9 arcminutes. Technical information and full resolution image at https://www.astrobin.com/w6tqxr/.

There are more distant galaxies in this field. The elliptical galaxy at 11 o'clock is MCG+09-26-054 (mag 15.5, *z*=0.031). Just to the left of UGC 10214 is a small spiral galaxy LEDA 2502068 (mag 17.21, *z* not given), while below the bright star HD 145223 (mag 8.35) on the right is a small spiral PGC 2503300 (2MASX J16065582+5528169, mag 16.86, *z*=0.12).



Location of the smaller interacting galaxy

The Arp Catalog of Peculiar Galaxies was published in 1966. The images in the catalog were taken from Mt. Wilson and Palomar Observatories. The full catalog, with negative images of each galaxy, is now on-line at http://ned.ipac.caltech.edu/level5/Arp/frames.html. The VV catalog was compiled by the Russian astronomer Boris Vorontsov-Velyaminov and is available as a text file at http://www.sai.msu.su/sn/vv/. Vorontsov-Velyaminov also compiled the more frequently cited Morphological Catalogue of Galaxies (MCG), which was based on examination of the plates of the Palomar Sky Survey.

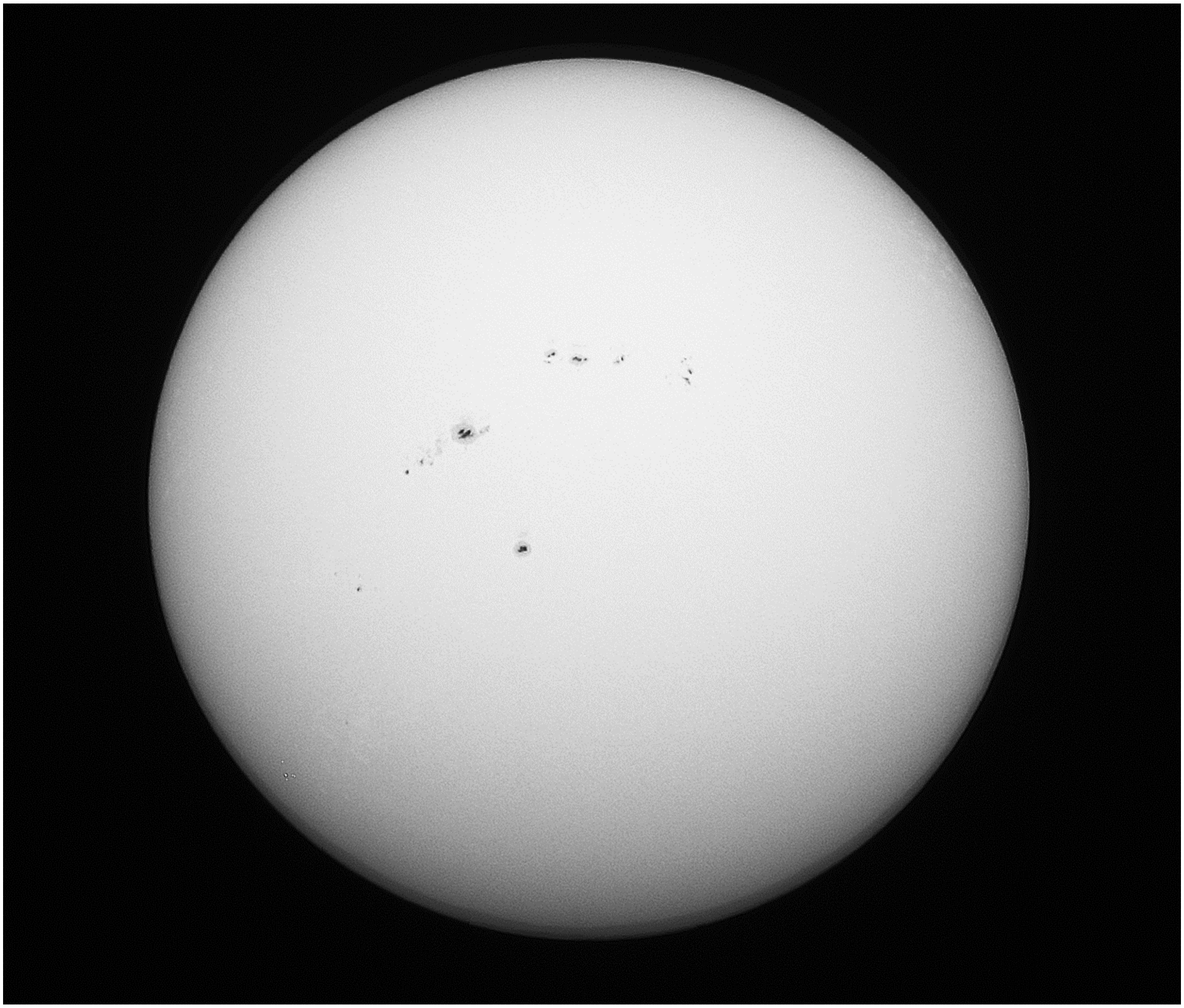
Two Galaxies by Arthur Miller

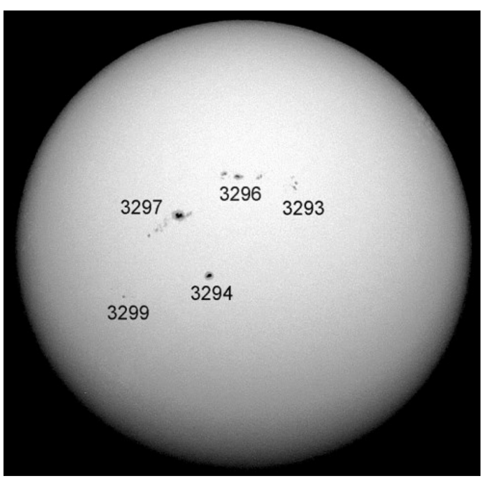
WAA member Arthur Miller images from his winter home in Arizona, using an 11-inch Celestron SCT.

NGC 3718 in Ursa Major is distorted by its gravitational interaction with NGC 3729, 11 arcminutes away, but just below the lower edge of this image.

NGC 4535 is a relatively face-on spiral in Virgo.

Sun in White Light by Larry Faltz



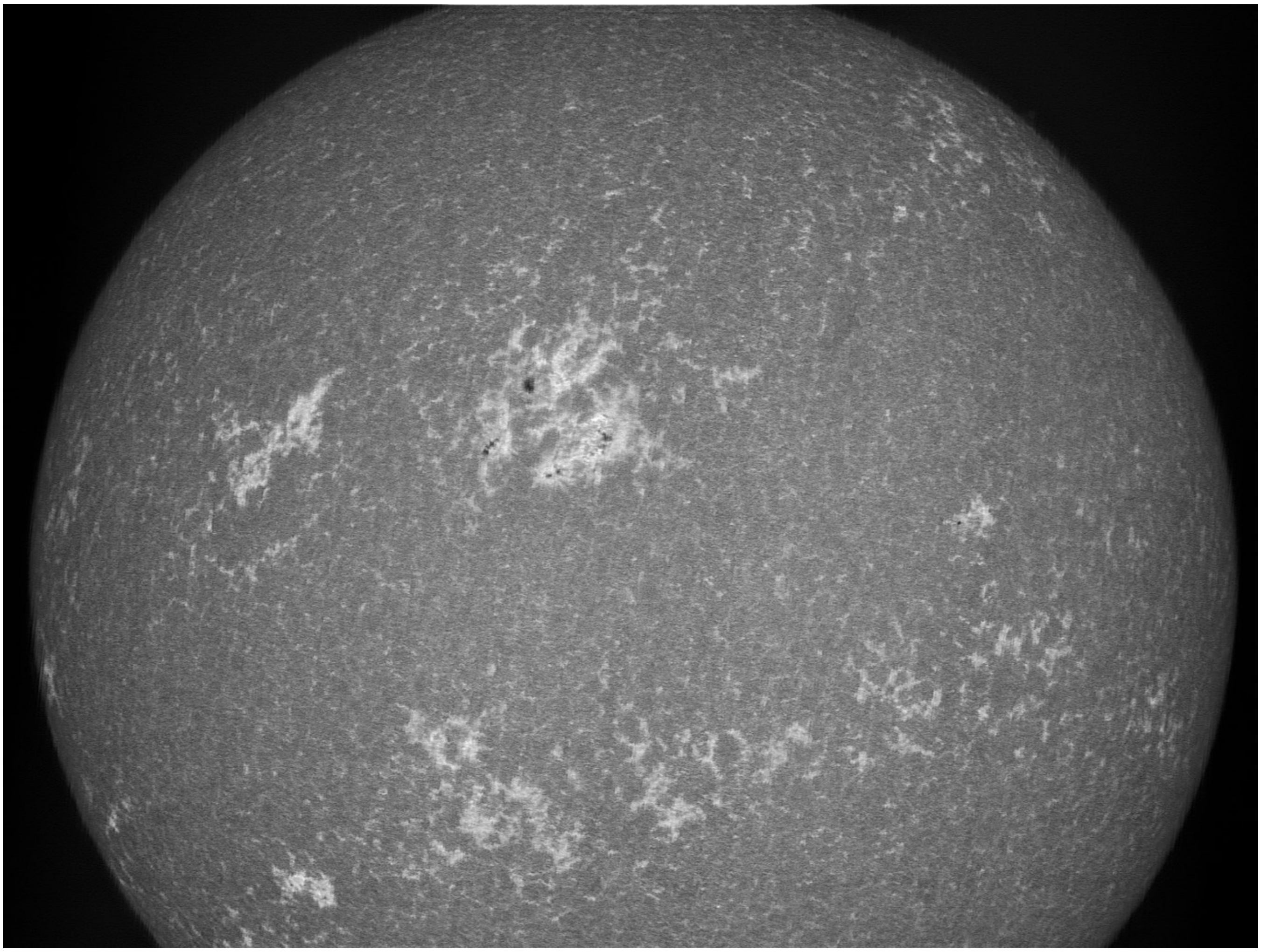


A very nice sunspot group appeared during the first week of May. On May 7, I made a quick shot with my venerable Stellarvue "Nighthawk" AT-1010 80-mm f/6 achromat refractor and Baader mylar filter on a SkyWAtcher AZ-GTI mount. Canon T3i DSLR, single frame at ISO 100, 1/3200 sec. Converted to monochrome.

Sunspots are cooler areas in the photosphere where magnetic field lines have become concentrated, reducing the flow of the underlying plasma and retarding convective heat loss.

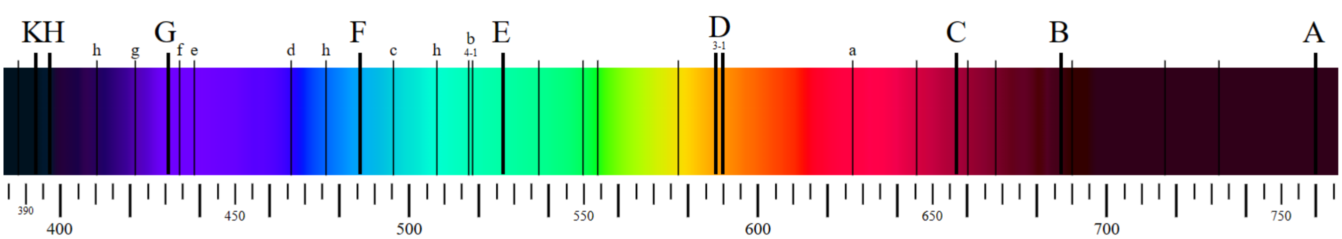
The active regions are numbered in the inset, as listed on spaceweather.com.

The Sun in the CaH Line on May 15, 2023 by John Paladini



John used his home-made spectroheliograph to capture the Sun in the near ultraviolet at the Ca H wavelength, 396.847 nm. The K line, also often chosen for imaging, is at 393.366 nm.

The solar absorption lines were named by Joseph Frauenhofer starting in 1816, but not correlated with specific elements until the studies of Kirchoff and Bunsen in 1859. Imaging the CaH and CaK wavelengths shows the magnetic structure of the Sun. The field is strongest in the bright regions.

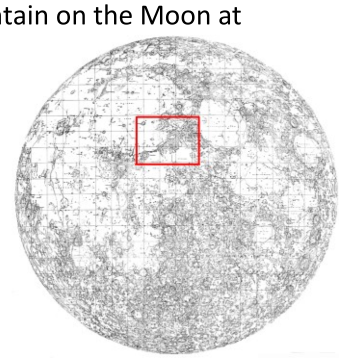


The most intense absorption lines in the visible solar spectrum are A and B (absorption from oxygen in the Earth's atmosphere), C (hydrogen alpha), D (sodium doublet), E (iron), F (hydrogen beta), G (iron and calcium, just 0.016 nm apart and so seen as a single line at this resolution) and H and K (calcium). A spectroheliograph allows imaging in any wavelength with a very narrow bandwith.

Eratosthenes and the Apennines by Larry Faltz

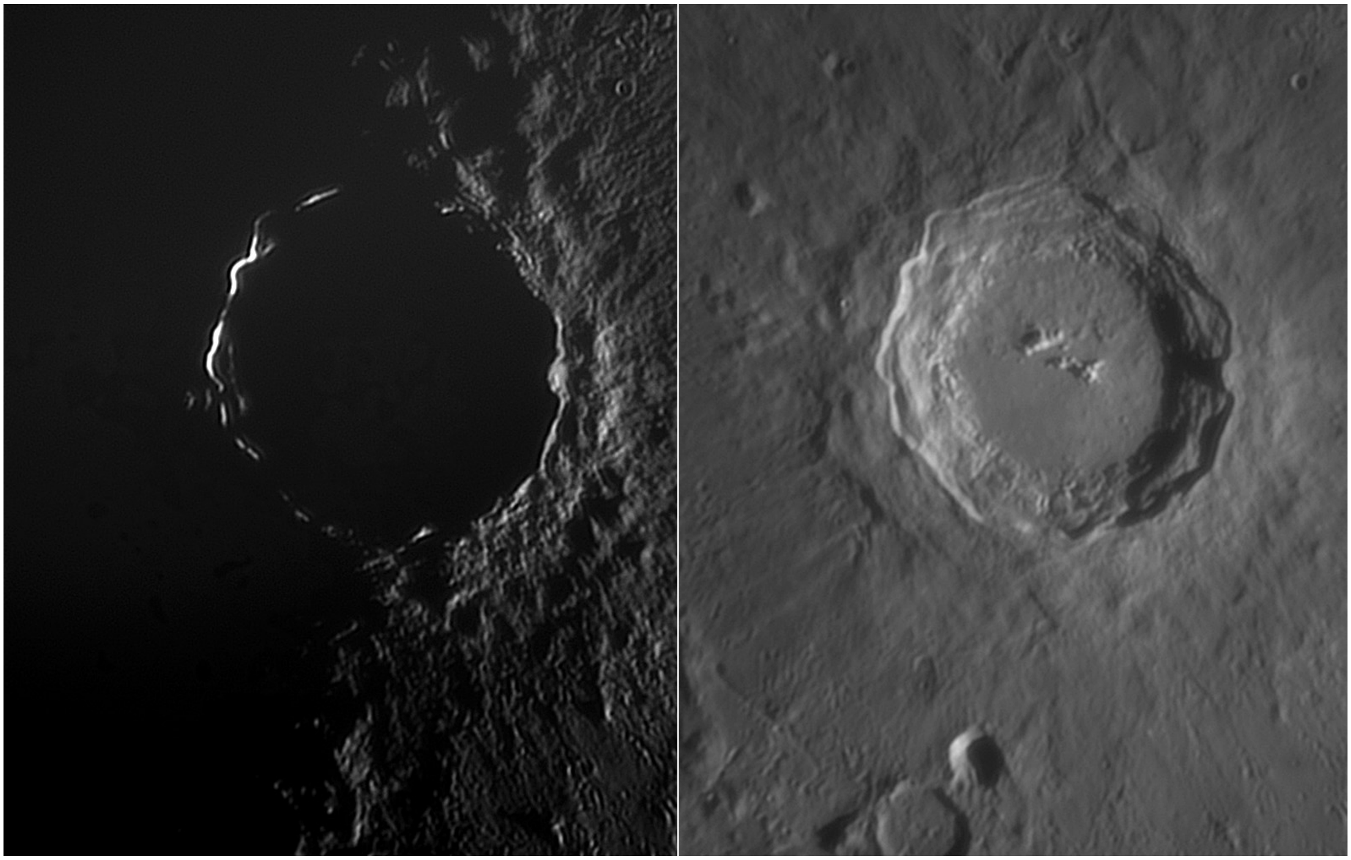
Gerald North, in his *Observing the Moon* (2000) writes "If any feature on the Moon can take the prize for being the most striking when seen through even the smallest telescope at the appropriate time, then surely it has to be the magnificent Montes Apenninus. The 'appropriate time' for this formation occurs twice every lunation near the first and last quarter Moon."

At 9:30 p.m. on May 28, 2023, the Moon was a bit past first quarter, 9.15 days old and 61% illuminated, perfect for examining the Apennines, so named by Johannes Hevelius in his famous 1647 map in *Selenographia*. The name persists even though Hevelius' appellations for lunar craters were supplanted by Riccioli in 1651. The crater Eratosthenes sits just past the southwestern limit of the mountain range. The flat crater Archimedes Is bisected at the upper edge of the image (sorry about that, but the camera's sensor is only 1920x1080 pixels). Below it is a rough area called the Montes Archimedes, giving way to the smooth lava floor of the southeastern edge of the Mare Imbrium. Between Archimedes and the northernmost peaks of the Apennines is a smooth area called the Palus Putredinus ("The Marsh of Decay"), so named by Riccioli for completely unclear reasons. Maybe he just had a bad day. In the center of the image is Mons Huygens, the highest mountain on the Moon at 18,046 feet elevation above the floor of the Mare Imbrium. Mountains on Earth are formed by tectonic plate movement, but lunar mountains are the product of impacts, in this case the huge blow that created the Mare Imbrium. The sharp crater on the upper left is Timocharis, while in the lower right the similarly sized Manilius sits at the northeastern edge of the Mare Vaporum.



Celestron CPC800 at f/10, ASI290MM camera, best 25% of 4,000 frames, stacked with Autostakkaert!3, wavelets in Registax 6.1, final brightness/contrast processing in Photoshop Elements.

What a Difference a Day Makes by Larry Faltz



On the left, the first rays of sunlight illuminate the top of the western wall of the crater Copernicus, which was right on the terminator when this image was made on May 28th. The interior of the crater was in complete darkness. Exactly 24 hours later, the Sun was high enough to show the central peak and the 93-km wide impact crater's floor and scalloped walls. The central peak rises 1.2 km from the crater floor, but the walls are 3.8 km high, and project a good bit above the surrounding plain.

Details around the outside of the eastern wall (to the right) in the 5/28 image show some of the complex topology that loses definition when the angle of the Sun increases. On the other hand, darkness shows nothing!

Both images were made with a Celestron CPC800, 2X Barlow, ASI290MM camera. Images are same scale.

North-south cross section of Copernicus (NASA, Lunar Reconnaissance Orbiter,
Northeast Planetary Data Center, NASA RPIF System

While making the image on the 29th, a neighbor stopped by with her six year-old daughter and the family dog. I switched out the camera and showed the Moon through an eyepiece. They loved the view. Looking at the impressive telescope, the daughter said to her mother, with some awe, "This must cost a hundred dollars!" I think she was just starting to be taught the concept of money, and $100 must have seemed a princely sum. Mom chuckled and replied "No, it's much more expensive." I mentioned that the 24-mm Televue Panoptic eyepiece we were using sells for $340. Trying to comprehend the value, the six year-old gasped and said, "Do you have that much money?" to which I could only look at the eyepiece and sigh, "Not anymore."

Research Highlight of the Month

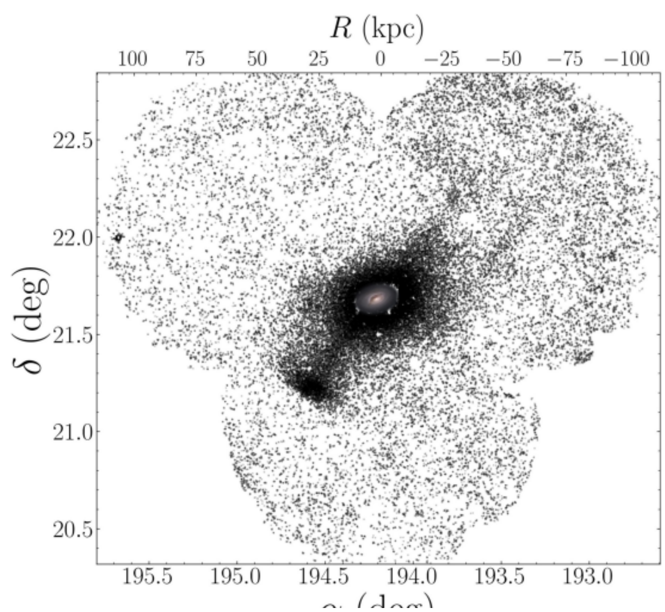
Smercina, A, et. al., Origins of the Evil Eye: M64's Stellar Halo Reveals the Recent Accretion of an SMC-mass Satellite. https://arxiv.org/pdf/2305.17135.pdf.

Abstract: M64, often called the "Evil Eye" galaxy, is unique among local galaxies. Beyond its dramatic, dusty nucleus, it also hosts an outer gas disk that counter-rotates relative to its stars. The mass of this outer disk is comparable to the gas content of the Small Magellanic Cloud (SMC), prompting the idea that it was likely accreted in a recent minor merger. Yet, detailed follow-up studies of M64's outer disk have shown no evidence of such an event, leading to other interpretations, such as a "flyby" interaction with the distant diffuse satellite Coma P. We present Subaru Hyper Suprime-Cam observations of M64's stellar halo, which resolve its stellar populations and reveal a spectacular radial shell feature, oriented ∼30° relative to the major axis and along the rotation axis of the outer gas disk. The shell is ∼45 kpc southeast of M64, while a similar but more diffuse plume to the northwest extends to >100 kpc. We estimate a stellar mass and metallicity for the southern shell of $M_\star=1.80 \pm 0.54\times10^8\ M_\odot$ and $[M/H] = -1.0$, respectively, and a similar mass of $1.42 \pm 0.71\times10^8\ M_\odot$ for the northern plume. Taking into account the accreted material in M64's inner disk, we estimate a total stellar mass for the progenitor satellite of $M_{\star,prog} \simeq 5\times10^8\ M_\odot$. These results suggest that M64 is in the final stages of a minor merger with a gas-rich satellite strikingly similar to the SMC, in which M64's accreted counter-rotating gas originated, and which is responsible for the formation of its dusty inner star-forming disk.

We've always called it the "Black Eye" galaxy, not the "Evil Eye," but it's also been paradoxically called the "Sleeping Beauty" galaxy. In moderate-sized telescopes, M64 has a distinct central star-like nucleus surrounded by dust, outside of which is a diffuse shell rich in gas. In 1992 the shell was found to rotate in the opposite direction from the galaxy's inner stars. For satellites in the solar system, retrograde motion indicates gravitational capture of a passing body. It makes sense to think that galaxies can interact in a similar manner, and the well-studied dynamics of the Milky Way clearly show detailed evidence of interaction with local dwarf galaxies and capture of their stars and gas. M64 displays dramatic evidence of capture on a massive scale.

The authors used the Subaru telescope on the summit of Mauna Kea to examine red giant branch stars in three regions surrounding the galaxy beyond the visible gas. They discovered a stellar halo on either side. They were able to conclude that the halo formed from a fairly recent merger, still continuing, of M64 with a satellite galaxy that has the size and metallicity of the Small Magellanic Cloud. It had previously been suggested that M64 interacted with an "almost dark" galaxy in the Coma cluster called Coma P. It may have in the past, but Coma P is now too distant (>5°) to participate in the current, ongoing interaction.

The morphology of the stellar shells suggest that the smaller northern shell formed from more loosely bound stars on an earlier passage of the infalling satellite galaxy, while the denser southern shell represents a pileup of stars following a more recent encounter, containing stars that were more closely bound to the inner regions of the disrupting satellite galaxy. ■



From Fig.2 of the paper, showing a spatial map of the stellar sources. An image of M64 is superimposed, to provide context for the spatial extent of the stellar halo.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
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.	$300	Larry Faltz lfaltzmd@gmail.com
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
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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