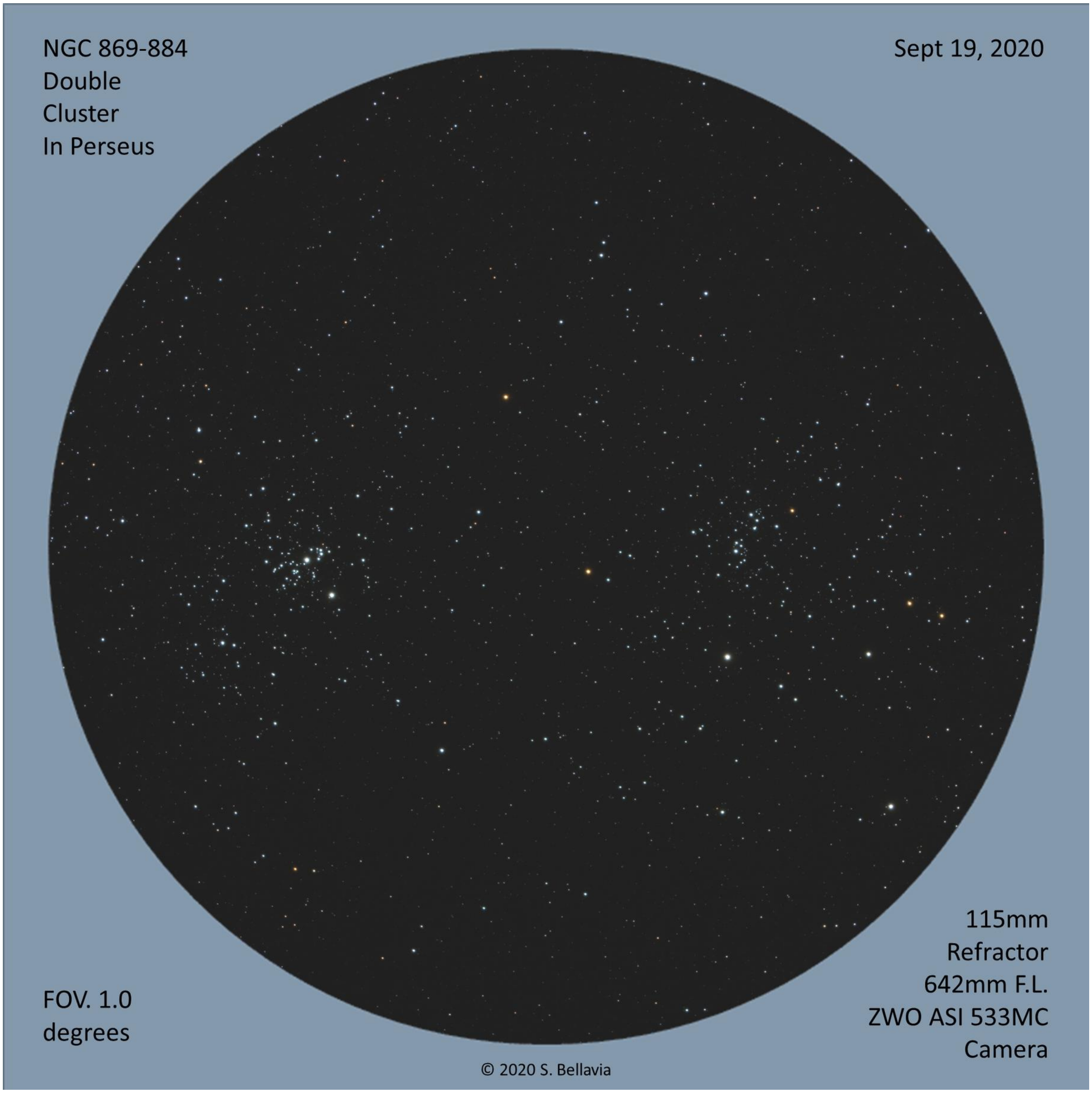
SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

December 2020



An eyepiece view of the Double Cluster by Steve Bellavia.

WAA December 2020 Meeting

Friday, December 4th at 7:30 pm

On-line via Zoom

Intensity Mapping of the Large Scale Structure of Matter

Paul O'Connor, Ph.D.
Brookhaven National Laboratory

Paul O'Connor is Senior Scientist at Brookhaven's Instrumentation Division. He was a member of the team that built the CCD camera for the Large Synoptic Survey Telescope (now the Vera Rubin Telescope) in Chile, the largest digital camera in the world. He is currently working on designing radio telescope instrumentation for improved mapping of the 21-cm HI (neutral hydrogen) line, with the goal of creating a 3-dimensional map of the matter density of the universe. This will be key to understanding the formation and evolution of galaxies and the behavior of the cosmic web.

Pre-lecture socializing with fellow WAA members and guests begins at 7:00 pm!

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

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

Also In This Issue

WAA January 2021 Meeting

Friday, January 15th at 7:30 pm

On-line via Zoom

Microquasars

Diana Hannikainen, Ph.D.
Observing Editor Sky & Telescope

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

Starway to Heaven

Ward Pound Ridge Reservation, Cross River, NY

Our next club star party will be in March 2021. Members are invited to view at Ward Pound Ridge Reservation on clear nights, provided they notify the park in advance and bring their ID cards.

New Members

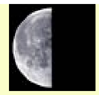
Uziel Crescenzi	Bronx
Rodrigo Morales	Hartsdale
Francesca Varga	Pleasantville
Carlos Vegerano	Bronx

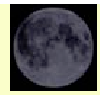
Renewing Members

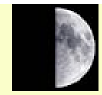
Edgar S. Edelmann	Tarrytown
Eileen Fanfarillo	Irvington
Sharon and Steve Gould	White Plains
John Higbee	Alexandria, VA
Bob Kelly	Ardsley
Robert Lewis	Sleepy Hollow
The Maida Family	Portchester
William Meurer	Greenwich, CT
Satya Nitta	Cross River
Olivier Prache	Pleasantville
Kevin Shea	Carmel
Woody Umanoff	Mount Kisco
Oliver E. Wayne and Elizabeth Scott	Cliffside Park, NJ

The December meeting is the official Annual Meeting of WAA. Ballots for the slate of officers were sent to members by email on November 18th. Votes must be received by 7:30 pm on December 4th.

ALMANAC For December
Bob Kelly, WAA VP for Field Events


3Q
12/7


New
12/14


1Q
12/21


Full
12/29

Find a clear southwestern sky to see Jupiter and Saturn early in December and follow them as they slink toward the horizon through the Great Conjunction on the 21st. You'll be able to cover them with one finger for a week around the 21st, so if the weather isn't going to be great that day, you still have several days around closest approach to see this impressive sight. Conjunctions of the two planets occur every 19.6 years, but there hasn't been one this close since 1623, when Galileo was still alive (and still had his eyesight)! See page 4 for more information on this rare event.

Saturn, magnitude +0.6, would be a prominent object if it wasn't paired with ten times brighter Jupiter at -2.0. It seems dull by comparison, belying its beauty in a telescope. While Jupiter's fantastic four (the Galilean moons) will still be visible in a telescope, Saturn's moons will be harder to see as it gets lower and more of our atmosphere gets in the way. It's also 20% farther away than at July's opposition.

Early morning Venus moves closer to the horizon, while still keeping over 20 degrees from the Sun. Keep track of the magnitude -3.9 morning star and you'll follow it into February.

Mercury passes by the Sun on the 20th. It's only a Solar & Heliospheric Observatory object this month.

Mars is still a bright red gem high in the evening sky. It's getting dimmer and smaller. Details will be harder to see even in a large telescope. Watch and see if the reddish tint fades this month. Observers are seeing dust storms expanding over the planet, so the lighter colored dust may take the edge off Mars's reddish glow.

It's also a good time to spend some of our longer evenings on the other outer planets, Uranus and Neptune, which are highest in the evening.

The meteors from the Geminid shower come slow and furious. They peak at a meteor or two per minute (on average) on the 14th at 01:00 UT, which is 8 p.m. on the 13th our time. You might see a satisfying number of chips off of asteroid 3200 Phaethon after dark on the evening of the 13th, unlike other showers which are vastly better after midnight.

We have some comets that might be observed in binoculars this month. C/2020 M3 ATLAS (magnitude around 8) dims as it moves across Auriga from magnitude +1.6 Elnath to magnitude 0 Capella in the evening sky. C/2020 S3 (Erasmus) is bright at magnitude 6-7 but sinks quickly into the morning Sun, moving across the northern part of Scorpius. It will show up in SOHO's cameras around Christmas.

The Big Dipper starts to rise from its annual scooping up of water on the northern horizon. Cygnus, the Northern Cross, flies to the northwestern horizon, taking the Milky Way with it. Orion looks lazy, lying on his side at its rising after sunset early in December. The hunter and his menagerie are well up in the evening sky by the end of the month.

Our Winter Solstice occurs at 5:02 a.m. on the 21st.

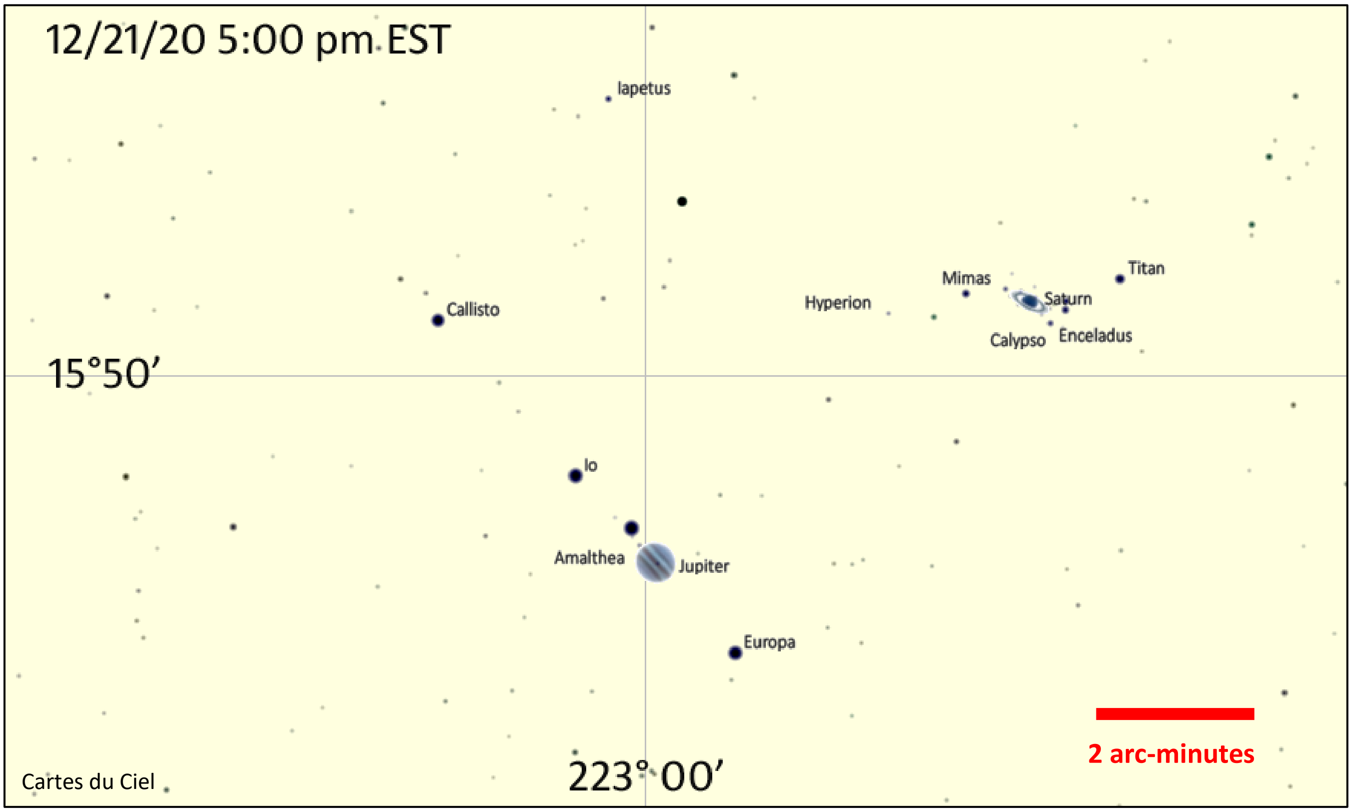
The earliest sunsets of the year are at 4:27 p.m. EST on the 7th and the 8th, so the evenings are going to get a bit brighter with sunset ten minutes later by the end of the year. Morning darkness will last later into early January. If you want to calculate sunrise and sunset times for yourself, make a spreadsheet from the NOAA Global Monitoring Laboratory, https://www.esrl.noaa.gov/gmd/grad/solcalc/index.html since the US Naval Observatory site is still down for repairs.

On the 14th, a Total Solar Eclipse will occur across southern South America. We won't even see a partial eclipse in the USA.

The brightest star to be occulted by the Moon this month will be ν Piscium on the evening of the 23rd. The magnitude +4.5 star, formerly known as 51 Ceti, will be covered up by the dark edge of 69% illuminated Moon just after 10 p.m. EST.

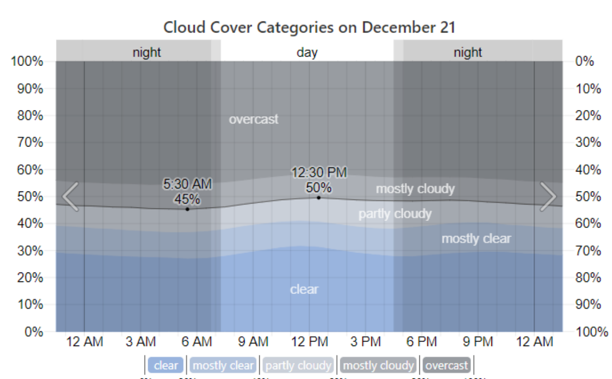
The International Space Station, with seven souls aboard, may be visible during the evenings through the 12th, and in the mornings starting on the 17th. ■

Viewing the Great Conjunction



On the day of closest approach (just 6 arc-minutes between them), the two planets will be very low in the southwestern sky. Jupiter will be at magnitude -2.0, Saturn at +0.6. Try to align on Jupiter as early as you can after sunset using your finder. The table below gives altitude of Jupiter, the lower of the two planets, for the important times that evening.

Time	Event	Jupiter
4:29 p.m.	Sunset	19° 30′
5:34 p.m.	Nautical twilight ends	11° 11′
6:07 p.m.	Astronomical twilight ends	06° 17′



From the northern edge of the center of the Meadow Parking Lot at Ward Pound Ridge Reservation (our usual star party site), the two planets should stay above the tree line until about 6:30 p.m., some surveying I did recently. [Call the park in advance if you plan to observe there.] Another possibility is along the Hudson River at a good elevation where the view would be above the top of the Palisades. You should survey any potential observing site to be sure you are not surprised and disappointed on the day of the event.

The possibility of cloudiness in late December is substantial. Historically, the skies in our area on December 21st are overcast or mostly cloudy 51% of the time, and mostly clear or clear only 30% of the time. You may have to console yourself with a view on another night; the planets will be within 1 degree of each other from the 12th to the 29th of December. But not a mere six arc-minutes, the closest since 1623.

The 2.6-magnitude difference between the planets will be a bit of challenge for imagers. LF

Member Profile: Leandro Bento

Home town: I'm originally from a town called Sao Goncalo in Rio de Janeiro's Metro area (Brazil). But I have been living in Westchester for most of my life in the U.S.

Family: A very small family, just my wife Lisa, myself and a cat.

How did you get interested in astronomy? The night sky always fascinated me since childhood. I didn't have a telescope but I used a pair of binoculars to scan the southern sky and I loved to check the star's different colors. I loved to just lie on the ground and stare into the sky and wonder what – and who – is out there.

Do you recall the first time you looked through a telescope? What did you see? Jupiter. After buying a cheap telescope at my job years ago, I noticed a very brilliant "star" shinning high in the winter sky and I was curious to what that was. My wife and I took that scope to the backyard – we lived in Yonkers at the time – and after much struggle to get that "star" in the eyepiece I saw a - crappy - image of Jupiter. Even though the optics weren't great, seeing the planet fascinated me and I was hooked again.

What's your favorite object(s) to view? I don't really have a favorite object as everything fascinates me. Everything is interconnected. But I enjoy the views of globular clusters through the eyepiece; they look magical as if there is fairy dust out in space.

What kind of equipment do you have? I have an Orion 12-inch Truss tube Dobsonian which is my main scope; a 6-inch Orion Newtonian that is somewhat portable and that I sometimes use to see bright objects and star colors from my deck; a Coronado PST solar scope; a good collection of eyepieces and the William Optics Redcat 51 I've been using now in my first steps doing astrophotography. [Leandro's spectacular wide-field image of the entire Veil Nebula appears on page 19 of this issue].

What kind of equipment would you like to get that you don't have? For astrophotography I'd like to have a good equatorial go-to mount, like the Sky-Watcher EQ6R Pro. I'm using the Ioptron Skyguider Pro (a tracker), which works well, but it is painful to point it anywhere in the sky by manually moving the scope and even almost impossible to properly frame it that way. I'd like a bigger Dobsonian of at least 16 inches for visual observing. I love Dobsonians. My photography needs automation, but I love to hunt for my object when doing visual.

Have you taken any trips or vacations dedicated to astronomy? Tell us about them. Not to any exotic location, but I went to RAC Summer Star Party in Massachusetts three times and twice to Cherry Springs State Park in Pennsylvania. In my first trip to the Summer Star Party, we had a beautiful clear night where I could see in great detail M51, M31, and the Dumbbell and Ring nebulas. I've never seen anything with such clarity since then. The detail visible on M31 was breathtaking, even looking through the 8-inch Meade SCT I had at the time.

Are there areas of current astronomical research that particularly interest you? Nothing specific. I read everything space related. I subscribe to both S&T and Astronomy magazines and read many books about astronomy and astrophysics.

Do you have any favorite personal astronomical experiences you'd like to relate? I haven't seen a total solar eclipse yet and I'm sure that must be the most fascinating astronomical experience ever, but I once saw, while observing the planets in Yonkers, a fireball fragmenting and traveling about 20 degrees of sky northward. It was like something out of a movie. While all meteors are great, nothing really beats a fragmenting fireball.

What do you do in "real life"? I work at the B&H Photo store in Manhattan as the floor manager for the Used Dept. It is a good job, and even though we are not an astronomy-related company (we do sell telescopes though), I get to talk and teach some people the principles of astrophotography and stargazing in general.

Have you read any books about astronomy that you'd like to recommend? A book thatwas released in 2016 prior to the solar eclipse, called *Sun-Moon-Earth, The History of Solar Eclipses From Omens of Doom to Einstein and Exoplanets*, by Tyler Nordgren. It is a great historical account and it explains well the dynamics of eclipses to the general public.

How did you get involved in WAA? After getting my Meade 8-inch SCT, which was my second telescope after the cheap one mentioned earlier, I wanted to get more involved in stargazing and I searched for the local astronomy club. I found WAA and I joined it. Larry took a picture of my wife and I next to the SCT in our first star party attendance ever, and that picture is still in the slideshow of WAA's main web page!

What WAA activities do you participate in? Unfortunately star parties are the only event I have been engaged in so far. I work long hours and I am usually tired when I get home. I had planned to get more involved this year in outreach events but the pandemic got in the way. Hopefully it will come to pass next year.

If you have or have had a position in WAA, what is it, what are/were your responsibilities and what do you want the club to accomplish? I never held any position in the club, but light pollution is my main concern. I've been living in Mohegan Lake (Cortlandt) in northern Westchester for four years and I've noticed a great increase in light pollution just in the time I've been living here. Maybe there is something we can do to raise awareness of light pollution and make some changes.

Besides your interest in astronomy, what other avocations do you have? I used to play the drums and I also play the *cavaco*. It is a little Brazilian four-string guitar that has the same roots of the Hawaiian Ukulele and the Portuguese machete. But they are not the same instrument.

Provide any other information you think would be interesting to your fellow club members, and don't be bashful! This is just for fun; I still have an instrument that got me hooked in astronomy back in the 80's. It's a wooden astrolabe I built (see photo) and it helped me measure the Sun's motion in the sky throughout the year and plot the Sun's position in different seasons. Also, it measured the star's positions. I could plot the nightly star's motion in a single night by measuring successively throughout the night, and the star's yearly motion when measured consecutively at the same time of night each day. I would then be able to plot the motions in a sky chart.

First Timer at Ward Pound Ridge

Greg Borrelly

It was a Saturday, a clear night, and a new moon. Sounds almost like fiction, but the conditions were perfect as my wife and I headed towards Ward Pound Ridge Reservation in October for our first observing session there since joining WAA. We raced against the setting sun in an attempt to get there before sunset to avoid setting up in the dark. Tonight's agenda is a mixture of visual observing and astrophotography. Both activities benefit from darker skies. The Clear Outside web site[1] shows my skies at Yonkers to be Bortle zone 8, 18.33 mag/arc-sec[2], while they show Bortle zone 4 and 20.67 at WPRR. That's more or less a three order magnitude difference. I crunched the numbers as we made our way through traffic, and my observing site at home comes out to be about 15 times brighter! In theory, when doing AP from home, I would need 15 times more exposure to get an image that matches the same quality as one taken at WPR, which is, of course, a huge difference! Three hours at WPR would yield an image matching in quality to a 45-hour image back at home, and all for a short 1-hour drive.

The target was the Wizard Nebula in Cepheus, Sh2-142. The open cluster NGC 7380, which is embedded in the nebula, was discovered by one of my favorite astronomers, Caroline Herschel, back in 1787. The Wizard is estimated to be 4 million years old. I could not be more thrilled for a better target. I planned my session using Telescopius,[2] framing the nebula using my telescope/camera field of view, and confirmed the time it would transit the meridian. The plan going in for the night was to grab three hours of exposure starting one hour before the Wizard transited the meridian.

When we arrived at the park, it was already dark. We drove as slow as possible[3] to avoid disturbing any wildlife going about their business in the dark. While our driving was slow, my mind was racing, and the slow-moving car seemed to fall behind as my mind left it and began the setup process. Eventually, my wife made a turn and saw several red lights moving around the dark. I was awed when I stepped outside of the car. Looking straight up, I could make out the Milky Way, and part of me wanted to lay on the ground and do nothing but stare at it. But I was already in a time crunch and had to get moving. I set up the AVX with my William Optics GT71 mounted on it.

Polar alignment was a mess. I could not see anything through the scope despite trying several long exposures. I knew I was severely out of focus, but I could not see anything on the LCD screen of my Canon T6i.

After struggling with this for longer than I care to admit, I went into panic mode. I looked around, ready to ask for help when I heard a conversation between two WAA members in the park that night. I could not make out anything they said, but I fancied myself able to understand that they were busy troubleshooting some issues in the dark. This feeling of solidarity renewed my spirits. I mounted the GT71 on my Twilight mount to make it easier to point the scope towards a bright source. After a short struggle, I managed to get Jupiter. I still don't understand today; I could not see Jupiter in the live preview like I usually can back home. I managed to finally focus by taking short subs on the Twilight and tweaking the focuser between shots. At last, success! I locked the focuser and mounted the GT71 back on the AVX.

The rest of the night went smoothly. I did a polar alignment in minutes using SharpCap and star aligned using the controller. I was imaging the Wizard in no time. It was time for my visual treat. I set up my 120ST on the Twilight. I spent the rest of the night in Cassiopeia, lost in a field of stars at times, getting the feeling I no longer stood on solid ground. Later during the night, I had the pleasure of meeting WAA President Paul Alimena. It was a great night!

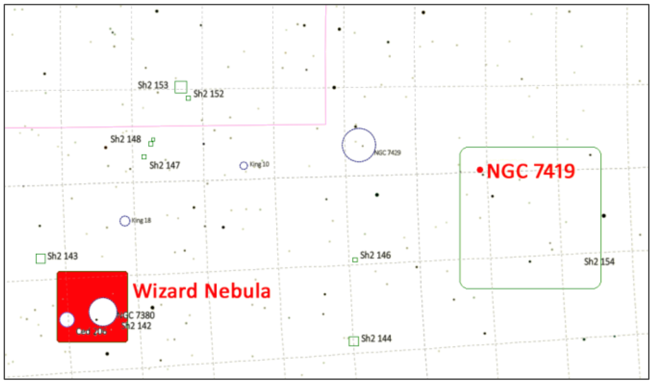
We made our way back home, making a stop at a Wendy's to grab some burgers. As I took my first bite, it hit me like a pile of bricks: I could not remember setting the location for my AVX when I was doing the alignment. I kept this in the back of my mind but sure enough when I got home and stacked the subs. I had a beautiful star field but no Wizard. With mixed feelings, I went to bed. The next morning I used https://nova.astrometry.net to upload one of my subs and plate-solve it. I had shot NGC 7419. I then went to Stellarium and discovered I had been some 2° 53' north of the Wizard. It was bittersweet but

[1] https://clearoutside.com/

[2] https://telescopius.com/

[3] 15 mph speed limit in the park anyway!

learning from my mistakes that night, I have made several improvements on my setup, and I'm looking forward to the next clear night.



A 4.4 x 2.7 degree section of the southern border of Cepheus (Cartes du Ciel)

Enlarged view of NGC 7419 from the full frame below

Editor's Note:

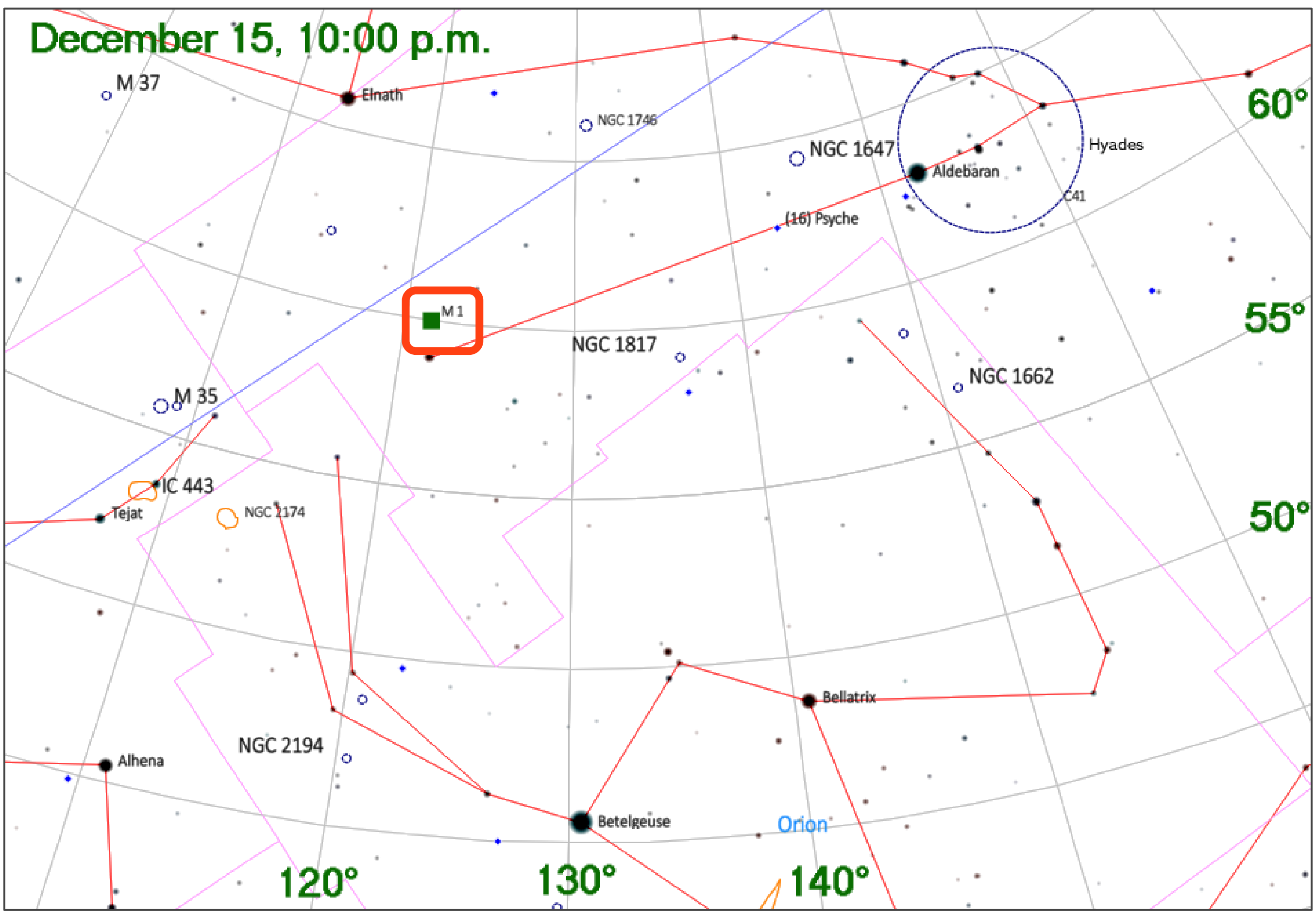
NGC 7419 is interesting in its own right. It has five red supergiant stars, the largest number in any open cluster discovered before the twentieth century. It is a prototype for calibration of more obscured clusters (see https://arxiv.org/pdf/1302.5649.pdf). This two arc-minute diameter cluster isn't mentioned by O'Meara, Harrington or French, but it does get a line listing in Burnham's *Celestial Handbook* with the description "pRi, cC" meaning "pretty rich, considerably condensed." Apparent magnitude 13, age 14 million years, distance 2,200 to 3,300 light years. Like NGC 7380, it was discovered in 1787 but the credit goes to William Herschel. Carolyn was undoubtedly there, writing down the information that William called out from his perch atop the "20-foot" re-flector.

Deep Sky Object of the Month: The Crab Nebula

Messier 1	
Constellation	Taurus
Object type	Supernova remnant
Right Ascension J2000	05h 34m 31.94s
Declination J2000	+22° 00′ 52.2″
Magnitude	8.4
Size	6′ x 4′
Distance	6,500 LY
NGC designation	1952

One of the most famous objects in the night sky but not often observed, the Crab Nebula is the detritus of the supernova of AD 1054. Its radius is now about 5.5 LY. The nebulosity was first noted in 1731 by John Bevis. At the center is a rapidly spinning neutron star, magnitude 16, pulsing every 33 milliseconds. Its magnetic field creates waves in the inner part of the nebula (see https://tinyurl.com/crabmag).

M1: Visibility for December 2020			
10:00 p.m. EST	12/1	12/15	12/31
Altitude	106° 19′	121° 32′	149° 38′
Azimuth	50° 34′	60° 03′	68° 27′



Observing Report: John Higbee and an 1857 Alvan Clark Refractor

John was the subject of our Member Profile last month. He is a graduate of the United States Naval Academy and now is in charge of the small observatory on the Academy's campus.

I spent Tuesday evening, October 6th, in the USNA Observatory with the historic 1857 Clark 7.75" refractor, viewing Jupiter, Saturn and Mars at length. I can honestly state that it was the best observing session I have had with any telescope in the last five years.

First, the details: The Clark has a focal length of 114 inches (2895 mm). We used three eyepieces:

- A Meade 55mm Plossl (yielding a magnification of 53 power)
- An Explore Scientific 32mm (yielding a magnification of 90 power)
- An Explore Scientific 14mm (yielding a magnification of 207 power)

Skies were beautifully clear – light wind from the south; transparency was very good, with some "boiling" intermittently. Temperatures dropped from the high 60s to the high 50s during the session.

I observed with a senior Midshipman who had just qualified as an observatory operator. We're working on getting a group of midshipmen qualified as operators so that the Observatory can be opened more often, and on short notice.

Jupiter:

53 power: the field of view showed the Galilean moons in a beautiful line, with two moons on each side of the planet.

90 power: When the skies steadied, significant detail was noted in the twin cloud bands north of the equatorial zone. The (not so) Great Red Spot was noted on the left hand side of the planet, several hours away from meridian transit.

Saturn:

53 power: the planet showed a sharp, small disc and rings image, with Titan clearly visible, in a not rich, but still pretty star field (the Clark's pinpoint star images never cease to amaze me).

90 power: the broad, bright equatorial band stood out clearly; Cassini's Division was visible in the *ansae* of the rings (I've been reading Rev. Webb's *Celestial Objects for Common Telescopes* and I am beginning to pick up some of his terminology); and several satellites were faintly visible in Saturn's close vicinity (I saw three, my fellow observer saw two).

207 power: Cassini's Division was visible around the whole of the rings; 3 close in satellites were visible; my fellow observer clearly saw the Crepe Ring (I didn't—the advantage goes to young eyes); the planet's shadow was evident on the ring to left of the disk.

Mars: **Phenomenal**!

53 power: when seeing steadied, large areas of gray-green were visible on the left side of the disk. The right side was orange-red with a tinge of white/violet on the right edge of the disk (violet thought due to chromatic aberration; white due to the polar cap).

90 power: More detail seen in the edge of the gray green mass…otherwise unchanged.

207 power: When seeing steadied, intricate detail on the grey/green mass's edge. Best Mars observing I have ever had!

We saw Syrtis Minor and Libya clearly, as well as Mare Cimmerium, including its two peninsular extensions. Syrtis Major was also clearly visible.

The really great part was that since we had no visitors, we could sit at the eyepiece for 10-15 minutes at a time, looking solely at each object during that period. It was a meditative experience unlike any other I had had, and visual acuity got better the longer we looked. This October on clear nights in Annapolis is going to be quite spectacular. ■

The End is Coming

Larry Faltz

It's not hard to imagine that we are approaching the End Times. The Covid-19 pandemic, conflagrations in the American West, melting of the Arctic ice cap, murder hornets, uncompromising political partisanship, accelerating economic inequality, the breakdown of traditional alliances, rampant disdain for science and the growing enthusiasm for patently absurd conspiracy theories suggest that we're on an inevitable slide to total destruction. And we actually are. The entire universe is scheduled to cease to exist, so what are you worrying about?

It seemed to be a good time for Katie Mack's new book *The End of Everything (Astrophysically Speaking),* which was published on August 4th. Mack is a young academic (Assistant Professor of Physics at North Carolina State University) pitching a popular account of something cosmic before she achieves, as she likely will, major scientific standing. It's in the spirit of Sarah Stewart Johnson's recent *The Sirens of Mars*, the story of the exploration of the red planet by NASA spacecraft, orbiters and landers. With Mars Perseverance on its way to the red planet, along with spacecraft from China and the United Arab Emirates, it's a good time to read Johnson's illuminating history. But Mars implies optimism: the search for life or the opportunity for emigration to save our species. Pessimism seems to be more in the spirit of the times, so Mack's book about the demise of everything is quite in order.

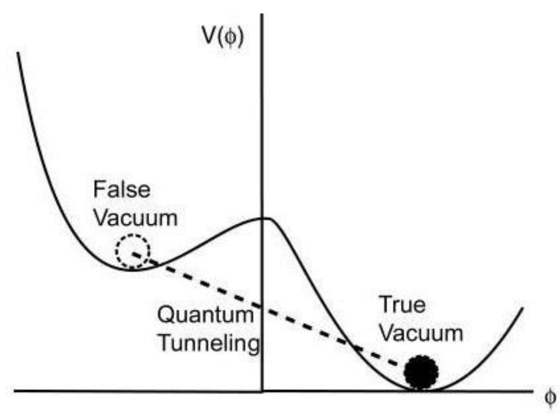
Mack describes five possible fates for the universe, namely the Big Crunch, Heat Death, the Big Rip, Vacuum Decay and a Bounce. On the way to lucid descriptions of these potential outcomes, one of which is surely inevitable, she touches on particle physics and describes the early universe as far back as the Planck time. She points out, as must be done in any book like this, that the failure of general relativity and quantum mechanics to play nicely together means we don't have a theory of quantum gravity and thus we reach a limit in our models of high-density states.

The five fates can be summarized briefly, and you are encouraged to read Mack's book for a fuller and more literate explanation:

Big Crunch: gravitational contraction to a single point containing everything in the universe because gravity beats Hubble expansion. Maybe the Big Bang starts all over again? Time estimate: it depends on how much "stuff" there is in the universe.

Heat Death: continued expansion, never reaching zero, or as now seems to be the case, accelerating. Eventually galaxy clusters separate from each other at a rate faster than the speed of light, so they disappear from the sky.[1] Then individual galaxies do the same thing. By the time this happens, stars burn out; the black holes radiate via Hawking radiation until they are gone. Entropy reaches a maximum. Time stops. The time frame for this varies over a wide range, all long.

Big Rip: Accelerated expansion due something called "phantom dark energy," like a cosmological constant with an equation of state[2] less than -1 (vs. the expected -1 for "regular" dark energy. Space expands so rapidly that eventually atoms and then subatomic particles are torn apart. The time estimate is at least 188 billion years, if phantom dark energy, whatever it is, really exists, which many physicists don't believe (anyway, we can't even explain "regular" dark energy).



Vacuum Decay: The Higgs field has a constant value greater than zero everywhere in space. Empty space is thus a "false vacuum," and the Higgs field could

[1] Although nothing can go faster than light in space, space itself can expand faster than the speed of light.
[2] The equation of state in cosmology describes the ratio of a perfect fluid's pressure to its density. The presumption is that the universe behaves as if it is a perfect fluid.

drop to the lower energy of the "true vacuum" by quantum tunneling. Subatomic particles would lose their mass, and matter would not be what it was before. A bubble of vacuum decay would spread from where the tunneling first happened throughout the universe at the speed of light. As soon as it reaches you, poof, you're gone! Estimated time: No one knows. It could happen tomorrow, or not ever. Given truly infinite time, it will happen, because in infinite time everything than can happen, will.

Bounce: Our universe might be a three-dimensional space within a four-dimensional (or higher) "brane" and from time to time these branes touch, resulting in a Big Bang. A number of these theories have been proposed, such as Roger Penrose's "Conformal Cyclic Cosmology" and Paul Steinhardt and Neil Turok's "ekpyrotic" universe. They arise from consideration of the fact that entropy must have been minimal at the time of the Big Bang, a thermodynamic state for which there is no clear explanation.

Mack has a conversational style and is prone to throw in a few little asides, off-handed humorous remarks and even some gentle self-deprecation, making the book light and easy to digest in spite of its cataclysmic subject. It's pitched to a lay audience, with no mathematics and few illustrations, but more knowledgeable amateur astronomers will find it entertaining and thought-provoking.

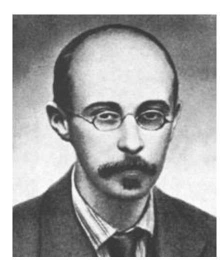
After reading Mack's book, I got interested in how astronomers and astrophysicists worked out the implications of cosmic expansion and how they calculated parameters for the end of the universe. The study of the End Times has its own name, "eschatology," from the Greek *eskhatos (ἔσχατος)*, meaning "last" or "extreme." Eschatology is a most lively subject within religion, but we can now do "scientific eschatology" by exploring the consequences of various scientific models of the universe.

The universe of Newton occupied a fixed, rigid grid of infinite space. Einstein's general relativity made space itself more flexible, but it was still infinite. Einstein believed the universe was eternal (in both directions of time, his Judaism not extending to a literal belief in Genesis). He recognized that gravity ought to pull all the mass in the universe together.[3] If the universe was eternal, how could it not have already contracted, having had an infinite amount of time to do so? We're here, aren't we? Since there needed to be a force opposing gravity, and he added the "cosmological constant," lambda (Λ), to lock things into place.

[3] Actually, Newton should have figured this out himself.

That the universe was not infinite and eternal should have been evident from what we now call Olbers's paradox. In 1826, German astronomer Heinrich W. M. Olbers (1758–1840) noted that if stars are distributed evenly throughout an infinite universe of infinite age, the night sky should display a uniform glow, since every line of sight would terminate at a star. No matter how far away it was, the light would have had enough time to reach us from an infinite past. In fact, the sky ought to be as bright as the surface of the Sun. (Actually Edmund Halley first intuited this paradox around 1720 in two papers presented to the Royal Society). So the universe is either not uniformly distributed, not infinite or not eternal. We now think the first proposition, uniformity is correct, at least on the largest cosmic scales. We're agnostic about infinity, but we're relatively certain about eternal. It's not. Uniformity (homogeneity and isotropy)[4] is not seen in the distribution of stars but of galaxies on a scale of perhaps hundreds of millions of light years. This fact was the third great contribution of Edwin Hubble. He's more well-known for determining in 1923 that the "Andromeda Nebula" (M31) was a distinct galaxy of stars external to the Milky Way and the discovery, with Milton Humason, in 1929 that the universe was expanding, with galaxies farther away from us having greater recession velocities. In 1934 Hubble showed that the distribution of galaxies was isotropic and homogeneous[5] to the limit seen in the largest telescope of the day, the 100-inch Hooker reflector at Mount Wilson.

In 1922, Alexander Friedmann found an exact solution of Einstein's equations of general relativity that was consistent with an expanding universe, the rate of expansion changing over time


Alexander Friedmann

[4] Homogeneity: any (large enough) volume of the universe is the same as any other; isotropy: the universe appears the same in whatever direction you look.

[5] That the universe should be, and is, isotropic and homogeneous is also called the "Cosmological Principle."

proportional to the average density of matter. This of course implied a beginning. This was more formally proposed by Georges Lemâitre in 1927 and utilized by George Gamow to make predictions about the atomic content of the universe that were consistent with observation.

The Friedman equation is worth looking at, even if you are not mathematically inclined. While Friedmann derived it from Einstein's famously complicated differential geometry equations of general relativity, it can actually be derived from Newton's equations and the principle of the conservation of energy. The Friedmann equation allows one to calculate the rate of change of the expansion of space. A common form is

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

where *H* is the Hubble constant,[6] *a* is the "scale factor", the dot over *a* indicates the time derivative (d*a*/dt), *G* is Newton's gravitational constant, *ρ* (rho) is the mass density (the amount of matter, baryons, neutrinos, dark matter and mass equivalent of ordinary energy in the volume a^3), *k* is +1 for positively curved space (spherical), zero for flat space or -1 for negatively curved space (saddle-shaped), *c* is a constant {not the speed of light) and Λ is the cosmological constant, an inherent repulsive force of empty space.

Understanding the scale factor is the essence of cosmology. If the universe is isotropic and homogeneous, there is a scale at which we can assert that its contents are essentially evenly spaced. At the current time, this is on the order of galaxy clusters. We set a coordinate system where each cluster is separated from its neighbors by a distance *a*. For cosmology, the important value is the rate of change of *a* and the ratio of the rate of change of *a* (that is d*a*/dt or $\dot{a}$) to *a* itself at whatever time we are considering. This is defined as the Hubble parameter ($H=\dot{a}/a$). The distance between the elements of an isotropic and homogeneous universe (now galaxy clusters but in the very early universe subatomic particles, at a later time hydrogen atoms) is always *a*. The actual distance in units such as nanometers, kilometers or megaparsecs will vary, but it's always *a* for the purposes of defining a coordinate system for the universe.

What's most important about this equation is that it says that the dynamics of the universe depends on just three things: its content (the first term), its geometry (the second term), and the intrinsic properties of space itself (the third term). Between 1929 and 1998, the assumption of most observers was that the cosmological constant, was zero.[7] No one was able to make any firm determination of the shape of space, but a lot of cosmologists seemed to believe *k*= +1 even though the local universe behaved as if it was flat (*k*=0).

That the universe is expanding doesn't mean it's not going to collapse (that is, if matter and ordinary energy are what it's made of). The force of the initial expansion must be tempered by the presence of matter, as Einstein assumed, but by how much? If there was enough matter, eventually the gravitational force would overcome the outward expansion, leading to a contraction and then a Big Crunch, the Big Bang in reverse. But perhaps there is not enough mass to do that, and so the expansion would slow, but never come to rest.[8]

The critical density is the amount of matter in the universe that would have enough gravity to exactly counterbalance the force of expansion (after infinite time). It is given by

$$\rho_c = \frac{3H^2}{8\pi G}$$

which is evident by substitution in the Friedmann equation (if k and Λ are zero). The question for cosmologists until the end of the 20th century was to

[6] More correctly called the Hubble parameter. It's the same everywhere in the universe at any given time, but it's not constant over cosmic time. It changes very, very slowly in our epoch.

[7] The meaning of the scale factor and the derivation of the Friedmann equation are brilliantly explained by Leonard Susskind in his 10-part classroom lecture series on Cosmology (the treatment is mathematical but not difficult), available on YouTube at https://tinyurl.com/Susskind2013Cosmology. I highly recommend this series. It's classroom teaching at its best.

[8] There's a third choice: the universe reaches an exact steady state where the rate of expansion is exactly balanced by the gravitational force of its matter. But nature abhors such exactitude, which would require the solution to have an infinite number of significant figures, all zero.

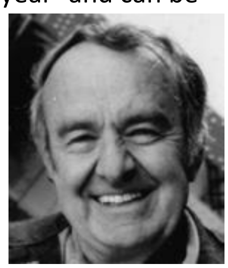
determine how much matter there was in the universe and what the current value of *H*. The amount of matter could be estimated from observations of galaxies and clusters. While dark matter was known to exist because of its influence on motion in galaxy clusters, as found by the redoubtable Fritz Zwicky in the 1930's, the amount of it in the universe as a whole was unknown but it was clearly much larger than the amount of actual (baryonic) matter.

Eternal expansion or inevitable collapse? This is expressed in the "deceleration parameter" q, which involves the second time derivative of the scale factor, in other words, the rate of change of the rate of change of the coordinates of the universe. The formal definition of q is

$$q = -\frac{\ddot{a}a}{\dot{a}^2}$$

(which I didn't really need to write, but I like using *Microsoft Equation*). If q_0 (q at the current time) is large enough (>½), expansion of space will reverse at some point in the future. That happens when $\dot{a}$ is zero.

On November 7, 1967, Allan Sandage, then considered the world's leading observational cosmologist, gave the Halley Lecture at Oxford University. The lecture was published the following year[9] and can be found on the NASA/ADS web site,[10] which archives a substantial amount of important astronomical information. Sandage describes the process used to measure the expansion rate and determine whether more distant galaxies, their photons having been emitted at an earlier epoch but just now reaching us, might be receding at a slightly faster speed than closer galaxies, meaning that expansion is slowing. Better data would allow q_0 to be explicitly determined.


Allan Sandage

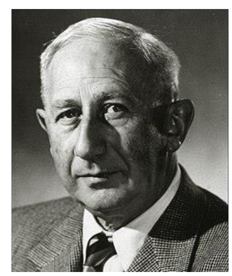
The recession velocity is determined from the redshift of a spectral line λ. The formula is

$$z = \frac{\lambda_{observed}}{\lambda_{rest}} - 1$$

It takes that form because you want the redshift at your position, when the two wavelengths are identical, to be zero. The velocity of an object at a given redshift is $v = z \times c$, where c is the speed of light.

We can determine the Hubble parameter at different epochs from Hubble's Law, $v = H \times D$, where H is the Hubble parameter and D is the distance.[11] We need some sort of "standard candle" to determine the distance to the galaxy or cluster. Hubble used Cepheid variables in the outer arms of Andromeda and other nearby galaxies in which he could resolve stars, but he had to find some other criterion for more distant galaxies. He assumed that galaxies were all pretty similar and so decided that their brightness was proportional to their angular size, and thus he could estimate their distances. It's not precisely true but it worked. For this and other reasons (interstellar dust being one of the most important), his value for H_0, the Hubble parameter at the current time, was much too high, about 500 km/sec/Mpc.

The work of Walter Baade in the 1940's at Mount Wilson provided a new tool. Baade came to U.S. from Germany in 1931. Brilliant but perhaps a little absent-minded, he neglected to become an American citizen and so was classified as an "enemy alien" during World War II. His movements were restricted. Most of the other astronomers at Mount Wilson turned to war work; the ineligible Baade was confined to Pasadena. He convinced the authorities that he should be allowed to go to Mt. Wilson Observatory (it's only seven miles from downtown Pasadena, but you have to drive 24 miles to get there). Baade not only had almost exclusive access to the 100-inch telescope, but since greater Los Angeles was blacked out during the war for fear of Japanese bombing, he also had pitch-black skies. In 1944, Baade was able to resolve stars in the center of M31, which allowed him to measure their colors and luminosities. This meant that by extrapolation the overall intensity of the cores of distant spiral galaxies whose


Walter Baade

9 Available at http://articles.adsabs.harvard.edu/pdf/1968Obs....88...91S

10 https://ui.adsabs.harvard.edu/

11 We are ignoring local ("peculiar") motion, a factor for nearby galaxies but not for distant ones. The Andromeda galaxy M31 has a red shift of −0.001001. It's coming right at us!

core stars could not be resolved could be used as a standard candle. Astronomers also developed complex luminosity corrections based on the distribution of intensities within the galaxies' spectra. Elliptical galaxies were thought to be older than spiral galaxies and thus should have more red stars. This was called the Stebbins-Whitford effect, first published in 1948, and used for a time to make spectrum-luminosity corrections, but it could not be confirmed and was withdrawn in 1956. Another useful observation was that the brightest elliptical galaxies in galaxy clusters had approximately the same luminosity, and so these could be used as "standard candles" for even more distant clusters.

Sandage's reduction of the data showed resulted in a q_0 that was positive and close to one, meaning that the universe would eventually collapse.

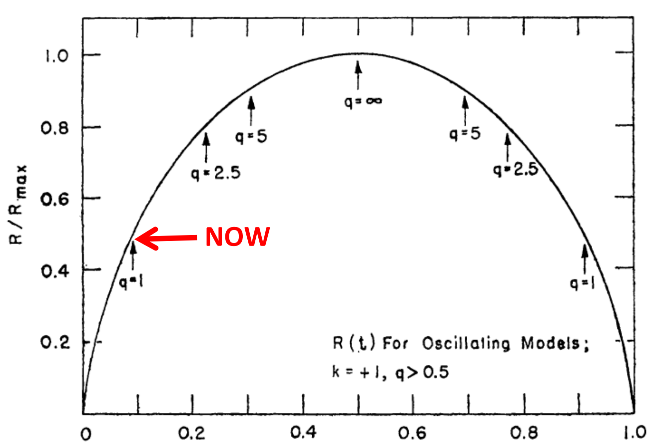
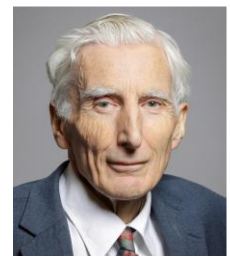


Fig 5 from Sandage. *R* is the scale factor. Sandage assumed the space had a positive curvature, but that has little impact on the dynamics as the scale factor reaches a maximum.

Being a scientist, Sandage was aware that his conclusions were dependent on many extrapolations and some assumptions that had not yet been proven. He noted that his conclusions were preliminary and more (and better) data was needed. It's interesting to read about his concerns. He bemoans the fact that there are few large telescopes (the 5-meter Hale telescope was by far the largest in the world) and there were none in the Southern Hemisphere at that time. He writes

> To fail because of lack of sufficient facilities is to lose the promise of the subject, which is nothing less than the time scale of genesis. For, once H_0 and q are known, the abscissa of Fig. 5 is fully calibrated in years and the history of the universe, from its birth to its death (and possible resurrection if it oscillates) is laid out for us to read.

His own guess for the scale of the abscissa was that the universe was about 13 billion years old (similar to current thinking), we are about 9% into the universe's life, that the reversal of expansion would happen in 35 billion years and that the Big Crunch would happen in 70 billion years.



Martin Rees

In 1969, Martin Rees, who is now Baron Rees of Ludlow and Great Britain's Astronomer Royal since 1995, looked at this problem from a more theoretical standpoint.[12] He considered some of the details of what would happen during a collapse, and showed that contraction is not a simple reversal of expansion because the evolution of structure during the lifetime of the universe alters the physics of contraction. He draws the following dire conclusion:

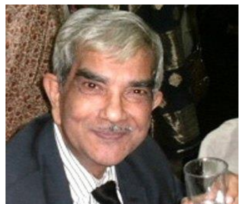
> If q_0>½, as the observations suggest, then the simplest appropriate cosmology is a closed model which will eventually collapse. During the contraction, clusters of galaxies, and then the galaxies themselves, will merge with one another. When $R/R_0 \leq 10^{-2}$ [*R* is Rees's term for the scale factor], the stars will behave like molecules of gas [with random speeds of ~ 3000 km sec^{-1}] until, at a stage when $R/R_0 \cong 10^{-4}$ and the mean density of the universe has risen to $\sim 10^{-17}$ gm cm^{-3}, they attain relativistic speeds. The stars are eventually destroyed by the influence of the external radiation (comprising the present black body background together with blue shifted emission from galaxies) which eventually becomes hotter and more intense than the radiation in stellar interiors.

In other words, we'll fry before we are crushed.

In 1975, James Gunn and Beatrice Tinsley published a paper in *Nature*[13] using new observations from Australia. Their data gave a value of the Hubble parameter of about 100 km/sec/Mpc. They asserted that the cosmological constant Λ was positive and that the universe would expand forever. The consequences of these suggestions were discussed in a pa-

[12] "The Collapse of the Universe: An Eschatological Study." *The Observatory*, 1969; 89: 193-198.
[13] "An Accelerating Universe" *Nature* 1975; 257, 454–457

per by Jamal Islam in 1977.[14] The average mass density of the universe, ρ, will asymptotically approach zero as the universe expands over very long times. Meanwhile, stars and galaxies are evolving. Stars will either explode as supernovas, turn into neutron stars or become white dwarfs, depending on their mass. An entire "galaxy will eventually consist of a gravitationally bound system of black holes, neutron stars, cold white dwarfs and cold interstellar matter in the form of planets, asteroids, meteorites, dust, etc." The time for an average galaxy to reach this state is not "many orders of magnitude more than 10^{11} years." (Our universe is currently 1.38 X 10^{10} years old.)


Jamal Islam

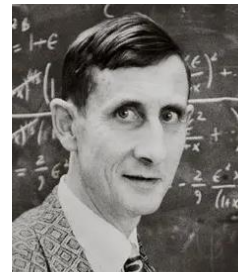
A galaxy itself will undergo gravitational contraction and eventually become a single black hole of about 10^{11} solar masses, with a Schwartzschild radius of the order of $^{1}/_{50}$ of a light year. Clusters of galaxies will then contract gravitationally, becoming a single supergalactic black hole in about 10^{31} years. These giant black holes will eventually radiate their mass-energy by Hawking radiation, because that's all they can do. This depends on the temperature of the cosmic microwave background radiation (CMB). A supergalactic black hole is a blackbody with a temperature of about 10^{-18} K.[15] The CMB cools as the universe expands (that is why it is just 2.75 K now even though it was 3 x 10^{3} K when it was emitted), and it won't reach a temperature at which heat can flow from the black hole to the CMB until about 10^{46} years from now. Then the black hole will slowly radiate and finally evaporate in about 10^{106} years.

At that time, the universe will exist of ever-cooling cosmic background radiation and some cold matter from small objects that never coalesced into black holes. These must ultimately decay into iron (^{56}Fe) through quantum tunneling, a process that will take about 10^{500} years. Any cold white dwarfs that may have managed to avoid falling into the supergalactic black holes at earlier times will collapse into neutron stars by quantum tunneling over a period of $10^{10^{77}}$ years, an amazingly long time (but not infinity).

[14] "Possible Ultimate Fate of the Universe," *Quarterly Journal of the Royal Astronomical Society*, 1977; 18:3-8
[15] The bigger the black hole, the lower the temperature!

Neutron stars will collapse to black holes via tunneling in approximately the same time, and then these will have to evaporate via Hawking radiation over 10^{106} years, which is truly nothing compared to $10^{10^{77}}$. The universe will then consist solely of radiation with a temperature asymptotically close to absolute zero, its entropy reaching a maximum.

Two years later, Freeman Dyson published a paper entitled "Time Without End: Physics and Biology in An Open Universe." Apparently Dyson was ambivalent about its publication, but a friend submitted it to *Reviews of Modern Physics* without his knowledge. The article was based on a series of lectures. It's a tour-de-force from a brilliant man. Dyson was at the Institute for Advanced Study, whose members are paid not just to think, but to *imagine*, and Dyson was one of the great imaginers. He passed away in February 2020 at the age of 96 after a lifetime of incredible productivity and creativity in theoretical physics, the philosophy of science, biology and other fields, to all of which he brought clever mathematical insights.


Freeman Dyson

The 1979 paper is divided into four parts: Philosophy, Physics, Biology and Communication. Dyson references Steven Weinberg's book *The First Three Minutes*, which came out to great acclaim in 1977. Dyson notes that "Thanks to Penzias and Wilson, Weinberg and others, the study of the beginning of the universe is now respectable…. But the end of the universe is another matter." Dyson writes

> At the end of his book about the past history of the universe, [Weinberg] adds a short chapter about the future. He takes 150 pages to describe the first three minutes, and then dismisses the whole of the future in five pages. Without any discussion of technical details, he sums up his view of the future in twelve words: "The more the universe seems comprehensible, the more it also seems pointless."
>
> Weinberg has here, perhaps unintentionally, identified a real problem. It is impossible to calculate in detail the long-range future of the universe without including the effects of life and intelligence.

Dyson suggests that it is not completely out of the question to postulate that the intelligent biologic creatures of the future could find ways of countering the irrevocable physics that leads to the bleak future that Islam describes. His paper asks three questions:

1. Does the universe freeze into a state of permanent physical quiescence as it expands and cools?
2. Is it possible for life and intelligence to survive indefinitely?
3. Is it possible to maintain communication and transmit information across the constantly expanding distances between galaxies?

Dyson takes care of the physics part of the problem with more explicit mathematics than was utilized by Islam.[16] He summarizes the math in the following table:

TABLE I. Summary of time scales.

Closed Universe	
Total duration	10^{11} yr
Open Universe	
Low-mass stars cool off	10^{14} yr
Planets detached from stars	10^{15} yr
Stars detached from galaxies	10^{19} yr
Decay of orbits by gravitational radiation	10^{20} yr
Decay of black holes by Hawking process	10^{64} yr
Matter liquid at zero temperature	10^{65} yr
All matter decays to iron	10^{1500} yr
Collapse of ordinary matter to black hole [alternative (ii)]	$10^{10^{26}}$ yr
Collapse of stars to neutron stars or black holes [alternative (iv)]	$10^{10^{76}}$ yr

Dyson goes on to imagine how biologic organisms could adapt to these future conditions. He mentions Fred Hoyle's

> black cloud,[17] a large assemblage of dust grains carrying positive and negative charges, organizing itself and communicating with itself by means of electromagnetic forces. We cannot imagine in detail how such a cloud could maintain the state of dynamic equilibrium that we call life. But we also could not have imagined the architecture of a living cell of protoplasm if we had never seen one.[18]

Ultimately, after some arcane mathematics and a number of seemingly outrageous but ultimately logical assumptions, Dyson concludes "An open universe need not evolve into a state of permanent quiescence. Life and communication can continue forever, utilizing a finite store of energy, if the assumed scaling laws are valid." The forms of life and communication would not be anything that we can reasonably relate to our current picture of what these words mean.

> I have only delineated in the crudest fashion a few of the physical problems that life must encounter in its effort to survive in a cold universe. I have not addressed at all the multitude of questions that arise as soon as one tries to imagine in detail the architecture of a form of life adapted to extremely low temperatures. Do there exist functional equivalents in low-temperature systems for muscle, nerve, hand, voice, eye, ear, brain and memory? I have no answers to these questions.

With regard to memory, Dyson notes

> I would like our descendants to be endowed not only with an infinitely long subjective lifetime but also with a memory of endlessly growing capacity. To be immortal with a finite memory is highly unsatisfactory; it seems hardly worthwhile to be immortal if one must ultimately erase all trace of one's origins in order to make room for new experience.

And so the field stood until 1998. The Big Crunch was still a possibility, maybe even the expectation. The large telescopes dreamed of by Sandage were constructed and a few went even into space, particularly the Hubble Space Telescope and the COBE CMB microwave detector, followed by WMAP and Planck. Mapping the CMB brought the very early, pre-structured universe (z=1,096, 13.8 billion years) into clearer focus. Type 1a supernovas became the main standard candle to probe into the past via optical astronomy, reaching z=1 (about 7 billion years). Automation and technology (in the form of CCD imagers, multi-object spectrometers and computerized object identification software) played a major role, with the result that investigators looking for *q* found that it was very much *less* than zero. They had a hard time believing it at first, but then the two groups working on the problem rushed to achieve priority. For a fine telling of this story, read Richard Panek's *The 4% Universe.*

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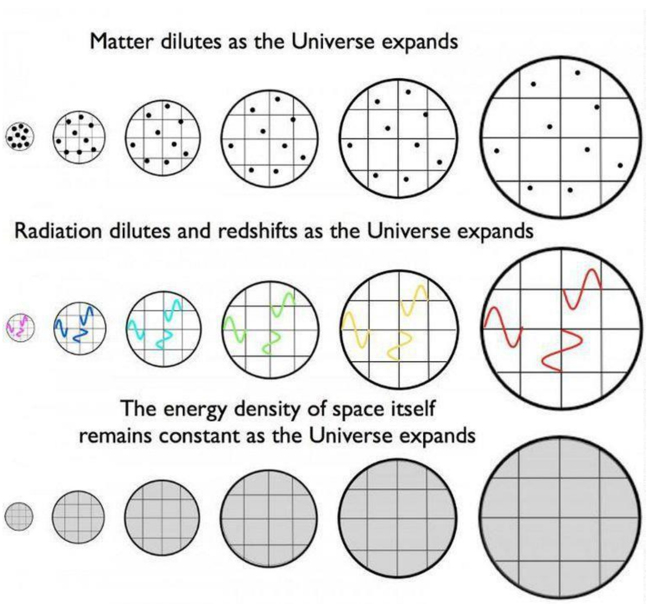
[16] Dyson assumes the proton is stable, which may or may not be correct. Certainly its lifetime is greater than 10^{31} years.

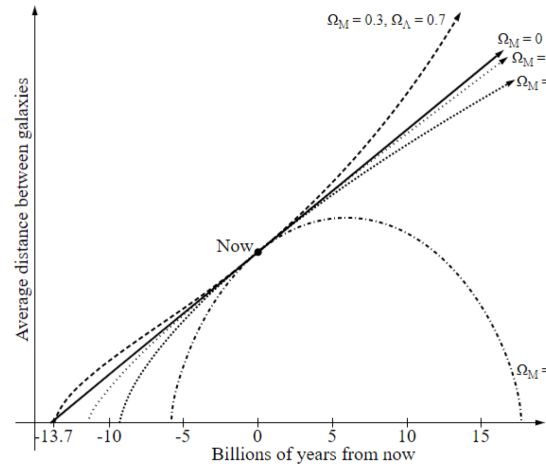
[17] *The Black Cloud* was a science fiction novel written by Hoyle, published in 1957. There are a plethora of StarTrek versions of this life-form.

[18] Speaking as a physician with a lot of basic science training, I can tell you that although we have learned a lot, we are still far away from really understanding the internal structure and workings of cells.

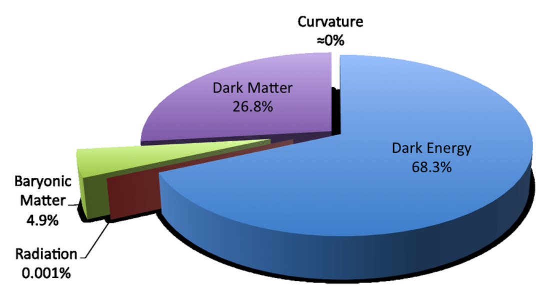
The initial rapid expansion after the Big Bang was slowed by the mass-energy of the hot nascent universe's enormous radiation content (recall $m=E/c^2$). After about 50,000 years of expansion and cooling, the contribution of matter (baryons, neutrinos and dark matter) to the expansion became greater than that of radiation, and the expansion rate slowed further. The density of matter scales with a^3 because the same amount of matter occupies a larger volume of space and volume grows as a^3. Radiation's contribution scales as a^4 because when space expands the radiation is redshifted, losing energy in addition to being diluted in the larger volume of space. So as a gets larger, radiation's mass-energy contribution waned faster than matter's. Today, ordinary radiation contributes essentially nothing to the rate of expansion. About five billion years ago Λ began to dominate the rate of expansion and now appears to be more important than matter. Since there is a constant amount of "dark energy" (Λ) in each unit of space, it doesn't scale with a at all. It just increases as space increases. In a dark energy-dominated universe, expansion increases exponentially, eventually growing faster than the speed of light, narrowing our cosmic horizon.



The density parameter $\Omega = \rho/\rho_c$ is the modern analog of the deceleration parameter. The critical density ρ_c is very, very close to 1. If Ω was due only to matter, the rate of expansion would slow further. But because of the dominance of Λ, it is speeding up and will continue to do so.



The currently accepted mass-energy density of the universe is 9.47 x 10^{-27} kg/m^3, which is equivalent to only 10 protons per cubic meter, but this includes the contributions of dark matter and dark energy. Results from Planck's 2018 data release are that the contribution to Ω from dark energy at the present time is 68.47% ± 0.73%. The equation of state of dark energy, w, is −1.03 ± 0.03,[19] the universe seems to be flat, and H_0 is 67.36 ± 0.54 km/sec/Mpc. This value of H_0 differs from the results of observations of the "near" universe (supernovas, galaxy distributions etc.), which pegs H closer to 73 km/sec/Mpc. That's a source of vast consternation and currently the hottest topic in cosmology.[20]



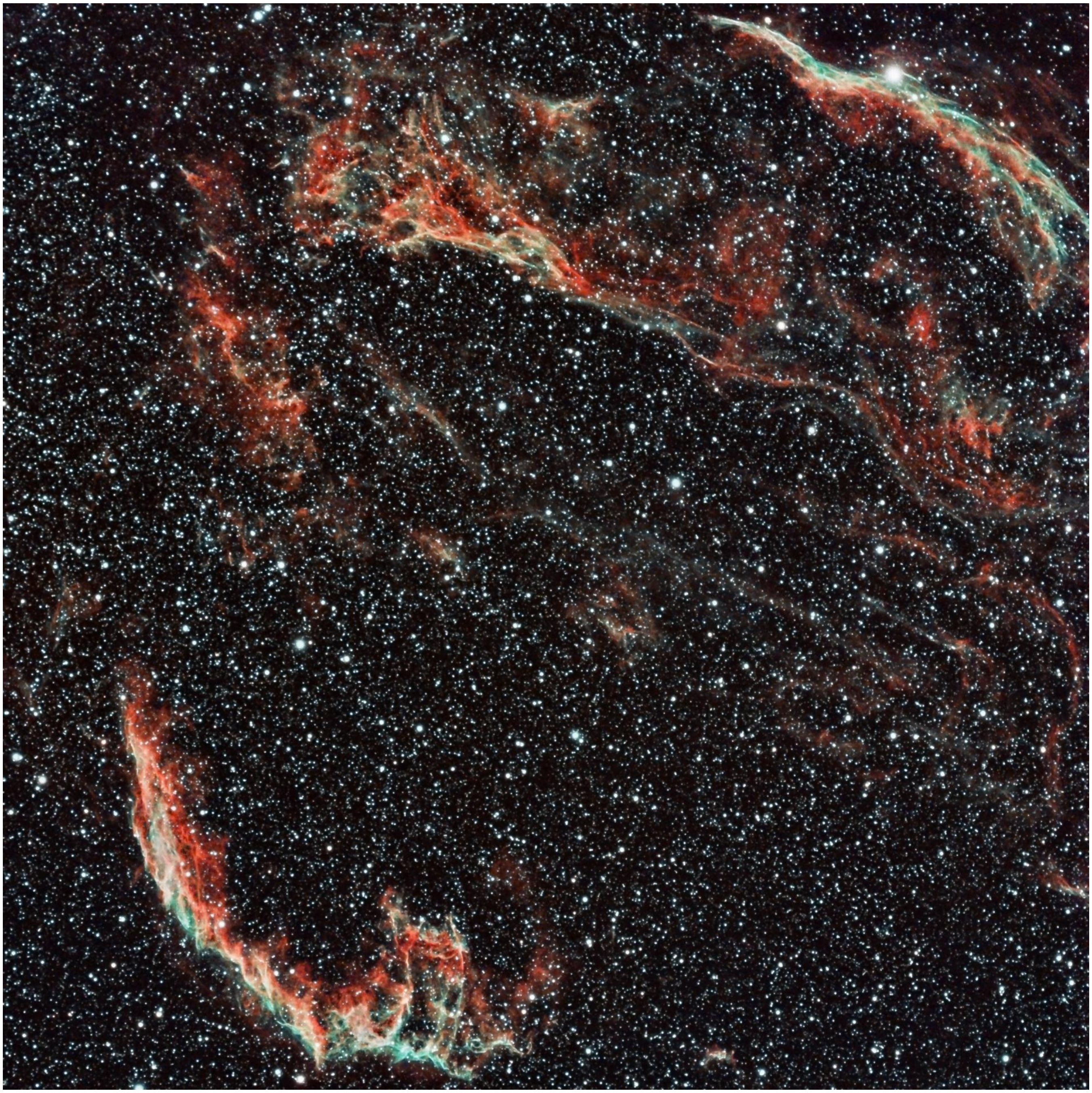
There is no limit to the value of the Hubble parameter when Λ becomes the only term that matters. The universe will continue to expand exponentially. Heat death is inevitable. Dyson's immortal, patient, infinitely memorious life forms are our only hope. ■

[19] Meaning dark energy is most likely to be an inherent property of space and not some other substance or force.

[20] For the most recent information on this fascinating problem, see the videos from the European Southern Observatory's June 2020 conference "Assessing Uncertainties in Hubble's Constant Across the Universe," on line at https://www.eso.org/sci/meetings/2020/H0/program.html

Images

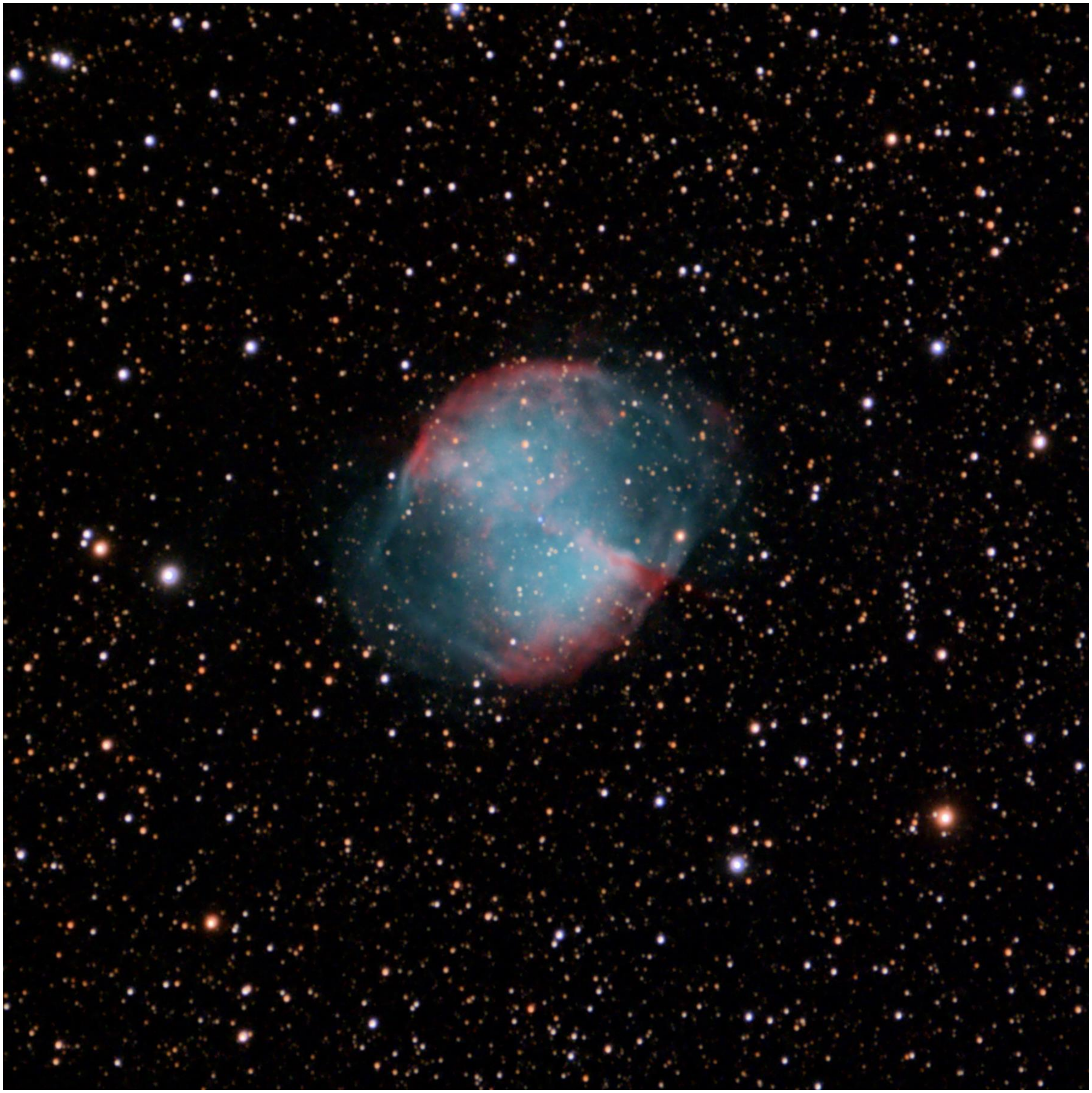
The Veil Nebula by Leandro Bento



Leandro made this image at Ward Pound Ridge Reservation in mid-September. A total of 71 minutes of exposure, with flats, darks and bias frames. William Optics Redcat 51 mm f/4.9 scope, ZWO ASI533MC Pro camera, Optolong L-enhance filter, Ioptron SkyGuider Pro tracker.

The wide field, more than 2½ degrees on the diagonal, is achieved by combining a small, fast refractor with a camera that has a 9 megapixel, 1-inch diagonal square sensor.

Dumbbell Nebula (Messier 27) by Robin Stuart



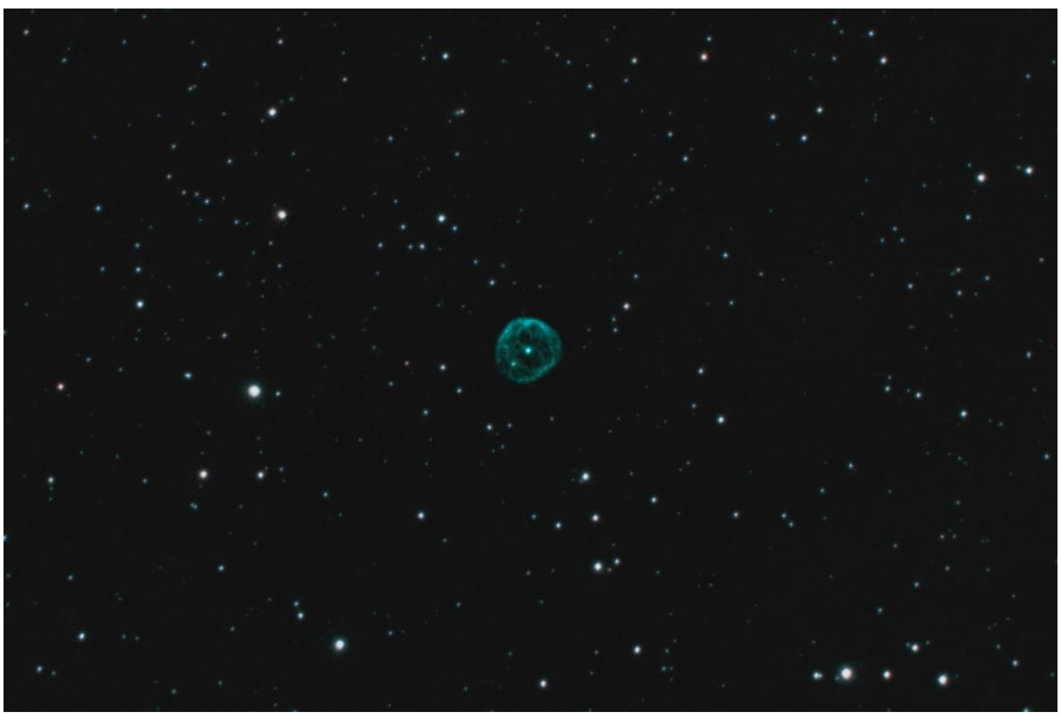
At around seven arcminutes across and magnitude 7.5, the Dumbbell Nebula (M 27) in Vulpecula, the Little Fox, is an easy target in the summer and fall skies. It's just a short star hop from the arrow tip of Sagitta. The planetary nebula itself lies 1,300 light-years from the Sun and is nearly three light-years across. The white dwarf star at its center, visible in the image, is a little more than half the mass of the Sun but only 1/20th its diameter. This makes one of the largest white dwarfs known.

The image is a stack of 54 two-minute subs taken over two nights in August from Valhalla with a Canon 60Da DSLR through a Televue NP127 and 2X Powermate.

For more on planetary nebulas, see p. 6 of the October 2015 SkyWAtch.

Two Planetary Nebulas by Steve Bellavia

The Fetus Nebula, NGC 7008 (PK 93+5.2, Herschel 1-192) is located in Cygnus. It was discovered on October 14, 1787 by William Herschel with the "20-foot" telescope at Slough (18.7" mirror made of speculum metal). Magnitude 12.0, dimensions 1.4' x 1', distance at least 2,800 light years.

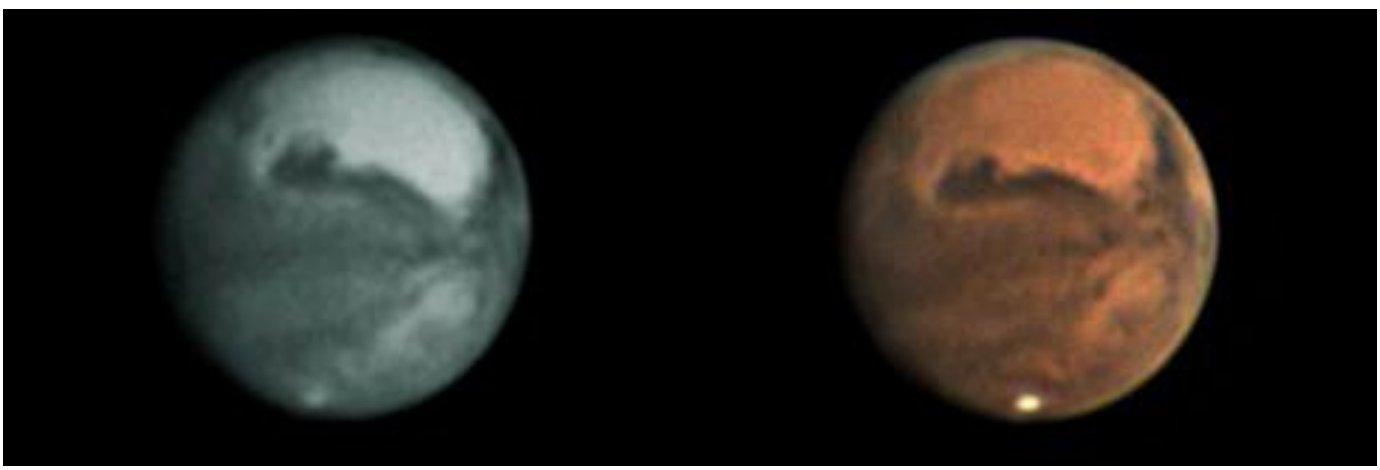


NGC 7094 in Pegasus, mag 13.6, 1.6' in diameter. Distance about 5,500 light years. Discovered on October 10, 1884 by famous comet-hunter Lewis Swift with the 16-inch Alvan Clark refractor at the Warner Observatory in Rochester, NY. Swift's obituary in the NY Times on February 2, 1902, reported that he discovered 15 comets and 1,342 nebulas.

Steve made these images in August at Cherry Springs State Park in Pennsylvania, with a guided Celestron 6-inch SCT (with an f/6.3 focal reducer) and ZWO ASI294 camera. He used a ZWO dual-band filter for both images.

NGC 7635 & M52 by Tony Bonaviso

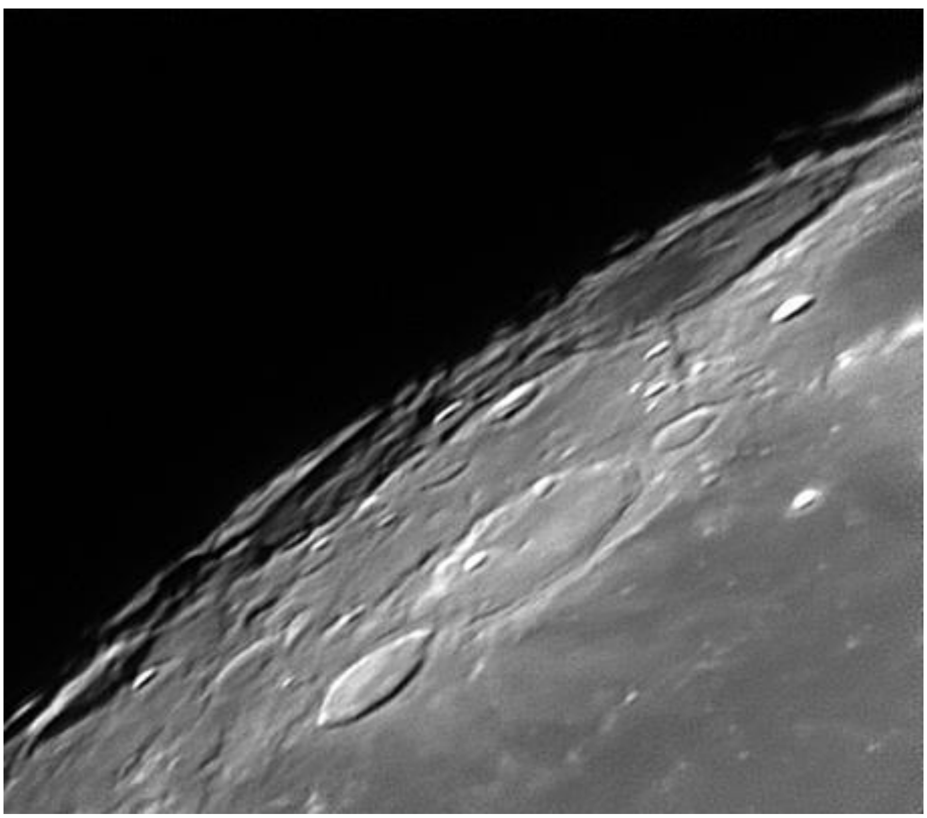
Tony made this image of the Bubble Nebula (NGC 7635) and open cluster Messier 52 in Cassiopeia with an Astro-Tech AT92 triplet refractor (506mm, f/5.6) on a Skywatcher EQ6R-pro mount. ZWO ASI294MC Pro camera, 50x300sec @-10C, 25x30sec@-10C flat frames, 21x300sec@-10C dark frames & 50 bias frames. Captured with Astrophotography Tool V3.86, guided With PHD2, processed in Pixinsight. The two objects are ½ degree apart.



John Paladini took advantage of excellent seeing in early November to capture more views of Mars with his 9.25” Celestron SCT and 2X Barlow. (L) 11/6/20 monochrome camera with infrared filter, (R) 11/7/20 with color camera. On 11/7 Mars’ slightly gibbous disc (98.6% illuminated).was 18.8 arc-seconds in diameter, 83% of its maximum diameter at closest approach on 10/6. On 12/1 Mars will have a diameter of 14.4”, 92% illuminated, and will shrink to 10.3”, 83% illuminated, on 1/1/21. Its next closest approach will be 12/2/22 (17.2”).

Greg Borrelly captured the Moon at 7:30 pm on October 24th. The 8-day Moon was 64% illuminated and 29½ degrees above the horizon.

William Optics GT71 refractor, Canon T6i, ISO 800, 1/1000 sec.



While waiting for Mars to rise on the night of September 30th, **Larry Faltz** grabbed a shot the terminator on the nearly-full (99.3% illuminated) waxing Moon. The foreground craters are (L to R) Cavalerius, Hevelius (with two smaller craters inside of it), and Lohrmann. The large walled plain on the upper right towards the lunar edge is Riccioli, and to its left is Hedin, the remnant of a walled plain. At the lower left is the crater Olbers, with dawn on its western wall. The western edge of the Oceanus Procellarium is at the lower right. About 450 km of the Moon's edge is shown. Celestron CPC800, Skyris 445 monochrome camera.

Solar Serendipity by Robin Stuart

While taking video November 8, 2020.in Valhalla to capture the small prominence on the Sun's upper limb Robin Stuart was “photobombed.” Robin writes:

I originally assumed that this was a flight out of Westchester County Airport and since it’s not far away. By viewing past radar records I determined that it's actually Air India AIC144 from Newark to Mumbai. The aircraft's position at the time is available from FlightAware. The instant at which its azimuth matches that of the Sun can be calculated. It gives 11h55m07s EST. The short exposure of 1.2 ms was able to effectively freeze the motion since at a speed of 412 knots the aircraft would only travel 10 inches in the interval. At the time this Boeing 787-8 Dreamliner was 5.3 miles away at 13,500 feet, almost directly over the Best Buy on Central Avenue, Hartsdale. At that distance the 186 foot long aircraft subtends 22.7 arc minutes which can be compared to the Sun's angular diameter at the time of 32.3 arc-minutes.

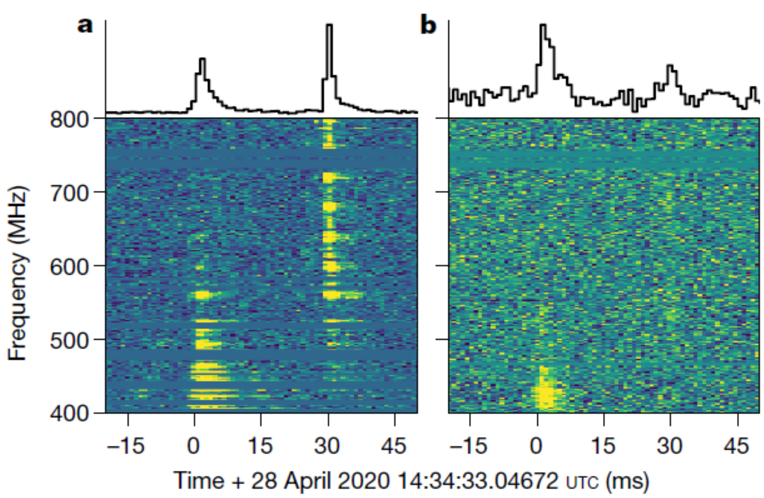
Research Highlight of the Month

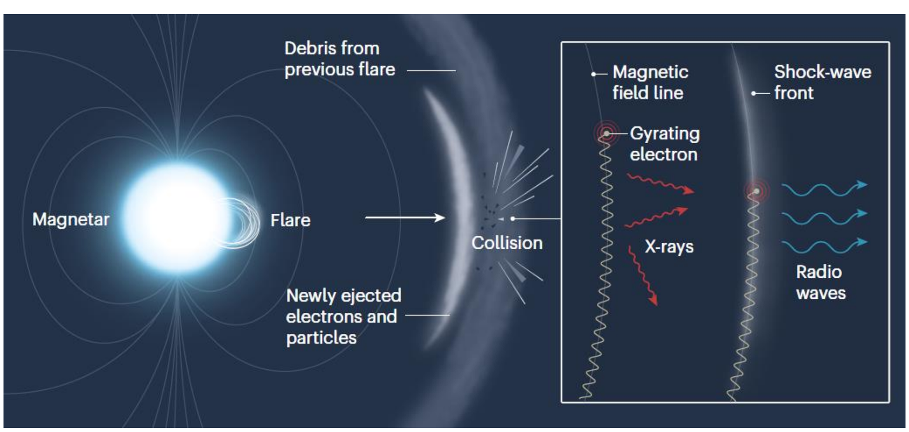
The CHIME/FRB Collaboration, A bright millisecond-duration radio burst from a Galactic magnetar, *Nature* 2020; 587: 54-58 (5 November 2020, https://doi.org/10.1038/s41586-020-2863-y)

Since their discovery in 2007 (the retrospective recognition of an event recorded in 2001), fast radio bursts (FRBs) have been a source of intrigue for astronomers. The single event was viewed skeptically until four more were reported in 2013. Since then, many have been seen. Most of the detections of these millisecond long radio spectrum events are unique, although at least twenty repeating sources have been found. Many theories for their origin have been proposed, with magnetars, highly magnetic, rapidly spinning neutron stars, the most likely candidates because the duration of the bursts is so short that they must originate in a very compact are of space. The FRBs have been localized to date all originate in distant galaxies. Up to now.

In April 2018, the Neil Gehrels Swift Observatory and Fermi Gamma Ray Observatory detected multiple high-energy emissions from a magnetar in the Milky Way, SGR 1935+2154. The next day, two radio telescope arrays detected an FRB (named FRB 200428) from the same region of the sky. Further detections in the high-energy X-ray band from three additional space telescopes followed, as well as a detection of lower-energy radio bursts by the Chinese FAST radio telescope, the world's largest.

FRB 200428 is the first FRB for which emissions in other EM bands have been found, and it's the first one to be localized to the Milky Way.





Top: Fig 1 from the paper, showing FRB 200428 as received by the CHIME radio telescope at the Dominion Radio Astrophysical Observatory in Penticton, British Columbia (panel a) and by the 10-meter disk antenna at the Algonquin Provincial Park, Ontario, Canada (panel b).

Bottom: A proposed mechanism for FRB formation. Magnetic field motions in the magnetar produce a sub-millisecond long flare of electrons which collides with previously emitted charged particles a distance away from the magnetar. This generates a moving shock front which produces even larger magnetic fields. Electrons then gyrate around these lines, producing radio waves. The shock wave also heats the electrons, causing them to emit X-rays. (Weltman, A, Walters, A, A fast radio burst in our own galaxy, *Nature* 2020; 587: 43-44 (commentary on the CHIME paper).

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Celestron Orange Tube C8	A gem from the 1970's! WAA has had this scope in storage for a long time. Serial #25778-6, labeled "Celestron Pacific," so it was made before Tom Johnson changed the company's name to "Celestron Inter-national" in 1978. Perfect condition, unblemished op-tics, comes with 110 volt power cable, finder and wedge, lacks only the tripod. Includes several eyepieces and other paraphernalia. You could also de-fork it and use the optical tube on a go-to GEM, which actually makes the most sense, although you might feel bad about getting rid of the iconic Celestron fork mount. Current Celestron 8" SCT optical tubes list for $679-$800.	$300	WAA ads@westchesterastronomers.org
Meade 395 90 mm achromatic refractor	Long-tube refractor, f/11 (focal length 1000 mm). Straight-through finder. Rings but no dovetail. 1.25" rack-and-pinion focuser. No eyepiece. Excellent condition. A "planet killer." Donated to WAA.	$100	WAA ads@westchesterastronomers.org
Atco 60-mm f/15.1 refractor	A classic Japanese refractor from the early 1970s. Obtained from the original owner about five years ago. It was used only a few times, then stored for 40+ years. Current owner used it maybe seven times. Very good condition. Comes with three eyepieces and a 1.25" eyepiece adaptor star diagonal. Straight-through finder. Equatorial mount with slow-motion adjustment knobs (screws). Wooden tripod, metal tube. Everything is original.	$150	Robert Lewis lewis@bway.net
WANTED	One of our members, a retired professional frustrated by the ever-increasing light pollution in Westchester, wants to know whether there are any other WAA'ers who might be interested to participate in a group purchase of property somewhere in upstate New York to build a small observatory with warm room and living facilities.		Contact Bill Caspe wbcaspe@mindspring.com
Want to list something for sale in the next issue of the WAA newsletter? Send the description and asking price to ads@westchesterastronomers.org. Member submissions only. Please submit only serious and useful astronomy equipment. WAA reserves the right not to list items we think are not of value to members.			
Buying and selling items is at your own risk. WAA is not responsible for the satisfaction of the buyer or seller. Commercial listings are not accepted. Items must be the property of the member or WAA. WAA takes no responsibility for the condition or value of the item, or for the accuracy of any description. We expect, but cannot guarantee, that descriptions are accurate. Items are subject to prior sale. WAA is not a party to any sale unless the equipment belongs to WAA (and will be so identified). Sales of WAA equipment are final. *Caveat emptor!*			