SkyWAAtch

NGC 891

Mauri Rosenthal captured this fine edge-on galaxy in September from his yard in Yonkers. The galaxy is 30 million light years distant and is said to resemble our Milky Way if viewed from the side. Mauri used his 3.5” Questar and a QHY163 monochrome astro camera and LRGB filters with SharpCap software that aligns and stacks exposures on the fly. Here 900 eight second exposures provided a total of two hours of data, further processed with PixInsight.

In This Issue . . .

Events for December

WAA November Lecture

"The Jellyfish Nebula, Cosmic-Ray Accelerator"
Friday December 1st, 7:30pm
Leinhard Lecture Hall,
Pace University, Pleasantville, NY

Dr. Brian Humensky is our presenter, who will speak on the Jellyfish Nebula. The Jellyfish is a supernova remnant resulting from the explosion of a massive star. Its expanding shock wave accelerates cosmic rays. Today, we see that shock wave interacting with clouds of gas left over from the star's birth. We can study this fascinating nebula from the radio to the optical to very-high-energy gamma rays, learning about the structure and dynamics of the nebula, the acceleration of cosmic rays at its shocks, and even clues about the nature of the progenitor star.

Dr. Brian Humensky is a faculty member in the Physics Department at Columbia University and works on the gamma-ray observatory VERITAS. He is involved in development of the next-generation Cherenkov Telescope Array. Free and open to the public. Directions and Map.

We will hold the brief but official WAA Annual Meeting at the beginning of the meeting.

Upcoming Lectures

Leinhard Lecture Hall
Pace University, Pleasantville, NY

Our speaker for January 2018 will be announced by eblast.

Starway to Heaven

Ward Pound Ridge Reservation,
Cross River, NY

There will be no Starway to Heaven observing dates for December, January or February. Monthly observing sessions will recommence in March 2018 (tentatively scheduled for March 17th).

New Members. . .

Colleen Shields - Peekskill
Richard Rubin - Somers
Robert Lally - New York
Om Barlinge - Scarsdale
John McConnell - Tuckahoe

Renewing Members. . .

Kevin Shea - Ossining
Steve Petersen - Briarcliff Manor
Edgar S Edelmann - Tarrytown
Woody Umanoff - Mount Kisco
Al Forman - Croton-on-Hudson
Walter Chadwick - Scarsdale
Andrea Anthony - Yorktown Heights
Larry and Elyse Faltz - Larchmont
Bob Kelly - Ardsley
Hans Minnich - Mahopac
Doug Baum - Pound Ridge
Jak Cukaj - Katonah

In December of 1972, Apollo 17 astronauts Eugene Cernan and Harrison Schmitt spent about 75 hours on the Moon in the Taurus-Littrow valley, while colleague Ronald Evans orbited overhead. This sharp image was taken by Cernan as he and Schmitt roamed the valley floor. The image shows Schmitt on the left with the lunar rover at the edge of Shorty Crater, near the spot where geologist Schmitt discovered orange lunar soil. The Apollo 17 crew returned with 110 kilograms of rock and soil samples, more than was returned from any of the other lunar landing sites. Forty five years later, Cernan and Schmitt are still the last to walk on the Moon.

Credit: APOD.

Image Credit: Apollo 17 Crew, NASA

Asteroid Viewing

Six asteroids (ok, minor planets) can be spotted in telescopes this month: 2Pallas dimming at magnitude +8.5, 8Iris dimming at +8.0, 349Dembowska holding at +9.7, 20Massalia brightening at +8.6 8Flora brightening at +8.7, and 1Ceres (dwarf planet!) brightening at +7.8. You'll need a finder chart or app to find them as they will look like the stars they appear to be among. Try: In-The Sky.org.

--Bob Kelly

ALMANAC

For December 2017 by Bob Kelly

Dec 3 Dec 10 Dec 18 Dec 26

Want dark skies? Then December is your month! However, if you are tired of coming home from your day job in the dark, the Earth's elliptical orbit (and a few other factors) means increasingly later afternoon illumination beginning in mid-December. By the end of December, we have 10 more minutes of evening sun than on December 1^{st}. Numerically, the darkest evenings are the nights with the earliest end of astronomical twilight – at 6:05pm from November 30^{th} through December 7^{th}.

Where did all the planets go? My neighbors must think it's strange for Bob to be out with no planets in range. Want to see the Saturn/Mercury pairing? Look low in the southwest on the horizon no more than 45 minutes after sunset on the third of the month. Then they'll join the video show at SOHO. More on that later.

Staying in the solar system, Uranus and Neptune lurk in the evening sky. Find your way through the wetlands of Aquarius to plus 3.7 magnitude Lambda Aquarii to see magnitude plus 7.9 Neptune a degree away. Uranus, at plus 5.7 is easier to see, but in the deep sky with faint Pisces.

Of course, December means Orion, the giant, swinging his legs up over the horizon by 7pm. This marks the opening of the winter constellation season, his bow aiming toward Taurus and the Pleiades, with a Sirius following. Can anyone take a photo of a person hoisting Orion into the sky?

The morning has the developing story of Jupiter and Mars, climbing out of the solar glare. Jupiter seems especially anxious to get moving, approaching fainter Mars by the end of the month. Can we wrap our heads around the concept that it is the Earth doing the moving, with the Sun and Mars and the background stars tripping along with Jupiter's the one not moving much relative to the stars?

Venus drops out of the morning sky, unless you have a clear southeastern horizon the first few days of the month. The Moon comes by to pose with Jupiter and Mars on the 13^{th} and 14^{th}. Mercury joins the scene, but very low in the southeast with Antares by the end of the month.

Sadly, we didn't get to see 1I/2017 U1, the first confirmed interstellar object in our solar system. It has a trippy name -'Oumuamua – Hawaiian for 'first messenger from far away'. It came from the direction of Vega, but when this messenger was there 300,000 years ago, the motions of stars in our galaxy means Vega probably wasn't there then.

Comet C/2017 O1 passes through Cepheus near Polaris. How long an exposure do you need to catch this 10^{th} magnitude comet as it fades further? The German comet group reports it as diffuse and large. Comet Heinze (C/2017 T1) may brighten to 9^{th} magnitude in Cancer after Christmas. It's going to be 'close' enough to Earth – passing 33 million miles away in early January – that observers will be able to see it move during a morning's observation.

On the evening of the 30^{th}, the 90 percent lit Moon will have a bright companion at its rising when first magnitude Aldebaran is a moon-width away. Aldebaran slips behind the dark limb of the bright moon after 6pm EST. It'll be back after 7pm.

The latest 'super' full moon will be on December 3^{rd}, with the largest moon on the morning of the 4^{th}. It will be the largest full moon of 2017. For the record, the full moon of January 2^{nd}, 2018 will be about eight hundred miles closer to Earth. Somewhat larger than normal tides occur for the days after a perigee full moon like these.

The Geminid meteor shower peaks on the 13^{th} and 14^{th}. This is a reliable shower; tens of meteors can be seen per hour. The highest rates are in the early morning, when Gemini is highest in the sky.

Planet watchers get a show in SOHO, the Solar and Heliospheric Observatory. Mercury passes through the Observatory's field from the 9^{th} through the 16^{th}, Saturn from the 13^{th} through the 30^{th} and Venus from the 7^{th} into January 2018. So, from the 13^{th} to the 16^{th}, you can see three planets in the background of the views of the flaring outer solar atmosphere. Antares leaves the view on the 9^{th}.

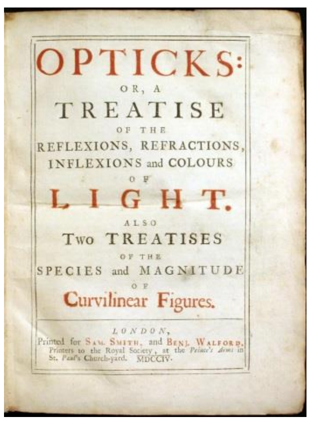
The International Space Station is a transient evening object through the 18^{th} and in the morning sky starting after Christmas. The Solstice occurs at 12:28pm on the 21^{st}

Merging Neutron Stars: A Glimpse into the Secrets of Gravity

Larry Faltz

> "Our Theory of Gravitation is as good as perfect: Lagrange, it is well known, has proved that the Planetary System, on this scheme, will endure for ever; Laplace, still more cunningly, even guesses that it could not have been made on any other scheme."
>
> Thomas Carlyle (1795-1881)
> *Sartor Resartus (The Tailor Retailored)*, (1833-34)

Of the four forces in nature, gravitation is the weakest and perhaps the most mysterious, although I have to say that all of the forces are pretty mysterious when you get down to the details. We don't directly perceive two of them, the strong and weak nuclear forces, although matter could not exist without them. We experience the world primarily as light and gravity. Of light we know quite a bit. Newton was the first person to try to understand light in a systematic way, dividing sunlight into its spectrum and making other experiments to elucidate how light behaved and what it might be made of. He put his experimental findings into the *Opticks* of 1704. Although the work is mainly a record of Newton's meticulous researches, he ventures off into all sorts of speculations. At the end of *Opticks* there are lengthy philosophical discussions in the form of "queries". The 31st and last query begins



> Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting, and inflecting them, but also upon one another for producing a great Part of the Phænomena of Nature? For it is well known, that Bodies act one upon another by the Attractions of Gravity, Magnetism, and Electricity; and these Instances shew the Tenor and Course of Nature, and make it not improbable but that there may be more attractive Powers than these. For Nature is very consonant and conformable to herself. How these Attractions may be perform'd, I do not here consider. What I call Attraction may be perform'd by impulse, or by some other means unknown to me. I use that Word here to signify only in general any Force by which Bodies tend towards one another, whatsoever be the Cause. For we must learn from the Phænomena of Nature what Bodies attract one another, and what are the Laws and Properties of the Attraction, before we enquire the Cause by which the Attraction is perform'd. The Attractions of Gravity, Magnetism, and Electricity, reach to very sensible distances, and so have been observed by vulgar Eyes, and there may be others which reach to so small distances as hitherto escape Observation; and perhaps electrical Attraction may reach to such small distances, even without being excited by Friction.

Newton believed that light was made up of "corpuscles." The spectrum would be caused by corpuscles of the different colors having dissimilar masses and thus being differentially deflected by the force of gravity. It was one of the rare things he was wrong about (but only in the details), but obviously his mind was open to other possibilities. We know now that mass, through its gravitational effect on spacetime, will bend light, but all colors to the same degree. That was an astonishing concept in 1919 when General Relativity was confirmed by Eddington's observation of the displacement of starlight near the eclipsed Sun, but it's now something we find mundane after seeing so many images of gravitationally lensed galaxies and quasars.

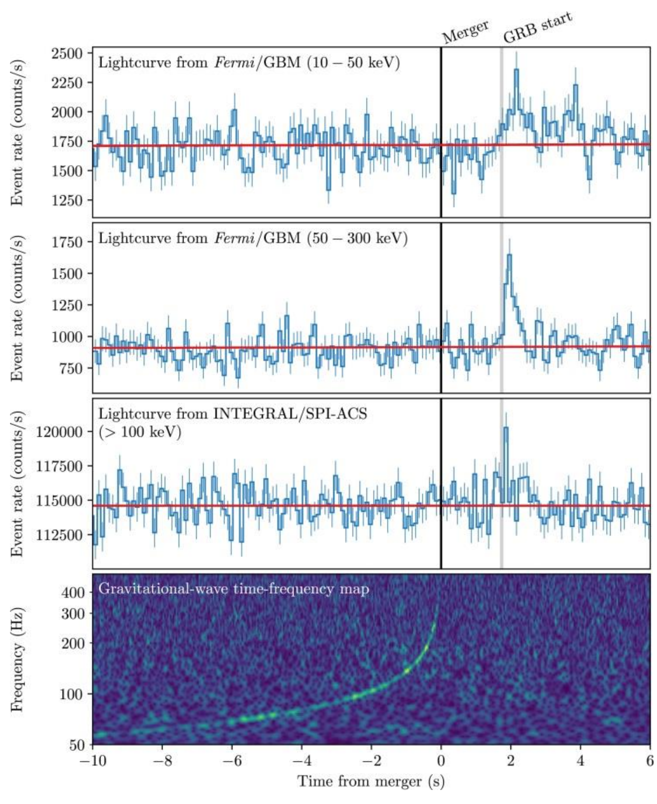
We have a pretty good idea…I mean physicists have a good idea, I only have an inkling…of the way matter and three of the four forces of nature work.[1] The theory of matter and energy is called the Standard Model, and it describes everything that is needed to understand electromagnetism, the weak force, and the strong force. The predictions of this theory are extraordinarily accurate. Its major limitation is that gravity isn't part of it. And we know that there's plenty of gravity around.

Should gravity be similar to the other forces? It would seem so: a gravitational "field" permeates all space. There are perfectly good rules about how to make predictions with it. It ought to work just like the other forces, which are quantized. Current views of cosmology predict that the four forces were all a single force prior to 10^{-43} seconds after the Big Bang. If gravity is to be a quantum field theory like the Standard Model it needs a quantum. Just as the photon is the quantum

[1] For an excellent non-mathematical introduction to quantum field theory, given by Cambridge theoretical physicist David Tong at the Royal Institution in London, check out https://www.youtube.com/watch?v=zNVQfWC_evg

of the electromagnetic field, a "graviton", should be the quantum of the gravitational field. We say mass curves space, but how?

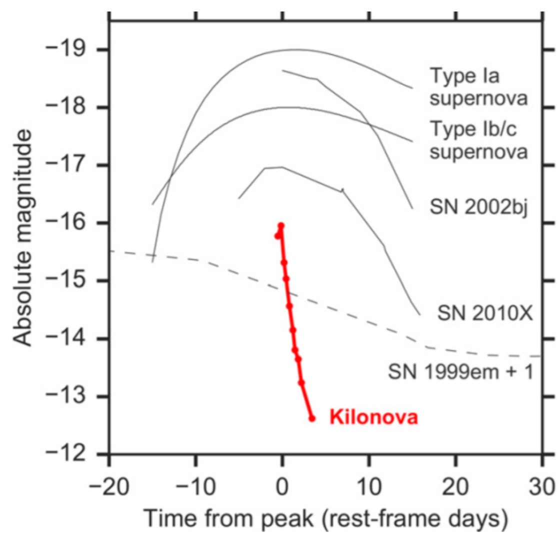
There are many alternatives to General Relativity. They go by names like Horndeski gravity, f(R) gravity, bimetric gravity, Jordan-Brans-Dicke gravity, mimetic Born-Infield gravity and numerous other arcane proposals. A few are quantum theories, including loop quantum gravity and string theory. Some include explanations for dark matter effects that don't involve new particles. A few seek to explain the accelerated expansion of the universe without invoking "dark energy" or a cosmological constant. Some even propose more than one type of graviton, or a graviton with mass and variable velocity that might explain dark energy. They all require complex and forbidding mathematics. Lots of theoretical papers are published describing the features of these new gravities, and how they might work in regimes of intense mass and energy, say around black holes or neutron stars. Are there ways to determine if one of them might be true?



GW170817: Signals from gamma ray satellites (top 3 panels) and LIGO (bottom panel)

We would need to look at the most gravitationally intense regions of space to have a chance at differentiating the different gravitational theories, and we finally have a way to do that: by the detection of gravitational waves from mergers of black holes and neutron stars using the LIGO (and now Virgo) interferometers.

GW150914, the merger of 35.4 solar mass and 29.4 solar mass black holes was detected on September 14, 2015, announced on February 11, 2016 and Nobel prized on October 3, 2017. Binary black hole mergers were also detected on December 26, 2015 (GW151226) and January 4, 2017 (GW170104). A LIGO detection on October 12, 2015 (LVT151012) did not reach statistical significance and so cannot be "officially" claimed as a black hole merger, but it probably was. On August 14, 2017, a couple of weeks after the Virgo detector in Italy joined the hunt, another BH-BH merger was found (GW170814).[2] Interest in this event was quickly swamped by a detection that matched models of a binary neutron star merger: a much longer duration and a higher frequency than the black hole events. Unlike the other discoveries, GW170817 had a confirmed optical counterpart. It is called a "kilonova" because the amount of optical energy released is a thousand-fold greater that a nova. But its light curve clearly shows it bears little resemblance to the usual stellar explosions.



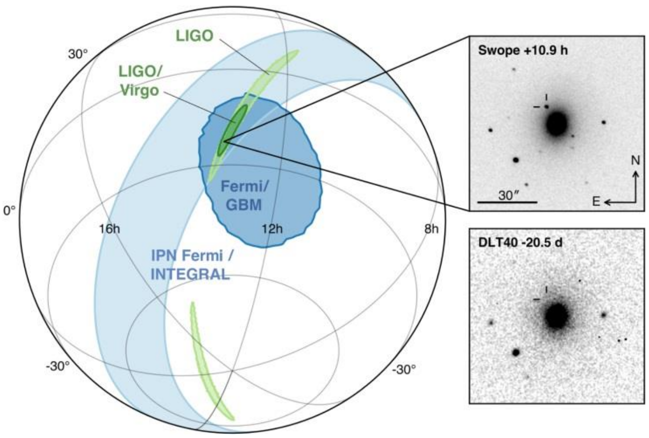
Light curve of the kilonova compared to other types of stellar explosions[3]

The importance of GW170817 cannot be overemphasized. The science that followed the detection illustrates the power and sophistication of modern research astronomy and the holistic nature of the astronomy

[2] Another binary black hole, GW170608, was announced in November just prior to the submission of his article.

[3] Arcavi, I, et. al., Optical emission from a kilonova following a gravitational-wave-detected neutron-star merger, https://arxiv.org/ftp/arxiv/papers/1710/1710.05843.pdf

community, which now is able to mobilize its resources with unprecedented speed and efficiency.



The location of GW170817 and discovery image by the 1-meter Swope telescope at Las Campanas Observatory in Chile. The pre-event comparison (lower image) was obtained 20.5 days earlier[4]

Within 2 seconds of the gravitational wave detection, gamma ray satellites Fermi (NASA) and Integral (ESA) detected a classic short gamma ray burst (named GRB170817A). sGRBs had been suspected of being binary neutron star mergers but optical counterparts had never been confirmed, so no follow-up science could be done to verify their nature. The addition of Virgo improved the spatial resolution of the gravitational wave detection because there were now three "eyes" sensitive to the signals, and with the additional resolution from the gamma ray instruments the source was narrowed to a 30 square degree ellipse in the southern hemisphere constellation Hydra. This is an area capable of being surveyed quickly by modern telescopes. The gamma ray detection was announced within minutes, but it took LIGO almost an hour to report the gravitational wave signals. An announcement was flashed to observatories around the world, and terrestrial telescopes of all sizes, many of them big instruments in Chile, were quickly programmed to look in that region as soon as the sun set. Sure enough, using galaxy-targeting strategies and wide-field imaging, a new object in the 12.4-magnitude elliptical galaxy NGC 4993 at a distance of about 130 million light-years was detected that night by 5 astronomy groups. The point-like source, given various names by the observatories that found it but now officially called AT2017gfo, had not been present on previous survey images, some just a few days old. Over 70 terrestrial visual and infrared telescopes as well as X-ray, microwave and radio telescopes were trained on the object. Even Hubble got in on the act.

Optically, the source reddened and faded over a week or so, very much unlike a supernova, whose light curve lasts for a longer period. Radio emissions, however, only began to be detected by the Jansky Very Large Array after about two weeks. From spectroscopic observations and intensities in the different electromagnetic bands, a fairly coherent picture of the astrophysics of the event has been built up.

A press conference on October 16th at the National Press Club, sponsored by the National Science Foundation, was broadcast on the Internet and is archived on YouTube.[5] It's worth watching in its entirety. The graphics are spectacular and articulate astronomers explain every important element of the story. There's lots of information on the LIGO web site as well.[6]

A large number of scientific papers were released on the same day as the press conference. The arXiv site listed 65 papers[7] that accompanied the announcement. Hundreds more are sure to be published in the coming weeks and months. The main paper summarizing all of the information will be published in the *Astrophysical Journal Letters* and apparently will have 4,600 authors, approximately one-third of all the professional astronomers in the world! The papers are of course quite technical, but many have narratives that are comprehensible by knowledgeable amateurs. A relatively non-technical introductory article[8] by Edo Berger of Harvard introduces papers published in *Astrophysical Journal Letters* and provides an excellent summary of the important aspects of the detection of electromagnetic radiation from the merger. Additional papers are being published in *Science*, *Nature* and other journals and there has already a vast amount of information in the lay science press.

The subjects in the initial slew of papers ranged widely: the detections themselves, the nature of the precursor neutron stars, the structure of the astrophysical environment surrounding the merger, the mechanism

[4] Abbott, et. al., Multi-messenger Observations of a Binary Neutron Star Merger, http://iopscience.iop.org/article/10.3847/2041-8213/aa91c9/meta#apjlaa91c9s2, to be published in Astrophysical Journal Letters

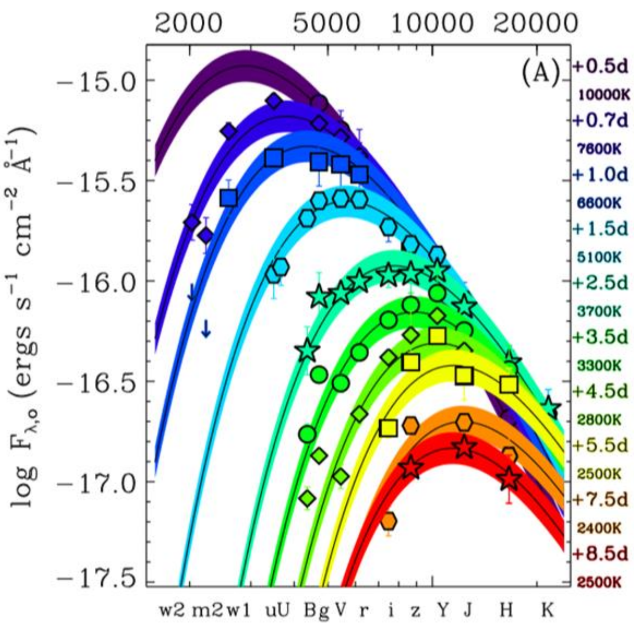
[5] https://www.youtube.com/watch?v=AFxLA3RGjnc&feature=youtu.be)

[6] https://www.ligo.caltech.edu/

[7] https://blogs.cornell.edu/arxiv/2017/10/16/gw170817/

[8] http://iopscience.iop.org/journal/2041-8205/page/Focus_on_GW170817

of the emission of gravitational waves, the sources of radiation emissions, the structure of the residual object and its astrophysical environment and fundamental physics and cosmology that might be extrapolated from the data, including the nature of dark matter and dark energy, theories of gravity and even extra dimensions. One paper[9] used the data to derive a value for the Hubble constant (H_0), the expansion rate of the universe at the current time. The value, 70 (+12,-8) km s^{-1} Mpc^{-1}, independently verifies the range of current estimates but does not distinguish between the most recent competing values from different surveys, which vary from 67 to 74. Additional observations of binary neutron star mergers will narrow the range and could provide the benchmark value of H_0.



Spectra of ATC 2017a at different times after the event. Note the shift to longer wavelengths as well as the fall-off in intensity.[10]

Many of the papers sought to fit the data to a range of models and simulations in order to understand each of the steps in the evolution of the merger. Does reality follow the expectations of theory? There were exhaustive descriptions of the strategies used by different teams to uncover the optical counterpart and to explain its unique spectroscopic signature. I was impressed by how much detail, thought and cooperation among sub-disciplines in astronomy goes into producing the analyses and validating the results.

The spectrum of AT2017gfo was unique for a nova-like object even beyond its unexpectedly rapid fall-off in intensity. Over a period of days, the peak intensity shifted to longer wavelengths as it faded. The explanation for this phenomenon was that in the neutron-rich environment of the merger, elements heavier than iron were created. These elements and their radioactive decay products preferentially emitted in the infrared band and then in radio waves.

It will clearly appeal to the popular imagination that most of the heavy elements, including nearly all the gold, platinum and uranium in the universe, appear to be made not in supernovas, as was previously thought, but in neutron star mergers. The "r-process" (r for rapid) is the prompt entry of an energetic free neutron into a nucleus. Many of the elements thus formed will be radioactive and would undergo beta decay, emitting an electron (and an electron antineutrino), increasing one atomic number but remaining at the same atomic weight. If another neutron came along before beta decay occurs, the nucleus gets heavier at the same atomic number, and the process can continue as long as the absorption rate overwhelms the rate of beta decay. The enormous numbers of neutrons in neutron stars, accelerated by energy from the merger, allows the r-process to proceed, making heavier and heavier elements. Combined with the ongoing beta decay of these neutron rich elements, a smorgasbord of stable and radioactive heavy elements and isotopes is created. These elements and isotopes powered the spectrum of the optical counterpart of GW170817 in the days following the event.

The r-process was one of the subjects of an influential 1957 paper "Synthesis of the Elements in Stars" by Margaret and Geoffrey Burbridge, William Fowler and Fred Hoyle.[11] This paper is called the B^2FH paper in astronomy vernacular. It was the first complete exposition of stellar nucleosynthesis of the heavy elements, countering a long-standing theory of George Gamow that proposed that all nuclei had been formed in the Big Bang. Hoyle had been working on stellar nucleosynthesis for some years, but it was Fowler who received the 1983 Nobel Prize for this work. Hoyle, whose theory about the steady state universe had by 1983 been thoroughly debunked and who was noted for having a somewhat irascible personality (recall he

[9] LIGO Collaboration, et. al., A Gravitational-Wave Standard Siren Measurement of the Hubble Constant https://export.arxiv.org/pdf/1710.05835

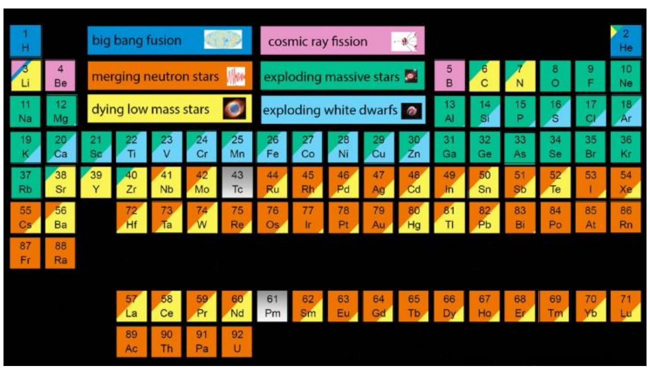
[10] M. R. Drout, et. al. Light Curves of the Neutron Star Merger GW170817/SSS17a: Implications for R-Process Nucleosynthesis, https://arxiv.org/pdf/1710.05443.pdf

[11] https://journals.aps.org/rmp/pdf/10.1103/RevModPhys.29.547

coined the term "Big Bang" as an insult) never received science's top award. B^2FH proposes that most of the r-process occurs in supernovas. Although the prolific Fritz Zwicky proposed the existence of neutron stars in 1937, they were not discovered until Bell and Hewish found pulsars in 1967 (for which Hewish but not Bell was awarded the Nobel Prize, another famous oversight by the Physics award committee). In 1957 supernova explosions were thought to be the most energetic processes in the cosmos.

The r-process requires conditions that fit a binary neutron star merger environment perfectly: temperatures above 10^9 K and a neutron density $>10^{22}$ cm^{-3}. In the interior of stars, where temperatures and densities are lower, the s-process (s for slow) also adds neutrons to nuclei but generally over times frames measured in years. This is distinct from nuclear fusion, which can only create nuclei up to ^{56}Fe.

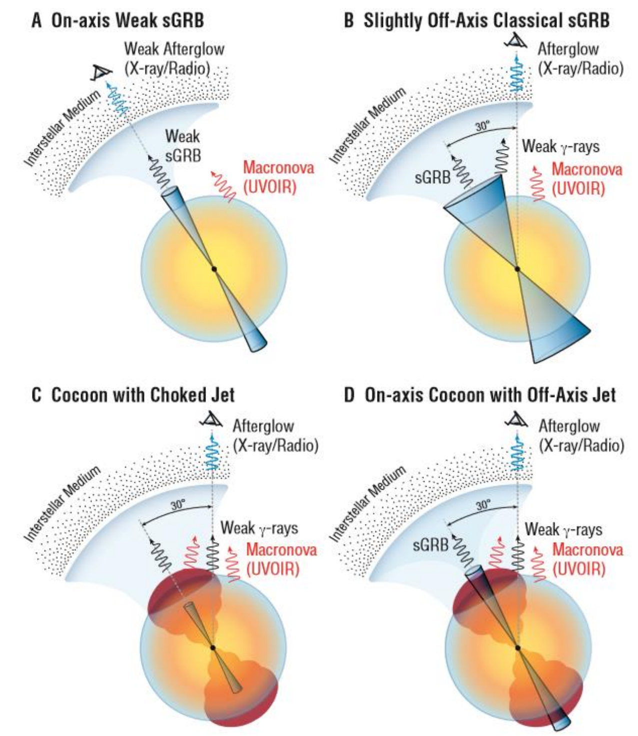
AT2017gfo confirms a new view of the periodic table, showing the origin of most of the heavy elements in neutron star mergers rather than supernovas.



The modern periodic table, indicating the sources of elements as we now think we know them

The only astronomical observatories that failed to yield data were neutrino detectors. None of the operating neutrino detectors on Earth, including the very sensitive IceCube detector at the South Pole, recorded *any* neutrinos from the event. This is a bit baffling, but the explanation given is that this is a consequence of the geometry of GW170817 and its aftermath, with neutrinos emitted in a specific direction and not directly at us.[12]

Many of the papers discussed physical models for the electromagnetic emission. There was a common perception that we were looking at the event "off axis", perhaps about 30 degrees from the rotational axis of the residual object, most probably a black hole but possibly a giant neutron star. Emissions come from several zones and structures within the environment of the final object.



Several models of the electromagnetic emissions from AT2017gfo[13]

GW170817 confirmed the long-held theory that short gamma ray bursts (SGRBs) are due to binary neutron star mergers (or perhaps a neutron star-black hole mergers, but one of these has not yet been definitively observed). sGRBs constitute about 30% of all gamma ray bursts, the most energetic events in the cosmos. Gamma ray satellites detect several sGRBs each week, but optical counterparts have been extremely rare. GRB170817A is the first one to be associated with gravitational waves and with a relatively nearby astrophysical object whose spectrum can be studied in detail.

Although the final post-merger structure is still being studied, it seems likely that the electromagnetic radiation was triggered by interactions in the matter cloud surrounding the merged neutron stars. The gamma rays that were detected by Fermi and Integral were

[12] Albert, A, et. al., Search for High-energy Neutrinos from Binary Neutron Star Merger GW170817 with ANTARES, IceCube, and the Pierre Auger Observatory https://arxiv.org/abs/1710.05839

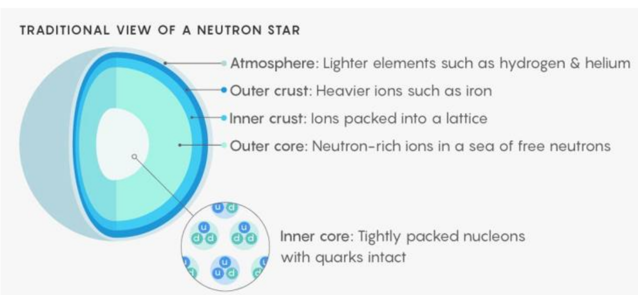
[13] Kasliwal, MM, et. al., Illuminating Gravitational Waves: A Concordant Picture of Photons from a Neutron Star Merger, https://arxiv.org/pdf/1710.05436.pdf

delayed because they were created after the instant of the merger. But that may not be the whole story.

Gamma ray emission could be delayed if the initial flux of gamma rays was so intense that electron-positron pair production transformed the energetic gamma rays into electrons and positrons, so called "pair production."

$$\gamma \rightarrow e^+ e^-$$

The electrons and positrons, having mass, will travel slower than the speed of light, so even if they subsequently annihilate to create new gamma rays in the reverse of the above reaction (making two 511 MeV gamma rays), time will have passed, although perhaps not enough for our purposes. Another source of delay is Compton scattering, the interaction of photons with charged particles, generally electrons. Multiple interactions cause the free path of the photons to be longer than the direct line of sight. This is why the (non-interacting) neutrinos from the Sun come out from the core at about the speed of light while the photons, light itself, take 100,000 years to reach the photosphere. Neutrinos from Supernova 1987a in the Large Magellanic Cloud arrived on Earth 4 hours earlier than the optical photons for the same reason.



Graphic by Lucy Reading-Ikkanda/Feryal Özel
Quanta Magazine

I would have thought that some electromagnetic radiation should have been emitted right at the time of the merger. Neutron stars are dense balls of rapidly moving matter, not all of which is neutrons. They have atmospheres, crusts and cores and enormous magnetic and gravitational fields. Charged particles passing through dense gravitational fields should produce Bremsstrahlung radiation. If the flux of this radiation increased in the mayhem of the merger, it might have been strong enough to be detected by one of the X-ray satellites currently in orbit. However, observations by the Swift and Chandra X-ray telescopes only commenced 14.9 hours and 2.3 days, respectively, after the trigger event.[14] In any case, the models assign emission of X-rays to the afterglow of the merger.

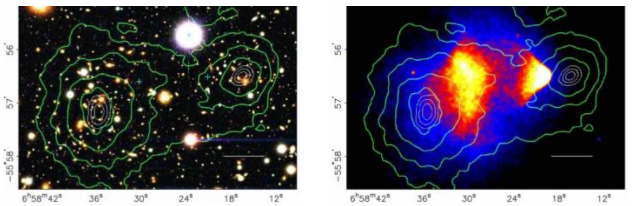
In spite of having passed every test to date, it's generally agreed that General Relativity is not the ultimate theory of gravity, since it is inconsistent with Quantum Mechanics. The environment of QM is discontinuous: electrons are either in this orbital or that one, and not in between even when they transition. Energy levels are discrete, described by integers. Probabilities go instantly from some value to one or zero. General Relativity is continuous. Space is curved locally by matter according to continuous functions. There is no "spooky action at a distance" as Einstein so cleverly termed the issue of entanglement in the famous 1935 Einstein-Rosen-Podolsky paper. It may be less difficult (although it's still really hard and hasn't been done yet) to make GR into a quantum theory than to put the genie back in the bottle and make QM a continuous one.

As mentioned earlier, there are a substantial number of alternative theories to gravitation, full of difficult concepts and exotic mathematics, which seek to replace General Relativity and solve problems that GR cannot address, such as the pre-Planck time state of the universe, the nature of dark energy or whether dark matter is matter at all. Of course, they need to reduce to GR in a lower-energy environment just as GR has to reduce to Newtonian gravity in very low energy environments like our everyday lives (except for GPS satellites, which are corrected for GR). Most of these exotic gravitations seem to be continuous theories. Unless they are quantum theories, gravity can't be unified with the other forces and describe the universe at its earliest time.

The most distinct effect attributed to dark matter is that the outer parts of galaxies are rotating too rapidly if only visible (baryonic) matter was present. Galaxy clusters also have excessive rotational velocity for the amount of baryonic matter detected. Fritz Zwicky detected this motion even before Vera Rubin systematically observed individual galaxies. Many types of dark matter particles have been proposed, both heavy (WIMPs) and light (axions, massive neutrinos) as well as other matter solutions, but it is possible that an alternative theory of gravity can account for this rotation. The most commonly cited theory is Modified

[14] Margutti, R, et. al., The Electromagnetic Counterpart of the Binary Neutron Star Merger LIGO/Virgo GW170817. V. Rising X-Ray Emission from an Off-axis Jet http://iopscience.iop.org/article/10.3847/2041-8213/aa9057

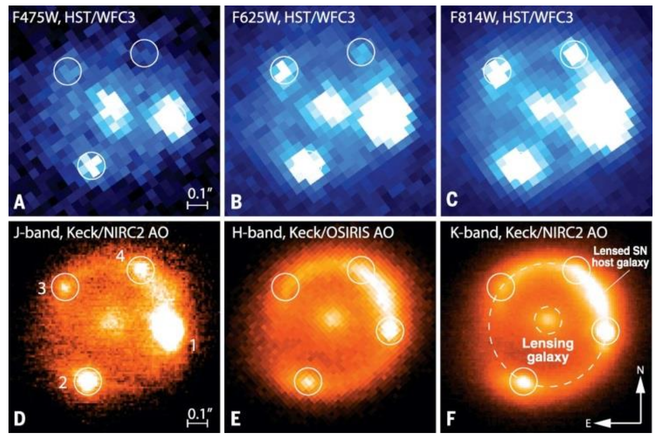
Newtonian Dynamics (MOND) where the gravitational constant varies slightly over galactic and cosmological distances. In its original form, MOND had serious drawbacks, including a requirement for supraluminal velocities (speeds greater than *c*) but later versions seem to have addressed these inconsistencies. However, in 2006 observations of gravitational lensing of background galaxies by two merging galaxy clusters, compared to the localization of the hot gas in the galaxies, were interpreted to require the existence of dark matter. This finding did not rule out alternative theories of gravity, but the authors claimed that to be credible any valid theory of gravity needs to allow some form of non-baryonic matter.



Images of merging galaxy cluster 1E0657-558: (L) Gravitational mass distribution determined by lensing of background galaxies using the Magellan telescope (R) Chandra image of hot gas in the cluster.[15]

The quantum of the gravitational field, the graviton, should be massless because the range of gravity is considered to be infinite, and massless particles move at *c* in a vacuum. It was thought that neutrinos were massless, but their ability to change flavor means they have some mass, tiny as it may be. This means they wouldn't move at *c*, but the difference between *c* and neutrino velocity has yet to be measured.

Is there evidence in gravitational wave detections of a "massive" graviton, massive in the sense of simply not being massless? A paper posted the day after the neutron star merger announcement[16] notes that the initial LIGO gravitational wave detection GW150914 had placed constraints on the graviton mass, requiring it to be $\leq 1.2\times10^{-22}$ eV, which means it could be massless but might not be. This is a *really* tiny amount of mass. For comparison, the mass of the lightest neutrino is thought to be about 0.4 eV, and the mass of the electron is 0.511×10^{6} eV. That's 28 orders of magnitude heavier than the proposed top limit of a graviton. Another paper[17] published that day suggested the difference between the velocity of a gravitational wave and an electromagnetic wave could be no greater than one part in 10^{15}. If the actual difference is in the 15^{th} decimal place, I calculated that at the distance of NGC 4993 the gravitational waves and the gamma rays would reach us about 4.4 seconds apart if they were emitted from exactly the same region of space at exactly the same time, with the gamma rays arriving *first*. That's not what seems to have happened.



The Hubble Space Telescope and the Keck Observatory resolved the positions of the SN images, the partial Einstein ring of the host galaxy, and the intervening lensing galaxy.[18]

Is it possible that interactions with the baryonic matter, dark matter or electromagnetic fields between NGC 4993 and us, particularly in the Milky Way, differentially retarded the gamma ray photons more than gravitons? One way that photons take longer than expected to reach us from their source is the Shapiro effect, also called gravitational time delay. The curvature of space around a massive object results in the photon's path being longer and so the time it arrives is later than if there had been no mass. This is a byproduct of the displacement of light due to gravitational lensing that Eddington used to prove General Relativity in 1919. The Shapiro effect was demonstrated in the solar system in 1966 by detecting delays in radar signals reflected from Venus and Mercury caused by the Sun. In 2016 the Hubble Space Telescope detected a supernova that was gravitationally lensed by a foreground galaxy. Four images of the supernova were seen, arriving at the detector at different times, the light paths differentially lengthened by the intervening

[15] Clowe, D, A Direct Empirical Proof of Dark Matter, https://arxiv.org/pdf/astro-ph/0608407.pdf

[16] Shoemaker, I, Murase, K, Constraints from the time lag between gravitational waves and gamma rays: Implications of GW170817 and GRB170817A, https://arxiv.org/pdf/1710.06427.pdf

[17] Baker, T, et. al., Strong constraints on cosmological gravity from GW170817 and GRB170817A, https://arxiv.org/pdf/1710.06394.pdf

[18] Goobar, A, iPTF16geu: A multiply imaged, gravitationally lensed type Ia supernova, *Science* 2017; 365: 291-295

mass. General Relativity suggests, however, that the retarding effect of the curvature of space by matter is the same for gravitational and electromagnetic radiation. Some of the competing theories of gravity do predict differences, as do theories that posit additional dimensions of space-time into which only gravitons can penetrate. Also, there's not enough matter, dark or otherwise, between NGC 4993 and us to matter.

If gravitons have mass and move slower than *c*, it may be that although the generation of the gamma rays occurred more than 1.74 seconds after the final merger, the gamma rays actually caught up a bit with the gravitational waves. I think it would be difficult to prove that, but the ingenuity of astronomers seems boundless. If there are additional neutron star events, as seems likely, the details may throw some light on the problem, so to speak.

Individual gravitons have never been detected. In the absence of a coherent quantum theory of gravity, their properties can't be rigorously determined. They are still truly theoretical particles. Can we figure out a methodology to detect an individual graviton and study it? I came across a remarkable 2006 paper by Tony Rothman, then at Princeton and now at NYU, and Stephen Boughn, from Haverford College. Entitled "Can Gravitons be Detected?"[19] the paper follows up a suggestion by the noted physicist Freeman Dyson who proposed that no physical experiment in the universe could be built to detect a single graviton. The paper is an exhaustive analysis of the factors that need to be taken into account to design a graviton detector, based on reasonable assumptions about potential graviton interactions with other particles. Recall that the strength of gravity at the level of subatomic particles is 10^{-39} as strong as electromagnetism! The authors note "Although physicists routinely speak as if bosons mediating the gravitational force exist, the extraordinary weakness of the gravitational interaction makes the detection of a gravitational quantum a remote proposition…. If so, is it meaningful to talk about gravitons as physical, or do they become metaphysical entities?"

The authors state "There are only a few conceivable sources of gravitons: spontaneous emission of gravitons from neutral hydrogen, black hole decay, bremsstrahlung from electron-electron collisions in stellar interiors and conversion of photons to gravitons by interstellar magnetic fields." They examine each source and make estimates of emission rates and interaction cross-sections. There is a good deal of physics and mathematics in the paper. But the conclusion is rather fascinating: it would take a detector made of hydrogen the mass of Jupiter, operating with 100% efficiency, to detect gravitons with a reasonable chance of success. The detector might have to be impossibly close to the source of the gravitons, but even putting it in tight orbit around a neutron star would only give one detection every 10 years, primarily because signals from gravitons interacting in the center of the detector wouldn't be able to get to the surface to register. In addition, because of noise from neutrino interactions, which in spite of their bashfulness have a cross-section with matter much higher than that of gravitons, the device would have to be shielded, and if you did that with enough lead to block the neutrinos, the device would collapse into a black hole! The paper concludes "Although...we have found no basic principle ruling out graviton detection, reasonable physics appears to do so." They do note that if and when gravitational waves are detected by LIGO (recall this article was from 2006), the detection will be of gravitational radiation, which is made of many gravitons (perhaps 10^{38} per cubic gravitational wave wavelength, I calculate to be about $1.25*10^{13}$ gravitons per cubic centimeter), but not of a distinguishable single graviton. An analogy is that we can easily see a beam of light with enormous numbers of photons but to see individual photons we have to decrease the light intensity and find an alternate means of detecting them, such as the photoelectric effect. We may never be able to determine the characteristics of the quantum of the gravitational force, and thus might be prevented from validating a quantum theory of gravity. But I'm not so sure, given the ingenuity of modern astronomers and physicists and the inevitable progression of science, that the graviton can stay hidden forever.

We are likely to see more astrophysics and theoretical physics coming out of GW170817 as the vast trove of data is analyzed by teams from around the world. It shows the fantastic organization, interconnectedness, creativity and civility of the modern research astronomy community. It's amazing how astronomers can get so many large research instruments pointed at a new object in so short a time. While no doubt some astronomers were upset at seeing their own observation programs interrupted in late August 2017, they should be proud to be present at this moment of scientific history, the birth of "multi-messenger astronomy."

[19] https://arxiv.org/pdf/gr-qc/0601043.pdf

Yonkers Library Telescopes modified by WAA

Many libraries around the country are offering "lend-a-telescope" programs. People can check out a telescope just as they would a book. Orion StarBlast 4.5" table-top Dobsonians are the preferred lending telescope. They're solid, have good optics and are easy for beginners to use. However, they need to be modified to ensure that all the parts remain together and curious users don't mess with the collimation ("Daddy, what are these knobs for?"). This involves placing a cover made from the bottom half of a 1-gallon Sterilite plastic juice container over the mirror end of the telescope, securing an 8-24 mm zoom eyepiece in the focuser with set screws, modifying the zero-power finder to use AA cells rather than a button cell, installing a 2" "moon port" in the dust cap and securing the cap with cord. The New Hampshire Astronomical Society has been a leader in this effort, placing telescopes at over 60 libraries around the Granite State. Hundreds of other libraries around the country are lending scopes, making patrons and librarians (and Orion, of course) very happy and spreading interest in astronomy, which can help local clubs like ours.

The Yonkers Library was given funds by the local Rotary to purchase and modify three telescopes. WAA was contacted and asked if we could assist in making the modifications. Three members of WAA's gearhead wing, Rich Steeves, John Paladini and Larry Faltz, volunteered to do the alterations.

Obtaining the parts was easy: everything could be obtained in a few days via Amazon. The cost of parts for each telescope came to about $35. We supplied the tools: a drill, a 8x32 tap and drill, screwdrivers, tape measure, glue, etc. The instructions we used were from the Astronomical League: (https://www.astroleague.org/files/library_telescope/Telescope%20Modifications.pdf).

On Saturday, October 21st, Rich, John and Larry spent about 2½ hours at the Grinton I. Will branch of the library, on Central Avenue near Tuckahoe Road, completing most of the modifications to the scopes and finishing one scope fully. Less than an hour was needed the following Saturday for Rich and Larry to finish the job. We learned a good bit about how to sequence the modifications for maximum efficiency and how to protect the optics during drilling and installation of the rear-end mirror cap (basically removing the mirror cell before drilling holes to mount the cover, an instruction that was not mentioned in the otherwise methodical instructions).

Of course, we had the foresight to bring along a laser collimator to ensure optical alignment before we placed the rear cap. True gearheads don't leave things like that to chance!

Rich Steeves and John Paladini working on the StarBlasts at the Yonkers Library (photo by Larry Faltz).

A small bag containing a flashlight, planisphere, observing handbook and instructions for use will be attached to the mount. A strict warning not to use the scope for solar viewing will be affixed to each tube. WAA will help out with the period maintenance of the telescopes, which will need occasional re-collimation. We think other Westchester libraries will ask for our help and we hope more members will participate if we put the call out via email blast.

Individual Member Viewing at Ward Pound Ridge Reservation

Many WAA members ask whether it's permissible to observe at Ward Pound Ridge Reservation (WPRR) on non-star party nights. Although the park is formally closed after dusk except for registered campers, our members would occasionally set up a telescope in the Meadow Parking Lot on a clear non-star party night for viewing or astrophotography. Years ago WAA had been granted this privilege by a former WPRR park manager, and one of our long-time members had a copy of an undated "to whom it may concern" letter on County letterhead listing Andrew O'Rourke as County Executive (served 1983-98). The occasional member presence in the park was accommodated by an understanding night park ranger. It helped that the decorum of our members was always civilized.

Over the past couple of years, however, an increasing number of non-WAA individuals, some claiming to be members, have been coming into the park at night to take advantage of the darkness for purposes other than stargazing. In addition, a recent legal review by the Parks Department showed that there were a large number of historical but informal relationships such as ours that created potential liability, for example open access to the trails at Ward Pound for local riding stables. In August, we were asked not to use the park for individual viewing until a formal arrangement between WAA and the county could be worked out.

The County Parks Department understands that astronomy is a legitimate use of a public park. We quickly came to an agreement after two cordial meetings and some email exchanges. WAA is being granted a Special Use Permit that allows any of our members to use the Meadow Parking Lot provided that they notify the park at least 24 hours in advance by calling (914) 864-7317, leaving a message if no one is in the office to answer. Observers must bring identification in the form of the ID card that we issued to all members on October 8th and will reissue each time membership is renewed. It comes as an attachment to the email acknowledging receipt of dues. It should be printed and carried with you when you observe. [Please note: some email programs tend to place these kinds of emails in a "Junk" folder. You should check that folder periodically, and if you know how to do it, have your email program allow all emails sent from a @westchesterastronomers.org address to go to your Inbox.] The park staff is well aware of the capricious nature of the weather and they understand that things can change at the last minute, but proactive communications is critical to maintaining the excellent relationship we have with the park.

The night ranger may ask you for your WAA ID card to verify your status under the Special Use Permit. Encourage non-members friends who want to observe to join WAA.

We agreed to add Westchester County to our general liability insurance policy as an "additional insured" for a nominal sum, well within our means. However, we and the park want users to understand that any individual use is at your own risk, so if you get eaten by a coyote, stung by a mosquito or drop your telescope you can't blame us!

Please do not schedule any public programs at WPRR without contacting WAA and the park. They want substantial notice for any large gatherings, since that may change their security plans. The park staff always needs to know in advance what to expect so they can fulfill their responsibilities for public safety.

We also want to remind everyone that WAA members must be proper stewards of the park. Most importantly that means no littering. You must carry out any refuse and leave the observing area in pristine condition. Alcohol consumption is discouraged, and even a low level of blood alcohol may impair scotopic night vision.

Many members would like company when they observe, whether at WPRR or at other locations. We have created the WAA OBSERVER'S GROUP as a forum on Google. If you join this group, you can receive emails from other members who are looking for observing company. There are currently 40 WAA members subscribed to the group.

You will need a GMAIL account, which is free. Anyone can join by going to groups.google.com, searching for WAA Observers and clicking "subscribe to this group." It works as a forum and an email group - all of the messages are kept in the forum but you can receive the emails as they are posted. They will go to your GMAIL account so you should set up your mail program (on computer and/or smartphone) to access that account.

WAA holds its star parties at the Ward Pound Ridge Reservation, Westchester's largest (and darkest) county park. Park management is very accommodating for these events and lists the star parties on their event schedule, encouraging campers to drop by.

Studying Storms from the Sky

Teagan Wall

The United States had a rough hurricane season this year. Scientists collect information before and during hurricanes to understand the storms and help people stay safe. However, collecting information during a violent storm is very difficult.

Hurricanes are constantly changing. This means that we need a lot of really precise data about the storm. It's pretty hard to learn about hurricanes while inside the storm, and instruments on the ground can be broken by high winds and flooding. One solution is to study hurricanes from above. NASA and NOAA can use satellites to keep an eye on storms that are difficult to study on the ground.

In Puerto Rico, Hurricane Maria was so strong that it knocked out radar before it even hit land. Radar can be used to predict a storm's path and intensity—and without radar, it is difficult to tell how intense a storm will be. Luckily, scientists were able to use information from a weather satellite called GOES-16, short for Geostationary Operational Environmental Satellite – 16.

The "G" in GOES-16 stands for geostationary. This means that the satellite is always above the same place on the Earth, so during Hurricane Maria, it never lost sight of the storm. GOES-16's job as a weather satellite hasn't officially started yet, but it was collecting information and was able to help.

From 22,000 miles above Earth, GOES-16 watched Hurricane Maria, and kept scientists on the ground up to date. Knowing where a storm is—and what it's doing—can help keep people safe, and get help to the people that need it.

Hurricanes can also have a huge impact on the environment—even after they're gone. To learn about how Hurricane Irma affected the Florida coast, scientists used images from an environmental satellite called Suomi National Polar-orbiting Partnership, or Suomi-NPP. One of the instruments on this satellite, called VIIRS (Visible Infrared Imaging Radiometer Suite), took pictures of Florida before and after the Hurricane.

Hurricane Irma was so big and powerful, that it moved massive amounts of dirt, water and pollution. The information captured by VIIRS can tell scientists how and where these particles are moving in the water. This can help with recovery efforts, and help us design better ways to prepare for hurricanes in the future.

By using satellites like GOES-16 and Suomi-NPP to observe severe storms, researchers and experts stay up to date in a safe and fast way. The more we know about hurricanes, the more effectively we can protect people and the environment from them in the future.

To learn more about hurricanes, see NASA Space Place: https://spaceplace.nasa.gov/hurricanes/en/

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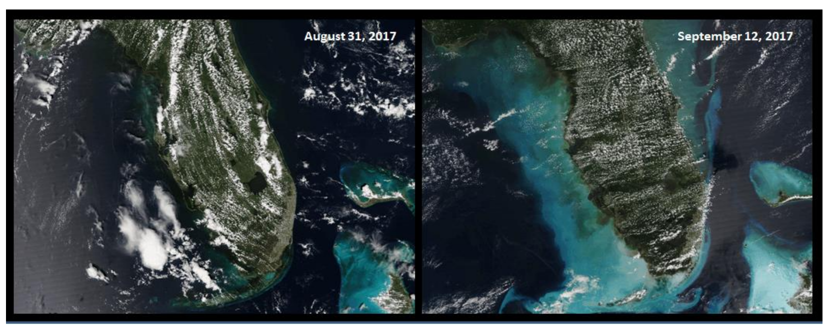

These images of Florida and the Bahamas were captured by a satellite called Suomi-NPP. The image on the left was taken before Hurricane Irma and the image on the right was taken after the hurricane. The light color along the coast is dirt, sand and garbage brought up by the storm. Image credit: NASA/NOAA

NASA Space Place spaceplace.nasa.gov

Astrophotos

This capture of the Andromeda Galaxy was shot from an unlikely locale -- Manhattan. On Halloween, the New York City Amateur Astronomers Association held their last public stargazing session for the season on the High Line and Mauri Rosenthal used that opportunity to focus his portable imaging rig on the galaxy. “Between the terror attack a few hours earlier, the parade in the Village, and the long awaited drop in temperature it was very quiet up there, so I was able to shoot two good hours of exposures,” explains Mauri. He used a ZWO ASI1600 color astro camera with a Borg 55FL astrograph mounted on an iOptron Cube Pro 8200 mount, and processed the image with PixInsight.

Courtesy of Scott Nammacher is a picture of the Pelican nebula, imaged in the Hubble pallet. Notes Scott: I shot it from my observatory upstate using a 12.5" Planewave scope and an SBIG 10XME camera. Shot 3000 secs in Ha, 4620 secs in OIII and 6200 secs in SII filters, all using bin 2 settings. Shot 5 minute subs. Collected shots with MaximDL and ACP software. Stacked with MaximDL, and processed pics with Photoshop. Pics were taken over time, in 2016 and 2017.

Member & Club Equipment for Sale
December 2017

Item	Description	Asking price	Name/Email
Edmund Astroscan reflector	105mm tabletop reflector. From 2001 in very good condition eyepiece. RKE eyepiece.	$55	Robert Lally Pl104@verizon.net
Orion Sirius Plossl eyepiece set	1¼" set in aluminum box, with filters and hybrid diagonal	$55	Robert Lally Pl104@verizon.net
Orion 6 X 50 finder scope	Straight-through finder. White , with mounting rings, new , unused, in box	$55	Robert Lally Pl104@verizon.net
AstroPhysics Mach 1 Go-to mount	GEM with Eagle pier, GoTo keypad controller w. protector, CP3 servo control box, PulseGuide software, polar alignment scope, 8" Dove plate, 10" multi use bar, 13.8 v regulated power supply, 6 lb weight, 9 lb weight. New, unused, vastly discounted, extraordinary bargain.	$2850	Robert Lally Pl104@verizon.net
Meade ETX-90 Maksutov	90 mm go-to alt-az. "Supercharged" by Dr. Clay. Tripod, carrying case, 25 mm eyepiece. All documentation. New condition. Donated to WAA.	$250	WAA ads@westchesterastronomers.org
Celestron Nexstar 8i	8" Schmidt-Cassegrain go-to scope on single arm alt-az mount. Excellent optics, mild tube blemishes. Hand control, dew shield, tripod. Diagonal, no eyepiece. Donated to WAA.	$500	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.	$200	WAA ads@westchesterastronomers.org
Interfit 487 large rolling storage bag	39½x22x16" fabric-sided standing gear bag with rollers, Velcro compartments. Excellent condition. Donated to WAA.	$50	WAA ads@westchesterastronomers.org
Ritchey-Chrétien 2.4 meter telescope	f/24. Corrected optics. Several cameras. Currently in low Earth orbit. Used. You pick up.	Free	Space Telescope Science Institute help@stsci.edu

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 only submit serous 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. Commercial listings are not accepted (No exceptions). Items must be the property of the member. WAA takes no responsibility for the condition or value of the item or accuracy of any description. 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). WAA is not responsible for the satisfaction of the buyer or seller. *Caveat emptor*!