Southwest Florida Astronomical Society
SWFAS

The Eyepiece
April 2016

Contents:

A MESSAGE FROM THE PRESIDENT

March is the last month for the $100,000 Philips Matching Grant. If successful in raising funds, this will mean getting a new or repaired roof for the Planetarium. All donations will be doubled by this grant through March. Please contribute through the CNCP website, www.calusanature.org. Thanks! RLM

In the Sky this Month

Moon: April – New - 7th; 1st Quarter - 13th; Full - 22nd; Last Quarter - 29th.
April 10 will witness an occultation (eclipse) of Aldebaran (the bright red star in Taurus) by the crescent moon around 6:30 pm.

The Planets: Mercury and Jupiter are visible in the evening, while four planets (Venus, Saturn, Mars, and Jupiter) remain visible in dawn's early light.

Mercury is visible soon after sunset in the west most of the month.
Jupiter rises early in the evening and is high in the east, reaching opposition March 8th. It remains visible throughout the night most of the month, shining at -2.4 magnitude. It's located in southeastern Leo.
Mars rises around midnight and shines above Antares in Scorpius. It will brighten noticeably during the month to -1.4 magnitude, brighter than any star, by month's end.
Saturn rises 40 minutes after Mars all month and shines at 0.2 magnitude. It is north and east of Scorpius, so you have a chance to compare the colors of reddish Antares with red-orange of Mars and deep gold of Saturn. This is most obvious as dawn approaches and the dimmer stars disappear.
Venus shines brightly as it rises only half an hour before sunrise for first third of the month before it drops out of sight.

International Space Station: The ISS returns to evening skies over Ft Myers from April 17 - 21. See this link for specific times: http://www.heavens-above.com/

Future Events

Star Party and Event Schedule

Date	Event	Location	Time	Info/Contact
April 7th Monthly Meeting	Monthly Meeting Program: Ted Wolfe, astrophotographer	Calusa Nature Center & Planetarium	7:30 pm	Brian Risley
April 8th 2nd Friday	Public Observing	Moore Observatory, FL SW St. College, Punta Gorda	Dusk	Tony Heiner, Tom Segur and Tom Burkett along with Dave Hanson
April 9th	Star Party	CRP	Dusk	Bruce Dissette
April 23rd 4th Saturday	Solar Observing	Ponce De Leon Park, Punta Gorda	9 am – Noon	Tom Segur
May 5th		Calusa Nature Center & Planetarium	7:30 pm	Brian Risley
May 7th	Star Party	CRP	Dusk	Bruce Dissette

May 13th 2nd Friday	Public Observing	Moore Observatory, FL SW St. College, Punta Gorda	Dusk	Tony Heiner, Tom Segur and Tom Burkett along with Dave Hanson
May 28th 4th Saturday	Solar Observing	Harbour Heights Park, Port Charlotte	9 am - Noon	Tom Segur

April Program –

Ted Wolfe, accomplished astrophotographer and monthly contributor to the Naples Daily News, will be presenting to the Southwest Florida Astronomical Society on Thursday, April 7. He has had many of his images published in Sky and Telescope and Astronomy magazines and has had an exhibit of his astrophotos on display at the Kennedy Space Center at Cape Canaveral. Additionally, permanent displays of his astrophotos can be seen at the Center for Space Studies at the University of Florida and in the Logan Science Center at the University of Notre Dame.

Mr. Wolfe will discuss his efforts to establish a remote set-up for operating his telescope in the Atacama Desert in Chile. Ted's presentation will describe this 4 year project including the frustrations, complications, and his experience being the only American involved in the adventure. Included in his presentation will be pictures of the locale, his telescope at the site, and some of his early test images. Mr. Wolfe's presentation will begin at 7:30pm at the Calusa Nature Center Planetarium in Fort Myers.

Minutes of the Southwest Florida Astronomical Society – March 3rd, 2016

submitted by Don Palmer, secretary

Notable April Events in Astronomy and Space Flight History

Compiled by Mike McCauley

April 1, 1997: Comet Hale-Bopp was perhaps the most widely observed comet of the 20th century and one of the brightest seen for many decades. It was visible to the naked eye for a record 18 months, twice as long as the previous record holder, the Great Comet of 1811. Hale–Bopp was discovered on July 23, 1995, at a great distance from the Sun, raising expectations that the comet would brighten considerably by the time it passed close to Earth. Although predicting the brightness of comets with any degree of accuracy is very difficult, Hale–Bopp met or exceeded most predictions when it passed perihelion on April 1, 1997. The comet was dubbed the Great Comet of 1997.

April 3, 1966: The Luna 10 spacecraft was launched towards the Moon from an Earth orbiting platform on March 31, 1966. The spacecraft entered lunar orbit on April 3, 1966 and completed its first orbit 3 hours later (on April 4, Moscow time). Luna 10 was battery powered and operated for 460 lunar orbits and 219 active data transmissions before radio signals were discontinued on May 30, 1966.

April 5, 1973: Pioneer 11 launched. Pioneer 11 is a 259 kilogram (569 lb.) robotic space probe launched by NASA on April 5, 1973 to study the asteroid belt, the environment around Jupiter and Saturn, solar wind, cosmic rays, and eventually the far reaches of the Solar System and heliosphere. It was the first probe to encounter Saturn and the second to fly through the asteroid belt and past Jupiter. Due to power constraints and the vast distance, last contact was on September 30, 1995.

April 9, 1959: NASA selects original seven Mercury astronauts. The Mercury Seven were the group of seven Mercury astronauts announced by NASA on April 9, 1959. They piloted the manned spaceflights of the Mercury program from May 1961 to May 1963. These seven original American astronauts were Scott Carpenter, Gordon Cooper, John Glenn, Gus Grissom, Wally Schirra, Alan Shepard, and Deke Slayton.

April 10, 1919: John C. Houbolt born. John Cornelius Houbolt (April 10, 1919 – April 15, 2014) was an aerospace engineer credited with leading the team behind the lunar orbit rendezvous (LOR) mission mode, a concept used to successfully land humans on the Moon and return them to Earth. This flight path was first endorsed by Wernher von Braun in June 1961 and was chosen for Apollo program in early 1962. The critical decision to use LOR was vital to ensuring that man reached the moon by the end of the decade as proposed by President John F. Kennedy. In the process, LOR saved time and billions of dollars by efficiently using existing rocket technology.

April 12, 1961: Yuri Gagarin is first human in space. Yuri Alekseyevich Gagarin (9 March 1934 – 27 March 1968) was a Russian Soviet pilot and cosmonaut. He was the first human to journey into outer space, when his Vostok spacecraft completed an orbit of the Earth on 12 April, 1961. Gagarin was awarded many medals and titles, including Hero of the Soviet Union. Vostok 1 was his only spaceflight, but he served as backup crew to the Soyuz 1 mission which ended in a fatal crash. Gagarin later became deputy training director of the Cosmonaut Training Centre outside Moscow, later named after him. Gagarin died in 1968 when the MiG-15 training jet he was piloting crashed.

April 14, 1629: Christiaan Huygens born. Christiaan Huygens, (14 April 1629 – 8 July 1695) was a prominent Dutch mathematician and scientist known particularly as an astronomer, physicist, probabilist and horologist. Huygens was a leading scientist of his time. His work included early telescopic studies of the rings of Saturn and the discovery of its moon Titan and the invention of the pendulum clock. He published major studies of mechanics and optics, and a pioneer work on games of chance.

April 16, 1867: Wilbur Wright born. The Wright brothers, Orville (August 19, 1871 – January 30, 1948) and Wilbur (April 16, 1867 – May 30, 1912), were two American brothers, inventors, and aviation pioneers who are credited with inventing and building the world's first successful airplane and making the first controlled, powered and sustained heavier-than-air human flight, on December 17, 1903 four miles south of Kitty Hawk, North Carolina. In 1904-1905 the brothers developed their flying machine into the first practical fixed-wing aircraft. Although not the first to build and fly experimental aircraft, the Wright brothers were the first to invent aircraft controls that made fixed-wing powered flight possible. The brothers' fundamental breakthrough was their invention of three-axis control, which enabled the pilot to steer the aircraft effectively and to maintain its equilibrium. This method became and remains standard on fixed-wing aircraft of all kinds.

April 17, 1970: Apollo 13 crew returns to earth. Apollo 13 was the seventh manned mission in the American Apollo space program and the third intended to land on the Moon. The craft was launched on April 11, 1970, from the Kennedy Space Center, but the lunar landing was aborted after an oxygen tank exploded two days later, crippling the Service Module upon which the Command Module (CM) depended. Despite great hardship caused by limited power, loss of cabin heat, shortage of potable water, and the critical need to jury-rig the carbon dioxide removal system, the crew returned safely to Earth on April 17. The flight passed the far side of the Moon at an altitude of 254 kilometers (137 nautical miles) above the lunar surface, and 400,171 km (248,655 mi) from Earth, a spaceflight record marking the farthest humans have ever traveled from Earth. The mission was commanded by James A. Lovell with John L. "Jack" Swigert as Command Module Pilot and Fred W. Haise as Lunar Module Pilot.

April 19, 1967: Surveyor 3 lands on moon. Surveyor 3 was the third lander of the American unmanned Surveyor program sent to explore the surface of the Moon. Launched on April 17, 1967, Surveyor 3 landed on April 19, 1967, at the Mare Cognitum portion of the Oceanus Procellarum. It transmitted a total of 6,315 TV images to the Earth. As Surveyor 3 was landing, highly reflective rocks confused the spacecraft's lunar descent radar. The engines failed to cut off at 14 feet (4.3 meters) in altitude as called for in the mission plans, and this delay caused the lander to bounce on the lunar surface. On the third impact, Surveyor 3 settled to a soft landing as intended. When the first lunar nightfall came on May 3, 1967, Surveyor 3 was shut down because its solar panels were no longer producing electricity. At the next lunar dawn (after 14 terrestrial days), Surveyor 3 could not be reactivated, because of the extremely cold temperatures it had experienced. This is in contrast with Surveyor 1, which was able to be reactivated twice after lunar nights. The Apollo 12 Lunar Module landed near Surveyor 3 on November 19, 1969. Astronauts Conrad and Bean examined the spacecraft and brought back about 10 kg of the Surveyor to Earth, including its TV camera, now on permanent display in the National Air and Space Museum in Washington, D.C. In 2009, the Lunar Reconnaissance Orbiter photographed the Surveyor 3 landing site around which astronaut foot tracks could be seen.

April 23, 1858: Max Planck born. Max Karl Ernst Ludwig Planck, (23 April 1858 – 4 October 1947) was a German theoretical physicist whose work on quantum theory won him the Nobel Prize in Physics in 1918. Planck made many contributions to theoretical physics, but his fame as a physicist rests primarily on his role as an originator of quantum theory, which revolutionized human understanding of atomic and subatomic processes. His name is also known on a broader academic basis, through the renaming in 1948 of the German scientific institution, the Kaiser Wilhelm Society, as the Max Planck Society which includes 83 different institutions.

April 25, 1990: Hubble Space Telescope deployed. The Hubble Space Telescope is a space telescope that was launched into low Earth orbit in 1990 and remains in operation today. Although not the first space telescope, Hubble is one of the largest and most versatile, and is both a vital research tool and a public relations boon for astronomy. The HST is named after astronomer Edwin Hubble, and is one of NASA's Great Observatories, along with the Compton Gamma Ray Observatory, the Chandra X-ray Observatory, and the Spitzer Space Telescope. With a 2.4-meter mirror, Hubble's four main instruments observe in the near ultraviolet, visible, and near infrared spectra. Hubble's orbit outside the distortion of Earth's atmosphere allows it to take extremely high-resolution images, with substantially lower background light than ground-based telescopes. Hubble has recorded some of the most detailed visible-light images ever, allowing a deep view into space and time. Many Hubble observations have led to breakthroughs in astrophysics, such as accurately determining the rate of expansion of the universe.

April 28, 1900: Jan Oort born. Jan Hendrik Oort (28 April 1900 – 5 November 1992) was a Dutch astronomer who made significant contributions to the understanding of the Milky Way. He was a pioneer in the field of radio astronomy. The New York Times called him "one of the century's foremost explorers of the universe", the European Space Agency website described him as, "one of the greatest astronomers of the 20th century," and states that he "revolutionized astronomy through his ground-breaking discoveries." In 1955, Oort's name appeared in Life Magazine's list of the 100 most famous living people. He has been described as "putting the Netherlands in the forefront of postwar astronomy." Oort determined that the Milky Way rotates and overturned the idea that the Sun was at its center. He also postulated the existence of invisible dark matter in 1932, which is believed to make up roughly 84.5% of the total matter in the Universe and whose gravitational pull causes "the clustering of stars into galaxies and galaxies into connecting strings of galaxies." He discovered the galactic halo, a group of stars orbiting the Milky Way outside the main disk. Additionally Oort is responsible for a number of important insights about comets, including the realization that their orbits “implied there was a lot more solar system than the region occupied by the planets.” The Oort cloud, Oort constants, and the Asteroid, 1691 Oort, were all named after him.

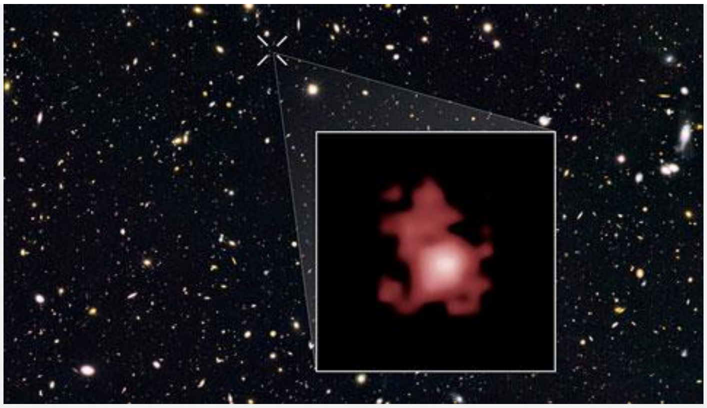
April 28, 1928: Eugene Shoemaker born. Eugene Merle Shoemaker (April 28, 1928 – July 18, 1997) was an American geologist and one of the founders of the field of planetary science. He is best known for co-discovering Comet Shoemaker–Levy 9 with his wife Carolyn S. Shoemaker and David H. Levy. In 1993, he co-discovered Comet Shoemaker–Levy 9 using the 18" Schmidt camera at Palomar Observatory. This comet was unique in that it provided the first opportunity for scientists to observe the planetary impact of a comet. Shoemaker–Levy 9 collided with Jupiter in 1994. The resulting impact caused a massive "scar" on the face of Jupiter. Most scientists at the time were dubious of whether there would even be any evident markings on the planet.

April 28, 1906: Bart Bok born. Bartholomeus Jan "Bart" Bok (April 28, 1906 – August 5, 1983) was a Dutch-born American astronomer, teacher, and lecturer. He is best known for his work on structure and evolution of the Milky Way galaxy, and for the discovery of Bok globules, which are small, dense, dark clouds of interstellar gas and dust that can be seen silhouetted against brighter backgrounds. Bok suggested that these globules may be in the process of contracting, before forming into stars. Bok married fellow astronomer Dr. Priscilla Fairfield in 1929, and for the remainder of their lives, the two collaborated so closely on their astronomical work that the Royal Astronomical Society said "it is difficult and pointless to separate his achievements from hers". The Boks displayed such great mutual enthusiasm for explaining astronomy to the public that *The Boston Globe* described them in 1936 as "salesmen of the Milky Way". They worked together on research and co-authored academic papers, and their general interest book *The Milky Way* went through five editions and was "widely acclaimed as one of the most successful astronomical books ever published". Bok's primary research interest was the structure of our galaxy. When he was asked by the editors of *Who's Who in America* to submit a statement concerning "Thoughts on My Life", he wrote, "I have been a happy astronomer for the past sixty years, wandering through the highways and byways of our beautiful Milky Way."

Hubble Finds Most Distant Galaxy Yet

By: Monica Young from S&T

Astronomers using the Hubble Space Telescope have measured a precise distance to a galaxy dwelling in the cosmic dawn.



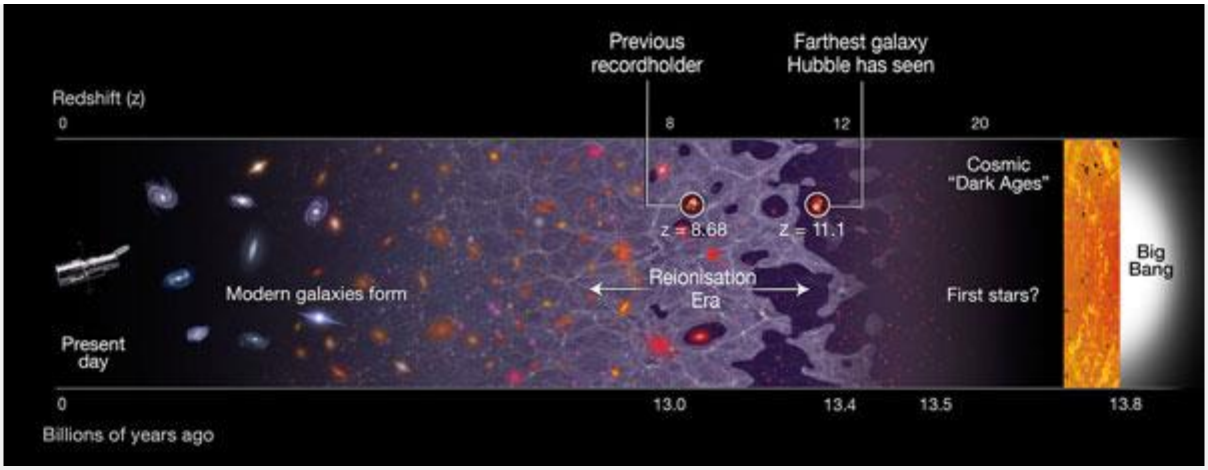
The Hubble Space Telescope has enabled a precise distance measurement to the galaxy dubbed GN-z11, which was furiously forming stars 400 million years after the Big Bang. The galaxy appears red in this infrared image, but if its light didn't have to traverse space and time to reach us, its new stars would be burning blue.
NASA / ESA / P. Oesch / G. Brammer / P. van Dokkum / G. Illingworth

Does the title give you a sense of déjà vu? Surely, you might think, we've probed the farthest stretches of the universe before. And we are indeed approaching the limit to what the Hubble Space Telescope can see of the cosmic dawn — yet the fortune-favored satellite still has some surprises in store for us.

Astronomers had already used Hubble to find hundreds of galaxies that existed less than 1 billion years after the Big Bang, as well as a handful that were around even earlier than that. Now, observations have zeroed in with greater precision than ever before on one particular object that breaks all previous distance records: a humdinger of a galaxy dubbed GN-z11 that dwells in a universe just 400 million years old (at a redshift of 11.1, in astronomer-speak).

Though the universe only started forming stars when it was about 100 million years old, this galaxy already holds a billion Suns' worth of mass in its stars. It's churning out even more at a rate between 14 and 34 solar masses a year — dozens of times higher than Milky Way's stars formation rate.

"It's amazing that a galaxy so massive existed only 200 million to 300 million years after the very first stars started to form," said Garth Illingworth (University of California, Santa Cruz) in a press release. "It takes really fast growth, producing stars at a huge rate, to have formed a galaxy that is a billion solar masses so soon."



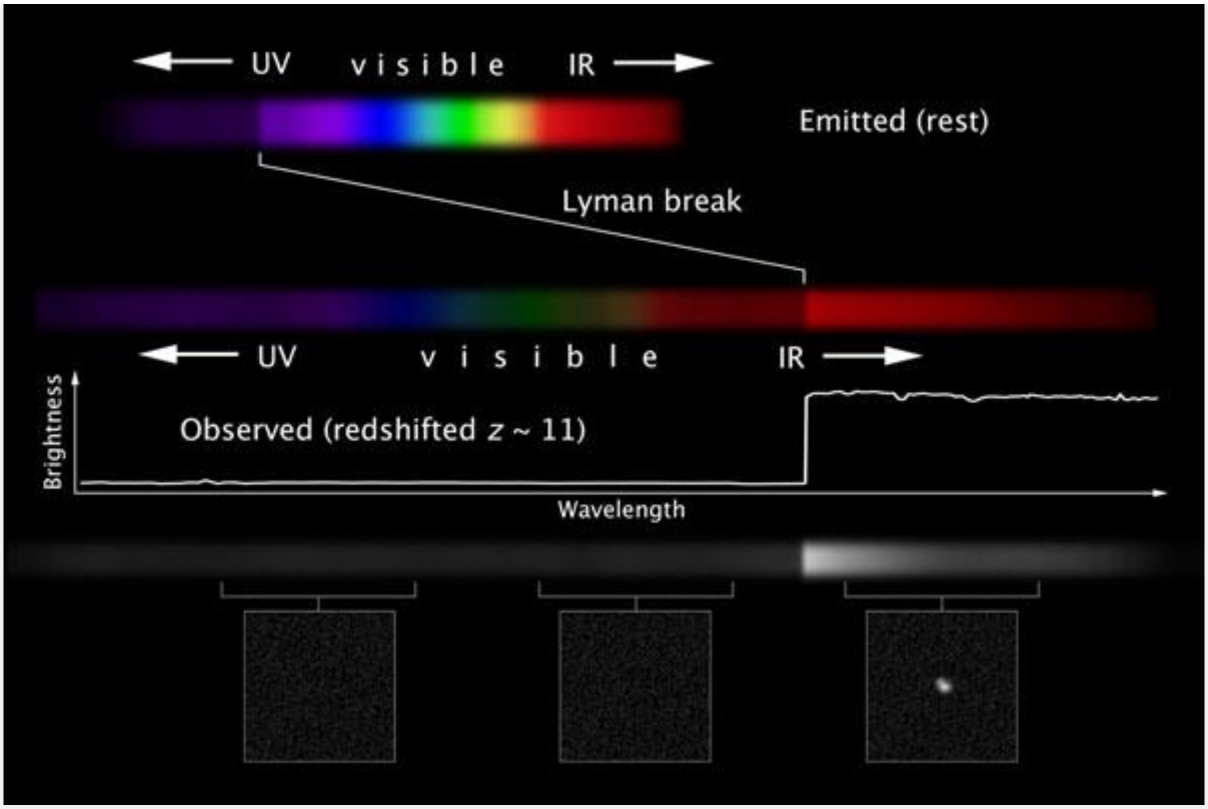
This diagram shows a timeline of the universe, stretching from the present day (left) all the way back to the Big Bang (right). The previous record-holder at a spectroscopic redshift of 8.68. *NASA / ESA / B. Robertson / A. Feild*

Thanks to its stars, GN-z11 is incredibly luminous, radiating three times the ultraviolet light typical of galaxies in that early era. That trait was key to measuring its distance with such high precision.

Once More, With Precision

When galaxies lie so far away, not only do they appear faint, but their light also shifts redward, the wavelengths stretching out as they traverse space and time. Light that was initially emitted at ultraviolet wavelengths has lengthened to infrared radiation by the time it arrives at Hubble's detectors.

Astronomers measure distance to these faraway galaxies by looking for a clear imprint in their spectra. Hydrogen that fills the early universe absorbs virtually all light at wavelengths shorter than 121 nanometers. So while a galaxy's light at longer wavelengths may pass through the universe relatively unmolested, light at wavelengths shorter than that magic number will disappear, absorbed into interstellar and intergalactic gas.



Galaxies emit light at many wavelengths, but some light will be absorbed by clouds of hydrogen gas. That break, where light is absorbed into gas clouds and disappears from the spectrum, shifts to longer wavelengths as the galaxy's light travels the long way to Earth. Taking a spectrum can identify the location of this break precisely, but often astronomers are limited to images rather than spectra. In the latter case, they look for a galaxy to disappear from images taken at shorter wavelengths.
NASA / ESA / C. Christian and Z. Levay

Locating this break in a spectrum gives astronomers an easy measure of how far a galaxy's light has shifted redward — its *spectroscopic redshift*. But easy is only as easy does: Hubble's deep looks capture regions of space teeming with faint and faraway galaxies (such as CANDELS), and it's far from easy to take the spectrum of every object in the field of view. Instead astronomers collect the poor man's version of a spectrum by taking pictures of the same field at many different wavebands. They locate the drop-off in light when they see a galaxy disappear from images taken at shorter wavebands. This process gives an object's so-called *photometric redshift*.

But photometric redshifts can be deceiving. A previous record-holder for the "most distant galaxy" title had the lovely name UDFj-39546284. Its photometric redshift of 11.9 placed it in a universe just 380 million years old. But follow-up spectra called that result into question: the galaxy might actually lie much closer to Earth than originally thought. The next most distant galaxy has a photometric redshift of 10.7.

Spectroscopic redshifts remain the golden standard for measuring distance — it's just been difficult to find galaxies bright enough to pass through a spectrograph with a legible result. GN-z11 happens to be exceptionally bright, and that's what enabled

Pascal Oesch (Yale) and his team to measure its redshift so precisely. The result will be published in the *Astrophysical Journal*.

This result may represent the edge of Hubble's reach, but it's only the beginning when it comes to future telescopes such as James Webb and WFIRST, whose longer-wavelength detectors will probe hundreds of galaxies even further back in cosmic time.

Mysterious Radio Burst Repeats Itself

By: Shannon Hall | from S&T

A brief burst of radio waves, known as a fast radio burst, has been observed repeating, enabling astronomers to settle its exotic origin.

This photo shows a three color composite of the Crab Nebula. Sitting in the center is a pulsar — a stellar core similar to what might cause this repeating fast radio burst. *ESO*

For nearly a decade, astronomers have strived to solve the puzzle of fast radio bursts (FRBs). Because these millisecond flashes of radio light appear extremely bright and yet very distant, astronomers suspect they could represent an entirely new class of astrophysical objects. So with every new FRB, they swivel their antennas toward the crime scene with the faint hope that a flash might appear again. But that hasn't happened — until now.

In November, 2012 a powerful burst washed over the Earth. Then two more bursts occurred on May 17, 2015, and eight more on June 2, 2015 — all came from the same patch of sky and the same distance. For the first time, astronomers observed a repeating FRB. The results, published March 3rd in *Nature*, suggest a rapidly spinning stellar core might explain this burst's origin.

"The repeating FRB is a sensation — I would trade five of ours for it," jokes Matthew Bailes (Swinburne University), who was not involved in this study. It's possible that no one wanted to find a repeating burst more than him. With only one observation back in 2007 (when the first FRB was discovered) he had a nagging concern that it might not be astrophysical at all. "I remember I actually had trouble sleeping because I just couldn't believe that something could be this bright and yet that far away," he says.

The fact that this FRB repeats assures Bailes that these odd signatures are in fact astrophysical. And to boot, it provides tantalizing hints about what might spark the explosion of radio waves. "It tells you without a doubt that this is not a cataclysmic event like a core-collapse supernova or a neutron star-neutron star merger because that kind of event destroys the object," says coauthor Jason Hessels (Netherlands Institute for Radio Astronomy). "There's nothing left over afterwards that's going to produce another burst."

Additional clues come from the bursts' unusual character. For example, the bulk of its emission flip flops between higher and lower frequencies — behavior similar to that produced by the highly magnetized pulsar rapidly spinning at the heart of the Crab Nebula. So lead author Laura Spitler (Max Planck Institute for Radio Astronomy) speculates that this FRB might point to a more energetic class of pulsars visible beyond the Milky Way. Future observations could verify this idea if astronomers could pin down a regular period for these bursts.

But that idea stands in stark contrast with multiple scenarios that try to explain these mysterious bursts. It also contradicts an observational result published last week, where for the first time, astronomers were able to zero in on a fast radio burst's host galaxy. Because it was an elliptical galaxy, well past its prime period for star formation, the find suggested that that FRB was likely caused when two aging stars coalesced.

Taken together, these two results could suggest that FRBs may have at least two origins: periodic outbursts of young stars that are likely closer to home and single outbursts of aging stars in the distant universe. Although Occam's razor might suggest a single origin is at play, astronomers have multiple examples of, well, multiple origins. Take gamma-ray bursts which can originate from either two neutron stars as they merge together or the single collapse of a rapidly rotating star. The universe tends to be messier than Occam would like. Regardless, both results show tremendous strides after a decade of near radio silence.

"We're definitely getting to the point where we're seeing the fruits of our efforts in the sense that we're doing quick rapid follow-up and we're looking with more telescopes," says Spitler. "But I wouldn't say that it's coming together in the sense that we're almost done. I really think that we're just getting started."

Although future observations will continue to shed light on the mysterious origins of these bursts, one thing is certain: the bursts are truly astrophysical. And thanks to that, Bailes sleeps much better at night now.

Reference:

L. G. Spitler et al. "A Repeating Fast Radio Burst."*Nature*. March 10, 2016.

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Gravitational Wave Astronomy Will Be The Next Great Scientific Frontier

By Ethan Siegel

Imagine a world very different from our own: permanently shrouded in clouds, where the sky was never seen. Never had anyone see the Sun, the Moon, the stars or planets, until one night, a single bright object shone through. Imagine that you saw not only a bright point of light against a dark backdrop of sky, but that you could see a banded structure, a ringed system around it and perhaps even a bright satellite: a moon. That's the magnitude of what LIGO (the Laser Interferometer Gravitational-wave Observatory) saw, when it directly detected gravitational waves for the first time.

An unavoidable prediction of Einstein's General Relativity, gravitational waves emerge whenever a mass gets accelerated. For most systems -- like Earth orbiting the Sun -- the waves are so weak that it would take many times the age of the Universe to notice. But when very massive objects orbit at very short distances, the orbits decay noticeably and rapidly, producing potentially observable gravitational waves. Systems such as the binary pulsar PSR B1913+16 [the subtlety here is that binary pulsars may contain a single neutron star, so it's best to be specific], where two neutron stars orbit one another at very short distances, had previously shown this phenomenon of orbital decay, but gravitational waves had never been directly detected until now.

When a gravitational wave passes through an objects, it simultaneously stretches and compresses space along mutually perpendicular directions: first horizontally, then vertically, in an oscillating fashion. The LIGO detectors work by splitting a laser beam into perpendicular "arms," letting the beams reflect back and forth in each arm hundreds of times (for an effective path lengths of hundreds of km), and then recombining them at a photodetector. The interference pattern seen there will shift, predictably, if gravitational waves pass through and change the effective path lengths of the arms. Over a span of 20 milliseconds on September 14, 2015, both LIGO detectors (in Louisiana and Washington) saw identical stretching-and-compressing patterns. From that tiny amount of data, scientists were able to conclude that two black holes, of 36 and 29 solar masses apiece, merged together, emitting 5% of their total mass into gravitational wave energy, via Einstein's $E = mc^2$.

During that event, more energy was emitted in gravitational waves than by all the stars in the observable Universe combined. The entire Earth was compressed by less than the width of a proton during this event, yet thanks to LIGO's incredible precision, we were able to detect it. At least a handful of these events are expected every year. In the future, different observatories, such as NANOGrav (which uses radiotelescopes to the delay caused by gravitational waves on pulsar radiation) and the space mission LISA will detect gravitational waves from supermassive black holes and many other sources. We've just seen our first event using a new type of astronomy, and can now test black holes and gravity like never before.

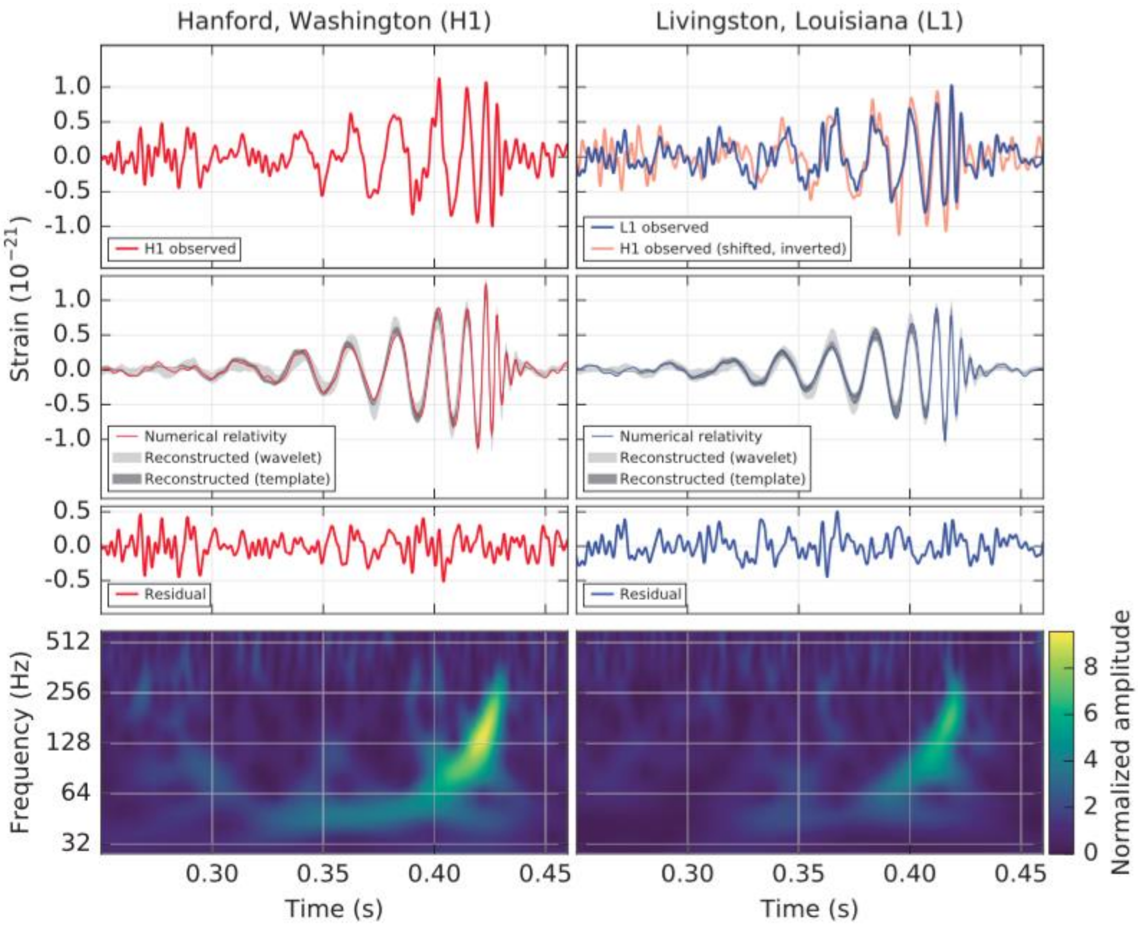

Image credit: Observation of Gravitational Waves from a Binary Black Hole Merger B. P. Abbott et al., (LIGO Scientific Collaboration and Virgo Collaboration), Physical Review Letters 116, 061102 (2016). This figure shows the data (top panels) at the Washington and Louisiana LIGO stations, the predicted signal from Einstein's theory (middle panels), and the inferred signals (bottom panels). The signals matched perfectly in both detectors.

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