Southwest Florida Astronomical Society
SWFAS

The Eyepiece
March 2016

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A MESSAGE FROM THE PRESIDENT

The weather is finally breaking. We had decent weather for STEMtastic, partly cloudy for the Oasis Star Party and great weather for the Burrowing Owl Festival.

What was missing at 2 of these events was club members. Tony and I were the only ones at STEMtastic and Ron Madl was the only one who came to help me for a few hours at the Burrowing Owl Festival. We did have great turnout at the Oasis Star Party. We really could have used a few others at the daytime events, even if only for an hour or two. As Ron can tell you, the scopes pretty much take care of themselves. What we need is people to answer questions and tell people about what to look for in the scopes.

This Friday night we are supposed to have the public Star Party at Rotary Park in Cape Coral. If we do have bad weather, the 11th is a fallback. We also have a club star party at the Caloosahatchee Regional Park this Saturday. Currently the north side is open, so we are a go. Weather is looking good for Saturday. Remember, get there early as the gates are still on the early closing times.

Public observing at the Moore Observatory at Florida Southwestern State College in Punta Gorda occurs on the 2nd Friday night of each month. We have several members involved in this including Tony Heiner, Tom Segur and Tom Burkett along with Dave Hanson. (http://www.fsw.edu/charlotte/observatory)

It is dues renewal time. Dues for 2016 are $20.00 and can be paid at the meeting or via mail to: SWFAS, Inc PO Box 100127 Cape Coral, FL 33910-0127.

Brian

This is last month for receiving donations that will be matched by the $100,000 Philips Matching Grant. If successful, this will mean getting a new or repaired roof for the Planetarium. We have several efforts to raise funds for a matching grant that runs thru March. Please check it out and save or add this link page to your FaceBook page. www.gofundme.com/calusanature Thanks! RLM

In the Sky this Month

Moon: March – Last Quarter- 1st; New- 9th; 1st Quarter- 14th; Full- 23rd; Last Quarter- 31st.

The Planets: Most planetary action continues in the early dawn hours. All five bright planets will be visible in the morning sky for the first few days of the month. Then we lose Mercury as it fades into dawn's early light. The other four remain in the morning sky all month. Daylight Saving Time begins March 13th.

Jupiter rises early in the evening all month while shining at -2.5 magnitude. It's located under the hind legs of Leo.
Mars rises around midnight and shines above Antares in Scorpius. It will brighten noticeably during the month to -0.5 magnitude by month's end.
Saturn rises in the early morning hours all month and shines at 0.5 magnitude. It is north and east of Scorpius, so you have a chance to compare the colors of reddish Antares with orange-yellow of Mars and deep gold of Saturn.
Venus shines brightly at -3.8 magnitude as it rises only an hour before sunrise.
Mercury is poorly positioned for easy viewing all month.

International Space Station: The ISS is visible in the morning during the first week of the month and makes visible passes over Ft Myers in the evening from 27th to 31st. See this link for specific times: http://www.heavens-above.com/

Future Events

Star Party and Event Schedule

Date	Event	Location	Time	Info/Contact
March 3rd Monthly Meeting	Dr Misconi: Research in Solar System Astronomy	Calusa Nature Center & Planetarium	7:30 pm	Brian Risley
March 4th	SWFAS Rotary Park Star Party	Rotary Park Cape Coral	7-10pm	Brian Risley
March 5th	Star Party	CRP	Dusk	Bruce Dissette
April 9th	Star Party	CRP	Dusk	Bruce Dissette
May 7th	Star Party	CRP	Dusk	Bruce Dissette

March Program –

Dr. Nebil Y. Misconi, retired professor at UCF and author of *An Immigrant's Journey into the Cosmos* will be presenting to the Southwest Florida Astronomical Society at the Calusa Nature Center and Planetarium on Thursday, March 3rd, at 7:30pm. Dr. Misconi will speak about his research into Solar System Astronomy including the dynamics of interplanetary dust, the gravitational effect of the inner planets on the symmetry of the dust complex, and the ever present threat of collisions by comets and asteroids on planet Earth. Interspersed throughout his presentation will be recollections of Dr. Misconi's experiences as an astronomer in Baghdad, Iraq, and the fulfillment of his dream of immigrating to the United States.

Minutes of the Southwest Florida Astronomical Society – February 4th, 2016

The program by Ray Wlodyka on Celestial Marine Navigation was presented before the business meeting. Thirty-nine people were present.

The regular monthly business meeting of the Southwest Florida Astronomical Society was called to order at approximately 8:30 pm by president Brian Risley in the Calusa Nature Center Planetarium.
Four visitors introduced themselves.

Ron Madl reported that the Nature Center now has four full time staff, and is moving in a positive direction. They are looking for companies or foundations to provide funding. If anyone has any suggestions on this, please forward the information to Ron.

All members are reminded that annual membership dues of $20 are now due and should be paid to treasurer Tony Heiner.

Previous events listed in the printed agenda were reviewed, and upcoming events listed in the printed agenda were discussed.

President Brian Risley is seeking suggestions for a completely safe solar viewing option that could be used by teachers.

Mike McCauley made a motion, seconded by Tony Heiner, to approve the January 7 minutes as e-mailed. The motion carried on a voice vote.

Treasurer Tony Heiner reported a January balance of $2214.08. Tom ______ made a motion, seconded by Becky Brooks, to accept the report. The motion carried on a voice vote.

The State corporate registration fee of $61.25 is due. Tony Heiner made a motion, seconded by Bill Francis, to pay it. The motion carried on a voice vote.

Mike McCauley suggested that, due to recent rains and Saturday's weather forecast, the Saturday Feb 6 CRP Star Party could be moved to Friday Feb 5 at the Cape Coral Seahawk Park. There was a general consensus to make the change.

Equipment coordinator Brian Risley reported that most of the scopes are in except for the CPCs used for public events.

Website Coordinator Bill Francis reported the calendar on the website is fixed.

Program Coordinator Mike McCauley reported that there is an opening for the May meeting. Contact Mike with suggestions.

The mailing list for the Astronomical League was updated in mid January.

A question was asked about scheduling a Messier Marathon. There was a discussion and no conclusion was reached, though early March is a good time to hold one.

The business meeting was adjourned at 9:01 pm.

submitted by Don Palmer, secretary

Notable March Events in Astronomy and Space Flight History

Compiled by Mike McCauley

March 1, 1927: George Abell was born. George Ogden Abell was an astronomer at UCLA who worked as a research astronomer, teacher, and administrator. He was also a popularizer of science and education, and a skeptic. Abell received his B.S., M.S., and Ph.D. from the California Institute of Technology. He began his career as a tour guide at the Griffith Observatory in Los Angeles. His best known work was his catalogue of clusters of galaxies collected during the Palomar Sky Survey. He discovered how cluster luminosity could be used as a distance scale and collated a famous list of 86 planetary nebulae in 1966 which includes Abell 39. The Abell catalogue is an almost complete list of approximately 4,000 clusters containing at least thirty members up to a redshift of z = 0.2. Together with Peter Goldreich, he correctly determined that planetary nebulae evolve from red giants. Abell was passionate about educating young people, serving for over twenty years as a faculty member at the Summer Science Program for high school students. The program memorializes him with its Abell Scholarship Fund. Abell was also passionate about debunking pseudoscientific claims. He was a co-founder of the Committee on Scientific Investigation of Claims of the Paranormal and contributed articles to their journal, The Skeptical Inquirer. Abell served as president of the Cosmology Commission of the International Astronomical Union and as president and member of the board of the Astronomical Society of the Pacific. He was elected a fellow of the Royal Astronomical Society in 1970. He was chairman of the UCLA Astronomy Department from 1968 to 1975. Asteroid 3449 Abell is named in his honor, as is The George Abell Observatory at the Open University in Milton Keynes, England.

March 1, 1966: Venera 3 impacts Venus. Venera 3 (Russian: meaning Venus 3) was a Venera program space probe that was built and launched by the Soviet Union to explore the surface of Venus. It was launched on 16 November 1965from Baikonur, Kazakhstan. The mission of this spacecraft was to land on the Venusian surface. The entry body contained a radio communication system, scientific instruments, and electrical power sources. The probe possibly crash-landed on Venus on 1 March 1966, making it the first spacecraft to impact on the surface of another planet. Its communications systems failed before it reached the planet.

March 1, 1982: Venera 13 returns first color photographs from surface of Venus. Venera 13 was a probe in the Soviet Venera program for the exploration of Venus. Venera 13 and 14, identical spacecraft built to take advantage of the 1981 Venus launch opportunity and launched 5 days apart; Venera 13 on 30 October, 1981, and Venera 14 on 4 November, 1981, both with an on-orbit dry mass of 760 kg. After launch and a four-month cruise to Venus the descent vehicle separated from the cruise stage and plunged into the Venusian atmosphere on 1 March 1982. After entering the atmosphere a parachute deployed. At an altitude of about 50 km the parachute was released and simple airbraking was used the rest of the way to the surface. Venera 13 landed approximately 950 km northeast of Venera 14, just east of the eastern extension of an elevated region known as Phoebe Regio. The lander had cameras to take pictures of the ground and spring-loaded arms to measure the compressibility of the soil. The quartz camera windows were covered by lens caps which popped off after descent. The area was composed of bedrock outcrops surrounded by dark, fine-grained soil. After landing, an imaging panorama was started and a mechanical drilling arm reached to the surface and obtained a sample, which was deposited in a hermetically sealed chamber, maintained at 30 °C and a pressure of about 0.05 atmosphere. The composition of the sample determined by the X-ray fluorescence spectrometer put it in the class of weakly differentiated melanocratic alkaline gabbroids. The lander functioned for 127 minutes (planned design life was 32 minutes) in an environment with a temperature of 457 °C (855 °F) and a pressure of 89 Earth atmospheres.

March 2, 1972: Pioneer 10 launched. Pioneer 10 is an American space probe, weighing 258 kilograms (569 pounds), that completed the first mission to Jupiter. Thereafter, Pioneer 10 became the first spacecraft to achieve escape velocity from the Solar System. This space exploration project was conducted by the NASA

Ames Research Center in California, and the space probe was manufactured by TRW Inc. It was launched on March 3, 1972, from Cape Canaveral, FL. Between July 15, 1972, and February 15, 1973, it became the first spacecraft to traverse the asteroid belt. Photography of Jupiter began November 6, 1973, at a range of 25,000,000 kilometers (16,000,000 mi), and a total of about 500 images were transmitted. The closest approach to the planet was on December 4, 1973, at a range of 132,252 kilometers (82,178 mi). During the mission, on-board instruments were used to study the asteroid belt, the environment around Jupiter, solar wind, cosmic rays, and eventually far reaches of the Solar System and heliosphere. Pioneer 10 crossed the orbit of Saturn in 1976 and the orbit of Uranus in 1979. On June 13, 1983, the craft crossed the orbit of Neptune, and became the first human-made object to leave the proximity of major planets of the Solar System. The mission came to an official end on March 31, 1997, when it had reached a distance of 67 AU from the Sun, though the spacecraft was still able to transmit coherent data. After March 31, 1997, Pioneer 10's weak signal continued to be tracked by the Deep Space Network to aid training of flight controllers in the process of acquiring deep space radio signals. The last successful reception of telemetry was on April 27, 2002; subsequent signals were barely strong enough to detect. The final, very weak signal from Pioneer 10 was received January 23, 2003 when it was 12 billion kilometers (80 AU) from Earth. Further attempts to contact the spacecraft were unsuccessful.

March 4, 1979: Jupiter’s rings discovered. Jupiter’s system of rings was the third ring system to be discovered in the Solar System, after those of Saturn and Uranus. It was first observed in 1979 by Voyager 1 space probe and thoroughly investigated in the 1990s by Galileo orbiter. It has also been observed by Hubble Space Telescope and from Earth for 23 years. Ground-based observations of the rings require the largest available telescopes. It comprises four main components: a thick inner torus of particles known as the "halo ring"; a relatively bright, exceptionally thin "main ring"; and two wide, thick and faint outer "gossamer rings", named after the moons of whose material they are composed: Amalthea and Thebe.

March 5, 1512: Gerardus Mercator was born 5 March 1512 in Rupelmonde, County of Flanders (modern-day Belgium). He died 2 December 1594 in Duisburg, Duchy of Cleves (modern-day Germany). He is renowned as the cartographer who created a world map based on a new projection which represented sailing courses of constant bearing as straight lines. In his own day he was the world's most famous geographer, but also had interests in theology, philosophy, history, mathematics and magnetism, and was an accomplished engraver, calligrapher and maker of globes and scientific instruments. Much of his knowledge is found in the copious legends on his wall maps and prefaces he composed for his atlas (the first in which the term "atlas" appears).

March 5, 1982: Venera 14 lands on Venus. Venera 14 was a probe in the Soviet Venera program for exploration of Venus. It was identical to Venera 13, built to take advantage of the 1981 Venus launch opportunity. It was launched on 4 November 1981and Venera 13 on 30 October 1981. After launch and a four-month cruise to Venus the descent vehicle plunged into the Venusian atmosphere on March 5, 1982. After entering the atmosphere a parachute was deployed. At an altitude of about 50 km the parachute was released and simple airbraking was used the rest of the way to the surface. Venera 14 landed about 950 km southwest of Venera 13 near the eastern flank of Phoebe Regio on a basaltic plain. The lander had cameras to take pictures of the ground and spring-loaded arms to measure compressibility of the soil. Quartz camera windows were covered by lens caps which popped off after descent. Venera 14, however, ended up measuring the compressibility of the lens cap, which landed right where the probe was to measure the soil. The composition of the surface samples was determined by an X-ray fluorescence spectrometer, showing it to be similar to oceanic tholeiitic basalts. The lander survived 57 minutes (planned design life was 32 minutes) in an environment with temperature of 465 °C (869 °F) and a pressure of 94 Earth atmospheres (9.5 MPa). Telemetry was maintained by the orbiting bus that carried signals from the lander's uplink antenna.

March 6, 2015: Dawn orbits dwarf planet Ceres. Dawn is a space probe launched by NASA in September 2007 with the mission of studying two of the three known protoplanets of the asteroid belt, Vesta and Ceres. It is currently in orbit about its second target, the dwarf planet Ceres. Dawn is the first spacecraft to orbit two extraterrestrial bodies, the first spacecraft to visit either Vesta or Ceres, and also the first to visit a dwarf planet, arriving at Ceres in March 2015, a few months before New Horizons flew by Pluto in July 2015. Dawn entered Vesta orbit on July 16, 2011, and completed a 14-month survey mission before leaving for Ceres in late 2012. Dawn entered Ceres orbit on March 6, 2015, and is predicted to remain in orbit perpetually after the conclusion of its mission. The Dawn mission is managed by NASA's Jet Propulsion Laboratory, with spacecraft components contributed by European partners from the Netherlands, Italy and Germany. It is the first NASA exploratory mission to use ion propulsion, which enabled it to enter and leave the orbit of multiple celestial bodies. Previous multi-target missions using conventional drives, such as the Voyager program, were restricted to flybys. The Dawn mission was designed to study two large bodies in the asteroid belt in order to answer questions about the formation of the Solar System, as well as to test the performance of its ion drive in deep space. Ceres and Vesta were chosen as two contrasting protoplanets, the first one apparently "wet" (i.e. icy and cold) and the other "dry" (i.e. rocky), whose accretion was terminated by the formation of Jupiter. The two bodies provided a bridge in scientific understanding between the formation of rocky planets and the icy bodies of the Solar System, and under what conditions a rocky planet can hold water. The Dawn mission's goal is to characterize the conditions and processes of the Solar System's earliest eon by investigating in detail two of the largest protoplanets remaining intact since their formation. The primary question the mission addresses is the role of size and water in determining the evolution of the planets. Ceres and Vesta are suitable bodies with which to address this question, as they are two of the most massive protoplanets. Ceres is geologically very primitive and icy, while Vesta is evolved and rocky. Their contrasting characteristics are thought to have resulted from them forming in two different regions of the early Solar System. There are three principal scientific drivers for the mission. First, the Dawn mission can capture the earliest moments in the origin of the Solar System, granting an insight into conditions under which these objects formed. Second, Dawn determines the nature of the building blocks from which terrestrial planets formed. Finally, it contrasts formation and evolution of two small planets that followed very different evolutionary paths, allowing scientists to determine what factors control that evolution.

March 7, 1792: John Herschel was born. Sir John Frederick William Herschel was an English mathematician, astronomer, chemist, inventor, and experimental photographer, who also did valuable botanical work. He was the son of Mary Baldwin and astronomer William Herschel, and the father of twelve children. Herschel originated the use of the Julian day system in astronomy. He named seven moons of Saturn (Mimas, Enceladus, Tethys, Dione, Rhea, Titan, and Iapetus) and four moons of Uranus (Ariel, Umbriel, Titania, and Oberon). He made many contributions to photography, and investigated color blindness and chemical power of ultraviolet rays. His Preliminary Discourse (1831), which advocated an inductive approach to scientific experiment and theory building, was an important contribution to philosophy of science. Herschel published a catalogue of his astronomical observations in 1864, as the General Catalogue of Nebulae and Clusters, a compilation of his own work and that of his father's, expanding on the senior Hershel's Catalogue of Nebulae. A further complementary volume was published posthumously, as the General Catalogue of 10,300 Multiple and Double Stars.

March 7, 1969: Apollo 9 astronauts complete first solo flight of lunar module. Apollo 9 was the third manned mission in the United States Apollo space program and the first flight of the Command/Service Module (CSM) with the Lunar Module (LM). Its three-person crew, consisting of Commander James McDivitt, Command Module Pilot David Scott, and Lunar Module Pilot Rusty Schweickart, spent ten days in low Earth orbit testing several aspects critical to landing on the Moon, including the LM engines, backpack life support systems, navigation systems, and docking maneuvers. The mission was the second manned launch of a Saturn V rocket. After launching on March 3, 1969, the crewmen performed the first manned flight of an LM, the first docking and extraction of an LM, two spacewalks, and the second docking of two manned spacecraft—two months after the Soviets performed a spacewalk crew transfer between Soyuz 4 and Soyuz 5. The mission proved the LM worthy of manned spaceflight. Further tests on the Apollo 10 mission would prepare the LM for its ultimate goal, landing on the Moon. They returned to Earth on March 13, 1969.

March 9, 1564: David Fabricius was born. David Fabricius was a German pastor who made two major discoveries in the early days of telescopic astronomy, jointly with his eldest son, Johannes Fabricius. Fabricius discovered the first known periodic variable star, Mira, in August 1596. At first he believed it to be "just" another nova, as the whole concept of a recurring variable did not exist at the time. When he saw Mira brighten again in 1609, however, it became clear that a new kind of object had been discovered in the sky. Two years later, his son Johannes Fabricius (1587–1615) returned from university in the Netherlands with telescopes that they turned on the Sun. Despite the difficulties of observing the sun directly, they noted the existence of sunspots, the first confirmed instance of their observation (East Asian annals suggest Chinese astronomers may have discovered them with the naked eye previously, and Fabricius may have noticed them without a telescope a few years before). The pair soon invented *camera obscura telescopy* so as to save their eyes and get a better view of the solar disk, and observed that the spots moved. They would appear on the eastern edge of the disk, steadily move to the western edge, disappear, and then reappear at the east again after the passage of the same amount of time that it had taken for it to cross the disk in the first place. This suggested that the Sun rotated on its axis, which had been postulated before but never backed up with evidence. Johannes published *Maculis in Sole Observatis, et Apparente earum cum Sole Conversione Narratio* ("Narration on Spots Observed on the Sun and their Apparent Rotation with the Sun") in June 1611. Unfortunately, after Johannes Fabricius' early death at age 29, the book remained obscure and was eclipsed by the independent discoveries of and publications about sunspots by Christoph Scheiner in January 1612 and Galileo Galilei in March 1612.

March 10, 1977: Rings discovered around Uranus. The planet Uranus has a system of rings intermediate in complexity between the more extensive set around Saturn and the simpler systems around Jupiter and Neptune. The rings of Uranus were discovered by James L. Elliot, Edward W. Dunham, and Jessica Mink. More than 200 years ago, in 1789, William Herschel also reported observing rings; some modern astronomers are skeptical that he could have actually seen them, as they are very dark and faint. By 1978, nine distinct rings were identified. Two additional rings were discovered in 1986 in images taken by the Voyager 2 spacecraft, and two outer rings were found in 2003–2005 in Hubble Space Telescope photos. In the order of increasing distance from the planet the 13 known rings are designated 1986U2R/ζ, 6, 5, 4, α, β, η, γ, δ, λ, ε, ν and μ. Their radii range from about 38,000 km for the 1986U2R/ζ ring to about 98,000 km for the μ ring. Additional faint dust bands and incomplete arcs may exist between the main rings. The rings are extremely dark—the Bond albedo of the rings' particles does not exceed 2%. They are probably composed of water ice with the addition of some dark radiation-processed organics. The definitive discovery of the Uranian Rings was made by astronomers Elliot, Dunham, and Mink, using the Kuiper Airborne Observatory. They planned to use the occultation of the star SAO 158687 by Uranus to study the planet's atmosphere. However, when their observations were analyzed, they found that the star disappeared briefly from view five times both before and after it was eclipsed by the planet. They deduced that a system of narrow rings was present. The five occultation events they observed were denoted by the Greek letters α, β, γ, δ and ε in their papers. These designations have been used as the rings' names since then. Later they found four additional rings: one between the β and γ rings and three inside the α ring. The former was named the η ring. The latter were dubbed rings 4, 5 and 6—according to the numbering of the occultation events in one paper. Uranus's ring system was the second to be discovered in the Solar System.

March 13, 1781: William Herschel discovers Uranus. Though Uranus is visible to the naked eye like the five classical planets, it was never recognized as a planet by ancient observers because of its dimness and slow orbit. Sir William Herschel announced its discovery on March 13, 1781, expanding the known boundaries of the Solar System for the first time in history. Uranus was the first planet discovered with a telescope. Uranus had been observed on many occasions before its recognition as a planet, but it was generally mistaken for a star. Possibly the earliest known observation was by Hipparchus, who in 128 BC may have recorded it as a star for his star catalogue that was later incorporated into Ptolemy's Almagest. The earliest definite sighting was in 1690 when John Flamsteed observed it at least six times, cataloguing it as 34 Tauri. The French astronomer Pierre Lemonnier observed Uranus at least twelve times between 1750 and 1769, including on four consecutive nights. Sir William Herschel observed Uranus on March 13, 1781 from the garden of his house in Bath, Somerset, England (now Herschel Museum of Astronomy), and initially reported it as a comet. Although Herschel continued to describe his new object as a comet, other astronomers had already begun to suspect otherwise. Finnish-Swedish astronomer Anders Johan Lexell, working in Russia, was the first to compute the orbit of the new object and its nearly circular orbit led him to a conclusion that it was a planet rather than a comet. Berlin astronomer Johann Elert Bode described Herschel's discovery as "a moving star that can be deemed a hitherto unknown planet-like object circulating beyond the orbit of Saturn". Bode concluded that its near-circular orbit was more like a planet than a comet. The object was soon universally accepted as a new planet. By 1783, Herschel acknowledged this to Royal Society president Joseph Banks: "By the observation of the most eminent Astronomers in Europe it appears that the new star, which I had the honour of pointing out to them in March 1781, is a Primary Planet of our Solar System." In recognition of his achievement, King George III gave Herschel an annual stipend of £200 on condition that he move to Windsor so that the Royal Family could look through his telescopes.

March 13, 1855: Percival Lowell was born. Percival Lawrence Lowell (March 13, 1855 – November 12, 1916) was an American businessman, author, mathematician, and astronomer who fueled speculation that there were canals on Mars. He founded the Lowell Observatory in Flagstaff, Arizona, and formed the beginning of the effort that led to the discovery of Pluto 14 years after his death. Lowell became determined to study Mars and astronomy as a full-time career after reading Camille Flammarion's *La planète Mars*. He was particularly interested in the canals of Mars, as drawn by Italian astronomer Giovanni Schiaparelli, who was director of the Milan Observatory. In 1894 Lowell chose Flagstaff, Arizona Territory, as the home of his new observatory. At an altitude of over 2,100 meters (6,900 feet), with few cloudy nights, and far from city lights, Flagstaff was an excellent site for astronomical observations. This marked the first time an observatory had been deliberately located in a remote, elevated place for optimal seeing. For the next fifteen years he studied Mars extensively, and made intricate drawings of the surface markings as he perceived them. Lowell published his views in three books: *Mars* (1895), *Mars and Its Canals* (1906), and *Mars as the Abode of Life* (1908). With these writings, Lowell more than anyone else popularized the long-held belief that these markings showed that Mars sustained intelligent life forms. His works include a detailed description of what he termed the 'non-natural features' of the planet's surface, including a full account of the 'canals', both single and double and the 'oases', as he termed the dark spots at their intersections and varying visibility of both, depending partly on the Martian seasons. He theorized that an advanced, desperate culture had built the canals to tap Mars' polar ice caps, the last source of water on an inexorably drying planet. While this idea excited the public, the astronomical community was skeptical. Many astronomers could not see these markings, and few believed that they were as extensive as Lowell claimed. As a result, Lowell and his observatory were largely ostracized. Although the consensus was that some actual features did exist which would account for these markings, in 1909 the sixty-inch Mount Wilson Observatory telescope in Southern California allowed closer observation of the structures Lowell had interpreted as canals, and revealed irregular geological features, the result of natural erosion. The existence of canal-like features was definitively disproved in 1960s by NASA's Mariner missions which, showed only a cratered Martian surface. Lowell's greatest contribution to planetary studies came during the last decade of his life, which he devoted to the search for Planet X, a hypothetical planet beyond Neptune. Lowell believed that the planets Uranus and Neptune were displaced from their predicted positions by the gravity of the unseen Planet X. Lowell started a search program in 1906 using a camera 5 inches (13 cm) in aperture. The small field of view of the 42-inch (110 cm) reflecting telescope rendered the instrument impractical for searching. From 1914 to 1916, a 9-inch (23 cm) telescope on loan from Sproul Observatory was used to search for Planet X. Although Lowell did not discover Pluto, Lowell Observatory did photograph Pluto in March and April 1915. In 1930 Clyde Tombaugh, working at the Lowell Observatory, discovered Pluto near the location expected for Planet X. Partly in recognition of Lowell's efforts, a stylized P-L monogram (♇) – the first two letters of the new planet's name and also Lowell's initials – was chosen as Pluto's astronomical symbol. However, it would subsequently emerge that the Planet X theory was mistaken. Pluto's mass could not be determined until 1978, when its satellite Charon was discovered. This confirmed what had been increasingly suspected: Pluto's gravitational influence on Uranus and Neptune is negligible, certainly not nearly enough to account for discrepancies in their orbits. Rather, they were due to an erroneous value for the mass of Neptune. Voyager 2's 1989 encounter with Neptune yielded a more precise value of its mass, and the discrepancies disappear when using this value. In 2006, Pluto was reclassified as a dwarf planet by the International Astronomical Union.

March 14, 1835: Giovanni Schiaparelli was born. Giovanni Virginio Schiaparelli was an Italian astronomer and science historian. Among Schiaparelli's contributions are his telescopic observations of Mars. In his initial observations, he named the "seas" and "continents" of Mars. During the planet's "Great Opposition" of 1877, he observed a dense network of linear structures on the surface of Mars which he called "canali" in Italian, meaning "channels" but the term was mistranslated into English as "canals." While the term "canals" indicates an artificial construction, the term "channels" connotes that the observed features were natural configurations of the planetary surface. From the incorrect translation into the term "canals", various assumptions were made about life on Mars. As these assumptions were popularized, the "canals" of Mars became famous, giving rise to waves of hypotheses, speculation, and folklore about the possibility of intelligent life on Mars. Among the most fervent supporters of the artificial-canal hypothesis was the American astronomer Percival Lowell, who spent much of his life trying to prove the existence of intelligent life on the red planet. After Lowell's death in 1916, astronomers developed a consensus against the canal hypothesis, but the popular concept of Martian canals excavated by intelligent Martians remained in the public mind for the first half of the 20th century, and inspired works of classic science fiction. Later, with notable thanks to the observations of the Italian astronomer Vicenzo Cerulli, scientists came to the conclusion that the famous channels were actually optical illusions. The popular speculations about canals were finally put to rest during the spaceflight era beginning in the 1960s, when visiting spacecraft photographed the surface with much higher resolution than Earth-based telescopes, confirming that there are no structures resembling "canals". An observer of objects in the solar system, Schiaparelli worked with binary stars, discovered the asteroid 69 Hesperia on 29 April 1861 and demonstrated that the Perseids and Leonids meteor showers were associated with comets. He proved, for example, that the orbit of the Leonids meteor shower coincided with that of the Comet Tempel-Tuttle. These observations led the astronomer to formulate the hypothesis that meteor showers could be the trails of comets.

March 14, 1879: Albert Einstein was born. Albert Einstein was a German-born theoretical physicist. He developed the general theory of relativity, one of the two pillars of modern physics (alongside quantum mechanics). Einstein's work is also known for its influence on the philosophy of science. Einstein is best known in popular culture for his mass–energy equivalence formula $E = mc^2$ (which has been dubbed "the world's most famous equation"). He received the 1921 Nobel Prize in Physics for his "services to theoretical physics", in particular his discovery of the law of the photoelectric effect, a pivotal step in the evolution of quantum theory. General relativity is a theory of gravitation developed by Einstein between 1907 and 1915. According to general relativity, the observed gravitational attraction between masses results from the warping of space and time by those masses. General relativity has developed into an essential tool in modern astrophysics. It provides the foundation for the current understanding of black holes, regions of space where gravitational attraction is so strong that not even light can escape. As Einstein later said, the reason for development of general relativity was that preference of inertial motions within special relativity was unsatisfactory, while a theory which from the outset prefers no state of motion (even accelerated ones) should appear more satisfactory. Consequently, in 1907 he published an article on acceleration under special relativity. In that article titled "*On the Relativity Principle and the Conclusions Drawn from It*", he argued that free fall is really inertial motion, and that for a free-falling observer the rules of special relativity must apply. This argument is called the equivalence principle. In the same article, Einstein also predicted the phenomena of gravitational time dilation, gravitational red shift and deflection of light. In 1911, Einstein published another article "*On the Influence of Gravitation on the Propagation of Light*" expanding on the 1907 article, in which he estimated the amount of deflection of light by massive bodies. Thus, the theoretical prediction of general relativity can for the first time be tested experimentally. In 1916, Einstein predicted gravitational waves, ripples in the curvature of spacetime which propagate as waves, traveling outward from the source, transporting energy as gravitational radiation. The existence of gravitational waves is possible under general relativity due to its Lorentz invariance which brings the concept of a finite speed of propagation of the physical interactions of gravity with it. By contrast, gravitational waves cannot exist in the Newtonian theory of gravitation, which postulates that the physical interactions of gravity propagate at infinite speed. The first, indirect, detection of gravitational waves came in the 1970s through observation of a pair of closely orbiting neutron stars, PSR B1913+16. The explanation of the decay in their orbital period was that they were emitting gravitational waves. Einstein's prediction was confirmed on 11 February, 2016, when researchers published direct observation, on Earth, of gravitational waves, exactly one hundred years after the prediction.

March 18, 1965: Voskhod 2 launched; Alexey Leonov takes world's first spacewalk. Voskhod 2 was a Soviet manned space mission in March 1965. The Vostok-based Voskhod 3KD spacecraft with two crew members on board, Pavel Belyayev and Alexey Leonov, was equipped with an inflatable airlock. It established another milestone in space exploration when Alexey Leonov became the first person to leave the spacecraft in a specialized spacesuit to conduct a 12 minute "spacewalk. Liftoff took place at 11:00 AM. As with Voskhod 1, a launch abort was not possible during the first few minutes, until the payload shroud jettisoned around the 2-1/2 minute mark. Cosmonaut Alexey Leonov donned a space suit and left the spacecraft while the other cosmonaut of the two-man crew, Pavel Belyayev, remained inside. Leonov began his spacewalk 90 minutes into the mission at the end of the first orbit and it lasted 12 minutes and 9 seconds. Leonov's only tasks were to attach a camera to the end of the airlock to record his spacewalk and to photograph the spacecraft. When he tried to use the still camera on his chest, the suit had ballooned and he was unable to reach down to the shutter switch on his leg. After his time outside the Voskhod, Leonov found that his suit had ballooned out to the point where he could not re-enter the airlock. He was forced to bleed off some of his suit's pressure, in order to be able to bend the joints, eventually going below safety limits. Leonov did not report his action on the radio to avoid alarming others, but Soviet state radio and television had earlier stopped their live broadcasts from the spacecraft when the mission experienced difficulties. The two crew members subsequently experienced difficulty sealing the hatch properly, followed by a troublesome re-entry in which a malfunction of the automatic landing system forced use of its manual backup. The spacecraft was so cramped that the two cosmonauts, both wearing spacesuits, could not return to their seats to restore the ship's center of mass for 46 seconds after orienting the ship for reentry and a landing in Perm Krai. The orbital module did not properly disconnect from the landing module, causing the spacecraft to spin wildly until the modules disconnected at 100 km. The delay of 46 seconds caused the spacecraft to land 386 km from the intended landing zone, in the inhospitable forests of Upper Kama Upland, somewhere west of Solikamsk. Although flight controllers had no idea where the spacecraft had landed or whether Leonov and Belyayev had survived, the cosmonauts' families were told that they were resting after having been recovered. The two men were both familiar with the harsh climate and knew that bears and wolves, made aggressive by mating season, lived in the taiga; the spacecraft carried a pistol and "plenty of ammunition". Although aircraft quickly located the cosmonauts, the area was so heavily forested that helicopters could not land. Night arrived, the temperature dropped to −5 degrees Celsius (23 degrees Fahrenheit), and the spacecraft's hatch had been blown open by explosive bolts. Warm clothes and supplies were dropped and the cosmonauts spent a freezing night in the capsule. Even worse, the electrical system malfunctioned so that the heater would not work, but fans ran at full blast. A rescue party arrived on skis the next day as it was too risky to try an airlift from the site. The advance party chopped wood and built a small log cabin and an enormous fire. After a more comfortable second night in the forest the cosmonauts skied to a waiting helicopter several kilometers away and flew first to Perm, then to Baikonur for mission debriefing.

March 23, 1912: Wernher von Braun born. Wernher Magnus Maximilian Freiherr von Braun (March 23, 1912 – June 16, 1977) was a German, later an American, aerospace engineer and space architect credited with inventing the V-2 rocket for Nazi Germany and the Saturn V for the United States. He was one of the leading figures in development of rocket technology in Nazi Germany, where he was a member of the Nazi Party and the SS. Following World War II, he was moved to the United States, along with about 1,500 other scientists, technicians, and engineers, as part of Operation Paperclip, where he developed rockets that launched United

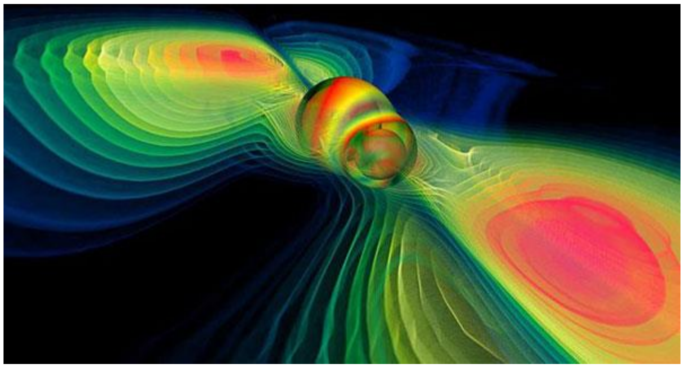
States’ first space satellite and first series of moon missions. In his twenties and early thirties, von Braun worked in Germany's rocket development program, where he helped design and develop the V-2 rocket at Peenemünde during World War II. Following the war, von Braun worked for the United States Army on an intermediate-range ballistic missile (IRBM) program before his group was assimilated into NASA. Under NASA, he served as director of the newly formed Marshall Space Flight Center and as the chief architect of the Saturn V launch vehicle, the super booster that propelled the Apollo spacecraft to the Moon. According to NASA, he is, "without doubt, the greatest rocket scientist in history", as well as the "Father of Rocket Science". In 1975, he received the National Medal of Science. He continued insisting on the human mission to Mars throughout his life.

March 25, 1655: Christiian Huygens discovers Titan, moon of Saturn. Titan was discovered by the Dutch astronomer Christiaan Huygens. Huygens was inspired by Galileo's discovery of Jupiter's four largest moons in 1610 and his improvements in telescope technology. Christiaan, with the help of his brother Constantijn Huygens, Jr., began building telescopes around 1650 and discovered the first observed moon orbiting Saturn with one of the telescopes they built. Titan orbits Saturn once every 15 days and 22 hours. Like our Moon and many of the satellites of the giant planets, its rotational period is identical to its orbital period; Titan is thus tidally locked in synchronous rotation with Saturn, and permanently shows one face to the planet. Its orbital eccentricity is 0.0288, and the orbital plane is inclined 0.348 degrees relative to the Saturnian equator. Titan is 5,151 kilometers (3,201 mi) in diameter, compared to 4,879 kilometers (3,032 mi) for the planet Mercury, 3,474 kilometers (2,159 mi) for the Moon, and 12,742 kilometers (7,918 mi) for Earth. Titan is the only known moon with a significant atmosphere, and its atmosphere is the only nitrogen-rich dense atmosphere in the Solar System aside from Earth's. Observations of it made in 2004 by Cassini suggest that Titan is a "super rotator", like Venus, with an atmosphere that rotates much faster than its surface. Observations from Voyager space probes have shown that Titan's atmosphere is denser than Earth's, with a surface pressure about 1.45 atm. It is also about 1.19 times as massive as Earth overall, or about 7.3 times more massive on a per surface area basis. It supports opaque haze layers that block most visible light from the Sun and other sources and renders Titan's surface features obscure. Titan's lower gravity means that its atmosphere is far more extended than Earth's. The atmosphere of Titan is opaque at many wavelengths and a complete reflectance spectrum of the surface is impossible to acquire from orbit. It was not until the arrival of the Cassini–Huygens spacecraft in 2004 that the first direct images of Titan's surface were obtained.

Gravitational Wave Detection Heralds New Era

By: Robert Naeye | S&T

IGO scientists have announced the direct detection of gravitational waves, a discovery that won't just open a new window on the cosmos — it'll smash the door wide open.



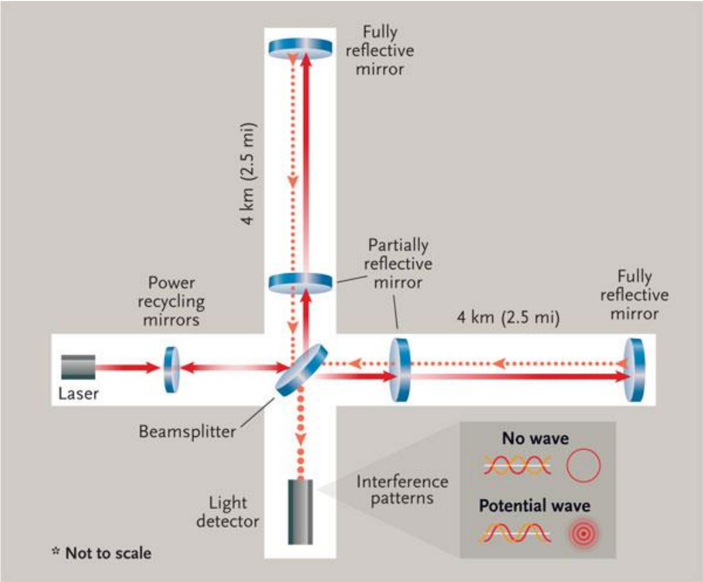
Two black holes coalesce in a still from a numerical simulation. Such predictions, based on Einstein's theory of general relativity match exactly what LIGO scientists discovered on September 14, 2015.
MPI for Gravitational Physics / Werner Benger / ZIB / Louisiana State University

Today, physicists announced the first-ever direct detection of gravitational waves, ripples in the fabric of spacetime predicted by Einstein's general theory of relativity. Two massive accelerating objects — in this case, a pair of stellar-mass black holes in a death-spiral — passed through spacetime like paddles sweeping through water, creating vibrations that could (barely) be felt on Earth. The results are published in *Physical Review Letters*.

"We have detected gravitational waves. We did it!" An elated David Reitze, executive director of LIGO, announces the result in the February 11th press conference.

It's been a recurring theme in history: When scientists open a new window on the universe, they make transformative discoveries. But when LIGO, short for Laser Interferometer Gravitational-Wave Observatory, caught waves from these two colliding black holes, it didn't just open a new window — it smashed a door wide open, promising a breathtaking new ability to study exotic and otherwise-undetectable cosmic phenomena. Don't be surprised if LIGO's founders, Kip Thorne, Ronald Drever, and Rainer Weiss, earn free round-trip tickets to Stockholm to collect a Nobel Prize.

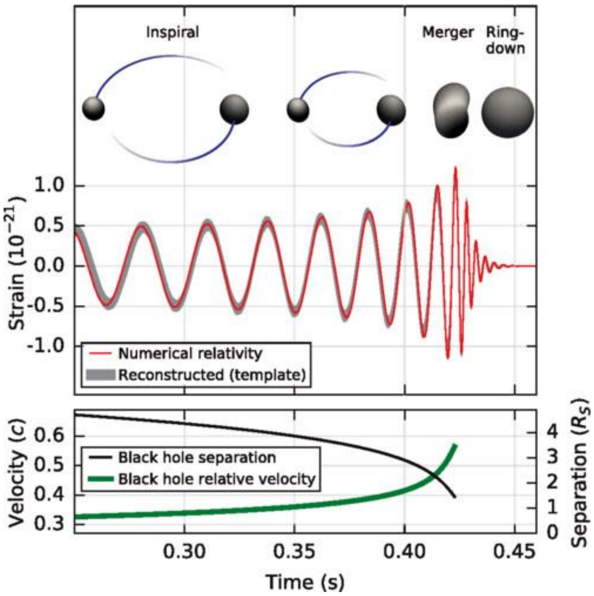
The Detection



In this schematic of LIGO, a beamsplitter sends light along two paths perpendicular to each other. Each beam bounces between two mirrors, one of which allows a fraction of the light through. When the two transmitted beams meet and interfere, they'll cancel each other out — if the length of the path they've each traveled has remained constant. But if a gravitational wave passes through, it'll warp spacetime and change that distance, creating an interference pattern. S&T: *Leah Tiscione*

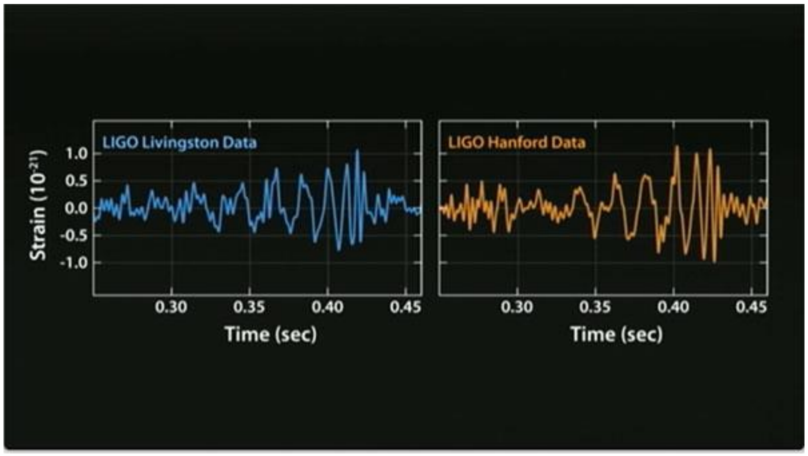
LIGO consists of two L-shaped facilities, one near Hanford, Washington, and the other near Livingston, Louisiana. At 5:51 a.m. (EDT) on September 14, 2015, both labs caught the gravitational-wave signature of two colliding black holes, shortly after both facilities were turned on following five years of intensive upgrades.

A series of gravitational waves from a distant galaxy first passed through the Livingston detector, then just 7 milliseconds later it passed through the detector in Hanford. Both instruments shoot infrared lasers through 4-kilometer-long arms of near-perfect vacuum. The laser light reflects off ultrapure, superpolished, and seismically isolated quartz mirrors. The passing gravitational waves slightly altered the path lengths in the arms of both detectors by about 1/1,000 the width of a proton. That slight change created a characteristic interference pattern in the laser light, an event LIGO scientists have dubbed GW150914.



LIGO didn't watch the whole many-year-long dance of the black hole duo, but it did see the last few cycles of the death spiral, the merger itself, and the "ringing" effect as the merged black hole settled into its new form. *B. P. Abbott & others, "Observation of Gravitational Waves from a Binary Black Hole", [Physical Review Letters]*

Based on the signal's amplitude (that is, the height of the gravitational wave), team members estimate that the colliding black holes had the masses of about 36 and 29 Suns, respectively. Milliseconds before they merged, these behemoths spun around each other at nearly the speed of light. LIGO watched all three predicted phases of the collision: the black holes' death spiral and ensuing merger, as well as the ringing of the merged object as it settled into its new form.



These are the actual gravitational waves detected by LIGO, first at Livingston then a fraction of a second later, in the Hanford detector. *LIGO*

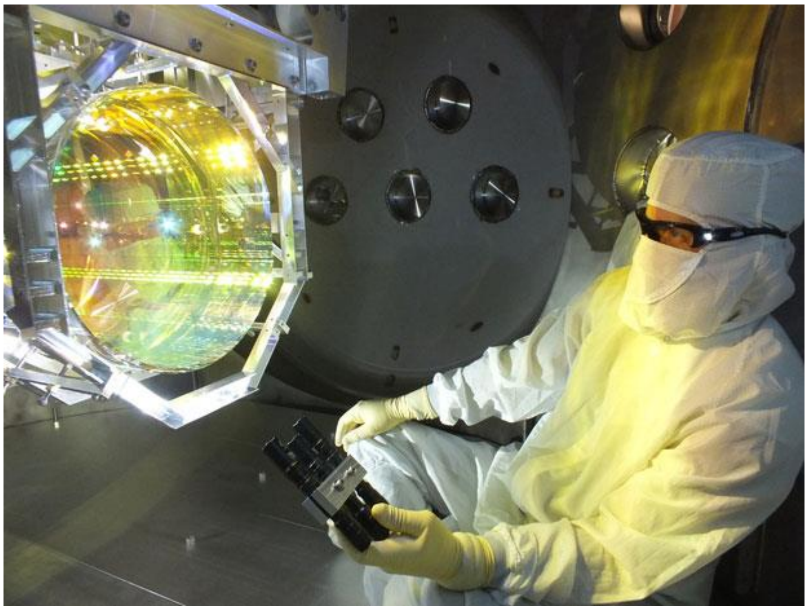
The merged black hole contains about 62 solar masses, so it's short three solar masses — the gravitational waves themselves carried away three solar masses worth of energy.

The minuscule difference in the waves' arrival times at the two facilities was exactly what's expected for gravitational waves, which travel at the speed of light. The LIGO team claims a 5.1-sigma detection, meaning the odds of the signal occurring by chance are about one in 3.5 million.

With only two detectors, LIGO can’t pinpoint the source’s exact location or host galaxy — it could come from anywhere within about 600 square degrees of sky, somewhere near the Large Magellanic Cloud in the Southern Hemisphere sky. Nor can they exactly pinpoint its distance, but measurements show the source lies between 700 million and 1.6 billion light-years away.

The beginning of this video (at 0:07) shows an all-too-brief simulation of the merging black holes and the extreme warping of spacetime around them:

A New Window on the Cosmos



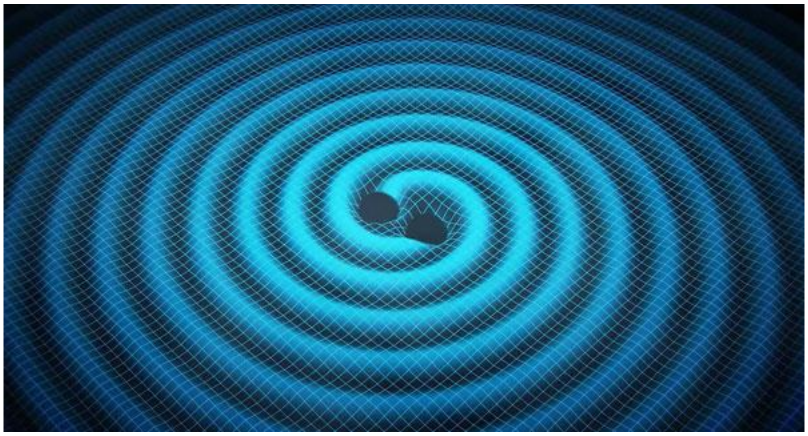
A LIGO technician checks the detector's optics for contaminants by illuminating its mirrors. *LIGO*

The direct detection of gravitational waves opens up an entirely new spectrum that doesn’t involve any form of light. “It’s a spectrum that carries entirely new kinds of information that have so far been largely invisible,” says physicist Robert Owen (Oberlin College).

Or, as Eric Katsavounidis (MIT and LIGO team member) puts it, "This is the end of the silent-movie era in astronomy."

Previously, radio astronomers studying pairs of neutron stars, the crushed, spinning remains of massive stars, had revealed compelling *indirect* evidence of gravitational waves. Einstein’s general theory of relativity says that gravitational waves should carry away orbital energy, and indeed, these pulsars’ orbits spiral inward at *exactly* the rate relativity predicts. Joseph Taylor and Russell Hulse shared the 1993 Nobel Prize in Physics for discovering the first of these systems.

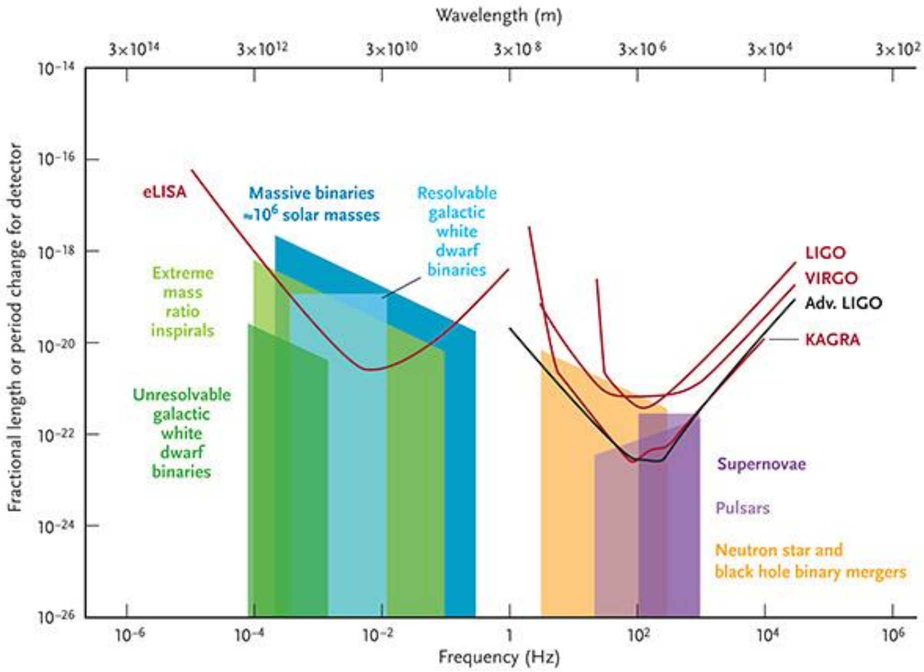
But direct detection has remained elusive because of the incredible difficulty of catching gravitational waves. Merging binaries involving black holes or neutron stars generate stupendous amounts of energy. “In terms of gravitational waves, for that one millisecond prior to merger, this binary black hole system was ‘brighter’ than all the rest of the universe combined!” Owen says. In fact, later calculations say that at its peak, the merging black was putting out 50 times more energy than the rest of the universe.


When two black holes twirl in a mutual orbit, they radiate gravitational waves, leaking orbital energy and spiraling in toward each other. This artist's concept portrays the radiating ripples on a 2D spacetime surface so we can better imagine it.
Swinburne Astronomy Productions

But the waves are incredibly difficult to detect because gravity is the weakest of the four known forces of nature, the strength of the waves fall off sharply as they traverse space, and because matter barely feels the presence of gravitational waves. “The gravitational waves from a distant galaxy that are detectable to LIGO are squeezing and stretching the Milky Way Galaxy by the width of your thumb,” says LIGO science team member Chad Hanna (Penn State University).

The National Science Foundation-funded $500 million LIGO experiment has been on the lookout for gravitational waves since 2002. But only recently, after a five-year rebuild and redesign to improve LIGO’s sensitivity, did the facilities have a realistic chance of catching these subtle spacetime ripples. LIGO began its first “advanced” observing run last fall, but improvements continue and future runs will have at least twice the sensitivity and enable LIGO to survey ten times the volume of space.

Theorists predict Advanced LIGO should catch an additional five binary black hole mergers in its next observing run. They also expect roughly 40 binary neutron star mergers every year it runs, and an unknown number of signals from black hole-neutron star mergers and supernovae. It's even possible that LIGO could detect exotic cosmic strings.



Gravitational waves — and the experiments designed to find them — cover a wide range of frequencies. This plot shows some possible sources of gravitational waves, and the approximate signal ranges and sensitivities for various gravitational wave detectors. (Not all sources and detectors are listed here: go to the source to create your own plot.)
S&T: Leah Tiscione; Source: C. J. Moore et al. / arXiv.org 2014

The direct detection of gravitational waves represents another triumph for Einstein, almost exactly 100 years after he predicted their existence — and despite the fact that he never thought they'd be detected. But as LIGO builds up a catalog of events in the coming years, and as other advanced detectors come online in Europe and Japan, physicists will be scrutinizing the waveforms in detail to see how closely they conform to general relativity's predictions.

Though this black hole merger went entirely according to Einstein's predictions, scientists hope to eventually see discrepancies that could provide vital clues to new physics, potentially reconciling contradictions between relativity and quantum theory.

"Gravitational-wave measurements will allow us to directly probe some of the most violent events in the universe, to directly measure the most tumultuous dynamics of spacetime geometry," says Owen. "Gravitational waves would allow us to probe how spacetime really behaves under the most radical of circumstances."

LIGO will prove a gold mine for astronomers: enabling them to study and build up a census of neutron stars, stellar-mass black holes, and other dim or otherwise impossible-to-detect objects in faraway galaxies. And LIGO also offers the tantalizing prospect of discovering new types of objects and phenomena hitherto unknown to science.

"We want to give ourselves plenty of opportunity to be surprised," says Hanna. "We don't want to open a new window to the universe and then refuse to look outside because we think we know what we'll see. We expect the bread-and-butter sources, but we certainly hope it doesn't stop there."

Mirror Assembled for Hubble's Successor

By: David Dickinson | S&T

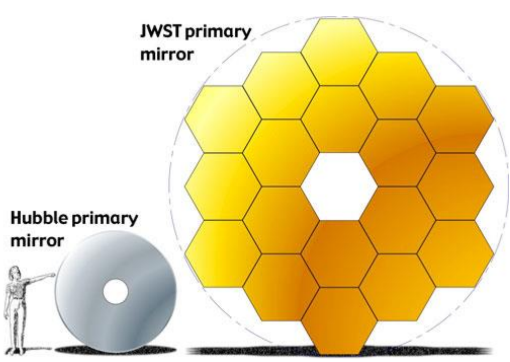
NASA has assembled the primary mirror for the James Webb Space Telescope, a big step on the way to the telescope's October 2018 launch.

The final segment of the James Webb Space Telescope is carefully put in place.
NASA / Chris Gunn

NASA's next big space observatory came one step closer to completion last week, as engineers placed the final segment of the James Webb Space Telescope's primary mirror.

The careful construction of the segmented mirror began in November 2015 at the Goddard Space Flight Center in Greenbelt, Maryland. Each hexagonal segment is 4.2 feet (1.3 meters) across, coated with gold and beryllium, and weighs 88 pounds. There are 18 mirror segments in all. Now fully assembled, the primary mirror is 21.3 feet (6.5 meters) in diameter, making JWST the largest telescope ever fielded in space.

"Scientists and engineers have been working tirelessly to install these incredible, nearly perfect mirrors that will focus light from previously hidden realms of planetary atmospheres, star forming regions, and the very beginnings of the universe," says associate administrator John Grunsfeld in a NASA press release.



A comparison of the primary mirror on the Hubble Space Telescope versus the James Webb Space Telescope. *NASA*

Often touted as the Hubble Space Telescope’s successor, the James Webb Space Telescope (JWST) will actually work at longer wavelengths than its famous cousin: from the long-wavelength end of the visual spectrum into the infrared regime. In that sense, it’s more of a follow-on to the Spitzer Space Telescope. JWST’s primary is also much larger than Hubble’s, which spanned only 2.4 meters, yet JWST’s overall observatory is actually lighter in mass.

The telescope takes its name from NASA's second administrator, James E. Webb, who ensured that NASA’s legacy would feature not just spaceflight but also space science.

On Target for 2018 Launch

The James Webb Space Telescope in the clean room with all segments in place.
NASA / Chris Gunn

NASA engineers performed the mirror assembly using a robotic arm to position each individual segment. Watch work continue in the Goddard clean room via the James Webb webcam.

“Completing the assembly of the primary mirror is a very significant milestone,” says Lee Feinberg (Goddard optical telescope element manager) in a recent NASA press release. “There is a huge team across the country who contributed to this achievement.” Ball Aerospace & Technologies Corp. built the mirror segments, and Northrop Grumman subcontractor Harris Corporation is carrying out the mirror assembly and installation.

The James Webb Space Telescope uses a three-mirror anistigmat optical configuration, a complex layout that eliminates coma, astigmatism, and spherical aberration. In the coming months, the Harris team will install the secondary mirror and the aft optics assembly. Then engineers at Goddard will conduct acoustic and vibration tests to assure the telescope can withstand a bone-jarring rocket launch. More testing follows: NASA plans to ship the James Webb Space Telescope to the Johnson Space Center in Houston, Texas, for extensive cryogenic optical testing, to ensure the instrument will function in the cold depths of space.

The James Webb Space Telescope is set to launch atop an Ariane 5 rocket from Kourou, French Guiana, in October 2018. Originally slated for a 2011 launch at a budget of $1.6 billion, delays and a ballooning budget led to a threatened cancellation. Yet the mission managed to weather stormy political winds when, instead of cancelling in 2011, Congress capped the budget for development at $8 billion. The assembly of the primary mirror has occurred on schedule for the targeted launch window.

Some Assembly Required

The James Webb Space Telescope has to fold up if it's going to fit inside the payload faring of the Ariane 5 rocket. Once launched, the telescope will head towards its new home in space: a lissajous (halo) orbit around the L2 Lagrangian point — that is, the telescope will orbit the Sun at a stable position on the opposite side from Earth, 700,000 miles beyond the Moon's orbit. Then all the parts will have to unfurl and work properly on their own. Unlike the Hubble Space Telescope, astronauts won't be able to visit the JWST for repairs. So why position it so far from Earth? The frigid location gives the telescope a close to noise-free observing environment — especially because with its sunshield, the telescope can block thermal interference from the Sun, Earth, and Moon.

Once open for business, JWST will give astronomers a new window on the universe. It will peer farther back into the early universe to see the first galaxies, penetrate interstellar dust clouds where stars are forming, and give us spectroscopic analysis of exoplanet atmospheres. In fact, James Webb will work in concert with another space-based observatory set to launch the year before it: the Transiting Exoplanet Survey Satellite (TESS), which aims to discover exoplanets around nearby red dwarf stars, ideal targets for JWST's infrared capabilities.

Exciting times, indeed: the next few years may well mark the dawn of a new golden age of space-based astronomy.

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