

Southwest Florida Astronomical Society SWFAS



The Eyepiece October 2016

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A MESSAGE FROM THE PRESIDENT

Fall has finally arrived. Hopefully it will bring clear skies!

We are starting our event season. This month we have International Observe the Moon night on the 8th and Ding Darling Days on the 16th. Becky Brooks will try again to have the club out to her house on the 13th. There is a Cub Scout event at Camp Miles on the weekend of the 22nd/23rd. Also, the Charlotte County group will be doing their monthly solar observing on the 15th. The public viewing at Moore Observatory on the FSW Punta Gorda Campus is on the 7th and will be the 1st Friday of each month at dusk.

Don't forget that next month we have John Jardine Goss, the president of the Astronomical League, as our speaker. Please pass the word around so that we have a full house for his visit. We are planning on doing a star party on Friday Nov 4th at Seahawk Park so that John can attend it. The plans are that he will do a program about Lunar Sketching and also discuss the Astronomical League as well as a general Q & A session about the Astronomical League.

Brian

In the Sky this Month

Moon:

October – 1st Quarter - 9th; Full – 16th; Last Quarter – 22nd; New – 30th.

The Planets:

Venus continues shining low on the southwestern horizon for about an hour after sunset all through the month. It crosses into Scorpius late in the month and moves between Saturn and Antares Oct. 27. Telescopes show a gibbous disk about 80% lit.

Saturn continues to offer great views of its rings at magnitude + 0.5 through the month. Its rings are open 26° from edge on. By month's end it will be low in the western horizon as it moves slowly east from Antares.

Mars is moving eastward across Sagittarius grazing the top of the Teapot during the month. It still shines a bright red, but is shrinking in disk size at magnitude +0.4.

Both Jupiter and Mercury are visible in the dawn hours from the 8th until mid-month. After that, Mercury gets lost in sunrise. Jupiter is visible 2 ½ hours before the sun by month's end.

International Space Station: The ISS is visible in the evening skies over Ft Myers October 19th – 21st with the best view at -3.5 magnitude on evening of the 19th.

The **Hubble Space Telescope** reappears in the evening during October from the 4th through 17th with best views beginning on 8th. Brightest magnitude of +0.7 is visible on 13th and 14th. See this link for specific times and routes:

<http://www.heavens-above.com/>

2017 The Year in Space Calendars

Order you're copy of *2017 The Year in Space* wall calendar or desk calendar now.

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Checks or cash for calendar orders will also be accepted at October 6th meeting.

Orders will be submitted October 15th, so order soon.

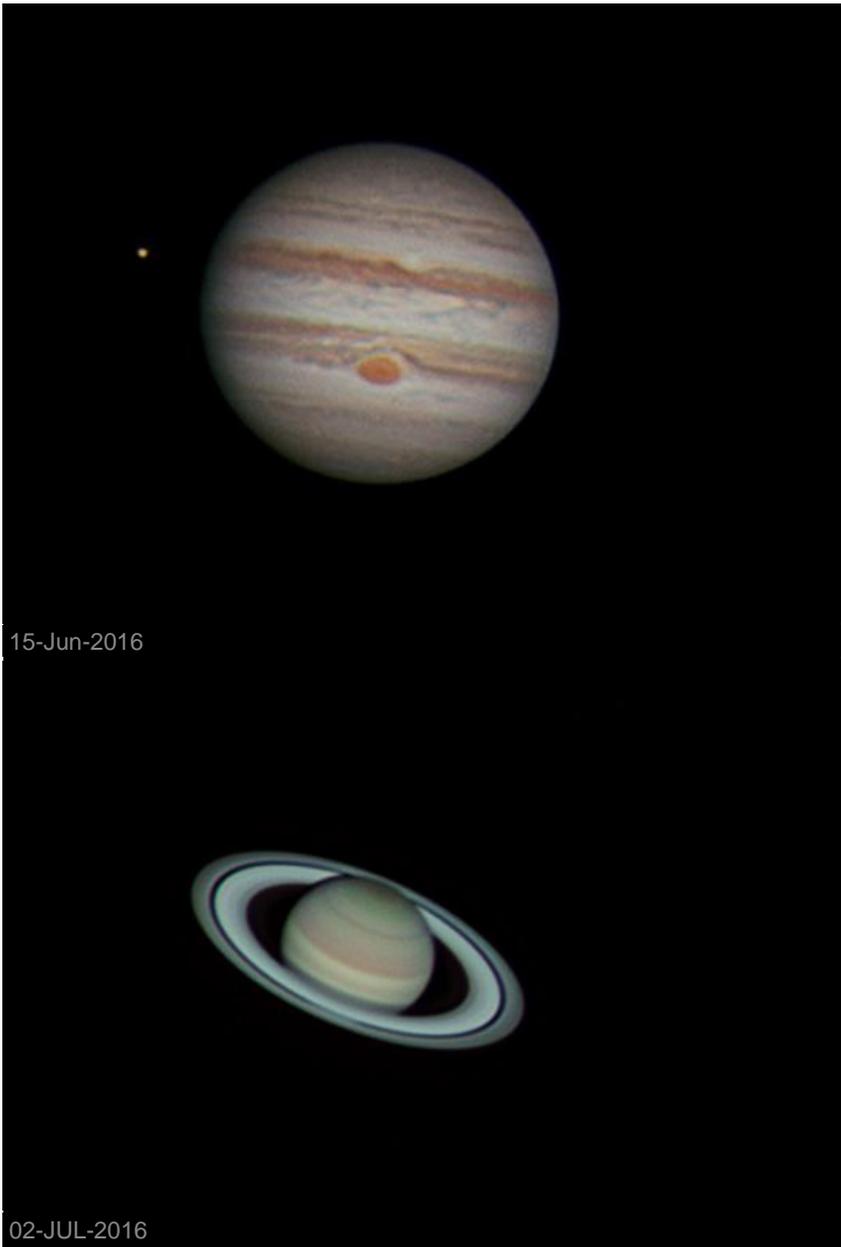
Photos by Chuck:



Prominences
on the Sun



Mercury Transit



Jupiter with Io and
Great Red Spot

Saturn



15-MAY-2016

Two great views of Mars.



14-JUN-2016

Future Events

Star Party and Event Schedule

Date	Event	Location	Time	Info/Contact
October 6 th	Monthly Meeting	Calusa Nature Center & Planetarium	7:30 pm	Brian Risley
October 7 th	Public Observing	Moore Observ. FSW Punta Gorda	Dusk	Tony Heiner
October 8 th	International Observe the Moon Night	Calusa Nature Center & Planetarium	Daytime/Evening	Bruce Dissette
October 13 th	Star Party	Becky Brooks'	Evening	Becky Brooks
October 15 th	Solar Observing	Bayshore Live Oak Park, Port Charlotte	9 am - noon	Tom Segur
October 16 th	Ding Darling Days	Ding Darling Sanibel	10am-3pm	Brian Risley
October 22 nd /23 rd	Scout Event	Camp Miles	Dusk-10pm 22 nd 23 rd Daytime	Brian Risley Tony Heiner
November 3 rd	Monthly Meeting – Astronomical League – President's Visit	Calusa Nature Center Planetarium	7:30pm	Brian Risley
November 4 th	Star Party	Seahawk Park Cape Coral	Dusk	Brian Risley
November 4 th	Public Observing	Moore Observ. FSW Punta Gorda	Dusk	Tony Heiner
November 19 th	Solar Observing	Harbour Fest, Sports Park (Stone Crabs Stadium), Port Charlotte	9 am – 3 pm	Tom Segur
December 1 st	Monthly Meeting – Election Meeting	Calusa Nature Center Planetarium	7:30pm	Brian Risley
December 2 nd	Public Observing	Moore Observ. FSW Punta Gorda	Dusk	Tony Heiner
December 17 th	Solar Observing	Ponce DeLeon Park, Punta Gorda	9 am - noon	Tom Segur

October Program – On Thursday, October 6, 2016, FGCU's Dr. Ken Watanabe, will once again present to the South West Florida Astronomical Society. He will discuss some of his experiences working at the NASA Goddard Space Flight Center and his present research on Terrestrial Gamma-ray Flashes (TGFs). Dr. Watanabe, and his FGCU students, have observed over 600 Sprites using optical cameras installed on the roof of the FGCU library. Studying the possible correlations between these Sprites and TGFs will enhance understanding of physics behind the TGFs. Potential ways that SWFAS can join and contribute to this project will be discussed as well. Dr. Watanabe's presentation will begin at 7:30pm on Thursday, October 6th, at the Calusa Nature Center and Planetarium. The Public is invited.

Minutes of the Southwest Florida Astronomical Society – September 1, 2016 will appear later.

Notable September Events in Astronomy and Space Flight History

Compiled by Mike McCauley

October 1, 1958: NASA founded. The National Aeronautics and Space Administration (NASA) is an independent agency of the executive branch of the US federal government responsible for the civilian space program as well as aeronautics and aerospace research. President Dwight D. Eisenhower established NASA in 1958 with a distinctly civilian (rather than military) orientation encouraging peaceful applications in space science. The National Aeronautics and Space Act was passed on July 29, 1958, to replace the National Advisory Committee for Aeronautics. The new agency became operational October 1, 1958. Since that time, most US space exploration efforts have been led by NASA, including the Apollo moon-landing missions, the Skylab space station, and later the Space Shuttle. Currently, NASA is supporting the International Space Station and is overseeing the development of the Orion Multi-Purpose Crew Vehicle, the Space Launch System and Commercial Crew vehicles. The agency is also responsible for the Launch Services Program which provides oversight of launch operations and countdown management for unmanned NASA launches. NASA science is focused on better understanding Earth through the Earth Observing System, advancing heliophysics through the efforts of the Science Mission Directorate's Heliophysics Research Program, exploring bodies throughout the Solar System with advanced robotic spacecraft missions such as New Horizons, and researching astrophysics topics, such as the Big Bang, through the Great Observatories and associated programs. NASA shares data with various national and international organizations such as the Greenhouse Gases Observing Satellite.

October 3, 1935: Charlie Duke born. Charles Moss "Charlie" Duke, Jr., (Brig Gen, USAF, Ret.), is an American engineer, retired U.S. Air Force officer, test pilot, and a former astronaut for NASA. As Lunar Module Pilot for Apollo 16 in 1972, he became the tenth and youngest person to walk on the Moon. In April 1966, Duke was one of 19 selected for NASA's fifth group of astronauts. In 1969, he was a member of the astronaut support crew for Apollo 10. He then served as CAPCOM for Apollo 11, the first landing on the Moon, where his distinctive Southern drawl became familiar to audiences around the world. As CAPCOM, he became the voice of Mission Control nervous by a long landing that almost expended all of the Lunar Module Eagle's fuel. Duke's first words to the Apollo 11 crew on the surface of the Moon were flustered, "Roger, Twank... Tranquility, we copy you on the ground. You got a bunch of guys about to turn blue. We're breathing again. Thanks a lot!" Duke was backup Lunar Module Pilot on Apollo 13, however shortly before the mission he caught German measles from a friend's child and inadvertently exposed the prime crew to the disease. As Ken Mattingly had no natural immunity to the disease, Mattingly was then replaced as Command Module Pilot by Jack Swigert. Mattingly would be reassigned as Command Module Pilot of Duke's flight, Apollo 16. Duke served as Lunar Module Pilot of Apollo 16 in 1972 where he and John W. Young landed at the Descartes Highlands and conducted three EVAs, making Duke the tenth person to walk upon the surface of the Moon. He also served as backup Lunar Module Pilot for Apollo 17. Duke retired from NASA in December 1975.

October 4, 1957: Sputnik 1 launched. Sputnik 1 was the first artificial Earth satellite. The Soviet Union launched it into an elliptical low Earth orbit on 4 October 1957. It was a 58 cm (23 in) diameter polished metal sphere, with four external radio antennae to broadcast radio pulses. It was visible all around the Earth and its radio pulses were detectable. This surprise success precipitated the American Sputnik crisis and triggered the Space Race, a part of the larger Cold War. The launch ushered in new political, military, technological, and scientific developments. Sputnik itself provided scientists with valuable information by tracking and studying the satellite from Earth. The density of the upper atmosphere was deduced from the drag on its orbit, and the propagation of its radio signals gave information about the ionosphere. Sputnik 1 was launched during the International Geophysical Year from Site No.1/5, in Kazakh USSR (now known as the Baikonur Cosmodrome). The satellite travelled at about 29,000 kilometers per hour (18,000 mph; 8,100 m/s), taking 96.2 minutes to complete each orbit. It transmitted on 20.005 and 40.002 MHz, which were monitored by amateur radio operators throughout the world. The signals continued for 21 days until the transmitter batteries ran out on 26 October 1957. Sputnik 1 burned up on 4 January 1958 after travelling about 70 million km (43.5 million miles) and spending three months in orbit.

October 5, 1882: Robert Goddard born. Robert Hutchings Goddard (October 5, 1882 – August 10, 1945) was an American engineer, professor, physicist, and inventor credited with creating and building the world's first liquid-fueled rocket, which he successfully launched on March 16, 1926 ushering in an era of space flight and innovation. Goddard and his team launched 34 rockets between 1926 and 1941, achieving altitudes as high as 2.6 km (1.6 mi) and speeds as fast as 885 km/h (550 mph). Goddard's work as both theorist and engineer anticipated many of the developments that were to make spaceflight possible. He has been called the man who ushered in the Space Age. Two of Goddard's 214 patented inventions — a multi-stage rocket (1914), and a liquid-fuel rocket (1914) — were important milestones toward spaceflight. His 1919 monograph *A Method of Reaching Extreme Altitudes* is considered one of the classic texts of 20th-century rocket science. Goddard successfully applied three-axis control, gyroscopes and steerable thrust to rockets, to effectively control their flight. Although his work in the field was revolutionary, Goddard received very little public support for his research and development work. The press sometimes ridiculed his theories of spaceflight. As a result, he became protective of his privacy and his work. Years after his death, at the dawn of the Space Age, he came to be recognized as the founding father of modern rocketry. He not only recognized the potential of rockets for atmospheric research, ballistic missiles and space travel but was the first to scientifically study, design and construct the rockets needed to implement those ideas.

October 7, 1885: Niels Bohr born. Niels Henrik David Bohr (7 October 1885 – 18 November 1962) was a Danish physicist who made foundational contributions to understanding atomic structure and quantum theory, for which he received the Nobel Prize in Physics in 1922. Bohr was also a philosopher and a promoter of scientific research. Bohr developed the Bohr model of the atom, in which he proposed that energy levels of electrons are discrete and that the electrons revolve in stable orbits around the atomic nucleus but can jump from one energy level to another. Although the Bohr model has been supplanted by other models, its underlying principles remain valid.

He conceived the principle of complementarity: that items could be separately analyzed in terms of contradictory properties, like behaving as a wave or as a stream of particles. The notion of complementarity dominated Bohr's thinking in both science and philosophy. Bohr founded the Institute of Theoretical Physics at the University of Copenhagen, now known as the Niels Bohr Institute, which opened in 1920. Bohr mentored and collaborated with physicists including Hans Kramers, Oskar Klein, George de Hevesy and Werner Heisenberg. He predicted the existence of a new zirconium-like element, which was named hafnium, after the Latin name for Copenhagen, where it was discovered. Later, the element bohrium was named after him.

October 8, 1873: Ejnar Hertzsprung born. Ejnar Hertzsprung (8 October 1873 – 21 October 1967) was a Danish chemist and astronomer, born in Copenhagen, Denmark. In the period 1911–1913, together with Henry Norris Russell, he developed the Hertzsprung–Russell diagram. Perhaps his greatest contribution to astronomy was the development of a classification system for stars to divide them by spectral type, stage in their development, and luminosity. The so-called "Hertzsprung–Russell Diagram" has been used ever since as a classification system to explain stellar types and stellar evolution. He also discovered two asteroids, one of which is 1627 Ivar, an Amor asteroid

October 15, 1829: Asaph Hall born. Asaph Hall III (October 15, 1829 – November 22, 1907) was an American astronomer who is most famous for having discovered the moons of Mars, Deimos and Phobos, in 1877. He determined the orbits of satellites of other planets and of double stars, the rotation of Saturn, and the mass of Mars.

October 19, 1910: Subrahmanyan Chandrasekhar born. Subrahmanyan Chandrasekhar, (October 19, 1910 – August 21, 1995), was an Indian American astrophysicist who was awarded the 1983 Nobel Prize for Physics with William A. Fowler "for his theoretical studies of the physical processes of importance to the structure and evolution of the stars". His mathematical treatment of stellar evolution yielded many of the best current theoretical models of the later evolutionary stages of massive star and black holes. The Chandrasekhar limit is named after him.

October 22, 1905: Karl Jansky born. Karl Guthe Jansky (October 22, 1905 – February 14, 1950) was an American physicist and radio engineer who in August 1931 first discovered radio waves emanating from the Milky Way. He is considered one of the founding figures of radio astronomy. At Bell Telephone Laboratories Jansky built an antenna designed to receive radio waves at a frequency of 20.5 MHz (wavelength about 14.6 meters). It was mounted on a turntable that allowed it to be rotated in any direction, earning it the name "Jansky's merry-go-round". It had a diameter of approximately 100 ft. and stood 20 ft. tall. By rotating the antenna on a set of four Ford Model-T tires, the direction of a received signal could be pinpointed. A small shed to the side of the antenna housed an analog pen-and-paper recording system. After recording signals from all directions for several months, Jansky eventually categorized them into three types of static: nearby thunderstorms, distant thunderstorms, and a faint steady hiss of unknown origin. He spent over a year investigating the source of the third type of static. The location of maximum intensity rose and fell once a day, leading Jansky to initially surmise that he was detecting radiation from the Sun. After a few months of

following the signal, however, the brightest point moved away from the position of the Sun. Jansky also determined that the signal repeated on a cycle of 23 hours and 56 minutes, the period of the Earth's rotation relative to the stars (sidereal day), instead of relative to the sun (solar day). By comparing his observations with optical astronomical maps, Jansky concluded that the radiation was coming from the Milky Way and was strongest in the direction of the center of the galaxy, in the constellation of Sagittarius.

October 25, 1877: Henry Norris Russell born. Henry Norris Russell (October 25, 1877 – February 18, 1957) was an American astronomer who, along with Ejnar Hertzsprung, developed the Hertzsprung–Russell diagram (1910).

Huge Meteorite "Gancedo" Found in Argentina

By: [David Dickinson](#) from S & T

A rare rock found in Argentina might be one for the record books.



Presenting . . . "Gancedo." This 30-ton meteorite, unearthed in early September 2016, is from the massive Campo del Cielo meteorite fall in northern Argentina.

Ministerio de Gobierno, Justicia y Relación con la Comunidad

Holy sputtering space rocks! Earlier this week, a team in Argentina excavated a monster: a 30-ton chunk of what is very probably an iron-nickel meteorite.

Named "Gancedo" after a nearby town, the rock was found in the heart of the known Campo del Cielo ("Field of Heaven" in Spanish) meteorite strewnfield. A team from the local Astronomy Association of Chaco dug the huge rock out of the ground on September 10th, and images of the find soon flooded the internet.

"While we hoped for weights above what had been registered, we did not expect it to exceed 30 tons," Mario Vesconi (Astronomy Association of Chaco) told the [Xinhua news service](#). "The size and weight [of Gancedo] surprised us." For comparison, the legal [maximum gross vehicle weight](#) for an 18-wheeler in the United States is 40 tons.

The team admits it'll take time to weigh the meteorite more precisely. The find will most likely end up ranking as the second-largest meteorite recovered from Campo del Cielo in the Chaco province of northern Argentina, after the 37-ton "El Chaco" uncovered in 1980.

Mammoth Meteorites

And the biggest space rock ever recovered? That title still safely belongs to the [Hoba meteorite](#) in Namibia, estimated to weigh more than 60 tons. This measurement is difficult to make because Hoba has never been moved from its discovery site. This massive chunk of iron fell to Earth around 80,000 years ago and is now a tourist attraction, still half-buried in the ground.



The Astronomy Association of Chaco team poses in front of their enormous space rock. *Ministerio de Gobierno, Justicia y Relación con la Comunidad*

Gancedo's fall to Earth occurred between 4,000 and 6,000 years ago. Locals knew of the fall for centuries, even making iron tools from meteorites found in the strewnfield. In the 16th century, the Spanish became interested in stories of a piece of iron that fell from the sky, and in 1774 don Bartolomé Francsico de Maguna led an expedition that [came across a mass of iron](#), referred to as Mesón de Fierro ("Table of Iron" in Spanish). Another 1,400-pound fragment from Campo del Cielo named Otumpa now resides at the British Museum in London. With more than 100 tons of meteorite recovered, Campo del Cielo is the top producer in terms of pure meteorite mass worldwide.

The Campo del Cielo strewnfield extends over an ellipse 3 km wide by 19 km long over an area northwest of Buenos Aires, and meteorites found here have a [polycrystalline coarse octahedrite composition](#) characteristic of iron-nickel meteorites. They are also unusually pure even among iron-nickel meteorites, consisting of 93% iron. Most of the remaining 7% is nickel, and less than 1% are trace elements.

The illicit meteorite trade surrounding Campo del Cielo has also made the news in the past few years, with arrests just last year by Argentine officials of [four smugglers trying to take a ton of meteorites](#) out of the country. Hopefully, Gancedo will prove too large to steal and find its fitting place in meteorite science and history.

Gaia Mission Maps 1 Billion Stars

By: [Jan Hattenbach](#) from S & T

The European Space Agency's Gaia mission has released its first data release, mapping a billion stars across the Milky Way and beyond



Artist's impression of Gaia mapping the stars of the Milky Way.
ESA / ATG medialab; background: ESO / S. Brunier

It's a gold mine of data that astronomers will be sifting through for decades to come, and it's just the beginning. At a press briefing in Madrid, Spain, European Space Agency (ESA) scientists presented the long-awaited first data release of the Gaia mission, containing accurate positions of roughly a billion stars in the Milky Way and nearby galaxies. Never before have astronomers measured such a quantity of stars to such a high precision.

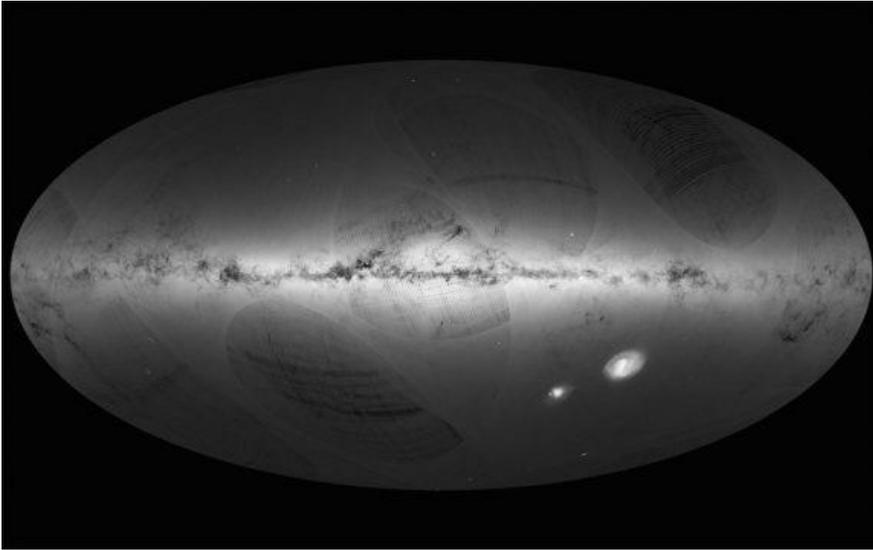
"The DR1 data are an important point in our mission, but it's just a starting point", says Timo Prusti, ESA Gaia Project Scientist, addressing and inviting the scientific community: "Please enjoy them with us!"

Mapping the Milky Way and Beyond

Gaia's main goal is to create an extraordinarily precise three-dimensional map of more than a billion stars throughout our galaxy and beyond. To do this, Gaia will monitor each of these stars about 70 times over a five-year period. It's looking for *stellar parallax*, the tiny apparent annual looping motion caused by our moving viewpoint on Earth.

Anthony Brown (Leiden University) presented the first version of the billion-star atlas, which gives star positions to a precision of a few microarcseconds for stars as faint as magnitude 20.7. That's half a million times fainter than what the naked eye can see.

The catalog's visual representation is an all-sky map with a spatial resolution comparable to that of the Hubble Space Telescope. "It's like taking a Hubble image – just of the entire sky", Brown explains.



The first all-sky view released by the ESA's Gaia mission shows stars in our galaxy – the Milky Way – and neighboring galaxies, like the Magellanic clouds (lower right) and the Andromeda galaxy M31, the largest galactic neighbor to the Milky Way, (in the lower left of the image). Below Andromeda, the Triangulum galaxy (M33) is also visible. The resolution of the image allows for individual stars in these galaxies to be studied. The curved features and darker stripes are artefacts due to Gaia's scanning procedure. They will gradually disappear as more data are gathered during the five-year mission.
ESA / Gaia / DPAC

But there's more. The data release also contains three-dimensional data showing the motion of the 2 million stars in our neighborhood bright enough for Gaia to measure their spectra and determine their speeds toward or away from Earth. The release also includes measurements of 3,200 *RR Lyrae stars*, variable stars vital to calculating the cosmic distance scale.

Gaia: Years in the Making

Almost three years after [Gaia's launch on December 19, 2013](#), the mission is starting to deliver on its promise. Nevertheless, the full work will take years. The final batch of data is expected to be released in 2023, about three years after the space mission has ended. For a selection of stars, though, scientists have already combined Gaia data with older parallax measurements, to make more accurate distance measurements available today.

To measure stellar parallaxes, it's necessary to pinpoint a star's position to a very high degree of accuracy. In fact, the technical infeasibility of measuring the minuscule movements of the apparently "fixed" stars in the 16th century, led Danish astronomer Tycho Brahe to reject the Copernican system of an Earth that orbits the Sun, rather than the other way around.

It wasn't until the 1830s that German astronomer Friedrich Wilhelm Bessel published the first reliable stellar parallax of a nearby star, 61 Cygni. Even in 1990, astronomers still had only measured parallaxes for 800 stars. Then Gaia's predecessor, ESA's Hipparcos satellite, was launched. Undisturbed by Earth's atmosphere, Hipparcos boosted the number of known parallaxes to about 50,000. But efforts stalled after Hipparcos' mission ended in 1997 — a NASA-designed Full-Sky Astrometric Mapping Explorer was scrapped in 2002 for budget reasons.

More Than Stars

Now the long wait has ended. Gaia outclasses Hipparcos in measurement accuracy and quantity by a large margin. With future releases scientists also expect to discover thousands of exoplanets, tens of thousands of asteroids, and even hundred thousands of white and brown dwarfs.

Gaia shows that astrometry is more than a dull accountant's job. Distances to the stars lay the foundation for virtually every other field of astronomy, astrophysics, and cosmology. Stellar parallaxes form the first and most fundamental step of the cosmic distance ladder. Without knowledge of the an object's three-dimensional position in space, its physical properties can at best only be guessed at.

Under ESA's policy, Gaia data are immediately available to the public. While raw data might only be of interest to professional astronomers, amateurs will enjoy [Gaia Sky](#), real-time, 3D astronomy visualisation software that runs on Windows, Linux, and OS X. The [Gaiaverse website](#) also hosts an archive for Gaia's big data. It's a huge task: Gaia is expected to produce more imaging data in its five-year lifetime than the Hubble telescope did in its first 21 years!

Moreover, combining Gaia's bonanza with other surveys, such as the recently released [GALAH](#) (Galactic Archaeology with HERMES) spectra of more than 250,000 Milky Way stars, will provide new insights for astronomers trying to understand the composition and evolution of our galaxy. Once completed, Gaia's census of our galactic neighbourhood will be used by generations of astronomers to come.



One Incredible Galaxy Cluster Yields Two Types of Gravitational Lenses

By Ethan Siegel

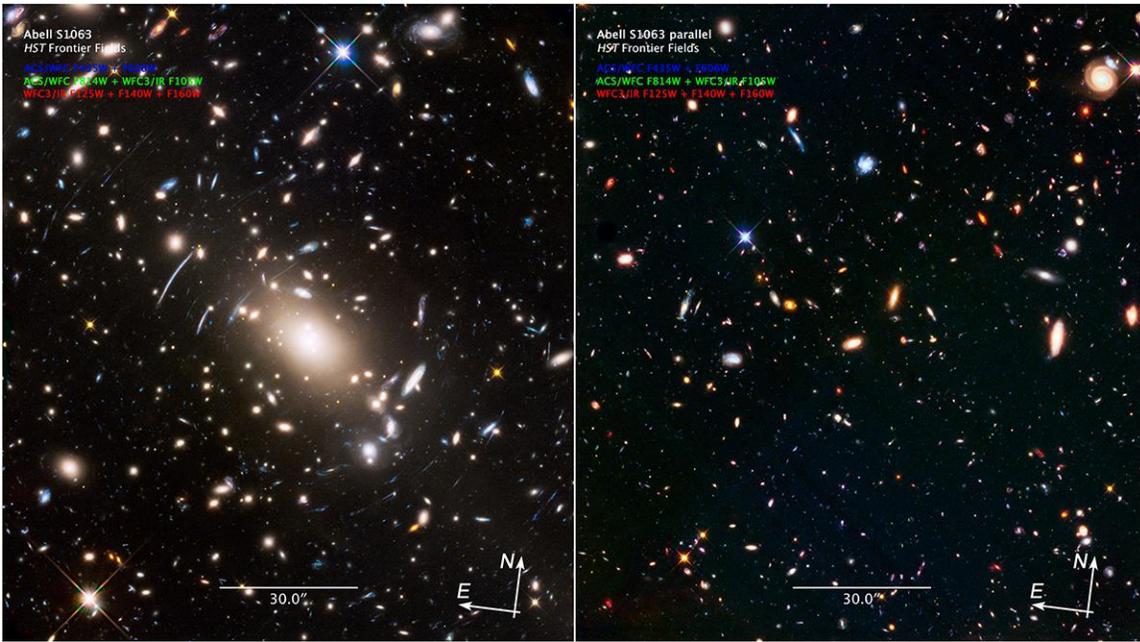
There is this great idea that if you look hard enough and long enough at any region of space, your line of sight will eventually meet a luminous object: a star, a galaxy or a cluster of galaxies. In reality, the universe is finite in age, so this isn't quite the case. There are objects that emit light from the past 13.7 billion years—99 percent of the age of the universe—but none before that. Even in theory, there are no stars or galaxies to see beyond that time, as light is limited by the amount of time it has to travel.

But with the advent of large, powerful space telescopes that can collect data for the equivalent of millions of seconds of observing time, in both visible light and infrared wavelengths, we can see nearly to the edge of all that's accessible to us.

The most massive compact, bound structures in the universe are galaxy clusters that are hundreds or even thousands of times the mass of the Milky Way. One of them, Abell S1063, was the target of a recent set of Hubble Space Telescope observations as part of the Frontier Fields program. While the Advanced Camera for Surveys instrument imaged the cluster, another instrument, the Wide Field Camera 3, used an optical trick to image a parallel field, offset by just a few arc minutes. Then the technique was reversed, giving us an unprecedentedly deep view of two closely aligned fields simultaneously, with wavelengths ranging from 435 to 1600 nanometers.

With a huge, towering galaxy cluster in one field and no comparably massive objects in the other, the effects of both weak and strong gravitational lensing are readily apparent. The galaxy cluster—over 100 trillion times the mass of our sun—warps the fabric of space. This causes background light to bend around it, converging on our eyes another four billion light years away. From behind the cluster, the light from distant galaxies is stretched, magnified, distorted, and bent into arcs and multiple images: a classic example of strong gravitational lensing. But in a subtler fashion, the less optimally aligned galaxies are distorted as well; they are stretched into elliptical shapes along concentric circles surrounding the cluster.

A visual inspection yields more of these tangential alignments than radial ones in the cluster field, while the parallel field exhibits no such shape distortion. This effect, known as weak gravitational lensing, is a very powerful technique for obtaining galaxy cluster masses independent of any other conditions. In this serendipitous image, both types of lensing can be discerned by the naked eye. When the James Webb Space Telescope launches in 2018, gravitational lensing may well empower us to see all the way back to the very first stars and galaxies.



Galaxy cluster Abell S1063 (left) as imaged with the Hubble Space Telescope as part of the Frontier Fields program. The distorted images of the background galaxies are a consequence of the warped space due to Einstein's general relativity; the parallel field (right) shows no such effects. Image credit: NASA, ESA and Jennifer Lotz (STScI)

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