SkyWAAtch

The Moon: Really Close Up

John Paladini took this image of 0.163 grams of the Dhofar 490 lunar meteorite with a 30-power stereomicroscope and a video camera. The sample John imaged is part of a 34-gram meteorite found in 2001 in the Dhofar region of Oman. Believed to be ejected from the Moon following a lunar impact, the sample's lunar origin can be surmised from its geology--similarities to the lunar crust—and composition (the concentration of certain elements such as sodium and manganese).

In This Issue . . .

Events for March 2015

WAA March Lecture

"*Galactic Cannibalism,*"
Friday March 6th, 7:30pm
Lienhard Lecture Hall, Pace University
Pleasantville, NY

The Milky Way has become the galaxy it is today partially through the consumption of smaller galaxies. New stars are only able to form in the Milky Way because of its continual consumption of gaseous fuel. In her presentation Dr. Mary Putnam will give an overview of the Milky Way's methods of consuming other galaxies with a focus on star formation fuel.

Professor Putman received her B.S. in Astronomy and Physics from University of Wisconsin-Madison and her Ph.D. in Astronomy and Astrophysics from the Australian National University (Mt. Stromlo Observatory). She has received a Hubble Postdoctoral Fellowship, the Cottrell Scholarship, and an NSF CAREER Award. She is now a Clare Boothe Luce Associate Professor at Columbia University. Free and open to the public. Directions and Map.

Upcoming Lectures

Lienhard Lecture Hall,
Pace University Pleasantville, NY

Our April 10th speaker will be Brother Robert Novak who will speak about astrobiology. Free and open to the public.

Starway to Heaven

Saturday March 14th, 6:30 pm.
Ward Pound Ridge Reservation,
Cross River, NY

This is our scheduled Starway to Heaven observing date for March, weather permitting. Free and open to the public. The rain/cloud date is March 21st. **Note**: By attending our star parties you are subject to our rules and expectations as described here. Directions.

WAA Apparel

Charlie Gibson will be bringing WAA apparel for sale to WAA meetings. Items include:

- Caps and Tee Shirts ($10)
- Short Sleeve Polos ($12)
- Hoodies ($20)
- Outerwear ($30)

Renewing Members. . .

Frank Jones - New Rochelle
Bob Quigley - Eastchester
William Sawicki - Bronx
Robert Rehrey - Yonkers
David Butler - Mohegan Lake
Curtis Jones - North Salem
Jonathan Gold - Ossining
Rick Bria - Greenwich
Alex Meleney - Greenwich
John Markowitz - Ossining

Join WAA at NEAF, April 18-19th Rockland Community College, Suffern, NY

NEAF is one of the largest astronomy shows in the world. Besides the many equipment, book and supply vendors there are lectures and, weather cooperating, the Solar Star Party. WAA will again have a booth at NEAF and we hope you will donate an hour or more of your time to help man the booth. Meet and mingle with fellow WAA members and other astronomy enthusiasts from all over the country, express your enthusiasm for our hobby and have a place to leave your stuff. Put NEAF in your calendar now.

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

On February 20th Larry Faltz took this picture of the conjuction of Venus, the Moon and Mars from Ward Pound Ridge with a Canon T3i.

Almanac
For March 2015 by Bob Kelly


Mar 5 Mar 13 Mar 20 Mar 27

March Madness. I think the NCAA tournament is bit overblown and overwhelming. Nonetheless, bowing to the season, I was going to do this article as a tournament bracket. But I don't have the graphics skills and it would perhaps lean towards the pretentious. Still there are so many pretty line-ups with bright objects this month; a playoff format might have been a good way to display the conjunctions.

For example, Jupiter approaches the Beehive Cluster this month, getting within 5 degrees of M44 by the end of the month. Consider this a 'play-in' game – the cluster of stars has no chance of outshining the king of the planets – and Jupiter doesn't get that close to M44, pulling up 5 degrees short when it ends its retrograde motion early next month. The cluster and Jupiter will actually look nicer with Jupiter standing off a ways from the Beehive, so you can still see it not overwhelmed by Jupiter's brilliance. In the meantime, Jupiter is still large enough to see wondrous sights with a telescope and the changing positions of its brightest moons. Jupiter celebrates its Spring Solstice with its moons lining up to cast shadows on each other. The best for North America is in the middle of the night on the 5th/6th; a more convenient one is after sunset on the 15th.

On the other end of the bracket, the Moon pairs up with a number of bright objects this month and easily outshines them, a sure bet for the finals. The Moon takes on Jupiter on the 3rd, Spica on the 8th and 9th, Saturn on the 12th, Mars on the 21st, Venus on the 22nd, the Hyades cluster on the 24th, and Jupiter in a return match on the 29th. It outshines them all, setting up the finals with the brightest object in our skies. Budding photographers should try to shoot for nice photos of these alignments. What's the simplest camera that can take a good shot of these scenes?

One would think the Sun would be the ultimate winner in our celestial shootout, but the Moon wins the championship on March 20th, eclipsing the Sun. The Spring Sun is low in the Arctic skies so the Moon will block out the Sun along a path over 250 miles wide. What's interesting is the eclipse occurs a few hours before the Spring Equinox, when the Sun would start to peek over the North Polar horizon. Geometrically, the Moon and Sun should be just below the horizon during the eclipse. But our atmosphere bends the Sun's light over the horizon. If the sky is clear, the entire eclipse will be visible from Santa's workshop with the eclipsed Sun rolling just above the horizon, covering about 60 degrees in azimuth during the event. The Astronomical Almanac spends some time discussing this event, giving Jean Mears credit for explaining this in his *Astronomical Morsels* in 1994.

In the intermediate rounds, the most evenly matched pairing from Earth's point of view is Mars and Uranus, closest together low in the evening sky on the 11th. They appear almost the same size in a telescope, and the color contrast of reddish Mars and bluish Uranus might be striking if they aren't overwhelmed by twilight. Venus overwhelmed Uranus on the 4th and stays well above Mars and Uranus after that.

Comet Lovejoy has performed better than the pundit's expectations. Find it after dark passing across the W of Cassiopeia, especially during the darker moonless skies of mid-March. While Lovejoy is fading, it should still be findable in binoculars, and easier to know where to look among the bright stars of Cassiopeia.

Saturn is the major attraction for early morning astronomers due south just before twilight begins.

Dark skies start an hour later and end about 7am after we turn on Daylight Time on the 8th. Don't forget to commemorate pi (π) day on 3.14 15 at 9:26:53.58979! Celebrate by calculating the radius of a circular argument.

The very shiny International Space Station sails through our twilight skies in the morning from the 9th through the end of the month.

Westchester Amateur Astronomers

A Year (or More) of Comets

Larry Faltz

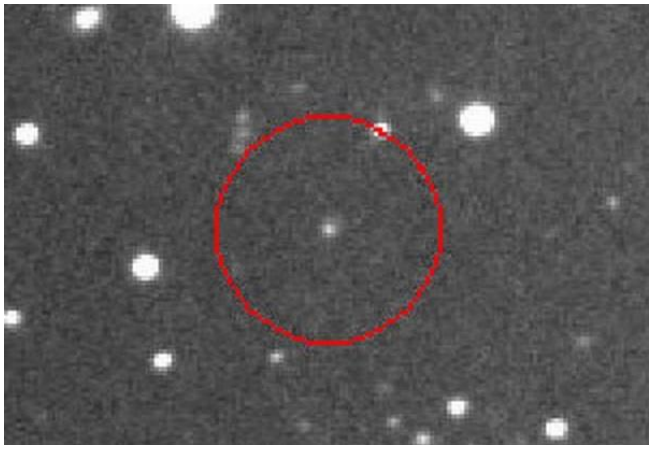
Who doesn't love comets? They occupy a special place in the celestial pantheon. They are pregnant with the possibility of grand spectacle. Neither predictable like the moon and planets nor momentary like meteors, their capriciousness both excites and frustrates astronomers and the public alike. Only total solar eclipses are more likely to entice non-astronomers to pay attention to the sky.

Four comets caught our attention as they made their way into our part of the Solar System in the past 15 months. While none of them were spectacular Hale-Bopp-like visual feasts, they brought plenty of scientific and popular interest. As I write this in late January, Comet Lovejoy (officially known as C/2014 Q2) is still shining at just over 5th magnitude in the evening sky near the Pleiades, moving quite dramatically against the starry background. Even though visually it appears as just a tail-less fuzzy blob, it is invigorating to see it flit across the sky, moving by about 2 degrees each night. By the time you read this, it will have faded somewhat after making perihelion on January 30, but it will still be visible in many amateur telescopes.

Comet Lovejoy, January 9, 2015, 80mm f/6 refractor from Larchmont, NY (LF)

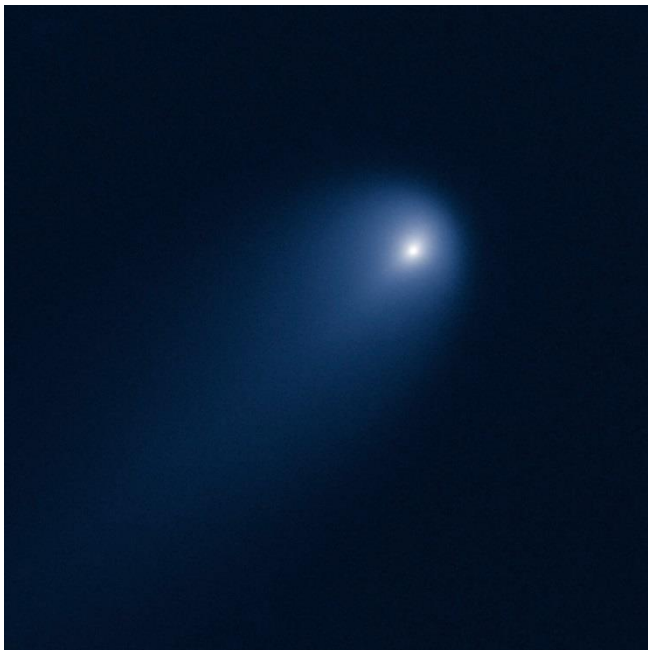
Lovejoy was discovered by amateur astronomer Terry Lovejoy using just an 8" SCT. Because of the ever-greater reach of professional telescopes and the computer-automated observation programs that they host, a large number of faint comets are discovered and tracked each year, whetting our appetites for a really grand display. Many are new visitors from the Oort cloud, the collection of icy bodies orbiting at the far reaches of the sun's gravitational well, about 1 light year away. Others are periodic comets, often with very elongated orbits, that are perturbed from time to time by Jupiter's gravity (Lovejoy had a period of 11,000 years but its orbit is being shifted to an 8,000-year period due to its gravitational dance with Jupiter). Like Lovejoy, comets are named after their discoverers but in the modern era it's increasingly hard for amateurs to scoop the big observing projects, although Terry Lovejoy has done it 5 times. So we have multiple comets named PANSTARRS, ISON, or LINEAR, just to cite three of the active ventures. Since most of the comets discovered in any given year are never going to be bright enough for amateur observation, we can refer to brighter comets by their project name rather than the exact designation, although you'll need to know the full moniker if you use planetarium software, such as The Sky or Cartes du Ciel, to search for the comet. Up-to-date comet ephemerides from the IAU Minor Planet Center in Cambridge, Massachusetts can be uploaded to modern planetarium software in a few seconds with a couple of mouse clicks.

This is very helpful when you are using a go-to mount to look for a comet. I wanted to image Lovejoy in early January from my light-polluted street but it was invisible in the scope's 50 mm finder. I connected my netbook to my already-aligned iOptron Minitower go-to mount, found the comet with the Cartes du Ciel search function, and clicked on it. The scope slewed to the comet's position and put it right in the center of the field.



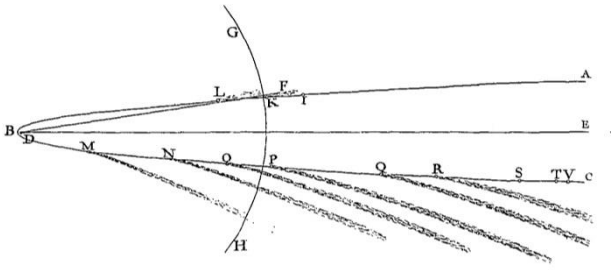
ISON (C/2012 S1) discovery image

Comets are notoriously fickle beasts, and in late 2013 we were reminded of that with a "Comet of the Century" non-event (not the first, and not the last, I'm sure), this one the notorious Comet ISON (C/2012 S1).



Comet ISON captured by Hubble, 4/10/13

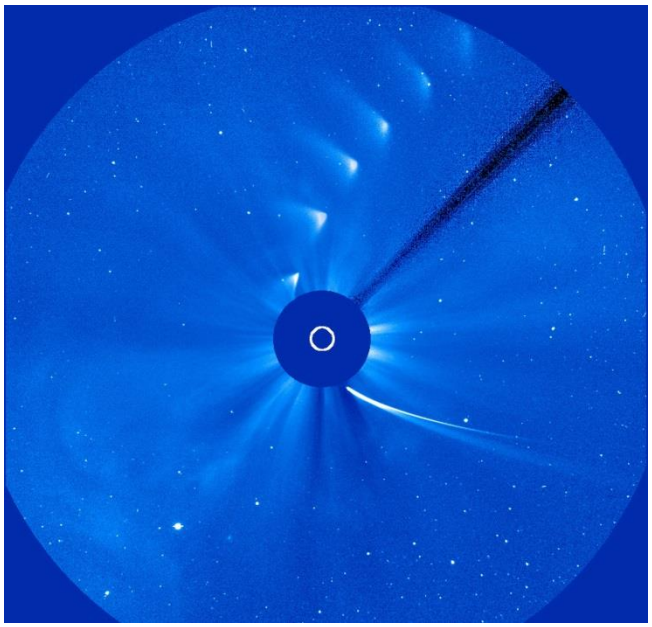
ISON was discovered on September 21, 2012 by two Russian astronomers, Vitali Nevski and Artyom Novichonok, using a 0.4-meter f/3 telescope, part of the International Scientific Optical Network, a collaboration managed by a unit of the Russian Academy of Sciences. ISON employs 20 telescopes in 10 countries (including one in the USA) to track solar system objects, primarily asteroids. The discovery CCD images showed a minute 18.8 magnitude dot; orbital calculations showed that it was about a billion kilometers from the sun, a bit inside the orbit of Saturn.



Newton's diagram of the Comet of 1680 in the *Principia*

Orbital elements showed that the comet would make perihelion very close to the sun's surface (about 1 million km) on November 28, 2013, but because its nucleus was thought to be relatively large, 5 km in diameter on the basis of observations by terrestrial and space telescopes, it was expected or perhaps merely hoped that it would survive, with its post-perihelion orbit making it a spectacular sight in the night sky from our latitude. In another burst of wishful thinking, it was even suggested that the orbit was similar to that of the Great Comet of 1680, a sun-grazer from the Oort Cloud that was visible in daylight and sported a tail almost halfway across the sky. This comet was famous not only for its breathtaking visual appearance but also for having its orbit analyzed by Isaac Newton in the *Principia Mathematica*. ISON's orbit was determined to be a hyperbola, an indication that it was a new comet from the Oort cloud.

Lieve Verschuier, *The Great Comet of 1680 over Rotterdam*. (Historisch Museum, Amsterdam)



Composite image of ISON at perihelion from SOHO's LASCO C3 camera. See animations on the SOHO web site.

The media bit on these predictions, and in spite of new observations from the Mars Reconnaissance Orbiter suggesting that the comet was only 0.5 km in diameter, it was off to the races. Telescope companies and vendors, always hoping to drum up business, fed the hype. That ISON's brightness failed to increase as predicted in the fall of 2013 didn't suppress media interest. One popular astronomy magazine suggested ISON might be "one of the greatest comets in human history." Well, "blessed is he who expects nothing, for he shall never be disappointed." (Alexander Pope)

We all know the sad outcome of Comet ISON. Like Icarus, it flew too close to the sun and broke up shortly before perihelion. Many people, including yours truly, watched the live Solar and Heliospheric Observatory (SOHO) internet broadcast at perihelion hoping for a spectacular show. Even if there was nothing to see, it was amazing to think that anyone in the world could link to a research satellite that transmitted live images of our star. SOHO's LASCO C3 camera showed a puff of gas in the comet's post-perihelion orbit, but the nucleus was gone.

Comets were thought in olden days to be harbingers of evil (for a fine book on the history and sociology of comets, read *Comets, Popular Culture and the Birth of Cosmology* by Sara Schechner Genuth, published in 1997 by the Princeton University Press). It's intriguing to think that the public disappointment that haunted astronomy after ISON's perihelion was just such a manifestation. While comets don't influence the course of human events the way the ancients thought, a direct impact on Earth would be quite another matter. The Tunguska impact in Siberia in 1908 is thought by many to have been caused by a cometary nucleus bursting in the atmosphere. We are often regaled on TV with images of civilization-destroying comet impacts, alternating with asteroids as the malefactors.

On May 6, 2014, Comet 209/P LINEAR, a periodic comet (5.09 years) discovered in 2004, made the 9th closest approach to Earth of any comet, some 0.0554 AU (8,290,000 km, about 5.2 million miles). The comet garnered the attention of the amateur community, but it never got brighter than magnitude 12. However, it was predicted that on the night of May 23-24, 2014 the Earth would pass through the dust trails this comet generated during all of its orbits from 1803 to 1924 (calculated from orbital elements after the 2004 discovery), with a shower of as many as 400 meteors per hour. That would have been an amazing show. But there was barely a blip in the meteor rate, once again showing how unpredictable comet realm really is. The Earth will pass through 209/P's 1939 stream on May 24, 2019. Perhaps then we will be rewarded with a shower, but it also may be that LINEAR has blown off most of its volatiles and is nearly "extinct," making 2019 another non-event.

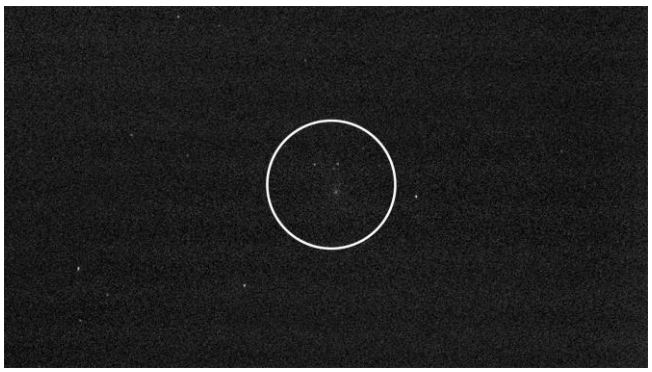
Comet 209/P LINEAR imaged at closest approach to Earth by the Virtual Telescope Project (17.5" telescope)

The danger of a cometary impact in 2014 was more real for Mars than it was for Earth. Comet Siding Spring (C/2013 A1), another visitor from the Oort Cloud, was discovered on January 3, 2013 by Robert McNaught in Australia. McNaught has discovered more than 50 comets and his name is associated with a naked-eye Oort Cloud comet (C/2006 P1) that while barely visible from the northern hemisphere was candidate for Comet of the Century in the southern. It was even given the moniker of "The Great Comet of 2007" in Australia.

Comet McNaught (C/2006 P1) (Fir0002/Flagstaffotos)

Initial orbital calculations for Siding Spring suggested that there would be a direct impact with Mars on October 19, 2014, but as the elements got refined a close approach of about 80,000 miles was confirmed. While the danger of impact was eliminated, there was concern that dust from the comet might harm the half-dozen orbiters currently surveying the red planet. NASA's missions, the Mars Reconnaissance Orbiter and the Mars Odyssey, were maneuvered into safer positions on the opposite side of the planet from the comet on the day of closest approach. All of the orbiters, including those of the European Space Agency and the Indian Space Research Organization, had the opportunity to study the comet. None appeared to have been damaged by cometary particles. The orbiters and the two operating surface rovers, Mars Curiosity and Opportunity, imaged the comet at close approach.

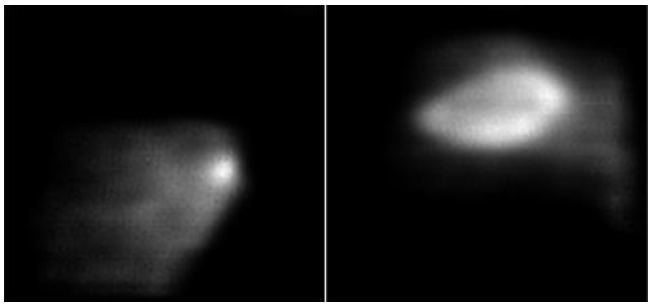
Composite Hubble image of Comet Siding Spring at close approach to Mars on October 19, 2014



Opportunity rover's image of Comet Siding Spring on October 19, 2014

A trove of scientific data was returned from the orbiters. The comet released thousands of kilograms of comet dust per hour containing magnesium, iron, sodium, potassium, manganese, nickel, chromium and zinc. The nucleus was determined to be between 400 and 700 meters in diameter, rotating once every 8 hours. MAVEN, the Mars Atmosphere and Volatile EvolutioN Mission, detected an intense meteor shower in the Martian atmosphere resulting from the comet's dust tail passing through the Martian atmosphere.

The best comet event of 2014 was, of course, the rendezvous of the European Space Agency's Rosetta spacecraft with Comet 67/P Churyumov–Gerasimenko and the landing of the Philae probe on the comet's surface. This is truly a milestone event in space exploration and solar system science, a capstone to nearly 40 years of exploration of comets from space. While comets are not direct interlopers in the ongoing course of human events, they may have had a more profound impact on our existence: they may have provided the organic compounds that seeded life on Earth. One of the consistent findings of recent research is the presence of carbon-containing molecules on cometary surfaces and in dust tails. While organic molecules may have been formed on Earth by the process of abiogenesis, as shown in the famous Miller-Urey experiment, energetic ultraviolet radiation, of which there is plenty in deep space, can interact with carbon, hydrogen atoms and ammonia molecules to form a variety of reactive organics. The evidence for this comes from spectroscopy and, more recently, direct chemical analysis.



Vega 1 images of the nucleus of Comet Halley, March 6, 1986

There have been 10 successful missions to comets since the dawn of the space age. The first, the International Cometary Explorer (ICE) was launched by NASA in 1978 as the International Sun/Earth Explorer 3 (ISEE-3). After it collected data on the solar wind and the local magnetic environment, it was repurposed to investigate the interaction between the solar wind and Comet 21P/Giacobini–Zinner. It flew through the comet's plasma tail on September 11, 1985, and confirmed the theory that comets are "dirty snowballs." Seven months later it transited the tail of Comet 1P/Halley, along with space probes Giotto (European

Space Agency), Vega 1, Vega 2 (Russian probes that initially studied Venus), Suisei and Sakigake (Japan). The Vegas returned the first images of a cometary nucleus.

Giotto, the first probe purpose-built for cometary research, was partially damaged by small particles when it made close approach (596 kilometers) to Halley and flew through its tail on March 14, 1986, but it continued to take photographs and obtain data. It was later sent to Comet 26P/Grigg–Skjellerup, passing at a distance of 200,000 km on July 10, 1992. Giotto's encounter with Halley provided a massive amount of scientific data. The nucleus was determined to be peanut-shaped, 15 km long and from 7 to 10 km wide. Only 10% of the surface was actively ejecting gas and particles. The ejected material was composed of 80% water, 10% carbon monoxide, 2.5% methane-ammonia, and some trace amounts of hydrocarbons, iron and sodium. It was expelled at 3 tons per second. The comet's density (0.3 gm/cm^3) and surface properties (rough, porous and dark) were also ascertained, and the data provided evidence that Halley had formed 4.5 billion years ago when ice and other volatiles condensed on interstellar dust particles. Halley's visual apparition in 1986 wasn't the Comet of the Century that it was in 1910, but the scientific outcome was remarkable.

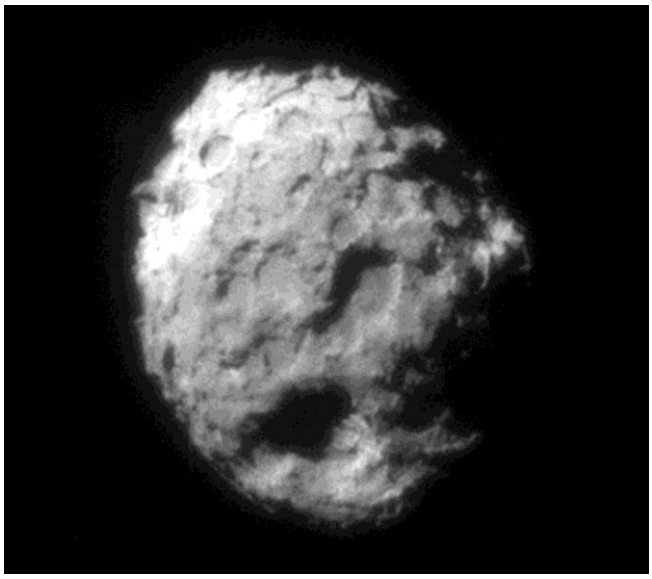
Giotto image of the nucleus of Comet Halley

Deep Space 1 was a technologically adventurous asteroid mission launched in 1998 that was extended to a rendezvous with Comet 19P/Borrelly. Although the probe had technical glitches, it passed the comet on September 21, 2001 and returned data and images.

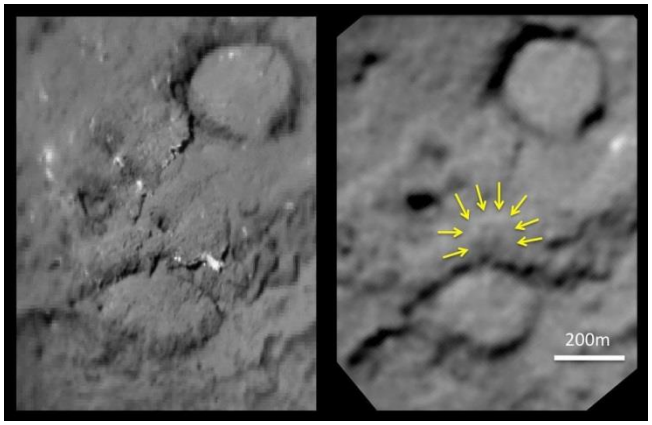
NASA's Stardust probe was launched in 1999 to collect samples of dust from the coma of Comet 81P/Wild and return them to Earth for analysis. It passed by the comet on January 2, 2004 and on January 15, 2006 it returned samples that have since been extensively analyzed. Over a million microscopic specks of dust were collected, the largest of which were 1 mm in size. Organics, minerals and metals were found, including the amino acid glycine.

Cometary dust grains collected by Stardust

On February 15, 2011 Stardust flew by Comet 9P/Tempel and imaged the surface, detecting the crater left by the Deep Impact probe, which had been launched in 2005 to shoot a projectile at the comet and examine the ejecta. The impact, on July 4, 2005, showed that the comet was more dusty and less icy than expected. A large dust cloud obscured Deep Impact's view of the crater. Deep Impact then was rechristened as EPOXI, the Extrasolar Planet Observation and Deep Impact Extended Investigation. It observed Comet 103P/Hartley, Comet Garradd (C/2009 P1) and our friend C/2012 S1 (ISON), the latter in January 2013 from a distance of 800 million kilometers. Deep Impact's images unfortunately contributed to the over-optimistic predictions for ISON.

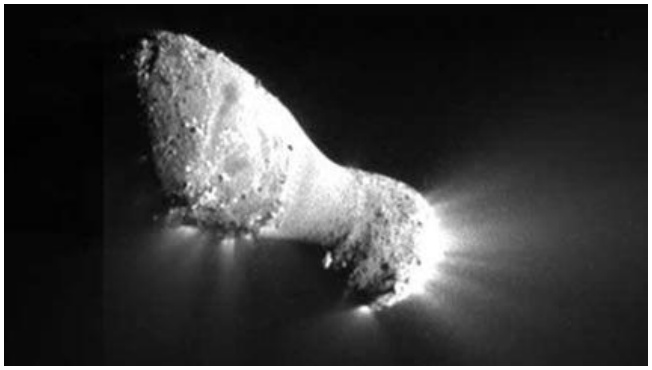


Comet 81P/Wild as seen by Stardust



Before (Deep Impact) and after (Stardust) images of the impact site of the Deep Impact projectile on Comet 9P/Tempel

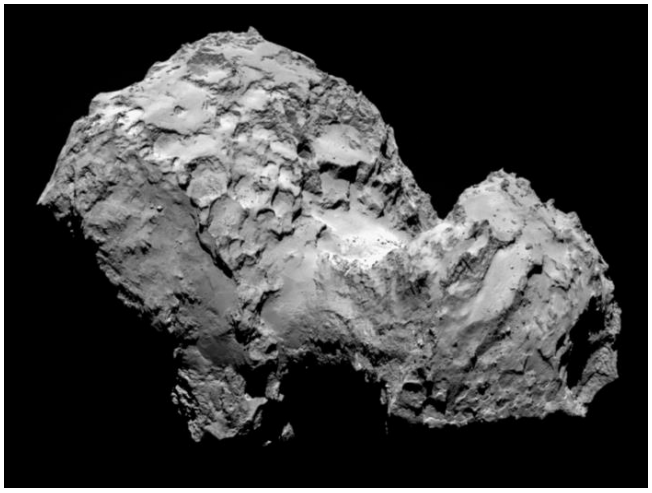
The ambitious Rosetta mission, launched in 2004, was not going to be a mere flyby. After delays rendered its original target unreachable, Rosetta was programmed to rendezvous with Comet 67/P Churyumov–Gerasimenko near the comet's apehelion. The mission calls for Rosetta to accompany 67/P as it rounds the sun (perihelion is in August 2015), making continuous observations as gas and particles stream from it under the influence of solar radiation and the solar wind. In addition, Rosetta carried the washing-machine sized Philae lander, which was designed to be dropped onto the comet's surface and directly sample its composition and properties.



Comet 103P/Hartley from EPOXI

Comet 67/P has a period of 6.44 years. Perihelion lies between the orbits of Earth and Mars and apehelion is just past the orbit of Jupiter. It's inclined just 7 degrees from the ecliptic. Most likely a Kuiper belt object, its orbit was perturbed in 1959 when it got a gravitational tug from Jupiter, kicking it into its present trajectory. At some point in the not-to-distant future, the giant planet's gravity will again warp the comet's track. It's done so many times in the past.

The Rosetta mission is a grand, visionary undertaking and its success is a testament to the scientific and engineering skill, and the persistence and patience, of its creators. Rosetta carries 11 instruments and Philae 10, including a drill and analyzer designed to directly examine cometary material. In the planning stages since the late 1980's, Rosetta was launched on March 2, 2004. The probe used 3 gravity assists from Earth and one from Mars on its way to meet Comet 67/P on August 6, 2014 3.7 astronomical units (344 million miles, just inside Jupiter's orbit) from the sun. During its approach it observed two asteroids, and then spent 2½ years in hibernation with its instruments powered down. After being awoken in January 2014, Rosetta started returning images that suggested the comet had an unusual shape, and by July this was confirmed. A high resolution image on August 3, 2014 from the main camera, OSIRIS (Optical, Spectroscopic and Infrared Remote Imaging System) showed the bi-lobed comet in glorious detail, which many compared to a "rubber duckie." From then on, high-resolution images and scientific data flooded into ESA's control center in Germany.

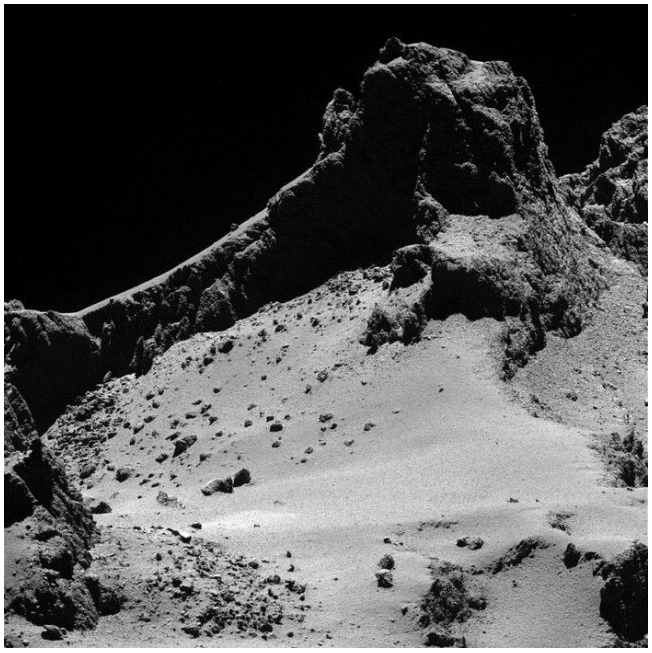


Extremely high resolution Rosetta image of Comet 67/P from 285 km, August 6, 2014

As Rosetta rode along with Comet 67/P in late summer and fall, it became evident that the comet was a world with complex geography and topography. The Philae lander was sent to the comet's surface on November 12, 2014 in an audacious attempt to gather material directly from the surface. The lander made contact but its clever retaining devices failed to deploy properly. After bouncing a few times in the minimal gravity it came to rest in the shadow of a cliff, where it ultimately ran out of power, unable to provide all of the data it was designed for. It's possible it can be

woken up later this year when the comet is closer to the sun and there is less of a shadow over Philae's solar panels. It appears that it is sitting at an angle that prevents its comet-sampling drill from being deployed, but mission engineers think its analyzer may have ingested some surface dust that could be studied if and when the power comes back on.

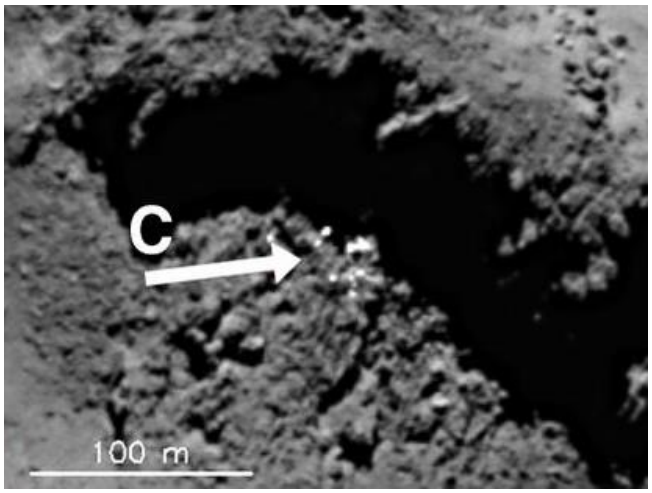
Even in this early part of the mission the scientific results have been prodigious. The first papers were published in *Science* in its issue of January 23, 2015.



The surface of Comet 67/P imaged from 8 km on October 14, 2014. Objects as small as 15 cm can be resolved.

One would think that after eons of orbits around the sun, the surface of a comet would be smoothed out by solar wind and radiation like a stone in a stream. But Comet 67/P is topologically complex. It's not clear whether its bi-lobed shape resulted from the combination of two spherical objects when the comet was born 4.5 billion years ago or is the result of mass loss from sublimation in the intervening years. Surface features show vast variations in height and breadth. There are craggy peaks, rock-strewn fields and sand dunes. It's not a smooth rubber duckie at all, but like the bath toy it would float in the tub, with a density of about 0.470 that of water, similar to cork. Its mass is currently about 10^{13} kg (110 million tons). The low density implies the lack of an internal structure, so the comet must be fluffy and highly porous but with some local density variations to account for the topology. Thermal processes resulting from the sun's radiation during 67/P's elliptical orbit may be the primary reason for the surface complexity, although contributions from solar wind particles and the magnetic environment of space may also play a role. Some researchers think that the heterogeneity is due to a complex, turbulent physical and chemical environment in the proto-solar nebula in which the comet formed.

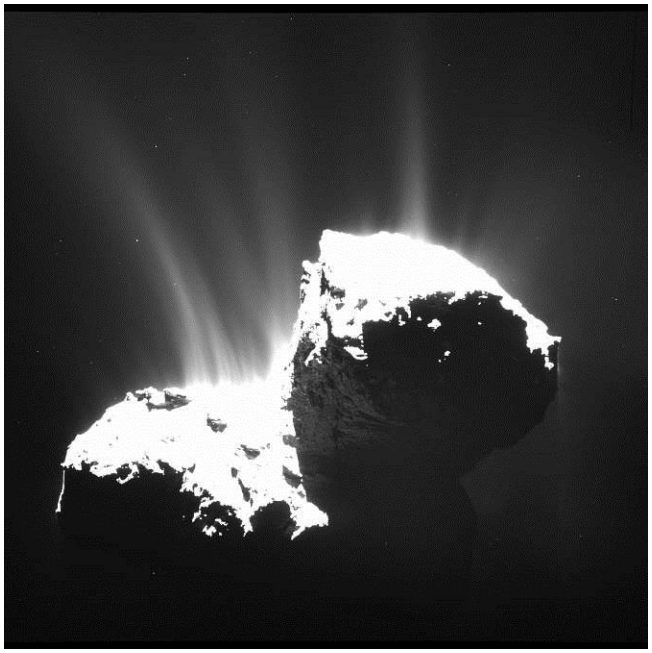
The comet's surface has a very low albedo, just 0.060, due to the presence of large amounts of nonvolatile organic molecules made of carbon, hydrogen and oxygen, with a dearth of nitrogen-containing organics. There appears to be a greater diversity of organics in 67/P than in other comets that have been spectroscopically analyzed. The coma seems to have more dust than gas by a factor of about 2. Most of the outflow arises from the neck of the comet, suggesting a mechanism for future break-up into at least two components. The nucleus emits dust grains of up to 2 cm in size. As the comet heats up, the surface cracks and gets rearranged to expose sub-surface zones that contribute more material to the jets. Heat below these zones can build up pressure, fostering potentially explosive eruption of gas and dust. A few exposed areas show tiny specks of high reflectivity suggesting water ice, but broad ice patches are not observed.



Bright patches (arrow) suggesting water ice (C)

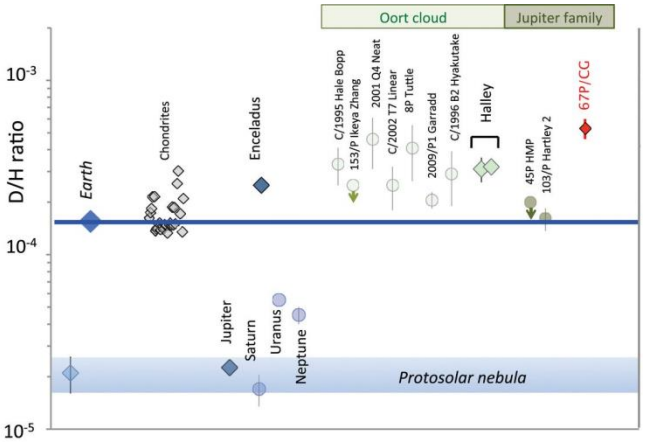
Perhaps the most intriguing result at this early stage is the finding from the probe's mass spectrometer that the ratio of deuterium to hydrogen is $(5.3 \pm 0.7) \times 10^{-4}$, a ratio three times higher than that found in Earth's oceans. This strongly suggests a different origin for water in Earth's oceans and in Jupiter-family objects such as 67/P. Current thinking is that during the Late Heavy Bombardment period water-ice-laden asteroids filled the nascent Earth's oceans. Chondrite meteors, thought the be closely related to Late Heavy Bombardment objects, seem to have a D/H ratio closer to

that of our oceans than other solar system objects, but it remains a hard fact that there is nothing quite like Earth water elsewhere in the solar system.

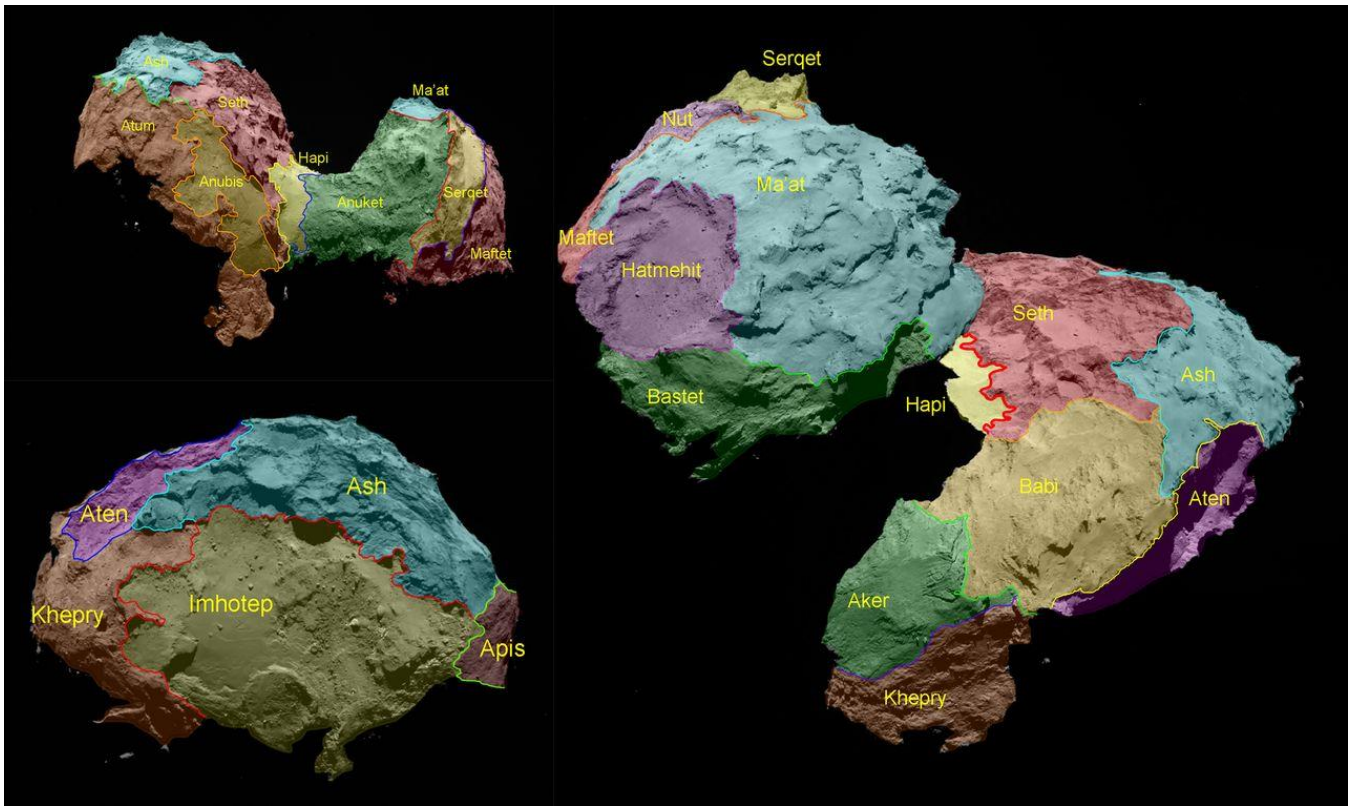


Jets of gas and dust shooting from the surface of Comet 67/P imaged on November 22, 2014 from a distance of 30 km. The surface has been overexposed to show the jets.

Over the next year, the information coming from Rosetta (and maybe even Philae) will vastly increase our understanding of comets, and in doing so will challenge and perhaps revolutionize our view of the origin and early history of the solar system. The Rosetta web site is constantly updated with images, background material and scientific updates.■

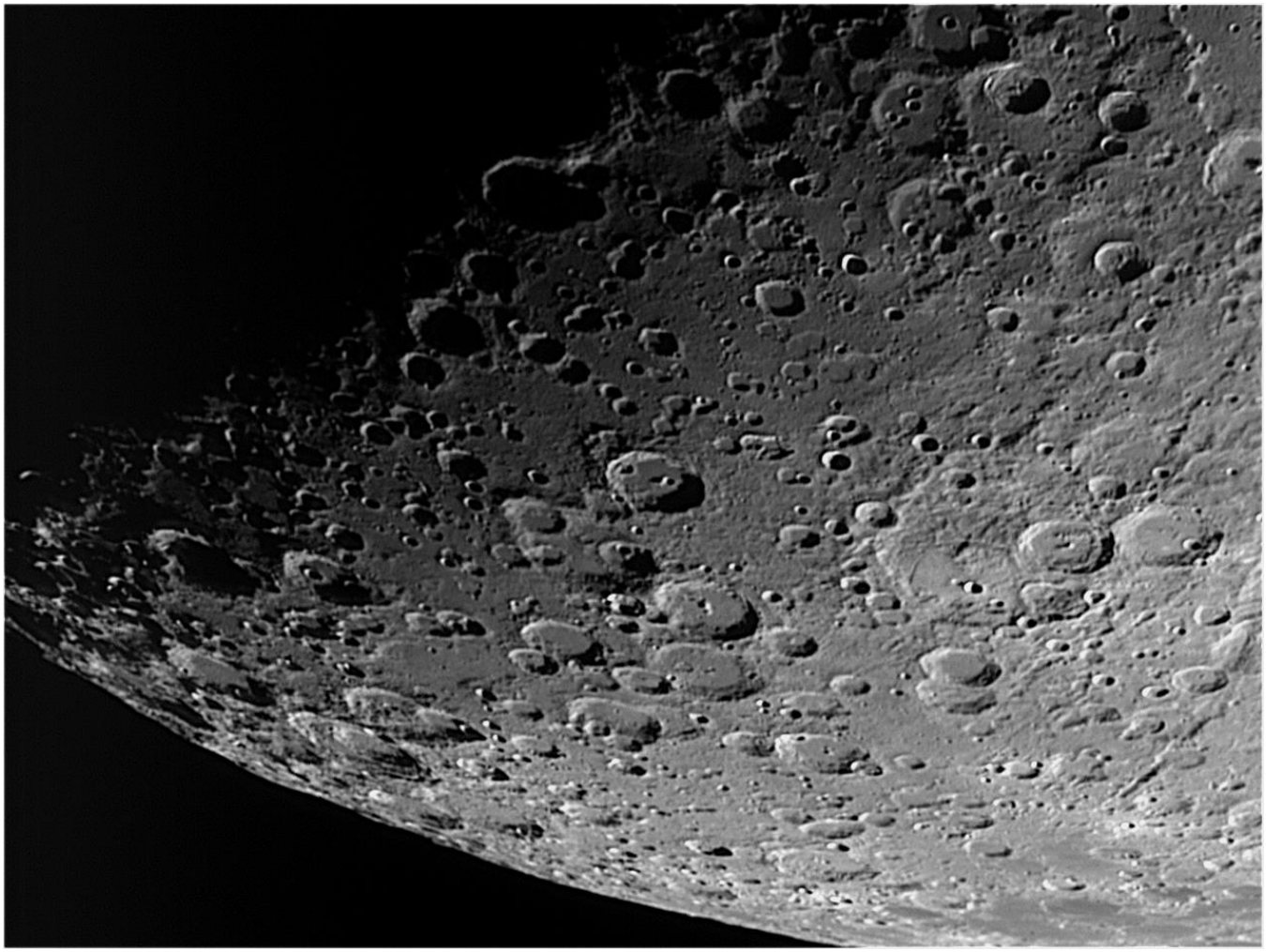


D/H ratios in different objects of the solar system (Altwegg, K, et. al., *Science* 23 January 2015: 1261952)



Surface regions of Comet Comet 67/P Churyumov–Gerasimenko (Thomas, N, et. al., *Science* 23 January 2015: aaa0440)

Crater Pitiscus



The heavily cratered southern lunar highlands east of the crater Clavius (invisible on the night side of the terminator) and south of the Mare Nectarum. In the center is the crater Pitiscus. The large, flat, ill-defined crater on the right is Janssen, with the younger Fabricius and Metius on its eastern (right-side) edge. Stellarvue SVR-105 f/7 triplet refractor, Celestron Skyris 445 camera, 25A red filter, best 500 of 5000 frames stacked with Registax. Image acquired 12/25/14. (Larry Faltz)

"Neil Armstrong: A Life of Flight" by Jay Barbree, Foreword by John Glenn

Reviewed by Paul Alimena

"Pilots take no special joy in walking. Pilots like flying." I read this ironic quote by Neil Armstrong in the news reports after his unexpected passing in 2012 and took special note of it as my son is a pilot and I've been on the periphery of his journey in the world of aviation. Neil Armstrong: A Life of Flight by NBC News space correspondent Jay Barbree with a foreword by John Glenn was published in 2014 and is an easily accessible, non-technical story of Armstrong's life as an aviator written by his friend and confidant of over 50 years.

I was interested to learn more about Armstrong, especially in light of the notable contrast between Armstrong's reserved persona and that of his much more conspicuous colleague from the Apollo 11 moon landing, Buzz Aldrin. Barbree is a pilot himself, and a veteran reporter of all 166 manned space missions conducted by NASA. After years of discussing the prospect of writing a chronicle of his story, Armstrong relinquished the role to his compatriot as an insider who would get the story right. "Jay, you write it. You're a pilot. You're one of us." The reader becomes part of a close knit circle of fellow pilots and astronauts, privy to conversations that may have just as likely been held over a

back yard fence or at a local watering hole as in the halls of NASA facilities.

The book follows Armstrong's career beginning with his duty as a fighter jet pilot in the Korean War, including an ejection during a mission and his perspective as a test pilot flying the X-15 during the early years of Russian success and American failure in the nascent space race. He joined the second astronaut corps and became the pilot of Gemini 8, conducting the first docking in space and then America's first emergency return from space after a stuck thruster caused the capsule to spin as much as 550 degrees per second. "That was truly a fantastic recovery. . . .and really proved why we have test pilots in those ships."

According to the author, Neil Armstrong did not seek to become the first human to walk on the moon. Armstrong was quiet but not shy, a private person who was a consummate professional and ultimate team player. He was selected to be mission commander of Apollo 11 and later his position as a commission leader in the investigation into the Challenger accident reflected the obvious high regard with which he was held. He was a proponent of America continuing its leading role in the pursuit of scientific knowledge up until the time of his passing. I thoroughly enjoyed reading this unique account of Armstrong's life events, including his successes, near misses, and personal tragedies. As Barbree recites in his introduction, "I will not report to you a single word he told me in confidence… (but) I shall write more about Neil Armstrong than he would have liked."

The Heavyweight Champion of the Cosmos

By Dr. Ethan Siegel

As crazy as it once seemed, we once assumed that the Earth was the largest thing in all the universe. 2,500 years ago, the Greek philosopher Anaxagoras was ridiculed for suggesting that the Sun might be even larger than the Peloponnesus peninsula, about 16% of modern-day Greece. Today, we know that planets are dwarfed by stars, which themselves are bound together by the billions or even trillions into galaxies.

But gravitationally bound structures extend far beyond galaxies, which themselves can bind together into massive clusters across the cosmos. While dark energy may be driving most galaxy clusters apart from one another, preventing our local group from falling into the Virgo Cluster, for example. On occasion, huge galaxy clusters can merge, forming the largest gravitationally bound structures in the universe.

Take the "El Gordo" galaxy cluster, catalogued as ACT-CL J0102-4915. It's the largest known galaxy cluster in the distant universe. A galaxy like the Milky Way might contain a few hundred billion stars and up to just over a trillion (10^{12}) solar masses worth of matter, the El Gordo cluster has an estimated mass of 3×10^{15} solar masses, or 3,000 times as much as our own galaxy! The way we've figured this out is fascinating. By seeing how the shapes of background galaxies are distorted into more elliptical-than-average shapes along a particular set of axes, we can reconstruct how much mass is present in the cluster: a phenomenon known as weak gravitational lensing.

That reconstruction is shown in blue, but doesn't match up with where the X-rays are, which are shown in pink! This is because, when galaxy clusters collide, the neutral gas inside heats up to emit X-rays, but the individual galaxies (mostly) and dark matter (completely) pass through one another, resulting in a displacement of the cluster's mass from its center. This has been observed before in objects like the Bullet Cluster, but El Gordo is much younger and farther away. At 10 billion light-years distant, the light reaching us now was emitted more than 7 billion years ago, when the universe was less than half its present age.

It's a good thing, too, because about 6 billion years ago, the universe began accelerating, meaning that El Gordo just might be the largest cosmic heavyweight of all. There's still more universe left to explore, but for right now, this is the heavyweight champion of the distant universe!

Learn more about "El Gordo" here: http://www.nasa.gov/press/2014/april/nasa-hubble-team-finds-monster-el-gordo-galaxy-cluster-bigger-than-thought/ El Gordo is certainly huge, but what about really tiny galaxies? Kids can learn about satellite galaxies at NASA's Space Place :

http://spaceplace.nasa.gov/satellite-galaxies/.

El Gordo

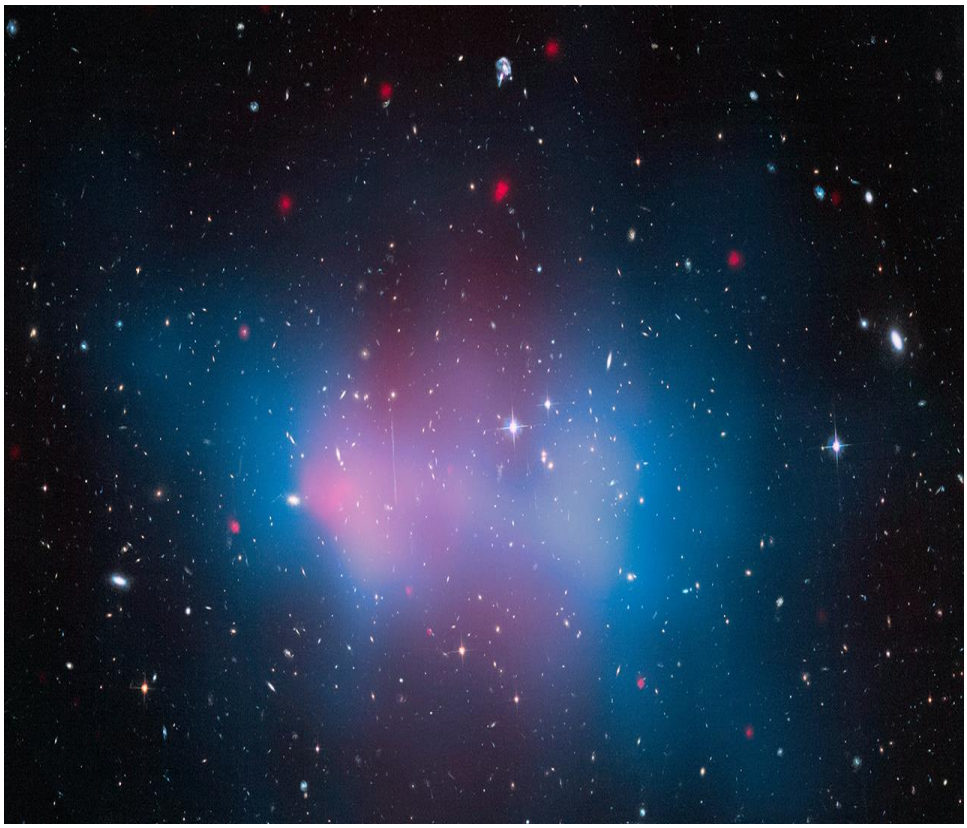
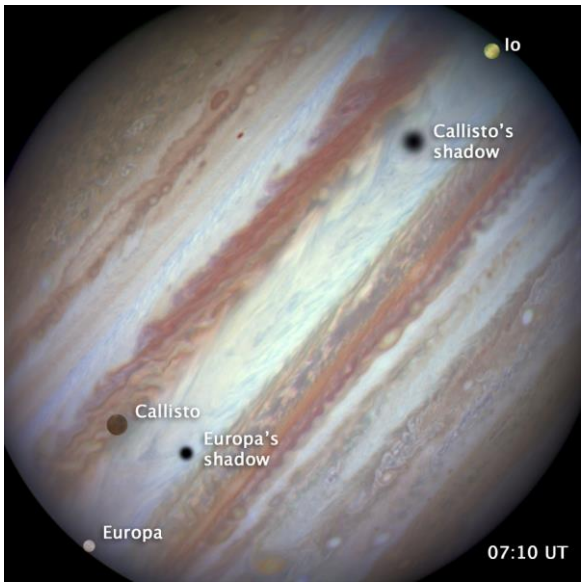


Image credit: NASA, ESA, J. Jee (UC Davis), J. Hughes (Rutgers U.), F. Menanteau (Rutgers U. and UI-UC), C. Sifon (Leiden Observatory), R. Mandelbum (Carnegie Mellon U.), L. Barrientos (Universidad Catolica de Chile), and K. Ng (UC Davis). X-rays are shown in pink from Chandra; the overall matter density is shown in blue, from lensing derived from the Hubble space telescope. 10 billion light-years distant, El Gordo is the most massive galaxy cluster ever found.



⬅Jupiter Triple-Moon Conjunction

Our solar system's ruling giant planet Jupiter and 3 of its 4 large Galilean moons are captured in this single Hubble snapshot from January 24. Crossing in front of Jupiter's banded cloud tops Europa, Callisto, and Io are framed from lower left to upper right in a rare triple-moon conjunction.

Credit: APOD