Liftoff

New Zealand's space exploration magazine

Issue 267
January-February 2012

The astronomy issue

Also inside:

- **Kepler finds more exoplanets**
- **Mars rover Opportunity starts new mission**

Liftoff

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Executive of the New Zealand Spaceflight Association.

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NZSA News and Notices

Auckland meetings

The next Auckland meetings are on **5 March** and **2 April** at 7:45 pm at MOTAT, Great North Road, Western Springs (entry via Stadium Rd).

The Auckland Branch meets at MOTAT on the first Monday of each month (except January).

Subscriptions 2011-2012

Subscription rates for 1 September 2011 to 31 August 2012 are as follows:

ORDINARY	$45
SENIOR CITIZEN	$40
STUDENT	$37.50

New subscriptions paid after 1 February 2012 may elect to receive *Liftoff* for only the second half year by paying half the above rates.

Note, too, that for each new member you introduce to the NZSA, providing they join for a full year and nominate you on their membership form, you will receive a credit of $5 against your next subscription. There is no limit to the number of credits you can qualify for.

Cover Photo: *This new image shows the Large Magellanic Cloud galaxy in infrared light as seen by the Herschel Space Observatory, a European Space Agency-led mission with important NASA contributions, and NASA's Spitzer Space Telescope. In the instruments' combined data, this nearby dwarf galaxy looks like a fiery, circular explosion. Rather than fire, however, those ribbons are actually giant ripples of dust spanning tens or hundreds of light-years. Significant fields of star formation are noticeable in the center, just left of center and at right. The brightest centre-left region is called 30 Doradus, or the Tarantula Nebula, for its appearance in visible light. The colours in this image indicate temperatures in the dust that permeates the Cloud. Colder regions show where star formation is at its earliest stages or is shut off, while warm expanses point to new stars heating surrounding dust. The coolest areas and objects appear in red, corresponding to infrared light taken up by Herschel's Spectral and Photometric Imaging Receiver at 250 microns, or millionths of a meter. Herschel's Photodetector Array Camera and Spectrometer fills out the mid-temperature bands, shown here in green, at 100 and 160 microns. The warmest spots appear in blue, courtesy of 24- and 70-micron data from Spitzer. (NASA/ESA)*

C O N T E N T S

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Editor's Corner

This month's issue is an all (or nearly all) astronomy issue – space-based astronomy, that is. The main feature is a collection of reports from the January 2012 American Astronomical Society meeting, a prestigious scientific shindig that brings together astronomers from all over the world to present their latest findings. The reports here are on findings from various space-based satellite observatories, including, of course, the flagship of them all, the Hubble Space Telescope.

The other main feature focuses on recent discoveries of exoplanets – planets beyond our own solar system – by NASA's Kepler space observatory. These discoveries include Earth-sized planets (though, it must be noted, not Earth-like, which is still the Holy Grail for planet-hunters).

The long-lived Opportunity Mars rover has now begun its ninth year on the red planet, a remarkable achievement for a craft that was only designed for a three-month life. In August it will hopefully be joined by the much larger and more capable Curiosity rover, now well on its way to Mars.

Unfortunately, the future is less rosy for future US Mars missions beyond Curiosity and the MAVEN orbiter scheduled for a 2013 launch. The Obama administration has gutted NASA's planetary exploration programme in the latest US budget, an effective cut of about 20 percent (though the overall NASA budget is only slightly lower than last year's). The chief culprit in this is the massive cost overruns for the Webb Space Telescope, which is now set to cost around US$8 billion. NASA's participation with ESA on several Mars orbiters and landers later this decade is now off, and ESA is consequently looking to the Russians to fill the gap. Let's hope Russia's abysmal record of Mars failures (the latest being Phobos-Grunt last year) does not continue with this new mission!

-- David Maclennan

ESA's new Vega launcher scores success on maiden flight

On 13 February 2012, the first Vega lifted off on its maiden flight from Europe's Spaceport in French Guiana. (ESA - S. Corvaja, 2012)

Vega, ESA's new launch vehicle, is ready to operate alongside the Ariane 5 and Soyuz launchers after a successful qualification flight this morning from Europe's Spaceport in Kourou, French Guiana. The first Vega lifted off at 10:00 GMT (11:00 CET, 07:00 local time) on 3 February 2012 from the new launch pad, and conducted a flawless qualification flight.

With Vega extending the family of launchers available at the spaceport, Europe now covers the full range of launch needs, from small science and Earth observation satellites to the largest missions like ESA's supply freighters to the International Space Station. Vega's light launch capacity accommodates a wide range of satellites – from 300 kg to 2,500 kg – into a wide variety of orbits, from equatorial to Sun-synchronous. Its reference mission is 1500 kg into a 700 km-high circular Sun-synchronous orbit. Vega will thus add to Europe's set of launch services next to the Ariane 5 heavy-lifter and the Soyuz medium-class launcher already in service. The combination of these three systems operating from French Guiana will also improve the efficiency of Europe's launch infrastructure by sharing its operating costs over a larger number of launches.

"In a little more than three months, Europe has increased the number of launchers it operates from one to three, widening significantly the range of launch services offered by the European operator Arianespace. There is not anymore one single European satellite which cannot be launched by a European launcher service," said Jean-Jacques Dordain, Director General of ESA. "It is a great day for ESA, its Member States, in particularly Italy where Vega was born, for European industry and for Arianespace."

Vega launcher development started in 2003. Seven Member States contributed to the programme: Belgium, France, Italy, the Netherlands, Spain, Sweden and Switzerland.

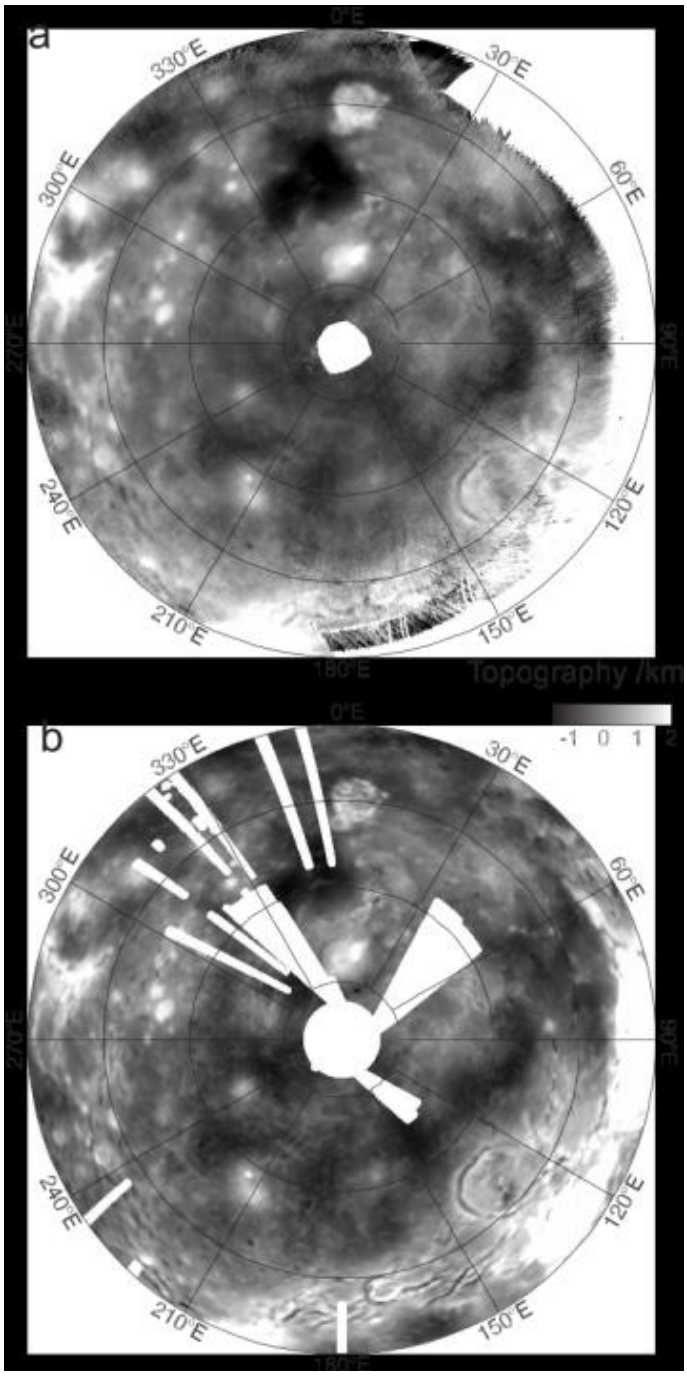
"Today is a moment of pride for Europe as well as those around 1000 individuals who have been involved in developing the world's most modern and competitive launcher system for small satellites," said Antonio Fabrizi, ESA's Director of Launchers. "ESA, with the technical support of the Italian and French space agencies, and about 40 industrial companies coordinated by the prime contractor ELV SpA, have made this enormous challenge a reality in under a decade of development."

Could Venus be shifting gear?

ESA's Venus Express spacecraft has discovered that our cloud-covered neighbour spins a little slower than previously measured. Peering through the dense atmosphere in the infrared, the orbiter found surface features were not quite where they should be.

Using the VIRTIS instrument at infrared wavelengths to penetrate the thick cloud cover, scientists studied surface features and discovered that some were displaced by up to 20 km from where they should be given the accepted rotation rate as measured by NASA's Magellan orbiter in the early 1990s. These detailed measurements from orbit are helping scientists determine whether Venus has a solid or liquid core, which will help our understanding of the planet's creation and how it evolved.

If Venus has a solid core, its mass must be more concentrated towards the centre. In this case, the planet's rotation would react less to external forces. The most important of those forces is due to the dense atmosphere – more than 90 times the pressure of Earth's and high-speed weather systems,



Topographic maps from Magellan and Venus Express clearly show the shift in surface features. At infrared wavelengths Venus Express was able to peer through the dense atmosphere and map surface features observed from both Earth-based radar imaging and with the Russian Venera 15 and 16 missions as well as NASA's Magellan spacecraft. By comparing the currently accepted rotation rate value for the planet from the Magellan mission, scientists discovered a 'shift' in surface features of up to 20 km caused by what they believe is a change in the rotation rate of the planet. (NASA/JPL/Magellan/P. Ford/ESA/Venus Express/P. Drossart/G. Piccioni)

which are believed to change the planet's rotation rate through friction with the surface.

Earth experiences a similar effect, where it is largely caused by wind and tides. The length of an Earth day can change by roughly a millisecond and depends seasonally with wind patterns and temperatures over the course of a year.

In the 1980s and 1990s, the Venera and Magellan orbiters made radar maps of the surface of Venus, long shrouded in mystery as well as a dense, crushing and poisonous atmosphere. These maps gave us our first detailed global view of this unique and hostile world. Over its four-year mission, Magellan was able to watch features rotate under the spacecraft, allowing scientists to determine the length of the day on Venus as being equal to 243.0185 Earth days. However, surface features seen by Venus Express some 16 years later could only be lined up with those observed by Magellan if the length of the Venus day is on average 6.5 minutes longer than Magellan measured. This also agrees with the most recent long-duration radar measurements from Earth.

"When the two maps did not align, I first thought there was a mistake in my calculations as Magellan measured the value very accurately, but we have checked every possible error we could think of," said Nils Müller, a planetary scientist at the DLR German Aerospace Centre, lead author of a research paper investigating the rotation.

Scientists, including Özgur Karatekin of the Royal Observatory of Belgium, looked at the possibility of short-term random variations in the length of a Venus day, but concluded these should average themselves out over longer timescales.

On the other hand, other recent atmospheric models have shown that the planet could have weather cycles stretching over decades, which could lead to equally long-term changes in the rotation period. Other effects could also be at work, including exchanges of angular momentum between Venus and the Earth when the two planets are relatively close to each other. "An accurate value for Venus' rotation rate will help in planning future missions, because precise information will be needed to select potential landing sites," noted Håkan Svedhem, ESA's Venus Express project scientist.

While further study is needed, it's clear that Venus Express is penetrating far deeper into the mysteries of this enigmatic planet then anyone dreamed.

NASA receives second highest number of astronaut applications

Despite the fact that flight opportunities will be few and far between in the foreseeable future, more than 6,300 individuals applied to become a NASA astronaut between 5 November 2011 and 27 January 2012, the second highest number of applications ever received by the agency. After a thorough selection process, which includes interviews and medical examinations, nine to 15 people will be selected to become part of the 21st astronaut class.

The Astronaut Selection Office staff will review the applications to identify those meeting the minimum requirements. Next, an expanded team, comprised mostly of active astronauts, will review those applications to determine which ones are highly qualified. Those individuals will be invited to Johnson Space Center for in-person interviews and medical evaluations.

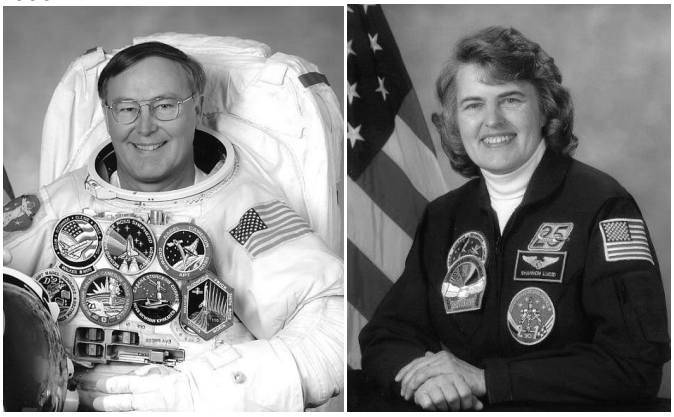
"We will be looking for people who really stand out," said Peggy Whitson, chief of the Astronaut Office at NASA's Johnson Space Center and chair of the Astronaut Selection Board. "Our team not only will be looking at their academic background and professional accomplishments but also at other elements of their personality and character traits -- what types of hobbies they have or unique life experiences. We want and need a mix of individuals and skills for this next phase of human exploration."

NASA expects to announce a final selection of astronaut candidates in the spring of 2013.

Veteran astronauts Lucid and Ross retire

The exodus of experienced NASA astronauts following the end of the Shuttle programme continues. The latest to announce their retirement from NASA are Shannon Lucid and Jerry Ross.

Lucid, who holds a doctorate in biochemistry, was selected by NASA in 1978. She joined five other women as the agency's first female astronauts. A veteran of five spaceflights, Lucid logged more than 223 days in space, and from August 1991 to June 2007, held the record for the most days in orbit by any woman in the world. Lucid is the only American woman to serve aboard the Russian Mir space station. She lived and worked there for more than 188 days, the longest stay of any American on that vehicle. Her time on Mir also set the single flight endurance record by a woman until Suni Williams broke it in 2006.



Astronauts Jerry Ross (left) and Shannon Lucid (NASA)

Ross joined NASA in 1979 as a payload officer and flight controller. In 1980, he was selected as an astronaut. He and Franklin Chang-Diaz are the only two astronauts to have flown into space seven times. In addition to Ross' spaceflight mission accomplishments, he went on to serve NASA in the critical role of managing the Vehicle Integration Test Office. Ross spent almost 1,400 hours in space and conducted nine spacewalks to rank third on the list of most extravehicular activity time in space.

Astronaut Janice Voss dies

NASA astronaut Janice Voss passed away from cancer on 7 February 2012 after a courageous battle. One of only six women who have flown in space five times, Voss' career was highlighted by her work and dedication to scientific payloads and exploration.

"As the payload commander of two space shuttle missions, Janice was responsible for paving the way for experiments that we now perform on a daily basis on the International Space Station," said Peggy Whitson, chief of the Astronaut Office. "By improving the way scientists are able to analyze their data, and establishing the experimental methods and hardware necessary to perform these unique experiments, Janice and her crew ensured that our space station would be the site of discoveries that we haven't even imagined.

"During the last few years, Janice continued to lead our office's efforts to provide the best possible procedures to crews operating experiments on the station today," Whitson added. "Even more than Janice's professional contributions, we will miss her positive outlook on the world and her determination to make all things better."

Voss (shown at left) began her career with NASA in 1973 while a student at Purdue University. She returned to NASA in 1977 to work as an instructor, teaching entry guidance and navigation to space shuttle crews. After completing her doctorate in 1987, she worked within the aerospace industry until she was selected as an astronaut in 1990.

Voss' first spaceflight mission was STS-57 in 1993, the first flight of the Spacehab module. She next flew on STS-63 in 1995, a mission to the Mir space station, and third flight of Spacehab. She also flew as a payload commander on STS-83 in 1997 with the Microgravity Science Laboratory, but the mission was cut short due to problems with one of the orbiter's three fuel power generation units. Voss, the crew and MSL flew again as the STS-94 MSL-1 Spacelab mission, focused on materials and combustion science research in microgravity.

Her last mission was STS-99 in 2000, a flight to the International Space Station as part of the Shuttle Radar Topography Mission which mapped more than 47 million square miles of the Earth's land surface. In total, Voss spent more than 49 days in space.

From 2004 to 2007, Voss served as the science director for the Kepler spacecraft at NASA's Ames Research Center. Voss most recently served as the payloads lead of the Astronaut Office's Station Branch.

Physicist and former astronaut John Grunsfeld heads NASA science directorate

Physicist and former astronaut John Grunsfeld is the new associate administrator for the Science Mission Directorate at the agency's headquarters in Washington. He succeeds Ed Weiler, who retired from NASA on 30 September 2011.

Grunsfeld's previous position was as deputy director of the Space Telescope Science Institute in Baltimore, which manages the science program for the Hubble Space Telescope and is a partner in the forthcoming James Webb Space Telescope. His background includes research in high energy astrophysics, cosmic ray physics and in the emerging field of exoplanet studies with specific interest in future astronomical instrumentation. A veteran of five space shuttle flights, Grunsfeld visited Hubble three times as an astronaut, performing a total of eight spacewalks to service and upgrade the observatory.

"John's understanding of the critical connection between scientific research and the human exploration of space makes him an ideal choice for this job," NASA Administrator Charles Bolden said announcing the appointment. "I look forward to working with him to take the agency's science programs to even greater heights and make more of the ground-breaking discoveries about Earth and our universe for which NASA is known."

Grunsfeld graduated from the Massachusetts Institute of Technology in 1980 with a bachelor's degree in physics. Returning to his native Chicago, he earned a master's degree and, in 1988, a doctorate in physics from the University of Chicago using a cosmic ray experiment on space shuttle Challenger for his doctoral thesis. From Chicago, he

John Grunsfeld is pictured during the STS-125 mission in 2009, the final servicing call to the Hubble Space Telescope (NASA)

joined the faculty of the California Institute of Technology as a Senior Research Fellow in Physics, Mathematics and Astronomy.

Grunsfeld joined NASA's Astronaut Office in 1992. He logged over 58 days in space on five shuttle missions, including 58 hours and 30 minutes of spacewalk time. He first flew to space aboard *Endeavour* in March 1995 on a mission that studied the far ultraviolet spectra of faint astronomical objects using the Astro Observatory. His second flight was aboard *Atlantis* in January 1997. The mission docked with the Russian space station Mir and exchanged U.S. astronauts living aboard the outpost. Grunsfeld then flew three shuttle missions - aboard *Discovery* in December 1999, *Columbia* in March 2002 and *Atlantis* in May 2009 -- that successfully serviced and upgraded the Hubble Space Telescope. He served as the payload commander on the 2002 mission and lead spacewalker in charge of Hubble activities on the 2009 flight. In 2004 and 2005, he served as the commander and science officer on the backup crew for Expedition 13 to the International Space Station.

Vesta likely cold and dark enough for ice

Though generally thought to be quite dry, roughly half of the giant asteroid Vesta is expected to be so cold and to receive so little sunlight that water ice could have survived there for billions of years, according to the first published models of Vesta's average global temperatures and illumination by the Sun.

"Near the north and south poles, the conditions appear to be favorable for water ice to exist beneath the surface," says Timothy Stubbs of NASA's Goddard Space Flight Center in Greenbelt, Md., and the University of Maryland, Baltimore County. Stubbs and Yongli Wang of the Goddard Planetary Heliophysics Institute at the University of Maryland published the models in the January 2012 issue of the journal *Icarus*. The models are based on information from telescopes including NASA's Hubble Space Telescope.

Vesta, the second-most massive object in the asteroid belt between Mars and Jupiter, probably does not have any significant permanently shadowed craters where water ice could stay frozen on the surface all the time, not even in the roughly 480-kilometre-diameter crater near the south pole, the authors note. The asteroid isn't a good candidate for permanent shadowing because it is tilted on its axis at about 27 degrees, which is even greater than Earth's tilt of roughly 23 degrees. In contrast, the Moon, which does have permanently shadowed craters, is tilted at only about 1.5 degrees. As a result of its large tilt, Vesta has seasons, and every part of the surface is expected to see the sun at some point during Vesta's year.

The presence or absence of water ice on Vesta tells scientists something about the tiny world's formation and evolution, its history of bombardment by comets and other objects, and its interaction with the space environment. Because similar processes are common to many other planetary bodies, including the Moon, Mercury and other asteroids, learning more about these processes has fundamental implications for our understanding of the solar system as a whole. This kind of water ice is also potentially valuable as a resource for further exploration of the solar system.

Though temperatures on Vesta fluctuate during the year, the model predicts that the average annual temperature near Vesta's north and south poles is less than roughly minus 200 degrees Fahrenheit (145 Kelvins). That is the critical average temperature below which water ice is thought to be able to survive in the top few metres or so of the soil, which is called regolith. Near Vesta's equator, however, the average yearly temperature is roughly minus 190 degrees Fahrenheit (150 Kelvins), according to the new results. Based on previous modeling, that is expected to be high enough to prevent water from remaining within a few meters of the surface. This band of relatively warm temperatures extends from the equator to about 27 degrees north and south in latitude.

"On average, it's colder at Vesta's poles than near its equator, so in that sense, they are good places to sustain water ice," says Stubbs. "But they also see sunlight for long periods of time during the summer seasons, which isn't so good for sustaining ice. So if water ice exists in those regions, it may be buried beneath a relatively deep layer of dry regolith."

The modeling also indicates that relatively small surface features, such as craters measuring around 10 kilometres in diameter, could significantly affect the survival of water ice. "The bottoms of some craters could be cold enough on average -- about 100 Kelvins -- for water to be able to survive on the surface for much of the Vestan year [about 3.6 years on Earth]," Stubbs explains. "Although, at some point during the summer, enough sunlight would shine in to make the water leave the surface and either be lost or perhaps redeposit somewhere else."

So far, Earth-based observations suggest that the surface of Vesta is quite dry. However, the Dawn spacecraft is getting a much closer view. Dawn is investigating the role of water in the evolution of planets by studying Vesta and Ceres, two bodies in the asteroid belt that are considered remnant protoplanets - baby planets whose growth was interrupted when Jupiter formed. Dawn is looking for water using the gamma ray and neutron detector (GRaND) spectrometer, which can identify hydrogen-rich deposits that could be associated with water ice. The spacecraft recently entered a low orbit that is well suited to collecting gamma ray and neutron data.

"Our perceptions of Vesta have been transformed in a few months as the Dawn spacecraft has entered orbit and spiraled closer to its surface," says Lucy McFadden, a planetary scientist at NASA Goddard and a Dawn mission co-investigator. "More importantly, our new views of Vesta tell us about the early processes of solar system formation. If we can detect evidence for water beneath the surface, the next question will be is it very old or very young, and that would be exciting to ponder."

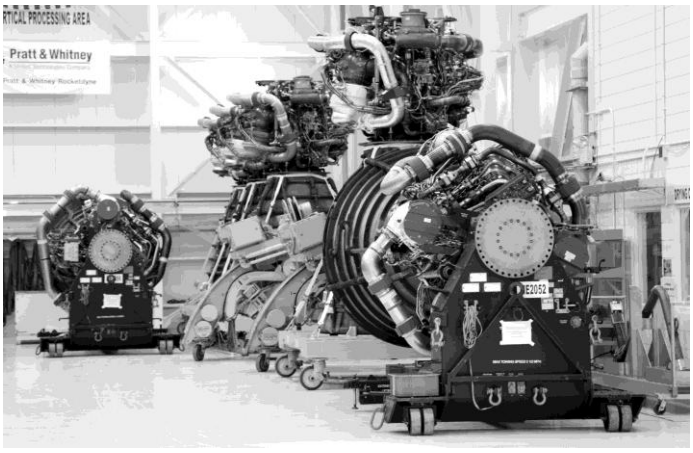
The modeling done by Stubbs and Wang, for example, relies on information about Vesta's shape. Before Dawn, the best source of that information was a set of images taken by NASA's

Hubble Space Telescope in 1994 and 1996. But now, Dawn and its camera are getting a much closer view of Vesta. "The Dawn mission gives researchers a rare opportunity to observe Vesta for an extended period of time, the equivalent of about one season on Vesta," says Stubbs. "Hopefully, we'll know in the next few months whether the GRaND spectrometer sees evidence for water ice in Vesta's regolith. This is an important and exciting time in planetary exploration."

NASA moves shuttle engines from Kennedy to Stennis

The relocation of the RS-25D space shuttle main engine inventory from Kennedy Space Center's Engine Shop in Cape Canaveral, Fla., is underway. The RS-25D flight engines, repurposed for NASA's Space Launch System, are being moved to NASA's Stennis Space Center in south Mississippi.

The Space Launch System (SLS) is a new heavy-lift launch vehicle that will expand human presence beyond low-Earth orbit and enable new missions of exploration across the solar system. The Marshall Space Flight Center in Huntsville, Ala., is leading the design and development of the SLS for NASA, including the engine testing program. SLS will carry the Orion spacecraft, its crew, cargo, equipment and science experiments to destinations in deep space.



RS-25D engines line the wall of the Engine Processing Facility at Kennedy Space Center, Fla. The 15 engines used during the Space Shuttle Program are being transfered to Stennis Space Center, Miss., where they will be stored for future use on NASA's new heavy-lift rocket, the Space Launch System, which will carry NASA's new Orion spacecraft, cargo, equipment and science experiments beyond low-Earth orbit. (NASA/KSC)

"The relocation of RS-25D engine assets represents a significant cost savings to the SLS Program by consolidating SLS engine assembly and test operations at a single facility," said William Gerstenmaier, NASA's Associate Administrator for Human Exploration and Operations Mission Directorate. The RS-25Ds -- to be used for the SLS core stage -- will be stored at Stennis until testing begins at a future date. Testing is already under way on the J-2X engine, which is planned for use in the SLS upper stage. Using the same fuel system -- liquid hydrogen and liquid oxygen -- for both core and upper stages reduces costs by leveraging the existing knowledge base, skills, infrastructure and personnel.

"This enables the sharing of personnel, resources and practices across all engine projects, allows flexibility and responsiveness to the SLS program, and it is more affordable," said Johnny Heflin, RS-25D core stage engine lead in the SLS Liquid Engines Office at Marshall. "It also frees up the space, allowing Kennedy to move forward relative to commercial customers."

The 15 RS-25D engines at Kennedy are being transported on the 1,126-kilometre journey using existing transportation and processing procedures that were used to move engines between Kennedy and Stennis during the Space Shuttle Program. They will be relocated one at time by truck. Built by Pratt & Whitney Rocketdyne of Canoga Park, Calif. the RS-25D engine powered NASA's space shuttle program with 100 percent mission success.

Cassini sees the two faces of Titan's dunes

A new analysis of radar data from the Cassini mission has revealed regional variations among sand dunes on Saturn's moon Titan, giving new clues about the moon's climatic and geological history.

Dune fields are the second most dominant landform on Titan, after the seemingly uniform plains, so they offer a large-scale insight into the moon's peculiar environment. The dunes cover about 13% of the surface, stretching over an area of 10 million square kilometres. For Earthly comparison, that's about the surface area of the United States.

Though similar in shape to the linear dunes found on Earth in Namibia or the Arabian Peninsula, Titan's dunes are gigantic by our standards. They are on average 1 to 2 kilometres wide, hundreds of kilometres long and around 100 metres high. However, their size and spacing vary across the surface, betraying the environment in which they have formed and evolved.

Using radar data from the Cassini spacecraft, Alice Le Gall, a former postdoctoral fellow at the Jet Propulsion Laboratory, Pasadena, Calif., who is currently at the French research laboratory LATMOS, Paris, and collaborators have discovered that the size of Titan's dunes is controlled by at least two factors: altitude and latitude.

In terms of altitude, the more elevated dunes tend to be thinner and more widely separated. The gaps between the dunes seem to appear to Cassini's radar, indicating a thinner covering of sand. This suggests that the sand needed to build the dunes is mostly found in the lowlands of Titan. Scientists think the sand on Titan is not made of silicates as on Earth, but of solid hydrocarbons, precipitated out of the atmosphere. These have then aggregated into grains about a millimetre in size by a still unknown process.

In terms of latitude, the sand dunes on Titan are confined to its equatorial region, in a band between 30 degrees south latitude and 30 degrees north latitude. However, the dunes tend to be less voluminous toward the north. Le Gall and colleagues think that this may be due to Saturn's elliptical orbit.

Titan is in orbit around Saturn, and so the moon's seasons are controlled by Saturn's path around the sun. Because Saturn takes about 30 years to complete an orbit, each season on Titan lasts for about seven years. The slightly elliptical nature of Saturn's orbit means that the southern hemisphere of Titan has shorter but more intense summers. So the southern regions are probably drier, which implies they have less ground moisture. The drier the sand grains, the more easily they can be transported by the winds to make dunes. "As one goes to the north, we believe the soil moisture probably increases, making the sand particles less mobile and, as a consequence, the development of dunes more difficult." says Le Gall.

Backing this hypothesis is the fact that Titan's lakes and seas are not distributed symmetrically by latitude. These reserves of liquid ethane and methane are predominantly found in the northern hemisphere, suggesting again that the soil is moister toward the north and so, again, the sand grains are less easy to transport by the wind.

"Understanding how the dunes form as well as explaining their shape, size and distribution on Titan's surface is of great importance to understanding Titan's climate and geology because the dunes are a significant atmosphere-surface exchange interface", says Nicolas Altobelli, ESA's Cassini-Huygens project scientist. "In particular, as their material is made out of frozen atmospheric hydrocarbon, the dunes might provide us with important clues on the still puzzling methane/ethane cycle on Titan, comparable in many aspects with the water cycle on Earth."

Chandra finds Milky Way's black hole grazing on asteroids

The giant black hole at the center of the Milky Way may be vapourizing and devouring asteroids, which could explain the frequent flares observed, according to astronomers using data from NASA's Chandra X-ray Observatory.

For several years Chandra has detected X-ray flares about once a day from the supermassive black hole known as Sagittarius A*, or "Sgr A*" for short. The flares last a few hours with brightness ranging from a few times to nearly one hundred times that of the black hole's regular output. The flares also have been seen in infrared data from ESO's Very Large Telescope in Chile.

"People have had doubts about whether asteroids could form at all in the harsh environment near a supermassive black hole," said Kastytis Zubovas of the University of Leicester in the United Kingdom, and lead author of the report appearing in the *Monthly Notices of the Royal Astronomical Society*. "It's exciting because our study suggests that a huge number of them are needed to produce these flares."

Zubovas and his colleagues suggest there is a cloud around Sgr A* containing trillions of asteroids and comets, stripped from their parent stars. Asteroids passing within about 160.9 million kilometres of the black hole, roughly the distance between the Earth and the Sun, would be torn into pieces by the tidal forces from the black hole. These fragments then would be vapourized by friction as they pass through the hot, thin gas flowing onto Sgr A*, similar to a meteor heating up and glowing as it falls through Earth's atmosphere. A flare is produced and the remains of the asteroid are swallowed eventually by the black hole.

"An asteroid's orbit can change if it ventures too close to a star or planet near Sgr A*," said co-author Sergei Nayakshin, also of the University of Leicester. "If it's thrown toward the black hole, it's doomed."

The authors estimate that it would take asteroids larger than about six miles in radius to generate the flares observed by Chandra. Meanwhile, Sgr A* also may be consuming smaller asteroids, but these would be difficult to spot because the flares they generate would be fainter. These results reasonably agree with models estimating of how many asteroids are likely to be in this region, assuming that the number around stars near Earth is similar to the number surrounding stars near the center of the Milky Way.

"As a reality check, we worked out that a few trillion asteroids should have been removed by the black hole over the 10-billion-year lifetime of the galaxy," said co-author Sera Markoff of the University of Amsterdam in the Netherlands. "Only a small fraction of the total would have been consumed, so the supply of asteroids would hardly be depleted."

Planets thrown into orbits too close to Sgr A* also should be disrupted by tidal forces, although this would happen much less frequently than the disruption of asteroids, because planets are not as common. Such a scenario may have been responsible for a previous X-ray brightening of Sgr A* by about a factor of a million about a century ago. While this event happened many decades before X-ray telescopes existed, Chandra and other X-ray missions have seen evidence of an X-ray "light echo" reflecting off nearby clouds, providing a measure of the brightness and timing of the flare. "This would be a sudden end to the planet's life, a much more dramatic fate than the planets in our solar system ever will experience," Zubovas said.

Very long observations of Sgr A* will be made with Chandra later in 2012 that will give valuable new information about the frequency and brightness of flares and should help to test the model proposed here to explain them. This work could improve understanding about the formation of asteroids and planets in the harsh environment of Sgr A*.

A new study provides a possible explanation of mysterious X-ray flares detected by the Chandra X-ray Observatory for several years in the region of Sagittarius A, or Sgr A*. The study suggests a cloud around Sgr A*, a supermassive black hole at the center of our Milky Way Galaxy, which contains hundreds of trillions of asteroids and comets that have been stripped from their parent stars. The flares occur when asteroids of six miles or larger in radius are consumed by the black hole. An asteroid that undergoes a close encounter with another object, such as a star or planet, can be thrown into an orbit headed towards Sgr A*. If the asteroid passes within about 100 million miles of the black hole, roughly the distance between the Earth and the Sun, it is torn into pieces by the tidal forces from the black hole. These fragments would then be vapourized by friction as they pass through the hot, thin gas flowing onto Sgr A*, similar to a meteor heating up and glowing as it falls through Earth's atmosphere. A flare is produced and eventually the remains of the asteroid are swallowed by the black hole. (NASA/CXC/M.Weiss)*

Reports from the 219th meeting of the American Astronomical Society

More than 2,700 astronomers from around the globe descended on Austin, Texas, from 8-12 January 2012 for the 219th meeting of the American Astronomical Society (AAS). We present below some of the findings reported at this gathering, covering some of the biggest mysteries in modern astronomy, including alien worlds, ancient galaxies and more.

The Milky Way contains at least 100 billion planets according to survey

Our Milky Way galaxy contains a minimum of 100 billion planets according to a detailed statistical study based on the detection of three extrasolar planets by an observational technique called microlensing.

Kailash Sahu, of the Space Telescope Science Institute in Baltimore, Md., is part of an international team reporting at the AAS conference in January that our galaxy contains a minimum of one planet for every star on average. This means that there is likely to be a minimum of 1,500 planets within just 50 light-years of Earth.

The results are based on observations taken over six years by the PLANET (Probing Lensing Anomalies NETwork) collaboration, which Sahu co-founded in 1995. The study concludes that there are far more Earth-sized planets than bloated Jupiter-sized worlds. This is based on calibrating a planetary mass function that shows the number of planets increases for lower mass worlds. A rough estimate from this survey would point to the existence of more than 10 billion terrestrial planets across our galaxy. The results are being published in the 12 January issue of the British science journal *Nature*.

The team's conclusions are gleaned from a planet search technique called microlensing. The technique takes advantage of the random motions of stars, which are generally too small to be noticed. If one star passes precisely in front of another star, the gravity of the foreground star bends the light from the background star. This means that the foreground star acts like a giant lens amplifying the light from the background star. A planetary companion around the foreground star can produce additional brightening of the background star. This additional brightening reveals the planet, which is otherwise too faint to be seen by telescopes.

The higher the mass of the "lensing" star, the longer is the duration of the microlensing event. Typical microlensing events due to a star last about a month. But the extra brightening due to a planet typically lasts a few hours to a couple of days. Using the microlensing technique, astronomers can determine a planet's mass. This method, however, does not reveal any clues about the world's composition.

Unlike other prominent planet-detection techniques, which measure the shadows of planets passing in front of their stars (transit) or measure the wobble of a star due to the gravitational tug of a planet (radial velocity and astrometry), the gravitational-lensing technique is unbiased in the selection of the host star. The other techniques work best for finding planets close to their stars with short orbital periods. But microlensing can detect a planet that is as far from its star as Saturn is from our Sun, or as close as Mercury is to our Sun. The technique is also sensitive to detecting planets as small as Mercury.

Wide-field survey campaigns such as OGLE (Optical Gravitational Lensing Experiment) and MOA (Microlensing Observations in Astrophysics) cover millions of stars every clear night in order to identify and alert stellar microlensing events as early as possible. Follow-up collaborations, such as PLANET, monitor selected candidates more frequently, 24 hours a day, using a round-the-world network of telescopes.

Of the approximately 40 microlensing events closely monitored, three showed evidence for exoplanets. Using a statistical analysis, the team found that one in six stars hosts a Jupiter-mass planet. What's more, half of the stars have Neptune-mass planets, and two-thirds of the stars have Earth-mass planets. Therefore, low-mass planets are more abundant than their massive counterparts. "This means, statistically, every star in the galaxy should have at least one planet, and probably more," said Sahu.

"Results from the three main techniques of planet detection are rapidly converging to a common result. Not only are planets common in the galaxy, but there are more small planets than large ones," said Stephen Kane, a co-author from NASA's Exoplanet Science Institute at the California Institute of Technology, Pasadena, Calif. "This is encouraging news for investigations into habitable planets."

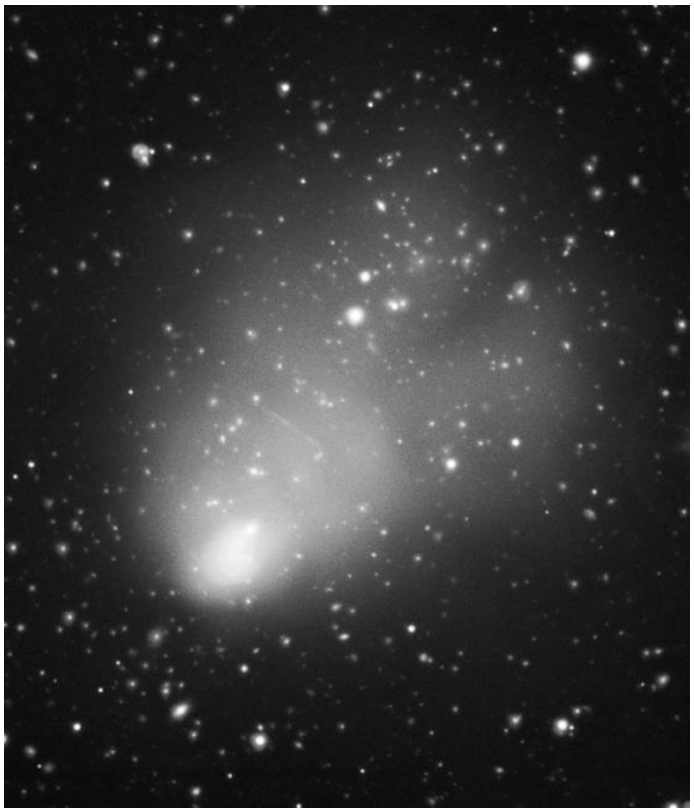
These results are independent from a gravitational-lens survey led by Takahiro Sumi of Osaka University in Japan, which estimates there are hundreds of billions of planets with orbits larger than Saturn's orbit, or are free-floating throughout the galaxy.

Chandra finds largest galaxy cluster in early universe

An exceptional galaxy cluster, the largest seen in the distant universe, has been found using NASA's Chandra X-ray Observatory and the National Science Foundation-funded Atacama Cosmology Telescope (ACT) in Chile. Officially known as ACT-CL J0102-4915, the galaxy cluster has been nicknamed "El Gordo" ("the big one" or "the fat one" in Spanish) by the researchers who discovered it. The name, in a nod to the Chilean connection, describes just one of the remarkable qualities of the cluster, which is located more than 7 billion light years from Earth. This large distance means it is being observed at a young age.

"This cluster is the most massive, the hottest, and gives off the most X-rays of any known cluster at this distance or beyond," said Felipe Menanteau of Rutgers University in New Brunswick, N.J., who led the study.

Galaxy clusters, the largest objects in the universe that are held together by gravity, form through the merger of smaller groups or sub-clusters of galaxies. Because the formation process depends on the amount of dark matter and dark energy in the universe, clusters can be used to study these mysterious phenomena. Dark matter is material that can be inferred to exist through its gravitational effects, but does not emit and absorb detectable amounts of light. Dark energy is a hypothetical form of energy that permeates all space and exerts a negative



A composite image shows El Gordo from NASA's Chandra X-ray Observatory, along with optical data from the European Southern Observatory's Very Large Telescope (VLT), and infrared emission from the NASA's Spitzer Space Telescope. (NASA/CXC)

pressure that causes the universe to expand at an ever-increasing rate.

"Gigantic galaxy clusters like this are just what we were aiming to find," said team member Jack Hughes, also of Rutgers. "We want to see if we can understand how these extreme objects form using the best models of cosmology that are currently available."

Although a cluster of El Gordo's size and distance is extremely rare, it is likely that its formation can be understood in terms of the standard Big Bang model of cosmology. In this model, the universe is composed predominantly of dark matter and dark energy, and began with Big Bang about 13.7 billion years ago.

The team of scientists found El Gordo using ACT thanks to the Sunyaev-Zeldovich effect. In this phenomenon, photons in the cosmic microwave background interact with electrons in the hot gas that pervades these enormous galaxy clusters. The photons acquire energy from this interaction, which distorts the signal from the microwave background in the direction of the clusters. The magnitude of this distortion depends on the density and temperature of the hot electrons and the physical size of the cluster.

X-ray data from Chandra and the European Southern Observatory's Very Large Telescope, an 8-meter optical observatory in Chile, show El Gordo is, in fact, the site of two galaxy clusters colliding at several million miles per hour. This and other characteristics make El Gordo akin to the well-known object called the Bullet Cluster, which is located almost 4 billion light years closer to Earth.

As with the Bullet Cluster, there is evidence that normal matter, mainly composed of hot, X-ray bright gas, has been wrenched apart from the dark matter in El Gordo. The hot gas in each cluster was slowed down by the collision, but the dark matter was not. "This is the first time we've found a system like the Bullet Cluster at such a large distance," said Cristobal Sifon of Pontificia Universidad de Catolica de Chile (PUC) in Santiago. "It's like the expression says: if you want to understand where you're going, you have to know where you've been."

Herschel and Spitzer see nearby galaxies' stardust

The cold dust that builds blazing stars is revealed in new images that combine observations from the Herschel Space Observatory, a European Space Agency-led mission with important NASA contributions; and NASA's Spitzer Space Telescope (see cover). The new images map the dust in the galaxies known as the Large and Small Magellanic Clouds, two of the closest neighbors to our own Milky Way galaxy.

The Large Magellanic Cloud looks like a fiery, circular explosion in the combined Herschel-Spitzer infrared data. Ribbons of dust ripple through the galaxy, with significant fields of star formation noticeable in the center, center-left and top right (the brightest center-left region is called 30 Doradus, or the Tarantula Nebula, for its appearance in visible light). The Small Magellanic Cloud has a much more irregular shape. A stream of dust extends to the left in this image, known as the galaxy's "wing," and a bar of star formation appears on the right.

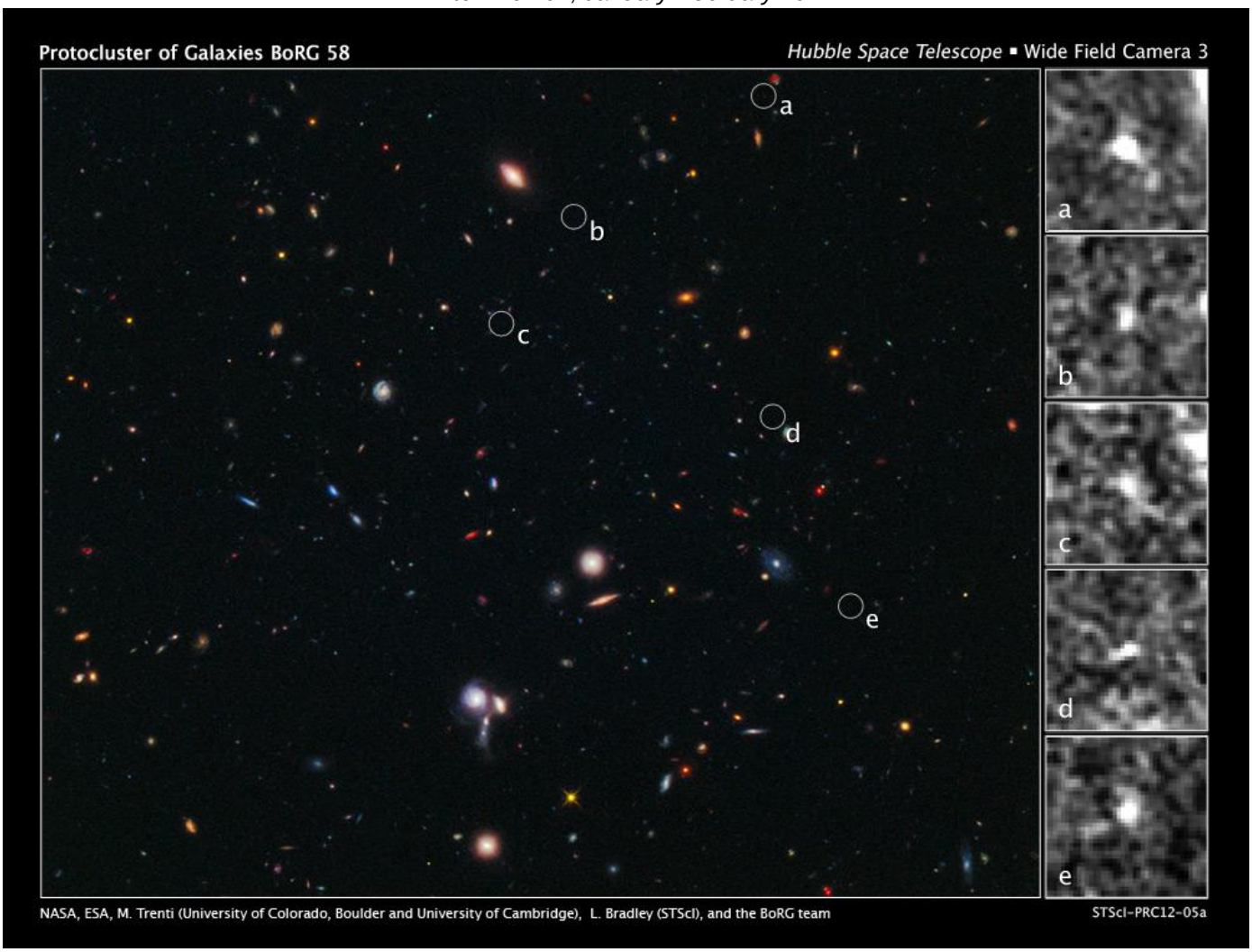
The colours in these images (see cover) indicate temperatures in the dust that permeate the Magellanic Clouds. Colder regions show where star formation is at its earliest stages or is shut off, while warm expanses point to new stars heating dust surrounding them. The coolest areas and objects appear in red, corresponding to infrared light taken up by Herschel's Spectral and Photometric Imaging Receiver at 250 microns, or millionths of a meter. Herschel's Photodetector Array Camera and Spectrometer fills out the mid-temperature bands, shown in green, at 100 and 160 microns. The warmest spots appear in blue, courtesy of 24- and 70-micron data from Spitzer.

"Studying these galaxies offers us the best opportunity to study star formation outside of the Milky Way," said Margaret Meixner, an astronomer at the Space Telescope Science Institute, Baltimore, Md., and principal investigator for the mapping project. "Star formation affects the evolution of galaxies, so we hope understanding the story of these stars will answer questions about galactic life cycles."

The Large and Small Magellanic Clouds are the two biggest satellite galaxies of our home galaxy, the Milky Way, though they are still considered dwarf galaxies compared to the big spiral of the Milky Way. Dwarf galaxies also contain fewer metals, or elements heavier than hydrogen and helium. Such an environment is thought to slow the growth of stars. Star formation in the universe peaked around 10 billion years ago, even though galaxies contained lesser abundances of metallic dust. Previously, astronomers only had a general sense of the rate of star formation in the Magellanic Clouds, but the new images enable them to study the process in more detail.

Hubble breaks new ground with distant supernova discovery

The Hubble Space Telescope has looked deep into the distant universe and detected the feeble glow of a star that exploded more than 9 billion years ago. The sighting is the first finding of an ambitious survey that will help astronomers place better



The composite image at left, taken in visible and near-infrared light, reveals the location of five tiny galaxies clustered together 13.1 billion light-years away. The circles pinpoint the galaxies. The sharp-eyed Wide Field Camera 3 aboard NASA's Hubble Space Telescope spied the galaxies in a random sky survey. The developing cluster is the most distant ever observed. The young galaxies lived just 600 million years after the universe's birth in the big bang. The average distance between them is comparable to that of the galaxies in the Local Group, consisting of two large spiral galaxies, the Milky Way and Andromeda, and a few dozen small dwarf galaxies. The close-up images at right, taken in near-infrared light, show the puny galaxies. The letters "a" through "e" correspond to the galaxies' location in the wide-field view at left. Simulations show that the galaxies will eventually merge and form the brightest central galaxy in the cluster, a giant elliptical similar to the Virgo cluster's M87. Galaxy clusters are the largest structures in the universe, comprising hundreds to thousands of galaxies bound together by gravity. The developing cluster presumably will grow into a massive galactic city, similar in size to the nearby Virgo cluster, a collection of more than 2,000 galaxies. (NASA, ESA, M. Trenti (University of Colorado, Boulder, and Institute of Astronomy, University of Cambridge, UK), L. Bradley (STScI), and the BoRG team)

constraints on the nature of dark energy, the mysterious repulsive force that is causing the universe to fly apart ever faster.

"For decades, astronomers have harnessed the power of Hubble to unravel the mysteries of the universe," said John Grunsfeld, associate administrator for NASA's Science Mission Directorate in Washington. "This new observation builds upon the revolutionary research using Hubble that won astronomers the 2011 Nobel Prize in Physics, while bringing us a step closer to understanding the nature of dark energy which drives the cosmic acceleration." As an astronaut, Grunsfeld visited Hubble three times, performing a total of eight spacewalks to service and upgrade the observatory.

The stellar explosion, nicknamed SN Primo, belongs to a special class called Type Ia supernovae, which are bright beacons used as distance markers for studying the expansion rate of the universe. Type Ia supernovae likely arise when white dwarf stars, the burned- out cores of normal stars, siphon too much material from their companion stars and explode. SN Primo is the farthest Type Ia supernova with its distance confirmed through spectroscopic observations. In these types of observations, a spectrum splits the light from a supernova into its constituent colours. By analyzing those colours, astronomers can confirm its distance by measuring how much the supernova's light has been stretched, or red-shifted, into near-infrared wavelengths because of the expansion of the universe.

The supernova was discovered as part of a three-year Hubble program to survey faraway Type Ia supernovae, opening a new distance realm for searching for this special class of stellar explosion. The remote supernovae will help astronomers determine whether the exploding stars remain dependable cosmic yardsticks across vast distances of space in an epoch when the cosmos was only one-third its current age of 13.7 billion years.

Called the CANDELS+CLASH Supernova Project, the census uses the sharpness and versatility of Hubble's Wide Field Camera 3 (WFC3) to assist astronomers in the search for supernovae in near- infrared light and verify their distance with

This image of supernova remnant 0509-67.5 was made by combining data from two of NASA's Great Observatories. Optical data of SNR 0509-67.5 and its accompanying star field, taken with the Hubble Space Telescope, are composited with X-ray images from the Chandra X-ray Observatory. The result shows soft green and blue hues of heated material from the X-ray data surrounded by the glowing pink optical shell, which shows the ambient gas being shocked by the expanding blast wave from the supernova. Ripples in the shell's appearance coincide with brighter areas of the X-ray data. The Type Ia supernova that resulted in the creation of SNR 0509-67.5 occurred nearly 400 years ago for Earth viewers. The supernova remnant lies in the Large Magellanic Cloud (LMC), a small galaxy about 170,000 light-years from Earth. The bubble-shaped shroud of gas is 23 light-years across and is expanding at more than 11 million miles per hour (5,000 kilometers per second). (NASA, ESA, CXC, SAO, the Hubble Heritage Team (STScI/AURA), and J. Hughes (Rutgers University)

spectroscopy. CANDELS is the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey and CLASH is the Cluster Lensing and Supernova Survey with Hubble. "In our search for supernovae, we had gone as far as we could go in optical light," said Adam Riess, the project's lead investigator, at the Space Telescope Science Institute and The Johns Hopkins University in Baltimore, Md. "But it's only the beginning of what we can do in infrared light. This discovery demonstrates that we can use the Wide Field Camera 3 to search for supernovae in the distant universe."

The supernova team's search technique involved taking multiple near-infrared images over several months, looking for a supernova's faint glow. After the team spotted the stellar blast in October 2010, they used WFC3's spectrometer to verify SN Primo's distance and to decode its light, finding the unique signature of a Type Ia supernova. The team then re-imaged SN Primo periodically for eight months, measuring the slow dimming of its light.

By taking the census, the astronomers hope to determine the frequency of Type Ia supernovae during the early universe and glean insights into the mechanisms that detonated them. "If we look into the early universe and measure a drop in the number of supernovae, then it could be that it takes a long time to make a Type Ia supernova," said team member Steve Rodney of The Johns Hopkins University. "Like corn kernels in a pan waiting for the oil to heat up, the stars haven't had enough time at that epoch to evolve to the point of explosion. However, if supernovae form very quickly, like microwave popcorn, then they will be immediately visible, and we'll find many of them, even when the universe was very young. Each supernova is unique, so it's possible that there are multiple ways to make a supernova."

If astronomers discover that Type Ia supernovae begin to depart from how they expect them to look, they might be able to gauge those changes and make the measurements of dark energy more precise. Riess and two other astronomers shared the 2011 Nobel Prize in Physics for discovering dark energy 13 years ago, using Type Ia supernova to plot the universe's expansion rate.

Hubble pinpoints farthest protocluster of galaxies ever seen

Using the Hubble Space Telescope, astronomers have uncovered a cluster of galaxies in the initial stages of development. It is the most distant such grouping ever observed in the early universe. In a random sky survey made in near-infrared light, Hubble found five tiny galaxies clustered together 13.1 billion light-years away. They are among the brightest galaxies at that epoch and very young — existing just 600 million years after the big bang (see picture, page 12).

Galaxy clusters are the largest structures in the universe, comprising hundreds to thousands of galaxies bound together by gravity. The developing cluster, or protocluster, is seen as it looked 13 billion years ago. Presumably, it has grown into one of today's massive "galactic cities," comparable to the nearby Virgo cluster of more than 2,000 galaxies. "These galaxies formed during the earliest stages of galaxy assembly, when galaxies had just started to cluster together," said Michele Trenti of the University of Colorado at Boulder and the Institute of Astronomy at the University of Cambridge in the United Kingdom. "The result confirms our theoretical understanding of the buildup of galaxy clusters. And, Hubble is just powerful enough to find the first examples of them at this distance."

Most galaxies in the universe reside in groups and clusters, and astronomers have probed many mature "galactic cities" in detail as far as 11 billion light-years away. Finding clusters in the early phases of construction has been challenging because they are rare, dim and widely scattered across the sky.

"We need to look in many different areas because the odds of finding something this rare are very small," said Trenti, who used Hubble's sharp-eyed Wide Field Camera 3 (WFC3) to pinpoint the cluster galaxies. "The search is hit and miss. Typically, a region has nothing, but if we hit the right spot, we can find multiple galaxies."

Hubble's observations demonstrate the progressive buildup of galaxies. They also provide further support for the hierarchical model of galaxy assembly, in which small objects accrete mass, or merge, to form bigger objects over a smooth and steady but dramatic process of collision.

Because the distant, fledgling clusters are so dim, the team hunted for the systems' brightest galaxies. These galaxies act as billboards, advertising cluster construction zones. From computer simulations, the astronomers expect galaxies at early epochs to be clustered together. Because brightness correlates with mass, the most luminous galaxies pinpoint the location of developing clusters. These powerful light beacons live in deep wells of dark matter, an invisible form of matter that makes up the underlying gravitational scaffolding for construction. The team expects many fainter galaxies that were not seen in these observations to inhabit the same neighborhood.

The five bright galaxies spotted by Hubble are about one-half to one-tenth the size of our Milky Way, yet are comparable in brightness. The galaxies are bright and massive because they are being fed large amounts of gas through mergers with other galaxies. The team's simulations show that the galaxies eventually will merge and form the brightest central galaxy in the cluster, a giant elliptical similar to the Virgo Cluster's M87.

These observations demonstrate the progressive buildup of galaxies. They also provide further support for the hierarchical model of galaxy assembly, in which small objects accrete mass, or merge, to form bigger objects over a smooth and steady but dramatic process of collision and collection. The observations are part of the Brightest of Reionizing Galaxies survey, which uses Hubble's WFC3 to search for the brightest galaxies around 13 billion years ago, when light from the first stars burned off a fog of cold hydrogen in a process called reionization.

The team estimated the distance to the newly found galaxies based on their colours, but the astronomers plan to follow up with spectroscopic observations, which measure the expansion of space. Those observations will help astronomers precisely calculate the cluster's distance and also yield the velocities of the galaxies, which will show whether they are gravitationally bound to each other.

Hubble solves mystery on source of supernova in nearby galaxy

Using the Hubble Space Telescope, astronomers have solved a longstanding mystery on the type of star, or so-called progenitor, which caused a supernova seen in a nearby galaxy (see picture, page 13). The finding yields new observational data for pinpointing one of several scenarios that trigger such outbursts.

Based on previous observations from ground-based telescopes, astronomers knew that a kind of supernova called a Type Ia created a remnant named SNR 0509-67.5, which lies 170,000 light-years away in the Large Magellanic Cloud galaxy. Theoretically, this kind of supernova explosion is caused by a star spilling material onto a white dwarf companion, the compact

remnant of a normal star, until it sets off one of the most powerful explosions in the universe. Astronomers failed to find any remnant of the companion star, however, and concluded that the common scenario did not apply in this case, though it is still a viable theory for other Type Ia supernovae seen.

"We know that Hubble has the sensitivity necessary to detect the faintest white dwarf remnants that could have caused such explosions," said lead investigator Bradley Schaefer of Louisiana State University (LSU) in Baton Rouge. "The logic here is the same as the famous quote from Sherlock Holmes: 'when you have eliminated the impossible, whatever remains, however improbable, must be the truth.'" The cause of SNR 0509-67.5 can be explained best by two tightly orbiting white dwarf stars spiraling closer and closer until they collided and exploded.

For four decades, the search for Type Ia supernovae progenitors has been a key question in astrophysics. The problem has taken on special importance over the last decade with Type Ia supernovae being the premier tools for measuring the accelerating universe.

Type Ia supernovae release tremendous energy, in which the light produced is often brighter than a whole galaxy of stars. The problem has been to identify the type of star system that pushes the white dwarf's mass over the edge and triggers this type of explosion. Many possibilities have been suggested, but most require that a companion star near the exploding white dwarf be left behind after the explosion. Therefore, a possible way to distinguish between the various progenitor models has been to look deep in the center of an old supernova remnant to search for the ex-companion star.

In 2010, Schaefer and Ashley Pagnotta of LSU were preparing a proposal to look for any faint ex-companion stars in the centre of four supernova remnants in the Large Magellanic Cloud when they discovered that the Hubble Space Telescope had already taken the desired image of one of their target remnants, SNR 0509-67.5, for the Hubble Heritage program, which collects images of especially photogenic astronomical targets.

In analyzing the central region, they found it to be completely empty of stars down to the limit of the faintest objects that Hubble can detect in the photos. Schaefer reports that the best explanation left is the so-called "double degenerate model" in which two white dwarfs collide.

There are no recorded observations of the star exploding. However, researchers at the Space Telescope Science Institute in Baltimore, Md. have identified light from the supernova that was reflected off of interstellar dust, delaying its arrival at Earth by 400 years. This delay, called a light echo of the supernova explosion also allowed the astronomers to measure the spectral signature of the light from the explosion. By virtue of the colour signature, astronomers were able to deduce it was a Type Ia supernova.

Because the remnant appears as a nice symmetric shell or bubble, the geometric center can be accurately determined. These properties make SNR 0509-67.5 an ideal target to search for ex-companions. The young age also means that any surviving stars have not moved far from the site of the explosion.

The team plans to look at other supernova remnants in the Large Magellenic Cloud to further test their observations.

Rare ultra-blue stars found in neighboring galaxy's hub

Peering deep inside the hub of the neighboring Andromeda galaxy, NASA's Hubble Space Telescope has uncovered a large, rare population of hot, bright stars. Blue is typically an indicator of hot, young stars. In this case, however, the stellar oddities are aging, Sun-like stars that have prematurely cast off their outer layers of material, exposing their extremely blue-hot cores.

Astronomers were surprised when they spotted these stars because physical models show that only an unusual type of old star can be as hot and as bright in ultraviolet light. While Hubble has spied these ultra-blue stars before in Andromeda, the new observation covers a much broader area, revealing that these stellar misfits are scattered throughout the galaxy's bustling center. Astronomers used Hubble's Wide Field Camera 3 to find roughly 8,000 of the ultra-blue stars in a stellar census made in ultraviolet light, which traces the glow of the hottest stars. The study is part of the multi-year Panchromatic Hubble Andromeda Treasury survey to map stellar populations across the Andromeda galaxy.

"We were not looking for these stars. They stood out because they were bright in ultraviolet light and very different from the stars we expected to see," said Julianne Dalcanton of the University of Washington in Seattle, leader of the Hubble survey.

The telescope spied the stars within 2,600 light-years of Andromeda's core. After analyzing the stars for nearly a year, Dalcanton's team determined that they were well past their prime. "The stars are dimmer and have a range of surface temperatures different from the extremely bright stars we see in the star-forming regions of Andromeda," said team member Phil Rosenfield of the University of Washington.

As these stars evolved, puffing up to become red giants, they ejected most of their outer layers to expose their blue-hot cores. When normal Sun-like stars swell up to become red giants, they lose much less material and therefore never look as bright in the ultraviolet.

"We caught these stars when they're the brightest, just before they become white dwarfs," said team member Leo Girardi of the National Institute for Astrophysics's Astronomical Observatory of Padua. "It is likely that there are many other similarly hot stars in this central part of Andromeda at earlier stages of their lives. But such stars are too dim for Hubble to see because they're mixed in with a crowd of normal stars."

The astronomers have proposed two possible scenarios to explain why these blue stars evolve differently. According to Rosenfield, the most likely scenario is that the stars are rich in chemical elements other than hydrogen and helium. Observations with ground-based telescopes have shown the stars in the galaxy's hub have an abundant supply of "heavy elements," which makes it easier for stars to eject lots of material into space late in life.

In this scenario radiation from the star is more efficient at pushing on gas laced with heavy elements, which drives away the material, like wind moving a thick sail. Although all the stars in the core are enriched in heavy elements, the bright blue stars may contain especially high amounts, which help trigger the mass loss. The study also shows that the number of blue stars decreases with distance from the core, tracing the drop in the amount of heavy elements.

Another possible explanation is that the blue stars are in close binary systems and have lost mass to their partners. This mass loss would expose the stars' hot cores. The astronomers were surprised to find that the ultra-blue stars are distributed in

the galaxy in the same way as a population of binary stars with similar masses that were found in X-ray observations by NASA's Chandra X-ray Observatory.

The astronomers' next step is to create simulations of these stars to try to determine which scenario is the one that leads them on a different evolutionary path.

RXTE helps pinpoint launch of 'bullets' in a black hole's jet

Using observations from NASA's Rossi X-ray Timing Explorer (RXTE) satellite and the National Science Foundation's (NSF) Very Long Baseline Array (VLBA) radio telescope, an international team of astronomers has identified the moment when a black hole in our galaxy launched superfast knots of gas into space. Racing outward at about one-quarter the speed of light, these "bullets" of ionized gas are thought to arise from a region located just outside the black hole's event horizon, the point beyond which nothing can escape.

"Like a referee at a sports game, we essentially rewound the footage on the bullets' progress, pinpointing when they were launched," said Gregory Sivakoff of the University of Alberta in Canada. "With the unique capabilities of RXTE and the VLBA, we can associate their ejection with changes that likely signaled the start of the process."

The research centred on the mid-2009 outburst of a binary system known as H1743-322, located about 28,000 light-years away toward the constellation Scorpius. Discovered by NASA's HEAO-1 satellite in 1977, the system is composed of a normal star and a black hole of modest but unknown masses. Their orbit around each other is measured in days, which puts them so close together that the black hole pulls a continuous stream of matter from its stellar companion. The flowing gas forms a flattened accretion disk millions of miles across, several times wider than our Sun, centered on the black hole. As matter swirls inward, it is compressed and heated to tens of millions of degrees, so hot that it emits X-rays.

Some of the infalling matter becomes re-directed out of the accretion disk as dual, oppositely directed jets. Most of the time, the jets consist of a steady flow of particles. Occasionally, though, they morph into more powerful outflows that hurl massive gas blobs at significant fractions of the speed of light.

In early June 2009, H1743-322 underwent this transition as astronomers watched with RXTE, the VLBA, the Very Large Array near Socorro, N.M., and the Australia Telescope Compact Array (ATCA) near Narrabri in New South Wales. The observatories captured changes in the system's X-ray and radio emissions as the transformation occurred.

From 28 May 28 to 2 June , the system's X-ray and radio emissions were fairly steady, although RXTE data show that cyclic X-ray variations, known as quasi-periodic oscillations or QPOs, gradually increased in frequency over the same period. On June 4, ATCA measurements showed that the radio emission had faded significantly.

Astronomers interpret QPOs as signals produced by the interaction of clumps of ionized gas in the accretion disk near the black hole. When RXTE next looked at the system on 5 June, the QPOs were gone. The same day, the radio emission increased. An extremely detailed VLBA image revealed a bright, radio-emitting bullet of gas moving outward from the system in the direction of one of the jets. On 6 June, a second blob, moving away in the opposite direction, was seen.

Until now, astronomers had associated the onset of the radio outburst with the bullet ejection event. However, based on the VLBA data, the team calculated that the bullets were launched on 3 June, about two days before the main radio flare. "This research provides new clues about the conditions needed to initiate a jet and can guide our thinking about how it happens," said Chris Done, an astrophysicist at the University of Durham, England, who was not involved in the study.

A super-sized version of the same phenomenon occurs at the center of an active galaxy, where a black hole weighing millions to billions of times our Sun's mass can drive outflows extending millions of light-years.

"Black hole jets in binary star systems act as fast-forwarded versions of their galactic-scale cousins, giving us insights into how they work and how their enormous energy output can influence the growth of galaxies and clusters of galaxies," said lead researcher James Miller-Jones at the International Center for Radio Astronomy Research at Curtin University in Perth, Australia.

RXTE mission ends

Meanwhile, after 16 years in space, NASA's Rossi X-ray Timing Explorer (RXTE) has made its last observation. The satellite provided unprecedented views into the extreme environments around white dwarfs, neutron stars and black holes. RXTE sent data from its last science observation to the ground early on 4 January 2012. After performing engineering tests, controllers at NASA's Goddard Space Flight Center in Greenbelt, Md., successfully decommissioned the satellite on 5 January.

RXTE far exceeded its original science goals and leaves astronomers with a scientific bounty for years to come. Data from the mission have resulted in more than 2,200 papers in refereed journals, 92 doctoral theses, and more than 1,000 rapid notifications alerting astronomers around the globe to new astronomical activity.

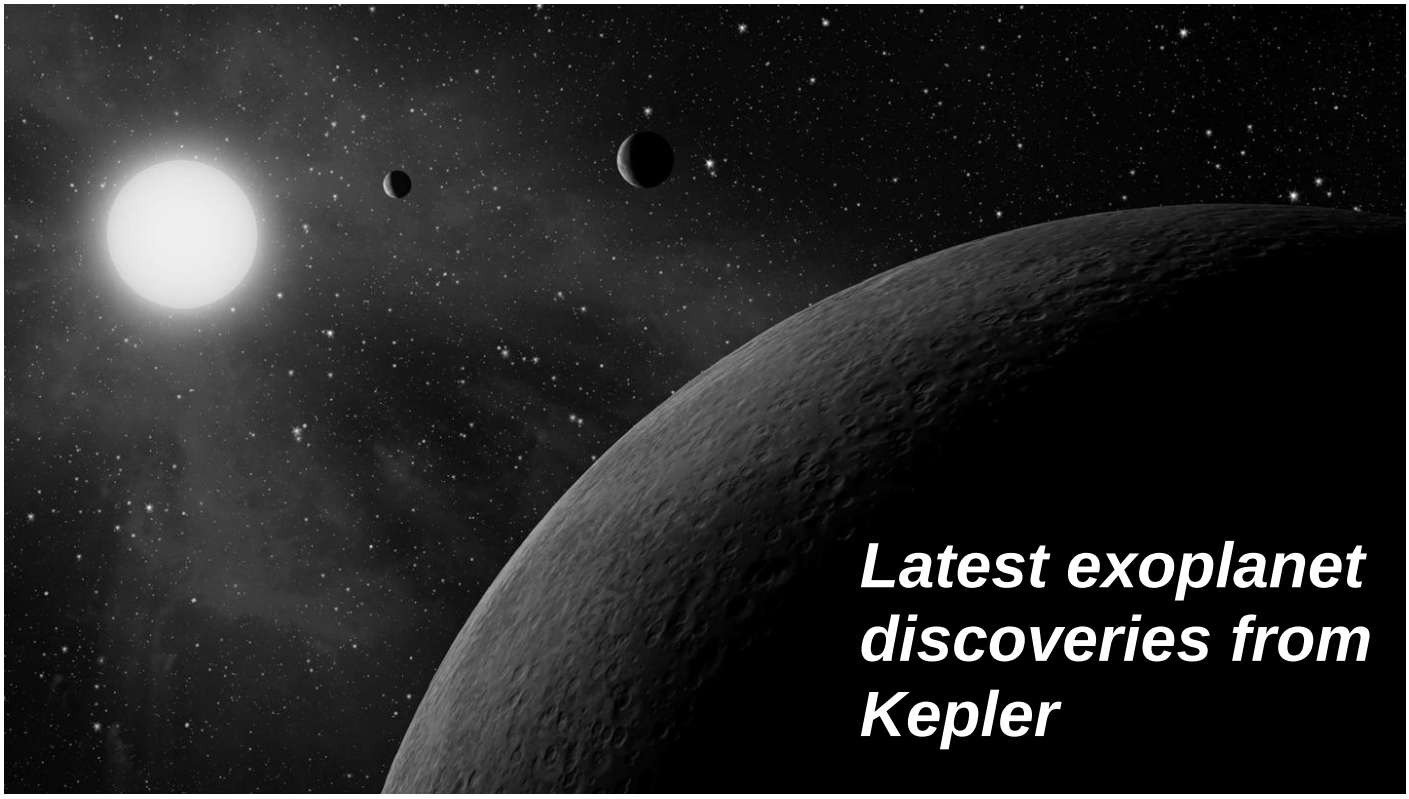
RXTE opened a new window into the workings of neutron stars and black holes. Using its data, astronomers established the existence of highly magnetized neutron stars (known as magnetars) and discovered the first accreting millisecond pulsars, a previously unseen stage in the formation of "recycled" millisecond radio pulsars that were first glimpsed in the early 1980s. The observatory also provided the first observational evidence of "frame-dragging" in the vicinity of a black hole, an effect predicted by Einstein's general theory of relativity.

RXTE carried three instruments. The Proportional Counter Array (PCA) and the High Energy X-ray Timing Experiment (HEXTE) could be directed to specific targets, while the third instrument, called the All-Sky Monitor, scanned about 80 percent of the sky every orbit, giving astronomers the ability to monitor the variable and often unpredictable X-ray sky and to record long-term histories of bright sources.

The astronomical community has recognized the importance of RXTE research with five major awards. These include four Rossi Prizes (1999, 2003, 2006 and 2009) from the High Energy Astrophysics Division of the AAS and the 2004 NWO Spinoza prize, the highest Dutch science award, from the Netherlands Organization for Scientific Research.

The mission was launched as XTE aboard a Delta II 7920 rocket on 30 December 1995, from Cape Canaveral Air Force Station in Florida. It was renamed RXTE in early 1996 in honour of Bruno Rossi, an MIT astronomer and a pioneer of X-ray astronomy and space plasma physics who died in 1993.

The 3,174.5-kilogram satellite is expected to re-enter the atmosphere between 2014 and 2023, depending in large part on solar activity.



This artist's concept depicts an itsy bitsy planetary system -- so compact, in fact, that it's more like Jupiter and its moons than a star and its planets. Astronomers using data from NASA's Kepler mission and ground-based telescopes recently confirmed that the system, called KOI-961, hosts the three smallest exoplanets known so far to orbit a star other than our Sun. The star, which is located about 130 light-years away in the Cygnus constellation, is what's called a red dwarf. It's one-sixth the size of the Sun, or just 70% bigger than Jupiter. The star is also cooler than our sun, and gives off more red light than yellow. The smallest of the three planets, called KOI-961.03, is actually located the farthest from the star, and is pictured in the foreground. This planet is about the same size as Mars, with a radius only 0.57 times that of Earth. The next planet to the upper right is KOI-961.01, which is 0.78 times the radius of Earth. The planet closest to the star is KOI-961.02, with a radius 0.73 times the Earth's. All three planets whip around the star in less than two days, with the closest planet taking less than half a day. Their close proximity to the star also means they are scorching hot, with temperatures ranging from 176 to 447 degrees Celsius. The star's habitable zone, or the region where liquid water could exist, is located far beyond the planets. (NASA)

Kepler confirms its first planet in habitable zone

NASA's Kepler mission has confirmed its first planet in the "habitable zone," the region around a star where liquid water could exist on a planet's surface. Kepler also has discovered more than 1,000 new planet candidates, nearly doubling its previously known count. Ten of these candidates are near-Earth-size and orbit in the habitable zone of their host star. Candidates require follow-up observations to verify they are actual planets.

The newly confirmed planet, Kepler-22b, is the smallest yet found to orbit in the middle of the habitable zone of a star similar to our Sun. The planet is about 2.4 times the radius of Earth. Scientists don't yet know if Kepler-22b has a predominantly rocky, gaseous or liquid composition, but its discovery is a step closer to finding Earth-like planets.

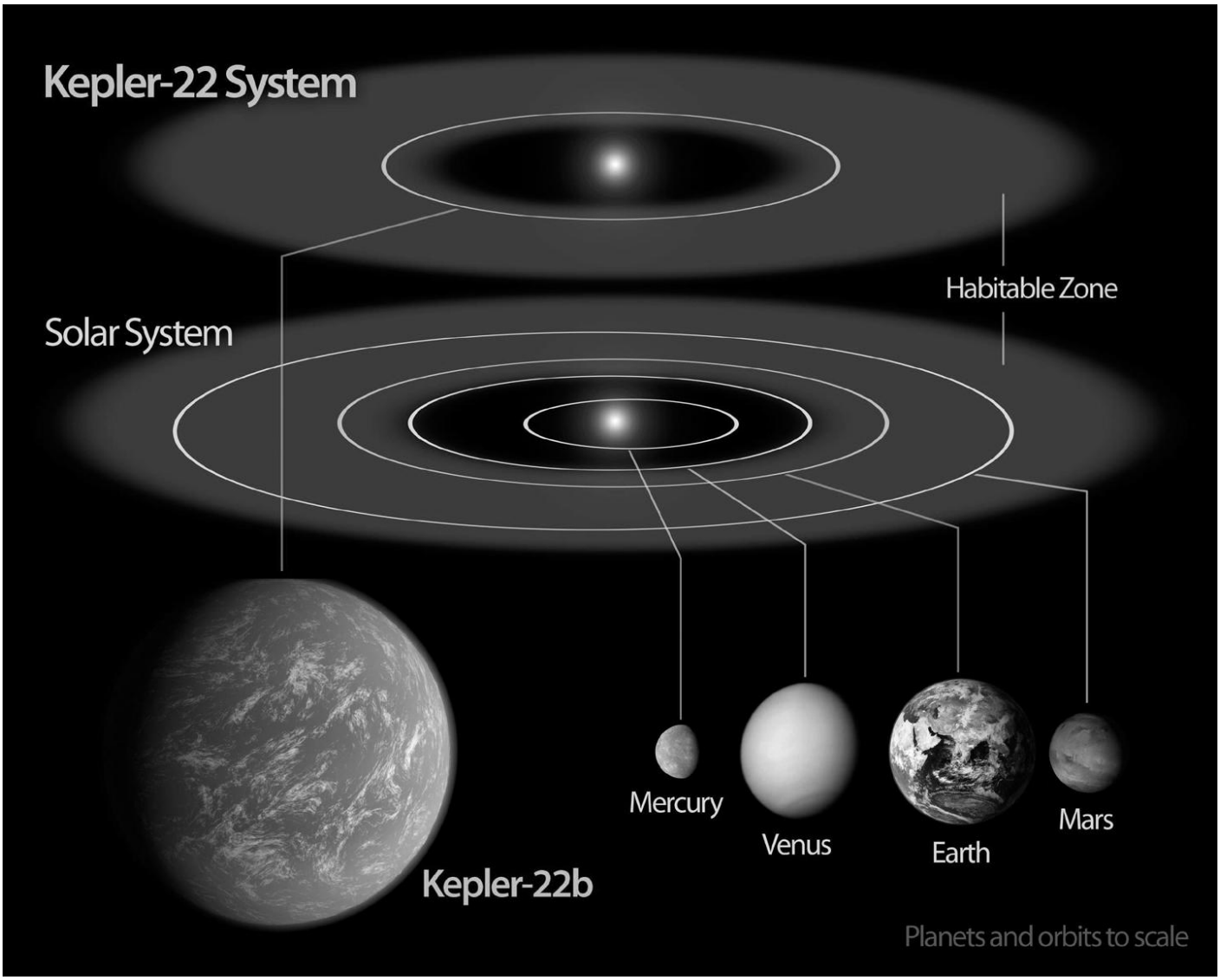
Previous research hinted at the existence of near-Earth-size planets in habitable zones, but clear confirmation proved elusive. Two other small planets orbiting stars smaller and cooler than our sun recently were confirmed on the very edges of the habitable zone, with orbits more closely resembling those of Venus and Mars.

"This is a major milestone on the road to finding Earth's twin," said Douglas Hudgins, Kepler program scientist at NASA Headquarters in Washington. "Kepler's results continue to demonstrate the importance of NASA's science missions, which aim to answer some of the biggest questions about our place in the universe."

Kepler discovers planets and planet candidates by measuring dips in the brightness of more than 150,000 stars to search for planets that cross in front, or "transit," the stars. Kepler requires at least three transits to verify a signal as a planet. "Fortune smiled upon us with the detection of this planet," said William Borucki, Kepler principal investigator at NASA Ames Research Center at Moffett Field, Calif., who led the team that discovered Kepler-22b. "The first transit was captured just three days after we declared the spacecraft operationally ready. We witnessed the defining third transit over the 2010 holiday season."

The Kepler science team uses ground-based telescopes and NASA's Spitzer Space Telescope to review observations on planet candidates the spacecraft finds. The star field that Kepler observes in the constellations Cygnus and Lyra can only be seen from ground-based observatories in spring through early fall. The data from these other observations help determine which candidates can be validated as planets.

Kepler-22b is located 600 light-years away. While the planet is larger than Earth, its orbit of 290 days around a sun-like star resembles that of our world. The planet's host star belongs to the same class as our sun, called G-type, although it is slightly smaller and cooler. Of the 54 habitable zone planet candidates reported in February 2011, Kepler-22b is the first to be confirmed. This milestone will be published in *The Astrophysical Journal*.



This diagram compares our own solar system to Kepler-22, a star system containing the first "habitable zone" planet discovered by NASA's Kepler mission. The habitable zone is the sweet spot around a star where temperatures are right for water to exist in its liquid form. Liquid water is essential for life on Earth. Kepler-22's star is a bit smaller than our Sun, so its habitable zone is slightly closer in. The diagram shows an artist's rendering of the planet comfortably orbiting within the habitable zone, similar to where Earth circles the Sun. Kepler-22b has a yearly orbit of 289 days. The planet is the smallest known to orbit in the middle of the habitable zone of a Sun-like star. It's about 2.4 times the size of Earth. (NASA/Ames/JPL-Caltech)

Since the last catalogue was released in February 2011, the number of planet candidates identified by Kepler has increased by 89 percent and now totals 2,326. Of these, 207 are approximately Earth-size, 680 are super Earth-size, 1,181 are Neptune-size, 203 are Jupiter-size and 55 are larger than Jupiter. The findings, based on observations conducted May 2009 to September 2010, show a dramatic increase in the numbers of smaller-size planet candidates. Kepler observed many large planets in small orbits early in its mission, which were reflected in the February data release. Having had more time to observe three transits of planets with longer orbital periods, the new data suggest that planets one to four times the size of Earth may be abundant in the galaxy.

The number of Earth-size, and super Earth-size candidates, has increased by more than 200 and 140 percent since February, respectively. There are 48 planet candidates in their star's habitable zone. While this is a decrease from the 54 reported in February, the Kepler team has applied a stricter definition of what constitutes a habitable zone in the new catalogue, to account for the warming effect of atmospheres, which would move the zone away from the star, out to longer orbital periods.

"The tremendous growth in the number of Earth-size candidates tells us that we're honing in on the planets Kepler was designed to detect: those that are not only Earth-size, but also are potentially habitable," said Natalie Batalha, Kepler deputy science team lead at San Jose State University in San Jose, Calif. "The more data we collect, the keener our eye for finding the smallest planets out at longer orbital periods."

First Earth-size planets beyond our solar system discovered

NASA's Kepler mission has discovered the first Earth-size planets orbiting a Sun-like star outside our solar system. The planets, called Kepler-20e and Kepler-20f, are too close to their

star to be in the so-called habitable zone where liquid water could exist on a planet's surface, but they are the smallest exoplanets ever confirmed around a star like our Sun.

The discovery marks the next important milestone in the ultimate search for planets like Earth. The new planets are thought to be rocky. Kepler-20e is slightly smaller than Venus, measuring 0.87 times the radius of Earth. Kepler-20f is slightly larger than Earth, measuring 1.03 times its radius. Both planets reside in a five-planet system called Kepler-20, approximately 1,000 light-years away in the constellation Lyra. Kepler-20e orbits its parent star every 6.1 days and Kepler-20f every 19.6 days. These short orbital periods mean very hot, inhospitable worlds. Kepler-20f, at 427 degrees Celsius, is similar to an average day on the planet Mercury. The surface temperature of Kepler-20e, at more than 760 degrees Celsius, would melt glass.

“The primary goal of the Kepler mission is to find Earth-sized planets in the habitable zone," said Francois Fressin of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., lead author of a new study published in the journal *Nature*. "This discovery demonstrates for the first time that Earth-size planets exist around other stars, and that we are able to detect them.”

The Kepler-20 system includes three other planets that are larger than Earth but smaller than Neptune. Kepler-20b, the closest planet, Kepler-20c, the third planet, and Kepler-20d, the fifth planet, orbit their star every 3.7, 10.9 and 77.6 days, respectively. All five planets have orbits lying roughly within Mercury's orbit in our solar system. The host star belongs to the same G-type class as our Sun, although it is slightly smaller and cooler. The system also has an unexpected arrangement: in our solar system, small, rocky worlds orbit close to the Sun and large, gaseous worlds orbit farther out. In comparison, the planets of Kepler-20 are organized in alternating size: large, small, large, small and large. "The Kepler data are showing us some planetary systems have arrangements of planets very different from that seen in our solar system," said Jack Lissauer, planetary scientist and Kepler science team member at NASA's Ames Research Center in Moffett Field, Calif. "The analysis of Kepler data continues to reveal new insights about the diversity of planets and planetary systems within our galaxy."

Scientists are not certain how the system evolved, but they do not think the planets formed in their existing locations. They theorize the planets formed farther from their star and then migrated inward, likely through interactions with the disk of material from which they originated. This allowed the worlds to maintain their regular spacing despite alternating sizes.

The Kepler space telescope detects planets and planet candidates by measuring dips in the brightness of more than 150,000 stars to search for planets crossing in front of, or transiting, their stars. The Kepler science team requires at least three transits to verify a signal as a planet. The Kepler science team uses ground-based telescopes and the Spitzer Space Telescope to review observations on planet candidates the Kepler spacecraft finds. The star field Kepler observes in the constellations Cygnus and Lyra can be seen only from ground-based observatories in spring through early fall. The data from these other observations help determine which candidates can be validated as planets.

To validate Kepler-20e and Kepler-20f, astronomers used a computer program called Blender, which runs simulations to help rule out other astrophysical phenomena masquerading as a planet.

On 5 December, the team announced the discovery of Kepler-22b in the habitable zone of its parent star. It is likely to be too large to have a rocky surface. While Kepler-20e and Kepler-20f are Earth-size, they are too close to their parent star to have liquid water on the surface. "In the cosmic game of hide and seek, finding planets with just the right size and just the right temperature seems only a matter of time," said Natalie Batalha, Kepler deputy science team lead and professor of astronomy and physics at San Jose State University.

Kepler finds three smallest exoplanets

Astronomers using data from NASA's Kepler mission have discovered the three smallest planets yet detected orbiting a star beyond our Sun. The planets orbit a single star, called KOI-961, and are 0.78, 0.73 and 0.57 times the radius of Earth. The smallest is about the size of Mars. All three planets are thought to be rocky like Earth but orbit close to their star, making them too hot to be in the habitable zone, which is the region where liquid water could exist. Of the more than 700 planets confirmed to orbit other stars, called exoplanets, only a handful are known to be rocky.

"Astronomers are just beginning to confirm the thousands of planet candidates uncovered by Kepler so far," said Doug Hudgins, Kepler program scientist at NASA Headquarters in Washington. "Finding one as small as Mars is amazing, and hints that there may be a bounty of rocky planets all around us."

Kepler searches for planets by continuously monitoring more than 150,000 stars, looking for telltale dips in their brightness caused by crossing, or transiting, planets. At least three transits are required to verify a signal as a planet. Follow-up observations from ground-based telescopes also are needed to confirm the discoveries.

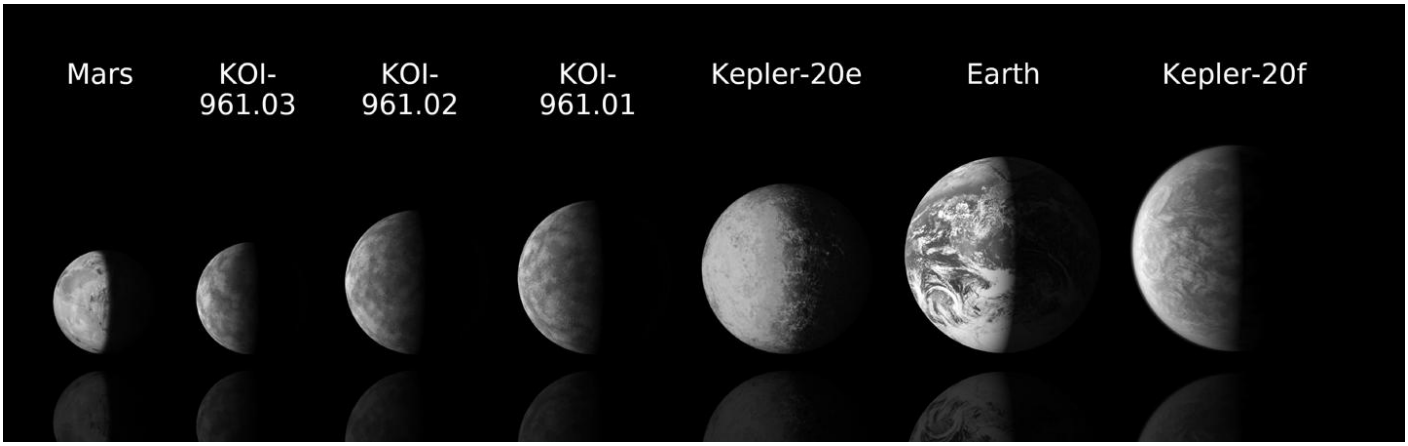
The latest discovery comes from a team led by astronomers at the California Institute of Technology in Pasadena. The team used data publicly released by the Kepler mission, along with follow-up observations from the Palomar Observatory, near San Diego, and the W.M. Keck Observatory atop Mauna Kea in Hawaii. Their measurements dramatically revised the sizes of the planets from what was originally estimated, revealing their small nature.

The three planets are very close to their star, taking less than two days to orbit around it. The KOI-961 star is a red dwarf with a diameter one-sixth that of our sun, making it just 70 percent bigger than Jupiter. "This is the tiniest solar system found so far," said John Johnson, the principal investigator of the research from NASA's Exoplanet Science Institute at the California Institute of Technology in Pasadena. "It's actually more similar to Jupiter and its moons in scale than any other planetary system. The discovery is further proof of the diversity of planetary systems in our galaxy."

Red dwarfs are the most common kind of star in our Milky Way galaxy. The discovery of three rocky planets around one red dwarf suggests that the galaxy could be teeming with similar rocky planets. "These types of systems could be ubiquitous in the universe," said Phil Muirhead, lead author of the new study from Caltech. "This is a really exciting time for planet hunters."

The discovery follows a string of recent milestones for the Kepler mission. In December 2011, scientists announced the mission's first confirmed planet in the habitable zone of a sun-like star: a planet 2.4 times the size of Earth called Kepler-22b. Later in the month, the team announced the discovery of the first Earth-size planets orbiting a sun-like star outside our solar system, called Kepler-20e and Kepler-20f.

For the latest discovery, the team obtained the sizes of the three planets (called KOI-961.01, KOI-961.02 and KOI-961.03) with the help of a well-studied twin star to KOI-961, Barnard's Star. By better understanding the KOI-961 star, they could then determine how big the planets must be to have caused the



This chart compares the smallest known exoplanets, or planets orbiting outside the solar system, to our own planets Mars and Earth. Astronomers using data from NASA's Kepler mission and ground-based telescopes recently discovered the three smallest exoplanets known to circle another star, called KOI-961.01, KOI-961.02 and KOI-961.03. The smallest of these, KOI-961.03, is about the size of Mars with a radius of only 0.57 times that of Earth. In December 2011, the Kepler team announced the discovery of Kepler-20e and Kepler-20f -- the first Earth-size planets ever found outside the solar system. All five of these small exoplanets have toasty orbits close to their stars, and do not lie in the more temperate habitable zone. The ground-based observations contributing to the KOI-961 discoveries were made with the Palomar Observatory, near San Diego, Calif., and the W.M. Keck Observatory atop Mauna Kea in Hawaii.

observed dips in starlight. In addition to the Kepler observations and ground-based telescope measurements, the team used modeling techniques to confirm the planet discoveries.

Prior to these confirmed planets, only six other planets had been confirmed using the Kepler public data.

Kepler discovers 11 new planetary systems

The Kepler mission has discovered 11 new planetary systems hosting 26 confirmed planets. These discoveries nearly double the number of verified Kepler planets and triple the number of stars known to have more than one planet that transits, or passes in front of, the star. Such systems will help astronomers better understand how planets form.

The planets orbit close to their host stars and range in size from 1.5 times the radius of Earth to larger than Jupiter. Fifteen are between Earth and Neptune in size. Further observations will be required to determine which are rocky like Earth and which have thick gaseous atmospheres like Neptune. The planets orbit their host star once every six to 143 days. All are closer to their host star than Venus is to our Sun.

"Prior to the Kepler mission, we knew of perhaps 500 exoplanets across the whole sky," said Doug Hudgins, Kepler program scientist at NASA Headquarters in Washington. "Now, in just two years staring at a patch of sky not much bigger than your fist, Kepler has discovered more than 60 planets and more than 2,300 planet candidates. This tells us that our galaxy is positively loaded with planets of all sizes and orbits."

Kepler identifies planet candidates by repeatedly measuring the change in brightness of more than 150,000 stars to detect when a planet passes in front of the star. That passage casts a small shadow toward Earth and the Kepler spacecraft. "Confirming that the small decrease in the star's brightness is due to a planet requires additional observations and time-consuming analysis," said Eric Ford, associate professor of astronomy at the University of Florida and lead author of the paper confirming Kepler-23 and Kepler-24. "We verified these planets using new techniques that dramatically accelerated their discovery."

Each of the newly confirmed planetary systems contains two to five closely spaced transiting planets. In tightly packed planetary systems, the gravitational pull of the planets on each other causes some planets to accelerate and some to decelerate along their orbits. The acceleration causes the orbital period of each planet to change. Kepler detects this effect by measuring the changes, or so-called Transit Timing Variations.

Planetary systems with Transit Timing Variations can be verified without requiring extensive ground-based observations, accelerating confirmation of planet candidates. This detection technique also increases Kepler's ability to confirm planetary systems around fainter and more distant stars. "By precisely timing when each planet transits its star, Kepler detected the gravitational tug of the planets on each other, clinching the case for 10 of the newly announced planetary systems," said Dan Fabrycky, Hubble Fellow at the University of California, Santa Cruz, and lead author for a paper confirming Kepler-29, 30, 31 and 32.

Five of the systems (Kepler-25, Kepler-27, Kepler-30, Kepler-31 and Kepler-33) contain a pair of planets where the inner planet orbits the star twice during each orbit of the outer planet. Four of the systems (Kepler-23, Kepler-24, Kepler-28 and Kepler-32) contain a pairing where the outer planet circles the star twice for every three times the inner planet orbits its star. "These configurations help to amplify the gravitational interactions between the planets, similar to how my sons kick their legs on a swing at the right time to go higher," said Jason Steffen, the Brinson postdoctoral fellow at Fermilab Center for Particle Astrophysics in Batavia, Ill., and lead author of a paper confirming Kepler-25, 26, 27 and 28.

Kepler-33, a star that is older and more massive than our sun, had the most planets. The system hosts five planets, ranging in size from 1.5 to 5 times that of Earth. All of the planets are located closer to their star than any planet is to our Sun.

The properties of a star provide clues for planet detection. The decrease in the star's brightness and duration of a planet transit combined with the properties of its host star present a recognizable signature. When astronomers detect planet candidates that exhibit similar signatures around the same star, the likelihood of any of these planet candidates being a false positive is very low. "The approach used to verify the Kepler-33 planets shows the overall reliability is quite high," said Jack Lissauer, planetary scientist at NASA Ames Research Center at Moffett Field, Calif., and lead author of the paper on Kepler-33. "This is a validation by multiplicity."

Durable rover beginning ninth year of Mars work

This mosaic of images taken in mid-January 2012 shows the windswept vista northward (left) to northeastward (right) from the location where NASA's Mars Exploration Rover Opportunity is spending its fifth Martian winter, an outcrop informally named "Greeley Haven." Opportunity's Panoramic Camera (Pancam) took the component images as part of full-circle view being assembled from Greeley Haven. The view includes sand ripples and other wind-sculpted features in the foreground and mid-field. The northern edge of the the "Cape York" segment of the rim of Endeavour Crater forms an arc across the upper half of the scene. Opportunity landed on Mars on 25 January 2004, Universal Time and EST. It has driven 34.4 km as of its eighth anniversary on the planet. In late 2011, the rover team drove Opportunity up onto Greeley Haven to take advantage of the outcrop's sun-facing slope to boost output from the rover's dusty solar panels during the Martian winter. Research activities while at Greeley Haven include a radio-science investigation of the interior of Mars, inspections of mineral compositions and textures on the outcrop, and monitoring of wind-caused changes on scales from dunes to individual soil particles. (NASA/JPL-Caltech/Cornell/Arizona State Univ.)

Eight years after landing on Mars for what was planned as a three-month mission, NASA's enduring Mars Exploration Rover Opportunity is working on what essentially became a new mission five months ago.

Opportunity reached a multi-year driving destination, Endeavour Crater, in August 2011. At Endeavour's rim, it has gained access to geological deposits from an earlier period of Martian history than anything it examined during its first seven years. It also has begun an investigation of the planet's deep interior that takes advantage of staying in one place for the Martian winter.

Opportunity landed in Eagle Crater on Mars on 25 January 2004, Universal Time and EST (24 January, PST), three weeks after its rover twin, Spirit, landed halfway around the planet. In backyard-size Eagle Crater, Opportunity found evidence of an ancient wet environment. The mission met all its goals within the originally planned span of three months. During most of the next four years, it explored successively larger and deeper craters, adding evidence about wet and dry periods from the same era as the Eagle Crater deposits.

In mid-2008, researchers drove Opportunity out of Victoria Crater, 800 metres in diameter, and set course for Endeavour Crater, 22 kilometres in diameter. "Endeavour is a window further into Mars' past," said Mars Exploration Rover Program Manager John Callas, of NASA's Jet Propulsion Laboratory, Pasadena, Calif.

The trek took three years. In a push to finish it, Opportunity drove farther during its eighth year on Mars -- 7.7 kilometres -- than in any prior year, bringing its total driving distance to 34.4 kilometres.

The "Cape York" segment of Endeavour's rim, where Opportunity has been working since August 2011, has already validated the choice of Endeavour as a long-term goal. "It's like starting a new mission, and we hit pay dirt right out of the gate," Callas said.

The first outcrop that Opportunity examined on Cape York differs from any the rover had seen previously. Its high zinc content suggests effects of water. Weeks later, at the edge of Cape York, a bright mineral vein identified as hydrated calcium sulfate provided what the mission's principal investigator, Steve Squyres of Cornell University, Ithaca, N.Y., calls "the clearest evidence for liquid water on Mars that we have found in our eight years on the planet."

Mars years last nearly twice as long as Earth years. Entering its ninth Earth year on Mars, Opportunity is also heading into its fifth Martian winter. Its solar panels have accumulated so much dust since Martian winds last cleaned them -- more than in previous winters -- the rover needs to stay on a sun-facing slope to have enough energy to keep active through the winter.

The rover team has not had to use this strategy with Opportunity in past winters, though it did so with Spirit, farther from the equator, for the three Martian winters that Spirit survived. By the beginning of the rovers' fourth Martian winter, drive motors in two of Spirit's six wheels had ceased working, long past their design lifespan. The impaired mobility kept the rover from maneuvering to an energy-favorable slope. Spirit stopped communicating in March 2010.

All six of Opportunity's wheels are still useful for driving, but the rover will stay on an outcrop called "Greeley Haven" until mid-2012 to take advantage of the outcrop's favorable slope and targets of scientific interest during the Martian winter. After the

winter, or earlier if wind cleans dust off the solar panels, researchers plan to drive Opportunity in search of clay minerals that a Mars orbiter's observations indicate lie on Endeavour's rim.

"The top priority at Greeley Haven is the radio-science campaign to provide information about Mars' interior," said JPL's Diana Blaney, deputy project scientist for the mission. This study uses weeks of tracking radio signals from the stationary rover to measure wobble in the planet's rotation. The amount of wobble is an indicator of whether the core of the planet is molten, similar to the way spinning an egg can be used to determine whether it is raw or hard-boiled.

Other research at Greeley Haven includes long-term data gathering to investigate mineral ingredients of the outcrop with spectrometers on Opportunity's arm, and repeated observations to monitor wind-caused changes at various scales.

The Mössbauer spectrometer, which identifies iron-containing minerals, uses radiation from cobalt-57 in the instrument to elicit a response from molecules in the rock. The half-life of cobalt-57 is only about nine months, so this source has diminished greatly. A measurement that could have been made in less than an hour during the rover's first year now requires weeks of holding the spectrometer on the target.

Observations for the campaign to monitor wind-caused changes range in scale from dunes in the distance to individual grains seen with the rover's microscopic imager. "Wind is the most active process on Mars today," Blaney said. "It is harder to watch for changes when the rover is driving every day. We are taking advantage of staying at one place for a while."

Mars-bound rover begins research in space

NASA's car-sized Curiosity rover has begun monitoring space radiation during its 8-month trip from Earth to Mars. The research will aid in planning for future human missions to the Red Planet. Curiosity launched on 26 November 2011 from Cape Canaveral, Fla., aboard the Mars Science Laboratory. The rover carries an instrument called the Radiation Assessment Detector (RAD) that monitors high-energy atomic and subatomic particles from the sun, distant supernovas and other sources. These particles constitute radiation that could be harmful to any microbes or astronauts in space or on Mars. The rover also will monitor radiation on the surface of Mars after its August 2012 landing.

"RAD is serving as a proxy for an astronaut inside a spacecraft on the way to Mars," said Don Hassler, RAD's principal investigator from the Southwest Research Institute in Boulder, Colo. "The instrument is deep inside the spacecraft, the way an astronaut would be. Understanding the effects of the spacecraft on the radiation field will be valuable in designing craft for astronauts to travel to Mars."

Previous monitoring of energetic-particle radiation in space has used instruments at or near the surface of various spacecraft. The RAD instrument is on the rover inside the spacecraft and shielded by other components of Mars Science Laboratory, including the aeroshell that will protect the rover during descent through the upper atmosphere of Mars.

Spacecraft structures, while providing shielding, also can contribute to secondary particles generated when high-energy particles strike the spacecraft. In some circumstances, secondary particles could be more hazardous than primary ones.

These first measurements mark the start of the science return from a mission that will use 10 instruments on Curiosity to assess whether Mars' Gale Crater could be or has been favorable for microbial life.

"While Curiosity will not look for signs of life on Mars, what it might find could be a game-changer about the origin and evolution of life on Earth and elsewhere in the universe," said Doug McCuistion, director of the Mars Exploration Program at NASA Headquarters in Washington. "One thing is certain: The rover's discoveries will provide critical data that will impact human and robotic planning and research for decades."

Curiosity rover carries coin for camera checkup

The camera at the end of the robotic arm on NASA's Mars rover Curiosity has its own calibration target, a smartphone-size plaque that looks like an eye chart supplemented with color chips and an attached penny (US one-cent piece). When Curiosity lands on Mars in August, researchers will use this calibration target to test performance of the rover's Mars Hand Lens Imager, or MAHLI. MAHLI's close-up inspections of Martian rocks and soil will show details so tiny, the calibration target includes reference lines finer than a human hair. This camera is not limited to close-ups, though. It can focus on any target from about a finger's-width away to the horizon.

Curiosity, the rover of NASA's Mars Science Laboratory mission, also carries four other science cameras and a dozen black-and-white engineering cameras, plus other research instruments. The spacecraft, launched on 26 November 2011, will deliver Curiosity to a landing site inside Mars' Gale Crater in August to begin a two-year investigation of whether that area has ever offered an environment favorable for microbial life.

The "hand lens" in MAHLI's name refers to field geologists' practice of carrying a hand lens for close inspection of rocks they find. When shooting photos in the field, geologists use various calibration methods. "When a geologist takes pictures of rock outcrops she is studying, she wants an object of known scale in the photographs," said MAHLI Principal Investigator Ken Edgett, of Malin Space Science Systems, San Diego. "If it is a whole cliff face, she'll ask a person to stand in the shot. If it is a view from a meter or so away, she might use a rock hammer. If it is a close-up, as the MAHLI can take, she might pull something small out of her pocket. Like a penny."

Edgett bought the special penny that's aboard Curiosity with funds from his own pocket. It is a 1909 "VDB" cent, from the first year Lincoln pennies were minted, the centennial of Abraham Lincoln's birth, with the VDB initials of the coin's designer â€“ Victor David Brenner -- on the reverse. "The penny is on the MAHLI calibration target as a tip of the hat to geologists' informal practice of placing a coin or other object of known scale in their photographs. A more formal practice is to use an object with scale marked in millimeters, centimeters or meters," Edgett said. "Of course, this penny can't be moved around and placed in MAHLI images; it stays affixed to the rover."

The middle of the target offers a marked scale of black bars in a range of labeled sizes. While the scale will not appear in photos MAHLI takes of Martian rocks, knowing the distance from the camera to a rock target will allow scientists to correlate calibration images to each investigation image.

Another part of MAHLI's calibration target displays six patches of pigmented silicone as aids for interpreting color and brightness in images. Five of them -- red, green, blue, 40-percent gray and 60-percent gray -- are spares from targets on NASA Mars rovers Spirit and Opportunity. The sixth, with a fluorescent pigment that glows red when exposed to ultraviolet light, allows checking of an ultraviolet light source on MAHLI.

The fluorescent material was donated to the MAHLI team by Spectra Systems, Inc., Providence, R.I. A stair-stepped area at the bottom of the target, plus the penny, help with three-dimensional calibration using known surface shapes.

Curiosity also carries calibration materials for other science instruments on the rover. "The importance of calibration is to allow data acquired on Mars to be compared reliably to data acquired on Earth," said Mars Science Laboratory Project Scientist John Grotzinger, of the California Institute of Technology, Pasadena.

The MAHLI calibration target, with its penny and a miniscule cartoon of a character named "Joe the Martian," serves an additional function: public engagement. "Everyone in the United States can recognize the penny and immediately know how big it is, and can compare that with the rover hardware and Mars materials in the same image," Edgett said. "The public can watch for changes in the penny over the long term on Mars. Will it change colour? Will it corrode? Will it get pitted by windblown sand?"

The Joe the Martian character appeared regularly in a children's science periodical, "Red Planet Connection," when Edgett directed the Mars outreach program at Arizona State University, Tempe, in the 1990s. Joe was created earlier, as part of Edgett's schoolwork when he was 9 years old and NASA's Mars Viking missions, launched in 1975, were inspiring him to dream of becoming a Mars researcher. Edgett said, "The Joe the Martian on Curiosity really is a 'thank you' from the MAHLI team to the folks who have provided us with the opportunity to study Mars, the U.S. taxpayers. He is also there to encourage children around the world to set goals that will help them achieve their dreams in whatever interests they pursue."

ESA's Mars Express radar gives strong evidence for former Mars ocean

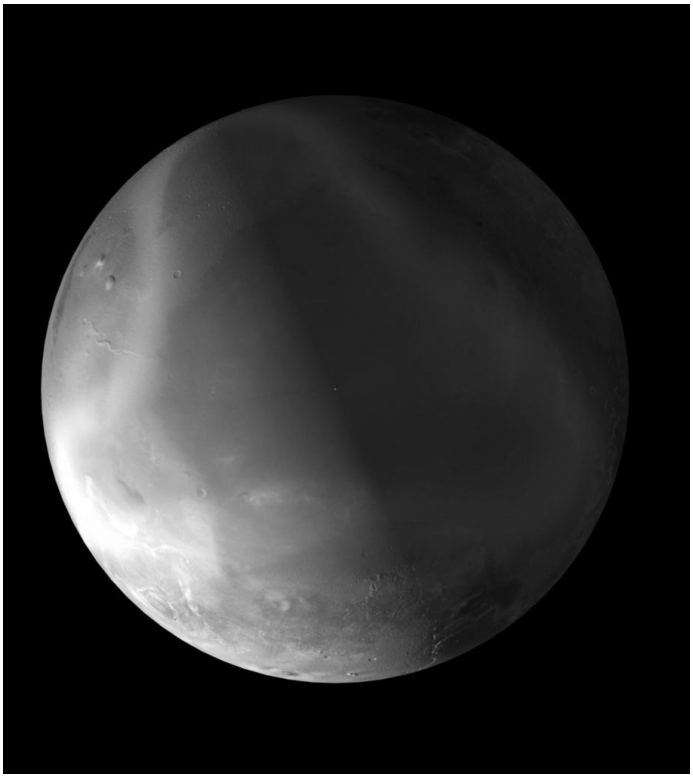
ESA's Mars Express has returned strong evidence for an ocean once covering part of Mars. Using radar, it has detected sediments reminiscent of an ocean floor within the boundaries of previously identified, ancient shorelines on Mars.

The MARSIS radar was deployed in 2005 and has been collecting data ever since. Jérémie Mouginot, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) and the University of California, Irvine, and colleagues have analysed more than two years of data and found that the northern plains are covered in low-density material. "We interpret these as sedimentary deposits, maybe ice-rich," says Dr Mouginot. "It is a strong new indication that there was once an ocean here."

The existence of oceans on ancient Mars has been suspected before and features reminiscent of shorelines have been tentatively identified in images from various spacecraft. But it remains a controversial issue.

Two oceans have been proposed: 4 billion years ago, when warmer conditions prevailed, and also 3 billion years ago when subsurface ice melted, possibly as a result of enhanced geothermal activity, creating outflow channels that drained the water into areas of low elevation.

"MARSIS penetrates deep into the ground, revealing the first 60–80 metres of the planet's subsurface," says Wlodek Kofman, leader of the radar team at IPAG. "Throughout all of this depth, we see the evidence for sedimentary material and ice." The sediments revealed by MARSIS are areas of low radar reflectivity. Such sediments are typically low-density granular materials that have been eroded away by water and carried to their final destination.



New results from the MARSIS radar on Mars Express give strong evidence for a former ocean of Mars. The radar detected sediments reminiscent of an ocean floor inside previously identified, ancient shorelines on the red planet. The ocean would have covered the northern plains billions of years ago. (ESA, C. Carreau)

This later ocean would however have been temporary. Within a million years or less, Dr Mouginot estimates, the water would have either frozen back in place and been preserved underground again, or turned into vapour and lifted gradually into the atmosphere. "I don't think it could have stayed as an ocean long enough for life to form."

In order to find evidence of life, astrobiologists will have to look even further back in Mars' history when liquid water existed for much longer periods. Nevertheless, this work provides some of the best evidence yet that there were once large bodies of liquid water on Mars and is further proof of the role of liquid water in the martian geological history.

"Previous Mars Express results about water on Mars came from the study of images and mineralogical data, as well as atmospheric measurements. Now we have the view from the subsurface radar," says Olivier Witasse, ESA's Mars Express Project Scientist. "This adds new pieces of information to the puzzle but the question remains: where did all the water go?"

Fifty years ago, on 20 February 1962, astronaut John H. Glenn became the first American to orbit the Earth during the three-orbit Mercury-Atlas 6 mission. Glenn named his spacecraft Friendship 7. (NASA photo)