VENDELINUS ASTRONOMY NEWSLETTER

Vendelinus Astronomy Newsletter

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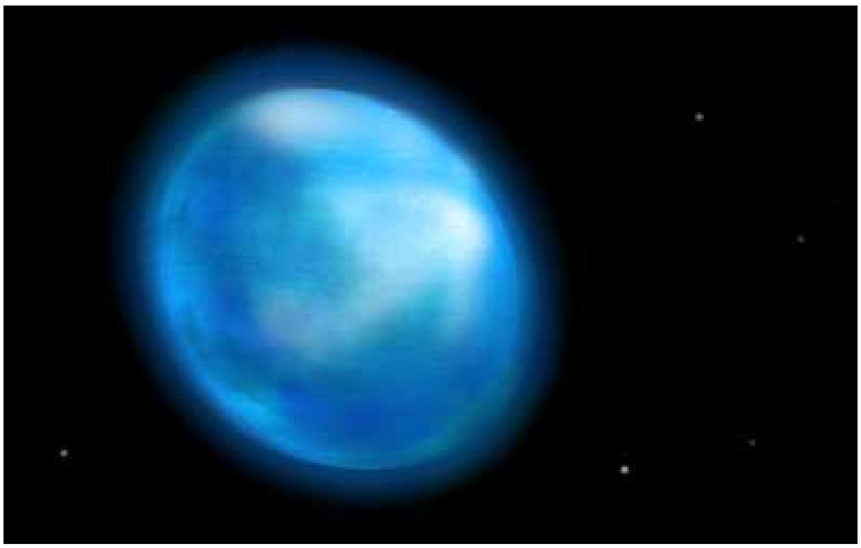

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1 Solar System

1.1 Mercury's Soft Center

Source: NFS Press Release, May 3rd, 2007 [1]

By tracking a subtle wobbling of the planet Mercury as it spins about its axis, researchers using a trio of ground-based telescopes have found strong evidence that the planet has a molten core.

In their paper, the researchers show that careful measurements of Mercury's spin–to an accuracy of one in 100,000–reveal that the planet's interior is decoupled from its exterior, providing strong evidence of a molten core.

Astronomer Jean-Luc Margot of Cornell University, Stan Peale of the University of California, Santa Barbara, Ray Jurgens and Martin Slade of the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., and Igor Holin of the Space Research Institute in Russia report their findings in the cover story of the May 4, 2007, journal Science.

While most models for the formation of Mercury suggest the planet has an iron-rich core, many predict that the core is solid after billions of years of cooling. Others predict that small amounts of sulfur and other trace elements mixed with the iron have lowered the core's freezing point, keeping the planet's outer core from completely solidifying over that time.

While peering into the deepest interior of a planet–even our own–is difficult even with on-site technology, the ground-based telescope data collected by Margot and his colleagues provided evidence that strongly supports the latter scenario, suggesting the core is at least partially molten and may contain at least small amounts of sulfur.

The researchers used National Science Foundation's (NSF) Arecibo Observatory in Puerto Rico, part of NSF's National Astronomy and Ionosphere Center, NSF's Robert C. Byrd Green Bank Telescope in W. Va., and the NASA/JPL 70-meter antenna at Goldstone, Calif., to beam radar signals to the planet and then carefully analyze the echoes that returned.

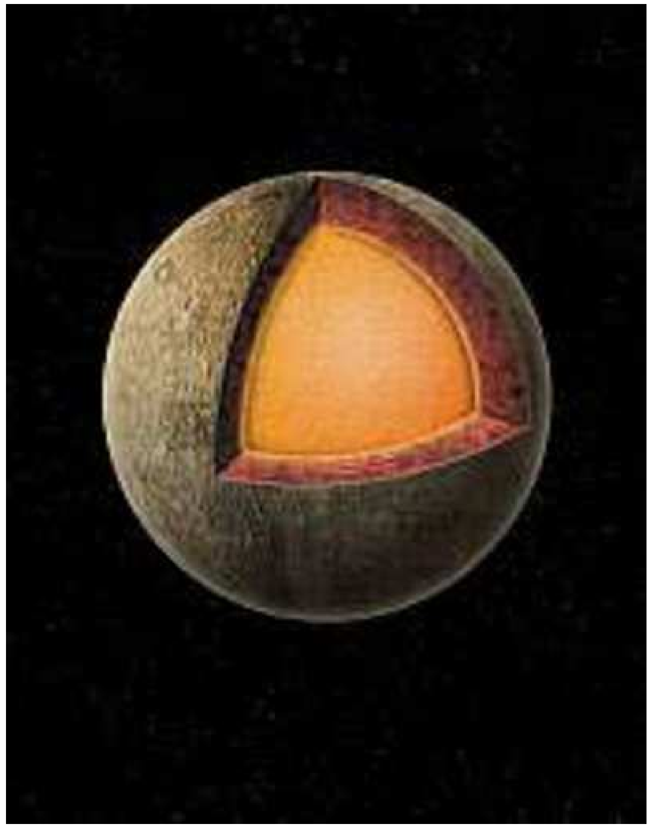


Figure 1: *An artist's rendition of the interior structure of Mercury suggests that the metallic core extends from the center through a large fraction of the planet. Ground-based telescope observations suggest that the outer core is molten. Credit: Nicolle Rager Fuller, National Science Foundation*

To obtain their measurements, the astronomers compared the properties of the return signal as it struck the distributed telescope locations on Earth's surface. The amplitude of the wobbling was twice what the researchers expected for a solid planet, but on par with an object that has a solid exterior and liquid core.

1.2 Spacecraft Aids in Forecast of Solar Radiation Storms

Source: NASA News, May 25th, 2007 [2]

The Solar and Heliospheric Observatory (SOHO) now enables scientists to forecast solar radiation storms, giving future astronauts, traveling to the moon and Mars, time to seek shelter and ground controllers time to safeguard satellites. The new method for the first time offers as much as one hour advance notice when a storm is approaching.

”Solar radiation storms are notoriously difficult to predict. They often take us by surprise, but now we’ve found a way to anticipate these events,” says Arik Posner, a physicist in NASA’s Science Mission Directorate, Washington. Posner is on temporary assignment to NASA from Southwest Research Institute, San Antonio. Posner developed the technique. His study appears in a recent issue of the journal Space Weather.

Solar radiation storms are swarms of electrons, protons and heavy ions accelerated to high speed by explosions on the sun. On Earth, humans are protected from these particles by Earth’s atmosphere and magnetic field. Astronauts in Earth orbit also are protected since Earth’s magnetic field extends far enough to shield them. Solar radiation storms are a potential risk factor for astronauts working on the surface of the moon or Mars since neither has a substantial magnetic field.

”A one hour warning would reduce the odds of being caught in a solar storm outside of a lunar habitat, where astronauts are most vulnerable,” says Francis Cucinotta, chief scientist for the NASA Space Radiation Program at NASA’s Johnson Space Center, Houston.

Spacecraft and satellites would also benefit. Subatomic particles striking computer processors and other electronics can cause onboard computers to suddenly reboot or issue nonsense commands. If a satellite operator knows that a storm is coming, the craft can be placed in a protective ”safe mode” until the storm passes.

The type of particle most feared by safety experts is the ion, an atom that has lost one or more of its charge-balancing electrons. Energetic ions can damage tissue and break strands of DNA, an effect not fully understood in terms of human disease.

The goal of researchers is to forecast when the ions will arrive. ”The key is electrons. They are always detected ahead of the more dangerous ions,” says Posner. While this has been known for years, only recently has this research turned the ”electrons first” aspect of radiation storms into a tool for forecasting.

Every radiation storm is a mix of electrons, protons and heavier ions. The electrons, being lighter and faster than the others, race out ahead. By measuring the ”rise time and intensity of the initial electron surge” Posner could predict how many ions were following and when they would arrive.

The key to the breakthrough was the Comprehensive Suprathermal and Energetic Particle Analyzer (COSTEP) instrument on board the observatory. COSTEP counts particles coming from the sun and measures their energies. Posner looked at hundreds of radiation storms recorded by COSTEP between 1996 and 2002, and was able to construct an empirical, predictive matrix that involved plugging an electron data into the matrix, and an ion forecast emerging.

After testing the results, the matrix was used on COSTEP data gathered in 2003, a year not yet analyzed and which formed no part of the matrix itself. The matrix was applied to the electron data and as a result, it successfully predicted all four major ion storms of 2003 with advance warnings ranging from 7 to 74 minutes.

”While the method is not yet perfect, I’d like to improve that,” Posner says. Improvements will come as Posner works his way through even more of COSTEP’s dataset.

”Launched with SOHO in 1995, COSTEP has been operating through an entire solar cycle including the recent solar maximum in 2001, and it is still going strong,” says Prof. Bernd Heber, COSTEP’s principle investigator at the University of Kiel, Germany.

The method is being considered by planners at the Johnson Space Center in their design of future lunar missions. ”Posner’s technique reduces the odds of exposure by more than 20 percent compared to current methods, allowing astronauts to venture farther from their outpost. That’s good for both science and exploration,” says Cucinotta.

”NASA’s Vision for Space Exploration will lead humans away from Earth’s protective magnetic cocoon and into the unprotected seas of outer space,” says Posner. ”New scientific knowledge concerning basic processes of space will ensure safe, effective achievement of NASA’s future space exploration activities.”

1.3 Cluster makes a shocking discovery

Source: ESA Press Release, May 14th, 2007 [3]

ESA’s Cluster was in the right place and time to make a shocking discovery. The four spacecraft encountered a shock wave that kept breaking and reforming predicted only in theory. On 24 January 2001, Cluster’s spacecraft observed shock reformation in the Earth’s magnetosphere, predicted only in theory, over 20 years ago. Cluster provided the first opportunity ever to observe such an event, the details of which have been published in a paper on 9 March this year.

The shock wave that sits above the Earth's surface is a natural phenomenon. It is located on the side facing the Sun, at approximately one quarter of the distance to the Moon, and is caused by the flow of electrically charged particles from the Sun.

This flow of electrically charged particles known as solar wind is emitted in a gusty manner by the Sun. When it collides with the Earth's magnetic field, it is abruptly slowed down and this causes a barrier of electrified gas, called the bow shock, to build up. It behaves in the same way as water being pushed out of the way by the front of a ship.

On 24 January 2001, the four Cluster spacecraft were flying at an approximate altitude of 105 000 kilometres, in tetrahedron formation. Each spacecraft was separated from the others by a distance of about 600 kilometres. With such a distance between them, as they approached the bow shock, scientists expected that every spacecraft would record a similar signature of the passage through this region.

Instead, the readings they got were highly contradictory. They showed large fluctuations in the magnetic and electric field surrounding each spacecraft. They also revealed marked variations in the number of solar wind protons that were reflected by the shock and streaming back to Sun.

"The features derived from three different scientific experiments on the Cluster satellites provide the first convincing evidence in favour of the shock reformation model," says Vasili Lobzin of the Centre National de la Recherche Scientifique, Orlans, France, who headed this study.

Vladimir Krasnoselskikh, also of the Centre National de la Recherche Scientifique, Orlans, France, who is a collaborator on this new research, had predicted the shock reformation model theoretically in 1985. It is a little similar to the way waves in the ocean build up and then break onto the shore, only to reform again, some way out to sea.

The detection has implications for the way astronomers investigate larger bow shocks around distant celestial objects. Bow shocks are related to some of the most energetic events in the Universe. Exploding stars and strong stellar winds from young stars cause them. Reforming bow shocks can also accelerate particles to extremely high energies and throw them across space.

Although the conditions that cause the reformation of a shock wave are rare around the Earth, they are common around these other celestial objects. "In astrophysical situations, the conditions needed for the bow shock to overturn and reform is almost always met," says Krasnoselskikh.

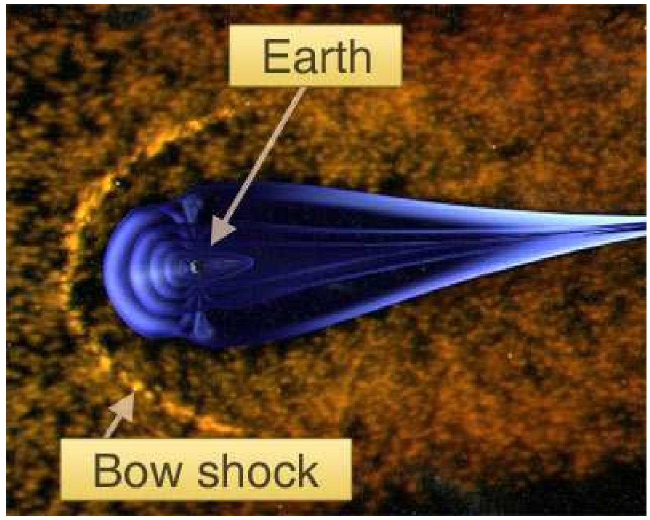


Figure 2: *This artist's impression shows a sketch of Earth's magnetosphere (in blue), embedded in the flow of the solar wind. Due to the interaction of permanently incoming solar wind (coming from the left of the figure) with Earth's magnetosphere, a permanent collisionless shock called the bow shock (depicted by the yellow arc) is formed. The bow shock forms in front of the nose of the magnetopause the external boundary layer of the magnetosphere. Credits: ESA*

The fact that Cluster has given scientists their first concrete data from such a bow shock reformation event is a valuable gift to space physicists. "This is a unique opportunity to study distant astrophysical objects in the kind of detail not available in any laboratory," says Krasnoselskikh.

"Understanding the physics of shocks is essential for comprehending both complex astrophysical phenomena and accurately forecasts of the nearby space environment," says Philippe Escoubet, Cluster and Double Star project scientist at ESA. "Once again Cluster has demonstrated the need for formation flying with multiple spacecraft to augment our knowledge of shocks."

1.4 Windows onto the abyss: cave skylights on Mars

Source: The Planetary Society Weblog, May 23rd, 2007 [4]

Today's set of image releases from the Mars Reconnaissance Orbiter HiRISE team included this one, of a fairly bland-looking lava plain to the northeast of Arsia Mons. Bland, that is, except for a black spot in the center. What's that black spot? It's a window onto an underground world.

This black spot is one of seven possible entrances to subterranean caves identified on Mars by Glen Cushing, Tim

Titus, J. Judson Wynne and Phil Christensen in a paper they presented at the Lunar and Planetary Science Conference in March (PDF format, 322k). Here's the figure from their paper that shows the seven caves, which they refer to by the names Dena, Chloe, Wendy, Annie, Abbey, Nikki, and Jeanne.

Their identifications were based upon Mars Odyssey THEMIS images, which achieve resolutions of a little better than 20 meters per pixel; having spotted the caves, they requested that the sharper-eyed HiRISE camera on Mars Reconnaissance Orbiter target the spots for more detailed imaging. The image above is the first one of these, and it shows the cave entrance called Jeanne. So what more can we learn from the HiRISE image? Let's check it out at full resolution (you'll have to click to enlarge for the full glory of 25 centimeters per pixel, a number I still goggle at every time I think about it).

The hope for the HiRISE images was that we could see some details from inside the hole. But as you can see by the highly stretched version at right, there is absolutely nothing visible inside that hole. It's black black black black black. HiRISE is a very sensitive instrument, and Mars' dusty atmosphere scatters quite a bit of light around, so there is certainly light entering that cave hole and bouncing around the interior. But it seems that the cave is so big and so deep that almost none of the light that enters the cave comes out. It's deep, and it's big; the hole that we see really is just a skylight on a big subterranean room. How big? We'll never know for sure without visiting it, but I expect that Cushing and his coauthors and the HiRISE team will be crunching the numbers on the illumination conditions and the sensitivity of the camera to put a lower limit on how deep that cave must be for HiRISE to be able to see nothing at all inside it.

Think about that. All these orbiters at Mars, and most of them are just seeing the surface and atmosphere. To be sure, there are two instruments up there – MARSIS on Mars Express and SHARAD on Mars Reconnaissance Orbiter – that are probing the shape of the subsurface with ground-penetrating radar. But neither of those instruments have the resolution necessary to tell us what the inside of this cave looks like. It might as well be in the greatest depths of space. Here there be dragons. What's down there? Are there stalactites and stalagmites and crystals, or is it just a vast open room or tunnel?

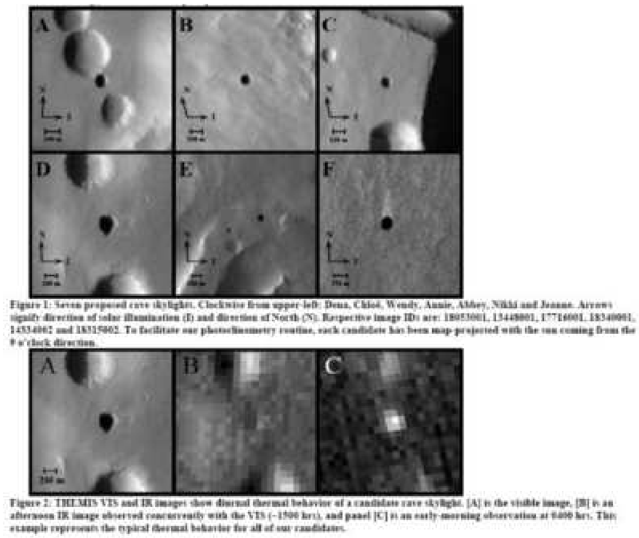


Figure 3:

Maybe these spots will be explored by Martian speleologists someday. But that day is a distant one, I'm sure. Earth speleologists are only now exploring some of the biggest holes in our world.

1.5 Mars Rover Spirit Unearths Surprise Evidence of Wetter Past

Source: JPL/NASA News Release, May 21st, 2007 [5]

A patch of Martian soil analyzed by NASA's rover Spirit is so rich in silica that it may provide some of the strongest evidence yet that ancient Mars was much wetter than it is now. The processes that could have produced such a concentrated deposit of silica require the presence of water.

Members of the rover science team heard from a colleague during a recent teleconference that the alpha particle X-ray spectrometer, a chemical analyzer at the end of Spirit's arm, had measured a composition of about 90 percent pure silica for this soil.

"You could hear people gasp in astonishment," said Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for the Mars rovers' science instruments. "This is a remarkable discovery. And the fact that we found something this new and different after nearly 1,200 days on Mars makes it even more remarkable. It makes you wonder what else is still out there."

Spirit's miniature thermal emission spectrometer observed the patch, and Steve Ruff of Arizona State University, Tempe, noticed that its spectrum showed a high silica content. The team has laid out plans for further study of the soil patch and surrounding deposits.

Exploring a low range of hills inside a Connecticut-sized basin named Gusev Crater, Spirit had previously found other indicators of long-ago water at the site, such as patches of water-bearing, sulfur-rich soil; alteration of minerals; and evidence of explosive volcanism.

"This is some of the best evidence Spirit has found for water at Gusev," said Albert Yen, a geochemist at NASA's Jet Propulsion Laboratory, Pasadena, Calif. One possible origin for the silica could have been interaction of soil with acid vapors produced by volcanic activity in the presence of water. Another could have been from water in a hot spring environment. The latest discovery adds compelling new evidence for ancient conditions that might have been favorable for life, according to members of the rover science team.

David Des Marais, an astrobiologist at NASA's Ames Research Center, Moffett Field, Calif., said, "What's so exciting is that this could tell us about environments that have similarities to places on Earth that are clement for organisms."

Spirit and its twin rover, Opportunity, completed their original three-month prime missions in April 2004. Both are still operating, though showing signs of age. One of Spirit's six wheels no longer rotates, so it leaves a deep track as it drags through soil. That churning has exposed several patches of bright soil, leading to some of Spirit's biggest discoveries at Gusev, including this recent discovery.

Doug McCuistion, director of NASA's Mars Exploration Program, said, "This unexpected new discovery is a reminder that Spirit and Opportunity are still doing cutting-edge exploration more than three years into their extended missions. It also reinforces the fact that significant amounts of water were present in Mars' past, which continues to spur the hope that we can show that Mars was once habitable and possibly supported life."

The newly discovered patch of soil has been given the informal name "Gertrude Weise," after a player in the All-American Girls Professional Baseball League, according to Ray Arvidson of Washington University in St. Louis, deputy principal investigator for the rovers.

"We've looked at dozens of disturbed soil targets in the rover tracks, and this is the first one that shows a high silica signature," said Ruff, who last month proposed using Spirit's miniature thermal emission spectrometer to observe this soil. That instrument provides mineral composition information about targets viewed from a distance. The indications it found for silica in the overturned soil prompted a decision this month to drive Spirit close enough to touch the soil with the alpha particle X-ray spectrometer. Silica commonly occurs on Earth as the crystalline mineral quartz and is the main ingredient in window glass. The Martian silica at the Gertrude Weise patch is non-crystalline, with no detectable quartz.

Figure 4: *NASA's Spirit rover has found a patch of bright-toned soil so rich in silica that scientists propose water must have been involved in concentrating it. Image credit: NASA/JPL/Cornell*

Spirit worked within about 50 yards or meters of the Gertrude Weise area for more than 18 months before the discovery was made. "This discovery has driven home to me the value of in-depth, careful exploration," Squyres said. "This is a target-rich environment, and it is a good thing we didn't go hurrying through it."

Meanwhile, on the other side of the planet, Opportunity has been exploring Victoria Crater for about eight months. "Opportunity has completed the initial survey of the crater's rim and is now headed back to the area called Duck Bay, which may provide a safe path down into the crater," said John Callas, project manager for the rovers at JPL.

1.6 Sharp Views Show Ground Ice on Mars Is Patchy and Variable

Source: NAS News. May 2nd, 2007 [6]

Using observations by NASA's Mars Odyssey orbiter, scientists have discovered that water ice lies at variable depths over small-scale patches on Mars.

The findings draw a much more detailed picture of underground ice on Mars than was previously available. They suggest that when NASA's next Mars mission, the Phoenix Mars Lander, starts digging to icy soil on an arctic plain in 2008, it might find the depth to the ice differs in trenches just a few feet apart. The new results appear in the May 3, 2007, issue of the journal Nature.

"We find the top layer of soil has a huge effect on the water ice in the ground," said Joshua Bandfield, a research specialist at Arizona State University, Tempe, and author of the paper. His findings come from data sent back to Earth by the Thermal Emission Imaging System camera on Mars Odyssey. The instrument takes images in five visual bands and 10 heat-sensing (infrared) ones.

The new results were made using infrared images of sites on far-northern and far-southern Mars, where buried water ice within an arm's length of the surface was found five years ago by the Gamma Ray Spectrometer suite of instruments on Mars Odyssey. The smallest patches detectable by those instruments are several hundred times larger than details detectable by the new method of mapping depth-to-ice, which sees differences over scales of a few hundred yards or meters.

The new approach uses thermal imaging as a thermometer to measure how fast the ground changes temperature during local spring, summer and fall. The dense, icy layer retains heat better than the looser soil above it, so where the icy layer is closer to the surface, the surface temperature changes more slowly than where the icy layer is buried deeper.

The resulting maps show that the nature of the surface soil makes a difference in how close to the surface the ice lies. Areas with many rocks at the surface, Bandfield explained, "pump a lot of heat into the ground and increase the depth where you'll find stable ice." In contrast, dusty areas tend to insulate the ice, allowing it to survive closer to the surface. "These two surface materials – rock and dust – vary widely across the ground, giving underground ice a patchy distribution," he said.

Computer models helped him interpret the temperature observations, he said. "They show areas where water ice would be only an inch or so under the soil, while in other areas ice could lie many feet below the surface."

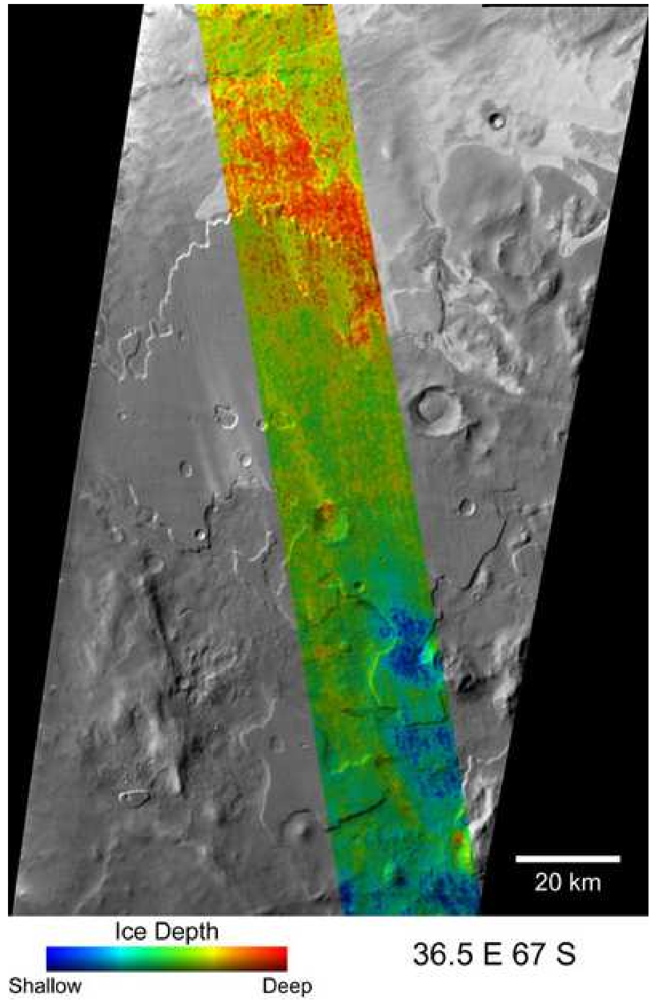


Figure 5: *This color-coded map indicates the depth to icy layers at a site in southern Mars. The dense, icy layer retains heat better than the looser soil above it, so where the icy layer is closer to the surface, the surface temperature changes more slowly than where the icy layer is buried deeper. Image credit: NASA/JPL/ASU*

The results fit long-term climatic models for Mars. These show the planet has been both warmer and colder in the past, similar to glacial cycles on Earth. Bandfield said, "The fact that ice is present near the depth of stability in the current Martian climate shows that the ground ice is responding to climate cycles." In turn, he added, this implies that water ice in the ground can swap places with water vapor in the atmosphere as the climate changes.

Philip Christensen of Arizona State University, Tempe, principal investigator for the Thermal Emission Imaging System, said, "Scientists have known for more than a decade that water is on Mars, mostly in the form of ice. What's exciting is finding out where the ice is in detail and how it got there. We've reached the next level of sophistication in our questions."

1.7 Generating pressures at the cores of giant planets

Source: UV Berkeley Press Release, May 2nd, 2007 [7]

Combining diamond anvils and powerful lasers, laboratory researchers have developed a technique that should be able to squeeze materials to pressures 100 to 1,000 times greater than possible today, reproducing conditions expected in the cores of supergiant planets.

Until now, these pressures have only been available experimentally next to underground nuclear explosions.

"This lets us explore a new regime of chemistry and reproduce the conditions of more extreme planets," said Raymond Jeanloz, a professor of astronomy and of earth and planetary science at the University of California, Berkeley.

Jeanloz and colleagues at Lawrence Livermore National Laboratory (LLNL), New Mexico State University and France's Atomic Energy Commission report their development in this week's online edition of the Proceedings of the National Academy of Sciences.

To date, Jeanloz and his colleagues have achieved pressures near 10 million atmospheres using the 30 kilojoule ultraviolet Omega laser at the University of Rochester's Laboratory for Laser Energetics in New York. They hope eventually to use the 2 megajoule laser of LLNL's National Ignition Facility to achieve more than a billion atmospheres of pressure.

Jeanloz was instrumental in the development 25 years ago of diamond anvil cells, which squeeze liquids and solids to pressures of 4 to 5 million atmospheres, slightly higher than the pressure at the center of the Earth. With diamond anvils, the temperature as well as pressure can be varied, and experimenters can study the compressed samples for long periods.

Laser-induced shock waves can produce tens of millions of atmospheres, but only for a split-second and at very high temperatures. This technique also requires lasers the size of a building.

"By combining the two, we can get to higher pressures and much higher densities than either of the methods alone," Jeanloz said. "High density is really important, because we are trying to understand what happens as you bring atoms really close together, and compare our observations to quantum mechanical calculations."

The combined methods also allow experimenters to tune the temperature over a wide range independent of density, something almost impossible to do with laser-induced shock waves alone. Though this is possible in diamond anvil cells, studying a tiny hot sample is challenging, according to Jeanloz.

With the development of techniques to reach high pressures, scientists are discovering an entirely new realm of chemistry, Jeanloz said.

"When we squeeze materials to a million atmospheres pressure, the chemistry is changed dramatically," he said. "Materials go from being transparent insulators to becoming metallic or even superconducting. The periodic table is completely changed at high pressures.

"There is reason to expect that when we go from the million atmosphere range to the billion atmosphere range, again there will be huge changes in chemical bonding and material properties."

Some of the most dramatic discoveries have involved the composition of material inside Earth. Diamond anvil experiments have shown that the most dominant mineral in Earth's mantle is perovskite, a combination of magnesium, silicon and oxygen formed only at extremely high-pressures, above 100,000 atmospheres. Jeanloz has shown through similar experiments that Earth's rocky mantle dissolves into the liquid metal core where they meet at the core-mantle boundary, about 1,800 miles under our feet.

An interest in even higher pressures comes as astronomers have discovered more than 200 planets outside our solar system, most of them giant planets and supergiant planets tens or hundreds of times bigger than Jupiter.

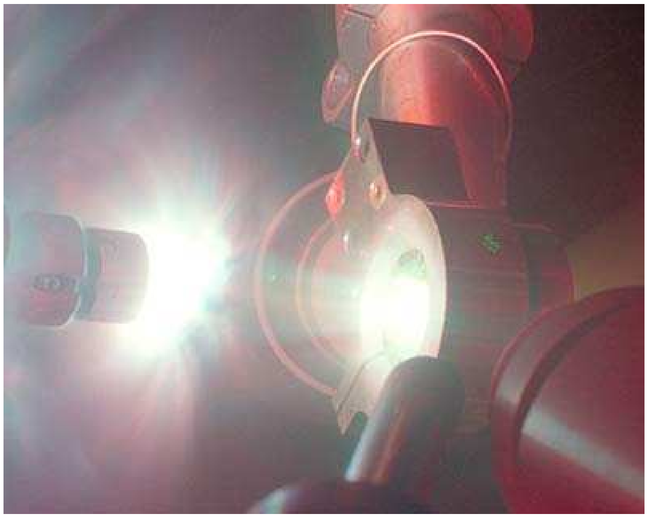


Figure 6: *A laser vaporizes a diamond cell, inducing a shock wave that produces pressures over 10 million times atmospheric pressure, greater than the pressure at Earth's core. The experiment was conducted at the Omega laser facility operated by the University of Rochester in New York. (Raymond Jeanloz/UC Berkeley)*

"The center of Jupiter is at about 70 million atmospheres," which until now has been inaccessible, Jeanloz said. "We want to be able to understand the hundreds of planets that have now been found that are massive enough that their central pressures are many hundreds of millions of atmospheres, and maybe a billion atmospheres."

In a diamond anvil, a tiny sample - either liquid or solid - is compressed between the tips of two diamonds. In the combined technique, several powerful laser beams zap one of the diamonds, vaporizing it and sending a shock wave through the sample that compresses it even more. The shock wave compresses the sample for 1 to 2 nanoseconds, enough time to study the properties of the sample, which can range from hydrogen and helium, the stuff of stars and giant planets, to elements that comprise Earth.

1.8 Cassini 'Cat Scan' Maps Clumps in Saturn's Rings

Source: JPL/NASA Press Release, May 22nd, 2007 [8]

Saturn's largest and most densely packed ring is composed of tightly packed clumps of particles separated by nearly empty gaps, according to new findings from NASA's Cassini spacecraft.

These clumps in Saturn's B ring are neatly organized and constantly colliding, which surprised scientists.

"The rings are different from the picture we had in our minds. We originally thought we would see a uniform cloud of particles. Instead we find that the particles are clumped together with empty spaces in between," said Larry Esposito, principal investigator for the Cassini ultraviolet imaging spectrograph at the University of Colorado, Boulder. "If you were flying under Saturn's rings in an airplane, you would see these flashes of sunlight come through the gaps, followed by dark and so forth. This is different from flying under a uniform cloud of particles."

Because previous interpretations assumed the ring particles were distributed uniformly, scientists underestimated the total mass of Saturn's rings. The mass may actually be two or more times previous estimates.

"These results will help us understand the overall question of the age and hence the origin of Saturn's rings," said Josh Colwell, assistant professor of physics at the University of Central Florida, Orlando, and a team member of the Cassini ultraviolet imaging spectrograph. A paper with these results appears in the journal Icarus.

Scientists observed the brightness of a star as the rings passed in front of the star on multiple occasions. This provided a measurement of the amount of ring material between the spacecraft and the star.

"Combining many of these occultations at different viewing geometries is like doing a CAT scan of the rings," said Colwell. "By studying the brightness of stars as the rings pass in front of them, we are able to map the ring structure in 3-D and learn more about the shape, spacing and orientation of clusters of particles."

The observations confirm that the gravitational attraction of ring particles to each other creates clumps, or "self-gravity wakes." If the clumps were farther from Saturn, they might continue to grow into a moon. But because these clumps are so close to Saturn, their different speeds around the planet counteract this gravitational attraction so that the clumps get stretched like taffy and pulled apart. The clumps are constantly forming and coming apart once they reach about 30 to 50 meters (about 100 to 160 feet) across.

"At any given time, most particles are going to be in one of the clumps, but the particles keep moving from clump to clump as clumps are destroyed and new ones are formed," added Colwell.

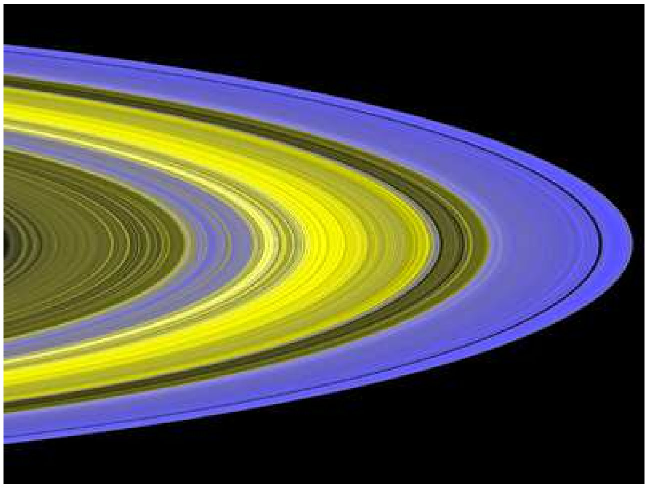


Figure 7: *This false-color image of Saturn's main rings was made by combining data from multiple star occultations using the Cassini ultraviolet imaging spectrograph. Image credit: NASA/JPL/University of Colorado*

In the dense B ring, the classical cloud model of the rings predicted that particles collide about twice per hour on average. "Our results show that the particles in the B ring spend most of their time in almost continuous contact with other particles," said Colwell. These clumps may act like supersized particles, changing the way the rings spread due to collisions.

The clumps are seen in all regions of the B ring that are not opaque. One surprising aspect of the measurements is that the clumps in the B ring are broad and very flat, like big sheets of particles. They are roughly 10 to 50 times wider than they are thick. Scientists are also surprised that the B ring clumps are flatter and have smaller spaces between them than those found in the neighboring A ring.

A picture of the rings based on these results is available at: [9] [10] and [11] .

1.9 Frictional heating explains plumes on Saturn's moon Enceladus

Source: UC Santa Cru News, May 16th, 2007 [12]

Rubbing your hands together on a cold day generates a bit of heat, and the same process of frictional heating may be what powers the geysers jetting out from the surface of Saturn's moon Enceladus.

Tidal forces acting on fault lines in the moon's icy shell cause the sides of the faults to rub back and forth against each other, producing enough heat to transform some of the ice into plumes of water vapor and ice crystals, according to a new study published in the May 17 issue of the journal Nature.

Francis Nimmo, assistant professor of Earth and planetary sciences at the University of California, Santa Cruz, and his coauthors calculated the amount of heat that could be generated by this mechanism and concluded that it is the most likely explanation for the plumes and other features observed in the south polar region of Enceladus. This region is warmer than the rest of the frozen surface of Enceladus and has features called "tiger stripes" that look like tectonic fault lines.

"We think the tiger stripes are the source of the plumes, and we made predictions of where the tiger stripes should be hottest that can be tested by future measurements," Nimmo said.

Driving the whole process is the moon's eccentric orbit, which brings it close to Saturn and then farther away, so that the gravitational attraction it feels changes over time.

"It's getting squeezed and stretched as it goes around Saturn, and those tidal forces cause the faults to move back and forth," Nimmo said.

Unlike some other proposals for the origin of the plumes, this mechanism does not require the presence of liquid water near the surface of Enceladus, noted coauthor Robert Pappalardo of NASA's Jet Propulsion Laboratory in Pasadena.

"The heat is sufficient to cause ice to sublimate, like in a comet–the ice evaporates into vapor, and the escaping vapor drags particles off into space," Pappalardo said.

The study does suggest, however, that Enceladus has a liquid ocean lying deep beneath the ice. That allows the ice shell to deform enough to produce the necessary movement in the faults. If the ice shell sat directly on top of the moon's rocky interior, tidal forces would not produce enough movement in the faults to generate heat, Nimmo said.

The frictional or "shear heating" mechanism is consistent with an earlier study by Nimmo and Pappalardo, in which they proposed that Enceladus reoriented itself to position the hot spot at the south pole (see earlier press release). In that study, the researchers described how the reorientation of Enceladus would result from a lower density of the thick ice shell in this region.

In the new paper, the researchers estimated the thickness of the ice shell to be at least 5 kilometers (3 miles) and probably several tens of kilometers or miles. They also estimated that the movement along the fault lines is about half a meter over the course of a tidal period.

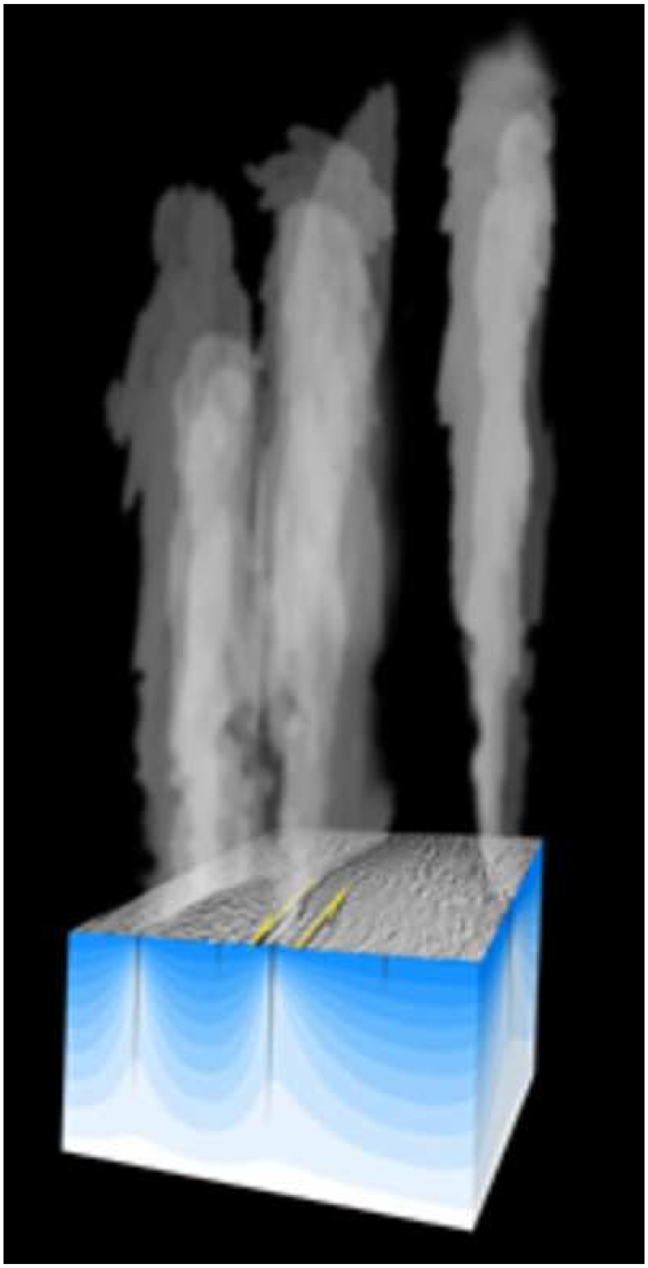


Figure 8: *Plumes of water vapor and other gases escape at high velocity from the surface of Enceladus, as shown in this artist concept. Credit: NASA/JPL.*

In addition to Nimmo and Pappalardo, the coauthors of the paper include John Spencer of the Southwest Research Institute in Boulder, Colorado, and McCall Mullen of the University of Colorado, Boulder. This study was funded by NASA's Planetary Geology and Geophysics and Outer Planets research programs.

Enceladus has sparked great interest among scientists, particularly since the discovery more than a year ago by NASA's Cassini spacecraft of the geysers shooting off its surface. This is one of two papers about Enceladus appearing in the May 17 issue of Nature. In the other paper, scientists explain how cracks in the icy surface of Enceladus open and close under Saturn's pull. Saturn's tides could control the timing of the geysers' eruptions, researchers suggest.

1.10 Cassini spacecraft reveals evidence of tholin formation at high altitudes in Titan's atmosphere

Source: SwRI News, May 10th, 2007 [13]

Scientists have long known that the lower atmosphere of Saturn's moon Titan contains organic aerosols, or tholins, formed from simple organic molecules, such as methane and nitrogen. Researchers had assumed these tholins formed at altitudes of several hundred kilometers, but new information gathered by three particle spectrometers aboard the Cassini spacecraft shows tholin formation happens in Titan's atmosphere at altitudes greater than 1,000 kilometers. The results also show tholins form differently than previously thought.

Scientists at Southwest Research Institute (SwRI), the University of Kansas, University College London and The University of Texas at San Antonio report results of the observations in the paper "The Process of Tholin Formation in Titan's Upper Atmosphere," published in the May 11 issue of Science.

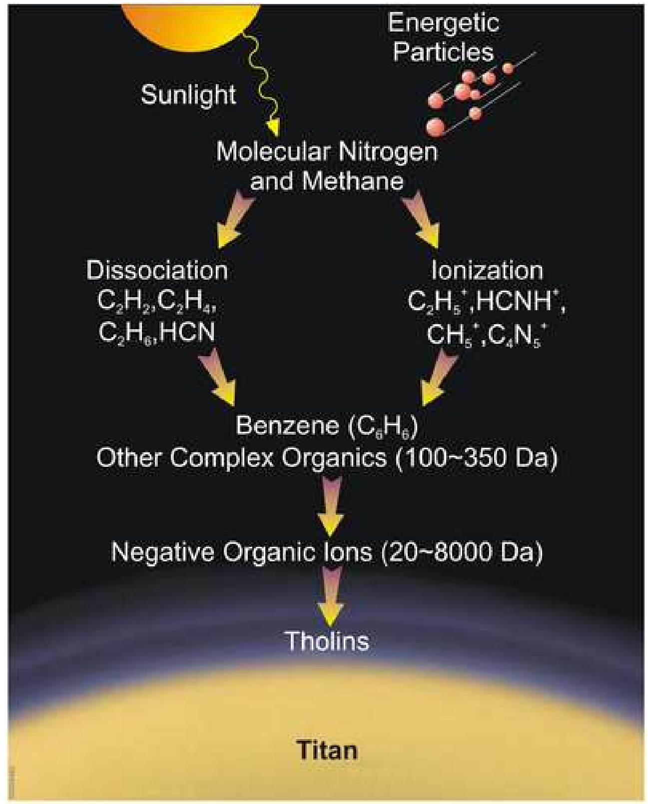
"Tholins are very large, complex organic molecules thought to include chemical precursors to life," said Dr. Hunter Waite, an Institute scientist in SwRI's Space Science and Engineering Division, and leader of Cassini's Ion Neutral Mass Spectrometer (INMS) team. ""Understanding how they form could provide valuable insight into the origin of life in the solar system."

During Cassini's first encounters with Titan, the INMS revealed an atmosphere dominated by nitrogen and methane. Of significance from measurements taken in later flybys, however, was the detection of benzene, a critical component in the formation of aromatic hydrocarbon compounds. At the same time, two other Cassini sensors that are part of the Cassini Plasma Spectrometer (CAPS) investigation, the Ion Beam Spectrometer (IBS) and Electron Spectrometer (ELS), measured large positive and negative ions.

"The negative ions were a complete surprise," said Dr. David Young, also an SwRI Institute scientist, and leader of the CAPS investigation. "This suggests they may play an unexpected role in making tholins from carbon-nitrogen precursors."

"An additional surprising point is the large numbers of negative ions we see during Cassini's lowest flybys above the surface," said Dr. Andrew Coates, a researcher at the Mullard Space Science Laboratory, University College London. "This newly discovered, and important, population represents a highly significant proportion of the whole ionosphere at these locations."

"Our analysis suggests that the organic compounds are formed through ion-neutral chemical processes, which then give rise to the complex negative ions found by the ELS," Waite added.



Tholin formation in Titan's upper atmosphere

Figure 9:

2 Astrophysics

2.1 XO-3b: Supersized planet or oasis in the 'brown dwarf desert'?

Source: Rice University News, May 30th, 2007 [14]

The latest find from an international planet-hunting team of amateur and professional astronomers is one of the oddest extrasolar planets ever cataloged – a mammoth orb more than 13 times the mass of Jupiter that orbits its star in less than four days.

Researchers from the U.S.-based XO Project unveiled the planet, XO-3b, at today's American Astronomical Society meeting in Honolulu. Christopher Johns-Krull, a Rice University astronomer and presenter of the team's results, said, "This planet is really quite bizarre. It is also particularly appropriate to be announcing this find here, since the core of the XO project is two small telescopes operating here in Hawaii."

"Of the 200-plus exoplanets found so far, XO-3b is an oddity in several respects," said XO Project director Peter McCullough, an astronomer at the Space Telescope Science Institute in Baltimore. "It's the largest and most massive planet yet found in such a close orbit, and given the proximity of the orbit to the star, we were surprised to find that the orbit is not circular but significantly elliptical."

Given all its eccentricities, XO-3b is likely to pique the interest of astronomers who study planet formation, McCullough said.

"We are intrigued that its mass is on the boundary between planets and 'brown dwarfs,'" Johns-Krull said, "There's still a lively debate among astronomers about how to classify brown dwarfs." Any stellar mass that's large enough to fuse hydrogen – anything more than about 80 Jupiter masses – is a star. Brown dwarfs are massive objects that fall short of being stars.

"The controversy lies at the lower end of the scale," said Johns-Krull, an assistant professor of physics and astronomy at Rice. "Some people believe anything capable of fusing deuterium, which in theory happens around 13 Jupiter masses, is a brown dwarf. Others say it's not the mass that matters, but whether the body forms on its own or as part of a planetary system."

By virtue of their mass, any planet big enough to contend for brown dwarf status should be easy for most planet hunters to spot. That's because astronomers don't actually look for planets when they scan the sky; they generally look for stars that wobble due to the gravitational pull of planets orbiting around them. The larger the planet, the more wobble it creates, so planet hunters using this "radial velocity" method expected to find a lot of brown dwarfs when they started scanning the sky for wobbling stars a decade ago. That hasn't happened, and the dearth of supersized objects has become known in the field as the "brown dwarf desert."

What also makes XO-3b intriguing is the fact that it's a "transiting planet," meaning it passes in front of its star during each orbit. Fewer than two dozen transiting planets have been identified, and XO-3b is the third found by the XO Project, which was designed specifically to look for them.

The XO Project benefits from its partnership between professional and amateur astronomers. The XO Project begins its search with a telescope located on Haleakala summit operated by the Institute for Astronomy of the University of Hawaii. The telescope is created from two commercially available 200-millimeter telephoto camera lenses. Using the Haleakala telescope, XO's professional team first identifies candidate stars that dim ever so slightly from time to time. XO's amateur astronomers observe these candidates over time and look for further evidence that the dimming is due to a transiting planet. Once enough evidence is in place, the professional team uses large telescopes – the 2.7-meter Harlan J. Smith Telescope and the 11-meter Hobby-Ebberly Telescope, both at the University of Texas McDonald Observatory in West Texas – to confirm the presence of a transiting planet.

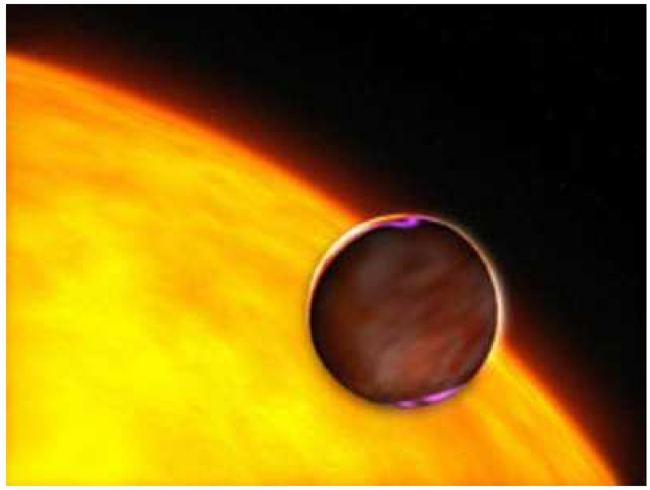


Figure 10: *Newly discovered planet XO-3b is similar to XO-1b, which was featured in this artist's representation in 2006*

"There are many astrophysical systems out there that mimic transiting planets," McCullough said. "The only way to sort out the real planets from the rest is to observe the stars more carefully. Observation time on big telescopes is scarce, and that's where our amateur partners come in, culling our long lists of candidates down to more manageable size to observe with the big telescopes. The XO Project benefits enormously from the clear skies of Haleakala and the availability of telescopes such as the Hobby-Ebberly, Spitzer, and Hubble and their capable staffs that operate them. The global reach and dedication of our amateur collaborators is especially noteworthy.

"I like to point out that Olympic athletes are amateurs too," McCullough said.

2.2 Discovery Narrows the Gap Between Planets and Brown Dwarfs

Source: Gemini Observatory Press Release, May 30th, 2007 [15]

The coolest-known star-like object beyond the solar system is giving astronomers a new look at the differences between massive planets and the smallest brown dwarfs. This newly discovered object, called ULAS J0034-00 and located in the constellation Cetus, has a record-setting surface temperature of 600-700 K, cooler than any known solitary brown dwarf. In addition, it's a relative lightweight, with an estimated mass of only 15-30 times that of Jupiter (although they both have about the same diameter).

The finding was announced today at the 210th American Astronomical Society meeting in Honolulu, Hawai'i, by an international team of astronomers that used the United Kingdom Infrared Telescope (UKIRT) and made followup observations with Gemini Observatory's Near Infrared Spectrograph (GNIRS) on Gemini South. Their discovery suggests that even lower-mass objects could be found. If so, they would continue to shrink the boundary between high-mass planets and the smallest brown dwarfs.

J0034 was discovered in the very early stages of the UKIRT Infrared Deep Sky Survey (UKIDSS)the world's deepest-ever near-infrared sky surveyusing an instrument called the Wide Field Camera (WFCAM). The brown dwarf is particularly remarkable since it has a lower temperature than any such object previously discovered. According to team leader Steve Warren of Imperial College London, "Only planets are cooler, and they are by definition bound to a parent star."

The discovery was initiated by post-doctoral researcher Daniel Mortlock, who first noticed the unusual object in the UKIRT survey images. "Identifying an object like J0034-00 is a more challenging version of finding a needle in a haystack," said Mortlock. "In this case it was like looking for a piece of slightly reddish straw rather than a nice shiny needle."

Follow-up spectroscopic observations, critical for determining the brown dwarf's temperature and likely mass were obtained with the Gemini South Telescope in Chile. "The infrared spectrum of J0034 confirmed that we had found a very cool brown dwarf," said Dr. Sandy Leggett of Gemini Observatory. "However, it wasn't until we made a detailed study of the water steam and methane features, and compared them to other brown dwarf spectra, that we realized we had the coolest dwarf ever seen."

The final piece of the puzzle–precisely determining J0034's distance accurately by using its apparent motion due to parallax as the Earth moves in its orbitwill have to wait for a year or so. However, astronomers expect to find that it is about 50 light-years away. This is closer to Earth than many of the stars that can be seen with the naked eye, and leaves open the exciting prospect of finding additional, even cooler objects lurking in our solar neighborhood.

According to Mortlock, finding the correct distance is important. "The model brown dwarf spectra, from which we make some of our inferences about the temperature and other properties of J0034, is probably 'incomplete', in the sense that not all the effects of the molecules in the brown dwarf's atmosphere are included fully," he said. "Thus, getting a completely independent distance measure (and hence an independent luminosity) is an important final check to make sure that J0034 has the size and temperature we think it does."

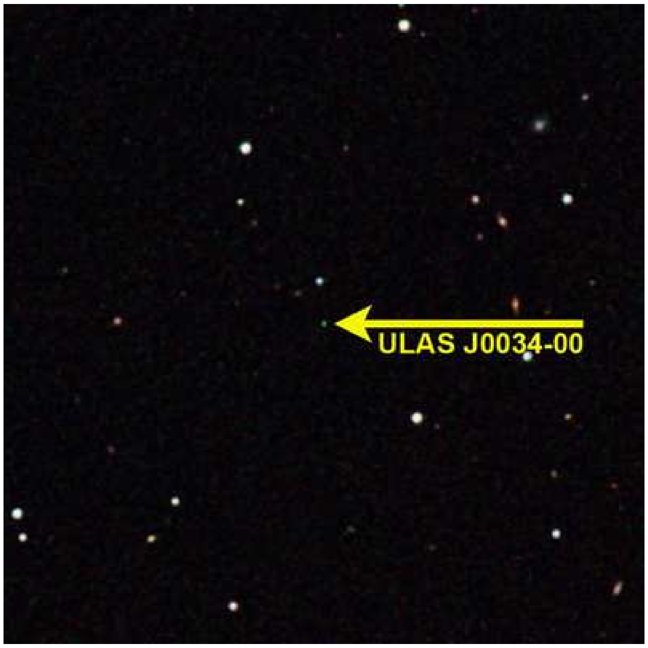


Figure 11: *Brown dwarf ULAS J0034-00. Image credit: Gemini*

J0034 was discovered in the UKIDSS survey's First Data Release (DR1), which covers only five per cent of the final survey area. Combined with the discovery of a number of hotter brown dwarfs in the same data, this implies that UKIDSS will likely discover even more exotic objects as it continues its census of the coolest stars in the solar neighborhood.

"Fully bridging the gap between stars and planets is one of the key aims of the UKIDSS survey, and it's wonderful to see these aims starting to be fulfilled at such an early stage of the survey program," said Dr. Andy Adamson, Associate Director of UKIRT.

UKIDSS is expected to be completed by 2012, by which time it will have covered almost a quarter of the sky and hopefully further explored the cool, low-mass objects that are defined somewhere between stars and planets.

2.3 Neptune-Sized Planet Covered in Super-hot Ice

Source: Universe Today, May 17th, 2007 [16]

One of the most dramatic extrasolar planetary discoveries of the year was announced this week; unfortunately, with little fanfare. Planet hunters uncovered a Neptune-sized planet orbiting a nearby star. This planet is close enough to its parent star that it's extremely hot - above 250 degrees Celsius. And yet the intense pressure from gravity forces large quantities of liquid water into solid ice.

The planet was discovered orbiting the nearby M-dwarf star GJ 436 using the planetary transit technique. This is where a sensitive instrument called a photometer measures the periodic dimming and brightening of a star as a planet passes in front. In August 2006, astronomers captured the first hint of the planet using the Observatoire Francois-Xavier Bagnoud (OFXB) observatory in St-Luc Switzerland. It was then confirmed using the Euler 1.2m telescope at La Silla Observatory in Chile.

The announcement was made in the paper Detection of transits of the nearby hot Neptune GJ 436 b, which has been accepted for publication in the journal Astronomy and Astrophysics Letters.

With more traditional planet hunting techniques, very little information can be found about the planet, other than its mass. But planetary transits offer a wealth of data. Since the light from the star dims, and the chemical composition of the light changes, astronomers can determine the planet's atmosphere by subtracting it from the star. They can measure both the mass, and the size of the planet, and measure the temperature of its surface.

According their calculations, GJ 436 b is approximately 50,000 km across; 4 times the radius of Earth, and approximately the size of Neptune. This makes is the smallest planet ever discovered using the planetary transit technique, and brings the possibility of uncovering Earth-sized planets tantalizingly closer. But unlike frigid Neptune, it orbits much closer than the orbit of Mercury, completing an orbit in just a few days. Even through the dwarf star it orbits is less luminous than our Sun, the planet orbits so close that it's heated above 250 degrees Celsius. This makes it the first "hot Neptune" ever discovered.

A planet with this amount of water ice must have formed outside the star's "snow line", where the protoplanetary disc is cool enough for water to condense. Some process must have brought it gradually closer to the parent star, to its current position today. Once the planet got close enough to the star its outer envelope of hydrogen and helium would have evaporated away, leaving the smaller icy core.

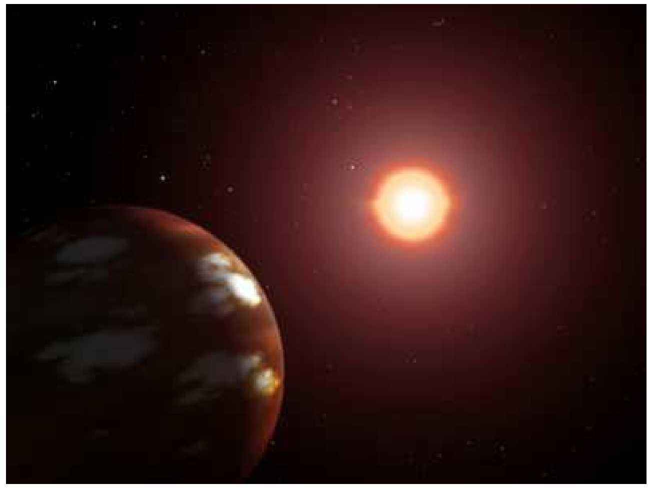


Figure 12: *Artist impression of GJ436. Image credit: NASA*

2.4 First Map of an Extrasolar Planet

Source: CfA Press Release, May 9th, 2007 [17]

For the first time, astronomers have created a rough map of a planet orbiting a distant sun-like star, employing a technique that may one day enable mapping of Earth-like worlds. Since the planet just charted is a gas giant and lacks a solid surface, the map shows cloud-top features. Using the Spitzer infrared space telescope, astronomers detected a bright hot spot that is offset from "high noon," where heating is greatest.

"We are getting our first good look at a completely alien world," said Heather Knutson, a graduate student at Harvard University and lead author of a paper about the research appearing in the May 10 issue of the journal Nature.

"We felt a little like Galileo must have felt when he first glimpsed Jupiter through the eyepiece of his telescope," Knutson continued.

Spitzer is only capable of mapping large, hot worlds - planets too hot for liquid water or life. However, the upcoming James Webb Space Telescope (scheduled for launch in 2013) may be able to map Earth-like worlds using the technique Knutson and her colleagues pioneered.

The team examined the planet, known as HD 189733b, using the Infrared Array Camera on board NASA's Spitzer Space Telescope. Infrared observations offer an advantage because the brightness difference between star and planet is lessened, making it easier to tease out the planet's signal.

Over the course of 33 hours, the team collected more than a quarter million data points. Although Spitzer could not resolve the planet into a disk, by measuring changes as the planet rotated, the team created a simple longitudinal map. That is, they measured the planet's brightness in a series of pole-to-pole strips across the planet's visible cloud-tops, then assembled those strips into an overall picture.

"We can see the changes in brightness as features in the planet's atmosphere rotate into and out of view," Knutson explained.

The map revealed a single "hot spot" that is about twice as big as the Great Red Spot on Jupiter and much hotter. The Great Red Spot is only about 30 degrees Fahrenheit warmer than its surroundings, with a temperature of -200 degrees F. In comparison, the hot spot on HD 189733b is a scorching 1700 degrees F.

Interestingly, researchers found that the hottest point on the planet is not the substellar point ("high noon" on the planet), but rather is offset by about 30 degrees longitudinally. They speculate that the shift is due to winds redistributing heat across the face of the planet.

"This planet has powerful jet streams. While Earth's jet stream blows at around 200 miles per hour, the jet stream on HD 189733b may blow as fast as 6,000 miles per hour, according to computer models," said co-author David Charbonneau (Harvard-Smithsonian Center for Astrophysics).

The distant planet's strong, hot winds may also help to keep the planet's night side warm. Without winds, the side facing the star would broil while the opposite side would freeze. However, the astronomers measured a maximum temperature difference of about 500 degrees F. The coldest regions on the night side remain a balmy 1200 degrees F.

"Every night is hot on this world," stated Knutson.

HD 189733b orbits a star slightly cooler and less massive than the Sun located about 60 light-years from Earth in the direction of the constellation Vulpecula. It is the closest known "transiting" planet to Earth.

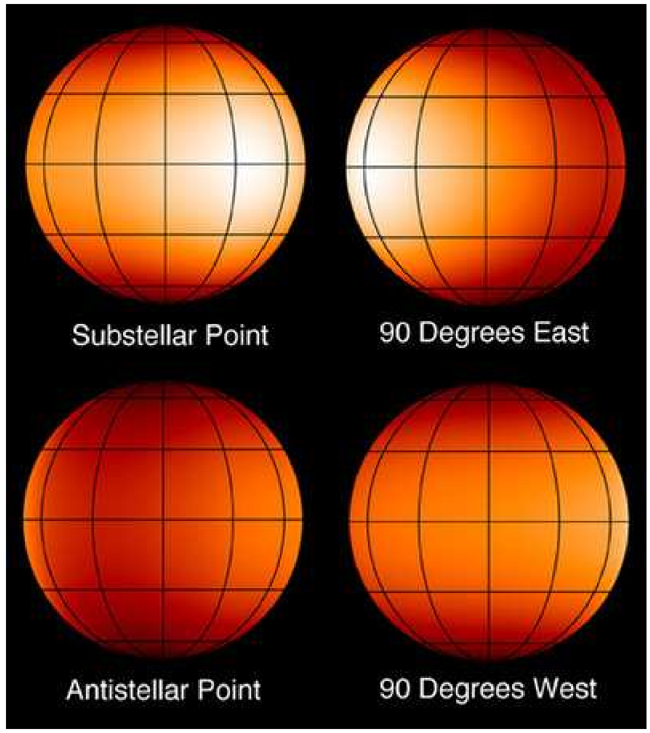


Figure 13: *Four views of the planet's cloudtops in infrared light, each centered at a point of longitude 90 degrees from the last. A grid of longitude lines is superimposed on the map. These views clearly show a hot spot that is offset from the substellar point (high noon) by about 30 degrees. The offset may indicate fast "jet stream" winds of up to 6,000 mph. Credit: NASA/JPL-Caltech/Heather Knutson (CfA)*

HD 189733b orbits its star at a distance of only three million miles, completing one revolution every 2.2 days. Its mass and physical size are both slightly larger than Jupiter.

2.5 COROT discovers its first exoplanet and catches scientists by surprise

Source: ESA Press Release, May 3rd, 2007 [18]

COROT has provided its first image of a giant planet orbiting another star and the first bit of 'seismic' information on a far away, Sun-like star, with unexpected accuracy. The unanticipated level of accuracy of this raw data shows that COROT will be able to see rocky planets - perhaps even as small as Earth - and possibly provide an indication of their chemical composition.

COROT, a CNES project with ESA participation, is a mission with a dual goal. It is the first space mission dedicated entirely to the search of extra-solar planets. It provides a wide-field survey of planets like our own at an unprecedented level of accuracy. It is also making the most comprehensive study ever of the interior of stars other than our Sun. Both objectives are achieved by analysing the behaviour of light emitted by a target star.

An exoplanet is detected by COROT due to a sudden decrease in the intensity of light or the 'light curve' of a parent star when a planet transits in front of it.

The study of stellar interiors or 'asteroseismology' is carried out by analysing the oscillations in the light curve of the star. The oscillations are created due to mechanical waves propagating in the star itself and they give a clue to the structure of its interior.

COROT's strength lies in the continued observation of the same targets in a given area of the sky. The observations have been on since the science operations began, 60 days ago. Another strong point is the accuracy with which it measures the variations in the luminosity of the star.

The first planet detected by COROT, now named 'COROT-Exo-1b', is a very hot gas giant, with a radius equal to 1.78 times that of Jupiter. It orbits a yellow dwarf star similar to our Sun with a period of about 1.5 days. 'COROT-Exo-1b' is situated roughly 1500 light years from us, in the direction of the constellation Unicorn (Monoceros). Coordinated spectroscopic observations from the ground have also allowed the determination of the mass of the planet, equivalent to about 1.3 Jupiter masses.

The scientific evaluation of the results that are streaming in will take some time. "The data we are presenting today is still raw but exceptional," says Malcolm Fridlund, COROT Project Scientist for ESA. "It shows that the on-board systems are working better than expected in some cases - up to ten times the expectation before launch. This will have an enormous impact on the results of the mission."

All the sources of noise and disturbance have not yet been taken into account in the data. This first exoplanet was detected with an error of only 0.0003 or 0.03 percent during one hour of observation.

On applying all the corrections to the light curves, the error will be reduced to only 5 parts out of 100 000. When many transits of the planet in front of the star are observed, the precision will approach just one or a few parts out of 100 000.

As a consequence, small planets down to the size of our Earth three times smaller than initially thought possible - will be in the grasp of COROT. The satellite may also be able, in specific circumstances, to detect subtle variations in the stellar light reflected by the planet itself. This would give an indication of its chemical composition.

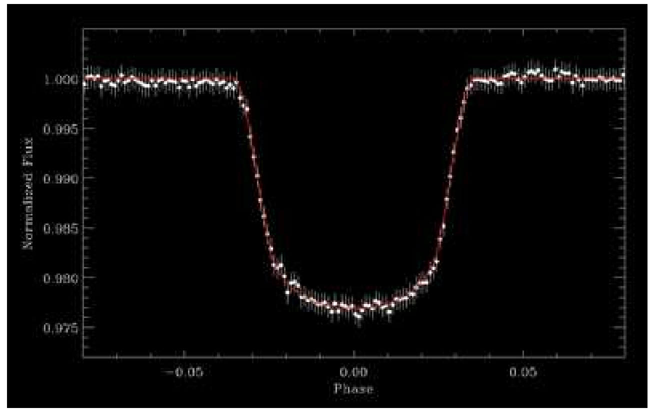


Figure 14: *Light 'drop' due to a planet transit seen by COROT*

The quality of the asteroseismological data is equally impressive. Excellent 'starquake' data were obtained during the first 60 days of observations, with a margin of error of less than one part per million.

COROT observed a bright Sun-like star continuously for 50 days, showing large, unexpected luminosity variations on time scales of a few days. This may be related to the star's magnetic activity.

The accuracy of these measurements was truly outstanding: with an error of five parts out of 100 000 in one minute (corresponding to one part per million over four minutes), COROT has already reached the maximum performance for a telescope of its size.

The preliminary analysis of the oscillations in stellar luminosity clearly shows the seismic signature typical of a Sun-like star. This analysis will eventually help scientists understand the star's internal structure and age.

2.6 Astronomers Discover Multi-Planet System Around Unexpected Star

Source: University of Texas News Release, May 23rd, 2007 [19]

University of Texas at Austin astronomers William Cochran and Michael Endl, working with graduate students Robert Wittenmyer and Jacob Bean, have used the 9.2-meter Hobby-Eberly Telescope (HET) at McDonald Observatory to discover a system of two Jupiter-like planets orbiting a star whose composition might seem to rule out planet formation. This NASA-funded study has implications for theories of planet formation.

Cochran and Endl have been monitoring the star, HD 155358, since 2001 using the High Resolution Spectrograph on HET. Their measurements of its ”radial velocity,” or motion toward and away from Earth, show that the star has a wobble in its motion, which is caused by unseen companions tugging on the star.

HD 155358 is slightly hotter than the Sun, but a bit less massive. Most important, it only contains 20 percent as much of the chemical elements called ”metals”elements heavier than hydrogen or heliumas the Sun. Along with one other star (called HD 47536), it contains the fewest metals of any star found to harbor planets.

Bean specializes in studying the metal contents of stars. His in-depth studies of the star’s spectrum revealed its metal-poor nature, and allowed him to deduce the star’s age of roughly 10 billion years.

One planet has an orbital period of 195 days and, at a minimum, is 90 percent as massive as Jupiter. It orbits HD 155358 at a distance of 0.6 AU. (An astronomical unit, or AU, is the Earth-Sun distance of 150 million kilometers, or 93 million miles.) The other planet orbits HD 155358 in 530 days, with a minimum mass half that of Jupiter, at a distance of 1.2 AU.

Wittenmyer used the University of Texas at Austin supercomputer ”Lonestar” to calculate the two massive planets’ orbits 100 million years into the future. The planets’ orbits are not circular, and they orbit close to each other and thus interact gravitationallythey push each other around.

”It’s like a dance,” Endl said. He explained that ”Rob’s calculations show us how the orbits change over time: first more eccentric, then more circular, and back again.” The system is stable, Endl said, and the pattern repeats about every 3,000 years.

According to Wittenmyer, ”The planets are trading eccentricity with each other. When one orbit is more circular, the other is more eccentric.”

The combination of massive planets orbiting a metal-poor star has consequences for theories of planet formation.

”There are two competing planet-formation models,” Endl said. Those models are known as the ”core accretion model” and the ”disk instability model.”

Both models start with a rotating cloud with a star forming at its center. As it rotates, the cloud flattens into a disk. Over time, dust in the disk begins to clump together to form the seeds that will eventually become planets. Where the two models differ is in terms of timescale.

In the core accretion model, a Jupiter-like planet forms in a two-step process. Over about a million years, a protoplanetary ”core” several times the mass of Earth forms through gravitational accumulation of solid materials. When it reaches this mass, it has enough gravity to then pull huge amounts of gas onto itself. Over several million more years, it grows into a gas giant planet.

This model relies on large amounts of heavy elements to be present in the diskand, of course, in the starto form the cores, Endl said.

”Most of the planets found using the radial velocity technique are found around metal-rich stars,” he said. ”That argues for the ’core accretion’ model. Many astronomers in this field agree that the higher fraction of planets around metal-rich stars is supporting evidence for the core-accretion model.”

”Having this process happen to form not just one, but two, planets around a star that had so little solid material available for planet-building is quite remarkable,” Cochran said.

The competing model of planet formation is called the disk instability model. It argues that the rotating disk of gas and dust around the forming star becomes unstable very soon after the disk forms, causes the disk to break into giant clumps. Gravity within each clump can cause the gas to collapse under its own gravity, forming giant planets in only several hundred years.

”Gas giant planets formed this way might not have any solid core at all,” Endl said.

Cochran and his colleagues argue that HD 155358 could have formed the two planets through either method of planet formation.

Figure 15: *McDonald Observatory's Hobby-Eberly Telescope sits atop Mt. Fowlkes in the Davis Mountains of West Texas. Photo: Marty Harris/McDonald Observatory*

"The major result of our discovery is that these planets required a very massive disk to form, several times more massive than we think our solar system disk was," Endl said. "This demonstrates that disk masses can vary significantly and might even be the most crucial factor in planet formation."

Cochran and colleagues first began using radial velocity techniques to search for planets from McDonald Observatory in the late 1980s, using the 2.7-meter Harlan J. Smith Telescope. The program continues today on both the Smith Telescope and HET, and Cochran's team has found planets orbiting several stars.

2.7 A Brown Dwarf Joins the Jet-Set

Source: ESO Press Release, May 23rd, 2007 [20]

Jets of matter have been discovered around a very low mass 'failed star', mimicking a process seen in young stars. This suggests that these 'brown dwarfs' form in a similar manner to normal stars but also that outflows are driven out by objects as massive as hundreds of millions of solar masses down to Jupiter-sized objects.

The brown dwarf with the name 2MASS1207-3932 is full of surprises. Its companion, a 5 Jupiter-mass giant, was the first confirmed exoplanet for which astronomers could obtain an image (see ESO 23/04 and 12/05), thereby opening a new field of research - the direct detection of alien worlds. It was then later found (see ESO 19/06) that the brown dwarf has a disc surrounding it, not unlike very young stars.

Now, astronomers using ESO's Very Large Telescope (VLT) have found that the young brown dwarf is also spewing jets, a behaviour again quite similar to young stars.

The mass of the brown dwarf is only 24 Jupiter-masses. Hence, it is by far the smallest object known to drive an outflow. "This leads us to the tantalizing prospect that young giant planets could also be associated with outflows," says Emma Whelan, the lead-author of the paper reporting the results.

The outflows were discovered using an amazing technique known as spectro-astrometry, based on high resolution spectra taken with UVES on the VLT. Such a technique was required due to the difficulty of the task. While in normal young stars - known as T-Tauri stars for the prototype of their class - the jets are large and bright enough to be seen directly, this is not the case around brown dwarfs: the length scale of the jets, recovered with spectro-astrometry is only about 0.1 arcsecond long, that is, the size of a two Euro coin seen from 40 km away.

The jets stretch about 1 billion kilometres and the material is rushing away from the brown dwarf with a speed of a few kilometres per second.

The astronomers had to rely on the power of the VLT because the observed emission is extremely faint and only UVES on the VLT could provide both the sensitivity and the spectral resolution they required.

Figure 16: *Jets from a Brown Dwarf (Artist's Impres-*

sion). Using ESO's VLT, astronomers found jets coming out from a 24 Jupiter-mass brown dwarf, showing that outflows are rather ubiquituous in the Universe and leading to the prospect that that young giant planets could also be associated with outflows. (c) ESO

"Discoveries like these are purely reliant on excellent telescopes and instruments, such as the VLT," says Whelan. "Our result also highlights the incredible level of quality which is available today to astronomers: the first telescopes built by Galileo were used to observe the moons of Jupiter. Today, the largest ground-based telescopes can be used to observe a Jupiter size object at a distance of 200 light-years and find it has outflows!"

Using the same technique and the same telescope, the team had previously discovered outflows in another young brown dwarf. The new discovery sets a record for the lowest mass object in which jets are seen.

Outflows are ubiquitous in the Universe, as they are observed rushing away from the active nuclei of galaxies - AGNs - but also emerging from young stars. The present observations show they even arise in still lower mass objects. The outflow mechanism is thus very robust over an enormous range of masses, from several tens of millions of solar mass (for AGNs) down to a few tens of Jupiter masses (for brown dwarfs).

2.8 XMM-Newton reveals X-rays from gas streams around young stars

Source: ESA Press Release, May 31st, 2007 [21]

XMM-Newton has surveyed nearly two hundred stars under formation to reveal, contrary to expectations, how streams of matter fall onto the young stars' magnetic atmospheres and radiate X-rays. The results defy astronomers' expectations, as the streams of falling matter interact with the hot corona, cooling it, while the ejected streams of gas heat up in shocks as they are ejected from the star.

The new XMM-Newton results paint a dramatic picture of the role magnetic fields play in star formation. "Star formation is a battle between gravity and everything else," says Manuel Guedel, Paul Scherrer Institut, Villigen, Switzerland, who leads a large project addressing magnetic activity in young stars within the constellation of Taurus.

Star formation results in a complicated system in which the young star is surrounded by a disc of gas and dust. This matter then follows one of three different routes. It finds its way onto the star through magnetic funnels, or stays in the disc to form planets, or is thrown clear of the system in a wind or jet created by the overall magnetic field.

With the help of ESA's X-ray observatory XMM-Newton, Guedel and his 25 international colleagues are now ready to report new details from the front line.

They used XMM-Newton to target stars in the nearby Taurus Molecular Cloud. This vast cloud in space is one of the star - forming regions nearest to Earth and contains over 400 young stars.

Most of these stars are still accumulating matter, a process known as accretion. As falling matter strikes the surface of the star, it typically doubles the temperature of the surface from 5000 Kelvin to 10 000 Kelvin. This produces an excessive amount of ultraviolet radiation emitted by the star and detected by XMM-Newton's Optical Monitor. Astronomers had thought that the same shock waves that caused the emission of the ultraviolet excess should also produce an excess of X-rays.

Confusingly enough, previous observations seemed to show that young stars that still accrete matter give off less X-ray emission. To investigate this mystery, amongst several others, ESA approved a large programme of observations with XMM-Newton. The space-borne observatory investigated the densest regions of the Taurus Molecular Cloud for a total of more than 7 days.

The new results from XMM-Newton propose a solution to the mystery. In addition, they bring forward unanticipated discoveries. "We have not seen the expected X-rays that the shocks should produce on the surface of some stars," says Guedel.

Instead, XMM-Newton's spectrometers revealed a new and subtle feature suggesting that the falling material cooled the hot X-ray emitting atmosphere of the young stars, suppressing the emission of X-rays.

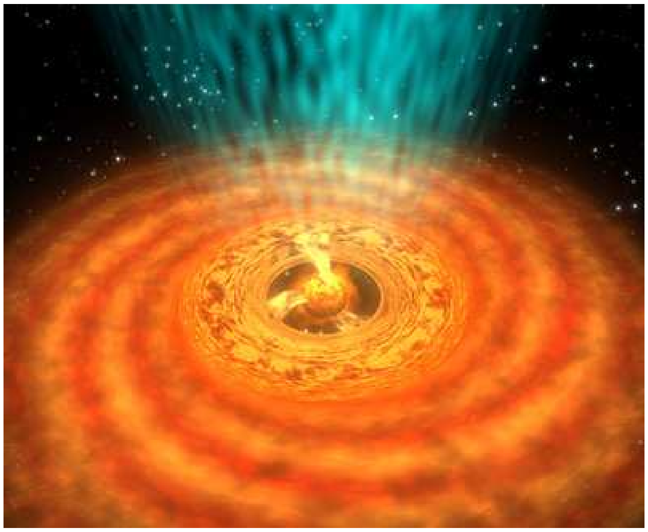


Figure 17: *Star formation, as shown in this artist's impression, results in a complicated system in which the young star is surrounded by a disc of gas and dust. This matter then follows one of three different routes. It finds its way onto the star through magnetic funnels, or stays in the disc to form planets, or is thrown clear of the system in a wind or jet created by the overall magnetic field. Credits: ESA*

In certain cases, namely in the more heavily accreting stars, the suppression of the X-rays was such that the team realised that an additional process was at work in these objects. In addition to cooling the outer stellar atmosphere, the gas streams falling onto the star were so dense that they absorbed most of the X-rays that the star's atmosphere had emitted.

Although such dense streams of gas should also contain dust that would obscure the star at visible wavelengths, the star is seen shining brightly. So what happens to this dust? The team can propose an answer to this as well. "The dust is heated so much by the radiation from the star, that it is vaporised before it can fall on the star," says Guedel.

The strong X-ray suppression allowed the team to discover yet another X-ray source associated with the same stars coming from relatively cool gas that does not suffer from absorption. "This emission must come from outside the accretion streams," says Guedel. The team interprets the X-rays as evidence that some gas streams ejected by the star form shock waves that heat up very strongly. The work gives astronomers powerful new insight into the tremendous forces at work in star formation.

2.9 Gazing up at the Man in the Star?

Source: NSF Press Release, May 31st, 2007 [22]

Using a suite of four telescopes, astronomers have captured an image of Altair, one of the closest stars to our own and a fixture in the summer sky.

While astronomers have recently imaged a few of the enormous, dying, red-giant stars, this is the first time anyone has seen the surface of a relatively tiny hydrogen-burning star like our own sun.

"The galaxy is shaped by the effects of relatively rare but powerful hot, rapidly rotating stars," says John Monnier of the University of Michigan, the lead author on the study that will appear on Science Express on May 31, 2007. "These stars have more in common with Altair than our own sun and understanding Altair will allow us to better understand how these influential stars scattered throughout the galaxy operate."

Monnier was part of an international team of astronomers that captured the image using four of the six telescopes at a facility on Mt. Wilson, Calif., operated by the Center for High Angular Resolution Astronomy (CHARA) at Georgia State University in Atlanta with partial support from the National Science Foundation (NSF).

The CHARA telescopes were able to make the breakthrough observation because they were outfitted with a novel system to clean up some of the distortions from Earth's atmosphere, a technology called the Michigan Infrared Combiner, developed with NSF support at the University of Michigan in Ann Arbor. Recent advances in fiber optic telecommunication technology made this new combiner possible.

"For looking at optical or infrared wavelengths of light, the CHARA telescope array has the world's longest spacing between telescopes and therefore the greatest ability to zoom in on the stars," adds Hal McAlister, CHARA director and a professor of astronomy at Georgia State.

Until now, astronomers could gather tremendous amounts of data from stars, but could not capture images of what the stars looked like. Even to the largest telescopes, stars looked like the points of light we all see when we peer up into the night sky.

Using the telescopes as an interferometer–a multi-telescope system that combines information from small, distantly spaced telescopes to create a picture as if taken from one large telescope–the researchers captured infrared lightwaves as if from a giant telescope 265 meters by 195 meters in dimension (100 times the size of the mirror on NASA's Hubble telescope and roughly 25 times the resolution).

"Without the interferometer, the ability to obtain such detailed images would not be possible with today's existing telescopes–or even the planned 30-meter telescopes," says Julian Christou, one of the NSF officers overseeing the research. "The critical component of the CHARA system is the beam combiner which allows the light from the individual small telescopes to be mixed together, which up to now had only been successfully used with radio telescopes such as the Very Large Array near Socorro, N.M."

The discovery is helping to answer questions about stars while raising others, particularly when researchers compare long-standing models to the new observations.

For example, Altair is a speedily spinning "rapid rotator", just like Vega, one of Altair's partners (with the slow-spinning supergiant Deneb) in the Summer Triangle in the night sky.

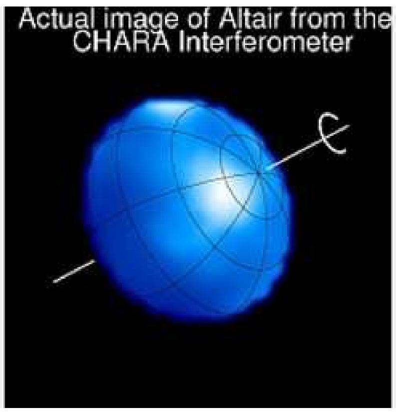


Figure 18: *The actual image of Altair as captured by the CHARA array outfitted with the Michigan Infrared Combiner. Credit: Ming Zhao, University of Michigan*

Altair spins so quickly, about 300 kilometers per second at its equator, that it's shape is distorted: the star is a full 22 percent wider than it is tall. The new telescope measurements confirmed the oblong shape, yet showed slightly different surface temperature patterns than what models predicted.

Altair is one of the closest stars in our neighborhood, only about 15 light years away, and the researchers hope to image Vega as well as more distant stars in the future.

"Imaging stars is just the start.We are going to next apply this technology to imaging extrasolar planets around nearby stars," said Ming Zhao, an astronomy graduate student at Michigan who carried out the detailed stellar modeling.

2.10 Two of the World's Largest Interferometric Facilities Team-up to Study a Red Giant Star

Source: ESO Press Release, May 31st, 2007 [23]

Using ESO's VLTI on Cerro Paranal and the VLBA facility operated by NRAO, an international team of astronomers has made what is arguably the most detailed study of the environment of a pulsating red giant star. They performed, for the first time, a series of coordinated observations of three separate layers within the star's tenuous outer envelope: the molecular shell, the dust shell, and the maser shell, leading to significant progress in our understanding of the mechanism of how, before dying, evolved stars lose mass and return it to the interstellar medium.

S Orionis (S Ori) belongs to the class of Mira-type variable stars. It is a solar-mass star that, as will be the fate of our Sun in 5 billion years, is nearing its gloomy end as a white dwarf. Mira stars are very large and lose huge amounts of matter. Every year, S Ori ejects as much as the equivalent of Earth's mass into the cosmos.

"Because we are all stardust, studying the phases in the life of a star when processed matter is sent back to the interstellar medium to be used for the next generation of stars, planets... and humans, is very important," said Markus Wittkowski, lead author of the paper reporting the results. A star such as the Sun will lose between a third and half of its mass during the Mira phase.

S Ori pulsates with a period of 420 days. In the course of its cycle, it changes its brightness by a factor of the order of 500, while its diameter varies by about 20 percent.

Although such stars are enormous - they are typically larger than the current Sun by a factor of a few hundred, i.e. they encompass the orbit of the Earth around the Sun - they are also distant and to peer into their deep envelopes requires very high resolution. This can only be achieved with interferometric techniques.

"Astronomers are like medical doctors, who use various instruments to examine different parts of the human body," said co-author David Boboltz. "While the mouth can be checked with a simple light, a stethoscope is required to listen to the heart beat. Similarly the heart of the star can be observed in the optical, the molecular and dust layers can be studied in the infrared and the maser emission can be probed with radio instruments. Only the combination of the three gives us a more complete picture of the star and its envelope."

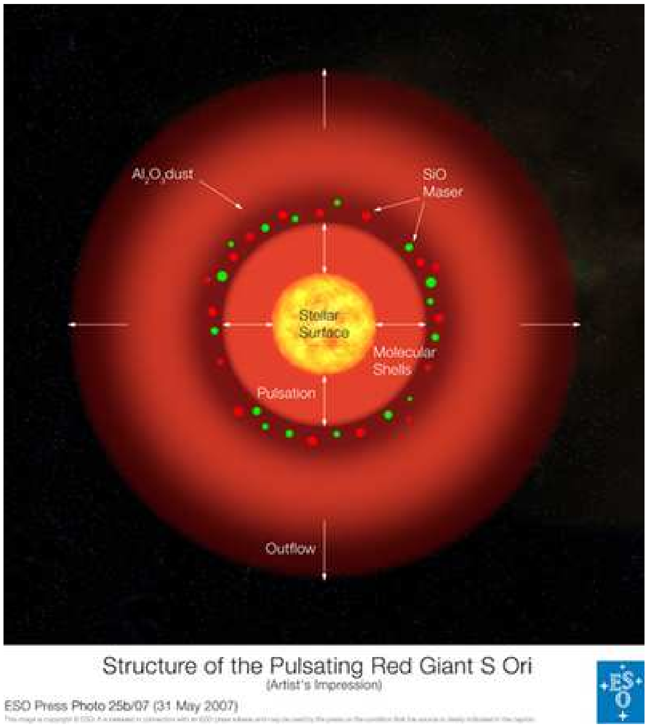


Figure 19: *Sketch of the structure of a pulsating red giant, as derived by the recent interferometric study on S Orionis. The environment around the parent star is made up by three main components: a molecular shell (inner red layer), a dust shell (outer red layer) and a maser shell (red and green speckles). Grains of aluminum oxide constitute most of the dust shell (observed in the infrared band), while the maser radio emission comes from silicon monoxide molecules. The maser spots velocities indicates that the gas is expanding, at a speed of about 10 km/s. (c) ESO*

The maser emission comes from silicon monoxide (SiO) molecules and can be used to image and track the motion of gas clouds in the stellar envelope roughly 10 times the size of the Sun.

The astronomers observed S Ori with two of the largest interferometric facilities available: the ESO Very Large Telescope Interferometer (VLTI) at Paranal, observing in the near- and mid-infrared, and the NRAO-operated Very Long Baseline Array (VLBA), that takes measurements in the radio wave domain.

Because the star's luminosity changes periodically, the astronomers observed it simultaneously with both instruments, at several different epochs. The first epoch occurred close to the stellar minimum luminosity and the last just after the maximum on the next cycle.

The astronomers found the star's diameter to vary between 7.9 milliarcseconds and 9.7 milliarcseconds. At the distance of S Ori, this corresponds to a change of the radius from about 1.9 to 2.3 times the distance between the Earth and the Sun, or between 400 and 500 solar radii!

As if such sizes were not enough, the inner dust shell is found to be about twice as big. The maser spots, which also form at about twice the radius of the star, show the typical structure of partial to full rings with a clumpy distribution. Their velocities indicate that the gas is expanding radially, moving away at a speed of about 10 km/s.

The multi-wavelength analysis indicates that near the minimum there is more dust production and mass ejection: in these phases indeed the amount of dust is significantly higher than in the others. After this intense matter production and ejection the star continues its pulsation and when it reaches the maximum luminosity, it displays a much more expanded dust shell. This clearly supports a strong connection between the Mira pulsation and the dust production and expulsion.

Furthermore, the astronomers found that grains of aluminum oxide - also called corundum - constitute most of S Ori's dust shell: the grain size is estimated to be of the order of 10 millionths of a centimetre, that is one thousand times smaller than the diameter of a human hair.

"We know one chapter of the secret life of a Mira star, but much more can be learned in the near future, when we add near-infrared interferometry with the AMBER instrument on the VLTI to our (already broad) observational approach," said Wittkowski.

2.11 FUSE Satellite Catches Collision of Titans

Source: Nasa News, May 28th, 2007 [24]

Using NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) satellite and ground-based telescopes, astronomers have determined, for the first time, the properties of a rare, extremely massive, and young binary star system.

The system, known as LH54-425, is located in the Large Magellanic Cloud, a satellite galaxy of our Milky Way. The binary consists of two O-stars, the most massive and luminous types of stars in the Universe.

Spectra obtained by Georgia State University astronomer Stephen Williams at the 1.5-meter (4.9 foot) telescope at the Cerro Tololo Inter-American Observatory in Chile show that the two stars contain about 62 and 37 times the mass of our Sun. ”The stars are so close to each other – about one-sixth the average Earth-Sun distance – that they orbit around a common center of mass every 2.25 days,” says Williams’ colleague Douglas Gies of Georgia State University, Atlanta. With a combined mass of about 100 suns, the system is one the most extreme binaries known. The stars are probably less than 3 million years old.

Each star blows off a powerful stellar wind, and FUSE’s observations have provided the first details of what happens when the two supersonic winds collide. The wind collision zone wraps around the smaller star and produces a curved surface of superheated gases that emit X-rays and far-ultraviolet radiation. FUSE is ideal for these measurements because the lines that best indicate the properties of stellar winds show up in the far ultraviolet part of the spectrum, where FUSE is most sensitive.

FUSE project scientist George Sonneborn of NASA Goddard Space Flight Center, Greenbelt, Md., is presenting these results today in a poster at the spring 2007 American Astronomical Society meeting in Honolulu, Hawaii.

The more massive star is shedding material at a rate of 500 trillion tons per second (about 400 times greater than the rate the sun loses mass through the solar wind), with a speed of 5.4 million miles per hour. The smaller star is ejecting mass at about one-tenth the rate of its sibling. The mass loss rate of both stars is consistent with other single stars having the same temperature and luminosity.

As the stars age and swell in size, they will begin to transfer substantial amounts of mass to each other. This process could begin in a million years. The stars are orbiting so close to each other that they are likely to merge as they evolve, producing a single extremely massive star like the more massive member of the Eta Carinae binary system. Eta Carinae is one of the most massive and luminous stars in the Milky Way Galaxy, with perhaps 100 solar masses.

Figure 20: *An artist depicts the binary system LH54-425, which consists of two very massive stars. The larger star’s powerful wind overpowers the smaller star’s wind, creating a region of hot gas where the outflows collide. LH54-425 is in the Large Magellanic Cloud, a satellite galaxy of the Milky Way about 165,000 light-years from Earth. Credit: NASA illustration by Casey Reed.*

”The merger of two massive stars to make a single super star of over 80 suns could lead to an object like Eta Carinae, which might have looked like LH54-425 one million years ago,” says Sonneborn. ”Finding stars this massive so early in their life is very rare. These results expand our understanding of the nature of very massive binaries, which was not well understood. The system will eventually produce a very energetic supernova.”

”These stars are evolving in the blink of an eye compared to the sun, which has looked pretty much the same for over 4 billion years,” adds Rosina Iping of the Catholic University, Washington and NASA Goddard, leader of the team that observed LH54-425 with FUSE. ”But this binary looks totally different from Eta Carinae even though there is maybe only one million years difference in age. These massive stars zoom through their life cycle really fast. Will this binary system produce something like Eta Carinae? We don’t know.”

2.12 Star is Found to be 13.2 Billion Years Old

Source: ESO Press Release, May 10th, 2007 [25]

How old are the oldest stars? Using ESO’s VLT, astronomers recently measured the age of a star located in our

Galaxy. The star, a real fossil, is found to be 13.2 billion years old, not very far from the 13.7 billion years age of the Universe. The star, HE 1523-0901, was clearly born at the dawn of time.

"Surprisingly, it is very hard to pin down the age of a star", the lead author of the paper reporting the results, Anna Frebel, explains. "This requires measuring very precisely the abundance of the radioactive elements thorium or uranium, a feat only the largest telescopes such as ESO's VLT can achieve."

This technique is analogous to the carbon-14 dating method that has been so successful in archaeology over time spans of up to a few tens of thousands of years. In astronomy, however, this technique must obviously be applied to vastly longer timescales.

For the method to work well, the right choice of radioactive isotope is critical. Unlike other, stable elements that formed at the same time, the abundance of a radioactive (unstable) isotope decreases all the time. The faster the decay, the less there will be left of the radioactive isotope after a certain time, so the greater will be the abundance difference when compared to a stable isotope, and the more accurate is the resulting age.

Yet, for the clock to remain useful, the radioactive element must not decay too fast - there must still be enough left of it to allow an accurate measurement, even after several billion years.

"Actual age measurements are restricted to the very rare objects that display huge amounts of the radioactive elements thorium or uranium," says Norbert Christlieb, co-author of the report.

Large amounts of these elements have been found in the star HE 1523-0901, an old, relatively bright star that was discovered within the Hamburg/ESO survey [1]. The star was then observed with UVES on the Very Large Telescope (VLT) for a total of 7.5 hours.

A high quality spectrum was obtained that could never have been achieved without the combination of the large collecting power Kueyen, one of the individual 8.2-m Unit Telescopes of the VLT, and the extremely good sensitivity of UVES in the ultraviolet spectral region, where the lines from the elements are observed.

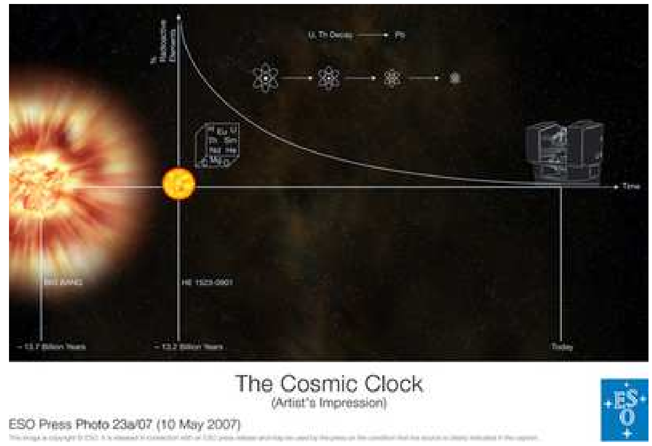


Figure 21: *From left: Recent cosmological studies show that the Big Bang occurred 13.7 billion years ago. The metal-poor star HE 1523 formed in our Milky Way galaxy soon afterward, cosmologically speaking: 13.2 billion years ago. The primitive star contained the radioactive heavy elements uranium and thorium, and the amounts of those elements decay over time, each according to its own half-life. Today, astronomer Anna Frebel of the The University of Texas atAustin McDonald Observatory and her colleagues have deduced the star's age based on the amounts of radioactive elements it contains compared to certain other "anchor" elements, specifically europium, osmium, and iridium. The study of the star's chemical make-up was made using the UVES spectrograph on the Kueyen Telescope, part of ESO's Very Large Telescope, at Paranal, in Chile. (c) ESO*

For the first time, the age dating involved both radioactive elements in combination with the three other neutron-capture elements europium, osmium, and iridium.

"Until now, it has not been possible to measure more than a single cosmic clock for a star. Now, however, we have managed to make six measurements in this one star", says Frebel.

Ever since the star was born, these "clocks" have ticked away over the eons, unaffected by the turbulent history of the Milky Way. They now read 13.2 billion years.

The Universe being 13.7 billion years old, this star clearly formed very early in the life of our own Galaxy, which must also formed very soon after the Big Bang.

2.13 How Dark Matter Might Have Snuffed Out the First Stars

Source: Universe Today, May 8th, 2007 [26]

What role did dark matter play in the early Universe? Since it makes up the majority of matter, it must have some effect. A team of researchers is proposing that massive quantities of dark matter formed dark stars in the early Universe, preventing the first generations of stars from entering their main sequence stage. Instead of burning with hydrogen fusion, these ”dark stars” were heated by the annihilation of dark matter.

And these dark stars might still be out there.

Just a few hundred thousand years after the Big Bang, the Universe cooled enough for first matter to coalesce out of a superheated cloud of ionized gas. Gravity took hold and this early matter came together to form the first stars. But these weren't stars as we know them today. They contained almost entirely hydrogen and helium, grew to tremendous masses, and then detonated as supernovae. Each successive generation of supernovae seeded the Universe with heavier elements, created through the nuclear fusion of these early stars.

Dark matter dominated the early Universe too, hovering around normal matter in great halos, concentrating it together with its gravity. As the first stars gathered together inside these halos of dark matter, a process known as molecular hydrogen cooling helped them collapse down into stars.

Or, that's what astronomers commonly believe.

But a team of researchers from the US think that dark matter wasn't just interacting through its gravity, it was right there in the thick of things. Their research is published in the paper ”Dark matter and the first stars: a new phase of stellar evolution”. Particles of dark matter compressed together began to annihilate, generating massive amounts of heat, and overwhelming this molecular hydrogen cooling mechanism. Hydrogen fusion was halted, and a new stellar phase - a ”dark star” - began. Massive balls of hydrogen and helium powered by dark matter annihilation, instead of nuclear fusion.

If these dark stars are stable enough, it's possible that they could still exist today. That would mean that an early population of stars never reached the Main Sequence stage, and still live in this aborted process, sustained by the annihilation of dark matter. As the dark matter is consumed in the reaction, additional dark matter from surrounding regions could flow in to keep the core heated, and hydrogen fusion might never get a chance to take over.

Dark stars might not be so long lasting, however. The fusion from regular matter might eventually overwhelm the dark matter annihilation reaction. Its evolution into a regular star wouldn't be halted, only delayed.

How could astronomers search for these dark stars?

They would be very large, with a core radius larger than 1 AU (the distance from the Earth to the Sun), so they might be candidates for gravitational lensing experiments. These observations use the gravity from nearby galaxies to serve as an artificial telescope to focus the light from a more distant object. This is the best technique astronomers have to find the most distant objects.

They could also be detectable by the annihilation products of the dark matter. If the nature of dark matter matches the Weakly Interacting Massive Particles theory, its annihilation would give off very specific radiation and particles in large quantities. Astronomers could look for gamma-rays, neutrinos, and antimatter.

A third way to detect them would be to search for a delay in the transition to the Main Sequence stage for the early stars. The dark stars could have interrupted this stage for millions of years, leading to an unusual gap in stellar evolution.

Perhaps these dark stars will give astronomers the evidence they need to finally know what dark matter really is.

2.14 Astronomers Identify a New Class of Cosmic Explosions

Source: Caltech News Release, May 23rd, 2007 [27]

Astronomers are announcing today the discovery of a new class of stellar explosions. The finding is based on observations of a flash seen in the Virgo cluster in a galaxy known as Messier 85.

According to Shrinivas R. Kulkarni, the team leader announcing the discovery of M85OT2006-1, the event is thought to have resulted from the merger of two ordinary stars 49 million years ago.

”The discovery of this enigmatic event is merely the proverbial tip of the iceberg for an emerging class of cosmic transients,” says Kulkarni, the MacArthur Professor of Astronomy and Planetary Science at the California Institute of Technology. The team, which consists of astronomers from Caltech and the University of California at Berkeley, is announcing its findings in the current issue of the journal Nature.

The puzzling explosion was discovered during the Lick Observatory Supernova Search with the Katzman Automatic Imaging Telescope, carried out by Alex Filippenko and Weidong Li of UC Berkeley. ”Though the primary scientific goal of the program is discovering supernovae and it's quite successful at doing that, it is gratifying to find new classes of transient objects such as M85OT2006-1," said Li, who is in charge of the daily operation of the supernova search.

Kulkarni and his Caltech colleagues had been speculating on possible new classes of cosmic explosions. They mounted a major follow-up program with the Palomar 60-inch telescope, the famous Hale 200-inch telescope, and the Keck telescopes atop Mauna Kea, Hawaii. Later, other telescopes in Hawaii and Chile were pressed into service.

The explosion was surprising because it was far too faint for a supernova, in which a star literally explodes, but clearly too bright for a nova or a thermonuclear explosion from the surface of a white dwarf star. Arne Rau, a postdoctoral fellow working with Kulkarni, said, "I was simply floored. In a short time we went from speculation to a real discovery. It was an exciting moment for me."

It took astronomers nearly a century to identify two major classes of cosmic explosions: novae and supernovae. Forty years ago gamma-ray bursts were added to the astronomical lexicon. M85OT2006-1 solidifies and defines a new class of cosmic explosions that the Caltech astronomers have dubbed as Luminous Red Novae. These events have very distinct (red) color and expand quite slowly when compared with novae, supernovae, and gamma-ray bursts.

The galaxy in which M85OT2006-1 exploded is composed mainly of old stars, which also indicates that the event probably arose from a population of stars with masses very similar to that of the sun. More than a decade ago, one other similar but poorly studied event was observed in the Andromeda galaxy.

Kulkarni speculates that the red luminous novae result when two stars merge and undergo what is called "common envelope evolution." Kulkarni added, "The common envelope phase has been inferred on strong theoretical grounds, but is now caught in flagrante delicto."

In a related study, Rau undertook observations of M85OT2006-1 with NASA's Spitzer Space Telescope. The object is detectable in the mid infrared a year after the explosion, long after it became too faint in the visual, even for the Hubble Space Telescope. The Spitzer telescope is particularly well suited for the study of cold matter in space. Rau added, "Spitzer was vital in confirming that this object is a cosmic oddball. It is hard to imagine both a bright explosion which is also so cold."

There is little doubt that the discovery of this new class of cosmic explosions will make astronomers inspect ongoing searches carefully for similar events. Future imaging surveys will likewise be energized by this discovery. Kulkarni added, "It is a nice feeling when you know you have created a new cottage industry in your field."

2.15 Astronomers Map Action in the Cosmic Suburbs

Source: UCDavis News, May 29th, 2007 [28]

A group of Hawaii and California astronomers led by Lori Lubin of the University of California, Davis, and Roy Gal of the University of Hawaii at Manoa has mapped, for the first time, where the action is in a mega-structure in the distant universe. The results were announced May 27 at the American Astronomical Society meeting in Honolulu, Hawaii.

Large galaxy clusters are typically considered the universe's metropolises, and for years many astronomers have focused their attention "downtown." However, this research shows that all the action is actually happening in the galactic suburbs.

"The most interesting thing that we've found so far is the incredible amount of activity occurring in galactic suburbia," said Lubin, who is the principal investigator of the Observations of Redshift Evolution in Large Scale Environments (ORELSE) Survey. "We see unusually large numbers of galaxies with high star formation rates, producing over 100 new suns per year, and with active central supermassive black holes."

ORELSE is one of the first comprehensive surveys of large-scale environments around very massive galaxy clusters between 6 and 9 billion light-years away. In this study, Lubin and her collaborators hope to gain insights into physical properties that affect galaxies in the cluster outskirts and understand the interactions that leave them forever changed.

Like grapes, the universe's galaxies come in clusters, and those clusters typically bunch together to form even more massive structures, or superclusters. Scientists refer to the large clusters at the heart of a supercluster as the Los Angeleses, New Yorks or Londons. Much like freeways connect big cities to smaller towns, a web of galaxies connects these large clusters to smaller groups of galaxies.

In the past, telescope limitations forced astronomers to focus their studies on either the centers of large clusters or random regions in the cosmic web. Now, with the latest ground-based and space-based telescopes, scientists are able to map larger areas.

"Our research is like mapping the whole Big Island of Hawaii instead of just Hilo," said Gal. "We have already discovered the largest known supercluster – a cluster of clusters – present when the universe was half its current age."

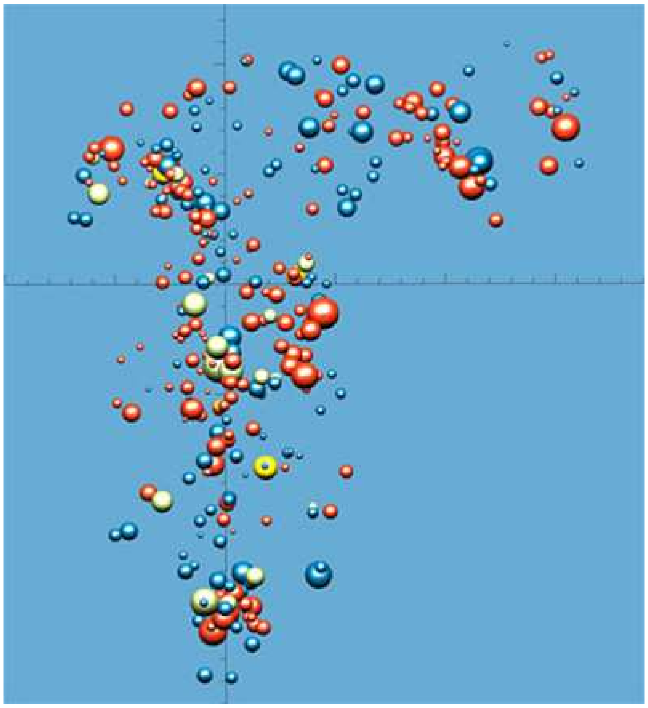


Figure 22: *Large clusters (cities), consisting mainly of less active galaxies (colored red), are connected by filaments and smaller groups (highways and suburbs) with younger, more active galaxies (blue). Galaxies with supermassive black holes, shown in yellow, tend to be away from the cluster centers. (Roy Gal/University of Hawaii)*

To see what is happening in the cluster suburbs, the team collected data with nine different telescopes, including the 10-meter Keck I and II telescopes, 8-meter Subaru and the 4-meter United Kingdom infrared telescopes on Mauna Kea, Hawaii; the 5-meter Palomar telescope in California; the 4-meter Kitt Peak telescope in Arizona; and the Very Large Array in New Mexico. For space-based observations, the team used three of NASA's Great Observatories: the Spitzer and Hubble space telescopes, and the Chandra X-ray Observatory.

"The Spitzer observations interest me. With Spitzer, we expect to discover even more galaxies containing voracious black holes. They may be hidden behind thick curtains of dust, but Spitzer will find them," said Gordon Squires, of the Spitzer Science Center, Pasadena, Calif., another co-investigator.

Team members also note that this study may provide valuable clues about our Milky Way galaxy's future. They say that our Milky Way is currently sitting in galactic suburbia and that our nearest cosmic metropolis is the Virgo Cluster of galaxies, located approximately 100 million light-years away.

2.16 New technique for 'weighing' black holes

Source: ESA Press Release, May 16th, 2007 [29]

ESA's XMM-Newton has helped to find evidence for the existence of controversial Intermediate Mass Black Holes. Scientists used a new, recently proven method for determining the mass of black holes. Nikolai Shaposhnikov and Lev Titarchuk, at NASA's Goddard Space Flight Center (GSFC), have used the technique to determine the mass of the black hole, Cygnus X-1, located in the constellation Cygnus (the Swan) approximately 10 000 light years away in our Galaxy, the Milky Way.

The elegant technique, first suggested by Titarchuk in 1998, shows that Cygnus X-1, part of a binary system, contains 8.7 solar masses, with a margin of error of only 0.8 solar masses. Cygnus X-1 was one of the first compelling black hole candidates to emerge in the early 1970s. The system consists of a blue supergiant and a massive but invisible companion.

Alternative techniques have previously suggested that the invisible object was a black hole of about 10 solar masses. "This agreement gives us a lot of confidence that our method works," says Shaposhnikov. It can help determine a black hole's mass when alternative techniques fail," adds Titarchuk.

Working independently from Shaposhnikov and Titarchuk, Tod Strohmayer and Richard Mushotzky, also from GSFC, and four colleagues, used Titarchuk's technique on XMM data and stumbled upon an Intermediate Mass Black Hole (IMBH)- the existence of which is in theory controversial.

They estimated that an ultraluminous X-ray source in the nearby galaxy, NGC 5408, harbours a black hole with a mass of about 2 000 Suns."This is one of the best indications to date for an IMBH," says Strohmayer.

The existence of IMBHs is controversial because there is no widely accepted mechanism for how they could form. But they would fill in a huge gap between black holes such as Cygnus X-1 - which form from collapsing massive stars and contain perhaps 5 to 20 solar masses - and the 'monsters' (up to thousand million solar masses) that lurk in the cores of large galaxies.

Titarchuk's method takes advantage of a relationship between a black hole and its surrounding accretion disk. Gas orbiting in these disks eventually spirals into the black hole. When a black hole's accretion rate increases to a high level, material piles up near the black hole in a hot region that Titarchuk likens to a traffic jam.

Titarchuk has shown that the distance from the black hole where this congestion occurs scales directly with the mass of the black hole. The more massive the black hole, the farther this congestion occurs and the longer the orbital period.

In his model, hot gas piling up in the congestion region is linked to observations of X-ray intensity variations that repeat on a nearly, but not perfectly, periodic basis. These Quasi-Periodic Oscillations (QPOs) are observed in many black hole systems. The QPOs are accompanied by simple, predictable changes in the system's spectrum as the surrounding gas heats and cools in response to the changing accretion rate.

Precise timing observations from NASA's Rossi X-ray Timing Explorer (RXTE) satellite have shown a close relationship between the frequency of QPOs and the spectrum, telling astronomers how efficiently the black hole is producing X-rays.

Using RXTE, Shaposhnikov and Titarchuk have applied this method to three stellar-mass black holes in the Milky Way and shown that the derived masses from the QPOs concur with mass measurements from other techniques.

Using ESA's XMM-Newton X-ray observatory, Strohmayer, Mushotzky, and their colleagues detected two QPOs in NGC 5408 X-1.

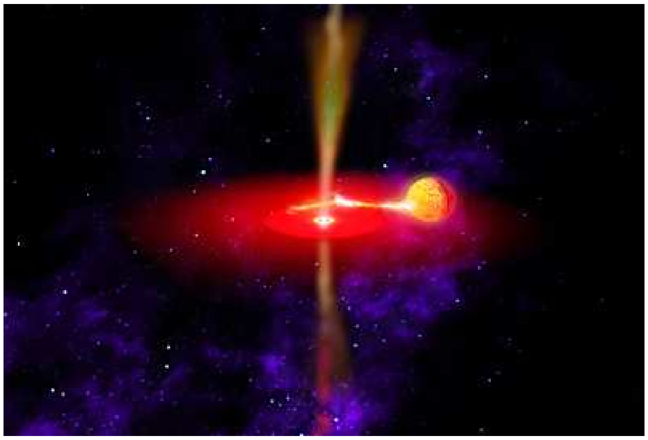


Figure 23: *The nature of Ultra Luminous X-ray (ULX) sources remains controversial, but many astronomers think that some or most of these objects consist of an intermediate-mass black hole that accretes matter from a companion star. Recent evidence suggests that a ULX in the galaxy NGC 5408 has a black hole of about 2 000 solar masses. Credits: NASA*

NGC 5408 X-1 is the brightest X-ray source in the small, irregular galaxy NGC 5408, 16 million light years from Earth in the constellation Centaurus. The QPO frequencies, as well as the luminosity and spectral characteristics of the source, imply that it is powered by an IMBH.

"We had two other ways of estimating the mass of the black hole, and all three methods agree within a factor of two," says Mushotzky. "We don't have proof this is an IMBH, but the preponderance of evidence suggests that it is."

One of the study's coauthors, Roberto Soria of the Harvard-Smithsonian Center for Astrophysics, thinks the black hole's mass is closer to one hundred Suns.

2.17 Spin of Supermassive Black Holes Measured for First Time

Source: University of Maryland Press Release, May 29th, 2007 [30]

Astronomers at the University of Maryland have made the first quantitative measurements of the spin of several supermassive black holes, information that is essential to understanding how these giant black holes develop and grow.

University of Maryland astronomy graduate student Laura Brenneman and Associate Professor of astronomy Christopher Reynolds have used observations by the European Space Agency's XMM-Newton X-ray telescope to examine the relativistically altered shape of the iron spectral line emitted from the accretion disks around these black holes. Comparing these data with new theoretical models for this spectral line, developed by Brenneman, they have generated measures of angular momentum, or the spin rate, of these objects. The black hole for which they have the best data is found at the center of the galaxy MCG-06-30-15. Their analysis indicates that this black hole is spinning very fast indeed, at least 98.7 percent of the maximum possible spin rate allowed by Einstein's Theory of General Relativity.

Brenneman and Reynolds, her thesis advisor at the University of Maryland, presented their findings at a press briefing at the American Astronomical Society's meeting in Honolulu Hawaiion May 29th.

"We really know very little about how supermassive black holes form and grow," said Reynolds. "We have models for how it can happen, but being able to determine spin rate is critical to our understanding of the process by which it actually happens."

One mechanism by which black holes can grow to be supermassive is through accretion of massive amounts of material, explained Reynolds, who together with Brenneman presented their findings. When black holes suck in matter they spin faster, thus a rapid rate of spin would indicate growth by accretion. Supermassive black holes can also be the product of a collision between black holes. Models indicate that such collisions tend to result in a supermassive black hole that spins at only a modest rate. Black holes can be completely defined by their mass and spin. Scientists have long been able to measure the mass of a black hole (through any number of methods), but, until now, measuring spin has been far more challenging.

Supermassive black holes have masses that are hundreds of thousands to billions of times that of the Sun. It is currently thought that most, if not all galaxies, including the Milky Way, contain supermassive black holes at their galactic centers.

2.18 Star Cluster Holds Midweight Black Hole, VLA Indicates

Source: NRAO Press Release, May 28th, 2007 [31]

Astronomers using the National Science Foundation's Very Large Array (VLA) radio telescope have greatly strengthened the case that supermassive black holes at the cores of galaxies may have formed through mergers of smaller black holes. Their VLA studies showed that a globular star cluster in the galaxy M31 probably has a black hole with 20,000 times the mass of the Sun at its core.

"That amount of mass is midway between the black holes left when giant stars explode as supernovae and the supermassive black holes with millions of times the mass of the Sun. It suggests that there is a clear path for forming the supermassive ones through successive mergers of smaller black holes," said James Ulvestad, of the National Radio Astronomy Observatory. Ulvestad, Jenny Greene of Princeton University, and Luis Ho of the Observatories of the Carnegie Institute of Washington presented their findings to the American Astronomical Society's meeting in Honolulu, Hawaii.

Black holes appear to be intimately connected with the formation of massive spherical bulges in galaxies. Astronomers have found a direct relationship between the mass of the black hole in such a galaxy and the mass of its central bulge. However, it is unclear whether small galaxies contain smaller black holes, and their discovery may lead to new insights about the impact of black holes on galaxy formation. As Greene stated, "In recent years, we have been detecting black holes with masses between 100,000 and a few million times the mass of the Sun, but less massive objects have been exceptionally difficult to find."

Based on observations with optical telescopes, Karl Gebhardt of the University of Texas at Austin, R. Michael Rich of UCLA, and Ho, suggested in 2002 that the globular cluster G1 in the Andromeda Galaxy (M31) contains a compact concentration of mass that is intermediate in mass between stellar and supermassive black holes. Other researchers disputed that conclusion. According to Ho, "In 2005, we obtained better data that clinched the case that the cluster really does contain a dark object with 20,000 times the mass of the Sun. What we can't be sure of, however, is whether the dark mass is a single object — that is, an intermediate-mass black hole — or a cluster of smaller dark objects such as neutron stars or stellar-sized black holes."

"Since this globular cluster, G1, is by far the best candidate for containing such an intermediate-mass black hole, we felt it was important to help resolve the question," Ho added.

Last year, researchers detected X-rays emitted from G1. That allowed Ulvestad and his team to apply a test that could distinguish between an intermediate-mass black hole and the smaller compact objects. Astronomers have found that, for a given X-ray brightness, a supermassive black hole is much brighter at radio wavelengths than a stellar-mass black hole.

Using the VLA, Ulvestad, Greene and Ho found that the radio brightness of G1 was between what would be expected for a stellar-mass black hole and what would be expected for a supermassive one. "The radio brightness nicely fits the prediction for a 20,000-solar-mass black hole," Ulvestad said.

Some globular clusters in our own Milky Way galaxy are suspected to contain black holes with masses just a few hundred times the mass of the Sun. These may be detected when the Expanded VLA, with much greater sensitivity than the current telescope, comes on line soon after 2010. "With this capability, we could close the gap between black holes with masses 10 times that of the Sun and those with masses more than 10,000 times that of the Sun," Ulvestad said. "This should lead to a greater understanding of their importance as stepping stones toward the most massive black holes we observe in the centers of many galaxies."

2.19 Hubble Finds Multiple Stellar 'Baby Booms' in a Globular Cluster

Source: Hubble News, May 2nd, 2007 [32]

Astronomers have long thought that globular star clusters had a single ”baby boom” of stars early in their lives and then settled into a quiet existence.

New observations by NASA’s Hubble Space Telescope, however, are showing that this idea may be too simple. The Hubble analysis of the massive globular cluster NGC 2808 provides evidence that star birth went ”boom, boom, boom,” with three generations of stars forming very early in the cluster’s life.

”We had never imagined that anything like this could happen,” said Giampaolo Piotto of the University of Padova in Italy and leader of the team that made the discovery. ”This is a complete shock.”

Globular clusters are the homesteaders of our Milky Way Galaxy, born during our galaxy’s formation. They are compact swarms of typically hundreds of thousands of stars held together by gravity.

”The standard picture of a globular cluster is that all of its stars formed at the same time, in the same place, and from the same material, and they have co-evolved for billions of years,” said team member Luigi Bedin of the European Space Agency, the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in Garching, Germany, and the Space Telescope Science Institute in Baltimore, Md. ”This is the cornerstone on which much of the study of stellar populations has been built. So we were very surprised to find several distinct populations of stars in NGC 2808. All of the stars were born within 200 million years very early in the life of the 12.5-billion-year-old massive cluster.”

Finding multiple stellar populations in a globular cluster so close to home has deep cosmological implications, the researchers said.

”We need to do our best to solve the enigma of these multiple generations of stars found in these Hubble observations so that we can understand how stars formed in distant galaxies in our early universe,” Piotto explained.

The astronomers used Hubble’s Advanced Camera for Surveys to measure the brightness and color of the cluster stars. Hubble’s exquisite resolution allowed the astronomers to sort out the different stellar populations. The Hubble measurements showed three distinct populations, with each successive generation appearing slightly bluer. This color difference suggests that successive generations contain a slightly different mix of some chemical elements.

”One assumption, although we have no direct proof,” said team member Ivan King of the University of Washington in Seattle, ”is that the successively bluer color of the stellar populations indicates that the amount of helium increases with each generation of stars. Perhaps massive star clusters like NGC 2808 hold onto enough gas to ignite a rapid succession of stars.”

The star birth would be driven by shock waves from supernovae and stellar winds from giant stars, which compress the gas and make new stars, King explained. The gas would be increasingly enriched in helium from previous generations of stars more massive than the Sun.

Astronomers commonly assume that globular clusters produce only one stellar generation, because the energy radiating from the first batch of stars would clear out most of the residual gas needed to make more stars. But a hefty cluster like NGC 2808, which is two to three times more massive than a typical globular cluster, may have enough gravity to hang onto that gas, which has been enriched by helium from the first stars. Of the about 150 known globular clusters in our Milky Way Galaxy, NGC 2808 is one of the most massive, containing more than 1 million stars.

Another possible explanation for the multiple stellar populations is that NGC 2808 may only be masquerading as a globular cluster. The stellar grouping may have been a dwarf galaxy that was stripped of most of its material due to gravitational capture by our galaxy.

Omega Centauri, the only other stellar system Piotto’s group found to have multiple generations of stars, is suspected to be the remnant core of a dwarf galaxy, Bedin said.

Although the astronomers’ search is only in its infancy, they say multiple stellar populations may be a typical occurrence in other massive clusters.

”No one would make the radical step of suggesting that previous work on other clusters is no longer valid,” King said. ”But this discovery shows that the study of stellar populations in globular clusters now opens up in a new direction.”

The team plans to use ESO’s Very Large Telescope in Chile to make spectroscopic observations of the chemical abundances in NGC 2808, which may offer further evidence that the stars were born at different times and yield clues to how they formed. They also will use Hubble to hunt for multiple generations of stars in about 10 more hefty globular clusters.

2.20 How to Spot the Speediest Black Holes

Source: CfA Press Release, May 23rd, 2007 [33]

Astronomers are hunting an elusive target: rogue black holes that have been ejected from the centers of their home galaxies. Some doubted that the quarry could be spotted, since a black hole must be gobbling matter from an accretion disk in order for that matter to shine. And if a black hole is ripped from the core of its home galaxy and sent hurling into the outskirts, the thinking goes, then its accretion disk might be left behind.

New calculations by theorist Avi Loeb (Harvard-Smithsonian Center for Astrophysics) give black hole hunters a reason to hope. Loeb showed that, generically, a black hole ejected from the center of a galaxy could bring its accretion disk along for the ride and remain visible for millions of years.

"Matter in the disk is swirling around the black hole much faster than the typical black-hole ejection speed. That matter is so tightly bound that it follows the black hole like a herd of sheep around a shepherd," said Loeb.

In the scenario examined by Loeb, two galaxies collide and merge. The spinning, supermassive black holes at the core of each galaxy coalesce, emitting powerful gravitational radiation in a preferred direction. Computer simulations recently demonstrated that the net momentum carried by the radiation gives the remnant black hole a large kick in the opposite direction. The black hole recoils at speeds of up to ten million miles per hour – fast enough to traverse an entire galaxy in a cosmically short time of only ten million years.

Although the prediction of recoiling black holes in galaxy mergers has been shown to be robust, it was unclear until Loeb's paper whether the phenomenon could have optically observable consequences. Loeb examined the question of whether the black hole could hold onto its accretion disk while being ejected. He found that as long as the gas within the disk was orbiting at a speed far greater than the black hole ejection speed, the accretion disk would follow the black hole on its journey.

Moreover, the gaseous disk should not be consumed during the earlier binary coalescence phase that precedes the ejection because the black hole binary tends to open a cavity in the disk, like a spinning blade in a food processor.

After the two black holes join to become one, the accretion disk could feed the remnant black hole for millions of years, allowing the black hole to shine brilliantly. Such black holes at cosmological distances are called quasars.

Before the black hole's fuel is exhausted, it could travel more than 30,000 light-years from the center of its galaxy. At typical cosmological distances, that would equate to a separation on the sky of about one arcsecond (the size of a dime viewed from one mile away). Such separations are challenging to detect, since the quasar's brightness may overwhelm the fainter galaxy.

The powerful release of energy by a quasar shapes the evolution of its host galaxy. Previous theoretical calculations assumed that a quasar is pinned to the center of its galaxy where most of the gas concentrates. "However, the feedback from a recoiled quasar would be distributed along its trajectory, and would resemble the visible track of a subatomic particle in a bubble chamber," commented Loeb.

His paper argues that although most of the kicked black holes would remain bound to their host galaxies, their feedback and growth would be different than previously envisioned.

"Most importantly, this work is a good motivation for observers to search for displaced quasars," added Loeb.

2.21 'Olympian Galaxy' Near Andromeda Gives Clues To How Galaxies Form

Source: Keck Observatory News, May 28th, 2007 [34]

A newly discovered dwarf galaxy in the Local Group has been found to have formed in a region of space far from our own and is falling into our system for the first time in its history, according to new data obtained at the W. M. Keck Observatory. An international team of astronomers report that the dwarf galaxy, Andromeda XII, marks the best piece of evidence for small galaxies which are just now arriving in our Local Group. The finding provides an important test for simulations of galaxy formation.

Dwarf galaxies and streams of stellar material mark the visible remnants of galactic merging events from which large galaxies are made. Cosmology models predict small galaxies form along a web of filamentary structures in the universe, and then gradually fall into dense groups and cluster environments. Small galaxies should still be falling into the Local Group, yet none have been found–until now.

"Other Local Group dwarf galaxies are thought to have extreme orbits, including Leo I, Andromeda XIV and Andromeda XI, but Andromeda XII really stands out as a contender for a new entrant into the Local Group," said the lead author of the study, Dr. Scott C. Chapman of the University of Cambridge, Institute of Astronomy. "The others have likely already been seriously harassed by Andromeda and the Milky Way."

Nicknamed the 'Olympian Galaxy' after the Twelve Olympians in the Greek Pantheon, Andromeda XII was first discovered in October 2006 during a wide-field survey taken with the Canada-France Hawaii Telescope's "MegaCam" instrument. It is the faintest dwarf galaxy ever discovered near to Andromeda (M31), and may have the lowest mass ever measured. Dwarf galaxies are the smallest stellar systems showing evidence for a substantial amount of dark matter.

Dr. Chapman's observations confirmed Andromeda XII is distinct from all other satellite galaxies in the Local Group. It is a fast-moving galaxy on a highly eccentric orbit, located at a great distance from the center of M31, about 115 kiloparsecs (375,000 light years). Importantly, Andromeda XII lies significantly behind M31 as viewed from the Milky Way, almost certainly falling in for the first time. Because Andromeda XII has lived its life in a very different environment than the Local Group, it gives astronomers a pristine object for studying star formation histories, dark matter distribution, and other parameters that would be influenced by the Local Group gravity that has affected all the in other dwarf galaxies.

"Andromeda XII may be the first galaxy of the local group ever observed that has not yet been disrupted by the strong gravity of the Local Group," said Dr. Jorge Penarrubia of the University of Victoria, a co-author of the study.

The DEIMOS spectrograph at Keck II, one of two 10-meter telescopes the W. M. Keck Observatory operates on the summit of Mauna Kea, was key in making the discovery. It was used to observe 49 stars in the region of Andromeda XII, and confirmed that eight were members of the new dwarf galaxy. Follow-up observations were also conducted at the Green Bank Telescope in West Virginia to measure the amount of interstellar gas in the galaxy, and the Subaru telescope in Hawaii helped determine a more precise distance.

"Without the spectra we obtained with DEIMOS, it would have been impossible to make any useful claims about the orbit of Andromeda XII, its evolution, its speed or its dark matter content," added Dr. Chapman.

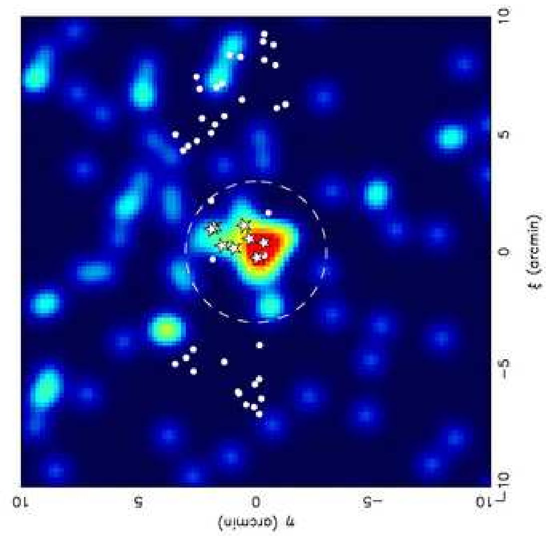


Figure 24: *Smoothed map of likely Andromeda 12 stars from CFHT-MegaCam image, with stars confirmed as members using Keck data Credit: Scott Chapman, University of Cambridge*

Andromeda XII is falling very quickly through the Local Group from behind Andromeda, the only one of Andromeda's satellites which exceeds the apparent escape velocity for Andromeda. It is possible that Andromeda XII may be just a short-term visitor. It is such a low-mass galaxy that it may not slow down much as it passes through the Local Group.

"It is a pleasure to see the speed of this new, fascinating member of the Local Group clocked using Keck II and DEIMOS," added W. M. Keck Observatory Director Taft Armandroff. "The powerful combination of Keck and DEIMOS has added many contributions to our understanding of Local Group galaxies."

The age of the Universe is not old enough for Andromeda XII to have started in the dense Local Group and be on its second trip through our system. Andromeda XII probably formed in a dense filament structure, toward the general direction of the M81 group. However, the distance is about three times too large for it to have actually come from the M81 group. A likely scenario is Andromeda XII formed in a filamentary region of space that connects the Local Group to the M81 group.

”The high speed of Andromeda XII really surprised me; I wasn’t expecting to see any of our newly discovered dwarfs moving so fast. We will likely have to revise our mass estimates of Andromeda upward as a result.” added Rodrigo Ibata.

A paper reporting the discovery, ”Strangers in the Night: The discovery of a Dwarf Spheroidal Galaxy on its First Local Group Infall,” will appear in an upcoming issue of the Astrophysical Journal. Funding was provided by a fellowship from the Canadian Space Agency and the Natural Sciences and Engineering Research Council of Canada. Additional support was provided by Adrian Jenkins who provided use of important computer simulations.

2.22 ”Missing Mass” Found in Recycled Dwarf Galaxies

Source: NRAO Press Release, May 10th, 2007 [35]

Astronomers studying dwarf galaxies formed from the debris of a collision of larger galaxies found the dwarfs much more massive than expected, and think the additional material is ”missing mass” that theorists said should not be present in this kind of dwarf galaxy.

The scientists used the National Science Foundation’s Very Large Array (VLA) radio telescope to study a galaxy called NGC 5291, 200 million light-years from Earth. This galaxy collided with another 360 million years ago, and the collision shot streams of gas and stars outward. Later, the dwarf galaxies formed from the ejected debris.

”Our detailed studies of three ’recycled’ dwarf galaxies in this system showed that the dwarfs have twice as much unseen matter as visible matter. This was surprising, because they were expected to have very little unseen matter,” said Frederic Bournaud, of the French astrophysics laboratory AIM of the French CEA and CNRS. Bournaud and his colleagues announced their discovery in the May 10 online issue of the journal Science.

”Dark matter,” which astronomers can detect only by its gravitational effects, comes, they believe, in two basic forms. One form is the familiar kind of matter seen in stars, planets, and humans – called baryonic matter – that does not emit much light or other type of radiation. The other form, called non-baryonic dark matter, comprises nearly a third of the Universe but its nature is unknown.

The visible portion of spiral galaxies, like our own Milky Way, lies mostly in a flattened disk, usually with a bulge in the center. This visible portion, however, is surrounded by a much larger halo of dark matter. When spiral galaxies collide, the material expelled outward by the interaction comes from the galaxies’ disks. For this reason, astronomers did not expect that ”recycled” dwarf galaxies formed from this collision debris would contain much, if any, dark matter.

When Bournaud and his international team of scientists used the VLA to study three dwarf galaxies formed from the debris of NGC 5291’s collision, they were surprised to find two to three times the amount of dark matter as visible matter in the dwarfs. They determined the dwarfs’ masses by measuring the Doppler shift of radio waves emitted by atomic Hydrogen at a frequency of 1420 MHz. The amount of shift in the frequency indicated the rotational speed in the galaxy. That, in turn, allowed the scientists to calculate the dwarf’s mass.

Images from two NASA satellites provided vital information about the dwarf galaxies. ”Using ultraviolet images from the Galex satellite and infrared data collected by the Spitzer satellite, we had previously shown that the dwarfs all along the debris stream were star-forming galaxies,” said Pierre-Alain Duc, also of the AIM laboratory (CEA/CNRS).

What is the dark matter in the dwarfs? The astronomers don’t believe it is the mysterious non-baryonic type, but rather cold Hydrogen molecules that are extremely difficult to detect.

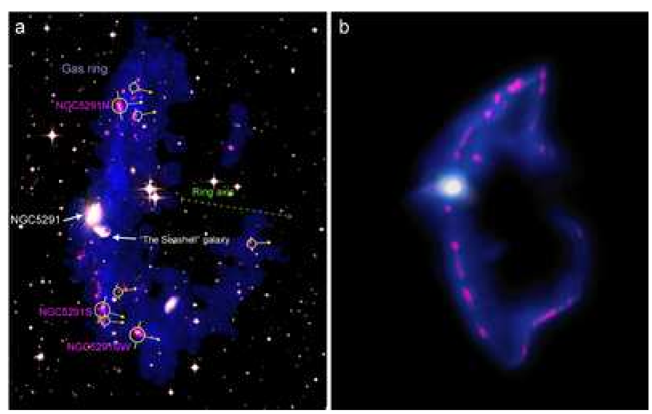


Figure 25: *Left: Composite radio/optical/ultraviolet image of NGC 5291 and its surroundings, including the debris propelled outward by collision with another galaxy. Blue is atomic Hydrogen observed with the VLA; white is optical; red is ultraviolet (Galex satellite). Red labels mark the dwarf galaxies studied in this research. Right: Detail of image produced by computer simulation of the galac-*

tic collision, showing debris ring and condensations that became star-forming dwarf galaxies. CREDIT: P-A Duc, CEA-CNRS/NRAO/AUI/NSF/NASA.

When the astronomers performed computer models of the collision of NGC 5291 to simulate the formation of the system seen today, the models left the resulting recycled dwarfs with almost no dark matter. These computer models had started off with all the dark matter in the galaxy's larger halo.

"The result of the computer models means that the additional mass we see in the real dwarfs came from the disks, not the haloes, of the larger galaxies that collided," Bournaud said. That additional mass, the scientists believe, almost certainly is "normal" baryonic matter, probably cold molecular Hydrogen.

While the discovery about NGC 5291's neighboring dwarf galaxies sheds new light on the composition of spiral galaxies, it doesn't tell the scientists anything about the non-baryonic dark matter, whose nature remains a mystery. "Still, this new information about the matter comprising galactic disks should help us work toward a better understanding of their formation and evolution," Bournaud concluded.

2.23 Hubble Finds Ring of Dark Matter

Source: Hubble News, May 15th, 2007 [36]

Astronomers using NASA's Hubble Space Telescope have discovered a ghostly ring of dark matter that formed long ago during a titanic collision between two massive galaxy clusters.

The ring's discovery is among the strongest evidence yet that dark matter exists. Astronomers have long suspected the existence of the invisible substance as the source of additional gravity that holds together galaxy clusters. Such clusters would fly apart if they relied only on the gravity from their visible stars. Although astronomers don't know what dark matter is made of, they hypothesize that it is a type of elementary particle that pervades the universe.

"This is the first time we have detected dark matter as having a unique structure that is different from both the gas and galaxies in the cluster," said astronomer M. James Jee of Johns Hopkins University in Baltimore, Md., a member of the team that spotted the dark-matter ring.

The researchers spotted the ring unexpectedly while they were mapping the distribution of dark matter within the galaxy cluster Cl 0024+17 (ZwCl 0024+1652), located 5 billion light-years from Earth. The ring measures 2.6 million light-years across. Although astronomers cannot see dark matter, they can infer its existence in galaxy clusters by observing how its gravity bends the light of more distant background galaxies.

"Although the invisible matter has been found before in other galaxy clusters, it has never been detected to be so largely separated from the hot gas and the galaxies that make up galaxy clusters," Jee said. "By seeing a dark-matter structure that is not traced by galaxies and hot gas, we can study how it behaves differently from normal matter."

During the team's dark-matter analysis, they noticed a ripple in the mysterious substance, somewhat like the ripples created in a pond from a stone plopping into the water.

"I was annoyed when I saw the ring because I thought it was an artifact, which would have implied a flaw in our data reduction," Jee explained. "I couldn't believe my result. But the more I tried to remove the ring, the more it showed up. It took more than a year to convince myself that the ring was real. I've looked at a number of clusters and I haven't seen anything like this."

Curious about why the ring was in the cluster and how it had formed, Jee found previous research that suggested the cluster had collided with another cluster 1 to 2 billion years ago. The research, published in 2002 by Oliver Czoske of the Argeleander-Institut fur Astronomie at the Universitat Bonn, was based on spectroscopic observations of the cluster's three-dimensional structure. The study revealed two distinct groupings of galaxies clusters, indicating a collision between both clusters.

Astronomers have a head-on view of the collision because it occurred fortuitously along Earth's line of sight. From this perspective, the dark-matter structure looks like a ring.

Computer simulations of galaxy cluster collisions, created by the team, show that when two clusters smash together, the dark matter falls to the center of the combined cluster and sloshes back out. As the dark matter moves outward, it begins to slow down under the pull of gravity and pile up, like cars bunched up on a freeway.

"By studying this collision, we are seeing how dark matter responds to gravity," said team member Holland Ford of Johns Hopkins University. "Nature is doing an experiment for us that we can't do in a lab, and it agrees with our theoretical models."

Dark matter makes up most of the universe's material. Ordinary matter, which makes up stars and planets, comprises only a few percent of the universe's matter.

Tracing dark matter is not an easy task, because it does not shine or reflect light. Astronomers can only detect its influence by how its gravity affects light. To find it, astronomers study how faint light from more distant galaxies is distorted and smeared into arcs and streaks by the gravity of the dark matter in a foreground galaxy cluster, a powerful trick called gravitational lensing. By mapping the distorted light, astronomers can deduce the cluster's mass and trace how dark matter is distributed in the cluster.

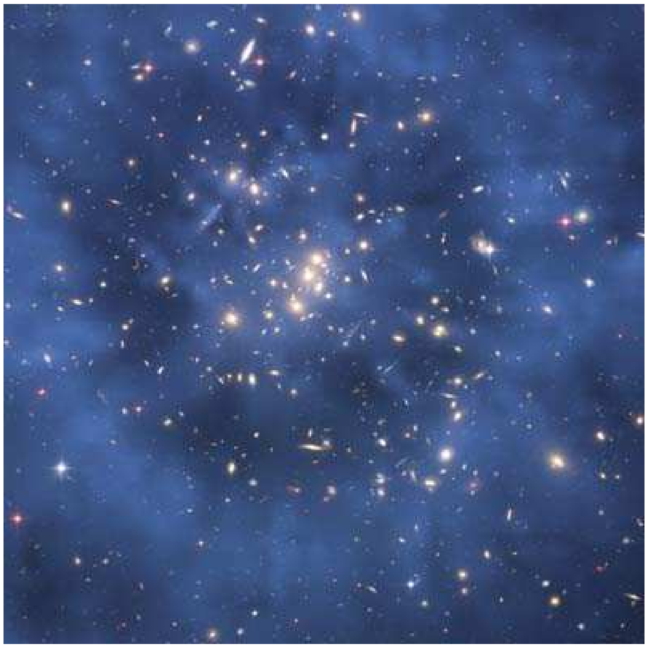


Figure 26: *This Hubble Space Telescope composite image shows a ghostly "ring" of dark matter in the galaxy cluster Cl 0024+17. The ring-like structure is evident in the blue map of the cluster's dark matter distribution. The map is superimposed on a Hubble image of the cluster. The ring is one of the strongest pieces of evidence to date for the existence of dark matter, an unknown substance that pervades the universe. The map was derived from Hubble observations of how the gravity of the cluster Cl 0024+17 distorts the light of more distant galaxies, an optical illusion called gravitational lensing. Although astronomers cannot see dark matter, they can infer its existence by mapping the distorted shapes of the background galaxies. The mapping also shows how dark matter is distributed in the cluster.*

"The collision between the two galaxy clusters created a ripple of dark matter that left distinct footprints in the shapes of the background galaxies," Jee explained. "It's like looking at the pebbles on the bottom of a pond with ripples on the surface. The pebbles' shapes appear to change as the ripples pass over them. So, too, the background galaxies behind the ring show coherent changes in their shapes due to the presence of the dense ring."

Jee and his colleagues used Hubble's Advanced Camera for Surveys to detect the faint, distorted, faraway galaxies behind the cluster that cannot be resolved with ground-based telescopes. "Hubble's exquisite images and unparalleled sensitivity to faint galaxies make it the only tool for this measurement," said team member Richard White of the Space Telescope Science Institute in Baltimore.

Previous observations of the Bullet Cluster with Hubble and the Chandra X-ray Observatory presented a sideways view of a similar encounter between two galaxy clusters. In that collision, the dark matter was pulled apart from the hot cluster gas, but the dark matter still followed the distribution of cluster galaxies. Cl 0024+17 is the first cluster to show a dark matter distribution that differs from the distribution of both the galaxies and the hot gas.

2.24 Galaxy Cluster Takes It to the Extreme

Source: Chandra Press Release, May 30th, 2007 [37]

Evidence for an awesome upheaval in a massive galaxy cluster was discovered in an image made by NASA's Chandra X-ray Observatory. The origin of a bright arc of ferociously hot gas extending over two million light years requires one of the most energetic events ever detected.

The cluster of galaxies is filled with tenuous gas at 170 million degree Celsius that is bound by the mass equivalent of a quadrillion, or 1,000 trillion, suns. The temperature and mass make this cluster a giant among giants.

"The huge feature detected in the cluster, combined with the high temperature, points to an exceptionally dramatic event in the nearby Universe," said Ralph Kraft of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass., and leader of a team of astronomers involved in this research. "While we're not sure what caused it, we've narrowed it down to a couple of exciting possibilities."

The favored explanation for the bright X-ray arc is that two massive galaxy clusters are undergoing a collision at about 4 million miles per hour. Shock waves generated by the violent encounter of the clusters' hot gas clouds could produce a sharp change in pressure along the boundary where the collision is occurring, giving rise to the observed arc-shaped structure which resembles a titanic weather front.

"Although this would be an extreme collision, one of the most powerful ever seen, we think this may be what is going on," said team member Martin Hardcastle, of the University of Hertfordshire, United Kingdom.

A problem with the collision theory is that only one peak in the X-ray emission is seen, whereas two are expected. Longer observations with Chandra and the XMM-Newton X-ray observatories should help determine how serious this problem is for the collision hypothesis.

Another possible explanation is that the disturbance was caused by an outburst generated by the infall of matter into a supermassive black hole located in a central galaxy. The black hole inhales much of the matter but expels some of it outward in a pair of high-speed jets, heating and pushing aside the surrounding gas.

Such events are known to occur in this cluster. The galaxy 3C438 in the central region of the cluster is known to be a powerful source of explosive activity, which is presumably due to a central supermassive black hole. But the energy in these outbursts is not nearly large enough to explain the Chandra data.

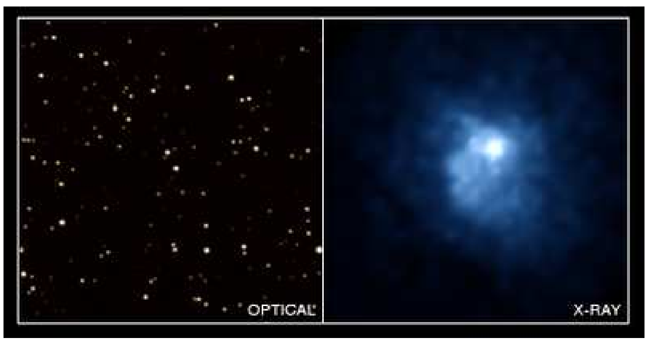


Figure 27: *Credit: X-ray: NASA/CXC/CfA/R.P.Kraft; Optical: Pal.Obs. DSS*

”If this event was an outburst from a supermassive black hole, then it’s by far the most powerful one ever seen,” said team member Bill Forman, also of CfA.

The phenomenal amount of energy involved implies a very large amount of mass would have been swallowed by the black hole, about 30 billion times the Sun’s mass over a period of 200 million years. The authors consider this rate of black hole growth implausible.

”These values have never been seen before and, truthfully, are hard to believe,” said Kraft.

2.25 Chandra Sees Brightest Supernova Ever

Source: Chandra Press Release, May 7th, 2007 [38]

The brightest stellar explosion ever recorded may be a long-sought new type of supernova, according to observations by NASA’s Chandra X-ray Observatory and ground-based optical telescopes. This discovery indicates that violent explosions of extremely massive stars were relatively common in the early universe, and that a similar explosion may be ready to go off in our own galaxy.

”This was a truly monstrous explosion, a hundred times more energetic than a typical supernova,” said Nathan Smith of the University of California at Berkeley, who led a team of astronomers from California and the University of Texas in Austin. ”That means the star that exploded might have been as massive as a star can get, about 150 times that of our sun. We’ve never seen that before.”

Astronomers think many of the first generation of stars were this massive, and this new supernova may thus provide a rare glimpse of how the first stars died. It is unprecedented, however, to find such a massive star and witness its death. The discovery of the supernova, known as SN 2006gy, provides evidence that the death of such massive stars is fundamentally different from theoretical predictions.

”Of all exploding stars ever observed, this was the king,” said Alex Filippenko, leader of the ground-based observations at the Lick Observatory at Mt. Hamilton, Calif., and the Keck Observatory in Mauna Kea, Hawaii. ”We were astonished to see how bright it got, and how long it lasted.”

The Chandra observation allowed the team to rule out the most likely alternative explanation for the supernova: that a white dwarf star with a mass only slightly higher than the sun exploded into a dense, hydrogen-rich environment. In that event, SN 2006gy should have been 1,000 times brighter in X-rays than what Chandra detected.

”This provides strong evidence that SN 2006gy was, in fact, the death of an extremely massive star,” said Dave Pooley of the University of California at Berkeley, who led the Chandra observations.

The star that produced SN 2006gy apparently expelled a large amount of mass prior to exploding. This large mass loss is similar to that seen from Eta Carinae, a massive star in our galaxy, raising suspicion that Eta Carinae may be poised to explode as a supernova. Although SN 2006gy is intrinsically the brightest supernova ever, it is in the galaxy NGC 1260, some 240 million light years away. However, Eta Carinae is only about 7,500 light years away in our own Milky Way galaxy.

”We don’t know for sure if Eta Carinae will explode soon, but we had better keep a close eye on it just in case,” said Mario Livio of the Space Telescope Science Institute in Baltimore, who was not involved in the research. ”Eta Carinae’s explosion could be the best star-show in the history of modern civilization."

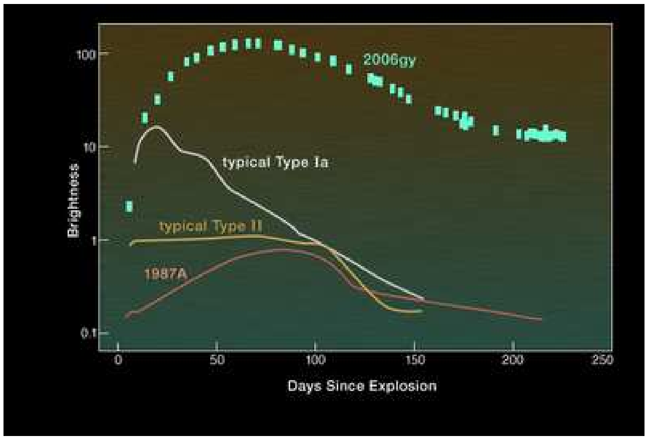


Figure 28: *This graph shows the intrinsic brightness of SN 2006gy and how it changes over time. The graphic also demonstrates how much brighter SN 2006gy is when compared to typical examples of the two main supernova classes. Type Ia supernovas involve the thermonuclear explosion of a white dwarf and type II supernovas are the collapse of a massive star. The famous supernova SN 1987A is also shown. Not only does SN 2006gy get much brighter than other supernovas but it stays very bright for much longer. (Credit: NASA/CXC/UC Berkeley/N.Smith et al.)*

Supernovas usually occur when massive stars exhaust their fuel and collapse under their own gravity. In the case of SN 2006gy, astronomers think that a very different effect may have triggered the explosion. Under some conditions, the core of a massive star produces so much gamma ray radiation that some of the energy from the radiation converts into particle and anti-particle pairs. The resulting drop in energy causes the star to collapse under its own huge gravity.

After this violent collapse, runaway thermonuclear reactions ensue and the star explodes, spewing the remains into space. The SN 2006gy data suggest that spectacular supernovas from the first stars - rather than completely collapsing to a black hole as theorized - may be more common than previously believed.

"In terms of the effect on the early universe, there's a huge difference between these two possibilities," said Smith. "One pollutes the galaxy with large quantities of newly made elements and the other locks them up forever in a black hole."

2.26 Gamma-Ray Bursts Active Longer Than Thought

Source: NASA News, May 22nd, 2007 [39]

Using NASA's Swift satellite, astronomers have discovered that energetic flares seen after gamma-ray bursts (GRBs) are not just hiccups, they appear to be a continuation of the burst itself.

GRBs release in seconds the same amount of energy our Sun will emit over its expected 10 billion-year lifetime. The staggering energy of a long-duration GRB (lasting more than a few seconds) comes from the core of a massive star collapsing to form a black hole or neutron star. In current theory, inrushing gas forms a disk around the central object. Magnetic fields channel some of that material into two jets moving at near-light speed. Collisions between shells of ejected material within the jet trigger the actual GRB.

Early in the mission, Swift's X-ray Telescope (XRT) discovered that the initial pulse of gamma-rays, known as prompt emission, is often followed minutes to hours later by short-lived but powerful X-ray flares. The flares suggested but did not prove that GRB central engines remain active long after the prompt emission.

After analyzing GRB 060714, named for its detection date of July 14, 2006, Hans Krimm of Universities Space Research Association, Columbia, Md. and NASA's Goddard Space Flight Center in Greenbelt, Md., and eight colleagues, have demonstrated that X-ray flares are indeed a continuation of the prompt emission, showing that GRB central engines are active much longer than previously thought.

Swift's Burst Alert Telescope (BAT) picked up the initial GRB in the constellation Libra. Then, from about 70 to 200 seconds after the initial burst, the BAT and XRT registered five flares. Each flare exhibited rapid and large-scale variability in intensity, but the overall energy steadily diminished from flare to flare. Moreover, the peak photon energy of each flare "softened" by progressing from gamma-rays to X-rays (from higher to lower energy).

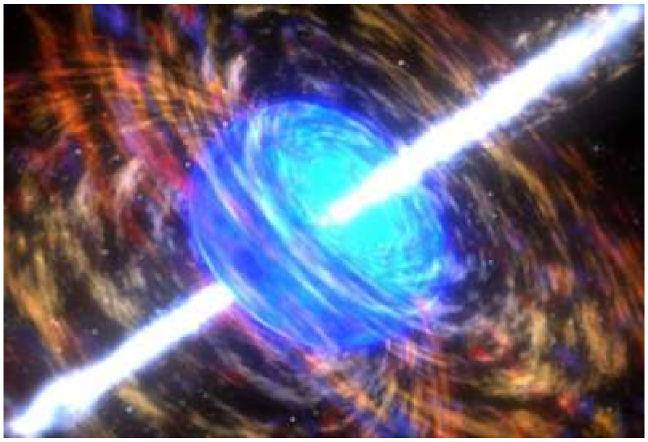


Figure 29: *This artwork depicts the central engine of a gamma-ray burst. A powerful jet of radiation and fast-moving particles blasts its way out of the central region of a dying star. The jet is presumably powered by material spiraling into a black hole or neutron star. Multiple episodes of infall provides fuel for the engine, leading to the burst and later X-ray flares. Credit: NASA / SkyWorks Digital.*

The prompt gamma-ray emission and the subsequent X-ray flares appear to form a continuously connected and evolving succession of events. "This pattern points to a continuous injection of energy from the central engine, perhaps fueled by sporadic infall of material onto a black hole. The black hole just keeps gobbling up gas and the engine keeps spewing out energy," says Krimm, whose paper is scheduled for publication in the August 10 Astrophysical Journal.

The rapid and large-scale variability of the X-ray flares argues strongly against the idea that they come from jets sweeping up the surrounding gas. Since the observed emission comes from a wide region, the afterglow should vary smoothly with time. Nobody has come up with a viable explanation for why the surrounding material would be so lumpy to lead to such rapid variability. "This particular GRB had a series of flares over a wide range in time that were bright enough that we could study their properties in detail," says study coauthor Jonathan Granot of the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University, Stanford, Calif. "It clearly shows a gradual evolution with time in the properties of the flares within the same GRB, while in other GRBs there are typically only one or two flares that are bright enough to be studied in detail, making it very hard to reach a similar conclusion." "This is a very important result," adds Swift principal investigator and study coauthor Neil Gehrels of NASA Goddard. "By chance, if you look at enough bursts you'll find the one that opens the door. GRB 060714 shows that everything happening in the first few minutes is driven by the central engine."

3 Space missions

3.1 NASA Pondering a Future Grapple on the James Webb Space Telescope

Source: NASA News, May 31st, 2007 [40]

When it launches in 2013 the James Webb Space Telescope will settle in an orbit roughly one million miles from the Earth. That distance is currently too far for any astronaut or any other existing NASA servicing capability to reach. Therefore, NASA is doing everything necessary to design and test the telescope on the ground using techniques that will ensure that it deploys and operates reliably in space.

However, NASA is looking into just how feasible it might be to perform emergency servicing operations on the Webb telescope if such a need were to arise and if such a servicing capability were to become available sometime in the future.

"We are currently studying the possibility of adding a lightweight grapple fixture to JWST," said John Decker, Deputy Associate Director of the JWST Project at NASA Goddard Space Flight Center, Greenbelt, Md. "A grapple fixture is a kind of a grab bar that would afford a means for a future manned or robotic servicing capability to safely attach to the telescope in space."

Once the engineers who are assessing the feasibility of adding the grapple feature have concluded the study, they will present the results to NASA Headquarters. At that time, there will be a determination as to whether the grapple feature will be added to the telescope. The assessment will finalize in 2008.

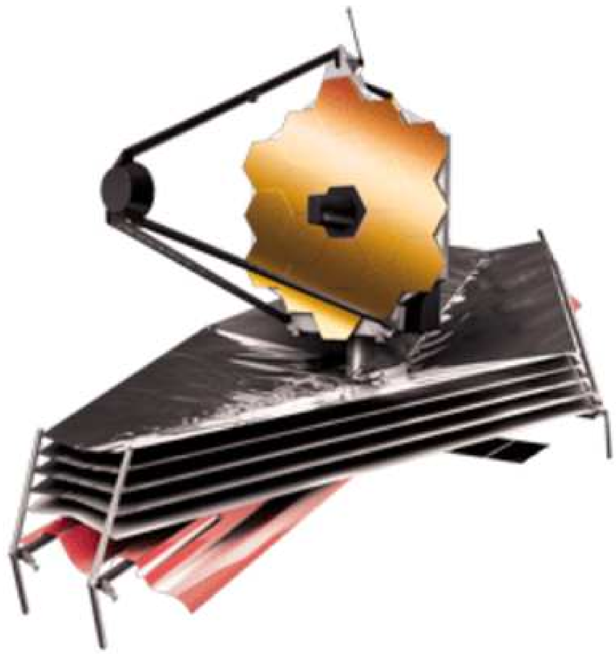


Figure 30: *Artist's rendition of the James Webb Space Telescope. Credit: NASA*

The James Webb Space Telescope is a 21st century space observatory that will peer back more than 13 billion years in time to understand the formation of galaxies, stars and planets and the evolution of our own solar system. It is expected to launch in 2013. The telescope is a joint project of NASA, the European Space Agency and the Canadian Space Agency.

3.2 Spitzer Space Telescope Gives Scientists Depth Perception

Source: Spitzer Press Release, May 30th, 2007 [41]

Astronomers now have a new "eye" for determining the distance to certain mysterious bodies in and around our Milky Way galaxy. By taking advantage of the unique position of NASA's Spitzer's Space Telescope millions of miles from Earth, and a depth-perceiving trick called parallax, they were able to pin down the most probable location of one such object. The findings will ultimately help astronomers better understand the different components of our galaxy.

"Forty years ago a visionary astronomer named Dr. Sjur Refsdal theorized that dark bodies could be located using parallax and a space telescope," said Andrew Gould of Ohio State University, Columbus, Ohio, who led the project. "It is truly remarkable that we have been able to prove him right with this Spitzer observation."

Spitzer is the only telescope that orbits the sun behind Earth, and is the farthest telescope from us with the ability to study distant stars. Currently, Spitzer is about 40 million miles (70 million kilometers) away from Earth. It will continue to drift farther and farther away at a rate of about 10 million miles (15 million kilometers) per year.

This great distance gives astronomers a great advantage. They can use Spitzer in the same way that a human brain uses two eyes to tell how far away objects are, a principle called parallax. With two eyes, we have two perspectives, which our brains combine to give us depth perception. In space, Spitzer acts as one eye, while a ground-based telescope acts as the other. With two very wide cosmic eyes, astronomers can determine the location of bodies within and just outside our galaxy.

Gould and his team are the first to use Spitzer to perform this astronomical feat. Their goal was to determine whether a previously identified dark matter candidate, called a massive compact halo object, or "Macho," is within our galaxy and contributing to its overall weight.

Our galaxy is heavier than it looks, with at least 80 percent of its mass consisting of mysterious, invisible dark matter. A large fraction of this dark matter is the exotic kind, different from the ordinary matter that makes up the familiar world around us. The rest might be so-called machos, which are ordinary-matter dark bodies that lurk in our galaxy's halo, the region that sits above and below its spiral disk. They are thought to be a combination of black holes, very faint stars and isolated planets.

Several suspected machos have been discovered in the past through a technique called microlensing, in which the dark bodies' gravity causes light from a passing background star to bend and brighten. But astronomers do not know whether these candidates are indeed machos in the galaxy halo, or other, non-macho objects just outside the Milky Way in small satellite galaxies. By pinpointing the location of the candidates, astronomers will learn whether they are in the halo and thus machos. This information, in turn, will help them figure out how much machos contribute to the total mass of our galaxy.

OGLE-2005-SMC-001 is one such macho candidate. It was first discovered by Andrzej Udalski, of the Optical Gravitational Lens Experiment (OGLE), and Warsaw University Observatory, Warszawa, Poland. Udalski and colleagues noticed that the dark object was causing a passing, background star to brighten. Gould and his team quickly sprang to action, following up with Spitzer observations of the short-lived event.

The data from both telescopes, or ”eyes,” were then combined and modeled through a series of complicated equations. The results indicate with 95 percent probability that OGLE-2005-SMC-001 is dark matter in our galaxy’s halo and therefore a part of its overall mass.

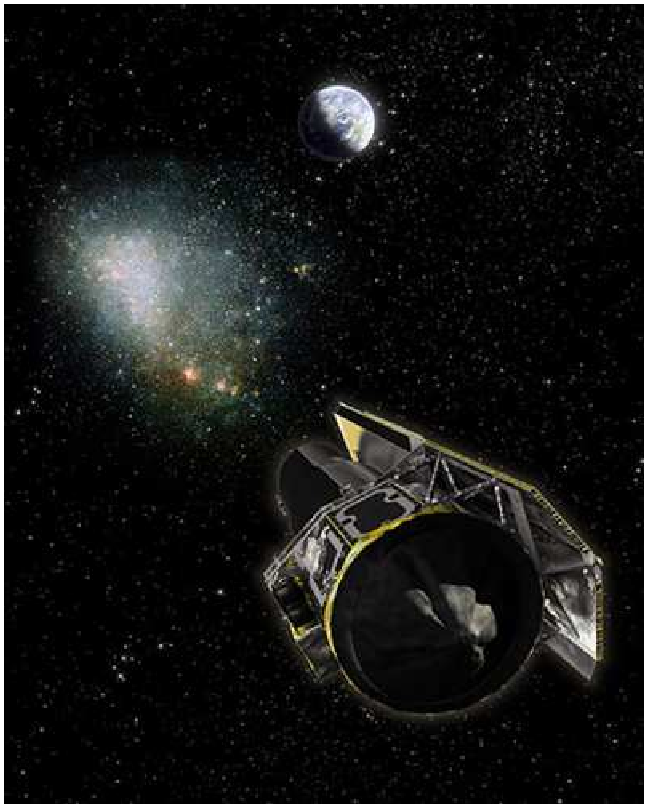


Figure 31: *Distance to Dark Bodies Credit: NASA/JPL-Caltech/R. Hurt (SSC)*

In addition, the data show that OGLE-2005-SMC-001 consists of two bodies circling around each other. Gould and colleagues think the objects could be a pair of black holes, a very rare sighting in our universe. However, there is a small chance this feature is actually just a regular pair of orbiting stars in a neighboring, satellite galaxy.

”It will be very exciting to locate and measure the masses of more dark objects in the future by applying this technique. And we might finally be able to unravel the mystery of machos,” said Subo Dong of Ohio State University, whose paper on OGLE-2005-SMC-001 has been accepted for publication in Astrophysical Journal. Dong presented the results today at a press conference, at the 210th meeting of the American Astronomical Society in Honolulu, Hawaii.

3.3 Spacewalk Complete, Debris Panels Installed

Source: NASA News, May 30th, 2007 [42]

Two International Space Station cosmonauts successfully completed a 5-hour, 25-minute spacewalk from the Pirs docking compartment airlock Wednesday, installing Service Module Debris Protection (SMDP) panels and rerouting a Global Positioning System antenna cable.

Additional SMDP panels will be installed on Zvezda during a second spacewalk by the cosmonauts, Commander Fyodor Yurchikhin and Flight Engineer Oleg Kotov, on June 6. During that spacewalk they also will install a section of an Ethernet cable on the Zarya module and a Russian experiment called Biorisk on Pirs.

Yurchikhin, the lead spacewalker, EV1, and Kotov, EV2, wore Russian Orlan spacesuits. It was the first spacewalk for both.

After leaving the Pirs airlock at 3:05 p.m. EDT, the spacewalkers moved to the Strela 2, one of the hand-operated cranes at the base of Pirs. They attached an extension to the Strela boom. With Kotov on the end of the extension, Yurchikhin extended the boom to a point over Pressurized Mating Adaptor 3 (PMA-3), on the Unity Node, a distance of about 60 feet.

Yurchikhin, with guidance from Kotov, maneuvered the Strela end effector to a grapple fixture on the SMDP Adaptor, a stowage rack. It is attached to PMA-3 and held three bundles of SMDP panels, a total of 17 of them. The assembly has been dubbed the ”Christmas Tree.”

Once the Christmas Tree was attached to Strela and released from PMA-3, Yurchikhin moved it and Kotov back to the small diameter of Zvezda. Yurchikhin joined Kotov there, and together they secured it to a grapple fixture on Zvezda.

They then left the SMDP task and moved aft on Zvezda’s large diameter. There they rerouted a cable for a Global Positioning System to be used with the European Automated Transfer Vehicle (ATV). The ATV is an unpiloted cargo carrier with almost twice the capacity of the Progress cargo craft. It is scheduled to make its first launch later this year.

That done, they moved back to the Christmas Tree on the forward end of Zvezda, where they removed and opened one of the three bundles of debris panels. That bundle, No. 4, held five panels. The aluminum panels vary in size but are about an inch thick. They typically measure about 2 by 3 feet and weigh 15 to 20 pounds.

Figure 32: *Flight Engineer Oleg Kotov guides a bundle of debris panels. Image credit: NASA TV*

Yurchikhin and Kotov installed the five panels on Zvezda's conical section, the area between Zvezda's large and small diameters.

Six SMDPs from bundle No. 1 were installed during an Aug. 16, 2002, spacewalk by Expedition 5 Commander Valery Korzun and Flight Engineer Peggy Whitson. Those SMDPs were delivered to the station by Endeavour during STS-111 in June 2002.

The remaining three bundles and their adaptor were delivered by Discovery during STS-116 last December and attached to PMA-3 by spacewalkers Bob Curbeam and Sunita Williams. Williams was intravehicular officer for Wednesday's spacewalk, advising and keeping the spacewalkers on schedule.

After the installation task, the spacewalkers moved back to Pirs and into the airlock. Hatch closure marking the end of the spacewalk was at 8:30 p.m.

3.4 UD scientists build an 'IceTop' at the bottom of the world

Source: University of Delaware Daily, May 23rd, 2007 [43]

The University of Delaware is helping to build a huge "IceCube" at the South Pole, and it has nothing to do with cooling beverages.

"IceCube" is a gigantic scientific instrument–a telescope for detecting illusive particles called neutrinos that can travel millions of miles through space, passing right through planets.

A poet might refer to them as stardust or ghosts from outer space. But to astrophysicists, neutrinos are the high-energy messengers from the universe, formed during such cataclysmic cosmic events as exploding stars and colliding galaxies.

When the novel telescope is completed in the next several years, a cubic kilometer of ice at the "bottom of the world" will provide a new eye into the heavens and some of the most distant and violent events in the cosmos.

The telescope, its third year of construction recently concluded, is an international effort involving more than 20 institutions. The project is funded primarily by the National Science Foundation, with additional contributions from Belgium, Germany, Japan and Sweden, as well as the U.S. Department of Energy and the Wisconsin Alumni Research Foundation.

The lead institution for the IceCube project is the University of Wisconsin, which is working in collaboration with UD and several other universities across the nation.

UD is building the telescope's surface array of detectors, aptly named "IceTop."

Thomas Gaisser, Martin A. Pomerantz Chair of Physics and Astronomy, is leading the UD project, which involves 16 scientists and technicians throughout in the physics and astronomy department and its affiliated research center, the Bartol Research Institute. The primary function of the institute is to carry out forefront scientific research, with a primary focus in physics, astronomy and space sciences.

"IceCube is already the world's largest neutrino telescope although it is less than half-finished," Gaisser said. "Its purpose is to use neutrinos as a novel probe of high-energy astrophysical processes to reveal their inner workings, which are obscured for ordinary telescopes using light and other wavelengths of the electromagnetic spectrum."

When completed in the next several years, the telescope will consist of more than 70 strings, each containing 60 optical detectors, frozen over a mile-and-a-half deep in the Antarctic ice cap.

Working in the harsh polar environment is no easy feat. On average, it takes a specially designed, 5-million-watt hot-water drill 48 hours–two full days–and 4,800 gallons of jet fuel to melt one of the holes for deploying a string of the telescope's sophisticated sensors. And approximately 200,000 gallons of melted ice is generated in the process.

Once a hole has been drilled, a deployment team begins lowering a string of 60 optical detectors into it. It takes 11 hours to deploy a single string and several days for the water in the hole to freeze again.

Then atop each of the deep ice strings, UD scientists and technicians are installing two 650-gallon tanks of water that each contain two optical detectors. The tanks are filled with water, and the freeze is controlled to produce perfectly clear ice, with no bubbles or cracks.

”The purpose of IceTop on the surface is to detect high-energy cosmic rays that interact in the atmosphere above IceCube,” Gaisser noted. ”By detecting the same events with IceTop and the deep detectors of IceCube, we expect to get new information about the origin of the most energetic particles in nature. At the same time, the surface detectors help IceCube reject the background of downward cosmic-ray events that obscures the signals of neutrinos coming up through the Earth from below.”

Each optical detector suspended in the ice is a computer and data acquisition system that has at its heart a photo multiplier tube, a device sensitive enough to detect a single photon of light.

As a neutrino passes through the ice, it occasionally slams into a molecule of ice. This collision generates other particles, called muons, that produce a small flash of light as they pass through the ice.

The optical detectors capture the flash of light and stamp it with a precise time code. This information is then relayed to the surface to the IceCube Lab, where the path of the particle can be reconstructed and scientists can trace where it came from, perhaps an exploding star or a black hole.

”We are now analyzing data obtained during 2006 with the 32 IceTop tanks and nine IceCube strings–a total of 604 digital optical modules,” Gaisser said. ”We added 13 more strings and 20 more tanks to IceCube in the season that just ended, and the detector will be completed over the next three or four seasons. Meanwhile, we expect to publish the first scientific results of IceCube this year and next, and we hope for new discoveries even before the detector is complete.”

Figure 33: *The telescope’s optical detectors are deployed in mile-and-a-half deep holes in the Antarctic ice.*

3.5 Gemini Instrument Damaged

Source: Gemini Observatory Press Release, May 15th, 2007 [44]

At the end of April, GNIRS was warmed up for routine cold head service. In the process of servicing the cold heads, the fast warm-up system and vacuum pumps were left on over the weekend; this has always been the normal operating procedure.

The GNIRS fast warm-up system has been used on the order of a dozen times without incident. The system has a completely independent controller that shuts off power to the heater resistors when the temperature set point is reached. It is independent of all other Gemini and GNIRS software. For some unknown reason the controller failed, resulting in continuously heating GNIRS until it reached temperatures near 200 C for an undetermined period of time. The fast warm-up system did not have thermal fuses or circuit breakers.

When Gemini staff arrived on Monday, they recognized there was a problem and shut the heaters off. They then allowed GNIRS to passively cool for several days with the pumps running. After the instrument had cooled, the dewar was opened and the main components inspected by a team of Gemini engineers and scientists. The ”Phase 1” assessment was carefully planned with input from the NOAO staff that built GNIRS.

After the initial inspection, it was obvious that some components were damaged, but many were clearly fine. Interestingly, vaporized plastic and resin condensed on the window, the outer vacuum jacket and radiation shields, which were the coolest parts (near ambient temperatures). Much of the interior was relatively clean of condensation.

In summary, the science detector, detector mount*, OIWFS detector*, fiberglass struts, plastic delrin spacers, filters*, window* and some sensor diodes were damaged. Asterisks indicate components for which spares are presently available.

The dewar and optical bench, most mechanisms, wiring, motors and electronics appear to be okay. As of May 11, we are still uncertain about the status of the gratings, the optical coatings and surfaces of the diamond turned mirrors, the cold head displacers, and the slit mechanism (delrin). These will be inspected in detail shortly.

GNIRS: The Next Phase

We are now entering the second phase of damage assessment, including testing all the motors and wiring. We are also testing possible techniques for cleaning the optics and other surfaces. The composition of the residue is being identified at a lab in Santiago. We are carefully examining everything in greater detail and looking into procuring replacement parts, including a new Aladdin array. To help us with the full assessment, Jay Elias (the GNIRS PI, NOAO) and John White (Gemini-North instrumentation engineer) have been on Cerro Pachn working with the Gemini-South team of engineers.

GNIRS: Recovery Plan

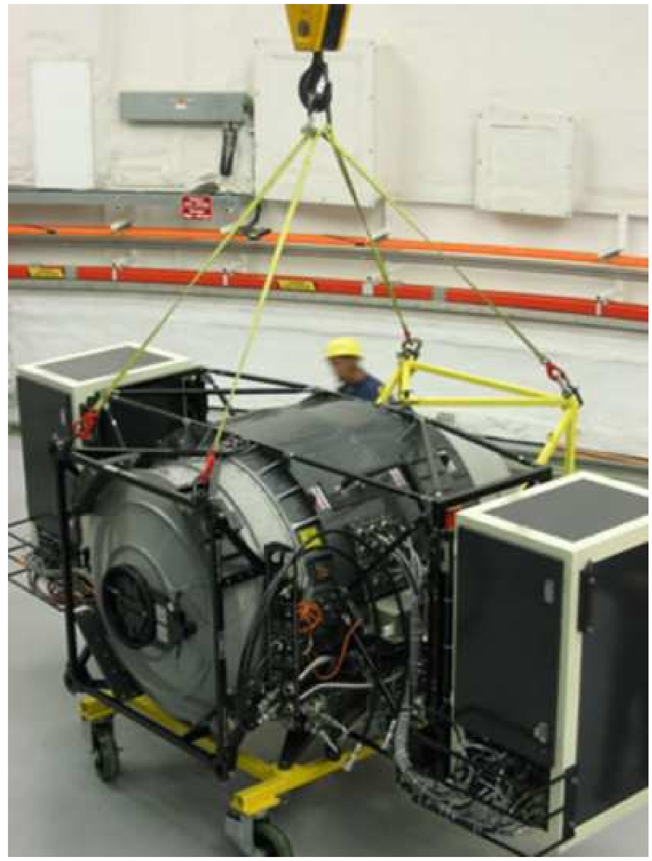


Figure 34: *GNIRS being hoisted at Gemini South.*

Once we have a full assessment of the damage, we will know what work needs to be done to bring GNIRS back to full functionality. At that point we will decide where to perform the work, and whose help will be needed to do it. It is worth emphasizing that GNIRS is not lostthe vast majority of its parts are fine. The work to fix GNIRS will be significant, though, and it will take several months. At a minimum, we will need to rebuild the fiberglass supports and reassemble the instrument. We will need to inspect the cooling systems. Some of the optics will need to be cleaned, and some may require re-polishing and re-coating. All the optics will have to be realigned and the mechanisms tested. A new array will be installed, tested, and characterized. Finally, we will recommission GNIRS on the telescope.

Gemini’s multi-instrument queue provides flexibility in dealing with the temporary loss of GNIRS. An agreement with NOAO to leave Phoenix at Gemini for the rest of 2007 is being negotiated. A special call for proposals was issued inviting proposals for additional bright-time programs using GMOS, T-ReCS and Phoenix. NICI commissioning is under way now, and the NICI campaign may begin in 2007B when NICI commissioning is complete. These will all be important steps to insure that the full scientific potential of the telescope is met while this unfortunate setback with GNIRS is fixed. GNIRS is one of our most important facility instruments, and we are optimistic about getting it back on line as soon as practical.

3.6 Walter Schirra, 1923-2007

Source: NASA News, May 3rd, 2007 [45]

Wally Schirra, the only astronaut to fly in the Mercury, Gemini and Apollo programs, has died. He was 84 years old.

Schirra's NASA career began with his selection as one of the original seven Mercury astronauts in 1959 and spans the period from Americas first tentative steps into space to the missions to the moon.

Schirra flew on the fifth Mercury flight in 1962, orbiting the Earth six times. He commanded Gemini 6A in 1965, a flight with Tom Stafford that had the historic distinction of being the first rendezvous of two manned, maneuverable spacecraft. Gemini 6A and Gemini 7 flew in formation for five hours, as close as one foot to one another.

Schirra also commanded Apollo 7, the first manned Apollo flight. During that 11-day flight in Earth orbit in 1968, he and fellow crewmembers Walt Cunningham and Donn Eisele tested the Apollo systems and proved it was ready to take astronauts to the moon.

In what was a precursor of things to come, Apollo 7 transmitted the first television feed live into commercial networks from space during its 260-hour flight.

"With the passing of Wally Schirra, we at NASA note with sorrow the loss of yet another of the pioneers of human spaceflight," NASA Administrator Michael Griffin said. "As a Mercury astronaut, Wally was of a member of the first group of astronauts to be selected, often referred to as the Original Seven."

Administrator's Statment

Fellow Mercury astronaut Scott Carpenter called Schirra a "dear friend, cherished comrade and a brother."

"Despite our good natured competition for flights into space," said Carpenter, "Wally strove to bring a smile to everyone he met and its with a smile that I will forever fondly remember him."

President Bush also mourned Schirra's passing. "His ventures into space furthered our understanding of manned space flight and helped pave the way for mankind's first journey to the Moon," said the President. "Laura and I join Wally's family and friends and the NASA community in mourning the loss of an American hero."

Schirra retired from the Navy as a captain and from NASA in 1969 and became a commentator with CBS Television. His enthusiasm and knowledge of the space program made him a widely known national and international figure.

He complemented Walter Cronkite and the two became a powerful space-coverage team. Schirra worked for CBS from 1969 to 1975. He also engaged in a range of business activities and in 1979 formed his own consultant company, Schirra Enterprises.

Walter M. Schirra was born in Hackensack, N.J., on March 12, 1923. He graduated from the U.S. Naval Academy in 1945, and from Naval Flight Training at Pensacola Naval Air Station, Fla., in 1947. After service as a carrier-based fighter pilot and operations officer, he attended the Naval Test Pilot School at Patuxent River, Md. He flew fighters during the Korean War under an exchange program with the Air Force.

Schirra was one of the original seven Mercury astronauts introduced to the public on April 1959. The seven were chosen from among 110 selected test pilots from the Air Force, Navy and Marine Corps, after exhaustive physical and psychological examinations.

In 1961, the program moved to the newly established Manned Spacecraft Center (now the Lyndon B. Johnson Space Center) near Houston. Schirra was enthusiastic and outgoing and like others among the Mercury astronauts, he was not above an occasional practical joke. "Levity makes life a lot easier," he once told a Houston reporter.

Schirra's Gemini flight with Stafford was something of an improvisation. They had been scheduled to rendezvous in orbit with an unmanned Agena to be launched 90 minutes before the Gemini liftoff. But six minutes after the Atlas-Agena left the pad it exploded, and the Gemini 6A launch was postponed.

Eventually it was decided to use Gemini 7 as a rendezvous target for Gemini 6A. Both were to be launched from Pad 19 at Cape Canaveral, so a record turnaround of the pad was necessary. Working around the clock, crews got the pad ready in just eight days after the Gemini 7 liftoff.

The Gemini 6A countdown reached zero on Dec. 12, 1965, and the rocket engines ignited then shut down. The two astronauts had to wait almost half an hour atop the fueled rocket before getting out of the capsule. The problem turned out to be minor, the failure of an electrical connection.

Figure 35: *NASA astronaut Walter Schirra in his Mercury flight suit. Photo credit: NASA.*

Three days later, Gemini 6A was launched without a hitch. The mission proved the spacecraft could be readily maneuvered. It was an encouraging development in the race to reach the moon.

By the launch of Apollo 7 in October 1968 – the first human flight in an Apollo spacecraft that had been much improved after the tragic Apollo 1 fire on the launch pad almost two years before – the moon landing seemed to be coming within reach. The success of the flight proved that it was.

Accomplishments of the mission commanded by Schirra resulted in the next flight, Apollo 8, becoming the first to orbit the moon.

Schirras military awards included the Navy Distinguished Service Medal, three Distinguished Flying Crosses, three Air Medals, two NASA Distinguished Service Medals, the NASA Exceptional Service Medal and the Philippines Legion of Honor.

He was awarded honorary doctorates by several institutions of higher learning.

He was active in a number of organizations and was a founding member and director of the Mercury Seven Foundation. He also was a director of the San Diego Aerospace Museum, a trustee of the Scripps Aquarium, and a member of the International Council of the Salk Institute.

4 Internet websites

[1] http://www.nsf.gov/news/news_summ.jsp?cntn_id=108803&org=OLPA&from=news
[2] http://www.nasa.gov/home/hqnews/2007/may/HQ_07-123_SOHO.html
[3] http://www.esa.int/esaCP/SEM3DCV681F_index_0.html
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[5] http://www.jpl.nasa.gov/news/news.cfm?release=2007-061
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[8] http://www.jpl.nasa.gov/news/news.cfm?release=2007-062
[9] http://www.nasa.gov/cassini,
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[44] http://www.gemini.edu/index.php?option=content&task=view&id=231
[45] http://www.nasa.gov/vision/space/features/walter_schirra.html

5 About Vendelinus and this newsletter

Vendelinus is the adult amateur astronomy section of the Europlanetarium in Genk, Belgium. It is also a Flemish Amateur-astronomy Club (VVS).The club exists officially since January 2000 and is named after the Limburg astronomer Gottfried Wendelen (1580-1667) born in Herk de Stad.

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E-mail: Tony Dethier, antoine.dethier@skynet.be

Website: http://users.pandora.be/lode.stevens/vendelinus/volks.html

The primary function of the Vendelinus Astronomy Newsletter is to provide our members monthly with an overview of the latest astronomical news, copied, pasted and packaged into one newsletter, so that they don't have to scan through the websites themselves. Because the contents consists of the original press releases, the language is English. The newsletter appears monthly at the beginning of the month and gives and overview of news from the previous month. It comes in two formats: as plain text and as a PDF document. In the latter format, colour figures are included. The newsletter is available by email (if I agree to include you in my mailing list) and on the web at:

http://www.warwick.ac.uk/go/erwin_verwichte/amateur/vndnews/

Erwin Verwichte