
# Vendelinus Astronomy Newsletter

## September 2004

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## Contents

# 1 Solar System

## 1.1 Moon and its Flock

*Source: JPL News Release, September 30th, 2004* [1]

In its own way, the shepherd moon Prometheus (102 kilometers, 63 miles across) is one of the lords of Saturn's rings. The little moon maintains the inner edge of Saturn's thin, knotted F ring, while its slightly smaller cohort Pandora (84 kilometers, or 52 miles across) guards the ring's outer edge.

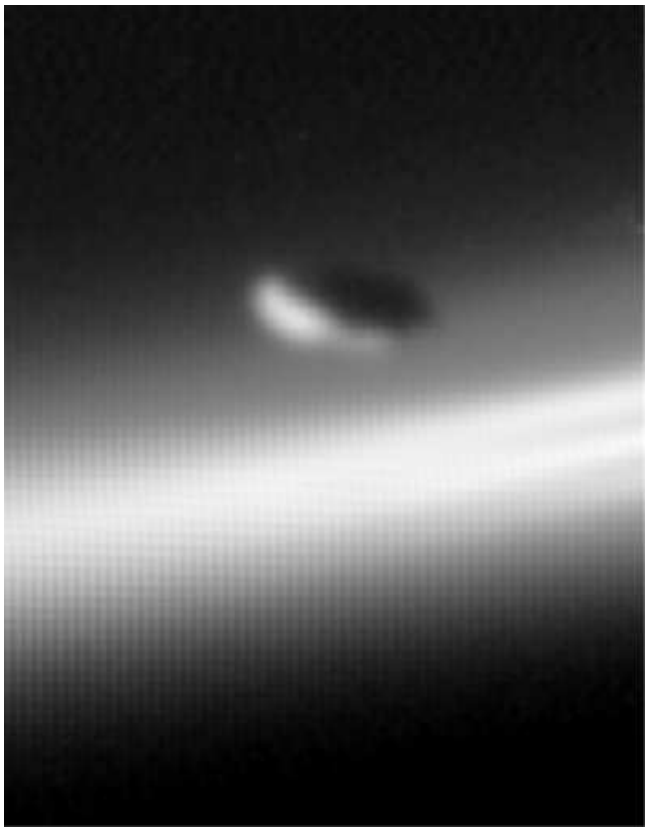

Figure 1: *Image Credit: NASA/JPL/Space Science Institute*

This view is a composite of nine raw images combined in a way that improves resolution and reduces noise. The final image was magnified by a factor of five. One of the component images was previously released (see PIA 06098).

The image clearly shows that Prometheus is not round, but instead has an oblong, potato-like shape. The moon was discovered during the Voyager mission, and scientists then noted ridges, valleys and craters on its surface. Hints of its varied topography are present in this view, although Cassini will likely obtain much better images of Prometheus later in the mission.

The component images were taken over about ten and a half minutes. During that time, the spacecraft's motion caused some blurring of the F ring in the background. Cassini was below the ring plane at the time the images were obtained, and the view here is across the rings toward the distant arm of the F ring. Sunlight is coming from below left.

These images were obtained with the Cassini spacecraft wide angle camera on July 1, 2004, around the time Cassini entered Saturn's orbit. The spacecraft's distance from the planet ranged from approximately 181,000 to 190,000 kilometers (112,000 to 118,000 miles) during the time the exposures were taken. The image scale is approximately 11 kilometers (7 miles) per pixel.

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Cassini-Huygens mission for NASA's Science Mission Directorate, Washington, D.C. The Cassini orbiter and its two onboard cameras were designed, developed and assembled at JPL. The imaging team is based at the Space Science Institute, Boulder, Colo.

For more information about the Cassini-Huygens mission, visit [2] and the Cassini imaging team home page, [3] .

## 1.2 ESO Views of Earth-Approaching Asteroid Toutatis

*Source: ESO Press Release, September 29th, 2004* [4]

Today, September 29, 2004, is undisputedly the Day of Toutatis, the famous "doomsday" asteroid.

Not since the year 1353 did this impressive "space rock" pass so close by the Earth as it does today. Visible as a fast-moving faint point of light in the southern skies, it approaches the Earth to within 1,550,000 km, or just four times the distance of the Moon.

Closely watched by astronomers since its discovery in January 1989, this asteroid has been found to move in an orbit that brings it close to the Earth at regular intervals, about

once every four years. This happened in 1992, 1996, 2000 and now again in 2004.

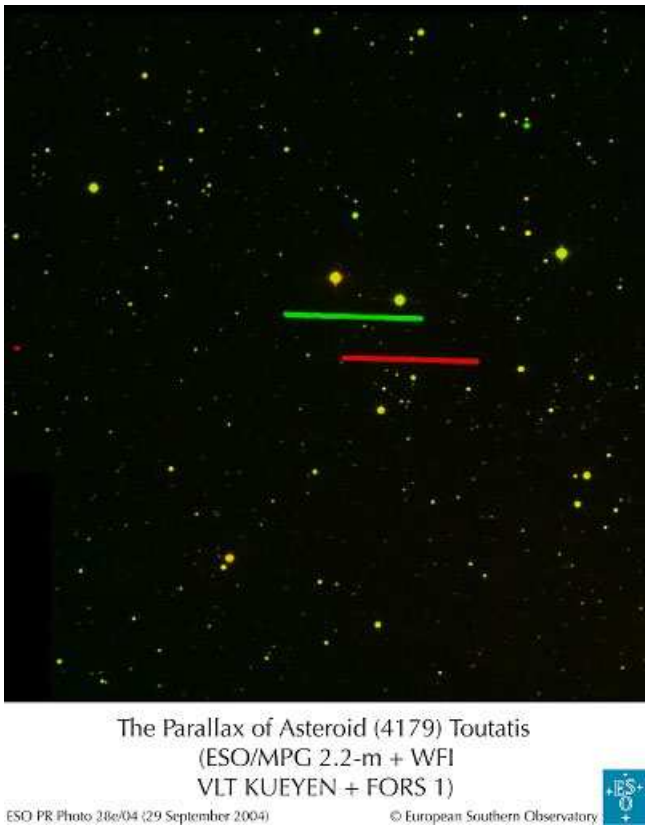


Figure 2: *a composite, false-colour image showing asteroid (4179) Toutatis moving in front of background stars, as seen from Paranal (red trail) and La Silla (green trail). The two photos used for this combination were obtained nearly simultaneously in the morning of September 29, at 02:30 hrs UT, when the asteroid was passing through the constellation of Triangulum Australe ("The Southern Triangle"). The offset between the two trails corresponds to the difference of the lines-of-sight from the two telescopes towards the object. Two 1-min images were taken almost simultaneously with the FORS-1 instrument on Kueyen, the second 8.2m VLT Unit Telescope on Paranal, and on the WFI camera installed on the ESO/MPI 2.2m telescope at La Silla. The WFI image was obtained though a R broad-band filter; on the VLT, a narrow band [O III] interference filter was used to attenuate the light of the bright asteroid. The images were then scaled and processed in order to compensate for the different characteristics of the two instruments (scale, orientation, distortion, sensitivity). The VLT image is displayed in red, the WFI image in green. As the stars are common to both images, they appear yellowish.*

Radar observations during these passages have shown that Toutatis has an elongated shape, measuring about 4.6 x 2.4 x 1.9 km. It tumbles slowly through space, with a rotation period of 5.4 days.

The above images of Toutatis were taken with the ESO Very Large Telescope (during a technical test) in the evening of September 28. They were obtained just over 12 hours before the closest approach that happens today at about 15:40 hrs Central European Summer Time (CEST), or 13:40 hrs Universal Time (UT). At the time of these observations, Toutatis was about 1,640,000 km from the Earth, moving with a speed of about 11 km/sec relative to our planet.

They show the asteroid as a fast-moving object of magnitude 10, about 40 times fainter than what can be perceived with the unaided, dark-adapted eye. They also prove that Toutatis is right on track, following exactly the predicted trajectory in space and passing the Earth at a safe distance, as foreseen.

Detailed calculations, taking into account all available observations of this celestial body, have shown that although Toutatis passes regularly near the Earth, today's passage is the closest one for quite some time, at least until the year 2562. The ESO observations, obtained at a moment when Toutatis was very close to the Earth, will help to further refine the orbital calculations.

The "parallax effect" demonstrated!

Simultaneous images obtained with telescopes at ESO's two observatories at La Silla and Paranal demonstrate the closeness of Toutatis to the Earth. As can be seen on the unique ESO PR Photo 28e/04 that combines two of the exposures from the two observatories, the sighting angle to Toutatis from the two observatories, 513 km km apart, is quite different. Astronomers refer to this effect as the "parallax". The closer the object is, the larger is the effect, i.e., the larger will be the shift of the line-of-sight.

Interestingly, the measured angular distance in the sky of the beginnings (or the ends) of the two trails (about 40 arcsec), together with the known distance between the two observatories and the position of Toutatis in the sky at the moment of the exposures fully define the triangle "Paranal-Toutatis-La Silla" and thus allow to calculate the exact distance to the asteroid.

It is found to be very close to that predicted from the asteroid's position in its orbit and that of the Earth at the moment of this unique observation, 1,607,900 km. This exceptional, simultaneous set of observations thus provides an indepen-

dent measurement of Toutatis' distance in space and, like the measured positions, a confirmation of its computed orbit.

More information about Toutatis is available at the dedicated webpage by the French discoverers (http://www.astrosurf.com/maury/asteroides/toutatis.html) and also at the specialised Near-Earth Objects - Dynamic Site (http://newton.dm.unipi.it/cgi-bin/neodys/neoibo?objects:Toutatis;main)

## 1.3 Mars Express latest findings give hints about water loss in the Martian atmosphere

*Source: ESA Press Release, September 27th, 2004* [5]

Recent results from the ASPERA-3 instrument on board Mars Express confirm that a very efficient process is at work in the Martian atmosphere which could explain the loss of water. Water is believed to have once been abundant on the Red Planet. Professor Rickard Lundin, leader of the ASPERA-3 team, describes these findings in a paper published in the latest issue of Science.

Mars is bombarded by a flood of charged particles from the Sun, commonly called the 'solar wind' and consisting of electrons and alpha particles. The solar wind erodes the atmosphere of Mars, and is believed to have stripped away a large amount of water that was present on the planet about 3800 million years ago.

Geological evidence, as recently confirmed by images from the High Resolution Stereo Camera (HRSC) onboard Mars Express, indicates that water flows and even an ocean in the northern hemisphere shaped the surface of Mars. Today, water still exists on the Red Planet, but less than in the past. Observations made earlier this year by the OMEGA instrument on Mars Express showed that Mars has vast fields of perennial water ice, stretching out from its south pole. The ASPERA-3 instrument on board Mars Express aims to answer the question of whether the solar wind interaction with the upper atmosphere of Mars contributes to the depletion of water. It is measuring a process called 'solar wind scavenging', or the slow 'invisible' escape of volatile gases and liquid compounds which make up the atmosphere and hydrosphere of a planet.

Using plasma spectrometers and a special imager to detect energetic neutral atoms, ASPERA-3 is making global and simultaneous measurements of the solar wind, the inflow of energetic particles, and also the 'planetary wind', which is the outflow of particles from the Martian atmosphere and ionosphere. Aspera 3 has established that the solar wind penetrates through the ionosphere and very deeply into the Martian atmosphere down to an altitude of 270 kilometres. This seems to be the reason for the acceleration processes that cause the loss of atmosphere on Mars.

## 1.4 Water and methane maps overlap on Mars: a new clue?

*Source: ESA Press Release, September 20th, 2004* [6]

Recent analyses of ESA's Mars Express data reveal that concentrations of water vapour and methane in the atmosphere of Mars significantly overlap. This result, from data obtained by the Planetary Fourier Spectrometer (PFS), gives a boost to understanding of geological and atmospheric processes on Mars, and provides important new hints to evaluate the hypothesis of present life on the Red Planet.

PFS observed that, at 10-15 kilometres above the surface, water vapour is well mixed and uniform in the atmosphere. However, it found that, close to the surface, water vapour is more concentrated in three broad equatorial regions: Arabia Terra, Elysium Planum and Arcadia-Memnonia.

Here, the concentration is two to three times higher than in other regions observed. These areas of water vapour concentration also correspond to the areas where NASA's Odyssey spacecraft has observed a water ice layer a few tens of centimetres below the surface, as Dr Vittorio Formisano, PFS principal investigator, reports.

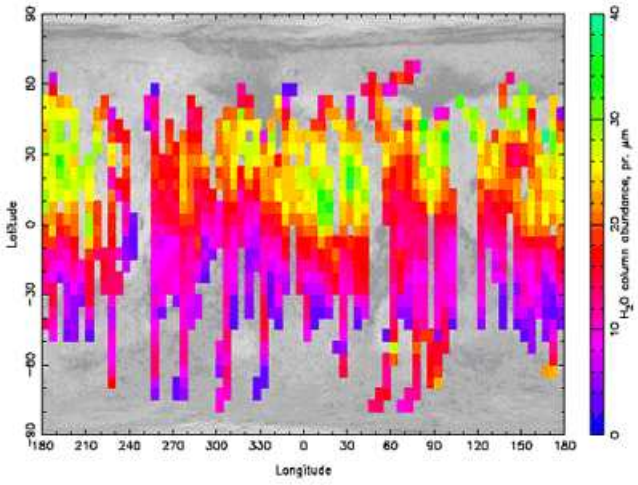


Figure 3: *This map shows the concentration of water vapour close to the soil around the equatorial region of Mars. The areas of least concentration are in purple, the highest in green. Credits: ESA/ASI/PFS team*

New in-depth analysis of PFS data also confirms that methane is not uniform in the atmosphere, but concentrated in some areas. The PFS team observed that the areas of highest concentration of methane overlap with the areas where water vapour and underground water ice are also concentrated. This spatial correlation between water vapour and methane seems to point to a common underground source.

Initial speculation has taken the underground ice layer into account. This could be explained by the 'ice table' concept, in which geothermal heat from below the surface makes water and other material move towards the surface. It would then freeze before getting there, due to the very low surface temperature (many tens of degrees Celsius below zero).

Further investigations are needed to fully understand the correlation between the ice table and the presence and distribution of water vapour and methane in the atmosphere.

In other words, can the geothermal processes which 'feed' the ice table also bring water vapour and other gases, like methane, to the surface? Can there be liquid water below the ice table? Can forms of bacterial life exist in the water below the ice table, producing methane and other gases and releasing them to the surface and then to the atmosphere?

The PFS instrument has also detected traces of other gases in the Martian atmosphere. A report on these is currently under peer review. Further studies will address whether these gases can be linked to water and methane and help answer the unresolved questions. In-situ observations by future lander missions to Mars may provide a more exhaustive solution to the puzzle.

## 1.5 Beware: Io Dust

*Source: Science@NASA, September 14th, 2004* [7]

Jupiter's moon Io is peppered with volcanoes, the hottest, most active volcanoes in our solar system. Sizzling vents spew plumes of gas and dust as much as 400 km high. They surge, spit, subside and surge again, non-stop.

The towering plumes, outlined by graceful arcs of rising and falling ash, are eerily beautiful. Their tops jut into space, freezing. Beneath them, scientists believe, it snows. Sulfurous flakes crystallize in the plume-tops and drift gently down to coat Io's colorful terrain.

High above the falling snow something unexpected happens: At the apex of the plumes, some of the ash and dust that ought to turn around and fall ... doesn't. Defying gravity, it keeps going up, not slowing but accelerating, 2 times, 10 times, hundreds of times faster than a speeding bullet, away from Io and into deep space.

Passing spacecraft beware: Io is shooting at you.

The Ulysses spacecraft, a joint mission of NASA and the European Space Agency, made the discovery in 1992 when, approaching Jupiter, it was hit by a breakneck stream of volcano dust.

"What a surprise," recalls Harold Krueger of the Max Planck Institute in Heidelberg, the principle investigator for Ulysses' dust detector. "We expected to encounter dust," he says. The solar system is littered with flakes from comets and asteroids. "But nothing like this."

The dust came in a tight stream, like water from a garden hose, and it was moving extraordinarily fast, about 300 km/s (670,000 mph). "This makes it some of the fastest-moving material in the solar system," says Krueger, "second only to the solar wind." Fortunately the dust-bits were small, similar in size to particles in cigarette smoke, so they didn't penetrate the ship's hull in spite of their extreme velocity.

At first, no one suspected Io. Ulysses was 100 million kilometers from Io when the stream blew by, supposedly beyond the reach of volcanic plumes. Plus, the speed of the dust didn't make sense. Particles emerge from Io's vents traveling 1 or 2 km/s, not 300 km/s.

Baffled, researchers considered several possibilities: Could Jupiter's dark rings be responsible? There's plenty of dust there, but how could rings manufacture fast-moving jets? Comet Shoemaker-Levy 9 was another suspect. The comet flew so close to Jupiter in 1992 that it was torn apart. Comets are known to produce streams of dust, but not so fast as the stream that hit Ulysses.

NASA's Galileo spacecraft eventually solved the puzzle. Like Ulysses, Galileo was pelted by dust when it approached Jupiter in 1995. Unlike Ulysses, which merely flew past the giant planet, Galileo settled into orbit. As data accumulated over a period of years, scientists were able to correlate volcanic activity with dust events, and they showed, furthermore, that dust streams were modulated by Io's orbital motion.

The source was definitely Io.

Regarding the extreme velocity of the dust: "Jupiter is responsible for that," explains Krueger.

Jupiter is not only a giant planet, but also a giant magnet, which spins once every 9 hours and 55 minutes. Spinning magnetic fields produce electric fields, and the electric fields around Jupiter are intense. Io-dust, like dust on your computer monitor, is electrically charged, so Jupiter's electric

forces naturally accelerate the grains. 300 km/s is no problem.

In 2000 when the Cassini spacecraft sailed past Jupiter en route to Saturn, it too was hit. Cassini's dust detector is more capable than Ulysses'. In addition to mass, speed, charge and trajectory, it can also measure elemental composition. Cassini found hints of sulfur, silicon, sodium and potassium–all signs of volcanic origin.

"This raises an interesting possibility," says Krueger. "We can analyze the hot interior of Io from a great distance." There's no need to get too close to the sizzling vents when you can catch the ash millions of miles away.

Figure 4: *A volcanic plume on Io, photographed by NASA's Galileo spacecraft.*

Io dust can even reach Earth, says Krueger, but don't expect a meteor shower. Bright meteors such as Perseids and Leonids are caused by sand-sized comet dust. Io dust is much smaller. A typical grain is only 10 billionths of a meter wide. If a bit of it disintegrated in Earth's atmosphere, you probably wouldn't notice.

Ulysses visited Jupiter again in early 2004 and once again the craft was pelted. Io's volcanoes were still at work. But something was wrong: The dust was shooting in the wrong direction.

"Io dust is supposed fly out of Jupiter's equatorial plane," says Krueger, "because that's the way the accelerating electric fields point." This time Ulysses approached Jupiter's north pole (75 degrees north latitude to be exact) where no dust should go. Yet the spacecraft was pelted anyway.

Jupiter, it seems, flings Io-dust in every direction, which is hard to understand, says Krueger. Future missions to the giant planet might unravel the mystery. Every blast of dust will remind: we've still got a lot to learn.

## 1.6 Cassini Discovers Ring and One, Possibly Two, Objects at Saturn

*Source: JPL News Release, September 9th, 2004* [8]

Scientists examining Saturn's contorted F ring, which has baffled them since its discovery, have found one small body, possibly two, orbiting in the F ring region, and a ring of material associated with Saturn's moon Atlas.

A small object was discovered moving near the outside edge of the F ring, interior to the orbit of Saturn's moon Pandora. The object was seen by Dr. Carl Murray, imaging team member at Queen Mary, University of London, in images taken on June 21, 2004, just days before Cassini arrived at Saturn. "I noticed this barely detectable object skirting the outer part of the F ring. It was an incredible privilege to be the first person to spot it," he said. Murray's group at Queen Mary then calculated an orbit for the object.

Scientists cannot yet definitively say if the object is a moon or a temporary clump. If it is a moon, its diameter is estimated at four to five kilometers (two to three miles) and it is located 1,000 kilometers (620 miles) from the F ring, Saturn's outmost ring. It is at a distance of approximately 141,000 kilometers (86,000 miles) from the center of Saturn and within 300 kilometers (190 miles) of the orbit of the moon Pandora. The object has been provisionally named S/2004 S3.

Scientists are not sure if the object is alone. This is because of results from a search through other images that might capture the object to pin down its orbit. The search by Dr. Joseph Spitale, a planetary scientist working with team leader Dr. Carolyn Porco at the Space Science Institute in Boulder, Colo., revealed something strange. Spitale

said, ”When I went to look for additional images of this object to refine its orbit, I found that about five hours after first being sighted, it seemed to be orbiting interior to the F ring,” said Spitale. ”If this is the same object then it has an orbit that crosses the F ring, which makes it a strange object.” Because of the puzzling dynamical implications of having a body that crosses the ring, the inner object sighted by Spitale is presently considered a separate object with the temporary designation S/2004 S 4. S4 is roughly the same size as S3.

In the process of examining the F ring region, Murray also detected a previously unknown ring, S/2004 1R, associated with Saturn’s moon, Atlas. ”We knew from Voyager that the region between the main rings and the F ring is dusty, but the role of the moons in this region was a mystery,” said Murray. ”It was while studying the F ring in these images that I discovered the faint ring of material. My immediate hunch was that it might be associated with the orbit of one of Saturn’s moons, and after some calculation I identified Atlas as the prime suspect.”

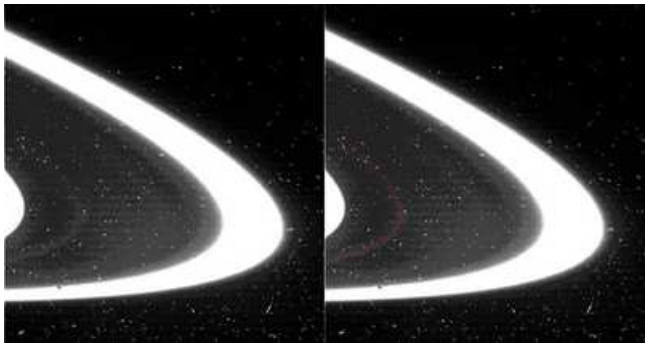

Figure 5: *A new found ring of material, S/2004 1 R, in the orbit of Saturn’s moon Atlas has been seen in this view of the region between the edge of Saturn’s A ring and the F ring. The image was taken by the Cassini spacecraft wide angle camera on July 1, 2004, just after the spacecraft had crossed the ring plane following Saturn orbit insertion. The maximum radial resolution is approximately 7 kilometers (4 miles) per pixel. The region from the A ring to the F ring spans some 3,500 kilometers (2,200 miles). The image has been enhanced to show the presence of faint ring material just beyond the edge of the A ring and in the orbit of Atlas (indicated by the red line in the image on the right). The moon Prometheus (102 kilometers or 63 miles across) can be seen close to the F ring at the lower left of the image. Image Credit: NASA/JPL/Space Science Institute*

The ring is located 138,000 kilometers (86,000 miles) from the center of Saturn in the orbit of the moon Atlas, between the A ring and the F ring. The width of the ring is estimated at 300 kilometers (190 miles). The ring was first spotted in images taken after orbit insertion on July 1, 2004. There is no way of knowing yet if it extends all the way around the planet.

”We have planned many images to search the region between the A and F rings for diffuse material and new moons, which we have long expected to be there on the basis of the peculiar behavior of the F ring,” said Porco. ”Now we have found something but, as is usual for the F ring, what we see is perplexing.”

Searches will continue for further detections of the newfound body or bodies seen in association with the F ring. If the two objects indeed turn out to be a single moon, it will bring the Saturn moon count to 34. The newfound ring adds to the growing number of narrow ringlets around Saturn.

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Cassini-Huygens mission for NASA’s Science Mission Directorate, Washington. The Cassini orbiter and its two onboard cameras were designed, developed and assembled at JPL. The imaging team is based at the Space Science Institute, Boulder, Colo. UK scientists are playing significant roles in the mission with involvement in six of the 12 instruments onboard the Cassini orbiter and two of the six instruments on the Huygens probe.

# 2 Astrophysics

## 2.1 Massive merger of galaxies is the most powerful on record

*Source: ESA Press Release, September 23rd, 2004* [9]

With ESA's XMM-Newton observatory, an international team of scientists has observed a nearby head-on collision of two galaxy clusters that has smashed together thousands of galaxies and millions upon millions of stars. It is one of the most powerful events ever witnessed. Such collisions are second only to the Big Bang in total energy output. The event details what the scientists are calling the 'perfect cosmic storm': galaxy clusters that collided like two high-pressure weather fronts and created hurricane-like conditions, tossing galaxies far from their paths and churning shock waves of 100-million-degree gas through intergalactic space.

This unprecedented view of a merger in action crystallises the theory that the Universe built its magnificent hierarchal structure from the 'bottom up' - essentially through mergers of smaller galaxies and galaxy clusters into bigger ones.

"Here before our eyes we see the making of one of the biggest objects in the Universe," said Dr Patrick Henry of the University of Hawaii, who led the study. "What was once two distinct but smaller galaxy clusters 300 million years ago is now one massive cluster in turmoil."

Henry and his colleagues, Alexis Finoguenov and Ulrich Briel of the Max-Planck Institute for Extraterrestrial Physics in Germany, present these results in an upcoming issue of the Astrophysical Journal. The forecast for the new supercluster, they said, is 'clear and calm' now that the worst of the storm has passed.

Galaxy clusters are the largest gravitationally bound structures in Universe, containing hundreds to thousands of galaxies. Our Milky Way galaxy is part of a small group of galaxies but is not gravitationally bound to the closest cluster, the Virgo Cluster. We are destined for a collision in a few thousand million years, though.

The cluster named Abell 754 in the constellation Hydra has been known for decades. However, to the scientists' surprise, the new observation reveals that the merger may have occurred from the opposite direction than what was thought. They found evidence for this by tracing the wreckage today left in the merger's wake, spanning a distance of millions of light years. While other large mergers are known, none has been measured in such detail as Abell 754.

For the first time, the scientists could create a complete 'weather map' of Abell 754 and thus determine a forecast. This map contains information about the temperature, pressure and density of the new cluster. As in all clusters, most the ordinary matter is in the form of gas between the galaxies and not locked up in the galaxies or stars themselves. The massive forces of the merging clusters accelerated intergalactic gas to great speeds. This resulted in shock waves that heat the gas to very high temperatures, which then radiated X-ray light, far more energetic than the visible light our eyes can detect. XMM-Newton, in orbit, detects this type of high-energy light.

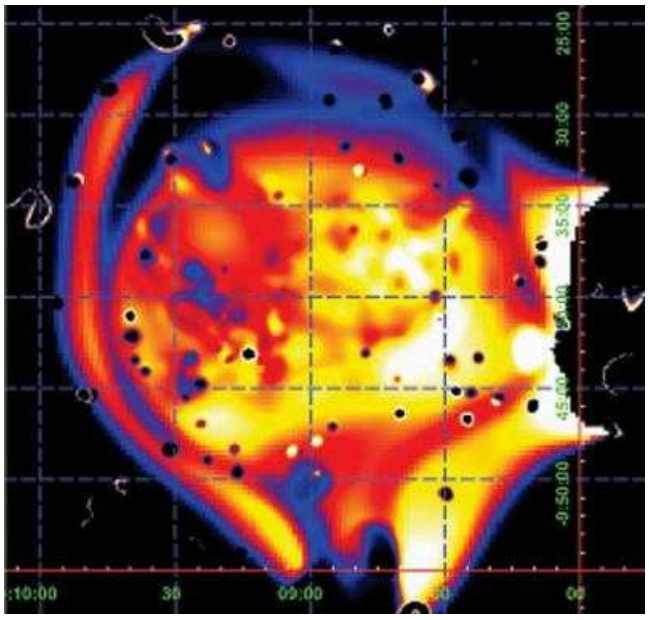

Figure 6: *This image shows the temperature of gas in and around the two merging galaxy clusters, based directly on X-ray data. The galaxies themselves are difficult to identify; the image highlights the hot 'invisible' gas between the clusters heated by shock waves. The white colour corresponds to regions of the highest temperature - million of degrees, hotter than the surface of the Sun - followed by red, orange, yellow and blue. Credits: ESA/ XMM-Newton/ Patrick Henry et al.*

The dynamics of the merger revealed by XMM-Newton point to a cluster in transition. "One cluster has apparently smashed into the other from the 'north-west' and has since made one pass through," said Finoguenov. "Now, gravity will pull the remnants of this first cluster back towards the core of the second. Over the next few thousand million of years, the remnants of the clusters will settle and the merger will be complete."

The observation implies that the largest structures in the Universe are essentially still forming in the modern era. Abell 754 is relatively close, about 800 million light years away. The construction boom may soon be over in a few more thousand million years though. A mysterious sub-

stance dubbed 'dark energy' appears to be accelerating the Universe's expansion rate. This means that objects are flying apart from each other at an ever-increasing speed and that clusters may eventually never have the opportunity to collide with each other.

X-ray observations of galaxy clusters such as Abell 754 will help to better define dark energy and also dark matter, an 'invisible' and mysterious substance that appears to comprise over 80 percent of a galaxy cluster's mass.

## 2.2 Hubble Approaches the Final Frontier: The Dawn of Galaxies

*Source: Hubble News Release, September 23rd, 2004* [10]

Detailed analyses of mankind's deepest optical view of the universe, the Hubble Ultra Deep Field (HUDF), by several expert teams have at last identified what may turn out to be some of the earliest star-forming galaxies. Astronomers are now debating whether the hottest stars in these early galaxies may have provided enough radiation to "lift a curtain" of cold, primordial hydrogen that cooled after the big bang. This is a problem that has perplexed astronomers over the past decade, and NASA's Hubble Space Telescope has at last glimpsed what could be the "end of the opening act" of galaxy formation. These faint sources illustrate how astronomers can begin to explore when the first galaxies formed and what their properties might be.

But even though Hubble has looked 95 percent of the way back to the beginning of time, astronomers agree that's not far enough. "For the first time, we at last have real data to address this final frontier - but we need more observations. We must push even deeper into the universe, unveiling what happened during the initial 5 percent of the remaining distance back to the big bang," said Richard Ellis of the California Institute of Technology in Pasadena, Calif.

In the past couple decades astronomers have amassed evidence that we live in a reionized or "refried universe." This so-called reionization epoch was a critical watershed for the evolving universe. During that early time cold hydrogen atoms drifting in space were pumped up with so much energy from the ultraviolet starlight that they were stripped of their electrons. The universe once again became transparent to light, like the Sun burning off a morning fog. This early period is called "reionization" because the primeval universe, which was hotter than our Sun, was initially ionized as a soup of hydrogen nuclei and free-moving electrons. As the universe cooled through the expansion of space, these electrons were captured by hydrogen nuclei to make neutral hydrogen. But the electrons were lost again when the first fiercely bright stars fired up.

The epoch of reionization is thought to have ended 0.5 to one billion years after the big bang. Constraints come from observations of quasars located with the Sloan Digital Sky Survey, and recent measures of polarization in the radiation emerging from the earliest phases of cosmic history recorded by the Wilkinson Microwave Anisotropy Probe (WMAP).

The major difficulty has been that galaxies at such a remote distance are very faint and are very hard to find. Only the most luminous galaxies can be relatively easily seen. Prior to the HUDF, astronomers did not have the sensitivity to accurately constrain the numbers of very distant sources at that epoch, and so there's been a long-standing debate whether normal galaxies were really capable of doing the reionizing job.

The sensitivity of Hubble's Advanced Camera for Surveys (ACS), combined with the penetrating power of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), finally revealed these long-sought faint galaxies. The HUDF shows that close to a billion years after the big bang the early universe was filled with dwarf galaxies, but no fully formed galaxies like our Milky Way. After careful analysis, they have been sorted out as between 54 and 108 dim, red smudges sprinkled across the HUDF image. From a hierarchical point of view, this means the universe started out as a bunch of "mom & pop" stores, which merged into businesses, and then into giant corporations - the majestic galaxies we see today.

HUDF research are being led by: Rodger Thompson (University of Arizona, Tucson, Ariz.) and collaborator Rychard Bouwens (University of California/Lick Observatory, Santa Cruz, Calif.); Haojing Yan (Spitzer Science Center, California Institute of Technology, Pasadena, Calif.) and Rogier Windhorst (Arizona State University, Tempe, Ariz.); Massimo Stiavelli (Space Telescope Science Institute, Baltimore, MD.); Andrew Bunker (University of Exeter and the University of Cambridge, UK); and Sangeeta Malhotra and James Rhoads (Space Telescope Science Institute). The teams used different techniques:

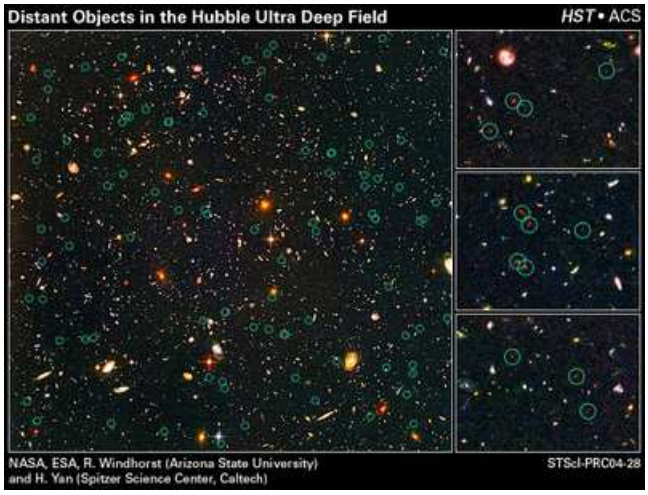


Figure 7: *Detailed analyses of mankind's deepest optical view of the universe, the Hubble Ultra Deep Field (HUDF), by several expert teams have at last identified what may turn out to be some of the earliest star-forming galaxies. The sensitivity of Hubble's Advanced Camera for Surveys (ACS), combined with the penetrating power of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), finally revealed these long-sought faint galaxies. The HUDF shows that close to a billion years after the big bang the early universe was filled with dwarf galaxies, but no fully formed galaxies like our Milky Way. After careful analysis, they have been sorted out as between 54 and 108 dim, red smudges sprinkled across the HUDF image. This image shows the full sample of candidates circled in green. Three enlargements at right show several dwarf objects that are at the limits of Hubble's present instrument capabilities. The HUDF is a small region of sky in the direction of the southern constellation Fornax. The faintest objects are less than one four-billionth the brightness of stars that can be seen with the naked eye. Their light has taken nearly 13 billion years to reach Earth, and so these objects represent some of the earliest star-forming galaxies to form in the universe. Credit: NASA, ESA, R. Windhorst (Arizona State University) and H. Yan (Spitzer Science Center, Caltech)*

The Bunker team identified a list of 50 probable distant galaxies in the Ultra Deep Field and distributed details of their work within a day of the images becoming publicly available. They isolated their distant sample using techniques developed with earlier, less sensitive, Hubble images tested through spectroscopic observations undertaken with the 10-meter W.M. Keck observatory in Hawaii. Bunker's team claims that the combined ultraviolet light from the galaxies located in the Ultra Deep Field is insufficient to reionize the universe. Perhaps the physics of star formation was different at these early times, or a further, yet more distant population is responsible.

The Stiavelli team shows that the same objects would be sufficient to reionize the universe, if they possessed much fewer heavier elements - anything heavier than helium - than those of present-day galaxies, and if the early galaxies contained more massive stars. Both these assumptions are reasonable at early epochs, since astronomers know that stars make the metals that exist in the universe. Early on, before most of the stars we see today had been formed, the amount of elements must have been much lower.

The Yan and Windhorst team started from the objects that are seen, and then carefully estimated the fraction of fainter galaxies that are not seen, even in the Hubble Ultra Deep Field. They found that the number of dwarf galaxies rapidly increases at fainter levels in the HUDF. This is like a cosmic "stock- market chart" but with very few large corporations and numerous "mom-and-pop corner stores." Yan and Windhorst conclude that this steep increase of the faint dwarf galaxy population collectively generates enough ultraviolet light to finish reionizing the universe by redshift 6, even if the amount of heavier elements was similar to that of present-day galaxies.

The HUDF NICMOS Treasury team (Thompson/Illingworth) has taken the UDF data and other ACS survey data to get the best possible estimate of the relative numbers of bright and faint galaxies around redshift 6, only 900 million years after the big bang. The papers, led by Rychard Bouwens, show that faint galaxies dominate at this epoch, compared to more recent times, and are likely to have played a significant role in the late stages of reionization. The team has also used the HUDF NICMOS data to detect a small sample of galaxies at higher redshifts (at z=7-8), 200 million years closer in time to the big bang. The amount of reionizing light at redshifts 7-8 appears to be lower than what is seen only 200 million years later at redshift 6.

The Malhotra and Rhoads team have found a "sheet" of galaxies in the HUDF. They find that the galaxy density near redshift z=5.9 (look-back time of 12.5 billion years) is four times the galaxy density in the rest of the surveyed HUDF "core sample." This supports theories of galaxy formation which predict that dense regions should be the first sites of galaxy formation. This evidence for an over density was bolstered by a complementary study, undertaken by Malhotra, Rhoads, and JunXian Wang, which uses the Cerro Tololo Inter-American Observatory to obtain a map of galaxies over a much wider area than the HUDF. Even

with its lower sensitivity and more limited coverage in distance, this map shows that "extra" galaxies are spread like a sheet, with the HUDF located near one edge of the structure. "The presence of such structures doubtlessly affected the reionization of the universe, because the ultraviolet light that separated intergalactic hydrogen atoms into protons and electrons would have been more intense where galaxies are more common. It is then likely that reionization proceeded at different speeds in different regions of the early universe," says Rhoads. This Hubble team used spectra to measure the distances of these galaxies very precisely.

The WFC3 built for Hubble is expected to see ten times as many distant infrared galaxies as the NICMOS. When launched, the JWST will have the light-gathering power to peruse an even earlier universe and actually see the very first stars and star clusters, which remain beyond even Hubble's reach. These still hypothesized ultra-bright stars formed only 200 million years after the big bang (at redshift z=20, and as deduced from the WMAP image of the cosmic microwave background). They are currently believed to have heated the universe so much back then, that smaller, normal stars had to wait for the hydrogen gas to re-cool and condense before they could form.

## 2.3 The Mouse That Soared

*Source: Chandra Press Release, September 23rd, 2004* [11]

Astronomers have used an X-ray image to make the first detailed study of the behavior of high-energy particles around a fast moving pulsar. The image, from NASA's Chandra X-ray Observatory, shows the shock wave created as a pulsar plows supersonically through interstellar space. These results will provide insight into theories for the production of powerful winds of matter and antimatter by pulsars.

Chandra's image of the glowing cloud, known as the Mouse, shows a stubby bright column of high-energy particles, about four light years in length, swept back by the pulsar's interaction with interstellar gas. The intense source at the head of the X-ray column is the pulsar, estimated to be moving through space at about 1.3 million miles per hour.

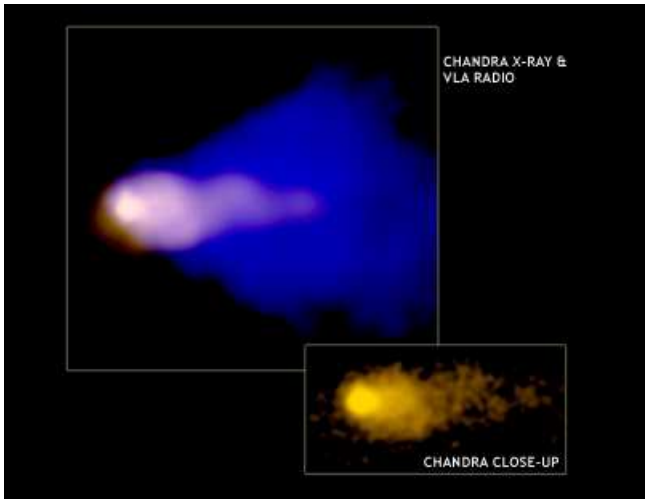


Figure 8: *Credit: NASA/CXC/SAO/B.Gaensler et al. Radio: NSF/NRAO/VLA.*

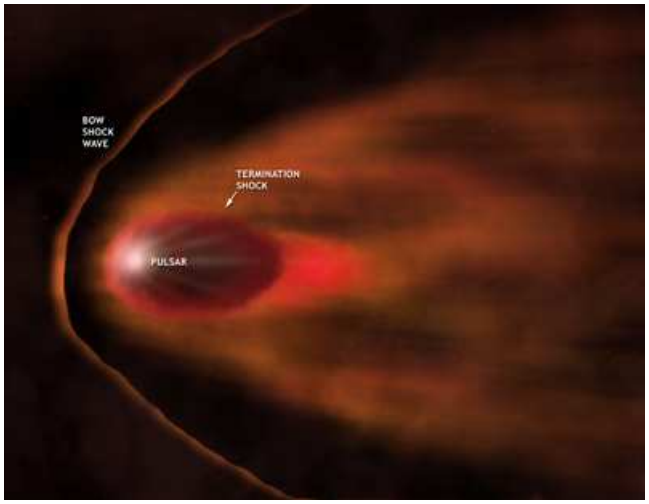


Figure 9: *This illustration shows the various zones around a pulsar (bright white dot) that is producing a wind of high energy particles as it moves supersonically through the interstellar medium. Immediately surrounding the pulsar is a cavity (shown in red) in which the wind flows freely outward. At the point where the pressure of the pulsar wind is balanced by external pressure, a termination shock is formed. Due to the pulsar's motion, this shock has a swept back, ellipsoidal shape. The acceleration of particles at the termination shock produces a bright arc, ring or ellipsoid, depending on the viewing angle and the motion of the pulsar. Beyond the termination shock the particles stream away to form a much larger cloud that is also swept back by the interaction with the interstellar gas. The large arc in front of*

*the pulsar is the bow shock wave that races ahead of the pulsar into the interstellar gas. (Illustration: CXC/M. Weiss)*

A cone-shaped cloud of radio-wave-emitting particles envelopes the X-ray column. The Mouse, a.k.a. G359.23-0.82, was discovered in 1987 by radio astronomers using the National Science Foundation's Very Large Array in New Mexico. It gets its name from its appearance in radio images that show a compact snout, a bulbous body, and a remarkable long, narrow, tail that extends for about 55 light years.

"A few dozen pulsar wind nebulae are known, including the spectacular Crab Nebula, but none have the Mouse's combination of relatively young age and incredibly rapid motion through interstellar space," said Bryan Gaensler of the Harvard-Smithsonian Center for Astrophysics and lead author of a paper on the Mouse that will appear in an upcoming issue of The Astrophysical Journal. "We effectively are seeing a supersonic cosmic wind tunnel, in which we can study the effects of a pulsar's motion on its pulsar wind nebula, and test current theories."

Pulsars are known to be rapidly spinning, highly magnetized neutron stars – objects so dense that a mass equal to that of the Sun is packed into a diameter of about 12 miles. Their formation is associated with a Type II supernova, the collapse and subsequent explosion of a massive star. The origin of a pulsar's high velocity is not known, but many astrophysicists suspect that it is directly related to the explosive circumstances involved in the birth of the pulsar.

The rapid rotation and strong magnetic field of a pulsar can generate a wind of high-energy matter and antimatter particles that rush out at near the speed of light. These pulsar winds create large, magnetized bubbles of high-energy particles called pulsar wind nebulae. The X-ray and radio data on the Mouse have enabled Gaensler and his colleagues to constrain the properties of the ambient gas, to estimate the velocity of the pulsar, and to analyze the structure of the various shock waves created by the pulsar, the flow of particles away from the pulsar, and the magnetic field in the nebula.

## 2.4 High Energy Mystery lurks at the Galactic Centre

*Source: PPARC News, September 22nd, 2004* [12]

A mystery lurking at the centre of our own Milky Way galaxy - an object radiating high-energy gamma rays - has been detected by a team of UK astronomers working with international partners. Their research, published today (September 22nd) in the Journal Astronomy and Astrophysics, was carried out using the High Energy Stereoscopic System (H.E.S.S.), an array of four telescopes, in Namibia, South-West Africa.

The Galactic Centre harbours a number of potential gamma-ray sources, including a supermassive black hole, remnants of supernova explosions and possibly an accumulation of exotic 'dark matter' particles, each of which should emit the radiation slightly differently. The radiation observed by the H.E.S.S. team comes from a region very near Sagittarius A*, the black hole at the centre of the galaxy. According to most theories of dark matter, it is too energetic to have been created by the annihilation of dark matter particles. The observed energy spectrum best fits theories of the source being a giant supernova explosion, which should produce a constant stream of radiation.

Dr. Paula Chadwick of the University of Durham said, "We know that a giant supernova exploded in this region 10,000 years ago. Such an explosion could accelerate cosmic gamma rays to the high energies we have seen - a billion times more energy than the radiation used for X-rays in hospitals. But further observations will be needed to determine the exact source."

Professor Ian Halliday, Chief Executive of the Particle Physics and Astronomy Research Council (PPARC) which funds UK involvement in H.E.S.S. said; "Science continues to throw out the unexpected as we push back the frontiers of knowledge." Halliday added "The centre of our Galaxy is a mysterious place, home to exotic phenomena such as a black hole and dark matter. Finding out which of these sources produced the gamma-rays will tell us a lot about the processes taking place in the very heart of the Milky Way."

However, the team's theory doesn't fit with earlier results obtained by the Japanese /Australian CANGAROO instrument or the US Whipple instrument. Both of these have detected high-energy gamma rays from the Galactic Centre in the past (observations from 1995-2002), though not with the same precision as H.E.S.S, and they were unable to pinpoint the exact location as H.E.S.S. has now done, making it harder to deduce the source. These previous results have different characteristics to the H.E.S.S. observations. It is possible that the gamma-ray source at the Galactic Centre varies over the timescale of a year, suggesting that the source is in fact a variable object, such as the central black hole.

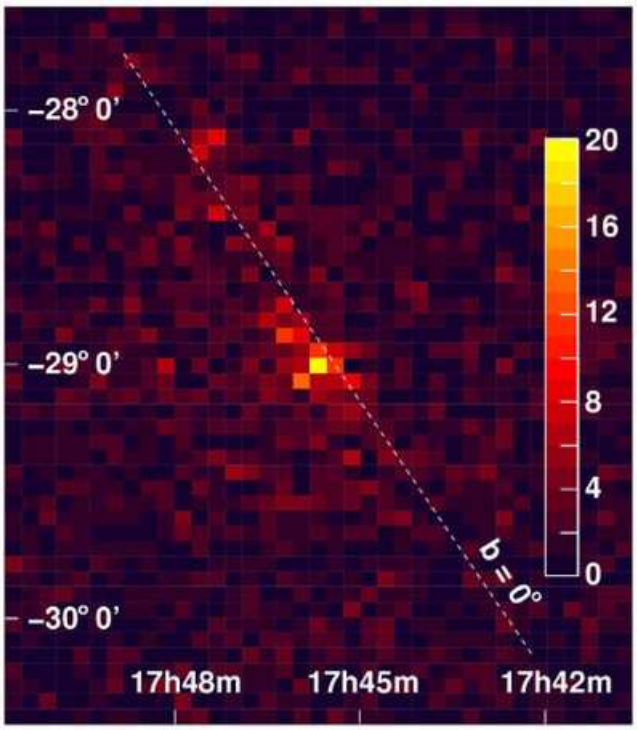


Figure 10: *The centre of our galaxy as seen in very high energy gamma rays. The brightest region may be associated with the supermassive black hole Sagittarius A*. The diagonal line shows where the plane of the galaxy lies. Copyright H.E.S.S. collaboration.*

The H.E.S.S. team (pdf 1.56MB) hopes to unravel the mystery with further observations of the Galactic Centre over the next year or two. The full array of four telescopes will be inaugurated on September 29th 2004.

## 2.5 The universe: It's not as violent as we think

*Source: Australian National University Media Release, September 17th, 2004* [13]

The universe has experienced far fewer collisions among galaxies than previously thought, according to a new analysis of Hubble Space Telescope data by an ANU researcher.

Astronomer Dr Alister Graham, from the Research School of Astronomy and Astrophysics, analysed a sample of galaxies located 100 million light years away - and discovered that the number of violent encounters between large galaxies is around one-tenth of the number earlier studies had suggested.

Although theoretical models predict that fewer collisions were involved in the evolution of the universe, Dr Graham's observations are the first that confirm these theories.

"The new result is in perfect agreement with popular models of hierarchical structure formation in our universe," Dr Graham said. "Galactically speaking, things appear to be a little safer out there."

For years, astronomers have known the collision and merger of galaxies resulted in the formation of larger galaxies. The biggest of these galaxies appear largely devoid of stars at their cores, a phenomenon believed to result from the damage caused by 'supermassive' black holes - from the smaller galaxies - as they merge near the centre of the new galaxy.

However, rather than requiring multiple mergers to clear away the stars from the heart of a galaxy, Dr Graham has shown just one collision between two galaxies is sufficient.

Using images from Hubble's Wide Field Planetary Camera 2, Dr Graham was able to examine galaxies 100 million light years away, whose cores had not been depleted of stars, providing an important insight into star distributions before any major collisions occurred. By considering the overall galaxy structure, he was able to more accurately measure the sizes of the depleted cores in the galaxies built by collision.

The result: the mass of the deficit of stars at the galaxies centres equalled rather than exceeded the mass of the black hole.

"If there had been 10 mergers, we would have found a star deficit 10 times the mass of the central black hole. Many galaxies have large central black holes but no depleted cores. It is therefore not the case that every black hole is formed by gobbling up its surrounding stars. Instead, we're observing the demolished cores of galaxies after the union of two massive cosmic wrecking balls."

Although small satellite galaxies have been captured by our galaxy, the Milky Way, it has not experienced a recent major merger. If it had, the plane of its disk, visible as a faint wide ribbon in the night sky, would have been scattered and dispersed across the heavens. Such a fate is expected in about three billion years when the Milky Way collides with a neighbouring spiral galaxy, Andromeda.

## 2.6 Astronomers Watch a Black Hole Eat a Meal

*Source: University of Cambridge, September 10th, 2004* [14]

Scientists have pieced together the journey of a bundle of doomed matter as it orbited a black hole four times, an ob-

servational first. Their technique provides a new method to measure the mass of a black hole; and this may enable the testing of Einstein's theory of gravity to a degree few thought possible.

A team led by Dr. Kazushi Iwasawa at the Institute of Astronomy (IoA) in Cambridge, England, followed the trail of hot gas over the course of a day as it whipped around the supermassive black hole roughly at the same distance the Earth orbits the Sun. Quickened by the extreme gravity of the black hole, however, the orbit took about a quarter of a day instead of a year.

The scientists could calculate the mass of the black hole by plugging in the measurements for the energy of the light, its distance from the black hole, and the time it took to orbit the black hole – a marriage of Einstein's general relativity and good old-fashioned Keplerian physics.

Iwasawa and his colleague at the IoA, Dr. Giovanni Miniutti, present this result today during a Web-based press conference in New Orleans at the meeting of the High Energy Astrophysics Division of the American Astronomical Society. Dr. Andrew Fabian of the IoA joins them on an article appearing in an upcoming issue of the Monthly Notices of the Royal Astronomical Society. The data is from the European Space Agency's XMM-Newton observatory.

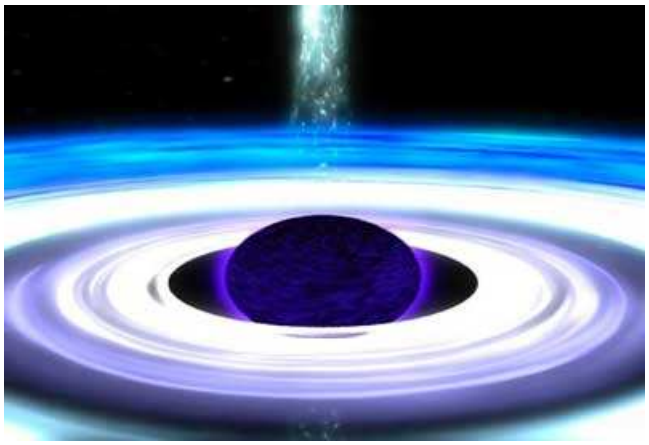

Figure 11:

The team studied a galaxy named NGC 3516, about 100 million light years away in the constellation Ursa Major, home to the Big Dipper (or, the Plough). This galaxy is thought to harbour a supermassive black hole in its core. Gas in this central region glows in X-ray radiation as it is heated to millions of degrees under the force of the black hole's gravity.

XMM-Newton captured spectral features from light around the black hole, displayed on a spectrograph with spikes indicating certain energy levels, similar in appearance to the jagged lines of a cardiograph. During the daylong observation, XMM captured a flare from excited gas orbiting the black hole as it whipped around four times. This was the crucial bit of information needed to measure the black hole mass.

The scientists already knew the distance of the gas from the black hole from its spectral feature. (The extent of gravitational redshift, or energy drain revealed by the spectral line, is related to how close an object is to a black hole.) With an orbital time and distance, the scientists could pin down a mass measurement – between 10 million and 50 million solar masses, in agreement with values obtained with other techniques.

While the calculation is straightforward, the analysis to understand the orbital period of an X-ray flare is new and intricate. Essentially, the scientists detected a cycle repeated four times: a modulation in the light's intensity accompanied by an oscillation in the light's energy. The energy and cycle observed fit the profile of light gravitationally redshifted (gravity stealing energy) and Doppler shifted (a gain and loss in energy as orbiting matter moves towards and away from us).

The analysis technique implies, to this science team's surprise, that the current generation of X-ray observatories can make significant gains in measuring black hole mass, albeit with long observations and black hole systems with long-lasting flares. Building upon this information, proposed missions such as Constellation-X or XEUS can make deeper inroads to testing Einstein's math in the laboratory of extreme gravity.

## 2.7 Is This Speck of Light an Exoplanet?

*Source: ESO Press Release, September 10th, 2004* [15]

Is this newly discovered feeble point of light the long-sought bona-fide image of an exoplanet?

A research paper by an international team of astronomers provides sound arguments in favour, but the definitive answer is now awaiting further observations.

On several occasions during the past years, astronomical images revealed faint objects, seen near much brighter stars. Some of these have been thought to be those of orbiting exoplanets, but after further study, none of them could stand up to the real test. Some turned out to be faint stellar companions, others were entirely unrelated background stars. This one may well be different.

In April of this year, the team of European and American astronomers detected a faint and very red point of light very near (at 0.8 arcsec angular distance) a brown-dwarf object, designated 2MASSWJ1207334-393254. Also known as "2M1207", this is a "failed star", i.e. a body too small for major nuclear fusion processes to have ignited in its interior and now producing energy by contraction. It is a member of the TW Hydrae stellar association located at a distance of about 230 light-years. The discovery was made with the adaptive-optics supported NACO facility [3] at the 8.2-m VLT Yepun telescope at the ESO Paranal Observatory (Chile).

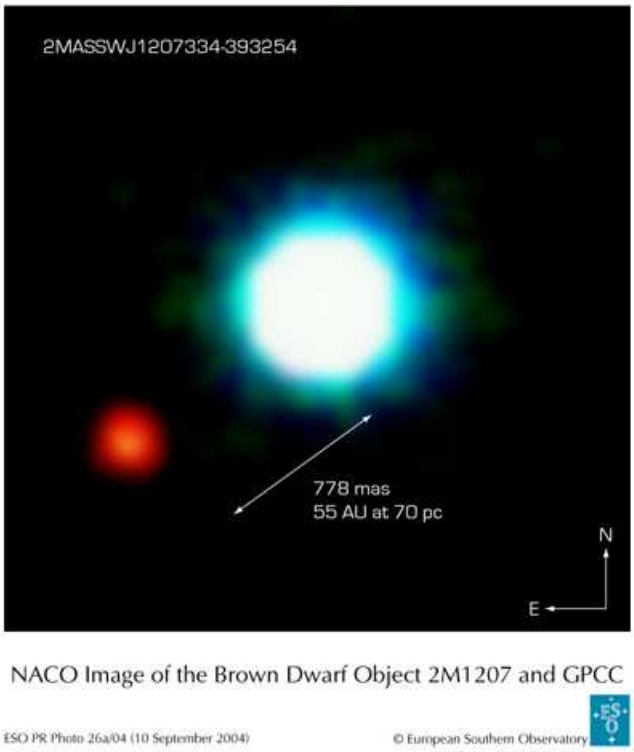


Figure 12: *This figure is a composite image of the brown dwarf object 2M1207 (centre) and the fainter object seen near it, at an angular distance of 778 milliarcsec. Designated "Giant Planet Candidate Companion" by the discoverers, it may represent the first image of an exoplanet. Further observations, in particular of its motion in the sky relative to 2M1207 are needed to ascertain its true nature. The photo is based on three near-infrared exposures (in the H, K and L' wavebands) with the NACO adaptive-optics facility at the 8.2-m VLT Yepun telescope at the ESO Paranal Observatory.*

The feeble object is more than 100 times fainter than 2M1207 and its near-infrared spectrum was obtained with great efforts in June 2004 by NACO, at the technical limit of the powerful facility. This spectrum shows the signatures of water molecules and confirms that the object must be comparatively small and light.

None of the available observations contradict that it may be an exoplanet in orbit around 2M1207. Taking into account the infrared colours and the spectral data, evolutionary model calculations point to a 5 jupiter-mass planet in orbit around 2M1207. Still, they do not yet allow a clear-cut decision about the real nature of this intriguing object. Thus, the astronomers refer to it as a "Giant Planet Candidate Companion (GPCC)".

Observations will now be made to ascertain whether the motion in the sky of GPCC is compatible with that of a planet orbiting 2M1207. This should become evident within 1-2 years at the most.

Just a speck of light

Since 1998, a team of European and American astronomers is studying the environment of young, nearby "stellar associations", i.e., large conglomerates of mostly young stars and the dust and gas clouds from which they were recently formed.

The stars in these associations are ideal targets for the direct imaging of sub-stellar companions (planets or brown dwarf objects). The leader of the team, ESO astronomer Gael Chauvin notes that "whatever their nature, sub-stellar objects are much hotter and brighter when young - tens of millions of years - and therefore can be more easily detected than older objects of similar mass".

The team especially focused on the study of the TW Hydrae Association. It is located in the direction of the constellation Hydra (The Water-Snake) deep down in the southern sky, at a distance of about 230 light-years. For this, they used the NACO facility at the 8.2-m VLT Yepun telescope, one of the four giant telescopes at the ESO Paranal Observatory in northern Chile. The instrument's adaptive optics (AO) overcome the distortion induced by atmospheric turbulence, producing extremely sharp near-infrared images. The infrared wavefront sensor was an essential component of the AO system for the success of these observations. This unique instrument senses the deformation of the near-infrared image, i.e. in a wavelength region where objects like 2M1207 (see below) are much brighter than in the visible range.

The TW Hydrae Association contains a star with an orbiting brown dwarf companion, approximately 20 times the mass of Jupiter, and four stars surrounded by dusty proto-

planetary disks. Brown dwarf objects are ”failed stars”, i.e. bodies too small for nuclear processes to have ignited in their interior and now producing energy by contraction. They emit almost no visible light. Like the Sun and the giant planets in the solar system, they are composed mainly of hydrogen gas, perhaps with swirling cloud belts.

On a series of exposures made through different optical filters, the astronomers discovered a tiny red speck of light, only 0.8 arcsec from the TW Hydrae Association brown-dwarf object 2MASSWJ1207334-393254, or just ”2M1207”, cf. PR Photo 26a/04. The feeble image is more than 100 times fainter than that of 2M1207. ”If these images had been obtained without adaptive optics, that object would not have been seen,” says Gael Chauvin.

Christophe Dumas, another member of the team, is enthusiastic: ”The thrill of seeing this faint source of light in real-time on the instrument display was unbelievable. Although it is surely much bigger than a terrestrial-size object, it is a strange feeling that it may indeed be the first planetary system beyond our own ever imaged.”

Exoplanet or Brown Dwarf?

What is the nature of this faint object? Could it be an exoplanet in orbit around that young brown dwarf object at a projected distance of about 8,250 million km (about twice the distance between the Sun and Neptune)?

”If the candidate companion of 2M1207 is really a planet, this would be the first time that a gravitationally bound exoplanet has been imaged around a star or a brown dwarf” says Benjamin Zuckerman of UCLA, a member of the team and also of NASA’s Astrobiology Institute.

Using high-angular-resolution spectroscopy with the NACO facility, the team has confirmed the substellar status of this object - now referred to as the ”Giant Planet Candidate Companion (GPCC)” - by identifying broad water-band absorptions in its atmosphere.

The spectrum of a young and hot planet - as the GPCC may well be - will have strong similarities with an older and more massive object such as a brown dwarf. However, when it cools down after a few tens of millions of years, such an object will show the spectral signatures of a giant gaseous planet like those in our own solar system.

Although the spectrum of GPCC is quite ”noisy” because of its faintness, the team was able to assign to it a spectral characterization that excludes a possible contamination by extra-galactic objects or late-type cool stars with abnormal infrared excess, located beyond the brown dwarf.

After a very careful study of all options, the team found that, although this is statistically very improbable, the possibility that this object could be an older and more massive, foreground or background, cool brown dwarf cannot be completely excluded. The related detailed analysis is available in the resulting research paper that has been accepted for publication in the European journal Astronomy & Astrophysics.

Implications

The brown dwarf 2M1207 has approximately 25 times the mass of Jupiter and is thus about 42 times lighter than the Sun. As a member of the TW Hydrae Association, it is about eight million years old.

Because our solar system is 4,600 million years old, there is no way to directly measure how the Earth and other planets formed during the first tens of millions of years following the formation of the Sun. But, if astronomers can study the vicinity of young stars which are now only tens of millions of years old, then by witnessing a variety of planetary systems that are now forming, they will be able to understand much more accurately our own distant origins.

Anne-Marie Lagrange, a member of the team from the Grenoble Observatory (France), looks towards the future: ”Our discovery represents a first step towards opening a whole new field in astrophysics: the imaging and spectroscopic study of planetary systems. Such studies will enable astronomers to characterize the physical structure and chemical composition of giant and, eventually, terrestrial-like planets.”

Follow-up observations

Taking into account the infrared colours and the spectral data available for GPCC, evolutionary model calculations point to a 5 jupiter-mass planet, about 55 times more distant from 2M1207 than the Earth is from the Sun (55 AU). The surface temperature appears to be about 10 times hotter than Jupiter, about 1000 C; this is easily explained by the amount of energy that must be liberated during the current rate of contraction of this young object (indeed, the much older giant planet Jupiter is still producing energy in its interior).

The astronomers will now continue their research to confirm or deny whether they have in fact discovered an exoplanet. Over the next few years, they expect to establish beyond doubt whether the object is indeed a planet in orbit around the brown dwarf 2M1207 by watching how the two objects move through space and to learn whether or not they move together. They will also measure the brightness of the GPCC at multiple wavelengths and more spectral observations may be attempted.

There is no doubt that future programmes to image exoplanets around nearby stars, either from the ground with extremely large telescopes equipped with specially designed adaptive optics, or from space with special planet-finder telescopes, will greatly profit from current technological achievements.

## 2.8 Scientists Gain Glimpse of Bizarre Matter in a Neutron Star

*Source: NASA News, September 8th, 2004* [16]

Scientists have obtained their best measurement yet of the size and contents of a neutron star, an ultra-dense object containing the strangest and rarest matter in the Universe.

This measurement may lead to a better understanding of nature's building blocks – protons, neutrons and their constituent quarks – as they are compressed inside the neutron star to a density trillions of times greater than on Earth.

Dr. Tod Strohmayer of NASA's Goddard Space Flight Center in Greenbelt, Md., and his colleague, Adam Villarreal, a graduate student at the University of Arizona, present these results today during a Web-based press conference in New Orleans at the meeting of the High Energy Astrophysics Division of the American Astronomical Society.

They said their best estimate of the radius of a neutron star is 7 miles (11.5 kilometers), plus or minus a stroll around the French Quarter. The mass appears to be 1.75 times that of the Sun, more massive than some theories predict. They made their measurements with NASA's Rossi X-ray Timing Explorer and archived X-ray data.

The long-sought mass-radius relation defines the neutron star's internal density and pressure relationship, the so-called equation of state. And this, in turn, determines what kind of matter can exist inside a neutron star. The contents offer a crucial test for theories describing the fundamental nature of matter and energy and the strength of nuclear interactions.

"We would really like to get our hands on the stuff at the center of a neutron star," said Strohmayer. "But since we can't do that, this is about the next best thing. A neutron star is a cosmic laboratory and provides the only opportunity to see the effects of matter compressed to such a degree."

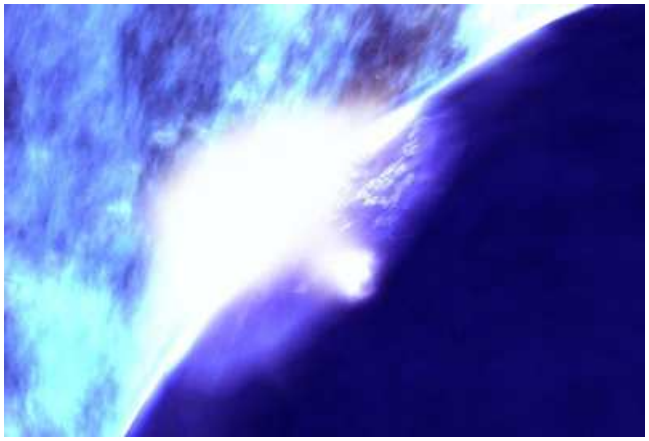

Figure 13:

A neutron star is the core remains of a star once bigger than the Sun. The interior contains matter under forces that perhaps existed at the moment of the Big Bang but which cannot be duplicated on Earth. The neutron star in today's announcement is part of a binary star system named EXO 0748-676, located in the constellation Volans, or Flying Fish, about 30,000 light-years away, visible in southern skies with a large backyard telescope.

In this system, gas from a "normal" companion star plunges onto the neutron star, attracted by gravity. This triggers thermonuclear explosions on the neutron star surface that illuminate the region. Such bursts often reveal the spin rate of the neutron star through a flickering in the X-ray light emitted, called a burst oscillation. (Refer to Items 1 - 6 for an artist's concept of this process. A movie and a detailed caption can be found in the blue column on the right.)

The scientists detected a 45-hertz burst oscillation frequency, which corresponds to a neutron star spin rate of 45 times per second. This is a leisurely pace for neutron stars, which are often seen spinning over 300 times per second.

The scientists next capitalized on EXO 0748-676 observations with the European Space Agency's XMM-Newton satellite from 2002, led by Dr. Jean Cottam of NASA Goddard. Cottam's team had detected spectral lines emitted by hot gas, similar in look to the lines of a cardiogram. These lines had two features. First, they were Doppler shifted. This means the energy detected was an average of the light spinning around the neutron star, moving away from us and then towards us. Second, the lines were gravitationally redshifted. This means that gravity pulled on the light as it tried to escape the region, stealing a bit of its energy.

Strohmayer and Villarreal determined that the 45-hertz frequency and the observed line widths from Doppler shifting

are consistent with a neutron star radius between 9.5 and 15 kilometers, with the best estimate at 11.5 kilometers. The relationship among burst frequency, Doppler shifting and radius is that the velocity of gas swirling around the star's surface depends on the star's radius and its spin rate. In essence, a faster spin corresponds to a wider spectral line (a technique similar to how a state trooper can detect speeding cars).

Cottam team's gravitational redshift measurement offered the first measure of a mass-radius ratio, albeit without knowledge of a mass and radius. This is because the degree of redshifting (strength of gravity) depends on the mass and radius of the neutron star. Some scientists had questioned this measurement, for the spectral lines detected seemed too narrow. The new results strengthen the gravitational redshift interpretation of the Cottam team's spectral lines (and thus the mass-radius ratio) because a slower-spinning star can easily produce such relatively narrow lines.

So, ever more confident of the mass-radius ratio and now knowing the radius, the scientists could calculate the neutron star's mass. The value was between 1.5 and 2.3 solar masses, with the best estimate at 1.75 solar masses.

The result supports the theory that matter in the neutron star in EXO 0748-676 is packed so tightly that almost all protons and electrons are squeezed into neutrons, which swirl about as a superfluid, a liquid that flows without friction. Yet the matter isn't packed so tightly that quarks are liberated, a so-called quark star.

"Our results are really starting to put the squeeze on the neutron star equation of state," said Villareal. "It looks like equations of state which predict either very large or very small stars are nearly excluded. Perhaps more exciting is that we now have an observational technique that should allow us to measure the mass-radius relations in other neutron stars."

A proposed NASA mission called the Constellation X-ray Observatory would have the ability to make such measurements, but with much greater precision, for a number of neutron star systems.

## 2.9 Motions in Nearby Galaxy Cluster Reveal Presence of Hidden Superstructure

*Source: Chandra Press Release, September 8th, 2004* [17]

A nearby galaxy cluster is facing an intergalactic headwind as it is pulled by an underlying superstructure of dark matter, according to new evidence from NASA's Chandra X-ray Observatory. Astronomers think that most of the matter in the universe is concentrated in long large filaments of dark matter and that galaxy clusters are formed where these filaments intersect.

A Chandra survey of the Fornax galaxy cluster revealed a vast, swept-back cloud of hot gas near the center of the cluster. This geometry indicates that the hot gas cloud, which is several hundred thousand light years in length, is moving rapidly through a larger, less dense cloud of gas. The motion of the core gas cloud, together with optical observations of a group of galaxies racing inward on a collision course with it, suggests that an unseen, large structure is collapsing and drawing everything toward a common center of gravity.

"At a relatively nearby distance of about 60 million light years, the Fornax cluster represents a crucial laboratory for studying the interplay of galaxies, hot gas and dark matter as the cluster evolves." said Caleb Scharf of Columbia University in New York, NY, lead author of a paper describing the Chandra survey that was presented at an American Astronomical Society meeting in New Orleans, LA. "What we are seeing could be associated directly with the intergalactic gas surrounding a very large scale structure that stretches over millions of light years."

The infalling galaxy group, whose motion was detected by Michael Drinkwater of the University of Melbourne in Australia, and colleagues, is about 3 million light years from the cluster core, so a collision with the core will not occur for a few billion years. Insight as to how this collision will look is provided by the elliptical galaxy NGC 1404 that is plunging into the core of the cluster for the first time. As discussed by Scharf and another group led by Marie Machacek of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., the hot gas cloud surrounding this galaxy has a sharp leading edge and a trailing tail of gas being stripped from the galaxy.

"One thing that makes what we see in Fornax rather compelling is that it looks a lot like some of the latest computer simulations," added Scharf. "The Fornax picture, with infalling galaxies, and the swept back geometry of the cluster gas - seen only with the Chandra resolution and the proximity of Fornax - is one of the best matches to date with these high-resolution simulations."

Figure 14: *A Chandra mosaic of images of the Fornax galaxy cluster reveals that the vast cloud of ten-million-degree Celsius gas surrounding the cluster core has a swept-back cometary shape that extends for more than half a million light years. This geometry suggests that the hot gas cloud is moving through a larger, but less dense cloud of gas, creating a ram pressure, or intergalactic headwind. Credit: NASA/CXC/Columbia U./C.Scharf et al.*

Over the course of hundreds of millions of years, NGC 1404's orbit will take it through the cluster core several times, most of the gas it contains will be stripped away, and the formation of new stars will cease. In contrast, galaxies that remain outside the core will retain their gas, and new stars can continue to form. Indeed, Scharf and colleagues found that galaxies located in regions outside the core were more likely to show X-ray activity which could be associated with active star formation.

The wide-field and deep X-ray view around Fornax was obtained through ten Chandra pointings, each lasting about 14 hours. Other members of the research team were David Zurek of the American Museum of Natural History, New York, NY, and Martin Bureau, a Hubble Fellow currently at Columbia.

# 3 Space missions

## 3.1 Venus Express spacecraft is complete

*Source: ESA Press Release, September 30th, 2004* [18]

The assembly of ESA's Venus Express spacecraft, ready for Europe's first mission to the second planet in the Solar System, is complete. Often referred to as 'Earth's twin', Venus holds many mysteries that intrigue scientists. The main question is why a planet similar to Earth in size, mass and composition could have evolved so differently over the course of the last four thousand million years.

Figure 15: *Artist's impression of Venus Express.*

Venus Express will make the first multispectral global examination of the atmosphere of Venus. Completely different from the one around Earth, the Venusian atmosphere ap-

pears to be hot and dense. Venus Express will investigate the choking 'greenhouse' effect, the hurricane-force winds that encircle the planet, and its mysteriously weak magnetic field.

Completion of assembly of the Venus Express spacecraft, including integration and testing of the flight equipment and experiments, at Alenia Spazio in Turin, Italy, is an important milestone.

Scheduled for launch on 26 October 2005, Venus Express is currently being made ready for shipment to Astrium, ESA's prime contractor, in Toulouse, France, in mid-October this year. There, further tests to prove the spacecraft's flight readiness will take place.

## 3.2 Halfway There: SpaceShipOne Hits Space Again

*Source: Fraser Cain for Universe Today, September 29th, 2004* [19]

There was a short delay and then SpaceShipOne took off at 1411 UTC (7:11am PDT) cradled under the White Knight carrier aircraft. It carried SpaceShipOne to an altitude of nearly 14 km (46,000 ft) and then released it.

Pilot Mike Melvill ignited the rocket, pointed the spacecraft directly up and accelerated to Mach 3, reaching the edge of space just a few minutes later - 100 km (62.5 miles).

The flight didn't go as smoothly as designer Burt Rutan had predicted, however. Shortly after igniting its hybrid rocket engine and heading up into space, SpaceShipOne went into a harrowing corkscrew roll, spinning more than 20 barrel rolls. Melvill cut the spacecraft's engine 11 seconds before it would have turned off automatically and was able to get control again. Melvill noted, "we would have gone much higher."

In order to win the 10 million dollars X-Prize, competitors need to complete the trip to space twice in two weeks carrying the pilot and the weight of two passengers. Instead of carrying dead weight, SpaceShipOne was filled with personal objects from the employees of the companies that built it.

Their next flight is expected to happen on October 4 - the 47th anniversary of the launch of Sputnik.


Figure 16: *Image credit: Scaled Composites.*

After the flight, Burt Rutan presented financier Paul Allen with tiny pine trees that had been carried into space. Rutan's company has invested more than 20 million dollars into SpaceShipOne, and recently inked a deal with Sir Richard Branson's Virgin Galactic to develop a larger version of the prototype that could carry 5 paying passengers into space; it could start flying within a few years.

## 3.3 Mars Orbiter Sees Rover Tracks Among Thousands of New Images

*Source: JPL News Release, September 27th, 2004* [20]

NASA's Mars Global Surveyor, starting its third mission extension this week after seven years of orbiting Mars, is using an innovative technique to capture pictures even sharper than most of the more than 170,000 it has already produced.

One dramatic example from the spacecraft's Mars Orbiter Camera shows wheel tracks of NASA's Mars Exploration Rover Spirit and the rover itself. Another tells scientists that no boulders bigger than about 1 to 2 meters (3 to 7 feet) are exposed in giant ripples created by a catastrophic flood.

Those examples are available online at [21] and [22] In addition, about 24,000 newly catalogued images that Mars Global Surveyor took between October 2003 and March 2004 have been added to the Mars Orbiter Camera Image Gallery at [23] These include additional pictures of the Mars Exploration Rover sites seen from orbit.

"Over the past year and a half, the camera and spacecraft teams for Mars Global Surveyor have worked together to develop a technique that allows us to roll the entire spacecraft so that the camera can be scanned in a way that sees details at three times higher resolution than we normally get," said

Dr. Ken Edgett, staff scientist for Malin Space Science Systems, San Diego, Calif., which built and operates the Mars Orbiter Camera. The technique adjusts the rotation rate of the spacecraft to match the ground speed under the camera.

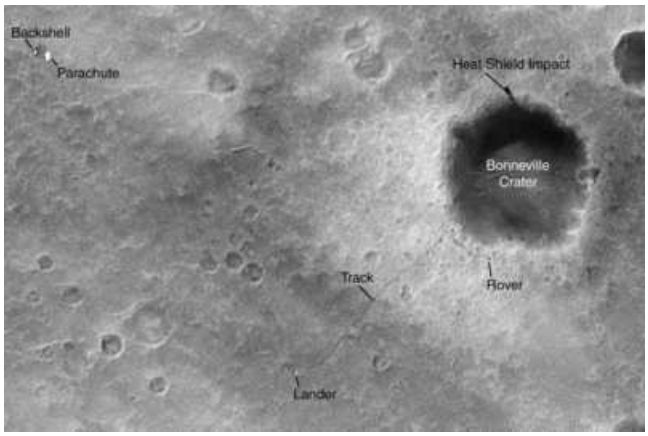


Figure 17: *Wheel tracks left by NASA's Mars Exploration Rover Spirit, and even the rover itself, are visible in this image from the Mars Orbiter Camera on NASA's Mars Global Surveyor orbiter. North is up in this image. The tracks and rover are in the area south of a crater informally named "Bonneville," which is just southeast of the center of the image. The orbiter captured this image with use of an enhanced-resolution technique called compensated pitch and roll targeted observation. It took the picture on March 30, 2004, 85 martian days, or sols, after Spirit landed on Mars. The rover had driven from its landing site to the rim of Bonneville and was examining materials around the crater's rim. In this portion of the plains inside the much larger Gusev Crater, Spirit created wheel tracks darker than the undisturbed surface, as seen in the rover's own images showing the tracks (for example, PIA05450). The contrast allows the tracks to show up in the image obtained from orbit. Also visible are Spirit's lander, backshell and parachute, and the scar where its heat shield hit the ground. The full image covers an area 3 kilometers (2 miles) wide, at 14.8 degrees south latitude and 184.6 degrees west longitude. Pixel size is about 1.5 meters (5 feet) by one-half meter (1.6 feet). Sunlight illuminates the scene from the upper left.*

"The image motion compensation is tricky and the spacecraft does not always hit its target. However, when it does, the results can be spectacular," Edgett said.

The Mars Orbiter Camera acquires the highest resolution images ever obtained from a Mars-orbiting spacecraft. During normal operating conditions, the smallest objects that can be resolved on the martian surface in these images are about 4 to 5 meters (13 to 16 feet) across. With the adjusted-rotation technique, called "compensated pitch and roll targeted observation," objects as small as 1.5 meters (4.9 feet) can be seen in images from the same camera. Resolution capability of 1.4 meters (4.6 feet) per pixel is improved to one-half meter (1.6 feet) per pixel. Because the maneuvers are complex and the amount of data that can be acquired is limited, most images from the camera are still taken without using that technique.

Mars Global Surveyor began orbiting Mars on Sept. 12, 1997. After gradually adjusting the shape of its orbit, it began systematically mapping the planet in March 1999. The Mars Orbiter Camera's narrow-angle camera has now examined nearly 4.5 percent of Mars' surface, including extensive imaging of candidate and selected landing sites for surface missions. The Mars Orbiter Camera also includes a wide-angle camera that observes the entire planet daily.

"Mars Global Surveyor has been productive longer than any other spacecraft ever sent to Mars, since it surpassed Viking Lander 1's longevity earlier this year and has returned more images than all past Mars missions combined," said Tom Thorpe, project manager for Mars Global Surveyor at NASA's Jet Propulsion Laboratory, Pasadena, Calif. The mission will complete its 25,000th mapping orbit on Oct. 11.

Principal goals for the orbiter's latest mission extension, beginning Oct. 1, include continued weather monitoring to form a continuous set of observations with NASA's next Mars mission, Mars Reconnaissance Orbiter, scheduled to reach the red planet in 2006; imaging of possible landing sites for the Phoenix 2007 Mars Scout lander and 2009 Mars Science Laboratory rover; continued mapping and analysis of key sedimentary-rock outcrop sites; and continued monitoring of changes on the surface due to wind and ice. Because the narrow-angle camera has imaged only a small fraction of the surface, new discoveries about surface features are likely to come at any time. The extension runs two years, through September 2006, with a budget of 7.5 million dollars per year.

Dr. James Garvin, NASA's chief scientist for Mars and the Moon, said, "Mars Global Surveyor continues to catalyze new science as it explores Mars at scales compatible with those that our Mars Exploration Rovers negotiate every day, and its extended mission will continue to set the stage for upcoming observations by the Mars Reconnaissance Orbiter."

Additional information about Mars Global Surveyor is available online at: [24] In addition to semi-annual releases of large collections of archived pictures, the Mars Orbiter

Camera team posts a new image daily and last year began soliciting public suggestions for camera targets on Mars. These materials can be viewed online at [25] . For more information about NASA and other space science programs on the Internet, visit [26]

### 3.4 Genesis Capsule Recovery Underway

*Source: Universe Today, September 9th, 2004* [27]

The Genesis sample return capsule entered Earth's atmosphere at 9:52:47 a.m. Mountain Daylight Time and entered the preplanned entry ellipse in the Utah Test and Training Range as predicted. However, the Genesis capsule, as a result of its parachute not deploying, impacted the ground at a speed of 311 kilometers per hour (193 miles per hour). The impact occurred near Granite Peak on a remote portion of the range. No people or structures were anywhere near the area.

"We have the capsule," said Genesis project manager Don Sweetnam of NASA's Jet Propulsion Laboratory, Pasadena, Calif. "It is on the ground. We have previously written procedures and tools at our disposal for such an event. We are beginning capsule recovery operations at this time."

By the time the capsule entered Earth's atmosphere, the flight crews tasked to capture Genesis were already in the air. Once it was confirmed the capsule touched down out on the range, the flight crews were guided toward the site to initiate a previously developed contingency plan. They landed close to the capsule and, per the plan, began to document the capsule and the area.

"For the velocity of the impact, I thought there was surprisingly little damage," said Roy Haggard of Vertigo Inc., Lake Elsinore, Calif., who took part in the initial reconnaissance of the capsule. "I observed the capsule penetrated the soil about 50 percent of its diameter. The shell had been breached about three inches and I could see the science canister inside and that also appeared to have a small breach," he said.

Figure 18:

The science canister from the Genesis mission was moved into the cleanroom at the U.S. Army Dugway Proving Ground in Utah early Wednesday evening. First, a team of specialists plucked pieces of dirt and mud that had lodged in the canister after the mission's sample return capsule landed at high speed in the Utah desert. The Genesis team will begin examining the contents of the canister on Thursday morning.

The Genesis mission was launched in August 2001 on a journey to capture samples from the storehouse of 99 percent of all the material in our solar system - the Sun. The samples of solar wind particles, collected on ultra-pure wafers of gold, sapphire, silicon and diamond, were designed to be returned for analysis by Earth-bound scientists.

JPL manages the Genesis mission for NASA's Science Mission Directorate, Washington. Lockheed Martin Space Systems, Denver, developed and operated the spacecraft. JPL is a division of the California Institute of Technology.

For information about the Genesis Sample Return Mission on the Internet, visit [28] For background information about Genesis, visit [29]

## 4 Internet websites

[1] http://saturn.jpl.nasa.gov/cgi-bin/gs2.cgi?path=../multimedia/images/small-moons/images/PIA06488.jpg&type=image
[2] http://saturn.jpl.nasa.gov
[3] http://ciclops.org
[4] http://www.eso.org/outreach/press-rel/pr-2004/phot-28-04.html
[5] http://www.esa.int/esaCP/SEM75BADFZD_index_0.html
[6] http://www.esa.int/SPECIALS/Mars_Express/SEML131XDYD_0.html

[7] http://science.nasa.gov/headlines/y2004/14sep_jupiterdust.htm
[8] http://saturn.jpl.nasa.gov/news/press-releases-04/20040909-pr-a.cfm
[9] http://www.esa.int/esaSC/SEMSKV9DFZD_index_0.html
[10] http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/28/text/
[11] http://chandra.harvard.edu/press/04_releases/press_092304.html
[12] http://www.pparc.ac.uk/Nw/SgrA.asp
[13] http://info.anu.edu.au/mac/Media/Media_Releases/_2004/September/_170904Galaxies.asp
[14] http://www-xray.ast.cam.ac.uk/
[15] http://www.eso.org/outreach/press-rel/pr-2004/pr-23-04.html
[16] http://www.gsfc.nasa.gov/topstory/2004/0908nsmatter.html
[17] http://chandra.harvard.edu/press/04_releases/press_090804.html
[18] http://www.esa.int/esaSC/SEMECMMKPZD_index_0.html
[19] http://www.universetoday.com/am/publish/spaceshipone_goes_to_space_again.html?2992004
[20] http://www.jpl.nasa.gov/news/news.cfm?release=2004-238
[21] http://www.msss.com/mars_images/moc/2004/09/27/
[22] http://mars.jpl.nasa.gov/mgs
[23] http://www.msss.com/moc_gallery/
[24] http://mars.jpl.nasa.gov/mgs/
[25] http://www.msss.com
[26] http://www.nasa.gov
[27] http://www.universetoday.com/am/publish/genesis_capsule_recovery_underway.html?992004
[28] http://www.nasa.gov/genesis
[29] http://genesismission.jpl.nasa.gov

# 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.

More information can be found at:

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E-mail: Patrick Vandeweert, patrick.vandeweert@ugine-alz.arcelor.com

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.astro.warwick.ac.uk/∼erwin** and follow link *amateur astronomy*

Erwin Verwichte