Vendelinus Astronomy Newsletter

May 2006

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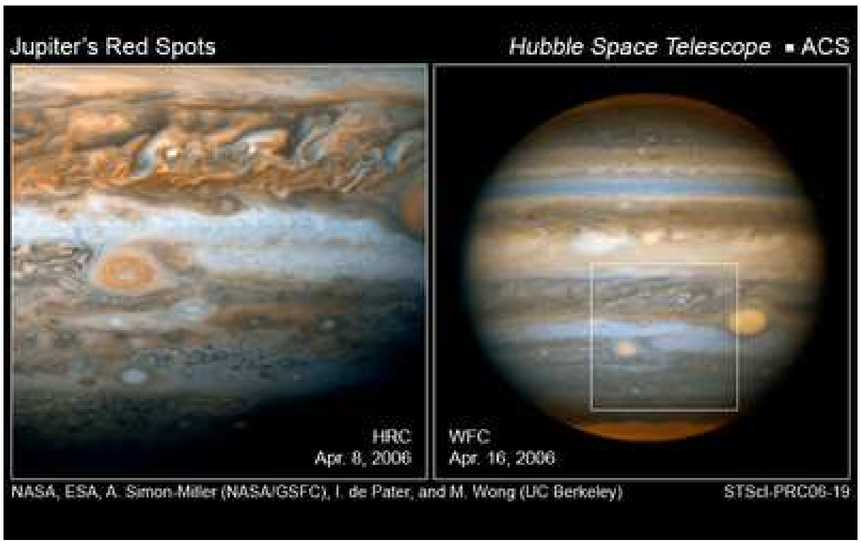

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1.1 Minerals go ”dark” near Earth’s core

Source: Carnegie Institute News Release, May 25th, 2006 [1]

Minerals crunched by intense pressure near the Earth’s core lose much of their ability to conduct infrared light, according to a new study from the Carnegie Institution’s Geophysical Laboratory. Since infrared light contributes to the flow of heat, the result challenges some long-held notions about heat transfer in the lower mantle, the layer of rock that surrounds the Earth’s solid core. The work could aid the study of mantle plumeslarge columns of hot upwelling magma believed to produce features such as the Hawaiian Islands and Iceland.

Crystals of magnesiowstite, a common mineral within the deep Earth, can transmit infrared light at normal atmospheric pressures. But when squashed to over half a million times the pressure at sea level, these crystals instead absorb infrared light, which hinders the flow of heat. The research will appear in the May 26, 2006 issue of the journal Science.

Carnegie staff members Alexander Goncharov and Viktor Struzhkin, with postdoctoral fellow Steven Jacobsen, pressed crystals of magnesiowstite using a diamond anvil cella chamber bound by two superhard diamonds capable of generating incredible pressure. They then shone intense light through the crystals and measured the wavelengths of light that made it through. To their surprise, the compressed crystals absorbed much of the light in the infrared range, suggesting that magnesiowstite is a poor conductor of heat at high pressures.

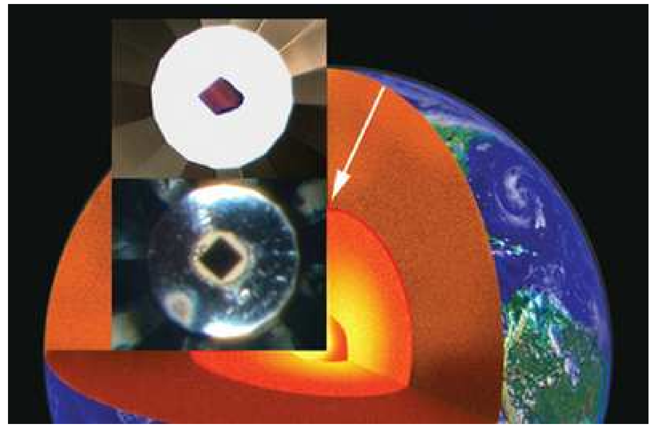

Figure 1: *Crystals of magnesiowstite, a common mineral within the deep earth, can transmit infrared radiation at normal atmospheric pressures (inset, top), but when squashed to over a half million times the pressure at sea level, they lose this ability (inset, bottom). The arrow shows the region near the core-mantle boundary where magnesiowstite is found. (Inset images used with permission of the American Association for the Advancement of Science, Science, May 26, 2006 issue; background image courtesy NASA and the Johns Hopkins Applied Physics Laboratory. Click image for high resolution version.)*

”The flow of heat in Earth’s deep interior plays an important role in the dynamics, structure, and evolution of the planet,” Goncharov said. There are three primary mechanisms by which heat is likely to circulate in the deep Earth: conduction, the transfer of heat from one material or area to another; radiation, the flow of energy via infrared light; and convection, the movement of hot material. ”The relative amount of heat flow from these three mechanisms is currently under intense debate,” Goncharov added.

Magnesiowstite is the second most common mineral in the lower mantle. Since it does not transmit heat well at high pressures, the mineral could actually form insulating patches around much of the Earth’s core. If that is the case, radiation might not contribute to overall heat flow in these areas, and conduction and convection might play a bigger role in venting heat from the core.

”It’s still too early to tell exactly how this discovery will affect deep-Earth geophysics,” Goncharov said. ”But so much of what we assume about the deep Earth relies on our models of heat transfer, and this study calls a lot of that into question."

1.2 ESA's Cluster flies through Earth's electrical switch

Source: ESA Press Release, May 19th, 2006 [2]

ESA's Cluster satellites have flown through regions of the Earth's magnetic field that accelerate electrons to approximately one hundredth the speed of light. The observations present Cluster scientists with their first detection of these events and give them a look at the details of a universal process known as magnetic reconnection. On 25 January 2005, the four Cluster spacecraft found themselves in the right place at the right time: a region of space known as an electron diffusion region. It is a boundary just a few kilometres thick that occurs at an altitude of approximately 60 000 kilometres above the Earth's surface. It marks the frontier between the Earth's magnetic field and that of the Sun. The Sun's magnetic field is carried to the Earth by a wind of electrically charged particles, known as the solar wind.

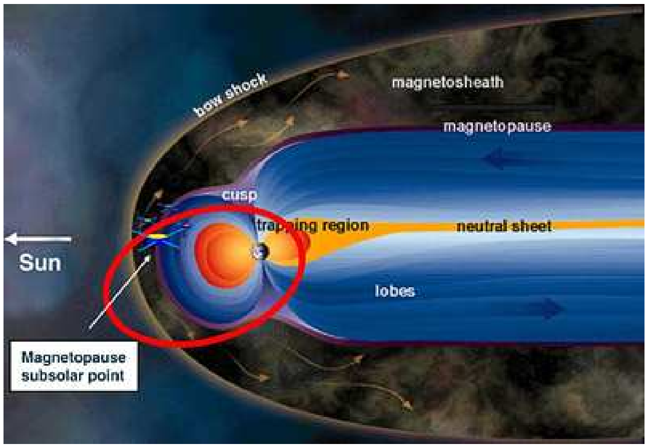

Figure 2: *Sketch of the Earth magnetosphere with Cluster orbit*

An electron diffusion region is like an electrical switch. When it is flipped, it uses energy stored in the Sun's and Earth's magnetic fields to heat the electrically charged particles in its vicinity to large speeds. In this way, it initiates a process that can result in the creation of the aurora on Earth, where fast-moving charged particles collide with atmospheric atoms and make them glow.

There is also a more sinister side to the electron diffusion regions. The accelerated particles can damage satellites by colliding with them and causing electrical charges to build up. These short circuit and destroy sensitive equipment.

Nineteen times in one hour, the Cluster quartet found themselves engulfed in an electron diffusion region. This was because the solar wind was buffeting the boundary layer, causing it to move back and forth. Each crossing of the electron diffusion region lasted just 10-20 milliseconds for each spacecraft and yet a unique instrument, known as the Electron Drift Instrument (EDI), was fast enough to measure the accelerated electrons.

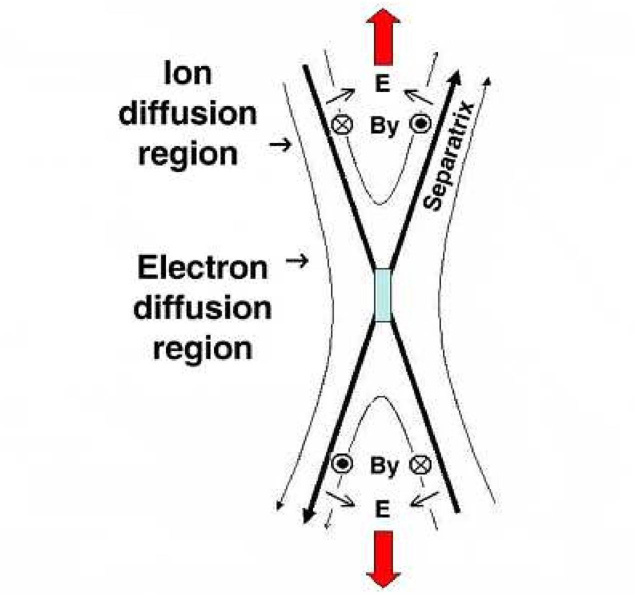

Figure 3: *This sketch shows a so-called electron diffusion region. It is a boundary just a few kilometres thick that occurs at an altitude of approximately 60000 kilometres above the Earth's surface, where electrons can be accelerated to approximately one hundredth the speed of light. On 25 January 2005, and for nineteen times in one hour, the Cluster quartet found themselves engulfed in an electron diffusion region. Credits: F.Mozer/UC Berkeley, USA*

The observation is important because it provides the most complete measurements yet of an electron diffusion region. "Not even the best computers in the world can simulate electron diffusion regions; they just don't have the computing power to do it," says Forrest Mozer, University of California, Berkeley, who led the investigation of the Cluster data.

The data will provide invaluable insights into the process of magnetic reconnection. The phenomenon occurs throughout the Universe on many different scales, anywhere there are tangled magnetic fields. In these complex situations, the magnetic fields occasionally collapse into more stable configurations. This is the reconnection and releases energy through electron diffusion regions. On the Sun, magnetic reconnection drives the solar flares that occasionally release enormous amounts of energy above sunspots. This work may also have an important bearing on solving energy needs on Earth. Nuclear physicists trying to build fusion generators attempt to create stable magnetic fields in their reactors but are plagued by reconnection events that ruin their configurations. If the process of reconnection can be understood, perhaps ways of preventing it in nuclear reactors will become clear. However, that still lies in the future. ”We need to do a lot more science before we fully understand reconnection,” says Mozer, whose aim is now to understand which solar wind conditions trigger the reconnection events and their associated electron diffusion regions seen by Cluster.

1.3 Long Range Solar Forecast

Source: Science@NASA, May 10th, 2006 [3]

The Sun’s Great Conveyor Belt has slowed to a record-low crawl, according to research by NASA solar physicist David Hathaway. ”It’s off the bottom of the charts,” he says. ”This has important repercussions for future solar activity.”

The Great Conveyor Belt is a massive circulating current of fire (hot plasma) within the Sun. It has two branches, north and south, each taking about 40 years to perform one complete circuit. Researchers believe the turning of the belt controls the sunspot cycle, and that’s why the slowdown is important.

”Normally, the conveyor belt moves about 1 meter per secondwalking pace,” says Hathaway. ”That’s how it has been since the late 19th century.” In recent years, however, the belt has decelerated to 0.75 m/s in the north and 0.35 m/s in the south. ”We’ve never seen speeds so low.”

According to theory and observation, the speed of the belt foretells the intensity of sunspot activity 20 years in the future. A slow belt means lower solar activity; a fast belt means stronger activity. The reasons for this are explained in the Science@NASA story Solar Storm Warning.

”The slowdown we see now means that Solar Cycle 25, peaking around the year 2022, could be one of the weakest in centuries,” says Hathaway.

This is interesting news for astronauts. Solar Cycle 25 is when the Vision for Space Exploration should be in full flower, with men and women back on the Moon preparing to go to Mars. A weak solar cycle means they won’t have to worry so much about solar flares and radiation storms.

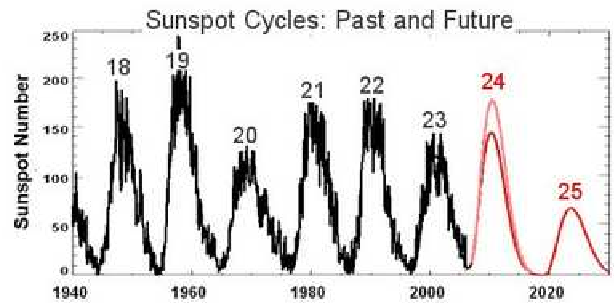

Figure 4: *In red, David Hathaway’s predictions for the next two solar cycles and, in pink, Mausumi Dikpati’s prediction for cycle 24.*

On the other hand, they will have to worry more about cosmic rays. Cosmic rays are high-energy particles from deep space; they penetrate metal, plastic, flesh and bone. Astronauts exposed to cosmic rays develop an increased risk of cancer, cataracts and other maladies. Ironically, solar explosions, which produce their own deadly radiation, sweep away the even deadlier cosmic rays. As flares subside, cosmic rays intensifyyin, yang.

Hathaway’s prediction should not be confused with another recent forecast: A team led by physicist Mausumi Dikpata of NCAR has predicted that Cycle 24, peaking in 2011 or 2012, will be intense. Hathaway agrees: ”Cycle 24 will be strong. Cycle 25 will be weak. Both of these predictions are based on the observed behavior of the conveyor belt.”

How do you observe a belt that plunges 200,000 km below the surface of the sun?

”We do it using sunspots,” Hathaway explains. Sunspots are magnetic knots that bubble up from the base of the conveyor belt, eventually popping through the surface of the sun. Astronomers have long known that sunspots have a tendency to driftfrom mid solar latitudes toward the sun’s equator. According to current thinking, this drift is caused by the motion of the conveyor belt. ”By measuring the drift of sunspot groups,” says Hathaway, ”we indirectly measure the speed of the belt.”

Using historical sunspot records, Hathaway has succeeded in clocking the conveyor belt as far back as 1890. The numbers are compelling: For more than a century, ”the speed of the belt has been a good predictor of future solar activity.”

If the trend holds, Solar Cycle 25 in 2022 could be, like the belt itself, ”off the bottom of the charts.”

1.4 Heavily eroded Aram Chaos

Source: ESA Press Release, May 30th, 2006 [4]

These images, taken by the High Resolution Stereo Camera (HRSC) on board ESA's Mars Express spacecraft, show Aram Chaos, 280-km-wide circular structure characterized by chaotic terrain.

The HRSC obtained these images during orbit 945 with a ground resolution of approximately 14 metres per pixel. The images show the region of Aram Chaos, at approximately 2 North and 340 East.

Aram Chaos is a 280-km-wide almost-circular structure located between the outflow channel Ares Vallis and Aureum Chaos. It is one of many regions located east of Valles Marineris and characterized by chaotic terrain.

As the name 'chaos' suggests, this terrain comprises large-scale remnant massifs, large relief masses that have been moved and weathered as a block. These are heavily eroded and dominate the circular morphology, or structure, which may have formed during an impact. As seen in the colour image, these remnant massifs range from a few kilometres to approximately ten kilometres wide and have a relative elevation of roughly 1000 metres.

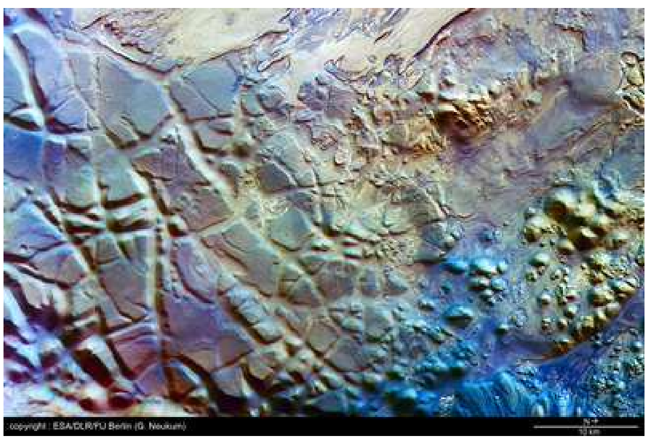

Figure 5: *Aram Chaos in false colour. Credits: ESA/DLR/FU Berlin (G. Neukum)*

The western region of the colour image is characterized by brighter material, which seems to be layered and could be the result of sedimentary deposition. Distinct layering, causing a terrace-like appearance, is also visible east of this brighter material and in the relatively flat region located in the northwest of the colour image.

Some scientists believe that the numerous chaotic regions located in the eastern part of Valles Marineris were the source of water or ice thought to have created the valleys that extend into Chryse Planitia. These regions are particularly interesting because they may yield clues to the relationship between Valles Marineris, the chaotic terrain, the valleys and the Chryse basin.

The colour scenes have been derived from the three HRSC-colour channels and the nadir channel. The perspective view has been calculated from the digital terrain model derived from the stereo channels. The anaglyph image was calculated from the nadir and one stereo channel. Image resolution has been decreased for use on the internet.

1.5 Hubble Snaps Baby Pictures of Jupiter's "Red Spot Jr."

Source: Hubble News, May 4th, 2006 [5]

NASA's Hubble Space Telescope is giving astronomers their most detailed view yet of a second red spot emerging on Jupiter. For the first time in history, astronomers have witnessed the birth of a new red spot on the giant planet, which is located half a billion miles away. The storm is roughly one-half the diameter of its bigger and legendary cousin, the Great Red Spot. Researchers suggest that the new spot may be related to a possible major climate change in Jupiter's atmosphere.

Dubbed by some astronomers as "Red Spot Jr.," the new spot has been followed by amateur and professional astronomers for the past few months. But Hubble's new images provide a level of detail comparable to that achieved by NASA's Voyager 1 and 2 spacecraft as they flew by Jupiter a quarter-century ago.

Before it mysteriously changed to the same color as the Great Red Spot, the smaller spot was known as the White Oval BA. It formed after three white oval-shaped storms merged during 1998 to 2000. At least one or two of the progenitor white ovals can be traced back to 90 years ago, but they may have been present earlier. A third spot appeared in 1939. (The Great Red Spot has been visible for the past 400 years, ever since earthbound observers had telescopes to see it).

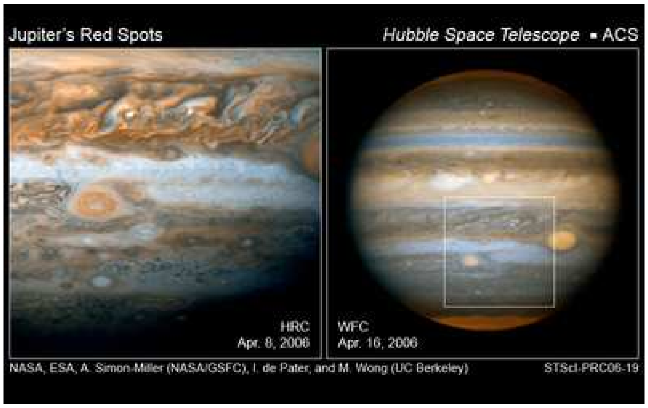

Figure 6:

When viewed at near-infrared wavelengths (specifically 892 nanometers a methane gas absorption band) Red Spot Jr. is about as prominent in Jupiter's cloudy atmosphere as the Great Red Spot. This may mean that the storm rises miles above the top of the main cloud deck on Jupiter just as its larger cousin is thought to do. Some astronomers think the red hue could be produced as the spots dredge up material from deeper in Jupiter's atmosphere, which is then chemically altered by the Sun's ultraviolet light.

Researchers think the Hubble images may provide evidence that Jupiter is in the midst of a global climate change that will alter its average temperature at some latitudes by as much as 10 degrees Fahrenheit. The transfer of heat from the equator to the planet's south pole is predicted to nearly shut off at 34 degrees southern latitude, the latitude where the second red spot is forming. The effects of the shut-off were predicted by Philip Marcus of the University of California, Berkeley (UCB) to become apparent approximately seven years after the White Oval collisions in 1998 to 2000.

Two teams of astronomers were given discretionary time on Hubble to observe the new red spot.

Left: This image, acquired April 8, 2006 with Hubble's Advanced Camera for Surveys (high-resolution channel), shows that the second red spot has a small amount of pale clouds in the center. A strong convective event, which is likely a thunderstorm, is visible as a bright white cloud north of the oval, in the turbulent clouds that precede the Great Red Spot. As the oval continues its eastward drift and the Great Red Spot moves westward, they should pass each other in early July. This contrast-enhanced image was taken in blue and red light. The group that performed this observation was led by Amy Simon-Miller (NASA Goddard Space Flight Center), Glenn Orton (Jet Propulsion Laboratory) and Nancy Chanover (New Mexico State University).

Right: Hubble's Advanced Camera for Surveys (wide field channel) took this image of the entire disk of Jupiter on April 16. The second red spot appears at southern latitudes, below the center of Jupiter's disk. The new spot is approximately the size of Earth's diameter. The image was taken in visible light and at near-infrared wavelengths, and does not represent Jupiter's true colors. The red color traces high-altitude haze blankets: the equatorial zone, the Great Red Spot, the second red spot, and the polar hoods.

1.6 NASA-Funded Study Says Saturn's Moon Enceladus Rolled Over

Source: JPL/NASA Press Release, May 31st, 2006 [6]

Saturn's moon Enceladus - an active, icy world with an unusually warm south pole may have performed an unusual trick for a planetary body. New research shows Enceladus rolled over, literally, explaining why the moon's hottest spot is at the south pole.

Enceladus recently grabbed scientists' attention when the Cassini spacecraft observed icy jets and plumes indicating active geysers spewing from the tiny moon's south polar region.

"The mystery we set out to explain was how the hot spot could end up at the pole if it didn't start there," said Francis Nimmo, assistant professor of Earth sciences, University of California, Santa Cruz.

The researchers propose the reorientation of the moon was driven by warm, low-density material rising to the surface from within Enceladus. A similar process may have happened on Uranus' moon Miranda, they said. Their findings are in this week's journal Nature.

"It's astounding that Cassini found a region of current geological activity on an icy moon that we would expect to be frigidly cold, especially down at this moon's equivalent of Antarctica," said Robert Pappalardo, co-author and planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "We think the moon rolled over to put a deeply seated warm, active area there." Pappalardo worked on the study while at the University of Colorado.

Rotating bodies, including planets and moons, are stable if more of their mass is close to the equator. "Any redistribution of mass within the object can cause instability with respect to the axis of rotation. A reorientation will tend to position excess mass at the equator and areas of low density at the poles," Nimmo said. This is precisely what happened to Enceladus.

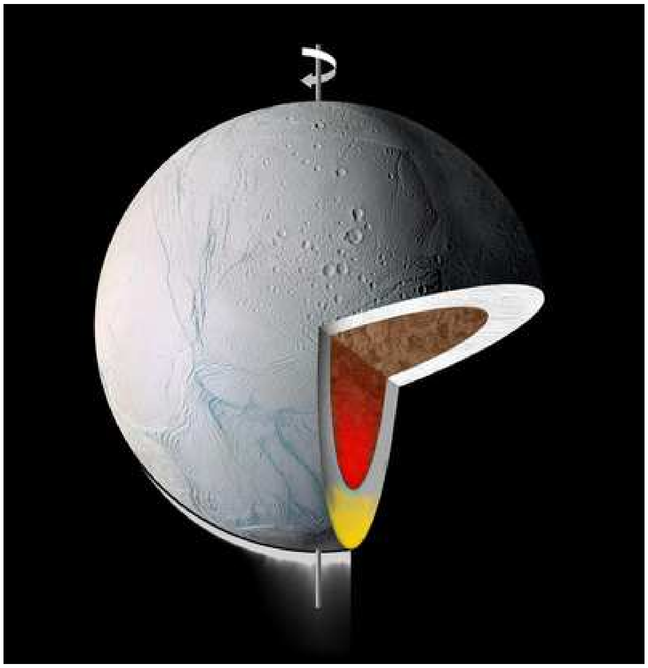

Figure 7: *This graphic illustrates the interior of Saturn's moon Enceladus. It shows warm, low-density material rising to the surface from within, in its icy shell (yellow) and/or its rocky core (red). Image credit: NASA/JPL/Space Science Institute*

Nimmo and Pappalardo calculated the effects of a low-density blob beneath the surface of Enceladus and showed it could cause the moon to roll over by up to 30-degrees and put the blob at the pole.

Pappalardo used an analogy to explain the Enceladus rollover. "A spinning bowling ball will tend to roll over to put its holes – the axis with the least mass – vertically along the spin axis. Similarly, Enceladus apparently rolled over to place the portion of the moon with the least mass along its vertical spin axis," he said.

The rising blob (called a "diapir") may be within either the icy shell or the underlying rocky core of Enceladus. In either case, as the material heats up it expands and becomes less dense, then rises toward the surface. This rising of warm, low-density material could also help explain the high heat and striking surface features, including the geysers and "tiger-stripe" region suggesting fault lines caused by tectonic stress.

Internal heating of Enceladus probably results from its eccentric orbit around Saturn. "Enceladus gets squeezed and stretched by tidal forces as it orbits Saturn, and that mechanical energy is transformed into heat energy in the moon's interior," added Nimmo.

Future Cassini observations of Enceladus may support this model. Meanwhile, scientists await the next Enceladus flyby in 2008 for more clues.

1.7 Titan's Seas Are Sand

Source: University of Arizona Press Release, May 4th, 2006 [7]

Until a couple of years ago, scientists thought the dark equatorial regions of Titan might be liquid oceans.

New radar evidence shows they are seas – but seas of sand dunes like those in the Arabian or Namibian Deserts, a University of Arizona member of the Cassini radar team and colleagues report in Science (May 5).

Radar images taken when the Cassini spacecraft flew by Titan last October show dunes 330 feet (100 meters) high that run parallel to each other for hundreds of miles at Titan's equator. One dune field runs more than 930 miles (1500 km) long, said Ralph Lorenz of UA's Lunar and Planetary Laboratory.

"It's bizarre," Lorenz said. "These images from a moon of Saturn look just like radar images of Namibia or Arabia. Titan's atmosphere is thicker than Earth's, its gravity is lower, its sand is certainly different – everything is different except for the physical process that forms the dunes and resulting landscape."

Ten years ago, scientists believed that Saturn's moon Titan is too far from the sun to have solar-driven surface winds powerful enough to sculpt sand dunes. They also theorized that the dark regions at Titan's equator might be liquid ethane oceans that would trap sand.

But researchers have since learned that Saturn's powerful gravity creates significant tides in Titan's atmosphere. Saturn's tidal effect on Titan is roughly 400 times greater than our moon's tidal pull on Earth.

As first seen in circulation models a couple of years ago, Lorenz said, "Tides apparently dominate the near-surface winds because they're so strong throughout the atmosphere, top to bottom. Solar-driven winds are strong only high up."

The dunes seen by Cassini radar are a particular linear or longitudinal type that is characteristic of dunes formed by winds blowing from different directions. The tides cause wind to change direction as they drive winds toward the equator, Lorenz said.

And when the tidal wind combines with Titan's west-to-east zonal wind, as the radar images show, it creates dunes aligned nearly west-east except near mountains that influence local wind direction.

”When we saw these dunes in radar it started to make sense,” he said. ”If you look at the dunes, you see tidal winds might be blowing sand around the moon several times and working it into dunes at the equator. It’s possible that tidal winds are carrying dark sediments from higher latitudes to the equator, forming Titan’s dark belt.”

The researchers’ model of Titan suggests tides can create surface winds that reach about one mile per hour (a half-meter per second). ”Even though this is a very gentle wind, this is enough to blow grains along the ground in Titan’s thick atmosphere and low gravity,” Lorenz said. Titan’s sand is a little coarser but less dense than typical sand on Earth or Mars. ”These grains might resemble coffee grounds.”

The variable tidal wind combines with Titan’s west-to-east zonal wind to create surface winds that average about one mile per hour (a half meter per second). Average wind speed is a bit deceptive, because sand dunes wouldn’t form on Earth or Mars at their average wind speeds.

Whether the grains are made of organic solids, water ice, or a mixture of both is a mystery. Cassini’s Visual and Infrared Mapping Spectrometer, led by UA’s Robert Brown, may get results on sand dune composition.

How the sand formed is another peculiar story.

Sand may have formed when liquid methane rain eroded particles from ice bedrock. Researchers previously thought that it doesn’t rain enough on Titan to erode much bedrock, but they thought in terms of average rainfall.

Observations and models of Titan show that clouds and rain are rare. That means that individual storms could be large and still yield a low average rainfall, Lorenz explained.

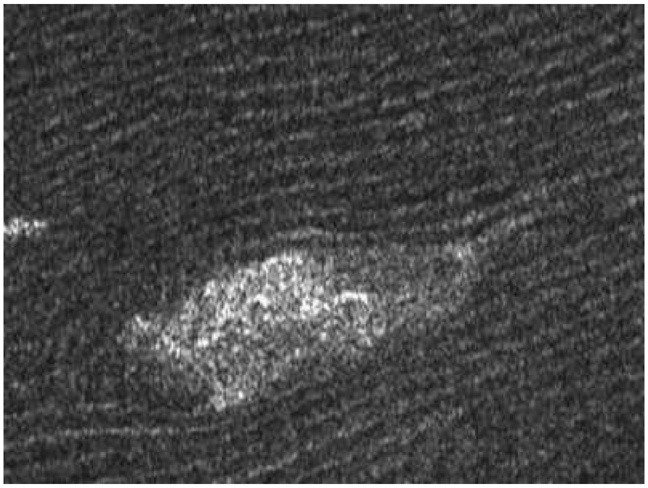

Figure 8: *Detail from a Cassini radar image of sand dunes on Titan. (Photo: NASA/JPL)*

When the UA-led Descent Imager/Spectral Radiometer (DISR) team produced images taken during the Huygens probe landing on Titan in January 2005, the world saw gullies, streambeds and canyons in the landscape. These same features on Titan have been seen with radar.

These features show that when it does rain on Titan, it rains in very energetic events, just as it does in the Arizona desert, Lorenz said.

Energetic rain that triggers flash floods may be a mechanism for making sand, he added.

Alternatively, the sand may come from organic solids produced by photochemical reactions in Titan’s atmosphere.

”It’s exciting that the radar, which is mainly to study the surface of Titan, is telling us so much about how winds on Titan work,” Lorenz said. ”This will be important information for when we return to Titan in the future, perhaps with a balloon.”

1.8 New capture scenario explains origin of Neptune’s oddball moon Triton

Source: UC Santa Cruz Press Release, May 10th, 2006 [8]

Neptune’s large moon Triton may have abandoned an earlier partner to arrive in its unusual orbit around Neptune. Triton is unique among all the large moons in the solar system because it orbits Neptune in a direction opposite to the planet’s rotation (a ”retrograde” orbit). It is unlikely to have formed in this configuration and was probably captured from elsewhere.

In the May 11 issue of the journal Nature, planetary scientists Craig Agnor of the University of California, Santa Cruz, and Douglas Hamilton of the University of Maryland describe a new model for the capture of planetary satellites involving a three-body gravitational encounter between a binary and a planet. According to this scenario, Triton was originally a member of a binary pair of objects orbiting the Sun. Gravitational interactions during a close approach to Neptune then pulled Triton away from its binary companion to become a satellite of Neptune.

"We've found a likely solution to the long-standing problem of how Triton arrived in its peculiar orbit. In addition, this mechanism introduces a new pathway for the capture of satellites by planets that may be relevant to other objects in the solar system," said Agnor, a researcher in UCSC's Center for the Origin, Dynamics, and Evolution of Planets.

With properties similar to the planet Pluto and about 40 percent more massive, Triton has an inclined, circular orbit that lies between a group of small inner moons with prograde orbits and an outer group of small satellites with both prograde and retrograde orbits. There are other retrograde moons in the solar system, including the small outer moons of Jupiter and Saturn, but all are tiny compared to Triton (less than a few thousandths of its mass) and have much larger and more eccentric orbits about their parent planets.

Triton may have come from a binary very similar to Pluto and its moon Charon, Agnor said. Charon is relatively massive, about one-eighth the mass of Pluto, he explained.

"It's not so much that Charon orbits Pluto, but rather both move around their mutual center of mass, which lies between the two objects," Agnor said.

In a close encounter with a giant planet like Neptune, such a system can be pulled apart by the planet's gravitational forces. The orbital motion of the binary usually causes one member to move more slowly than the other. Disruption of the binary leaves each object with residual motions that can result in a permanent change of orbital companions. This mechanism, known as an exchange reaction, could have delivered Triton to any of a variety of different orbits around Neptune, Agnor said.

An earlier scenario proposed for Triton is that it may have collided with another satellite near Neptune. But this mechanism requires the object involved in the collision to be large enough to slow Triton down, but small enough not to destroy it. The probability of such a collision is extremely small, Agnor said.

Another suggestion was that aerodynamic drag from a disk of gas around Neptune slowed Triton down enough for it to be captured. But this scenario puts constraints on the timing of the capture event, which would have to occur early in Neptune's history when the planet was surrounded by a gas disk, but late enough that the gas would disperse before it slowed Triton's orbit enough to send the moon crashing into the planet.

In the past decade, many binaries have been discovered in the Kuiper belt and elsewhere in the solar system. Recent surveys indicate that about 11 percent of Kuiper belt objects are binaries, as are about 16 percent of near-Earth asteroids.

"These discoveries pointed the way to our new explanation of Triton's capture," Hamilton said. "Binaries appear to be a ubiquitous feature of small-body populations."

The Pluto/Charon pair and binaries in the Kuiper belt are especially relevant for Triton, as their orbits abut Neptune's, he said.

"Similar objects have probably been around for billions of years, and their prevalence indicates that the binary-planet encounter that we propose for Triton's capture is not particularly restrictive," Hamilton said.

The exchange reaction described by Agnor and Hamilton may have broad applications in understanding the evolution of the solar system, which contains many irregular satellites. The researchers plan to explore the implications of their findings for other satellite systems.

1.9 X-Rays Fly As Cracking Comet Streaks Across the Sky

Source: NASA News, May 12th, 2006 [9]

Scientists using NASA's Swift satellite have detected X-rays from a comet that is now passing the Earth and rapidly disintegrating on what could be its final orbit around the sun.

Swift's observations provide a rare opportunity to investigate several ongoing mysteries about comets and our solar system, and hundreds of scientists have tuned in to the event.

The comet, called 73P/Schwassmann-Wachmann 3, is visible with even a small, backyard telescope. Peak brightness is expected next week, when it comes within 7.3 million miles of Earth, or about 30 times the distance to the Moon. There is no threat to Earth, however.

This is the brightest comet ever detected in X-rays. The comet is so close that astronomers are hoping to determine not only the composition of the comet but also of the solar wind. Scientists think that atomic particles that comprise the solar wind interact with comet material to produce X-rays, a theory that Swift might prove true.

Three world-class X-ray observatories now in orbit—NASA's Chandra X-ray Observatory, the European-led XMM-Newton, and the Japanese-led Suzaku—will observe the comet in the coming weeks. Like a scout, Swift has provided information to these larger facilities about what to look for. This type of observation can only take place in the X-ray waveband.

"The Schwassmann-Wachmann comet is a comet like no other," said Scott Porter of NASA's Goddard Space Flight Center in Greenbelt, Md., part of the Swift observation team. "During its 1996 passage it broke apart. Now we are tracking about three dozen fragments. The X-rays being produced provide information never before revealed."

The situation is reminiscent of the Deep Impact probe, which penetrated comet Tempel 1 about a year ago. This time, nature itself has broken the comet. Because Schwassmann-Wachmann 3 is much closer to both the Earth and the sun than Tempel 1 was, it currently appears about 20 times brighter in X-rays. Schwassmann-Wachmann 3 passes Earth about every five years. Scientists could not anticipate how bright it would become in X-rays this time around.

"The Swift observations are amazing," said Greg Brown of Lawrence Livermore National Laboratory in Livermore, Calif., who led the proposal for Swift observation time. "Because we are viewing the comet in X-rays, we can see many unique features. The combined results of data from several premier orbiting observatories will be spectacular."

Figure 9: *NASA's Swift satellite captured this image of comet 73P/Schwassmann-Wachmann 3 as it chanced to fly in front of the Ring Nebula. While comet Schwassmann-Wachmann is only about 7.3 million miles away, the Ring Nebula is about 2,300 light-years away (12,000 trillion miles). The image was created with Swift's UVOT telescope. The light captured here ranges from optical blue wavelengths into the ultraviolet band. The Ring Nebula, a remnant of a star explosion, is the lower, right-hand purplish object. Comet Schwassmann-Wachmann is the blue point in the center of the image surrounded by its halo and tail, shown here as a wine-colored glow.*

Swift is primarily a gamma-ray burst detector. The satellite also has X-ray and ultraviolet/optical telescopes. Because of its burst-hunting ability to turn rapidly, Swift has been able to track the progress of the fast-moving Schwassmann-Wachmann 3 comet. Swift is the first observatory to simultaneously observe the comet in both ultraviolet light and X-rays. This cross comparison is crucial for testing theories about comets.

Swift and the other three X-ray observatories plan to combine forces to observe Schwassmann-Wachmann 3 closely. Through a technique called spectroscopy, scientists hope to determine the chemical structure of the comet. Already Swift has detected oxygen and hints of carbon. These elements are from the solar wind, not the comet.

Scientists think that X-rays are produced through a process called charge exchange, in which highly (and positively) charged particles from the sun that lack electrons steal electrons from chemicals in the comet. Typical comet material includes water, methane and carbon dioxide. Charge exchange is analogous to the tiny spark seen in static electricity, only at a far greater energy.

By comparing the ratio of X-ray energies emitted, scientists can determine the content of the solar wind and infer the content of the comet material. Swift, Chandra, XMM-Newton and Suzaku each provide complementary capabilities to nail down this tricky measurement. The combination of these observations will provide a time evolution of the X-ray emission of the comet as it navigates through our solar system.

Porter and his colleagues at Goddard and Lawrence Livermore tested the charge exchange theory in an earthbound laboratory in 2003. That experiment, at Livermore's EBIT-I electron beam ion trap, produced a complex spectrograph of intensity versus X-ray energy for a variety of expected elements in the solar wind and comet. "We are anxious to compare nature's laboratory to the one we created," Porter said.

2 Astrophysics

2.1 Like Planet, Like Sun

Source: NASA Astrobiology Magazine, May 31st, 2006 [10]

A team of European astronomers, led by T. Guillot (CNRS, Observatoire de la Cte d'Azur, France), will publish a new study of the physics of Pegasids (also known as hot Jupiters) in Astronomy & Astrophysics. They found that the amount of heavy elements in Pegasids is correlated to the metallicity of their parent stars. This is a first step in understanding the physical nature of the extrasolar planets.

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Up to now, astronomers have discovered 188 extrasolar planets, among which 10 are known as "transiting planets". These planets pass between their star and us at each orbit. Given the current technical limitations, the only transiting planets that can be detected are giant planets orbiting close to their parent star known as "hot Jupiters" or Pegasids. The ten transiting planets known thus far have masses between 110 and 430 Earth masses (for comparison, Jupiter, with 318 Earth masses, is the most massive planet in our Solar System).

Although rare, transiting planets are the key to understanding planetary formation because they are the only ones for which both the mass and radius can be determined. In principle, the obtained mean density can constrain their global composition. However, translating a mean density into a global composition needs accurate models of the internal structure and evolution of planets. The situation is made difficult by our relatively poor knowledge of the behaviour of matter at high pressures (the pressure in the interiors of giant planets is more than a million times the atmospheric pressure on Earth). Of the nine transiting planets known up to April 2006, only the least massive one could have its global composition determined satisfactorily. It was shown to possess a massive core of heavy elements, about 70 times the mass of the Earth, with a 40 Earth-mass envelope of hydrogen and helium. Of the remaining eight planets, six were found to be mostly made up of hydrogen and helium, like Jupiter and Saturn, but their core mass could not be determined. The last two were found to be too large to be explained by simple models.

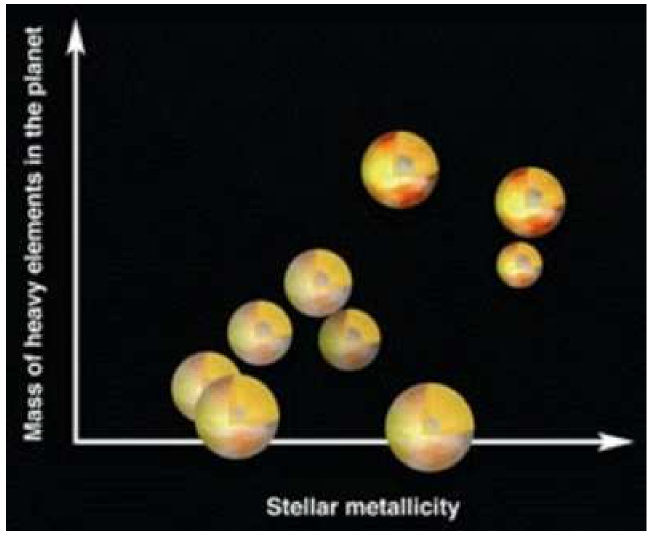

Figure 10: *Correlation between the amount of heavy elements in the transiting planets and the metallicity of their parent stars.*

Credit: Astronomy & Astrophysics

Considering them as an ensemble for the first time, and accounting for the anomalously large planets, Tristan Guillot and his team found that the nine transiting planets have homogeneous properties, with a core mass ranging from 0 (no core, or a small one) up to 100 times the mass of the Earth, and a surrounding envelope of hydrogen and helium. Some of the Pegasids should therefore contain larger amounts of heavy elements than expected. When comparing the mass of heavy elements in the Pegasids to the metallicity of the parent stars, they also found a correlation to exist, with planets born around stars that are as metal-rich as our Sun and that have small cores, while planets orbiting stars that contain two to three times more metals have much larger cores. Their results will be published in Astronomy & Astrophysics.

Planet formation models have failed to predict the large amounts of heavy elements found this way in many planets, so these results imply that they need revising. The correlation between stellar and planetary composition has to be confirmed by further discoveries of transiting planets, but this work is a first step in studying the physical nature of extrasolar planets and their formation. It would explain why transiting planets are so hard to find, to start with. Because most Pegasids have relatively large cores, they are smaller than expected and more difficult to detect in transit in front of their stars. In any case, this is very promising for the CNES space mission COROT to be launched in October, which should discover and lead to characterization of tens of transiting planets, including smaller planets and planets orbiting too far from their star to be detected from the ground.

What of the tenth transiting planet? XO-1b was announced very recently and is also found to be an anomalously large planet orbiting a star of solar metallicity. Models imply that it has a very small core, so that this new discovery strengthens the proposed stellar-planetary metallicity correlation.

2.2 Astronomers, Including Amateurs, Use Innovative Technique to Find Extrasolar Planet

Source: Hubble News, May 18th, 2006 [11]

An international team of professional and amateur astronomers, using simple off-the-shelf equipment to trawl the skies for planets outside our solar system, has hauled in its first ”catch.”

The astronomers discovered a Jupiter-sized planet orbiting a Sun-like star 600 light-years from Earth in the constellation Corona Borealis. The team, led by Peter McCullough of the Space Telescope Science Institute in Baltimore, Md., includes four amateur astronomers from North America and Europe.

Using modest telescopes to search for extrasolar planets allows for a productive collaboration between professional and amateur astronomers that could accelerate the planet quest.

”This discovery suggests that a fleet of modest telescopes and the help of amateur astronomers can search for transiting extrasolar planets many times faster than we are now,” McCullough said. The finding has been accepted for publication in the Astrophysical Journal.

McCullough deployed a relatively inexpensive telescope made from commercial equipment to scan the skies for extrasolar planets. Called the XO telescope, it consists of two 200-millimeter telephoto camera lenses and looks like a pair of binoculars. The telescope is on the summit of the Haleakala volcano, in Hawaii.

”To replicate the XO prototype telescope would cost 60,000 dollars,” McCullough explained. ”We have spent far more than that on software, in particular on designing and operating the system and extracting this planet from the data.”

McCullough's team found the planet, dubbed X0-1b, by noticing slight dips in the star's light output when the planet passed in front of the star, called a transit. The light from the star, called XO-1, dips by approximately 2 percent when the planet XO-1b passes in front of it. The observation also revealed that X0-1b is in a tight four-day orbit around its parent star.

Although astronomers have detected more than 180 extrasolar planets, X0-1b is only the tenth planet discovered using the transit method. It is the second planet found using telephoto lenses. The first, dubbed TrES-1, was reported in 2004. The transit method allows astronomers to determine a planet's mass and size. Astronomers use this information to deduce the planet's characteristics, such as its density.

The team confirmed the planet's existence by using the Harlan J. Smith Telescope and the Hobby-Eberly Telescope at the University of Texas's McDonald Observatory to measure the slight wobble induced by the planet on its parent star. This so-called radial-velocity method allowed the team to calculate a precise mass for the planet, which is slightly less than that of Jupiter (about 0.9 Jupiter masses). The planet also is much larger than its mass would suggest. ”Of the planets that pass in front of their stars, XO-1b is the most similar to Jupiter yet known, and the star XO-1 is the most similar to the Sun,” McCullough said, although he was quick to add, ”but XO-1b is much, much closer to its star than Jupiter is to the Sun.”

The astronomer's innovative technique of using relatively inexpensive telescopes to look for eclipsing planets favors finding planets orbiting close to their parent stars. The planet also must be large enough to produce a measurable dip in starlight.

The planet is the first discovered in McCullough's three-year search for transiting extrasolar planets. The planet quest is underwritten by a grant from NASA's Origins program.

McCullough's planet-finding technique involves nightly sweeps of the sky using the XO telescope in Hawaii to note the brightness of the stars it encounters. A computer software program sifts through many thousands of stars every two months looking for tiny dips in the stars' light, the signature of a possible planetary transit. The computer comes up with a few hundred possibilities. From those candidates, McCullough and his team select a few dozen promising leads. He passes these stars on to the four amateur astronomers to study the possible transits more carefully.

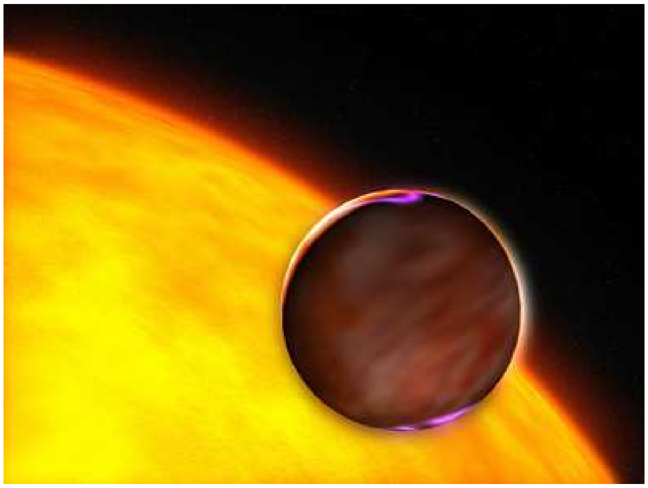

Figure 11: *This artist's impression shows a dramatic close-up of the extrasolar planet XO-1b passing in front of a Sun-like star 600 light-years from Earth. The Jupiter-sized planet is in a tight four-day orbit around the star. Credit: NASA, ESA and G. Bacon (STScI)*

From September 2003 to September 2005, the XO telescope observed tens of thousands of bright stars. In that time, his team of amateur astronomers studied a few dozen promising candidate stars identified by McCullough and his team. The star X0-1 was pegged as a promising candidate in June 2005. The amateur astronomers observed it in June and July 2005, confirming that a planet-sized object was eclipsing the star. McCullough's team then turned to the McDonald Observatory in Texas to obtain the object's mass and verify it as a planet. He received the news of the telescope's observation at 12:06 a.m. Feb. 16, 2006, from Chris Johns-Krull, a friend and colleague at Rice University.

"It was a wonderful feeling because the team had worked for three years to find this one planet," McCullough explained. "The discovery represents a few bytes out of nearly a terabyte of data: It's like trying to distill gold out of seawater."

The discovery also has special familial significance for the astronomer. "My father's mentor was Harlan J. Smith, the man whose ambition and hard work produced the telescope that we used to acquire the verifying data."

McCullough believes the newly found planet is a perfect candidate for study by the Hubble and Spitzer space telescopes. Hubble can measure precisely the star's distance and the planet's size. Spitzer can actually see the infrared radiation from the planet. By timing the disappearance of the planet behind the star, Spitzer also can measure the "ellipticity," or "out-of-roundness," of the planet's orbit. If the orbit is elliptical, then the varying gravitational force would result in extra heating of the planet, expanding its atmosphere and perhaps explaining why the object's diameter seems especially large for a body of its calculated mass.

"By timing the planet's passages across the star, both amateur and professional astronomers might be lucky enough to detect the presence of another planet in the XO-1 system by its gravitational tugs on XO-1b," McCullough said. "It's even possible that such a planet could be similar to Earth."

2.3 Trio of Neptunes and their Belt

Source: ESO Press Release, May 18th, 2006 [12]

Using the ultra-precise HARPS spectrograph on ESO's 3.6-m telescope at La Silla (Chile), a team of European astronomers have discovered that a nearby star is host to three Neptune-mass planets. The innermost planet is most probably rocky, while the outermost is the first known Neptune-mass planet to reside in the habitable zone. This unique system is likely further enriched by an asteroid belt.

"For the first time, we have discovered a planetary system composed of several Neptune-mass planets", said Christophe Lovis, from the Geneva Observatory and lead-author of the paper presenting the results

During more than two years, the astronomers carefully studied HD 69830, a rather inconspicuous nearby star slightly less massive than the Sun. Located 41 light-years away towards the constellation of Puppis (the Stern), it is, with a visual magnitude of 5.95, just visible with the unaided eye. The astronomers' precise radial-velocity measurements [2] allowed them to discover the presence of three tiny companions orbiting their parent star in 8.67, 31.6 and 197 days.

"Only ESO's HARPS instrument installed at the La Silla Observatory, Chile, made it possible to uncover these planets", said Michel Mayor, also from Geneva Observatory, and HARPS Principal Investigator. "Without any doubt, it is presently the world's most precise planet-hunting machine".

The detected velocity variations are between 2 and 3 metres per second, corresponding to about 9 km/h! That's the speed of a person walking briskly. Such tiny signals could not have been distinguished from 'simple noise' by most of today's available spectrographs.

The newly found planets have minimum masses between 10 and 18 times the mass of the Earth. Extensive theoretical simulations favour an essentially rocky composition for the inner planet, and a rocky/gas structure for the middle one.

The outer planet has probably accreted some ice during its formation, and is likely to be made of a rocky/icy core surrounded by a quite massive envelope. Further calculations have also shown that the system is in a dynamically stable configuration.

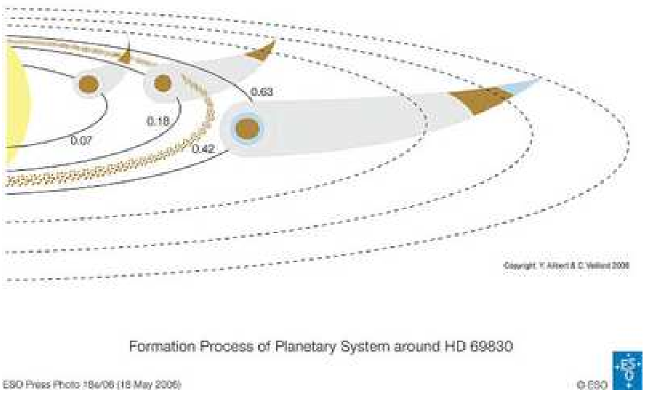

Figure 12: *Formation Process of the Planetary System around HD 69830. Credit: ESO*

The outer planet also appears to be located near the inner edge of the habitable zone, where liquid water can exist at the surface of rocky/icy bodies. Although this planet is probably not Earth-like due to its heavy mass, its discovery opens the way to exciting perspectives.

”This alone makes this system already exceptional”, said Willy Benz, from Bern University, and co-author. ”But the recent discovery by the Spitzer Space Telescope that the star most likely hosts an asteroid belt is adding the cherry to the cake.”

With three roughly equal-mass planets, one being in the habitable zone, and an asteroid belt, this planetary system shares many properties with our own solar system.

”The planetary system around HD 69830 clearly represents a Rosetta stone in our understanding of how planets form”, said Michel Mayor. ”No doubt it will help us better understand the huge diversity we have observed since the first extra-solar planet was found 11 years ago.”

2.4 Companion Explains ”Chameleon” Supernova

Source: Gemini Observatory Press Release, May 3rd, 2006 [13]

Using the Gemini South telescope in Chile, Australian astronomers have found a predicted ”companion” star left behind when its partner exploded as a very unusual supernova. The presence of the companion explains why the supernova, which started off looking like one kind of exploding star, seemed to change its identity after a few weeks.

The Gemini observations were originally intended to be reconnaissance for later imaging with the Hubble Space Telescope. ”But the Gemini data were so good we got our answer straight away,” said lead investigator, Dr. Stuart Ryder of the Anglo-Australian Observatory (AAO).

Renowned Australian supernova hunter Bob Evans first spotted supernova 2001ig in December 2001. It lies in the outskirts of a spiral galaxy NGC 7424, which is about 37 million light-years away in the southern constellation of Grus (the Crane).

The supernova was monitored over the next month by optical telescopes in Chile. Supernovae are classified according to the features in their optical spectra. SN2001ig initially showed the telltale signs of hydrogen, which had it tagged as a Type II supernova, but the hydrogen later disappeared, which put it into the Type I category.

But how could a supernova change its type? Only a handful of such supernovae, classified as ”Type IIb” to indicate their curious change of identity, have ever been seen. Only one (called SN 1993J) was closer than SN 2001ig.

Astronomers studying SN1993J had suggested an explanation: the supernova’s progenitor had a companion star that stripped material off the star before it exploded. This would leave only a little hydrogen on the progenitorso little that it could disappear from the supernova spectrum within a few weeks.

A decade later observations with the orbiting Hubble Space Telescope and one of the Keck telescopes in Hawai’i confirmed that SN 1993J did indeed have a companion. Ryder and colleagues wondered if SN2001ig might have had a companion as well.

Radio Light Curve Shows Lumps & Bumps

Radio observations also hinted at a companion.

Soon after SN2001ig was discovered, Ryder and his colleagues began monitoring it with a radio telescope, the CSIRO (Commonwealth Scientific and Industrial Research Organisation) Australia Telescope Compact Array in eastern Australia. The radio emission did not fall off smoothly over time but instead showed regular bumps and dips. This suggested that the material in space around the star that explodedwhich must have been shed late in its lifewas unusually lumpy.

Although the lumps might have represented matter periodically shed from the convulsing star, their spacing was such that another explanation seemed more likely: that they were generated by a companion in an eccentric orbit. As it orbited, the companion would have swept material shed by the progenitor into a spiral (pinwheel) pattern, with denser lumps at the point in the orbitperiastronwhere the two stars approached most closely.

Such spirals have been imaged around hot, massive stars called Wolf-Rayet stars by Dr Peter Tuthill of the University of Sydney, using the Keck telescopes. The bumps in the radio light-curve of SN2001ig were spaced in a way consistent with the curvature of one of the spirals Tuthill has imaged.

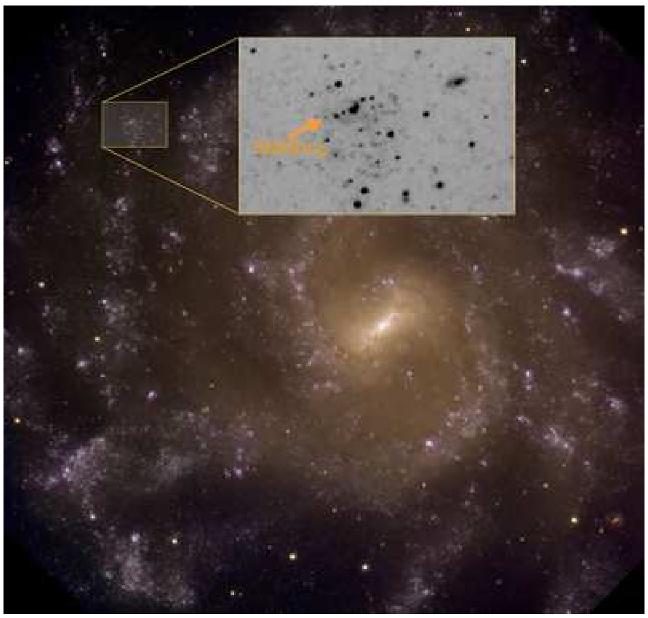

Figure 13: *The Galaxy NGC 7424 as imaged with the Gemini South Mulit-object Spectrograph. Inset shows field of SN2001ig as indicated by arrow. Credit: Gemini South GMOS Images, full Galaxy: Stuart Ryder & Travis Rector, inset Stuart Ryder*

"Stellar evolution theory suggests that a Wolf-Rayet star with a massive companion could produce this unusual kind of supernova," said Ryder.

If the supernova progenitor had a companion, it might be visible when the supernova debris had cleared. So the astronomers put in a request to observe with the GMOS (Gemini Multi-Object Spectrograph) camera on the 8-meter Gemini South telescope.

When the time came to observe, the "seeing conditions" (stability of the atmosphere) were excellent. Just an hour and a half was needed to image the supernova fieldand reveal a yellow-green point-like object at the location of the supernova explosion.

"We believe this is the companion," said Ryder. "It's too red to be a patch of ionized hydrogen, and too blue to be part of the supernova remnant itself."

The companion has a mass of between 10 and 18 times that of the Sun. The astronomers hope to use GMOS again in coming months to get a spectrum of the companion, to refine this estimate.

Binary companions could explain much of the diversity seen in supernovae, Ryder suggests. "We've been able to show the chameleon-like behaviour of SN2001ig has a surprisingly simple explanation," he said.

This is only the second time a companion star to a Type IIb supernova has been imaged, and the first time the imaging has been done from the ground.

2.5 XMM-Newton 'spare-time' provides impressive sky survey

Source: ESA Press Release, May 3rd, 2006 [14]

For the past four years, while ESA's XMM-Newton X-ray observatory has been slewing between different targets ready for the next observation, it has kept its cameras open and used this spare time to quietly look at the heavens. The result is a 'free-of-charge' mission spin-off a survey that has now covered an impressive 25 percent of the sky. The rapid slewing of the satellite across the sky means that a star or a galaxy passes in the field of view of the telescope for ten seconds only. However, the great collecting area of the XMM-Newton mirrors, coupled with the efficiency of its image sensors, is allowing thousands of sources to be detected.

Furthermore, XMM-Newton can pinpoint the position of X-rays coming from the sky with a resolution far superior to that available for most previous all-sky surveys. This is sufficient to allow the source of these X-rays to be found in many cases.

By comparing XMM-Newton survey's data with those obtained over a decade ago by the international ROSAT mission, which also performed an all-sky survey, scientists can now check the long-term stability, or the evolution, of about two thousand objects in the sky. An initial look shows that some sources have changed their brightness level by an incredible amount. The most extreme of these are variable stars and more surprisingly galaxies, whose unusual volatility may be due to large quantities of matter being consumed by an otherwise dormant central black hole.

The slew survey is particularly sensitive to active galactic nuclei (AGN) - galaxies with an unusually bright nucleus which can be traced out to a distance of ten thousand million light years.

While most stars and galaxies look like points in the sky, about 15 percent of the sources catalogued by XMM-Newton have an extended X-ray emission. Most of these are clusters of galaxies - gigantic conglomerations of galaxies which trap hot gas that emit X-rays over scales of a million light years. Eighty-one of these clusters are already famous from earlier work but many other clusters, previously unknown, appear in this new XMM-Newton sky catalogue.

Scientists hope that the newly detected sources of this kind also include very distant clusters which are highly luminous in X-rays, as these objects are invaluable for investigating the evolution of the Universe. Follow-up observations by large optical telescopes are now needed to determine the distances of the individual galaxies in the newly discovered clusters.

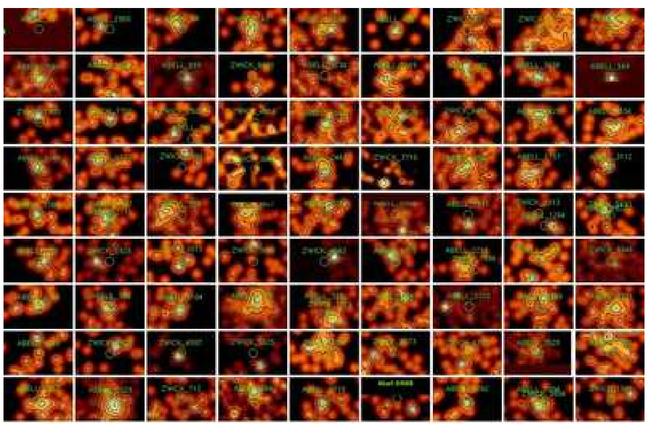

Figure 14: *Eighty-one galaxy clusters objects that make extended X-ray emissions - are know from former sky surveys (see image). Previously unknown sources of these kind are now being catalogued thanks to XMM-Newton's slew sky survey. Studying these objects, especially when highly luminous, is very important to investigate the evolution of the Universe. Credits: ESA and the XMM-Newton EPIC consortium*

Using traditional pointed observations, it takes huge amounts of telescope-time to image very large sky features, such as old supernova remnants, in their entirety. The slewing mechanism provides a very efficient method of mapping these objects, and several have been imaged including the 20 000 year-old Vela supernova remnant, which occupies a sky area 150 times larger than the full moon.

Extraordinarily bright, low-mass X-ray binary systems of stars (called 'LMXB') either powered by matter pulled from a normal star, or exploding onto the surface of a neutron star, or being consumed by a black hole - are observed with sufficient sensitivity to record their detailed light spectrum. Passes across these intense X-ray sources can help astronomers to understand the long-term physics of the interaction between the two stars of the binary system.

Many areas of astronomy are expected to be influenced by the XMM-Newton sky survey. Today, 3 May 2006, the XMM-Newton scientist have released a part of the catalogue resulting from the initial processing of the highest quality data obtained so far.

Such data correspond to a sky coverage of about 15 percent, and include more than 2700 very bright sources and a further 2000 sources of lower significance. Currently, about 55 percent of the catalogue entries have been identified with known stars, galaxies, quasars and clusters of galaxies.

A faster turn-around of slew-data processing is now planned to catch interesting transient (or temporary) targets in the act, before they have a chance to fade. This will give access to rare, energetic events, which only a sensitive wide-angle survey such as XMM-Newton's can achieve.

It is planned to continually update the catalogue as XMM-Newton charts its way through the stars. This will cover at least 80 percent of the sky, leaving a tremendous legacy for the future.

2.6 New Milky Way Companions Found

Source: RAS Press Release, May 8th, 2006 [15]

The Sloan Digital Sky Survey (SDSS-II) announced today (May 8) the discoveries of two new, very faint companion galaxies to the Milky Way.

The first was found in the direction of the constellation Canes Venatici (the Hunting Dog) by SDSS-II researcher Daniel Zucker at Cambridge University (UK). His colleague Vasily Belokurov discovered the second in the constellation Bootes (the Herdsman).

"I was poring over the survey's map of distant stars in the Northern Galactic sky - what we call a Field of Streams – and noticed an overdensity in Canes Venatici," Zucker explained. "Looking further, it proved to be a previously unknown dwarf galaxy. It's about 640,000 light years (200 kiloparsecs) from the Sun. This makes it one of the most remote of the Milky Way's companion galaxies."

Zucker emailed Belokurov with the news, and, just as discoveries often build upon one another, Belokurov excitedly emailed back a few hours later with the discovery of a new, even fainter dwarf galaxy. The new galaxy in Bootes, which Belokurov called 'Boo,' shows a distorted structure that suggests it is being disrupted by the Milky Way's gravitational tides. "Something really bashed Boo about," said Belokurov.

Although the dwarf galaxies are in our own cosmic backyard, they are hard to discover because they are so dim. In fact, the new galaxy in Bootes is the faintest galaxy so far discovered, with a total luminosity of only about 100,000 Suns. But because of its distance (640,000 light years) it appears almost invisible to most telescopes. The previous dimness record holder was discovered last year in Ursa Major using SDSS-II data.

New galactic neighbors are exciting in their own right, but the stakes in searches for ultra-faint dwarfs are especially high because of a long-standing conflict between theory and observations. The leading theory of galaxy formation predicts that hundreds of clumps of "cold dark matter" should be orbiting the Milky Way, each one massive enough in principle to host a visible dwarf galaxy. But only about ten dwarf companions have been found to date.

One possibility is that the galaxies in the smaller dark matter clumps are too faint to have appeared in previous searches, but might be detectable in deep surveys like SDSS-II.

"It's like panning for gold. Our view of the sky is enormous, and we're looking for very small clumps of stars," explained Cambridge University astronomer Wyn Evans, a member of the SDSS-II research team. Added collaborator Mark Wilkinson: "Finding and studying these small galaxies is really important. From their structure and their motions, we can learn about the properties of dark matter, as well as measure the mass and the gravity field of the Milky Way".

The new discoveries are part of the SEGUE project (Sloan Extension for Galactic Understanding and Exploration), one of the three component surveys of SDSS-II. SEGUE will probe the structure and stellar make-up of the Milky Way Galaxy in unprecedented detail.

"I'm confident there are more dwarf galaxies out there and SEGUE will find them," said Heidi Newberg of Rensselaer Polytechnic Institute, co-chair of SEGUE.

2.7 Earth is Safe from Gamma Ray Bursts

Source: RAS Press Release, May 10th, 2006 [16]

A gamma-ray burst (GRB) occurring in our own galaxy could decimate life on Earth, destroying the ozone layer, triggering climate change and drastically altering life's evolution. However, the good news is that results published online in the journal Nature show that the likelihood of a natural disaster due to a GRB is much lower than previously thought.

Long-duration GRBs are powerful flashes of high-energy radiation that arise from some of the biggest explosions of extremely massive stars. Astronomers have analysed a total of 42 long duration GRBs those lasting more than two seconds in several Hubble Space Telescope (HST) surveys.

They have found that the galaxies from which they originate are typically small, faint and misshapen (irregular) galaxies, while only one was spotted from a large spiral galaxy similar to the Milky Way. In contrast, supernovae (also the result of collapsing massive stars) were found to lie in spiral galaxies roughly half of the time.

These results, published in the May 10 online edition of the journal Nature, indicate that GRBs form only in very specific environments, which are different from those found in the Milky Way.

Andrew Fruchter, at the Space Telescope Science Institute, the lead author of the paper said, "Their occurrence in small irregulars implies that only stars that lack heavy chemical elements (elements heavier than hydrogen and helium) tend to produce long-duration GRBs."

This means that long bursts happened more often in the past when galaxies did not have a large supply of heavy elements. Galaxies build up a stockpile of heavier chemical elements through the ongoing evolution of successive generations of stars. Early generation stars formed before heavier elements were abundant in the universe.

The authors also found that the locations of GRBs differed from the locations of supernovae (which are a much more common variety of exploding star). GRBs were far more concentrated on the brightest regions of their host galaxies, where the most massive stars reside. Supernovae, on the other hand, occur throughout their host galaxies.

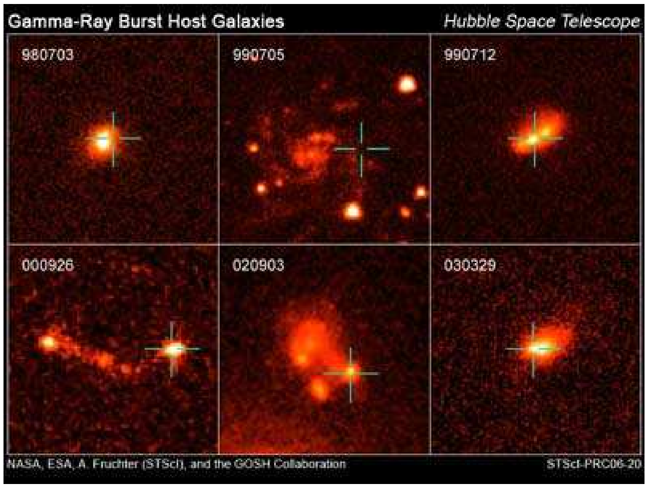

Figure 15: *This is a sampling of the host galaxies of long-duration gamma-ray bursts taken by NASA's Hubble Space Telescope.*

"The discovery that long-duration GRBs lie in the brightest regions of their host galaxies suggests that they come from the most massive stars perhaps 20 or more times as massive as our Sun," said Andrew Levan of the University of Hertfordshire, a co-author of the study.

However, massive stars abundant in heavy elements are unlikely to trigger GRBs because they may lose too much material through stellar "winds" off their surfaces before they collapse and explode. When this happens, the stars don't have enough mass left to produce a black hole, a necessary condition to trigger GRBs. The energy from the collapse escapes along a narrow jet, like a stream of water from a hose. The formation of directed jets, that concentrate energy along a narrow beam, would explain why GRBs are so powerful.

If a star loses too much mass, it may only leave behind a neutron star that cannot trigger a GRB. On the other hand, if the star loses too little mass, the jet cannot burn its way through the star. This means that extremely high-mass stars that puff away too much material may not be candidates for long bursts. Likewise, neither are the stars that give up too little material.

"It's a Goldilocks scenario," said Fruchter. "Only supernovae whose progenitor stars have lost some, but not too much mass, appear to be candidates for the formation of GRBs".

"People have, in the past, suggested that it might be possible to use GRBs to follow the locations of star formation. This obviously doesn't work in the universe as we see it now, but, when the universe was young, GRBs may well have been more common, and we may yet be able to use them to see the very first stars to form after the Big Bang," added Levan.

2.8 XMM-Newton reveals the origin of elements in galaxy clusters

Source: ESA Press Release, May 10th, 2006 [17]

Deep observations of two X-ray bright clusters of galaxies with ESA's XMM-Newton satellite allowed a group of international astronomers to measure their chemical composition with an unprecedented accuracy. Knowing the chemical composition of galaxy clusters is of crucial importance to understanding the origin of chemical elements in the Universe. Clusters, or conglomerates, of galaxies are the largest objects in the Universe. By looking at them through optical telescopes it is possible to see hundreds or even thousands of galaxies occupying a volume a few million light years across. However, such telescopes only reveal the tip of the iceberg. In fact most of the atoms in galaxy clusters are in the form of hot gas emitting X-ray radiation, with the mass of the hot gas five times larger than the mass in the cluster's galaxies themselves.

Most of the chemical elements produced in the stars of galaxy clusters - expelled into the surrounding space by supernova explosions and by stellar winds - become part of the hot X-ray emitting gas. Astronomers divide supernovae into two basic types: ?core collapse' and ?Type Ia' supernovae. The ?core collapse' supernovae originate when a star at the end of its life collapses into a neutron star or a black hole. These supernovae produce lots of oxygen, neon and magnesium. The Type Ia supernovae explode when a white dwarf star consuming matter from a companion star becomes too massive and completely disintegrates. This type produces lots of iron and nickel. Respectively in November 2002 and August 2003, and for one and a half day each time, XMM-Newton's made deep observations of the two galaxy clusters called ?Sersic 159-03' and ?2A 0335+096'. Thanks to these data the astronomers could determine the abundances of nine chemical elements in the clusters ?plasma' a gas containing charged particles such as ions and electrons.

Figure 16: *Galaxy clusters as seen by XMM-Newton. Credits: ESA and the XMM-Newton EPIC consortium*

These elements include oxygen, iron, neon, magnesium, silicon, argon, calcium, nickel, and - detected for the first time ever in a galaxy cluster - chromium. ”Comparing the abundances of the detected elements to the yields of supernovae calculated theoretically, we found that about 30 percent of the supernovae in these clusters were exploding white dwarfs (?Type Ia’) and the rest were collapsing stars at the end of their lives (?core collapse’),” said Norbert Werner, from the SRON Netherlands Institute for Space Research (Utrecht, Netherlands) and one of the lead authors of these results. ”This number is in between the value found for our own Galaxy (where Type Ia supernovae represent about 13 percent of the supernovae ?population’) and the current frequency of supernovae events as determined by the Lick Observatory Supernova Search project (according to which about 42 percent of all observed supernovae are Type Ia),” he continued.

The astronomers also found that all supernova models predict much less calcium than what is observed in clusters and that the observed nickel abundance cannot be reproduced by these models. These discrepancies indicate that that the details of supernova enrichment is not yet clearly understood. Since clusters of galaxies are believed to be fair samples of the Universe, their X-ray spectroscopy can help to improve the supernova models.

The spatial distribution of elements across a cluster also holds information about the history of clusters themselves. The distribution of elements in 2A 0335+096 indicates an ongoing merger. The distribution of oxygen and iron across Sersic 159-03 indicates that while most of the enrichment by the core collapse supernovae happened long time ago, Type Ia supernovae still continue to enrich the hot gas by heavy elements especially in the core of the cluster.

2.9 Hubble Captures a ”Five-Star” Rated Gravitational Lens

Source: Hubble News, May 23rd, 2006 [18]

NASA’s Hubble Space Telescope has captured the first-ever picture of a group of five star-like images of a single distant quasar.

The multiple-image effect seen in the Hubble picture is produced by a process called gravitational lensing, in which the gravitational field of a massive object in this case, a cluster of galaxies bends and amplifies light from an object in this case, a quasar farther behind it.

Although many examples of gravitational lensing have been observed, this ”quintuple quasar” is the only case so far in which multiple quasar images are produced by an entire galaxy cluster acting as a gravitational lens.

The background quasar is the brilliant core of a galaxy. It is powered by a black hole, which is devouring gas and dust and creating a gusher of light in the process. When the quasar’s light passes through the gravity field of the galaxy cluster that lies between us and the quasar, the light is bent by the space-warping gravity field in such a way that five separate images of the object are produced surrounding the cluster’s center. The fifth quasar image is embedded to the right of the core of the central galaxy in the cluster. The cluster also creates a cobweb of images of other distant galaxies gravitationally lensed into arcs.

The galaxy cluster creating the lens is known as SDSS J1004+4112 and was discovered in the Sloan Digital Sky Survey. It is one of the more distant clusters known (seven billion light-years away), and is seen as it appeared when the universe was half its present age.

Spectral data taken with the Keck I 10-meter telescope show that these are images of the same galaxy. The spectral results match those inferred by a lens model based only on the image positions and measurements of the light emitted from the quasar.

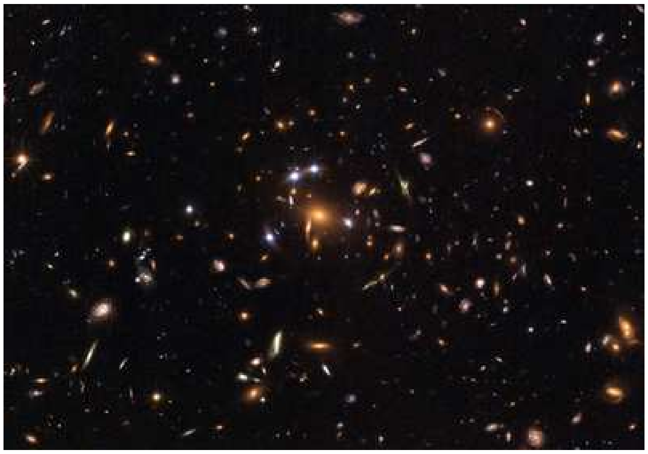

Figure 17:

A gravitational lens will always produce an odd number of lensed images, but one image is usually very weak and embedded deep within the light of the lensing object itself. Though previous observations of SDSS J1004+4112 have revealed four of the images of this system, Hubble's sharp vision and the high magnification of this gravitational lens combine to place a fifth image far enough from the core of the central imaging galaxy to make it visible as well.

The galaxy hosting the background quasar is at a distance of 10 billion light-years. The quasar host galaxy can be seen in the image as multiple faint red arcs. This is the most highly magnified quasar host galaxy ever seen.

The Hubble picture also shows a large number of stretched arcs that are more distant galaxies lying behind the cluster, each of which is split into multiple distorted images. The most distant galaxy identified and confirmed so far is 12 billion light-years away (corresponding to only 1.8 billion years after the Big Bang).

By comparing this image to a picture of the cluster obtained with Hubble a year earlier, the researchers discovered a rare event a supernova exploding in one of the cluster galaxies. The supernova exploded seven billion years ago, and the data, together with other supernova observations, are being used to try to reconstruct how the universe was enriched by heavy elements through these explosions.

2.10 The Cosmos Does Not Glimmer As We Thought

Source: Max Planck Society Press Release, May 8th, 2006 [19]

The H.E.S.S. telescope shows that extragalactic background light hardly dampens the gamma rays of distant quasars.

All throughout space, a cosmic background light shimmers. Stars, galaxies - all kinds of sources - contribute to it; the light is their leftovers, in fact. Now, astrophysicists have discovered that this light is hardly as intense as anyone had guessed. The researchers used two distant quasars as ”probes”, and recorded their gamma spectra using the H.E.S.S. telescopes in Namibia. These spectra turned out to be just a bit reddened; the background light seemed to only lightly obfuscate the quasars' radiation. These observations do not just shed light on the background light - but on topics as great as the birth and development of galaxies (Nature, April 20, 2006).

Stars, galaxies, quasars, and many other objects contribute to the fog of radiation in the universe. It permeates all of intergalactic space; it is the ”leftover” light that all these objects emit. Extragalactic background light - EBL - covers up epochs worth of stellar activity, from the time the first stars were created to the present. Scientists have been trying for a long time to measure this emission. Doing that directly is not easy, however, and extremely inaccurate, because Earth's atmosphere, the Solar System, and the Milky Way send out radiation which gets in the way of observing weak EBL.

One way out of this problem is observing quasars - the cosmic energy factories which have a huge black hole in their middle. These ”gravity traps” swallow up gas around them and spit some of it back as plasma, accelerated to nearly the speed of light. It is radiation bundled out of protons, electrons, and electromagnetic waves. Often, it can be hundreds of times wider than its mother galaxy. If this ”quasar spray” heads in the direction of Earth, the radiation can appear quite strong - astronomers call this a ”blazar”.

The two objects which H.E.S.S. researchers observed are both blazars. How to use them as probes? They send out very energetic gamma light particles, which lose strength on their way to Earth when they hit EBL photons. This causes the original blazar gamma spectrum to redden - like when the Sun nears the horizon at dusk and the Earth's atmosphere disperses more of the blue part of the sunlight than the red. The thicker the atmosphere, the redder the sun. Reddening depends on the thickness of the medium. This fact is the key to investigating the composition of EBL.

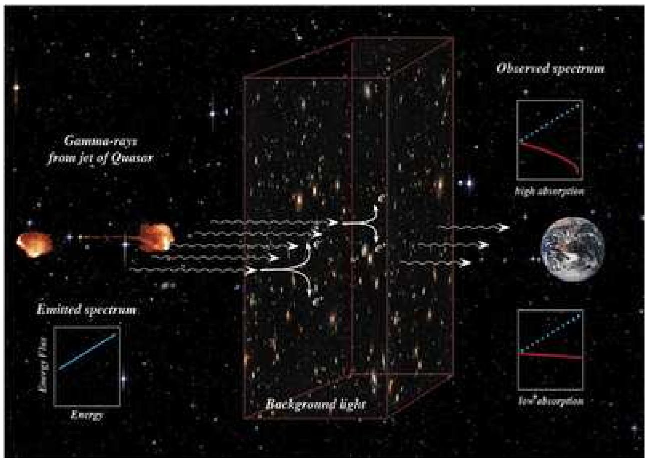

Figure 18: *Extragalactic Background Light comes into contact with gamma rays from a distant quasar. At higher densities, EBL photons come into a number of collisions with gamma light particles - absorption is strong and the spectrum clearly changes (above, right). At lesser EBL proton densities, absorption is weaker and the spectrum changes only a little (below, right). Image: H.E.S.S. collaboration*

Luigi Costamante of the Max Planck Institute for Nuclear Physics in Heidelberg says ”the main problem is that energy distribution in quasars can take many different forms. Until now, we could not really say whether any observed spectrum looks red because it truly had a strong reddening, or if it was that way from the beginning.”

This problem has been solved thanks to the gamma spectra of two quasars – H 2356-309 and 1ES 1101-232. These objects are more distant than any sources observed until now. The sensitivity of the H.E.S.S. telescope made it possible to investigate them. It turns out that EBL's intensity is not strong enough to redden quasar light; the spectra are too blue, and contain too many higher-energy gamma rays.

H.E.S.S. data has allowed the scientists to derive the maximum intensity of the diffused light. It is near the lowest limit resulting from the sum of the light of single galaxies visible in an optical telescope. That answers a question that has puzzled astronomers for years: is diffuse light created above all by the radiation from the first stars? The H.E.S.S. results seem to eliminate this possibility. There is also little room for contributions from other sources, like normal galaxies. Looking more closely at intergalactic space gives new perspectives on investigating gamma rays outside our own galaxy.

2.11 XMM-Newton digs into the secrets of fossil galaxy clusters

Source: ESA Press Release, April 27th, 2006 [20]

Taking advantage of the high sensitivity of ESA's XMM-Newton and the sharp vision of NASA's Chandra X-Ray space observatories, astronomers have studied the behaviour of massive fossil galaxy clusters, trying to find out how they find the time to form? Many galaxies reside in galaxy groups, where they experience close encounters with their neighbours and interact gravitationally with the dark matter - mass which permeates the whole intergalactic space but is not directly visible because it doesn't emit radiation.

These interactions cause large galaxies to spiral slowly towards the centre of the group, where they can merge to form a single giant central galaxy, which progressively swallows all its neighbours.

If this process runs to completion, and no new galaxies fall into the group, then the result is an object dubbed a 'fossil group', in which almost all the stars are collected into a single giant galaxy, which sits at the centre of a group-sized dark matter halo. The presence of this halo can be inferred from the presence of extensive hot gas, which fills the gravitational potential wells of many groups and emits X-rays. A group of international astronomers studied in detail the physical features of the most massive and hot known fossil group, with the main aim to solve a puzzle and understand the formation of massive fossils. In fact, according to simple theoretical models, they simply could not have formed in the time available to them!

The fossil group investigated, called 'RX J1416.4+2315', is dominated by a single elliptical galaxy located one and a half thousand million light years away from us, and it is 500 thousand million times more luminous than the Sun.

The XMM-Newton and Chandra X-ray observations, combined with optical and infrared analyses, revealed that group sits within a hot gas halo extending over three million light years and heated to a temperature of 50 million degrees, mainly due to shock heating as a result of gravitational collapse.

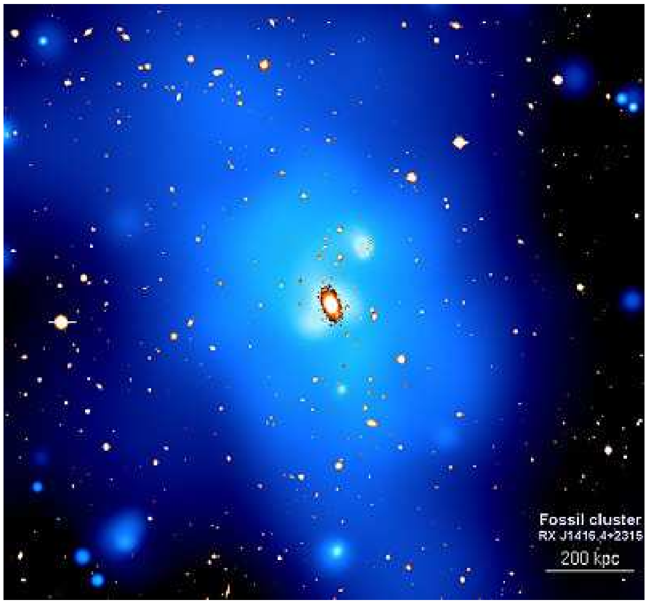

Figure 19: *XMM-Newton observes fossil galaxy cluster*

Such a high temperature, about as twice as the previously estimated values, is usually characteristic of galaxy clusters. Another interesting feature of the whole cluster system is its large mass, reaching over 300 trillion solar masses. Only about two percent of it in the form of stars in galaxies, and 15 percent in the form of hot gas emitting X-rays. The major contributor to the mass of the system is the invisible dark matter, which gravitationally binds the other components. According to calculations, a fossil cluster as massive as RX J1416.4+2315 would have not had the time to form during the whole age of the universe. The key process in the formation of such fossil groups is the process known as 'dynamical friction', whereby a large galaxy loses its orbital energy to the surrounding dark matter. This process is less effective when galaxies are moving more quickly, which they do in massive 'clusters' of galaxies.

This, in principle, sets an upper limit to the size and mass of fossil groups. The exact limits are, however, still unknown since the geometry and mass distribution of groups may differ from that assumed in simple theoretical models.

"Simple models to describe the dynamical friction assume that the merging galaxies move along circular orbits around the centre of the cluster mass", says Habib Khosroshahi from the University of Birmingham (UK), first author of the results. "Instead, if we assume that galaxies fall towards the centre of the developing cluster in an asymmetric way, such as along a filament, the dynamic friction and so the cluster formation process may occur in a shorter time scale," he continues. Such a hypothesis is supported by the highly elongated X-ray emission we observed in RX J1416.4+2315, to sustain the idea of a collapse along a dominant filament."

The optical brightness of the central dominant galaxy in this fossil is similar to that of brightest galaxies in large clusters (called 'BCGs'). According to the astronomers, this implies that such galaxies could have originated in fossil groups around which the cluster builds up later. This offers an alternative mechanism for the formation of BCGs compared to the existing scenarios in which BCGs form within clusters during or after the cluster collapse.

"The study of massive fossil groups such as RX J1416.4+2315 is important to test our understanding of the formation of structure in the universe," adds Khosroshahi. "Cosmological simulations are underway which attempt to reproduce the properties we observe, in order to understand how these extreme systems develop," he concludes.

2.12 When Dwarfs Gave Way to Giants

Source: Harvard-Smithsonian Center for Astrophysics Press Release, May 17th, 2006 [21]

The first galaxies were small - about 10,000 times less massive than the Milky Way. Billions of years ago, those mini-furnaces forged a multitude of hot, massive stars. In the process, they sowed the seeds for their own destruction by bathing the universe in ultraviolet radiation. According to theory, that radiation shut off further dwarf galaxy formation by both ionizing and heating surrounding hydrogen gas. Now, astronomers Stuart Wyithe (University of Melbourne) and Avi Loeb (Harvard-Smithsonian Center for Astrophysics) are presenting direct evidence in support of this theory.

Wyithe and Loeb showed that fewer, larger galaxies, rather than more numerous, smaller galaxies, dominated the billion-year-old universe. Dwarf galaxy formation essentially shut off only a few hundred million years after the Big Bang.

"The first dwarf galaxies sabotaged their own growth and that of their siblings," says Loeb. "This was theoretically expected, but we identified the first observational evidence for the self-destructive behavior of early galaxies."

Their research is being reported in the May 18, 2006 issue of Nature.

Nearly 14 billion years ago, the Big Bang filled the universe with hot matter in the form of electrons and hydrogen and helium ions. As space expanded and cooled, electrons and ions combined to form neutral atoms. Those atoms efficiently absorbed light, yielding a pervasive dark fog throughout space. Astronomers have dubbed this era the "Dark Ages."

The first generation of stars began clearing that fog by bathing the universe in ultraviolet radiation. UV radiation splits atoms into negatively charged electrons and positively charged ions in a process called ionization. Since the Big Bang created an ionized universe that later became neutral, this second phase of ionization by stars is known as the "epoch of reionization." It took place in the first few hundred million years of existence.

Figure 20: *The first dwarf galaxies to form in the universe sabotaged their own growth and that of their siblings by ionizing surrounding hydrogen gas. Early galaxies were small, containing only 100 million solar masses of material. Later galaxies required at least 10 billion solar masses to be assembled. This artist's conception shows a collection of hot, blue stars comprising an early dwarf galaxy surrounded by red hydrogen gas. Credit: David A. Aguilar (CfA)*

"We want to study this time period because that's when the primordial soup evolved into the rich zoo of objects we now see," said Loeb.

During this key epoch in the history of the universe, gas was not only ionized, but also heated. While cool gas easily clumps together to form stars and galaxies, hot gas refuses to be constrained. The hotter the gas, the more massive a galactic "seed" must be to attract enough matter to become a galaxy.

Before the epoch of reionization, galaxies containing only 100 million solar masses of material could form easily. After the epoch of reionization, galaxies required more than 10 billion solar masses of material to be assembled.

To determine typical galaxy masses, Wyithe and Loeb looked at light from quasars - powerful light sources visible across vast distances. The light from the farthest known quasars left them nearly 13 billion years ago, when the universe was a fraction of its present age. Quasar light is absorbed by intervening clouds of hydrogen associated with early galaxies, leaving telltale bumps and wiggles in the quasar's spectrum.

By comparing the spectra of different quasars along different lines of sight, Wyithe and Loeb determined typical galaxy sizes in the infant universe. The presence of fewer, larger galaxies leads to more variation in the absorption seen along various lines of sight. Statistically, large variation is exactly what Wyithe and Loeb found.

"As an analogy, suppose you are in a room where everybody is talking," explains Wyithe. "If this room is sparsely populated, then the background noise is louder in some parts of the room than others. However if the room is crowded, then the background noise is the same everywhere. The fact that we see fluctuations in the light from quasars implies that the early universe was more like the sparse room than the crowded room."

Astronomers hope to confirm the suppression of dwarf galaxy formation using the next generation of telescopes - both radio telescopes that can detect distant hydrogen and infrared telescopes that can directly image young galaxies. Within the next decade, researchers using these new instruments will illuminate the "Dark Ages" of the universe.

2.13 "Lighthouses in the Sky" Yield Biggest-Ever 3-D Map of the Cosmos

Source: Berkeley Lab Research News, May 15th, 2006 [22]

A team of astronomers led by Nikhil Padmanabhan and David Schlegel has published the largest three-dimensional map of the universe ever constructed, a wedge-shaped slice of the cosmos that spans a tenth of the northern sky, encompasses 600,000 uniquely luminous red galaxies, and extends 5.6 billion light-years deep into space, equivalent to 40 percent of the way back in time to the Big Bang.

Schlegel is a Divisional Fellow in the Physics Division of Lawrence Berkeley National Laboratory, and Padmanabhan will join the Lab's Physics Division as a Chamberlain Fellow and Hubble Fellow in September; presently he is at Princeton University. They and their coauthors are members of the Sloan Digital Sky Survey (SDSS), and have previously produced smaller 3-D maps by using the SDSS telescope in New Mexico to painstakingly collect the spectra of individual galaxies and calculate their distances by measuring their redshifts.

”What's new about this map is that it's the largest ever,” says Padmanabhan, ”and it doesn't depend on individual spectra.”

The principal motive for creating large-scale 3-D maps is to understand how matter is distributed in the universe, says Padmanabhan. ”The brightest galaxies are like lighthouses where the light is, is where the matter is.”

Schlegel says that ”because this map covers much larger distances than previous maps, it allows us to measure structures as big as a billion light-years across.” A natural ruler in space

The variations in galactic distribution that constitute visible large-scale structures are directly descended from variations in the temperature of the cosmic microwave background, reflecting oscillations in the dense early universe that have been measured to great accuracy by balloon-borne experiments and the WMAP satellite.

The result is a natural ”ruler” formed by the regular variations (sometimes called ”baryon oscillations,” with baryons as shorthand for ordinary matter), which repeat at intervals of some 450 million light-years.

”Unfortunately it's an inconveniently sized ruler,” says Schlegel. ”We had to sample a huge volume of the universe just to fit the ruler inside.”

Says Padmanabhan, ”Although the universe is 13.7 billion years old, that really isn't a whole lot of time when you're measuring with a ruler that's marked only every 450 million light-years.”

The distribution of galaxies reveals many things, but one of the most important is a measure of the mysterious dark energy that accounts for some three-fourths of the universe's density. (Dark matter accounts for roughly another 20 percent, while less than 5 percent is ordinary matter of the kind that makes visible galaxies.)

”Dark energy is just the term we use for our observation that the expansion of the universe is accelerating,” Padmanabhan remarks. ”By looking at where density variations were at the time of the cosmic microwave background” only about 300,000 years after the Big Bang ”and seeing how they evolve into a map that covers the last 5.6 billion years, we can see if our estimates of dark energy are correct.”

The new map shows that the large-scale structures are indeed distributed the way current ideas about the accelerating expansion of the universe would suggest. The map's assumed distribution of dark matter, which although invisible is affected by gravity just like ordinary matter, also conforms to current understanding. Dead, red galaxies

What made the big new 3-D map possible were the Sloan Digital Sky Survey's wide-field telescope, which covers a three-degree field of view (the full moon is about half a degree), plus the choice of a particular kind of galactic ”lighthouse,” or distance marker: luminous red galaxies.

”These are dead, red galaxies, some of the oldest in the universe in which all the fast-burning stars have long ago burned out and only old red stars are left,” says Schlegel. ”Not only are these the reddest galaxies, they're also the brightest, visible at great distances.”

The Sloan Digital Sky Survey astronomers worked with colleagues on the Australian Two-Degree Field team to average the color and redshift of a sample of 10,000 red luminous galaxies, relating galaxy color to distance. They then applied these measurements to 600,000 such galaxies to plot their map.

Padmanabhan concedes that ”there's statistical uncertainty in applying a brightness-distance relation derived from 10,000 red luminous galaxies to all 600,000 without measuring them individually. The game we play is, we have so many that the averages still give us very useful information about their distribution. And without having to measure their spectra, we can look much deeper into space.”

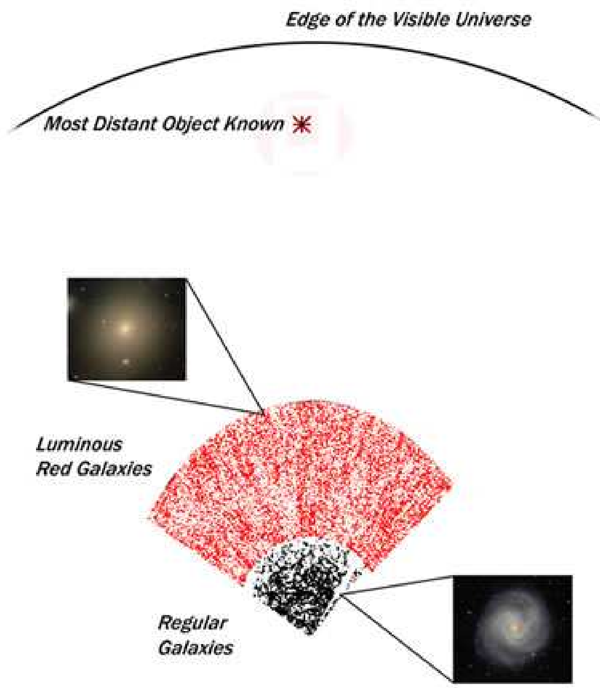

Figure 21: *A schematic view of the new SDSS three-dimensional map, which includes regular galaxies (black points) and luminous red galaxies (red points) and extends 5.6 billion light-years, 40 percent of the distance to the edge of the visible universe.*

Schlegel agrees that the researchers are far from achieving the precision they want. "But we have shown that such measurements are possible, and we have established the starting point for a standard ruler of the evolving universe."

He says "the next step is to design a precision experiment, perhaps based on modifications to the SDSS telescope. We are working with engineers here at Berkeley Lab to redesign the telescope to do what we want to do."

"The Clustering of Luminous Red Galaxies in the Sloan Digital Sky Survey Imaging Data," by Nikhil Padmanabhan, David J. Schlegel, Uro? Seljak, Alexey Makarov, Neta A. Bahcall, Michael R. Blanton, Jonathan Brinkmann, Daniel J. Eisenstein, Douglas P. Finkbeiner, James E. Gunn, David W. Hogg, ?eljko Ivezi?, Gillian R. Knapp, Jon Loveday, Robert H. Lupton, Robert C. Nichol, Donald P. Schneider, Michael A. Strauss, Max Tegmark, and Donald G. York, will appear in the Monthly Notices of the Royal Astronomical Society and is now available online at [23]

2.14 Scientists Predict How to Detect a Fourth Dimension of Space

Source: Duke University News, May 25th, 2006 [24]

Scientists at Duke and Rutgers universities have developed a mathematical framework they say will enable astronomers to test a new five-dimensional theory of gravity that competes with Einstein's General Theory of Relativity. Related

Charles R. Keeton of Rutgers and Arlie O. Petters of Duke base their work on a recent theory called the type II Randall-Sundrum braneworld gravity model. The theory holds that the visible universe is a membrane (hence "braneworld") embedded within a larger universe, much like a strand of filmy seaweed floating in the ocean. The "braneworld universe" has five dimensions – four spatial dimensions plus time – compared with the four dimensions – three spatial, plus time – laid out in the General Theory of Relativity.

The framework Keeton and Petters developed predicts certain cosmological effects that, if observed, should help scientists validate the braneworld theory. The observations, they said, should be possible with satellites scheduled to launch in the next few years. If the braneworld theory proves to be true, "this would upset the applecart," Petters said. "It would confirm that there is a fourth dimension to space, which would create a philosophical shift in our understanding of the natural world."

The scientists' findings appeared May 24, 2006, in the online edition of the journal Physical Review D. Keeton is an astronomy and physics professor at Rutgers, and Petters is a mathematics and physics professor at Duke. Their research is funded by the National Science Foundation.

The Randall-Sundrum braneworld model – named for its originators, physicists Lisa Randall of Harvard University and Raman Sundrum of Johns Hopkins University – provides a mathematical description of how gravity shapes the universe that differs from the description offered by the General Theory of Relativity.

Keeton and Petters focused on one particular gravitational consequence of the braneworld theory that distinguishes it from Einstein's theory.

The braneworld theory predicts that relatively small "black holes" created in the early universe have survived to the present. The black holes, with mass similar to a tiny asteroid, would be part of the "dark matter" in the universe. As the name suggests, dark matter does not emit or reflect light, but does exert a gravitational force.

The General Theory of Relativity, on the other hand, predicts that such primordial black holes no longer exist, as they would have evaporated by now.

”When we estimated how far braneworld black holes might be from Earth, we were surprised to find that the nearest ones would lie well inside Pluto’s orbit,” Keeton said.

Petters added, ”If braneworld black holes form even 1 percent of the dark matter in our part of the galaxy – a cautious assumption – there should be several thousand braneworld black holes in our solar system.”

But do braneworld black holes really exist – and therefore stand as evidence for the 5-D braneworld theory?

The scientists showed that it should be possible to answer this question by observing the effects that braneworld black holes would exert on electromagnetic radiation traveling to Earth from other galaxies. Any such radiation passing near a black hole will be acted upon by the object’s tremendous gravitational forces – an effect called ”gravitational lensing.”

”A good place to look for gravitational lensing by braneworld black holes is in bursts of gamma rays coming to Earth,” Keeton said. These gamma-ray bursts are thought to be produced by enormous explosions throughout the universe. Such bursts from outer space were discovered inadvertently by the U.S. Air Force in the 1960s.

Keeton and Petters calculated that braneworld black holes would impede the gamma rays in the same way a rock in a pond obstructs passing ripples. The rock produces an ”interference pattern” in its wake in which some ripple peaks are higher, some troughs are deeper, and some peaks and troughs cancel each other out. The interference pattern bears the signature of the characteristics of both the rock and the water.

Similarly, a braneworld black hole would produce an interference pattern in a passing burst of gamma rays as they travel to Earth, said Keeton and Petters. The scientists predicted the resulting bright and dark ”fringes” in the interference pattern, which they said provides a means of inferring characteristics of braneworld black holes and, in turn, of space and time.

”We discovered that the signature of a fourth dimension of space appears in the interference patterns,” Petters said. ”This extra spatial dimension creates a contraction between the fringes compared to what you’d get in General Relativity.”

Petters and Keeton said it should be possible to measure the predicted gamma-ray fringe patterns using the Gamma-ray Large Area Space Telescope, which is scheduled to be launched on a spacecraft in August 2007. The telescope is a joint effort between NASA, the U.S. Department of Energy, and institutions in France, Germany, Japan, Italy and Sweden.

The scientists said their prediction would apply to all braneworld black holes, whether in our solar system or beyond.

”If the braneworld theory is correct,” they said, ”there should be many, many more braneworld black holes throughout the universe, each carrying the signature of a fourth dimension of space.”

2.15 Penn State Researchers Look Beyond the Birth of the Universe

Source: Penn State Press Release, May 12th, 2006 [25]

According to Einstein’s general theory of relativity, the Big Bang represents The Beginning, the grand event at which not only matter but space-time itself was born. While classical theories offer no clues about existence before that moment, a research team at Penn State has used quantum gravitational calculations to find threads that lead to an earlier time. ”General relativity can be used to describe the universe back to a point at which matter becomes so dense that its equations don’t hold up,” says Abhay Ashtekar, Holder of the Eberly Family Chair in Physics and Director of the Institute for Gravitational Physics and Geometry at Penn State. ”Beyond that point, we needed to apply quantum tools that were not available to Einstein.” By combining quantum physics with general relativity, Ashtekar and two of his post-doctoral researchers, Tomasz Pawlowski and Parmpreet Singh, were able to develop a model that traces through the Big Bang to a shrinking universe that exhibits physics similar to ours.

In research reported in the current issue of Physical Review Letters, the team shows that, prior to the Big Bang, there was a contracting universe with space-time geometry that otherwise is similar to that of our current expanding universe. As gravitational forces pulled this previous universe inward, it reached a point at which the quantum properties of space-time cause gravity to become repulsive, rather than attractive. ”Using quantum modifications of Einstein’s cosmological equations, we have shown that in place of a classical Big Bang there is in fact a quantum Bounce,” says Ashtekar. ”We were so surprised by the finding that there is another classical, pre-Big Bang universe that we repeated the simulations with different parameter values over several months, but we found that the Big Bounce scenario is robust.”

While the general idea of another universe existing prior to the Big Bang has been proposed before, this is the first mathematical description that systematically establishes its existence and deduces properties of space-time geometry in that universe.

The research team used loop quantum gravity, a leading approach to the problem of the unification of general relativity with quantum physics, which also was pioneered at the Penn State Institute of Gravitational Physics and Geometry. In this theory, space-time geometry itself has a discrete 'atomic' structure and the familiar continuum is only an approximation. The fabric of space is literally woven by one-dimensional quantum threads. Near the Big-Bang, this fabric is violently torn and the quantum nature of geometry becomes important. It makes gravity strongly repulsive, giving rise to the Big Bounce.

"Our initial work assumes a homogenous model of our universe," says Ashtekar. "However, it has given us confidence in the underlying ideas of loop quantum gravity. We will continue to refine the model to better portray the universe as we know it and to better understand the features of quantum gravity."

3 Space missions

3.1 ESA's SOHO will lead a fleet of solar observatories

Source: ESA Press Release, May 24th, 2006 [26]

New funding, to extend the mission of ESA's venerable solar watchdog SOHO, will ensure it plays a leading part in the fleet of solar spacecraft scheduled to be launched over the next few years. Since its launch on 2 December 1995, The Solar and Heliospheric Observatory (SOHO) has provided an unprecedented view of the Sun and not just the side facing the Earth. Two teams have now developed techniques for using SOHO to recreate the conditions on the far side of the Sun. The new funding will allow its mission to be extended from April 2007 to December 2009.

Despite being over ten years old now, SOHO just keeps on working, monitoring the activity on the Sun and allowing scientists to see inside the Sun by recording the seismic waves that ripple across the surface of our nearest star.

More than 2300 scientists have used data from the solar observatory to forward their research, publishing over 2400 scientific papers in peer-reviewed journals. During the last two years, at least one SOHO paper has been accepted for publication every working day.

"This mission extension will allow SOHO to cement its position as the most important spacecraft in the history of solar physics," says Bernhard Fleck, SOHO's project scientist, "There is a lot of valuable work for this spacecraft still to do."

During the next two years, five new solar spacecraft will join SOHO in orbit. ESA is involved in two of these spacecraft. The Japan Aerospace Exploration Agency (ISAS/JAXA) has built Solar B and will launch it later this year. ESA will supply the use of a ground station at Svalbard, Norway in exchange for access to the data. Next year, ESA will launch Proba-2, a technology demonstration satellite that carries solar instruments. In particular, it will carry a complementary instrument to SOHO's EIT camera. Whilst EIT concentrates on the origin and early development of solar eruptions, Proba-2's camera will be able to track them into space.

NASA plans to launch the STEREO pair of spacecraft later this year, and the Solar Dynamics Orbiter in 2008. Far from making SOHO obsolete, these newer solar satellites embrace it as a crucial member of the team. SOHO will provide a critical third point of view to assist the analysis of STEREO's observations. Also, SOHO's coronagraph will remain unique. The instrument is capable of blotting out the glare from the Sun so that the tenuous outer atmosphere of the Sun is visible for study. "By next year, we will have a fleet of spacecraft studying the Sun," says Hermann Opgenoorth, Head of Solar System Missions Division at ESA. This will advance the International Living With a Star programme (ILWS), an international collaboration of scientists dedicated to a long-term study of the Sun and its effects on Earth and the other solar system planets.

ILWS will possibly culminate in the launch of the advanced ESA satellite, Solar Orbiter, around 2015. It is designed to travel close to the Sun, to gain a close-up look at the powerful processes at the heart of our Solar System.

Figure 22: *SOHO is a project of international cooperation between ESA and NASA. SOHO's science ranges from the Sun's hot interior, through its visible surface and stormy atmosphere, and out to distant regions where the wind from the Sun battles with a breeze of atoms coming from among the stars. Credits: ESA*

3.2 Hard-nosed Advice to Lunar Prospectors

Source: Science@NASA, May 22nd, 2006 [27]

Long before David Beaty became associate Chief Scientist for NASA's Mars Program, he was a prospector. Beaty spent 10 years surveying remote parts of Earth for precious metals and another 12 years hunting for oil.

And this qualifies him to work for NASA? Precisely.

Beaty has the kind of experience NASA needs as the agency prepares to implement the Vision for Space Exploration. "Mining and prospecting are going to be key skills for settlers on the Moon and Mars," he explains. "We can send them air and water and fuel from Earth, but eventually, they'll have to learn to live off the land, using local resources to meet their needs."

On the Moon, for instance, mission planners hope to find water frozen in the dark recesses of polar craters. Water can be split into hydrogen for rocket fuel and oxygen for breathing. Water is also good for drinking and as a bonus it is one of the best known radiation shields. "In many ways," notes Beaty, "water is key to a sustained human presence." Ice mining on the Moon could become a big industry.

Beaty has learned a lot from his long career prospecting, exploring and mining on Earth. Now, with an eye on other worlds, he has distilled four pieces of wisdom he calls "Dave's Postulates" for prospectors working anywhere in the solar system:

Postulate 1: "Wishful thinking is no substitute for scientific evidence."

"On Earth, banks won't lend money for less than proven reserves. From a bank's viewpoint, anything less than proven is not really there. This lesson has been learned the hard way by many a prospector," he laughs.

For NASA the stakes are higher than profit. The lives of astronauts could hang in the balance. "Proven reserves on the Moon can perhaps be thought of as having enough confidence to risk the lives of astronauts to go after it."

What does it take to "prove" a reservethat is, to know with confidence that a resource exists in high enough concentration to be produced?

Figure 23: *Robotic ice miner, an artist's concept. Credit: NASA/John Frassanito & Associates.*

"That depends on the nature of the deposit," explains Beaty. "Searching for oil on Earth, you can drill one hole, measure the pressure and calculate how much oil is there. You know that oil probably exists 100 feet away because liquids flow.

However, for gold you must drill holes 100 feet apart, and assay the concentration of gold every five feet down each hole. That's because the solid earth is heterogenous. 100 feet away the rocks may be completely different."

Deposits on the Moon aren't so well understood. Is lunar ice widespread or patchy, deep or shallow? Does it even exist? "We don't know," says Beaty. "We still have a lot to learn."

Postulate 2: "You cannot define a reserve without specifying how it can be extracted. If it can't be mined, it's of no use." Enough said.

Postulate 3: "Perfect knowledge is not possible. Exploration costs money, and we can't afford to buy all the information we want. We have to make choices, deciding what information is critical and what's not."

He offers the following hypothetical example:

"Suppose we decide to send a robot with a little drill and an onboard laboratory into Shackleton Crater, a place on the Moon with suspected ice deposits. We're going to have to think pretty carefully about that lab. Maybe it can contain only two instruments. What are the two things we most need to know?"

"Suppose further that someone on Earth has invented a machine that can extract water from lunar soil. But it only works if the ice is close to the surface and if the ice is not too salty." The choice is made. "We'd better equip the robot with instruments to measure the saltiness of the ice and its depth in the drill hole."

Finally, Postulate 4: "Don't underestimate the potential effects of heterogeneity. All parts of the Moon are not alike, just as all parts of Earth are not alike. So where you land matters."

Ultimately, says Beaty, if geologists and engineers work together applying these rules as they go, living off the land on alien worlds might not be so hard after all.

3.3 Akari delivers its first images

Source: ESA Press Release, May 22nd. 2006 [28]

AKARI, the new Japanese infrared sky surveyor mission in which ESA is participating, saw ?first light' on 13 April 2006 (UT) and delivered its first images of the cosmos. The images were taken towards the end of a successful checkout of the spacecraft in orbit. The mission, formerly known as ASTRO-F, was launched on 21 February 2006 (UT) from the Uchinoura Space Centre in Japan. Two weeks after launch the satellite reached its final destination in space a polar orbit around Earth located at an altitude of approximately 700 kilometres.

On 13 April, during the second month of the system checkout and verification of the overall satellite performance, the AKARI telescope's aperture lid was opened and the onboard two instruments commenced their operation. These instruments - the Far Infrared Surveyor (FIS) and the near-mid-infrared camera (IRC) - make possible an all-sky survey in six infrared wavebands. The first beautiful images from the mission have confirmed the excellent performance of the scientific equipment beyond any doubt.

AKARI's two instruments were pointed toward the reflection nebula IC4954, a region situated about 6000 light years away, and extending more than 10 light years across space. Reflection nebulae are clouds of dust which reflect the light of nearby stars. In these infrared images of IC4954 a region of intense star formation active for several million years it is possible to pick out individual stars that have only recently been born. They are embedded in gas and dust and could not be seen in visible light. It is also possible to see the gas clouds from which these stars were actually created.

"These beautiful views already show how, thanks to the better sensitivity and improved spatial resolution of AKARI, we will be able to discover and study fainter sources and more distant objects which escaped detection by the previous infrared sky-surveyor, IRAS, twenty years ago," says Pedro Garca-Lario, responsible for ?pointing reconstruction' - a vital part of the AKARI data processing - at ESA's European Space Astronomy Centre (ESAC), Spain. "With the help of the new infrared maps of the whole sky provided by AKARI we will be able to resolve for the first time heavily obscured sources in crowded stellar fields like the centre of our Galaxy," he continued.

With its near-mid-infrared camera, AKARI also imaged the galaxy M81 at six different wavelengths. M81 is a spiral galaxy located about 12 million light years away. The images taken at 3 and 4 microns show the distribution of stars in the inner part of the galaxy, without any obscuration from the intervening dust clouds. At 7 and 11 microns the images show the radiation from organic materials (carbon-bearing molecules) in the interstellar gas of the galaxy. The distribution of the dust heated by young hot stars is shown in the images at 15 and 24 microns, showing that the star forming regions sit along the spiral arms of the galaxy.

"It's a feeling of tremendous accomplishment for all of us involved in the AKARI project to finally see the fruits of the long years of labour in these amazing new infrared images of our Universe," said Chris Pearson, ESA astronomer located at ISAS and involved with AKARI since 1997, "We are now eagerly waiting for the next ?infrared revelation' about the origin and evolution of stars, galaxies and planetary systems."

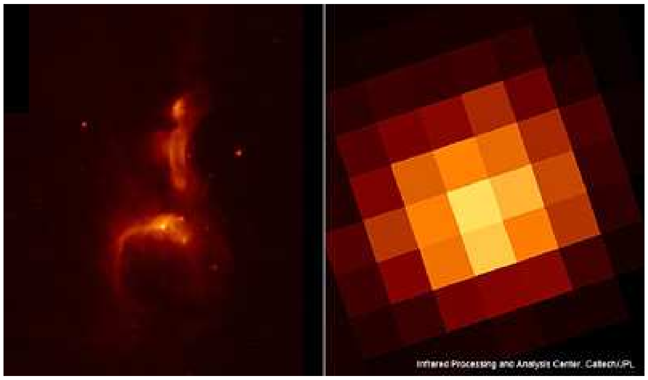

Figure 24: *Akari and IRAS images of a reflection nebula compared*

Having concluded all in-orbit checks, AKARI is now entering the first mission phase. This will last about six months and is aimed at performing a complete survey of the entire infrared sky. This part of the mission will then be followed by a phase during which thousands of selected astronomical targets will be observed in detail. During this second phase, as well as in the following third phase in which only the infrared camera will be at work, European astronomers will have access to ten percent of the overall pointed observation opportunity.

"The user support team at ESAC are enthusiastic about the first images. They show that we can expect a highly satisfactory return for the European observing programme," said Alberto Salama, ESA Project Scientist for AKARI. "Furthermore, the new data will be of enormous value to plan follow-up observations of the most interesting celestial objects with ESA's future infrared observatory, Herschel," he concluded.

3.4 Six new Earth Explorer missions selected for further study

Source: ESA Press Release, May 23rd, 2006 [29]

ESA has announced the shortlist of new Earth Explorer mission proposals within its Living Planet Programme. This is part of the selection procedure that will eventually lead to the launch of the fourth Earth Explorer Core mission during the first half of the next decade. The six missions cover a range of environmental issues with the aim of furthering our understanding of the Earth system and changing climate:

1) BIOMASS to take global measurements of forest biomass.

2) TRAQ (TRopospheric composition and Air Quality) - to monitor air quality and long-range transport of air pollutants.

3) PREMIER (PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation) to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.

4) FLEX (FLuorescence EXplorer) to observe global photosynthesis through the measurement of fluorescence.

5) A-SCOPE (Advanced Space Carbon and Climate Observation of Planet Earth) to improve our understanding of the global carbon cycle and regional carbon dioxide fluxes.

6) CoReH2O (Cold Regions Hydrology High-resolution Observatory to make detailed observations of key snow, ice and water cycle characteristics. The selection of these six mission proposals follows the release of the Call for Earth Explorer Core mission ideas in March 2005. ESA received 24 responses, which covered a broad range of Earth science disciplines, and in particular responded well to the priorities set by the Agency's Earth Science Advisory Committee (ESAC). These priorities focused on the global carbon and water cycles, atmospheric chemistry and climate, as well as the human element as a cross cutting issue.

The proposals were peer reviewed by scientific teams, and also appraised technically and programmatically. Based on these reviews, the ESAC evaluated the proposals and recommended the list of six mission ideas in order of priority. Following these recommendations, ESA's Programme Board for Earth Observation on 18-19 May approved the proposal of the Director of Earth Observation Programmes to initiate assessment studies for these six mission candidates.

Earth Explorer Core missions are ESA-led research missions and the budget limit for the current set is 300 M?. The first Earth Explorer Core Missions were selected in 1999: the Earth Gravity field and Ocean Circulation (GOCE) mission and the Atmospheric Dynamics Mission (ADM-Aeolus) to be launched in 2007 and 2008 respectively. The third Core mission, Earth Clouds Aerosols and Radiation Explorer (EarthCARE), was selected in 2004 and will be launched in 2012. In addition to the Earth Explorer Core missions, three Earth Explorer Opportunity missions are currently under implementation: SMOS for soil moisture and ocean salinity, CryoSat-2 for the study of ice sheets and sea ice, and Swarm, which is a constellation of small satellites to study the dynamics of the Earth's magnetic field and its interactions with the Earth system, due for launch in 2007, 2009 and 2010, respectively. The six mission candidates recently selected will significantly extend the scientific disciplines covered by ESA's Living Planet Programme. When the assessment studies have been completed, a subset of the six candidates will be selected for feasibility study, and the mission finally selected for implementation will be launched during the first half of the next decade. BIOMASS the mission aims at global measurements of forest biomass. The measurement is accomplished by a space borne P-band synthetic aperture polarimetric radar. The technique is mainly based on the measurement of the cross-polar backscattering coefficient, from which forest biomass is directly retrieved. Use of multi-polarization measurements and of interferometry is also proposed to enhance the estimates. In line with the ESAC recommendations, the analysis for this mission will include comparative studies to measure terrestrial biomass using P- or L-band and consideration of alternative implementations using L-band.

TRAQ the mission focuses on monitoring air quality and long-range transport of air pollutants. A new synergistic sensor concept allows for process studies, particularly with respect to aerosol-cloud interactions. The main issues are the rate of air quality change on regional and global scales, the strength and distribution of sources and sinks of tropospheric trace gases and aerosols influencing air quality, and the role of tropospheric composition in global change. The instrumentation consists of imaging spectrometers in the range from ultraviolet to short-wave infrared.

PREMIER Many of the most important processes for prediction of climate change occur in the upper troposphere and lower stratosphere (UTLS). The objective is to understand the many processes that link trace gases, radiation, chemistry and climate in the atmosphere concentrating on the processes in the UTLS region. By linking with MetOp/ National Polar-orbiting Operational Environmental Satellite System (NPOESS) data, the mission also aims to provide useful insights into processes occurring in the lower troposphere. The instrumentation consists of an infrared and a microwave radiometer.

FLEX The main aim of the mission is global remote sensing of photosynthesis through the measurement of fluorescence. Photosynthesis by land vegetation is an important component of the global carbon cycle, and is closely linked to the hydrological cycle through transpiration. Currently there are no direct measurements available from satellites of this parameter. The main specification is for instruments to measure high spectral resolution reflectance and temperature, and to provide a multi-angular capability. A-SCOPE The mission aims to observe total column carbon dioxide with a nadir-looking pulsed carbon dioxide DIfferential Absorption Lidar (DIAL) for a better understanding of the global carbon cycle and regional carbon dioxide fluxes, as well as for the validation of greenhouse gas emission inventories. It will provide a spatially resolved global carbon budget combined with diagnostic model analysis through global and frequent observation of carbon dioxide. Spin-off products like aerosols, clouds and surface reflectivity are important parameters of the radiation balance of the Earth. A contribution to Numerical Weather Prediction is foreseen in connection with accurate temperature profiles. Investigations on plant stress and vitality will be supported by a fluorescence imaging spectrometer.

Figure 25: *The Living Planet*

CoReH2O The mission focuses on spatially detailed observations of key snow, ice, and water cycle characteristics necessary for understanding land surface, atmosphere and ocean processes and interactions by using two synthetic aperture radars at 9.6 and 17.2 GHz. It aims at closing the gaps in detailed information on snow glaciers, and surface water, with the objectives of improving modelling and prediction of water balance and streamflow for snow covered and glacierised basins, understanding and modelling the water and energy cycles in high latitudes, assessing and forecasting water supply from snow cover and glaciers, including the relation to climate change and variability.

3.5 Breathing Moonrocks

Source: Science@NASA, May 5th, 2006 [30]

An early, persistent problem noted by Apollo astronauts on the Moon was dust. It got everywhere, including into their lungs. Oddly enough, that may be where future Moon explorers get their next breath of air: The moon's dusty layer of soil is nearly half oxygen.

The trick is extracting it.

"All you have to do is vaporize the stuff," says Eric Cardiff of NASA's Goddard Space Flight Center. He leads one of several teams developing ways to provide astronauts oxygen they'll need on the Moon and Mars.

Lunar soil is rich in oxides. The most common is silicon dioxide (SiO2), "like beach sand," says Cardiff. Also plentiful are oxides of calcium (CaO), iron (FeO) and magnesium (MgO). Add up all the O's: 43% of the mass of lunar soil is oxygen.

Cardiff is working on a technique that heats lunar soils until they release oxygen. "It's a simple aspect of chemistry," he explains. "Any material crumbles into atoms if made hot enough." The technique is called vacuum pyrolysis–pyro means "fire", lysis means "to separate."

"A number of factors make pyrolysis more attractive than other techniques," Cardiff explains. "It requires no raw materials to be brought from Earth, and you don't have to prospect for a particular mineral." Simply scoop up what's on the ground and apply the heat.

In a proof of principle, Cardiff and his team used a lens to focus sunlight into a tiny vacuum chamber and heated 10 grams of simulated lunar soil to about 2,500 degrees C. Test samples included ilmenite and Minnesota Lunar Simulant, or MLS-1a. Ilmenite is an iron/titanium ore that Earth and the Moon have in common. MLS-1a is made from billion-year-old basalt found on the north shore of Lake Superior and mixed with glass particles that simulate the composition of the lunar soil. Actual lunar soil is too highly prized for such research now.

In their tests, "as much as 20 percent of the simulated soil was converted to free oxygen," Cardiff estimates.

What's leftover is "slag," a low-oxygen, highly metallic, often glassy material. Cardiff is working with colleagues at NASA's Langley Research Center to figure out how to shape slag into useful products like radiation shielding, bricks, spare parts, or even pavement.

Figure 26: *Slag–a low-oxygen byproduct of Cardiff's device. Slag may prove useful as a raw material for bricks, pavement or radiation shielding.*

The next step: increase efficiency. "In May, we're going to run tests at lower temperatures, with harder vacuums." In a hard vacuum, he explains, oxygen can be extracted with less power. Cardiff's first test was at 1/1,000 Torr. That is 760,000 times thinner than sea level pressure on Earth (760 Torr). At 1 millionth of a Torr – another thousand times thinner – "the temperatures required are significantly reduced."

Cardiff is not alone in this quest. A team led by Mark Berggren of Pioneer Astronautics in Lakewood, CO, is working on a system that harvests oxygen by exposing lunar soil to carbon monoxide. In one demonstration they extracted 15 kg of oxygen from 100 kg of lunar simulant– an efficiency comparable to Cardiff's pyrolysis technique: more.

D.L. Grimmett of Pratt & Whitney Rocketdyne in Canoga Park, CA, is working on magma electrolysis. He melts MLS-1 at about 1,400 deg. C, so it is like magma from a volcano, and uses an electric current to free the oxygen: more.

Finally, NASA and the Florida Space Research Institute, through NASA's Centennial Challenge, are sponsoring MoonROx, the Moon Regolith Oxygen competition. A

250,000 dollar prize goes to the team that can extract 5 kg of breathable oxygen from JSC-1 lunar simulant in just 8 hours.

The competition closes June 1, 2008, but the challenge of living on other planets will last for generations.

Got any hot ideas?

3.6 Follow the Nitrogen to Extraterrestrial Life

Source: University of South California, May 4th, 2006 [31]

The great search for extraterrestrial life has focused on water at the expense of a crucial element, say USC geobiologists.

Writing in the Perspectives section of the May 5 issue of Science, four USC researchers propose searching for organic nitrogen as a direct indicator of the presence of life. Nitrogen is essential to the chemistry of living organisms.

Even if NASA were to find water on Mars, its presence only would indicate the possibility of life, said Kenneth Nealson, Wrigley Professor of earth sciences in USC College.

"It's hard to imagine life without water, but it's easy to imagine water without life," Nealson said.

The discovery of nitrogen on the Red Planet would be a different story.

"If you found nitrogen in abundance on Mars, you would get extremely excited because it shouldn't be there," Nealson said.

The reason has to do with the difference between nitrogen and carbon, the other indispensable organic element.

Unlike carbon, nitrogen is not a major component of rocks and minerals. This means that any substantial organic nitrogen deposits found in the soil of Mars, or of another planet, likely would have resulted from biological activity.

Dimming the hopes of life-on-Mars believers is the makeup of the planet's atmosphere. The abundant nitrogen in Earth's atmosphere is constantly replenished through biological activity. Without the ongoing contribution of living systems, the atmosphere slowly would lose its nitrogen.

The extremely low nitrogen content in the Martian atmosphere suggests that biological nitrogen production is close to zero.

However, the authors write, it is possible that life existed on Mars at some hypothetical time when nitrogen filled the atmosphere.

Co-author Douglas Capone, Wrigley Professor of environmental biology in USC College, said NASA should establish a nitrogen detection program alongside its water-seeking effort. He noted that next-generation spacecraft will have advanced sampling capabilities.

"What we're suggesting here is basically drilling down into geological strata, which they're going to be doing for water anyway," Capone said.

"The real smoking gun would be organic nitrogen."

Said Nealson: "If your goal is to search for life, it would be wise to include nitrogen."

In their acknowledgments, the authors thanked the students of the Spring 2004 Geobiology & Astrobiology course at USC, with whom Nealson and Capone began their discussion on how to search for life outside earth.

"That's really what stimulated this [paper]," Nealson said.

4 Internet websites

[1] http://carnegieinstitution.org/darkcrystal/default.html
[2] http://www.esa.int/esaCP/SEM8DA9ATME_index_0.html
[3] http://science.nasa.gov/headlines/y2006/10may_longrange.htm
[4] http://www.esa.int/SPECIALS/Mars_Express/SEMG4O9ATME_0.html
[5] http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/19/image/a
[6] http://www.jpl.nasa.gov/news/news.cfm?release=2006-080
[7] http://uanews.org/cgi-bin/WebObjects/UANews.woa/3/wa/SRStoryDetails?ArticleID=12614
[8] http://www.ucsc.edu/news_events/press_releases/text.asp?pid=867
[9] http://www.nasa.gov/mission_pages/swift/bursts/swift_comet.html
[10] http://www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1976&mode=thread&order=0&thold=0
[11] http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/22/full/

[12] http://www.eso.org/outreach/press-rel/pr-2006/pr-18-06.html
[13] http://www.gemini.edu/index.php?option=content&task=view&id=184&Itemid=0&limit=1&limitstart=0
[14] http://www.esa.int/esaCP/SEMA7OOFGLE_index_0.html
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[28] http://www.esa.int/esaCP/SEM8NF9ATME_index_0.html
[29] http://www.esa.int/esaCP/SEMHQH9ATME_index_0.html
[30] http://science.nasa.gov/headlines/y2006/05may_moonrocks.htm
[31] http://www.usc.edu/uscnews/stories/12380.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.

More information can be found at:

Europlanetarium, Planetariumweg 19, B-3600 Genk, tel:089/307990 / fax: 089/307991

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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