Vendelinus Astronomy Newsletter

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1.1 NASA's Grace Finds Greenland Melting Faster, 'Sees' Sumatra Quake

Source: NASA News, December 20th, 2005 [1]

In the first direct, comprehensive mass survey of the entire Greenland ice sheet, scientists using data from the NASA/German Aerospace Center Gravity Recovery and Climate Experiment (Grace) have measured a significant decrease in the mass of the Greenland ice cap. Grace is a satellite mission that measures movement in Earth's mass.

In an update to findings published in the journal Geophysical Research Letters, a team led by Dr. Isabella Velicogna of the University of Colorado, Boulder, found that Greenland's ice sheet decreased by 162 (plus or minus 22) cubic kilometers a year between 2002 and 2005. This is higher than all previously published estimates, and it represents a change of about 0.4 millimeters (.016 inches) per year to global sea level rise.

"Greenland hosts the largest reservoir of freshwater in the northern hemisphere, and any substantial changes in the mass of its ice sheet will affect global sea level, ocean circulation and climate," said Velicogna. "These results demonstrate Grace's ability to measure monthly mass changes for an entire ice sheet a breakthrough in our ability to monitor such changes."

Other recent Grace-related research includes measurements of seasonal changes in the Antarctic Circumpolar Current, Earth's strongest ocean current system and a very significant force in global climate change. The Grace science team borrowed techniques from meteorologists who use atmospheric pressure to estimate winds. The team used Grace to estimate seasonal differences in ocean bottom pressure in order to estimate the intensity of the deep currents that move dense, cold water away from the Antarctic. This is the first study of seasonal variability along the full length of the Antarctic Circumpolar Current, which links the Atlantic, Pacific and Indian Oceans.

Dr. Victor Zlotnicki, an oceanographer at NASA's Jet Propulsion Laboratory in Pasadena, Calif., called the tech-

nique a first step in global satellite monitoring of deep ocean circulation, which moves heat and salt between ocean basins. This exchange of heat and salt links sea ice, sea surface temperature and other polar ocean properties with weather and climate-related phenomena such as El Ninos. Some scientific studies indicate that deep ocean circulation plays a significant role in global climate change.

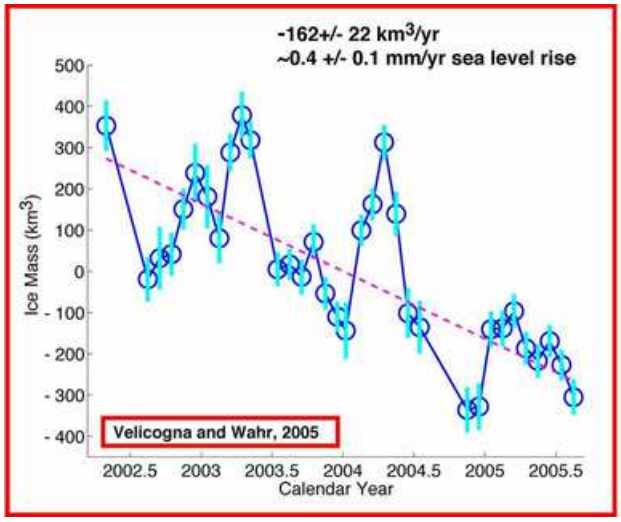

Figure 1: *This figure shows the ice mass loss in Greenland as observed by Grace over the period 2002-2005 measured in cubic kilometers per year. The ice mass loss observed contributes about 0.4 millimeters (.016 inches) per year to global sea level rise. Image credit: NASA/JPL/University of Colorado*

The identical twin Grace satellites track minute changes in Earth's gravity field resulting from regional changes in Earth's mass. Masses of ice, air, water and solid Earth can be moved by weather patterns, seasonal change, climate change and even tectonic events, such as this past December's Sumatra earthquake. To track these changes, Grace measures micron-scale changes in the 220-kilometer (137-mile) separation between the two satellites, which fly in formation. To limit degradation of Grace's satellite antennas due to atomic oxygen exposure and thereby preserve mission life, a series of maneuvers was performed earlier this month to swap the satellites' relative positions in orbit.

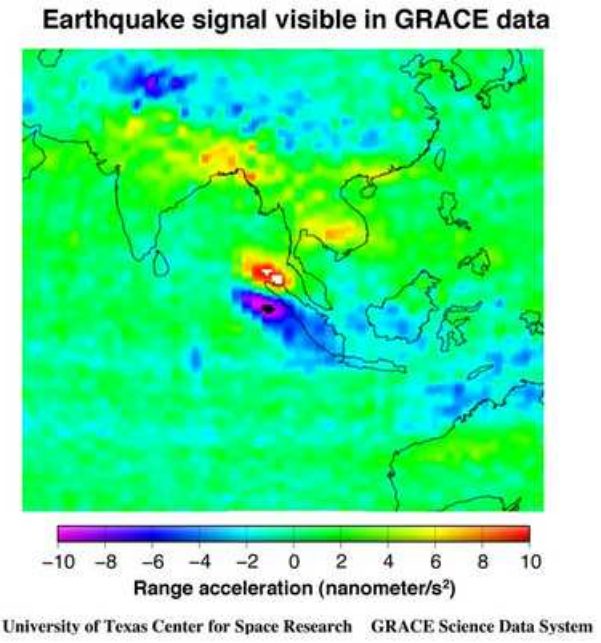

Figure 2: *This figure shows the effect of the December 2004 great Sumatra earthquake on the Earth's gravity field as observed by Grace. Image credit: NASA/JPL/University of Texas-CSR*

In a demonstration of the satellites' sensitivity to minute changes in Earth's mass, the Grace science team reported that the satellites were able to measure the deformation of the Earth's crust caused by the December 2004 Sumatra earthquake. That quake changed Earth's gravity by one part in a billion.

Dr. Byron Tapley, Grace principal investigator at the University of Texas at Austin, said that the detection of the Sumatra earthquake gravity signal illustrates Grace's ability to measure changes on and within Earth's surface. "Grace's measurements will add a global perspective to studies of large earthquakes and their impacts," said Tapley.

1.2 Oxygen in Ancient Atmosphere Rose Gradually to Modern Levels

Source: University of Maryland News, December 1st, 2005 [2]

The history of life on Earth is closely linked to the appearance of oxygen in the atmosphere. The current scientific consensus holds that significant amounts of oxygen first appeared in Earth's atmosphere some 2.4 billion years ago,

with a second large increase in atmospheric oxygen occurring much later, perhaps around 600 million years ago.

However, new findings by University of Maryland geologists suggest that the second jump in atmospheric oxygen actually may have begun much earlier and occurred more gradually than previously thought. The findings were made possible using a new tool for tracking microbial life in ancient environments developed at Maryland. Funded by the National Science Foundation and NASA, the work appears in the December 2 issue of Science.

Graduate researcher David Johnston, research scientist Boswell Wing and colleagues in the University of Maryland's department of geology and Earth System Science Interdisciplinary Center led an international team of researchers that used high-precision measurements of a rare sulfur isotope, 33S, to establish that ancient marine microbes known as sulfur disproportionating prokaryotes were widely active almost 500 million years earlier than previously thought.

The intermediate sulfur compounds used by these sulfur disproportionating bacteria are formed by the exposure of sulfide minerals to oxygen gas. Thus, evidence of widespread activity by this type of bacteria has been interpreted by scientists as evidence of increased atmospheric oxygen content.

"These measurements imply that sulfur compound disproportionation was an active part of the sulfur cycle by [1.3 billion years ago], and that progressive Earth surface oxygenation may have characterized the [middle Proterozoic]," the authors write.

The Proterozoic is the period in Earth's history from about 2.4 billion years ago to 545 million years ago.

"The findings also demonstrate that the new 33S-based research method can be used to uniquely track the presence and character of microbial life in ancient environments and provide a glimpse of evolution in action," said Johnston. "This approach provides a significant new tool in the astrobiological search for early life on Earth and beyond."

The Air That We Breathe

When our planet formed some 4.5 billion years ago, virtually all the oxygen on Earth was chemically bound to other elements. It was in solid compounds like quartz and other silicate minerals, in liquid compounds like water, and in gaseous compounds like sulfur dioxide and carbon dioxide. Free oxygen – the gas that allows us to breath, and which is essential to all advanced life – was practically non-existent.

Scientists have long thought that appearance of oxygen in the atmosphere was marked by two distinct jumps in oxygen levels. In recent years, researchers have used a method developed by University of Maryland geologist James Farquhar and Maryland colleagues to conclusively determine that significant amounts of oxygen first appeared in Earth's atmosphere some 2.4 billion years ago. Sometimes referred to as the "Great Oxidation Event," this increase marks the beginning of the Proterozoic period.

A general scientific consensus has also held that the second major rise in atmospheric oxygen occurred some 600 million years ago, with oxygen rising to near modern levels at that time. Evidence of multicellular animals first appears in the geologic around this time.

"There has been a lot of discussion about whether the second major increase in atmospheric oxygen was quick and stepwise, or slow and progressive," said Wing. "Our results support the idea that the second rise was progressive and began around 1.3 billion years ago, rather than 0.6 billion years ago."

In addition to Johnston, Wing's Maryland co-authors on the Dec. 2 paper are geology colleagues James Farquhar and Jay Kaufman. Their group works to document links between sulfur isotopes and the evolution of Earth's atmosphere using a combination of field research, laboratory analysis of rock samples, geochemical models, photochemical experiments with sulfur-bearing gases and microbial experiments.

1.3 Turning the Lights Off in Alaska

Source: Astrobiology Magazine, December 11th, 2005 [3]

After some 400 years of relative stability, Earth's North Magnetic Pole has moved nearly 1,100 kilometers out into the Arctic Ocean during the last century and at its present rate could move from northern Canada to Siberia within the next half-century.

If that happens, Alaska may be in danger of losing one of its most stunning natural phenomena - the Northern Lights.

But the surprisingly rapid movement of the magnetic pole doesn't necessarily mean that our planet is going through a large-scale change that would result in the reversal of the Earth's magnetic field, Oregon State University paleomagnetist Joseph Stoner reported at the annual meeting of the American Geophysical Union in San Francisco, Calif.

"This may be part of a normal oscillation and it will eventually migrate back toward Canada," said Stoner, an assistant professor in OSU's College of Oceanic and Atmospheric Sciences. "There is a lot of variability in its movement."

Calculations of the North Magnetic Pole's location from historical records goes back only about 400 years, while polar observations trace back to John Ross in 1838 at the west coast of Boothia Peninsula. To track its history beyond that, scientists have to dig into the Earth to look for clues.

Stoner and his colleagues have examined the sediment record from several Arctic lakes. These sediments - magnetic particles called magnetite - record the Earth's magnetic field at the time they were deposited. Using carbon dating and other technologies - including layer counting - the scientists can determine approximately when the sediments were deposited and track changes in the magnetic field.

The Earth last went through a magnetic reversal some 780,000 years ago. These episodic reversals, in which south becomes north and vice versa, take thousands of years and are the result of complex changes in the Earth's outer core. Liquid iron within the core generates the magnetic field that blankets the planet.

Because of that field, a compass reading of north in Oregon will be approximately 17 degrees east from "true geographic north." In Florida, farther away and more in line with the poles, the declination is only 4-5 degrees west.

The Northern Lights, which are triggered by the sun and fixed in position by the magnetic field, drift with the movement of the North Magnetic Pole and may soon be visible in more southerly parts of Siberia and Europe - and less so in northern Canada and Alaska.

In their research, funded by the National Science Foundation, Stoner and his colleagues took core samples from several lakes, but focused on Sawtooth Lake and Murray Lake on Ellesmere Island in the Canadian Arctic. These lakes, about 40 to 80 meters deep, are covered by 2-3 meters of ice. The researchers drill through the ice, extend their corer down through the water, and retrieve sediment cores about five meters deep from the bottom of the lakes.

The 5-meter core samples provide sediments deposited up to about 5,000 years ago. Below that is bedrock, scoured clean by ice about 7,000 to 8,000 years ago.

"The conditions there give us nice age control," Stoner said. "One of the problems with tracking the movement of the North Magnetic Pole has been tying the changes in the magnetic field to time. There just hasn't been very good time constraint. But these sediments provide a reliable and reasonably tight timeline, having consistently been laid down at the rate of about one millimeter a year in annual layers.

"We're trying to get the chronology down to a decadal scale or better."

What their research has told Stoner and his colleagues is that the North Magnetic Pole has moved all over the place over the last few thousand years. In general, it moves back and forth between northern Canada and Siberia. But it also can veer sideways.

"There is a lot of variability in the polar motion," Stoner pointed out, "but it isn't something that occurs often. There appears to be a 'jerk' of the magnetic field that takes place every 500 years or so. The bottom line is that geomagnetic changes can be a lot more abrupt than we ever thought."

Shifts in the North Magnetic Pole are of interest beyond the scientific community. Radiation influx is associated with the magnetic field, and charged particles streaming down through the atmosphere can affect airplane flights and telecommunications.

1.4 Earth Aurora: Chandra Looks Back At Earth

Source: Chandra Press Release, December 28th, 2005 [4]

A team of scientists observed Earth's north polar region ten times during a four-month period in 2004. As the bright arcs in this sample of images show, they discovered low-energy (0.1 - 10 kilo electron volts) X-rays generated during auroral activity. Other satellite observatories had previously detected high-energy X-rays from Earth's auroras.

The images - seen here superimposed on a simulated image of the Earth - are from approximately 20-minute scans during which Chandra was pointed at a fixed point in the sky while the Earth's motion carried the auroral region through the field of view. The color code of the X-ray arcs represents the brightness of the X-rays, with maximum brightness shown in red.

Auroras are produced by solar storms that eject clouds of energetic charged particles. These particles are deflected when they encounter the Earth's magnetic field, but in the process large electric voltages are created. Electrons trapped in the Earth's magnetic field are accelerated by these voltages and spiral along the magnetic field into the polar regions. There they collide with atoms high in the atmosphere and emit X-rays (see the accompanying illustration).

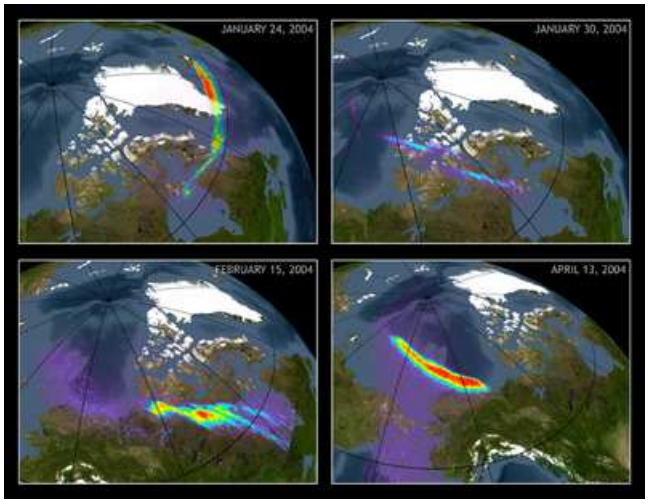

Figure 3: *Credit: NASA/MSFC/CXC/A.Bhardwaj & R.Elsner, et al.; Earth model: NASA/GSFC/L.Perkins & G.Shirah*

1.5 Cluster helps to protect astronauts and satellites against 'killer electrons'

Source: ESA Press Release, December 22nd, 2005 [5]

ESA's Cluster mission has revealed a new creation mechanism of killer electrons' - highly energetic electrons that are responsible for damaging satellites and posing a serious hazard to astronauts. Over the past five years, a series of discoveries by the multi-spacecraft Cluster mission have significantly enhanced our knowledge of how, where and under which conditions these killer electrons are created in Earth's magnetosphere.

Early satellite measurements in the 1950s revealed the existence of two permanent rings of energetic particles around Earth.

Usually called the Van Allen radiation belts', they are filled with particles trapped by Earth's magnetic field. Observations showed that the inner belt contains a fairly stable population of protons, while the outer belt is mainly composed of electrons in a more variable quantity.

Some of the outer belt electrons can be accelerated to very high energies, and it is these killer electrons' that can penetrate thick shielding and damage sensitive satellite electronics. This intense radiation environment is also a threat to astronauts.

For a long time scientists have been trying to explain why the number of charged particles inside the belts vary so much. Our major breakthrough came when two rare space storms occurred almost back-to-back in October and November 2003.

During the storms, part of the Van Allen radiation belt was drained of electrons and then reformed much closer to the Earth in a region usually thought to be relatively safe for satellites.

When the radiation belts reformed they did not increase according to a long-held theory of particle acceleration, called radial diffusion'. Radial diffusion theory treats Earth's magnetic field lines as being like elastic bands.

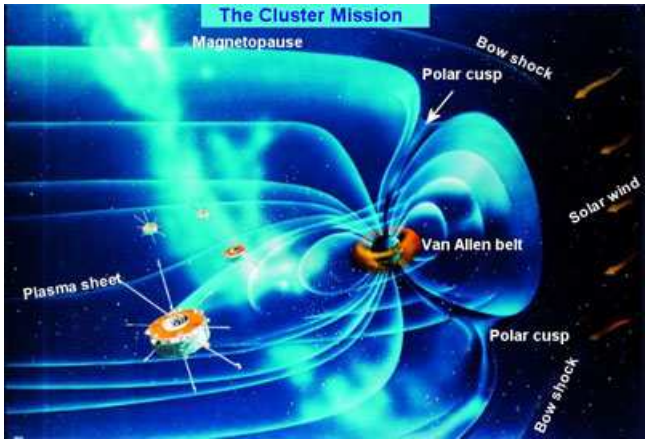

Figure 4: *This image shows the main regions of the magnetosphere which are being studied by Cluster.*

If the bands are plucked, they wobble. If they wobble at the same rate as the particles drifting around the Earth then the particles can be driven across the magnetic field and accelerated. This process is driven by solar activity.

Instead, a team of European and American scientists led by Dr Richard Horne of the British Antarctic Survey, Oxford, UK, used data from Cluster and ground receivers in Antarctica to show that very low frequency waves can cause the particle acceleration and intensify the belts.

These waves, named chorus', are natural electromagnetic emissions in the audio frequency range. They consist of discrete elements of short duration (less than one second) that sound like the chorus of birds singing at sunrise. These waves are among the most intense in the outer magnetosphere.

The number of killer electrons' can increase by a factor of a thousand at the peak of a magnetic storm and in the following days. Intense solar activity can also push the outer belt much closer to Earth, therefore subjecting lower altitude satellites to a much harsher environment than they were designed for. The radial diffusion theory is still valid in some

geophysical conditions. Before this discovery, some scientists thought that chorus emissions were not sufficiently efficient to account for the reformation of the outer radiation belt. What Cluster has revealed is that in certain highly disturbed geophysical conditions, chorus emissions are sufficient.

Thanks to the unique multipoint measurements capability of Cluster, the characteristic dimensions of these chorus source regions have been estimated for the first time.

Typical dimensions have been found to be a few hundred kilometres in the direction perpendicular to the Earth's magnetic field and a few thousands of kilometres in the direction parallel to this.

However, the dimensions found so far are based on case studies. "Under disturbed magnetospheric conditions, the chorus source regions form long and narrow spaghetti-like objects. The question now is whether those very low perpendicular scales are a general property of the chorus mechanism, or just a special case of the analysed observations, said Ondrej Santolk, of Charles University, Prague, Czech Republic, and main author of this result.

Due to our increased reliance on space based technologies and communications, the understanding of how, under which conditions and where these killer electrons are created, especially during magnetic storm periods, is of great iimportance.

1.6 An Explosion on the Moon

Source: Science@NASA, December 23rd, 2005 [6]

NASA scientists have observed an explosion on the moon. The blast, equal in energy to about 70 kg of TNT, occurred near the edge of Mare Imbrium (the Sea of Rains) on Nov. 7, 2005, when a 12-centimeter-wide meteoroid slammed into the ground traveling 27 km/s.

"What a surprise," says Marshall Space Flight Center (MSFC) researcher Rob Suggs, who recorded the impact's flash. He and colleague Wes Swift were testing a new telescope and video camera they assembled to monitor the moon for meteor strikes. On their first night out, "we caught one," says Suggs.

The object that hit the moon was "probably a Taurid," says MSFC meteor expert Bill Cooke. In other words, it was part of the same meteor shower that peppered Earth with fireballs in late October and early November 2005.

The moon was peppered, too, but unlike Earth, the moon has no atmosphere to intercept meteoroids and turn them into harmless streaks of light. On the moon, meteoroids hit the ground–and explode.

"The flash we saw," says Suggs, "was about as bright as a 7th magnitude star." That's two and a half times dimmer than the faintest star a person can see with their unaided eye, but it was an easy catch for the group's 10-inch telescope.

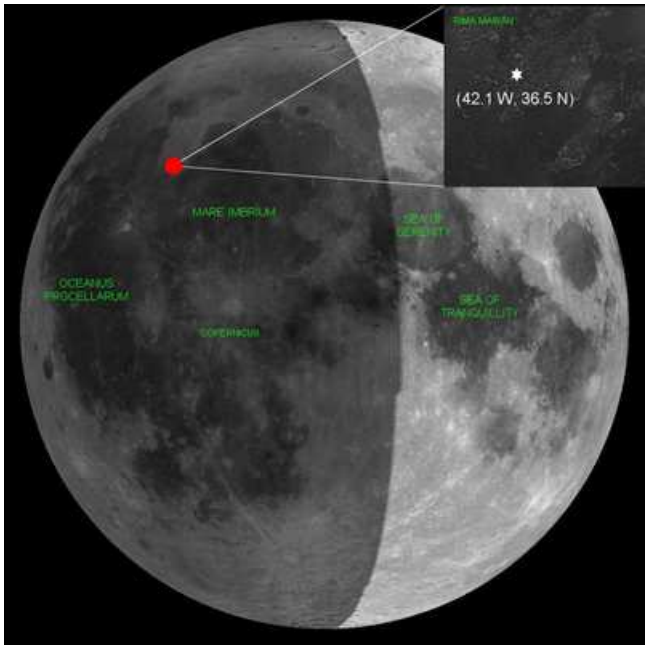

Figure 5: *The red dot marks the location of the Nov. 7, 2005, meteoroid impact. Credit: NASA/MSFC/Bill Cooke.*

Cooke estimates that the impact gouged a crater in the moon's surface "about 3 meters wide and 0.4 meters deep." As moon craters go, that's small. "Even the Hubble Space Telescope couldn't see it," notes Cooke. The moon is 384,400 km away. At that distance, the smallest things Hubble can distinguish are about 60 meters wide.

This isn't the first time meteoroids have been seen hitting the moon. During the Leonid meteor storms of 1999 and 2001, amateur and professional astronomers witnessed at least half-a-dozen flashes ranging in brightness from 7th to 3rd magnitude. Many of the explosions were photographed simultaneously by widely separated observers.

Since the Leonids of 2001, astronomers have not spent much time hunting for lunar meteors. "It's gone out of fashion," says Suggs. But with NASA planning to return to the moon by 2018, he says, it's time to start watching again.

There are many questions that need answering: "How often do big meteoroids strike the moon? Does this happen only during meteor showers like the Leonids and Taurids? Or can

we expect strikes throughout the year from 'sporadic meteors?'" asks Suggs. Explorers on the moon are going to want to know.

"The chance of an astronaut being directly hit by a big meteoroid is miniscule," says Cooke. Although, he allows, the odds are not well known "because we haven't done enough observing to gather the data we need to calculate the odds." Furthermore, while the danger of a direct hit is almost nil for an individual astronaut, it might add up to something appreciable for an entire lunar outpost.

Of greater concern, believes Suggs, is the spray"the secondary meteoroids produced by the blast." No one knows how far the spray reaches and exactly what form it takes.

Also, ground-shaking impacts could kick up moondust, possibly over a wide area. Moondust is electrostatically charged and notoriously clingy. (See "Mesmerized by Moondust" from Science@NASA.) Even a small amount of moondust can be a great nuisance: it gets into spacesuit joints and seals, clings to faceplates, and even makes the air smell when it is tramped indoors by moonwalkers. Could meteoroid impacts be a source of lunar "dust storms?" Another question for the future....

Suggs and his team plan to make more observations. "We're contemplating a long-term monitoring program active not only during major meteor showers, but also at times in between. We need to develop software to find these flashes automatically," he continues. "Staring at 4 hours of tape to find a split-second flash can get boring; this is a job for a computer."

With improvements, their system might catch lots of lunar meteors. Says Suggs, "I'm ready for more surprises."

1.7 Moon Storms

Source: Science@NASA, December 7th, 2005 [7]

Every lunar morning, when the sun first peeks over the dusty soil of the moon after two weeks of frigid lunar night, a strange storm stirs the surface.

The next time you see the moon, trace your finger along the terminator, the dividing line between lunar night and day. That's where the storm is. It's a long and skinny dust storm, stretching all the way from the north pole to the south pole, swirling across the surface, following the terminator as sunrise ceaselessly sweeps around the moon.

Never heard of it? Few have. But scientists are increasingly confident that the storm is real.

The evidence comes from an old Apollo experiment called LEAM, short for Lunar Ejecta and Meteorites. "Apollo 17 astronauts installed LEAM on the moon in 1972," explains Timothy Stubbs of the Solar System Exploration Division at NASA's Goddard Space Flight Center. "It was designed to look for dust kicked up by small meteoroids hitting the moon's surface."

Billions of years ago, meteoroids hit the moon almost constantly, pulverizing rocks and coating the moon's surface with their dusty debris. Indeed, this is the reason why the moon is so dusty. Today these impacts happen less often, but they still happen.

Apollo-era scientists wanted to know, how much dust is ejected by daily impacts? And what are the properties of that dust? LEAM was to answer these questions using three sensors that could record the speed, energy, and direction of tiny particles: one each pointing up, east, and west.

LEAM's three-decade-old data are so intriguing, they're now being reexamined by several independent groups of NASA and university scientists. Gary Olhoeft, professor of geophysics at the Colorado School of Mines in Golden, is one of them:

"To everyone's surprise," says Olhoeft, "LEAM saw a large number of particles every morning, mostly coming from the east or west–rather than above or below–and mostly slower than speeds expected for lunar ejecta."

What could cause this? Stubbs has an idea: "The dayside of the moon is positively charged; the nightside is negatively charged." At the interface between night and day, he explains, "electrostatically charged dust would be pushed across the terminator sideways," by horizontal electric fields. (Learn more: "Moon Fountains.")

Even more surprising, Olhoeft continues, a few hours after every lunar sunrise, the experiment's temperature rocketed so high–near that of boiling water–that "LEAM had to be turned off because it was overheating."

Those strange observations could mean that "electrically-charged moondust was sticking to LEAM, darkening its surface so the experiment package absorbed rather than reflected sunlight," speculates Olhoeft.

But nobody knows for sure. LEAM operated for a very short time: only 620 hours of data were gathered during the icy lunar night and a mere 150 hours of data from the blazing lunar day before its sensors were turned off and the Apollo program ended.

storm.jpg Dusty "twilight rays" sketched by Apollo 17 astronauts in 1972.

Astronauts may have seen the storms, too. While orbiting the Moon, the crews of Apollo 8, 10, 12, and 17 sketched "bands" or "twilight rays" where sunlight was apparently filtering through dust above the moon's surface. This happened before each lunar sunrise and just after each lunar sunset. NASA's Surveyor spacecraft also photographed twilight "horizon glows," much like what the astronauts saw.

It's even possible that these storms have been spotted from Earth: For centuries, there have been reports of strange glowing lights on the moon, known as "lunar transient phenomena" or LTPs. Some LTPs have been observed as momentary flashes–now generally accepted to be visible evidence of meteoroids impacting the lunar surface. But others have appeared as amorphous reddish or whitish glows or even as dusky hazy regions that change shape or disappear over seconds or minutes. Early explanations, never satisfactory, ranged from volcanic gases to observers' overactive imaginations (including visiting extraterrestrials).

Now a new scientific explanation is gaining traction. "It may be that LTPs are caused by sunlight reflecting off rising plumes of electrostatically lofted lunar dust," Olhoeft suggests.

All this matters to NASA because, by 2018 or so, astronauts are returning to the Moon. Unlike Apollo astronauts, who never experienced lunar sunrise, the next explorers are going to establish a permanent outpost. They'll be there in the morning when the storm sweeps by.

The wall of dust, if it exists, might be diaphanous, invisible, harmless. Or it could be a real problem, clogging spacesuits, coating surfaces and causing hardware to overheat.

Which will it be? Says Stubbs, "we've still got a lot to learn about the Moon."

1.8 Bacteria under Greenland ice may preview what scientists find under Mars' surface

Source: UCBerkeley News, December 14th, 2005 [8]

A University of California, Berkeley, study of methane-producing bacteria frozen at the bottom of Greenland's two-mile thick ice sheet could help guide scientists searching for similar bacterial life on Mars.

Methane is a greenhouse gas present in the atmospheres of both Earth and Mars. If a class of ancient microbes called Archaea are the source of Mars' methane, as some scientists have proposed, then unmanned probes to the Martian surface should look for them at depths where the temperature is about 10 degrees Celsius (18 degrees Fahrenheit) warmer than that found at the base of the Greenland ice sheet, according to UC Berkeley lead researcher P. Buford Price, a professor of physics.

This would be several hundred meters - some 1,000 feet - underground, where the temperature is slightly warmer than freezing and such microbes should average about one every cubic centimeter, or about 16 per cubic inch.

While Price is not expecting any time soon a mission to Mars to drill several hundred meters beneath the surface, methanogens (methane-generating Archaea) could just as easily be detected around meteor craters where rock has been thrown up from deep underground.

"Detecting this concentration of microbes is within the ability of state-of-the-art instruments, if they could be flown to Mars and if the lander could drop down at a place where Mars orbiters have found the methane concentration highest," Price said. "There are oodles of craters on Mars from meteorites and small asteroids colliding with Mars and churning up material from a suitable depth, so if you looked around the rim of a crater and scooped up some dirt, you might find them if you land where the methane oozing out of the interior is highest."

Price and his colleagues published their findings last week in the Early Online edition of the journal Proceedings of the National Academy of Sciences, and presented their results at last week's meeting of the American Geophysical Union in San Francisco.

Variations in methane concentration in ice cores, such as the 3,053-meter-long (10,016-foot-long) core obtained by the Greenland Ice Sheet Project 2, have been used to gauge past climate. In that core, however, some segments within about 100 meters, or 300 feet, of the bottom registered levels of methane as much as 10 times higher than would be expected from trends over the past 110,000 years.

Price and his colleagues showed in their paper that these anomalous peaks can be explained by the presence in the ice of methanogens. Methanogens are common on Earth in places devoid of oxygen, such as in the rumens of cows, and could easily have been scraped up by ice flowing over the swampy subglacial soil and incorporated into some of the bottom layers of ice.

Price and his colleagues found these methanogens in the same foot-thick segments of the core where the excess methane was measured in otherwise clear ice at depths 17, 35 and 100 meters (56, 115 and 328 feet) above bedrock. They calculated that the measured amount of Archaea,

frozen and barely active, could have produced the observed amount of excess methane in the ice.

”We found methanogens at precisely those depths where excess methane had been found, and nowhere else,” Price said. ”I think everyone would agree that this is a smoking gun.”

Biologists at Pennsylvania State University had earlier analyzed ice several meters above bedrock that was dark gray in appearance because of its high silt content, and identified dozens of types of both aerobic (oxygen-loving) and anaerobic (oxygen-phobic) microbes. They estimated that 80 percent of the microbes were still alive.

Figure 6: *A microbe from deep in Greenland ice in the process of dividing.*

Though methane has been detected in Mars’ atmosphere, ultraviolet light from the sun would have broken down the amount observed in about 300 years if some process was not replenishing the methane, Price noted. While interaction of carbon-bearing fluid with basaltic rock might be responsible, methanogens might instead take in subsurface hydrogen and carbon dioxide to make the methane, he said.

If methanogens are responsible, Price calculated that they would occur in a concentration of about one microbe per cubic centimeter at a depth of several hundred meters, where the temperature - about zero degrees Celsius (32 degrees Fahrenheit) or a bit warmer - would allow just enough metabolism for them to keep alive, just as the microbes in the Greenland ice sheet are doing.

1.9 Mars Region Probably Less Watery In Past Than Thought, Says Study

Source: University of Colorado News Release, December 21st, 2005 [9]

A region of Mars that some planetary scientists believe was once a shallow lakebed and likely habitable for life may not have been so wet after all, according to a new University of Colorado at Boulder study.

The new study indicates chemical signatures in the bedrock, interpreted in 2004 by the Mars Exploration Rover, or MER, mission team as evidence for widespread, intermittent water at Mars’ surface, may have instead been created by the reaction of sulfur-bearing steam vapors moving up through volcanic ash deposits. Known as Meridiani Planum, the region may have been more geologically similar to volcanic regions in parts of North America, Hawaii or Europe, said Thomas McCollom of CU-Boulder’s Center for Astrobiology.

”Our study indicates it was probably more like parts of Yellowstone, Hawaii or Italy than something like the Great Salt Lake,” said McCollom, also a research associate at CU-Boulder’s Laboratory for Atmospheric and Space Physics. ”We think it was far less favorable for past biological activity than other scenarios that have been proposed.”

A paper on the subject by McCollom and CU-Boulder Research Associate Brian Hynek of CU-Boulder’s LASP appears in the Dec. 22 issue of Nature.

A series of scientific papers published in December 2004 by the Mars Exploration Rover team and based on data gathered by the rover Opportunity, concluded that the Meridiani Planum region once probably had a large sea or huge lake that may have waxed and waned over eons. The authors proposed that the evaporation of surface and subsurface water over time left behind various chemical precipitates – predominately sulfate salts – which they interpreted as evidence for a watery environment that would have been conducive for life to exist.

But if the sulfate was the result of precipitation from an evaporating brine of surface and subsurface water as has been proposed, McCollom and Hynek contend the bedrock should be enriched with a large amount of positively charged atoms, known as cations, from minerals like iron, calcium and magnesium. But it is not, they said.

”We think the bedrock was laid down by enormous volcanic ash flows over time that were then permeated by sulfur dioxide-rich steam vapors,” said McCollom. ”The sulfur

dioxide and water combined to form sulfuric acid, which reacted with and altered the bedrock to give it its present chemical composition."

The new scenario does not require prolonged interaction between bedrock and a standing body of surface water as proposed by the MER team, and the process likely occurred at high temperatures, perhaps more than 200 degrees F, said McCollom. "Everything about the site seems to be consistent with our conclusions," he said.

"In our scenario, the water required to support the chemistry in this bedrock would only have had to have been around for months, years or perhaps as much as a few centuries," said Hynek. "This is very different than previous scenarios, which require that a much larger amount of water be present for many millennia."'

The European Space Agency's Mars Express spacecraft recently showed the chemistry of layered deposits surrounding the Meridiani Planum region is similar to the bedrock at the Opportunity landing site, implying the entire area hosted volcanic activity, said Hynek. The size of the suspected Meridiani Planum volcanic deposits appears much larger than any similar deposit on Earth and encompasses an area roughly the size of Arizona, according to the CU-Boulder researchers.

McCollom described the geology of the region as "solfatara-like,"' a term that originated from Solfatara Crater, a volcanic region near Naples, Italy, harboring vents that emit vapors. "While solfataras are riddled with vents and fissures giving off sulfurous vapors at the surface, the deposits we see at Meridiani probably represent the subsurface beneath such fissures," said McCollom.

On Earth, solfataras host microbes that are capable of using sulfur for sustenance, McCollom said. Some of the areas are now under study by astrobiologists looking to characterize extreme environments on Earth that support life.

"My view is that there is a good possibility there is life on Mars, probably in the subsurface," he said. "We know from examples on Earth that life can exist in extreme places, and Mars seems to have the necessary ingredients for that."

Hynek said that in the distant past, Meridiani Planum may have had all the necessary ingredients to support organisms like those found in solfataras. "But the unique and probably short-lived nature of the environment suggests it may not be the best place to look for evidence of Martian life today," he said.

1.10 Mars Express evidence for large aquifers on early Mars

Source: ESA Press Release, November 30th, 2005 [10]

Substantial quantities of liquid water must have been stably present in the early history of Mars. The findings of OMEGA, on board ESA's Mars Express, have implications on the climatic history of the planet and the question of its 'habitability' at some point in its history.

These conclusions were drawn thanks to data on Martian surface minerals obtained by OMEGA (Observatoire pour la Mineralogy, l'Eau, les Glaces et l'Activit), the visible and infrared mapping spectrometer on board ESA's Mars Express.

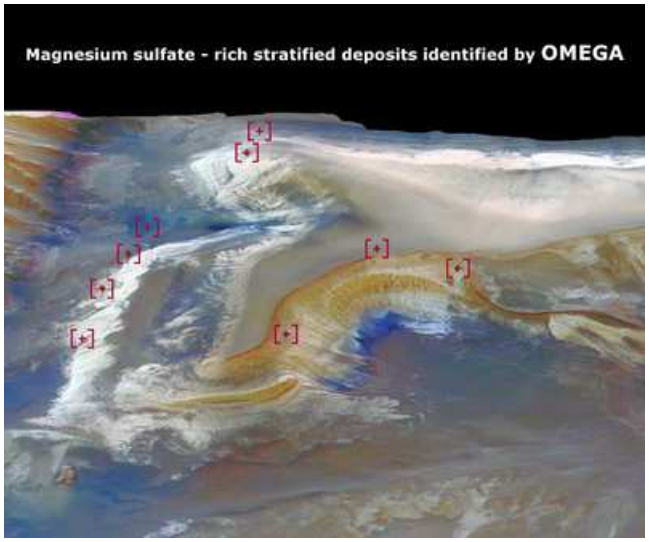

Figure 7: *A HRSC 3D perspective view of Candor Chasma (in false colours) characterised by the infrared images of OMEGA. It shows bright and brown deposits (red markers) that are rich in the mineral kieserite, a hydrated magnesium sulphate. Credits: ESA/OMEGA/HRSC*

From previous observations, Mars must have undergone water-driven processes, which left their signature in surface structures such as channel systems and signs of extensive aqueous erosion. However, such observations do not necessarily imply the stable presence of liquid water on the surface over extended periods of time during the Martian history.

1.11 On the Edge

Source: JPL/NASA Press Release, December 13th, 2005 [11]

Viewing Saturn's rings very close to edge-on produces some puzzling effects, as these two images of the F ring demonstrate.

The upper image was acquired from less than a tenth of a degree beneath the ringplane and shows a mysterious bulge. Such a feature has not been seen previously by the Cassini spacecraft from this angle. It is possible that, because of the very shallow viewing angle, the Cassini spacecraft's view takes a long path through the ring, making very faint material visible. It also may be that an embedded object of a kilometer or so in size stirs up the neighboring ring particles to create a bulge. Alternatively, an impact into an embedded moonlet that was covered with debris could produce a cloud like this.

Images taken by the Voyager spacecrafts showed clumps that might have been produced in these ways. Cassini's investigations will help to determine the vertical extent of such clumps and understand their origins.

The lower image was obtained from less than a hundredth of a degree beneath the ringplane. Across the center of the rings is a dark lane, giving them an appearance not unlike that of a spiral galaxy, seen edge-on.

Both images were taken using the clear spectral filters (predominantly visible light) on the Cassini spacecraft narrow-angle camera. The images have been magnified by a factor of two.

The top image was obtained at a distance of 3.6 million kilometers (2.2 million miles) from Saturn on Nov. 11, 2005 and shows wispy fractures on Dione's trailing hemisphere. The image scale is 22 kilometers (14 miles) per pixel. The bottom image was acquired at a distance of 2.5 million kilometers (1.6 million miles) from Saturn on Nov. 5, 2005. The image scale is 15 kilometers (9 miles) per pixel.

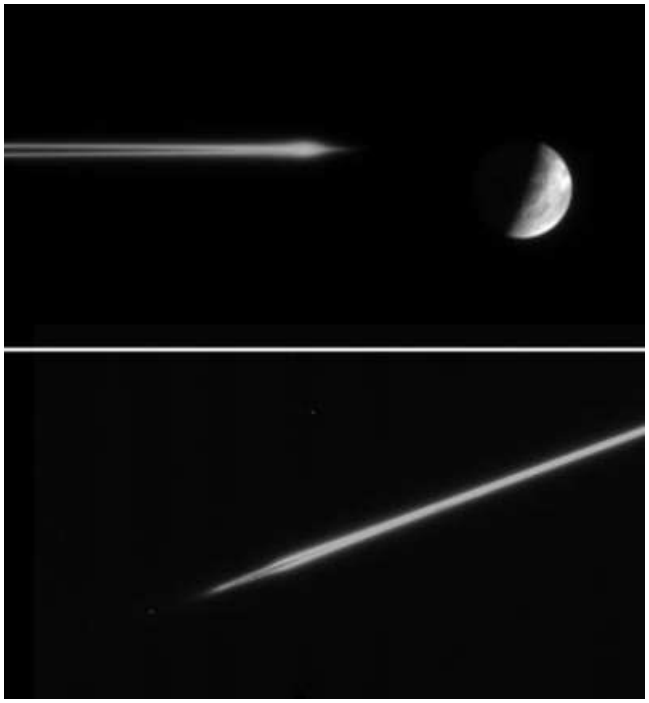

Figure 8:

1.12 Multiple Cassini Instruments Capture Enceladus Plume

Source: JPL/NASA Press Release, December 16th, 2005 [12]

Cassini observations by several instruments have revealed the source of Saturn's broadest and faintest ring. Recent observations show that tiny particles of frozen water ice are streaming outward into space from the south polar region of the moon Enceladus.

The source of geological activity on Enceladus is a mystery. "We're amazed to see ice geysers on this little world that was thought to be cold and dead long ago," commented Dr. Dale Cruikshank of NASA Ames Research center, a member of the visual and infrared mapping spectrometer team. "Some unexpected process is vigorously heating the interior of Enceladus, especially the south polar region, and causing the ejection of the plumes of ice particles."

As the icy plumes jet out from the moon, the larger particles probably follow paths that mostly bring them back to the surface, while the smaller particles are nudged by sunlight into orbits around Saturn.

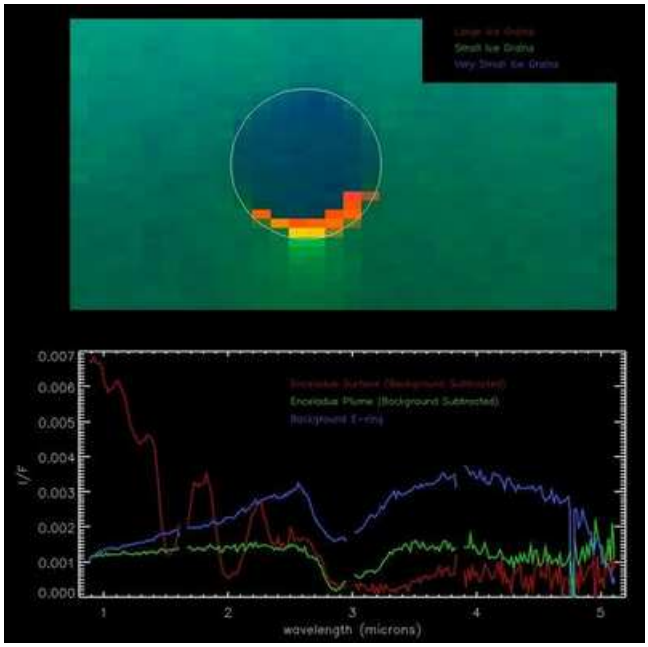

Figure 9: *Enceladus Plume: Cassini's visual and infrared mapping spectrometer measured the spectrum of the plumes originating from the south pole of the icy moon.*

"Most of these small particles probably re-impact the moon, but the smallest ones eventually disperse as a result of radiation (light) pressure and interactions with Saturn's magnetosphere to form the broad E ring," said Dr. Mark Showalter of the SETI Institute, Mountain View, Calif. Thus, the E ring is currently being regenerated by some kind of geological activity in the interior of Enceladus.

During the Cassini spacecraft's flyby on Nov. 26, the visual and infrared mapping spectrometer instrument measured the spectrum of the polar plumes of Enceladus. "We see a very clear signature of small ice particles in the plume data, in the form of a strong absorption band at 2.9 microns in an otherwise featureless spectrum," said Dr. Phil Nicholson, professor of astronomy at Cornell University, Ithaca, N.Y. Nicholson is a member of the visual and infrared mapping spectrometer science team.

The visual and infrared mapping spectrometer images of Enceladus show not only the plume over the south pole, but also the dark side of the moon, silhouetted against a foggy background of light from the E Ring. Measurements of the spectrum show a very similar signature of small ice particles to that in the plumes, confirming earlier expectations that Enceladus is indeed the source of the E ring.

Preliminary analyses suggest that the average size of the particles in the plume is about 10 microns (1/100,000 of a meter), whereas the particles in the E ring are about three times smaller. The sunlit surface of Enceladus itself is also composed of water ice, but with a much larger grain size than the plume.

1.13 NASA's Hubble Discovers New Rings and Moons Around Uranus

Source: NASA News, December 22nd, 2005 [13]

NASA's Hubble Space Telescope photographed a new pair of rings around Uranus and two new, small moons orbiting the planet.

The largest ring is twice the diameter of the planet's previously known rings. The rings are so far from the planet, they are being called Uranus' "second ring system." One of the new moons shares its orbit with one of the rings. Analysis of the Hubble data also reveals the orbits of Uranus' family of inner moons have changed significantly over the past decade.

"The detection of these new interacting rings and moons will help us better understand how planetary systems are formed and sustained, which is of key importance to NASA's scientific exploration goals," said Dr. Jennifer Wiseman, program scientist for Hubble at NASA Headquarters.

Since dust orbiting Uranus is expected to be depleted by spiraling away, the planet's rings must be continually replenished with fresh material. "The new discoveries demonstrate that Uranus has a youthful and dynamic system of rings and moons," said Mark Showalter of the SETI Institute, Mountainview, California.

Showalter and Jack Lissauer of NASA's Ames Research Center, Moffet Field, Calif., propose that the outermost ring is replenished by a 12-mile-wide newly discovered moon, named Mab, which they first observed using Hubble in 2003.

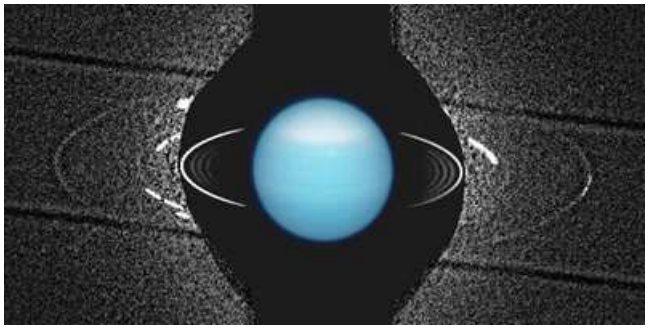

Figure 10: *The above image is a color composite made*

from short exposures, showing the disk of Uranus with some cloud features. Just to the left and right of the color image of the disk are a combination of deeper, panchromatic images showing Uranus's inner rings; the brightest is the Epsilon Ring. The satellite Mab is visible as eight dots adjacent to the outer ring on the right side.

Meteoroid impacts continually blast dust off the surface of Mab. The dust then spreads out into a ring around Uranus. Mab's ring receives a fresh infusion of dust from each impact. Nature keeps the ring supplied with new dust while older dust spirals away or bangs back into the moon.

Showalter and Lissauer have measured numerous changes to the orbits of Uranus' inner moons since 1994. The moon's motions were derived from earlier Hubble and Voyager observations. "This appears to be a random or chaotic process, where there is a continual exchange of energy and angular momentum between the moons," Lissauer said. His calculations predict moons would begin to collide as often as every few million years, which is extraordinarily short compared to the 4.5 billion year age of the Uranian system.

Showalter and Lissauer believe the discovery of the second ring, which orbits closer to the planet than the outer ring, provides further evidence that collisions affect the evolution of the system. This second ring has no visible body to resupply it with dust. The ring may be a telltale sign of an unseen belt of bodies a few feet to a few miles in size. Showalter proposes that a previous impact to one of Uranus' moons could have produced the observed debris ring.

Hubble uncovered the rings in August 2004 during a series of 80, four-minute exposures of Uranus. The team later recognized the faint new rings in 24 similar images taken a year earlier. Images from September 2005 reveal the rings even more clearly.

Showalter also found the rings in archival images taken during Voyager 2's flyby of Uranus in 1986. Uranus's first nine rings were discovered in 1977 during observations of the planet's atmosphere. During the Voyager encounters, two other inner rings and 10 moons were discovered. However, no one noticed the outer rings, because they are extremely faint and much farther from the planet than expected. Showalter was able to find them by a careful analysis of nearly 100 Voyager images.

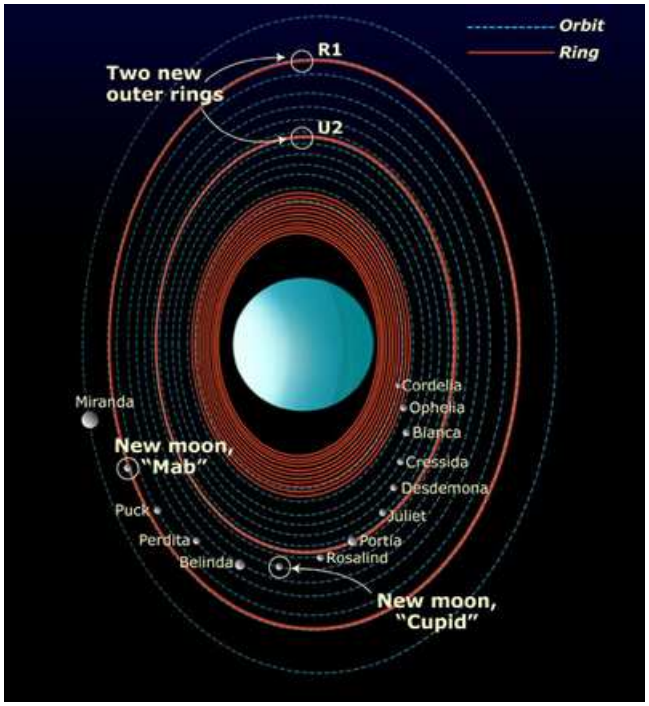

Figure 11:

Because the new rings are nearly transparent, they will be easier to see when they tilt edge-on. The new rings will increase in brightness every year as Uranus approaches its equinox, when the sun shines directly over the planet's equator. When it happens in 2007, all of the rings will be tilted edge-on toward Earth and easier to study. These research data will appear in an upcoming issue of the journal Science.

1.14 Discovery of a Large Kuiper belt object with an Unusual Orbit

Source: Canada-France-Hawaii Telescope Press Release, December 13th, 2005 [14]

A team of astronomers working in Canada, France and the United States have discovered an unusual small body orbiting the Sun beyond Neptune, in the region astronomers call the Kuiper belt. This new object is twice as far from the Sun as Neptune and is roughly half the size of Pluto. The body's highly unusual orbit is difficult to explain using previous theories of the formation of the outer Solar System.

Currently 58 astronomical units from the Sun (1 astronomical unit, or AU, is the distance between the Earth and the Sun), the new object never approaches closer than 50 AU, because its orbit is close to circular. Almost all Kuiper belt

objects discovered beyond Neptune are between 30 AU and 50 AU away. Beyond 50 AU, the main Kuiper belt appears to end, and what few objects have been discovered beyond this distance have all been on very high eccentricity (non-circular) orbits. Most of these high-eccentricity orbits are the result of Neptune ”flinging” the object outward by a gravitational slingshot. However, because this new object does not approach closer than 50 AU, a different theory is needed to explain its orbit. Complicating the problem, the object’s orbit also has an extreme tilt, being inclined (tilted) at 47 degrees to the rest of the Solar System.

The Discovery and Follow-up The object, which received the official designation 2004 XR 190 in the International Astronomical Union’s official announcement, was discovered during routine operation of the Canada-France Ecliptic Plane Survey (CFEPS) running as part of the Legacy Survey on the Canada France Hawaii Telescope. For now, the discoverers are using the temporary nickname ”Buffy” to identify the new object, although they have proposed a different official name in keeping with normal procedures for naming such objects.

Buffy was extracted from the mountain of Legacy Survey data (about 50 gigabytes per hour of operation) by powerful computers combing through the telescopic images and producing hundreds of candidates. Astronomers then sift through the candidates to identify the distant comets.

Astronomer Lynne Allen of the University of British Columbia was the first to lay eyes on the new object, as she completed the initial identification in the course of processing CFEPS data from December 2004. ”It was quite bright compared to the usual Kuiper belt objects we find”, said Dr. Allen, ”but what was more interesting was how far away it was.”

The object’s brightness implies it is likely between 500 and 1000 kilometers (300 to 600 miles) in diameter. Buffy is thus a very large Kuiper belt object, but about half a dozen are larger.

”We immediately realized that the object was about twice as far as Neptune from the Sun and that its orbit was potentially nearly circular,” said UBC professor Brett Gladman, who noticed the unusual nature of the object when determining its orbit, “but further observations were required.”

One to two years of observations of a Kuiper belt object are required before their orbits can be precisely measured. The first additional observations of Buffy came in October 2005 when Gladman and Phil Nicholson of Cornell University used the Hale 5-meter telescope to re-observe the object. Measurement of Buffy’s new position proved that the orbit was not only extremely tilted, inclined (tilted) at 47 degrees to the plane of the planetary system (essentially tying the record for a Kuiper belt object) but confirmed that Buffy was unlike any other previously-known object because it was on a nearly circular orbit while at a very large distance.

More measurements of Buffy’s position on images from telescopes at Kitt Peak National Observatories in Arizona by team members Joel Parker (Southwest Research Institute), as well as JJ Kavelaars (National Research Council of Canada, Herzberg Institute of Astrophysics) and Wes Fraser (University of Victoria), through November 2005 refined the estimate for Buffy’s closest approach to the Sun. Additional observations, to further confirm the orbit, where then provided by the CFHT Legacy Survey project. Astronomers will need to wait until February 2006 to measure the fine details of the Buffy’s orbit.

The team have reported their find to the Minor Planet Center, the clearinghouse for astronomical measurements of new minor planets. ”To find the first known object with a nearly circular orbit beyond 50 AU is indeed intriguing,” reacted Brian Marsden, director of the MPC.

Challenging Theories

Although it is neither the smallest, largest, nor most distant object discovered in this region, the new Kuiper belt object has a highly unusual orbit which challenges theories of the evolution of the Solar System.

Why is Buffy’s orbit considered so unusual? Only one other detected object, Sedna, remains further than 50 astronomical units (AUs) from the Sun throughout its entire orbit. However, Sedna is on a very elliptical orbit, swooping in to 76 AU before traveling back out beyond 900 AU. In contrast, Buffy spends all of its time in the narrow range between 52 and 62 AU from the Sun. Combined with the tilt in its orbit, this new object challenges current theories about the history of the early Solar System.

Astronomers have detected other Kuiper belt objects that spend most of their time beyond 50 AU. These are on very elliptical orbits, and almost all approach within 38 AU of the Sun. That close approach places those objects within the reach of the gravitational influence of Neptune. These objects are generally thought to have been scattered out to their present orbits by a gravitational slingshot with Neptune. This group of objects was thus called the ”Scattered Disk”.

Prior to the discovery of Buffy, a few other Kuiper belt objects were discovered which spend much of their time be-

yond 50 AU like those in the ”Scattered Disk”, yet did not approach within the gravitational reach of Neptune. This group has been named the ”Extended Scattered Disk”. Two of its members are 1995 TL8 and 2000 YW134, which approach to 40 AU of the Sun but have fairly elliptical orbits that take them back out beyond 60 AU. Two more extreme examples of the ”Extended Scattered Disk” are 2000 CR105, which approaches to 44 AU, and Sedna, which never comes closer to the Sun than 76 AU.

Due to their large eccentricities, these objects are likely to have been strongly perturbed by something, although it could not have been Neptune because they do not come close enough to be scattered by that planet’s gravitational force. As both Sedna and 2000 CR105 also travel beyond 500 AU from the sun, one theory is that after being scattered by Neptune, a passing star could have pulled their closest approaches away from the Sun.

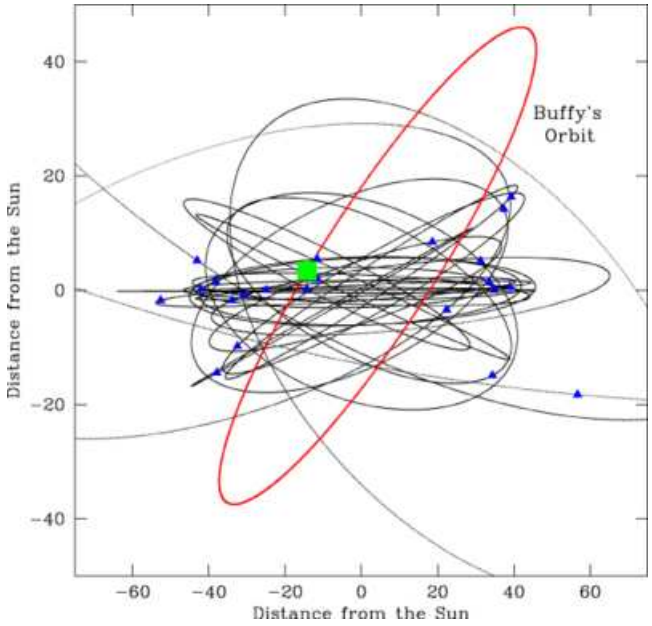

Figure 12: *An edge-on-view of the solar system to show the tilt of Buffy’s orbit.*

Buffy is clearly a member of the ”Extended Scattered Disk”. However, Buffy’s almost circular orbit makes it stand out from the other members. In addition, Buffy’s large orbital tilt is not so easily explained by the passing star idea. If a star could have affected Buffy so strongly, it should also have disrupted much of the main Kuiper belt as well. Since astronomers do not detect that strong disruption, a more complex theory is needed to explain Buffy’s orbit.

The elusive explanation may lie in side-effects from rearrangements of the Solar System early in its history. One possibility is that as Neptune’s orbit slowly expanded in the young Solar System, complex gravitational interactions could have caused some Kuiper belt orbits to circularize and tilt. While Buffy’s orbit could have been created this way, this theory would not seem to explain 2000 CR105 and Sedna. This new discovery is exciting because it causes us to rethink our understanding of how the Kuiper belt formed.

The Future

Over the last half decade, theories about the formation of our outer Solar System have been pushed to their limits: unusual Kuiper belt objects, like Buffy, which never come close to Neptune yet have high inclination must be explained.

Although theories that explain individual objects exist, reproducing the entire ensemble of known objects with one process poses a difficult challenge to current solar system models. Because the unusual objects, like Buffy, are very rare, astronomers are still scratching the surface of the dark corners of the Kuiper belt. Future large-scale surveys that systematically explore the Kuiper belt are the only way unlock the mysteries of what happened early in the history of our Solar System.

2 Astrophysics

2.1 Precursor to Proteins and DNA Found in Stellar Disk

Source: Keck Observatory News, December 20th, 2005 [15]

Astronomers at W. M. Keck Observatory have found for the first time some of the basic compounds necessary to build organic molecules and one of the bases found in DNA within the inner regions of a planet-forming disk. The object, known as "IRS 46," is located in the Milky Way galaxy, about 375 light years from Earth, in the constellation Ophiuchus. The results will be published in an upcoming issue of the Astrophysical Journal Letters.

"We see prebiotic organic molecules in comets and the gas giant planets in our own solar system and wonder, where did these chemicals come from?" said Dr. Marc Kassis, support astronomer at the W. M. Keck Observatory. "The Spitzer Space Telescope is letting us study these young stellar objects in new and revealing ways, giving us exciting clues about where life may form in the universe."

The two organic compounds found – acetylene and hydrogen cyanide – are commonly found in our own solar system, such as the atmospheres of the giant gas planets, the icy surfaces of comets, and the atmosphere of Saturn's largest moon, Titan. Another carbon-containing species detected, carbon dioxide, is widespread in the atmospheres of Venus, the Earth, and Mars.

"If you add hydrogen cyanide, acetylene and water together in a test tube, and give them an appropriate surface on which to be concentrated and react, you'll get a slew of organic compounds including amino acids and a DNA purine base called adenine," said Keck Astronomer Dr. Geoffrey Blake, of the California Institute of Technology in Pasadena and co-author of the paper. "Now, we can detect these same molecules in the planet zone of a star hundreds of light-years away."

The presence of gas-rich disks around young stars is well known, but little is understood about the chemical structure inside. The discovery of acetylene and hydrogen cyanide in one of these disks will help astronomers better understand these disks, where future solar systems may someday form and possibly result in life.

"Spitzer found something very unique – a young protostar with a dusty disk that, when viewed from Earth, appears tilted on the sky, similar to how some galaxies appear," Kassis explained. "This viewing angle let the team use Keck-NIRSPEC data to study the inner regions of the disk. The results told the team exactly how the disk was moving and suggest there may be a stellar wind coming from the inner region. Keck also helped measure the high temperatures and the particle concentration in the disk."

The dust and gas surrounding a young star blocks visible light, but lets longer wavelengths, such as infrared light, pass through. Astronomers can find out what this gas and dust is made of by separating the light into its component wavelengths, or colors.

Since 2003, the NASA Spitzer Space Telescope has allowed astronomers to use this technique to study molecular compounds in protoplanetary disks of young stellar objects. The Spitzer "c2d legacy program" has looked at more than 100 sources in five nearby star-forming regions and only one IRS 46 showed clear evidence of containing the organic compounds in the warm regions close to the star where terrestrial planets are most likely to form.

Figure 13: *An artist's conception of the dusty disk orbiting IRS 46. Image credit: NASA/JPL-Caltech/T. Pyle (SSC)*

"This infant system might look a lot like ours did billions of years ago, before life arose on Earth," said Fred Lahuis of Leiden Observatory in the Netherlands and the SRON Netherlands Institute for Space Research. Lahuis is the lead author of the paper describing the results.

While the precise events leading up to self-replicating nucleic acids remains unclear, the molecules of acetylene (C_2H_2) and hydrogen cyanide (HCN) have been shown to produce the base compounds necessary to build RNA and DNA. The team found that the abundance of hydrogen cyanide (HCN) was nearly 10,000 times higher than that found in cold interstellar gas from which stars and planets are born.

Models of early solar-system chemistry have historically centered on data from our own primitive solar system, but now discoveries of protoplanetary disks have opened the field to solar systems other than our own. Theoretical models have suggested that large quantities of complex organic

molecules would be present in the inner-most regions of these disks, but until now, no observational tests have been possible.

To help determine where, exactly, the organic-rich gas resides in IRS 46, the team also used submillimeter data from the James Clerk Maxwell Telescope on Mauna Kea. The faint signals observed again suggest that the material originates from the inner disk, perhaps no more 10 astronomical units from the parent star, similar in distance to where Saturn orbits the Sun in our own solar system. However, much additional work remains to be done to know this for certain.

”The gases are very warm, close to or somewhat above the boiling point of water on Earth,” said Dr. Adwin Boogert, also of Caltech. ”These high temperatures helped to pinpoint the location of the gases in the disk.”

The Keck-NIRSPEC results point to the presence of a stellar wind emerging from the inner region of the disk orbiting IRS 46. The wind may eventually blow away the dusty debris in the disk, perhaps revealing the presence of rocky, Earth-like planets in several million years.

2.2 Spitzer Team Says Debris Disk Could Be Forming Infant Terrestrial Planets

Source: University of Arizona Press Release, December 14th, 2005 [16]

Astronomers have found a debris disk around a sun-like star that may be forming or has formed its terrestrial planets. The disk - a probable analog to our asteroid belt - may have begun a solar-system-scale demolition derby, where the rocky remains of failed planets collide chaotically.

”This is one of a very rare class of objects that may give us a glimpse into what our solar system may have looked like during the formation of our terrestrial planets,” said Dean C. Hines of the Space Science Institute, a leader of the team that discovered the rare objects with NASA’s Spitzer Space Telescope.

”The target is essentially a star similar to our sun, seen at a time when the terrestrial planets in our solar system were thought to have formed,” Hines said. ”We see evidence that this star might have an asteroid belt, roughly at the distance Jupiter is from our sun.”

”This object is very unusual in the context of all the others we’ve looked at,” said University of Arizona assistant astronomy Professor Michael R. Meyer, a colleague in the discovery. Meyer directs a Spitzer Legacy project to study solar system formation and evolution in a sample of 328 young sun-like stars in the Milky Way. The project turned up the unusual system.

”This is the only such debris disk among the 33 sun-like stars we’ve studied in our project so far, and one of only five such objects known,” Meyer said.

The star, named HD 12039, is about 30 million years old, or the age of the sun when the terrestrial planets are thought to have been 80 percent complete and the Earth-moon system formed, the astronomers said. It is roughly 137 light years away, or the distance light travels in 137 years.

HD 12039 is a ”G” type star like our sun, a yellow star with surface temperatures between 5,000 and 7,000 degrees Fahrenheit. It hasn’t yet settled into the ”main sequence,” or mature nuclear-burning phase as our sun has. It’s eight percent brighter, just slightly cooler and a little more massive than our sun, or 1.02 solar masses.

The Spitzer team discovered that the star’s debris disk temperature is 110 degrees Kelvin, or minus 262 degrees Fahrenheit. That’s warmer than temperatures of the frigid outer debris disks that Meyer’s Spitzer team commonly finds around sun-like stars. They’ve found that between 10 and 20 percent of the sun-like stars in their sample so far – whether young, middle-aged or old – have outer disks like our Kuiper Belt beyond Neptune.

”The temperature of the dust in HD 12039’s strange, narrow debris ring puts it between four and six astronomical units from the star – smack dab where Jupiter is in our solar system,” Meyer said. (An astronomical unit, or AU, is the mean distance between Earth and the sun.)

”What’s curious about this disk is that there’s little if any dust inside four AU and beyond six AU. It’s a narrowly confined ring that could be similar in some ways to the outer rings we see around Saturn,” Meyer said.

Just as small moons shepherd the ice grains orbiting Saturn into discrete rings, and just as Jupiter tends the outer edge of our solar system’s asteroid belt, an unseen giant planet may be nudging dust into the narrow debris ring around this star, the astronomers said.

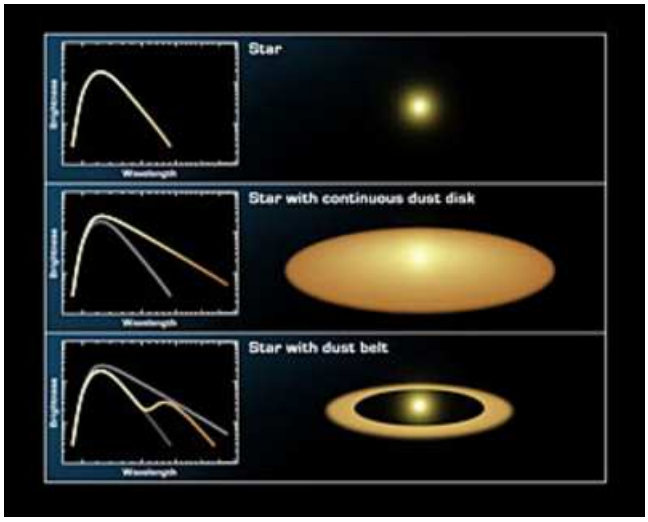

Figure 14: *Scientists can characterize a disk by looking at its infrared spectrum. (Credit: NASA/JPL-Caltech/T. Pyle, SSC*

”We think this is a tight, narrow ring of rocky objects similar to those in our asteroid belt, except this ring is five AU from its star, instead of two-to-three AU, the distance between our asteroid belt and the sun,” Meyer said.

”At 30 million years, the material we see in this star likely has to come from ground-up rocks in a zone where terrestrial planets could form,” Hines said.

NASA earlier this year announced a Spitzer telescope discovery of another of these alien asteroid belts. It orbits a two-billion-year-old sun-like star 35 light years away, at a distance comparable to that between Venus and the sun.

Based on Spitzer Telescope results to date, only one percent to three percent of the young, sun-like stars in our Milky Way have massive terrestrial debris disks, Meyer said.

”We could be witnessing a common, short-lived event through which all systems pass, or we could be seeing a rare example of a massive warm debris disk surrounding an unusual, sun-like star,” Meyer said.

2.3 Allo, Allo? Alpha Centauri is Ringing

Source: ESO Press Release, December 21st, 2005 [17]

Astronomers have used ESO’s Very Large Telescope in Chile and the Anglo-Australian Telescope in eastern Australia as a ’stellar stethoscope’ to listen to the internal rumblings of a nearby star. The data collected with the VLT have a precision better than 1.5 cm/s, or less than 0.06 km per hour!

By observing the star with two telescopes at the same time, the astronomers have made the most precise and detailed measurements to date of pulsations in a star similar to our Sun. They measured the rate at which the star’s surface is pulsing in and out, giving clues to the density, temperature, chemical composition and rotation of its inner layers - information that could not be obtained in any other way.

The astronomers from Denmark, Australia, and the USA used Kueyen, one of the four 8.2-m Unit Telescopes of ESO’s Very Large Telescope (VLT) at Cerro Paranal in Chile, and the 3.9-m Anglo-Australian Telescope (AAT) in New South Wales (Australia), to study the star Alpha Centauri B, one of our closest neighbours in space, about 4.3 light-years away.

Alpha Centauri is the brighter of the two ’Pointers’ to the Southern Cross. Alpha Centauri itself is a triple system and Alpha Centauri B is an orange star, a little cooler and a little less massive than the Sun.

Churning gas in the star’s outer layers creates low-frequency sound waves that bounce around the inside of the star, causing it to ring like a bell. This makes the star’s surface pulsate in and out by very tiny amounts - only a dozen metres or so every four minutes. Astronomers can detect these changes by measuring the small, associated wavelength shifts.

The researchers sampled the light from Alpha Centauri B for seven nights in a row, making more than 5 000 observations in all. At the VLT, 3379 spectra were obtained with typical exposure times of 4 seconds and a median cadence of one exposure every 32 seconds! At the AAT 1642 spectra were collected, with typical exposures of 10 s, taken every 90 s.

”From this unique dataset, we were able to determine as many as 37 different patterns (or modes) of oscillation”, says Hans Kjeldsen, from University of Aarhus (Denmark) and lead author of the paper describing the results.

The astronomers also measured the mode lifetimes (how long the oscillations last), the frequencies of the modes, and their amplitudes (how far the surface of the star moves in and out). Such measurements are a huge technical challenge. Indeed, the star’ surface moves slowly, at the tortoise-like speed of 9 cm a second, or about 300 metre an hour. The astronomers borrowed their high-precision measurement technique from the planet-hunters, who also look for slight Doppler shifts in starlight.

”So much of what we think we know about the universe rests on the ages and properties of stars,” said Tim Bedding, from the University of Sydney and co-author of the study. ”But

there is still a great deal we don't know about them."

By using two telescopes at different sites the astronomers were able to observe the Alpha Centauri B as continuously as possible.

"That's a huge advantage, because gaps in the data introduce ambiguity," said Bedding. "The success of the observations also depended on the very stable spectrographs attached to the two telescopes - UVES at the VLT and UCLES at the AAT - which analysed the star's light."

2.4 Astronomers Use Hubble to 'Weigh' Dog Star's Companion

Source: Hubble News, December 13th, 2005 [18]

For astronomers, it has always been a source of frustration that the nearest white-dwarf star is buried in the glow of the brightest star in the nighttime sky. This burned-out stellar remnant is a faint companion of the brilliant blue-white Dog Star, Sirius, located in the winter constellation Canis Major. Now, an international team of astronomers has used the keen eye of NASA's Hubble Space Telescope to isolate the light from the white dwarf, called Sirius B.

The new results allow them to measure precisely the white dwarf's mass based on how its intense gravitational field alters the wavelengths of light emitted by the star. Such spectroscopic measurements of Sirius B taken with a telescope looking through the Earth's atmosphere have been severely contaminated by scattered light from the very bright Sirius.

"Studying Sirius B has challenged astronomers for more than 140 years," said Martin Barstow of the University of Leicester, U.K., who is the leader of the observing team. "Only with Hubble have we at last been able to obtain the observations we need, uncontaminated by the light from Sirius, in order to measure its change in wavelengths."

"Accurately determining the masses of white dwarfs is fundamentally important to understanding stellar evolution. The sun will eventually become a white dwarf. White dwarfs are also the source of Type Ia supernova explosions that are used because of their brightness to measure the distances to distant galaxies and the expansion rate of the universe. Measurements based on Type Ia supernovae are fundamental to understanding 'dark energy,' a dominant repulsive force stretching the universe apart. Also, the method used to determine the white dwarf's mass relies on one of the key predictions of Einstein's theory of General Relativity; that light loses energy when it attempts to escape the gravity of a compact star."

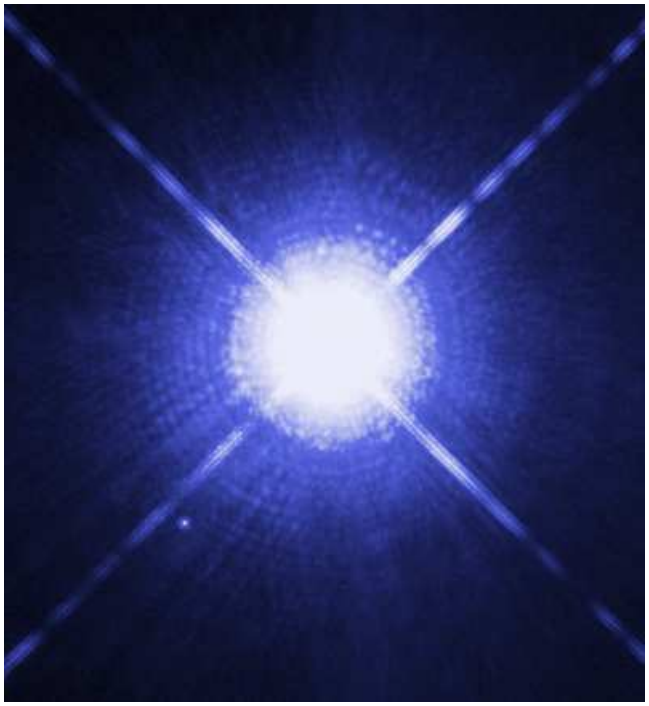

Figure 15:

Sirius B has a diameter of 7,500 miles (12,000 kilometers), less than the size of Earth, but is much more dense. Its powerful gravitational field is 350,000 times greater than Earth's, meaning that a 150-pound person would weigh 50 million pounds standing on its surface. Light from the surface of the hot white dwarf has to climb out of this gravitational field and is stretched to longer, redder wavelengths of light in the process. This effect, predicted by Einstein's theory of General Relativity in 1916, is called gravitational redshift, and is most easily seen in dense, massive, and hence compact objects whose intense gravitational fields warp space near their surfaces.

Based on the Hubble measurements of the redshift, made with the Space Telescope Imaging Spectrograph in February 2004, the team found that Sirius B has a mass that is 98 percent that of the sun. Sirius itself has a mass of two times that of the sun and a diameter of 1.5 million miles (2.4 million kilometers).

White dwarfs are the leftover remnants of stars similar to our Sun. They have exhausted their nuclear fuel sources and have collapsed down to a very small size. Sirius B is about 10,000 times fainter than Sirius itself, making it difficult to study with telescopes on the Earth's surface because its light is swamped in the glare of its brighter companion. Astronomers have long relied on a fundamental theoretical

relationship between the mass of a white dwarf and its diameter. The theory predicts that the more massive a white dwarf, the smaller its diameter. The precise measurement of Sirius B's gravitational redshift allows an important observational test of this key relationship.

The Hubble observations have also refined the measurement of Sirius B's surface temperature to be 44,900 degrees Fahrenheit, or 25,200 degrees Kelvin. Sirius itself has a surface temperature of 18,000 degrees Fahrenheit (10,500 degrees Kelvin).

At 8.6 light-years away, Sirius is one of the nearest known stars to Earth. Stargazers have watched Sirius since antiquity. Its diminutive companion, however, was not discovered until 1862, when it was first glimpsed by astronomers examining Sirius through one of the most powerful telescopes of that time.

2.5 Pulsar Racing Through Space Reveals Comet-Like Trail

Source: INAF Press Release, December 19th, 2005 [19]

A team led by Dr. Patrizia Caraveo of the Italian National Institute for Astrophysics (INAF) in Milan discovered this cometary trail with data from NASA's Chandra X-ray Observatory Archive. The discovery follows the team's discovery in 2003 using ESA's XMM-Newton of Geminga's twin X-ray tails stretching for billions of chilometers.

Together, these observations provide unique insight into the contents and density of the interstellar "ocean" Geminga is plowing through, as well as the physics of Geminga itself. Not only is Geminga close, only about 500 light years from Earth, it is cutting across our line of sight, offering a spectacular view of a pulsar in motion.

"Geminga is the only isolated pulsar we know of showing both a small comet-like trail and a larger tail structure," said Dr. Andrea De Luca of INAF's Istituto di Astrofisica Spaziale e Fisica Cosmica, lead author on an article about this discovery in Astronomy & Astrophysics. "This jettison from Geminga's journey through interstellar space provides unprecedented information about the physics of pulsars."

A pulsar is a type of rapidly spinning neutron star that emits steady pulses of radiation with each rotation, funnelled along strong magnetic field lines, much like a lighthouse beam sweeping across space. A neutron star is the core remains of an exploded star once at least eight times as massive as the sun.

These dense stars, only about 20 kilometers across, still contain roughly the mass of the sun. Neutron stars contain the densest material known. Like many neutron stars, Geminga got a "kick" from the explosion that created it and has been flying through space like a cannonball ever since.

De Luca said that Geminga's complex phenomenology of tails and a trail must be from high-energy electrons escaping the pulsar magnetosphere following paths clearly driven by the pulsar's motion in the interstellar medium.

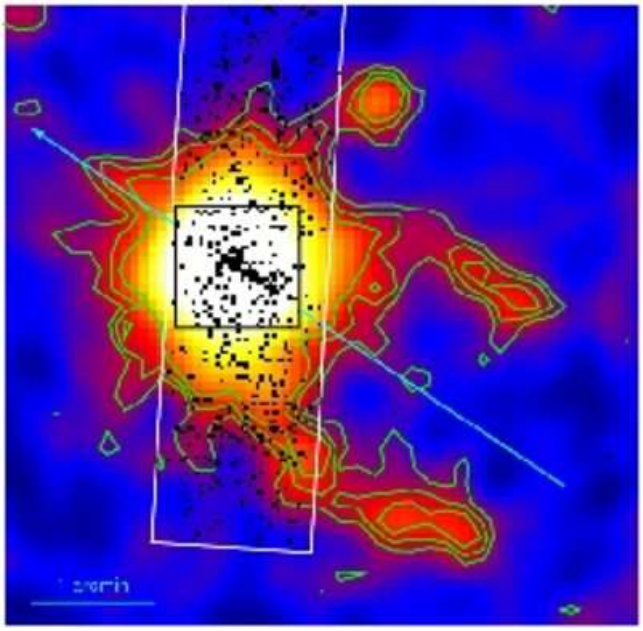

Figure 16: *Composite image of Geminga using Chandra and XMM-Newton data.*

Most pulsars emit radio waves. Yet Geminga is "radio quiet" and was discovered 30 years ago as a unique "gamma-ray only" source (only later was Geminga seen in the X-ray and optical light wavebands). Geminga generates gamma rays by accelerating electrons and positrons, a type of antimatter, to high speeds as it spins like a dynamo four times per second.

"Astronomers have known that only a fraction of these accelerated particles produce gamma rays, and they have wondered what happens to the remaining ones," said Caraveo, a co-author on the Astronomy & Astrophysics article. "Thanks to the combined capabilities of Chandra and XMM-Newton, we now know that such particles can escape. Once they reach the shock front, created by the supersonic motion of the star, the particles lose their energy radiating X-rays."

Meanwhile, an equal number of particles (with a different electric charge) should move in the opposite direction, aim-

ing back at the star. Indeed, when they hit the star's crust they create tiny hotspots, which have been detected through their varying X-ray emission.

The next generation of high-energy gamma-ray instruments - namely, the planned Italian Space Agency's AGILE mission and NASA's GLAST mission - will explore the connection between the X-ray and gamma ray behaviour of pulsars to provide clues to the nature of unknown gamma-ray sources, according to Prof. Giovanni Bignami, a co-author and director of the Centre d'Etude Spatiale des Rayonnements (CESR) in Toulouse, France. Of the 271 higher-energy gamma-ray objects detected by a NASA telescope called EGRET, 170 remained unidentified in other wavebands. These unidentified objects could be "gamma-ray pulsars" like Geminga, whose optical and X-ray light might be visible only because of its nearness to Earth.

Only about a dozen other radio-quiet isolated neutron stars are known, and Geminga is the only one with tails and trails and copious gamma-ray emission. Bignami named Geminga for "Gemini gamma-ray source" in 1973. In his local Milan dialect, the name is a pun on "gh minga," which means "it is not there." Indeed, Geminga was unidentified in other wavelengths until 1993, twenty years after its discovery.

2.6 Spitzer Exposes Our Galaxy's Deepest Secrets

Source: Spitzer Press Release, December 12th, 2005 [20]

Astronomers have at last found inner light! Only, they didn't find it through the typical Earthly methods of meditation, exercise and therapy. Instead, the light was discovered inside our Milky Way galaxy after hours of deep self-reflection with NASA's Spitzer Space Telescope.

The astronomers, who are members of the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) team, used Spitzer's heat-seeking infrared eyes to gaze at the dust-drenched plane of our galaxy. When they did this, the galaxy's obscuring clouds of gas and dust became transparent, revealing approximately 100 new star clusters, each containing tens to hundreds of stars.

According to lead investigator Emily Mercer, a graduate student at Boston University, Mass., the new clusters will tell astronomers a great deal about the structure of the Milky Way and star formation within the galaxy.

"These little guys were quite hard to find," said Mercer. "The discovery required sophisticated computer sifting of GLIMPSE data and careful inspection of the Spitzer images."

In the past, our galaxy wasn't so quick to give up its stellar secrets. Because we sit inside its flat, spiral disk, most of the galaxy appears as a thick blurry band of light that stretches across the sky. Many of the stars in this galactic plane cannot be detected with visible-light or ultraviolet telescopes. That's because the cool clouds of dust and gas that hover around the galaxy's center and make up galactic spiral arms block their starlight from our view.

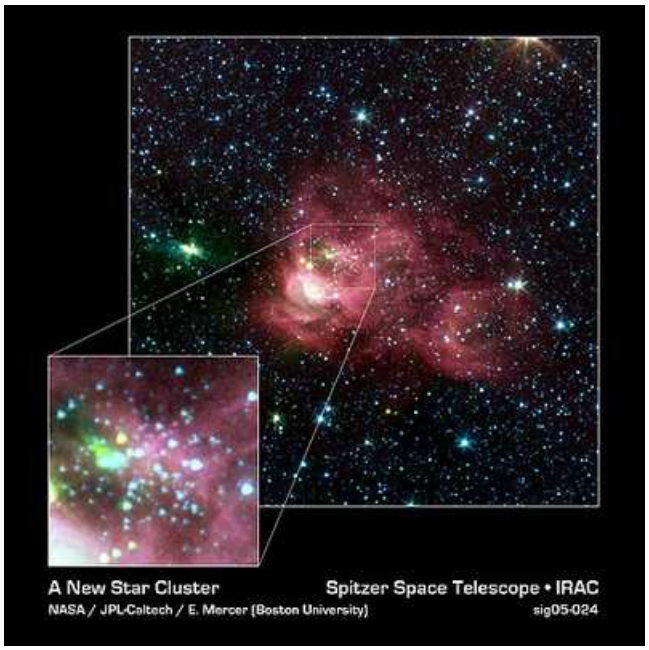

Figure 17: *New star cluster found by GLIMPSE Credit: NASA/JPL-Caltech/E. Mercer (Boston University)*

Two-thirds of the new star clusters were discovered through a computer method developed by Mercer and her advisor, Dr. Dan Clemens, also of Boston University. They used an algorithm to automatically sift through the GLIMPSE data for clusters. The rest were found using the traditional method of visually scrutinizing images for star clusters.

Mercer also found that there are nearly twice as many star clusters in the southern galactic plane, the portion of the galactic plane visible from the Earth's southern hemisphere, as in the northern galactic plane. She suspects that this observation may help astronomers map the location of the Milky Way's spiral arms.

"Emily has done a great job," says Clemens. "Her computer method for finding clusters has proved to be the most successful automated effort to date."

Both Clemens and Mercer are members of the multi-institutional GLIMPSE team, which is led by Dr. Edward Churchwell of the University of Wisconsin, Madison. The group was selected to survey the galactic plane with Spitzer's infrared array camera in November 2000 as part of Spitzer's Legacy program. So far, more than 30 million stars in the inner Milky Way have already been catalogued by GLIMPSE, and the team expects to identify more than 50 million stars by the end of the project.

"By making the galactic plane transparent, Spitzer opens a new door for astronomers to study the Milky Way," says Churchwell. "Some of the most interesting science likely to come out of this project will be serendipitous discoveries, which will open up entirely new avenues of inquiry."

2.7 Astronomers Use Laser to Take Clearest Images of the Center of the Milky Way

Source: UCLA News, December 20th, 2005 [21]

UCLA astronomers and colleagues have taken the first clear picture of the center of our Milky Way galaxy, including the area surrounding the supermassive black hole, using a new laser virtual star at the W.M. Keck observatory in Hawaii.

"Everything is much clearer now," said Andrea Ghez, UCLA professor of physics and astronomy, who headed the research team. "We used a laser to improve the telescope's vision a spectacular breakthrough that will help us understand the black hole's environment and physics. It's like getting Lasik surgery for the eyes, and will revolutionize what we can do in astronomy."

Astronomers are used to working with images that are blurred by the Earth's atmosphere. However, a laser virtual star, launched from the Keck telescope, can be used to correct the atmosphere's distortions and clear up the picture. This new technology, called Laser Guide Star adaptive optics, will lead to important advances for the study of planets in our solar system and outside of our solar system, as well as galaxies, black holes, and how the universe formed and evolved, Ghez said.

"We have worked for years on techniques for 'beating the distortions in the atmosphere' and producing high-resolution images," she said. "We are pleased to report the first Laser Guide Star adaptive optics observations of the center of our galaxy."

Ghez and her colleagues took "snapshots" of the center of the galaxy, targeting the supermassive black hole 26,000 light years away, at different wavelengths. This approach allowed them to study the infrared light emanating from very hot material just outside the black hole's "event horizon," about to be pulled through.

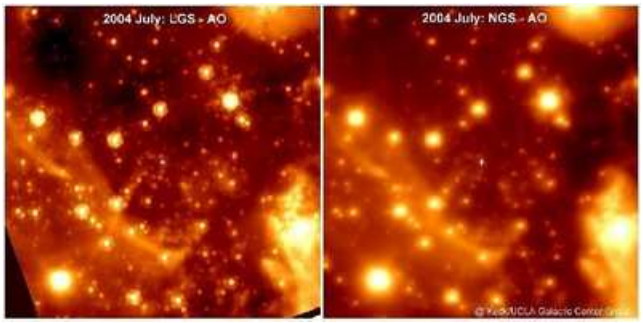

Figure 18: *The center of our Milky Way galaxy, as seen in the infrared using the Keck Laser Guide Star (left panel) and the Keck Natural Guide Star (right). The white cross marks the location of the supermassive black hole. Credit: W.M. Keck Observatory/UCLA Galactic Center Group*

"We are learning the conditions of the infalling material and whether this plays a role in the growth of the supermassive black hole," Ghez said. "The infrared light varies dramatically from week to week, day to day and even within a single hour."

The research, federally funded by the National Science Foundation, will be published Dec. 20 in the Astrophysical Journal Letters.

The research was conducted using the 10-meter Keck II Telescope, which is the world's first 10-meter telescope with a laser on it. Laser Guide Star allows astronomers to "generate an artificial bright star" exactly where they want it, which reveals the atmosphere's distortions.

Since 1995, Ghez has been using the W.M. Keck Observatory to study the galactic center and the movement of 200 nearby stars.

Black holes are collapsed stars so dense that nothing can escape their gravitational pull, not even light. Black holes cannot be seen directly, but their influence on nearby stars is visible, and provides a signature, Ghez said. The supermassive black hole, with a mass more than 3 million times that of our sun, is in the constellation of Sagittarius. The galactic center is located due south in the summer sky.

The black hole came into existence billions of years ago, perhaps as very massive stars collapsed at the end of their life cycles and coalesced into a single, supermassive object, Ghez said.

2.8 Perseus Spiral Arm of the Milky Way much closer than thought

Source: Max-Planck-Institute fur Radioastronomie Press Release, December 14th, 2005 [22]

The Perseus spiral arm, the nearest spiral arm in the Milky Way outside the Sun's orbit, lies only half as far from Earth as some previous results had suggested. An international team of astronomers including scientists from the Max-Planck-Institut fr Radioastronomie (MPIfR) has recently achieved the most accurate distance measurement ever to the Perseus arm. This was done by use of a vast array of radio telescopes in the USA called the Very Long Baseline Array, observing very bright spots within clouds of gas that contain methyl alcohol in the placental material surrounding a newly formed star called W3OH.

Dr. Xu Ye, an astronomer at Shanghai Observatory now working at the Max-Planck-Institut fr Radioastronomie and one of the members of the international team who made the measurements, stated that "we measured distance by the simplest and most direct method in astronomy - essentially the technique used by surveyors called triangulation." Specifically, the team used the changing vantage point of the Earth as it orbits the Sun to form one leg of a triangle. Measuring the change in apparent position of a source, they could calculate the source's distance by simple trigonometry (resulting in 6357130 light years).

This result resolves the longstanding problem of the distance to this spiral arm. In thje past, different methods of measuring distance have disagreed by more than a factor of 2. Prof. Karl Menten, another member of the team, states that "this confirms distances based on the apparent luminosity of young stars but disagrees with distances based on a model of the rotation of the Milky Way. The reason for the discrepancy is that young stars in the Perseus spiral arm have unexpectedly large motions."

The astronomers found that the young star is not moving in a circular orbit around the Milky Way, but deviates by 10% from circular. It is rotating more slowly and "falling" toward the center of the Milky Way. Team member Zheng Xing-Wu of Nanjing University points out that "the simplest explanation is that the cloud of gas out of which the star formed was gravitationally attracted by excess mass of material in the Perseus spiral arm."

"Studies such as ours are the first steps to accurately map the Milky Way," says Dr. Mark Reid, a member of the team from the Harvard-Smithsonian Center for Astrophysics. "We have established that the radio telescope we used, the Very Long Baseline Array, can measure distances with unprecedented accuracy–nearly a factor of 100 times better than previously accomplished." To get a feeling for this measurement one may visualize a person standing on the moon, holding a torch in his stretched-out hand. Let her turn around herself like an ice scater, but only making a single turn in the course of one year. The VLBA measurement is equivalent to measuring the torch's motion with an accuracy comparable to the torch's size.

The technique used is Very Long Baseline Interferometry (VLBI), where observations made with many telescopes are combined to achieve the resolution of an extraordinarily large telescope nearly the size of the Earth. The VLBA telescopes stretch from Hawaii over the continental United States to the Virgin Island of St. Croix, producing the resolution of an 8000 km diameter telescope. While the VLBA has extremely high resolution, it requires extremely bright and very compact radio sources such as masers for such measurements (a maser is the microwave equivalent of a laser.) Along with water, methanol is the most widespread maser molecule found in star-forming regions. The methanol spectral line used for the present experiment was discovered in the course of Prof. Menten's dissertation in the 1980s. In 1988, while working with Dr. Reid, they conducted the first VLBI observations of methanol masers; the target then was also W3OH. "Already then we dreamt of observations such as this one" says Menten.

In fact similar VLBA observations have also been made on water masers in W3OH. This effort, led by the MPIfR's Kazuya Hachisuka, yielded a distance similar to the methanol masers. "A splendid confirmation!" says Hachisuka. His team also includes Reid and Menten and a number of Japanese scientists.

The methanol observations are only the start of a very large-scale project that Reid and Menten have initiated. It will determine distances and motions of methanol masers all over the Milky Way. It has been granted a large block of VLBA observing time. In addition to the motions on the sky these observations also yield the star's velocity toward or away from the observer by measuring the Doppler shift of the methanol lines. The resulting three dimensional motions will deliver unique constraints not only on the rotation of the Milky Way but also on the distribution of the unseen Dark Matter that is postulated to surround it.

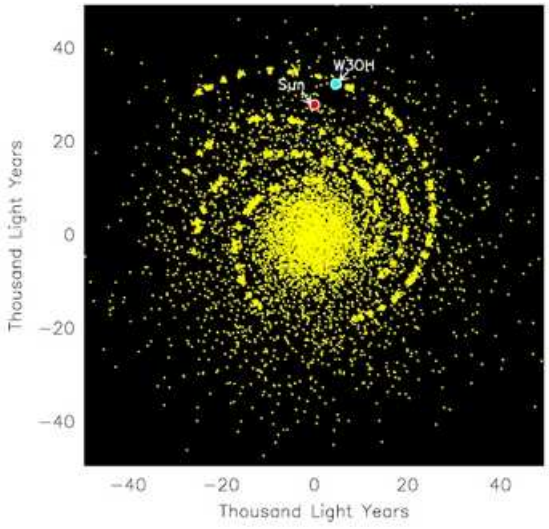

Figure 19: *Our Milky Way galaxy as an observer located far above its plane would see it. Shown are the known spiral arms. The locations of our solar system and of W3OH are indicated.*

While the method - simple trigonometry - sounds basic, the transformation into practical results requires a comprehensive understanding of VLBA and all aspects of the observations, including thorough modeling of the Earths' atmosphere which affects the incoming radio waves. Dr. Reid has dedicated many years of his life to reach the point were programs such as this one can be performed.

2.9 Flashes from the Past: Echoes from Ancient Supernovae

Source: Harvard-Smithsonian Center for Astrophysics Press Release ,December 21st, 2005 [23]

A team of astronomers has found faint visible echoes of three ancient supernovae by detecting their centuries-old light as it is reflected by clouds of interstellar gas hundreds of light-years removed from the original explosions.

Located in a nearby galaxy in the southern skies of Earth, the three exploding stars flashed into short-lived brilliance at least two centuries ago, and probably longer. The oldest one is likely to have occurred more than six hundred years ago.

The light echoes were discovered by comparing images of the Large Magellanic Cloud (LMC) taken years apart. By precisely subtracting the common elements in each image of the galaxy and looking by eye to see what variable objects remain, the team looked for evidence of invisible dark matter that might distort the light of stars in a transitory way, as part of a sky survey called SuperMACHO.

This careful image analysis also revealed a small number of concentric, circular-shaped arcs that are best explained as light moving outward over time, and being scattered as it encounters dense pockets of cool interstellar dust. Team members then fit perpendicular vectors to the curves of each arc system, which were found to point backwards toward the sites of three supernovae remnants, which were previously known and thought to be relatively young.

"Without the geometry of the light echo, we had no precise way of knowing just how old these supernovae were," said astronomer Armin Rest of the National Optical Astronomy Observatory (NOAO), lead author of a paper on the discovery in the December 22, 2005, issue of Nature. "Some relatively simple mathematics can help us answer one of the most vexing questions that astronomers can ask-exactly how old is this object that we are looking at?"

Just as a sound echo can occur when sound waves bounce off a distant surface and reflect back toward the listener, a light echo can be seen when light waves traveling through space are reflected back toward the viewer-in this case, the Mosaic digital camera on the National Science Foundation's Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile.

This technique can be extended to famous supernovae in history. "Imagine seeing light from the same explosion first seen by Johannes Kepler some 400 years ago, or the one recorded by Chinese observers in 1006," said Christopher Stubbs of the Harvard-Smithsonian Center for Astrophysics (CfA), co-author of the paper and principal investigator for the SuperMACHO program. "These light echoes give us that possibility."

In principle, astronomers can split the light echo into a spectrum to investigate what type of supernova occurred. "We have the potential with these echoes to determine the star's cause of death, just like the archaeologists who took a CT scan of King Tut's mummy to find out how he died," said co-author Arti Garg of CfA.

Figure 20: *In this artist's conception, the light of a hypothetical supernova in our Galaxy has reflected off of interstellar gas to create a "light echo," visible as a glowing ring behind the Earth-Moon system. Astronomers have discovered several such light echoes in the nearby galaxy called the Large Magellanic Cloud. Such echoes give scientists the possibility of studying ancient supernovae that exploded hundreds of years ago. Credit: David A. Aguilar (CfA)*

Astronomers can also use supernova light echoes to measure the structure and nature of the interstellar medium. Dust and gas between the stars are invisible unless illuminated by some light source, just as fog at night is not noticeable until lit by a car's headlights. A supernova blast can provide that illumination, lighting up surrounding clouds of matter with its strobe-like flash.

"We see the reflection as an arc because we are inside an imaginary ellipse, with the Earth at one focus of the ellipse and the ancient supernovae at the other," explained Nicholas Suntzeff of NOAO. "As we look out toward the supernovae, we see the reflection of the light echo only when it intersects the outer surface of the ellipse. The shape of the reflection from our vantage point appears to be a portion of a circle."

An unusual aspect of the arcs is that they generally appear to move much faster than the speed of light. This does not violate the cosmic speed limit, which states that any object cannot move faster than the speed of light. "What our telescopes see is the reflection moving, and not any physical object," Suntzeff added. "It is also very exciting that our observations confirm the visionary prediction of Fritz Zwicky in 1940 that light from ancient supernovae could be seen in echoes of the explosion."

2.10 Witnessing the Flash from a Black Hole's Cannibal Act

Source: ESO Press Release, December 14th, 2005 [24]

An international team of astronomers reports the discovery of a third short gamma-ray burst, associated with a nearby elliptical galaxy. The low level of star formation in such galaxies and the detection of a second long-lasting flare indicate that this gamma-ray burst is most likely the final scream of a neutron star as it is being devoured by a black hole.

Gamma-ray bursts (GRBs), the most powerful type of explosion known in the Universe, come in two different flavours, long and short ones. Over the past few years, international efforts have shown that long gamma-ray bursts are linked with the ultimate explosion of massive stars.

Very recently, the observations by different teams - including the GRACE and MISTICI collaborations that use ESO's telescopes - of the afterglows of two short gamma-ray bursts provided the first conclusive evidence that this class of objects originates most likely from the collision of compact objects, neutron stars or black holes.

On July 24, 2005, the NASA/PPARC/ASI Swift satellite detected another short gamma-ray burst, GRB 050724. Subsequent observations, including some with the ESO Very Large Telescope, allowed astronomers to precisely pinpoint the position of the object, lying about 13,000 light-years away from the centre of an elliptical galaxy that is located 3,000 million light-years away (redshift 0.258).

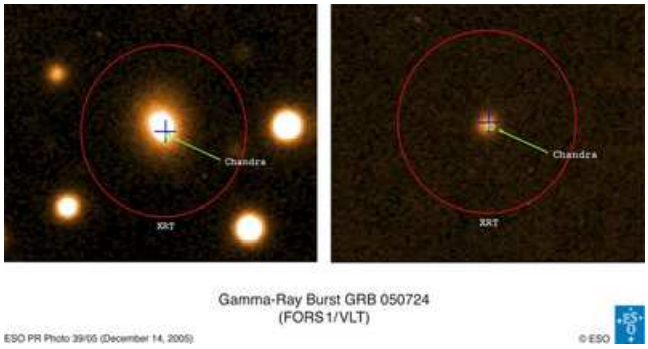

Figure 21: *(Left) VLT optical image taken on July 24, 12 hours after the burst, showing the position of the gamma-ray burst GRB 050724 as measured by the Swift X-Ray Telescope (XRT) and the Chandra X-ray satellite. The blue cross is the position of the optical afterglow. The burst positions are superimposed on a bright red galaxy at redshift z=0.258. (Right) Difference between two VLT images taken on July 24 and 29, clearly revealing the presence of the GRB.*

”From its characteristics, we infer that this galaxy contains only very old stars,” says Guido Chincarini (INAF-Brera and Milan University, Italy), co-author of the paper presenting the results. ”This is similar to the host galaxy of the previous short GRB which could be precisely localised, GRB 050509B, and very different from host galaxies of long bursts.”

These observations thereby confirm that the parent populations and consequently the mechanisms for short and long GRBs are different in significant ways. The most likely scenario for short GRBs is now the merger of two compact objects.

The observations also show this short burst has released between 100 and 1000 less energy than typical long GRBs. ”The burst itself was followed after about 200-300 seconds by another, less-energetic flare,” says Sergio Campana (INAF-Brera), co-author of the paper. ”It is unlikely that this can be produced by the merger of two neutron stars. We therefore conclude that the most probable scenario for the origin of this burst is the collision of a neutron star with a black hole.”

2.11 Galaxy Collisions Dominate the Local Universe

Source: NOAO News, December 6th, 2005 [25]

More than half of the largest galaxies in the nearby universe have collided and merged with another galaxy in the past two billion years, according to a new study using hundreds of images from two of the deepest sky surveys ever conducted.

The idea of large galaxies being assembled primarily by mergers rather than evolving by themselves in isolation has grown to dominate cosmological thinking. However, a troubling inconsistency within this general theory has been that the most massive galaxies appear to be the oldest, leaving minimal time since the Big Bang for the mergers to have occurred.

”Our study found these common massive galaxies do form by mergers. It is just that the mergers happen quickly, and the features that reveal the mergers are very faint and therefore difficult to detect,” says Pieter van Dokkum of Yale University, lead author of the paper in the December 2005 issue of the Astronomical Journal.

The paper uses two recent deep surveys done with the National Science Foundation’s 4-meter telescopes at Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory, known as the NOAO Deep Wide-Field Survey and the Multiwavelength Survey by Yale/Chile. Together, these surveys covered an area of the sky 50 times larger than the size of the full Moon.

”We needed data that are very deep over a very wide area to provide statistically meaningful evidence,” van Dokkum explains. ”As happens so often in science, fresh observations helped inform new conclusions.”

Figure 22: *The panels show several of the newly found*

galaxy collisions in the nearby universe, using the NOAO Deep Wide-Field Survey (NDWFS) and the Multiwavelength Survey by Yale/Chile (MUSYC).

Van Dokkum used images from the two surveys to look for telltale tidal features around 126 nearby red galaxies, a color selection biased to select the most massive galaxies in the local universe. These faint tidal features turn out to be quite common, with 53 percent of the galaxies showing tails, broad fans of stars trailing behind them or other obvious asymmetries.

"This implies that there is a galaxy that has endured a major collision and subsequent merger event for every single other normal' undisturbed field galaxy," van Dokkum notes. "Remarkably, the collisions that precede the mergers are still ongoing in many cases. This allows us to study galaxies before, during, and after the collisions."

Though there are not many direct star-to-star encounters in this merger process, such galaxy collisions can have profound effects on star formation rates and the shape of the resulting galaxy.

These mergers do not resemble the spectacular mergers of blue spiral galaxies that are featured in several popular Hubble Space Telescope images. But these red galaxy mergers appear to be much more common. Their ubiquity represents a direct confirmation of predictions by the most common models for the formation of large-scale structure in the Universe, with the added benefit of helping solve the apparent-age problem.

"In the past, people equated stellar age with the age of the galaxy," van Dokkum explains. "We have found that, though their stars are generally old, the galaxies that result from these mergers are relatively young."

It is not yet understood why the merging process does not lead to enhanced star formation in the colliding galaxies. It may be that massive black holes in the centers of the galaxies provide the energy to heat or expel the gas that needs to be able to cool in order to form new stars. Ongoing detailed study of the newly found mergers will provide better insight into the roles that black holes play in the formation and evolution of galaxies.

A series of images of different galaxies in this study that, taken together, represent a time sequence of a typical red galaxy merger, is available above. More information, including an animation of the mergers, is available from Yale University.

2.12 Perseus Cluster: Chandra Proves Black Hole Influence is Far Reaching

Source: Chandra Press Release, December 1st, 2005 [26]

An accumulation of 270 hours of Chandra observations of the central regions of the Perseus galaxy cluster reveals evidence of the turmoil that has wracked the cluster for hundreds of millions of years. One of the most massive objects in the universe, the cluster contains thousands of galaxies immersed in a vast cloud of multimillion degree gas with the mass equivalent of trillions of suns.

Enormous bright loops, ripples, and jet-like streaks are apparent in the image. The dark blue filaments in the center are likely due to a galaxy that has been torn apart and is falling into NGC 1275, a.k.a. Perseus A, the giant galaxy that lies at the center of the cluster.

Special processing designed to bring out low and high pressure regions in the hot gas has uncovered huge low pressure regions (shown in purple in the accompanying image overlay, and outlined with the white contour). These low pressure regions appear as expanding plumes that extend outward 300,000 light years from the supermassive black hole in NGC 1275.

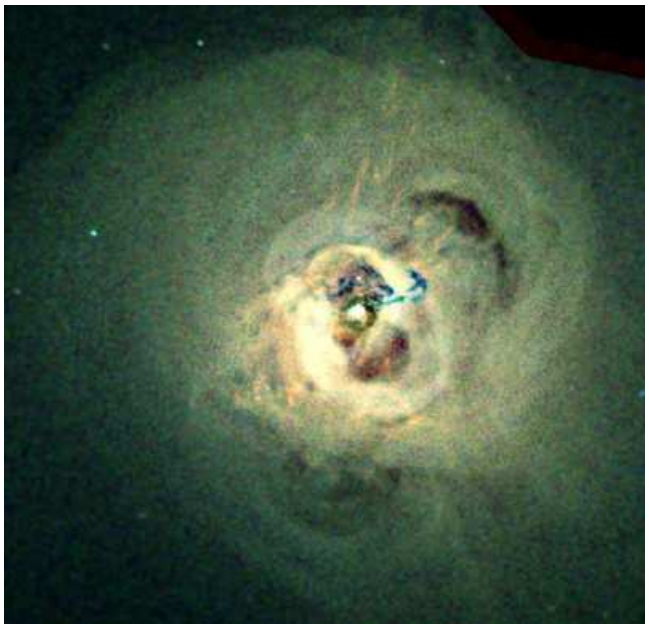

Figure 23: *Credit: NASA/CXC/IoA/A.Fabian et al.*

The hot gas pressure is assumed to be low in the plumes because unseen bubbles of high-energy particles have displaced the gas. The plumes are due to explosive venting from the vicinity of the supermassive black hole.

The venting produces sound waves which heat the gas throughout the inner regions of the cluster and prevent the gas from cooling and making stars at a high rate. This process has slowed the growth of one of the largest galaxies in the Universe. It provides a dramatic example of how a relatively tiny, but massive, black hole at the center of a galaxy can control the heating and cooling behavior of gas far beyond the confines of the galaxy.

2.13 Young Galaxies Grow Up Together in a Nest of Dark Matter

Source: Subaru Telescope Press Release, December 21st, 2005 [27]

Astronomers have found clear indications that clumps of dark matter are the nursing grounds for new born galaxies about twelve billion light years away. A single nest of dark matter can nurture several young galaxies. These results from researchers at the Space Telescope Science Institute, the National Astronomical Observatory of Japan, and the University of Tokyo confirm predictions of the currently dominant theory of cosmology known as the Cold Dark Matter model.

Recent studies suggest that dark matter out weighs ordinary matter by a factor of seven. Although dark matter cannot be seen directly through a telescope, it reveals itself to astronomers by its strong gravitational pull on nearby stars and gas, and even galaxies.

Galaxies are often clustered together and how they cluster is determined mostly by gravity.

By studying how galaxies cluster, it is possible to determine how dark matter is distributed and how it affects the birth and growth of galaxies. In the past, it was extremely difficult to study the clustering of young galaxies. Young galaxies appear faint due to their great distances, and finding enough of them to study how they cluster was an observational challenge.

Masami Ouchi from the Space Telescope Science Institute and colleagues used the Subaru telescope and its Suprime-Cam camera to study a piece of the sky in the constellation Cetus (the Whale) called the Subaru/XMM-Newton Deep Survey Field (SXDS; Reference 2). This piece of sky covers an area five times the size of the full moon. By taking deep and sensitive images of the field in three colors of visible light, the SXDS team was able to find about seventeen thousand (17,000) young galaxies twelve billion light years away. This number is ten times larger than previous studies of such young galaxies. Figure 2 shows the location of the galaxies, and figure 3 shows the relative strength of the correlation between pairs of galaxies with different separations.

Based on these data, the team found that: 1) There are many pairs of galaxies with separations less than eight hundred thousand (800,000) light years. 2) Even at large distances, galaxies are strongly clustered.

Both of these results are expected if the galaxies are nestled within clumps of dark matter. (Note 2 and 3) The SXDS team compared the observational results in detail to theoretical predictions based on a Cold Dark Matter model by team member Takashi Hamana (Reference 3) and found that the average clump of dark matter nests weighs as much as six hundred billion (600,000,000,000) Suns, and that a single clump of dark matter harbors multiple young galaxies.

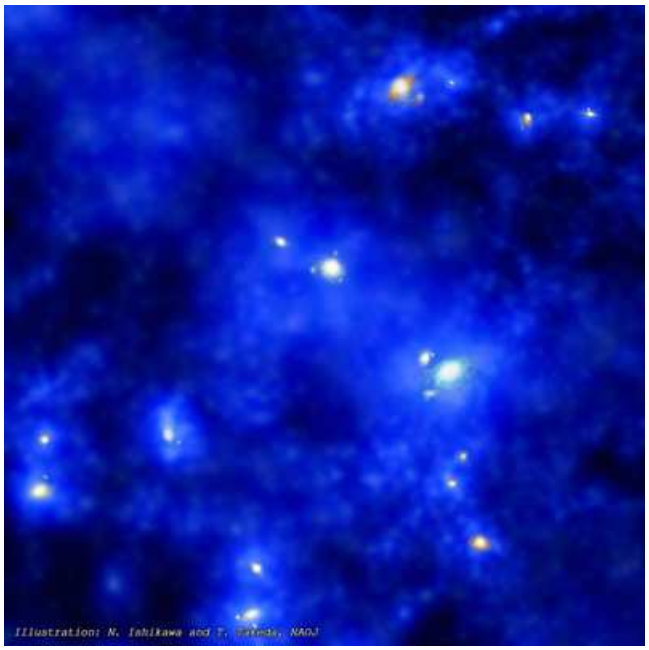

Figure 24: *A scientifically accurate artistic image of galaxies twelve billion light years away. The blue nebulosity is dark matter. Denser regions are white. The blue-white regions correspond to the dark matter clumps or dark matter halos where young galaxies are forming. (Image created by Naomi Ishikawa and Takaaki Takeda, National Astronomical Observatory of Japan)*

Independently, Nobunari Kashikawa from the National Astronomical Observatory of Japan and colleagues also used Subaru's Suprime-Cam camera to study an area of sky in the constellation Coma Berenices (Berenice's Hair) called the Subaru Deep Field (SDF; Reference 4). This field is only the size of one full moon but the data available are twice as

sensitive as the SXDS field data. The SDF team found about five thousand (5,000) young galaxies at a distance of twelve billion light years (Figure 4), and eight hundred (800)even younger galaxies at a distance of twelve billion five hundred million light years. The SDF team was also able to double check the identities of the young galaxies by taking spectral data of the galaxies with the Subaru and Keck telescopes. The SDF team independently obtained the results 1)+2) described above, and concluded that some single clumps of dark matter harbours multiple young galaxies. In the SDF images, it is possible to see several new born galaxies huddled together in a small area. (Figure 5) By comparing the SDF data in detail to high precision computer simulations of the growth of clumps in Cold Dark Matter by team member Masahiro Nagashima of Kyoto University (Reference 5), the SDF team concludes that heavier clumps of dark matter have more bright galaxies, and that this preference produces the correlations found in real observation (Note 4).

The two teams together have found the first concrete evidence that young galaxies in the early universe (Note 5) are nestled within clumps of dark matter, and that a single clump of dark matter nurses several young galaxies. Both teams took advantage of the Subaru telescope's unique ability to take deep sensitive images over a large area of sky.

2.14 Hot, massive haloes found around most spiral galaxies

Source: ESA Press Release, December 14th, 2005 [28]

Astronomers using ESA's XMM-Newton observatory have found very hot gaseous haloes around a multitude of spiral galaxies similar to our Milky Way galaxy. These 'ghost-like' veils have been suspected for decades but remained elusive until now. Galaxy 'haloes' are often seen in so-called 'starburst' galaxies, the locations of concentrated star formation, but the discovery of high-temperature haloes around non-starburst spiral galaxies opens the door to new types of measurements once only dreamed about.

For example, scientists can confirm models of galaxy evolution and infer the star-formation rate in galaxies like our own by 'calculating backwards' to estimate how many supernovae are needed to make the observed haloes.

"Most of these ghost-like haloes have never been confirmed before in X-ray energies because they are so tenuous and have a low-surface brightness," said Ralph Tllmann, from the Ruhr University in Bochum, Germany, lead author of the results.

"We needed the high sensitivity and large light-collecting area of the XMM-Newton satellite to uncover these haloes."

In starburst galaxies, which have prominent haloes, star formation and star death (supernovae) are concentrated in the core of the galaxy and occur during a short time period over the life of a galaxy. This intense activity forms a halo of gas around the entire galaxy, similar to a volcano sending out a plume.

So how can haloes form in the absence of intense star formation? Tllmann's group say that the entire disk of a spiral galaxy can 'simmer' with star-formation activity. This is spread out over time and distance. Like a giant pot of boiling water, the steady activity of star formation over millions and millions of years percolates outward to form the galaxy halo.

Two of the best-studied galaxies so far out of a group of 32 are NGC 891 and NGC 4634, which are tens of millions of light years away in the constellations Andromeda and Coma Berenices, respectively.

The scientists noted that these observations do not support a recent model of galaxy halo formation, in which gas from the intergalactic medium rains down on the galaxy and forms the halo. Galaxy halos contain about 10 million solar masses of gas. The scientists say it is a relatively straightforward calculation to determine how many supernovae are needed to create the halo. Supernovae are intricately tied to the rate of star formation in a given galaxy.

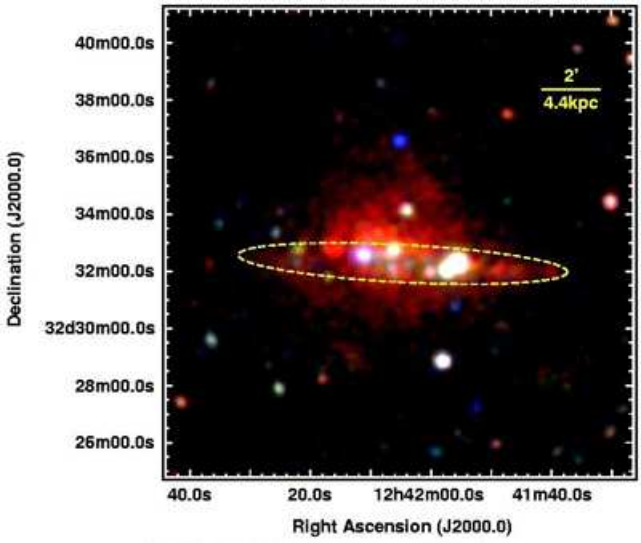

Figure 25: *This three-colour XMM-Newton image of NGC 4631 was created from merged EPIC pn and MOS images. Red, green and blue represent emission in the (0.2-1.0) keV, (1.0-2.0) keV, and (2.0-4.5) keV energy bands, respectively.*

The ellipse indicates the outer border of the H-alpha emitting disc. An extended soft X-ray halo is clearly visible which is most likely triggered by star formation related processes in the disc plane. Credits: ESA/AIRUB (R. Tllmann)

"With our data we will be able to establish for the first time a critical rate of star formation that needs to be exceeded in order to create such haloes," said Dr Ralf-Jrgen Dettmar, a co-author also from Ruhr University.

Once these haloes have formed, the hot gas cools and can fall down onto the galaxy's disk, the scientists said. The gas is involved in a new cycle of star formation, because pressure from this infalling gas triggers the collapse of gas clouds into new stars.

Some heavy elements might escape the halo into intergalactic space, depending on the energy of the supernovae. Further analysis of the chemical composition of the halo might reveal this.

This would determine the correctness of recent cosmological models on the evolution of galaxies, as well as provide evidence of how the elements necessary for life are distributed through the Universe.

2.15 JHU-STScI Team Maps Dark Matter in Startling Detail

Source: Johns Hopkins University Press Release, December 9th, 2005 [29]

Clues revealed by the recently sharpened view of the Hubble Space Telescope have allowed astronomers to map the location of invisible "dark matter" in unprecedented detail in two very young galaxy clusters.

A Johns Hopkins University-Space Telescope Science Institute team reports its findings in the December issue of Astrophysical Journal. (Other, less-detailed observations appeared in the January 2005 issue of that publication.)

The team's results lend credence to the theory that the galaxies we can see form at the densest regions of "cosmic webs" of invisible dark matter, just as froth gathers on top of ocean waves, said study co-author Myungkook James Jee, assistant research scientist in the Henry A. Rowland Department of Physics and Astronomy in Johns Hopkins' Krieger School of Arts and Sciences.

"Advances in computer technology now allow us to simulate the entire universe and to follow the coalescence of matter into stars, galaxies, clusters of galaxies and enormously long filaments of matter from the first hundred thousand years to the present," Jee said. "However, it is very challenging to verify the simulation results observationally, because dark matter does not emit light."

Jee said the team measured the subtle gravitational "lensing" apparent in Hubble images that is, the small distortions of galaxies' shapes caused by gravity from unseen dark matter to produce its detailed dark matter maps. They conducted their observations in two clusters of galaxies that were forming when the universe was about half its present age.

"The images we took show clearly that the cluster galaxies are located at the densest regions of the dark matter haloes, which are rendered in purple in our images," Jee said.

The work buttresses the theory that dark matter - which constitutes 90 percent of matter in the universe - and visible matter should coalesce at the same places because gravity pulls them together, Jee said. Concentrations of dark matter should attract visible matter, and as a result, assist in the formation of luminous stars, galaxies and galaxy clusters.

Dark matter presents one of the most puzzling problems in modern cosmology. Invisible, yet undoubtedly there - scientists can measure its effects - its exact characteristics remain elusive. Previous attempts to map dark matter in detail with ground-based telescopes were handicapped by turbulence in the Earth's atmosphere, which blurred the resulting images.

"Observing through the atmosphere is like trying to see the details of a picture at the bottom of a swimming pool full of waves," said Holland Ford, one of the paper's co-authors and a professor of physics and astronomy at Johns Hopkins.

The Johns Hopkins-STScI team was able to overcome the atmospheric obstacle through the use of the space-based Hubble telescope. The installation of the Advanced Camera for Surveys in the Hubble three years ago was an additional boon, increasing the discovery efficiency of the previous HST by a factor of 10.

The team concentrated on two galaxy clusters (each containing more than 400 galaxies) in the southern sky.

Figure 26: *Dark matter in the high-redshift cluster CL 0152-1357. Gravitational lensing analysis with the Advanced Camera for Surveys (ACS) reveals the complicated dark matter distribution (purple) in unprecedented detail when the Universe was at half its present age. The yellowish galaxies are the visible cluster member galaxies forming a filamentary structure, possibly in the process of merging. (Jee et al. 2005, Astrophysical Journal)*

”These images were actually intended mainly to study the galaxies in the clusters, and not the lensing of the background galaxies,” said co-author Richard White, a STScI astronomer who also is head of the Hubble data archive for STScI. ”But the sharpness and sensitivity of the images made them ideal for this project. That’s the real beauty of Hubble images: they will be used for years for new scientific investigations.”

The result of the team’s analysis is a series of vividly detailed, computer-simulated images illustrating the dark matter’s location. According to Jee, these images provide researchers with an unprecedented opportunity to infer dark matter’s properties.

The clumped structure of dark matter around the cluster galaxies is consistent with the current belief that dark matter particles are ”collision-less,” Jee said. Unlike normal matter particles, physicists believe, they do not collide and scatter like billiard balls but rather simply pass through each other.

”Collision-less particles do not bombard one another, the way two hydrogen atoms do. If dark matter particles were collisional, we would observe a much smoother distribution of dark matter, without any small-scale clumpy structures,” Jee said.

Ford said this study demonstrates that the ACS is uniquely advantageous for gravitational lensing studies and will, over time, substantially enhance understanding of the formation and evolution of the cosmic structure, as well as of dark matter.

”I am enormously gratified that the seven years of hard work by so many talented scientists and engineers to make the Advanced Camera for Surveys is providing all of humanity with deeper images and understandings of the origins of our marvelous universe,” said Ford, who is principal investigator for ACS and a leader of the science team.

3 Space missions

3.1 First Galileo satellite on orbit to demonstrate key technologies

Source: ESA Press Release, December 28th, 2005 [30]

The first Galileo demonstrator is in orbit, marking the very first step to full operability of Europe’s new global navigation satellite system, under a partnership between ESA and the European Commission (EC). Giove A, the first Galileo in-orbit validation element, was launched today from Baikonur, Kazakhstan, atop a Soyuz-Fregat vehicle operated by Starsem. Following a textbook lift-off at 05:19 UTC (06:19 CET), the Fregat upper stage performed a series of manoeuvres to reach a circular orbit at an altitude of 23 258 km, inclined at 56 degrees to the Equator, before safely deploying the satellite at 09:01:39 UTC (10:01:39 CET).

”Years of fruitful cooperation between ESA and the EC have now provided a new facility in space for improving

the life of European citizens on Earth" said ESA Director General Jean Jacques Dordain congratulating ESA and industrial teams on the successful launch.

This 600 kg satellite, built by Surrey Satellite Technology Ltd (SSTL) of Guildford, in the UK, has a threefold mission. First, it will secure use of the frequencies allocated by the International Telecommunications Union (ITU) for the Galileo system. Second, it will demonstrate critical technologies for the navigation payload of future operational Galileo satellites. Third, it will characterise the radiation environment of the orbits planned for the Galileo constellation.

Formerly known as GSTB-V2/A (Galileo System Test Bed Version 2), Giove A carries two redundant, small-size rubidium atomic clocks, each with a stability of 10 nanoseconds per day, and two signal generation units, one able to generate a simple Galileo signal and the other, more representative Galileo signals. These two signals will be broadcast through an L-band phased-array antenna designed to cover all of the visible Earth under the satellite. Two instruments will monitor the types of radiation to which the satellite is exposed during its two year mission.

The satellite is under the control of SSTL's own ground station. All systems are performing well, the solar arrays are deployed and in-orbit checkout of the satellite has begun. Once the payload is activated, the Galileo signals broadcast by Giove A will be carefully analysed by ground stations to make sure they satisfy the criteria of the ITU filings.

First step for Galileo A second demonstrator satellite, Giove B, built by the European consortium Galileo Industries, is currently being tested and will be launched later. It is due to demonstrate the Passive Hydrogen Maser (PHM), which, with a stability better than 1 nanosecond per day, will be the most accurate atomic clock ever launched into orbit. Two PHMs will be used as primary clocks onboard the operational Galileo satellites, with two rubidium clocks serving as backups.

Figure 27: *GIOVE-A deploys its solar arrays. Image credit: ESA*

Subsequently, four operational satellites will be launched to validate the basic Galileo space and related ground segments. Once this In-Orbit Validation (IOV) phase is completed, the remaining satellites will be launched to achieve Full Operational Capability (FOC).

Galileo will be Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be interoperable with the US Global Positioning System (GPS) and Russia's Global Navigation Satellite System (Glonass), the two other global satellite navigation systems. Galileo will deliver real-time positioning accuracy down to the metric range with unrivaled integrity.

Numerous applications are planned for Galileo, including positioning and derived value-added services for transport by road, rail, air and sea, fisheries and agriculture, oil prospecting, civil protection activities, building, public works and telecommunications.

3.2 SMART-1 uses new imaging technique in lunar orbit

Source: ESA Press Release, December 23rd, 2005 [31]

ESA's SMART-1 spacecraft has been surveying the Moon's

surface in visible and near-infrared light using a new technique, never before tried in lunar orbit. For the last few months, the Advanced Moon Imaging Experiment (AMIE) on board SMART-1, has been opening new ground by attempting multi-spectral imaging in the push-broom' mode. This technique is particularly suited to colour imaging of the lunar surface.

(Note that colour imaging' here does not mean natural colour, the colour bands of the AMIE filters are in the infrared region and are selected such that the intensity of the iron absorption line can be determined from brightness ratios of the images.)

In this mode, AMIE takes images along a line on the Moon's surface perpendicular to the ground track of the spacecraft.

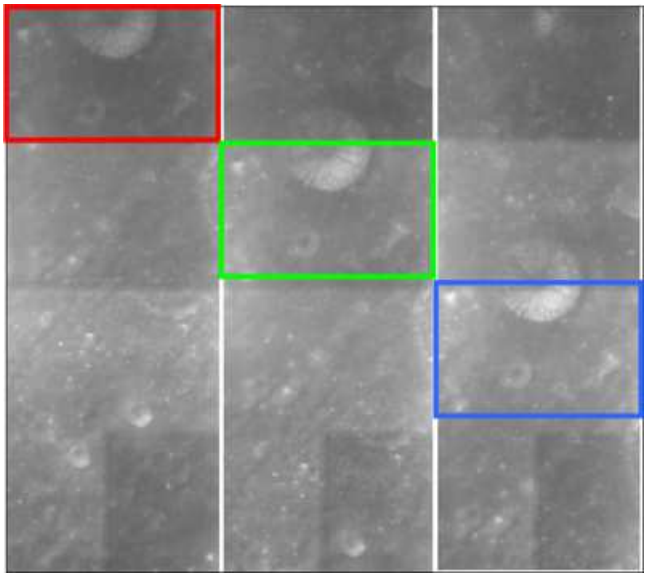

Figure 28: *The AMIE camera on board SMART-1 has three fixed-mounted filters which see the Moon in different colour bands. The figure shows four consecutive images taken by AMIE from left to right. The fixed filters are indicated by coloured frames. The images, taken only a few seconds apart, show how the surface is moving through the different filters. Credits: AMIE Team*

It relies on the orbital motion of the spacecraft to reposition it as it records a sequence of images known as an image swath'.

The AMIE camera on board SMART-1 has fixed-mounted filters which see the Moon in different colour bands. The figure shows four consecutive images taken by AMIE from left to right. The fixed filters are indicated by coloured frames. The images, taken only a few seconds apart, show how the surface is moving through the different filters. The spacecraft is moving over the Moon's surface at a speed of more than a kilometre per second!

By combining images showing the same feature on the Moon as seen through different filters, colour information can be obtained. This allows to study the mineralogical composition on the lunar surface, which in turn lets scientists deduce details of the formation of our celestial companion.

Whereas the multi-spectral camera aboard the US Clementine mission had constant illumination conditions, SMART-1's orbit will offer different viewing angles. AMIE's views correlated with Clementine data of the same lunar areas will allow scientists to better interpret such spectral data.

3.3 Possible evidence found for Beagle 2 location

Source: ESA Press Release, December 21st, 2005 [32]

The news that Beagle 2 may have been spotted on the surface of Mars in the immediate vicinity of where it was expected to land was welcomed by the European Space Agency. ESA's Mars Express spacecraft had delivered the Beagle 2 lander to Mars on 25 December 2003.

ESA's Director of Science David Southwood said, "If this turns out to be a definitive sighting then we can feel very pleased not only for the Beagle 2 team but also for everyone else involved in getting the probe to Mars and accurately into its descent."

"Although the discovery cannot make up for the loss of science, there can be more confidence that Beagle 2 made it down to the surface. The search itself has been not been easy and it says something for the persistence and dedication of the team that this report has emerged."

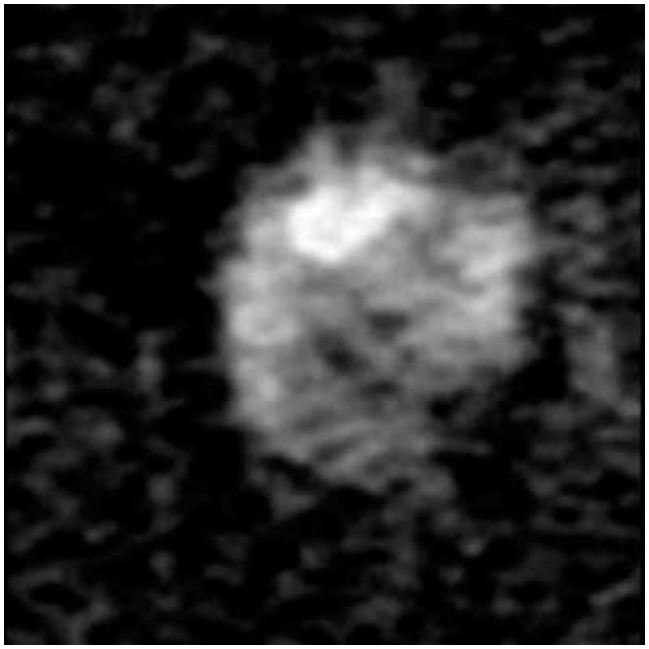

Figure 29: *A specially processed NASA Mars Global Surveyor (MGS) image taken by the Mars Orbiter Camera (MOC). The Beagle scientists believe that out of the many thousands of craters and hundreds of square kilometres of Beagle 2's landing ellipse, no other candidate site has come close to providing such compelling evidence of Beagle's landing. Impact ejecta can be seen similar to the one produced by MER-A's front shield in the Bonneville crater and a cluster of symmetrically arranged objects that match a successful gas bag segment separation, dropping the lander to the ground. Credits: NASA/JPL/Malin Space Science Systems/Virtual Analytics Ltd*

It is also important if the scenario of impact, as outlined by the team on the basis of the NASA Mars Global Surveyor spacecraft images, can be further investigated.

"This information, if consolidated, can limit what might have gone wrong two years ago and we can use it to increase our own confidence and faith in the methods used when we next face the challenge of going to Mars," added Southwood.

ESA received the go-ahead for a new European lander mission to Mars, Exomars, with the subscription by Member States for a new exploration programme, Aurora, just a few weeks ago at the ESA Council of Ministers in Berlin on 5-6 December 2005.

3.4 Mission to Mars via Antarctica

Source: ESA Press Release, December 21st, 2005 [33]

A few weeks before leaving for the Antarctic Concordia Station, the Italian-French crew that will spend over one year in one of the harshest, isolated environments on Earth, attended two days of preparatory training at ESA's Headquarters in Paris, France. During their stay at the research station the crew will participate in a number of ESA experiments the outcome of which will help prepare for long-term missions to Mars. As part of the Aurora Exploration Programme, ESA is considering participating in a human mission to Mars by the year 2030. Research projects are planned or are already underway to develop the technology and knowledge needed. By being involved in programmes that have requirements similar to those of a mission to Mars, ESA will gain experience on how best to prepare for such a challenging mission.

"The Concordia Station is an ideal location as it replicates certain aspects of a Mars mission," explains Oliver Angerer, ESA's coordinator for the Concordia research programme. "The crew lives in an extreme environment in one of the most remote places on Earth. During the winter the base is completely cut off with no visitors and no chance for rescue. In such an isolated location, the crew has to learn to be fully self-sufficient."

Cooperation Built and operated jointly by the French Polar Institute (Institut Paul Emile Victor, IPEV) and the Italian Antarctic Programme (Consorzio per l'attuazione del Programma Nazionale di Ricerche in Antartide, PNRA SCrl), the Concordia Station was completed in 2004. A letter of intent was signed with IPEV and PNRA in 2002 that enabled ESA to cooperate on some aspects of the project.

Capable of providing home to up to 16 crewmembers in the winter, the station consists of three buildings, which are interlinked by enclosed walkways. Two large cylindrical three-storey buildings provide the station's main living and working quarters, whilst the third building houses technical equipment, like the electrical power plant and boiler room.

Figure 30: *The Concordia Station is a scientific base built in Antarctica by the French Polar Institute (IPEV) and the Italian Antarctic Programme (PNRA) Credits: IPEV*

Last November, the first crew finished their winter-over which was dedicated to the technical qualification of the station . The summer season sees a swelling in the number of inhabitants as short-stay scientists take advantage of the less extreme weather (however, mean air temperature is about -30C during this time!). With the second crew now starting to gather at the remote research station, the summer season also marks a change over of the crew. Briefings Three scientists who are part of the next Concordia winter-over crew have already made the long journey to Antarctica. The rest of the crew, who will leave for the Antarctic research station during December, gathered at ESA's Headquarters in Paris for two days of pre-departure training. They received briefings about life at Concordia, including aspects such as safety and the implications of the Antarctic Treaty for activities at the station.

The seven crewmembers also heard about research at the station, including two special experiments for which they will act as subjects during their stay. In 2003, ESA coordinated together with the Concordia partners a Research Announcement for medical and psychological research, from which six proposals were selected.

The two experiments, which are the first to be implemented in the coming season, look at psychological adaptation to the environment and the process of developing group identity; issues that will also be important factors for humans travelling to Mars. For this research the crew will complete questionnaires at regular intervals throughout their stay.

ESA's Mistacoba experiment, which already started a year ago when the first crew started living at the station, will also continue after the crew rotation. Starting from a newly built clean environment, samples are taken from fixed locations in the base as well as from crewmembers themselves. The Mistacoba experiment will provide a profile of how microbes spread and evolve in the station - an isolated and confined environment - over time.

Water-recycling To protect the Antarctic environment, all waste materials must be removed from the Continent. For the Concordia Station, this means that all waste materials have to be appropriately treated. Regarding water, based on ESA life support technologies, ESA developed, together with PNRA and IPEV, a system to recycle the so-called 'grey water' collected from showers, laundry and dishwashing, which has been operating for a year in line with the requirements of the Concordia partners.

Other ESA activities for Concordia include the ongoing development of a system to monitor the health and well being of the crew, part of the Long Term Medical Survey (LMTS). Physiological parameters, collected using a vest-like item of clothing, will provide valuable data about the health and fitness of crew during long-term stays in harsh environments.

Real environment In mid-February the last plane of summer visitors will depart from Concordia leaving the crew to their own devices. "For those nine winter months the crew will experience extreme isolation," adds Oliver Angerer. "Concordia is a real operational environment, something we would never be able to simulate in a laboratory. This will enhance and complement our research and give us valuable insight we need to prepare for Mars."

3.5 Status of the Hayabusa

Source: JAXA News, December 14th, 2005 [34]

Hayabusa spacecraft currently undergoes the recovery operation to resume the communication with the ground stations. It was hit by an abrupt disturbing torque owing to the fuel leak that occurred before, and has been out of the ground contact since December 9th. The project team has a good expect to have the spacecraft resume the communication soon. However, the project is now not so sure to make the spacecraft return to earth in June of 2007 and has decided to lengthen the flight period for three years more to have it return to the Earth in June of 2010.

On December 8th, Usuda station observed the sudden shifts of the range-rate measurements at 4:13 UTC with the corresponding gradual decrease of signal intensity AGC (Automated Gain Controller) read. The measurement and the

intensity change slowly and are currently estimated due to the out-gassing effect that derived from the fuel leak-out at the end of last month. The leak occurred on November 26th and 27th. Since the beacon signal communication resumed on 29th, the project has made an effort to exclude the vapor gas of the fuel from the spacecraft. The project has by now identified the out-gassing has successfully been performed, as its exponential acceleration decay has shown so far.

On December 8th, the spacecraft was under the resume operation phase for the chemical propulsion, and was given a slow spin whose period is about six minutes. From the beginning of December, the project has introduced the Xenon gas thruster control strategy for emergency, replacing the chemical propulsion system. But the control capability of it was not enough strong for the spacecraft to withstand the disturbance on December 8th. Current estimation says the spacecraft may be in a large coning motion and that is why the spacecraft has not responded to the commands sent from the ground station.

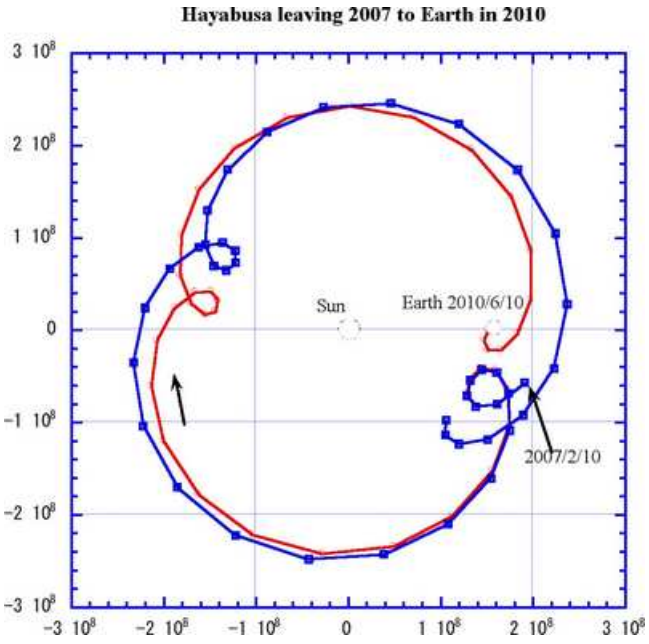

Figure 31: *New trajectory (red line) leaving Itokawa vicinity in spring of 2007, returning to Earth in June of 2010 is shown here. The Xenon gas consumption meets the current amount that remains. There will be some strategy needed and left for the operational discussion on how the attitude is protected against unexpected disturbance.*

The spacecraft has been out of communication since December 9th. Analysis predicting the attitude property relating to both the Sun and Earth shows that there will be high possibility counted on for the resumption of the communication from the ground for several months or more ahead. However, the spacecraft may have to undergo another long term baking cycle before it starts the return cruise operation using ion engines aboard. And it is concluded that the commencement of the return cruise during December is found difficult. The project has determined that the return cruise should start from 2007 so that the spacecraft can return to the Earth in June of 2010, three years later than the original plan, as long as no immediate resumption tales place very soon.

The spacecraft operation will shift from the normal mode to the rescue mode for several months to one year long. Long term predict indicates high probability of having the spacecraft communicated with the ground station again, with the spacecraft captured well in the beam width of the Usuda deep space antenna.(See Reference-3)

The spacecraft will take the advantage of Xenon gas attitude control again after enough length of baking operation. The Xenon gas that remains is adequate for the return cruise devised by the ion engines carried by Hayabusa.

The Hayabusa web page will report anything updated, as soon as it becomes available.

3.6 ESA accelerates towards a new space thruster

Source: ESA Press Release, December 13th, 2005 [35]

ESA has confirmed the principle of a new space thruster that may ultimately give much more thrust than today's electric propulsion techniques. The concept is an ingenious one, inspired by the northern and southern aurorae, the glows in the sky that signal increased solar activity. "Essentially the concept exploits a natural phenomenon we see taking place in space," says Dr Roger Walker of ESA's Advanced Concepts Team. "When the solar wind, a plasma' of electrified gas released by the Sun, hits the magnetic field of the Earth, it creates a boundary consisting of two plasma layers. Each layer has differing electrical properties and this can accelerate some particles of the solar wind across the boundary, causing them to collide with the Earth's atmosphere and create the aurora."

In essence, a plasma double layer is the electrostatic equivalent of a waterfall. Just as water molecules pick up energy as they fall between the two different heights, so electrically charged particles pick up energy as they travel through the layers of different electrical properties.

Researchers Christine Charles and Rod Boswell at the Australian National University in Canberra, first created plasma double layers in their laboratory in 2003 and realised their accelerating properties could enable new spacecraft thrusters. This led the group to develop a prototype called the Helicon Double Layer Thruster.

The new ESA study, performed as part of ESA's Ariadna academic research programme in association with Ecole Polytechnique, Paris, confirms the Australian findings by showing that under carefully controlled conditions, the double layer could be formed and remains stable, allowing the constant acceleration of charged particles in a beam. The study also confirmed that stable double layers could be created with different propellant gas mixtures.

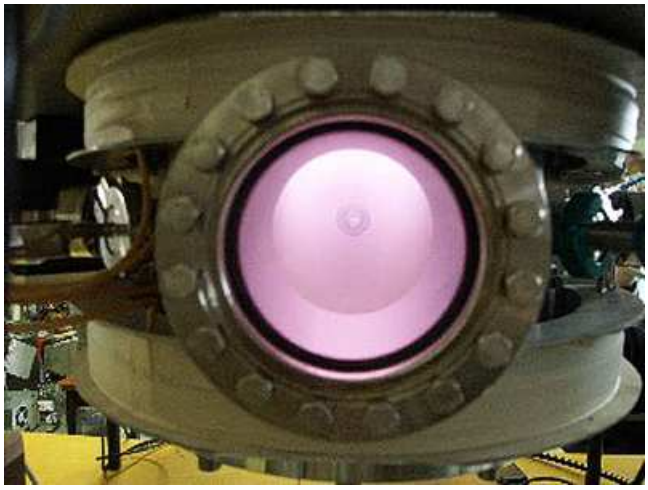

Figure 32: *Credits: LPTP, Ecole Polytechnique*

"The collaboration has been absolutely excellent," says Dr Pascal Chabert, of Laboratoire de Physique et Technologie des Plasmas, Ecole Polytechnique. "It has been a real kick-off for me and has given me lots of new ideas for plasma propulsion concepts to investigate with the Advanced Concepts Team. The new direction for our laboratory had led to a patent on a promising new electric propulsion device called an Electronegative Plasma Thruster."

To create the double layer, Chabert and colleagues created a hollow tube around which was wound a radio antenna. Argon gas was continuously pumped into the tube and the antenna transmitted helicoidal radio waves of 13 megahertz. This ionised the argon creating a plasma. A diverging magnetic field at the end of the tube then forced the plasma leaving the pipe to expand. This allowed two different plasmas to be formed, upstream within the tube and downstream, and so the double layer was created at their boundary. This accelerated further argon plasma from the tube into a supersonic beam, creating thrust.

Calculations suggest that a helicon double layer thruster would take up a little more space than the main electric thruster on ESA's SMART-1 mission, yet it could potentially deliver many times more thrust at higher powers of up to 100 kW whilst giving a similar fuel efficiency.

In the next steps, ESA will now construct a detailed computer simulation of the plasma in and around the thruster and use the laboratory results to verify its accuracy, so that the in-space performance can be fully assessed and larger high power experimental thrusters can be investigated in the future.

4 Internet websites

[1] http://www.jpl.nasa.gov/news/news.cfm?release=2005-176
[2] http://www.newsdesk.umd.edu/scitech/release.cfm?ArticleID=1178
[3] http://www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1801&mode=thread&order=0&thold=0
[4] http://chandra.harvard.edu/photo/2005/earth/
[5] http://www.esa.int/esaCP/SEMEHH8A9HE_index_0.html
[6] http://science.nasa.gov/headlines/y2005/22dec_lunartaurid.htm
[7] http://science.nasa.gov/headlines/y2005/07dec_moonstorms.htm
[8] http://www.berkeley.edu/news/media/releases/2005/12/14_methane.shtml
[9] http://www.colorado.edu/news/releases/2005/470.html
[10] http://www.esa.int/SPECIALS/Results_from_Mars_Express_and_Huygens/SEMA1UULWFE_0.html
[11] http://saturn.jpl.nasa.gov/multimedia/images/image-details.cfm?imageID=1901
[12] http://saturn.jpl.nasa.gov/news/features/feature20051216.cfm#
[13] http://www.nasa.gov/home/hqnews/2005/dec/HQ_05590_HST_Uranus_update.html
[14] http://www.cfeps.astrosci.ca/4b7/index.html

[15] http://www.keckobservatory.org/news/science/051220_irs46/051220.html
[16] http://uanews.org/cgi-bin/WebObjects/UANews.woa/1/wa/SRStoryDetails?ArticleID=12049
[17] http://www.eso.org/outreach/press-rel/pr-2005/pr-33-05.html
[18] http://hubblesite.org/newscenter/newsdesk/archive/releases/2005/36/full/
[19] http://www.innovations-report.com/html/reports/physics_astronomy/report-53103.html
[20] http://www.spitzer.caltech.edu/Media/happenings/20051212/
[21] http://newsroom.ucla.edu/page.asp?RelNum=6693
[22] http://www.mpifr-bonn.mpg.de/public/pr/pr-perseus_en.html
[23] http://www.cfa.harvard.edu/press/pr0539.html
[24] http://www.eso.org/outreach/press-rel/pr-2005/pr-32-05.html
[25] http://www.noao.edu/outreach/press/pr05/pr0511.html
[26] http://chandra.harvard.edu/photo/2005/perseus/
[27] http://subarutelescope.org/Pressrelease/2005/12/21/index.html
[28] http://www.esa.int/esaCP/SEMWAMVLWFE_index_0.html
[29] http://www.jhu.edu/news_info/news/home05/dec05/darkmatt.html
[30] http://www.esa.int/esaCP/SEMSRO8A9HE_index_0.html
[31] http://www.esa.int/esaCP/SEM9TL8A9HE_index_0.html
[32] http://www.esa.int/esaCP/SEMAPB8A9HE_index_0.html
[33] http://www.esa.int/esaCP/SEMBZA8A9HE_index_0.html
[34] http://www.isas.jaxa.jp/e/snews/2005/1214.shtml
[35] http://www.esa.int/esaCP/SEM6HSVLWFE_index_0.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

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

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

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

http://www.warwick.ac.uk/go/erwin_verwichte and follow link *amateur astronomy*

Erwin Verwichte