VENDELINUS ASTRONOMY NEWSLETTER

Vendelinus Astronomy Newsletter

January 2006

Erwin Verwichte
Erwin.Verwichte@warwick.ac.uk
http://www.warwick.ac.uk/go/erwin_verwichte/

Contents

1 Solar System

1.1 2005 Warmest Year in Over a Century

Source: NASA News, January 24th, 2006 [1]

The year 2005 was the warmest year in over a century, according to NASA scientists studying temperature data from around the world.

Climatologists at NASA's Goddard Institute for Space Studies (GISS) in New York City noted that the highest global annual average surface temperature in more than a century was recorded in their analysis for the 2005 calendar year.

Some other research groups that study climate change rank 2005 as the second warmest year, based on comparisons through November. The primary difference among the analyses, according to the NASA scientists, is the inclusion of the Arctic in the NASA analysis. Although there are few weather stations in the Arctic, the available data indicate that 2005 was unusually warm in the Arctic.

In order to figure out whether the Earth is cooling or warming, the scientists use temperature data from weather stations on land, satellite measurements of sea surface temperature since 1982, and data from ships for earlier years.

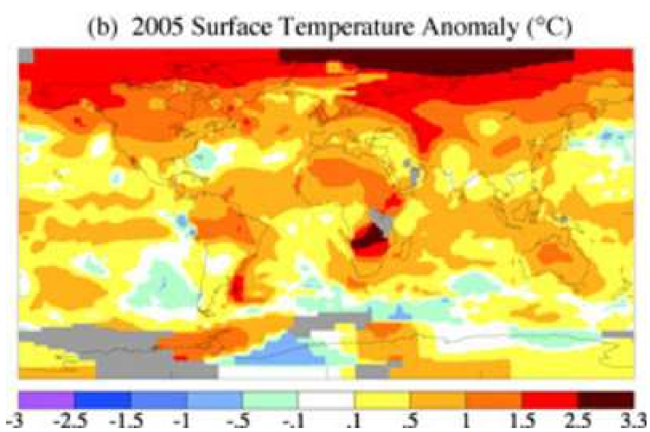

Figure 1: *This colorful global map of 2005 average temperatures shows areas that have warmed the most in red,*

to the areas that have cooled (in blue). Note that the Arctic has warmed significantly. These temperatures are from Dec. 2004 through Nov. 2005. Credit: NASA

Previously, the warmest year of the century was 1998, when a strong El Nino, a warm water event in the eastern Pacific Ocean, added warmth to global temperatures. However, what's significant, regardless of whether 2005 is first or second warmest, is that global warmth has returned to about the level of 1998 without the help of an El Nino.

The result indicates that a strong underlying warming trend is continuing. Global warming since the middle 1970s is now about 0.6 degrees Celsius (C) or about 1 degree Fahrenheit (F). Total warming in the past century is about 0.8 degrees C or about 1.4 degrees F.

”The five warmest years over the last century occurred in the last eight years,” said James Hansen, director of NASA GISS. They stack up as follows: the warmest was 2005, then 1998, 2002, 2003 and 2004.

Over the past 30 years, the Earth has warmed by 0.6 degrees C or 1.08 degrees F. Over the past 100 years, it has warmed by 0.8 degrees C or 1.44 degrees F.

Current warmth seems to be occurring nearly everywhere at the same time and is largest at high latitudes in the Northern Hemisphere. Over the last 50 years, the largest annual and seasonal warmings have occurred in Alaska, Siberia and the Antarctic Peninsula. Most ocean areas have warmed. Because these areas are remote and far away from major cities, it is clear to climatologists that the warming is not due to the influence of pollution from urban areas.

1.2 Space Probes Detect Enormous Natural Particle Accelerator

Source: NASA News, January 11th, 2006 [2]

A fleet of NASA and European Space Agency space-weather probes observed an immense jet of electrically charged particles in the solar wind between the Sun and Earth. The jet, at least 200 times as wide as the Earth, was powered by clashing magnetic fields in a process called ”magnetic reconnection”.

These jets are the result of natural particle accelerators dwarfing anything built on Earth. Scientists build miles-long particle accelerators on Earth to smash atoms together in an effort to understand the fundamental laws of physics.

Similar reconnection-powered jets occur in Earth's magnetic shield, producing effects that can disable orbiting spacecraft and cause severe magnetic storms on our planet, sometimes disrupting power stations.

The newly discovered interplanetary jets are far larger than those occurring within Earth's magnetic shield. The new observation is the first direct measurement indicating magnetic reconnection can happen on immense scales.

Understanding magnetic reconnection is fundamental to comprehending explosive phenomena throughout the Universe, such as solar flares (billion-megaton explosions in the Sun's atmosphere), gamma-ray bursts (intense bursts of radiation from exotic stars), and laboratory nuclear fusion. Just as a rubber band can suddenly snap when twisted too far, magnetic reconnection is a natural process by which the energy in a stressed magnetic field is suddenly released when it changes shape, accelerating particles (ions and electrons).

”Only with coordinated measurements by Sun-Earth connection spacecraft like ACE, Wind, and Cluster can we explore the space environment with unprecedented detail and in three dimensions,” says Dr. Tai Phan, lead author of the results, from the University of California, Berkeley. ”The near-Earth space environment is the only natural laboratory where we can make direct measurements of the physics of explosive magnetic phenomena occurring throughout the Universe.” Phan's article appears as the cover article in Nature on January 12.

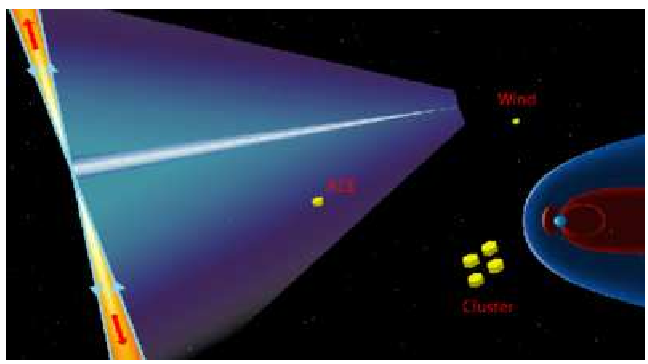

Figure 2: *This graphic represents NASA (ACE and Wind) and ESA (Cluster) spacecraft encountering solar particle jets spanning 2.5 million kilometers (about 1.5 million miles) in the solar wind. The particle jets (indicated by red arrows) are sandwiched between sheets of opposite magnetic fields (blue). Earth's magnetic environment is to the right in the background: The blue area represents a cross-section of the bow shock formed as the solar wind hits Earth's magnetic field, the red area is a cross-section of the magnetic field produced by the Earth, and the blue sphere*

in the center is the Earth. Credit: Matt Davis, Univ. of California, Berkeley

The solar wind is a dilute stream of electrically charged (ionized) gas that blows continually from the Sun. Because the solar wind is electrically charged, it carries solar magnetic fields with it. The solar wind arising from different places on the Sun carries magnetic fields pointing in different directions. Magnetic reconnection in the solar wind takes place when "sheets" of oppositely directed magnetic fields get pressed together. In doing so, the sheets connect to form an X-shaped cross-section that is then annihilated, or broken, to form a new magnetic line geometry. The creation of a different magnetic geometry produces extensive jets of particles streaming away from the reconnection site.

Until recently, magnetic reconnection was mostly reported in Earth's "magnetosphere", the natural magnetic shield surrounding Earth. It is composed of magnetic field lines generated by our planet, and defends us from the continuous flow of charged particles that make up the solar wind by deflecting them. However, when the interplanetary magnetic field lines carried by the solar wind happen to be in the opposite orientation to the Earth's magnetic field lines, reconnection is triggered and solar material can break through Earth's shield.

Some previous reconnection events measured in Earth's magnetosphere suggested that the phenomenon was intrinsically random and patchy in nature, extending not more than a few tens of thousands of kilometers (miles). However, "This discovery settles a long-standing debate concerning whether reconnection is intrinsically patchy, or whether instead it can operate across vast regions in space," said Dr. Jack Gosling of the University of Colorado, a co-author on the paper and a pioneer in research on reconnection in space.

The broader picture of magnetic reconnection emerged when six spacecraft the four European Space Agency Cluster spacecraft and NASA's Advanced Composition Explorer (ACE) and Wind probes were flying in the solar wind outside Earth's magnetosphere on 2 February 2002 and made a chance discovery. During a time span of about two and a half hours, all spacecraft observed in sequence a single huge stream of jetting particles, at least 2.5 million kilometers wide (about 1.5 million miles or nearly 200 Earth diameters), caused by the largest reconnection event ever measured directly.

"If the observed reconnection were patchy, one or more spacecraft most likely would have not encountered an accelerated flow of particles," said Phan. "Furthermore, patchy and random reconnection events would have resulted in different spacecraft detecting jets directed in different directions, which was not the case."

Since the spacecraft detected the jet for more than two hours, the reconnection must have been almost steady over at least that timespan. Another 27 large-scale reconnection events with the associated jets - were identified by ACE and Wind, four of which extended more than 50 Earth diameters, or 650,000 kilometers (about 400,000 miles). Thanks to these additional data, the team could conclude that reconnection in the solar wind is to be looked at as an extended and steady phenomenon.

The 2 February 2002 event could have been considerably larger, but the spacecraft were separated by no more than 200 Earth diameters, so its true extent is unknown. Two new NASA missions will help gauge the actual size of these events and examine them in more detail. The Solar Terrestrial Relations Observatory (STEREO) mission, scheduled for launch in May or June of 2006, will consist of two spacecraft orbiting the Sun on opposite sides of the Earth, separated by as much as 186 million miles (almost 300 million kilometers). Their primary mission is to observe Coronal Mass Ejections, billion-ton eruptions of electrically charged gas from the Sun, in three dimensions. However, the spacecraft will also be able to detect magnetic reconnection events occurring in the solar wind with instruments that measure magnetic fields and charged particles. The Magnetospheric Multi-Scale mission (MMS), planned for launch in 2013, will use four identical spacecraft in various Earth orbits to perform detailed studies of the cause of magnetic reconnection in the Earth's magnetosphere.

1.3 Life leaves subtle signature in the lay of the land, UC Berkeley researchers report

Source: UCBerkeley News, January 25th, 2006 [3]

One of the paradoxes of recent explorations of the Martian surface is that the more we see of the planet, the more it looks like Earth, despite a very big difference: Complex life forms have existed for billions of years on Earth, while Mars never saw life bigger than a microbe, if that.

"The rounded hills, meandering stream channels, deltas and alluvial fans are all shockingly familiar," said William E. Dietrich, professor of earth and planetary science at the University of California, Berkeley. "This caused us to ask: Can we tell from topography alone, and in the absence of the obvious influence of humans, that life pervades the Earth? Does life matter?"

In a paper published in the Jan. 26 issue of the journal Nature, Dietrich and graduate student J. Taylor Perron reported, to their surprise, no distinct signature of life in the landforms of Earth.

"Despite the profound influence of biota on erosion processes and landscape evolution, surprisingly,?there are no landforms that can exist only in the presence of life and, thus, an abiotic Earth probably would present no unfamiliar landscapes," said Dietrich.

Instead, Dietrich and Perron propose that life - everything from the lowest plants to large grazing animals - creates a subtle effect on the land not obvious to the casual eye: more of the "beautiful, rounded hills" typical of Earth's vegetated areas, and fewer sharp, rocky ridges.

"Rounded hills are the purest expression of life's influence on geomorphology," Dietrich said. "If we could walk across an Earth on which life has been eliminated, we would still see rounded hills, steep bedrock mountains, meandering rivers, etc., but their relative frequency would be different."

When a NASA scientist acknowledged to Dietrich a few years ago that he saw nothing in the Martian landscape that didn't have a parallel on Earth, Dietrich began thinking about what effects life does have on landforms and whether there is anything distinctive about the topography of planets with life, versus those without life.

"One of the least known things about our planet is how the atmosphere, the lithosphere and the oceans interact with life to create landforms," said Dietrich, a geomorphologist who for more than 33 years has studied the Earth's erosional processes. "A review of recent research in Earth history leads us to suggest that life may have strongly contributed to the development of the great glacial cycles, and even influenced the evolution of plate tectonics."

One of the main effects of life on the landscape is erosion, he noted. Vegetation tends to protect hills from erosion: Landslides often occur in the first rains following a fire. But vegetation also speeds erosion by breaking up the rock into smaller pieces.

"Everywhere you look, biotic activity is causing sediment to move down hill, and most of that sediment is created by life," he said. "Tree roots, gophers and wombats all dig into the soil and raise it, tearing up the underlying bedrock and turning it into rubble that tumbles downhill."

Because the shape of the land in many locations is a balance between river erosion, which tends to cut steeply into a slope's bedrock, and the biotically-driven spreading of soil downslope, which tends to round off the sharp edges, Dietrich and Perron thought that rounded hills would be a signature of life. This proved to be untrue, however, as their colleague Ron Amundson and graduate student Justine Owen, both of the campus's Department of Environmental Science, Policy and Management, discovered in the lifeless Atacama Desert in Chile, where rounded hills covered with soil are produced by salt weathering from the nearby ocean.

"There are other things on Mars, such as freeze-thaw activity, that can break rock" to create the rounded hills seen in photos taken by NASA's rovers, Perron said.

They also looked at river meanders, which on Earth are influenced by streamside vegetation. But Mars shows meanders, too, and studies on Earth have shown that rivers cut into bedrock or frozen ground can create meanders identical to those created by vegetation.

The steepness of river courses might be a signature, too, they thought: Coarser, less weathered sediment would erode into the streams, causing the river to steepen and the ridges to become higher. But this also is seen in Earth's mountains.

"It's not hard to argue that vegetation affects the pattern of rainfall and, recently, it has been shown that rainfall patterns affect the height, width and symmetry of mountains, but this would not produce a unique landform," Dietrich said. "Without life, there would still be asymmetric mountains."

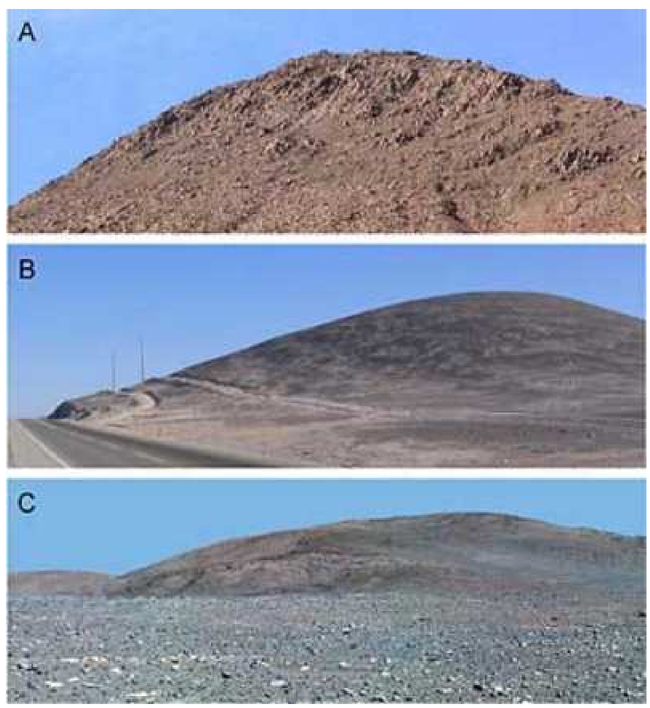

Figure 3: *Two hillslopes in the Atacama Desert of Chile: one of bedrock (A) and the other covered with soil (B)*

look amazingly like the Columbia Hills on Mars (C) once the yellowish grey Martian sky has been artificially colored blue and the red color of the rocks has been removed. (Mars image, acquired by the rover Spirit, courtesy of NASA/JPL/Cornell University)

Their conclusion, that the relative frequency of rounded versus angular landforms would change depending on the presence of life, won't be testable until elevation maps of the surfaces of other planets are available at resolutions of a few meters or less. "Some of the most salient differences between landscapes with and without life are caused by processes that operate at small scales," Perron said.

Dietrich noted that limited areas of Mars' surface have been mapped at two-meter resolution, which is better than most maps of the Earth. He is one of the leaders of a National Science Foundation (NSF)-supported project to map in high resolution the surface of the Earth using LIDAR (LIght Detection And Ranging) technology. Dietrich co-founded the National Center of Airborne Laser Mapping (NCALM), a joint project between UC Berkeley and the University of Florida to conduct LIDAR mapping showing not only the tops of vegetation, but also the bare ground as if denuded of vegetation. The research by Dietrich and Perron was funded by NSF's National Center for Earth-surface Dynamics, the NSF Graduate Research Fellowship Program and NASA's Astrobiology Institute.

1.4 Dust Found in Earth Sediment Traced to Breakup of the Asteroid Veritas 8.2 Million Years Ago

Source: Caltech News Release, January 18th, 2006 [4]

In a new study that provides a novel way of looking at our solar system's past, a group of planetary scientists and geochemists announce that they have found evidence on Earth of an asteroid breakup or collision that occurred 8.2 million years ago.

Reporting in the January 19 issue of the journal Nature, scientists from the California Institute of Technology, the Southwest Research Institute (SwRI), and Charles University in the Czech Republic show that core samples from oceanic sediment are consistent with computer simulations of the breakup of a 100-mile-wide body in the asteroid belt between Mars and Jupiter. The larger fragments of this asteroid are still orbiting the asteroid belt, and their hypothetical source has been known for years as the asteroid "Veritas."

Ken Farley of Caltech discovered a spike in a rare isotope known as helium 3 that began 8.2 million years ago and gradually decreased over the next 1.5 million years. This information suggests that Earth must have been dusted with an extraterrestrial source.

"The helium 3 spike found in these sediments is the smoking gun that something quite dramatic happened to the interplanetary dust population 8.2 million years ago," says Farley, the Keck Foundation Professor of Geochemistry at Caltech and chair of the Division of Geological and Planetary Sciences. "It's one of the biggest dust events of the last 80 million years."

Interplanetary dust is composed of bits of rock from a few to several hundred microns in diameter produced by asteroid collisions or ejected from comets. Interplanetary dust migrates toward the sun, and en route some of this dust is captured by the Earth's gravitational field and deposited on its surface.

Presently, more than 20,000 tons of this material accumulates on Earth each year, but the accretion rate should fluctuate with the level of asteroid collisions and changes in the number of active comets. By looking at ancient sediments that include both interplanetary dust and ordinary terrestrial sediment, the researchers for the first time have been able to detect major dust-producing solar system events of the past.

Because interplanetary dust particles are so small and rare in sediment-significantly less than a part per million-they are difficult to detect using direct measurements. However, these particles are extremely rich in helium 3, in comparison with terrestrial materials. Over the last decade, Ken Farley has measured helium 3 concentrations in sediments formed over the last 80 million years to create a record of the interplanetary dust flux.

To assure that the peak was not a fluke present at only one site on the seafloor, Farley studied two different localities: one in the Indian Ocean and one in the Atlantic. The event is recorded clearly at both sites.

To find the source of these particles, William F. Bottke and David Nesvorny of the SwRI Space Studies Department in Boulder, Colorado, along with David Vokrouhlicky of Charles University, studied clusters of asteroid orbits that are likely the consequence of ancient asteroidal collisions.

"While asteroids are constantly crashing into one another in the main asteroid belt," says Bottke, "only once in a great while does an extremely large one shatter."

The scientists identified one cluster of asteroid fragments whose size, age, and remarkably similar orbits made it a likely candidate for the Earth-dusting event. Tracking the orbits of the cluster backwards in time using computer models, they found that, 8.2 million years ago, all of its fragments shared the same orbital orientation in space. This event defines when the 100-mile-wide asteroid called Veritas was blown apart by impact and coincides with the spike in the interplanetary seafloor sediments Farley had found.

”The Veritas disruption was extraordinary,” says Nesvorny. ”It was the largest asteroid collision to take place in the last 100 million years.”

As a final check, the SwRI-Czech team used computer simulations to follow the evolution of dust particles produced by the 100-mile-wide Veritas breakup event. Their work shows that the Veritas event could produce the spike in extraterrestrial dust raining on the Earth 8.2 million years ago as well as a gradual decline in the dust flux.

”The match between our model results and the helium 3 deposits is very compelling,” Vokrouhlicky says. ”It makes us wonder whether other helium 3 peaks in oceanic cores can also be traced back to asteroid breakups.”

1.5 Hit and Run Planets

Source: Astrobiology Magazine, January 17th, 2006 [5]

Hit-and-run collisions between embryonic planets during a critical period in the early history of the Solar System may account for some previously unexplained properties of planets, asteroids, and meteorites, according to researchers at the University of California, Santa Cruz, who described their findings in the January 12 issue of the journal Nature.

The four ”terrestrial” or rocky planets (Earth, Mars, Venus, and Mercury) are the products of an initial period, lasting tens of millions of years, of violent collisions between planetary bodies of various sizes. Scientists have mostly considered these events in terms of the accretion of new material and other effects on the impacted planet, while little attention has been given to the impactor. (By definition, the impactor is the smaller of the two colliding bodies.)

But when planets collide, they don’t always stick together. About half the time, a planet-sized impactor hitting another planet-sized body will bounce off, and these hit-and-run collisions have drastic consequences for the impactor, said Erik Asphaug, associate professor of Earth sciences at UCSC and first author of the Nature paper.

”You end up with planets that leave the scene of the crime looking very different from when they came in–they can lose their atmosphere, crust, even the mantle, or they can be ripped apart into a family of smaller objects,” Asphaug said.

The remnants of these disrupted impactors can be found throughout the asteroid belt and among meteorites, which are fragments of other planetary bodies that have landed on Earth, he said. Even the planet Mercury may have been a hit-and-run impactor that had much of its outer layers stripped away, leaving it with a relatively large core and thin crust and mantle, Asphaug said. That scenario remains speculative, however, and requires additional study, he said.

Asphaug and postdoctoral researcher Craig Agnor used powerful computers to run simulations of a range of scenarios, from grazing encounters to direct hits between planets of comparable sizes. Coauthor Quentin Williams, professor of Earth sciences at UCSC, analyzed the outcomes of these simulations in terms of their effects on the composition and final state of the remnant objects.

The researchers found that even close encounters in which the two objects do not actually collide can severely affect the smaller object.

”As two massive objects pass near each other, gravitational forces induce dramatic physical changes–decompressing, melting, stripping material away, and even annihilating the smaller object,” Williams said. ”You can do a lot of physics and chemistry on objects in the Solar System without even touching them.”

A planet exerts enormous pressure on itself through self-gravity, but the gravitational pull of a larger object passing close by can cause that pressure to drop precipitously. The effects of this depressurization can be explosive, Williams said.

”It’s like uncorking the world’s most carbonated beverage,” he said. ”What happens when a planet gets decompressed by 50 percent is something we don’t understand very well at this stage, but it can shift the chemistry and physics all over the place, producing a complexity of materials that could very well account for the heterogeneity we see in meteorites.”

The formation of the terrestrial planets is thought to have begun with a phase of gentle accretion within a disk of gas and dust around the Sun. Embryonic planets gobbled up much of the material around them until the inner Solar System hosted around 100 Moon-sized to Mars-sized planets, Asphaug said. Gravitational interactions with each other and with Jupiter then tossed these protoplanets out of their circular orbits, setting off an era of giant impacts that probably lasted 30 to 50 million years, he said.

Scientists have used computers to simulate the formation of the terrestrial planets from hundreds of smaller bodies, but most of those simulations have assumed that when planets collide they stick, Asphaug said.

”We’ve always known that’s an approximation, but it’s actually not easy for planets to merge,” he said. ”Our calculations show that they have to be moving fairly slowly and hit almost head-on in order to accrete.”

It is easy for a planet to attract and accrete a much smaller object than itself. In giant impacts between planet-sized bodies, however, the impactor is comparable in size to the target. In the case of a Mars-size impactor hitting an Earth-size target, the impactor would be one-tenth the mass but fully one-half the diameter of the Earth, Asphaug said.

àle.jpg This is an image of the lunar highlands from the Consolidated Lunar Atlas, which was produced during the Apollo Era by the UA Lunar and Planetary Laboratory. Studies indicate this terrain was bombarded mostly by asteroids - not comets - that were flung into the inner solar system when the asteroid belt was destabilized by migrating giant planets. The Earth was similarly bombarded but geological activity has erased most evidence of that bombardment. The image was taken on 1 April 1966. Credit: LPL Space Imagery Center

”Imagine two planets colliding, one half as big as the other, at a typical impact angle of 45 degrees. About half of the smaller planet doesn’t really intersect the larger planet, while the other half is stopped dead in its tracks,” Asphaug said. ”So there is enormous shearing going on, and then you’ve got incredibly powerful tidal forces acting at close distances. The combination works to pull the smaller planet apart even as it’s leaving, so in the most severe cases the impactor loses a large fraction of its mantle, not to mention its atmosphere and crust.”

According to Agnor, the whole problem of planet formation is highly complex, and unraveling the role played by hit-and-run fragmenting collisions will require further study. By examining planetary collisions from the perspective of the impactor, however, the UCSC researchers have identified physical mechanisms that can explain many puzzling features of asteroids.

Hit-and-run collisions can produce a wide array of different kinds of asteroids, Williams said. ”Some asteroids look like small planets, not very disturbed, and at the other end of the spectrum are ones that look like iron-rich dog bones in space,” he said. ”This is a mechanism that can strip off different amounts of the rocky material that composes the crust and mantle. What’s left behind can range from just the iron-rich core through a whole suite of mixtures with different amounts of silicates.”

One of the puzzles of the asteroid belt is the evidence of widespread global melting of asteroids. Impact heating is inefficient because it deposits heat locally. It is not clear what could turn an asteroid into a big molten blob, but depressurization in a hit-and-run collision might do the trick, Asphaug said.

”If the pressure drops by a factor of two, you can go from something that is merely hot to something molten,” he said.

Depressurization can also boil off water and release gases, which would explain why many differentiated meteorites tend to be free of water and other volatile substances. These and other processes involved in hit-and-run collisions should be studied in more detail, Asphaug said.

”It’s a new mechanism for planetary evolution and asteroid formation, and it suggests a lot of interesting scenarios that warrant further study,” he said.

1.6 Moons Over the Kuiper Belt

Source: Astrobiology Magazine, January 18th, 2006 [6]

In the not-too-distant past, the planet Pluto was thought to be an odd bird in the outer reaches of the solar system because it has a moon, Charon, that was formed much like Earth’s own moon was formed. But Pluto is getting a lot of company these days. Of the four largest objects in the Kuiper belt, three have one or more moons.

”We’re now beginning to realize that Pluto is one of a small family of similar objects, nearly all of which have moons in orbit around them,” says Antonin Bouchez, a California Institute of Technology astronomer.

Bouchez discussed his work on the Kuiper belt at the winter meeting of the American Astronomical Society (AAS).

Bouchez says that the puzzle for planetary scientists is that, as a whole, the hundreds of objects now known to inhabit the Kuiper belt beyond the orbit of Neptune have only about an 11 percent chance of possessing their own satellites. But three of the four largest objects now known in the region have satellites, which means that different processes are at work for the large and small bodies.

Experts have been fairly confident for a decade or more that Pluto’s moon Charon was formed as the result of an impact, but that the planet seemed unique in this. According to computer models, Pluto was hit by an object roughly one-half its own size, vaporizing some of the planet’s material. A large piece, however, was cleaved off nearly intact, forming Pluto’s moon Charon.

Earth's moon is thought to have been formed in a similar way, though our moon most likely formed out of a hot disk of material left in orbit after such a violent impact.

Just in the last year, astronomers have discovered two additional moons for Pluto, but the consensus is still that the huge Charon was formed by a glancing blow with another body, and that all three known satellites-as well as anything else not yet spotted from Earth-were built up from the debris.

As for the other Kuiper belt objects, experts at first thought that the bodies acquired their moons only occasionally by snagging them through gravitational capture. For the smaller bodies, the 11 percent figure would be about right.

x̀ena.jpg Artist's concept of Xena and its moon. The sun and other planets appear in the distance. Credit: R. Hurt, IPAC

But the bigger bodies are another story. The biggest of all - and still awaiting designation as the tenth planet - is currently nicknamed "Xena." Discovered by Caltech's Professor of Planetary Science Mike Brown and his associates, Chad Trujillo of the Gemini Observatory and David Rabinowitz of Yale University, Xena is 25 percent larger than Pluto and is known to have at least one moon.

The second-largest Kuiper belt object is Pluto, which has three moons and counting. The third-largest is nicknamed "Santa" because of the time of its discovery by the Mike Brown team, and is known to have two moons.

"Santa is an odd one," says Bouchez. "You normally would expect moons to form in the same plane because they would have accreted from a disk of material in orbit around the main body.

"But Santa's moons are 40 degrees apart. We can't explain it yet."

The fourth-largest Kuiper belt object is nicknamed "Easterbunny" - again, because of the time the Brown team discovered it - and is not yet known to have a moon. But in April, Bouchez and Brown will again be looking at Easterbunny with the adaptive-optics rig on one of the 10-meter Keck telescopes, and a moon might very well turn up.

1.7 Pluto's moon Charon found to lack atmosphere

Source: MIT News, January 4th, 2006 [7]

If you want to learn something about a place that's billions of miles away, it helps to be in the right place at the right time.

Astronomers from MIT and Williams College were lucky enough to watch as Pluto's largest moon, Charon, passed in front of a star last summer. Based on their observations of the occultation, which lasted for less than a minute, the team reports new details about the moon in the Jan. 5 issue of Nature.

A second paper from another group, led by French astronomer Bruno Sicardy, also appears in this issue of Nature.

The MIT-Williams team was able to measure Charon's size to an unprecedented accuracy and determine that it has no significant atmosphere.

"The results provide insight into the formation and evolution of bodies in the outer solar system," said lead author Amanda Gulbis, a postdoctoral associate in MIT's Department of Earth, Atmospheric and Planetary Sciences.

Specifically, the team found that Charon has a radius of 606 kilometers, "plus or minus 8 kilometers to account for local topography or possible non-sphericity in Charon's shape," Gulbis said. That size, combined with mass measurements from Hubble Space Telescope data, show that the moon has a density roughly one-third that of the Earth. This reflects Charon's rocky-icy composition.

The team also found that the density of any atmosphere on the moon must be less than a millionth of that of the Earth. This argues against the theory that Pluto and Charon were formed by the cooling and condensing of the gas and dust known as the solar nebula. Instead, Charon was likely created in a celestial collision between an object and a proto-Pluto.

"Our observations show that there is no substantial atmosphere on Charon, which is consistent with an impact formation scenario," Gulbis said. Similar theories exist about the formation of the Earth-moon system.

The success of the MIT-Williams team in observing the Charon occultation bodes well for future adaptations of the technique the researchers used.

"We are eager to use (it) to probe for atmospheres around recently discovered Kuiper Belt objects that are Pluto-sized or even larger," said James Elliot, co-author of the Nature paper and a professor in MIT's Department of Earth, Atmospheric and Planetary Sciences and in the Department of Physics. Elliot has been observing stellar occultations by bodies in the solar system for more than three decades.

Jay Pasachoff, Williams College team leader and a professor in its Department of Astronomy, said, "It's remarkable that our group could be in the right place at the right time to line up a tiny body 3 billion miles away. The successful observations are quite a reward for all of the people who helped predict the event, constructed and integrated the equipment and traveled to the telescopes."

1.8 A Planet Colder Than It Should Be

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 3rd, 2006 [8]

Mercury is boiling. Mars is freezing. The Earth is just right. When it comes to the temperatures of the planets, it makes sense that they should get colder the farther away they are from the Sun. But then there is Pluto. It has been suspected that this remote world might be even colder than it should be. Smithsonian scientists now have shown this to be true.

Scientists continue to discuss whether Pluto is a planet or should be considered a refugee from the Kuiper belt. Whatever its classification, Pluto and its moon Charon are certain to harbor secrets about the early history of planet formation. Charon is roughly half the diameter of the planet itself, and they form a unique pair in our solar system. How they came to be together remains a mystery.

Located thirty times farther away from the Sun than the Earth, sunlight reaching the surface of Pluto is feeble at best, with daytime resembling dark twilight here at home. Pluto's temperature varies widely during the course of its orbit since Pluto can be as close to the sun as 30 astronomical units (AU) and as far away as 50 AU. (An AU is the average Earth-Sun distance of 93 million miles.) As Pluto moves away from the Sun, its thin atmosphere is expected to freeze and fall to the surface as ice.

Reflected sunlight gathered with instruments such as the Keck telescope in Hawaii and the Hubble Space Telescope suggested the surface of Pluto might be colder than it should be, unlike Charon's. However, no telescope capable of directly measuring their thermal emission (their heat) was able to peer finely enough to distinguish the two bodies. Their close proximity presented a formidable challenge since they are never farther apart than 0.9 arcseconds, about the length of a pencil seen from 30 miles away.

Figure 4: *In this artist's concept, Pluto and its moon Charon are seen from the surface of one of Pluto's newly discovered candidate satellites. Credit: David A. Aguilar (Harvard-Smithsonian Center for Astrophysics.*

Now, for the first time, Smithsonian astronomers using the Submillimeter Array (SMA) on Mauna Kea in Hawaii have taken direct measurements of thermal heat from both worlds and found that Pluto is indeed colder than expected, colder even than Charon.

"We all know about Venus and its runaway greenhouse effect," said Mark Gurwell of the Harvard-Smithsonian Center for Astrophysics (CfA), co-author on this study along with Bryan Butler of the National Radio Astronomy Observatory. "Pluto is a dynamic example of what we might call an anti-greenhouse effect. Nature likes to leave us with mysteries - and this was a big one."

During the observations, the SMA utilized its most extended configuration to obtain high-resolution interferometric data, allowing separate "thermometer" readings for Pluto and Charon. It found that the temperature of the ice-covered surface of Pluto was about 43 K (-382 degrees F) instead of the expected 53 K (-364 degrees F), as on nearby Charon. This fits the current model that the low temperature of Pluto is caused by equilibrium between the surface ice and its thin nitrogen atmosphere, not just with the incoming solar radiation. Sunlight (energy) reaching the surface of Pluto is used to convert some of the nitrogen ice to gas, rather than heat the surface. This is similar to the way evaporation of a liquid can cool a surface, such as sweat cooling your skin.

"These results are really exciting and fun as well," said Gurwell. "Imagine taking something's temperature from almost three billion miles away without making a house call!"

2 Astrophysics

2.1 Two new dusty planetary disks may be astrophysical mirrors of our Kuiper Belt

Source: UC Berkeley Press Release, January 19th, 2006 [9]

A survey by NASA's Hubble Space Telescope of 22 nearby stars has turned up two with bright debris disks that appear to be the equivalent of our own solar system's Kuiper Belt, a ring of icy rocks outside the orbit of Neptune and the source of short-period comets.

The debris disks encircling these stars fall into two categories - wide and narrow belts - that appear to describe all nine stars, including the sun, which are known to have debris disks linked to planet formation. In fact, the sharp outer edges of the narrow belts, such as the Kuiper Belt in our solar system, may be a tip-off to the existence of a star-like companion that continually grooms the edge, in the same way that shepherding moons trim the edges of debris rings around Saturn and Uranus.

Research astronomer Paul Kalas, professor of astronomy James Graham and graduate student Michael Fitzgerald of the University of California, Berkeley, along with Mark C. Clampin of Goddard Space Flight Center in Greenbelt, Md., will report their discovery and conclusions in the Jan. 20 issue of Astrophysical Journal Letters.

The newfound stellar disks, each about 60 light years from Earth, bring to nine the number of stars with dusty debris disks observable at visible wavelengths. The new ones are different, however, in that they are old enough - more than 300 million years - to have settled into stable configurations akin to the stable planet and debris orbits in our own solar system, which is 4.6 billion years old. The other seven, except for the sun, range from tens of millions to 200 million years old - young by solar standards.

In addition, the masses of the stars are closer to that of the sun.

"These are the oldest debris disks seen in reflected light, and are important because they show what the Kuiper Belt might look like from the outside," said Kalas, the lead researcher. "These are the types of stars around which you would expect to find habitable zones and planets that could develop life."

Most debris disks are lost in the glare of the central star, but the high resolution and sensitivity of the Hubble Space Telescope's Advanced Camera for Surveys has made it possible to look for these disks after blocking the light from the star. Kalas has discovered debris disks around two other stars (AU Microscopii and Fomalhaut) in the past two years, one of them with the Hubble telescope, and has studied details of most of the other known stars with disks.

"We know of 100-plus stars that have infrared emission in excess of that emitted from the star, and that excess thermal emission comes from circumstellar dust," Kalas said. "The hard part is obtaining resolved images that give spatial information. Now, two decades after they were first discovered, we are finally beginning to see the dust disks. These recent detections are really a tribute to all the hard work that went into upgrading Hubble's instruments during the last servicing mission."

The small sampling already shows that such disks fall into two categories: those with a broad belt, wider than about 50 astronomical units; and narrow ones with a width of between 20 and 30 AU and a sharp outer boundary, probably like our own Kuiper Belt. An astronomical unit, or AU, is the average distance between the Earth and sun, about 93 million miles. Our Kuiper Belt is thought to be narrow, extending from the orbit of Neptune at 30 AU to about 50 AU.

Most of the known debris disks seem to have a central area cleared of debris, perhaps by planets, which are likely responsible for the sharp inner edges of many of these belts.

Kalas and Graham speculate that stars also having sharp outer edges to their debris disks have a companion - a star or brown dwarf, perhaps - that keeps the disk from spreading outward, similar to the way that Saturn's moons shape the edges of many of the planet's rings.

"The story of how you make a ring around a planet could be the same as the story of making rings around a star," Kalas said. Only one of the nine stars is known to have a companion, but then, he said, no one has yet looked at most of these stars to see if they have faint companions at large distances from the primary star.

He suggests that a stray star passing by may have ripped off the edges of the original planetary disk, but a star-sized companion would be necessary to keep the remaining disk material, such as asteroids, comets and dust, from spreading outward.

If true, that would mean that the sun also has a companion keeping the Kuiper Belt confined within a sharp boundary. Though a companion star has been proposed before - most recently by UC Berkeley physics professor Richard Muller, who dubbed the companion Nemesis - no evidence has been found for such a companion.

A key uncertainty, Kalas said, is that while we can see many of the large planetesimals in our Kuiper Belt, we can barely detect the dust.

”Ironically, our own debris disk is the closest, yet we know the least about it,” he said. ”We would really like to know if dust in our Kuiper Belt extends significantly beyond the 50 AU edge of the larger objects. When we acquire this information, only then will we be able to place our sun correctly in the wide or narrow disk categories.”

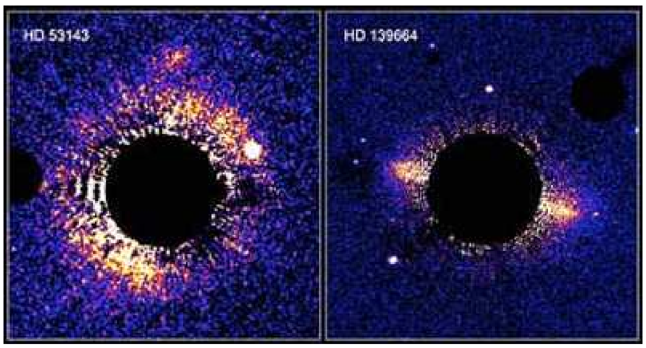

Figure 5: *These two bright debris disks of ice and dust appear to be the equivalent of our own solar system’s Kuiper Belt, a ring of icy rocks outside the orbit of Neptune and the source of short-period comets. The wide disk on the left, which is oblique to the line-of-sight, surrounds HD 53143, a K star slightly smaller than the Sun but about 1 billion years old. The narrow disk on the right, which is tipped nearly edge-on, encircles the star HD 139664, an F star slightly larger than the sun but only 300 million years old. The sharp outer edges of the narrow belt may be telltale evidence for the existence of an unseen companion that keeps debris gravitationally corralled, in the same way that shepherding moons trim the edges of debris rings around Saturn and Uranus. The false color images were taken with Hubble’s Advanced Camera for Surveys in September 2004. (Credit: NASA, ESA, P. Kalas/UC Berkeley)*

The star survey by Kalas, Graham, Fitzgerald and Clampin was one of the first projects of the Advanced Camera for Surveys aboard the Hubble, which was installed in 2002. The 22 stars were observed over a two year period ending in September 2004. The stars with debris disks detectable in visible light were HD 53143, a K star slightly smaller than the sun but about 1 billion years old, and HD 139664, an F star slightly larger than the sun but only 300 million years old.

”One is a K star and the other is an F star, therefore they are more likely to form planetary systems with life than the massive and short-lived stars such as beta-Pictoris and Fomalhaut,” he noted. ”When we look at HD 53143 and HD 139664, we may be looking at astrophysical mirrors to our Kuiper Belt.”

The disk around the oldest of the two stars, HD 53143, is wide like that of beta-Pictoris (beta-Pic), which was the first debris disk ever observed, about 20 years ago, and AU Microscopii (AU Mic), which Kalas discovered last year. Both beta-Pic and AU Mic are about 10 million years old.

The disk around HD 139664, however, is a narrow belt, similar to the disk around the star Fomalhaut, which Kalas imaged for the first time early last year. HD 139664 has a very sharp outer edge at 109 AU, similar to the sharp outer edge of our Kuiper Belt at 50 AU. The belt around HD 139664 starts about 60 AU from the star and peaks in density at 83 AU.

”If we can understand the origin of the sharp outer edge around HD 139664, we might better understand the history of our solar system,” Kalas said.

2.2 Icy Extrasolar Planet Discovered

Source: NSF News, January 25th, 2006 [10]

Using a relatively new planet-hunting technique that can spot worlds one-tenth the mass of our own, researchers have discovered a potentially rocky, icy body that may be the smallest planet yet found orbiting a star outside our solar system.

The discovery suggests the technique, gravitational microlensing, may be an exceptional technology for finding distant planets with traits that could support life.

”This is an important breakthrough in the quest to answer the question ’Are we alone?’” said Michael Turner, assistant director for the National Science Foundation (NSF) mathematical and physical sciences directorate. ”The team has discovered the most Earth-like planet yet, and more importantly, has demonstrated the power of a new technique that is sensitive to detecting habitable planets. It can probe a much greater portion of our galaxy and is complementary to other techniques.”

Figure 6: *ESO artist's rendition of the newly discovered extrasolar planet*

Located more than 20,000 light years away in the constellation Scorpio, close to the center of our Milky Way galaxy, planet OGLE-2005-BLG-390Lb is approximately five-and-a-half times the mass of Earth.

Orbiting a star one-fifth the mass of the sun at a distance almost three times that of Earth's orbit, the newly discovered planet is frigid: the estimated surface temperature is -364 degrees Fahrenheit (-220 degrees Celsius).

Although astronomers doubt this cold body could sustain organisms, researchers believe gravitational microlensing will bring opportunities for observing other rocky planets in the "habitable zones" of stars - regions where temperatures are perfect for maintaining liquid water and spawning life.

The discovery, authored by 73 collaborators from 32 institutions, appears in the Jan. 26 issue of the journal Nature.

OGLE (Optical Gravitational Lensing Experiment) project telescopes first observed the lensing event on July 11, 2005. In an attempt to catch microlensing events as they occur, OGLE scans most of the central Milky Way each night, discovering more than 500 microlensing events per year. But to detect the signature of low-mass planets, astronomers must observe these events much more frequently than OGLE's one survey per night.

So, when OGLE detected the July 11 lensing, its early warning system alerted fellow astronomers across the globe to microlensing event OGLE-2005-BLG-390 (for the 390th galactic bulge OGLE discovered in 2005). At that point, though, no one knew a planet would emerge.

"The only way to realize the full scientific benefit of our observations is to share the data with our competition," said co-author Bohdan Paczynski of Princeton University, who along with Andrzej Udalski of Warsaw University Observatory and their colleagues co-founded OGLE in 1997.

The telescopes of PLANET (Probing Lensing Anomalies NETwork) and RoboNet tracked the July 11 episode to completion, providing additional data and ultimately discovering the presence of a previously unknown planet. These telescopes collect observations more frequently in an attempt to detect the microlensing signature of planets.

"This discovery was possible because the sun never rises on the PLANET collaboration," said lead author and PLANET researcher Jean-Philippe Beaulieu of the Institut d'Astrophysique de Paris, France. "The global nature of the PLANET collaboration was crucial for obtaining data throughout the 24-hour planetary signal," he added.

Ironically, when preparing the final report, the researchers discovered that during its test runs, the new MOA (Microlensing Observations in Astrophysics) telescope, MOA-2, had taken additional measurements of the lensing event. The 6-foot (1.8-meter) aperture telescope has a wider field-of-view than the OGLE telescope, enabling it to observe 100 million stars many times per night. MOA-2 is one of several recent and future advancements that gravitational microlensing proponents hope will greatly increase the number of Earth-like planet discoveries.

OGLE also has plans to increase the field-of-view of its own telescope, and other microlensing groups are proposing to build a new telescope in South Africa. They have also proposed a space mission to see planets as small as Mars as well as free-floating planets that no longer orbit a host star.

"The new discovery provides a strong hint that low-mass planets may be much more common than Jupiters," said co-author and PLANET researcher David Bennett of the University of Notre Dame. Most extrasolar planets found so far have been Jupiter-sized.

"Microlensing should have discovered dozens of Jupiters by now if they were as common as these five-Earth-mass planets. This illustrates the primary strength of the gravitational microlensing method: its ability to find planets of low-mass," Bennett said.

Low-mass planets can yield signals that are too weak to detect with other methods. With microlensing, the signals of low-mass planets are rare but not weak. Thus, the rate of low-mass planet discoveries should increase dramatically if more microlensing events can be searched for planetary signals.

What is Microlensing?

The gravitational microlensing technique is based on a concept first discussed by Albert Einstein in the early 20th century. When astronomers observe a star, the light waves generally travel straight from the star to the telescope. However, if another star passes directly in between, even if great distances separate the two, the gravity of the nearer object acts like a lens and magnifies the incoming light.

Telescopes cannot resolve the details of the magnified image, but they do notice a peak in light intensity, and when a planet is present around the closer star, the planet's gravity adds a small peak of its own.

Astronomers can use those features to determine how large the planet is and how far away it is from its star. This method is 50 times more likely to detect planets of approximately twice the mass of Jupiter than it is to detect planets closer to the mass of Earth. Even relatively tiny, low-mass objects can give a strong peak signal if alignment is perfect.

Of the more than 150 planets discovered to date, almost all were discovered using a different technique, the radial velocity method. Stars with planets can wobble from the effect of their planets' gravity, and astronomers can use the wobble to determine the size and orbit of the objects. While incredibly effective, existing technology utilizing this method can find only large, Jupiter-like planets or smaller planets that orbit too close to their host stars to harbor life.

Because the newly discovered planet is only the third astronomers have detected using gravitational microlensing and already they have found a small, rocky body, the researchers believe there is a strong likelihood that rocky planets may be even more common than their gas-giant brethren. This prediction would agree with one of the models for solar system formation, core accretion, which suggests that small, rocky, "failed Jupiters" should be far more common than the massive gaseous planets.

2.3 Planetary Systems Can Form Around Binary Stars

Source: Carnegie Institute Press Release, January 10th, 2006 [11]

New theoretical work shows that gas-giant planet formation can occur around binary stars in much the same way that it occurs around single stars like the Sun. The work is presented today by Dr. Alan Boss of the Carnegie Institution's Department of Terrestrial Magnetism (DTM) at the American Astronomical Society meeting in Washington, DC. The results suggest that gas-giant planets, like Jupiter, and habitable Earth-like planets could be more prevalent than previously thought. A paper describing these results has been accepted for publication in the Astrophysical Journal.

"We tend to focus on looking for other solar systems around stars just like our Sun," Boss says. "But we are learning that planetary systems can be found around all sorts of stars, from pulsars to M dwarfs with only one third the mass of our Sun."

Two out of every three stars in the Milky Way is a member of a binary or multiple star system, in which the stars orbit around each other with separations that can range from being nearly in contact (close binaries) to thousands of light-years or more (wide binaries). Most binaries have separations similar to the distance from the Sun to Neptune (30 AU, where 1 AU = 1 astronomical unit = 150 million kilometers–the distance from the Earth to the Sun).

It has not been clear whether planetary system formation could occur in typical binary star systems, where the strong gravitational forces from one star might interfere with the planet formation processes around the other star, and vice versa. Previous theoretical work had suggested, in fact, that typical binary stars would not be able to form planetary systems. However, planet hunters have recently found a number of gas-giant planets in orbit around binary stars with a range of separations.

Boss found that if the shock heating resulting from the gravitational forces from the companion star is weak, then gas-giant planets are able to form in planet-forming disks in much the same way as they do around single stars. The planet-forming disk would remain cool enough for ice grains to stay solid and thus permit the growth of the solid cores that must reach multiple-Earth-mass size for the conventional mechanism of gas-giant planet formation (core accretion) to succeed.

Boss' models show even more directly that the alternative mechanism for gas-giant planet formation (disk instability) can proceed just as well in binary star systems as around single stars, and in fact may even be encouraged by the gravitational forces of the other star. In Boss' new models, the planet-forming disk in orbit around one of the stars is quickly driven to form dense spiral arms, within which self-gravitating clumps of gas and dust form and begin the process of contracting down to planetary sizes. The process is amazingly rapid, requiring less than 1,000 years for dense clumps to form in an otherwise featureless disk. There would be plenty of room for Earth-like planets to form closer to the central star after the gas-giant planets have formed, in much the same way our own planetary system is thought to have formed.

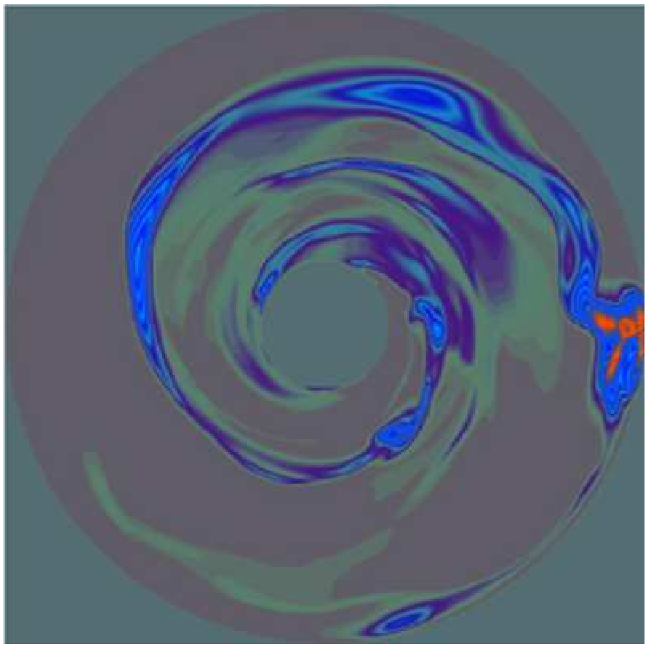

Figure 7: *Dense clumps capable of forming gas-giant planets form faster in the binary star disk than in the single star disk.*

Boss points out, ”This result may have profound implications in that it increases the likelihood of the formation of planetary systems resembling our own, because binary stars are the rule in our galaxy, not the exception.” If binary stars can shelter planetary systems composed of outer gas-giant planets and inner Earth-like planets, then the likelihood of other habitable worlds suddenly becomes roughly three times more probable–up to three times as many stars could be possible hosts for planetary systems similar to our own. NASA’s plans to search for and characterize Earth-like planets in the next decade would then be that much more likely to succeed.

One of the key remaining questions about the theoretical models is the correct amount of shock heating inside the planet-forming disk, as well as the more general question of how rapidly the disk is able to cool. Boss and other researchers are actively working to better understand these heating and cooling processes. Given the growing observational evidence for gas-giant planets in binary star systems, the new results suggest that shock heating in binary disks cannot be too large, or it would prevent gas-giant planet formation.

2.4 Rapidly Spinning Star Vega has Cool Dark Equator

Source: NOAO News, Janaury 10th, 2006 [12]

Strong darkening observed around the equator of Vega suggests that the fifth brightest star in Earth’s sky has a huge temperature difference of 4,000 degrees Fahrenheit from its cool equatorial region to its hot poles.

Models of the star based on these observations suggest that Vega is rotating at 92 percent of the angular velocity that would cause it to physically break apart, an international team of astronomers announced today in Washington, DC, at the 207th meeting of the American Astronomical Society.

This result confirms the idea that very rapidly rotating stars are cooler at their equators and hotter at their poles, and it indicates that the dusty debris disk known to exist around Vega is significantly less illuminated by the star?s light than previously recognized.

”These findings are significant because they resolve some confusing measurements of the star, and they should help us gain a much better understanding of Vega’s circumstellar debris disk,” says Jason P. Aufdenberg, the Michelson Postdoctoral Fellow at the National Optical Astronomy Observatory in Tucson, Arizona.

This debris disk arises mainly from the collision of rocky asteroid-like bodies. ”The spectrum of Vega as viewed from its equatorial plane, the same plane as the debris disk, should be about half as luminous as the spectrum viewed from the pole, based on these new results,” Aufdenberg explains.

The team obtained high-precision interferometric measurements of the bright standard star Vega using the Center for High Angular Resolution Astronomy (CHARA) Array, a collection of six 1-meter telescopes located on Mount Wilson, California, and operated by Georgia State University.

With a maximum baseline of 330 meters (1,083 feet), the CHARA Array is capable of resolving details as small as 200 micro-arcseconds, equivalent to the angular size of a nickel seen from a distance of 10,000 miles. The CHARA Array fed the starlight of Vega to the Fiber Linked Unit for Optical Recombination (FLUOR) instrument, developed by the Laboratoire d’Etudes Spatiales et d’Instrumentation en Astrophysique of the Observatoire de Paris.

One major consequence of Vega’s rapid rotation is a significant drop in the effective atmospheric temperature by approximately 2,300 Kelvin (4,000 degrees Fahrenheit) from the pole to the equator. This effect, known as ”gravity darkening," was first predicted by theoretical astronomer E. Hugo von Zeipel in 1924.

The CHARA/FLUOR measurements of the brightness distribution of Vega's surface also show it to be strongly "limb darkened." Limb darkening refers to the diminishing brightness in the image of a star from the center of the image to the edge or "limb" of the image.

v̀ega.gif This artist's concept contrasts Vega with our own Sun. Credit: J. Aufdenberg and NOAO/AURA/NSF

The new measurements are consistent with the "pole-on" model for Vega first proposed by Richard O. Gray of Appalachian State University, which proposes that Vega?s pole of rotation points toward Earth. The pole-on view of Vega means that the relatively cool equator corresponds to the limb of the star, such that the gravity-darkening effect further enhances the limb-darkening effect.

The CHARA/FLUOR data support the pole-on, gravity darkened model for Vega by showing that Vega's limb darkening is 2.5 times stronger at a wavelength of 2.2 microns than expected for a star with a single effective atmosphere temperature. Archival observations from the International Ultraviolet Explorer indicate that this model for Vega is not complete. At far ultraviolet wavelengths, below 140 nanometers, the model is generally too bright.

Located at a distance of 25 light-years from Earth in the constellation Lyra, Vega rotates about its axis once every 12.5 hours. For comparison, the Sun's average rotation period is approximately 27 Earth days. Vega is about 2.5 times more massive than the Sun, and 54 times brighter.

At Vega's rapid rate of rotation, the star's atmosphere is distorted, bulging 23 percent wider at its equator compared to its poles. This type of rotational distortion can be seen in images of the planet Saturn, where the planet's equatorial diameter is roughly 10 percent wider than the polar diameter. A direct measurement of Vega's rotational distortion is hidden by its pole-on appearance. However, the accurate angular diameter and darkening measured by CHARA/FLUOR are consistent with this distortion.

2.5 There's More to the North Star Than Meets the Eye

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 9th, 2006 [13]

We tend to think of the North Star, Polaris, as a steady, solitary point of light that guided sailors in ages past. But there is more to the North Star than meets the eye - two faint stellar companions. The North Star is actually a triple star system. And while one companion can be seen easily through small telescopes, the other hugs Polaris so tightly that it has never been seen directly - until now.

By stretching the capabilities of NASA's Hubble Space Telescope to the limit, astronomers have photographed the close companion of Polaris for the first time. They presented their findings today in a press conference at the 207th meeting of the American Astronomical Society in Washington, DC.

"The star we observed is so close to Polaris that we needed every available bit of Hubble's resolution to see it," said Smithsonian astronomer Nancy Evans (Harvard-Smithsonian Center for Astrophysics).

The companion proved to be less than two-tenths of an arcsecond from Polaris - an incredibly tiny angle equivalent to the apparent diameter of a quarter located 19 miles away. At the system's distance of 430 light-years, that translates into a physical separation of about 2 billion miles.

"The brightness difference between the two stars made it even more difficult to resolve them," stated Howard Bond of the Space Telescope Science Institute (STScI). Polaris is a supergiant more than two thousand times brighter than the Sun, while its companion is a main-sequence star. "With Hubble, we've pulled the North Star's companion out of the shadows and into the spotlight."

By watching the motion of the companion star, Evans and her colleagues expect to learn not only the stars' orbits but also their masses. Measuring the mass of a star is one of the most difficult tasks facing stellar astronomers.

Astronomers want to determine the mass of Polaris accurately because it is the nearest Cepheid variable star. Cepheids are used to measure the distance to galaxies and the expansion rate of the universe, so it is essential to understand their physics and evolution. Knowing their mass is the most important ingredient in this understanding.

"Studying binary stars is the best available way to measure the masses of stars," said science team member Gail Schaefer of STScI.

Figure 8: *There is more to Polaris than meets the eye - two faint stellar companions. The North Star is actually a triple star system. And while one companion (at top in this artist's concept) can be seen easily through small telescopes, the other hugs Polaris so tightly that it has never been seen directly - until now. By stretching the capabilities of NASA's Hubble Space Telescope to the limit, Smithsonian astronomer Nancy Evans and her colleagues have photographed the close companion of Polaris (seen here just above bright Polaris itself) for the first time. (Image not to scale.) Credit: Greg Bacon (STScI)*

"We only have the binary stars that nature provided us," added Bond. "With the best instruments like Hubble, we can push farther into space and study more of them up close."

The researchers plan to continue observing the Polaris system for several years. In that time, the movement of the small companion in its 30-year orbit around the primary should be detectable.

"Our ultimate goal is the get an accurate mass for Polaris," said Evans. "To do that, the next milestone is to measure the motion of the companion in its orbit."

2.6 Most Milky Way Stars Are Single

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 31th, 2006 [14]

Common wisdom among astronomers holds that most star systems in the Milky Way are multiple, consisting of two or more stars in orbit around each other. Common wisdom is wrong. A new study by Charles Lada of the Harvard-Smithsonian Center for Astrophysics (CfA) demonstrates that most star systems are made up of single stars. Since planets probably are easier to form around single stars, planets also may be more common than previously suspected.

Astronomers have long known that massive, bright stars, including stars like the sun, are most often found to be in multiple star systems. This fact led to the notion that most stars in the universe are multiples. However, more recent studies targeted at low-mass stars have found that these fainter objects rarely occur in multiple systems. Astronomers have known for some time that such low-mass stars, also known as red dwarfs or M stars, are considerably more abundant in space than high-mass stars.

By combining these two facts, Lada came to the realization that most star systems in the Galaxy are composed of solitary red dwarfs.

"By assembling these pieces of the puzzle, the picture that emerged was the complete opposite of what most astronomers have believed," said Lada.

Among very massive stars, known as O- and B-type stars, 80 percent of the systems are thought to be multiple, but these very bright stars are exceedingly rare. Slightly more than half of all the fainter, sun-like stars are multiples. However, only about 25 percent of red dwarf stars have companions. Combined with the fact that about 85 percent of all stars that exist in the Milky Way are red dwarfs, the inescapable conclusion is that upwards of two-thirds of all star systems in the Galaxy consist of single, red dwarf stars.

The high frequency of lone stars suggests that most stars are single from the moment of their birth. If supported by further investigation, this finding may increase the overall applicability of theories that explain the formation of single, sun-like stars. Correspondingly, other star-formation theories that call for most or all stars to begin their lives in multiple-star systems may be less relevant than previously thought.

Figure 9: *This artist's conception shows a rocky planet orbiting around a red dwarf star. Such planets may be more common than astronomers realized, since single red dwarfs are the most abundant stars in the galactic disk. Credit: ESO*

”It's certainly possible for binary star systems to 'dissolve' into two single stars through stellar encounters,” said astronomer Frank Shu of National Tsing Hua University in Taiwan, who was not involved with this discovery. ”However, suggesting that mechanism as the dominant method of single-star formation is unlikely to explain Lada's results.”

Lada's finding implies that planets also may be more abundant than astronomers realized. Planet formation is difficult in binary star systems where gravitational forces disrupt protoplanetary disks. Although a few planets have been found in binaries, they must orbit far from a close binary pair, or hug one member of a wide binary system, in order to survive. Disks around single stars avoid gravitational disruption and therefore are more likely to form planets.

Interestingly, astronomers recently announced the discovery of a rocky planet only five times more massive than Earth. This is the closest to an Earth-size world yet found, and it is in orbit around a single red dwarf star.

”This new planet may just be the tip of the iceberg,” said Lada. ”Red dwarfs may be a fertile new hunting ground for finding planets, including ones similar in mass to the earth.”

”There could be many planets around red dwarf stars,” stated astronomer Dimitar Sasselov of CfA. ”It's all in the numbers, and single red dwarfs clearly exist in great numbers.”

”This discovery is particularly exciting because the habitable zone for these stars - the region where a planet would be the right temperature for liquid water - is close to the star. Planets that are close to their stars are easier to find. The first truly Earth-like planet we discover might be a world orbiting a red dwarf,” added Sasselov.

2.7 Astronomers find magnetic Slinky in Orion

Source: UC Berkeley News, January 12th, 2006 [15]

Astronomers announced today (Thursday, Jan. 12) what may be the first discovery of a helical magnetic field in interstellar space, coiled like a snake around a gas cloud in the constellation of Orion.

”You can think of this structure as a giant, magnetic Slinky wrapped around a long, finger-like interstellar cloud,” said Timothy Robishaw, a graduate student in astronomy at the University of California, Berkeley. ”The magnetic field lines are like stretched rubber bands; the tension squeezes the cloud into its filamentary shape.”

Astronomers have long hoped to find specific cases in which magnetic forces directly influence the shape of interstellar clouds, but according to Robishaw, ”telescopes just haven't been up to the task ... until now.”

The findings provide the first evidence of the magnetic field structure around a filamentary-shaped interstellar cloud known as the Orion Molecular Cloud.

Today's announcement by Robishaw and Carl Heiles, UC Berkeley professor of astronomy, was made during a presentation at the American Astronomical Society meeting in Washington, D.C.

Interstellar molecular clouds are the birthplaces of stars, and the Orion Molecular Cloud contains two such stellar nurseries - one in the belt and another in the sword of the Orion constellation. Interstellar clouds are dense regions embedded in a much lower-density external medium, but the ”dense” interstellar clouds are, by Earth standards, a perfect vacuum. In combination with magnetic forces, it's the large size of these clouds that makes enough gravity to pull them together to make stars.

Astronomers have known for some time that many molecular clouds are filamentary structures whose shapes are suspected to be sculpted by a balance between the force of gravity and magnetic fields. In making theoretical models of these clouds, most astrophysicists have treated them as spheres rather than finger-like filaments. However, a theoretical treatment published in 2000 by Drs. Jason Fiege and Ralph Pudritz of McMaster University suggested that when treated properly, filamentary molecular clouds should exhibit a helical magnetic field around the long axis of the cloud. This is the first observational confirmation of this theory.

”Measuring magnetic fields in space is a very difficult task,” Robishaw said, ”because the field in interstellar space is very weak and because there are systematic measurement effects that can produce erroneous results.”

The signature of a magnetic field pointing towards or away from the Earth is known as the Zeeman effect and is observed as the splitting of a radio frequency line.

”An analogy would be when you’re scanning the radio dial and you get the same station separated by a small blank space,” Robishaw explained. ”The size of the blank space is directly proportional to the strength of the magnetic field at the location in space where the station is being broadcast.”

The signal, in this case, is being broadcast at 1420 MHz on the radio dial by interstellar hydrogen - the simplest and most abundant atom in the universe. The transmitter is located 1750 light years away in the Orion constellation.

The antenna that received these radio transmissions is the National Science Foundation’s Green Bank Telescope (GBT), operated by the National Radio Astronomy Observatory. The telescope, 148 meters (485 feet) tall and with a dish 100 meters (300 feet) in diameter, is located in West Virginia where 13,000 square miles have been set aside as the National Radio Quiet Zone. This allows radio astronomers to observe radio waves coming from space without interference from manmade signals.

Using the GBT, Robishaw and Heiles observed radio waves along slices across the Orion Molecular Cloud and found that the magnetic field reversed its direction, pointing towards the Earth on the upper side of the cloud and away from it on the bottom. They used previous observations of starlight to inspect how the magnetic field in front of the cloud is oriented. (There is no way to gain information about what’s happening behind the cloud since the cloud is so dense that neither optical light nor radio waves can penetrate it.) When they combined all available measurements, the picture emerged of a corkscrew pattern wrapping around the cloud.

”These results were incredibly exciting to me for a number of reasons,” Robishaw said. ”There’s the scientific result of a helical field structure. Then, there’s the successful measurement: This type of observation is very difficult, and it took dozens of hours on the telescope just to understand how this enormous dish responds to the polarized radio waves that are the signature of a magnetic field.”

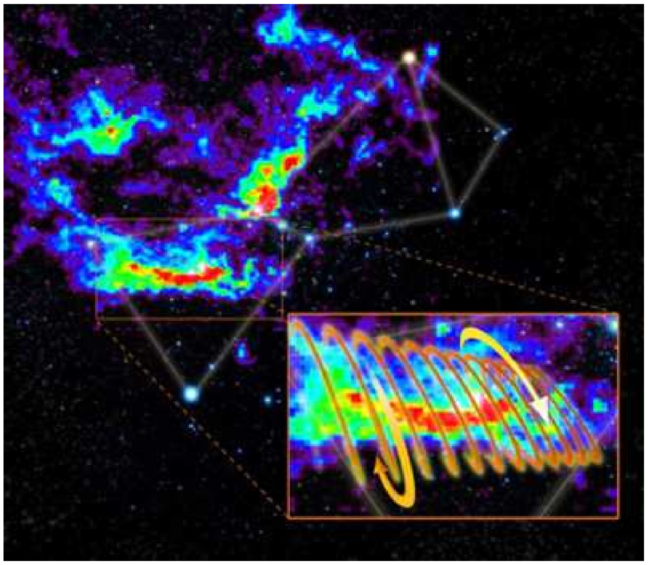

Figure 10: *The Orion Molecular Cloud superimposed on the Orion constellation, with the orange star Betelgeuse at the top corner and Rigel at the bottom. The inset shows the Slinky-like coils of the helical magnetic field surrounding the filamentary cloud. (Credit: Saxton, Dame, Hartmann, Thaddeus; NRAO/AUI/NSF)*

The results of these investigations suggested to Robishaw and Heiles that the GBT is not only unparalleled among large radio telescopes for measuring magnetic fields, but it is the only one that can reliably detect weak magnetic fields.

Heiles cautioned that there is one possible alternative explanation for the observed magnetic field structure: The field might be wrapped around the front of the cloud.

”It’s a very dense object,” Heiles said. ”It also happens to lie inside the hollowed-out shell of a very large shock wave that was formed when many stars exploded in the neighboring constellation of Eridanus.”

That shock wave would have carried the magnetic field along with it, he said, ”until it reached the molecular cloud! The magnetic field lines would get stretched across the face of the cloud and wrapped around the sides. The signature of such a configuration would be very similar to what we see now. What really convinces us that this is a helical field is that there seems to be a constant pitch angle to the field lines across the face of the cloud.”

However, the situation can be clarified by further research. Robishaw and Heiles plan to extend their measurements in this cloud and others using the GBT. They will also collaborate with Canadian colleagues to use starlight to measure the field across the face of this and other clouds.

”The hope is to provide enough evidence to understand what the true structure of this magnetic field is,” said Heiles. ”A clear understanding is essential in order to truly understand the processes by which molecular clouds form stars in the Milky Way galaxy.”

2.8 Astronomers Spot The Great Orion Nebula's Successor

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 11th, 2006 [16]

Astronomers announced today that they have found the next Orion Nebula. Known as W3, this glowing gas cloud in the constellation Cassiopeia has just begun to shine with newborn stars. Shrouds of dust currently hide its light, but this is only a temporary state. In 100,000 years - a blink of the eye in astronomical terms - it may blaze forth, delighting stargazers around the world and becoming the Grand Nebula in Cassiopeia..

”The Grand Nebula in Cassiopeia will appear in our sky just as the Great Nebula in Orion fades away,” said Smithsonian astronomer Tom Megeath (Harvard-Smithsonian Center for Astrophysics), who made the announcement in a press conference at the 207th meeting of the American Astronomical Society. ”Even better, its home constellation is visible year-round from much of the northern hemisphere.”

The Orion Nebula is one of the most famous and easily viewed deep-sky sights. It holds special significance for researchers as the nearest region of massive star formation.

The star formation process begins in a dark cloud of cold gas, where small lumps of material begin to contract. Gravity draws the gas into hot condensations that ignite and become stars. The most massive stars produce hot winds and intense light that blast away the surrounding cloud. But during the process of destruction, stellar radiation lights up the cloud, creating a bright nebula for stargazers to admire.

”Orion may seem very peaceful on a cold winter night, but in reality it holds very massive, luminous stars that are destroying the dusty gas cloud from which they formed,” said Megeath. ”Eventually, the cloud of material will disperse and the Orion Nebula will fade from our sky.”

Orion's Trapezium

Of special interest to Megeath is a system of four bright, massive stars at the center of Orion known as the Trapezium. These stars bathe the entire nebula with powerful ultraviolet radiation, lighting up nearby gas. Even a modest telescope reveals the Trapezium surrounded by billowing ripples of matter gleaming eerily across the vastness of space. Yet the Trapezium is only the tip of the iceberg, surrounded by more than 1000 faint, low-mass stars similar to the Sun.

”The question we want to answer is: why are these massive stars sitting in the center of the cluster?” said Megeath.

There are two competing theories to explain the Trapezium's location. One holds that the Trapezium stars formed apart from each other but descended to the center of the cluster, ejecting a spray of low-mass stars in the process. The other leading theory is that the Trapezium stars formed together in the center of the cluster and have not moved from their birthplace.

”Obviously, we can't go back in time and look at the Trapezium when it was still forming, so we try to find younger examples in the sky,” explained Megeath.

Such proto-Trapeziums would still be buried in their birth cocoons, hidden to visible-light telescopes but detectable by radio and infrared telescopes. Searches at those longer wavelengths have identified many regions where massive stars are forming, but could not determine whether the protostars were alone or in collections of four or more stars that could be considered Trapeziums.

Cassiopeia's Trapezium

Megeath and his colleagues examined one such protostellar clump in W3 using the NICMOS instrument on NASA's Hubble Space Telescope and the National Science Foundation's Very Large Array. They discovered that the object, which was thought to be a binary star, actually contained four or five young, massive protostars, making it a likely proto-Trapezium.

These protostars are so young that they appear to be still growing by accreting gas from the surrounding cloud. All of the stars crowd into a small area only about 500 billion miles across (just under one-tenth of a light-year), making this cluster more than 100,000 times denser than stars in the Sun's neighborhood. This suggests that the massive stars in Orion's Trapezium formed together in the center of the cluster.

Figure 11: *This artist's depiction simulates the view that amateur astronomers on Earth might enjoy 100,000 years from now, when the Grand Nebula in Cassiopeia lights up. Credit: David A. Aguilar (Harvard-Smithsonian Center for Astrophysics)*

The same physical processes that have carved the Orion Nebula now are molding the W3 nebula. The massive stars in this compact group are starting to eat away at the surrounding gas with ultraviolet radiation and fast stellar outflows. Eventually, they will destroy their dense cocoon and emerge to form a new Trapezium in the center of W3. However, the final form of the nebula and the time that it will reach maximum brilliance are uncertain.

"Who knows, in 100,000 years the emerging Grand Nebula in Cassiopeia may replace the fading Orion Nebula as a favorite object for amateur astronomers," said Megeath. "In the meantime, I think it will be a favorite target for professional astronomers trying to solve the riddle of massive star formation."

2.9 Two Exiled Stars Are Leaving Our Galaxy Forever

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 26th, 2006 [17]

TV reality show contestants aren't the only ones under threat of exile. Astronomers using the MMT Observatory in Arizona have discovered two stars exiled from the Milky Way galaxy. Those stars are racing out of the Galaxy at speeds of more than 1 million miles per hour - so fast that they will never return.

"These stars literally are castaways," said Smithsonian astronomer Warren Brown (Harvard-Smithsonian Center for Astrophysics). "They have been thrown out of their home galaxy and set adrift in an ocean of intergalactic space."

Brown and his colleagues spotted the first stellar exile in 2005. European groups identified two more, one of which may have originated in a neighboring galaxy known as the Large Magellanic Cloud. The latest discovery brings the total number of known exiles to five.

"These stars form a new class of astronomical objects - exiled stars leaving the Galaxy," said Brown.

Astronomers suspect that about 1,000 exile stars exist within the Galaxy. By comparison, the Milky Way contains about 100,000,000,000 (100 billion) stars, making the search for exiles much more difficult than finding the proverbial "needle in a haystack." The Smithsonian team improved their odds by preselecting stars with locations and characteristics typical of known exiles. They sifted through dozens of candidates spread over an area of sky almost 8000 times larger than the full moon to spot their quarry.

"Discovering these two new exiled stars was neither lucky nor random," said astronomer Margaret Geller (Smithsonian Astrophysical Observatory), a co-author on the paper. "We made a targeted search for them. By understanding their origin, we knew where to find them."

Theory predicts that the exiled stars were thrown from the galactic center millions of years ago. Each star once was part of a binary star system. When a binary swings too close to the black hole at the galaxy's center, the intense gravity can yank the binary apart, capturing one star while violently flinging the other outward at tremendous speed (hence their technical designation of hypervelocity stars).

The two recently discovered exiles both are short-lived stars about four times more massive than the sun. Many similar stars exist within the galactic center, supporting the theory of how exiles are created. Moreover, detailed studies of the Milky Way's center previously found stars orbiting the black hole on very elongated, elliptical orbits - the sort of orbits that would be expected for former companions of hypervelocity stars.

"Computer models show that hypervelocity stars are naturally made near the galactic center," said theorist Avi Loeb of the Harvard-Smithsonian Center for Astrophysics. "We know that binaries exist. We know the galactic center holds a supermassive black hole. So, exiled stars inevitably will be produced when binaries pass too close to the black hole."

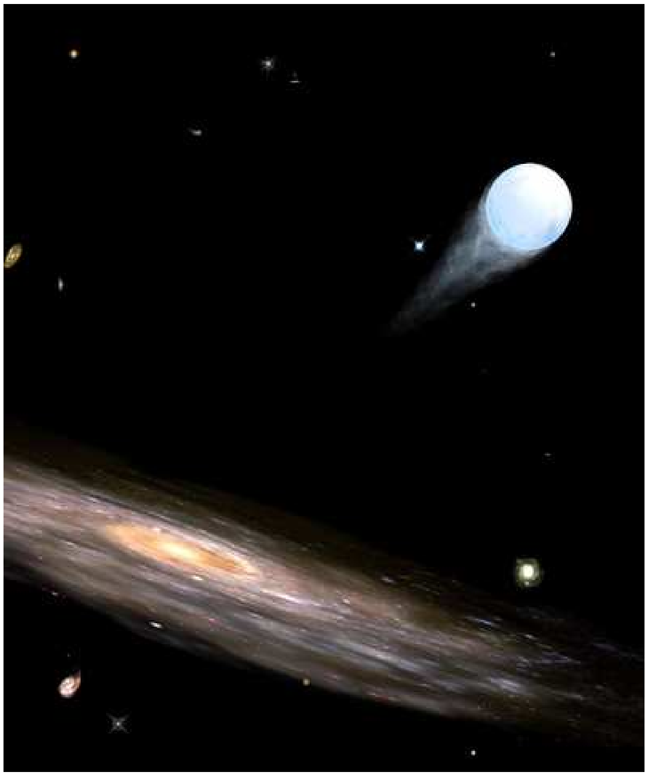

Figure 12: *A Smithsonian team of astronomers has found two "exiled" stars that were flung from the galactic center millions of years ago. Those stars are speeding out of the Milky Way at more than one million miles per hour, as shown in this artist's conception. Five exiled stars now are known, making them a new class of objects known as hypervelocity stars. Credit: Ruth Bazinet, CfA*

Astronomers estimate that a star is thrown from the galactic center every 100,000 years on average. Chances of seeing one at the moment of ejection are slim. Therefore, the hunt must continue to find more examples of stellar exiles in order to understand the extreme environment of the galactic center and how those extremes lead to the formation of hypervelocity stars.

The characteristics of exiled stars give clues to their origin. For example, if a large cluster of stars spiraled into the Milky Way's central black hole, many stars might be thrown out at nearly the same time. Every known hypervelocity star left the galactic center at a different time, therefore there is no evidence for a "burst" of exiles.

Hypervelocity stars also offer a unique probe of galactic structure. "During their lifetime, these stars travel across most of the Galaxy," said Geller. "If we could measure their motions across the sky, we could learn about the shape of the Milky Way and about the way the mysterious dark matter is distributed."

The first newfound exile, in the direction of the constellation Ursa Major, is designated SDSS J091301.0+305120. It is traveling out of the galaxy at a speed of about 1.25 million miles per hour and currently is located at a distance of about 240,000 light-years from the earth. The second exile, in the direction of the constellation Cancer, is designated SDSS J091759.5+672238. It is moving outward at 1.43 million miles per hour and currently is located about 180,000 light-years from the earth.

Both stars, although traveling at tremendous speeds through space, are located so far from the earth that their motion cannot be detected except with sophisticated astronomical instruments.

2.10 Integral identifies supernova rate for Milky Way

Source: ESA Press Release, January 5th, 2006 [18]

Using ESA's Integral observatory, an international team of researchers has been able to confirm the production of radioactive aluminium (Al 26) in massive stars and supernovae throughout our galaxy and determine the rate of supernovae - one of its key parameters. The team, led by Roland Diehl of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, determined that gamma rays from the decay of Al 26 originate from the central regions of our galaxy, implying that production of new atomic nuclei is an ongoing process and occurs in star-forming regions galaxy-wide.

Our environment is composed of chemical elements formed long ago by nuclear fusion reactions in stellar interiors and supernovae. This process of ?nucleosynthesis' leads to the emission of gamma rays, which easily reach us from all regions of our galaxy. ESA's Integral observatory has been measuring such gamma rays since October 2002. Doppler shifts in gamma rays caused by galactic rotation Roland Diehl and his colleagues were able to measure the Al 26 gamma-ray emissions along the plane of the inner galaxy.

However, because the disc of the galaxy rotates about its central axis, with the inner regions orbiting faster, gamma rays from decaying Al 26 observed from these regions should be moderated by the Doppler effect in a characteristic way. It is this characteristic pattern that has been found by Integral.

From this measurement, the team found that Al 26 decay gamma rays do indeed reach us from the inner regions of the galaxy, rather than from foreground regions along the same line of sight possibly caused by local and peculiar Al 26 production. These regions would not have the observed high relative velocity.

From these new observations, it is possible to estimate the total amount of radioactive Al 26 in our galaxy as is equivalent to three solar masses. This is a lot, given that Al 26 is an extremely rare isotope; the fraction estimated for the early Solar System is 5/100 000 of Al 26, in proportion to its stable aluminium isotope (Al 27).

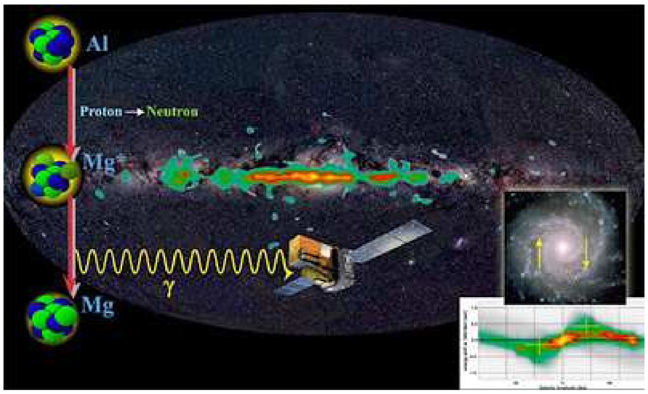

Figure 13: *Radioactive decay as measured by Integral from Al 26 decay, and the signature of galactic rotation.*

Because astrophysicists had inferred that the likely sources are mainly massive stars, which end their lives as supernovae, they could estimate the rate of such supernova events. They obtained a rate of one supernova every 50 years - consistent with what had been indirectly found from observations of other galaxies and their comparison to the Milky Way.

Integral's study of gamma rays will continue to operate for several more years. Astrophysicists hope to increase the precision of such measurements. Project leader Roland Diehl said, ”These gamma-ray observations provide insights about our home galaxy, which are difficult to obtain at other wavelengths due to interstellar absorption.”

2.11 Neutron Star Swaps Lead to Short Gamma-Ray Bursts

Source: Harvard-Smithsonian Center for Astrophysics Press Release, January 31th, 2006 [19]

Gamma-ray bursts are the most powerful explosions in the universe, emitting huge amounts of high-energy radiation. For decades their origin was a mystery. Scientists now believe they understand the processes that produce gamma-ray bursts. However, a new study by Jonathan Grindlay of the Harvard-Smithsonian Center for Astrophysics (CfA) and his colleagues, Simon Portegies Zwart (Astronomical Institute, The Netherlands) and Stephen McMillan (Drexel University), suggests a previously overlooked source for some gamma-ray bursts: stellar encounters within globular clusters.

”As many as one-third of all short gamma-ray bursts that we observe may come from merging neutron stars in globular clusters,” said Grindlay.

Gamma-ray bursts (GRBs) come in two distinct ”flavors.” Some last up to a minute, or even longer. Astronomers believe those long GRBs are generated when a massive star explodes in a hypernova. Other bursts last for only a fraction of a second. Astronomers theorize that short GRBs originate from the collision of two neutrons stars, or a neutron star and a black hole.

Most double neutron star systems result from the evolution of two massive stars already orbiting each other. The natural aging process will cause both to become neutron stars (if they start with a given mass), which then spiral together over millions or billions of years until they merge and release a gamma-ray burst.

Grindlay's research points to another potential source of short GRBs - globular clusters. Globular clusters contain some of the oldest stars in the universe crammed into a tight space only a few light-years across. Such tight quarters provoke many close stellar encounters, some of which lead to star swaps. If a neutron star with a stellar companion (such as a white dwarf or main-sequence star) exchanges its partner with another neutron star, the resulting pair of neutron stars will eventually spiral together and collide explosively, creating a gamma-ray burst.

”We see these precursor systems, containing one neutron star in the form of a millisecond pulsar, all over the place in globular clusters,” stated Grindlay. ”Plus, globular clusters are so closely packed that you have a lot of interactions. It's a natural way to make double neutron-star systems.”

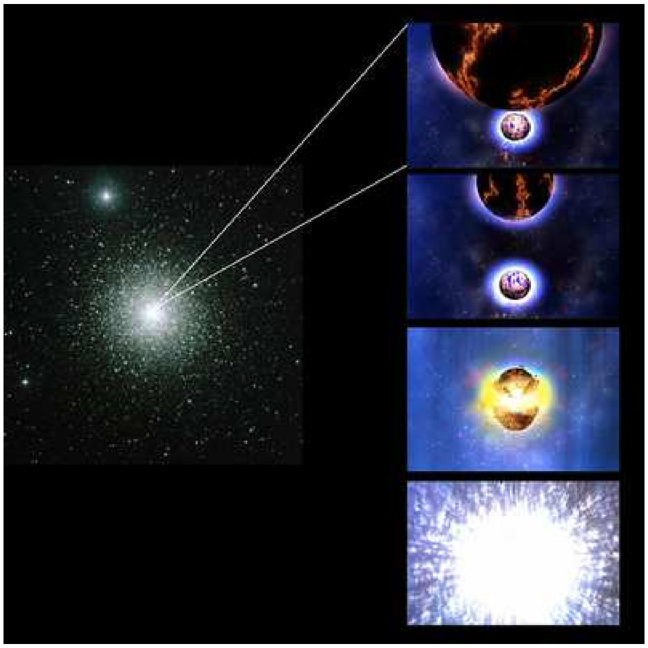

Figure 14: *The photograph at left shows the galactic globular cluster M15, which contains a double neutron star system that will eventually collide to create a gamma-ray burst, as shown in the inset images at right. The right-hand images are taken from a computer animation and shows several snapshots covering just a fraction of a second in total time, with time advancing from top to bottom. Recent research shows that such collisions may be the source of up to 30 percent of all short gamma-ray bursts observed from Earth. M15 Image Credit: NOAO/AURA/NSF; Merger Image Credit: NASA / Dana Berry*

The astronomers performed about 3 million computer simulations to calculate the frequency with which double neutron-star systems can form in globular clusters. Knowing how many have formed over the galaxy's history, and approximately how long it takes for a system to merge, they then determined the frequency of short gamma-ray bursts expected from globular cluster binaries. They estimate that between 10 and 30 percent of all short gamma-ray bursts that we observe may result from such systems.

This estimate takes into account a curious trend uncovered by recent GRB observations. Mergers and thus bursts from so-called "disk" neutron-star binaries - systems created from two massive stars that formed together and died together - are estimated to occur 100 times more frequently than bursts from globular cluster binaries. Yet the handful of short GRBs that have been precisely located tend to come from galactic halos and very old stars, as expected for globular clusters.

"There's a big bookkeeping problem here," said Grindlay.

To explain the discrepancy, Grindlay suggests that bursts from disk binaries are likely to be harder to spot because they tend to emit radiation in narrower blasts visible from fewer directions. Narrower "beaming" might result from colliding stars whose spins are aligned with their orbit, as expected for binaries that have been together from the moment of their birth. Newly joined stars, with their random orientations, might emit wider bursts when they merge.

"More short GRBs probably come from disk systems - we just don't see them all," explained Grindlay.

Only about a half dozen short GRBs have been precisely located by gamma-ray satellites recently, making thorough studies difficult. As more examples are gathered, the sources of short GRBs should become much better understood.

2.12 Mystery Solved: High-Energy Fireworks Linked to Massive Star Cluster

Source: Hubble News, January 9th, 2006 [20]

Call it the Bermuda Triangle of our Milky Way Galaxy: a tiny patch of sky that has been known for years to be the source of the mysterious blasts of X-rays and gamma rays. Now, a team of astronomers, led by Don Figer of the Space Telescope Science Institute (STScI) in Baltimore, Md., has solved the mystery by identifying one of the most massive star clusters in the galaxy. The little-known cluster, which has not been catalogued, is about 20 times more massive than typical star clusters in our galaxy, and appears to be the source of the powerful outbursts.

Supporting evidence for the hefty weight of this cluster is the presence of 14 red supergiants, hefty stars that have reached the end of their lives. They bloat up to about 100 times their normal size before exploding as supernovae. In fact, Figer's team believes that the blasts of X-rays and gamma rays were released in supernova explosions. Sightings of red supergiants are rare. Astronomers have spotted only about 200 such stars in the Milky Way. The lack of sightings is because the red supergiant phase is very short in astronomical terms, lasting about half a million to a million years.

"Only the most massive clusters can have lots of red supergiants, because they are the only clusters capable of making behemoth stars," Figer explained. "They are good signposts that allow astronomers to predict the mass of the cluster. This observation also is a rare chance to study huge stars just before they explode. Normally, we don't get to see stars before they pop off."

Figer will present his results on Jan. 9 at the 207th meeting of the American Astronomical Society in Washington, D.C. The 14 red supergiants in this cluster represent almost three times as many as in any other star cluster in our galaxy. The runner-up, NGC 7419, has five. Stars that become red supergiants weigh between 8 to 25 times our Sun's mass and are 6 to 15 million years old.

The team identified the star cluster as a potential behemoth from the newly found clusters compiled in the Two Micron All Sky Survey catalogue. Astronomer John MacKenty, also of STScI, performed follow-up observations of the cluster in Sept. and Oct. 2005 with a unique ground-based infrared spectrograph at Kitt Peak National Observatory in Arizona. Called the Infrared Multi-object Spectrograph, "the instrument has about 500,000 movable microscopic mirrors in its focal plane which allow astronomers to take infrared spectra of up to 100 stars at once," said MacKenty, the instrument's lead investigator. Spectra display stars' energy output as a series of individual wavelengths of light for study. The resulting patterns are akin to sets of fingerprints for stars, revealing characteristics such as composition, temperature, mass, and age. Astronomers plan to use similar technology on the Near Infrared Spectrograph aboard the James Webb Space Telescope, scheduled for launch in 2013.

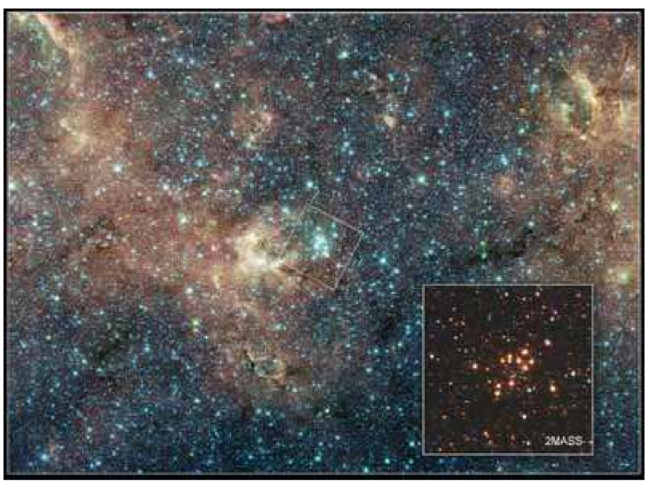

Figure 15: *Credit for Spitzer Image: NASA/JPL-Caltech, D. Figer (Space Telescope Science Institute/Rochester Institute of Technology), E. Churchwell (University of Wisconsin, Madison) and the GLIMPSE Legacy Team. Credit for 2MASS Image: NASA/NSF/2MASS/UMass/IPAC-Caltech and D. Figer (Space Telescope Science Institute/Rochester Institute of Technology)*

Figer relied on data from a variety of telescopes, including the Spitzer Space Telescope, to confirm that the infrared colors of the suspected red supergiants are consistent with those of known red supergiants. The red supergiants discovered by Figer's team are very bright, indicating that the cluster is a youngster of about 8 to 10 million years old. The cluster has to be young enough for astronomers to see these short-lived stars before they explode, yet old enough to have stars that have evolved to the red supergiant stage. The cluster's mass equals 20,000 times the mass of our Sun. An estimated 20,000 stars reside in the cluster.

The cluster is the first of 130 massive star cluster candidates that Figer and his team will study over the next five years using a variety of telescopes, including the Spitzer and Hubble Space telescopes. "We can only see a small part of our galaxy in visible light because a dusty veil covers most of our galaxy," Figer said. "I know there are other massive clusters in the Milky Way that we can't see because of the dust. My goal is to find them using infrared light, which penetrates the dusty veil."

The monster cluster's location, nearly two-thirds of the way to our galaxy's center and 18,900 light-years from Earth, is in an area known for energetic activity. Several observatories the High Energy Stereoscopic System, the International Gamma-Ray Astrophysics Laboratory and the Advanced Satellite for Cosmology and Astrophysics detected very high-energy X-rays and gamma rays from that region. Astronomers knew that something powerful was occurring there, but they couldn't identify the source.

2.13 Huge Star Cluster Discovered in Neighborhood of Milky Way

Source: Eberly College of Science, January 11th, 2006 [21]

A team of scientists from the Sloan Digital Sky Survey (SDSS), including a Penn State astrophysicist, has discovered a companion to the Milky Way galaxy that is so big it previously had been undetectable. The result is the topic of a press conference during the meeting of the American Astronomical Society now taking place in Washington, D.C.

The study, lead by Mario Juric of Princeton and Zeljko Ivezic of the University of Washington, found a collection of stars in the constellation Virgo that covers nearly 5,000 times the size of the full moon. Penn State Professor of Astronomy and Astrophysics Donald Schneider, a coauthor of the investigation, is the Chairman of the SDSS Quasar Science Group and the SDSS Scientific Publications Coordinator. "The star cluster is located only 30,000 light years from Earth," noted Schneider. "This is the same distance from us as is the Galactic Center, although the cluster lies in a different direction from the Center. It is likely that the cluster is the remnant of a small galaxy that has been captured and disrupted by the gravitational field of our galaxy."

The galaxy is a huge but very faint structure, containing hundreds of thousands of stars spread over an area area nearly 5,000 times the size of a full moon. Although the structure lies well within the confines of the Milky Way Galaxy, at an estimated distance of 30,000 light years from Earth, it does not follow any of Milky Way's three main components: a flattened disk of stars in which the Sun resides, a bulge of stars at the center of the Galaxy, and an extended, roughly spherical, stellar halo. Instead, the discoverers believe that the most likely interpretation of the new structure is a dwarf galaxy that is merging into the Milky Way.

"Some of the stars in this Milky Way companion have been seen with telescopes for centuries," explained Princeton University graduate student Mario Juric, who is principal author of the journal article describing what may well be our closest galactic neighbor. "But because the galaxy is so close, its stars are spread over a huge swath of the sky, and they always used to be lost in the sea of more numerous Milky Way stars. This galaxy is so big, we couldn't see it before."

The discovery was made possible by the unprecedented depth and photometric accuracy of the SDSS, which to date has imaged roughly 1/4 of the northern sky. "We used the SDSS data to measure distances to 48 million stars and build a 3-D map of the Milky Way," explained Zeljko Ivezic of the University of Washington, a co-author of the study. Details of this "photometric parallax" method, which uses the colors and apparent brightnesses of stars to infer their distances, are explained in a paper titled "Milky Way Tomography," submitted to The Astrophysical Journal.

"It's like looking at the Milky Way with a pair of 3-d glasses," said Princeton University co-author Robert Lupton. "This structure that used to be lost in the background suddenly snapped into view." The new result is reminiscent of the 1994 discovery of the Sagittarius dwarf galaxy, by Rodrigo Ibata and collaborators from Cambridge University. They used photographic images of the sky to identify an excess of stars on the far side of the Milky Way, some 75,000 light years from Earth. The Sagittarius dwarf is slowly dissolving, trailing streams of stars behind it as it orbits the Milky Way and sinks into the Galactic disk.

In the ensuing decade, a new generation of sky surveys using large digital cameras has identified numerous streams and lumps of stars in the outer Milky Way. Some of these lumps are probably new Milky Way companions, while others may be shreds of the Sagittarius dwarf or of other dissolving dwarf galaxies. Earlier SDSS discoveries include an apparent ring of stars that encircles the Milky Way disk and may be the remnant of another disrupted galaxy, and the Ursa Major dwarf, the faintest known neighbor of the Milky Way.

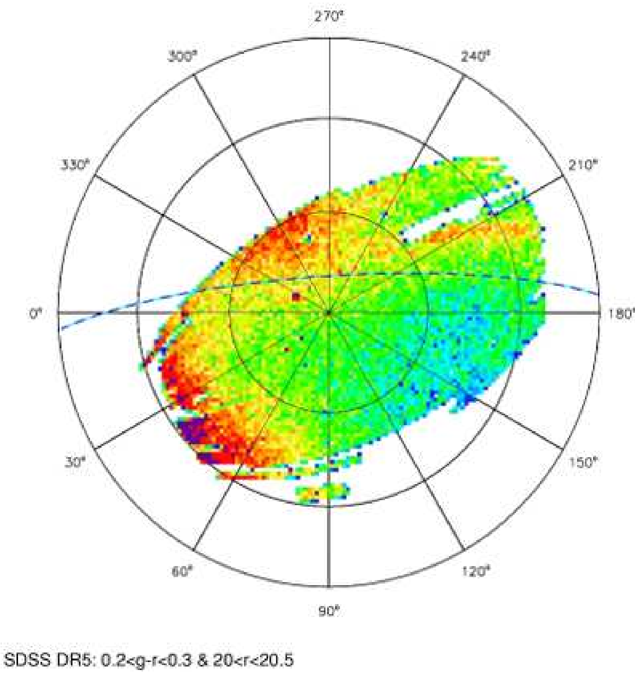

Figure 16: *Credit: M. Juric/SDSS-II Collaboration The figure, a map by Mario Juric of Princeton University, shows the counts of faint blue stars selected from a narrow magnitude and color range and corresponding to a distance from Earth of about 10 kpc. The map shows the view from far away above the galactic plane. Radial rays are lines of constant longitude, circles are lines of constant latitude, the North Galactic Pole is in the center, and the Galactic Center is towards left. The counts are shown on a logarithmic stretch, with a dynamic range of 10 increasing from blue to red. According to the standard Milky Way models, the top and bottom halves should be symmetric with respect to the horizontal line in the middle, because the Milky Way is believed to be symmetric around its rotation axis, which passes through the Galactic Center, and is perpendicular to this map. The discovery of the large overdensity of stars at the longitudes of about 300 degrees and latitudes of about 60 degrees breaks the expected symmetry and is at odds with the standard models. The dashed line shows the position of the plane containing debris from the Sagittarius dwarf*

galaxy that is being cannibalized by the Milky Way. While its proximity to the new structure suggests that perhaps the two may be related, the known Sagittarius debris is located about four times further away.

Preliminary evidence for the new dwarf galaxy, found toward the constellation Virgo, appeared in maps of variable stars by the SDSS and by the QUEST survey (a Yale University/University of Chile collaboration). ”With so much irregular structure in the outer Galaxy, it looks as though the Milky Way is still growing, by cannibalizing smaller galaxies that fall into it,” said Juric.

Another group of SDSS astronomers, led by Daniel Zucker of the Max Planck Institute of Astronomy in Heidelberg and Cambridge University’s Institute of Astronomy, has used the SDSS to find the two faintest known companions of the Andromeda Galaxy, which is the closest giant spiral galaxy similar in size to the Milky Way. ”These new Andromeda companions, alongside the new Milky Way neighbors, suggest that faint satellite galaxies may be plentiful in the Local Group,” said Zucker.

While the SDSS originally was designed to study the distant universe, its wide area, high precision maps of faint stars have made it an invaluable tool for studying the Milky Way and its immediate neighborhood. The 3-D map created by Juric and his collaborators also provides strong new constraints on the shape and extent of the Milky Way’s disk and stellar halo. Another Princeton graduate student, Nick Bond, is using the subtle motions of stars detected over the 5-year span of the SDSS observations to limit the amount of dark matter in the solar neighborhood. University of Washington graduate student Jillian Meyer is mapping the distribution of interstellar dust carefully studying the colors of stars found in both the SDSS and the infrared 2MASS survey.

Building on these many successes, the SEGUE project (Sloan Extension for Galactic Understanding and Exploration) will use the SDSS telescope, its 120-megapixel digital camera, and its 640-fiber optical spectrograph to carry out detailed studies of the structure and chemical evolution of the Milky Way. SEGUE is one of three components of SDSS-II, the three-year extension of the Sloan Survey that will run through mid-2008.

Fermilab scientist Brian Yanny, one of the SEGUE team leaders, is excited at the prospect of examining its just-completed, first season of observations. ”The SDSS has already told us surprising things about the Milky Way, but the most exciting discoveries should lie just ahead.”

2.14 Milky Way galaxy is warped and vibrating like a drum

Source: UC Berkeley News, January 9th, 2006 [22]

The most prominent of the Milky Way’s satellite galaxies - a pair of galaxies called the Magellanic Clouds - appears to be interacting with the Milky Way’s ghostly dark matter to create a mysterious warp in the galactic disk that has puzzled astronomers for half a century.

The warp, seen most clearly in the thin disk of hydrogen gas permeating the galaxy, extends across the entire 200,000-light year diameter of the Milky Way, with the sun and earth sitting somewhere near the crease. Leo Blitz, professor of astronomy at the University of California, Berkeley, and his colleagues, Evan Levine and Carl Heiles, have charted this warp and analyzed it in detail for the first time, based on a new galactic map of hydrogen gas (HI) emissions.

They found that the atomic gas layer is vibrating like a drum, and that the vibration consists almost entirely of three notes, or modes.

Astronomers previously dismissed the Magellanic Clouds - comprised of the Large and Small Magellanic Clouds - as a probable cause of the galactic warp because the galaxies’ combined masses are only 2 percent that of the disk. This mass was thought too small to influence a massive disk equivalent to about 200 billion suns during the clouds’ 1.5 billion-year orbit of the galaxy.

Nevertheless, theorist Martin D. Weinberg, a professor of astronomy at the University of Massachusetts, Amherst, teamed up with Blitz to create a computer model that takes into account the Milky Way’s dark matter, which, though invisible, is 20 times more massive than all visible matter in the galaxy combined. The motion of the clouds through the dark matter creates a wake that enhances their gravitational influence on the disk. When this dark matter is included, the Magellanic Clouds, in their orbit around the Milky Way, very closely reproduce the type of warp observed in the galaxy.

”The model not only produces this warp in the Milky Way, but during the rotation cycle of the Magellanic Clouds around the galaxy, it looks like the Milky Way is flapping in the breeze,” said Blitz, director of UC Berkeley’s Radio Astronomy Laboratory.

”People have been trying to look at what creates this warp for a very long time,” Weinberg said. ”Our simulation is still not a perfect fit, but it has a lot of the character of the actual data.”

Levine, a graduate student, will present the results of the work in Washington, D.C., on Jan. 9 during a 10 a.m. session on galactic structure at the American Astronomical Society meeting. Blitz will summarize the work later that day during a 12:30 p.m. press briefing in the Wilson C Room of the Marriott Wardman Park Hotel.

The interaction of the Magellanic Clouds with the dark matter in the galaxy to produce an enigmatic warp in the hydrogen gas layer is reminiscent of the paradox that led to the discovery of dark matter some 35 years ago. As astronomers built better and better telescopes able to measure the velocities of stars and gas in the outer regions of our galaxy, they discovered these stars moving far faster than would be expected from the observed number and mass of stars in the entire Milky Way. Only by invoking a then-heretical notion, that 80 percent of the galaxy's mass was too dark to see, could astronomers reconcile the velocities with known theories of physics.

Though no one knows the true identity of this dark matter - the current consensus is that it is exotic matter rather than normal stars too dim to see - astronomers are now taking it into account in their simulations of cosmic dynamics, whether to explain the lensing effect galaxies and galaxy clusters have on the light from background galaxies, or to describe the evolution of galaxy clusters in the early universe.

Some physicists, however, have come up an alternative theory of gravity called Modified Newtonian Dynamics, or MOND, that seeks to explain these observations without resorting to belief in a large amount of undetected mass in the universe, like an invisible elephant in the room. Though MOND can explain some things, Weinberg thinks the theory will have a hard time explaining the Milky Way's warp.

"Without a dark matter halo, the only thing the gas disk can feel is direct gravity from the Magellanic Clouds themselves, which was shown in the 1970s not to work," he said. "It looks bad for MOND, in this case."

Because many galaxies have warped disks, similar dynamics might explain them as well. Either way, the researchers say their work suggests that warps provide a way to verify the existence of the dark matter.

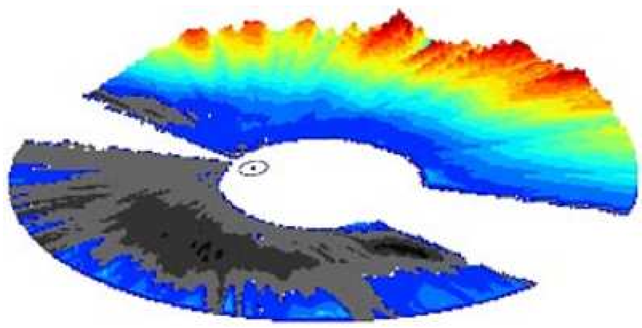

Figure 17: *An image, to scale, of the asymmetric, warped hydrogen layer of the Milky Way newly mapped by UC Berkeley astronomers. The colored contours are warped "up" with regard to the galactic plane, while the grey contours are warped "down." The white area at the center is where most of the stars are, and the position of the sun is given by the dot with a circle around it. The sun orbits the center of the galaxy and is moving to the upper right in this view. The white areas, including the wedges, are difficult to study from Earth because of our position within the disk. (Credit: Leo Blitz/Carl Heiles/Evan Levine-UC Berkeley)*

The starting point for this research was new spectral data released this past summer about hydrogen's 21-centimeter emissions in the Milky Way. The survey, the Leiden-Argentina-Bonn or LAB Survey of Galactic HI, merged a northern sky survey conducted by astronomers in the Netherlands (the Leiden/Dwingeloo Survey) with a southern sky survey from the Instituto Argentino de Radioastronoma. The data were corrected by scientists at the Institute for Radioastronomy of the University of Bonn, Germany.

Blitz, Levine and Heiles, UC Berkeley professor of astronomy, took these data and produced a new, detailed map of the neutral atomic hydrogen in the galaxy. This hydrogen, distributed in a plane with dimensions like those of a compact disk, eventually condenses into molecular clouds that become stellar nurseries.

With map in hand, they were able to mathematically describe the warp as a combination of three different types of vibration: a flapping of the disk's edge up and down, a sinusoidal vibration like that seen on a drumhead, and a saddle-shaped oscillation. These three "notes" are about 64 octaves below middle C.

"We found something very surprising, that we could describe the warp by three modes of vibration, or three notes, and only three," Blitz said, noting that this rather simple mathematical description of the warp had escaped the notice of astronomers since the warp's discovery in 1957.

”We were actually trying to analyze a more complex ’scalloping’ structure of the disk, and this simple, elegant vibrational structure just popped out,” Levine added.

The current warp in the gas disk is a combination of these three vibrational modes, leaving one-half of the galactic disk sticking up above the plane of stars and gas, while the other half dips below the disk before rising upward again farther outward from the center of the galaxy. The results of this analysis will be published in an upcoming issue of the Astrophysical Journal.

Weinberg thought he could explain the observed warp dynamically, and used computers to calculate the effect of the Magellanic Clouds orbiting the Milky Way, plowing through the dark matter halo that extends far out into the orbit of the clouds.

What he and Blitz found is that the clouds’ wake through the dark matter excites a vibration or resonance at the center of the dark matter halo, which in turn makes the disk embedded in the halo oscillate strongly in three distinct modes. The combined motion during a 1.5-billion-year orbit of the Magellanic Clouds is reminiscent of the edges of a tablecloth flapping in the wind, since the center of the disk is pinned down.

”We often think of the warp as being static, but this simulation shows that it is very dynamic,” Blitz said.

Blitz, Levine and Heiles are continuing their search for anomalies in the structure of the Milky Way’s disk. Weinberg hopes to use the UC Berkeley group’s data and analysis to determine the shape of the dark matter halo of the Milky Way.

2.15 Tidal Tales of Minor Mergers: Young Stars Where They Shouldn’t Be

Source: University of Arizona Press Release, January 11th, 2006 [23]

Arizona astronomers have discovered a population of what appear to be young star clusters where they aren’t supposed to be. The newborn stars appear to have formed in the debris of the NGC 2782 galaxy collision – debris that lacks what astronomers believe are some important ingredients needed to form stars.

A large, Milky Way-type galaxy collided with a much smaller galaxy in the NGC 2782 collision. It’s an example of the most common type of galaxy collision in the universe. Scientists believe that such collisions played an important role in the buildup of large galaxies in the early universe.

If confirmed, these newly discovered young star clusters and their environment could help shed light on the process of star formation, especially in the early universe in regions far from the crowded, active centers of galaxies.

Karen Knierman, a graduate student and Arizona/NASA Space Grant Fellow at The University of Arizona, and Patricia Knezek of the WIYN Consortium in Tucson, Ariz., are reporting the research at the American Astronomical Society meeting in Washington, D.C., today.

The astronomers found the star clusters by taking deep images of the galaxy collision with the 4 Megapixel CCD camera of the 1.8 meter (71-inch) Vatican Advanced Technology Telescope (VATT) at Mount Graham International Observatory in Arizona.

NGC 2782 lies about 111 million light years away toward the Lynx constellation. When the two galaxies of unequal mass collided about 200 million years ago, their gravitational pull ripped out two tails of debris with very different properties.

Beverly Smith of Eastern Tennessee University and collaborators studied the optical and gas properties of these two tails and published their results in 1994 and 1999. Studying the gas properties tells astronomers about neutral hydrogen gas and molecular gas – both important ingredients in star formation. Smith and collaborators found that the optically bright eastern tail has some neutral hydrogen gas and molecular gas at the base of the tail, and an optically bright, but gas-poor concentration at the end of the tail. The optically faint western tail is rich in neutral hydrogen gas, but has no molecular gas.

Knierman and Knezek found blue star clusters younger than 100 million years along both tails, indicating that those stars formed within the tails after the galaxy collision began.

”That’s surprising because the western tail lacks molecular gas, one of the key ingredients for star formation,” Knierman said.

Star clusters are thought to form from the collapse of giant molecular gas clouds. If this is the case, astronomers would expect to see remnants of the molecular gas which helped give birth to the stars.

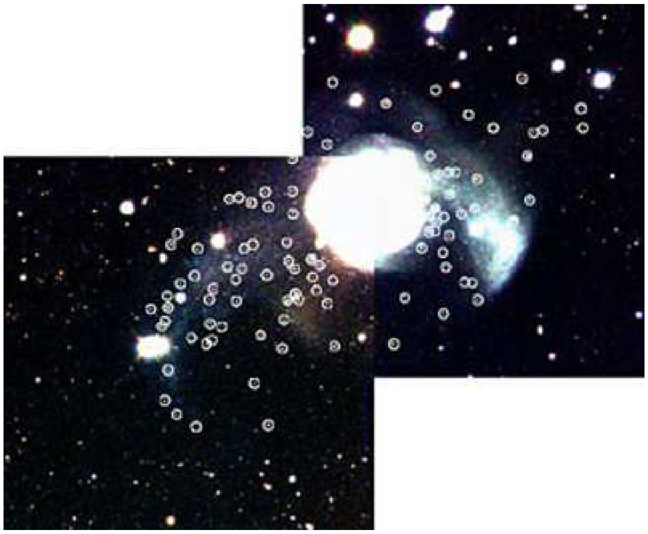

Figure 18: *Optical image of the galaxy merger NGC 2782 showing the location of young star clusters which formed in the sweeping tails of debris after the collision. Even though the gas properties of the two tails are different, both tails show unexpectedly similar populations of young star clusters. This material was presented to the American Astronomical Society meeting in Washington, D.C. on January 11, 2006. (Photo: Karen Knierman, UA Steward Observatory, and Patricia Knezek, WIYN/NOAO)*

Given Smith's earlier observations of gas in the debris tails, Knierman and Knezek expected they might see star formation in the eastern tail, where molecular gas is clearly present. But they didn't expect to see star formation in the western tail, where no molecular gas was detected. Finding young star clusters in the western tail should prompt astronomers to question their current models of star formation, the Arizona team said.

"Do we still need a model of giant molecular gas clouds?" Knierman asked. "Or do we need a different model - perhaps one with smaller clumps of molecular gas that might have been destroyed or blown away when these energetic young stars formed?"

Finding unexpected young star clusters in the western tail could help explain why stars form in other places where there may be little molecular gas, like the outer edges of the Milky Way galaxy or in the debris of other galaxy collisions, Knierman and Knezek noted.

"This has important implications in how star formation proceeded when our universe was young and galaxy collisions were much more common than they are today," Knierman said.

"Only recently have we become aware of the importance of the merging of small galaxies with larger systems in creating galaxies like our own Milky Way," Knezek added.

2.16 New evidence for a Dark Matter Galaxy

Source: PPARC Press Release, January 12th, 2006 [24]

New evidence that VIRGOHI 21, a mysterious cloud of hydrogen in the Virgo Cluster 50 million light-years from the Earth, is a Dark Galaxy, emitting no star light, was presented today at the American Astronomical Society meeting in Washington, D. C. by an international team led by astronomers from the National Science Foundation's Arecibo Observatory and from Cardiff University in the United Kingdom. Their results not only indicate the presence of a dark galaxy but also explain the long-standing mystery of its strangely stretched neighbour.

The new observations, made with the Westerbork Synthesis Radio Telescope in the Netherlands, show that the hydrogen gas in VIRGOHI 21 appears to be rotating, implying a dark galaxy with over ten billion times the mass of the Sun. Only one percent of this mass has been detected as neutral hydrogen - the rest appears to be dark matter.

But this is not all that the new data reveal. The results may also solve a long-standing puzzle about another nearby galaxy. NGC 4254 is lopsided, with one spiral arm much larger than the rest. This is usually caused by the influence of a companion galaxy, but none could be found until now - the team thinks VIRGOHI 21 is the culprit. Dr. Robert Minchin of Arecibo Observatory says; "The Dark Galaxy theory explains both the observations of VIRGOHI 21 and the mystery of NGC 4254."

Gas from NGC 4254 is being torn away by the dark galaxy, forming a temporary link between the two and stretching the arm of the spiral galaxy. As the VIRGOH1 21 moves on, the two will separate and NGC 4254's unusual arm will relax back to match its partner.

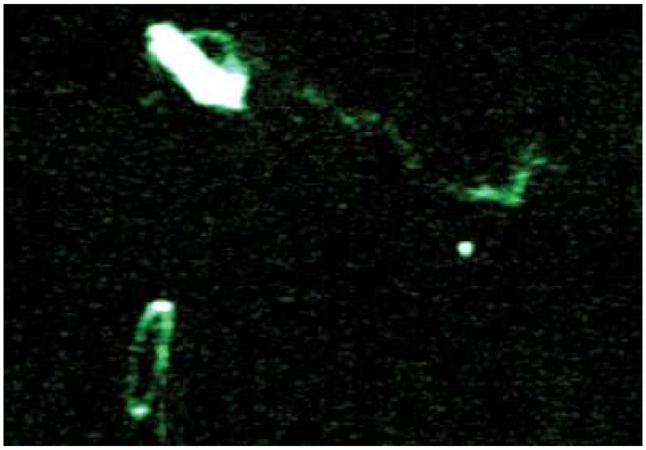

Figure 19: *Neutral hydrogen gas streams between NGC 4254 (top left) and the Dark Galaxy VIRGOH1 21 (centre right) in this image made from radio telescope observations at a wavelength of 21 centimetres. This interaction could explain the mystery of NGC 4254's peculiar lopsided shape. To the bottom left, a ring of gas can be seen around the galaxy NGC 4262. This material was presented to the American Astronomical Society meeting in Washington, D. C. on January 12, 2006. CREDIT: Arecibo Observatory / Cardiff University / Westerbork Synthesis Radio Telescope.*

The team have looked at many other possible explanations, but have found that only the Dark Galaxy theory can explain all of the observations. As Professor Mike Disney of Cardiff University puts it, "The new observations make it even harder to escape the conclusion that VIRGOHI 21 is a Dark Galaxy."

The team hope that this will be the first of many such finds. "We're going to be searching for more Dark Galaxies with the new ALFA instrument at Arecibo Observatory," explains Dr. Jon Davies of Cardiff University. "We hope to find many more over the next few years - this is a very exciting time!"

2.17 Elliptical Galaxy Gallery: Black Holes Stir Up Galaxies

Source: Chandra Press Release, January 10th, 2006 [25]

Chandra images of 56 elliptical galaxies have revealed evidence for unsuspected turmoil. As this sample gallery of X-ray (blue & white) and optical (gray & white) images shows, the shapes of the massive clouds of hot gas that produce X-ray light in these galaxies differ markedly from the distribution of stars that produce the optical light.

Except for rare cases, most violent activity in isolated elliptical galaxies was thought to have stopped long ago. Elliptical galaxies contain very little cool gas and dust, and far fewer massive young stars which explode as supernovas. Thus it was expected that the hot interstellar gas would have settled into an equilibrium shape similar to, but rounder than that of the stars.

Surprisingly, this study of elliptical galaxies shows that the distribution of hot gas has no correlation with the optical shape. A powerful source of energy must be pushing the hot gas around and stirring it up every hundred million years or so.

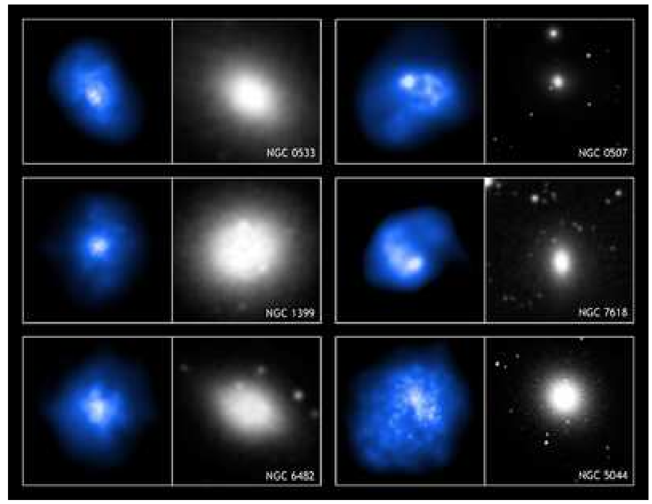

Figure 20: *Credit: X-ray: NASA/CXC/U. Ohio/T.Statler & S.Diehl; Optical: DSS*

Although supernovas are a possible energy source, a more probable cause has been identified. The scientists detected a correlation between the shape of the hot gas clouds and the power produced at radio wavelengths by high-energy electrons. This power source can be traced back to the supermassive black hole in the galaxies' central regions.

Repetitive explosive activity fueled by the infall of gas into the central supermassive black hole is known to occur in giant elliptical galaxies located in galaxy clusters. Scientists' analysis of the Chandra data indicates that the same phenomena are occurring in isolated elliptical galaxies as well.

2.18 Fossil Galaxy Reveals Clues to Early Universe

Source: Johns Hopkins University, Janaury 12th, 2006 [26]

A tiny galaxy has given astronomers a glimpse of a time when the first bright objects in the universe formed, ending the dark ages that followed the birth of the universe.

Astronomers from Sweden, Spain and the Johns Hopkins University used NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) satellite to make the first direct measurement of ionizing radiation leaking from a dwarf galaxy undergoing a burst of star formation. The result, which has ramifications for understanding how the early universe evolved, will help astronomers determine whether the first stars or some other type of object ended the cosmic dark age.

The team will present its results Jan. 12 at the American Astronomical Society's 207th meeting in Washington, D.C.

Considered by many astronomers to be relics from an early stage of the universe, dwarf galaxies are small, very faint galaxies containing a large fraction of gas and relatively few stars. According to one model of galaxy formation, many of these smaller galaxies merged to build up today's larger ones. If that is true, any dwarf galaxies observed now can be thought of as ”fossils” that managed to survive without significant changes from an earlier period.

Led by Nils Bergvall of the Astronomical Observatory in Uppsala, Sweden, the team observed a small galaxy, known as Haro 11, which is located about 281 million light years away in the southern constellation of Sculptor. The team's analysis of FUSE data produced an important result: between 4 percent and 10 percent of the ionizing radiation produced by the hot stars in Haro 11 is able to escape into intergalactic space.

Ionization is the process by which atoms and molecules are stripped of electrons and converted to positively charged ions. The history of the ionization level is important to understanding the evolution of structures in the early universe, because it determines how easily stars and galaxies can form, according to B-G Andersson, a research scientist in the Henry A. Rowland Department of Physics and Astronomy at Johns Hopkins, and a member of the FUSE team.

”The more ionized a gas becomes, the less efficiently it can cool. The cooling rate in turn controls the ability of the gas to form denser structures, such as stars and galaxies,” Andersson said. The hotter the gas, the less likely it is for structures to form, he said.

The ionization history of the universe therefore reveals when the first luminous objects formed, and when the first stars began to shine.

The Big Bang occurred about 13.7 billion years ago. At that time, the infant universe was too hot for light to shine. Matter was completely ionized: atoms were broken up into electrons and atomic nuclei, which scatter light like fog. As it expanded and then cooled, matter combined into neutral atoms of some of the lightest elements. The imprint of this transition today is seen as cosmic microwave background radiation.

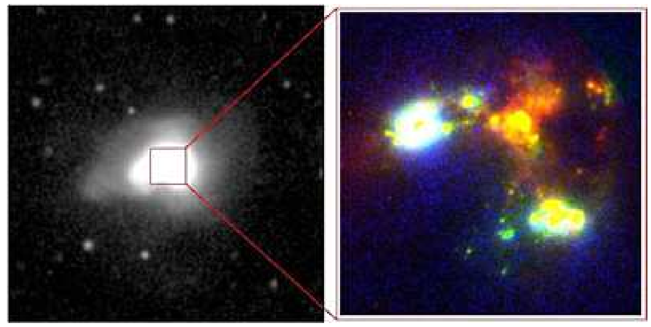

Figure 21: *Two views of the Haro 11 galaxy. The left hand panel shows a visible light image of Haro 11 acquired at the European Southern Observatories in Chile. North is up and East to the left. The image is 85 arcseconds on the side (114,000 light years at the distance of Haro 11; 1 arcsecond equals 1/3600 degrees). The right hand panel shows a false-color composite of the central part of the galaxy acquired with the Hubble Space Telescope. In this composite, a visible light image from the HST WFPC2 camera is coded in red, an ultraviolet light image from the HST ACS camera is coded in in green, and a spectral line emission image tracing neutral hydrogen (also from HST-ACS), excited by the kind of radiation detected by FUSE, is coded in blue. The ultraviolet light traces hot, young, stars, the visible light traces older, cooler, stars while the the line emission from hydrogen traces the interaction of energetic radiation with the gas in the galaxy. The size of the right hand image is 9.5 x 9.5 arcseconds, which at the distance of Haro 11 corresponds to 12,700 x 12,700 light years. The right hand panel is adapted from the paper by Kunth et al. 2003 in the Astrophysical Journal, Volume 597, page 266, and is reproduced by permission of the AAS.*

The present universe is, however, predominantly ionized; astronomers generally agree that this reionization occurred between 12.5 and 13 billion years ago, when the first large-scale galaxies and galaxy clusters were forming. The details of this ionization are still unclear, but are of intense interest to astronomers studying these so-called ”dark ages” of the universe.

Astronomers are unsure if the first stars or some other type of object ended those dark ages, but FUSE observations of ”Haro 11” provide a clue.

The observations also help increase understanding of how the universe became reionized. According to the team, likely contributors include the intense radiation generated as matter fell into black holes that formed what we now see as quasars and the leakage of radiation from regions of early star formation. But until now, direct evidence for the viability of the latter mechanism has not been available.

”This is the latest example where the FUSE observation of a relatively nearby object holds important ramifications for cosmological questions,” said Dr. George Sonneborn, NASA/FUSE Project Scientist at NASA's Goddard Space Flight Center, Greenbelt, Md.

2.19 Monster Black Holes Grow After Galactic Mergers

Source: Hubble News, January 10th, 2006 [27]

An analysis of the Hubble Space Telescope's deepest view of the universe offers compelling evidence that monster black holes in the centers of galaxies were not born big but grew over time through repeated galactic mergers.

”By studying distant galaxies in the Hubble Ultra Deep Field (HUDF), we have the first statistical evidence that supermassive black-hole growth is linked to the process of galaxy assembly,” said astronomer Rogier Windhorst, of Arizona State University in Tempe, Ariz., and a member of the two teams that conducted the analysis. ”Black holes grow by drawing in stars, gas, and dust. These morsels come more plentifully within their reach when galaxies merge.”

The two teams will present their results in a press conference on Jan. 10 at the 207th meeting of the American Astronomical Society in Washington, D.C.

The HUDF studies also confirm the predictions of recent computer simulations by Lars Hernquist, Philip Hopkins, Tiziana di Matteo, and Volker Springel of the Harvard Smithsonian Center for Astrophysics in Cambridge, Mass., that newly merging galaxies are enshrouded in so much dust that astronomers cannot see the black-hole feeding frenzy. The computer simulations, as supported by Hubble, suggest that it takes hundreds of millions to a billion years before enough dust clears so that astronomers can see the black holes feasting on stars and gas from the merger. The telltale sign that black holes are dining is seeing light from galaxies that varies with time.

The two HUDF teams believe they are seeing two distinct phases in galaxy evolution: the first phase - the tadpole stage - representing the early-merging systems where central black holes are still enshrouded in dust, and the much later ”variable-object phase,” in which the merged system has cleared out enough gas for the inner accretion disk around the black hole to become visible.

”The fact that these phases were almost entirely separate was a surprise, because it is commonly believed that galaxy mergers and central black-hole activity are closely related. Our nearby universe has mature galaxies, but in order to understand how they formed and evolved, we must study them over time,” Windhorst explained. ”The HUDF provides an actual look back in time to see snapshots of early galaxies so that we can study them when they were young.”

A link between the growth of galaxies through mergers and the feeding of the central black holes has long been suspected. The evidence, however, has been inconclusive for many years. ”The HUDF has provided very high-quality information. It is the first data we could use to test this theory, since it allowed us to study about 5,000 distant galaxies over a period of four months,” said Seth Cohen of Arizona State University and leader of one of the teams.

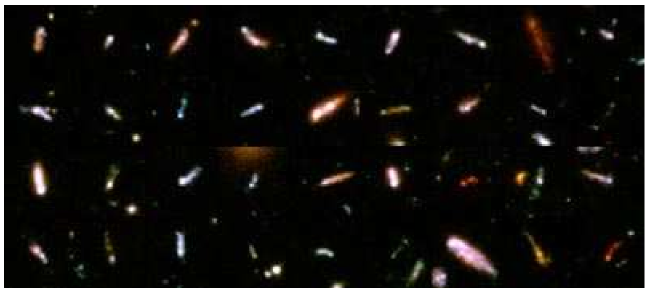

Figure 22: *Credit: NASA, A. Straughn, S. Cohen, and R. Windhorst (Arizona State University), and the HUDF team (Space Telescope Science Institute)*

The HUDF observations have now shed light on how the growth of monster black holes kept pace with that of galaxies. A team of astronomers, led by Amber Straughn of Arizona State University, searched the HUDF for ”tadpole galaxies,” so-called because they have bright knots and tails caused by mergers. These features are produced when the galaxies lose their gravitational grip on their stars, spewing some of those stars into space. The team found about 165 tadpole galaxies, representing about 6 percent of the 2,700 galaxies in the tadpole galaxy study.

”To our surprise, however, these tadpole objects did not show any fluctuation in brightness,” Straughn said. ”The flickering light when it is present comes from the material swirling around an accretion disk surrounding a black hole. The material is heated and begins to glow. As it spirals down toward the black hole, it can rapidly change in brightness. This study of tadpole galaxies suggests that black holes in newly merging galaxies are enshrouded in dust, and therefore, we cannot see them accreting material."

Cohen's team studied the brightness of about 4,600 HUDF objects over several weeks to many months. The Hubble team found that about 45 (non-tadpole) objects, representing 1 percent of the faint galaxies in the study, fluctuated significantly in brightness over time. This result indicates that the galaxies probably contain supermassive black holes that are feeding on stars or gas.

"A black hole's typical mealtime lasts at least a few dozen million years," Windhorst said. "This is equivalent to black holes spending no more than 15 minutes per day eating all their food - a veritable fast food diet."

The HUDF analysis also reinforces previous Hubble telescope studies of monster black holes in the centers of nearby, massive galaxies. Those studies showed a close relationship between the mass of a galaxy's "central bulge" of stars and that of the central black hole. Galaxies today have central black holes with masses ranging from a few million to a few billion solar masses.

2.20 Dying Star Reveals More Evidence for New Kind of Black Hole

Source: NASA News, January 5th, 2006 [28]

Scientists using NASA's Rossi X-ray Timing Explorer have found a doomed star orbiting what appears to be a medium-sized black hole a theorized "in-between" category of black hole that has eluded confirmation and frustrated scientists for more than a decade.

With the discovery of the star and its orbital period, scientists are now one step away from measuring the mass of such a black hole, a step which would help verify its existence. The star's period and location already fit into the main theory of how these black holes could form.

A team led by Prof. Philip Kaaret of the University of Iowa, Iowa City, announced these results today in Science Express. The results will also appear in the Jan. 27 issue of Science.

"We caught this otherwise ordinary star in a unique stage in its evolution, toward the end of its life when it has bloated into a red giant phase," said Kaaret. "As a result, gas from the star is spilling into the black hole, causing the whole region to light up. This is a well-studied region of the sky, and we spotted the star with a little luck and a lot of perseverance."

A black hole is an object so dense and with a gravitational force so intense that nothing, not even light, can escape its pull once within its boundary. A black hole region becomes visible when matter falls toward it and heats to high temperatures. This light is emitted before the matter crosses the border, called the event horizon.

Our galaxy is filled with millions of stellar-mass black holes, each with the mass of a few suns. These form from the collapse of very massive stars. Most galaxies possess at their core a supermassive black hole, containing the mass of millions to billions of suns confined to a region no larger than our solar system. Scientists do not know how these form, but it likely entails the collapse of enormous quantities of primordial gas.

"In the past decade, several satellites have found evidence of a new class of black holes, which could be between 100 and 10,000 solar masses," said Dr. Jean Swank, Rossi Explorer project scientist at NASA's Goddard Space Flight Center, Greenbelt, Md. "There has been debate about the masses and how these black holes would form. Rossi has provided major new insight."

These suspected mid-mass black holes are called ultraluminous X-ray objects because they are bright sources of X-rays. In fact, most of these black hole mass estimates have been based solely on a calculation of how strong a gravitational pull is needed to produce light of a given intensity.

Kaaret's group at the University of Iowa, which includes Prof. Cornelia Lang and Melanie Simet, an undergraduate, made a measurement that can be used in the equation to directly calculate mass. Using straightforward Newtonian physics, scientists can calculate an object's mass once they know an orbital period and velocity of smaller objects rotating around it.

"We found a rise and fall in X-ray light every 62 days, likely caused by the orbit of the companion star around the black hole," said Simet. "The velocity will be hard to determine, however, because the star is located in such a dust-obscured area. This makes it hard for optical and infrared telescopes to observe the star and make velocity calculations. Yet for now, knowing just the orbital period is very revealing."

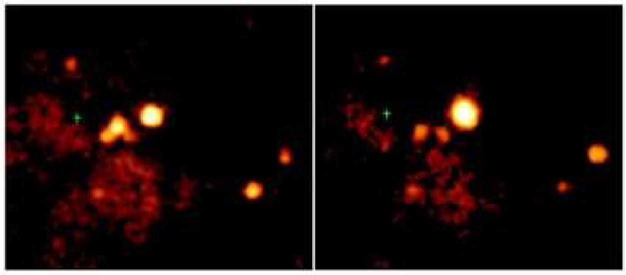

Figure 23: *A's Chandra X-ray Observatory captured this image of the central region of the starburst galaxy M82. From 1999-2000, this source was seen by Chandra to increase dramatically in intensity over a period of three months (compare right and left panels), an indication of black hole activity. With NASA's Rossi Explorer, a team led by Philip Kaaret has found evidence of a star (too small to be imaged) orbiting around the suspected black hole, called M82 X-1. This may confirm that M82 X-1 is part of a new "in-between" category called intermediate-mass black holes. Credit: NASA/SAO/CXC + High resolution images Credit: NASA/SAO/CXC*

The suspected mid-mass black hole, known as M82 X-1, is a well-studied ultra-luminous X-ray object in a nearby star cluster containing about a million stars packed into a region only about 100 light years across. A leading theory proposes that a multitude of star collisions over a short period in a crowded region will create a short-lived gigantic star that collapses into a 1,000-solar-mass black hole. The cluster near M82 X-1 has a high-enough density to form such a black hole. No normal companion could provide enough fuel to make M82 X-1 shine so brightly. But the 62-day orbital period implies that the companion must have a very low density. This fits the scenario of a bloated super-giant star losing mass at a rate high enough to fuel M82 X-1.

"With this discovery of the orbital period, we now have a consistent picture of the whole evolution of a mid-mass black hole binary," said Kaaret. "It was formed in a 'super' star cluster; the black hole then captured a companion star; the companion star evolved to the giant stage; and we now see it as an extremely luminous X-ray source because the companion star has expanded and is feeding the black hole."

2.21 Scientists find black hole's 'point of no return'

Source: MIT News, January 9th, 2006 [29]

Scientists have found new evidence that black holes are performing the disappearing acts for which they are known.

A team from MIT and Harvard has found that a certain type of X-ray explosion common on neutron stars is never seen around their black hole cousins, as if the gas that fuels these explosions has vanished into a void.

This is strong evidence, the team said, for the existence of a theoretical border around a black hole called an event horizon, a point from beyond which nothing, not even light, can escape.

Ron Remillard of the Kavli Institute for Astrophysics and Space Research at MIT in Cambridge, Mass., led the analysis and is discussing his team's result today at a press conference at the 207th meeting of the American Astronomical Society in Washington, D.C. His colleagues are Dacheng Lin of MIT and Randall Cooper and Ramesh Narayan of the Harvard-Smithsonian Center for Astrophysics in Cambridge.

The scientists studied a complete sample of transient X-ray sources detected with NASA's Rossi X-ray Timing Explorer during the last nine years. They detected 135 X-ray bursts from the 13 sources believed to be neutron stars, but none from the 18 suspected black holes.

Gas released by a nearby star can accumulate on the hard surface of a neutron star, and it will eventually erupt in a thermonuclear explosion. The more massive compact objects in this study suspected of being black holes appeared to have no surface. Gas falling toward the black hole seems to disappear.

"Event horizons are invisible by definition, so it seems impossible to prove their existence," said Remillard. "Yet by looking at dense objects that pull in gas, we can infer whether that gas crashes and accumulates onto a hard surface or just quietly vanishes. For the group of suspected black holes we studied, there is a complete absence of surface explosions called X-ray bursts."

A black hole forms when a very massive star runs out of fuel. Without energy to support its mass, the star implodes. If the star is more than 25 times more massive than our sun, the core will collapse to a point of infinite density with no surface. Within a boundary of about 50 miles from the black hole center, gravity is so strong that not even light can escape its pull. This boundary is the theoretical event horizon.

Figure 24: *Artist illustration of a black hole. Image credit: NASA*

Stars of about 10 to 25 solar masses will collapse into compact spheres about 10 miles across, called neutron stars. These objects have a hard surface and no event horizon.

Black holes and their neutron star cousins are sometimes located in binary systems, orbiting a relatively normal star companion. Gas from these stars, lured by strong gravity, can flow toward the compact object periodically. This process, called accretion, releases large amounts of energy, predominantly in the form of X-rays.

Gas can accumulate on a neutron star surface, and when conditions are ripe, the gas will ignite in a thermonuclear explosion that is visible as a one-minute event called a Type I X-ray burst. The suspected black holes – that is, the more massive types of compact objects in this study – behave as if they have no surface and are located behind event horizons.

The idea of using the absence of X-ray bursts to confirm the presence of event horizons in black holes was proposed in 2002 by Harvard's Narayan and Jeremy Heyl of the University of British Columbia in Vancouver.

3 Space missions

3.1 The Smell of Moondust

Source: Science@NASA, January 30th, 2006 [30]

Moondust. "I wish I could send you some," says Apollo 17 astronaut Gene Cernan. Just a thimbleful scooped fresh off the lunar surface. "It's amazing stuff."

Feel it?it's soft like snow, yet strangely abrasive.

Taste it?"not half bad," according to Apollo 16 astronaut John Young.

Sniff it?"it smells like spent gunpowder," says Cernan.

How do you sniff moondust?

Every Apollo astronaut did it. They couldn't touch their noses to the lunar surface. But, after every moonwalk (or "EVA"), they would tramp the stuff back inside the lander. Moondust was incredibly clingy, sticking to boots, gloves and other exposed surfaces. No matter how hard they tried to brush their suits before re-entering the cabin, some dust (and sometimes a lot of dust) made its way inside.

Once their helmets and gloves were off, the astronauts could feel, smell and even taste the moon.

The experience gave Apollo 17 astronaut Jack Schmitt history's first recorded case of extraterrestrial hay fever. "It's come on pretty fast," he radioed Houston with a congested voice. Years later he recalls, "When I took my helmet off after the first EVA, I had a significant reaction to the dust. My turbinates (cartilage plates in the walls of the nasal chambers) became swollen."

thermos.gif Apollo 12 astronaut Alan Bean displays a "thermos" for moondust–a.k.a. a Special Environmental Sample Container.

Hours later, the sensation faded. "It was there again after the second and third EVAs, but at much lower levels. I think I was developing some immunity to it."

Other astronauts didn't get the hay fever. Or, at least, "they didn't admit it," laughs Schmitt. "Pilots think if they confess their symptoms, they'll be grounded." Unlike the other astronauts, Schmitt didn't have a test pilot background. He was a geologist and readily admitted to sniffles.

Schmitt says he has sensitive turbinates: "The petrochemicals in Houston used to drive me crazy, and I have to watch out for cigarette smoke." That's why, he believes, other astronauts reacted much less than he did.

But they did react: "It is really a strong smell," radioed

Apollo 16 pilot Charlie Duke. ”It has that taste – to me, [of] gunpowder – and the smell of gunpowder, too.” On the next mission, Apollo 17, Gene Cernan remarked, ”smells like someone just fired a carbine in here.”

Schmitt says, ”All of the Apollo astronauts were used to handling guns.” So when they said ’moondust smells like burnt gunpowder,’ they knew what they were talking about.

To be clear, moondust and gunpowder are not the same thing. Modern smokeless gunpowder is a mixture of nitrocellulose (C6H8(NO2)2O5) and nitroglycerin (C3H5N3O9). These are flammable organic molecules ”not found in lunar soil,” says Gary Lofgren of the Lunar Sample Laboratory at NASA’s Johnson Space Center. Hold a match to moondust–nothing happens, at least, nothing explosive.

What is moondust made of? Almost half is silicon dioxide glass created by meteoroids hitting the moon. These impacts, which have been going on for billions of years, fuse topsoil into glass and shatter the same into tiny pieces. Moondust is also rich in iron, calcium and magnesium bound up in minerals such as olivine and pyroxene. It’s nothing like gunpowder.

So why the smell? No one knows.

ISS astronaut Don Pettit, who has never been to the moon but has an interest in space smells, offers one possibility:

”Picture yourself in a desert on Earth,” he says. ”What do you smell? Nothing, until it rains. The air is suddenly filled with sweet, peaty odors.” Water evaporating from the ground carries molecules to your nose that have been trapped in dry soil for months.

Maybe something similar happens on the moon.

”The moon is like a 4-billion-year-old desert,” he says. ”It’s incredibly dry. When moondust comes in contact with moist air in a lunar module, you get the ’desert rain’ effect–and some lovely odors.” (For the record, he counts gunpowder as a lovely odor.)

Gary Lofgren has a related idea: ”The gases ’evaporating’ from the moondust might come from the solar wind.” Unlike Earth, he explains, the moon is exposed to the hot wind of hydrogen, helium and other ions blowing away from the sun. These ions hit the moon’s surface and get caught in the dust.

It’s a fragile situation. ”The ions are easily dislodged by footsteps or dustbrushes, and they would be evaporated by contact with warm air inside the lunar module. Solar wind ions mingling with the cabin’s atmosphere would produce who-knows-what odors.”

Want to smell the solar wind? Go to the moon.

Schmitt offers yet another idea: The smell, and his reaction to it, could be a sign that moondust is chemically active.

”Consider how moondust is formed,” he says. ”Meteoroids hit the moon, reducing rocks to jagged dust. It’s a process of hammering and smashing.” Broken molecules in the dust have ”dangling bonds”–unsatisfied electrical connections that need atomic partners.

Inhale some moondust and what happens? The dangling bonds seek partners in the membranes of your nose. You get congested. You report strange odors. Later, when the all the bonds are partnered-up, these sensations fade.

Another possibility is that moondust ”burns” in the lunar lander’s oxygen atmosphere. ”Oxygen is very reactive,” notes Lofgren, ”and would readily combine with the dangling chemical bonds of the moondust.” The process, called oxidation, is akin to burning. Although it happens too slowly for smoke or flames, the oxidation of moondust might produce an aroma like burnt gunpowder. (Note: Burnt and unburnt gunpowder do not smell the same. Apollo astronauts were specific. Moondust smells like burnt gunpowder.)

Curiously, back on Earth, moondust has no smell. There are hundreds of pounds of moondust at the Lunar Sample Lab in Houston. There, Lofgren has held dusty moon rocks with his own hands. He’s sniffed the rocks, sniffed the air, sniffed his hands. ”It does not smell like gunpowder,” he says.

Were the Apollo crews imagining things? No. Lofgren and others have a better explanation:

Moondust on Earth has been ”pacified.” All of the samples brought back by Apollo astronauts have been in contact with moist, oxygen-rich air. Any smelly chemical reactions (or evaporations) ended long ago.

This wasn’t supposed to happen. Astronauts took special ”thermos” containers to the moon to hold the samples in vacuum. But the jagged edges of the dust unexpectedly cut the seals of the containers, allowing oxygen and water vapor to sneak in during the 3-day trip back to Earth. No one can say how much the dust was altered by that exposure.

Schmitt believes ”we need to study the dust in situ–on the moon.” Only there can we fully discover its properties: Why does it smell? How does it react with landers, rovers and habitats? What surprises await?

NASA plans to send people back to the moon in 2018, and they’ll stay much longer than Apollo astronauts did.

The next generation will have more time and better tools to tackle the mystery.

We've only just begun to smell the moondust.

3.2 Using a simple police scanner or ham radio, you can listen to a disembodied spacesuit circling Earth

Source: Science@NASA, January 26th, 2006 [31]

One of the strangest satellites in the history of the space age is about to go into orbit. Launch date: Feb. 3rd. That's when astronauts onboard the International Space Station (ISS) will hurl an empty spacesuit overboard.

The spacesuit is the satellite – "SuitSat" for short.

"SuitSat is a Russian brainstorm," explains Frank Bauer of NASA's Goddard Space Flight Center. "Some of our Russian partners in the ISS program, mainly a group led by Sergey Samburov, had an idea: Maybe we can turn old spacesuits into useful satellites." SuitSat is a first test of that idea.

"We've equipped a Russian Orlan spacesuit with three batteries, a radio transmitter, and internal sensors to measure temperature and battery power," says Bauer. "As SuitSat circles Earth, it will transmit its condition to the ground."

Unlike a normal spacewalk, with a human inside the suit, SuitSat's temperature controls will be turned off to conserve power. The suit, arms and legs akimbo, possibly spinning, will be exposed to the fierce rays of the sun with no way to regulate its internal temperature.

"Will the suit overheat? How long will the batteries last? Can we get a clear transmission if the suit tumbles?" wonders Bauer. These are some of the questions SuitSat will answer, laying the groundwork for SuitSats of the future.

SuitSat can be heard by anyone on the ground. "All you need is an antenna (the bigger the better) and a radio receiver that you can tune to 145.990 MHz FM," says Bauer. "A police band scanner or a hand-talkie ham radio would work just fine." He encourages students, scouts, teachers and ham radio operators to tune in.

Figure 25: *Russian Orlan Suit*

For years, Bauer and colleagues at Goddard have been connecting kids on Earth with astronauts on the ISS through the ARISS program (Amateur Radio on International Space Station). "There's a ham rig on the ISS, and the astronauts love talking to students when they pass over schools," Bauer explains. ARISS is co-sponsoring SuitSat along with the Radio Amateur Satellite Corporation (AMSAT), the American Radio Relay League (ARRL), the Russian Space Agency and NASA.

When will SuitSat orbit over your home town?

Use Science at NASA's J-Pass utility to find out. The online program will ask for your zip code?that's all. Then it will tell you when the ISS is going to orbit over your area. (Be sure to click the "options" button and select "all passes.") Because the ISS and SuitSat share similar orbits, predictions for one will serve for the other. Observers in the United States will find that SuitSat passes overhead once or twice a day?usually between midnight and 4 o'clock in the morning. At that time of day, SuitSat and the ISS will be in Earth's shadow and, thus, too dark to see with the naked eye. You'll need a radio to detect them.

"Point your antenna to the sky during the 5-to-10 minute flyby," advises Bauer, and this is what you'll hear:

SuitSat transmits for 30 seconds, pauses for 30 seconds, and then repeats. "This is SuitSat-1, RS0RS," the transmission begins, followed by a prerecorded greeting in five languages. The greeting contains "special words" in English, French, Japanese, Russian, German and Spanish for students to record and decipher. (Awards will be given to students who do this. Scroll to the "more information" area at the end of this story for details.)

Next comes telemetry: temperature, battery power, mission elapsed time. "The telemetry is stated in plain language?in English," says Bauer. Everyone will be privy to SuitSat's condition. Bauer adds, "Suitsat 'talks' using a voice synthesizer. It's pretty amazing."

The transmission ends with a Slow Scan TV picture. Of what? "We're not telling," laughs Bauer. "It's a mystery picture." (More awards will be given to students who figure out what it is.)

Students and teachers who want to try this, but have no clue how to begin, should contact their local ham radio club. There are thousands of them around the country. Click here to find a club near you. "Hams are notoriously outgoing; most would be delighted to help students tune in to SuitSat," believes Bauer.

Bauer expects SuitSat's batteries to last 2 to 4 days. "Although longer is possible," he allows. After that, SuitSat will begin a slow silent spiral into Earth's atmosphere. Weeks or months later, no one knows exactly when, it will become a brilliant fireball over some part of Earth?a fitting end for a trailblazer.

3.3 NASA Magnetic Field Mission Ends

Source: NASA News, January 20th, 2006 [32]

NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite recently ceased operations, bringing to a close a successful six-year mission. IMAGE was the premier producer of new discoveries on the structure and dynamics of the Earth's external magnetic field (magnetosphere) and its contents.

"The IMAGE mission showed us space around the Earth is anything but empty, and that plasma clouds can be imaged and tracked just as we do from space for Earth's surface weather," said Barbara Giles, IMAGE Program Scientist at NASA headquarters.

Prior to the launch of IMAGE, the energetic particles and electrically charged gas (plasma) surrounding the Earth were completely invisible to human observers. IMAGE enabled researchers to study the global structure and dynamics of the Earth's inner magnetosphere as it responded to energy from solar winds.

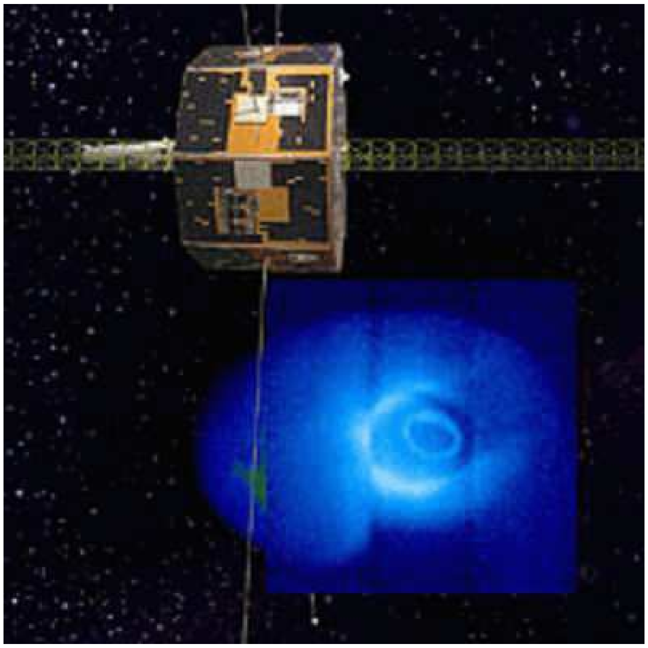

Figure 26:

"Nearly six years of imagery by the pioneering cameras on IMAGE revolutionized our understanding of geospace and our knowledge of its space weather," said James Burch, IMAGE principal investigator at the Southwest Research Institute, San Antonio.

IMAGE was launched on March 25, 2000. It successfully completed its two-year primary mission and continued providing data into December 2005, when it stopped responding to commands from ground controllers. Preliminary analysis indicated the craft's power supply subsystems failed, rendering it lifeless. The satellite is in an extended elliptical orbit and poses no threat to the planet.

IMAGE discoveries have been reported in more than 400 peer-reviewed publications. More than 20 Ph.D. theses were based on data from the mission. Science highlights include:

Confirmations: plasma plume creation, post-midnight peak in storm plasmas, the neutral solar wind, terrestrial origin of geospace storm plasmas and continuous nature of magnetic reconnection.

Discoveries: plasmaspheric shoulders and notches, proton auroras in unexpected places, surprisingly slow plasmasphere rotation, a hot oxygen geocorona and a secondary interstellar neutral atom stream.

Resolutions: the source of kilometric continuum radiation, solar- wind and auroral intensity effects on ionospheric out flow and the relationship between proton and electron auroras during geospace storms.

The IMAGE education and public outreach program received numerous awards for videos, books, primary and secondary school curricula, teacher training, museum exhibits, planetarium shows, student workbooks and web-based information.

The extensive archival database generated by IMAGE promises to yield new discoveries and will support investigations by other spacecraft and ground-based observatories for many years.

3.4 World's Largest Telescope

Source: PPARC Press Release, January 25th, 2006 [33]

European funding has now been agreed to start designing the world's largest telescope. The "Square Kilometre Array" (SKA) will be an international radio telescope with a collecting area of one million square metres - equivalent to about 200 football pitches - making SKA 200 times bigger than the University of Manchester's Lovell Telescope at Jodrell Bank and so the largest radio telescope ever constructed. Such a telescope would be so sensitive that it could detect TV Broadcasts coming from the nearest stars.

The four-year Square Kilometre Array Design Study (SKADS) will bring together European and international astronomers to formulate and agree the most effective design. The final design will enable the SKA to probe the cosmos in unprecedented detail, answering fundamental questions about the Universe, such as "what is dark energy?" and "how did the structure we see in galaxies today actually form?".

The new telescope will test Einstein's General Theory of Relativity to the limit - and perhaps prove it wrong. It is certain to add to the long list of fundamental discoveries already made by radio astronomers including quasars, pulsars and the radiation left over from the Big Bang. By the end of this decade the design will be complete and astronomers anticipate building SKA in stages, leading to completion and full operation in 2020.

Figure 27: *An image of how one element of the SKA might look*

The SKA concept was first proposed to observe the characteristic radio emission from hydrogen gas. Measurements of the hydrogen signature will enable astronomers to locate and weigh a billion galaxies.

As the University of Manchester's Prof Peter Wilkinson points out, "Hydrogen is the most abundant element in the universe, but its signal is weak and so a huge collecting area is needed to be able to study it at the vast distances that take us back in time towards the Big Bang". To which Prof Steve Rawlings, University of Oxford, adds,"The distribution of these galaxies in space tells us how the universe has evolved since the Big Bang and hence about the nature of the Dark Energy which is now making the universe expand faster with time".

Another target for the SKA is pulsars - spinning remnants of stellar explosions which are the most accurate clocks in the universe. A million times the mass of the Earth but only the size of a large city, pulsars can spin around hundreds of times per second. Already these amazing objects have enabled astronomers to confirm Einstein's prediction of gravitational waves, but University of Manchester's Dr Michael Kramer is looking further ahead. "With the SKA we will find a pulsar orbiting a black hole and, by watching how the clock rate varies, we can tell if Einstein had the last word on gravity or not", he says.

Prof Richard Schilizzi, the International SKA Project Director, stresses the scale of the instrument needed to fulfil these science goals. "Designing and then building, such an enormous technologically-advanced instrument is beyond the scope of individual nations. Only by harnessing the ideas and resources of countries around the world is such a project possible". Astronomers in Australia, South Africa, Canada, India, China and the USA are collaborating closely with colleagues in Europe to develop the required technology which will include sophisticated electronics and powerful computers that will play a far bigger role than in the present generation of radio telescopes. The European effort is based on phased array receivers, similar to those in aircraft radar systems. When placed at the focus of conventional mass-produced radio 'dishes', these arrays operate like wide-angle radio cameras enabling huge areas of sky to be observed simultaneously. A separate, much larger, phased array at the centre of the SKA will act like a radio fish-eye lens, constantly scanning the sky.

Funding for this global design programme has been provided by the European Commission's Framework 6 'Design Studies' programme, which is contributing about 27 percent of the total 38m Euro funding over the next four years. Individual countries are contributing the remainder. The UK has invested 5.6M (?8.3M) funding provided by PPARC. When coupled with the UK's share of the EC contribution, then the UK's overall contribution to the SKA Design Study (SKADS) programme is about 30 percent of the total.

The ?38M European technology development programme is funded by the European Commission and governments in eight countries led by the Netherlands, the UK, France and Italy. The programme is being coordinated by Ir. Arnold van Ardenne, Head of Emerging Technologies at The Netherlands ASTRON Institute. In van Ardenne's view "the critical task is to demonstrate that large numbers of electronic arrays can be built cost effectively - so that our dreams of radio cameras and radio fish-eye lenses can be turned into reality".

In the UK, a group of universities currently including Manchester, Oxford, Cambridge, Leeds and Glasgow, funded by PPARC, is involved in all aspects of the design but is concentrating on sophisticated digital phased arrays and the distribution and analysis of the enormous volumes of data which the SKA will produce. University of Cambridge's Dr Paul Alexander makes the point that "the electronics in the SKA makes it very flexible and allows for completely new ways of scanning the sky. But to make it work will require massive computing power". Designers believe that by the time the SKA reaches full operation, 14 years from now, a new generation of computers will be up to the task.

The geographical location of SKA will be decided in the mid-term future and several nations have already expressed interest in hosting this state of the art astronomical facility.

3.5 NASA's Pluto Mission Launched Toward New Horizons

Source: John Hopkins University Press Release, January 19th, 2006 [34]

The first mission to distant planet Pluto is under way after the successful launch today of NASA's New Horizons spacecraft from Cape Canaveral Air Force Station, Fla.

New Horizons roared into the afternoon sky aboard a powerful Atlas V rocket at 2 p.m. EST. It separated from its solid-fuel kick motor 44 minutes, 53 seconds after launch, and mission controllers at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Md., where the spacecraft was designed and built, received the first radio signals from New Horizons a little more than five minutes later. The radio communications, sent through NASA's Deep Space Network antennas in Canberra, Australia, confirmed to controllers that the spacecraft was healthy and ready to begin initial operations.

"Today, NASA began an unprecedented journey of exploration to the ninth planet in the solar system," says Dr. Colleen Hartman, deputy associate administrator for NASA's Science Mission Directorate, Washington, D.C. "Right now, what we know about Pluto could be written on the back of a postage stamp. After this mission, we'll be able to fill textbooks with new information."

Figure 28: *Image credit: NASA/KSC*

The 1,054-pound, piano-sized spacecraft is the fastest ever launched, speeding away from Earth at approximately 36,000 miles per hour, on a trajectory that will take it more than 3 billion miles toward its primary science target. New Horizons will zip past Jupiter for a gravity assist and science studies in February 2007, and conduct the first close-up, in-depth study of Pluto and its moons in summer 2015. As part of a potential extended mission, the spacecraft would then examine one or more additional objects in the Kuiper Belt, the region of ancient, icy, rocky bodies (including Pluto) far beyond Neptune's orbit.

"The United States of America has just made history by launching the first spacecraft to explore Pluto and the Kuiper Belt beyond," says Dr. Alan Stern, New Horizons principal investigator, from Southwest Research Institute in Boulder, Colo. No other nation has this capability. This is the kind of exploration that forefathers like Lewis and Clark, 200 years ago this year, made a trademark of our nation."

Over the next several weeks, mission operators at APL will place the spacecraft in flight mode, check out its critical operating systems and perform small propulsive maneuvers to refine its path toward Jupiter. Following that, among other operations, the team will begin checking and commissioning most of the seven science instruments.

"This is the gateway to a long, exciting journey," says Glen Fountain, New Horizons project manager from APL. "The team has worked hard for the past four years to get the spacecraft ready for the voyage to Pluto and beyond, to places we've never seen up close. This is a once-in-a-lifetime opportunity, in the tradition of the Mariner, Pioneer, and Voyager missions to set out for first looks in our solar system."

After the Jupiter encounter during which New Horizons will train its science instruments on the large planet and its moons the spacecraft will "sleep" in electronic hibernation for much of the cruise to Pluto. Operators will turn off all but the most critical electronic systems and check in with the spacecraft once a year to check out the critical systems, calibrate the instruments and perform course corrections, if necessary.

Between the in-depth checkouts, New Horizons will send back a beacon signal each week to give operators an instant read on spacecraft health. The entire spacecraft, drawing electricity from a single radioisotope thermoelectric generator, operates on less power than a pair of 100-watt household light bulbs.

3.6 Spacecraft, heal thyself

Source: ESA Press Release, January 20th, 2006 [35]

Building spacecraft is a tough job. They are precision pieces of engineering that have to survive in the airless environment of space, where temperatures can swing from hundreds of degrees Celsius to hundreds of degree below zero in moments. Once a spacecraft is in orbit, engineers have virtually no chance of repairing anything that breaks. But what if a spacecraft could fix itself? Thanks to a new study funded by ESA's General Studies Programme, and carried out by the Department of Aerospace Engineering, University of Bristol, UK, engineers have taken a step towards that amazing possibility. They took their inspiration from nature.

"When we cut ourselves we don't have to glue ourselves back together, instead we have a self-healing mechanism. Our blood hardens to form a protective seal for new skin to form underneath," says Dr Christopher Semprimoschnig, a materials scientist at ESA's European Space Technology Research Centre (ESTEC) in the Netherlands, who oversaw the study. He imagined such cuts as analogous to the 'wear-and-tear' suffered by spacecraft. Extremes of temperature can cause small cracks to open in the superstructure, as can impacts by micrometeroids - small dust grains travelling at remarkable speeds of several kilometres per second. Over the lifetime of a mission the cracks build up, weakening the spacecraft until a catastrophic failure becomes inevitable.

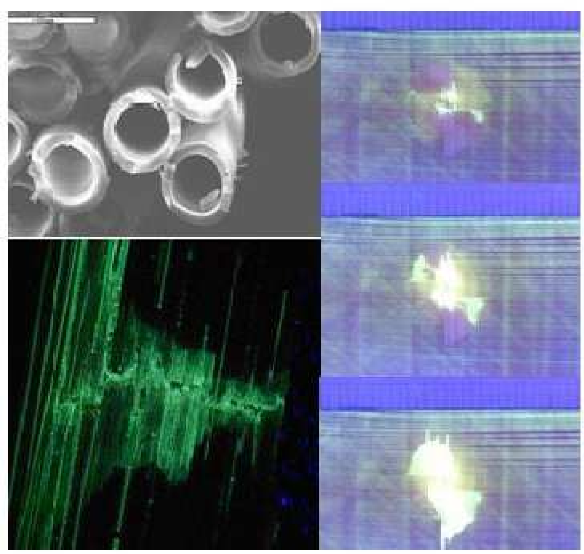

Figure 29: *Hollow fibres just 30 micrometres in diameter tread the new material. When damage occurs, the fibres*

break releasing liquids that seep into the cracks and harden, repairing the damage. Credits: ESA

The challenge for Semprimoschnig was to replicate the human process of healing small cracks before they can open up into anything more serious. He and the team at Bristol did it by replacing a few percent of the fibres running through a resinous composite material, similar to that used to make spacecraft components, with hollow fibres containing adhesive materials. Ironically, to make the material self-repairable, the hollow fibres had to be made of an easily breakable substance: glass. "When damage occurs, the fibres must break easily otherwise they cannot release the liquids to fill the cracks and perform the repair," says Semprimoschnig.

In humans, the air chemically reacts with the blood, hardening it. In the airless environment of space, alternate mechanical veins have to be filled with liquid resin and a special hardener that leak out and mix when the fibres are broken. Both must be runny enough to fill the cracks quickly and harden before it evaporates.

"We have taken the first step but there is at least a decade to go before this technology finds its way onto a spacecraft," says Semprimoschnig, who believes that larger scale tests are now needed. The promise of self-healing spacecraft opens up the possibility of longer duration missions. The benefits are two-fold. Firstly, doubling the lifetime of a spacecraft in orbit around Earth would roughly halve the cost of the mission. Secondly, doubling spacecraft lifetimes means that mission planners could contemplate missions to far-away destinations in the Solar System that are currently too risky.

In short, self-healing spacecraft promise a new era of more reliable spacecraft, meaning more data for scientists and more reliable telecommunication possibilities for us all.

3.7 NASA's Comet Tale Draws to a Successful Close in Utah Desert

Source: NASA News, January 15th, 2006 [36]

NASA's Stardust sample return mission returned safely to Earth when the capsule carrying cometary and interstellar particles successfully touched down at 2:10 a.m. Pacific time (3:10 a.m. Mountain time) in the desert salt flats of the U.S. Air Force Utah Test and Training Range.

"Ten years of planning and seven years of flight operations were realized early this morning when we successfully picked up our return capsule off of the desert floor in Utah," said Tom Duxbury, Stardust project manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "The Stardust project has delivered to the international science community material that has been unaltered since the formation of our solar system."

Stardust released its sample return capsule at 9:57 p.m. Pacific time (10:57 p.m. Mountain time) last night. The capsule entered the atmosphere four hours later at 1:57 a.m. Pacific time (2:57 a.m. Mountain time). The drogue and main parachutes deployed at 2:00 and 2:05 a.m. Pacific time, respectively (3:00 and 3:05 a.m. Mountain time).

Figure 30: *Stardust return capsule on the ground. Image credit: NASA*

"I have been waiting for this day since the early 1980s when Deputy Principal Investigator Dr. Peter Tsou of JPL and I designed a mission to collect comet dust," said Dr. Don Brownlee, Stardust principal investigator from the University of Washington, Seattle. "To see the capsule safely back on its home planet is a thrilling accomplishment."

The sample return capsule's science canister and its cargo of comet and interstellar dust particles will be stowed inside a special aluminum carrying case to await transfer to the Johnson Space Center, Houston, where it will be opened. NASA's Stardust mission traveled 2.88 billion miles during its seven-year round-trip odyssey. Scientists believe these precious samples will help provide answers to fundamental questions about comets and the origins of the solar system.

As they clustered around the Stardust sample return capsule, Donald Brownlee, Stardust principal investigator from the University of Washington in Seattle, warned his team they might not be able to see any comet dust. The tiny particles may have made such small tracks in the aerogel collector that they would not be visible to the naked eye.

Wearing white bunny suits in a clean room at Johnson Space

Center, the team anxiously examined the collector tray? and then broke into delighted celebration. Small black holes dotted the wispy aerogel tiles, and some were as large as half a centimeter wide.

The holes are carrot-shaped, with a large entry hole that tapers to a point. The first photograph of a cometary particle shows it residing in the very tip of the tunnel it drilled, like the dot of an exclamation point. The particle is only 11 microns across, and appears to be a transparent mineral grain.

"Scientifically, that's great, because there's been lots of discussion of whether comets contain minerals or glass," says Brownlee.

Michael Zolensky, Stardust curator and co-investigator from the Johnson Space Center in Houston, Texas, was among those excited to see evidence of the tiny comet grains. During Stardust's long seven-year journey to the comet Wild 2, he had given in to some pessimistic speculation.

"Maybe (the collection tray) wouldn't open properly. Maybe the particles would just smash all the aerogel out of the tray, and we'd come up with nothing at all. Or maybe (the aerogel) would even be covered with gunk from outgassing from the spacecraft," says Zolensky. "We were really worried about that, and got more and more worried as time went by. And so when we opened the tray just two days ago in the lab, we were relieved to find that everything went exactly right."

The scientists estimate they have up to a million comet particles, with a dozen or so that are the thickness of a human hair, and maybe even one that is larger than a millimeter. But it will take some time to know exactly what the aerogel collector tray holds.

"In the coming days we'll be documenting the positions and character of all the tracks, looking at some of them in more detail," says Brownlee. Afterwards, they will remove some of the aerogel tiles from the collector and pull out the particles so they can be studied with different instruments.

The Johnson Space Center will be sending out Stardust samples to about 150 scientists worldwide by next week. The first official science findings will be revealed at the Lunar and Planetary Science Conference being held in Houston in March.

The opposite side of the collector tray holds samples of interstellar dust. Any tracks made by these miniscule particles are not readily apparent, so it will take some time to scan the aerogel tiles and find them. The scientists estimate they have collected up to two hundred interstellar dust grains, each no larger than a micron in size. In a project called Stardust at home, volunteers can help locate these particles by using their home computers to examine images of the aerogel. More than 65,000 people have volunteered so far.

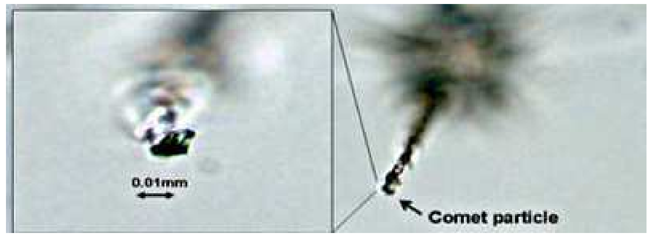

Figure 31: *Stardust Aerogel dust collector. Credit: NASA/JPL*

Stardust's sample return capsule returned to Earth on Sunday, January 15. The spacecraft had flown halfway to Jupiter to collect samples of interstellar dust and particles from the comet Wild 2. The comet dates from the formation of the solar system 4.6 billion years ago.

"We think that much of the Earth's water and organics - the molecules in our bodies - perhaps came from comets," says Zolensky. "So we'll learn a lot about the history of organics in the solar system. Basically it's like looking at our great great grandparents."

NASA launched another exploration mission on Thursday: New Horizons is now on its way to the planet Pluto. Brownlee notes that both Wild 2 and Pluto were born in the Kuiper Belt, a region of ice and dust that encircles the outer region of the solar system. Wild 2 was only recently kicked out of that region and now travels between the orbits of Mars and Jupiter.

Planetary processes will have altered Pluto over time, since planets even as cold as Pluto can experience interior heating. But because Wild 2 is a small comet that hasn't seen much solar heating, it's remained relatively unchanged since the birth of the solar system.

"Pluto is a fascinating place, but it's a planetary-sized object and so it's modified the materials that it came from," says Brownlee. "Wild 2 is four-and-a-half kilometers in diameter, and it has a large amount of volatiles in it. The vapor that we saw coming out of the comet when we flew by was generated when the ice got heated up to 150 Kelvin. That ice had never been hotter than that temperature, or it would have been lost. So there is a good link to the Pluto probe, in that we're sampling the materials that Pluto was made of."

4 Internet websites

[1] http://www.nasa.gov/vision/earth/environment/2005_warmest.html
[2] http://www.nasa.gov/centers/goddard/solarsystem/2006_mag_recon.html
[3] http://www.berkeley.edu/news/media/releases/2006/01/25_life.shtml
[4] http://pr.caltech.edu/media/Press_Releases/PR12787.html
[5] http://www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1837&mode=thread&order=0&thold=0
[6] http://www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1838&mode=thread&order=0&thold=0
[7] http://web.mit.edu/newsoffice/2006/charon.html
[8] http://www.cfa.harvard.edu/press/pr0601.html
[9] http://www.berkeley.edu/news/media/releases/2006/01/19_kuiper.shtml
[10] http://www.nsf.gov/news/news_summ.jsp?cntn_id=105759&org=OLPA&from=news
[11] http://carnegieinstitution.org/news_releases/news_0601_10.html
[12] http://www.noao.edu/outreach/press/pr06/pr0603.html
[13] http://www.cfa.harvard.edu/press/pr0602.html
[14] http://www.cfa.harvard.edu/press/pr0611.html
[15] http://www.berkeley.edu/news/media/releases/2006/01/12_helical.shtml
[16] http://www.cfa.harvard.edu/press/pr0605.html
[17] http://www.cfa.harvard.edu/press/pr0610.html
[18] http://www.esa.int/esaCP/SEMGPQ0VRHE_index_0.html
[19] http://www.cfa.harvard.edu/press/pr0612.html
[20] http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/03/full/
[21] http://www.science.psu.edu/alert/Schneider1-2006.htm
[22] http://www.berkeley.edu/news/media/releases/2006/01/09_warp.shtml
[23] http://uanews.org/cgi-bin/WebObjects/UANews.woa/5/wa/SRStoryDetails?ArticleID=12100
[24] http://www.pparc.ac.uk/Nw/d_galaxy2.asp
[25] http://chandra.harvard.edu/photo/2006/galaxies/
[26] http://www.jhu.edu/news_info/news/home06/jan06/haro.html
[27] http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/04/full/
[28] http://www.nasa.gov/centers/goddard/news/topstory/2005/new_blackhole.html
[29] http://web.mit.edu/newsoffice/2006/blackhole1.html
[30] http://science.nasa.gov/headlines/y2006/30jan_smellofmoondust.htm
[31] http://science.nasa.gov/headlines/y2006/26jan_suitsat.htm
[32] http://www.nasa.gov/home/hqnews/2006/jan/HQ_06030_IMAGE_quits.html
[33] http://www.pparc.ac.uk/Nw/SKA.asp
[34] http://www.jhuapl.edu/newscenter/pressreleases/2006/060119.asp
[35] http://www.esa.int/esaCP/SEMQKMMZCIE_index_0.html
[36] http://www.jpl.nasa.gov/news/news.cfm?release=2006-009

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