National Radio Astronomy Observatory

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National Radio Astronomy Observatory
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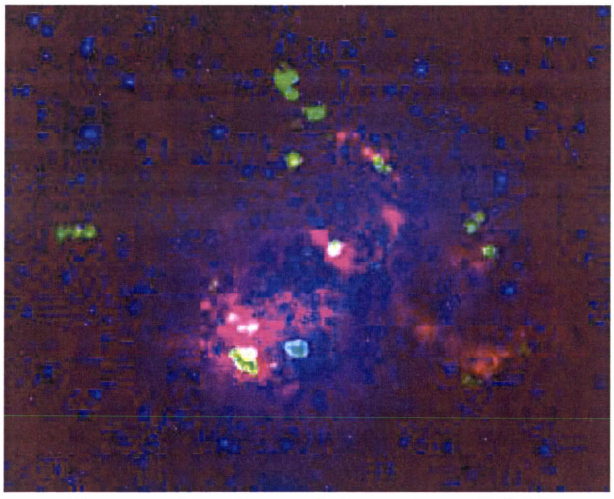
Surprising Image Revises Understanding Of Dwarf Galaxies -- Building Blocks of the Universe

An intensive study of a neighboring dwarf galaxy has surprised astronomers by showing that most of its molecular gas -- the raw material for new stars -- is scattered among clumps in the galaxy's outskirts, not near its center as they expected.



Composite view of the galaxy IC 10. Optical view in blue; Ionized hydrogen (H-alpha) in red; and molecular gas (CO) in green.

CREDIT: *OVRO, Caltech, NOAO, KPNO*

"This tells us that the galaxies we call dwarf irregulars are even more irregular than we thought," said Fabian

Walter, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM. "Our new work also shows that these galaxies probably are useful 'laboratories' for studying how stars were formed when the Universe was young," Walter added.

Walter worked with Christopher Taylor of the University of Massachusetts and Nick Scoville of Caltech. The scientists presented their results at the American Astronomical Society's meeting in Seattle, WA.

Using the millimeter-wave interferometer at Caltech's Owens Valley Radio Observatory, the astronomers combined 15 smaller images into a single mosaic to produce an image showing the location of Carbon Monoxide (CO) gas throughout a galaxy called IC 10, some 2.5 million light-years away. IC 10 is one of the Local Group of galaxies of which our own Milky Way is part. The telescope system was tuned to a frequency near 115 GigaHertz, where the CO molecule naturally emits radio waves.

"We found the clumps of CO gas far from the galaxy's center, and not near the regions of current star formation," Walter said. "This tells us that stars may, in fact, form way out there in the outskirts of the galaxy, where we didn't expect," he added.

Most of the galaxy's gas is atomic Hydrogen, composed of single Hydrogen atoms. Most of the galaxy's *molecular* gas is composed of Hydrogen molecules with two atoms each. Atomic Hydrogen can be seen with radio telescopes because it naturally emits at a radio frequency of 1420 MegaHertz. However, cold molecular Hydrogen cannot be observed with current telescopes. Instead, astronomers look for CO, which emits at several radio frequencies, and then estimate the amount of molecular Hydrogen based on how much CO they see.

Based on the new observations of CO, the astronomers concluded that IC 10 has much less molecular gas than previously thought and apparently has a much smaller percentage of molecular gas than our Milky Way. The astronomers add that dwarf galaxies in general are found to have less of the heavy elements than larger, spiral galaxies. They are thus probably more similar to galaxies in the early Universe when there had been less time for stars to produce the heavy elements and then return them to their surroundings through supernova explosions.

Studies of a dwarf irregular galaxy like IC 10 therefore give astronomers new insights about how stars formed in the distant past. In addition, many astronomers believe dwarf galaxies are the "building blocks of the Universe," from which larger galaxies were assembled through mergers.

"The beauty of this is that dwarf irregulars are the most numerous type of galaxy, and many, like IC 10, are relatively nearby. That means we can learn about star formation in such extreme environments by studying nearby dwarf galaxies. That's fortunate, because we cannot observe extremely distant galaxies with sufficient detail," Walter said.

Studies of molecules in galaxies also will benefit from the completion of the Atacama Large Millimeter Array (ALMA), an international millimeter-wave telescope project to be located in the high plains of northern Chile. With ALMA, astronomers will be able to study galaxies with greater detail and sensitivity to learn more about the nature of the building blocks of the Universe.

Research with the Owens Valley Radio Telescope, operated by the California Institute of Technology, is supported by NSF grant AST96-13717. The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

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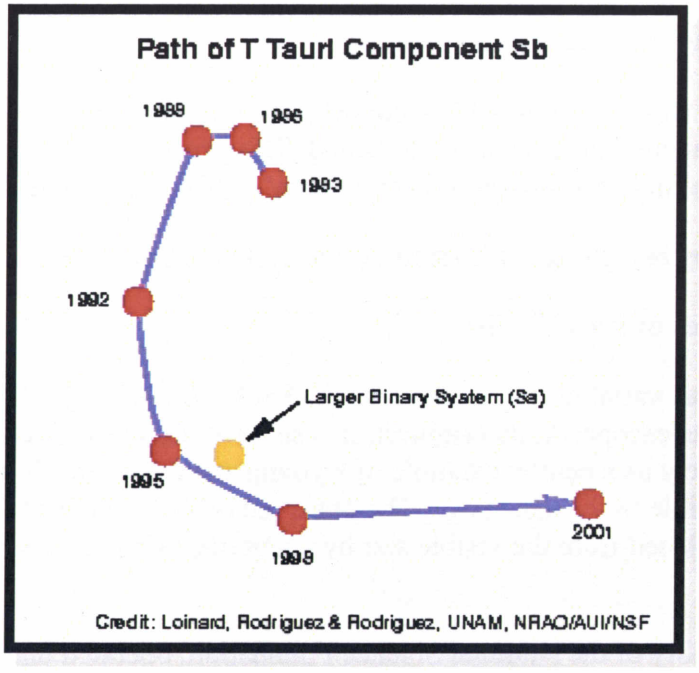
Young Star Probably Ejected From Triple System

Astronomers analyzing nearly 20 years of data from the National Science Foundation's Very Large Array radio telescope have discovered that a small star in a multiple-star system in the constellation Taurus probably has been ejected from the system after a close encounter with one of the system's more-massive components, presumed to be a compact double star. This is the first time any such event has been observed.



"Our analysis shows a drastic change in the orbit of this young star after it made a close approach to another object in the system," said Luis Rodriguez of the Institute of Astronomy of the National Autonomous University of Mexico (UNAM).

"The young star was accelerated to a large velocity by the close approach, and certainly now is in a very

different, more remote orbit, and may even completely escape its companions," said Laurent Loinard, leader of the research team that also included Monica Rodriguez in addition to Luis Rodriguez. The UNAM astronomers presented their findings at the American Astronomical Society's meeting in Seattle, WA.

The discovery of this chaotic event will be important for advancing our understanding of classical dynamic astronomy and of how stars evolve, including possibly providing an explanation for the production of the mysterious "brown dwarfs," the astronomers said.

The scientists analyzed VLA observations of T Tauri, a multiple system of young stars some 450 light-years from Earth. The observations were made from 1983 to 2001. The T Tauri system includes a "Northern" star, the famous star that gives its name to the class of young visible stars, and a "Southern" system of stars, all orbiting each other. The VLA data were used to track the orbit of the smaller Southern star around the larger Southern object, presumed to be a pair of stars orbiting each other closely.

The astronomers' plot of the smaller star's orbit shows that it followed an apparently elliptical orbit around its twin companions, moving at about 6 miles per second. Then, between 1995 and 1998, it came within about 200 million miles (about two times the distance between the Sun and the Earth) of its companions. Following that encounter, it changed its path, moving away from its companion at about 12 miles per second, double its previous speed.

"We clearly see that this star's orbit has changed dramatically after the encounter with its larger companions," said Luis Rodriguez. "By watching over the next five years or so, we should be able to tell if it will escape completely," he added.

"We are very lucky to have been able to observe this event," said Loinard. Though studies with computer simulations long have shown that such close approaches and stellar ejections are likely, the time scales for these events in the real Universe are long -- thousands of years. The chance to study an actual ejection of a star from a multiple system can provide a critical test for the dynamical theories.

If a young star is ejected from the system in which it was born, it would be cut off from the supply of gas and dust it needs to gain more mass, and thus its development would be abruptly halted. This process, the astronomers explain, could provide an explanation for the very-low-mass "failed stars" called brown dwarfs.

"A brown dwarf could have had its growth stopped by being ejected from its parent system," Loinard said.

The VLA observations were made at radio frequencies of 8 and 15 GHz.

T Tauri, the "Northern" star in this system, is a famous variable star, discovered in October of 1852 by J.R. Hind, a London astronomer using a 7-inch diameter telescope. At its brightest, it is some 40 times brighter than when at its faintest. It has been studied extensively as a nearby example of a young stellar system. While readily accessible with a small telescope, it is not visible to the naked eye. The observed orbital changes took place in the southern components of the system, displaced from the visible star by about one hundred times the distance between the Sun and the Earth.

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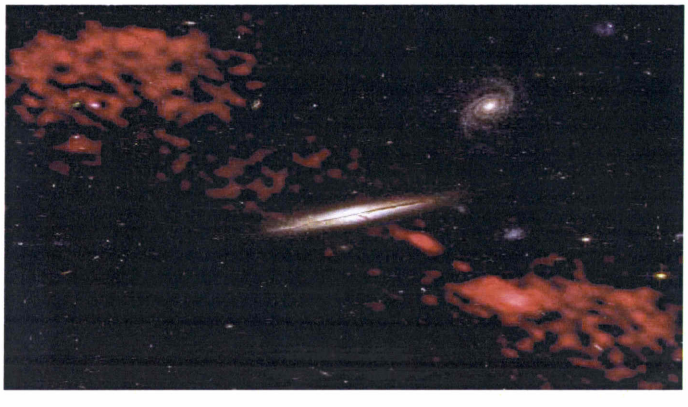
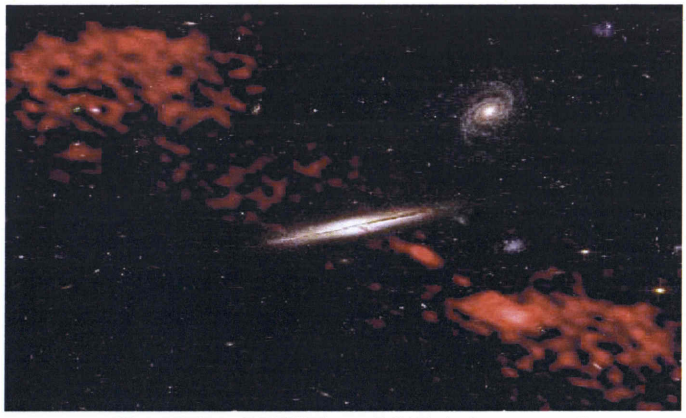
Giant Radio Jet Coming From Wrong Kind of Galaxy

Giant jets of subatomic particles moving at nearly the speed of light have been found coming from thousands of galaxies across the Universe, but always from elliptical galaxies or galaxies in the process of merging -- until now. Using the combined power of the Hubble Space Telescope, the Very Large Array (VLA) and the 8-meter Gemini-South Telescope, astronomers have discovered a huge jet coming from a spiral galaxy similar to our own Milky Way.





Combined HST and VLA image of the galaxy 0313-192. Optical HST image shows the galaxy edge-on; VLA image, shown in red, reveals giant jet of speeding particles. For more images, see this link below.

CREDIT: *Keel, Ledlow & Owen; STScI,NRAO/AUI/NSF, NASA*

"We've always thought spirals were the wrong kind of galaxy to generate these huge jets, but now we're going to have to re-think some of our ideas on what produces these jets," said William Keel, a University of Alabama astronomer who led the research team. Keel worked with Michael Ledlow of Gemini Observatory and Frazer Owen of the National Radio Astronomy Observatory. The scientists reported their findings at the American Astronomical Society's meeting in Seattle, Washington.

"Further study of this galaxy may provide unique insights on just what needs to happen in a galaxy to produce these powerful jets of particles," Keel said.

In addition, Owen said, "The loose-knit nature of the cluster of galaxies in which this galaxy resides may play a part in allowing this particular spiral to produce jets."

Astronomers believe such jets originate at the cores of galaxies, where supermassive black holes provide the tremendous gravitational energy to accelerate particles to nearly the speed of light. Magnetic fields twisted tightly by spinning disks of material being sucked into the black hole are presumed to narrow the speeding particles into thin jets, like a nozzle on a garden hose.

Both elliptical and spiral galaxies are believed to harbor supermassive black holes at their cores.

The discovery that the jet was coming from a spiral galaxy dubbed 0313-192 required using a combination of radio, optical and infrared observations to examine the galaxy and its surroundings.

The story began more than 20 years ago, when Owen began a survey of 500 galaxy clusters using the National Science Foundation's then-new VLA to make radio images of the clusters. In the 1990s, Ledlow joined the project, making optical-telescope images of the same clusters as part of his research for a Ph.D dissertation at the University of New Mexico. An optical image from Kitt Peak National Observatory gave a hint that this galaxy, clearly seen with a jet in the VLA images, might be a spiral.

Nearly a billion light-years from Earth, 0313-192 proved an elusive target, however. Subsequent observations

with the VLA and the 3.5-meter telescope at Apache Point Observatory supported the idea that the galaxy might be a spiral but still were inconclusive. In the Spring of 2002, astronauts installed the Advanced Camera for Surveys on the Hubble Space Telescope. This new facility produced a richly-detailed image of 0313-192, showing that it is a dust-rich spiral seen almost exactly edge-on.

"The finely-detailed Hubble image resolved any doubt and proved that this galaxy is a spiral," Ledlow said. Infrared images with the Gemini-South telescope complemented the Hubble images and further confirmed the galaxy's spiral nature.

Now, the astronomers seek to understand why this one spiral galaxy, unlike all others seen so far, is producing the bright jets seen with the VLA and other radio telescopes.

Several factors may have combined, the researchers feel.

"This galaxy's disk is twisted, and that may indicate that it has been disturbed by a close passage of another galaxy or may have swallowed up a companion dwarf galaxy," Keel said. He added, "This galaxy shows signs of having a very massive black hole at its core, and the jets are taking the shortest path out of the galaxy's own gas."

Owen points out that 0313-192 resides in a cluster of galaxies called Abell 428. The scientists have discovered that Abell 428 is not a dense cluster, but rather a loose collection of small groups of galaxies.

In order to see the large jets so common to elliptical galaxies, Owen said, "you may need pressure from a cluster's intergalactic medium to keep the particles and magnetic fields from dispersing so rapidly that the jet can't stay together."

However, "A spiral won't survive in a dense cluster," Owen said. Thus, the looser collection of galaxy groups that makes up Abell 428 may be "just the right environment to allow the spiral to survive but still to provide the pressure needed to keep the jets together."

In any case, the unique example provided by this jet-producing spiral galaxy "raises questions about some of our basic assumptions regarding jet production in galaxies," Owen said.

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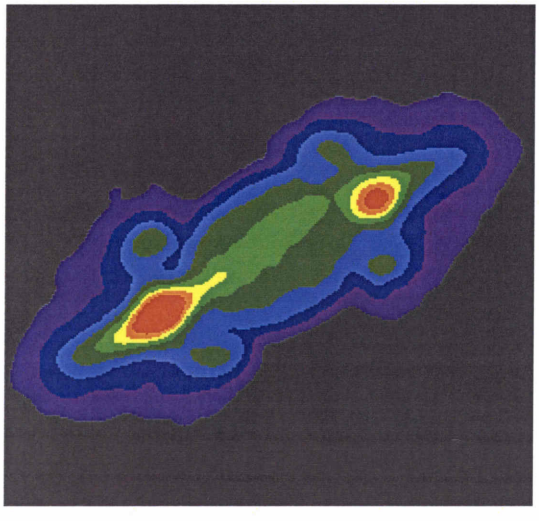
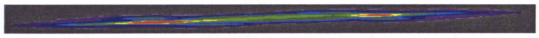
Speed of Gravity Measured for First Time

Taking advantage of a rare cosmic alignment, scientists have made the first measurement of the speed at which the force of gravity propagates, giving a numerical value to one of the last unmeasured fundamental constants of physics.

"Newton thought that gravity's force was instantaneous. Einstein assumed that it moved at the speed of light, but until now, no one had measured it," said Sergei Kopeikin, a physicist at the University of Missouri-Columbia.





VLA Image of Jupiter

CREDIT: *NRAO/AUI/NSF*

"We have determined that gravity's propagation speed is equal to the speed of light within an accuracy of 20 percent," said Ed Fomalont, an astronomer at the National Radio Astronomy Observatory (NRAO) in Charlottesville, VA. The scientists presented their findings to the American Astronomical Society's meeting in Seattle, WA.

The landmark measurement is important to physicists working on unified field theories that attempt to combine particle physics with Einstein's general theory of relativity and electromagnetic theory.

"Our measurement puts some strong limits on the theories that propose extra dimensions, such as superstring theory and brane theories," Kopeikin said. "Knowing the speed of gravity can provide an important test of the existence and compactness of these extra dimensions," he added.

Superstring theory proposes that the fundamental particles of nature are not pointlike, but rather incredibly small loops or strings, whose properties are determined by different modes of vibration. Branes (a word derived from membranes) are multidimensional surfaces, and some current physical theories propose space-time branes embedded to five dimensions.

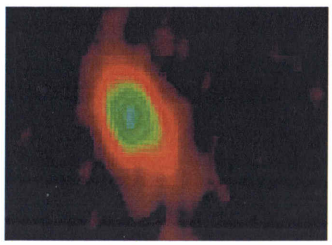
The scientists used the National Science Foundation's Very Long Baseline Array (VLBA), a continent-wide radio-telescope system, along with the 100-meter radio telescope in Effelsberg, Germany, to make an extremely precise observation when the planet Jupiter passed nearly in front of a bright quasar on September 8, 2002.

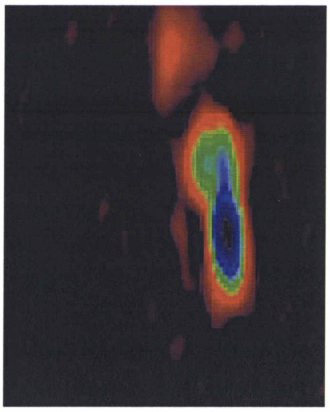
The observation recorded a very slight "bending" of the radio waves coming from the background quasar by the gravitational effect of Jupiter. The bending resulted in a small change in the quasar's apparent position in the sky.

"Because Jupiter is moving around the Sun, the precise amount of the bending depends slightly on the speed at which gravity propagates from Jupiter," Kopeikin said.

Jupiter, the largest planet in the Solar System, only passes closely enough to the path of radio waves from a suitably bright quasar about once a decade for such a measurement to be made, the scientists said.

The once-in-a-decade celestial alignment was the last in a chain of events that made measuring the speed of gravity possible. The others included a chance meeting of the two scientists in 1996, a breakthrough in theoretical physics and the development of specialized techniques that enabled the extremely precise measurement to be made.





Quasar J0842+1835, VLBA Image

CREDIT: *NRAO/AUI/NSF*

"No one had tried to measure the speed of gravity before because most physicists had assumed that the only way to do so was to detect gravitational waves," Kopeikin recalled. However, in 1999, Kopeikin extended Einstein's theory to include the gravitational effects of a moving body on light and radio waves. The effects depended on the speed of gravity. He realized that if Jupiter moved nearly in front of a star or radio source, he could test his theory.

Kopeikin studied the predicted orbit of Jupiter for the next 30 years and discovered that the giant planet would pass closely enough in front of the quasar J0842+1835 in 2002. However, he quickly realized that the effect on the quasar's apparent position in the sky attributable to the speed of gravity would be so small that the only observational technique capable of measuring it was Very Long Baseline Interferometry (VLBI), the technique embodied in the VLBA. Kopeikin then contacted Fomalont, a leading expert in VLBI and an experienced VLBA observer.

"I immediately realized the importance of an experiment that could make the first measurement of a fundamental constant of nature," Fomalont said. "I decided that we had to give this our best shot," he added.

To get the required level of precision, the two scientists added the Effelsberg telescope to their observation. The wider the separation between two radio-telescope antennas, the greater is the resolving power, or ability to see fine detail, achievable. The VLBA includes antennas on Hawaii, the continental United States, and St. Croix in the Caribbean. An antenna on the other side of the Atlantic added even more resolving power.

"We had to make a measurement with about three times more accuracy than anyone had ever done, but we knew, in principle, that it could be done," Fomalont said. The scientists tested and refined their techniques in "dry runs," then waited for Jupiter to make its pass in front of the quasar.

The wait included considerable nail-biting. Equipment failure, bad weather, or an electromagnetic storm on Jupiter itself could have sabotaged the observation. However, luck held out and the scientists' observations at a radio frequency of 8 GigaHertz produced enough good data to make their measurement. They achieved a precision equal to the width of a human hair seen from 250 miles away.

"Our main goal was to rule out an infinite speed for gravity, and we did even better. We now know that the speed of gravity is probably equal to the speed of light, and we can confidently exclude any speed for gravity that is over twice that of light," Fomalont said.

Most scientists, Kopeikin said, will be relieved that the speed of gravity is consistent with the speed of light. "I believe this experiment sheds new light on fundamentals of general relativity and represents the first of many more studies and observations of gravitation which are currently possible because of the enormously high precision of VLBI. We have a lot more to learn about this intriguing cosmic force and its relationship to the other forces in nature," Kopeikin said.

This is not the first time that Jupiter has played a part in producing a measurement of a fundamental physical constant. In 1675, Olaf Roemer, a Danish astronomer working at the Paris Observatory, made the first reasonably accurate determination of the speed of light by observing eclipses of one of Jupiter's moons.

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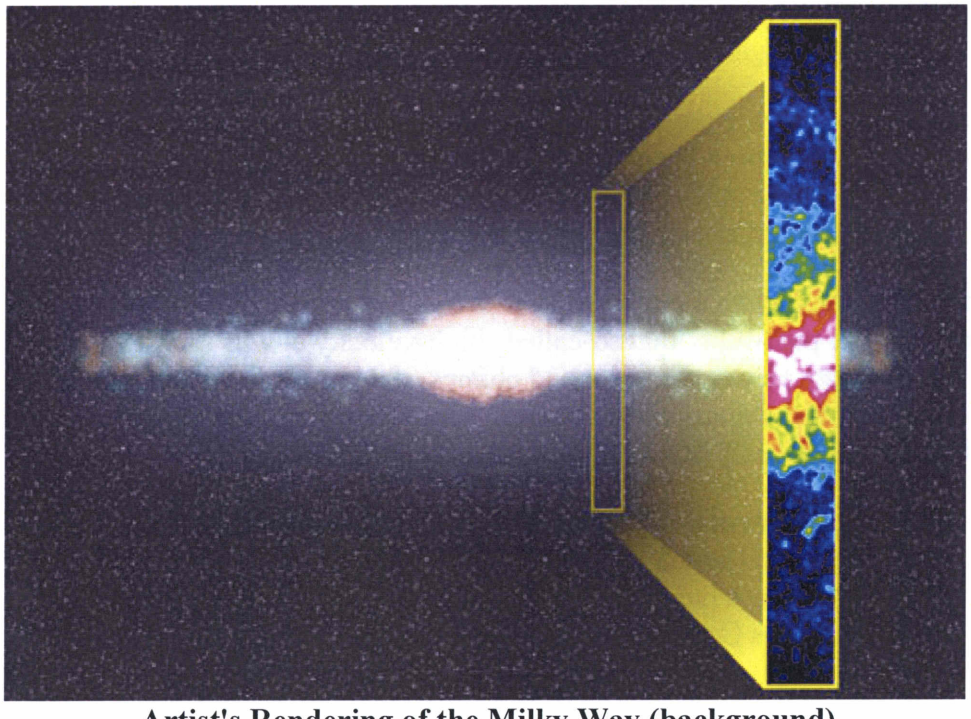
Clouds Dominate the Galactic Halo

Using the exquisite sensitivity of the National Science Foundation's Robert C. Byrd Green Bank Telescope (GBT), astronomer Jay Lockman of the National Radio Astronomy Observatory (NRAO) in Green Bank, W. Va., has produced the best cross-section ever of the Milky Way Galaxy's diffuse halo of hydrogen gas. This image confirms the presence of discrete hydrogen clouds in the halo, and could help astronomers understand the origin and evolution of the rarefied atmosphere that surrounds our Galaxy.

Lockman presented his findings at the American Astronomical Society meeting in Seattle, WA.



Artist's Rendering of the Milky Way (background) with insert showing GBT image of cross-section of neutral atomic Hydrogen

Credit: Kirk Woellert/National Science Foundation
Patricia Smiley, NRAO.

"The first observations with the Green Bank Telescope suggested that the hydrogen in the lower halo, the transition zone between the Milky Way and intergalactic space, is very clumpy," said Lockman. "The latest data confirm these results and show that instead of trailing away smoothly from the Galactic plane, a significant fraction of the hydrogen gas in the halo is concentrated in discrete clouds. There are even some filaments."

Beyond the star-filled disk of the Milky Way, there exists an extensive yet diffuse halo of hydrogen gas. For years, astronomers have speculated about the origin and structure of this gas. "Even the existence of neutral hydrogen in the halo has been somewhat of a puzzle," Lockman remarked. "Unlike the Earth's atmosphere, which is hot enough to hold itself up against the force of gravity, the hydrogen in the halo is too cool to support itself against the gravitational pull of the Milky Way."

Lockman points out that some additional factor has to be involved to get neutral hydrogen to such large distances from the Galactic plane. "This force could be cosmic rays, a supersonic wind, the blast waves from supernovae, or something we have not thought of yet," he said. Earlier this year, data taken with the newly commissioned GBT demonstrated that rather than a diffuse mist or other ill-defined feature - as many astronomers had speculated - the halo was in fact made up of well-defined clouds.

"The discovery of these clouds, each containing 50-to-100 solar masses of hydrogen and averaging about 100 light-years in diameter, challenged many of the prevailing theories about the structure and dynamics of the halo," said Lockman.

The clouds were discovered about 25,000 light-years from Earth toward the center of our Galaxy. The latest findings show the clouds extend at least 5,000 light-years above and below the Galactic plane.

Though the initial studies by Lockman revealed the presence of these clouds, the data were insufficient to conclusively show that they were present throughout the entire halo. These latest results provide valuable evidence that the earlier results were truly representative of the entire halo. "The richness and variety of this phenomenon continues to astound me," remarked Lockman.

Lockman's new studies also confirm that these clouds travel along with the rest of the Galaxy, rotating about its center. These studies clearly rule out the possibility that so-called "high-velocity clouds" were responsible for what was detected initially. High-velocity clouds are vagabond clumps of intergalactic gas, possibly left over from the formation of the Milky Way and other nearby galaxies. "One thing that is for certain is that these are not high-velocity clouds, this is an entirely separate phenomenon," said Lockman.

According to the researcher, the ubiquitous nature and dynamics of these newly discovered clouds support the theory that they are condensing out of the hot gas that is lifted into the halo through supernova explosions. When a massive star dies, it produces a burst of cosmic rays and an enormous expanding bubble of gas at a temperature of several million degrees Celsius. Over time, this hot gas will rise into the Milky Way's halo.

The results presented by Lockman suggest that, as some astronomers have predicted, the hot gas in the halo slowly cools and condenses into hydrogen clouds along with wispy filaments that connect them. When these clouds become as massive as many of those discovered by Lockman, they should then begin to fall back onto

the Galactic plane. This phenomenon is commonly referred to as a "galactic fountain."

"If the clouds were part of the galactic fountain process," Lockman said, "then it is likely that they are now falling back onto the Galaxy."

Radio telescopes are able to detect the naturally occurring radio emission from neutral atomic hydrogen. As hydrogen atoms move about in space, they can absorb small amounts of energy, sending the atom's single electron to a higher energy state. When the electron eventually moves back to its lower energy -- or resting state, it gives up a small amount of electromagnetic radiation at a wavelength of 21 centimeters.

The GBT, dedicated in August of 2000, is the world's largest fully steerable radio telescope. Its 100 by 110 meter dish is composed of 2004 individually hinged panels. It also has a unique offset feed arm, which greatly enhances the performance of the telescope, making it ideal for observations of faint astronomical objects.

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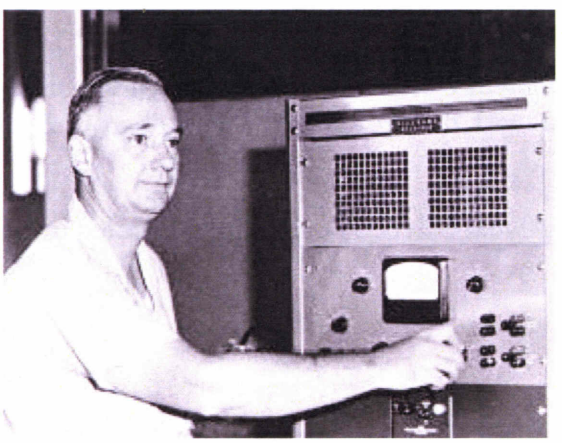
Grote Reber, Radio Astronomy Pioneer, Dies

Grote Reber, one of the earliest pioneers of radio astronomy, died in Tasmania on December 20, just two days shy of his 91st birthday.

Reber was the first person to build a radio telescope dedicated to astronomy, opening up a whole new "window" on the Universe that eventually produced such landmark discoveries as quasars, pulsars and the remnant "afterglow" of the Big Bang. His self- financed experiments laid the foundation for today's advanced radio-astronomy facilities.



Grote Reber
NRAO/AUI photo

"Radio astronomy has changed profoundly our understanding of the Universe and has earned the Nobel Prize for several major contributions. All radio astronomers who have followed him owe Grote Reber a deep debt

for his pioneering work," said Dr. Fred Lo, director of the National Radio Astronomy Observatory (NRAO).

"Reber was the first to systematically study the sky by observing something other than visible light. This gave astronomy a whole new view of the Universe. The continuing importance of new ways of looking at the Universe is emphasized by this year's Nobel Prizes in physics, which recognized scientists who pioneered X-ray and neutrino observations," Lo added.

Reber was a radio engineer and avid amateur "ham" radio operator in Wheaton, Illinois, in the 1930s when he read about Karl Jansky's 1932 discovery of natural radio emissions coming from outer space. As an amateur operator, Reber had won awards and communicated with other amateurs around the world, and later wrote that he had concluded "there were no more worlds to conquer" in radio.

Learning of Jansky's discovery gave Reber a whole new challenge that he attacked with vigor. Analyzing the problem as an engineer, Reber concluded that what he needed was a parabolic-dish antenna, something quite uncommon in the 1930s. In 1937, using his own funds, he constructed a 31.4-foot-diameter dish antenna in his back yard. The strange contraption attracted curious attention from his neighbors and became something of a minor tourist attraction, he later recalled.

Using electronics he designed and built that pushed the technical capabilities of the era, Reber succeeded in detecting "cosmic static" in 1939.

In 1941, Reber produced the first radio map of the sky, based on a series of systematic observations. His radio-astronomy work continued over the next several years. Though not a professional scientist, his research results were published in a number of prestigious technical journals, including *Nature*, the *Astrophysical Journal*, the *Proceedings of the Institute of Radio Engineers* and the *Journal of Geophysical Research*.

Reber also received a number of honors normally reserved for scientists professionally trained in astronomy, including the American Astronomical Society's Henry Norris Russell Lectureship and the Astronomical Society of the Pacific's Bruce Medal in 1962, the National Radio Astronomy Observatory's Jansky Lectureship in 1975, and the Royal Astronomical Society's Jackson-Gwilt Medal in 1983.

Reber's original dish antenna now is on display at the National Radio Astronomy Observatory's site in Green Bank, West Virginia, where Reber worked in the late 1950s. All of his scientific papers and records as well as his personal and scientific correspondence are held by the NRAO, and will be exhibited in the observatory's planned new library in Charlottesville, Virginia.

Reber's amateur-radio callsign, W9GFZ, is held by the NRAO Amateur Radio Club. This callsign was used on the air for the first time since the 1930s on August 25, 2000, to mark the dedication of the Robert C. Byrd Green Bank Telescope.

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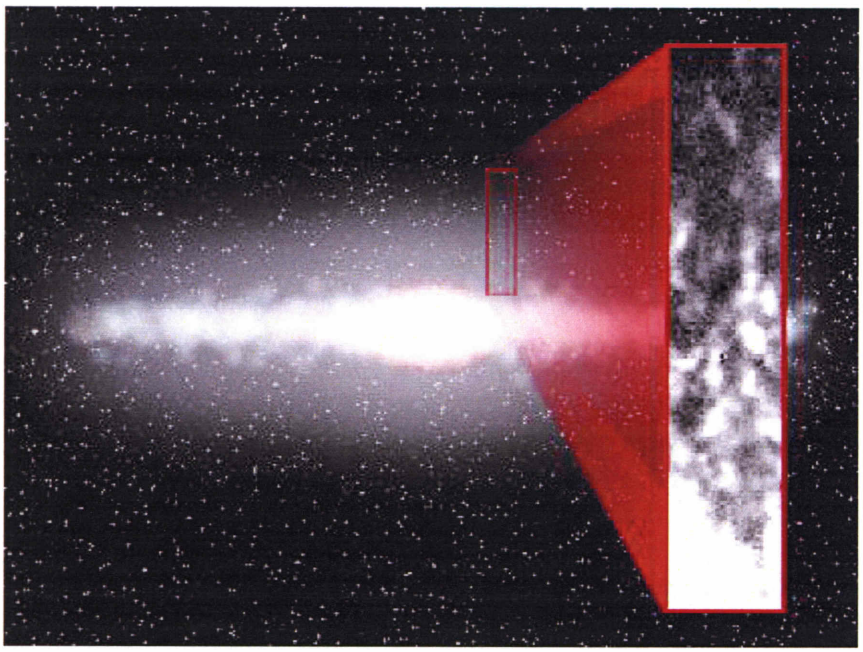
Newly Discovered Clouds Found Floating High Above Milky Way

GREEN BANK, WV -- New studies with the National Science Foundation's Robert C. Byrd Green Bank Telescope (GBT) have revealed a previously unknown population of discrete hydrogen clouds in the gaseous halo that surrounds the Milky Way Galaxy. These clouds were discovered in the transition zone between the Milky Way and intergalactic space, and provide tantalizing evidence that supernova-powered "galactic fountains" continually blast superheated hydrogen gas into our Galactic suburbs.



Artist's Rendering of the Milky Way (background) with insert showing GBT image of newly-discovered clouds of Hydrogen gas above the plane of the Galaxy.

Credit: Kirk Woellert/National Science Foundation.

Extending far above the star-filled disk of the Milky Way is an atmosphere, or halo, of hydrogen gas. "By studying this halo, we can learn a great deal about the processes that are going on inside our Galaxy as well as beyond its borders," said Jay Lockman, an astronomer with the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. "It has remained a mystery, however, how this halo formed and what has prevented gravitational forces from collapsing the gas into a thin layer long ago."

Some astronomers have speculated that this gas is distributed as a diffuse mist held up by either magnetic fields or cosmic rays streaming out of the plane of the Milky Way. Others believed that it is made of innumerable long-lived hydrogen clouds bobbing up and down like balls tossed by a juggler.

Early observations with other telescopes discovered that there was some neutral hydrogen gas floating far above the Galaxy's plane, but these instruments were not sensitive enough to reveal any structure or resolve questions about its origin.

Lockman's studies for the first time show a clear picture of the structure of the gas. Rather than a mist, the halo is in fact full of discrete clouds, each containing 50-to-100 solar masses of hydrogen and averaging about 100 light-years in diameter. "These objects were just below the ability of the older telescopes to detect," said Lockman, "but I looked with the GBT, and they popped right out." Lockman's results will be published in the *Astrophysical Journal Letters*.

The clouds were discovered about 15,000 light-years from Earth toward the center of our Galaxy, and about 5,000 light-years above the Galaxy's plane.

One of the most compelling facts revealed by the GBT is that the clouds are coupled dynamically to the disk of the Galaxy; that is, they follow along with the rotation of the rest of the Milky Way. Material from other sources crashing into the Milky Way would have different velocities and also appear quite different. "These are home grown objects, and not interlopers from outside our own Galaxy," said Lockman.

Although the origin of these newly discovered clouds is not yet known, one mechanism to explain how this gas could be lifted into the halo is through supernova explosions. When a massive star reaches the end of its life it erupts in a cataclysm that produces a burst of cosmic rays and an enormous expanding bubble of gas at a temperature of several million degrees Celsius. Over time, this hot gas can flow outward into the Milky Way's halo.

The question remains, however, what happens to this gas once it's ejected into the halo. One possibility is that it leaves the Galaxy as a wind, never to return. Some astronomers predict, however, that as the gas slowly cools it would condense into hydrogen clouds, eventually falling like raindrops back into the Milky Way, and forming what is referred to as a galactic fountain.

"If the clouds were formed by material ejected from the Galactic plane into the halo," Lockman said, "then it's possible that they are now falling back onto the Galaxy. This would then require a continuing flow of new material from supernova explosions into the halo to replenish the hydrogen gas that has rained back into the disk."

The researcher comments that further observations, now in progress, should clarify the properties of these halo clouds, determine their distribution throughout the Galaxy, show how they are related to other types of clouds, and reveal their internal structure.

Radio telescopes are able to detect the naturally occurring radio emission from neutral atomic hydrogen. As hydrogen atoms move about in space, they can absorb small amounts of energy, sending the atom's single electron to a higher energy state. When the electron eventually moves back to its lower energy -- or resting state, it gives up a small amount of electromagnetic radiation at radio frequencies. The individual energy of a single atom is very weak, but the accumulated signal from vast clouds of hydrogen is strong enough to be detected by sensitive radio telescopes on Earth.

The GBT, dedicated in August of 2000, is the world's largest fully steerable radio telescope. Its 100 by 110 meter dish is composed of 2004 individually hinged panels. It also has a unique offset feed arm, which greatly enhances the performance of the telescope, making it ideal for observations of faint astronomical objects. The GBT is completing its commissioning and early science program and will be moving into full time operation.

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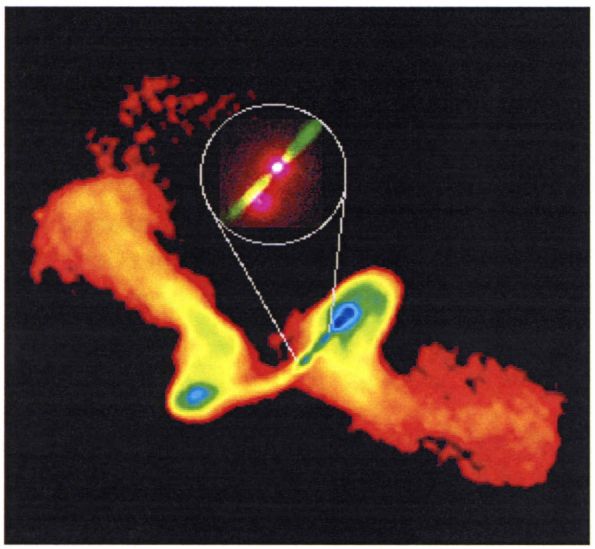
Scientists Detect "Smoking Gun" of Colliding Black Holes

Images from the National Science Foundation's Very Large Array (VLA) radio telescope have uncovered compelling evidence that supermassive black holes at the hearts of large galaxies collide when their host galaxies merge.

"What we have found is the smoking gun for black hole collision in merging galaxies," said David Merritt, an astrophysicist at Rutgers University in New Brunswick, New Jersey. Merritt and his colleague Ronald D. Ekers of CSIRO's Australia Telescope National Facility in Sydney, Australia, present their findings in the August 1 edition of *Science Express*.



VLA image of the galaxy NGC 326, with HST image of jets inset.
Click on image for larger view.
CREDIT: NRAO/AUI, STScI (inset)

When large galaxies merge, current models predict that their central black holes would sink toward the center of the combined galaxy and form a binary pair. "Most astronomers assume that nature finds a way to bring the black holes together, since we don't see strong evidence of binary black holes at the centers of galaxies," says Merritt. "What we have found in the VLA data is the first direct evidence that the black holes actually do coalesce."

The evidence for these mergers comes from the "jets" of radio emitting particles that shoot from the cores of large galaxies. These jets are oriented parallel to the spin axis of the supermassive spinning black hole and are generated by a disk of material being pulled into it.

Images taken with the VLA reveal that about 7 percent of radio emitting galaxies appear to have their jets flipped, forming what is known as an "X-type" radio source, so named because of the "X" shape of the radio lobes. "Flipped jets suggest that the black hole has suddenly been realigned," said Ekers.

These features are formed, the astronomers believe, when black holes collide in a cosmic version of a demolition derby. "Black holes are so large and so massive," said Merritt, "that the only thing we can imagine that would have enough force to realign them is another black hole." The astronomers' calculations show for the first time that even a small black hole can significantly impact the orientation of another one up to five times more massive.

The mechanism of how these objects collide, however, has not been well understood. Theory predicts that as the black holes draw near, they kick out the surrounding stars in their neighborhood, which initially provided the braking power to bring them together. Merritt believes that when the distance between the black holes shrinks to about the size of the solar system, they start to radiate away energy as gravity waves. This then brings the black holes closer and closer, causing them to spin faster and faster, until they eventually collide in an enormous burst of gravitational radiation.

Considering the large population of radio galaxies that appear to have flipped jets, and the estimated 100 million-year lifetime of the jets, the astronomers believe that these collisions happen somewhere in the Universe at the rate of about one a year. Proposed space-based gravitational wave detectors, therefore, should be able to detect these dramatic events.

The astronomers used existing images from the VLA to produce their results. "The VLA has dominated the whole field of radio galaxy studies. In this current research, the quality of the images has been of crucial importance. In each case, the evidence for the black hole having suddenly been realigned has been the detailed morphology of the radio galaxy. We've used the results of many observing programs using the VLA, involving many different groups from around the world," Ekers said.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

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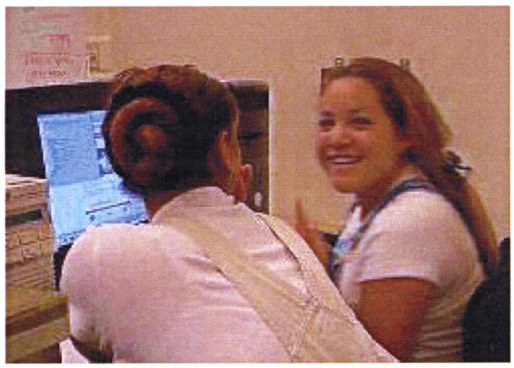
Socorro Students Translate NRAO Web Pages Into Spanish

Six Socorro High School students are spending their summer working at the National Radio Astronomy Observatory (NRAO) on a unique project that gives them experience in language translation, World Wide Web design, and technical communication. Under the project, called "Un puente a los cielos," the students are translating many of NRAO's Web pages on astronomy into Spanish.



"These students are using their bilingual skills to help us make basic information about astronomy and radio telescopes available to the Spanish-speaking community," said Kristy Dyer, who works at NRAO as a National Science Foundation postdoctoral fellow and who developed the project and obtained funding for it from the National Aeronautics and Space Administration.

The students are: Daniel Acosta, 16; Rossellys Amarante, 15; Sandra Cano, 16; Joel Gonzalez, 16; Angelica Hernandez, 16; and Cecilia Lopez, 16.

The translation project, a joint effort of NRAO and the NM Tech physics department, also includes Zammaya Moreno, a teacher from Ecuador, Robyn Harrison, NRAO's education officer, and NRAO computer specialist Allan Poindexter.

The students are translating NRAO Web pages aimed at the general public. These pages cover the basics of radio astronomy and frequently-asked questions about NRAO and the scientific research done with NRAO's telescopes.

"Writing about science for non-technical audiences has to be done carefully. Scientific concepts must be presented in terms that are understandable to non-scientists but also that remain scientifically accurate," Dyer said. "When translating this type of writing from one language to another, we need to preserve both the understandability and the accuracy," she added.

For that reason, Dyer recruited 14 Spanish-speaking astronomers from Argentina, Mexico and the U.S. to help verify the scientific accuracy of the Spanish translations. The astronomers will review the translations.

The project is giving the students a broad range of experience. "They are getting hands-on experience in language translation, in Web design and computer science, and learning some astronomy as well," said Dyer. "This is a challenging project, but these students are meeting the challenge well," she added.

The students are enthusiastic. "I've always been interested in stars and space, and I love working with computers," said Amarante.

"We are pleased that these local students are using their skills to enhance our public-education efforts," said NRAO's director of New Mexico operations James Ulvestad. "Our Web site is one of our best tools for informing the public about astronomy and the work done at our observatory. This translation project now allows us to reach an important new audience," Ulvestad added.

The students began the project in June and will complete the effort on July 26.

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June 19, 2002

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Water Fountains in the Sky:

Streaming Water Jets from Aging Star Provide Clues to Mystery of Planetary-Nebula Formation

Astronomers using the National Science Foundation's Very Long Baseline Array (VLBA) radio telescope have found that an aging star is spewing narrow, rotating streams of water molecules into space, like a jerking garden hose that has escaped its owner's grasp. The discovery may help resolve a longstanding mystery about how the stunningly beautiful objects called planetary nebulae are formed.

Artist's conception of W43A, with the aging star surrounded by a disk of material and a precessing, twisted jet of molecules streaming away from it in two directions.

Credit:
Kirk Woellert/National Science Foundation.

The astronomers used the VLBA, operated by the National Radio Astronomy Observatory, to study a star called W43A. W43A is about 8,500 light-years from Earth in the direction of the constellation Aquila, the eagle. This star has come to the end of its normal lifetime and, astronomers believe, is about to start forming a planetary nebula, a shell of brightly glowing gas lit by the hot ember into which the star will collapse.

"A prime mystery about planetary nebulae is that many are not spherical even though the star from which they are ejected is a sphere," said Phillip Diamond, director of the MERLIN radio observatory at Jodrell Bank in England, and one of the researchers using the VLBA. "The spinning jets of water molecules we found coming from this star may be one mechanism for producing the structures seen in many planetary nebulae," he added.

The research team, led by Hiroshi Imai of Japan's National Astronomical Observatory (now at the Joint Institute for VLBI in Europe, based in the Netherlands), also includes Kumiko Obara of the Mizusawa Astrogeodynamics Observatory and Kagoshima University; Toshihiro Omodaka, also of Kagoshima University; and Tetsuo Sasao of the Japanese National Astronomical Observatory. The scientists reported their findings in the June 20 issue of the scientific journal *Nature*.

As stars similar to our Sun reach the end of their "normal" lives, in which they are powered by nuclear fusion of hydrogen atoms in their cores, they begin to blow off their outer atmospheres, then eventually collapse to a white dwarf, about the size of the Earth. Intense ultraviolet radiation from the white dwarf causes the gas thrown off earlier to glow, producing a planetary nebula.

Planetary nebulae, many visible to amateurs with backyard telescopes, have been studied by astronomers for years. About 1600 planetary nebulae have been found, and astronomers believe many more exist in our Milky Way Galaxy. Some are spherical, but most are not, displaying a variety of often intricate, beautiful shapes. The fact that many of these objects are not spherical was long known, but a series of spectacular images made with the Hubble Space Telescope in 1997 reinforced that fact dramatically.

"The problem for scientists is, how do you get from a star that we know is a sphere to a planetary nebula that is far from being a sphere and yet came from that star," said Imai. Some theorists suggested that old stars must be somehow producing jets of material that help form the odd-shaped planetary nebulae, but such jets had, until now, never been seen.

W43A was known to have regions near it in which water molecules are amplifying, or strengthening, radio emission at a frequency of 22 GigaHertz. Such regions are called masers, because they amplify microwave radiation the same way a laser amplifies light radiation. Imai's team used the VLBA, the sharpest radio "eye" in the world, to find out where these masers are. To their surprise, they found that the maser regions are strung out in two curved lines, moving in opposite directions from the star at about 325,000 miles per hour.

"The path of the jets is curved like a corkscrew, as if whatever is squirting them out is slowly rotating, or precessing, like a child's top wobbles just before it falls down," said Diamond.

What is producing the jets? "We're not sure," Diamond said. "Traditional wisdom says that it takes a disk of material closely orbiting the star to produce jets, but we don't yet know how such a disk could be produced around such an old star," he added.

The astronomers are probably very lucky to have caught W43A in what they believe is a brief transitional stage of its life. "Our analysis of the water jets indicates that they are only a few decades old," Imai said. "Once the star collapses of its own gravity into a dense white dwarf, its intense ultraviolet radiation will rip apart the water molecules, making observations such as ours impossible," he added.

Planetary nebulae may be the worst-named class of objects in astronomy, because, despite the name, they have nothing to do with planets. The French astronomer Charles Messier discovered the first one, now known as the "Dumbbell Nebula" to amateur astronomers, in 1764. Sir William Herschel, who discovered the planet Uranus in 1781, later began a systematic survey of the entire sky and found more objects similar to the Dumbbell. Because their appearance resembled, to him, the appearance of Uranus in a telescope, he coined the term "planetary nebula," a name that has stuck ever since. Astronomers have long known that these objects are not actually related to planets, but the name has remained to confuse generations of students.

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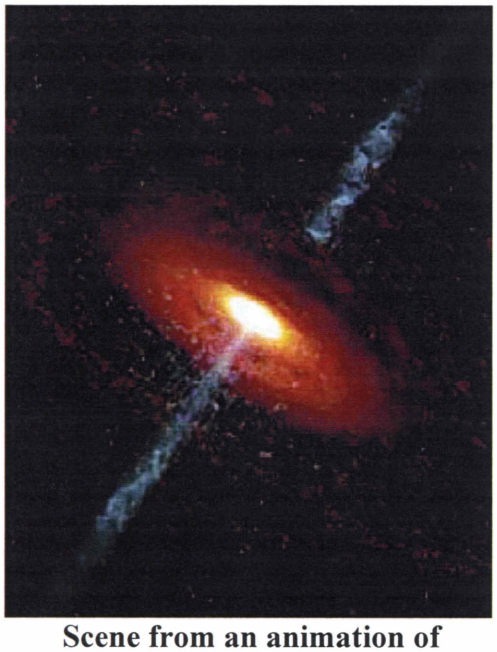
Supermassive Black Hole Mimics Smaller Cousins

Scientists have caught a supermassive black hole in a distant galaxy in the act of spurting energy into a jet of electrons and magnetic fields four distinct times in the past three years, a celestial take on a Yellowstone geyser.

This quasar-like "active" galaxy is essentially a scaled-up model of the so-called microquasars within our Milky Way Galaxy, which are smaller black holes with as much as ten times the mass of the sun. This means that scientists can now use their close-up view of microquasars to develop working models of the most massive and powerful black holes in the universe.



Scene from an animation of 3C 120. CREDIT: Cosmovision

These results -- published in the June 6 issue of *Nature* -- are the fruit of a three-year monitoring campaign

with the National Science Foundation's Very Long Baseline Array (VLBA), a continent-wide radio-telescope system, and NASA's Rossi X-ray Timing Explorer.

"This is the first direct, observational evidence of what we had suspected: The jets in active galaxies are powered by disks of hot gas orbiting around supermassive black holes," said Alan Marscher of the Institute for Astrophysical Research at Boston University, who led this international team of astronomers.

Active galaxies are distant celestial objects with exceedingly bright cores, often radiating with the brilliance of thousands of ordinary galaxies, fueled by the gravity of a central million- to billion-solar-mass black hole pulling in copious amounts of interstellar gas.

Marscher and his colleagues have established the first direct observational link between a supermassive black hole and its jet. The source is an active galaxy named 3C120 about 450 million light-years from Earth. This link has been observed in microquasars, several of which are scattered across the Milky Way Galaxy, but never before in active galaxies, because the scale (distance and time) is so much greater.

The jets in galaxy 3C120 are streams of particles shooting away perpendicularly from the plane of a black hole's accretion disk, moving at 98 percent of the speed of light. In microquasars, radio-emitting features become visible in a jet shortly after X rays from the accretion disk get dimmer -- as if the accretion disk suddenly flushes into the black hole and disappears, fueling the jet. These radio "blobs" then appear to move at faster-than- light speeds, an illusion caused by their ultra-high speeds and their orientation with respect to Earth.

Now the team of scientists sees this same phenomenon in 3C120. Roughly every ten months, the X-ray-emitting accretion disk around its supermassive black hole becomes suddenly dim, and a month later the telltale bright spot of radio emission appears in the jet. Over a three-year period, the team observed a series of radio blobs floating along the particle jet like smoke puffs, each time following a dip in the brightness of X rays from the accretion disk.

"What we are likely seeing is the inner part of the accretion disk becoming unstable and suddenly plunging into the black hole," said Marscher. "We detect a 'dip' in the X-ray flux as the hot gas in the disk disappears after it passes the event horizon. The remainder of the disk is channeled into the jets, which we see as a knot of radio emission bubbling away from the black hole. Slowly the accretion disk fills with more interstellar gas until about ten months later, when something disturbs the accretion disk orbit, and the whole thing flushes and blows again."

Joining Marscher on this observation and analysis are Svetlana Jorstad of Boston University; Jose-Luis Gomez of the Astrophysical Institute of Andalucia in Granada, Spain; Margo Aller of the University of Michigan; Harri Terasranta of the Helsinki University of Technology; Matthew Lister of NRAO; and Alastair Stirling of the University of Central Lancashire, England.

The VLBA is a continent-wide radio-telescope system, with one telescope on Hawaii, another on St. Croix in the Caribbean, and eight others in the continental United States. Part of the National Radio Astronomy Observatory, the VLBA offers the highest resolving power, or ability to see fine detail, of any telescope available. The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

The Rossi Explorer was launched by NASA in 1995 to study black holes, neutron stars and pulsars. The Rossi Explorer is operated by NASA Goddard Space Flight Center in Greenbelt, Md.

The research on 3C120 was supported by funding from the National Aeronautics and Space Administration and the National Science Foundation.

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June 3, 2002

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Binary Stars "Flare" With Predictable Cycles, Analysis of Radio Observations Reveals

Astronomers have completed a 5-year campaign to monitor continuously radio flares from two groups of binary star systems. This survey is of special interest because it provides evidence that certain binary star systems have predictable activity cycles like our Sun.

The survey, which ran from January 1995 to October 2000, was conducted with the National Science Foundation's (NSF) Green Bank Interferometer. The report was presented at the American Astronomical Society (AAS) meeting in Albuquerque, New Mexico, by Mercedes Richards of the University of Virginia, and her collaborators Elizabeth Waltman of the Naval Research Laboratory, and Frank Ghigo of the National Radio Astronomy Observatory (NRAO).

"This long-term survey was critical to our understanding of the short- and long-term magnetic cycles of these intriguing star systems," said Richards.

The survey focused on the binary star systems Beta Persei and V711 Tauri -- both are about 95 light-years from Earth. Beta Persei is the prototype of the "Algol" class of interacting binary stars. An Algol system contains a hot, blue, main sequence star, along with a cool, orange/red star that is more active than our Sun. V711 Tauri is an "RS Canum Venaticorum" binary, which contains two cool stars that behave like our Sun.

"Our survey was the longest-running continuous radio flare survey of Algol or RS Canum Venaticorum binary star systems," said Richards. A flare is an enormous explosion on the surface of a star, which is accompanied by a release of magnetic energy. Flares can be detected over the full range of wavelengths from gamma rays to the radio.

It is estimated that the energy release in a flare on the Sun is equivalent to a billion megatons of TNT. The strength of the magnetic field and the amount of activity it displays, like sunspots and flares, are directly related to the rotation or "spin" of the star. In Beta Persei and V711 Tauri, the cool star spins once every 3 days, compared to once every month in the case of the Sun. So the stars in these binary systems have magnetic fields that are ten times more powerful than our Sun, and they produce flares that are powerful enough to be detected with radio telescopes on Earth.

Richards and her collaborators used two different techniques to determine how often radio flares occur in these systems -- the "periodicity" of flaring activity. They found that flares occur every 50 to 60 days in both

systems, but the strongest periodicity was 49 ± 2 days for Beta Persei and 121 ± 3 days for V711 Tauri. "This means that we can expect to see a strong flare on Beta Per every 1 to 2 months, while strong flares on V711 Tau occur about every 4 months," said Richards.

The researchers also identified some long-term flaring cycles that are 1 to 4 years long. These long-term cycles may be related to magnetic cycles like the 11-year sunspot cycle on the Sun. Richards said, "It would be exciting if these long-term cycles are linked to magnetic cycles, but our survey was not long enough to confirm this result without the shadow of a doubt."

The continuous monitoring program also demonstrated that Beta Persei and V711 Tauri have active and inactive cycles. "This fact would not have been established if the systems had only been monitored sporadically," said Richards. "We could never be absolutely sure that no flares occurred at certain times unless we were monitoring the system all the time."

Many flares occurred during the active cycles, and almost no flares, or very weak flares, were ejected during the inactive cycles. Flares usually began with a massive burst of energy and then decayed slowly as the gas cools. The radio flares on the Sun typically last up to 2 days, but those in the two binary systems lasted for 10 to 40 days.

"Continuous monitoring of radio flares requires the availability of a dedicated telescope like the Green Bank Interferometer," said Richards. The interferometer is composed of two 85-foot radio dishes separated by 2,400 meters. During the survey, this telescope was operated by the National Radio Astronomy Observatory, with funding from the United States Naval Observatory, Naval Research Laboratory, NASA High Energy Astrophysics Program, and NRAO. The monitoring program ended when the interferometer was closed in October 2000.

Richards received funding for this research from the Air Force Office of Scientific Research, the National Science Foundation, and NASA.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

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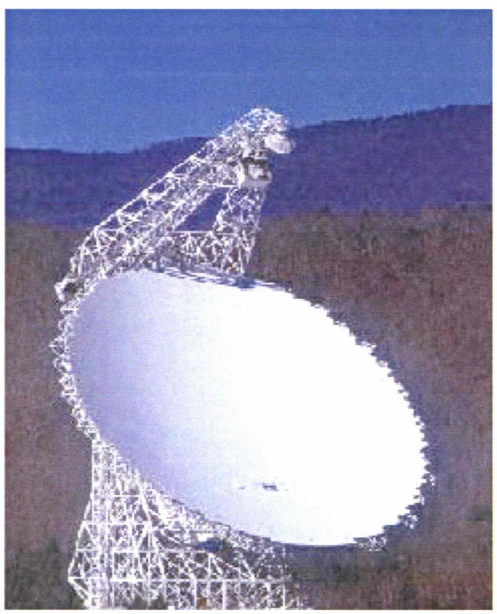
Youngest Radio Pulsar Revealed with Green Bank Telescope

Astronomers using the National Science Foundation's (NSF) newly commissioned Robert C. Byrd Green Bank Telescope (GBT) have detected remarkably faint radio signals from an 820 year-old pulsar, making it the youngest radio-emitting pulsar known. This discovery pushes the boundaries of radio telescope sensitivity for discovering pulsars, and will enable scientists to conduct observations that could lead to a better understanding of how these stars evolve.



Robert C. Byrd Green Bank Telescope

"Important questions about pulsars may be answered by long-term monitoring of objects such as the one we just detected," said Fernando Camilo of Columbia University in New York City. "Young pulsars are

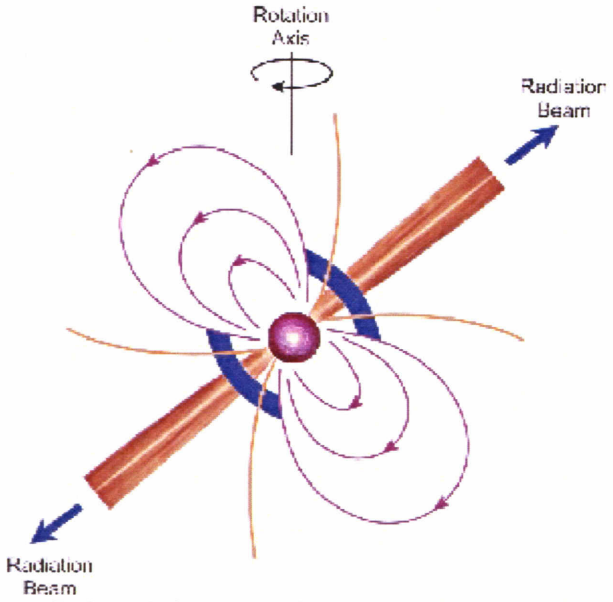
particularly rare, and being able to study such a young one at radio wavelengths provides an outstanding opportunity to learn critical facts about their evolution and workings." The results of this research, based on observations conducted on February 22-23, 2002, were accepted for publication in the *Astrophysical Journal Letters*.

Scientists have long suspected that a pulsar - a rapidly spinning, superdense neutron star - was born when a giant star ended its life in a cataclysmic supernova explosion observed in late summer of 1181, as suggested by Japanese and Chinese historical records. For the past 20 years, astronomers have searched this supernova remnant (3C58), located 10,000 light-years away in the constellation Cassiopeia, for the telltale pulsations of a newly born pulsar. Late in 2001, data from NASA's Chandra X-ray satellite confirmed its existence, but it remained an elusive quarry for radio telescopes.

"We believed from historical records and certainly knew from recent X-ray observations that this star was there," Camilo remarked, "but despite many attempts, no one had been able to find any radio pulsations from it because the signals are, it turns out, incredibly weak." For comparison, this pulsar's radio emission is some 250 times weaker than that from the famous pulsar in the Crab Nebula (the remnant of an explosion in the year 1054 recorded by Chinese astronomers and possibly also by Native Americans of the Anasazi tribe in modern-day Arizona and New Mexico).

"Although we knew what we were looking for," said Camilo "it took the new Green Bank Telescope with its unmatched sensitivity -- and, importantly, location in the National Radio Quiet Zone -- to make this remarkable detection."

A pulsar is formed when a massive star runs out of nuclear fuel and dies in a cataclysmic explosion called a supernova. The outer layers of the star are blown off into space, and are often seen as an expanding remnant shell of hot gas. The core of the star, with 40 percent more mass than our Sun, collapses under its own gravity to a sphere only about 10 miles in diameter, composed mostly of neutrons. These densest objects known in the Universe typically are born spinning very rapidly; the newly detected pulsar, known as PSR J0205+6449, presently rotates 15 times every second.



Pulsar Diagram: Click on image for more detail.

The spinning neutron star has very powerful magnetic and electric fields that accelerate electrons and other

subatomic particles, causing them to emit beams of radio waves, X-rays, and other forms of radiation. If these beams intersect the Earth as the star rotates, we can then detect the pulsar, as it appears to flash on-and-off, much like a lighthouse. As the pulsar ages, it gradually slows down and loses its rotational energy. After a few million years it is no longer powerful enough to generate radio emission and "turns-off."

By detecting this pulsar in the radio spectrum, astronomers may now follow its evolution with greater ease and flexibility than with X-ray telescopes on satellites, study the pulsar emission mechanisms, and also characterize the dynamic interstellar medium between the Earth and the pulsar.

"Finding a radio pulsar this young could be somewhat of a gold mine for years to come," noted Camilo. "We can very precisely measure how its rate of rotation changes over time, potentially inferring fundamental clues about what causes a magnetized neutron star to spin down. We also will make valuable comparisons to the X-ray data, which may help us determine exactly how these objects generate and emit radiation."

The researchers also point to the fact that this discovery bodes well for the GBT being able to study additional young pulsars that have previously escaped detection. "By using this magnificent new telescope, we should be able to discover other very young pulsars that we surmise are there, but are simply too weak to detect by any other means," said Camilo. "Measuring the luminosity and spectrum of a large sample of these stars will be crucial for making an accurate census of pulsars in our Galaxy."

The researchers used the new Berkeley-Caltech Pulsar Machine to process the signals from the GBT and record them for later analysis.

The group led by Camilo in this investigation consists also of: Ingrid H. Stairs (NRAO Green Bank, West Virginia); Duncan R. Lorimer, Michael Kramer, Maura A. McLaughlin (University of Manchester, Jodrell Bank Observatory, Cheshire, U.K.); Donald C. Backer (University of California, Berkeley); Scott M. Ransom (McGill University, Montreal, Canada); Bernd Klein, Richard Wielebinski, Peter Muller (Max-Planck-Institut fur Radioastronomie, Bonn, Germany); and Zaven Arzoumanian (Universities Space Research Association/NASA-Goddard Space Flight Center, Greenbelt, Maryland).

The GBT is the world's largest fully steerable radio telescope. It was dedicated on August 25, 2000.

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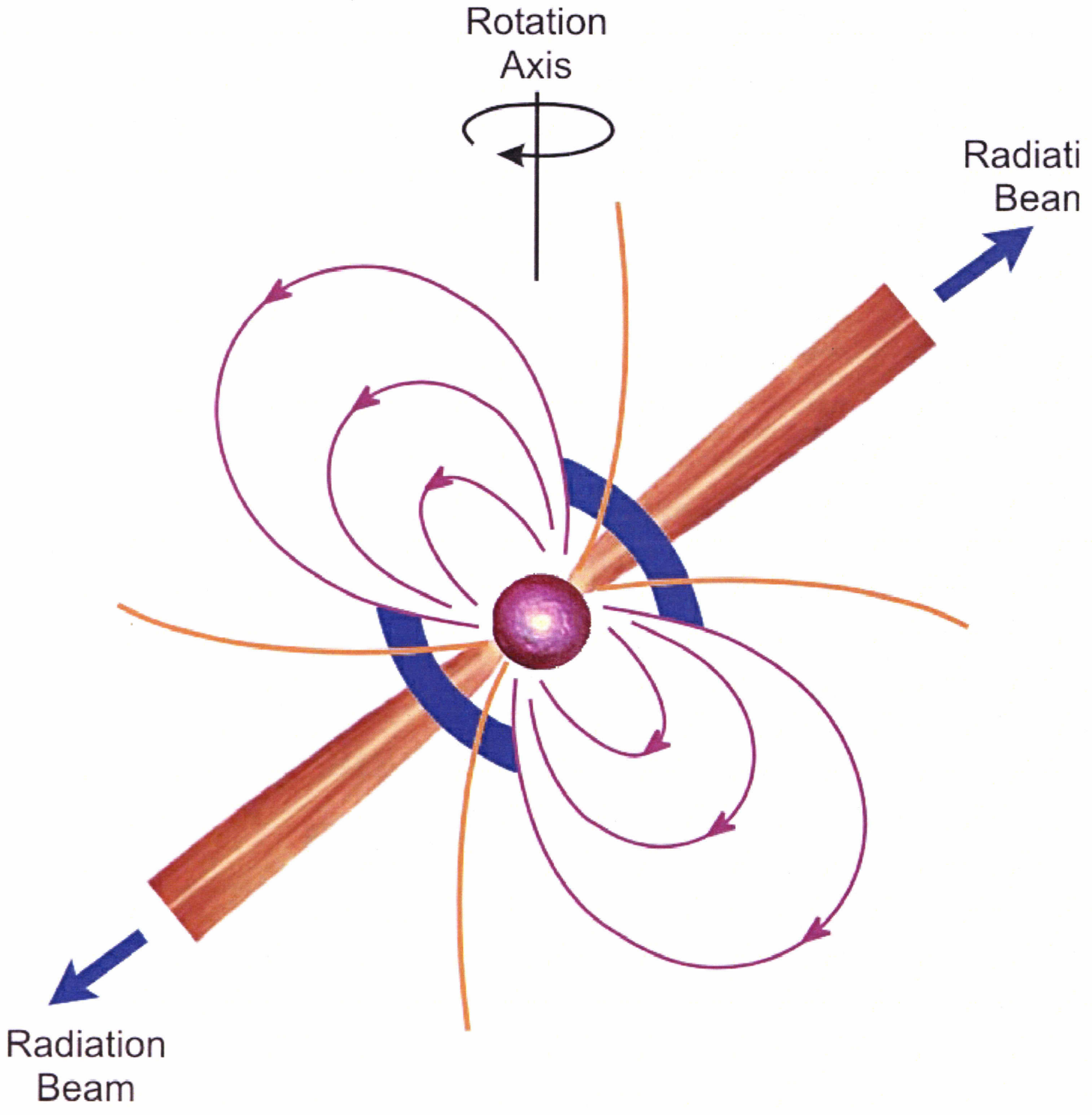
National Radio Astronomy Observatory



Pulsars: "Lighthouses" in the Sky

A pulsar is a rapidly spinning neutron star. It is a sphere composed mostly of neutrons, approximately 10 miles in diameter, but with 40 percent more mass than the Sun. A typical pulsar has a magnetic field a trillion times stronger than the Earth's, represented by the red belts emanating from its surface. These fields and associated electrical fields accelerate electrons and other subatomic particles to nearly the speed of light, causing them to emit beams of radio waves and other forms of radiation. As the pulsar rotates, these beams sweep across space. If the beams intersect the Earth, the pulsar can be seen switching 'on' and 'off,' much like a lighthouse.

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April 15, 2002

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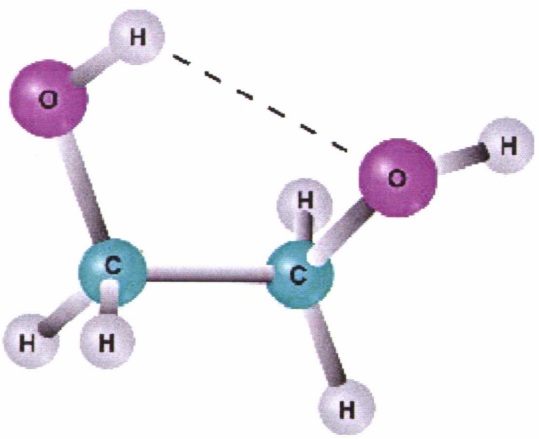
Scientists Discover Antifreeze in Space, Warming Theories on How and Where Life Begins

Ethylene glycol, the chemical commonly used as automobile antifreeze, was discovered recently in a massive interstellar cloud of dust and gas near the center of the Milky Way Galaxy. Scientists used the National Science Foundation's (NSF) 12 Meter Radio Telescope to detect this organic molecule.



Ethylene Glycol Molecule

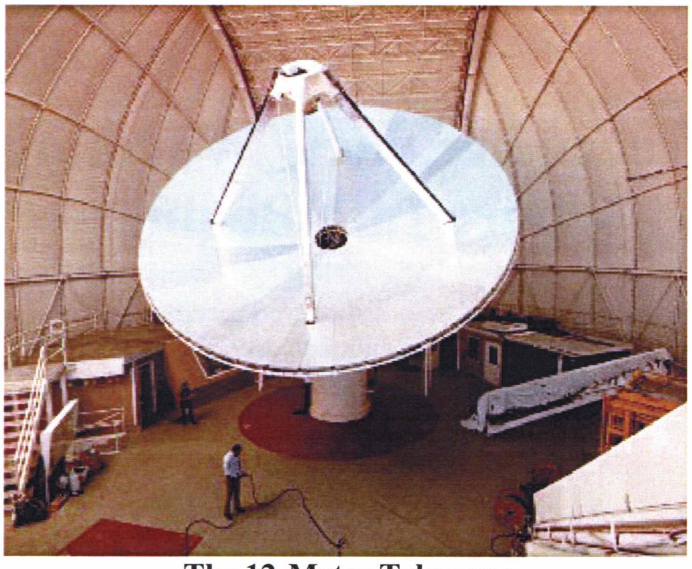
"Though we most commonly think of ethylene glycol as antifreeze, it actually is associated with the formation of more complex sugar molecules that are necessary for life," said Jan M. Hollis of NASA Goddard Space Flight Center in Greenbelt, Maryland. "Finding this molecule supports the view that prebiotic chemistry may first get started in interstellar space."

Hollis collaborated with Frank J. Lovas of the University of Illinois, Philip R. Jewell of the National Radio Astronomy Observatory (NRAO), and Laurent H. Coudert of the University of Paris at Campus d'Orsay to identify the ethylene glycol molecule. Their results were accepted for publication in the *Astrophysical Journal Letters*.

The scientific team detected ethylene glycol in the molecular cloud called Sagittarius B, located 26,000 light-years from Earth near the center of our Galaxy. Though rarefied by Earth standards, interstellar clouds like this one can enable complex chemical reactions over time scales of hundreds-of-thousands or even millions of years. About 130 different molecules are known to exist in interstellar clouds.

Ethylene glycol (a 10-atom molecule made up of carbon, hydrogen, and oxygen) is one of the five largest molecules ever discovered in space. It also is a chemically reduced form of 8-atom glycolaldehyde, the simplest member of the sugar family. This means that ethylene glycol can be produced from glycolaldehyde by the addition of two hydrogen atoms. Both molecules have now been detected in space by this team.

"These detections suggest that the production of more complex sugars, like ribose, may be occurring in interstellar clouds," Hollis said. Ribose sugar is required for the backbone structure of RNA; a less complex form, deoxyribose sugar, is required for the backbone structure of DNA.



The 12-Meter Telescope

"This discovery further demonstrates how important interstellar chemistry may be to understanding the creation of biological molecules on the early Earth," said Jewell. "Some scientists have even speculated that the Earth could have been 'seeded' with complex molecules from passing comets, which were formed from the condensing gas nebula that produced our Solar System."

Astronomers on Earth are able to detect and identify the faint radio emission of molecules in space as they tumble and vibrate within interstellar clouds, emitting radio waves at precise frequencies. These frequencies are unique to each molecule, and provide a "fingerprint" in the electromagnetic spectrum. Signals from other molecules can sometimes fall at nearby frequencies, in effect smudging the ethylene glycol fingerprint. The scientists used four different signals from ethylene glycol to secure its detection.

The researchers made their discovery with data taken in May 2000 with the 12 Meter Radio Telescope at Kitt Peak, Arizona, which has been a pioneering instrument in detecting molecules in space. Though operated by NRAO at the time, this telescope now is operated by the Steward Observatory of the University of Arizona. The research team plans future work on interstellar biomolecules using the new NRAO Robert C. Byrd Green Bank Telescope, which promises to be the most sensitive telescope yet for such work.

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April 8, 2002

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Astronaut to Present Space-Flown Flag to NRAO; Will Address Students at State Science Fair

A NASA Astronaut who carried a flag bearing the logo of the National Radio Astronomy Observatory (NRAO) on last month's Shuttle flight will return that flag to the observatory on Friday, April 12, at a ceremony in Socorro. Dr. John M. Grunsfeld, payload commander of the STS-109 flight, also will address students at the New Mexico State Science Fair on Saturday, April 13, on the campus of New Mexico Tech in Socorro.

Dr. John M. Grunsfeld

Grunsfeld, an astronomer who observed with NRAO's Very Large Array (VLA) radio telescope in 1991, carried the 3-by-5-foot NRAO flag aboard *Columbia* during the March 1-12 mission to service the Hubble Space Telescope. The NRAO flag, made by Socorro resident Dora Spargo, had been sent to the observatory's facilities in Socorro; Tucson, AZ; Green Bank, WV; and Charlottesville, VA, where NRAO employees signed it prior to the flight.

"With our signatures on that flag, we all felt like we were riding along with John aboard the Shuttle," said NRAO Director Paul Vanden Bout. "We are proud that NRAO was represented on a mission that was so important to astronomy," Vanden Bout added.

During the flight, Grunsfeld performed three of the five spacewalks in which crew members successfully upgraded the Hubble Space Telescope. The astronauts left the space observatory with a new power unit, a new camera and new solar arrays. The upgrades, said Grunsfeld, leave the orbiting telescope with "its discovery potential significantly increased."

STS-109 was Grunsfeld's fourth space flight and his second visit to Hubble. A research astronomer who received his bachelor's degree in physics from MIT and a Ph.D from the University of Chicago in 1988, Grunsfeld was selected to the astronaut corps in 1992. His first space flight, in 1995, featured astronomical observations using the Astro observatory, a three-telescope facility aboard the Shuttle *Endeavour*. In 1997, Grunsfeld rode *Atlantis* on a 10-day mission to the Russian space station *Mir*. In 1999, he performed two space walks during a *Discovery* mission to install new instruments on Hubble.

In 1991, while a senior research fellow at Caltech, Grunsfeld was the principal investigator for a series of VLA observations of a gamma-ray-emitting object, conducted at the same time the object was observed by the orbiting Compton Gamma Ray Observatory. "I still think fondly of my observations at the VLA," said Grunsfeld.

During his visit to New Mexico, Grunsfeld will formally present the NRAO flag to the observatory, along with documentation of its flight aboard *Columbia*. He also will address the awards ceremonies of the New Mexico State Science Fair. "We are particularly pleased that John's visit will allow him to speak to the science fair students," said Jim Ulvestad, NRAO's Assistant Director for New Mexico operations. "Those students will be able to hear from someone whose science training has literally taken him beyond the Earth," Ulvestad said.

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March 11, 2002

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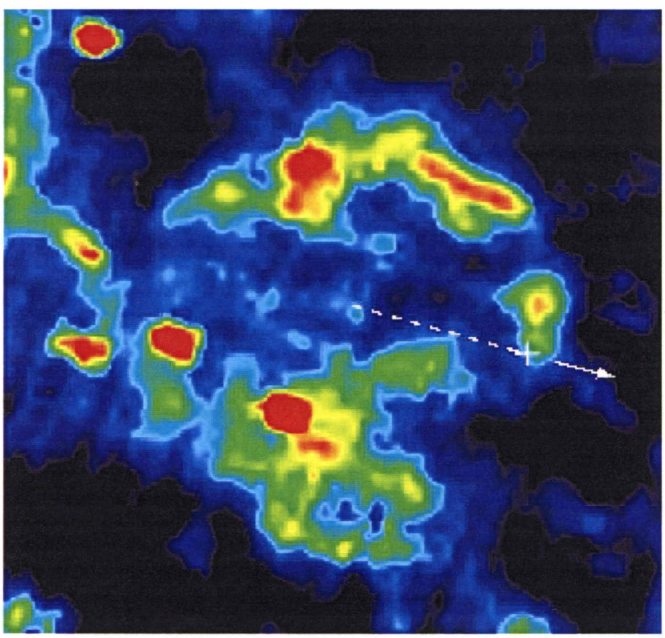
Age Discrepancy Throws Pulsar Theories into Turmoil

Astronomers using the National Science Foundation's Very Large Array (VLA) radio telescope have found a pulsar -- a spinning, superdense neutron star -- that apparently is considerably younger than previously thought. This finding, combined with the discovery in 2000 of a pulsar that was older than previously thought, means that many assumptions astronomers have made about how pulsars are born and age must be reexamined, according to the researchers.



Infrared Image of Supernova Remnant; Dashed Line and Arrow Indicate Pulsar's Motion Detected by VLA

"We are learning that each individual pulsar is a very complicated object, and we should assume nothing

about it," said Bryan Gaensler, of the Harvard-Smithsonian Center for Astrophysics in Cambridge, MA. "Our work makes it more difficult to put pulsars into neat categories, but ultimately will yield new insights into how pulsars are born," he added. The research is reported in the March 10 edition of the *Astrophysical Journal Letters*.

The astronomers studied a pulsar called B1951+32 and a supernova remnant called CTB 80, both nearly 8,000 light-years from Earth. The supernova remnant is the shell of debris from the explosion of a giant star. The explosion resulted from the giant star's catastrophic collapse into the superdense neutron star. By observing the pulsar and the supernova remnant from 1989 to 2000 with the VLA, the scientists were able to measure the movement of the pulsar, which, they found, is moving directly outward from the center of the shell of explosion debris.

"We've always felt that, if you see a pulsar and a supernova remnant close together, the pulsar had been born in an explosion at the center of the supernova remnant, but this is the first time that actual observational measurement shows a pulsar moving away from the center of the supernova remnant. It's nice to finally have such an example," said Joshua Migliazzo of the Center for Space Research at the Massachusetts Institute of Technology, another one of the researchers.

By tracking the pulsar's motion for more than a decade, the astronomers were able to calculate that it is traveling through space at more than 500,000 miles per hour. At that speed, the pulsar required about 64,000 years to travel from its birthplace -- the site of the supernova explosion -- to its present location. That means, the astronomers say, that the pulsar is about 64,000 years old.

This age, however, differs significantly from the age estimated by another method which has been used by astronomers for decades. This method uses measurements of the rotation rate of the neutron star and the tiny amount by which that rotation slows over time to arrive at an estimate called the pulsar's "characteristic age." For B1951+32, that method produced an estimated age of 107,000 years.

"Now we have a pulsar that is much younger than we thought. In 2000, a different pulsar was shown to be significantly older than we thought. That means that some of the assumptions that have gone into estimating the ages of these objects are unjustified," Migliazzo said.

The pulsar's rotation is thought to slow because the neutron star's powerful magnetic field acts as a giant dynamo, emitting light, radio waves and other electromagnetic radiation as the star rotates. The energy lost by emitting the radiation results in the star's rotation slowing down.

Previous estimates of pulsar ages have assumed that all pulsars are born spinning much faster than we see them now, that the physical characteristics of the pulsar such as its mass and magnetic-field strength do not change with time, and that the slowdown rate can be estimated by applying the physics of a magnet spinning in a vacuum.

"With one pulsar older than the estimates and one younger, we now realize that we have to question all three of these assumptions," said Gaensler.

Further research, the scientists say, should help them understand more about the conditions under which pulsars form and just how they get their spin in the first place. Neutron stars are formed in a fraction of a second as a massive star collapses onto itself, compressing its matter to the density of an atomic nucleus. During the collapse, the neutron star is thought to receive numerous "kicks" that spin it up.

The measurements of B1951+32's position were made in 1989, 1991, 1993 and 2000, with the VLA. The 2000 observations also used the Pie Town station of NSF's Very Long Baseline Array (VLBA), which improved the precision of the measurements. The other pulsar, which was found to be older than its estimated age, is called B1757-24 or "the duck." The report on its motion and age was published in *Nature* in July of 2000.

In addition to Gaensler and Migliazzo, the researchers are: Donald Backer of the University of California-Berkeley; Benjamin Stappers of ASTRON in the Netherlands; Eric Van Der Swaluw of the Dublin Institute for Advanced Studies in Ireland; and Richard Strom of ASTRON and the University of Amsterdam in the Netherlands.

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January 10, 2002

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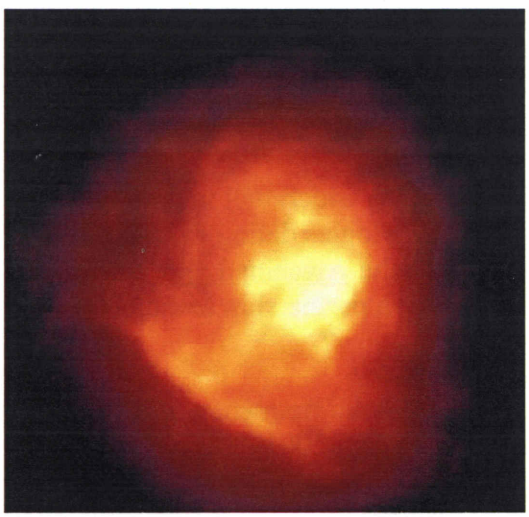
GBT, VLA Team Up to Produce New Image of Orion Nebula

Combining the best features of the National Science Foundation's (NSF) new Robert C. Byrd Green Bank Telescope (GBT) in West Virginia with those of the NSF's Very Large Array (VLA) in New Mexico, astronomers have produced a vastly improved radio image of the Orion Nebula and developed a valuable new technique for studying star formation and other astrophysical processes.



GBT-VLA Image of Orion Nebula

"Our GBT image of the Orion Nebula is the best image ever produced with a single-dish radio telescope and it illustrates the superb performance of this new telescope," said Debra Shepherd, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM. "By combining data from the GBT with that from the VLA, we get an image that reflects reality far better than images from the separate telescopes could do," she added. Shepherd worked with Ron Maddalena from NRAO in Green Bank and Joe McMullin, from NRAO in Socorro. The astronomers presented their work to the American Astronomical Society meeting in Washington, DC.

Single-dish radio telescopes such as the GBT, dedicated in 2000, are able to capture the large-scale structure of objects such as the Orion Nebula. However, they are unable to discern the fine detail revealed by multi-antenna arrays such as the VLA. Conversely, a VLA-like array is "blind" to the larger-scale structures. Combining the data from both types of radio telescopes to produce an image showing both large- and small-scale structures in the same celestial object has been a difficult, laborious task.

"We are developing new observing techniques and software to make this task much easier and quicker," said McMullin. "We now have achieved in hours what used to take months or even longer to do, but we are producing an observational tool that will allow astronomers to make much higher-fidelity images that will greatly improve our understanding of several important astronomical processes," McMullin added. For this observation, both the individual images from each telescope as well as the combined image were produced using the AIPS++ (Astronomical Information Processing System) software, developed, in part, by NRAO. The observers worked with Tim Cornwell, NRAO's Associate Director for Data Management, to develop the techniques used to combine the images.

The Orion Nebula, easily visible in amateur telescopes, is a giant cloud of gas some 1,500 light-years away in which new stars are forming. The GBT-VLA radio image, Shepherd said, shows new details that will allow scientists to better understand how ionized gas near the young, hot stars at the nebula's center flows outward toward the edge of the nebula.

The ability to produce combined GBT-VLA images also may revise scientists' understanding of other objects. For example, says NRAO Director Paul Vanden Bout, "Astronomers have seen many pockets of ionized Hydrogen gas in star-forming clouds with the VLA that are thought to be ultra-compact. It may be that they are, in fact, larger than thought and, using the GBT in addition to the VLA will show us the true picture."

The importance of this observing technique lies in its ability to greatly improve the fidelity of images. "By fidelity we mean how closely the image actually reflects reality. We now have a powerful new tool for improving the fidelity of our images when we look at objects that are close enough to appear relatively large in the sky but which also contain fine detail within the larger structure," Shepherd said. "This will have a big impact on a number of research areas such as star formation in our Galaxy, planetary nebulae, supernova remnants, as well as dynamics and star formation in near-by galaxies," she added.

The new technique also paves the way for effective use of the Expanded VLA, which will incorporate state-of-the-art electronics and digital equipment to replace now-aging technologies dating from the VLA's construction in the 1970s. In addition, the new capabilities can be used with the Atacama Large Millimeter Array (ALMA), a millimeter-wave observatory to be constructed in Chile as a partnership among North American, European and Japanese astronomers.

The combined GBT-VLA image was produced from observations made at a radio frequency of 8.4 GHz. The VLA observations were made in 2000 and the GBT observations in November of 2001.

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Graphics to Accompany This Story

GBT Image of Orion Nebula

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Embargoed for Release: 9:20 a.m., EST, Monday, January 7, 2002

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Stars Take Longer to Form, Need a 'Kick' to Get Started, Astronomers Say

Star formation is a longer process than previously thought, and is heavily dependent on outside events, such as supernova explosions, to trigger it, a team of astronomers has concluded. The scientists reached their conclusions after making a detailed study of a number of the dark gas clouds in which new stars are formed.

Optical image of the dark cloud L57, with white contours indicating submillimeter-wave emission from dust within the dark cloud.

"Our observations indicate that we need to drastically revise our ideas about the very early stages of star formation," said Claire Chandler, an astronomer at the National Radio Astronomy Observatory (NRAO) in

Socorro, New Mexico. Chandler, who worked with John Richer and Anja Visser at the Mullard Radio Astronomy Observatory in the United Kingdom, presented the results at the American Astronomical Society's meeting in Washington, D.C.

The astronomers observed the gas clouds with the SCUBA camera on the James Clerk Maxwell Telescope on Mauna Kea, Hawaii. This instrument is sensitive to submillimeter-wavelength radiation, which lies between radio waves and infrared waves in the electromagnetic spectrum. They studied clouds that previously had been observed with optical and infrared telescopes. The SCUBA images allowed them to see aspects of the clouds not visible at other wavelengths.

Some young "protostars" are so deeply embedded in their parent gas clouds that they are invisible to infrared telescopes, while others have become visible by consuming and blowing away much of their surrounding clouds. Earlier studies had indicated that the "invisible" stars are only about one-tenth as common as those visible to infrared telescopes.

"What we see in our study, however, is equal numbers of both types," said Chandler, who added, "This means that both stages probably have about the same lifetime -- roughly 200,000 years each."

Another conclusion coming from the study is that star formation is heavily dependent on a triggering event to get it started. Such a triggering event might be the shock wave from a supernova explosion that causes gas clouds to begin the gravitational collapse that ultimately results in a new star.

Another challenge to traditional wisdom about the early stages of star formation came in the team's analysis of data on starless cores -- gas clouds that have not yet begun their collapse into stars. The astronomers found that the starless cores in their study are on the verge of collapsing, and probably have shorter lifetimes than previously thought.

"This means that, contrary to what we thought before, you don't need strong magnetic fields to hold these things up against gravitational collapse, because they don't last that long," Chandler said. Much theoretical work on early star formation that focuses on the role of magnetic fields may need revision, the study indicates.

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January 4, 2002

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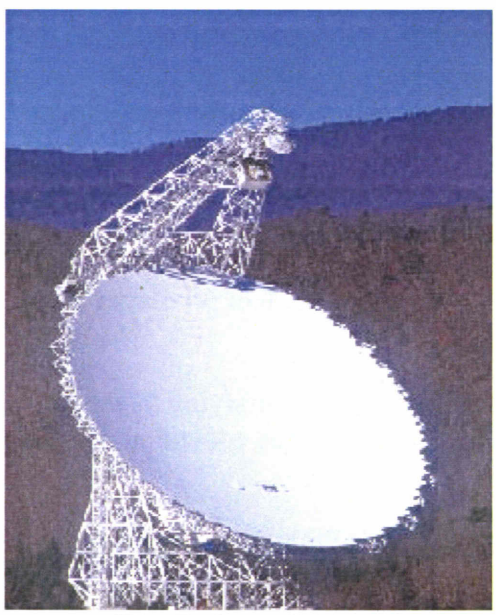
Newly Commissioned Green Bank Telescope Bags New Pulsars

Astronomers using the National Science Foundation's newly commissioned Robert C. Byrd Green Bank Telescope (GBT) have discovered a windfall of three previously undetected millisecond pulsars in a dense cluster of stars in the Milky Way Galaxy.



The Robert C. Byrd Green Bank Telescope

"This globular cluster, known as Messier 62, has been very well studied, and it would have been an exciting discovery to find just one new pulsar. The fact that we were able to detect three new pulsars at one time is simply remarkable," said Bryan Jacoby, a graduate student at the California Institute of Technology who led the research team. Results of the discovery were recently announced in an International Astronomical Union Circular.

Jacoby and his colleague Adam Chandler, also a graduate student at Caltech, used the GBT to search for new pulsars in addition to the three already known in this cluster. Their research was part of the GBT's Early Science Program, which allows scientific investigations during the testing and commissioning of the telescope. The researchers used the Berkeley-Caltech Pulsar Machine, a new instrument whose development was overseen by Donald Backer at the University of California at Berkeley, to process the signals from the GBT and record them for later analysis.

After their data were analyzed, the researchers discovered the telltale signatures of three additional pulsars and their white dwarf companion stars.

Pulsars are rapidly rotating neutron stars that emit intense beams of radio waves along their misaligned magnetic axes. When these beams intersect the Earth, we see the pulsar flash on and off. Due to their exquisitely steady rotation, pulsars allow astronomers to study the basic laws of physics and the ways in which these dense clusters and exotic stellar systems are formed.

Astronomers study globular clusters because they are among the oldest building blocks of our Galaxy. With their very dense stellar populations, these clusters are breeding grounds for unusual binary star systems, like the ones detected by the researchers.

All three pulsars are known as "millisecond pulsars" because they make one complete rotation in only a few thousandths of a second. One of these newly discovered pulsars spins at approximately 440 rotations per second, and the other two both spin about 300 times per second. All are orbited by white dwarfs with orbital periods ranging from 4 to 27 hours.

"This discovery demonstrates the remarkable sensitivity of the Green Bank Telescope," said Phil Jewell, site director for the National Radio Astronomy Observatory in Green Bank, W.Va. "The fact that these pulsars were never before detected in this highly studied area of the Galaxy shows that the GBT has outstanding capabilities and will be an important tool for astronomers to make very precise, very sensitive observations of the Universe.

The GBT is the world's largest fully steerable radio telescope. It was dedicated on August 25, 2000, after nearly 10 years of construction. Since that time, engineers and scientists at the NRAO in Green Bank have been testing the telescope and outfitting it with the sensitive receivers and electronics that will make it one of the world's premier astronomical instruments.

"As a graduate student," said Jacoby "this discovery was particularly satisfying, and I feel privileged to be part of the history of the Green Bank Telescope."

Shrinivas Kulkarni, the Caltech faculty advisor for this project, remarked, "it is very satisfying to see such discoveries being made by young people. GBT is poised to play a significant role in the education of young astronomers."

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January 2, 2002

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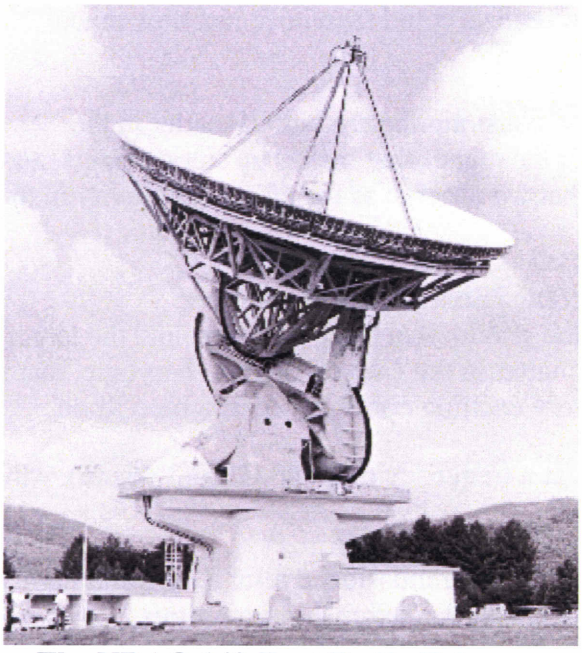
Helium-3 in Milky Way Reveals Abundance of Matter in Early Universe

Astronomers using the National Science Foundation's 140 Foot Radio Telescope in Green Bank, West Virginia, were able to infer the amount of matter created by the Big Bang, and confirmed that it accounts for only a small portion of the effects of gravity observed in the Universe. The scientists were able to make these conclusions by determining the abundance of the rare element helium-3 (helium with only one neutron and two protons in its nucleus) in the Milky Way Galaxy.



The NRAO 140-Foot Radio Telescope

"Moments after the Big Bang, protons and neutrons began to combine to form helium-3 and other basic elements," said Robert Rood of the University of Virginia. "By accurately measuring the abundance of this primordial element in our Galaxy today, we were able infer just how much matter was created when the

Universe was only a few minutes old." Rood and his colleagues, Thomas Bania from Boston University and Dana Balser from the National Radio Astronomy Observatory (NRAO), report their findings in the January 3 edition of the scientific journal *Nature*.

Rood began searching for helium-3 in the Milky Way Galaxy in 1978. At that time, scientists believed that stars like our Sun synthesized helium-3 in their nuclear furnaces. Surprisingly, Rood's observations indicated that there was far less of this element in the Galaxy than the current models predicted. "If stars were indeed producing helium-3, as scientists believed, then we should have detected this element in much greater concentrations," he said.

This unexpected discovery prompted Rood and his colleagues to broaden their search, and to look throughout the Milky Way for signs of stellar production of helium-3. Over the course of two decades, the researchers discovered that regardless of where they looked -- whether in the areas of sparse star formation like the outer edges of the Galaxy, or in areas of intense star formation near center of the Galaxy -- the relative abundance of helium-3 remained constant. By concurrently measuring the amount of hydrogen (also created by the Big Bang) in the same areas, the scientists were able to determine the relative abundance of helium-3.

"Since stellar processes appear to have little or no impact on the amount of helium-3 in the Galaxy, we were able to deduce two very important things," said Bania. "First, since our current models predict stellar production of helium-3, then we will need to rethink our understanding of the internal workings of stars like our Sun. Second, since helium-3 has not been created or destroyed in our Galaxy in any appreciable amounts, then what we detected is most likely equal to the abundance of primordial helium-3 created by the Big Bang."

The scientists were able to use this discovery to calculate how much "normal" matter was created during the Big Bang. (Normal matter is anything made of baryons, subatomic particles that include neutrons and protons.) The researchers made these calculations by taking what they know of the composition of the Universe today, and essentially running time in reverse. In this case, the ratio of helium-3 to hydrogen gives the ratio of baryons to photons (the density of radiation) just after the Big Bang. By using the rate of expansion of the Universe, given by the Hubble Constant, the scientists could then infer just how much normal matter was produced during the Big Bang.

"Our findings for helium-3 in fact support other studies that also constrain the amount of matter in the Universe," said Balser. "Taken together, these studies show that the matter that makes up stars, planets, and the visible Universe can only account for a small fraction of what we observe as the effects of gravity in the Universe."

Dark matter, which can be both baryonic (dead stars, rocks, etc.) and non-baryonic, and other as-yet-unidentified forces appear to be the primary sources of the gravity that holds galaxies, and the larger structures of the Universe, together. "The fact that most of the matter in the Universe is non-baryonic, that is to say not made of any particle we've ever seen on Earth, is a very exciting concept," commented Rood.

The astronomers conducted their research using measurements at a frequency of 8.665 GHz (3.46 cm), which is emitted naturally by ionized helium-3.

The 140 Foot Radio Telescope at the NRAO in Green Bank now is decommissioned after a long and highly productive career. "Though the 140 Foot Telescope enabled us to make remarkable observations," commented Rood, "we anticipate that the new Robert C. Byrd Green Bank Telescope will greatly increase our ability to continue this research."

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

National Radio Astronomy Observatory

In

THE

News

January 2002 - January 2003

Researchers: Gravity, Light Speed Match

Speed of Gravity Matches Speed of Light, Astronomers Conclude

The Associated Press

SEATTLE Jan. 8 — Astronomers have concluded that Einstein was right: The speed of gravity does match the speed of light. The astronomers took advantage of a rare planetary alignment to study one of the basic forces of nature. Edward B. Fomalout of the National Radio Astronomy Observatory and Sergei Kopeikin of the University of Missouri, Columbia, clocked the speed of gravity by measuring how light waves from a distant star were warped by the gravity of Jupiter as the planet passed between the Earth and the star. They found that the speed was in agreement with an assumption made by Albert Einstein. The famed scientist, who formulated basic theories about space, time and relativity, thought gravity moved at the speed of light, about 186,000 miles per second. But it was a value that, until now, was unmeasured and only assumed. "Einstein was right, of course," said Fomalout. Although the measurement established a number for one of the last fundamental unknown constants in physics, Fomalout admitted, "gravity is not well understood." The researchers used 10 radio telescopes scattered across the Earth from Hawaii to Germany to precisely measure how light from a distant quasar, a type of star, was bent as it passed by Jupiter on its way to the Earth. Jupiter is in the precise position for such a measurement only once a decade. To make the measurement, the instruments had to detect a minute deflection of the light as it streamed past Jupiter. Fomalout compared the required precision to being able to measure the size of a silver dollar sitting on the moon's surface, or to measuring the width of a human hair from 250 miles away. Craig Hogan, a University of Washington astronomer, said the achievement "is an important advance for physics," but he predicted that new techniques will be developed that will measure gravity's speed even more accurately. "You can expect a series of experiments now," he said. Fomalout and Kopeikin said their results are accurate within about 20 percent. Knowing the precise speed of gravity is important to physicists testing such modern ideas as the superstring, which holds that fundamental particles in the universe are made up of small vibrating loops or strings. It also affects some basic space-time theories. On the Net: American Astronomical Society:

Einstein Was Right

SEATTLE, Jan. 8, 2003

Einstein was right. The speed of gravity matches the speed of light, according to astronomers who took advantage of a rare planetary alignment to measure one of the fundamental forces of nature.

Edward B. Fomalout of the National Radio Astronomy Observatory and Sergei Kopeikin of the University of Missouri measured the amount that light from a distant star was deflected by the gravity of Jupiter as the planet passed in front of the star.

Albert Einstein, who formulated basic theories about space, time and relativity, had assumed that gravity moved with the speed of light, about 186,000 miles per second, "but until now, no one had measured it," said Kopeikin.

"Einstein was right, of course," said Fomalout.

The measurement is one of the last fundamental constants in physics to be established and Fomalout admitted, "gravity is not well understood."

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By Paul Recer

Einstein right: gravity fast as light

Wednesday, January 8, 2003 Posted: 10:38 AM EST (1538 GMT)

Astronomers used a once-in-a-decade alignment of Jupiter to study how the giant planet bent light from a distant star.

SEATTLE (AP) -- Einstein was right. The speed of gravity matches the speed of light, according to astronomers who took advantage of a rare planetary alignment to measure one of the fundamental forces of nature.

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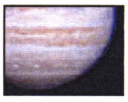
Einstein right: gravity fast as light



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January 8, 2003

Einstein Was Right on Gravity's Speed

By JOHN NOBLE WILFORD

SEATTLE, Jan. 7 - In a test critical to theories of cosmology, scientists have for the first time measured the speed at which the force of gravity moves. And, once again, it appears that Einstein has been proved right, scientists announced today at a meeting here of the American Astronomical Society.

``Newton thought that gravity's force was instantaneous," said Dr. Sergei Kopeikin, a physicist at the University of Missouri. ``Einstein assumed that it moved at the speed of light, but until now, no one had measured it."

By observing a slight ``bending" of radio waves when Jupiter passed nearly in front of a more distant cosmic object, scientists said they determined that gravity's propagation speed is equal to the speed of light. They said their finding was within an accuracy of 20 percent, which they considered good enough to conclude that gravity's velocity is probably indeed equal to the speed of light.

The result came as no surprise to other scientists. But it was a relief to have confirmation that an important assumption about the property of gravity rested on a firm foundation.

The speed of gravity was one of the last unmeasured fundamental constants of physics. No one had tried before, Dr. Kopeikin explained, because most physicists had assumed it could not be done with current technology. They were waiting until a system of new observing instruments, the Laser Interferometry Gravitational Observatory, was in full operation to detect gravitational waves in space.

The measurement was made on Sept. 8 using radio telescopes of the Very Long Baseline Array in the United States in conjunction with one in Germany. The simultaneous observations of Jupiter by such a broad system of telescopes were unusually sensitive to the slightest deflection of radio waves caused by the planet's gravity.

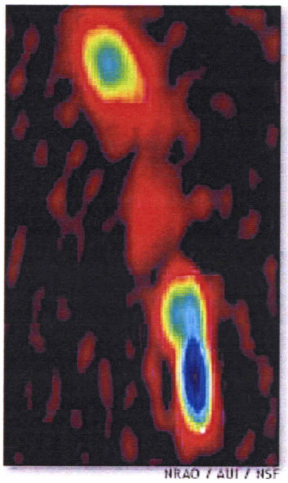
When light from a bright quasar, an object nine billion light-years away, passed near Jupiter, the planet's gravity shifted the quasar's radio signals. This resulted in a small change in the quasar's apparent position in the sky. Einstein was confirmed, scientists said, by the equivalent width of five human hairs seen at 250 miles.

``The precise amount of the bending depends on the speed at which gravity propagates from Jupiter," Dr. Kopeikin said.

Dr. Edward B. Fomalont, an astronomer at the National Radio Astronomy Observatory in Charlottesville, Va., who directed the test, said the 20 percent uncertainty in the measurement was ``within our experimental error," the result of distortions caused by clouds and air turbulence at the radio telescope sites.

Dr. Craig J. Hogan, an astrophysicist at the University of Washington who was not involved in the research, said an understanding of gravity was indispensable to developing theories combining particle physics and relativity. The test, he said, was ``a very high-precise method to see if it is actually true" that gravity propagates at the speed of light.

``Thankfully, it does," Dr. Hogan said. "Nobody has a theory that would have explained a different result."



NRAO / AUI / NSF

A false-color image, based on data from the Very Long Baseline Array and the Effelsberg radio telescope, shows the radio signature of the quasar J0842+1835. Observations of the quasar were used to estimate the speed of gravity.

First test of gravity's speed upholds Einstein

Speed matches speed of light, scientists say — but doubters persist

By Alan Boyle
MSNBC

SEATTLE, Jan. 7 — Albert Einstein can rest a little easier: The first effort to measure how quickly gravity exerts its influence indicates that it more or less matches the speed of light, scientists reported Tuesday. If the results had come out differently, it would have cast new doubt on Einstein's view of general relativity — and in fact, some doubters contend that the latest measurement by no means closes the case.

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Alan Boyle
SCIENCE EDITOR

THE MEASUREMENT, presented at this week's meeting of the American Astronomical Society in Seattle, was made by analyzing how radio waves from a quasar nearly 9 billion light-years from Earth were bent as they passed through Jupiter's gravitational field on Sept. 8.

Scientists have known for decades that gravity bends waves of electromagnetic radiation: The phenomenon played a key role in the first test of general relativity during a 1919 solar eclipse.

But it's only been in the last few years that astronomers have worked on putting a number to the propagation speed of gravity's effect. This speed is distinct from the much better-known rate of acceleration caused by gravity on Earth, which clocks in at 32 feet per second per second.

The classic illustration of the problem goes this way: Imagine that the sun were somehow snuffed out of existence in the blink of an eye. Would there be an instant disruption in Earth's orbit, sending it careening out of the doomed solar system, or would Earth continue to orbit a nonexistent star for eight minutes while the gravitational disturbance traveled 93 million miles (150 million kilometers) at the speed of light?

"Newton thought that gravity's force was instantaneous," Sergei Kopeikin, a physicist at the University of Missouri at Columbia, said in an written announcement of the results. "Einstein assumed that it moved at the speed of light, but until now, no one had measured it."

Kopeikin's partner in the research, Ed Fomalont of the National Radio Astronomy Observatory, said the propagation speed was equal to the speed of light within an accuracy of 20 percent. That may sound like a wide error margin, but the researchers said they were pleased with the results.

"Our main goal was to rule out an infinite speed of gravity, and we did even better," Fomalont said in the announcement. "We now know that the speed of gravity is probably equal to the speed of light, and we can confidently exclude any speed for gravity that is over twice that of light."

If gravity does propagate even 20 percent faster than light, it would break a cosmic speed limit imposed by Einstein's theories — and could hypothetically open the way to new methods of faster-than-light communication (hopefully on a smaller scale than snuffing out the sun).

HOW IT WAS DONE

The experiment was conducted by carefully charting how radio waves from the quasar, J0842+1835, were distorted in the night sky as Jupiter passed through the field of view. In 1999, Kopeikin laid out what Einstein's theory should predict about the pattern of distortion — then found that September's "once-in-a-decade" alignment should allow for a test of the theory.

Puzzles of physics

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He turned to Fomalont, who enlisted the aid of the National Science Foundation's Very Long Baseline Array, a continent-wide network of radio telescopes. A 330-foot (100-meter) radio telescope in Effelsberg, Germany, was added to the network to increase the accuracy of September's observations.

"We had to make a measurement with about three times more accuracy than anyone had ever done, but we knew in principle that it could be done," Fomalont said. Sunspot activity during the observations gave the researchers some cause for concern, but in the end, the data achieved a precision equal to the width of a human hair seen from 250 miles (400 kilometers) away, the researchers said.

If the speed of gravitational propagation were infinite, the apparent position of the quasar should have moved in a perfect circle due to the bending of the radio waves, Kopeikin said. Instead, it inscribed an offset ellipse, shaped roughly as would be expected if the speed of gravity and the speed of light were equal.

WHAT IT ALL MEANS

Kopeikin said the observation sheds light on one of the last unsettled fundamental constants of physics — and could play a role in the continuing quest to develop a "theory of everything" that unites gravitational theory and quantum mechanics.

"Our measurement puts some strong limits on the theories that propose extra dimensions, such as superstring theory and brane theories," he said. "Knowing the speed of gravity can provide an important test of the existence and compactness of these extra dimensions."

Commenting on the research, University of Washington cosmologist Craig Hogan said it was almost a given among mainstream theorists that the speed of gravity should equal the speed of light. But he agreed that the experiment would be useful in plotting the future course for extradimensional physics. "The frontiers of physics are very much concerned with small departures from Einstein's theories of space and time and gravity," he said.

Not all physicists are convinced that the results truly measured the propagation speed, however. In Astrophysical Journal Letters, Japanese physicist Hideki Asada argued that the experiment actually measured the speed of light rather than the speed of gravity.

Kopeikin, who submitted his own paper to the Astrophysical Journal Letters late last month, said at Tuesday's news briefing that Asada's argument was incorrect. "He made a mathematical mistake," Kopeikin said.

Astronomer Thomas Van Flandern, who has built up a following for his views outside the scientific mainstream, said in a September commentary that the experiment may have measured the speed of gravitational waves, but "can provide no information about the propagation speed of gravitational force, which is bounded by many experiments to be much

faster than light."

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The Daily Progress

WEDNESDAY January 8, 2003 Established in 1892 A Media General Newspaper Charlottesville, Virginia

Area man finds speed of gravity

Local scientist is first to get key measurement

By KATE ANDREWS
Daily Progress staff writer

A Charlottesville scientist announced Tuesday that he has taken the first measurement of the speed of gravity, a breakthrough in astronomy and physics.

Scientists long ago determined the speeds of sound and light, but until now, gravity's speed — consistent with that of light, 186,000 miles per second — has gone unmeasured.

"It's rare that you either get to think about or make a measurement that deals with a fundamental property," said Ed Fomalont, a scientist with the Charlottesville-based National Radio Astronomy Observatory. "This is one of the fundamental numbers that hasn't been measured."

See GRAVITY on A7

The Daily Progress/Rachel Zahumensky

Robert Brown (left) is deputy director of the National Radio Astronomy Observatory. Charles Blue is a spokesman for the observatory.

Gravity

Continued from A1

Fomalont and University of Missouri-Columbia scientist Sergei Kopeikin conducted the experiment in September, when the planet Jupiter aligned with a quasar.

Eleven large telescopes across the continental United States, Hawaii and the Caribbean measured radio waves between the planet and the quasar.

Using Kopeikin's extension of Albert Einstein's theory, the two scientists were able to judge the speed of gravity through light and radio waves within 20 percent accuracy — a low error rate for such an experiment, Fomalont said.

The discovery created quite a stir at NRAO, a National Science Foundation facility housed near the University of Virginia's McCormick Observatory.

"All this has been under wraps," said Robert Brown, the observatory's deputy director. "The scientists involved have an opportunity to make a splash among their peers. Most of us have been enormously curious."

"It's one of the most significant discoveries made at the observatory," spokesman Charles Blue added.

Fomalont and Kopeikin made their announcement Tuesday afternoon in Seattle, where the American Astronomical Society held its national conference.

Although Sept. 8, when Jupiter passed closest to the quasar, was the most important day of the experiment, Fomalont said much of the work took place in the months before.

Kopeikin studied the predicted 30-year orbit of Jupiter, leading to his contacting Fomalont, an expert on the Very Long Baseline Array, a series of giant telescopes like those seen in the 1997 movie "Contact."

Barring mechanical error or bad weather, the scientists knew the passage of Jupiter by the quasar was their best chance for measuring the speed of gravity. Meanwhile, teams from Japan and the National Air and Space Administration had the same goal.

Ironically, the discovery likely will help competitor NASA.

The same measurement tech-

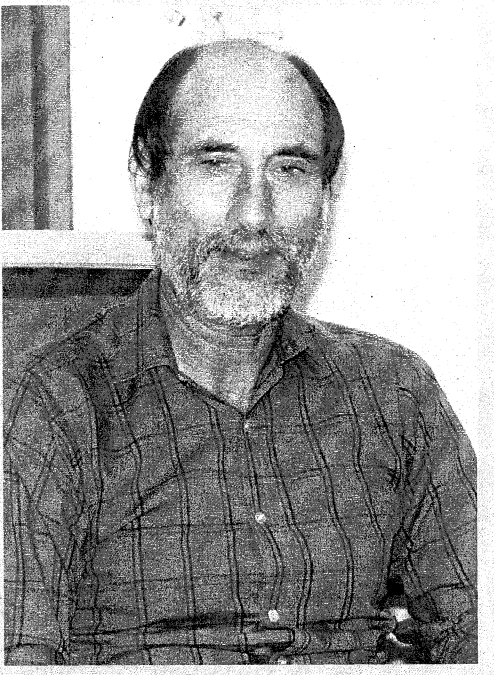
niques can be used to track spacecrafts, a resource NASA could have used in 1999, when an orbiter crashed into Mars.

The two scientists' five days of testing and observing — including four days of control experiments — preceded weeks of waiting for results.

"We were sort of biting our nails," Fomalont said. "We just hoped and prayed and said, 'We want this data.'"

When it arrived, Fomalont and Kopeikin processed the information, examining it from many different angles. After a month and a half, they knew the evidence was solid.

"Of course you can only hope that this would be accurate," Fomalont said, "and it was."



ED FOMALONT
Measured speed of gravity

'Our main goal was to rule out an infinite speed for gravity, and we did even better.'

—Ed Fomalont
National Radio Astronomy Observatory

Scientists Find an Einstein Notion Has Weight

Speed of Gravity—a Part of Relativity Theory— Measured Using Jupiter and Distant Quasar

By Kathy Sawyer
Washington Post Staff Writer

Einstein was right—again.

Using a rare alignment of Jupiter against a far-off quasar, scientists for the first time have succeeded in measuring the speed of gravity, a fundamental constant of physics described by Albert Einstein in his general theory of relativity.

The new number announced yesterday will curb some of the more exotic notions of theorists working to formulate a "theory of everything" that unifies concepts of particle physics with scientists' understanding of gravity, and presents a coherent portrait of nature from the tiniest subatomic particle to the most titanic structures in the cosmos.

Isaac Newton "thought that gravity's force was instantaneous," said Sergei Kopeikin, a physicist at the University of Missouri-Columbia who led the observing team. "Einstein assumed that it moved at the speed of light, but until now, no one had measured it."

At a meeting of the American Astronomical Society in Seattle, Kopeikin and colleagues announced their finding that the force of gravity propagates outward from a source at 1.06 times the speed of light (186,000 miles per second in a vacuum), with a 20 percent margin for error. If confirmed, the number rules out theories based on the notion that the speed of gravity is, as Newton conceived it, infinite or instantaneous.

In Einstein's conception, gravity is a warping of the space-time continuum, sometimes depicted graphically in terms of balls rolling around in a net. A massive object such as a bowling ball—or the planet Jupiter—makes a bigger hole, or "gravity well," in the webbing—the geometry of space—than a less weighty object, say, a baseball.

In everyday terms, gravity keeps people, cats and other untethered objects from flying off the planet. The sun's gravity keeps Earth and the other planets from flying off into space. If the sun suddenly vanished from the sky, it would take about eight and a half minutes for the last particle of sunlight to cross the 93 million-mile distance to Earth, leaving the planet in the dark. Based on the new number for the speed of gravity, at about the same moment the light went out, Earth would "feel" the end of the sun's gravitational influence and skid off into the cold void, said Ed Fomalont of the National Radio Astronomy Observatory in Charlottesville, who worked with Kopeikin on the project.

The scientists used the continent-wide Very Long Baseline Array, a radio-telescope system with sites in the continental United States, Virgin Islands and Hawaii, along with a 100-meter radio telescope in Effelsberg, Germany, to achieve the effect of a huge single instrument capable of a very precise observation. They were precise to the width of a human hair seen at 250 miles, Fomalont said.

"We had to make a measurement with about three times more accuracy than anyone had ever done," Fomalont said.

They took advantage of the once-in-a-decade alignment of Jupiter against a grouping of brilliant quasars billions of light years away. The alignment occurred Sept. 8. The scientists fretted about weather on Earth and possible electromagnetic storms on Jupiter, which could have ruined their plan. But they got lucky.

They compared their experiment to one done in 1919.

Einstein had predicted in 1915 that starlight passing the sun should be bent gravitationally by a certain amount. Four years later, a team led by Sir Arthur Eddington, a noted British astrophysicist, verified the prediction with measurements made during a solar eclipse. Eddington found that the position of stars in the sky appeared to move depending on whether the sun was near their line of sight—because of the deflection of the light by the Sun's mass.

Kopeikin and Fomalont used Jupiter, instead of the sun, because Jupiter moves relative to Earth in a way that the sun does not, and this motion was crucial to their experiment. Jupiter only passes close enough to the path of radio waves from a bright-enough quasar about once a decade, Kopeikin calculated. (Quasars are the most luminous and energetic objects known, brilliant beacons in far-off regions of the cosmos, and are believed to be galaxies with active black holes at their core.)

"Because Jupiter is moving around the sun, the precise amount of the bending depends slightly on the speed at which gravity propagates from Jupiter," Kopeikin said.

The effect they measured was a very slight bending of the radio waves emanating from the background quasar, caused by the gravitational influence of Jupiter. If the speed of gravity were infinite, the amount of bending would have been different.

A researcher in Japan has contended that the technique actually measured the speed of light, not gravity, but his interpretation is not attracting support.

Kopeikin and Fomalont spent considerable time conducting tests of the system on other days, to calibrate their margin of error and to account for the effects of Earth's atmosphere on the observations.

"No one had tried to measure the speed of gravity before, because most physicists had assumed that the only way to do so was to detect gravitational waves," Kopeikin said. Large instruments have been constructed to detect these gravitational ripples, believed to flow from events such as the collision of neutron stars.

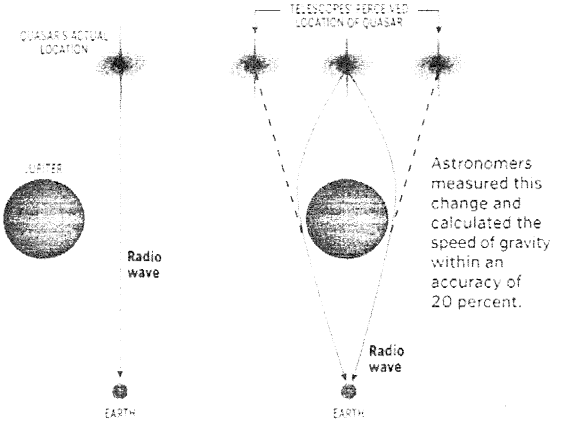
"Our main goal was to rule out an infinite speed for gravity, and we did even better, Fomalont said. "We can confidently exclude any speed for gravity that is over twice that of light."

Measuring Gravity's Speed

Astronomers took advantage of a rare cosmic alignment to measure the speed of gravity for the first time.

The jets from a quasar emit strong radio waves. Uninterrupted, the waves travel directly to Earth.

Jupiter moved nearly in front of the quasar, and the planet's gravity caused the radio waves to bend slightly. Because of the bending, an array of telescopes perceived the quasar in different locations.

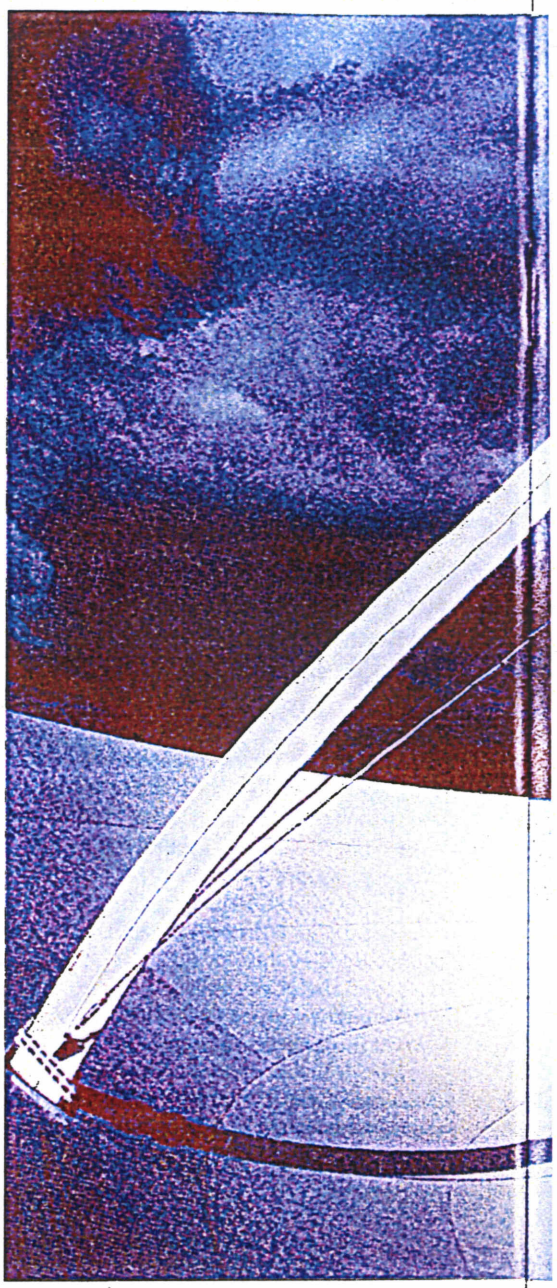


Astronomers measured this change and calculated the speed of gravity within an accuracy of 20 percent.

SOURCE: National Radio Astronomy Observatory

THE WASHINGTON POST

Newton thought it was instantaneous, Einstein assumed it travelled at the speed of light, but no one really knew how fast gravity goes till now. Radio astronomer Ed Fomalont and theoretical physicist Sergei Kopeikin tell the story of how they discovered the answer



How fast is gravity?

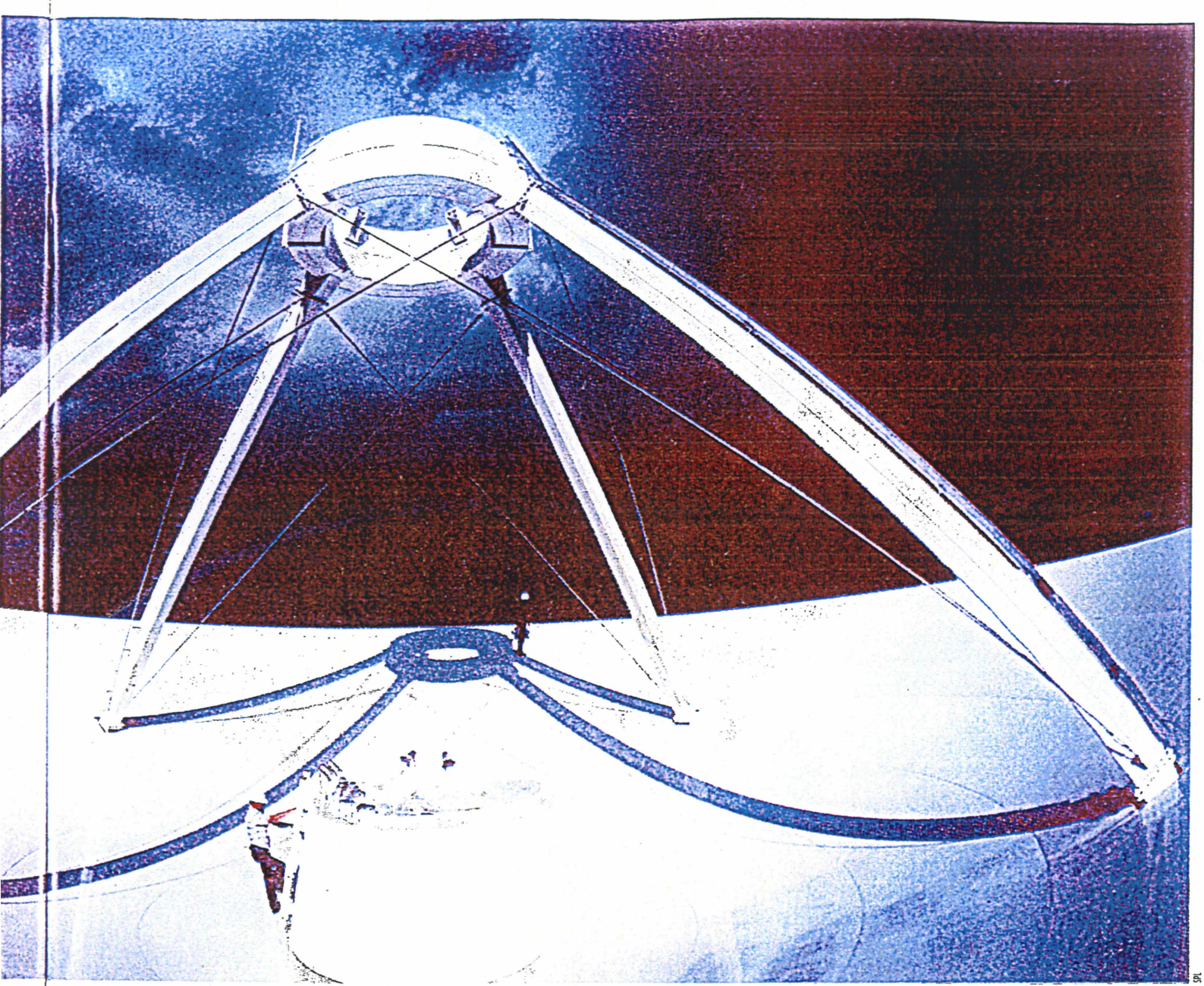
IF AN alien spacecraft suddenly plucked the Sun from the centre of the Solar System, how would the Earth respond? We know that the sky would become dark after 8.3 minutes, the time it takes light to travel from the Sun to the Earth. But what about the Sun's gravitational force?

Most scientists assume that gravity also travels at the speed of light. So the Earth would remain in orbit for 8.3 minutes and then, suddenly feeling no gravity, would continue off into space in a straight line. This assumption is implicit in the general theory of relativity, which Einstein devised in 1915 and is still our best working theory of space-time. But an assumption is all it is. It has never been tested.

Even worse, the assumption has come under pressure from the modern interest in what are called "brane worlds". These theories are a type of string theory that envisage extra spatial dimensions in addition to the space-time in which ordinary matter exists. In these theories, the extra dimensions are rolled up extremely small. Gravity can take a short cut through these dimensions, while light is confined to the world of ordinary matter, known as the "main brane".

If this is the way things work, gravitational waves could appear to travel faster than the speed of light in our world and yet not violate the equations of general relativity. So determining the speed of gravity could provide important evidence about the existence and compactness of these higher dimensions, and help to put some of the competing theoretical brane worlds to the test.

When an opportunity came up last year to measure the speed of gravity, through a combination of theoretical insight by one of us (Kopeikin) and an experimental technique developed by the other (Fomalont), we leapt at the chance. The opportunity came on 8 September 2002, when the planet Jupiter



The world's most powerful radio telescopes watched as Jupiter almost eclipsed a distant quasar

passed nearly in front of a bright radio quasar called J0842+1835. Our plan was to use the world's most powerful intercontinental array of radio telescopes to measure the apparent change in the quasar's position and thus to determine the speed of gravity. Now, after four months analysing our observations, we know the answer.

It is no secret why the assumed speed of gravity remained untested and unchallenged for so long. Most physicists thought that the speed of gravity shows itself only in the propagation of gravitational waves through space. And since no one has even detected gravitational waves, measuring how fast they travel was not on the agenda.

But people were missing something. Kopeikin realised that Einstein's theory could be reformulated in a way that made gravity analogous to electromagnetic radiation. Physicists have known for more than a century that a uniformly moving charge generates a constant electric and magnetic field whose strength depends on the magnitude of the charge, its velocity and the speed of light. The relationship is expressed in what are known to every physicist as Maxwell's equations. Crucially, this means that it is possible to calculate the speed of light from measurements of the electric and magnetic field of a moving charge, without having to detect electromagnetic waves directly.

In the same way, Kopeikin's reworking of general relativity expresses the gravitational field produced by a moving body in terms of the mass of the body, its velocity and the speed of gravity. If we could just get detailed information on the gravitational field of a massive moving body, we could use this to work out the speed of gravity.

The trouble is, getting hold of this information is not at all easy. One obvious probe might be to use "gravitational lensing". This is the apparent shift in position of a ▶

distant object that occurs when its light is deflected on the way to Earth as the rays pass through the gravitational field of a massive body. If that body is moving, measurement of the lensing effect should give us the information we require.

But there are problems. Although physicists have known for some time how a stationary body, or one moving at a uniform speed, lenses light, the equations that describe the deflection of light around a rotating, orbiting body looked totally intractable. Then in 1999 Kopeikin, who was then at the University of Jena in Germany, made a crucial breakthrough. To the surprise of physicists worldwide, he came up with an exact solution to these equations.

Being able to probe the gravitational field of a moving body is a start, but there are other problems, too. We also need to know the exact mass and orbit of the body that is lensing the light. Although the sky is full of stars and dark clusters that move in front of other light sources and deflect the light from them, we do not know the mass and velocity of most of these "cosmic lenses" nearly well enough.

One body for which we do have this information is Jupiter. Thanks to fly-bys by the Pioneer, Voyager and Galileo spacecraft, we know the planet's mass and orbital velocity with unparalleled precision. So to find the speed of gravity, all we need is an occasion where Jupiter moves in front of a good strong light source, lensing the rays on their way to Earth.

In 2000 Kopeikin compared the orbit of Jupiter for the next 30 years with catalogues of suitable radio sources. A close encounter of Jupiter with a radio source is a rare event, happening only about once every decade. But a close passage of Jupiter to the strong radio quasar J0842+1835 was due on 8 September 2002. Time was tight!

The two of us had met briefly in Tokyo in 1996. When Kopeikin was looking around for someone to help him make his observations, he recalled that Fomalont had been part of a team that some 20 years earlier had been taking accurate measurement of the bending of radio waves as they passed near the Sun. This sort of experience was just what was needed for the experiment. So Kopeikin contacted his old acquaintance and our partnership was born.

The lensing effect we were planning to measure would cause the apparent position of the quasar J0842 to shift slightly (see Graphic). The best way we have to measure this is to observe the quasar using an array of radio telescopes spaced as far apart as possible. From the time it takes for the distant body's radio signals to reach each telescope we can work out its position in the sky: put simply, if one telescope receives a signal before the other, the quasar must be closer to the telescope at which the signal arrives first.

To make our measurements as accurate as possible, we arranged to take measurements on the largest array we could get access to. We began with the US National Radio Astronomy Observatory's Very Long Baseline Array. It is made up of a series of 10 radio telescopes, each one 25 metres in diameter, stretching from Saint Croix in the US Virgin Islands in the east to Mauna Kea, Hawaii, in the west. To that we added the 100-metre radio telescope in Effelsberg, Germany, giving us a array that extended over 10,000 kilometres.

This should be able to pin down the position of a quasar to an accuracy of 10 microarcseconds, or about 5 billionths of the diameter of the full Moon. That is a resolution three times as high as anyone had previously achieved, yet it is the bare minimum needed to be able to tell whether Jupiter's gravity reaches Earth instantaneously, travelling at infinite speed, or takes a finite amount of time for the journey.

"We became the first two people to know the speed of gravity, one of the fundamental constants of nature"

Although we knew it was possible in principle to do our experiment, there were a worryingly large number of ways it could go wrong. Tiny changes in the locations of the telescopes due to continental drift and variations in the Earth's rotation rate could affect our measurements. A more serious problem was that the weather above each telescope could ruin them entirely: as the wind moves clouds over the various telescopes, the radio source can appear to jitter, masking the much smaller effect from Jupiter's gravity.

The key to dealing with these uncertainties was to find sources near J0842+1835 that would not be lensed by Jupiter on 8 September but were close enough in the sky to be subject to similar atmospheric conditions. With fast-alternating observations of several radio sources, we could measure the difference in positions much more accurately than the position of each one alone. In the end we picked two quasars to use as reference sources on the day.

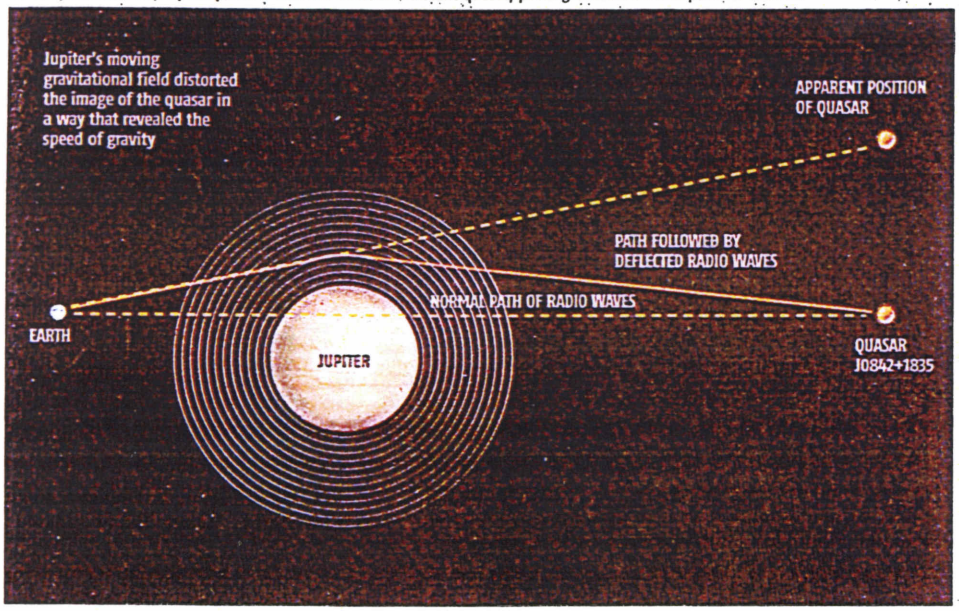
We had five observing days on the array of telescopes, each lasting 10 hours. The crucial day was, of course, 8 September, when the closest passage of Jupiter to J0842 occurred at 16.30 GMT. But that alone would not have been enough. Quasars are caused by outbursts of energy from a black hole in the centre of a galaxy, and this phenomenon can vary over time. So we also made observations on days when the effect of Jupiter's gravitational field on J0842 would be negligible, and also to check that our sources were not jittering in a way that might confound our measurements.

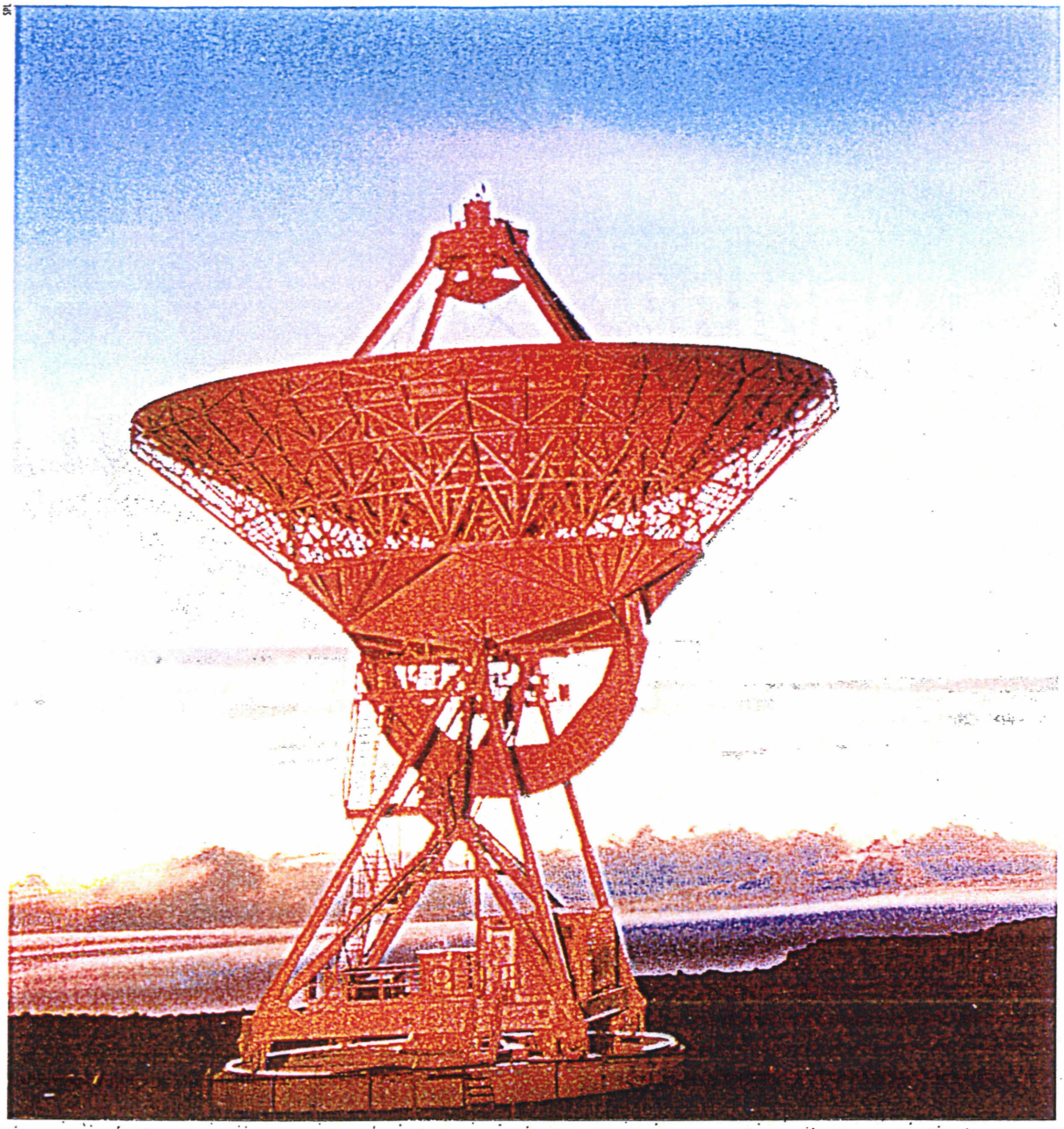
Perhaps our most serious worry concerned what was happening on Jupiter itself, or to be more precise, in its large and variable magnetosphere. This is a plasma of fast-moving electrons from the solar wind that become trapped by the Jovian magnetic field. Our fear was that the quasar radio waves passing near the planet's surface on 8 September could be warped by the magnetosphere. We were worried that if the magnetosphere was very active, this effect would be as large as the gravitational bending we were looking for.

We could have overcome this problem by

HOW FAST DOES GRAVITY GO?

On 8 September 2002, Jupiter passed almost in front of a distant quasar, putting Einstein's assumption to the test





The Very Long Baseline Array of radio telescopes stretches from Hawaii (left) to the Caribbean

observing at two different frequencies simultaneously, but this would have added complexity to the experiment, and decreased its overall accuracy, so we decided instead to bank on good Jovian weather.

The bet paid off, and everything did go well – until the big day itself. To our horror, on 8 September, the telescope at Saint Croix malfunctioned because of serious tape recording problems. Fortunately, it turned out that the data from other telescopes could compensate for the loss. We also had to discard about 15 per cent of our data because of bad weather.

Happily, this still left enough data for us to carry out the analysis. Comparing the position of J0842 on 8 September with its average position on the off-Jupiter days and plugging this into Kopeikin's formula for the gravitational field of the moving Jupiter gave us the answer we were looking for. We became the first two people to know the speed of gravity, one of the fundamental constants of nature.

Here it is: gravity does move at the same speed as light. Our actual figure was 1.06 times the speed of light, but we have an error of plus or minus 0.21. We are planning to announce our results this week at the American Astronomical Society's annual meeting in Seattle.

Our result rules out the possibility that gravity travels instantaneously, as Newton imagined. If it did, we would have seen a minutely different shift in the position of the quasar on the night of 8 September. This vindicates Einstein's instinct when formulating his general theory of relativity, which was to assume the speed of gravity was equal to the speed of light.

Our result also puts stringent limitations on the parameters of brane-world theories: in particular, it restricts how many extra dimensions there may be, and their size. The more compact the extra dimensions, the less able gravity is to take a short cut through them and the closer the speed of gravity must be to the speed of light.

We look forward to new theoretical efforts to unify fundamental forces with gravity that take this into account. We also hope that over the next decade Russia, Japan and the US will succeed in extending the largest radio telescope arrays beyond the diameter of the Earth by putting large radio telescopes in orbit, and that this will confirm and greatly increase the accuracy of our result.

Ed Fomalont is a scientist at the National Radio Astronomy Observatory in Charlottesville, Virginia. Sergei Kopeikin is a professor of theoretical physics at the University of Missouri-Columbia

New theories take flight on speed of gravity, light
Einstein's assumptions may be start of downfall

Monday, January 13, 2003
San Francisco Chronicle
CHRONICLE SECTIONS

Keay Davidson, Chronicle Science Writer

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Ninety-eight years after Albert Einstein began to transform physics, scientists continue to question his ideas.

So far, he's survived every crucial challenge, including the latest: a challenge to his premise that light and gravity travel at the same speed. Last week in Seattle, scientists announced that in fact, gravity and light travel at the same speed, at least within a 20 percent margin of error.

But 20 percent, they admit, is a huge margin of error, the kind of margin one expects in Enron accounting and Hollywood bookkeeping. To put it in perspective: Twenty percent of the speed of light is more than 36,000 miles per second, a distance equal to more than four times the diameter of Earth.

Conceivably, so huge a margin of error might conceal a significant difference in gravity and light speeds. So Einstein's challengers still hope to find flaws in his general theory of relativity.

They draw comfort from the history of science. Even the greatest scientific theories, like great civilizations and artistic epochs, tend to be mortal. They emerge, enthrall the world for a while, then fall, to be succeeded by more comprehensive theories.

HOW EINSTEIN UPSTAGED NEWTON

Physicists are especially haunted by the fate of

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Isaac Newton, Einstein's predecessor as the Grand Poobah of physics. Newton's notions survived repeated challenges for more than two centuries. To many, he was the greatest man who ever lived.

Then came the early 20th century, when Newton was upstaged by Einstein and his fellow relativity and quantum theorists. They showed how Newtonianism -- while dandy for explaining "everyday" phenomena such as falling apples and orbiting satellites -- founders on the scales of the very small (within atoms) and the very big (across galactic space). Einstein became the new Newton, the man of the century, as Time magazine anointed him in 2000.

But now, Einstein himself may be vulnerable. This is because of the recent challenge to one of his many key assumptions -- that light and gravity travel at the same speed, 186,284 miles per second.

According to that assumption, when you look at the moon, which is about 240, 000 miles away, you see it as it appeared slightly more than a second ago. Likewise, at any given moment, the attractive force of lunar gravity takes the same time to pass from the moon to Earth, where it influences oceanic tides.

But be warned: In science, "assumption" is a dangerous word. Einstein didn't formally prove the equality of gravity and light speed. He just took it for granted.

One can't really blame him: He was a busy guy, struggling to revamp physics and cosmology while accepting his Nobel Prize, opposing militarism, dining with Charlie Chaplin, explaining arithmetic to schoolgirls, and escaping the Nazis. He didn't have time to try to double-check every assumption that he plugged into his equations.

CALCULATING SLIGHT DIFFERENCE

Still, that unexamined assumption may be the beginning of his downfall. According to certain novel theories of physics and cosmology, gravity may indeed travel faster than light.

For example, physicists Csaba Csaki of Cornell University, Joshua Erlich of the University of Washington and Christophe Grojean of Saclay,

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France, have proposed what they call their "brane world scenario" of physics. ("Brane" stands for "membrane.")

They suspect the universe contains extra, undetected dimensions besides the three everyday dimensions of height, width and depth, plus the Einsteinian fourth dimension of time. Their calculations imply a slight difference in gravity and light speeds, perhaps just "a tiny fraction of a percent," Csaki told The Chronicle.

Over the centuries, physicists' estimates of the speed of gravity have varied wildly. In Newton's era, many assumed it was instantaneous. In 1825, the French astrophysicist Pierre-Simon Laplace estimated gravity traveled at least 10 million times faster than light. After Einstein's rise to fame, though, most physicists accepted his assumption that light and gravity speeds are equal.

That assumption was experimentally tested in September by radioastronomer Ed Fomalont of the National Radio Astronomy Observatory at Charlottesville, Va. , and Sergei Kopeikin, an associate professor of physics and astronomy at the University of Missouri at Columbia.

For their experiment, they observed how the gravitational pull of the giant planet Jupiter interacted with light from a superbright "quasar" 30 million light-years from Earth.

Since the late 1910s, astronomers have known that a strong gravitational source can bend the path of light. For example, the gravity of the sun will bend light from a star, making the star appear to be in a slightly different position.

A variation on this classic technique allowed Fomalont and Kopeikin to determine the speed of gravity emanated by Jupiter when it and the quasar passed within seven arc minutes of each other on Sept. 8. They observed the Jupiter-quasar encounter with 11 radiotelescopes around the world, up to 6,000 miles apart. Thanks to a technique called radio interferometry, they were able to treat the data from the 11 radiotelescopes as if they were a single giant radiotelescope 6,000 miles wide.

In advance, they calculated that if the speeds of light and gravity are the same, then the gravity of Jupiter should alter the apparent position of the quasar by an extraordinarily slight distance, equal to one-billionth the visual diameter of the

full moon.

"This is the most accurate astronomical measurement ever made, (equivalent to measuring) the width of a human hair 250 miles away," observatory spokesman Chuck Blue said last week.

OVERCOMING BAD WEATHER

In such cutting-edge scientific experiments, things rarely go smoothly. Fomalont and Kopeikin observed for a total of five days at all 11 radiotelescopes, resulting in 55 "radiotelescope days." Of those, eight "days" had observing problems that included bad weather and several short power glitches, Fomalont said.

Weather was the No. 1 headache. Rain, wind and clouds distort the atmosphere, refracting light from the quasar and shifting its apparent position in the sky.

Likewise, water in a glass refracts light from a soda straw, making it appear bent. Similar atmospheric turbulence causes the familiar "twinkling" of stars.

The resulting "radio twinkling" happens "on a slow time scale of minutes and moves the apparent position of the quasar by an amount which is typically 10 times larger than the effect we are trying to measure," Fomalont noted. In the end, such problems forced them to discard about 12 percent of their recorded data.

Still, last week at the American Astronomical Society meeting in Seattle, they were able to announce their conclusion: The speeds of gravity and light are the same, at least within a 20 percent margin of error.

"Had the weather been perfect everywhere -- no clouds, etc. -- I think we could have gotten to a 10 percent" margin of error, Fomalont added. Unfortunately, they won't be able to repeat the experiment for another 10 years: That's how long it'll be before a similar close encounter between Jupiter and a quasar.

The achievement draws praise from Csaki: "I am quite amazed that this really difficult measurement of the speed of gravity was possible at all without the direct observation of gravitational waves. I think this is clearly a very

important step."

Although the Fomalont-Kopeikin experiment didn't detect a difference between gravity and light speeds, as predicted by Csaki and his colleagues' theory, Csaki said "I am not surprised" because of the experiment's large margin of error.

Not everyone in the astrophysical community welcomed the Fomalont-Kopeikin experiment, though. According to Fomalont, "There are people who say there's no way the speed of gravity could be different from the speed of light" -- so why bother looking?

Such talk mystifies Fomalont: "You never know. Don't be a spoilsport!"

E-mail Keay Davidson at kdavidson@sfchronicle.com.

Grote Reber, Who Built First Radio Telescope for Astronomy, Dies at 90

By ANAHAD O'CONNOR

Grote Reber, a pioneering radio astronomer who built the first substantial radio telescope dedicated to astronomy and put it in his backyard in Wheaton, Ill., died on Friday in Tasmania, Australia, his home for some 50 years. He was 90.

Grote Reber

Mr. Reber was an engineering student in 1931 when Karl Jansky of Bell Telephone Laboratories, using a large antenna system, made his famous discovery of cosmic radio waves emanating from beyond the solar system.

Mr. Jansky's results received little attention from other scientists at the time, but Mr. Reber, who was also a ham radio operator, set out to determine whether the waves were coming only from the galaxy or from other celestial objects.

In 1937, using about a half-year's worth of salary he had saved from jobs at various radio manufacturers, Mr. Reber erected his telescope.

But much like Mr. Jansky's accomplishment, Mr. Reber's invention went relatively unnoticed, garnering the attention only of his puzzled neighbors.

"Jansky's discovery that the galaxy was giving off radio waves was considered such a strange finding at the time that no one appreciated it or followed up on it, except for Reber," said Dr. Woodruff Sullivan, an astronomer and a historian of science at the University of Washington.

"The two of them were the pioneers of radio astronomy," Dr. Sullivan said. "Before Reber, there was no radio astronomy — just `astronomy' because people only used optical telescopes."

Mr. Reber based his design for the telescope on a simple optical mirror, but on a much larger scale. A curved, or parabolic, dish was used to focus a wide range of radio frequencies. Made of sheet metal, the dish had a diameter of 31.4 feet and could focus radio waves to a point 20 feet above it.

A radio receiver that could amplify faint cosmic signals by a factor of several million was attached to the telescope, making the waves strong enough to be recorded and charted.

After two years of developing and testing receivers and roaming the sky with his telescope nightly, Mr. Reber published "Cosmic Static," a series of articles in The Astrophysical Journal that many scientists today use to mark the birth of intentional radio astronomy.

In 1944, he created the first contour radio map of the sky, with brighter areas indicating richer radio sources, the brightest being the center of the Milky Way.

Mr. Reber made increasingly detailed measurements and published them over the years in many prestigious journals, like Nature and The Journal of Geophysical Research.

The results of his surveys helped establish radio astronomy as a major field after World War II and his seminal radio telescope paved the way for the landmark discoveries of quasars, pulsars and the remnant glow left over from the Big Bang.

Mr. Reber went on to receive a number of major awards usually reserved for professional astronomers, including the American Astronomical Society's highest honor in 1962 and several lectureships.

Grote Reber was born in Chicago in 1911 and earned his bachelor's degree from the Armour Institute of Technology, now the Illinois Institute of Technology. He worked for the National Bureau of Standards in the late 1940's, before leaving for Hawaii and, ultimately, Tasmania to study the cosmos through holes in the layer of charged particles, or ionosphere, in the earth's atmosphere.

Mr. Reber's original radio telescope is on display at the National Radio Astronomy Observatory's site in Green Bank, W. Va., alongside a full-scale replica of Mr. Jansky's antenna.

NEW MEXICO'S LEADING NEWSPAPER

TUESDAY MORNING, NOVEMBER 20, 2001

Very Large Array Will Get $58 Million Upgrade

BY JOHN FLECK
Journal Staff Writer

The National Science Foundation has approved a proposal to upgrade the Very Large Array, a $58.3 million project to increase the telescope's power tenfold.

"It's real now," said Paul Vanden Bout, director of the National Radio Astronomy Observatory, which runs the VLA. "It's official."

"We're quite delighted," said Rick Perley, the Socorro astronomer who is the lead scientist for the upgrade project.

The project will use the array's existing radio dishes but completely upgrade the 1970s-era electronic systems used to collect and analyze the data.

The systems in use today were state of the art when the array was built in the 1970s, said project leader Peter Napier, but advances in computer and electronic technology mean the new system will be far more capable.

The upgrades will make the telescope 10 times more sensitive, able to do far more sophisticated astronomical observations, Perley said.

Located on the Plains of San Agustin west of Socorro, the array is made up of 27 radio antennas, each 82 feet in diameter.

They work in unison, collecting naturally emitted radio waves from planets, stars and galaxies, providing astronomers with a unique window on the universe.

Astronomers from all over the world use it, some collecting their data via the Internet and others making the pilgrimage to Socorro to work with the famed instrument.

It is the most productive Earth-based telescope, generating some

See **VLA** *on* **PAGE A2**

VLA Will Get $58 Million Upgrade

from **PAGE A1**

200 scientific papers a year, rivaled in scientific productivity only by the Hubble Space Telescope.

But its scientific capability is "severely limited" by the 20-year-old technology on which it is based, Perley said.

Project scientists have been working on a plan to upgrade the telescope for more than five years and, last month, submitted a formal proposal to the National Science Foundation, the federal agency that funds the telescope.

Last week, the foundation's governing board voted to approve the expansion project, which means that it will be included in the agency's annual budget.

The project will add fiber-optic data lines between the array's antennas and the central building where data is collected. It will also add a new computer to collect and analyze the data once it comes in, Napier explained.

The governments of Canada and Mexico have joined the project, contributing money and technology to the effort.

"The expansion of the VLA is very good news for New Mexico and its status, both nationally and internationally, as a scientific hub for astronomical research," said Sen. Pete Domenici, R-N.M., in a statement issued Monday.

Before the project's formal approval by the National Science Foundation, Domenici had helped arrange $10 million in initial funding to get the project under way.

New electronic instrumentation and a new data line will be added to one of the array's antennas in 2003 for testing, Napier said. Once the testing is completed, seven antennas per year will be converted, with the work to be done by 2008.

Beyond that, VLA scientists are also looking at the possibility of expanding the array's reach by adding more antennas elsewhere in New Mexico, which would sharpen the telescope's view.

New York firehouse that lost 12 of the 13 men it sent to the World Trade Center. Halberstam had not written about Richard Rocco, but in an important sense he had written about people like him.

"Going back to my days as a young reporter covering first the Civil Rights movement and

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U.S. builds database of terror suspects' fingerprints
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VLA Star Shines

Career of former Socorro graduate student takes off and brings astronomer back to his roots

Story by JOHN FLECK
Of the Journal

SOCORRO — Staff at the Very Large Array think of Shri Kulkarni as the kid who made good.

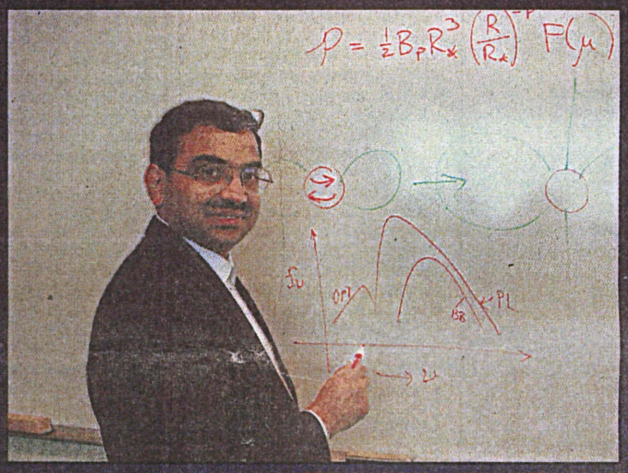
Two decades ago, Kulkarni was a young graduate student, living in a trailer on the Plains of San Agustin as one of the first astronomers to use the newly built VLA, a radio telescope spread across the plains.

Kulkarni still laughs about being a young man from India who didn't eat meat, trying to find something to eat at the one restaurant in the nearby town of Datil.

"There's one day a week, I think, they served vegetarian food," he recalled.

Last week, Kulkarni returned to Socorro as one of astronomy's international superstars.

His visit, which included a scientific talk to his colleagues and a public lecture, highlighted the remarkable diversity of his scientific career.



COURTESY CALIFORNIA INSTITUTE OF TECHNOLOGY

BACK WHERE HE BEGAN: Internationally known astronomer Shri Kulkarni, who began his career two decades ago at the Very Large Array, returned to Socorro on Friday for a pair of lectures about his work.

Unique range of work

Repeatedly at the forefront of new and different fields of astronomy, Kulkarni describes himself with a self-deprecating smile as having an attention deficit problem, unable to focus for too long on any one topic.

From a NASA effort to discover nearby planets to a breakneck race to study some of the most distant objects known in the universe, the 46-year-old Kulkarni's work spans an unusual breadth

See **ASTRONOMER** *on* **PAGE B5**

JOURNAL FILE

LISTENING CLOSELY: The Very Large Array of telescopes is made of 27 radio dish antennas about 50 miles west of Socorro.

Won't Dismiss DWI

Woman Claim Roadblock Un

BY SCOTT SANDLIN
Journal Staff Writer

The Court of Appea refused to dismiss th conviction of an Albuq woman who claimed th block at which she was s was unconstitutional.

John Higgins, attorn Esther Villas, argued t Albuquerque Police I ment officer's favorit operating the roadbloc dered his client's DWI a August 2000 an abuse of tion and therefore unc tional.

At issue was the roadb Coors and Paseo del N Aug. 5, 2000, supervised Murray Conrad. Conrad ed an officer in his co not to book a fellow o brother who also fa breath alcohol test th night at the same check

Conrad, who has sinc promoted to lieutenan disciplined after the ir APD investigated tha three other similar in while Conrad was head DWI Unit, according to reports.

Unlike Higgins' clie officer's brother was no to jail, nor was his entered into a log of indi tested.

In depositions taken Villas case, Conrad ac edged that that was a v of the department's st operating procedures.

The New Mexico Su Court this week turned request to review the court decision.

Appeals Court Judge Pickard, in a decision sig Judges James Wechsl Celia Foy Castillo, note ety checkpoints are pe as long as they compl guidelines establishe ensure that they're rea and as long as they prev arbitrary treatment motorists.

Courts in a series of de have required police to ment uniform procedur means of restricting the tion of field officers, th ion says. If they fail to d roadblock will not pass tutional muster.

But the court rejecte gins' contention that re a buddy's brother wa and parcel of the office cretion."

"Defendant's argume irregularities in post-st cedures invalidates th block itself is misguide court said.

"Sergeant Conrad ulti testified that he did n official discretion to drunk drivers, and he v ciplined for doing so. Th cannot say that thi involves any unconstit exercise of discretion

See **COURT** *on* **PA**

veterans and people better off today because of you. We will not forget you. Thanks for being there. Thanks for being a friend. You are at peace. God bless you. We love you."

In 1995, I spent two weeks in Vietnam with some of these men. They worked on a project in which American veterans were helping the Vietnamese to recover Vietnam's MIAs.

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Astronomer Comes Back to VLA Roots

from **PAGE B1**

at a time when most astronomers' work is highly specialized.

"He's really quite unique among scientists," said Dale Frail, a Very Large Array astronomer who is a friend and longtime collaborator of Kulkarni's.

Kulkarni's career has taken him from the humble trailer on the Plains of San Agustin to a faculty position at the California Institute of Technology, one of the most prestigious jobs in the business.

He is a regular user of the Hubble Space Telescope and the massive Keck Telescope in Hawaii, two of modern astronomy's most powerful instruments.

His discoveries

Most astronomers could make an entire career out of discovering a new kind of object in space. Kulkarni has discovered two so far, and is in the hunt for more.

In 1982, he was the first astronomer to see a "millisecond pulsar," a rapidly spinning super-dense star.

Thirteen years later, he found the first "brown dwarf," an object midway in size between a giant planet and a small star.

Both discoveries have become the topic of full careers for other scientists, while Kulkarni has cheerfully hopped off to tackle the next big thing.

"I like doing the first wave of stuff," said Kulkarni, who described the thrill of discovery as "a great adrenaline rush."

Work with VLA

Despite his long-ago departure from the Plains of San Agustin for his fast-rising academic career, Kulkarni continues to be one of the VLA's biggest users.

Today, he and Frail lead a team regularly using the telescope to study gamma ray bursts, which scientists hope will shed light on the early universe.

The bursts are caused by the brightest blasts known in the universe, and Kulkarni said they are becoming an invaluable tool for studying the early universe.

But the time he's spent on them, five years so far, is a long time for one topic for the peripatetic astronomer, and he's already eyeing his next big thing.

Another mission

The National Aeronautics and Space Administration calls it the Space Interferometry Mission — SIM — and its slogan is "searching for new worlds."

The massive new space-based telescope is an attempt to observe nearby stars with unprecedented precision in a hunt for new planets.

Kulkarni, who has signed on as one of the telescope's lead scientists, calls it "a big discovery machine".

Despite millennia of scanning the skies, there is still a lot for astronomers to discover, said Kulkarni, who believes he is around at a fortune time.

"Astronomy still has the freshness of undiscovered worlds and new phenomena," he said.

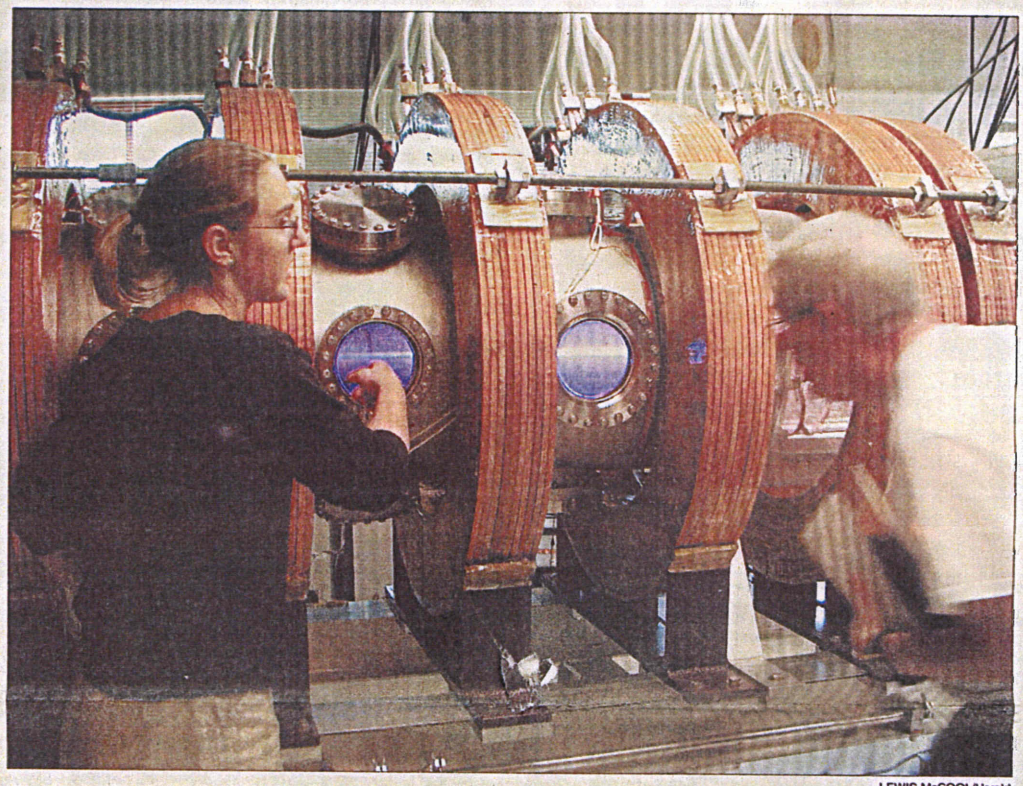
Star Party

LEWIS McCOOL/Herald

John Laning, of Tijeras, N.M., assembles his 17.5-inch Dobsonian telescope in preparation for observing during the ninth annual Enchanted Skies Star Party near Socorro, N.M., on Oct. 5.

Star gazers congregate under N.M. dark skies

By Lewis McCool
Herald Technology Editor



LEWIS McCOOL/Herald

New Mexico Tech student Sara Hawkes, of San Francisco, a third-year physics major, left, describes the college's $400,000 plasma generator to James Gilbert, of Mesa, Ariz., during the ninth annual Enchanted Skies Star Party near Socorro, N.M. The device is being used in a study at the college of the aurora borealis, or northern lights.

They came from Los Angeles, Chicago, Detroit, Tampa and points in between to take advantage of New Mexico's dark skies.

For the most part, they drove, their cars, trucks or vans packed with gear, bound for the research-oriented university New Mexico Tech in Socorro, and the ninth annual Enchanted Skies Star Party on Oct. 3-6.

"Traffic is light, the people are friendly, the sky is dark and this weekend, astronomy is king," said Dave Finley, star party co-founder and public information officer at the National Radio Astronomy Observatory's Array Operations Center on the Tech campus. The center controls the Very Large Array of 27 large radio telescopes at a site 50 miles west of Socorro and the Very Long Baseline Array of 10 similar scopes spread across the country.

Star party participants stayed up late to peer through a couple dozen telescopes of various sizes and designs. As promised, the skies were clear and dark, the nights comfortably cool. Most got the views they were hoping for: planets, brilliant star clusters, nebulas and distant galaxies.

Telescope aficionados had plenty of instruments to examine and compare, from a 70-millimeter (2¾-inch) refractor to a 22-inch Dobsonian reflector. The Etscorn Observatory on the Tech campus sports a 20-inch Dobsonian, 14-inch Schmidt-Cassegrain reflector and a 6-inch Shiefspiegler, an unusual unobstructed reflector in a rectangular housing.

Finley and Jon Spargo, NRAO's safety officer, organized the first Enchanted Skies gathering in 1994. It usually attracts 100 or more amateur astronomers of all skill levels. This year 105 people signed up, including five Durangoans.

"It's grown in many ways but not that it's too much for us to run or to overwhelm the attendees. It's warm and friendly. ... You meet a lot of people from all over. Their backgrounds are completely different," Finley said in an interview during the event.

The former journalist who spent 10 years reporting for the *Miami Herald* has found his niche.

"I go back a long way in astronomy," he said, "but it took awhile to really get into it."

Finley joined the staff at NRAO in 1992.

Spargo, an engineer, has worked at NRAO for 35 years. "I've worn more hats than I can recall," he said.

Spargo helped build the first two dish antennas at the Very Large Array and designed many of the array's computer systems and user interfaces.

Finley and Spargo realized that the Socorro area would be a great place for a large star party. In addition to its dark skies and the campus observatory, it has dozens of professionals working in astronomy and related fields who could serve as educational speakers.

"One of the joys of astronomy, whether it's amateur or professional, is sharing with the public," Finley said.

At night, star party participants took turns looking through the scopes. Dedicated participants kept at it until dawn, turning in after sunup. The professionals took to the stage in the afternoons.

Lisa Foley, a data analyst at NRAO, discussed "the cosmic zoo," with eagles, owls and crabs represented among the Milky Way's nebulas.

For newcomers to the hobby of astronomy, data analyst Jason

■ See STAR, Page 2D

LEWIS McCOOL/Herald

In his keynote address at the ninth annual Enchanted Skies Star Party in Socorro, N.M., on Oct. 4, astronomer and author Stephen Maran discusses black holes that many scientists believe exist at the center of galaxies.

Star: Astronomers gather in Socorro, N.M.

Continued from Page 1D

Wurnig suggested purchases to fit any budget. The range went from warm clothes and blankets to scopes the size most just dream of.

One evening shortly after dark, beginners were given a road map to the sky as Tech astronomy professor Dan Klinglesmith pointed out prominent constellations and suggested ways to find and remember them.

The aurora borealis, the northern lights or "fire in the sky" as they were called by Tech physics professor Chris Watts, were on display in photographs and simulation in the school's $400,000 plasma generator.

NRAO astronomer Debra Shepherd once trained space shuttle astronauts. Now she's researching star formation and described her studies of related celestial events and the search for planets beyond our solar system. Tools to directly spot such objects are probably 20 years away, she said.

Stephen Maran, the author of numerous books including *Astronomy for Dummies* and the party's keynote speaker, told of recent discoveries in space science, particularly the mounting evidence of large amounts of water just below the surface of Mars.

University of New Mexico professor Jack Brandt lectured on the importance of comets in his studies of the solar wind. He's working with NASA's Jet Propulsion Laboratory in an ongoing project and invited amateurs to participate.

In her talk, "Things That Go Bang in the Night," NRAO astronomer Michael Rupen described her studies of star deaths and the sudden, often spectacular events that accompany them. For her, part of the excitement is that the events occur over a relatively short time period, sometimes just hours instead of millions or billions of years typical of astronomical events.

But it wasn't all serious business and stargazing. Cowboy singer Doug Figgs entertained the crowd during a chuck-wagon dinner at a remote location about 15 miles southwest of Socorro, site of Saturday night's observations. Storyteller Lisa Wood, of the Albuquerque Astronomical Society, followed with myths, legends and ancient sky tales as her audience sat on straw bales around a campfire.

LEWIS McCOOL/Herald

Martin Ratcliffe, director of the planetarium at the Exploration Place in Wichita, Kan., left, and Dave Finley, public information officer for the National Radio Astronomy Observatory in Socorro, N.M., examine Ratcliffe's Schmidt camera during the ninth annual Enchanted Skies Star Party near Socorro on Oct. 5. Finley is co-founder of the star party.

Drawings for prizes were held nightly, with the grand prize a night's use of a telescope at Kitt Peak Observatory in southern Arizona.

There was an unexpected treat Friday night when Klinglesmith captured a rare digital image of an optical component of a distant gamma-ray burst using the college's 14-inch scope. The burst was only 15 hours old, and Klinglesmith was thrilled.

"I'm brand new to gamma-ray stuff," he said. Photographing the faint (19.6 magnitude) image was a first for the college.

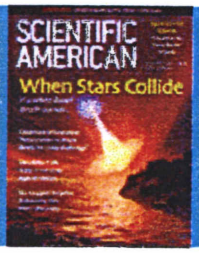
"Astronomy is an exciting adventure of discovery which all people may share," Finley said.

Planning for next year's event, Sept. 25-28, is under way. For details, visit the party's Web site at www.socorro-nm.com/starparty.

Reach Technology Editor Lewis McCool at lewis@durangoherald.com.

Caves: Tiny bats nest in Kartchner Caverns

Continued from Page 1D



NEWS

October 22, 2002

Hydrogen Clouds Spotted High above the Milky Way

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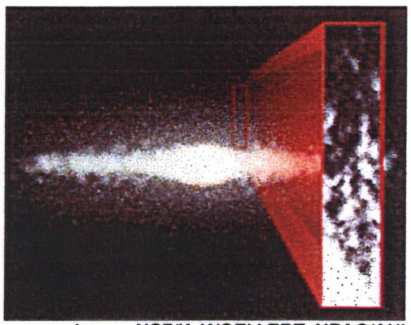
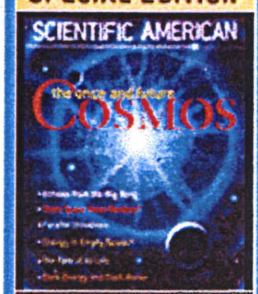


Image: NSF/K. WOELLERT; NRAO/AUI

Huge hydrogen clouds that measure 100-light-years across hover in the void between the Milky Way galaxy and intergalactic space, according to a new report. Previous research had revealed the presence of hydrogen gas floating above the plane of our galaxy. But where it came from or how it was distributed remained unclear due to instrument limitations. Now observations using the Robert C. Byrd Green Bank Telescope (GBT) have exposed the shape of the neutral hydrogen masses. "These objects were just below the ability of the older telescopes to detect," says F. Jay Lockman of the National Radio Astronomy Observatory, "but I looked with the GBT, and they popped right out."

In a paper accepted for publication in *Astrophysical Journal Letters,* Lockman reports that the group of clouds is located toward the center of the Milky Way, 15,000 light-years from the earth, and that each cloud contains between 50 and 100 solar masses of hydrogen. (The image shows an artist's conception of the Milky Way with an insert of GBT data.) He further notes that the clouds, which float about 5,000 light-years above the plane of our galaxy, are coupled to the Milky Way's movements. That is, as the galaxy spins, so do the clouds--an indication, Lockman says, that "these are home grown objects, and not interlopers from outside our own galaxy." One potential source is supernova explosions that continuously feed superheated hydrogen gas into the Milky Way's halo, which subsequently cools to form the clouds. Further radio telescope observations are underway to gather more information about the intricacies of the hydrogen clouds, including their inner structure. --*Sarah Graham*



Source: ***National Radio Astronomy Observatory (http://www.nrao.edu)***

Date: Posted 10/21/2002

Newly Discovered Clouds Found Floating High Above Milky Way

Green Bank, WV - New studies with the National Science Foundation's Robert C. Byrd Green Bank Telescope (GBT) have revealed a previously unknown population of discrete hydrogen clouds in the gaseous halo that surrounds the Milky Way Galaxy. These clouds were discovered in the transition zone between the Milky Way and intergalactic space, and provide tantalizing evidence that supernova-powered "galactic fountains" continually blast superheated hydrogen gas into our galactic suburbs.

Extending far above the star-filled disk of the Milky Way is an atmosphere, or halo, of hydrogen gas. "By studying this halo, we can learn a great deal about the processes that are going on inside our Galaxy as well as beyond its borders," said Jay Lockman, an astronomer with the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. "It has remained a mystery, however, how this halo formed and what has prevented gravitational forces from collapsing the gas into a thin layer long ago."

Some astronomers have speculated that this gas is distributed as a diffuse mist held up by either magnetic fields or cosmic rays streaming out of the plane of the Milky Way. Others believed that it is made of innumerable long-lived hydrogen clouds bobbing up and down like balls tossed by a juggler.

Early observations with other telescopes discovered that there was some neutral hydrogen gas floating far above the Galaxy's plane, but these instruments were not sensitive enough to reveal any structure or resolve questions about its origin.

Lockman's studies for the first time show a clear picture of the structure of the gas. Rather than a mist, the halo is in fact full of discrete clouds, each containing 50-to-100 solar masses of hydrogen and averaging about 100 light-years in diameter. "These objects were just below the ability of the older telescopes to detect," said Lockman, "but I looked with the GBT, and they popped right out." Lockman's results will be published in the Astrophysical Journal Letters.

The clouds were discovered about 15,000 light-years from Earth toward the center of our Galaxy, and about 5,000 light-years above the Galaxy's plane.

One of the most compelling facts revealed by the GBT is that the clouds are coupled dynamically to the disk of the Galaxy; that is, they follow along with the rotation of the rest of the Milky Way. Material from other sources crashing into the Milky Way would have different velocities and also appear quite different. "These are home grown objects, and not interlopers from outside our own Galaxy," said Lockman.

Although the origin of these newly discovered clouds is not yet known, one mechanism to explain how this gas could be lifted into the halo is through supernova explosions. When a massive star reaches the end of its life it erupts in a cataclysm that produces a burst of cosmic rays and an enormous expanding bubble of gas at a temperature of several million degrees Celsius. Over time, this hot gas can flow outward into the Milky Way's halo.

The question remains, however, what happens to this gas once it's ejected into the halo. One possibility is that it leaves the Galaxy as a wind, never to return. Some astronomers predict, however, that as the gas slowly cools it would condense into hydrogen clouds, eventually falling like raindrops back into the Milky Way, and forming what is referred to as a galactic fountain.

"If the clouds were formed by material ejected from the Galactic plane into the halo," Lockman said, "then it's possible that they are now falling back onto the Galaxy. This would then require a continuing flow of new material from supernova explosions into the halo to replenish the hydrogen gas that has rained back into the disk."

The researcher comments that further observations, now in progress, should clarify the properties of these halo clouds, determine their distribution throughout the Galaxy, show how they are related to other types of clouds, and reveal their internal structure.

Radio telescopes are able to detect the naturally occurring radio emission from neutral atomic hydrogen. As hydrogen atoms move about in space, they can absorb small amounts of energy, sending the atom's single electron to a higher energy state. When the electron eventually moves back to its lower energy -- or resting state, it gives up a small amount of

electromagnetic radiation at radio frequencies. The individual energy of a single atom is very weak, but the accumulated signal from vast clouds of hydrogen is strong enough to be detected by sensitive radio telescopes on Earth.

The GBT, dedicated in August of 2000, is the world's largest fully steerable radio telescope. Its 100 by 110 meter dish is composed of 2004 individually hinged panels. It also has a unique offset feed arm, which greatly enhances the performance of the telescope, making it ideal for observations of faint astronomical objects. The GBT is completing its commissioning and early science program and will be moving into full time operation.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement with Associated Universities, Inc.

Editor's Note: The original news release can be found at http://www.aoc.nrao.edu/epo/pr/2002/mwclouds/

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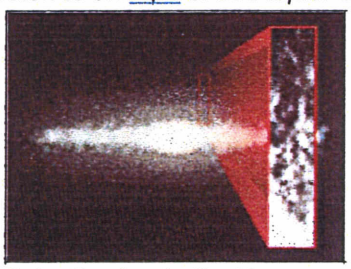


Galactic clouds floating over the Milky Way Galaxy, courtesy NSF/K Woellert; NRAO/AUI

High above us, at the edge of the galaxy, it's raining. But the rain out there is water; it's hydrogen.

Dr. Felix Lockman from the National Radio Astronomy Observatory has discovered clouds of hydrogen above the Milky Way. He thinks these clouds produced by supernovae, and are responsible for seeding our galaxy with dif chemical elements.

Related Links

- The National Radio Astronomy Observatory

Science eavesdrops on universe at N.M. observatory

By Peter Corbett
peter.corbett@arizonarepublic.com

MAGDALENA, N.M. — Black-and-blue storm clouds sizzling with lightning move in over the Plains of San Agustin, west of Magdalena.

The meteorological fury and a curtain of rain enhance the surreal scene across this high desert landscape: 27 230-ton antennas arranged in neat lines to capture radio waves from distant galaxies and star-forming nebulae. This is where the National Radio Astronomy Observatory operates its Very Large Array radio telescopes.

The antennas, which resemble huge TV satellite dishes, were featured in the 1997 movie *Contact*, in which actress Jodie Foster played a radio astronomer.

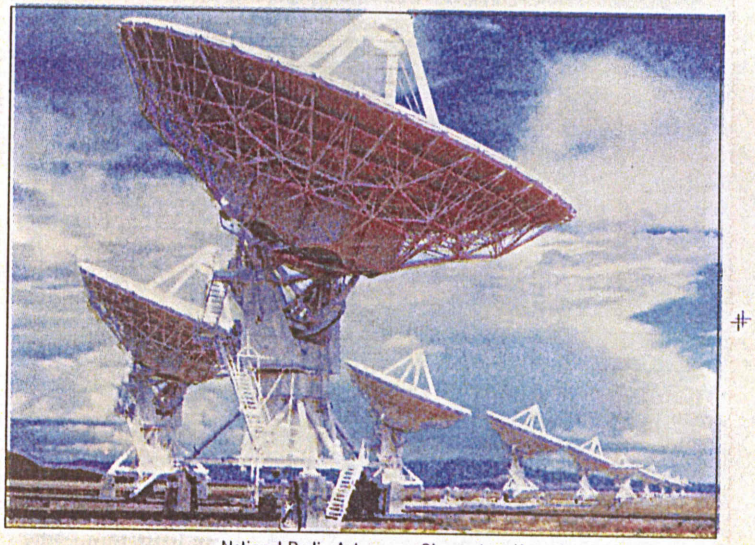
For the scientifically curious, seeing these towering antennas and touring the visitor center is worth the scenic, six-hour drive from Phoenix. But the trip really comes into focus when you add a stop in historic Magdalena, a former mining, cattle and railroad hub 25 miles from the observatory. And don't miss nearby Pie Town, for coffee and — what else? — fresh baked pies.

Lines of Very Large Array radio telescopes, which record radio waves from deep space, dot the Plains of San Agustin, near Magdalena, N.M.

At the observatory, just south of U.S. 60, travelers can see displays in the visitor center and take free, self-guided walking tours.

In connection with the ninth annual Enchanted Skies Star Party, which will be held Thursday through next Sunday in Socorro, an hour to the east, the observatory will offer free guided tours every

See **REGIONAL** Page T3



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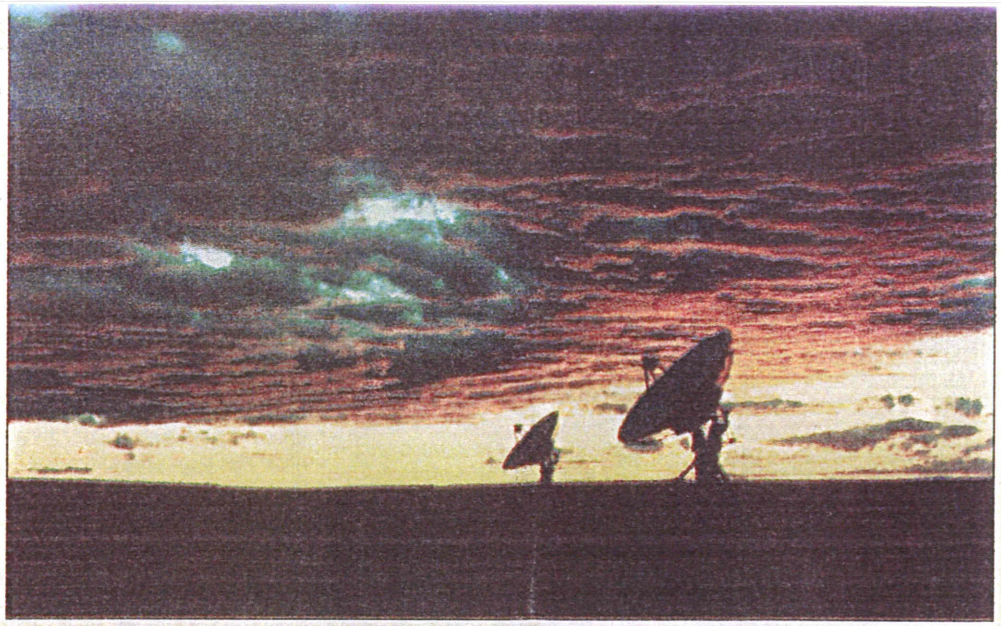


National Radio Astronomy Observatory/Associated Universities Inc.

A New Mexico sunset gathers beyond the Very Large Array telescopes. The 27 230-ton radio telescopes popped into the cultural mainstream in the 1997 film *Contact*, starring Jodie Foster.

Hollywood publicizes New Mexico observatory

REGIONAL from T1

half-hour from 10 a.m. to 2 p.m. next Sunday. More guided tours are planned at the observatory on Feb. 2.

So what is this scientific oddity?

The focus is far different than the Hollywood science that Dr. Ellie Arroway (Foster) obsesses over in *Contact*.

Scientists do not use the radio telescopes to listen to noises from space, said observatory spokesman Dave Finley.

"We're not doing searches for extraterrestrials," he said.

Instead, the instruments record radio emissions from space that astronomers, using computers, can convert into images.

Earlier this year, scientists using the New Mexico observatory and one in West Virginia produced a vastly improved radio image of the Orion Nebula and developed a valuable technique for studying star formation. The Orion Nebula is a giant cloud of gas 1,500 light-years away in which new stars are forming.

Contact's producers took other liberties as well, portraying Arizona's Canyon de Chelly as being in New Mexico. But overall, the movie was well-received at the observatory.

It portrayed astronomers in a favorable light, encouraged women to go into the predominantly male field, and increased tourism at the observatory, Finley said.

About 50,000 visitors a year, including school groups from Springerville and people from as far away as the East Coast, stop at the observatory.

The site was chosen for its remoteness, dry climate and 7,000-foot elevation.

The area includes vast recreation areas within the Cibola National Forest, including the Magdalena Mountains and 10,783-foot South Baldy Peak.

Reach the reporter at (602) 444-6862.

if you go

National Radio Astronomy Observatory

GETTING THERE: Magdalena and Socorro, N.M., are about 75 miles south of Albuquerque. For a scenic drive from Phoenix, take Arizona 87 north to Payson. Go east on Arizona 260 to Show Low, then east on U.S. 60 to Magdalena and Socorro.

STAR PARTY: The ninth annual Enchanted Skies Star Party, Thursday through next Sunday in Socorro, will feature stargazing, lectures and tours of nearby observatories. The keynote speaker is astronomer Stephen Maran, author of *Astronomy for Dummies*, who brings some comic relief to the serious subject of the cosmos. Cost is $45 for one person or $70 for a family of four.

OBSERVATORY: The National Radio Astronomy Observatory is 50 miles west of Socorro, just south of U.S. 60. It's open from 8:30 a.m. to sunset daily. There is a visitor center with exhibits and free, self-guided walking tours. Details: 1-(505)-835-7243 or www.aoc.nrao.edu/vla/html/vlahome/genpublic.html.

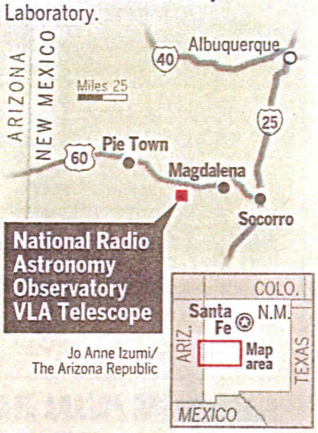
LIKE PIE?: The Daily Pie Cafe in Pie Town, N.M., 56 miles east of the Arizona state line on U.S. 60, is open from 10 a.m. to 8 p.m. Tuesdays through Saturdays and 10 a.m. to 5 p.m. Sundays. Call 1-(505)-772-2700.

DETAILS: For the Star Party, 1-(505)-835-0424 or www.socorro-nm.com/starparty.

■ To find out about motels, campgrounds and bed-and-breakfasts in Socorro and Magdalena, www.chamber@socorro-nm.com or www.magdalena-nm.com.

What's out there?

Find out what information is gathered from the far reaches of space at the National Radio Astronomy Laboratory.



Jo Anne Izumi/ The Arizona Republic

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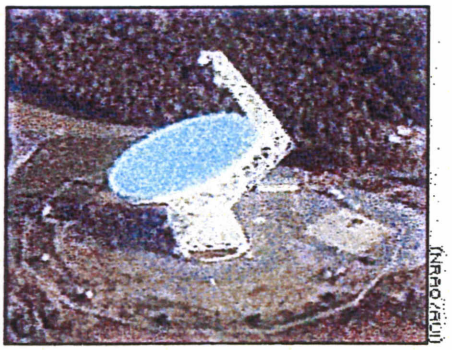

The Green Bank Telescope in West Virginia is the world's biggest moving land structure.

SAVE THIS EMAIL THIS
PRINT THIS MOST POPULAR

GREEN BANK, West Virginia (Reuters) -- Welcome to the National Radio Quiet Zone. Feel free to shout, play the tuba or let out a primal scream. Just don't think about using a microwave oven.

One stray zap from a microwave -- or a car's spark plugs, or even an electric blanket -- in the heart of the 13,000 square mile (33,670 square km) zone could interfere with science at the National Radio Astronomy Observatory at Green Bank, a patch of forested Appalachia just west of the Virginia border.

The quiet that the zone is meant to protect does not refer to sounds humans can hear; instead, it targets "noise" from human-made radio waves that might blot out the faint radio signals from distant stars, galaxies and pulsars.

The newest instrument at Green Bank is the biggest: a radio telescope so massive the Statue of Liberty, including the pedestal, could lie down on its blinding white observing surface with room to spare. Its 43-story height and 16 million lb (7.258 million kg) of tilting, turning mass make it the largest thing on land that moves.

This $79 million telescope is so sensitive, scientists worry that even the computers they use to monitor its workings could give off enough radiation to pollute the data.

Its control room, which has perhaps as many desktop computers as a small-town travel agency, located two miles (3.2 km) from the telescope, has windows

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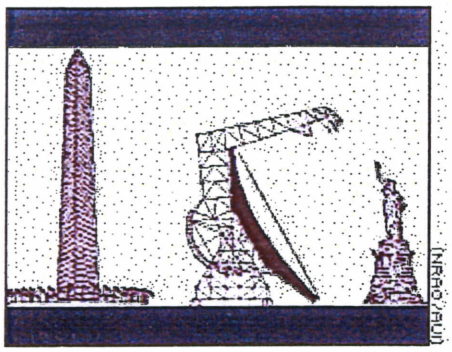
covered with copper mesh shades and doors as heavy as those on bank vaults to shield against radio interference.

Rules of the zone



The Green Bank Telescope sizes up pretty well with some notable national landmarks.

Not many people stay at the zone's center in Pocahontas County, chosen in 1958 because it had the sparsest U.S. population density east of the Mississippi and the surrounding mountains serve as natural radio wave shields.

Those who live here, live by the rules of the zone.

This means, among other things, limited radio reception. Radio stations must turn their transmitters away from the big telescopes at Green Bank so as not to interfere with the instruments of the National Radio Astronomy Observatory.

Cell phone towers are virtually non-existent. Wireless microphones are forbidden. To get to the middle of the installation, ordinary gas-powered vehicles are banned. Observatory staff use a fleet of 1960s-vintage diesel taxis and pick-up trucks, with no spark plugs or modern electronics.

"Interference is interference is interference, it doesn't matter where it comes from," said Wesley Sizemore, whose job it is to cut interference to a minimum in the Quiet Zone.

FM radio stations and television transmitters are fairly easy, Sizemore said in an interview; as long as they face away from the big telescopes, there is no problem. And satellites overhead are usually transmitting at different frequencies than those the scientists watch.

Garage-door openers and wireless microphones in the area close to the telescopes can be problematic. So can a bad thermostat, normal power lines or a heater's switch, Sizemore said. The most famous of the so-called unintentional radiators was an old dog's heating pad.

Nasty dog's heating pad

Sizemore generally gets a laugh from the tale of how he tracked broadband interference to an elderly couple's home in the town of Green Bank, down the road from the observatory.

"They had a little dog outside in the dog house and the dog was rather old,"

Sizemore said, chuckling at the memory. "I like most dogs, but this was an exceptionally nasty little dog, so they had to kind of corral him while I chased the interference. But I tracked it down to their dog house."

The couple had given the dog an electric heating pad to lie on, but because the pad was not meant to be used this way, it became defective and gave off bursts of radio interference every few minutes, Sizemore said.

The solution was simple: the observatory got the dog a heating pad that was made to be used outdoors.

"It cost us maybe $50...We're sitting here operating a radio telescope that costs many hundreds or thousands of dollars an hour to operate and it was basically receiving garbage," Sizemore said. "So it's to our benefit and it's good for public relations. Fifty dollars well spent."

Some fixes are less basic. The nearby Snowshoe ski resort wanted to put in a wireless local area network for their computers, but decided to hard-wire the network instead to avoid interference.

Seeing through cosmic dust

There are other radio telescopes around the world -- one huge installation is the Very Large Array in New Mexico, another is Arecibo in Puerto Rico -- but scientists believe Green Bank's big new telescope will be especially sensitive to incoming cosmic signals.

Officially named for Robert C. Byrd, the veteran senator famed for bringing federal dollars to West Virginia, the new instrument is called simply GBT by astronomers, short for Green Bank Telescope.

"The GBT will be such an enormous leap in sensitivity...a leap by factors of 10, which means a factor of 100 in observing time," telescope scientist Jay Lockman said in an interview. "So things which took many hours to detect could be detected in seconds."

When most people think of telescopes, they think of instruments that look at the universe in waves of light. While these can produce startling and beautiful images, they cannot see through the dust and gas of the cosmos, as radio telescopes can.

One famous image made by the orbiting Hubble Space Telescope shows a star-birth chamber known as the Pillars of Creation. Optical telescopes can only see the chamber; radio telescopes can see inside it, Lockman said.

"The action is all inside," Lockman said. "We can see that there are new stars being born in there, but Hubble will never see it in a million years." He paused. "Well, maybe in a million years, but only because the stars will have blown away the dust."

Loudest place in Quiet Zone

Ironically, one of the loudest places in the Quiet Zone is in the receiver room at the top of the GBT. This is where incoming radio waves that have been sensed by the big telescope's observing surface are channeled into computers to be

processed.

Ascent to the telescope's surface, which catches the incoming cosmic radio waves, is done via a short flight of steps, an elevator and a long catwalk. From there, another elevator goes up along a slanted track to the instrument's towering sub-reflector, which bounces the radio waves down into the reflector room.

A gentle chirping can be heard just outside the receiver room, but step inside and the chirp escalates to a rhythmic mechanical shriek. This is the sound of machines that remove as much of the atmosphere as possible from the pipeline that carries incoming radio waves to computers to be analyzed.

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July 14, 2002
Sunday Gazette-Mail
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Valley & State

Amateurs hear Green Bank's call

Radio astronomy group meets in state, donates telescope

By Rick Steelhammer
rsteelhammer@wvgazette.com

GREEN BANK — For one group of amateur astronomers, celestial observations take the form of strip charts, recorded bursts of radio noise and graphic displays on home computer monitors instead of visual images of heavenly bodies.

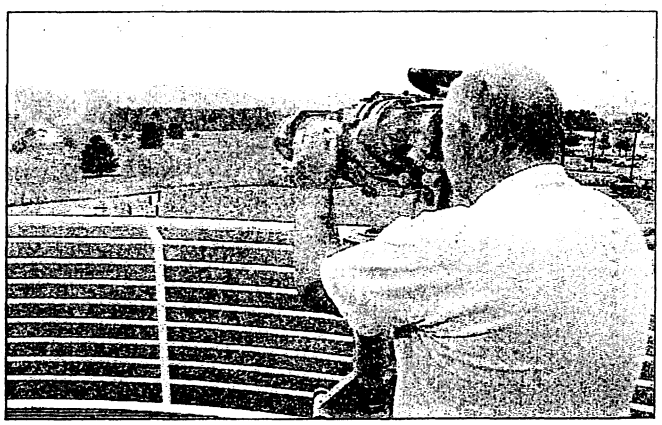
While many members of the Society of Amateur Radio Astronomers also enjoy stargazing with more familiar optical telescopes, they believe their best prospects for discovery will take place while operating their mostly self-assembled arrays of radio astronomy gear.

About 40 SARA members from across the nation gathered at the National Radio Astronomy Observatory in Green Bank last week, where they swapped information, presented research papers and made observations with the observatory's 40-foot radio telescope.

> *"The first few times my neighbor used his car polisher, I thought I was seeing an incredible solar storm."*
>
> James Van Prooyen, amateur radio astronomer

"Radio astronomy gives you the best opportunity to discov-

Please See **AMATEURS**, *Page* **7B**



KENNY KEMP/Sunday Gazette-Mail

Using high-powered binoculars, outgoing Society of Amateur Radio Astronomers President Tom Crowley scopes out the new Green Bank Telescope from the balcony outside the observatory's control room.

KENNY KEMP photos/Sunday Gazette-Mail

Members of the Society of Amateur Radio Astronomers put a backyard-sized radio telescope through its paces before donating it to the National Radio Astronomy Observatory in Green Bank.

AMATEURS

Continued From Page 1B

er as an amateur," said SARA member James Van Prooyen of Grand Rapids, Mich., an aerospace software engineer, who, in his spare time, is developing pulsar-detecting software for amateur radio astronomers.

Pulsars, black holes and quasars were all discovered through radio astronomy. In fact, radio astronomy has produced nearly 65 percent of what is known about the universe and its creation.

Large professional radio observatories like the Green Bank NRAO focus on deep sky objects for relatively brief periods of time with narrow beam widths. Amateur radio astronomers use broader beam widths over longer periods of time.

"Because we can see more of the sky at a time, there are areas where we can complement the professionals," said Van Prooyen. "For instance, they could give us an area to watch, and we could set up amateur pulsar patrols."

Amateur radio astronomers are involved in such projects as solar flare monitoring, meteor in-fall counts, and a project using software from NASA to monitor sporadic noise from Jupiter.

Some SARA members are also involved in a coordinated search for evidence of intelligent life elsewhere in the universe. That effort is being coordinated by the SETI (Search for Extraterrestrial Intelligence) Institute, an offshoot of a canceled NASA program that began at Green Bank — site of the world's first radio astronomy SETI search.

In 1994, when fragments of a comet struck Jupiter, SARA put together a group of 30 observers to monitor the impact.

Sue Ann Heatherly (left), director of the education program at the Green Bank National Radio Astronomy Observatory, explains the workings of the observatory's control room to a group of amateur radio astronomers.

"We had good data on the impact bursts, which was accepted by the NRAO," said SARA President Tom Crowley of Atlanta. "We were basically the only ones to see it."

With a modest investment in equipment, "amateur radio astronomers can observe 10 or 12 of the brightest objects in the sky, study the sun and observe solar flares and count incoming meteors," Crowley said. "We can look for new radio sources and detect changes in sources that are known, and help map the universe."

"You can get into radio astronomy with a short-wave radio and a dipole antenna," said Jeffrey Lichtman of Sunrise, Fla., who founded SARA 21 years ago. "All it takes to begin is $125 or so."

Most amateur observers make use of 10- to 16-foot antennas connected to radio receivers and home computers.

"I just got some 24-foot dishes from a satellite TV company," Van Prooyen said. "When I come here next year, I may submit a paper on what happens when I put them to use. I'll either call it 'Big Gain' or 'Big Pain.'"

Performing radio astronomy outside the federally mandated Radio Quiet Zone that restricts interference in the vicinity of the Green Bank NRAO can produce challenges to amateurs, Van Prooyen said.

"The first few times my neighbor used his car polisher, I thought I was seeing an incredible solar storm," he said.

While millions of amateur astronomers gaze the night skies with optical telescopes, there are fewer than 500 SARA members worldwide.

'A better opportunity to learn and discover'

"I think interest in radio astronomy is growing slowly," said Crowley, a retired AT&T executive, who owns an 18-inch optical telescope in addition to his radio telescope setup. "I think radio astronomy gives you a better opportunity to learn and discover, but the complexity is a little more intense."

To pursue a hobby in the more traditional form of astronomy, "you can just go to Kmart, buy a telescope and start looking," Crowley said. "Our club members like to play with technological toys. Many of us are amateur radio operators, too."

An interest in radios is the main attraction that led Sam Hevener of Richfield, Ohio, to take an interest in amateur radio astronomy. But there was another reason as well.

"I lived here from 1947 to 1950," he said, pointing toward the western end of the observatory's property. "I remember a big, wide-mouth hand pump, because there was no running water. The government bought my grandma's farm in about 1956."

Hevener said holding the SARA convention in Green Bank gave him an excuse to visit relatives, as well as the chance to learn more about radio astronomy.

SARA has held its annual meeting at the Green Bank NRAO every year since 1984.

"They take good care of us here," Lichtman said.

SARA members presented Green Bank officials with a small, amateur-scale radio telescope for use in the observatory's new visitor center, scheduled to open this fall on a knoll overlooking the world's largest fully steerable radio telescope — the 100-meter Green Bank Telescope, or GBT.

"It operates on the same concept as the big one, but just on one frequency," Lichtman said. "We call this the IBT, for Itty Bitty Telescope."

To contact staff writer Rick Steelhammer use e-mail or call 348-5169.

Scientists Probe Universe From Jackrabbit Country

Last Updated: June 24, 2002 03:39 PM ET

By Deborah Zabarenko

PLAINS OF SAN AGUSTIN, New Mexico (Reuters) - On this sun-blasted plateau, out among the jackrabbits and antelope, roadrunners and rattlesnakes, you had better turn off your cell phone.

The critters won't mind if the phone rings, but the astronomers might: this is where the most scientifically productive telescope on Earth observes the universe, and astronomers don't want human calls to jam the signal.

The telescope, known as the Very Large Array, or VLA, uses radio waves instead of light to monitor celestial bodies, catching these in 27 huge dishes that move along a Y-shaped railroad track stretching across 22 miles.

Each nine-story-high, 230-ton dish, or antenna, needs to move in concert with all the others, packing in close or spreading out along the rail lines to create a single lens on the cosmos, VLA director Jim Ulvestad said.

"This operates like a zoom lens, in a sense," Ulvestad said. "When the antennas are a long way apart, you get much higher resolution, you can see much finer detail. Whereas when they're in close ... they're more effectively a wide-angle lens, imaging big fields of view but not with very high resolution."

The images this monster lens captures can be surprising. Don't expect to see a big sphere with reddish-brown swirls when looking at the VLA's radio-wave picture of the planet Jupiter.

RED DOTS ON JUPITER?

Instead, it looks a bit like a child's painting of a crocodile, with red spots on the head and tail. The red dots are regions high above Jupiter's surface where electrons interacting with the planet's intense magnetic fields produce strong radio emission.

But why put this giant scientific instrument on a desolate dry lake bed, 7,000 feet above sea level and a two hours' drive from Albuquerque?

"The basic reason for the site is, you need someplace in the southern U.S. so you can see most of the sky, you need someplace high and dry, you need someplace away from radio-frequency interference," Ulvestad said during a recent tour of the VLA.

Cosmic radio sources are millions or even billions of times weaker than a cell phone transmission. Besides cell phones, radio telescopes can get interference from wireless computer networks, garage door openers and other systems incorporating microprocessors.

Another enemy of these big dishes is wind, which can sweep across these plains with the force to turn telescopes into massive sails; when this happens, technicians stow the antennas, facing them straight up.

Climbing up to the surface of a VLA dish is akin to climbing the mast of an ocean-going sailing ship, even when the antenna is in a walled garage undergoing maintenance. The dish -- a spare not currently in use -- trembles a bit with every step and only 10 people are permitted to ascend at one time.

If the VLA's terrain looks familiar, that may be because it served as a backdrop for the 1997 movie "Contact," in which Jodie Foster played an astronomer who detected the sounds of extraterrestrial life on the big telescope.

THEY LOOK LIKE EARS, BUT THEY'RE NOT LISTENING

This was largely artistic license, according to VLA officials: radio waves are not sound waves, and the VLA is not really listening to anything. Sound waves cannot travel through the vacuum of space, as radio waves can.

Radio waves can be made to carry information about sound, which radio broadcasters decode and transmit to listeners, but radio waves themselves have no sound at all.

What astronomers get from the VLA is numbers, which can be processed by computers to create pictures. Most astronomers observing with the VLA never come to the Plains of San Agustin, but get their results via computer.

The movieland notion that the VLA was working on the search for extraterrestrial intelligence was incorrect, even though some radio telescopes have helped in this research.

The VLA has been observing since 1980, with technology developed in the 1970s, and scientists have been hankering for an upgrade. In fact, work has already begun on the Expanded Very Large Array, a two-phase project that VLA scientist Rick Perley said would bring a tenfold improvement in function.

The first phase aims to replace the 1970s vintage data-processing technology at VLA; the second would construct eight more antenna stations around New Mexico that would be linked to the VLA.

Phase one is budgeted at $75 million, most of it to be paid for by the National Science Foundation with contributions from Canada and Mexico. Phase two would cost another $75 million.

Scientists discover water spewing from ancient star

By NINA LANZA
Scripps Howard News Service
June 21, 2002

- Radio astronomers have discovered rotating jets of water spewing from an ancient, dying star 8,500 light-years from Earth.

The corkscrew jets offer some clues, researchers say, about the evolutionary process of stars, and what the ultimate fate of our own star, the sun, may be. It also raises new questions about where the water fueling the jets came from and how it is produced by the dying star.

Researchers' findings are being reported in this week's issue of the British science journal Nature.

The research team was led by Hiroshi Imai of Japan's National Astronomical Observatory. Using New Mexico's Very Large Array (VLA) and much larger Very Long Baseline Array (VLBA) radio telescopes, the researchers detected radio signals coming from the distant star, known as W43A.

The astronomers say W43A is about to become a planetary nebula, a name that is given to dying stars when they collapse, leaving a glowing shell of gas and dust around themselves.

Planetary nebulae, despite their name, have nothing to do with planets. Astronomers observing them in the 18th century called them that because of their rounded shapes.

For years, astronomers have wondered why planetary nebulae are shaped as they are.

"A prime mystery about planetary nebulae is that many are not spherical even though the star from which they are ejected is a sphere," said Philip Diamond, one of the team's researchers, director of the MERLIN radio observatory in Jodrell Bank,

England.

"The spinning jets of water molecules we found coming from this star," Diamond explained, "may be one mechanism for producing the structures seen in many planetary nebulae."

Because the jets are spinning in a spiral away from the star, they cause distortions in its gas shell, the scientists report, and since the jets are only in certain areas, the shell becomes lopsided, making the nebula non-spherical.

They conclude that the jets are actually areas around the star that are filled with water molecules that are vibrating in such a way that they amplify the radio signals coming from the star itself. The radio signals cause the jets to emit light waves of a specific frequency, which allowed astronomers to detect and observe them.

This effect is known as a maser, which is a radio laser. Lasers work with visible light, while masers work with lower-energy radio waves. While masers can be made in a laboratory, they are a naturally existing phenomenon that are found throughout the universe.

What makes these masers special, the team says, is that they are appearing in a planetary nebula. Astronomers have theorized in the past that the odd shapes of planetary nebulae could be a result of such jets, but no jets have ever been observed until now.

Nature this week also features a separate commentary on the discovery by VLA radio astronomer Mark Clausen of Socorro, N.M., who said analysis suggests the water jets are only 30 years old.

"This strongly suggests that the star has indeed been caught in the act of transition to a planetary nebula," he reports.

Clausen writes that Imai and his team used the New Mexico-based telescopes "to determine the distribution of the water masers in the nebula with a precision 200 times greater than that of optical observations by (NASA's orbiting) Hubble Space Telescope."

Researchers still don't know what is producing the water jets.

(Contact Nina Lanza of The Tribune in Albuquerque, N.M., at http://www.abqtrib.com.)

New and Improving Retrieval of Signals From Distant Space

By JOHN NOBLE WILFORD

PLAINS OF SAN AUGUSTIN, N.M. — "This entire plain is one big telescope," Dr. James Ulvestad, an astronomer, said with proprietary pride.

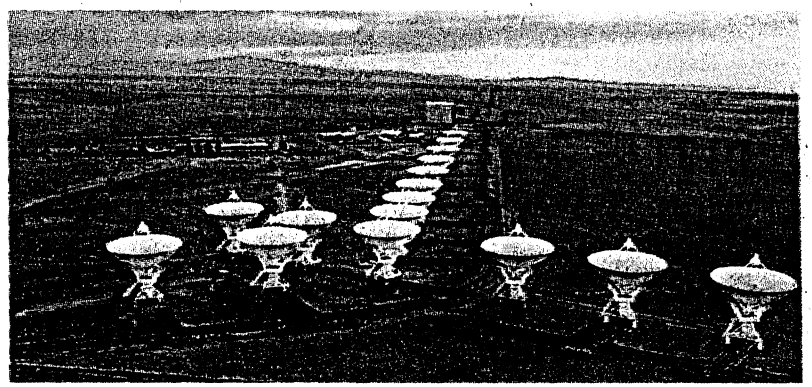
In three directions, reaching miles across an expanse of desert high (elevation 7,000 feet) and broad (almost as big as Connecticut), 27 radio telescopes stand at attention, like giant ears cocked to the heavens. Called the Very Large Array, the configuration of the 82-foot-wide dish antennas forms a huge Y on this ancient lake bed, and all of them work together, merging their observations as a unified telescope of cosmic discovery.

The combined antennas are receiving a blitz of energies in radio wavelengths from the hearts of galaxies, the peripheries of black holes and the scattering debris of exploded stars. They are yielding insights into where and how stars form and the nature of galaxies from the universe's early history.

But the Very Large Array could be better, astronomers say, and a program of technological improvements and eventual expansion has just begun. Dr. Ulvestad, assistant director of the National Radio Astronomy Observatory in nearby Socorro, N.M., noted that the antennas went into full service in 1980, and "we have been running a lot of the V.L.A. on technology of the 1970's."

The first phase of improvements, replacing all the electronics and communications at the array, is not expected to cause any interruption in observations. Antennas are to be taken out of operation one at a time, with a spare antenna available to maintain the full 27-instrument complement. The 230-ton antennas are moved about the desert on 80 miles of railroad track.

Recent visitors saw an example of the maneuverability. One antenna had been moved to the "barn," a semi-enclosed structure, for its regular three-year checkup and repairs, which were being overseen by an owl perched on a high steel girder. Yet radio data gathered by 27 other antennas continued to flow through a control room adorned by an autographed picture of Jodie Foster, who filmed several scenes from the movie "Contact" at the array.



Dave Finley from NARO/AUI

The Very Large Array — 27 antennas in the New Mexico desert — uses 80 miles of track and covers an area almost as big as Connecticut.

The planned renovation is scheduled to be completed in 2011. The National Science Foundation, the observatory's principal supporter, will pay for most of the $75 million project, with smaller amounts coming from Canada and Mexico.

Dr. Rick Perley, chief scientist for the project, said all the electronics modules in the receivers and data processors would be replaced with faster, more sensitive equipment. Old signal transmission circuits linking the antennas to the data-processing center will be replaced with more efficient fiber optics. As a result, the array is expected to observe radio signals with greater sensitivity and at more bandwidths. This should open to study objects that are one-tenth as bright as those detected before and do so in much less time.

The second phase of the project is expected to add eight more telescopes to the array.

Even though there is plenty of room here for more antennas, astronomers want to place the new ones some 60 and 150 miles away in southwestern New Mexico. With the wider dispersion, affording deeper views of the heavens, the Very Large Array will be, in effect, a single telescope the size not of a desert plain, but a quarter of a state.

Cat Food for Aardvarks, and Other Diets at the Zoo

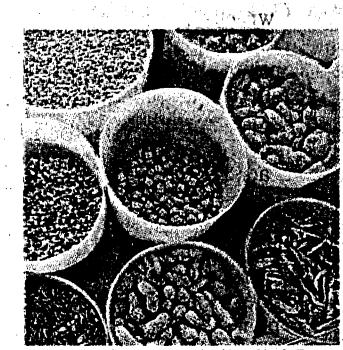
Continued From First Science Page

ground-up cat and primate kibble and are more active, breeding successfully and forming solid feces just as they do in the wild, "an important indication that we're on the right track," Dr. Edwards said.

Across the country, said Dr. Dierenfeld, "more and more zoos are seeing a zoo nutritionist on staff or as a consultant as an essential mis-

animals," she went on, "is to look at the composition of their natural foods and duplicate the nutrients even when you can't duplicate the foods."

This approach is now saving the chicks of carnivorous lesser adjutant storks, which remain in small numbers only in India and Thailand. Hatchlings at the zoo were developing weak leg bones and soft beaks, indicating a calcium deficiency. Yet their parents, who fed them faithful-



Librado Romero/The New York Times

Meal ingredients in the Bronx Zoo's animal kitchen.

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NRAO hosting scientists, media as astronomers gather in New Mexico

The National Radio Astronomy Observatory (NRAO) is hosting scientists and news-media representatives from across the U.S. at its Very Large Array (VLA) radio telescope as the American Astronomical Society (AAS) meets in Albuquerque through Thursday.

About 1,400 astronomers and space scientists will attend the 200th national meeting of the AAS at the Albuquerque Convention Center.

"We're taking advantage of this gathering that's practically in our back yard to show off our facilities to our scientific colleagues," said James Ulvestad, NRAO's director of New Mexico operations.

As the AAS meeting started Sunday, a special tour will bring more than 150 astronomers to the VLA for an in-depth look at the world-famous radio telescope.

On Thursday NRAO will host another special VLA tour, this one for science reporters from across the U.S. and other countries.

"Today's radio telescopes, including the VLA, are vitally important tools for answering some of the key questions of modern astronomy," Ulvestad said.

"In our Wednesday lecture session, we have leading scientists from the U.S., Mexico, and Europe telling how radio telescopes are providing data unavailable from any other source to researchers at the frontiers of astrophysics," he added.

NRAO also is showcasing its facilities and the scientific contributions of radio astronomy to the international contingent of science reporters who regularly attend the AAS meetings.

The AAS meetings routinely draw reporters from the U.S. and Europe, and often from Asia and the Pacific Rim as well, representing newspapers, magazines, cable and broadcast television, and Web news outlets.

In addition to the press tour of the VLA, Associated Universities, Inc., which operates the NRAO, is hosting a reception for the press corps attending the AAS meeting.

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So far this year, there have been 56 alcohol-related fatalities in New Mexico, nine percent more than 2001.

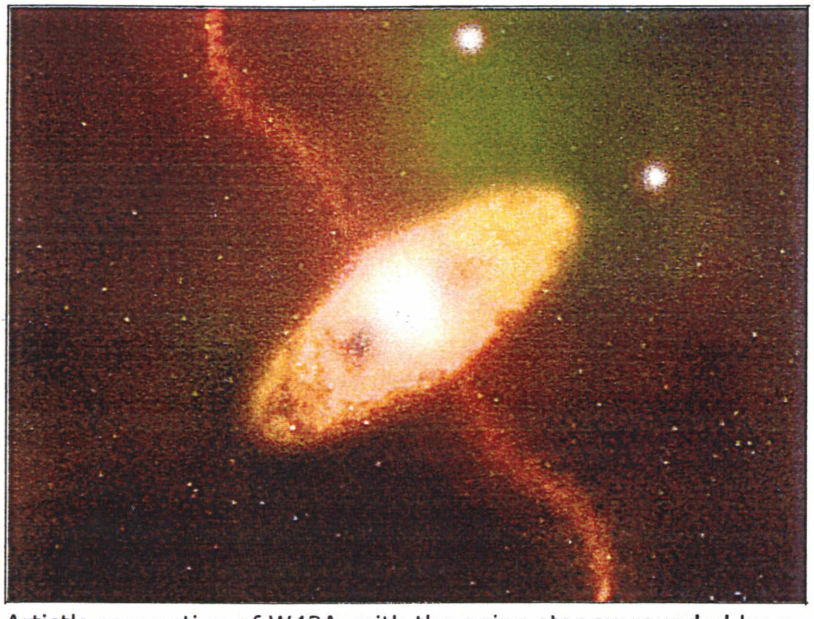
Overall, there have been 153 traffic fatalities in 2002, eight more than in 2001.

The Traffic Safety Bureau is the division of the New Mexico State Highway and Transportation Department that works with local New Mexico law enforcement to enforce the state's driving laws and encourage New Mexicans to drive safely.

Water fountains in the sky

NATIONAL RADIO ASTRONOMY OBSERVATORY NEWS RELEASE
Posted: June 19, 2002

Astronomers using the National Science Foundation's Very Long Baseline Array (VLBA) radio telescope have found that an aging star is spewing narrow, rotating streams of water molecules into space, like a jerking garden hose that has escaped its owner's grasp. The discovery may help resolve a longstanding mystery about how the stunningly beautiful objects called planetary nebulae are formed.



Artist's conception of W43A, with the aging star surrounded by a disk of material and a precessing, twisted jet of molecules streaming away from it in two directions. Credit: Kirk Woellert/National Science Foundation

The astronomers used the VLBA, operated by the National Radio Astronomy Observatory, to study a star called W43A. W43A is about 8,500 light-years from Earth in the direction of the constellation Aquila, the eagle. This star has come to the end of its normal lifetime and, astronomers believe, is about to start forming a planetary nebula, a shell of brightly glowing gas lit by the hot ember into which the star will collapse.

"A prime mystery about planetary nebulae is that many are not spherical even though the star from which they are ejected is a

sphere," said Phillip Diamond, director of the MERLIN radio observatory at Jodrell Bank in England, and one of the researchers using the VLBA. "The spinning jets of water molecules we found coming from this star may be one mechanism for producing the structures seen in many planetary nebulae," he added.

The research team, led by Hiroshi Imai of Japan's National Astronomical Observatory (now at the Joint Institute for VLBI in Europe, based in the Netherlands), also includes Kumiko Obara of the Mizusawa Astrogeodynamics Observatory and Kagoshima University; Toshihiro Omodaka, also of Kagoshima University; and Tetsuo Sasao of the Japanese National Astronomical Observatory. The scientists reported their findings in the June 20 issue of the scientific journal Nature.

As stars similar to our Sun reach the end of their "normal" lives, in which they are powered by nuclear fusion of hydrogen atoms in their cores, they begin to blow off their outer atmospheres, then eventually collapse to a white dwarf, about the size of the Earth. Intense ultraviolet radiation from the white dwarf causes the gas thrown off earlier to glow, producing a planetary nebula.

Planetary nebulae, many visible to amateurs with backyard telescopes, have been studied by astronomers for years. About 1600 planetary nebulae have been found, and astronomers believe many more exist in our Milky Way Galaxy. Some are spherical, but most are not, displaying a variety of often intricate, beautiful shapes. The fact that many of these objects are not spherical was long known, but a series of spectacular images made with the Hubble Space Telescope in 1997 reinforced that fact dramatically.

"The problem for scientists is, how do you get from a star that we know is a sphere to a planetary nebula that is far from being a sphere and yet came from that star," said Imai. Some theorists suggested that old stars must be somehow producing jets of material that help form the odd-shaped planetary nebulae, but such jets had, until now, never been seen.

W43A was known to have regions near it in which water molecules are amplifying, or strengthening, radio emission at a frequency of 22 GigaHertz. Such regions are called masers, because they amplify microwave radiation the same way a laser amplifies light radiation. Imai's team used the VLBA, the sharpest radio "eye" in the world, to find out where these masers are. To their surprise, they found that the maser regions are strung out in two curved lines, moving in opposite directions from the star at about 325,000 miles per hour.

"The path of the jets is curved like a corkscrew, as if whatever is squirting them out is slowly rotating, or precessing, like a child's top wobbles just before it falls down," said Diamond.

What is producing the jets? "We're not sure," Diamond said. "Traditional wisdom says that it takes a disk of material closely orbiting the star to produce jets, but we don't yet know how such a disk could be produced around such an old star," he added.

The astronomers are probably very lucky to have caught W43A in what they believe is a brief transitional stage of its life. "Our analysis of the water jets indicates that they are only a few decades old," Imai said. "Once the star collapses of its own gravity into a dense white dwarf, its intense ultraviolet radiation will rip apart the water molecules, making observations such as ours impossible," he added.

Planetary nebulae may be the worst-named class of objects in astronomy, because, despite the name, they have nothing to do with planets. The French astronomer Charles Messier discovered the first one, now known as the "Dumbbell Nebula" to amateur astronomers, in 1764. Sir William Herschel, who discovered the planet Uranus in 1781, later began a systematic survey of the entire sky and found more objects similar to the Dumbbell. Because their appearance resembled, to him, the appearance of Uranus in a telescope, he coined the term "planetary nebula," a name that has stuck ever since. Astronomers have long known that these objects are not actually related to planets, but the name has remained to confuse generations of students.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

Study Reveals Origin of Jets from Supermassive Black Hole

By Robert Roy Britt
Senior Science Writer
posted: 05:32 am ET
06 June 2002

ALBUQUERQUE, N.M. - The most massive black holes share much in common with their puniest cousins, according to a new study that found the first direct evidence for the source of energetic jets shooting out in two opposite directions from one of Nature's most impressive gravity wells.

Black holes swallow material so efficiently that even light cannot escape their clutches, and so they cannot be seen directly. But their surroundings are not completely efficient, and a good chunk of the material that swirls in toward a black hole is converted into X-rays and other energy that is cast back into space.

These byproducts allow astronomers to infer the existence of black holes.

Over the past eight years, stellar black holes weighing only as much as a few Suns have been found to direct some of their converted energy out along two narrow jets that travel in opposite directions along the objects' axis of rotation. Researchers connected these jets, detected in radio waves, to their source: the so-called accretion disk of material spiraling inward.

Theorists expected that supermassive black holes, which can pack the mass of billions of Suns into a small space at the center of a galaxy, should be using the same mechanism to produce their jets.

They do.

"This is the first direct, observational evidence of what we had suspected," said Boston University's Alan Marscher, who detailed his team's study here at the 200th meeting of the American Astronomical Society.

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Black Holes Find Mates at the Stars' Singles Bars

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Supermassive Black Hole Seen Under Construction

images

Scientists have caught a supermassive black hole in a distant galaxy in the act of spurting energy into a jet of electrons and magnetic fields four distinct times in the past three years, a celestial take on a Yellowstone geyser. (Artist's rendering courtesy Dr. Wolfgang Steffen, Project Cosmovision; University of Guadalajara, Mexico)

Some supermassive black holes, particularly in the distant and thus ancient universe, are found to be so actively consuming matter that their X-rays are bright well across time and space. These quasars, as they are called, can be brighter than thousands of ordinary galaxies.

In one quasar called 3C120, which is relatively nearby at just 450 million light-years away, Marscher and his colleagues detected jets of particles moving at 98 percent the speed of light. The emissions were detected in the form of radio waves by the National Science Foundation's Very Long Baseline Array.

The researchers used NASA's Rossi X-ray Timing Explorer satellite to determine that the radio emissions followed periods where the X-ray emissions from the disk were dimmer. They suspect the black hole is suddenly flushing material from one part of the system to another.

Over a three-year period, the team noted a series of X-ray dips, roughly every 10 months, each followed by a spurt of radio emissions.

"What we are likely seeing is the inner part of the accretion disk becoming unstable and suddenly plunging into the black hole," Marscher said.

The results are published in the June 6 issue of the journal *Nature*.

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when time BEGAN

Telescope helps give Socorro scientist a glimpse of the universe at its start

BY JOHN FLECK
Journal Staff Writer

After 15 years of trying, Socorro astronomer Steve Myers has finally seen the dawn of time.

Using data from a telescope in Chile, Myers and his colleagues have created the most detailed pictures ever seen of the universe's earliest visible moments.

The bumpy red and yellow images show the seeds of the galactic structure of the universe we live in today — something never seen before.

Astronomers say the research provides a key to understanding why the universe is the way we see it today, full of great clusters of galaxies and vast voids.

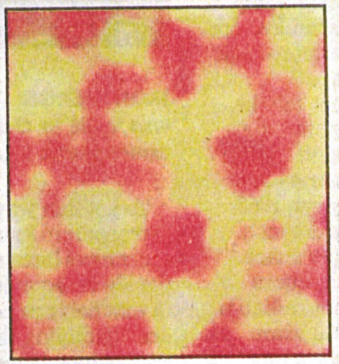
"How did the stuff we see in the universe develop?" Myers asked. "How did it evolve?"

The telescope's images also help confirm a growing scientific consensus that our universe is destined to keep expanding forever.

Myers is a member of the Cosmic Background Imager team, an international group of scientists based at the California Institute of Technology.

Using funding from the U.S. government's National Science Foundation, the scientists built a telescope in the high desert of Chile to look

See **SCIENTIST** *on* **PAGE A2**



CALIFORNIA INSTITUTE OF TECHNOLOGY

ECHOES OF THE PAST: An image taken by the Cosmic Background Imager telescope shows slight variations in temperature of the matter in the universe soon after the Big Bang.

Instant Veto By Johnson Invited

Session To Resolve Budget Tiff Starts

Borrego Blaze Balloons

Scientist Sees the Beginning

from **PAGE A1**

for the quiet afterglow of the Big Bang.

Myers, based at the National Radio Astronomy Observatory in Socorro, developed the computer techniques needed to sort through the data and understand what the scientists were seeing.

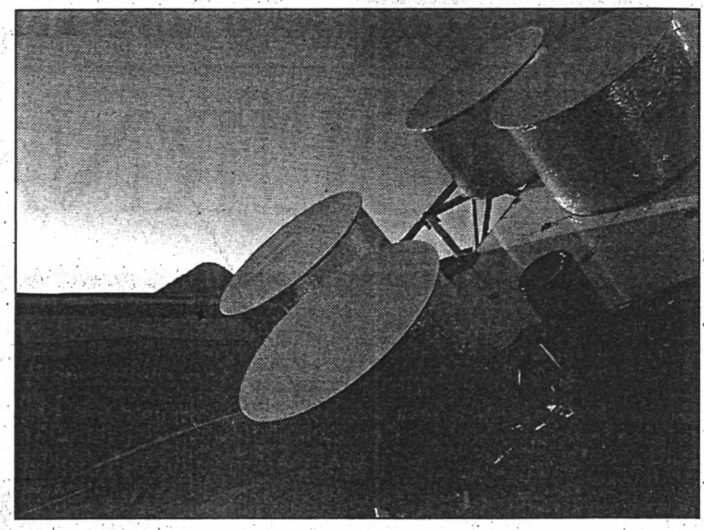
Anthony Readhead, the project's lead scientist, released the group's findings Thursday at a Washington, D.C., news conference.

The telescope was designed to detect heat from the faint afterglow of the Big Bang that astronomers believe created the universe more than 13 billion years ago.

Scientists cannot see the Big Bang directly, but the Cosmic Background Imager is the latest in a series of telescopes that, since 1965, have been able to detect a faint glow in empty space.

That glow, researchers believe, is remnant radiation from about 300,000 years after the Big Bang, a time when the universe was still a largely undifferentiated soup of individual atoms.

The glow looked incredibly smooth, like a pudding with no lumps. But scientists know that today's universe is incredibly lumpy. Most of the matter collected in places like our galaxy is surrounded by vast empty spaces.



COURTESY CALIFORNIA INSTITUTE OF TECHNOLOGY

HIGH PERCH: The Cosmic Background Imager telescope was built in the high desert of Chile so it would be above atmospheric interference.

To get that way, astronomers knew, there must have been some sort of barely detectable lumpiness in that early pudding — tapioca containing the seeds from which large structures like galaxies eventually formed.

In the 1980s, while a student at Caltech, Myers' doctoral thesis involved trying to find the early lumps. Like many others, he failed.

"We were all getting null results," Myers said in a telephone interview Thursday from his Socorro office.

Scientists at the time used to joke that they were proving Earth must not exist.

They realized that the lumps, tiny variations in the radiation from the early glow, could only be detected with an extraordinarily sensitive telescope. During the 1990s, they won federal funding and picked a site in the high Atacama Desert of Chile.

The site, at 16,700 feet, is so high that the buildings have extra oxygen pumped in for the scientists to breathe. When they are outside working on the telescope, they carry oxygen bottles, Myers said.

The altitude and dry mountain air give the telescope a clearer view of the heavens, and the telescope was able to detect tiny differences in temperature in the faint afterglow, explained Readhead.

"For the first time, we're seeing the seeds of galaxy clusters," Readhead said.

Scientists can't see back beyond 300,000 years after the Big Bang because the universe before that time was opaque and light did not escape. But astronomers can use the telescope's data to infer what went before, explained Alan Guth of the Massachusetts Institute of Technology.

Different theories about how the Big Bang unfolded make different predictions about what the lumpiness would look like. The new Cosmic Background Imager data support Guth's "inflation" theory.

The inflation theory suggests that the universe underwent a brief period of dramatic expansion an instant after the Big Bang, a time in which all the matter in the universe came to exist.

Borrego Blaze Prompts Evacuation

from **PAGE A1**

fire's behavior today.

State Police officers used sirens and loudspeakers to alert Truchas residents to evacuate Thursday afternoon, but some residents stayed behind to watch their homes or tend to livestock.

"It brings back old memories, not good ones."

DAVE RAMSAY, LOS ALAMOS RESIDENT

Bateman said.

No structures have burned yet, but two firefighters suf-

"We'll see how it pans out right now," he said. "Certainly, the people are more important."

A fire command post was set up at the National Guard Armory in Española, where additional Hot Shot and other firefighting crews arrived Thursday by bus. Several bulldozers were held there on standby.

Bateman said he has request-

gap between the nanoscale world and the visible one, says Gaub. Or the molecule might be directly attached to other nanoscale components.

Gaub cautions, "It will require several years of research to develop the necessary understanding of the basics and many more years to build up the technology in order to implement these effects in applications."

"I think it's the first kind of clear-cut example of a machine action... generated in a controlled way using a single-molecule system," comments James Gimzewski of the University of California, Los Angeles. —J. GORMAN

Heavenly Taffy

Galaxies in collision

Some bodies just like sticking together, whatever the means. Astronomers have discovered a pair of colliding galaxies connected by a bridge of high-speed electrons and elongated magnetic fields. A map of the bridge's radio emissions depicts bands that stretch like taffy between the galaxies.

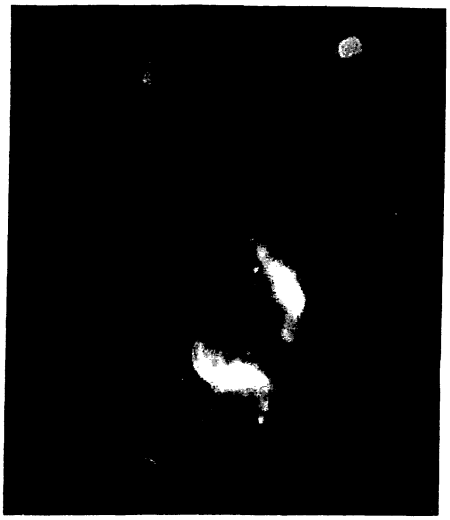
The galaxy pair, designated UGC 813/6, is only the second known to exhibit the taffy structure, notes James J. Condon of the National Radio Astronomy Observatory in Charlottesville, Va. By examining this structure, astronomers can reconstruct the original distribution of interstellar gas and magnetic fields within each of the galaxies, Condon says.

Condon's team spotted the first pair of taffy galaxies in 1990. The second pair confirms that the structure, though rare, isn't a fluke. Condon, with George Helou and Thomas H. Jarrett of the California Institute of Technology in Pasadena, describe the findings in the April *Astronomical Journal*.

The team's observations, taken with the Very Large Array radio telescope in Socorro, N.M., suggest that the magnetic fields and high-speed electrons that fill the bridge were ripped from the galaxies when the two rammed into each other. To generate the bridge, which spans some 50,000 light-years, galaxies must contain dense gas clouds and strike head-on, Condon says.

The new findings support the notion that each end of a magnetic field line within a galaxy is anchored to a dense gas cloud. As the galaxies collide and pass through each other, their dense clouds create a magnetic bridge, stretching out their magnetic field lines much as a taffy machine pulls taffy, Condon says. Energetic charged particles spiral around the field lines, illuminating the bridge as they radiate radio waves.

The head-on crashes that lead to bridges are in stark contrast to the majority of collisions, in which two galaxies come close enough for their mutual gravity to yank out streams of gas and stars yet remain a few hundred thousand light-years apart.



GALACTIC TAFFY Map shows two colliding galaxies (white) joined by a bridge of radio-wave-emitting electrons (pink).

"The observations provide a powerful new diagnostic tool for studying galaxies that have just undergone the remarkable feat of having passed bodily through another similar galaxy," comments Philip N. Appleton of Caltech. Because the bridge's radio emission fades after an astronomically brief 100 million years, "the radiation from particles trapped in these distended magnetic fields acts like cosmic signposts, telling

CONDON

Hidden Damage

Parkinson's harm to nerves in heart may explain dizziness and fainting

Standing up suddenly can precipitate an unsteady moment as the body struggles to ratchet up blood pressure in response to the posture change. In some people, particularly those with Parkinson's disease, a stronger woozy feeling indicates a transient low-blood-pressure condition, called orthostatic hypotension, which can lead to falls.

While the muscle rigidity and tremors of Parkinson's disease result from cell death in parts of the brain that produce the neurotransmitter dopamine, the cause of orthostatic hypotension is less clear. Recently, scientists have found evidence suggesting that nerve endings in the hearts of Parkinson's patients can be damaged. A new study now directly links such cardiac-nerve dysfunction with orthostatic hypotension.

Earlier work had also pointed to a role for the nervous system in the problems that many Parkinson's patients have with their bladder and digestive tract. The new study "really expands what we know" about damage to organs regulated by the autonomic nervous system, says Robert F. Pfeiffer, a neurologist at the University of Tennessee Health Science Center in Memphis. The autonomic nervous system guides functions—such as heart rate, blood pressure, and perspiration—for which there is no voluntary control.

To assess autonomic function in Parkinson's patients, neurocardiologist Shengting Li of the National Institute of Neurological Disorders and Stroke in Bethesda, Md., and his colleagues examined 56 volunteers, including 40 with Parkinson's disease. The average age was 62 years. Each participant was told to blow forcefully into a tube—a test designed to boost blood pressure. For all 17 Parkinson's patients with orthostatic hypotension, the rise in blood pressure was abnormally low, a sign of an impaired autonomic system. Only 6 of 23 Parkinson's patients without orthostatic hypotension had such a weak response. Among the healthy controls, blood pressure rose normally. The study appears in the April 23 *Neurology*.

In a separate test, the scientists injected dopamine tagged with a radioactive fluorine into each volunteer. A positron emission tomography (PET) scan revealed that all 17 Parkinson's patients with orthostatic hypotension had significantly less dopamine in the muscular left ventricle of the heart than did the healthy controls. This indicates that nerve terminals in those patients were not functioning, Li says. Roughly half the Parkinson's patients without orthostatic hypotension had significantly less nerve-terminal function than the controls did.

The scans also revealed diminished nerve activity in the kidneys and thyroid glands of the Parkinson's patients as compared with the controls.

Norepinephrine, a cousin of dopamine, also acts as a neurotransmitter within the autonomic nervous system. Whereas the majority of Parkinson's patients without orthostatic hypotension had blood concentrations of norepinephrine that shot up in a normal response to standing up from a lying-down position, none of the orthostatic -hypotension patients who were tested registered such an increase, Li and his colleagues report.

Previously, some scientists had theorized that the Parkinson's drug levodopa causes orthostatic hypotension. However, the new study suggests that the drug isn't responsible. Among the 17 patients with orthostatic hypotension, 4 had never taken levodopa and 3 had discontinued its use. —N. SEPPA

astronomers that something remarkable has just happened," he adds.

Because the most energetic electrons in the bridge radiate their energy the fastest, their intensity acts as a clock, indicating how long ago the galactic collision took place. Condon and his colleagues estimate that the impact that created the newly observed taffy pair occurred some 50 million years before the observed radio emission was generated.

The galaxies are now speeding away from each other at roughly 400 kilometers per second, but gravity will ultimately pull them back for a final merger. —R. COWEN

Feel the Burn

Alcohol sets pain-sensing nerves aflame

A splash of aftershave stings the face. A shot of whiskey shocks the throat. A swab of antiseptic on a raw wound causes a person to wince.

Scientists now appear to have found the common thread among these sensations: Alcohol makes certain pain-generating nerves trigger more easily than normal. In some cases, it tricks the nerves into behaving as if they are exposed to extreme heat. Suddenly, alcohol's nickname, firewater, has become especially apropos.

The new findings, reported in an upcoming *Nature Neuroscience*, emerge from research led by John B. Davis of GlaxoSmithKline in Harlow, England, and Peirangelo Geppetti of the University of Ferrara in Italy. The scientists focused on ethanol, the world's favorite form of alcohol, and its influence on a protein called the vanilloid receptor 1 (VR1). This receptor, which sits on the surface of some sensory nerve cells, first drew public attention when researchers learned that it responds to both high temperatures and capsaicin, the substance that makes certain peppers taste hot (*SN: 11/8/97, p. 297*).

"Many companies think it's a substantial target for developing a pain therapeutic," says Davis.

There have been some clues that alcohol affects nerves bearing VR1. For example, injecting alcohol near damaged nerves that cause chronic pain produces a temporary burning sensation but sometimes leads to pain relief. And Geppetti has had patients with esophagitis, or inflammation of the esophagus, who have reported that strongly alcoholic drinks cause an unusually intense burning in their throats.

Davis and Geppetti now have demonstrated an alcohol-VR1 connection in the laboratory. They've shown that ethanol triggers certain tissues, such as skin, to release the same neurochemical signals secreted when heat or capsaicin stimulate VR1-laden sensory nerves. Triggering nerves in such tissues with capsaicin eliminates a subsequent ethanol response—further indication that the alcohol acts on the same nerve cells.

In another experiment, the researchers applied to cells a solution containing just 3 percent ethanol. They found that the temperature needed to trigger VR1 falls from around 42° to around 34°C.

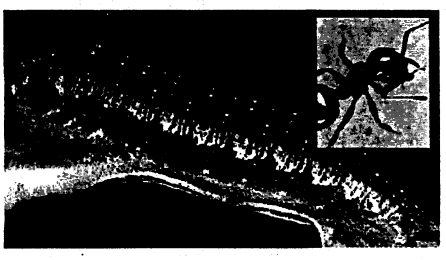
"The heat threshold for VR1 is lowered by ethanol down to temperatures which are at or below body temperatures [about 37°C]," says Davis.

From these results, the scientists speculate that adding alcohol to inflamed or damaged tissue produces a situation in which a person's body temperature activates VR1 and creates a painful, burning sensation. This may offer the first molecular explanation for why people with esophagitis should avoid alcoholic drinks, says Davis.

Geppetti adds that future drugs that block VR1 activity might help such people.

So far, the studies have been restricted to tissue in laboratory dishes. Davis notes, "We haven't shown directly that ethanol activates VR1 in a body."

Scientists might be able to obtain such evidence using mice that were genetically engineered to lack VR1, says David Julius of the University of California, San Francisco. One of the scientists who identified VR1 and showed that it responds to heat and capsaicin, he's interested in learning whether alcohol, capsaicin, and heat activate the receptor in the same way. —J. TRAVIS



YUK Repellant droplets on hairs of the European cabbage butterfly caterpillar send an ant into a cleaning frenzy (inset).

T. EISNER; R. SMEDLEY

No Tickling

Common caterpillars deploy defensive hair

Caterpillars of the European cabbage butterfly, which has invaded most of North America, turn out to bristle with a kind of defense system that scientists have not documented before.

The caterpillars sprout hairs that carry droplets of a novel predator repellent derived from a fatty acid, says Thomas Eisner of Cornell University. Ants tend to avoid the caterpillars or spend an unusual amount of time cleaning themselves after contact, Eisner and his colleagues report in an upcoming issue of the *Proceedings of the National Academy of Sciences*.

"Here's something new about a species that's dirt-common," marvels entomologist May Berenbaum of the University of Illinois at Urbana-Champaign. Eisner's team named the oddball repellents mayolenes after her. A footnote in the paper clarifies that this is an honor.

The repellent-dotted species, *Pieris rapae*, hitchhiked to Canada in 1860 from its native Eurasia and North Africa. The adult butterfly's chalky wings, with a dark spot or two, have become a familiar sight coast to coast in the United States. The repellent's defensive powers could easily have sped the species' proliferation, Eisner says.

Soft and slow, caterpillars often turn to chemical warfare, he explains. For example, some carry poisons that their fathers transferred to their mothers along with sperm. Other caterpillars, when attacked, regurgitate the remains of noxious plants.

Researchers had previously documented defensive glandular hairs in beetle pupae, and entomologists have speculated that the little droplets atop the hairs of the cabbage butterfly caterpillars might also offer some kind of protection. Eisner says he knows of no previous attempts to test the idea.

In one behavioral experiment, his team confined a predator, an ant species from the Northeast, with a European cabbage butterfly caterpillar or a mealworm of similar size. The ants probed the caterpillars much less often than they poked at mealworms. In another experiment, the scientists washed the caterpillars with solvent and then offered them to the ant. The deterrent effect had disappeared.

To look into the chemistry behind the deterrence, the researchers collected droplets from hundreds of caterpillars. The deterrent chemicals fell apart easily when exposed to heat and acids, so the team developed novel techniques. The researchers learned that mayolenes are derived from a common fatty substance, linolenic acid. However, the final compounds more closely resembles substances produced in plants' injury responses than in other caterpillar defenses, say the researchers.

Eisner says that he himself can't sniff anything repellant in the mayolenes, much to Berenbaum's relief. "If they're named after me, I sincerely hope they don't smell bad," she says. —S. MILIUS

VLA Scope Spots Black Hole Collision

Explosion Believed Largest Since Big Bang

BY JOHN FLECK
Journal Staff Writer

Astronomers using the Very Large Array have found evidence of massive black holes colliding in what would likely be the largest explosions the universe has seen since the Big Bang.

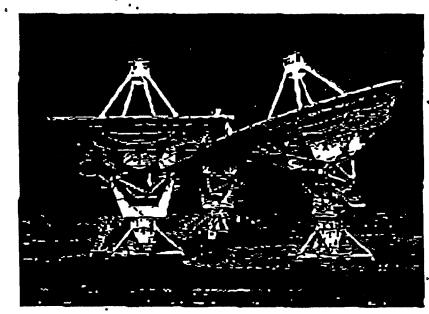
If the hypothesis holds up, the collisions could provide a tool to test Einstein's theory of relativity, explained Rutgers University astronomer David Merritt.

"The holy grail in this field is to test Einstein's equations," Merritt said.

Located west of Socorro, the Very Large Array is a specialized telescope that collects natural radio emissions from distant stars and galaxies.

Merritt and Ronald Ekers of the Australia National Telescope Facility published their findings Friday in the on-line version of the journal Science.

Like police officers reconstructing a crash by looking at skid marks and debris scattered across a highway, the scientists found evidence in Very Large Array images pointing to dramatic cataclysms as galaxies merge.



JOURNAL FILE PHOTO

BLACK HOLE BANG: Images from the Very Large Array radio telescopes west of Socorro have led some astronomers to hypothesize that massive black holes have collided, likely creating the universe's greatest explosions.

In a matter of seconds, two giant black holes merge into one, sending out a blast of invisible gravity waves more powerful than any other kind of known explosion in the universe, Merritt said.

Proposed satellites might be able to detect those waves, which could provide a test of Einstein's theory of general relativity.

The theory explains gravity's effect on space and matter, and some of the best tests of whether it is correct require incredibly massive, dense objects like black holes, Merritt explained.

The work grew out of a chance luncheon meeting last spring when both scientists were visiting the University of California at Berkeley.

Merritt was trying to work out the details of what would happen when two black holes were drawn together by gravity as galaxies merge. Ekers, who was director of the VLA in the 1980s, knew about VLA images that seemed to show the sort of thing Merritt was looking for.

Merritt's and Eker's work capitalizes on the Very Large Array's strength, peering into the heart of galaxies believed to have black holes at their center.

That is the biggest reason the radio telescope was originally built, explained VLA astronomer Frazer Owen.

Using less powerful telescopes, scientists had seen blurry blobs of radio emissions coming from the center of galaxies, but it has taken the precision of the VLA to see clearly the details of what is going on.

Astronomers now believe there are black holes at the center of the galaxies, objects so dense and massive that not even light can escape their gravitational pull.

They cannot be seen directly, but astronomers can see their side effects, stars, dust and gas being heated as they are sucked away into the hole.

One characteristic is long fiery jets shooting out of the top and bottom of a spinning black hole like cosmic blowtorches.

Merritt and Ekers found strange patterns in many black hole images taken by the VLA — X-shaped jets the scientists believe are left behind when two massive black holes collide.

Merritt acknowledged there might be other explanations, and Owen said the task now for astronomers is to look more closely with the VLA or other telescopes and see if the astronomers are right.

Power Failure Blankets Region

Blackout Affects N.M., West Texas

The Associated Press

EL PASO — Power was restored to all of El Paso late Friday afternoon after a regional power failure blacked out towns from New Mexico to far West Texas.

All of El Paso was without power for about 30 minutes Friday morning. Power had to be

HANGING AROUND

State Funds Decline By $1 Billion

Investment Managers Won't Panic About Stock Markets

BY DAVID MILES
Journal Capitol Bureau

SANTA FE — The value of the state's pension and permanent funds have dropped more than $1 billion over the past year, but fund managers say the sagging stock market has prompted them to make only minor changes in investment strategies.

The value of the land grant and severance tax permanent funds dropped by about $1.1 billion, or about 10 percent, during the fiscal year that

Especially for kids and their families

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BETTY DEBNAM | Richmond Times-Dispatch | TUESDAY, APRIL 16, 200

from The Mini Page by Betty Debnam © 2002 The Mini Page Publishing Company Inc

nvisible Wonders

Awesome Air Waves

atural waves

Our universe is full of wonders. mong them are the amazing ectromagnetic (e-LEC-tro-mag-NEH-c) waves.

To better understand these waves, ou might try something unusual, but we think it will help.

Take a little time to wave at the objects and people around you. Waving them will remind you that things nd people — without even trying to, without even moving — naturally end out, or emit, waves into the air.

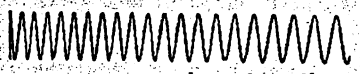
If we could see them, heir waves might look ke this.

Just about everything in the universe ives off these waves in all directions. hey are all around us. So humans nd objects on Earth and in the sky re natural sources of these lectromagnetic waves.

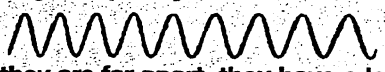
Making waves

Through the years, scientists have iscovered how we can make these nvisible electromagnetic waves work or us.

Scientists found that waves of different engths do different things. Different avelengths have different "frequencies."



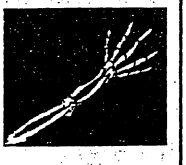
When waves are very close together, they ave a high frequency.



When they are far apart, they have a low equency.

X-ray waves

If we make the wavelengths very close together with a very high frequency, we can make X-rays that enable us to make pictures that doctors use to see what's going on inside our bodies.



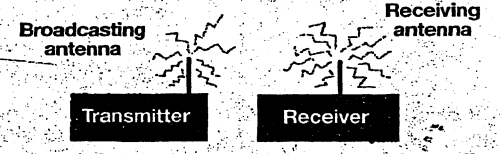
Microwaves

If we make a wavelength longer, we can make microwaves that we can use to cook our food in our microwave ovens.

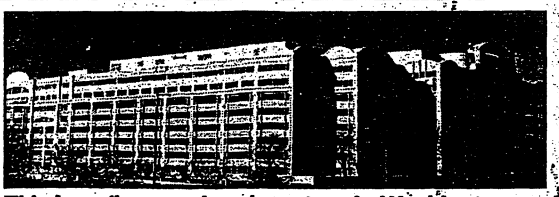
Radio waves

The longest waves of all are the radio waves. These special wavelengths carry pictures and sound. While we call them "radio" waves, they are also used for TV and cell phones and other ways to communicate.

For radios to work, you need:



The transmitter generates, or creates, the radio signal. The radio waves are sent over the airwaves. An antenna picks up the signal and passes it to the receiver.



This is radio wave headquarters in Washington, D.C. The Federal Communications Commission works out of this office. For fun, you might just wave if you happen to go by!

Setting up airwave rules

These radio wavelengths are so important that the government has set up a special group, or agency, called the *Federal Communications Commission

(*"Federal" has to do with our national government. A commission is a group that decides on important matters.)

The FCC, as it is called, sees that the billions of messages carried through the air on waves don't get all mixed up.

For example, each radio station is assigned a special frequency, or wavelength, of radio waves. Stations must be far enough apart in wavelength so that they don't interfere with each other.

A frequency of 1500 AM means these radio waves can move up and down 1,500,000 times a second. AM is a special band, or group, of frequencies.

To pick up those waves on your radio, you have to set your dial to 1500.

FM is another band of frequencies.

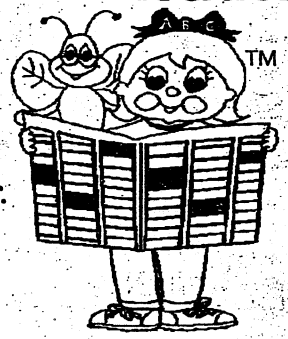
Radio, TV and cable channels must get licenses before they can operate. The FCC assigns them certain wavelengths, or frequencies.

The FCC also sets aside "bands" of radio waves for products such as remote-control garage door openers, radio-controlled toys and cell phones.

If you look on your portable radio, you might see a label that begins:

THIS DEVICE COMPLIES WITH PART 15 OF THE FCC RULES.

nd B. A. Reader



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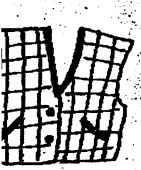

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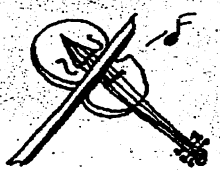


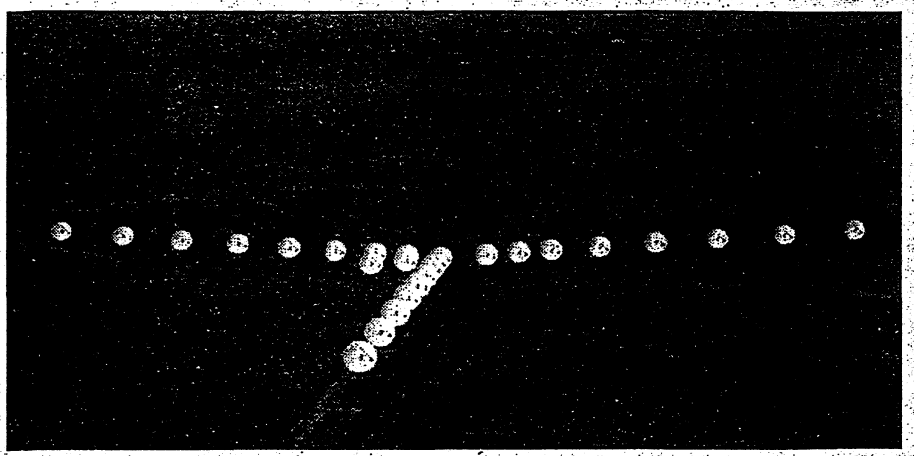
violin

not begin with the letter V?

V. Practice here.

Hh Ii Jj Kk Ll Mm
Uu (Vv) Ww Xx Yy Zz

What Radio Telescopes Scope Out



The Very Large Array is a very unusual group of radio telescopes. The series of 27 dishes is in the desert in New Mexico. They work together as one telescope.

• Distant galaxies

A galaxy is a collection of billions of stars. The galaxy we live in is called the Milky Way.

• Interstellar clouds

"Interstellar" means among the stars. The space between stars can hold gigantic clouds of dust and gas. These clouds are the places where new stars and planets are formed.

• Old and young stars

Stars are born, live out their lives and grow old. A star that grows very big is called a red giant. After a red giant collapses, it is called a white dwarf star.

Some stars explode when they are old and send stuff out into space. This might become parts of new stars and planets.

Other exploded stars might become very dense stars called neutron stars. Some of these stars might become a pulsar, or a star that spins rapidly, sending out beams of energy into space.

When the largest stars grow old and collapse, they become black holes. No light can escape from these holes.

•

hile doing many other things
ou can find: shovel • steak

- kite
- letter B
- caterpillar
- book
- word MINI
- carrot
- letter D
- pencil
- letter E
- pea pod

Basset Brown The News Hound's

Amazing Air Waves

TRY 'N FIND

Words and names that remind us of electromagnetic waves are hidden in the block below. Some words are hidden backward or diagonally. See if you can find: RADIO, WAVES, INVISIBLE, DISH, TRANSMIT, RECEIVE, UNIVERSE, DETECT, ASTRONOMERS, HOLES, SCIENTISTS, SPACE, TELESCOPE, STARS, BLACK, GALAXY, MILKY WAY.

A S T R O N O M E R S T T U M
W S T S I T N E I C S R E N I
D A A H G A L A X Y Q A L I L
B I V S R A T S I U B N E V K
L C S E J T C E T E D S S E Y

Collecting Radio Waves From Space

Wow! What a Telescope!

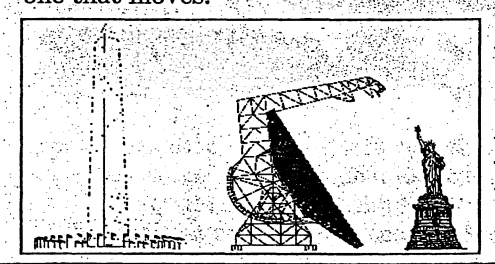
What's way out there in the universe? Scientists are using radio waves to find out.

Of all the different types of electromagnetic waves, radio waves are the longest. They might be as long as a football field or as short as a football.

The radio waves that occur naturally in the universe are not manufactured. They are silent. Scientists don't listen to them; they study them.

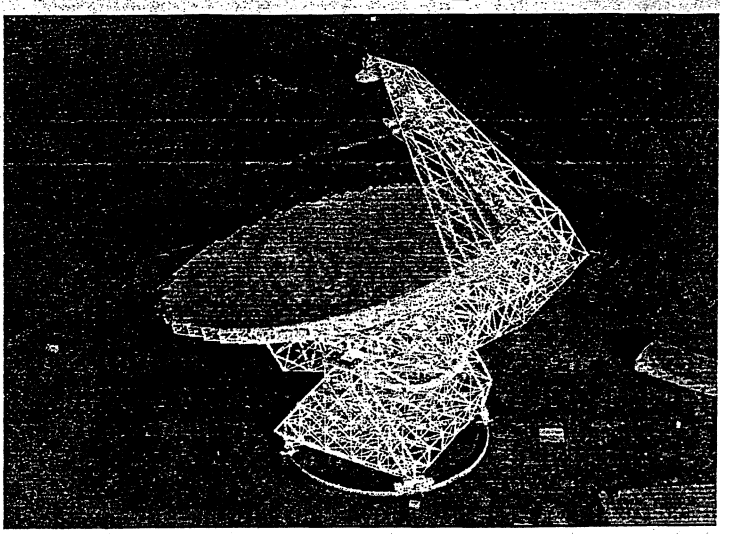
A really, really big telescope

In the mountains of West Virginia is the largest movable thing on land. It's a radio telescope. There are other radio telescopes in other parts of the world, but this is the largest one that moves.



It is very tall, almost as tall as the Washington Monument. Its dish is about 300 feet across (about the length of a football field).

The telescope is taller than the Statue of Liberty.



The Robert C. Byrd Green Bank Telescope is in West Virginia. It collects radio waves. It can only receive them; it does not send any. It takes a long time for some of the waves to reach Earth. Some of the might be millions of years old before they do.

What the telescope does

The telescope's job is to collect naturally occurring radio waves. By studying them, scientists can find out what is going on way out in space.

Space is filled with radio wave energy. Planets, stars, galaxies and even clouds of dust and gas give off radio waves that can be detected on Earth.

Collecting these waves is important to astronomers. By studying the data the telescope gathers, they can find out information about space that they could get no other way.

With "optical" telescopes, astronomers can see only what is actually visible. If clouds are in the way, or if the sun is shining, they don't get a good picture.

This is not the case with radio telescopes.

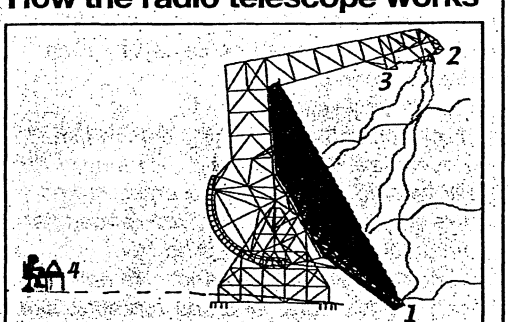
Quiet, please

Radio signals arriving on Earth from space are very weak. In fact, they are millions of times weaker than the manufactured signals sent out by the radios we listen to.

Because these radio waves from space are so weak, radio telescopes must be big and also far away from places where people live.

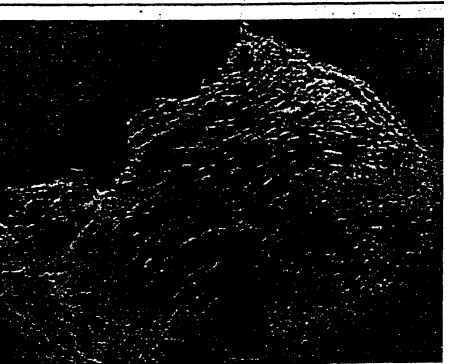
Such things as microwave ovens, radio and TV signals, and computers can interfere with the reception. The big dish enables the astronomers to focus the telescope on small areas.

How the radio telescope works



Radio astronomers collect radio waves from a tiny part of the sky, measure how strong they are, and then move on. As they move from point to point, they slowly build an image of what they are studying.

1. Radio waves from space bounce off the main dish.
2. They are reflected to a smaller dish at the top of the telescope (this is called a sub-reflector).
3. The signals are then sent to receivers (much like the radio receivers you have in your home — only they are much more sensitive).
4. The faint signals from space are amplified (made stronger) and sent to powerful computers that analyze them, which allows experts to make images to study.



An image of a part of the planet Venus take by the Green Bank Radio Telescope.

Teachers: A site to see: www.NRAO.edu.

The Mini Page thanks Chuck Blue, publi information officer for the National Radi Astronomy Observatory, for help with th issue. NRAO is a facility of the National Science Foundation.

Look through your newspaper for ads f items that might manufacture radio waves.

Next week, The Mini Page visits the stat Connecticut from A to Z.

The Mini Page is created and edited by
Betty Debnam

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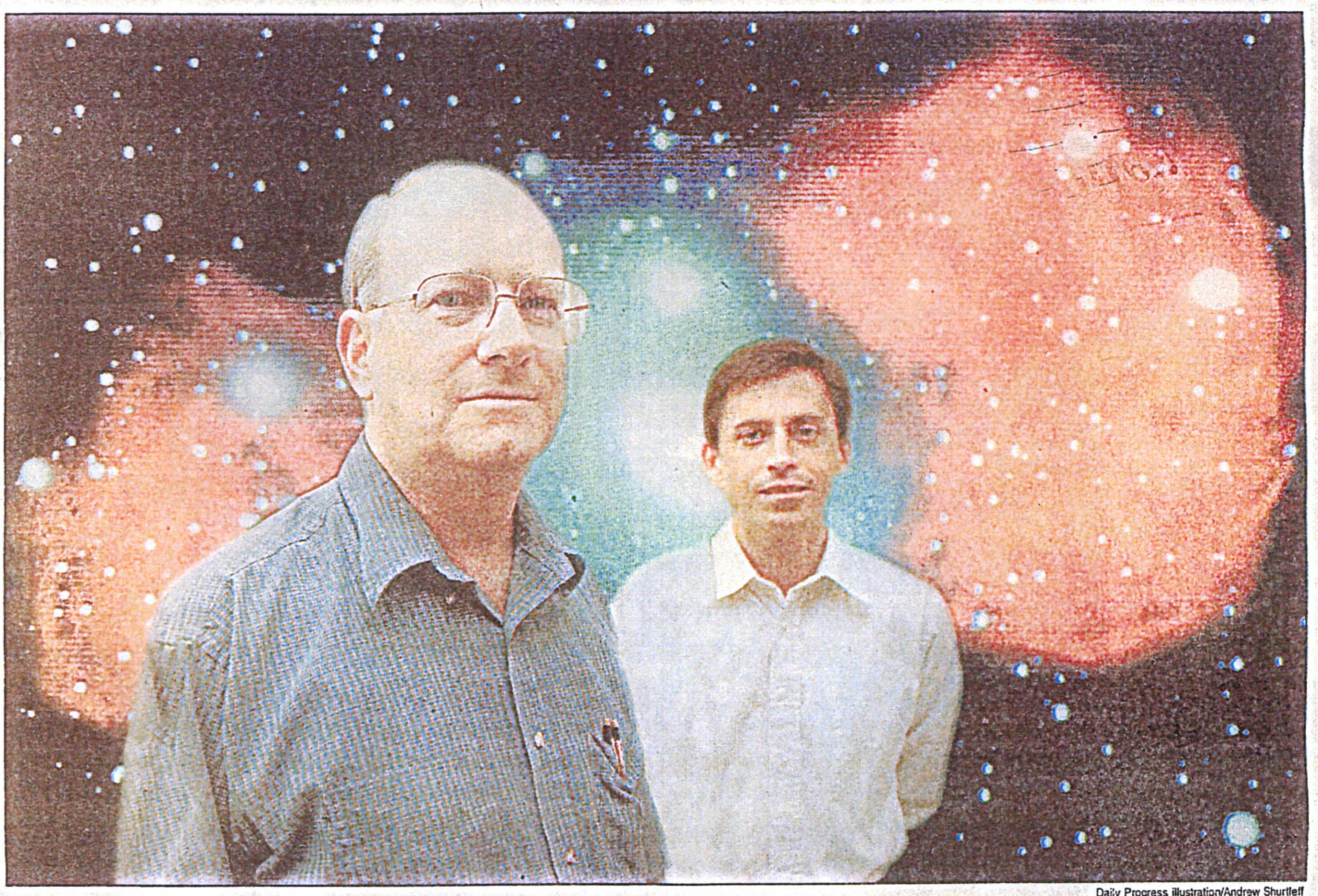
Wendy Dale

The Daily Progress
Lifestyles
Charlottesville, Virginia

Waves of the future



Daily Progress illustration/Andrew Shurtleff

Assistant director John Webber (left) and public information officer Charles E. Blue against a backdrop of a composite of the radio emission and visible light from the elliptical galaxy NGC 1316.

Charlottesville plays key role in a big array of technology

By DAVID A. MAURER
Daily Progress staff writer

The gigantic circular dishes cant toward the heavens as if in anticipation of some celestial occurrence.

Like improbable metal mushrooms, the 27 radio telescopes are spread out in a "Y" pattern across New Mexico's Plains of San Agustin.

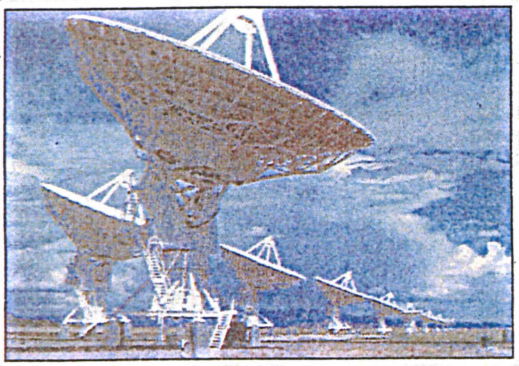
The impressive array was dramatically featured in the opening sequence in Jodie Foster's 1997 movie "Contact." In the film the antennas pick up a message and instructions from extraterrestrials.

In reality the "Very Large Array," as it's called, does things that are nearly as awe-inspiring.

The VLA was built and is operated by the National Radio Astronomy Observatory. What many people don't realize is that NRAO is headquartered in Charlottesville.

NRAO is a research facility of the U.S. National Science Foundation. Its job is to provide state-of-the-art radio telescope facilities for use by the scientific community.

Courtesy NRAO



The Very Large Array, 27 dishes that make up a radio telescope, is situated in New Mexico. The The National Radio Astronomy Observatory, headquartered in Charlottesville, operates the VLA.

Scientists and technicians at NRAO conceive, design, build, operate and maintain radio telescopes used by scientists from around the world. These telescopes study virtually every type of astronomical object known to man.

"The NRAO is the nation's premier radio astronomy observatory," said Charles E. Blue, public information officer for the organization. "But often when I talk to people in town and I tell them who I'm with, they say, 'Oh, I never heard of that. What do you do?'

"Sometimes I'll ask them if they've seen the movie 'Contact,' and most people will say they have. When I tell them about the connection, they're amazed.

"But even though we're headquartered here in Charlottesville, because we don't have any big antenna stuck 485 feet in the sky, there's not a heck of a lot to look at. And yet we're studying some of the observation data and we're building the really intricate components that make all this amazing astronomy happen."

Radio astronomy got its beginning in 1932 when Karl Janing discovered "cosmic static" while trying to figure out what was causing interference during transoceanic telephone calls. Because radio waves can provide much clearer pictures of formations in space than standard optical observation, profound advancements in our understanding of the universe have been made.

"A radio telescope is simply a very large reflector surface that collects and focuses radio waves from distant objects," said John C. Webber, assistant director in charge of

See WAVES on E4

Waves

Continued from E1

NRAO's central development laboratory on Ivy Road.

"It's different from an optical telescope, only in the fact that it works in radio waves rather than in light waves. Because the wavelength of radio waves are much larger than that of optical light, the radio telescope has to be much larger in physical size in order to make a focused beam.

"The beam size on the sky of a single dish antenna is limited by the size of that dish. The bigger the dish, the smaller the beam on the sky and the more finely it focuses in on the point in the sky."

It's been learned that the practical limit to the size of an antenna is about 100 meters in diameter. So one of the things that is done to get a finer and finer beam is to combine signals from many radio telescopes spread across a large area, such as the VLA in New Mexico.

"If the area over which the antennas are spread is, say, one mile, then we get the equivalent beam, after we combine the signals from all the antennas, of what we would get if we had been able to build a single telescope one mile in diameter," Webber said.

Combining antennas has led to the creation of huge arrays. Although the VLA goes out for 25 miles, it's small compared to NRAO's Very Long Baseline Array.

VLBA is made up of 10 giant dish antennas that start in Hawaii and stretch to the Virgin Islands. It's the world's largest dedicated, full-time astronomical instrument.

Since going into operation in May 1993, VLBA has provided scientists with invaluable knowledge on cosmic distances. It has also allowed them to perform firsts, such as making a movie of gas motions in the atmosphere of a star other than the sun and mapping the magnetic field of a star other than the sun.

"VLBA gives us essentially the one beam on the sky you would have gotten if you would have been able to make an antenna almost the size of the Earth," Webber said.

"We can get extremely small, extremely fine resolution. If you think about a copper penny and you think about the portrait of Lincoln and of Lincoln's nose and take that to the distance of San Francisco and look at it, Lincoln's nose is the size object we can see with a telescope as big as the Earth.

"Radio astronomers tend to call them images, but they're pictures of the sky as you would see it if your eyes were sensitive to radio waves and were the size of the Earth."

Since its formation in 1956, NRAO has played a key role in discovering the mysteries of deep space and its origin. Recently its central development laboratory on Ivy Road was singled out by the editors of Popular Science magazine for work on NASA's Microwave Anisotropy Probe.

Throughout the year, Popular Science reviews new products and technologies and features the top 100 in its annual "Best of What's New" edition. MAP was recognized as one of the best innovations in aviation and space for 2001.

On June 30, 2001, the MAP mission was launched from Cape Canaveral, Fla. According to Blue, the core technology of the MAP spacecraft was the development of cryogenic low-noise amplifiers here in Charlottesville by Marian Pospieszalski.

Aboard the MAP satellite are 80 of the handmade amplifiers, each of which is less than half the size of a deck of cards. Webber said without this key technology there would have been no mission.

"The purpose of the MAP satellite is to make a precision map or picture of the sky at radio wavelengths to a very high sensitivity," Webber said.

"That's very difficult to get from the ground, because of the interference of the Earth's atmosphere. The objective is to measure what is called a cosmic microwave background radiation, which was discovered in the early 1960s.

"What it is is the leftover fireball from the big bang."

The big-bang theory is based on the premise that the universe was created when a super dense primeval atom exploded about 15 billion years ago. It's widely believed by scientists that the universe has been expanding ever since.

Webber said that at the very beginning of the universe, as we understand its evolution, the universe was small in dimension, very dense and hot. As it expanded, it cooled. At a certain point in the cooling process, the atoms were far enough apart to allow the light that was there from the original big bang to leak through and make the universe transparent.

"At that time the temperature was on the order of 10,000 degrees," Webber said. "Since then, the universe has expanded and expanded and that light that started out some 15 billion years ago is still there.

"So we can look back at a time that is very close to the beginning of the universe before there were any stars or galaxies. And we can see the light that gives us a picture of the universe before anything we're familiar with ever formed."

Webber said because of the expansion, the effective temperature for the radiation has cooled from about 10,000 degrees down to about 3 degrees. During the next two years, MAP will study the tiny temperature differences within the cosmic microwave background radiation that are the faint remnants of the big bang.

The extraordinarily sensitive amplifiers on MAP allow it to measure slight temperature fluctuations to within millionths of a degree. All systems are working perfectly and scientists are hoping with the data to be received that the content, shape, history and ultimate fate of the universe can be divined.

Webber said NRAO's biggest project at the moment is ALMA, which stands for Atacama Large Millimeter Array. The array is being built on a high mountain site in the Atacama Desert of Chile.

"NRAO was the leader in getting ALMA going," Webber said. "This is an international project that has an array of 64 antennas.

"At the frequencies it will be operating at, it will allow us to see a different class of phenomena from either the VLA or optical telescopes.

"It will enable us to look at objects that constitute most of the matter in the universe. The other thing it will do is let us look at galaxies and matter that are much farther away than what we can see in the optical."

In the last decade, Webber said, technological advancements, including the Hubble Space Telescope, have allowed scientists to probe deeper than ever before into space. One of the more striking discoveries is that ordinary matter that we are familiar with makes up only a small percent of the mass of the universe.

"The overall structure of the universe and the galaxies is completely dominated by this dark matter of unknown nature," Webber said.

"And even more recently, it's been shown that matter appears to account for only about one-third of the energy of the universe. The other two-thirds is in the form of what's been called dark energy, which is something [Albert] Einstein actually invented in the 1920s to try to make his theory of general relativity consistent.

"Einstein ended up rejecting the idea of dark energy, saying it was too wild and a major mistake of his. But actually it's now been shown that apparently two-thirds of the energy of the universe is in a form not of matter but of an invisible kind of energy."

Webber admits this all sounds very metaphysical. Still, as scientists learn ever more about the workings of the universe, ideas that seemed like laughable science fiction a few decades ago are now proving true.

In the 1970s when Webber wa teaching Astronomy 101 to colleg students, the existence of blac holes was just a far-out theor Black holes were thought to be va areas in space with gravitation fields so powerful that neither ligh nor matter could escape.

Today, because of the advanc ment of radio astronomy, it's bee virtually proven that black hol exist. At least their existence is t only thing that can explain thes areas, given our current knowledg of the laws of the universe.

Another thing that fascinate Webber and his colleagues is hov interconnected everything in th universe seems to be. Everythin from the smallest particle to th largest seems to fit into a cosmi puzzle that is just now starting to b understood.

More and more powerful radi telescopes are being created in orde to explore these mysteries in space Recently the Robert C. Byrd Green Bank Telescope in Green Bank W.Va., has gone into operation.

The addition at Green Bank is th largest fully moveable radio telescop in the world. It's 485 feet tall an weighs 16 million pounds. The mas sive size allows it to be pointed with an accuracy of one arcsecond, which i equivalent to the width of a human hair seen six feet away.

Green Bank will study galaxies planets, asteroids, molecules in space and pulsars, which are tiny spinning stars that give off regular pulses of radio waves. About 200 scientists from around the world will visit there each year to gather information.

Green Bank is the site where NRAO first put down roots in 1956. When scientists started complaining about being isolated there, the management of the observatory began looking for a population center to move its administrative offices and laboratories.

Charlottesville was chosen because it was only a two-hour drive away and had the University of Virginia. NRAO receives no funding from the university, but UVa's astronomy department, like countless others, reaps the knowledge NRAO gathers.

With MAP hard at work and NRAO dishes constantly receiving new data, knowledge is being gained faster than ever before.

Webber feels what drives man to learn more and more comes from a basic human thirst for answers to some of life's biggest questions.

Questions such as: Who are we? How do we fit into the universe? Are we alone?

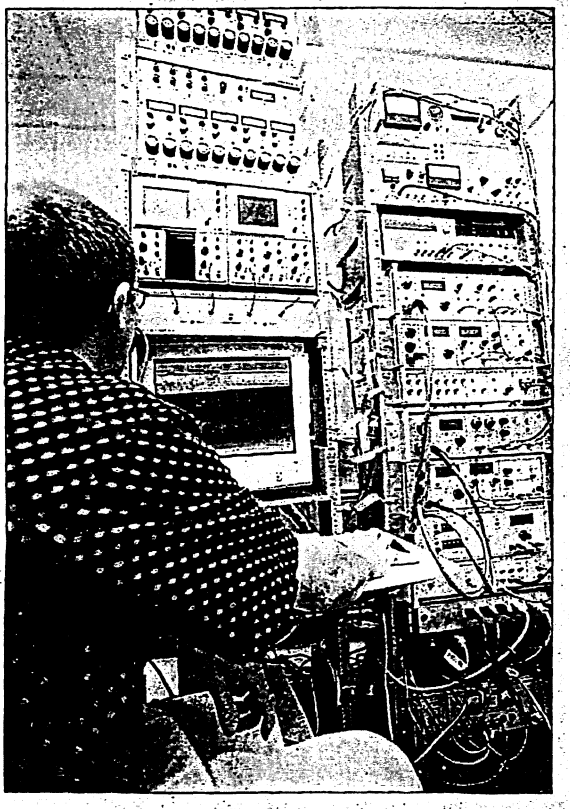
"I think people are interested in how the universe is put together and how it works," Webber said. "Look up at the sky at night and see all those stars and look in books and magazines and see pictures of objects you can see with telescopes.

"We see beautiful nebulae of different colors and exploded stars with colored rings around them. We see pictures of galaxies made of hundreds of millions of stars.

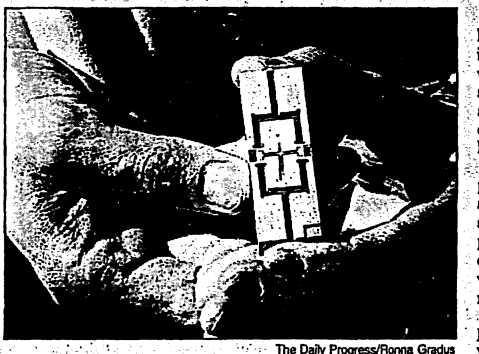
"It's only natural to wonder what our place is in all of this. How did we get here? What does the future hold?"

The Daily Progress/Ronna Gradus

NRAO's John Webber (right) shows Charles Blue one of the blocks that house microscopic transistors.



Technical specialist Kirk Crady works at a refrigerator and test station.



The Daily Progress/Ronna Gradus

The block's smallest detail measures at 1/5,000 of an inch.

The Daily Progress photos/Ronna Gradus

Tony Marshall, a machine shop foreman, works at precision milling machine.

Vine

ntinued from E1

set. Soon after the ship set sail

When Mazzei returned to Colle in 1783 he found his grape grow

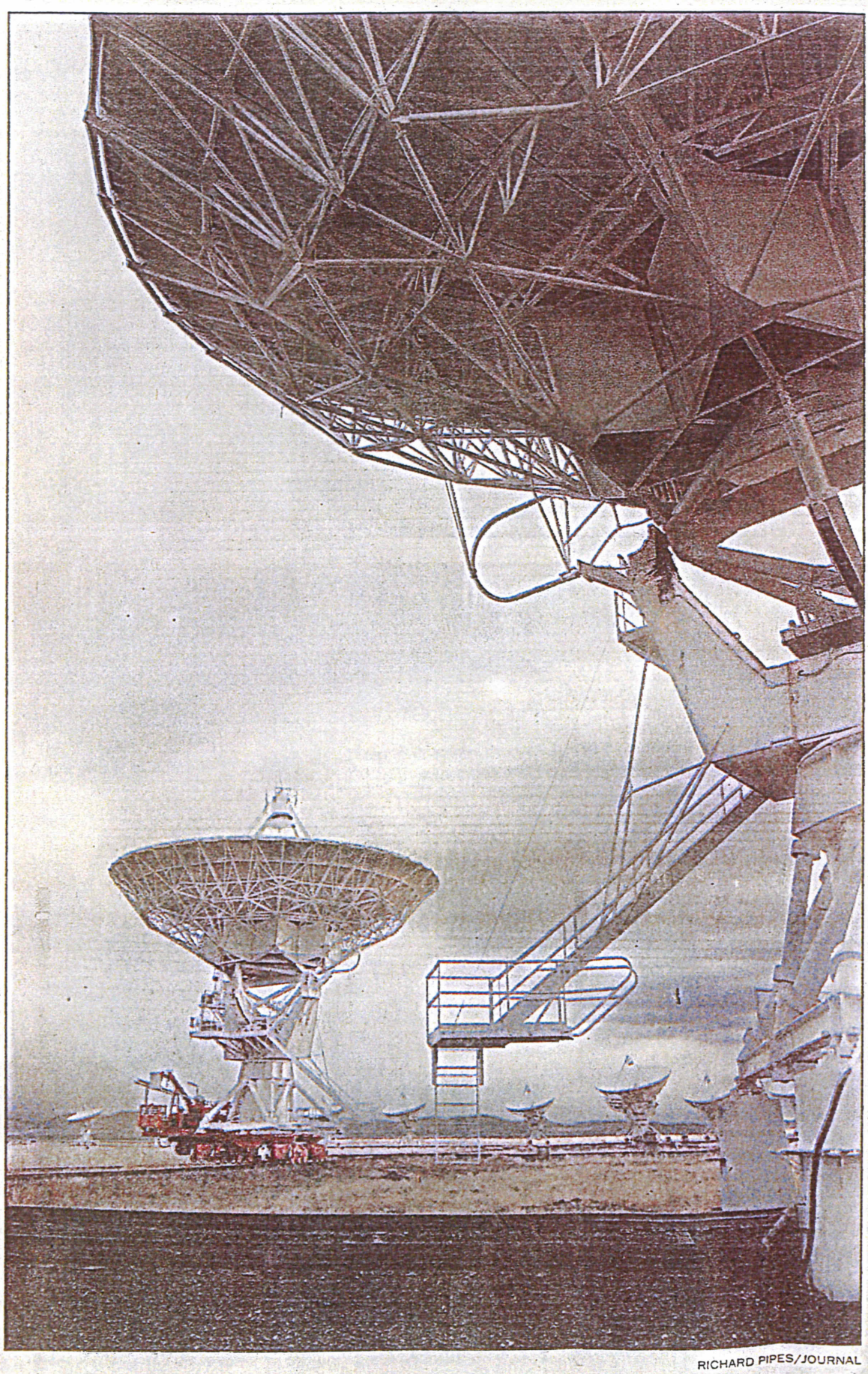
in 1788.

The work became the first history of the American Revolution available in Europe. It soon earned a reputation for being a

Prussia divided the country up, he fled.

Mazzei moved to Pisa, Italy, in 1792. The small town situated on the Tyrrhenian coast made a

STAR TOURS START SOON



RICHARD PIPES/JOURNAL

A transporter moves a radio telescope into a new configuration last week at the Very Large Array on the Plains of San Agustin, west of Socorro. The array, which collects naturally emitted radio waves from stars and galaxies, will be open Saturday for special guided tours. Story, B8.

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NEW MEXICO'S LEADING NEWSPAPER
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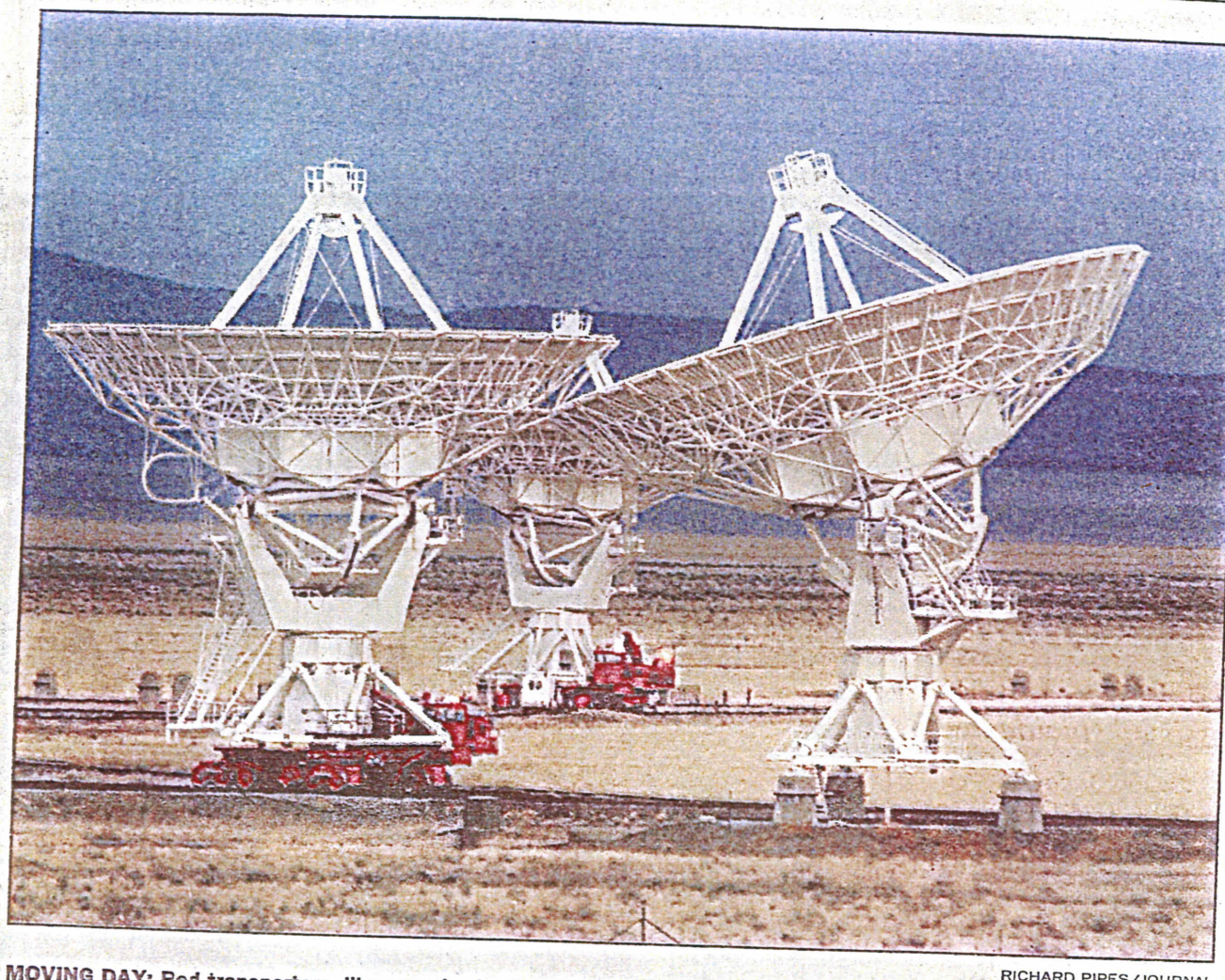
cities across 38 states. The
documents the cities from
1997, was published in t
issue of Preventive Magaz

He also says the department should test trucks it owns and get them fixed

department, said he was concerned when he learned about the issue and

It's an ongoing program. Trucks are going for repairs one at a time, he said.

day.



RICHARD PIPES/JOURNAL

MOVING DAY: Red transporters, like oversized railroad flatcars, move the Very Large Array's antennas into a new configuration last week. The array will be open for special guided tours Saturday.

Guides To Show Off VLA

Tours of the Very Large Array will be offered to visitors who may have questions about the 27 radio dish antennas

By John Fleck
Journal Staff Writer

New Mexicans have a special chance to tour one of the state's premier scientific institutions when the Very Large Array holds a day of special tours Saturday, according to spokesman Dave Finley.

Located on the Plains of San Agustin, the VLA uses 27 radio dish antennas, each 82 feet in diameter, to collect naturally emitted radio waves from stars and galaxies.

Funded by the federal government's National Science Foundation, the VLA is part of the National Radio Astronomy Observatory, an organization that operates radio telescopes across the western hemisphere.

The telescope is 22 years old, having been commissioned in 1980.

The VLA has an unstaffed visitor center that is open year-round, with self-guided tours for visitors. But guided tours are a relative rarity.

On Saturday, observatory staff will be on hand to give tours and answer questions about the array's scientific work, according to Finley. The tours begin at 10 a.m., noon and 2 p.m., he said, and no reservations are necessary.

The array is 50 miles west of Socorro on Highway 60. Signs lead from the highway to the visitor center.

Girl's Death 'Horrible Accident'

By Jeremy Packwood
Journal Northern Bureau

"His (Steve Alverson's) daughter used to come

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Dark Matter, Real Matter Work in Concert to Build Cosmos

Understanding Dark Matter and Light Energy

Probing Matter in the Early Universe

By SPACE.com Staff
posted: 10:21 am ET, 03 January 2002

Astronomers again have confirmed that the amount of normal matter created in the Big Bang is only a small portion of the total matter that must exist based on the gravitational effects seen in galaxies and large clusters of galaxies.

Just 13 percent of the universe is thought to be composed of "normal" matter, according to a recent study. Normal matter is anything made of baryons, subatomic particles that include neutrons and protons -- the stuff of plants, rocks and people.

The balance of material that must be out there is called "dark matter." Some of this is simply normal matter that can't be seen -- cold, dead stars and small rocks, for example. But the bulk of dark matter is thought to involve mysterious, unseen particles.

Researchers say dark matter is needed to explain why galaxies don't fly apart.

In the new study, astronomers spent two decades measuring helium-3, a rare isotope of helium that is thought to be a primordial element -- one that has been around since the universe began. Among their results was the discovery that helium-3 does not seem to be created or destroyed during star formation, so the amount they measured in our galaxy is likely representative of how much was present just moments after the Big Bang.

The results were presented in the Jan. 3 issue of the journal *Nature*.

"Moments after the Big Bang, protons and neutrons began to combine to form helium-3 and other basic elements," said Robert Rood of the University of Virginia. "By accurately measuring the abundance of this primordial element in our galaxy today, we were able infer just how much matter was created when the universe was only a few minutes old."

Rood and his colleagues, Thomas Bania from Boston University and Dana Balser from the National Radio Astronomy Observatory, conducted their study using the National Science Foundation's 140-foot radio telescope in Green Bank, West Virginia.

The researchers looked throughout the Milky Way Galaxy

for helium-3. No matter where they looked -- in areas of intense star formation or in quieter regions -- the relative abundance of helium-3 remained constant.

"Since helium-3 has not been created or destroyed in our Galaxy in any appreciable amounts, then what we detected is most likely equal to the abundance of primordial helium-3 created by the Big Bang," Bania said.

Bania added that the finding will force astronomers to rethink models of star formation and even the inner workings of the Sun.

More about Cosmology: Astronomy News by Topic

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Element reveals abundance of matter in early Universe

NATIONAL RADIO ASTRONOMY OBSERVATORY NEWS RELEASE
Posted: January 3, 2002

Astronomers using the National Science Foundation's 140 Foot Radio Telescope in Green Bank, W.Va., were able to infer the amount of matter created by the Big Bang, and confirmed that it accounts for only a small portion of the effects of gravity observed in the Universe. The scientists were able to make these conclusions by determining the abundance of the rare element helium-3 (helium with only one neutron and two protons in its nucleus) in the Milky Way Galaxy.

"Moments after the Big Bang, protons and neutrons began to combine to form helium-3 and other basic elements," said Robert Rood of the University of Virginia. "By accurately measuring the abundance of this primordial element in our Galaxy today, we were able infer just how much matter was created when the Universe was only a few minutes old." Rood and his colleagues, Thomas Bania from Boston University and Dana Balser from the National Radio Astronomy Observatory (NRAO), report their findings in the January 3 edition of the scientific journal Nature.

Rood began searching for helium-3 in the Milky Way Galaxy in 1978. At that time, scientists believed that stars like our Sun synthesized helium-3 in their nuclear furnaces. Surprisingly, Rood's observations indicated that there was far less of this element in the Galaxy than the current models predicted. "If stars were indeed producing helium-3, as scientists believed, then we should have detected this element in much greater concentrations," he said.

This unexpected discovery prompted Rood and his colleagues to broaden their search, and to look throughout the Milky Way for signs of stellar production of helium-3. Over the course of two decades, the researchers discovered that regardless of where they looked - whether in the areas of sparse star formation like the outer edges of the Galaxy, or in areas of intense star formation near center of the Galaxy - the relative abundance of helium-3 remained constant. By concurrently measuring the amount hydrogen (also created by the Big

Bang) in the same areas, the scientists were able to determine the relative abundance of helium-3.

"Since stellar processes appear to have little or no impact on the amount of helium-3 in the Galaxy, we were able to deduce two very important things," said Bania. "First, since our current models predict stellar production of helium-3, then we will need to rethink our understanding of the internal workings of stars like our Sun. Second, since helium-3 has not been created or destroyed in our Galaxy in any appreciable amounts, then what we detected is most likely equal to the abundance of primordial helium-3 created by the Big Bang."

The scientists were able to use this discovery to calculate how much "normal" matter was created during the Big Bang. (Normal matter is anything made of baryons, subatomic particles that include neutrons and protons.) The researchers made these calculations by taking what they know of the composition of the Universe today, and essentially running time in reverse. In this case, the ratio of helium-3 to hydrogen gives the ratio of baryons to photons (the density of radiation) just after the Big Bang. By using the rate of expansion of the Universe, given by the Hubble Constant, the scientists could then infer just how much normal matter was produced during the Big Bang.

"Our findings for helium-3 in fact support other studies that also constrain the amount of matter in the Universe," said Balser. "Taken together, these studies show that the matter that makes up stars, planets, and the visible Universe can only account for a small fraction of what we observe as the effects gravity in the Universe."

Dark matter, which can be both baryonic (dead stars, rocks, etc.) and non-baryonic, and other as-yet-unidentified forces appear to be the primary sources of the gravity that holds galaxies, and the larger structures of the Universe together. "The fact that most of the matter in the Universe is non-baryonic, that is to say not made of any particle we've ever seen on Earth, is a very exciting concept," commented Rood.

The astronomers conducted their research using measurements at a frequency of 8.665 GHz (3.46 cm), which is emitted naturally by ionized helium-3.

The 140 Foot Radio Telescope at the NRAO in Green Bank now is decommissioned after a long and highly productive career. "Though the 140 Foot Telescope enabled us to make remarkable observations," commented Rood, "we anticipate

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- Disk resembling asteroid belt found around star
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that the new Robert C. Byrd Green Bank Telescope will greatly increase our ability to continue this research."

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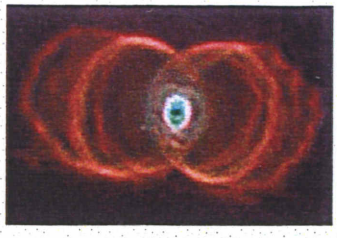
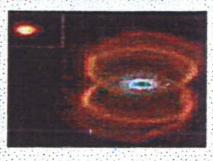


Astronomers Untangle Source of the Prettiest Pictures in Space

By SPACE.com Staff
posted: 07:00 am ET
04 November 2002

Among Nature's most beautiful constructs are symmetrical planetary nebula, huge cocoons of ga surrounding old stars. But astronomers have not been sure why the streaming filaments of color myriad shapes, such as the classic hourglass, instead of being spherical.

Images



The so-called Hourglass planetary nebula. The inset image is of an old red giant star, similar to those in the new observations. Both photos were taken by the Hubble Space Telescope.

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The prime suspect has long been magnetism, and a new study provides the first conclusive proo astronomers said Friday.

An international team of astronomers has made new observations that show that the magnetic fie four aging stars are at least 10 times stronger than that of our own Sun. This magnetism directs t the nebulae.

Planetary nebulae are mis-named because when astronomers first began to notice them with ear telescopes, they looked like planets, mere smudges of light in the sky. More powerful ground-bas telescopes and more recently the Hubble Space Telescope, have since brought the amazing det of these objects to life.

Here's how planetary nebulae are thought to form:

When stars like our Sun reach the end of their lives, they eject a large amount of material into the around them. This material, produced by nuclear fusion reactions in the star, forms a thick shell c dust. The material flows in a turbulent manner, but is also directed by the magnetic field lines.

The ejected material, containing elements such as carbon and oxygen, in eventually recycled int and planets and the building blocks of life itself.

The group, lead by Wouter Vlemmings of Leiden Observatory, observed four old stars with the U. Science Foundation's Very Long Baseline Array, a network of 10 radio telescopes operated by th National Radio Astronomy Observatory.

They detected radio emissions originating from clouds of water vapor ejected by the stars. In son circumstances, such a cloud can become a maser: the equivalent of a laser for radiation with lon wavelengths. One specific frequency of the emitted radiation, which is characteristic of water mol amplified enormously, resulting in a bright, clear signal. In this signal, the group detected a so-cal Zeeman-effect for the first time: subtle changes in the spectrum of the emission that can only be strong magnetic field at the location of the maser.

The effect is named after Pieter Zeeman, a 1902 Nobel Prize winner who discovered the effect of field on the spectrum of a light source in 1896.

The water masers occur at a large distance from the star -- about twice the distance between the Pluto -- so the magnetic field strength at the surface of the star must be much higher: The resear is 10 to 100 times the surface magnetic field strength of the Sun. This is sufficiently strong to play important role in the formation of non-spherical planetary nebulae, they said.

The work is detailed in the journal *Astronomy & Astrophysics*.

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January 8, 2002

In Dark Matter, New Hints of a Universal Glue

By DENNIS OVERBYE

Sometimes, defying its wont, science makes the cosmos look a little simpler. Recently it seems as if astronomers have been sprung from a long cosmological nightmare. Last month a consortium of astronomers announced that an analysis of some 130,000 galaxies showed that the the universe, at least on large scales, is structured pretty much the way it looks.

That might sound unremarkable, but it didn't have to come out that way.

"It was not a mad idea that galaxies don't trace the matter," said Dr. Licia Verde, an astronomer at Rutgers and Princeton Universities, who was the lead author of a paper submitted last month to the journal Monthly Notices of Royal Astronomical Society.

The reason is something called dark matter.

For centuries people have found meaning — or thought they did — in the sky, in the forms of the constellations, the sudden careering of comets, the stately dance of the planets, the filigree of galaxies, spanning space as far as the telescope can see, like an old jeweled fishing net cast across the void.

But what if all this is just an illusion? Suppose the real universe is something we can't see and all the glittering chains of galaxies are no more substantial, no more reliable guides to physical reality, than greasepaint on the face of a clown?

That was the humiliating prospect that astronomers faced in the 1980's, as they grudgingly came to accept that decades of astronomical observations were telling them that most of the universe was invisible. They could deduce that dark matter was there by its gravitational effect on the things they could see. If Newton's laws of gravity held over cosmic distances, huge amounts of it were needed to provide the gravitational glue to keep clusters of galaxies from flying apart, and to keep the stars swirling around in galaxies at high speed.

Cosmologists concluded that it was in fact dark matter, slowly congealing under its own weight into vast clouds that provided the scaffolding for stars and galaxies. And it was dark matter that would determine the fate of the universe: if there was enough of it, gravity would eventually reverse the expansion of the universe and cause a "big crunch." If not, the universe would expand forever.

Most gallingly, astronomers didn't even know whether the dark matter was

distributed the way stars and galaxies are. They had no clue to the whereabouts of most of the universe. Luminous matter, the story went, is like snow on mountaintops or foam on waves, but there could, in theory, be whole mountain ranges not quite high enough to be whitecapped, hiding in the darkness.

Noting that dark matter heavily outweighed the visible galaxies, four astronomers analyzed the results of an earlier galaxy mapping project, in 1980. There was no reason the ratio of dark to light matter should be the same everywhere "and there may well exist massive systems that emit essentially no light," read the report in the Astrophysical Journal, written by Marc Davis, John Huchra, David Latham and John Tonry, all then at the Harvard-Smithsonian Center for Astrophysics.

Or as Dr. Vera C. Rubin, an astronomer at the Carnegie Institute of Washington and a pioneer of dark matter research, said a year later: "We know very little about the universe. I personally don't believe it's uniform and the same everywhere. That's like saying the earth is flat."

The new results suggest that the universe, as mysterious as it essentially is, may not be entirely perverse. As Einstein once said, "The Lord God is subtle, but malicious he is not." But it was a close call.

"In principle galaxies could bear no resemblance to the underlying dark matter distribution," explained Dr. Verde, who performed the analysis with Dr. Alan F. Heavens of the University of Edinburgh.

"We were right to be worried," Dr. Heavens said.

The notion that the luminous universe might only be greasepaint was born of the quest for beauty. In the 1980's astronomical surveys showed that the galaxies were not distributed more or less uniformly around the sky, as had been thought, but were concentrated in sheets and clusters and long looping chains separated by huge, black, presumably empty spaces millions of light-years across.

But the gravitational pull from such striking disparities in the distribution of mass would tug the galaxies to and fro violently, distorting the orderly expansion of the universe, if the most fashionable cosmological theories were right.

Those theories held that the density of matter and energy in the universe was just high enough so that the gravitational attraction between the contents of the cosmos would eventually just balance the energy of their outward rush. As a result, space on the largest scales would show no geometrical warp: it would be "flat," in cosmological jargon.

Whatever wayward velocities the galaxies had, however, was relatively modest. Rather than give up the mathematically beautiful notion of a high density universe, some theorists suggested that astronomers might have to give up an equally beautiful and seemingly bedrock notion, namely that the universe is

what we see when we look up at the sky.

If the voids were just an illusion, and were not empty but just dark, cosmologists reasoned, there would be no gravitational fields tugging at the galaxies, which would explain why their so-called peculiar velocities were so low. They could keep their beautiful universe.

As the primordial clouds of dark matter grow and congeal, so this theory went, ordinary matter sinks to the center and lights up. But vast stretches of dark matter outside the center would go unflagged by visible galaxies, like mountains not quite high enough to attract snow, or reefs unmarked by buoys.

Figuring out exactly why galaxies would have formed in this pattern was another matter that engaged theorists' imaginations. Dr. Martin Rees, a cosmologist at Cambridge University and the astronomer royal of England, said he could imagine that galaxy formation could be catalyzed or impeded by some environmental event. Fierce radiation from the first quasars, for example, could ionize the protogalactic gas over large swaths of space, affecting its ability to collapse and light up.

In the 1990's, though, evidence began to mount, from the COBE satellite, which studied faint radio emanations from the Big Bang itself, and from other studies, that the density of matter was less than a third of the magic critical value needed for a perfectly "flat" universe.

In that case the clusters do not have the gravitational oomph to cause trouble and the lack of high velocities is not a problem. Luckily, theorists could still have a flat beautiful universe because the gap in the matter density was made up by the so-called dark energy that astronomers have recently discovered seems to be accelerating the expansion of the universe. But it is no longer a universe in balance; if the dark energy continues to prevail, astronomers say, the cosmos will blow apart, chilling all life.

In recent years, therefore, dark matter has surrendered some of its cachet to dark energy, but the identity of the dark matter is as mysterious as it ever was. Some of it may be ordinary matter, like rocks and dead stars. But most of it must be more exotic stuff — perhaps elementary particles left over from the Big Bang — according to a study published last week in the journal Nature by Dr. Robert Rood of the University of Virginia, and his colleagues. They measured the abundance of a rare form of helium in the Milky Way to determine the amount of "normal" matter produced in the Big Bang.

Nevertheless, the relationship between the light and the dark, once raised, continued to haunt astronomers. "It was perfectly reasonable if galaxies didn't cluster the same way as mass," said Dr. Heavens, adding, "the genie was out of the bottle."

He and Dr. Verde set out to measure the degree, technically known as bias, to which the distributions of luminous and dark matter were mismatched, using statistical techniques she had developed for her Ph.D. dissertation under his

supervision.

For a database, they turned to a catalog of the relative distances and positions on the sky of 130,000 galaxies that had been compiled by an international consortium of astronomers known as the 2-Degree Field Galaxy Redshift Survey, or 2dF for short, using the 12-foot-diameter Anglo-Australian Telescope near Coonabarabran, Australia.

By the time it is finished, the survey, which takes its name from the field of view of the telescope, should have mapped 250,000 galaxies out to a distance of around 500 million light-years.

As Dr. Verde explained, she and Dr. Heavens used statistics to analyze the shapes of the galaxy clusters in the sky. According to gravity theory and computer simulations, she said, dark matter, which only interacts gravitationally, should start out in rounded lumps and then gradually shape itself into filaments and sheets as these lumps collapse along their shortest axes first.

"The signature of gravity is filaments," Dr. Verde said. "If there is biasing you get a distribution that is not sheets and filaments — you get a different pattern."

The results, she and Dr. Heavens said, were clearly consistent with a filamentary structure, "like a web, not round hills and mountains."

"You would have to come up with a theory quite mad to get this pattern with biasing," Dr. Verde said. "Taken together, these measurements argue powerfully that the 2dFGRS galaxies do indeed trace the mass on large scales," she and 29 co-authors concluded in the recent paper.

The mountains are where the snow is. The universe is where the light is. Dr. Rees added: "2dF shows that things hang together. It could have not been that way. There is no evidence for enormous dark somethings with no galaxies associated with them."

At least in the present universe.

"Five billion years ago we would have gotten a different answer," said Dr. Heavens, explaining that galaxies probably did form first in concentrations at the centers of dark matter clouds but gradually spread into the hinterlands over cosmic history to reflect more accurately the overall distribution of matter, the as yet unknown cosmic stuff.

On average, galaxies today trace mass, and the astronomy of the invisible is thus also the astronomy of the visible.

Of course it was by following the light that astronomers were led into the darkness. Like the proverbial drunk looking under the streetlight for his keys, they never had any choice about where to look for the universe. "Thirty years ago we thought the universe was all stars. Now stars are just the tip of the

iceberg," said Dr. Michael Turner, a cosmologist at the University of Chicago. "There was a worry that the light in the sky was not faithfully tracing the distribution of matter. Large surveys went out looking for clumps of matter that didn't correspond to light.

"That story is now starting to come to an end."

Now if someone would just do something about that dark energy.

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Reach for the stars

NRAO director plans VLA expansion, local involvement

ROBERT MAGILL
EL DEFENSOR CHIEFTAIN

19 DEC 01

For Jim Ulvestad, Socorro isn't just any desert town.

"Almost every research astronomer in the world has heard of Socorro," he said. "This little town is really one of the few hubs for astronomy."

Ulvestad isn't just any astronomer. Earlier this month, he started as director of the Very Large Array/Very Long Baseline Array operations at the National Radio Astronomy Observatory here in Socorro.

"All of the people employed by the NRAO report to Jim," said Robert Brown, NRAO's deputy director, based in Charlottesville, Va.

As director of NRAO operations in New Mexico, Ulvestad has a distinct vision of the VLA's place in the field of astronomy and in the Socorro community.

Astronomy has captured the imagination through pop culture in movies like "Contact," which was filmed at the VLA. Ulvestad said if astronomers at the NRAO look at something far across the universe 5 billion light years away, they are looking at something that happened before the earth was formed.

"We're essentially looking back in time," he said. "That should be a very big deal."

Community

Peering into the heavens and looking back in time is part of the daily routine in Socorro.

"We all have a curiosity about the universe," Ulvestad said. "Right here in (Socorro's) backyard, we're learning things about the universe that nobody else can learn."

Scientists who make these discoveries look forward to coming to Socorro, and may be seen around town.

See **Ulvestad,** *Page 5*

Ulvestad: Socorro can be proud of astronomers

Continued from page 1

"If people in Socorro see these astronomers wander through El Sombrero or the (Socorro Springs) brew pub, they can be proud of that," Ulvestad said.

To augment its community presence, the NRAO is expanding its education program in Socorro.

"We've always been forthcoming about doing tours for Socorro schools," Ulvestad said. "We've just expanded our program by hiring a new education officer. One of the things we'll be doing over the next several years is expanding our program to work with the local schools."

He said the NRAO will meet with teachers from Socorro and as far away as Reserve and Truth or Consequences to find out how it can serve the schools better.

"They (teachers) went to school to get degrees in education or science education, but they don't necessarily know very much about astronomy," Ulvestad said. "One of the things we want to do is help them be able to teach astronomy and help bring the excitement of that into their schools."

Such teaching, he said, can be used as a tool to help students think analytically and understand how the scientific process works.

"If we can get our education program expanded into the local schools more, I think we can play a big role there," Ulvestad said.

Astronomy

Socorro's place in the world of astronomy is unique because the research done here is on a scale unparalleled anywhere else in the world — especially with new expansions at the VLA, Ulvestad said.

"The VLA is the most scientifically productive ground-based telescope in the world," said Dave Finley, NRAO public education officer.

Under Ulvestad, Brown said, "the big initiative at the observatory is the EVLA (Expanded Very Large Array)."

The mechanics of the VLA is based on 1970s technology and will be updated for the 21st century.

The first phase of the VLA's overhaul includes what Ulvestad described as a brain and circulatory system transplant, scheduled to be finished around 2009.

"It involves taking the current antennas and completely overhauling their electronics and putting in fiber optics, essentially putting in a new brain," said Ulvestad, who has worked periodically with the VLA since the late 70s.

He said the new "brain" will be a special-purpose data processor that will combine all the data from all the telescopes.

■ *See* **Ulvestad,** *Page 3*

Ulvestad: VLA will be in world's most efficient telescope

Continued from page 5

"The other part of the VLA expansion will be to expand it physically around the state of New Mexico," Ulvestad said.

Ulvestad

This phase of the expansion will be called the New Mexico Array, which will include eight new antennas around the state and fiber links to the Very Long Baseline Array, which uses antennas from all over North America.

Ulvestad said the sites for those antennas has not been decided. The physical expansion is a $75 million to $100 million project, Ulvestad added.

While there are other observatories around the world that do research similar to that done in Socorro, the VLA's imaging capabilities are superior to others. The VLA has 27 antennas and observes the heavens at 50 megahertz — a much higher frequency than the other arrays.

"We can study a lot of phenomena (the other arrays) can't study," Ulvestad said. "If you're observing at a 10-times higher frequency, you have 10 times the resolution."

He said the VLA's observing potential makes it a great candidate for expansion.

"We have those 27 big antennas sitting out there," he said, "and building antennas like that probably costs $6 million each. Nobody's ever going to do that again. We can take advantage of that by completely overhauling the electronics."

Because there are so many residents in Socorro with different backgrounds and philosophies, they can appreciate the meaning of the research done at the VLA, Ulvestad said.

"Whether it's about how stars form and how that relates to how planets form — and how that relates to how life forms — in terms of understanding things that are a part of the universe," he said, "I think that should be a very big deal to the people around here. (They) should take that as their own."

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