NRAO in the NEWS

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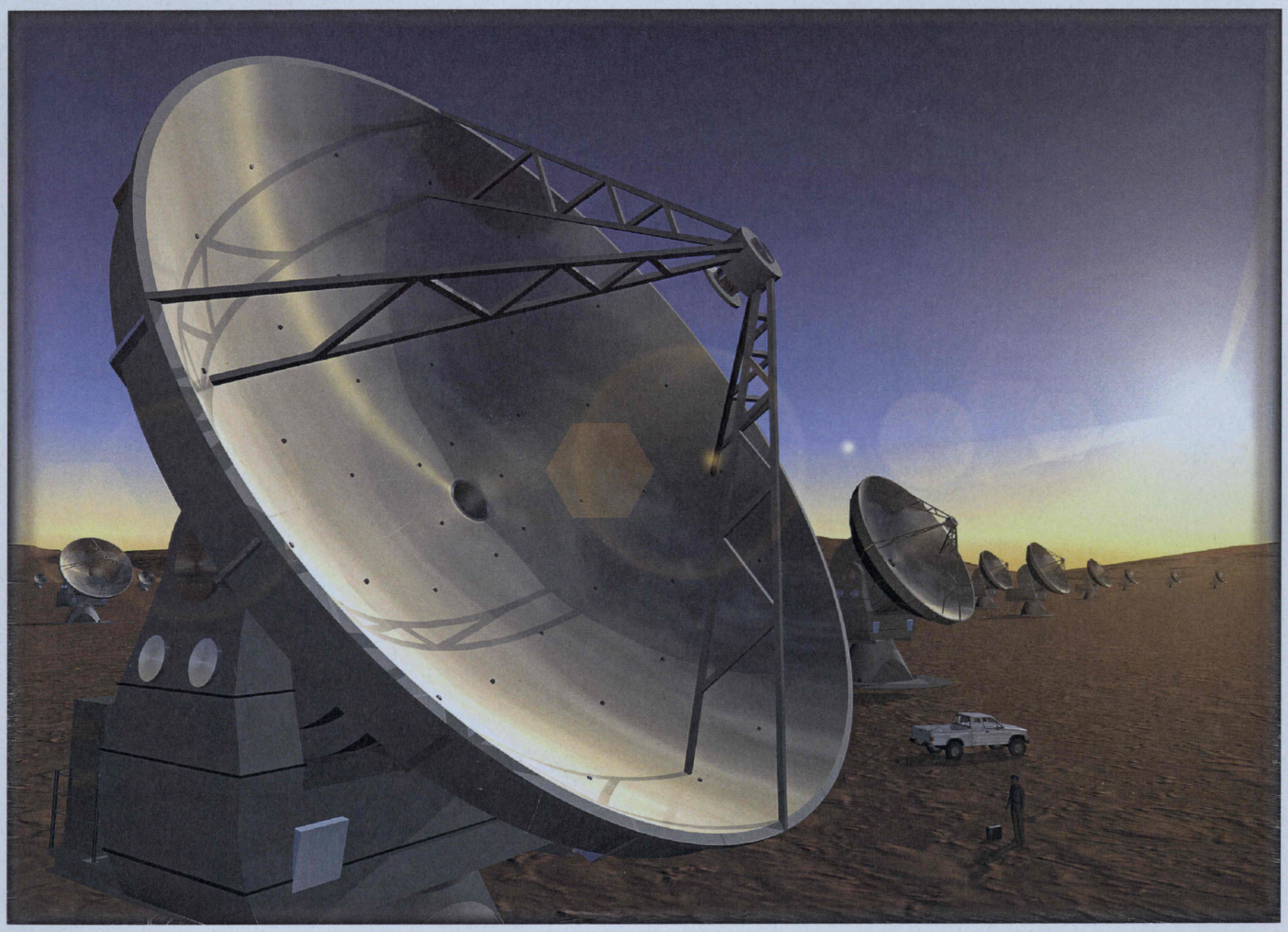

January 2003 — March 2004

PRESS RELEASES

National Radio Astronomy Observatory

Thursday, April 1, 2004

February 3, 2004

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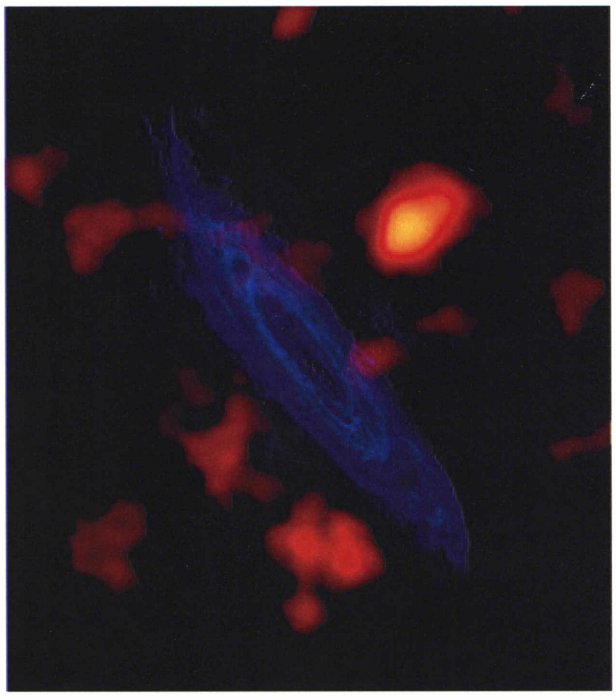
Galactic Building Blocks Seen Swarming Around Andromeda

Green Bank, WV - A team of astronomers using the National Science Foundation's Robert C. Byrd Green Bank Telescope (GBT) has made the first conclusive detection of what appear to be the leftover building blocks of galaxy formation -- neutral hydrogen clouds -- swarming around the Andromeda Galaxy, the nearest large spiral galaxy to the Milky Way.

This discovery may help scientists understand the structure and evolution of the Milky Way and all spiral galaxies. It also may help explain why certain young stars in mature galaxies are surprisingly bereft of the heavy elements that their contemporaries contain.

"Giant galaxies, like Andromeda and our own Milky Way, are thought to form through repeated mergers with smaller galaxies and through the accretion of vast numbers of even lower mass 'clouds' -- dark objects that lack stars and even are too small to call galaxies," said David A. Thilker of the Johns Hopkins University in Baltimore, Maryland. "Theoretical studies predict that this process of galactic growth continues today, but astronomers have been unable to detect the expected low mass 'building blocks' falling into nearby galaxies, until now."



Thilker's research is published in the Astrophysical Journal Letters. Other contributors include: Robert Braun of the Netherlands Foundation for Research in Astronomy; Rene A.M. Walterbos of New Mexico State University; Edvige Corbelli of the Osservatorio Astrofisico di Arcetri in Italy; Felix J. Lockman and Ronald Maddalena of the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia; and Edward Murphy of the University of Virginia.

The Milky Way and Andromeda were formed many billions of years ago in a cosmic neighborhood brimming with galactic raw materials -- among which hydrogen, helium, and cold dark matter were primary constituents. By now, most of this raw material has probably been gobbled up by the two galaxies, but astronomers suspect that some primitive clouds are still floating free.

This image depicts several long-sought galactic "building blocks" in orbit of the Andromeda Galaxy (M31). The newfound hydrogen clouds are depicted in a shade of orange (GBT), while gas that comprises the massive hydrogen disk of Andromeda is shown at high-resolution in blue (Westerbork Sythesis Radio Telescope).

CREDIT: NRAO/AUI/NSF, WSRT
(Click on Image for Larger Version)

Previous studies have revealed a number of clouds of neutral atomic hydrogen that are near the Milky Way but not part of its disk. These were initially referred to as high-velocity clouds (HVCs) when they were first discovered because they appeared to move at velocities difficult to reconcile with Galactic rotation.

Scientists were uncertain if HVCs comprised building blocks of the Milky Way that had so far escaped capture, or if they traced gas accelerated to unexpected velocities by energetic processes (multiple supernovae) within the Milky Way. The discovery of similar clouds bound to the Andromeda Galaxy strengthens the case that at least some of these HVCs are indeed galactic building blocks.

Astronomers are able to use radio telescopes to detect the characteristic 21-centimeter radiation emitted naturally by neutral atomic hydrogen. The great difficulty in analyzing these low-mass galactic building blocks has been that their natural radio emission is extremely faint. Even those nearest to us, clouds orbiting our Galaxy, are hard to study because of serious distance uncertainties. "We know the Milky Way HVCs are relatively nearby, but precisely how close is maddeningly tough to determine," said Thilker.

Past attempts to find missing satellites around external galaxies at well-known distances have been unsuccessful because of the need for a very sensitive instrument capable of producing high-fidelity images, even in the vicinity of a bright source such as the Andromeda Galaxy.

One might consider this task similar to visually distinguishing a candle placed adjacent to a spotlight. The novel design of the recently commissioned GBT met these challenges brilliantly, and gave astronomers their first look at the cluttered neighborhood around Andromeda.

The Andromeda Galaxy was targeted because it is the nearest massive spiral galaxy. "In some sense, the rich get richer, even in space," said Thilker. "All else being equal, one would expect to find more primordial clouds in the vicinity of a large spiral galaxy than near a small dwarf galaxy, for instance. This makes Andromeda a good place to look, especially considering its relative proximity -- a mere 2.5 million light-years from Earth."

What the GBT was able to pin down was a population of 20 discrete neutral hydrogen clouds, together with an extended filamentary component, which, the astronomers believe, are both associated with Andromeda. These objects, seemingly under the gravitational influence of Andromeda's halo, are thought to be the gaseous clouds of the "missing" (perhaps dark-matter dominated) satellites and their merger remnants. They were found within 163,000 light-years of Andromeda.

Favored cosmological models have predicted the existence of these satellites, and their discovery could account for some of the missing "cold dark matter" in the Universe. Also, confirmation that these low-mass objects are ubiquitous around larger galaxies could help solve the mystery of why certain young stars, known as G-dwarf stars, are chemically similar to ones that evolved billions of years ago.

As galaxies age, they develop greater concentrations of heavy elements formed by the nuclear reactions in the cores of stars and in the cataclysmic explosions of supernovae. These explosions spew heavy

elements out into the galaxy, which then become planets and get taken up in the next generation of stars.

Spectral and photometric analysis of young stars in the Milky Way and other galaxies, however, show that there are a certain number of young stars that are surprisingly bereft of heavy elements, making them resemble stars that should have formed in the early stages of galactic evolution.

"One way to account for this strange anomaly is to have a fresh source of raw galactic material from which to form new stars," said Murphy. "Since high-velocity clouds may be the leftover building blocks of galaxy formation, they contain nearly pristine concentrations of hydrogen, mostly free from the heavy metals that seed older galaxies." Their merger into large galaxies, therefore, could explain how fresh material is available for the formation of G-dwarf stars.

The Andromeda Galaxy, also known as M31, is one of only a few galaxies that are visible from Earth with the unaided eye, and is seen as a faint smudge in the constellation Andromeda. When viewed through a modest telescope, Andromeda also reveals that it has two prominent satellite dwarf galaxies, known as M32 and M110. These dwarfs, along with the clouds studied by Thilker and collaborators, are doomed to eventually merge with Andromeda. The Milky Way, M33, and the Andromeda Galaxy plus about 40 dwarf companions, comprise what is known as the "Local Group."

Today, Andromeda is perhaps the most studied galaxy other than the Milky Way. In fact, many of the things we know about the nature of galaxies like the Milky Way were learned by studying Andromeda, since the overall features of our own galaxy are disguised by our internal vantage point. "In this case, Andromeda is a good analogue for the Milky Way," said Murphy. "It clarifies the picture. Living inside the Milky Way is like trying to determine what your house looks like from the inside, without stepping outdoors. However, if you look at neighbors' houses, you can get a feeling for what your own home might look like."

The GBT is the world's largest fully steerable radio telescope.

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

Thursday, April 1, 2004

NRAO Home > Press Releases > VLBA "Movie" Gives Scientists New Insights On Workings of Mysterious Microquasars

(Print Friendly Version)

***Embargoed* For Release: 11:00 a.m., EST, Monday, January 5, 2004**

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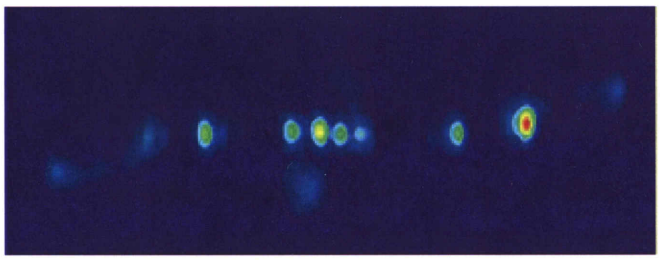
VLBA "Movie" Gives Scientists New Insights On Workings of Mysterious Microquasars

Astronomers have made a 42-day movie showing unprecedented detail of the inner workings of a strange star system that has puzzled scientists for more than two decades. Their work is providing new insights that are changing scientists' understanding of the enigmatic stellar pairs known as microquasars.

"This once-a-day series of exquisitely-detailed images is the best look anyone has ever had at a microquasar, and already has made us change our thinking about how these things work," said Amy Mioduszewski, of the National Radio Astronomy Observatory (NRAO), in Socorro, New Mexico.

The astronomers used the National Science Foundation's Very Long Baseline Array (VLBA), a system of radio telescopes stretching from Hawaii to the Caribbean, to follow daily changes in a binary-star system called SS 433, some 15,000 light-years from Earth in the constellation Aquila. Mioduszewski worked with Michael Rupen, Greg Taylor and Craig Walker, all of NRAO. They reported their findings to the American Astronomical Society's meeting in Atlanta, Georgia.

SS 433 consists of a neutron star or black hole orbited by a "normal" companion star. The powerful gravity of the neutron star or black hole is drawing material from the stellar wind of its companion into an accretion disk of material tightly circling the dense, central



Frame from SS 433 Movie:
End to end is some 200 billion miles.
CREDIT: Mioduszewski et al., NRAO/AUI/NSF

Image Files

Single Frame Overall Jet View (above image)

VLBA Movie (animated gif, 2.3 MB)

Animated graphic of SS 433 System (18MB)
(Created using software by
Robert Hynes, U.Texas)

object prior to being pulled onto that object. This disk propels jets of subatomic particles outward from its poles. In SS 433, the particles in the jets move at 26 percent of the speed of light; in other microquasars, the jet material moves at 90-95 percent of light speed. The disk in SS 433 wobbles like a child's top, causing its jets to move in a circle every 164 days.

Annotated brightening graphic

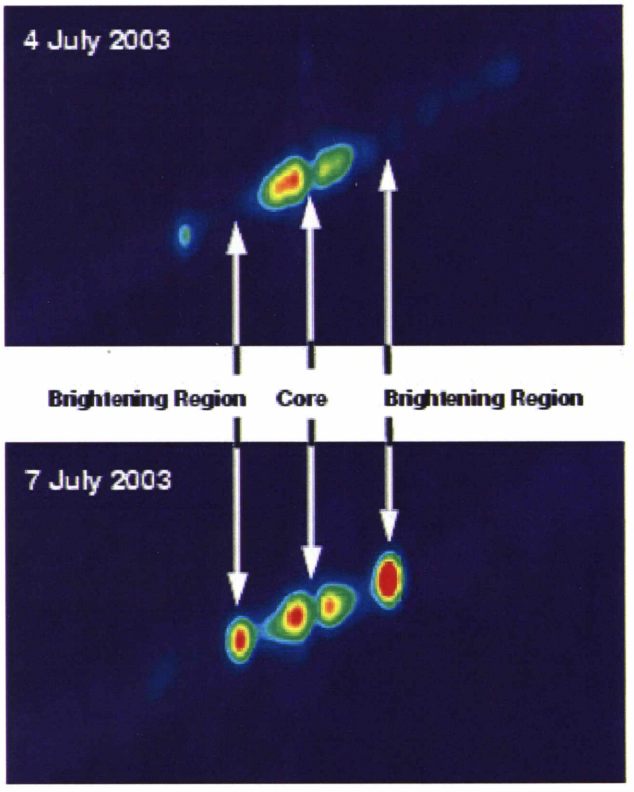
Unannotated brightening Frame 1

Unannotated brightening Frame 2

By imaging SS 433 daily, the astronomers were able to trace individual ejections of material in these jets as they moved outward from the center. In addition, they could track the jets' precession, the movement caused by the disk's wobble.

In other microquasars, blobs of material shot from the core become fainter, as seen with radio telescopes, as they move outward. However, in SS 433, blobs routinely brighten at specific distances from the core. From earlier studies, researchers had concluded that such brightening always occurs at one specific distance. The VLBA movie shows, instead, that there are multiple brightening regions and not all blobs brighten at all the regions.

"We think the ejected material brightens because it's slamming into something," Rupen said. "However, whatever it's hitting has to be replenished somehow so that the brightening can occur again when the jet sweeps through that area the next time," he added.



Mioduszewski et al., NRAO/AUI/NSF

"It also appears that it isn't always replenished, because the brightening doesn't always happen," Mioduszewski pointed out.

The VLBA movie revealed vital new information about another part of SS 433 -- material moving outward from the core, but not part of the superfast jets. This material moves outward in a direction not quite perpendicular to the direction of the jets. Discovered with the VLBA in 2000, this material had been seen only in one-time snapshots before, but the movie shows the steady evolution of its movement for the first time.

That motion was the key to a possible answer to two riddles -- the source of the slower-moving material itself and the source of whatever the jet blobs are hitting when they brighten.

"What seems most plausible to us is that the accretion disk is putting out a broad wind," Rupen explained.

That broad wind from the disk hits a denser wind coming from the "normal" companion star to generate the radio waves seen coming from the nonjet region. The same disk-generated wind could be the source of the material that replenishes the regions where the jet blobs brighten, the researchers say.

"The motion we measure for this slower-moving material is fast enough -- about 10,000 kilometers per second -- to put new material in a brightening region before the jet circles around to that spot again,"

Mioduszewski said.

Because accretion disks like that around the dense central star of SS 433 are known to be unstable, any wind put out by such a disk could vary, putting out symmetric chunks in opposite directions. This, the scientists think, may explain why the jet brightening regions don't always get replenished with the material needed to cause brightening.

"We still have more questions than answers about this microquasar, but the VLBA movie shows us that following the system on a daily basis with such greatly-detailed images is the most powerful tool available so far to understand these phenomena," Rupen said.

The astronomers now hope to follow SS 433 with the VLBA for an entire, 164-day cycle of the jet wobble. At the same time, they would like to observe the object with visible-light telescopes, then follow up with larger- scale images using the NSF's Very Large Array (VLA) radio telescope. The VLA images would trace blob motions in the jets beyond the distances traced with the VLBA.

SS 433 and Microquasars

SS 433 was first noted in the 1960s by astronomers Bruce Stephenson and Nicholas Sanduleak, who included it in a catalog they published of stars with unusual features in their spectra. As the 433rd object in Stephenson and Sanduleak's catalog, it became known as SS 433.

In 1978, David Clark and Paul Murdin identified SS 433 as the visible-light counterpart of a small object that had been found to be emitting both radio waves and X-rays. The small object also sat within a large supernova remnant called W50. Clark and Murdin, using the Anglo-Australian Telescope in Australia, also produced a spectrum of SS 433 that showed strange features. In addition, the object not only varied in its brightness, but features within the spectrum changed.

By 1979, further research, including work by Bruce Margon and George Abell, had shown that SS 433 was producing jets of material moving in opposite directions. The strange stellar system received a wealth of media coverage, dubbed "the star that is both coming and going" in one story. A 1981 *Sky & Telescope* article was entitled, "SS433 -- Enigma of the Century."

The late Robert Hjellming of NRAO spearheaded studies of motions within the radio-emitting jets of SS 433 in the early 1980s.

SS 433 was the first example of what are now termed microquasars, binary systems with either a neutron star or black hole orbited by another star, and emitting jets of material at high speeds. With the VLA's discovery of jets moving at 92 percent of the speed of light in an object called GRS 1915+105 in 1994, such systems became known as microquasars. Several others have since been discovered and studied.

Because microquasars in our own Milky Way Galaxy are thought to produce their high-speed jets of material through processes similar to those that produce jets from the cores of galaxies, the nearby microquasars serve as a convenient "laboratory" for studying the physics of jets. The microquasars are closer and show changes more quickly than their larger cousins.

The Very Long Baseline Array

The VLBA is a system of ten radio-telescope antennas, each with a dish 25 meters (82 feet) in diameter and weighing 240 tons. From Mauna Kea on the Big Island of Hawaii to St. Croix in the U.S. Virgin Islands, the VLBA spans more than 5,000

The VLBA

CREDIT: NRAO/AUI/NSF

miles, providing astronomers with the sharpest vision of any telescope on Earth or in space. Dedicated in 1993, the VLBA has an ability to see fine detail equivalent to being able to stand in New York and read a newspaper in Los Angeles.

The VLBA's scientific achievements include making the most accurate distance measurement ever made of an object beyond the Milky Way Galaxy; the first mapping of the magnetic field of a star other than the Sun; movies of motions in powerful cosmic jets and of distant supernova explosions; the first measurement of the propagation speed of gravity; and long-term measurements that have improved the reference frame used to map the Universe and detect tectonic motions of Earth's continents.

The VLBA is operated from the NRAO's Array Operations Center in Socorro, NM.

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

Thursday, April 1, 2004

NRAO Home > Press Releases > Astronomers Discover Most Distant Galaxy Showing Key Evidence For Furious Star Formation

(Print Friendly Version)

10 December 2003

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Astronomers Discover Most Distant Galaxy Showing Key Evidence For Furious Star Formation

Astronomers have discovered a key signpost of rapid star formation in a galaxy 11 billion light-years from Earth, seen as it was when the Universe was only 20 percent of its current age. Using the National Science Foundation's Very Large Array (VLA) radio telescope, the scientists found a huge quantity of dense interstellar gas -- the environment required for active star formation -- at the greatest distance yet detected.

A furious spawning of the equivalent of 1,000 Suns per year in a distant galaxy dubbed the Cloverleaf may be typical of galaxies in the early Universe, the scientists say.

"This is a rate of star formation more than 300 times greater than that in our own Milky Way and similar spiral galaxies, and our discovery may provide important information about the formation and evolution of galaxies throughout the Universe," said Philip Solomon, of Stony Brook University in New York.

While the raw material for star formation has been found in galaxies at even greater distances, the Cloverleaf is by far the most distant galaxy showing this essential signature of star formation. That essential signature comes in the form of a specific frequency of radio waves emitted by molecules of the gas hydrogen cyanide (HCN).

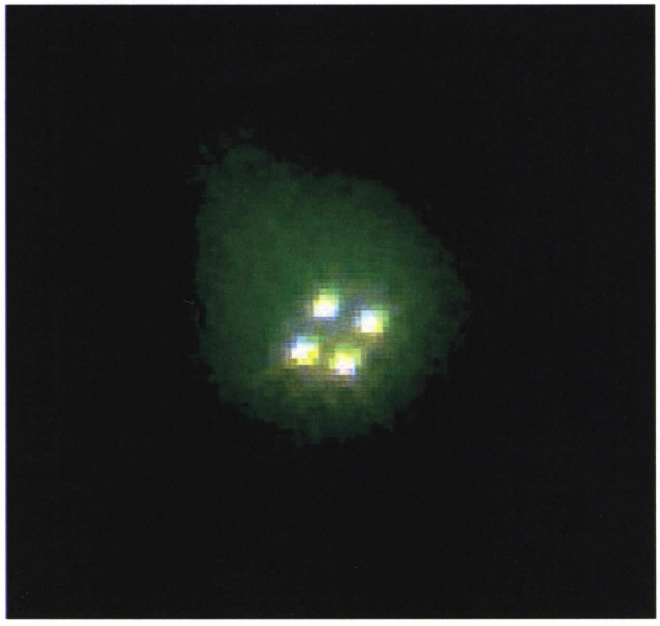
"If you see HCN, you are seeing gas with the high density required to form stars," said Paul Vanden Bout of the National Radio Astronomy Observatory (NRAO).

Solomon and Vanden Bout worked with Chris Carilli of NRAO and Michel Guelin of the Institute for Millimeter Astronomy in France. They reported their results in the December 11 issue of the scientific journal *Nature*.

In galaxies like the Milky Way, dense gas traced by HCN but composed mainly of hydrogen molecules is always associated with regions of active star formation. What is different about the Cloverleaf is the huge quantity of dense gas along with very powerful infrared radiation from the star formation. Ten billion times the mass of the Sun is contained in dense, star-forming gas clouds.

"At the rate this galaxy is seen to be forming stars, that dense gas will be used up in only about 10 million years," Solomon said.

In addition to giving astronomers a fascinating glimpse of a huge burst of star formation in the early Universe, the new information about the Cloverleaf helps answer a longstanding question about bright galaxies of that era. Many distant galaxies have supermassive black holes at their cores, and those black holes power "central engines" that produce bright emission. Astronomers have wondered specifically about those distant galaxies that emit large amounts of infrared light, galaxies like the Cloverleaf which has a black hole and central engine.



VLA image (green) of radio emission from HCN gas, superimposed on Hubble Space Telescope image of the Cloverleaf galaxy. The four images of the Cloverleaf are the result of gravitational lensing.

CREDIT: NRAO/AUI/NSF, STScI
(Click on Image for Larger Version)

"Is this bright infrared light caused by the black-hole-powered core of the galaxy or by a huge burst of star formation? That has been the question. Now we know that, in at least one case, much of the infrared light is produced by intense star formation," Carilli said.

The rapid star formation, called a starburst, and the black hole are both generating the bright infrared light in the Cloverleaf. The starburst is a major event in the formation and evolution of this galaxy.

"This detection of HCN gives us a unique new window through which we can study star formation in the early Universe," Carilli said.

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

Thursday, April 1, 2004

November 12, 2003

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Despite Appearances, Cosmic Explosions Have Common Origin, Astronomers Discover

A Fourth of July fireworks display features bright explosions that light the sky with different colors, yet all have the same cause. They just put their explosive energy into different colors of light. Similarly, astronomers have discovered, a variety of bright cosmic explosions all have the same origin and the same amount of total energy.

This is the conclusion of an international team of astronomers that used the National Science Foundation's Very Large Array (VLA) radio telescope to study the closest known gamma-ray burst earlier this year.

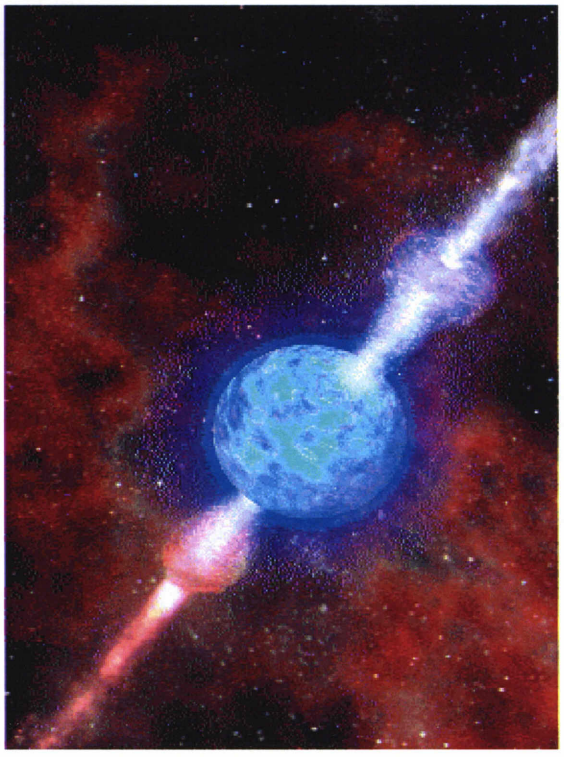
"For some reason we don't yet understand, these explosions put greatly varying percentages of their explosive energy into the gamma-ray portion of their output," said Dale Frail, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM. That means, he said, that both strong and weak gamma-ray bursts, along with X-ray flashes, which emit almost no gamma rays, are just different forms of the same cosmic beast. The research team reported their results in the November 13 issue of the scientific journal *Nature*.

The scientists trained the VLA on a gamma-ray burst discovered using NASA's HETE-2 satellite last March 29. This burst, dubbed GRB 030329, was the closest such burst yet seen, about 2.6 billion light-years from Earth. Because of this relative proximity, the burst was bright, with visible light from its explosion reaching a level that could be seen in amateur telescopes. As the burst faded, astronomers noted an underlying distinctive signature of a supernova explosion, confirming that the event was associated with the death of a massive star.

Since 1999, astronomers have known that the strong outbursts of gamma rays, X-rays, visible light and radio waves from these bursts form beams, like those from a flashlight, rather than spreading in all directions, like light from a bare bulb. The surprising result from the VLA studies of GRB 030329 is that there are two beams, not one. The scientists found that the gamma rays and the early visible-light and X-ray emission were coming from a narrow beam, while the radio waves and later visible-light emission came from another, wider beam.

"The strange thing is that some explosions seem to put most of their energy into the narrow beam, while others put most or nearly all their energy into the wider beam," Frail said. "This is telling us something very fundamental about the inner workings that drive these explosions," Frail added.

The mechanism producing these explosions is what scientists call a collapsar, which occurs when a giant star collapses of its own weight at the end of its normal, nuclear fusion-powered lifetime. In an ordinary supernova, such a collapse produces a neutron star. A collapsar, however, marks the death of a more-massive star and results in a black hole, a concentration of mass so dense that not even light can escape it.



Artist's Conception of Twin Jets in Energetic Cosmic Explosion

CREDIT: Dana Berry, SkyWorks Digital
(Click on Image for Larger Version)

After the black hole forms, its powerful gravitational pull sucks the star's remaining material toward it. This material forms a spinning disk around the black hole that lasts only a few seconds. During that time, the disk ejects material outward from its poles. A jet of material moving at nearly the speed of light emits gamma rays; slower material emits radio waves and visible light.

"Despite the differences in how much energy comes out in gamma rays, all these things seem to be caused by the same basic mechanism," said Edo Berger, a graduate student at Caltech and lead author of the *Nature* paper. "Our observations now give the data that will help us understand what causes the differences," he added.

"It was astounding to suddenly realize that these apparently very different cosmic beasts all are really the same thing," said Berger.

The next job, Frail said, is to learn if there are, in fact, two jets, or a single jet in which the central part encounters less resistance and thus can move outward at greater speeds.

Frail pointed out that the radio observations alone had the ability to show the total energy output of the burst, thus providing the breakthrough in understanding the common thread among the different types of explosions. "The key fact is that the optical, X-Ray and gamma-ray telescopes missed 90 percent of the energy put out by this burst," Frail added.

"As the VLA Expansion Project progresses and the sensitivity of the VLA improves in the coming years, it will become an even more important tool in unravelling this mystery," Frail said.

"The exciting part of this new discovery is that explosions that we once thought were quite different now

appear to all have a common origin," Frail concluded. "That insight, of course, gives us the new challenge of explaining how a single mechanism can make itself look so different," he added.

In addition to Berger and Frail, the other authors of the paper are Professor Shri Kulkarni of Caltech; Guy Pooley of Cambridge University's Mullard Radio Astronomy Observatory; Vince McIntyre and Robin Wark, both of the Australia Telescope National Facility; Re'em Sari, associate professor of astrophysics and planetary science at Caltech; Derek Fox, a postdoctoral scholar in astronomy at Caltech; Alicia Soderberg, a graduate student in astrophysics at Caltech; Sarah Yost, a graduate student in physics at Caltech; and Paul Price, a postdoctoral scholar at the University of Hawaii's Institute for Astronomy. Berger and Soderberg earlier worked on gamma-ray-burst studies as summer students at NRAO.

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

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November 6, 2003

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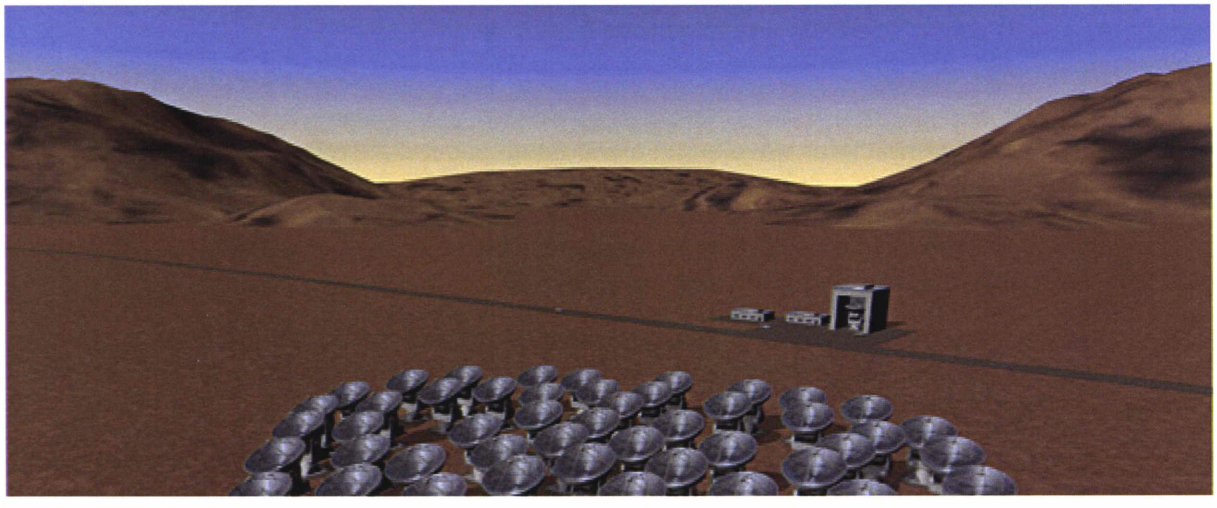
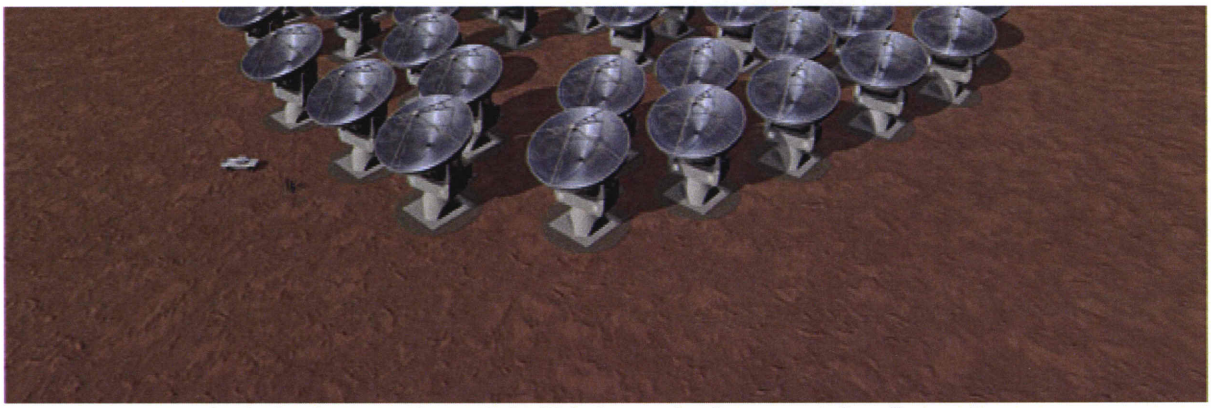
ASTRONOMERS BREAK GROUND ON ATACAMA LARGE MILLIMETER ARRAY (ALMA) *WORLD'S LARGEST MILLIMETER WAVELENGTH TELESCOPE*

Scientists and dignitaries from North America, Europe, and Chile broke ground today (Thursday, November 6, 2003) on what will be the world's largest, most sensitive radio telescope operating at millimeter wavelengths.

ALMA - the Atacama Large Millimeter Array - will be a single instrument composed of 64 high-precision antennas located on the Chajnantor plain of the Chilean Andes in the District of San Pedro de Atacama, 16,500 feet (5,000 meters) above sea level. ALMA's primary function will be to observe and image with unprecedented clarity the enigmatic cold regions of the Universe, which are optically dark, yet shine brightly in the millimeter portion of the electromagnetic spectrum.





Artist's Conception of ALMA Array in Compact Configuration
(Click on Image for Larger Version)

Other Images Available:

Artist's conception of the antennas for the Atacama Large Millimeter Array
Moonrise over ALMA test equipment near Cerro Chajnantor, Chile
VertexRSI antenna at the VLA test site

The Atacama Large Millimeter Array is an international astronomy facility. ALMA is an equal partnership between Europe and North America, in cooperation with the Republic of Chile, and is funded in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC), and in Europe by the European Southern Observatory (ESO) and Spain. ALMA construction and operations are led on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI), and on behalf of Europe by ESO.

"The U.S. National Science Foundation joins today with our North American partner, Canada, and with the European Southern Observatory, Spain, and Chile to prepare for a spectacular new instrument," said Dr. Rita Colwell, director of the U.S. National Science Foundation. "The Atacama Large Millimeter Array will expand our vision of the Universe with "eyes" that pierce the shrouded mantles of space through which light cannot penetrate." Wayne Van Citters, Division Director for the NSF's Division of Astronomical Sciences represented Dr. Colwell at this ceremony.

"ALMA will be a giant leap forward for our studies of this relatively little explored spectral window towards the Universe," said Dr. Catherine Cesarsky, Director General of ESO. "With ESO leading the European part of this ambitious and forward-looking project, the impact of ALMA will be felt in wide circles on our continent. Together with our partners in North America and Chile, we are all looking forward to the truly outstanding opportunities that will be offered by ALMA, also to young scientists and engineers."

SCIENCE WITH ALMA

ALMA will receive millimeter and sub-millimeter wavelength electromagnetic radiation from space. This portion of the spectrum, which is more energetic than most radio waves yet less energetic than visible and infrared light, holds the key to understanding a great variety of fundamental processes, including planet and star formation, and the formation and evolution of galaxies and galaxy clusters in the early Universe. The possibility to detect emission from organic and other molecules in space is of particularly high interest.

"ALMA will push the limits of engineering to provide a telescope array at a fantastic site for astronomers to peer at the beginnings of the Universe, galaxies, stars and planets, and perhaps even life," said Dr. Fred K.Y. Lo, director of the National Radio Astronomy Observatory (NRAO).

The millimeter and sub-millimeter radiation that ALMA will study is able to penetrate the vast clouds of dust and gas that populate interstellar and intergalactic space, revealing previously hidden details about astronomical

objects. This energy, however, is blocked by atmospheric moisture here on Earth. To conduct research in this critical portion of the spectrum, astronomers need a site that is very dry, and preferably at a very high altitude where the atmosphere is thinner. Extensive tests showed that the sky above the high-altitude Chajnantor plain in the Atacama Desert has the unsurpassed clarity and stability needed to perform efficient observations with ALMA.

ALMA OPERATION

ALMA will be the highest altitude, full-time ground-based observatory in the world.

Work at this altitude, however, is very challenging. To help ensure the safety of the scientists and engineers at ALMA, operations will be conducted from the Operations Support Facility, a compound located close to the cities of Toconao and San Pedro de Atacama, which is at a more comfortable 2,900 meters (9,500 feet) above sea level.

Phase 1 of the ALMA Project, which included the design and development, was completed in 2002.

The beginning of Phase 2 of this project happened on February 25, 2003, when the NSF and ESO signed an agreement to construct and operate ALMA. Construction will continue until 2012; however, initial scientific observations are planned in 2007, with a partial array of the first antennas. ALMA's operation will progressively increase until 2012 with the installation of the remaining antennas. The entire project will cost approximately $552 million U.S. (in FY 2000 dollars).

Earlier this year, the ALMA Board selected Professor Massimo Tarenghi, formerly manager of ESO's VLT (Very Large Telescope) Project, to become ALMA Director. He is confident that he and his team will succeed. "We may have a lot of hard work in front of us," he said, "but all of us in the team are excited about this unique project. We are ready to work for the international astronomical community and to provide them in due time with a unique instrument allowing trailblazing research projects in many different fields of modern astrophysics."

HOW IT WILL WORK

ALMA will be composed of 64 high-precision antennas, each 12 meters in diameter. The ALMA antennas can be repositioned, allowing the telescope to function much like the zoom lens on a camera. At its largest, ALMA will be 14 kilometers (8.7 miles) across. This will allow the telescope to observe the fine-scale details of astronomical objects. At its smallest, approximately 150 meters (492 feet) across, ALMA will be able to study the large-scale structures of these same objects.

ALMA will function as an interferometer, meaning it will combine the signals from all its antennas (two at a time) to simulate a telescope the size of the distance between the antennas.

With 64 antennas, ALMA will generate 2016 individual antenna pairs (baselines) during its observations. To handle this much data, ALMA will rely on a very powerful, specialized computer called a correlator, which will perform 16,000 million-million operations per second.

Currently, the two prototype ALMA antennas are undergoing rigorous testing at the NRAO's Very Large Array site, near Socorro, New Mexico.

INTERNATIONAL COLLABORATION

For this ambitious project, ALMA has become a joint effort among several nations and scientific institutions. This will be the first truly global project of ground-based astronomy, an essential development in view of the increasing technological sophistication and the high costs of the front line astronomy installations.

"Today marks the official start of construction," said Dr. Colwell. "But the ALMA partnership also breaks ground with a novel collaboration that ensures equal access by astronomers on at least three continents. International partnerships are quickly becoming the norm of the millennium, enabling organizations and nations to combine funds to achieve greater scientific capability. NSF is proud to participate in the creation of an instrument that will provide unprecedented power for science and immeasurable knowledge for all."

At the groundbreaking in Chile, the ALMA partners unveiled the ALMA logo.

ATACAMA LARGE MILLIMETER ARRAY

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

NOTE: A brochure on ALMA is available in pdf format.

National Radio Astronomy Observatory

Thursday, April 1, 2004

August 12, 2003

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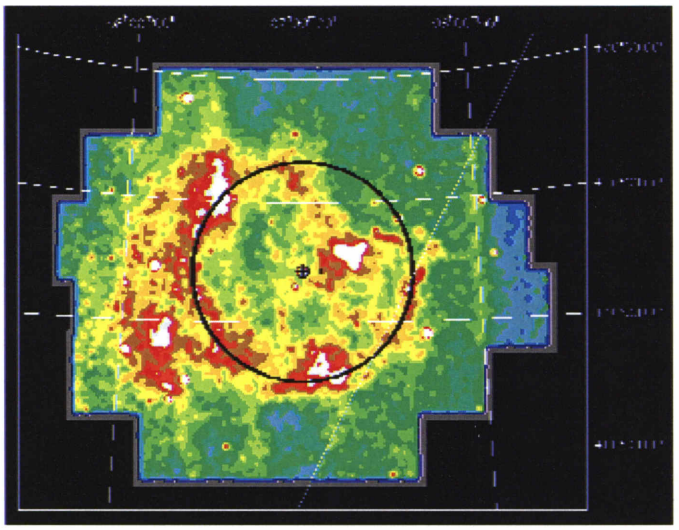
Distance Measurement Solves Astrophysical Mysteries

Location, location, and location. The old real-estate adage about what's really important proved applicable to astrophysics as astronomers used the sharp radio "vision" of the National Science Foundation's Very Long Baseline Array (VLBA) to pinpoint the distance to a pulsar. Their accurate distance measurement then resolved a dispute over the pulsar's birthplace, allowed the astronomers to determine the size of its neutron star and possibly solve a mystery about cosmic rays.

"Getting an accurate distance to this pulsar gave us a real bonanza," said Walter Brisken, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM.

The pulsar, called PSR B0656+14, is in the constellation Gemini, and appears to be near the center of a circular supernova remnant that straddles Gemini and its neighboring constellation, Monoceros, and is thus called the Monogem Ring. Since pulsars are superdense, spinning neutron stars left over when a massive star explodes as a supernova, it was logical to assume that the Monogem Ring, the shell of debris from a supernova explosion, was the remnant of the blast that created the pulsar.



The Monogem Ring, in X-Ray Image by ROSAT satellite

However, astronomers using indirect methods of determining the distance to the pulsar had concluded that it was nearly 2500 light-years from Earth. On the other hand, the supernova remnant was determined to be only about 1000 light-years from Earth. It seemed unlikely that the two were related, but instead appeared nearby in the sky purely by a chance juxtaposition.

Brisken and his colleagues used the VLBA to

make precise measurements of the sky position of PSR B0656+14 from 2000 to 2002. They were able to detect the slight offset in the object's apparent position when viewed from opposite sides of Earth's orbit around the Sun. This effect, called parallax, provides a direct measurement of distance.

CREDIT: Max-Planck Institute, American Astronomical Society
(Click on Image for Larger Version)

"Our measurements showed that the pulsar is about 950 light-years from Earth, essentially the same distance as the supernova remnant," said Steve Thorsett, of the University of California, Santa Cruz. "That means that the two almost certainly were created by the same supernova blast," he added.

With that problem solved. the astronomers then turned to studying the pulsar's neutron star itself. Using a variety of data from different telescopes and armed with the new distance measurement, they determined that the neutron star is between 16 and 25 miles in diameter. In such a small size, it packs a mass roughly equal to that of the Sun.

The next result of learning the pulsar's actual distance was to provide a possible answer to a longstanding question about cosmic rays. Cosmic rays are subatomic particles or atomic nuclei accelerated to nearly the speed of light. Shock waves in supernova remnants are thought to be responsible for accelerating many of these particles.

Scientists can measure the energy of cosmic rays, and had noted an excess of such rays in a specific energy range. Some researchers had suggested that the excess could come from a single supernova remnant about 1000 light-years away whose supernova explosion was about 100,000 years ago. The principal difficulty with this suggestion was that there was no accepted candidate for such a source.

"Our measurement now puts PSR B0656+14 and the Monogem Ring at exactly the right place and at exactly the right age to be the source of this excess of cosmic rays," Brisken said.

With the ability of the VLBA, one of the telescopes of the NRAO, to make extremely precise position measurements, the astronomers expect to improve the accuracy of their distance determination even more.

"This pulsar is becoming a fascinating laboratory for studying astrophysics and nuclear physics," Thorsett said.

In addition to Brisken and Thorsett, the team of astronomers includes Aaron Golden of the National University of Ireland, Robert Benjamin of the University of Wisconsin, and Miller Goss of NRAO. The scientists are reporting their results in papers appearing in the *Astrophysical Journal Letters* in August.

The VLBA is a continent-wide system of ten radio- telescope antennas, ranging from Hawaii in the west to the U.S. Virgin Islands in the east, providing the greatest resolving power, or ability to see fine detail, in astronomy. Dedicated in 1993, the VLBA is operated from the NRAO's Array Operations Center in Socorro, New Mexico.

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

Thursday, April 1, 2004

NRAO Home > Press Releases > Giant Gas Cloud Made of Atoms Formed in First Stars Revealed in Universe's Most Distant Quasar

(Print Friendly Version)

July 23, 2003

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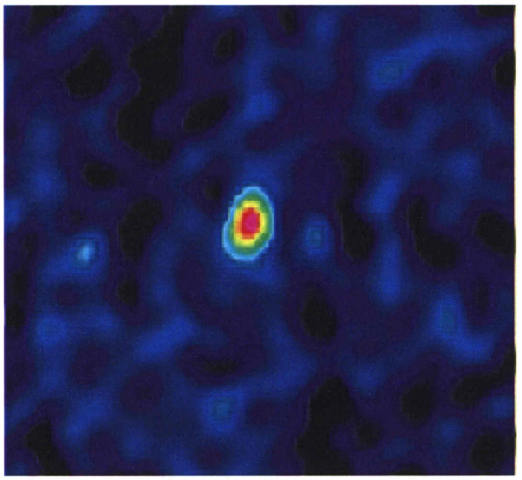
Giant Gas Cloud Made of Atoms Formed in First Stars Revealed in Universe's Most Distant Quasar

Astronomers studying the most distant quasar yet found in the Universe have discovered a massive reservoir of gas containing atoms made in the cores of some of the first stars ever formed. The carbon-monoxide gas was revealed by the National Science Foundation's Very Large Array (VLA) and the Plateau de Bure radio interferometer in Europe. The gas, along with the young galaxy containing it, is seen as it was when the Universe was only one-sixteenth its current age, just emerging from the primeval "Dark Ages" before light could travel freely through the cosmos.

"Our discovery of this much carbon monoxide gas in such an extremely distant and young galaxy is surprising. It means that, even at a very early time in the history of the Universe, galaxies already had huge amounts of molecular gas that would eventually form new generations of stars," said Chris Carilli, of the National Radio Astronomy Observatory (NRAO) in Socorro, New Mexico.

The distant galaxy, dubbed J1148+5251, contains a bright quasar powered by a black hole at least a billion times more massive than the Sun. The galaxy is seen as it was only 870 million years after the Big Bang. The Universe now is 13.7 billion years old. J1148+5251 would have been among the first luminous objects in the Universe.

The original atoms formed in the Universe within the first three minutes of the Big Bang were only hydrogen and helium. Carbon and oxygen -- the atoms making up carbon monoxide -- had to be made in the thermonuclear furnaces at the cores of the earliest stars.



VLA Image of J1148+5251

CREDIT: NRAO/AUI/NSF

"The carbon and oxygen atoms in the gas we detected were made by some of the first stars ever formed, only about 650 million years after the Big Bang. In the next 200 million years or so, those stars -- probably very different stars from those we see today -- exploded as supernovae, spreading the carbon and oxygen out into space. Those atoms then cooled and combined into the carbon monoxide molecules we detected with our radio telescopes," said Fabian Walter, a Jansky Postdoctoral Fellow at the NRAO. Walter is lead author of a research paper in the July 24 issue of the scientific journal *Nature*, and, with Carilli and K.Y. Lo of NRAO, did the VLA observations. Frank Bertoldi of the Max-Planck Institute in Germany and Pierre Cox of the Institute of Space Astrophysics in Orsay, France, led the collaborators using the Plateau de Bure telescope.

(Click on Image for Larger Version)

J1148+5251 Timeline

Time Since Big Bang	Event
<300,000 years	Universe Fully Ionized
300,000 years	Hot charged particles cool and combine into neutral atoms; Universe becomes opaque; "Dark Ages" begin.
~200 million years	First luminous objects form; Reionization begins.
~650 million years	Stars forming in galaxy J1148+5251; Make carbon, oxygen atoms and begin to blast these atoms into interstellar space
870 million years	J1148+5251 has accumulated massive reservoir of cool molecular gas containing Carbon Monoxide (CO) molecules; Radio waves from these molecules begin their journey to Earth.
One billion	Reionization complete; Universe is

The discovery gives scientists a tantalizing direct view of one of the earliest galaxies in the young Universe, and raises questions about the nature of the first stars and how galaxies and quasars formed.

"The Universe in which this galaxy existed is a very different Universe from the one we know today," Walter said.

For about 300,000 years after the Big Bang, the Universe was filled with very hot gas which eventually became protons and electrons. Then, through expansion, the Universe cooled and the protons and electrons combined into neutral atoms that absorbed light and other forms of electromagnetic radiation. This period, from 300,000 years after the Big Bang, until a few hundred million years later when the first stars and galaxies began forming, is known as the cosmic Dark Ages.

As the first stars and galaxies formed, intense radiation from the stars began to break apart -- or ionize -- the neutral atoms, allowing light once again to pass. As each new star's radiation ionized interstellar atoms, it formed a transparent "bubble" in the opaque Universe. The Universe began to resemble a cosmic Swiss cheese, with the holes growing larger until, about a billion years after the Big Bang, the holes all met each other and the Universe became fully transparent once again. This period is known as the Reionization Era of the Universe.

In fact, combining the radio observations with data from optical telescopes shows that the transparent "bubble" around J1148+5251 is about 30 million light-years in diameter. "This is direct evidence that we are seeing this object helping reionize the Universe," Walter said.

The amount of molecular gas in the galaxy -- a mass more than 10 billion times that of the Sun -- tells the scientists that things were happening quickly in the early Universe.

"This is as much mass as we see in big galaxies today, and it had little time, astronomically speaking, to accumulate," said Carilli.

Also, the most popular theory for how big galaxies formed is that they were built up over long spans of time by multiple mergers of smaller galaxies. "That's why it's so surprising to see such a massive galaxy so early in the Universe," said Walter.

Studies of J1148+5251 and other distant objects yet to be discovered will help scientists find the answers to their questions about the Universe's early stars

years	transparent, ending "Dark Ages."
13.7 billion years	Radio waves from J1148+5251's CO molecules arrive at radio telescopes on Earth.

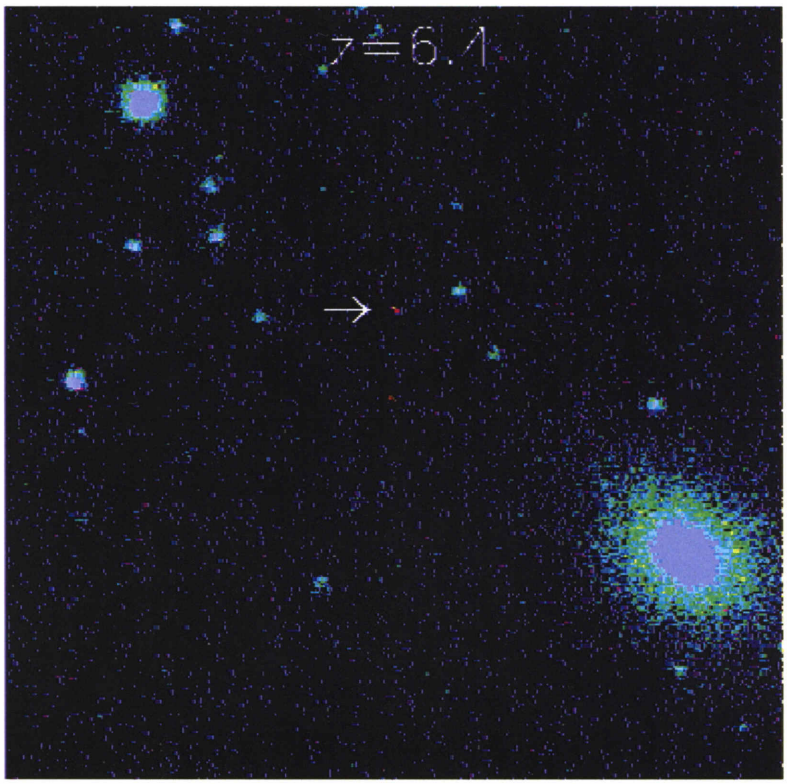
and galaxies.

The radio observations of J1148+5251 gave astronomers a look at the galaxy itself, Walter emphasized, while optical telescopes showed only light coming from the bright quasar "engine" at the galaxy's core. Walter added that more VLA observations now being planned are aimed at producing an image of the young galaxy.

In addition, Walter also looks forward to studying other objects deeper into the era of reionization, both with the expanded VLA (EVLA) and with the Atacama Large Millimeter Array (ALMA), a joint North America-Europe project to be built in Chile.

"With the EVLA and ALMA, we will be able to study the structures and dynamics of similar systems in great detail," Walter said.

J1148+5251 was discovered by the Sloan Digital Sky Survey, using a 2.5-meter optical telescope at Apache Point, NM, earlier this year. At a distance of more than 12.8 billion light-years, it is the most distant quasar yet found in the Universe. Followup observations at the W.M. Keck Observatory in Hawaii showed a clear signature of light absorption indicating that the object is seen at the end of the reionization era. This signature, found using a spectroscope to analyze light from the object, is known as the Gunn-Peterson Effect, after James Gunn and Bruce Peterson, who predicted it in 1965.



SDSS Discovery Image of J1148+5251: Quasar is Red Dot Pointed Out by Arrow

CREDIT: Sloan Digital Sky Survey
At Apache Point Observatory
(Click on Image for Larger Version)

The carbon monoxide gas was found using radio telescopes that detected radio waves emitted by the gas molecules. The wavelength of this radio emission was greatly increased by the Doppler Effect produced by the expansion of the Universe. For example, at the great distance of J1148+5251, waves that left the galaxy with a length of less than one millimeter were received by the VLA at a wavelength of more than six millimeters.

In addition to Walter, Carilli and Lo, who used the VLA to observe J1148+5251, other team members led by Bertoldi and Cox used the Institute of Millimeter Radio Astronomy's (IRAM) Plateau de Bure radio interferometer in France. These included Roberto Neri of IRAM; Alain Omont of the Paris Institute of Astrophysics; and Karl Menten of Germany's Max Planck Instutute for Radioastronomy. Xiaohui Fan of the University of Arizona's Steward Observatory and Michael Strauss of Princeton University were the Sloan Digital Sky Survey collaborators on the *Nature* paper.

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under cooperative agreement by Associated Universities, Inc.

Additional Graphic Available:

Caltech Graphic of Reionization Era (1.14MB)

The above graphic should be credited: S. G. Djorgovski et al. & Digital Media Center, Caltech

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Modified on Tuesday, 12-Aug-2003 14:10:44 EDT

National Radio Astronomy Observatory

Thursday, April 1, 2004

June 11, 2003

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Scientists Celebrate VLBA's First Decade As Astronomy's Sharpest "Eye" on the Universe

Scientists from around the globe are gathered in Socorro, New Mexico, to mark the tenth anniversary of the National Science Foundation's Very Long Baseline Array (VLBA) , a continent-wide radio telescope that produces the most detailed images of any instrument available to the world's astronomers.

The VLBA

CREDIT: NRAO/AUI/NSF

Nearly 200 scientists are presenting 160 research papers on topics including geophysics, star and planet formation, supernova explosions, galaxies, supermassive black holes, and future directions of research and instrumentation in astronomy. The meeting is sponsored by the National Radio Astronomy Observatory (NRAO) and the New Mexico Institute of Mining and Technology (NM Tech). The meeting is being held on the NM Tech campus in Socorro.

"In ten years of operation, the VLBA has made landmark contributions to astronomy. In this scientific meeting, we are acknowledging those contributions and looking forward to an even more exciting future of frontier research," said James Ulvestad, director of VLA/VLBA operations for the NRAO.

"The presentations at this meeting show that the VLBA is being used to study a much broader range of astronomical objects than was anticipated by its designers," said Prof. Roger Blandford of Caltech, who delivered the meeting's opening Keynote Address.

Dedicated in 1993, the $85-million VLBA includes ten, 240-ton radio-telescope antennas, ranging from

Hawaii in the west to the U.S. Virgin Islands in the east. Two are in New Mexico, one near Pie Town in Catron County and the other at Los Alamos. The VLBA is operated from the NRAO's Array Operations Center in Socorro.

Acting like a giant eye 5,000 miles wide, the VLBA can produce the sharpest images of any telescope on Earth or in space. Its ability to see fine detail, called resolving power, is equivalent to being able to stand in New York and read a newspaper in Los Angeles.

The VLBA's scientific achievements include making the most accurate distance measurement ever made of an object beyond the Milky Way Galaxy; the first mapping of the magnetic field of a star other than the Sun; "movies" of motions in powerful cosmic jets and of distant supernova explosions; the first measurement of the propagation speed of gravity; and long-term measurements that have improved the reference frame used to map the Universe and detect tectonic motions of Earth's continents.

In coming years, scientists plan to use the VLBA, along with other radio-telescope facilities, to gain important new insights on astronomical bodies ranging from nearby stars to the most distant galaxies, seen as they were billions of years ago. The VLBA also will help improve the celestial coordinate system used for spacecraft navigation and other purposes.

Blandford outlined a number of future research challenges, including understanding how pulsars produce their powerful beams of light and radio waves, learning how supermassive black holes and their nearby environments produce superfast cosmic jets, trying to understand solar bursts, using gravitational lenses to study the distant Universe, and understanding the mechanisms of gamma ray bursts and their "afterglows."

"I am heartened to see the number of young astronomers at this meeting who are using the VLBA and will use it to help answer these important scientific questions," Blandford added.

Closer to home, the VLBA can be "turned around" to produce extremely precise measurements on the Earth. This capability allows scientists to study the motion of Earth's tectonic plates, to track "wobbles" in our planet's rotation, and to measure subtle changes attributed to atmospheric motions and climate change.

The meeting in Socorro began June 8 and runs through June 12.

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

Modified on 22 May 2003 Wednesday, 11-Jun-2003 19:21:29 EDT

National Radio Astronomy Observatory

Thursday, April 1, 2004

EMBARGOED For Release: 10:00 a.m., CDT, May 28, 2003

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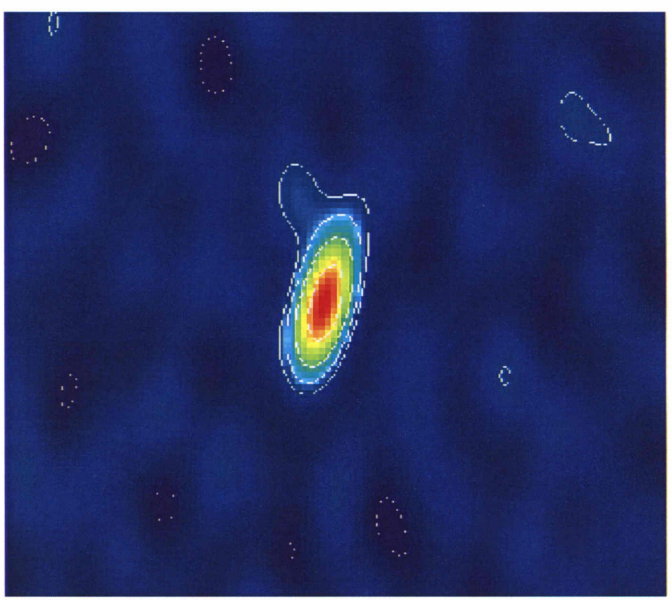
Closest Gamma Ray Burst Providing Scientists With Crucial Test for Burst Physics

The closest Gamma Ray Burst (GRB) yet known is providing astronomers with a rare opportunity to gain information vital to understanding these powerful cosmic explosions. Extremely precise radio-telescope observations already have ruled out one proposed mechanism for the bursts.

"This is the closest and brightest GRB we've ever seen, and we can use it to decipher the physics of how these bursts work," said Greg Taylor of the National Radio Astronomy Observatory (NRAO) in Socorro, NM. Taylor worked with Dale Frail, also of the NRAO, along with Prof. Shri Kulkarni and graduate student Edo Berger of Caltech in studying a GRB detected on March 29, 2003. The scientists presented their findings to the American Astronomical Society's meeting in Nashville, TN.

Taylor and Frail used the National Science Foundation's (NSF) Very Long Baseline Array (VLBA) and other radio telescopes to study the burst, known as GRB 030329. In a series of observations from April 1 to May 19, they determined the size of the expanding "fireball" from the burst and measured its position in the sky with great precision.



At a distance of about 2.6 billion light-years, GRB 030329 is hardly next door. However, compared to other GRBs at typical distances of 8-10 billion light-years, it presents an easier target for study.

"We only expect to see one burst per decade this close," said Frail.

The precise measurement of the object's position allowed the scientists to show that one theoretical model for GRBs can be ruled out.

This model, proposed in 2000, says that the radio-wave energy emitted by the GRB comes from "cannonballs" of material shot from the explosion at extremely high speeds.

"The 'cannonball model' predicted that we should see the radio-emitting object move across the sky by a specific amount. We have not seen that motion," Taylor said.

VLBA IMAGE of GRB 030329

CREDIT: NRAO/AUI/NSF
(Click on Image for Larger Version)

The currently standard "fireball model" of GRBs says that the radio emission comes from a rapidly-expanding shock wave. This model was first proposed by Peter Meszaros, Bohdan Paczynski and Sir Martin Rees, who won the American Astronomical Society's Bruno Rossi Prize in 2000 for their work. In this standard model, as the shock wave expands outward, the emission becomes fainter, but the center of the observed emission does not change position.

The cannonball model, however, proposes that the emission arises from distinct concentrations of matter shot outward from the burst. As they move farther from the burst, their motion should be detected as a change in their position in the sky. On April 3, proponents of the cannonball model predicted a specific amount of motion for GRB 030329 and suggested that the VLBA's sharp radio "vision" could detect the motion and confirm their prediction.

Instead, "our observations are consistent with no motion at all," Taylor said. "This is at odds with the cannonball model -- they made a specific prediction based on their model and the observations do not bear them out," he added.

The scientists' direct measurement of the size of the GRB fireball also will provide new insights into the physics behind the burst.

"By directly measuring the size and the expansion rate, we can start putting some real limits on the physics involved," Taylor said. First, he said, "We already can confirm that the fireball is expanding at nearly the speed of light, as the standard model predicts. Next, once our May observations are fully analyzed, we can put limits on the energy of the burst and provide a test of the standard model."

Taylor and Frail observed GRB 030329 with the VLBA on April 1 and April 6. On April 22, they used the 100-meter radio telescope in Effelsberg, Germany in addition to the VLBA. On May 19, they used the VLBA, the Very Large Array (VLA) in New Mexico, the NSF's Robert C. Byrd Green Bank Telescope in West Virginia, and the Effelsberg telescope.

In addition to gamma-ray and X-ray observations, visible light from GRB 030329 was observed by 65 telescopes around the world. At its brightest, the visible light from this burst was detectable with moderate-sized amateur telescopes.

Gamma Ray Bursts were first detected in 1967 by a satellite monitoring compliance with the 1963 atmospheric nuclear test-ban treaty. For three decades thereafter, astronomers were unable to determine their distances from Earth, and thus were unable to begin understanding the physics underlying the explosions. In 1997, the first distance measurements were made to GRBs, and the NSF's Very Large Array (VLA) detected the first radio emission from a GRB afterglow.

Once scientists determined that GRBs originate in distant galaxies and that they probably occur in regions of those galaxies where stars are actively forming, some 200 proposed models for what causes GRBs were reduced to a handful of viable models.

Most scientists now believe that GRBs arise from a violent explosion that ends the life of a star much more massive than the Sun. Whereas such an explosion as a typical supernova leaves a dense neutron star, a

GRB explosion leaves a black hole, a concentration of mass with gravitational pull so strong that not even light can escape it.

The VLBA is a continent-wide system of ten radio- telescope antennas, ranging from Hawaii in the west to the U.S. Virgin Islands in the east, providing the greatest resolving power, or ability to see fine detail, in astronomy. Dedicated in 1993, the VLBA is operated from the NRAO's Array Operations Center in Socorro, New Mexico.

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

Thursday, April 1, 2004

NRAO Home > Press Releases > VLBA Reveals "Supernova Factory"

(Print Friendly Version)

EMBARGOED For Release: 10:00 a.m., CDT, May 27, 2003

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VLBA Reveals Dust-Enshrouded "Supernova Factory"

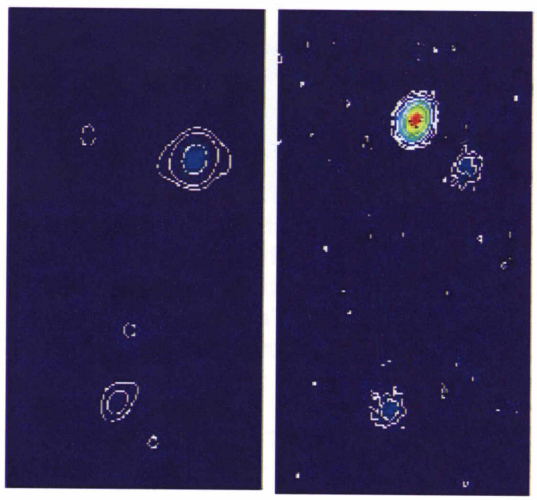
Using the National Science Foundation's Very Long Baseline Array (VLBA) radio telescope, astronomers have discovered a newly-exploded star, or supernova, hidden deep in a dust-enshrouded "supernova factory" in a galaxy some 140 million light-years from Earth.

"This supernova is likely to be part of a group of super star clusters that produce one such stellar explosion every two years," said James Ulvestad, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM. "We're extremely excited by the tremendous insights into star formation and the early Universe that we may gain by observing this 'supernova factory,'" he added.

Ulvestad worked with Susan Neff of NASA's Goddard Space Flight Center in Greenbelt, MD, and Stacy Teng, a graduate student at the University of Maryland, on the project. The scientists presented their findings to the American Astronomical Society's meeting in Nashville, TN.

"These super star clusters likely are forming in much the same way that globular clusters formed in the early Universe, and thus provide us with a unique opportunity to learn about how some of the first stars formed billions of years ago," Neff said.

The cluster is in an object called Arp 299, a pair of colliding galaxies, where regions of vigorous star



VLBA IMAGES of "Source A" in Arp 299. At left, image made in 2002 shows only two prominent objects in the field of view. A 2003 image, right, shows bright new object later confirmed as a supernova.

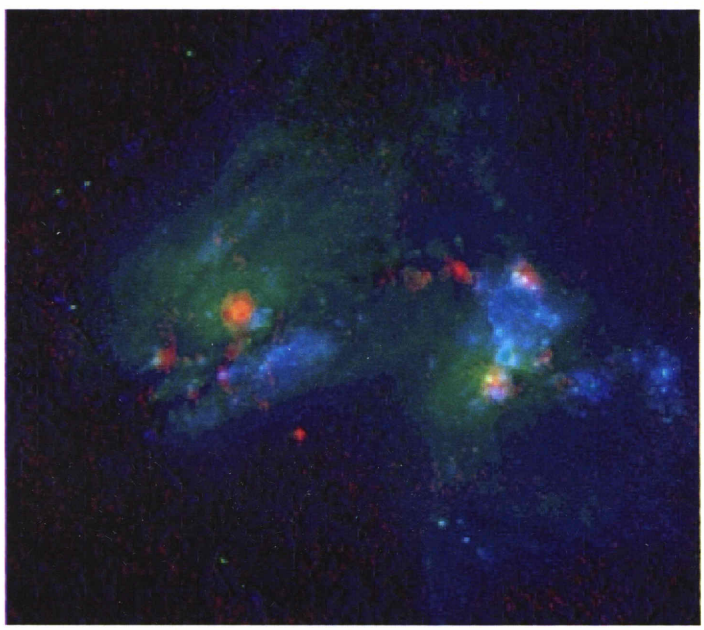
CREDIT: Ulvestad, Neff & Teng, NRAO/AUI/NSF

formation have been found in past observations. Since 1990, four other supernova explosions have been seen optically in Arp 299.

(Click on Image for Larger Version)

Observations with the NSF's Very Large Array (VLA) earlier showed a region near the nucleus of one of the colliding galaxies which had all the earmarks of prolific star formation. The astronomers focused on this region, prosaically dubbed "Source A," with the VLBA and the NSF's Robert C. Byrd Green Bank Telescope in 2002, and found four objects in this dusty cloud that are likely young supernova remnants. When they observed the region again in February 2003, there was a new, fifth, object located only 7 light-years from one of the previously detected objects.

More observations on April 30-May 1, 2003, showed that this new object has typical characteristics of a supernova explosion by a young, massive star.



Multiwavelength Image of the colliding-galaxy pair Arp 299 using data from the VLA and Hubble Space Telescope. Here, radio emission is shown as red, infrared as green, and ultraviolet as blue.

CREDIT: NRAO/AUI/NSF, STScI, NASA
(Click on Image for Larger Version)

"This supernova is exploding in a very dense environment, quite different from the environments of supernova explosions that can be seen in visible light," Teng said. "This is the kind of dense environment in which stars likely formed in the early Universe," she added.

The astronomers believe the super star cluster in Arp 299 saw its most recent peak of star formation some 6-8 million years ago, and now its massive stars, 10-20 times (or more) as massive as the Sun, are ending their lives in supernova explosions. Super star clusters typically contain up to a million stars, which is why the scientists think Source A will see frequent supernova explosions.

"We plan to keep watching this region, and hope that we can study numerous supernovae, and gain important new information about the processes of star formation, both in the early Universe and at the present time," Neff said.

"Because of the dust and the distance, only a radio telescope with the VLBA's ability to see fine detail can find the supernovae in this region," Ulvestad said.

The VLBA is a continent-wide

Artist's Conception of the dust-enshrouded supernova factory in Arp 299. Bright circles are the shocks from new supernova explosions.

CREDIT: NASA/Walt Feimer
(Click on Image for Larger Version)

system of ten radio- telescope antennas, ranging from Hawaii in the west to the U.S. Virgin Islands in the east, providing the greatest resolving power, or ability to see fine detail, in astronomy. Dedicated in 1993, the VLBA is operated from the NRAO's Array Operations Center in Socorro, New Mexico.

The VLBA has made landmark contributions to astronomy, including making the most accurate distance measurement ever made of an object beyond the Milky Way Galaxy; the first mapping of the magnetic field of a star other than the Sun; "movies" of motions in powerful cosmic jets and of distant supernova explosions; the first measurement of the propagation speed of gravity; and long-term measurements that have improved the reference frame used to map the Universe and detect tectonic motions of Earth's continents.

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National Radio Astronomy Observatory

Thursday, April 1, 2004

For Release: Thursday, May 22, 2003

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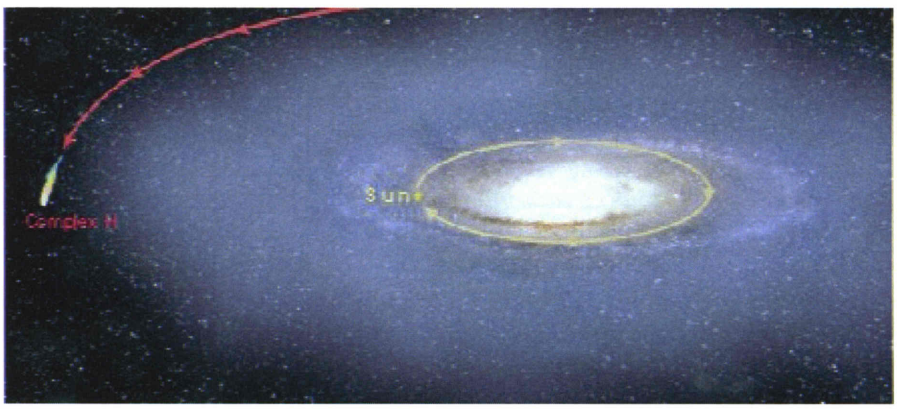
GBT Reveals Satellite of Milky Way in Retrograde Orbit

New observations with National Science Foundation's Robert C. Byrd Green Bank Telescope (GBT) suggest that what was once believed to be an intergalactic cloud of unknown distance and significance, is actually a previously unrecognized satellite galaxy of the Milky Way orbiting backward around the Galactic center.

Jay Lockman of the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia, discovered that this object, known as "Complex H," is crashing through the outermost parts of the Milky Way from an inclined, retrograde orbit. Lockman's findings will be published in the July 1 issue of the Astrophysical Journal, Letters.



Artist's rendition of the path of satellite galaxy Complex H (in red) in relation to the orbit of the Sun (in yellow) about the center of the Milky Way Galaxy. The outer layers of Complex H are being stripped away by its interaction with the Milky Way. The hydrogen atmosphere (in blue) is shown surrounding the visible portion (in white) of the Galaxy. CREDIT: *Lockman, Smiley, Saxton; NRAO/AUI*

"Many astronomers assumed that Complex H was probably a distant neighbor of the Milky Way with some unusual velocity that defied explanation," said Lockman. "Since its motion appeared completely unrelated to Galactic rotation, astronomers simply lumped it in with other high velocity clouds that had strange and unpredictable trajectories."

High velocity clouds are essentially what their name implies, fast-moving clouds of predominately neutral atomic hydrogen. They are often found at great distances from the disk of the Milky Way, and may be left over material from the formation of our Galaxy and other galaxies in our Local Group. Over time, these objects can become incorporated into larger galaxies, just as small asteroids left over from the formation of the solar system sometimes collide with the Earth.

Earlier studies of Complex H were hindered because the cloud currently is passing almost exactly behind the outer disk of the Galaxy. The intervening dust and gas that reside within the sweeping spiral arms of the Milky Way block any visible light from this object from reaching the Earth. Radio waves, however, which have a much longer wavelength than visible light, are able to pass through the intervening dust and gas.

The extreme sensitivity of the recently commissioned GBT allowed Lockman to clearly map the structure of Complex H, revealing a dense core moving on an orbit at a 45-degree angle to the plane of the Milky Way. Additionally, the scientist detected a more diffuse region surrounding the central core. This comparatively rarefied region looks like a tail that is trailing behind the central mass, and is being decelerated by its interaction with the Milky Way.

"The GBT was able to show that this object had a diffuse 'tail' trailing behind, with properties quite different from its main body," said Lockman. "The new data are consistent with a model in which this object is a satellite of the Milky Way in an inclined, retrograde orbit, whose outermost layers are currently being stripped away in its encounter with the Galaxy."

These results place Complex H in a small club of Galactic satellites whose orbits do not follow the rotation of the rest of the Milky Way. Among the most prominent of these objects are the Magellanic Clouds, which also are being affected by their interaction with the Milky Way, and are shedding their gas in a long stream.

Since large galaxies, like the Milky Way, form by devouring smaller galaxies, clusters of stars, and massive clouds of hydrogen, it is not unusual for objects to be pulled into orbit around the Galaxy from directions other than that of Galactic rotation.

"Astronomers have seen evidence that this accreting material can come in from wild orbits," said Butler Burton, an astronomer with the NRAO in Charlottesville, Virginia. "The Magellanic clouds are being torn apart from their interaction with the Milky Way, and there are globular clusters rotating the wrong way. There is evidence that stuff was going every-which-way at the beginning of the Galaxy, and Complex H is probably left over from that chaotic period."

The new observations place Complex H at approximately 108,000 light-years from the Galactic center, and indicate that it is nearly 33,000 light-years across, containing approximately 6 million solar masses of hydrogen.

Radio telescopes, like the GBT, are able to observe these cold, dark clouds of hydrogen because of the natural electromagnetic radiation emitted by neutral atomic hydrogen at radio wavelengths (21 centimeters).

Globular clusters, and certain other objects in the extended Galactic halo, can be studied with optical telescopes because the material in them has collapsed to form hot, bright stars.

The GBT is the world's largest fully steerable radio telescope. It was commissioned in August of 2000, and continues to be outfitted with the sensitive receivers and components that will allow it to make observations at much higher frequencies.

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

Thursday, April 1, 2004

April 3, 2003

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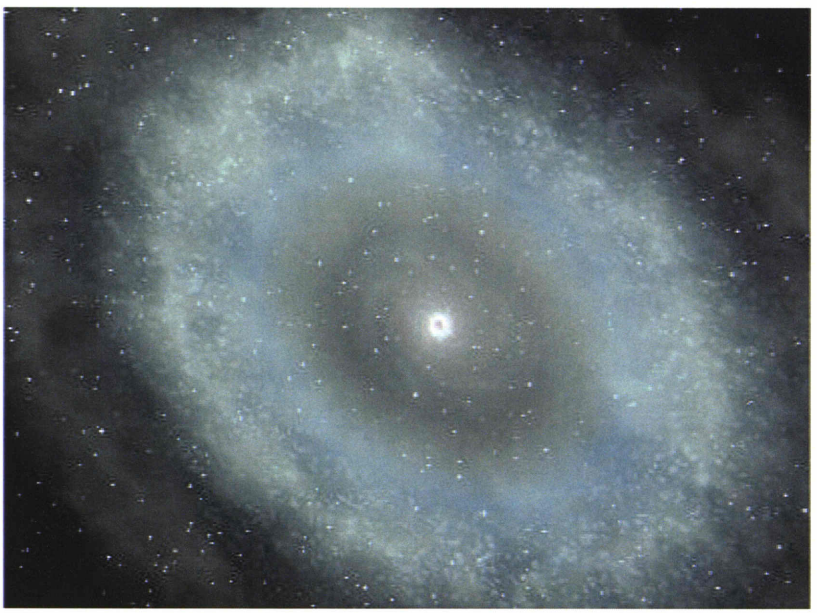
Giant Cosmic Lens Reveals Secrets of Distant Galaxy

Using the National Science Foundation's Very Large Array (VLA) radio telescope and helped by a gigantic cosmic lens conveniently provided by nature, an international team of astronomers has discovered that a young galaxy had a central disk of gas in which hundreds of new stars were being born every year -- at a time when the Universe was only a fraction of its current age.

"This unique look into a very distant, young galaxy gives us unprecedented insight into the process that produced both tremendous numbers of stars and supermassive black holes in forming galaxies," said Chris Carilli, of the National Radio Astronomy Observatory (NRAO) in Socorro, NM, leader of the research team. "This work strongly supports the idea that the stars and the black holes formed simultaneously," he added. The research was published in the April 4 issue of *Science Express*.

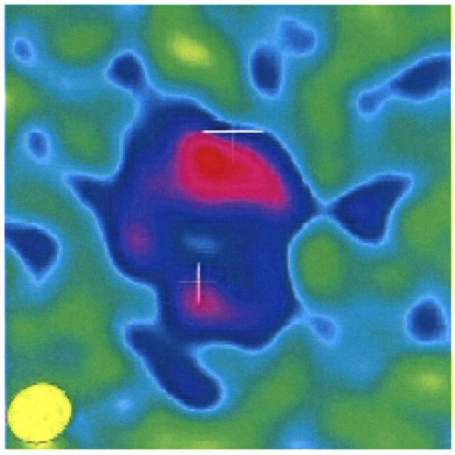


Artist's Conception of the Star-Forming Disk
(Click on Image for Larger Version)

The astronomers studied a quasar called PSS J2322+1944, about 12 billion light-years from Earth. The quasar is an extremely luminous object powered by the supermassive black hole at the core of a galaxy. At the distance of this quasar, the scientists see the object as it was when the Universe was less than 2 billion years old, about 15 percent of its current age.

The discovery required a huge

assist from nature. To find the star-forming disk, the astronomers needed to observe natural radio emission from the carbon monoxide (CO) molecule, an important component of the gas that forms stars. However, this molecule emits radio waves at frequencies much higher than the VLA is capable of receiving. At PSS J2322+1944's distance of 12 billion light-years, however, the expansion of the Universe stretched the radio waves, reducing their frequency. CO emission at 230 GigaHertz was shifted to 45 GigaHertz, within the VLA's range.



VLA Image of PSS J2322+1944
(Click on Image for Larger Version)

That alone was not enough. The distance that made it possible to receive the radio waves from the quasar also meant that the object was too far away for the VLA to discern the detail required to show the disk. Once again, nature stepped in to help, providing another galaxy directly between the quasar and Earth to form a gravitational lens.

"What we needed wasn't just any old gravitational lens, but a nearly-perfect alignment of the distant quasar, mid-distance galaxy, and Earth -- and that's what we got," said Geraint Lewis of the University of Sydney in Australia, another member of the team. With such a perfect alignment, the quasar image was distorted into a ring, called an "Einstein Ring." The VLA images were the first to show the Einstein Ring of PSS J2322+1944.

"We never would have seen the disk of CO gas near the center of this galaxy without the gravitational lens," said Carilli. "The lens boosted the signal and magnified the image to reveal the disk's structure in unprecedented detail," he added.

For several years, astronomers have noted that the masses of black holes are directly proportional to the sizes of central bulges of stars in galaxies. This led to the speculation that formation of the black holes and of the stars are somehow related to each other. Scientists hypothesized that gas being drawn towards a galaxy's central black hole is the same gas from which large numbers of stars are forming.

Studies of more-nearby galaxies supported such speculation, but the question remained whether the idea could be applied to the very early Universe, when the first galaxies and black holes formed.

"This new observation gives strong support to the idea that large numbers of stars were forming in young galaxies at the same time that their central black holes were pulling in additional mass," said Pierre Cox, of the Institute for Space Astrophysics of the University of Paris.

The astronomers believe that galaxies in the early Universe were frequently disrupted by nearby encounters with other galaxies, "feeding" the central black hole with gas. The gas formed an extensive, spinning disk around the galaxy's center, some of it eventually falling into the black hole and some of it forming new stars.

In PSS J2322+1944, the astronomers believe that new stars with a total mass equal to some 900 times that of the Sun were forming in the 13,000-light-year-diameter disk every year. At that rate, the scientists say, most of the stars in a large elliptical galaxy could form in only about 100 million years.

PSS J2322+1944 is one of the most luminous quasars in the Universe. It was first discovered by George Djorgovski and his collaborators from the California Institute of Technology (Caltech), using the digitized Palomar Observatory Sky Survey. Later studies led by Cox and Alain Omont of the Astrophysical Institute of Paris using the IRAM millimeter-wave facilities in Europe (the 30-meter telescope and the Plateau de Bure Interferometer) showed that it had a huge reservoir of dust and molecular gas, the fuel for star formation. Optical observation at the W.M. Keck Observatory in Hawaii showed a double image that indicated gravitational lensing. All these factors, the scientists said, made it an ideal candidate for study with the VLA.

"Our guess paid off handsomely. Finding that Einstein Ring with the VLA gave us the tool we needed to see what was going on inside that very distant galaxy," said Carilli. "There are fewer than 100 gravitational lenses known so far, and we were extremely lucky to find one that allowed us to help resolve the specific scientific question we were studying."

Gravitational lenses were predicted, based on Albert Einstein's General Theory of Relativity, in 1919. Einstein himself showed in 1936 that a perfectly-aligned gravitational lens would produce a circular image, but felt that the chances of actually observing such an object were nearly zero. The first gravitational lens was discovered in 1979, and the first Einstein Ring was discovered by researchers using the VLA in 1987. PSS J2322+1944 is the first Einstein Ring detected through the signature emission of a molecule and the most distant yet found.

PSS J2322+1944 may be able to make another contribution to science. Astronomers believe that gravitational lenses may serve as a tool for precisely measuring great distances in the Universe. If a distant quasar varies in brightness over time, the multiple images formed by a gravitational lens would show that variation at different times. By monitoring such time differences and using a mathematical model of the specific gravitational lens, the distance to the quasar can be measured.

"This quasar, if it shows brightness variations in the future, may be such a 'Golden Lens,' long sought to refine our measurement of very great distances," said Lewis.

In addition to Carilli, Lewis, Djorgovski, Cox and Omont, the research team includes Ashish Mahabal of Caltech and Frank Bertoldi of the Max-Planck Institute for Radio Astronomy in Bonn, Germany.

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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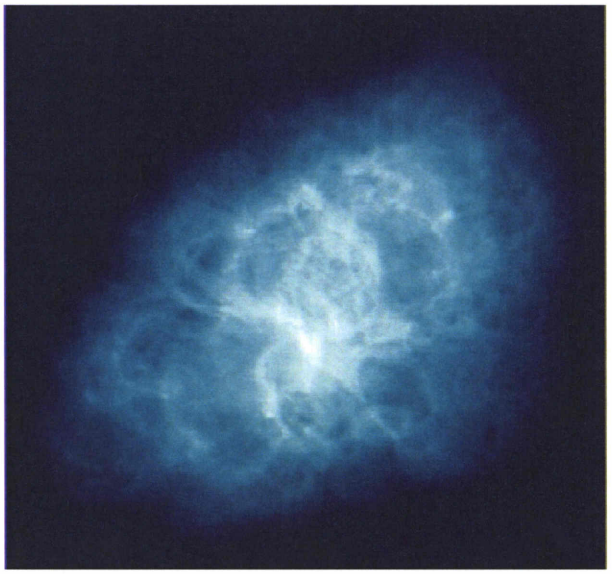
Pulsar Bursts Coming From Beachball-Sized Structures

In a major breakthrough for understanding what one of them calls "the most exotic environment in the Universe," a team of astronomers has discovered that powerful radio bursts in pulsars are generated by structures as small as a beach ball.

"These are by far the smallest objects ever detected outside our solar system," said Tim Hankins, leader of the research team, which studied the pulsar at the center of the Crab Nebula, more than 6,000 light-years from Earth. "The small size of these regions is inconsistent with all but one proposed theory for how the radio emission is generated," he added.



The other members of the team are Jeff Kern, James Weatherall and Jean Eilek. Hankins was a visiting scientist at Arecibo Observatory in Puerto Rico at the time the pulsar observations were made. He and Eilek are professors at the New Mexico Institute of Mining and Technology (New Mexico Tech) in Socorro, NM. Kern is a graduate student at NM Tech and a predoctoral fellow at the National Radio Astronomy Observatory (NRAO) in Socorro. Weatherall is an adjunct professor at NM Tech, currently working at the Federal Aviation Administration. The astronomers reported their discovery in the March 13 edition of the scientific

journal *Nature*.

VLA Image of Crab Nebula
(Click on Image for Larger Version)

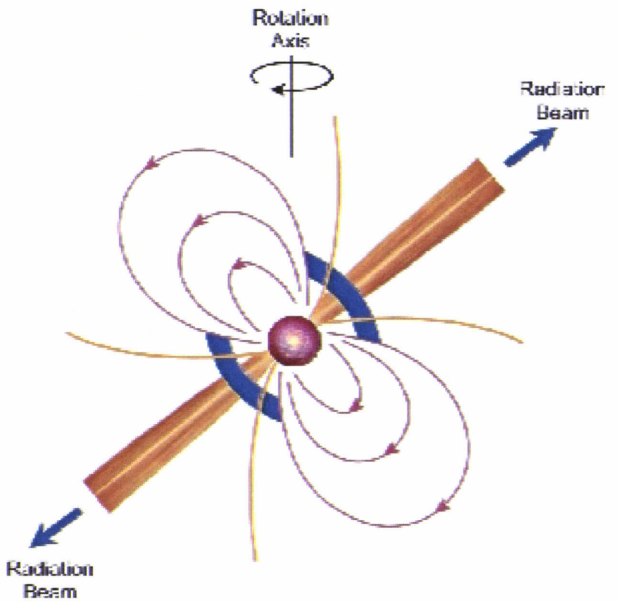


Diagram of a Pulsar
(Click on Image for Larger Version)

Pulsars are superdense neutron stars, the remnants of massive stars that exploded as supernovae. Pulsars emit powerful beams of radio waves and light. As the neutron star spins, the beam sweeps through space like the beam of a lighthouse. When such a beam sweeps across the Earth, astronomers see a pulse from the pulsar. The Crab pulsar spins some 33 times every second.

British radio astronomers discovered pulsars in 1967, one receiving the Nobel Prize for the discovery. In the years since, the method by which pulsars produce their powerful beams of electromagnetic radiation has remained a mystery.

With the help of engineers at the NRAO, Hankins and his team designed and built specialized electronic equipment that allowed them to study the pulsar's radio pulses on extremely small time scales. They took this equipment to the National Science Foundation's giant, 1,000-foot-diameter radio telescope at Arecibo. With their equipment, they analyzed the Crab pulsar's superstrong "giant" pulses, breaking them down into tiny time segments.

The researchers discovered that some of the "giant" pulses contain subpulses that last no longer than two nanoseconds. That means, they say, that the regions in which these subpulses are generated can be no larger than about two feet across -- the distance that light could travel in two nanoseconds.

This fact, the researchers say, is critically important to understanding how the powerful radio emission is generated.

A pulsar's magnetosphere -- the region above the neutron star's magnetic poles where the radio waves are generated -- is "the most exotic environment in the Universe," said Kern. In this environment, matter exists as a plasma, in which electrically charged particles are free to respond to the very strong electric and magnetic fields in the star's atmosphere.

The very short subpulses the researchers detected could only be generated, they say, by a strange process in which density waves in the plasma interact with their own electrical field, becoming progressively denser until they reach a point at which they "collapse explosively" into superstrong bursts of radio waves.

"None of the other proposed mechanisms can produce such short pulses," Eilek said. "The ability to examine these pulses on such short time scales has given us a new window through which to study pulsar radio emission," she added.

The Crab pulsar is one of only three pulsars known to emit superstrong "giant" pulses. "Giant" pulses occur occasionally among the steady but much weaker "normal" pulses coming from the neutron star.

Some of the brief subpulses within the Crab's "giant" pulses are second only to the Sun in their radio brightness in the sky. Although the mechanism that converts the plasma energy to radio waves in the

Crab's "giant" pulses may be unique to the Crab pulsar, it is feasible that all radio pulsars may operate the same way. The research team now is observing signals from other pulsars to see if they are fundamentally different. The subpulses in the Crab's "giant" pulses are so strong that the team's equipment could detect them even if they originated not in our own Milky Way Galaxy, but in a nearby galaxy.

The Crab Nebula is a cloud of glowing debris from a star that was seen to explode on July 4, 1054. Chinese astronomers noted the bright new star that outshone the planet Venus and was visible in daylight for 23 days. A rock carving at New Mexico's Chaco Canyon probably indicates that Native American skywatchers also noted the bright intruder in the sky.

The nebula was discovered by John Bevis in 1731 and independently rediscovered by French astronomer Charles Messier on August 28, 1758. Messier made the Crab Nebula (named because of its crab-like shape) the first object in his famous catalog of non-stellar objects, a catalog widely popular among amateur astronomers with small telescopes.

In 1948, radio emission was discovered coming from the Crab Nebula. In 1968, astronomers at Arecibo Observatory discovered the pulsar in the heart of the nebula. The following year, astronomers at Arizona's Steward Observatory discovered visible-light pulses also coming from the pulsar, making this the first pulsar found to emit visible light in addition to radio waves.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation..

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February 25, 2003

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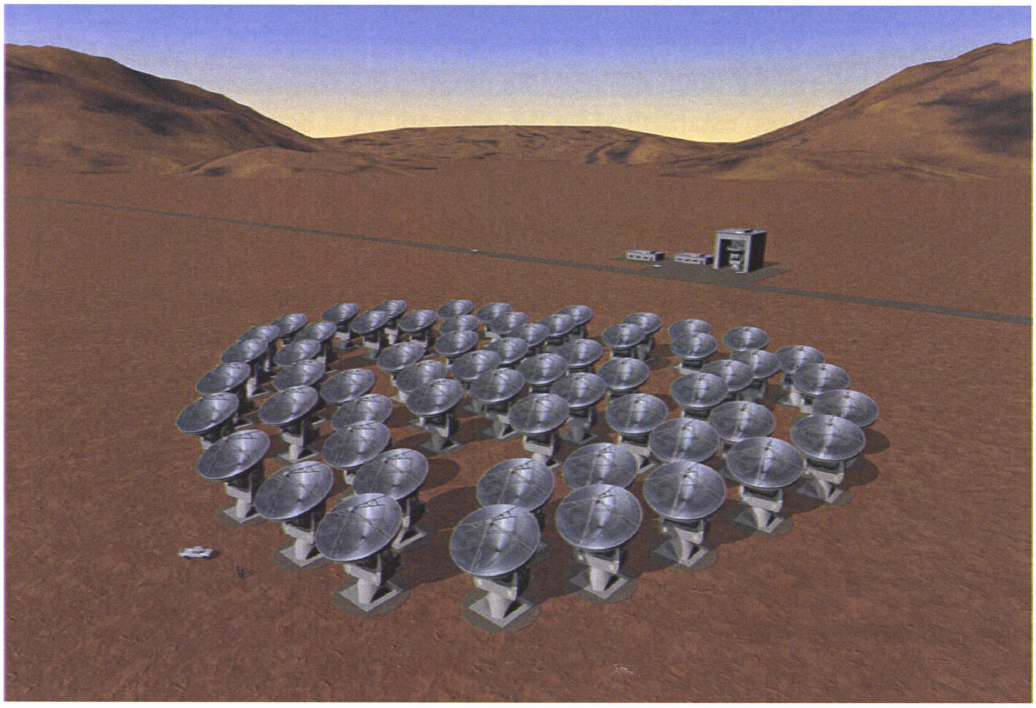
U.S. and European ALMA Partners Sign Agreement

Green Light for World's Most Powerful Radio Observatory

Dr. Rita Colwell, director of the U.S. National Science Foundation (NSF), and Dr. Catherine Cesarsky, director general of the European Southern Observatory (ESO), today signed a historic agreement jointly to construct and operate ALMA, the Atacama Large Millimeter Array, the world's largest and most powerful radio telescope operating at millimeter and sub-millimeter wavelengths.

"With this agreement, we usher in a new age of research in astronomy," said Dr. Colwell. "By working together in this truly global partnership, the international astronomy community will be able to ensure the research capabilities needed to meet the long-term demands of our scientific enterprise, and we will be able to study and understand our Universe in ways that have previously been beyond our vision."



Artist's Conception of ALMA Array in Compact Configuration

Dr. Cesarsky also commented, "This agreement signifies the start of a great project of contemporary astronomy and astrophysics. Representing Europe, and in collaboration with many laboratories and institutes on this continent, we together look forward toward wonderful research projects. With ALMA, we may learn how the earliest galaxies in the Universe really looked like, to mention but one of the many eagerly awaited opportunities with this marvelous facility."

When complete in 2011, ALMA will be an array of 64, 12-meter radio antennas that will work together as one telescope to study millimeter and sub-millimeter wavelength light from space. These wavelengths of the electromagnetic spectrum, which cross the critical boundary between infrared and microwave radiation, hold the key to understanding such processes as planet and star formation, the formation of early galaxies and galaxy clusters, and the detection of organic and other molecules in space.

The ALMA partners will construct the telescope at an altitude of 16,500 feet in the Atacama Desert in the Chilean Andes. This unique site is perhaps the best location on Earth to study millimeter and sub-millimeter light because these wavelengths are absorbed by moisture in the atmosphere. "Astronomers will have a pristine view of that portion of the electromagnetic spectrum from the ALMA site," said Colwell.

ALMA is a joint project between Europe and North America. In Europe, ESO is leading on behalf of its ten member countries and Spain. In North America, the NSF executes the project through the National Radio Astronomy Observatory (NRAO), which is operated under cooperative agreement by Associated Universities, Inc. (AUI). The National Research Council of Canada will partner with the NSF in the North American endeavor.

"The NRAO is very pleased to have the leading role in this project on behalf of the North American partners," said Dr. Fred K.Y. Lo, director of the NRAO in Charlottesville, Virginia.

"ALMA will be one of astronomy's premier tools for studying the Universe," said Nobel Laureate Riccardo Giacconi, president of AUI. "The entire astronomical community is anxious to have the unprecedented power and resolution that ALMA will provide."

The President of the ESO Council Professor Piet van der Kruit agrees: "ALMA heralds a breakthrough in sub-millimeter and millimeter astronomy, allowing some of the most penetrating studies of the Universe ever made. It is safe to predict that there will be exciting scientific surprises when ALMA enters into operation."

By signing this agreement, ESO and the NSF give the green light for the joint construction of the ALMA telescope, which will cost approximately $552 million U.S. (in FY 2000 dollars). To oversee the construction and management of ALMA, a joint ALMA Board has been established by the partners. This board met for the first time on February 24-25, 2003, and witnessed the signing at the NSF headquarters in Arlington, Virginia.

Dr. Joseph Bordogna, deputy director of the NSF, represented Dr. Colwell at the actual ceremony.

Chile, the host country for ALMA, has shown its support for the telescope by issuing a Presidential decree granting AUI permission to work on the ALMA project, and by signing an agreement between ESO and the government of the Republic of Chile. These actions by the government of Chile were necessary formal steps to secure the telescope site in that country.

ESO is an intergovernmental, European organization for astronomical research. It has ten member countries. ESO operates astronomical observatories in Chile and has its headquarters in Garching, near Munich, Germany.

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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January 27, 2003

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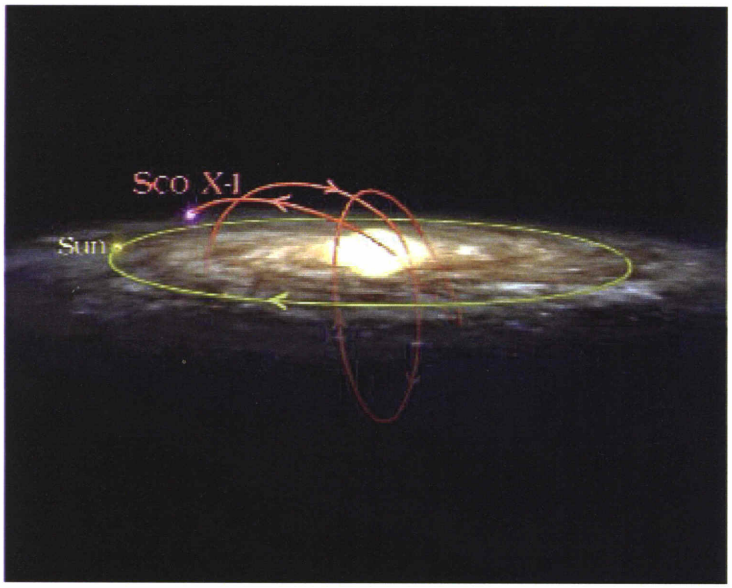
Astronomers Trace Microquasar's Path Back in Time

Astronomers have traced the orbit through our Milky Way Galaxy of a voracious neutron star and a companion star it is cannibalizing, and conclude that the pair joined more than 30 million years ago and probably were catapulted out of a cluster of stars far from the Galaxy's center.



Path of Microquasar (red) and Sun (yellow) through the Milky Way Galaxy for the past 230 million years.

Animations:
GIF Version
MPEG Version

CREDIT: *Mirabel & Rodrigues, NRAO/AUI/NSF*

The pair of stars, called Scorpius X-1, form a "microquasar," in which material sucked from the "normal" star

forms a rapidly-rotating disk around the superdense neutron star. The disk becomes so hot it emits X-rays, and also spits out "jets" of subatomic particles at nearly the speed of light.

Using precise positional data from the National Science Foundation's Very Long Baseline Array (VLBA) and from optical telescopes, Felix Mirabel, an astrophysicist at the Institute for Astronomy and Space Physics of Argentina and French Atomic Energy Commission, and Irapuan Rodrigues, also of the French Atomic Energy Commission, calculated that Scorpius X-1 is not orbiting the Milky Way's center in step with most other stars, but instead follows an eccentric path far above and below the Galaxy's plane.

Scorpius X-1, discovered with a rocket-borne X-ray telescope in 1962, is about 9,000 light-years from Earth. It is the brightest continuous source of X-rays beyond the Solar System. The 1962 discovery and associated work earned a share of the 2002 Nobel Prize in physics for Riccardo Giacconi.

Mirabel and Rodrigues used a number of published observations to calculate the path of Scorpius X-1 over the past few million years.

"This is the most accurate determination we have made of the path of an X-ray binary," said Mirabel.

By tracing the object's path backward in time, the scientists were able to conclude that the neutron star and its companion have been traveling together for more than 30 million years. They also speculated on the birthplace of Scorpius X-1.

"The neutron star, which is the remnant left over from the supernova explosion of an even more massive star, either came from the Milky Way's disk, or from a globular cluster at a considerable distance from the disk," said Rodrigues. Globular clusters are clumps of millions of stars in the outskirts of the Galaxy.

If it came from the Galaxy's disk, the scientists say, it would have had to receive a powerful one-sided "kick" from the supernova explosion to get into its present eccentric orbit. While this is possible, they conclude that a more likely scenario is that the neutron star came from a globular cluster.

"Probably, this neutron star picked up its companion and was thrown out of its globular cluster by a close encounter with other stars at the cluster's core," Mirabel said. The scientists published their results in the January 30 issue of the journal *Astronomy and Astrophysics*.

The same pair of researchers traced a similar path of a black hole and its companion star in 2001. Also that year, other astronomers produced a "movie" showing motions in the jet of material ejected from the disk around Scorpius X-1's neutron star.

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January 8, 2003

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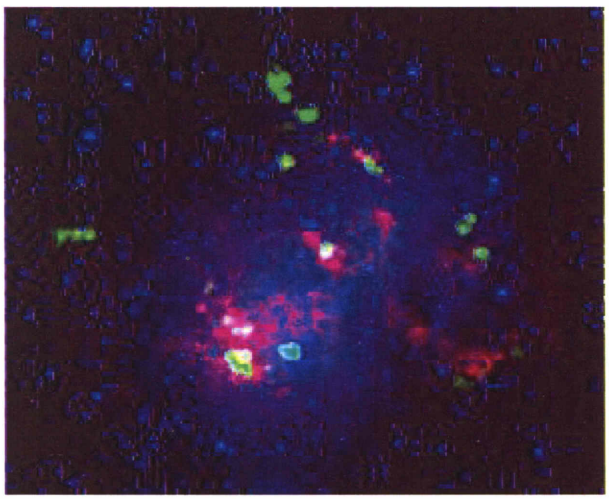
Surprising Image Revises Understanding Of Dwarf Galaxies -- Building Blocks of the Universe

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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January 8, 2003

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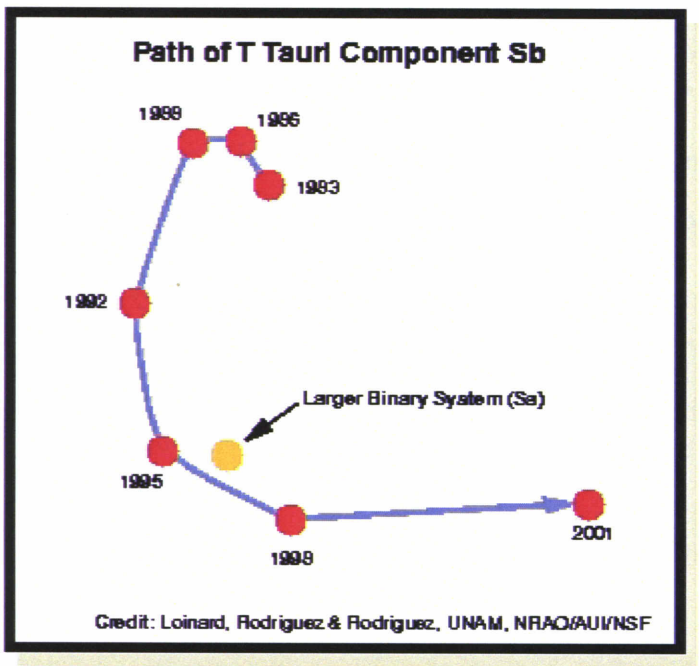
Young Star Probably Ejected From Triple System

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.

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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January 8, 2003

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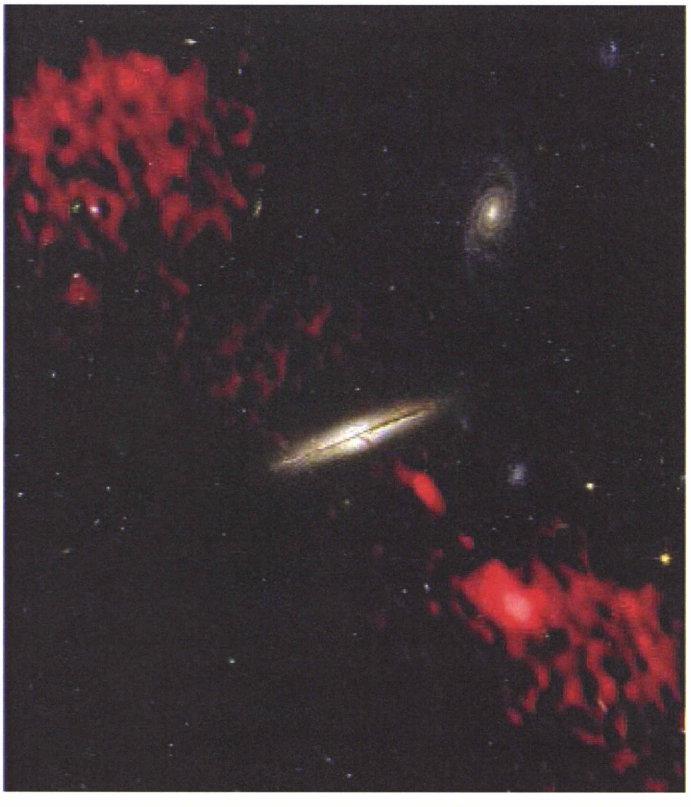
Giant Radio Jet Coming From Wrong Kind of Galaxy

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.

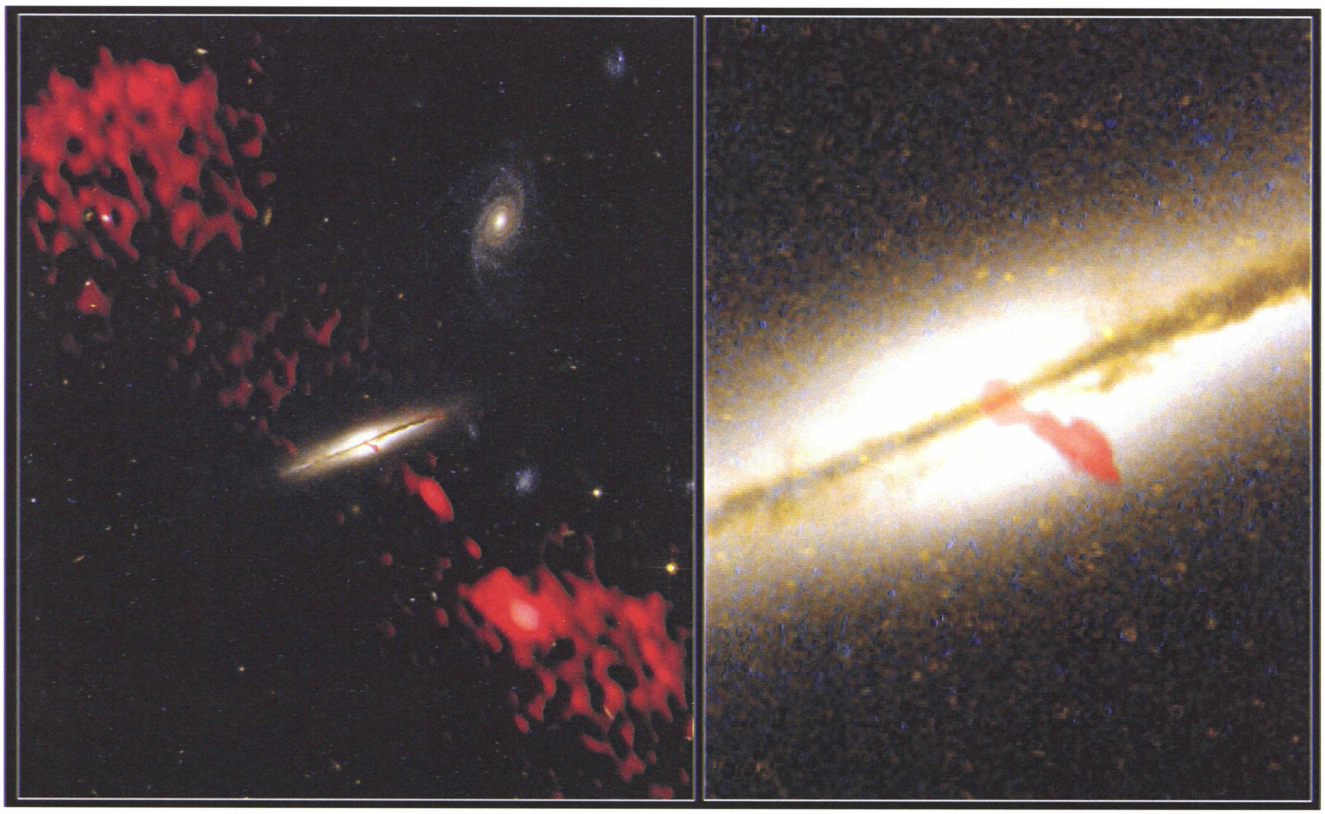
"This galaxy's disk is twisted, and that may indicate that it has been disturbed by a close passage of another galaxy or may have swallowed up a companion dwarf galaxy," Keel said. He added, "This galaxy shows signs of having a very massive black hole at its core, and the jets are taking the shortest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



These are composite images of the galaxy 0313-192, the first spiral galaxy known to be producing a giant radio-emitting jet. The image at left represents two views of the galaxy that astronomers have combined into one photograph. The view of the galaxy and its surrounding environment was taken by the Hubble Space Telescope's Advanced Camera for Surveys. The red material in the image represents the radio-emitting jet, which was taken by the Very Large Array. The galaxy is seen edge-on. At right is a close-up of the Hubble telescope image. Another red overlay from a higher-resolution Very Large Array picture shows the inner portion of the jet.

Credit: NASA, W. Keel (University of Alabama), M. Ledlow (Gemini Observatory), F. Owen (NRAO) and AUI/NSF

(Print Friendly Version)

January 7, 2003

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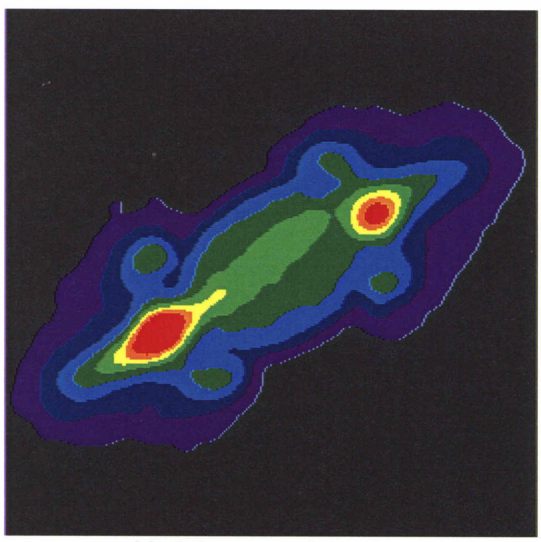
Speed of Gravity Measured for First Time

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.

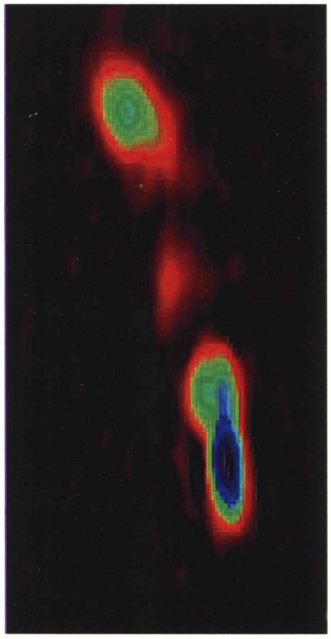
The scientists used the National Science Foundation's Very Long Baseline Array (VLBA), a continent-wide radio-telescope system, along with the 100-meter radio telescope in Effelsberg, Germany, to make an extremely precise observation when the planet Jupiter passed nearly in front of a bright quasar on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

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

Wednesday, January 28, 2004

January 7, 2003

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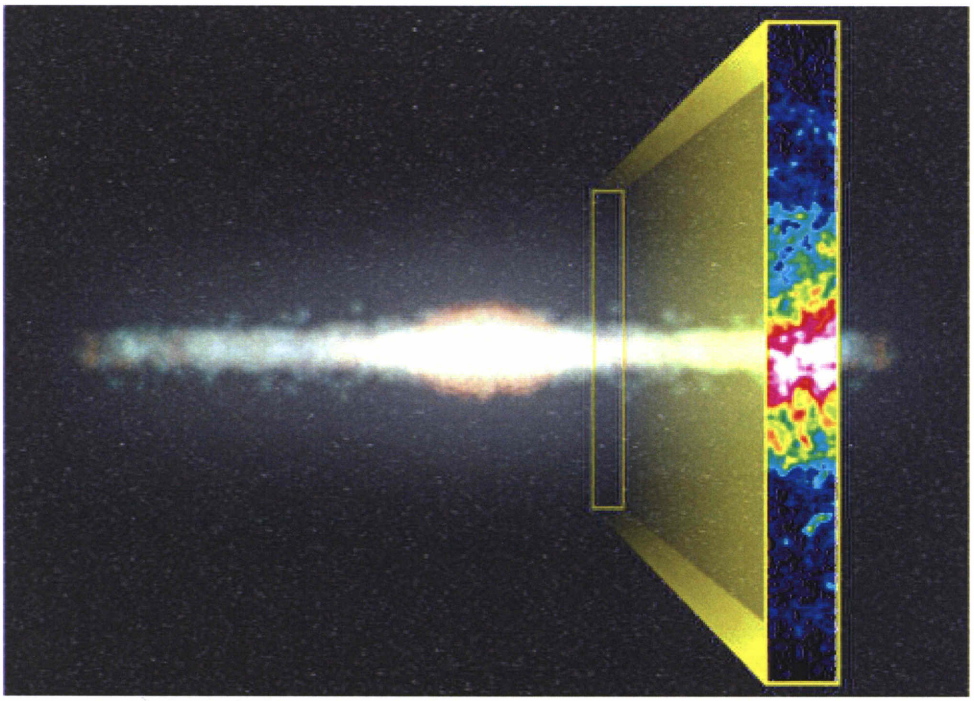
Clouds Dominate the Galactic Halo

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.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under

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Modified on Monday, 14-Apr-2003 15:24:14 EDT

IN THE NEWS

IQ alert

Big brains head this way

BY COURTENEY STUART
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JEN FARIELLO

The National Radio Astronomy Observatory is getting bigger in Charlottesville.

ASTRONOMERS note that masses are hurtling toward Charlottesville. But don't worry, they may not wreak destruction on our historic hamlet, and they could raise the average IQ a few points.

Those masses are masses of flesh, astrophysicists who'll be moving to town over the next two years. They'll make Charlottesville the center of the universe, so to speak, for the study of radiation emitted as long as 13.5 million years ago by the Big Bang and other celestial activity.

Since when is Charlottesville such an astronomic mecca?

It dates back to 1965, when the National Radio Astronomy Observatory put its headquarters in Charlottesville. And although NRAO is not directly affiliated with UVA (it's under the umbrella of the National Science Foundation), proximity to the university played a role, says NRAO spokesman Chuck Blue.

The reason for the sudden growth is ALMA, a massive "array telescope" similar to the Socorro, New Mexico-based Very Large Array, or VLA, seen in the movie *Contact* and also operated by NRAO.

The ALMA itself (it stands for Atacama Large Millimeter Array) won't be here in Charlottesville, but rather 16,500 feet above sea level in the Chilean Andes. When completed in 2012, ALMA will be the world's largest array telescope with 64 dishes— compared to VLA's 27— operating in unison to pick up millimeter and submillimeter wavelength light. Scientists here in Charlottesville and Europe (location TBA) will spend years pouring over the data, hoping to get the Biggest Bang for their buck (or Euro).

NRAO is probably best known for its giant radio telescope in Green Bank, West Virginia. At 17 million pounds, 485 feet in height, and diameter over 100 yards, it's the largest moving machine on the planet. It was built during the 1990s after an earlier dish at the same site collapsed under its own weight in 1988.

That dish, just slightly smaller than the current one, lasted about 26 years, and NRAO's Blue says it was never meant to last. "It was built for a 10-year project," he explains. Fortunately, the collapse of the massive dish didn't injure anyone. "It gracefully laid itself down in the middle of the night," says Blue.

Radio telescopes are complicated instruments. Unlike optical telescopes that rely on mirrors to reflect light to a focal point, radio telescopes use a dish to collect radio waves that are then sent through a computer for analysis. But these are not your DirecTV dishes. At millions of dollars apiece, the radio telescope dishes have unbelievable accuracy. Blue says ALMA would be able to measure the diameter of the period at the end of a sentence from over a mile away.

While VLA focuses on centimeter and larger wavelengths, ALMA, which will cost over $550 million, will be the first array telescope to focus on the smallest wavelengths— those that provide a look billions of years back in time. Galaxy and star formations can be studied using millimeter and submillimeter radiation, while longer wavelengths allow the study of phenomena such as black holes.

Because of the wavelength specificity, ALMA, though powerful, would not be used to identify alien life forms intent on an earthly encounter. (Rood says a telescope called Arecibo in Puerto Rico spends a few weeks each year seeking extraterrestrial contact.)

NRAO's presence has been a major boon for Jefferson's university, says UVA Astronomy Chair Robert Rood.

"It helps us recruit grad students and faculty," says Rood, whose says it helped lure him to UVA in 1973. "I probably wouldn't have come here when I did if it weren't for NRAO," Rood says.

NRAO currently has 104 local employees, including scientists, engineers, and administrative staff, according to Blue, but that number will increase by at least 35 by 2006.

To make room for the added brainpower, NRAO is expanding its primary location, a stately campus commonly known as Stone Hall, at 520 Edgemont Road at the foot of UVA's Observatory Hill.

NRAO has also begun renting the former Institute of Textile Technology building about two miles from Charlottesville across from the Boar's Head Inn. That 9.2-acre property was purchased by Ivy Road Properties LLC in August for $6.6 million.

Since ALMA will have 64 dishes spread out over as much as 10 kilometers, collapse won't be a concern. However, keeping all dishes functioning as a unit will be a constant challenge.

It's a challenge NRAO assistant director Mark Adams says the astronomy world is buzzing about.

"We're all very excited," he says. ■

Ghosts of Andromeda

February 05, 2004

>> About this Image

Previous Image of the Day

Luna Looms

February 04, 2004

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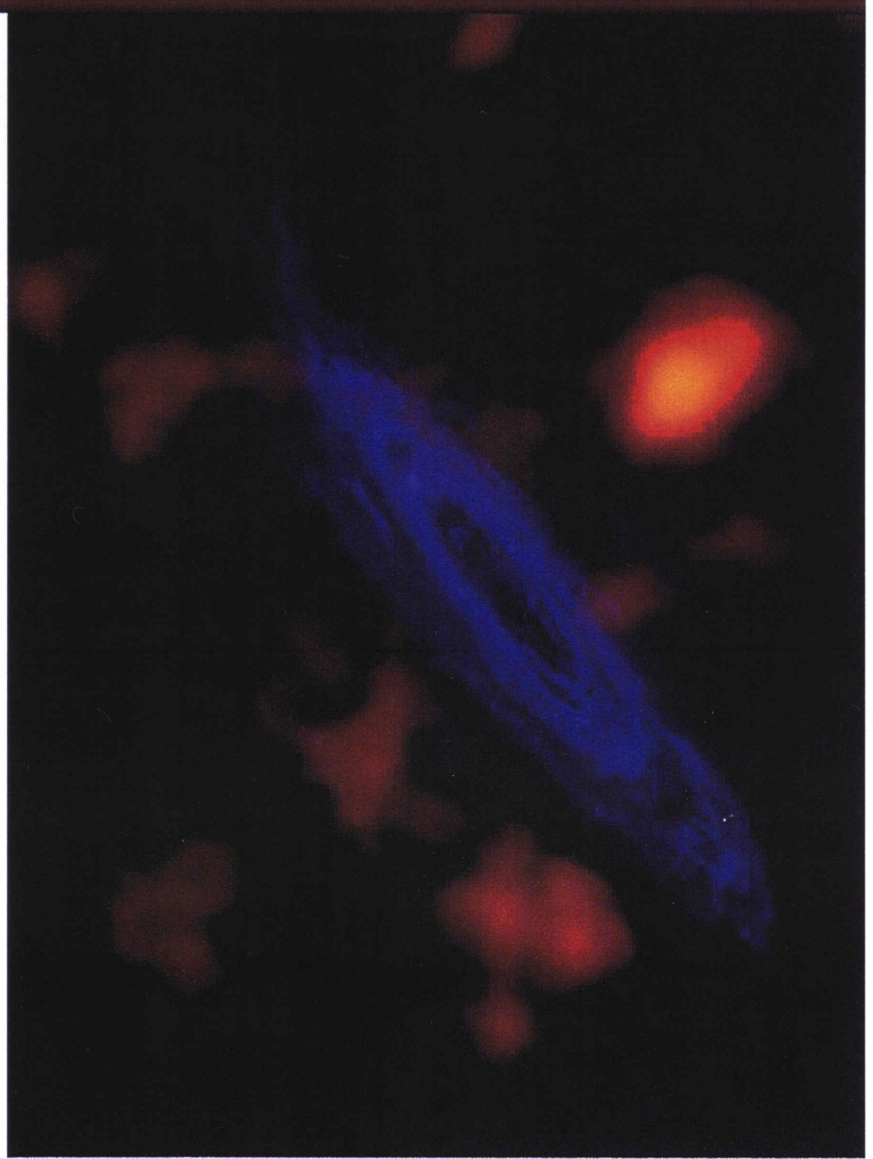

Ghosts of Andromeda

This new image of the nearby Andromeda galaxy represents th conclusive detection of what appear to be the leftover building formation. Clouds of neutral hydrogen swarm around the large galaxy.

The image, released yesterday, was made with the National Sc Foundation's Robert C. Byrd Green Bank Telescope.

This discovery might help scientists understand the structure a evolution of the Milky Way and all spiral galaxies, astronomers also could help explain why certain young stars in mature gala surprisingly bereft of the heavy elements that their contempora contain.

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"Giant galaxies, like Andromeda and our own Milky Way, are th
form through repeated mergers with smaller galaxies and throu
accretion of vast numbers of even lower mass 'clouds' -- dark c
that lack stars and even are too small to call galaxies," said Da
Thilker of the Johns Hopkins University in Baltimore, Maryland
"Theoretical studies predict that this process of galactic growth
today, but astronomers have been unable to detect the expect
mass 'building blocks' falling into nearby galaxies, until now."

The new findings are detailed in the Astrophysical Journal Lett
detailed explanation of the findings ishere.

Credit: NRAO/AUI/NSF, WSRT

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Issue 12.02 - February 2004

The Quiet Zone

Cell phones, pagers, Wi-Fi, Bluetooth - the wireless revolution is everywhere. Except here.

By John Geirland

I'm 1 mile east of command central in the Quiet Zone, sitting in a Dodge pickup with Wesley Sizemore, Keeper of the Quiet. In a world saturated with radio waves, the Quiet Zone is a haven and an anomaly. A unique combination of geography and legislation has rendered its 13,000 square miles nearly free of electromagnetic pollution. Sizemore's job is to keep it that way. On this freezing afternoon, he's showing me the scene of his most storied success: a double-wide modular home amid brown grass and patches of snow in Pocahontas County, West Virginia (population 8,996).

Photo by Jonathan Manzo

One morning several years ago, Sizemore got a call. Broadband interference - noise, in common parlance - was wreaking havoc with the sensitive equipment at command central. After loading up his truck with a receiver, amp, spectrum analyzer, and directional antenna, he thundered into the countryside. Every quarter mile or so, he stopped, whipped out the antenna, and scanned the electromagnetic spectrum for spikes of activity. He methodically triangulated his way to this spot, where an elderly couple live with a nasty old dog penned in back. The couple had given the mutt a heating pad to lie on, but the pad had become worn; cracks in the wiring were causing tiny electric arcs to leap across the gaps. "Not enough electricity to shock the dog," Sizemore explains, but enough to produce a radio-frequency signal. He promptly disposed of the heating pad and bought the couple a new one. Just one more small step in humankind's exploration of the cosmos.

The Quiet Zone is a generous margin of mountainous terrain and rustic communities surrounding the Robert C. Byrd Green Bank Telescope, a 485-foot, 17 million-pound structure that emerges improbably from this remote valley. Astronomers here observe the universe by studying faint radio waves emitted by stars, evaporating comets, and distant galaxies. These signals inhabit many areas of the electromagnetic spectrum - often the same areas prized by broadcasters, cellular providers, and other communications companies.

The subjects of radio astronomy are astronomically large, but the signals they produce are astronomically weak by the time they reach Earth. These emissions are measured in Janskys, named for the father of radio astronomy, Karl Jansky. A Jansky is based on 0.00000000000000000000000001 watts - and that's a big signal at Green Bank. Even a musical greeting card playing at the base of the telescope could produce anomalous spikes in the data of an unlucky astronomer trying to study stellar gases. If the interference is strong enough, the telescope's ultrasensitive first amplifier - cooled by liquid helium to minimize internal noise - shuts down.

Sizemore, 49, has safeguarded the telescope and its mission since 1983. One minute he's running signal propagation models, the next he's sledgehammering the base of a power-line pole to rejigger its insulation, and then he's alerting the site director about an unexpected incursion: North American flying squirrels tagged with telemetry transmitters, a project of the US Fish & Wildlife Service.

In the past few years, however, Sizemore's job has become overwhelming. The wireless revolution has swept the country beyond the Zone. First pagers and cell phones, then satellite radio, souped-up walkie-talkies, Wi-Fi, and Bluetooth - one after another, these technologies have cranked up the surrounding cacophony. There are even sources of radio-frequency interference raining from the sky: Transmissions from a Russian Glonass satellite recently derailed efforts to study a faraway cluster of galaxies.

Sizemore's efforts to shield Green Bank's radio waves from the encroachment of civilization may make him seem a quaint relic of the past. Actually, he's a harbinger of the future: The problems that keep him awake at night are increasingly everyone else's problems, too.

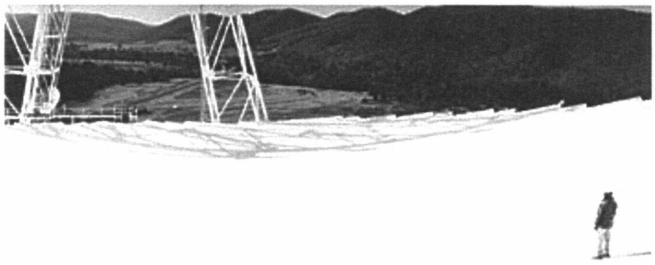


Photo by Jonathan Manzo
Chief antenna engineer Robert Anderson surveys the 13,000-square-mile National Radio Quiet Zone from the center of the world's largest fully steerable radio telescope.

While electromagnetic spectrum is a finite resource, the number and variety of gadgets emitting electromagnetic energy continue to grow. As the airwaves become more crowded, signals from devices operating in neighboring frequencies spill into one another's bands. When spectrum allocation frays at the edges, devices go haywire: Garage doors open and close by themselves, phone conversations blare over baby monitors. The stakes also can be frighteningly high, as when emergency workers can't coordinate a disaster response effort. Some observers fear that interference is becoming so severe that soon there won't be enough spectrum to go around.

Sizemore has been feeling that way for a long time. He has been tracking down and stifling stray

signals for more than two decades; engineers and regulators are just beginning to explore ways of operating in a spectrum-saturated environment. "In terms of the RFI issue," says Green Bank site director Philip Jewell, "we're the canary in the coal mine."

The astronomers who selected Green Bank as the site for the telescope in the mid-1950s chose carefully. The surrounding Allegheny Mountains provided a natural shield against radio and television broadcasts. Flanked by national forests teeming with black bears and wild turkeys, the area would remain undeveloped in perpetuity. And for all its physical isolation, it was only a day's drive from many East Coast universities. Even back in the '50s, though, farsighted scientists feared that radio-frequency emitters would eventually creep into the area. More aggressive protection would be necessary.

Thus, in 1958 the FCC set aside a rectangular-shaped territory the size of Massachusetts and Connecticut combined and called it the National Radio Quiet Zone, to be administrated by the National Radio Astronomy Observatory, a government-funded research facility in Charlottesville, Virginia. The NRAO later built other radio telescopes - in Socorro, New Mexico (the setting for the film Contact with Jodie Foster), and Tucson, Arizona - but it never again had the clout to impose quiet around them. Today, Green Bank is radio astronomy's crown jewel. Over the years, the telescope has played a key role in understanding the behavior of pulsars, searching for extraterrestrial life, and probing the halo of hydrogen that surrounds the Milky Way galaxy. It's one of the few facilities on the planet where radio astronomers can make observations at most points along the electromagnetic spectrum.

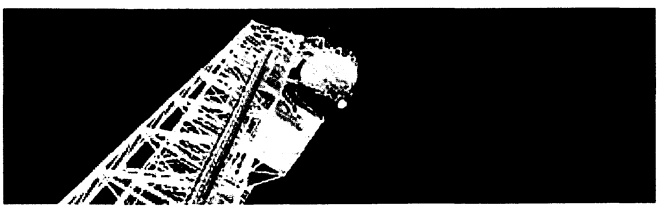
All major transmitters in the Zone are required to coordinate their operations with the national observatory. Radio stations point their antennas away and operate at reduced power. Cell phone base stations are few and far between, and entirely absent deep in the Zone. Even incidental electromagnetic emitters are regulated: Power lines must be buried 4 feet belowground. The wireless LAN card in your laptop? Forget about it.

"Your cell phone and pager won't work here," Sizemore warned me before I came out for a visit. He was right. As I negotiate the snowy switchbacks on Route 250 West, my cell phone passes out of service while the FM dial gradually becomes depopulated. By the time I reach the tiny burg of Green Bank, all I can get is a static-shrouded episode of *A Prairie Home Companion* from a radio station outside the Zone.

The facility itself looks like any high tech office building, except for the full-scale replica of the antenna Jansky used in 1932 to discover "mysterious radio waves" emanating from the Milky Way - a natural phenomenon that, for a time, he mistook for communications from an alien civilization.

The next morning, I meet Sizemore for breakfast in the dining hall. He shows up in a black leather jacket and an earth-toned, Navajo-print flannel shirt. His beard is a thicket of graying bristles. Sizemore grew up in the mountain hamlet of Trout, West Virginia. He spent six years in the Navy, during which he was stationed in the Bahamas and the Mediterranean before returning to West Virginia to attend Bluefield State College. Then he was off to the Cleveland Institute of Electronics, where he earned an associate degree in electrical engineering. He's an Appalachian-high tech hybrid who makes his own wine and listens to NPR.

He's also a verbal snowplow when he gets worked up about the Quiet Zone. Once he latches onto a subject like "tropo-scatter" or "free space loss," he's unstoppable. "I take the maintaining of the Quiet Zone very personal," he explains in a West Virginia lilt. "It's my way of making a contribution to the body of mankind's knowledge."



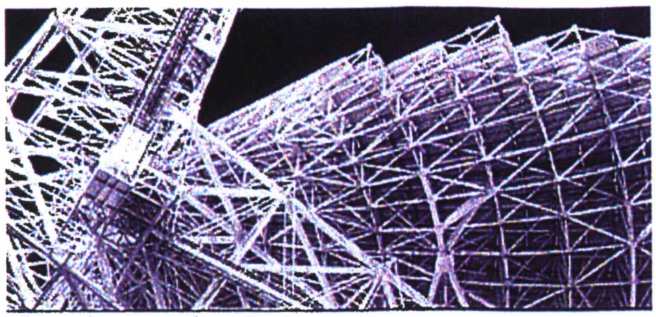


Photo by Jonathan Manzo
Sections of the 100-by-110-meter telescope, which is made up of 2,004 actuator-driven panels.

The quiet lets astronomers measure electromagnetic waves thrown off by space-borne molecules when they become heated or collide. Each type of molecule emits energy in a unique frequency band; hydrogen, the most abundant molecule in the universe, is in the 1,400 to 1,427-MHz range. This band and a few others have been set aside by international treaty exclusively for radio astronomy. In practice, spillage from neighboring bands can cause interference even in these tiny slivers of spectrum.

Although just about any electronic or electromechanical device can blind Green Bank's telescope, the biggest culprit in the first category is the observatory itself. After all, it's a high tech operation crammed with sophisticated electronics and PCs. Green Bank director Jewell believes that some of the steps taken to mitigate interference at the facility may someday be adopted in the wider world, such as innovative circuit board designs and extensive shielding. The cafeteria's microwave oven is kept in a shielded cage. Large chambers designed to absorb radio waves - including a 5,000-square-foot conference room - have been built to make sure that, as Sizemore tells it, "radiation generated in the building stays in the building." Outside, spark plugs are notorious radio-frequency emitters, so Green Bank maintains a fleet of diesel-powered, electronics-free '69 Checker cabs and '70s Dodge trucks.

Thousands of tourists visit Green Bank each year, many of them stuffing their day packs with cell phones, two-way radios, and similar wireless gadgetry. The good news is that these devices operate at low power levels. The bad news is that they're mobile. The FCC doesn't control unlicensed transmitters, but West Virginia's Radio Astronomy Zoning Act prohibits any RFI-generating device - licensed or not - within 2 miles of the telescope.

Sizemore is more anxious about pervasive emitters: cellular telephones, two-way pagers, wireless email. Under FCC rules known as geographic area licensing, service providers can erect transmitters anywhere in a designated region without notifying the commission of the exact location. The policy worries Sizemore. "We don't know where the final transmitter sites will be," he says, which makes it difficult to assess the impact of a new transmitter on the telescope's operations ahead of time.

Meanwhile, there are more immediate challenges. Sizemore wants to show me a transmitter that poses a direct danger to the telescope, a kind of electromagnetic sword of Damocles. "Dress warmly," he warns.

The next morning, we're standing on the icy patio of the Sunrise Backcountry Hut, a remote cabin on top of a mountain a couple miles from the Snowshoe Mountain ski resort. Sizemore was right about bundling up. It's 14 degrees, and snow flurries whirl overhead.

Snowshoe wants to install a transmitter to relay the cabin's smoke-detector alarm to headquarters. But the cabin is only 7.5 miles from the telescope, with no mountains in between. If the alarm went off and the transmitter relayed its signal, the result, Sizemore says, would be "catastrophic."

Before the resort can install the transmitter, it must obtain a waiver from Green Bank. And when it comes to waivers, Sizemore's standard line is "If you're going to make a buck with it, don't ask!" But this case is different. Public safety trumps research.

The trick is to configure the system so it won't blow an amp at Green Bank the moment a hapless lodger attempts to cook blackened salmon. It may be possible to equip the emergency transmitter with a directional antenna aimed at a 90-degree angle away from the telescope toward a Verizon wireless base station in Warm Springs Mountain, Virginia, about 40 miles south. Then the base station would redirect the signal back to Snowshoe. Sizemore and Nathan Sharp, a lanky Green Bank technician, test the idea with their own equipment, which includes an antenna that looks like a high tech coatrack. "Slow and easy. Keep going to the right," he tells Sharp, who is gripping the antenna. "That's a nice strong signal there."

While Sizemore and Sharp fiddle with the antenna, I catch a bumpy snowmobile ride down the mountain to talk to Jim Haas, VP of resort services at Snowshoe. Haas, a pale, beefy man with a wispy soul patch, wears a blue jacket and matching Snowshoe cap.

The smoke detector is just one detail in a much larger system that Snowshoe has had to adapt to Quiet Zone priorities, Haas tells me. "It has made our communications more difficult and cost us more money," he says without rancor. The resort has staff operating on both sides of the mountain, and normal practice would be to install a repeater at the peak to boost signals to employees' handsets. But that would fry the telescope, so he's had to install hardwired components at double the cost.

Still, Haas isn't complaining. "Wesley has worked as hard as anyone to find ways for us to operate," he says. Haas has been an employee at Snowshoe for more than 25 years - he knows the rules of the Quiet Zone. Skiers are a different matter. "People are bringing Motorola Talkabouts on the mountain," he says, and there's little Sizemore can do about that.

Photo by Jonathan Manzo
Wesley Sizemore at his desk with a directional antenna.

By the time I get back up to the Sunrise Lodge, Sizemore is showing the Snowshoe staff how the directional antenna can be placed under the metal roofing, further shielding the telescope from the transmitter's signal. The beauty of the scheme is in its economical use of power and spectrum. A typical antenna would radiate 48 watts of power in all directions. The directional antenna concentrates only 3 watts in one direction - toward the Verizon tower - accomplishing the same goal far more efficiently.

Sizemore's solution is typical of his stingy approach toward spectrum. He uses an optical analogy to make his point. "Why do we have streetlights that shine up into the night sky?" he asks. "We're illuminating the bellies of airplanes for no reason. So why would you have an antenna radiating in all directions when you want to communicate in one direction?"

As I gaze out over the snowy Allegheny Mountains, I imagine the area surrounding the Quiet Zone as a huge mosaic of RF emitters. Sizemore's job is to fit all the pieces into a harmonious whole - and to do so constantly, in an ever changing landscape. This concept, as it happens, may be the ultimate solution to the interference problem everywhere.

There's no question that use of the electromagnetic spectrum is sharply increasing. In 1994, the

FCC projected that by 2000 there would be 54 million users of mobile wireless services in the US; the actual number reached 110 million. In spite of industry woes, the number of cellular base stations worldwide is expected to climb from 1.3 million in 2003 to 1.6 million by 2006, serving 1.8 billion wireless users. Meanwhile, short-range and satellite transmissions are multiplying.

The parts of the spectrum set aside for unlicensed devices - the 900-MHz, 5.7-GHz, and 2.4-GHz bands - are getting especially noisy. Recent technologies like Bluetooth and Wi-Fi are choking these frequencies. To make matters worse, the popular 2.4-GHz band shares space with medical, scientific, and industrial devices, like the huge microwave ovens used to dry plywood.

The soft signs of a growing interference problem are everywhere. Cordless phones in the 2.4-GHz band interfere with Wi-Fi. Until recently, some radar detectors (popular among truckers for spotting police) disrupted terminals used to authorize credit cards at gas stations or pipe Muzak into burger joints.

Some RFI effects are as comical as they are unexpected. Errant radio waves caused mischief on the *Spider-Man* movie set when emissions from a high-powered walkie-talkie tweaked a timing processor on a generator, killing the lights in the middle of a tear-jerking scene.

Other incidents have been more serious. Six years ago, broadcasts from Dallas-based WFAA, the country's first digital TV station, interfered with wireless heart monitors at Baylor University Medical Center. (The hospital spent $200,000 on new machines.) And last May, a baby monitor hindered air-traffic control communications as pilots approached London's Luton Airport.

Some experts fear this is the leading edge of a spectrum meltdown, but others have high hopes for new technology. Dennis Eaton, chair of the Wi-Fi Alliance, is undaunted by reports of Bluetooth devices hopping all over Wi-Fi connections or interference between overlapping hot spots operating on the same frequency. "I put my faith in the engineers who are designing new equipment," he says.

Eaton may be right. Already, phased-array antennas can make more efficient use of existing spectrum. An approach known as cognitive radio might have an even bigger impact. Unlike your local Top 40 radio station, which transmits 24/7, unlicensed wireless devices tend to use the airwaves intermittently. At any particular moment, the spectrum is rife with unoccupied frequencies, or "white holes." Cognitive radio hunts out these holes and makes temporary use of them. If this technology catches on, every Wi-Fi base station or cordless phone could contain its own little Wesley Sizemore.

Indeed, radios are getting smarter. In January 2003, the US Department of Defense reached an agreement with technology companies requiring manufacturers to enable Wi-Fi devices to detect activity in frequencies used by military radar and, if they sense it, to avoid those parts of the spectrum. FCC rule changes are enabling manufacturers to produce Bluetooth devices that sniff out Wi-Fi signals and dodge them by broadcasting in other frequencies.

Such strategies may ease interference problems in the larger world, but the Quiet Zone is a different matter. Sizemore fears that cognitive radio would allow people to use spectrum bands that previously had been quiet - creating another source of noise rather than a solution. The more the FCC loosens the regulatory reins - allowing cognitive radio, instituting geographic area licensing, opening more spectrum to unlicensed users - the more difficult it becomes to maintain the quiet in the Zone. Even if the outside world does evolve into a laissez-faire commons, as some observers advocate, the Quiet Zone must remain an embattled bastion of command and control.

Sizemore gives me a final spin around the observatory grounds. He looks tired. He drives past one of the smaller radio telescopes, used in 1961 by astronomer Frank Drake, who created the famous equation for estimating the number of intelligent civilizations in the universe. Sizemore is playing a high-stakes endgame. He's determined to protect this last clear portal to the cosmos. "The Quiet Zone is like a wilderness," he says softly. "Once it's gone, it's gone for good."

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FRIDAY MORNING, JANUARY 2, 2004

FINAL

GRAYING of the universe

Researchers using VLA scan the sky and find a 'dark energy' that is influencing how the cosmos ages

BY JOHN FLECK
Journal Staff Writer

A survey of the sky begun a decade ago with the Very Large Array has paid off with new details about how our universe is aging.

Writing in Thursday's edition of Nature, a pair of astronomers report the astronomical equivalent of the first few gray hairs as the universe approaches middle age.

They are signs that a mysterious "dark energy" is influencing how the universe grows old.

Still shrouded in mystery, "dark energy" is a poorly understood force that acts in opposition to gravity, causing our universe to expand.

Its discovery in 1998 turned the science of cosmology on its head, and new findings this year about dark energy were ranked by Science magazine as "the breakthrough of the year."

Now come Stephen Boughn and Robert Crittenden, who used the VLA's sky atlas and data from two satellites to track the way dark energy exerts its subtle tug on light from the far edge of the universe.

Boughn, from Haverford College in Pennsylvania, and Crittenden, from the University of Portsmouth in England, turned to the VLA atlas because it was one of the most complete maps of the sky available.

"There just aren't that many maps like that out there," Boughn said this week in a telephone interview.

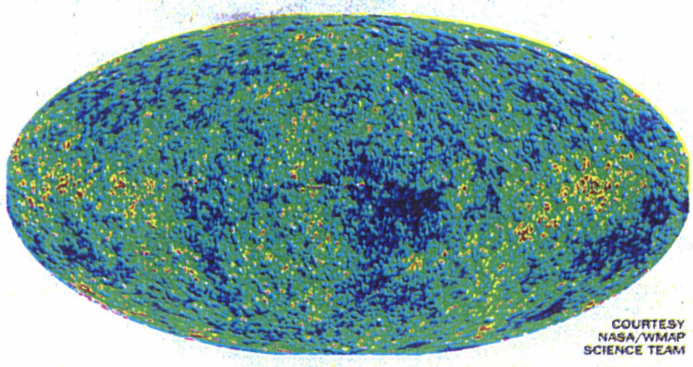
Begun in 1993, the VLA Sky Survey mapped the location of every object in the sky that is visible from New Mexico, said Rick Perley, one of the National Radio Astronomy Observatory scientists who worked on the project.

Over a four-year period, the VLA team took 217,466 images

See UNIVERSE on PAGE A2

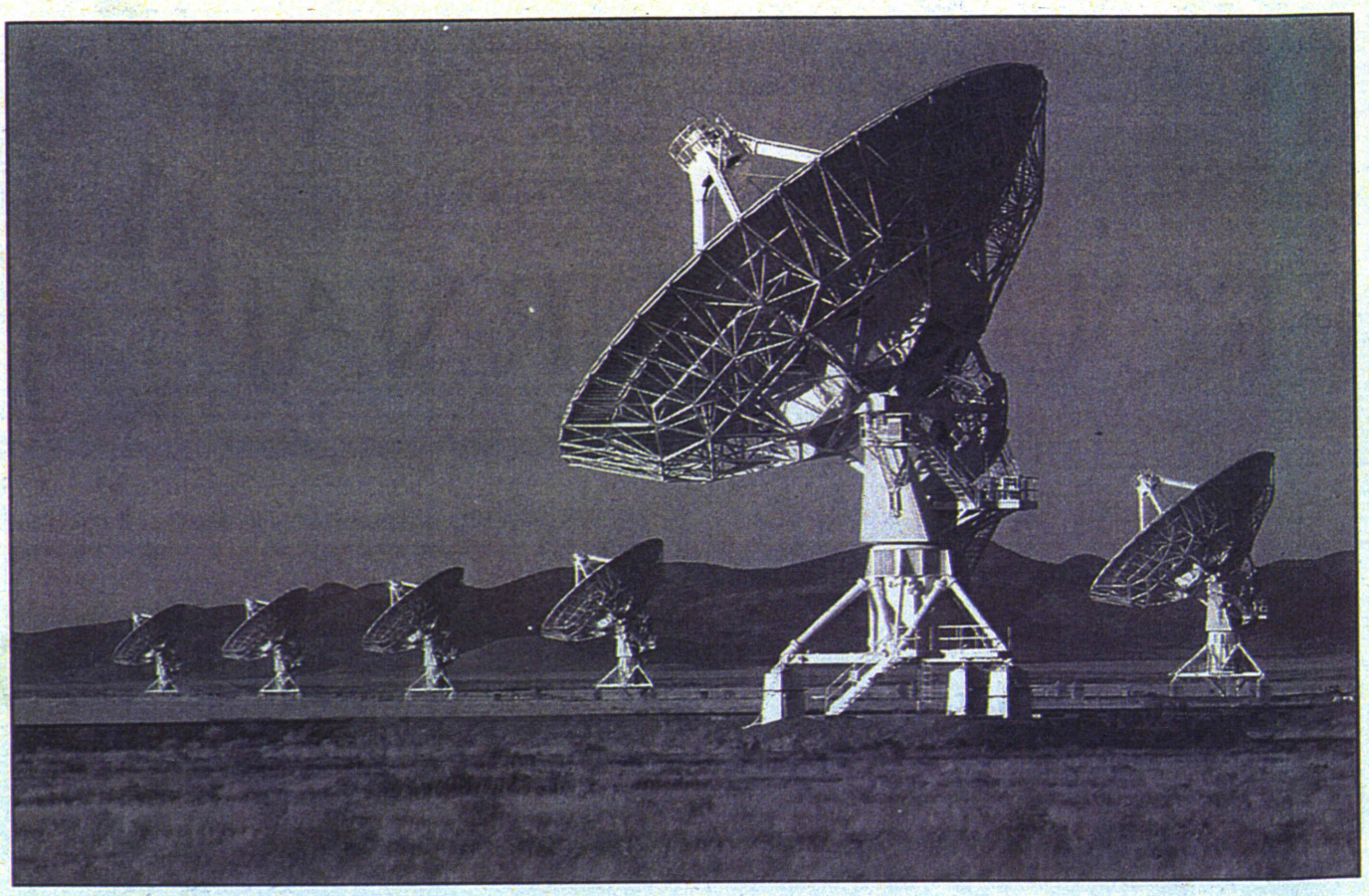
JOURNAL FILE

Data from the Very Large Array is helping explain the strange "dark energy" that is driving the new-found expansion of our universe.



COURTESY NASA/WMAP SCIENCE TEAM

Astronomers combined this satellite sky map of faint distant light with data from the Very Large Array to show how "dark energy" is changing the structure of our universe.



JOURNAL FILE

Very Large Array telescopes spent four years during the 1990s building a vast sky atlas that is now being used to shed light on fundamental cosmology.

Universe Getting Gray Hairs

from **PAGE A1**

of the sky, recording the location and brightness of some two million stars and galaxies.

The survey was done so a complete set of data would be available for future researchers to test out their ideas, explained Perley.

"That's exactly what the purpose of it was," Perley said.

Boughn and Crittenden put the data to good use.

They were trying to understand how dark energy influences light as it passes through vast clusters of galaxies.

The light they were looking at originated at the far edge of the universe.

Like a marble rolling down the side of a bowl, the light should speed up as it heads into a galaxy, then slow down again coming out the other side.

But because the dark energy is pushing things apart the whole time, the gravitational bowl changes shape as the light is passing through it. The roll coming up out of the bowl is easier, and the result can be detected in the frequency of the light, Boughn explained.

Boughn used the VLA data to pinpoint where clusters of galaxies were located, then compared that to the frequency of distant light collected by a NASA satellite called the Wilkinson Microwave Anisotropy Probe.

Comparing the Wilkinson data to a second sky map, made with a satellite in the 1980s, showed the same thing, Boughn and Crittenden wrote in Nature.

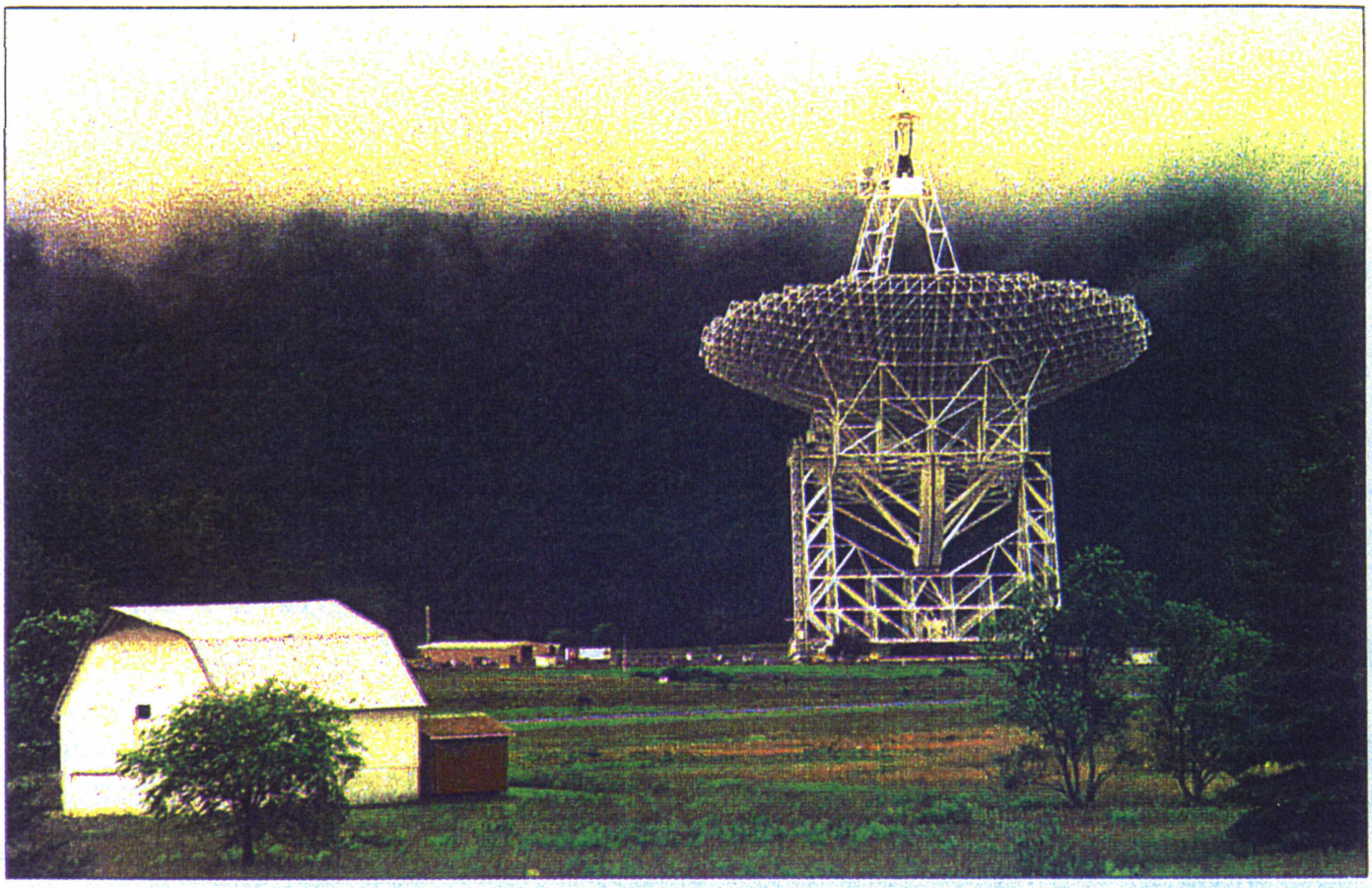
The result provides an independent confirmation for dark energy's existence, Boughn said. It also gives scientists a new tool for studying the details of how the dark energy is influencing the evolution of the universe's large-scale structure, as gravity tugs galaxies together while dark energy pushes them apart.

Similar studies are already under way, including one using the massive archive of data collected by the Sloan Digital Sky Survey, a project based at the Apache Point Observatory in southern New Mexico.

Boughn praised the VLA survey team, saying the new result demonstrates the value of making careful maps of the sky, even if one has no idea how they might be used.

"There often are all kinds of unexpected things," he said.

Report Warned of U.S. Invasion Plans



CHRIS GORST/THE ASSOCIATED PRESS

The Green Bank Telescope, the most massive moving structure on land, is one of three operated by the Charlottesville-based National Radio Astronomy Observatory.

Distant galaxies come to life

Science center offers tours, exhibits and more at W.Va. site

BY PETER CLEARY
MEDIA GENERAL NEWS SERVICE

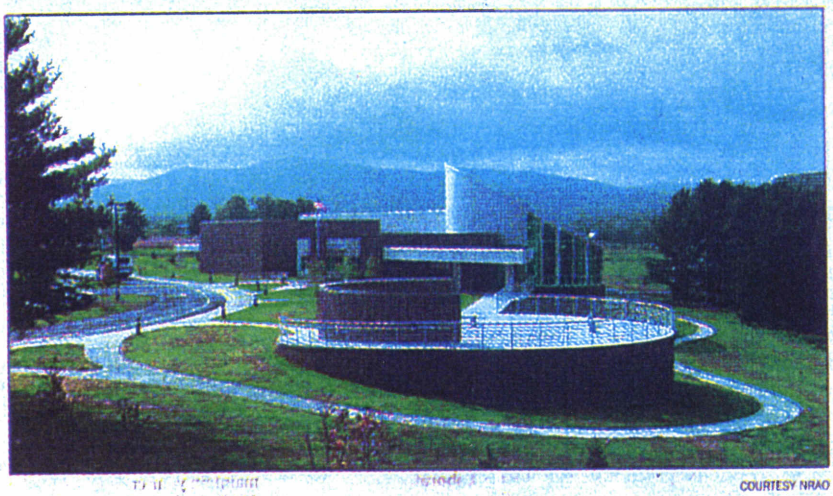
The chance to travel through distant galaxies and explore the stuff that stars are made of can be found just a few hours west of Charlottesville in the mountains of West Virginia.

The National Radio Astronomy Observatory opened a new science center in October at its facility in Green Bank, W.Va. The center, which offers free admission and tours, contains hands-on exhibits about the workings of the universe and a tour through the history of radio telescopy. Visitors also can view the Green Bank Telescope, which is the most massive moving structure on land, according to Charles Blue, NRAO spokesman. "It's really a fun place to go run around and grab onto things."

Visitors will find answers to many of their most stellar questions. In addition to exhibits on radio wavelengths, astronomy enthusiasts can experience how a pulsar works. A pulsar is a small, dense, rapidly spinning star that sends out periodic pulses of radiation. "It's sort of like a stellar lighthouse," Blue said. Visitors can turn a crank to spin the pulsar model and experience the pulse of the star through bursts of light and sound emitted by the exhibit.

While visitors can learn about the discoveries of radio telescopes in the new center, perhaps the highlight of a visit to Green Bank is the opportunity to view a telescope nearly as tall as the Washington Monument. The telescope is one of three operated by the Charlottesville-based NRAO, which include the Very Large Array in New Mexico and the Very Long Baseline Array — a configuration of radio telescopes spanning from the Virgin Islands to Hawaii.

The Green Bank Telescope is so sensitive to radio signals that only diesel cars are allowed within two miles of it. The firing of the spark plugs contained in most cars would interfere with the extraplanetary signals recorded by the telescope, according to Blue. Additionally, the science center is lined with copper to block radio interference generated by its equipment from reaching the telescope. "Everything has that nice coppery-red tint to it," Blue said of the center.



COURTESY NRAO

The National Radio Astronomy Observatory's new science center in Green Bank, W.Va., contains hands-on exhibits about the workings of the universe and the history of radio telescopy.

If you go

To visit the science center and telescope, take Interstate 64 to Staunton then head west on U.S. 250 until you reach Route 92/28 South, which leads to the facility.

The center is open from 10 a.m. to 5 p.m. Wednesdays through Sundays, except Easter, Thanksgiving and the day after, Dec. 24-26 and 31 as well as Jan. 1.

For more information, call (304) 456-2150 or visit www.gb.nrao.edu.

In addition to the state-of-the-art Green Bank Telescope, the facility contains the first radio telescope built. Grote Reber, an electrical engineer, wanted to map the sky, so in 1937 he built a new type of telescope in his mother's back yard in Illinois.

That telescope, which ushered in a new era of astronomy, is part of the Green Bank collection. The facility also houses a full-size reproduction of the first antenna to record a radio signal from beyond the Earth and the first telescope built to search for extraterrestrial life. "These are taking you past the history of astronomy," Blue said.

» Peter Cleary is a staff writer at the Daily Progress in Charlottesville.

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The biggest moving structure on land

Observatory opens visitors center at Green Bank telescope in W.Va.

By Peter Cleary
Daily Progress staff writer

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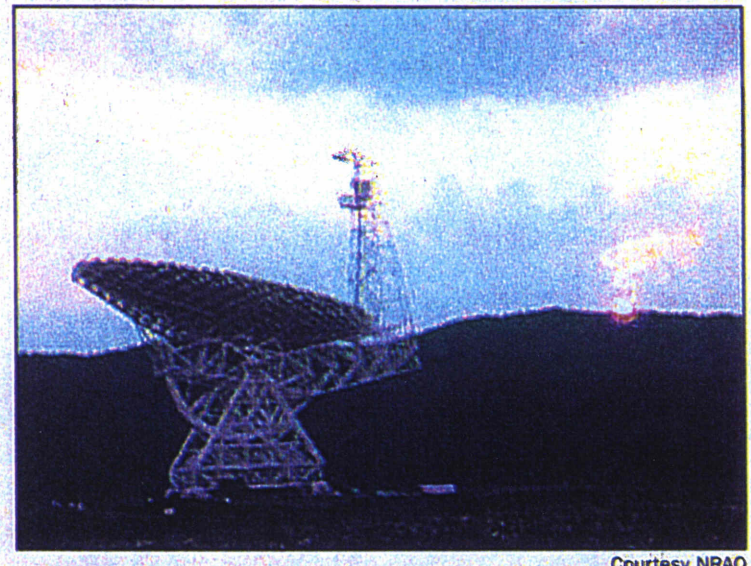
See CENTER on A8

Courtesy NRAO

The telescope, shown here from within, is almost as tall as the Washington Monument.



Courtesy NRAO

At the National Radio Astronomy Observatory's new science center, visitors can view the observatory's massive Green Bank telescope.

At a Glance

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Center

Continued from A1

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On the Web

www.gb.nrao.edu

In addition to the state-of-the-art Green Bank Telescope, the facility contains the first radio telescope built. Grote Reber, an electrical engineer, wanted to map the sky, so in 1937 he built a new type of telescope in his mother's back yard in Illinois. That telescope, which ushered in a new era of astronomy, is part of the Green Bank collection. The facility also houses a full-size replica of the first antenna to record a radio signal from beyond the Earth and the first telescope built to search for extraterrestrial life. "These are taking you past the history of astronomy," Blue said.

To visit the science center and telescope, take Interstate 64 to Staunton, then head west on U.S. 250 until you reach Route 92/28 South, which leads to the facility.

Sunday Gazette-Mail
Time Well Spent

November 09, 2003

Green Bank opens Science Center

- Panorama of W.Va., universe on display

By **Rick Steelhammer**
STAFF WRITER

GREEN BANK — In the Green Bank telescope's control room, astronomer Jim Braatz typed a series of commands on a computer keyboard and, across a meadow a half-mile away, the world's largest moving structure turned on its tracks, then tilted to focus on a new position in deep space.

"I like to do these observations in real time," said Braatz, who had been at the controls for the past 30 hours. "I like to be able to change the program as the data come in. And right now, we're observing at the highest frequencies, and things can more easily slip out of focus."

Braatz, a resident astronomer at the Green Bank National Radio Astronomy Observatory, is studying the centers of active galaxies — galaxies with energy-emitting cores, like black holes. In "normal" galaxies, energy emission is limited to the radiation put out by stars.

As the black holes draw in gases from their surroundings, vast amounts of gravitational energy are released.

"We're looking at water molecules swirling through black holes," Braatz said, staring at a graph on his computer screen showing the speed and intensity of the molecules, as tracked by the Green Bank Telescope's 100-meter dish.

By observing how fast the molecules are moving — about 7,600 kilometers per second in the case of the active galaxy being observed by Braatz — astronomers can measure the mass of black holes, and learn more about their character. They can also use the information to more precisely measure the distance to galaxies.

By relying on radio astronomy rather than the optical variety, researchers like Braatz can cut through 30,000 light years of cosmic dust to study distant galaxies and cosmic structures like quasars, masers and black holes millions of light years away.

▶Photos

Visitors samp the glass-wa Café in the n Radio Astron Observatory Center can ta sweeping vie observatory g the mountain them.

Tour guide D makes a stop 100-meter R Green Bank largest mova the world.

Astronomer uses the new Telescope to molecules pa a black hole galaxy in dee

Radio astronomers tackle some of mankind's biggest questions: How did the universe begin? Will it ever end? Are we alone?

The newly opened Science Center at Green Bank tells the public how those and other questions are being answered, in addition to explaining how radio astronomy works, and how it came into being.

The $8 million Science Center includes a museum-style exhibit hall, live science demonstrations, video presentations on astronomy, the Starlight Café, the Galaxy Gift Shop and sweeping views of the observatory's array of radio telescopes and the Allegheny Mountain ridges behind them.

"With that for a background," said Arlene Walton, who works the reception desk in the new Science Center's glass-walled lobby, "I've got the best seat in the world."

Exhibits include a model of a pulsar that visitors can take for a spin, and an 8-foot-tall working scale model of the new Green Bank Telescope, which visitors can rotate and spin, simulate an observing session and analyze data collected. A communications link allows those working the GBT model to eavesdrop on science being done with the real telescope.

Outside, visitors can take in a full-size replica of the antenna Karl Jansky used to first detect cosmic radio waves in 1932, when trying to track down the source of interference in the newly installed trans-Atlantic radio telephone service.

Nearby is the first true radio telescope, built by amateur radio operator Grote Reber in his Wheaton, Ill., back yard, using sheet metal and Ford Model-T parts. Also on the grounds is the 85-foot Tatel Telescope astronomer Frank Drake used to conduct the first-ever scientific search for extraterrestrial intelligence at Green Bank in 1960.

The new Science Center also is the departure point for free guided bus tours of the observatory's array of radio telescopes.

"The public's response to the Science Center has been great," said Sue Ann Heatherly, who coordinates the Green Bank observatory's public education programs. "We doubled our normal number of visitors through October, and our goal is to eventually see as many as 100,000 visitors a year."

The Science Center will remain open through the winter, moving from a seven-day-a-week schedule to Wednesdays through Sundays, from 10 a.m. to 5 p.m.

"We're hoping a lot of the Snowshoe people will stop by," said Heatherly. "We don't really know what kind of a response we'll get, since we've never been open to the public in winter before."

"It's fantastic that we now have a facility that communicates the excitement of our science to schoolchildren and the general public," said Phil Jewell, the Green Bank Observatory's site director.

Across the observatory's access road from the new Science Center, a dormitory complex for visiting high school and middle school students is nearing completion.

"One of our goals is to host every school student in West Virginia at least once before they graduate from high school," said Heatherly.

The Science Center was designed and built to prevent stray electromagnetic radiation from leaking into the surrounding environment, where it could interfere with radio astronomy observations. Large metal doors, wire-mesh windows and copper-clad walls are used to prevent radiation from escaping.

"Computers, lights and other electronic equipment emit small amounts of electromagnetic radiation at radio wavelengths," said Jewell. "The most important work going on at the NRAO in Green Bank is research, and we make sure that all the elements of the observatory, including the Science Center, are engineered to mitigate interference."

Visitors enter Science Cen in a guided b observatory g

The new, $8 Science Cen Bank include 4,000-square hall, featurin displays expl astronomy, it and its histor

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Tour buses used to carry visitors on tours of the observatory grounds make use of diesel engines, to avoid interference from spark plugs. Tour guide Dave Curry said observatory technicians periodically track down sources of interference from the surrounding Pocahontas County countryside.

"They rebuilt one family's doorbell system, and they replaced another person's electrical heating pad that was being used in a dog house," he said.

The observatory's remote location on a site sheltered by tall mountain ridges was chosen to shelter radio telescopes from unwanted interference. It is located in the center of the National Radio Quiet Zone, a 13,000 square-mile area set aside by the Federal Communications Commission as a preserve for radio astronomy.

The observatory is a National Science Foundation facility, operated by Associated Universities Inc., a nonprofit coalition of nine Northeastern universities, which operate four other radio astronomy observatories for the NSF.

Tours take place on the hour, and last about one hour, including a science demonstration and a short film on radio astronomy. There is no fee or admission charge.

The National Radio Astronomy Observatory at Green Bank is located on W.Va. 92/28, about 25 miles north of Marlinton.

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

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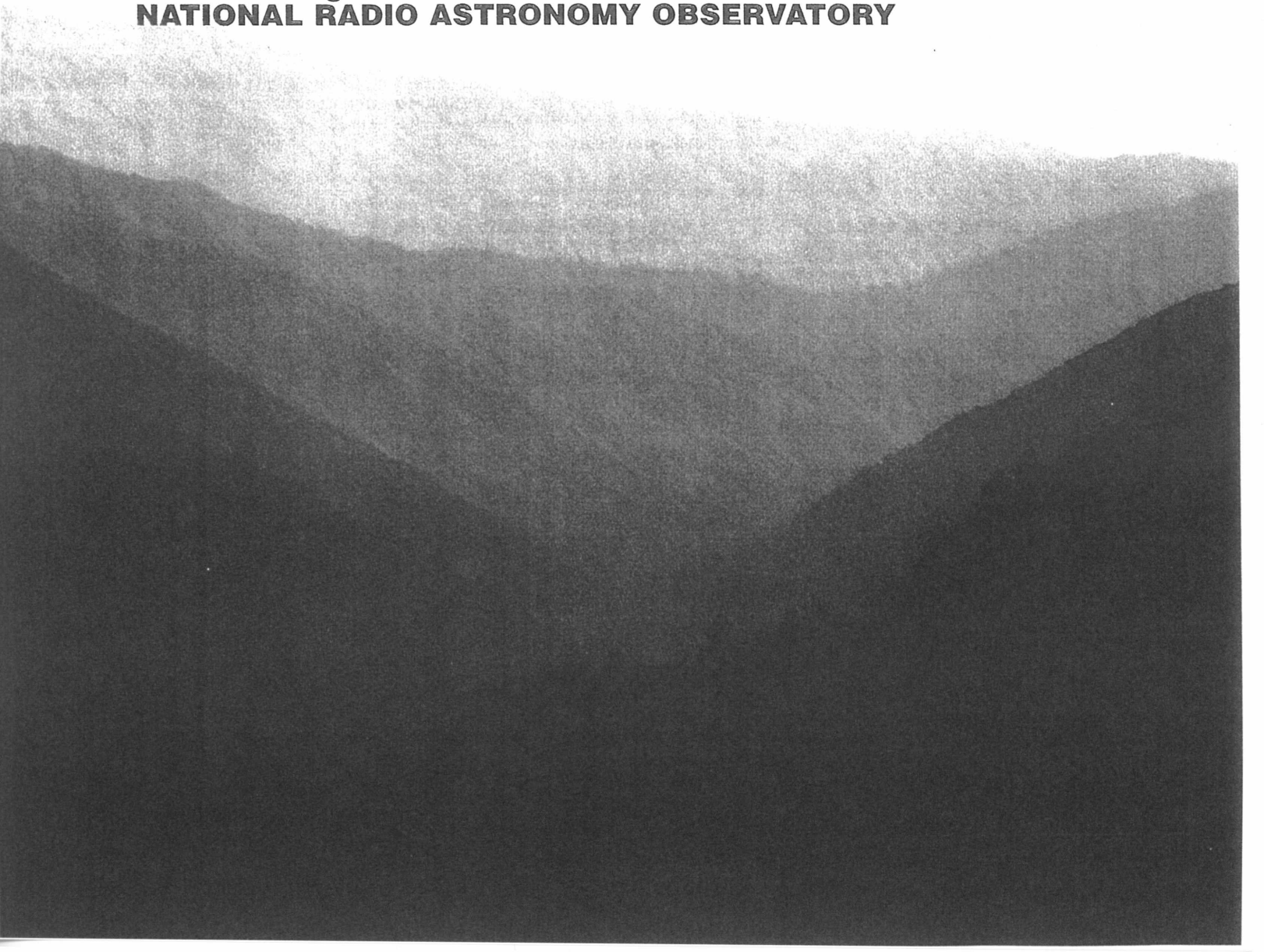
THE Courier

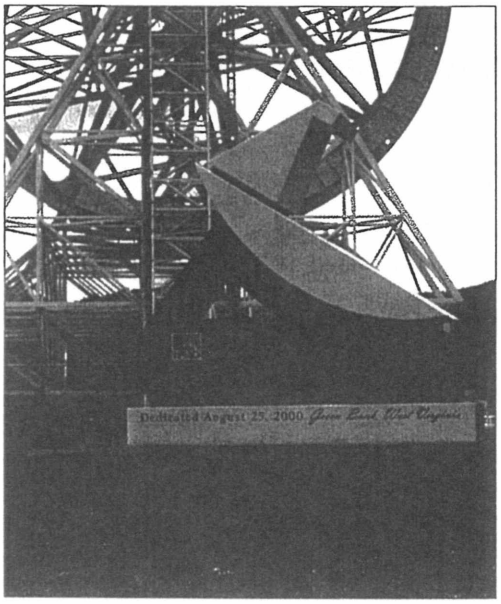
A PUBLICATION OF FIRST CITIZENS BANCSHARES AND SUBSIDIARIES • NOVEMBER 2003

Mountain Treasures

MARTHA GUY AND AVERY COUNTY

The Amazing Work of the Green Bank
NATIONAL RADIO ASTRONOMY OBSERVATORY





Catching the Waves

THE GREEN BANK NATIONAL RADIO ASTRONOMY OBSERVATORY

A customer with a unique business

What does West Virginia have in common with Arizona and New Mexico?

No, this isn't a set-up for a joke.

They have in common federally mandated quiet zones where you'd find it very difficult to tune in a radio station and impossible to get a cell phone signal. The reason? These states are home to the nation's only three National Radio Astronomy Observatory (NRAO) telescope facilities.

The Green Bank NRAO is located practically across the street from First Citizens' Arbovale office in quiet Pocahontas County, W.Va. The observatory — a Bank customer for more than 30 years — designs, builds and operates sophisticated radio telescopes that help scientists study radio waves.

The optical telescopes most of us are familiar with help us see the light waves emanating from objects in space. In 1932 a scientist discovered that many astronomical objects emit radio waves, too, and the first radio telescope — a strictly home-made job that even used Model T Ford parts — was built a few years later. It wasn't long before radio astronomy became an important field of research.

Radio telescopes have distinct advantages over their optical counterparts. For instance, light rays can be obscured by clouds, dust, brighter light and other things that don't affect radio waves. That's why radio telescopes can work night and day regardless of weather conditions. But they are sensitive to static.

The eight radio telescopes at Green Bank — which look like huge satellite dishes — use extremely sensitive receivers to capture the weak radio signals transmitted from space. Man-made interference from things like cell phone and radio towers and even microwaves and spark plugs can hinder the observatory's work. In fact, visitors ride in spark-plug-free diesel vans to get an up-close look at the radio telescopes. Nearby Snowshoe resort had to get special permission to install a very weak cell phone transmitter for its guests.

The population in rural Pocahontas County hovers around 9,000 and is not predicted to grow very much anytime soon. The observatory is snuggled in a wide valley protected by the surrounding mountains. Its secure location allows the NRAO tight control of the static that can interfere with telescope reception.

Remember the popular movie "Contact" starring Jodie Foster? Parts of it were filmed at the NRAO's New Mexico facility. Unlike the movie, in real life the radio waves coming from space aren't converted to audible sound — nothing but "white noise" would result.

Instead, a radio telescope's perfectly curved dish reflects waves to a receiver. Scientists use computer technology to digitize the data, assigning colors to show radio wave intensity. The resulting "pictures" are striking and colorful, though the colors aren't true.

According to observatory tour guide Micah Johnson, people's assumptions that you "hear" with a radio telescope is one of the many misconceptions about this specialized work. "We have visitors ask about what weird things we've heard with the telescopes," he said. "And a lot of people believe they're used for secret military studies or to try to locate extraterrestrial life."

One of those beliefs is correct. The SETI (Search for Extraterrestrial Intelligence) Institute has used the West Virginia observatory for its work. But so far, no big discoveries. (Taking advantage of guests' fascination with such mysteries, Johnson adds humor to his tours by using plastic aliens as road hazards en route to the telescopes.)

Anyone with legitimate, related science projects can use the free NRAO facilities — even high school students. In particular, people come from far and wide to take advantage of the West Virginia observatory's pride and joy: The Robert G. Byrd Green Bank Telescope, fondly called the GBT.

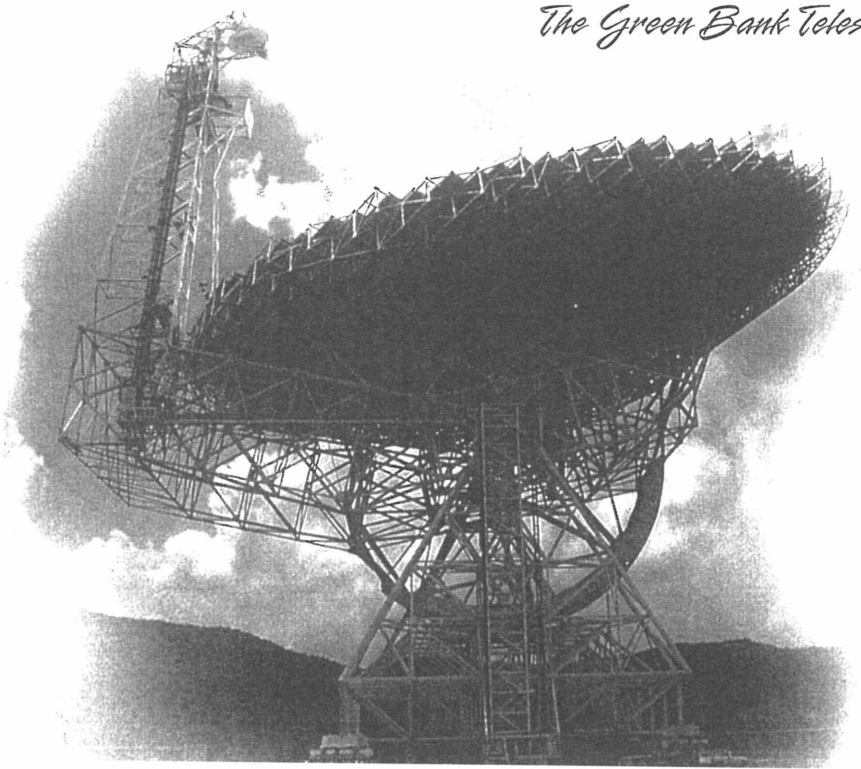
The GBT is the world's largest fully steerable radio telescope. Completed in 1991 at a cost of $79 million, the telescope's dish is nearly two acres across, or about the length of one and one-half football fields. The telescope is taller than the Statue of Liberty and weighs 16 million pounds, or roughly the same as a 747 airplane.

Why so large? So that it can detect radio waves that are a billion billion times weaker than AM radio signals. Many radio waves weaken as they take so long to come so far. In fact, radio telescopes are still receiving signals from the "Big Bang" 13 billion years ago.

What's it like living with such an amazing facility practically in your back yard? Pocahontas residents are fairly indifferent when it comes to the observatory. Cows graze contentedly despite the mammoth GBT in the background, and many humans — including some of our own First Citizens associates — haven't ever toured the decades-old facility.

Nonetheless, the NRAO draws plenty of visitors from out of town, out of state and even across the globe. "They're a great community partner," said Area Executive Dan Withers. "The observatory has done a lot to further the tourist trade in Pocahontas County, and we're all appreciative."

The Green Bank Telescope



Thanks for the Business

In addition to the West Virginia, Arizona and New Mexico facilities, the National Radio Astronomy Observatory (NRAO) has corporate offices in Virginia and a developing facility in Chile that's part of an international project. The NRAO employs 600 people, about 120 of them in West Virginia. The government funds used by all locations are funneled through First Citizens Bank.

"I've worked with other companies and banks over the years, and I have to say that First Citizens ranks up there as the best relationship I've experienced at the corporate level," said Accountant Tim Kelly, primary keeper of the banking relationship. "We like the way First Citizens does things. Your employees treat us so well, and we like your products."

Millions of dollars flow through the NRAO's First Citizens accounts every month, and that amount will increase significantly now that the Chile project is gearing up.

Operations at the other facilities continue to grow, too. The Green Bank observatory opened a brand-new visitor center earlier this year complete with hands-on exhibits, a gift shop, café and daily tours.

Want to visit? Check out the observatory's Web site at www.nrao.edu for more information, maps, etc. Free guided tours are available seven days a week Memorial Day through October, and on Wednesday through Sunday from November through May.

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Vol. 24, No. 65

Magdalena, New Mexico • Monday, September 15, 2003

VLA Opens New Full-Time Gift Shop

Mountain Mail staff reports

The visitor center at the Very Large Array radio telescope now has a gift shop. The new facility is open every day from 9 a.m. until 4 p.m.

The center offers many items with the logo and images of the National Radio Astronomy Observatory (NRAO), books and other educational materials, as well as jewelry from the Alamo Navajo reservation. The visitor center and gift shop are at the site of the Very Large Array (VLA), 50 miles west of Socorro on Highway 60. The VLA Visitor Center was opened in 1983 and has been in continuous operation since then, but with no staff. With the opening of the gift shop, the center is staffed for the first time.

"We've long known that visitors to the VLA, who come from around the world, want to take home a souvenir. Now, we're happy to offer them that," said NRAO education officer Robyn Harrison.

The visitor center and gift shop are operated by the Observatory's Education and Public Outreach division, and proceeds from the sales support improvements to the visitor center and a number of educational efforts aimed at both students and the general public.

The gift shop is in a new addition to the visitor center, constructed this year.

"By having a staffed gift shop, we feel we are improving the quality of the visitor's experience, which will make the VLA more popular as a tourist destination," said Jim Ulvestad, NRAO's Assistant Director for New Mexico Operations. He also noted that the New Mexico Department of Transportation recently installed signs on Interstate 25 directing tourists to the VLA.

"We recognize that tourism is an important part of New Mexico's economy, and we want to do our part to attract visitors and extend their stays in our state," Ulvestad said.

The hours are for the gift shop only; the visitor center is open from 8:30 a.m. until sunset every day.

The VLA Visitor Center includes videos and displays about astronomy and the cutting-edge scientific research done with the VLA. A walking tour takes visitors around the facility and up close to one of the 230-ton dish antennas.

The next guided tours are scheduled for Saturday, October 4. For more information, see the website at www.vla.nrao.edu.

News in Science
abc.net.au/science/news

News in Science

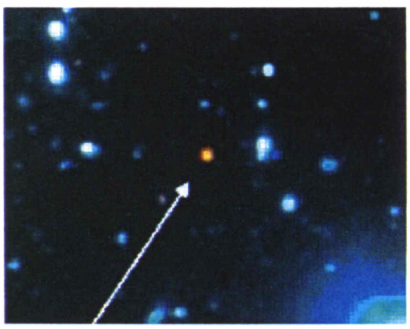
Space & Astronomy News - Quasar shows star birth at dawn of time - 25/07/2003

[This is the print version of story http://www.abc.net.au/science/news/space/SpaceRepublish_910345.htm]

Quasar shows star birth at dawn of time

Wilson da Silva
ABC Science Online

Friday, 25 July 2003



This 13-billion-year-old quasar, in red, was already packed with the stuff stars are made of; it's called J1148+5251 *(Keck)*

The oldest object known, a superhot quasar powered by a black hole a billion times larger than our Sun, has been found to harbour molecular gas - suggesting stars were forming as early as 13 billion years ago.

The discovery, by a team of U.S. and European astronomers led by Dr Fabian Walter of the National Radio Astronomy Observatory in New Mexico, USA, indicates large quantities of molecular hydrogen were created rapidly in even the youngest galaxies. Their report appears in the latest issue of the journal, *Nature*.

"This is important because it is molecular gas out of which stars form," Walter told ABC Science Online. "That's very nice proof that star formation was going on even that far back in the history of the universe."

The quasar, an extremely distant celestial object pumping out several thousand times the energy of our entire galaxy, is embedded in a distant galaxy known as J1148+5251. "The light

from that quasar travelled 13 billion years to reach us here on Earth ... [it left] when the universe was only one-sixteenth to today's age - that's only around 800 million years after the Big Bang," Walter said.

The team detected vast quantities of carbon monoxide. The only atoms formed by the Big Bang at the very dawn of the universe were hydrogen and helium. Carbon and oxygen - the atoms making up carbon monoxide - had to be made in the thermonuclear furnaces at the cores of the earliest stars.

"Carbon and oxygen are elements that have to produced in stars, and the mere fact that we see carbon monoxide at these early times tells us that there must have been a generation of stars actually producing that gas - which pushes back the earliest epoch of star formation," he said.

The carbon and oxygen atoms detected were made by some of the first stars ever formed, about 650 million years after the Big Bang. In the next 200 million years or so, those stars - likely different from any we see today - exploded as supernovae, casting the carbon and oxygen made in their cores across the cosmos.

"Those atoms then cooled and combined into the carbon monoxide molecules we detected with our radio telescopes," said Walter, who is attending the 25th General Assembly of the International Astronomical Union in Sydney this week.

The quasar was producing these gases when the universe was only just emerging from the primeval 'dark ages' - a time before light could travel freely through the cosmos, when the universe was different from the one we know today.

"After the Big Bang, everything was an extremely hot place. It took a long time - about 300,000 years - for the universe to cool down and actually form atoms. We believe the quasar we've found was one of the very first luminous sources," he said.

And there was a lot of the molecular gas found: more than 10 billion times the amount found in the Sun, telling astronomers that things were happening much faster in the early universe than had been thought.

The team used the Very Large Array of 27 radiotelescope dishes in New Mexico, coupled with the Plateau de Bure radio interferometer in France. Combining radio observations with data from optical telescopes showed that the visible bubble of mass around the nascent galaxy was about 30 million light-years in diameter.

with Pauline Newman, Radio National

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A giant cloud containing carbon monoxide has been spied in the most distant known galaxy in the Universe.

Light from the galaxy was emitted when the Universe was just a sixteenth of its current age. Astronomers say the traces of gas prove that star formation got started astonishingly quickly in the young Universe.

"The presence of carbon monoxide is very interesting because carbon and oxygen first need to form in stars of some sort, then be expelled by explosions," says team leader Fabian Walter of the National Radio Astronomy Observatory in Socorro, New Mexico.

The most distant known galaxy in the Universe is a "quasar" called J1148+5251, which contains a black hole at least a billion times heavier than the Sun. It shines so brightly because material being dragged inwards by the hole's powerful gravitational field gets heated to enormous temperatures.

Ballooning fireball

Earlier in 2003, astronomers discovered that the quasar lies so far away that its light has taken 12.8 billion years to reach the Earth. In other words, astronomers are seeing the galaxy as it was 12.8 billion years ago, only 870 million years after the Universe was born in the Big Bang.

The only elements created in the ballooning Big Bang fireball were hydrogen and helium. At some later point, galaxies of stars started to form. Nuclear reactions in the stars would have churned out heavier elements like carbon, nitrogen and oxygen.

Now Walter's team has seen the spectral fingerprint of carbon monoxide in J1148+5251, which they studied using radio telescope arrays in New Mexico and the French Alps.

For this gas to be present so early in the Universe's life, a generation of stars must have already lived and died in explosions that littered heavy elements across space.

Given typical stellar lifetimes, astronomers estimate that the stars would have started forming about 650 million years after the Big Bang, then exploded during the following 200 million years. Carbon and oxygen from the exploded stars would then have cooled and bonded to form carbon monoxide.

Very young, very big

The observations also suggest the quasar contains a reservoir of cool molecular hydrogen 20 billion times more massive than the Sun. This would provide plentiful raw materials for building more stars.

Astronomers had assumed that such massive congregations of material only built up after long periods of slow mergers between small galaxies. But the huge mass of material in J1148+5251 suggests that just 870 million years after the Big Bang, it was already as heavy as the big galaxies seen today.

"It's so surprising to see such a massive galaxy so early in the Universe," says Walter, who now hopes to find out how it got so monstrous so quickly.

Journal reference: *Nature* (vol 424, p 406)

Hazel Muir

Return to news story

El Defensor Chieftain

SOCORRO, NEW MEXICO • JUNE 7, 2003

VLBA marks 10 years as sharpest "eye" on universe

Submitted to El Defensor Chieftain

Scientists from around the globe will gather in Socorro June 8-12 to mark the 10th anniversary of the National Science Foundation's Very Long Baseline Array, a continent-wide radio telescope that produces the most detailed images of any instrument available to the world's astronomers.

Nearly 200 scientists will present 160 research papers on topics including geophysics, star and planet formation, supernova explosions, galaxies, super-massive black holes, and future directions of research and instrumentation in astronomy.

The meeting is sponsored by the National Radio Astronomy Observatory and the New Mexico Institute of Mining and Technology. The meeting will be held on the NM Tech campus in Socorro.

"In 10 years of operation, the VLBA has made landmark contributions to astronomy. In this scientific meeting, we are acknowledging those contributions and looking forward to an even more exciting future of frontier research," said James Ulvestad, director of VLA/VLBA operations for the NRAO.

Dedicated in 1993, the $85-million VLBA includes ten, 240-ton radio-telescope antennas, ranging from Hawaii in the west to the U.S. Virgin Islands in the east.

Two are in New Mexico, one near Pie Town in Catron County and the other at Los Alamos. The VLBA is operated from the NRAO's Array Operations Center in Socorro.

Acting like a giant eye 5,000 miles wide, the VLBA can produce the sharpest images of any telescope on Earth or in space. Its ability to see fine detail, called resolving power, is equivalent to being able to stand in New York and read a newspaper in Los Angeles.

■ *See* **VLBA,** *Page 3A*

VLBA: Accomplishments vary

continued from page 1A

The VLBA's scientific achievements include making the most accurate distance measurement ever made of an object beyond the Milky Way Galaxy; the first mapping of the magnetic field of a star other than the Sun; "movies" of motions in powerful cosmic jets and of distant supernova explosions; the first measurement of the propagation speed of gravity; and long-term measurements that have improved the reference frame used to map the Universe and detecttectonic motions of Earth's continents.

Just this month, astronomers announced that they had used the VLBA to discover a "supernova factory" of exploding stars in a distant galaxy and to rule out one proposed theory for how gamma ray bursts work.

In coming years, scientists plan to use the VLBA, along with other radio-telescope facilities, to gain important new insights on astronomical bodies ranging from nearby stars to the most distant galaxies, seen as they were billions of years ago.

The VLBA also will help improve the celestial coordinate system used for spacecraft navigation and other purposes.

In addition, the VLBA can be "turned around" to produce extremely precise measurements on the Earth. This capability allows scientists to study the motion of Earth's tectonic plates, to track "wobbles" in our planet's rotation, and to measure subtle changes attributed to atmospheric motions and climate change.

Biggest Blast in Cosmos Reveals Its Dark Heart

By JOHN NOBLE WILFORD

NASHVILLE, May 28 — While taking X-ray pictures of flares from the Sun in December, a scientific spacecraft happened to detect a tremendous blast of gamma rays from several billion light-years away. The observation, astronomers say, showed the driving force behind what appear to be the most powerful explosions in the universe.

In a report here today at a meeting of the American Astronomical Society, researchers from the University of California at Berkeley said the coherence and alignment, the polarization, of the gamma radiation implied that the tremendous burst of energy originated from a region of highly structured magnetic fields.

The large-scale field, the scientists said, was being generated by the rapid rotation of the extremely dense core object, a black hole or a neutron star, remaining after the explosion of a huge star.

The polarization of the high-energy radiation from the explosion, Dr. Steven E. Boggs of Berkeley said, "is telling us that the magnetic fields themselves are acting as the dynamite driving the explosive fireball we see as a gamma ray burst."

Gamma ray bursts, first detected serendipitously in 1967 by an American space satellite that was monitoring compliance with the 1963 atmospheric nuclear test-ban treaty, were long one of the most intractable mysteries in astronomy. A burst flashes about once a day in different places in space, shines brightly for a brief time and then fades into a lingering afterglow.

Only in 1997 did scientists convince themselves that, luminous as they are, the bursts come from far beyond Earth's galaxy, the Milky Way. Their sources were then identified as extremely large stars, many times as massive as the Sun, that collapsed and exploded with much more force than the usual supernovas.

Now, other astronomers agreed, the spacecraft findings have apparently solved the physics of how some exploding stars produce such tremendous bursts of gamma rays, the most powerful in the electromagnetic spectrum.

"This is definitely a milestone," said Dr. Chryssa Kouveliotous, a specialist on gamma ray burst who was not involved in the research. She is an astronomer at the Marshall Space Flight Center of NASA in Huntsville, Ala.

Another independent astronomer, Dr. Donald Lamb of the University of Chicago, said the discovery was "just absolutely astounding."

A detailed report of the findings by Dr. Boggs and Dr. Wayne Coburn, a Berkeley researcher, was published last week in the journal Nature. In an accompanying commentary, Dr. Eli Waxman of the Weizmann Institute of Science in Israel said the research might "shed light on the identity of the sources of gamma ray bursts, as well as on the mechanism by which the gamma rays are produced."

But Dr. Waxman said it was too soon to rule out the possibility that the polarization "might also arise in a randomly oriented magnetic field." Further research and theoretical analysis is needed, he said.

Dr. Boggs conceded that his interpretation would not be fully accepted until the phenomenon of a polarized gamma ray beam was observed from other bursts. That may not be easy. Although several hundred bursts occur each year, many are too distant and dim for such analysis, or they are observed well after they have faded. And a spacecraft would have to be in just the right position to catch the burst in its field of view.

A European spacecraft, launched in October, has two gamma ray instruments, and their software is being modified to make them sensitive to polarization.

The Berkeley discovery was made by the Rhessi satellite. Launched early last year, it is operated by Berkeley scientists for the National Aeronautics and Space Administration. Though primarily an X-ray observatory, the satellite is also equipped to detect gamma rays.

On Dec. 6, the satellite picked up a flood of gamma rays from a burst, designated GRB021206. The burst peaked for about 6 seconds and then faded over 30 seconds. The measured gamma rays, the scientists reported, were 80 percent polarized, about the maximum possible polarization from electrons that spiral around magnetic fields.

"It is very surprising that this is so highly polarized," Dr. Coburn said. "It is difficult to imagine how you can have an area of very aligned magnetic fields when there is a massive supernova explosion going on and stuff flying all over the place."

Most gamma ray bursts occur at distances of 8 billion to 10 billion light-years. But on March 29, astronomers detected the closest one yet known, at 2.6 billion light-years, close enough for unusually detailed study.

A radiation burst several billion light-years away.

In other reports at the meeting, radio astronomers said they could precisely measure the expanding shock wave from the close burst. They found that the expansion was at nearly the speed of light, as predicted in the standard "fireball" model of the immediate aftermath of a burst. And as the wave expanded, the center of the observed radio emissions did not change position, also as predicted.

In an alternative model, scientists proposed that matter was being shot out of the explosion in distinct concentrations like cannonballs. If so, the motions of such an outflow would be detectable in the radio emissions.

But they were not, Dr. Dale A. Frail of the National Radio Astronomy Observatory in Socorro, N.M., said. The findings not only supported the standard model, he said, but are also "sufficient to rule out predictions of the cannonball model."

The close March 29 burst also afforded the Hubble Space Telescope a bright photographic target for its advanced survey camera. Dr. Andrew Fruchter of the Space Telescope Science Institute in Baltimore said the burst was in a relatively small galaxy, 5,000 light-years wide, that appeared to be a breeding ground of young and especially massive stars. It is just the sort of place, astronomers are finding, where stars explode with gamma ray ferocity.

Artesia Daily Press

MAY 29 2003

Astronomers excited about galactic merger

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SOCORRO, N.M. (AP) — Astronomers are watching two small galaxies merge 140 million light years away to gather information on what might have happened in the Milky Way 10 billion years ago.

The observations could help prove that the galaxy was formed from several smaller galaxies clustering together, said James Ulvestad, assistant director of the National Radio Astronomy Observatory, which runs the Very Large Array telescope in western New Mexico.

"The models that people have for the universe are hierarchical — first, little galaxies form, and those merge with each other to form bigger galaxies," Ulvestad said. "This all happened in the first billion years of the universe. We suspect that kind of process is how big galaxies like the one we live in formed, but because it happened so long ago, it's hard to prove."

Ulvestad and other astronomers used the Very Long Baseline Array — a group of radio telescopes that stretch across the United States but are operated in Socorro — to hone in on an area called Arp 299, where the galaxies merged 140 million years ago. The light is only now reaching the Earth.

"Inside the pair of galaxies we've detected remnants of recent — relatively speaking — explosions of five massive stars, which are 10 times or more massive than our sun," Ulvestad said.

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WEDNESDAY MORNING, MAY 28, 2003

FINA

Colliding Galaxies Spark Supernova Show

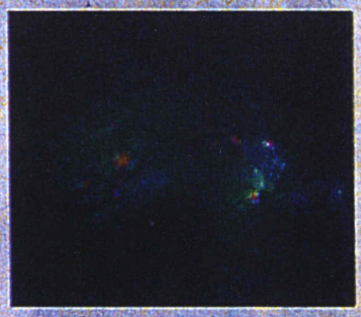
BY JOHN FLECK
Journal Staff Writer

When galaxies collide, the sparks that fly are actually exploding stars, according to new work by a New Mexico astronomer.

Using the Very Long Baseline Array, Socorro astronomer Jim Ulvestad and his colleagues took the most detailed pictures ever made of two colliding galaxies, showing what they are calling a "supernova factory," the likes of which has never been seen before.

The astronomers saw the supernovas — exploding stars — when they pointed their telescopes at a pair of colliding galaxies seen in the Big Dipper, Ulvestad said Tuesday in a telephone interview from Nashville, Tenn.

They were hunting for a nearby example of a process that must have been much more common in the early universe, Ulvestad said.



COURTESY NRAO/AUI/STSCI/NASA

PHOTO A SMASHING SUCCESS: Combined images from the Hubble Space Telescope and the Very Large Array show two galaxies colliding in a region where astronomers have found what they call a "supernova factory."

Ulvestad and colleagues Stacy Teng of the University of Maryland and Susan Neff of NASA's Goddard Space Flight

See **COLLISIONS** *on* **PAGE A3**

Collisions Spark Supernovas

from **PAGE A1**

Center presented their findings Tuesday at the American Astronomical Society's spring meeting in Nashville.

Ulvestad, in addition to being a working astronomer, is director of the National Radio Astronomy Observatory's Socorro site, headquarters for the Very Large Array and the Very Long Baseline Array.

When galaxies collide, the gargantuan, slow-motion crash unleashes a burst of star formation as shock waves pass through the dense clouds of dust and gas in the galaxies' midst, Ulvestad said. Some of those new stars then explode in dramatic supernovas.

Astronomers ... expected they would see such forces at work, but there are few such collisions to be found near enough.

Over the past year, Ulvestad and his colleagues turned their telescopes to a pair of colliding galaxies known as "Arp 299," located some 140 million light-years away.

While that might sound far — it has taken the galaxies' light 140 million years to reach Earth — in the vastness of the universe it is relatively nearby.

Astronomers expect that in the early universe, galaxy collisions were common. Understanding the wreckage is, therefore, important to understanding the galaxies and stars today, Ulvestad said. "Even our galaxy probably started out that way," Ulvestad said.

But collisions near enough to study with Earth-bound telescopes are few and far between. "By looking at something close-by, we can see it in a lot more detail," he said.

Astronomers have looked at Arp 299 many times before. Since 1990, they have seen evidence of four supernovas. But the traditional optical telescopes used for those observations, which do their work by gathering visible light, have serious drawbacks for scientists trying to understand Arp 299.

The main problem, according to Ulvestad, is that the area where the stars are exploding is a very dusty place, opaque to visible light.

Because the stars' naturally emitted radio waves pass right through the dust, radio telescopes like the VLBA can still see the action.

The VLBA, a collection of radio telescopes spanning the globe from Hawaii to the Virgin Islands, has a second advantage. By combining the data collected by the array's 10 telescopes, astronomers can get high-resolution images of the heart of the colliding galaxies, something impossible with conventional telescopes.

Peering in the heart of the crash last year, in a region where stars are rapidly being formed because of the collision, the astronomers found the remnants of four exploded stars.

When they returned for another look in February, they saw a fifth.

It is that unusual rate of star explosion that led the astronomers to dub the region a "supernova factory." Our own galaxy, by comparison, sees only one supernova every hundred years or more.

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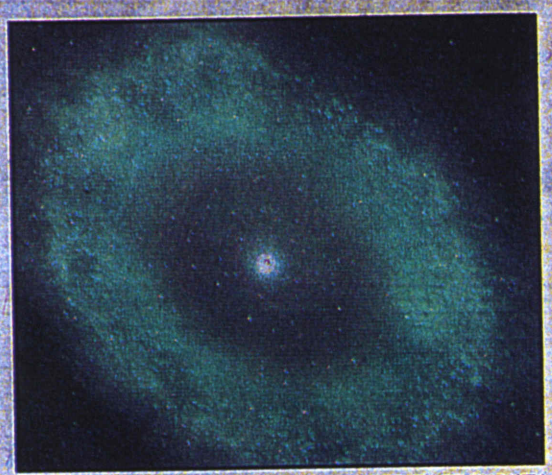
FINAL ★★

Astronomers Start at the Beginning



COURTESY GERAINT LEWIS, UNIVERSITY OF SYDNEY

THE EARLY YEARS: Astronomer Geraint Lewis created this artistic rendering of a young galaxy he and his colleagues are studying. The stars are so far away that the astronomers are effectively seeing back to near the dawn of time.

■ *Scientists use nature and New Mexico's Very Large Array to understand how the first galaxies were formed*

BY JOHN FLECK
Journal Staff Writer

SOCORRO — Chris Carilli's task is like trying to see what grows at the bottom of a murky pond.

The pond, in this case, is the universe. At the murky bottom, barely visible through the muck of space and time, is the birth of a thousand suns.

With a combination of persistence, technology and luck, Carilli and his colleagues have for the first time seen baby stars swirling around a massive black hole.

The stars are so far away, and it has therefore taken their light so long to get here, that the astronomers are effectively seeing back near the dawn of time.

See **ASTRONOMERS** *on* **PAGE A10**

Astronomers Probe Depths of Early Galaxies

from PAGE A1

There, in the early universe, the first galaxies were forming, and Carilli and his colleagues are struggling to understand how. How did the dust and gas of the early universe coalesce to form the planets, stars and galaxies we see around us today?

It is hard work. The things they are trying to see, even the brightest ones, are so far away that they are almost impossibly faint with even the best telescopes.

But by exploiting a lucky quirk of nature, the astronomers were able to train the Very Large Array on a distant quasar last October and see traces of the birth of stars.

In a paper published online Thursday by the journal Science, the scientists argue that they have solved one of astronomy's classic chicken-and-egg dilemmas.

Galaxies are huge clusters of hundreds of billions of stars with black holes at their center. "The bigger the galaxy," Carilli said, "the bigger the black hole."

"There's always been this open question," Carilli said. "What forms first? Black holes or stars?"

The answer, the researchers say in their Science paper, is both.

Blasting out from the Big Bang, the early universe was little more than a rapidly expanding soup of dust and gas. But gravity started pulling bits together, and over time the soup grew lumpy.

As the lumps grew larger, the tug of their gravity grew stronger, pulling in more and more dust and gas from the space around them.

"All this stuff comes crashing together," Carilli explained.

At THE heart of the lump, so much dust and gas comes together that light cannot escape the tug of its gravity — a black hole. Around it, dust and gas swirling toward the center are heated to extraordinary levels, creating a bright beacon that astronomers know as a quasar.

But what is happening around the black hole? Are stars forming in the larger disk of dust and gas the seeds of a bright new galaxy?

To find out, Carilli and his colleagues have been focusing their telescopes on scores of quasars, looking for telltale starlight.

They hit pay dirt in October with a quirky quasar prosaically labeled "QSO PSS 2322+1944."

Originally found in a sky survey done by astronomer George Djorgovski at the California Institute of Technology, the quasar allowed the scientists to exploit a unique trick of physics.

Located some 10 billion light years away, the quasar would under ordinary circumstances be too faint to see with even the most powerful telescopes.

But a second galaxy somewhere between here and the distant galaxy is acting like a lens, its gravity bending, focusing and amplifying the light from the distant quasar enough for Carilli and his colleagues to see it.

"You can use it sort of like a natural telescope," Carilli explained.

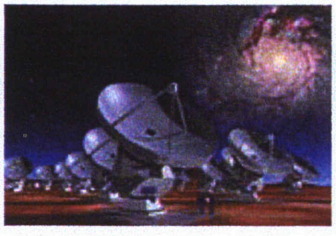
The metaphor of a murky pond is apt. The resulting image, on the desk in Carilli's office at the Very Large Array's operations center in Socorro looks more like an amoeba than stars forming in a galaxy.

But analysis of the spectrum of light being emitted gives it away. The formation of massive stars — lots of them — is the only explanation, Carilli said.

By looking across 10 billion light years of space, the scientists are seeing the quasar and new stars as they existed just 2 billion years after the Big Bang. That is early in the history of the universe, but not early enough.

The scientists are already trying to do the same thing with even older, more distant quasars, peering back in time to the point at which the universe's first light began emerging.

"That's an area that's still pretty wide open," said Carilli. "This is a really fun time."



Radio Star: ALMA Telescope to See Stellar Birth, Galactic History

TECH WEDNESDAY

By Tariq Malik
Staff Writer
posted: 07:00 am ET
05 March 2003

Witnessing the birth of a star or the early days of a galaxy is all about distance. The further out a peers into space, the better for astronomers hoping to glimpse the early universe.

An international group of astronomers plan to do just that with one of the largest radio telescopes constructed. The new tool, an array or more than five dozen radio antennas pointed skyward, will cosmic emissions bordering the microwave and infrared wavelengths that may even allow resear the formation of organic molecules in space.

ALMA

Plans for the new telescope, called the Atacama Large Millimeter Array (ALMA), are the result of preparation on both sides of the Atlantic. That preparedness came to a head last week, when the Southern Observatory (ESO) and the National Science Foundation (NSF) agreed to fund the $5 project's construction in Chile's high Atacama Desert.

TECH WEDNESDAY

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An artist's view of the completed Atacama Large Millimeter Array (ALMA) in Chile's Atacama Desert. Here, the array is arranged in a compact configuration. Click to enlarge.

CLICK TO VIEW

One of two prototype radio telescope antennas under testing to decide which will make up ALMA's 64 telescope array. Click to enlarge.

CLICK TO VIEW

Bleak and empty now, the future ALMA site shown here is at an altitude of 16,500 feet (5,000 meters). The arid location will allow radio astronomers to make observations at submillimeter wavelengths. Click to enlarge.

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TODAY'S DISCUSSION

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"ALMA will be the first large-scale millimeter telescope in the world," said Charles Blue, spokesm National Radio Astronomy Observatory (NRAO), in a telephone interview. The observatory is coc North American involvement in the project, including Canada as well as the U.S., for the NSF.

The new observation tool will consist of an array of 40-foot (12-meter) radio telescopes, 64 in all, together to make up the world's largest radio telescope to observe at millimeter and submillimete wavelengths. Emissions at these levels have wavelengths longer than infrared, but shorter than r and aren't visible by the naked eye.

Using an observing method called interferometry, ALMA will collect and combine observations fro antennas to generate some of the sharpest images ever taken of the night sky. Its maximum diar span more than eight miles (14 kilometers) when construction is completed in 2011.

Astronomers began testing a prototype telescope for ALMA at the Very Large Array (VLA) in Soc Mexico earlier this year. That 12-meter dish gained first light in mid-January, with ALMA research a second version - this one from the ESO - to be installed for testing sometime in July.

"We'll be testing and characterizing both instruments, leading up to the final selection of a standa for ALMA," radio astronomer Richard Simon told *SPACE.com*. Simon has spent the last five year NRAO planning for the new telescope array's construction. "We're scheduled to break ground on project by the end of the year."

Radioing back from the edge of the universe

Radio astronomers hope ALMA's capabilities will push aside the veil on the earliest days of the u allow for detailed observation of galaxy formation. The array is expected to resolve distant object to 10 times better than the Hubble Space Telescope or the VLA.

"ALMA will be on the lookout as far back in time as you possibly can reach," Simon said, adding t instrument could detect protogalaxies, a cauldron of stars and gas in the midst of becoming a full galaxy. "We expect that it will be able to detect signatures from planets as they form and stars as collapse and condense from an accretion of gas."

Large, hot extrasolar planets - like those on the scale of Jupiter in size - may even be observed d than watching the wobble of a star as it moves. The "wobble" method infers the existence of an e planet by the gravitational effect it has on a parent star.

Pinpoint accuracy

While optical telescopes can be constrained by the amount of visible light detected, ALMA shoulc interstellar dust to observe the emissions emanating from the interior of interstellar clouds of gas.

Since organic molecules like ethanol tend to reside inside gaseous clouds, with temperatures of a degrees Kelvin (-263 degrees Celsius), ALMA researchers should be able to detect them and use observations to learn about the cloud's internal composition and motion through space, Simon sa

The array is also expected to pinpoint objects 10 milliarcseconds wide in the sky. Arcseconds are measuring tool astronomers use to find the size of an object in space, with 60 arcseconds in one and 60 arcminutes in one degree. The full moon, for example, is about the equivalent of 30 arcmi

ALMA should also monitor a range of interstellar emissions ranging in wavelengths from 3 millime maximum on down to one-third of a millisecond. There should be little overlap between the new a NRAO's other large interferometry instruments, such as the VLA, because of the wavelengths AL monitor.

"There won't be almost any overlap at all there," Blue said. "The VLA primary makes observation centimeter level, but ALMA will be a great additional tool."

The sheer size of the array, however, will outstrip its current submillimeter counterparts in France and Hawaii, each of which sports only a handful of radio telescopes working together. Not only w peering out into the Southern Hemisphere - the others are all north of the equator - but its more s receiver, wider bandwidth capacity and better vision put it spades in front of submillimeter arrays The researchers at those arrays, though, also have also a hand in ALMA's development.

"We're collaborating with those groups on some of the computing and calibration issues for the n Simon said.

Location, location, location

One of the keys to ALMA's expected performance lies in its Chilean home. The location chosen f telescope is near Cerro Chajnantar in the Atacama Desert, about 16,500 feet (about 5,000 meter level. Since most emissions in the millimeter and submillimeter range are absorbed by moisture i atmosphere, the arid high-altitude desert environment is crucial for ALMA researchers.

"One of the challenges of observing at the submillimeter wavelength is that the atmosphere is no Simon said. "The [ALMA site] is an unbelievable place, with huge, flat terrain and clarity of the air is what you'd expect from a mountain region."

ALMA planners rejected potential sites in the southwest United States and atop Hawaii's Mauna I the Keck Observatory, before settling for the Atacama location, he added.

The area is no stranger to telescopes, either. A pair of ESO observatories - Paranal and La Silla · observations from there and engineers are planning to use the area as the future site for the Ove Large Telescope, or OWL. That telescope would be ALMA's optical cousin, and secure the title o largest optical telescope with a 109-yard (100-meter) aperture.

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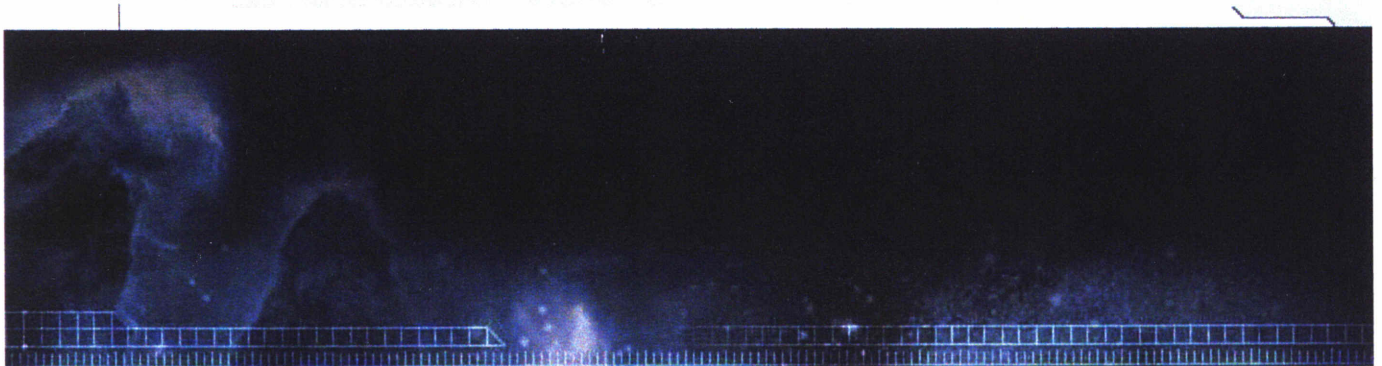

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