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IN THIS ISSUE:

A REPORT ON THE SURVEY
April 13, 1995
By: Russ Childers

The all-sky survey is continuing as scheduled. Currently, the declination of the **Radio Observatory** is +15 degrees 00 minutes. This means that the survey is past the 47 percent point. We started at +62 degrees 20 minutes in September, 1993, and will finish the survey at -36 degrees 00 minutes in October, 1996.

We have received repaired HEMT and GAsFET Low Noise Amplifiers, and the HEMTs have been installed. The noise level with the HEMTs appears to be half to a quarter of what it was with the GAsFET amplifiers. This is good news, because we can now detect sources weaker than those detectable with the GAsFETs.

I was surprised by a strong continuum source on February 10, 1995. It was detected by the **LOBES SETI** system, and by the digital strip chart recorder. The declination was +20 degrees 00 minutes. This declination is special, because it falls in the realm of where the sun travels through its path in the sky. On the summer solstice, the sun is at +23 degrees declination, and on the winter solstice the sun is at -23 degrees.

This "surprise" source did not coincide with the transit of the sun, however: it occurred at 1:24 Universal time. This off sun time but in-sun region lead me to reason that this could be the Earth's Moon. The next day, another strong continuum source showed up, this time at 2:13 Universal time. This 49-minute gap seemed to be right for the Moon. Sure enough, after looking at a planet-tracking program, the Moon appeared at the meridian at the above times and dates. It is unclear whether the Moon's spectrum as seen by **LOBES** is flat, or whether there are narrowband phenomena. If the Moon is reflecting earth-bound radio sources which are in the 1.4-1.7 GHz range scanned by **LOBES**, there is a chance that they will be reflected. There is nothing to stop **LOBES** from tracking any narrowband sources it detects from the Moon, however to date there has been no Moon tracking. Recall that in *2001 A SPACE ODYSSEY*, radio waves were detected going from the monolith on the Moon to Jupiter. **LOBES** is on the lookout for such a signal aimed at the Earth.

I am grateful for the work Mark Sundstrom is putting into analysis of digital continuum data. Mark has impressed our group with his speedy computer programming and quick grasp of astronomy. Eventually, Mark will have a system which will produce contour maps not unlike those in the original sky survey. Mark's data processing is slightly different from that which I have done, and it is refreshing to see a new perspective on a project I have been working on for more than a year.

The survey continues...

COORDINATOR'S CORNER
By: Phil Barnhart

With the next **Open House** just around the corner we need desparately to complete the planning at the May 6 session at the **RO**. All available volunteers should be there. We can not assign tasks in absentia. We need a viable (*pliable?*) replacement for Steve Janus at the foot of the Parabolic reflector — alias Station #3. Come out and make the day.

Jerry Ehman has made considerable progress in reanalysing the original **WOW!** data. Considerably more computer power today than in 1978 means lots of data massaging and trying can go on. The results will be posted as we garner more data for the **Planetary Society Project**.

We still remain in the dark about the future of the observatory. We are almost

certain that an immediate beginning on the **Argus Project** is in order. It will be very difficult in a few years to stare out on the old hog farm and not see a three acre telescope standing there. We need a Jurassic Park for magnificent scientific instruments.

Keep the faith. We will progress into the next generation of Radio Astronomy instruments.

ULYSSES SPACECRAFT MAKES CLOSEST APPROACH TO SUN

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The Ulysses spacecraft will cross the Sun's equator March 12 and make its closest approach to that body on its way to the northern polar region of the Sun.

The spacecraft will pass within 200 million kilometers (*124 million miles*) of the Sun at 11:40 Universal Time (*3:40 a.m. Pacific Standard Time*), the closest it has ever been or ever will be to the Sun since it was launched on October 6, 1990, said Donald Meyer, Ulysses deputy mission operations manager at **NASA's Jet Propulsion Laboratory**. Distance from Earth at perihelion, or closest approach to the Sun, will be approximately 346 million kilometers (*215 million miles*).

Ulysses is crossing rapidly into the northern hemisphere now, traveling at a rate of about 0.8 degrees in latitude per day and a velocity of approximately 117,000 kilometers per hour (*73,000 miles per hour*), with respect to the Sun.

For the last month the spacecraft has been collecting data on the equatorial region of the Sun. This will continue for the next month, until Ulysses begins to see features from the northern hemisphere of the Sun, said Peter Beech, mission operations manager from the European Space Agency.

All spacecraft operations and science experiments continue to go well. A radio science experiment is currently under way to measure the electron content of the Sun's fiery outer atmosphere, called the corona, as Ulysses passes in back of the Sun

as seen from Earth.

MARS PATHFINDER SCIENCE STATUS: INVESTIGATING THE LANDING SITE

Mat Golombek, Mars Pathfinder Project Scientist

February 17,1995

At present most of the scientists associated with the **Mars Pathfinder** mission are busy building the three science instruments (*Imager for Mars Pathfinder, Alpha Proton X-ray Spectrometer, and the Atmospheric Structure/Mleteorology Package*) for the spacecraft and rover. Over the next year the instruments will be built, tested and calibrated before and after integration on the spacecraft. The progress and status of the instruments will be reported in a future status report. However, in addition to building the instruments a smaller number of scientists are attempting to learn everything possible about the place we plan to land the spacecraft on the martian surface. This status report will focus on this topic.

As previously announced, the project has decided to land where Ares Vallis opens into Chryse Planitia on Mars (*19.5 degrees North latitude, 32.8 degrees West longitude*). The rationale for choosing this location is that it represents a place where there is the potential for sampling a wide variety of different rocks that make up the planet Mars in the small area accessible to the rover (*a few tens of meters*). One of the areas of greatest scientific return possible from the Pathfinder mission is in its ability to learn about the mineralogy and chemical composition of the various materials at the landing site. Imaging rocks and other materials at the landing site with a variety of spectral filters should allow discrimination of different pyroxene and iron oxide minerals. The rover would then be directed to different interesting rocks, where the alpha proton x-ray spectrometer would be used to determine their elemental composition. Close-up images of the rocks would also be taken by the color and monochrome cameras on board the rover, allowing discrimination of any millimeter-sized crystals present in the rock. Using all these data together, scientists will attempt to determine the mineralogy of the rock. If the mineralogy can be determined, then a tremendous amount of information can be inferred with regard to the processes and environment in which the rock formed. The greater the number of different rocks that can be studied at the landing site, the more that can be learned about the geologic history of the planet. Because the Ares Vallis floods drained from the ancient highlands, which include some of the planet's oldest rocks, Pathfinder may enable scientists to determine how the planet differentiated into a

crust and mantle and whether early Mars was both warmer and wetter than at present (*and thus more like the early Earth*).

Images of the surface of Mars at the meter scale (*of interest to a lander*) currently exist only at the two Viking landing sites. The reason for this is that images of Mars taken from orbit are at a scale insufficient to resolve lander-sized objects. At the Ares site, for example, the highest-resolution Viking Orbiter images are at about 40 meters per picture element (*pixel*). That means that when Pathfinder lands on Mars, virtually all of its observations will he taken within a single pixel of the orbiter images. Predicting what the surface will look like at the meter scale is virtually impossible from such coarse-resolution images.

For this reason, other remote sensing techniques must be used to attempt to understand the nature of the surface. Such techniques include Earth-based radar, which can give information about the roughness of the surface at a scale of 10-100 meters. In addition, **Viking Infrared Thermal Mapper** (*IRTM*) observations can be used to infer the relative abundance of rocks on the surface (*as opposed to dust*) and the albedo and color of the Viking images can be used to infer the relative amounts of bright martian dust and dark rocks. Scientists studying Mars are actively involved in using these data sets to learn as much as possible about the surface at the landing site. In addition, because Mars is presently near opposition with the Earth, additional Earth-based radar data are being acquired of areas of interest.

Another way to learn about Ares Vallis is to study similar features here on Earth. Ares Vallis is one of the largest outflow channel on Mars, which form when enormous quantities of water flow over the surface during a short period of time. A well-known similar feature on the Earth can be found in the Channeled Scablands of Washington State. Large streamlined islands and channels were carved when ice that dammed a large glacial lake (*Lake Missoula — about the size of Lake Ontario*) ruptured and the water drained to the Pacific Ocean over a period of about two weeks. Ares Vallis flood involved substantially greater quantities of water (*roughly the entire volume of all five Great Lakes*) draining into the martian northern lowlands. Another group of scientists is using knowledge gained from studying the Channeled Scablands on Earth to better understand similar large-scale features visible in the orbiter images of Mars.

GALILEO MISSION STATUS
April 1, 1995

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On March 16 the Galileo project completed the final checkout of its atmospheric probe, found it to be healthy and ready for deployment from the orbiter in July.

The probe's battery and the accelerometers in the atmospheric structure instrument were performing exactly as they had during the December 1992 checkout. In addition, the neutral mass spectrometer was pumped out. The probe telemetry was stored simultaneously in the orbiter's computer memory and on tape, in a validation of the data strategy designed for the December 7 probe mission.

A small trajectory correction maneuver planned for April 12 will fine-tune the spacecraft's aim toward the probe's point of entry into Jupiter's atmosphere. After the probe is deployed July 13 to fly independently to its Jupiter atmospheric mission, the orbiter will be redirected with a large maneuver towards its aim point just 1,000 kilometers (*620 miles*) above Io.

Galileo continues to operate normally, spinning at about 3 rpm and transmitting coded telemetry at 10 bits per second to ground stations at **NASA/JPL's Deep Space Network**. The telemetry includes science memory readouts twice a week from the magnetometer, interplanetary dust detector and extreme ultraviolet spectrometer, as well as engineering measurements and memory readouts remaining from the probe checkout.

The spacecraft is currently 721 million kilometers (*448 million miles*) from Earth, having traveled 3.64 billion kilometers since its launch in October 1989. It has only 250 days and 148 million kilometers (*92 million miles*) to go to reach Jupiter. Its speed in solar orbit is currently 7.65 kilometers per second (*more than 17,000 mph*).

TOPEX/POSEIDON MISSION STATUS

April 1, 1995

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The satellite and sensors continue to operate as expected and ground system computers are performing well. The satellite tape recorders have been played back and the daily science and engineering data products are being produced.

On Monday, the satellite begins its 94th 10-day data collection cycle. The science data team reports it is now processing the data for cycle 93 and that the interim geophysical data records for cycle 92 have been shipped to the **Physical Oceanography Distributed Active Archive Center** (*PODAAC*) at the **Jet Propulsion Laboratory** for distribution to scientific investigators.

ULYSSES MISSION STATUS

April 1, 1995

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The Ulysses spacecraft crossed the ecliptic plane in which most of the planets orbit the Sun on March 13, one day after making its closest approach to the Sun since it was launched on October 6, 1990. The spacecraft passed within about 1.3 astronomical units (*200 million kilometers or 124 million miles*) of the Sun and conducted a radio science experiment to measure the electron content of the Sun's fiery outer atmosphere, known as the corona.

The experiment was carried out using Ulysses' S-band transmitter, in conjunction with its X-band transmitter, to beam signals through the corona and back to Earth. Preliminary results of the radio science data revealed a large coronal streamer — a

distinctly bounded region of enhanced coronnl density — extending outward from the Sun into interplanetary space at between 15 degrees and 21 degrees south of the Sun's equator. First results of the radio science experiment will be reported at this week's meeting of the **European Geophysical Society** in Hamburg, Germany.

All spacecraft operations and science experiments continue to go well aboard the spacecraft. Flight controllers have begun continuous Earth-pointing maneuvers to keep the spacecraft properly oriented as its axial boom is again illuminated by the Sun, causing a slight wobbling onboard the craft. This phase of the mission, when the spacecraft's boom is heated by the Sun, will continue into September.

Today Ulysses is about 21 degrees north of the Sun's equator, traveling at a heliocentric velocity of about 116,300 kilometers per hour (*72,300 miles per hour*). The spacecraft begins the second phase of its primary mission — its northern solar polar pass — when it reaches 70 degrees north of the Sun's equator on June 19.

VOYAGER MISSION STATUS
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Both spacecraft are healthy and are continuing to make observations of their interplanetary environment as they leave the solar system.

They are using their ultraviolet spectrometers to map the heliosphere and study the incoming interstellar wind. The cosmic ray detectors are seeing the energy spectra of interstellar cosmic rays in the outer heliosphere. The magnetometer sensors are still measuring the strength and direction of the solar magnetic field. The plasma detectors looking back at the Sun record the solar wind parameters. The low-energy charged particle experiment studies the energy spectra of particles coming from the Sun. The plasma wave instrument is studying the incoming signals from the direction of the heliosphere.

Voyager 1 is currently 8.8 billion kilometers (*5.5 billion miles*) from Earth and is

traveling at a speed of 63,000 kilometers per hour (*39,100 miles per hour*). Voyager 2 is 6.8 billion kilometers (*4.2 billion miles*) from Earth and is traveling at a speed of 58,000 kilometers per hour (*36,100 miles per hour*).

The total distance Voyager 1 has traveled since its September 5, 1977 launch, called the arc length, is 10,595,000,000 kilometers (*6,584,000,000 miles*). The total distance Voyager 2 has traveled since its August 24, 1977 launch is 10,026,000,000 kilometers (*6,230,000,000 miles*).

ACTIVITY REPORT
By: Herb Johnson

I have a day job, working on documentation for a set of computer programs developed at Educational Testing Service. This contract will last thru Nov 1995. So, my **Observatory** activities and traffic will decline a bit. However, I am considering a trip to the *Dayton Hamfest*, so I might be in the neighborhood. Meanwhile, my **Observatory** activities will be at a reduced pace from last year. But a lot of my prior work is now completed.

SENDING DATA

I've waited for something to emerge from the discussion on how to send data to the **Observatory**. Apparently the method of choice will be UUENCODE and the mail system. It would be nice to have a designated "generic" receiver (*person*) for reports or other non-specific traffic. Broadcasting it via the listserver has previously been discouraged. Please correct my conclusions if they are in error.

PUNCHCARDS

My report and database on the punchcard data archives has been delayed pending the outcome of sending data, and recent demands on my time. Also, I have not received the last bits of info on the "missing" boxes Joe Mitchell has located. I still intend to send a paper and disk copy to Bob Dixon for the archives, and presumably an electronic copy to Joe Mitchell. I'm pleased he has taken up this project!

PREVIOUS REPORTS

My reports on the continuum chart recorder and a technical summary of the 1976-

83 **SETI** program are completed, and have been reviewed by the appropriate people. Paper and disk copies will be sent to Bob; and the electronic copies are in the hands of Russ Childers, Angelo Capenella (*chart recorder*) and Bob Dixon and Dr. Ehman (***SETI***). The latter report provided me with the notes I sent to Bob on his recent "history" article to be published in *SETIQuest*: Bob graciously thanked my input. Angelo provided a lot of history on developing the chart recorder, and Russ and Angelo provided most of the technical info. The **SETI** program summary was derived from Ehman's report on the software, Bob's history article, Mark Abel's 1985 report, and my own research in the Archives. Thanks to all who helped! I hope these reports will be useful to others. I'd be pleased to directly share these two reports through the maillist, or to interested individuals, if there are no objections. I have no problems, but as a matter of courtesy I'd like it to be confirmed that this is OK.

SLIDE SHOW

These reports will also provide material for my continuing work on the "generic slide show", which is also derived from Bob's "history" article. I will also include information and text from articles in *Signals*, and slides of photos and viewgraphs taken by myself and others at the observatory. When complete, I will of course ask all sources for approval and permissions. Again, I note the goal is to make a slide show available for the **Observatory**, with text and references. It can be used as-is, or slides or information taken from it to respond to questions or inquiries. I note requests for pictures, articles, presentations, and points of information occur often at the **Observatory**.

CONTINUUM

I have made no recent progress on Russ's programs and data on the continuum, but we correspond occasionally on **WHOA's** and other event phenomena.

PULSARS AND WAVELETS

And, I continue my correspondence with Phil Schumacher on pulsar signal analysis. He has UUENCODED some of his test results and I have received them intact. I continue to have an interest in the subject. In that regard, I can report a brief discussion about WAVELETS and pulsar detection strategies. I recently attended a

lecture at the Princeton Plasma Physics Lab by Dr. Ingrid Daubechies, a well-known authority on wavelets. Afterwards, I briefly described the wavelets would be a more useful detection stragegy than FFT or related methods. She opinioned that, as a pulsar signal is of a simple shape — namely a pulse — that wavelets would not be particularly useful. A signifigant quality of wavelet analysis is its ability to be adapted to variations in the signal's shape (*i.e. harmonic content*): a finer resolution of detection for those rapidly-changing portions of the waveform, and gross resolution of detection where the waveform is flat. Consequently, as a pulse has only "one" shape, wavelets offer no benefit. While this was a brief discussion, it made sense to me as I have described it.

Hmmm...I seem to have been pretty busy this quarter! Again my thanks to all who have supported my activities and who have corresponded with me.

PIONEER 10 & 11 STATUS
4/1/95

Pioneer 10
Distance from Earth: 9.3 billion KM. Round-trip Light Time: 17 hours, 15 minutes.

Active Instruments:
Plasma Analyzer; Charged Particle Instrument; Cosmic Ray Telescope; Geiger Tube Telescope; Ultraviolet Photometer.

As the spacecraft power continues to decline, the instruments are operated according to a power-sharing schedule. Individual instruments, or groups of instruments, are turned on at a time such that the total power consumption is within the available power range.

Pioneer 11
Distance from Earth: 6.5 billion KM. Roundtrip Light Time: 11 hours, 57 minutes.

The Pioneer 11 spacecraft is out of communication at this time. The Earth moved out of the spacecraft antenna beam in January 1995. A precession maneuver, needed to aim the spacecraft high gain antenna toward the Earth, could not be performed in January because the Sun was out of view of the spacecraft Sun sensor. The motion of the Earth will bring the antenna beam back into view, starting on 16 May 1995, and the spacecraft will be re-acquired at that time.

The available power from the Pioneer 11 spacecraft **Radio-Isotope Thermoelectric Generators** (*RTG*) is declining to the point where there will be insufficient power for any instrument by December 1995. Between June and August 1995, Pioneer 11 will be used as a test-bed to study its performance under sub-normal voltage conditions.

Despite the possibility that the tests may cause the spacecraft to fail permanently, the knowledge gained will be invaluable for future operation of Pioneer 10 in late 1997 and 1998. *Project Manager: Fred Wirth*

HUBBLE MONITORS WEATHER ON NEIGHBORING PLANETS

The weather on Mars: *another cool and clear day. Low morning haze will give way to a mostly sunny afternoon with high clouds. The forecast for Venus: hot, overcast, sulfuric acid showers will continue. Air quality is slightly improved as smog levels subside."*

That kind of weathercast is now possible as **NASA's Hubble Space Telescope** serves as an interplanetary weather satellite for studying the climate on Earth's neighboring worlds, Mars and Venus.

To the surprise of researchers, Hubble is showing that the Martian climate has changed considerably since the unmanned Viking spacecraft visited Mars in the mid-1970s, which was the last time astronomers got a close-up look at weather on the Red Planet for more than just a few months. Hubble images of clouds and spectroscopic detection of an ozone abundance in Mars' atmosphere, all indicate that the planet is cooler, clearer and drier than a couple of decades ago.

In striking contrast, Hubble's spectroscopic observations of Venus show that the atmosphere continues to recover from an intense shower of sulfuric "acid rain" triggered by the suspected eruption of a volcano in the late 1970s. This is similar to what happens on Earth when sulfur dioxide emissions from coal power plants are broken apart in the atmosphere to make acid rain. On Venus, this effect takes place on a planetary scale.

Although the close-up visits by numerous unmanned spacecraft provided brief glimpses of weather on these planets, the long-term coverage offered by Hubble has never before been possible. Knowledge about the weather is critical to planning

future missions to these worlds. In the case of Mars, being able to predict the weather will be critical prior to human exploration of the planet.

Studying conditions on Mars and Venus might also lead to a better understanding of Earth's weather system. Apparently, processes that occurred early in the solar system's history sent terrestrial planets along very different evolutionary paths. The neighboring planets are grand natural laboratories for testing computer models that will lead to a general theory of the behavior of planetary atmospheres.

The Space Telescope Science Institute is operated by the **Association of Universities for Research in Astronomy, Inc.** (*AURA*) for **NASA**, under contract with the **Goddard Space Flight Center**, Greenbelt, MD. The Hubble Space Telescope is a project of international cooperation between **NASA** and the **European Space Agency** (*ESA*).

NEW EVIDENCE REPORTED FOR MILKY WAY BLACK HOLE

LONDON (*Reuter*) - Astronomers reported more evidence Thursday that a vast black hole in the Milky Way galaxy is steadily sucking in clouds of gas and affecting nearby stars.

Observations indicate the black hole is in **Sagittarius A***, a radio source at the center of the Milky Way, the galaxy of the Earth's solar system.

Black holes are still theoretical because no one has actually seen one — just evidence that something large but invisible is affecting nearby stars, and of "accretion disks" of matter being pulled into the black holes.

As the matter is sucked into the black hole — itself a collapsed star that attracts matter and energy so strongly that none can escape — it lets off energy in the form of X-rays and radio signals. Radio telescopes can detect this.

But they have recently found that material being pulled into the suspected black hole at Sagittarius A* does not emit the predicted amount of energy.

Ramesh Narayan and colleagues at the **Harvard-Smithsonian Center for Astrophysics** in Cambridge, Mass., tackled this and came up with a theoretical model that would explain it.

Most of the energy released is carried along with the gas and lost into the black hole of mass...rather than appearing as radiation," they wrote in the science journal *Nature*.

According to their model, more than 99.9 percent of the energy was being sucked into the black hole.

1995 RO OPEN HOUSE SCHEDULED

The 1995 RO Open House is scheduled for May 13th. It will be held at the Radio Observatory, beginning at noon. As we expect quite a turn-out, we will need quite a bit of volunteer assistance. If you can help out, please contact Dr. Barnhart at (614) 823-1516 or electronically as *pbarnhar@magnus.acs.ohio-state.edu*; or Dr. Dixon electronically as *rdixon@magnus.acs.ohio-state.edu*. Of course, if you know of anyone or any groups interested in attending, please let them know!

HUBBLE VIEWS PLANET NEPTUNE AND ASTEROID VESTA

The latest surprising findings on the planet Neptune and the asteroid Vesta will be presented in the next Space Astronomy Update at 2 p.m. EDT, Wed., April 19, in the **NASA** Headquarters auditorium, 300 E St. SW, Washington, DC.

Entitled, "*Hubble Looks at the Outer Solar System*", the event will feature panelists Dr. Heidi Hammel of the **Massachusetts Institute of Technology**, and Dr. Ben Zellner of **Georgia Southern University**.

Hubble images will show the new dark spot in the northern hemisphere of the distant planet Neptune. Only last June Hubble revealed that a great dark spot in the southern hemisphere — discovered by the Voyager 2 spacecraft in 1989 — had mysteriously disappeared.

Hubble images of the asteroid Vesta will show a complex surface with a geology similar to that of terrestrial worlds such as Earth or Mars. The battered ancient surface — the oldest terrain ever seen in the Solar System — allows astronomers to peer below the crust. Vesta is unique in being the only asteroid astronomers actually can study in a laboratory — thanks to a collision blasting a piece of the asteroid's surface into space which eventually fell to Earth. The fragment will be displayed at the event.

The event will be carried live on **NASA** Television with questions and answers from participating **NASA** Centers. **NASA Television** is broadcast on Spacenet 2, transponder 5, channel 9, C-Band, located at 69 degrees West longitude, with horizontal polarization. Frequency will be on 3880.0 megahertz, with audio on 6.8 megahertz.

GRAVITATIONAL LENSING MAY HELP DETECT BROWN DWARFS

WASHINGTON (*AP*) - Researchers using starlight bent by gravity to probe the halo of the Milky Way galaxy say that failed stars called "brown dwarfs" may make up 20 percent of the dark, unseen matter in the galaxy.

Kem Cook of the **Lawrence Livermore National Laboratory** said Tuesday that a survey of eight million background stars over a 400-day period detected four instances where starlight was bent by the effect of gravity as it streaked toward the Earth. Cook said a telescope scanning the heavens detected what are called lensing events. These occur when starlight, coming from background stars much farther out in space, is bent by gravity as it streaks past celestial bodies closer to the Earth. This bent light gives a specific instrumental signature that allows astronomers to determine the size of the celestial bodies causing the lensing.

In effect, the lensing forms a probe for detecting unseen objects in the halo of the Milky Way. Such bodies are called massive compact halo objects, or **MACHOs**.

Cook said the four lensing events detected by his team were caused by a form of **MACHOs** called brown dwarfs, starlike objects that are about 4 percent of the size of the sun, the Earth's nearest star. He said such bodies may account for about 20 percent of the cold, dark matter thought to surround the Milky Way.

Brown dwarfs are thought to be spheres of gas and dust that did not become large enough to ignite internal nuclear fires of even a small star.

Existence of the unseen matter is based on calculations of how much mass the galaxy should contain for its billions of stars to move in the way that has been observed. Astronomers believe there is not enough lighted, visible matter to account for all of the mass in the galaxy. The mass which is not seen must be chilled and without light, and, hence, astronomers call it cold, dark matter.

Astronomers search for the cold, dark matter by observing the influence of its gravity to other objects.

Cook's reported on the Lawrence Livermore study at a national meeting here of the **American Physical Society**.

[Back to List of Issues in Volume 11] | **[Back to List of Volumes]** | **[HOME]**

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