1769 VENUS TRANSIT • MISSION TO PLUTO • CHEAP RADIO ASTRONOMY

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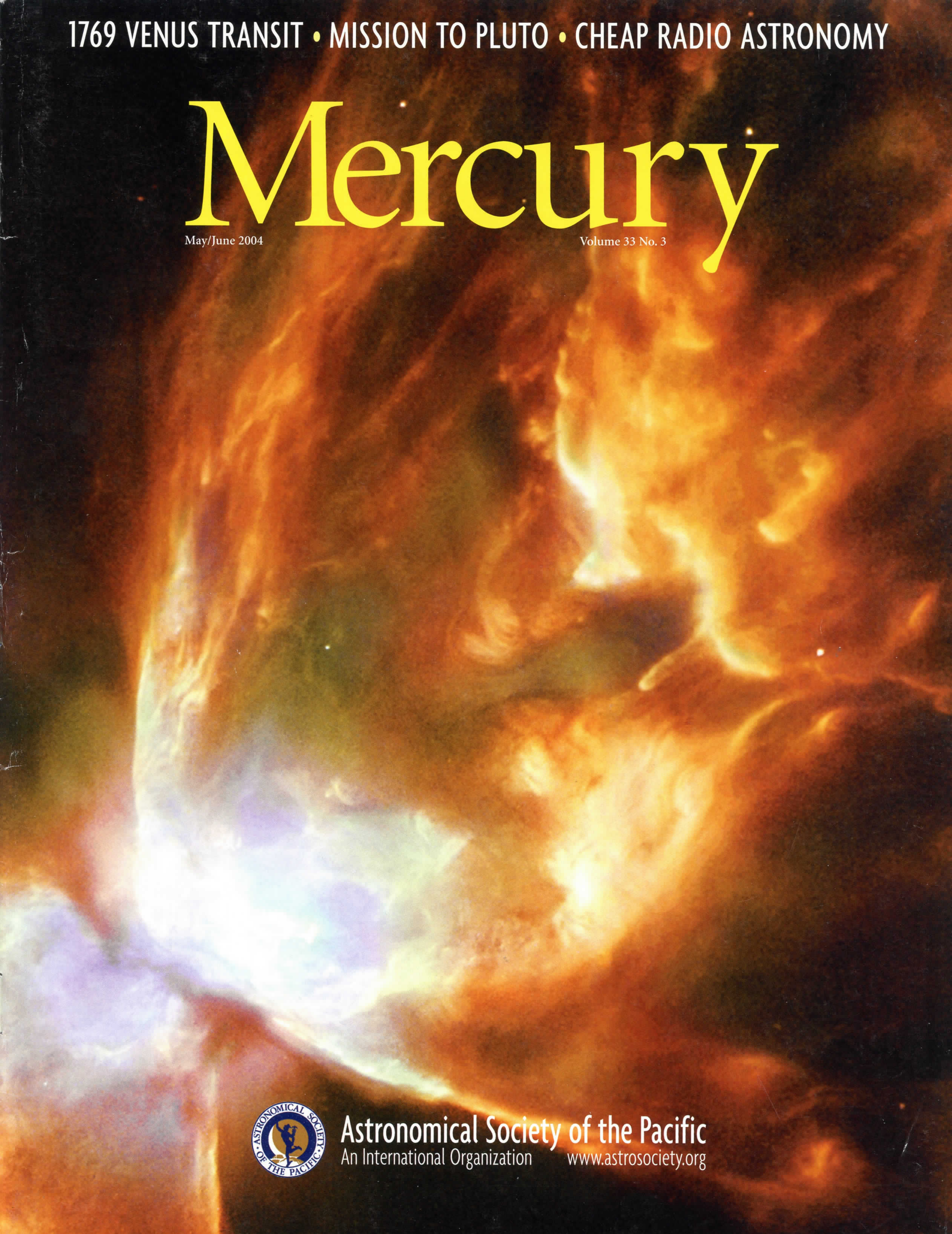

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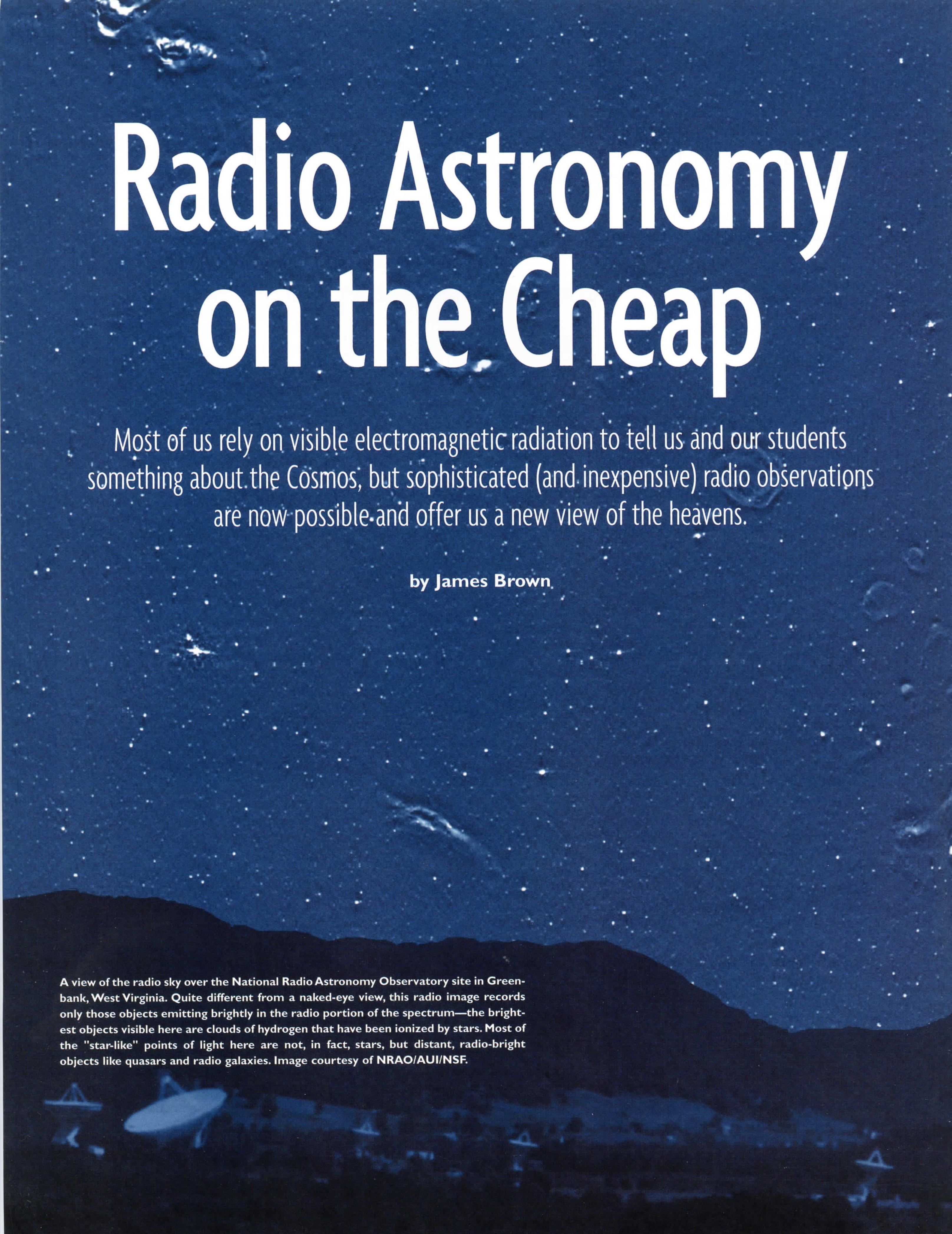
Radio Astronomy on the Cheap

Most of us rely on visible electromagnetic radiation to tell us and our students something about the Cosmos, but sophisticated (and inexpensive) radio observations are now possible and offer us a new view of the heavens.

by James Brown



A view of the radio sky over the National Radio Astronomy Observatory site in Greenbank, West Virginia. Quite different from a naked-eye view, this radio image records only those objects emitting brightly in the radio portion of the spectrum—the brightest objects visible here are clouds of hydrogen that have been ionized by stars. Most of the "star-like" points of light here are not, in fact, stars, but distant, radio-bright objects like quasars and radio galaxies. Image courtesy of NRAO/AUI/NSF.

Turning his antenna skyward, Jansky discovered a signal that repeated not every twenty-four hours, but every twenty-three hours and fifty-six minutes.

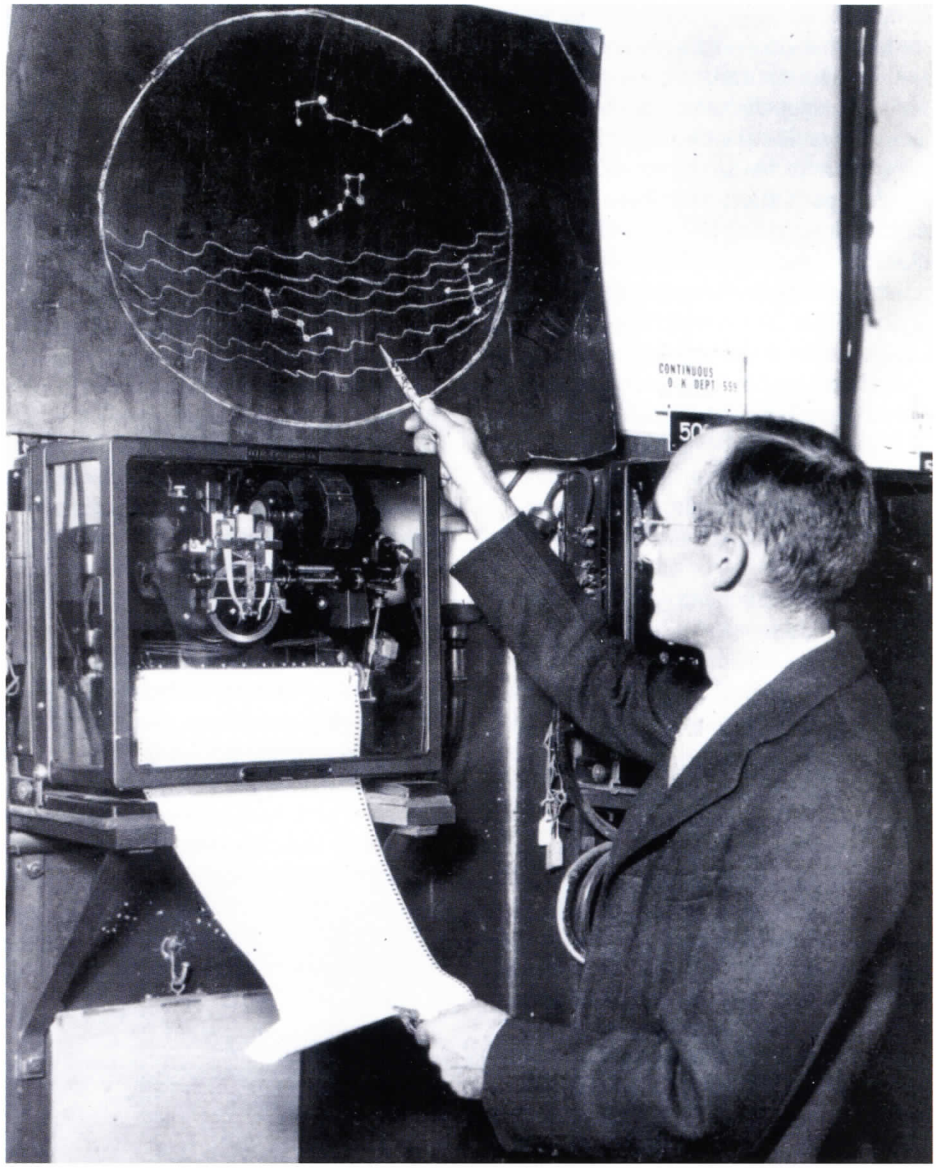
This is characteristic of rotation of Earth relative to the stars and other objects far outside our solar system. Radio astronomy had its birth in 1932 when Karl Guthe Jansky built an antenna for Bell Labs. The instrument was designed to receive radio waves at a frequency of 20.5 MHz and be part of an investigation into the potential use of "short waves" for transatlantic radiotelephone service. He eventually figured out that the radiation was coming from the Milky Way and was strongest in the direction of the center of the Galaxy, toward the constellation Sagittarius.

Grote Reber learned about Jansky's discovery and wanted to continue the work and learn more about "cosmic" radio waves. Yet Reber was unable to find employment with astronomical observatories to study the waves because none of the observatories were hiring in the middle of the Great Depression. He decided to study radio astronomy on his own, and in 1937 he built his own radio telescope in his backyard in Wheaton, Illinois.

Reber spent long hours every night scanning the skies with his telescope. He had to do the work at night because there was too much radio interference from the sparks in automobile engines during the daytime. From 1938 to 1943, Reber made the first surveys of radio waves from the sky and published his results both in engineering and astronomy journals. His work was so robust that his accomplishments insured that radio astronomy would become a major field of research following World War II. Research groups in many countries began building bigger and better antennas and receivers to follow up on Reber's discoveries. And the rest, as they say, is astronomical history.

Everyone's Radio Astronomy

I was first introduced to radio astronomy in my university astronomy classes. As part of an astronomy-class field trip in the mid 1970s, I visited the National Radio Astronomy Observatory at Green Bank, West Virginia, and immediately fell in love with the idea of radio astronomy. At the time, it



Karl Guthe Jansky (above), in about 1933, was the first to detect radio emissions coming from the Milky Way, strongly concentrated in the direction of the center of our galaxy. Image courtesy of NRAO/AUI/NSF.

Grote Reber (left) was inspired by the foundational discoveries and work of Jansky and built his own backyard radio telescope at his home in Illinois. He confirmed Jansky's discovery of concentrated radio emission from the center of the Galaxy and discovered bright radio sources in other constellations. Image courtesy of NRAO/AUI/NSF.

seemed impossible to me for a private individual, like Reber, to become involved with any aspect of radio astronomy, much less be one of its founders, but this is not the case any longer. Just consider Project Radio JOVE.

Radio JOVE is an educational program, sponsored by NASA's Goddard Space Flight Center in Greenbelt, Maryland, in which students and amateur scientists observe and analyze the natural radio emissions of Jupiter (hence, the use of Jupiter's Roman name, Jove) and the Sun. This Project is a joint effort of NASA's Space Science Data Operations Office, the Department of Astronomy at the University of Florida, the Florida Space Grant Consortium, high school teachers, and volunteers.

Radio JOVE is intended for high school science classes, for college science courses or laboratories, and for anyone else who would like to participate. The Project's goals are to

- educate people about planetary and solar radio astronomy, space physics, and the scientific method;
- provide teachers and students with an astronomy exercise as a science-curriculum support activity by building and using a simple radio telescope receiver/antenna kit;
- create an on-line radio observatory that provides real-time data for those with internet access; and
- facilitate interactions among participating schools and individuals by fostering exchanges of ideas, data, and observing experiences.

The Radio JOVE antenna is a simple affair, and installation and check-out are not complicated. Photo courtesy of the Radio JOVE program.

Available from *radiojove.gsfc.nasa.gov*, the Radio JOVE Kit consists of a receiver, which is designed to receive at 20.1 MHz, and a set of phased dipole antennas. The cost of the Radio JOVE receiver and antenna kits is a modest $135 (to recover materials expenditures), and this cost includes receiver kit, antenna kit, and necessary software.

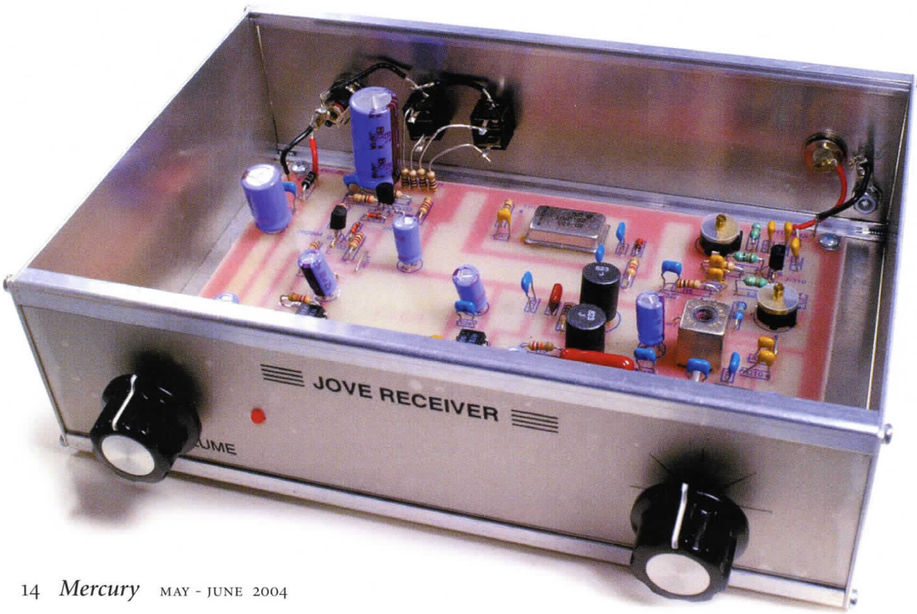
The receiver is not difficult to construct because all the parts are included and should only take you several hours to build and test. If you feel that the project is beyond your capabilities, however, you might seek the assistance of a local amateur (ham) radio operator or club. Locating a nearby ham to assist you may be as easy as contacting a local ham club. Questions about the Radio JOVE Project can also be directed to individuals on the Project's Master Helpers List at *rj_project@radiojove.gsfc.nasa.gov*.

How do schools join the Project?

Usually a science teacher or an interested group within the school does the Project. For example, one teacher with students who are interested in extra science credit can have the students build the receiver and antenna, and then they all learn to use it. A teacher can also use the equipment for group projects within science classes. Sometimes the kit is even built for a science class teacher and then loaned out to interested students or groups of students.

How many schools are using it?

More than 630 kits have been distributed with about three-fourths of them going to schools. A number of kits have also gone out to individual ham radio operators, interested groups (e.g. planetaria, science clubs, scout troops, etc.), and just plain interested individuals.



The Radio JOVE Kit (above) consists of a receiver (left) designed to receive at 20.1 MHz, a set of phased dipole antennas, and necessary software. The Kit is available from *radiojove.gsfc.nasa.gov*. Photos courtesy of the Radio Jove program.

The Solar Radio Program

The Sun emits radio waves with wavelengths from centimeters to tens of meters, under both quiet and disturbed conditions in patterns, known variously as noise storms, bursts, and sweeps. The types of solar events that dominate the Radio JOVE data are referred to as "sweep-frequency radio bursts." Solar radio bursts are associated with solar flares—energetic events in which the Sun emits radio waves, hard x rays, and gamma rays—and can last from a few seconds to an hour. The categorizing of such bursts is based on several factors, but here, generally, are the types of solar radio bursts as a function of frequency of emitted radiation:

Type I
frequency range 150 – 350 MHz

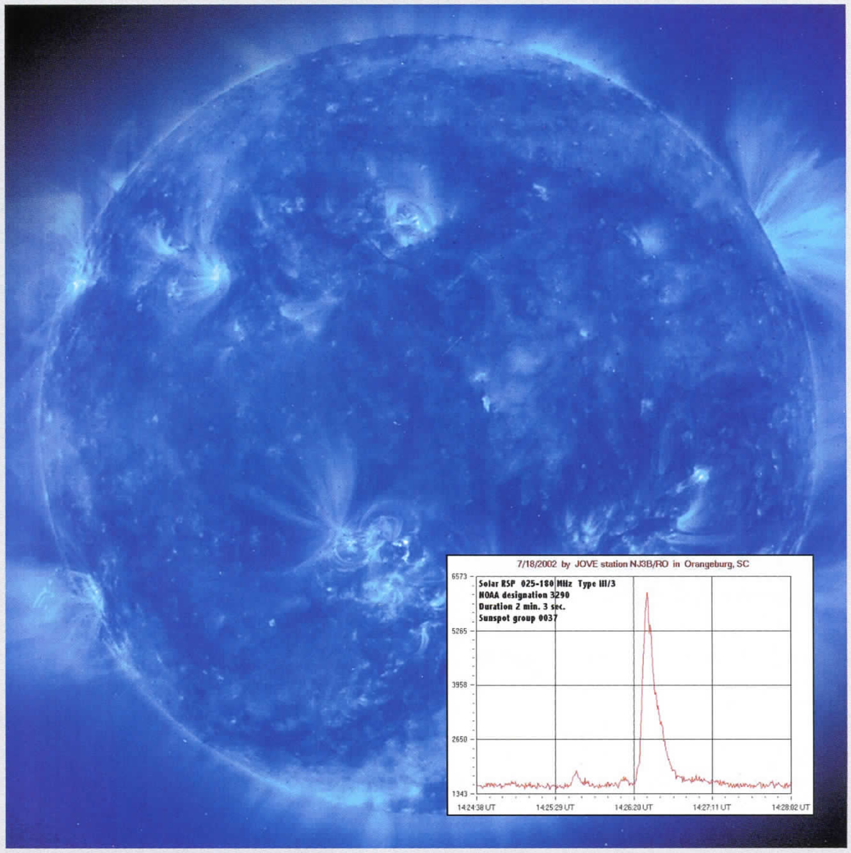
Type II
frequency range < 20 – 150 MHz

Type III
full frequency range

Type IV
frequency range 20 – 200 MHz

Type V
frequency range < 10 – 120 MHz

The equipment of Project Radio JOVE is most sensitive to primarily Type III and Type V bursts, although other types can be observed with the Radio JOVE equipment. These types of emission are subjectively rated on an intensity scale of 1 to 3, with 3 representing the most intense. A given event could be listed, for example, as Type III/1, III/2, or III/3, depending on its intensity.



A Type III/3 solar event observed on 18 July 2002. Plot courtesy of the author. Solar image courtesy of SoHO (ESA and NASA).

During my year-long solar-observing project, I witnessed a number of different radio bursts. The actual events I observed were of multiple types; perhaps not surprisingly, the majority of the bursts were of low- to mid-energy, but I did observe all types. Interestingly, NOAA does not collect data for any solar events below 25 MHz, and since the Radio JOVE receiver is designed for optimum reception at 20.1 MHz, the JOVE radio telescope can record data that NOAA does not. This means that Radio JOVE participants are likely contributors to our knowledge of lower frequency solar activity. — *J. B.*

What are the students learning?

Hopefully students learn about the mysteries of the Sun and Jupiter as revealed by radio emissions, but they also encounter the scientific method from the very beginning. They hear about the strange and mysterious emissions that come from, say, the Sun and are compelled to learn more about them firsthand. If they are particularly curious, students may formulate a hypothesis regarding the science and set out to see if their hypothesis is true or not through their observations. Usually this process leads them to more [interesting] questions. In addition, the students share what they have learned by contributing their data to a pool for use by others and by telling others what they have concluded.

Is the Project encouraging students to become scientists?

A rigorous survey of student participants has yet to be done, but there is anecdotal evidence that some students participating in Radio JOVE are pursuing science careers. Several children have used elements of Radio JOVE experiments as science fair projects and won awards, and a few are majoring in science in college. Would they have done this even if they had not been involved in Radio JOVE? Probably, but it's hoped by the Project's developers and supporters that this is the type of experience that will orient better the students to their future careers. Moreover, Radio JOVE is marvelous for those kids who are at an impressionable age and who might not, for lack of such a real science experience, see science as a viable or even interesting path.

Radio JOVE at Work

Project Radio JOVE is an excellent and inexpensive way for educators—or anyone, for that matter—interested in radio astronomy to get started. The Project's equipment has dual ability to permit you to observe both Jovian and solar radio bursts. Let me describe the power and utility of Radio JOVE by introducing a one-year, solar-observing project I conducted.

Most of the time, solar activity is of little concern in our everyday life, but the Sun goes through cycles of high and low activity that repeat approximately every eleven years. Episodic solar activity has a number of effects that are important to us. A radiation dose from energetic solar particles is an occasional hazard for astronauts and for electronics on satellites. And concomitant geomagnetic field disturbances may damage power systems, disrupt communications, degrade high-tech navigation systems, or create spectacular aurorae. Indeed, when the space environment is disturbed by eruptions from the Sun, various technological devices—on Earth and in orbit and on which our lives seemingly depend—can be affected.

Studies of the Sun's radio emissions began soon after British astronomer J. S. Hey discovered solar radio emission in 1942. I began my Radio JOVE solar observations nearly fifty years later, on 5 October 2000, and observed almost continuously for one year. Local power-line interference prevented me from observing for a few months in early 2000. Radio JOVE participants will soon learn, however, that, if power-line noise is a problem, the Project equipment is very portable and that you can work with your local power company to locate and correct the problems causing the interference.

I started my solar observing runs each morning near sunrise and ended them each evening near sunset. Once started, the Radio JOVE equipment ran unattended. Such a routine can be an advantage for a teacher with a busy class schedule: because the computer records all the data, it is quite easy to review them at your leisure. To verify my observations, each evening I would go to the NOAA Solar Indices gopher website (*gopher://solar.sec.noaa.gov:70/11/indices/events*) and compare its list of solar events during the day to those in my day's data run. In the course of the year, I recorded ninety solar radio events. A complete listing of my data is available on my website at *www.draco.scsu.edu/radioastro.html.*

All of my observations were made from the same location and with the standard Radio JOVE antenna setup and alignment. While the JOVE receiver was used for the vast majority of observations, I also experimented with several other receivers for comparison. In addition, I started with the Windows-based JOVE chart software, which is included with the Radio JOVE Kit, but I later switched to SkyPipe, which you can find at *www.radiosky.com/skypipeishere.html.* SkyPipe is the software now recommended by the JOVE program.

Radio Astronomy for the Masses

Radio JOVE is a superb way to open up another area of astronomy to students, amateus astronomers, and anyone interested in an inexpensive electronics and data-collection project. While at times frustrating, I found the entire process, from conception to final data manipulation a very rewarding experience. It made me feel a little like Grote Reber who built the first working radio telescope dish and who began the real science of radio astronomy.

The most difficult part of the observations for me was getting clear reception. Through persistence, I was finally able to get the local power company to eliminate the interference problems. Another source of unwanted noise is thunderstorms. A lightning discharge will produce radio noise to which the Radio JOVE receiver is very sensitive. The strength of the noise produced is proportional to the distance to the lightning discharge, but even a distant thunderstorm can produce enough noise on your receiver to obscure even strong solar radio bursts. To protect your equipment, the best practice is to disconnect your antenna from the receiver when it is not in use.

Once you have conquered the interference problems, the real joy begins as you plan your program of Sun and/or Jupiter observations. During solar maximum, Radio JOVE provides nearly constant gratification because you are likely to observe a solar radio burst or multiple bursts on any given day. Even though we are currently on the downward slope of the current solar cycle (see "There Goes the Sun," p. 9), there are still several years of good observations ahead.

And do not forget mighty Jupiter, shining right now among the stars of Leo. Either Jupiter or the Sun make fitting objects for your first forays into the science of radio astronomy as participants in Project Radio JOVE. **m**

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The Solar Radio Program

The Space Environment Center (SEC), headquartered in Boulder, Colorado, is one of the eleven Environmental Research Laboratories of the National Oceanic and Atmospheric Administration (NOAA). SEC conducts research in solar-terrestrial physics, develops techniques for forecasting solar and geophysical disturbances, and provides real-time monitoring and forecasting of solar and geophysical events. SEC's research scientists, working toward a better understanding of the Sun-Earth connection, study the Sun's electromagnetic, particle, and magnetic-field emissions and the processes by which they affect Earth's space environment.

For those interested in projects utilizing their Radio JOVE equipment for solar observations or monitoring, the SEC website, located at *www.sec.noaa.gov*, is an excellent source of information on the local, interplanetary environment. — *J. B.*