

National Astronomy and Ionosphere Center
Arecibo Observatory
Arecibo, Puerto Rico 00612
Cornell University, Ithaca, New York 14853

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The following report covers the period July 1997 through June 1998.

1. FACILITIES

The Arecibo Observatory is the primary research facility of the National Astronomy and Ionosphere Center (NAIC). The NAIC is operated as a visitor-oriented national research center by Cornell University under a cooperative agreement with the National Science Foundation (NSF). Partial support for the planetary radar program is provided by the National Aeronautics and Space Administration (NASA). Typically about 80% of the available observing time has gone to astronomical research programs, the remaining 20% going to research programs in atmospheric sciences (aeronomy).

The Arecibo Observatory is located about 12 km south of Arecibo, a city on the north coast of Puerto Rico about 80 km west of San Juan. The principle instrument of the observatory is a 305-m-diameter spherical radio reflector antenna. Radio sources can be tracked within 20 degrees of the zenith using moveable feeds suspended above the stationary reflector. The observatory latitude of 18°21'N gives a declination coverage of about $-1^{\circ}39'$ to $+38^{\circ}21'$. Depending upon their declinations, celestial objects may be within view at Arecibo for up to 2h40m each day.

Other facilities operated by the observatory include an optical facility and a high-power HF transmitting array. The optical and HF facilities are normally used for airglow observations and ionospheric heating experiments, respectively.

Operational support at Arecibo includes a scientific staff, an electronic maintenance and development shop, mechanical engineering and maintenance services, a computing center, technical library, drafting services, living accommodations for visiting scientists, and a cafeteria. Additional support is provided by the NAIC staff at Cornell University in Ithaca, New York, where a small electronics development group, some business functions, and a small scientific group are located.

2. TELESCOPE UPGRADE AND RECOMMISSIONING

The Observatory recently completed a major upgrade to the telescope, funded jointly by the NSF and NASA. The main component of the upgrade was the installation of a Gregorian subreflector feed system to replace most of the line feeds. Other parts of the upgrade included installation of a new, more powerful S-band transmitter and construction of a ground screen to eliminate spillover noise. Installation of the S-band transmitter in the Gregorian dome was completed in early summer of 1997 and the new radar tested out successfully. The new antenna drive systems were commissioned in September 1997 and full telescope tracking capability with both the Gregorian and 430 MHz (carriage house)

feeds was achieved the following month. The first test observations ("first light") with the completed Gregorian system were made in the third week of October, 1997. At that time the telescope commissioning phase began, which included pointing and calibration tests for use in making final adjustments to the optical focus and alignment. The remainder of 1997 was devoted to these commissioning tests, a limited schedule of normal (tracking-mode) pulsar observations with the 430-MHz carriage-house feed, some pulsar search observations, atmospheric science observations with the 430 MHz radar, and additional upgrade-related work. A major component of the upgrade work was the readjustment of the azimuth track alignment, which went into the spring of 1998 and enforced strong limitations on azimuth motion in the meantime. Fortunately, most of this period had already been scheduled for atmospheric science work (including major heating and rocket campaigns), most of which did not require telescope motion. After these campaigns and the completion of the azimuth track work, a final series of pointing tests was made and the first Gregorian observing proposals were scheduled in May and June of 1998.

The commissioning tests showed the Gregorian performance to be close to expectations at L-band, but antenna gain was about 1.5 dB too low at S-band. Antenna pointing proved to be very accurate and repeatable, but was complicated by a pitch-and-roll problem related to details of the attachment and alignment of the Gregorian on the azimuth arm. It is suspected that the performance shortfall at S-band and higher frequencies is an optical alignment problem that can be dealt with once the Gregorian dome attachment is realigned to correct for pitch and roll. This dome realignment work was scheduled for early December of 1998 and Gregorian observing was scheduled to resume in the second week of January, 1999.

3. INSTRUMENTATION

In the past, most observations with the Arecibo telescope used spherical aberration correcting line feeds mounted on one of two "carriage houses" on the azimuth arm. The telescope upgrade has replaced most of the line feeds with a single Gregorian subreflector system. Multiple feed horns at the Gregorian focus will eventually provide continuous frequency coverage between 300 MHz and 10 GHz. Receiving systems currently available on the Gregorian include 430 MHz, 600-700 MHz, L-band (1.1-1.7 GHz), S-band (2.38 GHz), C-band (3.95-5.85 GHz) and X-band (8.0-10.0 GHz). Replacing the 40-ft line feeds increases the maximum sensitivity at 1415 and 1665 MHz from 8 K/Jy to 12 K/Jy and lowers the minimum system temperature to 20 K. A new 1-MW S-band radar system has also been installed on the Gregorian. Once final refinements are made to the optical alignment, the new radar is expected to be more sensitive than the old S-band system by a zenith angle dependent fac-

tor of between 10 and 40. Carriage House #1 and its associated systems (including the 430 MHz feed and the 430 MHz radar) have been retained, and a 430 MHz transmitting capability is planned for the Gregorian. The 430 MHz line feed has a sensitivity of 18 K/Jy and a beamwidth of 10 arcmin. This feed can be connected to a 2.5 MW peak-power (150 kW average power) radar transmitter; this 430 MHz radar is normally used for incoherent backscatter observations of the ionosphere. Radar observations of planets and other deep-space objects are normally made with the S-band (2380 MHz) radar, although the 430 MHz radar can also be used in cases where a lower radar frequency is desired.

Telescope pointing and realtime data acquisition are controlled using a network of VMEbus single-board computers running the VxWorks operating system kernel. Custom-built data acquisition devices ("backends") include (1) a general-purpose A/D system capable of sampling four analog channels at up to 10-MHz rates with programmable resolutions of 1 to 12 bits per sample per channel, (2) an (interim) 50-MHz, 4096-lag Spectral Line Correlator with programmable bandwidth from 195 kHz to 50 MHz, (3) a 50-MHz Radar Decoder, (4) a 100-MHz Spectral Line Correlator being developed, (5) a 10-MHz bandwidth Pulsar Search/Timing Machine with up to 256 channels, and (6) a wideband continuum/polarimetry instrument being developed. An S2 VLBI system is also available. Additional realtime signal processing capability is provided by four Skybolt i860-based VMEbus single-board computers with 240 MFLOPS peak combined capacity.

Data are recorded on 8mm tape using helical scan (Exabyte) recorders; short runs may be recorded on disk and accessed over the local area network. The analysis network consists of about forty Sun Microsystems workstations, about 70 GBytes of disk, and several 8mm (one 4mm) helical scan tape drives. Software available includes several interactive data reduction and display packages like ANALYZ, AIPS, IRAF, CLASS, IDL and MATLAB, the IMSL and PORTLIB mathematical subroutine libraries, specialized libraries for ephemeris calculation and data format conversions, and the FrameMaker desktop publishing system. Hard-copy devices include three black-and-white laser printers (two 1200dpi and one 600dpi) and one 300dpi dye-sublimation color printer. The Observatory network also includes about fifty IBM-AT compatibles and two Apple Macintosh computers with associated peripherals, and is connected to the Internet via a dedicated 56Kbps link.

4. OBSERVING PROPOSALS

The Arecibo Observatory welcomes and encourages research projects by qualified scientists from other institutions. A complete explanation of proposal submission and evaluation procedures can be found on the observatory's Web site (<http://www.naic.edu>). Proposals are evaluated on a trimester basis, with submission deadlines of February 1, June 1, and October 1 of any given year. The normal scheduling window for a proposal begins four months after the corresponding deadline. All proposals are evaluated by anonymous referees outside of NAIC. Electronic proposal submission is preferred. This involves e-mailing the standard

observatory Cover Sheet along with an attached Postscript file containing the body of the proposal. The Cover Sheet can be obtained by sending an empty e-mail to cover@naic.edu. Those proposers who cannot submit electronically, or who cannot provide a Postscript version of the body, may send their proposals to: **Director, Arecibo Observatory, HC3 Box 53995, Arecibo, PR 00612.**

5. STAFF

The NAIC scientific staff is located in both Arecibo, Puerto Rico and on the Cornell campus in Ithaca, New York. Dr. Paul F. Goldsmith, Director of NAIC, is based in Ithaca.

The observatory's Director of Operations, Dr. Daniel R. Altschuler, is based in Arecibo. NAIC-affiliated scientists and their areas of specialization are listed below.

5.1 Arecibo Staff

D. R. Altschuler - *Active Radio Sources*

M. M. Davis - *Pulsars, Extragalactic Line and Continuum*

Jo Ann Eder - *Extragalactic Astronomy, 21-cm Spectral Line Observations*

J. Friedman - *Optical Observations of Ionosphere*

T. Ghosh - *Low Frequency Variability, Active Galactic Nuclei, Interstellar Scintillation, VLBI*

S. A. Gonzalez - *Ionospheric Observations*

J. K. Harmon - *Planetary Radar, Solar Wind*

B. M. Lewis - *Normal Galaxies, Interstellar Medium, OH/IR Stars, Circumstellar Shells*

D. R. Lorimer - *Pulsars*

B. MacPherson -

Ionospheric Modeling

M. C. Nolan - *Planetary Radar, Asteroid Science*

K. L. O'Neil - *Extragalactic Astronomy*

C. J. Salter - *Galactic Continuum, AGN's, HI Absorption in Pulsars*

M. P. Sulzer - *Atmospheric Physics, Ionospheric Modification*

C. A. Tepley - *Airglow, Ionospheric Radar, Lidar Studies*

K. M. Xilouris - *Pulsars*

Q. Zhou - *Ionospheric Observations*

5.2 Cornell Staff

D. B. Campbell - *Planetary Radar*

J. M. Cordes - *pulsars, Interstellar Medium*

R. Giovanelli - *Extragalactic and Galactic Lines*

P. F. Goldsmith - *Molecular Clouds and Star Formation*

M. P. Haynes - *Extragalactic and Galactic Lines, Galaxies and Clusters*

M. C. Kelley - *Ionospheric Electrodynamics, Atmospheric Science*

Y. Terzian - *Planetary Nebulae, Interstellar Medium*

5.3 Summer Student Program

The Observatory conducts a Summer Student Program in astronomy and atmospheric sciences. For this program a small number of undergraduate and graduate students are chosen to spend the summer at Arecibo engaged in research

programs under the supervision of staff scientists. Applications for the Summer Student Program should be submitted to NAIC by early February.

The NAIC summer students for the summer of 1998 were:

Angel Alejandro, *Univ. of Puerto Rico*
 Monique Aller, *Wellesley Coll.*
 Yira Cordero, *Univ. of Puerto Rico*
 Ingrid Daubar, *Cornell Univ.*
 Simon DeDeo, *Harvard Univ.*
 David Kaplan, *Cornell Univ.*
 Dale Kocevski, *Univ. of Michigan*
 Felix Mercado, *Univ. Metropolitana*
 Ben Oppenheimer, *Harvard Univ.*
 Celia Salmeron, *Univ. of Houston*

6. COMMITTEES

6.1 AU&SAC Committee

The Arecibo Users and Scientific Advisory Committee (AU&SAC) meets annually in Puerto Rico to advise the NAIC on the future needs for instrumentation and facilities. The current committee members are:

T. M. Bania, *Boston Univ.*
 J. M. Dickey, *Univ. of Minnesota*
 D. Emerson, *NRAO*
 R. Foster, *Naval Res. Lab.*
 T. Kane, *Penn. State Univ.*
 M. F. Larsen, *Clemson Univ.*
 F. J. Lockman, *NRAO*
 D. D. Meisel, *SUNY*
 P. C. Myers, *Harvard-Smithsonian CFA*
 R. D. Norrod, *NRAO*
 J. P. Sheerin, *Eastern Michigan Univ.*
 S. E. Thorsett, *Princeton Univ.*

6.2 NAIC-VC Committee

The National Astronomy and Ionosphere Center Visiting Committee (NAIC-VC), appointed by Cornell to review the management and research programs of the Observatory, normally meets once a year. The current members are:

H. C. Carlson, *Phillips Lab.*
 J. N. Hewitt, *MIT*
 T. L. Killeen, *Univ. of Michigan*
 S. Kulkarni, *Cal. Inst. of Tech.*
 K. M. Menten, *Max-Planck-Inst.*
 P. Palmer, *Univ. of Chicago*
 R. G. Roble, *NCAR*
 J. E. Salah, *Haystack Obs.*
 P. R. Schwartz, *Naval Res. Lab.*
 J. van Gorkom, *Columbia Univ.*

7. PROGRAM HIGHLIGHTS

This period saw the winding down of the telescope upgrade project and the resumption of tracking-mode observations. This allowed for an expansion in the number and variety of observing programs that could be scheduled, including pulsar confirmation and timing, spectral line (HI)

observations, S-band radar observations, and space-VLBI observations. However, the telescope had still not returned to completely normal operation at the time this report was written, and a substantial fraction of the telescope time during the report period (July 1997 to June 1998) was devoted to Upgrade-related activities, including telescope testing, adjustment, and recommissioning. In this section we summarize some of the highlights of the science done in the past year by visiting scientists and observatory staff as part of formal, refereed observing proposals to NAIC. Here, as in previous years, we do not cover atmospheric science programs, which are outside the purview of this report.

7.1 Pulsars

Drift-scan pulsar search observations continued to be scheduled during times when remaining upgrade work restricted or prevented telescope motion. The observations were made by five different groups and used the Penn State Pulsar Machine (PSPM) as a backend. The PSPM has been made available to general users by its developer, A. Wolszczan (Penn St.). The upgrade searches have covered 70% of the sky visible from Arecibo. More than 100 pulsars have been discovered in Arecibo drift-scan searches since 1990, with most of these from Upgrade-era searches since 1994.

A number of groups attempted confirmation of candidates from their respective upgrade drift-scan pulsar searches. A. Wolszczan (Penn State) succeeded in confirming 5 new pulsars from the PSU/NRL search. Likewise, A. Somer and D. Backer (UC Berkeley) confirmed an additional 3 objects (PSRs J0030+0454, J0711+0933, and J1312+0932) from the candidate list assembled by A. Zepka (Hitachi) from an analysis of the data from the Berkeley/Cornell search. Of these objects, J0030+0454 has a 4.8-millisecond rotation period. A further 21 candidates were also observed by these same observers, and analysis is proceeding for these. S. Anderson and F. Jenet (Caltech) confirmed a bright new 65-msec pulsar, PSR J2017+1948, from the Caltech drift scan search, and also confirmed five additional slower pulsars from the pre-upgrade Caltech intermediate-latitude survey. In addition, J. Cordes (Cornell) acquired data on 12 candidates from the pre-Upgrade piggy-back pulsar search, while K. Xilouris (NAIC) took data on 10 candidates from the STScI/NAIC drift-scan search.

Post-Upgrade pulsar timing has been initiated by several teams. These observations were undertaken both from the Carriage House at 430 MHz, and from the Gregorian Dome at L-band. A. Wolszczan (Penn St.) timed three pulsars which had been regular timing targets before the Upgrade, finding excellent agreement between the measured pulse arrival times and the values extrapolated from pre-Upgrade ephemerides. Included among these was PSR B1257+12, the pulsar with its own planetary system. A. Wolszczan and S. Anderson (Penn St.) found similar good agreement with the existing ephemeris for the 4.6-msec pulsar, PSR J1709+23, discovered in the early days of the PSU/NRL drift-scan search. They also confirmed the 23-day binary-orbit model derived previously for this object.

A. Somer and D. Backer (Berkeley) used the Arecibo-Berkeley Pulsar Processor (ABPP) to further refine period

parameters and determine accurate dispersion measures for newly discovered pulsars from the Berkeley/Cornell upgrade drift-scan search. The new millisecond pulsar, J0030+0454, was found to have a period derivative that was negative at one epoch but positive at a later one; further measurements will determine the parameters of this long-period binary system. Observations of PSR J0631+1036 indicated that the pre-Upgrade timing model is still accurate. Their observations used a combination of the 430-MHz Carriage House receiver and 1400- and 1660-MHz tunings of the L-band receiver in the Gregorian dome.

D. Backer (Berkeley) and collaborators observed the strong millisecond pulsars, J1713+0747 and B1937+21, simultaneously at Arecibo and Effelsberg. The coordinated L-band observations were made through identical backends, and will be used to constrain the timing uncertainties due to propagation through the interstellar medium. The 1.4-GHz timing residuals for B1937+21 were excellent.

I. Stairs (Princeton) and colleagues commenced preliminary pulsar timing observations using the Princeton Mk-IV machine. This included L-band observations of the fastest millisecond pulsar, PSR B1937+21, yielding timing uncertainties of less than one-fifth of a microsecond, and observations of PSR J0621+1002, a neutron star-white dwarf binary pulsar discovered by the Princeton group during their Upgrade survey.

A consortium of observers from UC Berkeley, Caltech, Jodrell Bank, MIT, NRL, Penn State, and Princeton began regular timing observation of standard millisecond pulsars. The principal investigators for this collaborative venture are D. Backer (UC Berkeley), I. Stairs (Princeton) and S. Anderson (Caltech). The measurements have involved some half dozen targets, using 4 or 5 separate pulsar backends (provided by different groups) observing simultaneously by tapping off the same IF signal. The initial results indicate that the timing residuals achieved at L-band by the various backends are unprecedentedly small, the many innovations in data-taking hardware providing significant improvements over the system available pre-Upgrade. This, plus the excellent signal-to-noise ratios already achieved at L-band, allows timing residuals below 100 nanoseconds, an accuracy that opens new scientific horizons to pulsar timing. Such timing observations provide an extremely powerful tool when searching for pulsar companions with masses as low as asteroids, can probe the differential acceleration caused by the Galactic disk, yield sensitive measures of the structure of the interstellar gas, and approach the precision needed to study long-period gravitational waves. In addition, coordinated timing measurements using the different pulsar backends sharing the same IF signal help determine the role that instrumentation plays in delimiting the timing precision at the sub-microsecond level. Further, it is now possible to switch between 430 and 1420 MHz in about 30 seconds, which can be used to yield sensitive measures of the structure of the interstellar gas, and also permit the removal of interstellar effects from timing.

D. Lorimer (MPIfR, Bonn) and K. Xilouris (NAIC) began a deep pulsar search in supernova remnants (SNRs). They acquired data at many positions, with an average integration

time of 23 min on each. While most observations were made at 430 MHz using the Carriage House, the L-band receiver in the Gregorian dome was employed for two of the SNRs. Data reduction is presently underway at the Cornell Theory Center. Pulsars associated with SNRs are of great interest, and these observers are attempting to constrain the birth properties of neutron stars. In addition, they expect to address the question of what fraction of supernovae produce neutron stars.

K. Xilouris (NAIC) made observations that placed stringent upper limits on the flux density of the Geminga X-ray pulsar at 47 and 430 MHz. These limits are of special importance in view of recent claims of a detection of the object near 100 MHz by Russian astronomers.

S. Anderson and F. Jenet (Caltech) installed and brought on line the Caltech CBR (Caltech Broadband Recorder) machine. First observations with this instrument included single-pulse measurements of a number of pulsars.

Weisberg (Carleton), K. Xilouris (NAIC) and collaborators initiated L-band measurements of the HI absorption spectra of distant pulsars. To make these observations they used the new Caltech CBR backend. They will use their spectra together with a galactic rotation model to kinematically determine the pulsar distances. These will then be combined with the dispersion measures of the targets to derive the mean electron densities along the lines of sight. The latter values will be used to calibrate models of the galactic electron-density distribution.

7.2 Spectral Line

R. Giovanelli and M. Haynes (Cornell) observed nearby inclined spiral galaxies for which I-band images already exist. The measured HI velocities are being used via the Tully-Fisher technique to estimate secondary distances, the local density field being reconstructed from the resultant peculiar velocities. These were the first commissioning-phase observations to use the new Gregorian system and were intended primarily to test the system performance for L-band science. The conclusion from these initial observations was that the L-band performance of the new system was a significant improvement over the old system, due not only to the better sensitivity and pointing afforded by the Upgrade, but also to the enhanced capabilities of the new correlation spectrometer.

K. O'Neil, G. Bothun, and J. Schombert (U. Oregon) made HI observations to determine the gas content and redshift of a sample of low surface brightness (LSB) galaxies. The galaxy sample was derived from their own CCD survey of LSB galaxies lying primarily in the direction of the Pegasus and Cancer galaxy clusters. LSB galaxies are a significant contributor to the total galaxy mass and critical to understanding the distribution and formation of galaxy types. The CCD survey found over 120 previously undetected LSB galaxies with colors ranging from very blue to very red. In 58.5 hr of observing, 27 galaxies were detected using 5-min ON/OFF pairs. The detected galaxies have sizes in the range $10 < r_{27} < 47$ arcsec (or scale lengths between 3 and 20 arcsec), inclinations from 20 through 85 deg (determined photometrically), and central surface brightnesses in the

range $22.0 < \mu_{B(0)} < 24.8$ mag/arcsec². The individual galaxies were detected between 1372 and 1420 MHz, showing the identified objects to range from nearby dwarf galaxies to large, intrinsically fairly luminous galaxies. Additionally, the colors of the detected galaxies lie within $-0.9 < U - B < 1.0$ mag, $0.2 < B - V < 1.7$ mag, showing successful detections for galaxies covering the evolutionary LSB galaxy spectrum, and representing the first-ever radio detection of a red LSB galaxy. While most LSB galaxies are extremely blue and HI-rich, the class of red LSB galaxies might be the descendants of faded starburst systems which have exhausted their HI several Gyr ago. The HI mass of these systems will be critical in resolving their star formation histories. These observers also detected several new dwarf galaxies in the 6,000–10,000 km/sec range, important to large scale structure mapping, as well as detecting a couple of low-redshift Malin objects.

J. Schombert (U. Oregon), J. Eder (NAIC), S. Djorgovski (Caltech) and S. Odewahn (U. Minnesota) began a series of observations to determine the redshift and HI content of a test sample of new LSB galaxies identified from fields of the Caltech Digitized Second Palomar Sky Survey (DPOSS). During the few hours of observing assigned to date, 8 candidates were detected. These detections of extremely small ($d \sim 15$ arcsec), faint, gas-rich galaxies demonstrates that Arecibo observations will be critical for applying the anticipated large DPOSS LSB catalogs to tests of biased galaxy formation, LSB galaxy evolution and dwarf galaxy formation. The newly discovered objects would be too faint for efficient optical redshift measurement.

7.3 VLBI

Arecibo's drive to become a full participant in global Very Long Baseline Interferometry (VLBI) took some major steps this year. In particular, the Observatory entered the field of Space VLBI. In July of 1997, Arecibo made its first 18-cm wavelength observation in support of the recently launched 8-m orbiting antenna, HALCA, of the Japanese VSOP (VLBI Space Observatory Programme) Project. The observations were successful, with fringes being obtained from the Arecibo-spacecraft baseline on radio source J1527+312. A second Arecibo/HALCA observation in December on the compact extragalactic sources J1125+265 and J1159+292 failed due to problems at the Madrid tracking station. An L-band run on the quasar J1602+334 took place in June of 1998, and fringes were detected over the entire tracking pass to Arecibo. The first Arecibo C-band observations with HALCA were made on the quasars J2212+239 and J2139+143 in May of 1998, and strong fringes were found for all baselines (which included the NRAO 140-ft). Although Arecibo C-band sensitivity is presently somewhat below its design target, the signal-to-noise ratios obtained were 1000:1 between Arecibo and the 140-ft, 100:1 between Arecibo and HALCA, and 20:1 between HALCA and the 140-ft. Correlation for J2139+143 is awaited. These C-band targets form part of the VSOP Survey of the 5-GHz continuum emission from all flat-spectrum sources at $b > 10$ deg with 5-GHz flux densities greater than 1 Jy.

Early in 1997, NAIC submitted a consortium proposal (with NRAO as consortium partner) to the NSF Major Research Instrumentation (MRI) Program for the purchase of a VLBA-compatible system for Arecibo. This proposal was recently approved, with the cost to be shared between Cornell University and the MRI Program. When this equipment is purchased and in place, the Arecibo telescope will be capable of joining in a wide range of VLBI observations in conjunction with the VLBA, the global VLBI network, and future space VLBI, as well as ad-hoc arrays of the world's largest frequency-agile telescopes. In another development, A. Rogers (Haystack Observatory) kindly supplied Arecibo with a phase calibration unit which will be used in all future VLBI runs.

7.4 Radar Astronomy

S. Ostro (JPL) and colleagues made radar observations of the small near-Earth asteroids 4183 Cuno and 1994 AH2 in May-June of 1998. Both objects were detected, making these the first asteroid detections and the first real science with the upgraded S-band radar. (The first echoes of any kind using the new radar were obtained from Mercury on May 9, but these observations were intended only to test and calibrate the radar system on an easy target). Both asteroids were detected in the CW mode, which yields Doppler spectra but no range discrimination. The spectrum of 1994 AH2 was relatively narrow, suggesting that this object is smaller and more reflective than expected or that its pole was nearly pointed toward the Earth.

D. Campbell (Cornell) and colleagues made a successful radar detection of the newly discovered comet LINEAR (C/1998 K5) in June of 1998. The detection was weak, which was not surprising given how insignificant this object appeared in optical observations. A very low radar cross section of 0.03 km² was measured for this object, placing it in the same class as another very small (1-km-size) comet, Sugano-Saigusa-Fujikawa, detected at Arecibo in 1983. Although the radar detection was hardly spectacular, this was a nice early example of a target that was only detectable because of the improved sensitivity afforded by the Upgrade.

8. OBSERVING PROGRAMS

8.1 Pulsars

Timing Observations of Three Recently Discovered Millisecond Pulsars - Anderson, S.B. (Caltech), Foster, R.S. (NRL), Wolszczan, A. (Penn St.)

Confirmation of Intermediate Latitude Pulsar Survey Candidates - Anderson, S.B. (Caltech), Kulkarni, S.R. (Caltech), Navarro, J. (Norway)

A High Time Resolution Study of Pulsar Emission - Jenet, F.A. (Caltech), Anderson, S.B. (Caltech), Prince, T.A. (Caltech), Kaspi, V.M. (MIT)

Observations of Pulsar Candidates from AO Declination Drift Searches - Zepka, A. (Hitachi), Backer, D. (Berkeley), Cordes, J. (Cornell), McLaughlin, M. (Cornell), Arzoumanian, Z. (Cornell), Somers, A. (Berkeley)

Timing Observations of 8 Pulsars from Recent AO Searches - Zepka, A. (Hitachi), Backer, D. (Berkeley), Cordes, J. (Cornell), McLaughlin, M. (Cornell), Arzoumanian, Z. (Cornell), Somer, A. (Berkeley)

An Ultra Fast Sampled, All Sky Search for Millisecond and Sub-millisecond Pulsars (Candidate Confirmation) - Wolszczan, A. (Penn St.), Anderson, S.B. (Penn St.), Foster, R. (NRL) *An Opportunistic Search for Millisecond Pulsars (Candidate Confirmation)* - Fruchter, A. (STScI), Eder, J. (NAIC), Vazquez, A. (NAIC)

Precision Pulsar Metrology - Backer, D.C. (Berkeley), Somer, A. (Berkeley), Foster, R.S. (NRL), Cadwell, B. (NRL), Wolszczan, A. (Penn St.)

Biweekly Timing Observations of Millisecond Pulsars - Stairs, I.H. (Princeton), Nice, D.S. (Princeton), Taylor, J.H. (Princeton), Thorsett, S.E. (Princeton), Camilo, F. (Manchester)

High Precision Timing of Millisecond Pulsars - Anderson, S.A. (Caltech), Jenet, F.A. (Caltech), Kaspi, V.M. (MIT), Kulkarni, S. (Caltech), Prince, T.A. (Caltech), Wolszczan, A. (Penn St.)

Coherent timing Observations of PSRs B1534+12 and B1855+09 - Stairs, I.H. (Princeton), Taylor, J.H. (Princeton), Thorsett, S.E. (Princeton), Xilouris, K.M. (NAIC)

Time Transfer with Millisecond Pulsars - Backer, D.C. (Berkeley), Somer, A. (Berkeley), Xilouris, K. (NAIC), Kramer, M. (Max Planck), Lange, C. (Max Planck), Lestrade, J.F. (Paris), Cognard, I. (Paris)

Pulsar Distance and Galactic Electron Density Determinations via 21 cm Absorption Measurements - Weisberg, J. (Carleton), Xilouris, K. (NAIC), Salter, C.J. (NAIC), Johnston, S. (RcfTA), Koribalski, B. (ATNF)

A Dual-frequency Search for Pulsars in Supernova Remnants - Lorimer, D.R. (MaxPlanck), Xilouris, K. (NAIC), Kramer, M. (Max Planck)

Gamma-Ray Source SGR 1900+14 - Xilouris, K. (NAIC), Kouveliston, C. (USRA)

8.2 Spectral Line

The Density Field in the Local Universe - Giovanelli, R. (Cornell), Haynes, M. (Cornell)

Redshifts for Faint Galaxies at Low Galactic Latitudes - Pantoja, C.A. (UPR), Altschuler, D. (NAIC), Giovanardi, C. (Arecric), Giovanelli, R. (Cornell), Huchra, J.P. (Harvard)

A 21-cm study of 127 Newly Discovered Nearby LSB Galaxies - O'Neil, K.L. (Oregon), Bothun, G.D. (Oregon), Schombert, J.M. (Oregon)

New Low Surface Brightness Galaxies from the Caltech Digital POSS - Eder, J. (NAIC), Schombert, J. (Oregon), Djorgovski, S.G. (Caltech), Odewahn, S.C. (Minnesota)

8.3 VLBI

Support of Space VLBI - Salter, C.J. (NAIC)

8.4 Radar Astronomy

Radar Observations of Asteroids 6037 (1988EG) and 4183 Cuno - Ostro, S.J. (JPL), Benner, L.A.M. (JPL), Camp-

bell, D.B. (NAIC), Giorgini, J.D. (JPL), Hudson, R.S. (Wash. St.), Nolan, M.C. (NAIC), Rosema, K.D. (JPL), Yeomans, D.K. (JPL)

Radar Observations of Asteroids 8201 (1994AH2) and 1987OA - Ostro, S. (JPL), Benner, L.A.M. (JPL), Campbell, D.B. (Cornell), Giorgini, J.D. (JPL)

Observations of Comet C/1998 K5 - Campbell, D.B. (Cornell), Harmon, J. (NAIC), Nolan, M. (NAIC), Perillat, P. (NAIC), Black, G. (Cornell), Ostro, S. (JPL)

PUBLICATIONS

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