

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

The following report covers the period July, 2001 through June, 2002.

## 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 85% of the available observing time has gone to astronomical research programs, the remaining 15% 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.

Besides the main antenna, the observatory maintains an optical facility for passive airglow and lidar observations. This facility can be used independently or in conjunction with ionospheric radar experiments using the main antenna.

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

## 2. INSTRUMENTATION

Most of the telescope's receivers are mounted on a Gregorian subreflector system. Receiving systems currently available on the Gregorian include 327-MHz, 430-MHz, 610-MHz, L-band (consisting of two separate systems: an "L-narrow" receiver for 1.37–1.45 GHz and an "L-wide" receiver for 1.15–1.73 GHz), S-band (consisting of three separate systems: an "S-low" receiver for 1.8–3.1 GHz, an "S-radar" receiver for 2.33–2.43 GHz, and an "S-high" receiver for 3–4 GHz), C-band (3.95–5.85 GHz), and X-band (8.0–10.0 GHz). The current sensitivities for these Gregorian systems are 11 K/Jy (327 MHz), 12 K/Jy (430 MHz), 8 K/Jy (610 MHz), 8–11 K/Jy (L-band), 7–10 K/Jy (S-band), 5–8 K/Jy (C-band), and 1.5–5 K/Jy (X-band). In addition to the Gregorian systems, there is the original 430-MHz "Carriage House" line feed (18 K/Jy), which is used both for passive

radio astronomy and as the feed for a 430-MHz pulsed radar system (150 kW average power). This radar is the prime instrument for ionospheric incoherent scatter experiments, but can also be used for planetary radar observations. A 430-MHz transmitting capability is also available on the Gregorian for use in dual-beam ionospheric radar observations. The prime instrument for planetary radar observations is the S-band (2380 MHz) radar installed on the Gregorian. This radar is a CW (non-pulsed) system with 1 MW transmitted power and a phase-coding capability for delay-Doppler observations. A third (47 MHz) radar system is also available on the Carriage House. More details and updates on system specifications and availability can be accessed on the observatory Web site ([www.naic.edu](http://www.naic.edu)).

Computer control of telescope pointing and data acquisition is effected using a network consisting of VMEbus single-board computers running the VxWorks kernel as well as PCs running the open-source Linux OS. A remote observing capability is available for projects using standard instrument modes supported by the user interface (AOCONTROL). Data acquisition backends include (1) a general-purpose A/D system capable of sampling four analog channels at up to 10-MHz rates with resolutions of 1 to 12 bits per sample per channel, (2) a 16384-channel Spectral Line Correlator with four RF sub-bands independently bandwidth-adjustable from 195-kHz to 50-MHz, (3) a 50-MHz Radar Decoder, (4) a 100-MHz Pulsar Spectrometer with on-line pulse folding capability, and (5) a 20-MHz 8-bit portable fast sampler with an integrated high-speed data recorder. An S2 VLBI recorder and a Mark 4/VLBA system are also available.

Data can be recorded, depending on application requirements, on (1) 8mm tape using helical scan (Exabyte) drives, (2) 1/2-inch Digital Linear Tape, or (3) disk for access over the local area network.

The data reduction network consists of: over fifty CPUs, including SPARC-based workstations, Intel x86-based PCs, and servers; over 3 TBytes of disk; several 8mm and 4mm helical scan tape drives and DLT tape drives for data backup and archiving. An optical (Compact Disc) recording facility is also available. Data reduction software includes the commercial packages IDL from Research Systems and MATLAB from The Math Works, as well as public-domain packages like ANALYZ, AIPS, IRAF, CLASS and AIPS++. The Observatory is connected to the Internet via a 155-Mbps link shared with the University of Puerto Rico.

## 3. OBSERVING PROPOSALS

The Arecibo Observatory welcomes and encourages research projects by qualified scientists from other institutions. 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. A complete explanation of proposal submission and evaluation procedures can be found on the observatory Web site ([www.naic.edu](http://www.naic.edu)). Electronic proposal submission is preferred. The body of the proposal (a narrative giving the scientific and technical justification) should be e-mailed as a Postscript file to [proposal@naic.edu](mailto:proposal@naic.edu). The proposer must also submit a separate cover sheet, preferably using our Web-based form. 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.

Those wishing to include Arecibo in their VLBI observations should submit proposals directly to the VLBA, EVN, or Global networks as usual, rather than to Arecibo.

#### 4. STAFF

The NAIC scientific staff is located in both Arecibo, Puerto Rico and on the Cornell campus in Ithaca, New York. The 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.

##### 4.1 Arecibo Staff

D. R. Altschuler - *Active Radio Sources*  
 A. Deshpande - *Pulsars, Interstellar Medium*  
 P. Freire - *Pulsars*  
 J. Friedman - *Optical Obs. of Ionosphere*  
 T. Ghosh - *VLBI, AGNs, ISS*  
 S. A. Gonzalez - *Ionospheric Radar*  
 J. K. Harmon - *Planetary Radar, Solar Wind*  
 E. Howell - *Asteroid and Comet Studies*  
 D. Janches - *Ionosphere and Meteor Studies*  
 B. M. Lewis - *Normal Galaxies, OH/IR Stars*  
 M. C. Nolan - *Planetary Radar, Asteroids*  
 K. L. O'Neil - *Extragalactic Astronomy*  
 S. Raizada - *Atmospheric Sciences, Lidar*  
 C. J. Salter - *Gal. Continuum, AGNs, VLBI*  
 V. Slysh - *Extragalactic Astronomy, VLBI*  
 M. P. Sulzer - *Ionospheric Radar*  
 C. A. Tepley - *Airglow, Lidar, Ionosphere*  
 P. Hofner - *Molecular Lines*  
 C. Pantoja - *Extragalactic Astronomy*

##### 4.2 Cornell Staff

D. B. Campbell - *Planetary Radar*  
 J. M. Cordes - *Pulsars, Interstellar Medium*  
 D. T. Farley - *Ionospheric Studies*  
 R. Giovanelli - *Extragalactic and Galactic Lines*  
 P. F. Goldsmith - *Molecular Clouds, Star Form.*  
 M. P. Haynes - *Galaxies and Clusters*  
 D. Hysell - *Ionospheric Studies*  
 M. C. Kelley - *Ionospheric Studies*  
 Y. Terzian - *Planetary Nebulae, ISM*  
 L. Baker - *Res. Support Spec. (Technical)*  
 G. Cortes - *Sr. Res. Assoc. (Technical)*

#### 4.3 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 2001 were:

A. Helton, *U. Iowa*  
 C.-F. Kao, *Penn. St.*  
 D. Moser, *U. Illinois*  
 J. Deneva, *Vassar*  
 I. Rodriguez, *U. Puerto Rico*  
 L. Chomiuk, *Wesleyan*  
 M. Boyer, *U. Minnesota*  
 M. Rodgers, *U. Ohio*  
 R. Wilcox, *U. Washington*  
 S. Stevenson, *Wesleyan*  
 S. Morris, *U. Chicago*

#### 5. COMMITTEES

##### 5.1 AU&SAC Committee

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

G. D. Bothun, *U. Oregon*  
 J. R. Fisher, *NRAO-Greenbank*  
 R. Kerr, *Scientific Solutions, Inc.*  
 L. Magnani, *U. Georgia*  
 J.-L. Margot, *Caltech*  
 J. M. Mathews, *Penn. St.*  
 I. H. Stairs, *U. British Columbia*  
 D. R. Stinebring, *Oberlin College*  
 S. C. Unwin, *Jet Propulsion Lab.*  
 H. A. Wootten, *NRAO-Charlottesville*

##### 5.2 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:

M. F. A'Hearn, *U. Maryland*  
 S. K. Avery, *U. Colorado*  
 M. J. Reid, *Harvard-Smithsonian CFA*  
 H. A. Zebker, *Stanford*

#### 6. PROGRAM HIGHLIGHTS

*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.*

## 6.1 Spectral Line Radio Astronomy

Li and Goldsmith (Cornell) continued their studies of HI absorption in Galactic clouds. They have found a good correlation between narrow HI absorption and OH emission. A sample of 32 nearby dark clouds was surveyed and HI narrow-line absorption (HINLA) found in most of the clouds showing OH emission. The peak velocity and line width of HINLA and OH are similar. HINLA reveals a steady state population of HI inside molecular clouds maintained by cosmic ray dissociation of  $H_2$  (possibly in combination with other processes). The positive correlation between HINLA and molecular tracers make HINLA a very useful atomic tracer of molecular clouds. The narrowness and strength of HINLA make it an ideal Zeeman tracer. Compared to OH emission, the primary (if not the only) Zeeman tracer of dark clouds, HINLA is usually 10 times stronger. The promise of HINLA for measuring magnetic fields will be explored via Arecibo observations.

Koo (Seoul), Heiles (Berkeley), Stanimirovic (NAIC), and Troland (Kentucky) attempted to measure the magnetic field strength in two SNRs, IC443 and W51C, from HI Zeeman observations. Among SNRs with high-velocity shocked atomic gas, only these two have strong enough HI emission for a Zeeman observation. The observations have established realistic upper limits of  $B \sim 100 \mu\text{G}$  for the magnetic field in both SNRs. Koo *et al.* also mapped the distribution of shocked HI gas in IC443.

Stanimirovic (NAIC), Chomiuk (Wesleyan), Bhat (NAIC), Lorimer (Jodrell Bank), Salter (NAIC), and Urošević (Belgrade) looked for connections between SNR G42.8+0.6, SGR 1900+14, and PSR J1907+0918. The project spans a number of radio astronomical disciplines, including pulsar search and polarimetry, multi-frequency full-Stokes continuum mapping, and HI and OH spectral-line mapping. Several approaches to constraining the distances of PSR J1907+0918 and the SNR are being attempted, including deriving their rotation measures and searching for HI absorption by clouds situated in front of the SNR. Examining the HI distribution over the same velocity range as the OH absorption, a feature is seen that matches the structure of the SNR remarkably well and gives a distance of  $11 \pm 3$  kpc. If this were truly the distance to G42.8+0.6, it would lie far beyond SGR 1900+14 (distance  $\sim 5.7$  kpc from its X-ray spectrum), although it could be consistent with the distance of PSR J1907+0918, for which the distance estimate is 7.8 kpc.

Hoffman (Lafayette) and Salpeter (Cornell) have mapped HI in the fields of four low column density sources at velocities appropriate to high velocity clouds (HVCs) identified with the Green Bank 140-ft by Lockman *et al.* (LPMU). All were found to be quite clumpy on the scale of the Arecibo beam, much like the mini-HVCs found earlier by Hoffman and Salpeter superimposed on the outskirts of two HVCs. Each mini-HVC subtends 5-10 Arecibo beams and has peak column density  $N_{HI} < 2 \times 10^{19} \text{ cm}^{-2}$ . Thus far, this team has identified a total of 13 mini-HVCs. The implications of their low central column densities for ionization mechanisms (photo and collisional), for  $Ly\alpha$  and other absorption lines in

quasar and AGN spectra, and for the HVC distance controversy remain to be determined.

Balkowski, Cayatte, van Driel (Paris Observatory), Hernández, O’Neil (NAIC), Duc (CEA, France), Dickey (Minnesota), Iglesias-Páramo (Lab. d’Astrophys. de Marseille, France), Vílchez (IAA, Spain), and Thuan (Virginia) conducted an HI line search in a dozen HI clouds in the Hercules Cluster without optical counterparts on the Palomar Sky Survey. These clouds had been reported as tentative detections in the 1997 VLA HI survey of the cluster by Dickey. Subsequent CCD photometry by this team has shown faint optical counterparts for two of the reported clouds, whose VLA HI detections are now reconfirmed at Arecibo. Although the Arecibo sensitivity should have permitted the detection of the other tentatively reported HI clouds, none were reconfirmed, showing once again that intergalactic HI clouds without optical counterparts are very rare.

Bolatto, Simon, Robishaw (Berkeley), and Walter (Caltech) have completed a program to study HI in the Leo Triplet, one of the nearest strongly interacting groups of galaxies. The best pre-existing HI observations of this system were made in 1976-77 by Haynes *et al.* using Arecibo to observe the three main galaxies and the tidal tail to the east of NGC3628 on an irregular ( $\sim 5'$ ) grid following the emission. With the upgraded telescope, Bolatto *et al.* were able to map a much larger area, sampled on a regular  $1'$  grid, and with better sensitivity and velocity resolution. Cloud A is coincident in position and velocity with the galaxy pair UGC6387, probably a background source. The other new source (Cloud B) is at the systemic velocity of the Triplet, implying an HI mass  $\sim 10^7 M_\odot$ , and appears to have no optical counterpart.

Flint (DTM) and Impey (Arizona) took HI spectral line data as part of an ongoing program to characterize the dwarf galaxy membership in the Leo I group. The Leo I sample provides an opportunity to probe the faint end of the galaxy luminosity function, testing cosmological models which significantly overpredict the number of dwarfs observed in Local-Group-like groups. The primary challenge of measuring the luminosity function to these limits is determining group membership for each galaxy candidate. Fainter dwarfs have increasingly lower surface brightness, which makes optical, spectroscopic redshifts and direct distance measurements very difficult. However, fainter dwarfs also appear to have larger neutral gas fractions, making Arecibo HI-line observations the perfect complement to optical spectra at brighter luminosities. Preliminary results from 40 hr of targeted HI observations have doubled the number of confirmed dwarf galaxy members in Leo I. These optically-selected dwarf members probe HI gas masses as low as  $5 \times 10^6 M_\odot$ , which is comparable to the lowest-mass dwarf irregulars in the Local Group.

Lee (Arizona), Salzer (Wesleyan), Impey (Arizona), Thuan (Virginia), and Gronwall (Johns Hopkins) made 21cm observations of a complete sample of 109 low luminosity ( $M_B > -18.0$ ), nearby ( $cz < 11,000$  km/s),  $H\alpha$ -selected star-forming galaxies from the KISS catalog. The detection rate was 89%. Examining the KISS composite B- and V-band survey images, they find that 9% have companions of

comparable or greater optical brightness within the 3.5-arcmin Arecibo beam. By computing an HI mass function for this sample, it is shown that the low luminosity star-forming galaxies in KISS contain 10-15% of the overall HI in the Universe. They find that  $\rho_{HI} = 7.0 \times 10^6 \text{ M}_{\odot}/\text{Mpc}^3$ , or  $\Omega_{HI} = 4.5 \times 10^{-5}$  with a  $\sim 20\%$  statistical error. The HI mass function of this sub-population does not exhibit a steeply rising slope at low masses, consistent with the result that gas richness ( $M_{HI}/L_B$ ) does not increase at a significant level with decreasing galaxy luminosity. In the range  $10^8 < M_{HI}/M_{\odot} < 10^9$ , they find that 25-50% of all galaxies are currently undergoing a strong episode of star formation.

Monnier-Ragaine, van Driel, and Balkowski (Paris Observatory), Schneider (UMASS), Jarrett (IPAC) and O’Neil (NAIC) are finishing the collection of HI data on 1000 low surface brightness (LSB) galaxies from the 2MASS survey, of which 400 were observed at Arecibo and 600 at Nancay. About 30% of the objects were detected. So far, the data have shown lots of quite gas-rich objects, but none with the record high  $M_{HI}/L_B$  ratios found for some red cluster LSBs.

Schneider (UMass), Huchra (CfA), and Pantoja (UPR) have initiated a program to obtain  $\lambda 21$ -cm HI line spectra for low Galactic latitude galaxy candidates identified from 2MASS. This near-infrared survey minimizes the effects of obscuration from the Milky Way, allowing galaxy identification deep into the Zone of Avoidance, where optical galaxy catalogs are incomplete. Some 200 candidates were observed during 2001 toward both the Galactic center and anticenter regions accessible from Arecibo. This project is currently in progress, with data acquisition and analysis ongoing.

Terzian (Cornell), Lewis (NAIC), and Arecibo REU summer students Chomiuk (Wesleyan), Morris (Chicago), and Moser (Illinois) observed recombination lines from interstellar clouds at C- and S-band. One nebula, S88, coincides with a compact red object, is associated with a thermal radio source, and is embedded in a complex molecular cloud. Several molecular species have been detected from its vicinity. The ionized plasma of the nebula undergoes recombinations that at high quantum levels result in line emission at radio frequencies. This team measured the  $H125\alpha$  (3.4 GHz) and  $H109\alpha$  (5.0 GHz) lines from S88. In the same program, recombination lines were detected from six planetary nebulae.

Goodman (CfA) and Heiles (Berkeley) made the first known attempt to detect the Zeeman effect in the 700-MHz lines of CH. If the Zeeman effect were to be detectable in these, such measurements would offer the best non-maser probe yet of magnetic fields in dense molecular gas. After nearly 100 hr of observations, CH lines were clearly detected in absorption against HII regions in several massive star-forming regions. There are also hints of Zeeman detections.

Evans, Mueller (Texas), and Goldsmith (Cornell) made Arecibo  $H_2CO$  observations of three pre-protostellar clouds: L1544, L1498, and L1512. After four nights they had integration times of  $\sim 100$  min for each central position and an average rms of 0.015K. The line was about 0.5K at each central position and hyperfine components were clearly visible. Somewhat unexpectedly, the observed sources are all considerably more extended than the map coverages, which may be indicative of an increase in the abundance of  $H_2CO$

away from the cloud centers. This would be a surprise in terms of the cloud chemistry. This team is now completing the maps of these three clouds. They will combine this data with other cm- and mm-wave data to determine accurate densities for the clouds and model the density as a function of position.

Ford, Neufeld (Johns Hopkins), and Goldsmith (Cornell) used the Arecibo telescope to obtain the first detection of OH molecules in the circumstellar envelope of the extreme carbon star IRC+10°216 (CW Leonis), providing additional evidence for the presence of icy bodies in orbit around that star. The OH detected at Arecibo is believed to arise from the photodissociation of circumstellar water vapor by interstellar ultraviolet radiation; the new result thereby provides an important confirmation of a previous direct detection of  $H_2O$  around IRC+10°216 by the Submillimeter Wave Astronomy Satellite (SWAS). Detailed calculations by Ford and Neufeld (2001) indicate that 10–100 Earth masses of orbiting ice at a distance of 75–300 AU from the star are required to supply the observed amounts of  $H_2O$  and OH throughout the AGB phase; this is comparable to the amount of ice originally believed to have been present in our own solar system’s Kuiper belt.

Neufeld (Johns Hopkins), Kaufman (San Jose State), Goldsmith (Cornell), Hollenbach (NASA Ames), and Plume (Calgary) have combined the first detection of  $H_2O$  in a diffuse cloud with extensive Arecibo OH observations along the same line of sight (to W51). These observations are particularly valuable because the absorption lines of both molecular species appear optically thin in the 6 km/s feature towards the bright HII region. Although the region of massive star formation is estimated to be at 6.5 kpc, the diffuse cloud is likely relatively close to us. The particular importance of observing these two species together is that they provide a test of laboratory measurements of a key chemical reaction in dense interstellar clouds.

Araya and Hofner (UPR) conducted an Arecibo C-Band (4-6 GHz) spectral scan towards IRC+10°216 (CW Leo). This is a late-type carbon-rich star with extensive mass loss. It is also the strongest source of circumstellar mm-wave spectral lines due to the large number of carbon-based molecules in its envelope and its relative proximity to the Solar System (290 pc). The strongest line detected corresponds to the rotational transition  $J = 2-1$  of the  $HC_5N$  molecule. Nine additional spectral line candidates were detected, which will need confirmation. As part of this project, the team will estimate the column density of  $HC_5N$ , as well of other detected molecules, and establish constraints on abundances of non-detected molecules.

Slysh (NAIC) measured the four OH ground state transitions in all Stokes parameters for most of the Galactic Plane OH masers accessible from Arecibo. The goal of the survey is to find linearly polarized spectral features which can be used in future VLBI observations for simultaneous phase calibration of both LCP and RCP channels. The first part of the survey in the Anticenter region has been completed, and several new linearly polarized masers have been found.

Lewis (NAIC) reobserved the set of Arecibo OH/IR stars following a 12-yr break, finding six “dead” OH/IR stars (i.e.,

examples that no longer have detectable 1612-MHz masers). However, the identification of “dying” stars would be greatly expedited if other diagnostics were known. With this end in view, Lewis and Engels (Hamburg, Germany) have looked for clues in the observational record of FV Boo (15060+0947), a currently “dying” star. They find that the earliest premonition for most occurs with the presence of a strong 22-GHz maser close to the stellar velocity. This is followed in time by the development of similar OH (usually 1665-MHz) features, which are rare. The presence of water and 1665-MHz features in FV Boo point to it having already (by 1985) passed from the phase in which dust couples photon momentum into the circumstellar shell, to the alternate state in which mass-loss is only supported at a much more modest rate by stellar pulsation; also, it had already passed on to the subsequent state in which the outer dust shroud has been so diluted by its ongoing expansion without replacement, that interstellar UV is degrading molecules in its new inner shell. Further, the persistent absence over 1999-2002 of any main-line emission at velocities  $< -13.2$  km/s, though this was present in 1985, points to a continuing and expected decline in both the current expansion velocity and mass-loss rate, as well as to the obliteration of most of the molecules that previously existed around  $-14$  km/s.

Baan (Westerbork), Hofner, and Araya (UPR) conducted a C-band survey of extragalactic formaldehyde. They observed the  $\text{H}_2\text{CO}$  ( $1_{10-1_{11}}$ ) transition (4829.67 MHz) toward 63 extragalactic objects. The sample comprises: (1) earlier detected sources, particularly the tentative detections from Baan *et al.* (1993), (2) ultra-luminous FIR galaxies known to have OH megamasers, plus those with OH absorption, and (3) nearby FIR galaxies, in particular spiral galaxies. Also observed simultaneously was the  $\text{H}110\alpha$  recombination line (4874.16 MHz) towards a sub-sample of 54 sources. The observations have resulted in a total of ten sure or tentative detections. These comprise four  $\text{H}_2\text{CO}$  absorbers, five  $\text{H}_2\text{CO}$  emitters, and one  $\text{H}110\alpha$  emitter. They also report the first detection of  $\text{H}110\alpha$  from the giant HII region NGC 604 in the galaxy M33, plus a weak  $\text{H}_2\text{CO}$  absorption toward this source.

Lovell (Agnes Scott), Howell (NAIC), Schloerb (FCRAO), Lewis (NAIC), and Hine (NAIC) observed OH in several comets. The  $\lambda 18$ -cm OH lines are a valuable diagnostic of conditions in comet comae. The brightness of the OH lines is related to the total OH production in the coma, and the line shape contains information on the gas outflow velocity.  $\Lambda$ -doublet transitions responsible for the  $\lambda 18$ -cm OH emission come from a process in which OH molecules are excited from the ground state by strong solar UV lines and then decay radiatively. This may cause the  $\Lambda$ -doublet levels to be either inverted or anti-inverted depending on the comet’s heliocentric radial velocity. Owing to the pointing limitations at Arecibo, C/2000 WM1 (LINEAR) was observed when the heliocentric velocity gave small values for the predicted inversion, although the observed spectra for this comet show very interesting line shapes which provide valuable constraints on the inversion models. For every observation of C/2000 WM1 (and also of 153P/Ikeya-Zhang), transitional spectra of unusual shapes were seen, likely rep-

resenting the transition from anti-inversion to inversion of the  $\Lambda$ -doublet.

## 6.2 Pulsar Radio Astronomy

Camilo, Gotthelf, Halpern, Mirabal (Columbia), Lorimer (Jodrell Bank), Bhat (NAIC), Wang, and Lu (UMass) used Arecibo to discover pulsations from PSR J1930+1852, a young, energetic pulsar at the center of the supernova remnant (SNR) G54.1+0.3. A signal was found with a period of 136.8 ms and maximum signal-to-noise ratio of 20.7 at  $\text{DM} = 308$  pc/cm<sup>3</sup>. From several 45-min Arecibo integrations, they obtained an accurate  $P$  and  $\dot{P}$ , deriving a characteristic age of 2900 yr (estimating an actual age for the pulsar and SNR in the range 1500-6000 yr), spin-down luminosity of  $1.2 \times 10^{37}$  erg/s and surface magnetic dipole field strength of  $1.2 \times 10^{13}$  G. This places PSR J1930+1852 in the group of ten pulsars with the highest known values of spin-down luminosity and lowest apparent ages. The broader significance of this discovery lies in the realization that young pulsars can be extremely faint; with a flux density of 0.06 mJy at 1180 MHz and luminosity (for a distance of approximately 5 kpc) of about 1 mJy kpc<sup>2</sup> at 1400 MHz, this pulsar (plus a few recently discovered ones) is at least an order of magnitude fainter than previously known young pulsars.

Jacoby, Anderson (Caltech), Frail (NRAO), and Keohane (NCSSM) searched for radio pulsations from the SNR IC443. Their search targeted the soft X-ray point seen with Chandra, which is surrounded by diffuse radio emission that appears to be a pulsar wind nebula. This point source is not at the center of the SNR where previous pulsar searches have focused. To date, analysis of Arecibo observations at 430 MHz, 1.4 GHz, and 2.4 GHz shows no sign of radio pulsations. Similarly, less-deep VLA observations at 1.4 GHz reveal no radio point source, pulsed or unpulsed. This team concludes that the X-ray point source is most likely a pulsar which is unobservable because its radio beams do not intersect the earth.

Kaspi, Ransom, Hessels (McGill), Stairs (NRAO), and Lorimer (Jodrell Bank) have processed pulsar search data taken on ten globular clusters. They report the discovery of four new millisecond pulsars: a binary pulsar in M5, two pulsars (one isolated, one binary) in M13, and a binary pulsar in M71. Prior to this search effort, M5 and M13 were each known to contain an isolated and a binary pulsar, while no pulsars were known in M71. For the new 2.4-ms pulsar, M5C, variations in the measured periods and accelerations indicate that this pulsar is a member of a binary system. M5C undergoes eclipses with an orbital period of 2.1 hr and has a companion with a mass  $\geq 0.04 M_{\odot}$ . The 3.1-ms pulsar, M13D, was detected twice in 10-min sections of data taken on different days, though very different accelerations indicate that it is a member of a binary system. Observations gave an orbital period of 14 hr and a companion mass of  $\geq 0.17 M_{\odot}$ . M71A is an eclipsing 4.8-ms system in a 4.2-hr orbit around a very low-mass companion ( $\geq 0.03 M_{\odot}$ ), typical of the burgeoning class of eclipsing binary millisecond pulsars.

Roberts, Hessels, Ransom, Kaspi (McGill), Freire

(NAIC), Crawford (Haverford), and Lorimer (Jodrell Bank) observed two X-ray sources, AX J1907.4+0549 and AX J2021.1+3651. This led to the discovery of a young ( $\sim 17,000$  yr), energetic (spin-down luminosity  $3.4 \times 10^{36}$  erg/s), 104-ms pulsar in the direction of AX J2021.1+3651. An association with the X-ray source is highly probable. Furthermore, PSR J2021+3651 lies in the error box of the hard-spectrum, low-variability,  $\gamma$ -ray source, 3EG J2021+3716. This association, along with its high spin-down luminosity, strongly suggests that PSR J2021+3651 emits pulsed  $\gamma$ -rays, an exciting prospect as there are currently only a handful of confirmed  $\gamma$ -ray pulsars.

Bogdanov (Penn State), Soltysinski (Szczecin) and Wolszczan (Penn State) have completed an initial study of PSR J1752+23, a “bursting” pulsar discovered in the Penn State/Arecibo pulsar surveys and characterized by unusually long nulling periods. PSR J1752+23 spends 70-80% of its time in a “quasi-null” state. The “on-states” occur once every 400-600 periods and last for  $\sim 100$  periods. With  $P=0.409$  s and  $\dot{P}=0.6 \times 10^{-15}$  s/s, J1752+23 is a fairly typical member of the slow pulsar population. However, it does not follow the standard assumption that nulling pulsars fall close to the hypothetical “death line” in the  $P-\dot{P}$  diagram. Similarly, it does not conform to the common description of nulling, as it switches off gradually rather than suddenly. The emission characteristics of PSR J1752+23 make it exceptional among the pulsar population. Since neither the timing nor pulse profile morphology data indicate any pulse arrival time and/or pulse shape variability that could be due to orbital motion or precessional beam wobble of the pulsar, it seems most natural to assume that its unusual properties are related to the pulse emission mechanism.

McLaughlin (Jodrell Bank) and Cordes (Cornell) completed a search for isolated, dispersed radio pulses from the spiral galaxy M33. This was undertaken in the hope of detecting Crab-like objects emitting “giant” pulses with 100–1000 times mean pulse strengths. The search detected several pulses at high DM which are consistent with signatures of astrophysical origin and may well be pulses from extragalactic pulsars.

Lorimer, McLaughlin (Jodrell Bank), Xilouris (U. Virginia), Backer (UCB), Cordes (Cornell), Fruchter (STScI), Arzoumanian (Goddard), and Lommen (Amsterdam) have been processing drift-scan data taken with the 430-MHz Carriage House feed towards the end of the Arecibo upgrade (1996-98). Of 33 pulsars detected, ten are new. Highlights of these discoveries include a 5.79-ms pulsar at high  $b$  and a 55.7-ms pulsar in the Galactic anticenter. For the latter, a preliminary phase-connected timing solution suggests a solitary object with a spin-down age of  $\sim 2$  Myr and a magnetic field of only  $\sim 2 \times 10^{11}$  G. If confirmed by further observations, this places the pulsar in a fairly unique position in the  $P-\dot{P}$  diagram.

Stairs (NRAO), Thorsett (UCSC), Taylor (Princeton), and Wolszczan (Penn State) have performed long-term timing of the relativistic double-neutron-star binary pulsar B1534+12. Like PSR B1913+16, B1534+12 provides stringent tests of the predictions of general relativity. For B1534+12, measured values of the advance of periastron, the time dilation

parameter, and the shape of the Shapiro delay agree with the GR predictions to within 0.05%. The derived orbital period derivative, affected by the relative acceleration of the pulsar system and the Solar System Barycenter, provides a refined pulsar distance of  $1.02 \pm 0.05$  kpc. The masses of the two neutron stars can also be derived from the timing solution. It is now clear that the observed recycled pulsar is significantly less massive than its younger companion, contrary to expectations from most binary evolution theories in which mass is transferred from the companion to the older neutron star.

Lorimer (Jodrell Bank), Xilouris (Virginia), Fruchter (STScI), Stairs (NRAO), Vazquez, and Eder (NAIC) have begun regular timing of PSR J0407+16, a 25.7-ms pulsar discovered in the Arecibo-upgrade 430-MHz drift scan searches. Earlier observations revealed the pulsar to be a member of a binary system with a 680-day orbital period and a  $0.003 M_{\odot}$  mass function. These data imply that the orbiting companion has a mass of  $\geq 0.2 M_{\odot}$  and is most likely a low-mass white dwarf. The orbital period of J0407+16 is by far the longest known for a millisecond ( $< 30$  ms) pulsar and second only to PSR B0820+02 for low-mass binary pulsar systems. A complete knowledge of the orbit, spin, and kinematics of this unique binary system should improve our knowledge on the origin and evolution of long-period binary pulsars.

Freire (NAIC), Anderson, Jenet (Caltech), and Navarro (Schlumberger) undertook a timing project aimed at confirming the eccentricity and characteristic age of PSR J2016+1947, a binary pulsar ( $P=64.94$  ms,  $DM=34$  pc/cm<sup>3</sup>) found in 1990 in an Arecibo intermediate galactic latitude search. The PSR J2016+1947 system promises to excel as a tool to test the Strong Equivalence Principle (SEP), the basic foundation of General Relativity. This principle requires the universality of free fall, even for objects that have very significant gravitational self-energies. Thus, both PSR J2016+1947, with its very large (negative) self-gravitation energy of about 15% of the total mass (depending on the equation of state for cold matter at high densities), and the white dwarf companion, with its negligible self-gravitational energy, should fall in the Galactic gravitational field with the same acceleration. However, if the assumption of SEP is wrong, as postulated in many alternative gravitational theories, (i.e., if  $|\Delta|=|1-m_I/m_G| \neq 0$ , where  $m_I$  and  $m_G$  are the inertial and gravitational masses of the pulsar), the accelerations for the pulsar and the white dwarf will be different. The effect on an MSP/white-dwarf binary produces an increase in the eccentricity of the system (the “Nordvedt” effect), and this becomes more pronounced for wider orbits.

Hankins, Kern (New Mexico Tech), Cordes (Cornell), Bhat (NAIC), and McLaughlin (Jodrell Bank) investigated the Crab pulsars’s frequency evolution and polarization properties, particularly above 1 GHz, to refine the interpretation of the Crab in terms of the inner and outer gap models of pulsar emission. In the first phase of this project, observations were made in early 2002 in multiple frequency bands accessible to Arecibo’s 430-MHz, L-, S- and C-band receivers. Observational goals are two-fold: (a) To achieve much finer sampling in frequency of the average pulse profile to see how the pulse components appear and disappear, and (b)

to obtain new statistics for the giant pulses and, in particular, to compare giant-pulse polarization with the average polarization in order to investigate from where the giant pulses originate. Data from observations made so far enable this team to form Stokes parameter profiles for seven different frequency bands from 0.4 to 4.2 GHz.

Gupta (NCRA, India), Bhat (NAIC) and Gangadhara (IIA, India) made single-pulse observations of a sample of bright, well-known pulsars to carry out a detailed study of radio-pulsar emission geometry. This was motivated by the work of Gupta and Gangadhara, where a new method for analyzing single-pulse data to determine the total number of emission components is used to detect new emission components for several pulsars from 320-MHz GMRT data. From these detections, they showed that the pulsar emission region contains multiple hollow emission cones surrounding a central core beam. Further, the conal beams show systematic retardation and aberration effects. This provides a new way to estimate the emission heights and polar cap locations of the emission cones and could prove to be a powerful tool to study pulsar emission geometry. Observations of most bright, Arecibo-visible pulsars with multi-component profiles were made, largely at 432 and 1175 MHz, with a few also being observed at 2250 and 5000 MHz. Basic data reduction has been largely completed, and detailed analysis for modeling the emission geometry is underway.

Stanimirovic (NAIC), Weisberg (Carleton), Dickey (Minnesota), and Anderson (Caltech), searched several pulsars with known HI absorption for detectable OH lines at 1665 and 1667 MHz. They found deep, narrow OH absorption lines for PSR B1849+00 at both 1665 and 1667 MHz. These absorption lines correspond to an interstellar cloud directly in front of the pulsar. Emission-absorption studies have been very successful at probing the properties of the ISM towards both strong background continuum sources and pulsars. The great advantage that pulsars offer for such studies is that they turn on and off, allowing the absorption and emission spectra to be measured without moving the telescope. This eliminates errors introduced into the absorption spectrum by small scale variations in the emission. While the HI absorption against pulsars has been commonly detected, little work on OH absorption has been done until now.

Stinebring (Oberlin) and collaborators continued to study the phenomenon of pulsar “scintillation arcs” that they identified through Arecibo observations in 1999. These arcs arise from interference between various parts of the spatially coherent pulsar image. They find dynamic spectra to be remarkably rich in features when explored with Arecibo’s sensitivity. Stinebring analyzes a dynamic spectrum by taking its two-dimensional power spectrum, forming what is known as a secondary spectrum, in which the scintillation arcs appear as sharply delineated parabolic arcs. These correspond to a quilted or cross-hatch pattern in the dynamic spectrum. What causes the arcs? Although this is not yet fully clear, the essential ingredient is interference between a bright central core of the image and a more extended halo around this, both caused by scattering off electron density variations in the ISM. A simple model with all scattering taking place in a thin screen along the line of sight allows them to relate ob-

servable features of the scintillation arcs to the screen location.

### 6.3 Radar Astronomy

Magri (U. Maine) and Nolan (NAIC) made radar observations of 24 mainbelt asteroids between mid-2001 and mid-2002. Most of these were CW observations to obtain data on reflectivity, roughness, and rotation state. In addition, four of the objects, including Vesta, yielded low-resolution delay-Doppler images (which provide information on target size and shape).

Nolan, Howell (NAIC), Ostro, Benner (JPL), Margot (Caltech), and Magri (U. Maine) observed 21 near-Earth asteroids (NEAs) during the reporting period. The highlight of the Arecibo NEA program was the discovery of three more binary NEAs, bringing the total number of binary NEAs to six. These new binaries generally conform to the characteristics of the first three discovered; rapidly rotating, roughly spherical primaries with secondaries approximately 1/3 the size of the primary. It is now clear that 10–20% of NEAs are binaries, in good agreement with predictions based on other observations. An important objective of the radar measurements and analyses is estimation of bulk densities for these binaries.

Campbell (Cornell), Black (U. Virginia), Carter (Cornell), and Ostro (JPL) made S-band radar observations of Titan, achieving uniform longitude coverage at 22.5 deg intervals. It was found that most of the echo power is in a broad diffuse component, although a narrow (occasionally very narrow) specular return is also seen at most longitudes. The brightest radar feature coincides with the brightest feature in the near-IR HST and ground-based imagery. The low cross sections and small widths of the specular echoes could be considered evidence for liquid hydrocarbon lakes, although the apparent low cross sections assume the scattering properties are homogeneous over the scattering area. If, instead, there is substantial diffuse reflection from the subradar region, then the intrinsic specular reflectivity would be higher and, hence, more consistent with a smooth non-liquid surface.

Nicholson, Campbell (Cornell), French (Wellesley), Nolan (NAIC), and Margot (Caltech) made S-band radar imaging observations of the rings of Saturn. This was the third set of yearly observations in a program intended primarily to study azimuthal asymmetries in the radar reflectivity of the A and B rings as a function of ring-plane tilt. This parallels a study by French of the rings’ optical asymmetries using the HST. The radar asymmetry is found to be concentrated in the A ring. The radar asymmetry has an amplitude of 25%, which is 2–3 times larger than the optical asymmetry. The asymmetry is thought to be associated with gravitational wakes generated by individual large ring particles. By continuing to image the rings as their tilt angle decreases, valuable information will be obtained on both the small-scale wake structures and the vertical thickness of the rings.

Black (NRAO), Campbell, Carter (Cornell), Nolan (NAIC), and Ostro (JPL) made the first radar detection of Saturn’s third largest moon, Iapetus. The echo showed “normal” radar reflection properties, very unlike those of the icy Galilean satellites of Jupiter. Since the detection was of the

bright (trailing) hemisphere of Iapetus, which is known to be very icy, the normal reflection is a puzzle. Radar observations of the 10-times darker leading hemisphere are planned for early 2003.

Nolan, Howell, Harmon (NAIC), and Margot (Caltech) made a radar detection of the comet C/2001 A2 (LINEAR). This is only the eighth comet detected with radar. Although there was no clear evidence of a nucleus echo, a moderately strong echo was detected from large coma grains. The echo gave a radar cross section of 4 km<sup>2</sup> and a circular polarization ratio of 0.35. This was the first convincing detection of a depolarized echo from coma grains, which implies a maximum grain size of at least several centimeters. This comet was notable for its outbursting and fragmentation, and it is likely the observed coma echo is related to that activity.

Harmon (NAIC), Campbell (Cornell), and Slade (JPL) made S-band radar observations of Mercury in the summers of 2001 and 2002. These were long-code delay-Doppler measurements designed to yield full-disk images in both circular polarizations. The data have produced high-quality images covering large areas of the planet. The most interesting results have come from the hemisphere left unimaged by the Mariner-10 spacecraft, where several very prominent radar-bright features can be found. The new data have yielded the best images yet of the previously known bright features A, B, and C (all of which show an impact origin). Also, although the observing aspect for the putative north polar ice was less advantageous than in previous years, the new images were useful in confirming the existence of all of the low-latitude ice features seen previously at latitudes between 70–75N.

## 6.4 VLBI

Lazio (NRL), Goss, Brogan (NRAO), Faison (Northwestern), Zauderer, and DePree (Agnes Scott) used Arecibo to observe 3C 138 in an HI-absorption VLBI experiment. Such experiments have been carried out numerous times toward 3C 138. Faison and Goss (2001) were able to map the opacity variations, which can exceed 0.8 in optical depth, across the face of the source and confirmed that structure on size scales of order 10 AU exist in the ISM. How such small-scale structure originates and is maintained in the neutral ISM is not well-understood. The objective of the present experiment was to image the HI absorption toward 3C 138 with sufficient sensitivity to confirm or refute the tentative detection of Zeeman splitting in their earlier observations.

Momjian (Kentucky), Romney, Carilli (NRAO), and Troland (Kentucky) used Arecibo in their VLBA/VLA observation of the Luminous Infrared Galaxy, NGC 7674. One major goal for this study is to determine the distribution and kinematics of neutral gas leading to an estimate of the gravitational mass at the center of the galaxy powering the nuclear starburst and/or the AGN phenomena. The impact of having Arecibo join with the VLBA is a boost in sensitivity by a factor of 4.1.

Fix (Alabama) and Mutel (Iowa) carried out a pilot program to observe six long-period variable OH masers using the VLBA plus Arecibo and the phased-VLA. The large collecting areas of Arecibo and the phased-VLA will result in high angular resolution polarization maps with high dynamic

range and sensitivity. From this pilot project, Fix and Mutel hope to identify one or two stars for a long-term synoptic study of the changes in the relationship of structure at the three OH frequencies, as well as models for maser pumping and polarization. They also hope to determine the parallaxes of the masers with milliarcsec accuracy.

Arzoumanian (GSFC), Chatterjee, Cordes (Cornell), and McLaughlin (Jodrell Bank) continued their studies of PSR J1740+1000, discovered in one of the Arecibo-upgrade 430-MHz drift-scan searches. This pulsar is of interest as its small age and large height above the Galactic plane (derived from its DM) imply a very high velocity. Since its discovery, monthly timing has been undertaken in support of high-energy and VLBA observations. J1740+1000 is weak and shows strong scintillation, with an average L-band flux density of ~1 mJy. The VLBA alone lacks the sensitivity to detect this pulsar with sufficient signal-to-noise for astrometry. Fortunately, Arecibo, with a collecting area some 15 times that of the entire VLBA, can provide the necessary boost in sensitivity. In March, 2002, Arecibo joined the VLBA for a successful phase-referenced observation, and strong fringes were detected for the pulsar on all baselines to Arecibo. It is expected that sub-milliarcsec astrometry will be possible, and a proper motion (and possibly a parallax) can be measured in future observations.

## 7. OBSERVING PROGRAMS

*The following list gives the numbers, titles, and coauthors of all observing proposals scheduled on the Arecibo telescope during the period from July, 2001 through June, 2002.*

### 7.1 Spectral Line Radio Astronomy

A1119 - *A Search for Neutral Hydrogen in a Complete Sample of Seyfert Galaxies Testing the Implications of Unified Scheme* - Ghosh, T., Eder, J., Salter, C. (NAIC).

A1256 - *Extragalactic Radio Recombination: A Pilot Project* - Hofner, P. (UPR), Terzian, Y. (Cornell), Kurtz, S. (UNAM), Kubik, D. (NAIC).

A1312 - *Light Travel Time Dimensions for  $|b| > 10^\circ$  OH/IR Stars* - Lewis, B. (NAIC).

A1359 - *KISS Dwarfs: The HI Properties of a Complete Sample of Active Star-forming Dwarf Galaxies* - Lee, J. (U. Arizona), Salzer, J. (Wesleyan), Impey, C. (U. Arizona), Gronwell, C. (Johns Hopkins).

A1387 - *Variability in OH Megamasers* - Darling, J., Giovanelli, R., Cordes, J. (Cornell).

A1389 - *A Study of the Gas Phase of Radio Galaxies and Quasar Hosts at Low Redshifts* - Ghosh, T., Salter, C., Altschuler, D. (NAIC), Saikia, D. (NCRA).

A1408 - *The Magellanic Stream* - Stanimirovic, S. (NAIC), Dickey, J. (U. Minnesota), Hedden, A., Kirchner, A. (Carleton).

A1444 - *V1511 Cyg: The Prototype for Newly Born OH/IR Stars* - Lewis, B. (NAIC).

A1445 - *A Search for Newly Born OH/IR Stars* - Lewis, B. (NAIC).

A1451 - *Confirmation of Low Mass Systems in the NGC 628 Galaxy Group* - Braun, R. (NFRA), Burton, W. (Leiden).

A1456 - *Studies of the Large-Scale Galactic Magnetic Field via the Zeeman Effect* - Troland, T. (U. Kentucky), Crutcher, R. (U. Illinois).

A1457 - *A Crucial Test of the Role of Magnetic Fields in Star Formation* - Troland, T. (U. Kentucky), Crutcher, R. (U. Illinois).

A1459 - *2MASS Galaxies in the Zone of Avoidance* - Schneider, S. (U. Mass.), Huchra, J. (Harvard), Pantoja, C. (UPR).

A1474 - *Regular Monitoring of Calibration Parameters for the AO Receivers* - Heiles, C. (Berkeley), Salter, C., Perillat, P. (NAIC).

A1475 - *KISS Dwarfs: The HI Properties of a Complete Sample of Active Star-forming Dwarf Galaxies* - Lee, J. (U. Arizona), Salzer, J. (Wesleyan), Impey, C. (U. Arizona).

A1511 - *Low Surface Brightness Galaxies in X-ray Emitting Clusters* - O'Neil K. (NAIC), Bothun, G. (U. Oregon).

A1514 - *Formaldehyde Absorption of CBR: What Happens at Low Temperature and High Density?* - Evans, N. (U. Texas), Goldsmith, P. (NAIC), Mueller, K. (U. Texas).

A1516 - *High Velocity Clouds W413 and W479* - Hoffman, G., Hirani, A. (Lafayette).

A1517 - *Peculiar Motions within the Pisces-Perseus Supercluster* - Haynes, M., Giovanelli, R., Springob, C., Catinella, B. (Cornell).

A1518 - *OH Masers for VLBI* - Slysh, V. (Astro. Space).

A1520 - *A Deep Search for OH and HI toward the Carbon-Rich AGB Star IRC+10216* - Neufeld, D., Ford, S. (Johns Hopkins).

A1522 - *HI Zeeman Observations of Shocked Gas in Old Supernova Remnants* - Koo, B.-C. (U. Seoul), Heiles, C. (Berkeley), Troland, T. (U. Kentucky), Stanimirovic, S. (NAIC).

A1524 - *Followup on the Arecibo Set of OH/IR Stars* - Lewis, B. (NAIC).

A1526 - *A C-Band Spectral Line Scan of IRC+10216* - Hofner, P. (UPR), Goldsmith, P. (NAIC), Davis, M. (SETI Inst.), Takano, S. (Nobeyama U.).

A1532 - *OH Spectroscopy of Comet 2001 A2 (LINEAR)* - Howell, E. (NAIC), Lovell, A. (Agnes Scott), Schloerb, F. (U. Mass.), Nolan, M. (NAIC).

A1534 - *Observations of Kreutz Family Comets Discovered by SOHO* - Howell, E., Nolan, M. (NAIC).

A1542 - *Followup on "Birth" and "Death" among Arecibo OH/IR Stars* - Lewis, B. (NAIC).

A1544 - *Formaldehyde Emission in Galaxies* - Baan, W., Klockner, H. (U. Groningen), Hofner, P., Araya, E. (UPR).

A1545 - *Mapping Dark Molecular Clouds with HI Narrow Line Absorption* - Li, D., Goldsmith, P. (Cornell).

A1546 - *HI Measurements of Dwarf Galaxies in the Leo I Group* - Flint, K., Bolte, M. (Lick), Impey, C. (Steward Obs.).

A1547 - *Magnetic Fields in Photodissociation Regions from Zeeman Splitting of Carbon Recombination Lines* - Heiles, C. (Berkeley).

A1550 - *Absorption Studies of Molecular Clouds along the Line of Sight to W49 and W51* - Goldsmith, P. (NAIC), Melnick, G. (Harvard), Neufeld, D. (Johns Hopkins), Plume, R., Borgin, T. (Harvard).

A1552 - *An HI Study of the Ly $\alpha$  Absorber Galaxy Connection* - Putman, M., Rosenberg, J., Stocke, J., Shull, M., McLin, K. (U. Colorado).

A1569 - *OH Observations of Molecular Clouds* - Sandstrom, K., Goodman, A. (Harvard).

A1578 - *HI-Rich Dwarf Galaxies and HI Clouds without Optical Counterparts in the Hercules Cluster* - van Driel, W., Cayatte, V. (Paris Obs.), Duc, P.-A. (CEA), Balkowski, C. (Paris Obs.).

A1581 - *Extended Atomic Hydrogen in the Leo Triplet* - Bolatto, A. (Berkeley), Walter, F. (Caltech), Simon, J. (Berkeley), Dahlem, M. (ESO), Robishaw, T. (Berkeley).

A1584 - *HI Properties of a Large Complete Sample of Optically Selected Galaxies in Nearby Voids* - Grogin, N. (STScI), Lee, J. (U. Arizona), Dell'Antonio, I. (Brown).

A1585 - *A Search for 6.7 GHz Methanol Masers Associated with OH Megamasers at  $0.12 < z < 0.25$*  - Darling, J., Goldsmith, P., Li, D. (Cornell).

A1586 - *Is There an Intra-Group Medium in Spiral-Rich Galaxy Groups* - Rosenberg, J., Putman, M., Stocke, J. (U. Colorado).

A1587 - *The OH Light Curve of IRAS 22402+1045* - Lewis, B. (NAIC).

A1589 - *On the Imminent "Death" of the OH/IR Star 15060+0947* - Lewis, B. (NAIC).

A1610 - *Radio Frequency Observations of Cometary OH, CH, and H<sub>2</sub>CO* - Howell, E., Lewis, B. (NAIC), Schloerb, F. (U. Mass.), Lovell, A. (Agnes Scott), Nolan, M. (NAIC).

A1621 - *Mapping of Low Density Sources from the Murphy-Lockman Survey* - Hoffman, G. (Lafayette), Salpeter, E. (Cornell).

A1626 - *Finishing Mapping Clouds with HI Narrow Line Absorption* - Li, D., Goldsmith, P. (Cornell).

A1656 - *Spectroscopic Observations of Comet Ikeya-Zhang (P/2002 C1)* - Howell, E., Lewis, B. (NAIC).

## 7.2 Pulsar Radio Astronomy

P1019 - *Precision Pulsar Metrology* - Backer, D., Somer, A., (UC-Berkeley), Foster, R., Cadwell, B. (NRL), Wolszczan, A. (Penn St.).

P1134 - *A Search for Giant Pulses from M33 and Nearby Globular Clusters* - McLaughlin, M. (Cornell), Arzoumanian, Z. (NASA), Cordes, J. (Cornell), Hankins, T. (NRAO).

P1228 - *Masses, Space Motions and Long-Term Timing of Two Intermediate Mass Binary Pulsar Systems* - Camilo, F., Stairs, I. (Jodrell Bank), Nice, D., Splaver, E., Taylor, J. (Princeton), Xilouris, K. (NAIC).

P1281 - *Interstellar Scintillations: Probing Pulsars and the ISM* - Stinebring, D. (Oberlin), McLaughlin, M., Cordes, J. (Cornell).

P1296 - *Searching for Pulsars in the Sagittarius Spiral Arm* - Arzoumanian, Z., McLaughlin, M., Cordes, J. (Cornell), Backer, D. (Berkeley).

P1345 - *Timing Measurements of 20 Recently Discovered Pulsars* - Feiler, G. (Torun), Kizilton, B., Wolszczan, A. (Penn St.).

P1396 - *A Pilot Search of Young and Rapidly Rotating Pulsars in the Galactic Plane* - Lorimer, D. (Jodrell Bank),

Cordes, J., McLaughlin, M. (Cornell), Arzoumanian, Z. (NASA).

P1409 - *A Pulsar Absorption Study of Very Small Scale Structure in Interstellar HI* - Weisberg, J. (Carleton), Stanimirovic, S. (NAIC), Anderson, S., Jenet, F. (Caltech).

P1423 - *Probing the Interstellar Electron Density with New Parkes Multibeam Survey Pulsars* - Bhat, R. (NAIC), Cordes, J., Chatterjee, S. (Cornell), Lazio, J. (NRL), Manchester, R. (CSIRO), Lyne, A. (Jodrell Bank).

P1425 - *Timing of Three Recently Discovered Pulsars* - McLaughlin, M. (Cornell), Arzoumanian, Z. (NASA), Cordes, J. (Cornell), Lorimer, D. (NAIC), Chatterjee, S. (Cornell).

P1426 - *Pulsar Phase-Resolved Spectra at High Frequencies: Investigation of the Radio Emission Mechanism* - Bhat, R. (NAIC), Backer, D., Lommen, A. (UC-Berkeley).

P1427 - *Measuring the Galactic Magnetic Field Using the Newly Discovered Pulsars (and Measuring their Spectral Indices, Too)* - Nice, D. (Princeton), Camilo, F. (Columbia).

P1428 - *Parallax Measurements of PSR J0030+0451* - Lommen, A., Backer, D. (UC-Berkeley).

P1429 - *New Single-Pulse Observations of PSR 0611+22* - Nowakowski, L., Sotero, N. (UPR).

P1434 - *High Time Resolution Measurements of Core and Conal Pulsars* - Hankins, T., Eilek, J., Kern, J., Weatherall, J. (New Mexico Tech).

P1436 - *A 20cm Search for Pulsars in Globular Clusters Using WAPP* - Kaspi, V. (MIT), Stairs, I. (NRAO), Lorimer, D. (NAIC).

P1477 - *Multifrequency Timing of PSR B1257+12 and PSR B1534+12* - Wolszczan, A., Bogdanov, S. (Penn. St.).

P1479 - *Long-Term Timing of PSR B1534+12* - Stairs, I. (NRAO), Thorsett, S. (UCSC), Taylor, J. (Princeton).

P1481 - *Probing the Nano-Hertz Gravitational Wave Background with a Pulsar Timing Array* - Backer, D., Lommen, A. (UC-Berkeley), Nice, D., Splaver, E. (Princeton), Stairs, I. (NRAO).

P1507 - *Timing and Polarimetry of Relativistic Binary Pulsar B1913+16* - Weisberg, J. (Carleton), Taylor, J. (Princeton).

P1508 - *Caltech-Arecibo Drift Survey: Verification of Pulsar Candidates* - Chandler, A., Anderson, S., Kulkarni, S., Prince, T. (Caltech).

P1509 - *Caltech-Arecibo Drift Survey: Timing of New Pulsars* - Chandler, A., Anderson, S., Kulkarni, S., Prince, T. (Caltech).

P1510 - *A Search for Radio Pulsations from Isolated Neutron Stars* - Jacoby, B., Kaplan, D., Kulkarni, S., Anderson, S. (Caltech).

P1525 - *Continuum and Spectral Line Observations of SNR G42.8+0.6 and PSR J1907+0918* - Stanimirovic, S., Salter, C. (NAIC), Lorimer, D. (Jodrell Bank), Urosevic, D. (U. Belgrade).

P1555 - *Timing of New Pulsars Discovered in the Parkes Multibeam Survey* - Stairs, I. (NRAO), Camilo, F. (Columbia), Hobbs, G., Lyne, A., Kramer, M. (Jodrell Bank).

P1556 - *Deep Pulse Searches of Two Galactic Gamma Ray Sources* - Kaspi, V., Roberts, M., Hessels, J. (McGill), Freire, P. (NAIC).

P1557 - *Probing the Galaxy's Electron Content and Magnetic Field Using Newly Discovered Pulsars* - Bhat, R. (NAIC), Camilo, F. (Columbia), Cordes, J. (Cornell), Lorimer, D. (Jodrell Bank), Nice, D. (Princeton).

P1558 - *Understanding the Emission Geometry of Radio Pulsars* - Gupta, Y., Bhat, R. (NAIC), Gangadhara, R., Ahmadi, P. (India).

P1560 - *Searching for the Radio Counterpart to the Geminga Gamma-Ray Pulsar* - Camilo, F., Halpern, J., Mirabel, N. (Columbia).

P1562 - *Probing the Local ISM with Pulsars: The North Polar Spur and the GSH 23800+09 Superbubble* - Bhat, R. (NAIC), Gupta, Y. (NCRA-TIFR), Salter, C. (NAIC).

P1566 - *A Search for Gamma-Ray Pulsars* - Freire, P. (NAIC).

P1592 - *Searching for the Radio Counterpart to the Neutron Star in SNR G54.1+0.3* - Camilo, F. (Columbia), Weng, D., Lu, F. (U. Mass.), Bhat, R. (NAIC), Lorimer, D. (Jodrell Bank).

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P1597 - *New Single-Pulse Observations of Three Strong Pulsars* - Nowakowski, L. (UPR).

P1598 - *Multiwavelength Behavior of Pulsar Scintillation Arcs* - Stinebring, D. (Oberlin), Cordes, J. (Cornell), McLaughlin, M. (Nuffield).

P1599 - *Searching for the Radio Counterpart to the Young Neutron Star in IC443* - Camilo, F., Halpern, J., Mirabel, N. (Columbia), Arzoumanian, Z. (NRAO).

P1600 - *Timing a Millisecond Pulsar in a Long-Period Orbit* - Lorimer, D. (Manchester), Xilouris, K. (U. Virginia), Stairs, I. (NRAO), Fruchter, A. (STScI), Eder, J., Vazquez, A. (NAIC).

P1611 - *Searching for Pulsed Radio Emission from the Isolated Neutron Star RBS1223* - Freire, P. (NAIC).

P1614 - *Frequency Dependence of the Crab Nebula Pulsar Polarization Characteristics* - Hankins, T., Kern, J. (New Mexico Tech), Cordes, J. (Cornell), Bhat, R. (NAIC).

P1636 - *A Complete 1.4 GHz Search for Pulsars in Globular Clusters* - Kaspi, V., Ransom, S., Hessels, S. (McGill), Stairs, I. (NRAO), Freire, P. (NAIC).

P1641 - *Ultra-High Time Resolution Measurements of the Crab Giant Radio Pulses* - Hankins, T., Kern, J., Eilek, J., Weatherall, J. (New Mexico Tech).

### 7.3 Radar Astronomy

R1361 - *A Two-Year Radar Survey of Fifty Mainbelt Asteroids* - Magri, C. (U. Maine), Nolan, M. (NAIC), Ostro, S., Giorgini, J. (JPL).

R1504 - *Radar Imaging of Asteroid CU3* - Benner, L., Ostro, S. (JPL), Nolan, M. (NAIC), Margot, J-L. (Caltech).

R1505 - *Radar Imaging of Asteroid Mathilde in Summer 2001* - Magri, C. (U. Maine), Nolan, M. (NAIC), Ostro, S. (JPL), Hudson, R. (Washington St.), Giorgini, J., Yeomans, D. (JPL).

R1506 - *Radar Observations of Mercury in 2001* - Harmon, J. (NAIC), Slade, M. (JPL), Campbell, D. (Cornell).

R1527 - *Radar Observations of 2000 EE104 in April 2001* - Nolan, M., Howell, E. (NAIC).

R1531 - *Radar Observations of Comet 2001 A2 (LINEAR)* - Nolan, M., Howell, E., Harmon, J. (NAIC), Margot, J.-L. (Caltech).

R1536 - *S-band Radar Imaging of Saturn's Rings* - Nicholson, P. (Cornell), French, R. (Wellesley), Black, G. (NRAO), Margot, J.-L. (Caltech), Campbell, D. (Cornell).

R1537 - *Radar Observations of Io at 12.6 cm* - Carter, L. (Cornell), Black, G. (NRAO).

R1538 - *S-band Radar Observations of Titan and Iapetus in 2001* - Campbell, D. (Cornell), Black, G. (NRAO), Ostro, S. (JPL).

R1539 - *Radar Imaging of Asteroids 4 Vesta and 654 Zelinda in 2001-2002* - Magri, C. (U. Maine), Nolan, M., Howell, E. (NAIC), Ostro, S., Giorgini, J. (JPL), Hudson, R. (Washington St.), Yeomans, D. (JPL).

R1541 - *Radar Observations of Three Dynamically Distinctive Near Earth Asteroids* - Ostro, S. (JPL), Hudson, R. (Washington St.), Renner, L. (JPL), Nolan, M. (NAIC), Margot, J.-L. (Caltech), Giorgini, J. (JPL).

R1570 - *Radar Observations of Near Earth Asteroid 2001 ME1* - Nolan, M. (NAIC), Margot, J.-L. (Caltech), Campbell, D. (Cornell), Howell, E. (NAIC).

R1573 - *Radar and OH Observations of Comet C/2000 WM1 (LINEAR)* - Campbell, D. (Cornell), Howell, E., Harmon, J. (NAIC), Margot, J.-L. (Caltech).

R1574 - *Radar Observations of 2001 SP263* - Howell, E., Nolan, M. (NAIC).

R1601 - *Radar Observations of Mercury in 2002* - Harmon, J. (NAIC), Slade, M. (JPL), Campbell, D. (Cornell).

R1602 - *Radar Imaging of Asteroid 1999 GU3* - Benner, L., Ostro, S. (JPL), Hudson, R. (Washington St.), Nolan, M. (NAIC), Margot, J.-L. (Caltech), Giorgini, J. (JPL), Black, G. (NRAO), Plavec, P. (Czech).

R1603 - *Radar Observations of Two Distinctive Near Earth Asteroids* - Ostro, S. (JPL), Hudson, R. (Washington St.), Benner, L. (JPL), Nolan, M. (NAIC).

R1604 - *Radar Observations of Near Earth Asteroids in March 2002* - Nolan, M., Howell, E. (NAIC), Campbell, D. (Cornell), Benner, L., Ostro, S., Giorgini, J. (JPL), Margot, J.-L. (Caltech), Plavec, P. (Czech.)

R1605 - *Completing the Radar Survey of Fifty Mainbelt Asteroids* - Magri, C. (U. Maine), Nolan, M. (NAIC), Ostro, S., Giorgini, J., Yeomans, D. (JPL).

R1612 - *Radar Observations of Near Earth Asteroid 2001 UP* - Nolan, M., Howell, E. (NAIC).

R1613 - *Radar Observations of Asteroid 2001 SE286* - Margot, J.-L. (Caltech), Nolan, M., Howell, E. (NAIC), Campbell, D., Nicholson, P. (Cornell), French, R. (Wellesley), Ostro, S., Benner, L., Giorgini, J. (JPL).

R1616 - *Radar Observations of Near Earth Asteroid 2001 YP3* - Nolan, M., Howell, E. (NAIC).

R1645 - *Radar Observations of Near-Earth Asteroid 2002 AL14 in July 2002* - Nolan, M., Hine, A., Howell, E. (NAIC), Campbell, D. (Cornell), Benner, L., Ostro, S. (JPL), Margot, J.-L. (Caltech).

R1660 - *Radar Observations of Asteroid 2002 FC* - Ostro, S. (JPL), Nolan, M. (NAIC).

## 7.4 VLBI

V1190 - *Arecibo Support of the VSOP Space-VLBI Project* - Hirabayashi, H. (ISAS), Fomalont, E. (NRAO).

ED018 - *Network VLBI* - Desmurs, J.-F. (Cornell).

GP030 - *Network VLBI* - Porcas, R. (MPIfR).

EP034 - *Network VLBI* - Pihlstroem, Y. (NRAO).

BF63 - *Network VLBI* - Fix, J. (U. Alabama).

BC113 - *Network VLBI* - Chatterjee, S. (Cornell).

GL026 - *Network VLBI* - Lonsdale, C. (Haystack).

BL106 - *Network VLBI* - Lazio, J. (NRL).

## 7.5 Special

S1145 - *Project Phoenix: SETI Targeted Search Observations* - Tarter, J. (SETI Inst.).

S1530 - *Summer Student's (2001) Hands-on Observing* - Bhat, R., Eder, J., Ghosh, T., Stanimirovic, S. (NAIC).

## PUBLICATIONS

*The following is a list of publications by NAIC staff or by outside users of the Arecibo telescope. These contributions appeared in the open literature or were in press during the period from July, 2001 through June, 2002.*

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