Robert L. Brown named as new NAIC Director

Robert Brown, a noted astrophysicist and observatory administrator, widely experienced in international collaboration, has been chosen as the new Director of the National Astronomy and Ionosphere Center. He took up his new position on May 5 succeeding Paul Goldsmith, who stepped down on January 1 to return to full-time research and teaching (see NAIC’s November, 2002 newsletter). Don Campbell, NAIC Associate Director was Acting Director in the interim period.

Bob comes to us from NRAO and in recent years has played a leading role in the international group that is constructing the Atacama Large Millimeter Array (ALMA) observatory in Chile. He has been both associate and deputy director of NRAO since 1985, spearheading not only the United States involvement in ALMA but also managing NRAO participation in NASA’s Space VLBI Project. From 1977 to 1980 he was assistant director of NRAO operations in Green Bank, and from 1984 to 1985 he was assistant director of NRAO operations in Tucson. He received his B.A. from the University of California-Berkeley in 1965, and his M.S. and his Ph.D. from the University of California-San Diego, both in 1969. At NRAO he has been involved in studies, both theoretical and observational, of the interstellar medium, the galactic center and distant galaxies.

Bob’s intends to spend “an appreciable amount of time at the telescope” and plans to make the observatory even more accessible to the scientists who use it. This means, in his words, “providing a level of support that is somewhat enhanced over what has been historically provided. We need staff to assist potential users in all phases of scientific research, from proposal writing to calibration and data reduction. (…) What could expand Arecibo’s usage even further is a capability for broad question-solving by letting researchers anywhere access archival data, perhaps through the National Virtual Observatory initiative, or by having the observatory staff undertake observations on behalf of specific users.”

We extend to Bob a warm welcome to the NAIC and the Arecibo Observatory.

INDEX

New NAIC Director .................. 1
State of the Observatory .............. 2
Space and Atmospheric Sciences.... 2
Radio Astronomy ...................... 4
NSF Management Review of NAIC 6
Solar System Studies .............. 20
2002 REU Summer Program ....... 22
Computer Department ................ 25
Workshops held at Arecibo ........ 26
New Scheduler ....................... 29
Inaugural Gordon Lecture .......... 30
NAIC Policy on Press Releases..... 30
Comings and Goings ................. 30
Literary Award for “Hijos” .......... 31
Job Openings ......................... 33
Seminars since the last newsletter 34

The NAIC is operated by Cornell University under a Cooperative Agreement with the National Science Foundation.
State of the Observatory
R. L. Brown

In 2003 the NAIC is in a state of transition. The Gregorian upgrade project is complete and successfully met its ambitious goals; receivers are available (or soon will be) for frequencies from 430 MHz to 10 GHz, with continuous coverage above 1.2 GHz; the S-band radar system is in routine operation; the figure of the primary mirror has been readjusted to provide unrivaled sensitivity across the entire spectrum for which an observing capability is offered to researchers; and the atmospheric sciences program has been enriched by the dual beam radar capability. This is the realization of past planning. Looking to the future, we see ALFA as a major initiative in radio astronomy (see NAIC Newsletter, Nov. 2002), the proposed ionospheric heating facility as a major initiative in atmospheric sciences, and the conceptual design of an X-band radar system as the next major initiative in planetary radar astronomy. There is also an opportunity now to consider longer-term initiatives that build on, or even supplant, existing capabilities leading to new “discovery space”. It’s a welcome, and exciting, time of transition.

The multi-feed ALFA receiver will bring with it a new way of observing, new requirements for the management and archiving of spectral line and continuum data bases, and an altogether new paradigm for the involvement of the scientific community with NAIC. ALFA is much more than a receiver capable of generating 7 times as much data in the 21-centimeter band as the existing single-beam receivers. It allows astronomers to develop projects that necessarily require mapping large regions of the sky; in some cases these will be the sort of exploratory research that the Arecibo telescope has proved to be so successful in promoting in the past. But the enormous ALFA data rate also requires astronomers to think in terms of automated systems for data taking, data filtering (for RFI, spectral baseline instabilities or other corrupting effects), validation, calibration, and archival storage such that the data are available for use by others. Groups of astronomers with common research goals are organizing themselves as teams or consortia to share the effort and the benefits from ALFA observations (see Workshops article, page 26). How these consortia share tasks with NAIC to the greatest benefit of all is a question to be answered. There are few applicable models from which ideas may be harvested. This makes considering such issues exciting and important.

We have recently submitted a proposal for a new High Frequency (HF) facility that will permit atmospheric researchers to study the interaction between a powerful radio wave and the ionospheric plasma in a region where strong Langmuir turbulence may be excited (see the following article). The HF facility is an ideal scientific complement to the unique 430 MHz incoherent scatter radar in a quiet magnetic-mid-latitude environment. The NAIC also provides a suite of modern atmospheric optical instruments and the infrastructure to support visiting scientists who bring to the Observatory additional instrumentation and other experimental requirements. HF studies at Arecibo tie together aeronomy, space physics, plasma physics and education in a unique combination that allows for an effective implementation of NSF’s strategic plan for enhancing diversity, making state of the art infrastructure available to the community, and providing opportunities for advance discovery and understanding of science and engineering. Altogether, it’s an exciting prospect.

The planetary radar program is being transferred from NASA sponsorship to the NSF astronomy research portfolio. By necessity, this transfer provides an opportunity to reassess goals as it removes pre-existing constraints. Among the ideas to be considered are moving the radar to a higher frequency, X-band, to achieve even better angular resolving power. The move to NSF also brings with it further creative stimula-

Space and Atmospheric Sciences
Sixto González

Our brief report for this issue begins with the observations over the last two quarters or so. Bob Kerr and John Noto (Scientific Solutions Inc.) visited several times in this period and collaborated with Sixto González Mike Sulzer, Craig Tepley, Raúl Garcia, and Carlos Vargas (all NAIC) to study the topside and exosphere using our ISR and the instruments in our optical lab. For many of the observing campaigns the weather was bad or there were problems with the IR Fabry-Perot that is used for observing the He 1083 nm emission. During the night of October 1, 2002 we observed the effects of a geomagnetic storm on the topside. Figure 1 illustrates some of the results including: 1) evidence for two strong poleward surges in the thermosphere, 2) spread-F conditions right before sunrise, and 3) an He layer that rose and fell in synchronization with the F-region motions. Another campaign occurred in late March 2003 followed by a short campaign in early May.

In the most recent campaign, Bob Kerr was at Arecibo for about a week to study the twilight decay of the O 732 nm thermospheric emission. Together with Craig Tepley and Raúl García, Kerr used our facility’s Fabry-Perot interferometer and Ebert-Fastie spectrometer to measure the O linewidth and intensity during
almost a week.

ers who agreed to be ‘bumped’ off the schedule, which caused them a delay of several evening and morning twilight periods. Skies were generally good, allowing us to gather a reasonable data set for this particular experiment. The purpose of the study was to look for possible evidence of so-called, “hot oxygen” at low-latitudes.

We supported World Day studies in October, November, December and March. The March World Day was a ‘floating’ world day and was moved in response to two X-class solar flares that occurred on March 17 and 18. The observations were successful and we thank all the inconvenienced observers who agreed to be ‘bumped’ off the schedule, which caused them a delay of almost a week.

Qihou Zhou (Miami University), Jonathan Friedman, Craig Tepley, and Shikha Raizada (all NAIC) have been carrying out observations in support of the NASA TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) satellite. These observations include two short (8-hour) validation runs each month and two multi-day periods during the solstices to achieve their science goals.

The first set of observations were in early January 2003, and the first solstice campaign was held from January 28 to February 3 in conjunction with mesopause metals observations of Jonathan Friedman, Craig Tepley, Shikha Raizada, and Qihou Zhou, along with Rubén Delgado (UPR-Río Piedras) and Diego Janches (PSU/NAIC). The

goals of the TIMED project are twofold: first, to validate the TIMED observations through cross-calibrations with ground-based instruments, of which Arecibo is one of many; and second, to coordinate with TIMED observations in an attempt to resolve a number of open questions regarding D- and E-region ionosphere phenomena. The scientific questions include: 1) the ion composition of the D-region, 2) tides and waves in the mesosphere including their latitudinal extent and evolution, and 3) the wind shear mechanism for the formation of Eₐ layers.

Diego Janches continued his regular meteor observations in the months of October through December 2002 and then again in May 2003. In March, he did a great job hosting the meteor workshop described in this issue (page 27). Also in March we received a visit from Paloma Farias Gutierrez and Johannes Wiig (PSU) who came to install a new all sky imaging system. John Mathews’ group at PSU assembled this system using NSF funds. It is intended to be a user owned public access instrument, and we expect to have the images available on-line soon.

Ulf von Zahn (IAP Kühlungsborn, Germany) visited for a little over a week at the end of October 2002. In February and March 2003 Peter Menzel (IAP & U. of Rostok) visited to help establish daytime observations with the K lidar. Also in February, Josef Höffner (IAP) visited for a little over a week to discuss the global structure of the mesopause metals layer and climatology. Lara Waldrop (Boston Univ.) and Farzad Kamalabadi (Univ. Illinois) visited in March. Lara is helping with the analysis of some of the data from the topside campaigns described above, and Farzad is collaborating with our radio science group primarily in the area of optimal inversion of our ISR data.

We recently improved our lidar capabilities by installing a second (new) dye laser in April. That allows us to study three metallic species simultaneously. We pump the two dye lasers by splitting...
Radio Science group:

1. The proposal to reestablish our HF ionospheric interaction facility mentioned in the “State of the Observatory” article was submitted in April 2003. We are currently finalizing a sub-contract for the final electrical design of the facility (antenna feed, transmission lines, baluns, etc.), the completion of which, simultaneous with the proposal review process, will allow the earliest completion date if the project is funded since the final checks on the design will occur at an earlier date. These checks include structural safety studies and evaluation of the impact of operation on the AO facility.

2. Our program to modernize the venerable 430 radar system continues. We are currently obtaining the best performance we have enjoyed in years for single beam operation from the carriage house, but some more work needs to be done to achieve similar performance in dual beam mode. In particular, we need a second very good monoplexer (the device which serves as the final protection for the receiver front end) so that both systems will have the lowest system noise over the full altitude range and will operate reliably under all conditions. We expect this work to be completed over the summer.

3. On a related note, during the month of March we installed and tested a model 5773 klystron. We had no problems in the installation and obtained full power immediately. (For those not familiar with these tubes, they are an updated high efficiency version of the “classic” model 3403’s we have been using for more than 20 years.) We have over a dozen of these tubes that we obtained from Clear Air Force base in Alaska (see November 2002 NAIC newsletter), and so for the first time in may years the ‘spare tube’ situation is well in hand. We are currently considering the best strategy for tube usage. Should we continue using our old 3403s since they might not work after a prolonged storage, or should we realize the benefits of higher efficiency operation immediately?

4. We continue our development of our digital receiver project. The LINUX driver for the Echotek card we have purchased is done, and preliminary tests have been successful. We hope to do an initial test with real data during the summer and have an IF sampling, digitally filtered data taking system in place in the fall of this year for use in at least a few modes. We are currently designing the software for data collection. We have determined that the first feature that we need is a “digital oscilloscope”. The old-fashioned but essential radar “A scope” is no longer effective at the analog level since the bandwidth is too wide. Therefore, it is necessary to display the digitally filtered data (or at least selected subsets of it) in a mode similar to the standard “A scope”.

The Brightest Pulses in the Observable Universe: Observations of Giant Pulses from the Crab Nebula Pulsar

The Crab Nebula Pulsar is famous for its sporadic emission of ‘giant’ pulses. With individual examples reaching brightness temperatures as high as $10^{32}$ K in $\mu$s resolution observations, and much higher ($\sim 10^{37}$ K) at nanosec resolutions, the Crab Pulsar’s giant pulses are the brightest known pulses in the observable Universe. Their study is rewarding in many ways, and they represent important evidence for theories of the pulsar emission mechanism. In addition, they serve as especially sensitive probes of the pulsar’s host, the Crab Nebula. Furthermore, the Crab Pulsar may signify the presence of other source classes in the transient radio universe that could represent targets for proposed widefield telescopes such as LOFAR and SKA.

Of the over-1400 known pulsars, the Crab Pulsar is remarkable for the highly atypical nature of its pulse profile; specifically, for the peculiar, highly unusual, frequency dependence of its pulse structure. In order to characterize the detailed spectral dependence of its pulse components, and the rates of occurrence and statistics of the giant pulses, Jim Cordes (Cornell), Ramesh Bhat (MIT), Tim Hankins (NMT), Maura McLaughlin (Jodrell) & Jeff Kern (NMT) have conducted an extensive multi-frequency campaign of the Crab Pulsar at Arecibo, using all available Gregorian-dome receivers, as well as the Observatory’s fast-dump, real-time correlator system, the Wide-band Arecibo Pulsar Processor (WAPP). Data were taken over a frequency range from 0.43 to 8.8 GHz at time resolutions of $\sim 10–100 \mu$s, from Jan – May 2002. This has led to several interesting results pertaining to the nature of the giant pulses and their frequency dependence, and valuable insights into
the influence of the Crab Nebula on the pulsar’s radio emission.

The observations show that giant pulses occur only in the main pulse (MP) and interpulse (IP) components, and that giant pulses ‘follow’ the IP in pulse phase as it shifts to earlier phases above ~4 GHz (Fig. 1). This may suggest that the same physical region is responsible for both the low-frequency and the shifted high-frequency IP. Further, there is strong evolution of the relative strengths of the MP and IP as a function of frequency; specifically, the ratio of peak IP to peak MP steadily decreases from 0.43 to 2 GHz, stays low from 2.5 to 3.5 GHz, and rises at higher frequencies such that the IP is much stronger than the MP at 8.8 GHz. The strongest giant pulse observed (at 0.43 GHz), with a peak flux density ~130 times the flux of the Crab Nebula (or ~155 kJy), has signal to noise ratio of \(5\sigma\) (Fig. 2). With the Arecibo-WAPP combination, the brightest giant pulses are potentially detectable (5-\(\sigma\)) to distances of ~1.6 Mpc.

The high time and frequency resolutions inherent in the data enabled these observers to identify and quantify frequency structure in individual giant pulses using a scintillating, amplitude-modulated, polarized shot-noise model (SAMPSON). The frequency structure is unresolved at and below 1.5 GHz, but well-resolved between 2 and 4 GHz. Further, the frequency structure associated with multipath propagation decorrelates on very short timescales (~25 ± 5s at 1.5 GHz). These measurements imply a scintillation pattern speed ~540 kms\(^{-1}\), or 3 times larger than the transverse pulsar speed from HST proper motion measurements. The most plausible interpretation is that the multipath propagation is strongly influenced by the Nebula filaments, thus providing useful constraints on filament motions. For example, pulsar-filament distances of ~1 pc would imply transverse filament speeds of ~18 kms\(^{-1}\), and even larger motions for the case of combined effects of filaments and the intervening ISM.

---

The PSR J0407+1607 Binary System

Since Feb 2002, Dunc Lorimer (Jodrell), Kiriaki Xilouris (UVA), Andy Fruchter (STScI), Ingrid Stairs (UBC), Fernando Camilo (Columbia), Angel Vázquez & Jo Ann Eder (NAIC) have been carrying out regular timing observations of the binary msec pulsar, J0407+1607. As detailed in NAIC Newsletter No. 34, this pulsar, discovered in a drift-scan survey by Fruchter in 1994, is a 25.7-ms pulsar in a 669-day orbit about a low-mass (~0.2 M\(_{\odot}\)) companion. Prior to the present timing, a phase-connected timing solution had not been possible due to the irregular spacing of observations, and the large covariances between the orbital parameters and the pulsar position. A solution has now been obtained thanks to the independent detection of this pulsar at Parkes by the McGill pulsar group (Scott Ransom, Jason Hessels, Mallory Roberts & Vicky Kaspi). Follow-up Arecibo observations by that group have resulted in a refined position, allowing the present observations to be
NSF Management Review of NAIC

R. L. Brown

The five year Cooperative Agreement between the National Science Foundation (NSF) and Cornell University for “Support of the National Astronomy and Ionosphere Center for Research in Radio and Radar Astronomy and Atmospheric Science” began October 1, 1999 and will expire September 30, 2004. The governing body of the NSF, the National Science Board (NSB) has recently affirmed its desire that NSF facility management Cooperative Agreements be treated by the NSF with the same competitive, peer-review, process as are research proposals from individual investigators. Here the intent, as with research proposals, is to assure that NSF support is given to those programs that provide the greatest potential for scientific innovation as judged by the scientists most involved in the research fields most affected. To achieve this end, the NSB has stated its position that the decision to award a Cooperative Agreement should result from a competitive process.

The NSF has implemented this directive in three steps. In the first step, the NSF conducts a management review using knowledgeable outside consultants to establish an objective assessment of the role of its facilities, of the community of users each facility serves, of the development plans for the facility as formulated by the facility management, and of the effectiveness of the organization that manages the facility. In the second step, the NSF uses the report of the management review to draft material describing the facility and the NSF goals for the facility to be included in an open solicitation for proposals from organizations interested in operating the facility. The third and final step is the peer-review competition when an NSF-convened panel of scientists and management experts assesses the proposals and makes an award recommendation to the NSF. That recommendation is reviewed by the NSF Director and forwarded with the Director’s comments to the NSB for a decision.

NAIC has completed the first phase of this process. The NSF Cornell/NAIC Management Review Committee met on December 18/19, 2002 at the Arecibo Observatory. The committee was chaired by a knowledgeable Arecibo user, Professor W. Butler Burton, recently retired from the University of Leiden in the Netherlands. Presentations were made by Cornell University officials, Observatory department heads and others. Although it was very difficult in the brief period that was allocated to the presenters to communicate the full scope of activities, progress, plans and problems for any aspect of the Observatory operation, each of the speakers uniformly conveyed a frank and thorough assessment of his or her activity or involvement that was greatly appreciated by the committee. The committee report has been submitted to the NSF.

Over the next approximately 15 months we expect the next two phases of the NSF competitive procurement for the NAIC Cooperative Agreement to occur. We expect this activity to have very little impact on Observatory operations; hopefully it will be invisible to Arecibo users. But the result of this important process, we believe, will lead to a better understanding by the NSF of the unique scientific capabilities and potential of the Arecibo Observatory, and of the research community it serves, that will manifest itself in an increased commitment by the NSF for support of NAIC. If so, Arecibo users will certainly see, and benefit by, that renewed commitment.

properly phase connected. The resulting timing residuals now span over 450 days and are shown in Fig 3.

Using the new solution, the orbital eccentricity of this system is now known to reasonable precision (0.00097 ± 0.00002) and is in line with theoretical predictions for long-period binary pulsars (e.g. Phinney, 1992, PTRSA, 341, 39-75). Further, like the 635-day binary pulsar J2016+1947, discussed by Freire et al. in Newsletter No. 35, J0407+1607 will provide an excellent test of general relativity and in particular the strong equivalence principle. This test, along with other follow-up work, requires an extension to the current timing solution by increasing the existing timing baseline forward and including the earlier timing data. Work on achieving this is now in progress.

The Timing of Upgrade Drift-Scan Pulses

Dunc Lorimer, Maura McLaughlin (Jodrell), Zaven Arzoumanian (GSFC), Kiriaki Xilouris (UVA), Jim Cordes (Cornell), Don Backer (Berkeley), Andrea Lommen (Franklin & Marshall) & Andy Fruchter (STScI) have begun timing observations for the new pulsars discovered by the Arecibo PSPM drift-scan surveys described in NAIC Newsletter No. 35. So far, 11 new pulsars have been confirmed in the survey of over 1000 deg².

Highlights include a 55.7-ms pulsar, J0609+2130, for which an ephemeris has now been obtained, two msec pulsars (still under investigation) and several bright long-period pulsars. Early suspicions that PSR J0609+2130 was a relatively young pulsar (see Newsletter No. 35), proved to be incorrect. Its timing solution, now spanning almost a year, show it to be old (characteristic age ~2 Gyr) with a relatively weak magnetic field (5 × 10⁹ G). J0609+2130 is similar in many respects to J2235+1506, discovered in a pre-upgrade drift-scan survey (Camilo, Nice & Taylor, 1993, ApJ, 412, p. L37) and thought to be a relic of a
disrupted double neutron-star binary system (i.e. a “failed” Hulse-Taylor binary pulsar!). Of the long-period pulsars found so far, the most interesting is J0815+09, it having a most unusual pulse profile (Fig. 4, left) which defies standard classification schemes (e.g. Rankin, ApJ, 1993, 405, p. 285). Single-pulse PSPM data show an extremely ordered pattern in the individual pulses (see Fig. 4, right). The unusual profile morphology and the drifting subpulse behavior are under further study as the timing observations continue.

New Details of Single Pulses and Average Profiles for PSR B0950+08

The wideband Gregorian receivers and new pulsar backends of the Arecibo telescope open up new avenues for single-pulse pulsar studies of unprecedented quality. Leszek Nowakowski (UPR), Neftali Sotero (UPR), Ramesh Bhat (NAIC) & Dunc Lorimer (Jodrell) have undertaken a study of several bright pulsars in the Arecibo sky for details related to the mode-switching, nulling and drifting phenomena. Analysis also aims at the integrated profiles and their relationship to locations of emission regions in the magnetospheres of pulsars. In the first phase of the project, 1175-MHz observations have been made of 5 pulsars using the WAPP backend. This combination of frequency and backend is the most sensitive currently available for Arecibo pulsar studies. Observations were made in polarimetric mode, since one of the goals is to attempt single-pulse polarimetry of these pulsars. Analysis and interpretation are currently underway.

Several new results have emerged from studies of intensity dependence of the pulse structure and stability, illustrated in Figs. 5 & 6 for PSR B0950+08. This pulsar shows both a main pulse (MP) and interpulse (IP); the former is composed of 3 components and the latter 2. The third component of the MP dominates the average profile of the strongest pulses, which is narrower than the average profile of all data. In contrast, the average profile of the weakest pulses is dominated by the second component, and is broader than the average profile. A histogram analysis (Fig. 6) of the locations of these components reveals that the first MP component, albeit prominent in the weakest pulses (up to 6% of the strength of the strongest pulses), is highly stable in its phase within the pulse window. Unlike the other two MP components, which frequently exhibit short drifts in both directions, this component never seems to show any trends of drifting.

The IP structure is clearly double, and is in agreement with the result of Everett & Weisberg (2001, ApJ, 553, p. 341) from pre-upgrade observations. The first component is always the weaker, although it appears more often than the second (Fig. 6). Further, there is evidence for a new, third component that is most prominent in the weakest pulses, in which there is only a trace of the other 2 components. The bridge of emission between MP and IP seems to be fairly stable in its strength, and is most prominent in the weakest pulses. It remains a puzzle whether the MP and IP are emitted from 2 opposite magnetic poles (nearly orthogonal rotator) or from one pole (nearly aligned rotator), where the geometry of the emission region is such that there are 2 maxima per period. Adopting the more commonly favored model of an orthogonal rotator, our results suggest that the weaker pulses are emitted from higher altitudes in the magnetosphere.

The Arecibo 430-MHz Intermediate Latitude Pulsar Survey

Between 1989-91, the 430-MHz Carriage-House receiver (430-CH) was used by José Navarro (then Caltech) to carry out a pulsar survey at intermediate Galactic latitudes (i.e., 7° < |b| < 20°). The motivation for such a survey is that the number of msec pulsars detectable from Arecibo at 430 MHz is predicted to be maximal near \( b \sim 20° \) (e.g., Cordes & Chernoff, 1997, 482, p. 971). This Intermediate Latitude Survey (ILS) covered 130 deg² of sky. A total of 6121 pointings were made, each of 66.4 s duration. The data analysis was completed in 1993, producing 4 detections of previously known pulsars and 13 new pulsar candidates.

It was only in Dec 1997, when the telescope was again able to point post-upgrade, that Stuart Anderson (Caltech), using 430-CH and the PSPM as back-end, confirmed the first 6 new pulsars from...
the ILS, PSRs J1814+1130, J1819+1305, J1828+1359, J2016+1947, J2017+2043 & J2048+2255 (Fig. 7). These were timed for 2 yr, some until early 2000, revealing that 5 are normal, isolated objects with characteristic ages between 7 and 300 $\times$ $10^6$ yr and rotational periods between 284 and 1060 ms. However, the remaining pulsar, PSR J2016+1947, has a rotational period of 63.9 ms, and a characteristic age $> 1.8 \times 10^9$ yr. This pulsar is part of a binary system with a 0.3-M$_\odot$ white-dwarf companion. The orbital period is unusually long for such a system, 635 days, and the orbital eccentricity is $\sim$0.0012. Timing of this binary system was resumed by Paulo Freire (NAIC) in Jul 2002, with the aim of conclusively determining its orbital parameters and characteristic age, made especially difficult by the long binary period. Once these are determined, new and more stringent upper limits on the violation of the Strong Equivalence Principle will probably be obtained (see Newsletter No. 35).

One of the isolated ILS pulsars, PSR J1819+1305, (P = 1.06 s, DM = 64.9 cm$^{-3}$ pc) was later discovered independently in a Parkes survey (Edwards et al., 2001, MNRAS, 326, 358). Paulo now finds that the object nulls for about 50% of the time. The nulls exhibit a remarkable periodicity of about 53 rotations. The emission characteristics of this pulsar are now being studied in more detail by Deshpande & Rankin.

Discovery of PSR J1837+1221 in the same Parkes survey, coinciding in position, period and DM with one of the 7 ILS candidates not confirmed in 1997, motivated Paulo to try confirming the other 6 candidates. So far, 2 new pulsars have been confirmed (Fig. 7): PSR J1756+18, (P = 0.744 s, DM = 71 cm$^{-3}$ pc) and PSR J2050+13 (P = 1.220 s, DM = 52 cm$^{-3}$ pc). It is unclear why these were not confirmed in 1997, but telescope pointing was certainly poor then following upgrade work. These 2
pulsars are now being timed at 327 MHz. The larger bandwidth and lower frequency, plus the larger beam (which reduces problems related to uncertainties in the pulsar position) all contribute to better detections for these 2 pulsars. For this reason, 327 MHz will be used for a new Arecibo drift-scan pulsar survey (see below).

The ILS and the Swinburne Intermediate Latitude Survey detected an average of 1 recycled pulsar per 14 detections, a proportion similar to that of previous 430-MHz Arecibo surveys of the Galactic disk. This seems indicative that the basic assumption that motivated these surveys (more recycled pulsars at the intermediate latitudes) is not founded in reality. This might indicate that the scale height for recycled pulsars is larger than previously thought, and these results will have to be incorporated in future studies of the Galactic pulsar population.

The Arecibo 327-MHz Pilot Drift-Scan Pulsar Survey

A new pulsar survey began on 26 Apr, 2003, the Arecibo 327-MHz Pilot Survey of Paulo Freire (NAIC), Dunc Lorimer, Maura McLaughlin (Jodrell), Jim Cordes (Cornell), Ramesh Bhat (MIT), Michael Kramer & Andrew Lyne (Jodrell). This survey is made possible by several recent advances. One is the installation of the 327-MHz receiver, which has a bandwidth of over 30 MHz, compared to the 10 MHz available with the 430-MHz line-feed (430-CH) system. However, the telescope gain with the 327-MHz system is only 11 K/Jy, compared to 20 K/Jy for 430-CH.

The combination of system temperatures, gains and bandwidths makes these two receivers equally sensitive, in the sense that for the same integration time, a continuum source with the same flux density at the two frequencies would produce detections with similar signal-to-noise ratios. However, pulsars are steep spectrum sources; generally, their flux densities at 327 MHz are about a factor of two larger than at 430 MHz, producing similarly enhanced signal-to-noise ratios. This has been confirmed to be the case for several well-known pulsars. Hence, the 327-MHz receiver increases the distance to which a given pulsar is detectable by a factor of ~√2 compared to the 430-CH system. The volume being covered by a 327-MHz survey is thus ~ (√2)^3, or ~2.8 times, that of a 430-CH survey. As the HPBW is larger at 327 MHz (15°) than with 430-CH (9°), a 327-MHz drift-scan survey should detect up to three times more pulsars per unit time as the prolific Arecibo 430-CH drift-scan surveys, while needing only 0.6 times as many beams to cover the Arecibo sky.

A critical question is that of RFI. Observations by Paulo show that, surprisingly, the situation is considerably better at 327 MHz than at 430 MHz, further enhancing the potential of this receiver for pulsar searches. Such a survey also has the advantage of easy scheduling; any gap in the schedule is useful for the survey.

Another recent development making a 327-MHz survey possible is the high spectral resolution enabled by the WAPP spectrometers. Using 1024 channels and a 256 µs sampling time, this survey retains sensitivity to msec pulsars with DMs up to 100 cm⁻³ pc. The large data volumes generated can easily be stored on Mammoth-2 tapes. Data from the present survey will be analyzed at Jodrell Bank, where Dunc Lorimer & Maura McLaughlin have considerable experience analyzing Arecibo drift-scan data with the COBRA Beowulf cluster. Some data will also eventually be processed at Cornell by Paulo Freire & Jim Cordes.

The Most Perfect Circle in the Universe

PSR J1738+0333 is a msec pulsar of 5.85-ms rotational period. It was discovered in 2001 in a high Galactic latitude survey made with the 20-cm multi-beam receiver at Parkes by Bryan Jacoby (Caltech) & Matthew Bailes (Swinburne, Australia). It is now being timed at Arecibo by Paulo Freire.

This pulsar is a member of a binary system with a 0.1-M₆ white dwarf companion. Of all the pulsar-white dwarf binaries in the Galactic disk, this has the second shortest orbital period, only 8.5 hr. Parkes measurements indicate that its eccentricity is < 10⁻⁵. This is not extraor-
binary, as the eccentricity predicted for this type of system by models that describe MSP formation is of the order of $10^{-7}$. However, because of Arecibo’s much larger collecting area, plus the new L-wide receiver and the option of using 4 WAPPS simultaneously, Arecibo timing measurements can now be much more precise (see Fig. 8).

These timing measurements aim at determining the binary’s precise position, enabling studies at other frequencies, measurement of proper motion and, if possible, the system parallax. They also aim at the possible measurement of a relativistic effect, the Shapiro delay, from which the inclination ($i$) of the orbit and the masses of both components of the system can be obtained. To date, this effect has not been measured for this system, and the inclination of the orbit seems to be quite small. However, this unfortunate fact is not entirely negative as the lack of a Shapiro delay enables a very precise measurement of the orbital eccentricity. Including the data obtained at Arecibo, this is now known to be $< 5 \times 10^{-6}$. Knowing the size of the pulsar orbit about the system center of mass projected along the line-of-sight ($a = 102,000$ km/sin $i$), they can say that the size difference between the semi-major and semi-minor axes of the orbit (given by $a e^2$) is $< 2.5$ mm/sin $i$.

With improved data processing, and more high-precision data, it might be possible to improve the measurement of the eccentricity by a factor of 10. If, as predicted, no eccentricity is measured, we will then know that the orbit does not deviate from a perfect circle by more than $25 \mu$m/sin $i$, or about the size of a human cell. Amongst all the objects known to mankind, this will probably be that which most resembles an ideal, geometric circle. Presently, the record goes to the orbit of PSR J1012+53, known to be circular to within 150µm (Lange et al., 2001, MNRAS, 326, p. 274). Another system being timed at Arecibo, PSR J0751+1807, might be measured to even greater accuracy than PSR J1738+0333.

Such circularity, if very well determined for a set of tight binary pulsars, is interesting for several reasons. It allows measurements of the most fundamental properties of spacetime, like the Lorenz invariance, which is really a statement that empty spacetime is isotropic and has no preferred reference frames. If it is not, then either the motion of the binary relative to the preferred frame, or the anisotropy of space itself, should induce an eccentricity along the direction of motion and/or along the direction of the spacetime anisotropy (Bell, J., 1999, Pulsar Timing, General Relativity and the Internal Structure of Neutron Stars, p. 31). It should be noted that no physical theory of the nature of spacetime capable of explaining the relativistic motion of binary pulsars questions these basic principles (Esposito-Farèse, 1999, Pulsar Timing, General Relativity and the Internal Structure of Neutron Stars, p. 13), but it is still a good thing to improve on the observational limits, as it is impossible to foresee the predictions of future theories of gravitation. With time, this system might also be useful for putting upper limits on the variation of the gravitational constant with time, which is still a topic of debate in cosmology.

The Resolution of Distance Ambiguities for Inner Galaxy Massive Star-Formation Regions

Christer Watson (Wisconsin), Esteban Araya (UPR-RP), Marta Sewilo, Ed Churchwell (Wisconsin), Peter Hofner (UPR-RP) & Stan Kurtz (UNAM, Mexico) carried out the second Arecibo Survey of H110α and H$_2$CO 6 cm lines toward regions of massive star formation in the inner Galaxy. The project’s main objective was to resolve the distance ambiguity of massive star forming regions located in the galactic longitude range of the SIRTF/GLIMPSE survey visible from Arecibo.

Distances to such regions are primarily determined via kinematic methods since the regions are highly obscured by interstellar dust, i.e. photometric determinations are not possible. The kinematic method to determine distance is based on the axially symmetric velocity field of the galactic plane as described by the rotation curve $\Theta(R)$ (e.g. Brand & Blitz, 1993, A&A, 275, p. 67). The inversion of such a velocity field, for a given LSR radial velocity, gives a unique solution for the galactocentric distance (GD). However the LSR distance has two solutions for sources located at GD$_{source} <$ GD$_{Sun}$. This is commonly referred to as the distance ambiguity problem.

Araya et al. (ApJS, 2002, 138, p. 63; see also NAIC Newsletter No. 31) observed the recombination line H110α (4874.15 MHz) and the H$_2$CO $J_{K_a}=1_{11}-1_{10}$ (4829.66 MHz) transition to resolve the distance ambiguity and estimate distances to 20 ultracompact HII regions (UCHII). The same technique has been used in this project for a larger sample (54 UCHII regions in total). The measurements were made with the C-band receiver using standard ON/OFF+diode observations. Five minutes on-source was enough to detect most sources. However, some required 10-15 min on-source to improve the signal-to-noise ratio and confirm weak features in the bandpass.

Figure 9: Spectrum of H$_2$CO (upper) and H110α (lower) toward the massive star forming region G35.04-0.50. The solid line indicates the tangent point velocity. (Courtesy: Esteban Araya)

In addition to the determination of intrinsic properties of massive star forming regions, such as luminosity and presence of extended radio-continuum emission, these observations allow studies of galactic structure. The distribution of the sources observed in this project, plus other regions studied in similar works, is shown in Fig. 10. Despite the data scatter, this figure clearly shows the presence of 3 spiral arms within the 30°–70° galactic longitude range. The results of these Arecibo observations, together with an extended discussion, have been recently published (Watson et al., 2003, ApJ, 587, p. 714). The results reported by Watson et al., in addition to recent GBT observations, are being used by Sewilo et al. (in preparation) for further studies of the kinematics and structure of the Milky Way (see Fig. 11).

Figure 11: Galactic longitude as a function of LSR velocity for several samples, including the present observations. The kinematics of the Perseus arm is well resolved within the Galactic longitude range observed. Clear kinematic signatures of other spiral arms are also detected. (Courtesy: Marta Sewilo)

A C-band Spectral Scan of the Dark Cloud TMC-1

Most known cosmic molecules have been detected in the mm-wave region. This is clearly related to the fact that, in general, the simplest (and hence lightest) molecules are the most abundant cosmic molecular species. Their most intense rotational lines arise at mm and submm wavelengths. Heavier molecules with large permanent dipole moments have detectable rotational lines at lower frequencies in the microwave bands. Transitions between low energy levels are more favorable in terms of line intensities, especially in the regions of low or modest density (e.g., translucent clouds) and low temperature, such as inner parts of dark clouds, which are the coldest gaseous clouds as they have no internal energy sources and are shielded from external sources by their own gas and dust.

Another reason why observations at low frequencies are needed is that the line intensities of molecules less abundant than \( \sim 10^{-12} \) relative to \( \mathrm{H}_2 \) lie below the confusion level in the mm-wave region. In such cases, sensitive observations at low frequencies, which are less “contaminated” by the emission of simple molecules, may help. In addition, hyperfine splitting is often negligible at high frequencies, but detectable at low frequencies (HCN, HCN, etc.). Hyperfine splitting may be used to analyze line opacities and hence to obtain correct molecular column densities and abundances.

In view of these advantages, Sergei Kalenskii, Slava Slysh (ASC, Russia), Paul Goldsmith (Cornell) & Lars Johansson (Onsala, Sweden) observed the famous molecular cloud TMC-1 at low frequencies. The entire Arecibo C-band (4–6 GHz) was observed with an rms sensitivity about 17–18 mK (~2 mJy). In addition, a number of selected lines within the C- and X-bands (8 – 10 GHz) were observed with longer integration times. From the spectral scan, they detected the already known H$_2$CO, HCN & HCN lines. However, in more sensitive observations at selected frequencies they detected lines of CS, CS, C$_2$H, HCN, HCC$^+$CN, HCN, HCN & HCN, about half of which were detected for the first time (Fig. 12). Their results demonstrate that low frequency observations can be useful for the study of cold molecular clouds. Most of the new lines were detected at X-band; therefore molecular observations around 10 GHz seem more promising than those at lower frequencies.

Figure 12: Spectra of hyperfine components of the 2–1 HCN and 5–6 HCN lines and newly detected 1–0 CS and 15–14 HCN lines. (Courtesy: Sergei Kalenskii)
An unexpected result is the weakness of the tentatively detected \( 3_2^2 - 2_2^2 \) C\(_2\)S line at 5402.6 MHz. The C\(_2\)S column density derived from the line intensity and assuming LTE is \( 2 \times 10^{12} \) cm\(^{-2}\), a factor of 20 below that derived previously from higher frequency observations. Very differently, their C\(_3\)S column density (\( 3 \times 10^{13} \) cm\(^{-2}\)) agrees well with that derived previously. This is most likely indicative of the subthermal excitation of the \( 3_2^2 - 2_2^2 \) C\(_2\)S transition.

**OH Zeeman Observations toward Dark Clouds**

Tom Troland (Kentucky) & Dick Crutcher (Illinois) have been carrying out a long-term project to observe the Zeeman effect in dark-cloud cores. The observations have involved sensitive measurements of Stokes parameter I & V line profiles in the quasi-thermal 1665- and 1667-MHz OH lines. These lines have high Zeeman sensitivity and probe \( n(H_2) \sim 10^4 \) cm\(^{-3}\). They aim to test the current "standard model" of low-mass star formation — self-gravitating magnetically supported molecular clumps that undergo core collapse when ambipolar diffusion reduces magnetic support in central regions.

Star formation is known to occur in molecular cores. A key question about this process is the role of the magnetic field. Does the field control the evolution of the cores toward star formation, or does the field play only a secondary role? The role of magnetic fields in a molecular core is determined by the mass-to-flux ratio \( M/\Phi \), a measure of the ratio of gravitational-to-magnetic energies. If the core is pervaded by a poloidal field connected to an external medium, then there exists a critical mass-to-flux ratio \( (M/\Phi)_{crit} = c_B / G^{1/2} \), where \( c_B \) is a constant that depends upon the distribution of mass and flux within the cloud. For a uniform sphere, \( c_B = 1/2\pi \). For convenience they define \( \lambda = (M/\Phi)/(M/\Phi)_{crit} \). As long as flux-freezing is maintained, \( \lambda \) remains constant during core evolution. If \( \lambda > 1 \), the magnetic field alone cannot prevent gravitational collapse, and the core is magnetically supercritical. Such a core must collapse if it does not have support from other mechanisms, such as internal motions. If \( \lambda < 1 \), the magnetic field prevents gravitational collapse regardless of the external pressure. Such a core is magnetically subcritical, and it can never form stars as long as flux freezing is maintained.

In many ways, the critical mass-to-flux ratio of a molecular cloud is analogous to the Chandrasekhar limit. Both parameters define the stability of a self-gravitating system, and both parameters can change with time. If the mass of a white dwarf eventually exceeds the Chandrasekhar limit owing to accretion from a binary companion, then the star collapses and is destroyed. If the mass-to-flux ratio of a molecular cloud eventually exceeds the critical value owing to ambipolar diffusion, then the cloud collapses to form stars.

The parameter \( \lambda \) can be determined observationally from Zeeman effect measurements of the field strength \( B \), and from estimates of the (proton) column density \( N_H \) of a core. This possibility follows from the fact that \( \lambda = B_{crit}/B \), where \( B \) is the average field strength through the core, and \( B_{crit} = 0.60 \times 10^{-21} c_B^{-1} N_H \) (\( \mu G \)). Measurements of \( B \) and \( N_H \) should be made along the symmetry axis (i.e. along the mean field direction) of the core. Otherwise, \( B \) is underestimated since the Zeeman effect is only sensitive to the line-of-sight field strength, \( B_{los} \). Also, \( N_H \) is overestimated if it is measured at an angle to the symmetry axis of an oblate spheroid, the geometry predicted by the simplest magnetic support models. Since \( \lambda \approx N_H/B \), both observational effects result in an overestimate of \( \lambda \). So an individual core that is magnetically subcritical may appear supercritical, instead. Therefore, the question of the value of \( \lambda \), and hence the role of \( B \) in core evolution, must be approached statistically via observations of a large number of cores.

Arecibo is uniquely capable of addressing this issue toward nearby molecular clouds via the Zeeman effect in 1665- and 1667-MHz OH emission lines. The telescope beam is well matched to the sizes of star-forming cores within a few 100 pc. At a distance of about 150 pc (e.g. the Taurus dark clouds) the Arecibo beam samples a region 0.12 pc
across. At greater distances of order a kpc, the beam samples a region of order 1 pc, comparable to the sizes of molecular clumps containing $10^3$–$10^4 M_\odot$. The system temperature in the upgraded system is low (~40 K with the original L-band wide receiver, now ~25 K with the new system) for all but the highest zenith angles. Hence, a 1-σ sensitivity of 2–5 µG is reached after 10 hr integration toward a typical molecular core. No other known technique (including the Zeeman effect in other molecular species) offers this level of sensitivity to magnetic fields in molecular cores. Finally, instrumental circular polarization with the L-band wide feed is low (Heiles, Arecibo Technical & Operations Memo, 99-02).

The first results from this survey included a detection of the OH Zeeman effect toward the Taurus dark cloud core L1544, with $B_{\text{los}} = +11 \pm 2$ µG (Crutcher & Troland, 2000, ApJ, 537, p. L139). This field strength implies $\lambda > 1$, or too weak a magnetic field to support the cloud against gravity. Evidence has been presented by others suggesting that L1544 has infall motions and may be collapsing. The observations of the Perseus-Taurus region have now been completed, and analysis is underway. An example result is the strong detection (as yet unpublished) obtained for L1448 (Fig. 13), for which $B_{\text{los}} = -26 \pm 4$ µG. Observations of the Cygnus region are just beginning.

By the end of this project, Tom & Dick will have sensitive observations of magnetic field strengths toward several dozen dark cloud cores. These data will enable a statistically meaningful study of the mean value of mass-to-flux ratios in cores and answer the question of whether magnetic fields control the process of star formation.

**OH/IR Stars with 2MASS Counterparts**

Derek Kopon (Cornell), Murray Lewis (NAIC) & Yervant Terzian (Cornell) identified 134 (32%) of the Arecibo OH/IR stars ($0^\circ < \text{Dec} < 38^\circ$) with 2MASS counterparts using data from the second release. The whole 2MASS dataset is available as of 27th March 2003, and its J, H, & K magnitudes allow a J-H v H-K plot for 121 of the stars. This is known to exhibit a linear correlation for OH/IR stars, in which the most translucent shells have the hottest colors (small index values) ~1600 K, and the most opaque colors ~550 K. However, the patently detached shells of proto-planetary nebulae (PPN) with very red IRAS colors are also known to map back along the locus, rather than extending its red end; such shells are far more transparent in the near-IR than their IRAS colors would otherwise suggest, so old PPN can have very blue near-IR colors. However, this reasoning can be reversed; by coding the Arecibo sample of shells relative to a (25-12) µm color threshold of $-0.25$, $-0.30$, $-0.35$, etc. successively, which is a measure of the thickness of the dusty shell, one finds that MOST (~85%) of OH/IR stars map back along the color locus, and therefore must have detached shells. This is illustrated in Fig. 14 with the subset having (25-12) µm $> -0.25$. While some of the objects with detached shells evolve immediately into PPN, the majority are expected to repeat a cyclical mass-loss phase. The paucity of normal shells undergoing secularly stable, copious mass-loss while exhibiting 1612-MHz masers implies that the 1612-MHz emission phase in most stars is very brief. Consequently, most heavy mass-loss from AGB stars is seemingly tied to developments accompanying the rapid changes in luminosity following a He-shell flash on the core of the star, the only evolutionary phase with comparably brief changes. This conclusion inverts our current paradigm.

**Probably the Most Sensitive VLBI Yet: The Supernova Remnants in Arp 220**

The merging galaxy Arp 220 is among the most intensively studied of extragalactic objects, and for good reason. As the prototypical luminous infrared galaxy, it exhibits extreme far-infrared luminosity (~ $10^{12} L_\odot$), and a wide variety of molecular lines originating in an extremely dense central condensation of dusty gas. It is also the prototypical OH megamaser galaxy, and is the system in which pc-scale OH megamaser features were first discovered. The unique status of Arp 220 arises because at a distance of only 76 Mpc, it is the nearest example of a truly powerful IR galaxy, and the associated phenomena can thus be studied in greater detail than in any other such galaxy. It is the focus of considerable attention in the search for unambiguous evidence of starburst or AGN activity, in order to shed light on the ultimate origin of the quasar-like bolometric luminosity, and on the possibility of an evolutionary sequence triggered by galaxy merger events.

In 1996, what was then one of the largest VLBI experiments ever was conducted on Arp 220, using the compact OH maser peak as a convenient phase reference. This permitted continuum imaging of the galaxy with high sensitivity, revealing the existence of roughly a dozen unresolved sub-mJy point sources scattered across the nuclear region of the galaxy. This was interpreted as spectacular evidence of an ongoing burst of intense star formation traced by radio supernovae (RSN). Both the OH maser results (Lonsdale et al., 1998, ApJL, 493, p. L13) and the continuum results (Smith et al., 1998 ApJL, 493, p. L17) have significant implications for the field. However, these studies were
severely sensitivity-limited, allowing only modest spectral resolution on the masers, and probing only the peak of the RSN luminosity function. Nearly all the RSN were found in the westernmost of the two nuclei in Arp 220, and only 2 very faint candidates were seen in the eastern nucleus.

In Nov 2002, a new VLBI experiment was conducted by Colin Lonsdale (Haystack), Carol Lonsdale (IPAC), Gene Smith (UCSD) & Phil Diamond (Jodrell) which included several large European dishes, the VLBA, the phased-VLA, the GBT, and Arecibo. When combined with almost continuous recording at a rate of 256 Mbit/sec, this experiment is probably the most sensitive VLBI observation to date. A preliminary continuum image, Fig. 15, boasts a rms noise level of only 8 µJy/beam, and this can be reduced by further processing to perhaps as low as 6 µJy/beam. The more than 3-fold improvement in SNR afforded by Arecibo, the GBT and a wider recording bandwidth has resulted in the detection of roughly 30 RSN candidates in Arp 220, about 10 of which are found in the eastern nucleus. The brightest source in the field of view is slightly below 1 mJy.

This preliminary image constitutes dramatic evidence that intense star formation is occurring in both nuclei, and not just the western one. It is of particular importance to deduce the supernova rate in luminous IR galaxies as a measure of the intensity and luminosity of star formation activity. By probing the luminosity function of these RSN more deeply with the new observations, and combining the data from several epochs to develop accurate light curves, a refined estimate of the RSN rate will be possible. Further data processing will reveal many more details about the maser emission. For example, weak maser amplification along lines of sight to the 30 RSN candidates will constitute a valuable probe of detailed properties in regions inaccessible to other techniques because of opacity and lack of resolution. Future VLBI observations with Arecibo may have the sensitivity to observe these phenomena in other IR galaxies.

The Variability of OH Megamasers

Jeremy Darling (Carnegie) has undertaken, (1) a long-term monitoring program of four OH megamasers (OHMs), and (2) a program to characterize short-term variability of two OHMs with strong emission lines (the time-scales sampled range from 1 day to about 1 month). Long-term monitoring is designed to measure or constrain accelerations in OH lines due to orbital motions in gas. As is seen in nearby OHMs, the masing gas often appears in the form of a torus suggesting a large concentration of mass, and accelerations in lines combined with some information about the geometry of the masing gas can indicate a geometrical distance, as it has in the water-maser galaxy NGC 4258. Short-term monitoring constrains the size scales of variable and quiescent masing regions and provides strong constraints on maser models and the physical setting for OHMs. The monitoring on one of the proposed OHMs, IRAS 02524+2046, was completed in January 2003 (see Fig. 16). Extra time was requested on this object to study the daily fluctuations seen in many line components. Jeremy hopes to find signatures of delays in the data which would be indicative of angular separations between masing components and provide a crude geometrical picture of the masing. However, this will depend on good models of interstellar scintillation.

The Magnetic Field in a Damped Lyman-Alpha Absorber

Wendy Lane (NRL) & Carl Heiles (Berkeley) have attempted to measure the magnetic field in the z=0.0912 HI 21cm/Damped Lyman-alpha absorption system towards the quasar B0738+313 via Zeeman splitting. This system is one of the strongest known redshifted 21-cm absorbers visible from Arecibo, making it an ideal candidate for this experiment. Preliminary results indicate that the upper limit on the strength of the line-of-sight magnetic field is \( B_L = 2 \pm 2.25 \mu G \). This is consistent with measurements made in HI clouds in our Galaxy. As Zeeman splitting is not sensitive to magnetic fields oriented perpendicular to the line of sight, no conclusions can be drawn about the total magnetic field in this system.

**Figure 17:** The HI absorption spectrum of 3C258 expressed as fractional absorption vs radial velocity, where fractional absorption = \((S_{\text{cont}} - S(\nu))/S_{\text{cont}}\), being the “unabsorbed” continuum flux density of the source. The dotted lines show the 6 Gaussian components fitted to the spectrum, while the crosses mark the residuals after these are subtracted from the spectrum. (Courtesy: Tapasi Ghosh)

**Detection of HI Absorption in 3C258**

Compact Steep Spectrum (CSS) radio sources are a subclass of FRII radio sources having both linear sizes of less than 20 kpc and steep high frequency radio spectra. Observational evidence implies that these objects are young, and asymmetrically distributed gas is found close to their nuclei. In a search for HI absorption and OH emission or absorption against a sample of 16 CSS and other radio sources, S. Jeyakumar (U. Koeln, Germany), D.J. Saikia (NCRA, India), Chris Salter, Tapasi Ghosh (NAIC) & Juergen Stutzki (U. Koeln, Germany) have found a complex, multi-component HI absorption system towards 3C258.

The CSS radio galaxy, 3C258, lies at a redshift of 0.165, and has two radio lobes separated by only about 380 pc. Assuming a spin temperature of T (K), and a covering factor of unity, the total neutral-hydrogen column density is about \(4.5 \times 10^{18}\) T cm\(^{-2}\). Six Gaussian components with rather narrow velocity widths (half-height widths between \(\sim 4\) and 10 kms\(^{-1}\)) fit the feature well (Fig. 17). Compared to other known CSS HI-absorption spectra, 3C258 contains probably the most complex absorption system, with the fitted components having about an order of magnitude narrower velocity widths than most features in other CSS sources (e.g. Vermeulen et al., AstroPh/0304291).

Although detailed modeling of the HI gas seen in absorption in this galaxy will require VLBI imaging of the line and continuum emission, it is difficult to imagine that a single rotating disk/torus would produce such a complex absorption system. It may be that jet-ISM interactions play the dominant role in shaping the structure/properties of the object. In fact, the signature of disturbance is perhaps already evident in its optical image. The HST image of 3C258 (Fig. 18, reproduced from De Vries et al., 1997, ApJS, 110, 191) displays arc-like structure of high surface brightness, with a larger, fainter tail extending to the northeast, roughly perpendicular to the bright central arc. The overlaid radio continuum image (5-GHz MERLIN; Akujor et al., 1991, MNRAS, 250, 215) is at right angles to the central region and contains the entire VLBI double-lobe structure (Sanghera et al. 1995, A&A, 295, p. 629).

Neither OH absorption nor OH mega-maser emission is detected against 3C258 or any other of the radio sources observed. This is of interest given the conclusions of Darling & Giovanelli (NAIC Newsletter, No. 31) who searched for OH megamasers in nearby AGN which are undetected by IRAS, but failed to find OH lines associated with AGN in quiescent (non-interacting) systems, placing stringent limits on the influence of AGN in forming OHMs in non-interacting galaxies.

**A Search for Low Mass HI Clouds in the Local Hubble Volume**

Riccardo Giovaneli, Kristine Spekkens, Chris Springob, Karen Masters, Barbara Catinella & Martha Haynes (Cornell) have begun a spectral line mapping program designed to detect HI clouds down to a mass limit of \(10^{6.5}\) M\(_{\odot}\) in the very local universe. While the main objective of this program is to probe the faint end of the HI mass function, it will also allow a comparison of the quality of baselines derived from drift-scan and on-the-fly (OTF) mapping, a question with significant ramifications for future ALFA extragalactic HI survey strategies. Furthermore, this pilot project will be useful in developing software and analysis tools necessary to tackle the massive amounts of data that will be produced by ALFA projects. The first 100 hr of observations were made in Jan and Apr, 2003. This allocation amounts to one third of the time that simulations predict will be...
needed to derive a statistically meaningful result.

CDM numerical simulations predict the existence of large numbers of low-mass halos, well in excess of the faint tail of the galaxy luminosity function. This prediction has prompted the reevaluation of the idea that some, relatively compact, high velocity HI clouds may be the “missing” population of low-mass halos in the Local Group. Large blind HI surveys (with few systems detected with $M_{\text{HI}} < 10^8 \, M_\odot$, and almost none with $M_{\text{HI}} < 10^7 \, M_\odot$) disagree by an order of magnitude in the estimate of the space density of objects with masses of $M_{\text{HI}} \sim 10^7 \, M_\odot$. The current survey aims at resolving this discrepancy.

The program takes advantage of the fact that the ratio of low-mass to high-mass halos in numerical simulations appears to be the same in high and low density regions. Square-degree sized fields are mapped, centered on known galaxy groups for which primary distance indicators give distances of 3–10 Mpc. Maps of this size will inevitably include a large number of continuum sources (as is seen in the map of the NGC 2683 region shown in Fig. 19), which provide a challenge in the data reduction process.

The observing mode varies as a function of the target group’s distance. The more distant groups required 12 s (or more) integration per beam to achieve the required HI mass limit. Therefore, observations of those areas were made in drift-scan mode. Nearer groups were observed using OTF mapping, with a slew rate set such as to reach the mass limit (3 s per beam in the fastest case).

Preliminary results suggest that short integration time OTF mapping, in which the telescope is driven at a rate of up to half the maximum slew speed, results in data quality that is indistinguishable from data taken in drift-scan mode. That is, the channel-to-channel rms is the same in both cases, and no long period oscillations are introduced by the fast slew rate. Preliminary quantitative results were presented by Kristine Spekkens at the Extragalactic ALFA workshop held at Arecibo in March (see: http://alfa.naic.edu/extragal/meeting1/minutes/ALFALFAsprouts.html).

These observations represent just the first step in a larger HI mapping project, with more surveys planned for use with ALFA, with the goal of achieving survey coverage across the entire Arecibo sky. On-going work involves experimentation with the best methods to perform bandpass calibration and subtraction, continuum cleaning, beam characterization and deconvolution, noise characterization, and HI signal detection and extraction.

### Calibration of the SDSS Spectroscopic Line Width Scaling Relations

Determination of the rotational parameters of disk galaxies is of crucial importance for several areas of observational cosmology, ranging from galactic structure and dynamics, to galaxy formation and evolution across cosmic time. In particular, scaling relations such as the Tully-Fisher (TF) relation are used to determine the extragalactic distance scale, map the large-scale velocity and mass distribution, and constrain N-body simulations of cosmological scenarios. The latter suggest that disk scaling relations should change as galaxies evolve. For example, even at modest redshifts ($z \sim 0.4$), it is suggested that the co-moving star formation rate is higher than today so that, for a given gravitational potential, the associated luminosity may be higher by a factor of 3. It is thus important to ascertain the scale within which a relation such as TF yields cosmologically unbiased results and to determine how the mass-to-light ratio $M/L$ varies with lookback time, a diagnostic of galaxy evolution. Several recent studies based on optical spectroscopy reveal an intriguing state of conflict in this field. Results vary between the inferences that, even at modest redshifts, $M/L$ is substantially different (in excess of a magnitude) from that at $z=0$, to ones that infer no significant change out to $z \sim 1$.

At low $z$, rotational widths are usually derived either from HI line profiles or via optical Hα rotation curves. At higher $z$, long-slit/IFU spectroscopy currently exists for only a few dozen objects. In contrast, the large on-going Sloan Digital Sky Survey (SDSS) promises to deliver, over the next few years, a million galaxy spectra from which linewidths can be derived. The main obstacle to applying the copious SDSS linewidths for comparison with similar scaling relations at low $z$ arises from the need for common calibration of the wide measures obtained using fundamentally different techniques and over the largest possible redshift range. The SDSS fiber diameter limits the spatial scale over which the linewidth is measured, so that its measures are most applicable at intermediate to high $z$. Since the most prominent Hα line can be traced only up to $z < 0.4$, application of the method to higher $z$ will require use of linewidths from other species such as [OII]λ3727Å and [OIII]λ5007Å. It is therefore impor-
Jeff Gardner (U. Pitt), Barbara Catinella, Martha Haynes, Riccardo Giovanelli (Cornell) and Andy Connolly (U. Pitt) observed the HI emission from a sample of galaxies with $0.04 < z < 0.09$ that are included in the SDSS spectroscopic survey and for which optical long-slit spectra have already been obtained with the Palomar 5-m telescope. A detection rate of 85% was achieved; use of the radar blanker proved critical to avoid RFI from the FAA radars. Total integration times between 25 and 250 min were required in order to achieve an average rms noise of about 0.3 mJy and peak signal-to-noise ratio >6, depending on the HI content and profile width. Widths have now been extracted and a comparison is being made of the linewidths measured by different tracers/techniques and with the results of simulations of the instrumental limitations. The cross calibration of the optical and radio TF relations constitutes a major part of Barbara Catinella’s Ph.D. research at Cornell.

Fig. 20 shows the HI profile for the galaxy AGC 241061, the fastest rotator in the target sample, showing an observed HI line width of 786 km s$^{-1}$, and that which required the longest integration time (250 min). Figs. 21 & 22 show the corresponding H$\alpha$ rotation curve (obtained at Palomar) and the I-band image (obtained at Kitt Peak).

**Local Group Studies**

Tim Robishaw, Josh Simon & Leo Blitz (Berkeley) used two observing runs in the second half of 2002 to continue their Arecibo investigation of an apparently interacting system that consists of a high-velocity cloud (HVC) and a Local Group dwarf galaxy. The HVC was discovered by Robishaw, Simon & Blitz (ApJ, 2002, 580, p. L129) during their survey of Local Group dwarfs observable with Arecibo. Due to the faint HI tails that they saw extending away from the main body of the HVC, and the proximity of the HVC to the Local Group dwarf spheroidal galaxy LGS 3, they proposed that the two objects were interacting tidally. Already unique because of this possible interaction (implying a distance of ~700 kpc to the HVC), the HVC was rendered even more intriguing by the finding that it contains a smooth velocity field indicative of rotation: the HVC has a 16 kms$^{-1}$ gradient along its major axis. The rotation curve of the HVC shows that it is dark matter dominated, with 80% of its mass in dark matter if it is located at 700 kpc; the ratio of total-to-HI mass gets larger if its distance gets closer.

The first new data set acquired by Tim, Josh & Leo consists of an on-the-fly map covering a similar area to the published one, but with much more integration time and a corresponding increase in sensitivity. They also made the new map about 30’ wider to facilitate the use of their standing-wave removal routine (see Robishaw et al. 2002, or NAIC Newsletter No. 33). This map, displayed in Fig. 23, shows the tidal tails much more clearly than the original lower sensitivity data. The tails can now be seen as spatially continuous structures, and their connection to the main body of the HVC is obvious. One feature of the tails that will certainly receive further study is
their apparently discontinuous velocity field. These observers recently made a VLA mosaic of the HVC and LGS 3 that they will combine with the Arecibo map to increase the angular resolution by a factor of four. With the high-sensitivity, high-resolution combined map, they will test the tidal interaction hypothesis by comparing it with theoretical models. This, they hope, will elucidate the history of the system and provide further constraints on the structure of the HVC.

For the second set of new observations, Tim, Josh & Leo mapped out a much larger area (4° × 6°) centered on the HVC in order to check whether this region contained any other unknown HI clouds. They verified that the HVC and LGS 3 are the only HI-rich objects within several degrees; however, they also discovered that the western tail of the HVC extends much further to the southwest than had been revealed by their previous maps.

They also mapped their ninth Local Group dwarf galaxy, the dwarf irregular IC 1613. This new map (Fig. 24) shows some of the small-scale structure in the ISM of IC 1613, including a bright cloud (T_e = 18 K!) east of center and two HI holes near the center. The very low-amplitude rotation of this galaxy is also visible in their data. This is the first Nyquist-sampled single-dish map of IC 1613. They plan to use the data from the 9 dwarfs to study the radial profiles of velocity dispersion and HI column density in dwarf galaxies. The HI distributions at low column densities can be compared to the predictions of current theories about the behavior of neutral gas when subjected to the metagalactic UV radiation field (e.g., Sternberg, McKee & Wolfire, 2002, ApJS, 143, p. 419), while the velocity dispersions of gas in the outer parts of dwarfs can be used to test the hypothesis that dwarf galaxies have much larger dark matter halos than previously realized (Stoehr et al., 2002, MNRAS, 335, p. L84; Hayashi et al., 2003, ApJ, 584, p. 541).

**An HI Survey of Nearby Luminous Compact Blue Galaxies**

Recently, D.J. Pisano (ATNF), Catherine Garland, Jonathan Williams (Hawaii), Rafael Guzman (Florida), & Francisco-Javier Castander (IEEC-Barcelona) began a study of the HI content and kinematics of nearby Luminous Compact Blue Galaxies (LCBGs) as part of a larger multiwavelength campaign to better understand their more distant analogs. LCBGs at intermediate redshifts are blue, vigorously star-forming, high surface brightness galaxies which undergo dramatic evolution. They are not necessarily related to the more commonly known Blue Compact Dwarfs. At z~1, LCBGs have a total star formation rate equal to that of grand design spirals, but their number density is decreased by an order of magnitude by z~0. It is not known what drives their rapid evolution, nor what is their final state.

To date D.J. and collaborators have obtained HI spectra for 14 nearby LCBGs selected from the Sloan Sky Survey using Arecibo in service observing mode. The observations were conducted by Héctor Hernández (NAIC), and were of very high quality. Based on a preliminary analysis of these galaxies and others observed with the GBT, nearby LCBGs are HI-rich, with masses ranging from 5×10^8 to 9×10^9 M☉, and have large dynamical masses, ranging from 5×10^10 to 2×10^11 M☉. Using IRAS fluxes to determine star formation rates, they find that their sample has gas depletion time scales ranging from 5×10^8 to 10^10 yr. These properties imply that while LCBGs are a diverse collection of galaxies, they tend to be high mass objects which have the potential for future bursts of star formation. They will be observing more LCBGs at Arecibo in the coming year yielding data on all 70 LCBGs within 200 Mpc.

**The Effect of the Cluster Environment on Galaxy Evolution in the Pegasus I Cluster**

Understanding the rapid evolution of the star formation rate in rich clusters of galaxies since z=0.5, first documented by Butcher & Oemler (1978, ApJ, 219, p. 18; 1984, ApJ, 285,p. 426), remains a central issue in extragalactic astronomy. Subsequent spectroscopy and HST imaging has revealed a higher fraction of spiral galaxies in distant clusters than in present epoch clusters (Dressler & Gunn, 1983, ApJ, 270, p. 7; Dressler et al., ApJS, 122, p. 51). The heart of the problem, then, is to explain the rapid evolution in the spiral population since z=0.5 and, in particular, how they can be so effectively
transformed into S0 galaxies in present epoch clusters. It has long been evident that the cluster environment is capable of removing the gas from a galaxy via ram pressure stripping (Gunn & Gott, 1972, ApJ, 176, p. 1). However, several tidal perturbation scenarios have also been suggested that could drastically deplete the ISM in spiral galaxies by inducing large episodes of star formation (Moore et al., 1996, Nature, 379, 613; Bekki, 1999, ApJ, 510, p. L15).

While the most dramatic evidence for evolution in cluster galaxies is seen at higher z, several studies have revealed a surprising amount of similar evolutionary processes ongoing in nearby clusters, albeit at a reduced level (Caldwell et al., 1993, AJ, 106, p. 473; Caldwell & Rose, AJ, 113, p. 492). Recently, Lorenza Levy & Jim Rose (UNC) have been approaching the important issue of what transforms spirals into S0’s by concentrating on nearby clusters, where the increased spatial resolution and S/N ratio allows far more diagnostic information to be extracted regarding the relative roles of gas removal mechanisms.

Their study has focused on obtaining HI observations of the Pegasus I cluster for the purpose of identifying the cluster mechanism responsible for the observed evolution. The Pegasus cluster represents a unique environment, of particular interest because it has a richness similar to the Virgo cluster, while at the same time a virtually undetectable level of X-ray emission, and very low velocity dispersion. The low velocity dispersion, coupled with the lack of a dense hot ICM, indicates that ram pressure stripping should not play a significant role in this environment. Nevertheless, important environmental effects are taking place in the cluster, as a number of early-type galaxies exhibit evidence for recent, centrally concentrated, star formation. Thus Pegasus I provides an unusual situation in which to isolate the effects of tidal perturbation on the evolution of its galaxies, unless tidal stripping is more effective in low velocity dispersion environments than previously considered.

It has recently been shown, contrary to previous studies (Bothun, Schommer, & Sullivan, 1982, AJ, 87, p. 725), that at least some spirals in Pegasus I have a deficiency in HI content (Solanes et al., 2001, ApJ, 548, p. 97). This has very important implications with regard to the evolution of cluster galaxies, i.e., ram pressure sweeping may play a significant role in galaxy evolution in a wider variety of environments that previously considered. Lorenza & Jim’s main goal is to clarify the conflicting claims regarding whether there is HI depletion in spirals in the Pegasus cluster. Resolving this issue is fundamental to determining whether ram pressure stripping is effective in a wider variety of cluster environments than previously thought.

With the above goal in mind, they have acquired new 21-cm observations of 48 spiral galaxies in the Pegasus I cluster, with the improved sensitivity of the Gregorian feed system. Uncertainties in the HI fluxes have now been reduced to the point where other uncertainties, i.e., optical angular diameters, apparent blue magnitudes, and morphological types, now represent the principal error in diagnosing HI depletion in the Pegasus spirals. With their new HI observations, in conjunction with better blue magnitudes than were available for previous studies, they conclude that there is no sign of overall HI deficiency for spirals in the Pegasus I cluster. Although there may be isolated cases of individual galaxies in Pegasus I with a smaller HI content than expected for their size and morphological type, these are clearly the exception and not the norm in the cluster.

“Blue Edge” Galaxies in the Pisces-Perseus Field
Juan Cabanela & Megan Roscioli (Haverford) have made HI observations to acquire a large enough sample of “blue edge” galaxies in the Pisces-Perseus supercluster (PPS) region to map out their distribution relative to the large-scale structure of the PPS. The scientific goal is to obtain a better understanding of the environments that host Low Surface Brightness (LSB) galaxies and, as established in Cabanela & Dickey (2002, AJ, 124, p. 78), the “blue edge” galaxies (named for their location in a POSS I color-magnitude diagram) appear to be LSB galaxies as well. An examination of the z distribution of the 19 “blue edge” galaxies detected by Cabanela & Dickey revealed that these have a very similar redshift-space distribution to those “normal” high surface brightness galaxies already cataloged in the PPS field. Based on this finding, Juan & Megan were awarded Arecibo observing time to make HI observations of over 150 “blue edge” galaxies in the Pisces-Perseus field in the hope of building up a catalog of LSBs there. The observations were completed over 9 nights in Sept & Nov 2002. From 150 targets, they detected some 86 of their “blue edge” galaxies in HI, meaning that they now have identified over 100 likely LSBs in the field of a single supercluster.

An initial result from a “by eye” examination of the z distribution of their...
Solar System Studies
Don Campbell, Mike Nolan, and Ellen Howell

Venus revisited:

The exploration of the surface of Venus under the planet’s thick cloud cover was one of the telescope’s prime objectives during the early years of Arecibo and was a major motivation for NASA providing the funds for a high powered S-band radar transmitter during the first upgrade of the telescope in the 1970s. Arecibo observations of Venus through the mid-1980s made the first images of the planets surface with sufficient resolution that different terrain types could be clearly recognized. Impact crater counts derived from these images provided the first solid evidence that the surface of Venus was quite young with an average age of less than one billion years. In the years just prior to the Magellan mission to Venus, the Arecibo imagery was one of the main resources for studies of the planet’s surface.

With resolutions of 150 m to 250 m Magellan synthetic aperture radar (SAR) images of the surface of Venus obtained in the early 1990s have about ten times better resolution than can be obtained with Arecibo, so there was little interest in Arecibo radar observations of the planet over the following decade. However, the Magellan radar was a single polarization radar transmitting and receiving horizontal linear polarization and could not study the polarization properties of the reflected signal. These properties are sensitive to the presence of thin deposits on the surface and provide some information about their electrical properties. A fraction of the radar wave is reflected from the atmosphere-surface interface with the remainder transmitted into the surface where it is normally absorbed. However, in the case of a thin (no more than a few wavelengths) surface layer overlying a higher refractive index subsurface the transmitted wave will be reflected from the underlying subsurface through the surface layer and contribute to the radar echo power. For a purely circularly polarized incident wave, which has equal amplitudes in any two orthogonal linear polarizations, the reflected wave will be partly linear polarized since, for a smooth atmosphere-surface interface, the reflection and transmission coefficients depend on the orientation of the linear polarization relative to the plane of incidence. Hence, the presence of linearly polarized power in the reflected echo is indicative of penetration and subsurface scattering of the incident wave. Tor Hagfors, a former NAIC Director, pioneered this technique in the 1960s for studies of the lunar regolith and it was greatly refined by former Cornell graduate student Nick Stacy for further studies of the Lunar surface.

The greatly improved post upgrade sensitivity of the Arecibo S-band radar system made such measurements possible for Venus. From observations in 1999 and 2001 Cornell graduate student Lynn Carter has made images of the surface of Venus in all four polarization Stokes’ parameters and mapped the degree of linear polarization over the surface. There are a surprising number of features in the maps strongly correlated with such terrain features as impact crater haloes, volcanic dome fields, and wind blown deposits indicating that significant areas of the surface of Venus are covered by thin deposits of, probably, fine grained material. This means that the surface of Venus may look surprisingly different in visible wavelength images than it does at the 13 cm wavelength of the Magellan radar due to the penetration of the radar wave into the surface. Figure 1 shows the Arecibo degree of linear polarization image and the Magellan radar image of a region around the small 6 km diameter crater Nelike.
Updates on the Asteroid Observing Program

Asteroid 2002 NY40 passed within 0.0035 AU of the Earth (1.4 times the distance of the moon) on August 18 and was observed at a number of optical/infrared telescopes and radar systems, including the Arecibo 12.6-cm radar. Due to the very short round-trip-light travel time, the observed Doppler bandwidth, (as low as 3.8 seconds) we performed a bi-static observation with reception of the radar echo at both Arecibo (when possible) and the 100-m Greenbank Telescope (GBT) of the National Radio Astronomy Observatory. A series of range-Doppler images taken of this object is shown in Figure 3. The part of the asteroid closest to the earth is at the top of the images with distance along the line-of-sight from the earth (range) increasing from top to bottom, and Doppler frequency increasing to the right. The overall appearance is that of two lobes joined together, similar to other apparent ‘contact binaries’ that have been observed. On August 18 the two lobes are at roughly the same range, and we estimate the range depth of 22 and 16 image pixels implying 165 and 120 meters radii for the left and right lobes respectively. If the lobes are roughly spherical, the long axis is then at least 570 meters. The observed Doppler bandwidth, which indicates the projected rotation velocity in the line of sight, was largest on August 16 at 0.84 Hz. The rotation rate of 2002 NY40 was determined from optical lightcurves (the variation in the amount of reflected sunlight as the asteroid rotates) to be 19.99 hours. Using this rotation rate, the observed bandwidth requires a linear extent of 610-m. It is likely that on this date the viewing geometry was near the equator so that the true extent of the asteroid is close to 600 m. This then gives an average optical albedo (reflectivity) of 0.17 ± 0.03, using the H magnitude of 19.669 ± 0.128 determined by M. Hicks from photometry at Table Mountain Observatory.

Ellen Howell (NAIC) and collaborators also obtained near-Infrared spectra of this asteroid using the NASA Infrared Telescope Facility in Hawaii. The medium resolution spectrometer, SpeX, was used to measure the reflectance spectrum from 0.8 to 2.5 microns. They also observed in the 2.6 to 3.5 micron region, which has a significant thermal component longwards of 3.0 microns for objects near 1 AU. The reflectance spectrum is a remarkably good match to LL6 ordinary chondrites. Thermal modeling in the 3 micron region gives an estimated albedo of 0.15 – 0.25, which is consistent with the value of 0.17 ± 0.03 obtained from the radar images. Laboratory measurements of LL6 ordinary chondrites show albedos closer to 0.2, but with a wide range of values within a single meteorite.

It is unusual to find asteroid and meteorite spectra that match this closely. This may be in part because it is rare that near-Earth asteroids are as well observed as 2002 NY40, with shape estimates from the radar observations and high-qual-

A Lunar excursion:

Bruce Campbell (National Air and Space Museum) and collaborators are scheduled to perform 70 cm radar observations of the Moon in June aimed at imaging the south polar region and other areas. This relatively long wavelength is being used in order to penetrate the maximum distance into the lunar surface to search for subsurface ice deposits at the south pole and to possibly penetrate the full depth of the regolith in other areas. Results from earlier Arecibo observations by the same group are shown in Figure 2.
The asteroid 4 Vesta has an enigmatic surface. It is the second largest in the asteroid belt. It cannot be extremely heavily cratered, as its surface is chemically the crust of a differentiated object, which would be removed by heavy cratering. Yet many meteorites (the “HED” achondrites) and small asteroids (the “chips off Vesta” discovered by Richard Binzel and collaborators) appear to have been delivered to Earth as the result of a very large impact event, leading to the hypothesis that a large crater could be found on the surface. Colors and shape determined from HST imaging are consistent with such a crater. Vesta is also the target of the DAWN spacecraft mission.

Radar measurements can measure shape directly, without confusion by albedo features. Vesta had its best radar observing opportunity for the next century in April 2003. At that time M. Nolan (NAIC) and collaborators obtained delay-Doppler images of Vesta, which will be used to improve the shape model, and particularly to look for features related to the probable presence of a large crater.

In early May, asteroid (5381) Sekhmet was discovered to be a binary system (Figure 4). It was also seen to be rather smaller (< 1 km diameter) than predicted from optical observations (1.7 km), so that it has high optical and radar albedos and a quite rapid rotation rate (about 2.5 hours). This is the seventh binary near earth asteroid that has been discovered with either the Arecibo transmitters and/or Goldstone radar systems.

Binary asteroids are important because it is possible to determine asteroid bulk density from the orbital parameters and object sizes; both of which are directly measured by the radar, but are almost impossible to determine by other ground-based means. The frequency of binary asteroids, and the spin rates of the bodies, provide constraints on near-Earth asteroid formation and delivery.

**Personnel:**

Tony Crespo retired at the end of April (see “comings and goings”), after many years of keeping the S-Band transmitter operational under often adverse conditions, regularly repairing the transmitter during the day so that he could operate it at night. Everyone in the planetary radar community is greatly in his debt. Víctor Negrón continues day-to-day operation and maintenance of the transmitter. A search for an engineer for all of the Arecibo transmitters is underway.

The NSF Research Experience for Undergraduates (REU) program sponsored eight undergraduates and one teacher. The NASA Capability Enhancement program, based at the University of Puerto Rico, sponsored one student, Ingrid Plá Rodríguez, who worked with Sixto González and Craig Tepley. In addition, a graduate level student, Samantha

The 2002 NAIC REU summer students, from left to right; Front: Rebecca Wilcox, Martha Boyer, Samantha Stevenson, Andrew Helton, and Daniel Kao; Back: Stephanie Morris, Danielle Moser, Laura Chomiuk, Julia Deneva, and Martin Rodgers. (photo by Daniel Kao). Not pictured are Ingrid Plá and José Gerena.

The 2002 NAIC Arecibo Observatory Summer Program

Ramesh Bhat, Lisa Wray, Qihou Zhou

Eleven students from colleges and universities in the mainland and Puerto Rico participated in the NAIC Summer Student Program at the Arecibo Observatory in 2002. The program also included a local high school science teacher, José Gerena, from Luís Muñoz Marín public school in Barranquitas. He worked with José Alonso on projects in conjunction with the Visitor Center and its teacher training workshops.

The students worked on individual research projects in radar and radio astronomy, atmospheric science and computing with their advisors.

In addition to a large number of summer student talks by the observatory staff and visiting scientists, the students also had the opportunity to work on several specially designed hands-on observing projects. Mike Nicolls (Cornell University), who was a summer student at the Observatory in 2001, returned for three weeks to continue research with Sixto González and Néstor Aponte. Mike had a very productive and fruitful summer, working on technical aspects as well as science.

The 2002 NAIC Summer Program

Ramesh Bhat, Lisa Wray, Qihou Zhou

Eleven students from colleges and universities in the mainland and Puerto Rico participated in the NAIC Summer Student Program at the Arecibo Observatory in 2002. The program also included a local high school science teacher, José Gerena, from Luís Muñoz Marín public school in Barranquitas. He worked with José Alonso on projects in conjunction with the Visitor Center and its teacher training workshops.

The students worked on individual research projects in radar and radio astronomy, atmospheric science and computing with their advisors.

In addition to a large number of summer student talks by the observatory staff and visiting scientists, the students also had the opportunity to work on several specially designed hands-on observing projects. Mike Nicolls (Cornell University), who was a summer student at the Observatory in 2001, returned for three weeks to continue research with Sixto González and Néstor Aponte. Mike had a very productive and fruitful summer, working on technical aspects as well as science.

The 2002 NAIC Arecibo Observatory Summer Program

Ramesh Bhat, Lisa Wray, Qihou Zhou

Eleven students from colleges and universities in the mainland and Puerto Rico participated in the NAIC Summer Student Program at the Arecibo Observatory in 2002. The program also included a local high school science teacher, José Gerena, from Luís Muñoz Marín public school in Barranquitas. He worked with José Alonso on projects in conjunction with the Visitor Center and its teacher training workshops.

The students worked on individual research projects in radar and radio astronomy, atmospheric science and computing with their advisors.

In addition to a large number of summer student talks by the observatory staff and visiting scientists, the students also had the opportunity to work on several specially designed hands-on observing projects. Mike Nicolls (Cornell University), who was a summer student at the Observatory in 2001, returned for three weeks to continue research with Sixto González and Néstor Aponte. Mike had a very productive and fruitful summer, working on technical aspects as well as science.

The 2002 NAIC REU summer students, from left to right; Front: Rebecca Wilcox, Martha Boyer, Samantha Stevenson, Andrew Helton, and Daniel Kao; Back: Stephanie Morris, Danielle Moser, Laura Chomiuk, Julia Deneva, and Martin Rodgers. (photo by Daniel Kao). Not pictured are Ingrid Plá and José Gerena.
Steinbock (Wesleyan University), was supported by funding from the NAIC.

The students had many observing opportunities this summer with the 1000-ft Arecibo telescope. All the students worked on specially designed hands-on observing projects. The topics included pulsar, continuum, spectral-line and radar astronomy, supervised by the observatory staff (Paulo Friere, Ramesh Bhat, Tapasi Ghosh, Chris Salter, Karen O’Neil, Ellen Howell and Mike Nolan). In addition, some students took advantage of the opportunity to work with Yervant Terzian (Cornell University) and Murray Lewis (NAIC) on a radio recombination line (RRL) project. Their observations led to successful detections of several RRLs towards the planetary nebulae and supernova remnants. Along with the students, Lisa Wray, a receiver engineer at the Observatory also took part in the hands-on observing projects.

The projects involved planning and performing the observations, reducing and analyzing the data, and giving short presentations on their experience and findings. Three students had their own observing programs as part of their summer projects. The astronomy students presented the results from their summer research at the winter AAS meeting in Seattle, Washington (see below for more details).

Rounding out the technical and educational aspect of the summer, the students this year showed an admirable adventurous spirit in exploring life outside the Observatory. Staff-organized trips to local beaches, festivals and attractions only whetted their appetite. They soon took the initiative and guided themselves to almost every corner of the island. They visited the El Yunque rain forest, snorkeled the bioluminescent bay in La Parguera — a southern beach, visited Luquillo beach on the east side, drove through the famous coffee plantations in the central mountain range, discovered the world-class Ponce Art Museum. Staff member Diego Janches introduced the students to a local diving instructor, and seven out of the eleven students participated in a 20 hour course to obtain their SCUBA diving certification.

Not content with covering the island of Puerto Rico, many scouted out neighboring islands including Tortola, Culebra, Vieques, Mona, St. John and St. Thomas.

Thanks to the administrative staff of the Observatory, the housing situation for this year’s students was very convenient and comfortable. All were housed onsite in the Visiting Scientists Quarters. They were provided all the necessities plus some luxuries — kitchenettes and computers in each housing unit, and satellite TV in some units.

2002 Summer Student Projects:

Supported by NSF REU Funds:

Martha Boyer (University of Minnesota) worked on a project that involved studies of pulsar emission regions at multiple frequencies. Her advisor, Yashwant Gupta from National Centre for Radio Astrophysics, India, was on a sabbatical visit at the Arecibo Observatory. The work involved development and extension of the analysis software for a variety of statistical studies of the pulse structure at multiple radio frequencies.

The project employed use of some of the high quality single-pulse data taken with the Giant Metre-wave Radio Telescope (GMRT) in India, and also from the Effelsberg 100-m telescope in Germany and the Lovell 76-m telescope in Jodrell Bank, U.K. Martha’s work focused on determination of locations of core and conal components of pulsars as a function of the pulse intensity and radio frequency. Their analysis reveals that for most pulsars the core component arrives earlier in phase for more intense pulses.

This shift in phase is seen to be larger for lower frequencies (< 1 GHz), and nearly disappears at high radio frequencies (~5 GHz). These findings are in support of the hypothesis that more intense pulses originate at higher altitudes in the pulsar magnetosphere than less intense pulses. The results were presented in a poster paper at the winter AAS meeting.

Laura Chomiuk (Wesleyan University) studied the connections between supernova remnants (SNR) G42.8+0.6 and two angularly nearby neutron stars, SGR 1900+14 and PSR J1907+0918. This project employed several radio astronomical disciplines, including pulsar search and polarimetry, HI and OH spectral-line mapping, and full-Stokes continuum mapping. Laura was jointly supervised by Snezana Stanimirovic (now Berkeley) and Chris Salter (NAIC), and the project also included Dunc Lorimer (Jodrell Bank), Ramesh Bhat (NAIC) and Dejan Urosevic (Belgrade) as co-investigators. Several interesting results have emerged so far, some being quite puzzling. The L- and S-band continuum maps confirm the SNR to possess a well-defined shell showing pronounced edge brightening. The OH 1665/1667-MHz data reveal a small-diameter absorption patch projected against the SNR interior, at a radial velocity of 18 km/s. The line ratios measured for the 4 OH transitions are far from the expected 1:5:9:1 for thermal equilibrium. An HI feature is also evident at 18 km/s, closely mimicking the structure of the SNR. Polarimetry on PSR J1907+0918 yields an RM of 730 rad/m². The OH and HI features have a (far) distance estimate of ~11 ± 3 kpc. This is larger than the estimate of ~5.7 kpc for SGR 1900+14, but not inconsistent with the latest estimate of 7.8 (~1.1, +0.9) kpc for the pulsar. Laura presented her results in the winter AAS meeting in Seattle, WA.

José Gerena, a high school science teacher from the Luis Muñoz Marin public school in Barranquitas, was the 2002 Teacher-in-Residence at the Ángel Ramos Foundation Visitor Center. He worked under the supervision of José Alonso. The teacher takes part in educational research projects, and also contributes to the outreach activities. In his capacity as the resident teacher, Gerena was engaged for most of the summer with...
the organization of the teacher workshop held at the Visitor Center. He designed several experiments for the CBL Laboratory interface that were implemented in the workshop this summer. He also prepared the assessment tools for the workshop evaluation.

Andrew Helton (University of Iowa) worked with Slava Slysh (Astro Space Center of the Lebedev Physical Institute, Moscow, Russia) who was on a long sabbatical visit at the Arecibo Observatory. The project involved all-Stokes survey of OH masers of star forming regions, with the specific goal of searching for possible Zeeman pairs. Andrew worked on data taken with the 1000-ft telescope by his advisor prior to his arrival (April 2002) in the summer. The observations were made with the L-wide receiver with the four sub-correlators centered at 1612, 1665, 1667 and 1720 MHz. The observations were aimed at refining the positions and finding potential sources of Zeeman pairs for future VLBI follow up observations. They find eleven possible pairs from the Arecibo data. Additionally, an OH maser was discovered near a known methanol maser 40.2–0.2m, and it was also found to be a source of possible Zeeman pair. As part of this project, Andrew also developed IDL-based routines for the calibration and reduction of all-Stokes data taken with Arecibo. The results were presented as a poster paper at the AAS meeting.

Daniel Kao (Penn State University) worked with Craig Teply on a project titled “Lidar configuration and observation of Raman scatter from N$_2$ and H$_2$O”. The project involved designing and building of a 3-channel lidar receiver for a Nd: YAG transmitter to observe Raman scattering from N$_2$ and H$_2$O. They combined Rayleigh (at the laser wavelength of 532 nm) and Raman scatter data from N$_2$ (at 607 nm) to extend the lower range of the atmospheric temperature profile down to 4 km. Observations of Raman scatter from water vapor were made at 660 nm and combined with the N$_2$ Raman scatter data to derive the water vapor mixing ratio profile from 2.5 to 11 km.

The receiver configuration was designed such that measurements of Mie scatter will also be possible, and this will facilitate studies of the relative sizes and shapes of aerosols in the atmosphere. Further, when equipped with the appropriate narrow band-pass filters, observations of both O$_2$ and O$_3$ Raman scattering will be feasible with the same receiver.

Daniel presented his work at the Arecibo Friends Workshop in the 2002 CEDAR meeting held in Longmont, Colorado.

Stephanie Morris (University of Chicago) worked on two different projects. Her main project, under the guidance of Jeff Hagen, involved development of a web-based GUI (Graphical User Interface) for tracking and monitoring the pressure and temperature of the compressors used in the telescope’s receiver systems. Hardware to collect these data is currently under construction. The telescope has recently been outfitted with a new wind speed monitor, which logs the wind speed and direction for every second. Stephanie developed a GUI for the display and monitoring of these data. The GUI could be later extended as a web-based tool for the display and monitoring of the compressor parameters. Stephanie also worked on a pulsar astronomy project, under the supervision of Ramesh Bhat, where newly discovered pulsars from the Parkes multibeam survey are used to study the Galaxy’s magnetic field structure. She adapted and customized the software to combine pulsar polarization data taken with the WAPP (Wideband Arecibo Pulsar Processor) at different observing days. This will help to improve upon the quality of polarization results, especially for relatively weaker and/or less polarized pulsars. The software will also allow accurate calibration and correction of instrumental polarization, and hence will be an important tool for precision pulsar polarimetry with Arecibo.

Danielle Moser (University of Illinois, Urbana–Champaign) worked with Diego Janiches on interplanetary dust studies using the UHF dual-beam radar facility at the Observatory. Data are from observations of micrometeor flux in the upper atmosphere, conducted in January 2002, where three areas of the sky were simultaneously covered, yielding over 20000 events. Danielle’s work involved calculation of their line-of-sight velocities, precise in-atmospheric decelerations and determination of the orbits. The analysis reveals that majority of the detected particles have elliptical orbits, suggesting their confinement to the solar system. Danielle studied the orbits of these dust particles, and their distribution with respect to the ecliptic plane, based on a/e (semi-major axis vs eccentricity) diagrams. The diagrams for the north, line and south pointings are very dissimilar, and are suggestive of evolution of dust (the meteorides) along the drag lines. While many particles with a/e combinations along the drag lines are seen farthest (north) from the ecliptic plane, eccentricities approach the parabolic limit of unity for those closest to the ecliptic plane. Such an evolution was predicted by Morfill and Gruen (1979), but was never observed before. This result was presented by Diego in recent ACM conference in Berlin, Germany and its publication is currently in preparation.

Martin Rodgers (Miami University) studied the morphologies of sporadic E layers over Arecibo, using the Arecibo data from years 1995–2000 taken by his advisor, Qihou Zhou and colleagues. Martin developed several IDL-based tools to study the statistical nature of the layers, including layer location, peak electron density, layer thickness and movement of layers.

The results were compared for diurnal, seasonal and solar cycle variances, and reveal several interesting trends. The main trend is an inverse relation between the occurrence and intensity of E’s to the solar cycle; the number and intensity of layers is lower at solar maximum than those seen at solar minimum. Another intriguing trend is a maximum of occurrences in March and minima in both April and October. At the end of the summer
Qihou left the Arecibo Observatory to take up a faculty position at Miami University in Oxford Ohio. This will give ample opportunity for Martin to continue to work on this project with Qihou. They plan to carry out further detailed research to confirm these trends, and also extend the work through analysis of more data taken over recent years.

Rebecca Wilcox (University of Washington) worked on Arecibo data obtained by her advisor, Karen O’Neil (now at NRAO), over recent years, with the main goal of creating a standard galaxies catalog. The work involved reduction and analysis of the data, comparison with the published data in the literature, and detailed examination of different kinds of HI profiles. Rebecca also developed some IDL-based routines to simplify the reduction process, which output a number of parameters including flux and the velocity width. The analysis shows several galaxies where the Arecibo high-resolution HI profiles do not match their previously published descriptions. Specifically, there are profiles that are intermediate between Gaussian (dwarf galaxies) and two-horned (spiral galaxies), where the profiles tend to be “Gaussian-like” but with definite indications of rotation in the form of small horns or flat tops. Additionally, there are several “lopsided Gaussian” profiles for galaxies, where the velocity widths favor two-horned profiles. A plausible interpretation is an imbalance of gas in the galaxy.

Further work will involve calculation of distances and HI masses of the galaxies and study of the Tully-Fisher relation. Rebecca presented her results in a poster paper at AAS meeting.

Supported by Other Funds:

Julia Deneva (Vassar College) worked with Paulo Freire on developing a method for the determination of the orbital parameters of binary pulsars. The conventional method involved fitting a Keplerian model to a series of period measurements, where the accuracy is limited by the number of measurements and initial guess values. A recent method (Friere et al. 2001) uses the measured pulsar periods and accelerations to determine these parameters, and works even for very sparse data sets. The method is independent of the epochs of individual observations. Julia’s work this summer involved its software implementation and testing using simulated data. The new method works well for data sets of 20 or more period-acceleration measurements (elliptical orbits) or just 4-5 period-acceleration measurements (circular case), and yields fitted parameters that are close to those used in the simulation. The uncertainties in the fitted parameters are deduced using Monte Carlo simulation techniques. This method will be particularly useful for weak pulsars where, because of interstellar scintillation, positive detections are often few and far apart in time. It is also the best possible way of obtaining first order estimates of the orbital parameters for use in time/period orbital fitting, even when the sampling is not sparse. This work was presented in a poster paper at AAS meeting in Seattle.

Ingrid Plá Rodríguez (University of Puerto Rico – Mayagüez), an Industrial Engineering major, put her knowledge and skills of optimizing products and quality control to use for the benefit of the Department of Space and Atmospheric Sciences (SAS) at the Observatory. Her project titled “The New and Improved World of SAS” encompassed several smaller projects, most of which were done under the guidance of Sixto González. Among her main contributions to the group are creation of a World Days Worksheet to replace the conventional observing log books. Ingrid undertook the rather tedious task of converting the information from several log books into these work sheets, and in the process searched for and filled in some important information that was lacking in the log books.

She also worked on a compilation of all the atmospheric science experiments done at Arecibo from 1994 through June 2002, and she updated the web-based publication lists of both the SAS group and visiting scientists. Ingrid also took part in some of the Lidar experiments with Craig Tepley, and in the Spectral Line hands-on observing project with Karen O’Neil.

Samantha Stevenson (Wesleyan) was jointly supervised by Tapasi Ghosh and Jo Ann Eder. Her research focused on HI evolution studies of infrared (IR) selected active galactic nuclei (AGN) galaxies. HI 21-cm spectra were obtained for four 12 micron selected samples: Seyfert 1, Seyfert 2, starburst and nonactive galaxies. One of the goals was to examine the effects of the infrared selection criterion on the infrared evolution characteristics for the galaxies. A comparison of the HI properties of the non-active IR-selected galaxies with those for an optically-selected sample of UGC galaxies (Haynes & Roberts 1994) showed no significant difference. Another interesting result is that, while the 12 micron sample shows definite global evolutionary trends, no difference was noted between the evolutions of Seyfert 1, 2, starburst and non-active galaxies. This may indicate that Seyfert 1 and 2 galaxies are not in different evolutionary stages (in a statistical sense), but could be explained through models of the unified scheme for AGN. Future work will involve a more complete collection of infrared data for all galaxies with HI data available, to allow better statistical studies, and also to examine the cross-comparison between different classes of galaxies.

Samantha will present her results at the winter AAS meeting in Seattle.
pulsar observing programs. The Fast Ethernet (100 Mbps) interfaces on the machines are being upgraded to gigabit speed, and local disk storage buffers to 1.5 TBytes each, using 6x250 GB SCSI-IDE RAID units. A Quantum SDLT tape drive (160 GB native cartridge capacity at 15 MBytes/s) will soon become available for backups.

ASP cluster arrives
The Berkeley/Princeton/UBC-developed computing cluster, christened the ASP (Arecibo Signal Processor) is here! The machine consists of nineteen dual-Xeon-CPU chasses, with an integrated gigabit ethernet switch. Initial interfacing to the ABPP (Arecibo-Berkeley Pulsar Processor) has just been completed as of this writing. The group’s first priority is to use the machine for high-precision pulsar timing with realtime coherent dedispersion over a 128 MHz bandwidth performed by the cluster nodes.

CIMA observing interface
Jeff Hagen’s re-engineered telescope user interface, CIMA (http://www.naic.edu/~jeffh/cima.html) has been in use for several months and will replace the old “aocontrol” GUI. Jeff had earlier employed a “multicast” technique to make instantanous telescope status information accessible to any point on the Observatory network. These tools should facilitate integration of visitor-provided instruments.

Data archive search tools
Phil Perillat has developed search tools for the Observatory spectral-line data archive using the IDL platform (http://www.naic.edu/~phil/talks/ausac03/talk.pag1). Together with Phil’s IDL package for the 50 MHz correlator, users can perform a wide variety of data reduction and “mining” operations over the entire set of data taken over several years. A Web interface for position-keyed searches, based on the IDL tools, is under development by Gomathi Thai.

Workshops held at the Arecibo Observatory

ALFA Pulsar Consortium Workshop
Paulo Freire

The First ALFA Pulsar Consortium Workshop was held on 1–2 November 2002 at the Learning Center of the Arecibo Observatory. This meeting, the first of a series of similar Consortium meetings aimed at several different areas of radio astronomy, was aimed at forming a world-wide consortium of researchers with an interest and capacity to implement large-scale pulsar surveys.

The participants were particularly excited by the prospect of a large-scale survey of the galactic plane visible from the Arecibo telescope made with the new ALFA beam array, at frequencies of 1400 MHz. This has the potential to find something like 1000 new pulsars, a number of the same order of magnitude, but larger, than that of the Parkes Multibeam survey (PMB).

The Consortium has recommended that a back-end be built that can use the full 300 MHz bandwidth of each of the seven ALFA receivers, for maximum sensitivity to weak pulsars. The consortium has also agreed that, in order to increase the sensitivity to millisecond pulsars compared to previous surveys (in this case, increasing the detection volume for this kind of object by a factor of about one hundred compared to the PMB), the ALFA pulsar survey should be conducted with a faster sampling rate (64 µs) and, more importantly, with a spectral resolution of 1024 channels over the 300 MHz of the ALFA band. This represents a ten-fold increase in spectral resolution compared to the PMB, which enables the detection of millisecond pulsars at ten times larger DMs, as the dispersive smearing across each channel is ten times smaller.

This increased sensitivity to millisecond pulsars comes at an enormous cost: the ALFA pulsar survey is likely to produce near 1 Petabyte of data over the several thousand hours of the survey, the storage of this is likely to cost hundreds of thousands of dollars. Processing these amounts of data will also be very challenging. The participants and their institutions have, or are in the process of acquiring, large Beowulf clusters that will be capable of processing these giant data sets.

The meeting report can be downloaded from the pulsar consortium’s website (http://alfa.naic.edu/alfa_pulsar.html). Jim Cordes has been elected as Consortium Chair and Paulo Freire as the Consortium’s point of contact at NAIC. The consortium has also created five different subcommittees charged with survey optimization (head: Jim Cordes) data archiving (head: Vicky Kaspi), data acquisition (head: Ingrid Stairs), software (provisional head: Vicky Kaspi) and follow-up observations (head: Bryan Gaensler). These have been maintaining e-mail contact and have recently begun a pilot survey to test some of the aspects related to the data management, RFI excision and data processing, i.e., the whole data pipeline.

SKA International Meetings
Yervant Terzian

During January 16 to 19, 2003 the International Square Kilometer Array Steering Committee (ISSC) met at the Arecibo Observatory to consider the proposed SKA designs and to discuss SKA related policy issues. More than 20 members and guests participated including leading radio astronomers from Europe, Australia, South Africa, Japan, Canada and the U.S. Many attendees were visiting the observatory for the first time. The SKA timetable calls for a selection of the construction site by the end of 2005, and a final design selection by the end of 2007. Construction of the project may begin by the end of the decade. The stipulated SKA frequency range is from 150 MHz to 22 GHz. It is not likely that a single design can accommodate this entire band, and hybrid models are being investigated. The next International SKA Workshop and ISSC meetings will take
place in Geraldton, Western Australia at the end of July 2003.

Arecibo was the perfect meeting place to contemplate the largest radio telescope of the future. Many thanks to the Observatory and its staff for their gracious hospitality.

**NASA Education and Outreach Workshop for Scientists and Engineers**

José L. Alonso

The Arecibo Observatory hosted the NASA Education and Outreach Workshop for Scientists and Engineers on February 5–8, 2002. The meeting, held at the Ángel Ramos Foundation Learning Center, provided an opportunity to discuss astronomy outreach initiatives that are being developed by the NASA Goddard Space Flight Center (GSFC), the Arecibo Observatory and the University of Puerto Rico. Twenty-one scientists, engineers, and educators from these institutions shared different examples of education and outreach activities that are being implemented. Participants had the opportunity to tour the Observatory and meet our staff.

**Synopsis of the 10-12 March 2003 Arecibo Radar Meteor Workshop**

Diego Janches

On March 10-12, 2003, the Radar Meteor Workshop was held at the Ángel Ramos Foundation Visitor Center at the Arecibo Observatory (AO). Over 50 participants from 10 different countries attended, including USA, Israel, Czech Republic, Russia, Australia, Sweden, England, Japan, Canada and Puerto Rico. The attendance of five graduate and one undergraduate student were fully supported by the conference organizing committee—several senior scientists were similarly supported. The workshop was made possible thanks to the support of the National Science Foundation (NSF), the Air Force Research Laboratory (AFRL), and the Arecibo Observatory. The Scientific Organizing Committee included Dr. Edmond Murad (AFRL), Prof. Iwan Williams (University of London), Prof. John D. Mathews (Penn State University) and Dr. Diego Janches (AO).

Topics concerning the aeronomical and astronomical issues related to detection and study of the micrometeor influx in the upper atmosphere were treated in detail. Issues addressed included the micrometeor velocity distributions and the presence of hyperbolic meteoroids, meteoroid mass fluxes and their relation to upper atmosphere metallic layers, and radio science issues surrounding radar study of meteors. The latter topic concerned the differences and similarities between radar meteor observations using traditional trail-echo radars and high power, large aperture systems, in particular the presence and/or absence of observational biases in each technique. A complete list of speakers as well as the workshop photo gallery is available online at (http://www.naic.edu/~djanches/radarWorkshop). As a result of the conference, a special issue in *Atmospheric Chemistry and Physics* is in preparation. Deadline for manuscript submission is October 1, 2003.

**1st Workshop of the Extragalactic ALFA Consortium**

Karen O’Neil

Thirty members of the Extragalactic ALFA (E-ALFA) consortium, representing 9 different countries and 22 institutions, met in Arecibo during 14–17 March, 2003 for the first E-ALFA consortium meeting. The first half of the workshop was devoted to organized talks and discussions, while the second part was spent in discussion.
The talks began with the staff of Arecibo Observatory providing a great overview of both the Arecibo telescope and the ALFA system. We also heard talks by members of the Pulsar and Galactic Consortia describing observing projects in which their groups are interested, as well as a number of talks from the E-ALFA consortium members on their experience with large scale surveys (both in the radio and optical) and on potential ideas for E-ALFA surveys.

During the meeting discussions we identified five distinct surveys of interest:

- Fast all (Arecibo) sky
- Galaxies and Environment, to examine properties of galaxies in a wide variety of environments, including the Virgo Cluster, Canes Venatici, around large, local galaxies, and around dwarf galaxy groups
- ZOA, to look at the large, local structure in the ZOA
- Deep Strip, a 1x300 degree survey designed to trace the HIMF to at least 1 magnitude fainter than previous surveys and across a variety of environments
- Very Deep, which will look at only ~0.4 sq. degrees of the sky, but will be designed to detect galaxies with $M_{HI} = 10^{9.5} M_\odot$ out to $z = 0.015$.

A “white paper,” discussing the basics of the surveys, consortium organization and guidelines, etc. is being drafted by the workshop participants and should be available to the community by 1 July, 2003. Another meeting of the consortium is planned for Fall, 2003.

Summaries from the meeting, a list of participants, a description of the white paper, etc. are available on-line at (http://alfa.naic.edu/extragal/meeting1/results.htm).

**Galactic-ALFA (GALFA): The First Consortium Workshop**

Chris Salter

The Galactic-ALFA (GALFA) Consortium is an organization that aims at coordinating Galactic HI, Continuum, and Recombination Lines studies to be made with the Arecibo L-band Feed Array (ALFA).

Twenty-five members of the GALFA Consortium, representing 16 institutions from 5 different countries, met in Arecibo between 21 and 23 March, 2003 to formally constitute the Consortium. An organizational structure was agreed upon, with Paul Goldsmith (Cornell) as the elected Chair of the GALFA consortium.

The three sub-consortia for Galactic HI, recombination-line and continuum studies will be led by Snezana Sta-
nimirovic (Berkeley), Yervant Terzian (Cornell) and Russ Taylor (Calgary) respectively. More details on the organization, meeting proceedings, etc. are to be found via: (http://alfa.naic.edu/alfa_galactic.html). Membership of the GALFA consortium is still open (see http://alfa.naic.edu/consort/join.html), and we encourage interested scientists to join as soon as possible. There is a lot of interesting work to be done in terms of defining requirements (especially in terms of spectrometer capability), observing techniques, data reduction, and data archiving, and we are eager to get additional committed individuals involved.

During the first Consortium meeting, other points that were addressed included determining local Arecibo “Points of Contact” for GALFA Consortium activities. The individuals are:

> Murray Lewis (blewis@naic.edu — Galactic HI)
> Tapasi Ghosh (tghosh@naic.edu — Continuum)
> Mayra Lebrón (mlebron@naic.edu — Recombination lines).

Proposed Scientific directions within the areas of interest of the different sub-consortia, which were discussed at the March 2003 meeting, include the following:

§ Galactic HI:
1. HI Low Latitude Study of the Galactic Plane, Study of Line Wings, Self-Absorption
2. High Latitude Clouds, Turbulence
3. Magellanic Stream, Halo clouds
4. HI disk-halo interaction
5. HI in and around molecular clouds
6. HI in multiwavelength studies of the ISM (aka HI & FUV)
7. HI in cold clouds

§ Recombination-line Studies.

§ Continuum Survey: Total Intensity and Linear Polarization.

The Second GALFA meeting will take place at Boston University on the 18th of June, immediately following the Boston University conference on “Milky Way Surveys: The Structure and Evolution of Our Galaxy” (June 15-17, 2003). For details, see (http://alfa.naic.edu/galactic/meeting2/). We expect to have ongoing discussions about spectrometer requirements, software, and to continue to refine the scientific case for observations associated with the above areas of interest.

---

**John Harmon ends a decade of scheduling; Héctor Hernández assumes responsibility**

*Daniel R. Altschuler*

After more than ten years scheduling the Arecibo telescope, John Harmon has stepped down from this demanding and never-ending task. We salute the dedicated effort that John has sustained over these years.

After careful consideration of our options, we have assigned this difficult task to Héctor Hernández, who has been supporting our operations with service observing activities.

Héctor is in charge of placing projects on the schedule following the recommendations of the Arecibo Scheduling Advisory Committee (ASAC), and in coordination with users. The Head of Radio Astronomy, the Observatory Assistant Director, the Associate Director for SAS, and the Observatory Director will support the scheduling process, resolving all matters of prioritization, conflict, and use.
The NAIC Policy on Press Releases

One of NAIC’s missions is to keep the general public informed about the exciting research work that is being done at the Arecibo Observatory in the fields of radio and radar astronomy and atmospheric sciences. Consequently, all of our users who have research projects or results that are of potential interest to the general public are encouraged to consider publicizing them via a press release. NAIC can provide assistance with the preparation and distribution of news releases both directly and via the very experienced staff at the Cornell University News Service. If a release related to work at the Arecibo Observatory is being issued by your own or another institution then it must be coordinated with NAIC and, through NAIC, with the National Science Foundation. In this case NAIC/Cornell may also wish to issue a joint release. Information about, and assistance with, press releases can be obtained through the NAIC Director’s office (director@naic.edu).

Inaugural William and Elva Gordon Lecture held at Arecibo Observatory
Daniel R. Altschuler

In November 12 of 2002 we inaugurated the annual lecture series named for William E. Gordon and his wife Elva. Gordon was a professor of Electrical Engineering at Cornell University, Ithaca, N.Y., when he conceived of an instrument to study the properties of the ionosphere, the Earth’s upper atmosphere.

Harold Ewen, a retired engineer who was a doctoral candidate at Harvard University in 1951 when he designed and built a horn antenna that made the first detection of hydrogen radio emission from interstellar space, gave the inaugural lecture. The lecture was held in the Ángel Ramos Foundation Visitor Center at the Observatory to an audience of about one hundred visitors.

The lecture series is endowed by another Arecibo pioneer, engineer Tom Talpey, and his wife, Elizabeth. Talpey was a member of the engineering team led by Gordon that spent three years in Puerto Rico in the early 1960s building the Arecibo Observatory, which received its first radio signals in 1963.

Ewen made the first detection of atomic hydrogen in interstellar space with the collaboration of the late Harvard physicist Edward Purcell, who was to share the 1952 Nobel Prize in physics for development of nuclear magnetic resonance in measuring magnetic fields in the nuclei of atoms. Purcell obtained a grant of $500 from the American Academy of Arts and Sciences to build the horn antenna. Ewen then designed the antenna and the mixer and receiver, which used a frequency-switching technique to cancel out systematic effects, a novel technique for astronomy at the time.

After completing his doctorate, Ewen joined the Harvard faculty and was co-director of the Harvard Radio Astronomy Project from 1952 to 1958. He left Harvard in 1982 to devote himself to his two companies, Ewen Knight Corp. and Ewen Dae Corp., which provided radio equipment for major academic, government and industrial research laboratories. Since 2001 he has been a research professor at the University of Massachusetts. His famous horn antenna is now at the National Radio Astronomy Observatory, Green Bank, W.Va.

Calixto Rodríguez
Bienvenido a Calixto Rodríguez
Eddie Castro

Calixto joined the Electronics Department in March, 2003 as a Receiver/Electronics Engineer. He graduated from the University of Puerto Rico, Mayagüez, where he obtained a BSEE degree (Telecommunications Engineering) and with an MBA degree (Operations Management – Statistical Process Control) from the Río Piedras Campus. He is a CIAPR (Colegio de Ingenieros y Agrimensores de PR) licensed Engineer (PE). During his 14 years of professional career, he had the opportunity to work in the Telecom Industry (PR & USA) where he developed an expertise in fiber optics and telecom networks (including C-band satellite earth stations). He also worked for the Department of Commerce (US Patent & Trademark office) as a Patent Examiner in Washington, DC. Calixto will be working in several areas at the Arecibo Observatory including radio astronomy receivers, cryogenics, RFI mitigation and timing–synchronization systems.
Bienvenido a Giacomo Comes
Eddie Castro
Giacomo Comes joined the Electronics Department as an engineer April 16. He studied in Italy in the Polytechnic of Bari, where he obtained a degree in Electronic Engineering in 1992 with full marks. He has worked in Bari (Italy), Strasbourg (France), and Bonn (Germany). At the Physikalisches Institut at Bonn University he was system administrator of a chip-design UNIX cluster as well as a chip-design engineer for more than seven years.

In October 2002 he married Mayra Lebrón (see below) and two months later they moved to Puerto Rico to start a new experience. We want to wish them a happy and long stay in Arecibo.

Adios a Rob Wilson
Sixto González
Rob Wilson left in May after spending 9 months at Arecibo. Rob was a recipient of the CEDAR post doc award and spent the first year at Penn State University and finished his term here. While at Arecibo he primarily studied E-region phenomena in particular the relationship between sporadic-E, sudden atom layer enhancements, and turbulence as exhibited in quasi-periodic coherent echoes observed by VHF radars.

Bienvenida a Mayra Lebrón
Chris Salter
Mayra Lebrón joined the staff of the Radio Astronomy Department as a Research Associate in December 2002. She is a native of Puerto Rico, hailing from the town of Maunabo on the eastern coast of the island. She obtained her bachelor’s degree in Applied Physics from the University of Puerto Rico at Humacao, and also spent 10 weeks at the Arecibo Observatory as one of our summer students.

Mayra got both her Master’s degree and Ph.D. from the Instituto de Astronomía de la Universidad Nacional Autónoma de México (UNAM). Her thesis advisors for her doctorate were Drs. Luis Rodríguez and Susana Lizano, the thesis being entitled “A Study of the Gas around High-Mass Young Stars”. Between 2000 and joining NAIC, Mayra was a Postdoctoral Research Fellow at the MPIfR, Bonn, working within their Millimeter Astronomy Group. While in Bonn, she worked on photodissociation regions and regions of high-mass star formation using carbon recombination line and molecular line observations.

Since joining us in Arecibo, Mayra has been very active in helping with the initial organization of the Galactic ALFA (GALFA) Consortium, taking a leading role with Yervant Terzian in the setting up of the GALFA recombination-line subconsortium. Mayra has also taken over as Friend of our X-Band receiver. After only six months here, it is already hard to imagine the Observatory without Mayra’s energetic presence.

In welcoming (or should I say “welcoming back”?) Mayra to our ranks, we also extend our greetings to her husband, Giacomo Comes, who has joined our Electronics Department. Also to be mentioned are their “instantly acquired” family of Lady and Rex, the dogs, and Charcoal, the kitten.

Felicitades en su retiro a Antonio Crespo
Don Campbell
It is always hard to farewell someone who for many years has been both a valued colleague and a major contributor to the Observatory’s success. This is certainly true for Tony Crespo. Tony

Award for Hijos de las Estrellas
“Hijos de las Estrellas”, the book written by Daniel Altschuler (also as Children of the Stars) and published by Cambridge University Press, was awarded the second prize for the best book of the year 2001 by the Institute of Puerto Rican Literature. According to Eduardo Morales Coll, president of the Institute, it is the first time in the history of these awards, started in 1938, that a book of this genre is recognized.

In the photo, Eduardo Morales Coll, President of the Institute of Puerto Rican Literature hands award to Daniel. (photo courtesy of the the Institute for Puerto Rican Literature)
started working at the Observatory in 1973 as a telescope operator. However, his strong interest in electronics led to his being transferred in 1975 to the maintenance department to work with Tom Dickinson as an electronics technician helping to maintain the then new 420 kW S-band transmitter and low noise maser amplifiers used for planetary studies. Talent and enthusiasm brought rapid promotion first to manager of the Higuillales interferometer antenna site in 1977 and then, in 1981, to engineer with responsibility for the S-band transmitter and maser system. This was Tony’s title until he retired in early May but it does not describe the full range of his contributions. In addition to looking after the transmitter, he was involved in many other activities of importance to the Observatory, such as supervising the upgrading and maintenance of the antennas and transmission lines of the Islote High Frequency (HF) transmitting facility and designing and supervising the installation of the Observatory’s security camera system. Tony was, of course, also heavily involved with the design, procurement and installation of the new 1.0 MW S-band transmitter as part of the recent upgrading of the Arecibo telescope and has been responsible for its operation and maintenance ever since.

Without Tony Crespo’s willingness to devote whatever time it took, day, night or weekend, to keep the S-band transmitter operational, the tremendous success rate of the Observatory’s planetary radar observations could not have been achieved, and many important contributions to planetary science would not have been obtained. Everyone involved in planetary radar studies with Arecibo is indebted to Tony for his dedication to the success of the program and we all wish him well for the future.

Buena suerte a Karen O’Neil
Chris Salter

Sadly for NAIC, Karen O’Neil left us in January 2003 after over four years with the Radio Astronomy Department at Arecibo. Her arrival in October 1998 was heralded shortly before by Hurricane Georges which made Arecibo (and the whole of Puerto Rico) sit up and take notice. Karen certainly lived up to this “whirlwind introduction” with her remarkable level of energy and proactive approach to all situations. Coupling these aspects with her deep astronomical insight and extensive technical abilities, she has been a unique asset to the Observatory.

Karen is an expert in the study of Low Surface Brightness galaxies, her contributions to the topic having featured in many of the “Astronomical Highlights” sections in this Newsletter over recent years. However, it is hard to remember that she joined us with a track record mainly as an optical astronomer. It speaks volumes that on arrival in Arecibo, she immediately began contributing in a major way to our operations at this “very radio astronomical” observatory. Apart from her astronomy, Karen was the newsletter co-editor for 1 1/2 years; she contributed immensely towards our web pages, system documentation, receiver calibration, data reduction approaches, control system interfaces, as well as just about everything else really! Many of our readers will have benefited during their Arecibo stays by having had Karen as their “Friend of the Telescope”. She was also a major player in many local organizing committees for conferences and workshops at the Observatory, and took a major part in the establishment of the Extragalactic ALFA (E-ALFA) Consortium. In this latter respect, we should not forget that it was Karen who coined the acronym, ALFA.

Now, this West Virginian girl returns to her home state, taking up a position on the scientific staff at Green Bank. Happily, her husband, Paul, a lecturer in Physics at the University of Puerto Rico, Arecibo, in recent years, has also joined the Green Bank staff in their Software Development Division. Karen and Paul, we miss you both badly, not only workwise but socially too. Come back soon — we are only a short “hop” away — and don’t forget that “El Perro Tuna” needs to keep up his Spanish from time to time!

Muchas gracias a Slava Slysh
Chris Salter

At the turn of this year, Professor Slava Slysh departed the shores of Puerto Rico to return to the Astro Space Center of the Lebedev Physical Institute in Moscow. Slava spent 15 months with us at Arecibo, and in contributing his remarkable depth of experience and astronomical insight to our operations did much towards raising the scientific and technical temper of the Observatory. While with us he pursued polarization observations of Galactic OH masers (see Newsletter No. 34), and
line searches and other molecular-line studies between $\lambda 3$ and 7.5 cm (e.g. see the Astronomy Highlights in this issue). He also made significant contributions towards understanding the optics of the upgraded telescope, and contributed meaningfully to discussions on the future of NAIC.

Slava’s keen sense of humor and great friendliness will be much missed at the Observatory. He and his wife, Elvira, lived in the small settlement of Juego de Bola while they were with us, where Elvira painted some enchanting canvases of the village. Slava and Elvira, we would like to wish you all the very best back in Moscow from all of us here. We only hope that you were able to “import” a little of the Caribbean sunshine with you on your return home to brighten those dark winters?

---

**Job Openings**

**Postdoctoral Research Associate in Space and Atmospheric Sciences**

One postdoctoral position in the area of atmospheric science, with two-year tenure, is currently open at the Arecibo Observatory in Puerto Rico. The starting date is flexible and review of applications will begin immediately. This position will remain open until filled. Applicants should have a doctoral degree in atmospheric or physical science or in a related engineering field, obtained within the last few years, and have ability and interest in pursuing independent research. As a staff member at Arecibo, the successful candidate will also be expected to assist visiting observers in his or her area of specialty, and to help define and implement improvements in instrumentation and procedures.

We will consider applications in all specialized areas of atmospheric research. However, specific areas that we are most interested in reinforcing our capabilities at Arecibo include: studies of the F- and E-region ionosphere and thermosphere utilizing combined incoherent scatter radar and passive optical sensors; resonance LIDAR probing of the mesosphere; and high altitude protonospheric investigations using UHF and VHF radars. An experimental background in multiple remote sensing techniques, such as radar and optics, would be advantageous.

Applicants should send a resume including a list of publications, the names of three references, and a plan for research activity that would be conducted at Arecibo. These materials should be forwarded to the Office of the Director, NAIC, Cornell University, Space Sciences Building, Ithaca, NY 14853-6801. For more information please contact Sixto González (sixto@naic.edu). NAIC is operated by Cornell University under a cooperative agreement with the National Science Foundation. EOE/AAE. For further information about NAIC and the Arecibo Observatory see [http://www.naic.edu](http://www.naic.edu).

**Head of Radio Astronomy — Senior Research Associate**

The National Astronomy and Ionosphere Center (NAIC) has an opening for the Head of the Radio Astronomy research program at the Arecibo Observatory in Puerto Rico; the appointment will be made at the level of Senior Research Associate for a period of 5 years, with renewal based on appropriate review. NAIC is an NSF-funded National Center for research in radio and radar astronomy, and in atmospheric science, accepting observing proposals from scientists worldwide. The Arecibo 305-m telescope has recently been upgraded with a Gregorian reflector system and new instrumentation that permits observations within a frequency range spanning 300 MHz to 10 GHz. This upgrade has resulted in significant improvements in available bandwidths, system noise and gain.

The Arecibo Observatory is located in the karst hills of the beautiful Caribbean island of Puerto Rico. A stimulating research environment is provided by approximately 20 resident staff scientists, postdoctoral fellows and graduate students, as well as over 200 visiting scientists per year. In addition, physics and engineering faculty and students of the University of Puerto Rico have a cooperative research and educational association with the Observatory. NAIC and the Arecibo Observatory are operated by Cornell University under a cooperative agreement with the National Science Foundation.

The Head of Radio Astronomy is responsible for promoting observing capabilities, supervising the Arecibo staff radio astronomers, supporting and encouraging the scientific staff in their personal research, monitoring the performance of the telescope and its instrumentation to maintain data reliability (e.g. telescope pointing and calibration), and arranging for the provision of assistance to visiting astronomers, as needed, to help them realize their research goals. In consultation with the NAIC staff astronomers and the community of users, the Head of Radio Astronomy will develop programs for instrument development, software, and user services.

Importantly, the Head of Radio Astronomy is expected to use the Arecibo research facilities in his or her own research endeavors and, for that reason, we particularly encourage applications from individuals with observational interests in such areas as pulsars, HI and OH in our galaxy and external galaxies, molecular probes of star formation, and high sensitivity VLBI. A 7-element multibeam system at 21 cm is scheduled for initial observations in late 2004 that will provide additional research opportunities.

A Ph.D. in astronomy or a related field is required. The successful candidate will be an employee of Cornell University, and hence eligible for all applicable University/Observatory benefits. Salary and benefits are attractive and include a relocation allowance. Details will depend upon the candidate’s qualifications and experience. Application evaluations are currently in progress. Please send a complete resume of academic, profes-
sional and personal data, a research plan, and names and contact information of at least three references, to: The Director, National Astronomy and Ionosphere Center, Cornell University, Space Sciences Building, Ithaca, NY 14853-6801. EOE/AAE. For further information about NAIC/Arecibo Observatory, see (http://www.naic.edu).

Recent Colloquia

May 14, 2003, Steve Torchinsky, Canadian Space Agency, “The Odin satellite: design, integration, test, and some results”

May 13, 2003, R. Ramachandran, Berkeley University, “Dynamical Properties of Polarization in Pulsar Radiation”

May 8, 2003, Leslie Sage, University of Maryland, “How to publish a paper in Nature”

April 3, 2003, Avinash Deshpande, Arecibo Observatory, “Vela, its X-ray nebula and the polarization of the pulsar radiation”

March 18, 2003, Ed Salpeter, Cornell University, “Heavy Elements in the Galaxy and Tuberculosis in the USA”

February 21, 2003, Rob Wilson, AO-NAIC & Penn State Univ., “Recent Observations of Atomic Layer Enhancements and Temperatures with the Arecibo Potassium Lidar”

February 20, 2003, Josef Höfther, Leibniz Institute for Atmospheric Physics, Germany, “Observations of NLCs, temperatures and PMSEs at Svalbard, 78° N”

February 6, 2003, Emmanuel Momjian, NRAO, “Sensitive VLBI continuum and HI absorption observations of interacting/merging galaxies”


December 02, 2002, Paul Jones, ATNF, Australia, “The search for biomolecules in Sagittarius B2 with the Australia Telescope”

December 03, 2002, Maria Hunt, Univ. of New South Wales, “Massive Star Formation from Colliding Molecular Clouds: The case for RCW 36 and RCW 57”

November 19, 2002, Geoff Wright, Univ. of Sussex, UK, “Feedback Model for Radio Pulsars”

November 18, 2002, Joanna Rankin, Univ. of Vermont, “Subbeam Circulation and the Physics of Pulsar Emission”


November 4, 2002, Dan Wertheimer, UC Berkeley, “Searching For ET With Four Million Collaborators: SETI@home, SERENDIP, SEVENDIP, SPOCK and Astropulse”

October 29, 2002, Diego Janches, Penn State/AO, “Diego’s Turn (on-going debate on meteors)”

October 25, 2002, John Mathews and Diego Janches, Penn State/AO, “Reply”

October 24, 2002, Ulf von Zahn, Leibniz-Institute of Atmospheric Physics, “Remarks on the total meteoritic mass flux into the Earth’s Atmosphere”

October 24, 2002, Erik Muller, ATNF, Australia, “An analysis of the HI in the Magellanic Bridge”

October 17, 2002, Paulo Freire, “Recent results on pulsars presented in Crete”