

National Astronomy and Ionosphere Center Arecibo Observatory



NEWSLETTER

March 1999, Number 27

Beginning with the June 1, 1999 proposal deadline for Arecibo Observatory, we will have a WWW form for the proposal cover sheet. A preliminary version is available for browsing at: <http://www.naic.edu/~ehowell/cover.html>. Comment and suggestions for improvements are welcome. The body of the proposal will still be submitted as a PostScript® file, sent by electronic mail, or hardcopy by regular mail. - *Ellen Howell*

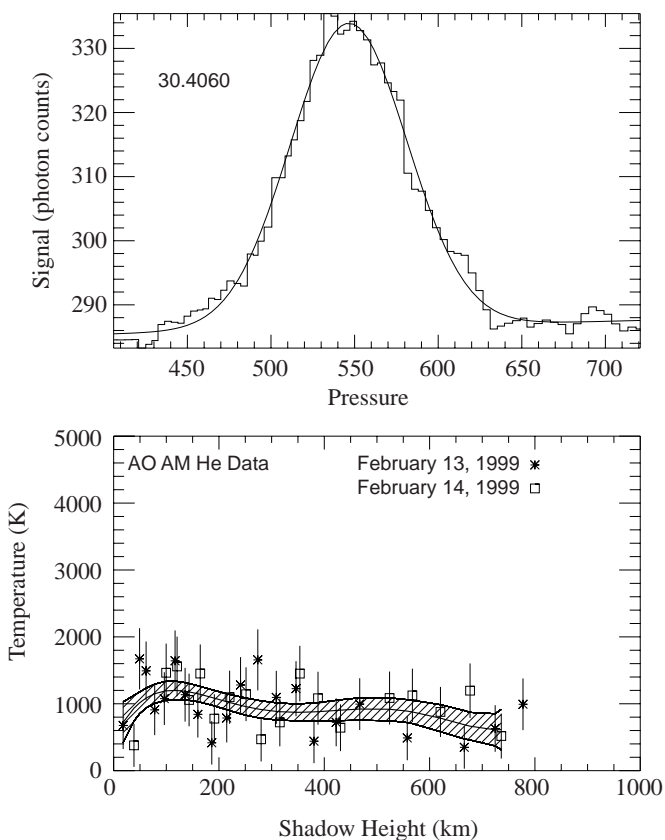


Fig. 1: The top panel shows the metastable He 10830 Å NIR Doppler profile in the morning twilight at Arecibo on February 13, 1999. The spectrum was obtained using a NIR Fabry-Perot Spectrometer with a total integration time of 2.5 minutes. The bottom panel shows upper thermospheric and exospheric temperatures derived from the 10830 Å linewidths. The cross-hatched area envelopes the mean temperature to one standard deviation. (Courtesy of Robert Kerr, Scientific Solutions, Inc.)

Atmospheric Science Highlights

Craig Tepley and Nestor Aponte

Several studies of the upper atmosphere took place at Arecibo since the last NAIC Newsletter went to press. We begin with a more complete description of the topside ionospheric experiment that occurred in late November of last year, which we only briefly mentioned in that report.

In November, we conducted the Plasmaspheric Observations of Light Ions in the Topside Exosphere (POLITE) World Day campaign from the 22nd through the 25th. One goal of POLITE is to advance our appreciation of the topside light ion morphology and

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dynamics through a combination of modeling efforts and coordinated observations made by the incoherent scatter radar chain and by DMSP (Defense Meteorological Satellite Program) overflights. The use of the full latitudinal and longitudinal extent of the radar chain was critical to this campaign in that one key objective was to study the latitudinal and longitudinal variations of hydrogen, oxygen, and helium ions. Simultaneous measurements of neutral oxygen, hydrogen, and helium are also important to explore the coupling between ion and neutral species in the lower part of the topside ionosphere.

For this particular campaign, the observations during, or near to the solstices were of special interest because significant asymmetries in field-aligned ion flows are at their maximum during these periods. In the winter, the helium ion layer descends in altitude and increases in strength, making the observations easier for most other incoherent scatter radars. Because of its vast sensitivity, Arecibo, on the other hand, is well positioned to study the helium ion layer throughout the entire year. We ran the radar for about 60 hours during the core period of POLITE with optical measurements on the associated nights.

During POLITE, and for a similar adjacent study proposed by Robert Kerr et al. (Scientific Solutions, Inc.), Kerr and his student Steve Oetting installed their infrared Fabry-Perot interferometer in the Airglow Lab to observe the He 10830-Å metastable emission that originates in the thermosphere. Their instrument provided critical data on the final piece of the ion-neutral chemistry of the high-altitude ionosphere by furnishing relevant information on neutral helium to compare with He⁺ measured with the radar. We can also extract O⁺ and H⁺ concentrations from radar spectra — the neutral counterparts were determined from optical measurements of the O 8446-Å and H_α 6563-Å airglow using the Observatory's photometers.

In addition, for these studies we re-configured one of our own Fabry-Perot interferometers to be sensitive to H_α by changing the etalon plate spacing and performing a number of other instrument changes. High-spectral resolution studies of H_α help us determine the flux of potentially “hot” hydrogen atoms that may have sufficient energy and velocity to escape the Earth's atmosphere. Several additional nights of observation were made throughout the rest of the year to support these winter-time high-altitude studies, even during times when radar observations were unavailable. The purpose of the extended optical runs was to gear-up for a major, early spring topside ionospheric campaign that is taking place as this Newsletter goes to press.

In mid-January, Silvia Duhau (U. of Buenos Aires) together with Michael Kelley (Cornell U.) and Mike Sulzer (NAIC) carried out several radar runs. The purpose of their experiment was to verify, or not, various rocket Langmuir probe measurements showing elevated electron temperatures in the lower part of the E-region ionosphere during winter months around noon. The specific goals of these incoherent scatter radar measurements were to:

1. make the most accurate possible E-region measurements of electron temperature (T_e) and ion temperature (T_i), preferably by more than one independent method, and
2. look for enhancements in the plasma line, possibly indicating a tail in the electron distribution.

One set of temperature measurements was obtained from coded long pulse ion line observations. Also, an independent measurement of T_e/T_i was obtained by comparing the coded long pulse plasma line electron density measurements with measurements derived from the ion line power profile. Once the near field response of the radar was determined, very high quality measurements of T_e/T_i became possible down to 103 km.

In the first three days of the experiment we obtained simple power profiles, as well as ion and plasma, and coded long pulse ion line measurements in order to determine the behavior of the E-region. The last two days used coded long pulse ion and plasma line measurements, recording the raw data on exabyte tape. It is these measurements that give extremely high quality plasma line profiles, but the analysis is very computationally intensive. About one fourth of the data have been analyzed, covering one of the noon periods. So far, no evidence of elevated temperatures has been found.

Analysis of the data is continuing. Duhau is developing a collision model for the lower E-region so that accurate temperature measurements can be obtained using the ion line spectra. The goal is to obtain two independent measurements of T_e/T_i over the entire E region.

The use of the high quality plasma line profiles in combination with high resolution ion line measurements (made from the same radar pulses by recording two channels at once) is a new technique. Preliminary results indicate that it is possible to use the same data, which extends up to about 190 km to measure the molecular ion fraction with sufficient accuracy to make comparison with models useful. The difficulty with molecular ion fraction measurements is that the molecular and O⁺ masses are so close that it is not possible to distinguish them and simultaneously measure T_e/T_i because the effects on the spectrum are very similar. With T_e/T_i otherwise determined, the different masses can be seen, although it requires a lot of independent samples to obtain useful results.

A new focused World Day experiment was initiated this past February, called the Global Ionosphere-Thermosphere Coupling Study (a.k.a. GITCS). It was a three-day study proposed by Mike Kosch (Max Planck Institut für Aeronomie) and Chantal Lathuillere (Centre National de la Recherche Scientifique - CNRS). The objectives of this

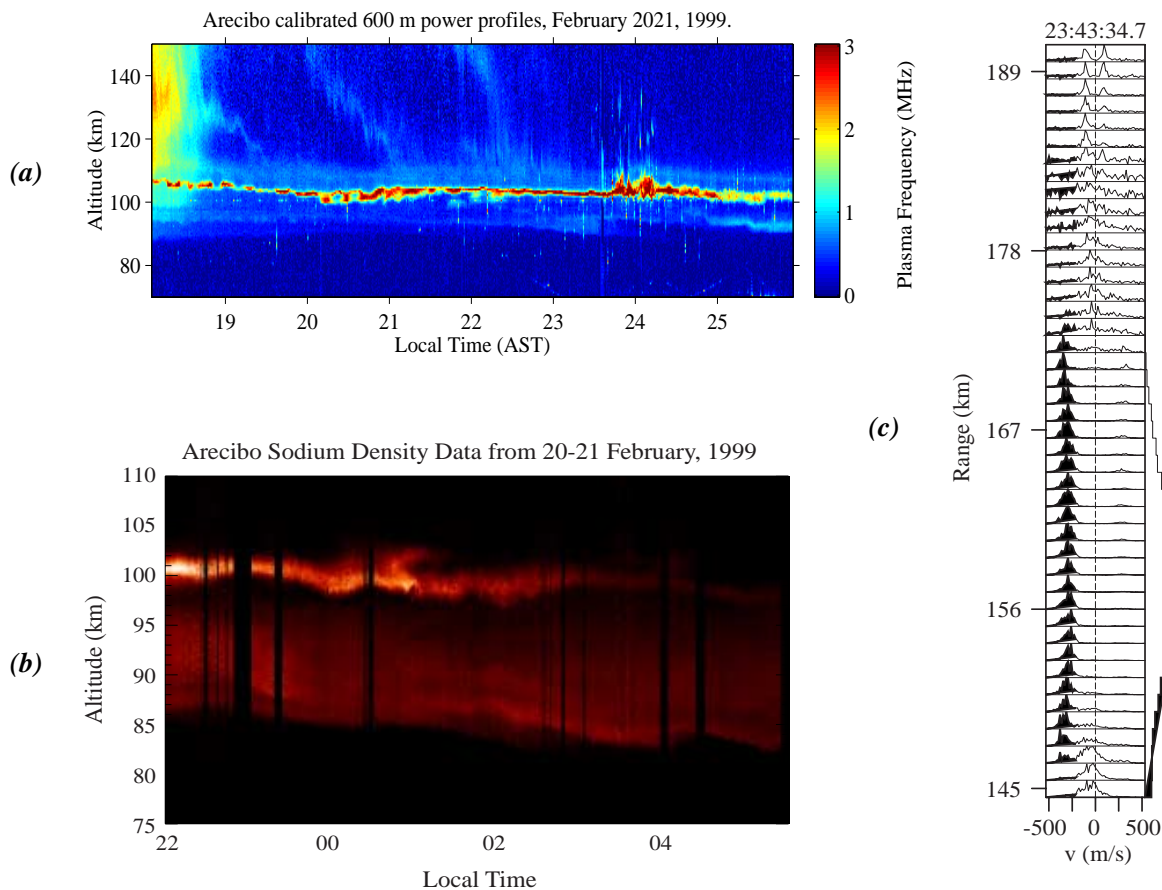


Fig. 2: A “sporadic event” as seen from the (a) 430 MHz incoherent scatter radar power profile, (b) the Na resonance density lidar and (c) CUPRI, occurred at around midnight local time on the night of February 20-21, 1999. Unusually long-lived sporadic E and Na enhancement layers were observed near 101 km altitude on this night. Plasma frequencies exceeded 3 MHz and the Na densities were above 10,000 per cc in the layers. At the same time, line-of-sight Doppler velocities measured by CUPRI exceeded 250 m/s. The 2-sec average spectra are from February 20, 1999 at 23:43:34 AST. The y-axis is range (actual height is near 100 km), and the x-axis is Doppler velocity. On the right hand side of the spectral plots is the power profile. (2a courtesy of Nestor Aponte, 2b courtesy of Jonathan Friedman, 2c courtesy of Wes Swartz)

multi-radar, multi-optical experiment were twofold. First, simultaneous radar and optical measurements of key ionospheric and thermospheric parameters, such as, electron concentration, ion and electron temperatures, and ion velocities observed parallel to the Earth’s magnetic field, will be used to constrain global models of the thermosphere. Two key models used in this study are the University College of London 3D Thermospheric model and the Grenoble TRANSCAR model. A second objective of GITCS is to determine ion-neutral collision frequencies in the F-region ionosphere between O and O⁺ using meridional neutral winds either measured directly via optical interferometry, or in-

ferred from incoherent scatter radar measurements of ion drifts. The atomic oxygen concentration and neutral temperature needed to determine O-O⁺ collision frequencies will be taken from models of the neutral atmosphere or from direct measurement where available.

During the month of February, the Arecibo 430 MHz radar ran for nine consecutive nights (Feb. 12-20). This was part of a combined effort by Kelley and Erhan Kudeki (U. of Illinois) to investigate the effects of geomagnetic storms and substorms in the ionosphere over Arecibo, as well as E-region layer formation, dynamics and plasma instabilities. The Arecibo radar measurements were complemented by several other in-

struments, including two coherent radars from Cornell (CUPRI, run by Wes Swartz) and Illinois (Kudeki), two imagers from Cornell (Francisco García) and Los Alamos (Tom Armstrong), and the Arecibo sodium resonance lidar and photometers. Several nights were quite active in the E-region. In particular, the night of February 20-21 had a spectacular event near 100 km altitude which was observed almost coincidentally by all three radars and the lidar (see Fig. 2). At nearly the same time a very disturbed F-layer drifted overhead with structure quite similar to an event observed in June 1998. More-

over, we were treated to a geomagnetic storm during February 18-19. This storm prevented the usual midnight collapse during the night of the 18th and also raised the height of the F-peak by about 100 km. This storm resulted in spectacular airglow images showing plasma depletions surging pole-ward at high velocity. The success of the project was much aided by the willingness of astronomer Carl Heiles (UC Berkeley) to trade time on the telescope on an active night for time later in the week.

As mentioned above, we supported Kudeki et al.’s study with optical observations of the lower thermosphere and upper mesosphere. Craig Tepley (NAIC) and Eva Robles (NAIC) carried out Fab-

A Note to Arecibo Telescope Users

During 1998 there were three proposal deadlines for which 128 proposals were received. The total telescope time requested was approximately 11,500 hours; clearly we are very heavily oversubscribed at present. This is particularly so as currently we still need to dedicate a significant fraction of available telescope time for instrumental tests and calibration, and software development.

As a consequence of the above, it is likely that many highly graded proposals will not be scheduled within the eight-month window during which they are active, and following which non-scheduled proposals automatically cease to be valid, as per established procedures. Nevertheless, if you wish your unscheduled proposal to remain active after the eight months, the recommended strategy is to re-submit it twelve months after the deadline for which it was originally received, thus keeping it in the queue. Note that on resubmission it will receive a new proposal number, while the old version will be retired. Our current proposal cover sheet contains an entry for declaring that this is a re-submission with no changes, in which case the proposal will not be sent to the referees. Of course, if you have made changes either in response to referee comments, or for other reasons, you should indicate this at the appropriate place on the cover sheet and the modified proposal will be sent for refereeing.

We have placed our schedule on the web to provide you with a better feel of the current situation. Our goal is to schedule four-month blocks as much in advance as possible, but this is still difficult at present. Please note that unless you have specified on the cover sheet certain scheduling constraints we assume that you will be available to come to Arecibo when scheduled.

- *Daniel Altschuler*

ry-Perot measurements of neutral winds and photometric observations of various upper mesospheric airglow emissions, such as, O(¹S), OH, and O₂. The neutral temperature at different heights in the atmosphere are extracted from these airglow data. Ann Chojnacki (Cornell U.) and Jonathan Friedman (NAIC) also operated our resonance fluorescence lidar on many of the nights of the experiment measuring the structure of the mesopause region between approximately 80 and 105 km altitude using the sodium layer as a tracer. An interesting example of the detailed dynamics present at this altitude range is shown in Fig. 2b, also from the night of Feb. 20-21, where we see the influence of pronounced atmospheric gravity waves that strongly reveal their presence in the Na layer. The enhanced Na layer near 101 km was very unusual in that it was long lived. These layers normally last on the order of an hour, while on this particular night it was apparent throughout the 7+ hour observation period.

A four-day World Day, Lower Thermosphere Coupling Study (LTCS) occurred in early March. This particular experiment was somewhat of a merger

between two different scientific focuses — the “standard” tidal study characteristic of LTCS observations in the past, with the influence of magnetic storms on ionospheric conditions. Generally, the effects of magnetic storms on the ionosphere are more pronounced at higher altitudes and are believed to have very little influence deep within the atmosphere.

With the hope of catching an intense geomagnetic disturbance by flexibly scheduling a “floating” observation window for this experiment, the March 1999 LTCS attempted to quantify whether or not there is a major, or even minor, storm effect on the lower thermosphere. Unfortunately, initial results are somewhat inconclusive because only a small amount of magnetic activity was observed during the experiment. This study was a pilot project for the upcoming CEDAR-TIMED investigations that begin next year after the launch of the NASA TIMED satellite that will study the upper mesosphere and lower thermosphere.

Pulsar Observers Explore Turbulent Milky Way

Dan Stinebring (Oberlin College)

We know that the interstellar medium is inhomogeneous on a tremendously wide range of size scales: all the way from the size of spiral arms down to microturbulence as small as 10⁶ cm. Pulsar scintillation observations are the best technique available for probing the ionized ISM in the size scale range from 10⁸ cm to 10¹⁴ cm. In January 1999 a group of us from Cornell University and Oberlin College converged on Arecibo Observatory for a two-week session of pulsar scintillation observations. Observing for about 70 hours at both 430 and 1400 MHz, we investigated scintillation from a group of about 15 strong pulsars. These were pilot observations to demonstrate that we could obtain useful scintillation data with unprecedented frequency and time resolution. The observations were highly successful. Not only did the telescope and the spectrometer work with very few problems, but the pulsars and the ISM cooperated, too. We have seen some features in the new data that are unlike any that we have seen

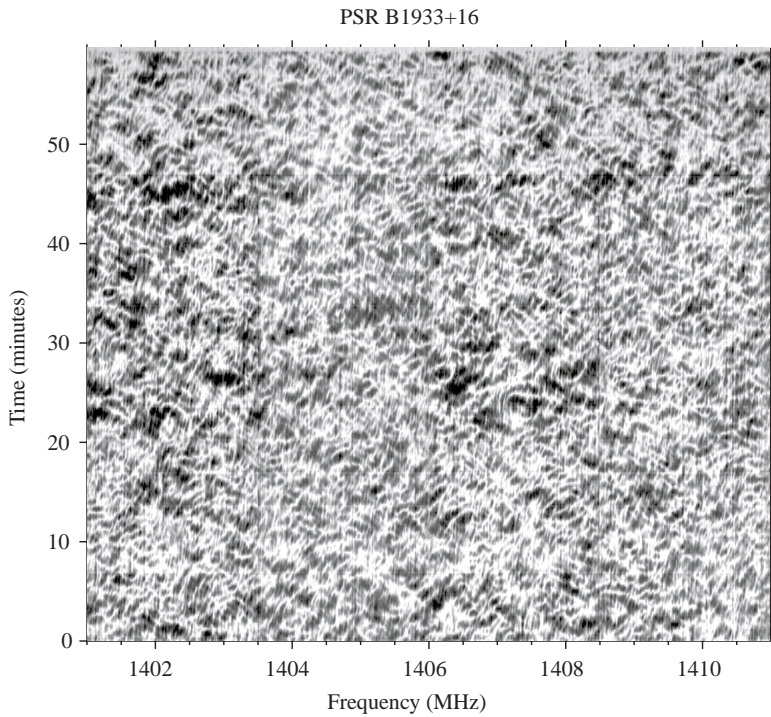


Fig. 3: The dynamic spectrum of the interstellar scintillations of pulsar, PSR B1933+16, at a frequency of 1406 MHz. The observations represent a one-hour track on the source.

before and have given us the incentive for a deeper analysis of scintillation behavior.

The Cornell part of our group consisted of Jim Cordes and graduate student Maura McLaughlin. The Oberlin contingent was made up of four undergraduates (Kate Becker, Joaquín Espinoza Goodman, Mark Kramer, and Jim Sheckard) and Dan Stinebring. The four undergraduates were able to join the observing trip because of generous support from the National Science Foundation (NSF). We posed a bit of a shock to the computer group at first, descending in such numbers before their new computers had arrived, but within a few days we were well set with workstations and had distributed our observing and processing tasks around the group. Although this was a first visit to Arecibo for the Oberlin students, McLaughlin was an invaluable guide in all facets of the observations. She quickly helped orient both the other students and myself in the intricacies of obtaining and handling the large quantities of data in-

herent in these observations (~5 MB/s data rates). Soon we were in a productive routine of observing followed by rapid-turnaround analysis of the data that allowed us to adjust our observing schedule for the following night.

The success of our observations depended critically on a new spectrometer that is coming into routine operation: the AOFTM, which faithful readers of these pages will know is the Arecibo Observatory Fourier Transform Machine. This spectrometer can take a 10-MHz wide bandpass and split it into 1024 frequency channels. What sets it apart from other spectrometers is that it produces spectral estimates every 0.1 ms, allowing for the accumulation of spectra at different phase windows of a pulsar pulse. This can be accomplished even for millisecond pulsars, a few of which we included in our observing list. Fortunately, McLaughlin and Cordes, along with Zaven Arzoumanian of Cornell developed most of the software for the AOFTM and were able to make small

modifications to facilitate our data-taking.

Our data analysis consisted of producing dynamic spectra from the much larger quantity of raw data we obtained in each pulsar observation. A dynamic spectrum is a two-dimensional array, each row of which is the spectrum of the pulsar (for a particular phase window) for an integration time that we set to be 10 seconds. Over the course of a 1-2 hour long observation, these spectra build up to show the dynamic behavior of the pulsar spectrum (see Fig. 3). The time variation of the spectrum is caused by the relative motion of the pulsar, the ISM, and the observatory during the observations. Since pulsars are high-velocity objects (space velocities in the range of 200-400 km/s and beyond), the pulsar motion dominates.

We had several scientific goals for these observations. One was to look for occurrences of strong refraction in the ionized ISM. We wanted to scan a group of promising pulsars looking for occasions when the signal from the pulsar got split into a small number of discrete ray paths by refracting structures in the ISM. Such occasions show up as interference patterns in the dynamic spectrum, which can then be analyzed further to extract information about the bending angle of the rays, the number of discrete ray bundles, and the amount of flux density in each bundle. Such studies have been pursued in the past, but we believe that the post-upgrade Arecibo telescope can make substantial new contributions to this field, both because of the improved telescope performance, the increased frequency agility, and the AOFTM and future instrumentation. Arecibo's unique sensitivity is vital to these observations, as is the high frequency resolution of the AOFTM, since the interference patterns we are looking for are often faint, and the most interesting of them occur as rapidly oscillating patterns across the dynamic spectra.

Such incidents of strong refraction are interesting not only for what they tell

us about the ISM but also for how we can use them to learn about the pulsar magnetosphere. Pioneering work by Cordes and Alex Wolszczan (Penn State U.) at Arecibo in the 1980's demonstrated that episodes of refractive fringing allow nearly nanoarcsecond angular resolution indirect views of the pulsar emitting region. By comparing the dynamic spectrum produced at one portion of the pulse profile with that at another we can set limits on, or even detect, the transverse separation of the emitting regions giving rise to different portions of the pulse profile.

Finally, one of us (Cordes) has developed a technique whereby scintillation observations and VLBI proper motion measurements of a pulsar can be combined to obtain an improved distance determination. This is particularly important for pulsars at high galactic latitude where the Taylor and Cordes electron distribution model fails to specify the distance because the pulsar is above the bulk of the galactic plane electrons that contribute to the dispersion measure. High quality dynamic spectra obtained at several epochs are necessary input to this technique.

Since returning to our home institutions, we have been busy analyzing the data obtained in January. We plan on making at least one presentation on these data at the upcoming AAS meeting in Chicago, but we can mention some preliminary highlights of the data set here. First of all, despite persistent interference, particularly at 430 MHz, the data were of consistently high quality. The AOFTM appears able to handle high levels of RFI and keep it relatively isolated from other frequency channels. In our first pass through the data we ran across several dynamic spectra that are unlike any we have observed before or are familiar with in the literature. For example, the dynamic spectrum of PSR 1933+16 shown in Fig. 3 has a complicated mottled appearance that is unlike the standard dynamic spectrum, which is generally more like a large body of water interrupted by islands of brighter

intensity. In the spectrum shown here it is not possible to clearly delineate between scintillation maxima and minima. The scintillation structure has taken on a more complicated structure. We are not yet sure why this is so, although we conjecture that we are seeing the interference between 5-10 discrete ray bundles. We have further work to do to see if this idea holds up. However, we want to further analyze this dynamic spectrum to extract more information about the interfering rays and hence the structures in the ISM that are producing the pattern. The detection and analysis of fine-scale complicated features such as those shown here would not be possible without Arecibo's sensitivity and the frequency resolution provided by the AOFTM.

Another intriguing pattern in some of the dynamic spectra is the presence of very low-level interference patterns that have roughly the same orientation angle but a wide range of ridge line separations, similar to flying perpendicular to the prevailing ridge line of an older mountain range like the Appalachians. What is remarkable in the patterns that we are seeing is how narrow and regular are their spectral signatures, seen most clearly by forming the 2-d power spectrum of the dynamic spectrum. The wisp-like features we see must result from the interference between a well-defined ray bundle and some more extended feature of the image. The extended feature has to be somewhat one-dimensional in character to explain the results, however. Again, we need further analysis and modeling to fully understand what these high quality data are telling us.

We returned from our observing run with new questions uncovered rather than old questions answered. We find it is taking some time to get used to the high resolution and high dynamic range of these new spectra. They are different enough from previous results that we will be forced to improve the sophistication of our modeling. Although these data did not easily fall into familiar categories, the uncovering of new phenom-

ena is part of the excitement that keeps bringing us back to "El Radar".

Radio Astronomy Highlights

Kiriaki Xilouris and Chris Salter

HI in the Milky Way and External Galaxies

Herbig-Haro (HH) objects are shock fronts formed by the interaction of high-velocity flows of gas ejected by newly born stars and the ambient medium. Outflows from young stars, which have been observed with velocities of up to 500 km s^{-1} , play a major role in the dispersion of ambient gas around young embedded stars. In addition, the combined kinetic energy input of many outflows into the surrounding gas may alter the properties of the parent cloud by the generation of turbulent motions. Recently, it has been found that not only do parsec-scale HH flows exist, but that they are also quite common. This has sparked major interest on the impact of these energetic mass flows on their environment. Giant HH flows are either comparable in length or longer than associated CO outflows, and have sizes about an order of magnitude larger than the cloud cores from which they originate. Many HH objects are found in regions where there is little or no CO emission and lie well outside the boundary of the parent dark cloud against a rich background of stars and galaxies. Thus it is evident that they have blown out of their parent molecular cores and clouds and into the low-density intercloud medium (ICM). Once out of the cloud, the flows inject mass and energy directly into the surrounding ICM. Mass outflows from young stars can heat, ionize, dissociate, and entrain material in the ICM. One or more shocks associated with the same flow can accelerate the entrained ICM gas to velocities greater than those of the quiescent cloud. It has also been proposed that the cumulative action of many outflows and shocks may be the primary agent in the production of turbulence in molecular clouds and the surrounding ICM.

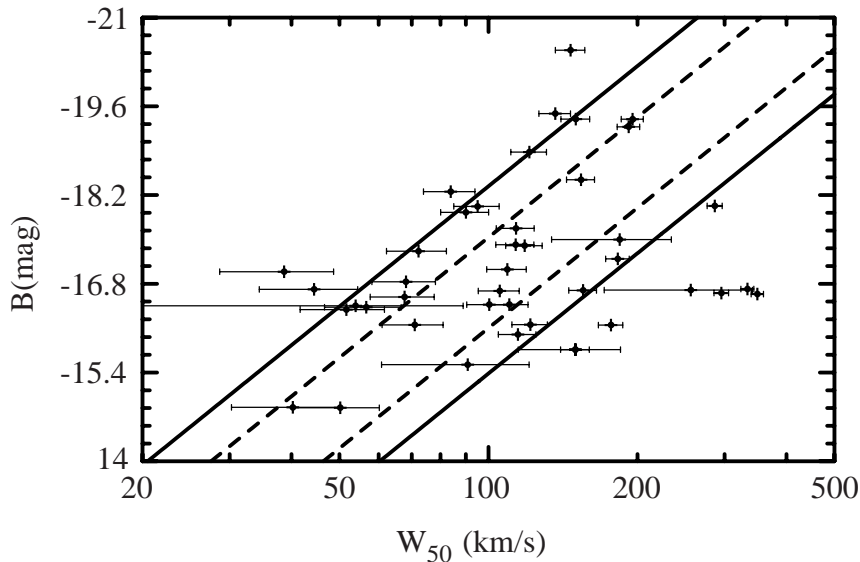


Fig. 4: The 50% velocity widths versus absolute B magnitude for all galaxies detected by the survey of O'Neil, Bothun, & Schombert. The solid and dashed lines are the 1σ and 2σ fits to the Tully-Fisher relation for previously detected low surface brightness galaxies by Zwaan, et al. (1995). (Courtesy Karen O'Neil)

In Jan 1999, Héctor Arce & Alyssa Goodman (CfA) searched for high-velocity neutral hydrogen (HI) entrained by shocks produced by giant HH flows in the low-density ICM. Their targets were HH objects lying well outside the dark cloud inhabited by the outflow source, previously discovered in the optical. They are certain that there is accelerated gas at these positions, the tricky part is to detect it. All of the positions they looked at suffer from Galactic HI “contamination”, and thus it is very probable that any observed high-velocity emission contains both background (Galactic) emission and the high-velocity entrained gas it is desired to detect. To cope with this problem, these observers took a number of OFF positions (different for each source) situated less than $10'$ around the ON-source position. The spectra of the OFFs (together adding up to have the same integration time as the ON position) were averaged and then subtracted from the ON position in an attempt to subtract the Galactic emission from the ON spectra. To beat down the noise, integrations of many hours were taken on each position. Ultimately they hope to detect very low-emission high-velocity wings in the (ON - OFF) spectra, indicative of high-velocity gas accelerated by

HH flow-produced shocks. Detection of the high-velocity wing will enable calculation of the amount of energy these giant HH flows deposit in the ICM, and how much they contribute to ICM turbulence. The results obtained from these observations, in conjunction with published optical/IR spectral and photometric observations of the same HH objects, will aid understanding of the effects which mass outflows from young stars have on the low-density ICM and the process of gas entrainment by shocks. In addition, this combination of observations will advance our knowledge of the physical characteristics of the ICM.

Karen O'Neil (NAIC), Greg Bothun, & Jim Schombert (Oregon) undertook a HI survey of over 100 low surface brightness (LSB) galaxies between Jun and Nov, 1998. This resulted in 41 detected galaxies with $22.0 \text{ mag arcsec}^{-2} < \mu(0)_B < 25.0 \text{ mag arcsec}^{-2}$. The detections range in color from very blue through the first $\lambda 21$ -cm detection of very red LSB galaxies, while their HI mass-to-luminosity ratios vary from reasonably gas poor ($M_{\text{HI}}/L_B = 0.1 M_\odot/L_\odot$) to possibly the most gas rich galaxies ever detected ($M_{\text{HI}}/L_B = 46 M_\odot/L_\odot$). Analysis of the structural properties of these galax-

ies shows a diverse population, ranging from dwarfs to intrinsically luminous systems, though no large, Malin I-type galaxies were identified. They found no correlation between the galaxies' color and M_{HI}/L_B , and in fact found red LSB galaxies with $M_{\text{HI}}/L_B > 9 M_\odot/L_\odot$. However, contradicting the idea that star formation in these galaxies has been delayed only in those regions with an underdensity of HI gas, is their discovery that the highest M_{HI}/L_B values correspond to galaxies with scale lengths less than 2 kpc. Additionally, they have found no correlation between velocity widths and central surface brightness or M_{HI}/L_B for these galaxies, showing a lack of support, but by no means discrediting, galaxy formation theories which rely on a $\mu(0)$ dependence on angular momentum. Finally, the most significant discovery of this survey is a complete lack of correlation between the rotational widths of the galaxies and their absolute magnitudes. Attempts to fit the galaxies to even the broadened HI Tully-Fisher relation of Zwaan et al. (MNRAS, 273, L35, 1995) failed (see Fig. 4). It thus appears likely that the observed HI Tully-Fisher relation, like the Freeman (ApJ, 160, 811, 1970) law concerning galaxy surface brightnesses, is merely a selection effect, showing not a law of galaxy formation but merely our limited ability to view the Universe.

Molecular-Line Studies

Wendy Lane & Frank Briggs (Kapteyn) searched for redshifted 1665- and 1667-MHz OH absorption in two low-redshift $\lambda 21$ -cm absorbers along the line of sight to the QSO B0738+313. With the new correlator, both transitions could be observed simultaneously for both redshift systems by setting four separate 3.125-MHz wide subcorrelators at frequencies near 1360 and 1540 MHz in the band of the L-wide receiver. No absorption was seen to a 3σ limit of 0.12% in either system. During the observations, 10 min was also spent observing the $\lambda 21$ -cm absorption in the lower redshift system (Fig. 5). This observation resolved both

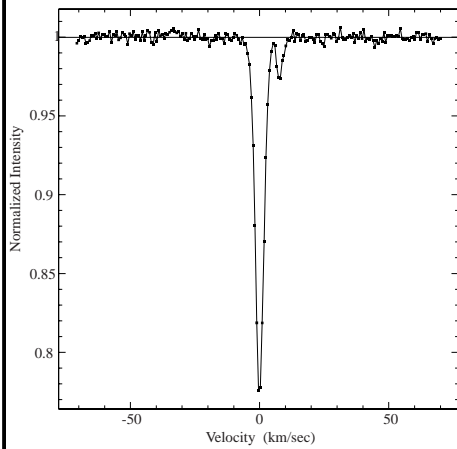


Fig. 5: A 10-minutes ON, 10-minutes OFF observation of the 121-cm line at $z=0.0912$ towards the QSO B0738+313. Channel spacing is 0.7 km/s^{-1} , allowing this extremely narrow line to be resolved for the first time. (Courtesy Wendy Lane)

the main line and the second, weaker component for the first time. The extreme narrowness of the absorption profiles constrains the kinetic temperature of the absorbing gas to be less than 350 K. The HI column density in the $\lambda 21$ -cm lines calculated with the kinetic temperature is only half of that measured in the Damped Ly α line for this system. It seems likely that the “missing” gas might lie in a warmer phase component not detected by these observations.

Jeremy Darling & Riccardo Giovanelli (Cornell) have discovered the galaxy IRAS 06487+2208 to be an OH Megamaser by observations of the 1665- and 1667-MHz OH lines redshifted to about 1457 MHz ($cz = 43080 \text{ km/s}^{-1}$). IRAS fluxes for the object give an infrared luminosity of $L_{\text{IR}} \sim 10^{12.5} h_{75}^{-2} L_{\odot}$, placing it in the class of ultraluminous infrared galaxies ($L_{\text{IR}} > 10^{12} L_{\odot}$), and making it a good megamaser candidate. IRAS 06487+2208 is unresolved in the Digitized Sky Survey, so these observers cannot say if the object is an interacting system. The 1667-MHz line is the stronger of the two OH lines ($S_{1667}/S_{1665} \sim 6$), with an

isotropic luminosity of $10^{2.8} h_{75}^{-2} L_{\odot}$. This line exhibits a full width at half-maximum of 241 km/s^{-1} . There are clearly a number of different sources spread over a range of velocities which contribute to the 1667-MHz line, including an OH absorber. As a test of the validity of the detection, the 1665-MHz line was plotted at the same velocity as that at 1667 MHz (Fig. 6) such that the two lines, if genuine, would show some correspondence of features. The two lines do indeed show some similar characteristics, most notably an absorption feature near the center of both. IRAS 06487+2208 was selected to be a strong FIR source, but radio-quiet (from NVSS, $S_{1.4 \text{ GHz}} = 10.8 \text{ mJy}$) to minimize standing waves in the bandpass.

In the Arecibo sky there are 355 IRAS sources with an LRS 2n spectral type, which are expected to have detectable OH masers. Only 52% do. This poses the question of just why there are so many objects without masers. During the past months, Lewis (NAIC) has made OH observations of the last 40, rather blue, objects in the sample, which he has also searched for 22-GHz water

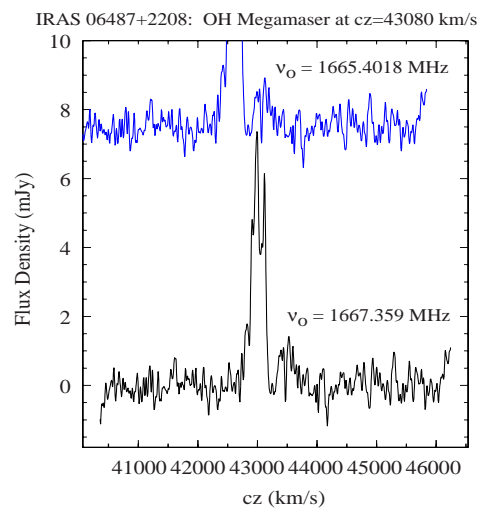


Fig. 6: The OH spectrum of ultraluminous infrared galaxy, IRAS 06487+2208, which is redshifted to $cz = 43080 \text{ km/s}^{-1}$. The upper trace shows the spectrum shifted such that the 1665-MHz line coincides with that from the 1667-MHz transition in the lower trace. The spectrum spans 25 MHz. The upper trace is offset arbitrarily in flux density to ease viewing of the correspondence of peaks and the absorption feature present in the two lines. (Courtesy Jeremy Darling)

masers. The percentage exhibiting masers is surprisingly independent of their IR colors. It now seems likely that the 2n sources without masers are predominantly objects that have passed through a recent thermal pulse, and so are at a phase where the new energy from He burning is enhancing their luminosities, thus lengthening their periods, and so increasing their mass-loss rates. Such stars experience a sudden coupling between their gaseous shells and radiatively driven dust, when the gas density becomes sufficient to slow down dust particles.

This in turn results in an abrupt increase in the expansion velocity of the circumstellar gas, which causes it to move beyond the prior equilibrium distribution of screening dust; in effect the objects without masers are those without a sufficient dust screen to protect their molecules. This scenario suggests that these objects should also have systematically longer pulsation periods, which they do.

Lewis has also begun a project to improve the quality of existing data on the Arecibo set of OH/IR stars. The first segment of this project was to confirm the nature of objects with $|b| > 10^\circ$ and red IR colors, most of which are associated with young stellar objects where these overlap the IR color range of the reddest OH/IR stars. Three of the 1612-MHz detections, 03220+3035, 04236+2559 & 04305+2414 have solitary 1665-, 1667- and 1612-MHz features at just the same velocity, and so are probably YSO. However, as a result of this work, Lewis has found a new proto-planetary nebula with OH emission, 19386+0155, an object very like the prototypical example, 18095+2704, found at Arecibo 10 yr ago. The accompanying spectra (Fig. 7) were observed simultaneously, and result from 15 min ON-source integration.

Rachel Kleban (Cornell) & Paul Goldsmith (NAIC/Cornell) continue their series of OH-absorption measurements in the 1612-, 1665-, and 1667-MHz lines of OH, against seven radio-continuum background sources. A

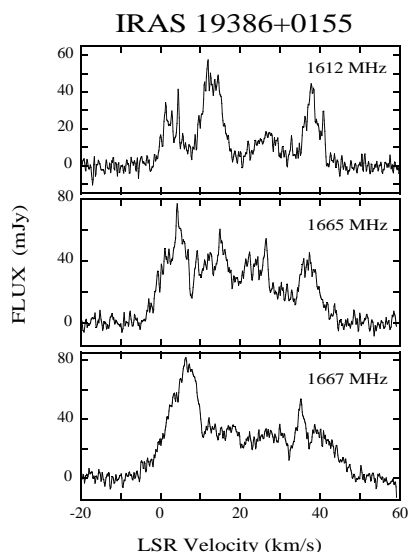


Fig 7: Spectra of the 1612-, 1665- and 1667-MHz OH lines from IRAS 19386+0155. The data were taken on 11 October 1998, with a resolution of 0.14 km s^{-1} . (Courtesy Murray Lewis)

sample absorption spectrum is shown in Fig. 8. The sources are located near dense cores in the Taurus molecular cloud, the observers having previously made small emission maps at these sites in CO, ^{13}CO , and C^{18}O . These observations are the second of an on-going set, and the sources will be reobserved sev-

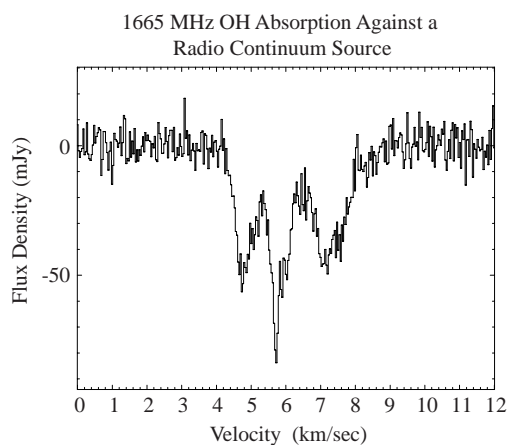


Fig. 8: The 1665-MHz, OH-absorption spectrum against a background radio continuum source seen through a dense region of the Taurus molecular cloud complex. The spectrum is the average of both polarizations, with 40-min total integration, and a resolution of 0.035 km s^{-1} . Position switching in a hexagonal pattern around the central continuum source was used. (Courtesy Rachel Kleban)

eral more times in OH and H_2CO , beginning in March 1999. The aim is to look at how the spectra change with time as the parallax from the earth's orbit and differential galactic rotation change the relative positions of the clouds and radio sources. The data will be combined with a radiative transfer model to investigate the small-scale structure of molecular clouds at a variety of scales.

Pulsars

Most encouragingly, during the past few months Arecibo has welcomed to the Observatory several enthusiastic newcomers to pulsar research. These young scientists have made their presence felt and left their mark here. Five of these, Andrea Somer (Berkeley), Eric Splaver & Walter Brisken (Princeton), Adam Chandler (Caltech) & Macej Konacki (Penn State), are graduate students currently working on Ph.D. projects based largely on data acquired with the upgraded telescope. They have enlivened the Observatory with their presence and excited the local staff with their new ideas and projects. Already experts in their field, and close to thesis completion, are Frederick Jenet (Caltech) & Maura McLaughlin (Cornell) who have performed impressive research using instruments that they have assisted in developing, and software which in large part they themselves wrote. We wish all these young people well with their studies and look forward to their continued participation at the Observatory.

An additional influx of lively young people came with a group of undergraduates from Oberlin College under the guidance of Dan Stinebring (see previous article). They visited the Observatory for four weeks, getting involved with pulsar observing and experiencing the culture of radio astron-

omy first hand. Bernie Kuan & Claire Petersen (Carleton) were also here getting started in radio astronomy by studying kinematic distances to pulsars with multi-epoch HI-absorption observations of pulsars with Joel Weisberg (Carleton) and Kiriaki Xilouris (NAIC).

Remote pulsar observing has now become a regular practice at Arecibo, starting with the Arecibo-Berkeley Pulsar Processor (ABPP) and continuing with the Penn State Pulsar Machine (PSPM) and the Caltech Baseband Recorder (CBR). Although still in its infancy, the appearance of remote observing demonstrates how easy it is to observe with Arecibo from the comfort of one's own office. Hopefully, with the imminent appearance of a faster internet connection and a sophisticated user interface, remote observing will become a routine part of pulsar observing at Arecibo. We point interested users to our web site, (<http://www.naic.edu/~pulsar/observing.html>), where the operation of each machine is described, as are the ways to observe pulsars with the upgraded telescope.

Fruchter (STScI), Xilouris, Lorimer & Eder (NAIC) and Angel Vázquez (NAIC) have been observing a newly discovered 25-ms pulsar from the STScI/NAIC drift-scan upgrade search to establish its timing properties. The lack of any supernova remnant in its vicinity, together with its height above the galactic plane (1 kpc), suggest that this is not a young object. Indeed, it seems to fall in the rare class of recycled millisecond pulsars with periods between 10 and 40 ms. At present, there are only 4 known class members, suggesting a very interesting evolutionary history. Two slower pulsars, PSR J1905+06 and J0329+16, with periods of 989.6 and 893.4 ms respectively, have been confirmed from a list of 8 candidates resulting from the STScI/NAIC drift-scan search.

Lorimer has used the Cornell Theory Center (CTC) to analyze a large volume of pulsar search data taken with the PSPM. These 430-MHz pointed obser-

vations were made around the positions of optically identified white-dwarf stars in Oct 1998. The results of this search will help in establishing the frequency of millisecond pulsars and white dwarf stars possessing a hydrogen-dominated surface.

Extensive searching at 430 and 1410 MHz by Xilouris, Lorimer and collaborators has not revealed periodic radio signals related to the magnetar, SGR 1907+14. Neither folding modulo the X-ray period of the magnetar, nor searching for individual bright pulses, have identified periodic features. Following the recent claim of radio-pulse detection from this source at low radio frequencies by Shitov (IAUC No. 7110), test observations were also made at 47 MHz. The band around 47 MHz is heavily interfered by ground communication signals making data reduction very difficult.

The facility pulsar spectrometer, the Arecibo Observatory Fourier Transform Machine (AOFTM), is working very dependably and data-taking software is running smoothly. The acquisition of a 108-Gbyte disk array allows the data to be written directly to disk, facilitating remote observing and freeing the observer from the constraints of tape-drive speed.

Jim Cordes (Cornell), McLaughlin and collaborators have been using the 160-node SP2 super-computer of the CTC for most of their AOFTM data processing. The CTC has recently acquired Mammoth and DLT tapes drives, making the porting of data from Arecibo much simpler. Using the AOFTM, this group has confirmed several new pulsars from pre-upgrade drift-scan and piggy-back searches, and many more await confirmation. One of these pul-

sars has a very large apparent \dot{p} , and future timing observations will better constrain its parameters. The same group has obtained several pointings towards the LMXB, 0614+091. Currently the data are being processed in short chunks, with acceleration searches increasing the sensitivity to short-period binaries. They have also obtained 20 half-hour pointings towards the nearby galaxy, M33, and are searching for isolated dispersed pulses in the hopes of detecting or constraining the number of Crab-like pulsars in that system. Further, as a result of an L-band search for pulsars in the Sagittarius spiral arm, this group reports several interesting candidates which await confirmation. The data reduction is on-going.

In Jan 1999, a team from Cornell (Cordes & McLaughlin) and Oberlin College (Stinebring, Kate Becker, Joaquín Espinoza Goodman, Mark Kramer & Jim Sheckard) conducted a

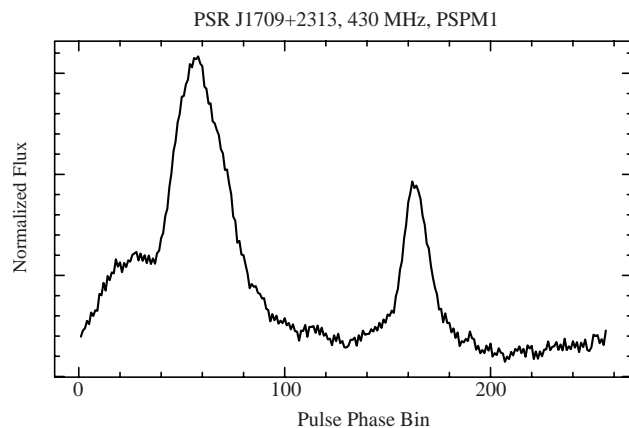


Fig. 10: The pulse profile of PSR J1709+2313 at 430 MHz made with the PSPM.

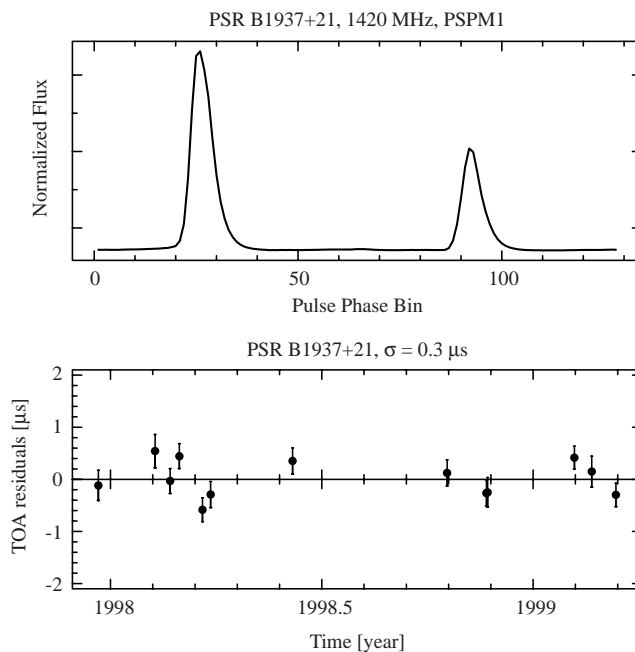


Fig. 9: PSPM observations made at 1420 MHz of the millisecond pulsar, PSR B1937+21; a) the pulse profile, and b) the timing residuals.

two-week session of pulsar scintillation observations. Such observations are the best available technique for probing the ionized ISM on size scales between 10^8 cm and 10^{14} cm. Observing for about 70 hr at both 430 and 1400 MHz, they investigated scintillation from a group of about 15 strong pulsars. Details of these observations can be found in the accompanying article on page 4 by Dan Stinebring.

Since Nov 1997, several millisecond pulsars have been timed with the PSPM by Anderson (Caltech), Konacki, Wolszczan (PSU) & Xilouris. The PSPM's performance has been monitored by timing the fastest known millisecond pulsar, PSR B1937+21, at 1400 MHz. A long-term rms residual of $0.3 \mu\text{s}$ achieved for this pulsar (Fig. 9) serves as an illustration of the PSPM's current timing capabilities. As the result of continuing timing observations of a 4.6-ms pulsar, PSR J1709+2313 (Fig. 10), detected by the PSU/NRL group shortly before the Arecibo upgrade, Anderson, Konacki & Wolszczan have obtained a timing model which successfully phase-connects the pre- and post-upgrade pulse

New Receiver Testing Laboratory

For a long time we have wanted to have a facility to allow us to measure system temperatures of low-noise-receivers for our telescope. We recently completed construction of this Receiver Testing Laboratory located near the Lidar Laboratory. Here, receivers can be mounted on a table which can be jacked through an opening on the roof to get a clear view of the sky.



Photo by Luis Murray

arrival-time measurements for this object. PSR J1709+2313 is a 22.7-day binary pulsar with very low eccentricity, small spindown rate, and low proper motion, all characteristic of low-mass binary millisecond pulsars.

The 14 known globular-cluster pulsars visible from Arecibo have been regularly timed by Sri Kulkarni (Caltech) and collaborators. These long-term observations are being made remotely, and will eventually lead to a determination of the mass in the two relativistic binary systems within these clusters. Furthermore, the positions of the pulsars in the clusters, very precisely determined by timing, will allow studies of the cluster internal structure.

With a new data-taking system and software, a Caltech group led by Frederick Jenet is trying to get a fresh look at high time-resolution observations of both fast and slow pulsars, giving new insights into the emission mechanism. It is hoped that with this fresh approach they will contribute towards unlocking the secrets of the pulsar magnetosphere.

The Coordinated Pulsar Timing experiment is an organized effort from four groups to obtain biweekly observations aimed at simultaneously timing as many as 12 millisecond pulsars using five different backends. Already it has made its 14th successful timing run. The groups hope to achieve submicrosecond timing uncertainties, giving the most accurate pulsar timing to date as the total extent of the observations increases. For the most recent run, the first “Observers of

the Month”, Eric Splaver (Princeton) and Michael Kramer (Berkeley) were present at Arecibo to help with the run.

Somer, Backer (Berkeley) and collaborators report that they have phase-connected observations of PSR J0030+04 which indicate that this newly discovered source is a very nearby, isolated, 4.8 ms pulsar.

Tim Hankins (NMIMT) and collaborators have made simultaneous, multi-frequency observations of single pulses between Arecibo and the VLA. Hankins took the VLA data, with local staff responsible for the Arecibo observations.

VLBI

Arecibo participated in a 5-GHz VSOP observation of the quasar J0149+05 on 16 Nov 98. Sadly, the data handling unit aboard the HALCA satellite ceased to work just before the experiment. Nevertheless, the terrestrially observed data were correlated at the Penticton correlator in Canada. Signal-to-noise ratios of 1253:1 were found between Arecibo and the Green Bank 140-ft telescope, while 310:1 resulted from the baseline between Arecibo and Noto, Sicily.

On 02 Dec 98, Arecibo participated in its first scheduled terrestrial VLBI for many years. This was organized to serve as a test session by a Russian team, coordinated by Igor Molotov, Sergey Likhachev & Andrey Chuprikov (Astro Space Center). The observations were made at λ 18 cm, with the targets including an OH/IR star, 2 pulsars and a qua-

sar. The observations await correlation at Penticton.

Since HALCA’s return to observations in Jan 1999, five 5-GHz observations have been made as part of VSOP operations. In these, the extragalactic objects, J0226+343, J0955+335, J1124+322, J1135+301 & J0911+338 served as targets. The tapes recorded have been sent to Penticton and Mitaka, Japan, for correlation.

Job Opportunity

RFI Engineer - Arecibo Observatory

Following completion of the Gregorian Upgrade, the Arecibo Observatory offers a much increased frequency coverage and wider bandwidths to its users. However, given the recent explosion in global communications and the ever-increasing usage of the radio spectrum, achieving the full potential of the “new” telescope represents a challenge (for more information see, <http://www.naic.edu/~tghosh/smargin/index.html>). We invite applications from qualified persons interested in joining the Arecibo Observatory Electronics Department in its efforts to meet this challenge.

The successful candidate will work towards minimizing emissions from on-site equipment; design, maintain and upgrade RFI monitoring and mobile detection equipment and organize searches for sources of interference. To ensure coexistence with other spectrum users, he/she will work with local spectrum

users and authorities both under the Puerto Rico Coordination Zone (PRCZ) agreement and in response to complaints from telescope users. He/she will also be responsible for the maintenance and improvements of our data and voice communication systems, including local and external networks.

Eligibility: The minimum qualification required is a BSE degree in electrical engineering, plus at least three years experience in relevant areas. Good communication skills and a working knowledge of Spanish are highly desirable.

The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University. AAE/EOE.

Send Applications to :

Attn.: Human Resources Department
RFI Engineer
ARECIBO OBSERVATORY
HC 3 Box 53995
Arecibo, PR 00612

Deadline: April 15, 1999

Comings and Goings

¡Se retira Don José!



Photo by Tony Acevedo

Don José

Carmen Segarra and Jonathan Friedman

Recientemente se acogió al sistema de retiro nuestro compañero **José López**

Álvarez, conocido cariñosamente como “Tío Pino”, “Don José”, “Cheíto-tun-tún”, “El Jardinero”, “El Tórtolo”, etc. Siempre lo recordaremos por sus características Típicas, como por ejemplo: “¡amigo!”, “¡te quiero!”, “que lindo estás”, “que bien te ves” y por los abrazos a nuestra gente. Estuvo con nosotros entre febrero 21 del 1983 al 5 de marzo de 1999. Le deseamos a nuestro querido compañero, mucha salud, prosperidad y disfrute en su jubilación.

An era ended at the Arecibo Observatory with the retirement of **José López Álvarez**, affectionately known as “Tío Pino” (uncle Pine), “Don José”, “Cheíto-tun-tún”, “El Jardinero” (The Gardener), “El Tórtolo” (The Dove), etc. Nearly all who visit the Observatory for even a short time have come to know our charming gardener. Much missed will be his shouts of: “¡amigo!”, “¡te quiero!” (I love you!), “que lindo estás” (how cute you are!), “que bien te ves” (how well you look), and for his frequent and indiscriminate hugs. Don José joined the Observatory February 21, 1983 and retired on March 5, 1999. We hope that our dear friend will enjoy in his retirement much health and prosperity. We dearly wish that he comes to visit us frequently and see, first and foremost, the work done here by his hands.

New Arrivals

Jeffrey Hagen

Arun Venkataraman



Jeffrey Hagen, Senior Scientific Programmer Analyst at NRAO's 12m telescope in Tucson, AZ, has joined the AO Computer Department on leave from NRAO for one year. He brings his considerable expertise in development of real-time control systems and VME-based data acquisition. We thank NRAO for lending us Jeff's skills at a critical time in AO's post-Upgrade era.

Jean-Luc Margot

Jean-Luc Margot comes to the Planetary Radar Astronomy Group as a Post-Doc. He did his Ph.D. work at Cornell University under Don Cambell, and completed his thesis entitled



Jean-Luc

“Lunar Topography from Earth-based Radar Interferometric Mapping.” He successfully defended his thesis on Feb. 5, 1999. Soon after he moved here to Arecibo.

Jean-Luc hails from Louvain Belgium, and he completed his 5-year degree in Electrical Engineering at the University of Louvain, where he graduated with “grande distinction” in June 1993. He wrote an undergraduate thesis on observations of atmospheric water vapor content using satellite microwave measurements.

His first observing proposal at Arecibo is for the imaging of asteroid Golevka using radar interferometry techniques, an extension of his thesis work. With Mike Nolan, he plans to transmit from Arecibo, and to receive the radar echoes simultaneously at Arecibo and DSS-63 in Madrid, Spain.

Jean-Luc comes to Puerto Rico with is wife, Karin, an electrical engineer working for a local biomedical products company. Outside of their highly tech-

nical workdays, Jean-Luc and Karin enjoy spelunking, a useful hobby in both Puerto Rico and Belgium.

Gene Lauria



Gene recently moved permanently to Arecibo as part of the “advance team” of the Ithaca Laboratory move. Gene came to NAIC in 1993. He has a Masters’ of Engineering degree from the U. of Massachusetts, Amherst with a speciality in Electromagnetics. The move does more than bring his large reservoir of electromagnetic expertise to the Observatory site, it unites him with his spouse, pulsar astronomer Kiriaki Xilouris in time for their first anniversary.