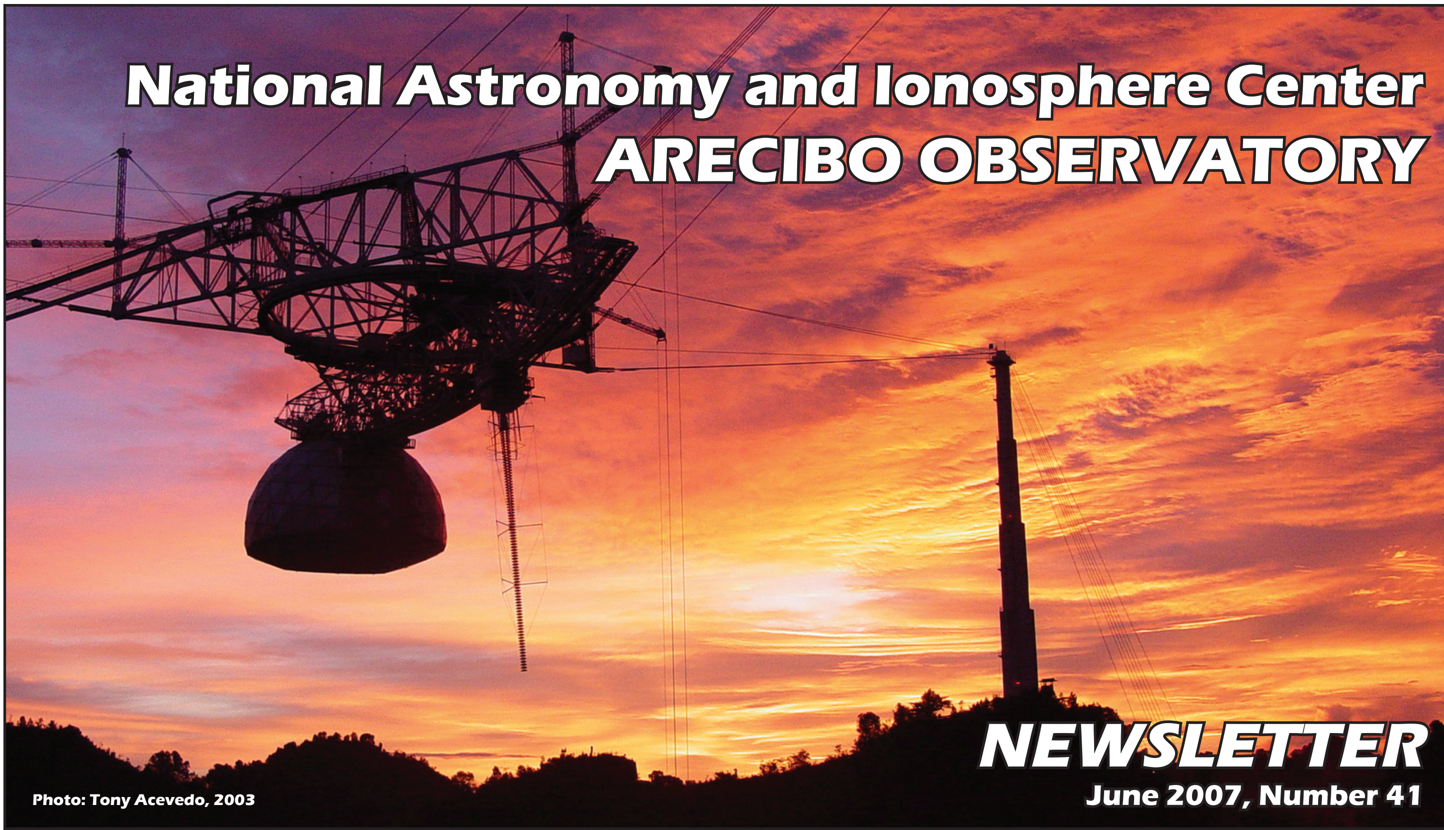

Studies and Applications of the "Electron lines" with the Arecibo Incoherent Scatter Radar

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Introduction

When *Gordon* [1958] first proposed measuring the weak radio wave scattering from electrons in the upper atmosphere, he postulated that the spectral bandwidth of the returned signal should be given by the electron thermal speed, and that the radar backscatter cross section should be given by the cross section of a single electron (σ_e) multiplied by the number of electrons, which comes as a result of the incoherent nature of the scattering process (the positions of the electrons, or equivalently the phases of the backscattered signal from each electron, are random variables resulting from the random thermal motion). Gordon's idea led to the conception of the Arecibo Observatory.

However, the returns measured by Arecibo and other incoherent scatter radars (ISRs – all built as a result of Gordon's idea) did not exhibit the spectral properties expected (although the total scattering cross section was more or less in agreement). The true spectrum turned out to be narrower than that expected for pure incoherent scatter, and this was explained by a series of authors (e.g., *Dougherty and Farley*, 1960, *Salpeter*, 1960) as the result of the effects of the

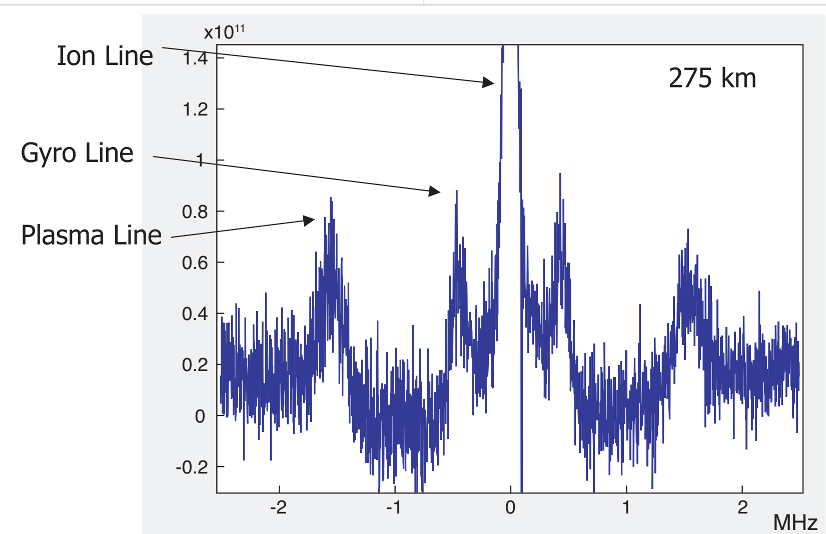

Fig. 1: Full incoherent scatter spectral measurements showing the ion line, gyro, and plasma line. Adapted from Aponte et al. [2007] but based on the measurements of Bhatt et al. [2006].

CONTENTS

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ions in controlling the motion of the electrons on scales larger than the Debye length (the electrostatic shielding distance of a plasma). A robust theory was developed over the subsequent decade that included the effects of a background static magnetic field, partial ionization (collisions with neutrals), and unequal electron and ion temperatures. The very robust theory and the independence of most parameters makes incoherent scatter one of the most precise tests of kinetic plasma theory and the most powerful tool for probing the ionosphere, allowing for the direct extraction of the electron density, ion composition, electron and ion temperatures, plasma drifts, etc. from measurements to this so-called ion line (which can be thought of as scatter from Landau-damped ion-acoustic waves).

However, there are other "resonances" (besides the ion line) predicted by incoherent scatter theory that remained for the most part subjects of intellectual curiosity because of their relatively weak intensity. These lines, which may be grouped and referred to as electron lines, occur at large Doppler shifts (hundreds of kilohertz to tens of megahertz) and can be very narrow. The two sets of lines are the so-called gyro lines (associated with scatter from electron-cyclotron waves) and the plasma lines (associated with scatter from electron plasma or Langmuir waves).

The plasma line occurs at a frequency close to the electron plasma frequency, which is proportional to the square root of the electron density, and was first measured in the 1960's, confirming the theoretical predictions. Its detectability is a result of being enhanced during the daytime from its thermal level by energetic photoelectrons released during the ionization process. The line, when detectable, allows for a sensitive measure of electron density and is used by most ISRs for calibration purposes, but with an experimental technique (necessitated by measurement difficulties) that gives poor range (altitude) resolution but excellent frequency resolution. The gyro line, on the other hand, before a couple of years ago, remained difficult to study, with only a few possible detections (at Arecibo and the European ISR, EISCAT). Measurements of both the plasma and gyro lines have become relatively routine at Arecibo in the last few years.

An example of full spectral measurements is shown in Figure 1 where the up- and down-shifted plasma lines, gyro lines, and ion lines are all evident, as measured with a long (500 μs) pulse [*Bhatt et al.*, 2006]. This capability is unique to Arecibo (as a result of its sensitivity) and has opened doors for new measurement techniques and scientific investigations.

Plasma Line Measurements

One of the most accurate methods for measuring the electron density in the upper atmosphere is using the plasma line resonance, which occurs close to the plasma frequency as predicted by incoherent scatter theory [*Dougherty and Farley*, 1960; *Salpeter*, 1960; 1961]. The information in the plasma line resonance lies in the frequency of the return, not in the shape of the spectrum, as is the case for the ion line. Frequency measurements are much more accurate than power / amplitude measurements (since they do not depend on receiver gains and system losses, which are often difficult to measure and highly variable) so using the plasma line resonance frequency as an ionospheric diagnostic is particularly useful.

One of the first methods for using the plasma line as a diagnostic tool was developed by *Showen* [1979], who used a long radar pulse and the so-called plasma-line cutoff. This technique results in a narrow spike at the frequency corresponding to the critical frequency of the *F2* region, allowing accurate determination of the peak density in the *F* region. More recently, a modern coded long pulse (CLP) plasma line technique has been developed, as reported by *Djuth et al.* [1994], based on the method of *Sulzer* [1986]. This technique allows the plasma-line resonance frequency to be measured very accurately as a function of altitude with high range resolution (up to 75 meters) and high time resolution (5–10 seconds). This high resolution has allowed *Djuth et al.* [1994] to study small density fluctuations caused by gravity wave activity.

An example of a full plasma line spectrum (up- and down-shifted plasma lines) obtained using the CLP technique on April 1, 2006 is shown in Figure 2. The narrow spikes correspond to the plasma resonance frequencies. The plasma resonance frequency occurs close to the plasma frequency, f_p (~$9\sqrt{n_e}$) when the density is sufficiently large. The method results in a high-resolution electron density profile [*Aponte et al.*, 2007; *Djuth et al.*, 1994], with a statistical uncertainty better than 0.05% (yeah, percent) and an absolute uncertainty of a few percent (because of secondary terms in the dispersion relation for Langmuir waves). We should point out that only Arecibo has measured the plasma line with a coded pulse (resulting in the high resolution).

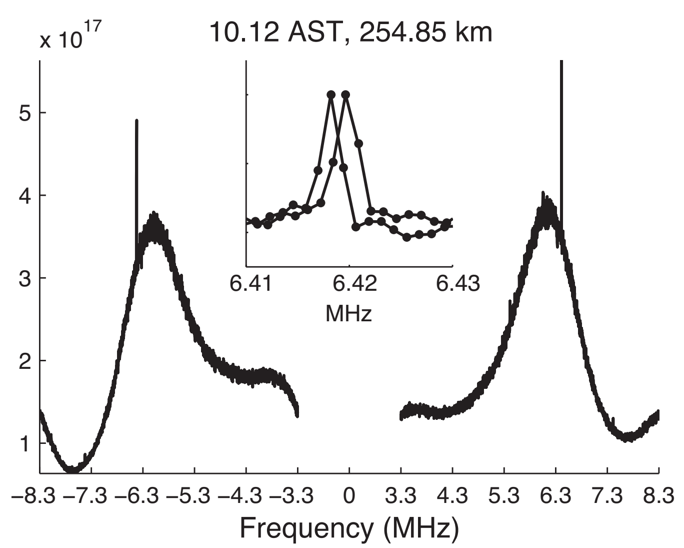
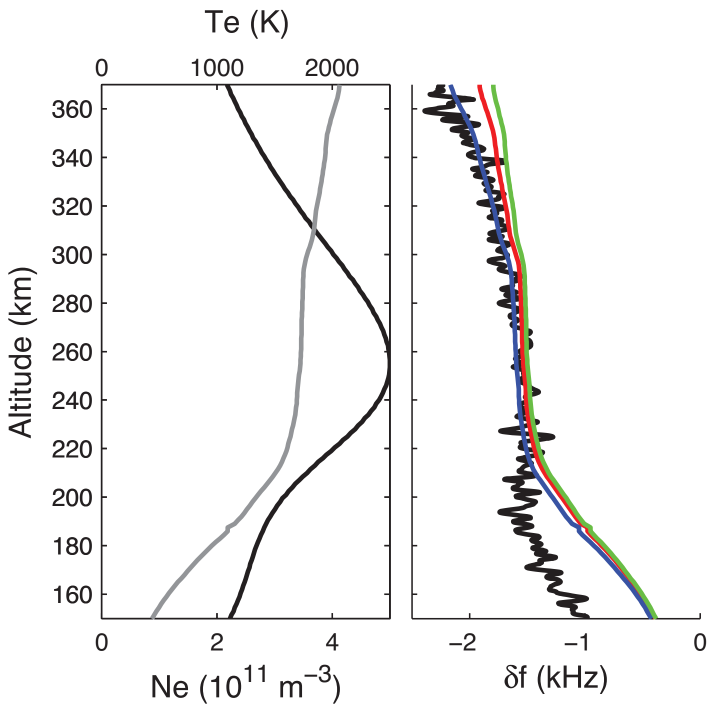


Fig. 2: Example of full plasma line spectrum measured on April 1, 2006. The y axis corresponds to un-normalized power. The inset is a zoomed-in plot of the normalized peak with the down-shifted line folded over to positive frequencies. From Nicolls et al. [2006]

In addition to the high-resolution density information contained in the plasma line, there is a weak asymmetry in the up- and down-shifted plasma line frequencies. That is, they occur at slightly different frequencies (~ 1–3 kHz in a plasma line frequency of several MHz). This asymmetry, evident in the insert in Figure 2, is a result of the fact that the transmission and reception frequencies are different for the up- and down-shifted lines, due to the sizable frequency shift of the plasma line. The difference in frequencies predicted by linear theory is approximately $\delta f = 0.869\ T_e$, where T_e is the electron temperature in Kelvin. However, it turns out that the offset predicted above does not hold for sufficiently low densities and high temperatures, and kinetic effects (including a magnetic field) must be considered. This realization led to the approach taken by *Nicolls et al.* [2006], and validation of these effects is the subject of a current Arecibo investigation.

Fig. 3: Example of measurements on April 1, 2006, near 10:00 LT. The left panel shows a plasma density profile inferred from the plasma line offset (black curve, lower axis) along with the electron temperature from the ion line (gray curve, top axis). No molecular ions were used in the ion line fit. The right panel is the measured plasma line frequency difference (black), the prediction from linear theory (green), the prediction from kinetic theory neglecting the magnetic field (red), and the prediction from kinetic theory with α = 45° (blue). From Nicolls et al. [2006]



One of the important implications of the aforementioned asymmetry is the potential to extract electron temperature. While this asymmetry has been investigated before, the Arecibo high-resolution measurements provide the possibility for a routine measurement of T_e throughout the *F* region and topside ionosphere with high time and range resolution. As an example, we show a profile measured on April 1, 2006 near 10:00 local time (LT) in Figure 3. In this experiment, we used a configuration where the linefeed was pointed vertically, and we measured the up- and down-shifted plasma line frequencies along with the ion line (using a Multiple Radar Auto-Correlation Function—MRACF mode). The left panel shows the electron density from the plasma line and the electron temperature deduced from fits to the ion line with molecular ions neglected, and the right panel shows the measured δf (black), which is a few minutes' average, the predicted δf using linear theory (green), the predicted δf using kinetic theory but neglecting the magnetic field (red), and the predicted δf using kinetic theory but including the magnetic field (blue). Near the *F* peak, the linear relation does reasonably well since the plasma density is sizable. Above the *F* peak, the kinetic effects become important, and we see that the theory including the magnetic field does an excellent job of reproducing the observed δf. Below 200 km the curves diverge for many reasons. In particular, the autocorrelation functions (ACFs) were processed neglecting the molecular ions, which is incorrect, and molecular ions would have the effect of increasing the electron temperature (increasing the magnitude of the predicted plasma line offset). Secondly, it turns out that the MRACF mode may not be satisfactory at low altitudes [*Aponte et al.*, 2007] where the range smearing effects of the long pulse become important. In recent experiments, we have combined this mode with a coded long pulse ion line technique at low altitudes. Other effects might be associated with photoelectrons and currents, which are interesting topics of investigation.

In a previous NAIC Newsletter (number 40, December 2006, Figure 18) results of the plasma line analysis and comparison with temperatures from the ion line were presented. These show very good agreement in the altitude region where molecular ions are not important and the ion line method is effective. It is very clear that the plasma line asymmetry technique gives electron temperatures in agreement with ion line fits, providing a new ionospheric diagnostic [*Nicolls et al.*, 2006].

F1-region Composition and Temperature Measurements

One might reasonably ask: if we can get the electron temperature from the ion line, what is the benefit of these plasma line measurements? In addition to the important intellectual curiosity arguments, measuring N_e and T_e using the plasma line has some important scientific applications, one of which has been investigated by *Aponte et al.* [2007]. In recent times there has been a renewed interest in measuring the molecular ion composition in the *F*1 region using incoherent scatter (IS) radars. This parameter is important as it relates to the composition of the neutral atmosphere in that region, for which there are no direct ground-based measurements available. Furthermore, in order to measure accurate electron and ion temperatures in the *F*1 region with an incoherent scatter radar, it is absolutely necessary to use the correct molecular ion composition. This is because there exists a temperature-mass ambiguity in incoherent scatter theory—a change in composition (mass) and a change in temperature cannot be distinguished. This is not a problem in the *F*2 region and topside where the masses of the ion species are sufficiently different to make this effect unimportant, but it is a problem in the *F*1 region, where molecular ions exist. This is a major limitation for ISRs. The plasma line provides an independent measurement of electron density as a function of altitude, and can be combined with ion line power (zero lag) measurements to determine the ratio T_e/T_i. This measurement of T_e/T_i can then be used to constrain fits of the ion line to determine the molecular composition. This method has been implemented by *Aponte et al.* [2007] and provides the first true molecular ion composition profiles from an ISR. Some of these results are shown in the top panel of Figure 4. The two columns of this figure show fits done on a height-by-height basis, as well as fits that assumed a molecular composition profile shape (a hyperbolic tangent model). The plot of the molecular ion fraction (as well as the other parameters) covers the altitude range from 175 to 320 km, so it misses the lower part of the *F*1 region and it includes part of the *F*2 region. From the color image we see that molecular ions make up most of the ion density at the lower altitudes. For this example of winter/equinox and low solar flux conditions, there are 50% or more molecular ions below 190 km basically at all times.

Future work in this area will use the electron temperature measured by the plasma line asymmetry technique as an additional constraint in the *F*1-region fitting process. Aponte et al. have shown that constraining T_e is far better than simply constraining T_e/T_i, and constraining both temperatures will be even more powerful. Additional projects under investigation include attempting to model the neutral composition and temperatures in the region, and investigating the ion composition and temperatures in ion layers (intermediate layers) that are observed frequently at Arecibo.

Gyro Line Measurements and Theory

The gyro lines are a symmetric pair of resonance lines in the incoherent scatter (IS) spectra, and can be thought of as the scatter from electron cyclotron waves in the ionospheric plasma, in the presence of a magnetic field. The presence of the gyro line was predicted in the IS theory including a magnetic field [*Salpeter*, 1961] but was not observed until the late 1970's by *Behnke and Hagen* [1978] using very long integrations. This was the only reported observation of the gyro line, at least at Arecibo (much work was done at EISCAT to try to detect the lines, e.g. *Bjorna et al.* [1990]), until a few years ago when *Sulzer and González* [2002] reported some baffling observations of the gyro and plasma lines in an Arecibo newsletter article. More recently, many observations (published and unpublished) by Bhatt and coworkers have shed light on the gyro and plasma line features that seem to exist on a daily basis near dusk and dawn.

The gyro line is offset from the transmit frequency by $\sim\Omega_{ce}\cos\alpha$, Ω_{ce} being the electron gyro frequency and α being the angle between the radar wave vector and the magnetic field. This offset is about 500–1000 kHz at Arecibo. The line is very hard to detect even with the Arecibo radar. During low electron density and temperature conditions, the gyro line seems to become stronger due to coupling with the plasma line as that line moves to low frequencies.

A new set of gyro line experiments was performed during the PARS Summer School in August 2004 at Arecibo, approximately thirty years after

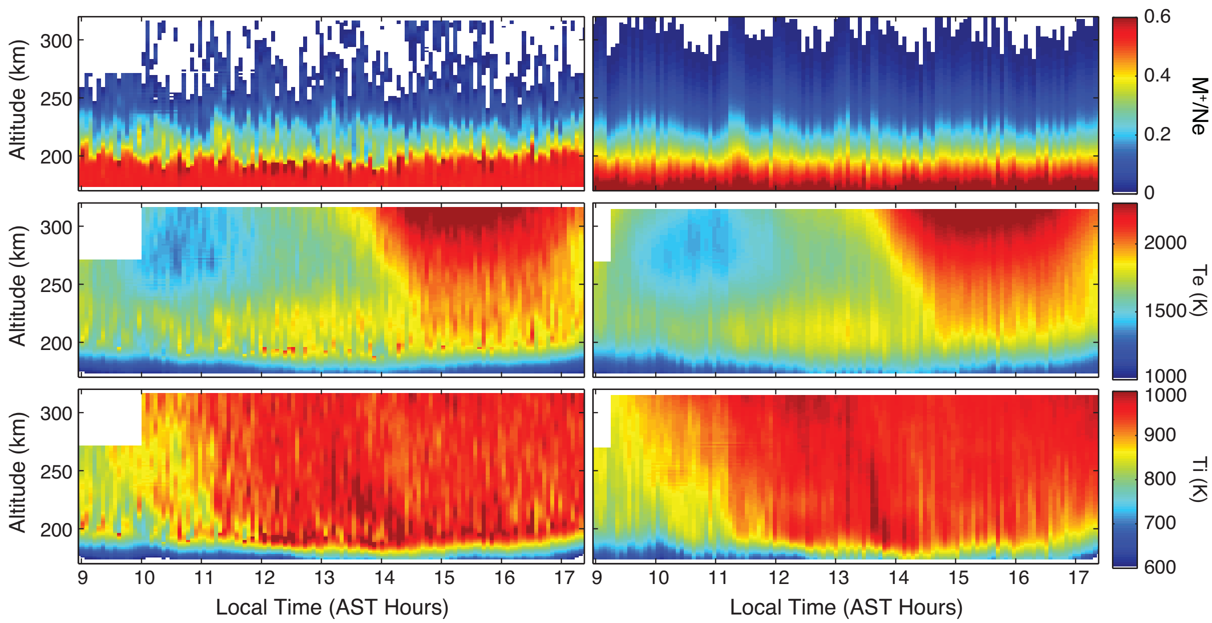


Fig. 4: Results from height-by-height fits (left) and fits with hyperbolic tangent model (right). For each side, the top panel is molecular ion fraction, the middle panel is the electron temperature, and the bottom panel is the ion temperature. From Aponte et al. [2007].

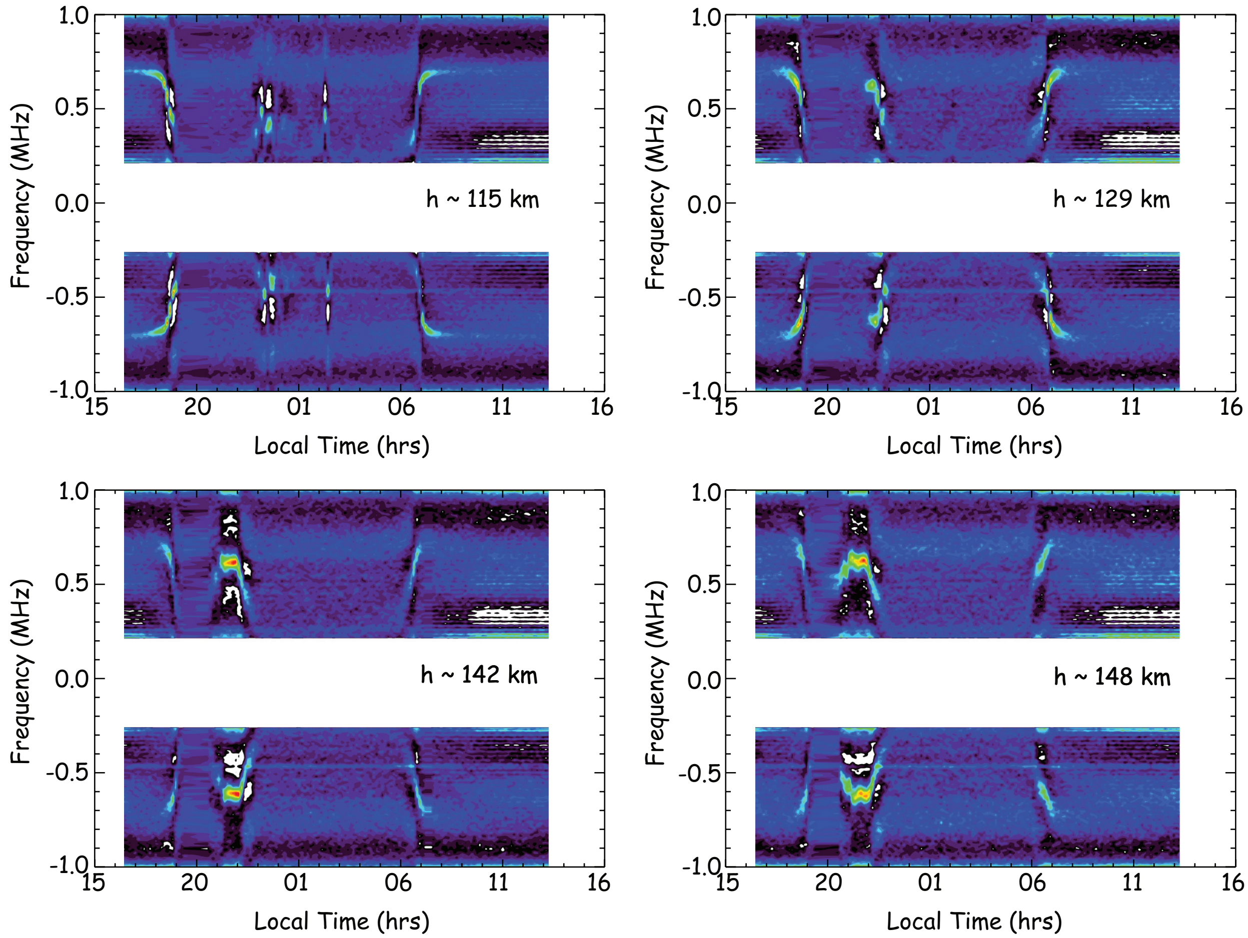


Fig. 5: Composite images (detrended spectra as a function of time) for four altitudes on March 4–5, 2006. From Janches and Nicolls [2007].

the first detection of the gyro line by *Behnke and Hagen* [1978]. Some of those observations are shown in Figure 1 where the gyro and plasma lines are clearly evident at low frequencies. The range resolution of these experiments is quite poor as the transmission was an uncoded pulse of length 500 μs (75 km). The new experiments show clear evidence for the gyro line in the incoherent scatter (IS) spectra during the dawn period *Bhatt et al.* [2006]. Subsequent experiments were carried out during the winter months to see the effect of conjugate photoelectrons on the gyro line and the IS spectra in general. A full spectral analysis for the IS theory indicates that the property of the gyro line being stronger during the low electron and temperature conditions was predicted in the theory [*Janches and Nicolls,* 2007].

An investigation of the gyro line at *E* and *F*1 region heights was done by *Janches and Nicolls* [2007] by retrospectively analyzing data taken with a 45 μs (6.75 km) pulse, originally designed for meteor studies. Surprisingly, the gyro line was observed as a recurrent feature especially near dusk and dawn. These higher resolution measurements, while not useful for *F*-region studies, made clear the diurnal variation of the gyro resonance line. Gyro line spectra were observed during the sunset and sunrise periods for all days studied (eight days in total, in different seasons), confirming that the sunrise and sunset enhancement of the gyro line is an everyday occurrence. A composite of the 7-minute integrated spectra between the afternoon and evening of March 4th and the morning of March 5th, 2006 for four selected altitudes is presented in Figure 5. For the purposes of the color images, the ion line feature has been blanked out and the baseline noise spectra have been subtracted using a polynomial fit. In Figure 5, a surprising feature of the diurnal behavior of the gyro line can be observed at every altitude. For reference, local sunset time was about 18:35 AST (Atlantic Standard Time, UT – 4 hours) and sunrise was at about 06:40 AST. During the late afternoon, the enhanced line is present at the expected frequency (±700 kHz). As the sun sets, the intensity of the line increases and the frequency drops towards zero in less than 30 minutes. During the nighttime, the line is not detected and just before sunrise the opposite behavior to that at sunset is observed. The absolute value of the frequency increases quickly from 0 to ~ 700 kHz, and the intensity also peaks in a near mirror image to the sunset period. Once sunrise has passed, the frequency remains constant while the intensity decreases through the rest of the day. An interesting feature occurs near about 21:00–22:00 AST when the gyro line seems to reappear, showing up first at the highest altitudes. This feature was hypothesized by *Janches* *and Nicolls* [2007] to possibly be the result of an intermediate layer passing through the field of view.

The results of some recent experiments performed by *Bhatt et al.* with a longer pulse (500 μs) are shown in Figure 6, and these show similar behavior to the *Janches and Nicolls* [2007] observations. The IS spectra are plotted as a function of time during the morning of Nov 21, 2006. The plasma lines can be observed beginning at about 06:30 AST, near dawn when photoelectrons begin to enhance the line. In fact, it seems as though two plasma lines are observed, which are most likely two separate ionospheric layers (recall that the pulse width is 75 km, so at 140 km includes contributions from the *E* region to lower *F* region). The gyro line can be seen at ~ 500 kHz and appears well before sunrise.

Observations of the full incoherent scatter spectrum are shedding light on the incoherent scatter physics at low plasma densities. Arecibo is unique in its ability to study this region of the IS spectrum and the results are proving to be surprising and unexpected, opening new avenues for scientific research.

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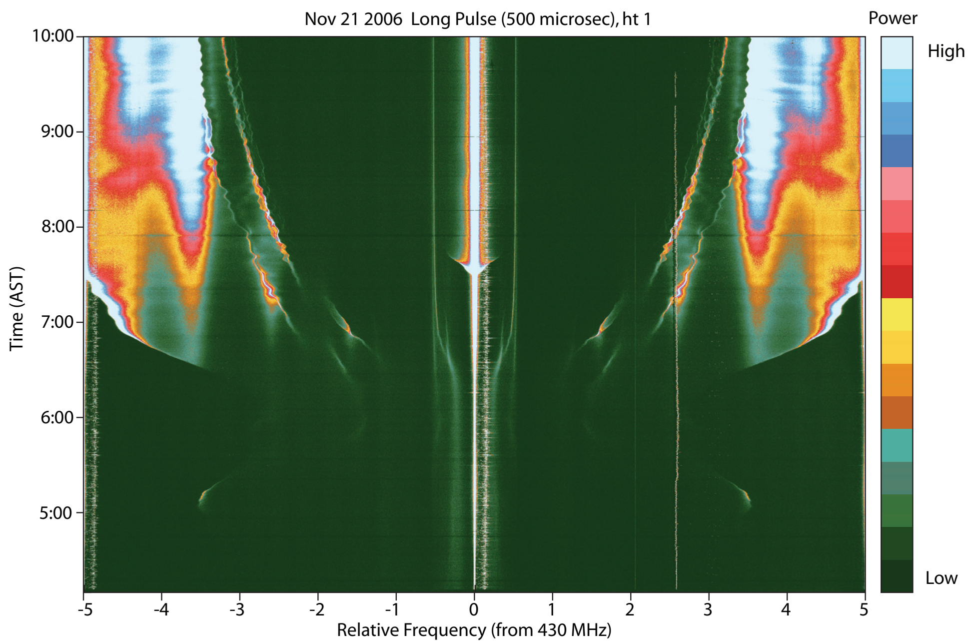

Fig. 6: Dawn time spectra obtained for an altitude of 140 km on Nov 21, 2006. The appearance of the plasma line at ~ 1 MHz is due to the sunrise at this altitude at 05:47 AST. (Courtesy: M. Sulzer)

Pulsar Nulling: New Insights from (Almost) Nothing

Joanna Rankin and Jeff Herfindal (Univ. Vermont), Stephen Redman (Penn State) and Geoffrey Wright (Sussex Univ., UK)

So called 'null' pulses are one of the great mysteries of pulsar emission. How can a star capable of sending bright radio signals across the Galaxy suddenly stop for a pulse or three? Nulling, along with "drifting" subpulses and "mode changing," are the "big three" phenomena that pulsar emission theories need to explain.

Nulls are a piece of Arecibo history, as it was *Don Backer* (as a Cornell grad student in 1970 living in Esperanza) who first identified them in B1237+25, aka A(recibo)P(ulsar)1237. It was AO's great sensitivity which permitted him to argue that during nulls a pulsar seemed to turn-off completely. He found that nulls had a noise-like power distribution, and he could detect no significant power even when he averaged hundreds of them!

While there is no adequate theory of nulling, pulsar people have come to think of nulling as a largely random cessation of a pulsar's emission. Some stars have been found to null much of the time and others little or perhaps not at all. But even this scant information is available for only a few score of the stronger pulsars, because nulls must be distinguished from weak pulses, at least to

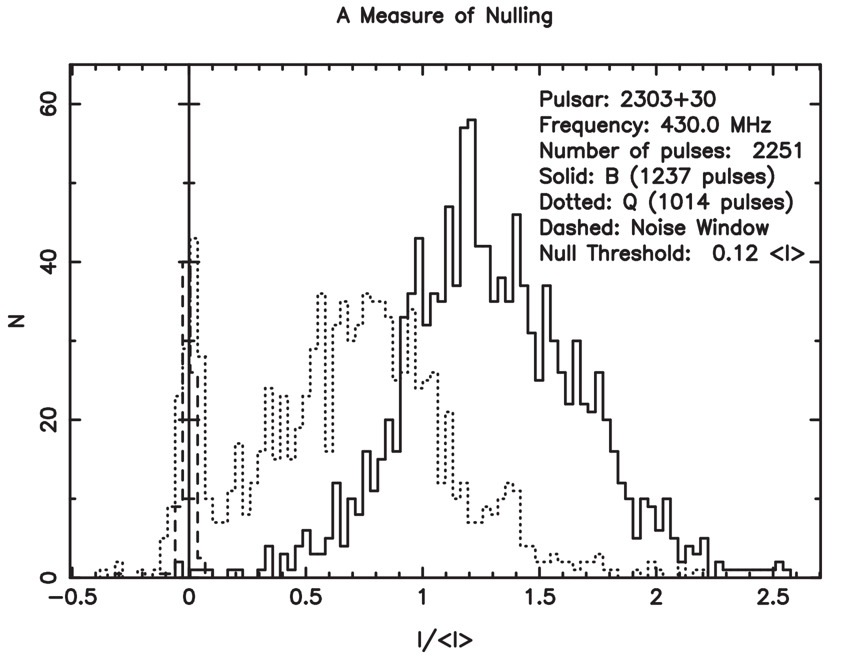

Fig. 7. Null histogram for B2303+30's two modes. The B(right) mode (solid curve) nulls hardly at all, while nulls comprise some 20% of the Q(uiescent)-mode (dotted curve) pulses. Here, we see that the Q-mode nulls have nearly the same intensity distribution as the off-pulse noise (scaled down here by a factor of 15 to match the the Q-mode distribution). (Courtesy: S. Redman)

some extent. Raw sensitivity is thus the name of the game for nulling studies but, strangely, almost all such work has been done elsewhere since Backer (e.g., *Ritchings*, 1976, at Jodrell Bank).

We first got interested in nulls largely because they interrupted the drifting subpulses in some stars. But when we really began to look at the null sequences in certain pulsars, it became increasingly clear that they did not behave at all as we had come to expect.

The beautifully irregular drifting patterns of pulsar B2303+30 (née AP2303) first attracted our attention because its B(right) mode never appeared to null. Rather, all the nulls seemed to occur within or adjacent to Q(uiescent)-mode intervals. Closer study of remarkably sensitive AO P-band polarimetric (hereafter RSAOPP) observations documented mode-specific null fractions in this star for the very first time [*Redman et al.*, 2005], as shown in Figure 7.

A study of pulsar B1237+25 (née AP1237), also using recent RSAOPP observations, showed that its emission "sputtered" weakly during nulls [*Srostlik and Rankin*, 2005], a situation also recently seen in B0818–13 by *Janssen and van Leeuwen* [2004]. In B1237+25 the RSAOPP single pulse sequences (hereafter PSs) permitted us to detect pulsar radiation using linear polarization that was too weak to identify using the total intensity. One can also see sputtering episodes in pulsar B1133+16 in Figure 8 (right panel), and in similar displays showing the full polarization, one can see many instances of pulses with negligible total power but linear polarization which is appropriate at that particular longitude.

Deep RSAOPP observations of the Cambridge pulsar B0834+06 also showed a strange effect: a strong tendency for nulls to occur in alternate pulses. Figure 8 (left panel) illustrates this behavior (e.g. at 12:10–12:20, and 13:20–13:30), and note also that the nulls tend to occur on the weak phase of the star's odd-even pulse modulation! What sort of nulls are these? Also surprising is the exceptionally sensitive null histogram in Figure 9: First, even though the noise is confined to a tiny region about zero, the distribution continues between the "pulses" and "nulls," making it impossible to fully distinguish between them. Second, "null power" showing

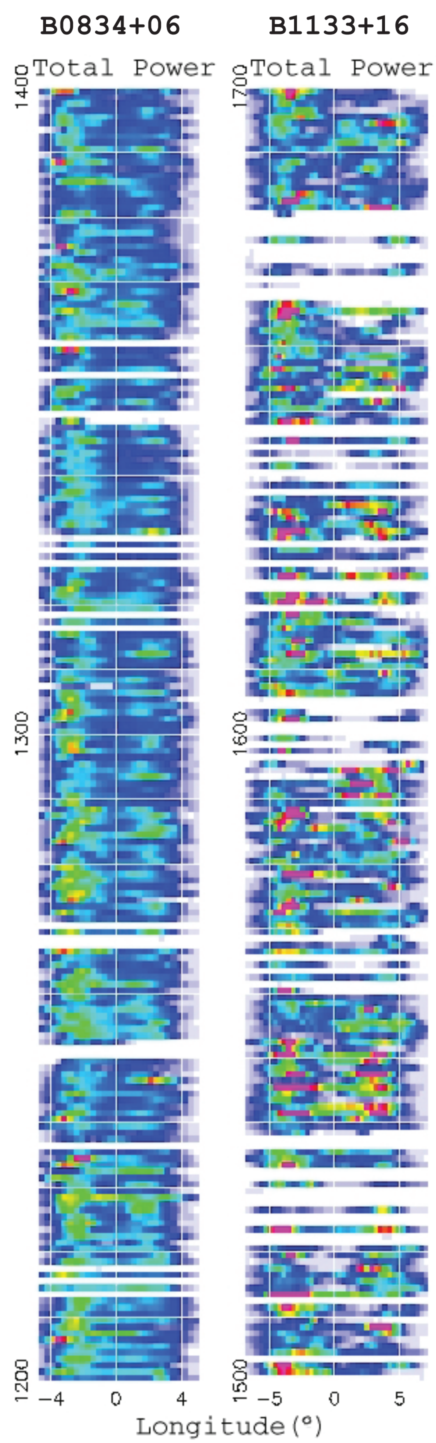

Fig. 8: Color intensity displays of B0834+06 (left) and B1133+16 (right) from AO P-band observations (white < blue < cyan < green < yellow < red). In B0834+06 note the strange prevalence of nulls (white regions) in alternate successive pulses—two groups of three in the left PS—as well as its odd-even pulse modulation. Also note the occasional nulls in both stars which affect only one of their two components. (Courtesy: J. Herfindal)

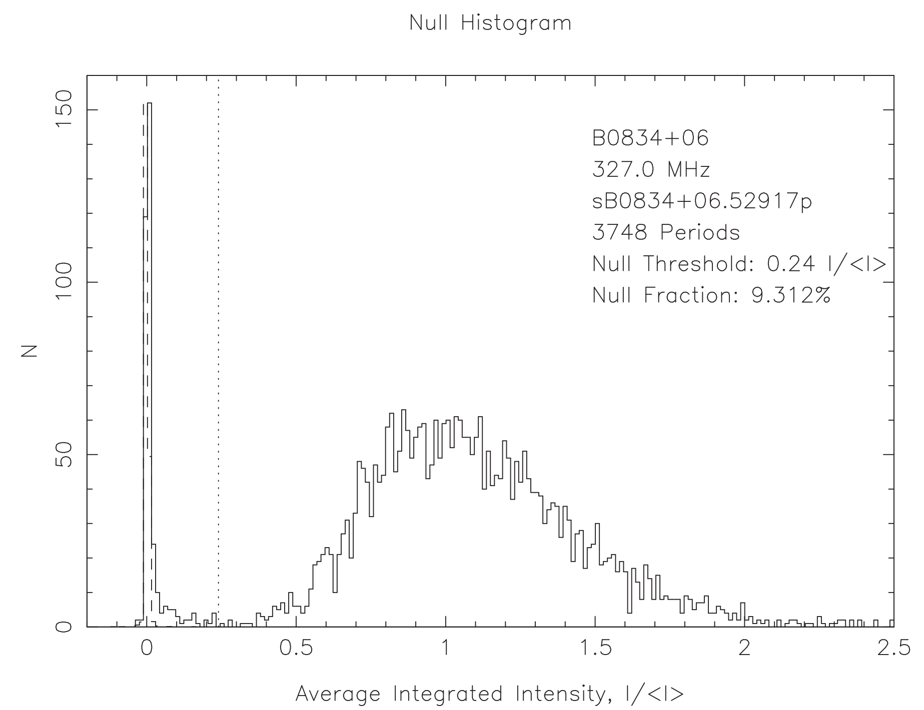

Fig. 9: Intensity distribution showing B0834+06's pulses and nulls (solid) as well as that of the off-pulse noise (dashed). Note that the energies fall continuously between the bright pulses and nulls, so only an arbitrary distinction is possible (dotted). (Courtesy: J. Rankin & G. Wright)

the pulsar's profile shape and polarization can be detected in the average of even the weakest portion (<0.05 <*I*>) of those in Figure 9. Further, Figure 10 shows the distribution of "burst" lengths—the number of pulses between nulls—as well as the expected frequency for a 9.2% null rate. As we had seen, burst-length 1 is overabundant, while those for 0 (adjacent nulls) and 3 are underabundant. Even the peaks for burst lengths of 8, 10 and 12 are expected if the nulls tend to cycle with the pulsar's 2.17-rotation-period modulation [*Rankin and Wright*, 2007a]. Such "nulls" as these—both cyclic and with measurable power—surely do not indicate any complete failure of the star's emission!

A complete surprise was pulsar J1819+1305, rediscovered at AO in 2003 by *Navarro, Anderson and Freire*, which they found to have "periodic nulls". Figure 11 from recent RSAOPP observations gives a particularly good example. The remarkable thing is that all our PSs of this pulsar exhibit fluctuation spectra dominated by a very strong and narrow feature at some 57 rotation periods, even when their time sequences appear much less regular than that in Figure 11 [*Rankin and Wright*, 2007b]. How can we understand why such a PS does not produce a "forest" of responses in addition to this principal one?

Given that the RSAOPP observations provide an unprecedentedly low threshold for null delineation, we have also begun to study the statistics of null occurrence in general, so as to test whether it is random or not. This work is very much in progress, with statistical tests being applied to the observed bi-level null sequences. However, early results suggest that many pulsars with largish null fractions also have non-random null distributions [*Redman and Rankin*, 2007].

B1133+16 has been our most recent surprise. This brightest of the original four Cambridge pulsars shows no systematic subpulse drift but is known to have 15% null pulses. Also, early studies revealed a weak fluctuation feature with a long period of some 33 stellar rotations. This pulsar is so bright that RSAOPP observations are hardly needed, but as with B0834+06 in Figure 10 they permit us to see that its emission has a continuous power distribution from the pulses down to the nulls. Strangely, its PSs also have far too many (some 5%) "partial nulls" affecting only one component or the other—some examples can be seen in Figure 8—such that each nulls about 20% of the time. This pulsar's emission is unusually sporadic, and interstellar scintillation also strongly modulates its intensity, so that the above periodicity is not easy to measure.

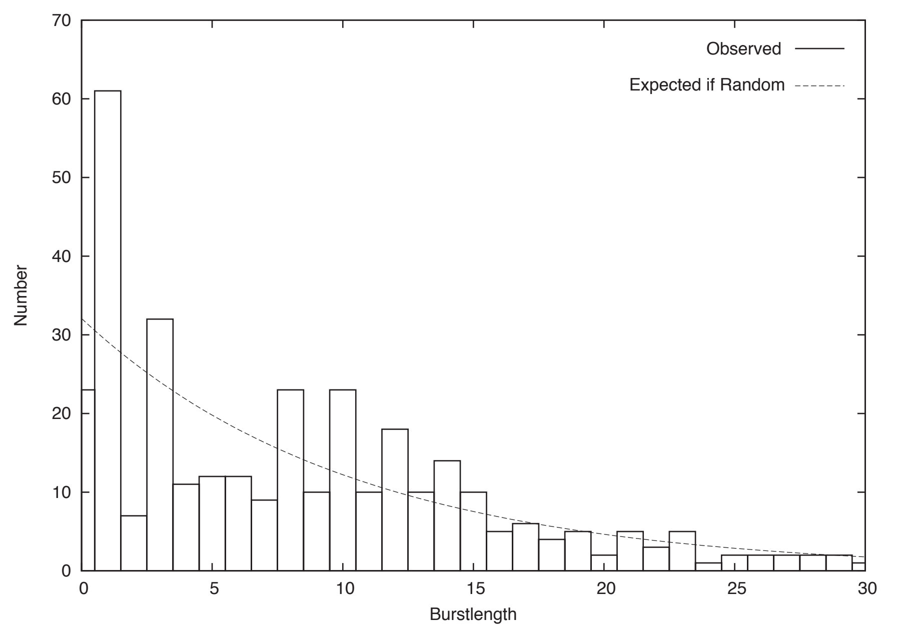

Fig. 10: Histogram of burst lengths for the B0834+06 observation shown in Figs. 8 and 9. A "burst" is defined as the number of contiguous pulses between full nulls, and successive full nulls are counted as bursts of zero length. The expected frequency of burst lengths is also given assuming that the nulls were distributed randomly with the measured 9.2% frequency. (Courtesy: G. Wright)

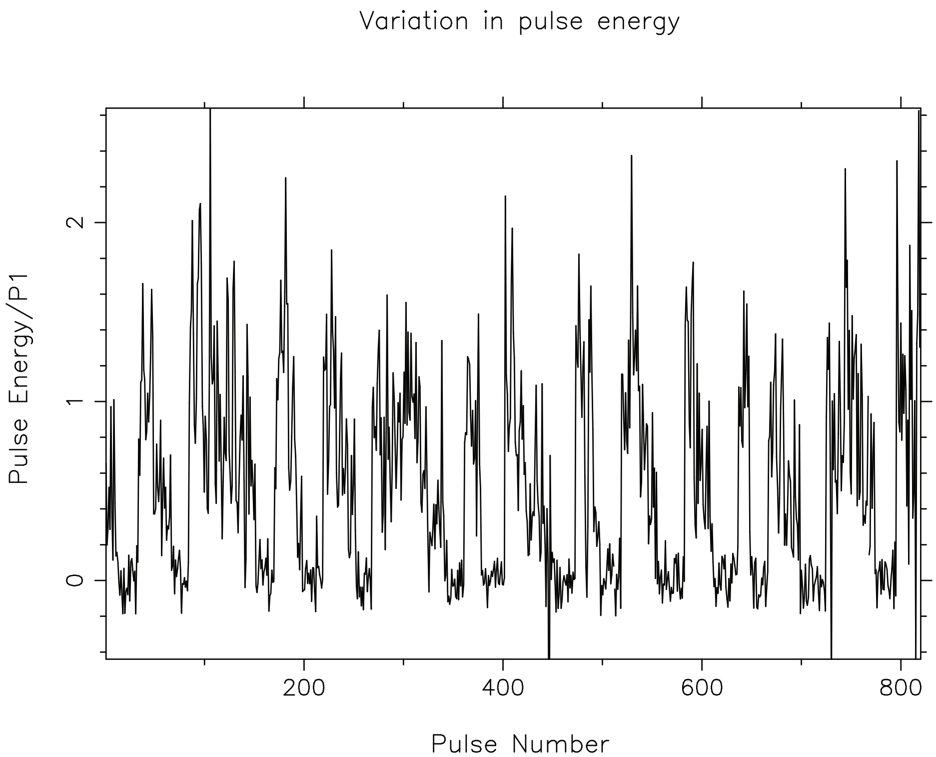

Fig. 11: Pulse energy vs. number for a RSAOPP observation of pulsar J1819+1305. Note the "periodic nulls" which, though not fully regular, are more nearly so in this PS than the others. (Courtesy: J. Rankin)

We therefore decided to try quelling all these intensity variations radically as follows: a scaled-down average profile was substituted for the pulses and a suitably tapered half-average pulse was inserted for the bright side of the partial nulls. To our surprise, fluctuation spectra of these artificially "quelled" PSs exhibited the 33-period modulation feature more strongly [*Herfindal and Rankin*, 2007]. Thus, the periodicity must be produced by the pattern of the nulls—and the nulls themselves must be periodic in some manner, even in this pulsar with so little orderly modulation of its pulses!

How are we to understand these results? They show that the "big three" phenomena of drifting and nulling (as well as mode-changing from other evidence) are highly interrelated. If drifting subpulses are produced by a rotating "carousel" of "beamlets" [as in the classic *Ruderman and Sutherland*, 1975 theory], then we have to ask whether these nulls can also somehow be produced by a carousel of something like the structure found for B0943+10 by *Deshpande and Rankin* [2001]. The answer appears to be yes, though we certainly do not yet understand all the details. Some nulls may represent "empty" passes of our sightline through the carousel's pattern of "beamlets". Such an idea has a strong appeal for the highly patterned nulling of B0834+06, but it is not as clear how it could produce the longer null periodicities we see in B1133+16 and J1819+1305, for instance. And in some cases, nulling may still represent a shutdown of a pulsar's emission, as in the weeks-long nulls of pulsar B1931+24 [*Kramer, et al.*, 2006].

Pulsars still have much to teach us about how they generate their fascinating and complex emission, and the Arecibo Observatory remains the very best place anywhere to do this work.

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E- and F-region Morphologies

Ilgin Seker (Penn State)

The Penn State All-sky Imager (PSASI), a camera that records images of the airglow, at AO has been operating since 2003. This imager has filters at 630 and 557.7 nm to observe neutral oxygen emissions from the *F* region and *E* region, respectively. PSASI-acquired data on neutral structures in the *F* region are presented in Figure 12 and in the *E* region in Figure 13. These images represent a summary and are not intended to give any detailed information.

F-region neutral structures have varied morphology, as shown in Figure 12. Explaining these requires a variety of information that can be provided by other co-located information, such as Fabry-Perot interferometers that measure neutral winds. Imaging also works in conjunction with the 430-MHz radar (see Figure 12b, center) and other airglow-observing instruments (Figure 12a, right) to study the neutral and ionized atmosphere. Models (Figure 12b, right) can be fine-tuned using these data.

In the Figure 13a, we show an example of mesospheric bores that occur in the lower *E* region. A bore is a type of solitary wave often observed in rivers and canals. Other on-site measurements support these measurements, for example the temperature lidar observes the inversion layers necessary to sustain these bores. Gravity waves modulate the airglow brightness (Figures 13b and c), the third dimension of which is often seen in the vertical profiles of metal atom densities with the lidars.

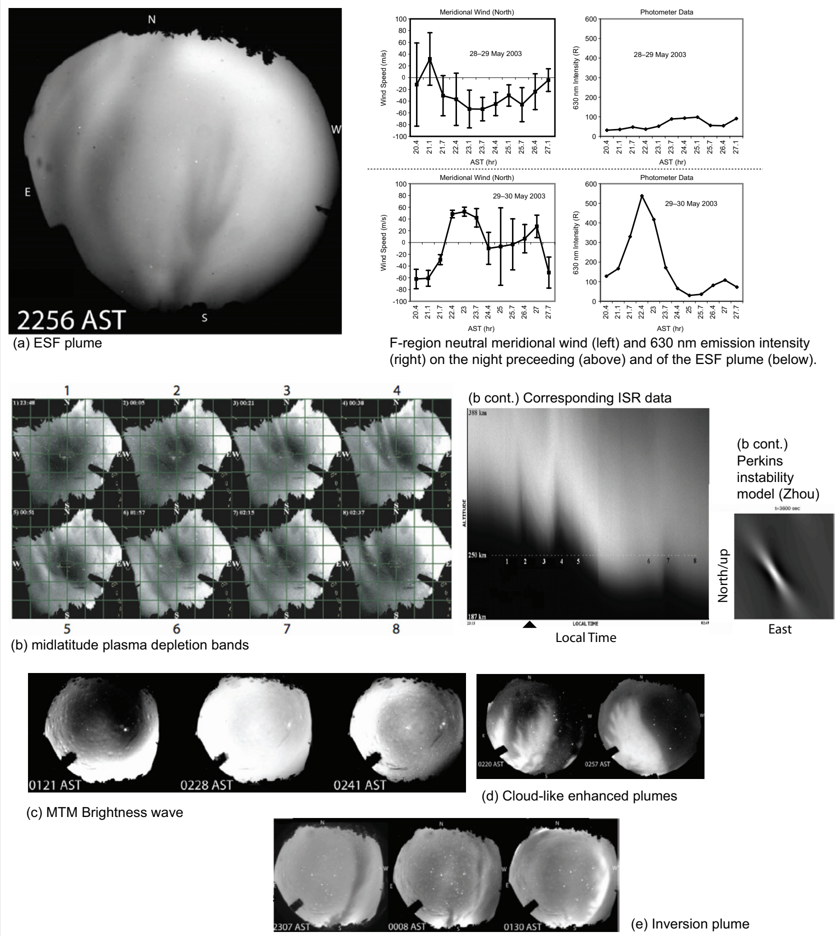


Fig. 12: F-region morphologies:

a. *Fork-like ESF plumes reach AO latitudes during high geomagnetic activity (left). Wind and brightness measurements indicate meridional wind reversal and a sharp increase in airglow intensity during the event (right).*
b. *All-sky frames show the propagation of mid-latitude plasma depletion bands as dark areas (left-to-right and top-to-bottom) (left). Corresponding ISR data showing electron density on a range-time scale, local midnight is indicated by the triangle. These are observed frequently during low Kp (i.e. low solar activity), and are thought to be generated by the Perkin's instability. The model result (by Qina Zhou) shows a map of conductivity in space (right).*
c. *A typical midnight collapse at AO covering PSASI's field of view is shown in a sequence covering 80 minutes.*
d. *A rare observation of enhanced fractals, or finger-like, plumes.*
e. *A very rare inversion event during which a depleted plume becomes enhanced.*

(Courtesy: I. Seker)

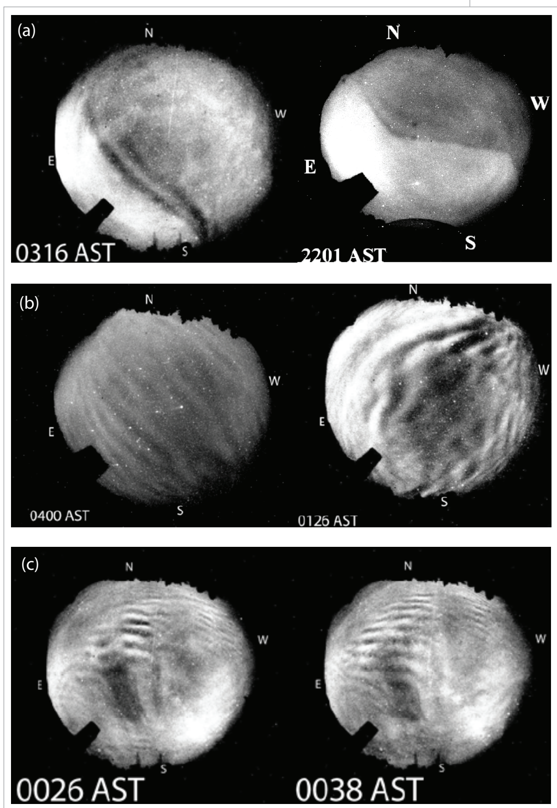


Fig. 13: E-region morphologies:

a. *Mesospheric bores are strong wavefront events with sharp boundaries that can produce enhancements or depletions in the airglow brightness.*
b. *Gravity waves covering the whole field-of-view are observed regularly over AO, and they sometimes become turbulent.*
c. *Ripple-waves are also very common and are thought to be generated by breaking gravity waves. Here are two images of a sequence where gravity waves became turbulent and produced ripple structures.*

(Courtesy: I. Seker)

AGES

Robert Minchin

The Arecibo Galaxy Environment Survey (AGES) is carrying out blind HI surveys in a number of targeted fields covering a total of 200 square degrees. The aim of the survey is to uncover how the HI population varies with environment, and to this end the sample regions span the full range of galactic densities from the Local Void to the Virgo Cluster. Most of the fields are 20 square degrees in size, although four are only 5 square degrees, and the total survey area will be 200 square degrees, which is expected to take 2000 hours of telescope time to complete.

So far, three 5-square-degree regions have been completed: the field around the isolated galaxy NGC 1156 (February 2006), the field around the galaxy pair NGC 7332 and NGC 7339 (September 2006), and the first of two fields in the Virgo Cluster (February 2007). A central 5-square-degree strip through Abell 1367 has also been taken to full sensitivity (April 2007), although this region as a whole is only 25% finished.

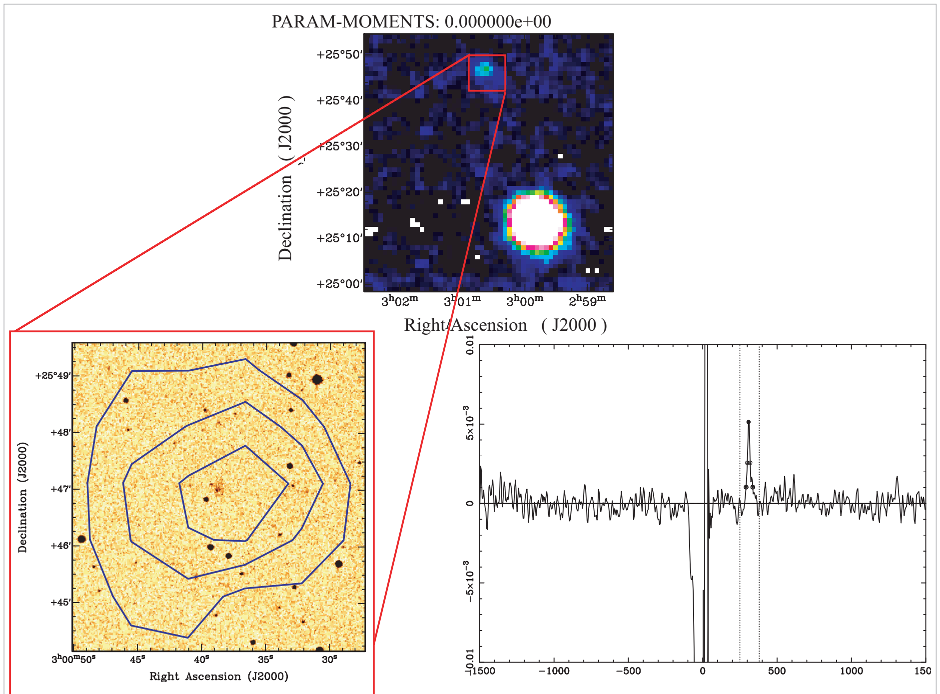


Fig. 14: (Top) channel map of AGES J030037+254707, a newly-detected companion to NGC 1156. NGC 1156 is the larger of the two detections centered at ~02:59:30, +25:22:00. (Lower left): Expanded view of AGES J030037+254707 showing the HI contours (3, 4 & 5 sigma) overlaid on a SuperCOSMOS B-band image. (Lower right): The HI spectrum for AGES J030037+254707. The vertical dotted lines show the region of the spectrum over which the HI properties were derived; the peak, 50% and 20% flux levels are also highlighted. (Courtesy: R. Minchin)

The survey began in January 2006 with the region around NGC 1156, a nearby (~7 Mpc), isolated galaxy. Figure 14 shows a previously undiscovered dwarf companion to NGC 1156 separated from NGC 1156 by 81 kpc on the sky. The new object is barely seen in the SuperCOSMOS *B*-band image (lower left), but is readily detected by AGES due to its HI signature. The HI mass of the new object is 1.3×10^6 solar masses ($M_\odot$). The AGES team expects to detect many such low-mass galaxies, most of which will be previously uncatalogued, as well as a host of other HI details such as tidal bridges, streams, High Velocity Clouds and maybe even inter-galactic HI clouds.

Figure 15 highlights an HI galaxy of mass ~ 6×10^8 $M_\odot$. This object does not appear in the SuperCOSMOS image at all, suggesting this might be a galaxy with gas, dark matter, but no stars; a so-called dark galaxy. The optical extinction in the region around NGC 1156 is unusually high for the Galactic latitude, in the vicinity of the supposed dark object, the extinction is A_B = 1.5 mags highlighting the need for deeper follow-up optical observations. Follow-up optical observations of the galaxy taken in Summer 2006 have still not confirmed an optical association with this galaxy, although conditions were not ideal to be able

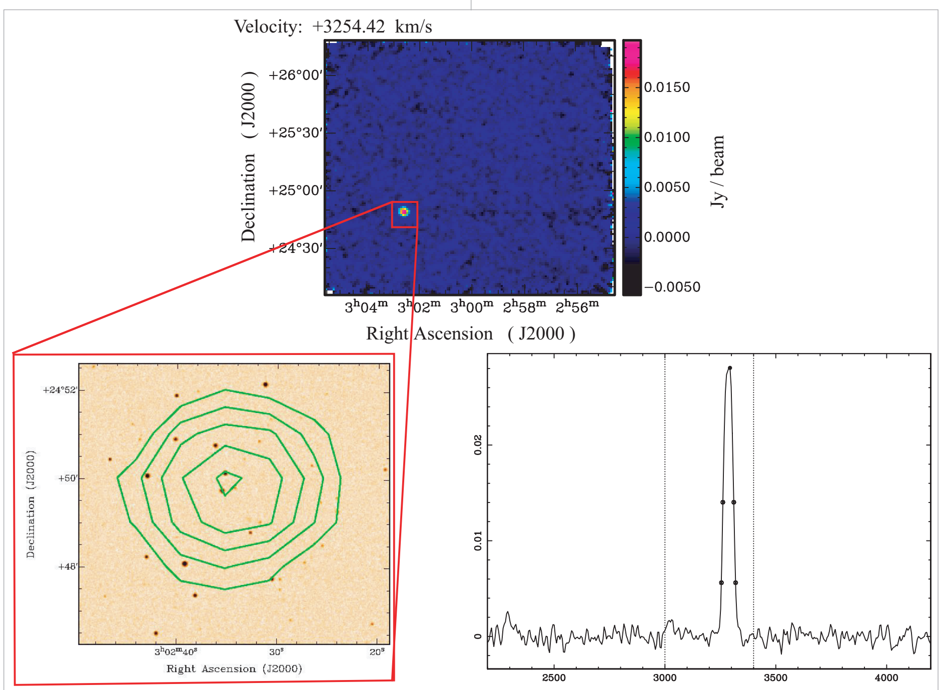


Fig. 15: (Top) channel map of AGES J030234+244938, a possible dark galaxy. (Lower left): expanded view of AGES J030234+244938 showing the HI contours (3, 5, 10, 15, 20 sigma) overlaid on a SuperCOSMOS B-band image. (Lower right): The HI spectrum for AGES J030234+244938. The vertical dotted lines show the region of the spectrum over which the HI properties were derived, the peak, 50% and 20% flux levels are also highlighted. (Courtesy: R. Minchin)

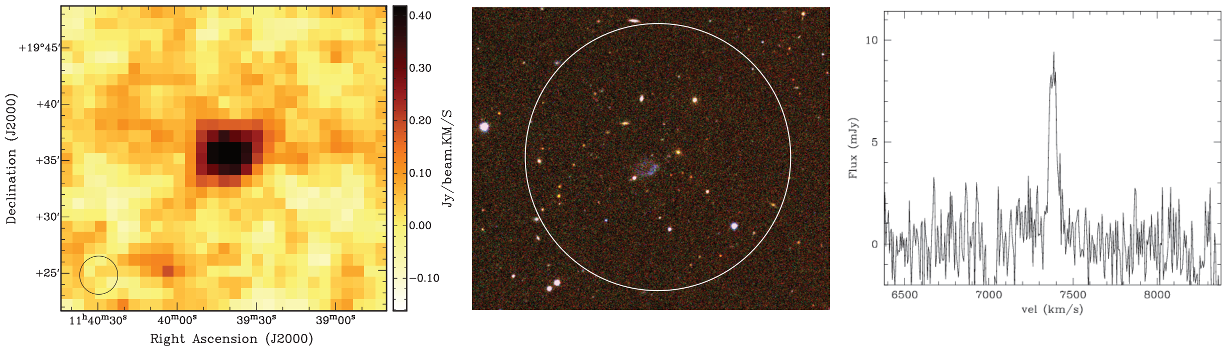


Fig. 16: An example of a gas-rich low surface-brightness galaxy detected in the AGES A1367 cube. This object is clearly detected in HI, as shown in the moment zero map (left; summed over a 100 km/s velocity range) and in the HI spectrum (right), but it is barely visible in the SDSS gri optical image (centre). (Courtesy: R. Minchin)

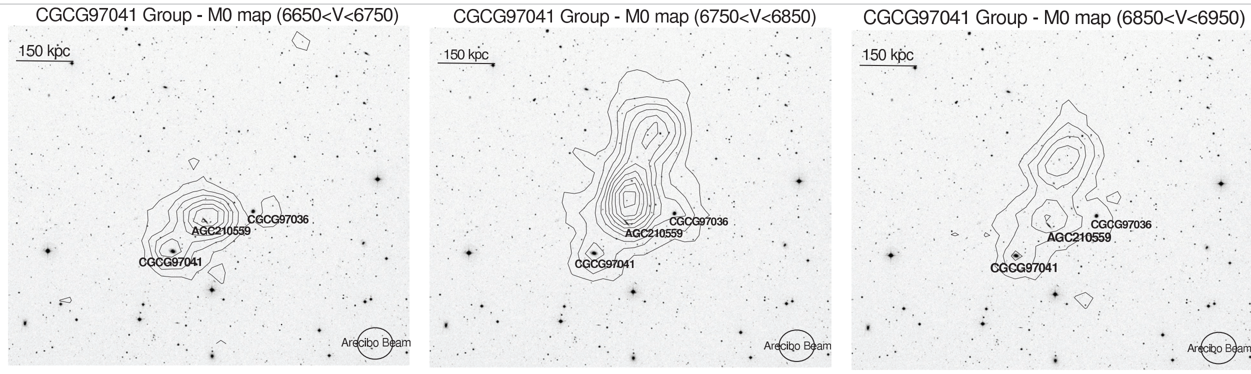


Fig. 17: HI distribution in the vicinity of the CGCG 97041 group, an interacting group composed of at least three star forming galaxies located at a projected distance of ~1 degree from the centre of Abell 1367. Three moment zero maps (summed over 100 km/s velocity ranges) are superimposed on the DSS optical image. Circle in bottom right is the size of the Arecibo beam, or 3.3 arcminutes. (Courtesy: R. Minchin)

to put stringent surface brightness limits on the galaxy.

In May 2006, AGES began observations of the Abell 1367 field (5×4 degrees), covering an area of 5×1 degrees in the range 11:34<RA<11:54, 19:20<Dec<20:20, mapping all of the cluster core and part of the infalling regions. The mean integration time in these data was ~240 sec (80% of the final exposure time) leading to a mean rms of ~1 mJy/beam at a velocity resolution of 5 km/s (this inner region was taken to full sensitivity in April 2007, but the new data are still being reduced). Over eighty HI sources (~70% of which are new) have been detected so far, spanning a redshift interval of 1,000 to 20,000 km/s. In some cases HI emission is associated with low surface-brightness galaxies ($\mu_e(g)$ > ~24.5 mag/sq. arcsec), barely visible in the SDSS (Figure 16). Interesting HI features are detected in correspondence with three groups in the outskirts (1–2 degrees from the cluster centre) of Abell 1367 (CGCG 97027, CGCG 97041 and CGCG 97068), suggesting that strong environmental effects are currently perturbing the evolutionary history of these galaxies, well before their infall into the cluster core (see Figure 17).

The survey of the NGC 7332/9 galaxy pair, carried out in August and September 2006, has revealed two previously unknown gas-rich dwarfs in the vicinity (Figure 18). These are the first confirmed dwarf galaxies in the system, although a candidate dwarf galaxy has been previously as-

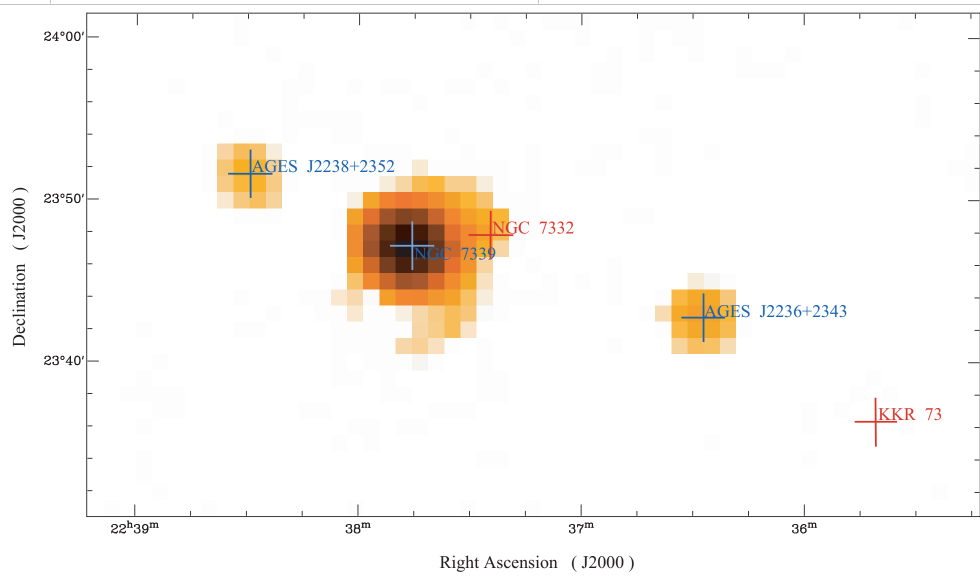


Fig. 18: Moment zero map of the NGC 7332 group showing the detections of NGC 7339 and the two new AGES detections along with the positions of the undetected lenticular galaxy NGC 7332 and the dwarf spheroidal galaxy KKR 73. It can be seen that the position of NGC 7332 lies within the gas disc of NGC 7339. (Courtesy: R. Minchin)

sociated with the pair on the basis of its optical appearance. The survey also confirmed the interpretation of *Haynes* [1981] that the gas seen at the position of the lenticular galaxy NGC 7332 is not associated with it but with NGC 7339. This gas is at a higher velocity than that obtained for NGC 7332 through optical spectroscopy and is connected both spatially and in velocity with the gas in NGC 7339. Indeed, although the disc of NGC 7339 shows disturbances in its velocity field, there is no significant extension towards NGC 7332 — the gas is merely part of the ordinary disc.

The region behind NGC 7332/9 has thrown up around forty HI detections, of which the majority are not previously catalogued. These range from bright galaxies through faint, LSB galaxies to galaxies to which no optical counterpart can be seen on the digitized sky survey. Deeper optical data will be necessary to fully exploit this data set.

The Platform Painting Project

Robert Kerr

A project to clean and paint the 900-ton platform suspended above the telescope primary is underway at the Arecibo Observatory. Spensieri Painting, LLC, of Syracuse, NY is performing the work under contract to Cornell University. The Project Manager is Lynn Baker, Research Support Specialist at NAIC/Cornell. Spensieri equipment began to arrive at the observatory on March 20, and rigging for containment structures enclosing subsections of the platform began shortly thereafter. A contractor crew of approximately 15 is expected to complete the painting project around July 1 – depending on weather conditions. A time lapse movie (one picture each five minutes) showing project progress is available on our web site, www.naic.edu.

Telescope operations were maintained through the first day of May, as rigging operations, permit acquisition, and platform preparation proceeded. Pointing accuracy of the telescope during April degraded slowly as weight was removed and painting equipment was distributed on the platform, but daily calibration and adjustment retained acceptable pointing accuracy for most of the month. The ALFA receiver array has been removed from the dome, and will be serviced during the painting project period.

Because variable but significant lead concentrations are found in the existing paint on the platform, the entire project is being treated as a lead mitigation project. Containment structures on the platform and total project cost are not greatly impacted by this condition, however, since environmental control for surface preparation and paint adherence are essential in the tropical conditions. Arecibo Observatory is proud of its commitment to environmental quality on-site and in the surrounding region. All project procedures pertaining to health and environmental issues have been reviewed by, and are being monitored by, the Environmental Quality Board of Puerto Rico.

The painting project is a $3.9M effort that guarantees reliable telescope operation well into the future. The decision to initiate the effort has no bearing on findings of the Senior Review. Any future funding profile for the observatory will be supported, however, by superior telescope maintenance.

ALFA comes down for servicing as the telescope painting begins.

From the Director's Office

Robert L. Brown

At NAIC, among the daffodils, crocuses and robins that are certain signs of spring, appear also the sequence of annual reviews, meetings of the Visiting Committee, the AUSAC, the NSF Program Plan review, and the NSF budget review that mark the spring season for us. In addition, this spring we also had the opportunity to present to a NSF management review as one of the steps in the NSF process leading to a decision as to whether the NSF Cooperative Agreement for management and operation of NAIC should be competed or not when the present Cooperative Agreement with Cornell expires in 2010. Five major reviews in less than three months have kept us all very busy! A synopsis of the meetings is presented elsewhere in this Newsletter.

Meanwhile, preparations for the project to clean and recoat the structural steel on the telescope platform have made telescope scheduling uniquely challenging for the past six months. Repeatedly, we have been led to believe the project would start imminently only to discover that things had been delayed owing to incomplete project staffing, shipping or certification. Thanks to the cooperation of the telescope users, and to the dependable equanimity of Héctor Hernández, the telescope scheduler, science operations on the telescope proceeded with only minimal interruptions. The telescope was shut down, and the painting project began the last week in April; a report of the painting project also can be found elsewhere in this Newsletter.

Implementation of the recommendations of the NSF Senior Review continues to be a challenge for NAIC. The loss of more than 25% of the astronomy-supported staff positions owing to the measures taken to reduce the scope of the astronomy program so as to reduce its operating cost, has meant that the remaining staff have seen their responsibilities increase. Efforts continue to restore a manageable balance between the scope of staff responsibilities and the staff time required to carry out those responsibilities. Across the board, NAIC staff members are to be praised for their flexibility and creativity in dealing with this unfortunate situation. Additionally, the transition to a reduced scope of user services has not been without its difficulties. Problems remain to be resolved in such visible services such as cafeteria hours and airport pickup procedures. The user suggestions we've received in these areas are greatly appreciated.

Our efforts to deal with the budgetary shortfalls have led to a variety of initiatives involving sponsorship arrangements with U.S. agencies other than NSF, with the government of Puerto Rico, and with foreign institutions having shared interest in the continued scientific success of the Arecibo Observatory. The gestation time for all such initiatives is measured in years owing to the timescales involved in the planning and budget cycle in the U.S. and elsewhere.

Finally, there have also been some prominent personnel changes at NAIC. We are delighted to welcome Bob Kerr as the new Arecibo Observatory director replacing Tim Hankins who filled the position on an interim basis for the past six months. As an academic researcher at Boston University, a program manager at NSF, and as an entrepreneurial founder of Scientific Solutions, Inc., Bob brings a wealth of new experience to the task, not least of which being his fund-raising experience. But as experience comes to NAIC, so experience goes: Dianna Marsh, our Administrative Director, has announced her intention to leave NAIC in September of this year to become the administrator of the new Cornell Institute for Cell and Molecular Biology. Her deep commitment to the goals of NAIC, dependable support, and good cheer will be missed.

Radio Astronomy Highlights

The G-ALFA Multi-Phase View of ISM Structure: A Perseus Prelude

Steven Gibson (NAIC)

The interstellar medium (ISM) is a turbulent matrix of neutral and ionized gas particles, dust grains, and magnetic fields. To understand the energetics governing the ISM and the role they play in star formation and galaxy evolution, it is critical to image a variety of ISM constituents at high resolution and sensitivity over large areas, using radio wavelengths to avoid dust extinction. The G-ALFA surveys are well placed to address this goal. The Radio Recombination Line group (GALFA-RRL; PI: Y. Terzian) has a major survey of the Galactic plane in the final planning stages. The GALFA Continuum Transit Survey group (GALFACTS; PI: A. R. Taylor) has conducted several test observations and will begin an all-sky full-Stokes continuum survey later this year with the new spectrometer. Finally, the GALFA-HI group has already completed a number of smaller projects and has been running the high-latitude "Turn On GALFA Survey" (TOGS; PI: M. Putman) commensally with the ALFALFA and AGES E-ALFA projects since September 2005. Two other large HI surveys will begin soon: an Inner Galaxy low-latitude HI survey awaits the end of telescope painting (I-GALFA; Co-PIs: B.-C. Koo and S. Gibson), and a shallow all-sky HI survey will run commensally with GALFACTS (TOGS2; Co-PIs: C. Heiles and S. Stanimirovic).

Many operational issues for commensal observing of HI and polarized continuum were resolved in the fall of 2006 with an ALFA HI mapping survey of the Perseus Molecular Cloud region (A2174 PI: L. Knee) and a GALFACTS continuum survey observing the same pointings via the WAPP spectrometer (A2294 Co-PIs: A. R. Taylor and C. Salter). The maps in Figure 19 are the result of work by Lewis Knee, James Di Francesco, Kevin Douglas, Josh Goldston, and Steven Gibson on the HI side, and Chris Salter, Tapasi Ghosh, Russ Taylor, and Jeff Dever on the continuum side, together with the assistance of Mikael Lerner.

Sample Perseus images of GALFA-HI 21cm-line and full-Stokes continuum emission are shown in Figure 19 along with maps of molecular (CO) gas, thermal dust, and ionized gas optical emission for comparison. Together, these observations trace most of the key ISM constituents in this part of the sky. The unparalleled sensitivity of ALFA with the 305-m dish allows much finer HI velocity sampling than comparable synthesis array surveys, which is invaluable for studying the coldest HI features. It also enables full-Stokes spectropolarimetry of "continuum" radiation to extract Faraday rotation measures.

The GALFA-HI emission appears to envelop the molecular cloud gas traced by CO. The HI shows remarkable fine-scale structure in both space and

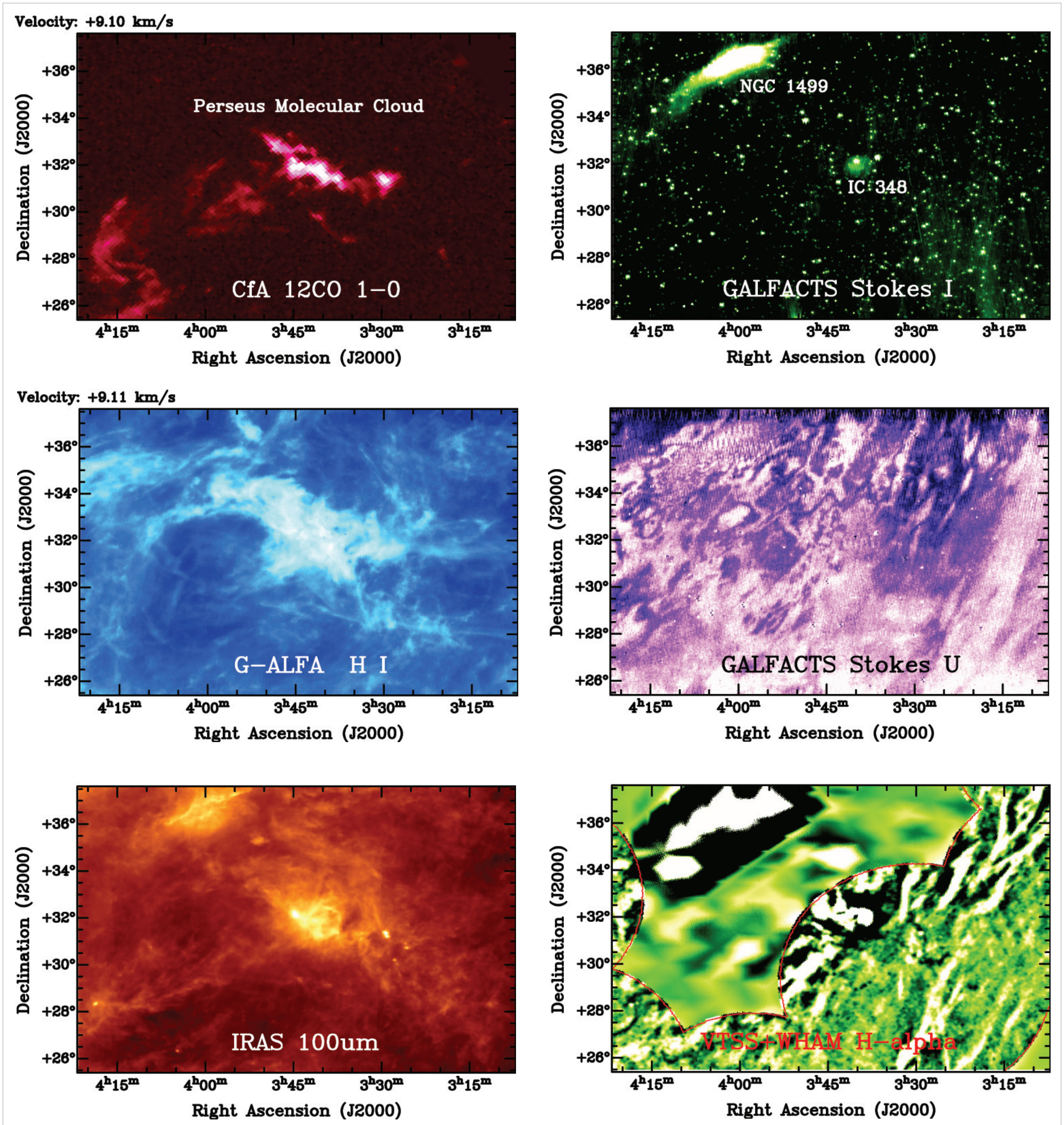


Fig. 19: Perseus Molecular Cloud Region. LEFT PANELS (top to bottom): CfA ^{12}CO J = 1 - 0 line (Dame et al., 2001), GALFA HI 21cm line (A2174), and IRAS 100 μm dust emission; RIGHT PANELS: GALFACTS Stokes I and U continuum (A2294) and VTSS+WHAM Hα (Finkbeiner, 2003). Only one velocity channel is shown in HI and ^{12}CO. The GALFACTS maps are preliminary and not fully processed. The edge of the higher-resolution VTSS Hα coverage in marked in red; Hα structure larger than ~ 1° has been removed to highlight narrow filaments. The HI image was produced by Kevin Douglas. The GALFACTS images were produced by Jeff Dever.

velocity, including dark pockets of cold HI in several self-absorption features (e.g., near 3^h55^m+33.7°). A variety of long, narrow-line emission filaments are also produced by cold gas. Only one velocity channel of HI and CO is shown; the HI data cover ± 750 km s^{-1} with 0.184 km s^{-1} per channel to ensure excellent sampling of cold spectral lines. The 3.3′ HI beam is very similar to that of IRAS 100 μm emission maps. In many respects, the GALFA-HI survey adds a much-needed velocity dimension to IRAS dust images. At the ~ 250-parsec distance of the Perseus Molecular Cloud, 1° on the map subtends ~ 3.5 pc.

The Stokes I continuum data show a complementary view of the ionized gas, including clear detections of the California Nebula (NGC 1499; $4^h + 36°$) and IC 348 ($3^h\ 40^m +32°$) HII regions. Most background point sources are active galactic nuclei. At a different velocity than that of the Perseus Molecular Cloud, HI gas appears north of the California Nebula but ends abruptly at an ionization front near $4^h + 37°$, which also coincides with a bright ridge of IRAS dust emission. IC 348 is probably embedded in the Perseus Molecular Cloud, but the California Nebula lies approximately twice as far away.

The Stokes U polarized continuum data trace the magneto-ionic medium, in which variations in electron density and line-of-sight magnetic field strength cause Faraday rotation of the diffuse polarized Galactic synchrotron background. High electron column densities cause depolarization from Faraday wrapping confusion; this can be seen toward the California Nebula and perhaps IC 348. Elsewhere, combined analysis of the polarized intensity and electron column can reveal magnetic field structures not otherwise visible in the ISM. The radio continuum maps in Figure 19 are of limited sensitivity, because they are taken from only one WAPP channel and are not fully processed. However, the reality of the Stokes U Faraday structures is clearly demonstrated by a number of coincident ionized gas filaments traced by optical Hα emission.

Timing Observations of PSR J1453+1902

Dunc Lorimer (WVU)

Dunc Lorimer (WVU), Maura McLaughlin (WVU), David Champion (McGill) and Ingrid Stairs (UBC) have recently published timing observations of PSR J1453+1902 using the Penn State Pulsar Machine. This 5.79-ms pulsar, one of eleven found during upgrade drift-scan searches carried out by this group at 430 MHz, is solitary and has a proper motion of 8 ± 2 mas yr^{-1}. Although the pulsar is a relatively weak object, its high Galactic latitude and large angular offset in the sky from other millisecond pulsars may make it an important addition to the collection of millisecond pulsars being monitored. At the nominal distance of 1.2 kpc estimated from the pulsar's dispersion measure, this corresponds to a transverse speed of 46 ± 11 km s^{-1}, typical of the millisecond pulsar population. From an analysis of the current sample of 55 millisecond pulsars currently known and contrary to previous claims, the group find no strong evidence for the luminosities of isolated millisecond pulsars to be different from their binary counterparts. The authors demonstrate that the apparent differences in the luminosity distributions seen in samples selected from 430-MHz surveys can be explained by small number statistics and observational selection biases. An examination of the sample from 1400-MHz surveys shows no differences in the distributions. The simplest conclusion from the current data is that the spin, kinematic, spatial and luminosity distributions of isolated and binary millisecond pulsars are consistent with a single homogeneous population. A paper describing these results in detail has recently been submitted to MNRAS.

The ALFA Zone of Avoidance Survey Yields New Galaxies, and Redshifts for Known Galaxies

Patricia Henning (UNM) and Christopher Springob (NRL)

The Extragalactic ALFA Zone of Avoidance team is mapping the distribution of low-Galactic-latitude galaxies and large scale structures through detection of galaxies' 21-cm emission with ALFA. This Zone of Avoidance (ZOA) survey finds new "HI galaxies" that are hidden behind the Milky Way, and also provides redshifts for partially-obscured galaxies known at other wavelengths. In this way, we are illuminating the large scale structure in the local Universe in the low-Galactic-latitude sky where it is currently poorly mapped. The ZOA survey is one of the Extragalactic ALFA projects, and proceeds in tandem with Galactic ALFA and Pulsar ALFA projects. This "commensal" style of observing, using multiple backends simultaneously, increases enormously the scientific throughput of the telescope, making very efficient use of observing hours. This is particularly important during the heavily over-subscribed Galactic Plane time.

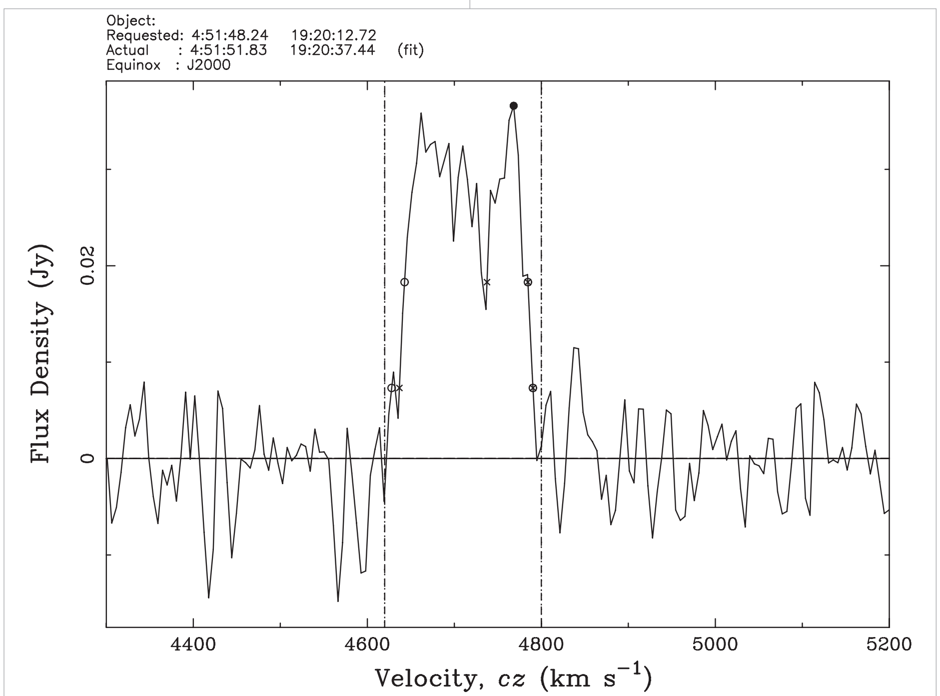


Fig. 20: Spectrum of an HI galaxy in the Zone of Avoidance discovered by ALFA. This galaxy has no catalogued counterpart in any other waveband. (Courtesy: C. Springob, P. Henning & the EALFA ZOA Team.)

Two regions behind the Milky Way have been observed with ALFA to date: a 38-square-degree area around l = 40, and a 100-square-degree region near l = 190. These "precursor" observations, done commensally with Galactic ALFA projects in the meridian-nodding, or "basketweave" mode, reached an RMS sensitivity of 5–6 mJy per beam, which is as sensitive as the Parkes ZOA survey (e.g. *Donley et al.*, 2005, AJ, 129, 220), but in a small fraction of the time. The first region observed, toward the heavily-obscured inner Galaxy, was selected to overlap the northern extension of the Parkes ZOA survey, so we could quickly check the performance of the observing and analysis systems with known HI sources. We detected 10 "HI galaxies" in this area, including 7 of the Parkes galaxies as expected, and three more HI sources—one associated with an IRAS galaxy, and two newly-discovered galaxies. Because of the thick obscuration in the optical, and confusion in the NIR, only the IRAS galaxy has a cataloged counterpart in any other waveband in this region. In the lower-extinction, less-confused outer Galaxy region, 51 of the 62 galaxies detected by ALFA have counterparts (mostly 2MASS), but only 24 have previously published redshifts. Figure 20 shows a profile of one of the ALFA galaxies, discovered in this anti-center region, which was unknown before our observations.

A full survey of the accessible inner Galaxy, l = 30–75 deg, and within 10 degrees of either side of the Galactic plane, will begin after the telescope becomes available again, post-painting. These observations will be conducted in the same basketweave mode as the precursor work described here. We will also conduct a deeper ZOA survey simultaneously with both a long-integration survey for pulsars and a survey for Galactic radio recombination lines. This deep survey will cover 5 degrees on either side of the plane, and will start in the inner Galaxy, with plans to cover the ZOA in the anticenter longitude range as well.

First Millisecond Pulsar (MSP) Found with ALFA

David Champion (McGill Univ.)

Recently, the ALFA Pulsar Consortium announced the discovery of the first millisecond pulsar (MSP) found with ALFA, PSR J1903+03 (see http://www2.naic.edu/~pulsar/highlights/highlights_ALFA_1903+03.shtml). This is the most distant MSP to be found in the Galactic plane. With a spin period of only 2.15 ms, this is also the 11th fastest known pulsar. This demonstrates the unique ability of the ALFA pulsar survey to find fast-spinning MSPs deep into the Galaxy.

The short spin period of MSPs is thought to be the result of a protracted episode of accretion of matter from a companion star onto the neutron star (hundreds to thousands of Myr). For this to happen, the companion has to evolve very slowly; this implies it must have been born as a main-sequence star with a relatively small mass. Such stars evolve into low-mass white dwarfs; and indeed all companions to Galactic MSPs are thought to be white dwarf stars (WD). The orbits of these binary systems become highly circularized by tidal effects while the companion is a main-sequence star. Because there are no abrupt changes in mass when the companion becomes a WD, these MSP-WD systems retain their low-eccentricity orbits, as observed for all Galactic MSPs (see, e.g., http://www2.naic.edu/~pulsar/highlights/highlights_1738+0333.shtml).

PSR J1903+03 is completely different from all other Galactic MSPs. Its companion is massive (more than one solar mass), and its 95-day orbit has an eccentricity of 0.44 (see Figure 21). The orbital eccentricity and companion mass are more typical of what one would find among double neutron stars (DNSs), like the famous relativistic system, PSR B1913 +16. In those systems, the progenitor of the companion neutron star had to be a massive star (more than 8 solar masses). Such stars evolve on timescales of a few tens of millions of years; this means that there is not much time for accretion to spin up the pulsar. The result is that in DNS systems the spun-up pulsar always has spin periods of tens of Hz, ~10 times slower than that of an MSP.

It is not just the spin period that makes PSR J1903+03 different from DNS systems. Its orbital period, 95 days, is 5

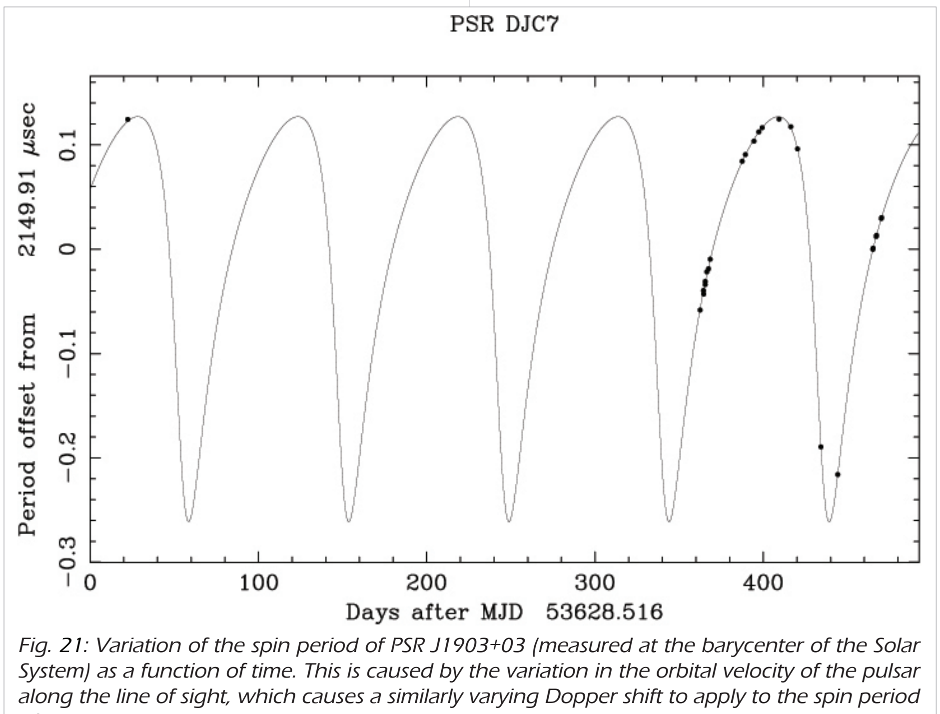


Fig. 21: Variation of the spin period of PSR J1903+03 (measured at the barycenter of the Solar System) as a function of time. This is caused by the variation in the orbital velocity of the pulsar along the line of sight, which causes a similarly varying Dopper shift to apply to the spin period of the pulsar. (Courtesy: D. Champion)

times longer than the orbital period of PSR J1811-1736, 18.8 days, the longest known for a DNS. Indeed among DNS systems the longer the orbital period the slower the accretion resulting in a longer spin period, for instance, PSR J1811-1736 has a spin period of 104 ms. If PSR J1903+03 had formed in the same way as a DNS, one would expect it, given its wide orbital period, to spin slower than PSR J1811-1736, not 50 times faster.

The formation of PSR J1903+03 is a mystery. The known paths of stellar evolution in binary systems can not produce such an outcome. We have several hypotheses, but they are all very tentative at this stage. Perhaps the best one is that this system formed in a globular cluster, where, because of the high stellar density, it exchanged its original WD companion for a more massive companion. Such encounters always produce binary systems with eccentric orbits, and the ejection of the previous WD could indeed "kick" the binary out of its cluster. The likelihood of finding such a system wandering in the Galactic star fields, away from its original cluster, is not yet clear, perhaps this is the first representative of that population. PSR J1903+03 is clearly a very interesting puzzle.

CIMA News

Mikael Lerner

WAPP Dual-Board Capability: The WAPP dual-board capability has finally been implemented. This is the mode when the two boards of each WAPP are used as independent spectrometers allowing each WAPP to cover up to 200-MHz bandwidth. With this mode it is thus possible to double the bandwidth covered with the WAPP during single-pixel receiver observations from 400 MHz to 800 MHz, and the mode has thus often been referred to as the "800-MHz mode". This is certainly what it is mostly going to be used for but there is nothing preventing an observer from using the

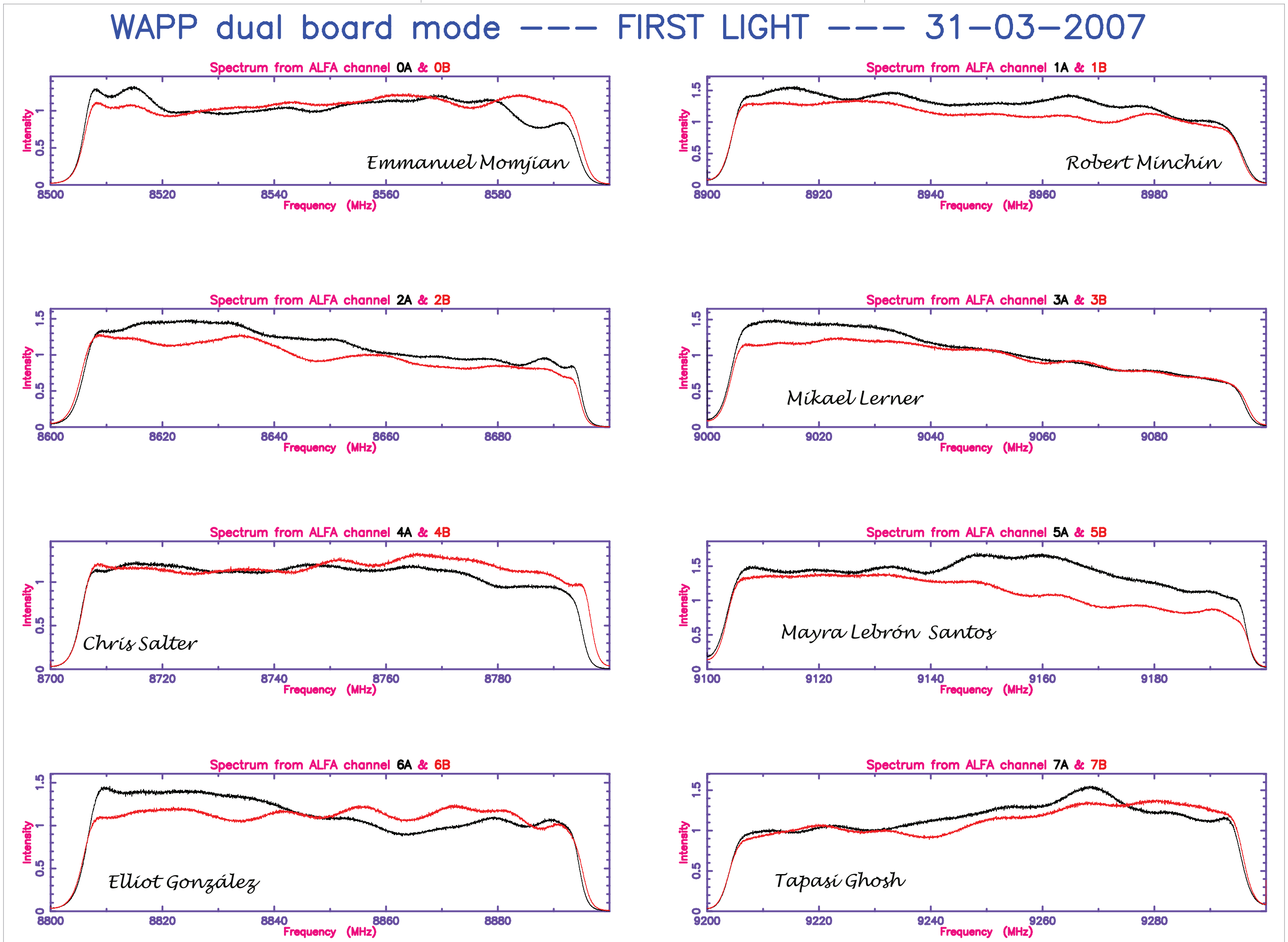


Fig. 22: First scientific light for the WAPP dual board capability. The diagram shows bandpass curves (two polarizations) for the eight 100- MHz bands covering 8500-9300 MHz observed with the X-band receiver during the first night of dual-board observing. The labels incorrectly say "ALFA beams", since the ALFA quick-look display was used to create this figure. The diagram also bears the names of the staff members participating in the observation. (Courtesy: M. Lerner)

dual-board mode with narrower bandwidths all the way down to 0.1953125 MHz.

The dual-board mode has so far been tested in spectral line mode and two spectral line projects have already been using it, with first scientific data taken on the night between 31 March and 1 April (see Figure 22). No testing has been done in pulsar mode yet. The reason for this is that the dual-board mode requires the new version of CIMA (version 2.3) which is still under development and, at the time of this writing, the pulsar set-up had yet to be modified to handle the new capabilities.

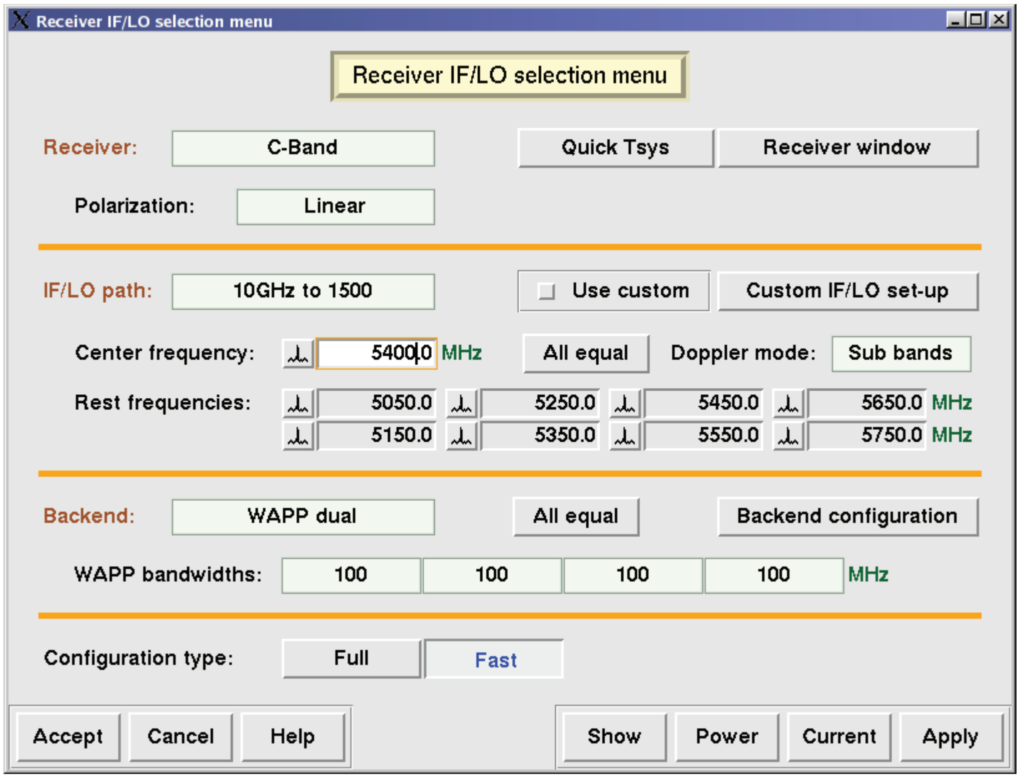


Fig. 23: The new 'Receiver IF/LO selection menu' from CIMA 2.3 needed to use the WAPP dual board capability. In this example, eight 100 MHz bands covering 5000-5800 MHz in C-band has been selected for observing. Courtesy: M. Lerner)

The following freedoms and restrictions apply in the current implementation of the dual-board mode:

- Any WAPP or any combination of WAPPs can be used. You don't need to run all WAPPs and you don't need to select WAPPs in sequential order. If you, for some reason, want to use only WAPP-2 and WAPP-4, you can do that.

- It is either dual-board mode or single-board mode for all selected WAPPs. If you select to use dual-board mode, all enabled WAPPs will be running in dual-board mode. You cannot mix and have one WAPP running in dual-board mode and another one running in single-board mode.

- You can only have one bandwidth selection per WAPP. When using dual-board mode, both boards on the same WAPP will use the same bandwidth. You will thus only see one bandwidth menu for each WAPP in the user interface when you are running dual-board mode. You can, however, select different bandwidths for different WAPPs. If you want to cover 600 MHz of band and at the same time get some high resolution spectra of two known lines in your band, you could set up three of the WAPPs to use 100 MHz and set the fourth one to use a narrow bandwidth.

- You can use any bandwidth selection normally available for the WAPPs from 0.1953125 to 100 MHz.

- You can use any WAPP configuration normally available for the WAPPs. As with the bandwidths, the same configuration will be applied to both the boards on each WAPP, but you can have different configurations on different WAPPs. NOTE though that "2 chan, 9-level auto" and "9-level, polarization" cannot be used together with 100-MHz bandwidth.

Figure 23 shows an example of how to set up an observation for dual-board mode with the new "Receiver IF/LO selection menu" in CIMA version 2.3. In this example, the C-band receiver has been chosen and the backend has been selected to be "WAPP dual" to allow us to cover 800 MHz between 5000 and 5800 MHz with the center frequency set to 5400 MHz. The rest frequencies for the eight boards have then been put in with a separation of 100 MHz. The first line of rest frequencies refers to the first board of each WAPP while the second line refers to the second board. Note the order of the frequencies; an observer is, of course, free to put the selected bands in any order, but this is the order that will make the consecutive bands to be numbered sequentially in the CIMAFITS file.

In the example given, we have set the boards with 100 MHz separation. This may not be the optimal set-up for projects like searches for molecular lines, since the bandpass falls off at the edges of each band (see the bandpass shape in Figure 22). For such projects it may be better to have a bit of overlap (10–15 MHz) at the edges to ensure that any interesting line doesn't fall in the gap with reduced sensitivity between the boards.

The data is currently written to FITS-files similar to ALFA data. The INPUT_ID keyword is given a value between 0 and 7 to indicate which board the data refers to, with 0 and 1 being board A and B on WAPP-1. The two arrays SYNFRQ and MIXER are 4-value arrays and are set up to contain the synthesizer frequencies and mixer settings for the four A-boards in records with INPUT_ID = 0, 2, 4 and 6 and for the four B-boards in records with INPUT_ID = 1, 3, 5 and 7. Other variables have currently not been modified.

For pulsar data, the files will look very much like ALFA data. However, there will be a change of the pulsar file headers to include information on the eight channels (currently the headers only list four channels).

CIMA Version 2.3: Development of the next version of CIMA, version 2.3, is currently going on. So far it has been used by a couple of projects, since this is the version needed when using the WAPPs in dual-board mode. This does, however, not mean that it is ready to use yet, since it is still in a development phase. CIMA 2.3 is big overhaul of the CIMA frontend, i.e. the user interface, with a number of the windows being redesigned. This is done to increase functionality, to remove ambiguities, to improve awareness and to make CIMA easier and more intuitive to use. Some of the larger modifications involve a new general window for the IF/LO set-up (see Figure 23), a new facility for saving and loading configuration files and new log handling. CIMA 2.3 will be available after the telescope has been painted.

NAIC Review Meetings

Robert L. Brown

As mentioned earlier, this spring there have been five major reviews of NAIC in less than 3 months. The purposes of these various committees, the goals of their reviews, the composition of the review panels, and the sponsors of the reviews, are different. But there is only one NAIC to review. For this reason, it should not be surprising to see substantial overlap in the review reports. Two of the committees, the AUSAC and the Cornell/NAIC Visiting Committee are particularly germane to the NAIC user community; we discuss these two committee reports here.

AUSAC: The Arecibo Users and Scientific Advisory Committee, AUSAC, is composed of ten active research scientists who either use the Arecibo Observatory for their personal research or make use of the data products and/or services of the Observatory. The AUSAC report made a series of pragmatic recommendations to the immediate and long-term consequences of the Senior Review report recommendations on NAIC.

The AUSAC recommendations regarding the immediate impact of the SR recommendations are the following:

- AUSAC acknowledges the SR guidelines to split observing time with 80% for surveys and 20% for PI projects. However, AUSAC emphasizes that the 20% time for PI science should be considered an absolute lower limit and that its preservation will be vital to protect the interests of the broad AO user community. In light of ongoing community discussions on implementing SR recommendations, AUSAC advises a flexible approach to this survey/non-survey ratio that balances scientific promise with budgetary constraints.
- We endorse the proposal to 'mothball' the C-hi, S-hi, S-lo, 610 MHz, 47-MHz receivers with the options to reactivate them when proposal pressure warrants. AUSAC would like to see proposal statistics for these Rx's next year.
- AUSAC accepts the necessitated cutbacks in observing time during the weekdays, assuming it results in an overall cost savings, but stresses that the loss of 2 out of 3 remaining observing days is substantial. We would like to see VLBI and highly ranked TOO (target of opportunity) projects scheduled during the day when needed. We also strongly encourage AO to schedule regular observations during all non-maintenance (weekend) days, especially during highly oversubscribed LST times.
- AUSAC wishes to highlight the unique and important capabilities of the S-band planetary radar, which were not discussed in the Senior Review Report. We strongly encourage searching for funds to continue this program including non-NSF funding and potential private sources.
- To reduce the strain on staff, AO should explore a policy that would require first-time users to work with an experienced non-staff AO user.
- AUSAC applauds the continuation of NAIC travel support for visiting scientists. Reduction of services offered to visiting scientists (airport transportation, for example) should be implemented with safety and ease of use in mind.
- Alternatives to any major changes in cafeteria services should be pursued. An expanded night lunch program, a shielded microwave, access to kitchen facilities after hours, hot plates in visiting quarters, or delivery from nearby restaurants are possibilities.
- As AO reacts to the SR recommendations and makes plans for the future, AUSAC can best advise NAIC and serve as a resource if the committee is kept informed of changes that affect users and scientific capabilities at the Observatory. AUSAC would welcome updates 'year round', not just during the relatively

brief annual AUSAC meetings.

The AUSAC also notes the following long range implications of the SR recommendations:

- AUSAC recommends that AO focus on key science projects in consultation with the AO users and broad astronomy community, in preparation for making the strongest science case possible for continued support of AO at the upcoming decadal review. Projects that leverage Arecibo's abilities as an SKA pathfinder instrument should be emphasized.
- AUSAC urges NAIC to aggressively advertise for a broad based workshop/meeting at AO to investigate new paradigms for AO operations, potential new science initiatives, and instrumentation development through university based grant funded initiatives. AUSAC views participation of AO engineers and staff as critical to the success of this meeting, and AO users should be strongly urged to attend.
- AUSAC encourages investigation of several new initiatives that may enable exciting science, including a high-z HI receiver, a small antenna for VLBI calibration, a new HF ionospheric Modification Facility, and AO conjugate opportunities in Argentina.
- AUSAC supports that multiple possible avenues of funding are being pursued. AUSAC feels that AO should explore hiring professional fundraising and public relations personnel to assist with this task and augment ongoing staff effort by bringing specialized skill to private fundraising activities.
- To encourage prompt data release from the ALFA surveys, AUSAC recommends that approval of future ALFA survey time be dependent on community access to survey data. AUSAC strongly feels that survey archival and dissemination activities will require a full-time AO position filled by someone who will serve as liaison to the ALFA consortia, NVO and the CTC.

Visiting Committee: The charge given by Cornell to the Visiting Committee differs substantively from the AUSAC charge. The Visiting Committee is charged to review and make recommendations on NAIC's management performance. While the AUSAC is concerned with user services, the VC is concerned with programmatic planning, personnel and budget, for example. However, the SR recommendations strongly influenced the VC management discussion just as it did with the AUSAC discussion of user issues. The following two paragraphs selected from the Executive Summary of the VC report convey the flavor of the VC analysis and report discussion. The Visiting Committee met in February, four weeks after the AUSAC meeting.

> *This year the visit of the Committee followed the publication of the report of the NSF Senior Review. The budgetary consequences of the SR recommendations have had tremendous impact on the Observatory. The VC questions some of the conclusions of the SR and the reasoning behind the recommendations and time scales. The need to work within the constraints of the resulting budget cuts, while at the same time move forward on the critical refurbishment of the telescope structure, has resulted in very significant reduction in human resources and curtailing of the astronomical capability of AO at a time when the power and promise of the AO for astronomical discovery has reached a new high. NAIC is attempting to steer a course in response to these realities that will allow AO to continue to work to the imperative of effectively exploiting the unique resource of the largest radio collecting area in the world to the benefit of the national and international community of scientists. However, it is clear to the VC that this situation has severely stressed the staff and resources at the Observatory and that AO is at a crossroads. It will be critical for NAIC to develop a vision and strategic plan for the role of AO in the advance of astronomy in the next decade that engages the broad national community and all the stakeholders in the future of AO.*
>
> *The scientific programs of the Observatory in Space and Atmospheric Sciences, Radio Astronomy and Radar Astronomy continue to be first rate. This report lists several accomplishments in all areas that have high impact and are enabled by the unique capabilities of the Arecibo facility. The scientific staff at AO can be justifiably proud of their leadership in several of these projects, their stewardship of the Observatory and their commitment to technical excellence.*

All of us at NAIC are grateful to the many individuals who willingly give of their time serving on our review committees in order to share their wisdom and insight with us. We will strive to implement their recommendations over the course of the year confident that the advice we receive will indeed benefit our institution in ways that are meaningful for our staff and users.

Proposal Handling

Two issues arise now concerning telescope scheduling. The first issue concerns the bookkeeping needed to satisfy the Senior Review mandated 80/20 division of time between surveys and other PI projects. The second is concerned with fitting all of the large ALFA surveys into the schedule now that the FPGA spectrometers are being commissioned, where upon every one of the ALFA surveys can operate.

The 2007 Arecibo Users Scientific and Advisory Committee (AUSAC) encouraged us to be flexible about how we "book" proposals as survey/non-survey, while recognizing that the baseline division of telescope time is meant to be 80/20. We therefore book every proposal as a survey that can logically be called that, irrespective of the amount of time it requests. The AUSAC goal, of course, is to reserve as much time as possible for the traditional "single investigator" proposals. This suggestion does not imply that more proposals should be given a skeptical review; it refers only to the way we report telescope usage at the end of the year.

This interpretation also implies that large non-ALFA survey proposals can also compete for time with the ALFA surveys. The need to fit any such together with the existing ALFA surveys into the telescope schedule requires that the whole set of large proposals be considered together by the same panel. This will be done once a year, in August, so the results of the review stand for a year. Hence, large new proposals, which consequently need skeptical review, should be submitted by the February 1st deadline in order to be skeptically and expeditiously reviewed in August, after going through the usual scientific merit review. Large proposals need an annual report that will be considered with all the others in August.

Bottom line: February 1st is the annual deadline for large proposals. Large proposals submitted at other times will be given the regular scientific merit review in the trimester submitted, but the skeptical review will be delayed until the following August.

SALTO

Jonathan Friedman

SALTO, which stands for "Secure Arecibo's Long-Term Operations", is a task force consisting of a number of Arecibo Observatory staff members: Jonathan Friedman, Space and Atmospheric Sciences, Chair; Paulo Freire and Chris Salter, Radio Astronomy; Mike Nolan, Planetary Astronomy; José Alonso, Visitor Center; Héctor Camacho, Electronics; José Cordero, Administration; and Edgardo Cruz, Operations. SALTO was formed during the month of January in the wake of the NSF Astronomy Facilities Senior Review Recommendations to cut funding to Arecibo by more than half over a 4-year period. SALTO seeks to identify and pursue funding opportunities for the Observatory, either directly or by helping staff to obtain support through proposals to both federal and private sources.

SALTO will also work with the scientific staff to produce press releases from its scientific results in order to publicize the excellent research that can be uniquely carried out with the Arecibo facility. Within Puerto Rico we hope to place these articles in El Nuevo Día and other local publications. For broader dissemination, the Cornell Press Office has provided us with a contact with whom we will work to publicize the Observatory nationally and internationally.

SALTO is also exploring new funding avenues, such as: university collaborations, both national and international; federal funding agencies and programs outside of the National Science Foundation's Astronomy Division; and private, grassroots, and foundation sources. The government of Puerto Rico is another potential source of support, and SALTO is in contact with elected officials in an active exploration of possibilities.

We would very much appreciate receiving your ideas and input, and we greatly value your support!

COMINGS AND GOINGS

Tim Hankins: In Appreciation

Robert L. Brown

Thank you Tim for your service as Arecibo interim director, September 2006 to March 2007.

In the summer of 2006 when it became clear that the process to select a new Observatory director would not conclude until well past the September 15, 2006 date that Sixto González had announced as the date that he would step down from the position, it was clear to me that we would need an interim director. The person we would need would have to be available to come to the Observatory in mid-September and stay for an indeterminate period giving us time to appoint a permanent director and time for that permanent director to arrive on-site. Moreover, I felt the interim director must be someone who knows AO very well so that s/he could work effectively from day-one.

The only person I could think of who met all those criteria was Tim Hankins. Tim had just retired from New Mexico Tech and was celebrating his retirement by sailing with his wife in Maine. Knowing it would be a hard sell to suggest that he come to work at AO rather than spend his days sailing, I phoned Tim and made the offer. Understandably, he said no. But by the time we finished talking he was saying he wanted to think about it. He phoned me back the next day to say he'd do it. I tell this story in order to let you know why he decided to accept the job. Here's what Tim said: "I've used the Arecibo Observatory for more than 30 years. The people at the Observatory helped me in everything I've done, and I've never done anything for them. This is my chance to return the favor."

With a terrific attitude like that there was no doubt that Tim would be successful. And he most certainly was. I am sure he didn't plan on having to deal with the release of the NSF Senior Review report and the unfortunate way NAIC was treated in the report. I know he wasn't planning on having to deal with the first large-scale reduction in force in the 40+ year history of the Arecibo Observatory. But deal with them he did, fairly and conscientiously, just as he dealt with every issue, large and small.

It was a pleasure to have Tim at NAIC as the AO interim director. Thanks Tim. And best of luck with the banjo lessons—when you're ready, and playing well, we look forward to your concert by the pool. [Is it an oxymoron to say "playing well" when talking about the banjo?].

Welcome Bob Kerr

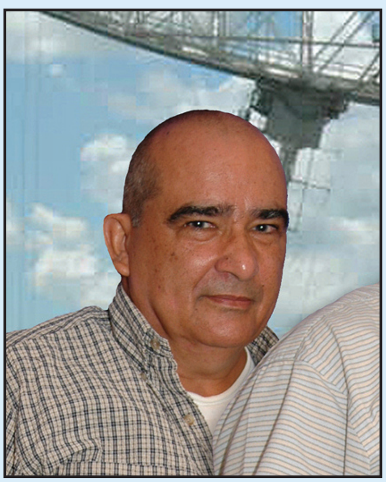
Robert Brown & Sixto González

It is a pleasure to welcome Robert Kerr to the Arecibo Observatory staff as the new Arecibo Observatory director. Bob was selected by an Observatory-wide committee after a very competitive search; he began his new position at the end of February. He is very familiar to many members of the NAIC staff as a result of his having been an active user of the Arecibo telescope and optical facilities for more than 20 years.

Bob received a B.S. in Physics from Ohio University in 1979, a M.S. in Atmospheric Science from the University of Michigan in 1981. He received a PhD in Atmospheric Science from the University of Michigan in 1986 and it was in doing his thesis research that he began visiting the Arecibo Observatory and collaborating with Craig Tepley (NAIC). After his first efforts

Buena Suerte Tony!

Edgar Castro



Tony Nolla is retiring!! We're happy for him, but who will be willing to pamper those receivers with the enthusiasm and dedication that Tony gave them for 40 years? ET?

Antonio "Tony" Nolla, a native of Cataño, joined the Electronics Department's receiver section in 1967 after graduating from the *Instituto Técnico de San Juan*. During the early years of the telescope, Yagi antennas were used as point feeds. Tony became an expert at building and tuning them. Many veteran radio astronomers remember working with Tony during their student days at the Observatory.

Tony continued his trajectory of excellence and made many contributions to the Observatory upgrades. He has been an asset to AO. It was a great honor for me to have had Nolla on my team. I wish him an enjoyable retirement and good health. God bless!!

at looking at oxygen and hydrogen emission lines in Jupiter and comet Halley, Bob moved on to specialize in studying H alpha emissions in the Earth's upper atmosphere and exosphere. Subsequent to obtaining his PhD, he joined the technical staff at the Aerospace Corporation in El Segundo, CA and then moved on to the astronomy faculty at Boston University, serving at BU from 1988 to 1997. From 1997 to 2004 Bob was at Scientific Solutions, Inc., initially as Director of Research and then as CEO. More recently he has been a program manager for the aeronomy program at the National Science Foundation.

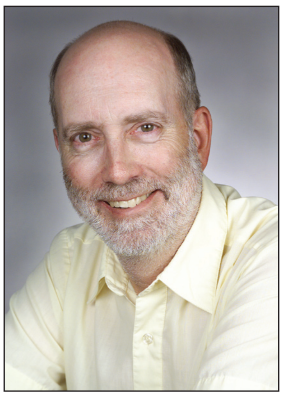
Bob brings to the Observatory a wealth of new ideas gained as a result of his broad experience in academia and in industry. This will be important to the Observatory as we continue to make the transition to an operating model in which a higher and higher premium is placed on being able to do more with fewer resources. Bob's leadership in guiding this transition will help to insure a very rich scientific future for the Observatory, its staff, and its community of users.

Please join us in welcoming Bob to the Observatory and in supporting him as he deals with his new responsibilities.

Kurt Kabelac and Dave Overbaugh Retire

Don Campbell

After 32 years of service to NAIC, Kurt Kabelac took early retirement in February as a result of the staff reductions at NAIC. Kurt joined NAIC's technical staff in Ithaca in March 1975 when the first upgrading of the Arecibo telescope was approaching completion. The upgrading included the first S-band (2.38 GHz) transmitter which was funded by NASA with the primary aim of obtaining radar images of the surface of Venus beneath its dense cloud cover at about 2-km resolution. This also required the construction of the 30.5-m Los Canos interferometer antenna – an effort led by the then associate director of the observatory, Rolf Dyce – and a digital "decoder" or cross correlator, which provided the high-time-resolution needed. Kurt's first six months or so were spent working with Val Boriakoff, who designed the decoder, and Dan Mittler, an engineer, on the construction the device. After this project was finished, Kurt continued to work with Val and Dan until early 1979, when he transferred to the development group at NAIC's Brown Road laboratory working with George Peter, Lynn Baker and, later, Jon Hagen plus the other technical staff at the lab. At Brown Road and after the lab moved to Maple Ave in Febuary 1989, Kurt worked on a long series of projects in support of the Observatory. These included the development and production of line feeds, the S-band maser receivers, numerous other receiver systems, filter banks for pulsar research, local oscillator systems, the mini-Gregorian (a test of concept project in preparation for the Gregorian upgrade), transmission lines for the Islote Heating facility, the cable wrap in the Gregorian dome, components for the ALFA system. The development laboratory and its staff played a key role in keeping Arecibo at the technical forefront of radio and radar astronomy and atmospheric science.



None of this touches on Kurt's real passion, which is Moxie. For those who wonder what this is, it was the first mass produced carbonated soft drink and was advertised with such jingles as "Just make it Moxie for mine". It is still the state drink of Maine. We wish Kurt well in his retirement and hope that he stays "full of Moxie"!

Dave Overbaugh left NAIC in January as a result of the recent staff cutbacks. Having been the machinist in the Space Sciences Building at Cornell, Dave was already well known by NAIC's Ithaca technical staff when he joined NAIC as a machinist in the Maple Ave Development Laboratory in May 1992, working under Jon Hagen and Lynn Baker. At this time, all the hardware for the 3 km or so of coaxial line needed for the upgrade of the Arecibo Islote Ionospheric Modification (Heating) Facility was being built in the lab, a huge task, and additional help from someone with Dave's skills was badly needed. After this project was finished, Dave contributed to numerous projects related to the Gregorian upgrading project that required his skills as a machinist and welder. These included the cable wrap system in the Gregorian dome, numerous dewars, horns and compressor housings for the receiving systems, the S-band transmitter's rotary coaxial joint, hardware for the dome's receiver room rotary floor and the targets and other hardware for the surveying of the primary and secondary reflectors.

As Dave says, one of the real pluses of his job was the opportunity to spend several summers and many shorter visits in Arecibo working with the technical staff at the Observatory. Another was the two weeks he spent in Greenland with Bill Hoffman salvaging parts from the decommissioned BMEWS radar at Thule for use with the Arecibo 430-MHz transmitting system. Best wishes, Dave!

SINGLE-DISH SUMMER SCHOOL

The National Radio Astronomy Observatory (NRAO) Green Bank and the National Astronomy and Ionosphere Center (NAIC) Arecibo Observatory are organising the ***fourth NAIC-NRAO*** school on single-dish radio astronomy. The summer school will take place July 8-15, 2007 at the NRAO in Green Bank, West Virginia. The purpose of the school is to allow students, postdocs, and experts in other fields of astronomy to explore emerging techniques and applications of single-dish radio astronomy.

The school will consist of an intensive series of lectures from world-class experts as well as hands-on projects in radio astronomy. Participants will be given the opportunity to make observations using the Green Bank and Arecibo telescopes and become familiar with the observation and data-reduction process.

The primary goals are

- to provide participants with a strong grounding in fundamental elements of single-dish radio astronomy and its relation to other observing techniques,
- to give an overview of current and emerging capabilities of single-dish radio telescopes and associated instrumentation,
- to provide practical experience with a single-dish telescope and to introduce participants to the hardware and software used in taking and reducing observations.

Lecturers and participants are invited to contribute posters describing research conducted with single-dishes.

Proceedings of the Single-Dish School, published in the ASP Conference Series, will be provided to this year's participants as part of the registration fee.

The number of participants will be limited to approximately 40 people. A registration fee of $200 will include

- **travel between Green Bank and Dulles airport,**
- **welcome reception,**
- **social events,**
- **school banquet,**
- **a copy of the proceedings.**

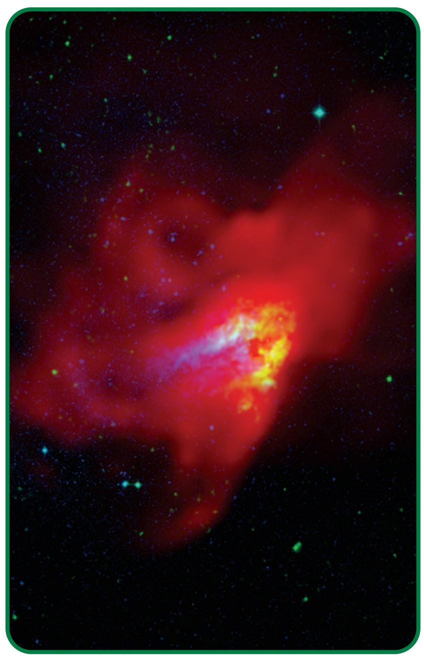
Announcements and further information can be found at the single-dish summer school website at http://www.gb.nrao.edu/sdss07

SDSS4

July 8 -15, 2007

National Radio Astronomy Observatory
Green Bank, West Virginia

http://www.gb.nrao.edu/sdss07

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Andrew Cumming (McGill)
Vicky Kaspi (McGill)
Robert Rutledge (McGill)
Zhongxiang Wang (McGill)
Montréal 2007
Keynote Public Lecture: Prof. S. Jocelyn Bell Burnell, CBE, FRS, FRAS
Conference Opening: Prof. Antony Hewish, FRS, Nobel Laureate
Conference Summary: Prof. Joseph H. Taylor, Nobel Laureate

NAIC/Arecibo is convening a meeting entitled

"Frontiers of Astronomy with Large Single-Dish Radio Telescopes"

To be held in Washington, DC on 12-13 September 2007

The focus of this meeting is to look at the strongest science cases foreseen for the Arecibo telescope 5-15 years into the future in a largely post-ALFA-survey time-frame. This meeting will not only explore new technology that may assist in exploiting unique capacities of the telescope, even in a world where the SKA is a reality, but also the scientific return from continued monitoring programs, such as the timing of milli-second pulsars.

We have two hopes for the meeting. The first is that it catalyze the development of white papers on key science projects for submission to the Astronomy & Astrophysics Decadal Survey (AADS), with a view to making the strongest science case possible for continued support of the Observatory. The second is that through consultation with the whole of the Arecibo user community, we garner their thoughts on future science, investigate new paradigms for AO operations, and investigate new ideas about instrumentation and software development through university-based grant-funded initiatives.

We expect this meeting to develop white papers on a number of science topics to feed into both the AUI process (home page at www.aui.edu/future_committee/index.php), and into the upcoming AADS. The output from the meeting should be organized along topic lines, as there is a considerable expectation that the AADS will organize its work in that fashion, rather than by wavelength as in the past. While we need to consider the science topics in an instrument neutral fashion, our emphasis will naturally be towards the areas where the Arecibo telescope can make a crucial contribution.

Scientific Organising Committee:
Murray Lewis (Chair), Chris Salter (Secretary), Chris Carilli, Lynn Carter, Jim Cordes, Colin Lonsdale, Lee Mundy, Snezana Stanimirovic, Russ Taylor, and Ira Wasserman.

NAIC has a starting web page for these activities at http://www.naic.edu/~astro/future.shtml

Another link, to the European equivalent of the decadal survey, is http://www.astronet-eu.org/-Science-Vision-

Please feed your ideas, thoughts and embryonic white papers directly to Murray Lewis (blewis@naic.edu), or to the member of the SOC most closely associated with your type of work. Should you be unable to attend, consider who else might be able to further your ideas, and who NAIC ought to contact as a result. Send Murray their names, and send them this circular.

Chicago-3 Community Workshop

14–15 September 2007

The third in the series of community workshops addressed to the issue of how the international SKA project best satisfies the scientific priorities of U.S. astronomy at meter and centimeter wavelengths in the next decade and beyond, will be held September 14 and 15 in Washington, D.C. The Chicago-3 Community Workshop, "Implementation of the SKA Program for the U.S. Community", is co-sponsored by NAIC, NRAO and the US SKA Consortium.

The "Chicago" series of community workshops began with an initial meeting near the Chicago airport in February 2006 and continued with the much larger Tucson meeting in August 2006. The result of the Chicago-2 Tucson meeting was a specific plan of action that focused on the key science motivating U.S. participation in the international SKA endeavor given the broader context of U. S. astronomy ambitions at all wavelengths. Chicago-3 is the opportunity for the all of us in the U. S. community to express the motivating key science in terms of a practical, coherent, U.S. SKA development program that can be presented in a way that emphasizes its full scientific excitement to the next decadal survey committee.

Chicago-3 is an open community workshop. Please plan on joining us:

Implementation of the SKA Program for the U.S. Community
September 14–15, 2007
Hall of the States Building
444 North Capitol St., NW
Washington, DC

The Hall of the States Building is directly across the plaza from Union Station in DC—very easy to reach! Additional workshop information, including travel and lodging information, will be distributed soon.

Notes to Observers

1. We would like to remind our readers that when you publish a paper using observations made with the Arecibo Observatory, please provide us with a reprint of your article. Reprints should be sent to: Librarian, Arecibo Observatory, HC3 Box 53995, Arecibo, PR 00612. Or, if you do not order reprints, please send publication information to csegarra@naic.edu.

2. Additionally, any publication that makes use of Arecibo data should include the following acknowledgement: "The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation."

http://www.naic.edu

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