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Arecibo Observatory

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Photo: Jonathan Friedman and John Toohey, 2002

Lunar Polar Ice: Mirage or Reality?

Don Campbell (Cornell University) and Bruce Campbell (Smithsonian Institution)

The last Apollo mission to the Moon in 1972 and the last robotic mission by the Soviet Union in 1976 heralded the end of an era of intense study of our nearest celestial neighbor. A few researchers continued to carry out remote sensing observations, analyze the returned lunar samples, etc., but there were no new missions to the Moon until the US Clementine mission in 1994. The Lunar Prospector orbiter, a NASA Discovery mission, followed in 1998. Since then, several countries have carried out, or developed plans for, new missions to the Moon. NASA's plans to return to the Moon with landers and, possibly, long-term bases has led to a renewed interest in the Moon in the United States, albeit from the viewpoint of exploration and as a "stepping stone" to Mars. The first planned mission under this program is the Lunar Reconnaissance Orbiter/Lunar Crater Observation and Sensing Satellite (LRO/LCROSS) mission scheduled for launch in late 2008. The search for evidence of water ice at the poles is one of the objectives of most of the instruments on the LRO orbiter, and the LCROSS portion of the mission involves impacting the second stage rocket into one of the permanently shadowed areas at the poles and the detection of any resulting water vapor plume.

Two of the most publicized results from the Clementine and Lunar Prospector orbiters are related to the possible presence of water ice at the lunar poles. Since the 1960s there have been suggestions that there may be water ice deposits on impact crater floors that are in permanent shadow from the Sun. The angle between the Moon's rotation axis and the normal to the ecliptic plane — the Moon's obliquity — is only 1.54°, so that the limb of the Sun never rises more than ~2° above the horizon at the lunar poles. The absence of an atmosphere and the very poor thermal conductivity of the lunar regolith means that the temperatures in the bottoms of impact craters, or other areas that never see the Sun, would be less than 100°K, and any water ice would be stable for an extremely long time. Water could be brought to the Moon by cometary or asteroidal impacts, and the water molecules would migrate to these cold traps.

In the mid-1970s, just after the completion of the first Arecibo upgrading project, observations with the new 2.38 GHz (S-band) radar system led to the discovery that the surfaces of the icy Galilean satellites of Jupiter have very unusual radar reflection properties: their radar albedoes are greater than unity, indicating that they preferentially reflect the signal back towards the radar — similar to a highway sign at night — and they return most of the echo power in the same sense (SC) of circular polarization as that transmitted [1]. A mirror-like surface would return all the power in the opposite (OC) sense of circular polarization to that transmitted. Consequently, unlike the surfaces of, say, the terrestrial planets, icy

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surfaces have circular polarization ratios (CPRs) — the ratio of the reflected power in the SC sense to that in the OC sense — greater than unity. It is now thought that the explanation for these properties is due to the very low propagation loss for radio waves in low temperature water ice, lossless scattering by voids or similar refractive index interfaces and the coherent addition of the emergent ray in the backscatter direction with its path reversed twin. The angular width of the scattering lobe about the backscatter (zero phase) direction is dictated by the mean distance in wavelengths between the two emergent rays and can only be measured via a bi-static radar experiment. This "coherent backscatter effect" was known in the optical research community, and its possible explanation for the odd scattering behavior of low temperature icy surfaces in the solar system was pointed out by Bruce Hapke of the University of Pittsburgh [2].

It has generally been thought that only low loss icy surfaces can support the coherent backscatter effect giving rise to radar echoes with albedoes greater than unity and inverted CPRs. Consequently, in 1992 when Earth-based radars discovered echoes with these properties from the poles of Mercury [3,4] it was assumed that the reflections were from icy surfaces, a considerable surprise at the time. It quickly became clear from Arecibo observations by John Harmon and his colleagues [5] that the areas with ice-like radar properties were coincident with the floors of impact craters that are in permanent shadow, considerably strengthening the argument that the radar echoes originated from ice deposits.

The discovery of possible ice deposits at the poles of Mercury resulted in renewed interest in the possibility that there are similar deposits at the poles of the Moon. In 1994 a bi-static radar experiment was conducted from the Clementine orbiter using the telemetry system as a transmitter and receiving the echo with one of NASA's DSN 70-m antennas. The objective was to see if there were any locations at the lunar poles that exhibited an increase in the CPR as the bi-static angle — the phase angle — went through zero as predicted by the coherent backscatter effect. A small increase was observed for the pass over the lunar south pole which was interpreted as coming from the Earth-facing inner wall of the 19-km crater Shackleton located at the pole and possibly indicating the presence of water ice [6]. The statistical significance of the measurement, the association with Shackleton — the resolution of the bistatic radar measurements was many thousands of square kilometers — and whether the increase in the CPR was due to ice, have been controversial ever since.

The 5.15° tilt of the Moon's orbital plane relative to the ecliptic plane combined with its 1.5° obliquity means that a radar on the Earth can rise up to ~7° above the horizon at the poles, considerably higher than the Sun, and, consequently, can view some but not all of the terrain that is in permanent solar shadow. Arecibo radar imaging observations made in the 1990s by Nick Stacy, a Cornell graduate student, [7] (Figure 1) showed that the inner wall of Shackleton does have a high CPR but also strongly suggested that high CPR's are associated with rough surfaces around young impact craters and on the inner slopes of larger craters independent of the degree of solar illumination and, hence, are not necessarily indicative of the presence of ice.

In 1998 the neutron spectrometer instrument on the Lunar Prospector orbiter detected elevated concentrations of hydrogen at the lunar poles [8]. The spectrometer had very poor spatial resolution, 45 km at best, so it could not isolate local concentrations. However, at about the same time Jean-Luc Margot, then a graduate student at Cornell, used Earth-based radar interferometric techniques [9] to obtain digital elevation models of the polar regions of the Moon allowing, via ray tracing, many of the areas that are in permanent shadow to be identified (Figure 2). If the hydrogen detected by Lunar Prospector is in the form of water molecules, still a topic of considerable discussion, then averaged over this shadowed terrain at the poles it is equivalent to approximately 1% by weight in the upper meter of the lunar regolith [10]. These measurements set a limit on the amount of water ice that can be present at least in the upper layer of the lunar surface. If the hydrogen is in the form of water, then the only issue is whether there are localized concentrations.

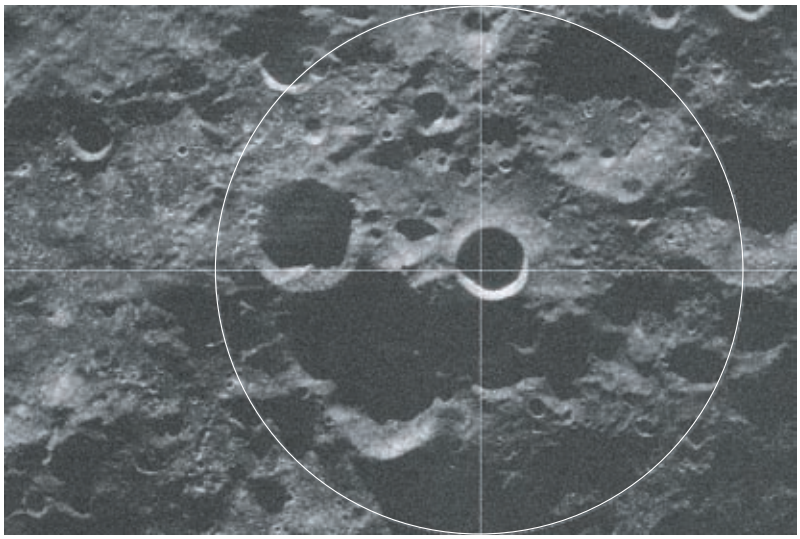

Fig. 1: Nick Stacy's 13 cm Arecibo radar image of the south pole with a resolution of 125-m [7]. The circle denotes 87.5°S latitude. Much of this area is in permanent solar shadow. The radar was ~ 7° above the horizon at the pole and the black areas are in shadow under the radar illumination. Shackleton crater, 19 km in diameter, is at the pole; Shoemaker crater, 51 km in diameter, is to its upper right with about 50% of its floor visible to the radar. The Lunar Prospector orbiter was impacted into Shoemaker crater in the hopes of throwing up a cloud of water vapor that would be detectable from Earth.

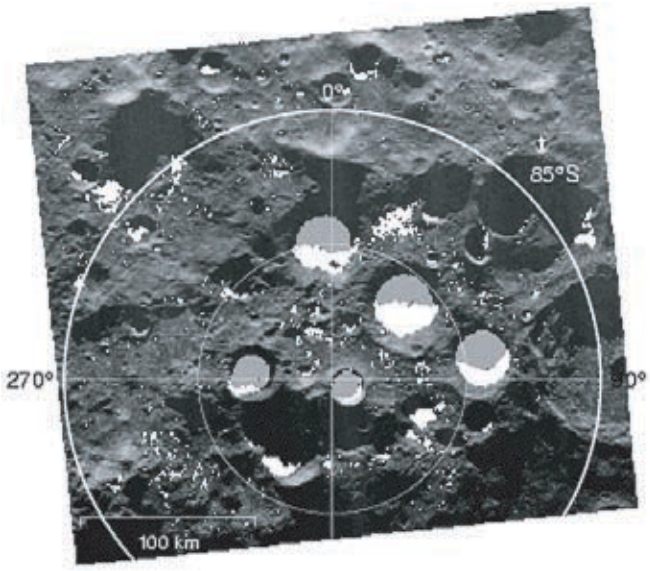

Fig. 2: Jean-Luc Margot's radar image of the south pole showing the areas in permanent shadow (white) based on ray tracing using a radar-interferometrically derived Digital Elevation Model [9]. Grey areas are thought to be in shadow based on impact crater symmetry assumptions. Some of the areas in radar shadow (black) could also be in solar shadow.

In order to gain a better understanding of the origin of the high circular polarization radar echoes from the lunar south pole we and our collaborators, Lynn Carter (Smithsonian Institution), Jean-Luc Margot (Cornell) and Nick Stacy (Defence Science and Technology Organization, Australia) initiated new 13-cm radar observations aimed at imaging this area at resolutions as high as 20 m and examining the full polarization properties of the reflected signal. Since the Arecibo 13-cm radar system cannot receive echoes from solar system objects with round-trip-light times of less than about 15 seconds — the time to the Moon and back is only 2.5 sec — we used Arecibo as the transmitting site and received the echo with the 100 m Robert C. Byrd Green Bank Telescope (GBT) of the National Radio Astronomy Observatory in West Virginia. A circularly polarized wave was transmitted and both senses of circular polarization received with the GBT. Our primary interest was in the circular polarization properties, the CPR, of the echo, so that to date we have only reduced the data to images in the two polarizations. Future work will examine the linear polarization properties of the echoes, which can provide information about surface versus sub-surface scattering and crater wall slopes.

In April 2005, when Arecibo and the GBT were ~7° above the horizon at the lunar south pole, we imaged the south pole covering an area extending from a few degrees on the far side across the pole to about 70° south on the near (Earth facing) side. The range resolution was ~20 m. In the Doppler dimension we coherently processed ~51 minutes of data to give a frequency resolution of ~0.0003 Hz, resulting in a spatial resolution on the lunar surface also of ~20 m. The transmitted power was 200 kW, giving a very high signal-to-noise ratio in the resulting images. Unfortunately, for reasons that we do not fully understand, this very high S/N ratio resulted in significant calibration problems between the two polarizations making it difficult to obtain a well calibrated circular polarization ratio image. In October 2005, we repeated the measurements at lower spatial resolution, ~100 m, using a transmitter power of 20 kW. The resulting images were well calibrated, providing good estimates of the CPR over the scene and allowing us to calibrate the higher resolution CPRs obtained from the April data.

Figure 3 shows the radar image and the CPR ratio image superposed on the radar image obtained in October 2005. Because the echo power in each pixel is one measurement of a scintillating signal, averaging is necessary before forming the ratio of the SC and OC images to give the CPR. Consequently, the resolution of the CPR image is ~500 m with a statistical uncertainty in each value of about 10%. The surprising aspect of the CPR image

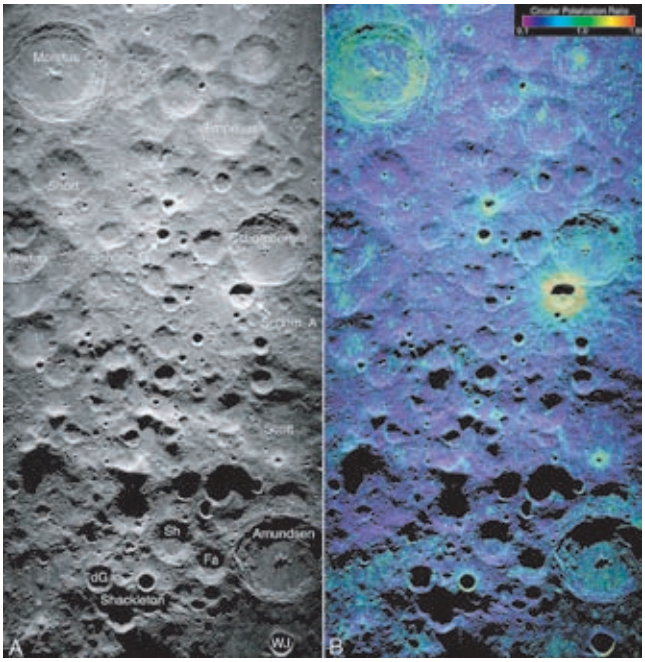

Fig. 3: Arecibo/GBT radar image data from October 24, 2005 for a region covering the south pole and the nearside to latitude ~68°S. The south pole is on the left rim of Shackleton. North is 3.5° counter-clockwise from the centerline of this image (zero longitude grazes the east rim of Moretus). Spatial resolution 100 m/pixel; polar stereographic projection. (A) Opposite-sense (OC) radar image at 100 m resolution. Major craters labeled: Sh=Shoemaker, Fa=Faustini, dG=de Gerlache, WJ=Wiechert J. (B) Circular polarization ratio (CPR) at 500 m resolution presented as color overlay on the radar backscatter image. Note the very high CPRs for Schomberger A and many other smaller craters (from [12]).

was the very high CPR values at latitudes that are clearly sunlit during the lunar day. The inner Earth-facing wall of Shackleton does have CPR values greater than unity but so do the walls and proximal ejecta of young craters throughout the imaged area. The most extreme example of this is Schomberger A at 70°S latitude. The floor, walls and close-in ejecta blanket of this very young Copernican-age crater have CPR's that range up to about 2. It is abundantly clear that high CPRs are correlated with the very rough rocky ejecta around young impact craters and on their floors and inner slopes, and not with the degree of solar illumination. While there are a few examples of radar echoes from non-ice surfaces with CPRs greater than unity (e.g. a small number of asteroids and the SP lava flow in the San Francisco Peaks near Flagstaff, Arizona), it has been generally thought that only icy surfaces can support the coherent backscatter effect giving rise to high CPRs, and, hence, greater than unity CPRs are indicative of icy surfaces. This is clearly not the case, although the nature of the scattering from rough areas associated with young impact craters that gives rise to the high CPRs is not understood. It is possible that a coherent backscatter effect is at least partly responsible, which may account for the Clementine results.

Due to the Clementine results and its close proximity to the pole, Shackleton crater is of great interest as a possible repository of water ice. However, neither the Arecibo/GBT radar system nor the Clementine bi-static radar experiment could observe more than a portion of the inner Earth facing wall. (Clementine's receiving antenna was on the Earth and was only 5.5° above the horizon at the lunar south pole so that its view of the area was slightly worse than that of Arecibo and the GBT when we acquired the data.) The upper portion of this wall is sunlit at least part of the time and its identification as a possible repository for ice by the Clementine experimenters [11] rests on an apparent increase in the CPR in the permanently shadowed part of the lower slope that was visible to the Arecibo radar during Stacy's 1990s

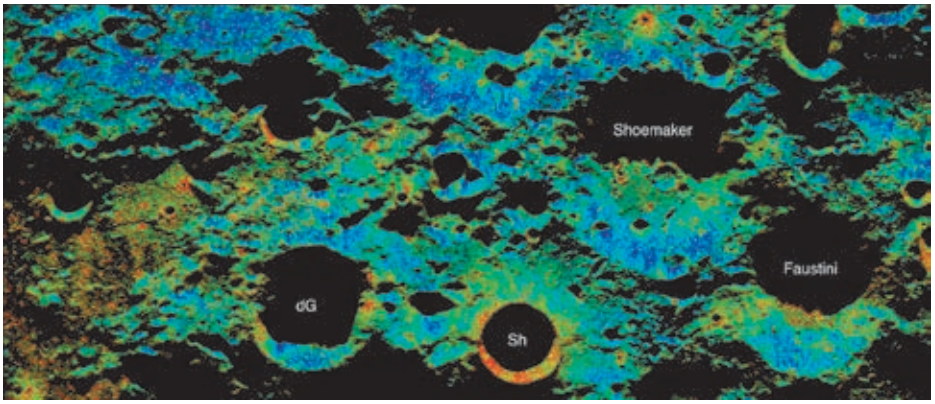

Fig. 4: The circular polarization ratio (CPR) at ~120 m resolution from the April, 2005 data. The CPR increases from blue (~0.3) to red (>1.0). Note the strong correlation of the CPR with small craters and the inner slopes of some larger craters including Shackleton (Sh). Shackleton is a relatively young Eratosthenian age (1.2 to 3.2 b.y.) crater while Shoemaker and Faustini are significantly more degraded and thought to be at least 3.9 billion years old.

observations. The new data (Figure 4) shows that the CPR is high over the entire slope and probably arises from scattering from what is essentially a scree slope.

The results of this work suggest that the only real evidence that there may be ice at the lunar poles rests on the hydrogen measurement by the Lunar Prospector orbiter and is dependent on the assumption that the hydrogen is in the form of water molecules and not due to, say, solar wind implanted protons or their reaction products having a much longer lifetime in shadowed terrain than they do in sunlit areas. There is no real evidence that any water ice is in concentrated deposits with scattering properties similar to those at the poles of Mercury. Given this, any planning for a future base at one of the poles should be based on ice, if it is present, being relatively uniformly distributed at low concentrations in the lunar regolith. Areas of higher concentration cannot be entirely ruled out but we have no evidence for them at this time.

This article is based on a recent paper published in *Nature* [12].

Acknowledgements: The observations could not have been carried out without the assistance of the dedicated staff of the Arecibo and Green Bank observatories. John Chandler of the Smithsonian Astrophysical Observatory provided the lunar ephemeris observing files. The work was supported in part by grants from the NASA Planetary Astronomy and Planetary Geology and Geophysics Programs and, primarily, by the National Science Foundation through its support of NAIC and NRAO.

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2006 Gordon Lecture

Jocelyn Bell Burnell reflects on pulsars, the process of discovery, and being a female pioneer

Lauren Gold, Cornell Chronicle

In her first days as a graduate student at the University of Cambridge, Jocelyn Bell was given a set of tools. Pliers. Wire cutters. Screwdrivers.

"The message was very clear," she says. Astronomy would not be ladylike work.

To begin with, she and a few classmates would take 120 miles of wire and cable, a four-acre field, their understanding of physics and their best sledgehammering skills, and they would build a radio telescope.

Forty years later, Bell Burnell (she married soon after receiving her Ph.D.), a visiting professor at the University of Oxford, is known for her 1967 discovery of pulsars: the key to understanding such fundamental forces as gravity and the strong nuclear force. She spoke June 27 on *Reflections on the Discovery of Pulsars* at Cornell's Arecibo Observatory in Puerto Rico as the 2006 William E. and Elva F. Gordon Distinguished Lecturer.

Today, we know that the discovery of pulsars would change astronomy. And we know Bell's discovery led to a Nobel Prize for her thesis adviser, Antony Hewish; with credit to Bell in the form of various other prestigious prizes following later. ("I reckon I've done pretty well out of not getting the Nobel Prize," she says with a smile.)

But it all started with a plan to write her Ph.D. thesis on quasars, or quasi-stellar radio sources — very compact, distant sources that emit extremely high amounts of energy.

"In the mid-1960s quasars had just been recognized as very distant objects," she says. "They were extremely sexy things." She and Hewish were working on the theory that quasars could be identified because their waves of electromagnetic energy become distorted by the solar wind and appear to radio telescopes as if they are scintillating. "The plan was that we would repeatedly survey the sky for twinkling sources," she says. "And they would be the quasars."

During that tedious process, Bell noticed occasional "bits of scruff" among her data. At best, she thought then, it was some kind of man-made interference; at worst, it could be faulty wiring of the telescope on her part. And then there was the unsettling possibility that beings — which she and Hewish called Little Green Men — were sending a transgalactic greeting.

Ruling out each of these possibilities was a painstaking process. After they'd succeeded, Bell and Hewish published their findings in the journal *Nature*.

"The press caught wind of it — and somehow caught wind of the idea that it might be signals from little green men — and they descended," Bell Burnell says. "And when they discovered that S.J. Bell (her first name is Susan) was a female, they descended even faster."

They asked Hewish about the astrophysical significance of the discovery. And then they turned to Bell Burnell for the "human interest" side: her body measurements, how many boyfriends she had, if she would undo a few shirt buttons for the photos.

"They just did not know what to make of a young female scientist," says Bell Burnell. "That's just the way the world was."

Since then, Bell Burnell has studied wavelengths from gamma rays to infrared. Now, she is most intrigued by microquasars: pairs of stars, one of which is a neutron star or a black hole, that mimic quasars by inexplicably sending out intermittent, narrow jets of material. They may have a lot to teach us, she says in her brisk, cheerful Irish lilt — "when we get round to looking. And I hope we will soon."

NSF Astronomy Senior Review Recommendations for NAIC:

NAIC Statement and Implementation Plan

Robert L. Brown

The NSF division of astronomical sciences (AST) released the report of the Senior Review panel on November 3rd. The report, *http://www.nsf.gov/mps/ast/ast_senior_review.jsp*, includes three recommendations for NAIC. These are:

1. Reduce NSF astronomy division support for Arecibo to $8M over the next 3 years;

2. Schedule the survey programs for 80% of the time used for astronomy on the telescope through 2010;

3. In 2011, plan either to close Arecibo or operate it with a much smaller astronomy budget; additional funds to be provided by other sources.

The Cornell/NAIC statement in response to the Senior Review report follows.

Cornell/NAIC Statement

Cornell fully supports the goals of the Senior Review and shares in the view that science is a forward-looking enterprise; new research facilities are essential to future progress. Cornell is also proud of the scientific achievements that have been made at the NAIC Arecibo Observatory by creative researchers over the more than 40 years that Cornell has managed and operated the Observatory. We appreciate the supportive words of praise in the SR report congratulating Cornell on its effective operation of the facility.

The NAIC Arecibo Observatory is a facility of the National Science Foundation. Cornell manages NAIC on behalf of the U.S. scientific community for the advancement of radio science. The principal stakeholder in NAIC is the U.S. scientific community. If the U.S. scientific community, through the Senior Review or some similar community-based, informed, process recommends that changes should be made in the way NAIC is funded or in the scope of the services it provides to the community, Cornell/NAIC will work conscientiously with the community and its NSF sponsor to implement those changes.

The Senior Review recommends that over the next 3 years the NSF funding for support of the NAIC astronomy program should be decreased by nearly 25%, from an annual budget of $10.5M to annual budget of $8M. Cornell/NAIC is prepared to make the changes in the scope of the NAIC astronomy program, and in the operating structure of the Arecibo Observatory, that will enable the adjustment to a much reduced astronomy program to be made. In planning for such changes we recognize, as did the Senior Review report, that there is every reason to expect that the Arecibo Observatory can be scientifically productive for the next decade and even further into the future. In order for this to happen, Cornell has pointed out to the NSF that the long-term safety of the Arecibo telescope requires that the accumulated corrosion on the telescope platform must be removed and the platform re-painted. NSF has endorsed this view and a plan is in place to clean and paint the platform in 2007, a multi-million dollar project to be done via a financial partnership between NSF and Cornell. The platform painting will give the telescope a structural lifetime of 20 years.

The Senior Review is less sanguine about the priority NSF astronomy funding for NAIC deserves in competition with that of other facilities, particularly new facilities, in the period beyond 2010. The SR report mentions that NSF may want to reduce NAIC astronomy operations funding even further, below $8M/year, in 2011. The report also suggests that NSF may want to consider closing the Arecibo Observatory after 2011. And finally the SR report notes that the SR charge is to advise NSF for the period between decadal surveys, and hence issues that apply to the post-2010 years are subjects for the next decadal survey committee to consider; they are not issues on which the SR recommendations are germane. Clearly, there is no community consensus yet on the priorities for the next decade, and there cannot be until the decadal survey is conducted. In light of this situation, Cornell/NAIC will take no actions that will limit the options available to the decadal survey committee. In particular, no planning will be done, or actions taken, leading to closure of the Arecibo Observatory.

The primary recommendation of the SR report for NAIC/Arecibo Observatory, that funding for the astronomy program be reduced from $10.5M annually to $8M annually over 3 years, is one that Cornell/NAIC will implement by reducing the scope of the astronomy program. Although this cut of nearly 25% in the budget of the NAIC astronomy program will necessitate that major changes be made, it will also motivate NAIC to focus on developing new research capabilities, particularly those that enable high-priority, community-based, radio science initiatives such as the international Square Kilometer Array to proceed expeditiously to completion.

Response to Specific Questions

1. The Senior Review recommends a decrease in AST support for Arecibo to $8M over the next 3 years. Is it feasible to manage that large of a decrease in operations funding and still maintain a viable astronomy program at the Arecibo Observatory?

Answer: *The astronomy program at the NAIC Arecibo Observatory presently (FY2007) has an annual operating budget of approximately $10.5M. These funds are used not only to operate the Arecibo telescope and maintain the Observatory site, but they provide support to the 250 scientists and students who come annually to the Observatory to conduct their programs of observational research. The budget reduction proposed by the SR, a reduction of nearly 25%, cannot be accommodated by trimming Observatory programs across the board. Instead, it*

necessitates a change in the scope of the astronomy program with the elimination of some research capabilities in order to maintain the viability of others, and to ensure the potential for future growth in research areas of greatest promise.

2. Will a personnel layoff be necessary?

Answer: *The NAIC budget breaks down into costs that are either personnel costs (salaries, wages, benefits) or materials costs (utilities, supplies, services). Personnel costs are 75% of the budget, and materials costs are 25% of the budget. Just to keep the lights on after a budgetary reduction of 25% will necessitate personnel layoffs. To the extent possible, the reduction in force will be handled through voluntary retirements and elimination of open positions.*

3. What are some of the likely specific consequences of the reduction in funding for the NAIC Arecibo Observatory astronomy program?

Answer: *The scope of the astronomy program will change from one in which the NAIC Arecibo Observatory offers a full range of instrumentation and support services for radio astronomical research, to a more limited program that focuses on the unique ability of the world's largest radio telescope to survey and study faint objects in the universe. Specific reductions in scope of the astronomy program include the following:*

We will eliminate all AST-supported NAIC program elements that are not directly related to operation of the NAIC astronomy research program. We will reduce the number of telescope observing hours for astronomy to approximately 3800 hours per year. (Now it is 4800 hours per year).

- *Nearly all astronomy observations on the telescope will be scheduled at night, leaving the days free for maintenance activities.*
- *We will do telescope and instrument maintenance 8 hours per day, 5 days per week (Monday-Friday).*
- *Because 80% of the astronomy observations will be for survey observations, we will reduce the number of receivers available for astronomy observations from 13 to 6. This will make it easier to maintain the remaining receivers.*
- *The survey observations require less local support. Accordingly, scientific and support services in many areas will be reduced.*
- *We will encourage remote observations to reduce the number of on-site visitors requiring Observatory assistance. This will enable us to reduce the cafeteria hours, and trips to the airport, for example. Student visits for training will still be encouraged.*
- *We will continue to operate the Arecibo Planetary Radar in FY2007 as we seek additional support for it from NSF and other sources.*

4. The SR report recommends that only 20% of the astronomy observing time be allocated to research programs of individual investigators with the remaining 80% of the time being allocated to survey programs. The SR makes this recommendation based on their assessment of the greater scientific value of the surveys and on the expectation that Observatory scientific and observing support can be reduced as a result. Is this feasible?

Answer: *The astronomy survey programs on-going at the Arecibo Observatory are being conduced by large groups of researchers, 40 or more researchers involved with each survey is typical, whose combined skills encompass all aspects of observational research. For this reason, Observatory services, in all areas, necessary to support the survey programs are less than for more traditional individual-investigator research programs.*

5. The SR report mentions that much of the survey work will be completed by 2010 and hence 2010 is a suitable year to consider making major changes to NAIC. Do you agree with the SR statement and the conclusion drawn from that statement?

Answer: *The report states (6.2.1, p. 62) that "much of the survey work will be completed by 2010". That statement is incorrect. When asked by the Senior Review panel, "When will the surveys be half done"? we responded that the current surveys would be *half* done in five years. Furthermore, this time would of course be extended if the telescope operates for fewer hours each year as a result of staff reductions. We also noted that three additional approved survey programs were still awaiting the scheduled delivery of survey-specific signal processors, spectrometers, and that these new surveys would start upon delivery of the new spectrometers (January 2007). They too would require 5-years to be half completed, or 10 years to be completed. Further, all the surveys make discoveries that demand follow-up. The most interesting discoveries are faint sources and/or time-variable/periodic phenomena: both require Arecibo's collecting area to deliver their ultimate science outcomes.*

Unfortunately, the SR report appears to have based its recommendation regarding the close out date for the Arecibo Observatory on the erroneous premise that the ALFA surveys would somehow come to conclusion in 2010. We encouraged AST to investigate the logic that led to this recommendation and take the appropriate steps to revise it as part of their implementation plan.

6. What is the effect of the Senior Review recommendations on the Arecibo Planetary Radar program?

Answer: *NAIC has issued a separate statement on this issue. In brief, NAIC is concerned that the Senior Review report includes only a single reference to the Arecibo planetary radar. And that reference is to discoveries made several decades ago, ignoring the long list of recent achievements given, for example, in the NAIC report to the SR. Regrettably, the failure of the SR to appreciate the critical role of the Arecibo planetary radar may lead to its demise. The SR*

report (6.2.1, p. 62) states "The SR was advised that a minimum feasible operating cost for Arecibo is $8M, even when it is largely working in survey mode." The $8M budgetary number does not include any support for the planetary radar program: the $8M operating budget applies, as the report notes, when the Observatory is doing astronomical surveys. The operating cost of the Arecibo planetary radar is $1M per year, a figure NAIC supplied to the SR. Therefore, the SR recommendation that the funding for NAIC be decreased to $8M, together with the SR recommendation that the NAIC astronomy program focus on survey programs, is a recommendation to terminate the Arecibo planetary radar program. The community should have been told this explicitly in the SR report if indeed that was the intended conclusion of the SR panel. Cornell/NAIC has expressed its concern about the lack of clarity, and candor, in the SR report regarding the Arecibo planetary radar program.

It is the position of Cornell/NAIC that the Senior Review failed to understand the role of the Arecibo Planetary Radar and, in particular, it failed to appreciate that the two primary SR recommendations for NAIC had the effect of terminating this critical program. This error can be rectified by revising the SR recommendation for NAIC from "the SR recommends a decrease in AST support for Arecibo to $8M …", to "the SR recommends a decrease in AST support for Arecibo to $9M…" The additional $1M per year in NAIC operations funding preserves the operation of the Arecibo planetary radar without violating the apparent SR objective of diminishing NAIC funding overall. The $1M per year in incremental operations funding is one-half of one-percent of the current AST annual budget. NAIC believes this change should be a key element in the AST implementation plan for the Senior Review recommendations. We have communicated this suggestion to Wayne van Citters, the AST division director.

NAIC will continue operating the Arecibo Planetary Radar until the end of FY2007. Operation beyond this date depends on the availability of funds.

7. The SR report recommends that the Arecibo Observatory be closed if external funding is not found for the NAIC astronomy program after the year 2011. What is the Cornell position on this recommendation?

Answer: *Cornell believes the SR was acting beyond its charge in making this recommendation. The SR was charged as follows: "The committee is asked to examine the impact and the gains that would result by redistribution ~$30M of annual spending from Division funds. These funds would be obtained by selective reductions in the operations of existing facilities and instrumentation development programs, possibly in combination with opportunities to deliver scientific knowledge at reduced cost to NSF or increased efficiency through new operating modes." Thus, the charge to the SR is a budgetary question, not a programmatic question. The decision to construct new NSF facilities or close existing NSF facilities is a NSF decision; the SR was not established to address this issue.*

In any case, the SR report properly notes that its recommendations refer to the mid-term period between decadal reviews of astronomy and astrophysics. The SR report states: "If Arecibo is kept operating beyond 2011, it is expected that this will only be a limited term extension, pending deliberations of the next decadal survey". Cornell agrees with the statement that the continued operation of the Arecibo Observatory, and the continued operation of all NSF-supported programmatic activities, is an issue to be assessed as part of the next decadal survey. It is not an issue for review by the SR.

8. What is the effect of the SR recommendations on the program of ionospheric research at the Arecibo Observatory?

Answer: *The ionospheric research program at Arecibo is supported independent of the astronomy program. Funding for the ionospheric research program comes from the Upper Atmospheres division of the NSF Geosciences directorate. It is not affected directly by the actions of astronomy division senior review process. However, there will be indirect effects. The ionosphere research program is funded as an incremental cost to the operation of the astronomy program. As support for the astronomy program declines the incremental cost required to support the ionospheric research program will increase. However, there is no reason to think that the scope of the ionospheric research program will need to change as a result of the increasing cost burden on the ionospheric program, unlike the situation with the astronomy program at the Arecibo Observatory.*

Limits on Telescope Availability in 2007

Robert L. Brown

Platform Painting Project

In 2003 NAIC contracted with the engineering firm of Ammann & Whitney (A&W) to perform a condition survey of the Arecibo telescope. A&W reported that the telescope was generally in good condition, but corrosion was a persistent problem on many of the structural elements on the telescope platform, and the platform steel needed to be cleaned and painted.

In order to understand what, precisely, needed to be done to clean and paint the telescope platform we engaged KTA, Inc., a painting consulting company, to conduct a thorough analysis of the condition of the paint on the telescope platform and advise us on the technical specifications that were needed for contract painting of the structure. The KTA study revealed that the corrosion problems on the telescope were traceable to millscale that formed as part of the fabrication process used for the steel in the construction of the telescope in the early 1960s. Briefly, millscale is an oxidized layer that is formed when steel is rolled into the desired shape as the final step in the steel fabrication process. It is a thin crusty layer that is

now removed by sandblasting the steel once the newly-formed steel has cooled. In the 1960s this step was routinely omitted. Over time, the millscale pulls away from the steel allowing water to penetrate into the underlying steel. One cannot paint over the millscale, it has to be abrasively removed, i.e. the steel has to be sandblasted.

We are in the process of contracting with an industrial painting company to blast and clean all the structural steel on the telescope platform. The task is complicated by the presence of lead-based primer on the steel. All the blasting and cleaning will have to be done in an enclosed environment so that the residual, lead-contaminated, abrasive material can be captured and disposed of as hazardous waste. Work will begin in late January 2007 and continue through March. The painting contractor will work two shifts each day. During this time there may be limited opportunities for the telescope to be used during the third shift for observations that can be done as drift scans and with the understanding that pointing may not be repeatable (as weight on the platform is re-positioned by the painting contractor daily). Héctor Hernández, the telescope scheduler, will contract the PIs of those proposals that can, in principal, make use of any time that does not conflict with the painting project. Generally, the telescope will be unavailable for science from late January to mid-April.

Receivers

Among the measures necessary for NAIC to take to reduce its expenditures to the point that the Observatory staff and functions can be supported by an annual AST budget of no more than $8M is to limit the number of receivers available to the astronomy program. Fewer receivers means that the staff effort going into receiver maintenance functions, in all of their aspects, can be reduced. This frees up the time of the scientific and engineering staff to undertake new initiatives, and it reduces costs. We will follow the Senior Review Recommendations to give priority to those receivers necessary for support of the ALFA survey programs, including those needed for follow up observations, and add to those receivers the C-band and X-band receivers that enable the Arecibo telescope to participate in HSA and global VLBI observations. These criteria lead to the following list of receivers that we will fully support for the astronomy program in the future:

» 327 MHz

» 430 MHz (maintained by the ATM program)

» ALFA

» L-Band wide

» S-Band narrow (for planetary radar observations)

» C-Band

» X-Band

At the February 1, 2007 proposal deadline, and in all subsequent proposal deadlines, we will accept proposals for use of any of the above receivers in the usual way. The remaining astronomy receivers will, in general, not be removed from the telescope but instead will be "mothballed" with the cryogenics turned off. Astronomers may propose to use these receivers on an as-available basis: the Observatory will attempt to schedule them when there are several proposals in the queue requesting their use.

Restricting the number of receivers available for immediate use is solely a cost-cutting measure, one of many that will enable the astronomy program at the Observatory to function on a much-reduced budget. We sincerely regret that this step is necessary and apologize to those users who are inconvenienced by it.

Skeptical Review of Large Proposals

Robert L. Brown

As the emphasis of the astronomy program is increasingly focused on large survey programs, let me remind those requesting more than 300–400 hours of observing time that their proposals will be subject to a skeptical review following the scientific review given to all Arecibo proposals. In special circumstances, the NAIC director may seek a skeptical review for proposals requesting fewer telescope hours. Proposals for large programs can be up to 12 pages in length (excluding figures, but including references and the target list or area of sky to be studied).

The skeptical review panel is composed of external experts who are all experienced with astronomical surveys. The purpose of their evaluation is to advise NAIC as to whether scheduling the proposal is a meritorious use of the telescope time.

The skeptical review panel will assess:

- The scientific potential of the proposal;
- Whether the total duration proposed for the project is well-defined and commensurate with the scientific priority;
- Whether Arecibo is the most appropriate instrument for the project;
- Whether there should be any proprietary "holding time" for the data, and, if so, for how long;
- Whether the plan for execution of the observational program is complete, whether the software system for the reduction of the data is appropriate for the needs of the observations, and whether the observing technique is well suited to the observing program proposed;
- The plan for making data products accessible to others through the Virtual Observatory.

The skeptical review panel meets as a body, usually by teleconference, and their recommendations are forwarded to the proposers by the NAIC director with a recommended course of action that the Observatory will follow. An annual report, to be evaluated by the skeptical

review panel, is required to continue the project, from one year to the next.

The skeptical review process adds at least an additional trimester to the time required for large proposals to be considered for scheduling on the telescope. See Section 5.7 of *http://www.naic.edu/science/proposals_set.htm*

Radio Astronomy Highlights

Compiled by Murray Lewis

Deriving Constraints on Alternative Theories of General Relativity

Paulo Freire

PSR J1738+0333 is a 5.85-ms pulsar in a binary system with an orbital period of 8.5 hours, and a companion white dwarf (WD) with a mass of ~0.2 solar masses. This millisecond pulsar (MSP) was found with the Parkes 64-m radio telescope in a search led by Bryan Jacoby (then at Caltech) and Matthew Bailes (Swinburne). Paulo Freire has made timing observations of this pulsar for the last 3 years, so preliminary results have been presented here before. The RMS uncertainty in pulse times of arrival of 200 ns for one hour of integration on each WAPP makes this one of the most precisely timed pulsars ever. Its orbit has a small apparent eccentricity of about 0.0000011, which implies that the orbit itself does not depart from being exactly circular (with a radius of 102,000 km sin *i*, where *i* is the inclination) by more than 80 microns (and, yes, this value is correct).

Recent optical work constrains the masses of the pulsar and its companion. Using the Magellan telescope, Marten van Kerkwijk identified the companion star and measured its spectrum, which is very similar to the 0.203 solar mass companion of PSR J1909-3744. Further, the radial-velocity curve was measured using Gemini South (see Figure 5), from which one can derive its mass ratio of 8.1±0.3. The pulsar's mass is therefore ~1.6±0.2 solar masses (assuming a 10% uncertainty in the mass of the companion). This is interesting as, were it to be measured more precisely, it could exclude some models for the behavior of matter (equation of state, EOS) at densities higher than that of the atomic nucleus. It is also important because it allows a calculation of the expected rate of orbital decay due to the emission of quadrupolar gravitational waves (the sort predicted by GR) of $-(3.4\pm0.6)\times10^{-14}$ s/s. This is very important, because asymmetric systems like this (where one of the components has a much larger self-gravitational energy than the other) can be used to constrain alternative theories of gravitation in a way that is impossible for double neutron star systems.

This calculated period derivative, which is ~60 times smaller than that of the Hulse-Taylor binary, suggests that the orbital period should shorten by ~1 microsecond/yr. After 3 years of timing Paulo finds a measured value of $-(4.4\pm2.9)\times10^{-14}$ s/s, or 1.4±0.9 μs/yr. The difference between the predicted and observed values is the smallest ever measured. This in turn introduces the tightest constraints yet on the dipolar gravitational wave emission predicted by alternative theories of gravitation. If we interpret the limit on the emission of gravitational waves as a constant ω in the Brans-Dicke formulation for gravity, we then obtain $\omega > 2300\ (s/0.2)^2$: the previous pulsar limit is $\omega > 1300\ (s/0.2)^2$ (the variable *s* is the change in the binding energy of the neutron star as a function of the gravitational constant G which is not fixed for the Brans-Dicke theory: it is predicted to be in the range 0.1 to 0.3, depending on the unknown equation of state). However, ω is infinite in General Relativity (GR). Hence, Paulo's result, while less restrictive than the $\omega > 40{,}000$ derived from the Cassini spacecraft, is obtained in the strong-field regime, which is the only regime that can constrain all alternative theories of gravitation.

There is considerable potential for improving this test of GR. Continued timing of PSR J1738+0333 over the next 5(10) years should increase the precision of the measured orbital period derivative by a factor of 10(40). If the measured value then conforms to prediction, the uncertainty of the prediction itself (6×10^{-15} s/s) becomes the limiting factor in the precision of this test, as the kinetic effects can be accurately corrected from precise knowledge of the proper motion and parallax. We would then achieve an

Status of the search for the new Arecibo Observatory Director

Robert L. Brown

For the past three months, an Observatory search committee has led the effort to find a new director for the Arecibo Observatory. This committee is broadly representative of the entire Observatory and includes among its members people who have worked for several directors and, as a result of that experience, have been able to provide specific guidance about the abilities that are most desired in the new director.

We employed a professional search firm to help the committee identify potential candidates. A short list of four people was established. Telephone interviews with all four were followed by personal visits of the candidates to the Observatory. On the basis of all this information a prioritized list of the candidates was determined and an offer was made to the candidate at the top of the list.

We expect to conclude the search process and name the new director before the end of this calendar year.

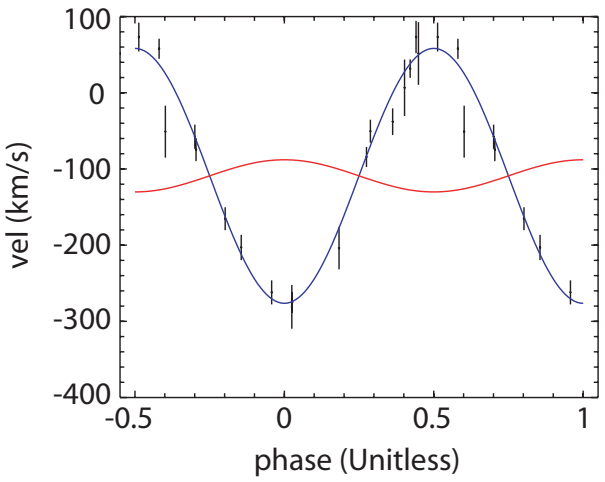


Fig. 5: Measured radial velocities of the white dwarf companion to PSR J1738+0333 as a function of orbital phase, from measurements of the Doppler shift of its spectral lines. The blue curve represents the best fit model. The red curve represents the line-of-sight velocity of the pulsar as a function of orbital phase; the amplitude of this curve is roughly 8 times smaller (Courtesy: Marten van Kerkwijk).

order of magnitude improvement on all previous pulsar limits on dipolar gravitational wave emission, and anticipate a limit of $\omega > 15{,}000\ (s/0.2)^2$. However, simply by improving our knowledge of the mass ratio through averaging more measurements and by measuring the orbital decay more precisely, we should be able to determine the pulsar and companion masses very accurately, which might be very important for the study of the EOS.

P-ALFA survey finds its first millisecond pulsar

The P-ALFA survey has discovered 35 new pulsars to date. These were found using the "quicklook" processing. This program degrades the data by a factor of 16 in time and frequency resolution to allow for almost real-time searching of pulsars. However, by doing this, the reduction process has systematically degraded its sensitivity to fast pulsars and pulsars at high dispersion measures (DMs). The P-ALFA consortium intends to re-reduce all its data while exploiting its full frequency and time resolution.

During the past summer, Patrick Lazarus, an undergraduate student at McGill University, worked with David Champion, Jason Hessels and Vicky Kaspi on P-ALFA data reduction. They worked on a series of python scripts developed to automatically process the P-ALFA data with full resolution using Scott Ransom's (NRAO) PRESTO routines. These scripts also load the results into a database, to be hosted by the Cornell Theory Center. Finally, Patrick developed a viewer that connects to the database and allows candidates to be browsed and flagged. As part of the testing of the scripts and the pipeline, several disks worth of data have been processed, and the pulsars seen in the "quicklook" processing were again readily detected. In addition, one new pulsar has been discovered, PSR J1903+03. It was detected with a S/N of 24.2, a spin period of 2.15 ms, and a DM of ~300 cm^{-3} pc. From the confirmation and timing observations made to date, it is clear that this millisecond pulsar (MSP) is in a binary system with an orbital period of several hundred days.

Outside globular clusters this is the 5th fastest spinning pulsar known: when globular cluster pulsars are also included, it is the 11th. This object has the highest DM known for any MSP. This is extremely important — it confirms the fact that the P-ALFA survey can see MSPs deep into the disk of the Galaxy, far from the Solar System, where the vast majority of MSPs await discovery. MSPs, particularly those in binary systems, are important for many areas of astrophysics (see, for instance, the previous article on PSR J1738+0333).

Using models of the electron distribution of the Galaxy and the pulsar population, Duncan Lorimer (West Virginia Univ.) predicts that the present observing system (i.e. 100 MHz bandwidth, 268-s integrations) will detect 120 MSPs in the area $32 < l < 77$ and $|b| < 5$. There are currently only 9 known MSPs in this area that are not in globular clusters. This prediction has to be taken with caution, because the effects of scattering are very important in this case, and they are to a large extent unknown. Nevertheless, they agree with the predictions made by Paulo Freire at the 205th AAS meeting in Washington D.C. (*http://www2.naic.edu/alfa/pulsar/AAS205.76.06.ppt*). He used pulsar DM distributions to show that, if the Parkes Multi-beam survey had the same time (64 μs) and spectral (0.39 MHz) resolution of the P-ALFA survey, it would have detected between 40 and 60 MSPs in the portion of the Arecibo sky it surveyed. These would probably have a flat distribution of DMs from 0 to 400 cm^{-3} pc. In reality, it detected four MSPs, all with DMs below 40 cm^{-3} pc. Pulsars at higher DMs were lost because of dispersive smearing across its 3-MHz filters. Furthermore, because of the relatively small dwell times, the P-ALFA surveys have unprecedented sensitivity to MSPs in binary systems with short orbital periods.

Discovering 120 new MSPs would triple the number of known MSPs in the disk of the Galaxy. Tripling the bandwidth of the system, a feat to be achieved with the new P-ALFA spectrometers, will definitely increase the number of discoveries. Will this prediction be verified? Patrick Lazarus found 1 new MSP after searching 200 pointings (about 1400 beams). This represents about 4 square degrees; the full survey is to cover an area of about 440 square degrees. So we may find a large number of MSPs after all.

The HI sky at 3.4 arcmin resolution: Crossing a threshold

Carl Heiles (Univ. of Berkeley)

LDS versus GALFA

The current 21-cm line survey standard is the Leiden-Dwingeloo Survey (LDS). With angular resolution 36 arcmin, the LDS beam area is about 100 times larger than Arecibo's. How do LDS and GALFA maps compare? We use the largest individual region that we have

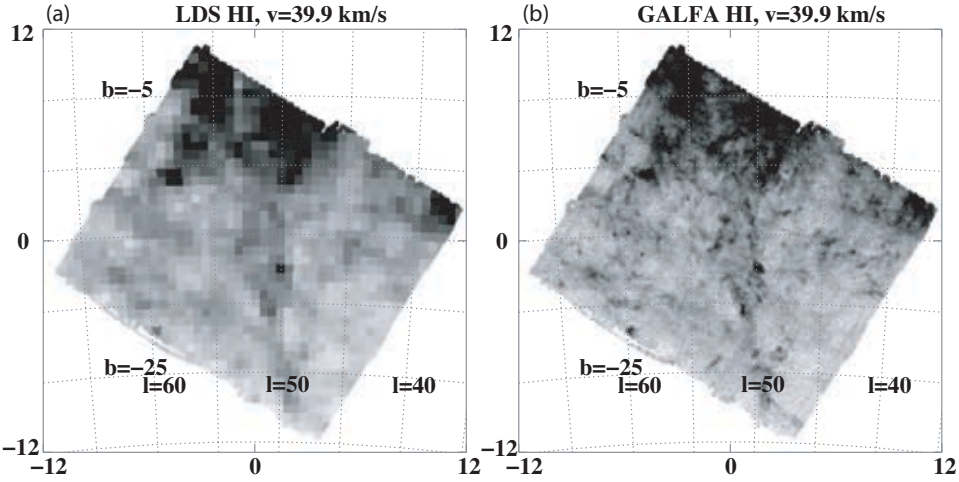


Fig. 6: Comparing LDS and GALFA maps at v= 39.9 km s^{-1}. (Courtesy: Carl Heiles)

observed, a 15.4°×17.4° region centered near (*l,b*)=(53°,15°). We needed to make a quick map, so we used the boustrophedonic mapping mode to cover the 268° area at about 13 deg^2 per hour. Apart from being faster and intrinsically less sensitive, this mode has no "crossing points" so it is more stripey than maps made with our usual basketweave mode. Nevertheless, it's pretty good!

Figure 6 compares the LDS and GALFA maps at v=39.9 km s^{-1}; the maps are stereographic projections with exactly the same stretch and contrast. The underappreciated stereographic projection has two valuable properties. First, it is one of the very few projections that is *conformal*, which means that shapes are locally preserved. Second, it is the only projection for which both small and great circles always appear as circles, which is important in ISM studies because many objects (like supershells) are intrinsically circular, or approximately so.

The difference in detail between the GALFA and LDS maps is obvious and familiar to those of us who wear strong glasses. Maps at other velocities give the same impression: the detail afforded by GALFA's resolution makes the difference between a blobby mush and the clarity required to discern what's happening. *We cross a threshold at which GALFA resolves the HI structure into clearly-defined corpuscles and filaments*.

At 39.9 km s^{-1}, Galactic rotation puts the distance at ~2.9 kpc. The HI structure breaks up into discrete clouds, some of which are connected by weaker filaments; at the center of the map these clouds lie 750 pc off of the Galactic plane. These are the counterparts of Lockman's (2002 ApJ 580, L47) discrete halo clouds — we see dozens, and are looking forward to analyzing them statistically!

High velocity clouds and their interaction with the halo gas at high |z|

High-Velocity Clouds (HVCs) have been around for decades, but their origins and properties remain elusive. Most people think they fall from the Galactic halo and originate from either satellite debris or condensations in the hot Galactic halo medium. Understanding HVCs is among the core scientific drivers for TOGS (Turn-On GALFA Spectrometer Survey) and TOGS2. GALFA's sensitivity and resolution provided a surprising insight into such questions by revealing details of a Very-High-Velocity Cloud (VHVC) and its gas dynamics. In the GALFA group's second published paper, Peek et al. (2006, astro-ph/0610429)[1], examined a small VHVC cloud complex in detail and showed that small, diffuse clouds were torn from the largest cloud by viscous drag from the gaseous Galactic halo.

Figure 7 covers V_{lsr}=–300 to –450 km s^{-1} and exhibits a VHVC complex that is morphologically similar to that of Peek et al. (2006). In particular, there is one fastest-moving, massive cloud with peak column density ~8×10^{19} cm^{-1} with cleanly sculpted edges that contains an unresolved core. It is accompanied by a broad distribution of slower VHVC "chaff" with rougher edges that are scattered into loose groups. As with the Peek et al. complex, this morphology suggests an interaction between the massive cloud and the ambient Galactic halo gas. We anticipate that this morphology is common; if so, it is a strong constraint on the gas dynamics at work in the halo.

The crosses in Figure 7 indicate previously identified clouds in this cloud complex. We have detected at least 20 new VHVCs, many of which reside in an archipelago in the lower right of the image. We detect clouds having column densities less than half, and total fluxes 5 to 10 times lower, than previously detected in this region; our minimum detectable column density is 3.4×10^{17} cm^{-2} per pixel. This opens up new territory for small and low-brightness HVCs and, as explained by Peek et al., their physical interpretation.

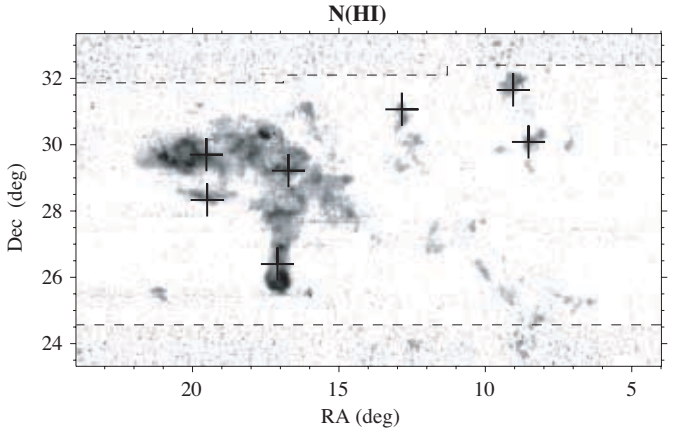


Fig. 7: A VHVC Complex (–300 to –450 km s^{-1}). (Courtesy: Carl Heiles)

[1]Josh Goldston is now known as Josh Peek in anticipation of his formal name change upon his impending marriage to Katie Peek. Unlike most of us, Josh is not a procrastinator and prefers to produce confusion now instead of later in his career.

The technical details of this map are worth a few comments because it illustrates the quality of different data products, and in particular our final TOGS data products. The data consist of (1) TOGS data covering 1.6 deg^2 per hour and (2) GALFA basketweave data covering covering 8.5 deg^2 per hour. The central portion of the image between the dashed lines, where the noise is low, is covered by both datasets. These observing modes have no azimuth rotation and their combination produces lots of crossing points, so the striping is minimal and, in the middle portion, the integration time is high. In this middle region, the overall quality is similar to what we will obtain when combining TOGS and TOGS2 data. This particular map has rms noise 0.07 K in each 2′×2′×1.5 km s^{-1} voxel.

AGES survey finds new galaxies in the NGC 7332 group

Robert Minchin

The Arecibo Galaxy Environment Survey (AGES) recently covered five square degrees around the NGC 7332/7339 galaxy pair. The survey detected the large spiral galaxy, NGC 7339 along with two previously unknown dwarf galaxies in the group (AGES J2238+2352 and AGES J2236+2343). The lenticular galaxy NGC 7332 and the dwarf spheroidal galaxy KKR 73 were not detected, but upper limits can be set on their neutral hydrogen masses. The survey also found at least twenty galaxies in the volume behind the group, out to a redshift of ~17,000 km/s. With the commissioning of the new E-ALFA correlator early next year, it is expected that AGES will find more of the distant sources in future fields.

Arecibo Survey of HI Emission from Disk Galaxies at Intermediate Redshift

Barbara Catinella

The evolution of the Tully-Fisher relation (TFR) over cosmic time is much debated. If galaxies were more luminous in the past, we should observe an offset in the TFR derived independently at high and low redshift z (i.e., a change of its zero point). However, studies based on optical spectroscopy (e.g. Flores et al. 2006, AAP, 455, 107) have reached conflicting conclusions. Results vary from substantial luminosity evolution (in excess of one magnitude with respect to the z=0 TFR) even at modest z, to no significant change up to $z \sim 1$. Evidence for evolution of the TFR, or lack thereof, remains inconclusive.

Barbara Catinella (NAIC-Arecibo) and collaborators at Cornell (M.P. Haynes and R. Giovanelli) and the University of Pittsburgh (J.P. Gardner and A.J. Connolly) have undertaken a targeted survey with the 305-m Arecibo radio telescope to detect HI-line emission from disk galaxies at z>0.16 (i.e. at frequencies below 1220 MHz). Among other applications, this dataset will be used to study the evolution of the TFR at intermediate redshifts. Compared to optical widths, HI measurements sample a larger fraction of the disks, where the rotation curves are typically flat, and are not affected by slit smearing, by misalignment, or by aperture effects. Thus, in contrast to studies based on optical spectroscopy, radio observations allow a direct, technique-independent comparison with the local TFR.

Naturally, detection of 21 cm emission from galaxies at z>0.1 is difficult: the signals are weak, accurate redshifts of the targets need to be known in advance, the presence of radio frequency interference restricts the accessible redshift windows, and the larger number of galaxies sampled by the antenna beam at higher redshift leads to increased confusion problems. In fact, these observations have only recently become feasible thanks to technical improvements at

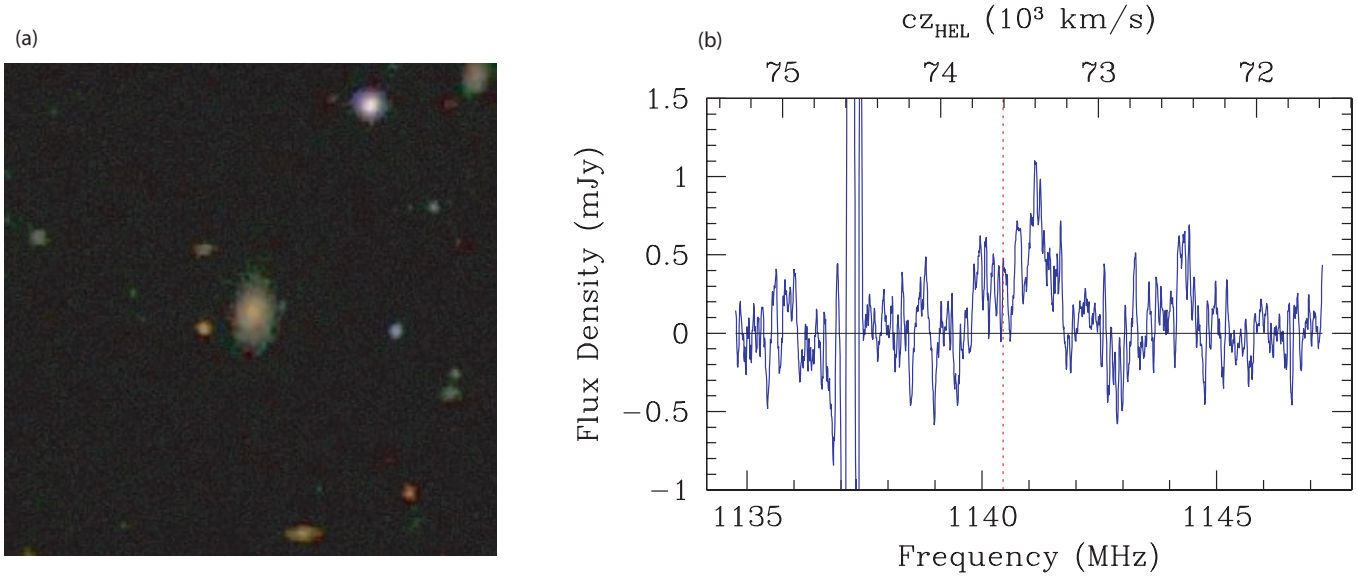


Fig. 8: (Left) SDSS image of the galaxy J142735.69+033434.2 (from the SDSS Sky Server web page at http://cas.sdss.org/dr5/en/*); the size of the field shown is 1.3′. (Right) Calibrated, smoothed HI spectrum obtained at Arecibo. The vertical red line indicates the frequency corresponding to the SDSS redshift (z=0.2455). The total on-source integration time is 176 minutes. This represents the highest redshift detection of HI emission from a normal galaxy to date.*

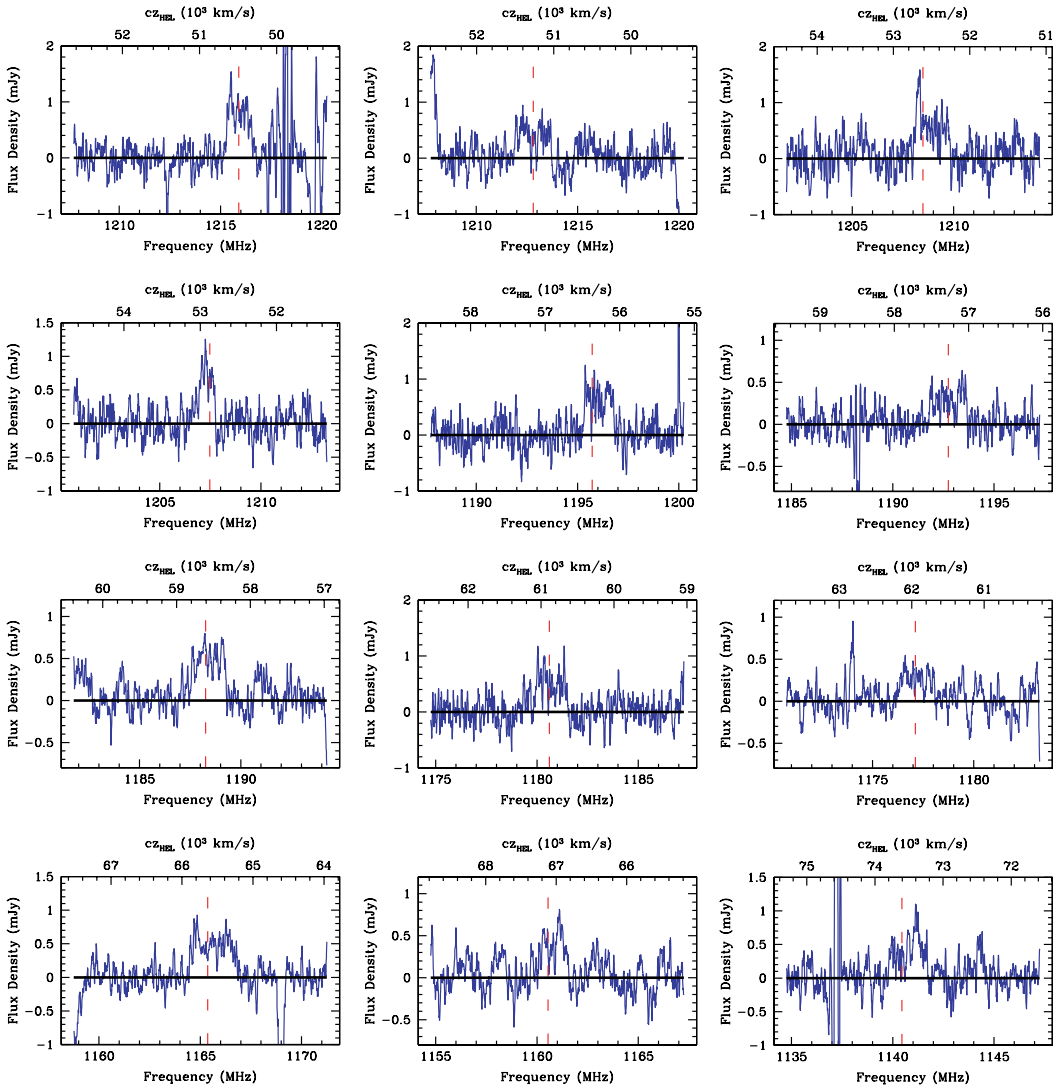


Fig. 9: Calibrated, smoothed HI spectra, ordered by increasing redshift z (top-left to bottom-right), of 12 of 20 galaxies detected at Arecibo. The red lines indicated the frequencies corresponding to the SDSS redshifts of the targets. (Courtesy: Barbara Catinella)

Arecibo (Gregorian upgrade, a new L-wide receiver in 2003, with access to frequencies down to 1.12 GHz), and to the availability of the Sloan Digital Sky Survey[2].

The group's targets for HI spectroscopy at Arecibo were extracted from the SDSS database on the basis of their redshift, optical emission-line strength, inclination, disk morphology, and relative isolation (to minimize confusion within the beam). HI profiles of adequate quality for velocity-width measurements were obtained for 20 galaxies with $0.17 \leq z \leq 0.25$, with average total integration times between 2 and 6 hours. Figure 8 shows the highest redshift detection of HI emission from a normal galaxy to date (z=0.2455). The HI spectra of 12 of the 20 detections are presented in Figure 9. Analysis of the selection biases of this sample, necessary to establish if there is a change of the TFR zero point based on this dataset, is in progress.

[2] Funding for the Sloan Digital Sky Survey (SDSS) and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the U.S. Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web site at *http://www.sdss.org/*, hosts its database, which provides high quality photometric images, accurate redshifts, and line-emission information for a large number of galaxies.

HI and OH spectral line studies of the ULIRG IRAS 23327+2913:

María Ximena Fernández, Emmanual Momjian, Tapasi Ghosh, and Chris Salter

As part of the NAIC summer research program for undergraduates, under the supervision of Tapasi Ghosh, Emmanuel Momjian, and Chris Salter (NAIC), María Ximena Fernández (Vassar and Dartmouth) worked on a project that focused on 85 galaxies from the 2 Jy IRAS-NVSS Sample with far-IR luminosities >109 L_{sun}. This subsample contained objects that lay in the R.A. (B1950) range 20h–00h. The project resulted in several new HI and OH detections, both in emission and absorption. Among the most interesting of these was the discovery of HI and OH-megamaser emission from the Ultra-Luminous Infrared Galaxy (ULIRG) IRAS 23327+2913 ($L_{IR} = 1.15 \times 10^{12}\ L_{sun}$; z~0.107). This ULIRG is a system of two galaxies separated by about 20 kpc at the beginning stages of interaction (Dinh-Vi-Trung et al. 2001, ApJ, 556, 141), see Figure 10. The northern galaxy is disturbed, while the southern one is a normal spiral with a very thick bar structure. Dinh-Vi-Trung et al. report the detection of CO(1-0) only from the apparently undisturbed southern component.

Follow-up observations of this ULIRG were made by the group in October 2006. Figure 11 shows the HI spectrum from IRAS 23327+2913. The central velocity of the dominant spectral feature indicates that this HI emission is associated with the southern component, while the weaker "shoulder" at ~32,000 km/s corresponds to the redshift of the northern component. Figure 12 shows the OH megamaser spectrum, with the dominant feature from the 1667 MHz

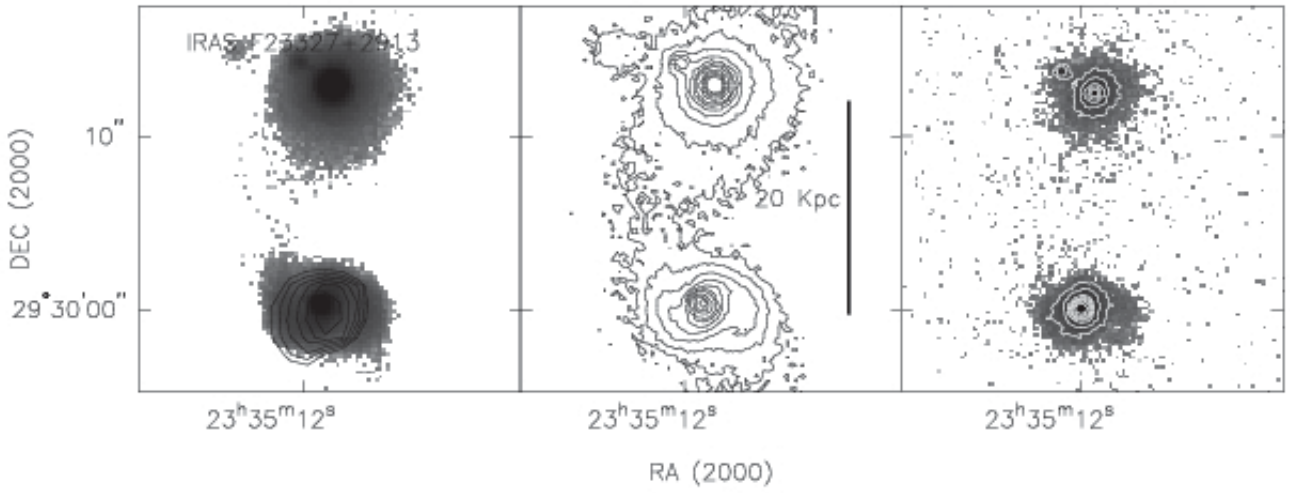


Fig. 10: Left frame: the contour plots of the CO(1-0) emission from IRAS 23327+2913 overlaid on the R-band image. Central frame: contour plot of the same R-band image at the same scale. Right frame: K-band image (Dinh-Vi-Trung et al. 2001).

transition: this has a broad, probably double-peaked, structure. The 1665 MHz transition is very tentatively detected and corresponds to the feature at ~32,700 km/s. The central velocity of the OH 1667 MHz line suggests that the megamaser emission from the system is more likely to be associated with the southern component. No megamaser emission is detected at the velocity corresponding to the northern, disturbed, component of this ULIRG. The results presented here, combined with the CO(1-0) observations of Dinh-Vi-Trung et al. (2001), show that IRAS 23327+2913 does not fit into the commonly accepted scenario for ULIRGs of a merger between two disk galaxies, where the two progenitors of the merger are strongly disturbed during the interacting phase, with the final product of the merger resembling an elliptical galaxy (Mihos & Hernquist 1996, ApJ, 464, 641).

Extragalactic Zeeman Detections in OH Megamasers

Tim Robishaw, Carl Heiles, and Eliot Quataert (Berkeley) spent 10 nights in February observing 1667 MHz OH megamaser (OHM) emission in 6 ULIRGs. They discovered 16 Gaussian components with significant Zeeman splitting in 4 of the 6 galaxies yielding line-of-sight field strengths between 0.3–18 mG. The top left panel of Figure 13 shows the Stokes *I* profile for Arp 220, the archetypal ULIRG; the profile is decomposed into 18 Gaussian components, an amazing 7 of which show significant Zeeman-splitting detections in the Stokes *V* profile in the bottom left panel. Their largest detected field, with a line-of-sight magnitude of 18 mG, is seen in one of only three known OH gigamasers, at a *z* of 0.217 (right panels of Figure 13).

The extraordinarily high gas densities and energy densities in ULIRGs make them natural locations to expect very

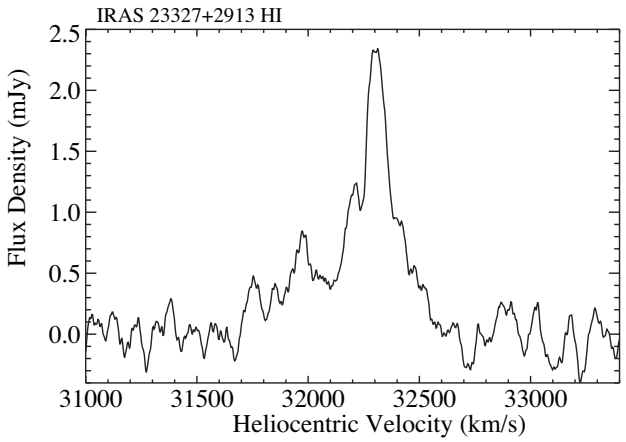


Fig. 11: Spectrum of the HI 21-cm line emission from the ULIRG IRAS 23327+2913. The velocity resolution is 29 km/s. (Courtesy: M. X. Fernández, E. Momjian, T. Ghosh, & C. Salter)

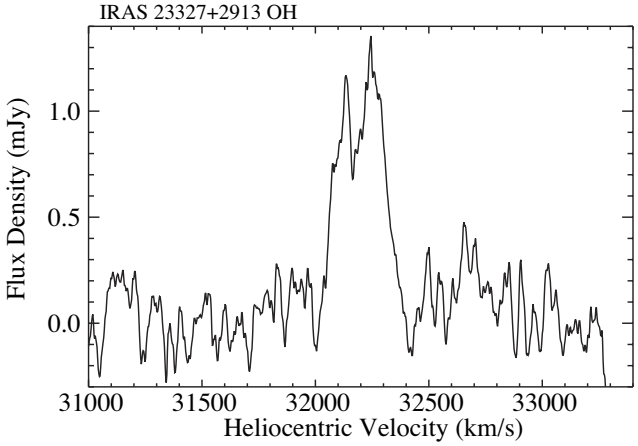


Fig. 12: Spectrum of the OH 18-cm megamaser emission from IRAS 23327+2913. The broad, probably double-peaked, dominant spectral feature corresponds to the 1667 MHz transition from the southern component of the system. The 1665 MHz line is tentatively detected and corresponds to the spectral feature at ~32,700 km/s. The velocity resolution is 27 km/s. (Courtesy: M. X. Fernández, E. Momjian, T. Ghosh, & C. Salter)

strong magnetic fields. Much of the radio emission in ULIRGs is resolved on scales ~100 pc with VLA observations (Condon et al. 1991, ApJ, 378, p. 65). High-resolution observations of Arp 220 (Rovilos et al. 2003, MNRAS, 342, p. 373) show that the OHMs arise in this region as well. Minimum energy and equipartition estimates imply fields of strength 1–10 mG. This would suggest that ULIRGs are a natural place to look for fields, but the ULIRG-OHM connection was only established recently by Jeremy Darling (Univ. of Colorado) using Arecibo! Extragalactic H_2O masers have been unsuccessfully probed for Zeeman splitting, but the splitting coefficient of OH is 1000 times greater than H_2O! A single detection of extragalactic Zeeman splitting had been made prior to these observations, but this was in absorption of HI against a background source (Sarma et al. 2005, AJ, 130, p. 2566). The new Arecibo results increase the sample of extragalactic Zeeman detections by 16-fold and demonstrate that OHMs are a sensitive extragalactic magnetometer and a promising new tool for probing the astrophysics of distant galaxies.

Tim, Carl and Eliot plan to extend their survey using Arecibo and the GBT and to make high-sensitivity VLBA observations of Arp 220 with Anuj Sarma (DePaul Univ.) to directly measure the Zeeman splitting in each masing region.

HI from Black-hole Host Galaxies

Jeremy Darling (U. Colorado)

In an ongoing project, Luis Ho (Carnegie Observatories), Jeremy Darling (U. Colorado), and Jenny Greene (Princeton U.) have been conducting the first systematic neutral hydrogen (HI) survey of active galactic nuclei (AGN) host galaxies whose black hole (BH) masses and accretion rates are known. This puts important constraints on a number of properties relevant to understanding the relationship between BHs and their host galaxies. The survey has detected HI gas in a high fraction of objects, and places useful upper limits on the non-detections.

Preliminary results demonstrate that optically selected Type 1 AGN host galaxies are *gas-rich*. The HI content of these galaxies, normalized to the optical luminosity of the host galaxy, is *normal*, not gas-poor. This result severely challenges recent models of AGN feedback that suggest that when the AGN is optically revealed, it should have blown away a significant fraction of the cold ISM in the host galaxy.

The HI line widths give us key constraints on the dynamical properties of the galaxies. From the inclination-corrected rotation widths, the host galaxy optical luminosity can be derived via the Tully-Fisher relation. From the line widths and the optical sizes, a rough estimate of the total dynamical mass of the host galaxy can be obtained. Ho, Darling, & Greene find that the dynamical mass is correlated with the BH mass, providing a new empirical correlation to study the relationship between BH mass and host galaxy properties, akin to the well-known correlations between BH mass and bulge stellar velocity dispersion or

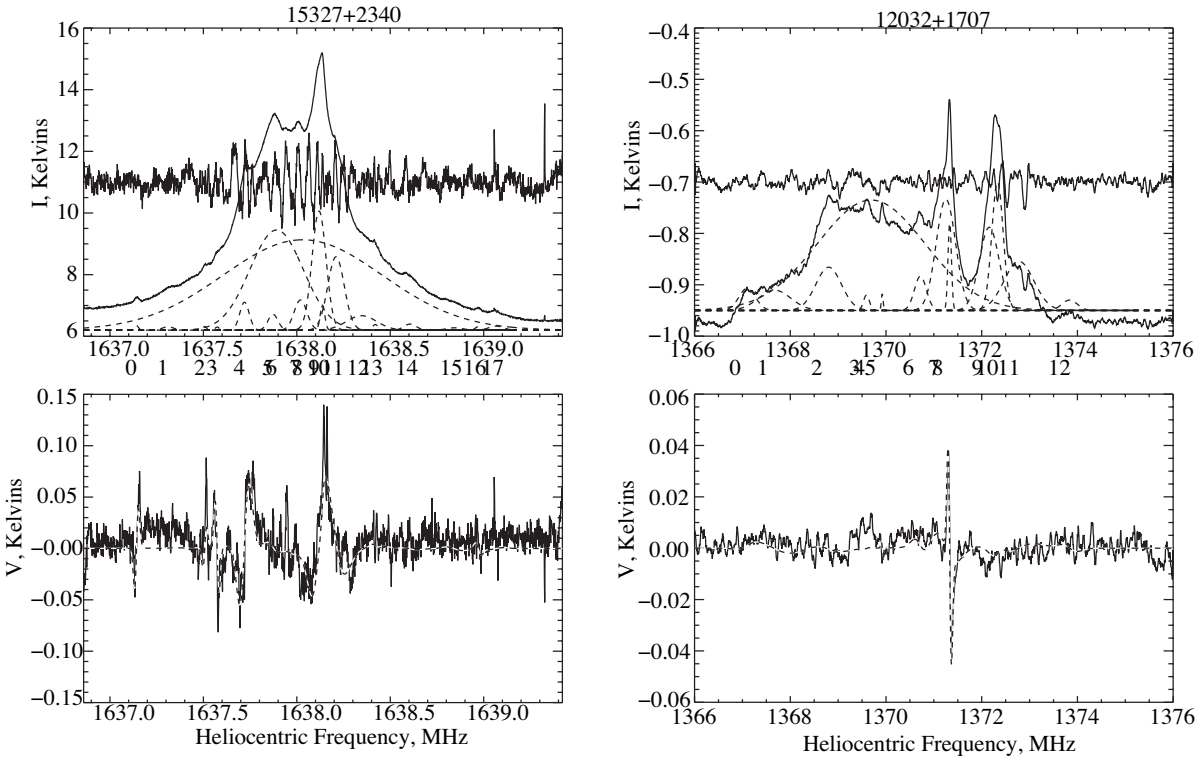


Fig. 13: (Left) OHM emission from Arp 220. The top plot shows Stokes I *with components from a Gaussian decomposition as dashed lines. The solid line in the center of the vertical axis shows an inflated view of the Stokes* I *residuals. The bottom plot shows Stokes* V *with the best fit plotted as a dashed line. The integers shown between the top and bottom plots label the Gaussian components. (Right) OHM emission from the gigamaser IRAS F12032+1707. (Courtesy: Jeremy Darling)*

luminosity. Furthermore, the BH mass is correlated with the maximal rotation velocity inferred from the HI line width, albeit with significantly more scatter than has been claimed in the literature.

These new insights into the connection between galaxies and AGNs challenge current ideas of AGN feedback and the co-evolution of galaxies with their resident massive black holes. The survey continues at Arecibo.

OH/IR Star Mass Loss

Murray Lewis

An important gap in our understanding of the evolution of stars of modest mass, like our Sun, is the absence of an ab initio understanding of mass-loss at their asymptotic giant branch (AGB) phase. We have no accepted theoretical constraints on the rate or on the evolution of the mass-loss rate (*dM/dt*) from AGB stars, and so work with ad hoc relations adapted to inferred rates of *dM/dt*. This has been one reason for studying OH/IR stars. Recent work by Murray Lewis (NAIC) shows that the problem has now become more complex, as when NIR and OH observations are combined with modelling results, they suggest that the *dM/dt* of OH/IR stars is strongly modulated on a much longer time-scale than the pulsational periods of the stars.

Previous pointers to this occur in CO mapping of the carbon star IRC+10216, and in Hubble images of the Cat's Eye and Egg nebulae, which exhibit a sequence of concentric rings underlying all of their other structure. The NIR colors of OH/IR stars define a tight linear locus extending over five orders of magnitude in a 2MASS two-color plot. Lewis (AJ 132, 489) models this using the radiative transfer code DUSTY, and finds that the NIR colors of a set of models from a range of constant *dM/dt* exactly trace the locus provided one uses a cold-silicate dust opacity, and starts with a stellar spectral energy distribution (SED) matching its bluest colors. It is then easy to model the detached shell that grows under the normal expansion of a thick, dust-shell model when *dM/dt* is set to zero: these models also follow the locus. One byproduct is the association of a chronology with their NIR colors, which shows that it takes < 100 yr for a shell to traverse the entire color locus. And much the most rapid color evolution naturally occurs while dust is departing from the vicinity of the dust-formation radius, where it has its maximum volume density. This is the key finding.

The first evidence for a general deep modulation of *dM/dt* is from massive OH/IR stars and is based on combining modelling results with the distribution of NIR colors of cohorts of stars selected on the basis of their MIR colors: 80% of those with the reddest MIR colors fall near the middle of the locus rather than at its red end, where they would occur if their shells were generated by a constant *dM/dt* (Lewis et al. AJ 127, 501). This is only explicable for thermally pulsing OH/IR stars if these stars have a strongly modulated *dM/dt*.

The second line of evidence comes from modelling the rapid loss of 1612 MHz masers from low-mass OH/IR stars. Four of those in the Arecibo sky have completely lost their 1612 MHz masers in the last 20 yr, and one, from the 472 day LPV IRAS 19479+2111, recently turned *on* again. Gray, Howe and Lewis (MNRAS 364, 783) modelled the speed of the decline in maser intensity, by constructing the set of time-dependent OH column densities arising when *dM/dt* goes abruptly to zero after being constant for 300 yr, together with a time-dependent radiative transfer model for the generation of the masers. These models match the decline of the masers, and show they are pumped through the 53 μm transitions. These are sensitive to the reprocessing of the stellar SED by the innermost dust shell, which is vacated first when $dM/dt = 0$. This leads to a weakening of the pump and to the loss of the maser. The rapid switching *on* and *off* of these masers is thus shown to be an artifact of a strongly modulated *dM/dt* from an OH/IR star that had a modest progenitor mass.

With both massive and low-mass stars exhibiting strongly modulated mass-loss rates, stellar structure calculations are doomed to rely for some time to come on an average *dM/dt*, and to infer this from observations. This finding also helps us to interpret the NIR color–magnitude plots of carbon stars from Spitzer observations of Local Group galaxies, which show lightly populated "echo sequences" tracking the fundamental and first overtone sequences.

An Update on H_2CO 6-cm Emission

Esteban Araya & Peter Hofner (New Mexico Tech & NRAO)

Esteban Araya and Peter Hofner have been observing the 6-cm transition of formaldehyde (H_2CO), which is detected ubiquitously in *absorption* toward molecular clouds in our Galaxy. There are two reasons for this: 1. the energy level of the lower state transition is just 15.2 K above ground, so in the conditions typically existing within molecular clouds they can easily absorb 6-cm radiation from background continuum sources such as HII regions (e.g. Araya et al. 2002, ApJS, 138, 63); and 2. the lower energy level of the transition can be overpopulated by collisions with H_2 molecules (e.g. Thaddeus 1972, ApJ, 173, 317), which effectively lowers the excitation temperature of the transition to less than 3 K, and thus allows absorption against the Cosmic Microwave Background. However, H_2CO 6-cm *emission* is a very much less common phenomenon. Prior to the ongoing work of Araya et al. just three regions in the Galaxy were known to harbor Galactic H_2CO 6-cm maser emission, and thermal H_2CO 6-cm emission had been reported toward the Orion BN/KL region and (tentatively) toward L1551 (Duncan et al. 1987, MNRAS, 224, 721). However Araya et al. (2004, ApJS, 154, 541) were able to confirm megamaser emission towards three extragalactic objects using Arecibo.

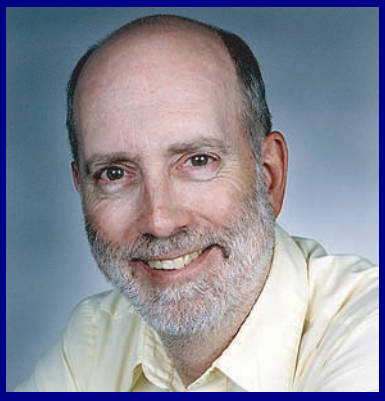
Araya et al. (2006, AJ, 132, 1851) recently used Arecibo to check the tentative detection of thermal H_2CO 6-cm emission by Duncan et al. (1987)

Jennifer Ruiz – (Temp)
Purchasing Clerk
Arecibo

José M. Rivera – (Temp)
Laborer
Arecibo

Kelmer Milian – (Temp)
Laborer
Arecibo

Eric López – (Temp)
Laborer
Arecibo



Kurt Kabelac – (32 years)
Technical Services Supervisor
Ithaca

David Overbaugh – (25 years)
Equipment Technician
Ithaca

Staff Layoffs

The Editors

As mentioned in the article on page 6 regarding NAIC's Implementation Plan of the Senior Review recommendations, staff layoffs have taken place in order to work within the smaller budget. The photos in these pages are *some* of the people who have lost their jobs as a result, along with their job titles and years of service. Photos were only used with permission of the former employee. In addition to those shown, 5 ½ academic positions in the astronomy department have also been eliminated, which will result in the departures of several scientific and engineering staff members over the course of the next 6–18 months.

Victor Iguina – (42 years)
Electronic Maintenance Engineer
Arecibo

Jorge L. Padilla – (40 years)
Draftsman
Arecibo

José Rosa – (35 years)
Electronic Technician
Arecibo

Manuel Morales – (16 years)
Computer Maintenance Engineer
Arecibo

Myrna Gerena – (14 years)
HR & Payroll Assistant
Arecibo

José Capó – (10 years)
Electronic Technician
Arecibo

Carlos Lebrón – (4 years)
Guard
Arecibo

toward L1551. They obtained an 8′ × 8′ full-beam spaced map of the H_2CO 6-cm distribution in the region, but found no emission. Hence the Orion BN/KL region is currently the only known *thermal* H_2CO 6-cm emission region in our Galaxy. These observations of L1551 also show that the H_2CO 6-cm line traces (in absorption) not only the quiescent molecular material but also gas kinematic products of the star formation process (see Figure 14).

The successful Arecibo survey for H_2CO 6-cm *masers* by Araya et al. (2004, ApJS, 154, 579), during which they discovered the fourth Galactic example of this rare type of maser in IRAS 18566+0408, led them to extend their search to regions outside the Arecibo sky using the VLA and the Green Bank Telescope (GBT). This resulted in the discovery of maser emission in G23.71–0.20 (Araya et al. 2006a), see Figure 15. With the newly detected maser regions a quite interesting picture of H_2CO maser emission is strengthened: these masers seem to be exclusively associated with very young phases of massive star formation such as hot molecular cores and hypercompact HII regions. Hence, the rarity of these masers may be a consequence of specific physical conditions that only occur during the process of massive star formation (e.g., Mehringer et al. 1995, ApJ, 452, 304).

The maser in IRAS 18566+0408 and its variability are particularly interesting because the maser coincides with a circumstellar disk candidate (Zhang, *personal communication*), so the maser could be tracing molecular material in a disk around a young massive stellar object. High angular resolution observations of the maser would be ideal to image the maser spots, measure their brightness temperatures for modeling, and establish the position angle of the spots with respect to the putative disk. However, during the quiescent phase the maser components are too weak for VLBA observations. Thus, a long term monitoring program of the maser in IRAS 18566+0408 is being conducted with Arecibo to search for new maser bursts that could allow simultaneous VLBA observations. This program started in May 2006. While a new maser burst has not been detected yet, the data does suggest a slow, monotonic decrease of the peak flux density. The multi-epoch observations of the maser in IRAS 18566+0408 are giving further observational constraints on the maser properties, and are offering new clues to the puzzle of astrophysical H_2CO 6-cm masers.

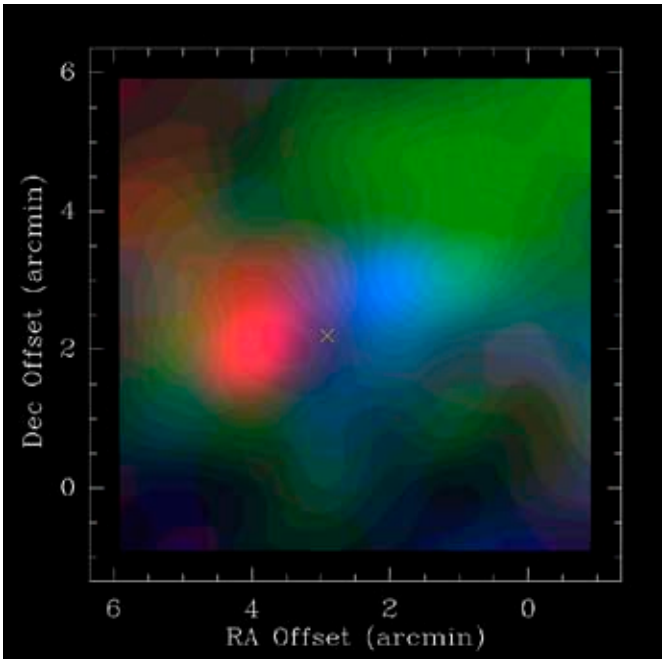


Fig. 14: Integrated-intensity map of the H_2CO 6-cm absorption in L1551. The red, green, and blue contours show the velocity integrated intensity map of the red wings, line core, and blue wings of the H_2CO line profiles, respectively. The position of the young low mass stellar object IRS5 is shown with a "×". The H_2CO absorption traces not only the quiescent molecular material (green) but also the molecular outflow in the region. (Courtesy: Peter Hofner)

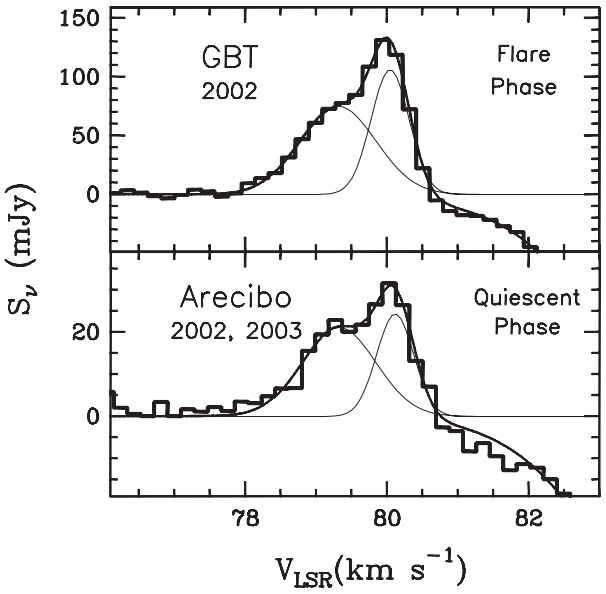


Figure 15: H_2CO 6-cm maser profile during the flare (upper panel) and the quiescent phase (lower panel). Each spectrum is a combination of several observations made during each phase. Note that neither the peak velocity or line width changed during the flare phase with respect to the quiescent phase (Courtesy: Peter Hofner)

The New SETI Sky Survey with ALFA

A powerful new commensal sky survey using the multibeam ALFA receiver has just been started by the SETI group at Berkeley. Dan Werthimer began these observations in June 2006 after he installed the first half of his new multibeam SETI instrumentation at the telescope. He plans to conduct observations for several years, by piggybacking on the ALFA sky surveys carried out by the pulsar, extragalactic, and galactic consortia. So every ALFA survey is now commensal with at least one undemanding partner.

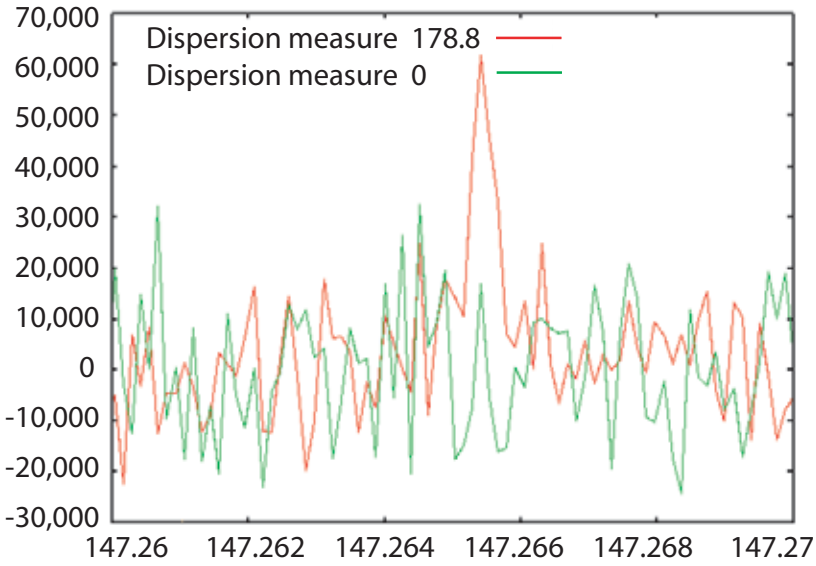
Although the Berkeley group has continuously conducted commensal SETI observations at Arecibo via carriage house one for over 10 years, the new ALFA-based survey enormously improves survey efficiency and sensitivity, with its larger bandwidth, much better system temperature, and systematic sky coverage.

A high-school student pulsar program

Melissa Ilardo

After reviewing data on currently known giant-pulse emitting pulsars, I noticed that many of the known pulsars in this set, including B0531+21, B1937+21, B0540+69, and B1821–24, had extremely high rotational energy loss rates (Ė). Because of this, I selected three pulsars with Ė values in the top 5% of the distribution from all pulsars to search for giant pulses. My chosen pulsars were J1913+1011, B1951+32, and J1930+1852, for which, prior to my research, there had been no specific searches for giant pulses. I was granted 6 hours of telescope time at the Arecibo Observatory for this project, and spent two hours observing each of the three pulsars. I was unable to definitively identify giant pulses in any of the three, though I observed "large" pulses in J1913+1011. The largest pulse I observed in this pulsar had a strength of approximately 13 times the average pulse intensity. Standard definitions of "giant" pulses usually require at least 20 times the average strength. I believe that PSR J1913+1011 deserves further study as a result of the large pulses I observed from it.

I proposed an observing program and visited the Observatory in June to carry it out with the help of Paulo Freire. I'm 17 years old, I study at the North Carolina School of Science and Mathematics, which is a selective residential high school for students from the state of NC interested in science and math (*http://www.ncssm.edu*). My school is in Durham NC, but my home is in Charlotte NC. I enjoy playing the violin, and I have been playing since I was 4 years old. I also enjoy traveling, especially to the Caribbean, where I like to SCUBA dive. This summer, in addition to coming to Arecibo, I also spent four weeks studying at Cambridge University in England.



A "large" pulse from J1913+1011 in an intensity vs. time plot.

Dan plans to run two SETI instruments in parallel: The SETI@home multibeam data recorder, which is running now, records time domain baseband data from ALFA's 7 beams and 2 polarizations. Although SETI@home's bandwidth is relatively small, the subsequent data analysis by SETI@home volunteers is powerful, covering 13 octaves of bandwidth and time scale, using coherent integration to search for a variety of signal types, including signals with drift rates up to 50 Hz per second. Indeed SETI@home is Earth's most powerful supercomputer, averaging 200 Teraflops.

The SERENDIP 5 multibeam spectrometer that is currently being assembled at Berkeley will replace the SERENDIP 4 single-beam, 168 million channel spectrometer in the summer of 2007. SERENDIP 5 will analyze ALFA's full 300 MHz band on seven beams and two polarizations, but will not be as sensitive as SETI@home.

NAIC-NRAO School on Single Dish Radio Astronomy 2007

The Green Bank (NRAO) and Arecibo (NAIC) observatories are organizing the fourth NAIC-NRAO School on Single Dish Radio Astronomy. This summer school will take place from 8-15 July 2007 at the Green Bank Observatory, West Virginia. It is mainly intended for graduate students, postdocs, and experts in other fields of astronomy who would like to explore emerging techniques and applications of single-dish radio astronomy. Details of how to register for the school, along with a preliminary scientific program, will be made publicly available shortly through the Arecibo and Green Bank websites (*http://www.naic.edu* and *http://www.gb.nrao.edu*).

Solar System Astronomy

Mike Nolan, Ellen Howell and Amy Lovell

Comet 73P/Schwassmann-Wachmann 3 made a close approach to the Earth in May 2006, and presented an excellent observing opportunity: The best since C/Iras-Araki-Alcock 1983. The comet has split into several fragments, and Mike Nolan and John Harmon (NAIC) obtained radar images of two of the nucleus fragments and the first-ever radar "image" of the coma of fragment "B". Ellen Howell (NAIC) obtained spatially-resolved OH spectra to determine water outflow flux and velocity.

Radar observations of asteroid (99942) Apophis in May by Lance Benner (JPL) and Mike Nolan reduced the uncertainty in its orbit, reducing the predicted probability of a collision with the Earth in 2036 by about a factor of two, to about 1 in 40,000.

A radar-derived shape model of the near-Earth asteroid binary system 1999 KW4 appears in two companion articles to appear in *Science* (see Figure 16). The first paper, by Steve Ostro (JPL) et al. (*Science*, 2006, doi: 10.1126/science.1133622), shows how the high-resolution radar images allow the shape of the larger component ("Alpha") to be determined to within 3% in each dimension. Since the binary orbit determines the mass, they accurately determined the density (1.97 ± 0.24 g/cm^3).

Together, Alpha's size, shape, spin, density, and porosity reveal it to be an unconsolidated gravitational aggregate close to its breakup point, suggesting that KW4's origin involved spin-up and disruptive mass shedding of a loosely bound precursor object, probably within the past million years, and perhaps much more recently. The disruption may have been caused by tidal effects of a close encounter with a planet or by torques due to thermal radiation of absorbed sunlight (the "YORP" effect). The near-circularity of Alpha's pole-on profile further suggests that the disruption may have produced a quasi-circular disc of particles rather than merely a prolate elongated body.

Fig. 16: Shape of asteroid binary system 1999 KW4, as derived from the range-Doppler echoes of the Arecibo S-band radar. (Courtesy: Mike Nolan)

The second paper, by Daniel Scheeres (Univ. of Michigan) and collaborators (*Science*, 2006, doi: 10.1126/science.1133599) examines the dynamics of the binary system. They determined that solid-body effects and a coupling between rotational and orbital motion can be more pronounced and can have different time scales than with the other binaries that nature has provided (binary stars, the Earth-Moon and Pluto-Charon systems, and much larger binary asteroids like the Ida-Dactyl system). Previous studies of binary system dynamics have not had to wrestle with interactions of components whose shapes are irregular and asymmetrical and whose interiors are nonrigid, porous assemblages of granular materials. The new research establishes the techniques needed to investigate binary NEAs and discloses phenomena critical to understanding how these asteroids originated and evolved.

The 3-MW gas turbine generator that powers the S-band radar system was found to have a serious fault during a routine inspection in July this year. It has now been repaired, and operations should have resumed by the time of publication of this newsletter.

Beginning in January 2000, the Saturn system has been observable for about half an hour per night at Arecibo: The transmitter is run for 30 minutes, then the telescope performs other observations until it is time to receive the echoes an hour and a half later.

A number of programs have been observing Saturn's rings and satellites. After the 2007 apparition, Saturn will head south of the Arecibo declination range until 2028, and the observers are looking forward to a final observing season in January and February 2007.

Observations of Comet SWAN (C/2006 M4)

The long-period Comet SWAN (C/2006 M4) was discovered 12 July 2006 on SOHO spacecraft images. The comet experienced an outburst on 25 October (IAUC 8766) and had brightened by more than 4 visual magnitudes. This brightening behavior in a long-period comet often suggests a fragmentation of the nucleus. Fragmentation events generally result in a dramatic increase in gas production and could lead to total disruption of the body. Observations of split and fragmenting comets such as this provide an important view of the fresh, unprocessed interior ices that are preserved from the time of the formation of the comet in the early solar system.

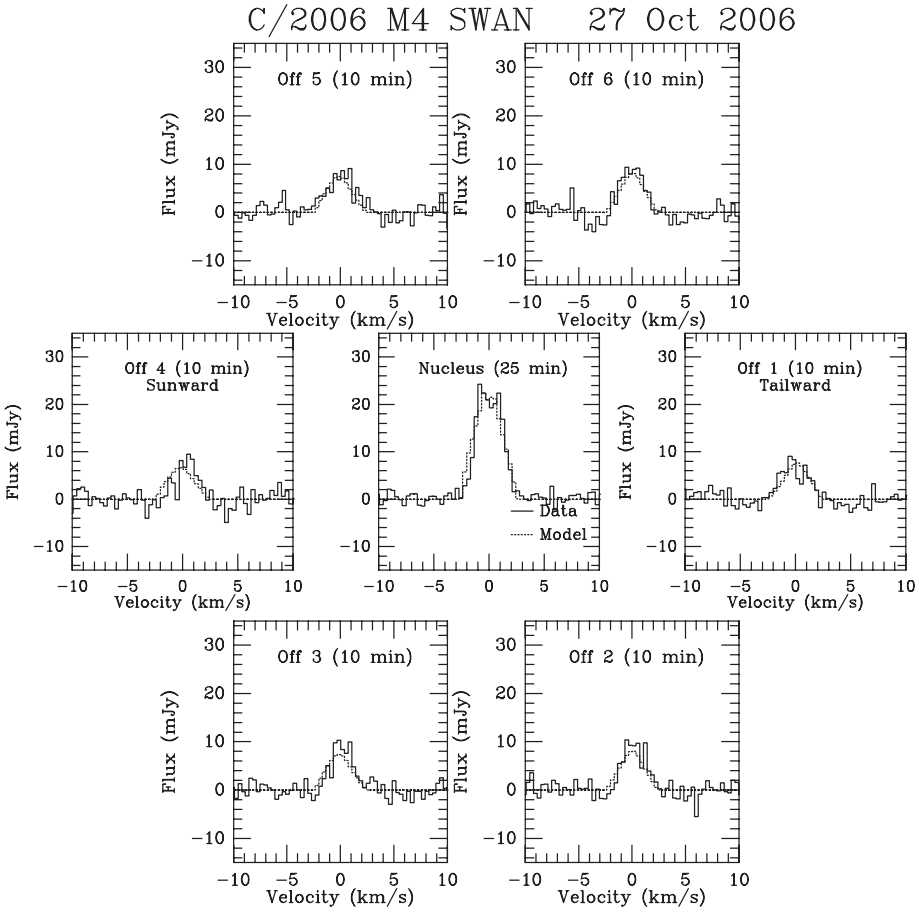


Fig. 17: The OH 1667 MHz line of Comet SWAN (C/2006 M4) on 27 October 2006. The nucleus position is in the center, and each outer position is 4.1 arcminutes away from the nucleus in the coma, which corresponds to 179,000 km at the comet. The model spectra are shown as dotted lines along with the data. The model assumes hemispherical symmetry, so deviations in individual off spectra may indicate jets or asymmetries in the coma. (Courtesy: Ellen Howell)

Fortunately, the Arecibo Observatory is quite responsive to targets of opportunity, particularly during daytime hours when many other astronomical observations cannot be done. We observed Comet SWAN on 27-29 October, and detected the 1665 and 1667-MHz OH lines. We observed using L-wide, centered on the nucleus position, and in a hexagonal pattern 4.1 arcmin away, which corresponds to 179,000 km at the distance of the comet. The 1667-MHz spectra are shown in Figure 17, with model fits shown as dotted lines. The hexagon is oriented with the sunward and tailward direction as projected on the sky. Over the three-day period, there were only minor changes in observed line strength, and those could be attributed to expected changes in excitation of the OH as the comet moved with respect to the sun. More detailed analysis is continuing. Additional observations may indicate whether this new activity will continue, or if this was a one-time event and the comet will gradually fade back to previous brightness levels. As mentioned above, these data will be particularly interesting for comparison with our recent observations of the fragments of periodic Comet 73P/Schwassmann-Wachmann 3.

Space and Atmospheric Sciences (SAS)

Mike Sulzer, Craig Tepley, and Jonathan Friedman

Space Weather, Storm Effects, and Ionosphere Thermosphere Coupling:

World Day experiments took place in June and September. A four-day World Day experiment in June had a CAWSES (Climate And Weather of the Sun-Earth System) focus and targeted high-latitude ion convection. A general two-day run was scheduled in September to specifically compare GPS and ISR measurements, during which many of the radars utilized a wide F-region coverage as well as Topside ionosphere observations.

In July we supported the VLF studies of M. C. Lee and his students from MIT. Fabry-Perot interferometer (FPI) observations of O(^{1}D) 630-nm thermospheric winds and intensities were made with our facility instruments, while Lee and students fielded their all-sky imager in the new wing of the Airglow Laboratory. Additionally, both the Boston University imager (Steve Smith et al.) and the Penn State imager (John Mathews et al.) were running, providing additional support during these as well as additional studies.

The MiniME FPI (John Meriwether and students from Clemson University) was removed in July 2006 for deployment in Alaska. This instrument spent 1½ years at Arecibo while John and his students ironed out bugs and prepared it for remote observations.

In July we supported a mesospheric/D-region gravity wave study by Qihou Zhou (Miami U.). These daylight observations alternated with nocturnal F-region studies by Romina Nikoukar (Univ. of Illinois), who is carrying out PhD thesis work devising optimal ISR pulse coding techniques to eliminate range-smearing. Following these observations, Qihou stayed on with a second observing proposal to study intermediate ion layers during both day and night. These observations were coupled with the D-region studies during daytime hours. Later in the month, Mike Nicolls (SRI) carried out plasma line studies that are described in some detail later in this article. These alternated with observations by M. C. Lee mentioned above, and D-region ion spectrum measurements by Shikha Raizada (NAIC).

In early August John Mathews and Johannes Wiig (Penn State Univ.) tested

a meteor detection technique. In this technique, a small 430 MHz Yagi antenna is hung side-by-side with the 430-MHz line feed. The goal is to measure meteor trajectories within the 430-MHz beam in the near field. The purpose of this study was to improve the estimate of the global influx of extraterrestrial meteoric input to the Earth's atmosphere. Later in August, Frank Djuth (Geospace Research Inc.) carried out studies of gravity waves in the thermosphere and of using the natural plasma line as a radar diagnostic. Following these runs, Diego Janches (CoRA), working with the lidar group at Arecibo, carried out radar/lidar studies of meteor input. Also, Dennis Riggin (CoRA) undertook measurements of MLT-region momentum fluxes and vertical-horizonal wind variances. Lara Waldrop (Univ. of Illinois) made observations designed to glean the neutral O density in the upper thermosphere to topside ionosphere.

In late September Lara began a series of experiments that represent a new look at the O-O^+ collision cross-section and the so-called, "Burnside Factor". In these observations she uses the incoherent-scatter radar (ISR) to derive the meridional neutral wind from the ion drifts and diffusion velocity along the magnetic field line. Comparing simultaneous direct measurements of the neutral wind at night using a Fabry-Perot interferometer one can infer a scaling factor that allows for the balance in momentum. This work has just begun, but we expect better results than those obtained previously due to instrumental improvements in both the ISR and FPI.

In mid-September Marcus Rapp (Leibniz Institute for Atmospheric Physics) carried out an experiment to detect incoherent scatter from charged meteoric dust particles in the D-region. In addition to the September World Day (above), there were a number of other proposals that made use of the ISR. Mike Kelley (Cornell) used the ISR as a diagnostic for developing ion layer and conductivity measurements from GPS occultation measurements. These occultations can, in theory, be inverted to extract parameters such as ion densities, but the measurements need to be verified and calibrated. For this reason, they employed the Arecibo ISR simultaneously with the GPS measurements. Lara Waldrop returned for more observations in September as well, and Mike Nicolls was back again as well to continue his plasma line measurements.

October continued an extended period of SAS activity. Lara was back for more measurements of the Burnside Factor. Asti Bhatt (Cornell) came to make observations of the Gyro line enhancements, apparently caused by conjugate-point electron excitation, before dawn. Hien Vo (NAIC) carried out observations of zonal electric fields and their interactions with the solar wind during substorm activity. Finally, José Fernández (NAIC) carried out measurements of E-region ion-neutral collision frequencies as part of a long-term study of their seasonal variability.

Plasma line measurements

We have made the first successful measurement of electron temperature in the ionosphere using the very small difference in the plasma frequency, as modulated by up and down going waves. This is a difficult measurement, and the analysis requires the use of a very accurate plasma dispersion relationship. It has been attempted at other incoherent scatter facilities as well as previously at Arecibo; the current effort has made good use of the earlier work, and the new results are reported in Nicolls et al. (*GRL*, 33, L18107, doi:10.1029/200gGL027222).

The most fundamental property of a plasma is the Langmuir oscillation driven by the restoring force resulting from separating the negative electrons and positive ions. When the thermal motion of the electrons is included, the result is a propagating wave for frequen-

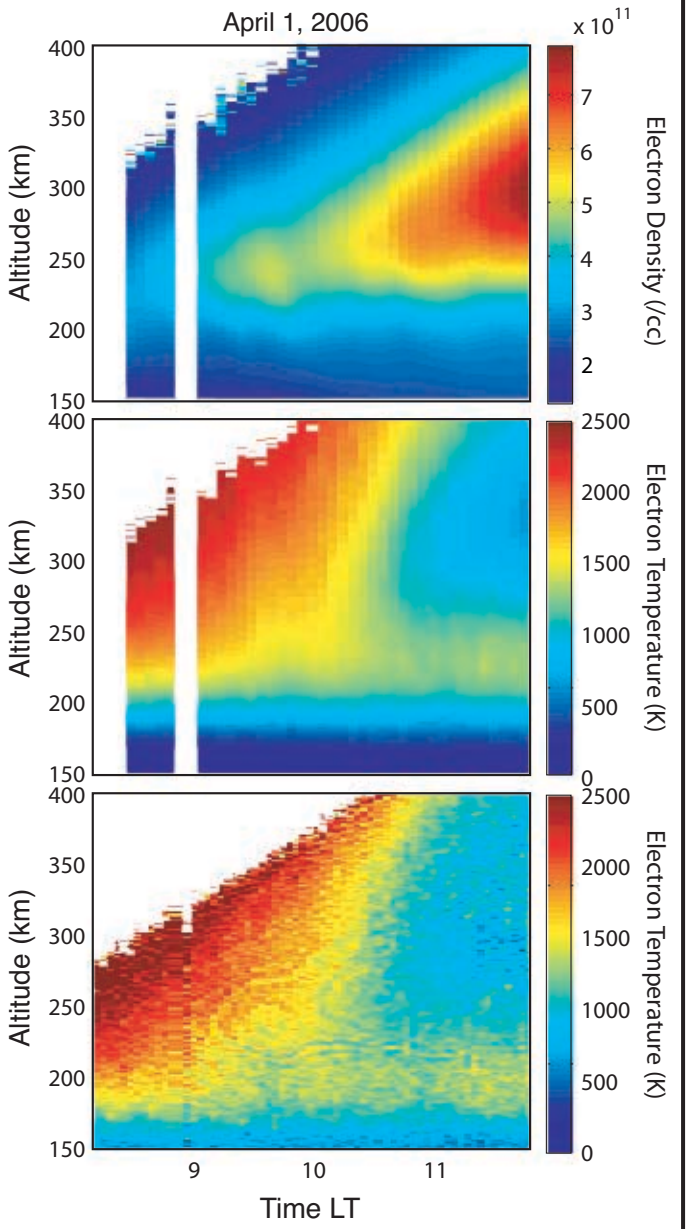


Fig. 18: Results from plasma line measurements. The upper panel shows electron density measurements using the plasma line technique, while the middle and lower panels show electron temperatures as measured by the ion line and plasma line methods, respectively. Note the differences in temperatures beginning below about 225 km. (Courtesy: Mike Sulzer)

cies above the Langmuir oscillation, approximately obeying the Bohm-Gross dispersion relationship. A random set of these waves exists all the time in the ionospheric plasma at the thermal level, but the damping of photo-electrons tremendously enhances these waves during the day. The scattering of an E&M wave from these waves is the part of the incoherent spectrum that we see with the 430 MHz radar.

The plasma line has always been important at Arecibo, even though less used than the ion line. With the improvement of data-taking capabilities—in particular our new digital receiver—and greater data storage and computational capabilities, very high quality plasma line measurements are approaching the status of a regular capability. Such measurements have been made for over a decade, for example Djuth's study of gravity waves from range-time variations of the plasma frequency (GRL 31, L16801, 2004), but the applications for the technique are increasing as it becomes easier to use.

The radar matches different **K**-vector magnitudes for the up- and down-going waves, and the full kinetic dispersion relationship is used to turn the measured frequency difference into an electron temperature. Useful plasma frequencies start at about 3 MHz and are limited to about 8 MHz when using the line feed, or higher with the Gregorian. A typical shift from the cold plasma resonance is about 200 KHz. A typical difference between the up and down frequencies is a bit under 2 KHz. The new results are shown in Figure 18. The top panel shows the electron density computed from the plasma line measurements; the middle shows the electron temperature as measured in the normal way with the ion line. The bottom shows the new temperature measurements from the plasma line frequency differences. *Systematic differences in the lower altitudes are the result of ignoring the molecular ion fraction in the ion line analysis. In fact, the measurement of Te independent from the ion line will be used to improve the molecular ion fraction measurements.*

Lidar measurements in the Mesosphere and Lower Thermosphere

Summer and new graduate student participation envigored lidar observations in the Mesosphere and Lower Thermosphere (MLT) over the past several months. Israel González (UPR-M) returned for a second summer, supported by the PaSSER program (see REU article, below). With his presence, considerable progress was made towards eventual daylight measurement capability with the potassium Doppler lidar. Jonathan Fentzke (Univ. of Colorado), working together with Diego Janches and Jonathan Friedman (NAIC), developed and demonstrated a meteor detection mode for the lidar. Although he only applied it to the potassium lidar, it will work with any lidar. In fact, it will be tested on the sodium resonance lidar at the ALOMAR lidar observatory in Norway this autumn.

Xinzhao Chu (Univ. of Colorado) returned as a visitor this summer for one month. She and Jonathan Friedman are comparing the MLT thermal structures at Arecibo and Maui. Maui is only 2° north of Arecibo and 90° west, yet it turns out that there are distinct and surprising differences in their thermal structures, in addition to features in common that are not observed at mid latitudes. One of the features not seen at mid-latitudes is the semi-annual oscillation (SAO) of temperature at all altitudes in the lidar's range (roughly 80 to 105 km). The SAO is a little-understood phenomenon, though it extends through the stratosphere and mesosphere. It was originally observed in zonal wind measurements and is known to be a reversal in the mean zonal winds that occurs in the tropics and at polar latitudes. Recent analyses of satellite observations from both the UARS and TIMED platforms have shown this phenomenon in temperatures, and airglow measurements from Brazil and Hawaii have also observed it. It is believed to be strongly latitude dependent, and it may be associated with the strong meridional flow in the mesosphere that produces the cold summer mesopause at mid and high latitudes. In Figure 19 we show the seasonal variation in temperature over Arecibo at 4 different altitudes. All show distinct semi-annual variability.

In another area of interest, Shikha Raizada has been investigating the distribution of K and Na with altitude and time obtained during simultaneous observations over Arecibo. Although both Na and K are alkali metals, and thus chemistry would dictate their distributions to be similar, this is not always the case. She has found very distinct differences in these distributions, particularly in the lower half of the metal layer region, below 90 km.

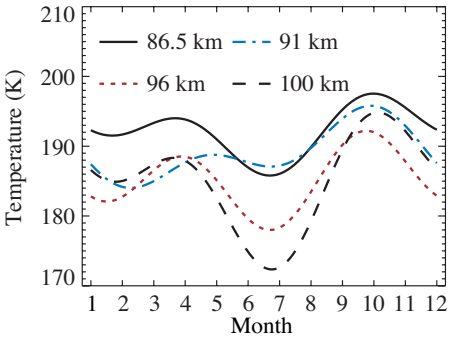


Fig. 19: Seasonal temperatures at altitudes of 86.5, 91, 95, and 100 km as observed with the Arecibo K lidar. (Courtesy: Jonathan Friedman)

In the autumn, Johannes Wiig and Paloma Farias left Arecibo to enroll in the graduate program in Aerospace Engineering at the University of Colorado. Once they finish their coursework, Paloma will return to Arecibo to work on the daytime lidar project with Jonathan Friedman, while Johannes will continue with Xinzhao Chu at Colorado, supported by a program that aims to advance mesospheric lidar science and technology through a collaboration between four CEDAR-supported plus Arecibo lidar groups. This program, called the Consortium of Resonance and Rayleigh Lidars (CRRL), presently includes as members lidar programs from Colorado State University, the University of Illinois, CoRA, and the University of Colorado. Under the CRRL is the CRRL Technology Center (CTC), which will be supporting Johannes and includes the involvement of the Arecibo lidar program through the participation of Jonathan Friedman. As

part of CTC-related work, we have been supporting Jocelyn Oh, who is a student in Electrical Engineering at the Univ. of Arkansas, Little Rock and UPR-Mayagüez. She is working with Jonathan on technology development for the daytime lidar, and she is providing documentation that will be part of Arecibo's contribution to the CTC. Jocelyn developed a high-speed light chopper system that protects the lidar detector from low altitude-scattered light that can saturate or damage the detectors.

Stratosphere-Troposphere Lidar

Allen Lizarraga and Vazjier Rosario (both UPR-M) are working on various aspects of the aerosol concentration of the lower atmosphere. Lizarraga worked with both Shikha Raizada and Craig Tepley on a project to complete the Arecibo aerosol lidar multi-channel receiver configuration during the summer. This is needed to characterize the aerosol size distribution that is derived from aerosol optical thickness obtained via multi-wavelength lidar measurements across the spectrum. Vazjier is working with Craig to design a portable aerosol lidar that will be built at (UPR-M) and will be used in future collaborative campaigns with Arecibo.

Daniel Comarazamy, a master's student at UPR-M, worked with Craig Tepley to assimilate aerosol data into the regional climate models that are under development at the UPR-M. We have been collecting these data, as well as measuring the column abundance of ozone and water vapor during the last several years using portable, multi-wavelength radiometers. The current state of climate models tends to assume a constant aerosol loading in the atmosphere, however, the measurements show a significant variation throughout the year, particularly during the summer when Saharan dust is present in the Caribbean atmosphere. A paper was recently published where we show that inclusion of the measured aerosol data in the models helps to better predict local rainfall patterns (Comarazamy et al., 2006, *JGR*, 111, D09205).

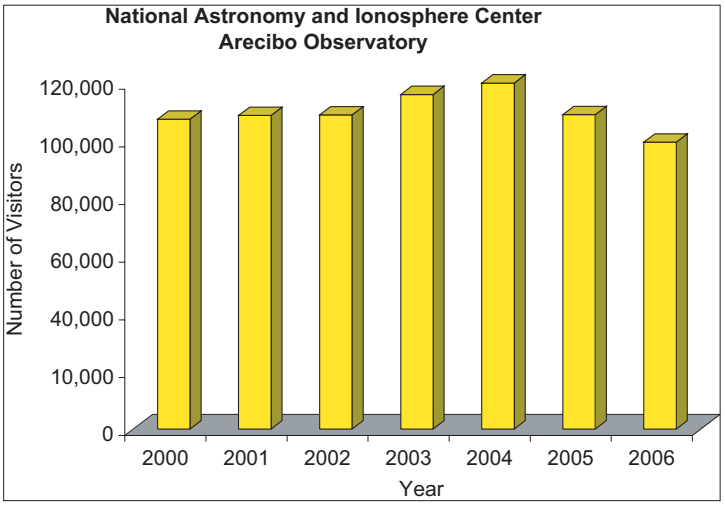
Improved performance from the Gregorian 430 system for Aeronomy Observations

Jon Hagen redesigned (from his home in NYC) the 430-MHz turnstile junction for the Gregorian system to achieve greater isolation between the transmit and the receive ports. The improved performance of this new turnstile has enabled the use of the cooled radio astronomy receiver for radar observations. System sensitivity has improved > 25% making the Gregorian dome receiver the preferred system even for single beam studies at higher zenith angles!

Education and Outreach

José Alonso

In 2006 the Visitor Center completed its ninth year of operation, and attained the one-million visitor landmark. As in previous years, the Visitor Center hosted many special events for the general public and for the Arecibo Observatory community in general. These included the Arecibo Conjugate Workshop, the Geoscience Workshop, and the Gordon Lecture. Three educational workshops were offered on the issue of pseudo-science, and we hosted an astronomy summer camp for 25 middle school students. We updated 15 displays at the Visitor Center and are in the process of updating and adding new panels. In 2006 we experienced a 9% decrease in the number of visitors to the Arecibo Observatory as compared to the previous year. The tourism industry in Puerto Rico has also reported a 10% drop in room occupancy for the period. A slow economy and new restrictions imposed on school field trips by the Department of Education has impacted the visitation to the site. The Visitor Center has taken several administrative measures to make the operation more efficient.



From Arecibo to the Universe Summer Camp

During the week of June 11 to 16, the Arecibo Observatory hosted the residential summer camp *From Arecibo to the Universe* for 25 middle school students from participating ALACIMA schools. All participants completed the program successfully. As part of the summer camp activities, students had the opportunity to tour the Arecibo Observatory and meet scientists, engineers, and technical staff. Through these interactions, participants were able to enrich their experience and learn about professional careers.

From Arecibo to the Universe was designed as an introductory astronomy workshop developed through hands-on activities on the solar system, stars, galaxies, and the universe. Participants learned to use an optical telescope and performed astronomical observations on Saturn, Jupiter, and the Sun. In addition, they learned to identify the summer constellations and the names of the brightest stars.

The program included a dedicated period of 2 hours each day for recreation. Under constant supervision by our summer camp staff and a professional lifeguard, participants enjoyed our swimming pool and basketball/volleyball facilities. This effort was sponsored by the ALACIMA project, which is an NSF

sponsored Math-Science Partnership award to the University of Puerto Rico.

Pseudoscience Workshops

In an effort to improve the level of science literacy on the Island, the Puerto Rico Space Grant program sponsored a series of workshops on the topic of pseudoscience. The presentation of pseudoscientific topics in the media (radio, TV, press, web) appears to be increasing. Topics include: UFO's, astrology, magnetic healing, and many others. Pseudoscientific ideas are many times presented as "scientific knowledge" and this creates a serious confusion in the general public; particularly in students, teachers and journalists.

We offered two residential workshops (3 days each) for science teachers and two workshops (1 day each) for journalists. Each session allowed participants to establish the difference between science and pseudoscience, and to identify the basic elements that are common to pseudoscientific ideas.

Arecibo Geoscience Diversity Project

The third year of our NSF sponsored *Geoscience Diversity* program went very well. Students and teachers from four schools and 8 undergraduates from the UPR participated in the program. This year we had participation from the Domingo Aponte Collazo School in Lares, Fernando Callejo School in Manatí, the Esther Feliciano Mendoza School in Aguadilla, and the Enrique Borras School in Arecibo. Each school provided a team of 5 students and a science teacher. Two schools (Lares and Manatí) worked with the UPR on a research program at the Caño Tiburones wetland. Here they measured water quality and identified bacteria in aquatic plants known to absorb metal ions. The Aguadilla and Arecibo schools worked at the Arecibo Observatory comparing different galaxy populations using data collected by the ALFALFA survey. Participants presented their research projects at the Arecibo Geoscience Congress, held at the Arecibo Observatory on April 29, 2006.

Connecting to Arecibo

Rick Jenet

Students in South Texas got their first glimpse into the Arecibo Observatory Control Room via a new webcam that links the University of Texas at Brownsville (UTB) and the Puerto Rico observatory. On October 23, 2006, operator Wilfredo Portalatin turned to the camera and waved at the students — they roared with excitement at this first encounter. The cell phone and laptop connection is the first step for this group as they start to build an Arecibo Remote Command Center (ARCC).

Rick Jenet, a professor at UTB, received an NSF Career Grant that is funding the construction of the ARCC. This facility will allow high school, undergraduate, and graduate students to work in teams to perform actual observations of radio pulsars. They will use the data both to search for low-frequency gravitational waves and constrain the cosmic population of super-massive black hole binary systems. The first project the students will be observing for is the PALFA project.

The ARCC students have been working on designs of the UTB Remote Command Center for the past six weeks. During their planning, students worked with limited budget and space while dreaming and designing a facility ideally suited for remote viewing. Student designs have incorporated items such as a star-field projection onto the ceiling of the room to give a visual representation of the portion of the sky currently being observed. They also designed a conference area for presentations. The myriad of control windows necessary will be displayed on a series of interlinked projection screens and monitors.

One of the unusual aspects of the ARCC program is the level of integration of high school students. Currently, there are 13 high school junior and senior students who are a part of the ARCC research group. These students are led by Andy Miller, a Porter High School phys-

Students in the ARCC research group huddle around Rick Jenet as they have a real-time view of the Arecibo control room.

ics and astronomy teacher. The students attend group meetings at the university campus on Monday nights. These meetings give them the opportunity to collaborate with the undergraduate students, graduate students, and research scientists that form the group.

A special thanks to the people at Arecibo who helped with the camera installation: Phil Perillat, Tim Hankins, Arun Venkataraman, and Rey Vélez.

2006 REU Program

Shikha Raizada

The Arecibo Observatory organized its 2006 REU summer student program for 10 weeks from the end of May to mid August. This program exposes students to various activities with the aim of motivating them to pursue their future career in research. The selection process is highly competitive with 11 students getting selected from different universities out of nearly 115 applicants. These eleven students were funded from different sources, (a) eight were supported by the NSF REU grant, (b) two recent graduates supported by NAIC, and (c) one was selected on the basis of the Observatory Director's discretion. In addition, three students from UPR-Mayagüez (UPR-M) worked at the Observatory and were funded by the Partnership for Space Science Education and Research (PaSSER) program, and one was supported by 'Fundación Comunitaria de Puerto Rico' and worked on a project related to education and outreach activity to promote science for the disabled. Apart from this, there were two graduate students from the University of Colorado (CU) supported by Colorado Research Associates (CoRA), working with their Ph.D. supervisor Dr. Diego Janches (CoRA), who used the facilities at the Observatory for their research work. These students, Amal Chandran and Jonathan Fentzke, participated in the REU activities and also gave 20-minute presentations towards the end of the program. One of the highlights of this year's program was the participation of students from U.S. universities, and two from outside the U.S. One student (Sonia Buckley) attends college in the U.K. and one (Ximena Fernández) is originally from Colombia, which allowed students from diverse backgrounds to interact.

Professors Julio Urbina (Penn State University) and José Rosado (UPR-M) visited the Observatory this summer and mentored a few REU students. Also, Prof. Carmen Pantoja (UPR Río Piedras — UPR-RP) and her student spent a month working at the Observatory's Ángel Ramos Visitor Center to develop techniques for promoting science among the vision and hearing impaired. Several Observatory staff members gave lectures to the students with the objective of introducing them to the fundamentals and applications of the various instruments available on site. The talks included a variety of topics covering areas related to astronomy, ionospheric science, planetary radar, and electronics with focus on the current research activities using the facilities at the Observatory. This was complemented with a visit to the 500-ft high platform that contains several receivers. The engineers and technical staff showed them the 430-MHz transmitters, which was beneficial to the engineering students. A very distinguished visitor, Dr. Jocelyn Bell, was invited to the Observatory as the 2006 William E. and Elva F. Gordon Distinguished Lecturer. During her visit, she gave a popular lecture on "Reflections on the Discovery of Pulsars" on 27 June 2006. A get-together was arranged that allowed female scientists and students to interact with her and gave them an excellent opportunity to discuss issues related to women in science. Also, several visitors to the Observatory gave talks that were attended by the REU students. This list includes: D. Campbell, P. Taylor, Eliana Nossa (all Cornell), X. Chu (CU), G. Cortés (NAIC, Cornell), D. Werthimer (UC Berkeley), and J.C. Morales (University of Turabo).

The research experience for REU students comprised a mandatory project (individual) and an optional project (group of 3 to 4 students) as a part of a hands-on experiment. The mandatory project involved either real time observations or previously obtained data and their analysis/interpretation. Those who wanted to obtain experience on the procedures related to observing were offered participation in hands-on experiments that were conducted by Arecibo staff members Mayra Lebrón, Chris Salter and Tapasi Ghosh. Three runs were scheduled that provided students an excellent opportunity to get their 'hands dirty'. A summary of the hands-on experiments is provided later in this document.

The students were asked to give 20-minute presentations summarizing the project they worked on during their stay at the Observatory. Some of the students will present their work in meetings/conferences. The aeronomy students plan to participate in the CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions) meeting in June 2007. Similarly, the astronomy students will present posters at the meetings of the American Astronomical Society in October 2006 and January 2007. It is worth mentioning that one of the students (Ms. X. Fernández) who worked with T. Ghosh, C.S. Salter and E. Momijan discovered a new galaxy and has expressed her interest in participating in follow-up work and to pursue astronomy as her future career.

There is a famous saying that 'All work and no play makes Jack a dull boy'. To make sure that students got a chance to experience life outside the Observatory, a variety of activities were arranged that gave them an opportunity to explore the culture and nature of the

Caribbean island. Many thanks to all the administrative staff, especially María-Judith Rodríguez, Lucy López, Wilson Arias, Carmen Segarra, Carmen Torres, Eva Robles, José Cordero, and all the drivers for their cooperation and time. As a welcome to students, a BBQ was organized near the recreational area. We encouraged students to give us feedback about their interests and tried to organize events accordingly. Some students became certified for scuba diving and then visited places like the Mona and Vieques Islands that are famous for their beautiful beaches and sea life. This gave them a chance to camp, hike and snorkel in different locations. The students spent a weekend camping in the El Yunque Rain Forest. Also, a cultural trip to Old San Juan was arranged that was coupled with a visit to the Bacardí factory that is famous for manufacturing the most popular rum in the world. There was an educational trip to the Institute of Tropical Ecosystem Studies located in the Rain Forest, which also hosts REU students and is coordinated by Dr. Alonso Ramírez. This was later reciprocated by a visit to the Observatory by the Rain Forest REU students. A trip to a cultural festival in the nearby town of Hatillo was organized that exposed students to the local music, dance and food. On many occasions, students were accompanied by staff members (P. Freire, J. Wiig, P. Farias, and H. Vo), who followed along to several beaches and other scenic spots. We also took them out to the cinema and dance establishments. Toward the end of the summer, another BBQ was arranged to welcome the Rain Forest REU students and also to give a farewell to our own students. The two groups played volleyball and exchanged their experiences. On several occasions, the students organized evening get-togethers at the VSQ and invited staff members and vice-versa.

2006 Summer Student Projects

Supported by NSF REU Funds:

Heidi Brooks is currently a senior at Reed College. As an REU student, she worked with Dr. Ellen Howell and studied the orbits of binary asteroids in the near-earth population as a means for obtaining measurements of their densities. She worked primarily with radar-obtained delay Doppler images of asteroids 2003 YT1, 2002 BM26, and 2006 GY2. She recorded the range separation of the primary and secondary asteroids at various time intervals, as well as their respective bandwidths. The values obtained for range separation were plotted versus time and fitted to sine curves, as would result from the (assumed) circular orbits of the secondaries. They were found to exhibit the following periods: 2003 YT1, 36.7 ± 1.8 hours; 2002 BM26, either 12.5 ± 0.2 or 25.8 ± 0.3; and 2006 GY2, 11.7 ± 0.2 hours. Additional data for YT1, along with the use of a modeling program called Shape allowed constraints to be placed on the geometry of the system. From these inputs, Heidi was able to calculate the mass and volume of the primary to be $(1.27 \pm 0.39) \times 10^{12}$ kg and 0.63 ± 0.10 km^3, respectively, resulting in a final estimate of the density to be 2.01 ± 0.70 g/cm^3.

Sonia Buckley is a first-year undergraduate student at Trinity College Dublin, Ireland, studying Natural Sciences. She worked with Johannes Wiig to calibrate the Pennsylvania State University all-sky imager. The all-sky imager is a sensitive digital camera that collects images of the entire night sky for the purpose of studying airglow events. Sonia's project involved the intensity calibration and flat-fielding of the imager. To do this, many images had to be taken of a light source of known intensity under different conditions. The imager was dismounted from its position in the airglow laboratory and set up underneath a ^{14}C calibration source. The calibration data was collected over the course of several nights to avoid light contamination. Sonia then used IDL to analyze these results and carry out the calibration. The program doframe.pro for automatically flat-fielding and converting pixel counts to intensity values of any image taken with the camera was created using the results of the calibration. All the results and IDL programs will be posted on the web at *http://allsky.ee.psu.edu* along with the images taken every night with the all-sky imager so that anyone can access the data. This means that the calibration data will be used when studying the images to obtain more accurate, understandable images.

Knicole Colón is a senior at the College of New Jersey**.** She worked with Dr. Mayra Lebrón on reducing and analyzing the 18-cm (1665, 1667, 1612, and 1720-MHz), 6-cm (4765, 4751, and 4660-MHz) and 5-cm (6031, 6035, 6049, and 6017-MHz) OH lines, as well as the 4830-MHz H_2CO and the 6668-MHz CH_3OH lines, all arising in the massive star-forming region IRAS 19111+1048. All lines were observed on July 4–5, 2005 using the Arecibo Telescope L-band, C-band and C-high receivers. The analysis was completed using Arecibo routines for reducing correlator data. Maser emission was confirmed in the 1665, 1667, 6031, and 6035-MHz OH lines, and each maser line was accompanied by an absorption feature. By comparison with previous studies, all but the 6031-MHz line appear to be highly variable. The 6-cm OH lines, the 18-cm (ground-state) and 5-cm (excited-state) OH satellite lines, and the absorption features in the four masing lines were found to exhibit weak and broad spectral profiles located at velocities slightly higher than that of the source, indicating that their appearance may be due to a form of quasi-thermal excitation rather than the masing process. Currently there is no evidence for either H_2O or CH_3OH masers, but massive CO outflows have been detected through previous studies. Along with the detection of OH masers, these properties place IRAS 19111+1048 in a late stage of protostellar evolution in which the HII region has expanded and developed enough to allow for conditions that are unable to generate H_2O or CH_3OH masers. As a separate result, the near and far kinematical distances to this source were determined to be, respectively, 4.4 and 7.6 kpc.

Kevin Graf is a senior at Cornell University and worked with Ganesh Rajago-

palan. His work focused on the C-high receiver at the Observatory that is mostly used for 6.7-GHz Methanol Maser line surveys. However, there is interest in upgrading the receiver to a dual-beam receiver for continuum observations. The receiver possesses two feed horns and two front-end receiver chains. The planned implementation of Dicke-switching at rates of approximately 10 Hz following the dewar should nullify the 1/*f*-noise from fluctuating atmospheric emissions. The type WBA13 MMIC amplifiers used at the C-High Receiver front-end, however, possess Heterojunction-FETs, which are known for 1/*f*-noise that can limit the sensitivity of continuum observations. Using the test setups assembled and verified this summer, the stability of the type WBA13 MMIC amplifiers, as well as of the C-high Receiver as a whole, will be characterized. The Allan Variance of the samples should offer recommended integration times and switching rates. These results should guide the process of the dual-beam upgrade as well as provide useful information to observers who use the receiver for continuum observations.

Heather Hanson is a senior at the University of Wyoming. She worked with Dr. Mike Nolan and her project focused on the asteroid 105 Artemis, which is a C-type main-belt asteroid that has been observed to contain hydrated minerals on at least a portion of its surface. Seventy-five percent of all asteroids belong to the C-type classification. These asteroids are often observed to have absorption bands near 0.7-microns and 3.0-microns. The 0.7-micron absorption feature indicates the presence of iron bearing phyllosilicates that are related to hydrated minerals, while the broad 3.0-micron absorption is caused by overlapping absorption bands from H_2O and OH layers in hydrated minerals. Often the 0.7-micron band is not observed but hydrated minerals are present and absorption at 3.0-microns is seen. To further understand the link between the absence and/or presence of the different bands, radar data from the Arecibo Observatory and spectra from the IRTF on Mauna Kea have been obtained for a number of asteroids. Many of the radar data show irregular, non-symmetric bright features that may be linked to the reflectivity of the surface, and therefore the composition instead of the shape of the asteroid. Both radar observations and near-infrared spectra of 105 Artemis have been obtained and analyzed. Heather coordinated the radar and spectral data using lightcurve data obtained from the amateur astronomy community. Through a modeling program called Shape, these data were used to make a simplified 3D model of 105 Artemis in order to map the areas where hydrated minerals have been observed. Once mapped, the link between the hydrated minerals and radar-bright areas can be tested.

Clinton Mielke is a senior at the University of Arizona, Tucson. He worked with Dr. Paulo Freire this summer, the resident pulsar expert. Paulo gave him the choice between two projects to work on, and stepping up to the challenge, he decided to undertake both. First, he worked on a numerical simulation of a particular binary pulsar system. By using the 4th-order Runge-Kutta algorithm, he tested the general relativistic perturbation on the pulsar's orbit and found a precession of the periastron over a specific timescale that agreed with theoretical models. Unfortunately, the amount of drift has been found to be too small to observe, so although his code worked well, the binary system is not a strong candidate for testing General Relativity.

On his second project, Clinton wrote an orbital fitting program that uses the Levenberg-Marquardt method to perform a least squares fit. When given an input file of epochs and periods, the algorithm finds Keplerian orbital elements and a few additional parameters for the particular system in question. This program will likely become a valuable tool for astronomers in the pulsar community, as no open source alternative seems to exist for this particular application. He will be coordinating his efforts with Paulo over the upcoming few months to modify this application and bring it into use amongst all who need it.

Isobel Ojalvo is a senior student at Rensselaer Polytechnic Institute in Troy, NY studying physics and mathematics. Her REU summer project supervisors were Drs. Steven Gibson and Robert Minchin. Her REU project was to determine what is needed to put data obtained from the Arecibo L-Band Feed Array (ALFA) onto the Virtual Observatory (VO) and to implement a preliminary database and website. The VO is an international collaboration to make large astronomical surveys available to the public with a suite of search and intercomparison tools. Isobel's focus was on the VO interface for ALFA surveys of the Galactic interstellar medium (GALFA) and HI environments around other galaxies (AGES), both of which are generating large, 3-dimensional data sets. She used the scripting language Perl as a common gateway interface to access the data and investigated how to provide a web-interface that will allow users outside the Observatory to extract subsets of the data via the World Wide Web.

Daniel Rucker is a fourth-year undergraduate student at University of Arkansas at Little Rock, majoring in Systems Engineering. He worked under the supervision of Prof. Julio Urbina and Ryan Seal on the development and implementation of an FPGA-based radar controller for the Space and Atmospheric Sciences Group at the Arecibo Observatory. This device will be integrated with the recently developed multi-channel digital receiver acquisition system to conduct radar observations. The radar controller will provide up to 16 control signals: sample start trigger to the receiver board, T/R switching, RF pulse, blanking, coding, etc. It will also control two 8-bit digital-to-analog converters (DACs) for multi-frequency signal generation. The device is an external module that is programmed via the USB 2.0 port and offers a total of 50 I/O pins. Configuration and operation of the device is achieved with a general-purpose computer through a graphical interface under Linux OS.

Supported by NAIC funds:

David Bowen graduated from Cornell University in May 2006. This summer he worked with Ganesh Rajagopalan on a project related to signal interference. Broadband signal information is vital to identifying and diagnosing signal interference in radio astronomy and radar experiments at the Arecibo Observatory. Previously, data available remotely has been band-limited and has not revealed effects of system problems and RFI from sources such as lightning. Data from an instrument capable of displaying the broadband signal needs to be available to remote users at the time of their experiments. These remote users include engineers in their homes in the Arecibo area as well as scientists in arbitrary locations around the world.

Using an Agilent E4403B ESA-L series spectrum analyzer, broadband signal information must be made available. Since the data must reach potentially around the world, the data must be available through an internet gateway, or web server. Two solutions were implemented: LabVIEW programs using the web publishing utility and a Java client/server program pair. LabVIEW was more easily implemented, but required the overhead of a runtime engine to be interactive (called *embedded mode*). At the cost of refresh rate, LabVIEW web publishing could exist in a *monitoring mode* that does not require a runtime engine. Both methods were implemented and are available. The Java client/server pair was also implemented. Java would not require a runtime engine and offers a high refresh rate, at the cost of more difficult implementation and more difficult future upgrades and modifications. Given a stable Java client/server pair, the Java version would be better for scientists who won't have the LabVIEW runtime engine.

María Ximena Fernández is a senior currently enrolled in a dual degree program, where she studies Physics and Astronomy at Vassar College and Engineering Sciences at Dartmouth College. At the Observatory, she worked with Drs. Tapasi Ghosh, Emmanuel Momjian, and Chris Salter analyzing HI 21-cm and OH 18-cm spectral line observations of a group of luminous infrared galaxies (LIRGs). These galaxies emit most of their energy at infrared wavelengths and are found in interacting/merging systems. The intense infrared luminosity ($L_{ir} > 10^{11}$ $L_{\odot}$) is due to the dust heating from extreme starburst and/or active galactic nuclei energy sources. In 2004, Arecibo observations were made using the L-Band Wide receiver of 85 LIRGs from the 2 Jy IRAS-NVSS sample. The sample was observed with ON/OFF or double position switching (DPS) modes, depending on the radio continuum flux density of the target sources, and the data were reduced with IDL. The team detected HI in 82 galaxies (16 new detections), and OH in 7 galaxies (5 new detections). In some cases, the HI spectra showed the classic Gaussian or double horn distributions, while the majority exhibited distorted features indicating that they are in an interacting/merging system. IRAS 23327+2913 is considered to be the most intriguing source in the sample. This ultra-luminous infrared galaxy (ULIRG, $L_{ir} > 10^{12}$ L_{o}), which is described in the literature as a pair of nuclei in the beginning stages of interaction, was detected in both neutral hydrogen and OH megamaser emission from the system, which had not been reported before.

Brandon Taylor graduated from the University of Texas at Austin this past May with a degree in Electrical Engineering. While there, he worked in ionospheric research at the Applied Research Laboratories. Prior to coming to the Arecibo Observatory, he also spent a summer as an REU student at the MIT Haystack Observatory.

This summer, he worked with Dr. Hien Vo on a project to statistically analyze Subauroral Polarization Streams (SAPS). SAPS, which can be detected by elevated ion drifts equatorward of the auroral oval, are associated with disturbed ionospheric conditions. A better understanding of these events can improve ionospheric models and reduce errors in GPS and other satellite communications.

Brandon's project was aimed at exploiting the continuous data collection of DMSP satellites to provide a better statistical analysis of SAPS than had previously been performed. He developed an algorithm to automatically process a year's worth of satellite data and to detect and quantify high ion drifts as SAPS. Additional code was written to compare various properties of these SAPS in a variety of geomagnetic conditions. In addition to the results achieved this summer, the project will be extended by Dr. Vo.

Supported by PaSSER funds:

Edvier Cabassa-Miranda, a sophomore at The University of Puerto Rico at Mayagüez, worked with Prof. Julio Urbina (PSU) and used Coqui II observations from the 50-MHz radar located near Salinas, Puerto Rico, to measure observed counts of both specular and non-specular meteor trails in the E-region ionosphere. These observations were made over a time span ranging from 18:00 to 08:00 on various days in 1998 and 1999. The Coqui II radar has two sub-arrays, both pointed to the north in the magnetic meridian plane, perpendicular to the magnetic field elevation angle of approximately 41 degrees. Traditional meteor radars require trail specularity (trail perpendicular to radar beam) for a reflection, but over the last decade, two new types of radar-meteor reflections, known as meteor head echoes and non-specular trails, have become known. He attempted to see if this radar is capable of detecting the head echoes. He analyzed the signals by removing unwanted interference using some routines that he developed in IDL. Now the future work is to try to generate range-time-intensity images to see the head echoes. He would also like to conduct simulations.

Israel González-Pérez, Jr., who is an undergraduate in electrical engineering at The University of Puerto Rico at Mayagüez, returned to Arecibo this summer

to continue a project started during the previous summer under the tutelage of Dr. Jonathan Friedman (NAIC). This is the construction of a test bed and calibration system for a Faraday filter. The purpose of the filter system is to take measurements of the temperature and potassium content in the mesosphere during the daytime, utilizing LiDAR technology. The test bed is composed of a tunable single-mode external cavity diode laser, the filter, a potassium vapor cell in an oven with fluorescence detection, and a Fabry-Perot etalon. The oven and controller circuit, constructed during the summer of 2005, heat a potassium spectrum cell, and we use the laser to excite fluorescence in a "Doppler-free" configuration. Since the emission lines of the potassium are well known, it is possible to use the system to tune the laser and obtain a reliable wavelength scale for the filter calibration measurements.

The challenge for this past summer was to install the Fabry-Perot etalon and to detect fluorescence from the vapor cell in the "Doppler-free configuration". Unfortunately, in the course of these measurements it was discovered that the cell did not actually contain potassium. Another cell was bought for the system and a new oven fabricated in order to use it. The work for the summer was basically the modification of the new oven and the construction of the Fabry-Perot etalon. As the summer was ending, Israel was able to get an assignment to finish the project through the University of Puerto Rico, thanks to Prof. José Rosado. Israel is now putting the working elements of this system into a standard arrangement for long-term use.

Melissa Rivera is currently an undergraduate student in Electrical Engineering at The University of Puerto Rico at Mayagüez, with a strong interest in Communications, Physics and Astronomy. She is also the Vice-President of the Caribbean Astronomical Society of Puerto Rico. Her project at the Observatory focused on analysis of data from Jicamarca Observatory using its radar named JULIA (Jicamarca Unattended Long-term Investigations of the Ionosphere and Atmosphere), and she was advised by Prof. José Rosado (UPR-M). This study analyzed perturbations in the electric field as a result of geomagnetic substorms on equatorial latitudes. The method that she used to obtain conclusions for these phenomena is called Superposed Epoch Analysis, which is a very powerful technique. It consists of sorting data into categories and comparing means for different categories. This method must be applied carefully and logically.

The analysis of the radar data shows disturbances in the daytime equatorial geomagnetic H-field associated with specific phases of isolated substorms. Three well-documented substorms were examined in India, but now with this investigation, she has found more than 102 days of perturbations at different hours and different days in 2004 and 2005. This pattern of response constitutes the first-time evidence for the occurrence of equatorial H-field perturbations related to the growth phase as well as the expansion phase of individual substorms.

Back row (left to right): Edvier Cabassa, Clinton Mielke, Daniel Rucker, Melissa Rivera. Middle Row (left to right): Brandon Taylor, Heather Hanson, and David Bowen (leaning on table). Front row (left to right): Dr. Shikha Raizada, Knicole Colón, Sonia Buckley, Isobel Ojalvo, and Kevin Graf (leaning on table). Not shown: Heidi Brooks, María Ximena Fernández, Israel González, and Gloria Isidro.

Funding from Other Sources:

Gloria Isidro worked at the Visitor Center under the supervision of Drs. Carmen Pantoja and José Alonso with a scholarship from the "Fundacion Comunitaria de Puerto Rico." She is a graduate student at the Department of Mathematics at The University of Puerto Rico, Río Piedras. This summer she developed a guide for the Observatory for blind visitors. The guide consists of three documents in Braille with text and high relief figures describing the parts of the telescope, important terms used in radio astronomy, and frequently asked questions. Together with Prof. Carlos La Rosa (UPR-Utuado) a tactile model of the telescope was also developed. These materials will help in making the Arecibo Observatory a more accessible facility and an Observatory for all.

AUSAC 2007 Meeting

The Editors

The 2007 meeting of the Arecibo Users and Science Advisory Committee (AUSAC) will be held at the Observatory January 16 and 17. With the Senior Review recommendations encouraging heavy emphasis on the astronomy survey programs and a substantial reduction in the astronomy budget still very much in the air, the committee discussion of Observatory priorities this year will be especially interesting and important.

If you have issues you would like the AUSAC to discuss, or questions that need answers, please contact any member of the committee.

CIMA NEWS

Mikael Lerner

The current version of CIMA is version 2.2 which was installed on May 25th and became the default version on June 23rd. Apart from the new observing modes already described in Newsletter 39 in June, a new basketweaving mode has been added which nods the telescope in zenith angle on the meridian. The already existing basketweaving mode is normally used in a similar way, although it is not restricted to the meridian, but does it by nodding in declination and tracking in right ascension with a negative sidereal rate applied to keep the azimuth stationary.

A new utility called 'lastcimalog' has been added to the CIMA family. This is a stand-alone program that shows the last part of the observing log from the current or latest observing session. The log shown is taken from the log file and thus contains more information than what is shown in the CIMA log window during an observation. It was mainly developed for the telescope operators, so they more easily can check the log during remote observations, but it can also be used by others for checking out an observation or trouble-shooting.

A problem for WAPP pulsar observers has been found: when using the WAPPs with 100 MHz bandwidth and WAPP configuration files created from the WAPP pulsar window (`.wapp`-files) or general CIMA configuration files (`.gui`-files) created after `.wapp`-files have been used, it is possible that the destination frequency for the WAPPs was incorrectly set to 275 MHz instead of 250 MHz. More information about the problem is found at *http://www.naic.edu/~cima/bad_wapp_2.txt*. The problem was fixed on October 11th.

Two bugs related to CIMAFITS-files have also been found and corrected. Positional data in the headers of CIMAFITS-files were incorrect for the first 20 seconds after UT midnight roll-over. This bug was fixed on April 4th and affects CIMAFITS-files version 1.02 and earlier. Another bug affecting the calculation of the parallactic angle ('PARA_ANG') was corrected on May 10th and affects CIMAFITS-files version 1.03 and earlier.

Comings and Goings

Visiting Scientists in Ithaca

Martha Haynes

ALFALFA Project

In a November 16 meeting in Ithaca, Jamie Lomax presented her senior thesis project based on ALFALFA. Oded Spector had just arrived from Tel Aviv University as well. He is getting started on an ALFALFA-based Ph.D. thesis.

Dr. Rebecca Koopmann, an Associate Professor in the Department of Physics and Astronomy at Union College is on sabbatical at Cornell as a visiting NAIC scientist (through July 2007) and as a member of the ExtraGalactic group working on the ALFALFA survey. Becky is especially interested in the connection between HI and star formation in nearby spiral galaxies and has done extensive work on how galaxies in the Virgo cluster differ from their more isolated counterparts. While at Cornell, Becky has become immersed in the ALFALFA project, conducting observations, making grids and extracting sources. Her particular research focus is on the study of early-type galaxies in Virgo that are detected by ALFALFA. This October, Becky visited Georgia Southern University where she gave a colloquium on ALFALFA and helped Sarah and Jim Higdon install the ALFALFA IDL-based reduction pipeline. Sarah will travel to Arecibo for a week in January 2007 with two GSU undergraduate students to conduct the ALFALFA observations. Becky has hosted the very successful 2005 and 2006 undergraduate ALFALFA workshops held at Union College. She is leading the ALFALFA undergraduate education team development of educational materials and activities especially geared for undergraduates involved in ALFALFA. Through Becky, we are sure there will be a steady stream of undergraduates who have the thrill of discovering new galaxies!

Dr. Noah Brosch is on sabbatical from Tel Aviv University's School of Physics and Astronomy and from the Directorship of its Wise Observatory. His research interests range from star formation processes in dwarf galaxies to small objects in our Solar System (asteroids and meteors). Among his various tasks, one of the more challenging is being the Principal Investigator of the UV space telescope TAUVEX, built in Israel and scheduled to be launched in 2007. The visit to Cornell has allowed Noah to become familiar with the ALFALFA data acquisition and pipeline and to plan out the scientific study of star formation in extremely isolated galaxies, ones which are unlikely to have experienced interactions in recent cosmic times. He has been joined most recently by his graduate student Oded Spector. Oded is working on the criteria by which the isolated sample will be selected; the study of these galaxies will serve as the basis for his Ph.D. dissertation research. Noah and Oded will spend several weeks in Arecibo in December 2006 to conduct the ALFALFA observations. We wish Noah great success with TAUVEX and look forward to finding out just what triggers star formation in galaxies that don't have any neighbors.

COMINGS AND GOINGS

Front: Noah Brosch (Wise Obs/Tel Aviv U/NAIC), Sabrina Stierwalt (Cornell grad student), Martha Haynes (Cornell/NAIC), Jamie Lomax (St. Lawrence senior) Rear: Oded Spector (Tel Aviv U. grad student), Riccardo Giovanelli (Cornell), Tom Balonek (Colgate/NAIC), Amelie Saintonge (Cornell grad student), Ann Martin (Cornell grad student), Brian Kent (Cornell grad student), Becky Koopmann (Union/NAIC) Credit: Photo by Patrick Taylor

Dr. Thomas Balonek, a Professor of Physics and Astronomy at Colgate University, is on sabbatical at Cornell as a visiting NAIC scientist (through April 2007) and is a member of the ExtraGalactic group to work on the ALFALFA survey. His research specialty is the radio and optical variability of quasars and AGN but, since becoming involved in ALFALFA last year, he has gotten very excited about the study of HI in galaxies and groups of galaxies.

During his stay at Cornell, Tom has been participating in the ALFALFA observations both in Arecibo and remotely, and is now one of the ALFALFA "expert observers". He just spent Thanksgiving at Arecibo introducing ALFALFA (and Arecibo!) to Aileen O'Donoghue, Jeff Miller, and Jamie Lomax, a senior St. Lawrence University. Tom's current ALFALFA project is a study of the spiral-rich Zwicky Cluster ZwCL 1400+0949 and its environs.

Tom began this work last year as the senior research project of his student Brian Walsh, who is now a graduate student at Boston University. It might be remembered that Tom was a summer student at Arecibo in 1973, but we both promise to keep pictures taken during that summer secret!

Tom Balonek

Courtesy Tom Balonek

Jamie Lomax, Aileen O'Donoghue and Jeffrey Miller; all from St. Lawrence University

Photo by Tony Acevedo

Tim Hankins

Al rescate desde Socorro …

The Editors

Tim Hankins joined the staff as interim site director on September 18 to fill the gap after Sixto González' term ended and while the search for a new site director is still ongoing. Tim is recently retired from New Mexico Tech, in Socorro, where he was a Professor of Physics. He has a long association with Arecibo going back to 1970, when he was a graduate student and first lived in Puerto Rico. Following his PhD, he joined the staff in 1974 and left in 1981. He has been a user of Arecibo throughout his career in his research on the fine-scale structure of pulsars. Tim will serve as site director until a new site director is hired, or until mid-March. Bienvenidos Tim!

Bienvendios Amy Lovell

The Editors

Amy Lovell came to Arecibo in August as a sabbatical visitor from Agnes Scott College, in Decatur GA, where she is an Associate Professor of Astronomy. Amy is also the head of the Arecibo Users and Scientific Advisory Committee. Amy is accompanied by her husband, David Smith, and their two children, Eron and Allen. Amy will be working on OH observations of comets with Ellen Howell. We welcome Amy and family to Arecibo!

Photo by Tony Acevedo

Amy Lovell


Johannes Wiig

Buena Suerte Paloma & Johannes

Jonathan Friedman

Paloma Farias Gutiérrez and Johannes Wiig left the Arecibo Observatory after nearly two years, where they were supported by John Mathews (Penn State) and worked on an assortment of projects. Johannes worked with Arvid Ahrberg (Penn State) and John Mathews on a Yagi antenna used for meteor observations. Both Johannes and Paloma worked hard helping Ilgin Seeker, a grad student at Penn State, maintain, calibrate, and operate the PSU UOPA all-sky imager. Paloma also got involved with the installation of a magnetometer from Mark Moldwin's group at UCLA. Paloma and Johannes are now graduate students at the University of Colorado and will be working on MLT projects using resonance lidar. In fact, Paloma is supported by a grant with Jonathan Friedman and will be returning to Arecibo to complete here PhD. Surf's up!


Paloma Farias

Two new telescope operators

José Cruz

In October we had 2 new arrivals in the control room (telescope operations), Wilson Hernández and Elliot González. Wilson comes to us from HP in Aguadilla, while Elliot comes to us from


Elliot González

Photo by Tony Acevedo

Software Systems consultants Inc. Both candidates have excellent knowledge in computers and software skills.

Buena Suerte Evelyn and Willie!

José Cruz


Evelyn Nelson

Photo by Tony Acevedo

Evelyn Nelson left the observatory at the end of June in search of new horizons. She was with us a very short time, but she made a strong impression. Not only was she a quick learner and competent telescope operator from early on, but she also demonstrated excellent technical and interpersonal skills that reached outside of the Control Room. Good Luck Evelyn!!

Willie Torres also left at the of July and relocated to Georgia. Willie served as a telescope operator for 15 years and was well liked and respected by staff and visitors alike. In addition to his competence in the control room, he organized summer volleyball tournaments during his early

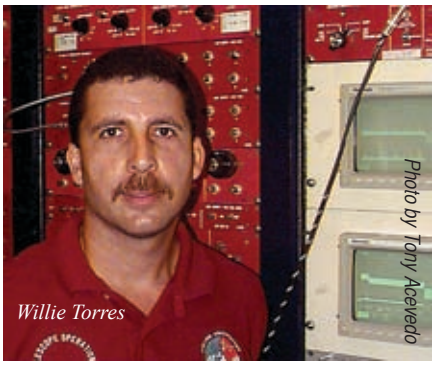

Willie Torres

Photo by Tony Acevedo


Wilson Hernández

Photo by Tony Acevedo

years at Arecibo. This was curtailed by an accident, but his positive "can do" attitude was always welcome. Best of luck, Willie!

Good Luck to Arvid Ahrberg

Editors

Arvid Ahrberg left the observatory in April, after a four month visit. He worked with John Mathews on a project to place a Yagi antenna on the carriage house for interferometric detection of meteor trails (see C&G article for Johannes Wiig). Arvid worked hard in his quiet way and managed to have a lot of fun. We hope to see Arvid back in Puerto Rico in the not too distant future. Hasta entonces, good luck Arvid!


Arvid Ahrberg

Photo by Tony Acevedo

New Cafeteria Hours

The Observatory cafeteria has started operating on a reduced schedule. On weekdays, breakfast hours are from 7:00 AM to 9:30 AM and lunch hours are from 11:30 AM to 1:30 PM. The cafeteria will close at 2:30 PM weekdays and is hereafter closed on weekends and holidays.

Amendments to the Observatory Travel Policy

For official visitors whose travel costs are being assisted by NAIC:
The Observatory has changed the policy for transportation to and from local airports (San Juan---SJU and Aguadilla---BQN). For this reason, we now offer those visitors two options:

1. The Observatory will reimburse up to $200 for car rental expenses for transportation between the Observatory and local airports (above). Eligible observers seeking such reimbursement must provide their original rental contract and receipt with the travel reimbursement claim form.

2. For visitors who cannot or prefer not to drive, who are unable to rent a car, or whose long stay at the Observatory make car rental cost excessive, the Observatory will arrange transportation for airport pickup and return by an Observatory driver and vehicle or by a local taxi company .

All visitors must communicate their travel arrangements to Carmen Segarra (*csegarra@naic.edu*) with a copy to Carmen Torres (*ctorres@naic.edu*) at least one month in advance to allow sufficient time to make appropriate arrangements. Note that *publicos* (private shuttle services) are no longer allowed to pick up passengers at the San Juan airport.

Other rules for the Arecibo Travel Support remain as they are listed on the Observatory's web site (*http://www.naic.edu/science/logistics.htm*). Please address any specific questions to Carmen Segarra.

Proposal Deadline

The next deadline for proposal submission is 1 February 2007 (although proposals may be submitted at any time). Submission for a given deadline implies that the observations are requested to be initially scheduled during the four-month period which starts four months after that deadline. Proposals have a validity of two four-month cycles. If a proposal has not been scheduled after this second period, it will not be considered further unless it is resubmitted.

A complete list of receivers available for this deadline can be seen at *http://www.naic.edu/~astro/RXstatus*.

Use of the Arecibo Observatory is available on an equal competitive basis to all scientists from throughout the world to pursue research in radio astronomy, radar astronomy and atmospheric sciences. Observing time is granted on the basis of the most promising research. Potential users of the telescope should submit a proposal to the Observatory Director describing their desired observations and the scientific justification for these. The procedures for submitting proposals, the mechanics of evaluation and the life-cycle of these proposals, are outlined at *http://www.naic.edu/~astro/proposals*.

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, HC03 Box 53995, Arecibo, PR 00612. Or, if you do not order reprints, please send publication information to csegarra@naic.edu for our records.

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."

Let's save those trees and printing costs! If you'd like to receive notification to download future newsletters from our web site and discontinue receiving paper copies, please email Jill Tarbell at jtm14@cornell.edu. Thanks!

http://www.naic.edu

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