Minutes of the Second ALFA Galactic Consortium (GALFA) Meeting

Boston University, Boston MA

June 18, 2003

The meeting started at the early hour of 8:00 AM. Thanks to our host, Tom Bania, we had a nice room equipped with all necessary visual presentation equipment. The GALFA consortium thanks him for making the effort to arrange for this, as well as the very agreeable dinner which followed the Second GALFA Consortium meeting.

Bob Brown (Director, NAIC) started with a summary of how NAIC views ALFA, and stated that he saw it as a “partnership”, rather than “users” plus “facility”. He is eagerly encouraging involvement of observers with the observatory. The question: “How much time will be made available for ALFA projects?” was asked, and the answer was that the fraction would be in the range 30 to 50 percent, and that the best way to get more time for ALFA or GALFA projects was to have a strong scientific case.

Paul Goldsmith (GALFA Consortium Chair) then reviewed the expectations for the meeting. Within a month, we should submit our “white paper” to NAIC. Drafts of all sections are in hand, but some are lacking references, and others, figures. He encouraged the appropriate coordinators (1) to get “finished” documents to him IN LATEX within three weeks; and (2) to send separately a short highlights section, to be used in the Executive Summary Section. This should also summarize key points regarding spectrometer, observing techniques, commensality, etc.

Paul reminded participants the the ALFA front end is on scheduled to be delivered to Arecibo in April 2004. There is this great urgency in starting on spectrometer development program if there are going to be commensal observations carried out. We also need to make progress on planning for
data reduction, a proposal for test observations (1 October deadline).

A short review of scanning observations with ALFA was presented, reviewing the technique of rotating the feed array by about 22 degrees, and thus getting 7 more or less equally spaced beams on the sky. The beam size will be 3.4’ x 3.1’. The Nyquist sampling interval ($\lambda/2D$) is equal to 102” x 90”, and the average beam spacing will be 125”. Thus, we do NOT get Nyquist sampling perpendicular to the scan direction. Projects have thus proposed various forms of “double” scanning, which can be interpreted to mean scanning with half-beam spacing, to achieve better-than-Nyquist sampling.

Some other numbers that may be useful:

Area of sky visible using Arecibo telescope = 13,200 square degrees
Area of Galactic plane visible = 195$|b_{max}|$ square degrees (scan from $-b$ to $+b$ degrees)

Drift scan rate is 15" cos$\delta$. < cos$\delta$ > = 0.9 for Arecibo. This yields a sky coverage range of 3.7 square degrees per hour. For “double” scanning the coverage rate is 1.85 square degrees per hour.

The Consortium next heard presentations of these science write-ups for the three sub-consortia, which are Continuum, Recombination Line, and HI.

Chris Salter gave a review of “GALFACTS” the all–Stokes parameter continuum survey of the whole Arecibo sky. They want to have 300 MHz coverage, with approximately 1000 channels, for RFI and RM studies. The great virtue of Arecibo is that it covers all spatial frequencies down to zero, while giving quite good angular resolution. The survey is proposed to be done in basket–weave fashion, with purely elevation scans on the meridian. This results in the sidelobes at least being a function only of one coordinate. At the 2.5 degree/minute elevation slew rate, one gets about 1.33 second per Nyquist sample. A key point is that while the total intensity will likely be confusion limited, the polarized intensity should not be. Thus, there is the possibility of getting at a great deal of exciting science. A continuous (“winking”) calibration would be desirable (this may already exist in principle, but needs to be tested). Pilot observations using L–wide receiver of known polarized sources would be very valuable in refining observing technique. Commensal observing with ALFALFA and possibly GALFA–HI projects is possible.

A variety of questions followed about observing techniques, gain calibration, data dump speed (e.g. transient science not just RFI excision). It was pointed
out that if the calibration modulation was done at high rate, for example 1 kHz, and the spectrometer has to be dumped for every half period, then the frequency resolution will be adversely affected.

Mayra Lebron (Arecibo) reviewed the plans of the Radio Recombination Line Sub–Consortium. In comparison with Hα, radio recombination lines benefit from having no extinction, but the continuum can be an issue. RRL studies include H, He, C (these are well-separated), and heavy element lines.

From the observations, the election temperature, $T_e$, distance, identification of thermal sources, and determination of the He/H abundance ratio can be carried out, and the interface between HII region and molecular clouds effectively studied. In this regard, PDR regions are also detected in CII 158 micron emission. This can be very effectively combined with carbon radio recombination lines (CRRL), which better trace the dense gas.

The goals of a GALFA–RRL study would be larger coverage in b, with better continuum determination, yielding $T_e$ and He/H, unravelling galactic structure, and maps of CRRL regions. L–band recombination lines include 163-174 alpha lines and 205-219 beta lines (in the range 1225–1525 MHz). The proposed survey covers $b = -5$ to $+5$ degrees, $l = 31$ to $77$ degrees and $170$ to $205$ degrees. Assuming that ten H recombination lines can be observed simultaneously, 300 seconds integration time will be required. Thus, this is a 

**staring** project. Commensal observation with a Galactic Plane pulsar search appears plausible.

Questions were asked about RFI, and Mayra indicated that 8 RRL lines have been observed at Arecibo and one is definitely very negatively impacted. It is not anticipated that this line will be observed.

Snezana Stanimirovic reviewed the HI GALFA observing projects. These were presented broken down into seven low–latitude projects and two high–latitude projects. The various scientific goals, sky coverages, integration times, and observing modes were presented. These form such an impressive set of exciting science that it is not really feasible to go through them all here. We include a summary viewgraph presented earlier by Paul Goldsmith. Note that the all specific numerical results must be regarded with caution at this point as the observing techniques are being reconsidered in light of the good effects expected from the elevation scanning while at the meridian approach (as compared to e.g. drift scanning).
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<thead>
<tr>
<th>CATEGORY</th>
<th>Observing Project</th>
<th>Int Time/Ptg or Nyq. Sam (s)</th>
<th>Area Covered (deg^2)</th>
<th>Total Time (hr)</th>
<th>Commensality</th>
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<td>HIGH-LATITUDE</td>
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<td>Turbulence</td>
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<td>HI and Mol Clouds</td>
<td>double drift</td>
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<td>1000</td>
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<td>Cold Neutral Medium</td>
<td>double drift</td>
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<td>Disk-Halo</td>
<td>staring</td>
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<td>HI Clouds in Halo</td>
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<td>all-sky</td>
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<td>E-gal(ALFALFA)!?</td>
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<td>Hi latitude line wings</td>
<td>double drift</td>
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<td>Hi latitude clouds</td>
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<td>Low-latitude GP survey</td>
<td>double drift</td>
<td>800</td>
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<td>Wings@forbidden vel.</td>
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<td>Full Stokes Survey</td>
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<td>Recombination Line</td>
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<td>Galactic Plane Survey</td>
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<td>PSR GP Survey</td>
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A number of interesting topics were addressed in questions which followed. These included data access. In this regard, a proprietary time is not yet decided, but there will definitely be public access. Some discussion of an idea apparently floated somewhere within NAIC about “locking up” the data followed, and this concept was broadly and roundly rejected by the consortium members as being totally unacceptable as well as contrary to current trends in astronomy. Data archiving also was discussed. It was felt that this is an NAIC responsibility, but that it may be possible to get additional support from NVO funds for developing tools for data mining. While NSF does not pay for archiving in the same way as NASA (supporting e.g. IPAC), it was felt that NSF does recognize the importance of accessible data archives, and that NAIC would have to get the funds to make this a reality.

The next section of the meeting was devoted to discussing two proposals for GALFA–specific spectrometers.

Paul presented the first, on behalf of NAIC, and in particular Jeff Hagen, who at the first consortium meeting had talked (in a somewhat preliminary fashion) about a “software FFT” spectrometer. The basic idea is that a commercial board plugged into PC PCI bus samples the two polarizations from an ALFA pixel, digitally downconverts them, and samples them. The existing ECHOTEK board does complex sampling of 5 MHz bandwidth, after digital downconversion and filtering, with the input in up to 40 MHz. This means that a separate mixing stage to convert from the ALFA IF frequency range of 100 to 400 MHz will be required. The computer CPU carries out FFTs of chunks of data 8192 samples long, then squares the real and imaginary parts, and sums them.

A 2.4 GHz Xeon CPU is 95 percent loaded carrying out these tasks, but in a year, it will probably be straightforward. Some diagrams and sample output of spectra containing noise and dela–function like signals were shown, indicating that this system really does exist and that it works! No tests have been run on S/N ratio, etc. and this could be a problem area, as emphasized in following talk by Carl Heiles. The parts budget for the overall system is 7 cards ($35,000) plus 8 PCs ($16,000), and the downconverter ($5000). The total parts cost is thus $56,000 (excluding spares). The eighth PC will coordinate the data taking and store the data from the entire array. The strong points of this approach are that is very close to being demonstrated as ready; it would be easy to replicate as there is no custom hardware or circuit
boards, and it is obviously readily upgradable as better PCs and boards become available. It does not address the issue of multiple recombination lines, beyond the fact that ECHOTEK board can handle two 2.5 MHz bands instead of 1.5 MHz band, and could thus do two successive RRLs. The signal to noise ratio issue must also be addressed.

Carl Heiles next gave a review of different types of digital spectrometers, focusing on signal to noise issues. He emphasized that the FFT approach yields an output channel response of the form \([\sin(x)/x]^2\), where \(x\) is proportional to the offset from channel center, as compared to \(\sin(x)/x\) for an autocorrelator (the difference is just since to get the power spectrum from the FFT you square the Fourier Transform of the voltage input as a function of time, while for the autocorrelator, the power spectrum is the Fourier Transform of the autocorrelation function. However, even the \(\text{sinc}^2\) response does not drop off fast enough to really isolate the response to an RFI spike. Thus, additional “weighting” is required, and if you do this by tapering the same samples within a data block (e.g. 8192 samples mentioned above), you end up losing about a factor of two in the signal to noise ratio if you compute \textbf{ONLY} the FFTs of successive data blocks. To obtain the maximum S/N, you have to do the FFT of data blocks offset by fractions of the block length. Based on numerical simulations, Carl showed that by the time you have included 4 offsets, you are fairly close to maximum S/N ratio, and with 8 offsets, you are very close.

Carl then discussed Berkeley proposal to use a field programmable gate array (FPGA) to carry out FFT, but using the polyphase filter algorithm, you get the effect of 1/8 block length offsets, with only approximately a factor of two increase in computational effort. The detailed description of this project is given in a separate document, and the total cost (parts plus labor) is estimated to be about $150,000. There are different options, but at the present time, these do NOT address the multiple RRLs, although extension to include 10 input segments should be relatively straightforward from the point of view of the digital part, albeit complex and costly in terms of multiple mixers and local oscillators.

Consortium members went to various restaurants and held discussions on various topics during lunch.

Immediately following lunch, Bob Brown communicated to Paul Goldsmith NAIC’s position on spectrometer development, and this was shared with the
members. NAIC will support the Berkeley development effort by providing $40,000 which should lead to development of prototype spectrometer by the end of the year. Simultaneously, Jeff Hagen will be assigned to essentially full-time work developing the software–FFT approach, optimizing choice of A/D card and software, and leading to an on–telescope demonstration within three months. A decision about which route to follow to a complete system will be made when the two systems have reached appropriate levels of development, likely by the end of 2003. Paul will write up draft statements of work for Berkeley and NAIC approaches. The consortium membership was extremely happy with NAIC’s support, and commitment to the development of a GALFA–specific spectrometer that will satisfy scientific needs and will allow commensal observing to ensure efficient use of the telescope.

The next discussion topic was that of data reduction. Juergen Kerp presented the pipeline developed by Christian Bruens (Uni Bonn), which has been very successfully used with Parkes multibeam HI data, and is written in C++ within AIPS++ environment. There are three stages:

1. I: [on line]: raw data processed with basic baseline removal (allows quick look at data) → $T_0$
2. II: [off-line]: calibration, RFI identification and excision, and baseline subtraction → $T_a$
3. III: [off-line]: stray radiation correction? → $T_b$

Juergen informed the consortium that Christian has very generously offered to make his data reduction pipeline software available to GALFA. A vigorous discussion ensued, which touched on issue of IDL vs. AIPS++, and the uncertainty in the latter due to dissolution of AIPS++ consortium. The general feeling is that despite limited success, the future of AIPS++ was very doubtful. One reason is the very slow speed of interpreted (glish) vs .compiled code. IDL is very attractive in that you can include subroutines written in C++. But IDL is extremely expensive in Europe, and small groups, such as Uni Bonn, simply cannot afford it.

Members were dealing with different concepts for optimizing the pipeline. One such mentioned was having C++ code from Christian’s software transplanted to IDL, which being a commercially supported product with large
user base, should be quite stable. Some arrangement might be made to support this, in terms of license, etc. Another point brought up was that the griddle tool in AIPS++ is very useful, and it would be a shame not to be able to use it. The approach should be to find out exactly what language that code is written in, and see whether it, too, might be transplanted to a different environment. It was mentioned that NAIC is searching to hire an additional programmer to work on data reduction and archiving for ALFA, and getting a new person started on such a well-defined task, especially with help from consortium members, might work out quite well. Support from other NAIC staff would probably be greater for IDL based system than anything else. It was decided that Paul will contact Christian Bruens and ask him what he can see himself doing, and what he thinks is the best route to follow.

The discussion then expanded to more general issue of data reduction and analysis, including the vexing issue of correcting for stray radiation as well as the near-in (coma) sidelobes of the off-axis array elements. There are various possible approaches, most would be very computationally intensive, and also demanding in terms of peoples’ time to get them to work. This might require additional support, as could be available from NSF ITR program, but it was mentioned that it has been hard to get reviewers (panels) excited about task of astronomy data reduction.

Another topic got focused attention—that of preparing a proposal for test observations. Carl Heiles agreed to coordinate this effort and write the proposal (1 October 2003 deadline). This will include testing different observing strategies (drift, basket weave,...) experiment with getting rid of instrumental effects (frequency switching; median passband correction; use of larger bandwidth spectrometers to fit the “ripple” pattern). ”Who will do the observing (and presumably the work of analyzing data?” was a good question that was asked. While presumably a lot will have to be done by consortium (non-NAIC) members, it was mentioned that there will be two new postdocs at Arecibo by the Fall, as well as possibly a new senior radio astronomy staff member.

Finally, some aspects of Consortium issues were discussed. The next meeting should probably be in January 2004 time frame, with possible locales including Arecibo and Atlanta (associated with winter AAS meeting). The logistics of getting to and from Arecibo are a little extra hassle, but having
meeting there (at least every other one) does get a much larger range of staff involved. There could also be a demonstration of NAIC software–FFT system (at least), as well as other good advantages. On the other hand, many will be in Atlanta, but not all. This will be resolved by email, and possibly by telecon; it was indicated that the consortium members felt that continuing telecons were a good idea.

Please do not forget that the GALFA web site is

http://alfa.naic.edu/alfa_galactic.html

These minutes were edited by Paul Goldsmith, based on the excellent on-line notes taken by Di Li.