Progress Report and Request for Continuation of the ALFALFA Survey
31 July 2008

R. Giovanelli for the ALFALFA Collaboration

Overview of progress to date: ALFALFA, the Arecibo Legacy Fast ALFA Survey, is a two-pass drift scan spectral line survey intended to cover 7000 deg^2 of high galactic latitude sky visible from Arecibo, with ∼eight times the sensitivity, four times the angular resolution, three times the spectral resolution, and 1.6 times the total bandwidth of HIPASS. The survey is intended to map, with complete 2-pass coverage, the region from 0° to +36° in declination and from 22^h <R.A.< 3^h (the "fall sky") and 7^h30^m <R.A.< 16^h30^m (the "spring sky"). Because of its wide areal coverage, moderate depth and photometric accuracy, ALFALFA is providing a legacy dataset for the astronomical community at large, serving as the basis for numerous studies of the local extragalactic Universe. The fixed azimuth "minimum intrusion" technique which ALFALFA employs delivers high data quality and observing efficiency: with the exception of hardware failures, science data are acquired during ∼ 97% of each assigned observing block and 99% exclusive of setup/shut down. Furthermore, the TOGS program has run commensally with ALFALFA since August 2005, with the observing burden for TOGS borne by the ALFALFA team. As of July 15, 2008, ∼ 40% of the survey area has been fully mapped and sources have been extracted from Level II spectral data products (3-D cubes) covering about 25% of the total sky area. Three catalogs extracted from the Level II data have appeared in the refereed literature (Giovanelli *et al.* 2007; Saintonge *et al.* 2008; Kent *et al.* 2008a). SQL searchable databases and plotting tools are made public when their associated presentation papers are accepted for publication (as per VO requirement). To date, 14 papers based on ALFALFA have appeared in the refereed literature, and several others are submitted or in advanced stages of preparation. Numerous papers and posters have been presented at conferences; see: *http://egg.astro.cornell.edu/pubs.php.*

Team members have web access to preliminary, searchable source catalogs for the planning and execution of multiwavelength followup observations. Because ours is an open consortium, scientists motivated to undertake a specific science project are encouraged to join the ALFALFA team and submit a proposal to the ALFALFA Oversight Committee (OC). Upon approval of their proposed project by the OC, new members then gain access to the ALFALFA dataset in advance of its public release. This policy is stimulating a continuous increase in the number of ALFALFA-based projects and seeds multiwavelength observing programs using other facilities as well as numerical simulations; see: *http://egg.astro.cornell.edu/projects/projects.php.*

The ALFALFA IDL-based data reduction, signal extraction and ancillary software package has been exported to 20+ sites where it is in regular use by team members. Well-developed documentation, websites, and hands-on training in observation and reduction techniques are provided to new team members by ALFALFA experts. Numerous members of the ALFALFA team have spent time at Cornell to receive intensive training in the observing, data reduction and data analysis process; other communications include the use of telecons and visits by the Cornell experts to other sites. Two ALFALFA-based Ph.D.s have been completed, seven others are underway, and two more junior students are formulating thesis plans; see *http://egg.astro.cornell.edu/alfalfa/projects/phdprojects.php.* The ALFALFA dataset has already served as the basis of eight senior thesis projects and over two dozen undergraduates have been involved in research projects and/or workshop activities; see *http://egg.astro.cornell.edu/alfalfa/projects/ugradprojects.php.*

For the sake of brevity, we include here the URLs of websites where various documents previously submitted to NAIC or containing information of direct relevance can be obtained:

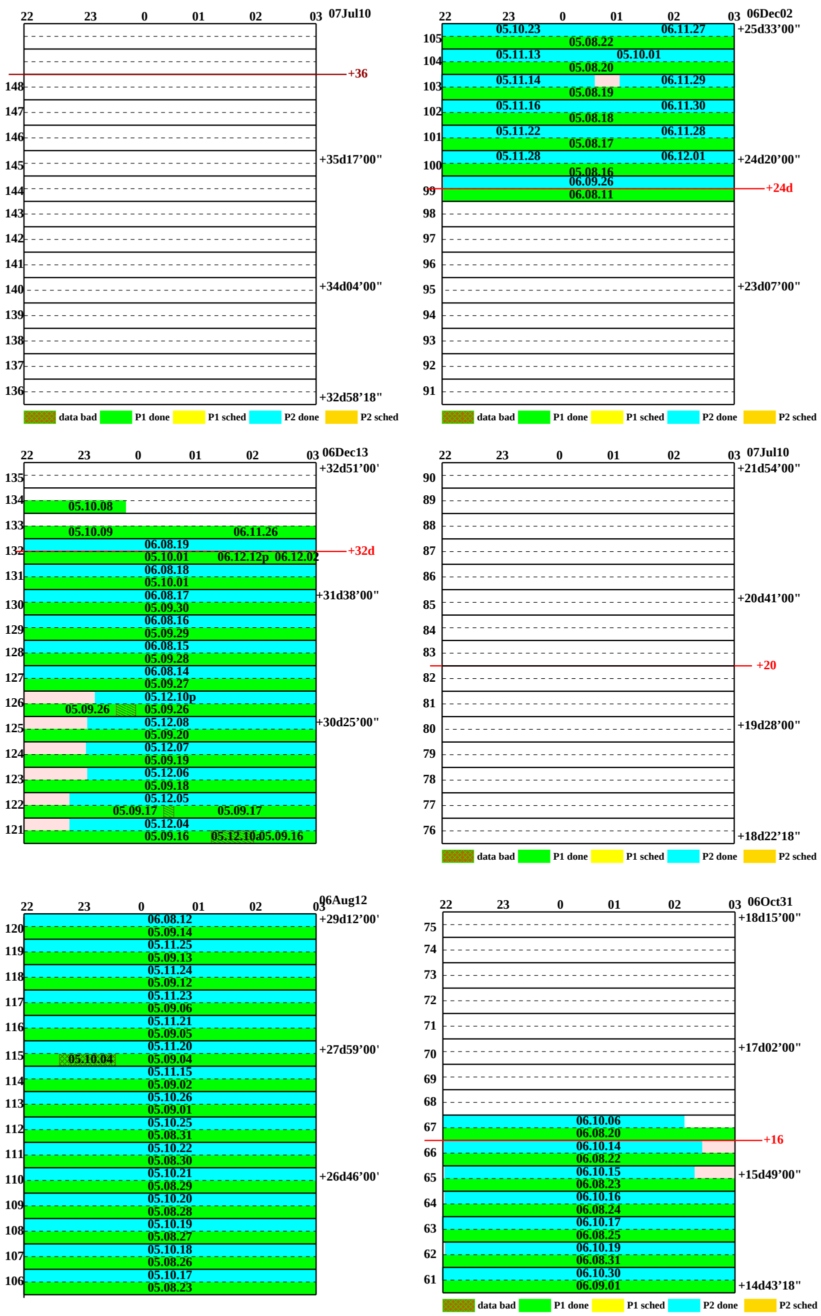
- ALFALFA survey public website
  http://egg.astro.cornell.edu/alfalfa/
- ALFALFA documentation website (including the original proposal and prior annual reports)
  http://egg.astro.cornell.edu/alfalfa/docs/index.php
- ALFALFA observing team website
  http://www.naic.edu/∼a2010/galaxy_a2010.html
- Cornell HI digital archive website
  http://arecibo.tc.cornell.edu/hiarchive

ALFALFA highlights since July 2007: As described in previous reports, the ALFALFA collaboration is engaged in many activities which revolve around the survey and its applications for science, education, training and outreach. Here we provide only updated information which specifically outlines the current status of the A2010 observing program and ALFALFA survey team accomplishments in the last year. Previous annual reports contain earlier highlights.

• **A2010 Observational Program:** As of 15Jul08, Project A2010 has been scheduled for 2597 hours of telescope time or 59% of the original request. Drift scan data have been acquired during 443 separate observing sessions since February 2005. A well defined and well documented protocol of tasks and their assignments insures observing efficiency and data quality; See: *http://www.naic.edu/∼a2010/whodoeswhat.htm*. Haynes oversees the sequence of observations. At all times, a trained ALFALFA observer oversees the observing sequence, including execution of the TOGS calibration before and after the A2010 time when TOGS calibration time is allocated. The observer is also responsible for maintaining a standard log file (made accessible to the TOGS team) and performing regular data quality checks. At the end of the observing session, the observer updates the observing team web pages and starts a script which converts the FITS files to IDL structures. The "data monitor", a different person located at Cornell, checks the observer's notes, takes any required actions recommended by the observer, transfers the raw IDL files to Ithaca and updates the scheduling web pages. New datasets are calibrated, bandpass subtracted and spot checked every few days as an additional check on data quality. Further Level I processing is organized to generate datasets covering contiguous areas so that final 3-D grids can be produced.

In terms of efficiency, ALFALFA records data continuously, with an "open shutter" rate of 99%. About 5% of the allocated time is used for setup and telescope slew time; in practice, during another 5% of the time, the LST range is outside of the survey map area. Because time is often allocated in blocks shorter than optimal for our mapping strategy but for the convenience to the AO scheduler trying to accommodate multiple observing programs, the actual time allocation leads to some loss of optimal efficiency and coverage for the ALFALFA program. However, lost telescope time is minimal; only 9 full sessions have been totally lost due to hardware failures (2% of sessions).

Graphical illustrations of the actual map coverage are shown in Figure 1 for the "fall" sky, 22^h <R.A.< 3^h and Figure 2 for the "spring" sky: 7^h30^m <R.A.< 16^h30^m (right), separately. Completed observations of each area in the two passes are illustrated separately, with green highlighting the first pass, and cyan, the second. The date of each observing block is indicated as YY.MM.DD. Bad data are highlighted in brown and are generally replaced by a second set of observations. Pink shaded areas denote those intended to be mapped in the current scheduling year. Note that full resolution, updated images can be found at *http://egg.astro.cornell.edu/alfalfa/scheds/index.php* along with more detail summary information of completed and planned observations.



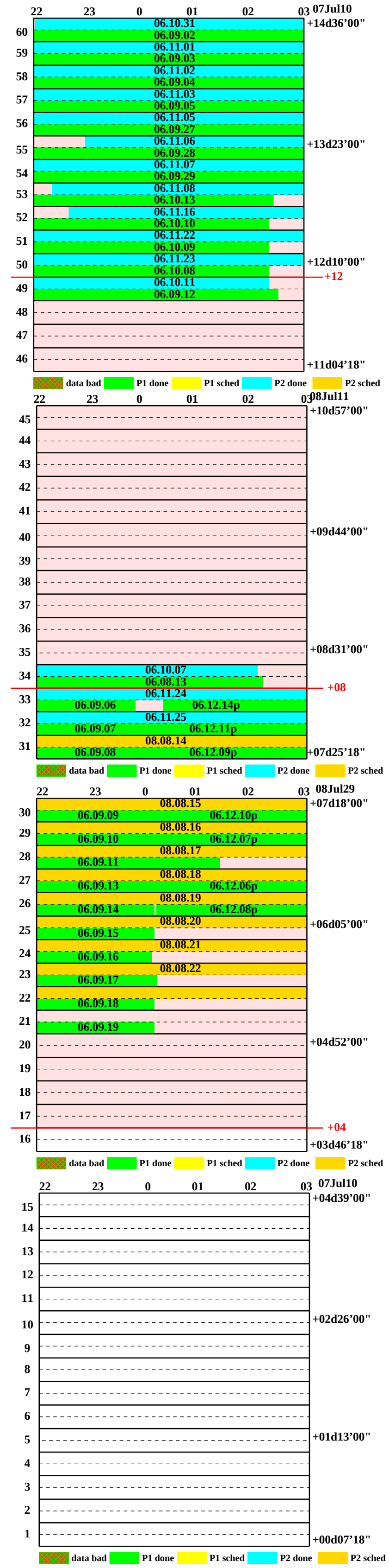
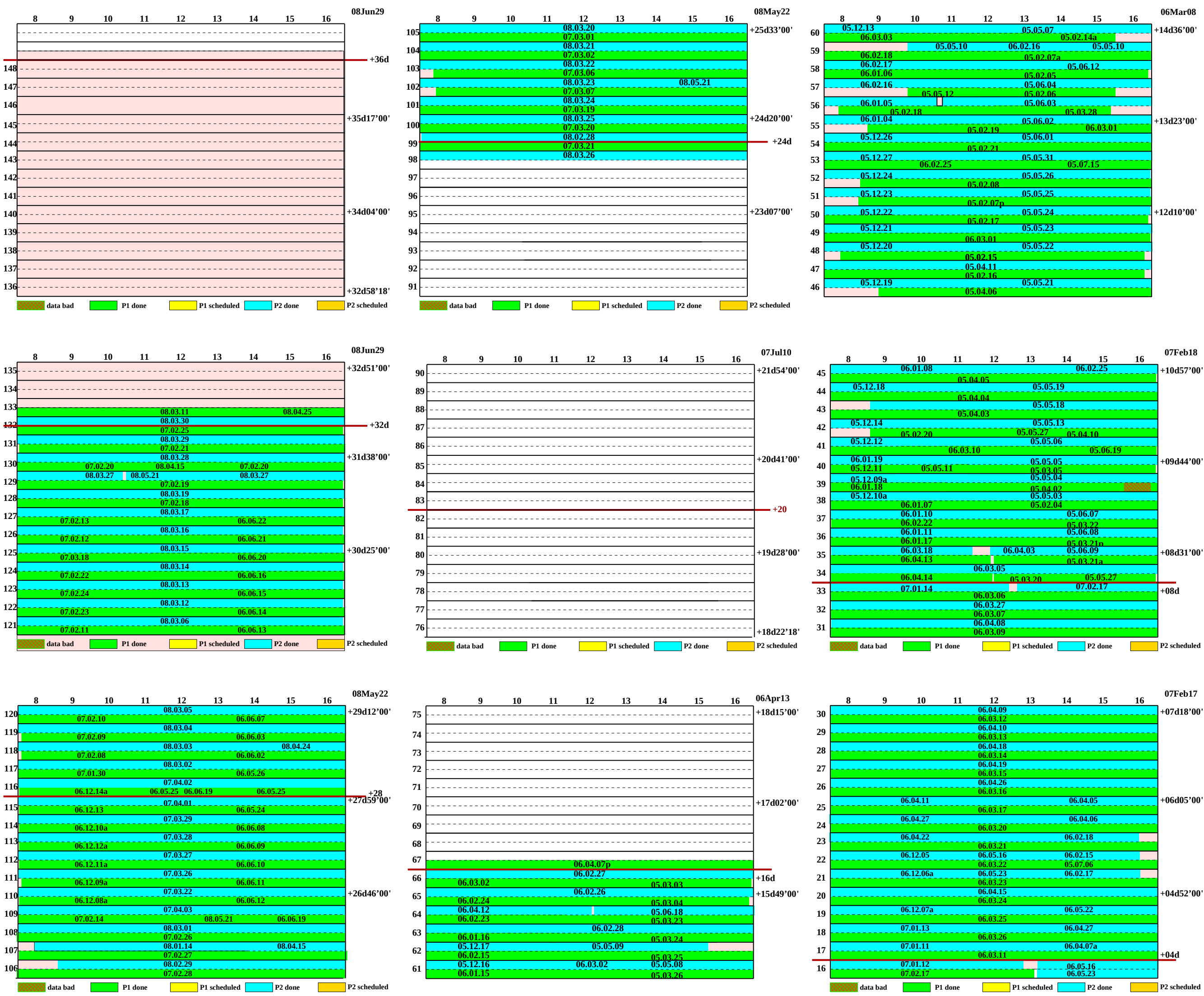


Figure 1: Actual A2010 sky coverage for "Fall" area:
$22^h00^m <$R.A.$< 03^h00^m$ as of 28Jan2007.
The vertical axis is declination, indicated by ALFALFA drift designation.
Both passes are indicated, along with observing dates.
No data were acquired during Fall 2007.
Higher resolution images are available at:
http://egg.astro.cornell.edu/alfalfa/scheds/status_fall08.php



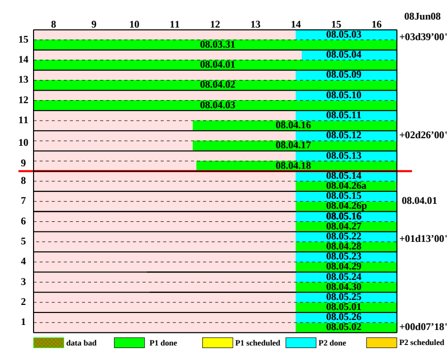


Figure 2: Actual A2010 sky coverage for "Spring" area: 7^h30^m <R.A.< 16^h30^m as of 01June2008.
Both passes are indicated, along with observing dates.
Higher resolution images are updated regularly at:
http://egg.astro.cornell.edu/alfalfa/scheds/status_spr08.php

- **Science Highlights:**

Although still in the early stages, ALFALFA is already delivering on its promised scientific harvest. Here are some of the most interesting results achieved in the last year:

HI census: A comparison of ALFALFA and HIPASS is clear from inspection of Figure 3. The working catalog used to make this diagram covers 20% of the final ALFALFA survey volume and includes 6235 high quality sources, 1407 "priors" (lower S/N but with a likely optical counterpart of coincident redshift) and ~ 300 possible high velocity clouds. Of the ~ 7900 ALFALFA sources displayed, HIPASS would detect fewer than a few dozens to its completeness level, and a few percent to its overall detection limit; in fact, the HIPASS catalog includes only 290 objects in the same region of sky (which it fully sampled).

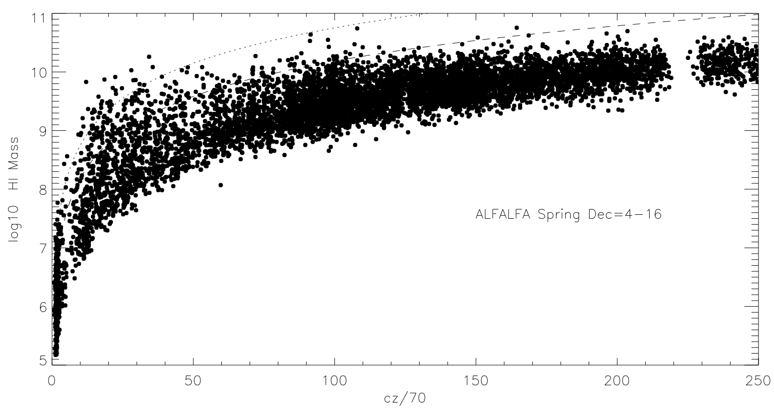


Figure 3: Spänhauer plot of 7938 HI sources in the region R.A.=[7.5^h–16.5^h], Dec=[4°–16°]. Nearby objects of uncertain distance, possibly galactic HVCs, "pollute" the plot at $M_{HI} < 10^{6.5}$. The two superposed lines identify the HIPASS completeness limit for sources of 200 km s^{-1} linewidth (dotted) and the overall detection limit (dashed). Note that due to RFI, ALFALFA is effectively blind in the redshift range between approximately 15000 and 16000 km s^{-1} because of the FAA radar at 1350 MHz (although the radar was silent for several months this spring).

Figure 4 shows a cone diagram of the status of redshift observations in a nearby slice of the sky covered by both ALFALFA and SDSS, focusing on the local volume out to $cz < 8000$ km s^{-1}. The sky area extends from $07^h30^m <$ R.A. $< 16^h30^m$ and $+08° <$ Decl. $< +16°$. Different symbols show the locations of subsets with redshifts derived from optical observations only (red open circles), HI only (blue filled circles) and both (green open circles). The central region of this strip is dominated by the Leo and Virgo regions within the Local Supercluster at $cz < 2000$ km s^{-1}, while the eastern half shows the southern edge of the "Great Wall" and the filaments leading to Coma further to the north. Clearly the optical surveys, in this case mainly SDSS plus targeted surveys of groups and clusters, dominate the highest density regions, while the gas-rich galaxies trace the filamentary structures in more detail. Note that ALFALFA contributes a host of new redshifts at the nearer distances; these are typically low surface brightness, faint galaxies which populate the lowest density quartile.

A first tantalizing result has been obtained by Saintonge *et al.* (in preparation) who analyzed the ALFALFA catalog covering a portion of the nearby void in front of the Pisces-Perseus Supercluster at $cz \sim 2000$ km s^{-1}. Within a volume of 460 Mpc^{-3}, ALFALFA detects not a single galaxy. In contrast, we would have expected to detect 38 HI sources in such a volume based on scaling the predictions of the Mare Nostrum simulation (Gottlöber *et al.* 2003) with a dark–to–HI mass ratio

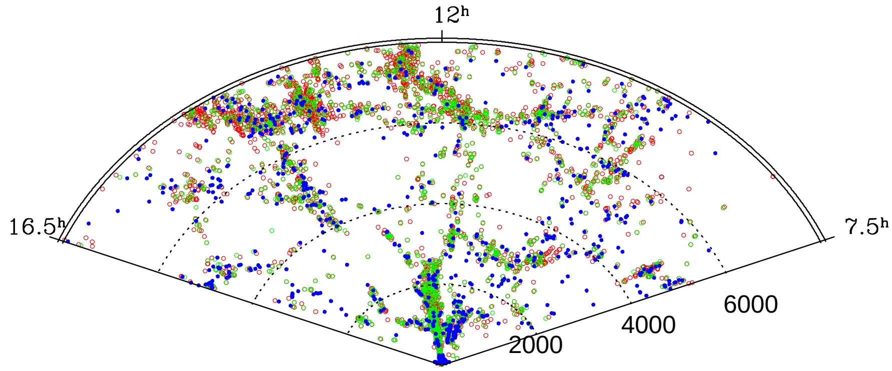


Figure 4: Radial distribution of 5670 galaxies with measured radial velocities $cz < 8000$ km s^{-1} in the ALFALFA strip from $07^h30^m <$ R.A. $< 16^h30^m$ and $+08^\circ <$ Decl. $< +16^\circ$. Different colors denote galaxies whose redshifts are drawn from, respectively, optical only (red), HI only (blue) and both (green). The HI-rich galaxies trace the same structures seen by optical surveys; the few "void" galaxies seen here are gas rich as expected. When complete, ALFALFA will provide a statistically complete picture of the local filament and void population. From Haynes (2008).

of 10:1. It is not clear if this discrepancy, based on only 2% of the ALFALFA catalog, is real or just another example of the perils of volume limitations. Once sufficient volume is sampled, ALFALFA will be able to place stringent constraints on the local void population and its possible challenge to the ΛCDM paradigm (Peebles 2001). Lack of volume sampling would also explain the discrepancies between conclusions on the spatial correlation function proposed by different groups analyzing the same HIPASS dataset (Basilakos *et al.* 2007, Meyer *et al.* 2007). The median cz of the ALFALFA survey is near 8000 km s^{-1} (versus $<$ 3000 km s^{-1} for HIPASS), the typical scalelength of baryonic acoustic oscillations. ALFALFA is the *only* large–scale HI survey which samples a fair volume of the Universe.

Moreover, a large fraction of HIPASS sources suffer from confusion because of the large Parkes telescope beam, making the identification of optical counterparts difficult and often impossible without follow–up, higher resolution HI observations. The smaller Arecibo beam largely obviates the problem: more than 95% of ALFALFA sources can be unambiguously associated with the correct optical counterpart. Confusion within the Parkes beam severely limits the HIPASS findings on the HI content of early type galaxies (Oosterloo *et al.* 2007). As viewed by ALFALFA so far, 40% of the Local Supercluster E/SO's *outside Virgo* have measurable HI if not coincident with their stellar components, then near them (Grossi *et al.* in preparation).

A Blind HI Survey of the Virgo Region: The initial ALFALFA results cover the central region of the Local Supercluster, in and around the Virgo Cluster (Giovanelli *et al.* 2007; Kent *et al.* 2008a). The northern part of the cluster, now fully mapped by ALFALFA to a detection limit of 2×10^7 $M_\odot$, is shown in Figure 5. The image clearly illustrates the impact of the ICM on gas content of galaxies. A number of HI streams, without optical counterparts but some of which can be tracked over degrees ($1^\circ \simeq 300$ kpc at the cluster distance (Kent *et al.* 2007; Haynes *et al.* 2007; Koopmann *et al.* 2008; Kent *et al.* 2008b). Many of these features are detected near the column density limit of ALFALFA ($\sim 5 \times 10^{18}$ cm^{-2}), suggesting that ALFALFA — while allowing us to see these structures for the first time — may be seeing just "the tip of the iceberg". A recent discovery is the ∼500 kpc HI stream southwest of the HI-rich pair NGC 4532/DDO 137 (Koopmann *et al.* 2008). Including diffuse emission, the structure has a total mass of up to 7 x 10^8 $M_\odot$, equivalent to ∼10% of the system's HI mass.

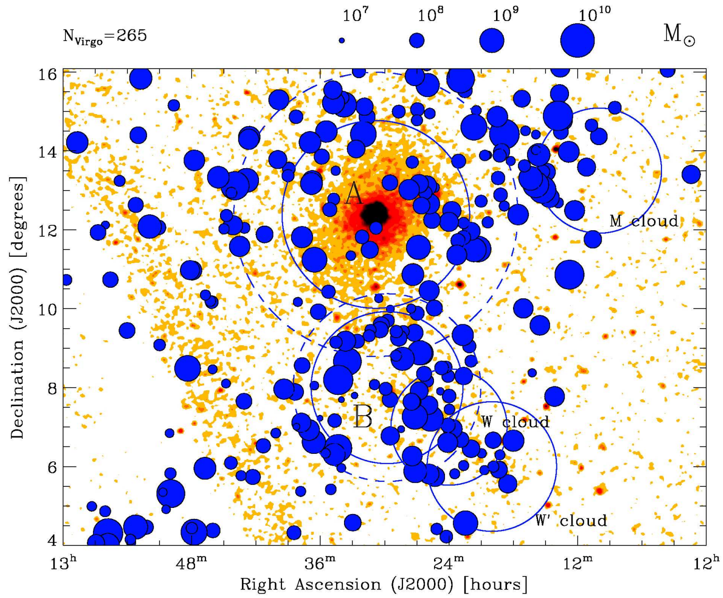


Figure 5: Global composite image of the Virgo cluster region. The ROSAT X ray image is displayed in orange shading. HI sources detected by ALFALFA and assigned to membership in one of the Virgo subclusters are shown as blue filled circles; their size is proportional to their HI mass. Dashed blue circles outline the main substructures, the A and B clusters and the M, W and W′ clouds (Binggeli, Tammann & Sandage 1987). The well-known HI deficiency of galaxies in the cores of clusters A and B is captured by this image. From Kent (2008).

On-going work includes derivation of the HI mass function in Virgo; a significant absence of high HI mass systems is apparent, caused by the well-known HI deficiency of cluster spirals (Kent 2008). Members of the ALFALFA collaboration are exploiting multiwavelength data and numerical simulations to explore the detailed properties of the galaxy population and the mechanisms likely at play in the Virgo region (di Serego Alighieri *et al.* 2007; Gavazzi *et al.* 2008; Kent *et al.* 2008b).

Dwarf galaxies: ALFALFA is specifically designed to detect very low mass galaxies in the local universe. HIPASS detected fewer than two dozen sources with HI mass $< 10^{7.3}$ $M_\odot$; ALFALFA is on track to detect a few hundred. Besides its sensitivity advantage, ALFALFA's superior spectral resolution allows detection of HI lines as narrow (FWHM) as 10 km sec^{-1} (Saintonge 2007a; Saintonge *et al.* 2008), characteristic of the lowest mass halos. In addition to Virgo, observations are now complete for the Leo region, including the two groups Leo I at 10 Mpc and Leo II at 17.5 Mpc and include, just for that relatively small volume, almost 100 objects with HI mass $< 10^8$ $M_\odot$. Stierwalt *et al.* (in preparation) are finalizing the derivation of the HI mass function for Leo I, accounting for the effects of incompleteness and bias and tidal debris; future ALFALFA coverage will include several other groups at ~ 10 Mpc for comparison. Members of the ALFALFA team are conducting a coordinated campaign of optical imaging and long-slit spectroscopy, GALEX imaging and HI synthesis studies to probe the impact of local environment of the population of low HI mass, gas-rich dwarf galaxies discovered by ALFALFA (Saintonge 2007b, Stierwalt *et al.* in preparation).

On-going accretion in M33?: ALFALFA is cataloging high velocity clouds associated with the Milky Way; several such clouds close to M33 have also been discovered in the ALFALFA dataset (Grossi *et al.* 2008). The interpretation of these clouds is difficult, but if they are associated with M33, the total gas mass associated with them is $\geq 5 \times 10^7$ M$_\odot$. If the gas is steadily falling towards the M33 disk, it can provide the fuel needed to sustain the current star formation rate of 0.5 $M_\odot$yr^{-1}. This paper has been selected to be featured on the front page of the A&A issue in which it is appearing.

High HI mass galaxies ALFALFA detects galaxies with HI masses as high as $10^{10.8} M_\odot$, representative of the massive disks likely to be studied at high redshift. Many of these are large, luminous galaxies with well-delineated spiral arms. Some have extended, low surface brightness disks. As a class, these objects provide a glimpse of the gas-rich component of the "transition mass" systems targeted by the GALEX-Arecibo-SDSS survey (A2335: D. Schiminovich P.I.) and the optically-selected gas-rich galaxies detected at Arecibo at $z \sim 0.2$ (Catinella *et al.* 2008). Several ALFALFA team projects are underway to study these objects and their properties as a class, and the ALFALFA data catalog is being used by the GASS team to plan their observing program.

ALFALFA as a testbed for HI structure measurements: A number of experiments currently under construction attempt to detect HI photons emitted in the epoch of reionization or even earlier. It may also be possible to extend HI structure observations developed for these EOR experiments to lower redshift. However, the practical limitations to HI structure measurements are foreground subtraction and systematic control. Because of its sensitivity and depth, the ALFALFA dataset may offer unique insight into the limitations of such diffuse 3-D power spectrum observations. Morales and Bowman are performing an HI autocorrelation analysis in diffuse fields using the ALFALFA dataset to explore applications of this novel technique to dark energy and large scale structure studies.

The Undergraduate ALFALFA (ALFALFA-U) Groups of Galaxies Project: Nearby groups of galaxies provide useful laboratories for studies of the impact of environment on gas content, morphology, star formation rate, nuclear activity, etc. Members of the ALFALFA-U team have begun a collaborative study of selected groups of galaxies included in the ALFALFA volume; most are also included in the RASSCALS X-ray survey (Mahdavi *et al.* 2000). Using ALFALFA and complementary data available in the literature or from digital databases like SDSS, trends in stellar mass, color, gas content, location within the group, etc will be investigated. By pooling together the work undertaken by different institutions within the ALFALFA-U, we will be able to undertake a comparative study of environmental effects in groups of different richness, X-ray luminosity, velocity dispersion, etc. This project involves undergraduates at the participating institutions, is forming the basis of numerous senior thesis/research projects and fosters the continued engagement of members of the ALFALFA-U team, most of whom teach at principally undergraduate institutions. Telecons are held monthly to discuss issues associated with science and data analysis. A mini-workshop centered on the groups of galaxies project was held on July 16, 2008. Team members, including undergraduate students, from Colgate, Siena, Skidmore and Siena met at Union College for the day while others from Cornell, George Mason, Georgia Southern, Lafayette and St. Lawrence joined by telecon. Students gave progress reports on their work to date, and faculty discussed how to coordinate efforts to perform the science analysis. See: *http://egg.astro.cornell.edu/alfalfa/ugradteam/uat_union0807.php*.

References

Basilakos, S. *et al.* 2007, M.N.R.A.S. 378, 301.
Binggeli, B., Tammann, G.A. & Sandage, A. 1987, Astro.J. 94, 251.
Catinella, B. *et al.* 2008, Ap.J.(Lett.) (submitted).
Gavazzi, G. *et al.*, 2008, A&A 482, 43.
Giovanelli, R. *et al.*, 2005, Astro.J. 130, 2589.
Giovanelli, R. *et al.*, 2007, Astro.J. 133, 2569.
Gottlöber, S. *et al.*, 2003, M.N.R.A.S. 344, 715
Grossi, M. *et al.*, 2008, A&A (in press).

Haynes, M.P. 2008, *Il Nuovo Cimento B* 123, 2008-10442-9
Haynes, M.P., Giovanelli, R. & Kent, B.R. 2007 Ap.J.(Lett.) 665, L19-22.
Kent, B.R., *et al.* 2008a, Astro.J. 136, 713.
Kent, B.R., *et al.* 2008b, Ap.J. (submitted).
Kent, B.R. 2008, Ph.D. thesis, Cornell University.
Koopmann, R.A., *et al.* 2008, Ap.J.(Lett.) 682, L85.
Mahdavi, A.*et al.*, 2000, Ap.J. 534, 114
Meyer, M.J.*et al.* 2007, Ap.J. 654, 702.
Oosterloo, T.A. *et al.* 2007, A&A 465, 787.
Peebles, P.J.E. 2001, Ap.J. 557, 495.
Saintonge, A. 2007a, Astro.J. 133, 2087.
Saintonge, A. 2007b, Ph.D. thesis, Cornell University.
Saintonge, A., *et al.* 2008, Astro.J. 135, 588.
di Serego Alighieri, S., *et al.*, 2007, A&A 474, 851.

- **ALFALFA Refereed Papers since Aug 1, 2007:**

  1. Kent, B.R., Spekkens, K., Giovanelli, R., Haynes, M.P., Momjian, E., Cortés, J.R., Hardy, E. & West, A. 2008, Ap.J. (submitted)
  2. Grossi, M., Giovanardi, C., Corbelli, E., Giovanelli, R., Haynes, M.P., Martin, A.M., Saintonge, A. & Dowell, J.D. 2008, A&A (in press)
  3. Koopmann, R.A., Giovanelli, R., Haynes, M.P., Kent, B.R., Balonek, T.J., Brosch, N., Higdon, J.L., Salzer, J.J. & Spector, O. 2008, ApJL 682, L85
  4. Kent, B.R., Giovanelli, R., Haynes, M.P., Martin, A.M., Saintonge, A., Stierwalt, S. Balonek, T.J., Brosch, N. & Koopmann, R.A., 2008, Astro. J., 136, 713
  5. Haynes, M.P. 2008, Il Nuovo Cimento B 123, 2008-10442-9
  6. Giovanelli, R. 2008, Il Nuovo Cimento B 123, 2008-10447-4
  7. Gavazzi, G., Giovanelli, R., Haynes, M.P., Fabello, S., Fumagalli, M., Kent, B.R., Koopmann, R.A., Brosch, N., Hoffman, G.L., Salzer, J.J. & Boselli, A. 2008, A&A 482, 43
  8. Saintonge, A., Giovanelli, R., Haynes, M.P., Brosch, N., Hoffman, G.L., Kent, B.R., Martin, A.M., & Stierwalt, S. 2008, Astro. J. 135, 588
  9. di Serego Alighieri, S., Gavazzi, G., Giovanardi, C., Giovanelli, R., Grossi, M., Haynes, M.P., Kent, B.R., Koopmann, R.A., Pellegrini, S., Scodeggio, M. & Trinchieri, G. 2007, A& A 474, 851

In addition, a number of papers and posters were presented at conferences by team members. For a complete listing, see *http://egg.astro.cornell.edu/alfalfa/pubs.php*.

Seven other papers, listed below by subject (not exact title), are in the advanced stages of preparation and should be submitted within the next few months. Several other manuscripts are in early draft stages, and we can anticipate with confidence a steady stream of ALFALFA-related publications and a growing list of first authors, many of whom are early career astronomers. Note that Kent, Martin and Stierwalt are graduate students and Grossi is a postdoc.

1. Giovanelli, R. *et al.* (in preparation) : ALFALFA catalog of the complete Spring region from $+12°$ to $+16°$ ($\sim$2480 HI detections)

2. Haynes, M.P. *et al.* (in preparation): ALFALFA catalog of the complete Spring region from +08° to +12° (∼2460 HI detections)
3. Kent, B.R. *et al.* (in preparation): The HI mass function of the Virgo Cluster
4. Koopmann, R.A. *et al.* (in preparation): ALFALFA catalog of the Spring +07° declination strip (∼1300 HI detections)
5. Martin, A.M. *et al.* (in preparation): ALFALFA catalog of the Fall +25° declination strip (∼540 HI detections)
6. Grossi, M. *et al.* (in preparation): HI in field ellipticals
7. Stierwalt, S. *et al.* (in preparation): ALFALFA catalog of the Leo region and derivation of the HI mass function in the Leo group

• **ALFALFA graduate theses completed since Aug 1, 2007:** Amélie Saintonge completed her Cornell Ph.D. in August 2007 on *Properties of Low Mass Dwarf Galaxies in the ALFALFA Survey*; she is currently a postdoctoral research associate at the University of Zurich. Having defended his thesis *Toward the Virgo Cluster: On the Study of Neutral Hydrogen in the Local Universe* on 23Jun08, Brian Kent will receive his Ph.D. from Cornell in August 2008 and will assume a Jansky Fellowship at the National Radio Astronomy Observatory in Charlottesville.

• **ALFALFA senior theses and research projects completed since Aug 1, 2007:** Five senior theses were completed during AY '07-08: Peter Shively (Colgate '08; adviser T. Balonek), Tristan Wolfe (St. Lawrence '08; adviser A. O'Donoghue), Shawn Golley (St. Lawrence '08; adviser A. O'Donoghue), Nate Calabro (Union '08; adviser R. Koopmann) and Arthur Sugden (Wesleyan; adviser J. Salzer).

• **Growth of the ALFALFA Team** In keeping with the adopted ALFALFA guidelines for the science collaboration, a number of new, specific science projects, have been proposed and approved by the ALFALFA Oversight Committee; more are expected in the coming months. Active project summaries can be found at *http://egg.astro.cornell.edu/alfalfa/projects/projects.php.*

Team projects, new since Aug 2007:

- *"Fast rotators in the ALFALFA sample"*, (Lead: Salucci)
- *"HI in tidal dwarf candidates"*, (Leads: S. Higdon/J. Higdon)
- *"ALFALFA detections of the most gas-rich GASS targets"*, (Leads: Catinella and Schiminovich)
- *"The low mass end of the Tully-Fisher relation"*, (Leads: Blanton, Geha, West)
- *"Extended HI emission around the Pegasus dwarf galaxy"*, (Leads: Brosch and Hoffman)
- *"CO in high HI mass ALFALFA detections"*, (Leads: Yun and Chung)
- *"Comparison of SDSS/ALFALFA sample selection"*, (Leads: Rosenberg and West)
- *"ALFALFA detections in the 2MTF survey"*, (Lead: Masters)
- *"Simulations of extended features found in ALFALFA"* (Leads: Kornreich and Kent)
- *"Impact of the group environment from ALFALFA"* (Leads: Haynes and the Undergraduate ALFALFA Groups Team)
- *"ALFALFA SPROUTS in diffuse fields: Understanding foreground subtraction for EOR experiments using ALFALFA"* (Lead: Morales and Bowman)

Graduate student thesis projects, new since Aug 2007:

- *"The group environment in the Coma-A1367 supercluster'*, (K. Hess, U. Wisc; Adviser: Wilcots)
- *"Definition of HI Deficiency from ALFALFA"*, (M.C. Toribio, Barcelona; Adviser: Solanes)
- *"Bar Fraction in the Virgo cluster"*, (L. Giordano, Zurich; Advisers: Tran and Moore)

• **The ALFALFA-U Collaboration:** The ALFALFA-U team is a consortium of 14 institutions engaged in an NSF-sponsored program to promote undergraduate research within the ALFALFA project. Current institutional members are Colgate, Cornell, George Mason, Georgia Southern, Humboldt State, Lafayette, St. Lawrence, Siena, Skidmore, Union, University of Puerto Rico - Rio Piedras, University of Wisconsin - Stevens Point, Wesleyan University and West Texas A&M. Funding is provided by an NSF grant to R. Koopmann (Union), T. Balonek (Colgate, and S. Higdon (Georgia Southern) which provides summer research stipends for seven undergraduates, computer hardware and software licenses for each institution, communications support for regular teleconferences, and travel support for observing and attendance at the annual workshop in Arecibo. The first Undergraduate ALFALFA workshop was held at Arecibo January 13-14, 2008. All of the team member institutions were represented as well as one additional college (St. Mary's College of California). Lectures were given by Haynes, Giovanelli, Kent, Stierwalt and Hoffman, and an A2010 observing session was conducted overnight. It was a huge success; see: *http://egg.astro.cornell.edu/alfalfa/ugradteam/ugradj08.php*. This summer, 16 undergraduates associated with ALFALFA-U are engaged in research centered on ALFALFA.

• **Training by experts at Cornell:** Several ALFALFA team members have spent time visiting at Cornell for training in ALFALFA software and data reduction and for research planning. During the past year, visitors included Jessica Rosenberg and her undergraduate student Lisa Horne (George Mason U.), Barbara Catinella and Guinevere Kauffmann (MPIA), Tim Heckman (Johns Hopkins), David Schiminovich (Columbia) and Andrew West (UC Berkeley). In addition, graduate students Jayce Dowell (Indiana), Kelley Hess (U. Wisconsin), Oded Spector (Tel-Aviv) and Mari Carmen Toribio (U. Barcelona) spent periods in Ithaca working with Giovanelli and Haynes on ALFALFA data analysis and its incorporation into their various Ph.D. thesis projects.

• **Training by experts at Arecibo:** Because of the hiatus in observing caused by the painting project, fewer members of the ALFALFA team visited Arecibo to observe in the last year than would have otherwise. David Kornreich (Humboldt State) spent his sabbatic leave in residence at Arecibo. Other onsite observers included Eric Wilcots, Kelley Hess and Melissa Jacquart (U. Wisconsin) and Lyle Hoffman and Shelvean Kapita (Lafayette Coll.) We anticipate that the practice of training ALFALFA users, especially students, on site at Arecibo will pick up again next year.

• **Software development:** The ALFALFA-IDL package was further developed and extended by Giovanelli and Kent. Additional applications under development this year include a module contributed by graduate student Jayce Dowell (Indiana) which implements a first order sidelobe "CLEAN" algorithm (he has used this successfully to identify previously-unrecognized objects with very extended HI disks) and another module to derive upper limits to the HI flux at arbitrary positions within the ALFALFA grids. The latter was first developed by Marco Grossi (Arcetri) during a visit to Cornell and is being further extended by Jessica Rosenberg (George Mason).

A critical feature of the ALFALFA catalog development and analysis made possible by the precision with which the centroid of the HI signal can be determined involves the identification of optical counterparts and the derivation of optical colors, stellar masses, star formation rates, nuclear activity etc. using other public databases. At Cornell, an ancillary database providing crossreference to

SDSS and NED has been constructed using a combination of PYTHON and IDL scripts. A general purpose library providing IDL tools for science analysis is being developed; routines allow access to other Cornell ExtraGalactic Group databases, estimate distances according to flow models, primary distances and group catalogs, and convert from observables to intrinsic properties using all available data in the multiwavelength ALFALFA database. These routines and databases are made available to members of the team for ALFALFA-related science applications.

The software has been successfully deployed at the following institutions: Cornell U., Obs. Astrof. Arcetri, Arecibo, U. Barcelona, Colgate U., U. Colorado, George Mason, Georgia Southern U., Harvard-SAO/Center for Astrophysics, Humboldt State, INAF-Milano, Indiana U., Lafayette Coll., Siena Coll., Skidmore Coll., St. Lawrence U., Union Coll., U. Colorado, U. Minnesota, U. Wisconsin-Madison, U. Wisconsin-Stevens Point, Wesleyan U., U. Zurich. It runs on lots of laptops, too, wherever they are.

• **Data archive:** The ALFALFA archive is available on a SQL database server at the Cornell Center for Advanced Computing (CAC; formerly CTC); see *http://arecibo.tc.cornell.edu/hiarchive.* The archive is SQL and cone searchable and spectra can be downloaded in VOTable, FITS and ASCII format. A JAVA-script based plotting tool was developed to complement the VO-Plot tool for users who do not have access to the required plug-in. The ALFALFA spectral data are also available through the NASA Extragalactic database.

• **Data curation and preservation:** We are actively involved in a Cornell collaboration involving the CU Center for Advanced Computing and other large dataset holders, including the PALFA consortium, for development of hardware and software tools for the permanent storage of and access to the ALFALFA data archive. ALFALFA is one of the datasets included in the Discover Research Service Group at the Cornell Center for Advanced Computing, recently funded by the Cornell Provost's Office (J. Cordes and J. McCue PIs), and by a joint JHU-Cornell DataNet (S. Chaudury, PI) proposal submitted to the NSF Cyberinfrastructure Initiative. We work closely with Adam Brazier to insure that our digital datasets are included in the overall NAIC archive and access planning. Haynes serves on the Faculty Oversight Committee for the Cornell Center for Advanced Computing and, through AUI, is involved in a proposal submitted to NSF/NASA for the U.S. Virtual Astronomy Observatory.

• **Dataset and product status**: Processing of the data is proceeding according to schedule. Raw data in FITS format are converted to IDL and transferred to Cornell daily. Processing to Level I usually occurs within days to weeks using a standard pipeline in ALFALFA-IDL. A laborious part of Level I processing is the flagging of RFI, a necessary (unfortunately) and extremely beneficial exercise. Construction of final data products in some areas is limited by the incomplete coverage of datasets due to the spottiness of time allocation, but we are engaged in systematic reduction of selected, fully sampled areas. A few points are worthy of note:

- ALFALFA acquires data at a rate of about 1 GB/hour. Raw data is archived at Arecibo by NAIC. About 4 TB of Level I datasets (2-D) are currently housed at Cornell for quick access; about 2 TB of Level II datasets (3-D) are also housed at Cornell. Reduction status (both Level I and Level II) is available on the team-only website. If the skeptical review panel needs access to this site, it can be provided upon request. Priority in processing is given to completing Level I processing of datasets needed to yield full coverage of contiguous areas for gridding purposes and regular checks to insure data quality.
- Both Level I and Level II datasets are produced by numerous team members following a very strict protocol and after several extensive training sessions by a reduction "expert". Each

Level I and Level II dataset is later checked for quality by a senior member of the team before being delivered into the archive. Final catalog production is also carried out by a senior individual, providing a second check. Haynes oversees the Level I process and Giovanelli, Level II.

- The construction of 3-D grids proceeds as datasets become complete. To minimize data transfer, all grids are produced at Cornell. Each grid represents a square of $2.4° \times 2.4°$ of sky, with contiguous grid centers separated from each other by 2°. Pointing corrections derived from the NVSS sources in the grids themselves are applied as part of the grid preparation process; since ALFALFA employs a drift scan technique, an entire strip of grids at the same declination and hence zenith angle is used to derive pointing corrections. As of 15Jul08, about 2000 grids have been generated and sources extracted from them, corresponding to 25% of the final survey dataset. Because of the need to maintain uniformity and high quality, source extraction is being undertaken only by a small group of experts trained and monitored by Giovanelli. Persons involved in signal extraction/catalog construction are required to spend several weeks working at Cornell on this task prior to working back at home. Both Giovanelli and Haynes are involved in final catalog checkout to insure uniformity and quality control. See further discussion under **Issues of concern** below.
- Signal extraction within the 3-D datasets is performed using a Fourier domain technique (Saintonge 2007a) and makes use of confirmation in both polarizations, both passes and adjacent beams. Signals are categorized according to signal-to-noise ratio and coincidence with optical counterpart where applicable. Followup LBW observations have been undertaken to verify detection reliability schemes.
- Some ALFALFA projects require early access to the Level II data for purposes other than catalog construction; such datasets are available to team members upon request, within necessary limitations imposed by security and data transfer issues.

- **Multiwavelength followup and complementary efforts**: The followup observations team is engaged in a coordinated effort to obtain a wide variety of data with other major facilities. Time has been granted for ALFALFA-related observations on the Very Large Array, the GMRT, the Green Bank Telescope, FCRAO, SPITZER, GALEX, the Palomar 5m telescope and the Very Large Telescope. Using principally smaller telescopes, the ALFALFA-Hα team has acquired more than 1000 images of ALFALFA detections in a continuing, coordinated effort. In addition, Kornreich, Kent and Adams are using GADGET-2 to perform numerical simulations of tidal stripping events and high speed encounters in Virgo and of tidal interactions in loose groups.

- **Issues of concern**:

  - **Quality control of data processing and data product production**: The skeptical review committee has in the past rightfully raised concerns about the maintenance of standards for delivering uniform high quality data products. We share the committee's concerns, and we believe the process we have put in place to train team members engaged in data processing, to have an expert oversee each step, and to introduce redundancy (multiple, different checks) is working. Level I processing is fundamentally more straightforward and accessible to individuals with lesser expertise; a larger number of individuals are engaged in this activity, but still each is trained by an "expert" and each dataset is checked (and feedback provided) before release into the Level I archive. The Level II processing, which includes final 3-D grid production, source extraction and catalog construction, is undertaken by fewer individuals who are fully vested in the outcome (e.g., graduate students who are pursuing ALFALFA catalog-related Ph.D. research and fully engaged team members), each of whom has participated in a several week "full immersion" training session with IDL-ALFALFA in Ithaca and has passed a set of quality standards overseen by Giovanelli. Giovanelli and Haynes run independent and distinct tests on the final catalog to insure uniformity of depth, parameter extraction and optical counterpart identification. We are confident that this attention to detail, definition and assignment of responsibility (albeit shared) and process to provide training and feedback is proving successful in maintaining ALFALFA data quality and homogeneity.

- **Scheduling and sky coverage**: We understand that Arecibo telescope time, particularly in certain LST ranges, is in great demand. However, if compromises as to sky coverage impacting ALFALFA must be made, we request that careful attention to ALFALFA science priorities be given. There is currently no Arecibo staff member actively engaged in ALFALFA, and we would hope to be consulted directly as to what specific compromises would yield least impact, especially on projects already underway.
- **Spectrometer uncertainties**: As of this date, we still have not tested the new E-ALFA spectrometer. The ALFALFA technical requirements of spectral resolution and bandwidth are met adequately by the WAPPs, so one option for us is simply to continue to use them. However, recurrent WAPP failures continue to occur periodically and have been the major source of telescope time loss in the past three years. Once the new E-ALFA spectrometer is in routine use, we will request telescope time to test it in our standard observing mode. Following conversations with Ganesh Rajagopalan in June 2008, we will continue to use the WAPPs to complete areas with partial sky coverage in Fall 2008 but we may migrate to the new spectrometer in 2009.

- **Additional activities planned to date during 2008–9**:
  - We will continue to provide training sessions for less experienced ALFALFA team members on site in Arecibo.
  - We will continue to provide data reduction training sessions for ALFALFA team members in Ithaca.
  - We will continue to provide training and project planning visits to Cornell for graduate students from other institutions who are initiating ALFALFA-based Ph.D. theses.
  - We will continue to participate in the development of the Cornell cyberinfrastructure initiative in collaboration with the Cornell Center for Advanced Computing.
  - Additional organized activities of the undergraduate ALFALFA consortium will include regular teleconferences to discuss the collaborative galaxy groups project. Another undergraduate workshop at Arecibo is planned for January 2009.
  - We anticipate organizing a general team meeting during the summer of 2009 in Ithaca.

• **Plan for the Next Year**: Our request for the next year maintains continued steady progress towards completion of the ALFALFA survey in a timely manner. The timeliness issue reflects the needs of the large number of people now invested in ALFALFA, some of whom have early career constraints to complete theses, find permanent jobs or submit tenure packages. To maintain pace and momentum, we request a continued allocation of 700-900 hours in the next scheduling year.

Figure 6 illustrates the current and proposed ALFALFA sky coverage, particularly in the context of local large scale structure. Completed regions, general containing bands of 4°-wide "tiles", are shown in blue. Areas with partial coverage but not yet complete are shaded in magenta, while new regions which we propose to survey next are shaded green. Our original request planned to complete two sets of 4° tiles per year. As is evident from the figures here, the allocation of telescope time has not been adequate to match that pace, so that our request for the next year assumes that we will spend much of the time completing regions already initiated and that only two new bands of tiles will be started. For the year beginning 01Jul08, we propose to complete the partially-covered +06° set of tiles in the "fall" and +02° one in the "spring". Our additional goal is to begin and complete the +10° one (fall) and +34° one (spring). The priority for coverage of these strips is motivated by the desire to achieve the principal ALFALFA science objectives, with special attention to the timely acquisition of datasets required for PhD theses. Particular reasons for the choice of these particular sets of tiles are:

- Completion of the Dec = +06° fall strip will provide full overlap with the optical SMUDGES strip being surveyed at BVI wavelengths (van Zee).
- The fall Dec = +10° strip will fill in the gap between the +06° and the +14° bands and will provide adequate sampling of the anti-Virgo region to allow comparison of the HI mass function in the Virgo and anti-Virgo environments within the same sampling volume.
- The spring Dec = +02° band of tiles includes several nearby loose groups and structures of great interest, including the southeast extension of the Virgo cluster; observations of the region from 14^h–16^h30^m were completed in Spring 2008, but completion of the entire strip is of high priority for on-going local studies of the HI mass function in the Leo-Virgo region and the southeast extension of the Virgo cluster.
- The spring Dec = +34° band of tiles includes the southern extension of the nearby Canes Venatici group region at comparable distance to Virgo.

Summary of Request: Completion of a single strip of ALFALFA 4° tiles in 2-pass mode requires 33 observing sessions with the second half occurring 3-9 months after the first. We understand that it is more convenient for the AO scheduler to schedule A2010 in more, but shorter blocks, which we can then stitch together to provide complete coverage of the ALFALFA survey region. Such a scheme, while somewhat less efficient and more burdensome in terms of bookkeeping, is acceptable to us as long as sky coverage is eventually completed. We therefore request for the period 01Aug08-30Jun09 that A2010 be scheduled for **the equivalent of 66 sessions from LST 21^h40^m to 03^h10^m during the period Aug08-Jan09** and **the equivalent of 66 sessions from LST 07^h10^m to 16^h40^m during the period Dec08-Jun09**. The tiles we propose to complete in this period are +6° and +10° (fall) and +04° and +34° (spring). As always, TOGS will run commensally with ALFALFA.

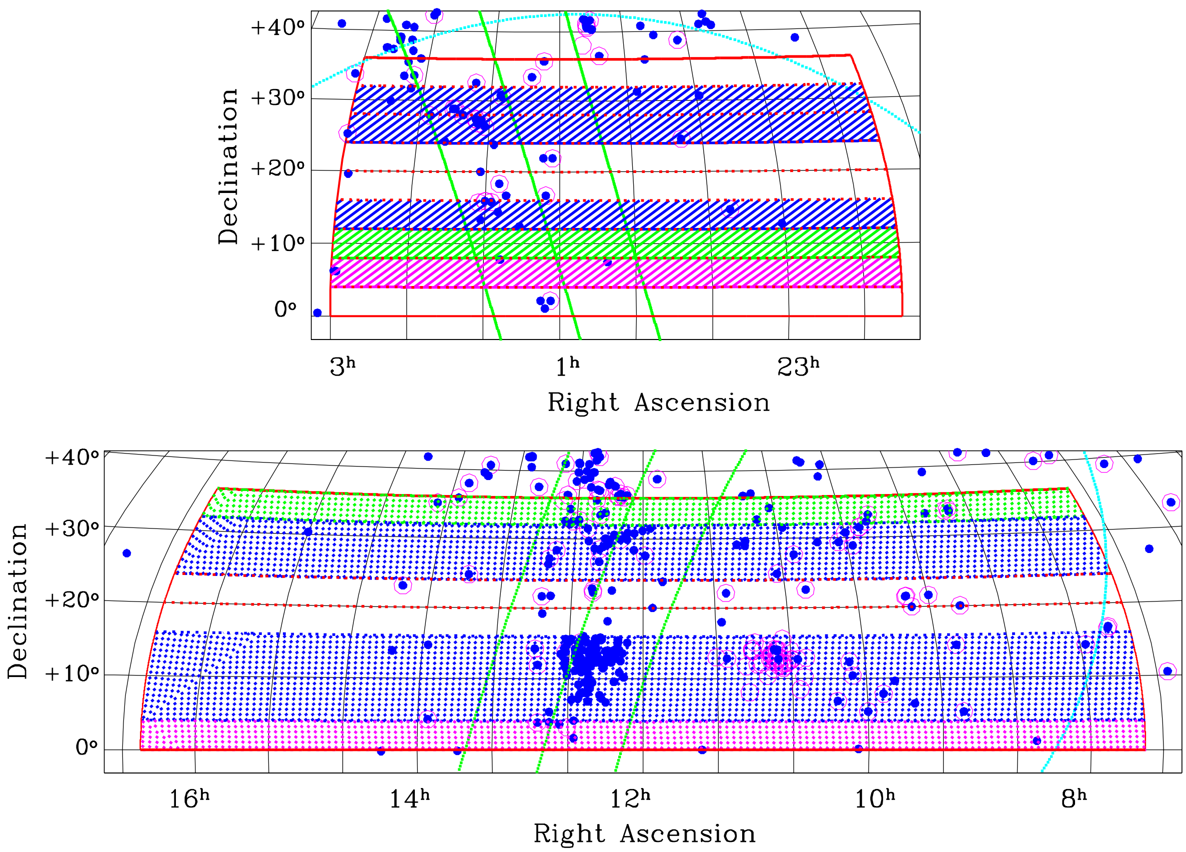


Figure 6: Proposed A2010 sky coverage status and proposed coverage: Fall 2008 (upper) and Spring 2009 (lower). Blue shaded areas outline the (essentially) complete coverage as of 15Jul2008, from 7^h30^m <R.A.< 16^h30^m, $+4°$ < Dec.< $+16°$ and 22^h <R.A.< 3^h, $+12°$ < Dec.< $+16°$ and $+24°$ < Dec.< $+32°$. The actual observational details are provided in Figures 1 and 2. The allocation requested here for the year starting 01Jul2008 aims to complete 4° wide tiles, begun previously, at Dec. = +06° (fall) and Dec. = +02° (spring) shown as the magenta shaded areas. We will then initiate the survey of the Dec. = +10° (fall) and Dec. = +34° (spring) tiles, shaded green in each panel. The solid red lines outline the proposed survey area for the full ALFALFA survey, while dotted red lines make the designated ALFALFA tile boundaries. The cyan line traces b = +20°, while the green lines trace SGL = −10°, 0° and +10°. Blue filled circles mark galaxies with observed heliocentric recessional velocities cz < 700 km s^{-1} while open magenta circles denote objects believed to lie with 10 Mpc, based largely on primary distances (Karachentsev *et al.* 2004).