The Arecibo Legacy Fast ALFA (ALFALFA) Extragalactic HI Survey

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Abstract. The Arecibo Legacy Fast ALFA (ALFALFA) survey is a program aimed at obtaining a census of HI-bearing objects over a cosmologically significant volume of the local universe. When complete in ∼3–4 years, it will cover 7000 square degrees of high latitude sky using the 305 m telescope and the seven-beam Arecibo L-band feed array (ALFA). As of May 1, 2008, almost 60% of the required observations are complete and a catalog exists in preliminary form for 25% of the final sky area. ALFALFA is detecting about twice as many HI sources as predicted based on previously published HI mass functions and should deliver a final catalog of > 25000 extragalactic HI sources. ALFALFA will detect hundreds of galaxies with HI masses less than $10^{7.5} M_\odot$ and similarly large numbers greater than $10^{10.3} M_\odot$. Its centroiding accuracy allows for the immediate identification of highly probably optical counterparts to each HI detection. Fewer than 3% of all extragalactic HI sources, and $< 1\%$ of ones with $M_{HI} > 10^{9.5} M_\odot$ cannot be identified with a stellar counterpart. The hundreds of HI sources with observed line widths of $20 - 30$ km s^{-1} include a population of optically faint dwarf galaxies. The objects with highest HI masses exhibit a range of morphologies, optical colors and surface brightnesses, but most appear to be massive disk systems. The latter represent the population likely to dominate future studies of HI at high redshift.

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THE ALFALFA SURVEY PROGRAM

ALFALFA, the Arecibo Legacy Fast ALFA Survey, is a two-pass spectral line survey to cover 7000 deg^2 of high galactic latitude sky[1] with ∼eight times the sensitivity, four times the angular resolution, three times the spectral resolution, and 1.6 times the total bandwidth of the HI Parkes All-Sky Survey (HIPASS)[2]. The ALFALFA survey strategy has been designed specifically to exploit Arecibo's superior sensitivity, angular resolution and digital technology to conduct a census of the local HI universe over a cosmologically significant volume[3][4]. The effective integration time is ∼40 sec per beam area, yielding approximately 2.2 mJy at 10 km s^{-1} resolution (after Hanning smoothing). 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.$< 3^h$ and $7^h30^m <$R.A.$< 16^h30^m$. The fixed azimuth, "minimum intrusion" observing technique[5][6] delivers extremely high data quality and observing efficiency (99% "open shutter" time). Because of its wide areal coverage 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 survey was initiated in February 2005; as of May 1, 2008, ∼ 60% of the survey observations have been completed.

The ALFALFA team is an open collaboration of more than 60 researchers from 34 institutions in 13 countries. Anyone with an interest in the science that can

be done with the ALFALFA dataset and the willingness to contribute to the collective effort is welcome to join. Guidelines for joining ALFALFA can be found at http://egg.astro.cornell.edu/alfalfa/joining.php. The ALFALFA survey is also serving as the backbone for student research projects at both the graduate and undergraduate level. One Ph.D. thesis[7] based on ALFALFA is already complete; currently ten graduate students from six different institutions are working on Ph.D. dissertations centered on ALFALFA research. Current ALFALFA team projects are summarized at http://egg.astro.cornell.edu/alfalfa/projects/teamprojects.php. The undergraduate ALFALFA program supports the participation of faculty and students at 14 institutions engaged in research, observing and educational exchange. An undergraduate workshop http://egg.astro.cornell.edu/alfalfa/ugradteam/ugradj08.php is held at Arecibo each year. Eight ALFALFA senior theses have been undertaken so far.

Data processing for ALFALFA makes us of the IDL-based ALFALFA pipeline developed at Cornell and exported successfully to more than 16 institutions running both Linux and MacOS. Heavy use is made of Virtual Observatory protocols and web services for real-time cross-correlation with public multiwavelength databases. The identification of HI sources in the gridded data is performed using a Fourier domain matched filter signal extraction technique [8]. Simultaneously, the most probable optical counterpart, where such exists, is identified using public OIR survey datasets. In addition to the most reliable, high S/N detections, sources of lower S/N but which coincide in both position and redshift with known optical galaxies are also included, but flagged as such, in the catalog of detections. Data catalogs and products are available at http://arecibo.tc.cornell.edu/hiarchive/alfalfa/.

Two catalogs of HI sources extracted from 3-D spectral data cubes have been published[6][9] and a third has been submitted[10]. Several additional publications should be submitted this summer, including a completed catalog of the $\sim$1600 square degrees in the region $7^h30^m <$R.A.$< 16^h30^m$, $+04^\circ <$ Dec $< +16^\circ$. In the latter area, ALFALFA detects $>$ 6200 high quality sources versus 290 for HIPASS.

ALFALFA: EARLY SCIENCE

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

HI census: ALFALFA is now on course to detect $>$ 25000 sources, twice as many objects as we predicted [1] based on the HI mass functions derived from previous surveys. Fewer than 3% of all extragalactic HI sources, and $<$ 1% of ones with $M_{HI} > 10^{9.5} M_\odot$ cannot be identified with a stellar counterpart.

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[6] [10]. A number of extensive ($>$ 250 kpc) HI streams or complexes, suggestive of tidal or "harassment" debris, have been discovered [11] [12][13], all on the outskirts of the cluster. 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[14]. Members of the ALFALFA collaboration are exploiting multiwave-

length data and numerical simulations to explore the detailed properties of the galaxy population and the mechanisms likely at play in the Virgo region[15][16].

Dwarf galaxies and high velocity clouds: ALFALFA is specifically designed to detect very low mass galaxies in the local universe. Besides its sensitivity advantage, its superior spectral resolution allows detection of HI lines as narrow (FWHM) as 20 km sec^{-1}[7][8], characteristic of low mass halos. 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[7]. ALFALFA is cataloguing high velocity clouds associated with the Milky Way; several such clouds close to M33 have also been discovered in the ALFALFA dataset [17].

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 GASS survey presented by David Schiminovich and the optically-selected gas-rich galaxies detected at Arecibo at $z \sim 0.2$ as reported by Barbara Catinella in this volume.

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