ALFALFA: The Arecibo Legacy Fast ALFA Survey
The 2005 Summer Undergraduate Observing Program

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Abstract

The Arecibo Legacy Fast ALFA (ALFALFA) project is a blind HI survey covering 7000 deg^2 of the sky and is expected to detect at least 20,000 HI sources. In addition, ALFALFA will contribute to the understanding of the evolution of galaxies in relation to their environments. Following the same techniques and procedures as the general ALFALFA survey, we plan to observe a nearby loose group of galaxies, LGG 362. This group should have at least six HI sources. At the distance of the group (12.59$\pm$1.74 Mpc), we expect to find HI masses as low as 1.2×10^7 M$_\odot$ for a 3σ detection. Compared to current ALFALFA data on parts of the dense Virgo cluster and a nearby void, this subset of data will contribute to the survey by providing observations of an intermediate galaxy density environment.

Introduction

As the most abundant element in the Universe, HI provides extensive information concerning the structure and content of not only individual galaxies, but also groups and clusters. The current Arecibo Legacy Fast ALFA (ALFALFA) survey aims to trace the large-scale distribution of extragalactic HI over 7000 deg^2 out to a redshift of z $\sim$ 0.06, with $\sim$ 5 km s^{-1} spacing (Giovanelli et al. 2005). Over the course of five years, it will cover the sky between $0^\circ <$ Dec. $< +36^\circ$ and over two blocks of Right Ascension, respectively 07^h30^m to 16^h30^m and 22^h00^m to 3^h00^m. As a blind survey, it is unbiased to previously-discovered or bright galaxies; based on simulations in Giovanelli et al. (2005), the survey should detect some 20,000 extragalactic HI line sources, providing HI redshifts, masses, and rotational widths. As opposed to previous large HI surveys (such as HIPASS and HIJASS), ALFALFA's $3.5'$ beam provides significant improvement in spatial resolution, and therefore fewer followup synthesis observations will be necessary to allow identification of their optical counterparts.

ALFALFA will also address current issues in astronomy; current numerical simulations of cold dark matter (CDM) models predict a higher number of dwarf dark matter halos than the observed population of dwarf satellite galaxies in the Local Group (e.g., Kauffmann et al. 1993, Klypin et al. 1999). Because the majority of galaxies are low-mass and therefore optically faint (e.g., Springob et al. 2005), the high sensitivity and numerous detections of ALFALFA should also provide a robust determination of the low end of the HI mass function (HIMF). Unlike optically-selected HI surveys, blind HI surveys are not biased against low surface brightness galaxies; ALFALFA therefore will probe the faint, lower mass end of the HIMF. However, ALFALFA does not purport to detect dwarf ellipticals or dwarf spheroidals due to their lack of HI gas.

In addition to CDM models, ALFALFA will also explore the evolution and dynamics of galaxies within large scale structures such as the Virgo Cluster. By comparing regions of high galaxy density to regions of low density, information about the evolution of galaxies in relation to their environments can be extracted. It will also allow measurement of the HI diameter function, as well as search for local HI tidal features and OH megamasers in the redshift range $0.16 < z < 0.25$. A final goal is the observation of HI absorbers at redshifts within the range of the survey.

Finally, ALFALFA will provide numerous educational and research opportunities for both undergraduate and graduate students.

Observations and Data Reduction

The current observations are scheduled for July 6th between 18:45 and 20:30 AST, which corresponds to a Right Ascension range of 13^h18^m to 15^h03^m for objects at transit; our declination, chosen from the ALFALFA master drift list, is $\delta(\mathrm{J2000}) = 05°13'54''$. This takes place during a workshop for undergraduates involved in the ALFALFA project. While the majority of the work, both during observing and throughout reduction, will be carried out by the twelve undergraduates attending the workshop, graduate students experienced with remote observing as well as the software package involved in reduction will be available for assistance if necessary. Because the project seeks to fit in with the current ALFALFA survey and therefore uses the same observing techniques, data will be reduced using the current ALFALFA data reduction pipeline. In fact, the team of undergraduates will promptly reduce the data on the day following observations, July 7th, during the undergraduate workshop.

Our choice to mimic the observing techniques of the ALFALFA survey is necessary if we are to use the existing reduction pipeline. Observations are taken in "DecJ fixed-Azimuth Drift Mode," in which the telescope is pointed at the meridian and the sky sweeps by. This follows the minimum-intrusion principle employed by ALFALFA, as beam parameters can change as the telescope tracks (Giovanelli et al. 2005). By keeping the telescope fixed, instrumental effects are much more easily removed.

Observations in "DecJ fixed-azimuth drift mode" allow for an integration time of 14 seconds per polarization, per beam. Because extragalactic HI is generally unpolarized, we will add both polarizations of each beam together, yielding a total integration time of 28 seconds per beam. The rms noise of a single drift, after the position-frequency map has been spatially smoothed to the spatial resolution of the telescope, can be found from the calculation by Giovanelli et al. (2005), using the same assumptions as in sections 4.1 and 6 of that paper:

$$S_{rms} \cong 3.5 \left(\frac{res}{10}\right)^{-1/2} \mathrm{mJy},$$

where res is the velocity spacing in km s^{-1}. Using a spectral resolution of 10 km s^{-1}, we obtain an rms noise of 3.5 mJy.

Focus of Observations

In order to mesh with the general ALFALFA survey, our observations and science goals are, overall, the same as those of ALFALFA. However, we have chosen our drift not only to focus on science applicable to ALFALFA, but also to complement our own scientific interests. Because we first chose to cover a region of the sky slated to be observed in the ALFALFA sky in the future, we were limited to a declination in the master drift list selected for observation. The primary focus of our chosen drift ($\delta(\mathrm{J2000}) = +05°13'54''$) covers the majority of the LGG 362, a nearby loose group of galaxies (Garcia 1993). Garcia (1993) found seven member galaxies, and six more galaxies in the field have been added by the Sloan Digital Sky Survey (SDSS). An SDSS image of the group is shown in Figure 1.

As an area of intermediate galaxy density, observations of LGG 362 nicely complement the existing ALFALFA dataset; regions of two extremes of galaxy density, sections of both Virgo and a local void, have already been observed. The addition of a region of intermediate density would allow the survey to trace differences in the HI content of these three different regions.

The choice of the LGG 362 group is a result of many factors. Haynes (1981) detected three members galaxies using Arecibo (Figure 2), while a subsequent paper (Haynes & Giovanelli 1981) revealed both HI absorption and emission in the spectrum of NGC 5363, a group member galaxy. Although Haynes (1981) found no evidence of tidal interactions, the group was heavily sampled only near NGC 5364. As shown in Figure 2, much of the intra-group area was unobserved; ALFALFA observations will fully cover the upper half of LGG 362, therefore filling in the holes. We do not expect to detect NGC 5364; based on measurements by Fouque (1984), the HI intensity drops by a factor of 4 at $4'$ from the center. The declination of NGC 5364 is $\delta(\mathrm{J2000}) = 05°00'52''$, so the measured HI extent only comes to $\delta = 05°04'52''$. This is still over $1'$ south of the lowest detectable declination in our drift ($\delta = 05°06'05''$). Similar results were obtained by inspection of the HI contour map from Haynes (1981); because our sensitivity is roughly equal, we should only detect HI in NGC 5364 in the same areas as the published map.

The observations of detectable galaxies, however, will yield a second measurement of these galaxies, including an estimate of their HI masses and further understanding of the HI absorption feature. As in Haynes (1981), our detection of NGC 5338 will be, if anything, marginal. The total flux and velocity width of the signal measured by Haynes (1981) are 0.75 Jy km s^{-1} and 91 km s^{-1}, respectively. With a spectral resolution of 10 km s^{-1}, ALFALFA's noise is $\sim$3.5 mJy; this leads to a a detection at a level of approximately 2.4σ. Therefore, with lower spectral resolution, NGC 5338 may be detected at a higher sigma, but it may only be marginal. However, spectra from SDSS show that an additional two galaxies in our range contain Hα emission, a good indication that HI will also be detected in these galaxies (Figure 3). Future ALFALFA and SDSS observations have a large overlap, and and will complement each other in the detection of small or previously-undiscovered galaxies. The fourth data release from SDSS is expected in July 2005.

Interactions between galaxies in groups are also common, and often lead to features such as tidal tails or detached HI clouds (e.g., Hibbard et al. 2001). The high sensitivity of the survey will allow us to detect previously-unknown features if they exist. We adopt the distance to NGC 5338, measured to be 12.59 ± 1.74 Mpc (Tonry et al. 2001), for the distance of the group. Taking the velocity width of a detection to be 30 km s^{-1}, the lower HI mass limit that we can detect is 1.2×10^7 $M_\odot$ and 2.0×10^7 $M_\odot$ (3σ and 5σ detections, respectively).

In keeping with the goals of the general ALFALFA survey, the rest of the drift will focus on the detection of new galaxies and HI clouds, while the subset of the observations that include LGG 362 will enhance our understanding of galaxy dynamics and evolution within groups. Inspection of the region of the sky covered by the entire drift yields at least seven spiral galaxies over the entire observing session. Two of these, NGC 5764A and NGC 5764B, are an interacting pair; however, they lie at a redshift where RFI occasionally exists. Barring ground-based interference, we may be to detect evidence of this interaction in addition to the LGG 362 group.

Summary of Technical Requirements

As part of the July 2005 ALFALFA undergraduate workshop, we have been granted an hour and forty-five minutes of time on July 6, 2005 with ALFA, covering the RA range 13^h18^m and 15^h03^m for objects on the meridian. The LGG 362 group lies midway through this observing block. We will use the Wideband Arecibo Pulsar Processor (WAPP) system as a correlator with a bandwidth of 100 MHz, centered at 1385 MHz. The frequency range of 1335 to 1435 MHz allows us to cover a velocity range of approximately -2,000 km s^{-1} to 18,000 km s^{-1}. Spectra will be recorded once a second in 600s drifts, between which a noise diode will be fired for calibration. In keeping with the principles of the ALFALFA minimum-intrusion policy, we will not require LO Doppler tracking during the observations.

Figures

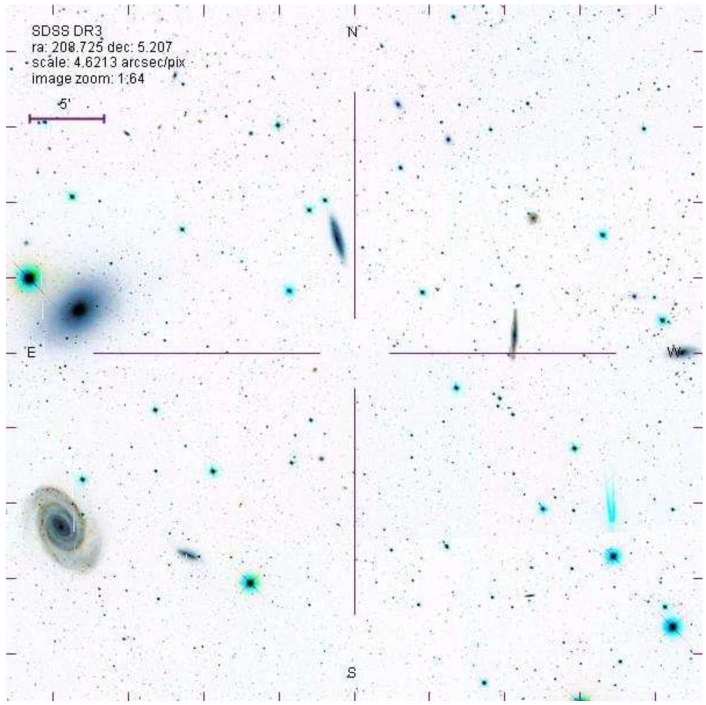

Figure 1: An SDSS image of the LGG 362 group, centered at $\alpha(\mathrm{J2000}) = 13^h54^m54^s$, $\delta = +05°12'25''$. NGC 5363 is located in the middle left area of the image, while the four other galaxies in the central strip are expected detections. NGC 5364, the other large galaxy in the group, is located in the lower left corner.

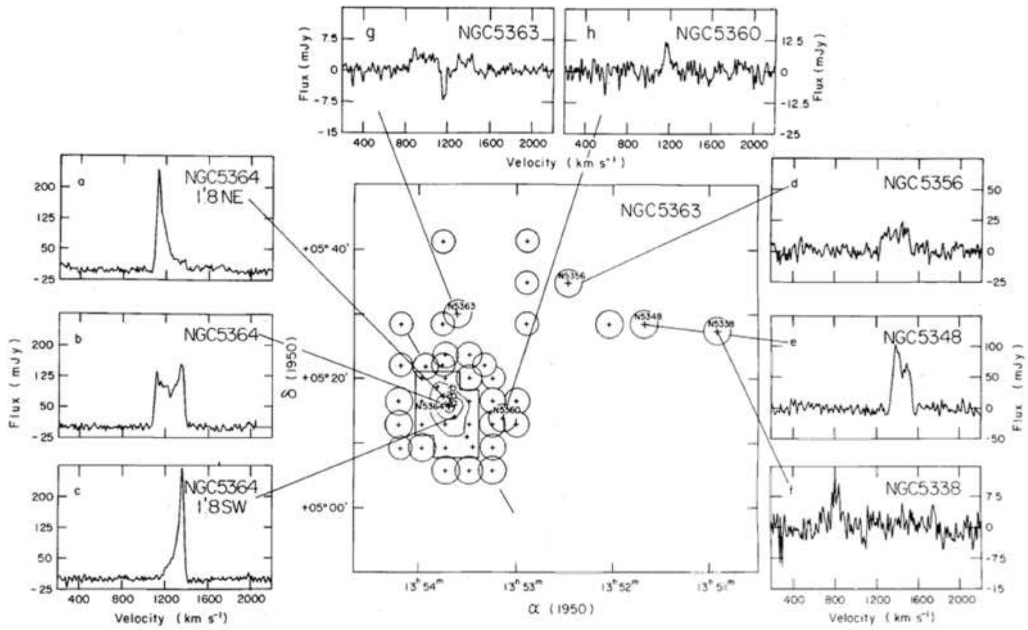

Figure 2: A map of pointings and corresponding spectra from Haynes (1981) of the LGG 362 group. The drift at δ(J2000) = $+05°13'54''$will cover NGC 5363, NGC 5356, NGC 5348, and NGC 5338, as well as three other expected detections not shown in this image.

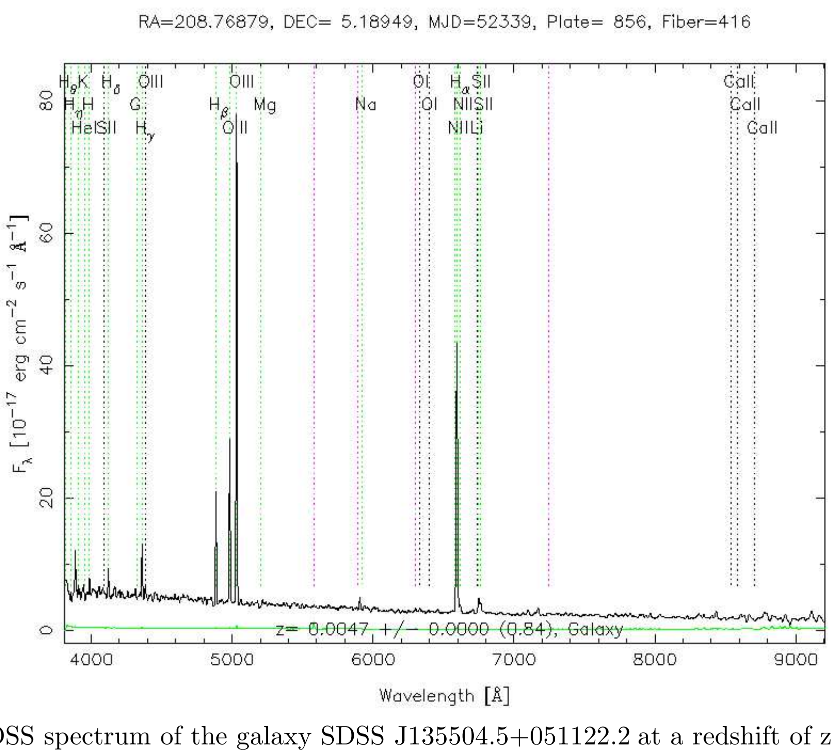

Figure 3: An SDSS spectrum of the galaxy SDSS J135504.5+051122.2 at a redshift of z = 0.0047. Because it visually appears to be a dwarf irregular and its spectra has a strong Hα line, it is likely that HI will be detected.

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