ALFALFA: The Arecibo Legacy Fast ALFA Survey
The January 2012 Undergraduate ALFALFA Team Workshop
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Abstract

The Arecibo Legacy Fast ALFA (ALFALFA) survey is a blind extragalactic neutral hydrogen (HI) survey. The survey covers an area of 7000 deg^2 within a declination range of 0° to +36° with right ascension from 07^h30^m to 16^h30^m and 22^h00^m to 3^h00^m. The study works towards identifying and cataloging over 35,000 HI sources in the local universe (up to z $\sim$ 0.06). The 2012 Undergraduate ALFALFA Team (UAT) workshop will take place January 16-18, focusing on six promising dark galaxy candidates from the 2011 ALFALFA survey. Follow up observations on these candidates will be completed using the L-Band Wide (LBW) receiver with a 1320-hipass filter.

Introduction

The detection of HI gas can provide useful information regarding galaxy structure, formation, and environmental interactions. The Arecibo Legacy Fast ALFA (ALFALFA) Survey covers 7000 deg^2 of the sky from declination 0 to +36 degrees and right ascension from 07^h30^m to 16^h30^m and 22^h00^m to 3^h00^m (Giovanelli et al. 2005). It detects the emission of the 21-cm line, an indicator of HI gas, with the corresponding frequency of 1420 MHz. The ALFALFA survey can detect the 21-cm line within a redshift of about z=0.06 and is able to provide information on HI redshifts, masses, and rotational widths. Because the ALFA detector consists of 7 beams, the survey can be completed more quickly than previous HI surveys such as HIPASS and HIJASS. ALFALFA also has better sensitivity and resolution than these past HI surveys. The full width half maximum for the HIJASS and HIPASS surveys were 12 arcmin and 15.5 arcmin respectively while the ALFALFA survey is 3.5 arcmin (Giovanelli et al. 2007). Additionally, ALFALFA is a blind survey and therefore not biased in favor of optically bright galaxies.

The α.40 catalog is a catalog containing data from 40% of the ALFALFA survey sky region (equivalent to 2800 deg^2). From the over 30,000 HI sources detected so far in the survey, 15,855 sources were documented in the α.40 catalog. Of these sources, 1,013 do not have optical counterparts, and only 199 of these are believed to be actual extragalactic detections (Haynes et al. 2011). These sources could be actual dark galaxies, OH megamasers, or high velocity clouds (HVCs) associated with the Milky Way Galaxy. It may also be determined from follow up observation that a source was not a reliable detection. These follow up observations are used to determine the reliability of the possible detection, better match optical counterparts with the detections, verify if a detection is an actual dark galaxy, a megamaser, HVC, or other object, and improve spectrum data from the galaxy.

The survey, started in February 2005, has already finished observing the spring sky with the ALFA detector. However, further observations in this region using the L-Band Wide (LBW) receiver still must be completed. These follow up observations are the focus of the 2012 undergraduate ALFALFA workshop.

Follow up studies will be carried out with the LBW receiver instead of the ALFA detector. The LBW receiver detects frequencies of 1100-1800 MHz and the additional 1320-hipass filter limits this frequency range to 1280-1470 MHz. The LBW receiver is a single beam detector as opposed to the 7 beam ALFA detector. As a result, a full sky survey with the LBW detector would be much less efficient than one with the ALFA, but the LBW does have several advantages. The LBW receiver has higher gain and has a lower noise temperature than ALFA, which is needed for gathering data on weakly detected targets or targets of significant interest that need to be verified as actual detections. Using the single beam LBW and tracking targets as they move across the sky gives a longer detection window and data acquisition time. With ALFALFA, the integration time is about 40 seconds; with LBW, we will track for 3 minutes. Thus actual sources will be detected with a higher signal to noise (S/N) ratio. Finally, although the LBW is capable of only one beam, the known locations of these follow up targets allow precise targeting.

The 2012 Undergraduate ALFALFA workshop will focus on these follow up observations using the LBW receiver, concentrating on six of the best candidates for dark galaxies discovered by the ALFALFA survey. The LBW receiver will be used to verify their existence. A total of 20 undergraduate students, 2 graduate students, and 11 faculty members from 14 different schools are members of the fifth NSF-sponsored Undergraduate ALFALFA team. This conference at Arecibo will be an invaluable opportunity for hands on experience at Arecibo and direct participation in ALFALFA.

Observations and Data Reduction

The total scan time for each target will be 7 minutes using the LBW receiver and an on-source/off-source data collection technique that is similar to the two drift strategy of ALFALFA. Unlike ALFA, which lets the sky drift by overhead, the LBW receiver will be set to track the source as it moves across the sky. In order to flat field the image, data is taken over a period of blank sky (the off source) over the same altitude and azimuth path traveled by the target (the on source). Each on-off pair takes about 7 minutes to complete – 3 minutes on source, 1 minute to move back, and 3 minutes off source. By analyzing the differences in the two passes, corrections can be made during data reduction for local environmental noise as well as background sky noise using bandpass subtraction.

After observations have been made and the data have been reduced, the spectra will be analyzed with an interim 50 MHz correlator. The LBW receiver samples two orthogonal polarization states, each of which can be treated independently in this stage of analysis.

Focus of Observations

The observations to be carried out are to complement the existing ALFALFA survey by revisiting likely HI sources with no optical counterpart data. Table 1 provides six example HI sources which appear to have no optical counterpart. The LBW receiver will be used during the 2012 UAT workshop to determine if the original detections of these sources are reliable and if so what each object is (dark galaxy, OH maser, HVC, etc.). All six sources are code 1 sources (meaning a S/N greater than 6.5 and a reliable detection; Haynes et al. 2011). These particular sources have a S/N greater than 10 (as indicated in Table 1) and do not have other sources nearby. There is a wide range in the velocities of the six dark galaxy candidates.

Object	Right Ascension (deg)	Declination (deg)	Velocity(km s^{-1})	S/N (ALFALFA)
HI111126.2+052051	167.8583	5.3456	13,148	16.6
HI113816.1+120706	174.5683	12.1158	3,371	14.9
HI122047.0+253809	185.2029	25.6386	7,116	13.2
HI122829.2+112458	187.1225	11.4139	16,299	10.9
HI130336.6+074945	195.9025	7.8272	2,977	16.7
HI143817.7+052500	219.5729	5.4147	1,499	16.6

Table 1: **Six most probable dark galaxy candidates in followup survey**

Figures 1,2, and 3 are the spectra and SDSS images of three of the six dark galaxy candidates. These images were taken from the ALFALFA LoveData galcat routine display of each source. Figure 1 presents dark galaxy candidate HI113816.1+120706. This HI source has a velocity of 3,371 km s^{-1}and a Gaussian spectrum. An optical source located at right ascension 174.56 degrees and declination 12.11 degrees is galaxy NGC 3773 and has a velocity of 982 km s^{-1}as indicated by the NASA/IPAC Extragalactic Database (NED). This discrepancy indicates that NGC 3773 is not an optical counterpart.

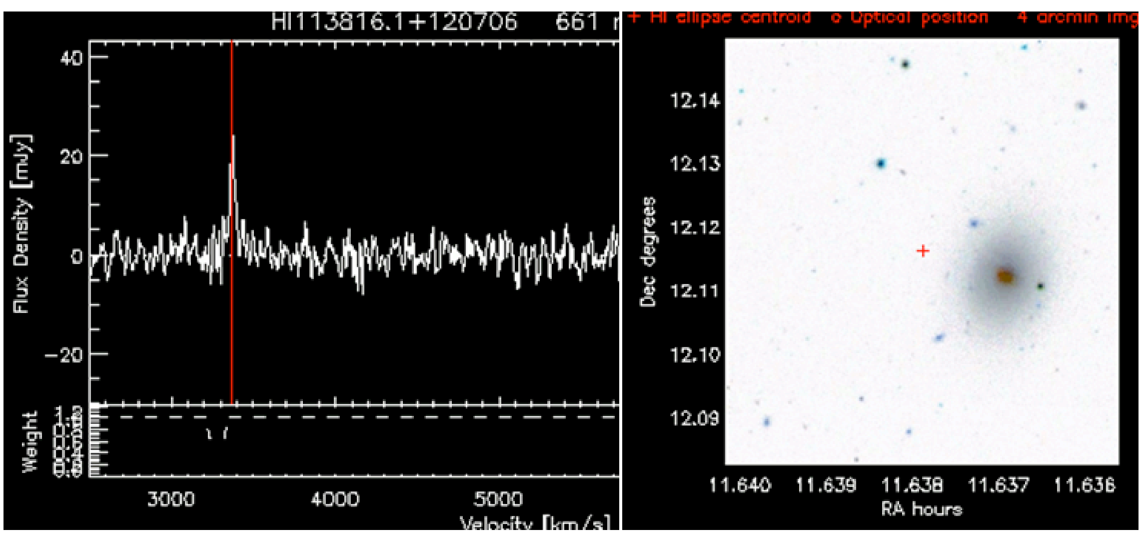

Figure 1: **Spectrum and SDSS image of HI113816.1+120706 from galcat.**

HI122829.2+112458 (Figure 2) is a dark galaxy candidate with a wider spectrum possibly indicating rotation. Its velocity is 16,299 km s^{-1}which is much larger than HI source HI113816.1+120706. There are small optical sources that are located near the center of the HI source. However, only one of these optical sources has an optical spectrum. This galaxy, VCC 1099, is centered over 1.25 arcmin away from the HI sources center and has a velocity of 1,625 km s^{-1}, ten times slower than the HI source.

Figure 3 shows dark galaxy candidate HI130336.6+074945 with aasymmetric profile. Looking at the SDSS

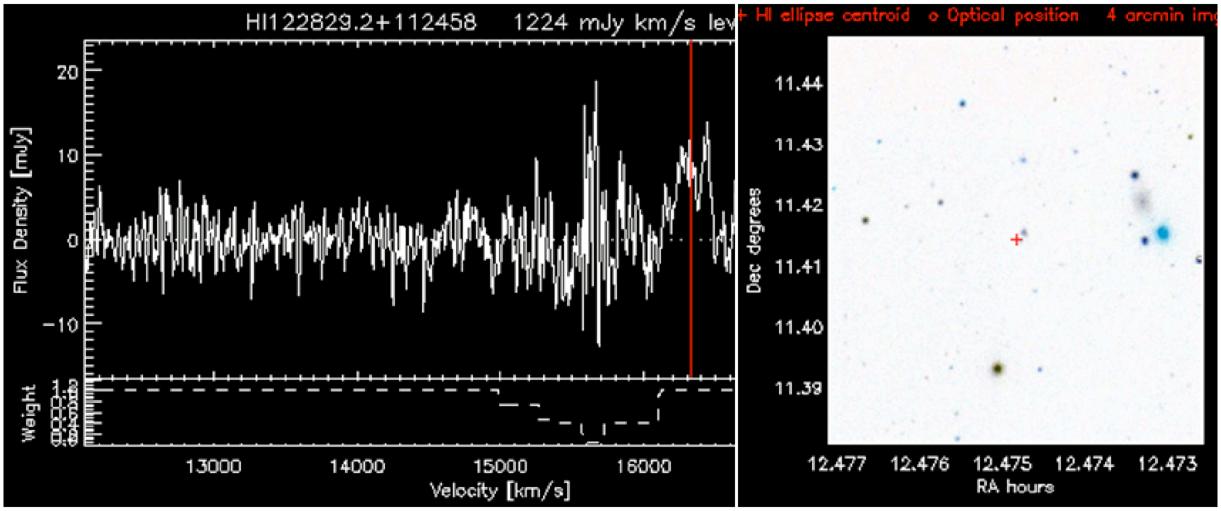

Figure 2: **Spectrum and SDSS image of HI122829.2+112458 from galcat.**

image it shows there are no optical objects near the HI source.

Using the LBW receiver we will be able to confirm the HI emission of these candidates. After determining if these sources are reliable detections further optical studies can be conducted to determine the presence of any faint optical sources and, if so, to obtain a spectrum to confirm that the optical redshift corresponds to the 21-cm redshift. Follow up interferometry can be obtained for reliable candidates to study gas velocities at higher resolution.

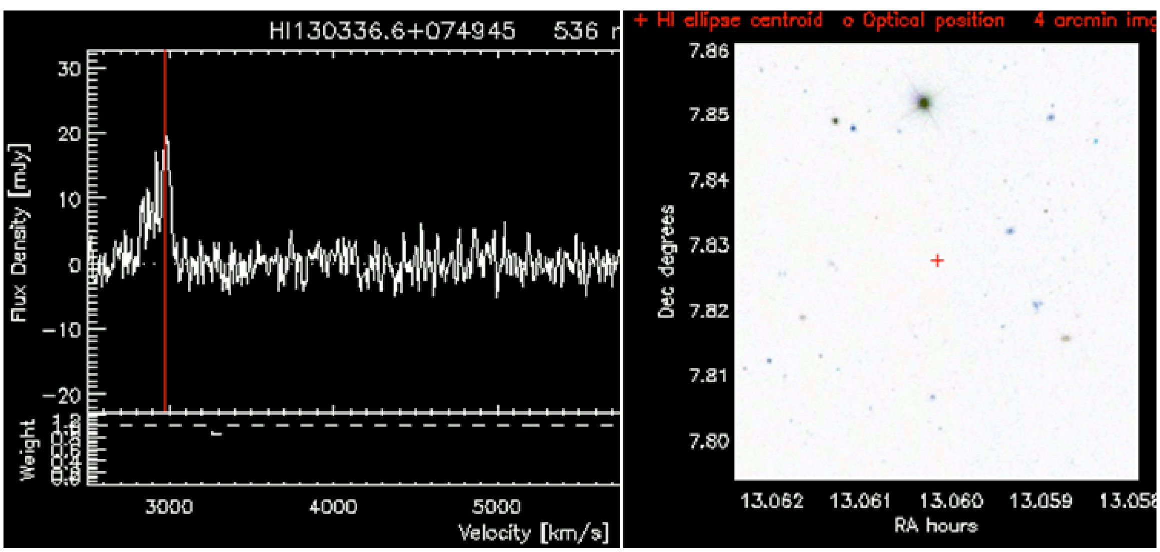

Figure 3: **Spectrum and SDSS image of HI130336.6+074945 from galcat.**

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