HI Measurements of Galaxy UGC11362 with Arecibo

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1. Abstract

Here we present our method and results for observations of galaxy UGC11362 with the Arecibo radio telescope. We used the L-wide receiver at four frequencies: 3 OH lines (which received no signal) and the 21 cm line (which did receive a signal). From the HI spectrum we found the galaxy to have a systemic velocity of 4204.74 km s\(^{-1}\), an HI flux of 4.49 Jy km s\(^{-1}\), and a line-width of 193 km s\(^{-2}\). The systemic velocity and line-width agree with previous measurements. Previous studies, however, have found an HI flux of 3.7 Jy km s\(^{-1}\), which differs significantly from our findings. From our measurements we calculated a distance of 56.06 Mpc, a rotational velocity 96.5 km s\(^{-1}\), and dynamical mass of \(1.769 \times 10^{10} M_\odot\).

2. Introduction

Astronomy 460: Experiences in Astronomical Observing—an undergraduate research methods class at the University of Wisconsin, Madison—was able to secure observing time with the 305 m Arecibo radio telescope in Puerto Rico. The class (Ballering, Beardsley, Birdsall, Bryan, Hunt, and Wilson) with supervision from Prof. Stanimirovic used the telescope time to observe several galaxies, some of which were well-known and others only hinted at by recent Spitzer IR surveys (Marleau et al., 2008). This paper focuses on the data from one of the well-known galaxies, UGC11362, located at R.A. 18h49m56.10s and Dec. +23d15m16.0s (J2000). O’Neil (2004), in his 21 cm line survey of 108 galaxies performed with Arecibo, quantifies the heliocentric radial velocity, velocity width, and HI flux of UGC11362. This paper details the observation and data analysis of our UGC11362 study and compares our results with O’Neil’s findings.

3. Observations

We observed UGC11362 with Arecibo’s L-wide receiver. The observing (s2425) was conducted remotely on October 16, 2008 from the University of Wisconsin, Madison campus. A position switching (ON/OFF) observing method was used with 2 minutes of integration time at each position. Two observing runs were performed, totaling 4 minutes of on-source integration time for each of the two polarizations. One of the four WAPP (Wideband
Arecibo Pulsar Processor) boards was centered at the HI 21cm line (1420 Mhz) and three of the WAPP boards were centered at OH emission frequencies (1720 Mhz, 1665 Mhz, and 1667 Mhz). Each WAPP board had a 12.5 Mhz frequency bandwidth and 2048 frequency channels. For the HI board this corresponded to a velocity bandwidth of 2641 km s$^{-1}$ and a 1.29 km s$^{-1}$ velocity resolution.

4. Data Analysis

Spectra for each WAPP board were produced from the data (Figure 1). While no signal was seen in any of the OH frequencies, a distinct double-horn galaxy spectrum was observed from HI data. To produce Figure 1 the data for each polarization in each observing run was calibrated by calculating (ON-OFF)/OFF. The spectrometer counts were converted to Kelvins using calibration data taken as part of the observing procedure. The Kelvins were converted to Janskies using the known Arecibo gain for each frequency (e.g. at 1420 Mhz the gain is 10 K/Jy). For each WAPP board the four spectra (two polarizations from two observing runs) were averaged. A linear polynomial was fit to the noise regions of each spectra and the polynomial subsequently subtracted from the spectra to zero its baseline. Finally, each spectrum was smoothed by applying a 5-point moving average, yielding the spectra shown in Figure 1.

From the HI spectra we deduced many parameters of UGC11362. The region of the spectrum with intensity above 0.01 Jy was deemed to be signal. The galaxy had a systemic (central) velocity of 4204.74 km s$^{-1}$ (redshift $z=0.014$). Assuming a Hubble constant of $H_0 = 75$ km s$^{-1}$ Mpc the distance to the galaxy was calculated from Hubble’s Law.

$$D = \frac{v}{H_0} = \frac{4204.74 \text{ km s}^{-1}}{75 \text{ km s}^{-1} \text{ Mpc}^{-1}} = 56.06 \text{ Mpc}$$

The total HI flux was found by integrating the spectrum of the signal.

$$S = \int I dv = 4.49 \text{ Jy km s}^{-1}$$

Using the distance and the HI flux we calculated the total mass of atomic hydrogen in the galaxy.

$$M[M_\odot] = 2.36 \times 10^5 \times D^2[\text{Mpc}] \times S[\text{Jy km s}^{-1}] = 3.33 \times 10^9 M_\odot$$
From the HI spectra we saw that the line-width of the galaxy was $\Delta V = 193 \text{ km s}^{-1}$ and the rotational velocity was $V_r = \frac{1}{2}\Delta V = 96.5 \text{ km s}^{-1}$.

We found from the NED database that UGC11362 has angular diameter $\alpha = 1.0 \text{ arcmin} = 2.909 \times 10^{-4} \text{ rad}$. The radius of the galaxy was calculated.

$$r_{op} = \frac{1}{2} \alpha D = \frac{1}{2} \times 2.909 \times 10^{-4} \text{ rad} \times 56060 \text{ kpc} = 8.154 \text{ kpc}$$

Using the radius and the rotational velocity we calculated the dynamical mass of the galaxy.

$$M_t [M_{\odot}] = 2.33 \times 10^5 \times V_r^2 [(\text{km s}^{-1})^2] \times r_{op} [\text{kpc}] = 1.769 \times 10^{10} M_{\odot}$$

5. Interpretation

O’Neil measured a radial velocity of $4205 \pm 2 \text{ km s}^{-1}$, which agreed with our findings. When calculating signal width at 20% of the peak intensity O’Neil got $207 \pm 14 \text{ km s}^{-1}$, which was consistent with our result only at the low end of its error range. When calculating signal width at 50% of the peak intensity he got $192 \pm \text{ km s}^{-1}$, which matched our findings. Note that O’Neil collected data at three different velocity resolutions (0.65 km s$^{-1}$, 1.3 km s$^{-1}$, and 8.5 km s$^{-1}$). Here we reference his 1.3 km s$^{-1}$ results as we also used this velocity resolution.

Our HI flux calculation (4.49 Jy km s$^{-1}$) falls outside the error range of O’Neil’s HI flux calculation (3.70 ± 0.2 Jy km s$^{-1}$). Somehow O’Neil’s and our intensity/temperature (y-axis) values differed while O’Neil’s and our frequency/velocity (x-axis) values agreed. The discrepancy could be due to differences in calibration data, in the gain factor used, in the baseline fitting, or in the data itself. O’Neil used longer integration time (5 minutes on source and 5 minutes off source) than we did, so his results should be trusted over ours. O’Neil also referenced an earlier study of UGC11362 with Arecibo (Schneider et al. 1990) that found a flux of 3.74 ± 0.2 Jy km s$^{-1}$, which encourages O’Neil’s flux result over ours.

Comparing our HI mass with our dynamic mass calculations we found that only 18.8% of our galaxy’s mass is accounted for by HI. Some of the remainder is accounted for by stars and the rest by dark matter.
6. Conclusion

Using the Arecibo radio telescope we successfully observed the galaxy UGC11362 at the 21 cm line. The systemic velocity was found to be 4204.74 km s$^{-1}$, the distance 56.06 Mpc, the HI flux 4.49 Jy km s$^{-1}$, the HI mass $3.33 \times 10^9 M_\odot$, the line-width 193 km s$^{-1}$, the rotational velocity 96.5 km s$^{-1}$, and dynamical mass $1.769 \times 10^{10} M_\odot$. Our HI flux results differed from the literature, where the HI flux is pegged at 3.7 Jy km/s. Consequently, our HI mass result would also differ from previous studies. While we did not measure any unknown quantities or test a new observing method, we did confirm that our telescope setup was done correctly, which was useful to establish the reliability of our observations of unknown galaxies. Finally, the observing session was successful in instructing a class of undergraduate students—who would normally not have the opportunity to use a telescope like Arecibo—in the methods of radio observation and data reduction.

7. References

Fig. 1.— Four emission spectra (one HI and three OH) from the direction of UGC11362. The data were taken with Arceibo in October 2008. The spectra are averages of two observing files, each with two polarizations. The OH spectra show no signal. The HI spectra shows a feature centered at 4205 km s$^{-1}$ with line-width 193 km s$^{-1}$.