Measuring the Atomic Hydrogen and Distance of Ultra Diffuse Galaxies

Olivia Krugman, Luke Leisman, and the UAT

Valparaiso University Department of Physics and Astronomy

What are UDGs?

- Ultra-diffuse galaxies are galaxies with very spread out stars
- UDGs are difficult to see because they have very few stars per pixel ("low surface brightness")
- Diffuse due to spread out stars – we want to know why

Figure 1: image of the UDG NGC 1052-DF2

Where do we get the data?

The Arecibo and Green Bank Telescopes

- Radio telescopes, Arecibo has better resolution and sensitivity, but GBT can see more of the sky
- These detect the electromagnetic waves emitted by hydrogen gas at 21 cm

Figure 2: Arecibo in Arecibo, Puerto Rico

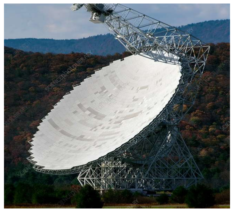

Figure 3: Green Bank telescope in Green Bank, WV

Main Points

1. UDGs are quite mysterious due to their stars being so spread out.
2. To find their distances and atomic hydrogen (HI) gas's mass, we must analyze their HI spectra.
3. Code is being developed to analyze these spectra more efficiently.

How do we find the properties of UDGs?

- Atomic hydrogen (HI) detections are an excellent method for observing and learning about UDGs since they tell us a lot about a source:
- the measured frequency of the spectral line tells us the speed the galaxy is moving away from us due to Doppler Shift
- the recessional speed of the galaxy allows us to calculate its distance using Hubble's Law
- The flux density of the galaxy tells us how bright it is in milliJanskys
- The velocity width (W50) tells us the width of the peak at 50% on either side
- The rotation velocity tells us the speed at which the galaxy is rotating due to its size and its amount of matter

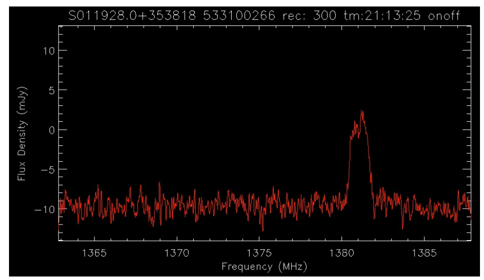

Figure 4: Spectrum (Flux Density in milliJanskys vs Frequency in MegaHertz) of atomic hydrogen emission from a galaxy measured by the Arecibo Telescope

How we turn Telescope Signal into Measurements

- Previous students started a pipeline for dealing with Green Bank data; the pipeline reads in the data, fits out waves in the spectrum, and removes radio interference.
- I worked on improving and fixing the pipeline, writing code in IDL (Interactive Data Language); my improvements made it possible to analyze small portions of the code, and to better remove wiggles in the baseline.
- I also developed Python code for calculating distances and HI masses from our spectrum fits.

```
m = c*D**2*S

print(f"The HI mass is {m:0.2f} solar masses.")
print(f"{np.log10(m):0.2f}")

The HI mass is 1138661962.24 solar masses.
9.06
```

Figure 5: An example of the code used to calculate the mass of the atomic hydrogen where c is the constant 2.356*10^5, D is distance, and S is the change in flux density.

What did we find?

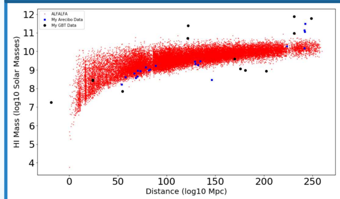

Figure 6: Graph of HI Mass (log10 solar masses) vs Distance (log10 MegaParsecs); red dots are the ALFALFA catalog, blue dots are Arecibo fits, and black dots are GBT fits

This graph shows that the Arecibo and GBT data are mostly consistent with the ALFALA data, but we still have potential concerns with radio interference (points brighter than were known to exist).

Future Work

Now that the code is created, the rest of the galaxies in the data log can be run through GBTIDL and cataloged. Once we measure all of the HI masses and distances, we will be able to determine if UDGs have abnormal amounts of HI gas and any other abnormal properties.

References

- Leisman et al., 2017
- Haynes et al., 2018
- Greco et al., 2018
- Van Dokkum et al., 2015
- LBW ALFALFA Data Reduction Instructions

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