Opportunities for Research and Education with a Small Radio Telescope

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Abstract

A small radio telescope offers a wide range of opportunities for students and educators to explore the vast universe through radio waves. The incoming radio waves are slightly shifted due to the Doppler effect and the phenomenon is utilized to determine the speeds of target objects. This survey serves as a good introduction to Radio Astronomy and understanding the structure of the Milky Way. Using the knowledge and understanding of the galactic survey, further experiments can be conducted

Introduction

A radio telescope is a sophisticated tool for amateur radio astronomers to explore the depths of the universe with incoming radio waves from different sources such as galaxies or pulsars. Hydrogen is the most abundant element (75%) in the universe which makes it ideal for observations using the radio portion of the electromagnetic radiation spectrum. The connection between radio waves and cold neutral Hydrogen atoms (H1) is due to a phenomenon known as Hydrogen Spin flip transition where an electron changes its spin from a higher energy level to a lower energy level (Burton, 1988). The difference in energy levels corresponds to the 21-cm wavelength H1 line that is commonly observed using professional and amateur astronomy equipment. Receivers specialized to operate at 1420 MHz (corresponding to the H1 21-cm line) are used to observe the incoming radio waves to detect for any subtle shifts in frequency and intensity. These subtle shifts in frequency, known as Doppler shifts, can be used to measure the velocity of the source object being observed.

Figure 1: The 3-m dish at the University of Scranton on the roof of the Loyola Science Center. It is currently in need of major repair or replacement with similar specification.

The University of Scranton Physics and Engineering department is in the process of finding a replacement for its current radio telescope set up which has been out of order for a few years. The replacement is intended to have similar specifications as the current dish with some additional improvements. The dish will have a 3-meter diameter antenna which is mounted at the base, along with an azimuth/elevation positioning system which is all attached to a 1420 MHz receiver through a feed.

Mass Estimation of Milky Way using H1 Measurements

Method/Experiment

The telescope will be used to conduct a study of Galactic Hydrogen by the detection of the 1420 MHz signals. These signals are caused by the Hydrogen electron spin flip transitions which due to the abundant presence of Hydrogen in the universe is detected on Earth.

The telescope will be pointed using the celestial coordinates which consist of right ascension and declination. The celestial coordinates will be obtained by converting galactic coordinates consisting of a latitude and longitude which are centered on the Milky Way. The latitude is the height above the galactic plane and longitude is the length across it. For this study, the longitude is varied in 5 degree increments to collect data. The reason for this conversion is mere convenience.

Data and Analysis

The collected data will be plotted in a *Frequency vs. Signal Strength* plot to determine the peak signal strength. The frequency corresponding to that peak is what we will use for our doppler shift of the incoming signal from the hydrogen spin flip.

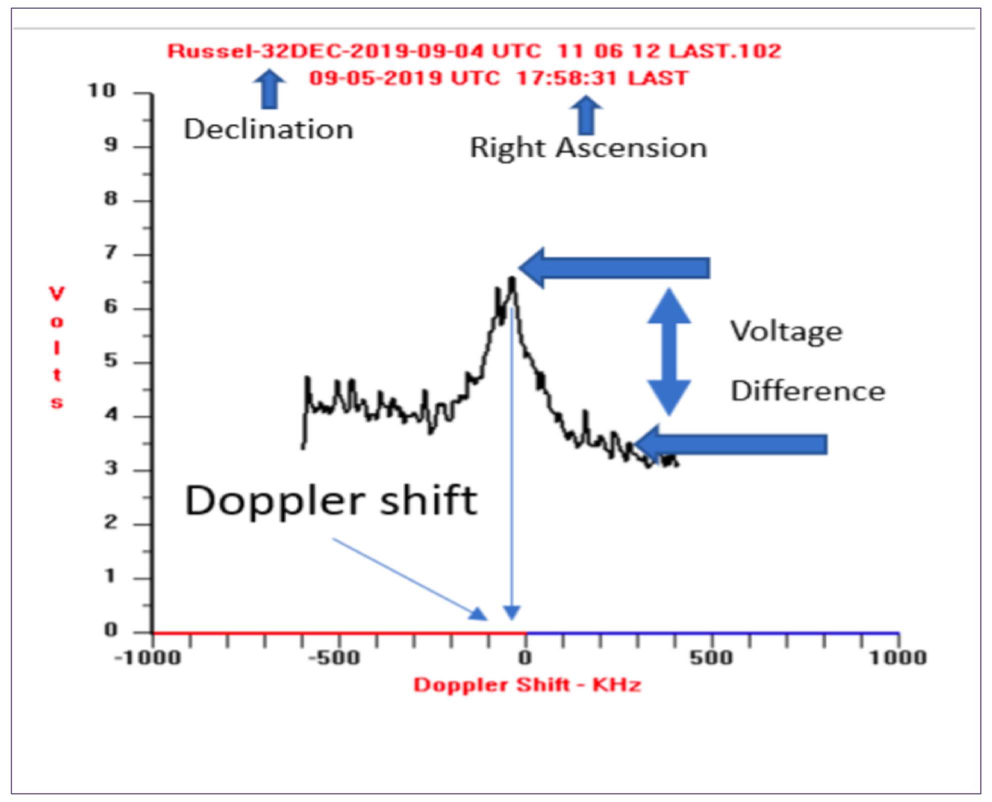

Figure 2: An example of a *Frequency vs. Signal Strength* plot. It can be seen that the frequency corresponding to the peak is slightly lower than 0 kHz due to Doppler shift (Russel, 2019)

The frequency corresponding to the peak will then be used with Doppler shift to figure out the speed the target object is moving at. If the frequency is higher than the set frequency (1420 MHz) then the distance is closing; if it is lower, then the distance is opening between the objects. The target objects are the galactic arms Cygnus, Perseus and Orion.

These speeds can be plotted against the longitudes in the galactic coordinates at which the dish will be pointing that particular day to make the velocity-galactic longitude maps. These speeds can be used to make a calculation for the rotation rate of the Milky Way and then be used to estimate the mass of the galaxy.

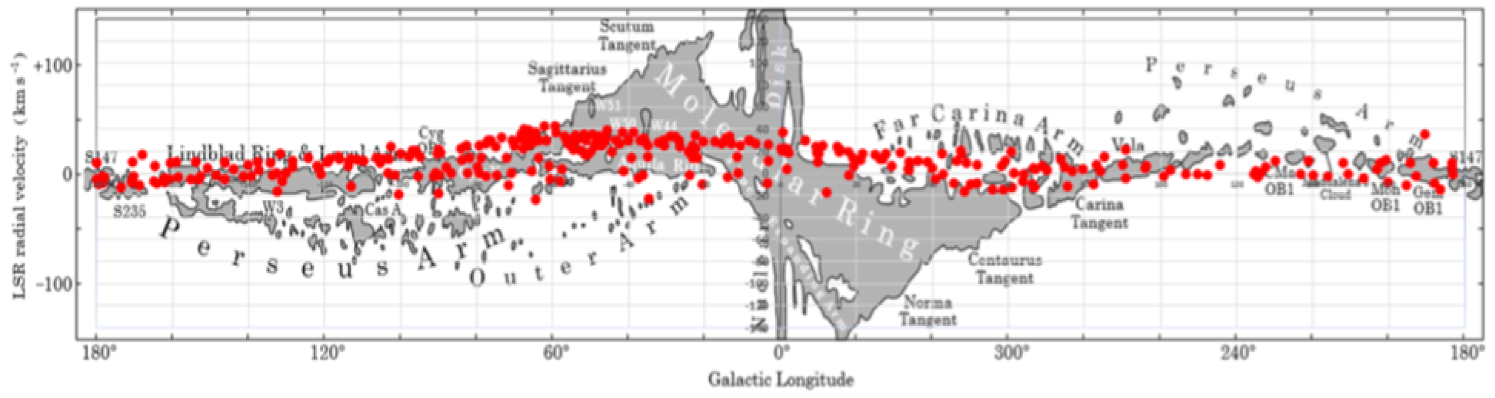

Figure 3: An example of a *velocity-galactic longitude* map (red) overlaid on another velocity-galactic longitude plot (in grey) produced by the Harvard-Smithsonian Center for Astrophysics with labeled galactic arms (Russel, 2019)

This particular experiment will be useful for us to replicate existing results which can be useful for students interested in radio astronomy to learn the basics of H1 measurements, and the features of the Milky Way galaxy. At the same time, this can ensure that our setup is working.

Further Experimentation and Projects

Fast Radio Bursts

Unknown origins and random detection which is subject of interest for many radio astronomers.

Black hole merger

This is expected to happen in a year or so and there might be some radio activity that could potentially be picked up by radio telescopes.

Designing swappable feed and other modifications

Greater frequency bandwidth and flexibility. Another suggestion: Physical gizmo for polarization. Magnetic fields through polarization can tell us about the type of dust in arms which can allow learning about star formation.

Conclusion

The galactic study of the galaxy is a great stepping stone to transition to advanced radio astronomy for studying deep space sources such as pulsars.

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