The Magellanic Stream

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1 Abstract

2 Introduction

The Magellanic Clouds are satellite galaxies of the Milky Way in the southern direction relative to the Milky Way's galactic plane at about 50 kiloparsecs away. They are large cloud structures home to regions of rapid star formation. A very large stream of dust cloud stretching between the Magellanic Clouds and stretching far away from the end of the Small Magellanic Cloud was discovered about half a century ago. It spans nearly 180 degrees in the sky from the view of the Earth. Using the Leuschner Dish, we receive radio signals from the stream. We then replicate a 2-D image of the stream with those signals by applying image processing and staistical techniques. Ultimately, the product reflects reality in galactic space, using galactic coordinates with a velocity dimension to indicate relative depth.

3 Methods and Procedure

It is particularly convenient for radio astronomy to study cosmic-scale objects due to the universality of the photons corresponding to the energy release of the hydrogen hyperfine transition. The physics of this study is centered on astrophysical techniques for interpretating the data sets collected by the dish at the hyperfine hydrogen line and how to manipulate the data sets to extrapolate information that would be used to image the source.

3.1 Galactic Coordinates and the Local Group

While equatorial coordinates are useful for assigning stellar locations on the intra-galactic scale, galactic coordinates for convenient for mapping Local Group objects on the inter-galactic scale, which consists of the Milky Way, the Andromeda, and the Triangulum galaxies with many surrounding dwarf and satellite galaxies. At the origin of the galactic coordinate system is the Sun. The galactic longitude (l) begins counterclockwise in the direction towards the galactic center. The latitude (b) is centered on the galactic plane. For example, the Large Magellanic Cloud during the J2000 epoch has equatorial coordinates of

$(ra = 80.894°, dec = -69.756°)$ with a corresponding galactic coordinates of $(l = 280.465°, b = -32.889°)$. The coordinates can be changed from equatorial to galactic through an epoch-dependent rotation matrix; for the J2000 era, it is:

$$R_{(ra,dec)\to(l,b)} = \begin{pmatrix} -0.054876 & -0.873437 & -0.483835 \\ 0.494109 & -.0444830 & 0.746982 \\ -0.867666 & -0.198076 & 0.455984 \end{pmatrix} \tag{1}$$

The goal here is to map the Magellanic Stream in 3-D coordinates of (l,b,v) where v is relative velocity, which indicates depth and other regional variations.

3.2 The 21-cm Hyperfine Transition Line of Hydrogen

3.3 Emission and Absorption Lines from Distant Sources

3.3.1 Broadening

3.3.2 The Line Profile Function

3.4 Intensity Calibration

In order to produce meaningful data for mapping, we calibrate the intensity of our data to produce temperature spectra that can show the variations among the values of our data. The calibration is done through the following equation:

$$T_{sys} + T(\nu) = \Big[\frac{P_j^{Online,CalOff}}{P_j^{Offline,CalOff}}\Big]\Big[\frac{\sum_{j=0}^{2J-1} P_j^{Offline,CalOff}}{\sum_{j=0}^{2J-1}(P_j^{Offline,CalOn} - P_j^{Offline,CalOff})}\Big]T_{Cal} \tag{2}$$

T_{sys} is the frequency independent portion of the total system temperature. It comes from the electronics in our tools and the interference of sources, such as the Earth's atmosphere and the galaxy's synchrotron radiation, other than our target. $T(\nu)$ is the frequency dependent temperature and is what we would want as the data from our source. P is power and j denotes a specific frequency with J being the total number of discrete frequencies in our data. Offline and Online denote the status of our oscillator; CalOff and CalOn denote the status of the presence of the noise, whose corresponding temperature is T_{Cal}.

4 Data

Data were taken in ranges of 58° to 90° in longitude and 60° to 82° in latitude. Each set of coordinates corresponds to several pointings of 358 average (of the Local Oscillator on and off) samples per pointing. Each pointing consists of four sets of array data varying among the on or off status of the local oscillator and of the noise data array. The initial data shows the power received as a function of frequency. The following shows the data set for a pointing. All data sets received are similar in shape, but differ in subtleties and the location of the 'spike.'

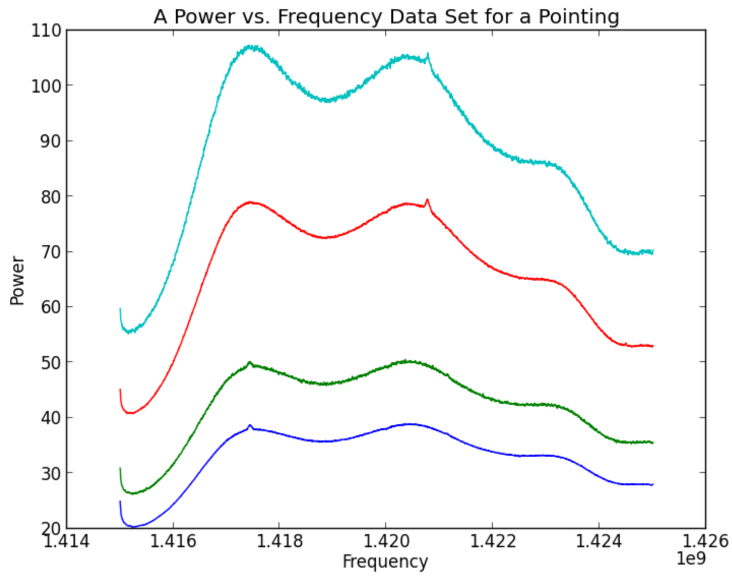

Figure 1: Plots showing data for a pointing at the $(66.0°, -72.0°)$ coordinate. From the lowest power to highest power curves: oscillator on and noise off; oscillator and noise on; oscillator and noise off; oscillator off and noise on.

5 Analysis

We apply the calibration method described above to the data from the 58° to 90° pointing. T_{Cal} is about 100 K. The first bracket in the calibration equation suggests that that ratio is frequency dependent, so we are free to choose any pair of corresponding points for that calculation refers to the shape of the data; it is a ratio of the online array to the offline array. The second bracket is the holistic frequency independent system temperature, taking into account the entire range of frequencies.

6 Conclusion