Studying the Properties of Diffuse Atomic Halo Gas Surrounding the Milky Way and M83

Pallavi Maladkar, The North Carolina School of Science and Mathematics

Motivation

Diffuse atomic gas permeating and surrounding galaxies constitutes a large fraction of galactic baryonic mass [3]. We focus on determining the spatial extent and kinematics of gas structures along lines of sight to Messier 83 by employing absorption line spectroscopy. These lines of sight are at close projected separation from each other. We calculate column densities of ionized Ca II gas observed around the Milky Way and Messier 83 along these lines of sight, and study the small scale variation in the density and masses of the gas clouds.

Introduction

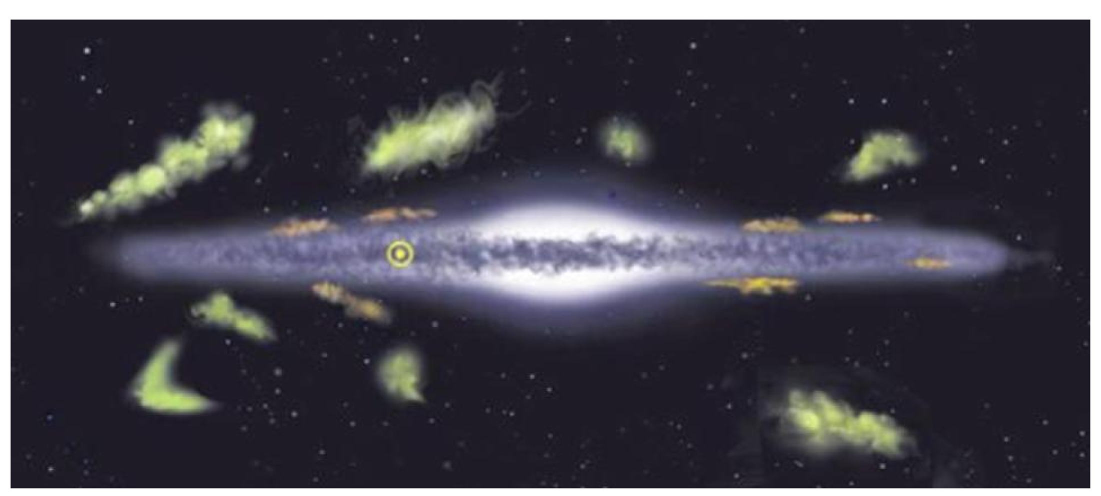

Figure 1: Schematic of galactic halo clouds orbiting spiral galaxy [2]

- Understanding the properties of galactic halo clouds (green and orange, Figure 1), provides an inside look at gas accretion. Ca II (singly ionized Ca) traces dense atomic gas at around 10^4 K.
- In order to parameterize the gas accretion rate, we require the following properties of atomic gas clouds: mass, infall velocity, and galactocentric distance [4]. We can determine properties of size, column density, and line of sight (LOS) velocity through atomic absorption spectroscopy. These properties will later be used to find the masses and kinematic variables of the clouds.
- Our data were obtained at the ESO Very Large Telescope in Chile as part of the program, "Mapping the Cool Circumgalactic Medium and Disk Interface of M83 with Calcium II". The FLAMES/GIRAFFE spectrograph was used, with a resolving power of 22,700.

Methods

- We analyze the spectra of 126 pointings oriented inside and surrounding Messier 83 (Figure 2, left).
- We consider ionized Ca II gas and use detected H and K absorption lines to determine LOS velocities from measured wavelengths.

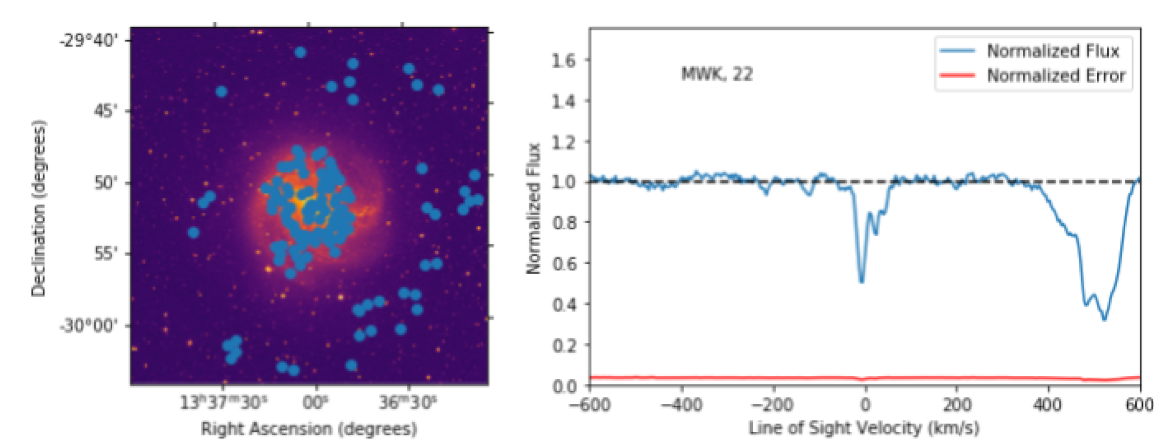

Figure 2: Left: Pointings on M83 galaxy [1]; Right: Normalized flux for one line of sight, Ca II K line (P. Maladkar)

- To normalize each spectrum, we divide the spectrum by a polynomial fit to the continuum of the background source (Figure 2, right).
- The 0 km/s signal indicates gas in the Milky Way interstellar medium, while the 550 km/s signal indicates a high velocity cloud orbiting M83.
- We find equivalent widths of signals by calculating the area between the spectrum and normalized flux=1 over LOS velocity ranges enclosing the signals. This is done for signals near 0 km/s and 550 km/s. We calculate corresponding Ca II column densities.

Results

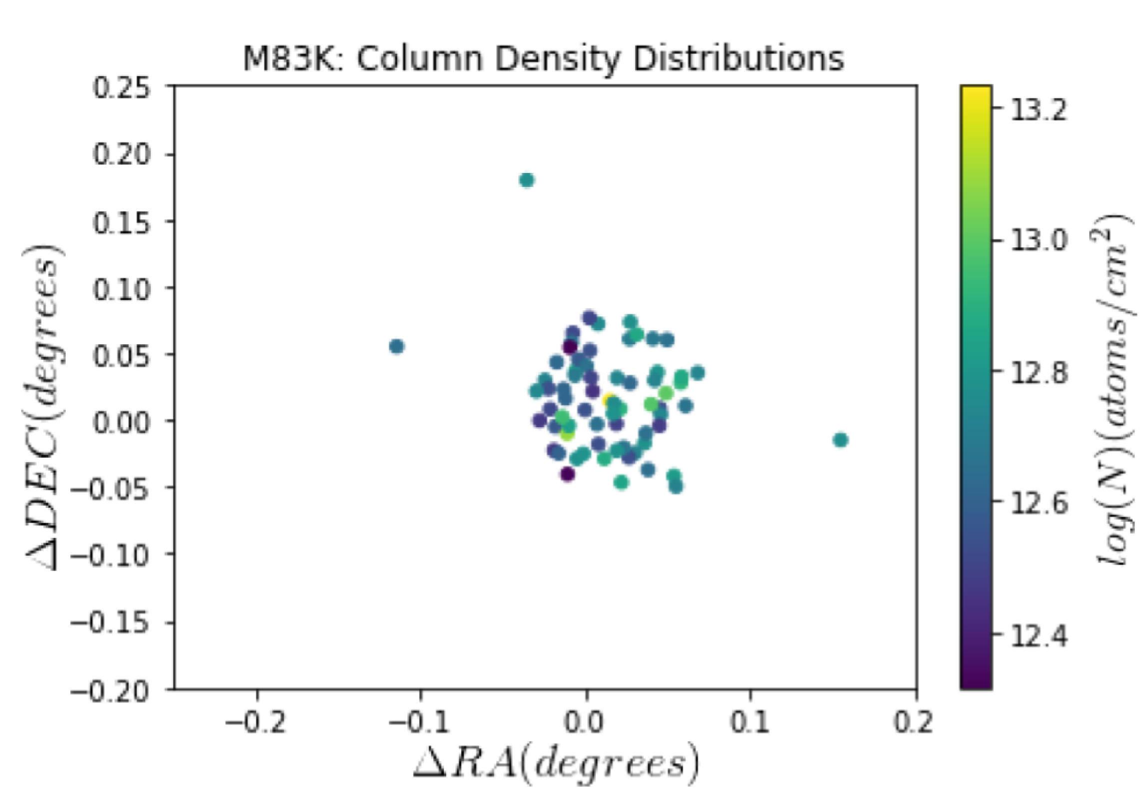

Figure 3: Ca II column density distribution in M83 halo (~550 km/s), K absorption line (P. Maladkar)

- To gain a realization of the spatial extent of the atomic gas clouds, we plot the spatial distribution of the statistically significant pointings relative to the mean position of all pointings (Figure 3).
- We create a color-heat map to represent the logarithm of the column density at each pointing.

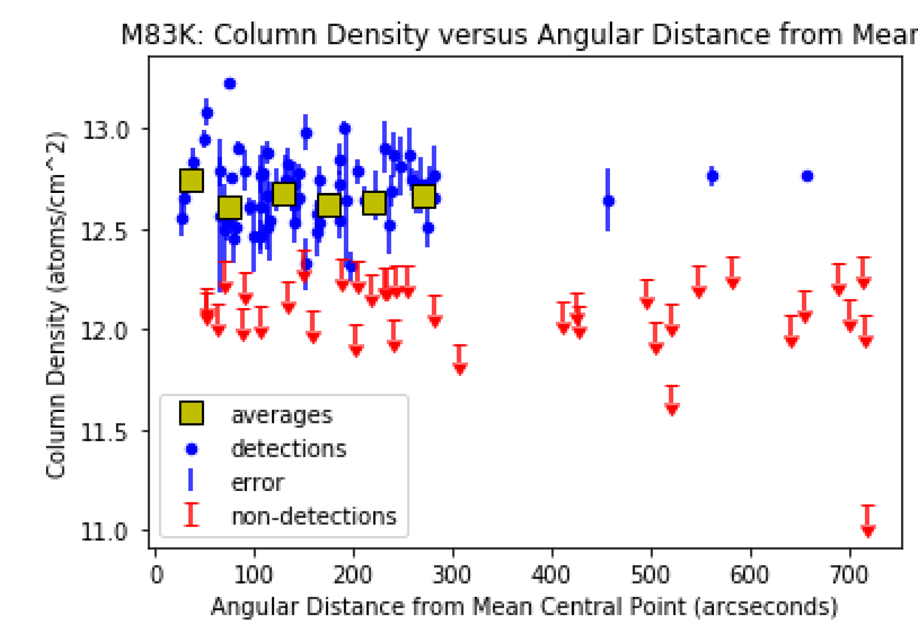

Figure 4: M83 cloud, column density variation from mean central point (P. Maladkar)

- We plot the angular separation of the pointings from the mean position of all pointings on the x-axis, and plot column density on the y-axis (Figure 4).
- We attempt to see a trend in column densities by averaging the detections over 50 arcsecond ranges (yellow squares). We observe a fairly constant distribution, suggesting the presence of many cloudlets of similar size.

Model

- We construct a "toy" model, in which all 126 cloudlets are spheres with the same radius R, density, and randomly assigned impact parameter d. One such model cloudlet is shown in Figure 5.

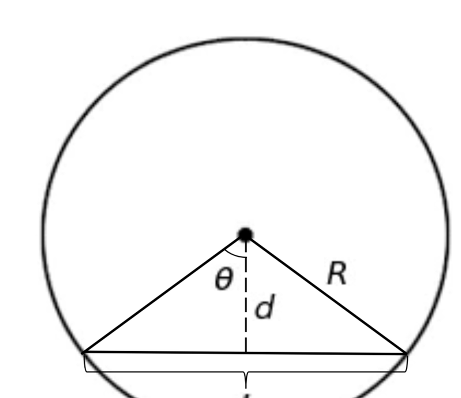

Figure 5: Geometric representation of cloudlet toy model; R is the radius, d is the impact parameter, l is the portion of the line of sight to the pointing that passes through the cloud. (P. Maladkar)

- From our toy models, we compare the predicted column densities to observed column densities to find associated reduced χ^2 values. We vary the radius and density of each model to minimize the reduced χ^2 (Figure 6).

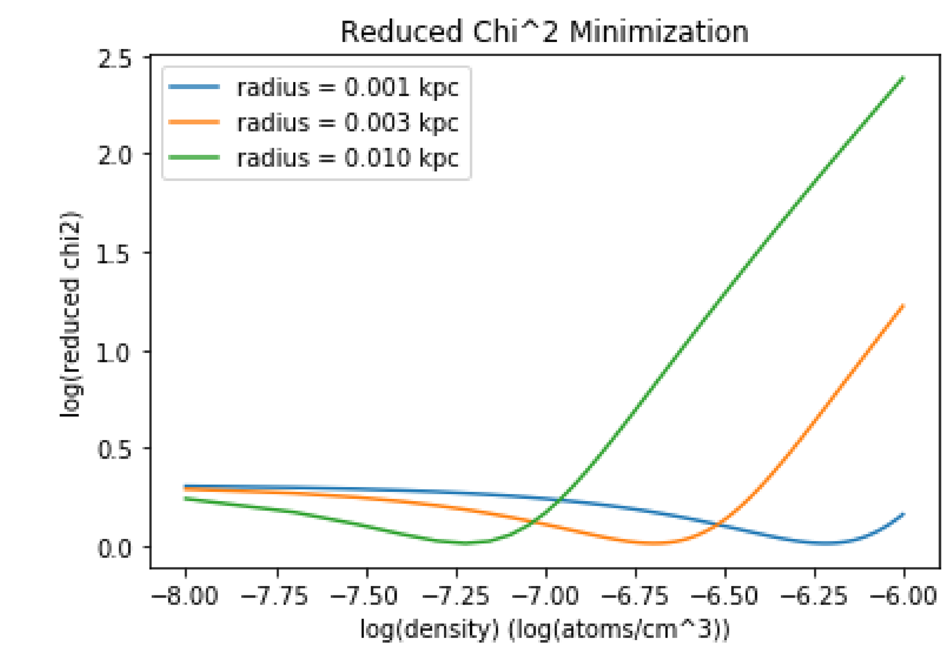

Figure 6: Reduced χ^2 minimization of toy model, each curve representing a different cloudlet radius (P. Maladkar)

Conclusions

- We observe numerous detections for the LOS velocity range -90 to 40 km/s and 400 to 600 km/s, indicating the presence of diffuse atomic gas orbiting the Milky Way and M83, respectively.
- The fairly constant distribution of column densities as distance increases from the mean of all pointings suggests the presence of many similar cloudlets of gas constrained in size by non-detections (Figure 4).
- We find that our reduced χ^2 value is minimized with a cloudlet radius of $3 \cdot 10^{-3}$ kpc and a density of $2 \cdot 10^{-7}$ atoms/cm^3, represented by the orange curve in Figure 6.

References

[1] R. Bordoloi. *Unpublished.*

[2] I. Kallick. *Galactic Halo Clouds.* Scientific American, Jan 2004.

[3] N. Lehner, J. C. Howk, C. Thom, A. J. Fox, J. Tumlinson, T. M. Tripp, and J. D. Meiring. High-velocity clouds as streams of ionized and neutral gas in the halo of the Milky Way. *Monthly Notices of the Royal Astronomical Society*, 424(4):2896–2913, October 2012.

[4] P. Richter. Gas Accretion onto the Milky Way. 430:15, Jan 2017.