The Effects of the Galactic Center on the Ionization of the Magellanic Stream

Elaine M. Frazer[1], Andrew J. Fox[1], Joss Bland-Hawthorn[2], Kathleen A. Barger[3]

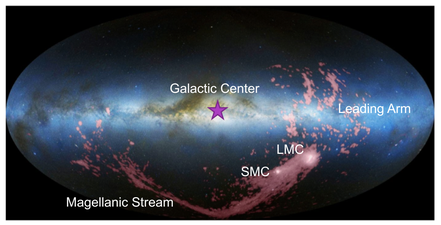
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. University of Sydney, Sydney, NSW, Australia. 3. Texas Christian University, Fort Worth, TX, United States

1. Introduction

The Magellanic System around our Milky Way (MW) galaxy consists of:

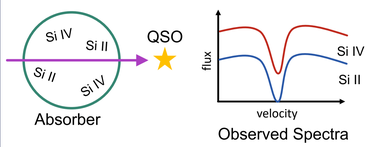
- the **Large and Small Magellanic Clouds** (LMC and SMC)
- the **Magellanic Stream** ("the Stream"): a filamentary system of multi-phase gas created primarily through tidal interactions between the LMC and SMC ~2Gyr ago
- the **Leading Arm** (LA): a fragmented group of clouds that leads the LMC and SMC on their orbits around the galaxy

Right: H I observations of the Magellanic System in Galactic coordinates, shown in pink (Nidever et al. 2010).

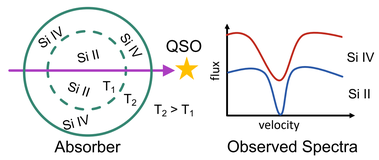


Fox et al. 2014 have observed highly-ionized gas in the Stream and LA. There are at least two models for how this was created:

The **Seyfert flare model** (Bland-Hawthorn et al. 2013): the Stream (but not the LA) is photoionized by an energetic flash at the Galactic Center (GC)



The **two-phase model**: the high ions arise in turbulent or conductive mixing layers between the cool Stream/LA and the hot Galactic corona



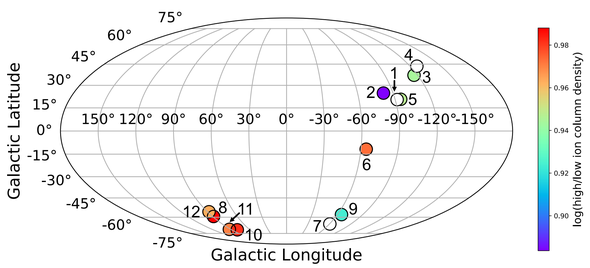
We use HST/COS absorption spectra to look for **(1)** evidence of enhanced ionization in the Stream below the Galactic pole (see box 3), **(2)** differences between the profiles of low-ion and high-ion absorption components in the Stream and LA (see box 4), and **(3)** differences between the distribution of absorption strengths in the Stream and LA (see boxes 5 and 6.)

2. Data and Analysis

- We study 6 sightlines through the Stream and 6 through the LA with far UV absorption spectra taken with the Cosmic Origins Spectrograph on Hubble from Fox et al. 2014 and 2018.
- We use the Python package `VoigtFit` (Krogager 2018) to fit multi-component Voigt profiles to low and high ions for each sightline. We fit O I, C II, S II, Si II, Si III, Si IV, and C IV, where detected.
- The `VoigtFit` module outputs the redshift, b-value (line width), and column density for each component fit.

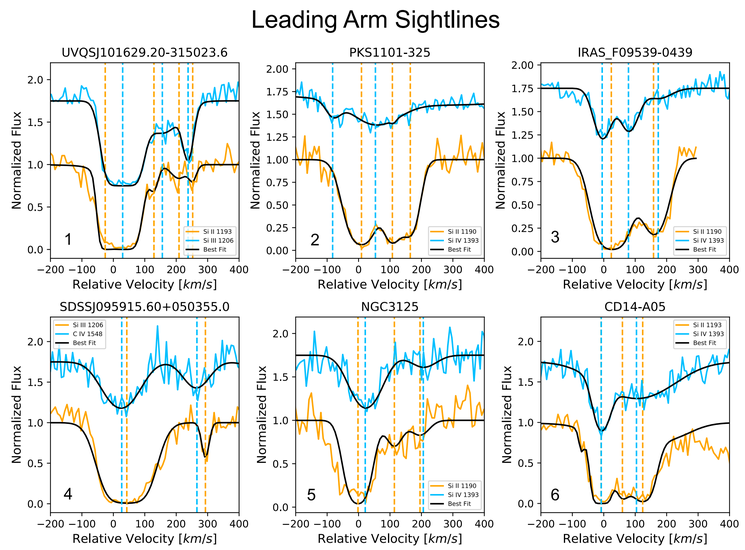
3. Ion Ratio vs. Location

The plot below shows the ratio of total column density for a low/high ion pair for each sightline in our sample. The pairs will be either Si IV/Si II or C IV/ C II. Sightlines with white circles do not have measurements for those ions from VoigtFit. The Stream sightlines 8, 10, 11, and 12 (where we would expect the effects from the GC to be) all have elevated high-ion density.



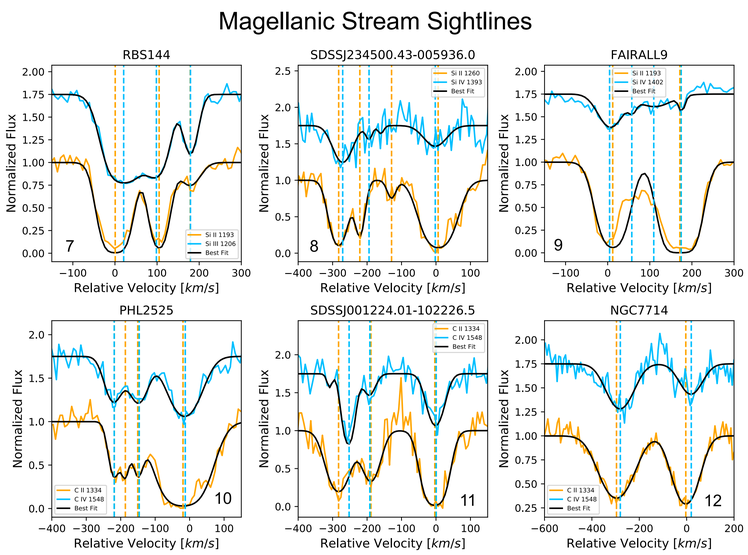
4. Alignment of Different Stream and LA Sightline Components

The alignment of low- and high-ion components in different sightlines could lend evidence for the Seyfert model, while mis-alignment could point towards the two-phase model.



Above: The VoigtFit profiles for each LA sightline. Each figure shows the spectrum of a low ion and high ion plotted by relative velocity and offset flux, along with their best-fit lines. The dashed lines give the center redshift position of each component. The small number in the corner marks where each sightline lies on the map in box 3.

- We see many examples of mis-aligned components: sightlines 1, 3, 4, 6.
- Components seen in high ions, but not low ions: sightlines 1 and 3.
- Components seen in low ions, but not high ions: sightlines 5 and 6.

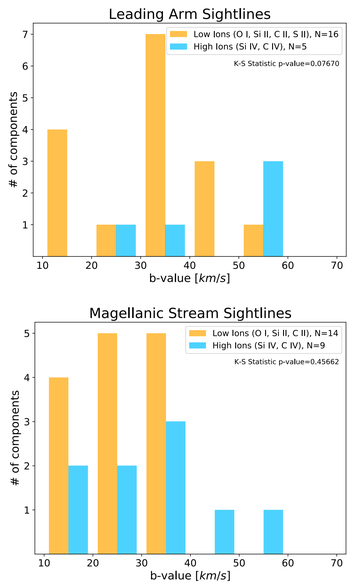


Above: The VoigtFit component fits to each Stream sightline. The figures are as described above.

- We see fewer examples of mis-aligned components: sightline 8 only.
- Components seen in high ions, but not low ions: sightline 9.
- Components seen in low ions, but not high ions: sightlines 8 and 10.

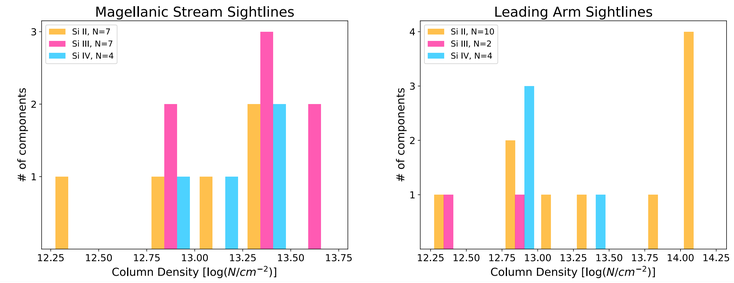
5. Distribution of b-values

- The figures to the right show the distribution of b-values (line width) of the low- and high-ion components of both the Stream and LA sightlines. High-ion components being wider in general than the low-ion components supports the two-phase model.
- We use the Kolmogorov–Smirnov (K-S) test to determine the probability that the high- and low-ion populations are statistically distinct. The p-values are printed inside each plot. In the LA, there is 93% confidence that the high-ion components are distinctly larger than the low-ion components. We do not see this in the Stream.



6. Distribution of Column Densities

We compare the distribution of the column densities of Si II, Si III, and Si IV components of the Stream and LA sightlines. The LA is much closer to the Milky Way disk where the density of the ambient gas is higher, so one may expect to observe stronger high-ion absorption in those sightlines. The figures below show the opposite: stronger high-ion absorption in the Stream sightlines than in the LA. This could potentially be related to the GC flare or the density of the surrounding gas.



7. Conclusions & Acknowledgements

- There is evidence for slight high-ion enhancement in the Stream in the region below the Galactic Center, as seen in the map of high/low ion ratios in box 3.
- Five of 12 sightlines exhibit mis-aligned low- and high-ion components (box 4). Four of these are in the LA, while only one is in the Stream.
- In the LA, we find the high-ion components are distinctly broader than the low-ion ones, whereas in the Stream, no difference is found (box 5).
- We observe stronger high-ion absorption in the Stream than in the LA (box 6).

Future work includes expanding our sightline sample to include all 69 from Fox et al. 2014.

References:

Bland-Hawthorn, J., Maloney, P. R., et al. 2003, ApJ, 778, 1
Bland-Hawthorn, J., et al. 2018, ApJ submitted
D'Onghia, E. & Fox, A. J., 2016, ARA&A, 54, 363
Fox, A. J., Wakker, B. P., Barger, K. A., et al. 2014, ApJ, 787, 147
Fox, A. J., Barger, K. A., Wakker, B. P., et al. 2018, ApJ, 854, 142
Krogager, J. K., 2018, VoigtFit, https://arxiv.org/abs/1803.01187
Nidever, D. L., Majewski, S. R., & Burton, W. B. 2010, ApJ, 723, 1618
Richter, P., Fox, A. J., Wakker, B. P., et al. 2018, ApJ, 865, 145

Questions?
Email efrazer@stsci.edu or scan the QR code above for author info.