Explosive galactic weather: Winds from the largest cloud in the local group

Stone Gebhart[1], Lauren Sdun[1], Katherine Anthony[1,2], Kat Barger[1]

[1]Texas Christian University, [2]Messiah University

Background:

The Large Magellanic Cloud (LMC), a small neighboring galaxy around one Milky Way diameter away, provides a unique opportunity to study outflowing gas clouds in great detail. Massive stars in the LMC undergo supernova explosions when they die, blasting gas in all directions. If the gas escapes from the galaxy, a galactic wind is formed. Using data from the Hubble Space Telescope, we can try to better understand how this wind moves and its physical properties. Because there can be numerous of these gas clouds in each direction, we often detect complex patterns that we are characterizing with a Gaussian fitting algorithm. Thoroughly studying the resolved galactic wind of the LMC will ultimately contribute to our understanding of the processes that drive galaxy evolution.

Fig 1. The LMC photographed by the European Space Agency's VISTA Telescope

Research Task:

The HI4PI surveys of neutral hydrogen in this galaxy described the emission structure of the gas associated with it. Although those characterizations can fit the brighter structures, they fail with the fainter substructures. The residual plot below depicts the difference between the observations and their fit; if they matched up well, this chart would just include noise. However, the substructure suggests that there is room for improvement.

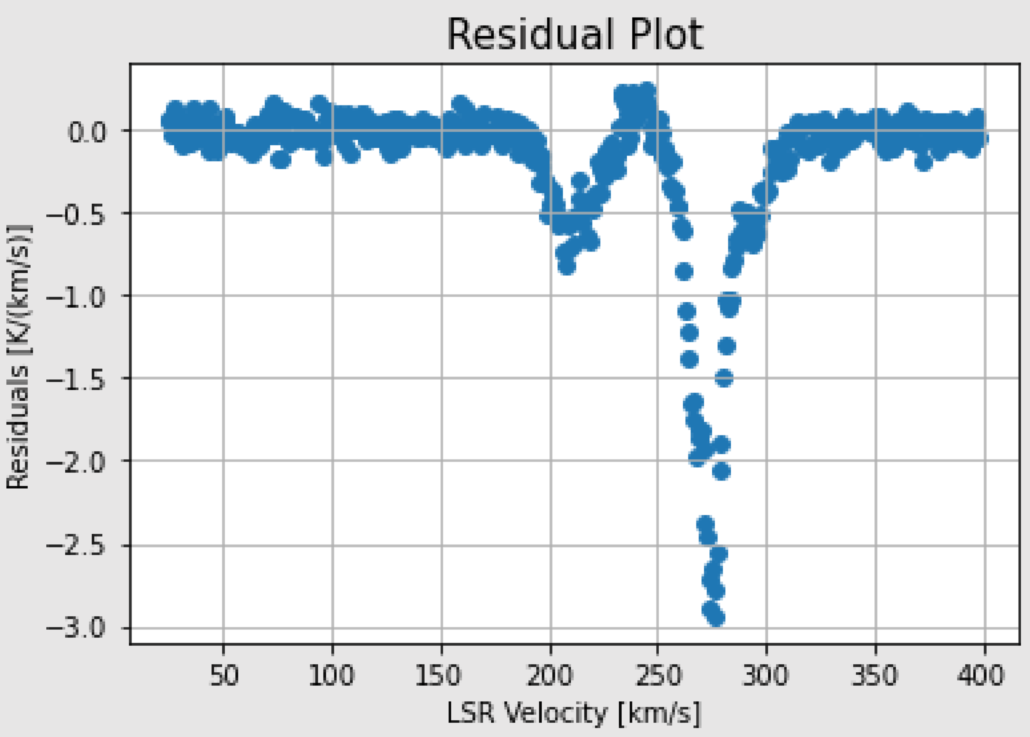


Fig 2. Residual plot comparing the existing fits to the spectrum. Residual plots show how close a given fit line is to the original fit line. The residual is given by the original data fit minus the predicted fit. The large amount of residual noise found at a LSR velocity of 270 km/s indicates that the fit is not precise.

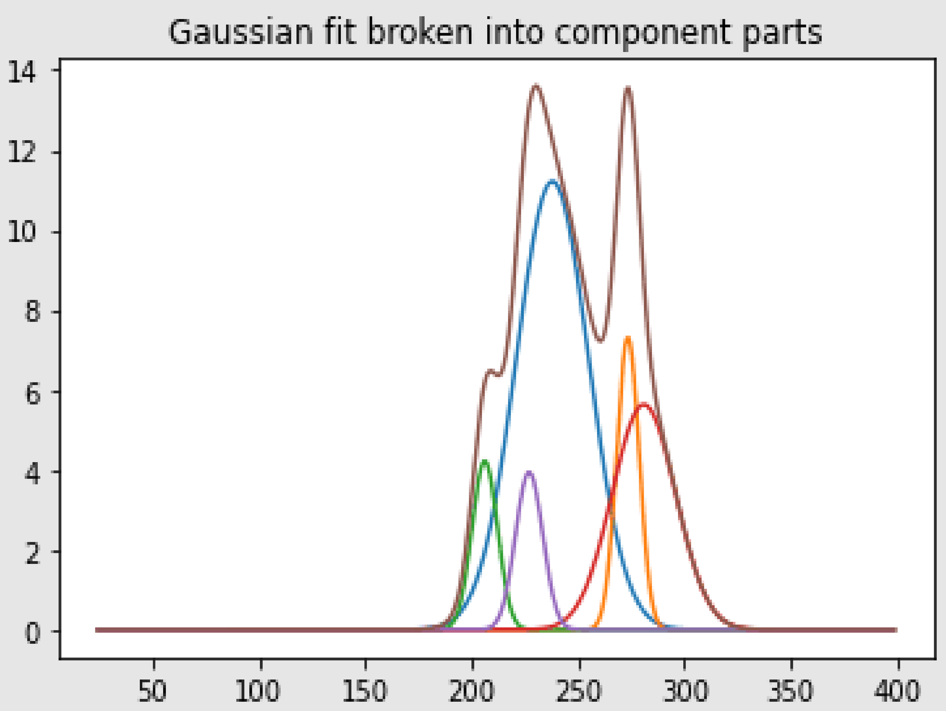
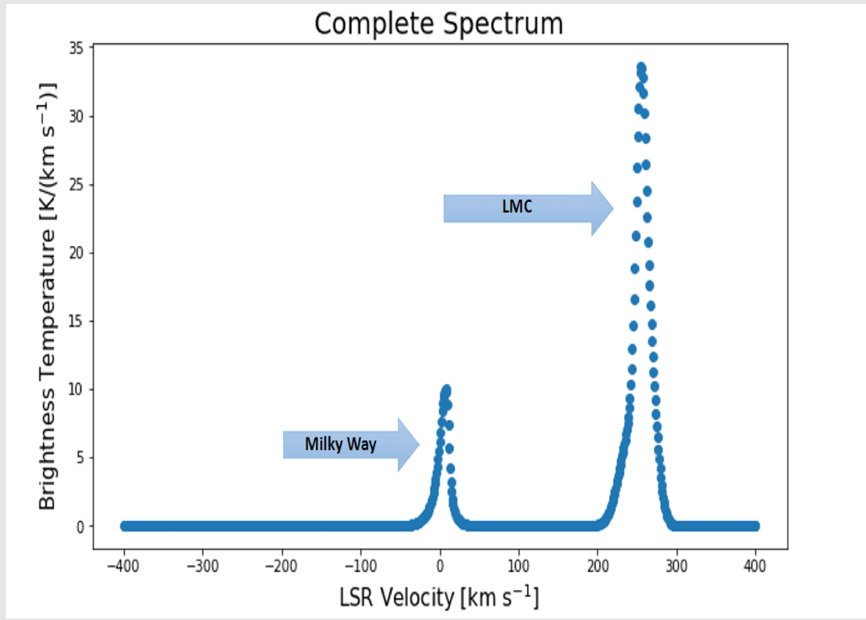


Fig 3. The component parts of our fit, which will be summed to create the total fit

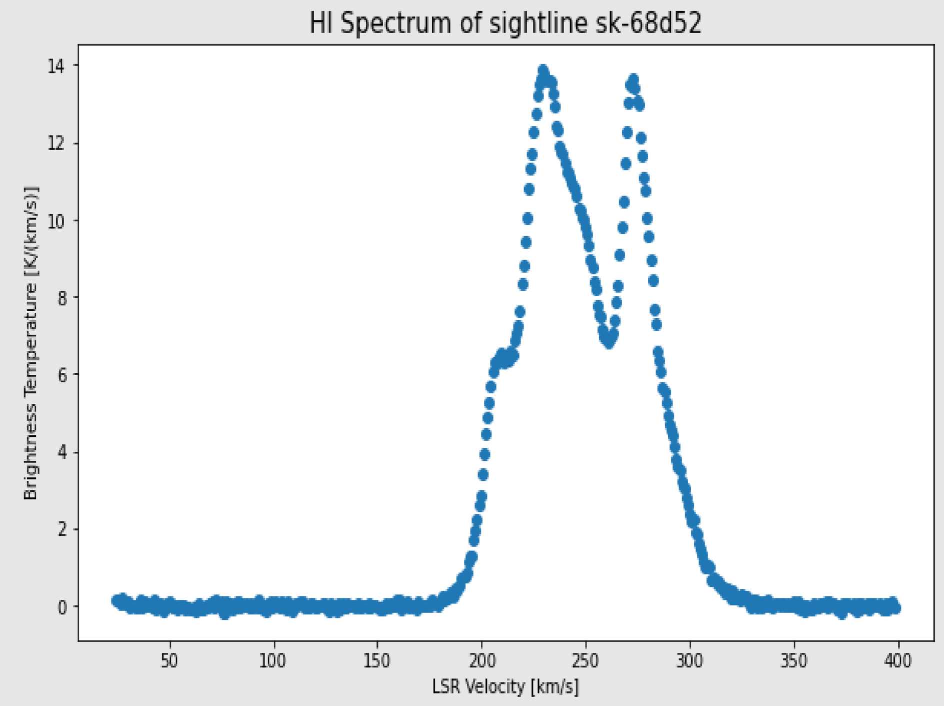
Procedure:

We used spectral observations from the HI4PI Survey[3].

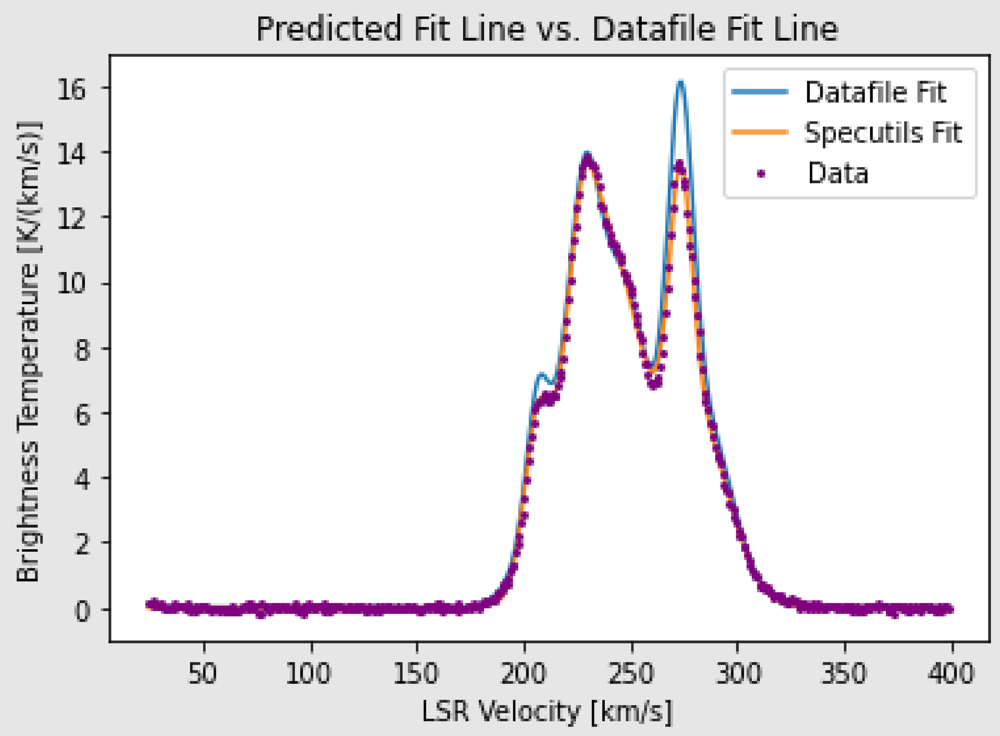
1. **Gaussian Distribution:** The first step in our study involves a deep understanding of the behavior of gas particles in a cloud. In essence, the random movements of these particles along the line of sight follow a Gaussian or normal distribution. This statistical principle is foundational to our analysis.
2. **Identifying multiple gas clouds:** The spectral observations reveal a multi-component structure, suggesting the existence of more than one gas cloud along the line of sight. Therefore, the emissions we observe are a blend from different gas clouds, including those from our target: the Large Magellanic Cloud
3. **Isolating the LMC:** To focus our study on the LMC, we mask out the unnecessary Milky Way data.
4. **Fitting Gaussians:** We then fit Gaussians to the isolated data. Our goal is to create a better fitting Gaussian than the one provided by the HI4PI Survey. This step involves using Python fitting routines like Specutils
5. **Comparing Results:** Finally, we compare our Gaussian fits to those provided by the HI4PI Survey. This comparison allows us to determine the efficacy of our models and helps us refine them for better accuracy.



Step 3



Step 4



Step 5

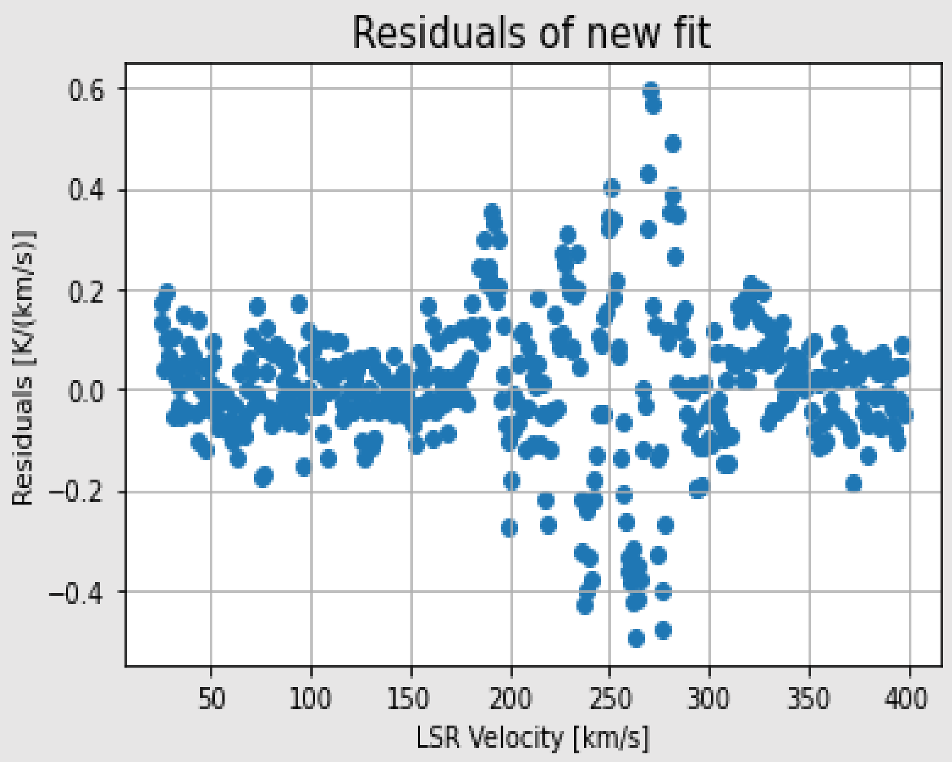


Fig 4. Residuals after fitting using Specutils, a Python routine that is able to fit multiple Gaussian profiles at once, which produced more accurate fits. There is still some variation, but it is between -0.4 and 0.6K/(km/s), as opposed to the -3 to 0 K/(km/s) range from before.

Results:

Because our new residuals are close to 0 K, it suggests that the fits are likely better than those provided by the HI4PI survey. This allows for more accurate constraints on the kinematics of the gas in the LMC, thereby improving predictions about the gas belonging to the wind and its total mass. This in turn would enhance understanding of the processes driving galaxy evolution and their impact on star formation

Contact:
Stone Gebhart
Texas Christian University Department of Physics and Astronomy
Stone.Gebhart@TCU.edu

Lauren Sdun
Texas Christian University Department of Physics and Astronomy
lauren.sdun@tcu.edu

References:
[1]NASA/ESA
[2]HI4PI Collaboration: Bekhti et al. 2016

Acknowledgements:
We gratefully acknowledge support for this research from the National Science Foundation's Research Experience for Undergraduates program (PHY-1852267).
Thanks to David Nidever for providing the Gaussdecomp Python package, which is available on GitHub.