Massive Winds Triggered by Supernovae in the Large Magellanic Cloud Galaxy

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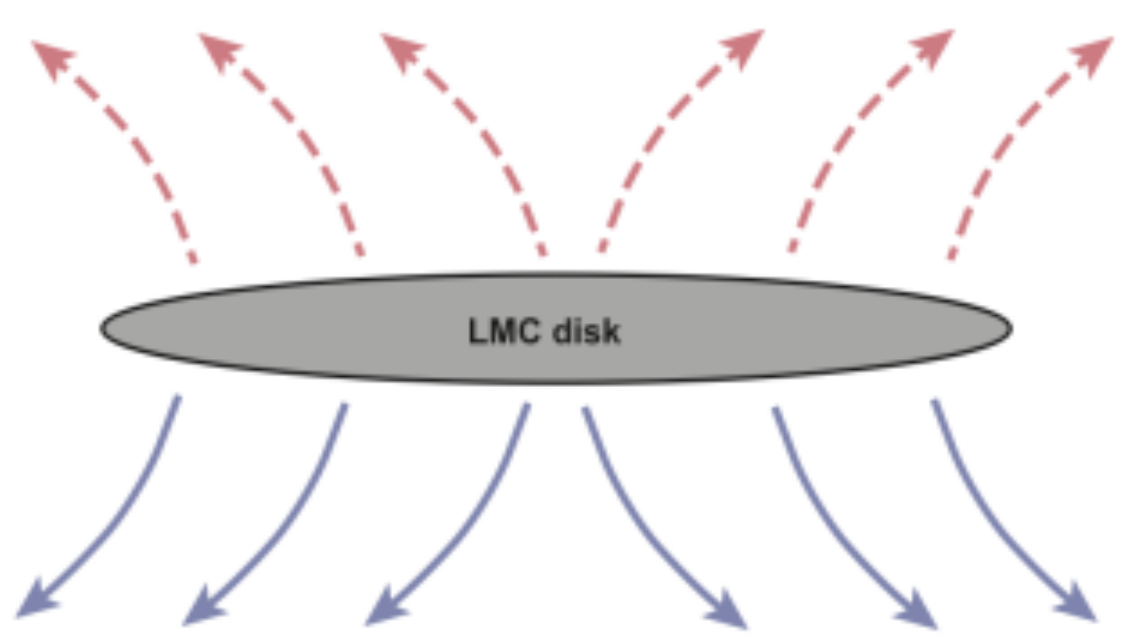
Massive amounts of gaseous material are being ejected from the nearby Large Magellanic Cloud (LMC). Deciphering how baryons cycle in and out of galaxies is crucial for our understanding of how galaxies evolve and with the LMC at only one Milky Way diameter away, we are provided with an excellent opportunity to explore this cycle in detail. As this gaseous wind is being thrown outward, some of it may fall back into the grasp of the host galaxy while the rest will be sent hurtling into space directed toward the Milky Way. The star-forming lifetime of a galaxy is dependent on the gas supply it has and therefore dependent on the galactic processes that occur. Galaxies losing gas will not be able to form as many new stars compared to those who can maintain a supply of gas. We have combined spectroscopically resolved observations to (1) fully map the near-side galactic wind of the LMC, (2) determine the properties of this gaseous outflow including its morphology, extent, mass, and outflow rate, and (3) estimate how much energy is needed to eject this gas and which regions within the LMC are driving this outflow. Understanding the properties of this galactic wind will provide invaluable information regarding galaxy evolution and surrounding environments, galactic feedback, and the LMC's possible influence on the Milky Way.

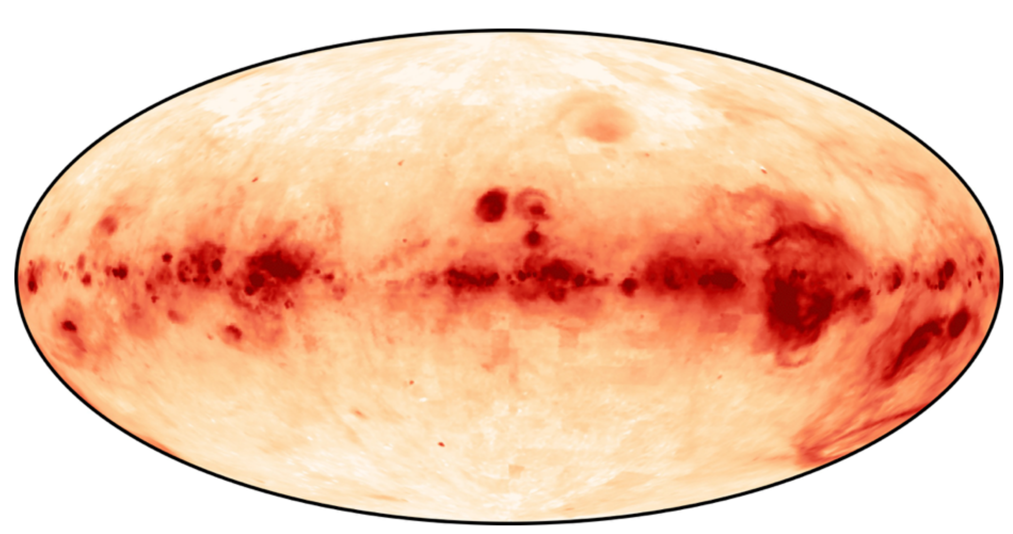
Summary

In one of the closest galaxies to our own, the Large Magellanic Cloud (LMC) is spewing out massive amounts of gas aimed toward our Milky Way (MW) galaxy. This gas contains over 10 million times the mass of the Sun[1,2] and is traveling at speeds up to 100 km/s away from the LMC. For such a massive wind to travel at those speeds, an extremely powerful event must have thrust this cloud into motion. Recent studies have shown the potential catalyst for the ejection of this cloud to be tied to supernovae reactions inside the LMC. This gas ejection is likely associated co-added supernovae activity within the disk of the LMC. Using kinematically resolved observations of the Hα emission, we are able to—for the first time—map 10–20 kpc off the disk of this galaxy to make better estimates of the extent and therefore the mass of this wind. These estimates will enable us to better predict the fate of this gas and its influence on the nearby environment and the overall evolution of the galaxy itself.



Instrumentation and Data Reduction

- Wisconsin Hα Mapper (WHAM, left figure[3])
- Fabry-Perot spectrometer to observe the Hα emission line
- Extremely high sensitivity to detect faint emission



- Numerous spectra can be combined to produced kinematically emission maps, like the map of our Galaxy (see right figure[4,5])
- Over 3,500 spectra taken of near-side

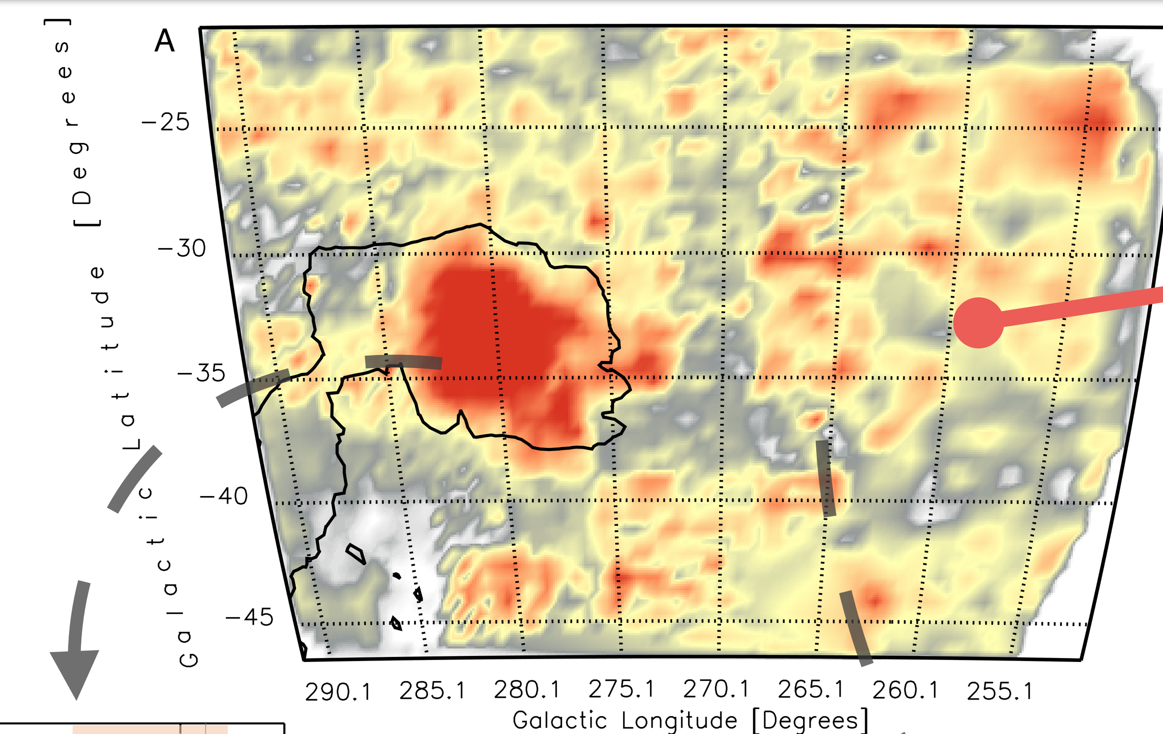
Results

To utilize the WHAM data effectively, we produce emission maps of the near-side LMC wind. To construct an emission map, we take individual spectrum and integrate the flux across a specific velocity range: 90 < V_{LSR} < 225 km/s. This omits emission from the disk of the LMC as well as the Milky Way.

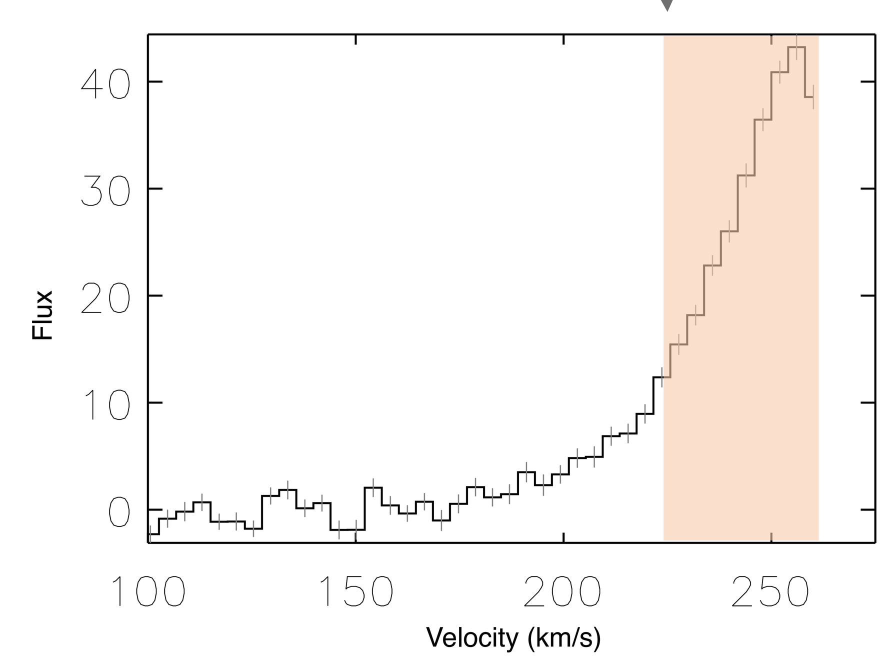
In Figure A, it is seen that Hα emission is widespread across the region of the LMC. This emission suggests the potential impact the wind may have on the surrounding environment. By further dividing the emission map into four evenly spaced velocity windows we are able to view how the wind evolves in velocity space. Studying the winds' mass, morphology, and kinematics, using this emission-line data, helps answer how the wind will alter the nearby environment and also alter the LMC's survival and evolution.

Emission Maps

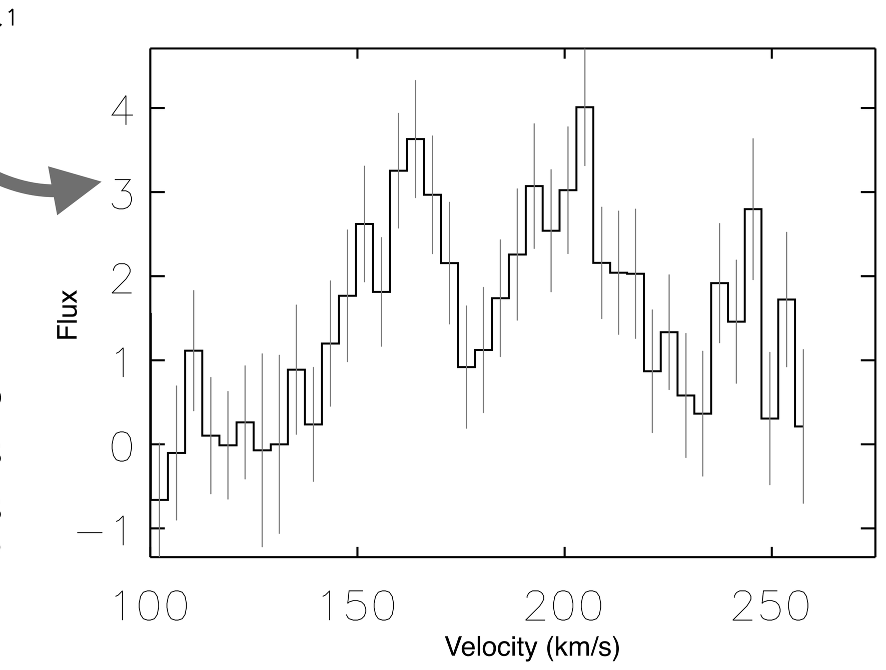
Emission Maps: Tells us how much emission is present at each point in the map. The total emission will be used to calculate the mass of the wind.

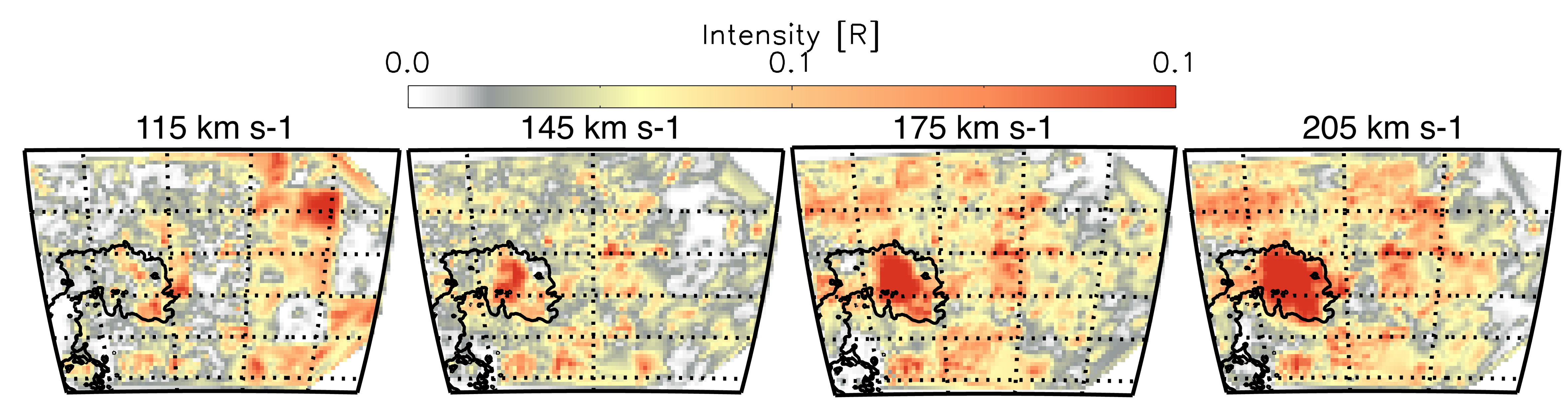


Widespread Emission: Indicator of how the emission extends off the LMC. The wind, therefore, can play a role in the dynamics of the surrounding medium.



Channel Map: Dividing the emission map into four separate emission maps centered at different velocities helps visualize the winds' kinematics and morphology.





Mass Estimations and Conclusions

Figures B and C represent emission spectra that construct the emission map that is shown in Figure A. Mass estimates were calculated using the equation below. It was determined that the wind contains **(4.11 +/- 0.64) x 10^7 M⊙** worth of ionized material in the velocity range of 150 - 210 km/s. This range is representative of a near-side wind coming off the LMC. This mass estimate agrees with prior work performed by Barger et al. 2016 which estimated the near-side wind to have a lower limit mass of 1.5 x 10^7 M⊙.

$$M_{\rm ionized} = 1.27\times 10^3 \left(\frac{D}{12.4\rm kpc}\right)^2 \left(\frac{\rm EM}{\rm pc\ cm^{-6}}\right)\left(\frac{n_e}{\rm cm^{-3}}\right)^{-1} M_\odot$$

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[1] Barger et al. 2016, ApJ, 817, 91
[2] Lehner el at. 2009, ApJ, 702, 940
[3] Photo Credit: L.M. Haffner
[4] Haffner+2018 (in prep)
[5] Haffner et al. 2010, ASPC, 438, 388

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