Outflows from Protostars in L1448

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Outline

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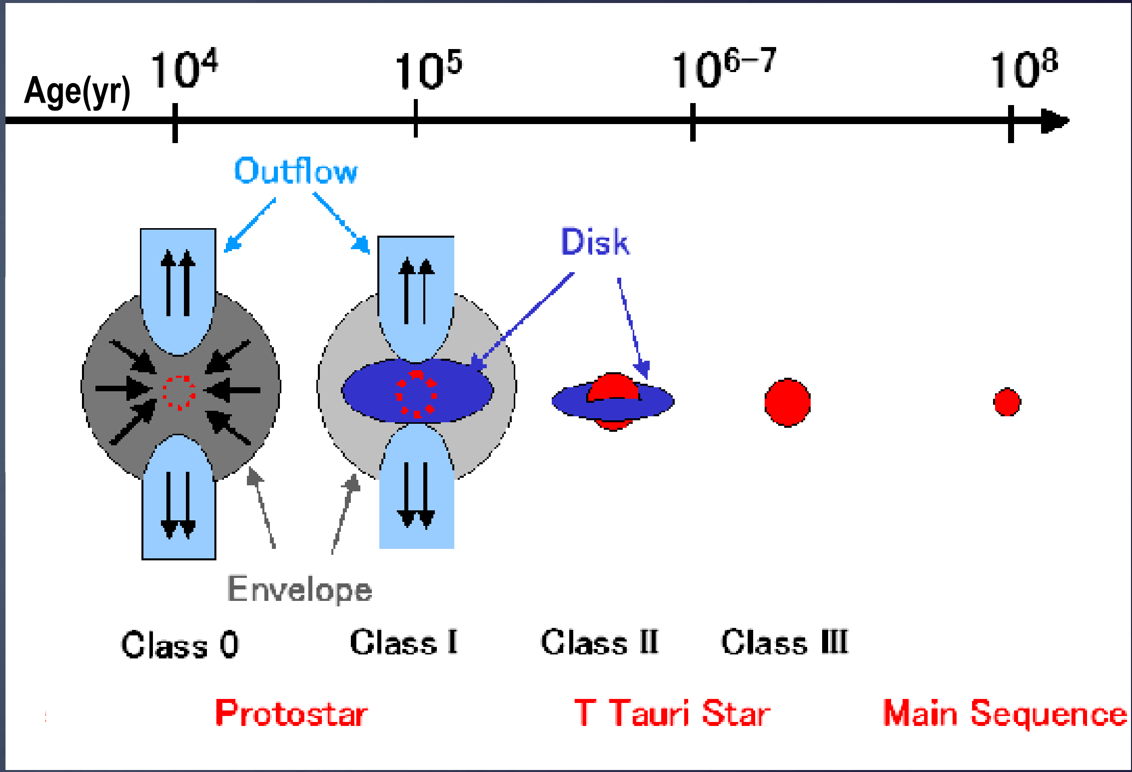
Goal of this Project

- To observe the region L1448 and all of the protostar systems to get a better understanding of the effects of the outflows on the protostars and the molecular cloud
- To get a better understanding of the feedback from the outflows onto the protostar and the molecular cloud
- This will be done by tracing ^{12}CO and ^{13}CO in the outflows from the protostar systems

Protostars

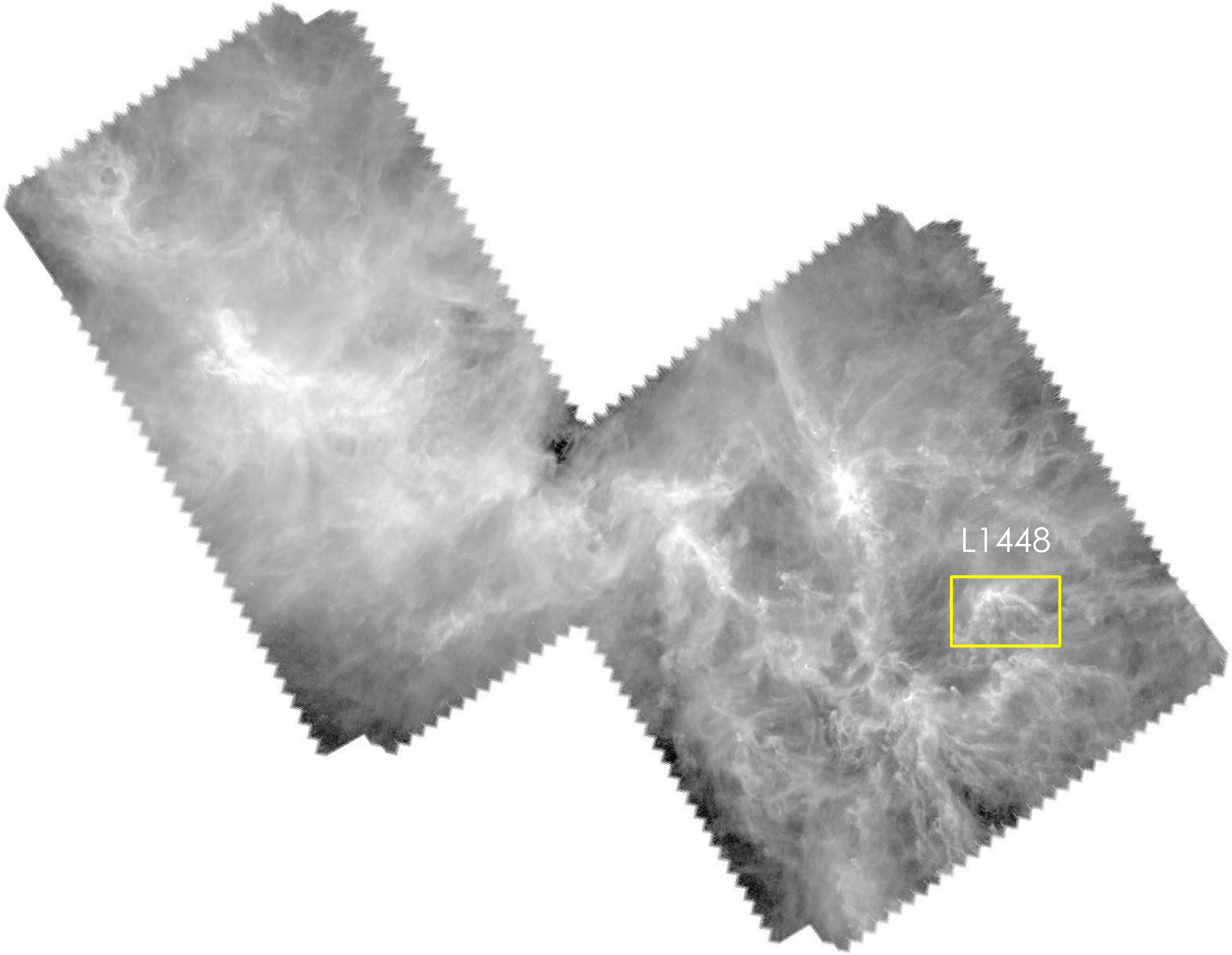
- Protostars are very young stellar objects that are still in the process of forming in dense molecular clouds
  - Types: Class 0, Class 1, Class 2
- L1448 protostars are class 0
- Outflows are a good way to observe class 0 protostars and details such as mass, momentum, and energy that is blown off



http://inspirehep.net/record/1332467/plots

Reasoning Behind Observing CO

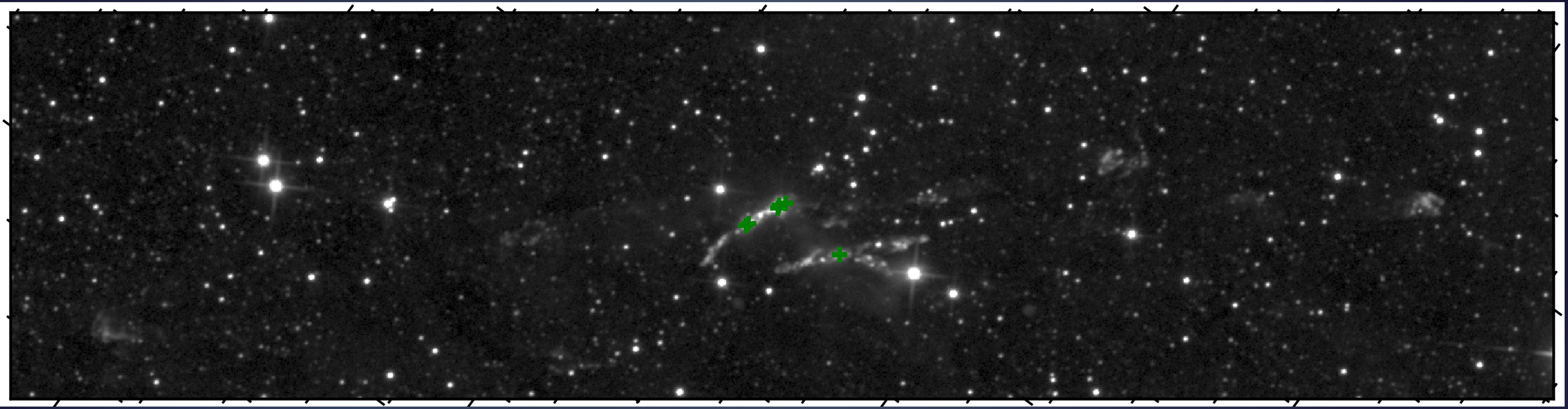
- ^{12}CO is the second most abundant molecule in the molecular cloud
- Due to the cloud having a temperature of approximately 10 to 20 Kelvin, it's difficult to trace H_2
- Luckily, ^{12}CO traces H_2 and from previous studies, ^{12}CO traces outflows really well
- ^{13}CO is less abundant but still traces H_2 and can give more information especially when ^{12}CO optically thick


L1448

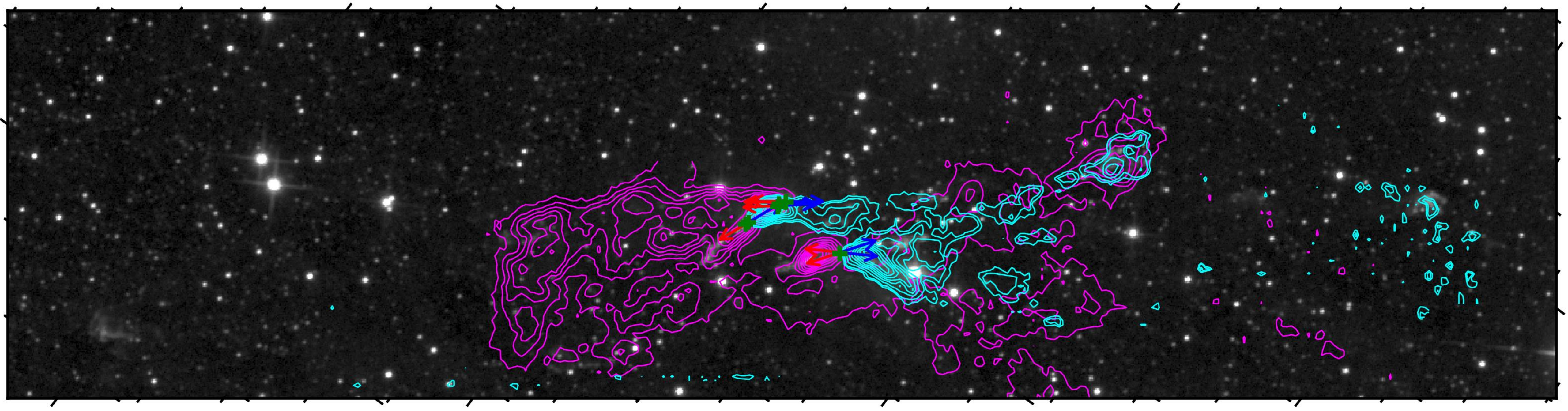
Data

- Observations:
  - Use data taken by Nick Reynolds at Arizona Submillimeter Telescope
  - The image file gives data in the form of a data cube which has three axes that are galactic longitude, galactic latitude, and frequency
- First step: Contoured Integrated Intensity Maps
  - Get a better view of the outflows and to find what protostar systems are giving out the particular outflows
  - Allows us to observe where the high and low velocities are at

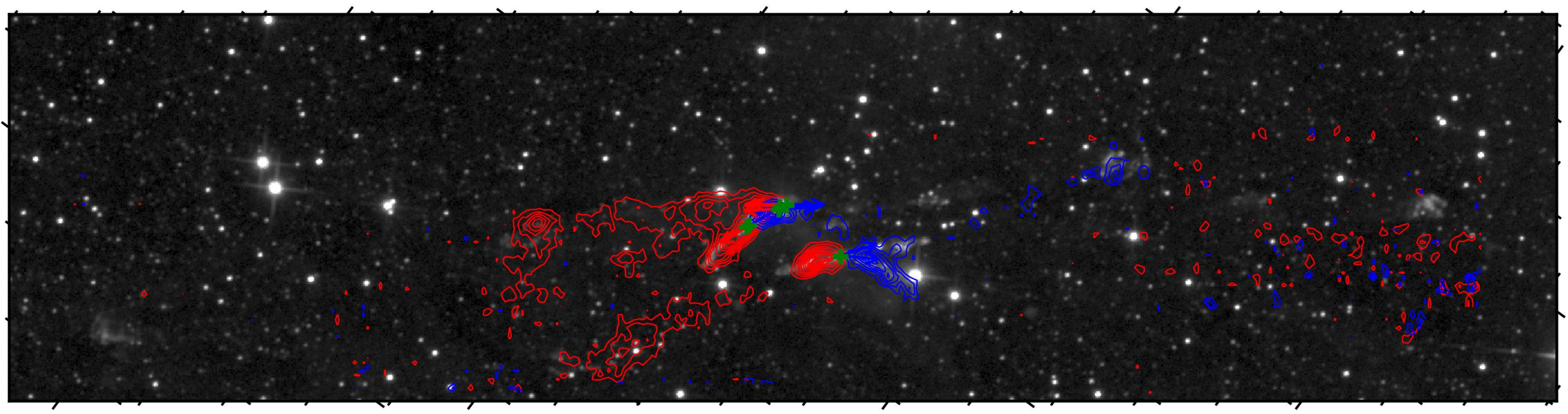
WISE Image With Protostar Locations



Low Velocity Integrated Intensity Map of ^{12}CO



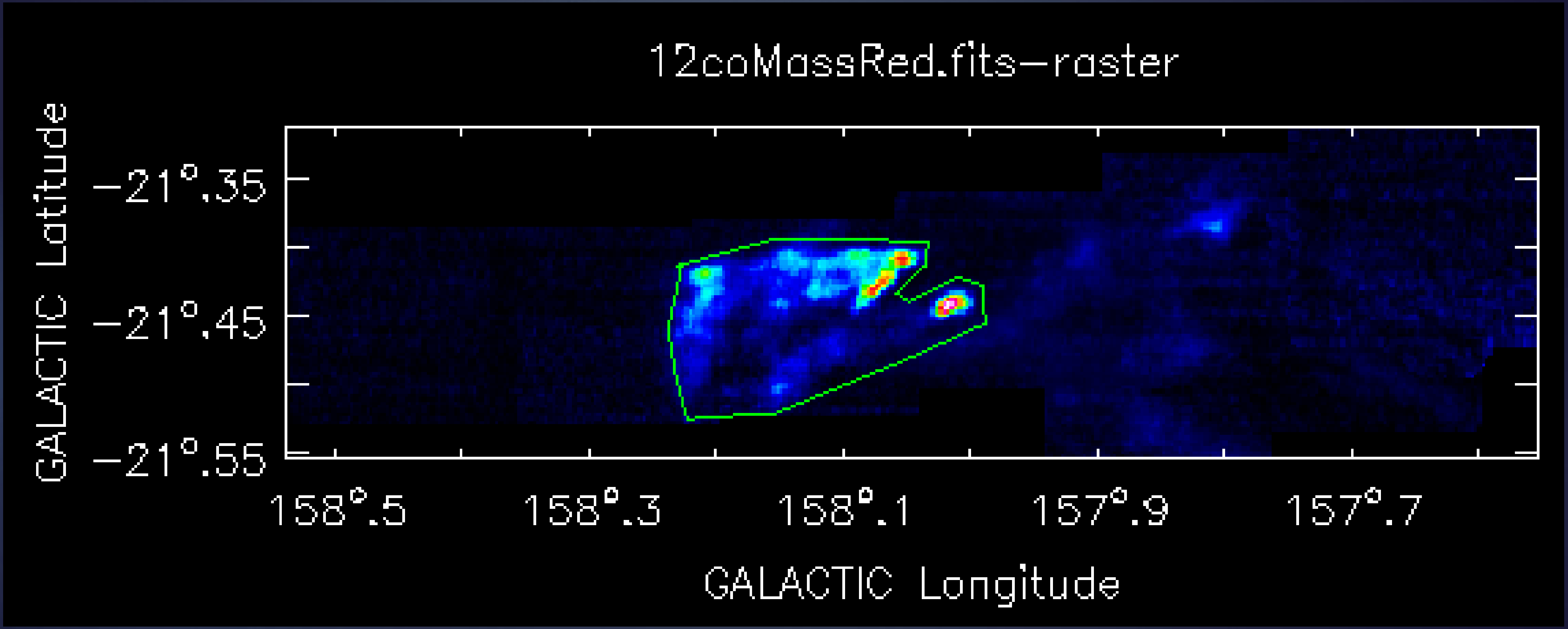
High Velocity Integrated Intensity Map of ^{12}CO



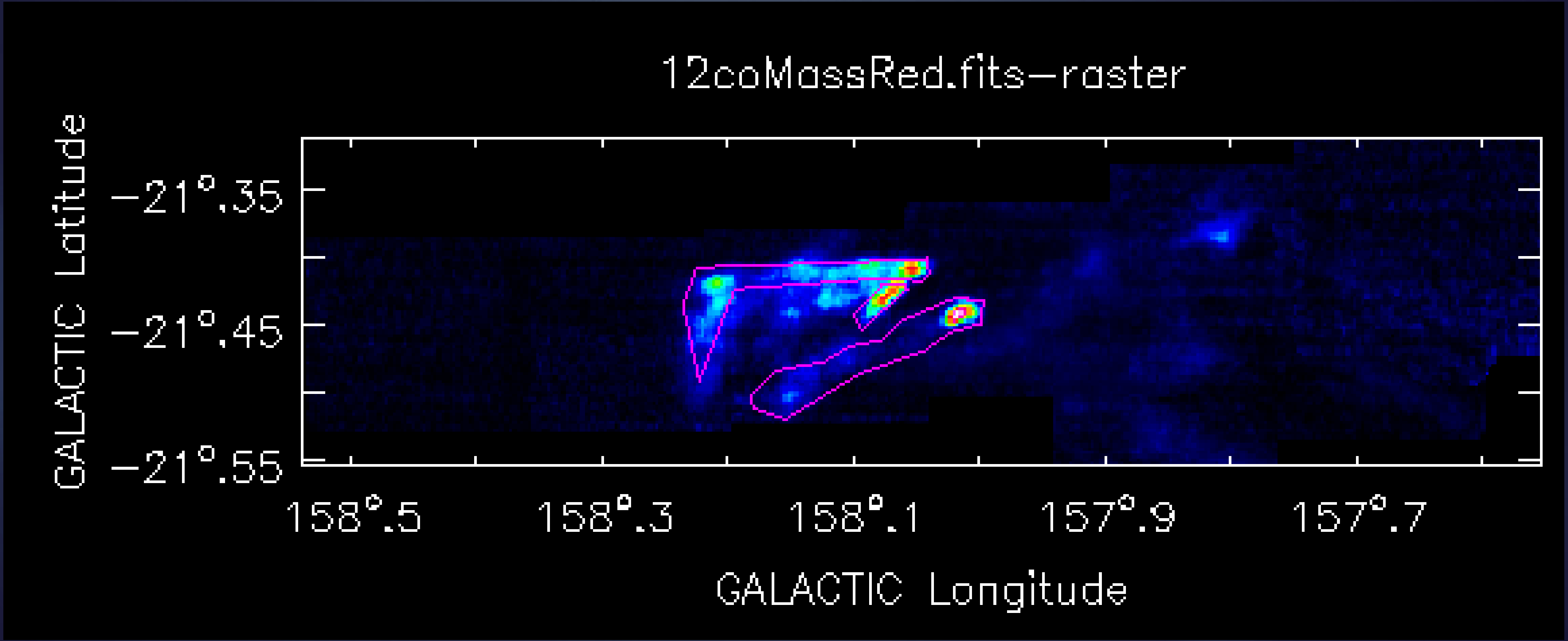
Analysis

- Second Step: Create Mass, Momentum, and Energy Maps
  - A program was created that takes the intensity of each pixel then turned that data into a column density
  - Took the column density and then created the mass, momentum, and Energy Maps of the outflows
  - With the help of the contour maps three different types of regions were made to capture the outflows: total, conservative, and liberal
  - Then maps were run in *the Common Astronomy Software Application (CASA)* to read the data in each region

Mass Map


12coMassRed.fits–raster
GALACTIC Latitude
–21°.35
–21°.45
–21°.55
158°.5
158°.3
158°.1
157°.9
157°.7
GALACTIC Longitude

Mass Map



12coMassRed.fits–raster
GALACTIC Latitude
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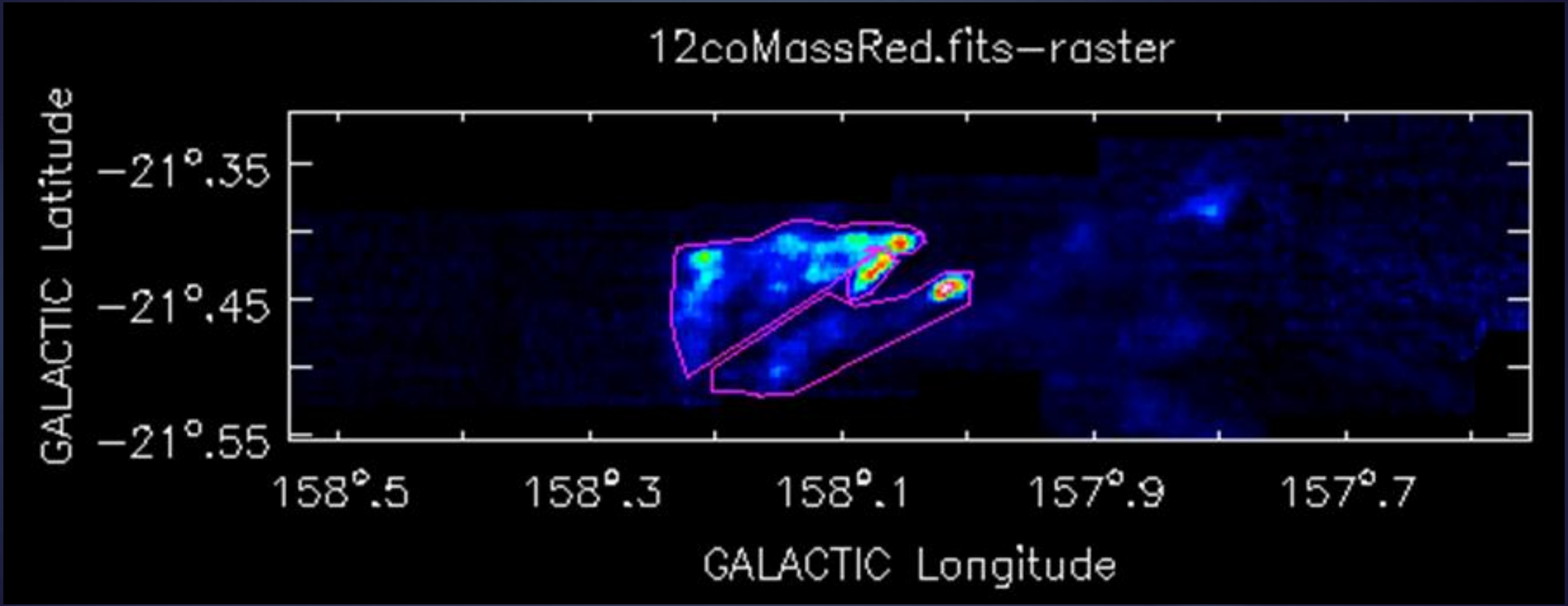
Mass Map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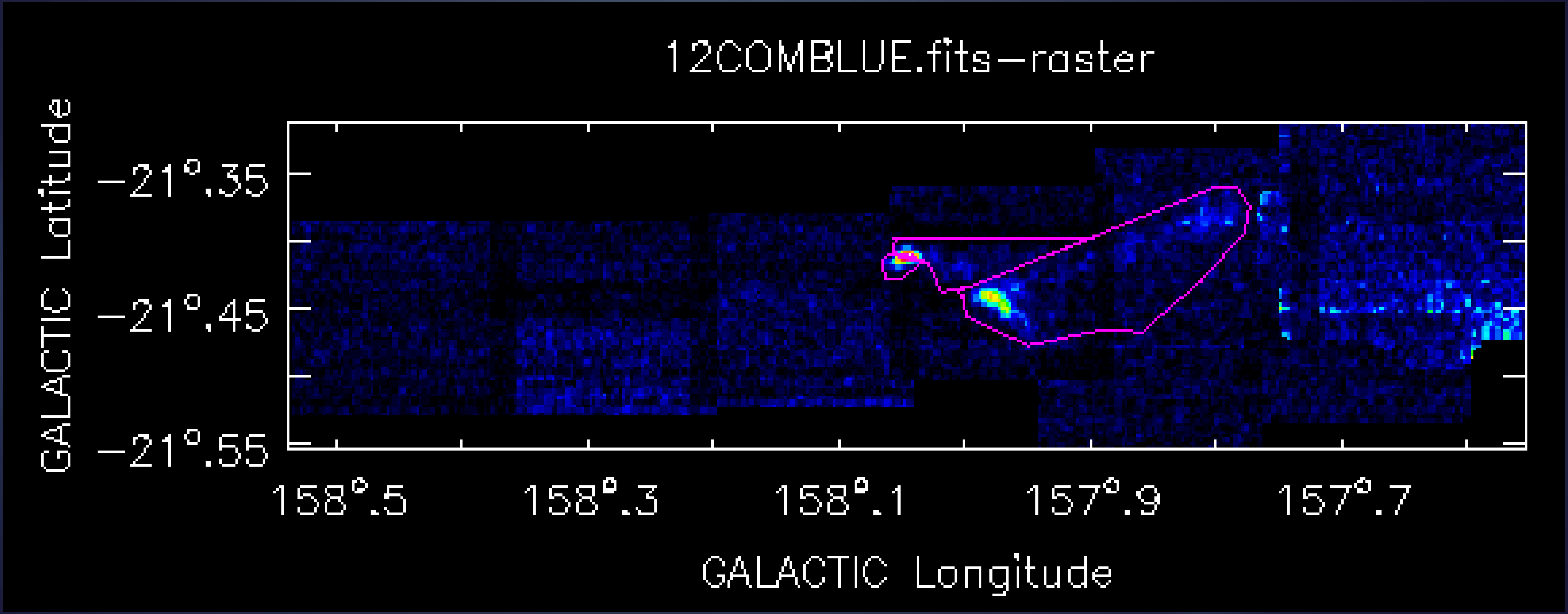
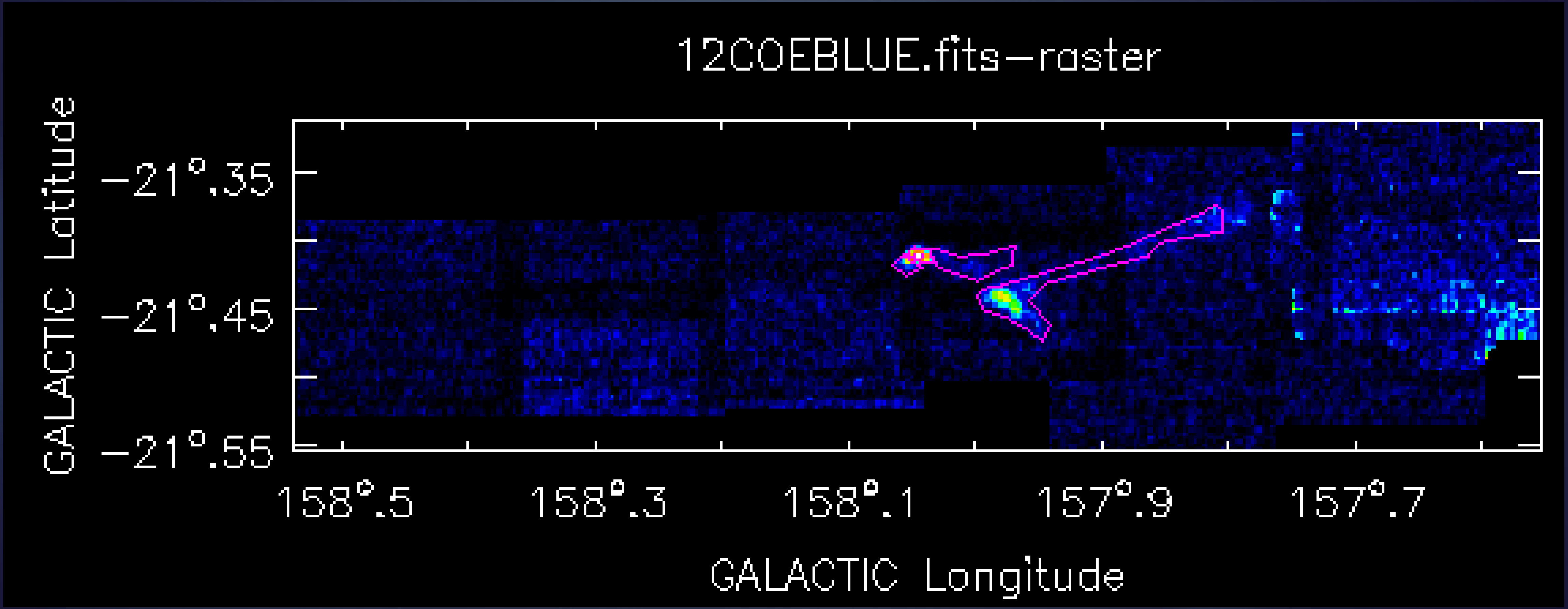
−21°.55
158°.5
158°.3
158°.1
157°.9
157°.7
GALACTIC Longitude

Momentum Map



Energy Map


12COEBLUE.fits–raster
GALACTIC Latitude
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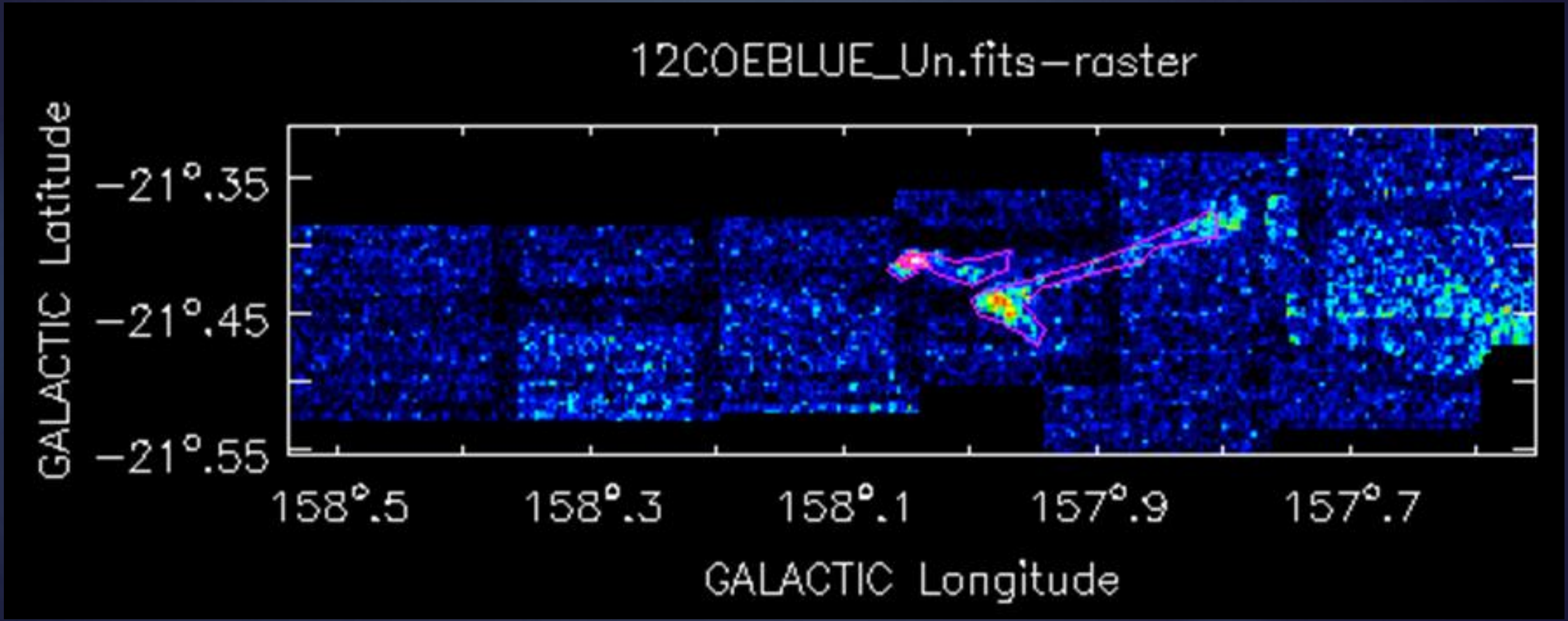
−21°.45
−21°.55
158°.5
158°.3
158°.1
157°.9
157°.7
GALACTIC Longitude

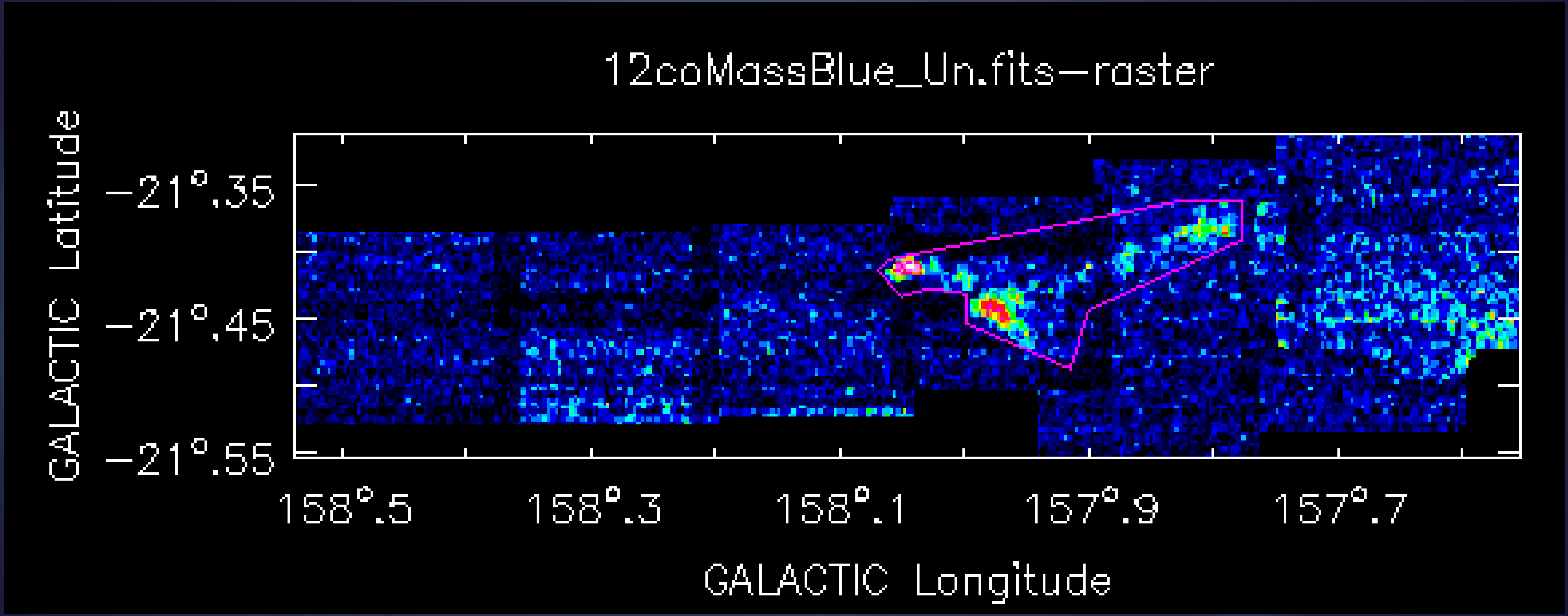
Analysis

- Third Step: Calculate Uncertainty
  - Using the same program that created the mass, momentum, and energy maps overestimated the uncertainty of the intensity in each pixel
  - Can use *CASA and the three regions again to pull out the data for the outflows*

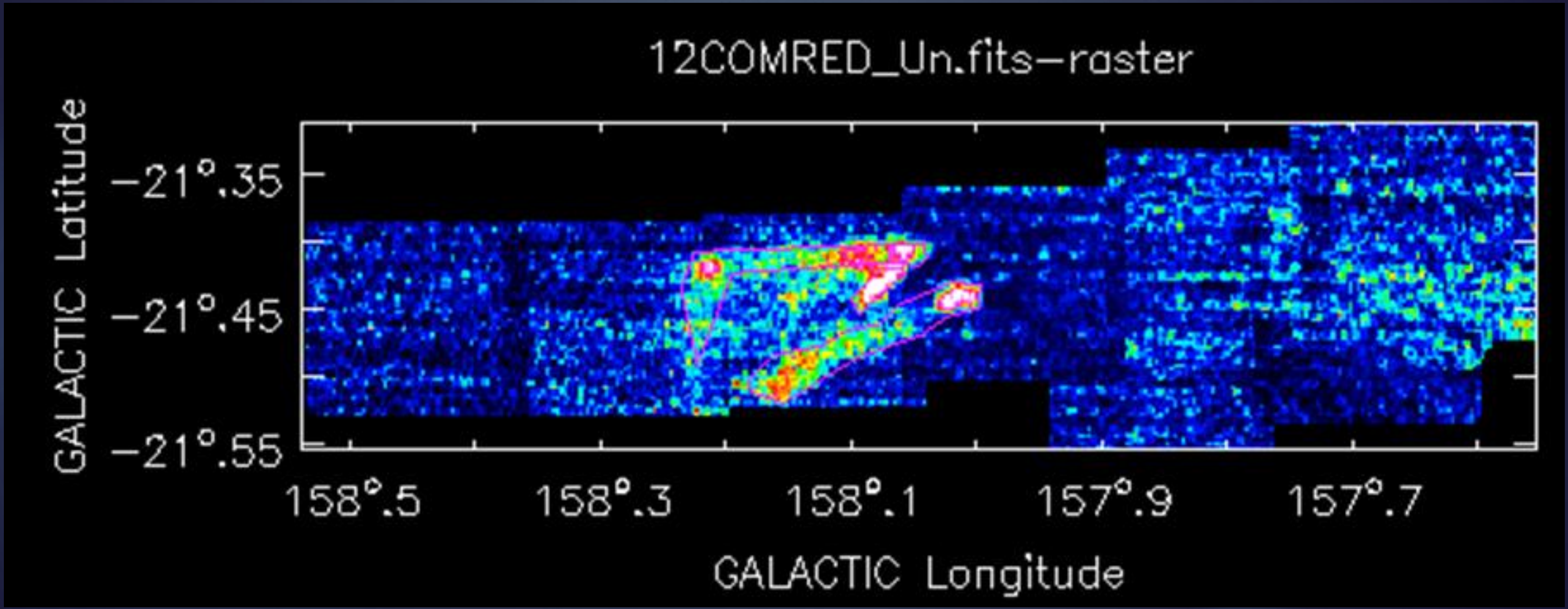
Uncertainty of Blue Shifted Energy



Uncertainty of Blue Shifted Mass



Uncertainty of Red Shifted Momentum



Notable Data from Maps

- Mass ($M_\odot$)
  - L1448NW, IRS3A, and Per 33 has the largest liberal mass with 0.143 ± 0.00325
- Momentum ($M_\odot$ km s^{-1})
  - L1448NW, IRS3A, and Per 33 has the largest liberal momentum with 0.704 ± 0.08722
- Energy (10^{43} erg)
  - IRS2 has the largest liberal energy with 2.53 ± 0.80673

Next Step

- To add the ^{13}CO image to the analysis
- Add the ^{13}CO data with ^{12}CO to then make a more accurate column density and to then get accurate outflow mass, momentum, and energy

Summary

- Created integrated intensity Maps to find and verify where outflows are coming from
- Created mass, momentum, and energy maps
- With the help of *CASA* was able to differentiate outflows for total, conservative, and liberal regions
- Created uncertainty maps to state uncertainties in each region

References

- McMullin, J. P., Waters, B., Schiebel, D., Young, W., & Golap, K. 2007, Astronomical Data Analysis Software and Systems XVI (ASP Conf. Ser. 376), ed. R. A. Shaw, F. Hill, & D. J. Bell (San Francisco, CA: ASP), 127

- *The SMT is operated by the Arizona Radio Observatory (ARO), Steward Observatory, University of Arizona.*