

# The Impact of the M43 HII Region on the Orion A Molecular Cloud

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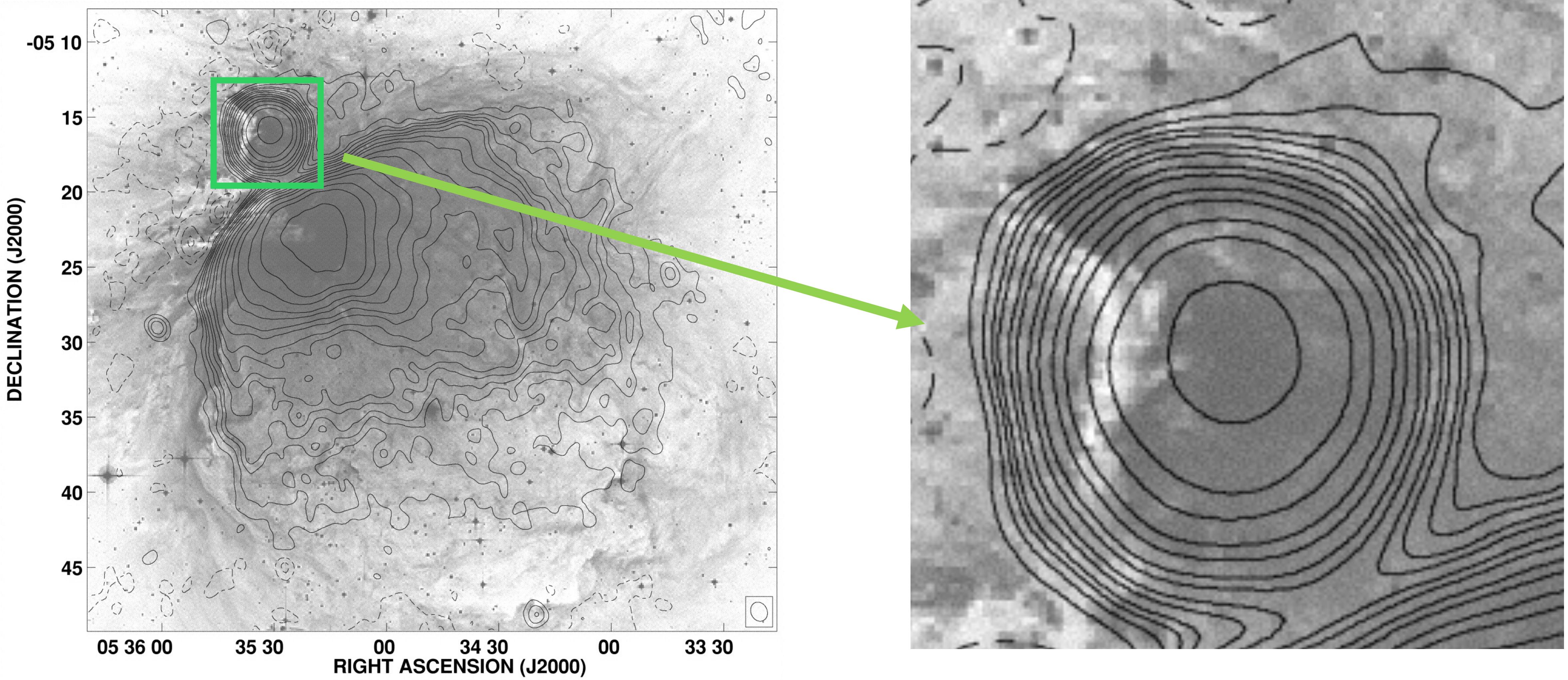
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# The M43 HII Region

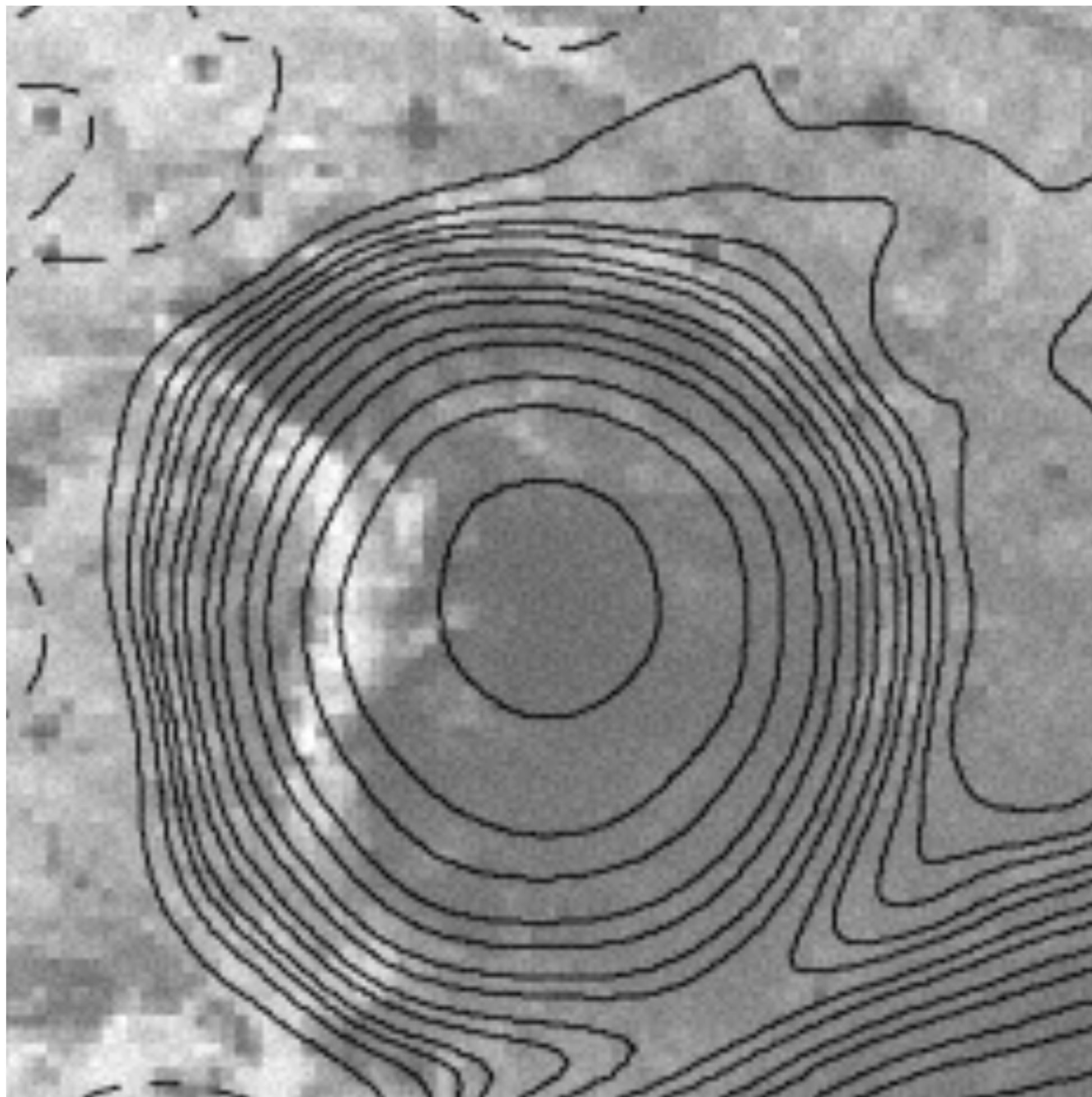


*M43 Nebula Image: Image: NASA/ESA,  
Hubble Space Telescope Orion Treasury  
Project Team*

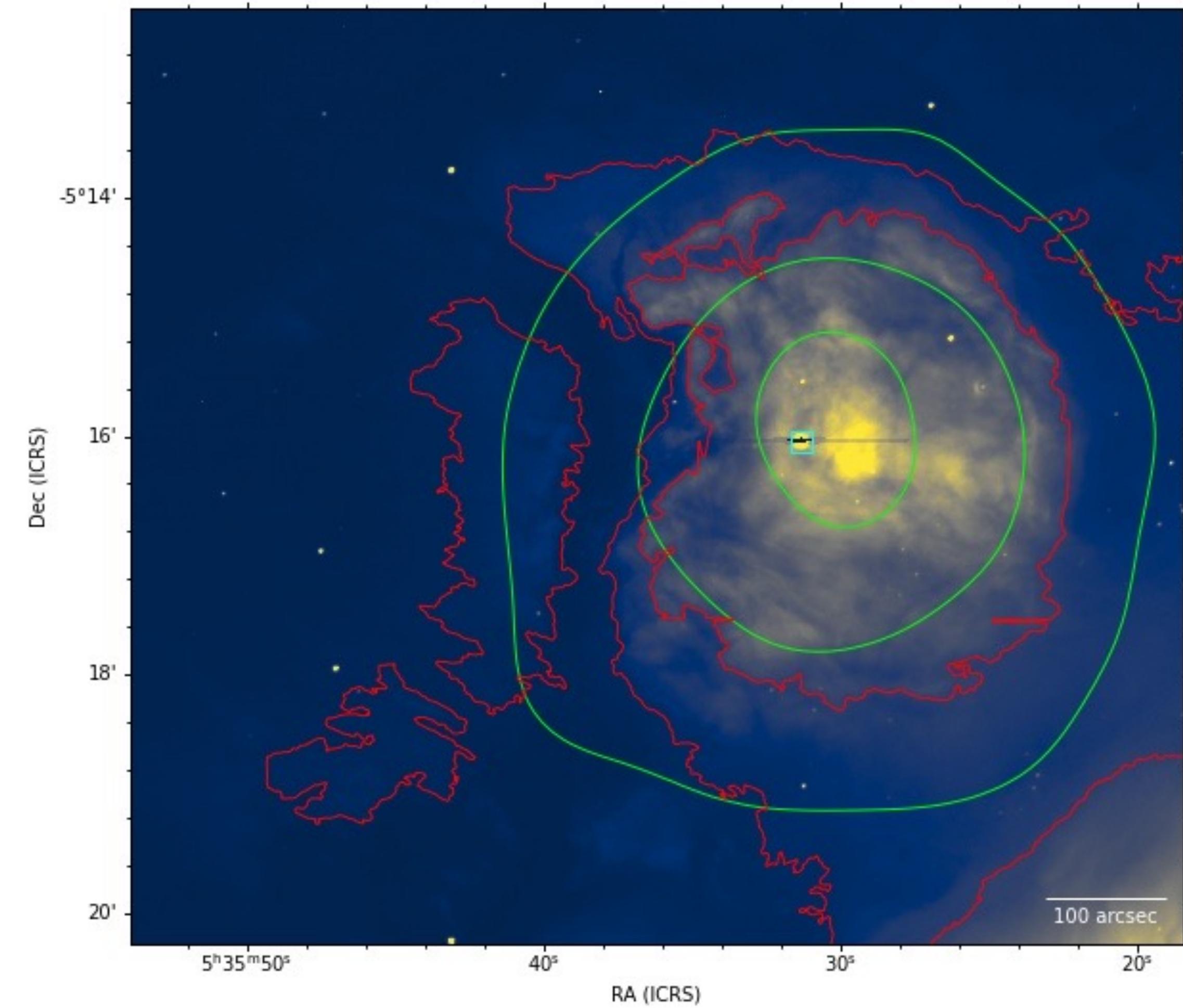
# Radio Continuum of Orion Molecular Cloud



# Radio Continuum

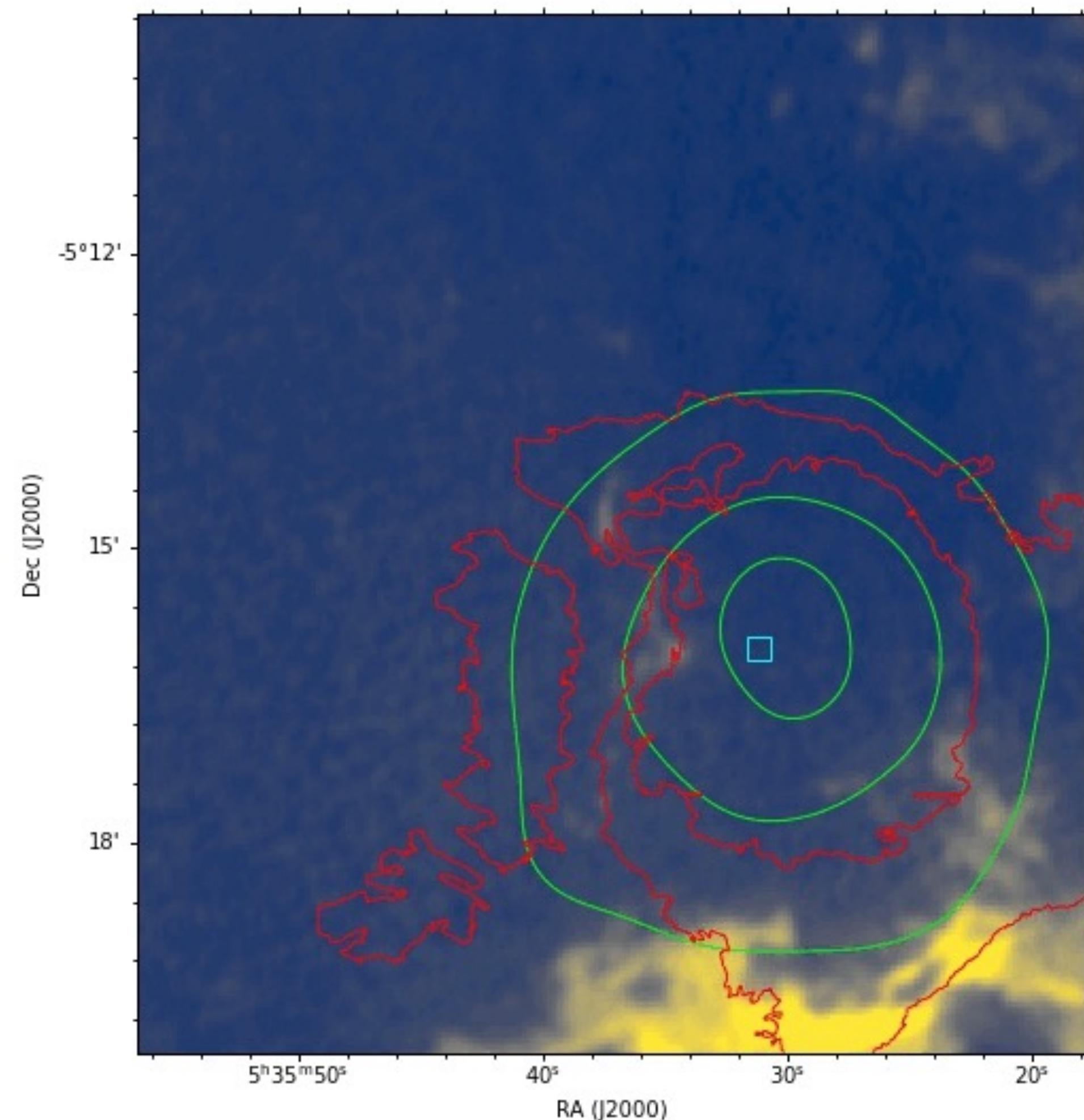


# M43 Traced in H-Alpha



# Quantifying the impact of M43 on the Orion A Molecular Cloud

Column Density  
Mass  
Momentum  
Kinetic Energy  
Average Intensity Profiles



# DATA SOURCES

**CARMA NRO ORION SURVEY:**  
 $^{12}\text{CO}$ ,  $^{13}\text{CO}$  and  $\text{C}^{18}\text{O}$  (1-0) Velocity Cubes

**SOFIA-GREAT:**  
CII Velocity Cubes

**OWENS-VALLEY RADIO  
OBSERVATORY:**  
CN, CS Velocity Cubes



CARMA Interferometer

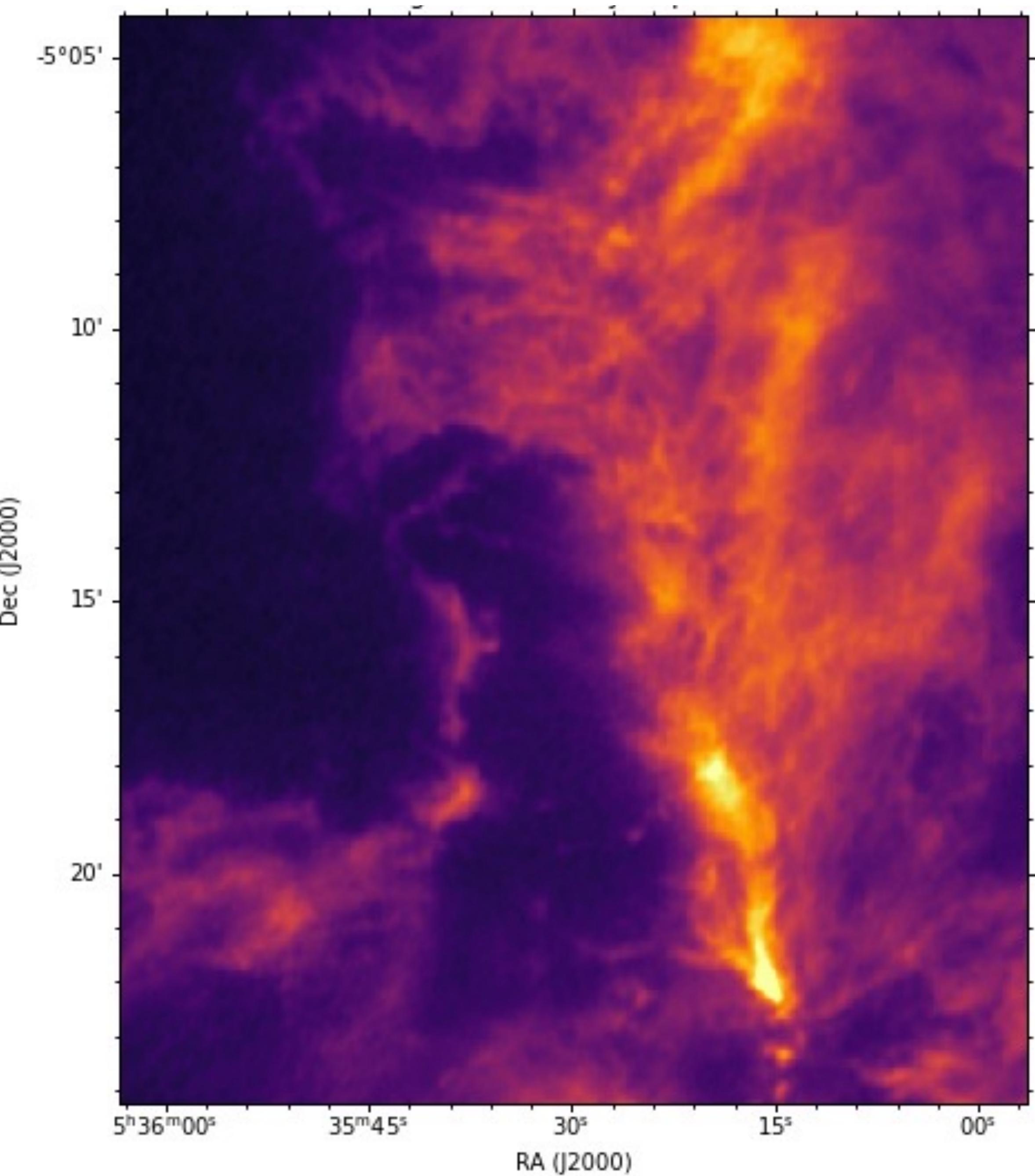
# Computing the Column Density of M43

$^{13}\text{CO}$  Optical Depth Equation

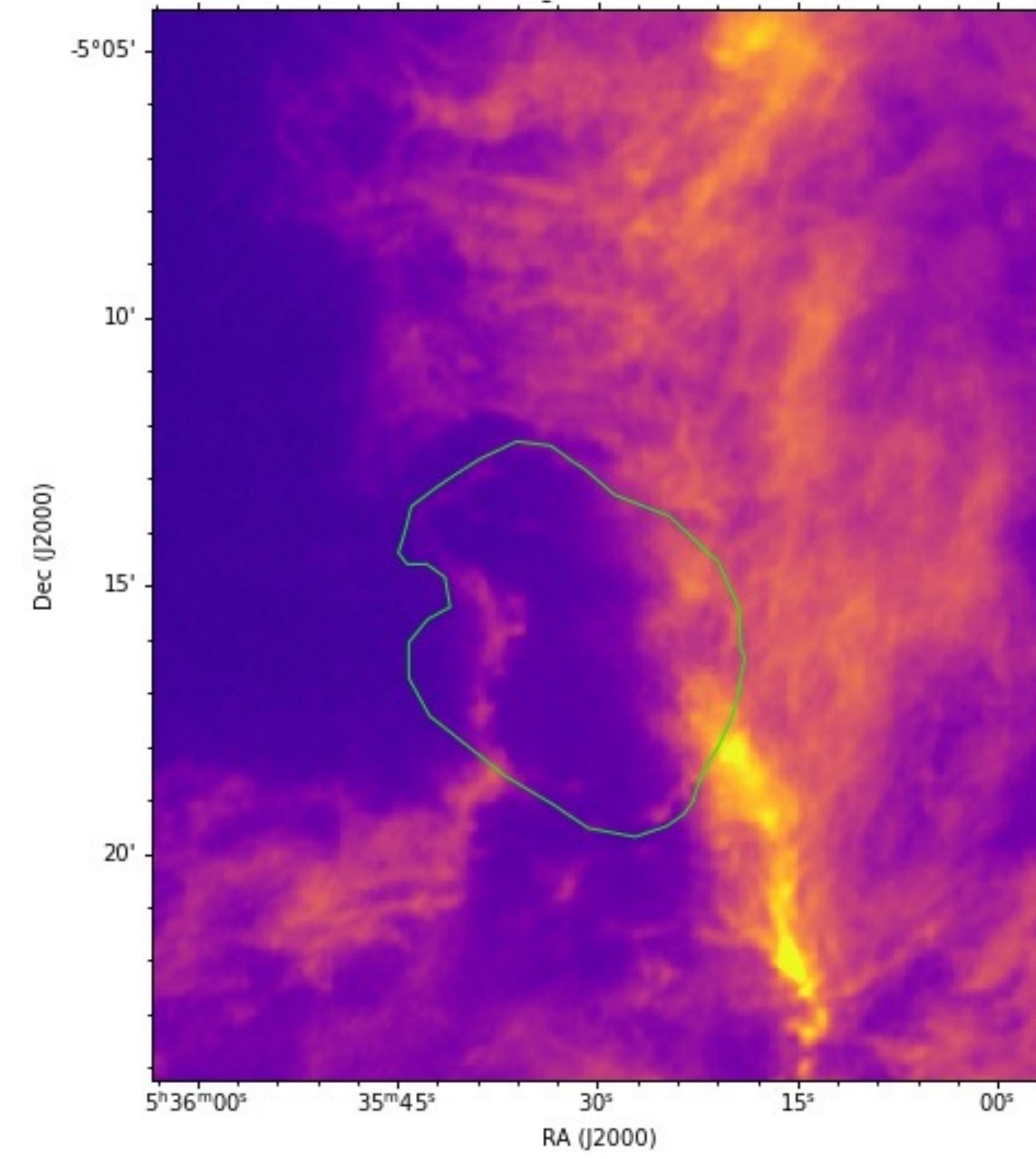
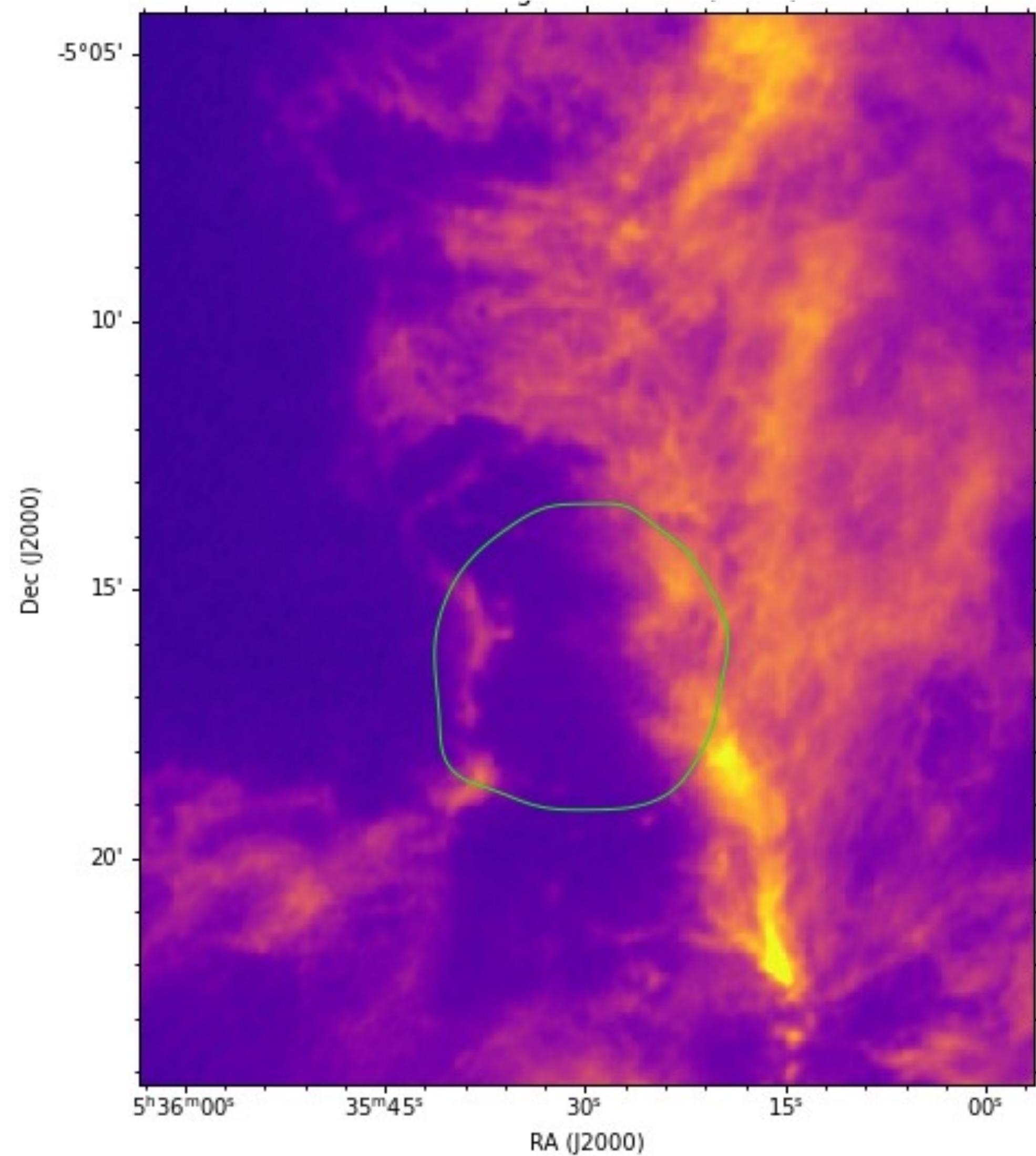
$$\tau(^{13}\text{CO}) = -\ln \left[ 1 - \frac{T_{\max}(^{13}\text{CO})/5.3 \text{ K}}{1/(e^{5.3 \text{ K}/T_{\text{ex}}} - 1) - 0.16} \right]$$

$^{13}\text{CO}$  Column Density Equation

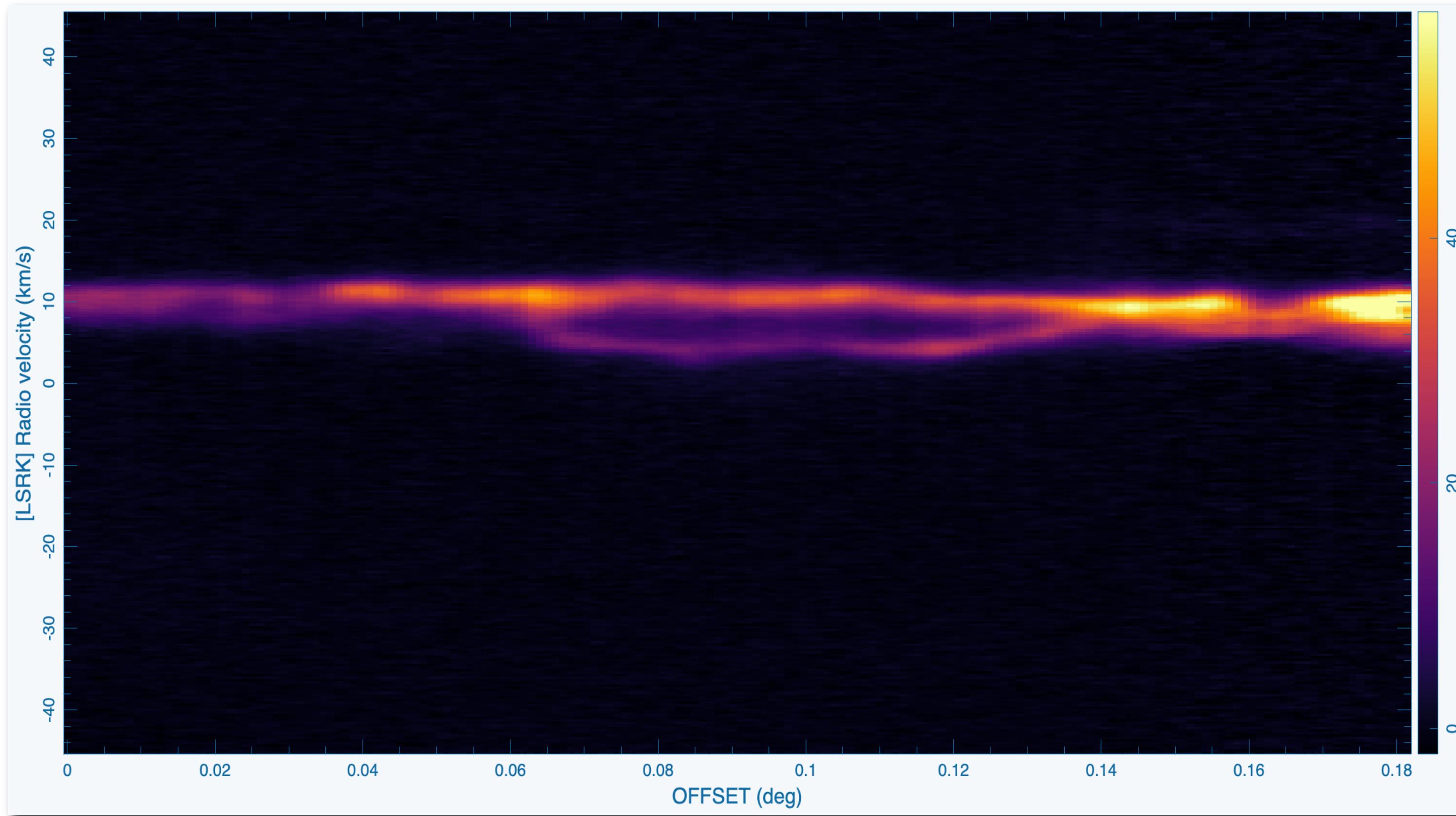
$$N(^{13}\text{CO}) = \left[ \frac{\tau(^{13}\text{CO})}{1 - e^{-\tau(^{13}\text{CO})}} \right] 3.0 \times 10^{14} \frac{W(^{13}\text{CO})}{1 - e^{-5.3/T_{\text{ex}}}} \text{ cm}^{-2}$$



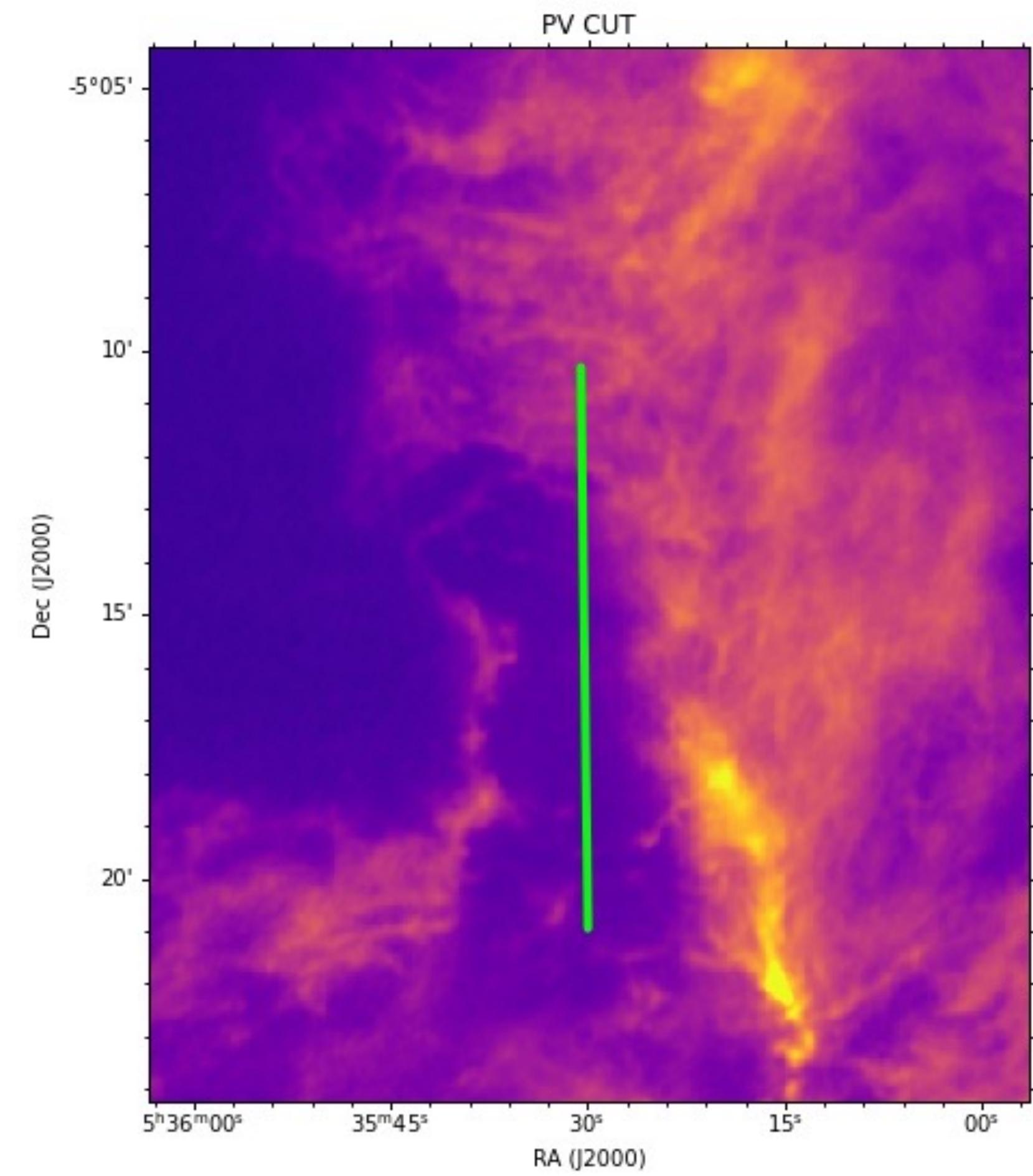
# Determining the extent of the M43 Region



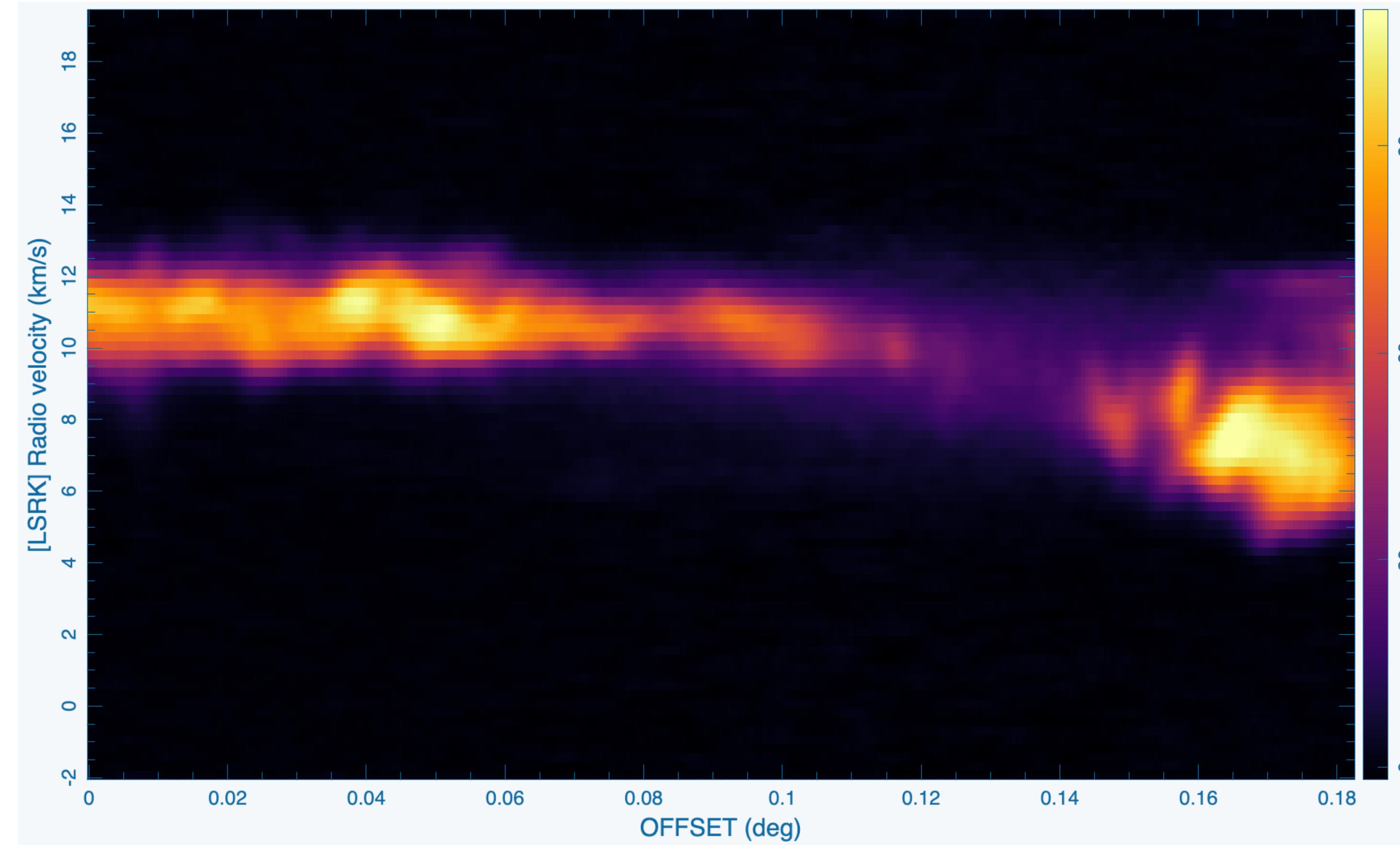
# Expansion Velocity via P-V Diagrams



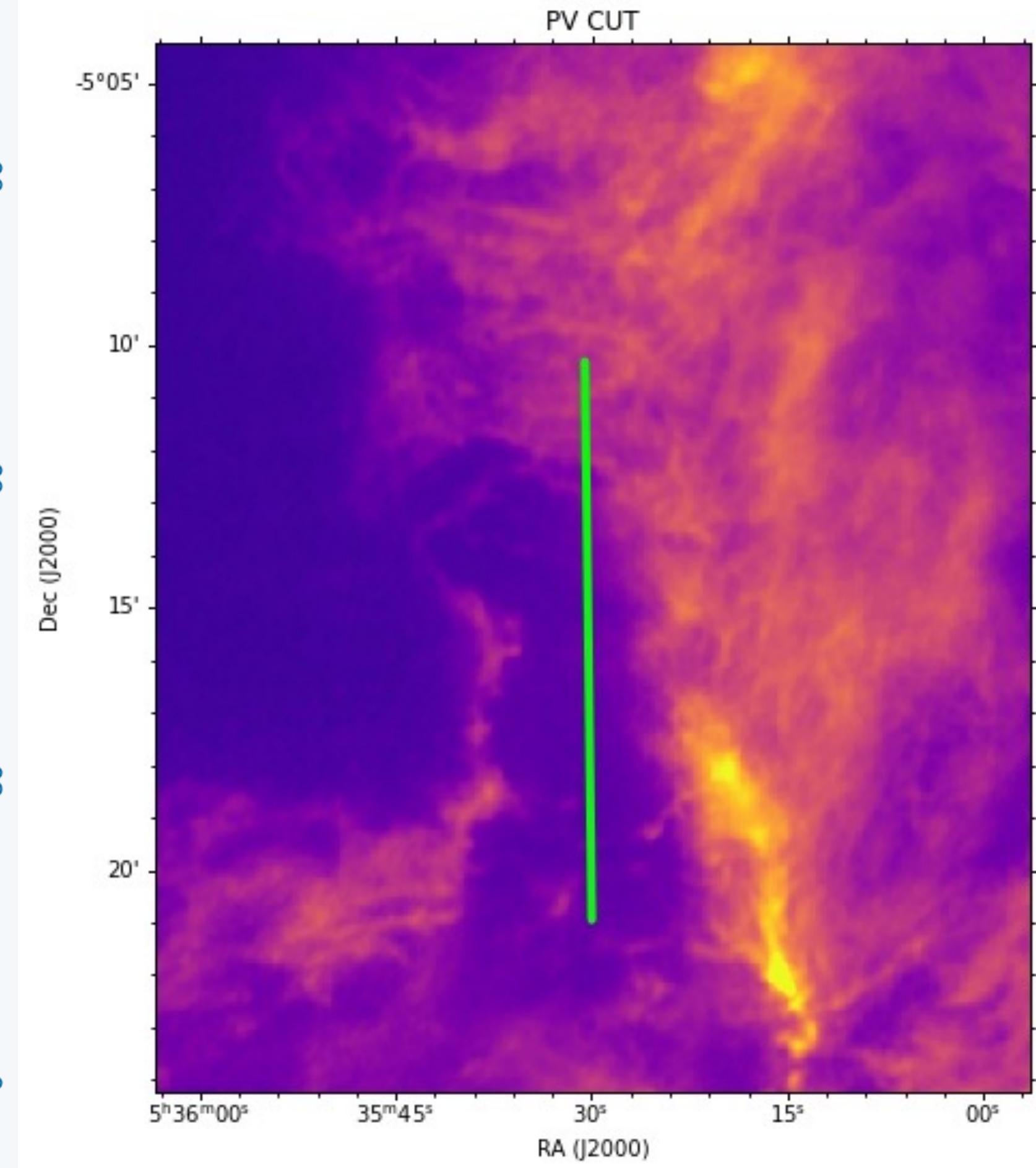
Position-Velocity Diagram of M43 in CII



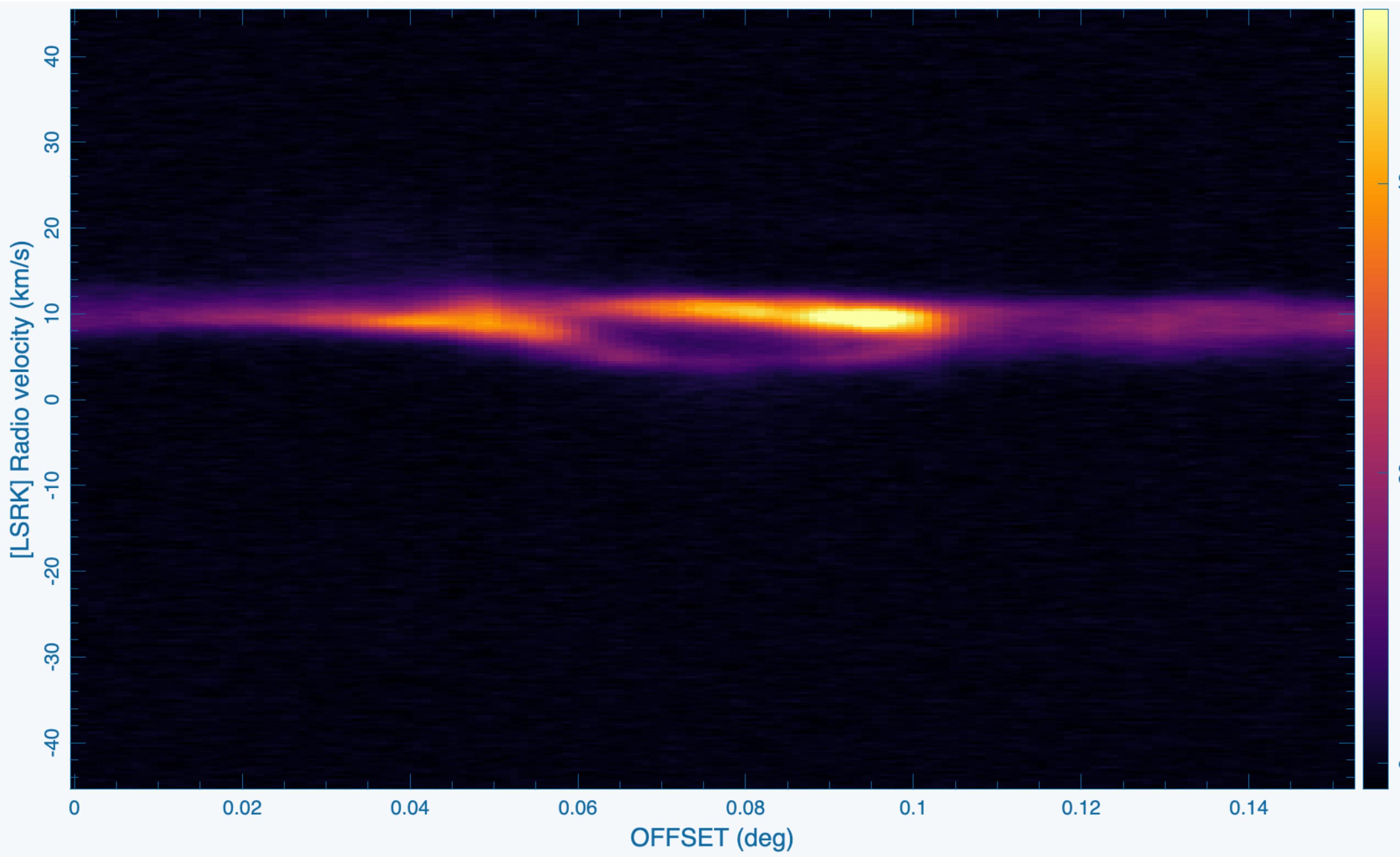
# Expansion Velocity via P-V Diagrams



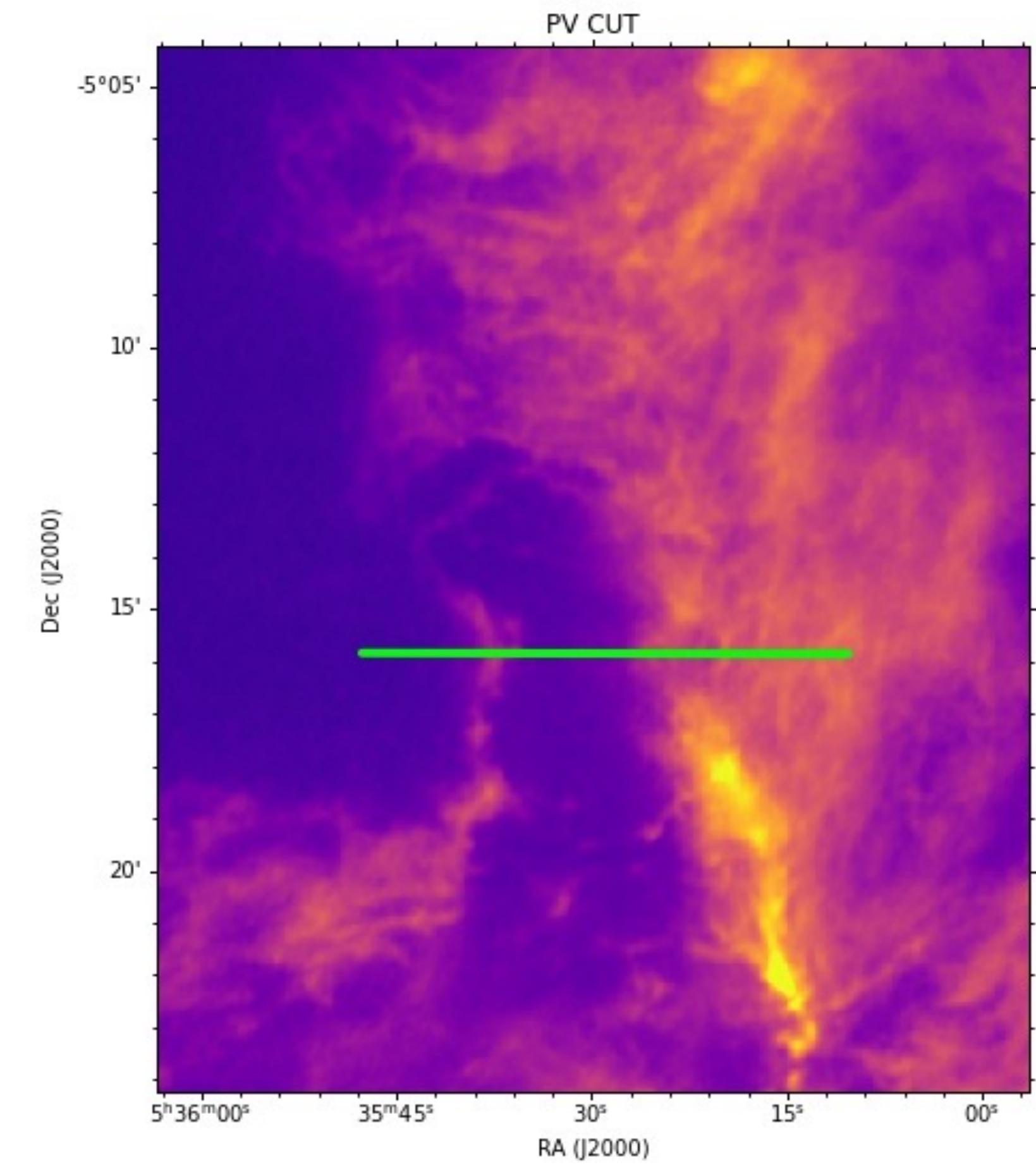
Position-Velocity Diagram of M43 in 13CO



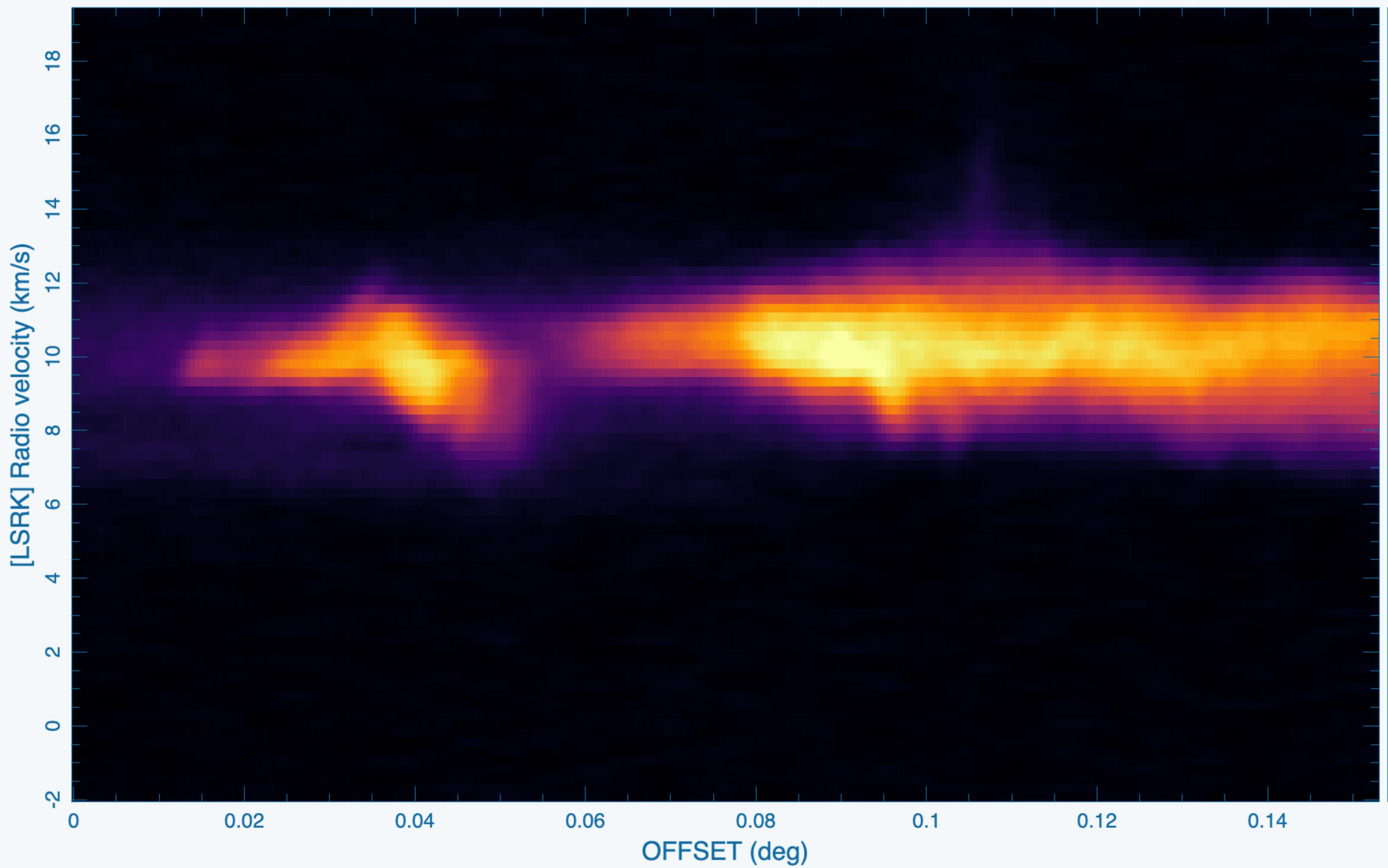
# Expansion Velocity via P-V Diagrams



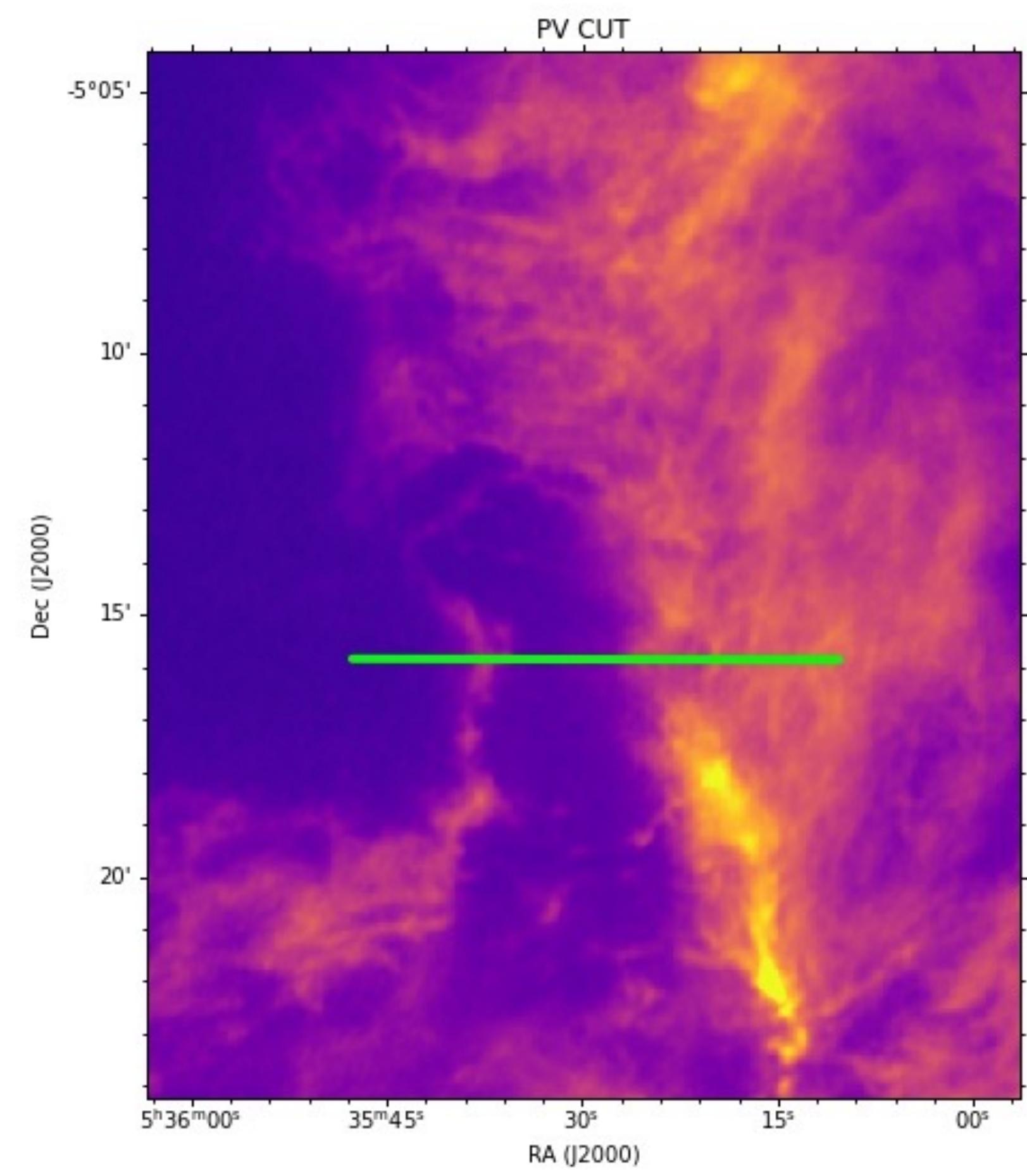
Position-Velocity Diagram of M43 in CII



# Expansion Velocity via P-V Diagrams



Position-Velocity Diagram of M43 in 12CO

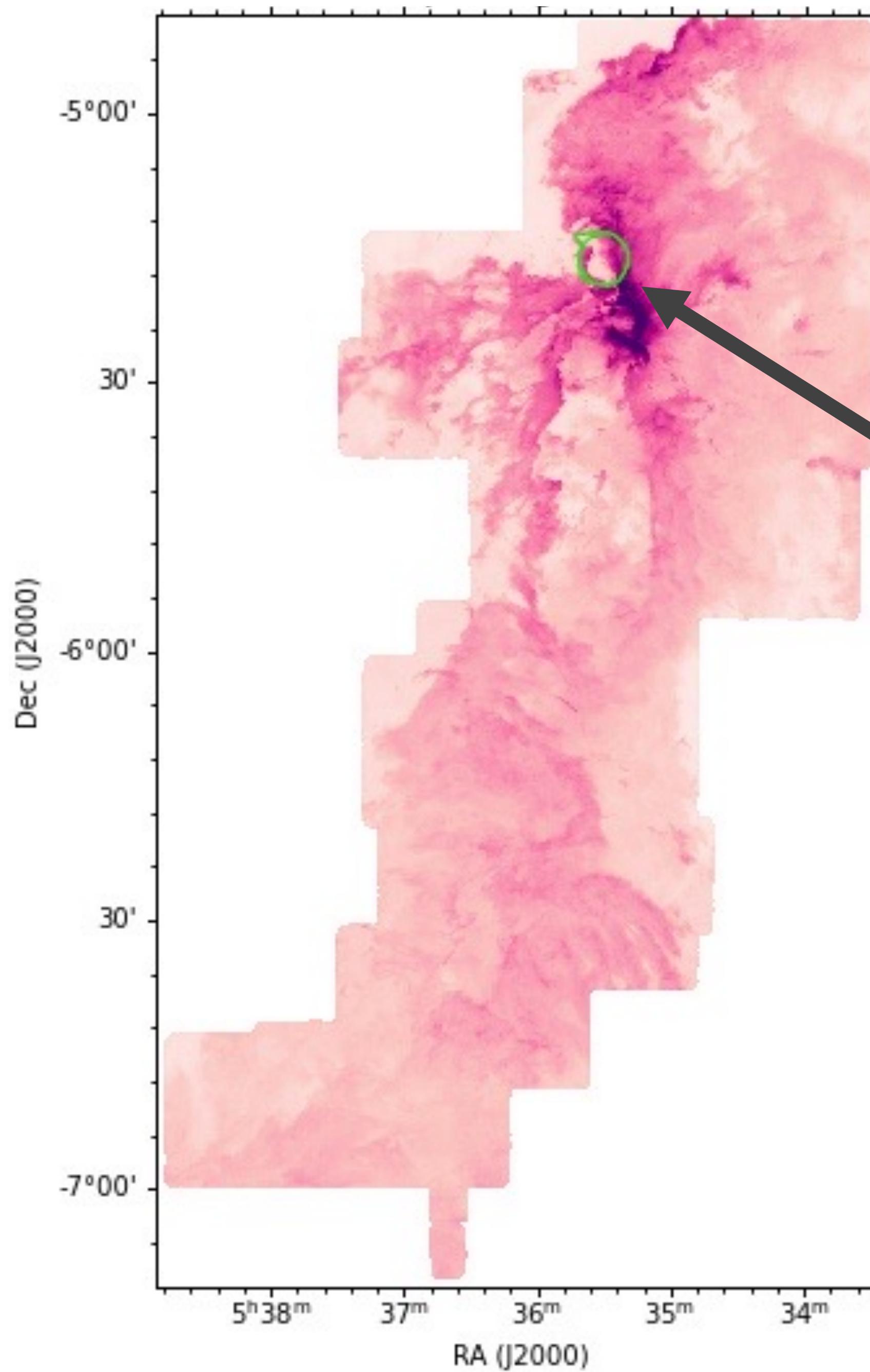


# Mass and Kinematics Estimates

Column Density Estimate	Mass (Solar Masses)	Momentum (Solar Masses* km/s)	Kinetic Energy (Ergs)
Not Optically Thin	$6.60 \times 10^2 - 7.60 \times 10^2$	$4.0 \times 10^3 - 4.5 \times 10^3$	$2.3 \times 10^{47} - 2.7 \times 10^{47}$
Optically Thin	$5.70 \times 10^2 - 6.60 \times 10^2$	$3.5 \times 10^3 - 4.0 \times 10^3$	$2.0 \times 10^{47} - 2.4 \times 10^{47}$

Difference in results between estimates with CD 1 (using variable opacity) and CD 2 (assuming optically thin) indicates that

$^{13}\text{CO}$  gas in the cloud is NOT optically thin



## Plausibility of Mass Estimates

**Mass of Entire Orion A Molecular Cloud:**  
 $\sim 10^5$  Solar Masses

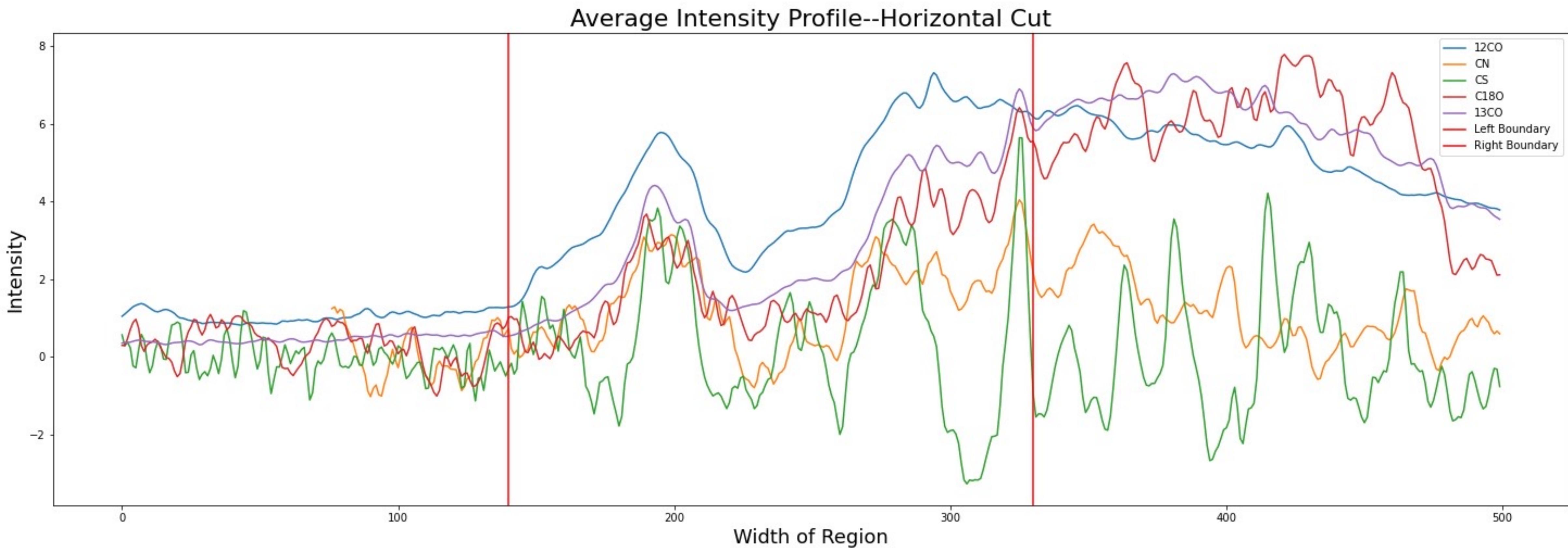
**Mass Estimate of M43 HII Region:**  
 $\sim 5.70 \times 10^2 - 6.70 \times 10^2$  Solar Masses

# Plausibility of Kinematics Estimates

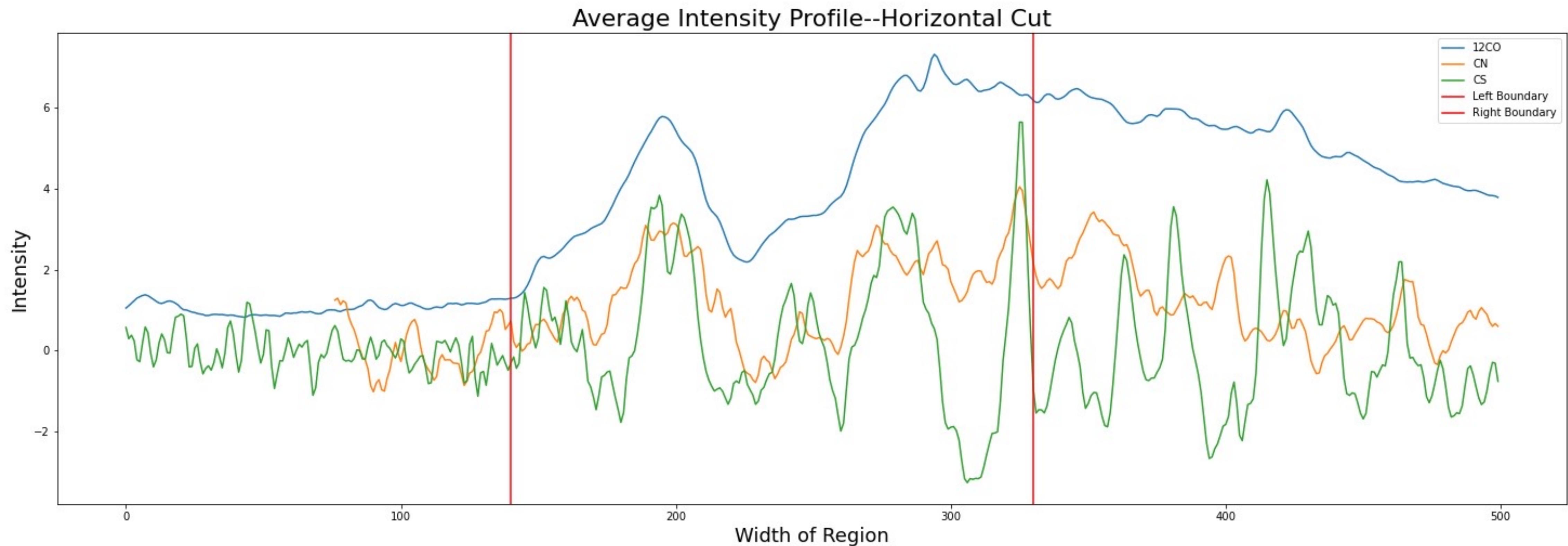
**HII Region Kinetic Energies and Momentums should be  
HIGHER than stellar outflows  
LOWER than supernova emissions**

Source	Momentum (Solar Mass x km/s)	Kinetic Energy (ergs)
<b>Stellar Outflows</b> <small>Feddersen et al., Astrophysical Journal 2018</small>	50-200	$2.0 \times 10^{45} - 6.0 \times 10^{45}$
<b>M43 HII Region</b>	$4.0 \times 10^3 - 4.5 \times 10^3$	$2.3 \times 10^{47} - 2.7 \times 10^{47}$
<b>Supernovae</b> <small>Walch et. Al., Royal Astronomical Society 2015</small>	$2.8 \times 10^4$	$\sim 10^{51}$

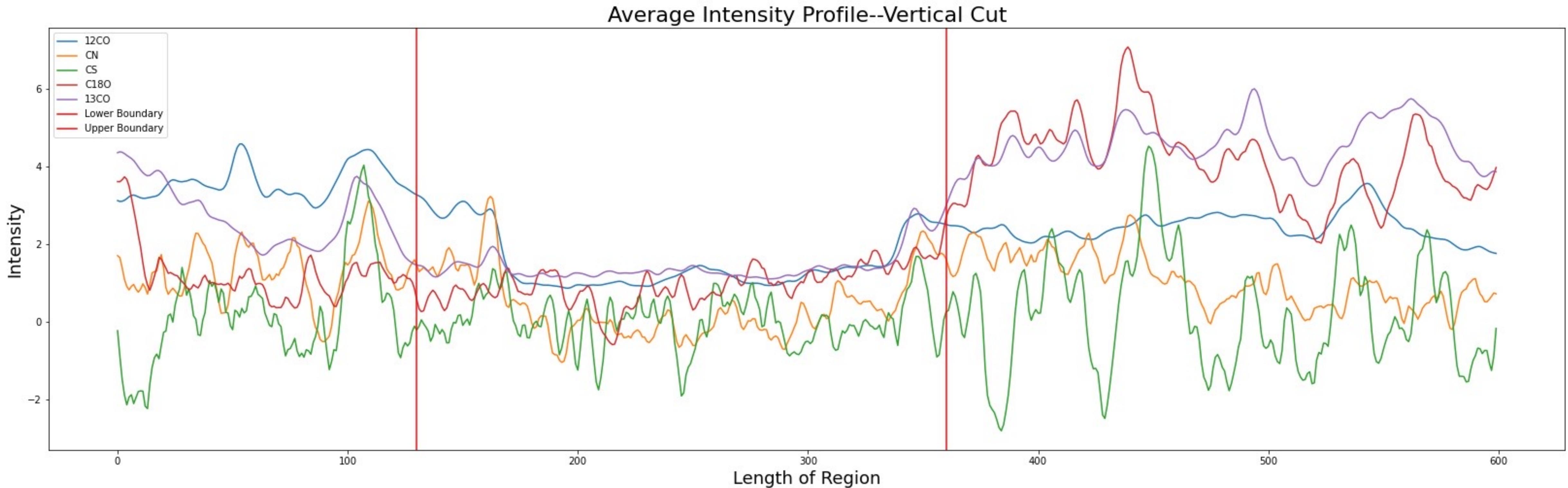
# Average Intensity Profiles



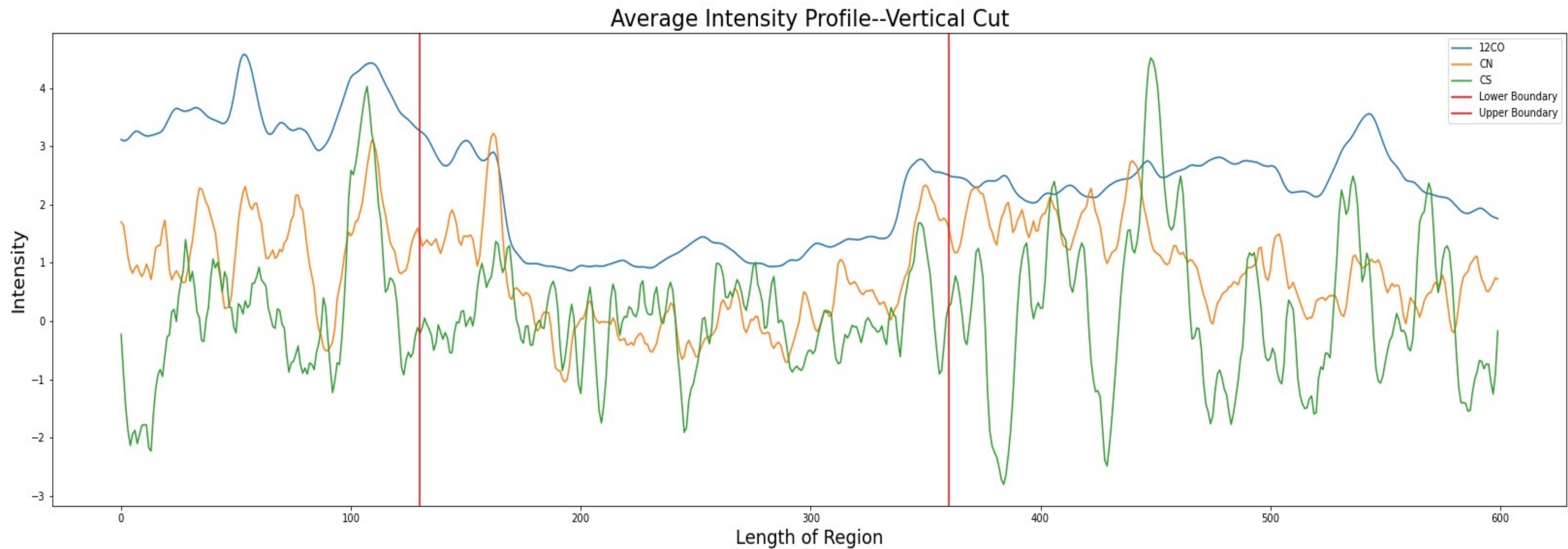
# Average Intensity Profiles



# Average Intensity Profiles



# Average Intensity Profiles

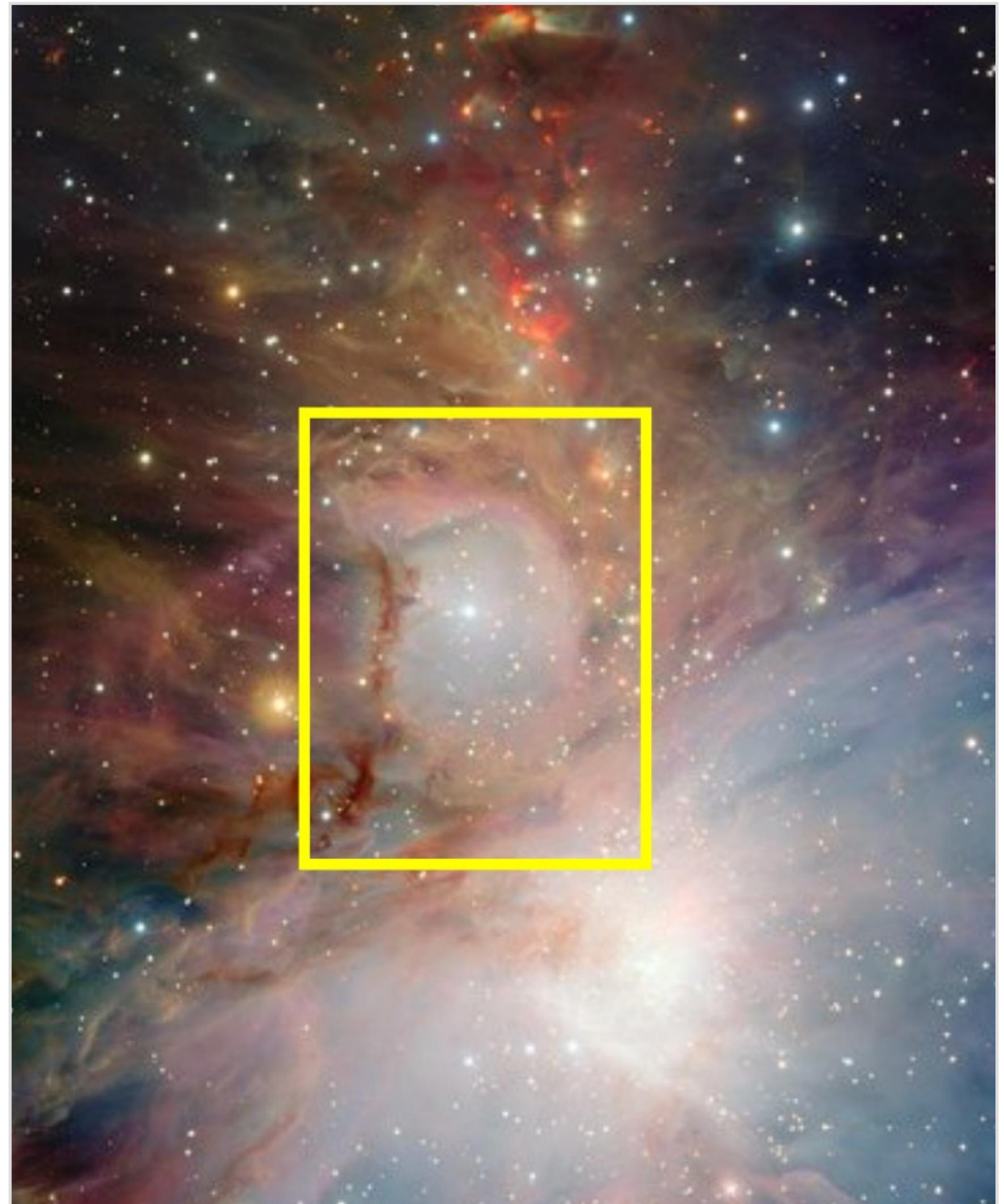


# Conclusions

Successfully quantified the impact of the M43 HII region on the surrounding molecular gas

Created a framework to reproduce this analysis on other HII regions

Identified interesting behavior in CN, CS that warrants further study for better understanding of how these gasses trace HII regions



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# Acknowledgements

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**Yale Department of Astronomy**

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