

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

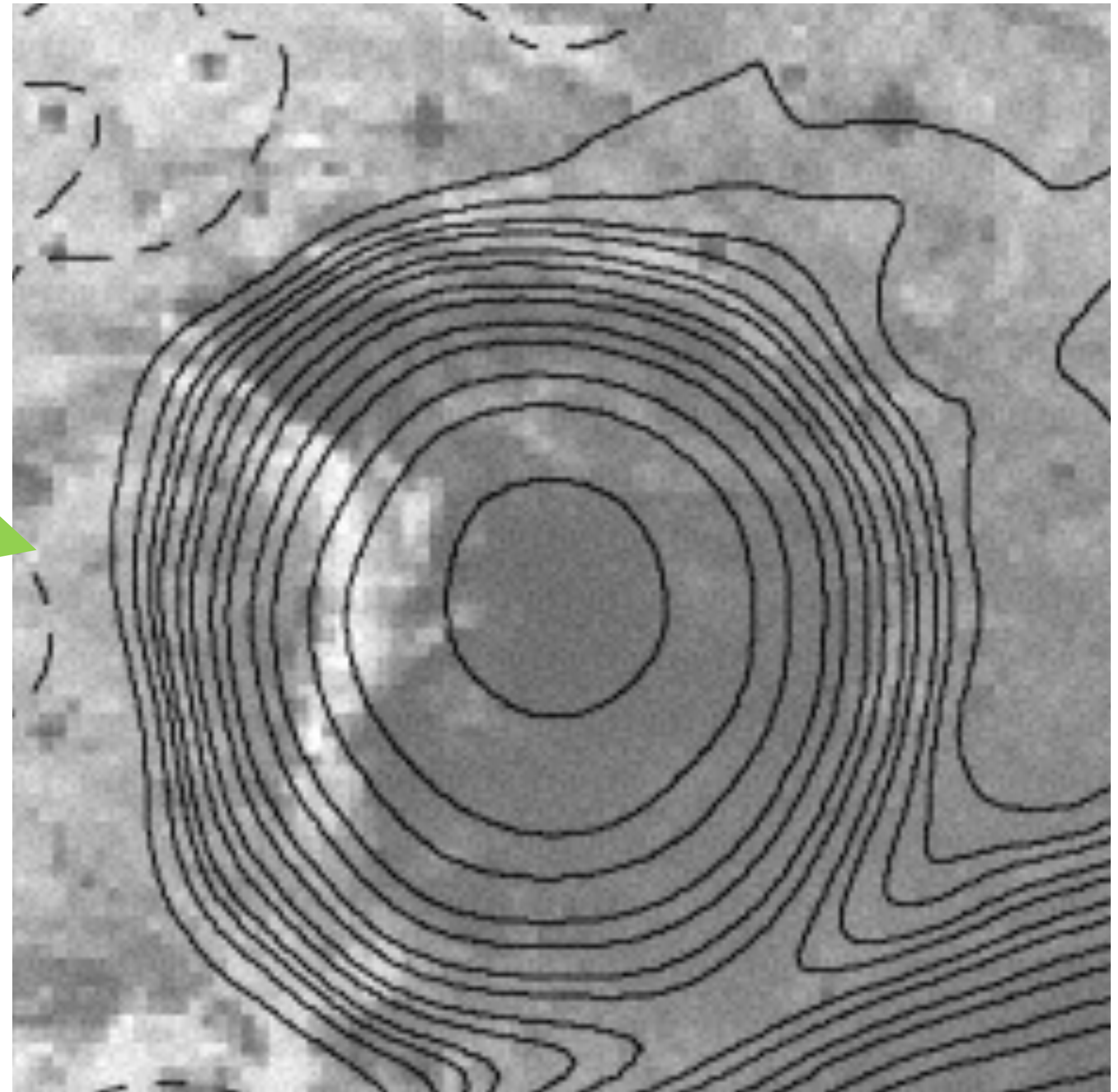
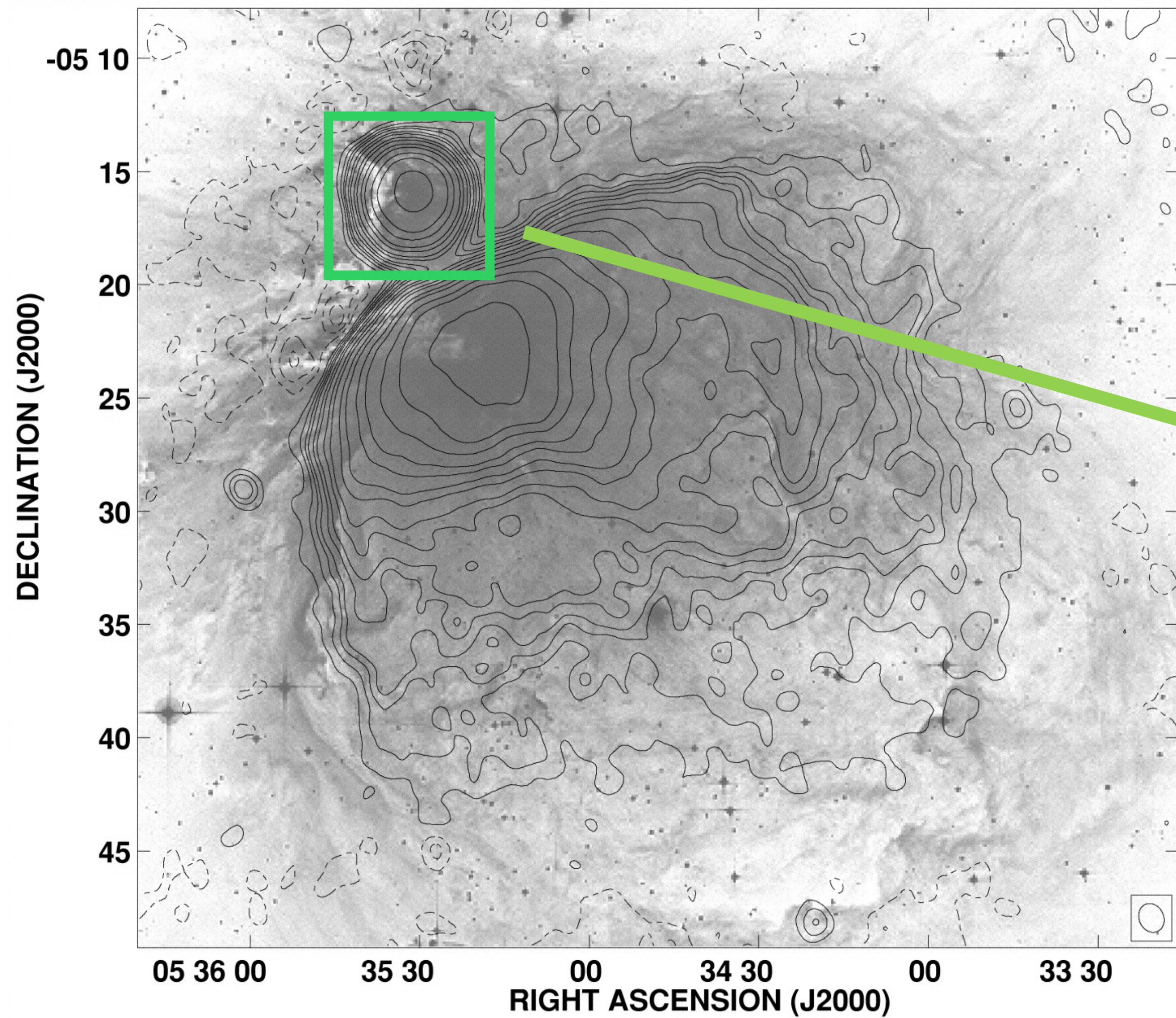
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The M43 HII Region



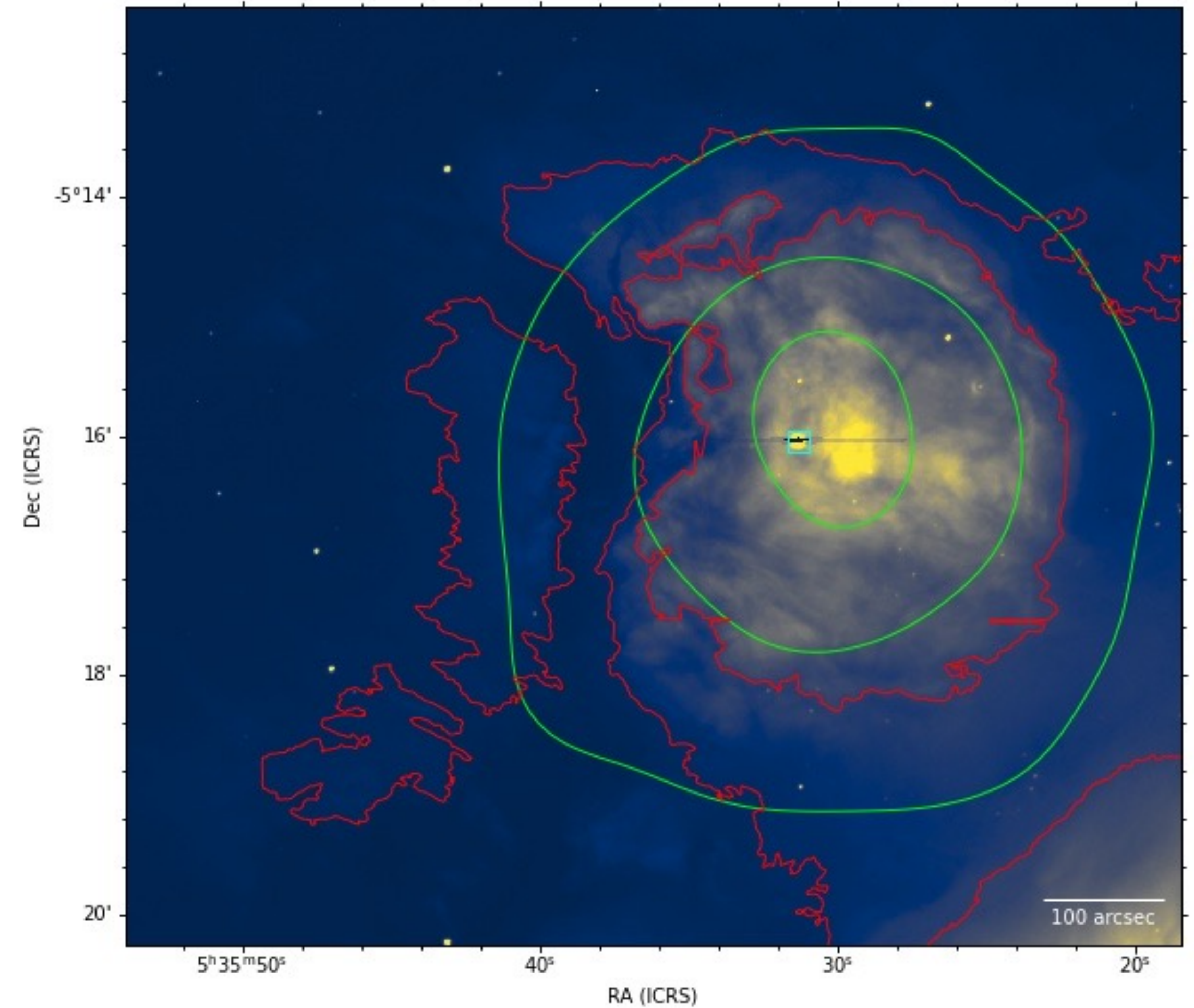
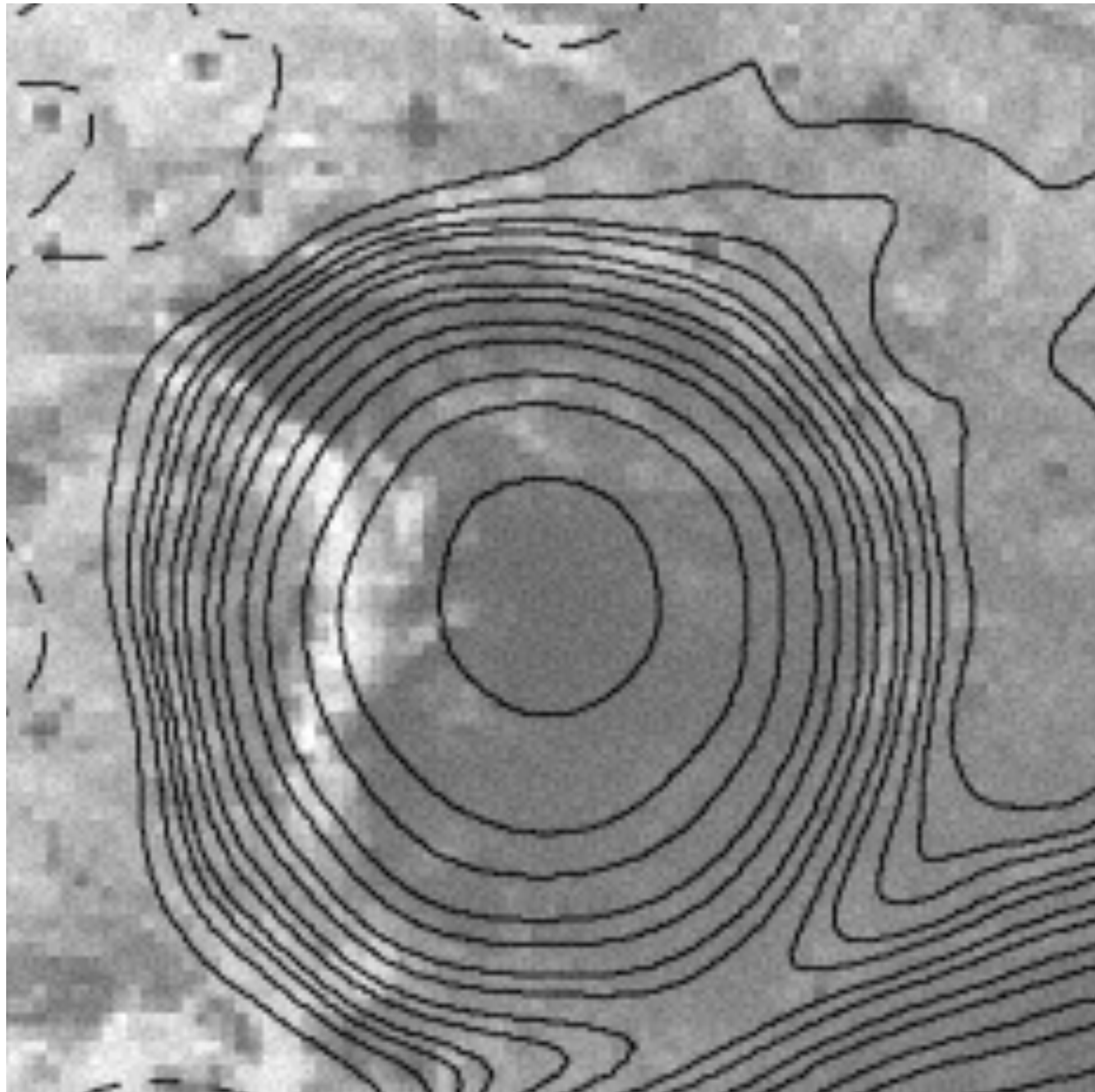
*M43 Nebula Image: Image: NASA/ESA,
Hubble Space Telescope Orion Treasury
Project Team*

Radio Continuum of Orion Molecular Cloud



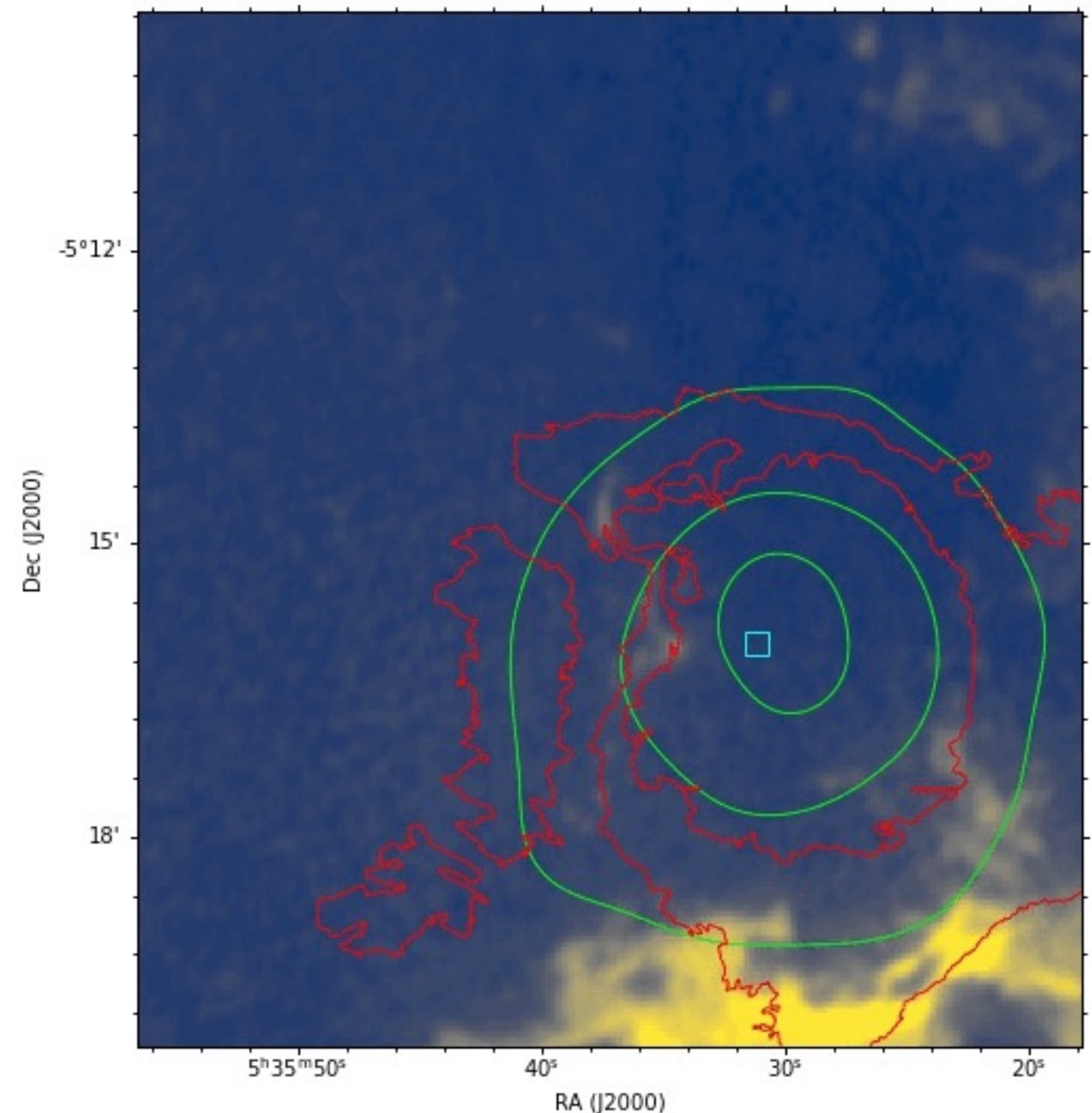
Radio Continuum

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}CO , ^{13}CO and C^{18}O (1-0) Velocity Cubes

SOFIA-GREAT:

CII Velocity Cubes

OWENS-VALLEY RADIO

OBSERVATORY:

CN, CS Velocity Cubes



CARMA Interferometer

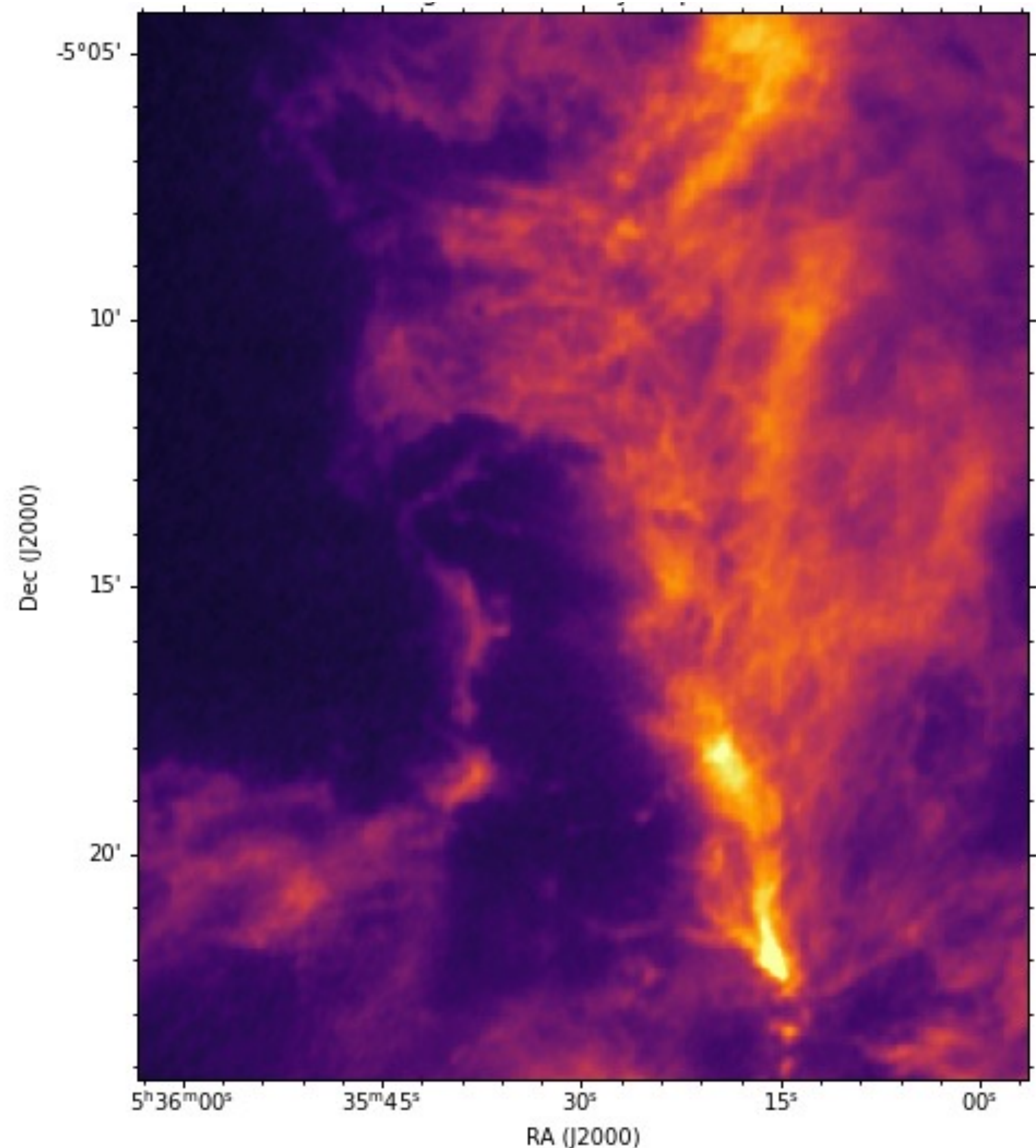
Computing the Column Density of M43

^{13}CO Optical Depth Equation

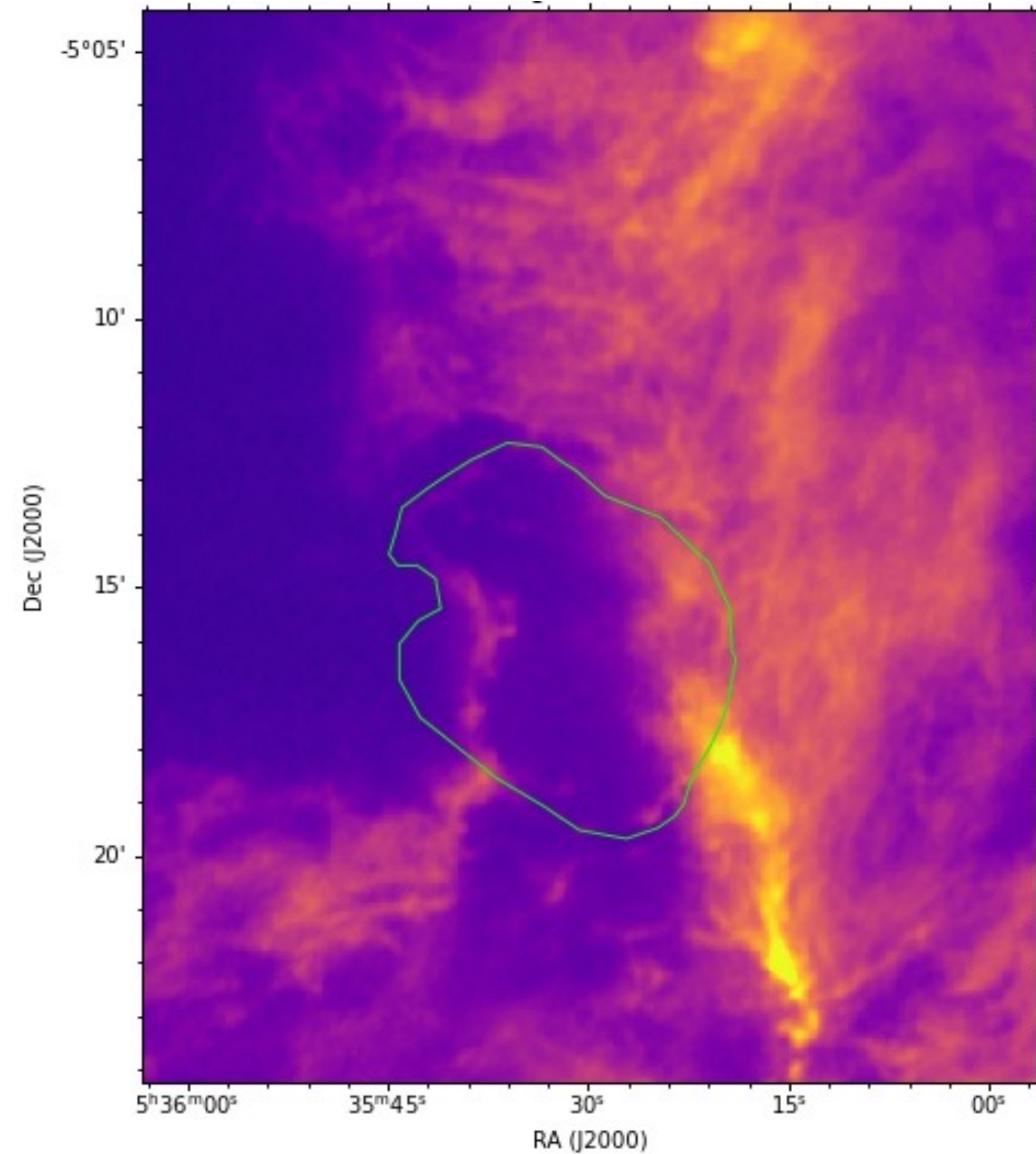
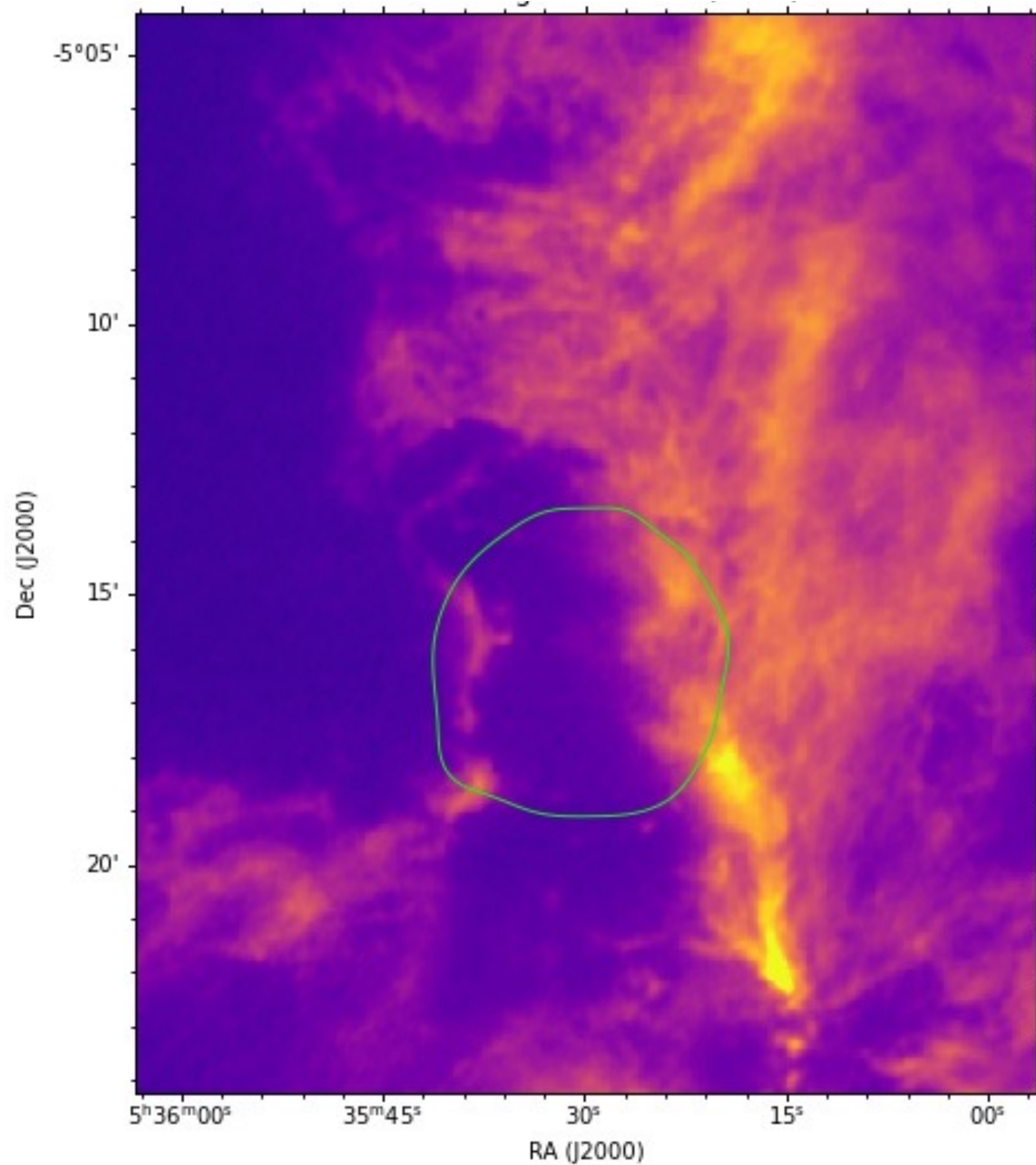
$$\tau(^{13}\text{CO}) = -\ln \left[1 - \frac{T_{\text{max}}(^{13}\text{CO})/5.3 \text{ K}}{1/(e^{5.3 \text{ K}/T_{\text{ex}}} - 1) - 0.16} \right]$$

^{13}CO Column Density Equation

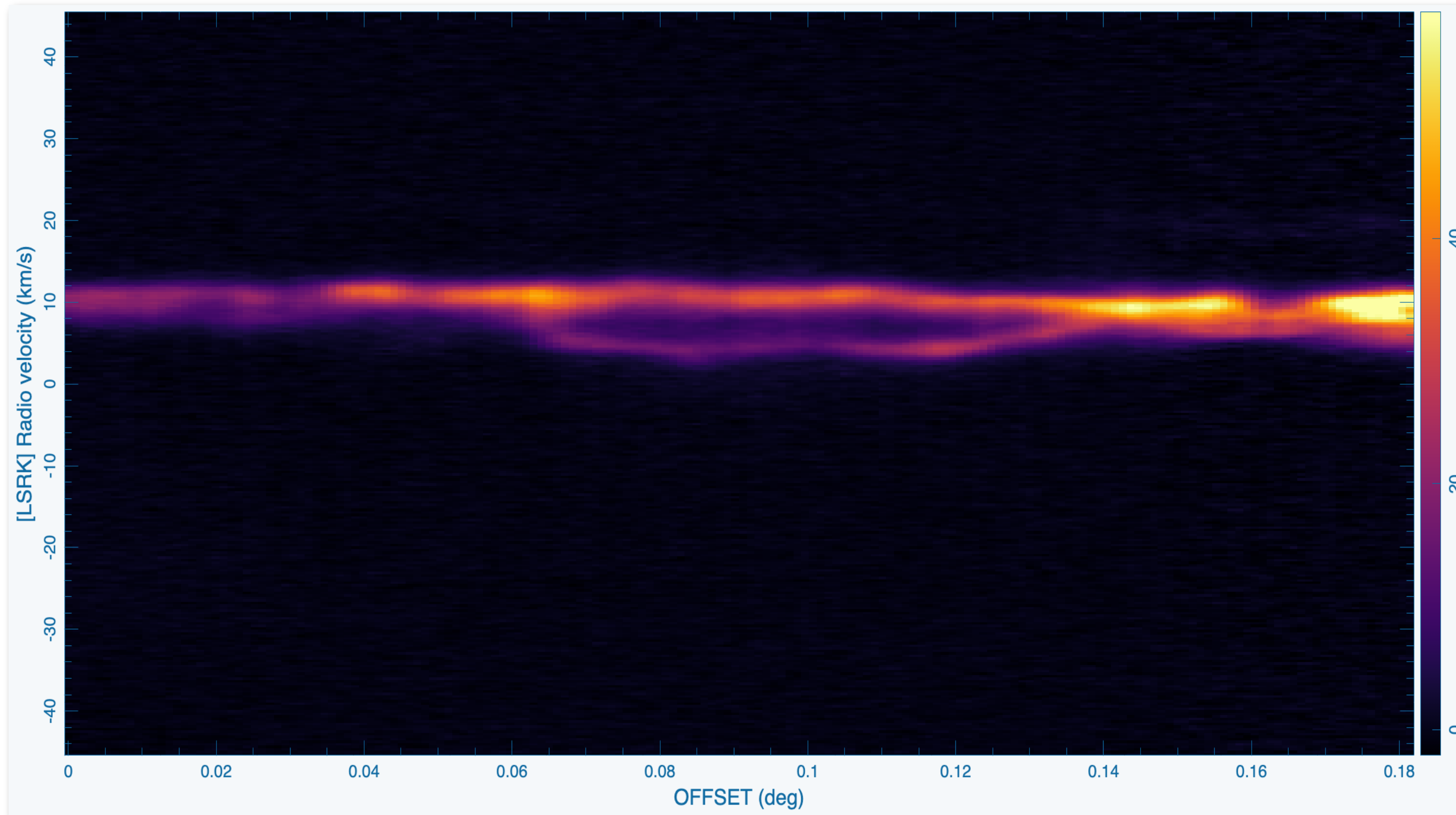
$$N(^{13}\text{CO}) = \left[\frac{\tau(^{13}\text{CO})}{1 - e^{-\tau(^{13}\text{CO})}} \right] 3.0 \times 10^{14} \frac{W(^{13}\text{CO})}{1 - e^{-5.3/T_{\text{ex}}}} \text{ cm}^{-2}$$



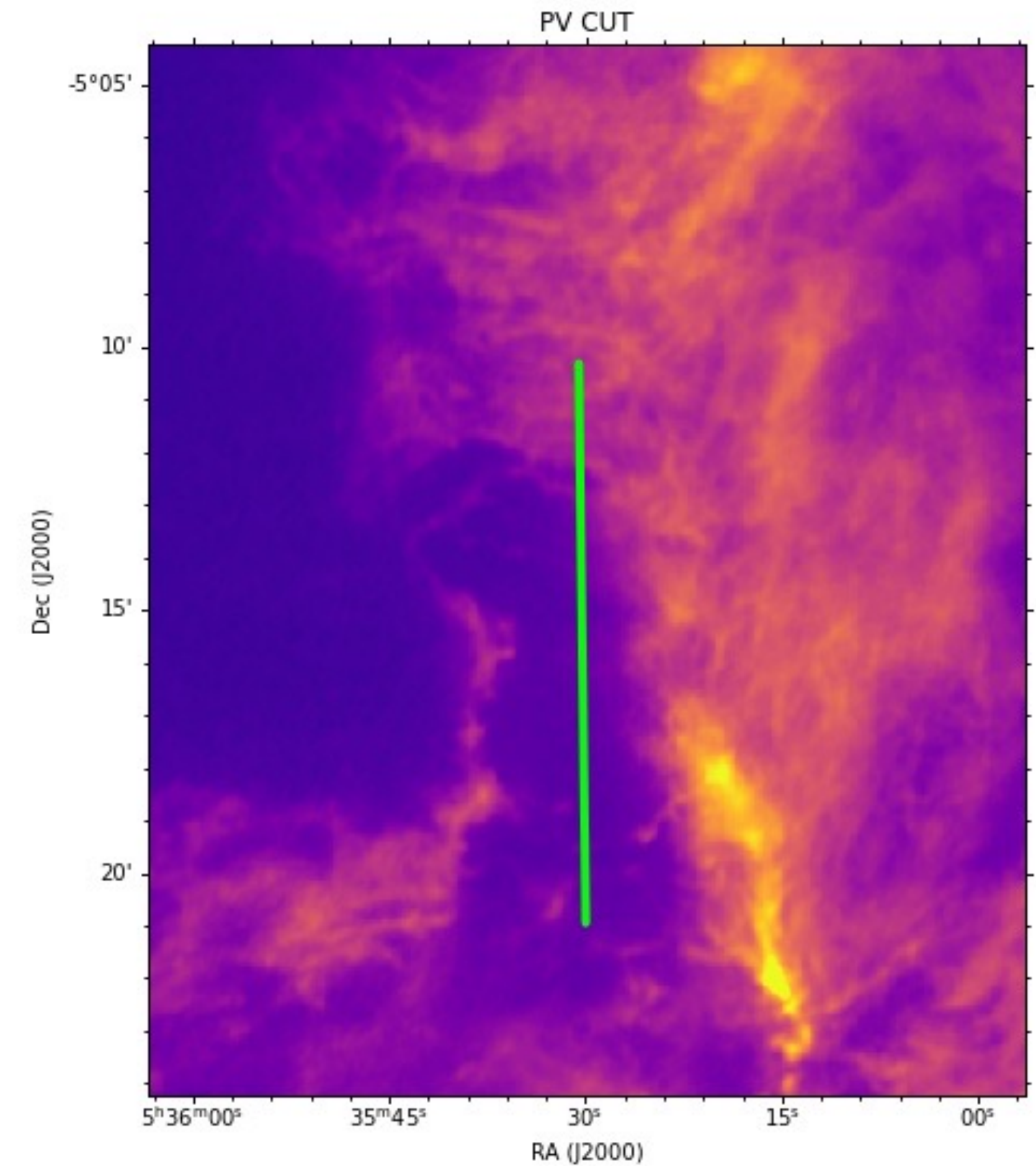
Determining the extent of the M43 Region



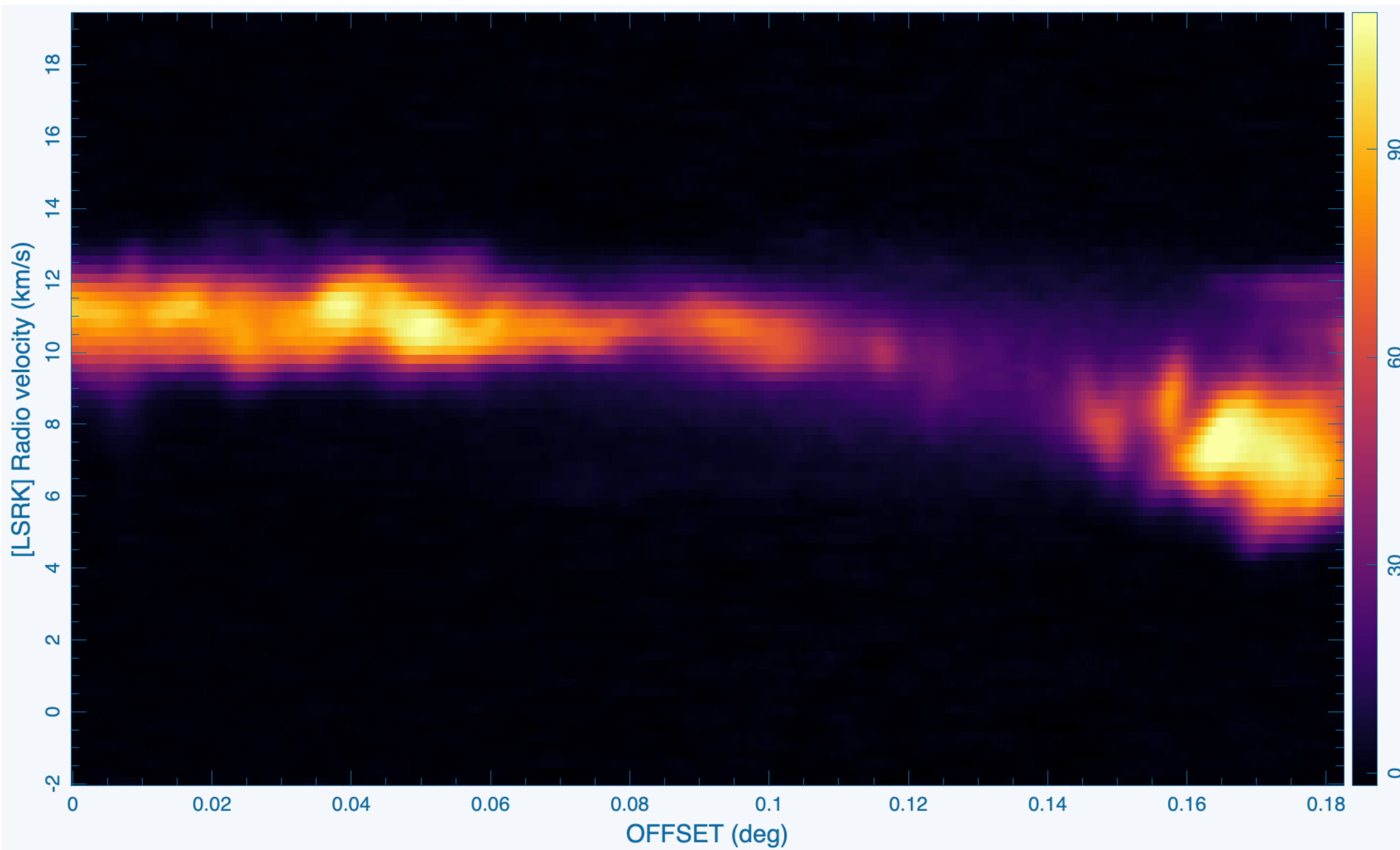
Expansion Velocity via P-V Diagrams



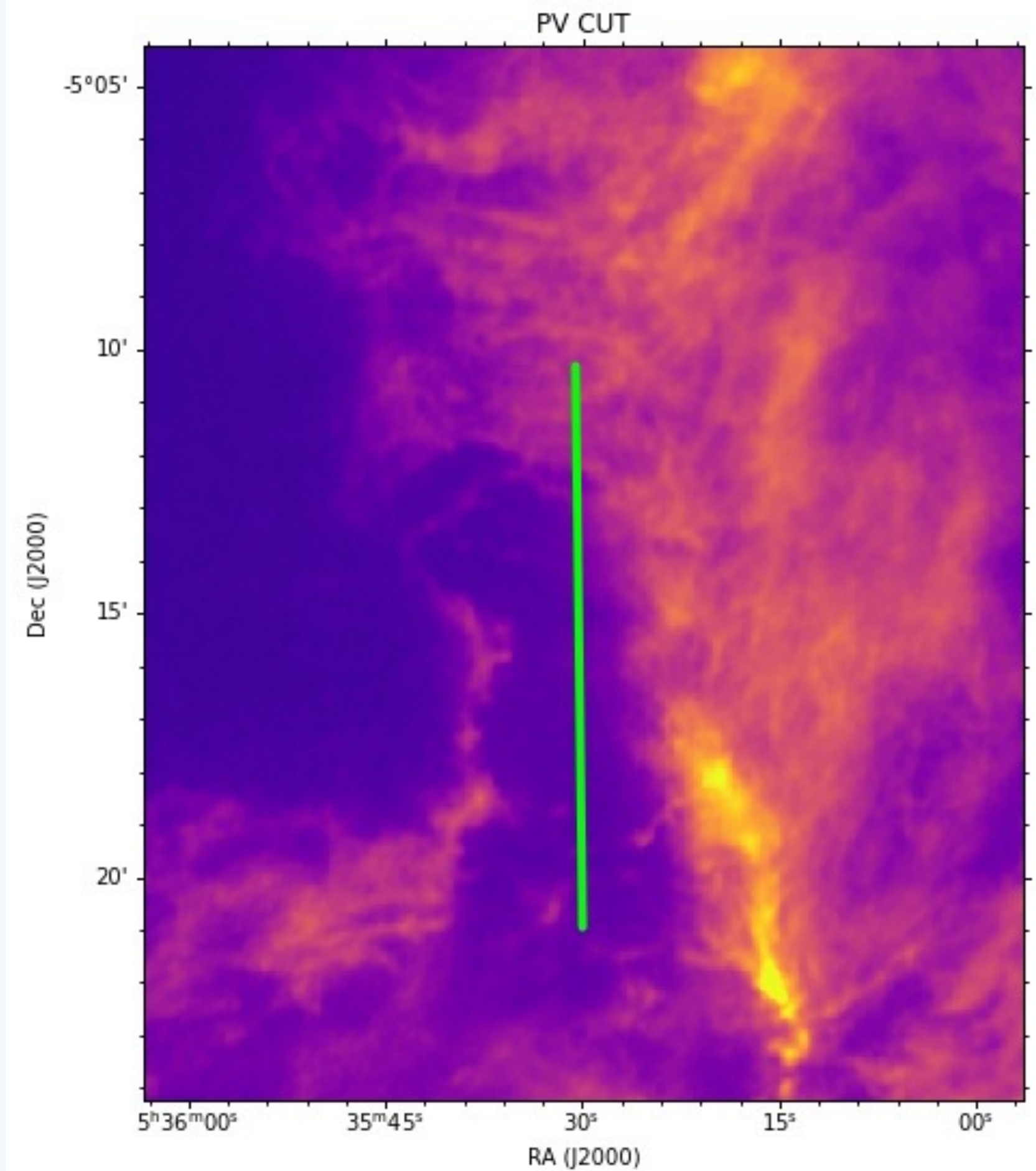
Position-Velocity Diagram of M43 in CII



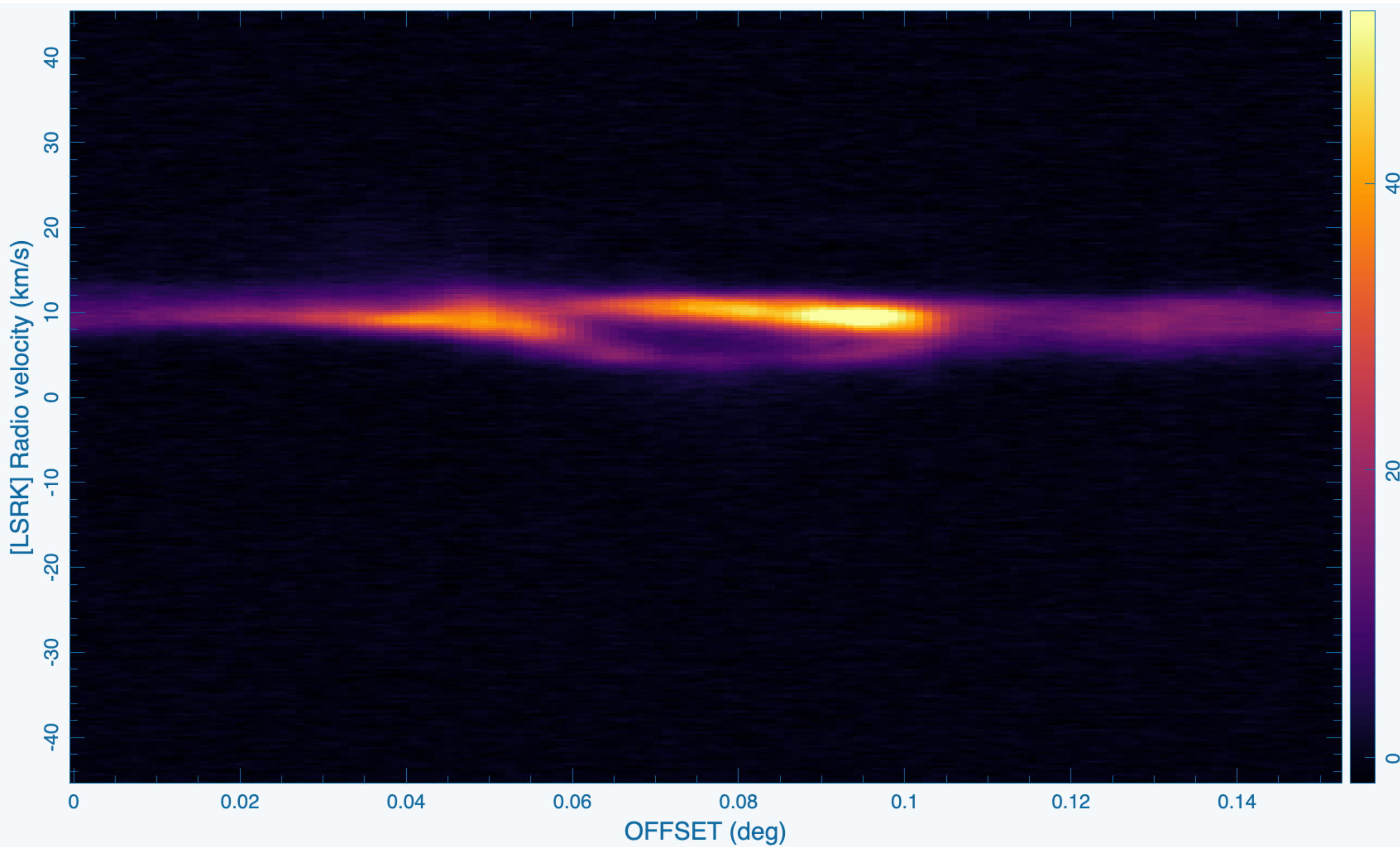
Expansion Velocity via P-V Diagrams



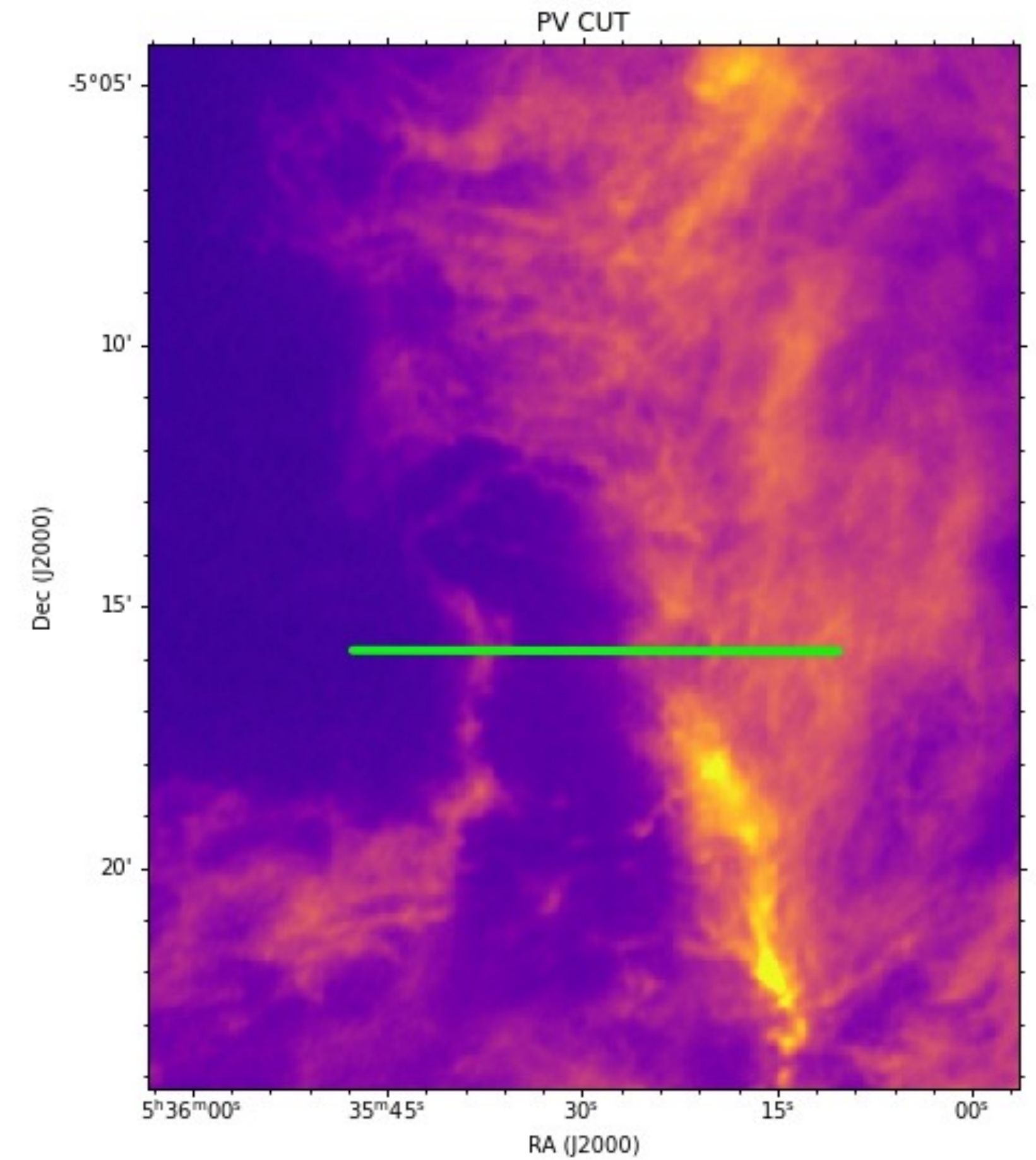
Position-Velocity Diagram of M43 in ^{13}CO



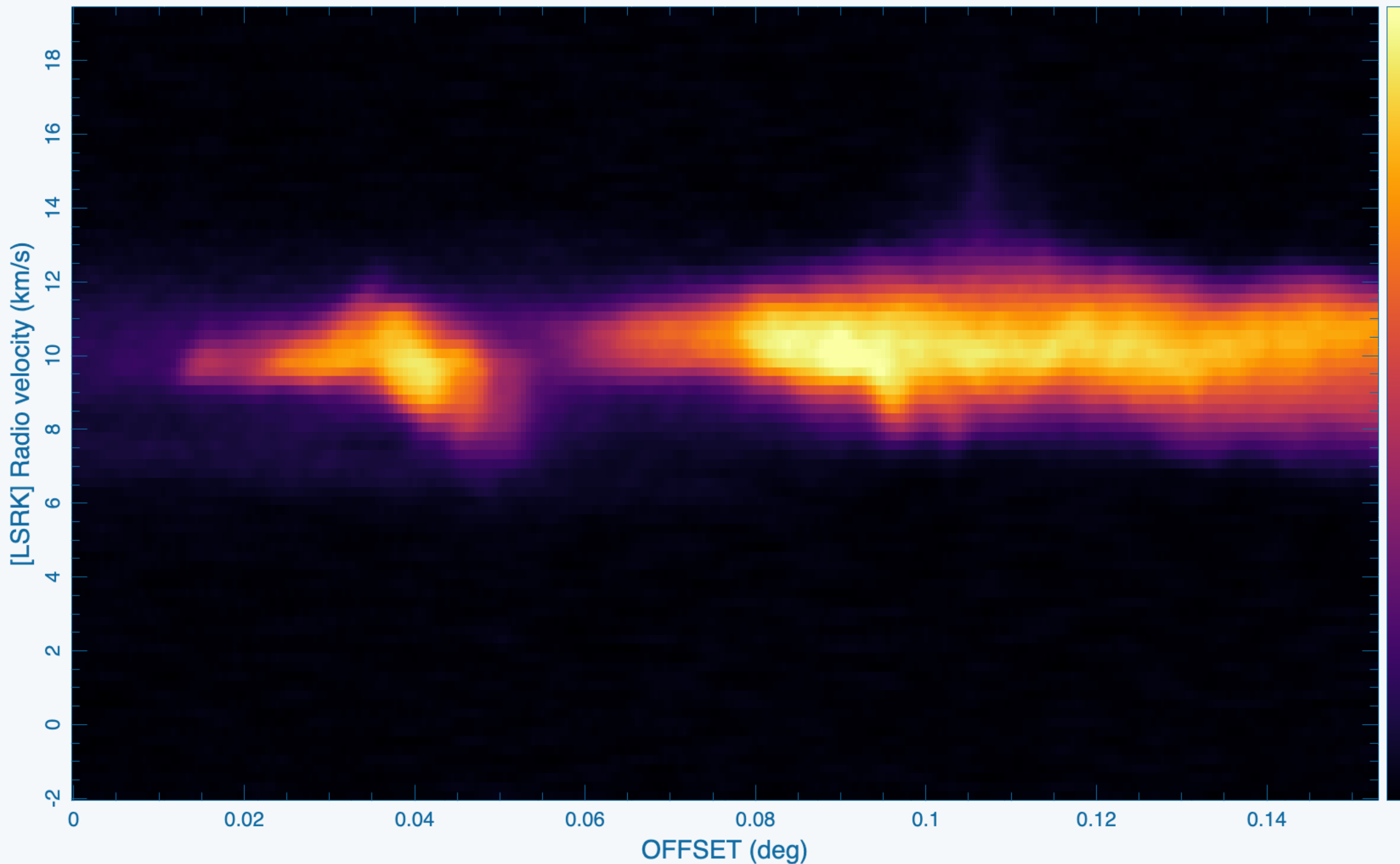
Expansion Velocity via P-V Diagrams



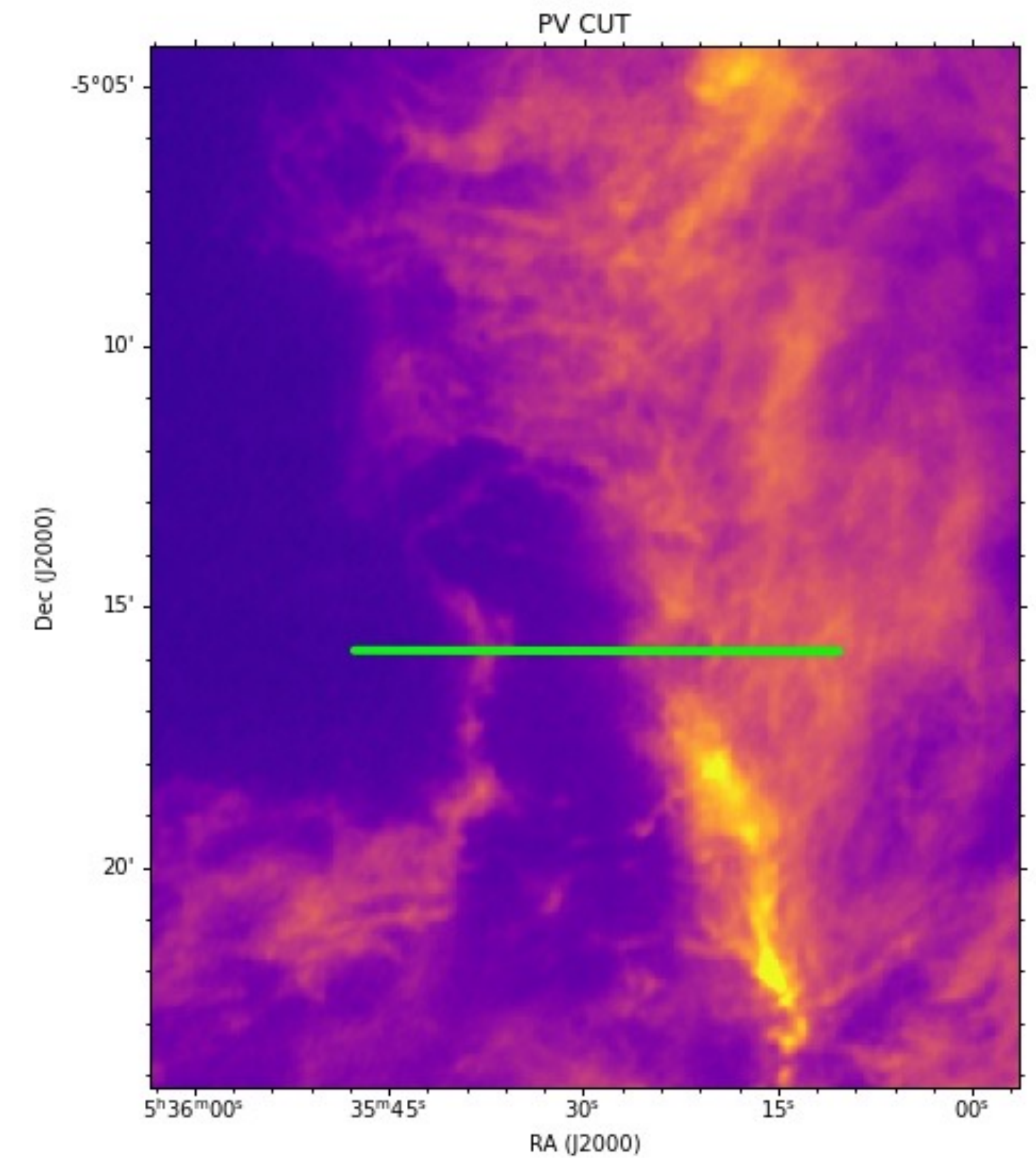
Position-Velocity Diagram of M43 in CII



Expansion Velocity via P-V Diagrams



Position-Velocity Diagram of M43 in 12CO



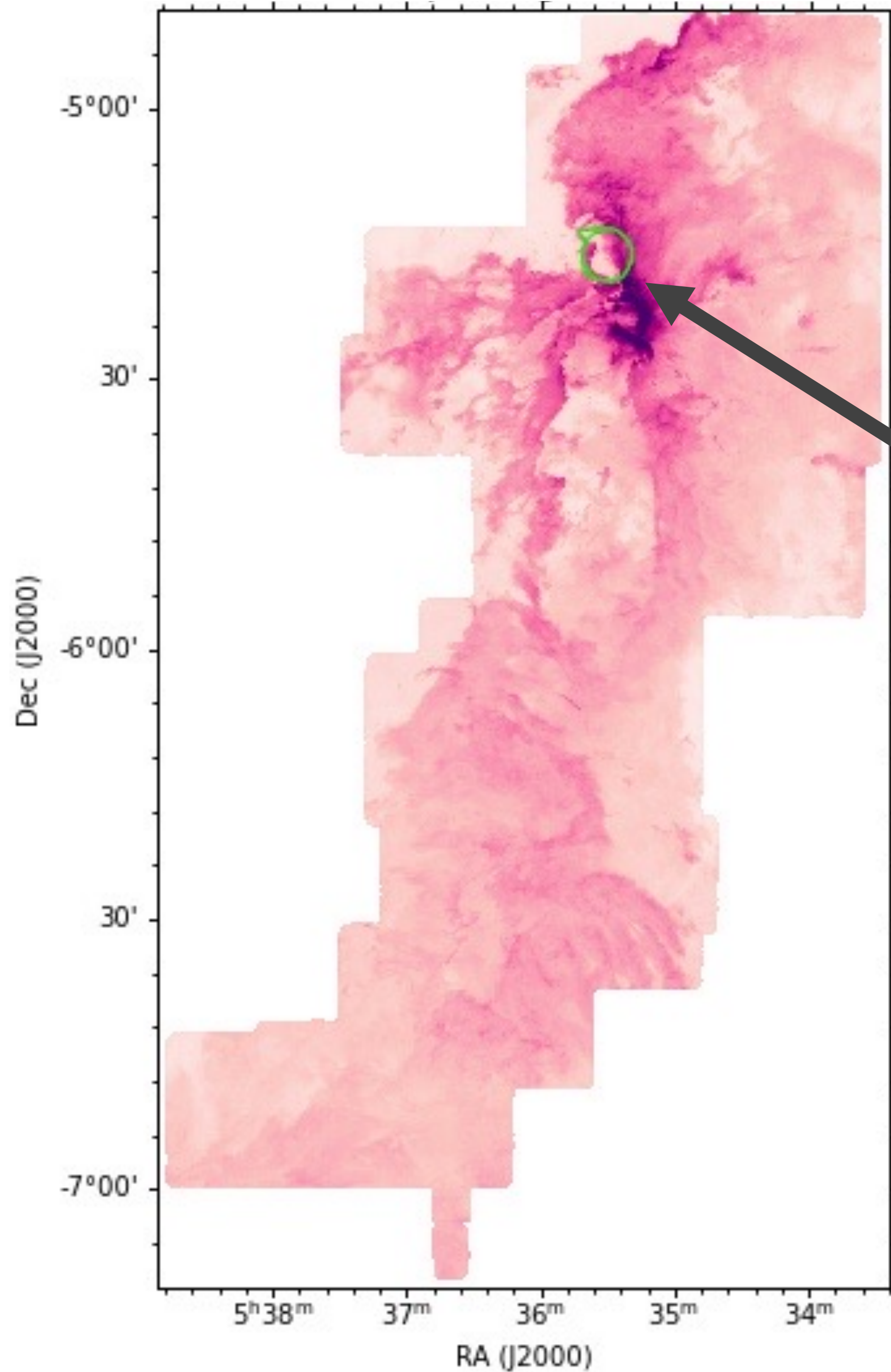
Mass and Kinematics Estimates

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}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**

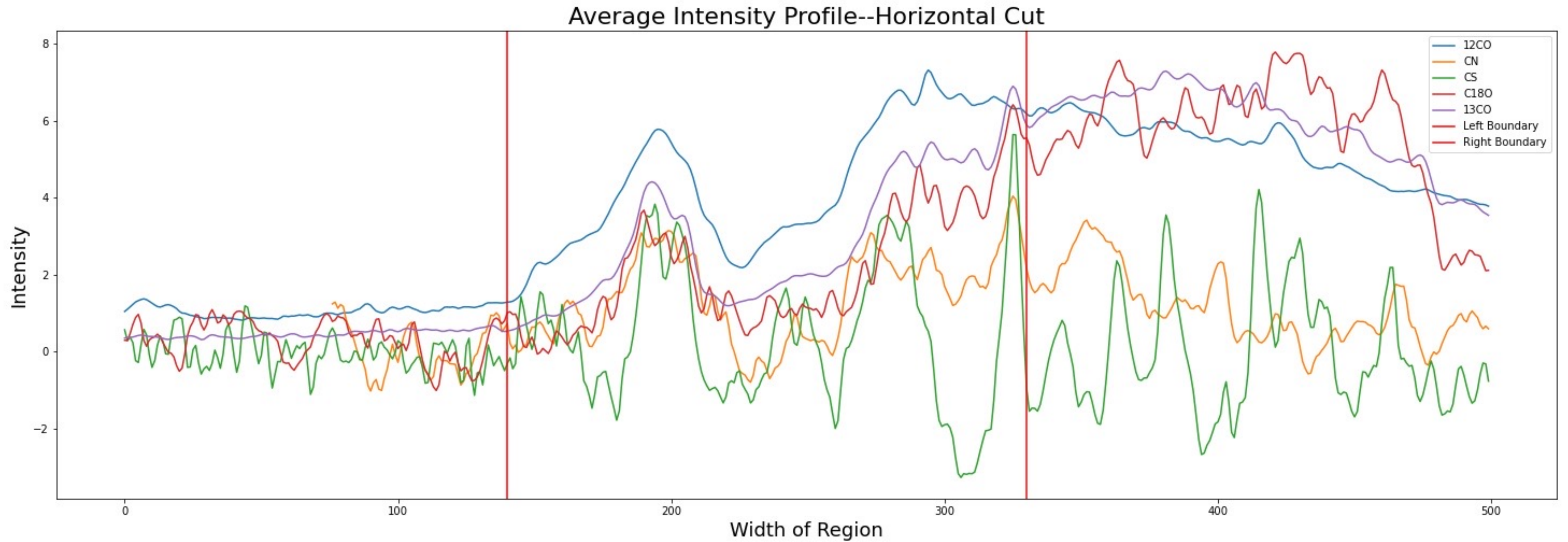
**Mass Estimate of M43 HII
Region:
 $\sim 5.70 \times 10^2 - 6.70 \times 10^2$
Solar Masses**

Plausibility of Kinematics Estimates

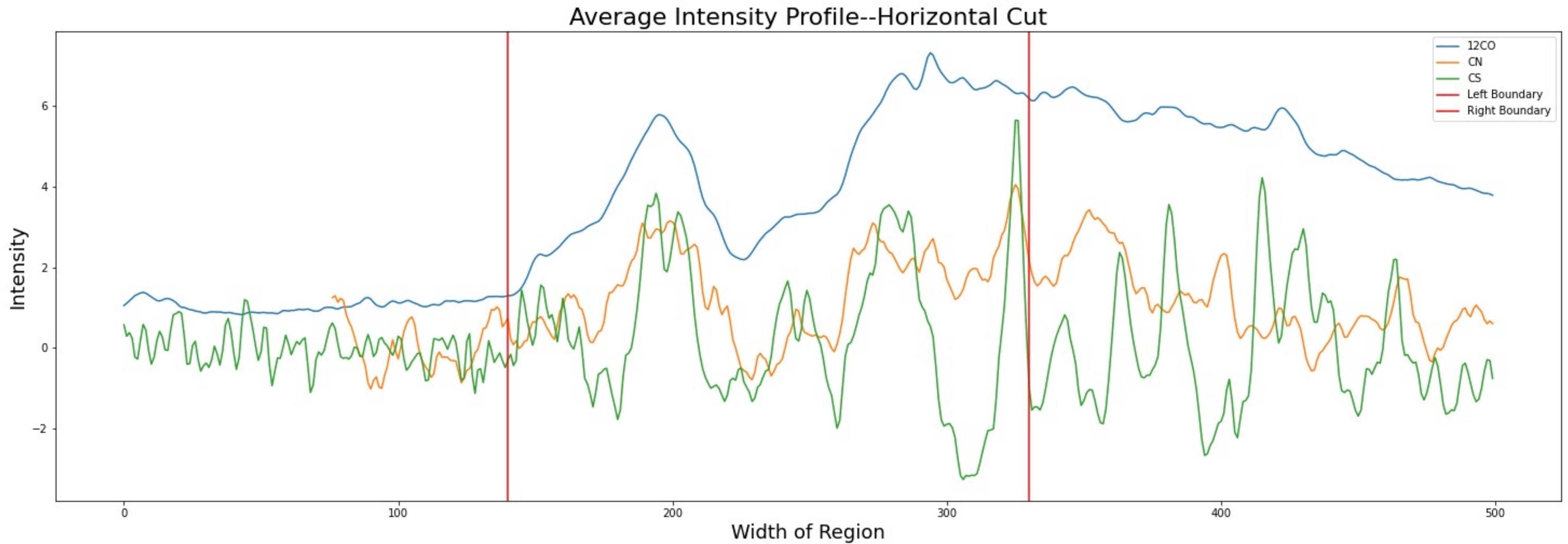
HII Region Kinetic Energies and Momentums should be
HIGHER than stellar outflows
LOWER than supernova emissions

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

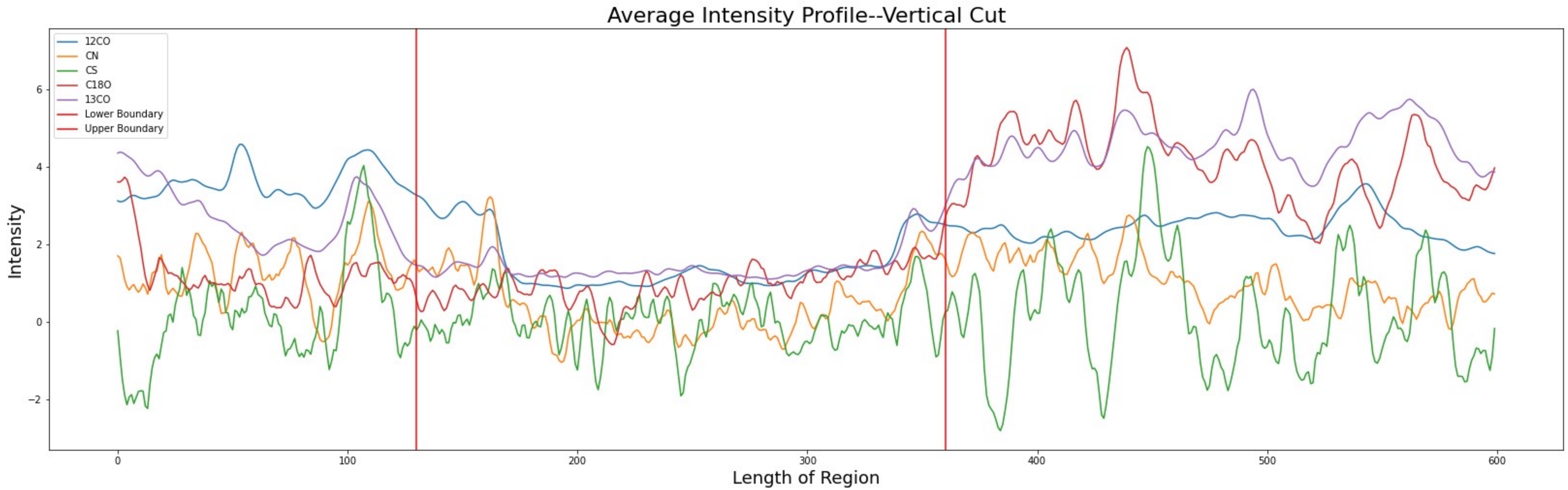
Average Intensity Profiles



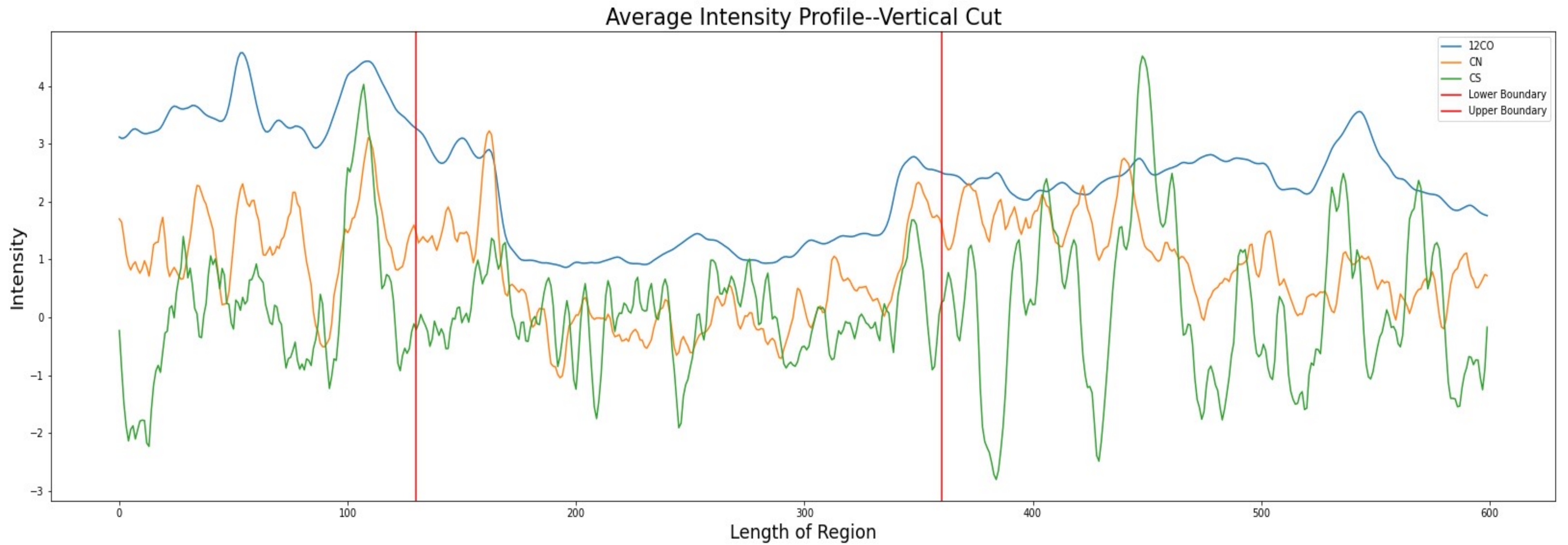
Average Intensity Profiles



Average Intensity Profiles



Average Intensity Profiles

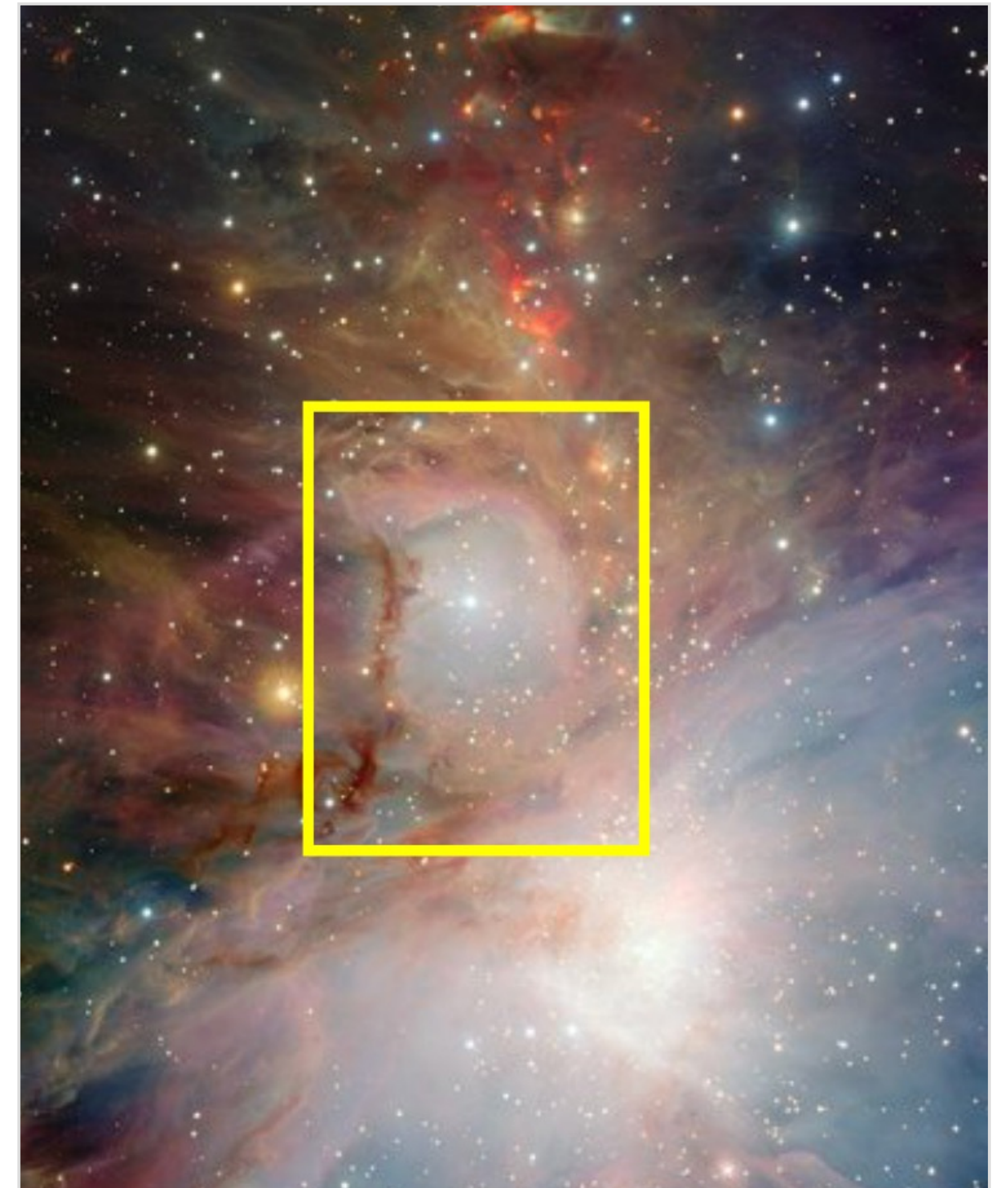


Conclusions

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



Acknowledgements

Yale Department of Astronomy

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