

Testing The Excitation Mechanism Of H30 α RRL In High-Mass Protostellar Object IRAS 16445-4459

C. J. Nicholas,^{1*} J. O. Chibueze² and S. P. Phiri¹

1. Department of Physics - Copperbelt University Zambia School Of Mathematics and Natural Sciences

2. UNISA center for Astrophysics and Space Science, Department of Mathematical Sciences, UNISA, Florida Park, Roodeport, South Africa

*chidinicholasj@gmail.com



ABSTRACT

We present a study of protocluster subsample I16445-4459 using high-resolution ALMA band 6 ($\lambda \sim 1.3$ mm) QUARKS survey selected for UC H II regions traced by the H30 α Radio recombination line (RRL) and MeerKAT 1.3 GHz observation G340.248-00.046 to investigate the excitation mechanism of the H30 α RRL in the high-mass forming region. The source reveals the detection of the RRL indicating ionized dense gas region. This detection exhibits diverse physical properties from its radio continuum with core mass of 918 M_{\odot} at 100K and 446 M_{\odot} at 200K, its ionizing photon rate $S^* = 1.05 \times 10^{47} \text{ s}^{-1}$ ($\log S^* = 48.02$) corresponds to the total Lyman continuum output of small young stellar cluster containing several early O-type or early B-type stars which is typical of a compact or embedded H II region in active star-forming complex. The hydrogen column density ranges between 2.59 (at 100K) and 1.26 cm^{-2} (at 200K). Detection of the H30 α radio recombination line in this region reveals a single-Gaussian profile with a peak amplitude of 0.567 ± 0.017 Jy/beam and a centroid velocity of -127.2 ± 0.3 km/s. The velocity dispersion is $\sigma = 10.5 \pm 0.5$ km/s, yielding a FWHM of 24.6 ± 1.1 km/s, and a baseline offset of -0.056 ± 0.015 Jy/beam. These H30 α line characteristics indicate the presence of ionized gas with significant turbulent or bulk motions, possibly tracing a compact HII region or thermal jet associated with massive star formation. The line's width and velocity features are consistent with ionized gas dynamics in energetic star-forming environments, supporting its origin in an active, embedded massive protostellar core.

Introduction

IRAS 16445-4459 is massive star forming region masses $M \geq 8M_{\odot}$ which is part of QUARKS survey by Liu, X et al (2024). The H30 α radio recombination line (RRL) at 231.9 GHz traces ionized gas in HII regions, providing physical and kinematic properties, critical for modeling massive star formation in molecular clouds. This study analyzes MeerKAT and ALMA H30 α observations of a Galactic HII region to derive physical parameters amid complex line-of-sight structure. Key goals: Testing the H30 α excitation mechanism within IRAS 16445-4459.

Methodology

Data Sources: Utilized calibrated ALMA Band 6 H30 α (231.9 GHz) visibilities from the QUARKS survey; MeerKAT 1.3 GHz continuum background (Geodhart et al. 2024); WISE mid-IR overlays (Anderson et al. 2014).

Imaging: Self-calibrated and imaged ALMA data in CASA (v6.5+), using TCLEAN (robust=0.5, uv-taper=5-10k λ for $\sim 1''$ resolution); registered MeerKAT continuum as background.

Analysis: Extracted moment-0 masked spectra; fitted H30 α Gaussians (astropy.specutils + lmfit) for V_{peak} , ΔV , T_b ; generated moment maps (0,1,2) with APLpy, overlaid on WISE for HII context.

Results

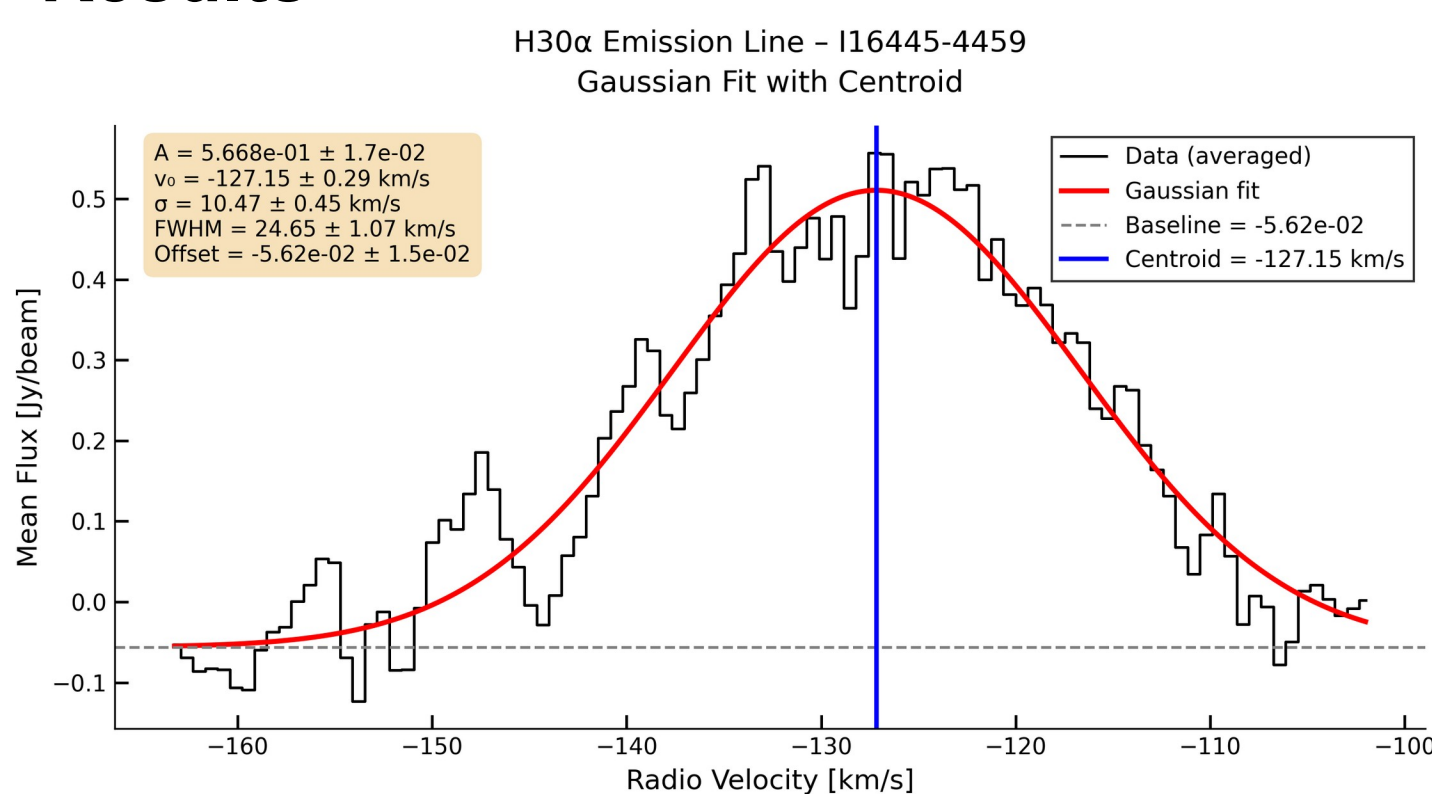


Fig 1: 2D Gaussian fitting of the H30 α RRL detected in the region

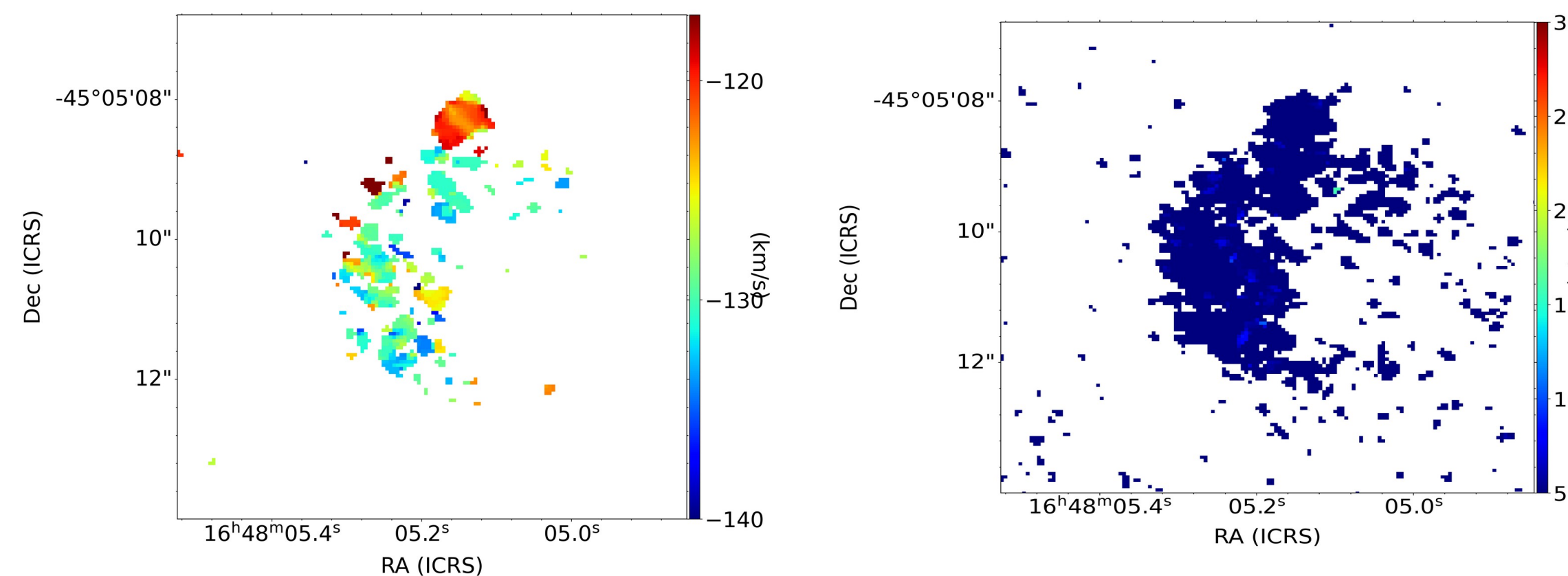
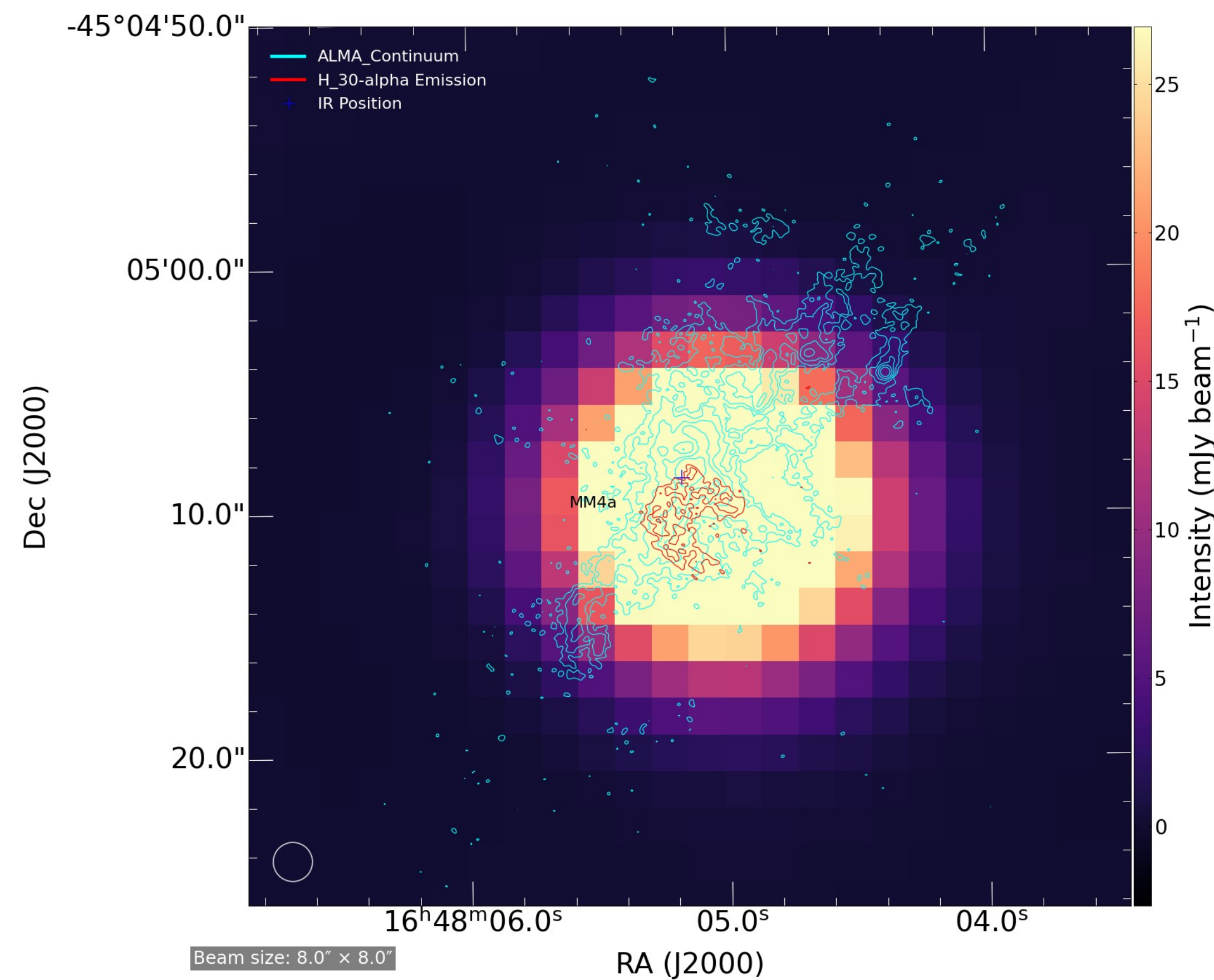


Fig 3: First and second moment maps of H30 α RRL showing rotation and dispersion respectively

CONTINUUM PARAMETERS		RR LINE 2D GAUSSIAN PARAMETERS	
Integrated Flux Sv, (mJy)	47.4 ± 4.2	Amplitude	5.668 x 10 ⁻¹ ± 1.7 x 10 ⁻²
Peak Flux(mJy beam ⁻¹)	28.67±0.56	Velocity (km/s)	-127.15 ± 0.29
Position Angle(Deg)	104±12	Sigma	10.47 ± 0.45
Ionizing Flux S* (10 ⁴⁷ s ⁻¹)	1.05 (log S* = 48.02)	FWHM	24.65 ± 1.07
Col. Density (10 ²⁶ cm ⁻²)	2.59 (at 100K) and 1.26 (at 200K)	Offset	5.62x10 ⁻² ± 1.5x10 ⁻²
Mass of Core	18 M \odot (at 100K) & 446M \odot (at 200K)		

Conclusion

I16445-4459 is a Galactic massive HII region in which H30 α RRL was detected. The detected line was overlaid on both ALMA and MeerKAT continuum of the source as well the infrared peak position indicated by the blue cross in the overlay all showing alignment showing. The moment 1 map shows a fragmented rotating structure and the second moment map shows a little higher dispersion from inside and lesser towards the outer parts. The Ionizing Flux, Column density and Mass of Core reflects the enhanced emission efficiency of warmer dust extremely dense environments, regions of high and low-mass stars.

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References

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