

More Insights into the Distribution of Gases and Outflows in G358.46–0.39 Star Forming Region

C. J. Ugwu^{1*}, J. O. Chibueze¹, W. O. Obonyo¹ and M. Seidu²

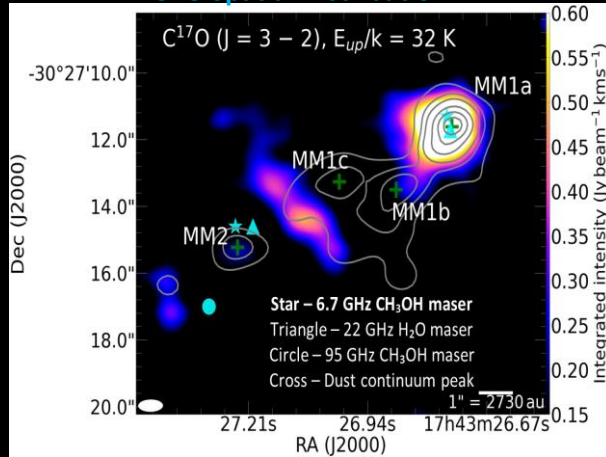
¹UNISA Centre for Astrophysics and Space Sciences (UCASS), College of Science, Engineering and Technology, University of South Africa; ²Centre for Space Research, North-West University, Potchefstroom, 2520, South Africa

*ugwucj@unisa.ac.za

ABSTRACT

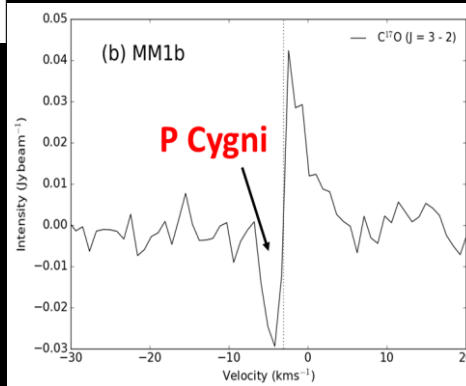
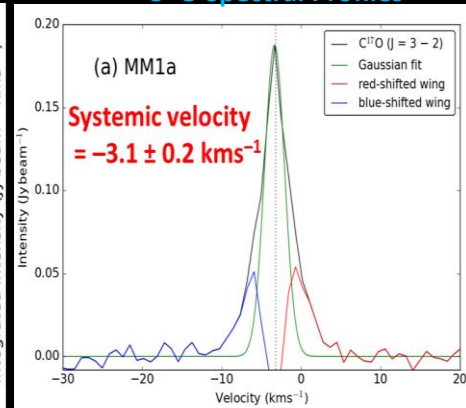
Understanding the physical and dynamical conditions of massive star-forming cores is essential for constraining how high-mass stars assemble their mass and shape their environments. G358.46–0.39 is a massive proto-cluster previously identified to host 4 cores, yet its internal gas structure, chemical complexity, and driving sources of outflow activity remain poorly characterized. To provide a clearer picture of its protostellar nature, we analyzed ALMA Band 7 archival data to investigate the spatial distribution of key molecular tracers – $C^{17}O$ and SiO, as well as to quantify the energetics of associated outflows. The integrated $C^{17}O$ map reveals filamentary and dumbbell-like structures that likely represent gas compressed by the expansion of the H II region around MM2, offering new insight into the large-scale gas morphology. SiO emission uncovers spatially overlapping blue- and red-shifted lobes, consistent with a bipolar outflow driven by an unresolved young stellar object (YSO) in MM1a. We derived the mass, momentum, energy and associated rates of outflows and found that the SiO outflow morphology differs from the previously reported ^{12}CO outflow. These differences suggest that the SiO and ^{12}CO outflows originate from separate YSO disks – one likely face-on and the other edge-on, pointing to multiplicity within MM1a.

$C^{17}O$ Spatial Distribution

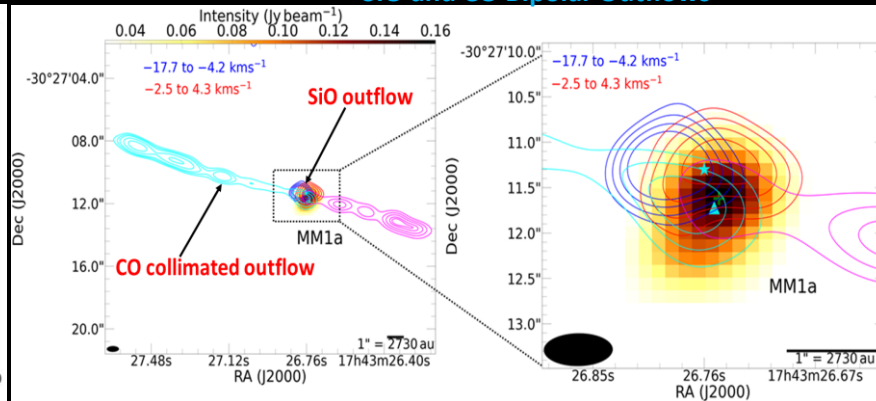


Dominant $C^{17}O$ emission in MM1a, most actively forming core
No or weak emission in MM1b and MM1c due to low gas column density
Weak emission in MM2 due to impact of H II region
Blue- and red-shifted wings sign of outflow or rotation in MM1a
Blueshifted absorption resembles P Cygni profile indicating outflow or infall

$C^{17}O$ Spectral Profiles



SiO and CO Bipolar Outflows



Different morphologies of SiO and CO outflow lobes suggesting at least 2 unresolved YSOs in MM1a

Same direction of SiO and CO outflow lobes may imply SiO tracing densest part of the outflows

Disk of YSO driving SiO outflow likely face-on, while that of CO edge-on, pointing to multiplicity within MM1a. Higher resolution observations needed to confirm this scenario

Estimated outflow properties consistent with observations and simulation of massive star forming regions, with values higher than expected for a single driving source, suggesting multiple driving YSOs in MM1a

Outflow lobe	$ v_{max} - v_{sys} $ (km s ⁻¹)	$\dot{M}_{outflow}$ (M_{\odot})	$\dot{P}_{outflow}$ ($M_{\odot} km s^{-1}$)	$E_{outflow}$ (erg)	R_{max} (pc)	t_d (yr)
^{12}CO ($J = 3 - 2$)						
Blue	46.9	1.92 ± 0.02	58.6 ± 5.6	$3.2 \pm 0.3 \times 10^{46}$	0.201 ± 0.021	$4.2 \pm 0.4 \times 10^3$
Red	45.4	0.666 ± 0.007	19.7 ± 2.9	$1.04 \pm 0.15 \times 10^{46}$	0.106 ± 0.011	$2.3 \pm 0.2 \times 10^3$
Average		1.295 ± 0.014	39.2 ± 4.2	$2.11 \pm 0.23 \times 10^{46}$		$3.2 \pm 0.3 \times 10^3$
SiO ($J = 8 - 7$)						
Blue	12.1	172.6 ± 1.8	195.2 ± 28.8	$1.6 \pm 0.2 \times 10^{47}$	0.016 ± 0.002	$1.1 \pm 0.1 \times 10^3$
Red	4.8	61.1 ± 0.6	32.9 ± 3.1	$1.4 \pm 0.1 \times 10^{46}$	0.019 ± 0.002	$2.5 \pm 0.3 \times 10^3$
Average		116.9 ± 1.2	114.1 ± 15.9	$8.7 \pm 1.2 \times 10^{46}$		$1.8 \pm 0.2 \times 10^3$

CONCLUSIONS

This work provides new evidence that MM1a hosts a massive, actively accreting protostar surrounded by complex gas motions and multiple outflow structures, shedding light on early stages of massive star formation

REFERENCES

Csengeri, T., Bontemps, S., Wyrowski, F., Motte, F., Menten, K. M. et al. (2017). ALMA Survey of Massive Cluster Progenitors from ATLASGAL Limited Fragmentation at the Early Evolutionary Stage of Massive Clumps. *A&A*, 600, L10
Ugwu, C. J., Chibueze, J. O., Obonyo, W. O., Seidu, M. (2026). Insights on Gas Distribution and Dynamics in Massive Proto-cluster G358.46–0.39: Possible Multiplicity in G358.46–0.39 MM1a. *NA*, 123, 102498