Radio Emissions of Infrared Dark Clouds: Molecular Transitions and Continuum Maps

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Overview

- Background on MYSOs and Massive Star Formation Models
- Archive Data: Massive Starless Core Survey
- Results
- Conclusions and Next Steps

Massive Young Stellar Objects (MYSOs)

Massive young stellar objects are high mass cores that are in the process of forming a star.

Difficulties with Observing MYSOs:

- They live for short periods of time
- Their mass is hard to constrain

Competitive Accretion Model

The Competitive Accretion Model envisions that massive stars are formed from further accretion onto low mass protostars over large timescales.[1,2,3]

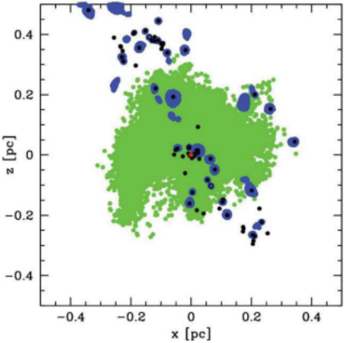


Figure: Simulation where green dots represent gas that will accrete onto the massive sink (red dot). Black dots represent protostars and blue dots represent the gas bound by cores.[4]

[1] Bonnell et al. 2001
[2] Bonnell et al. 2004
[3] Barnes et al. 2021
[4] Smith et al. 2009

(Quasi) Monolithic Collapse Model

The (Quasi) Monolithic Collapse Model predicts that massive protostars are formed in a similar manner to low-mass protostars through the core initially having enough mass to collapse and form a massive protostar.[5][6]

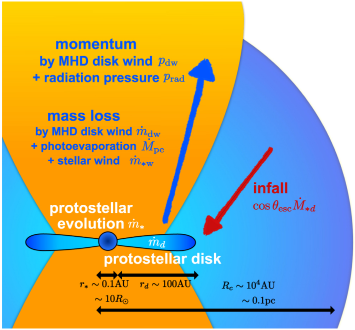


Figure: Schematic view of massive star formation through core accretion with various feedback processes.[7]

[5] McKee et al. 2003
[6] Tan et al. 2013
[7] Kei et al. 2017

The InfraRed Dark Clouds (IRDCs)

An IRDC is a cold molecular cloud that is dense enough to block infrared radiation. They are observed as dark spots on infrared images.[8]

ALMA Surveys:

- Kong et al. 2017 - N_2D^+ Line Emission in IRDCs
- Li et al. 2020 - CO and SiO Outflows in IRDCs
- Liu, M. et al. 2021 - SiO Outflows in IRDCs

VLA Surveys:

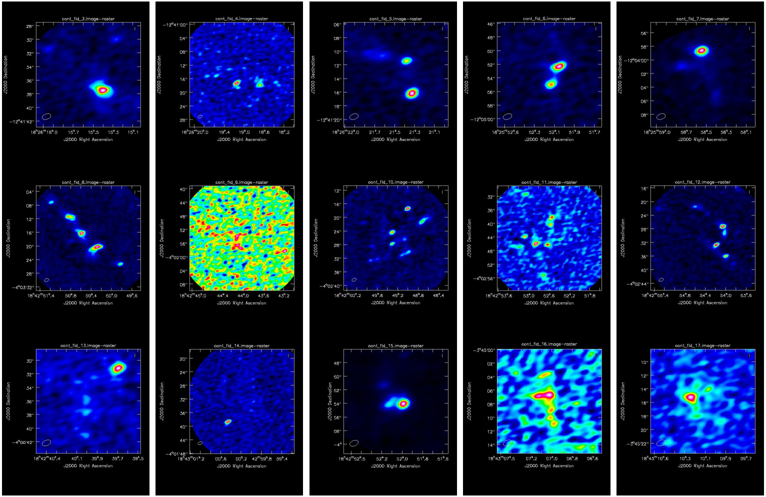
- Liu, M. et al. 2021 - C-Band Observations in IRDCs
- Purser et al. 2021 - Radio Jets in MYSOs and IRDCs

and many more...

We searched the archives for other bright cores in IRDC and to further study the sources identified in the Kong et al. 2017 survey.

[8] Butler et al. 2009

Massive Starless Core Survey



ALMA Band 6, centered on 231 GHz. Project Code: 2013.1.00806[9]

[9] Kong et al. 2017

Cores with Line Emissions

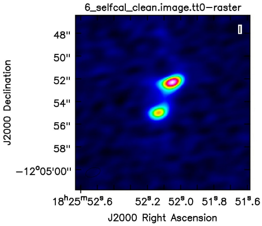


Figure: IRDC-B1, G019.27+00.07 MM2 Peak Flux: 10 mJy/beam

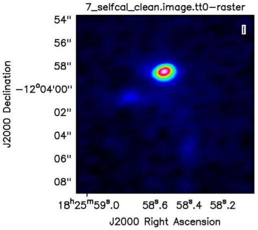


Figure: IRDC-B2, G019.27+00.07 MM1 Peak Flux: 16 mJy/beam

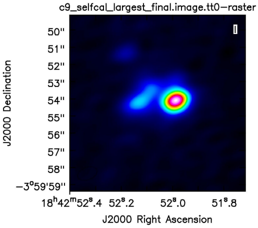


Figure: IRDC-C9, G028.34+00.07 MM1 Peak Flux: 70 mJy/beam

IRDC-C9

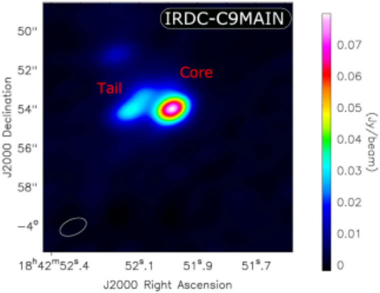


Figure: IRDC-C9 Self-Calibrated Continuum Image.[10]

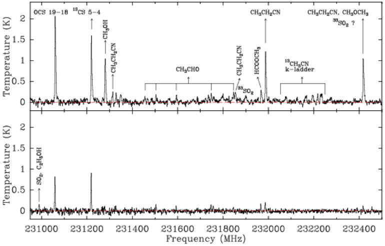


Figure: IRDC-C9 Spectra in the Core (top) and Tail (bottom).[10]

[10] Beaklini et al. 2020

IRDC-C9

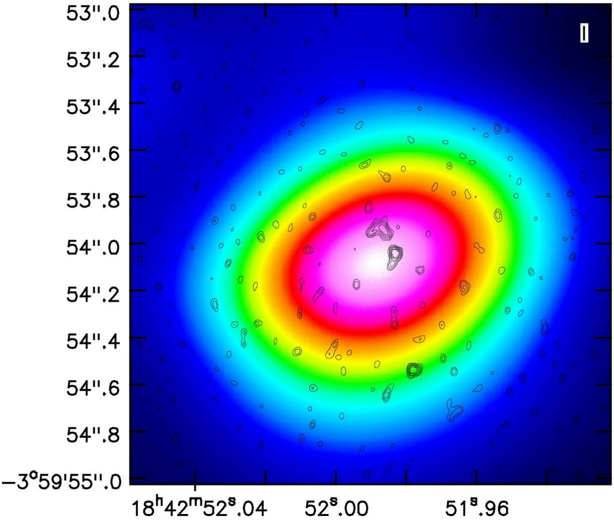


Figure: C9 self-calibrated ALMA archive continuum image at 231 GHz with VLA archive continuum at 6 GHz in contours (0.3 through 0.8σ in increments of 0.1).

IRDC-C9

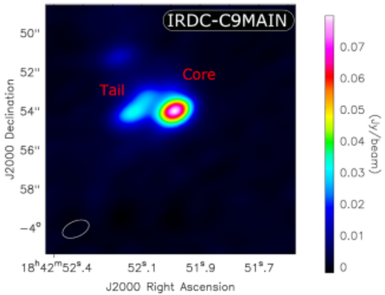


Figure: IRDC-C9 Self-Calibrated Continuum Image.[10]

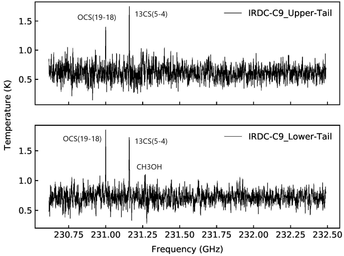


Figure: IRDC-C9 Emission Spectrum in the Upper (top) and Lower (bottom) tail.

[10] Beaklini et al. 2020

Spectrum Analysis of IRDC-B1, IRDC-B2, and IRDC-C9

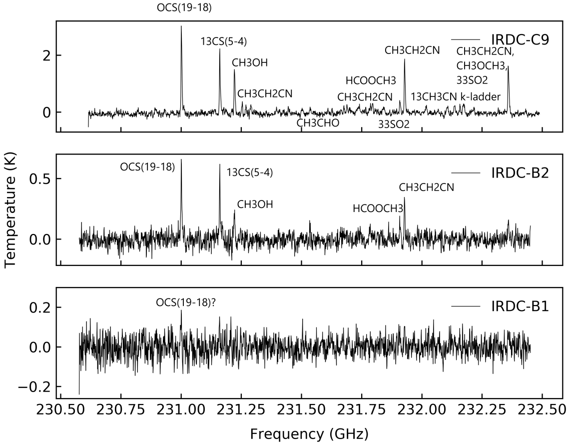


Figure: Continuum-Subtracted Emission Spectrum for IRDC-C9 (top), IRDC-B2 (middle), and for IRDC-B1 (bottom). Lines are labeled for each source.

Spectrum Analysis of IRDC-B2 and IRDC-C9

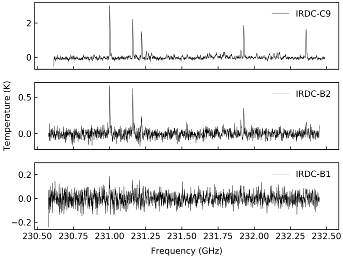


Figure: Continuum-Subtracted Emission Spectrum for IRDC-C9 (top), IRDC-B2 (middle), and for IRDC-B1 (bottom).

	IRDC-B2	IRDC-C9
$\frac{OCS}{^{13}CS}$	1.066	1.266
$\frac{^{13}CS}{CH_3OH}$	2.566	1.148
$\frac{HCOOCH_3}{CH_3CH_2CN}$	0.609	0.487
$\frac{CH_3CH_2CN}{\text{Peak at } 232.411 GHz}$	1.155	1.093

Figure: A table hosting ratios of peaks in the emission spectra of B2 and C9.

Conclusions

- We have found bright cores in IRDCs that show line emissions from sulfur-bearing and complex organic molecules
- These bright cores can be found as isolated cores or in clumps of cores at different stages of evolution

Next Steps

- Search the archives for more bright cores
- Figure out if these bright cores are protostars
  - Jets are a clear tracer of protostars
  - Methane is a tracer for outflows which can be used to find jets
- Place constraints on the physical conditions required to form these bright cores

Thank you!

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