Study the Physical Structure of IRAS 16293-2422 A
Thanks to High Angular Resolution ALMA Data

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Study the formation of low-mass stars

(Karssemeijer et al. 2012)

(Green et al. 2001)
IRAS 16293-2422 (hereafter IRAS16293)

- Class 0 proto-binary system consists of source A & B
- Source A is active with multiple components.
- Source B exhibits narrow line with no clearly signature of outflow =>(young evolutionary stage?!)
The Atacama Large Millimeter/submillimeter Array (ALMA)

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Data: Scientific Verification data (taken on April 16-17th, 2012)

Observation: with 7 pointing mosaic @ RA=16h 32m 22.7s
Dec=-24d28’32.5’’

Total on-source integration time: ~2 hours

Angular resolution (beam): 0.22’’

Spectral resolution: 0.4 km/s

Observing frequency: ~686-704GHz
Calibration and imaging

- Standard data calibration by Common Astronomy Software Applications package (CASA 4.1.0)

- Imaging: Spectral line emission
  
i. We only focused on source A, more active than source B.
  
ii. Methanol lines (686.7, 688.6, 689.2 and 689.8 GHz)
Analysis tool: Rotational diagram

\[ \ln \left( \frac{N_u}{g_u} \right) = -\frac{1}{T_{\text{rot}}} \]

- Optically thin

\[ \tau \ll 1 \Rightarrow N_u = \frac{8\pi kv^2 I}{hc^3 A_{ul}} \]

- Local thermodynamic equilibrium

\[ N_u = \frac{N_{\text{tot}}}{Z(T)} g_u e^{-E_u/kT} \]
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Results—Rotational Diagram

Integrated intensity = area under the curve [Jy/beam*km/s]
The data marked as red circle at 680 K is very uncertain because:
1. Contamination from unknown line(s)
2. The data is noisy

This is excluded.

\[ T = 241 \pm 50 \text{K} \]

\[ N(CH_3OH) = (4 \pm 2) \times 10^{15} \text{cm}^{-2} \]
Mom[0] = integrated line intensity map
Mom[1] = velocity field map
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Results—Moments Map[2]

Mom[2] = velocity dispersion
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(Kristensen et al. 2013)
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Question?

CH$_3$OH (9(3,7)-8(2,6))

CO(J=6-5) Loinard et al. 2013

Why?
• Excitation temperature ~240K

• Column density $\sim 4 \times 10^{15} \, cm^{-2}$

• Spatial distribution: methanol & CO emission from moment zero map seem to be from the same (shocked) region.

• Kinematic property: methanol emission dynamically linked to the shell (rotation pattern), whereas CO linked to the outflows (no rotation).

Future work: identify ALL the methanol lines in 4 SPWs, and study the outflows in more details.
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