

HOT CORINOS OUTFLOWS vs SHOCK INTERACTION OF LOW MASS CLASS 0 HOW ORGANIC MOLECULES OBSERVATIONS CAN TELL ?

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Introduction

Class 0 object IRAS 16293-2422 (hereafter I16293) is a low mass protostar located in the ρ ophiuchus cloud complex at a distance 160 pc from the sun. High angular resolution observation revealed that I16293 is a protobinary system of two components with a projected separation of $\sim 5''$ (~ 840 AU) and have mass of 0.61 (northwest component or I16293B) and 0.49 (southeast component or I16293A) solar mass.

I16293 is particularly interested in the aspect of astrochemistry due to its similar chemical compositions and physical activities to those of high mass star formation region. Single dish survey by van Dishoeck et al (2005) have concluded that I16293 consists of a cold ($T_{kin} \sim 10-20$ K) outer molecular envelope of $20''$ in size, a warmer ($T_{kin} \sim 40$ K) circumbinary envelope of $10''-15''$ in size, and a hot ($T_{kin} > 80$ K) region of dense gas only $3''-10''$ in size. However, with higher resolution telescopes and interferometric array, Ceccarelli et al. (1999,2000), Schoier et al. (2002) have shown that the hot core region of I16293 is very compact $\sim 1''$ (~ 150 AU) and has a molecular inventory rich in complex molecules, similar to hot molecular cores associated with massive protostars.

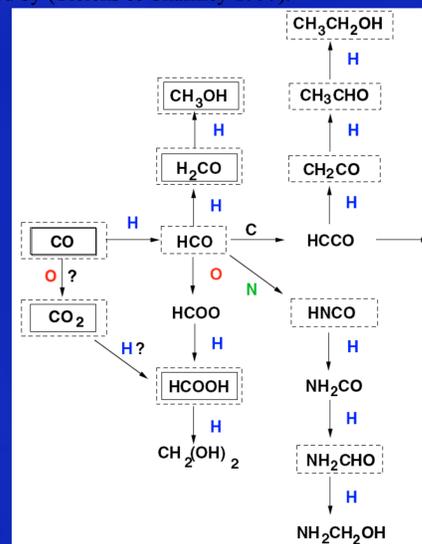
The hot cores are thought to have their origin in grain-mantle evaporation and the subsequent rapid gas phase reactions. The low-mass counterpart is called hot corino. In the hot corino model, complex molecules are assumed to evaporate through passive heating therefore are more associated in the region of continuum peaks. However, in some sources the line emission peaks offset from the continuum source, which disagree with the hot core model and are more associated to the interaction of outflow from the hot cores with the outer envelope to create shocks. The presences of large number of S-bearing and Si-bearing also favor the shocks model (Blake et al. 1994).

Schoier et al. 2002 have found a drop abundance in several molecules such as H₂CO, CH₃OH, HC₃N, CH₃CN which is interpreted as evidence of thermal evaporation of ices in the inner dense and hot regions of the envelope. However, the hot core region of I16293 is very small (~ 150 AU) comparable to the circumstellar envelope (1500 – 15000AU), the large change in physical size leads to the chemical time scales that only a small fraction of the dynamical age. Therefore, a “hot core” model only maybe difficult to explain more complex species.

The aim of this study is to use high spectral and spatial resolution interferometric technique to distinguish the shock chemistry and passively heated hot corino models. By distangle the uv-data, one hopes to constrains the chemical abundances and physical properties at different parts of the low mass star along the radial direction.

Hot core chemistry around IRAS 16293-2422

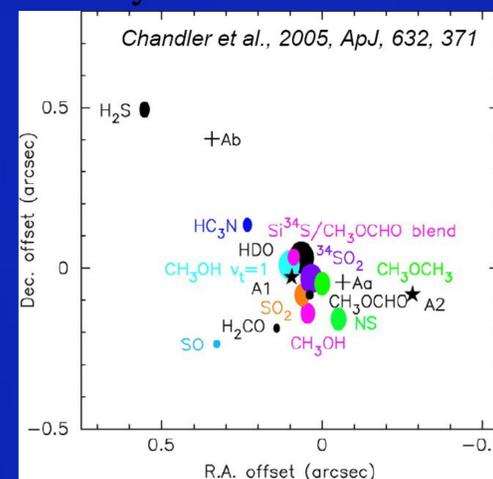
This SMA survey of I16293 have detected varieties of organic molecules: HNCO, CH₃CN, CH₃¹³CN, CH₂CO, CH₃CHO, C₂H₅OH (Bisschop 2007), CH₃OCHO, CH₃OCH₃, CH₃CH₂CN (strongly blended with CH₃CHO), CH₃OH, ¹⁵CH₃OH (need to be confirmed), HCOOH (need to be confirmed), CH₂CHCN (need to be confirmed) (this work). Most of the molecules were also detected by single dish surveys of Van Dishoeck 1994, Schoier 2002. All the detected molecules are mainly the products of grain-surface chemistry routes involving hydrogenation of CO proposed by (Tielens & Chamley 1997).



Integrated line intensity:

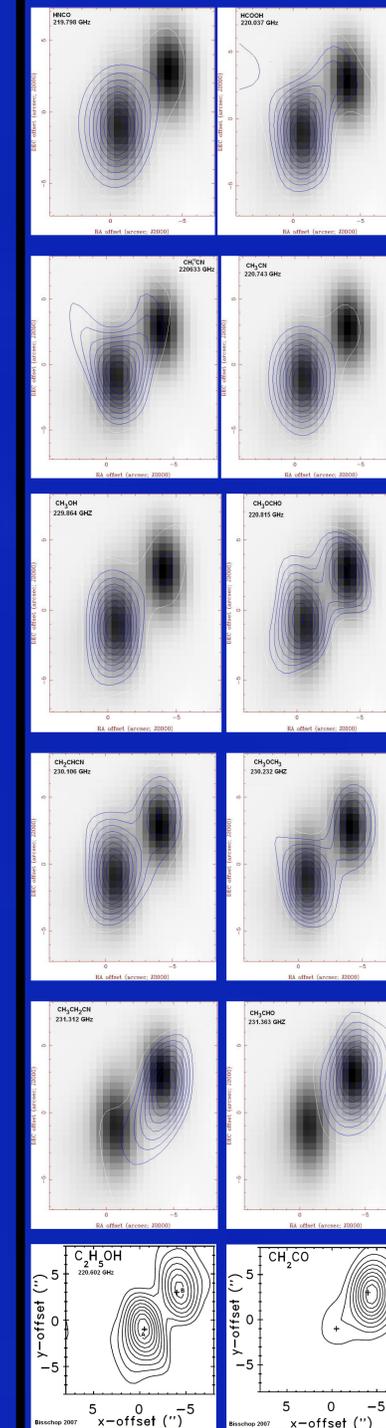
There exists significant physical differences between the two sources A & B. The emission can be divided into 3 groups: emission only from source A (, CH₃CN, CH₃¹³CN, emission only from source B (CH₂CO, CH₃CHO, CH₃CH₂CN), emission from both sources (C₂H₅OH, CH₂CHCN, CH₃OCH₃, CH₃OCHO, HNCO, CH₃OH, HCOOH). Most of these transitions lines have the narrow width 0 – 5 kms⁻¹.

Shock chemistry



IRAS16293-2422A: high excitation transitions have their origin close to a shock (A1) rather than the lowmass protostar (Aa) (Chandler et al. 2005).

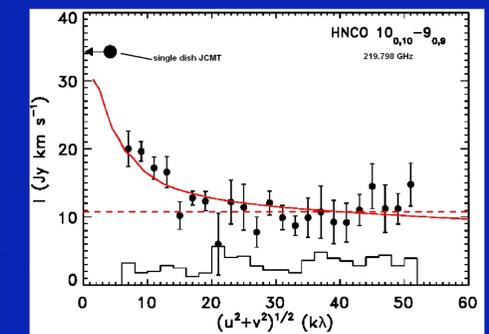
Maps:



Integrated emission maps of several lines of organic molecules toward sources A & B of I16293. The contour levels are at 10%,20%...of the peak in the maps. The emission is integrated over small velocity width of $\sim 0 - 5$ kms⁻¹

Discriminate compact hot core emission and extended cold envelope:

Some transition lines, especially low excitation transition lines show drop profiles in the visibility amplitudes as the projected interferometric baseline lengths increase. It implies that the molecules are either frozen-out as the densities increase or the molecules are evaporated out from the hot cores. This also shows ability to constrain the physical and chemical conditions along the radial direction.



Visibility amplitudes of the emission as a function of the projected interferometric baseline length. The red solid line represents a fit to the flux at different baselines using Schoier et al (2002) model with a “jump” in the abundance at 90 K (Bisschop 2007)

Bisschop (2007) found that HNCO shows a clear drop abundance profile. However, if I16293 hot core chemistry is identical to high mass hot cores, then more molecules such as CH₃OH, C₂H₅OH, H₂CO a The aim is to analyze all the transitions lines that are possible show the “drop” profiles signature, then to fit the data in (u,v) plane and constrain the rotation temperatures and relative abundances of different regions in the radial direction.

Implications:

Distinguish the shock chemistry and hot core chemistry of I16293 is not an easy task. The most probable solution is organic molecules originate from both processes. However, detailed radiative transfer modelling for all molecular lines emissions required to answer it quantitatively. By fitting the uv data directly, the emission from cores and envelopes can be distinguished.

Since two sources have quite different chemistry, they probably possess different chemical time scales and also dynamical time scales. Each source may have different chemistry inventory from another. Therefore further higher interferometric observations are needed to unveil the chemical relations between complex organic molecules inside I16293 and the chemical differences between the two components.

Whatever the precise origins differ, the molecules inner envelope of I16293 can be incorporated into the growing circumstellar disks and becomes part of the material from which planetary bodies are formed.

Future works:

Implement radiative transfer modeling to derive the abundances of organic molecules originated from the hot cores and their physical properties to unveil the chemical processes occur inside I16293. Investigate the velocity fields of these transitions lines to study the chemical time scales and dynamics of organic molecules.

References:

- Bisschop, S., PhD thesis, Leiden university, 2007
- Blake et al, 1994, ApJ, 428, 680
- Ceccarelli et al. 2000a, A&A, 355, 1129
- Chandler, C.J. 2005, ApJ, 632, 371
- Schoier, F. L., et al. 2007, A&A, 389, 908
- Tielens, A. G. G. M. & Chamley, S. B. 1997, Origin Life Evol., B., 27, 23
- Van Dishoeck et al. 1995, ApJ, 447, 760

Observations:



SMA specifications:

- 8 x 6 meter antennae
- Receivers at 230 GHz, 345 GHz and 690 GHz
- 2 GHz bandwidth with 10 GHz sideband separation
- Located on top of Maunakea
- Angular resolution of 1.5-2.5'' in compact configurations and better than 1'' in extended configurations

Data:

- Obtained on 18th of February 2005 with 6 antenna in compact configuration (15 baselines)
- spectral setup: 219.4–221.3 GHz(LSB)&229.4–231.3GHz(USB)
- Synthesized beam: 5.5'' x 3.2''
- 24 chunks, 128 channels/chunk ---> spectral resolution 1.1 kms⁻¹
- excellent weather conditions: $\tau_{225GHz} < 0.03$
- Other papers from this data: Yeh et al (07). Bisschop (2007)