

Formaldehyde formation pathways constrained by isotopic ratios in the prestellar core L1689B

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Why formaldehyde (H₂CO) ?

This molecule is **abundant** in dense cores and acts as a precursor to complex organic molecules. It is a **valuable tracer** of chemical evolution, as it can form both in the gas phase and on the surface of dust grains. We measured **H₂¹²CO/H₂¹³CO** and the **ortho-to-para ratio** of formaldehyde in L1689B to better **constrain** its **formation** pathways in prestellar cores.

Two key diagnostics

H₂¹²CO/H₂¹³CO Isotopic RAtio (IRA)

- **Gas phase formation** : $O + CH_3 \rightarrow H_2CO + H$
 - ▶ CH₃ depleted in ¹³C via ion-neutral fractionation
→ **IRA** >> **¹²C/¹³C elemental**
- **Grain surface formation** : CO ice hydrogenation
 - ▶ inherits carbon isotopic ratio from CO ice
→ **IRA** ≈ **¹²C/¹³C elemental** ~ 71 [1]

Ortho-to-Para Ratio (OPR)

- OPR → 3 at high T (statistical limit)
 - OPR < 3 suggests cold gas-phase formation
- It provides complementary chemical constraints.

Deriving H₂¹²CO/H₂¹³CO

We analyse the spectra of the detected molecules with CLASS from GILDAS to **extract** the **integrated intensities** of their rotational transition lines.

We **model** those intensities with the non-LTE radiative transfer code *Molpop*^[2] from which we infer through **Bayesian sampling** the parameters :

- Temperature
- H₂ density
- **Column densities** of the selected species

Studied postions in L1689B

Figure 1 shows the **prestellar core L1689B** which contains measurable amounts of formaldehyde.

With the **IRAM 30m radiotelescope** we observe at the **center (black cross on figure 1)** the following isotopologues :

- H₂¹²CO : self-absorbed transitions lines, not used for ratio computation
- H₂¹³CO : used for ratio computation
- H₂¹²C¹⁸O : used for ratio computation

At the **central position** we find H₂¹³CO/H₂¹²C¹⁸O then we use H₂¹²C¹⁸O/H₂¹²CO^[3] to **infer H₂¹²CO/H₂¹³CO (IRA)** and **OPR**.

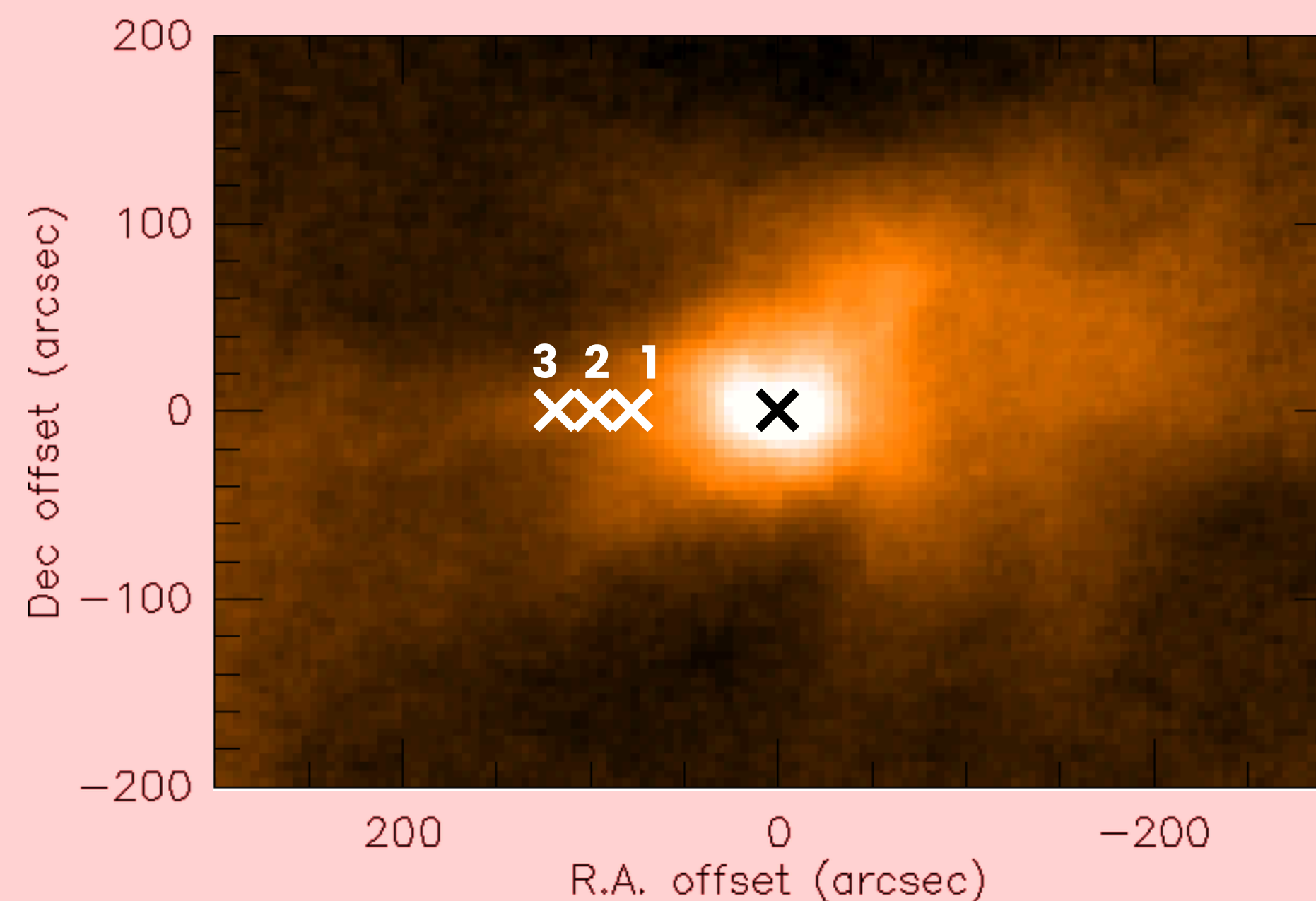


Figure 1 : The target L1689B observed in the infrared (Andre et al. 2010)

On the **horizontal cut (white crosses on figure 1)** we observe the non self-absorbed transitions lines of H₂¹²CO and H₂¹³CO from which we directly **derive IRA** and **OPR**.

Findings

Central position

We determine the following parameters :

$$IRA = 56_{-11}^{+14} \sim {}^{12}C/{}^{13}C = 71_{-13}^{+13} \rightarrow \text{Formation on grains}$$

T	n(H ₂)	OPR
9.3 K	2 × 10 ⁵ cm ⁻³	3.3

The combination of a **low IRA** value (**56**), consistent with the local elemental ratio (71^[1]), and an **OPR close to** the statistical limit **3** supports the case for a **grain-surface formation** pathway for H₂CO in L1689B. These results point toward a **CO ice** reservoir as the **dominant origin** of the observed H₂CO in the center of the core.

It is important to note that our dataset does not provide sufficient leverage to constrain the **temperature** and the **H₂ density** of the core, since the two parameters exhibit a strong degeneracy in our modelling.

Horizontal cut

The derived **IRA** values are significantly **lower** than the elemental ¹²C/¹³C ratio : 37, 40 and 25 respectively for position 1, 2 and 3 in figure 1.

The **OPR** values fluctuate around 3 but remain largely **unconstrained**. While these results are intriguing, they are **difficult to interpret** given the broad error bars and model limitations.

References

- [1] Wilson, T. L. 1999, Reports on Progress in Physics, 62, 143–185
- [2] Asensio Ramos, A. & Elitzur, M. 2018, Astronomy & Astrophysics, 616, A131
- [3] J. Graglia 2024, Private communication