High-*J* CO survey of low-mass protostars observed with *Herschel*-HIFI

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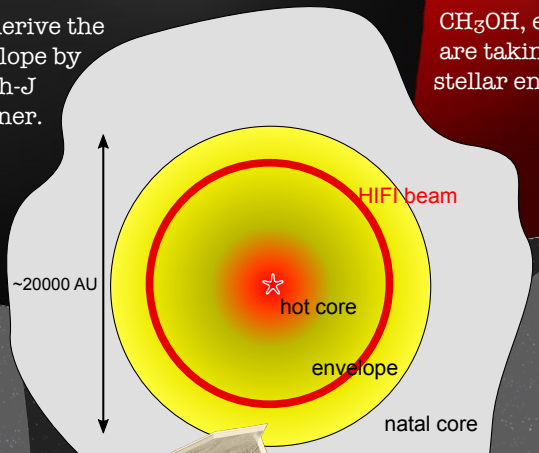
Introduction

CO line emission is the main tracer of the physical structure and column density of molecular clouds in which young stellar objects (YSOs) form.

- A sample of 13 Class 0 and 13 Class I YSOs (d=100-400 pc) is observed in CO with Herschel-HIFI as part of the **Water in star-forming regions with Herschel (WISH)** key program.
- CO observations are complementary to those of water, since the chemistry is simpler and better understood, allowing for an understanding of freeze-out and desorption processes in the envelope and provide a reference to other molecules.
- High-J CO lines, including ^{12}CO, ^{13}CO and C^{18}O 10–9 and C^{18}O 5–4, 9-8 lines are observed (E_{up}~250-300 K), which trace the warmer material (T>50 K) in the envelope.
- The goal of this project is to derive the chemical structure of the envelope by comparing both low- and high-J CO lines in a coherent manner.

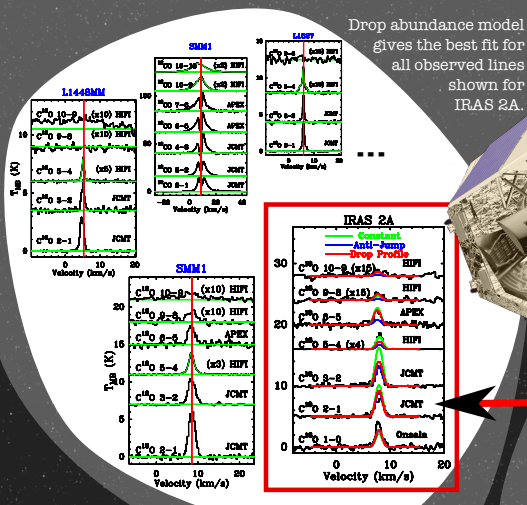
Results

- Analysis of the C^{18}O lines provides independent evidence for significant freeze-out in the coldest regions and evaporation back into the gas phase T>25 K.
- The abundance in the outermost part of the envelope, X_0, is the canonical value of 2×10^{-4}; however the inner abundance, X_{in}, is a factor of 3–5 lower than X_0.
- This work will allow further quantification on photodissociation and transformation of CO into CO_2, CH_3OH, etc. on dust grains which are taking place in the protostellar envelope.

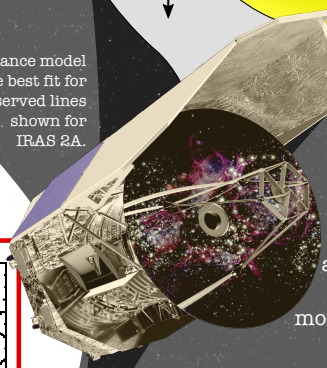


Data

Spectrally resolved HIFI CO data are compared with lower-J CO lines (e.g., J = 3–2) obtained over the last decade with various ground-based telescopes, including the APEX-CHAMP$^+$ array receiver.



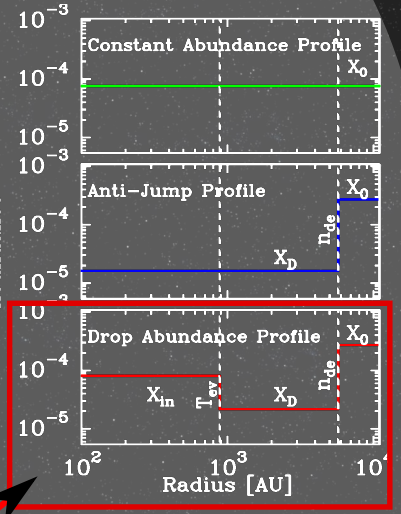
Drop abundance model gives the best fit for all observed lines shown for IRAS 2A.

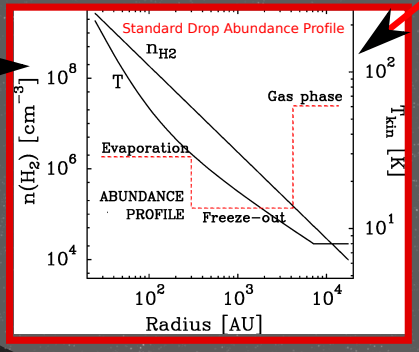


Abundance models that were examined.

Line intensities are used to constrain the molecular abundances by comparison to radiative transfer modeling of the line strengths for a given envelope.

Abundance Studies





RATRAN models for several abundance profiles; intensities convolved with beam.

Constant: The simplest abundance profile cannot simultaneously reproduce all line intensities.

Anti-jump: is used to constrain X_{out} and n_{de}. Low-J C^{18}O lines fitted well, but higher-J lines underproduced.

Drop-abundance: Best fit to data if inner abundance is increased to 1.5×10^{-7} (CO=8×10^{-5}) above T_{ev}=25K.

References

(1) Yildiz et al. 2010, A&A, 521, L40
(2) Kristensen et al. 2010, A&A, 521, L30
(3) Jørgensen et al., 2002, A&A, 389, 908; 2005, A&A, 435, 177
(4) Van Dishoeck et al, 2011, PASP, 123, 138
(5) Wampfler et al. in prep.

Center Image: R. Visser

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