High-*J* CO lines from low- to high-mass YSOs: the dynamics of protostellar envelopes

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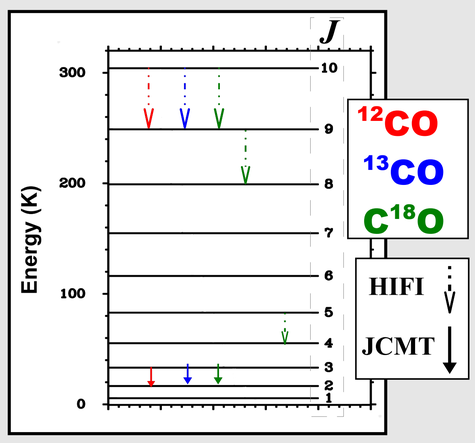
INTRODUCTION

In order to form a complete understanding of star formation, it is crucial to determine the similarities and differences between low- and high-mass young stellar objects (YSOs) from both a physical and chemical perspective.

The *Herschel* key program WISH [1] targets 51 protostars with luminosities ranging from 0.8 to 10^5 L_{sun} through observations of H_2O and CO.

Observed CO lines:



Sample of YSOs with HIFI:

- 26 low-mass (**LM**)
- 6 intermediate-mass (**IM**)
- 19 high-mass (**HM**)

Why CO?

- Probes different physical structures of the protostar.
- Easily excited and thermalized.
- High and stable abundance.

Q: Is high-mass star formation a scaled-up version of low-mass star formation?

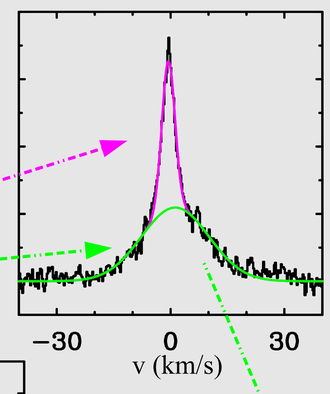
Conclusions...

- ✔ **Strong linear correlation between the high-*J* CO lines strengths and bolometric luminosity.**
- ✔ **Similar line profiles from low- to high-mass for all CO isotopologues with increasing width with L_{bol} and/or *J* level.**
- ✔ **Similar dynamics in protostellar envelopes independently of the mass of the YSO.**

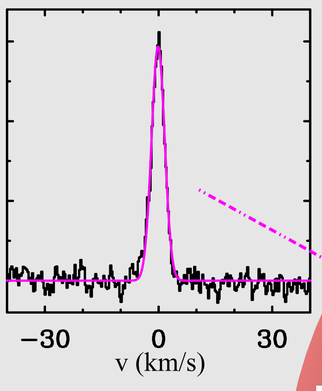
OBSERVATIONS

Line profiles

- **^{12}CO line profiles decomposed into two Gaussians components:**
  - Narrow: **quiescent envelope material.**
  - Broad: **entrained outflowing gas.**



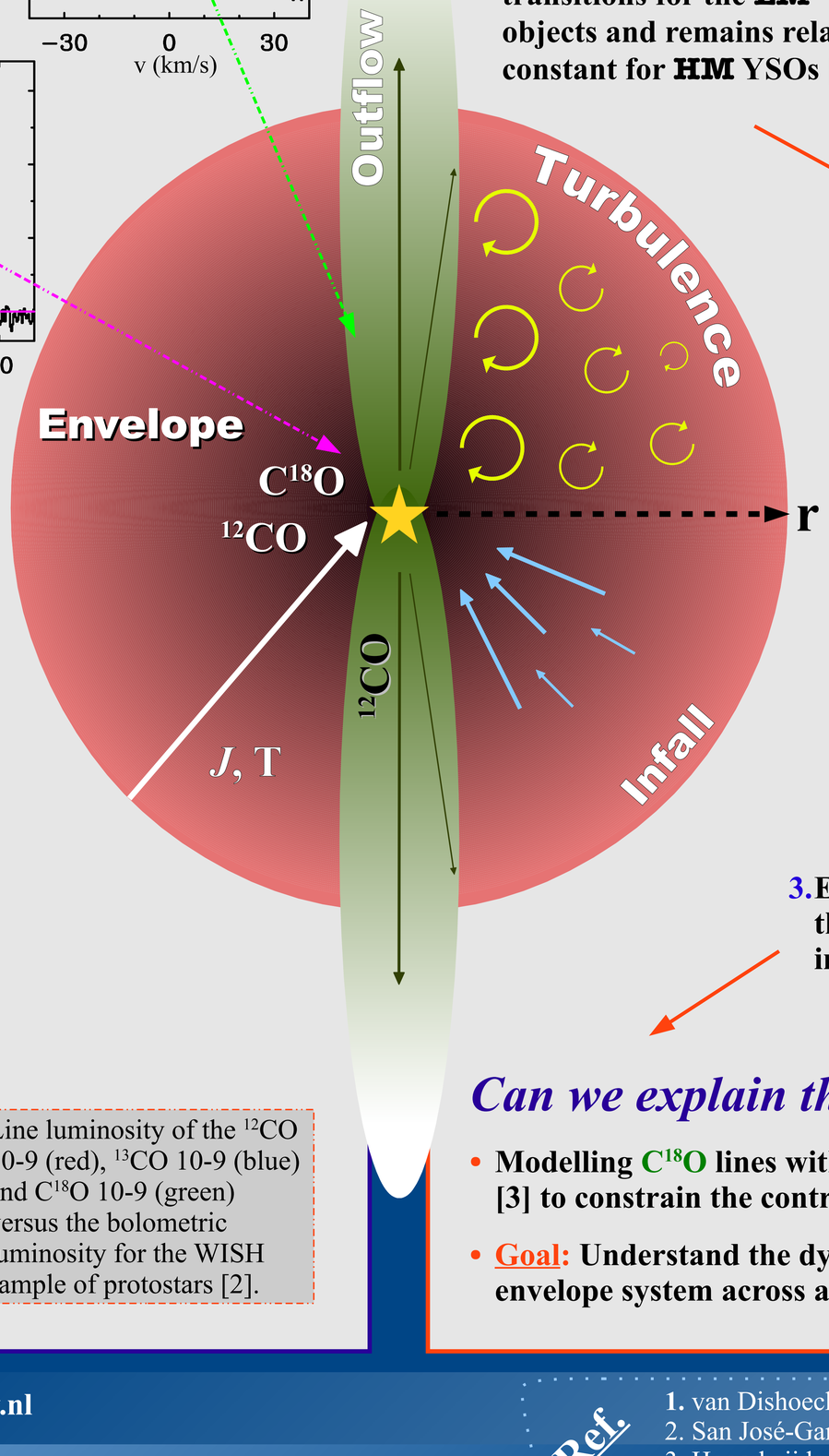
- **C^{18}O line profiles show a single narrow Gaussian component: Quiescent envelope material.**



Line luminosity

- **Correlation between the line luminosity (L_{CO}) and bolometric luminosity (L_{bol}) for all the observed lines [2].**
- **High-*J* CO lines primarily trace the bulk of dense gas.**

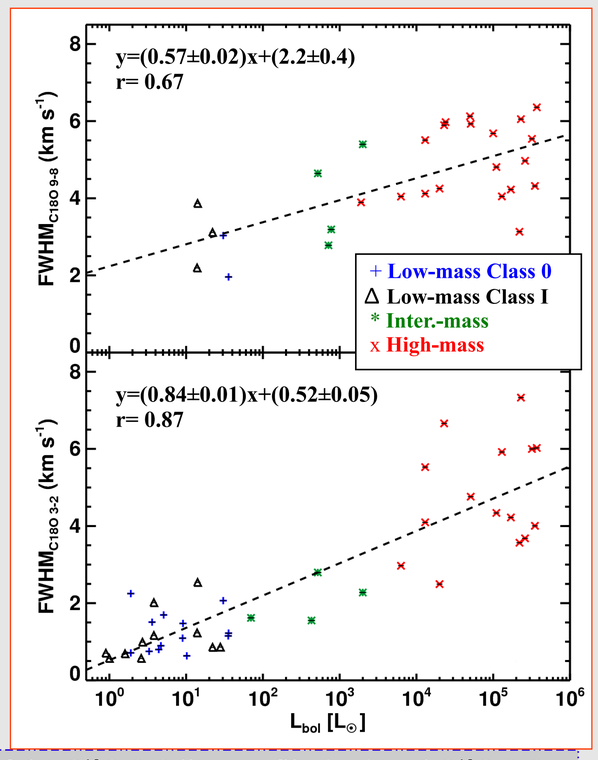
Line luminosity of the ^{12}CO 10-9 (red), ^{13}CO 10-9 (blue) and C^{18}O 10-9 (green) versus the bolometric luminosity for the WISH sample of protostars [2].



DYNAMICS

What do we know?

1. **Non-thermal motions (turbulence and/or infall) dominate in protostellar envelopes and determine the line-width of the C^{18}O profiles.**
2. **The width of the C^{18}O lines becomes larger at higher *J* transitions for the LM objects and remains relatively constant for HM YSOs [2].**
3. **Entrained outflowing gas (broad ^{12}CO) related to the quiescent envelope material (narrow C^{18}O) independently of the mass of the YSO [2].**



Width of the C^{18}O 9-8 line profile (top) and C^{18}O 3-2 (bottom) versus the source bolometric luminosity [2].

Can we explain these relations?

- **Modelling C^{18}O lines with the non-LTE radiative transfer code *RATRAN* [3] to constrain the contribution of infall and turbulence on the line profile.**
- **Goal: Understand the dynamics of protostellar envelopes and the outflow-envelope system across a large range of masses [4].**

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Ref.

1. van Dishoeck et al. 2011, PASP, 123, 138
2. San José-García et al. 2013, A&A, 553, A125
3. Hogerheijde & van der Tak 2000, A&A, 362, 697
4. San José-García et al. in prep.