LINKING HIGH-*J* CO EMISSION FROM LOW- TO HIGH-MASS PROTOSTARS WITH HERSCHEL-HIFI

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INTRODUCTION

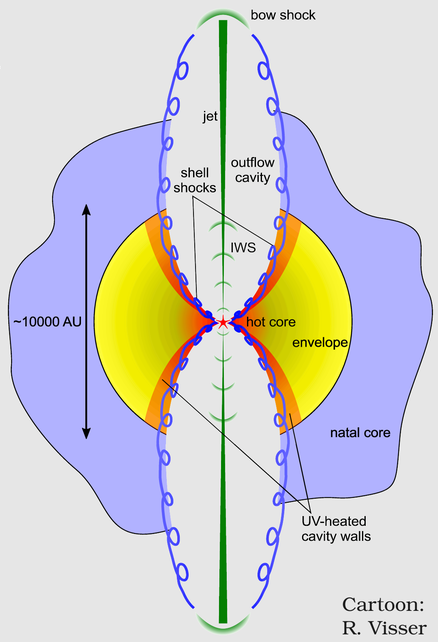
Many different physical and chemical processes take place during the embedded phase of star formation. Most protostellar studies focus either on low-m or high-mass young stellar objects (YSOs). Therefore, a mass evolutionary trail is still needed. One of the goals of the WISH key program is to use CO and H_2O observations to provide such a trail.

CO as a diagnostic:

- Probes the components of the protostellar environment:
  - ^{12}CO: traces the molecular outflow.
  - C^{18}O: trace the quiescent envelope gas.
  - ^{13}CO: both.

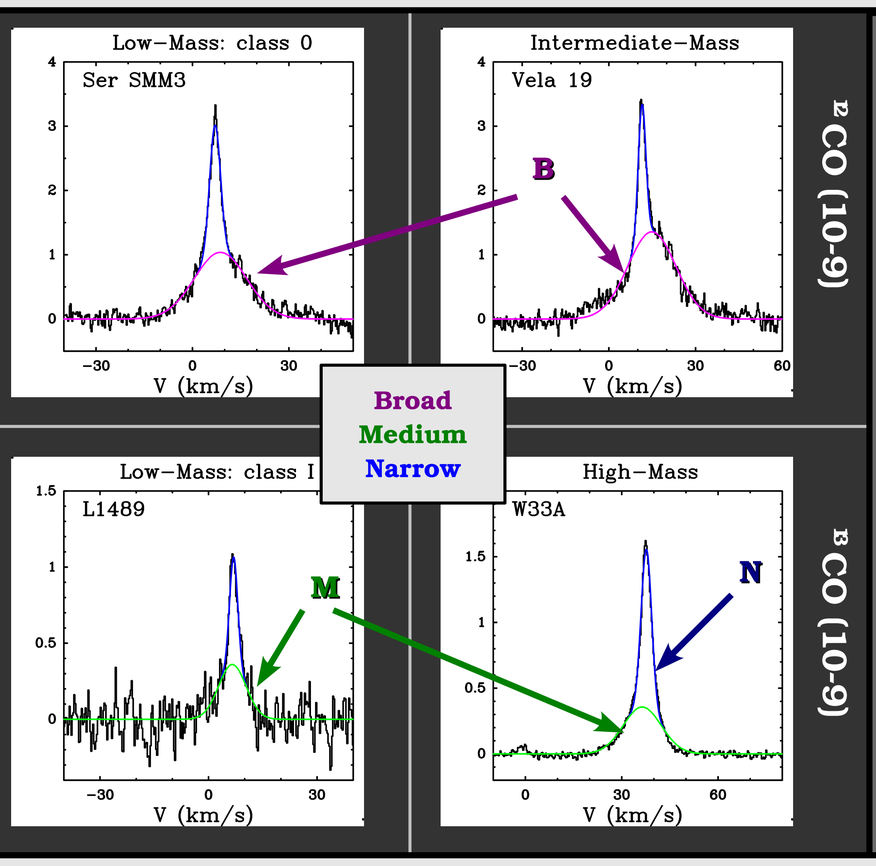
GOAL:

- **Constrain the physical and chemical structure of protostellar environments as a function of mass.**
- **Compare properties of CO and its isotopologue emission lines.**
- **Provide a reference for H_2O and other molecules.**



Cartoon: R. Visser

1) RESULTS: Line profiles



- Decomposition of the ^{12}CO (10-9) and ^{13}CO (10-9) line profiles in different velocity components:
  - **Broad** (FWHM > 15 km/s): outflowing gas.
  - **Medium** (FWHM ~5-15 km/s): shocked gas in the inner dense envelope.
  - **Narrow** (FWHM < 5 km/s): quiescent envelope.

OBSERVATIONS

- ^{12}CO 10-9 (E_u=304 K), ^{13}CO 10-9 (E_u=291 K) and C^{18}O 5-4 (E_u=79 K), 9-8 (E_u=237 K), 10-9 (E_u=290 K) emission lines, observed with HIFI on *Herschel*, for a sample of **26 low-, 6 intermediate- and 19 high-mass YSOs**.
- All observations performed within the "Water in star-forming regions with Herschel" Key Program.
- Comparison with lower-*J* transitions observed by ground-based telescopes (JCMT, APEX-CHAMP+).

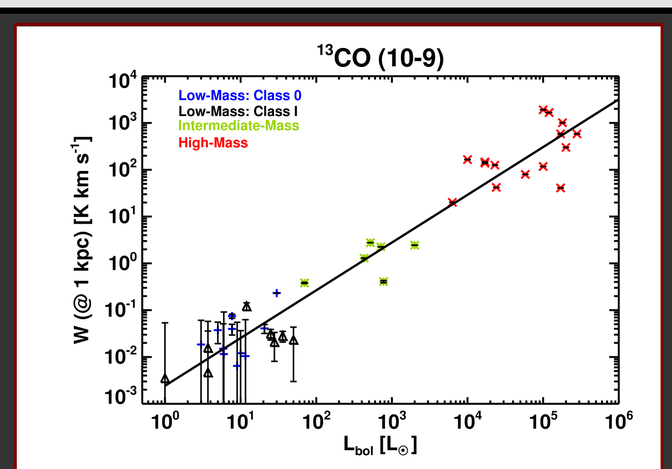
CONCLUSIONS

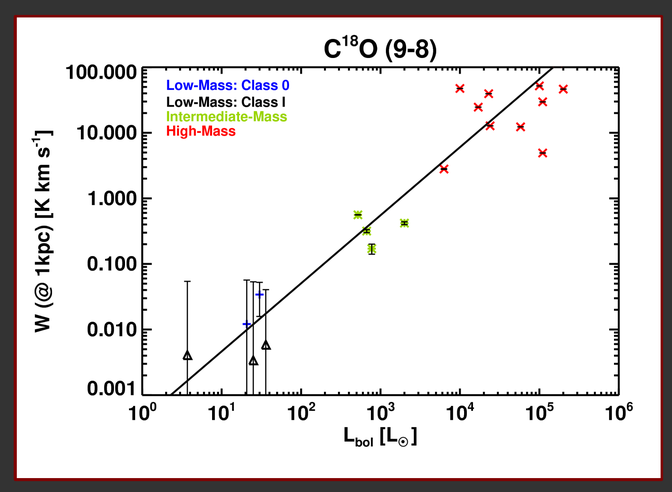
- **Multiple velocity components identified in the ^{12}CO (10-9) and ^{13}CO (10-9) spectra.**
- **Ratio of the width of the different velocity components remarkably constant over the large range of luminosity (from < 1 $L_\odot$ to > 10^4 $L_\odot$).**
- **Integrated intensity proportional to L_{bol} for all the CO and isotopologue emission lines across the mass spectrum.**
- **C^{18}O (9-8) good tracer of warm (T > 50 K) quiescent gas.**

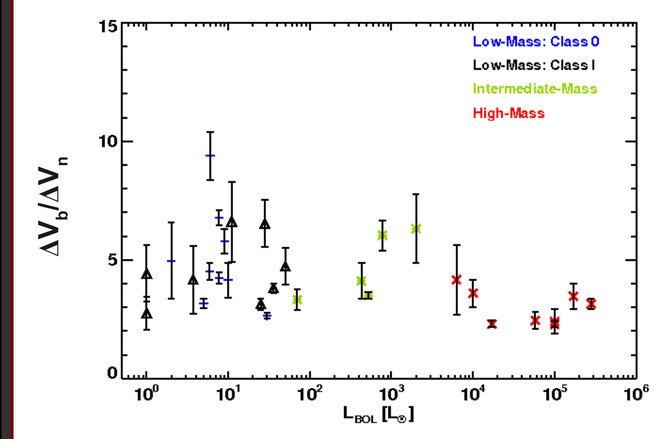
2) RESULTS: Correlations

- Correlation between the integrated intensity, ***W***, and L_{bol}, observed in **all CO and isotopologue lines** for all the objects.
- Slope ~ 1: ***W*** proportional to L_{bol}

Integrated intensity is normalized to a distance of 1 kpc.







- Correlation between the ratio of the velocity components for the ^{12}CO and ^{13}CO (10-9) spectra and L_{bol}.

$\Delta V_b/\Delta V_n$ = FWHM($V_{broader}$)/FWHM($V_{narrower}$)

FUTURE WORK

- Study excitation of components (line ratios).
- Look for correlations with H_2O lines.

References:
1)L.E. Kristensen et al. 2010, A&A, 521 L30
2) U.A. Yıldız et al. 2010, A&A, 521, L40

Spitzer image of Serpens, courtesy of NASA