Herschel / PACS survey of deeply-embedded low-mass young stellar objects

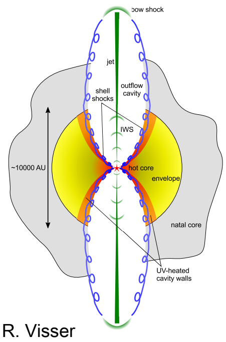
Agata Karska[1,2], G. Herczeg[3], E.F. van Dishoeck[1,2], L.E. Kristensen[2], S.F. Wampfler[4] and WISH team

[1]MPE, Garching, Germany [2]Sterrewacht Leiden, The Netherlands [3]Peking University, China, [4]University of Copenhagen, Denmark

Main questions

- Which physical processes are responsible for the observed line emission?
- On which spatial scales does a YSO interact with its surroundings?
- How do CO, H_2O, OH, OI contribute to the far-IR gas cooling?

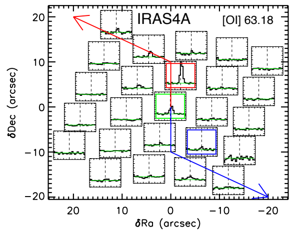
Spatial scales of line emission



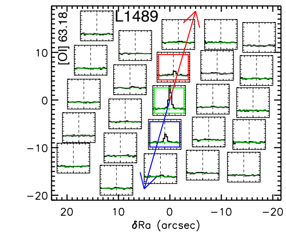
R. Visser

Patterns of line emission:

Outflow dominated



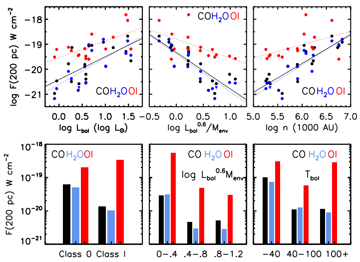
On-source dominated



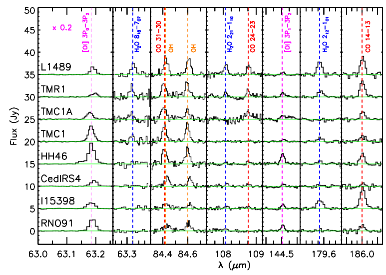
Emission on ~10^4×10^4 AU vs. ~10^3×10^3 AU scales.

Line emission

Flux correlation plots



Detections of CO, H_2O, OH, OI



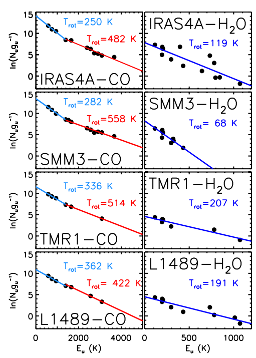
Highly-excited H_2O in Class I objects!

Conclusions

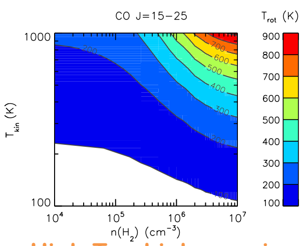
- Line emission spatially associated with the outflows, originates in shocks / UV-heated cavity walls
- H_2O is a major far-IR gas coolant
- Total far-IR gas cooling decreases with time and is stronger for more luminous objects

Boltzmann diagrams

CO and H_2O rotational diagrams



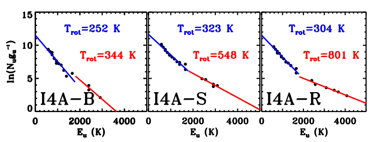
Physical conditions



High-T_{kin}, high-n regime

CO: T_{rot1}~300 K, T_{rot2}~500-700 K, H_2O: T_{rot}~100-200 K

CO ladders in NGC1333 IRAS4A

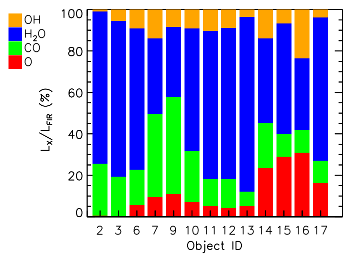


T_{rot} varies with position on ~2000 AU scales

Far-IR gas cooling budget

Relative contributions of CO, H_2O, OH, OI

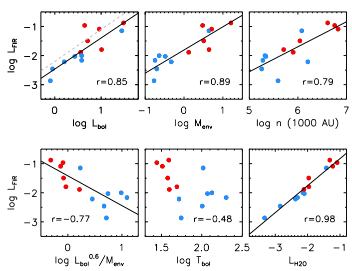
(calculations include the entire PACS array)



H_2O	25-75 %
CO	5-50 %
OI	5-30 %
OH	1-15 %

H_2O dominates the gas cooling

Comparison with envelope parameters



$L_{FIR}=L(H_2O)+L(CO)+L(OH)+L(OI)$

Total far-IR gas cooling:

- strongly correlates with L_{bol}, M_{env}, density
- decreases with time