Water in low-mass star-forming regions: Abundances and energetics

Lars E. Kristensen

R. Visser, E.F. van Dishoeck, U.A. Yildiz, S.D. Doty, G.J. Herczeg, F.-C. Liu, B. Parise, J.K. Jørgensen, T.A. van Kempen, C. Brinch, S.F. Wampfler, S. Bruderer, A.O. Benz, M.R. Hogerheijde and the WISH team

WISH

WISH team: **E.F. van Dishoeck**, Y. Aikawa, R. Bachiller, A. Baudry, M. Benedettini, A. Benz, E. Bergin, P. Bjerkeli, G. Blake, S. Bontemps, J. Braine, A. Brandeker, C. Brinch, S. Bruderer, S. Cabrit, P. Caselli, J. Cernicharo, L. Chavarria, C. Codella, F. Daniel, C. Dedes, P. Encrenaz, A.M. di Giorgio, C. Dominik, S. Doty, H. Feuchtgruber, M. Fich, W. Frieswijk, A. Fuente, T. Giannini, J.R. Goicoechea, Th. De Graauw, F. Helmich, F. Herpin, G. Herczeg, M. Hogerheijde, T. Jacq, J. Jørgensen, D. Johnstone, A. Karska, M. Kaufman, E. Keto, L. Kristensen, B. Larsson, B. Lefloch, D. Lis, R. Liseau, M. Marseille, C. McCoey, G. Melnick, D. Neufeld, B. Nisini, M. Olberg, G. Olofsson, L. Pagani, O. Panić, B. Parise, J. Pearson, R. Plume, C. Risacher, D. Salter, N. Sakai, J. Santiago, P. Saraceno, R. Shipman, M. Tafalla, F. van der Tak, T. van Kempen, R. Visser, S. Viti, S. Wampfler, M. Walmsley, F. Wyrowski, S. Yamamoto, U.A. Yildiz

~75 team members in ~35 institutes in ~10 countries

WISH

WISH

What?

- Water In Star-forming regions with Herschel
- HIFI Guaranteed time key programme,
PI: E.F. van Dishoeck (Leiden Observatory, NL)
- 425h being observed (HIFI and PACS)

Goal:

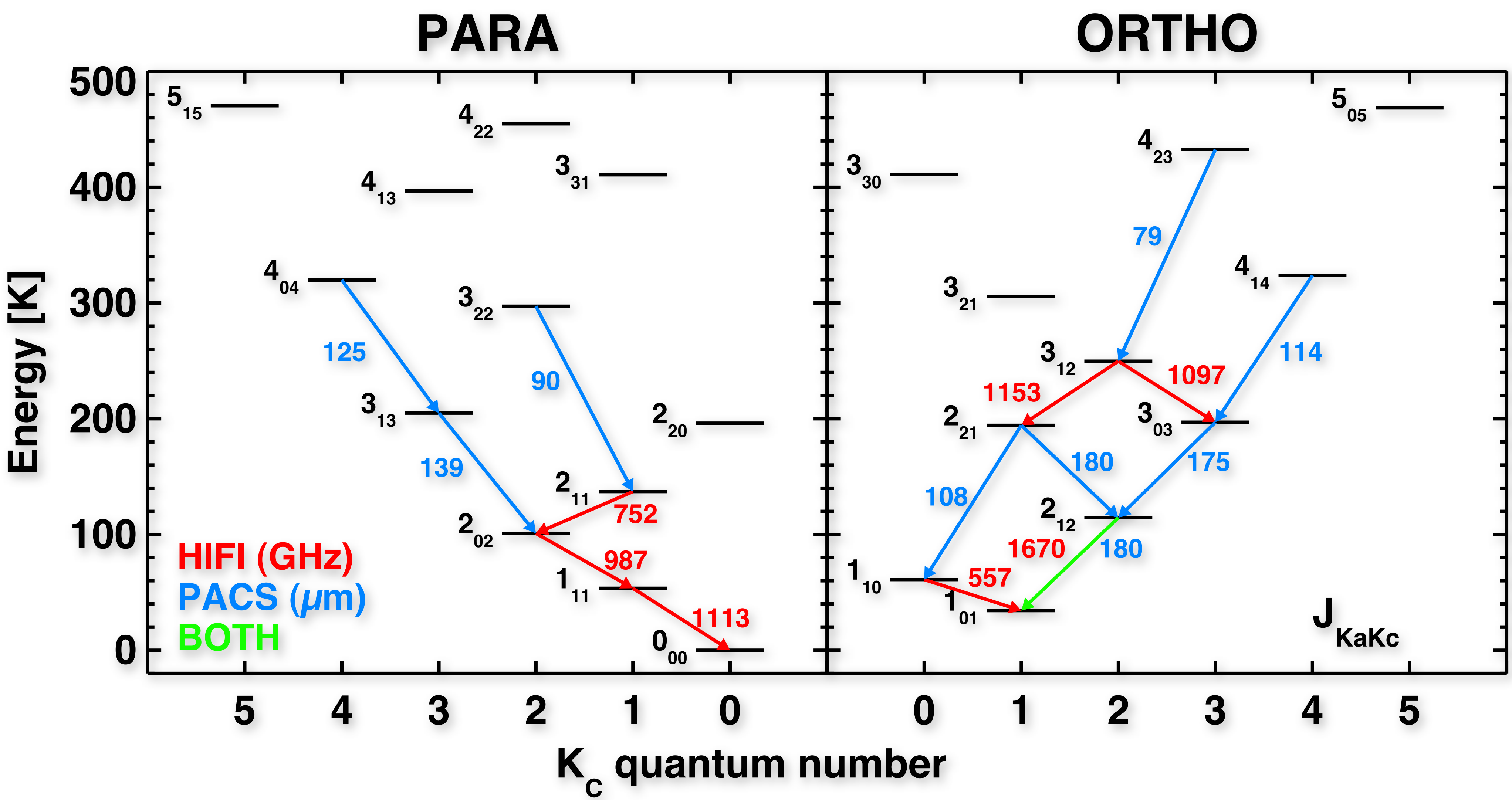
- Use H_2O to trace physical and chemical conditions

Why H_2O ?

- Dynamical probe: outflow, infall, quiescent...
- Main reservoir of O
- Important for life on Earth

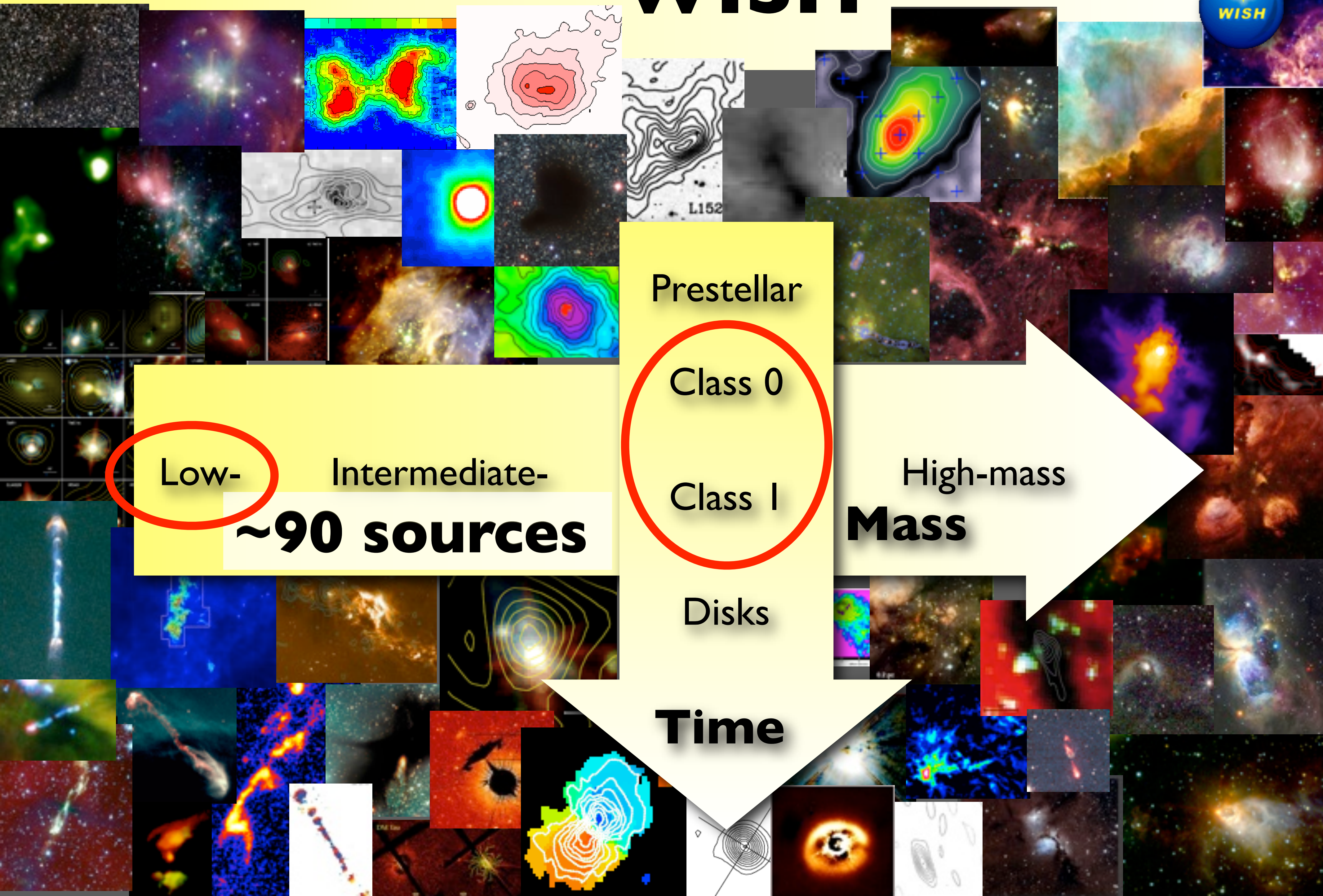
van Dishoeck et al. (in prep.)

Water



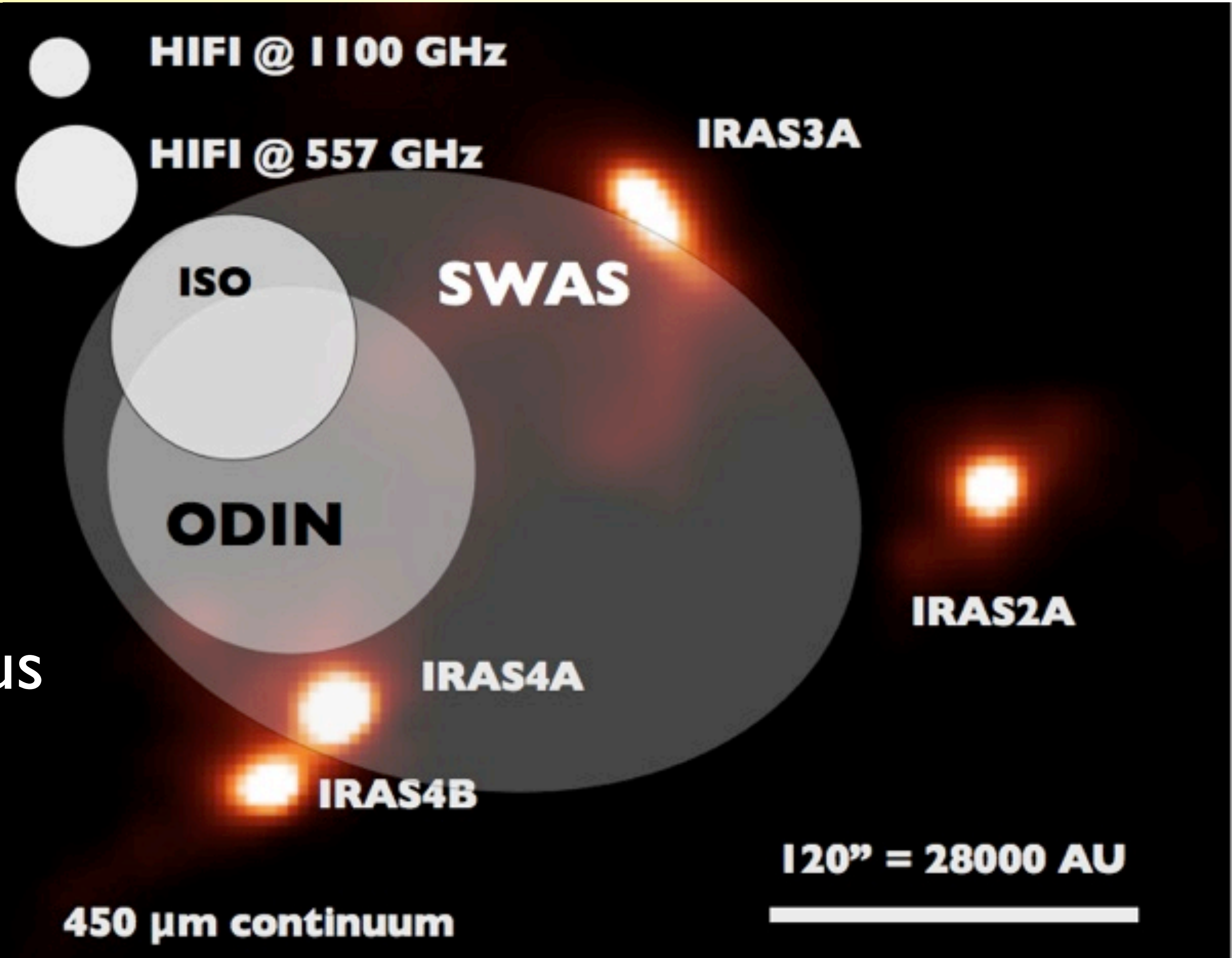
Target lines with different E_{up} to probe different T

WISH


Prestellar
Class 0
Class I
Disks
Time
Low-
Intermediate-
High-mass
~90 sources
Mass

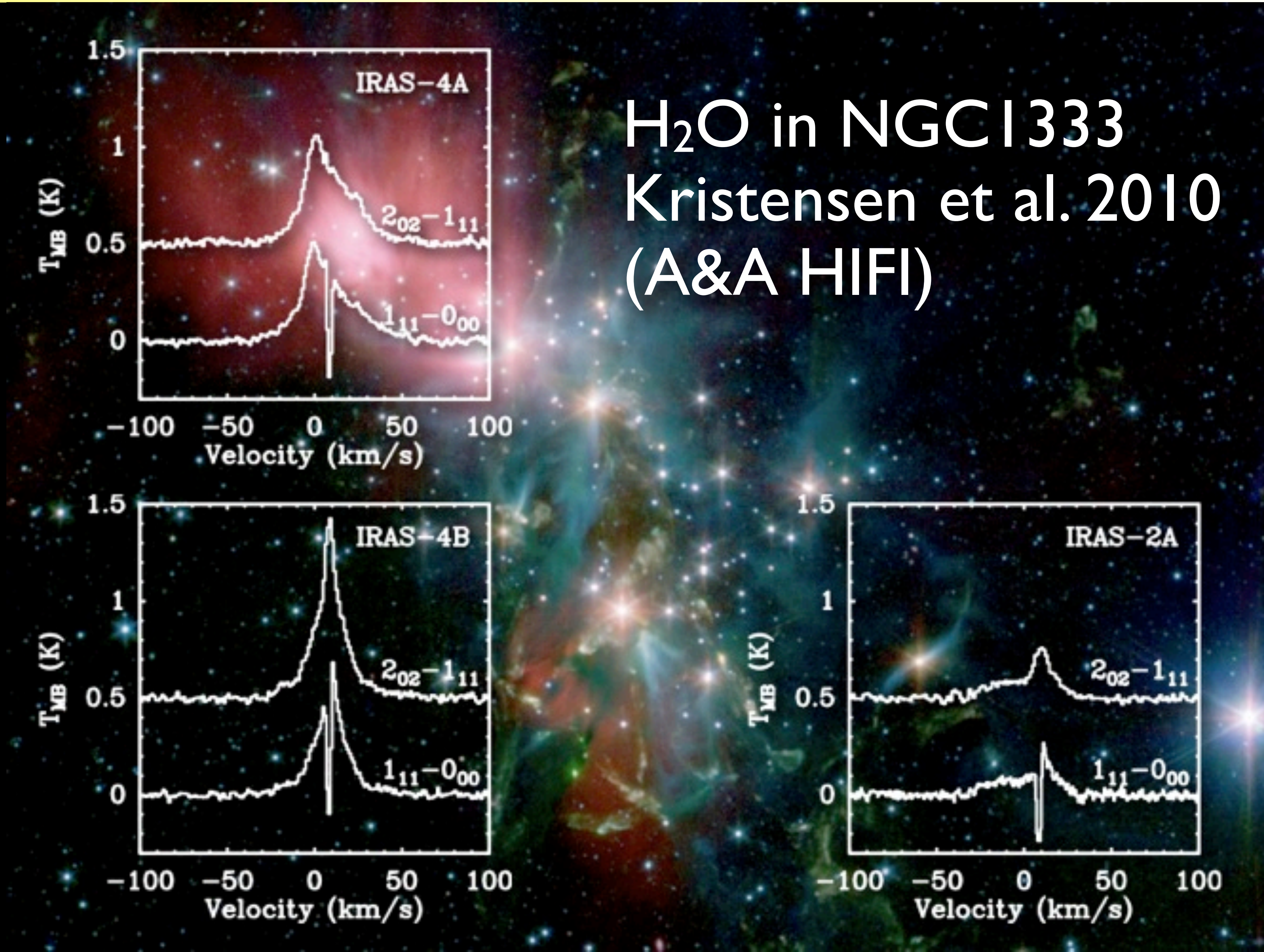
Low-mass YSO - NGC1333

Higher spatial resolution and sensitivity than previous instruments



(Di Francesco et al. 2008)

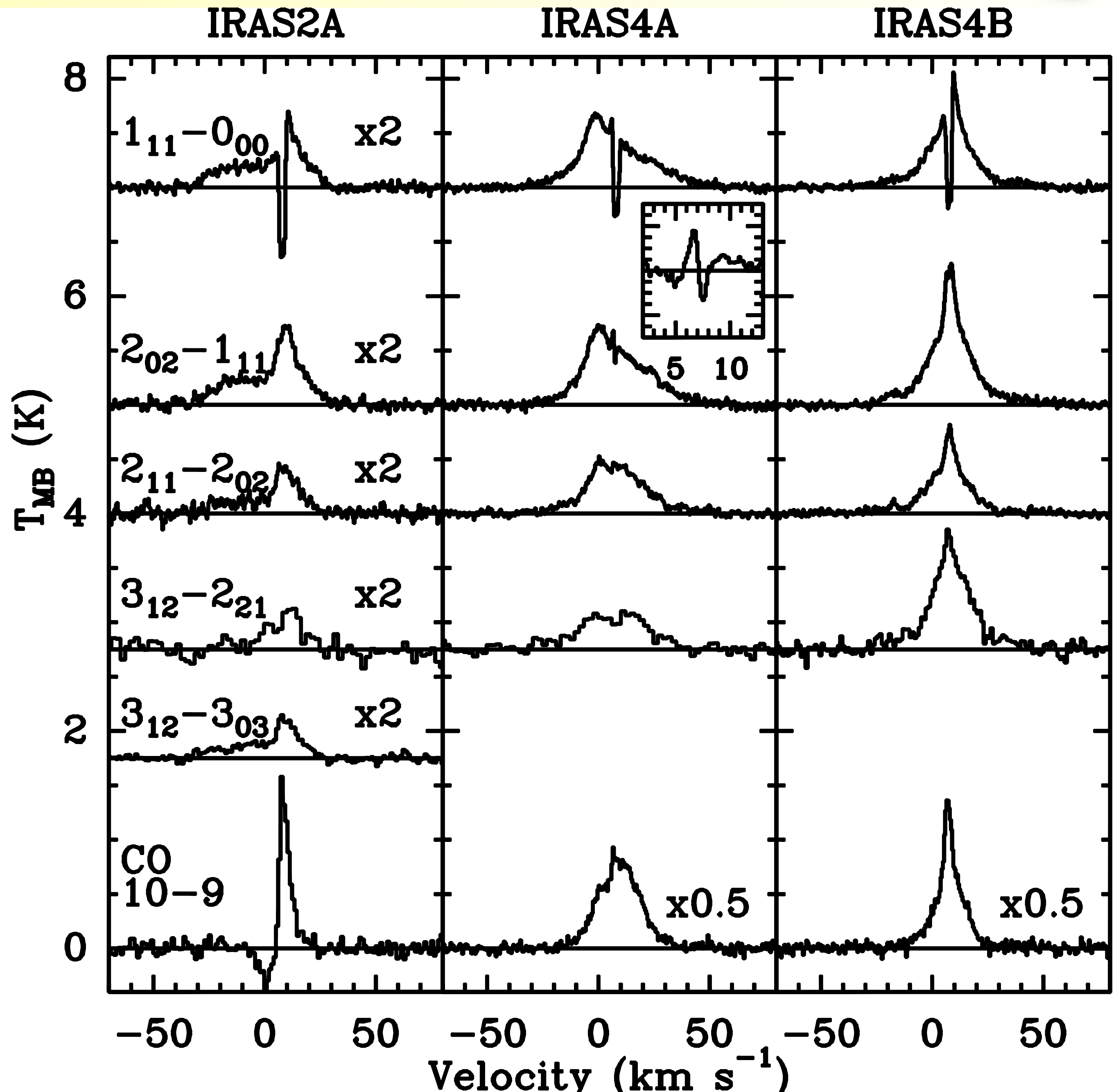
Low-mass YSO - NGC1333



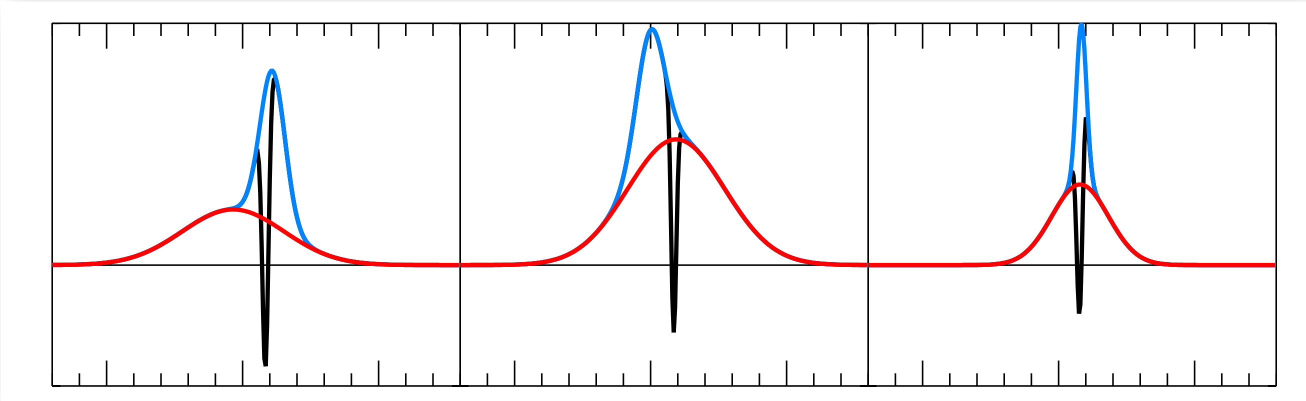
H_2O in NGC1333
Kristensen et al. 2010
(A&A HIFI)

H_2O line profiles

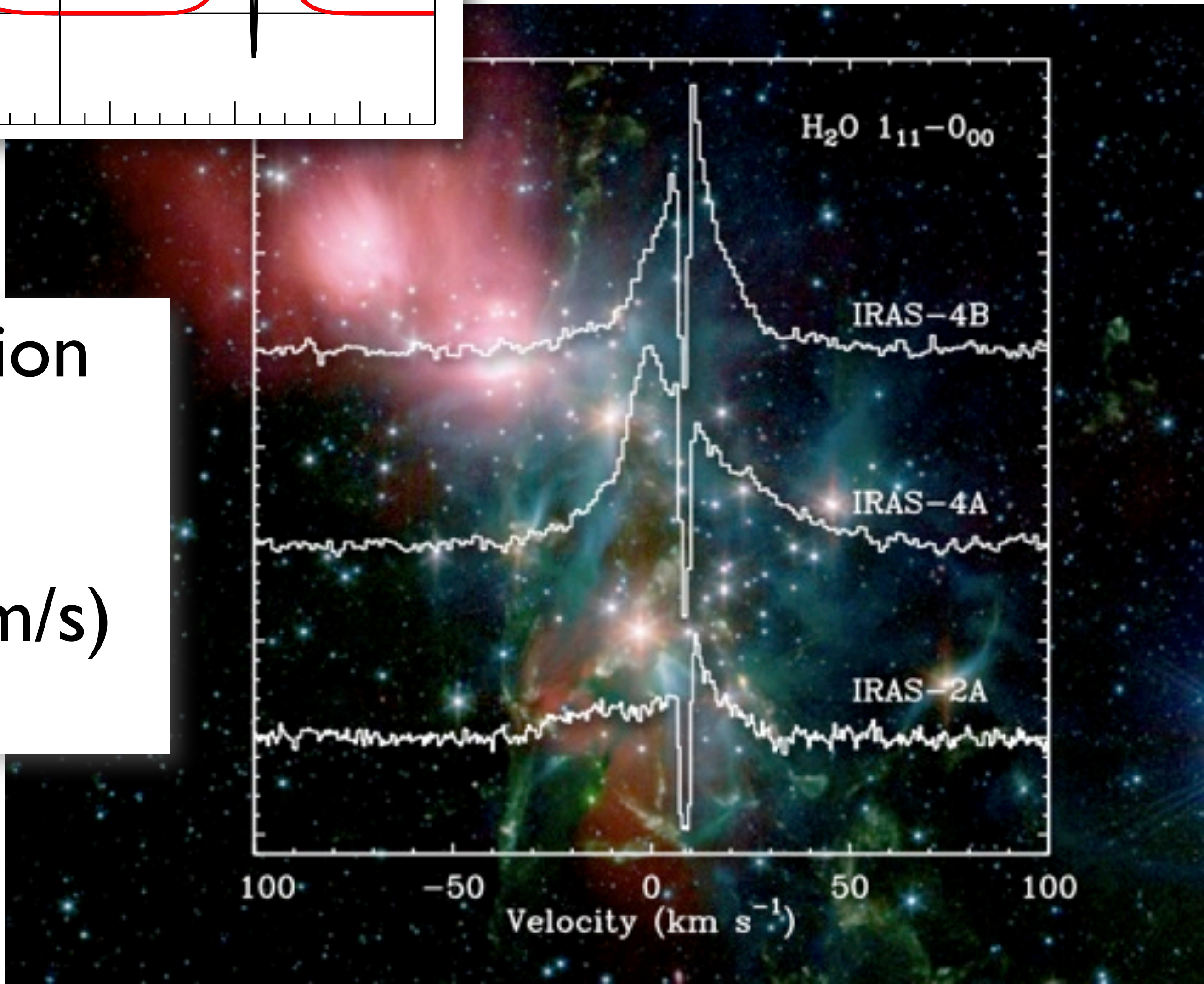
- Complex line profiles !
- Broad, v > 50 km/s
- Inverse P-Cygni profile: infall in the envelope
- Saturated absorption



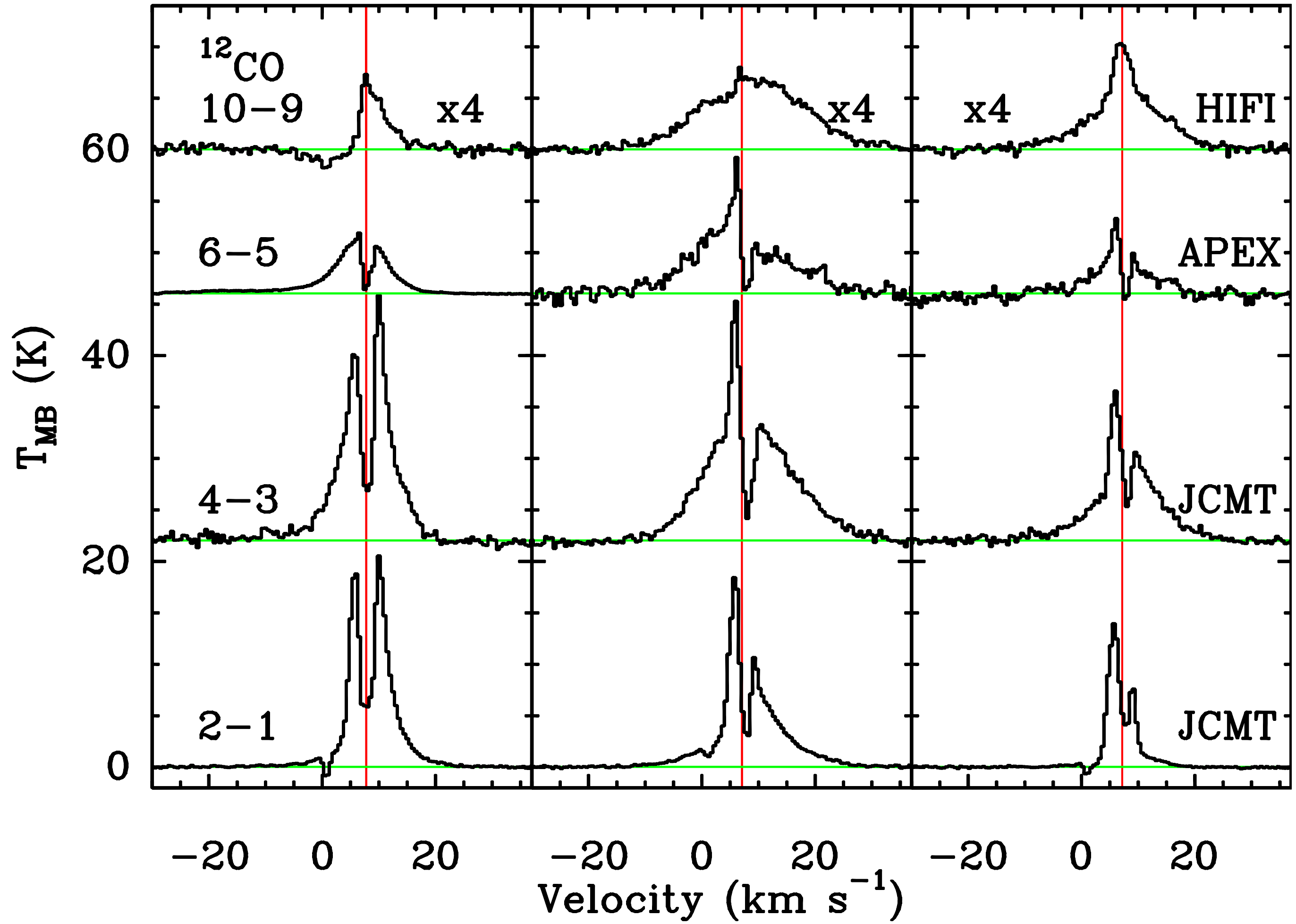
H_2O decomposition



Gaussian decomposition in 3 parts:
Broad (> 25 km/s)
Medium-broad (>5 km/s)
Narrow (< 5 km/s)



CO line profiles

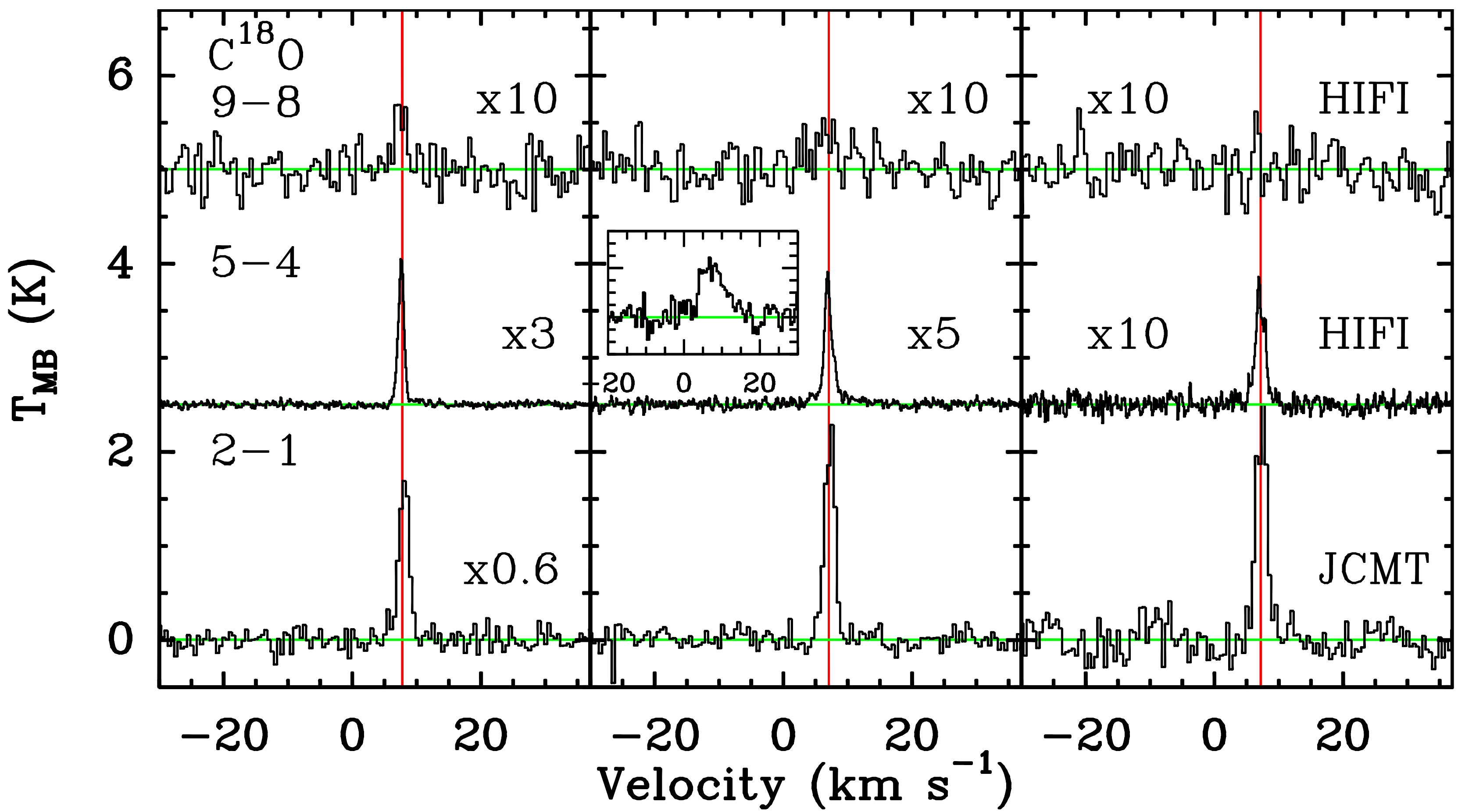


Not as complex line profiles as H_2O

Medium + broad components detected

(Yildiz et al. 2010)

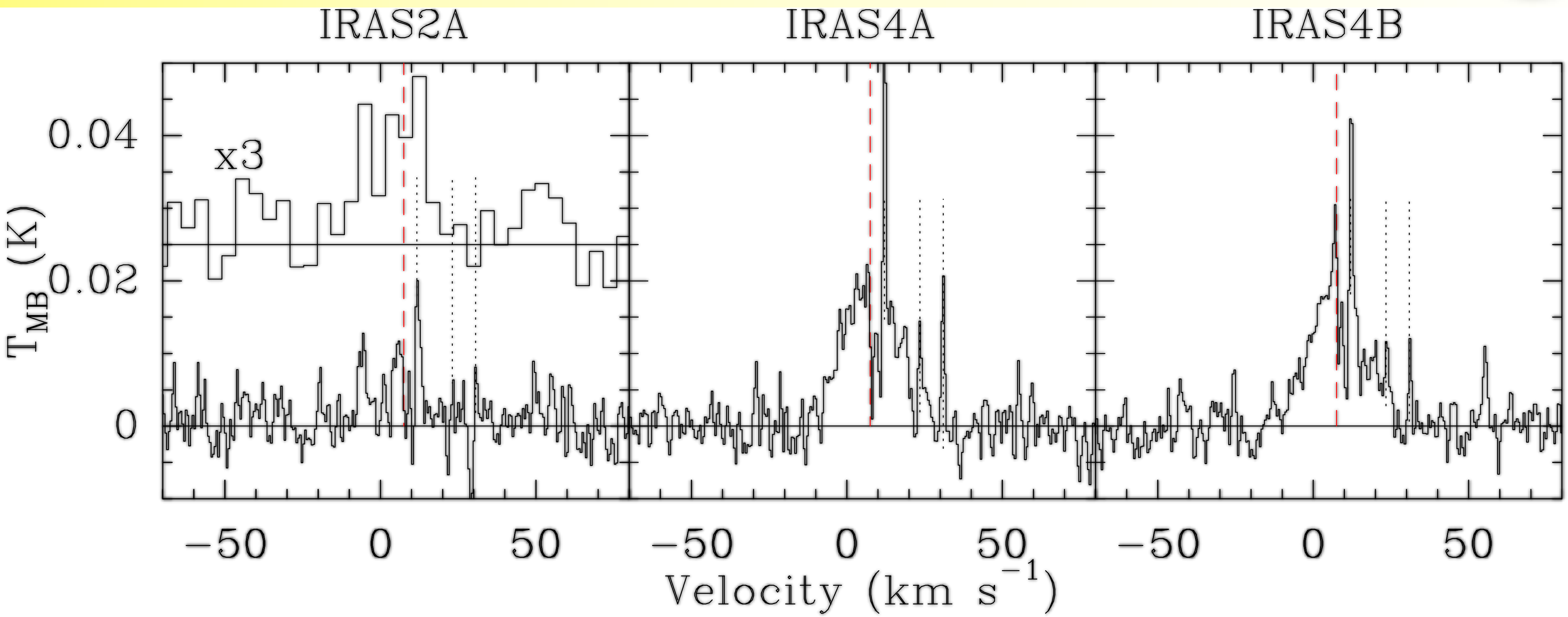
$C^{18}O$ line profiles



$C^{18}O$ narrow - origin in envelope

Exception: $C^{18}O$ 5-4 in IRAS4A, medium comp.

Low-mass YSO - NGC1333



$H_2{}^{18}O$ broad - origin in shocks

H_2O sputtering and $O + H_2 \rightarrow H_2O$ at high T

Observed in conjunction with CH

Origin of shocks

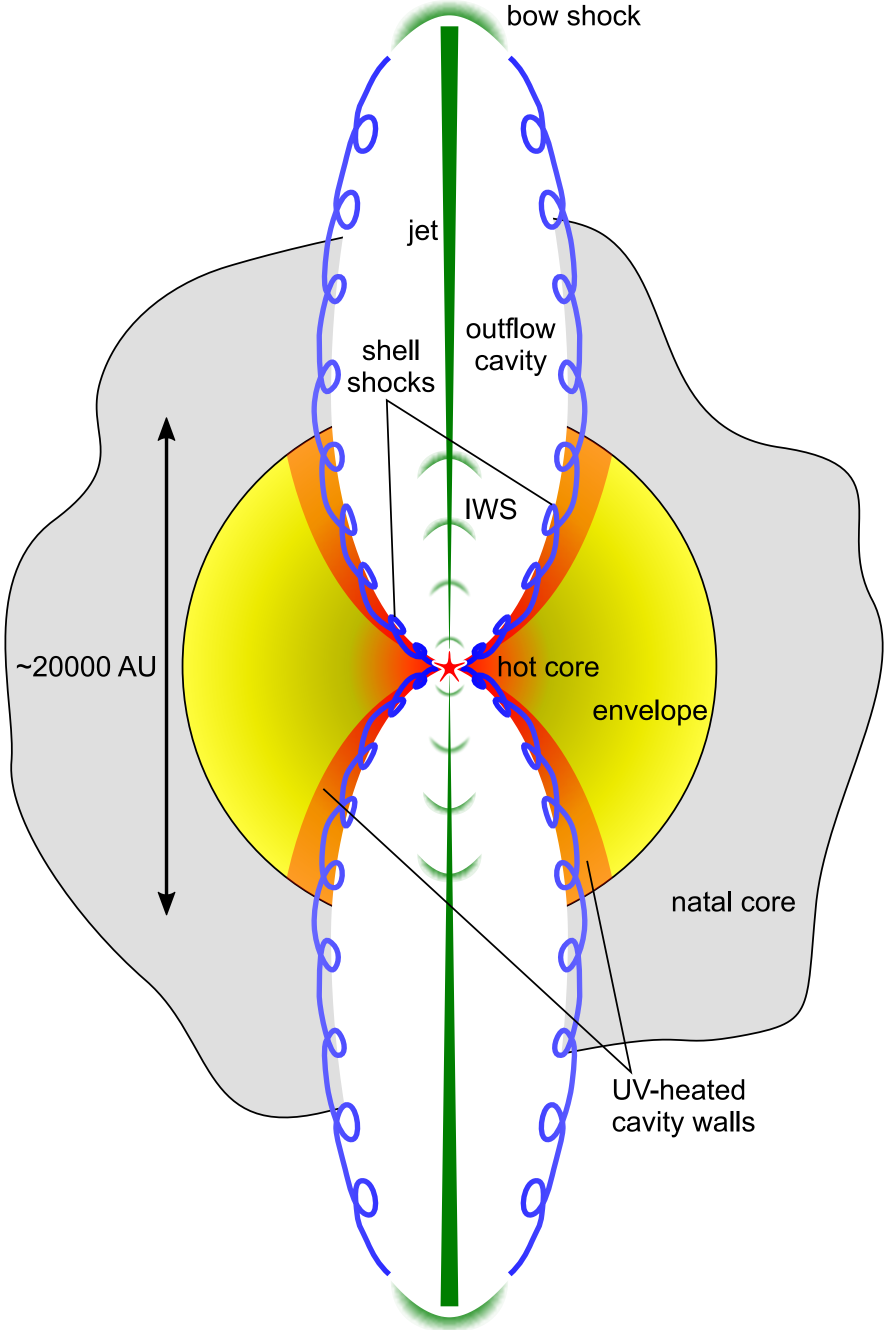
Several possibilities:

- Jet

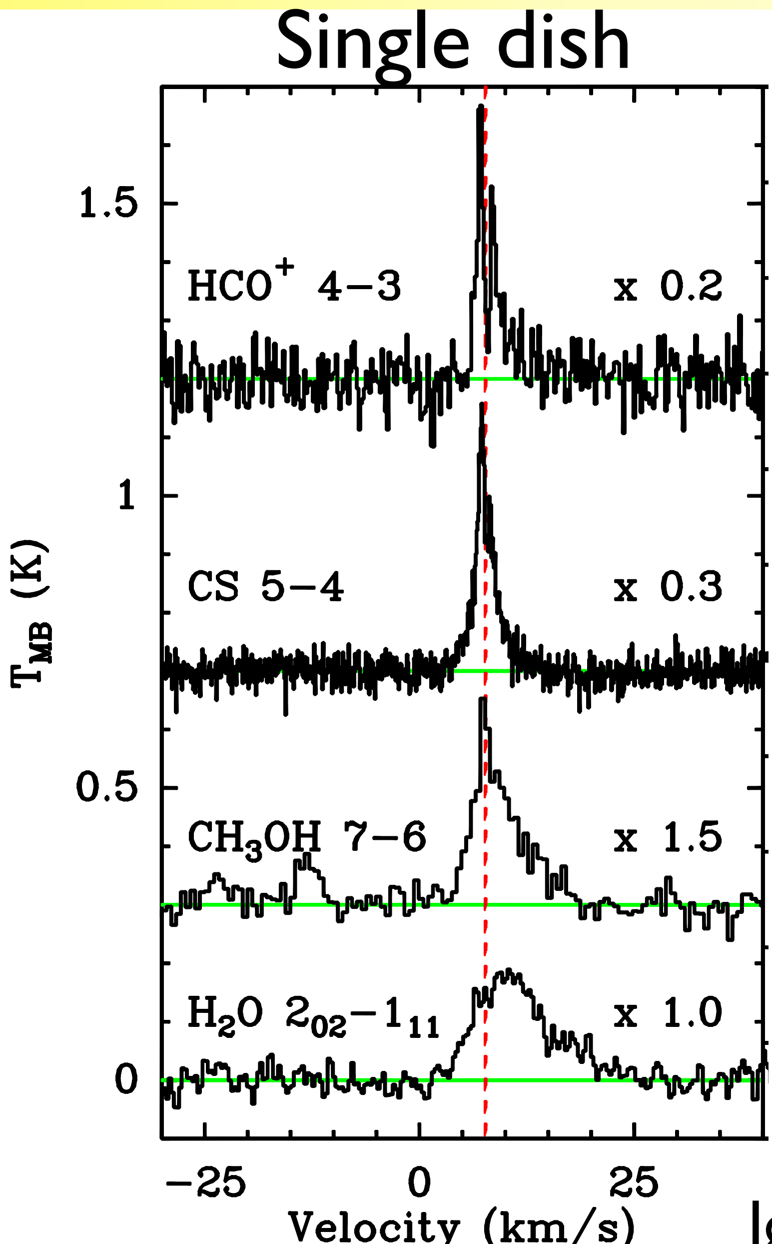
- Internal working surfaces

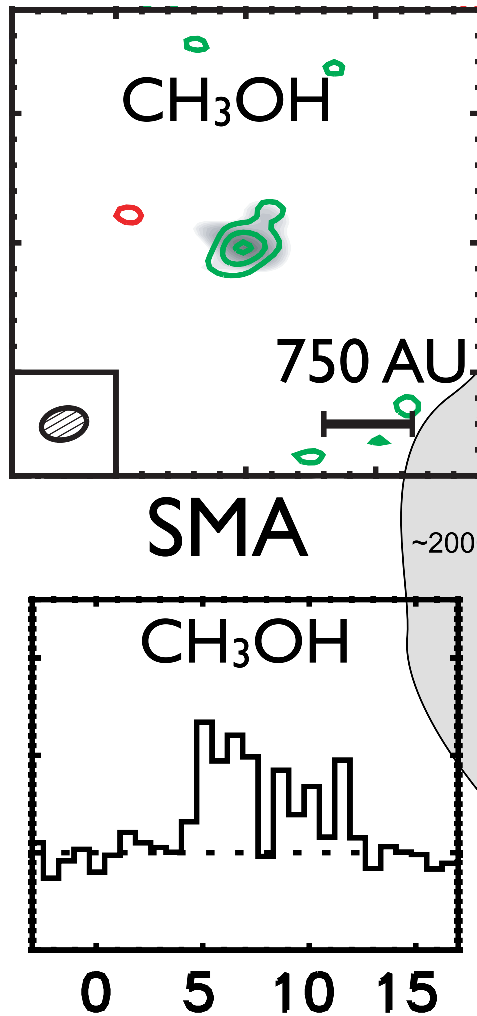
- Jet bow shock

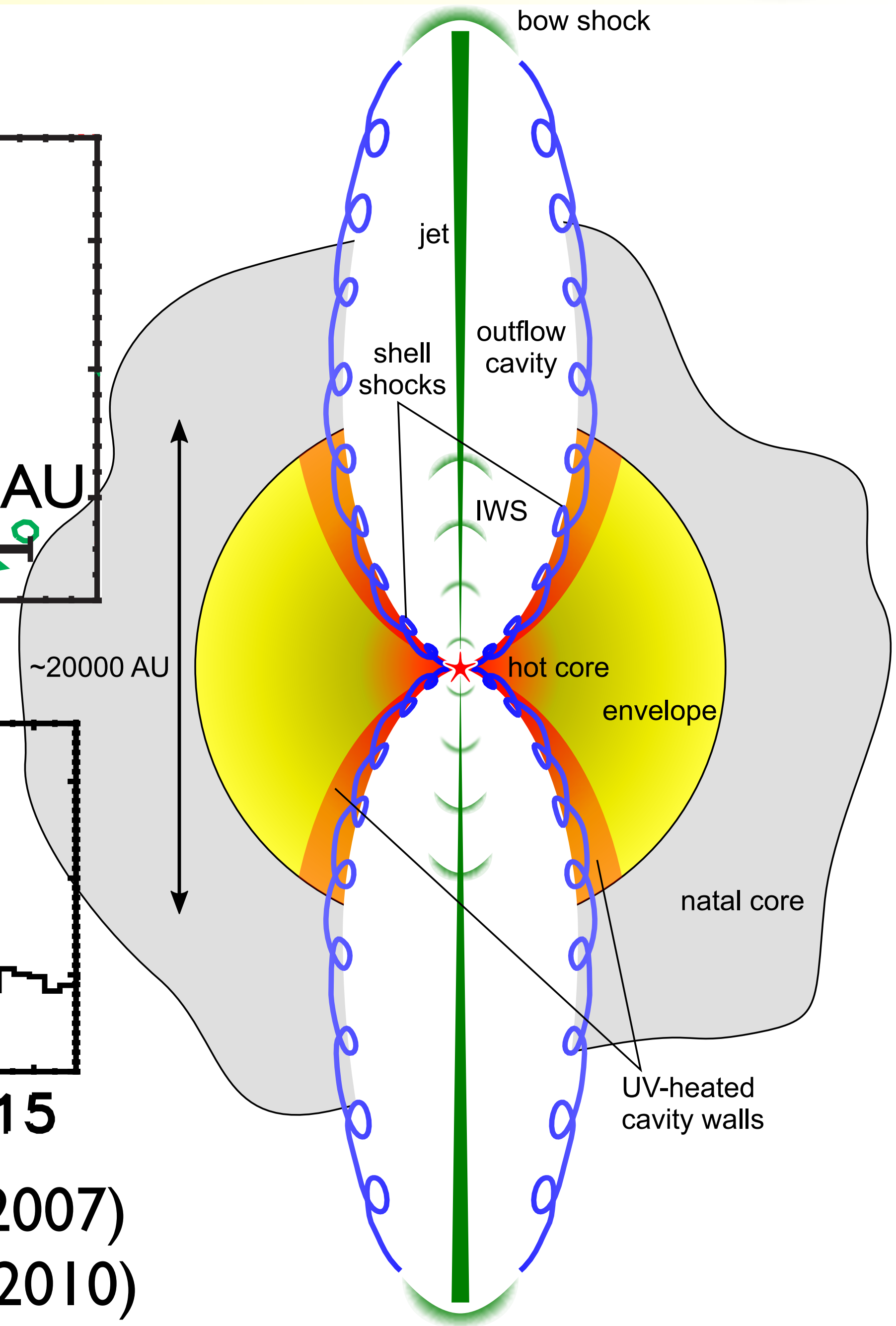
- Shells along the outflow cavity induced by wide-angle wind



Origin of shocks - medium

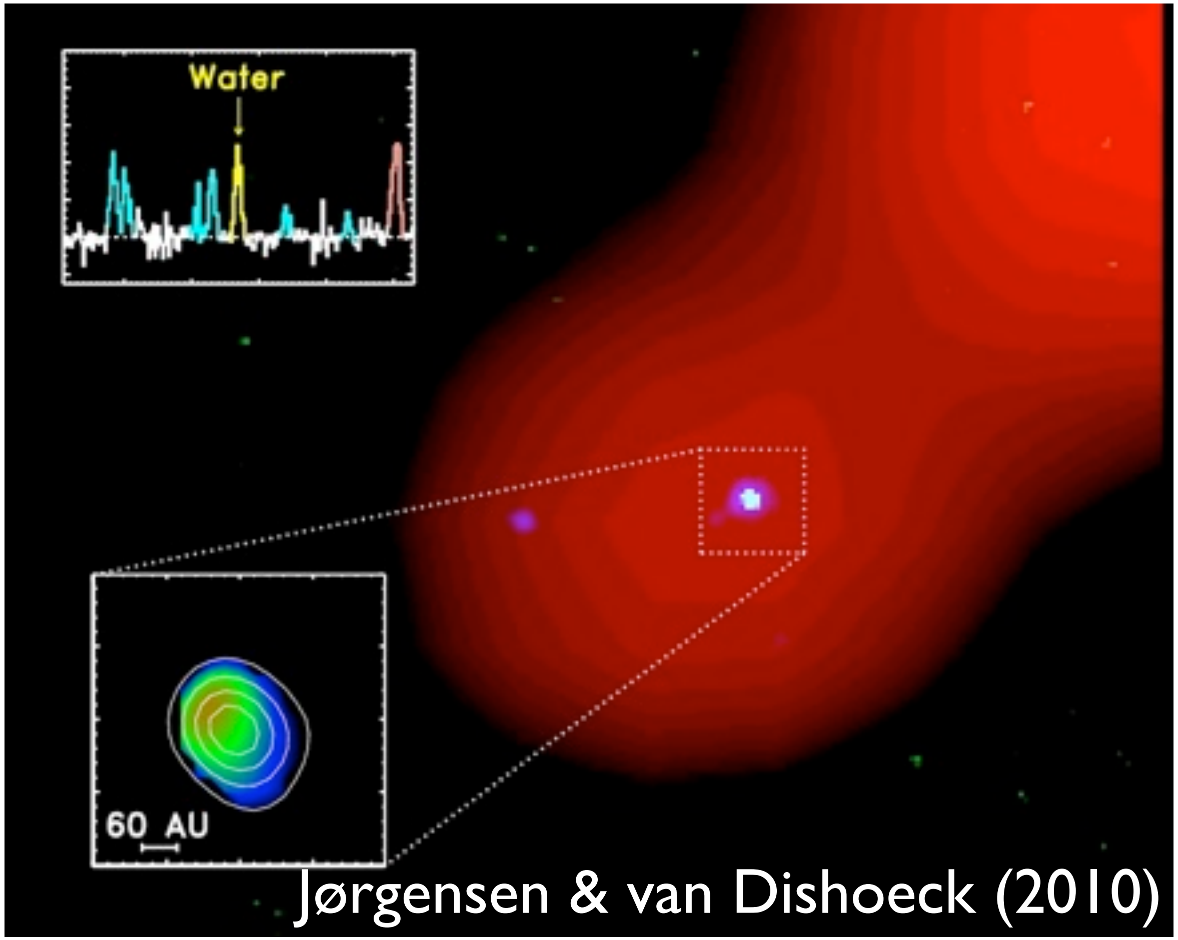




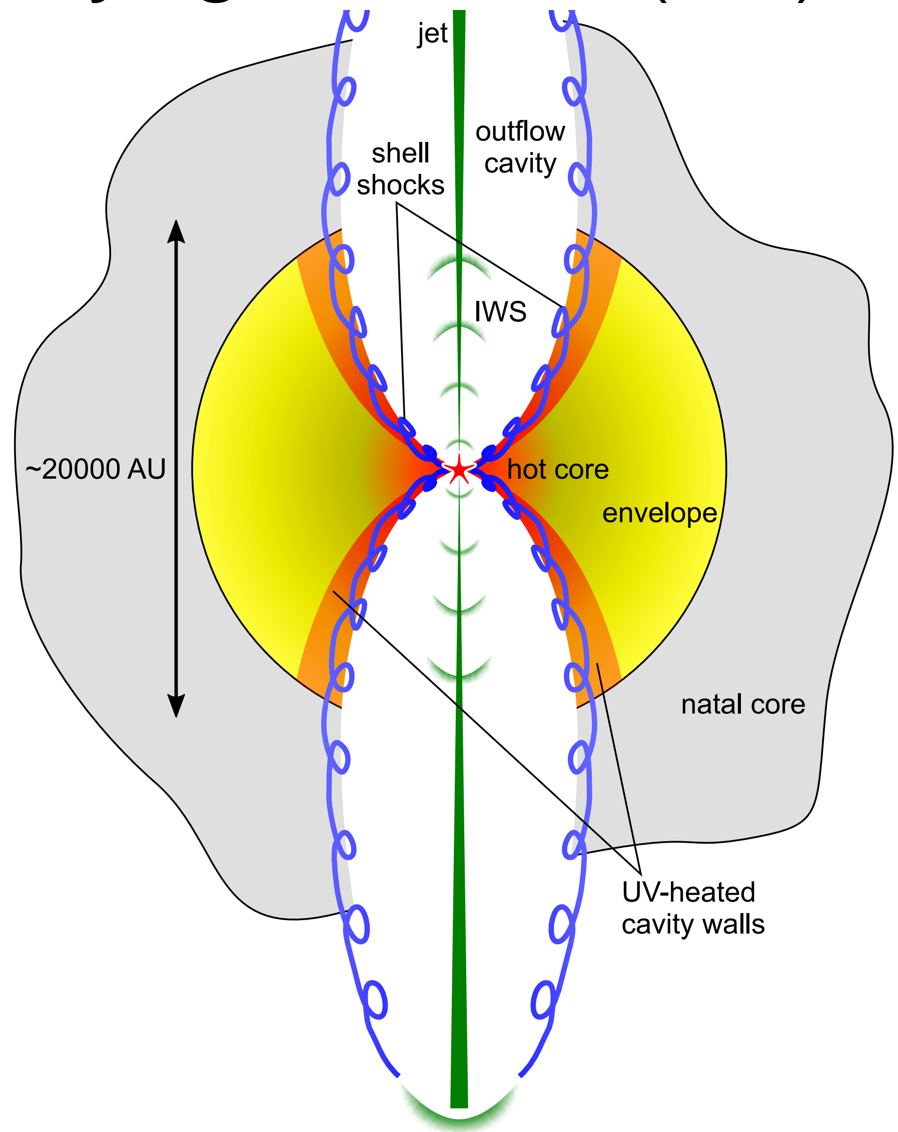


Jørgensen et al. (2007)
Kristensen et al. (2010)

H_2O - IRAS4B



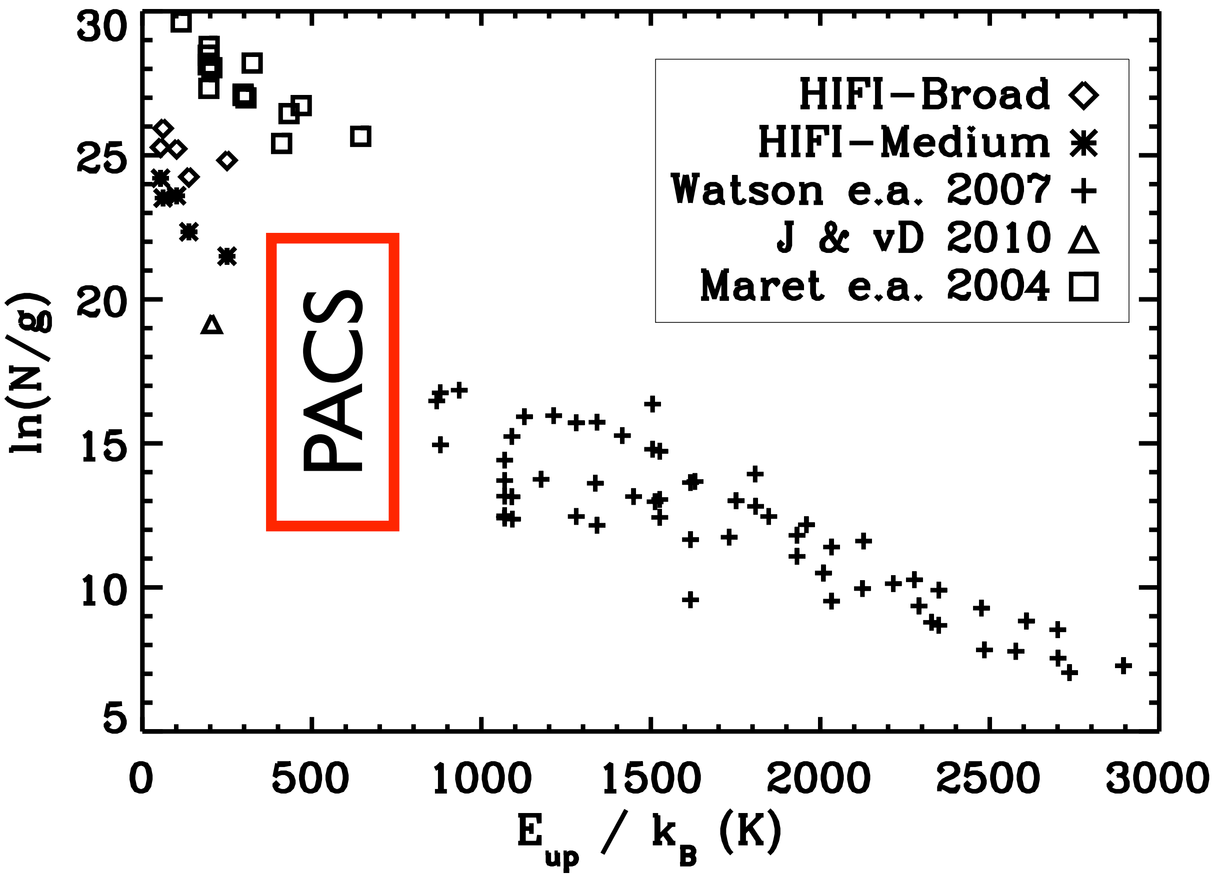
See also poster by Jørgensen et al. (P17)



$H_2{}^{18}O$ detected in one source

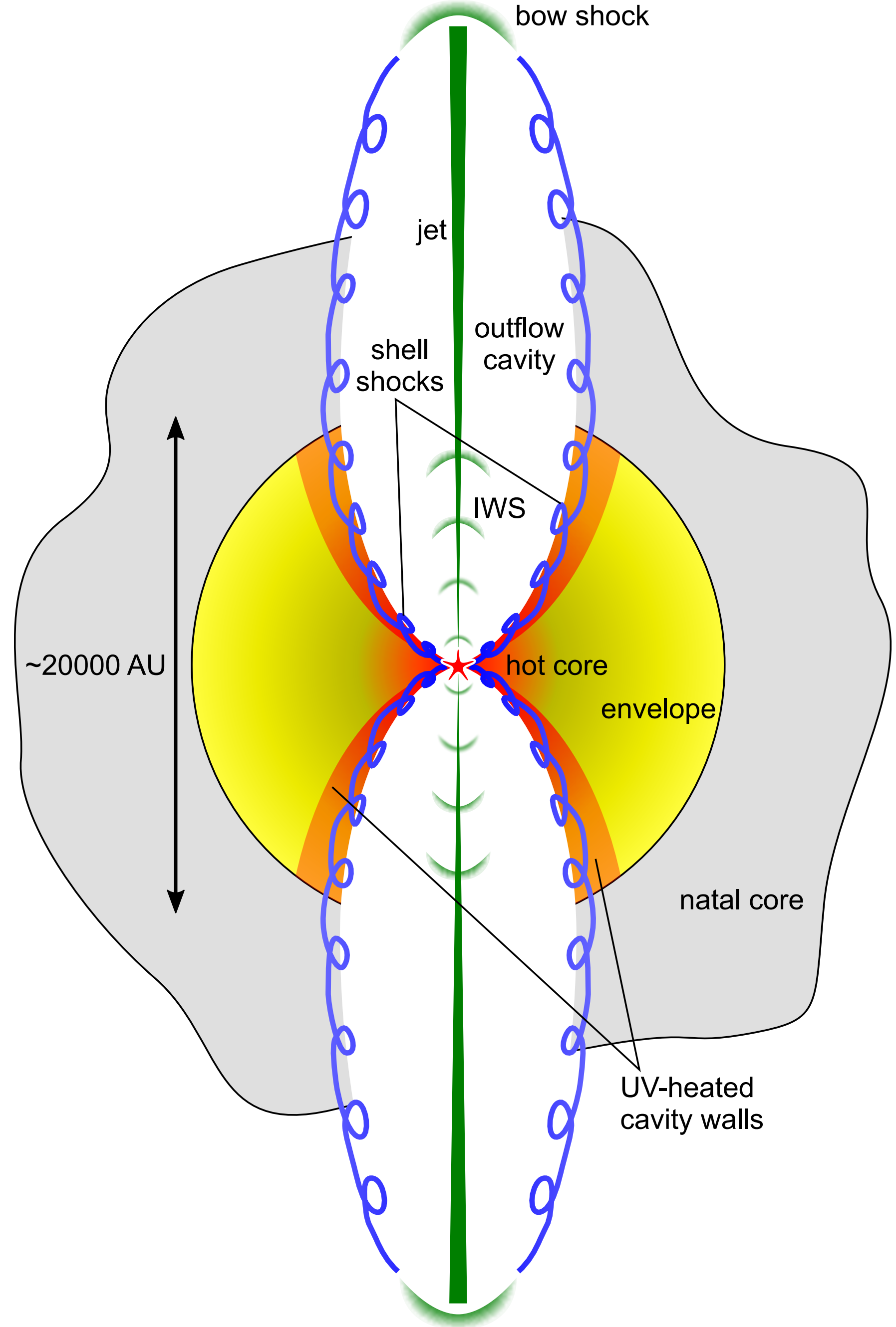
Narrow (~1 km/s)

H_2O - IRAS4B

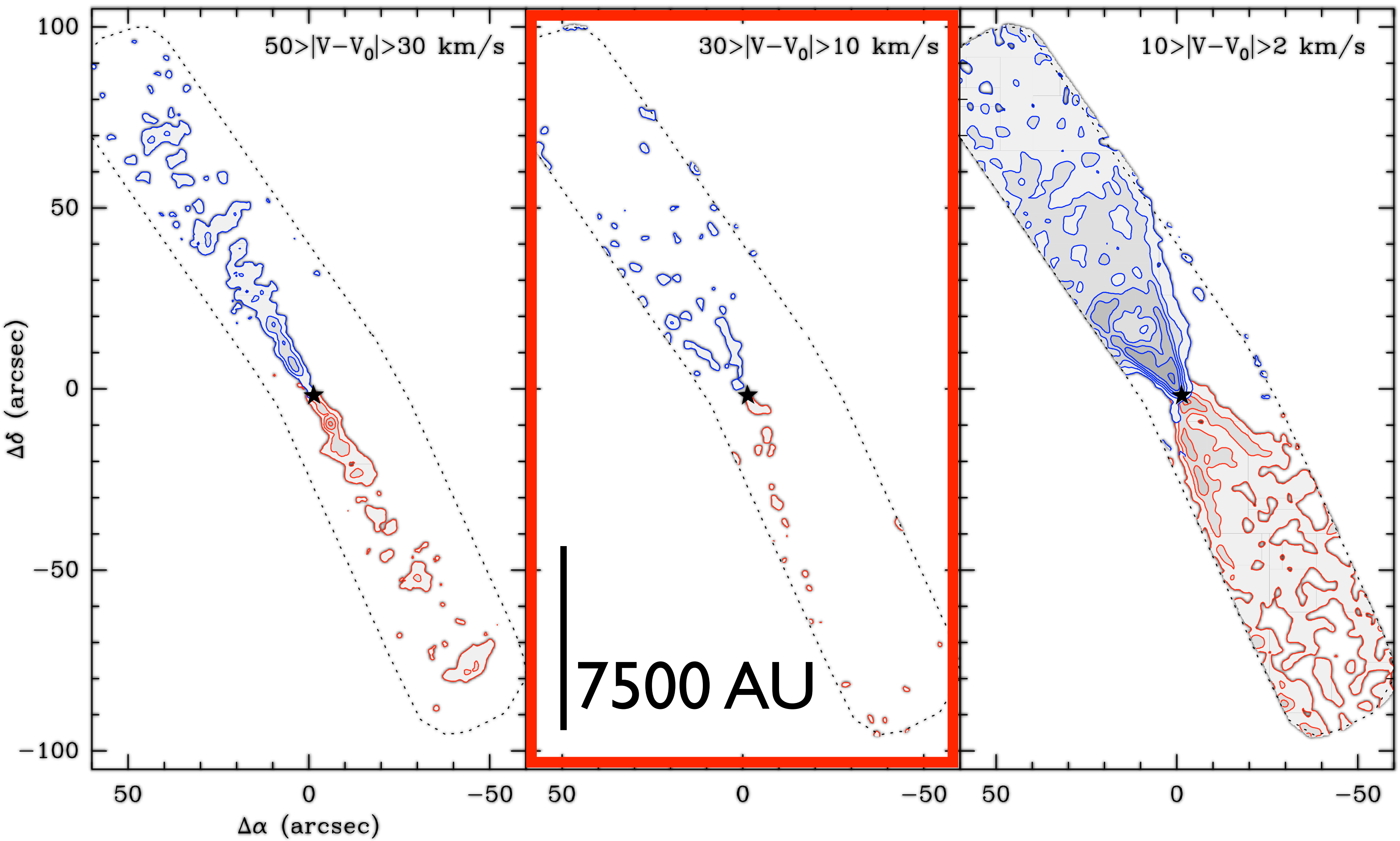


Spitzer detection of excited H_2O

Origin: accretion shock ?
Not in agreement with narrow $H_2{}^{18}O$ linewidth !



Origin of shocks - broad



Broad component in NGC1333 = IHV in IRAS04161

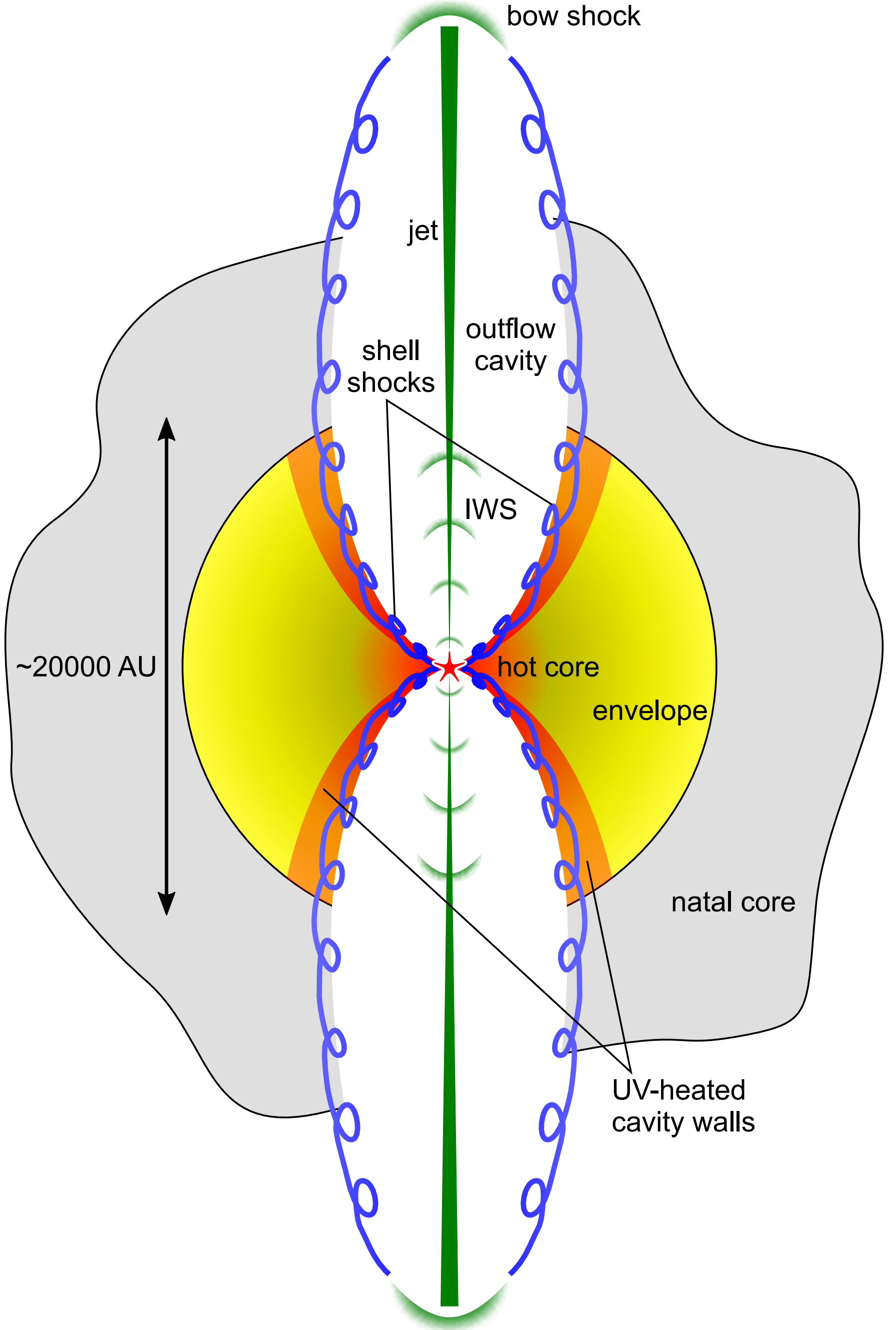
(Santiago-Garcia et al. 2009)

Origin of shocks

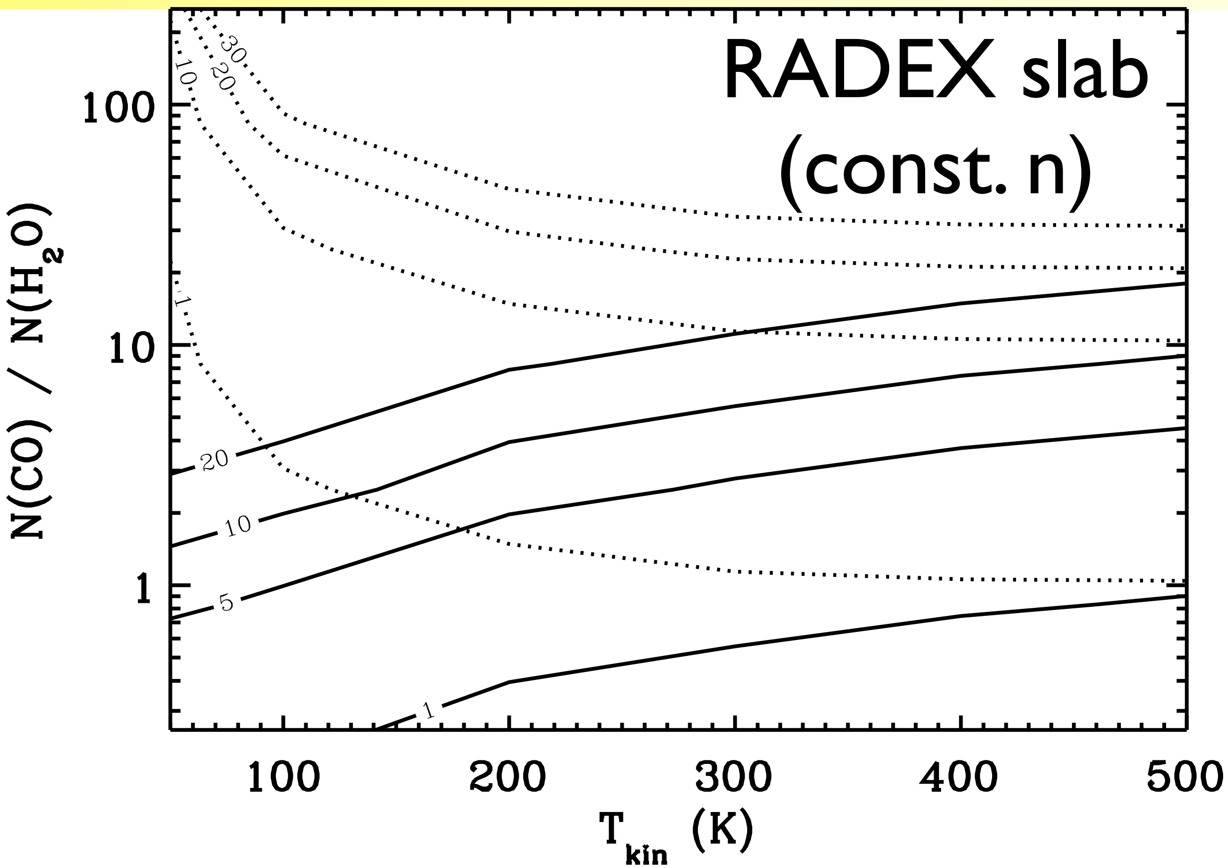
Possible interpretation:

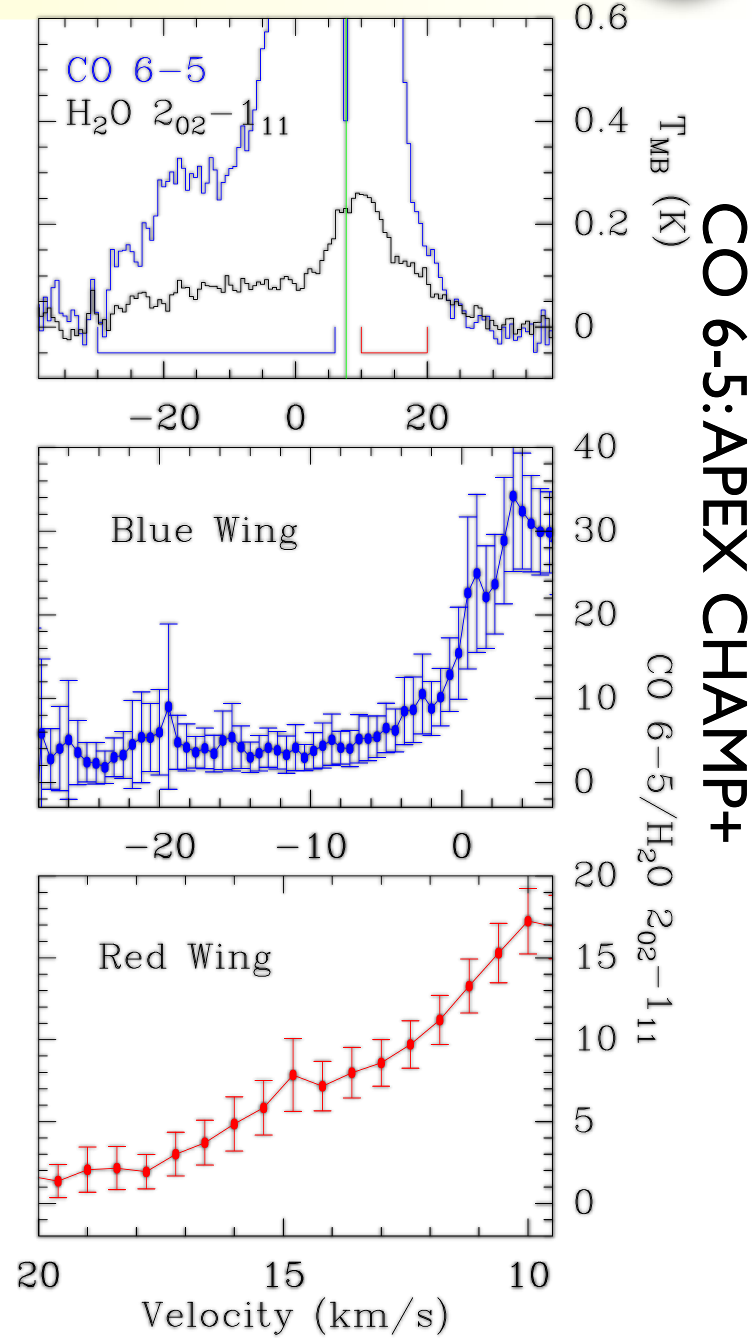
Broad component:
Shocks along cavity walls;
> 1000 AU

Medium-broad component:
Small-scale shocks close to the source; < 1000 AU



H_2O abundance - shocks

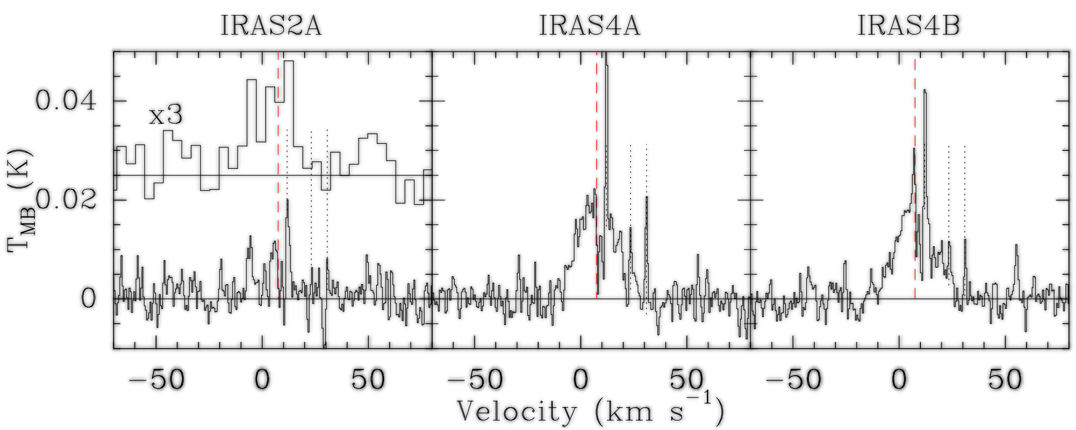




H_2O/CO ~ 1-10, i.e.,
$x(H_2O) \sim 10^{-5} - 10^{-4}$

Fraction of outflow gas where
$O + H_2 \rightarrow H_2O$ = ~ 10%

H_2O abundance - envelope

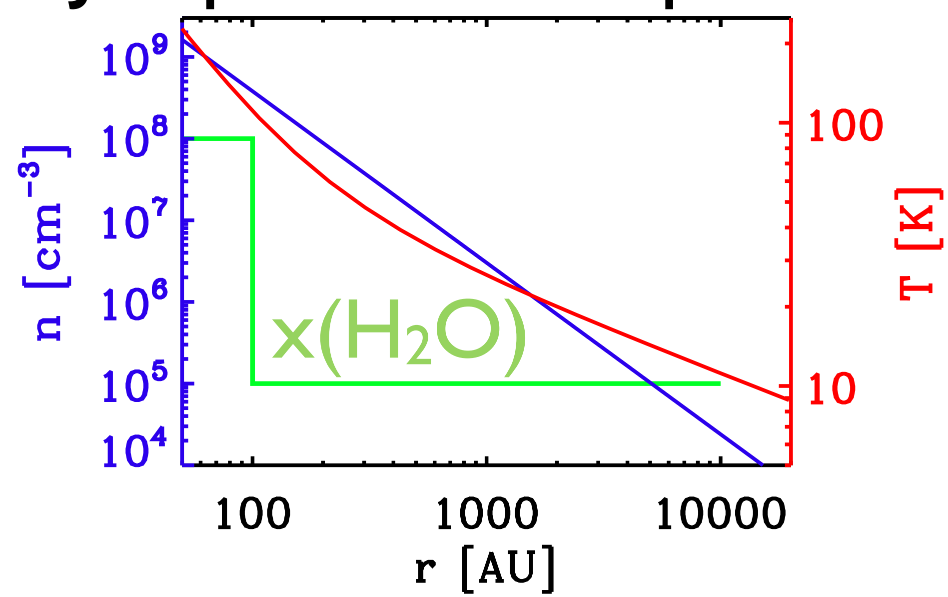


No clear envelope signs in $H_2{}^{18}O$ 1_{10} - 1_{01} profile

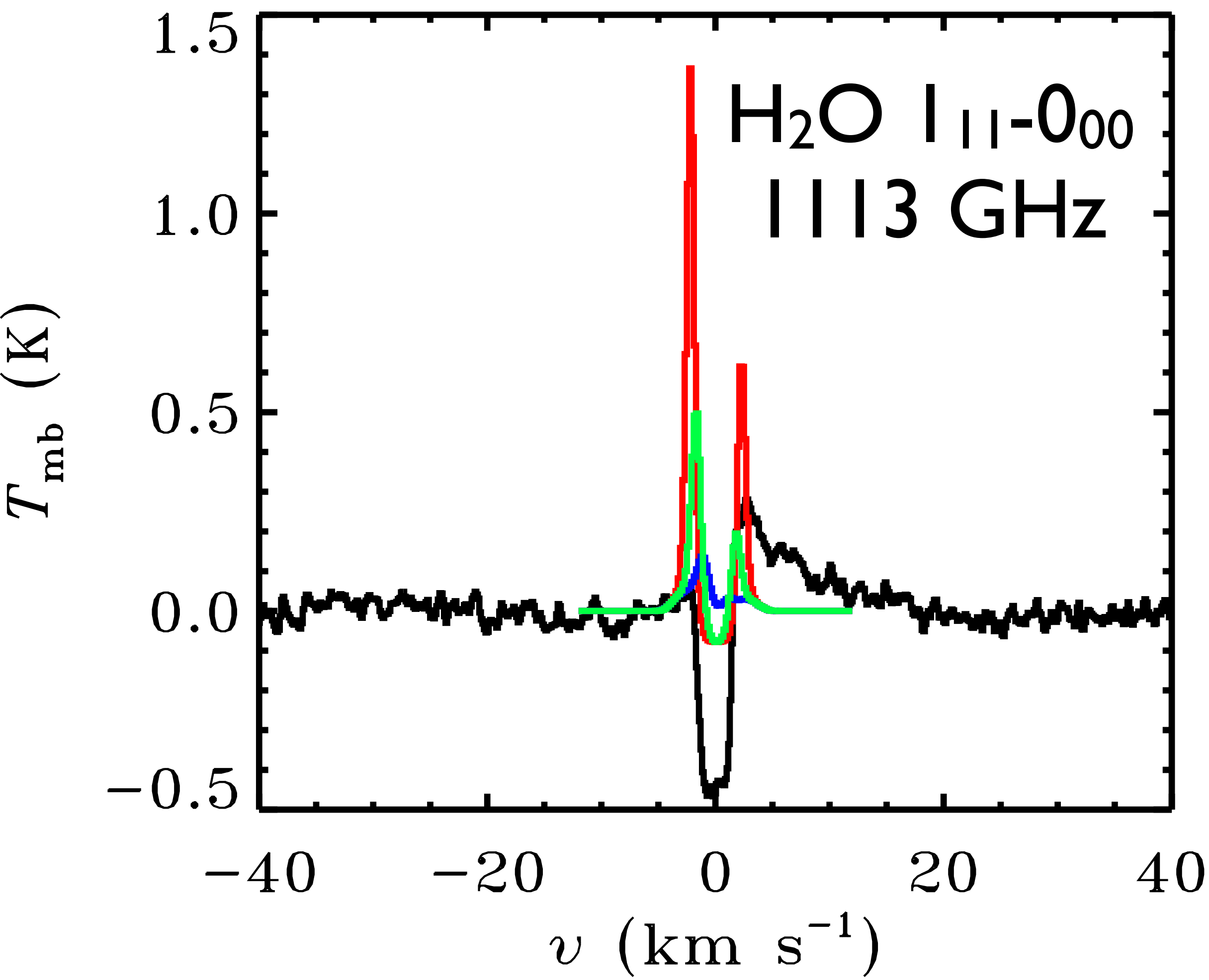
Strategy:

- absorption in H_2O 1_{11}-0_{00} for $x_{in}(H_2O)$
- upper limit on $H_2{}^{18}O$ 2_{02}-1_{11} for $x_{out}(H_2O)$

Jump-abundance profile



H_2O abundance - envelope



$x_{in}(H_2O) = 10^{-5}$

$x_{out}(H_2O) = 10^{-7}$

$x_{out}(H_2O) = 10^{-8}$

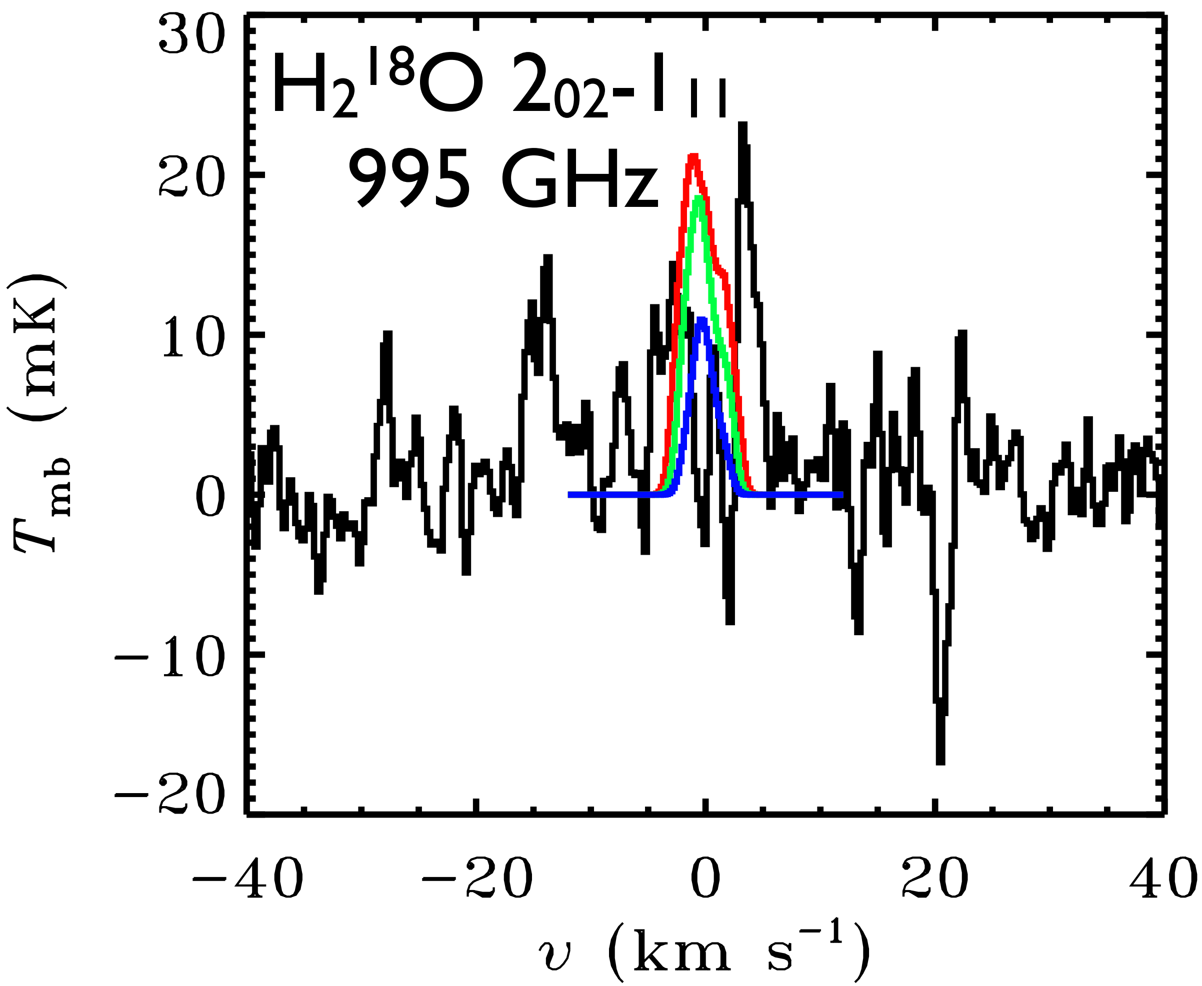
$x_{out}(H_2O) = 10^{-9}$

$x(H_2O)(T < 100\ K) \sim 10^{-8}$

Well constrained

Liu et al. subm.
Visser et al. in prep.

H_2O abundance - envelope



$x_{out}(H_2O) = 10^{-8}$

$x_{in}(H_2O) = 10^{-4}$

$x_{in}(H_2O) = 10^{-5}$

$x_{in}(H_2O) = 10^{-6}$

$x(H_2O)(T > 100\ K) < 10^{-5}$

Only upper limit

Modeling in progress !

(Visser et al. in prep.; next talk)

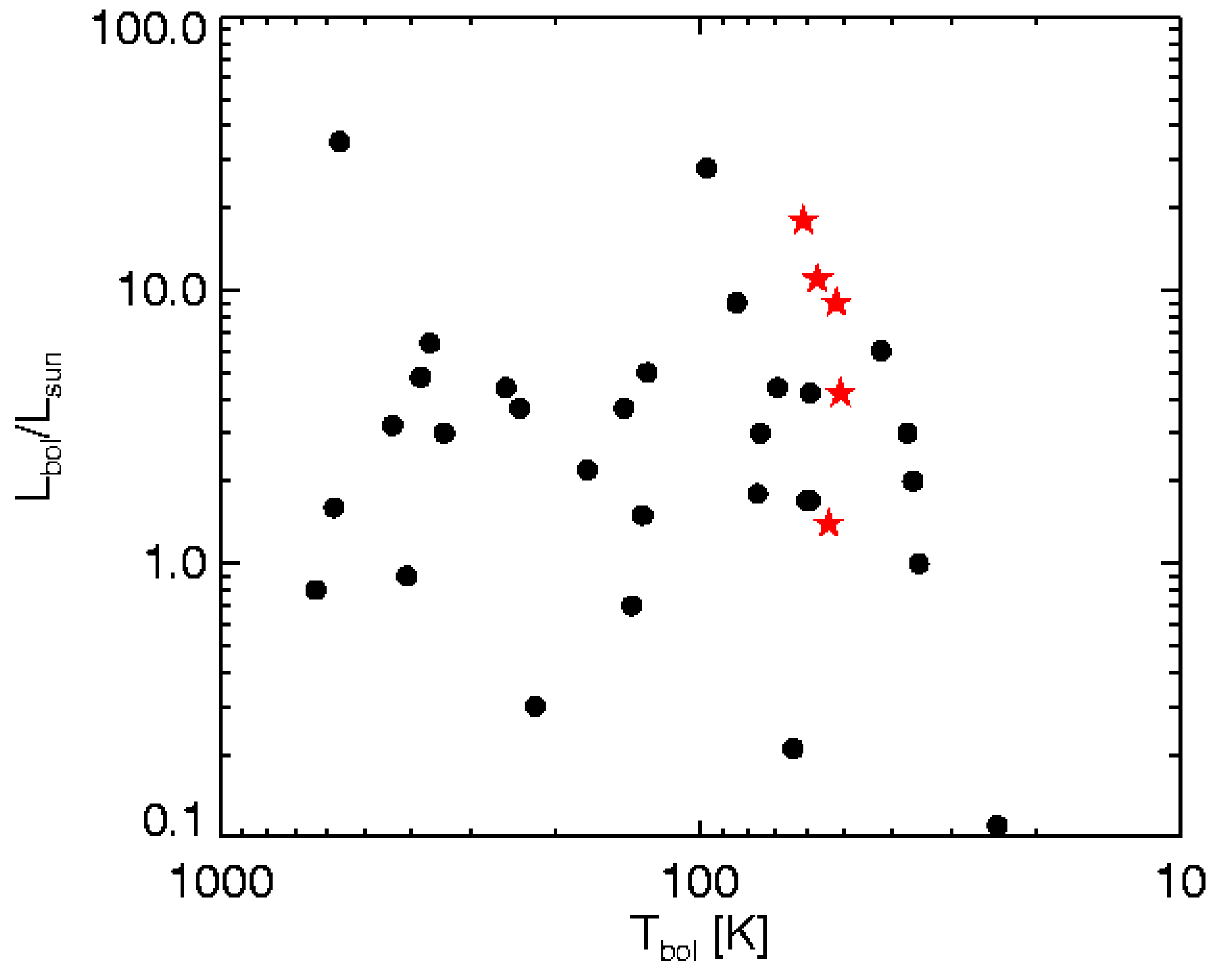
Outlook

WISH:

Sample of 29 low-mass Class 0/I sources

18/29 sources observed in 557 GHz line

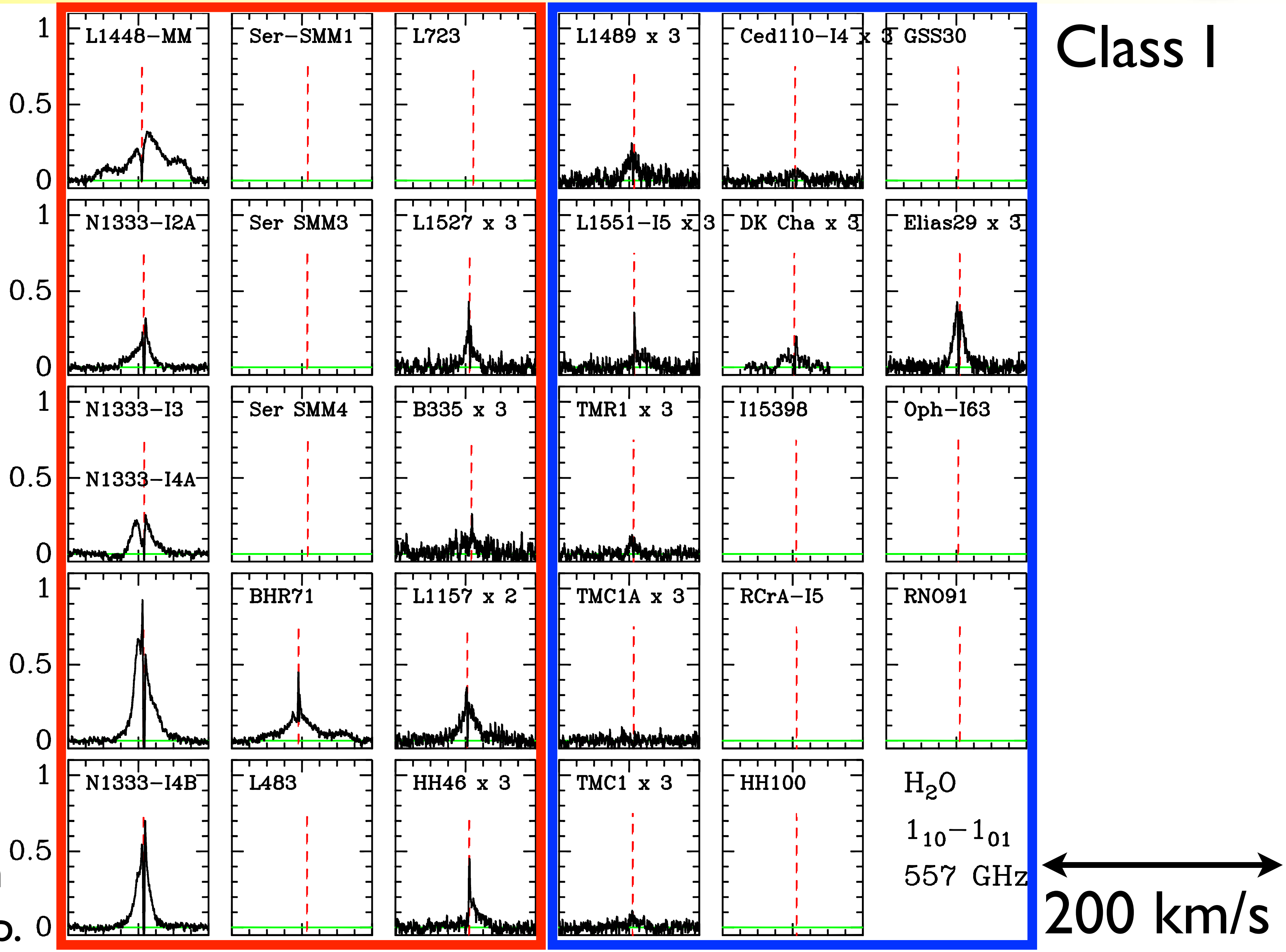
Data coming in... (No. 18 reduced today)



Outlook

Class 0

Class I



Kristensen
et al. in prep.

Outlook

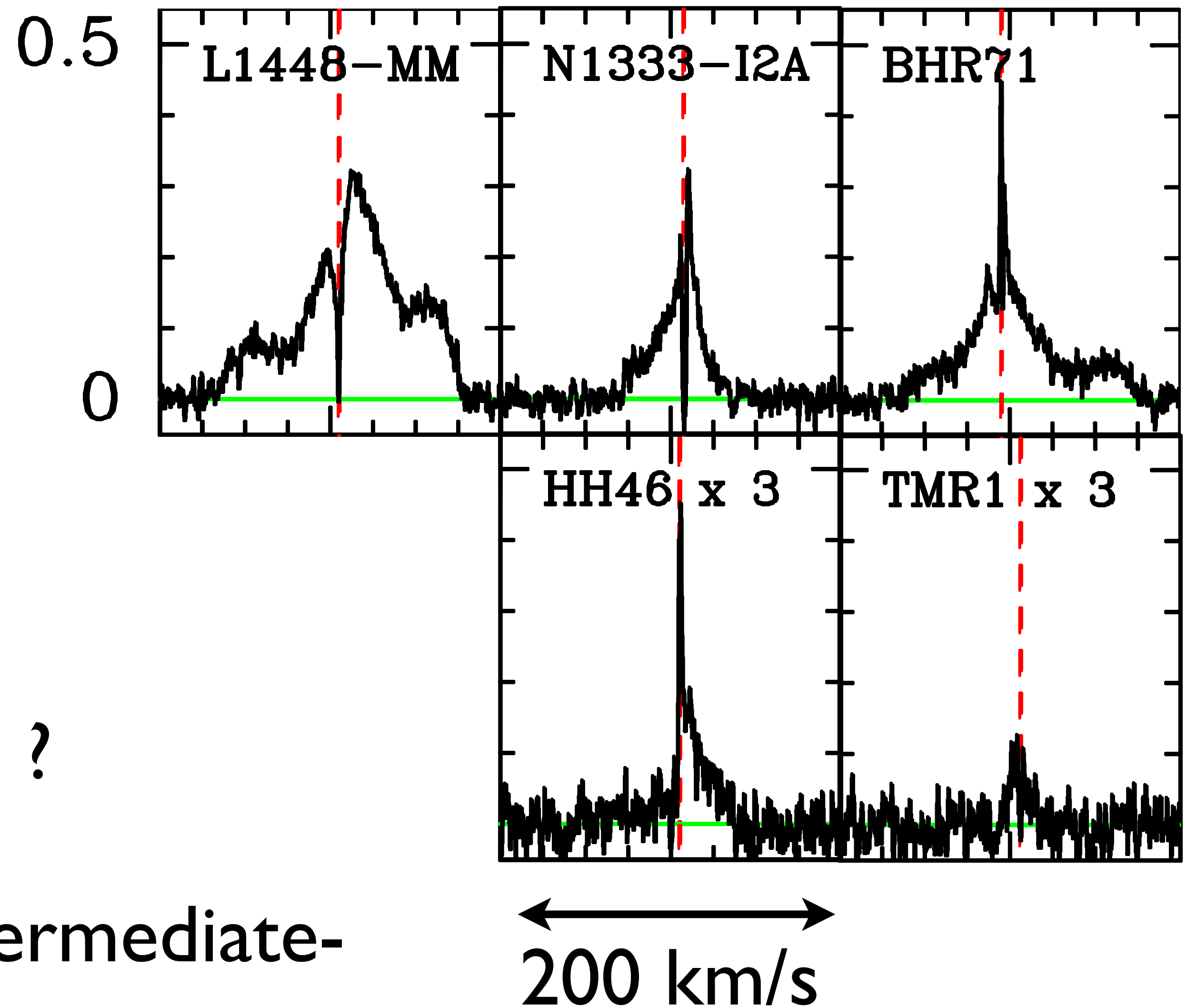
Next steps:

- Model line profiles

- Evolutionary trends ?

- Abundance variations ?

- Comparison with intermediate- and high-mass SF regions



Conclusions

- HIFI is delivering spectacular data!

- H_2O data reveal many surprises:
  - If it moves, it emits H_2O
  - H_2O abundances in shocks constrained
  - Hot core is hard to see (even in $H_2^{18}O$)

- Further (detailed) modeling in progress (see next talk)