Water as tracer of the stormy stages of star formation

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and the WISH team

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
- Complementary to CO

Why H_2O ?

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

15 first-results papers + van Dishoeck et al. (PASP, subm.)

Prestellar

Class 0

Class I

Disks

Low-

Intermediate-

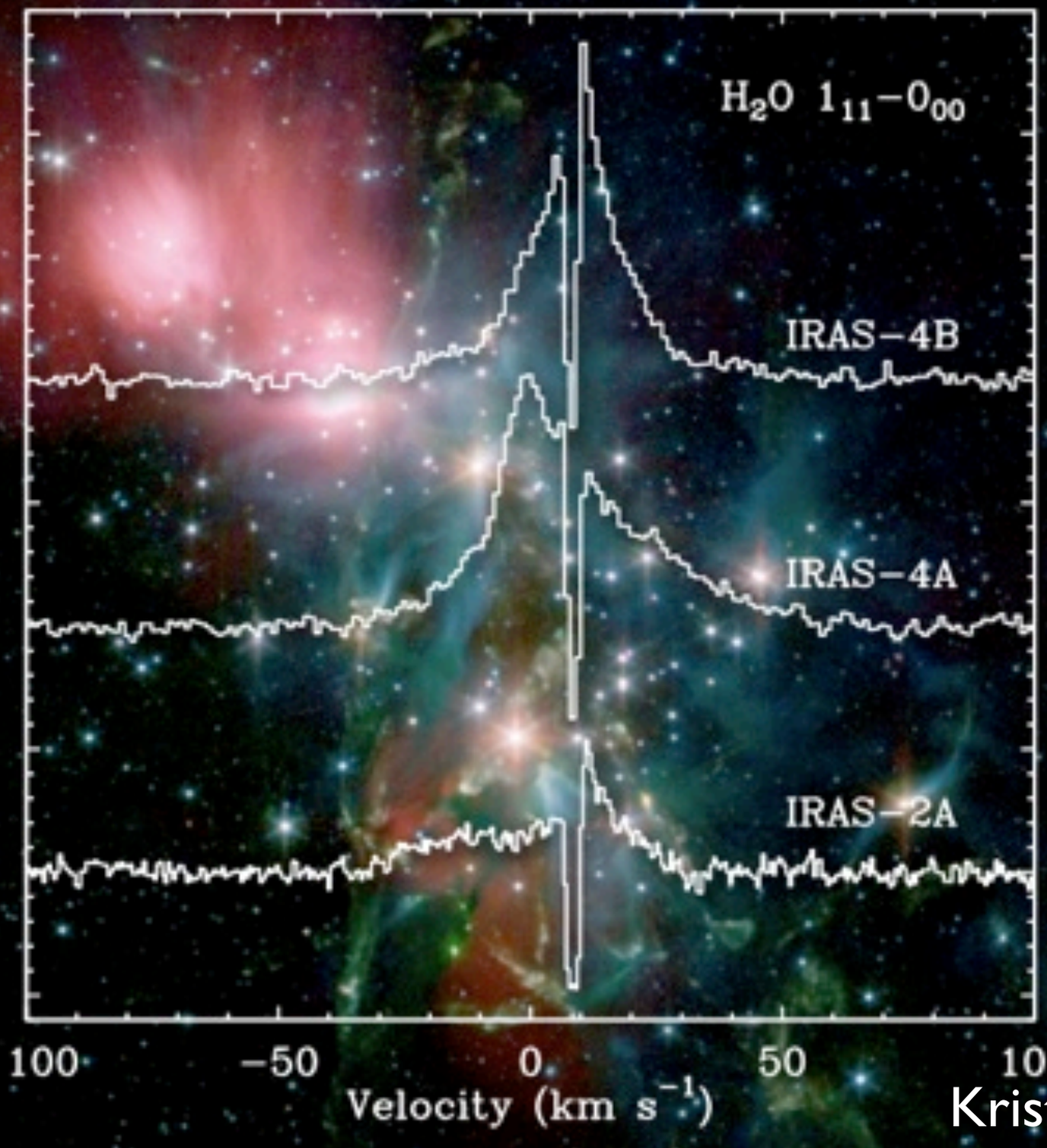
High-mass

Mass

Time

~80 sources

Observations



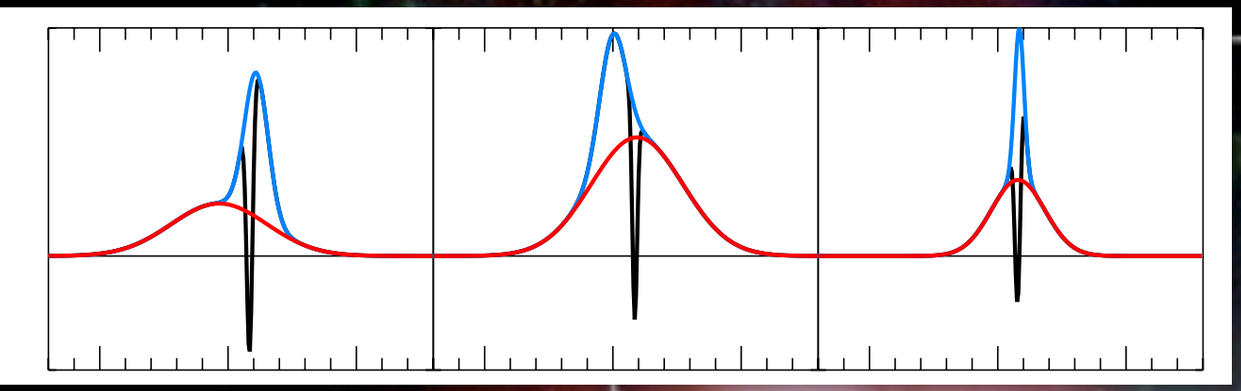
NGC1333

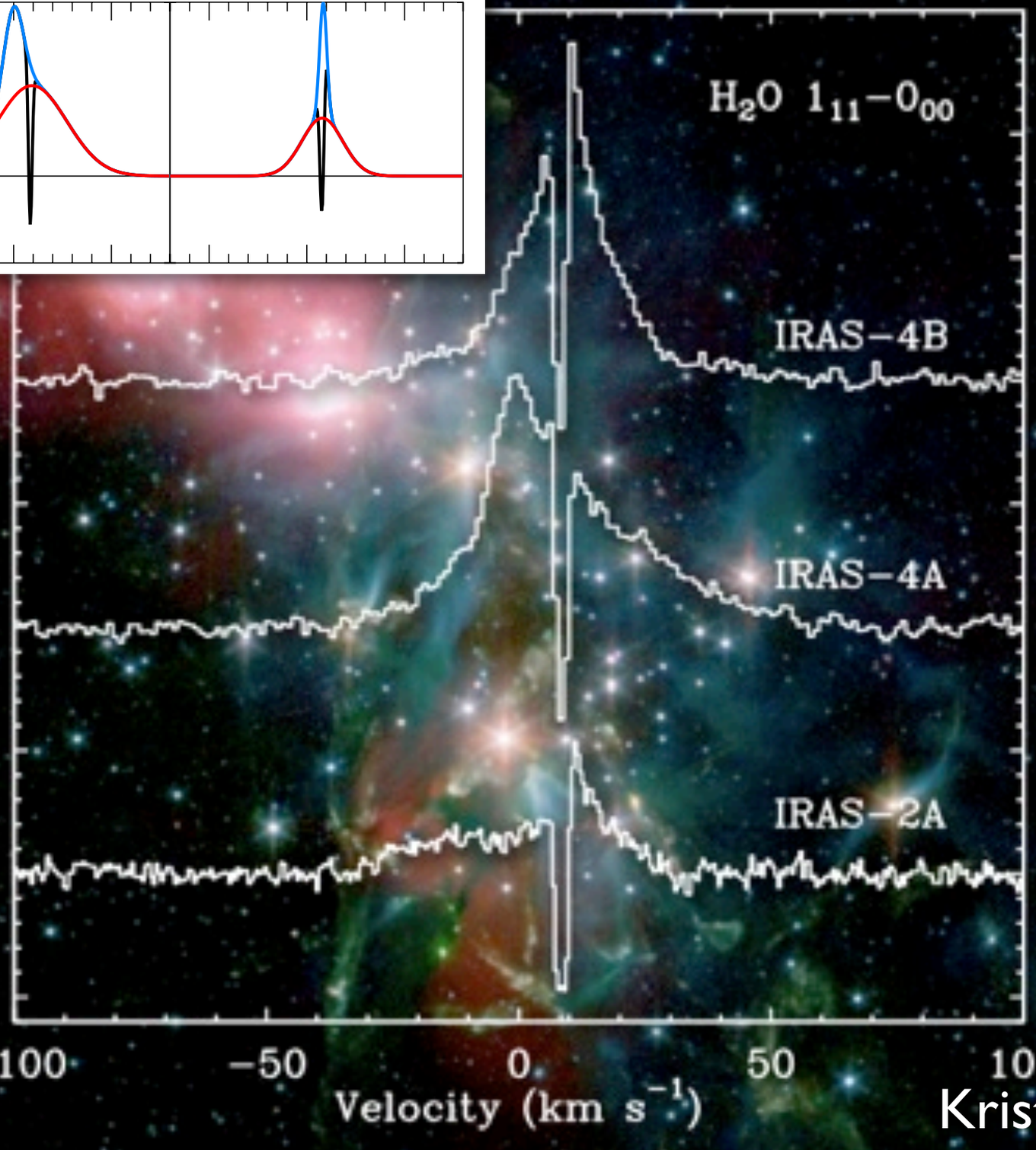
Nearby low-mass star-forming region

D ~ 235 pc
L ~ 6-20 $L_\odot$

Kristensen et al. (2010)

Observations





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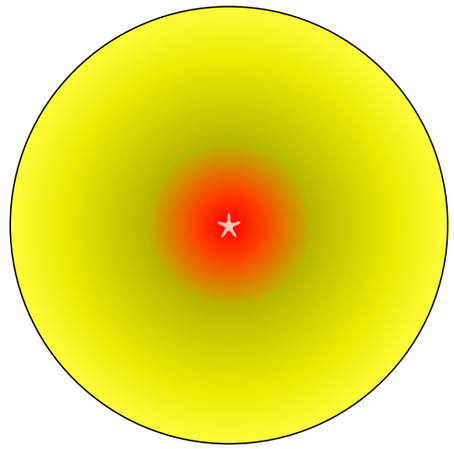
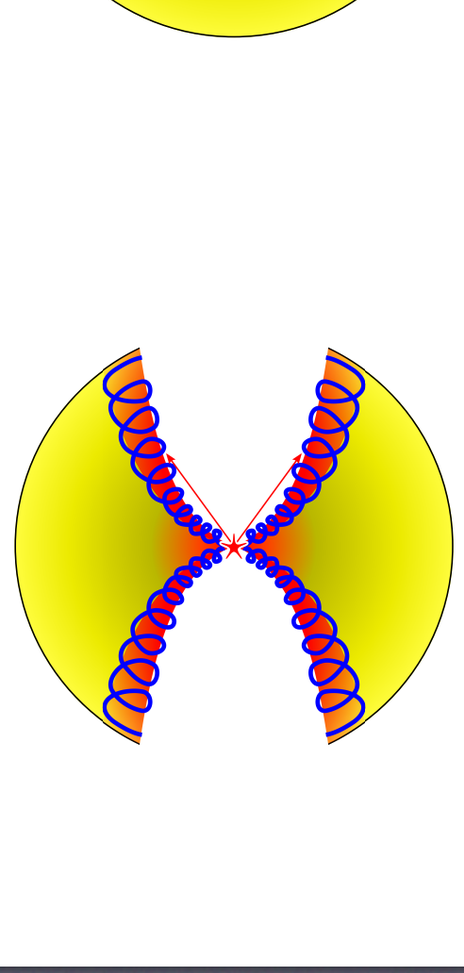
Energetic input

Passively heated molecular envelope



UV-illuminated cavity walls



Small-scale shocks in cavity walls

Molecular jet, internal working surfaces

(Visser, Kristensen et al. in prep.)

Energetic input

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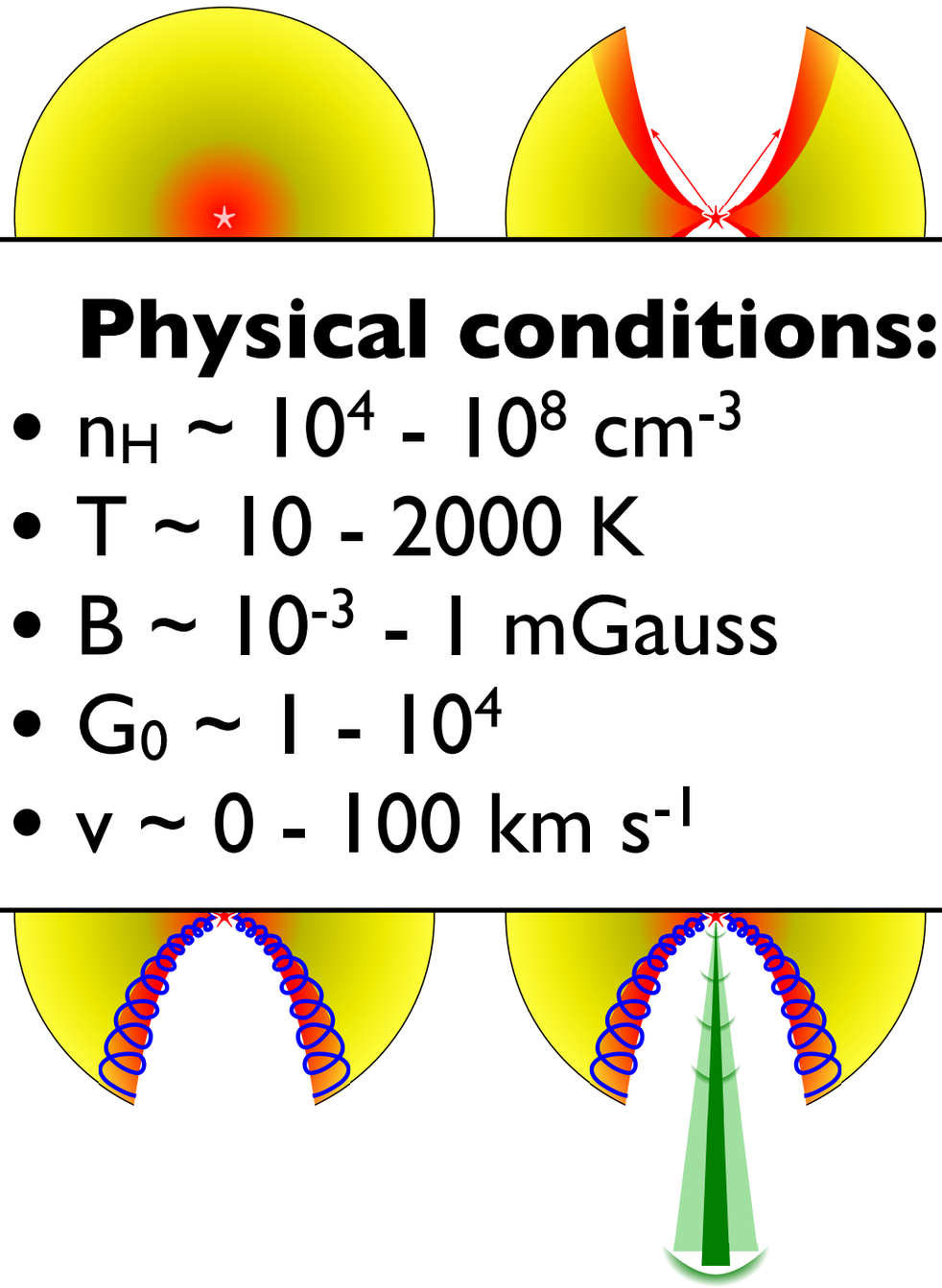


Physical conditions:

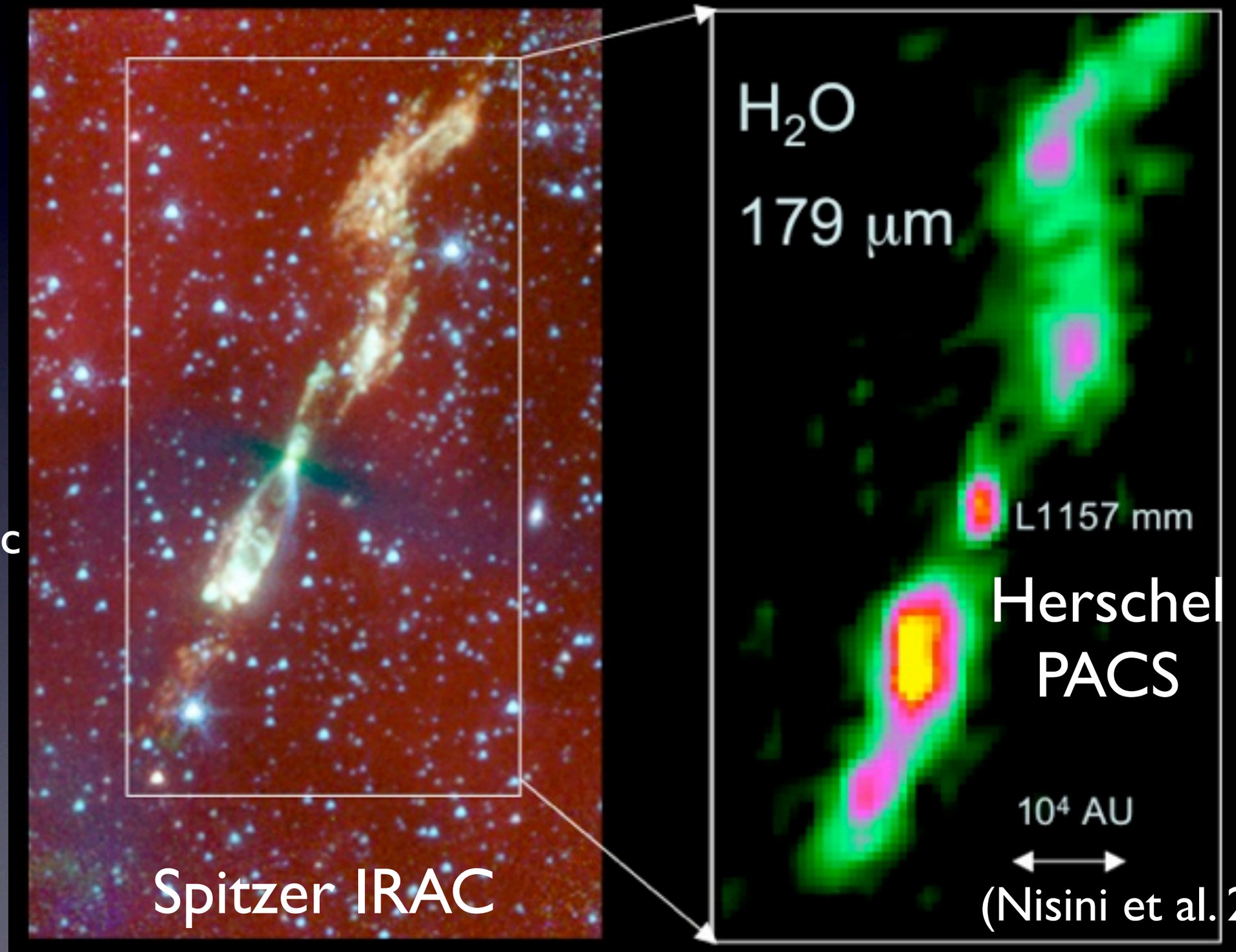
- $n_H \sim 10^4$ - 10^8 cm^{-3}
- T ~ 10 - 2000 K
- B ~ 10^{-3} - 1 mGauss
- $G_0 \sim 1$ - 10^4
- v ~ 0 - 100 km s^{-1}

UV-illuminated cavity walls

Molecular jet, internal working surfaces

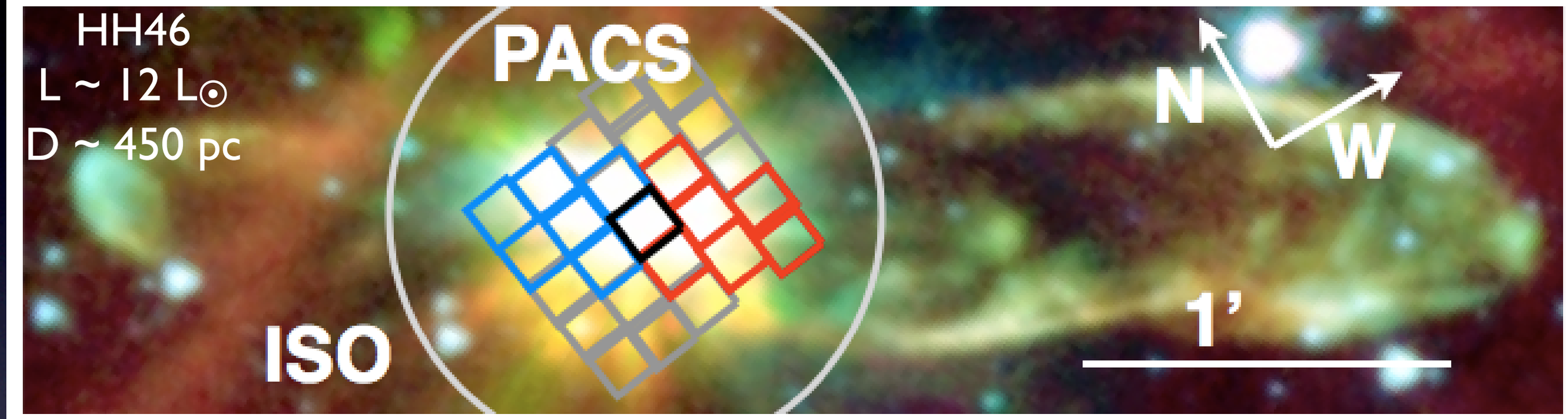
(Visser, Kristensen et al. in prep.)

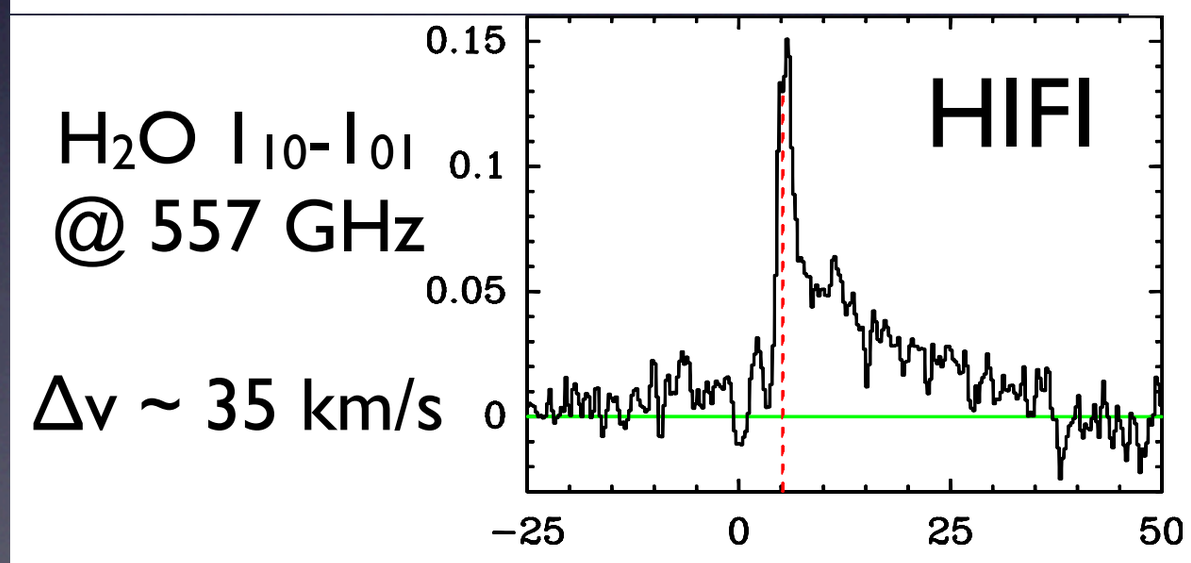
First Herschel H_2O map

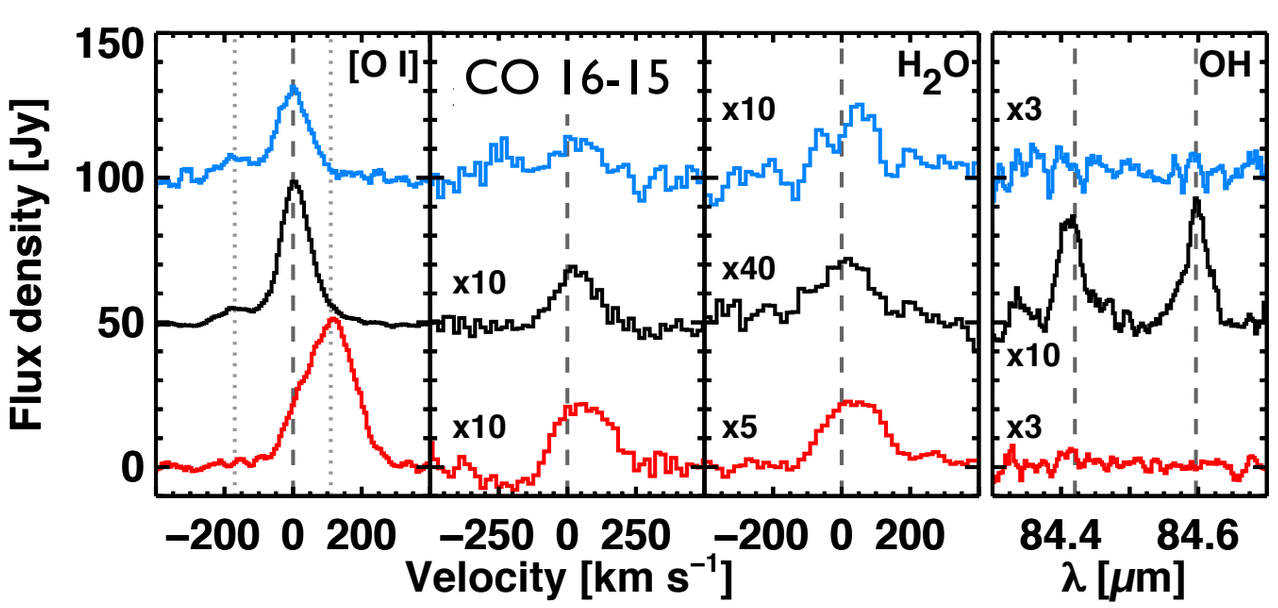


(Nisini et al. 2010)

HH46







Kristensen et al. in prep.; van Kempen, Kristensen et al. (2010)

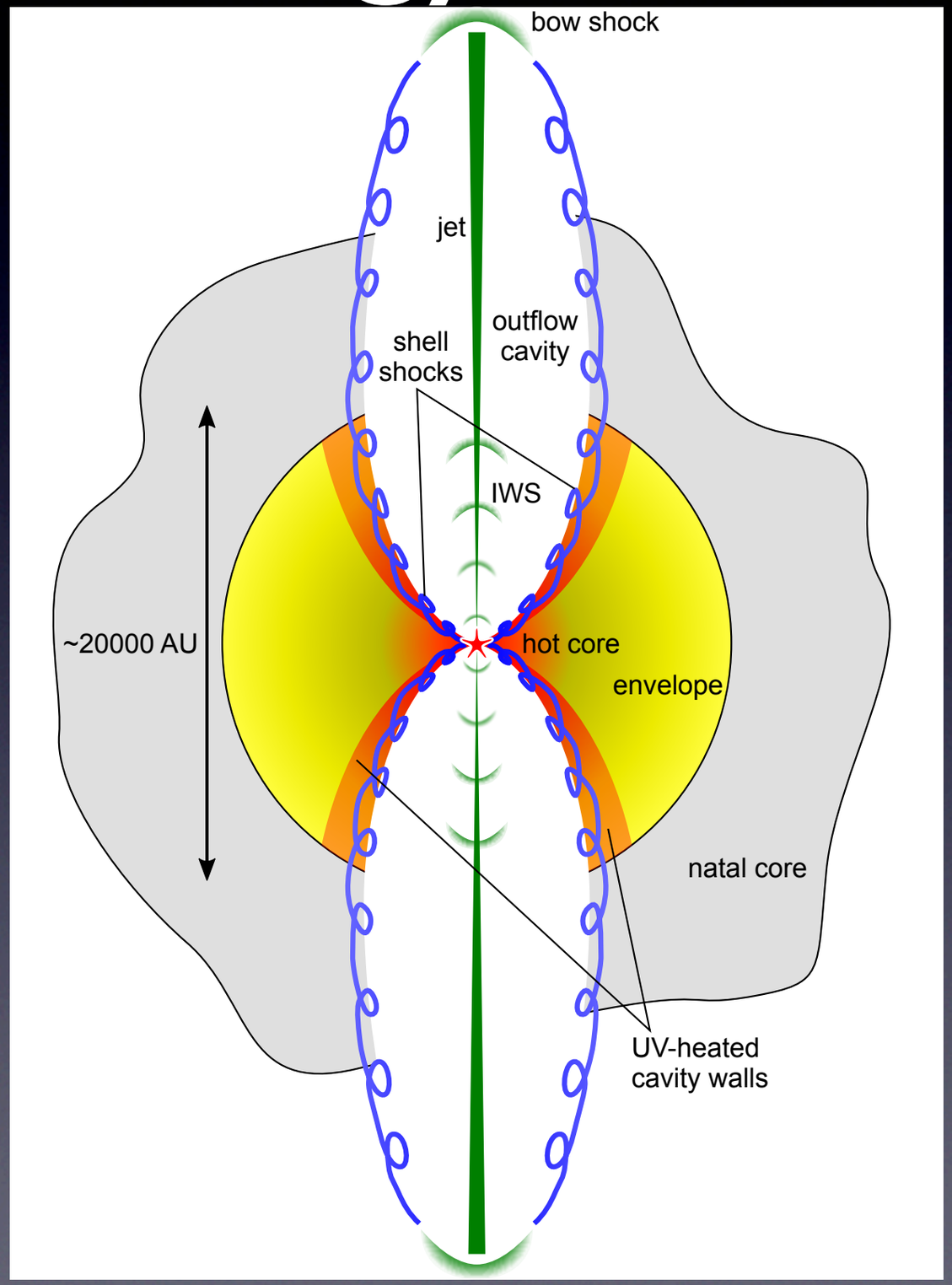
Modelling strategy

Step 1:
Split YSO into different components

Step 2:
Model each component using state-of-the-art models

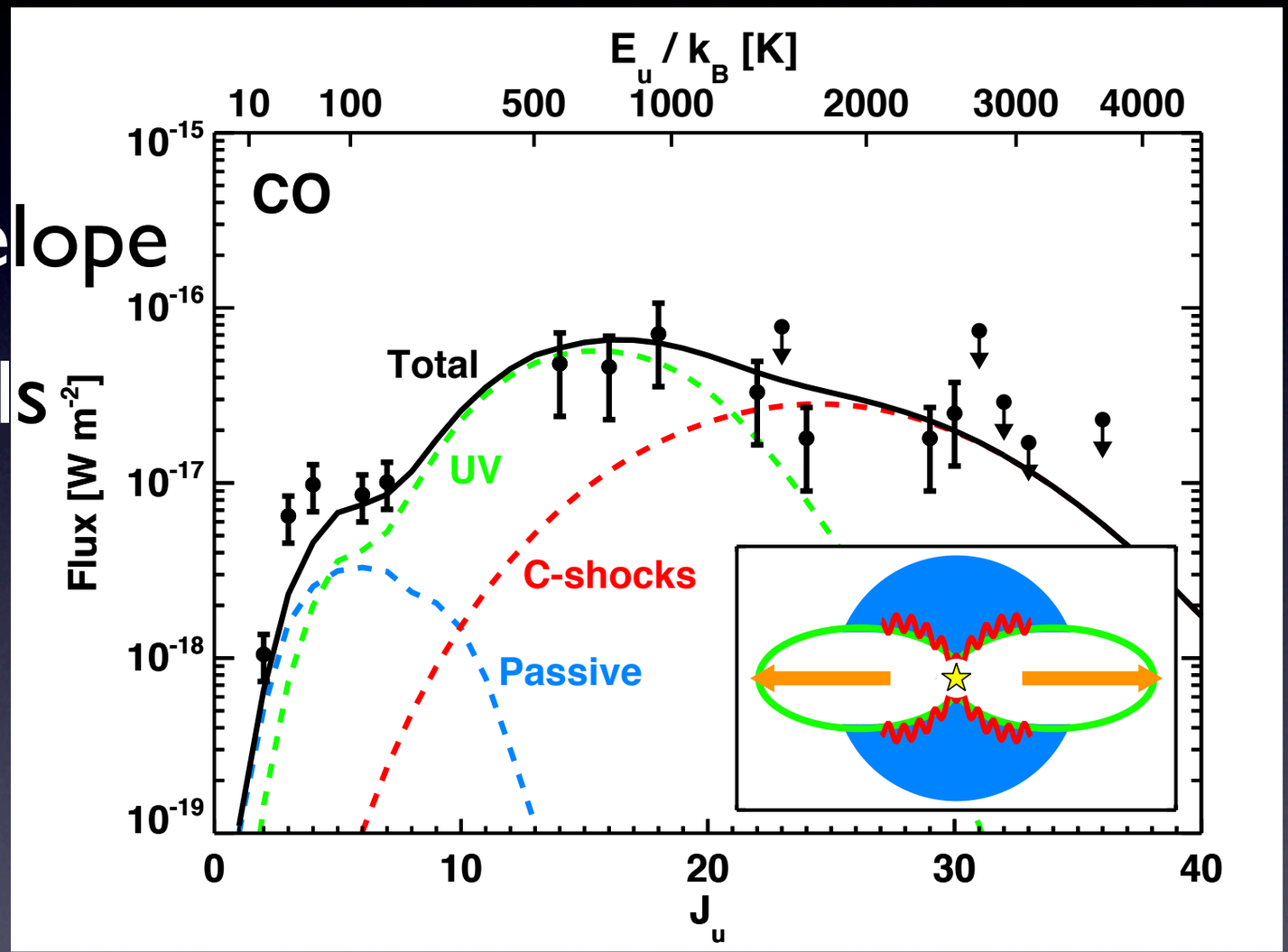
Status:
Working for CO
(Yildiz et al. 2010, Visser et al. in prep.)

Goal:
Do this for H_2O



Decomposing CO

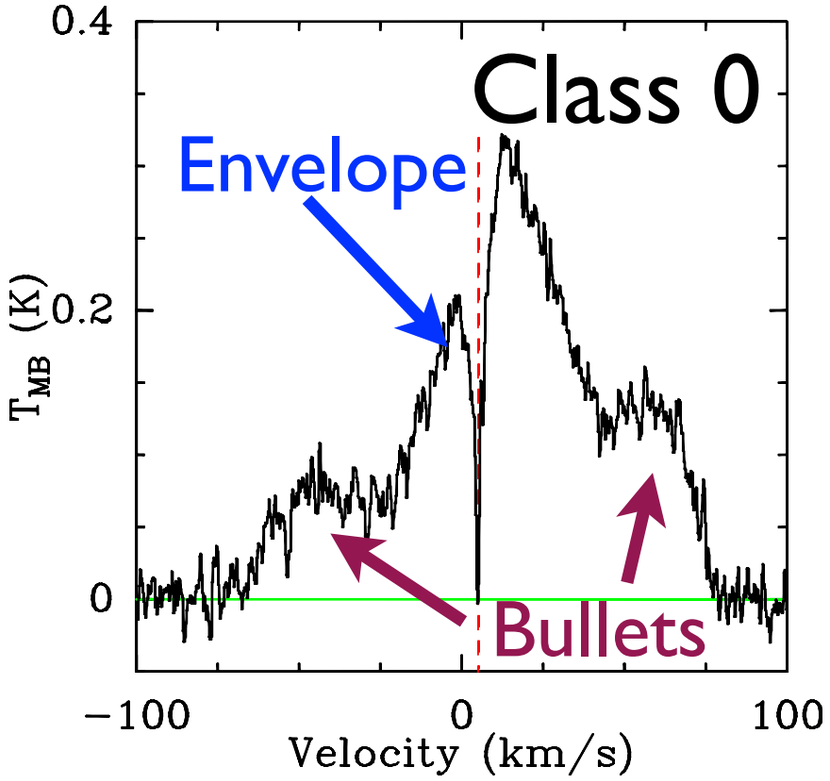
- Three mechanisms:
  - Passively heated envelope
  - UV-heated cavity walls
  - Shocks
- Free parameters:
  - UV-luminosity (0.1-1.0 $L_\odot$)
  - v_{shock} (20 km/s)

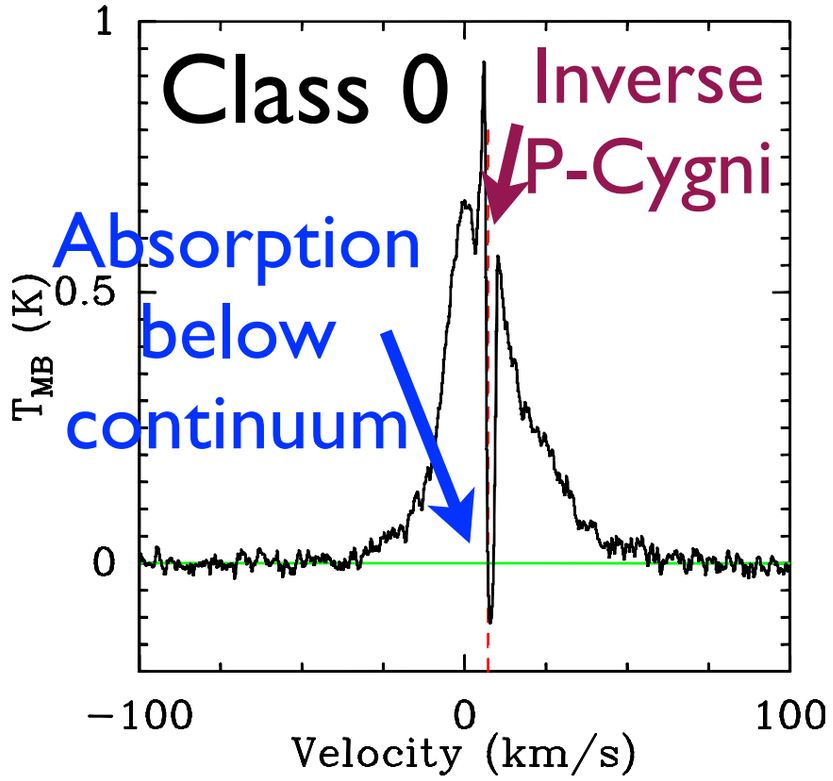


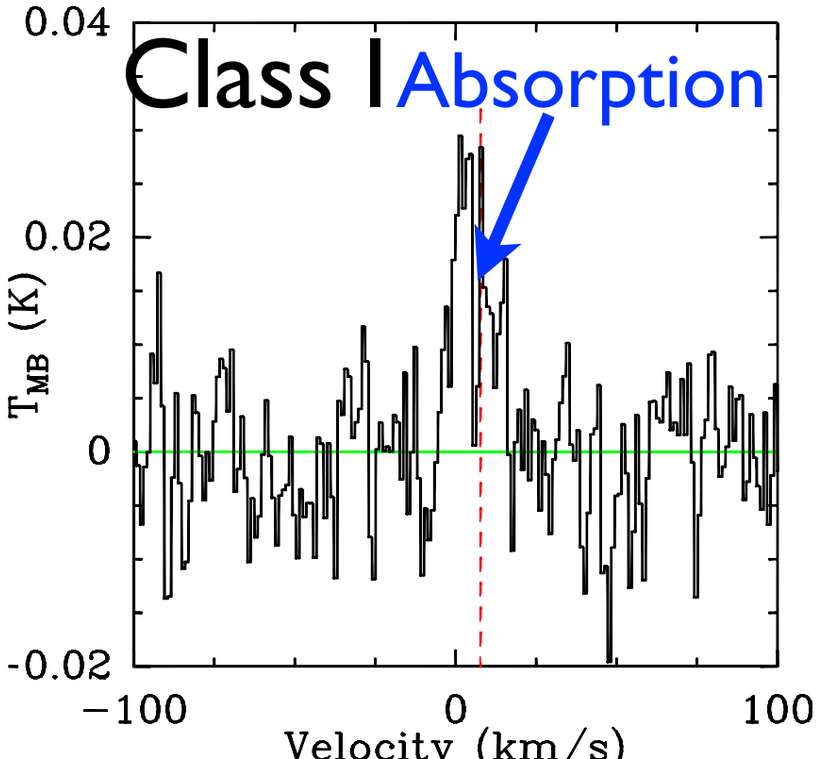
Seen in all YSOs!

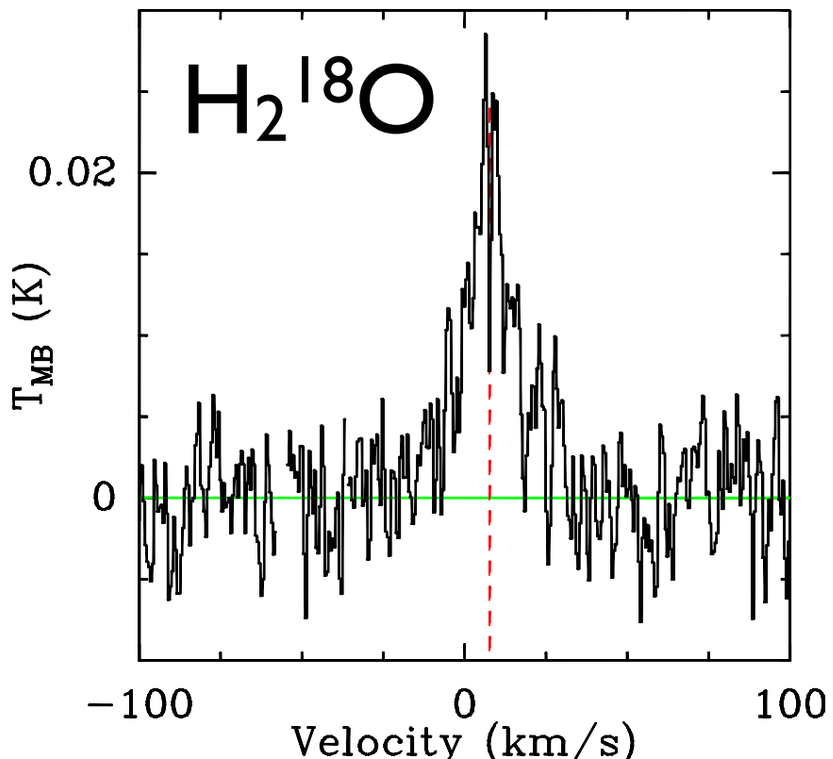
van Kempen, Kristensen et al. (2010)

H_2O profile safari









HIFI observations of H_2O 1_{10}-1_{01} at 557 GHz

If it moves, it emits H_2O!

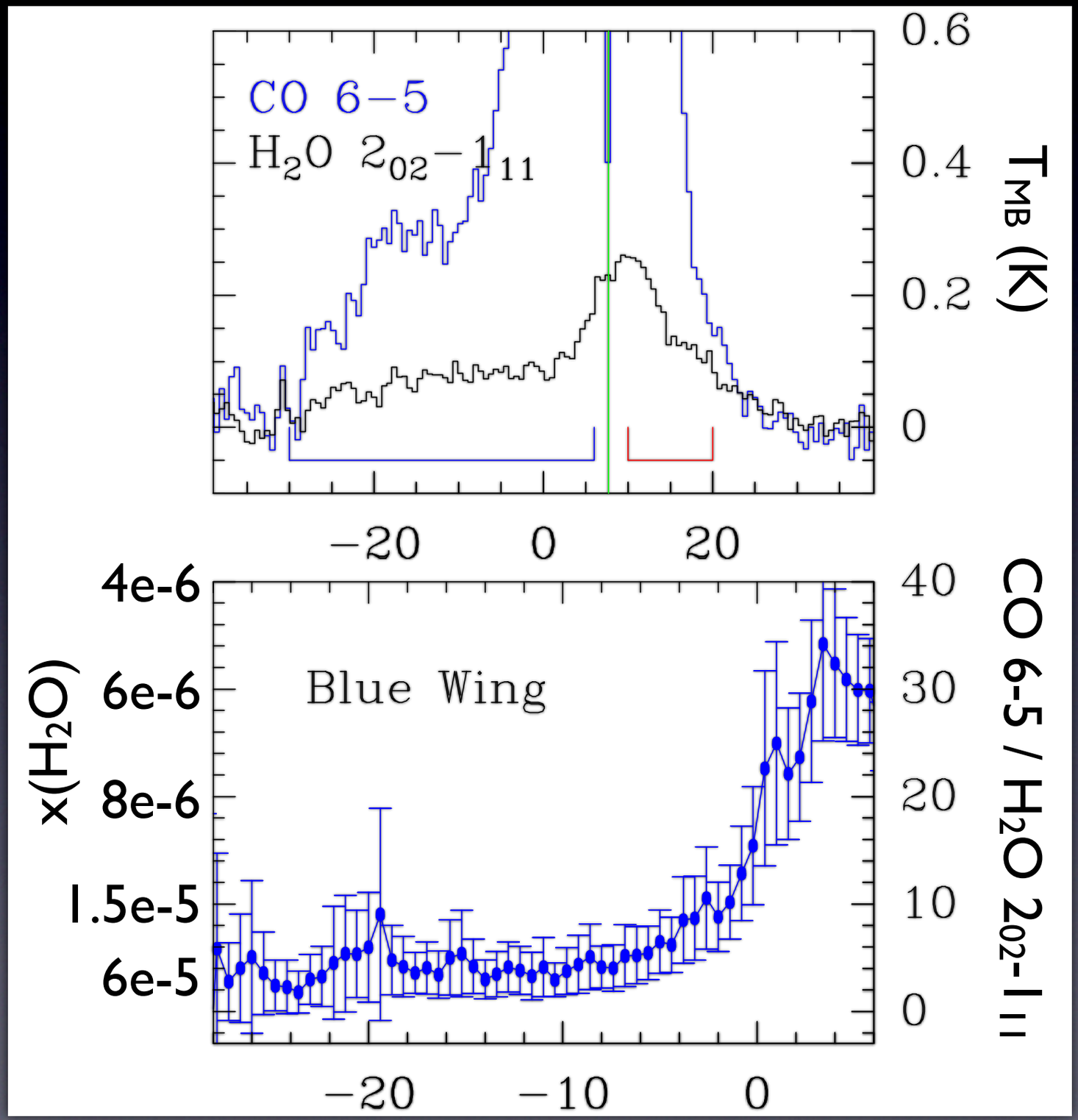
Kristensen et al. (2010); Kristensen et al. in prep.

H_2O abundance

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

Consistent with, e.g., Orion (Franklin et al. 2008)

Fraction of outflow gas where O + H_2 -> H_2O: ~ 10%



Take-home messages

- H_2O:
  - Detected in all (low-mass) YSOs
  - If it moves, it emits water
    - x(H_2O) increases with velocity in shocks
    - Quiescent abundance is low
- Modelling:
  - 3-component model (passive+UV+shocks) works

Origin of H_2O emission