Water in star-forming regions with Herschel

- Introduction and motivation
- A 495 hr key-program for Herschel
  - Low- /Intermediate-mass YSOs
    - Pre-stellar cores
    - Class 0/I sources
    - Outflows
  - High-mass YSO's
  - Circumstellar disks

http://www.strw.leidenuniv.nl/WISH

Motivation: H_2O as chemical and physical probe

- H_2O abundance shows large variations in SF regions: $<10^{-8}$ – $3.\ 10^{-4}$ => unique probe of different physical regimes
  - Natural filter of warm gas
- Main reservoir of oxygen => affects chemistry of all other species
- Traces basic processes of freeze-out onto grains and evaporation, which characterize different stages of evolution

pre-stellar cores => YSO's => disks => comets

Motivation (cont'd)

- H_2O as a dynamical probe of warm high density gas: infall, outflow, quiescent gas, mixing, …
- H_2O's role in the thermal balance: when and where does H_2O become dominant heating or cooling agent?
- HDO/H_2O: determined by gas-phase or grain-surface processes? Relation with comets?
- H_2O as a radiative transfer challenge: high/low optical depths, masers, ….
- HIFI legacy

Proposed Herschel-HIFI key program

- Survey a selected set of H_2O lines in star-forming regions ranging from pre-stellar cores to low-, intermediate- and high-mass YSO's and circumstellar disks
- Include isotopic lines: $H_2{}^{18}O$, $H_2{}^{17}O$ (HDO from ground)
- Include limited maps of H_2O (outflows, … ~2'x2')
- Include chemically related species: O, OH, H_3O^+
- Include a few key high-J CO lines
- Include radiation diagnostics (UV, X-rays)
- Complementary PACS data

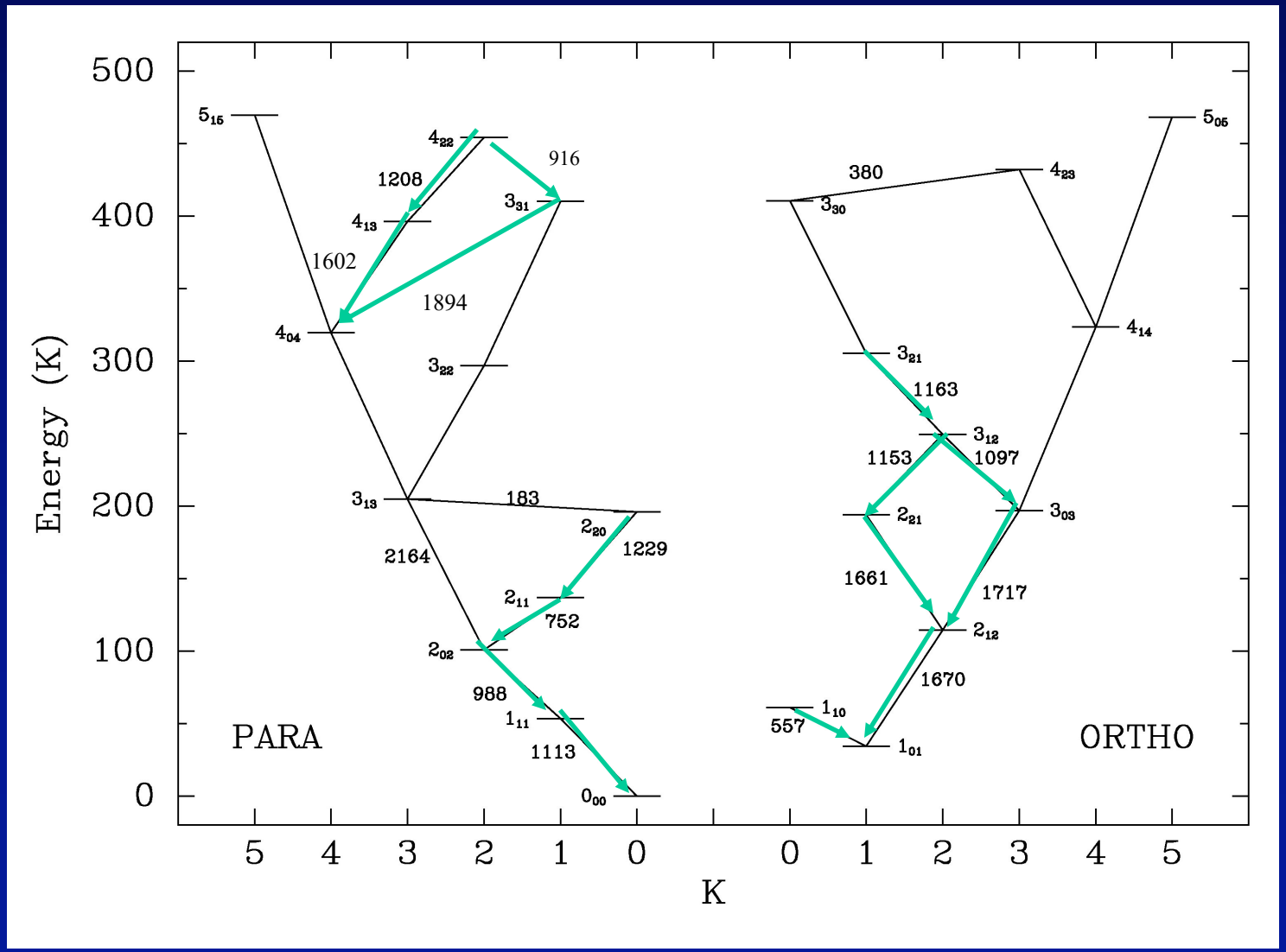
Herschel/HIFI data will be unique

HIFI is a major step forward because of:

- **higher spatial resolution (3-5 w.r.t. SWAS/ODIN, 8 with ISO-LWS)**
- **higher sensitivity (10 w.r.t. SWAS/ODIN)**
- **higher spectral resolution => shocks vs. quiescent H_2O (10^4 w.r.t. LWS)**
- **lines arising from large range of energy levels**

At least factor 10 deeper than ISO-LWS

H_2O HIFI lines

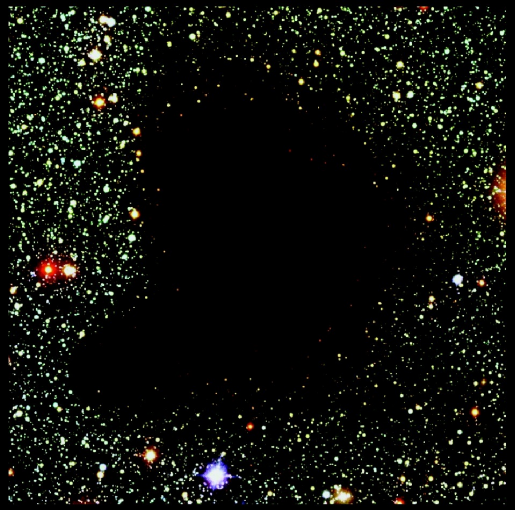


Observe common set of lines for all YSOs

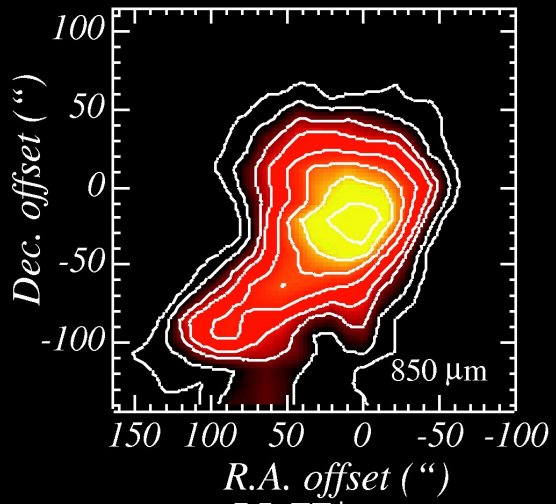
Low-Mass: Pre-stellar cores

B68

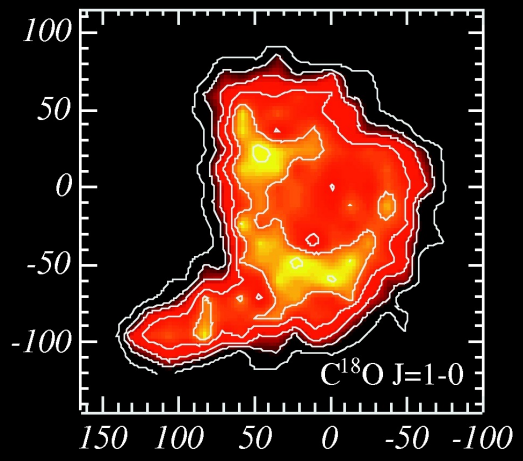
Optical



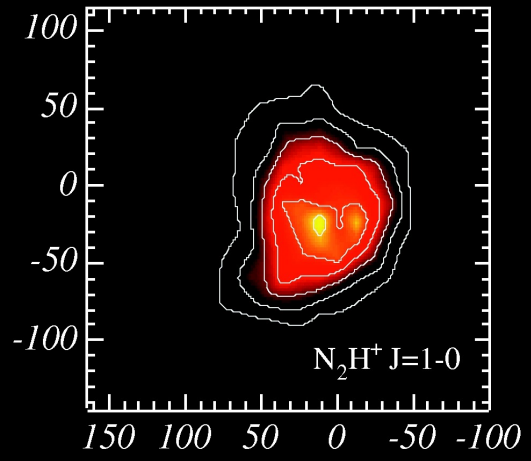
Submm continuum



CO



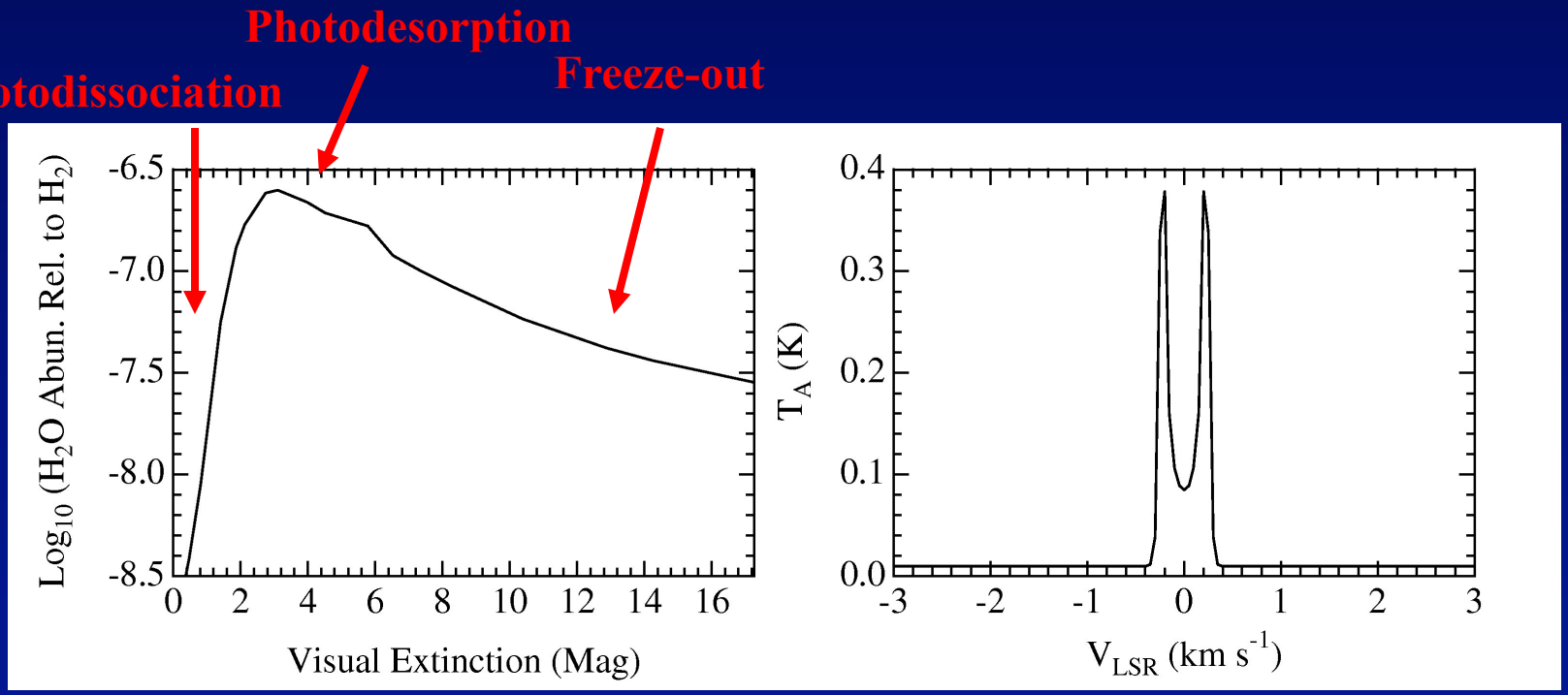
N_2H^+



More than 90% of all molecules except most volatile species frozen out on T~10 K grains: how and where is H2O ice formed?

Bergin et al. 2002
Caselli et al. 2002

Model B68 water profile



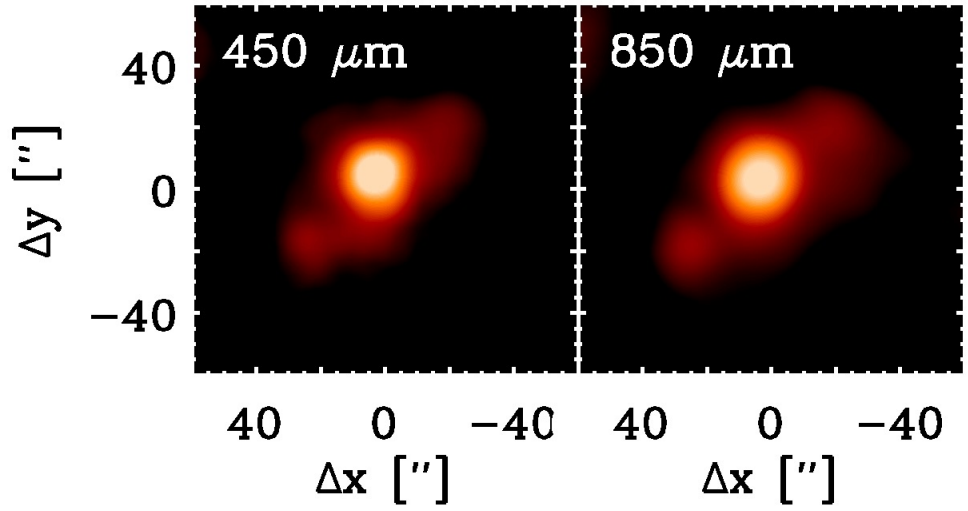
- Where does onset for H_2O ice formation and freeze-out occur?
- How effective are non-thermal desorption mechanisms?

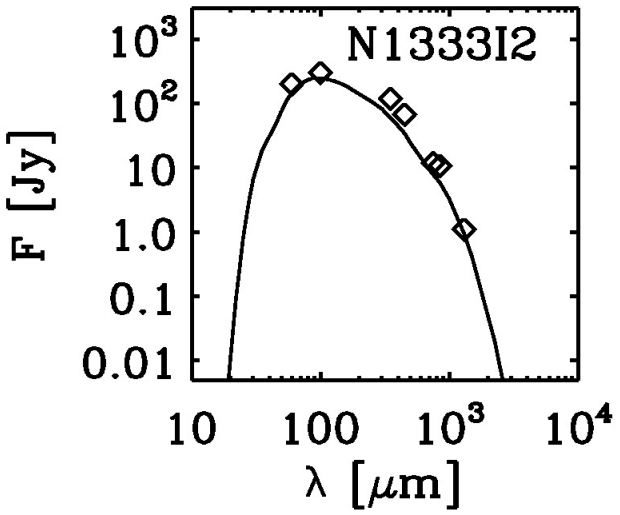
Predicted H_2O profile and strength depends sensitively on various processes and on thermal structure core

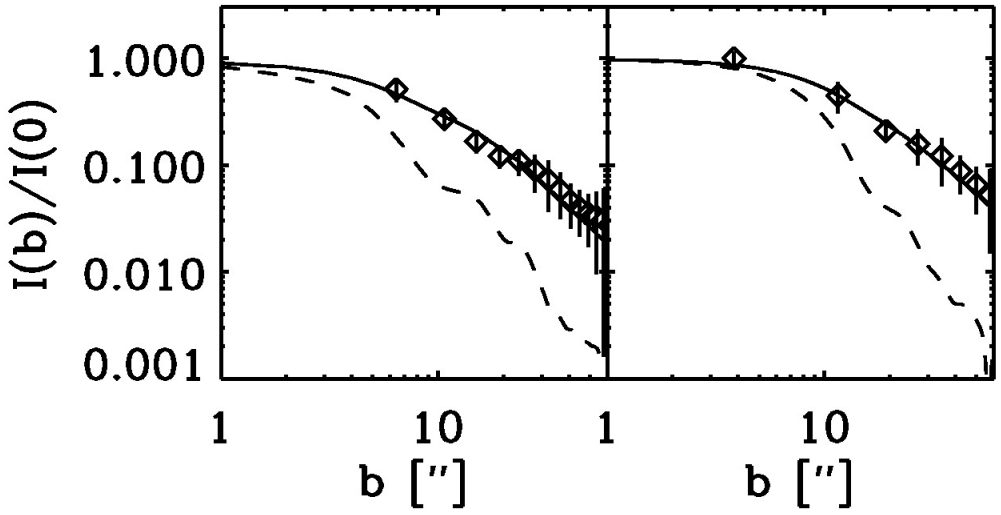
Bergin et al.

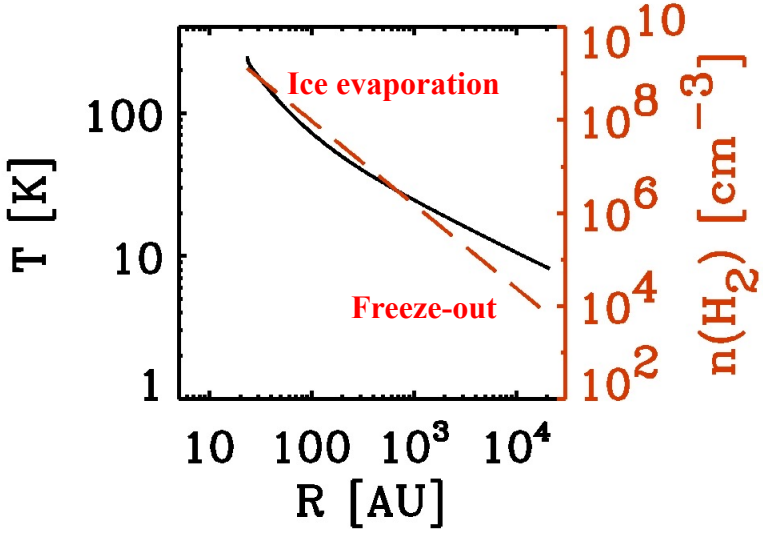
Submillimeter emission

Probing the physical structure



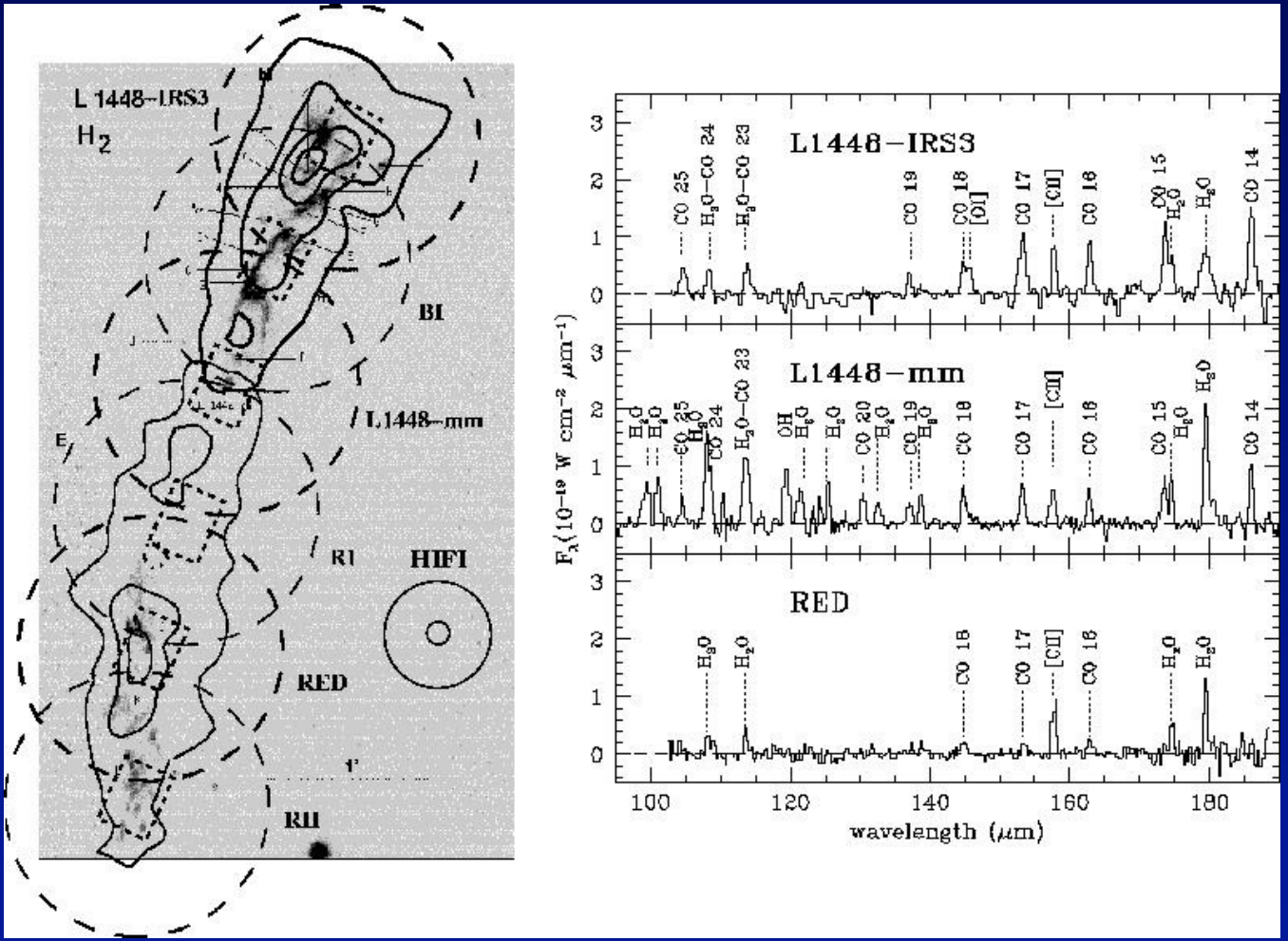






Jørgensen et al. 2003

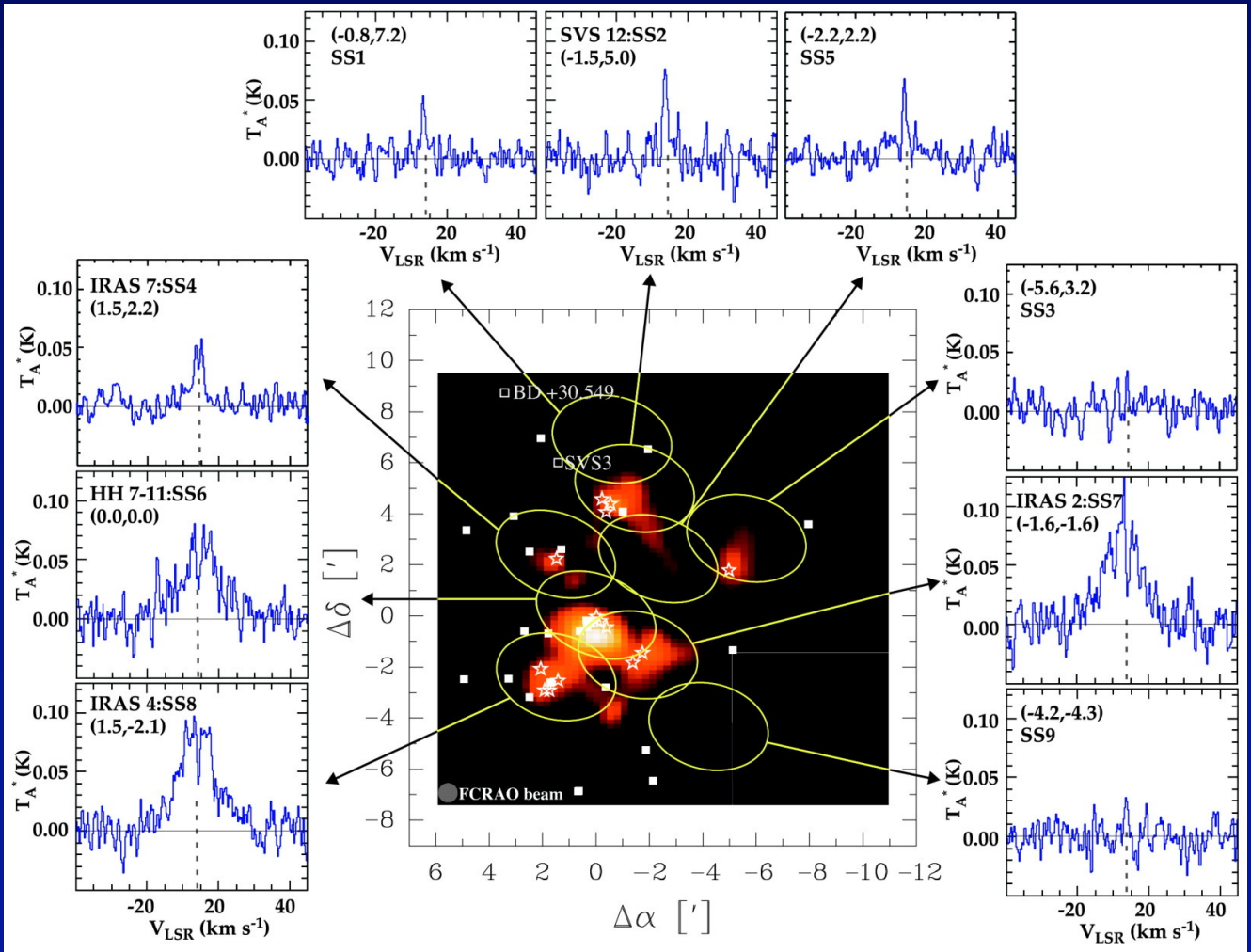
Low-Mass: Class 0 sources



-What is origin of strong H_2O emission?
Quiescent envelope or outflow?

Nisini et al. 1999
Ceccarelli et al. 1998

SWAS map of NGC 1333



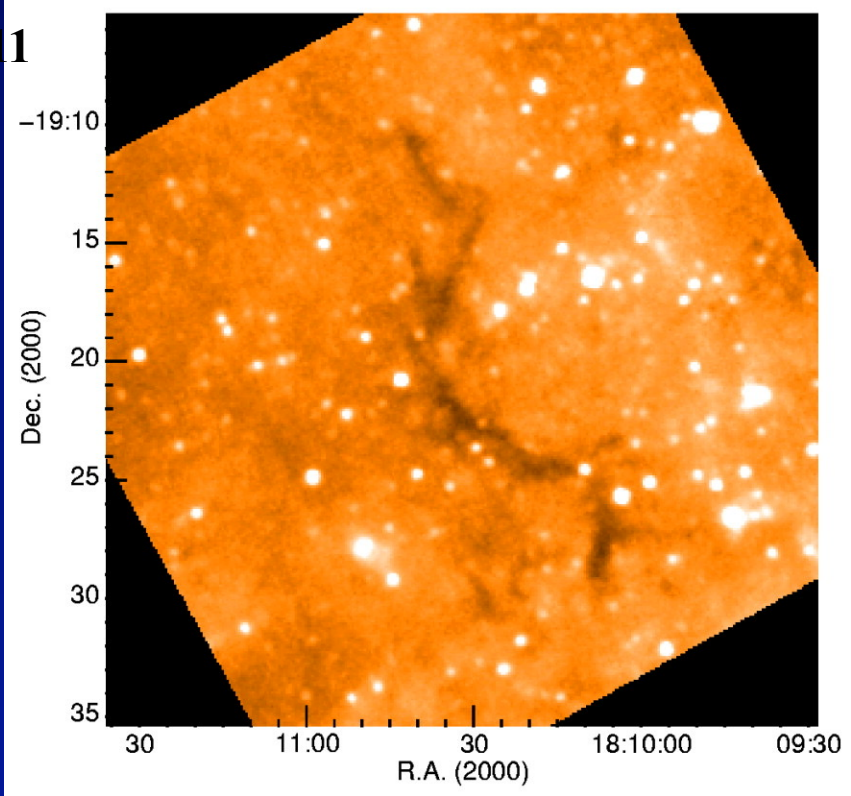
Bergin et al. 2003

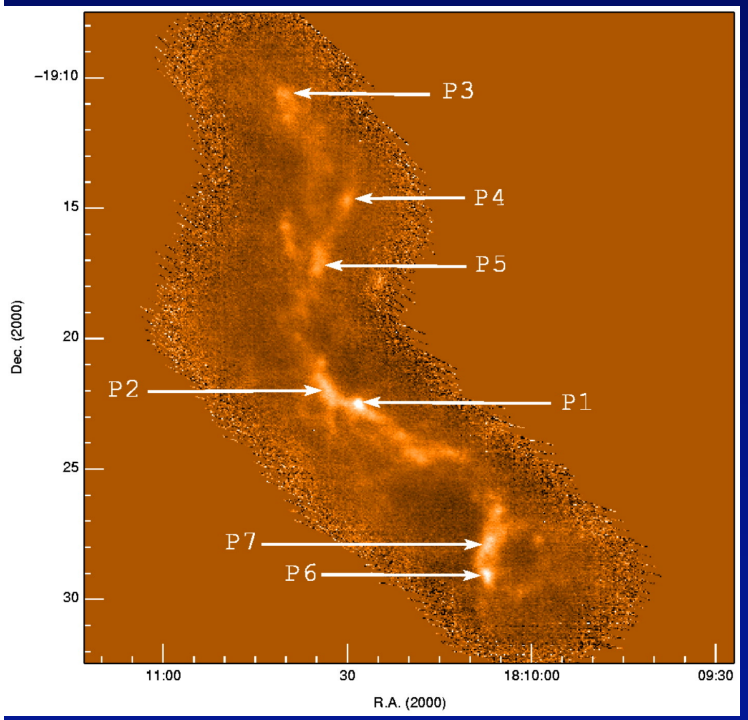
High-Mass Pre-Stellar cores

G11.11

MSX

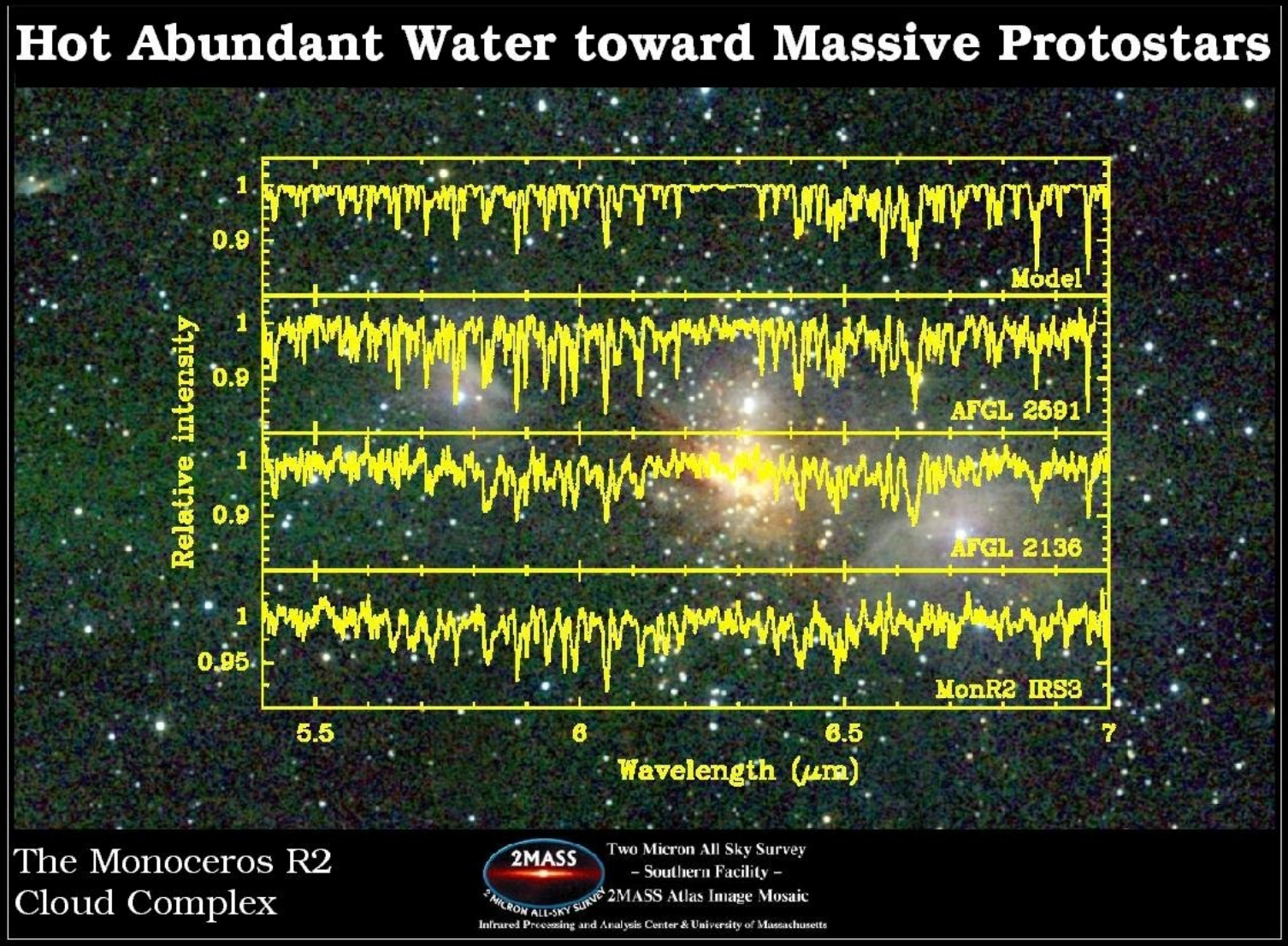
SCUBA





- Precursors of high-mass YSOs?

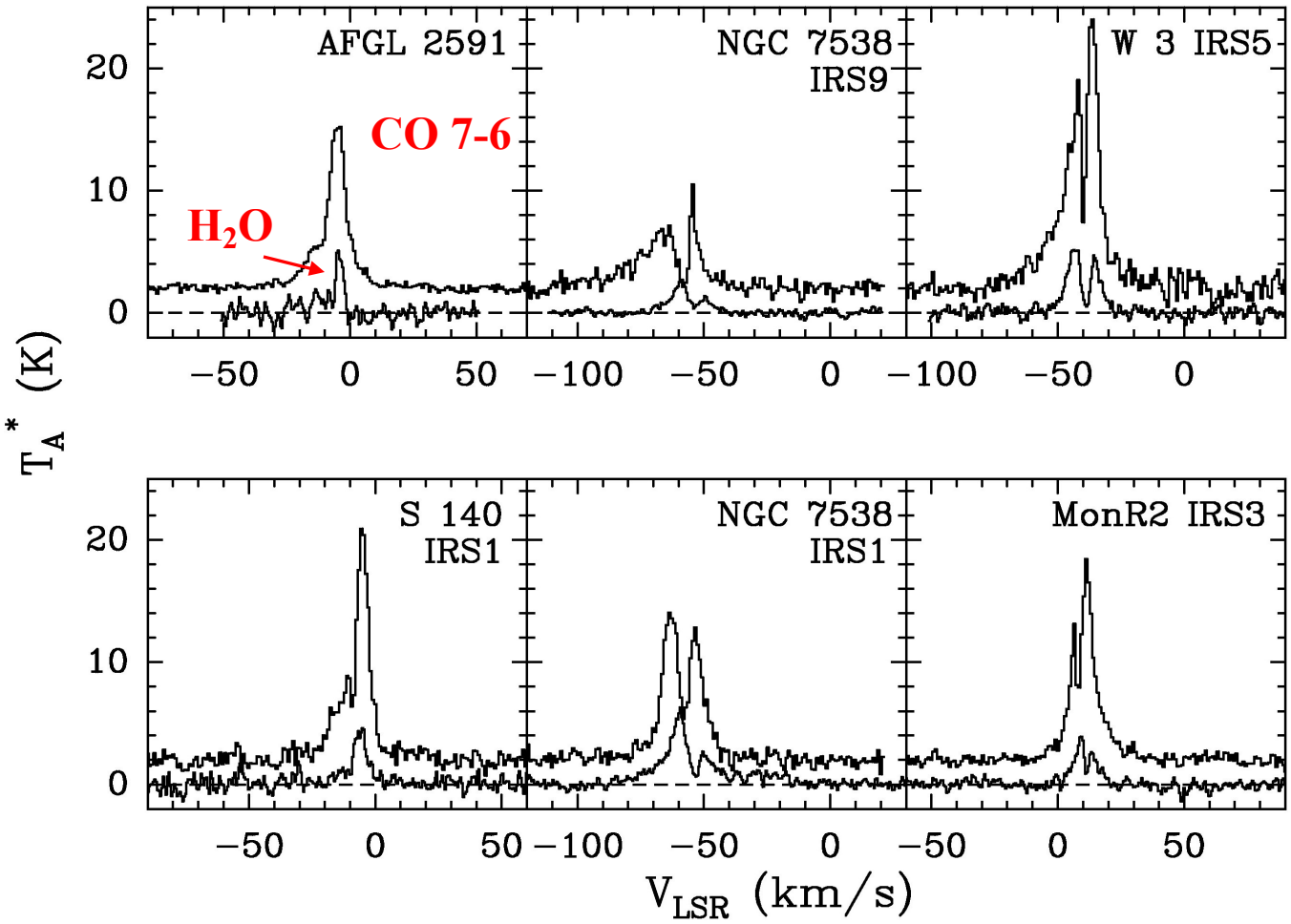
Johnstone et al. 2003



ISO data

Boonman et al. 2003

SWAS data massive YSOs

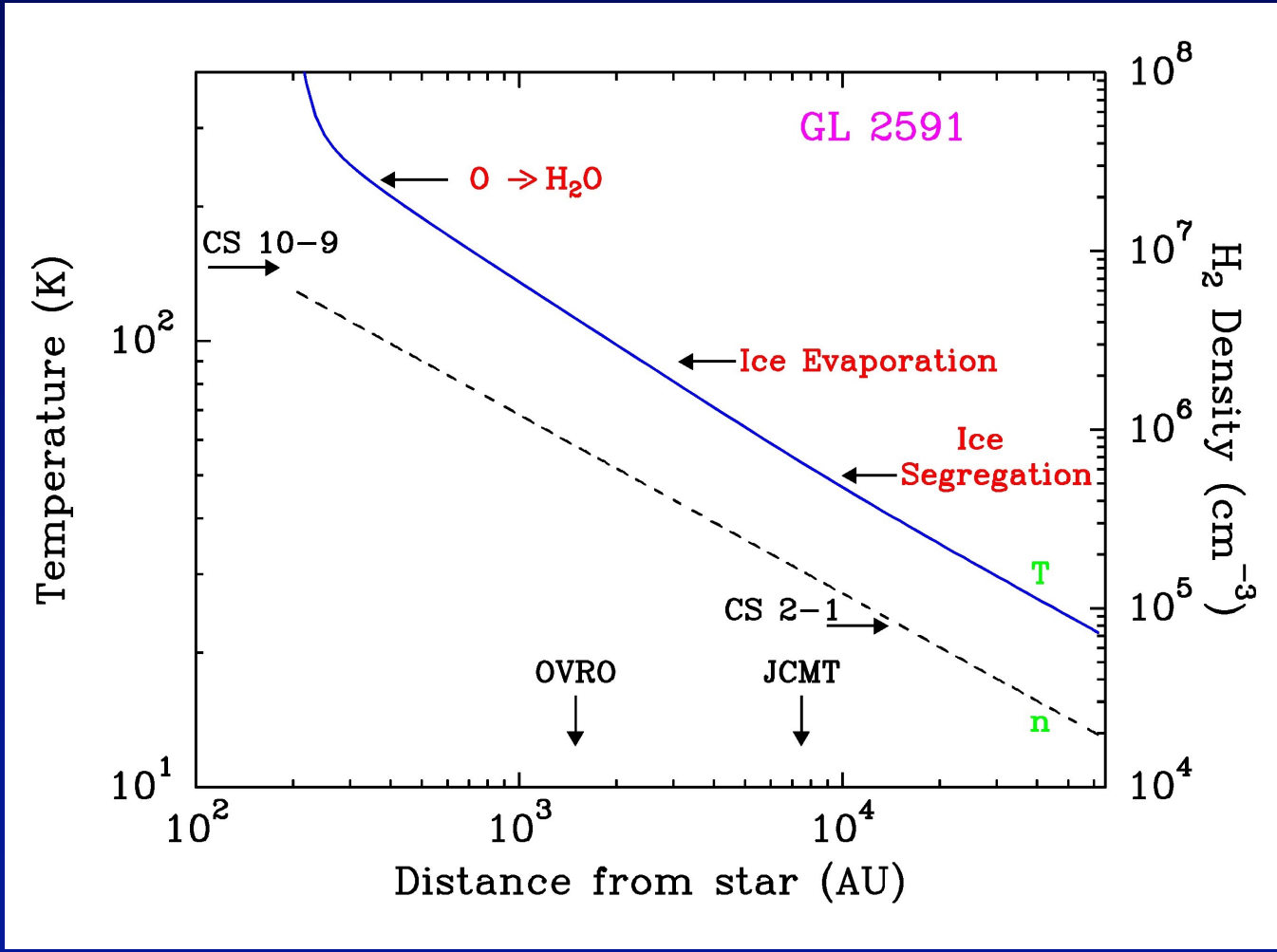


Compare with JCMT CO 7-6 data to assess contribution outflow (at most 50%)

Snell et al. 2000

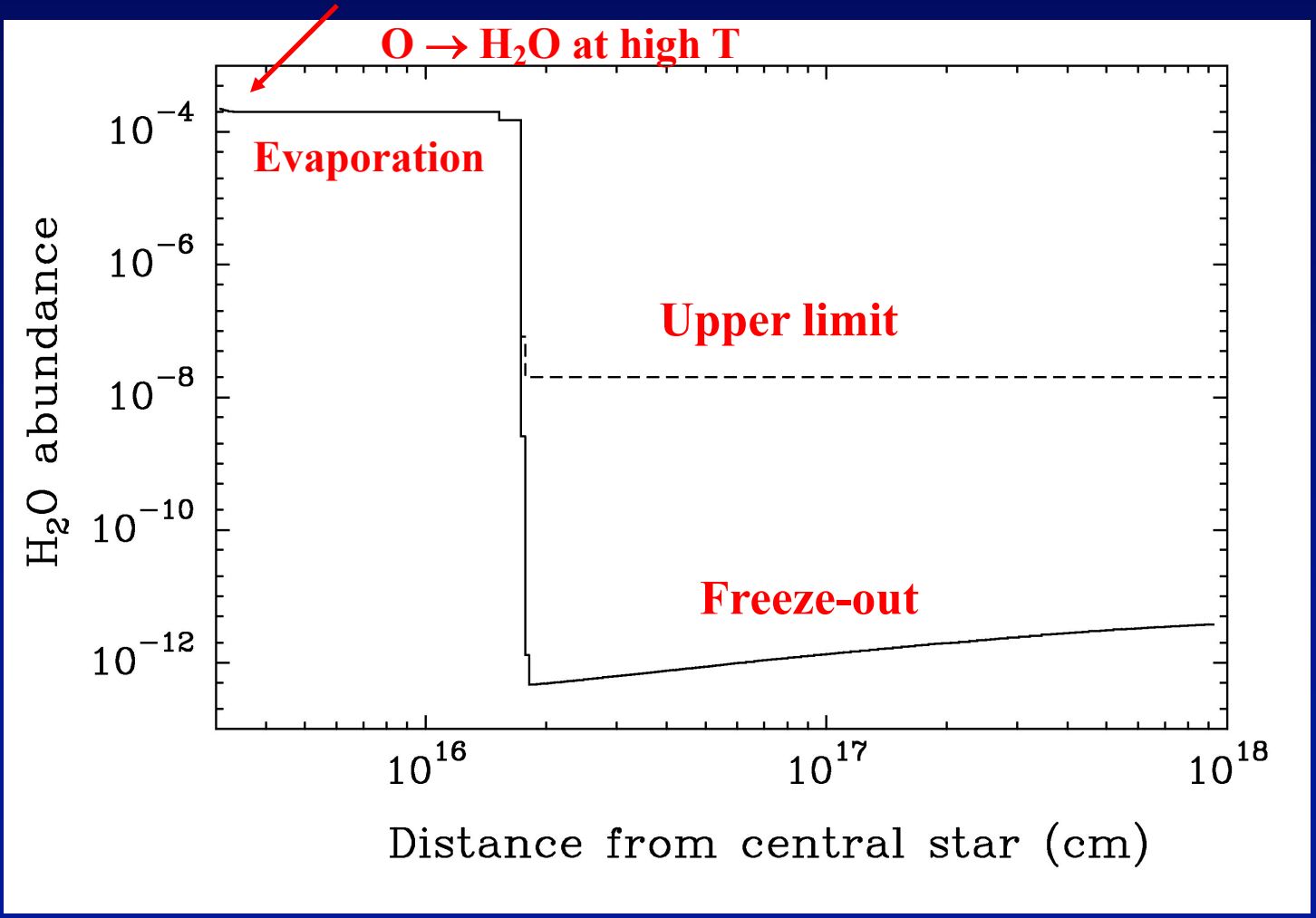
Boonman et al. 2003

Typical temperature and density structure YSO

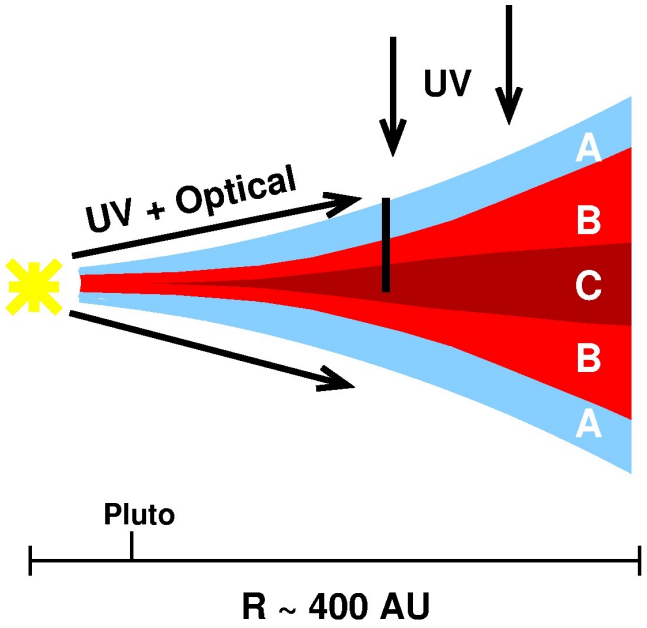


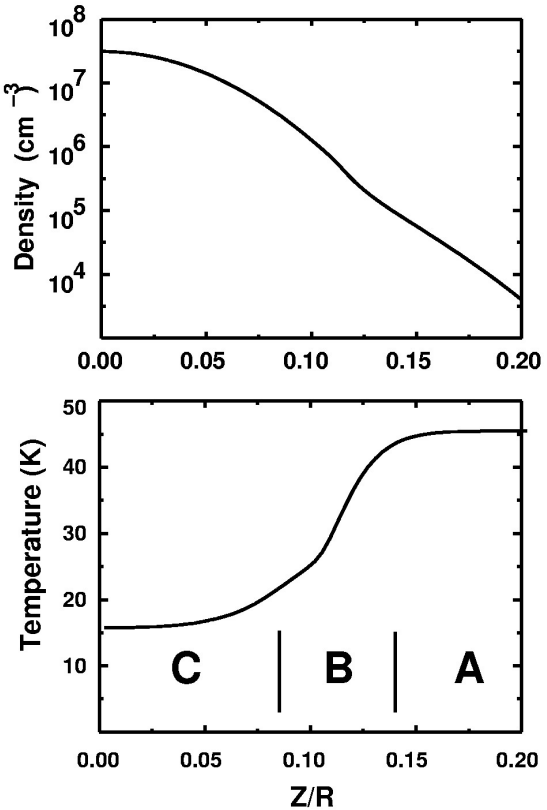
Van der Tak et al. 1999, 2000

Predicted abundance profile in YSOs

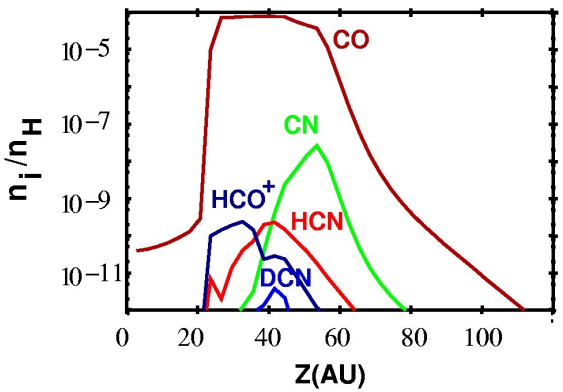


H_2O in protoplanetary disks





- Can H_2O trace dynamical processes in disks, i.p. vertical mixing?
- Importance of photodesorption?



Van Zadelhoff et al. 2003
Aikawa et al. 2002