Water high resolution spectroscopic observations of protostars with Herschel

Fabrice Herpin

LAB-Bordeaux

France

on behalf of the WISH team

WISH

SRON

Max-Planck-Institut für Radioastronomie

LAB

Observatoire Aquitain des Sciences de l'Univers

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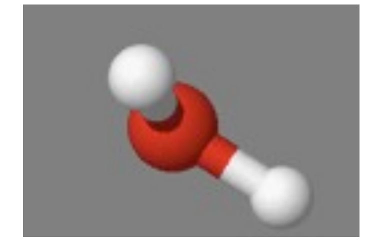
CENTRO DE ASTROBIOLOGÍA

Water in star-forming regions with Herschel
PI: E. van Dishoeck

- A 418 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

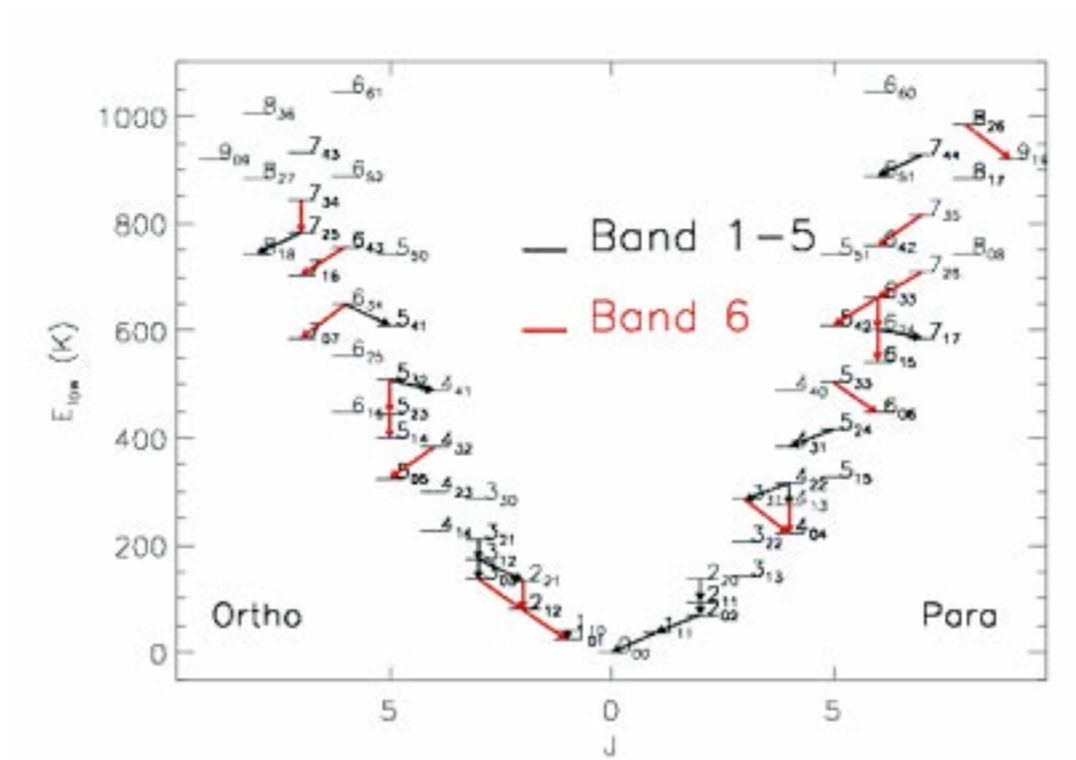
Motivation:
H_2O as chemical and physical probe



- H_2O abundance shows large variations in SF regions: $<10^{-9} - 10^{-4}$

  ⇒ unique probe of different physical regimes

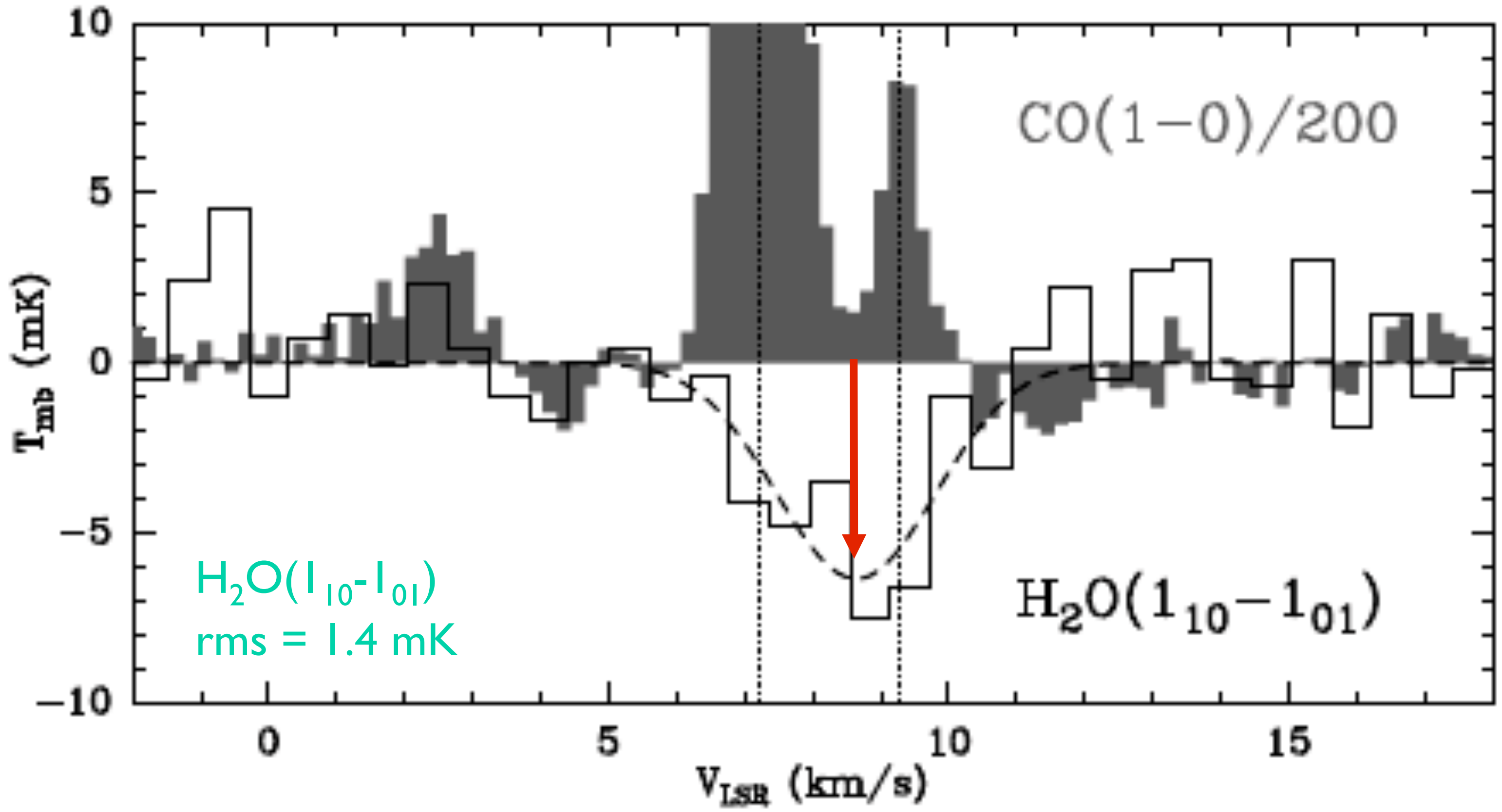
- Traces basic processes of freeze-out onto grains and evaporation, which characterize different stages of evolution
- Natural filter of warm gas
- Main reservoir of oxygen ⇒ affects chemistry of all other species
- H_2O as a dynamical probe of warm high density gas: infall, outflow, quiescent gas, mixing, …
- H_2O's role in the thermal balance: when and where does H_2O become dominant heating or cooling agent?



Prestellar cores:
first measurement of water vapor in dark regions

L1544

Caselli et al. (2010)



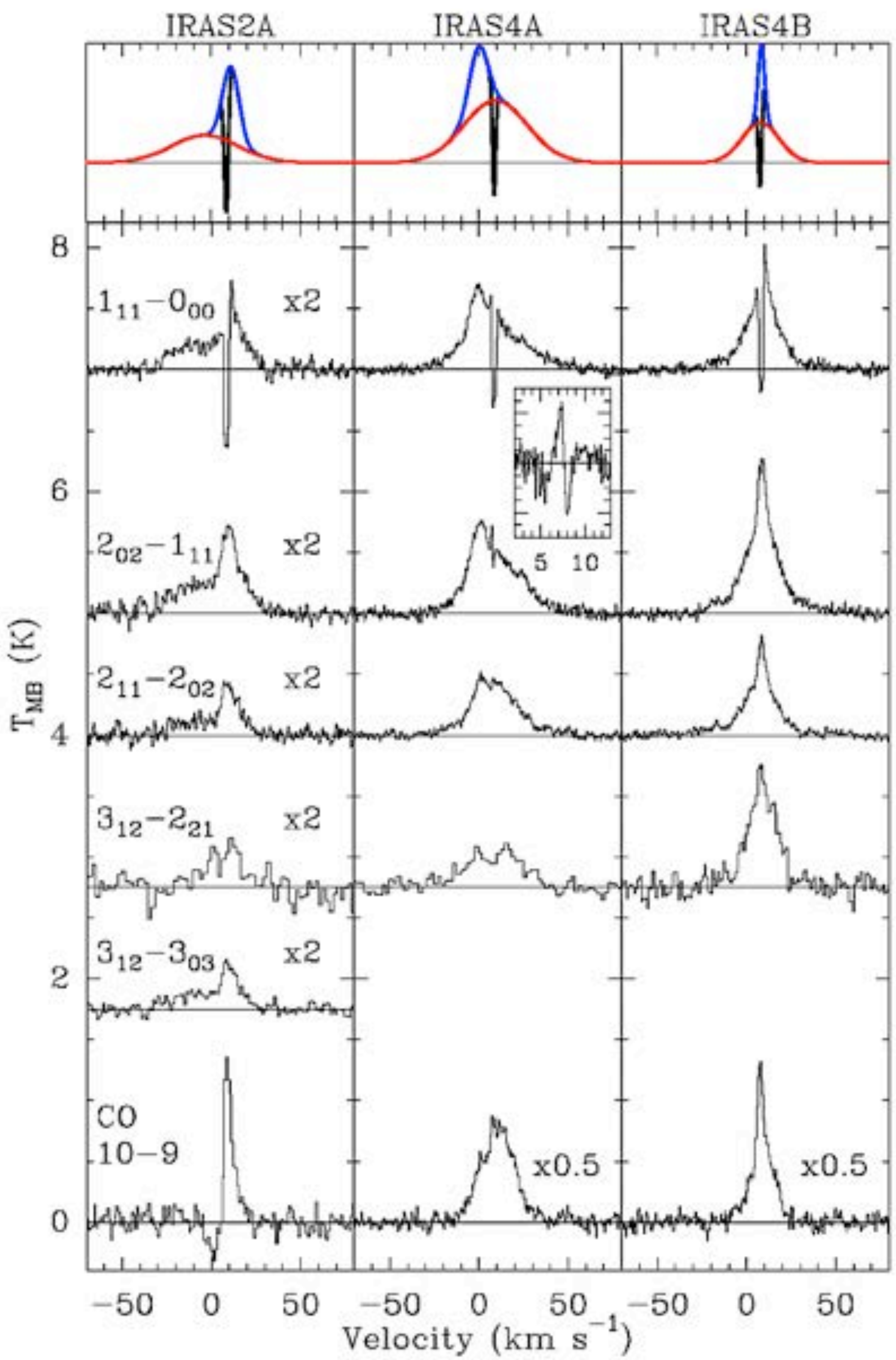
$X(H_2O) < 10^{-9}$ for $n=10^5$ cm^{-3}

Low H_2O Column densities

Low-mass protostars: NGC1333

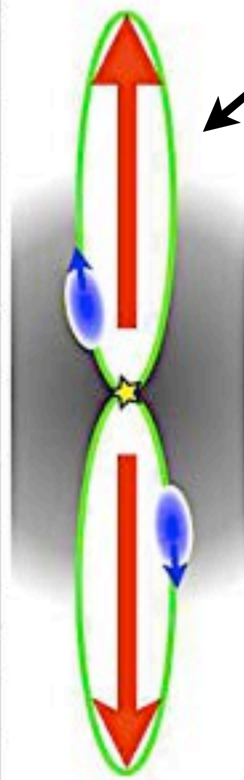
Kristensen et al. (2010)

H_2O spectra of the three NGC1333 sources



decomposition into broad (>25 kms^{-1}), medium (~5–10 kms^{-1}) and narrow (<5 kms^{-1}) components.

physical origin of each component



bulk of emission arises from shocks, both on small scales (few hundred AU) and in large-scale molecular jets.

The inset shows a zoom on the inverse P Cygni profile in the H_2O 2_{02}– 1_{11} line of IRAS4A
⇒ infall in the envelope.

High H_2O abundance in the ejections (10^{-5}-10^{-4})
but low in the envelope (~10^{-9})

Montag, 10. Oktober 2011

High-mass protostars

- **F. Herpin**, L. Chavarria, A. Baudry, S. Bontemps, J. Braine, T. Jacq (Bordeaux)
- **F. van der Tak**, R. Shipman, F.P. Helmich, Y. Choi (Groningen)
- **F. Wyrowski**, S. Leurini, T. Csengeri (Bonn)
- J. Cernicharo, J. Goicoechea, F. Daniel (Madrid)

Set of observations

- pointed HIFI obs of 14 lines in 19 sources, including isotopic lines: $H_2^{18}O$, $H_2^{17}O$ + deep HIFI 1_{10}-1_{01} obs of four infrared-dark cloud cores

  ⇒ abundance + distribution of H_2O in envelopes

- Include chemically related species: O, OH, H_3O^+
- Include a few key high-J CO lines
- Include radiation diagnostics (UV, X-rays)
- maps of H_2O: HIFI 1_{10}-1_{01} & 2_{02}-1_{11} mini-maps + 1_{11}-0_{00} large maps & PACS maps in 4 lines of 6 proto-clusters

  ⇒ water in massive outflows, filling, cooling & chemistry of intra-cluster gas

- Complementary PACS data

evolution ↓

Pre-stellar cores
G11.11−0.12-NH_3-P1
G11.11−0.12-SCUBA-P1
G28.34+0.06-NH_3-P3
G28.34+0.06-SCUBA-P2

mIR-quiet HMPOs
IRAS05358+3543
IRAS16272−4837
NGC6334-I(N)[a]
W43-MM1
DR21(OH)[a]

mIR-bright HMPOs
W3-IRS5
IRAS18089−1732[a]
W33A[a]
IRAS18151−1208
AFGL2591[a]

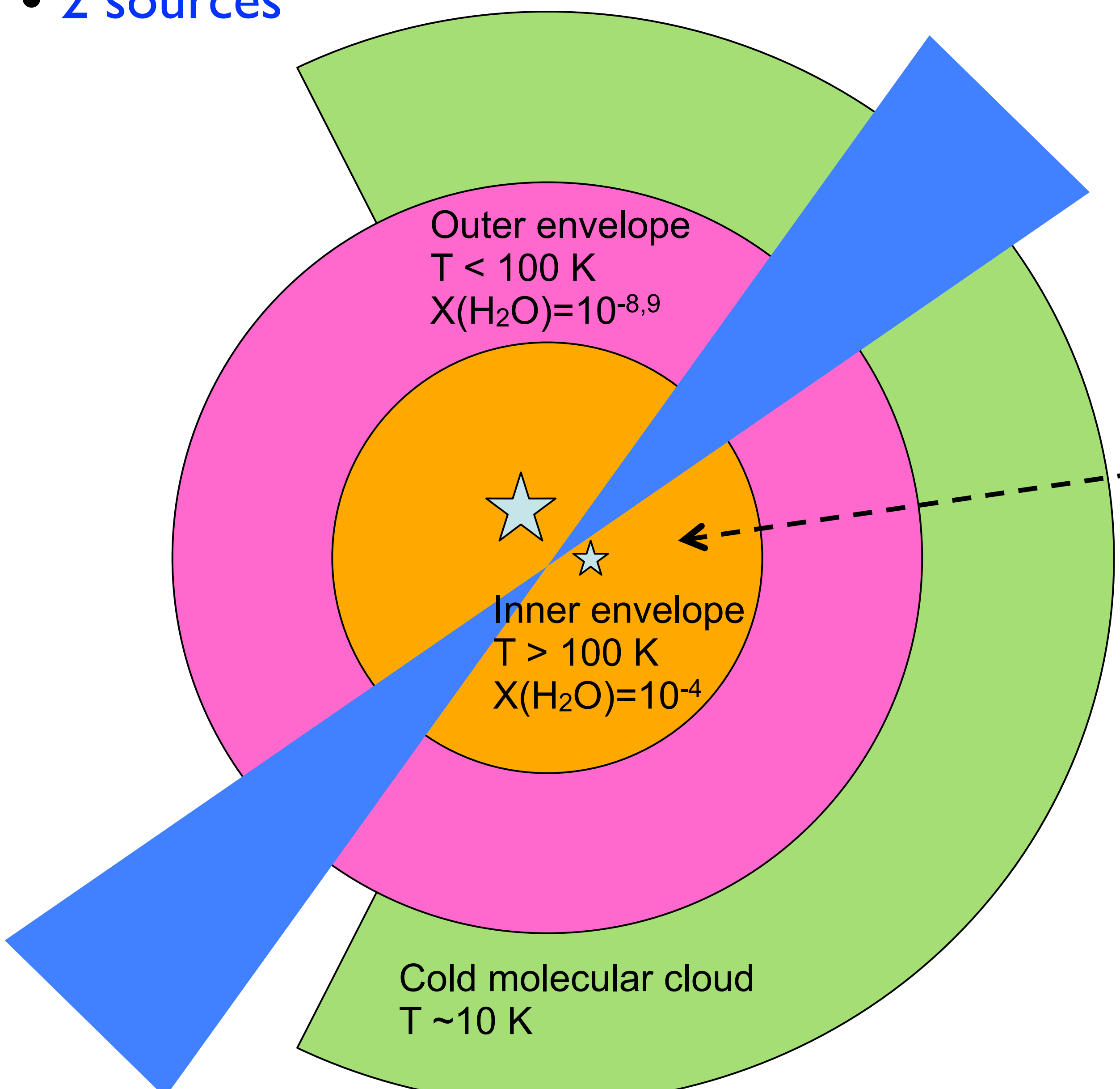
Hot Molecular Cores
G327−0.6
NGC6334-I[a]
G29.96−0.02[a]
G31.41+0.31 (IRAS20126+4104)

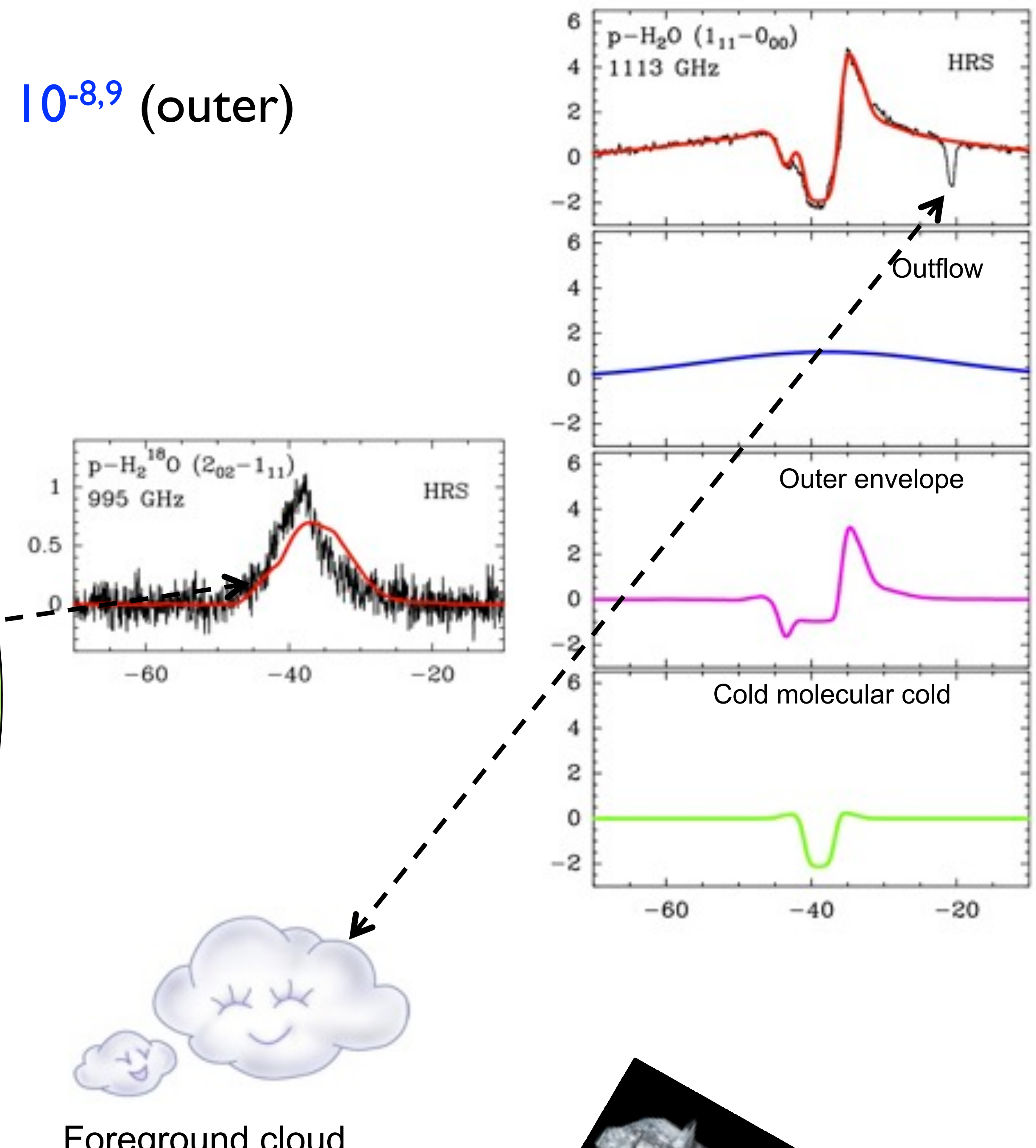
UC HII Regions
G5.89−0.39
G10.47+0.03
G34.26+0.15
W51N-e1[a]
NGC7538-IRS1[a]

High-mass protostars: W3-IRS5

Chavarria, Herpin, Jacq et al. (2010)

- outflow
- no infall
- cold outer envelope (T≤10 K)
- H_2O abundance jump : 10^{-4} (inner, T>100 K) - $10^{-8,9}$ (outer)
- 2 sources



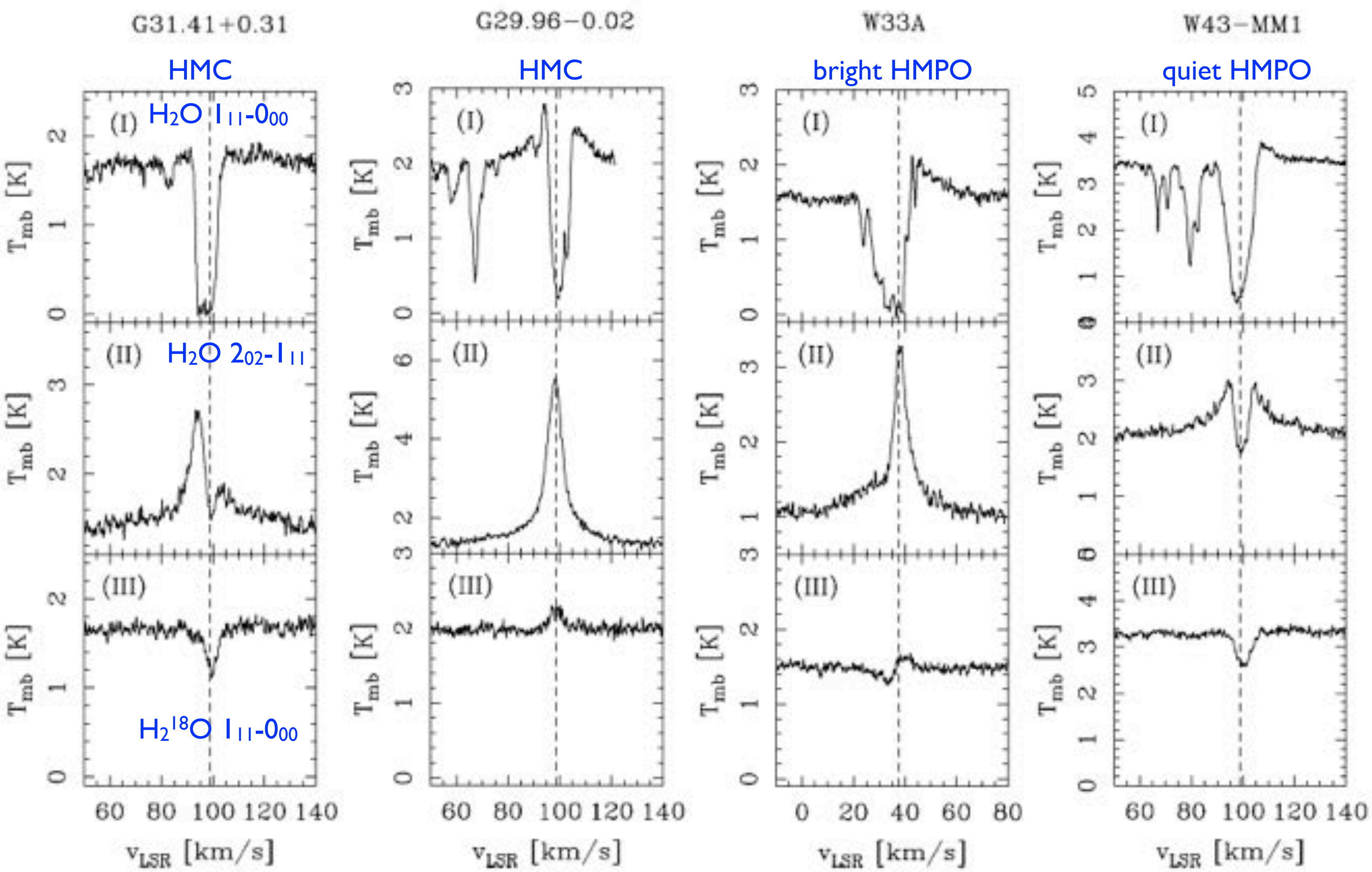


HERSCHEL SPACE OBSERVATORY

High-mass protostars

Marseille, van der Tak , Herpin et al. (2010)
Chavarria et al. (in preparation)

Source	X_{in}	X_{out}	V_{tur} (km/s)	$V_{inf/exp}$ (km/s)
IRAS 05358	$1 \cdot 10^{-6}$	$1.5 \cdot 10^{-8}$	1.9	1.9
IRAS 16272	$5 \cdot 10^{-7}$	$3.0 \cdot 10^{-9}$	2.0	- 0.2
NGC 6334 IN	$4 \cdot 10^{-7}$	$4.0 \cdot 10^{-9}$	2.0	- 0.1
W43 MM1	$1.4 \cdot 10^{-4}$	$8.0 \cdot 10^{-8}$	2.5	- 2.9
DR 21 (OH)	$6 \cdot 10^{-7}$	$4.0 \cdot 10^{-8}$	2.6	-



HERSCHEL SPACE OBSERVATORY

High-mass protostars: W43MM1

Herpin et al. (in preparation)

Components :

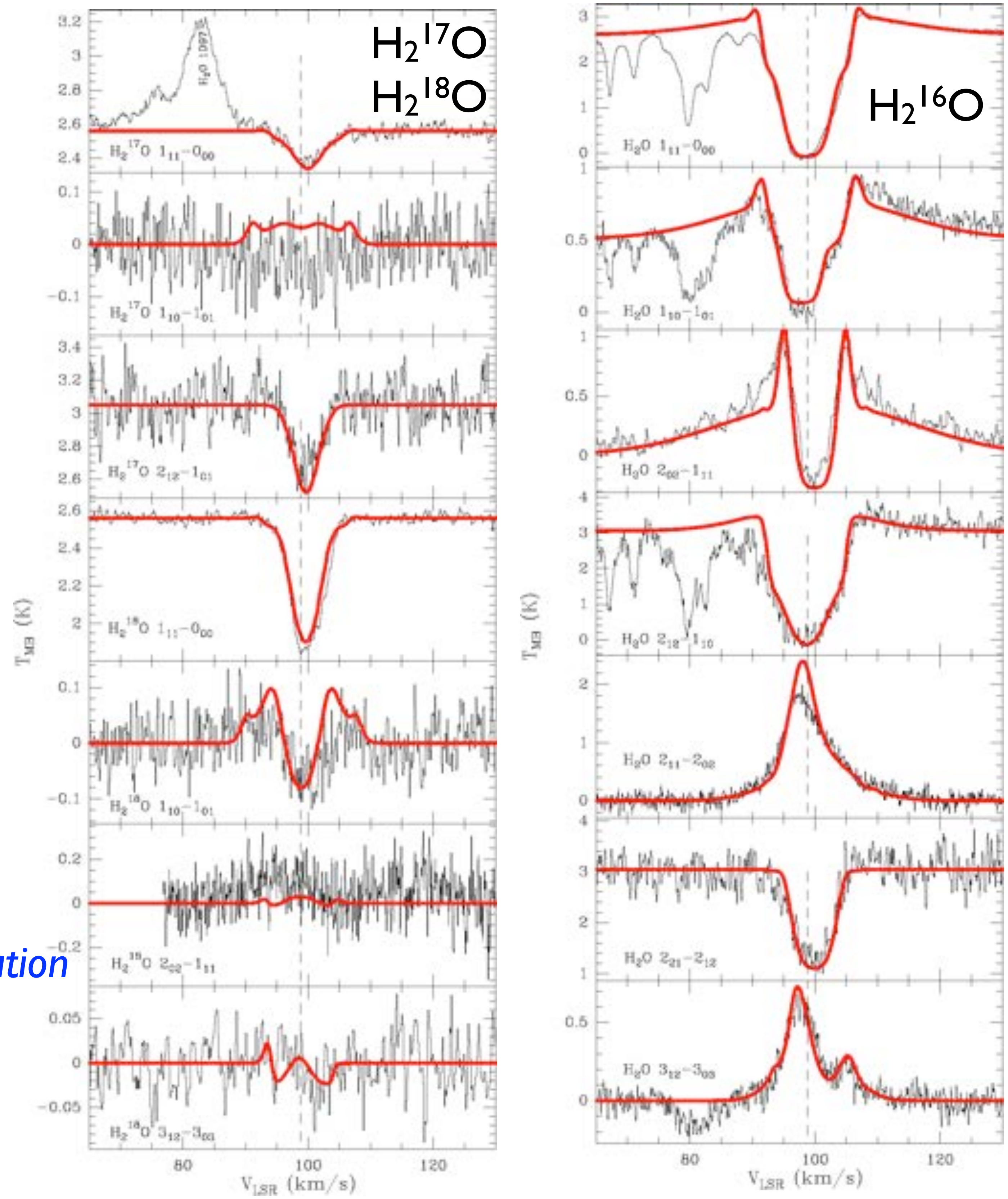
- broad (FWHM=20-35 km/s)
- medium (FWHM=5-10 km/s)
- (narrow, 3 km/s)

Parameter	
X_{H_2O}	8.0 (±1.0) $\times 10^{-8}$
Post-jump X_{H_2O}	1.4 (±0.4) $\times 10^{-4}$
o/p	3 ±0.2
$X_{^{18}O/^{17}O}$	4.5 ±0.3
$X_{^{16}O/^{18}O}$	450 ±30
V_{tur} (km s^{-1})	2.2-3.5
$V_{out\,flow}$ (km s^{-1})	10.2-35.5
V_{infall} (km s^{-1})	-2.9
V_{LSR} (km s^{-1})	99.4

→ **$\dot{M} \simeq$ 3.5-4.0 10^{-2} $M_\odot$/yr**

⇒ estimated accretion luminosity ($\simeq$94 $L_\odot$)

⇒ *high enough to overcome the expected radiation pressure.*

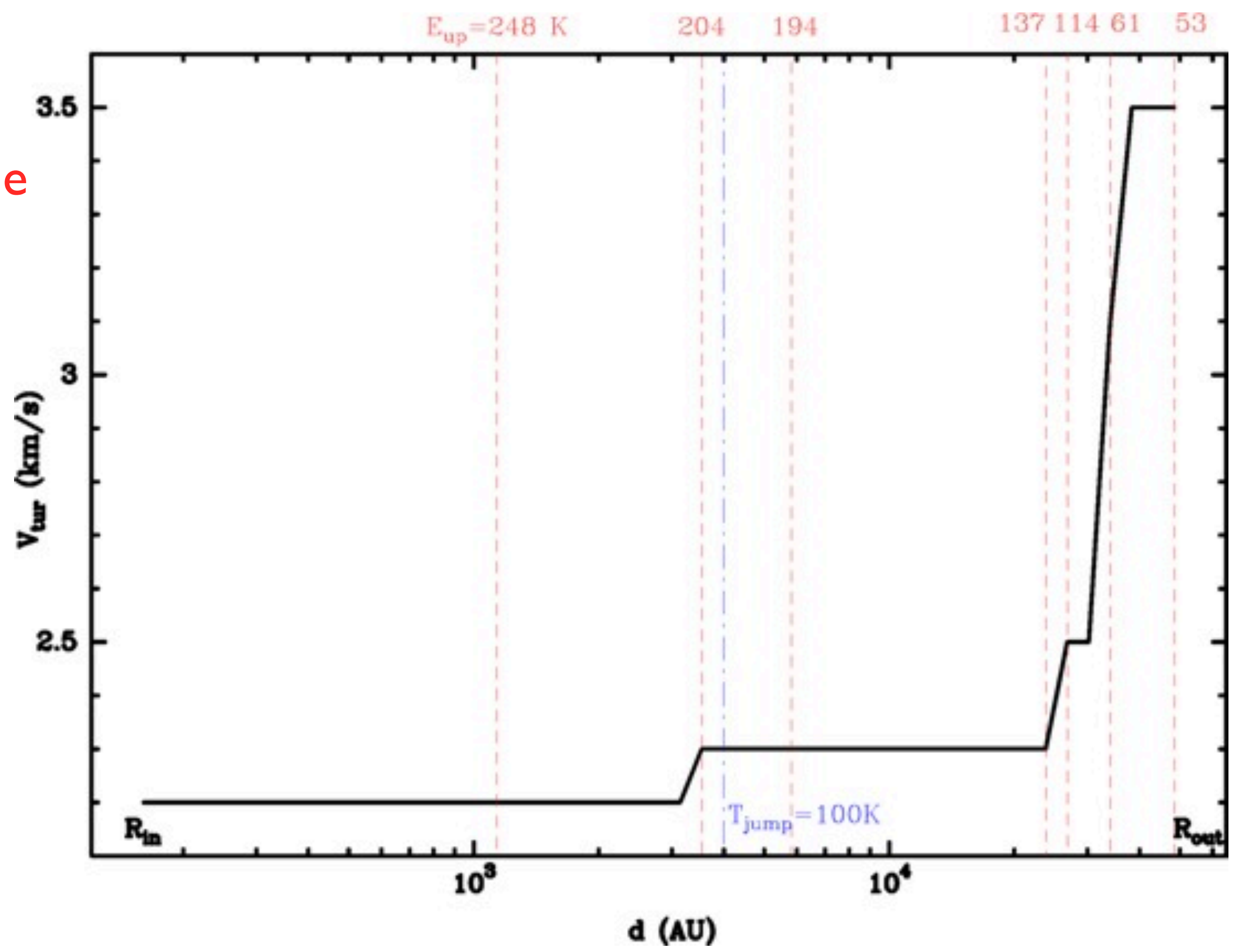


High-mass protostars: W43MM1

Herpin et al. (in preparation)

Highly supersonic turbulence + variation of the turbulent velocity with the distance to the central object.

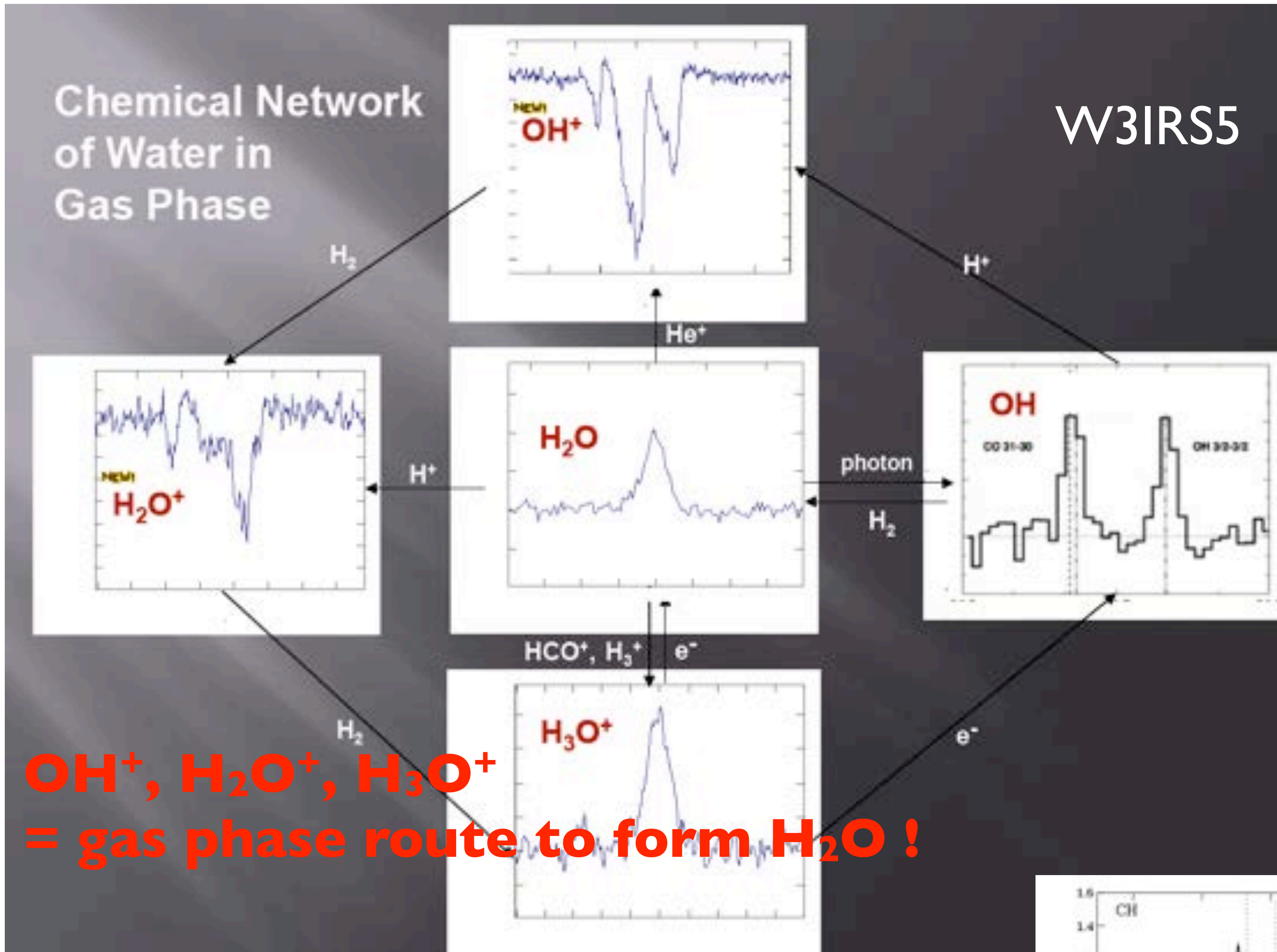
While not in clear disagreement with the competitive accretion scenario, this behavior is predicted by the turbulent core model.



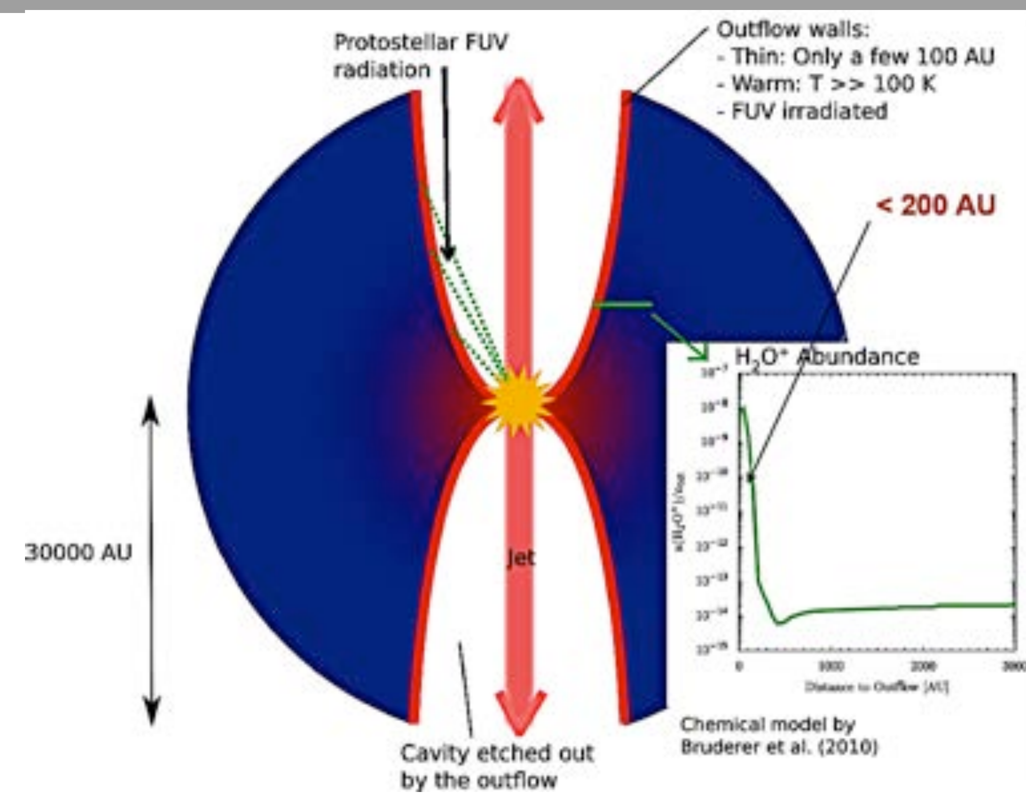
HERSCHEL SPACE OBSERVATORY

Chemistry

Benz et al. (2010), Bruderer et al. (2010)

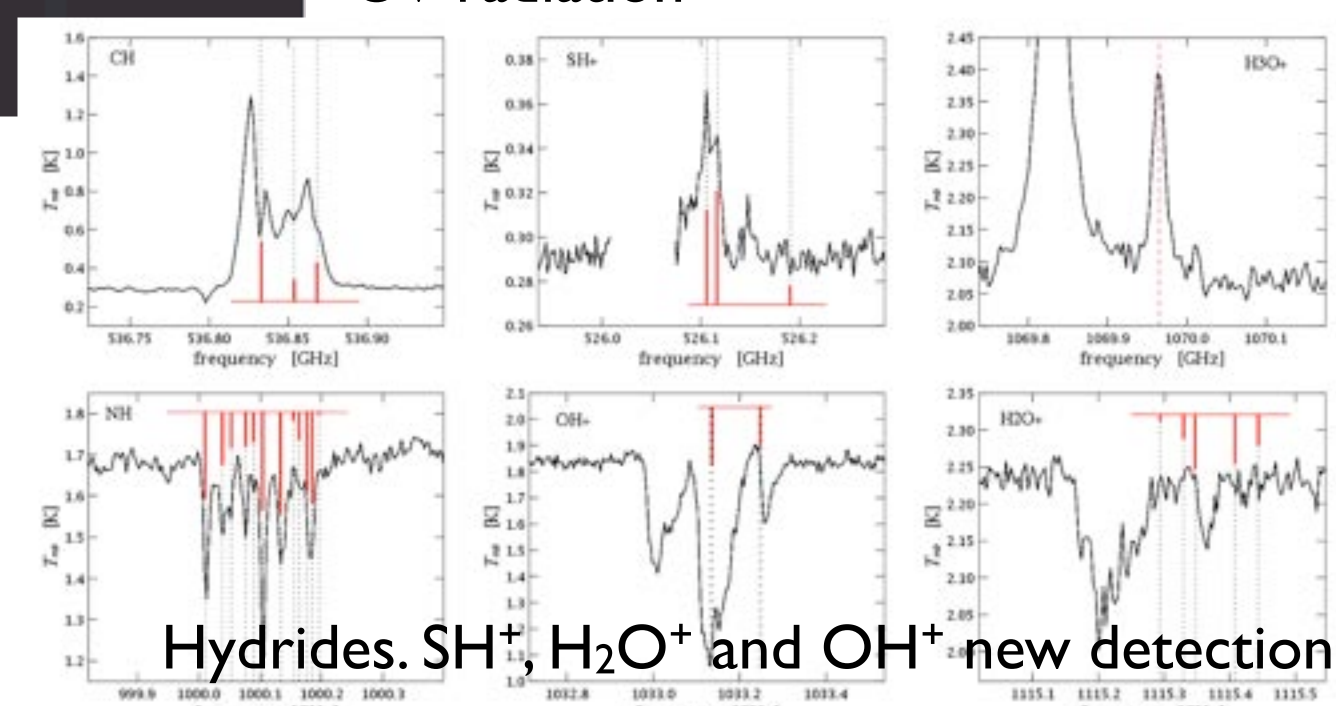


OH$^+$, H$_2$O$^+$, H$_3$O$^+$
= gas phase route to form H$_2$O !



Main emission region in outflow walls, heated and irradiated by protostellar UV radiation

Variations of the H$_2$O$^+$/H$_2$O ratio towards massive star forming regions *(Wyrowski et al. 2010)*



Hydrides. SH$^+$, H$_2$O$^+$ and OH$^+$ new detections.

WISHes for CCAT

Why CCAT :

- South hemisphere (next year: only APEX and ALMA, maybe ATCA)
- big dish (high spatial resolution, complementary to ALMA)
- exceptional transmission in high frequency bands (only facility beyond 1000 GHz)

Christmas list:

- CO and 13CO 9-8 around 900-1000 GHz
- HCN and HCO+ 11-10, 12-11 around 1000 GHz
- HDO 1-0 line around 900 GHz
- high spectroscopic resolution (1/1000000)
- line mapping facilities (e.g. HERA-30m)
- 3mm band ?
- continuum and line polarimetry (Stokes parameters ?)

HERSCHEL SPACE OBSERVATORY