Water in star-forming regions with Herschel (WISH): *Recent results and emerging trends*

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www.strw.leidenuniv.nl/WISH

Aquila / W40
Herschel mage 8 pc
André & Gould Be

Water In Star-forming regions with Herschel
The WISH team

Leiden, December 2011

Toledo, June 2011

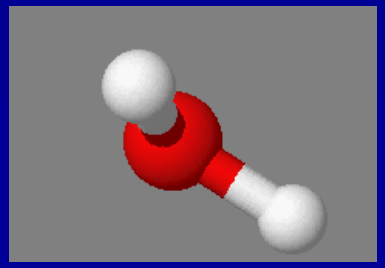
70+ scientists from 30 institutions (PI: EvD)
15 papers in Herschel A&A first results issues,
25 papers total, see WISH website

Summary in van Dishoeck et al. 2011, PASP

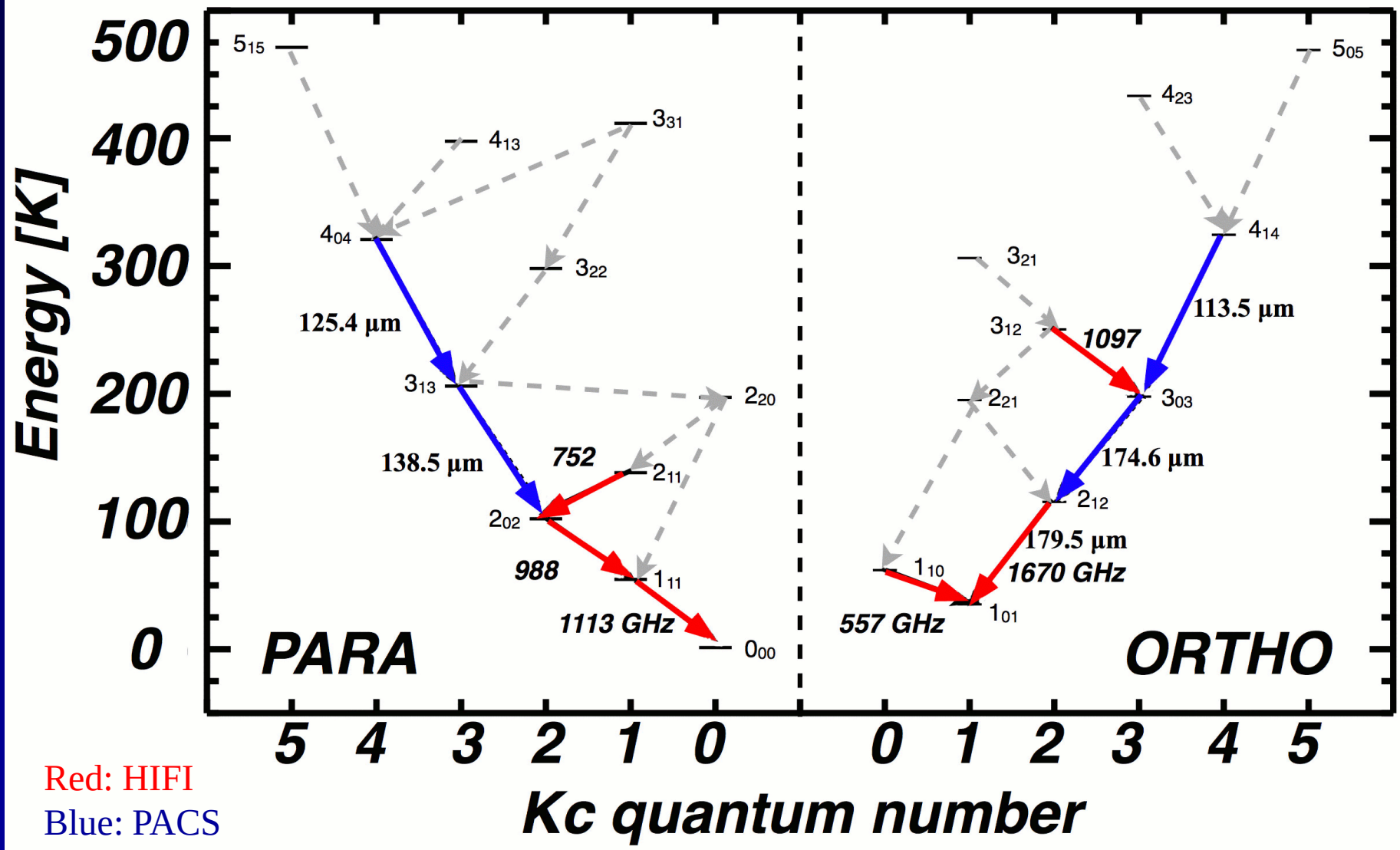
WISH

WISH questions

- Which physical components does water trace?
  - Quiescent envelope, hot core, outflows, disks, …
  - Gas cooling budget
- Where is water formed in space and by which processes?
  - Gas vs grains
- What is the water ‘trail’ from clouds to planets?
  - Origin of water on Earth



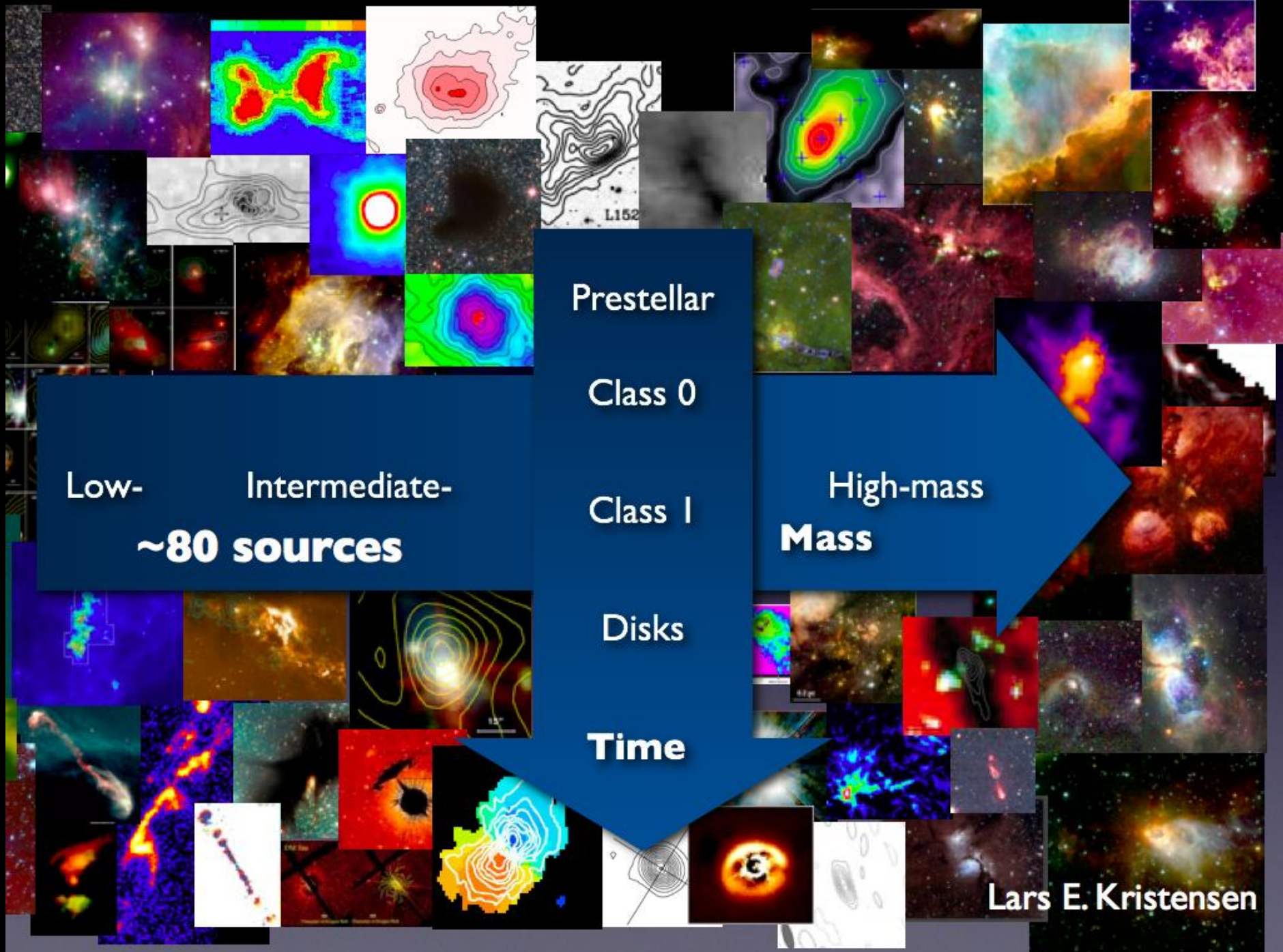
H_2O lines: HIFI and PACS



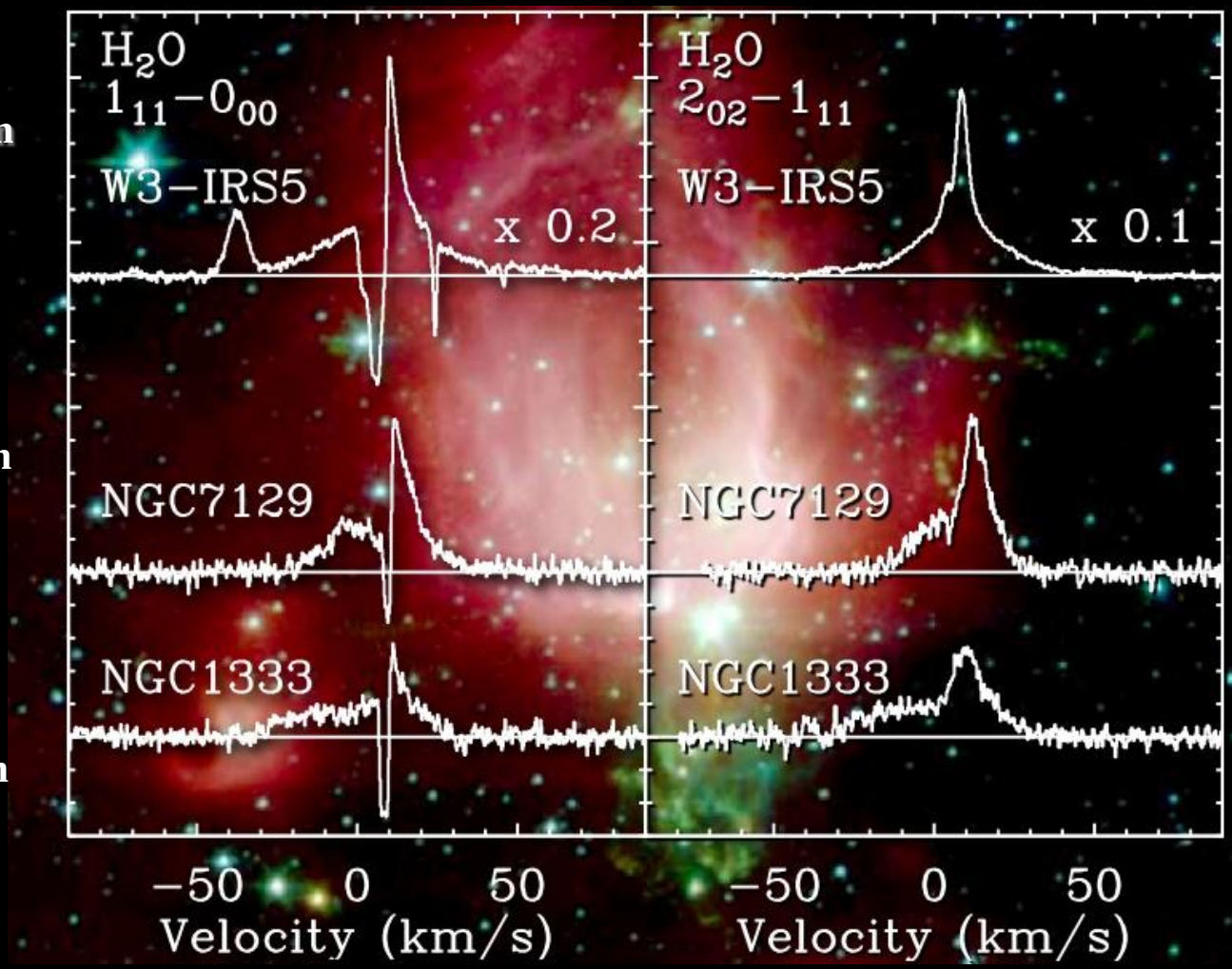
Red: HIFI

Blue: PACS

Observe mix of low- and high-excitation lines to probe cold and hot environments; Include ^{12}CO 10-9, ^{13}CO 10-9, C^{18}O 9-8, PACS


Prestellar
Class 0
Class I
Disks
Time
Low-
Intermediate-
High-mass
~80 sources
Mass
Lars E. Kristensen

Water reveals diverse kinematic components
From low to high mass protostars

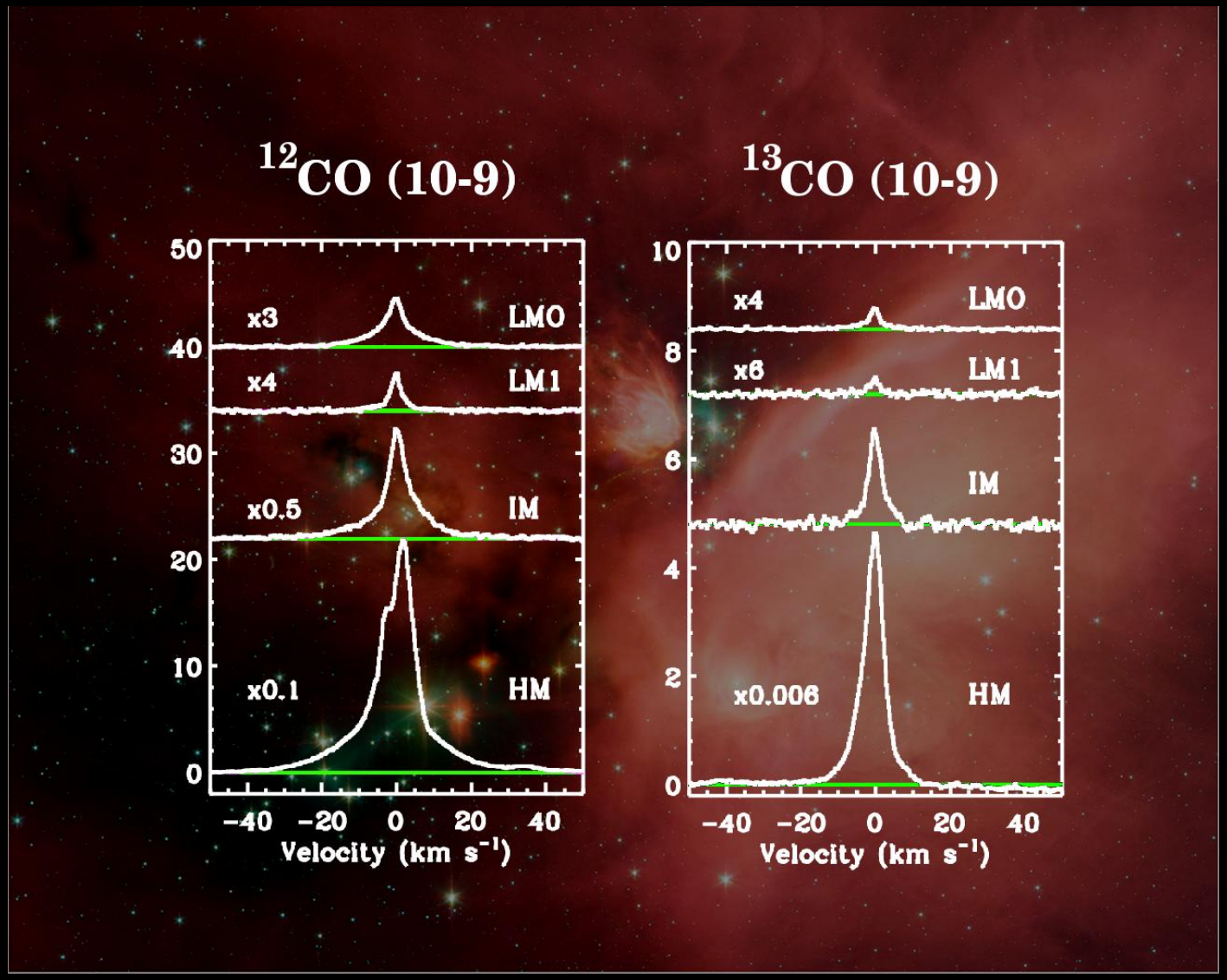


Kristensen et al. 2010
Johnstone et al. 2010
Chavarria et al. 2010

Note similar profiles: broad, medium and narrow

Even $H_2{}^{18}O$ lines dominated by broad emission for low mass

CO 10-9 from low to high mass

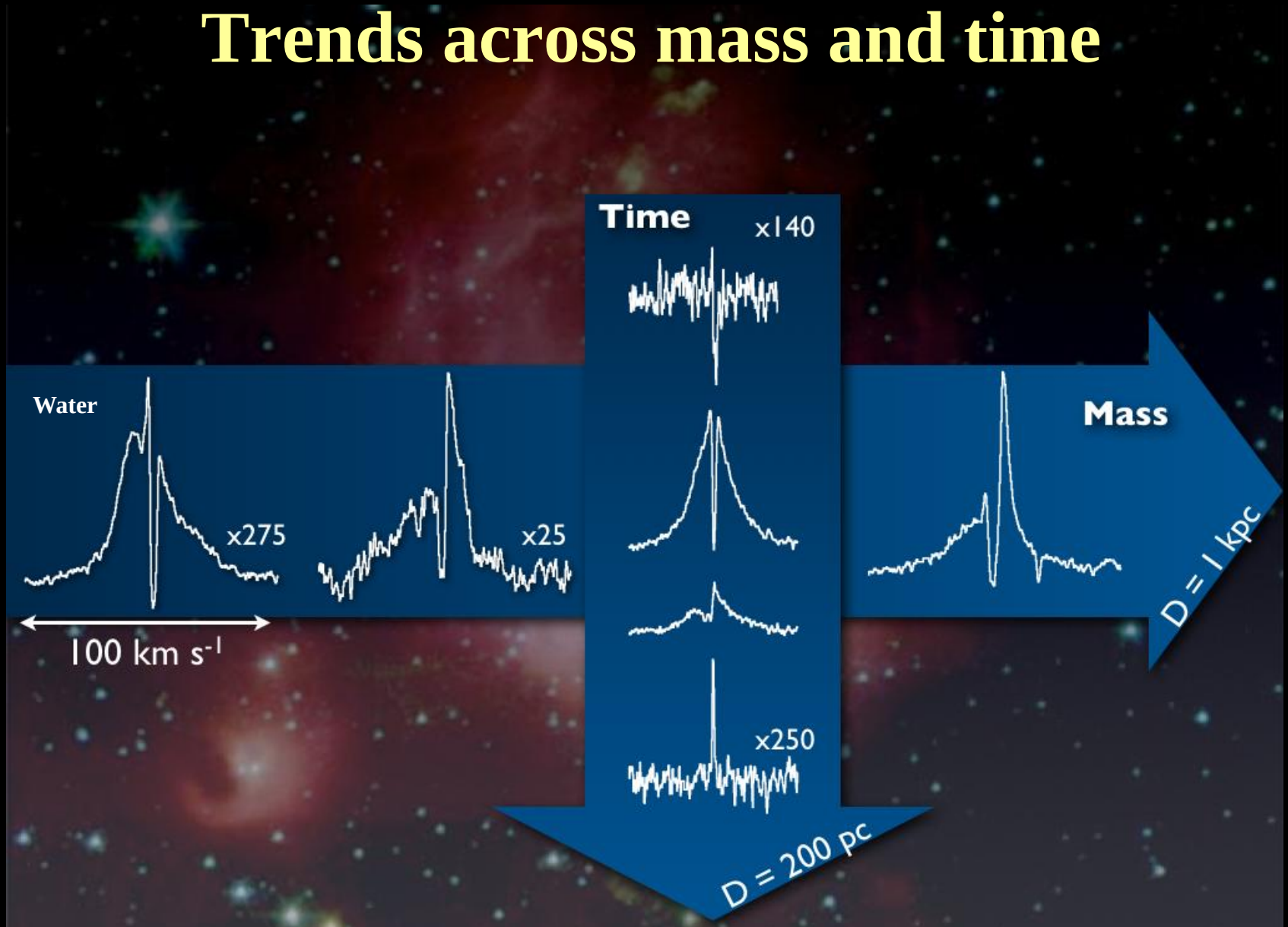


Stacked lines

Note similarity profiles

San Jose-Garcia et al.

Trends across mass and time



- Similar profiles from low to high mass protostars except for scale
- Water only bright in embedded phase, not in cores or disks

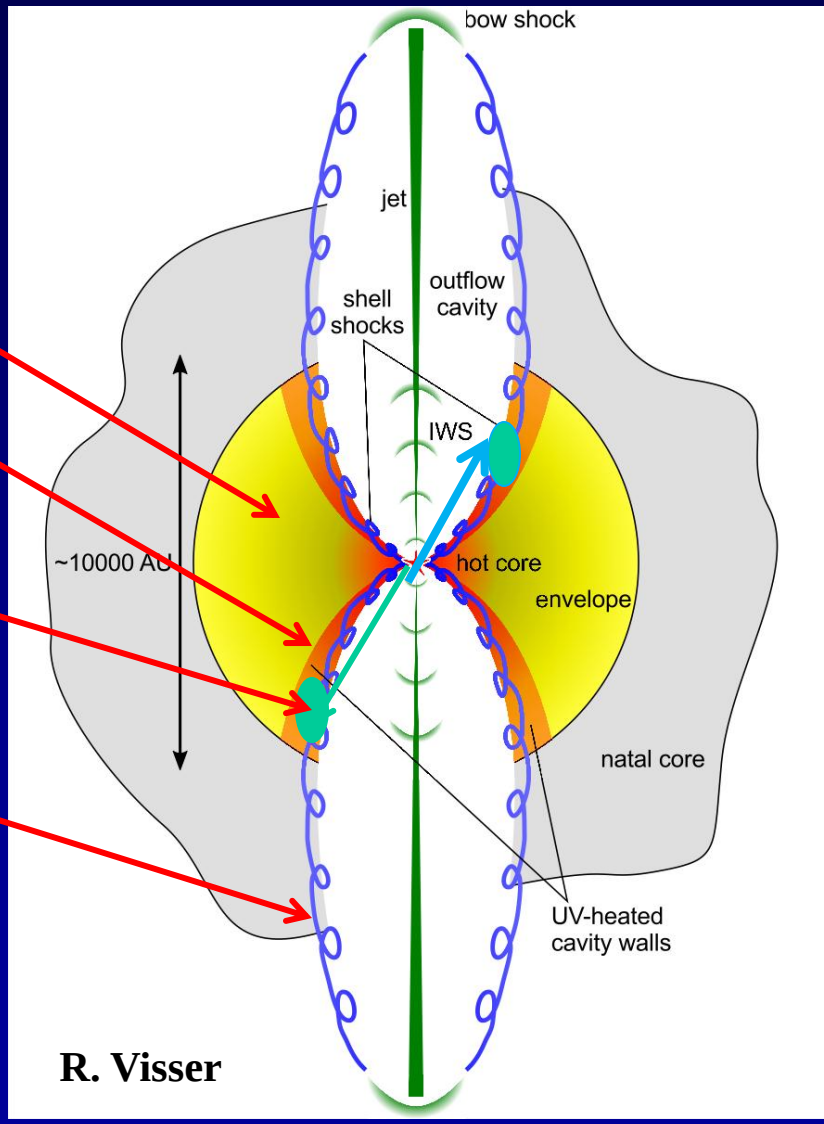
Where is the water?

Lake Louise
August 2010

- ‘Streaming’ along the walls?
- Inside the cavity?
- As ice in the envelope?

Physical components

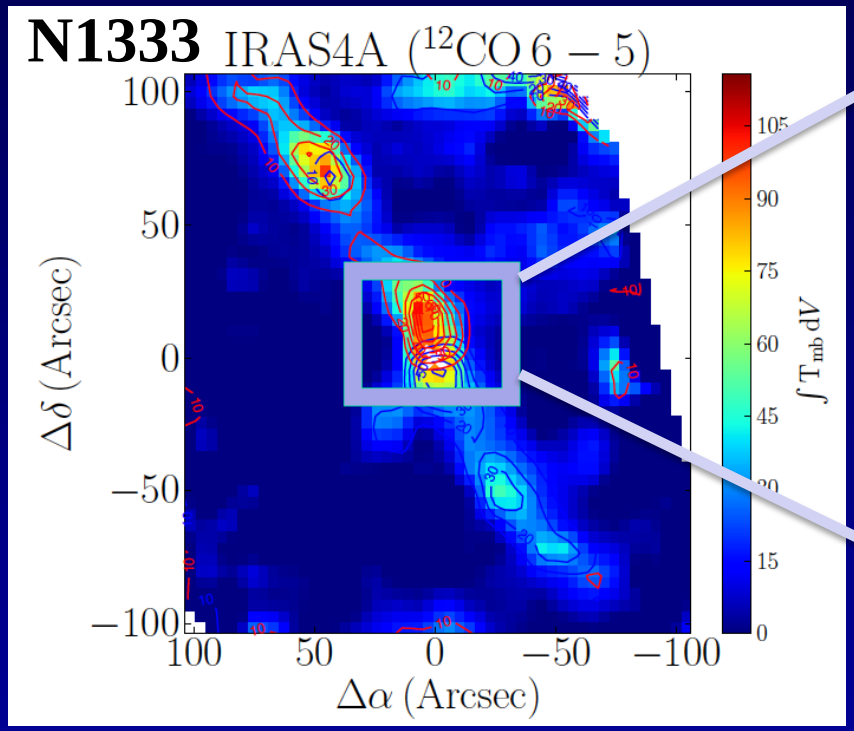
- Quiescent envelope
  - Narrow absorption/emission
- UV-heated cavity walls
  - Narrow emission CO mid-*J*
- Currently shocked gas
  - H_2O broad, CO high-*J*
- Entrained outflow gas
  - CO low-*J*



Talks Lars Kristensen
and Ruud Visser, Poster Joe Mottram

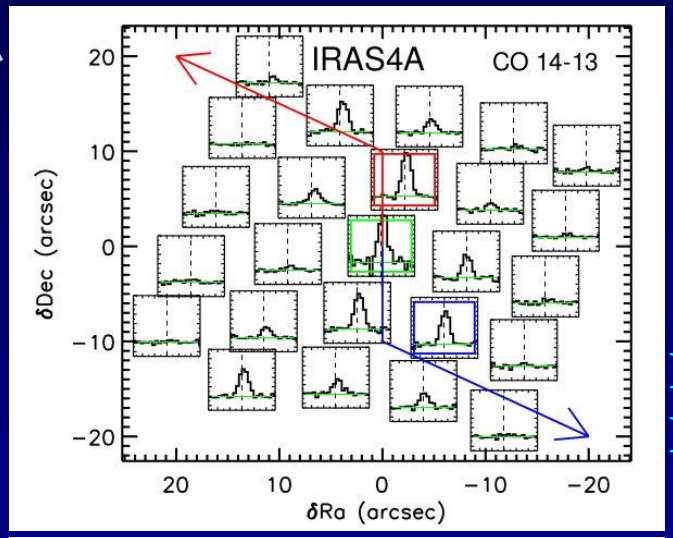
Spatial distribution CO vs H_2O

APEX-CHAMP$^+$ CO 6-5

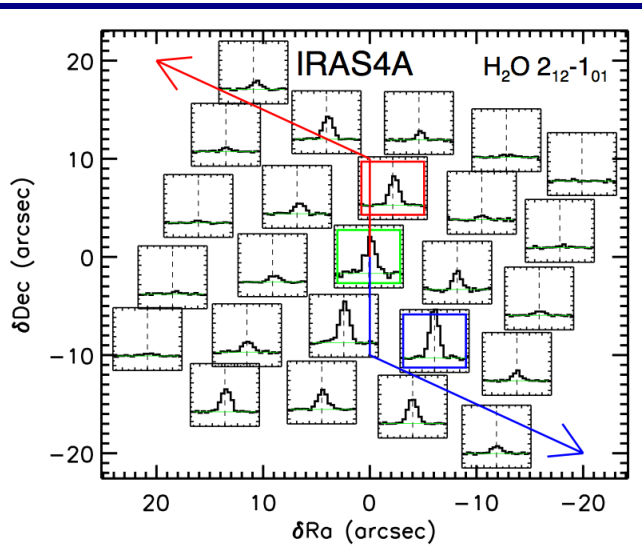


Poster Yildiz+2012

Herschel/PACS
CO 14-13 vs H_2O 2_{12}-1_{01}



Poster Karska

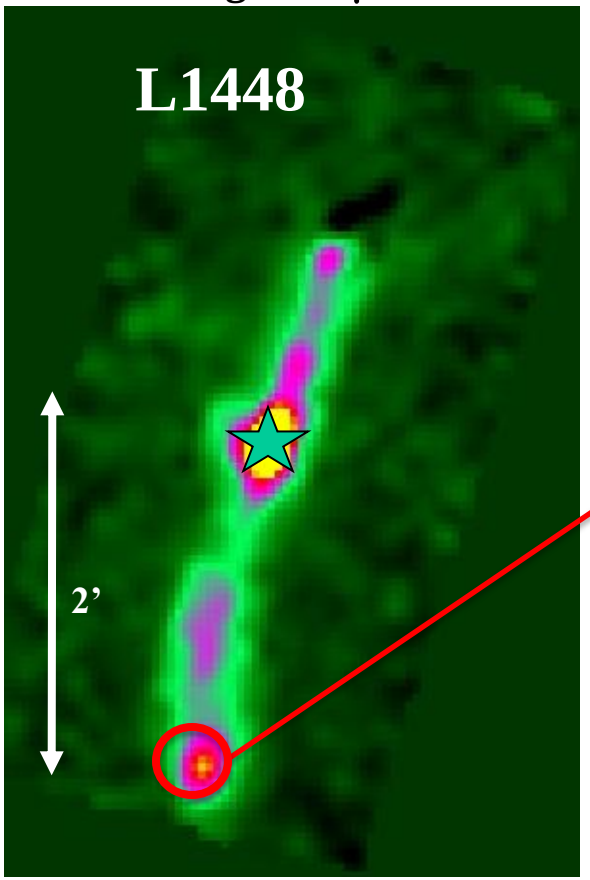


OH: Poster Wampfler

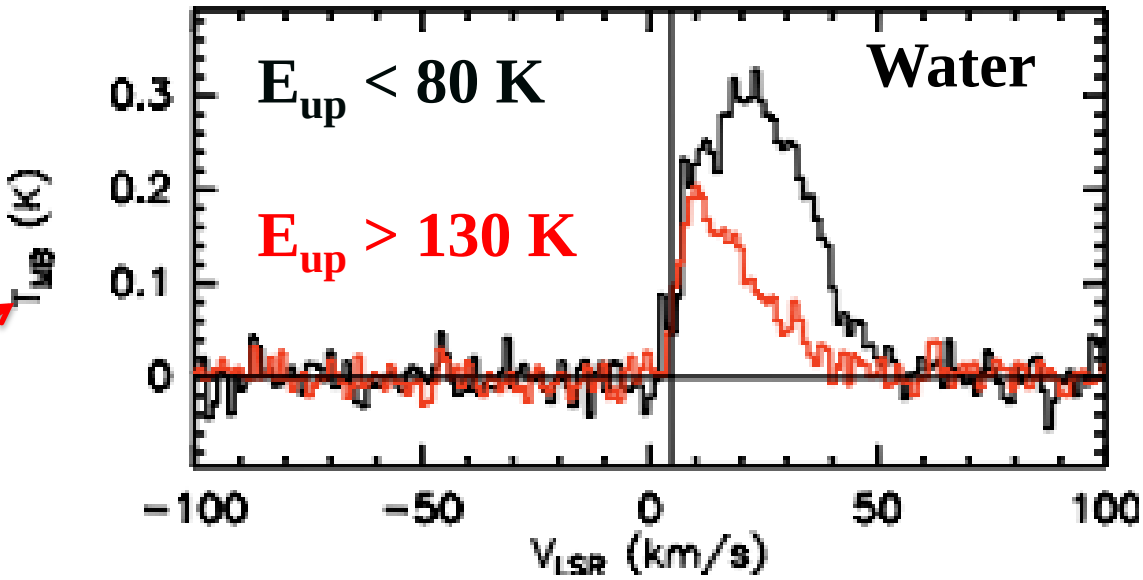
Water follows outflow and high-*J* CO, not low-*J* CO

Shocking water lines

PACS image 179 μm line



L1448 R4

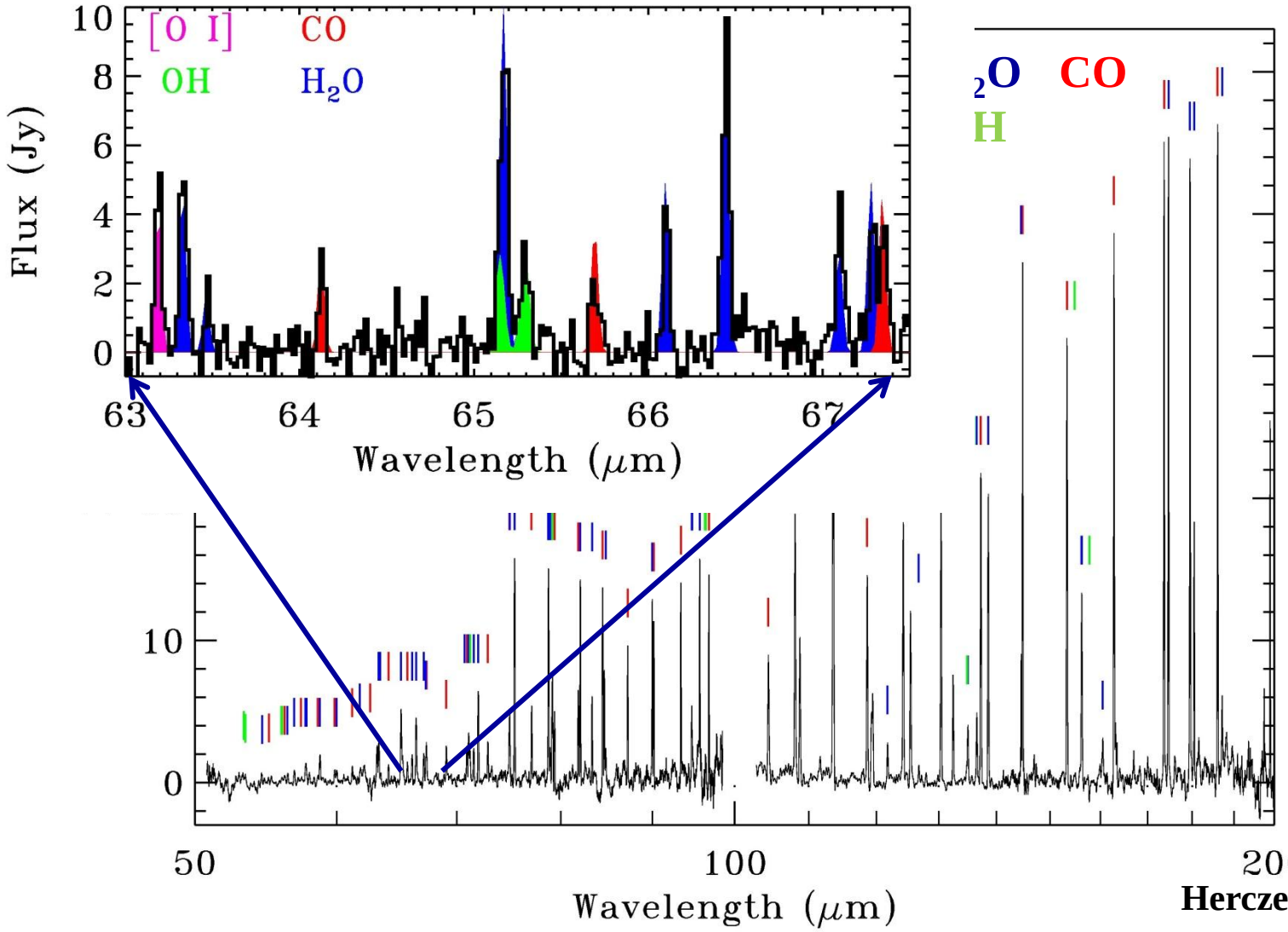


Santangelo et al. 2011
Vasta et al. 2011

- Lower excitation lines trace higher velocities

Poster Santangelo et al.

Rich far-IR shock spectra

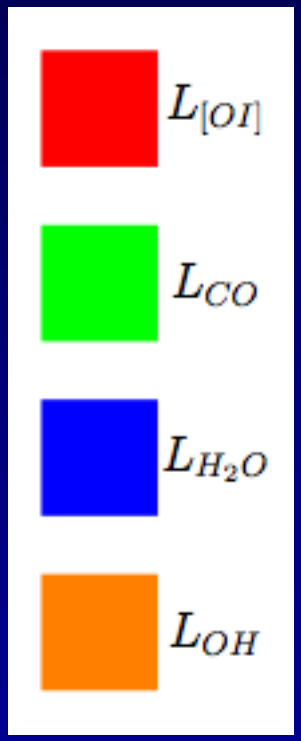


NGC1333 IRAS4B PACS Spectral scan

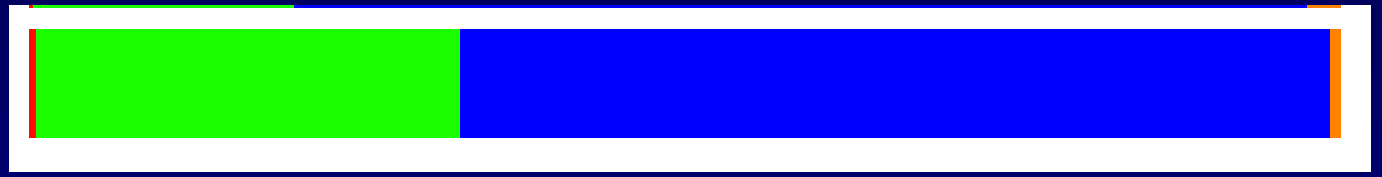
Herczeg et al. 2012

- All lines assigned to 4 species, from levels up to several thousand K

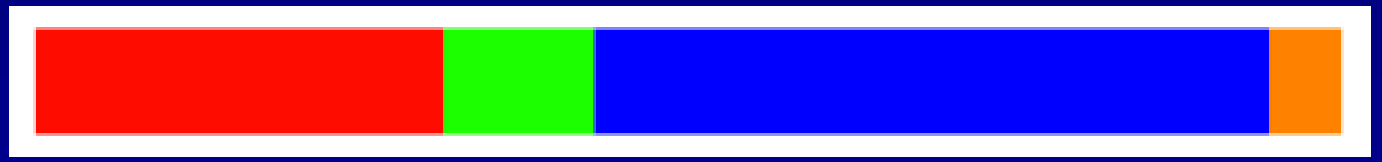
Far-IR cooling budget



NGC 1333 IRAS 4A (Class 0)



HH 46 (Class I)



Karska+, in prep.

- **Cooling by [OI] marginal in Class 0, but rises with evolution**
- **H_2O dominates far-IR cooling of deeply embedded YSOs**

Conclusion 1

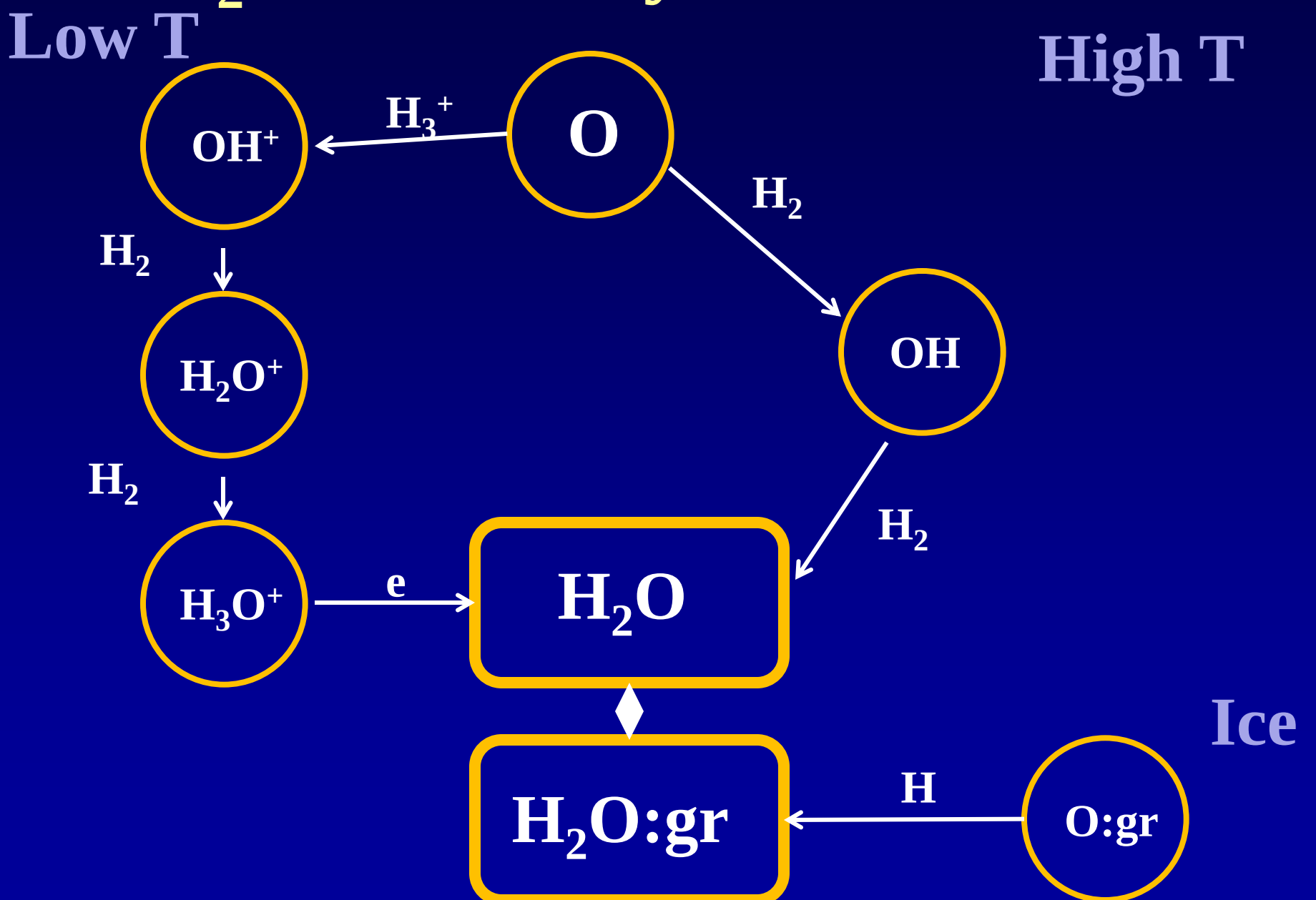
- **Water reveals different physical components of protostellar environment more effectively than does CO**
  - **Kinematic information crucial!**
- **Emission dominated by high n (>10^5 cm^{-3}), high T (>400 K) shocks**
- **Far-IR cooling budget being quantified**
- **Processes similar from low- to high-mass YSOs**

WISH =

Water IS Hot

M. Tafalla

H_2O chemistry: three routes



Pre-stellar cores: where is water formed?

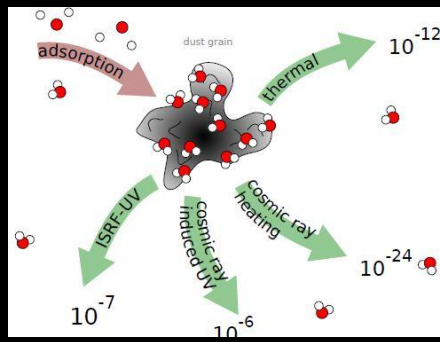
B68

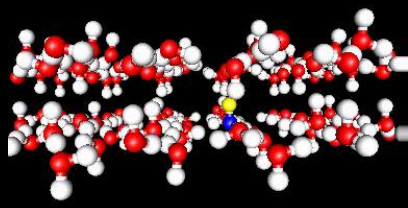
H_2O gas= Ice formation / Photodesorption

Ice

H_2O gas ring

Alves et al. 2001
Bergin et al. 2002



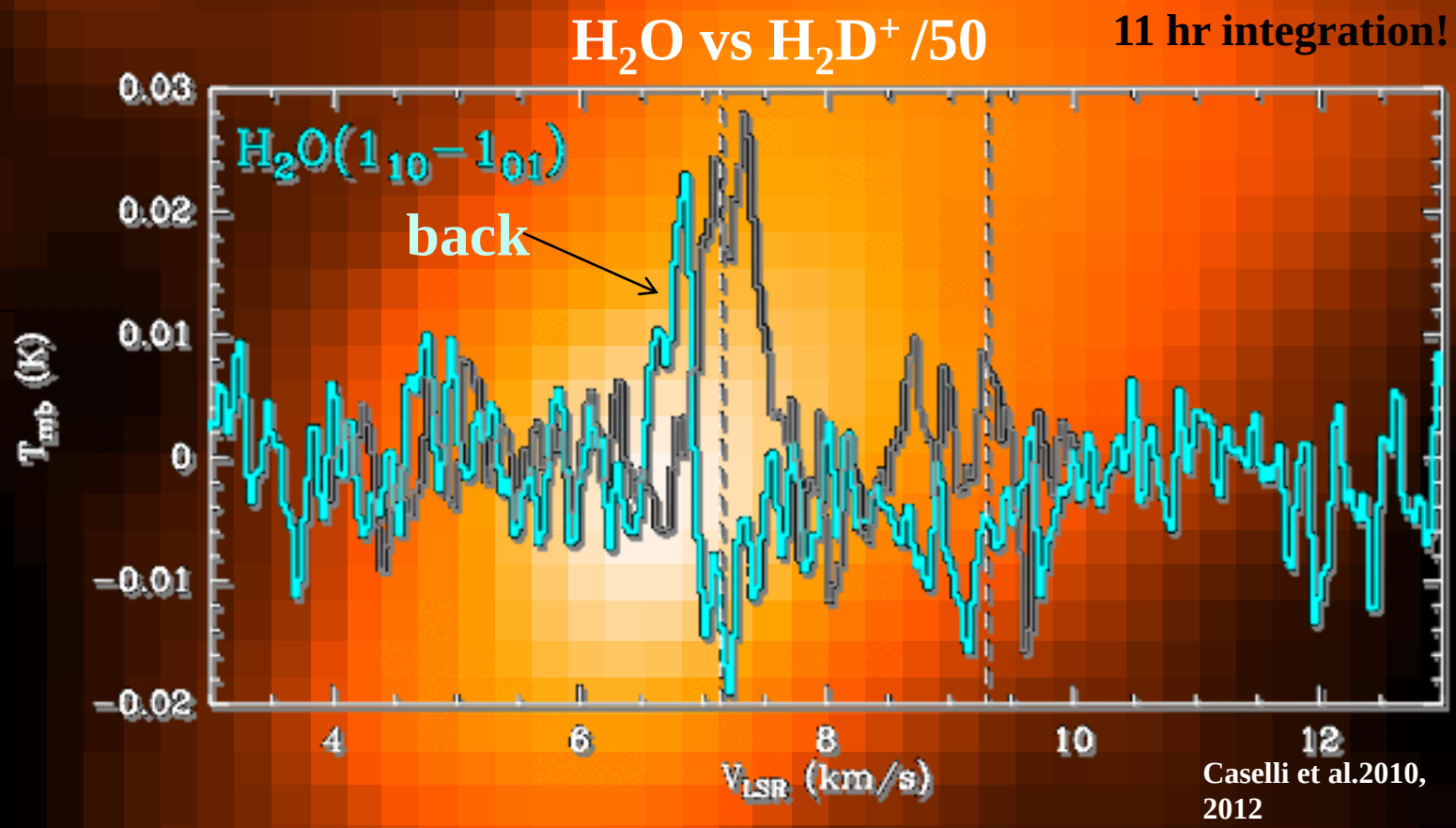


Lab + Theory

n=2.10^4 – 5.10^6 cm^{-3}, T=10 K
Layer of water gas where ice is photodesorbed

A&vD2008
Öberg et al. 2009

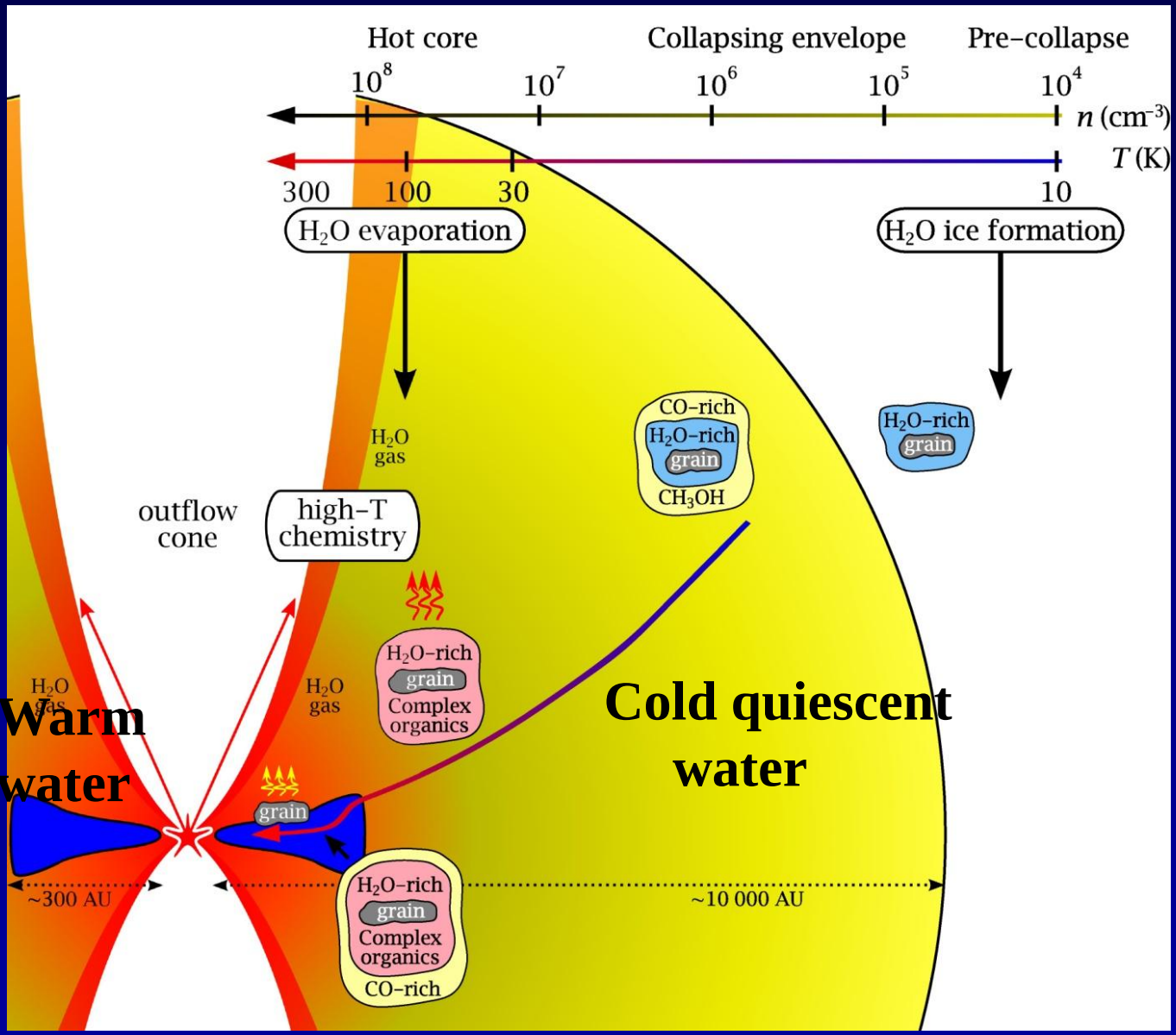
The prestellar core L1544



- Emission requires high central density ~10^7 cm^{-3}
- Profile indicates infall of 0.1 km/s at 1000 AU

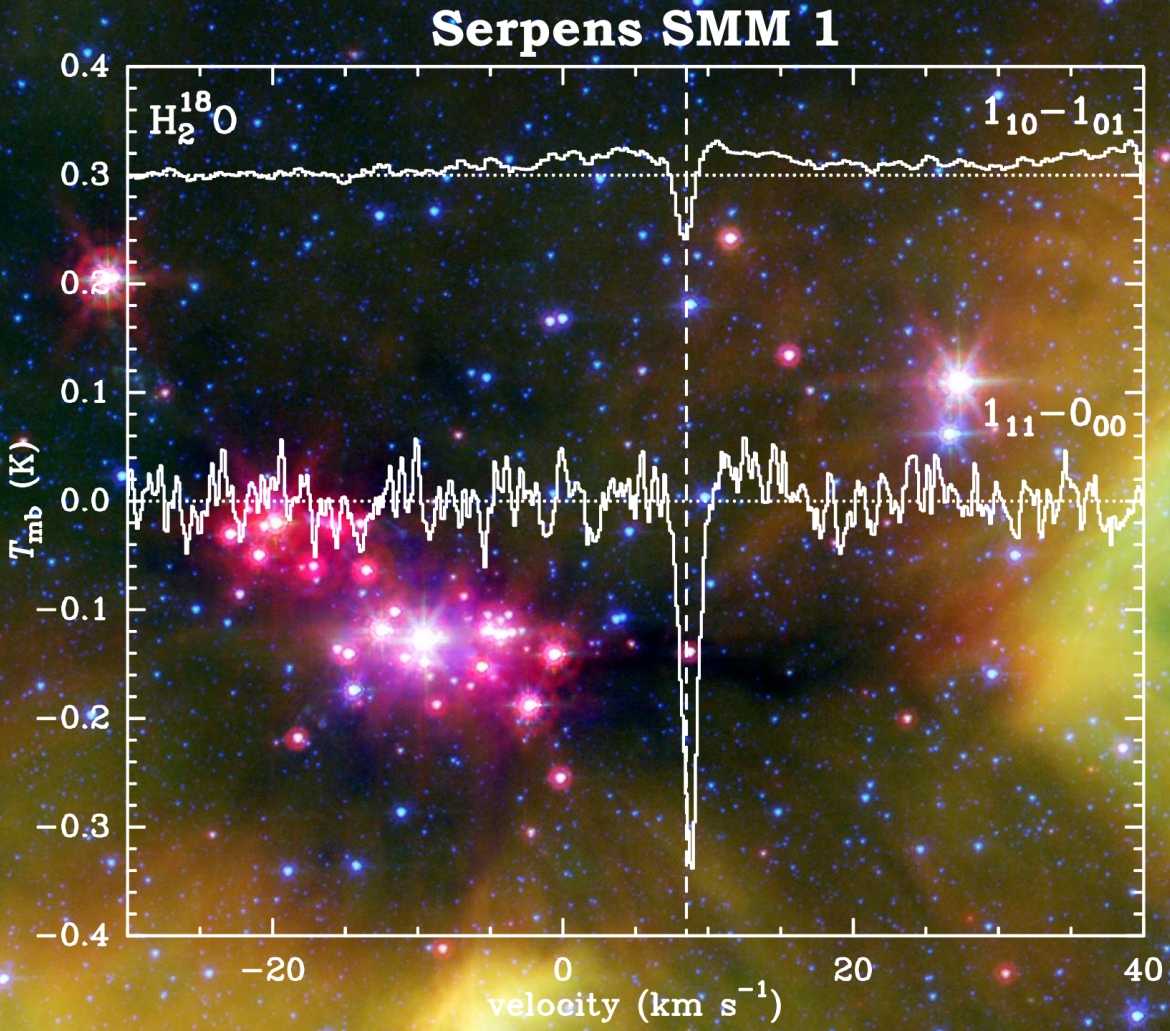
1.3 mm continuum map from Ward-Thompson et al. (1999)

How much water is where?



Visser et al. 2009
Herbst & vD 2009

Cold outer envelope

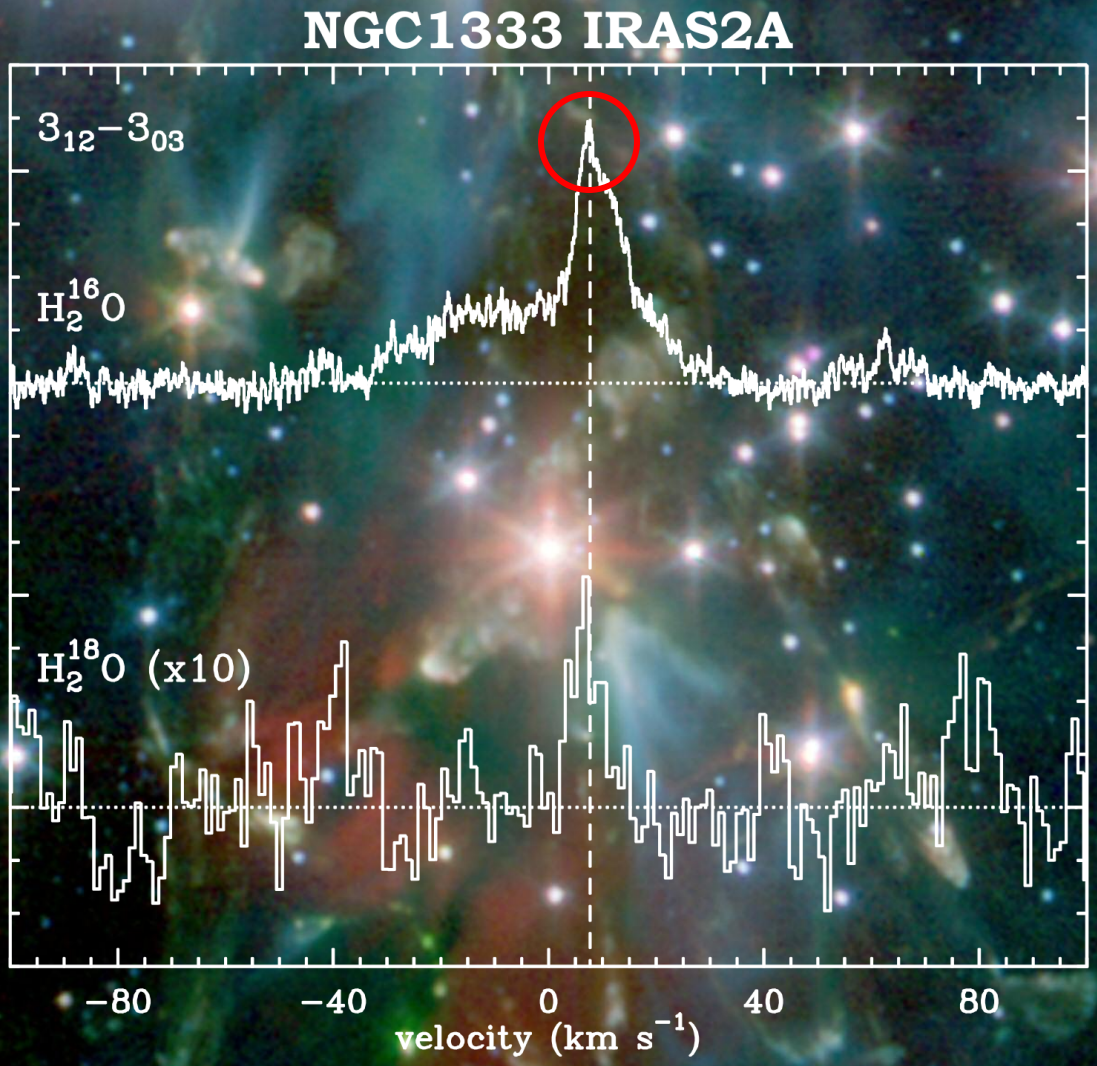


Continuum and emission subtracted

Schmalzl et al. poster

- Outer envelope abundance ~10^{-8} - 10^{-9}

Warm inner abundance

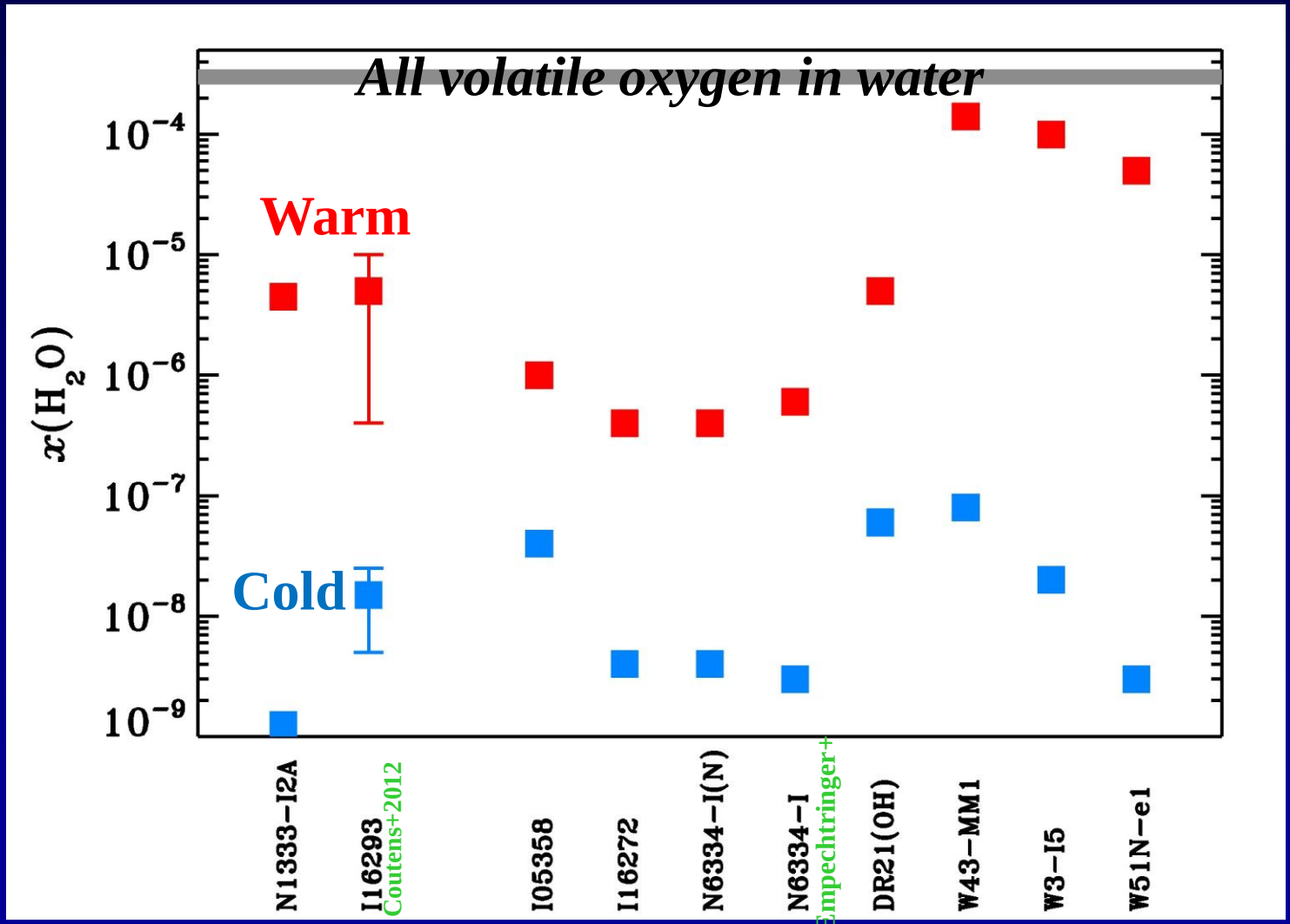


-Deep 5 hr integration on excited line reveals narrow $H_2{}^{18}O$

- Abundance only ~few $\times 10^{-6}$

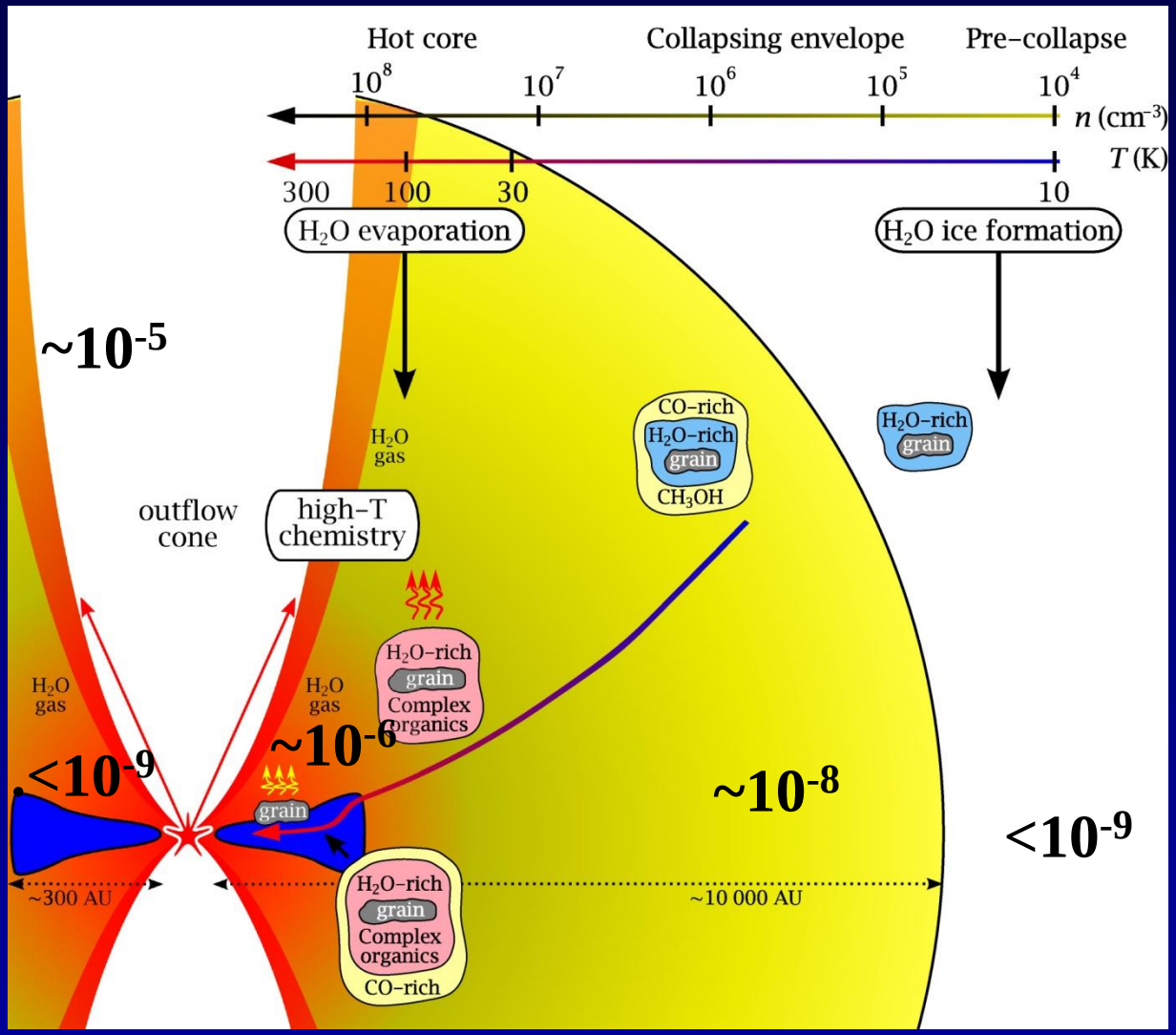
Talk Herpin, poster Choi

Warm and cold water abundances



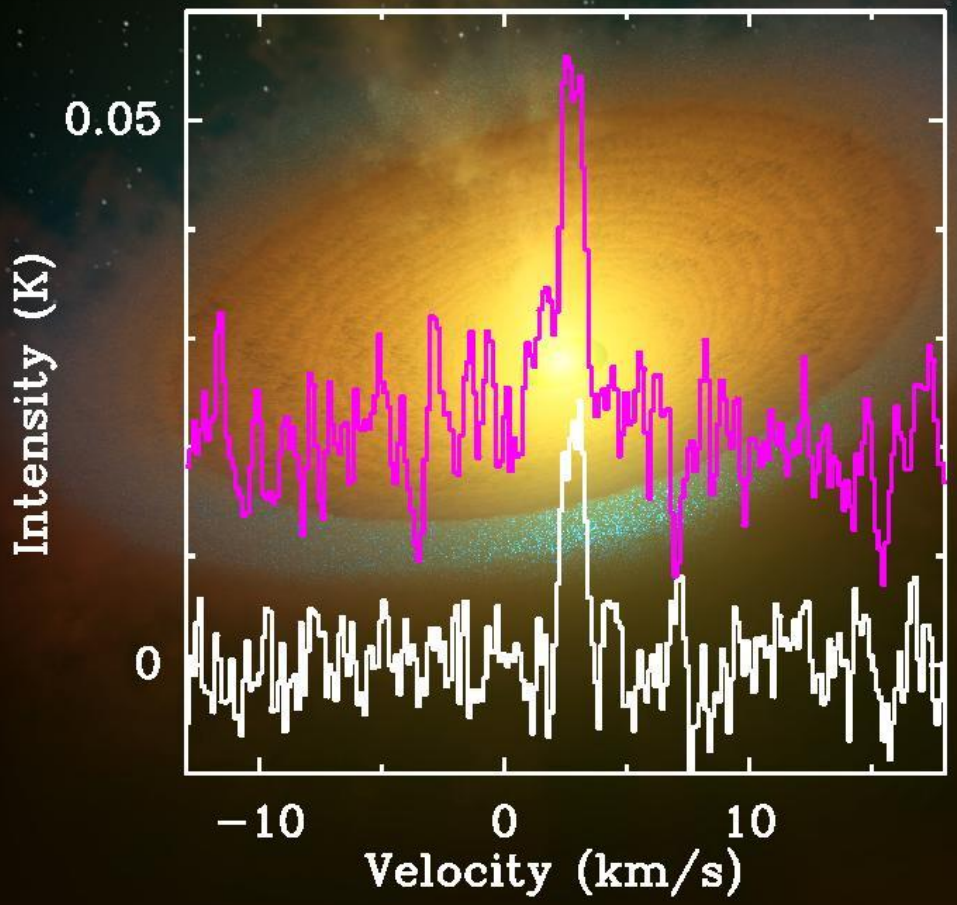
- Why is warm abundance not > 10^{-4}?
- What causes variations from source to source?

How much water is where?



Visser et al. 2009
Herbst & vD 2009

Detection of cold water in disks



p-H_2O 1_{11}-0_{00}
1113 GHz

o-H_2O 1_{10}-1_{01}
557 GHz

Hogerheijde et al. 2011, Science

Talk Michiel Hogerheijde

WISH

Conclusions 2

- Water is formed mostly on grains
  - Some in shocks at high *T*
- Photodesorption controls gas-phase water abundance in cold clouds and disks
- Water abundance in hot cores is lower than expected
  - Both low- and high-mass sources
- Water is transported into disks mostly as ice

Stay tuned for more water stories during the day