A laboratory study of the OD stretching mode band in H_2O:HDO ice mixtures.

Preliminary Results

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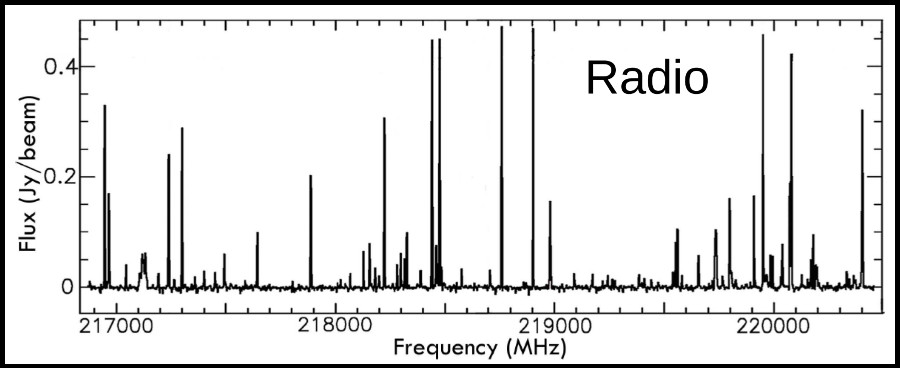
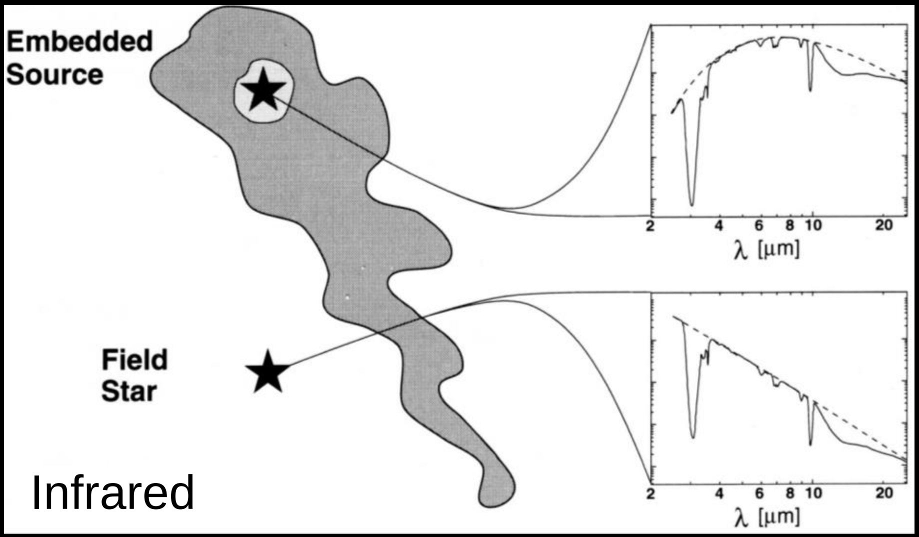
Observations of dense molecular clouds

Gas phase molecules

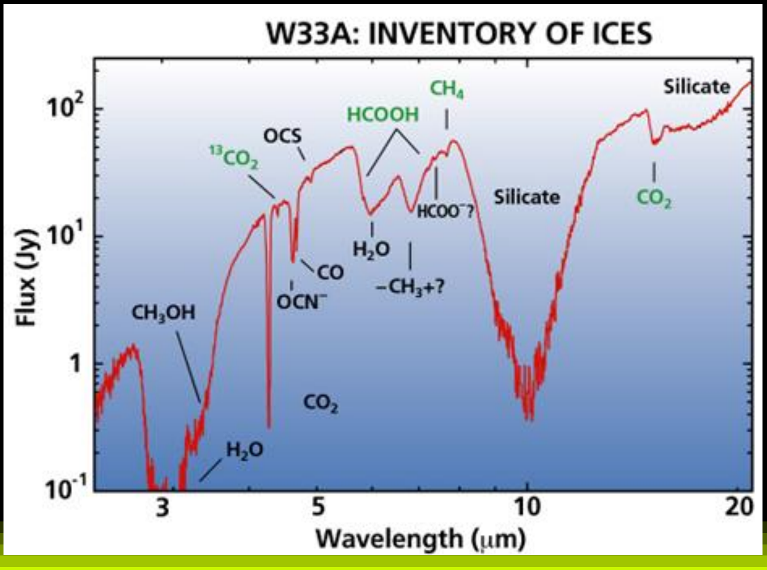


Solid phase molecules

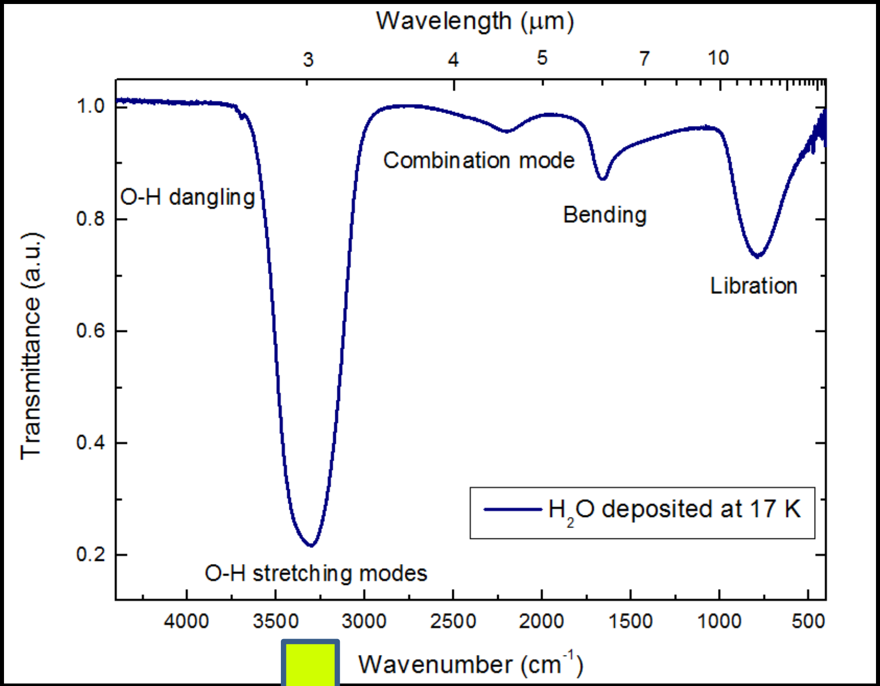


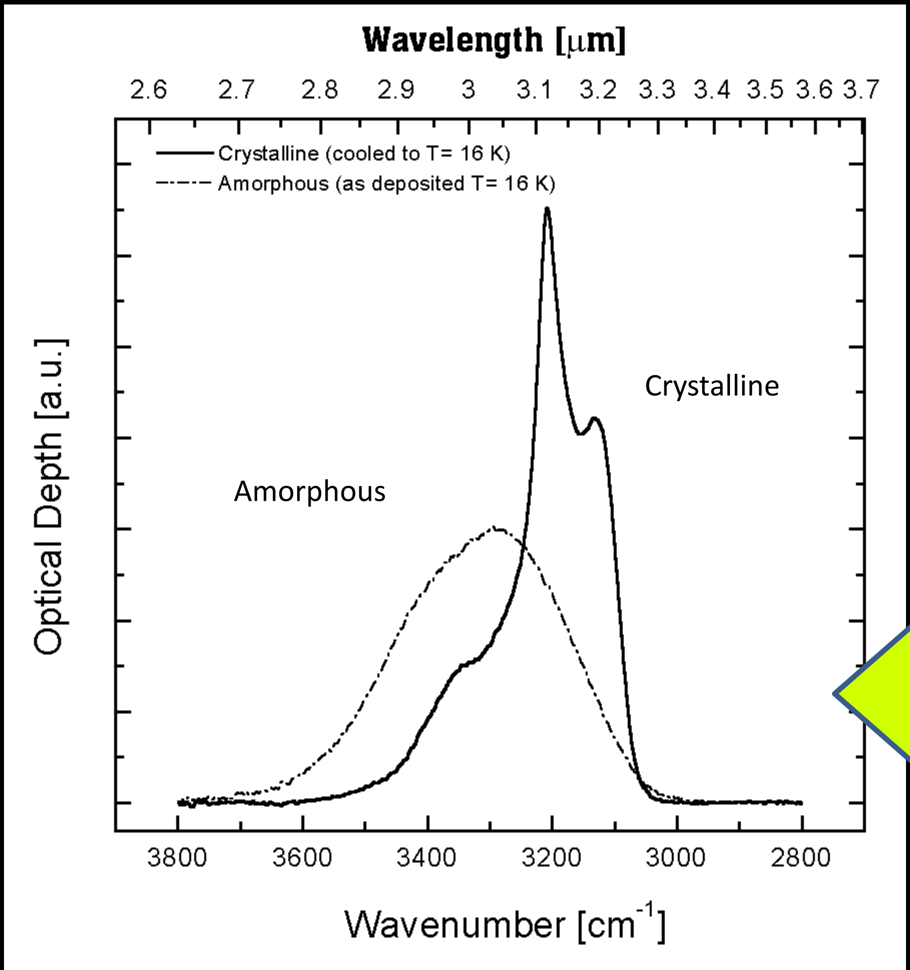
It is generally accepted that other molecules are also present in icy grain mantles.

Species	Abundance	References
H_2O	100	
CO	0-144	Chiar et al. 1994; Pontoppidan et al. 2003; Aikawa et al. 2012
CO_2	10-32	Gerakines et al. 1999; Pontoppidan et al. 2003; Aikawa et al. 2012
CH_3OH	3-30	Allamandola et al. 1992; Dartois et al. 1999; Boogert et al. 2008
CH_4	2-10	Boogert et al. 2007; Oberg et al. 2008
NH_3	5-10	Tielens 1984; Lacy et al. 1998
H_2CO	3-7	Schutte 1994
XCN^-	1-8	Tegler et al. 1995; Aikawa et al. 2012
SO_2	0.3-0.8	Boogert et al. 1997
OCS	0.04-0.1	Palumbo et al. 1997



H_2O laboratory spectra



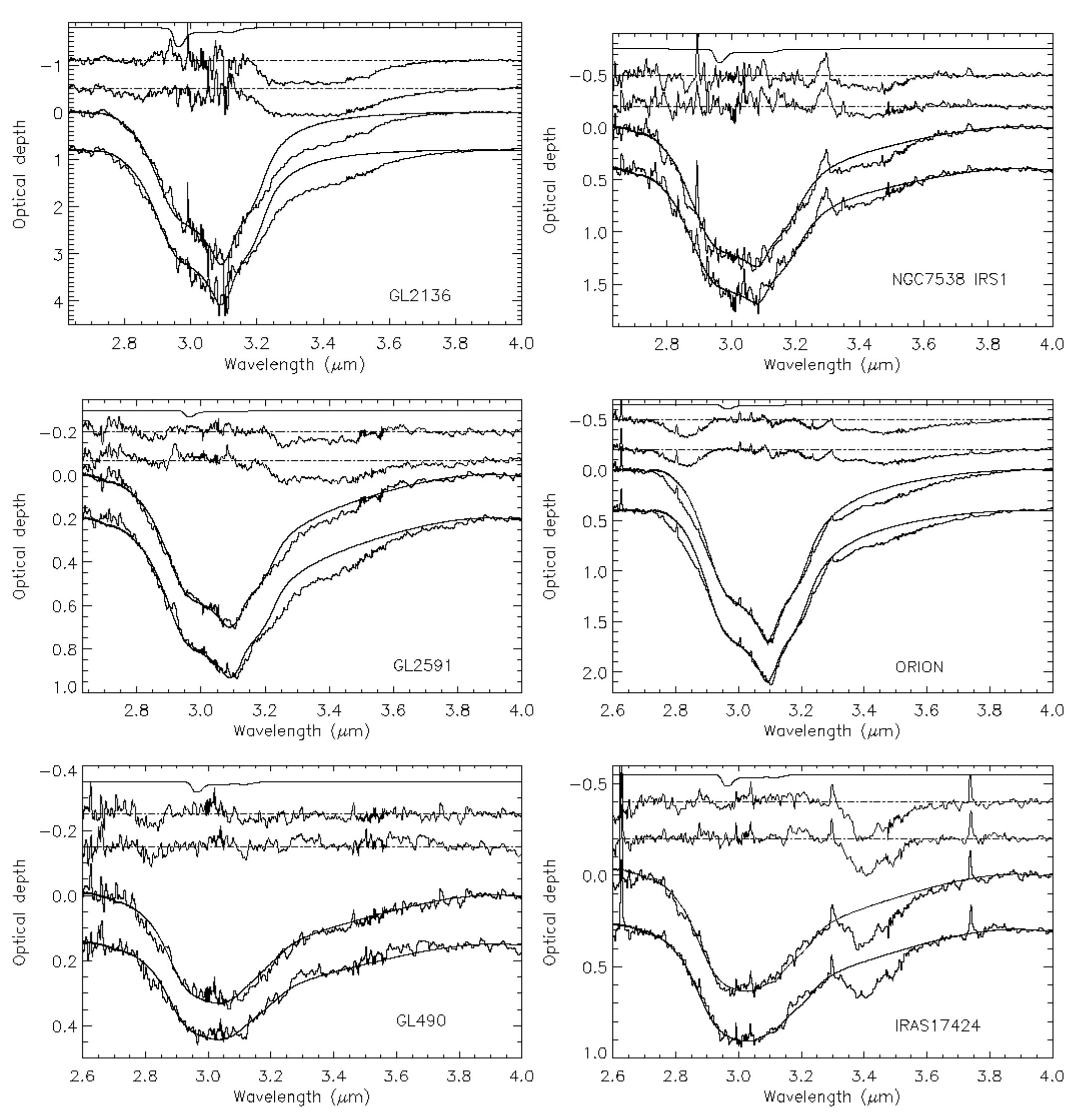


O-H stretching modes in H_2O ice.

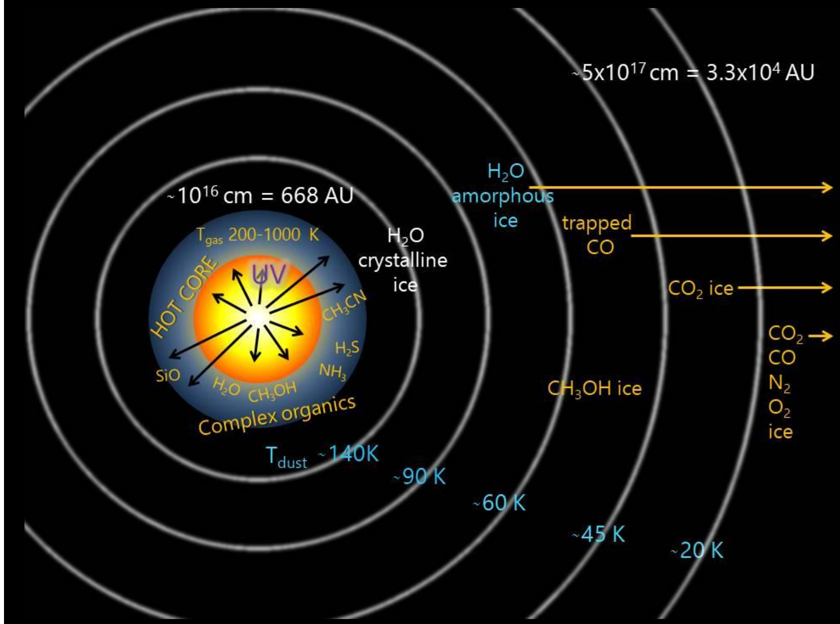
Difference between amorphous (dash line) and crystalline (solid line) water ice.
In our experimental conditions ($P=10^{-9}$ mbar) H_2O undergoes transition from amorphous to crystalline phase at about 155 K.

Leto & Baratta 2003, A&A 397, 7

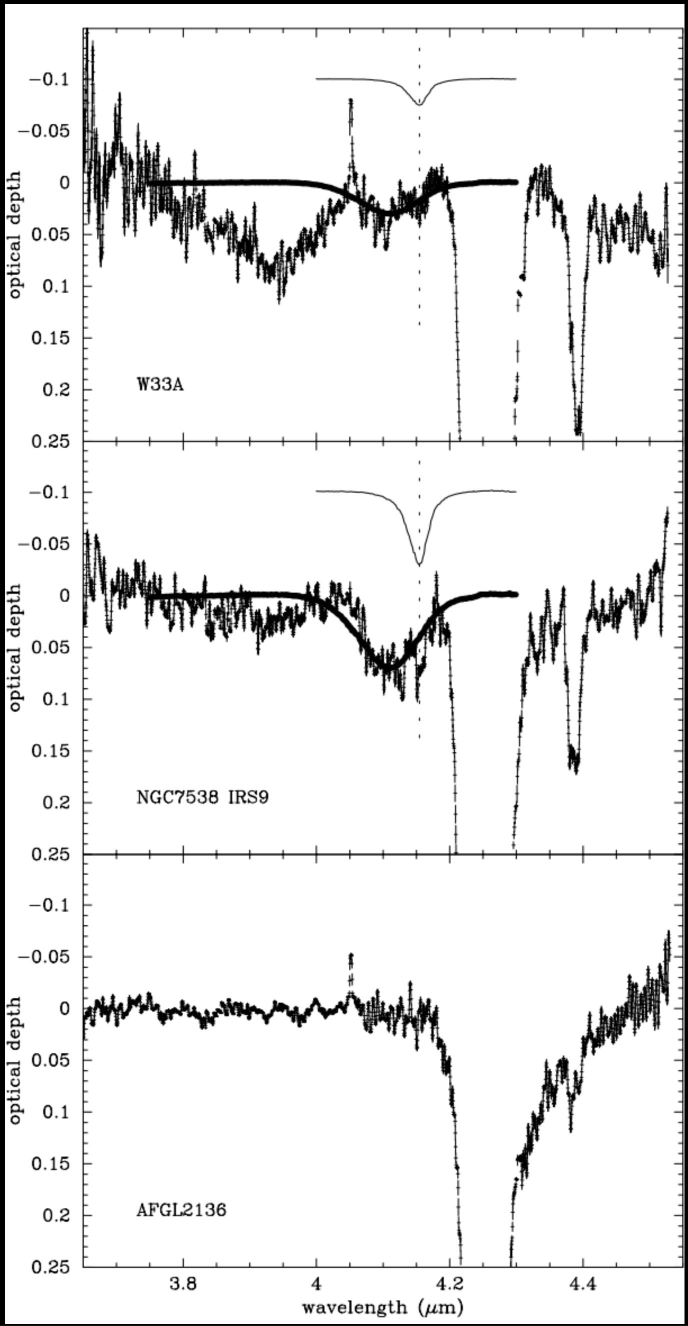
H_2O ice: a comparison between laboratory and astronomical infrared spectra



Water ice shows various states of "crystallinity".
ISO-SWS



Dartois and d'Hendecourt 2001, A&A 365, 144



HDO: a comparison between laboratory and astronomical infrared spectra acquired with ISO.

The thick solid lines superimposed on the optical depth spectra of W33A and NGC7538 IRS9 correspond to the laboratory spectrum of a mixture of ~1% of HDO in amorphous H_2O-ice.

The thin solid lines plotted above the same spectra correspond to a mixture of ~0.7% of HDO in crystalline H_2O-ice (displaced for clarity); the dotted vertical lines mark the peak position of the laboratory band.

Texeira et al. 1999, A&A 347, L19

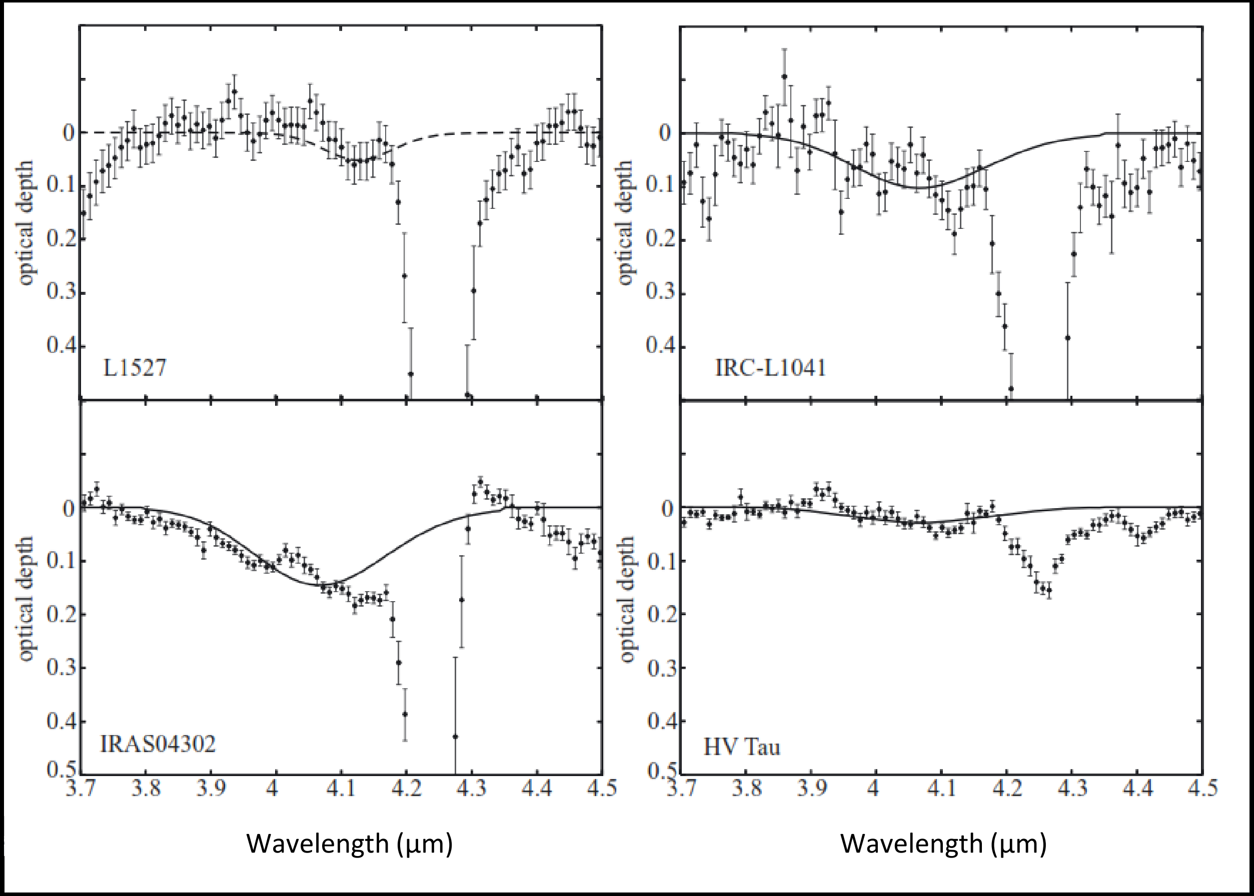
HDO toward Young Stellar Objects

Aikawa et al. 2012 report the observations made with the InfraRed Camera on board of AKARI telescope.

Tentative detection of the O-D stretching band of HDO toward L1527, IRC-L1041, IRAS 04302 and HV Tau.

They also report about the amount of HDO.

HDO/H_2O= 2% - 22%



Aikawa et al. 2012, A&A 538, A57

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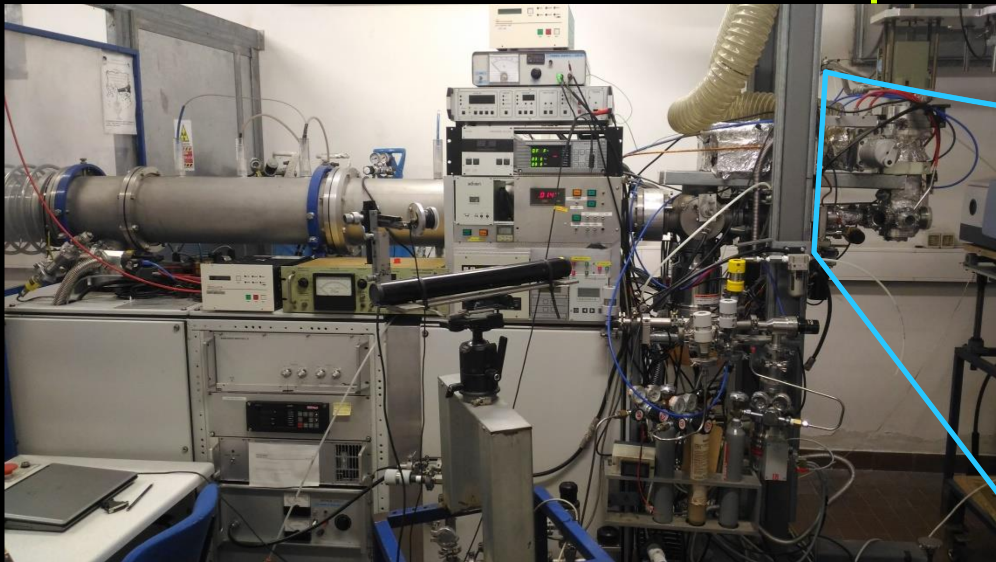
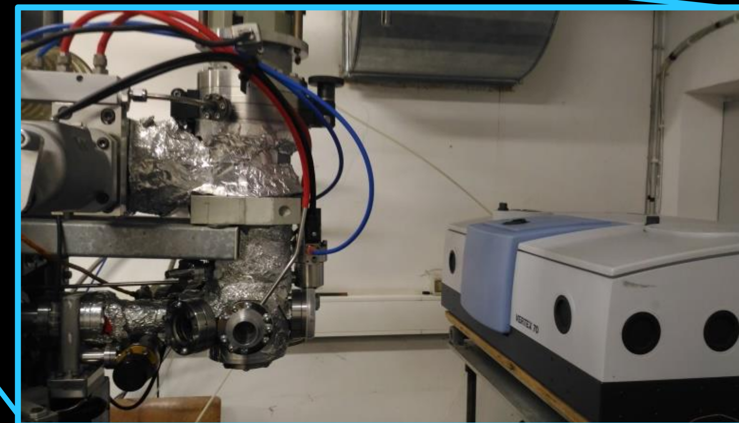
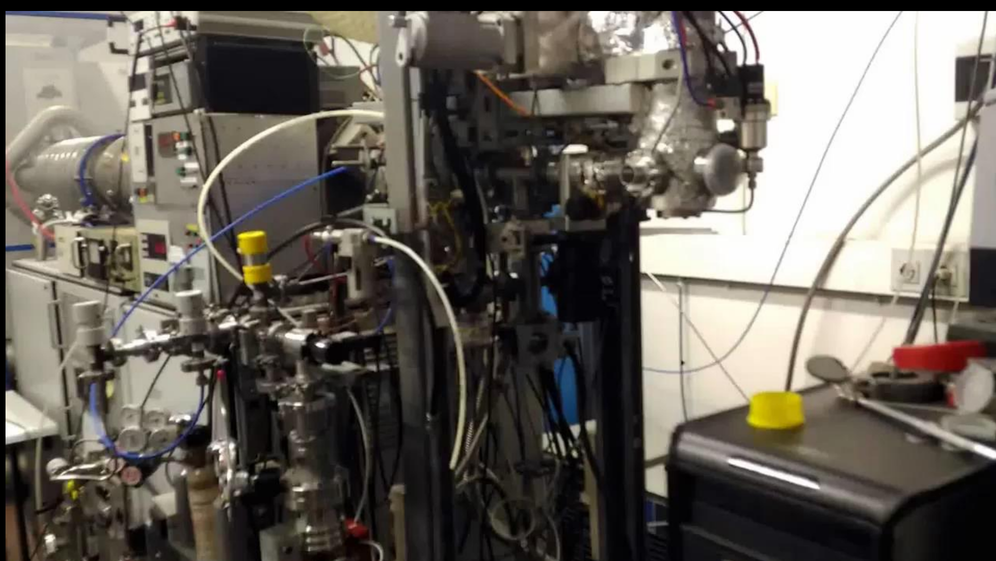
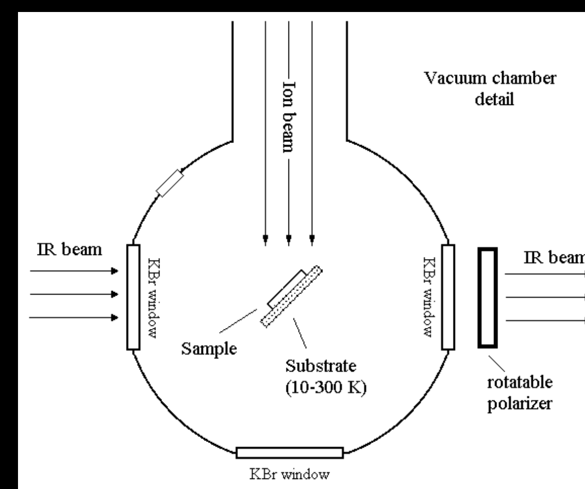
LASp Catania



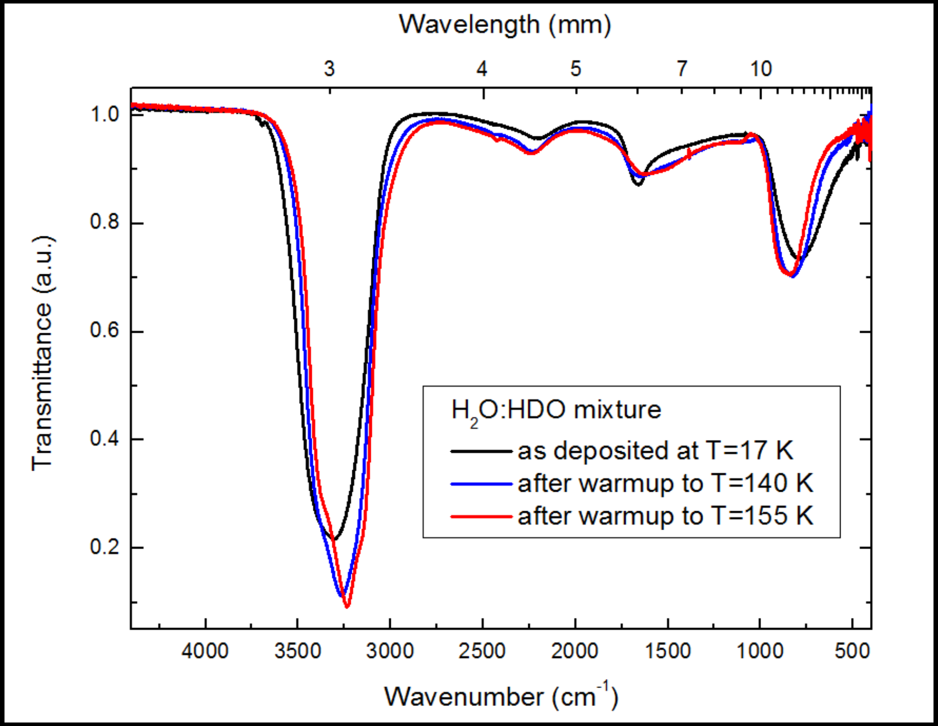


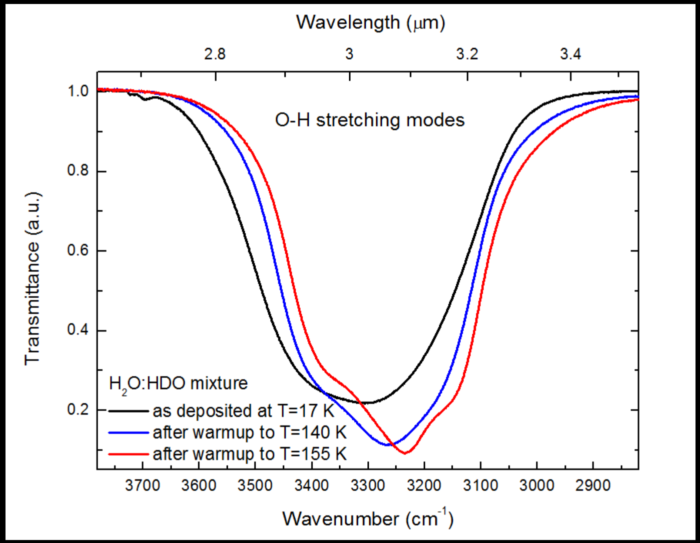


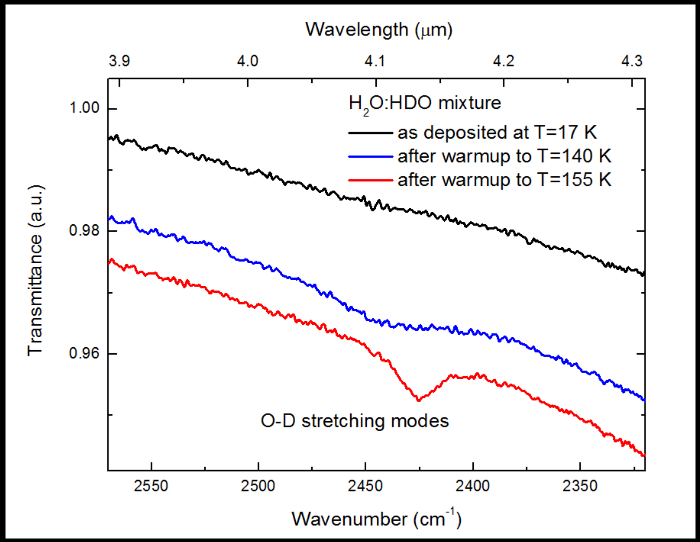


T=10-300 K |High vacuum=10^{-9} mbar | up to 200 keV ions | IR and Raman spectroscopy

Thermal processing of H_2O:HDO mixtures



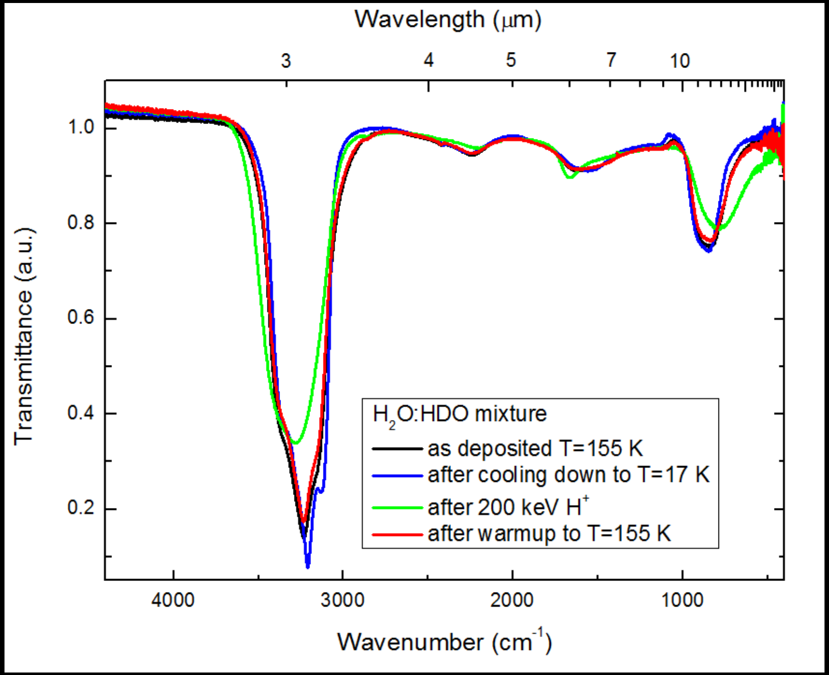


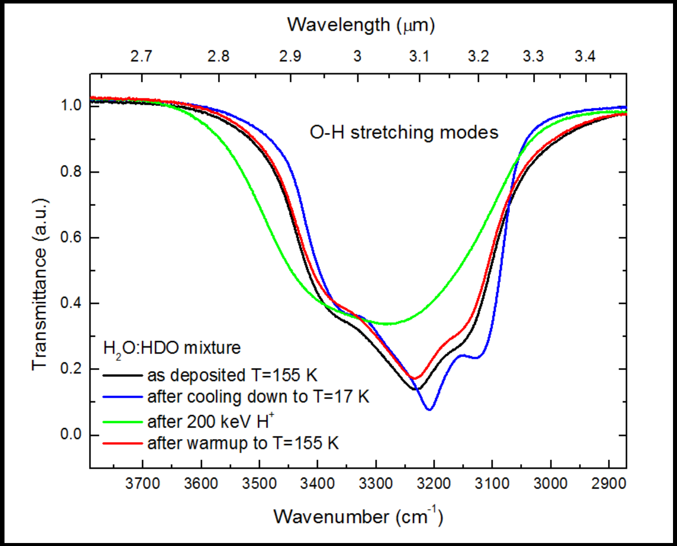


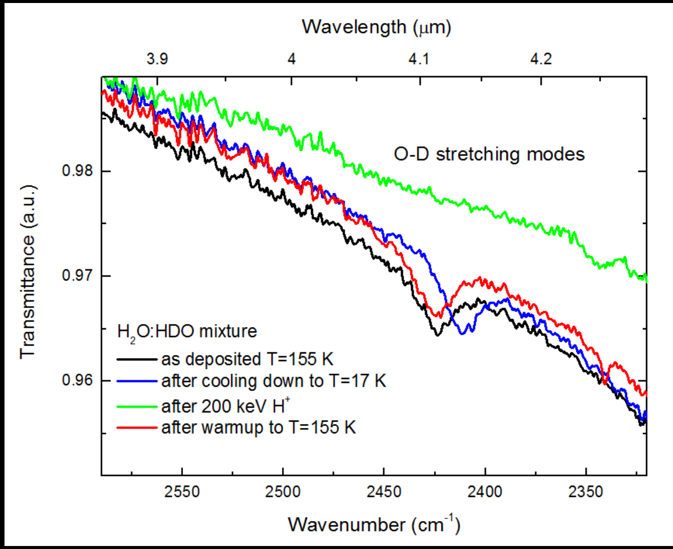
FT-IR spectra of H_2O:HDO mixture deposited at 17 K (black line) and after warmup to 140 K (blue line) and 155 K (red line).

The O-D stretching mode appears when the sample starts its transition to the crystalline phase.

Energetic processing of H_2O:HDO mixture





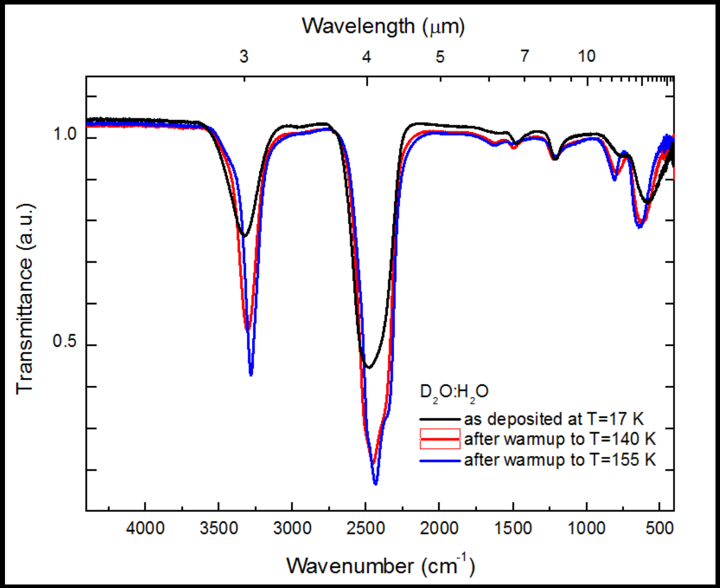


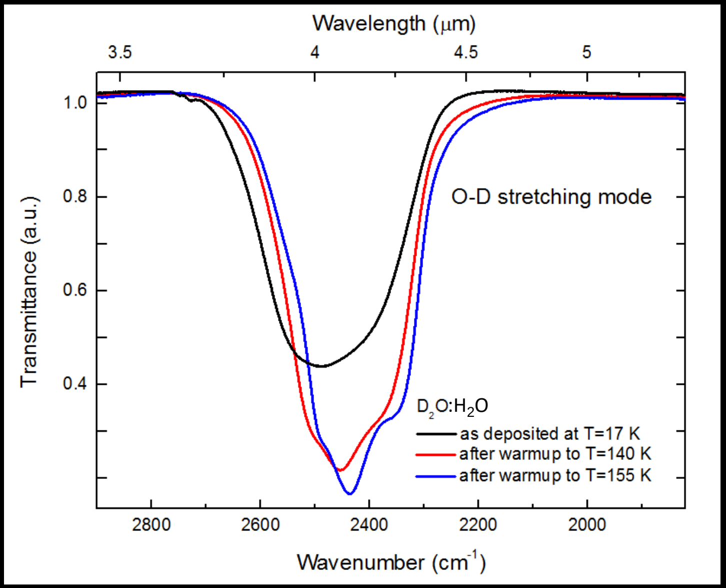
FT-IR spectra of H_2O:HDO mixture deposited at 155 K (black line), cooled down to 17 K (blue line) and irradiated with 200 keV H^+(green line).

The E.P. induce the crystalline-to-amorphous transition, and the O-D stretching band disappears.

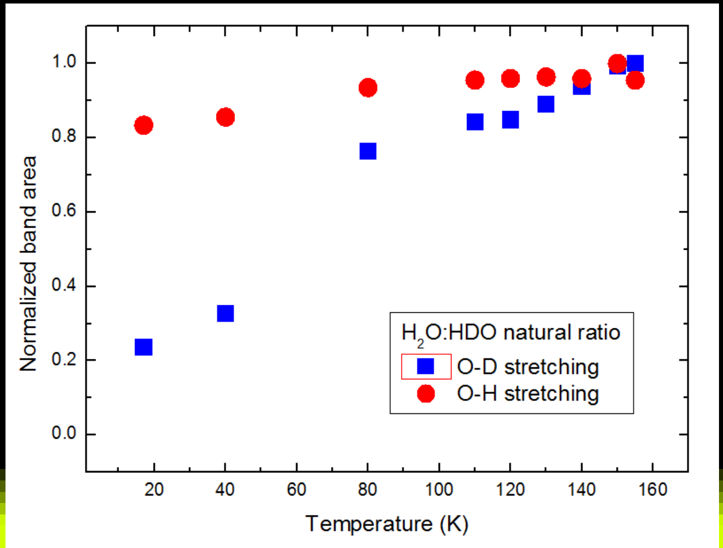
After the warmup (red line) the sample goes back to the crystalline phase.

A measure of the O-D stretching mode band area D_2O highly concentrated mixture.

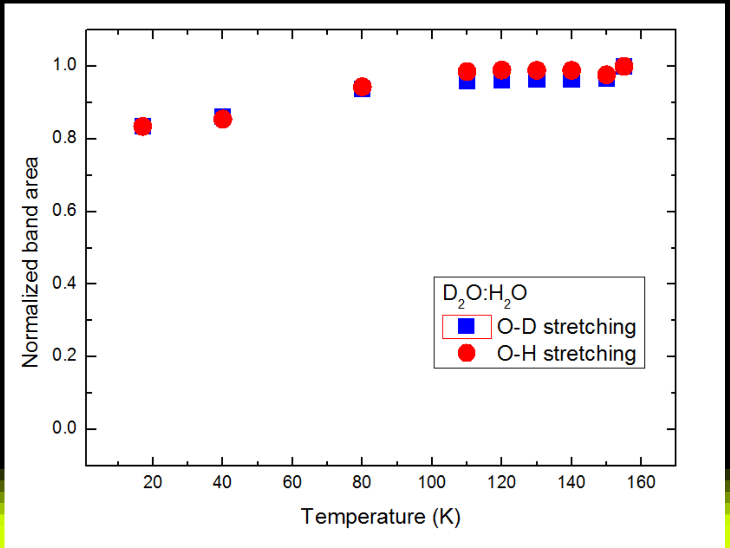




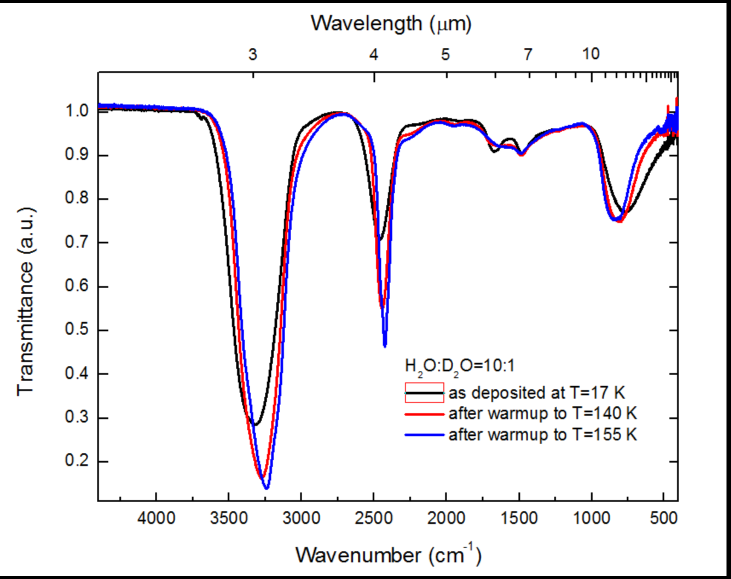
O-D Normalized band area for a diluted mixture

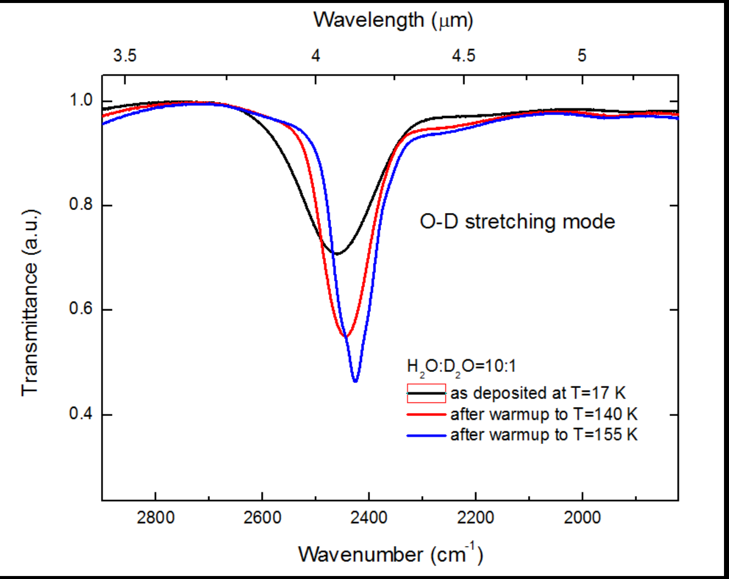


O-D Normalized band area for a concentrate mixture

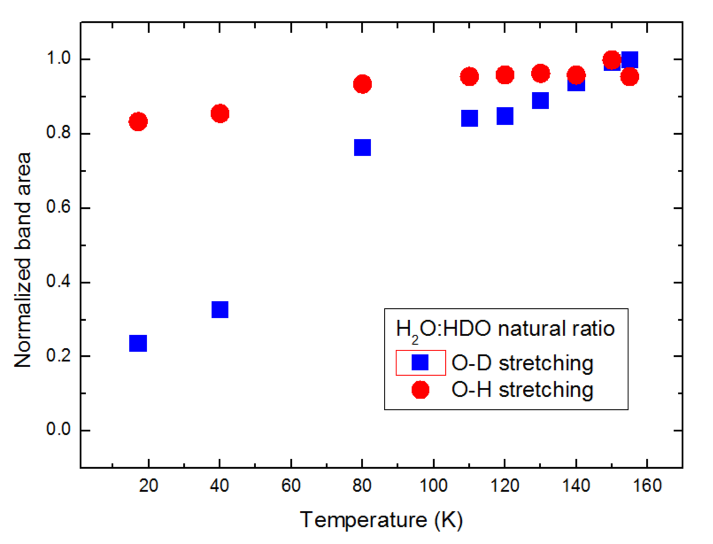


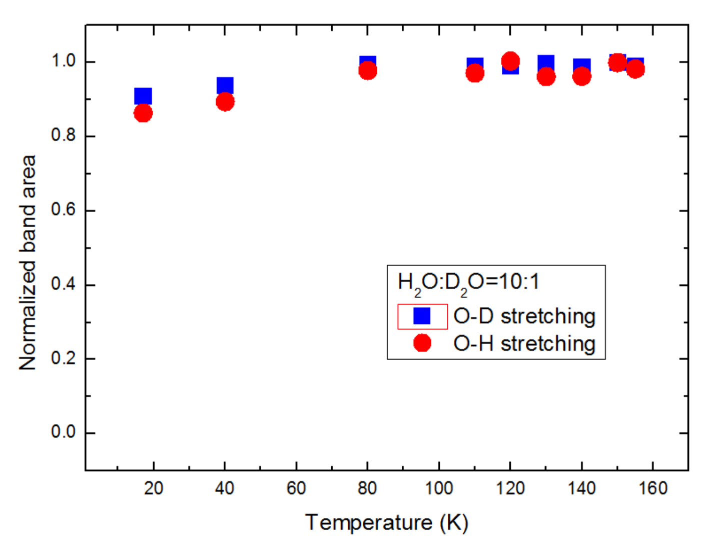
A measure of the O-D stretching mode band area in a D_2O low concentrated mixture.



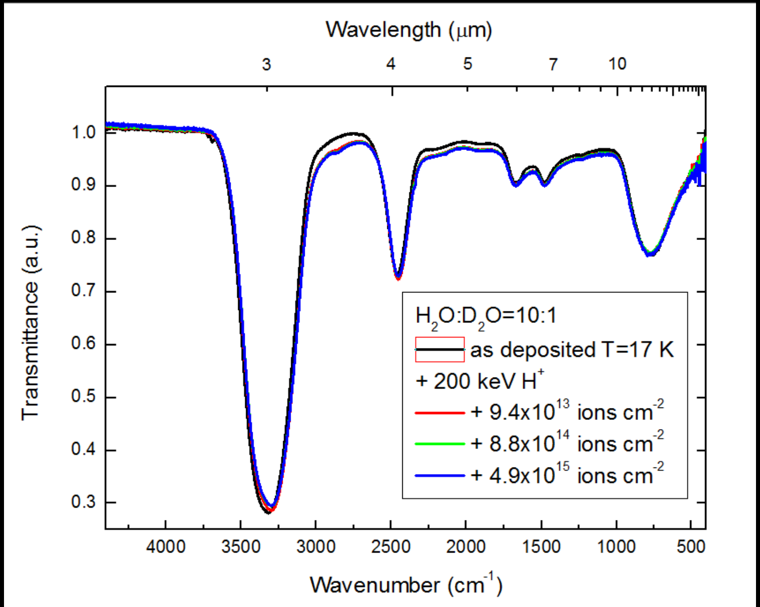


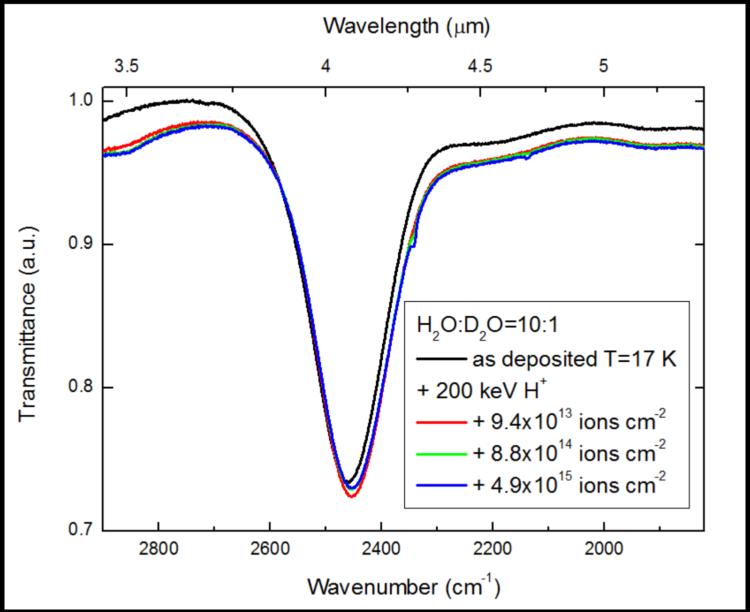
O-D Normalized band area for a diluted mixture



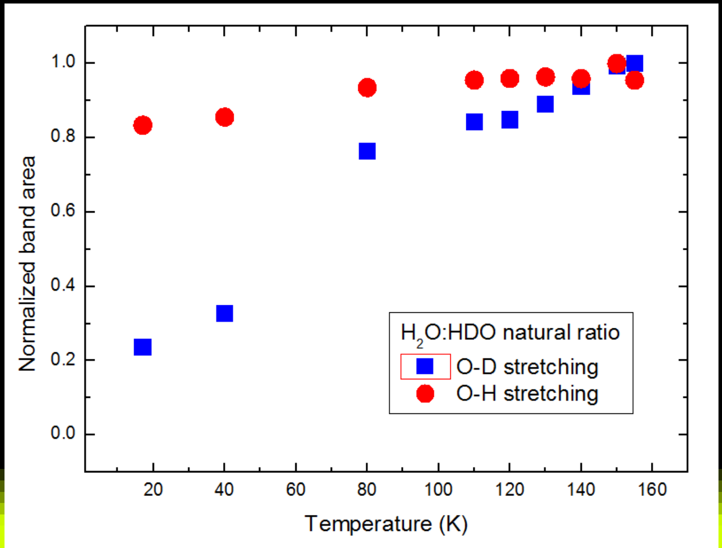


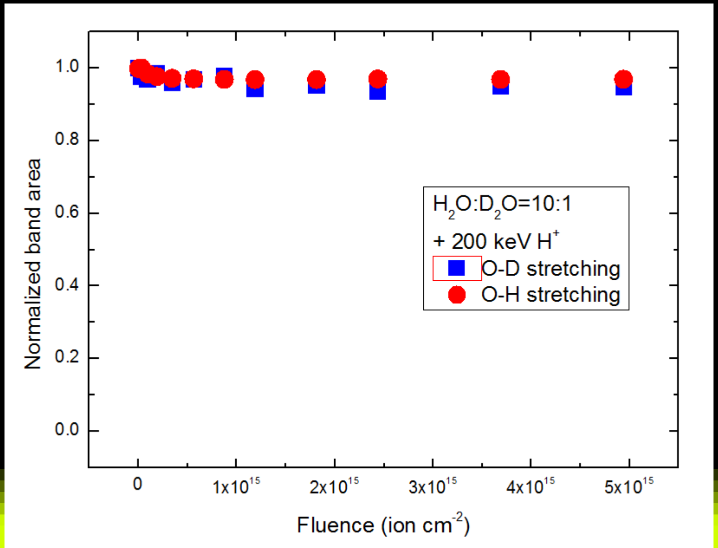
Energetic processing of $H_2O:D_2O$ mixture

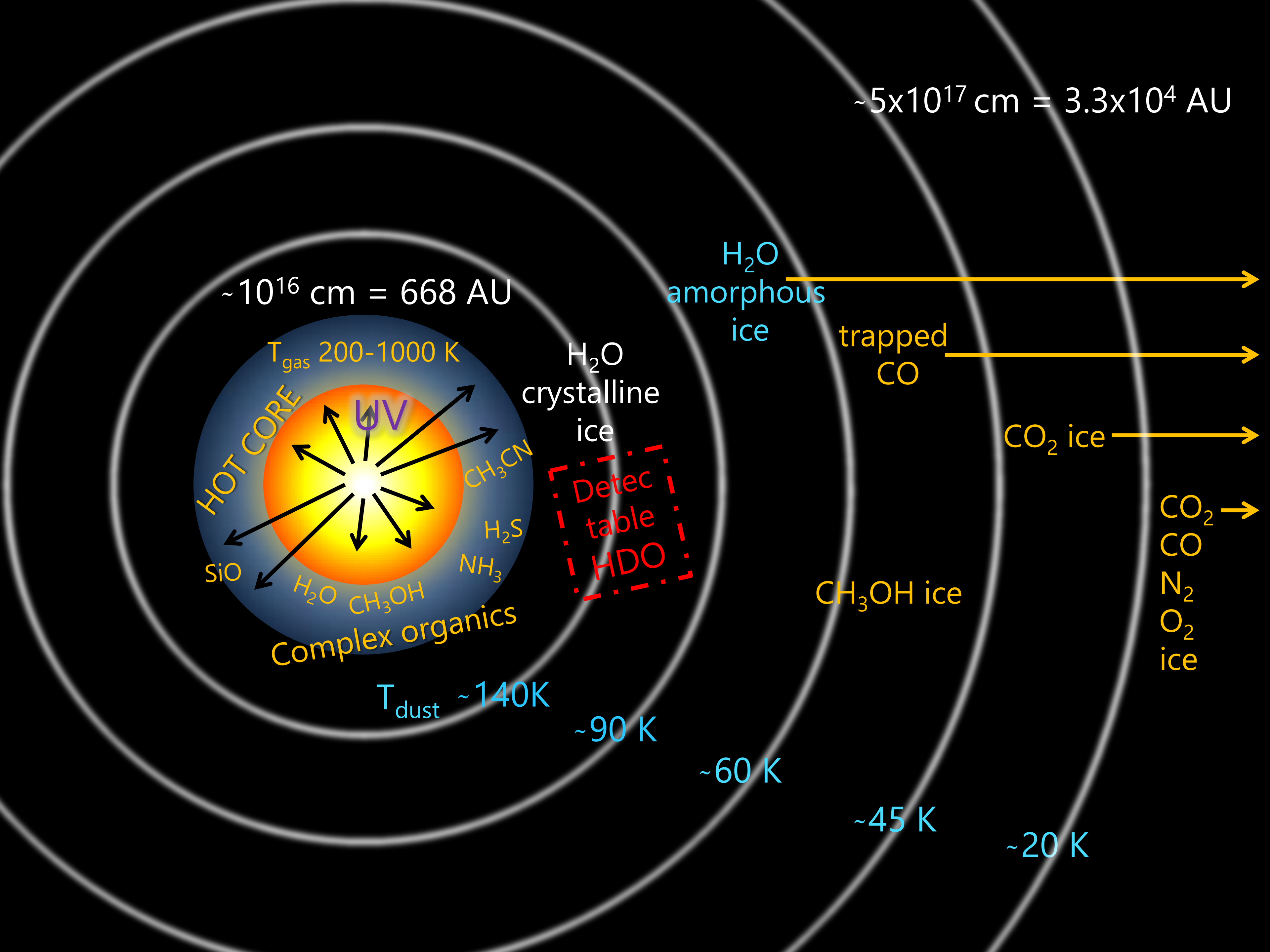




O-D Normalized band area for a diluted mixture





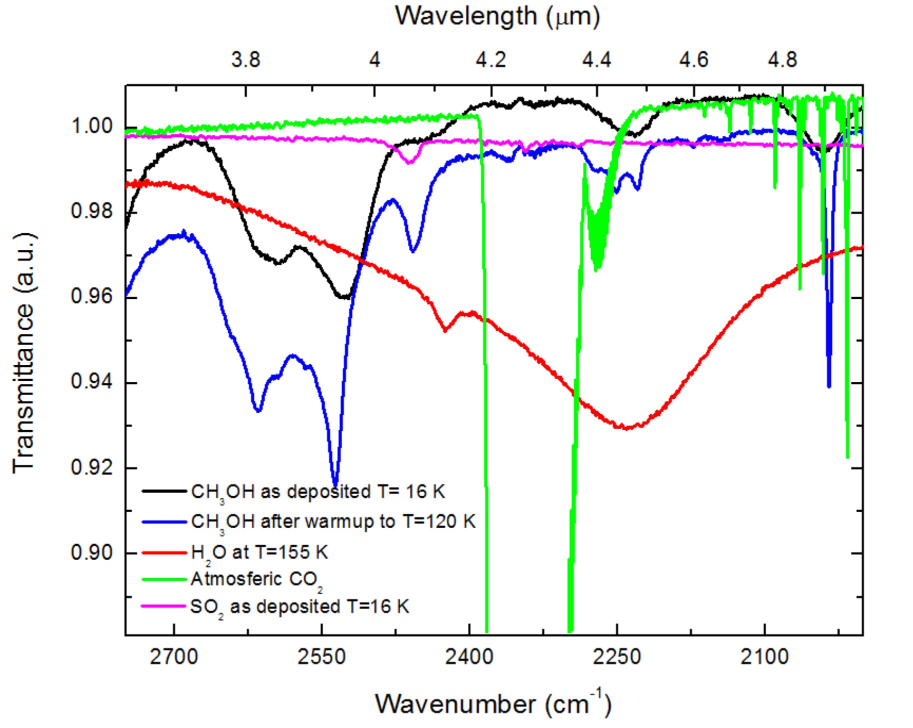


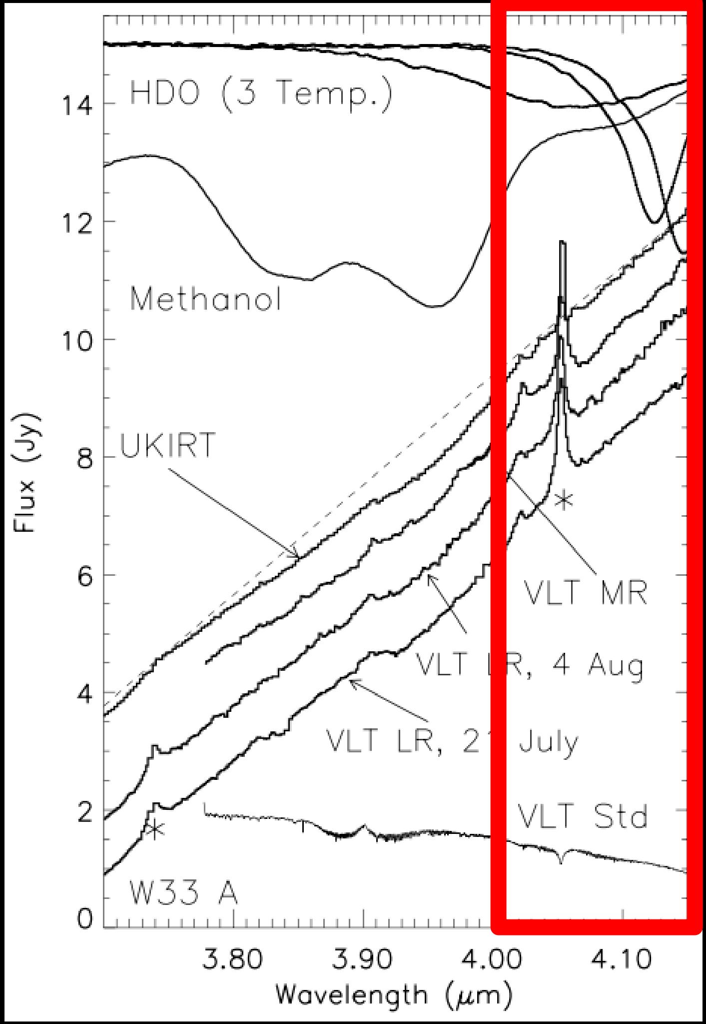
~5x10^17 cm = 3.3x10^4 AU
~10^16 cm = 668 AU
T_gas 200-1000 K
HOT CORE
UV
CH3CN
H2S
NH3
SiO
H2O CH3OH
Complex organics
H2O crystalline ice
Detec table HDO
H2O amorphous ice
trapped CO
CO2 ice
CO2 CO N2 O2 ice
CH3OH ice
T_dust ~140K
~90 K
~60 K
~45 K
~20 K

HDO 4.1 µm band in interstellar ices: detection problems

The O-D stretching mode of HDO is in the range 4.03-4.17 µm.

- **VLT-ISAAC** LWS3-LR spectral domain: 2.55-4.2 µm and 4.45-5.1 µm.
- **UKIRT-CGS4** spectral domain: 3.55-4.19 µm.
- Overlap of CH_3OH, SO_2 and atmospheric CO_2 bands.





Comparison between laboratory spectra of HDO and methanol and ground-based spectra acquired with VLT-ISAAC and UKIRT-CGS4 spectrometers for W33A.

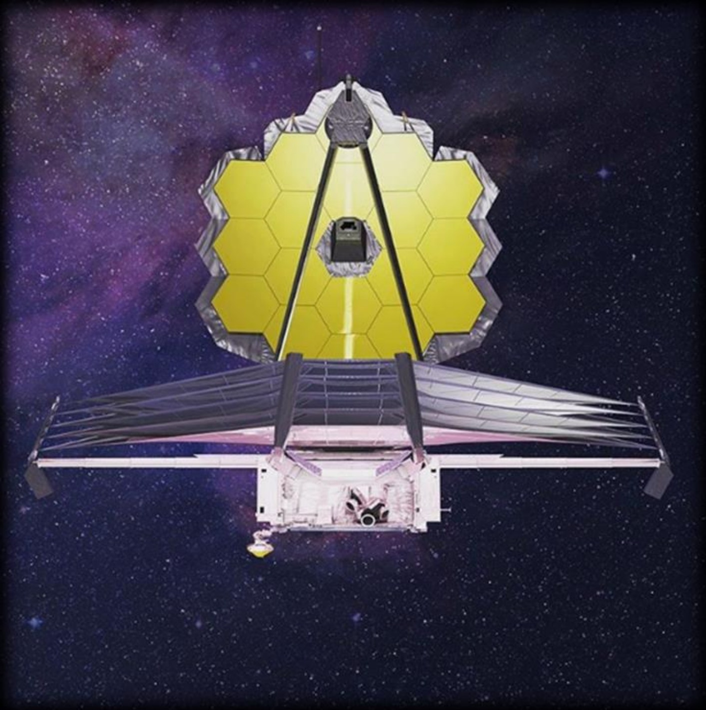
Dartois et al. 2003 A&A 399, 1009

Conclusions

Laboratory experiments

In highly diluted and amorphous mixtures, the detection of the O-D stretching mode of HDO is challenging. O-D stretching mode narrowing with growing temperature.

It is just possible to determine an upper limit.



Observations

Detection problems:

- SO_2 and CH_3OH bands overlap
- Atmospheric CO_2 absorption

They make possible just tentative detections

High sensitivity is requested

2018: JWST has an higher sensitivity

Thank you