Herschel observations of deuterated water towards high-mass star-forming regions

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1.1 Deuterated water

HDO

- The HDO chemistry occurs in a low-density, cold medium.
- Further gas-phase reactions lead to enhanced [HDO]/[H_2O] ratios.
- To determine the temperature at which water was synthesized.
- To study deuterium fractionation processes and chemical formation of water.

1.2 Water deuterium fraction

D/H ratio

- Interstellar medium
  - D/H ~1.5×10^{-5} (Linsky 2003)
- Low-mass protostars
  - HDO/H_2O ~ 0.03 (inner), < 0.002 (outer) in IRAS16293-2422 (Parise et al. 2005)
  - HDO/H_2O > 0.01 (inner), ~ 0.07 (outer) in NGC1333-IRAS2A (Liu et al. 2011)
- High-mass star-forming regions
  - $HD^{18}O/H_2{}^{18}O$ ~ 0.02 in Orion KL HC (Bergin et al. 2010)
  - $HDO/H_2{}^{17}O$ ~ 0.001 in Orion KL HC (Persson et al. 2007)
  - HDO/H_2O ~ $2\text{-}6 \times 10^{-4}$ in W3 $(OH)/(H_2O)$ (Helmich et al. 1996)
  - HDO/H_2O ~ 1×10^{-4} (W3 IRS5), ~ 70×10^{-4} (W33A), ~ 8×10^{-4} (AFGL 2591), and ~ 30×10^{-4} (NGC 7538 IRS1) (van der Tak et al. 2006)

- Higher D/H ratio using other molecules than using H_2O

2.1 Sources & Observations

Sources & Obs.

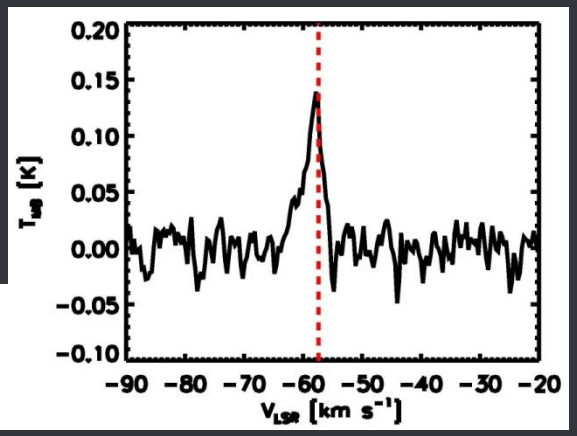
- We observed 5 high-mass star-forming regions with HDO 1_{11}-0_{00} (893.6 GHz, E_{up}= 43 K).

- W3 IRS5 (HMPO)
  - d = 2.0 kpc
  - L = 1.2x10^5 $L_\odot$
- G327-0.6 (HMC)
  - d = 3.3 kpc
  - L = 2.5x10^4 $L_\odot$
- NGC7538 IRS1 (UCHII)
  - d = 2.7 kpc
  - L = 1.1x10^5 $L_\odot$
- IRAS16065-5158
  - d = 4 kpc
  - L = 2.9x10^5 $L_\odot$ (Faundez et al. 2004)
- G8.67-0.36 (UCHII)
  - d = 4.8 kpc
  - L = ~ 10^4 $L_\odot$ (Wood & Churchwell 1989; Fish et al. 2003)

3.1 HDO Obs.

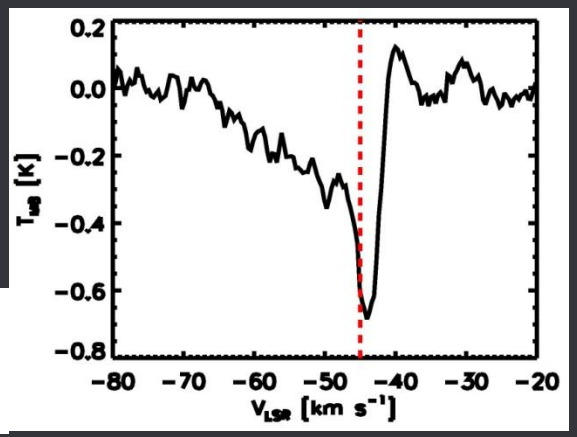
HDO Observations

NGC7538 IRS1
$L=1.1\times10^5\ L_\odot$
d=2.7 kpc



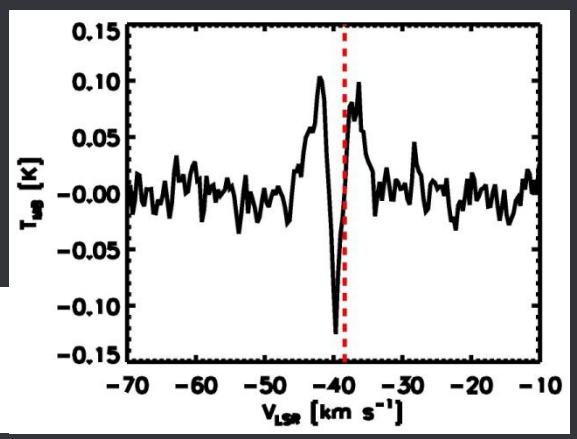
- Emission line
  - NGC7538 IRS1
  - blue wing

G327-0.6
$L=2.5\times10^4\ L_\odot$
d=3.3 kpc



- Absorption line
  - G327-0.6 and G8.67-0.36
  - blue wing

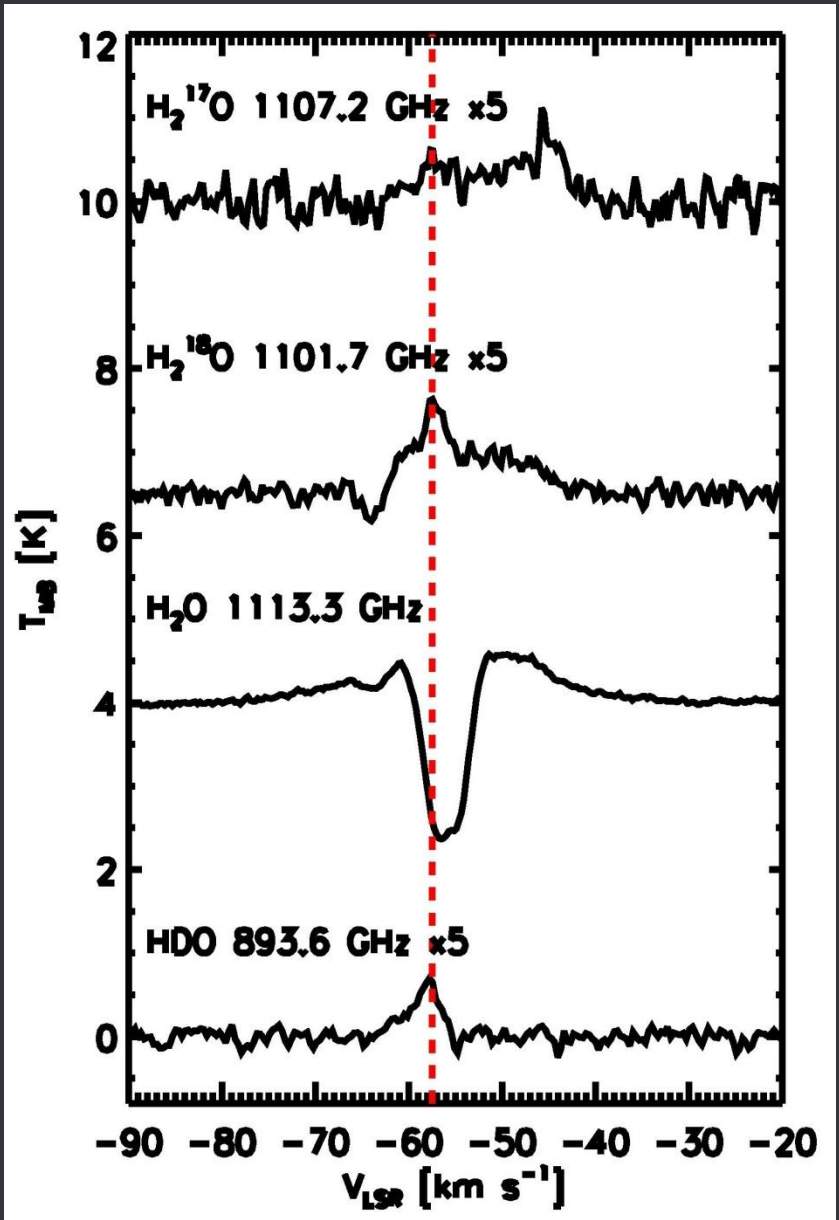
W3 IRS5
$L=1.2\times10^5\ L_\odot$
d=2.0 kpc



- Mix of Absorption and emission lines
  - W3 IRS5
  - Similar line profile with IRAS16293-2422 (Stark et al. 2004; Parise et al. 2004, 2005)

3.2 HDO Obs.

NGC7538 IRS1

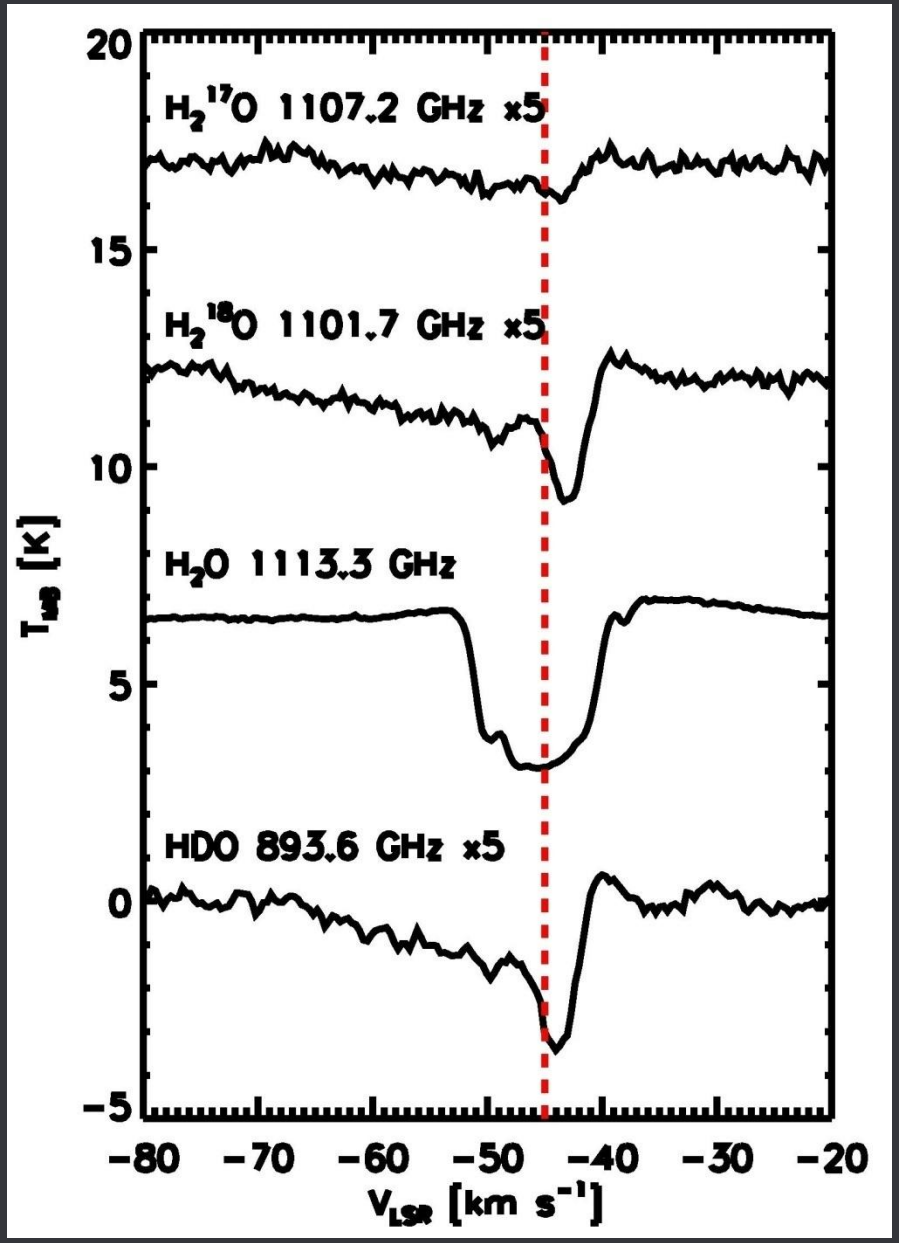


- **Emission** in HDO, $H_2{}^{18}0$, and $H_2{}^{17}O$ lines
- **Absorption** in H_2O line

- **Blue** wing in HDO line
- **Red** wing in H_2O, $H_2{}^{18}0$, and $H_2{}^{17}O$ lines

3.3 HDO Obs.

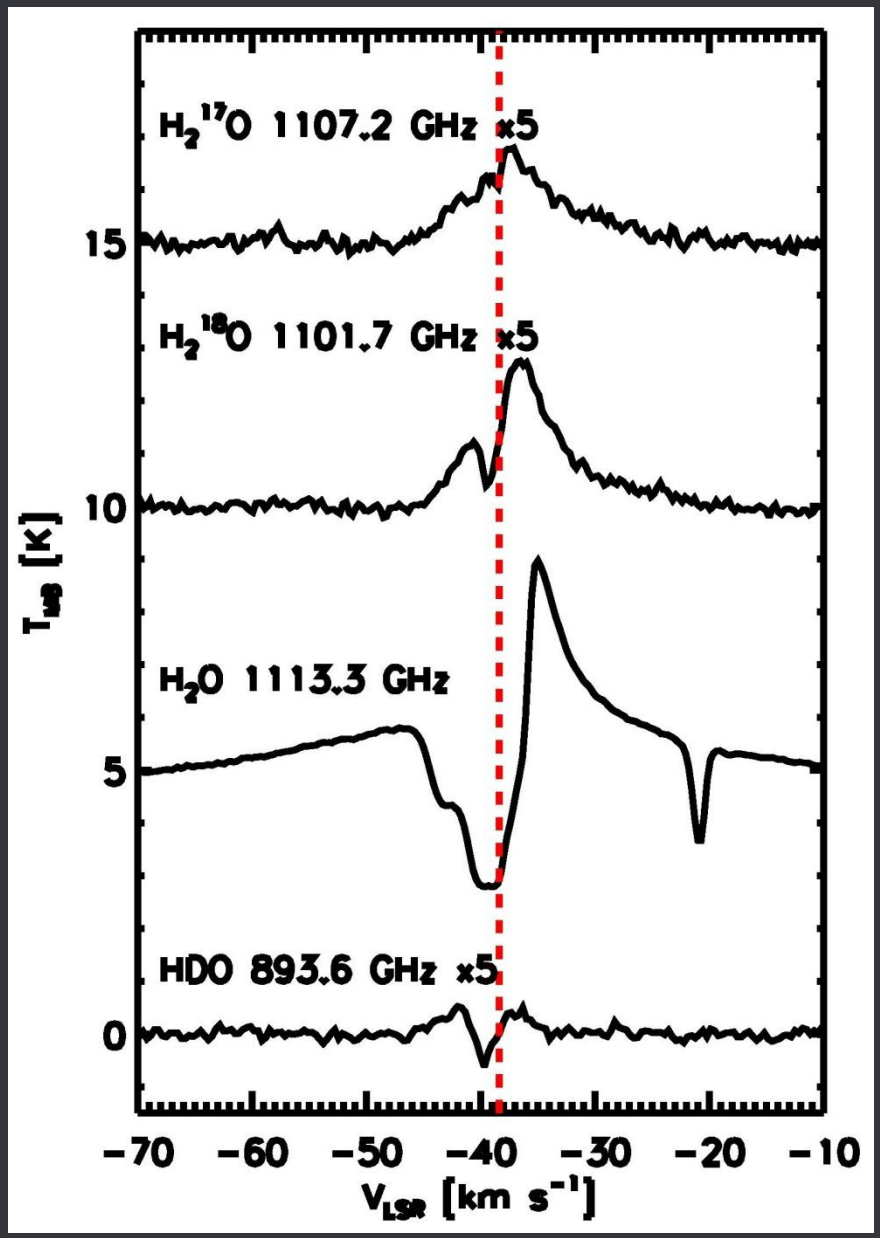
G327-0.6



- **Absorption** and blue wing in HDO, H_2O , $H_2{}^{18}0$, and $H_2{}^{17}O$ lines

3.4 HDO Obs.

W3 IRS5



- **Mix** of absorption and emission in HDO and H_2O lines
- **Emission** in $H_2{}^{18}O$ and $H_2{}^{17}O$ lines

4.1 Summary & Future Works

- Summary
  - Emission in NGC 7538 IRS1
  - Absorption in G327-0.6 and G8.67-0.36
  - Mix of emission and absorption in W3 IRS5
  - The HDO line is similar with $H_2{}^{18}O$ and $H_2{}^{17}O$ lines

- Future Works
  - Calculate column density
  - Run RATRAN using the physical structure by Luis
  - Measure D/H ratio
  - Compare with other sources
  - Compare with chemical model results