The abundance of H_2O and HDO in Orion KL from Herschel/HIFI

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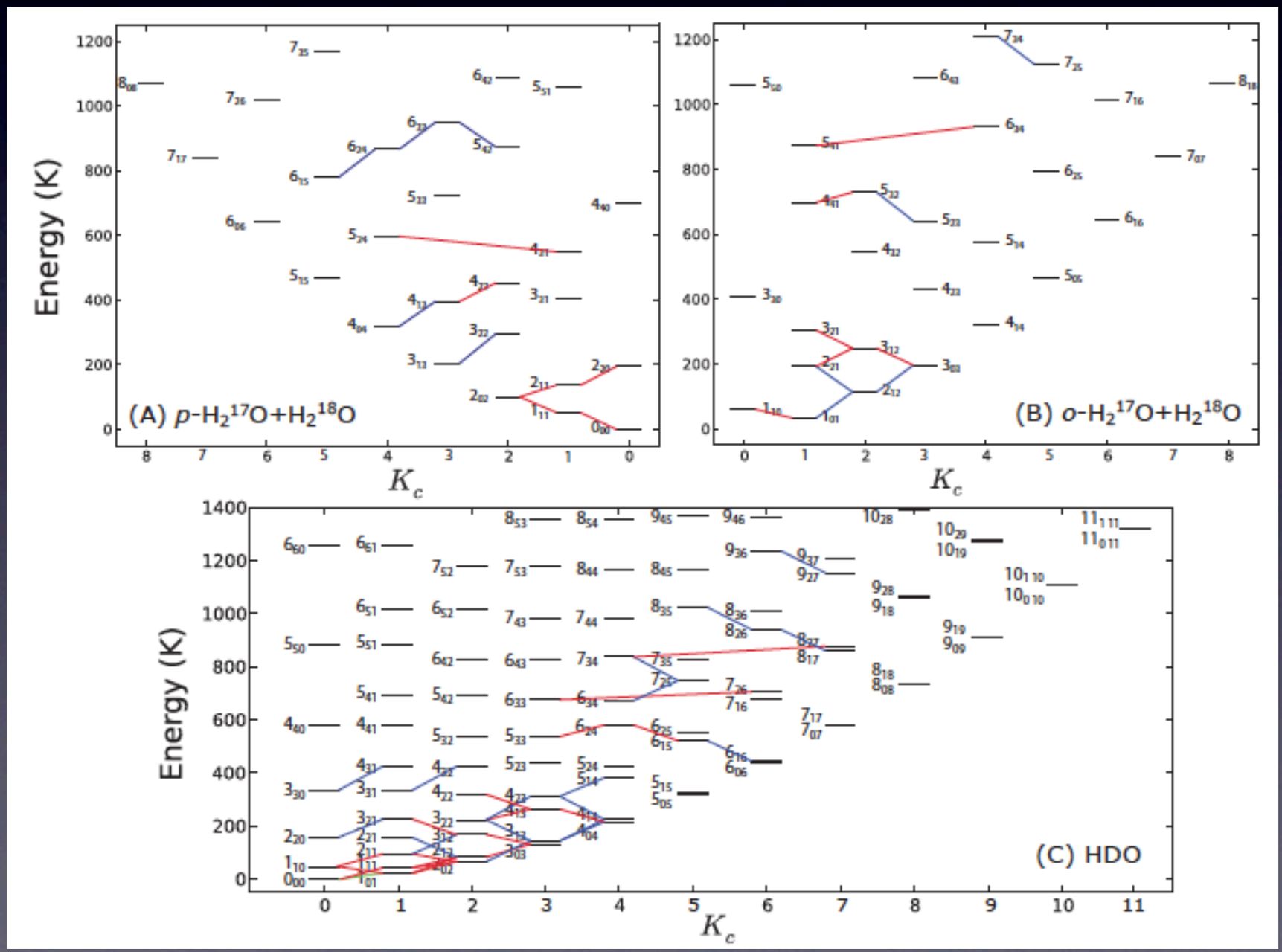
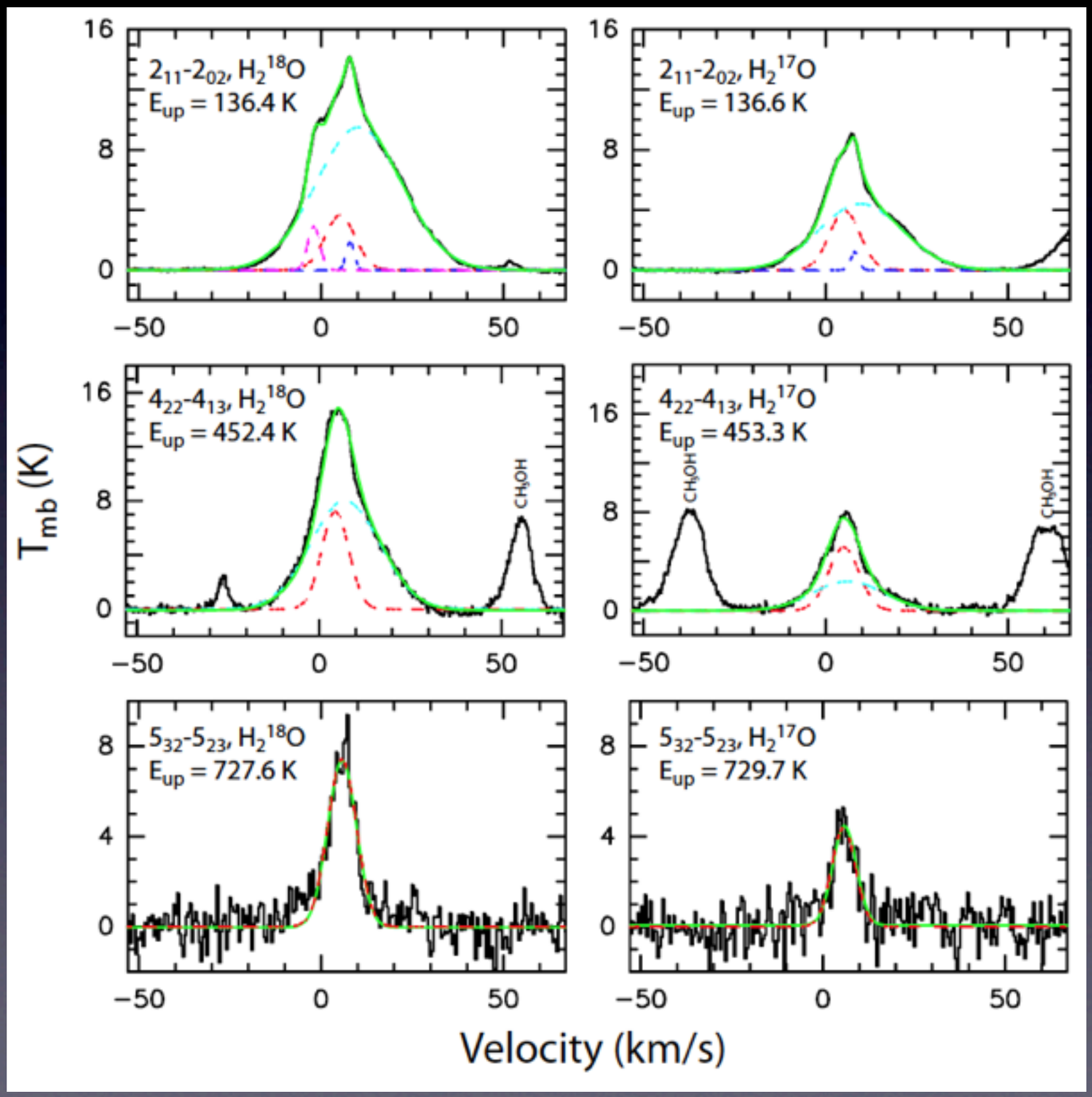


Data Set:

- 20 $H_2{}^{18}O$
- 14 $H_2{}^{17}O$
- 37 $HD^{16}O$
- 6 $HD^{18}O$
- 6 D_2O

Only unblended lines used in the analysis

Multiple Components



Lines can be decomposed into 3 components:

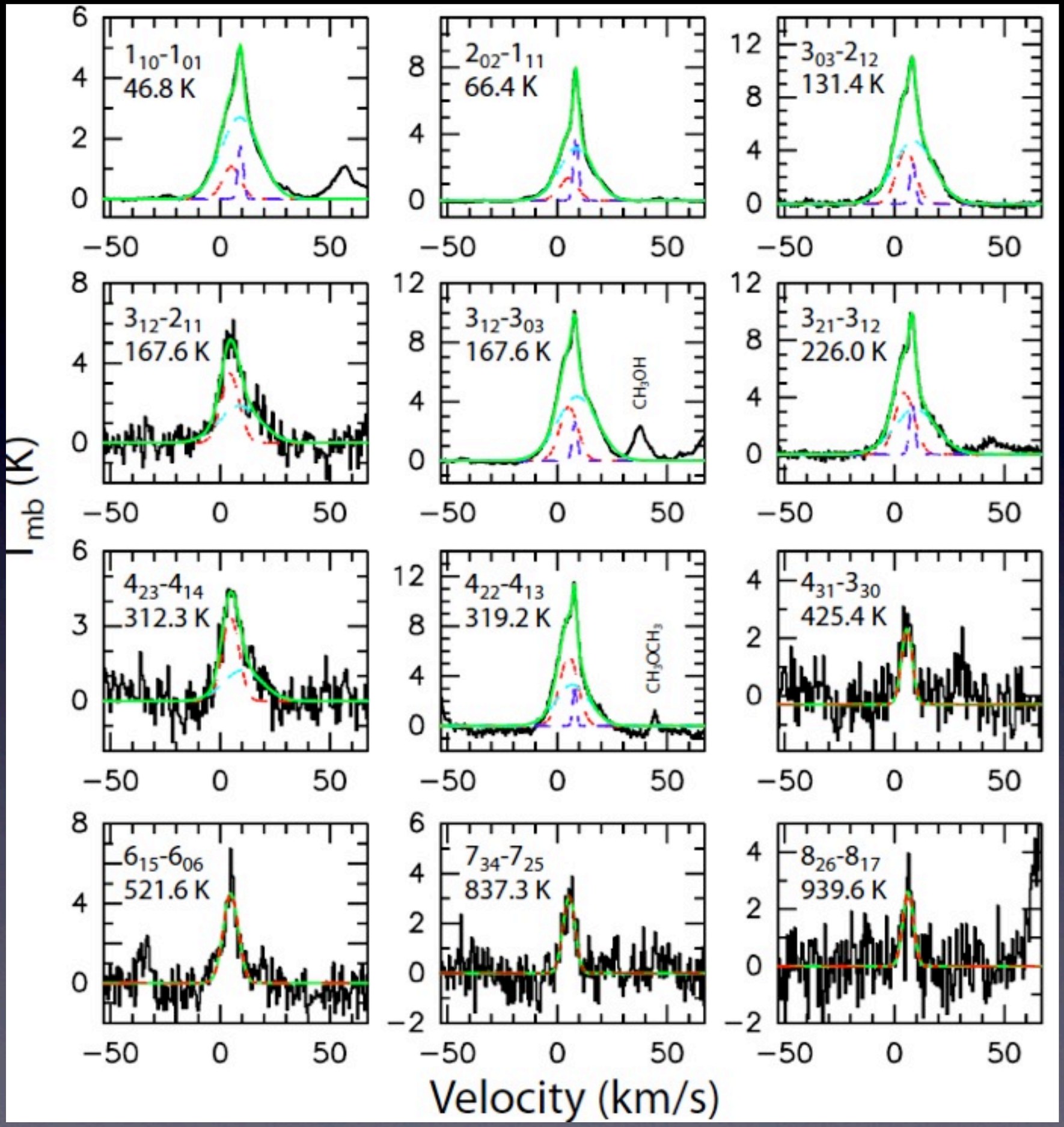
- Hot core (velocity 5 km/s, line width 5–10 km/s)
- Compact Ridge (velocity 8 km/s, line width 3 km/s)
- Plateau (velocity 9 km/s, line width 25 km/s)

Very high optical depths

Non-LTE excitation

Column densities sensitive to the assumed source size

HDO

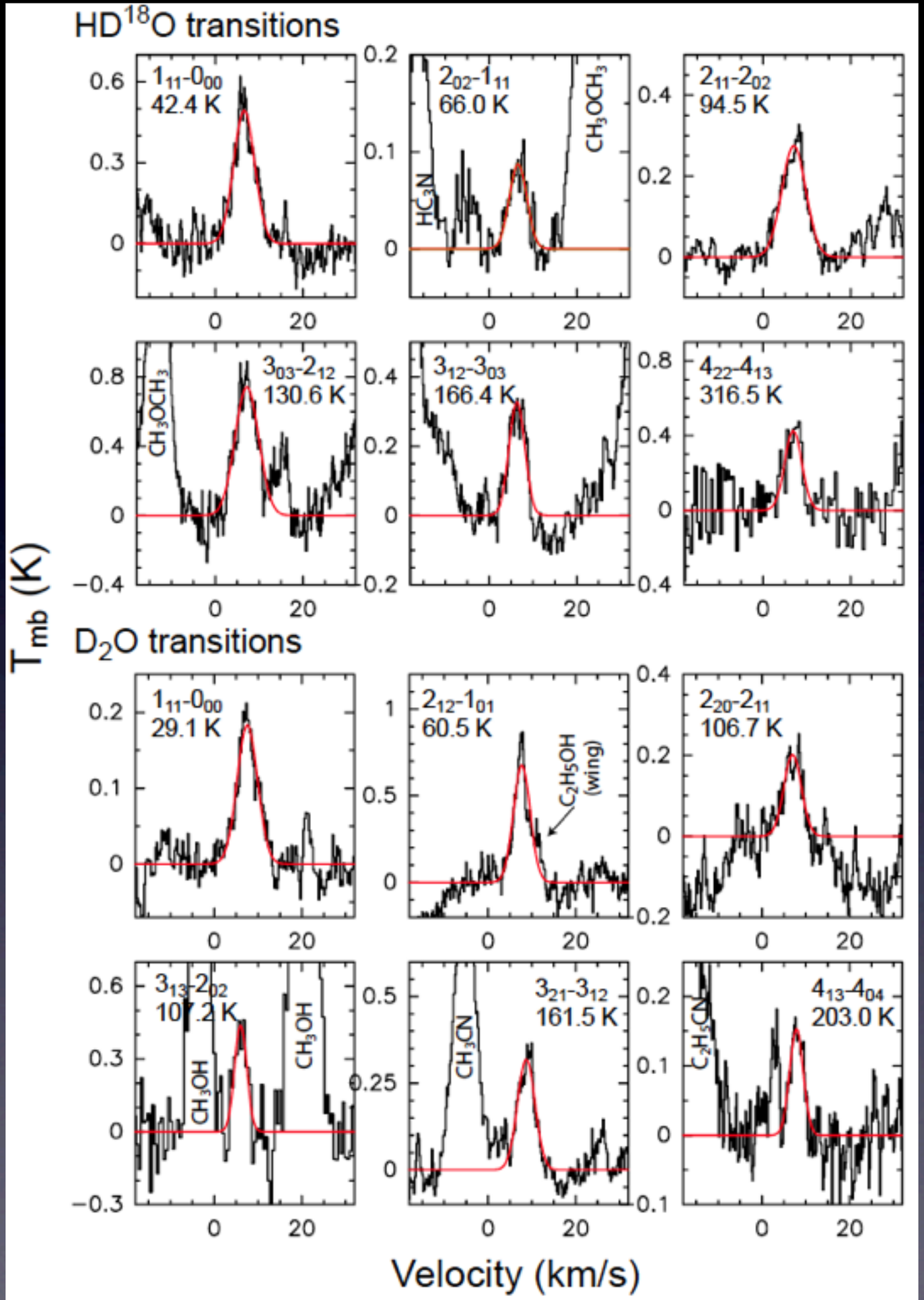


Column densities:

- Direct summation method
- Radex modeling

No collisional rates above 450 K

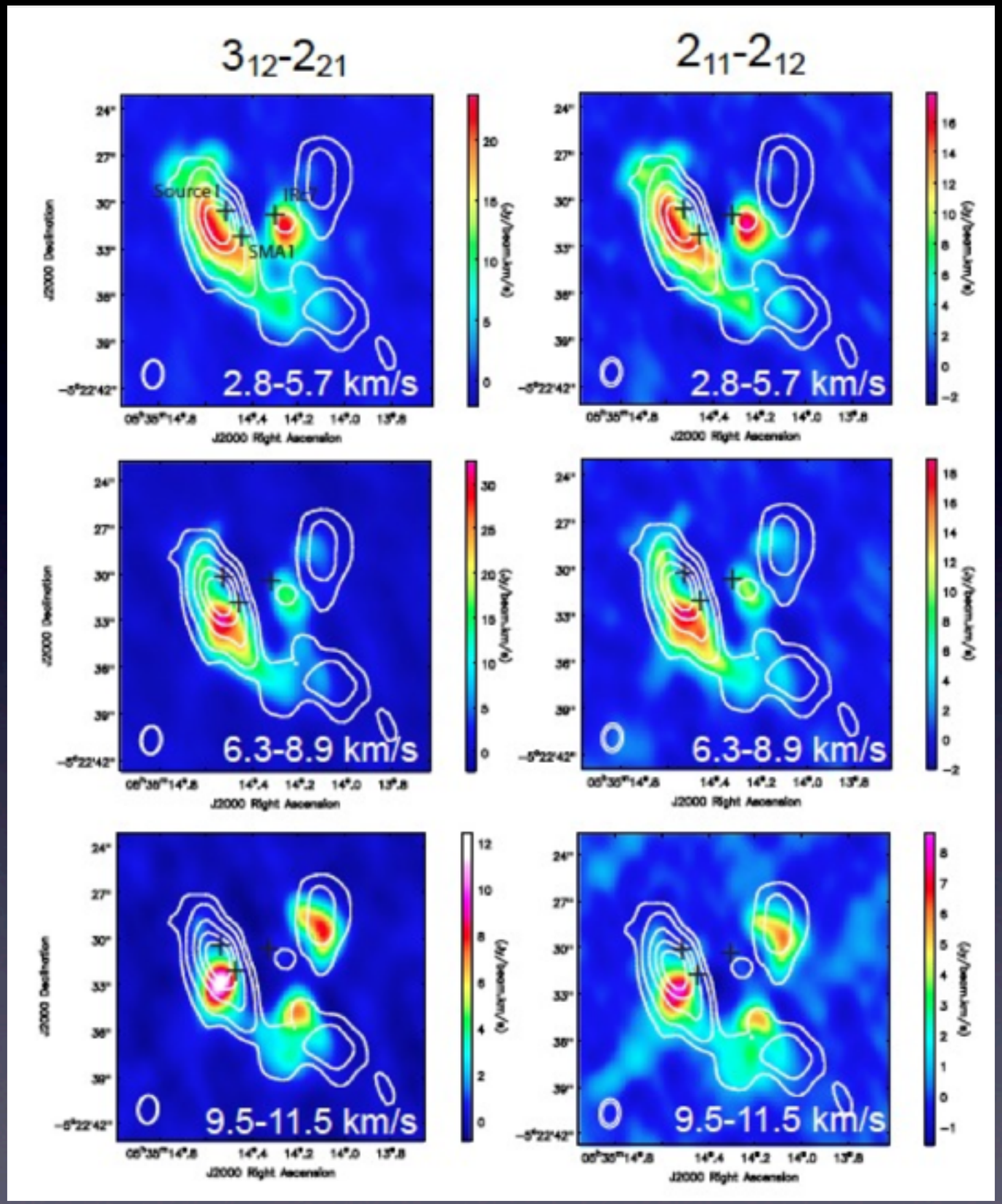
Radiative pumping—H_2S observations indicate enhanced IR flux at $\lambda < 100$ mic



$HD^{18}O$ and D_2O

- Detection of $HD^{18}O$ confirmed
- Implies either very high D/H ratio or very high H_2O column density in some component (velocity does not exactly match the known components)
- Need accurate source size to model the emission
- ALMA SV data provide spatially resolved images!

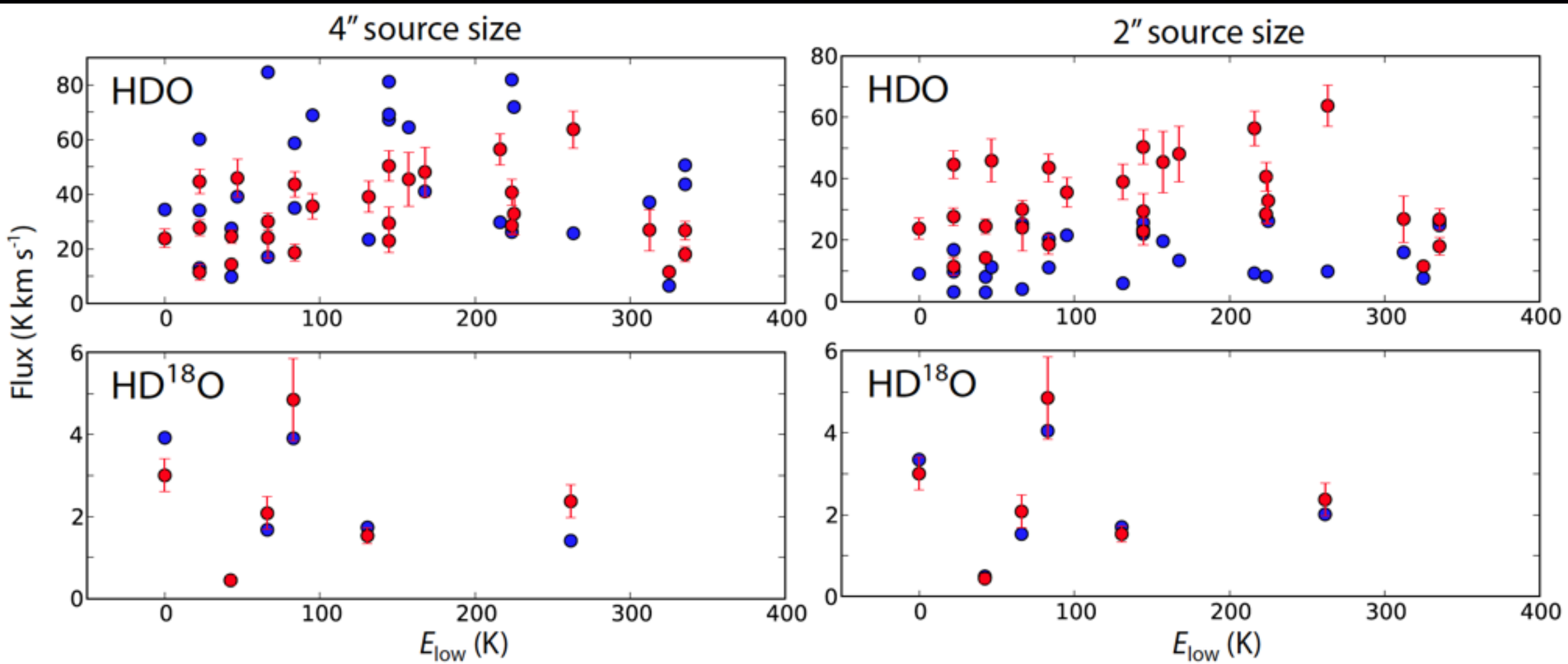
HDO with ALMA



Conturs 230 GHz continuum
Color HDO

- Multiple components
- Bright HDO emission in a small clump (2" in size) at ~7 km/s
- Agrees with $HD^{18}O$ velocities
- Analysis of water lines also consistent with emission from this small clump
- Additional components also contribute

Hot Core Radex Models



- $HD^{18}O$ emission comes entirely from the small clump, not coincident with any known continuum sources
- Additional components contribute to HDO emission

Revised D/H Values

Table 1. Summary of H_2O and HDO column densities in Orion KL.

Component	θ_s (")	$N(H_2)$ (cm^{-2})	$N(H_2O)$ (cm^{-2})	$\chi(H_2O)$	$N(HDO)$ (cm^{-2})	[HDO]/[H_2O]
Hot Core (compact)	2″	3.1×10^{23}	2.0×10^{20}	6.5×10^{-4}	4.0×10^{17}	0.0020
Hot Core (extended)	5″	3.1×10^{23}	2.0×10^{18}	6.5×10^{-6}	6.3×10^{15}	0.0032
Compact Ridge	6″	3.9×10^{23}	1.8×10^{18}	4.6×10^{-6}	9.0×10^{15}	0.0052
Plateau (emission)	30″	2.8×10^{23}	8.8×10^{17}	3.1×10^{-6}	1.2×10^{15}	0.0014
Absorbing gas	extended	9.0×10^{22}	2.4×10^{17}	2.7×10^{-6}	5.5×10^{13}	0.00023

[a]Relative to H_2.

- The small hot core clump has the highest water column density and abundance—water molecules recently evaporated from grain mantles
- Significant deuteration seen in the hot core, compact ridge (highest) and plateau components
- D_2O/HDO ~ 0.0024 in the hot core
- Foreground outflowing gas has a lower D/H ratio—modified by gas-phase neutral-neutral chemistry ($OH+H_2 \rightarrow H_2O+H$)

THE ABUNDANCE, ORTHO/PARA RATIO, AND DEUTERATION OF WATER IN THE HIGH-MASS STAR FORMING REGION NGC 6334 I

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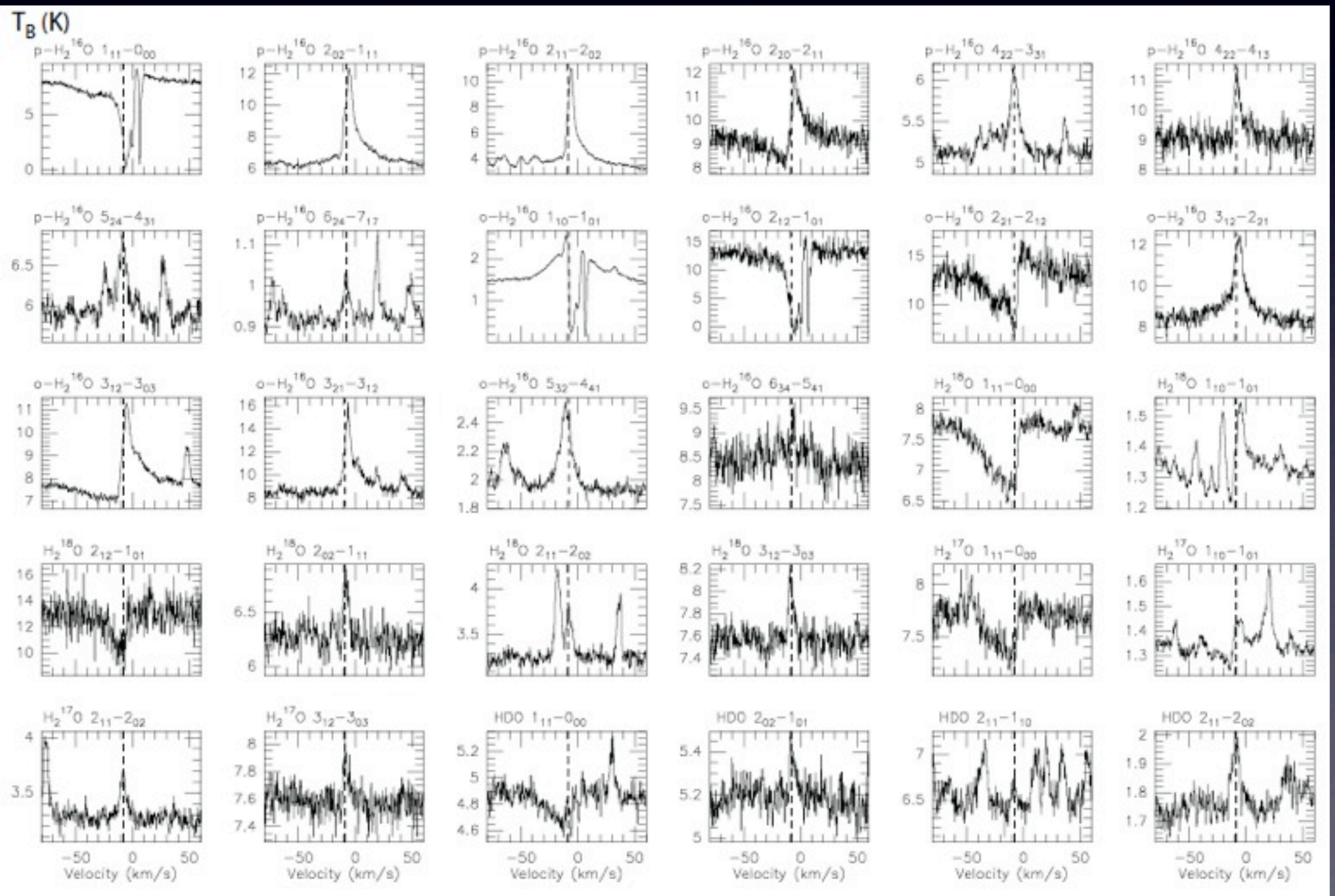
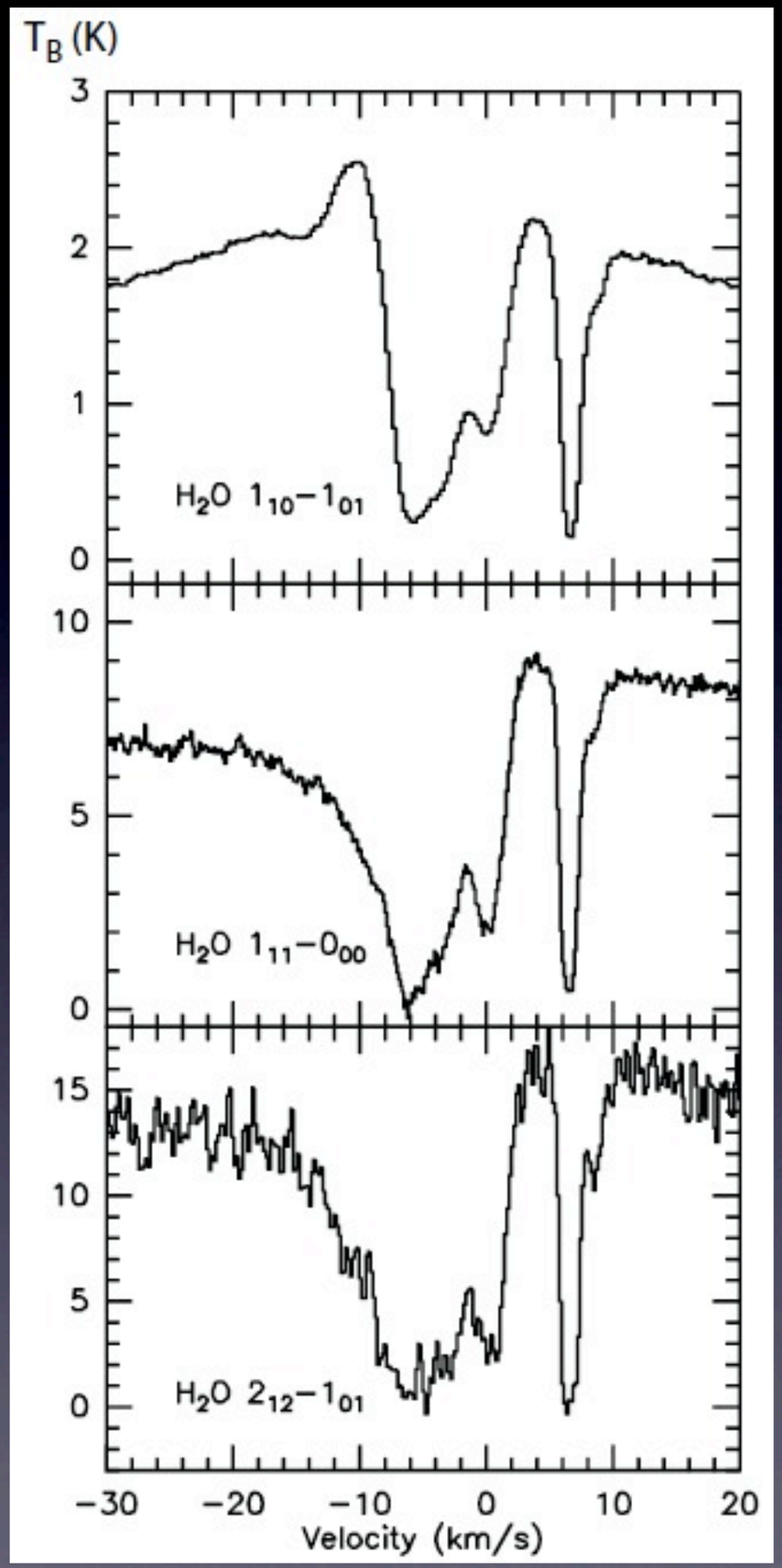


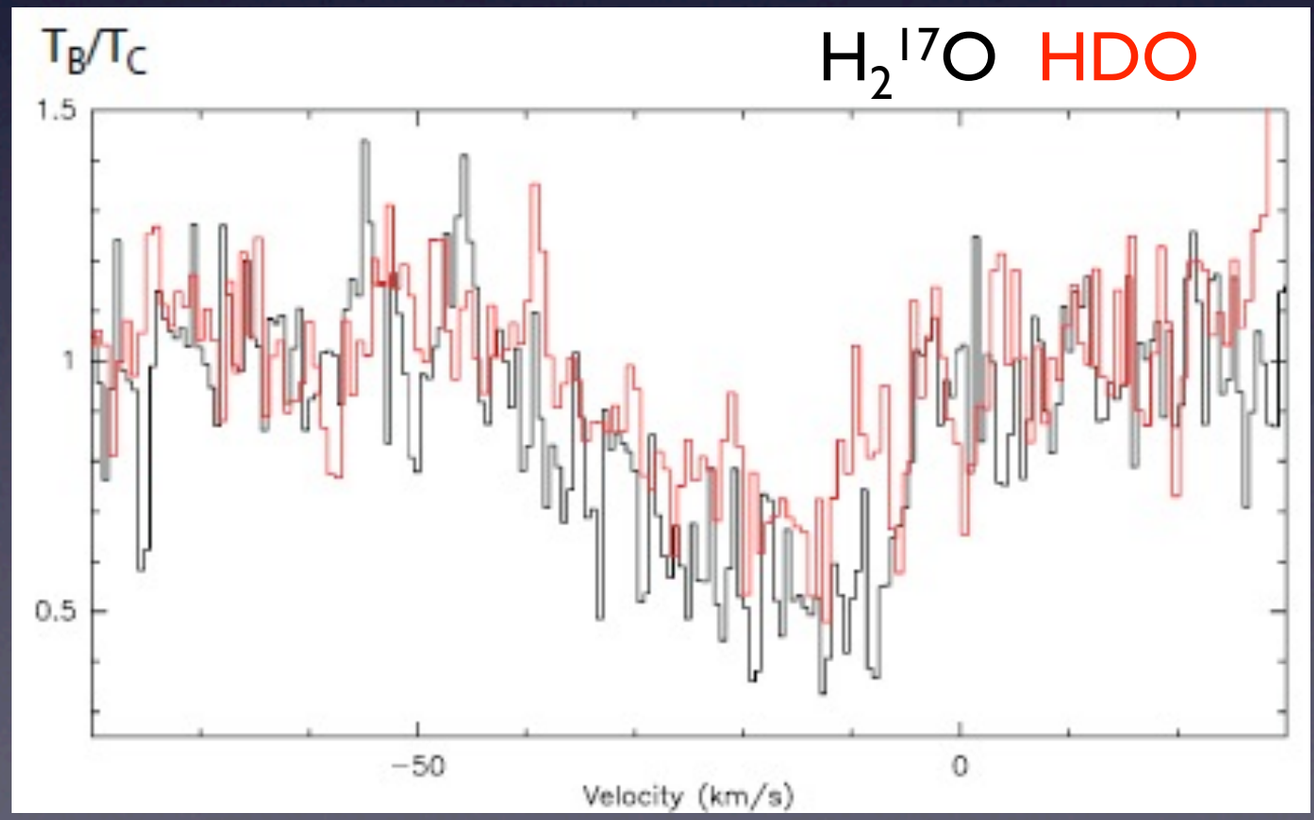
Data Set:

- 30 transitions of $H_2{}^{16}O$, $H_2{}^{18}O$, $H_2{}^{17}O$ and HDO

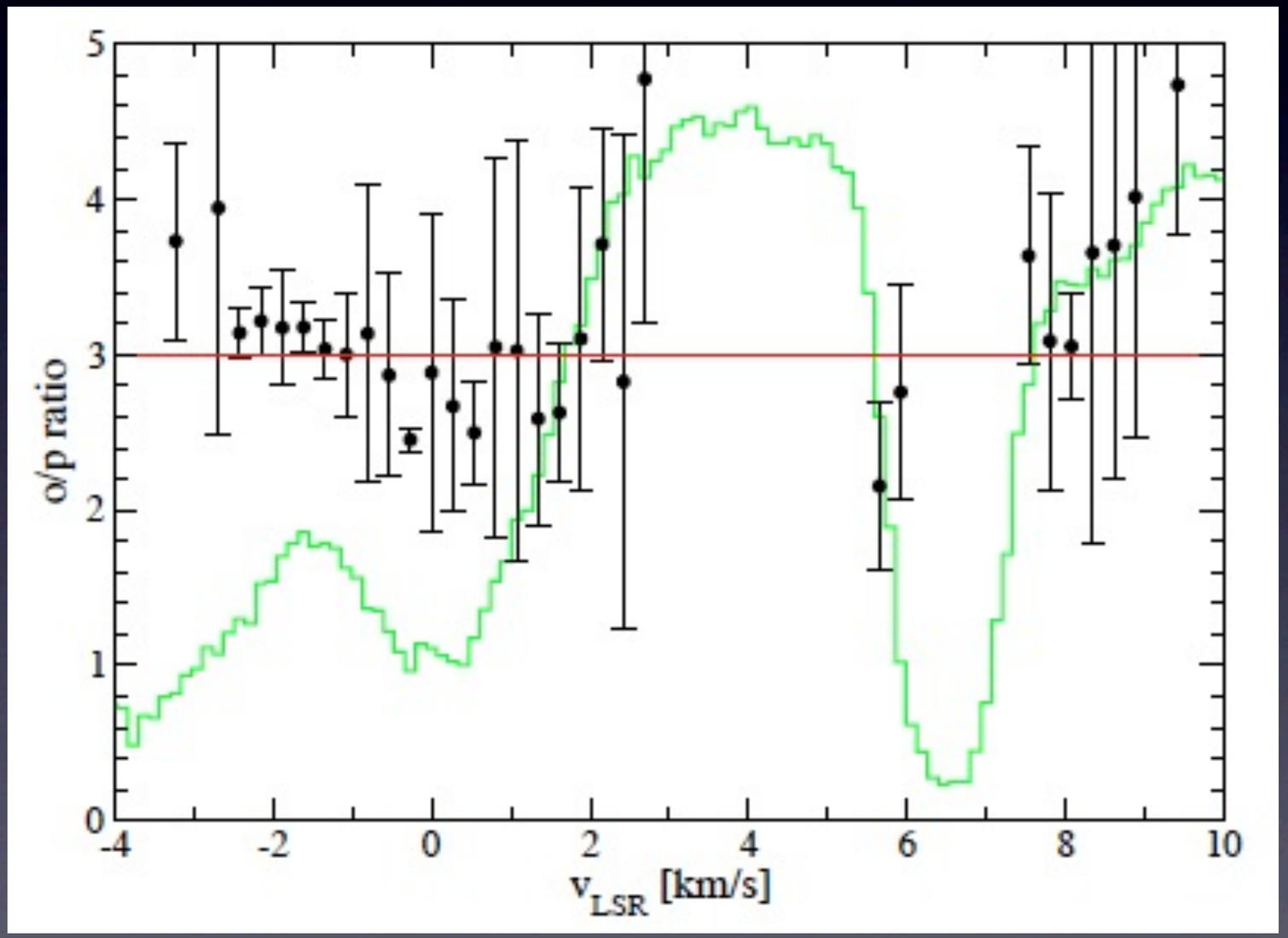
Multiple Components



- Hot core (velocity -8 km/s)
- Envelope (velocity -6 km/s)
- Outflows (cold and warm components)
- Multiple foreground clouds

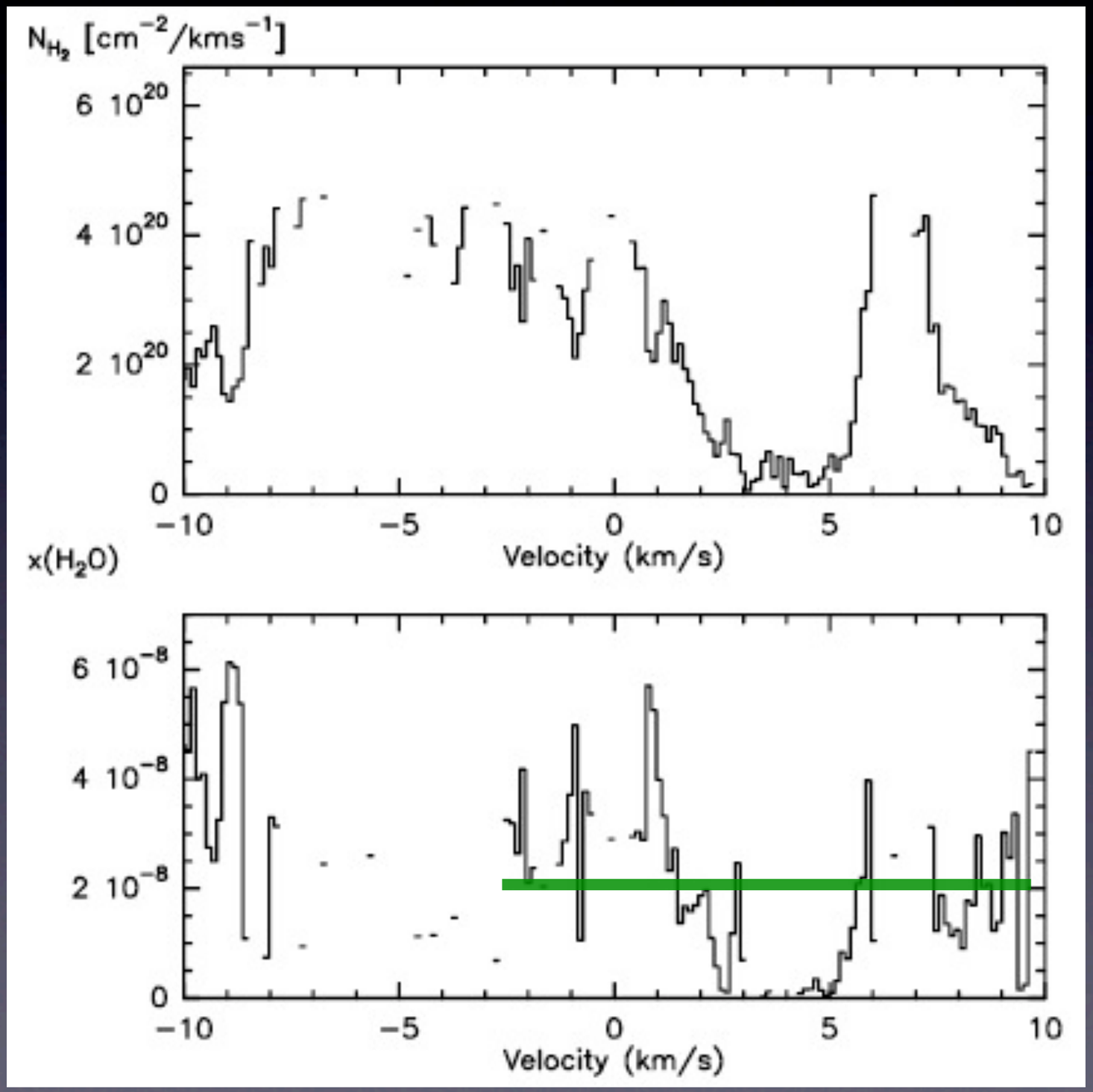


Water OPR



- Addition of the 1669 GHz line allows direct determination of the excitation temperature: 6.5 K
- High for diffuse clouds, but absorption also seen in the ground state para-NH_3 line (dense gas)
- Revised OPR consistent with the high-temperature limit of 3

Water Abundance and D/H



- H_2 column density based on HF absorption measurements
- Foreground clouds and envelope ~10^{-8}
- Hot core ~10^{-6}
- Relatively low gas and dust temperature ~100 K
- Time-dependent effects
- Significant fraction of water molecules still locked up in grain mantles
- HDO/H_2O~2 10^{-4} in outflow and hot core (similar to the outflow absorption component in Orion)

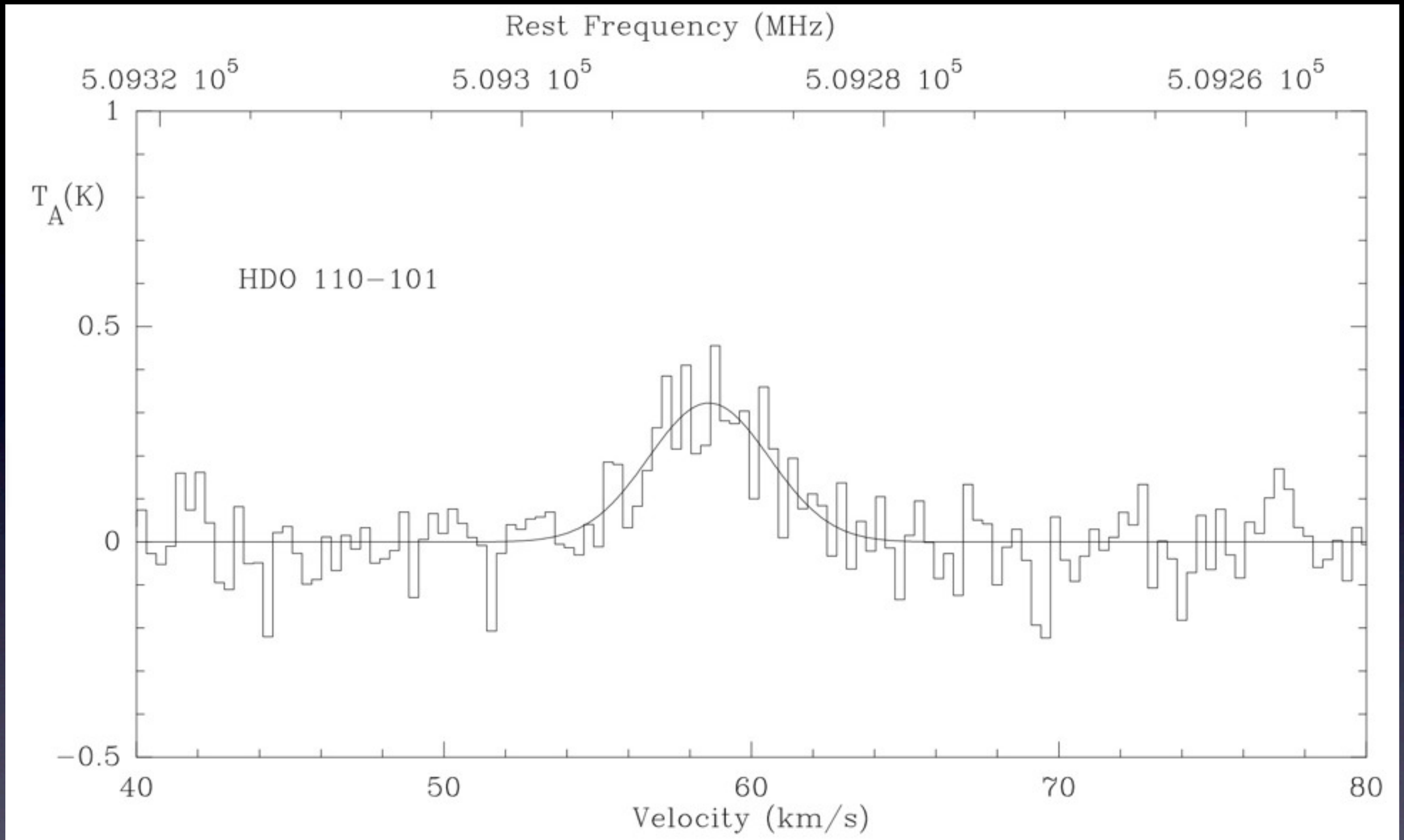


Fig. 2. Spectrum of the 509 GHz HDO line toward G34.26+0.15 (the fit is shown as a grey line)