CHESS, Herschel Chemical Survey of Star Forming Regions
The Solar Type Protostar IRAS16293-2422

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on behalf the CHESS IRAS16293 sub-team

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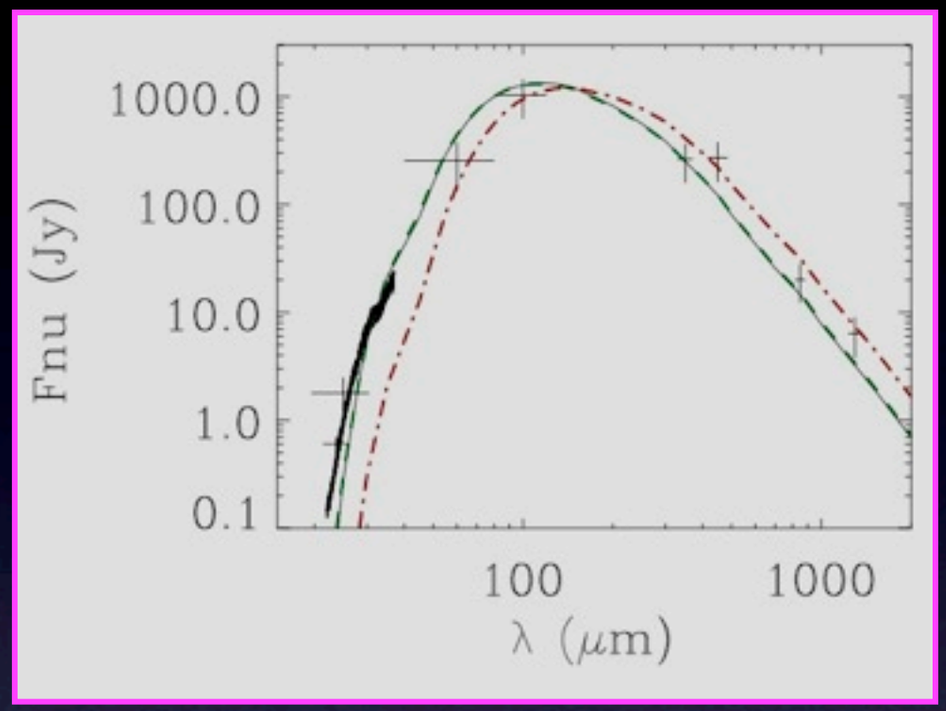
Studying the molecular content of SFR

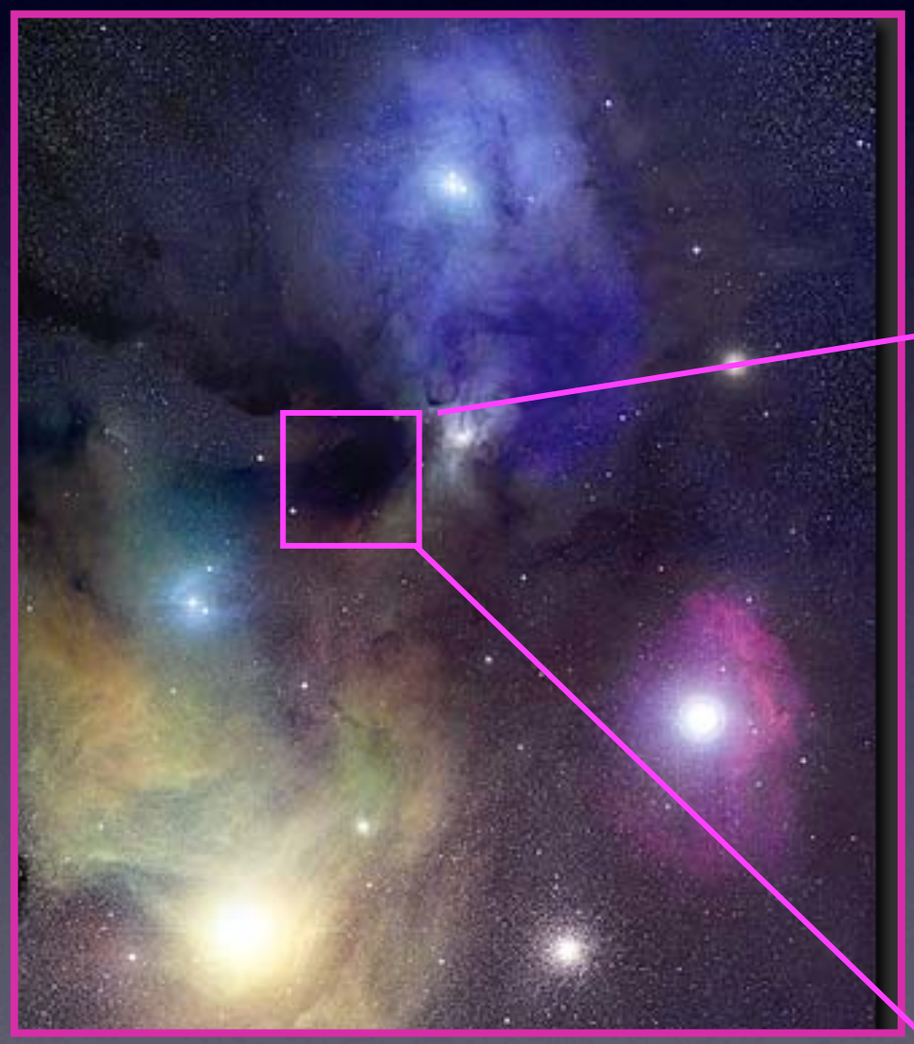
- The molecular complexity
  - How complex are complex molecules in SFR's ?
  - When and how are they formed, what are their destiny ?
  - Are they incorporated in the bricks forming the future planetary systems (meteorites, comets, planets…) ?
- Lines are very powerful diagnostic tools
  - Different lines from the same molecule are excited in regions of different temperature and density
  - Different molecules are formed in regions with different internal and external conditions, and have different chemical history

Unbiased Spectral Surveys of Star Forming Regions are a precious and unavoidable tool to study Star Formation

A Class-0 Solar-Type Protostar

IRAS16293-2422 is a ~ 20 Lo Protostar in the ρ Ophiuchus complex (120 pc)



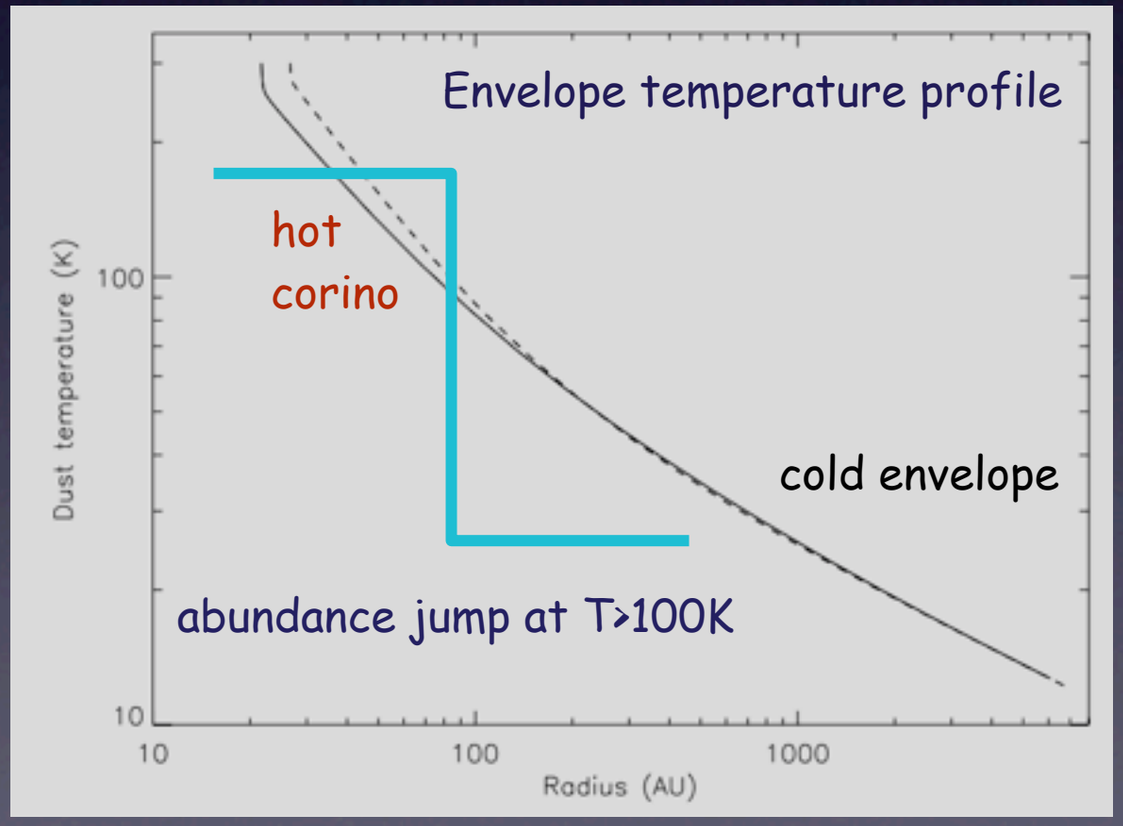


Class 0 are cold (< 30K) sources of a few M_O, emitting mostly in the mm/ submm range

Evidence of grain mantle sublimation

- At T_{dust}> 100K the abundance of "mantle" molecules like H_2CO and CH_3OH jump by 2 or more orders of magnitude

- The sublimated molecules show the super-deuteration phenomenon
=> they were formed during the Pre-Stellar Core phase

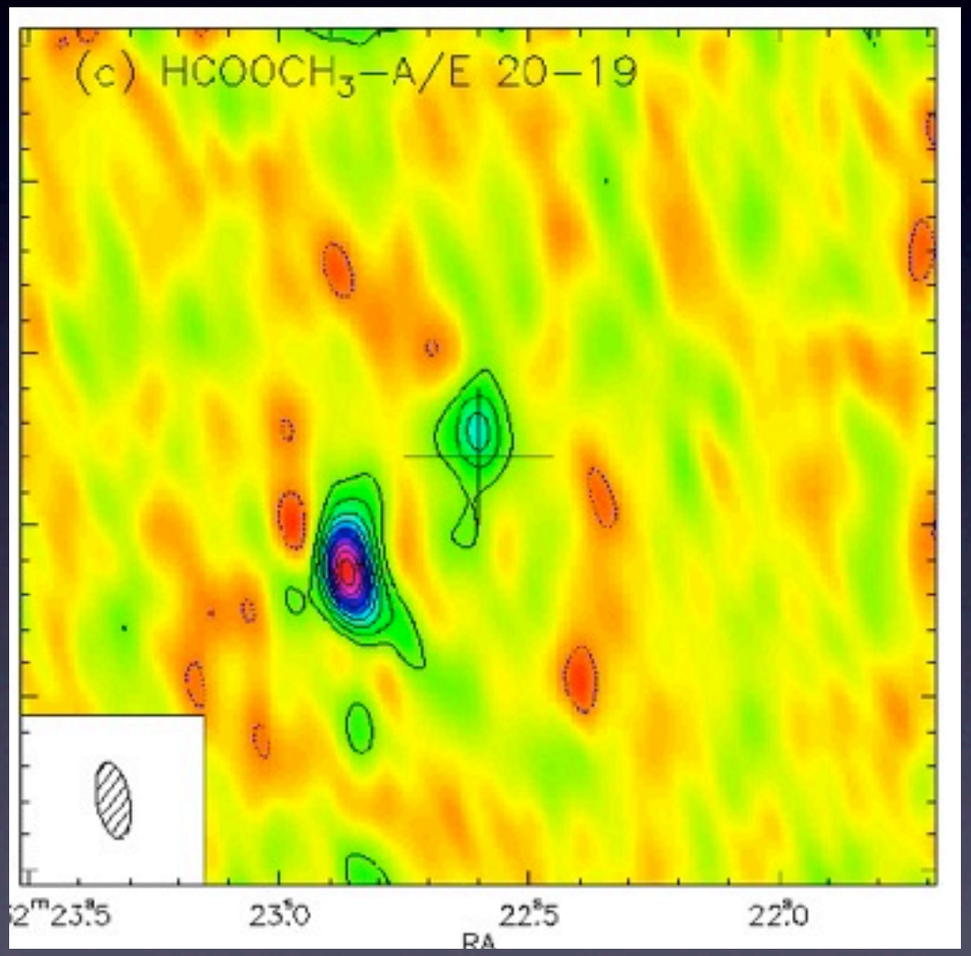


CH_2DOH / CH_3OH > 0.5
CH_3OD / CH_3OH ~ 0.04
CHD_2OH / CH_3OH ~ 0.2
$HDCO$ / H_2CO ~ 0.15
D_2CO / H_2CO > 0.05
CD_3OH / CH_3OH ~ 0.03

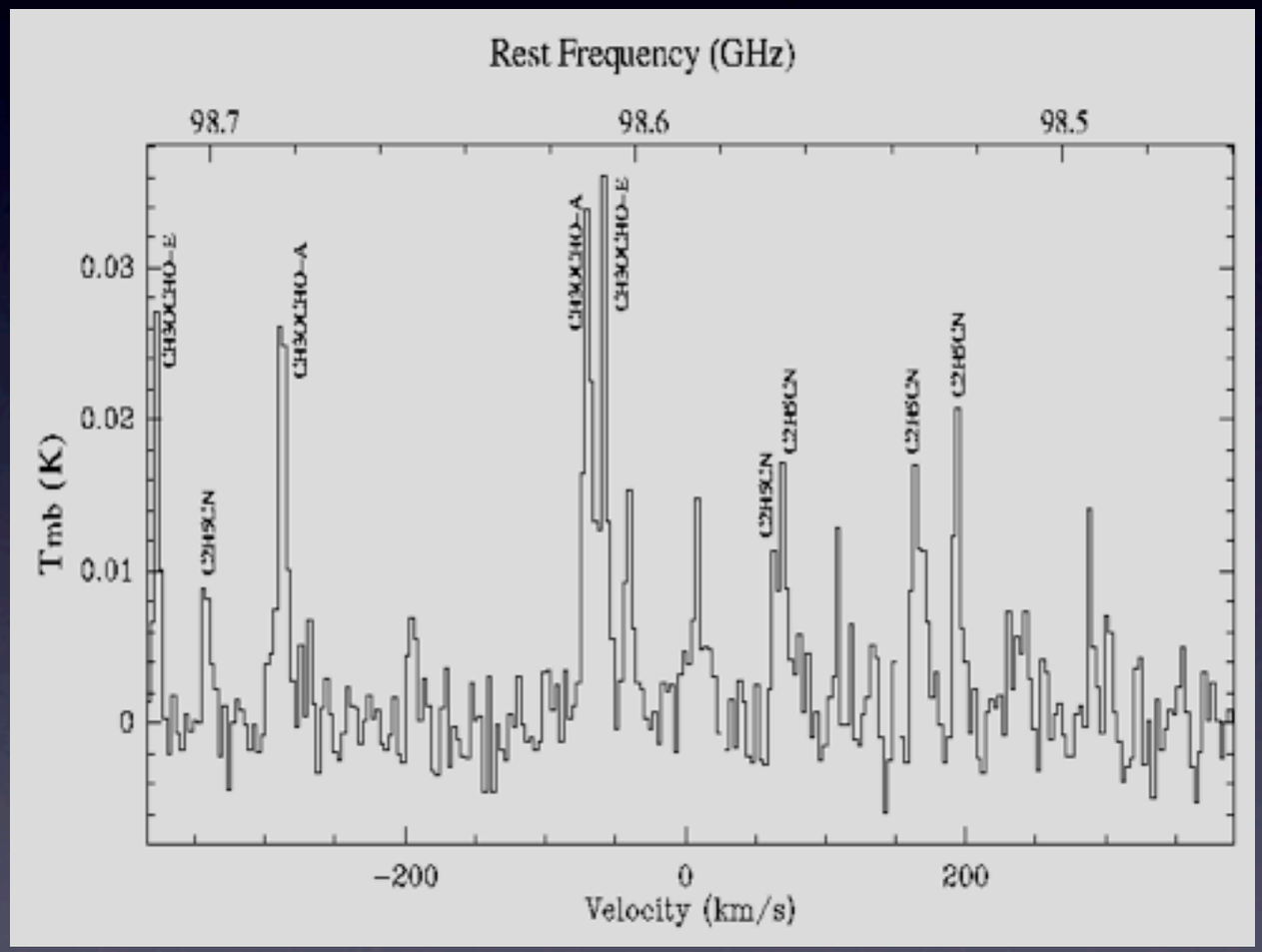
Ceccarelli et al. 1998; Loinard et al. 2000, Parise et al. 2002 & 2004

Hot Corinos

- Compact (< 100 AU), warm (~ 100 K), dense (> 10^7 cm^{-3}) enriched of Complex Organic Molecules (COMs)



Kuan et al. 2004; Bottinelli al. 2004



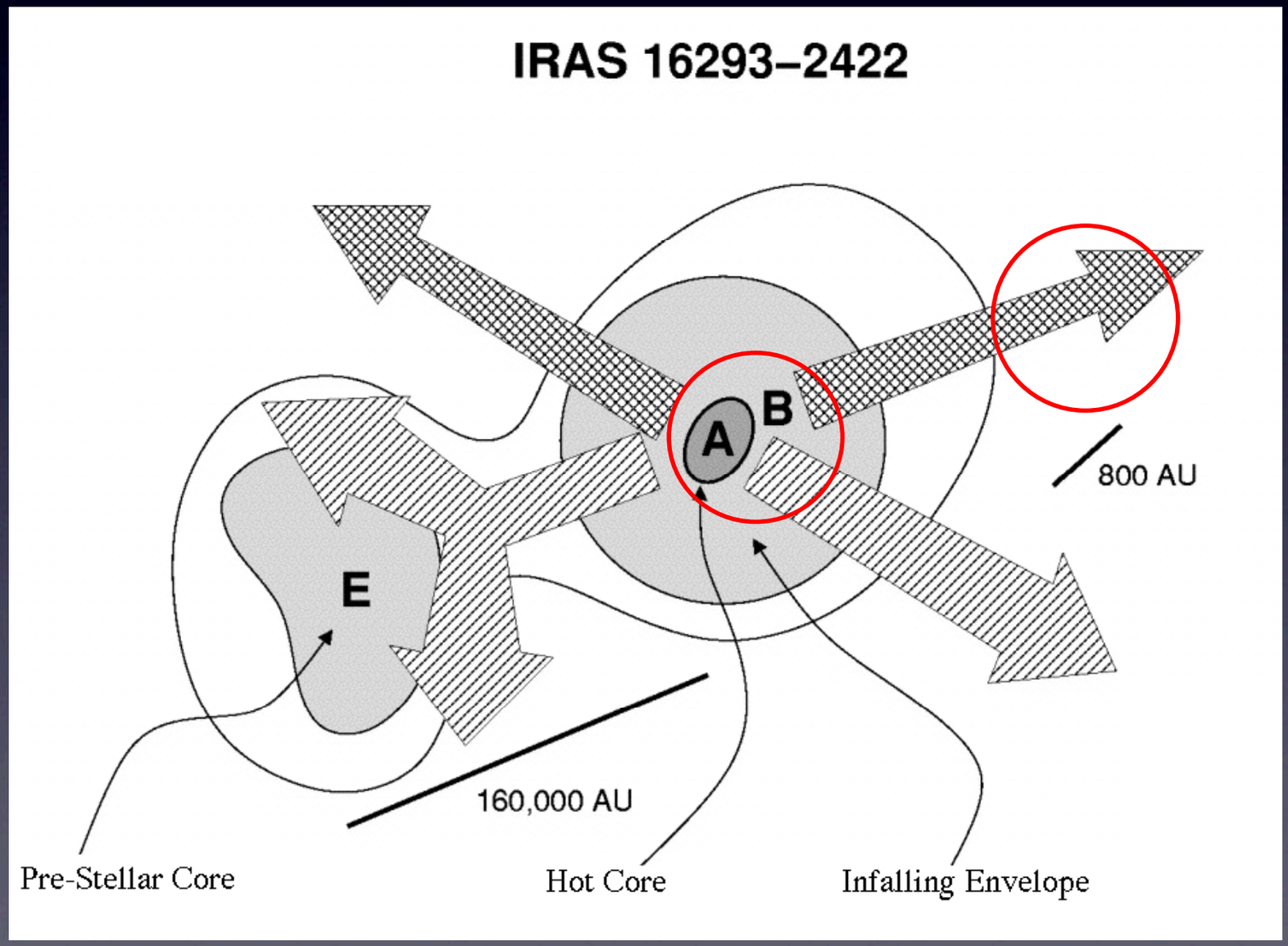
Cazaux et al.. 2003

Detected : methyl formate, dimethyl ether, formic acid, methyl cyanide, ethyl cyanide....

Why IRAS16293-2422 ?

- It is the brightest solar-type Class 0 source known to date
- A lot of studies are already conducted towards this source, in all frequency ranges

Envelope +
binary system +
a little of outflow
in the HIFI beam,
particularly at low
frequencies



What Herschel HIFI brings ?

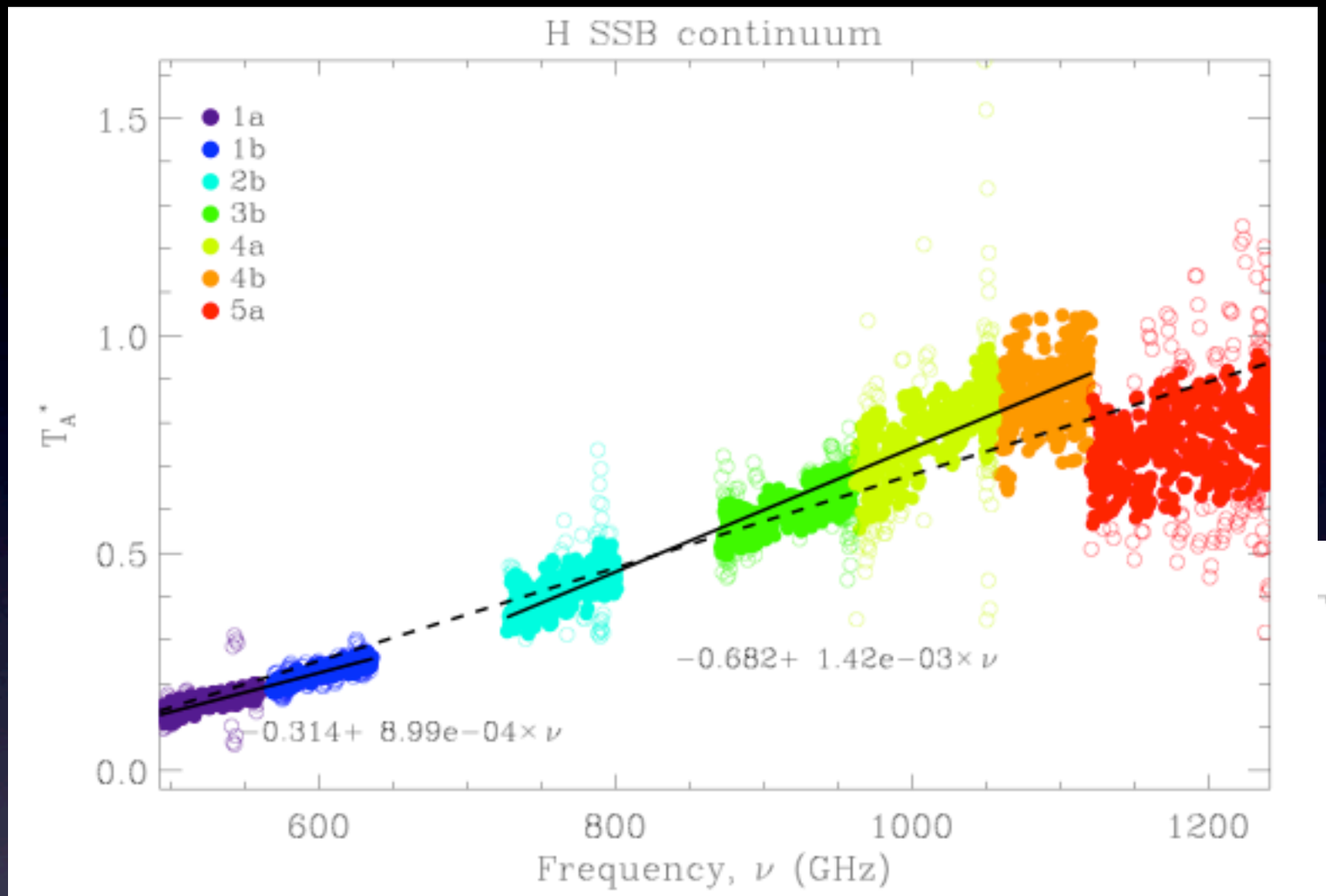
- Unbiased Spectral Survey in a frequency range mostly inaccessible from the ground
- Complementary of an existing spectral survey in the mm range from IRAM-30m and JCMT (80-365 GHz)
- In a very broad range (480-1910 GHz) with the same instrument, in the same observing (very good) conditions
- Observations performed in SDP and PSP1 in March and April 2010 (1a, 1b, 2b, 3b, 4a, 4b, 5a, part of 6a, 6b, 7a)
- Still pending (September ?) 2a, 3a, may be 5b, 7b

Data Processing

- Data were processed with HIPE (see Ott et al. poster) up to Level-2 data + IA processing + deconvolution, or in CLASS after exporting level-2 data (see Maret et al. poster)
- Sensitivity is as predicted by HSPOT in SIS bands (480-1200 GHz)
- Sensitivity is worse by about a factor 2 wrt HSPOT predictions in HEB bands (> 1400 GHz)
- Continuum is observed, and needed to derive column-densities of species only seen in absorption

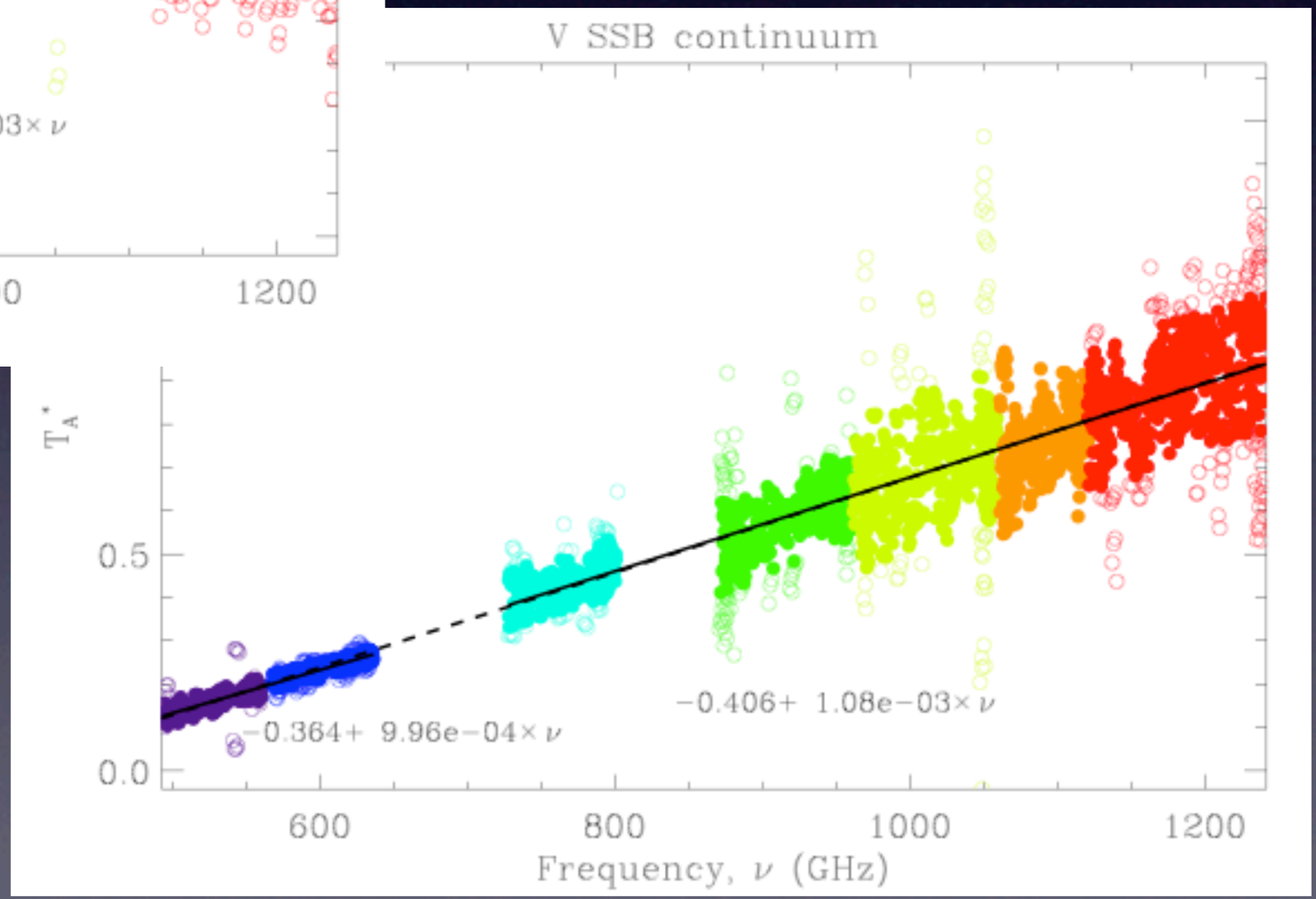
Data processing and data analysis are preliminary
They can and they will be improved in the coming weeks

Continuum

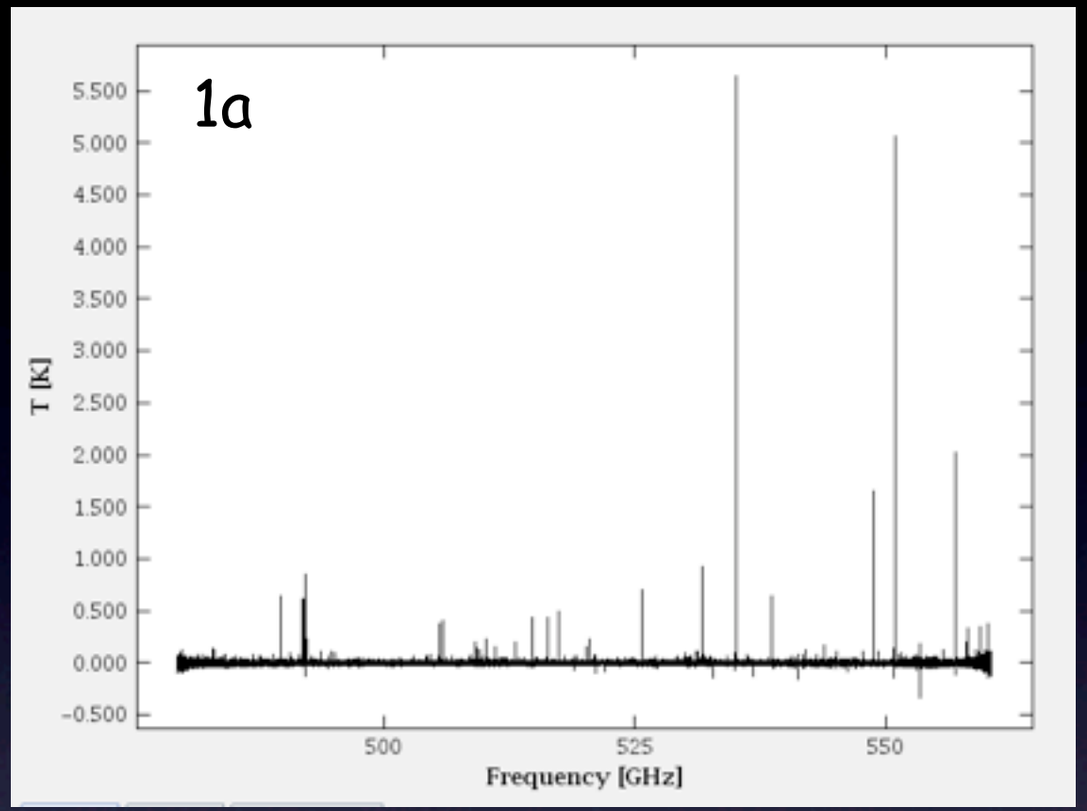


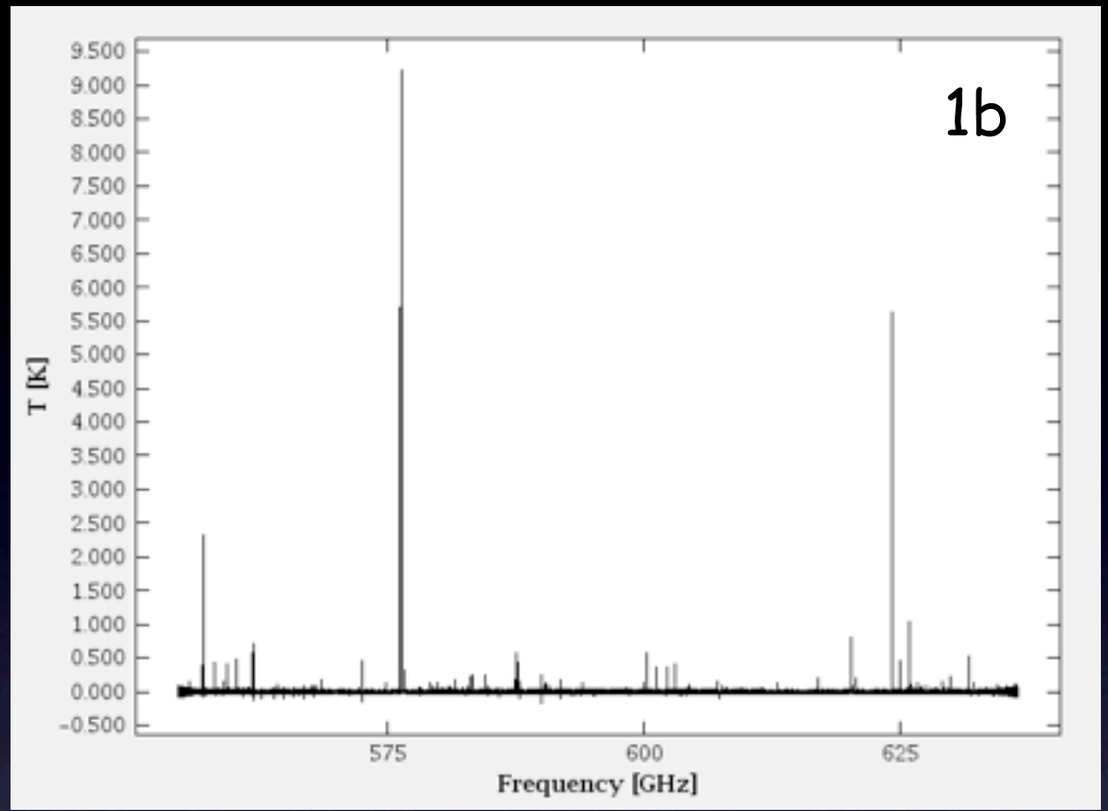
V-polar

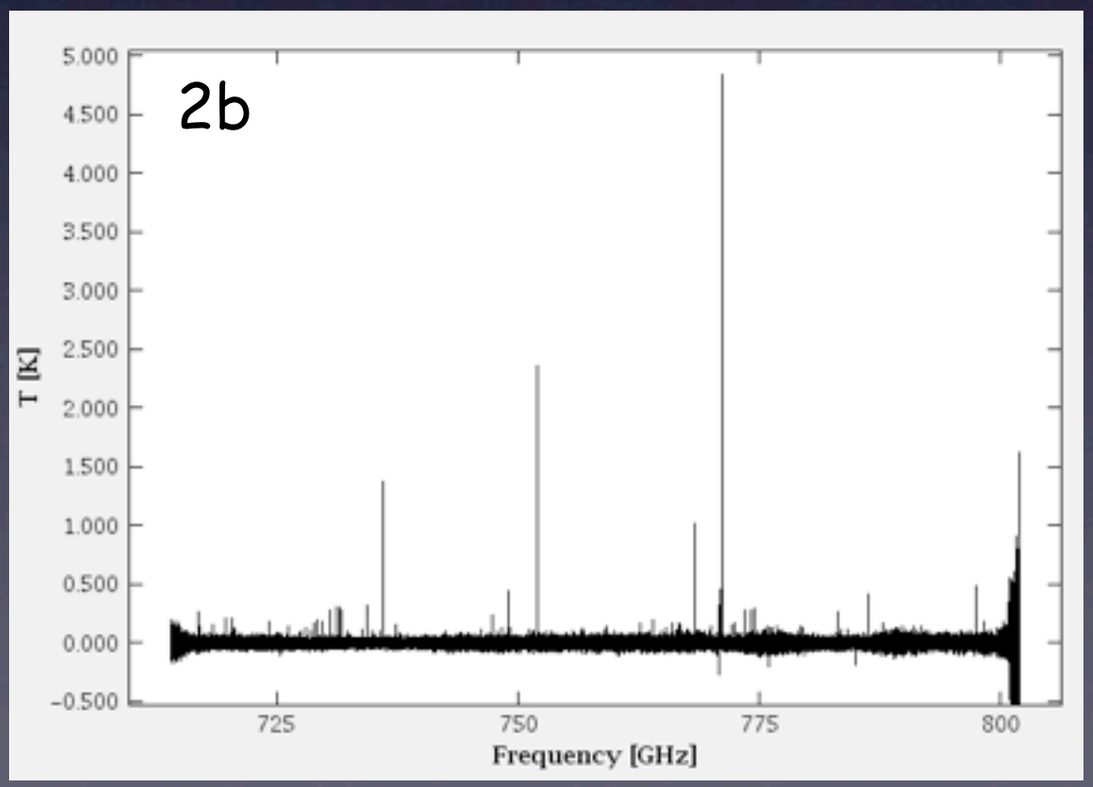
H-polar

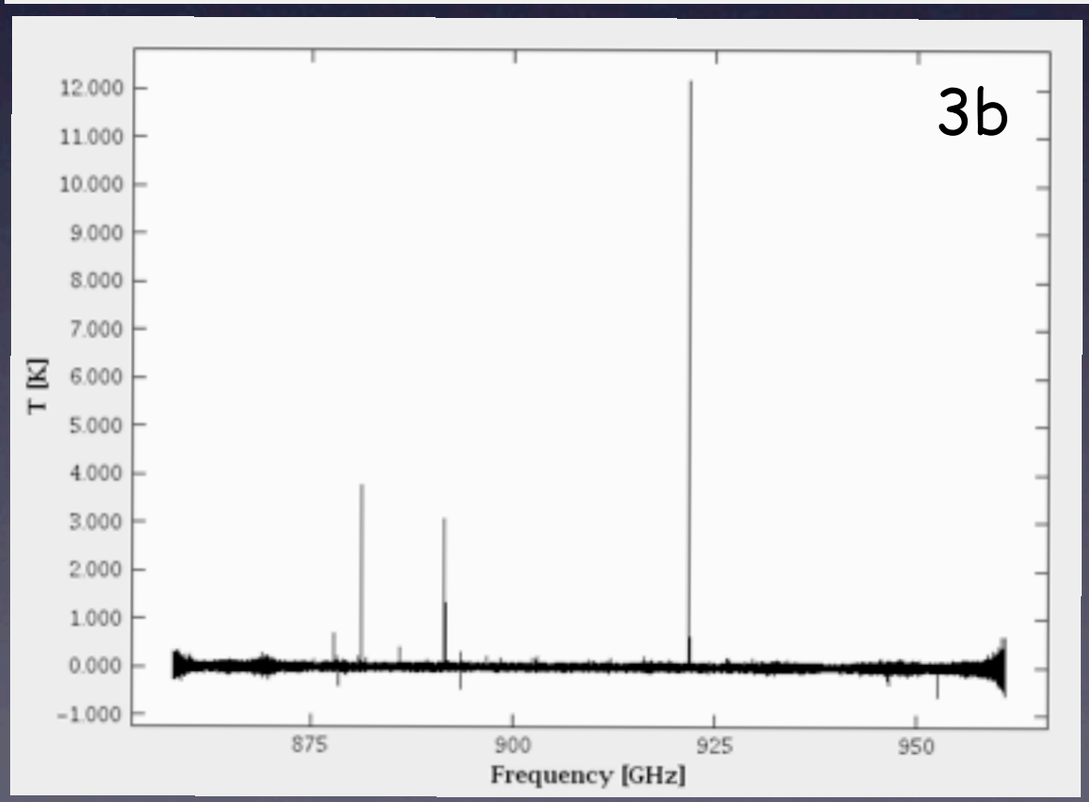


Some broad range spectra

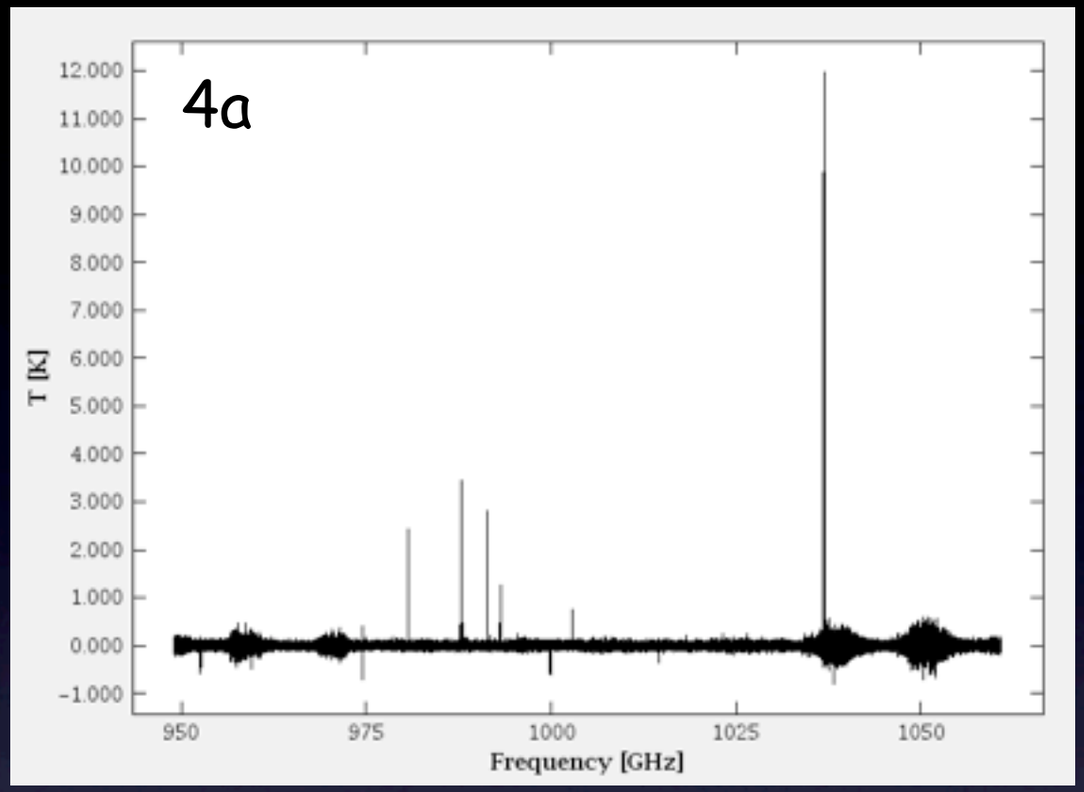


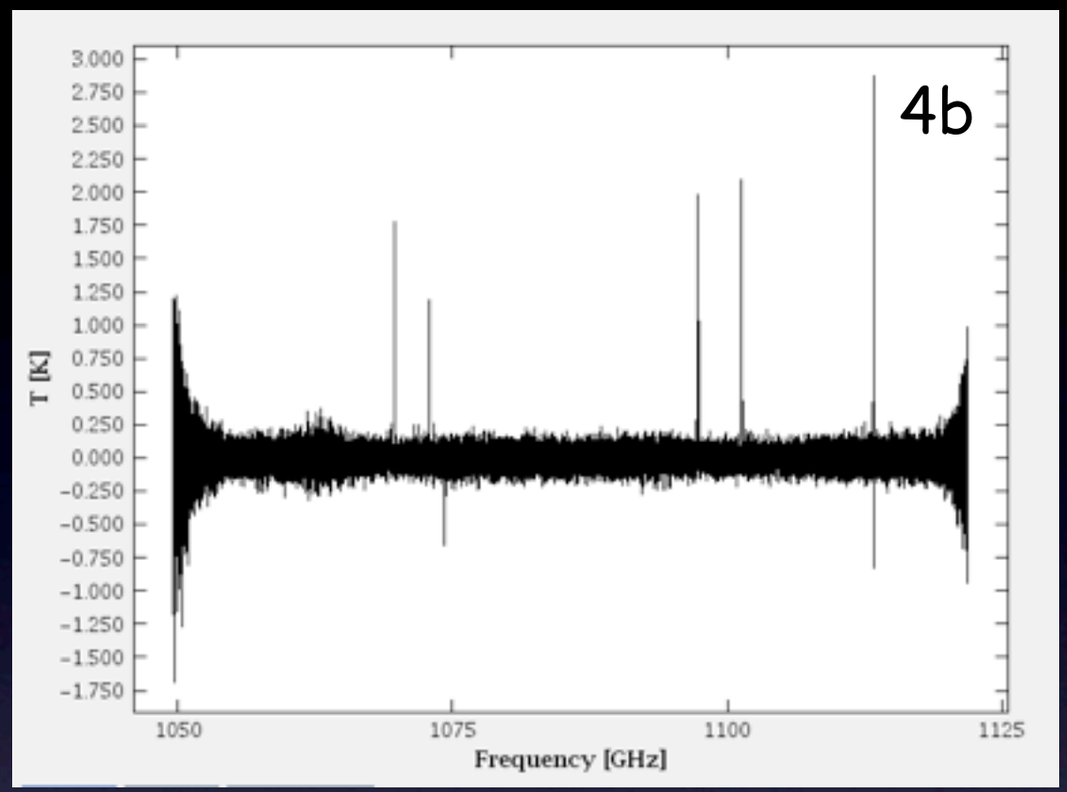


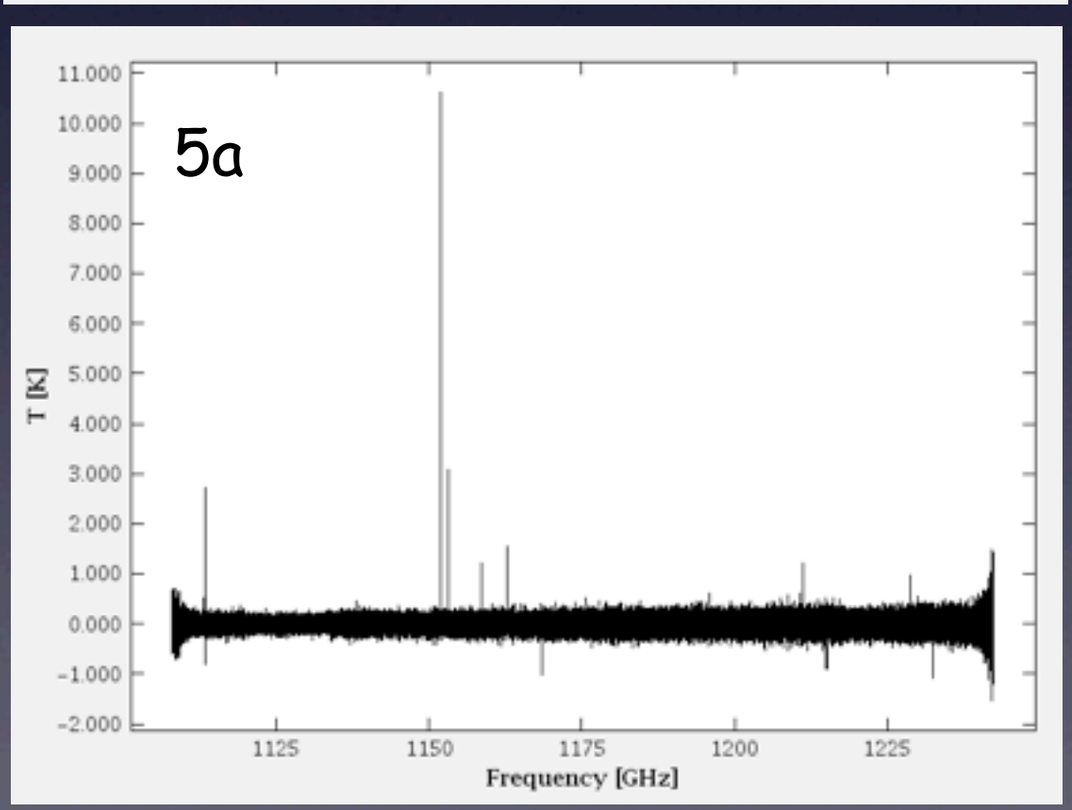


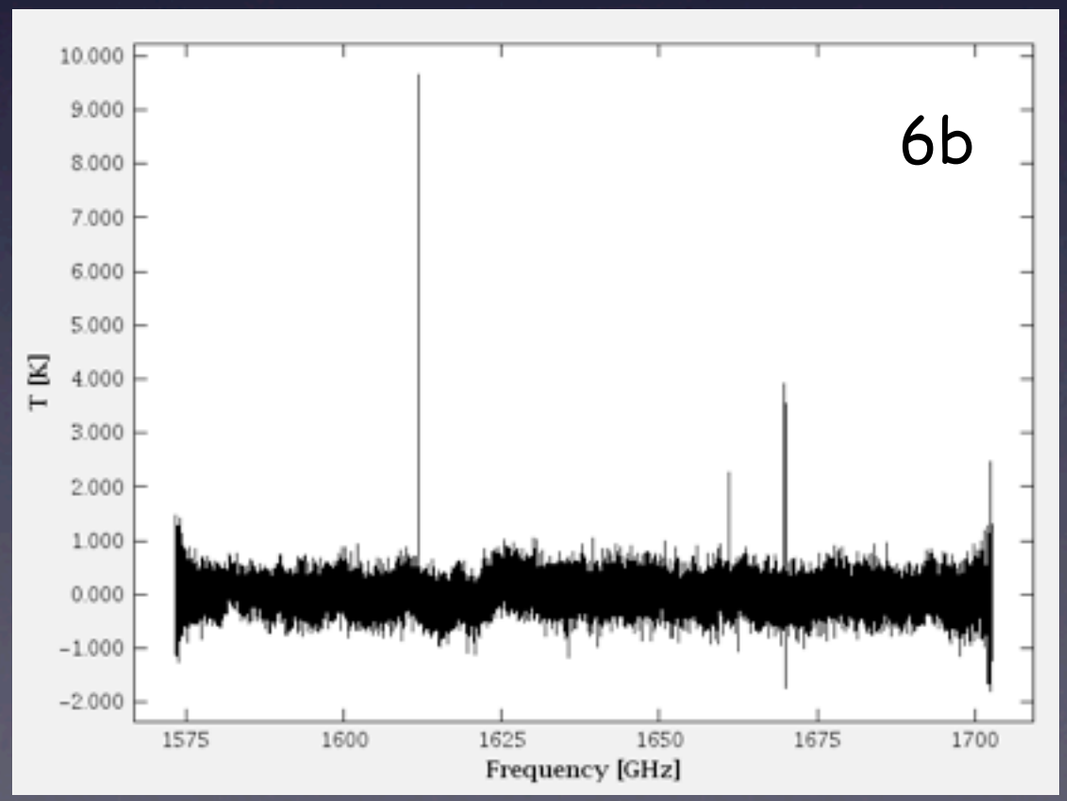


Some broad range spectra

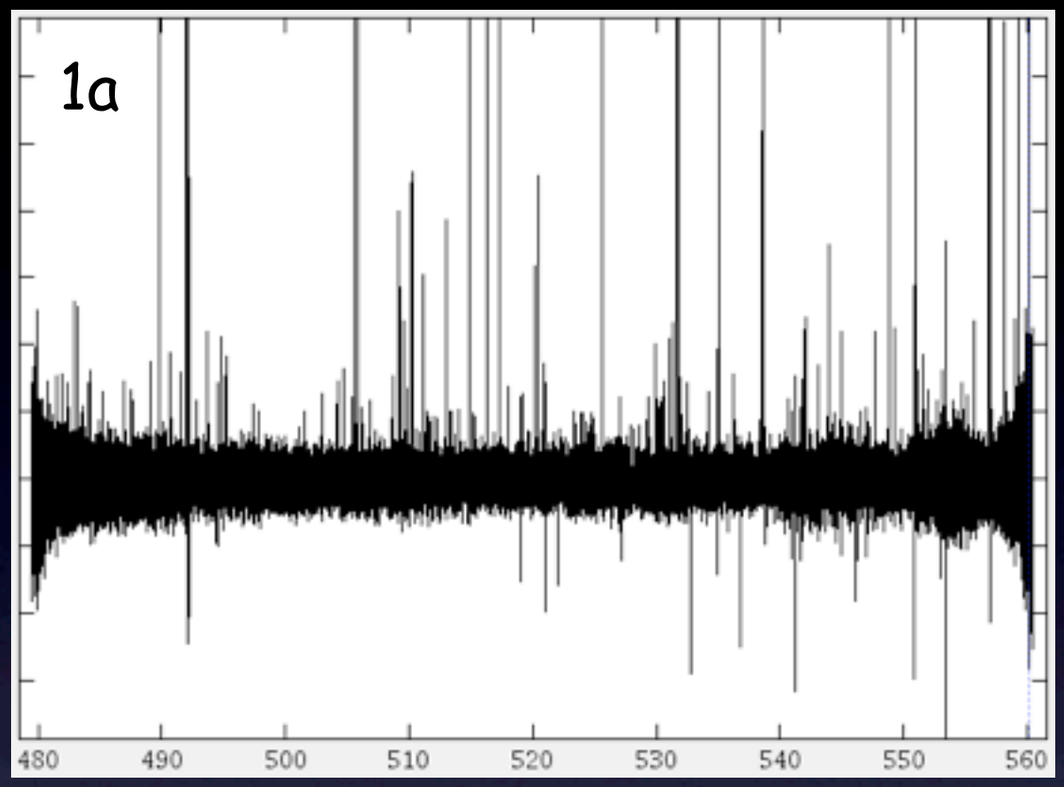


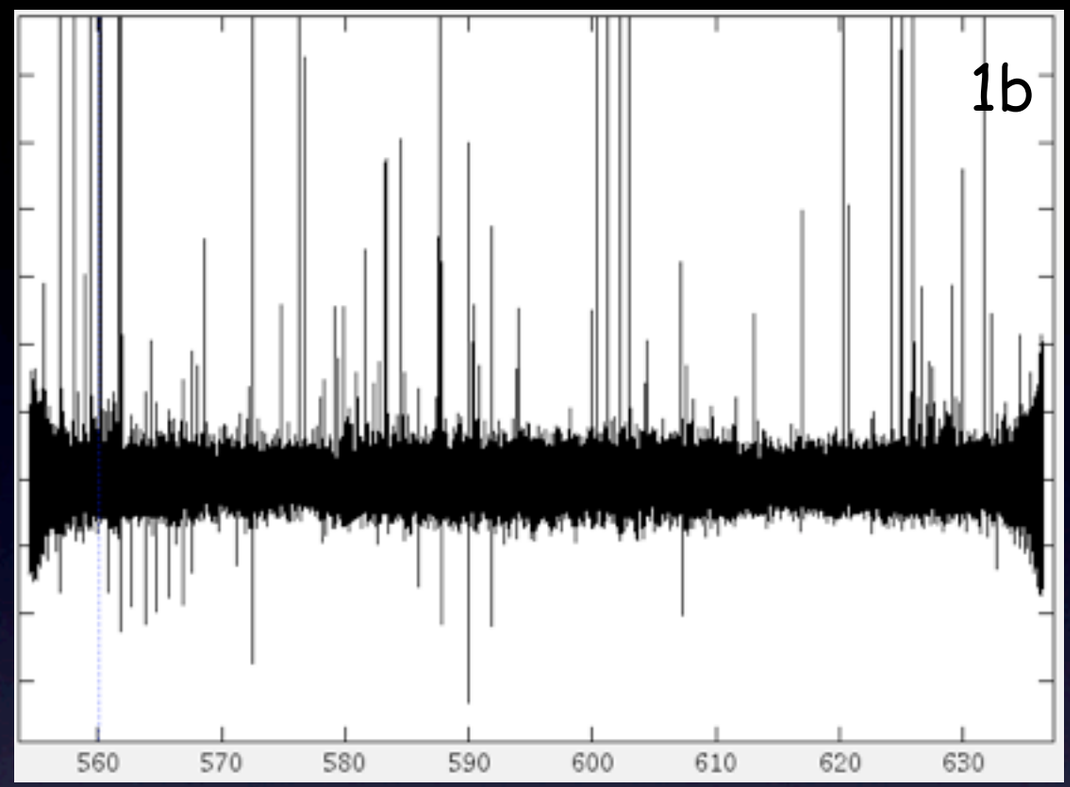


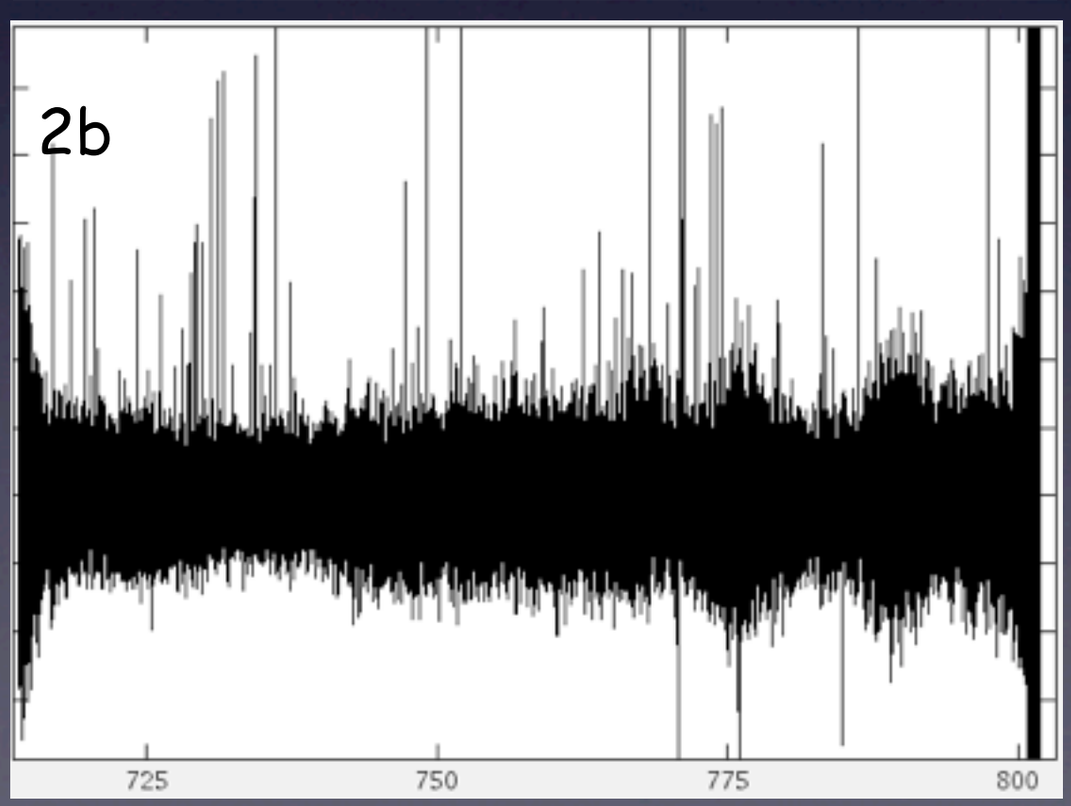


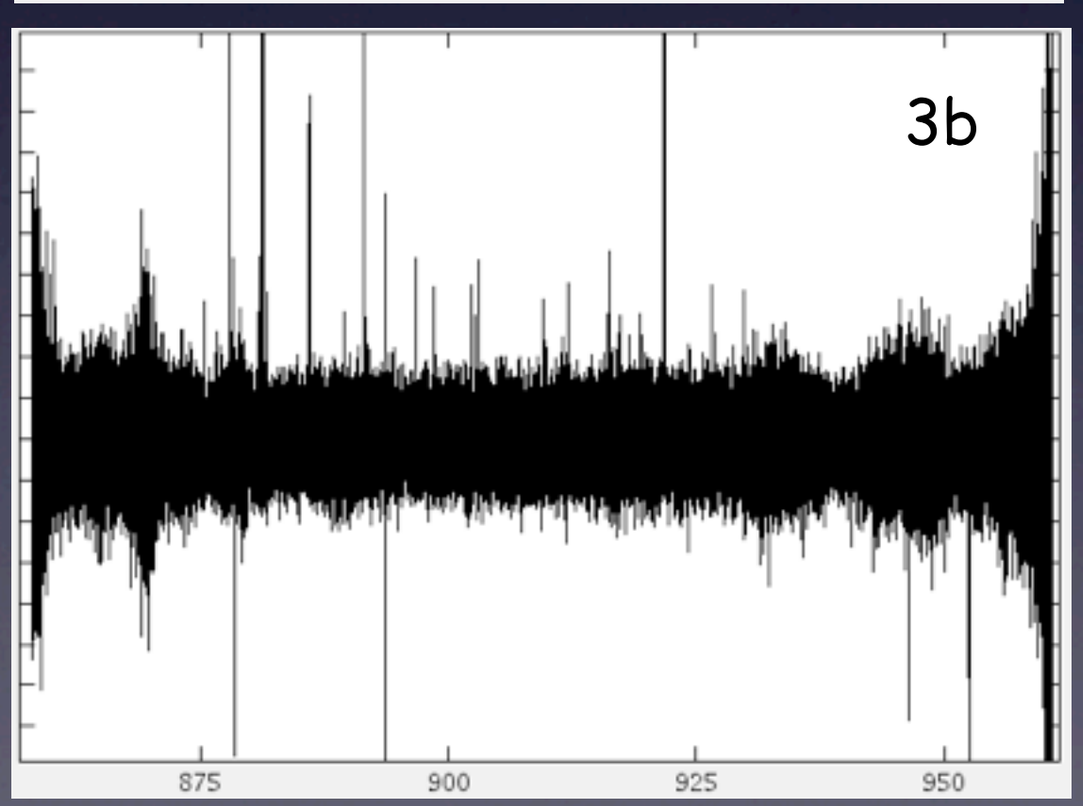


Some broad range spectra

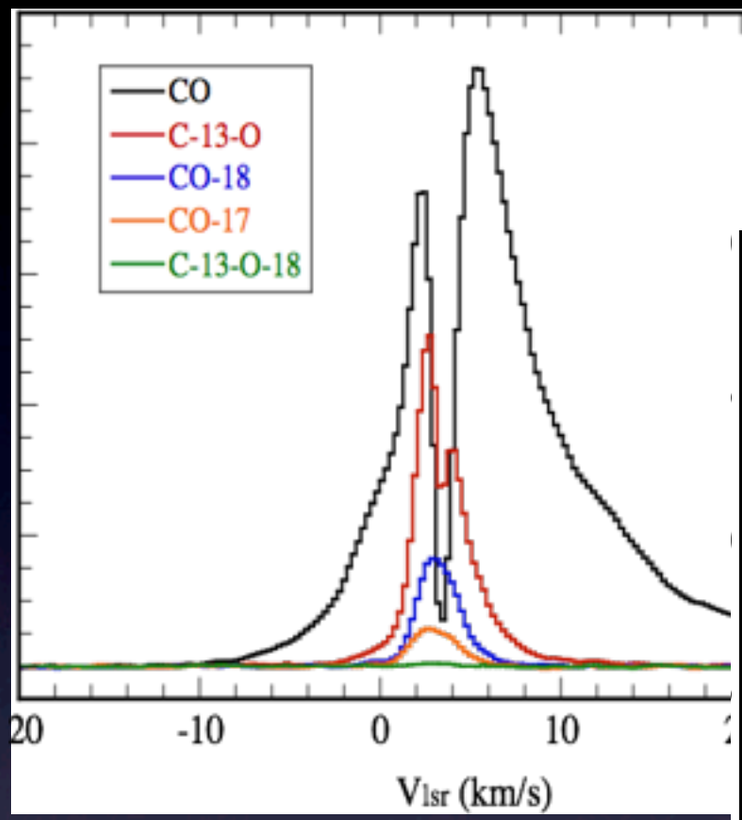






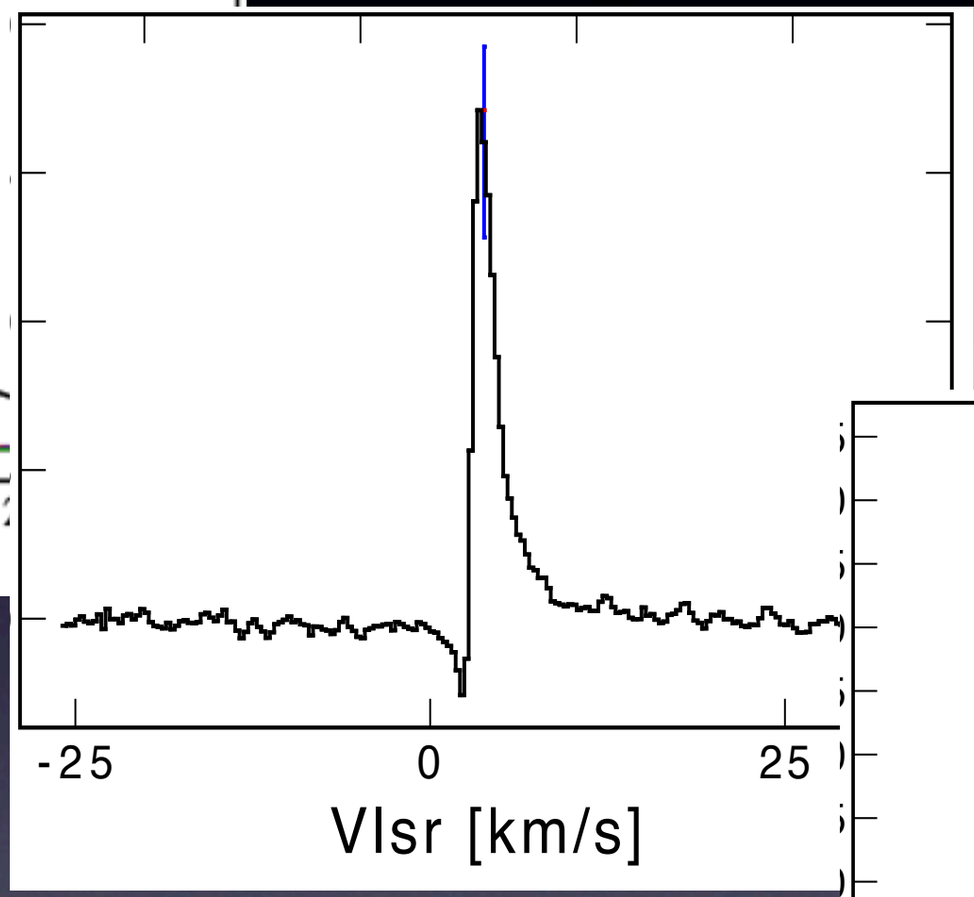


The "obvious" species



CO

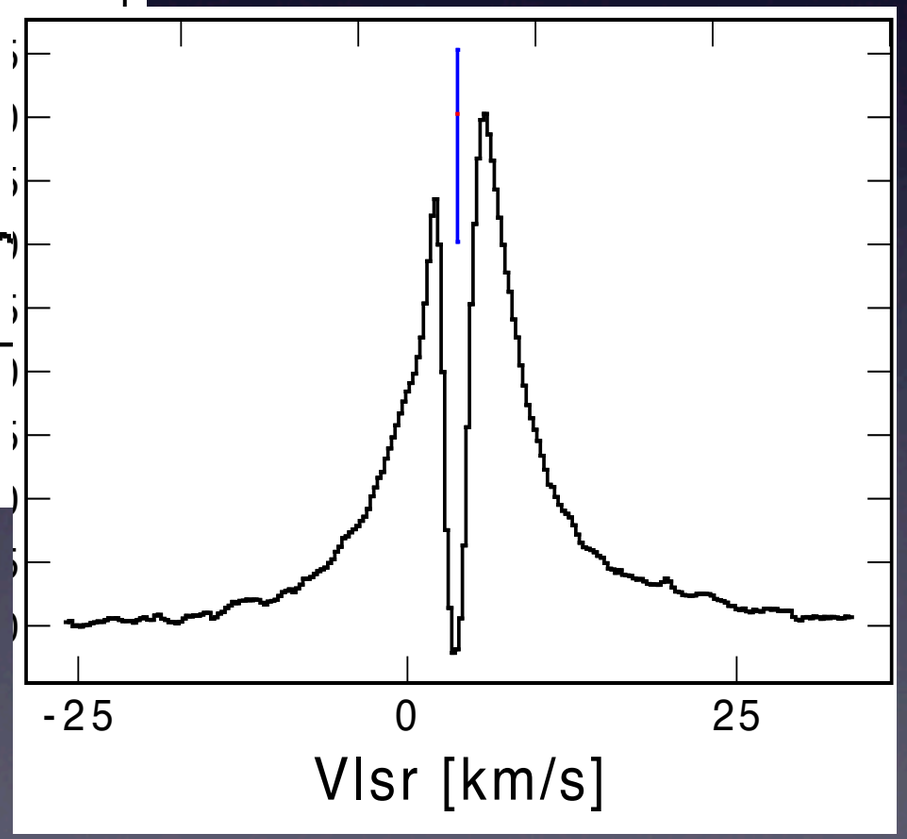
+ isotopes



Ceccarelli et al. 2010, in prep.

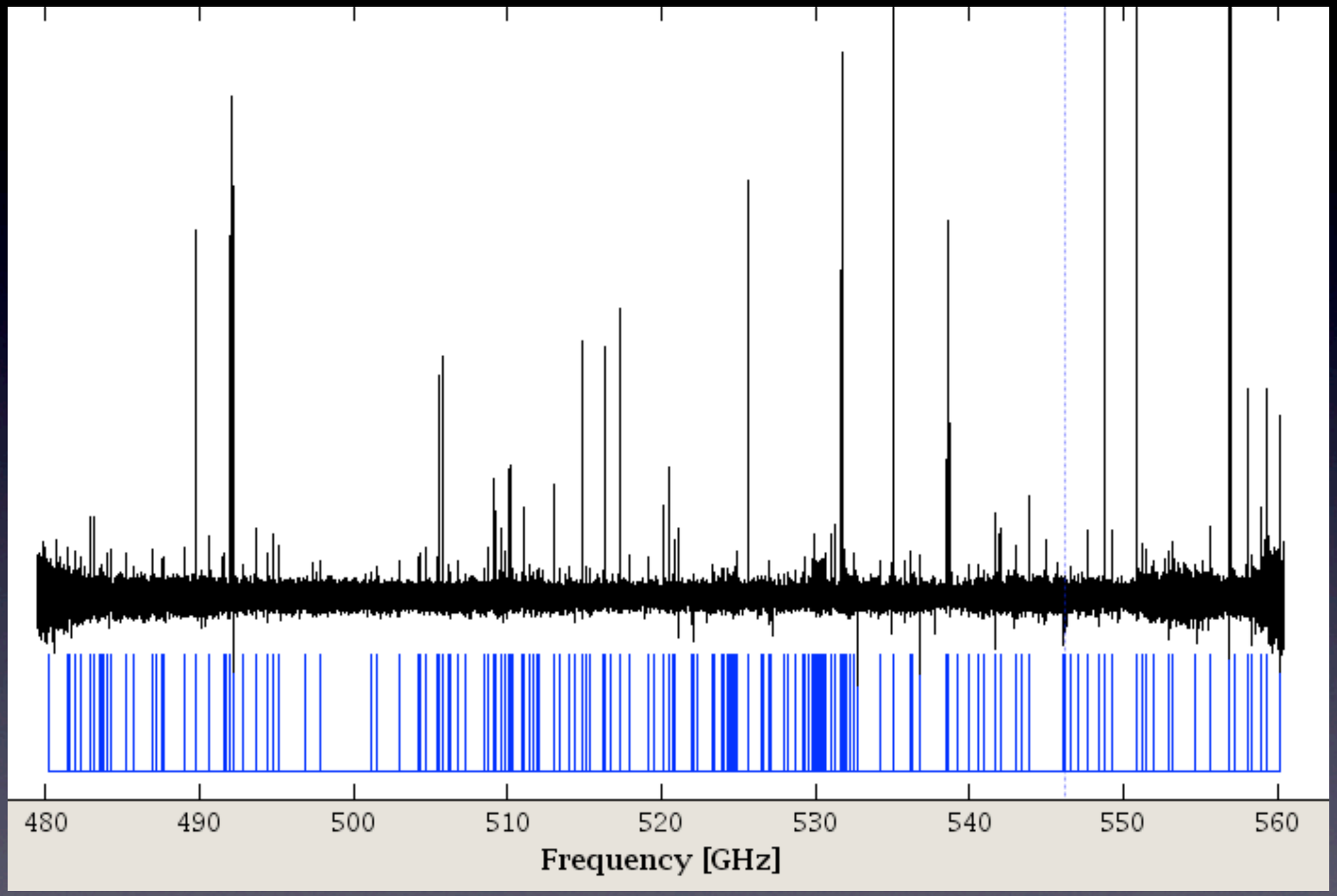
H_2O

CI



Caux et al. 2010, in prep.

Line identification



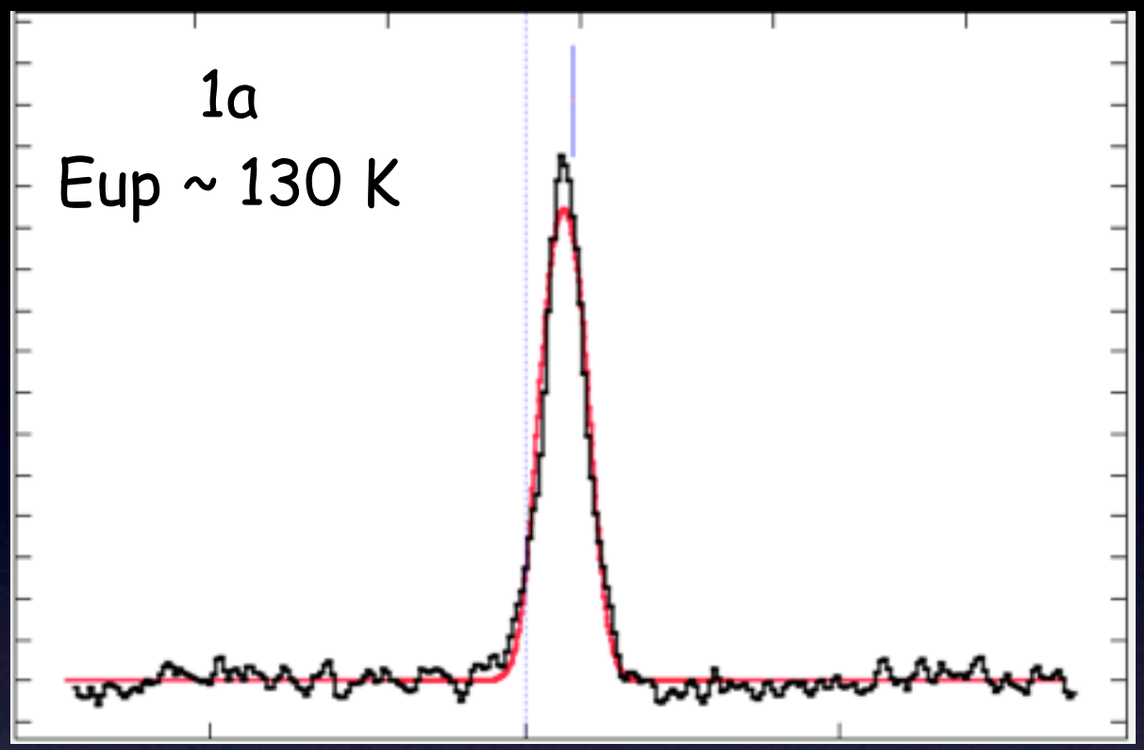
Band 1a an extremely rich spectrum with absorption lines

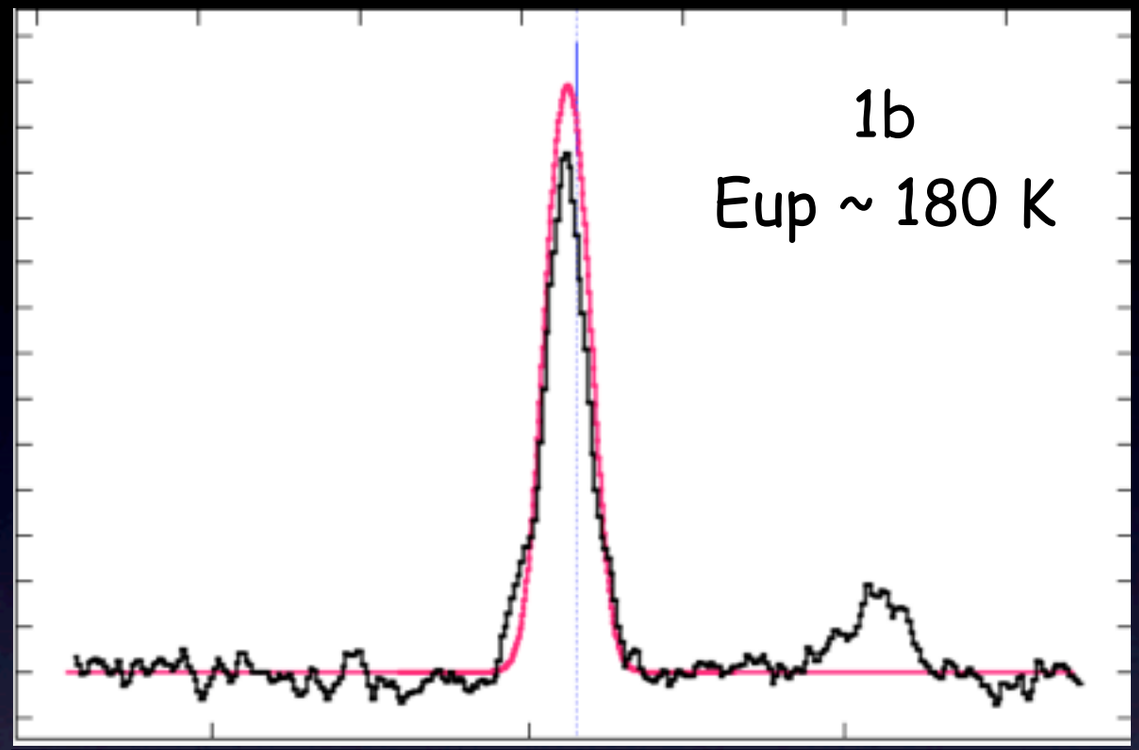
Species

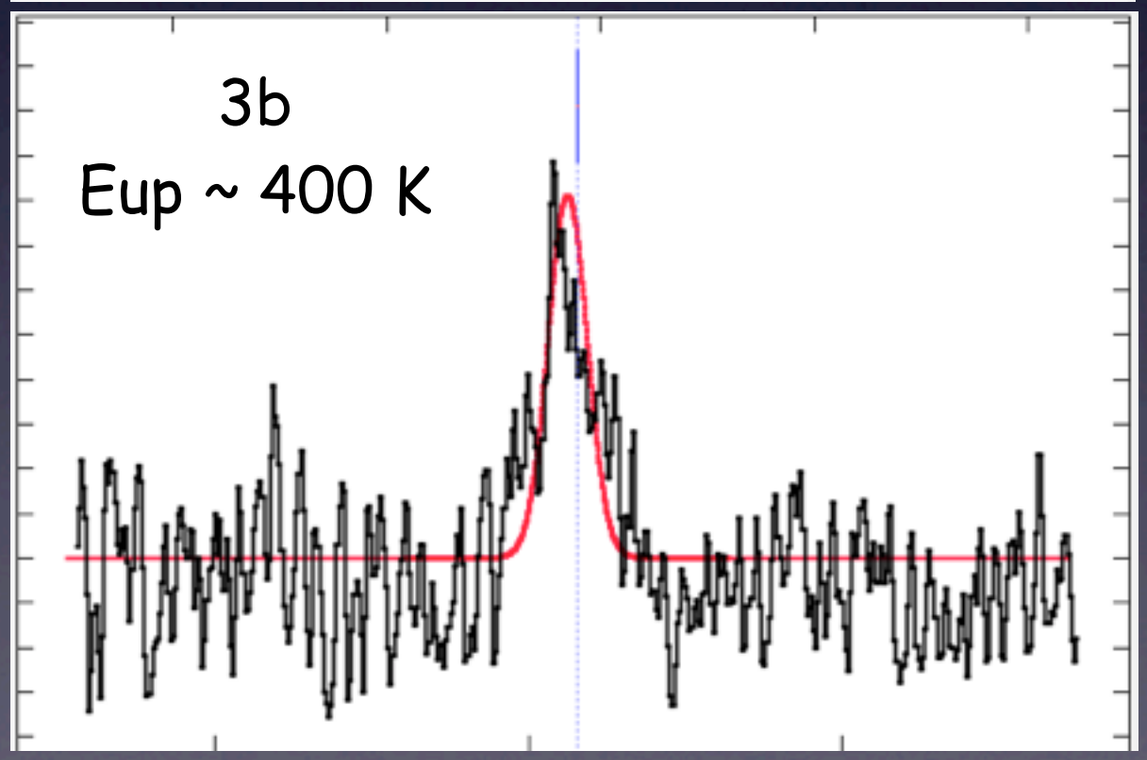
HCO^+	+ isotopes	+ D	SiO
H_2CO	+ isotopes	+ D	HNC
HCN	+ isotopes	+ D	OCS
H_2S	+ isotopes	+ D	N_2H^+
H_2O	+ isotopes	+ D	NO
CS	+ isotopes		ND
CO	+ isotopes		CCH
SO	+ isotopes		PN
SO_2	+ isotopes		H_2CS
CH_3OH	+ isotopes		CH_3OCH_3

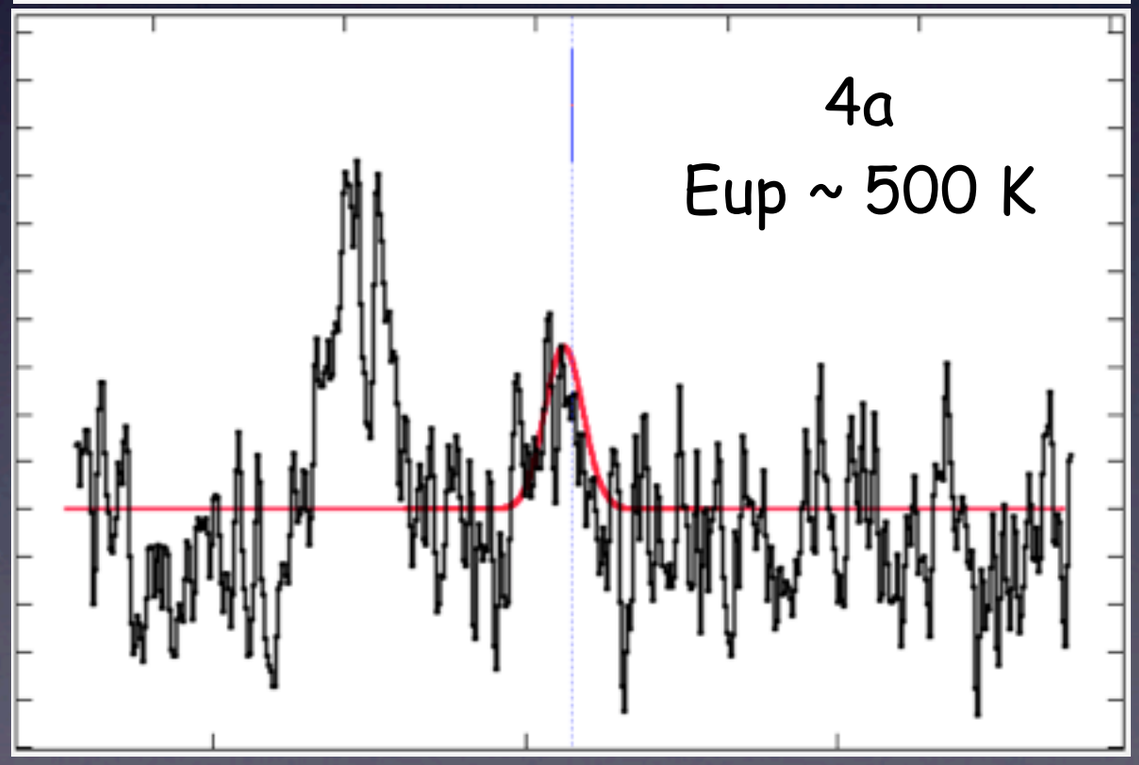
Band 1a : ~ 150 lines at 5 σ

CS LTE modeling

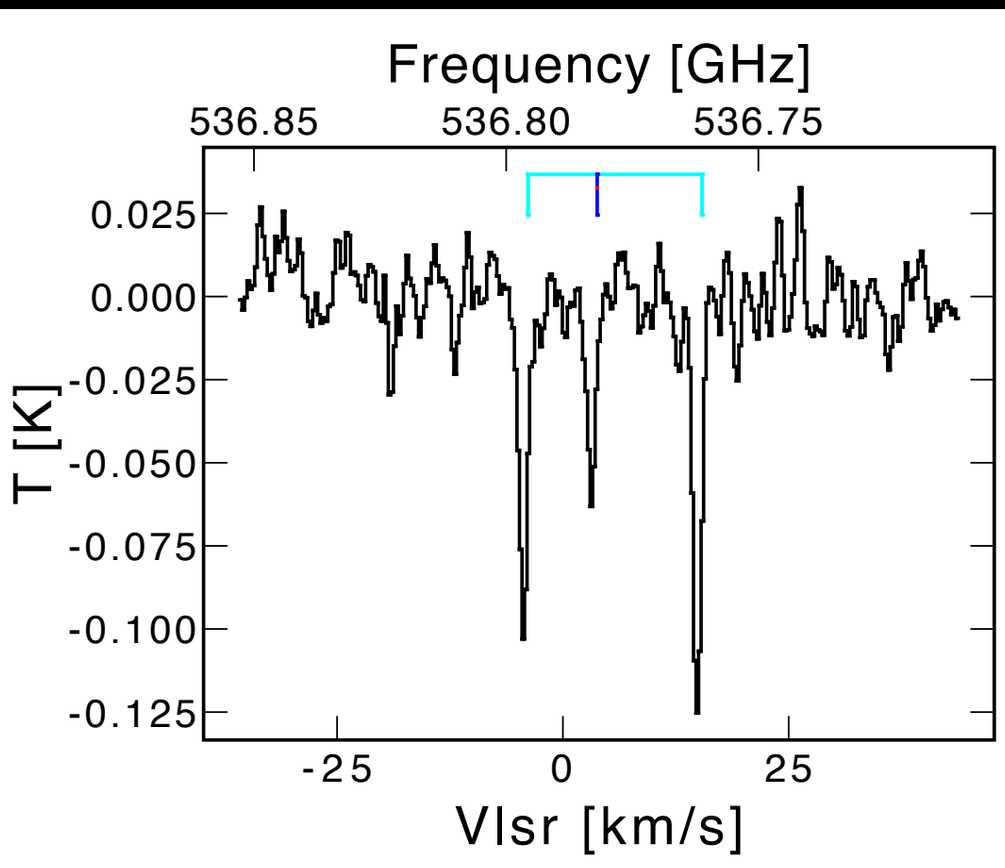




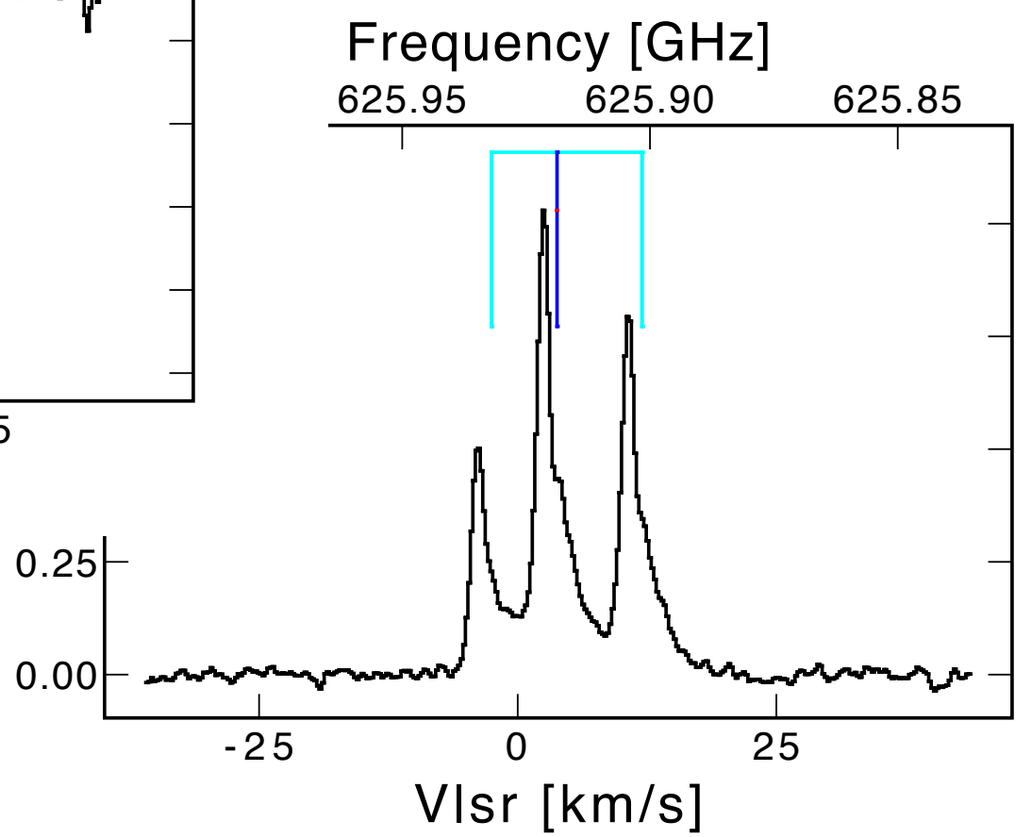




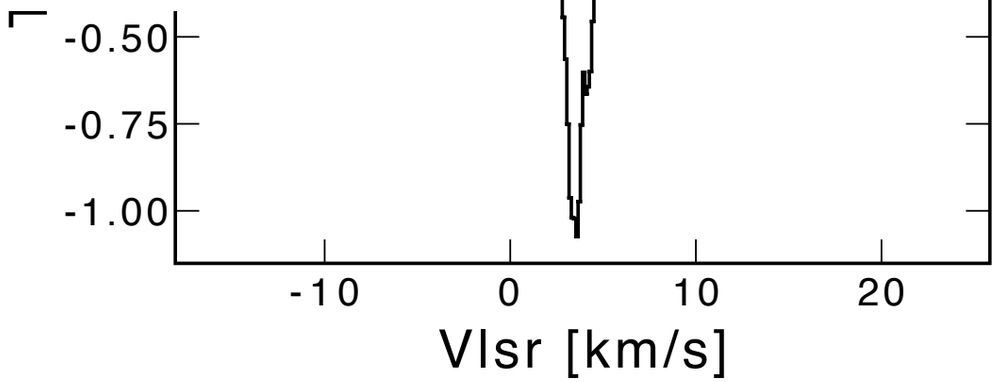
Hydrides

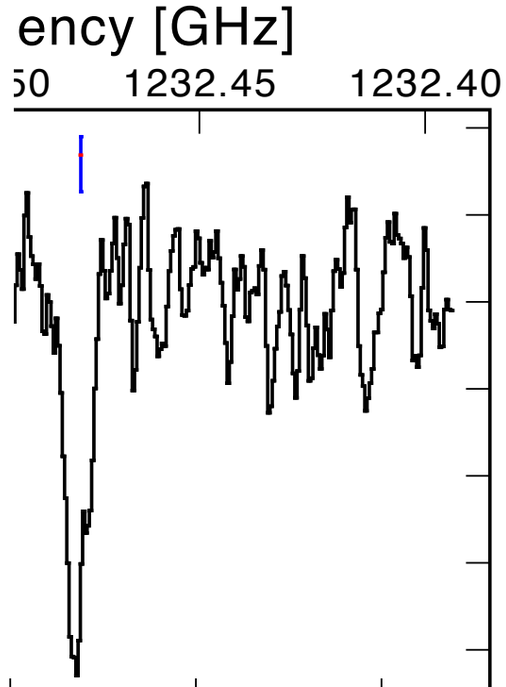


CH



HF

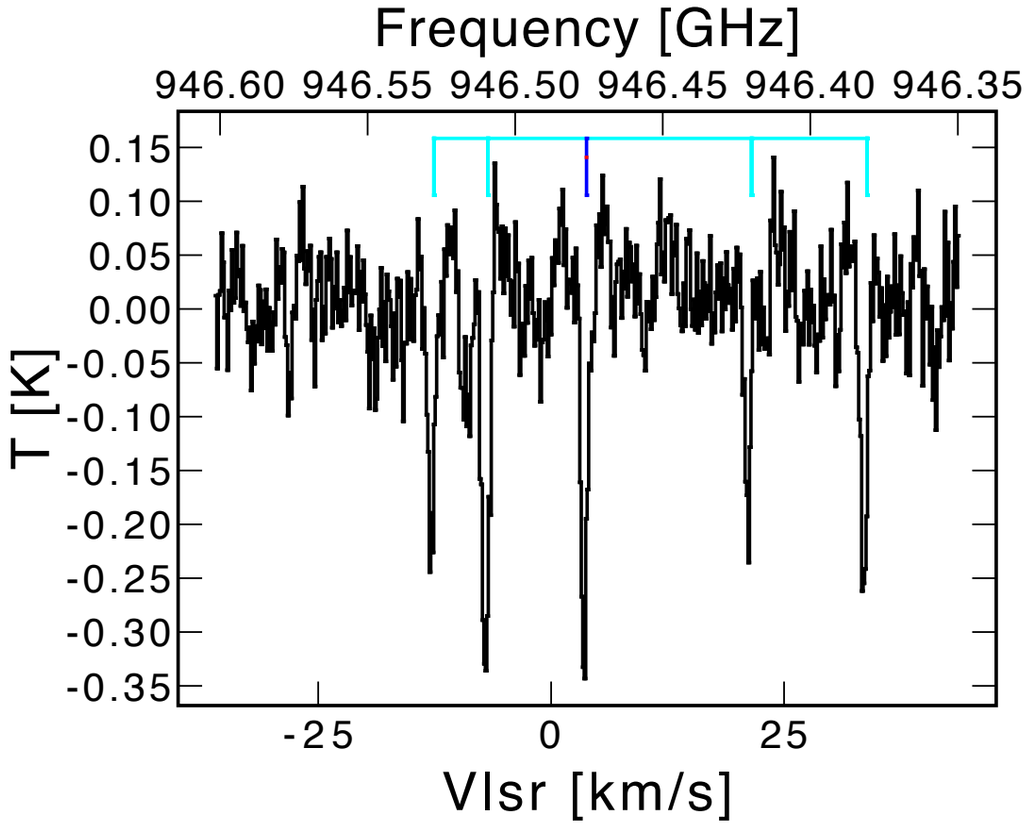




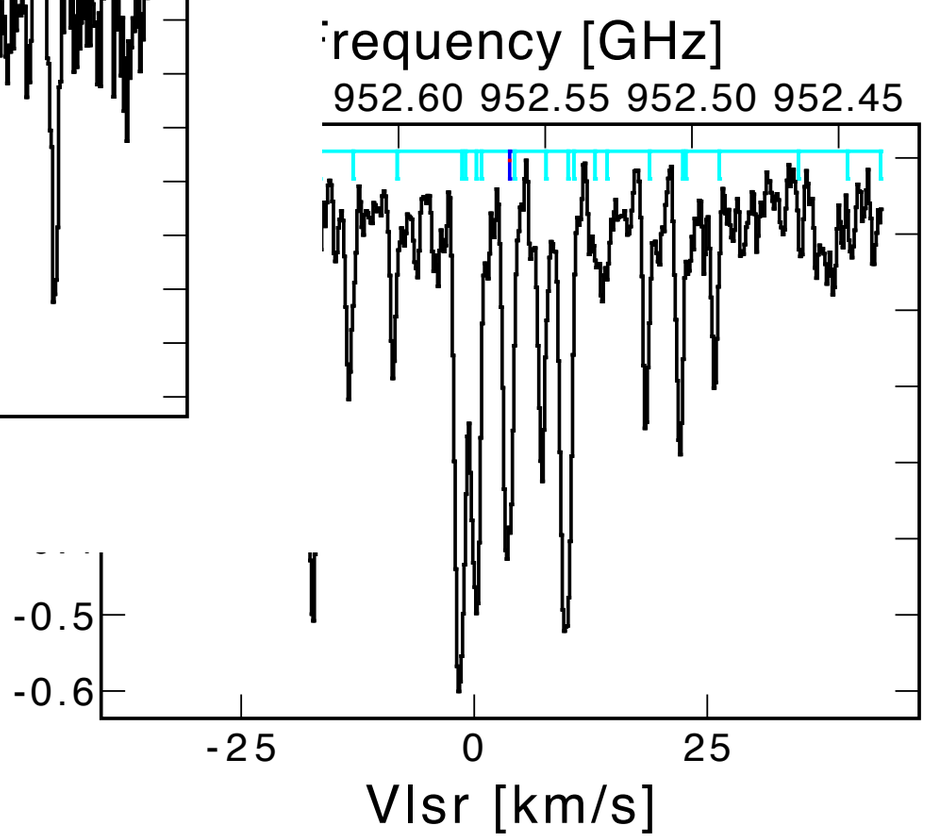
HCl

N-Species

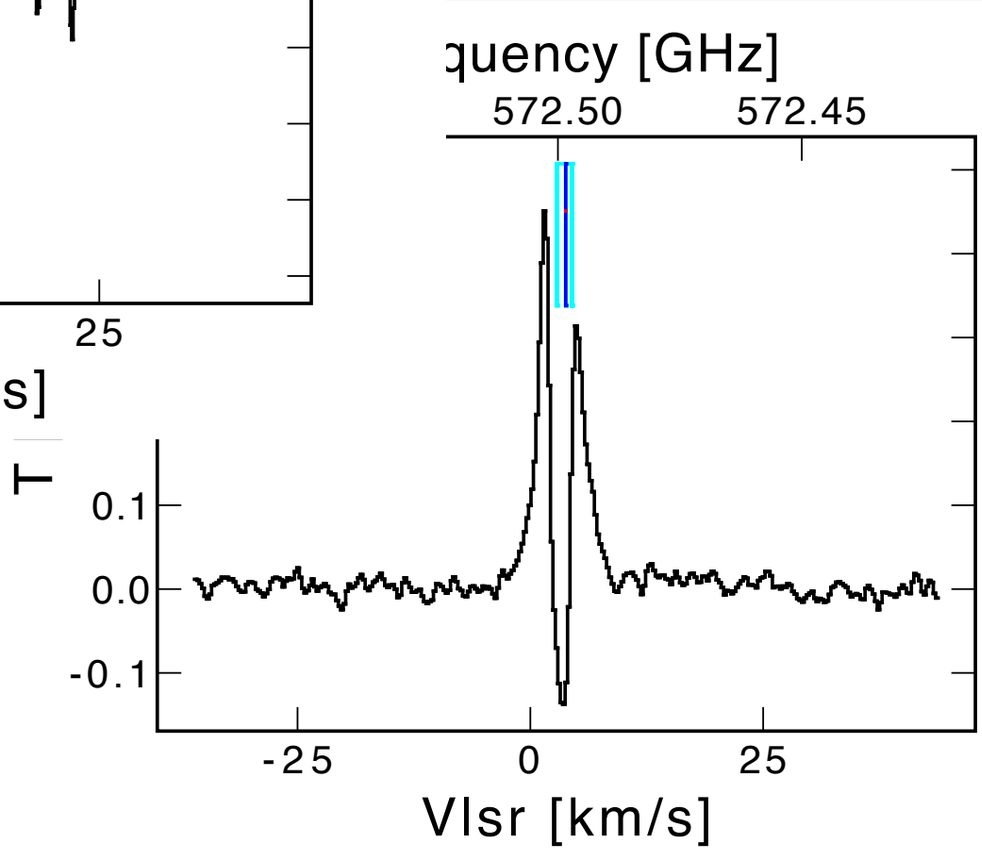
NH



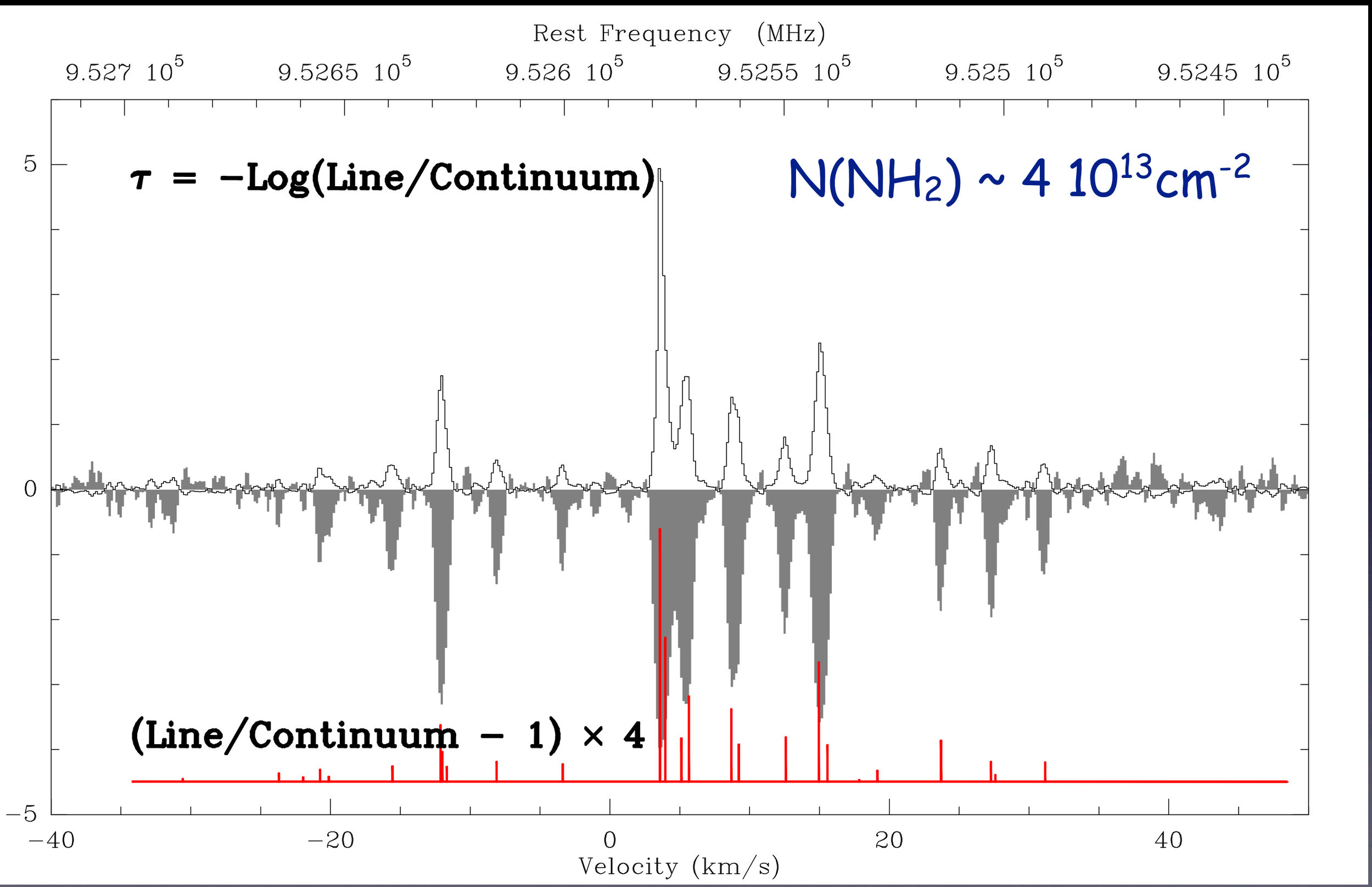
NH_2



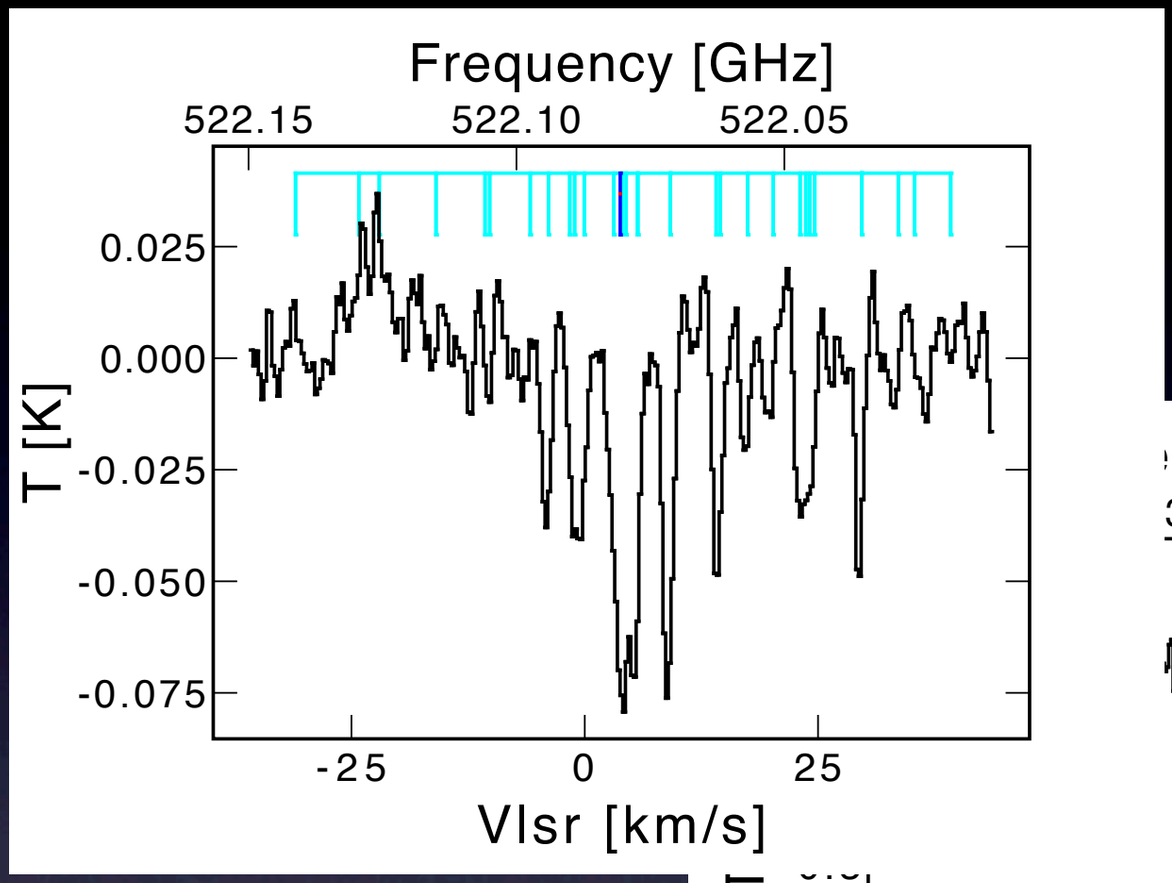
NH_3



NH_2

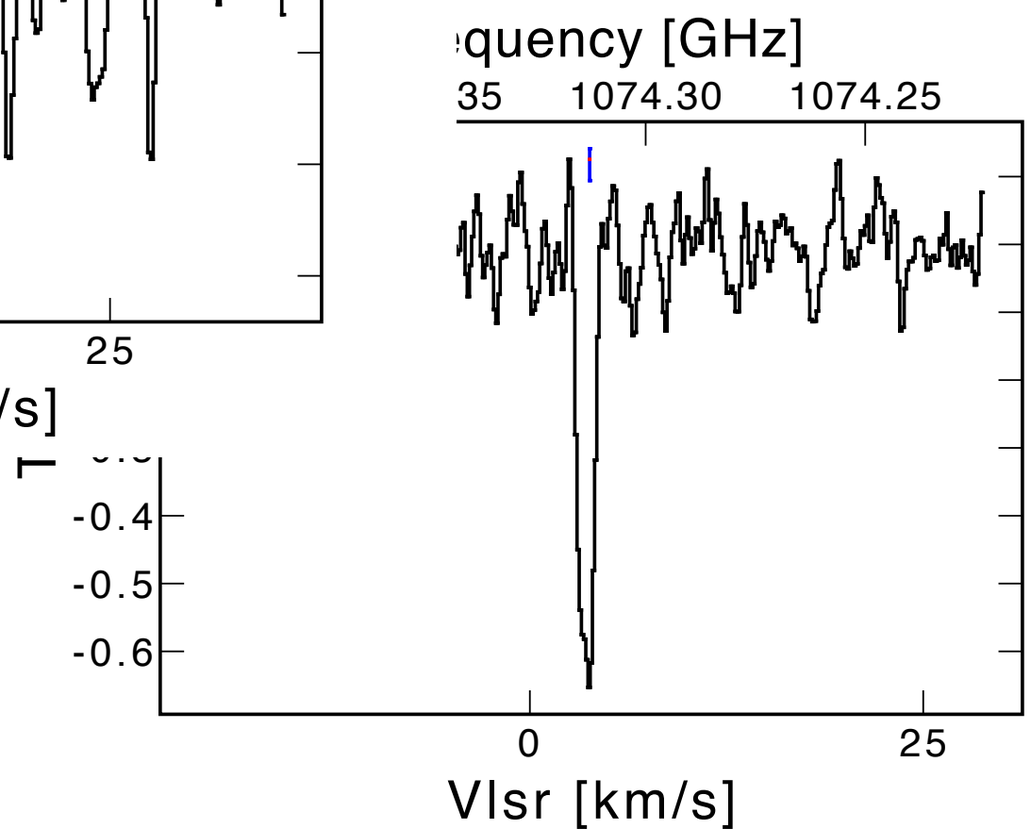

Rest Frequency (MHz)
9.527 10^5
9.5265 10^5
9.526 10^5
9.5255 10^5
9.525 10^5
9.5245 10^5
τ = −Log(Line/Continuum)
N(NH2) ~ 4 10^13 cm^-2
(Line/Continuum − 1) × 4
5
0
−5
−40
−20
0
20
40
Velocity (km/s)

Deuterated N-Species



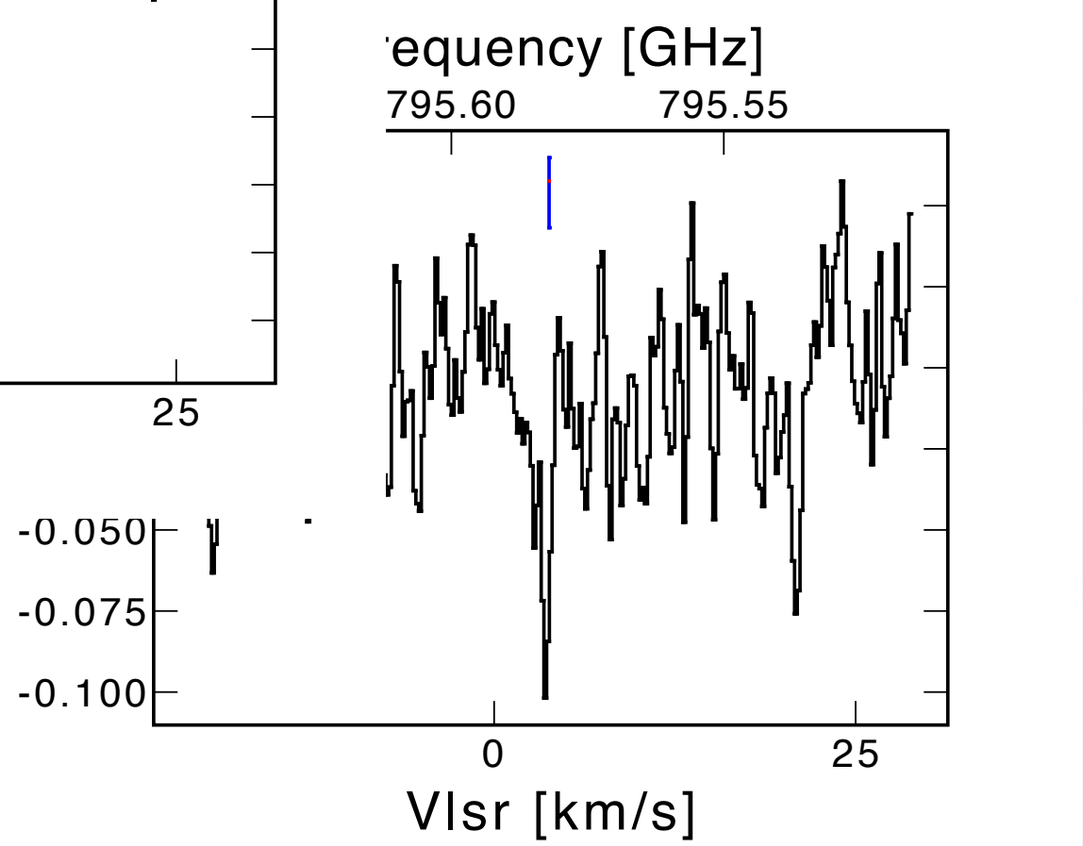
ND

First detection of the ND radical
(one tentative detection in Orion KL
with Odin by Olofsson et al. 2007)



NH_2D

NHD_2



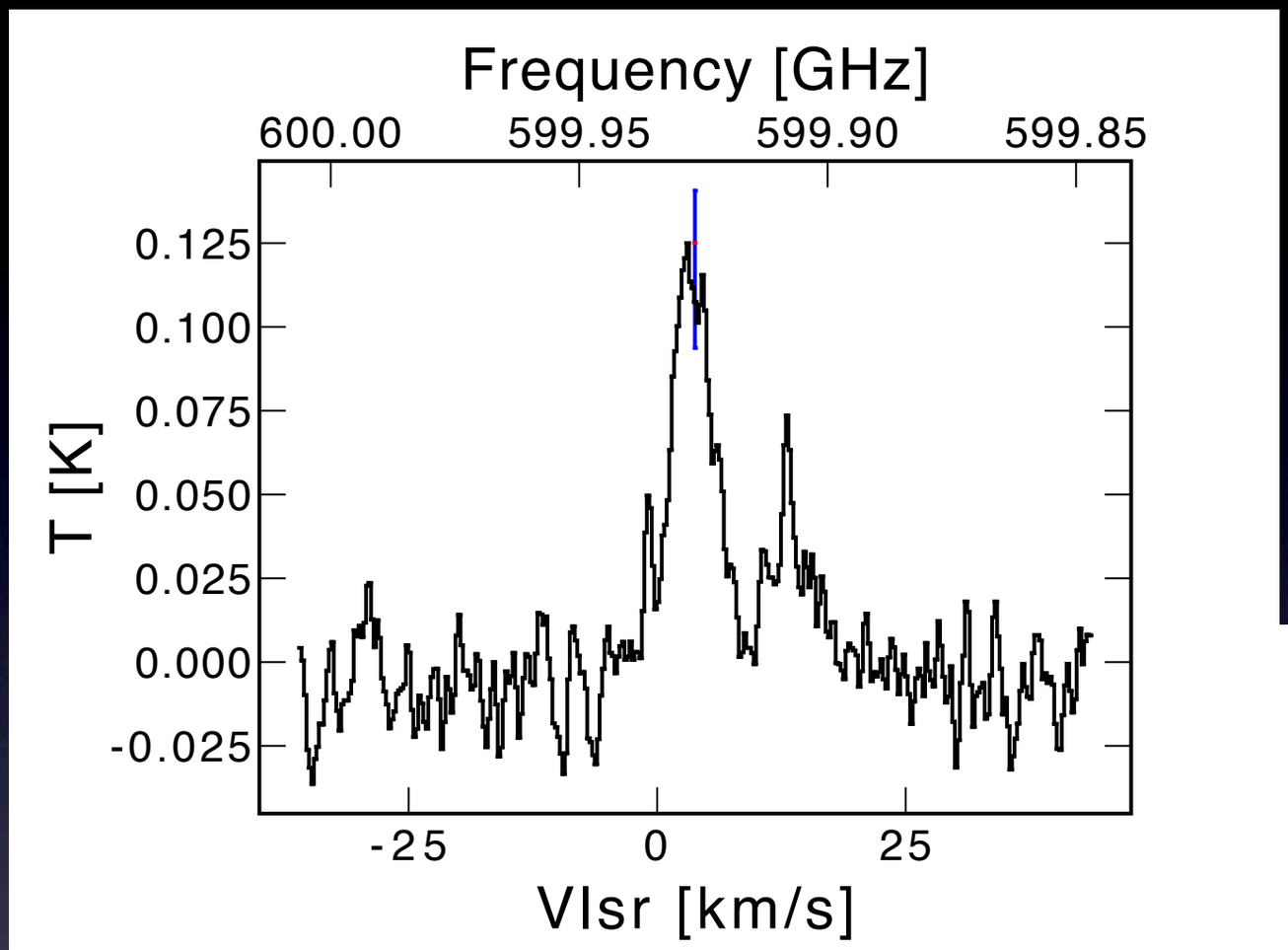
$N(NH) \sim 2\ 10^{14} cm^{-2}$

$N(ND) \sim 8.5\ 10^{13} cm^{-2}$

$ND/NH \sim 45\%$

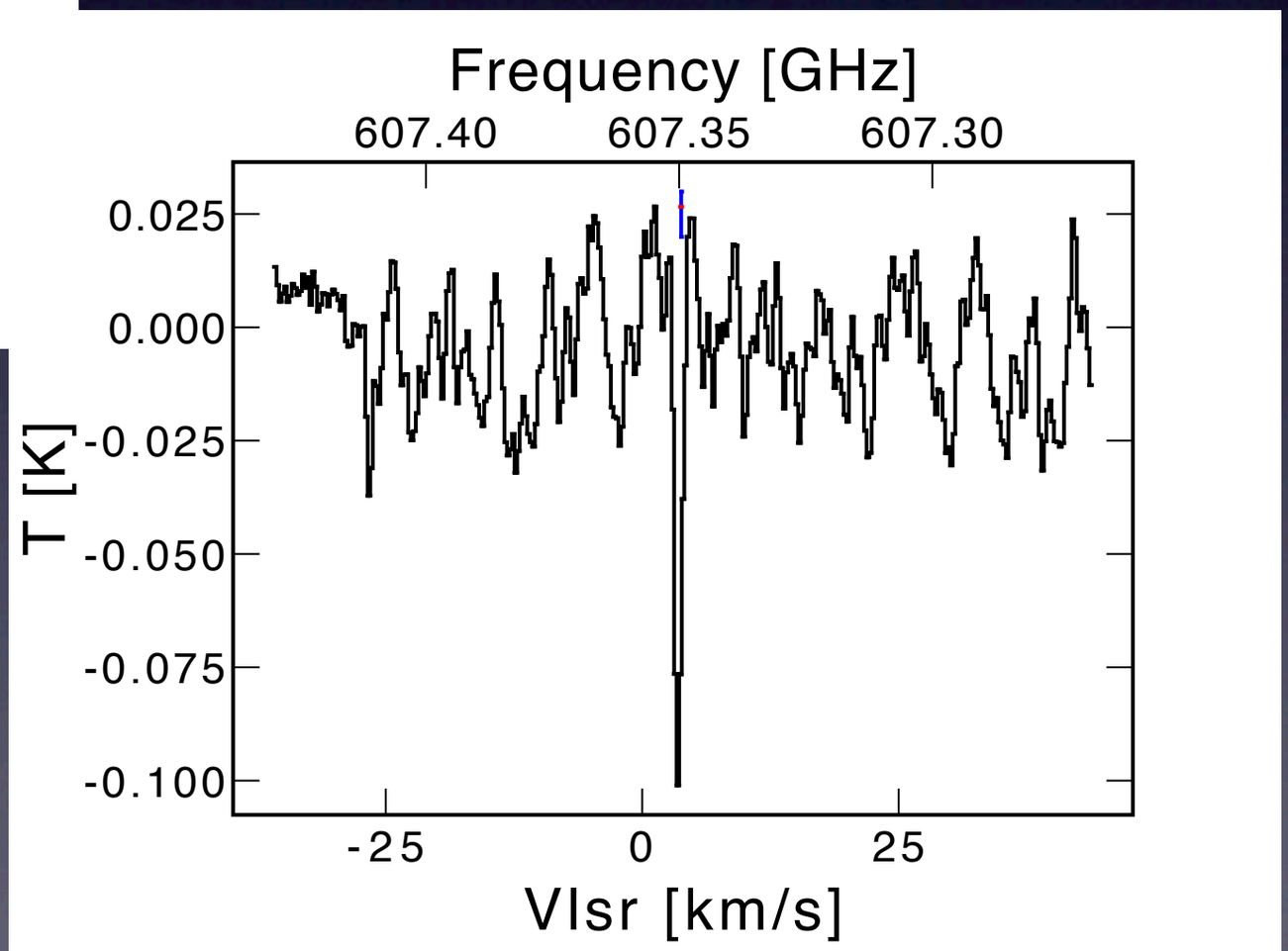
Bacmann et al. 2010, in prep

Deuterated water



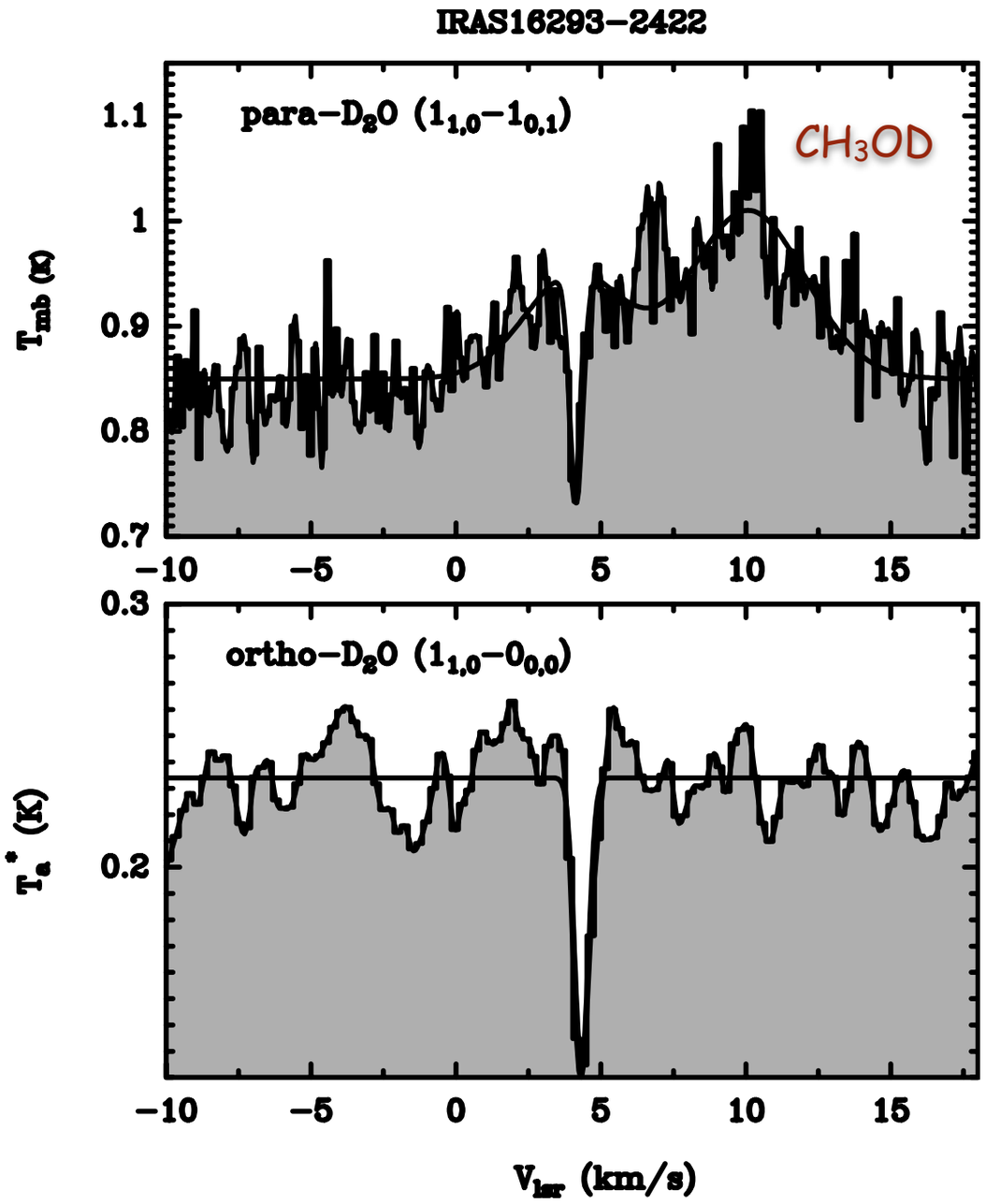
HDO

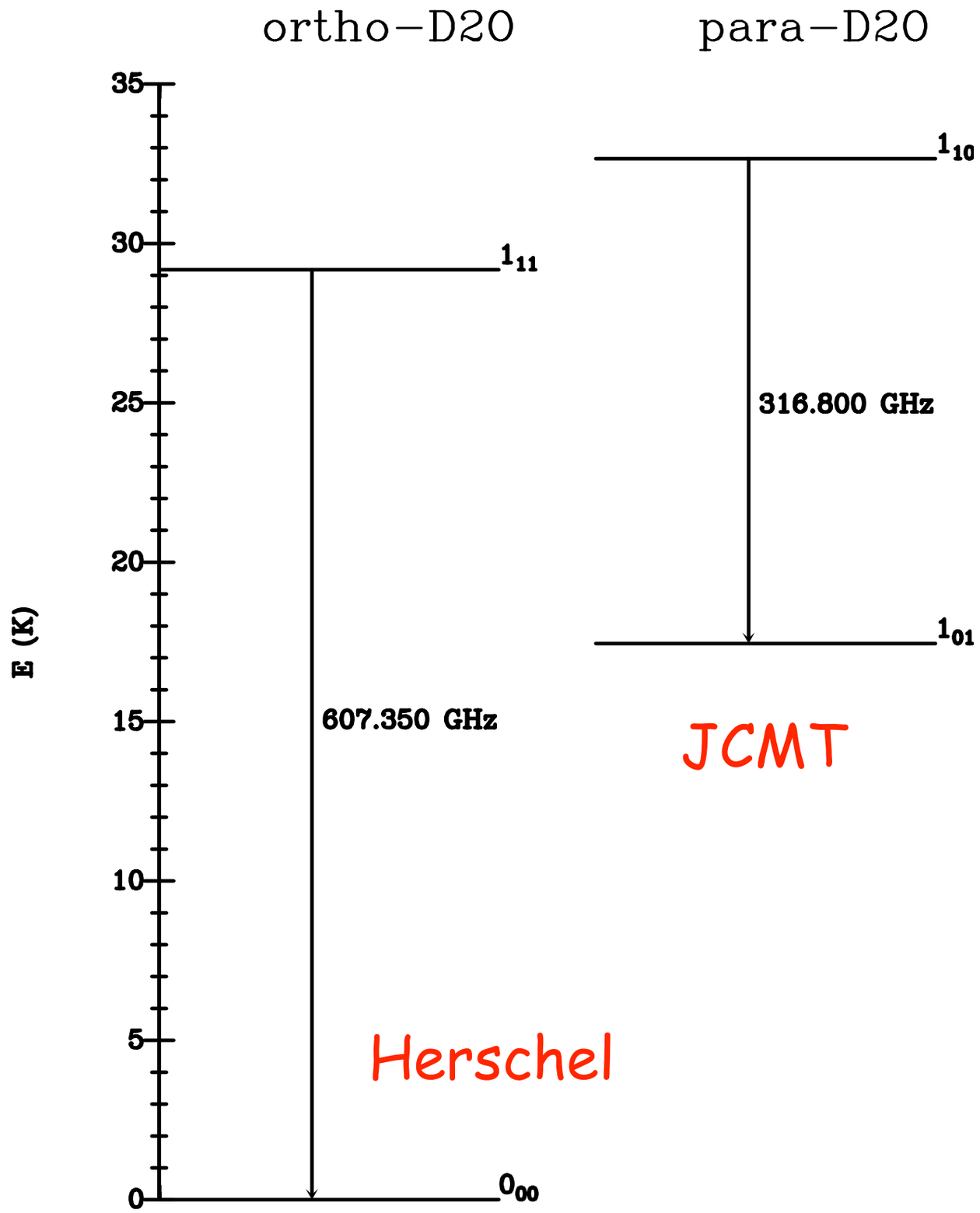
$o\text{-}D_2O$



Heavy water OPR

p-D_2O : Butner et al. 2007





Heavy water OPR

Spectroscopy : CDMS

ortho and para separation : CASSIS database (http://cassis.cesr.fr)

Collision coefficients at 20 K (Wiesenfeld et al. in prep)

Using T_k = 20K and $n(H_2) = 10^6$ cm^{-3}

$N(o\text{-}D_2O) = (1 \pm 0.4)\ 10^{12}$ cm^{-2} $N(p\text{-}D_2O) = (1.2 \pm 0.5)\ 10^{12}$ cm^{-2}

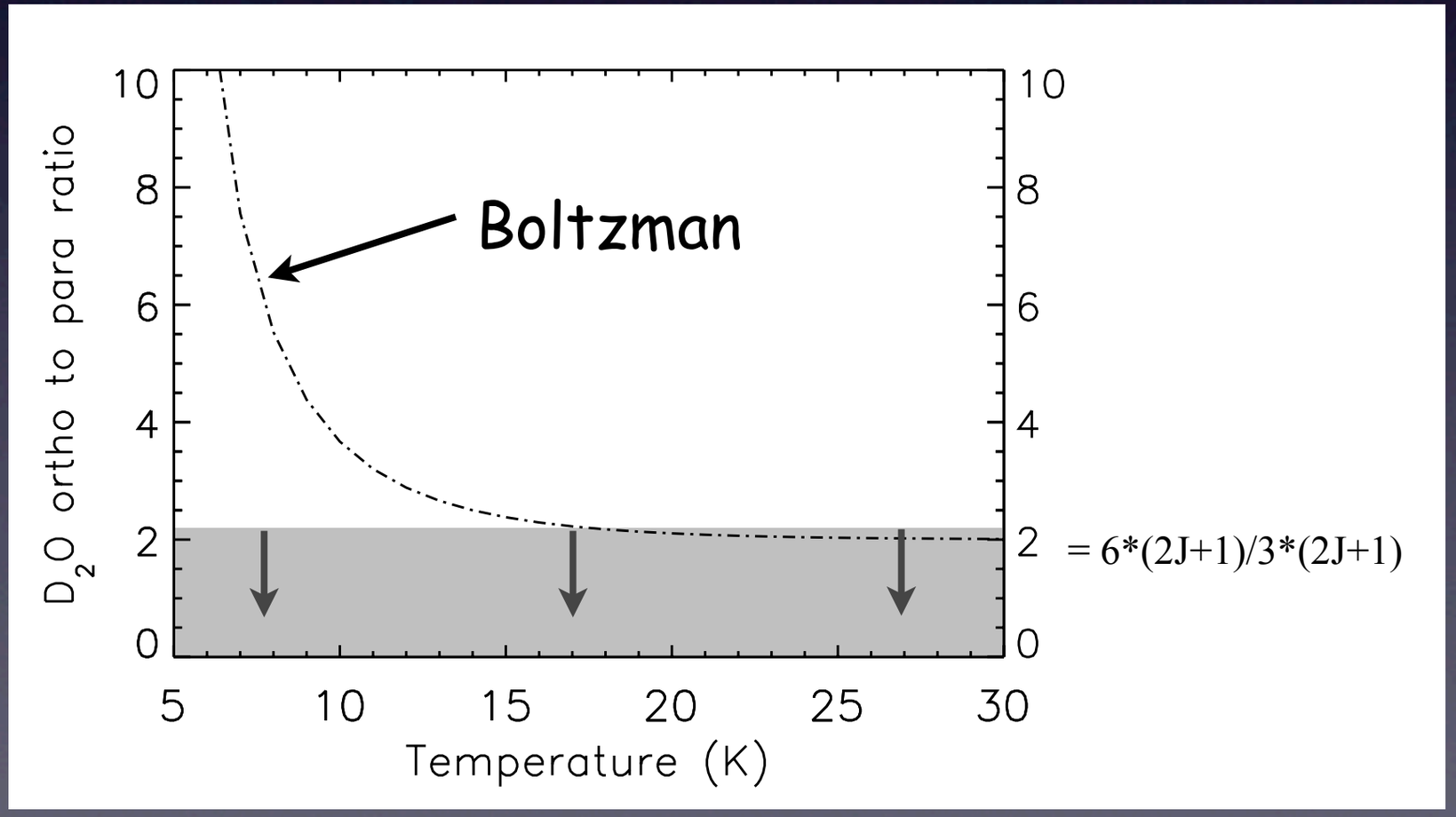
OPR = 1.2 ± 0.9

From ISO

$N(H_2O) \sim 9\ 10^{15}$

$D_2O/H_2O \sim 2\ 10^{-4}$

Vastel et al. 2010, in prep



Conclusion

HIFI is a very powerful and fast Spectral Survey machine

Low-mass Protostars, although fainter than High-mass Protostars have a very rich submillimeter spectrum

The scientific analysis of the IRAS16293 spectrum is just beginning, but as expected, is full of surprises, and the comparison with those of intermediate and high-mass Protostars is very promising.