

An Orion KL line survey with the Odin submm satellite

**An extended surveying campaign using 4 tunable receivers
in the opaque 'windows' around 487 and 557 GHz.**

Started: February 2004

Completed: October 2005

- Spacecraft & project description
- Results (spectra, analysis etc)
- Publications (format, timeline)

Spectral scan authors A.O.H. Olofsson, C. Persson, Å. Hjalmarson,
P. Bergman, P. Bernath, J. Black, U. Frisk, W. Geppert, T.
Hasegawa, N. Koning, B. Larsson, A. Lecacheux, S. Kwok, A.
Nummelin, M. Olberg, Aa. Sandqvist, K. Volk and E.S. Wirström
and contributions from the entire Odin Team!

odin

An aeronomy and astronomy mission

Launch on Start-1
Control and downlink to Esrange
3-axis stabilized using reaction wheels
Star trackers, gyros and sun sensors
250 kg (80 kg payload)
Height 2 m, width 3.8 m
340 W solar panels
15 arc sec pointing in staring mode
1.2 arc min reconstructed in aeronomy
Polar, 600 km alt. 18:00 asc. node orbit



- ◊ Joint venture with Sweden, Canada, Finland, and France
- ◊ Prime contractor and responsible for operation: Swedish Space Corporation
- ◊ Radiometer system assembly/testing, and data processing at the Onsala Space Observatory



Launched in Feb. 2001 ⇒ **5 yr operation!**

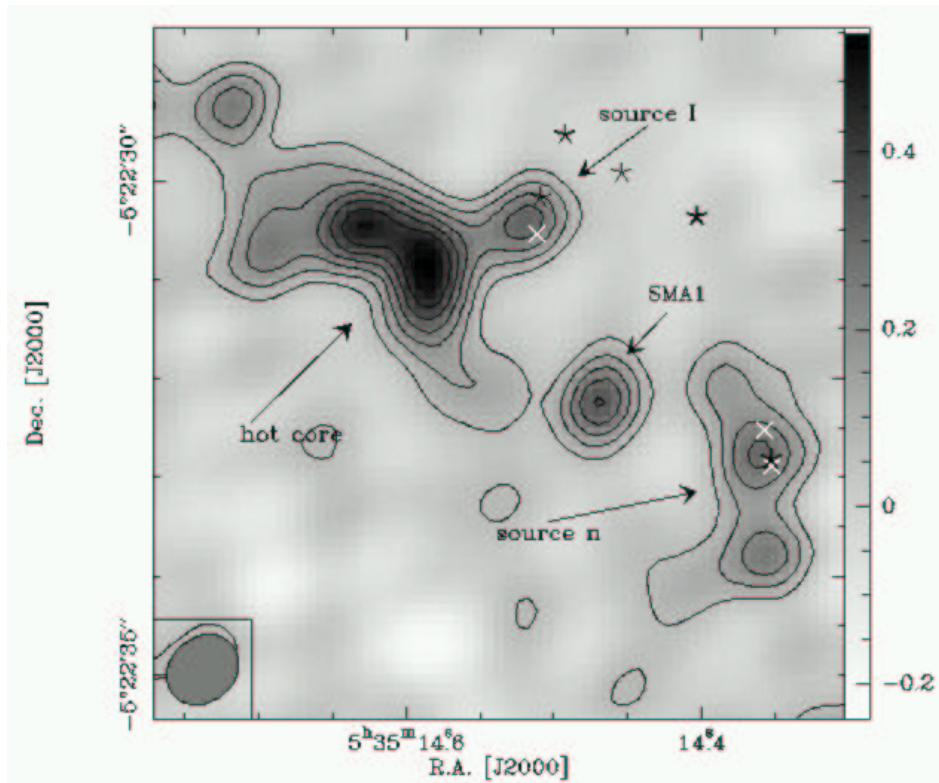
...and still in remarkably good health (with a favorable outlook for at least another year).

No new similar survey observations planned at this time,
but search for primordial molecules will continue!

4-1



Complex source structure: characteristic line velocities, widths, sizes, chemical make-ups, temperatures etc.



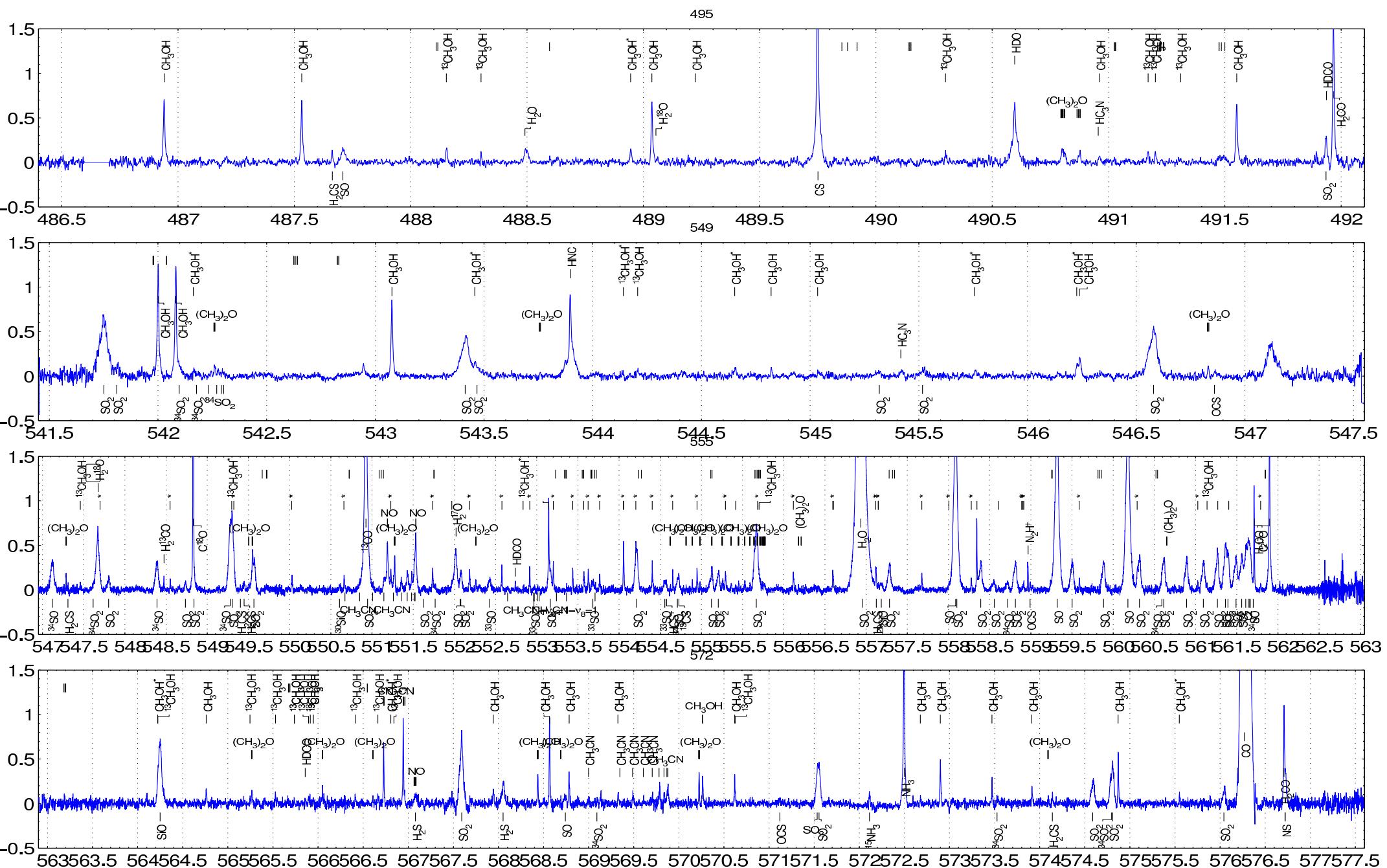
Beuther et al. (2004,2005)

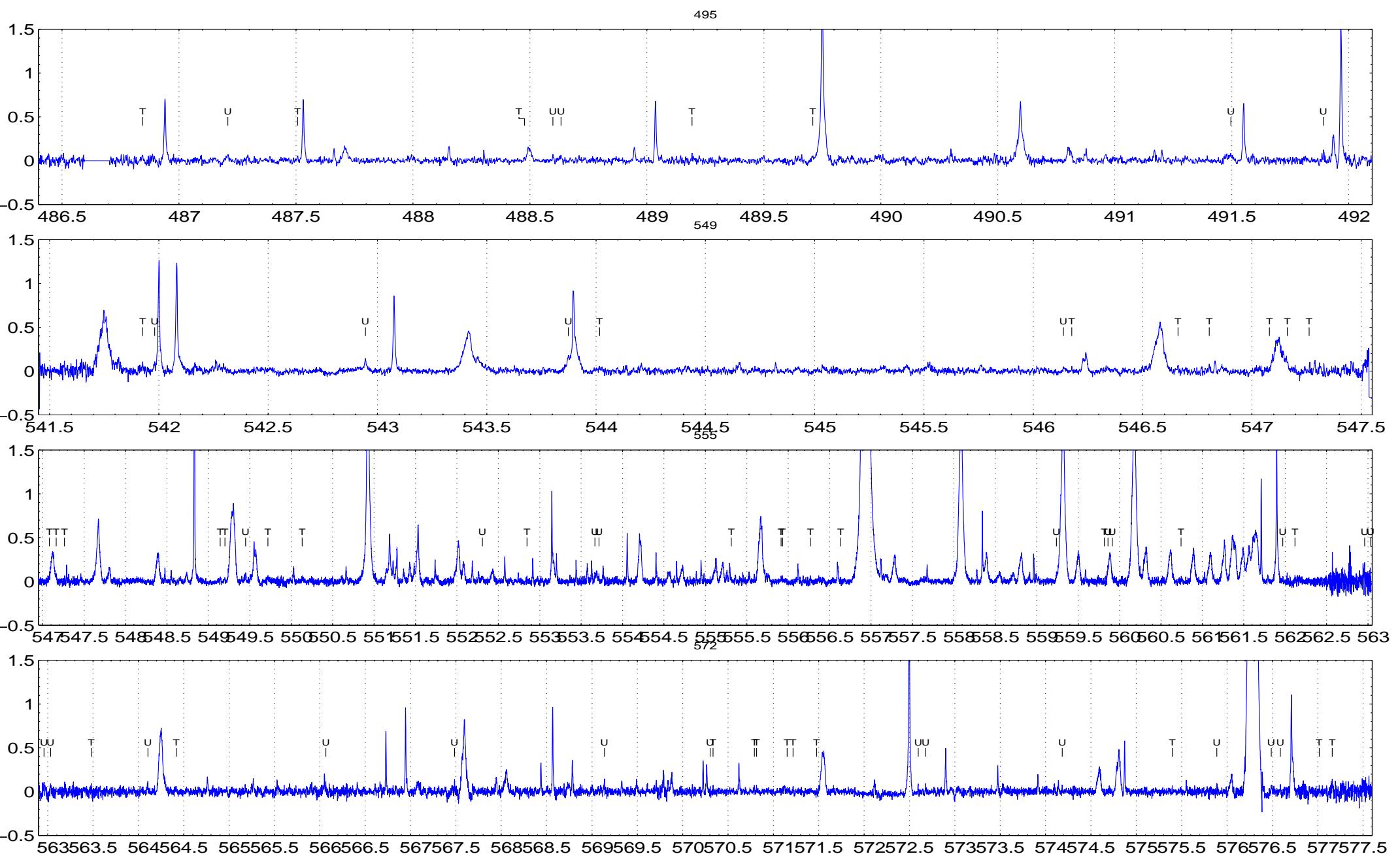
Implementation details

- **Position switching**
 - 1 min. cycle time ($\sim 24\text{s}$ on / 24s off)
 - Ref.pos. $30'$ E w.r.t. Orion KL
- **25 orbits/tuning**
 - ...in $\frac{1}{2}$ GHz steps at 1 GHz bandwidth
 - $\Rightarrow 25\text{h}/\text{channel}$ (1 MHz)
- **Simultaneous observations:**
 - 555(AOS) & 572(AC1+2) B-side
 - or
 - 549(AOS) & 495(AC1+2) A-side

Implementation cont'd

- **In total 1100 orbits**
 - ...conducted in 54 separate observing runs
 - ...durations between 3 and 29 orbits (average 20)
 - ...up to 3 settings per obs.
- **42 GHz frequency coverage**
 - 495: 486.4–492.1
 - 549: 541.4–547.6
 - 555: 546.9–563.1
 - 572: 562.9–577.6





Results overview

Tabell 1: Survey overview

Property	Value
Bandwidth covered	40 GHz
Number of lines detected ^a	348
Line density	8 GHz ⁻¹ (range: 4–20 ⁻¹)
Line intensity range	0.05–80 K
Number of molecules detected ^b	39
Typical RMS reached	~25 mK/1 MHz channel
Total line luminosity ^c	5×10^{26} W
Mean line-to-continuum ratio ^d	0.2

^aIncl. U-lines.^bIncluding isotopologues.^cAssuming $\eta_{bf}=0.5$.^dNear 550 GHz

Integrated brightness distribution

CO: 47%, H₂O: 17%, SO₂: 11%, SO: 9%, CH₃OH: 5%

Σ : 89%

MOLECULES OBSERVED BY Odin:

CO	^{13}CO	C^{18}O	C^{17}O	CI	$\boxed{\text{O}_2 \text{ !!!}}$
$\text{o-H}_2\text{O}$	$\text{o-H}_2^{18}\text{O}$ (x2)	$\text{o-H}_2^{17}\text{O}$	$p\text{-H}_2\text{O}$	HDO	
$\boxed{\text{ND ?}}$	NH_3	$^{15}\text{NH}_3$	N_2H^+	CN	NO
CS	^{13}CS	HCS^+	H_2S	OCS (46-45 & 47-46)	NS
SO	^{34}SO	^{33}SO	$\boxed{\text{SH}^- \text{ ?}}$	$\boxed{\text{SO}^+ \text{ ?}}$	SO_2
SiO(13-12)	^{29}SiO	^{30}SiO		HNC	HNCO ?
HC_3N (54-53 & 60-59)			CH_3CN ($J = 31-30$ & $30-29$, $K = 0-10$; also $\nu_8 = 1$)		
H_2CO	H_2^{13}CO	HDCO	$\text{H}_2\text{C}^{18}\text{O}$?		H_2CS
CH_3OH ($\nu_t = 0$ & 1)	$^{13}\text{CH}_3\text{OH}$ ($\nu_t = 0$ & 1)		$(\text{CH}_3)_2\text{O}$	HCOOCH_3	- A & E

Also: Some 70 U-lines & Abundance limit for PH

Spectroscopic databases *invaluable*

CDMS (Cologne): Holger Müller et al.

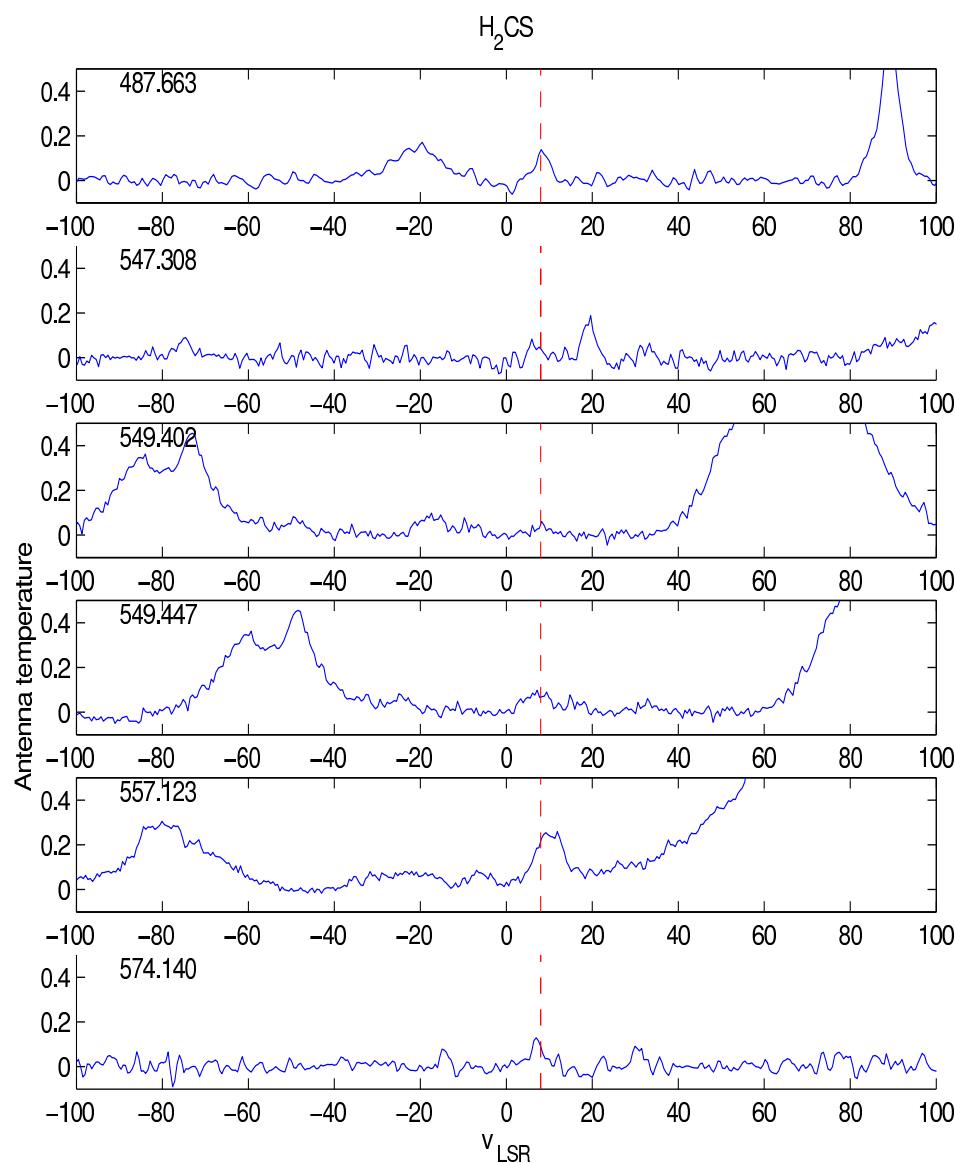
<http://www.ph1.uni-koeln.de/vorhersagen/>

JPL: John Pearson et al.

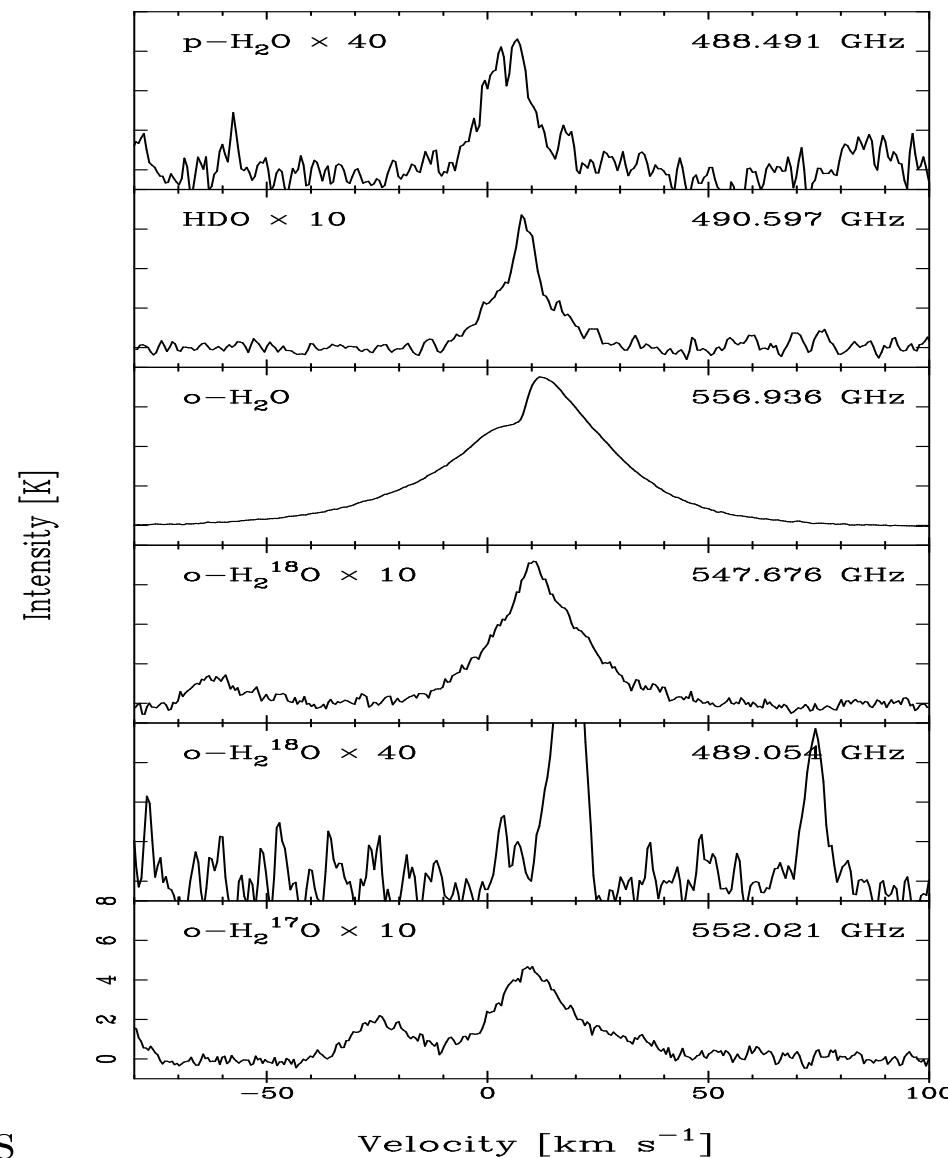
<http://spec.jpl.nasa.gov/>

SLAIM03: Frank Lovas

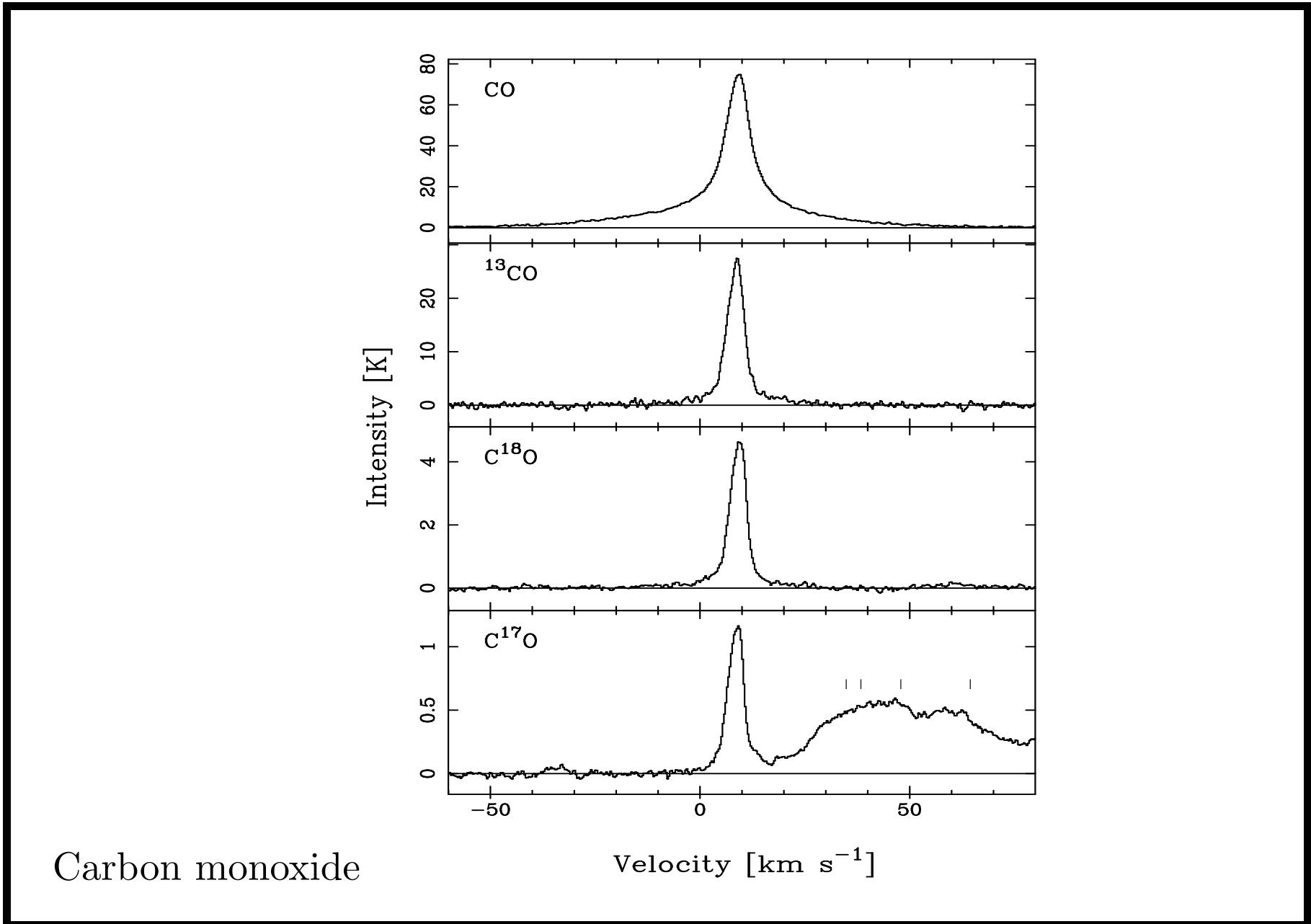
Not web-published (yet?) but some data at NIST.

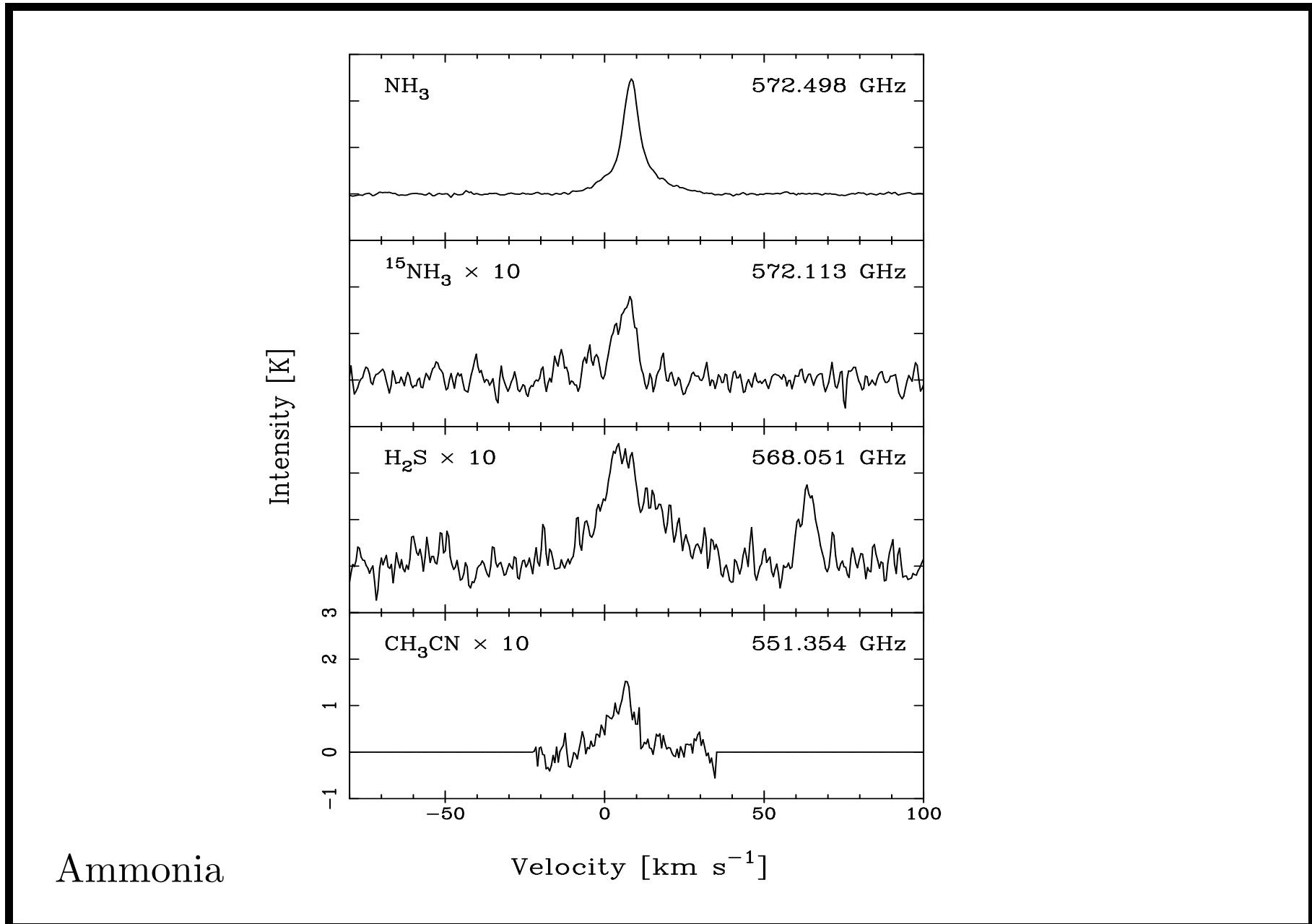


Example

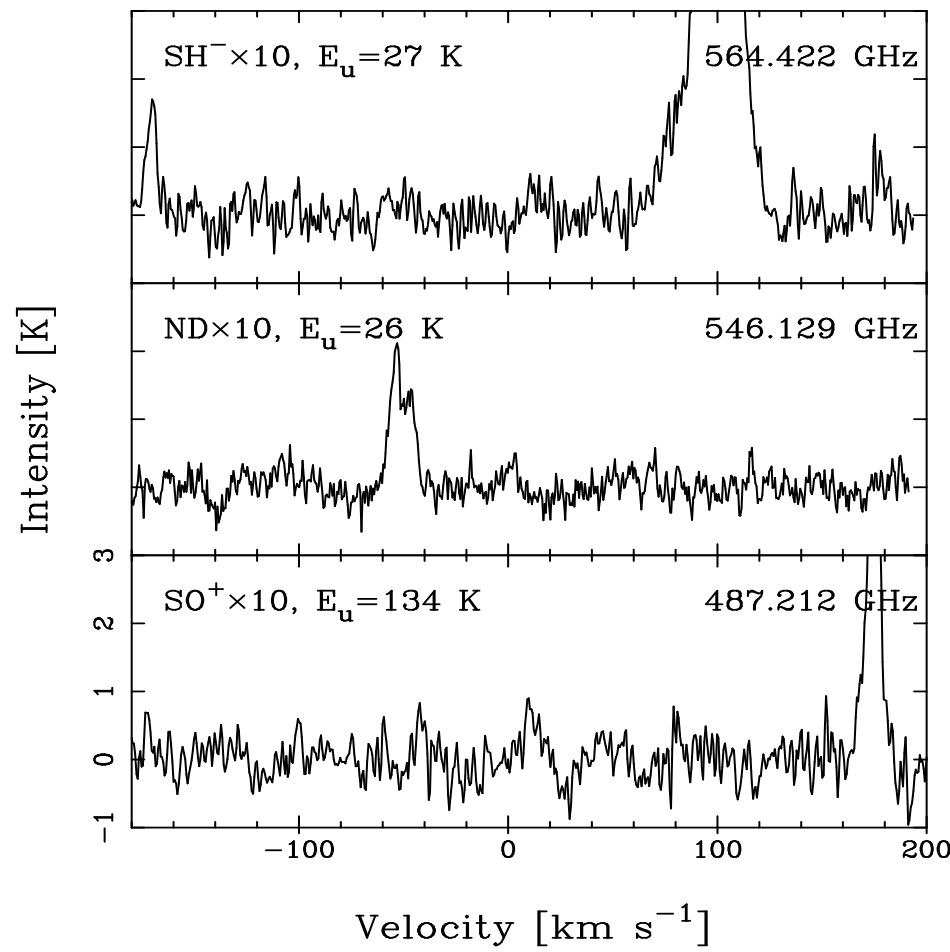


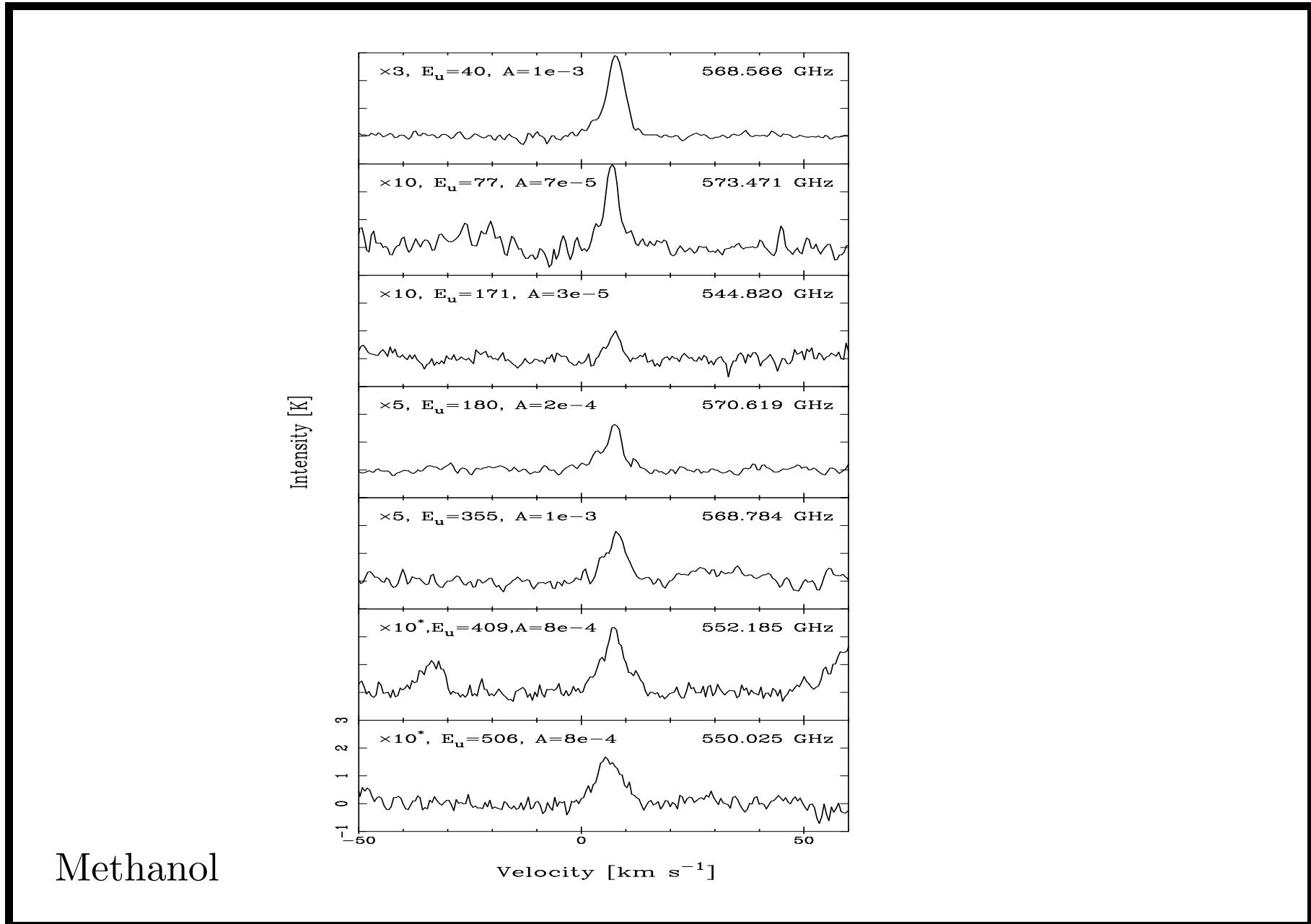
Water variants

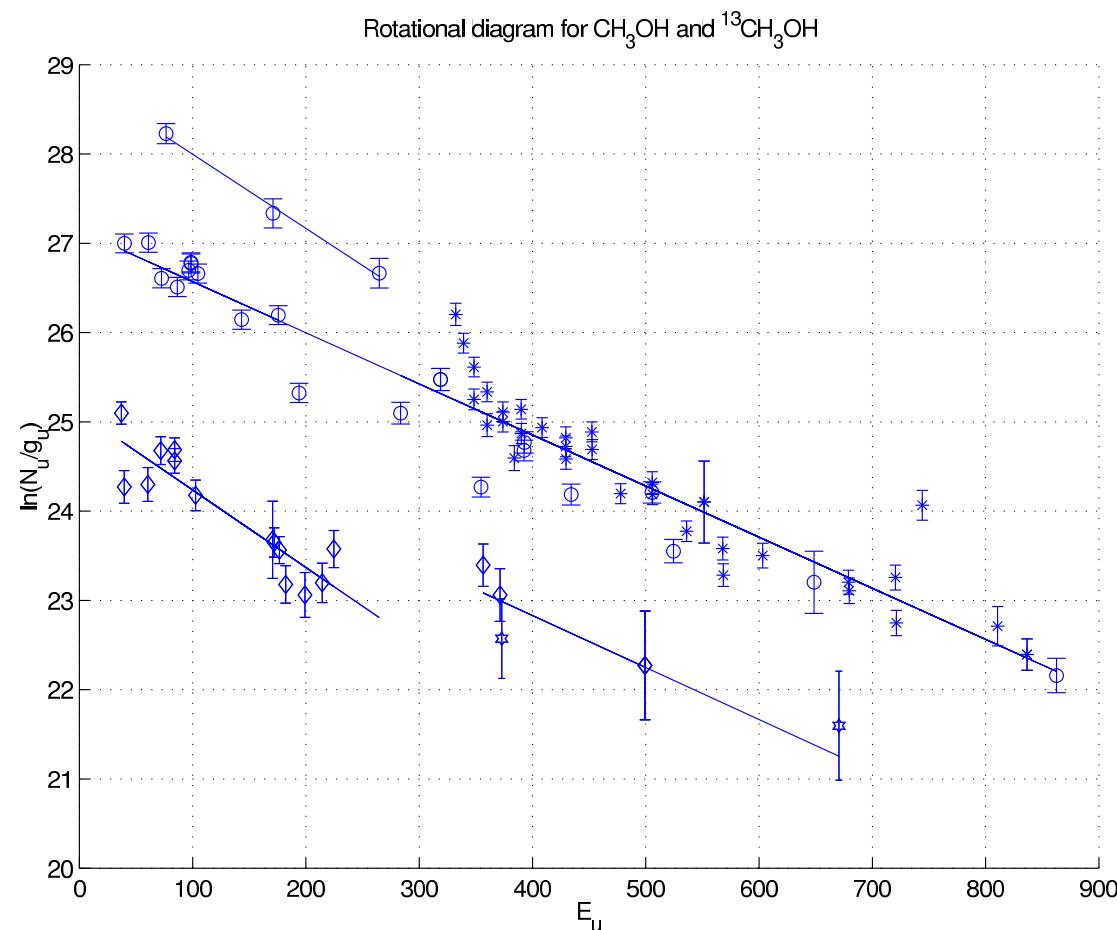


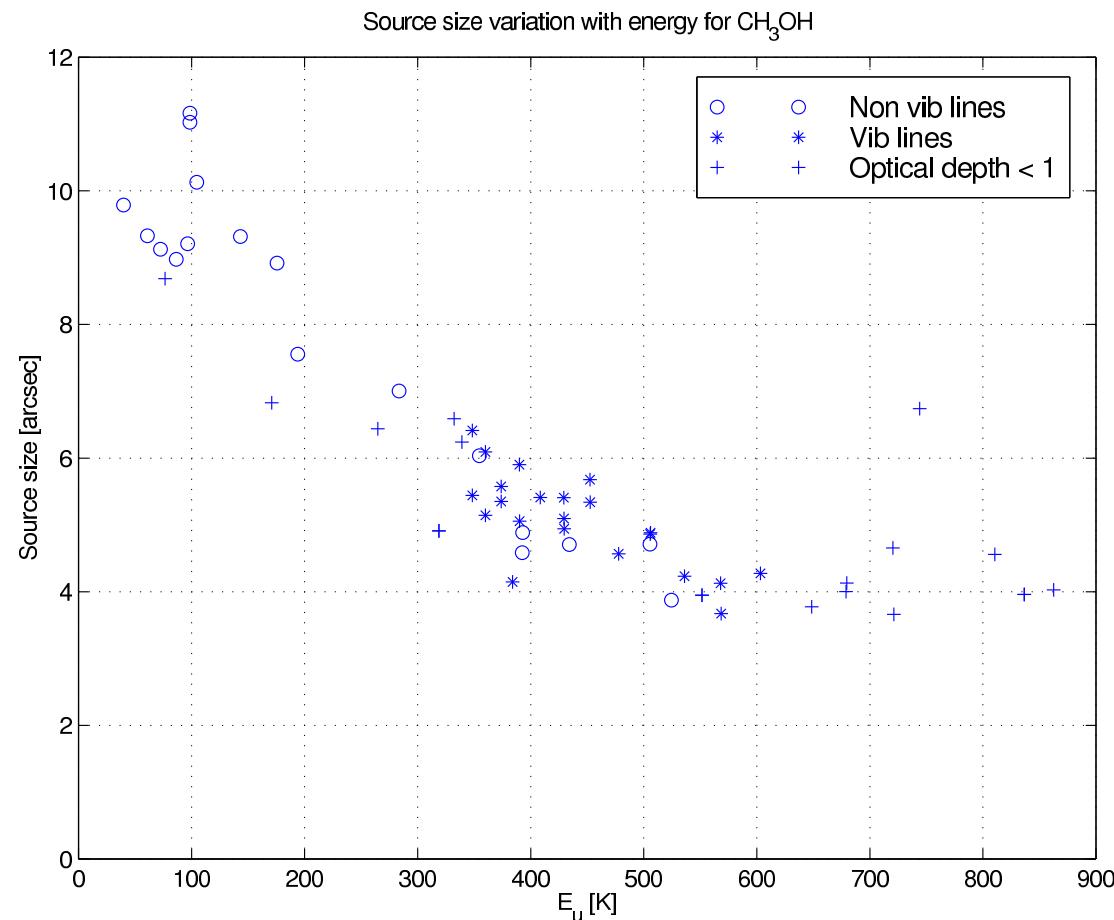


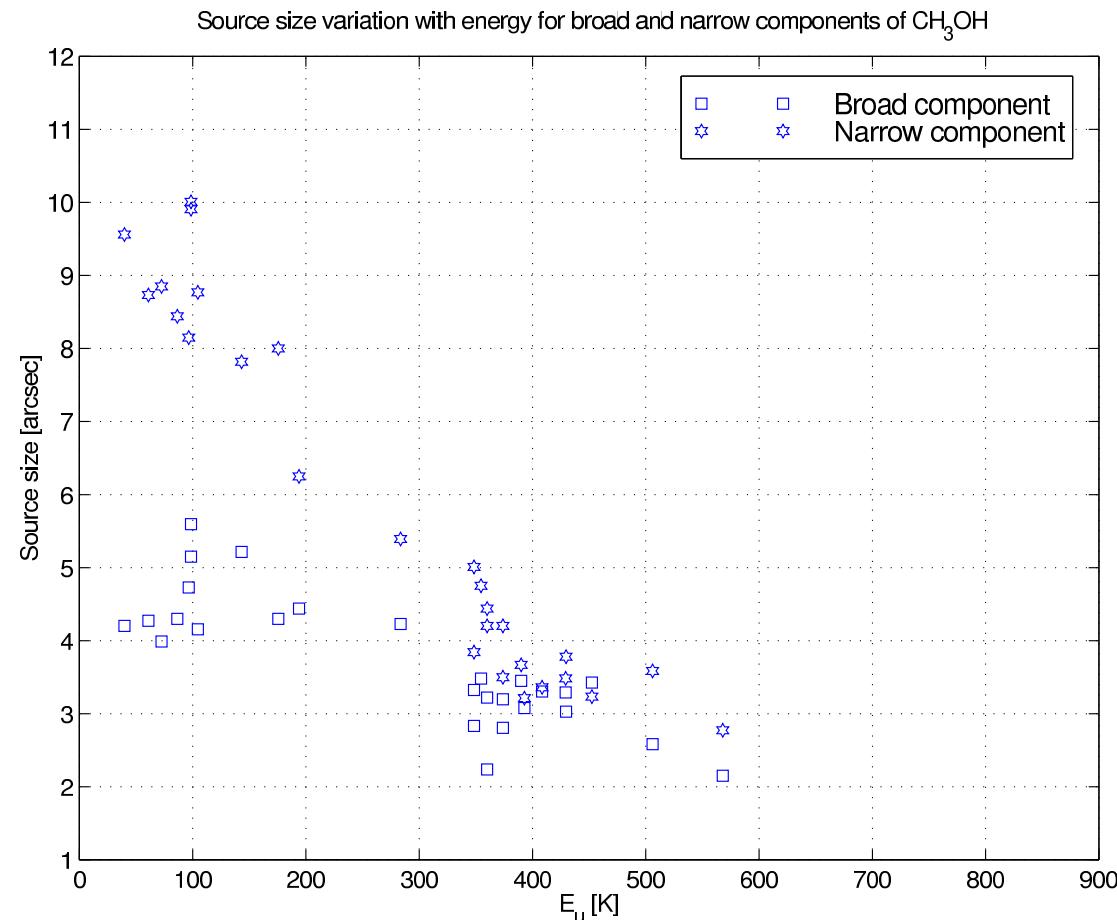
“Intriguing tentative assignments”

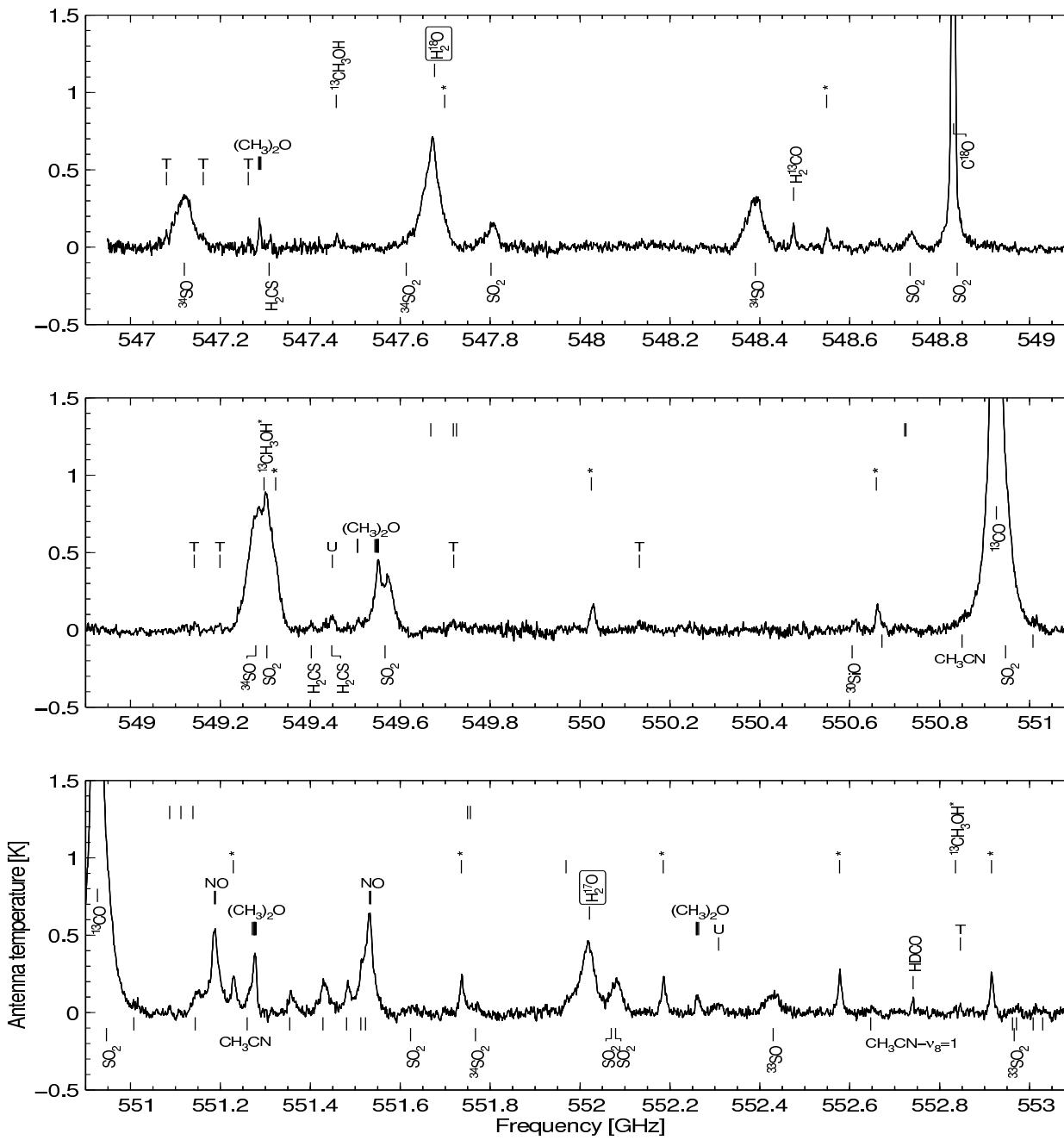












Results summary

- Successful completion of 42 GHz scan (1st from space!)
- High accuracy of intensity and frequency calibration
- Multiple lines allowing rot.diag.analysis for 7 molecules
- Demonstrate that line blending critical, “the whole view” needed
- Source profiling, origin of emissions investigated
- Up to \sim 70 U-lines (but all weak)
- Very tentative:
 SH^- , SO^+ , ND
- Not found:
 O_2 (at 487 GHz), PH

Publications (soon but some work left...)

Paper I & II:

Olofsson, A.O.H., Persson, C., et al. 2006,

“A spectral survey of Orion KL from 487-492 and 542-577 GHz with the Odin satellite. I. The observational data.” To be submitted to A&A

Persson, C., Olofsson, A.O.H. et al. 2006,

“A spectral survey of Orion KL from 487-492 and 542-577 GHz with the Odin satellite. II. Analysis and interpretation.” To be submitted to A&A

See also:

Poster at this meeting (NB! Not fully up-to-date)