FAPESP
The LLAMA Workshop
FAPESP, São Paulo, August 8-9, 2011

LLAMA Workshop

ASTROPHYSICAL MASERS

Which molecules

- Although the number of molecules that present maser emission is very small, they provide extremely large scientific information

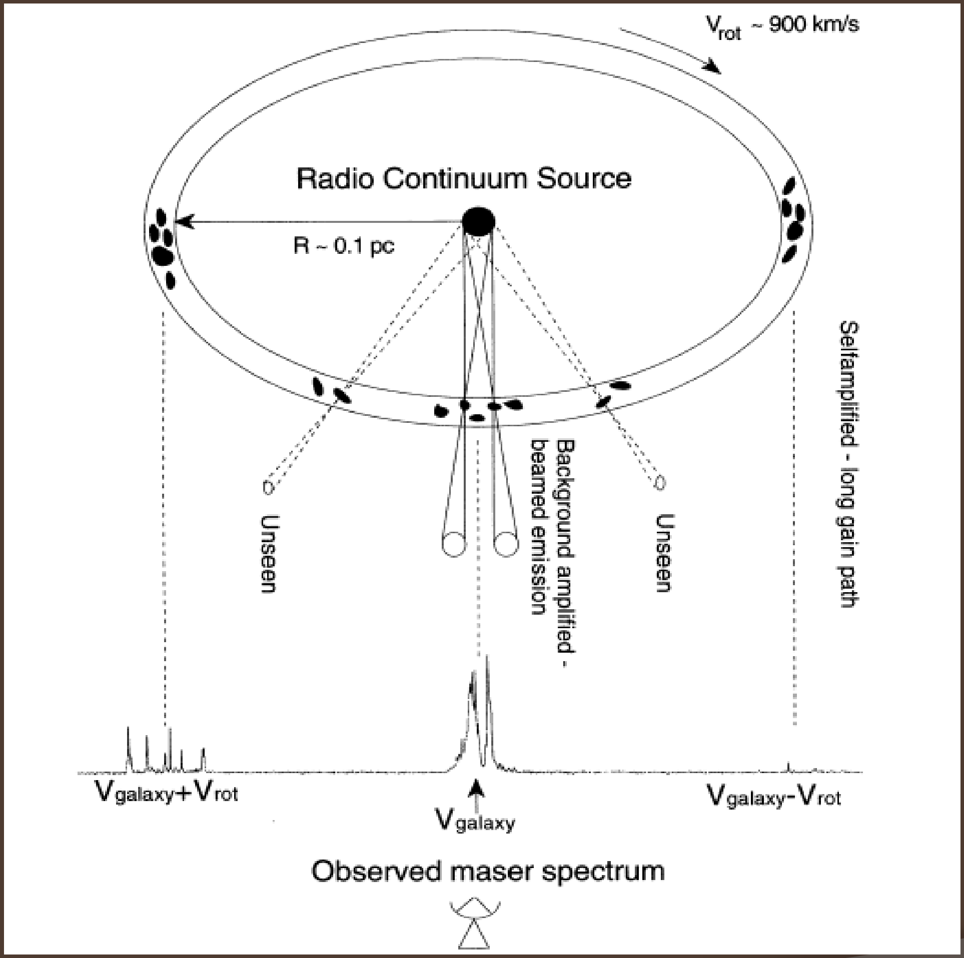
OH	1665 -1667-1720	MHz
H_2O	22.2 - ………….	GHz
SiO	43 – 86	GHz
CH_3OH (Methanol)	6.7 – 12.2 - …….	GHz
NH_3	23	GHz
Recombination lines	> 20	GHz

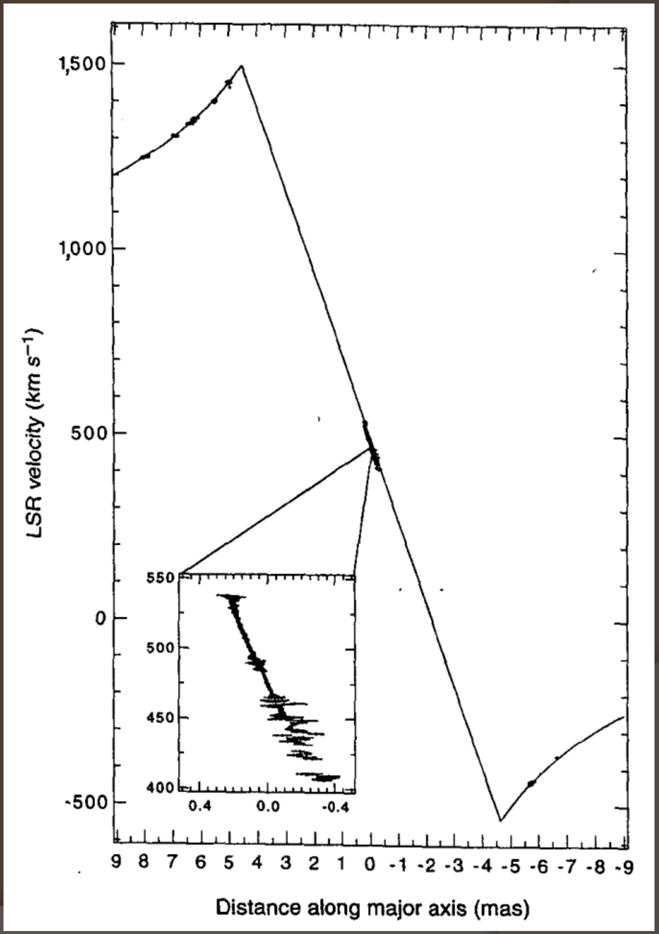
Sizes

- Maser amplification requires velocity coherence along large distances
- For this reason the projected sizes of maser spots are small ($\sim 10^{15}$ cm)
- For the same reason the lines are narrow (< 1 km s^{-1}).
- Maser spots are found in clumps, extending on distances of 10^{17} cm
- The different spots have different velocities, extending for hundreds of km s^{-1}, forming a wide profile.

Sizes

NGC 5248 Mega-maser (Greenhill et al. 1995)
D = 6.4 Mpc





Where to find them

- Star forming regions : OH, H_2O, methanol
- Evolved stars (Asymptotic Giant Branch, Mira variables,……): OH, H_2O, SiO
- Proto-Planetary Nebulae: OH, H_2O
- Supernova remnants

- AGNs: OH, H_2O, methanol (recent in Andromeda)

- UCHII: recombination lines
- Dense cores in molecular clouds: NH_3

How to Observe them

- Single dish
- Interferometry : VLA, ATCA, VLBI

- First scientific work with the Itapetinga radiotelescope in the 70's (except Solar Physics)

- Led to the discovery of water maser sources in star formation regions of the Southern Hemisphere

- Also observations of water maser and SiO sources in the envelopes of giant evolved stars.

- Detection of the first megamaser in NGC4945 (dos Santos & Lépine 1979)

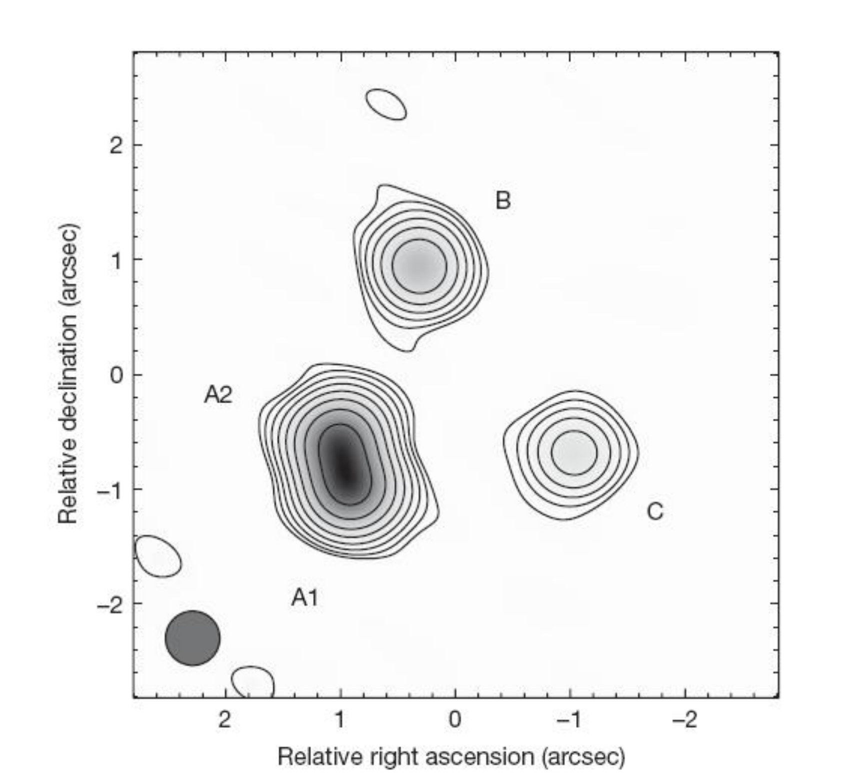
- Discovery of the strongest polarized water source in Orion (Abraham et al. 1981).

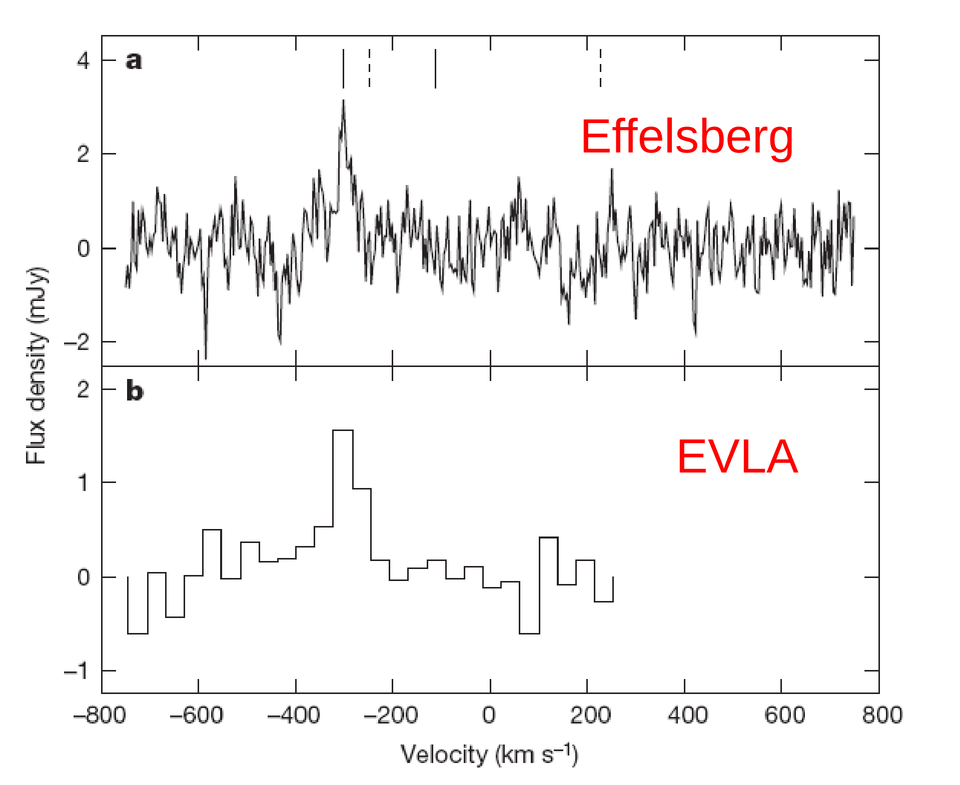
What can we learn from them?

- Star forming regions: existence of YSOs
- Physical conditions for pumping
- Existence of protoplanetary disks
- Magnetic field
- Evolved stars: velocities, paralaxes, proper motions
- Rotation curve, spiral arms
- Megamesers: existence of BH (mass determination)
- Extragalactic distance scale

Highlights: gravitationally lensed water maser at z=2.64

Impellizzeri et al. (2009)



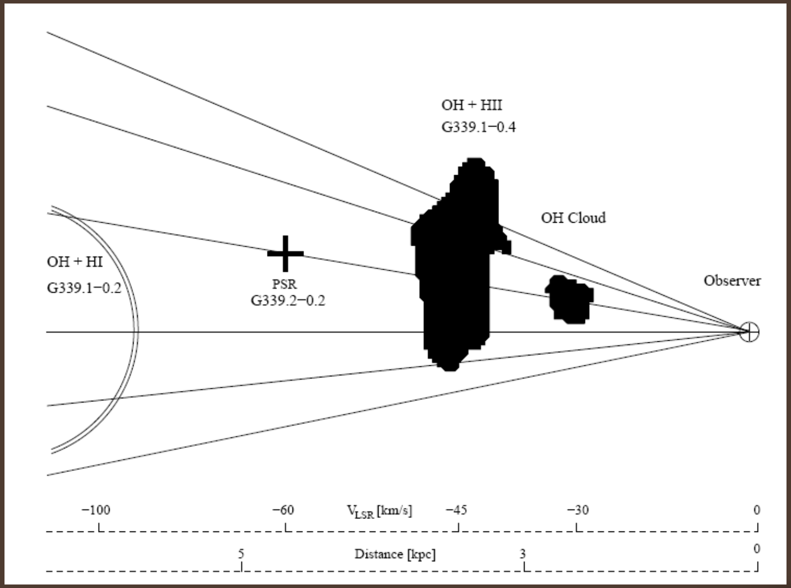


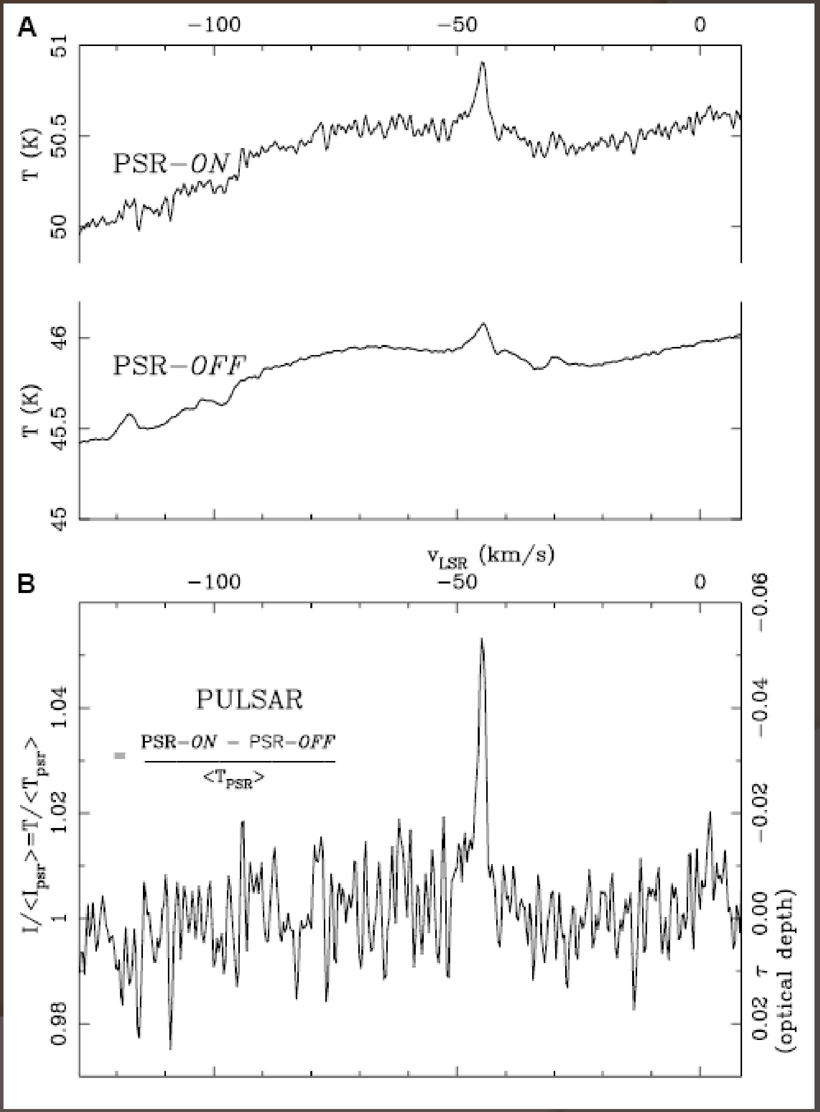
Quasar J0414+0534 lensed by an elliptical galaxy at z=0.958

Highlights: pulsed OH Maser Emission Stimulated by a Pulsar

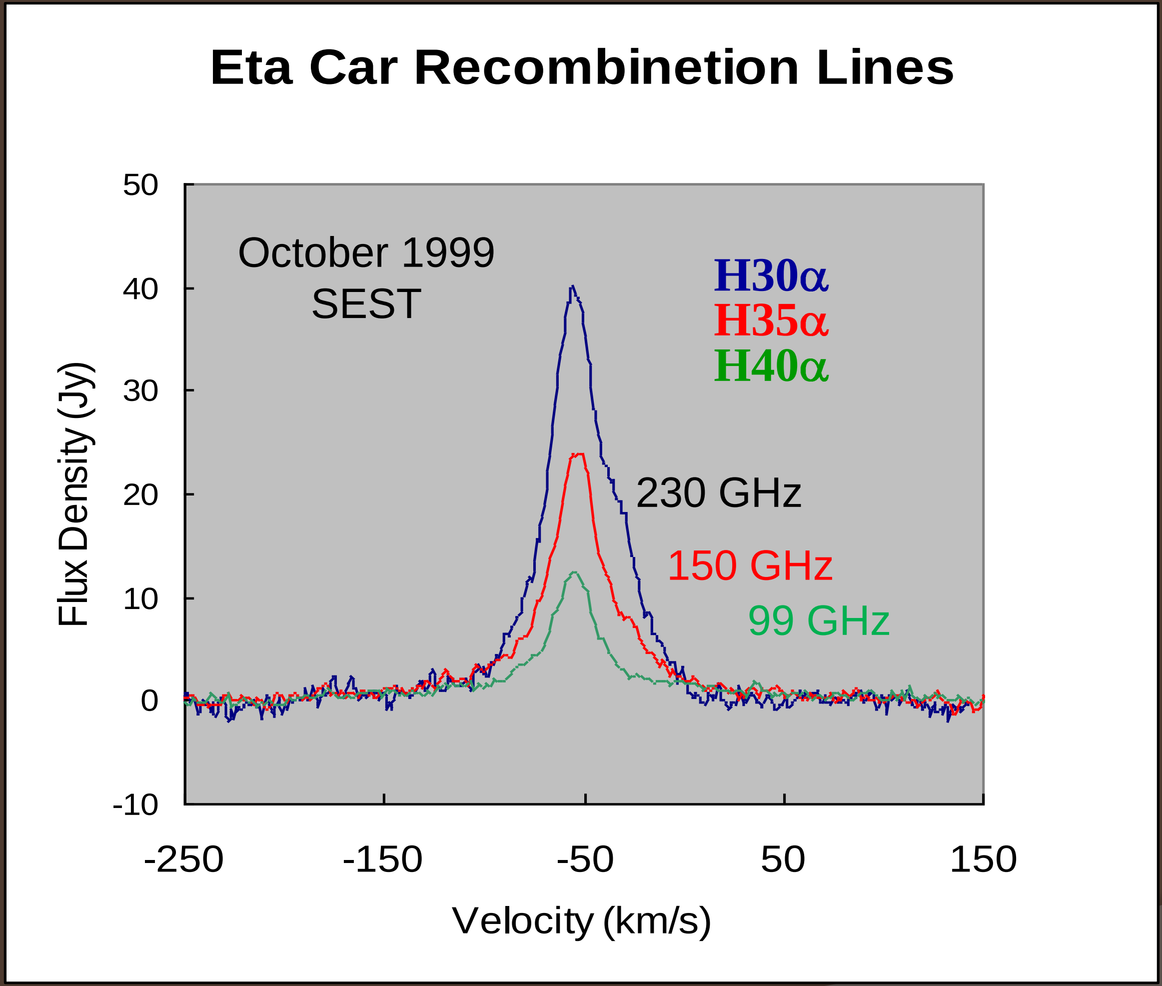
Weisberg et al. (2005)

PSR B1641-45



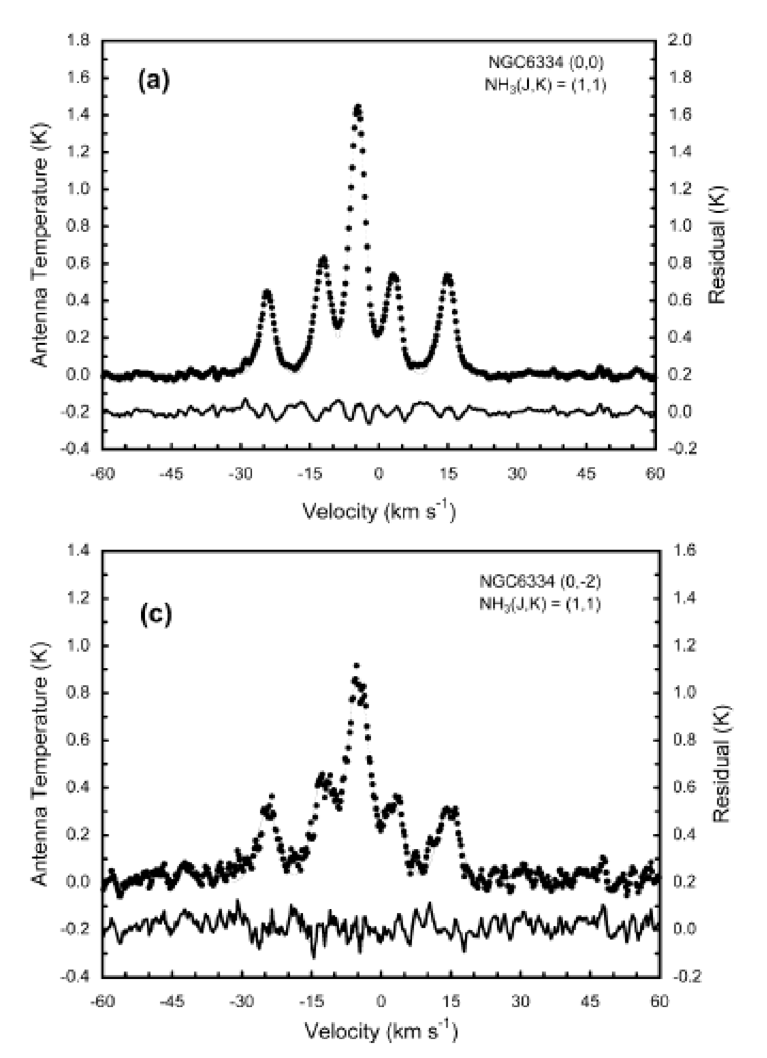


H recombination lines (masers)



Amplification
10-30

NH_3 masers



Caproni, Abraham & Vilas Boas (2000)

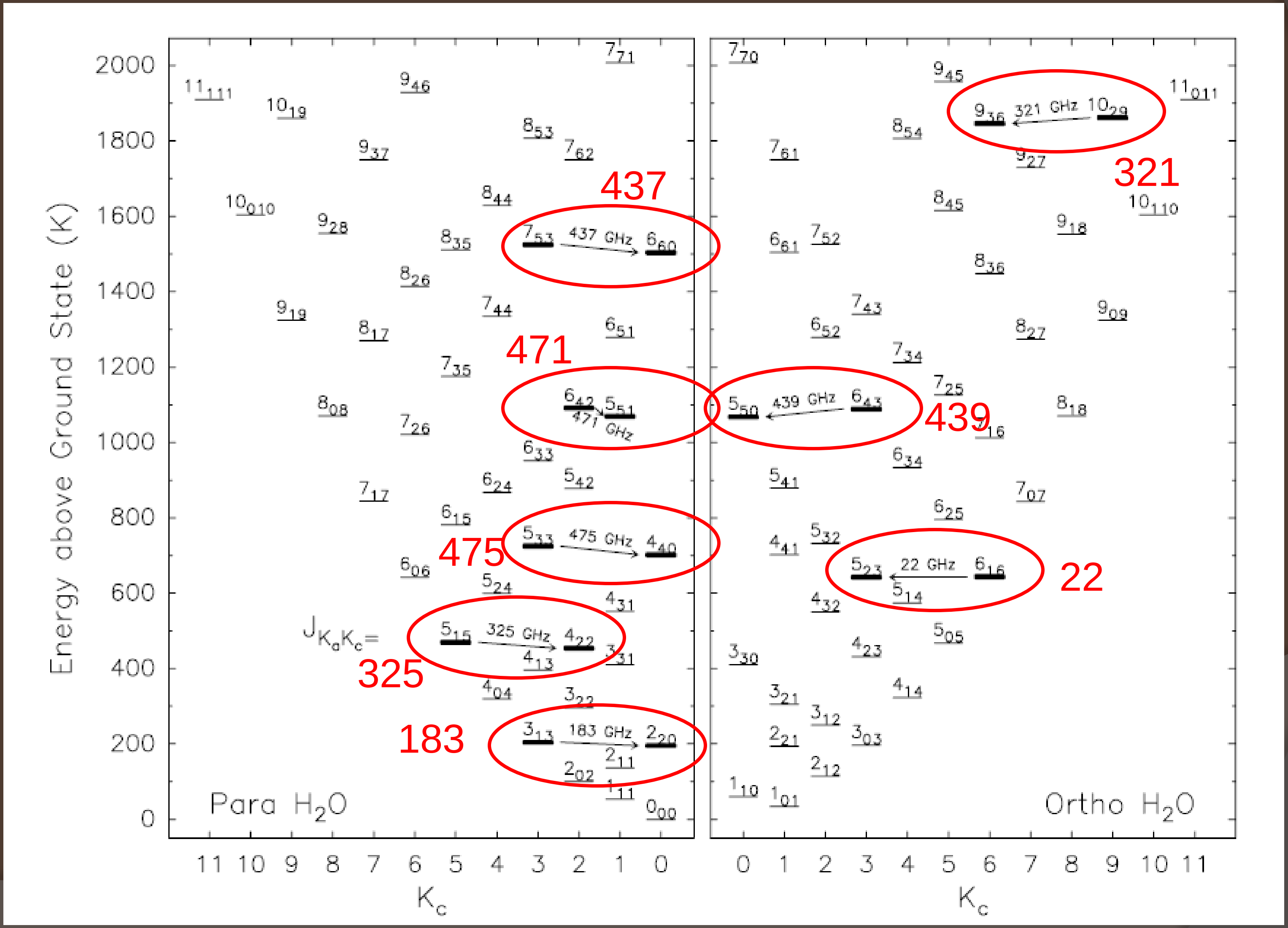
Table 4. The physical parameters for I(N)w and I(N)e regions calculated in non-LTE conditions. The uncertainties are given in parenthesis.

	NGC 6334 I(N)w	NGC 6334 I(N)e
L_{cl} (10^{-3} pc)	6.7(0.8)	7.5(1.7)
M_{cl} ($M_\odot$)	0.21(0.03)	0.24(0.06)
f_{JK}	0.33(0.03)	0.10(0.01)
K_{cl} (10^3)	36(10)	9(4)
ζ_{cl} (10^3 pc^{-3})	$6(2) \leq \zeta_{cl} \leq 33(11)$	0.72(0.36)
t_{coll} (10^5 years)	$4(2) \leq t_{coll} \leq 22(9)$	230(155)
$\bar{n}_{H_2}$ (10^4 cm^{-3})	$1.7(0.6) \leq \bar{n}_{H_2} \leq 9.5(3.4)$	0.23(0.13)
X_{NH_3} (10^{-9})	6.2(2.3)	7.2(3.0)
M_{tot} ($10^3 M_\odot$)[a]	7.6(2.3)	2.1(1.2)
M_{vir} ($10^3 M_\odot$)[b]	0.67(0.06)	0.15(0.02)

[a] Total mass of whole clumps which are contained in the telescope beam.
[b] Mass obtained from the Virial Theorem.

Observing with LLAMA

Menten et al. (2008)



Possible frequencies for LLAMA

The 10 Frequency Bands of the ALMA antennas

ALMA Band	Frequency Range (GHz)	Receiver Noise (K) over 80% of the RF band	Temperature (K) at any RF Frequency	To be produced by	Receiver Technology
1	31 - 45	17	26	tbd	HEMT
2	67 - 90	30	47	tbd	HEMT
3	84 - 116	37	60	HIA	SIS
4	125 - 163	51	82	NAOJ	SIS
5*	162 - 211	65	105	OSO	SIS
6	211 - 275	83	136	NRAO	SIS
7	275 - 373	147	219	IRAM	SIS
8	385 - 500	196	292	NAOJ	SIS
9	602 - 720	175	261	NOVA	SIS
10	787 - 950	230	344	NAOJ	SIS

tbd: to be decided
IRAM: Institut de Radio Astronomie Millimétrique (Grenoble, France)
HIA: Herzberg Institute of Astrophysics (Victoria, Canada)
NAOJ: National Astronomical Observatory of Japan (Mitaka, Japan)
NOVA: Nederlandse Onderzoekschool voor Astronomie (Groningen, the Netherlands)
NRAO: National Radio Astronomy Observatory (Charlottesville, USA)
OSO: Onsala Space Observatory/Chalmers University (Onsala, Sweden)
* EU FP6 receivers from Onsala