First VLBA observations of ^{28}SiO J=1-0, v=3 maser emission from AGB stars

Jean-François DESMURS

(OAN-Spain)

&

J.Alcolea, V.Bujarrabal, R.Soria - OAN

M.Lindqvist, P.Bergman - Onsala Space Observatory

OUTLINE of the talk

I. Why observing SiO J=1-0, v=3 maser??

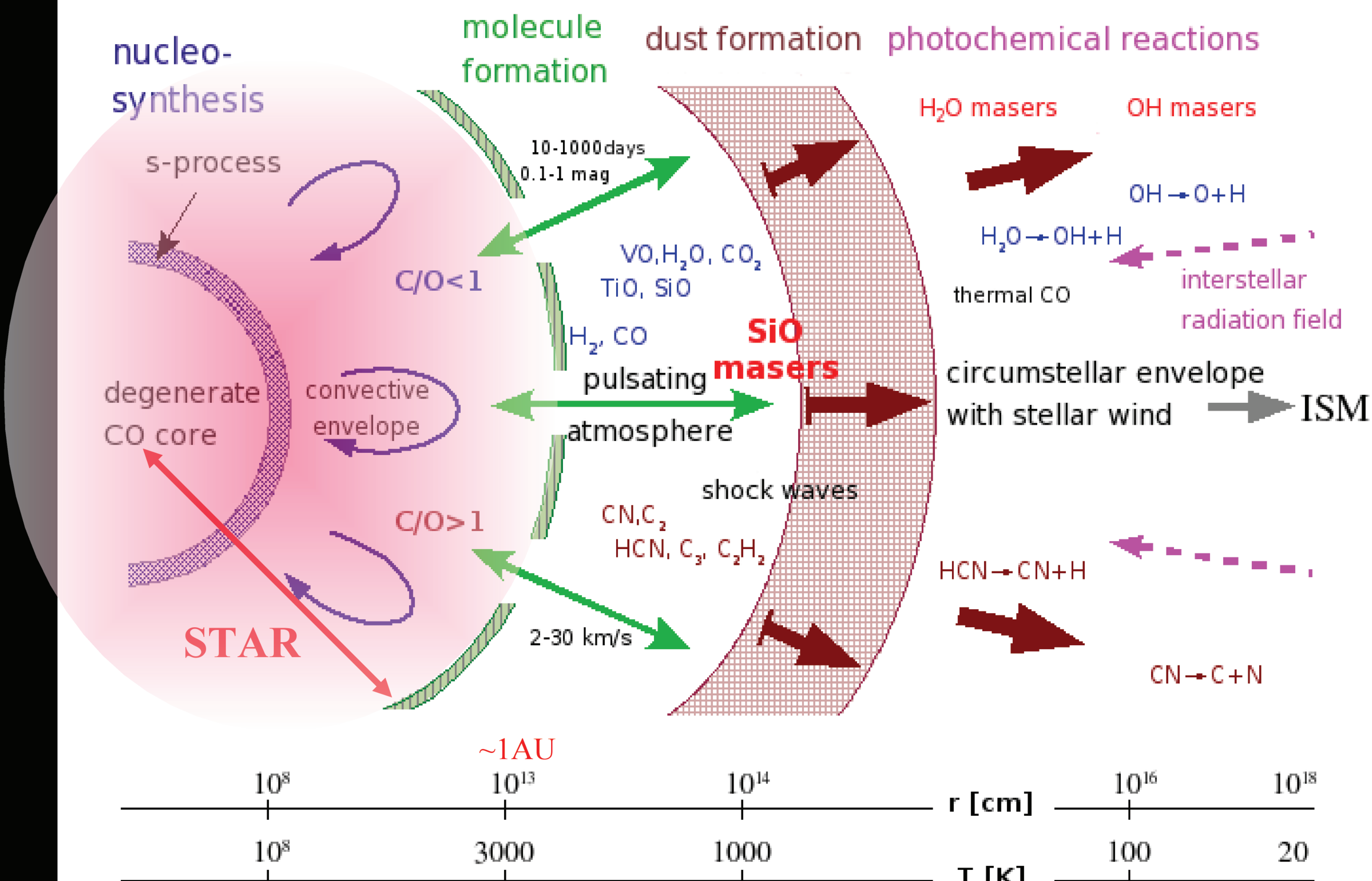
II. Single dish Observations: Onsala-20m

III. VLBA Observations

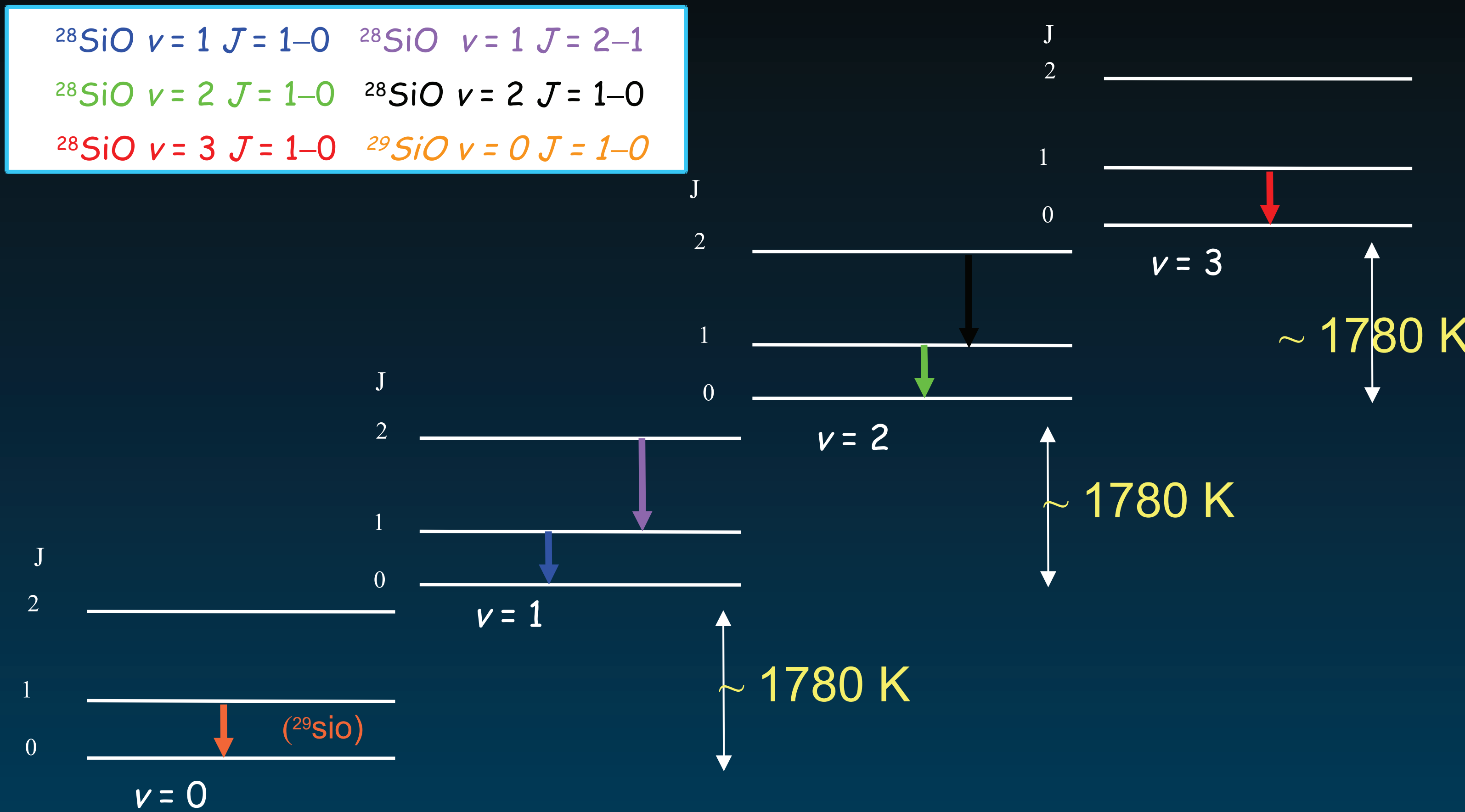
R Leo, TX Cam, U Her, IK Tau

VI. Conclusions

Schematic view of an AGB star

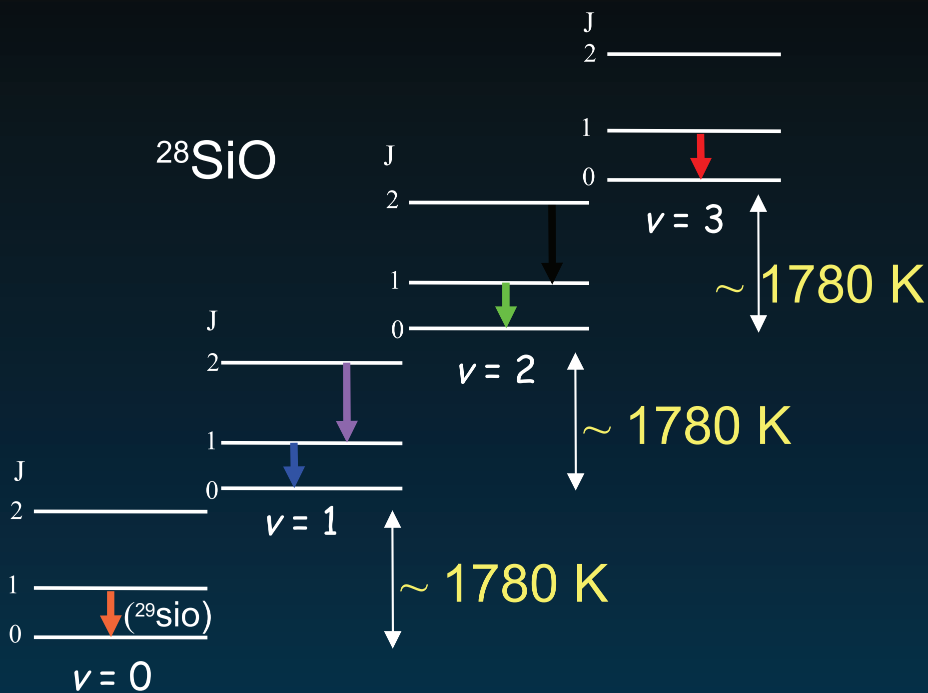


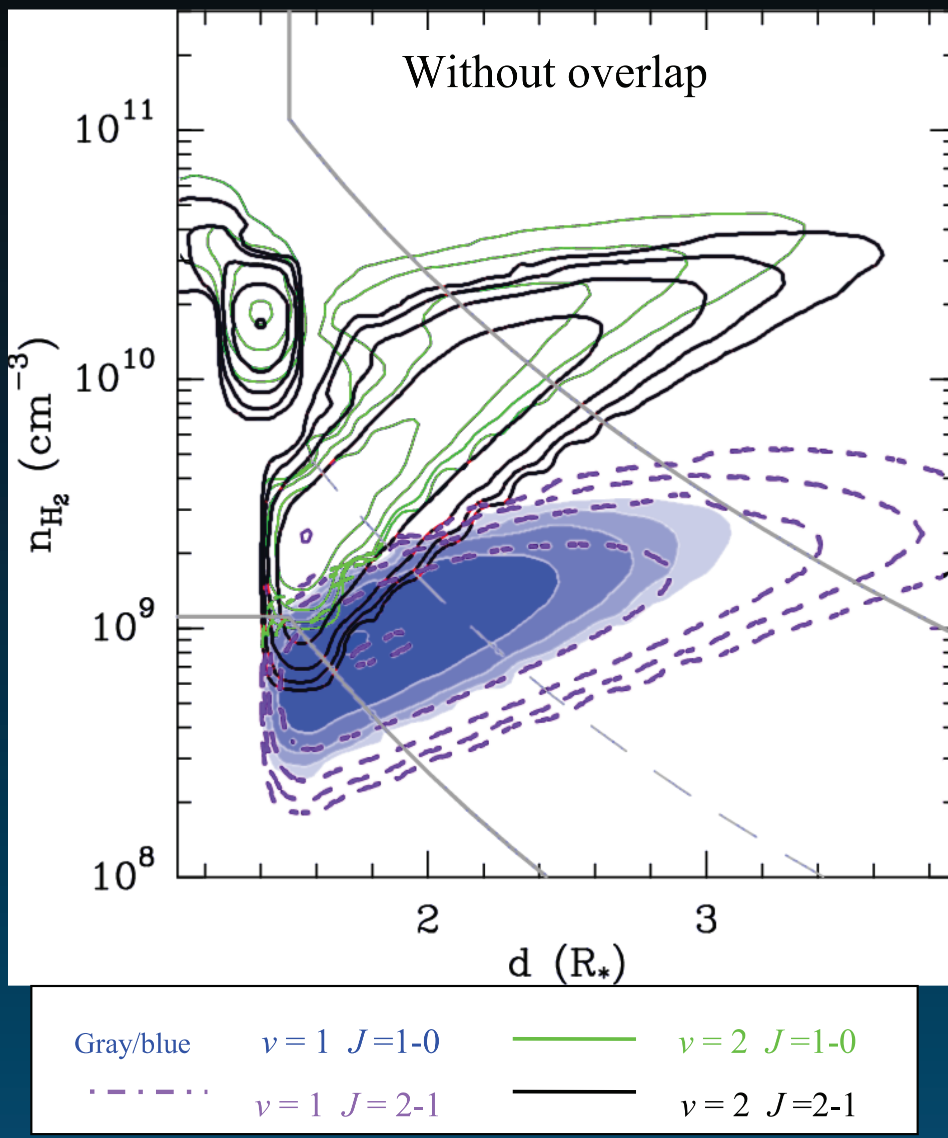
^{28}SiO Energy diagram :



BUT J=2-1 and J=1-0 require practically the same excitation conditions (separated by only few K!!)

^{28}SiO Energy diagram :





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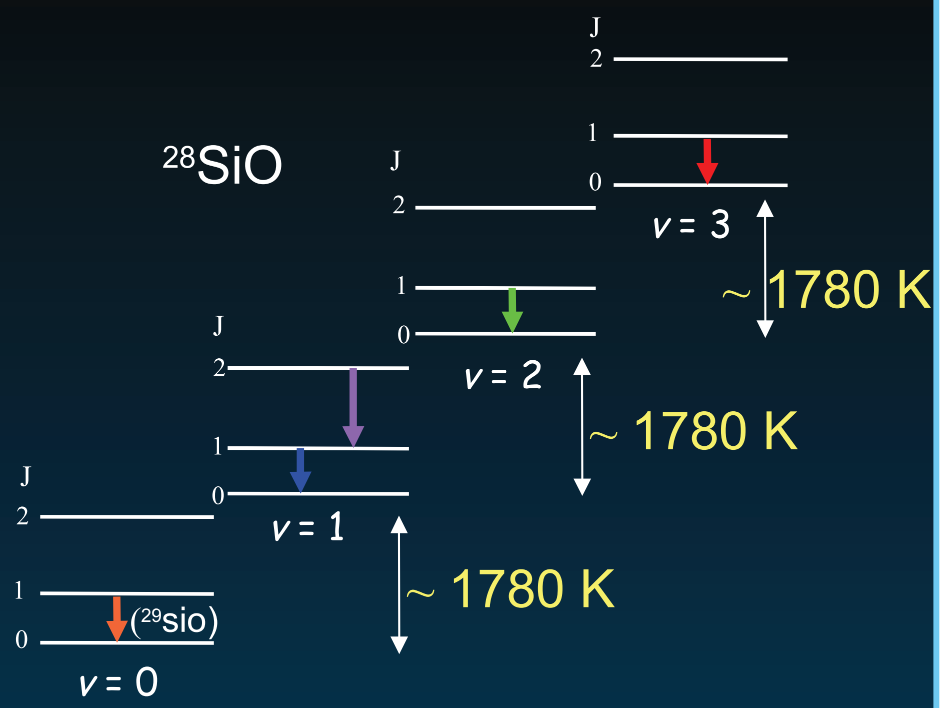
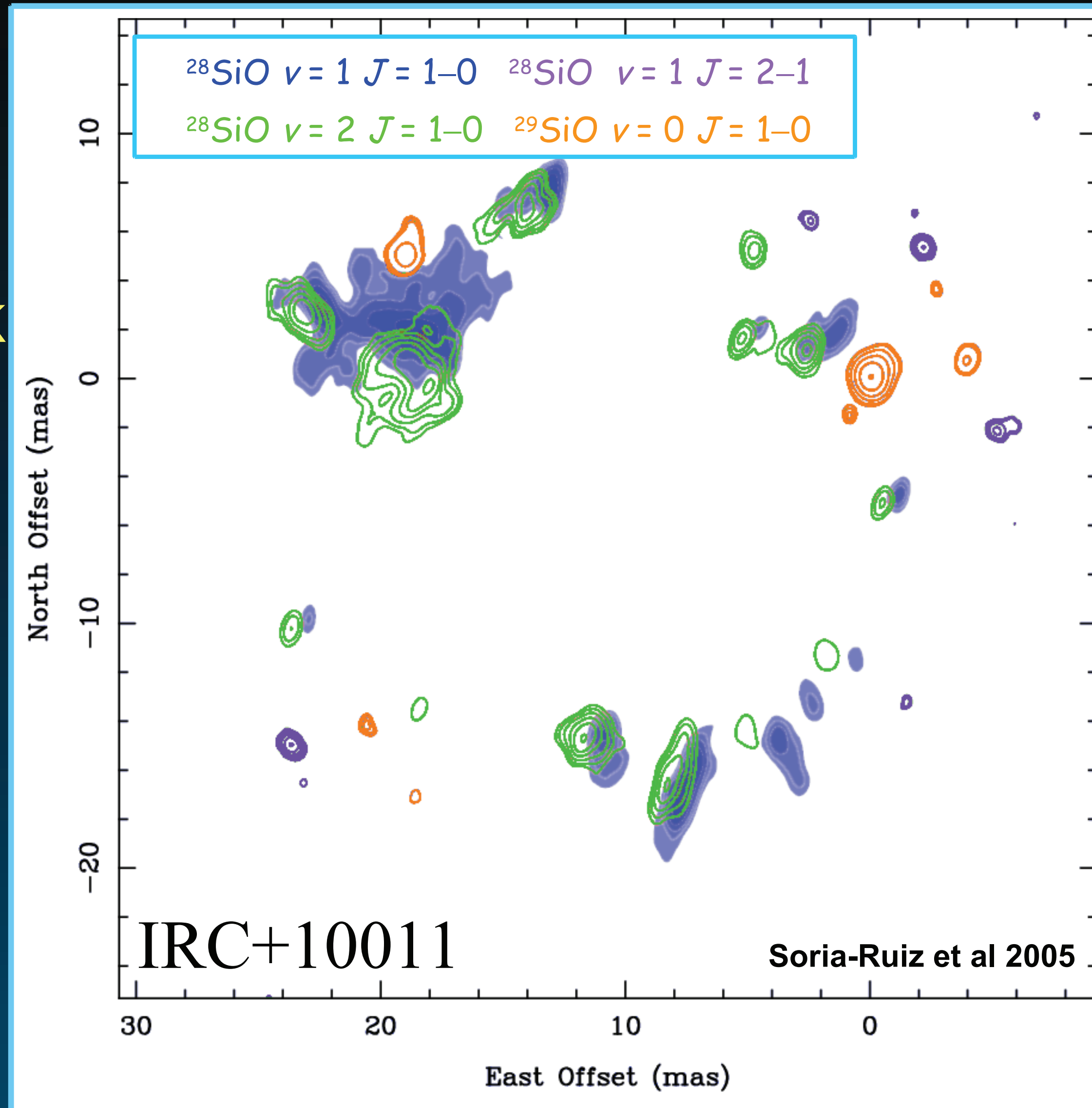




- Spatial distribution completely different for both ro-vibrational transition.

- Very weak SiO v=2 J=2-1 transition in O-type AGBs

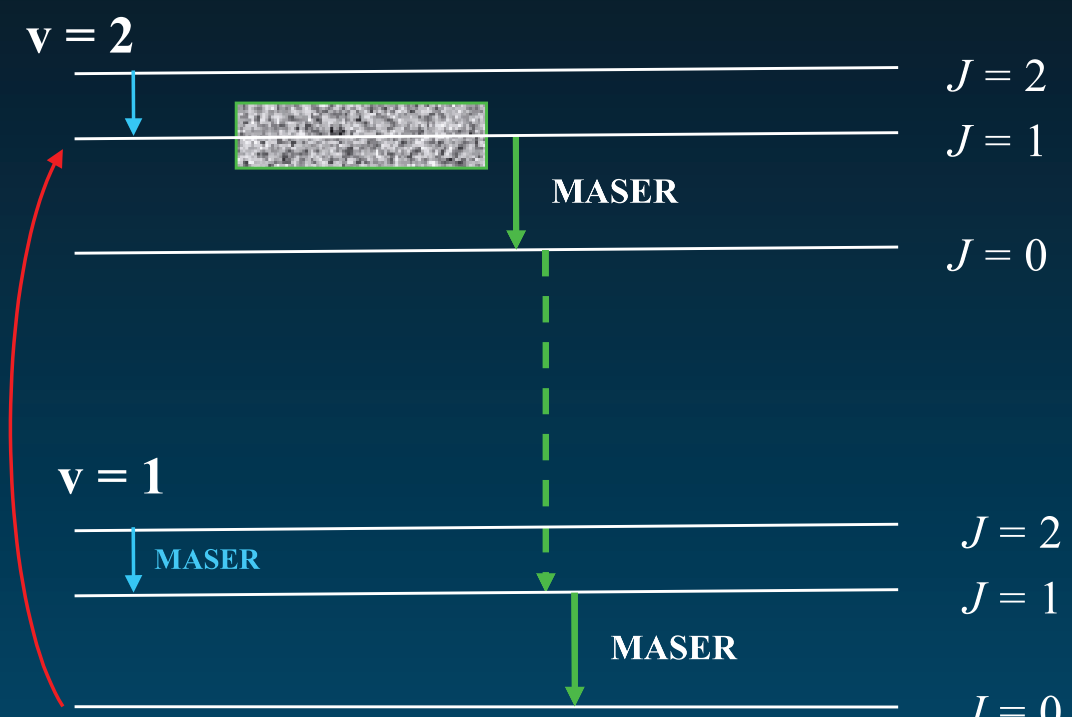
Soria-Ruiz et al. 2005: Contradiction with all the pumping mechanisms of the SiO masers! → Lines overlapping SiO / H2O

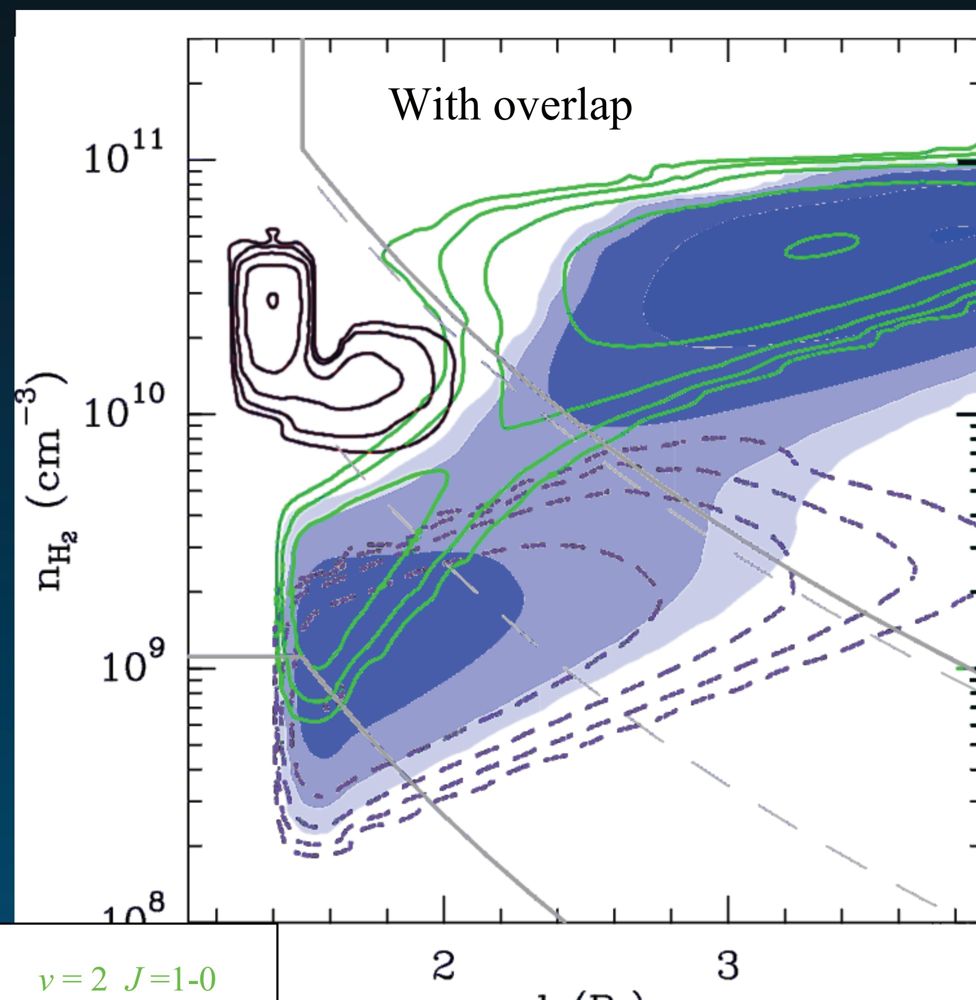
Lines overlap with H_2O line in O type stars ([C]/[O]<1)

Mechanism suggested to explain

- The quenching of the maser $v = 2\ \ J = 2{-}1$(Olofsson et al. 1981)
- The $v = 1\ \ J = 2{-}1$ distribution (Soria et al. 2005)

$$H_2O\text{: } \nu_2 = 0\ \ 12_{75} \rightarrow \nu_2 = 1\ \ 11_{66} \quad \& \quad \text{SiO: } v = 1\ J = 0 \rightarrow v = 2\ J = 1$$





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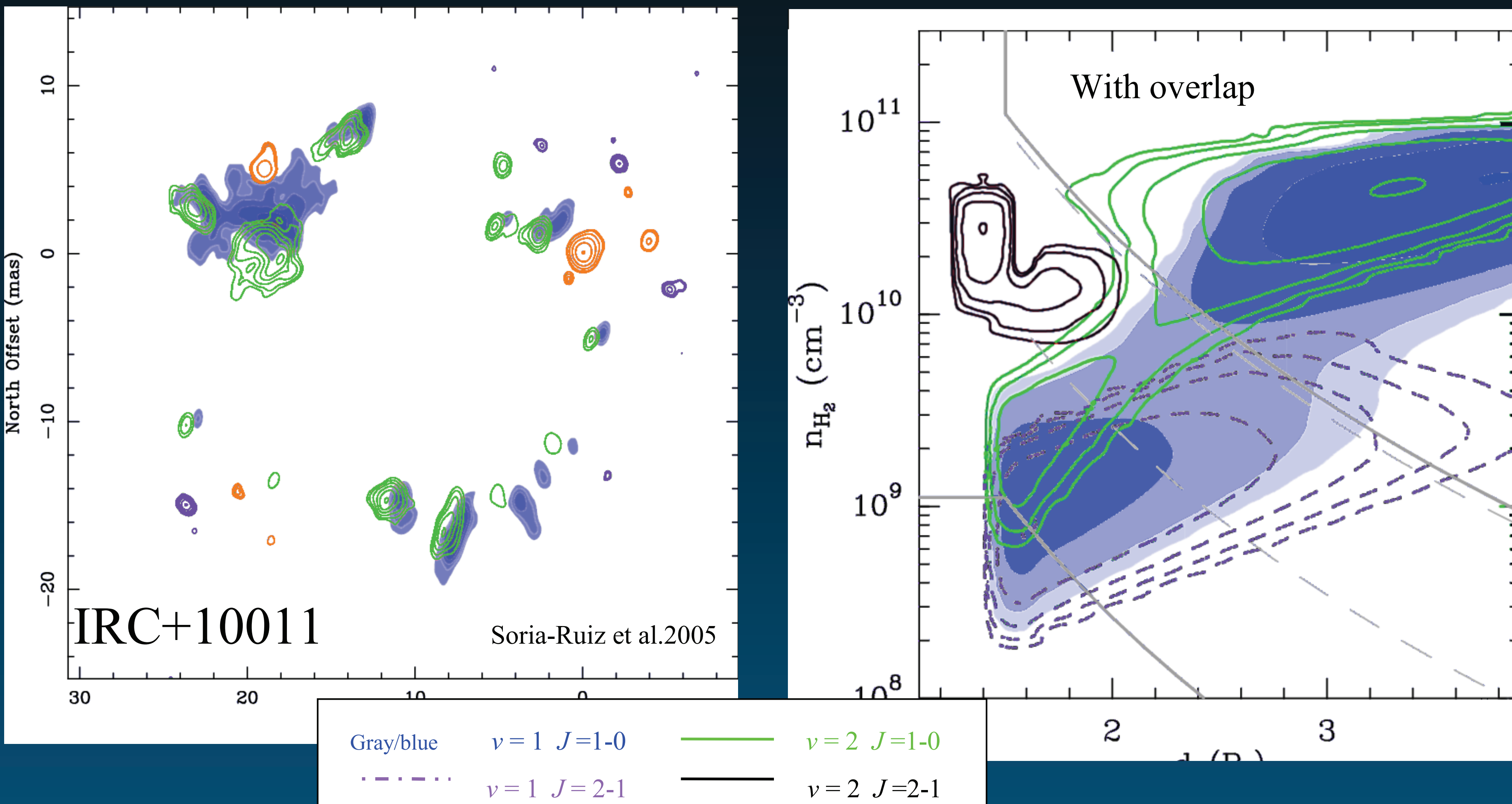
- the quenching of the maser $v = 2$ $J = 2\!-\!1$ (Olofsson et al. 1981) and
- The $v = 1$ $J = 2\!-\!1$ distribution (Soria et al. 2005)

$$H_2O\text{: } \nu_2 = 0 \;\; 12_{75} \rightarrow \nu_2 = 1 \;\; 11_{66} \quad \& \quad \text{SiO: } v = 1\; J = 0 \rightarrow v = 2\; J = 1$$



Why Observing SiO J=1-0, v=3??

To test models: v=3 is **not** directly affected by IR lines overlapping

► Must appear in inner ring (higher energy level, ~1800°K)

► Spatial distribution should be different compare to the J=1-0, v=1 & 2 and of course to the J=2-1, v=1

But SiO J=1-0, v=3 is very variable!!

Onsala-20m Monitoring Observations

Monitoring of a list of 19 sources

Source	RA(J2000)	Dec(J2000)	V_{LSR}
Y Cas	00:03:21.300	+55:40:50.00	-18.0
IRC+10011	01:06:25.980	+12:35:53.00	+11.0
W And	02:17:32.961	+44:18:17.77	-38.0
o Cet	02:19:20.793	-02:58:39.51	+45.0
IK Tau	03:53:28.840	+11:24:22.60	+34.0
U Ori	05:55:49.169	+20:10:30.69	-36.0
TX Cam	05:00:50.390	+56:10:52.60	+09.0
V Cam	06:02:32.297	+74:30:27.10	+08.0
R Cnc	08:16:33.828	+11:43:34.46	+17.0
R Leo	09:47:33.490	+11:25:43.65	-01.0
R LMi	09:45:34.283	+34:30:42.78	+02.0
RU Her	16:10:14.515	+25:04:14.34	-10.0
U Her	16:25:47.471	+18:53:32.87	-16.0
R Aql	19:06:22.252	+08:13:48.01	+46.0
GY Aql	19:50:06.336	-07:36:52.45	+33.0
χ Cyg	19:50:33.922	+32:54:50.61	+12.0
RR Aql	19:57:36.060	-01:53:11.33	+30.0
μ Cep	21:43:30.461	+58:46:48.17	+24.0
R Cas	23:58:24.873	+51:23:19.70	+25.0

Table 1. List of sources monitored using the Onsala 20 m Telescope.

We selected 4 good candidates:

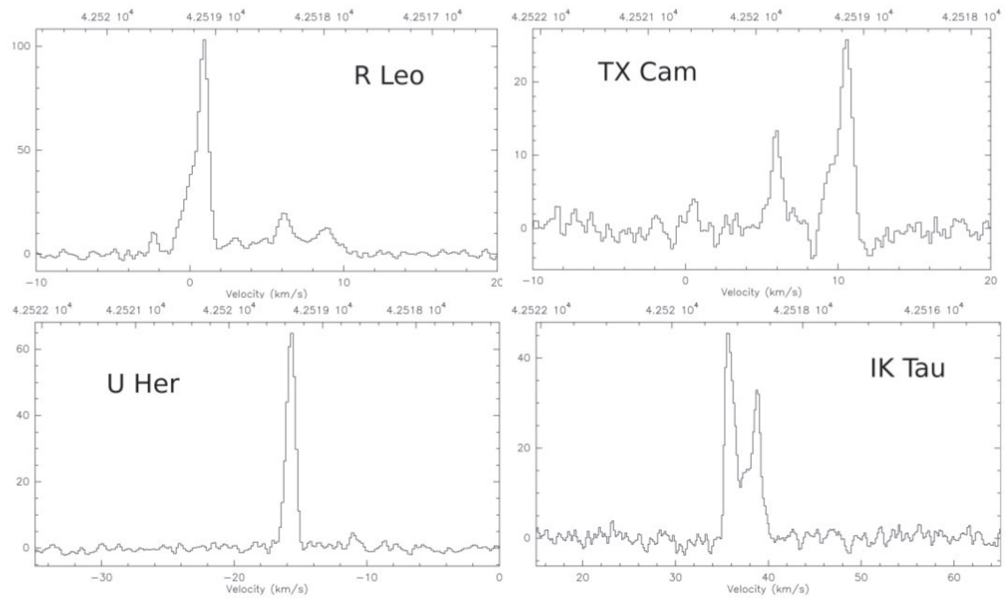


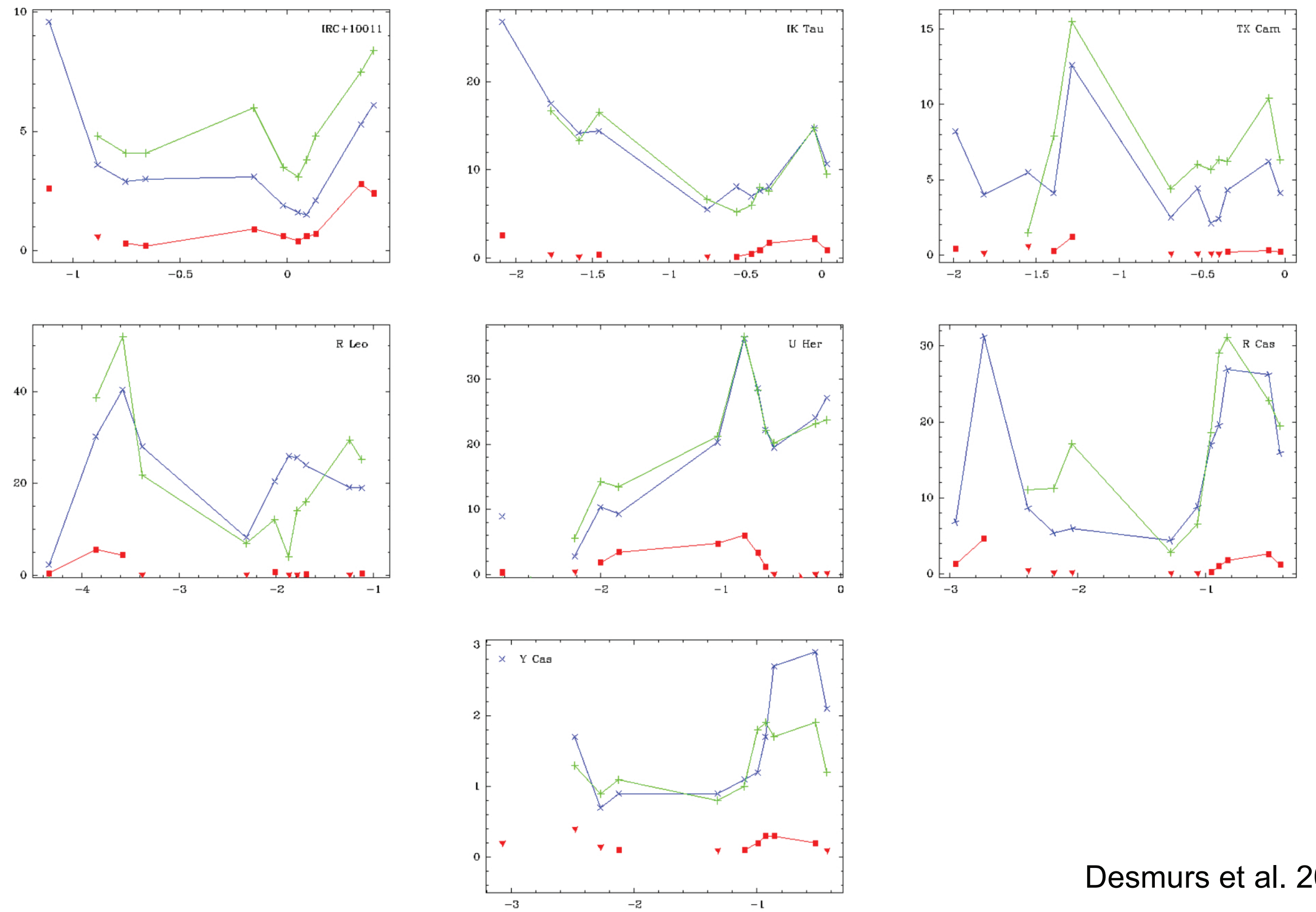
Fig. 1. Single-dish spectra of the SiO J=1−0 v=3 maser emission from the AGB stars, R Leo (November, 2009), TX Cam (January, 2010), U Her (April, 2011), and IK Tau (October, 2011). The intensity scale is in Jy.

Desmurs et al. 2014

Flux Variation intensity with time

v=3,J=1-0 flux variation is similar as the other two lines

J.-F. Desmurs et al.: SiO masers from AGB stars in the vibrationally excited *v*=1, *v*=2, and *v*=3 states



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v=1 J=1-0
v=2 J=1-0
v=3 J=1-0

Fig. 2. Flux variation intensity (in Jy) with time (phase of the variability cycle of the source) from our monitoring with the Onsala telescope, of *v*=1, *v*=2, *v*=3 (respectively blue cross, green plus and red square, triangles denote upper limits detection) for the sources detected more often than in two epochs in *v*=3 *J*=1–0. See observing dates in Table 3.

VLBA Observations

We use a least 6 antennas (and up to 10) in 2009-2011.

Quasi-simultaneous observations of ^{28}SiO J=1-0:

- v=1 ---> 43.122 GHz
- v=2 ---> 42.820 GHz
- v=3 ---> 42.519 GHz

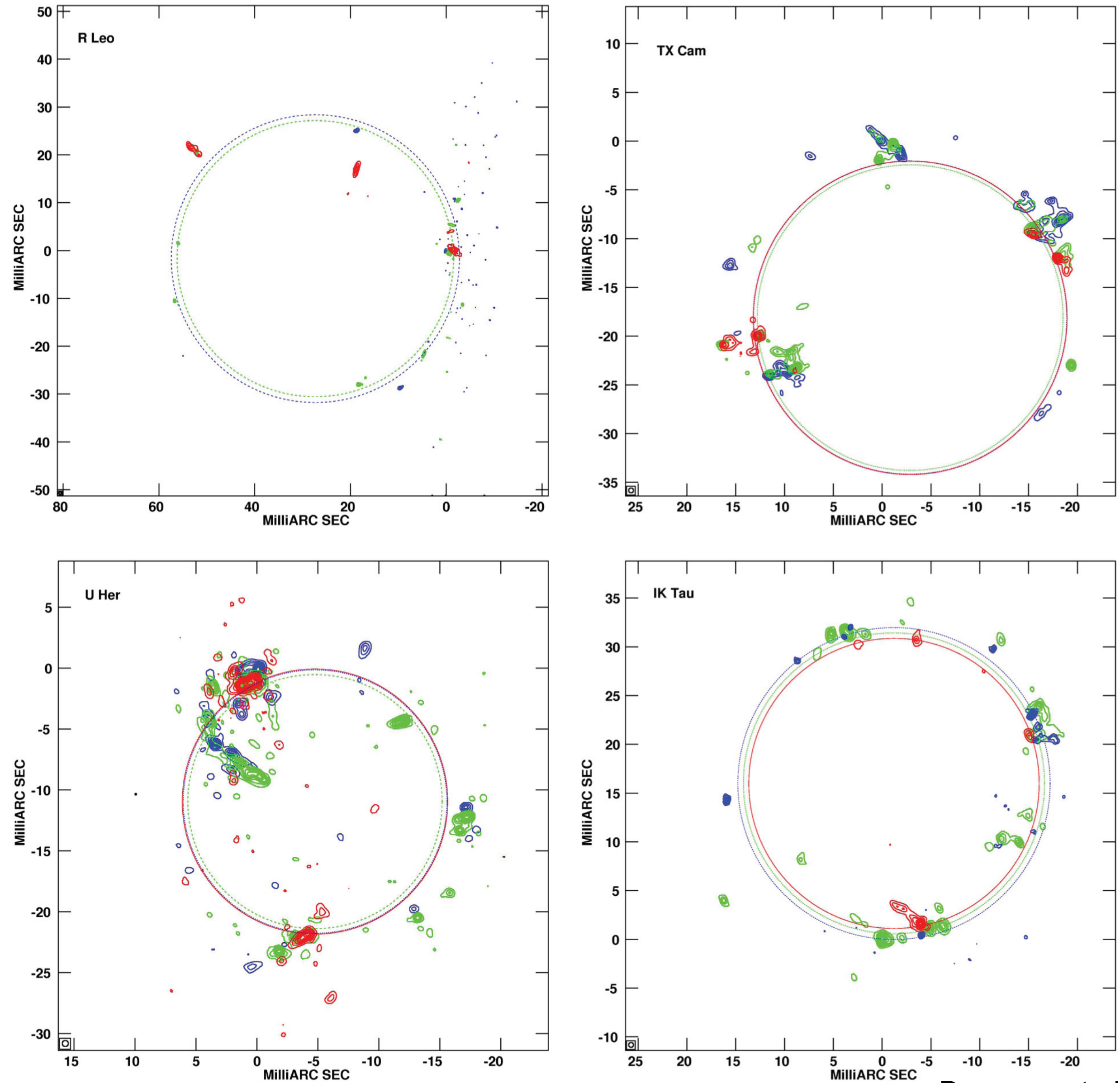
<u>No absolute position</u>!!

Maps:

- → Resolution Beam: 0.5x0.5 mas (natural beam)
- → Pixel size: 0.1 mas
- → Map size: ~100x100 mas
- → Frequency resolution ~0.2 km/s
- → rms per channel ~ 5 mJy/beam

Very similar distribution for SiO J=1-0, v=1, v=2 and v=3 !

J.-F. Desmurs et al.: SiO masers from AGB stars in the vibrationally excited v=1, v=2, and v=3 states



v=1 J=1-0
v=2 J=1-0
v=3 J=1-0

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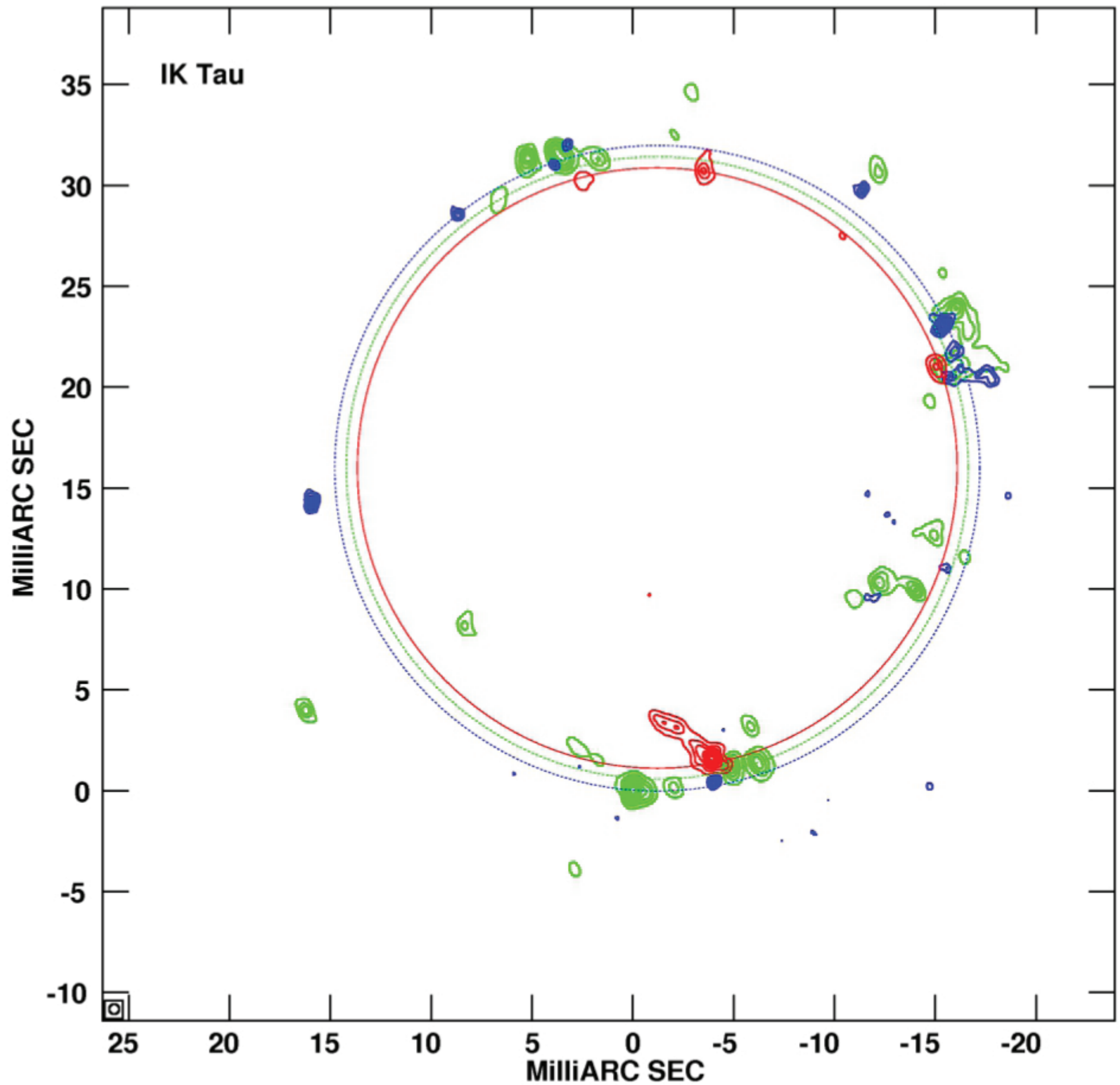
Fig. 3. VLBA maps of SiO J=1–0 v=1 (in blue), v=2 (in green), and v=3 (in red) maser emissions from R Leo (upper left, November 13, 2009), TX Cam (upper right, January 31, 2010), U Her (lower left, April 17, 2011), and IK Tau (lower right, November 04, 2011). To ease the comparison between the three maser lines, using the same color code, we plotted the fitting rings obtained with ODRpack for each maser transition (see Table 2).

Very similar distribution for SiO J=1-0, v=1, v=2 and v=3 !

And in IK Tau, v=3 clearly show up in a slightly inner ring!



v=1 J=1-0
v=2 J=1-0
v=3 J=1-0

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How line overlap affect v=3 with respect to v=1&2?

→ v=3 is not affected!

But v=1 & 2 are displaced to higher density

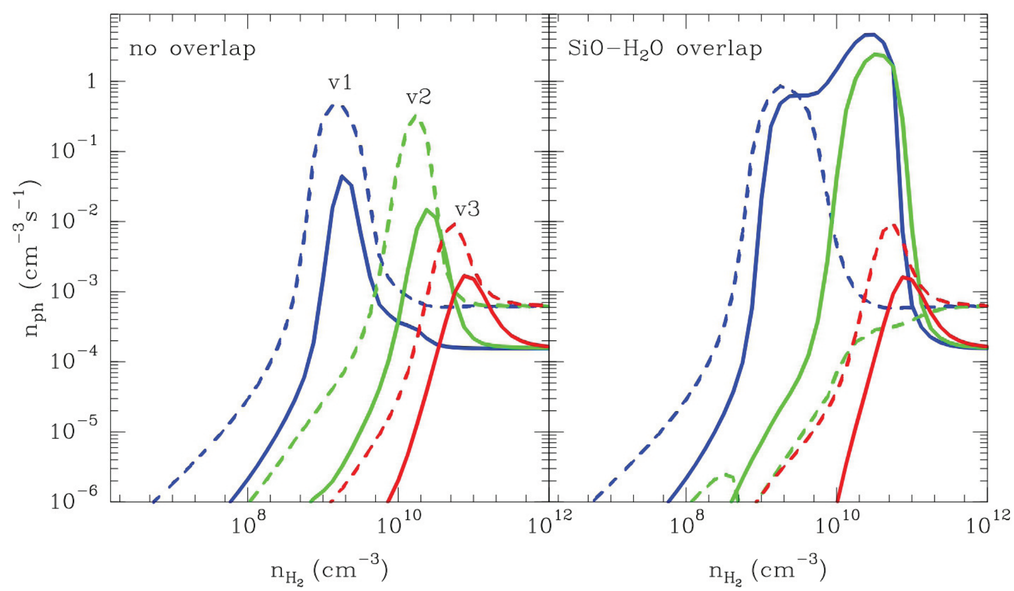

Fig. 4. Effects of the SiO-H_2O line overlap on the excitation of the SiO maser emission for the three first vibrationally excited levels, v=1, v=2, v=3 (blue, green and red respectively) J=1−0 (solid lines) and J=2−1 (dashed lines). The number of emitted photons (s^{-1} cm^{-3}) in the maser transitions as a function of H_2 density is shown. Left panel: model calculations that do not include the effects of the line overlap. Right panel: model results including the line overlap.

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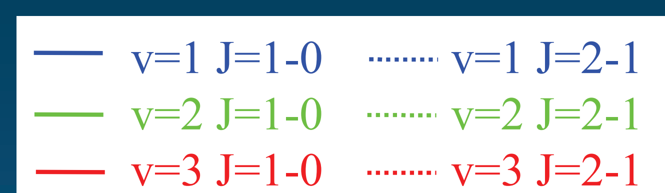

Conclusions

For our 4 sources, v=1, v=2 & v=3, J=1-0 present very similar spatial brightness distributions.

v=3 shows ring-like pattern and is coincident or slightly inner than those of v=1 & v=2, J=1-0

→ Despite our initial expectation, this is compatible with present models predictions <u>including lines overlapping</u>!!

Thank You