Simultaneous VLBA polarimetric observations of the v={1,2} J=1-0 and v=1, J=2-1 SiO maser emission towards VY CMa: maser morphology and pumping

L. Richter, A. Kemball and J. Jones
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Observations and data reduction

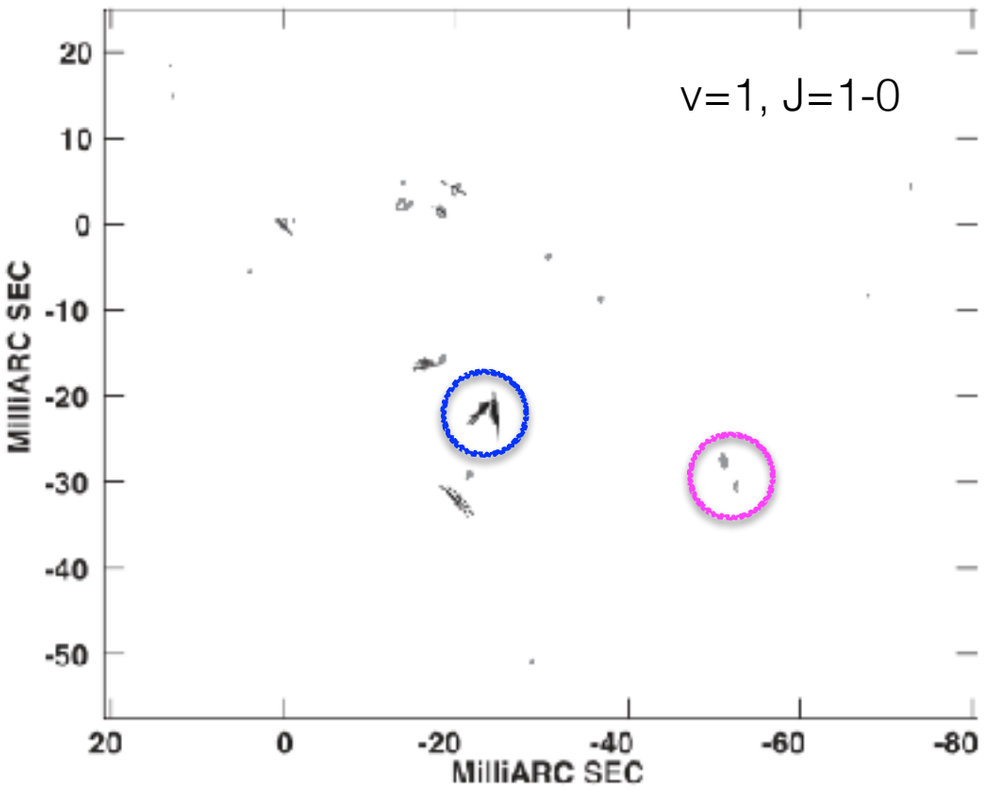
2003-12-20 and 23: Epoch 1
2007-3-5 and 19: Epoch 2

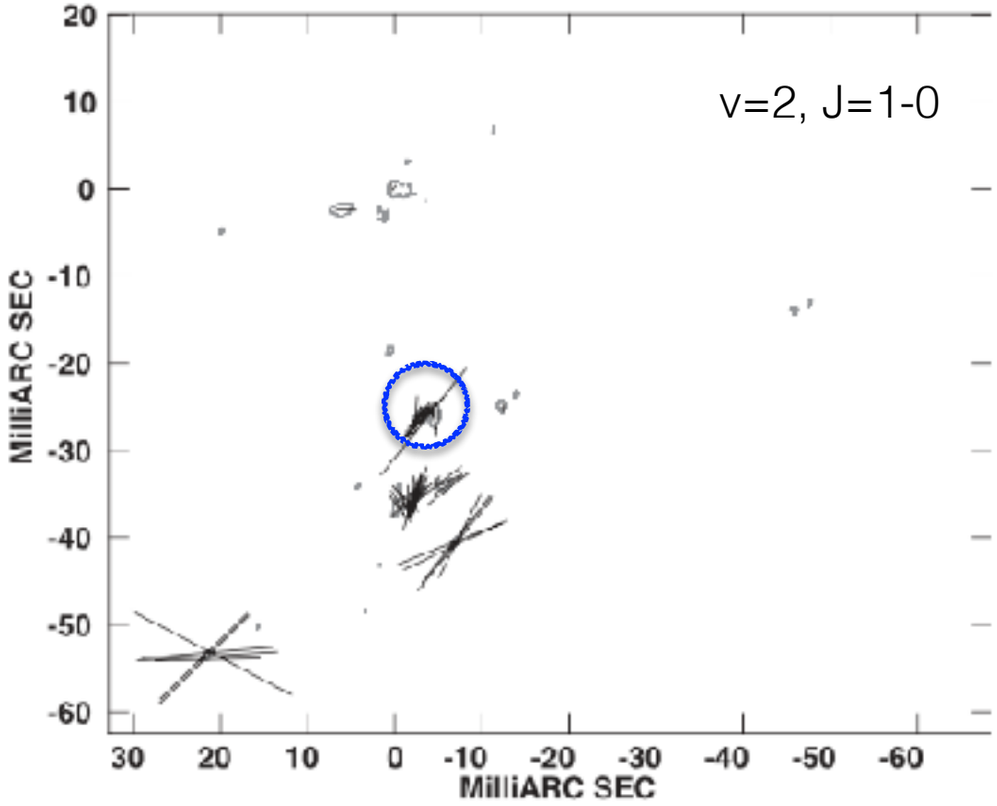
How to align the SiO maser maps of different transitions
Phase self-calibration: absolute astrometric information lost
Cross-correlation method: uncertainty of map alignment in each epoch < 0.05 mas

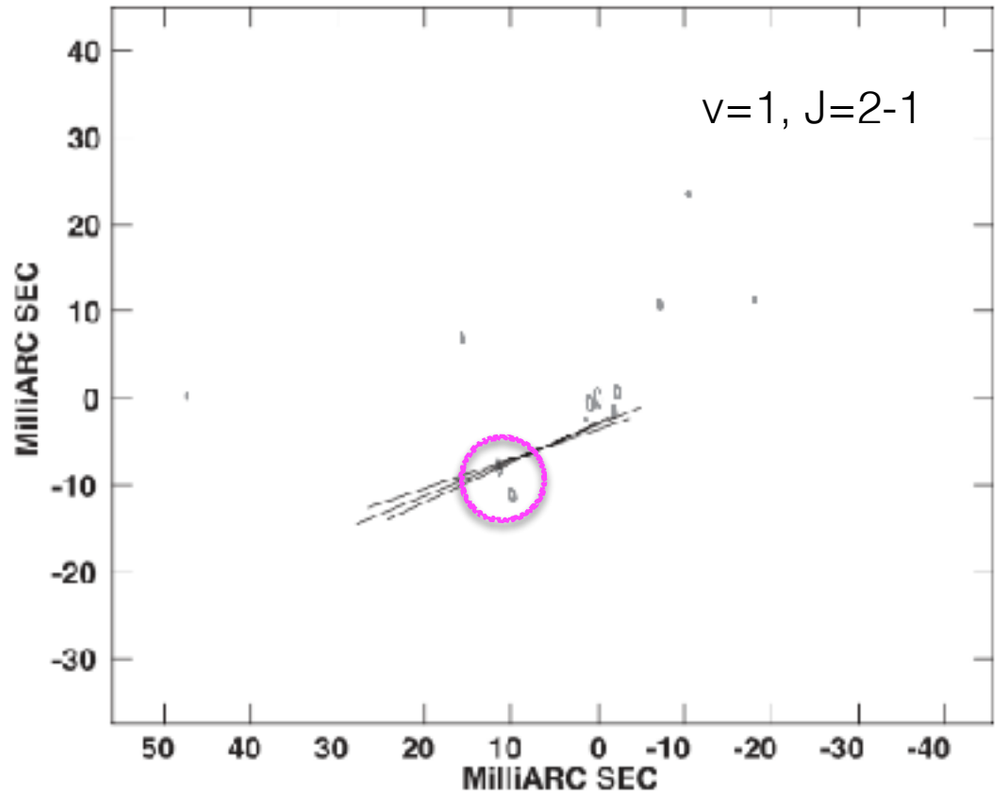
Epoch 2: Overlaid transition maps were restored with the same v=1 J=1-0 beam size. -> aids component-level interpretation

Epoch 1: Overlaid transition map was restored with the intrinsic beam size of each deconvolve map.

Results and discussion

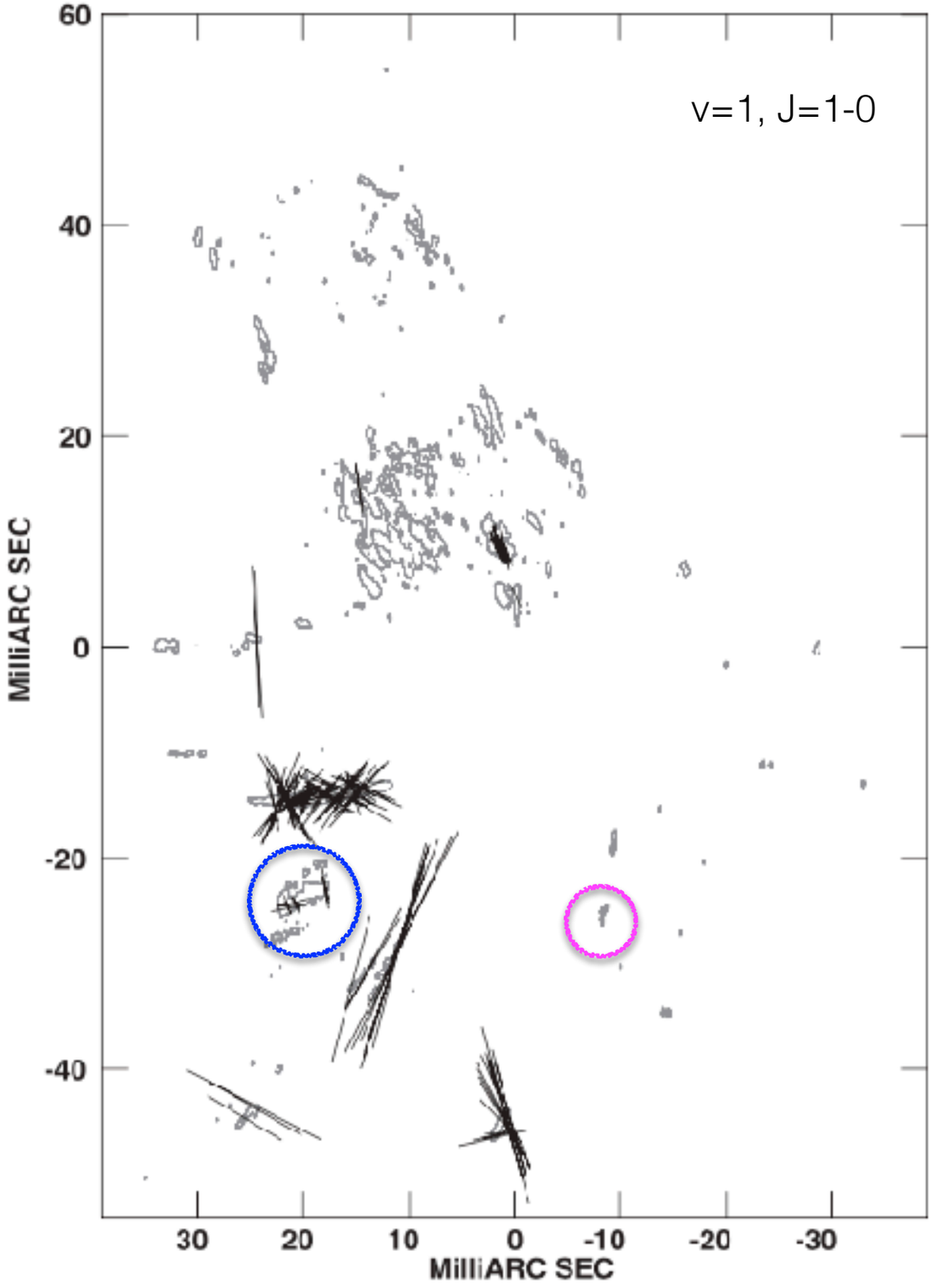


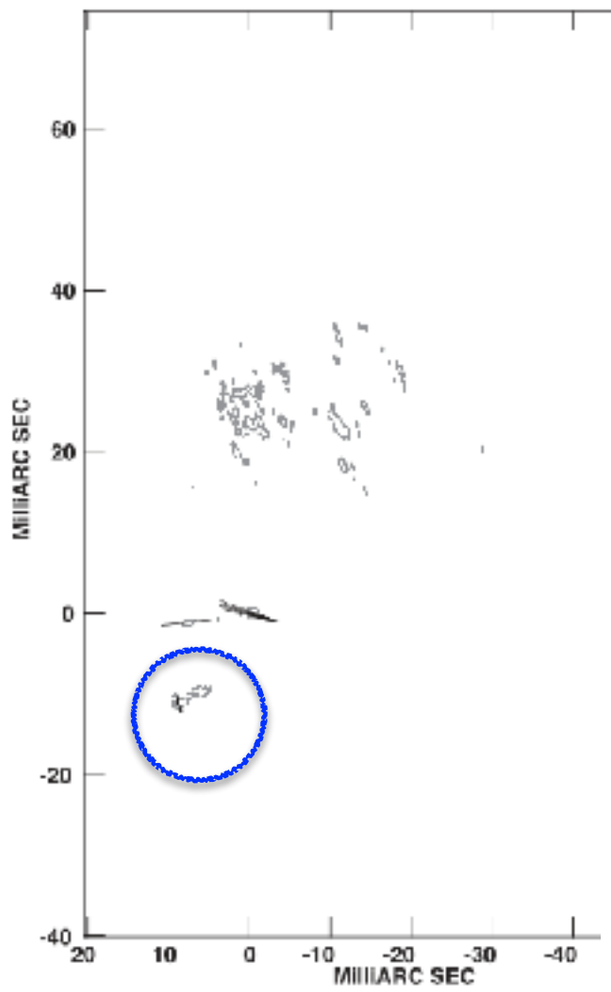


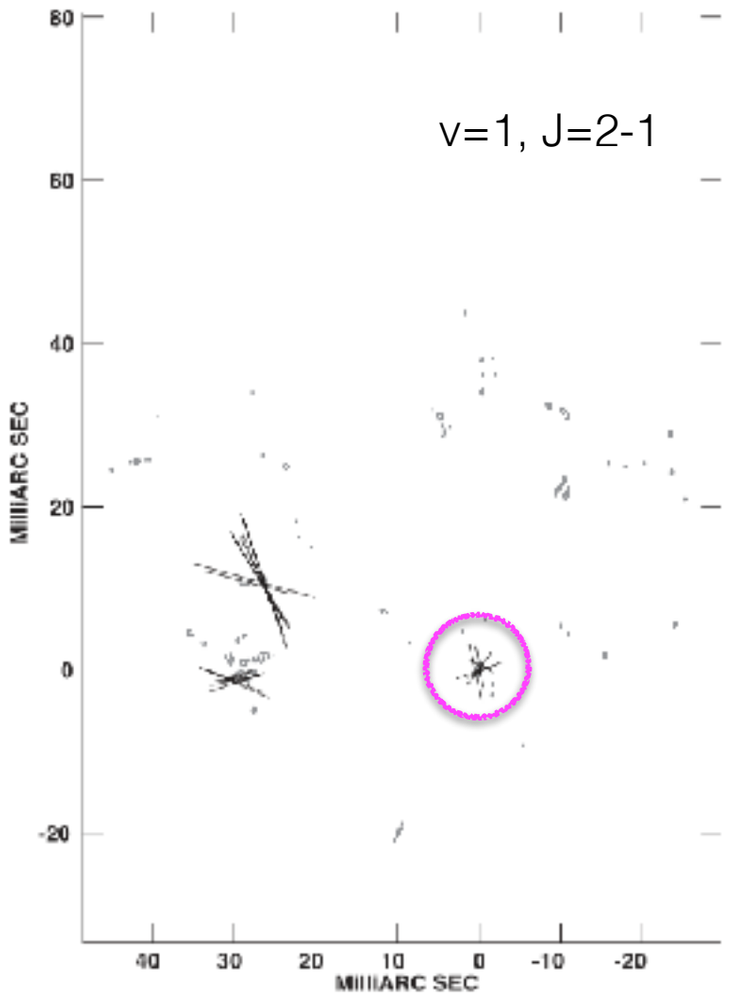


Epoch 1

Results and discussion



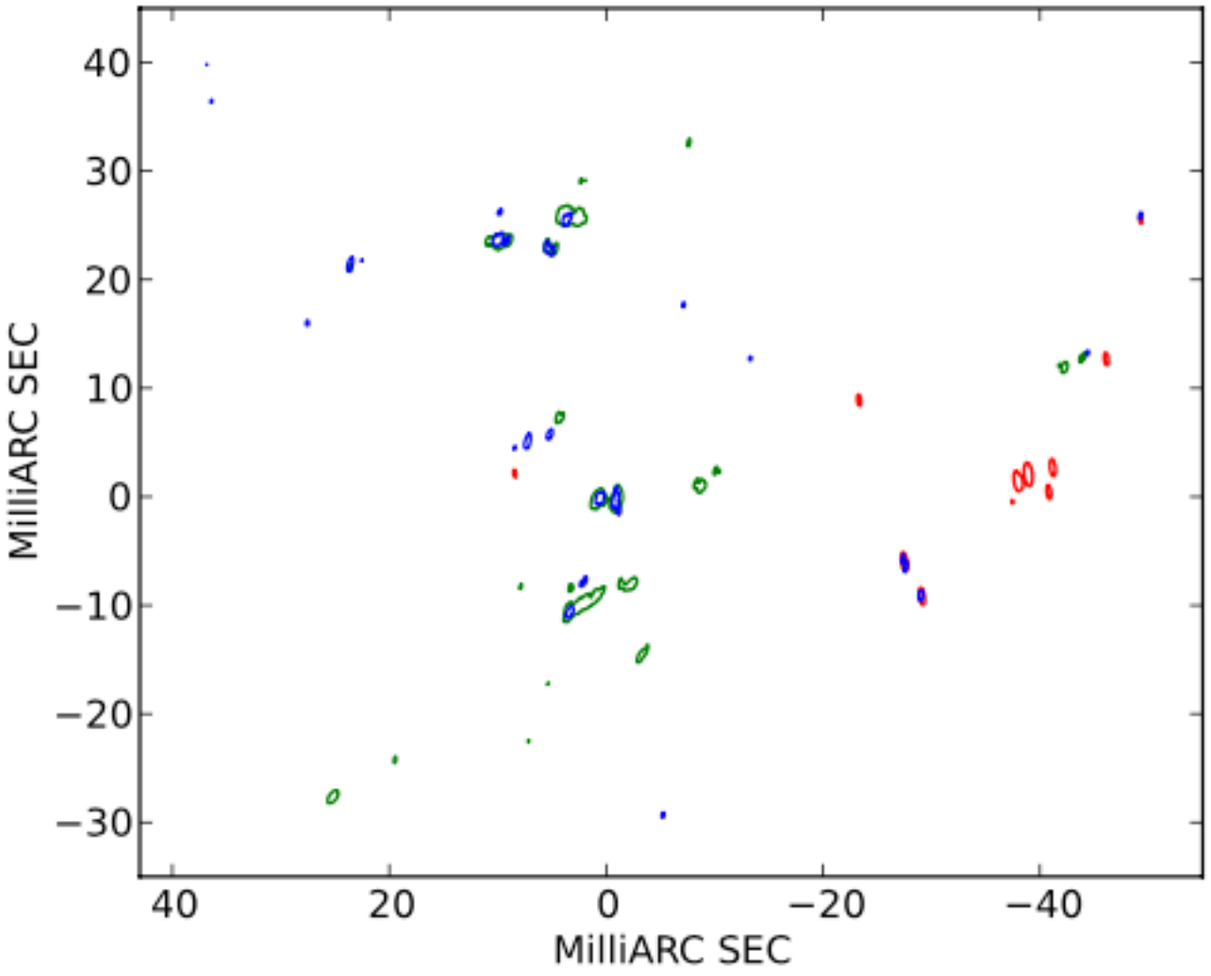




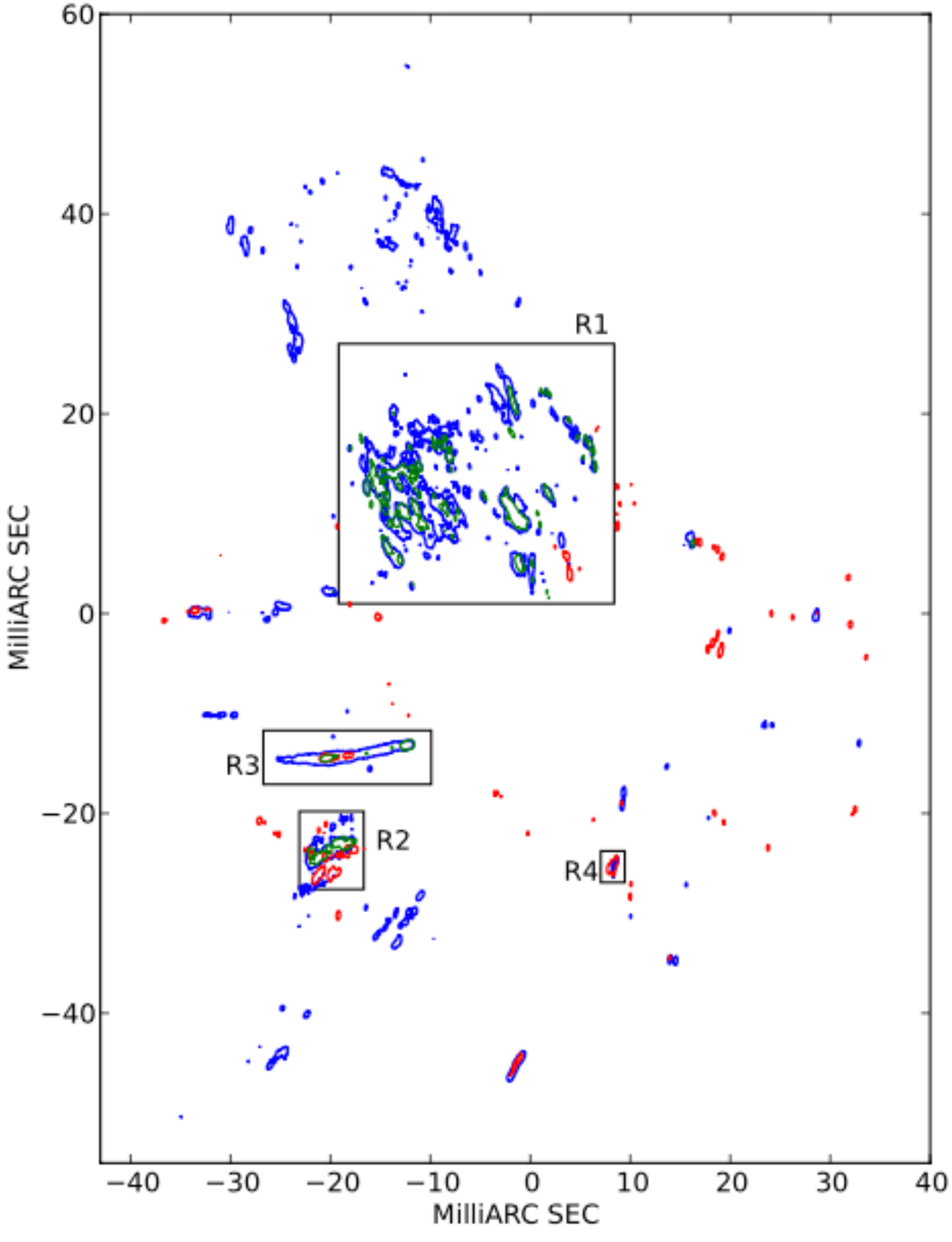
Epoch 2

Results and discussion

Epoch 1



Epoch 2

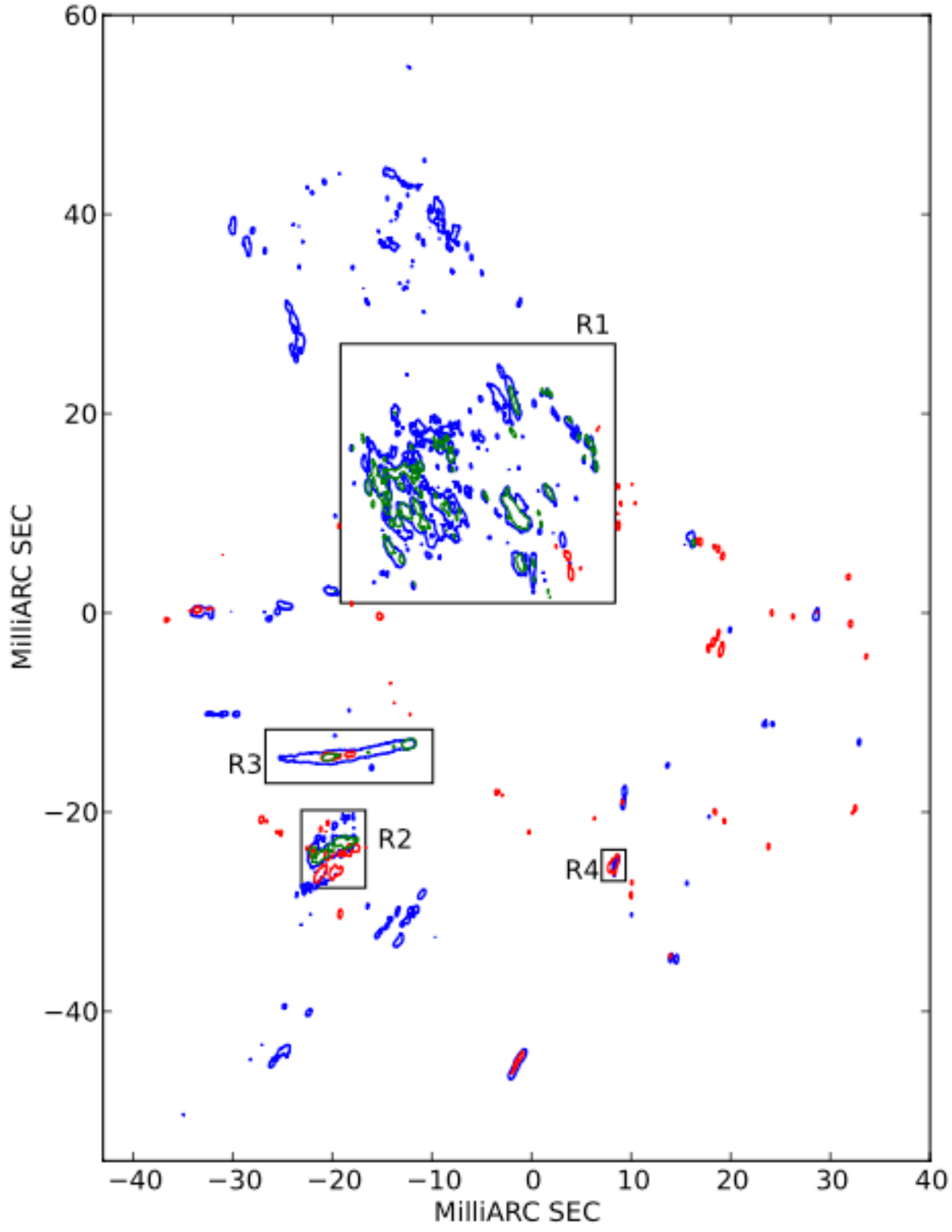


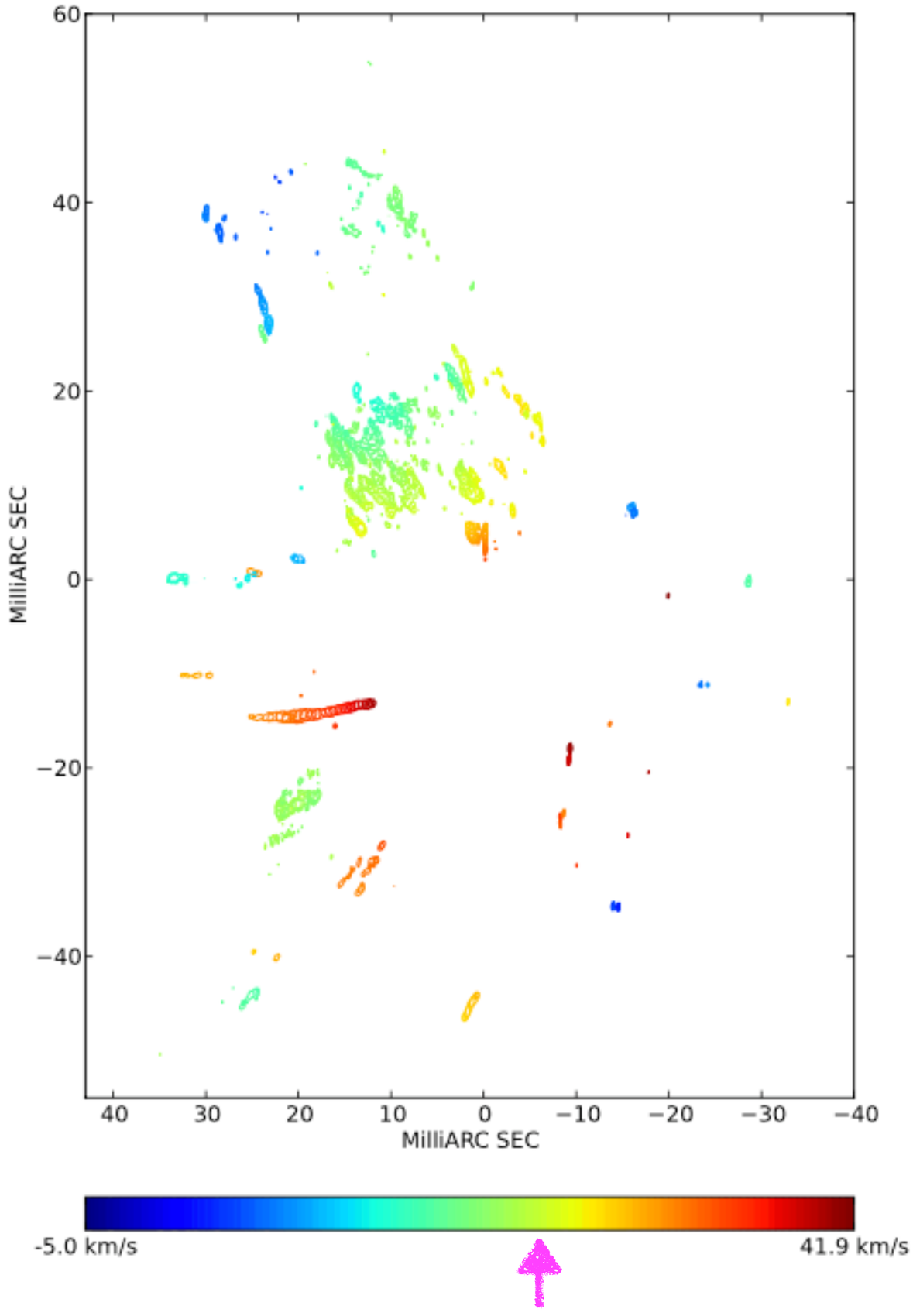
Blue: v=1, J=1-0

Green: v=2, J=1-0

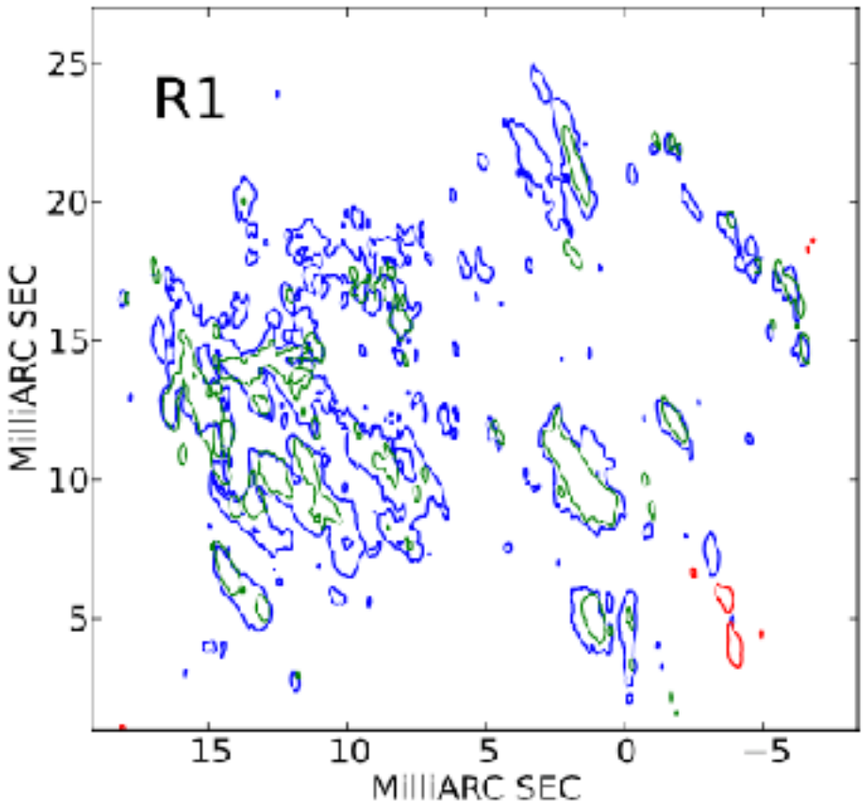
Red: v=1, J=2-1

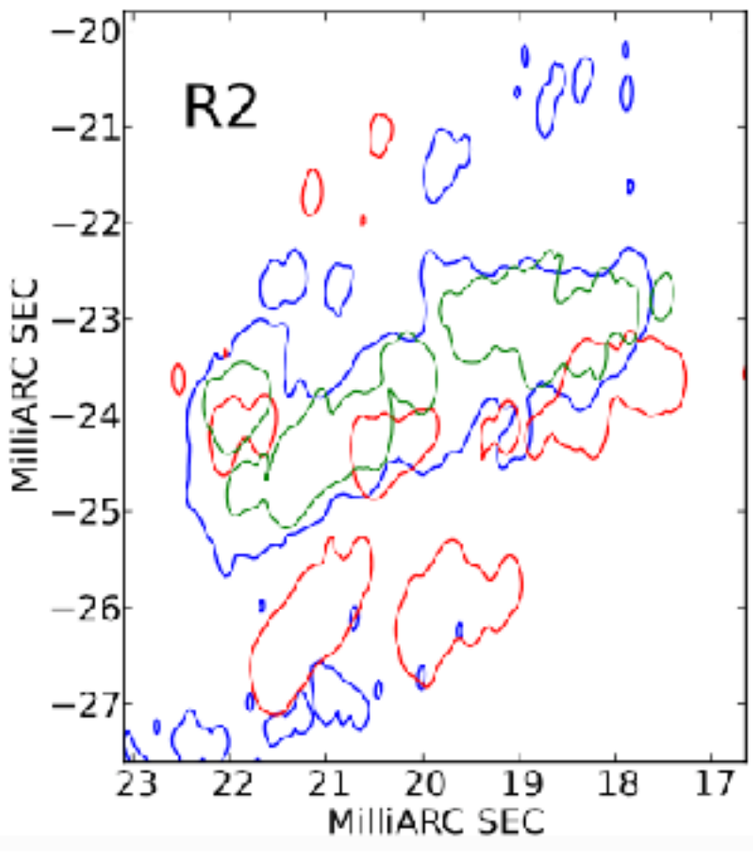
Results and discussion

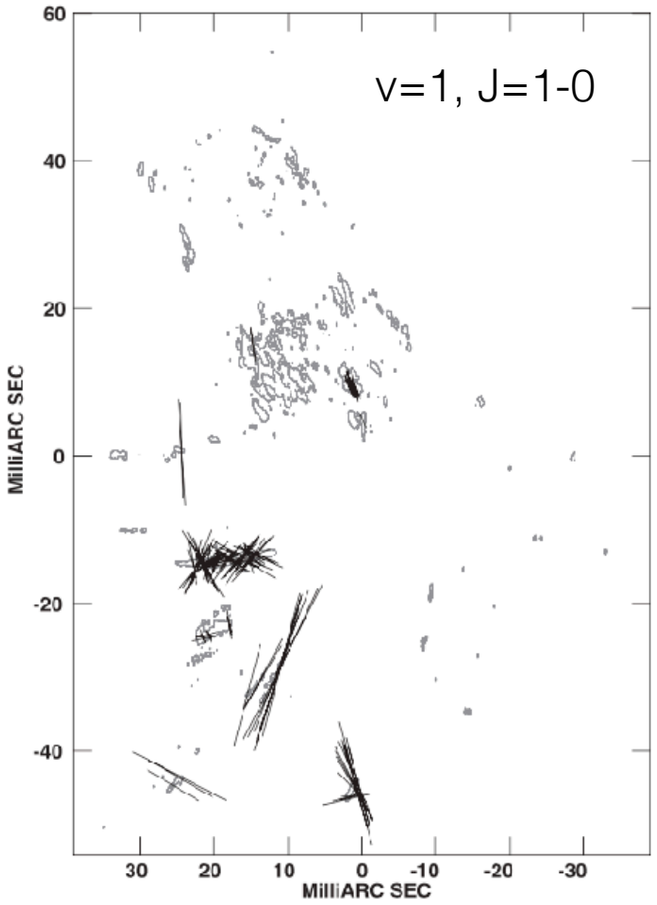


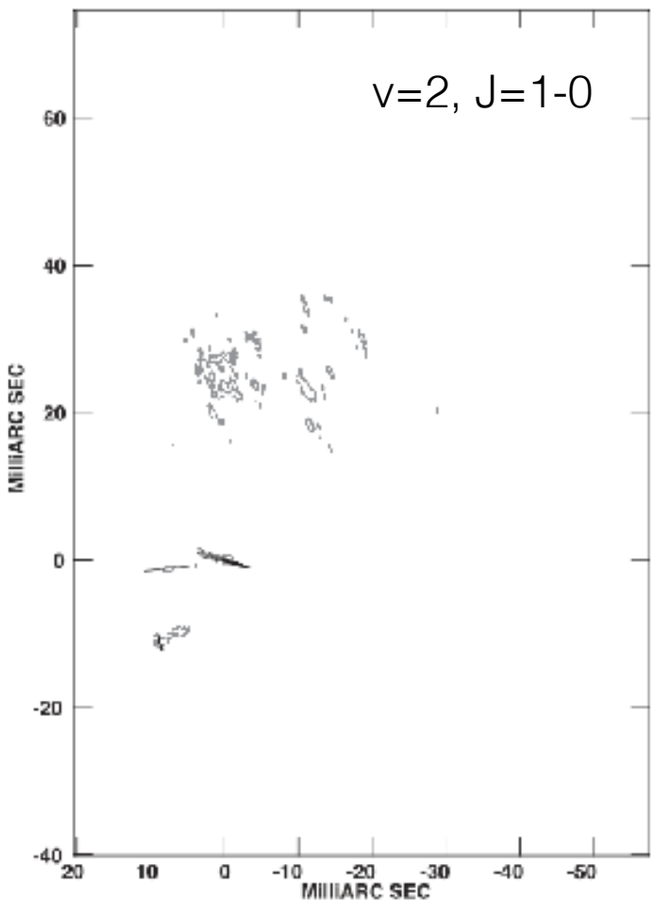


Results and discussion







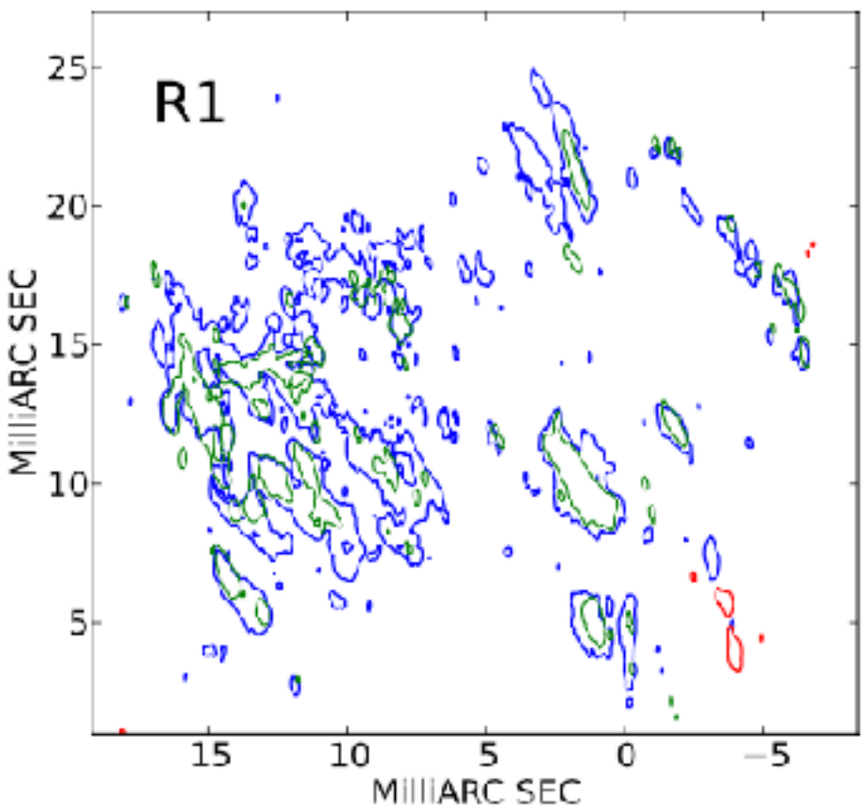


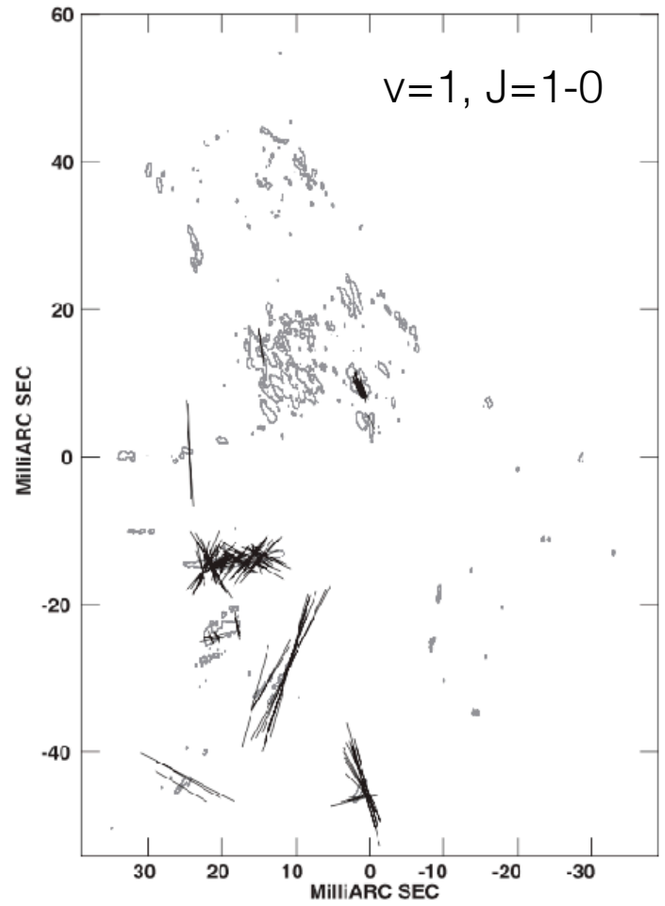
Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

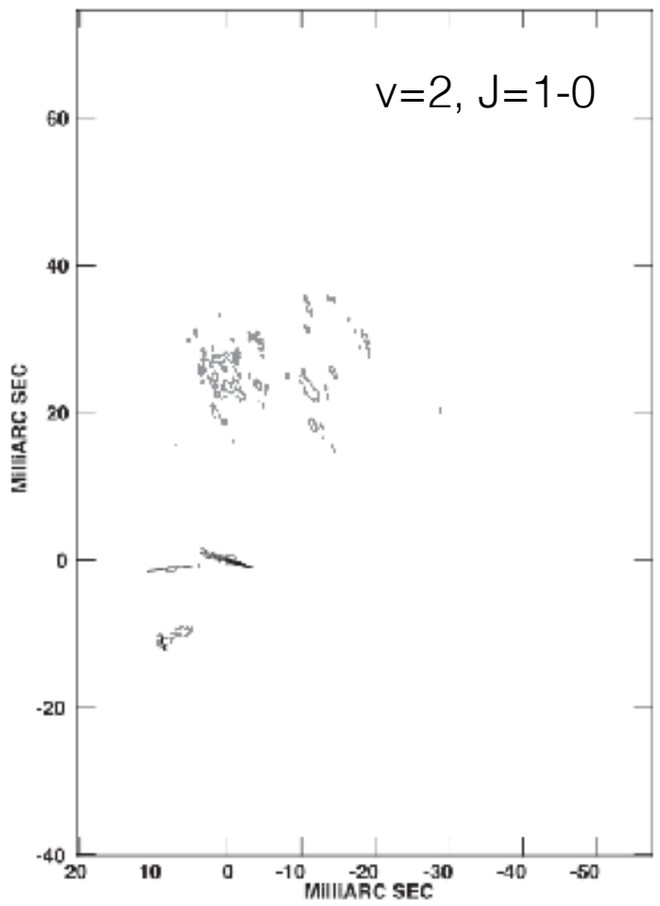
Very well overlapped v=1 and v=2 J=1-0
-> predominant collisional pumping
-> line overlap via radiative pumping

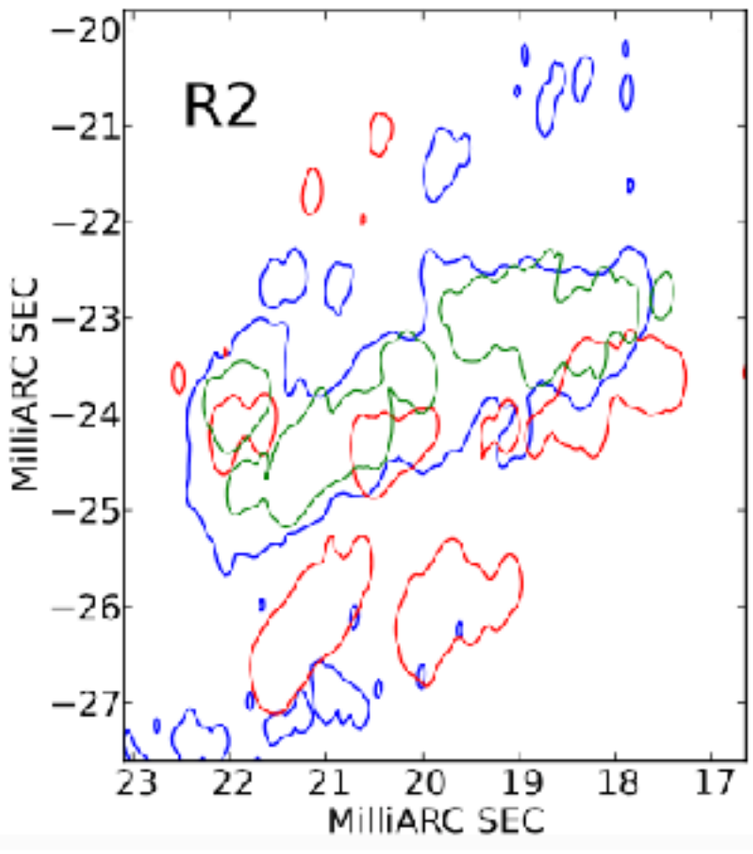
R1: very weak linear pol.
v=1 four features polarized (~10%)
v=2 no pol.

Results and discussion





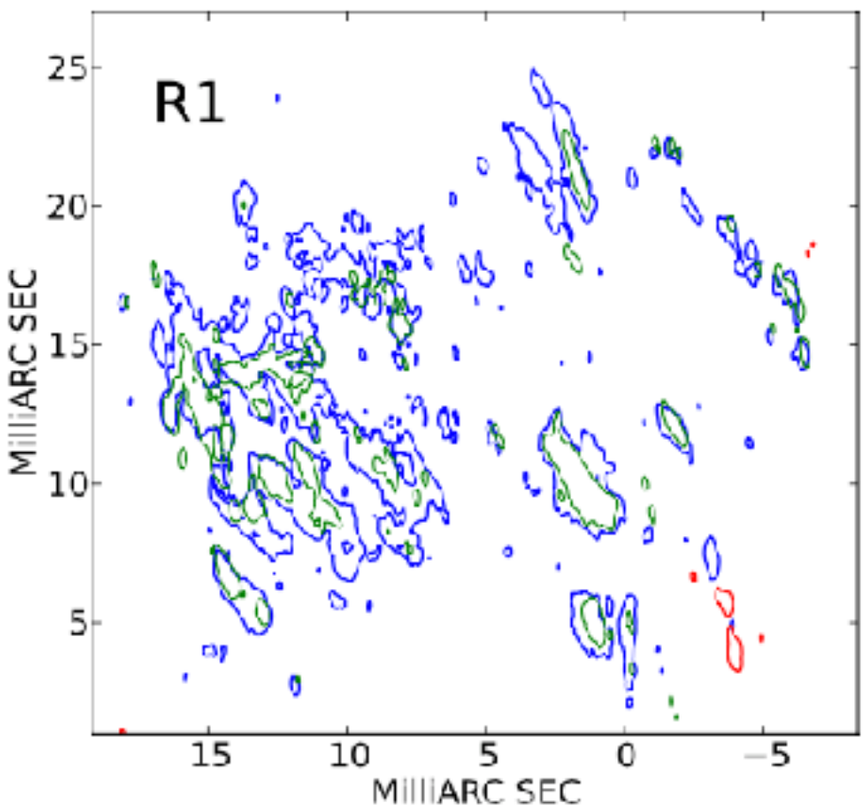


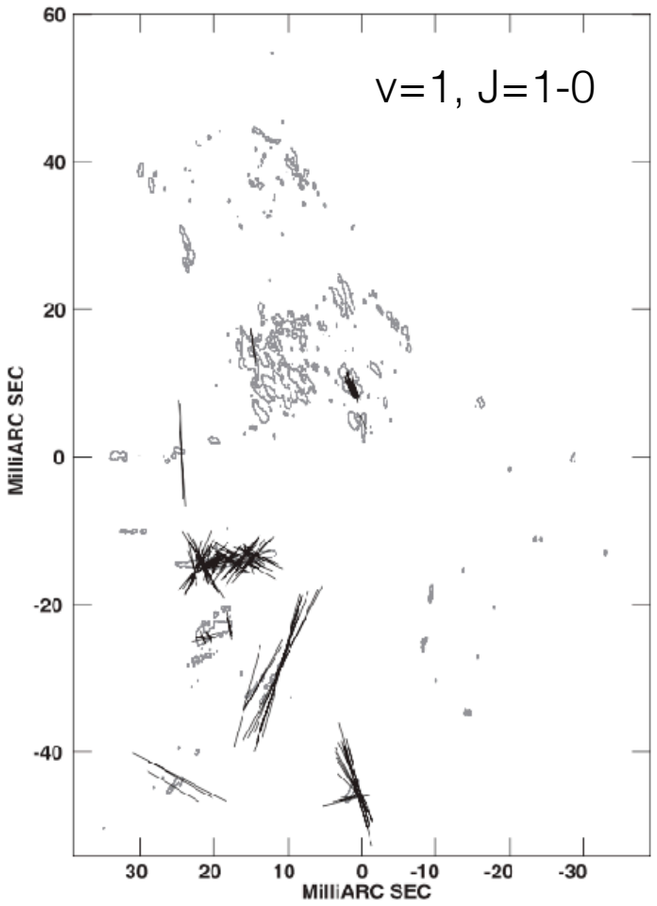


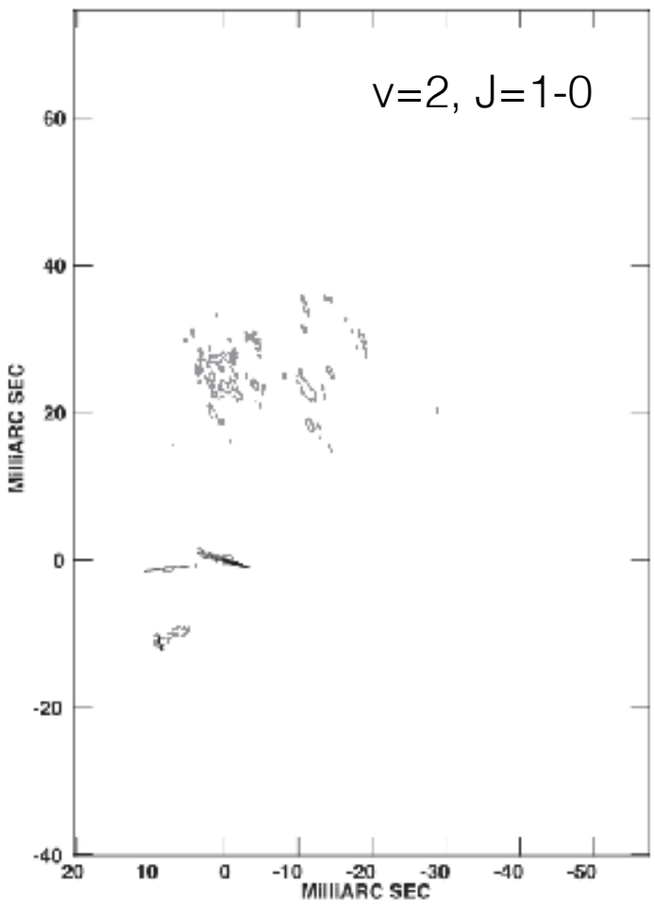
Linear pol.: natural characteristics of radiative pumping (being weaker further from central star)
Wide radial extent of the maser emission in R1 with weak linear pol. of v=1 and no pol. of v=2
-> contrary to radiative pumping scheme

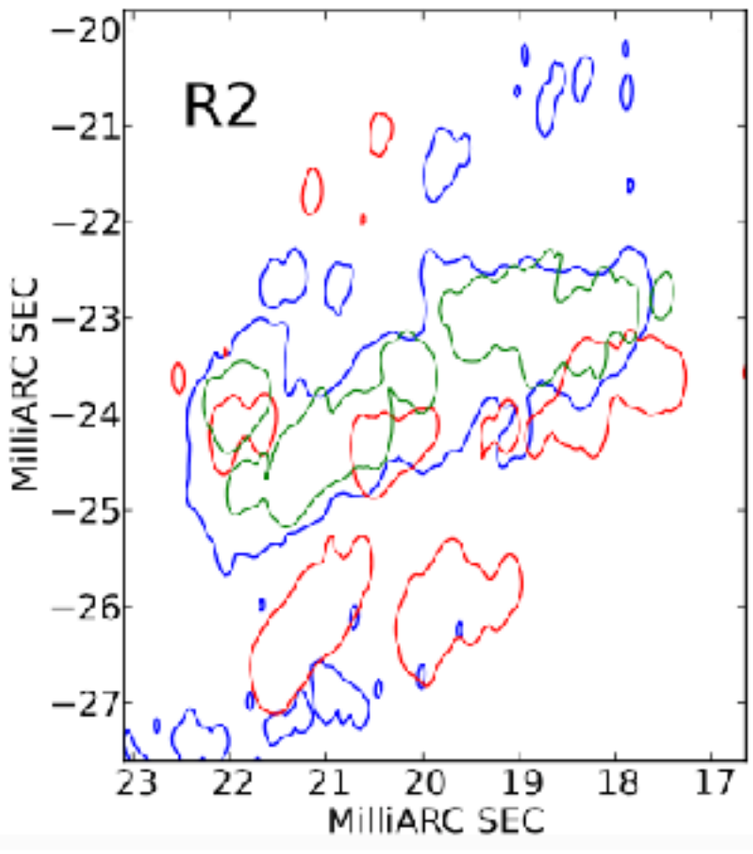
Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

Results and discussion





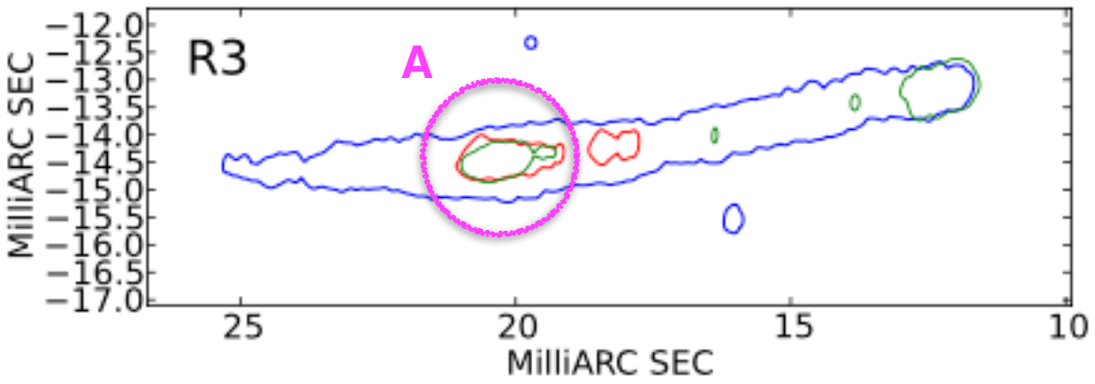


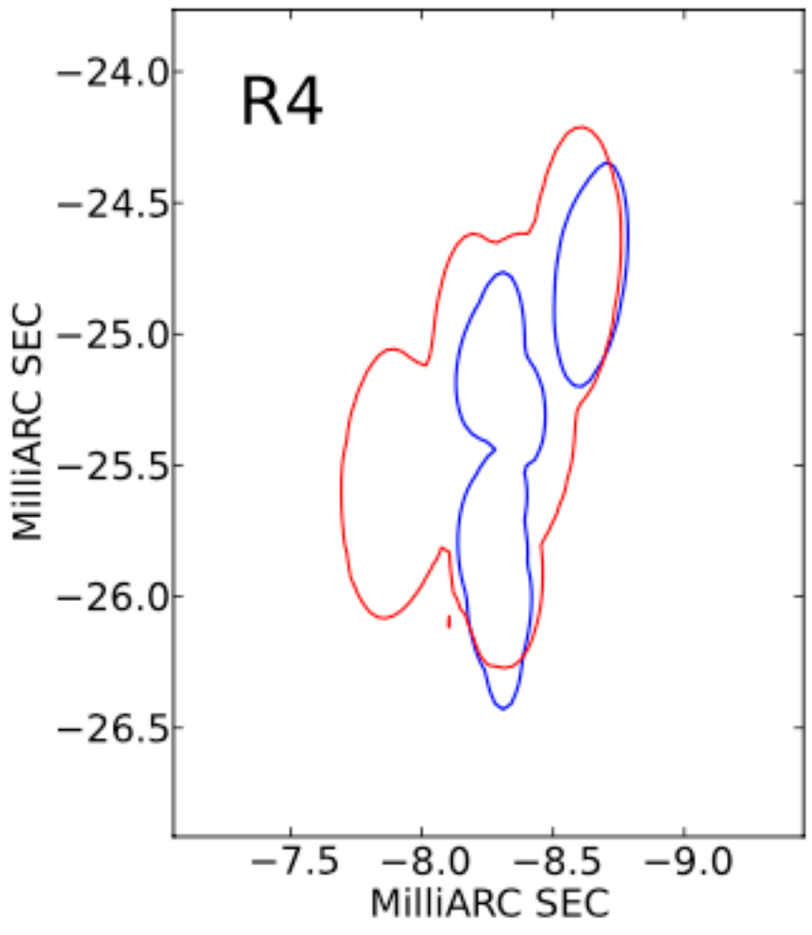


R2
Very strong spatial coincidence of v=1 and v=2
IF line overlap mechanism causes this
THEN observed spatial overlap between
the v=1 J=1-0 and v=1 J=2-1 lines would only occur
under a very restricted set of envelope conditions.

Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

Results and discussion



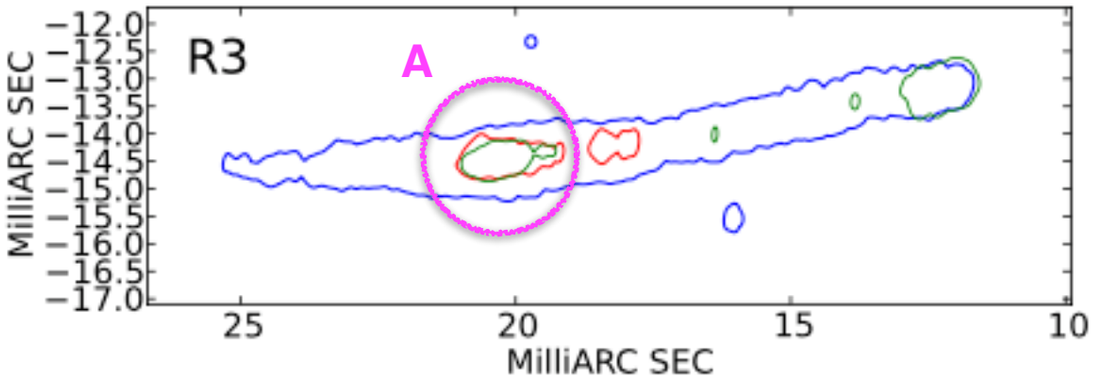


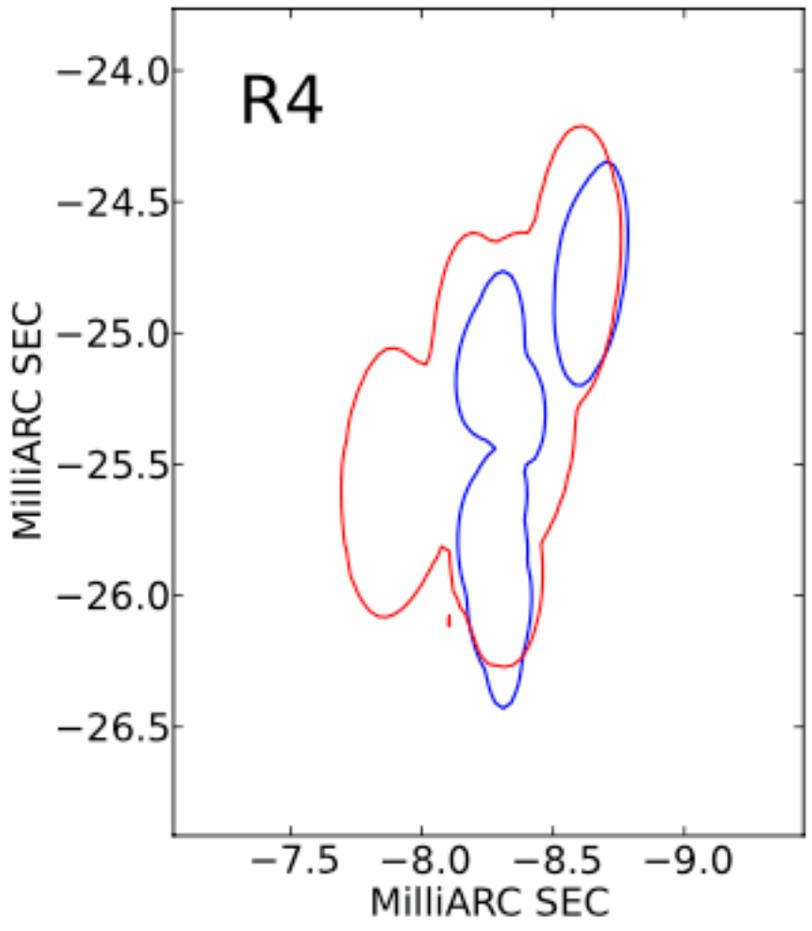
Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

R3
The v=2 J=1-0 emission is located within two subsets of the v=1 J=1-0 emission regions
one: at the peak, the other: inner end
v=2 is closet to the star
-> rad. pumping: line overlap
-> coll. pumping: higher density condition

All transitions occur and are overlapped at A.
-> Longest coherent path (gain) length at A
-> Competitive gain effect (maser saturation causes the coupling of the different vibrational transitions)

Results and discussion





Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

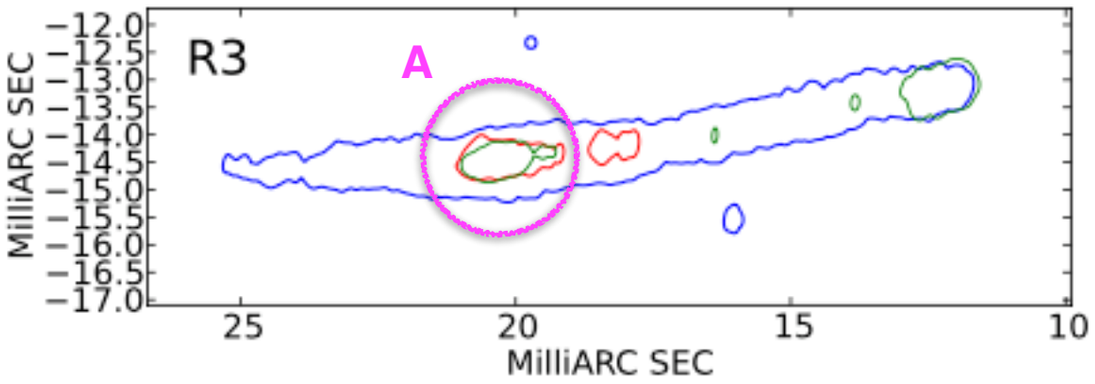
R3
Nedoluha and Watson (1990): linear pol. decreasing with maser saturation

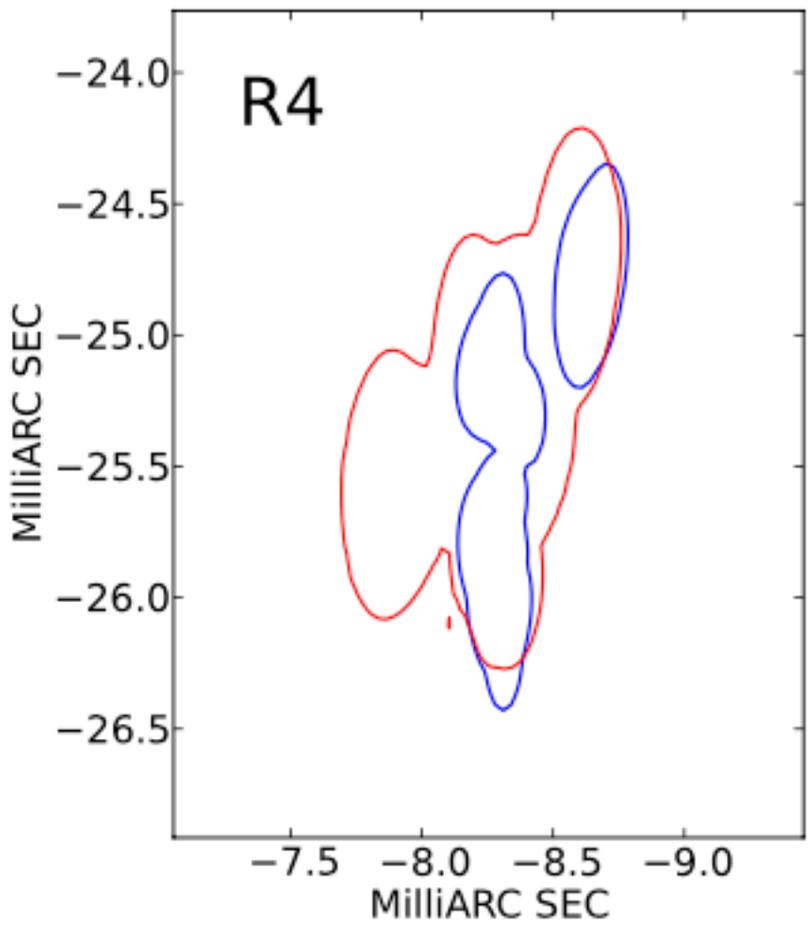
Western and Watson (1984): linear pol. increasing with maser saturation

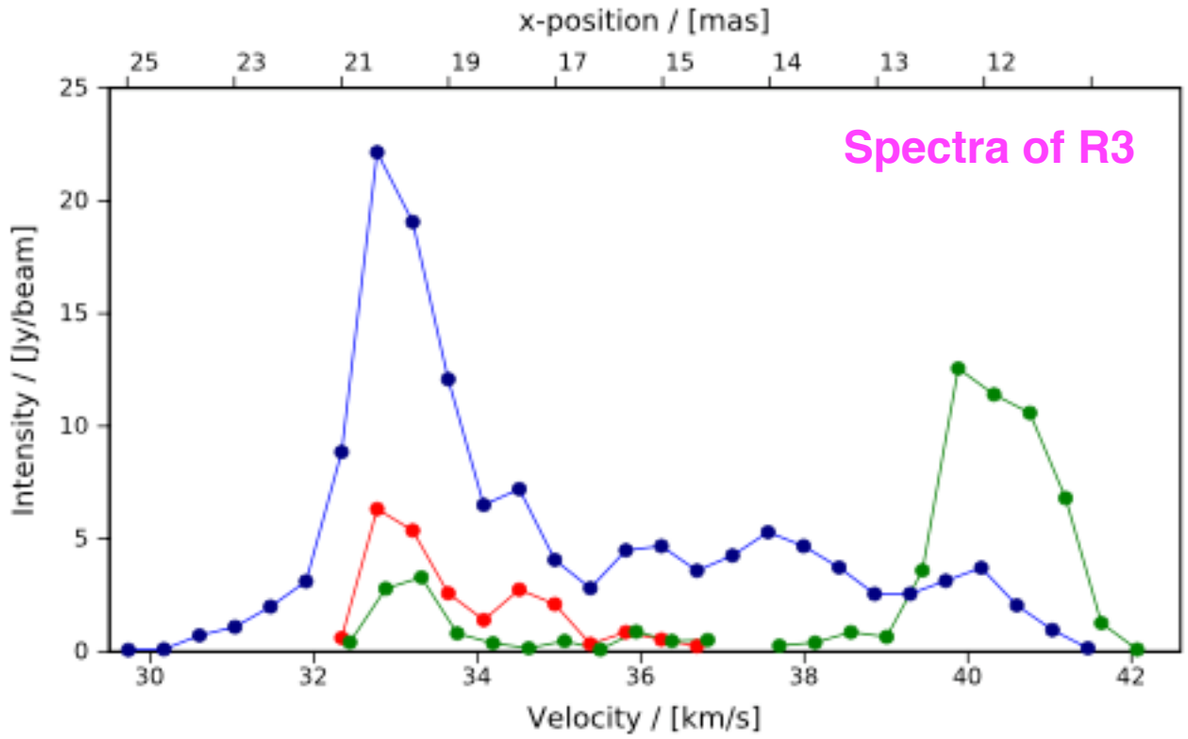
Elitzur (1991): linear pol. level is the same in the unstaturated and saturated masers

In this work, strong linear pol. of all transitions in R3
J=1-0: 1~20 %
J=2-1: 25~40 %

Results and discussion







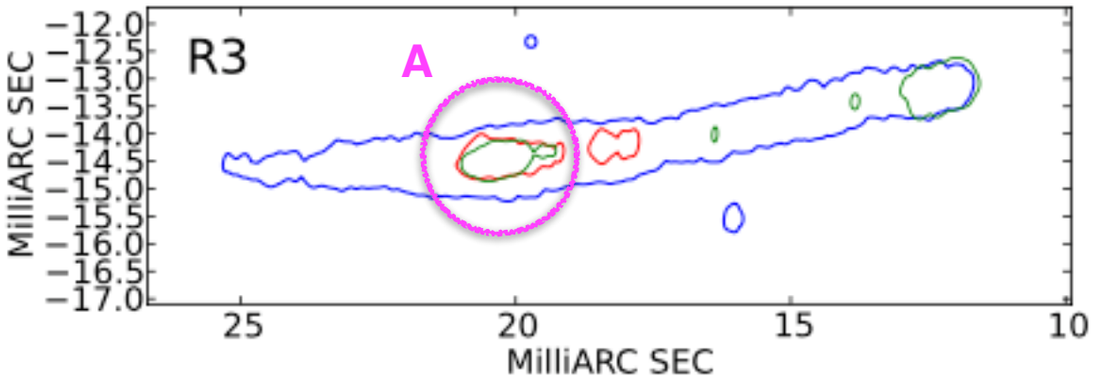
Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

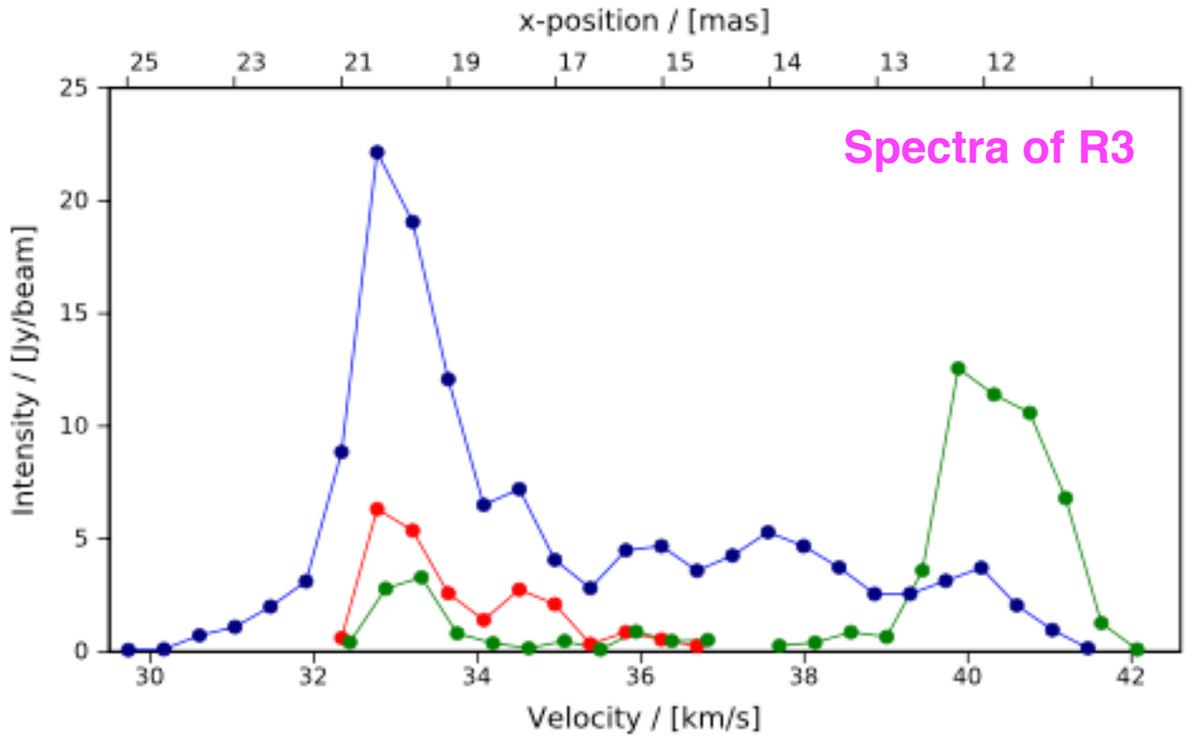
v=1 J=1-0 and v=1 J=2-1
Generally little overlap have been found.

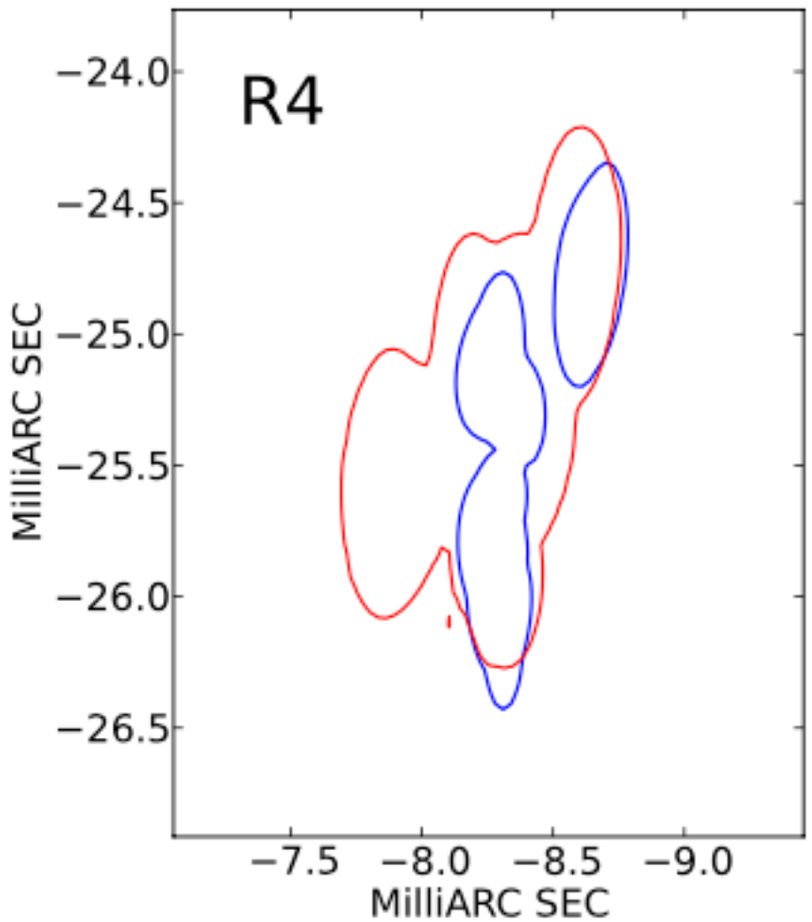
In this work, several overlapped regions are found (in R2 and R3).

Similar spectra shapes of v=1 J=1-0 and v=1 J=2-1
-> expect similar spatial distribution
-> found the similar spatial overlap only in R3

Results and discussion







Blue: v=1, J=1-0
Green: v=2, J=1-0
Red: v=1, J=2-1

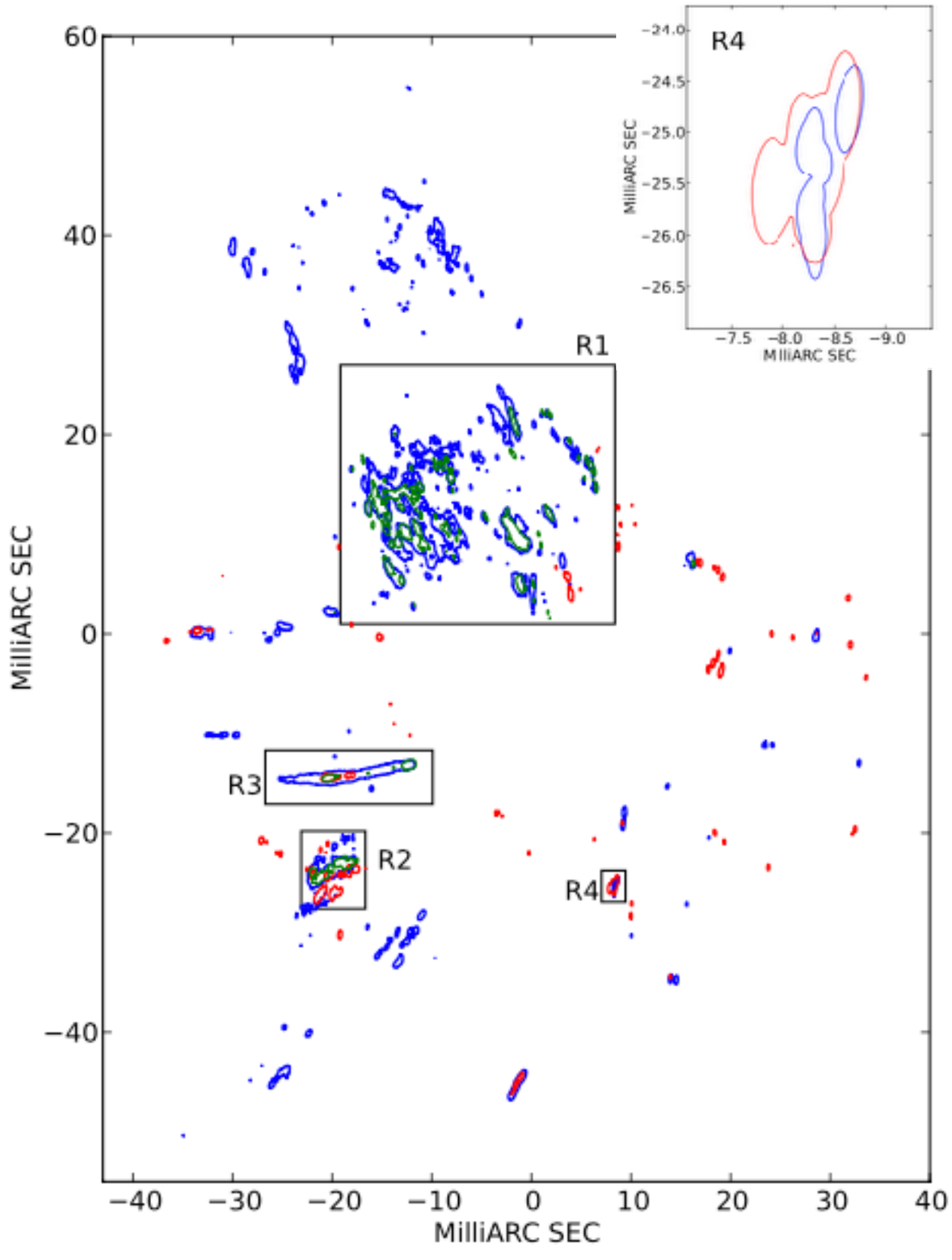
Alcolea (2004): coincidence of v=1 J=1-0 and v=1 J=2-1

Humphreys (2002): stronger intensity of J=2-1 than J=1-0

Doel (1995): predominant coll. pumping
J=2-1 is stronger than J=1-0 for intermediate density
For high and low density: J=2-1 is weaker than J=1-0

Weaker J=2-1 of this work -> low density in overlap regions (consistent with Phillips 2003 for R Cas)

Results and discussion



Doel (1995): Most of J=2-1 do not have J=1-0 counter part.
-> western part of overlapped map
-> imply intermediate density

R1
Doel (1995): notable absence of J=2-1
-> low density

IF line overlap via rad. pumping causes the close correspondence of v=1 and v=2
THEN absence of J=2-1 imply high density.
(Soria-Ruiz 2004)

R4
I (J=2-1) > I (J=1-0)
J=2-1 is more spatially extended
No v=2 J=1-0 emission
Significant pol.
J=1-0: ~8%
J=2-1: ~19%