

Correlation between variable pulsation phase and SiO masers distribution

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Stellar phase dependence of SiO $v=2$ and $v=3$ maser distribution

- **Observation**

Telescopes: VERA + NRO45m
Dates: 2012/3/24-25, 5/20-21
Targets: 12 O-rich variable stars

Emission lines: SiO $v=2/v=3$ $J=1 \rightarrow 0$ v : vibrational energy level
 J : rotational energy level

$v=2/3$ synthetic maps

• WX Psc, W Hya, T Cep, R Leo

- **$v=2/v=3$ maser distributions**

- The $v=2/3$ masers spots appear in common region

T Cep

H₂O-SiO line overlapping mechanism

- The $v=3$ maser region is clearly different from $v=2$

W Hya, WX Psc, R Leo

Collisional pumping mechanism

- **The $v=3$ maser pumping mechanism depends on stellar phase.**

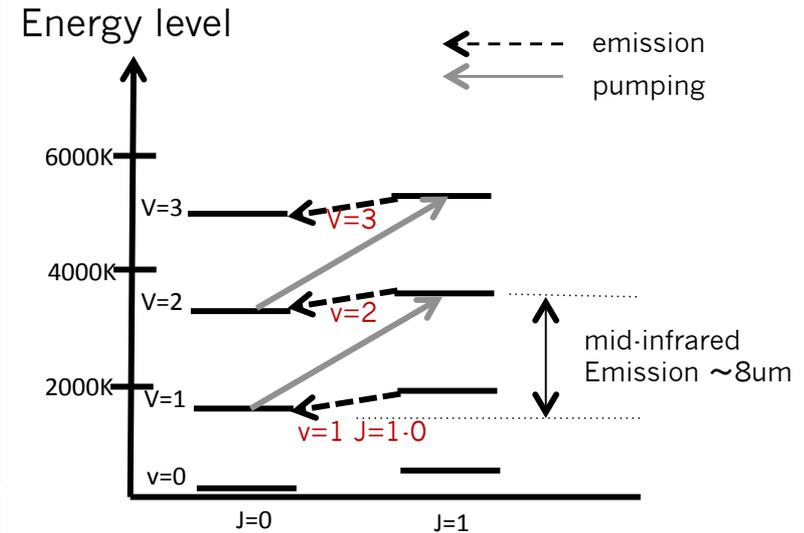
mid-infrared radiation brighten



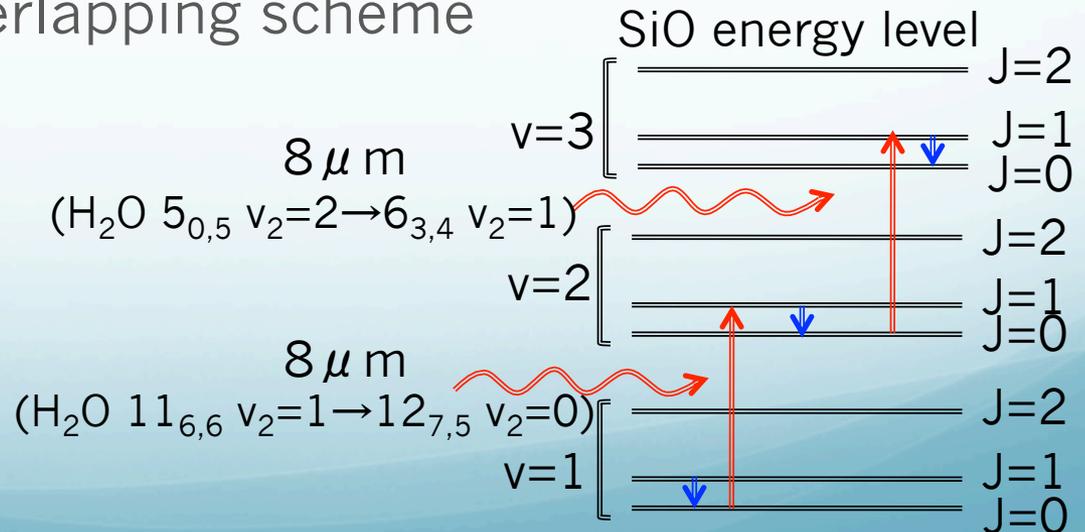
line overlapping mechanism

Pumping mechanism

- Collisional pumping
Collision of SiO and Hydrogen molecules
- Radiative pumping
 - Stellar radiative pumping
(Star Temperature $\sim 2500\text{K}$)
 - H_2O —SiO line overlapping scheme

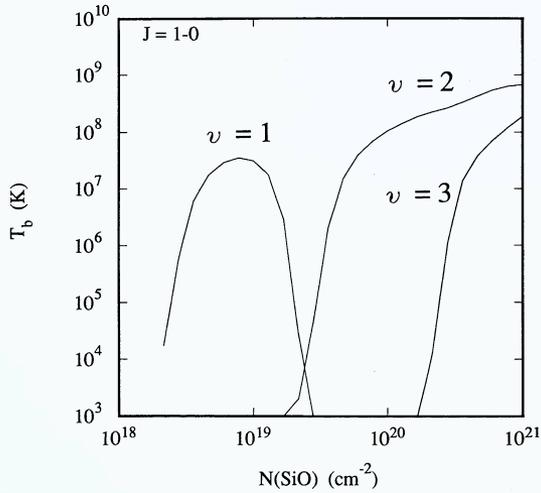


- ✧ mid-infrared emission from H_2O pump SiO energy level
- ✧ $v=1, 2, 3$ masers spots appear in spatial common region



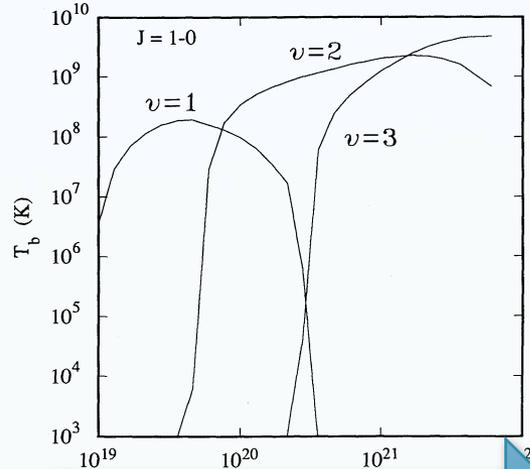
SiO maser spots distributions

□ Stellar Radiative pumping

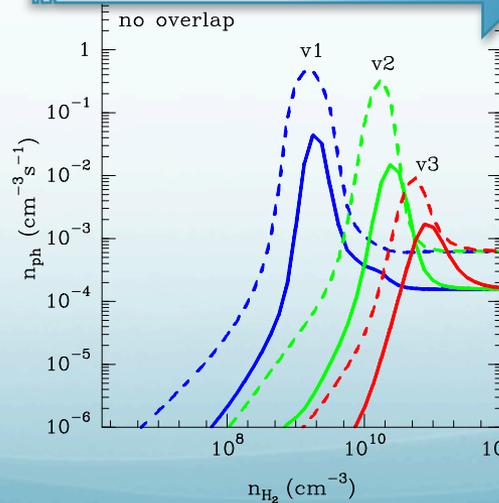


(Lockett & Elitzur, 1992)

□ Collisional pumping

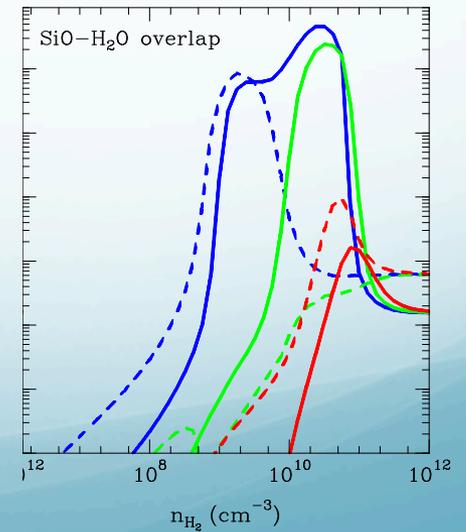


Toward central star



□ H₂O-SiO Line overlapping

(J. -F. Desmurs, et al., 2014)

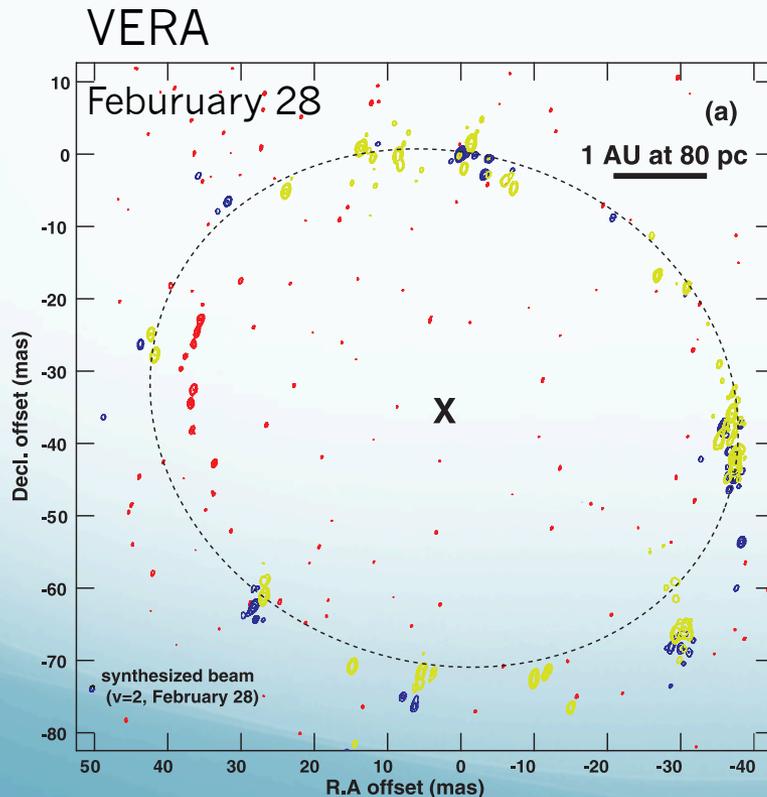


Particularity of $v=3$ line emission

- Multiple lines VLBI observation includes $v=3$ line emission (W Hya)

(Imai, et al., 2010)

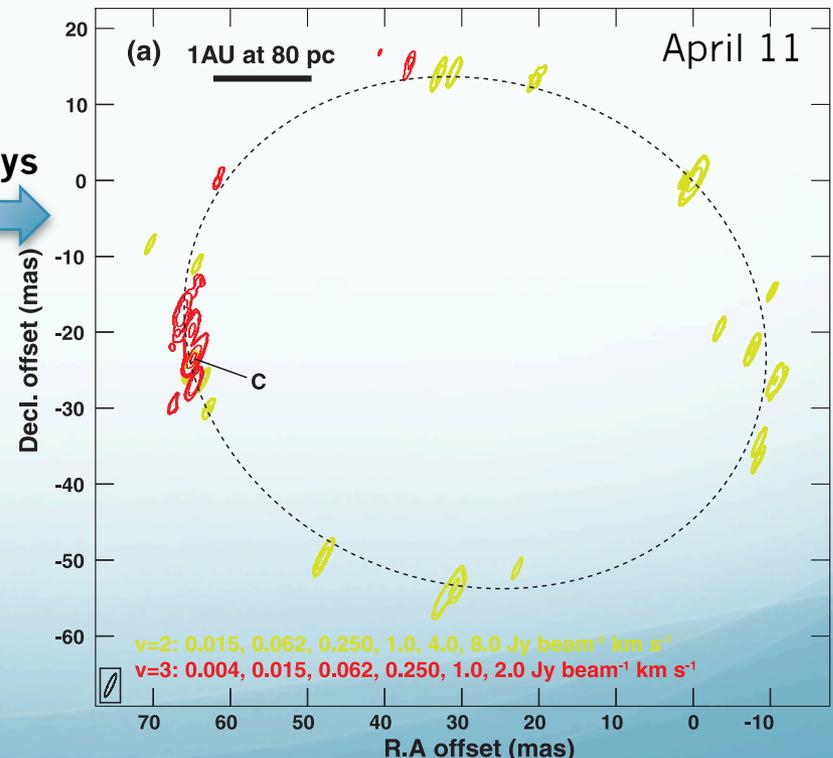
Dark blue : $v=1$ J=1-0
Yellow-green: $v=2$ J=1-0
Red : $v=3$ J=1-0



42 days



VERA+NRO45m+NICT34m



Observations & Data Reduction

Telescopes: VERA + NRO45m

Dates: 2012/3/24-25
2012/5/20-21

Maser lines: $v=2/v=3$
($J=1-0$)

Scan time: 1-4 hours

Data Reduction:

Solution of $v=2$ bright
maser spot



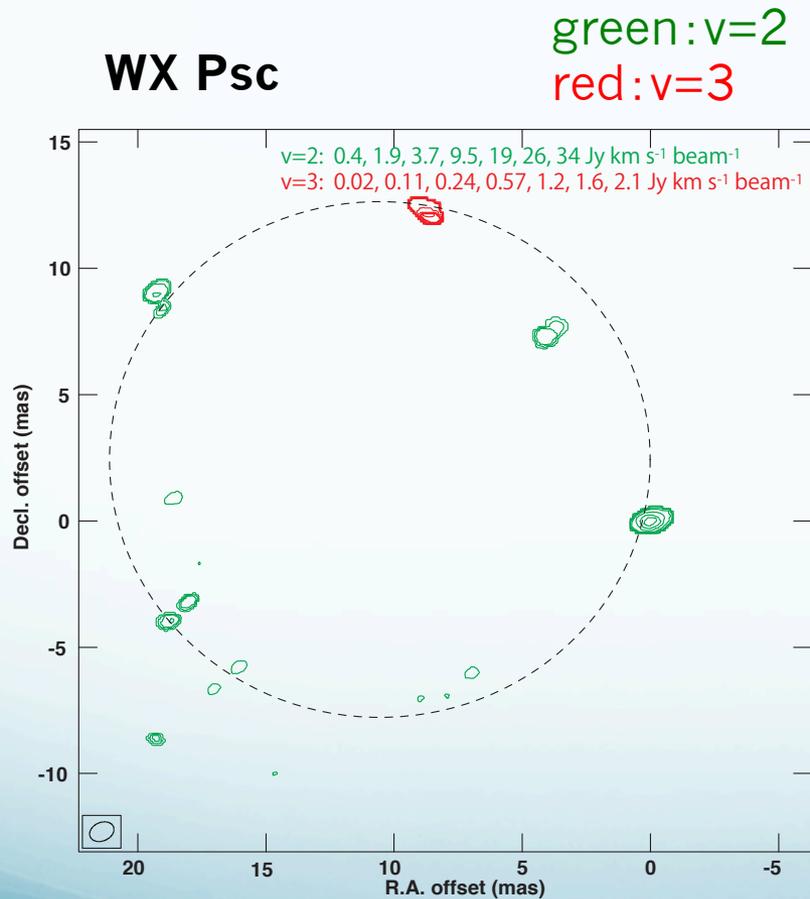
apply

Other velocity channel of
 $v=2$ and $v=3$ masers

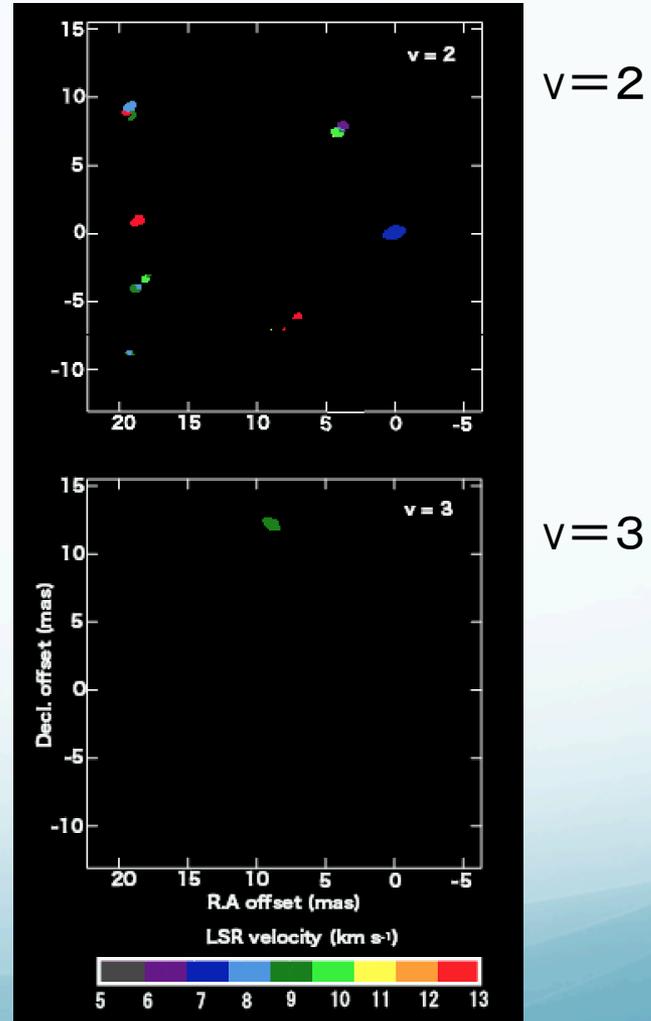
Target source	$v=3$ line	$v=2/v=3$ map
WX Psc	yes	yes
U Ori		
VY CMa		
AP Lyn		
R Leo	yes	yes
W Hya	yes	yes
RU Her		
U Her		
RS Vir		
V4120 SGR	yes	
V1111 Oph		
T Cep	yes	yes

Results & Discussion

- WX Psc



Line of sight velocity



Dashed-line circle is assumed that $v=2$ maser spots appear ring-like distribution around central star

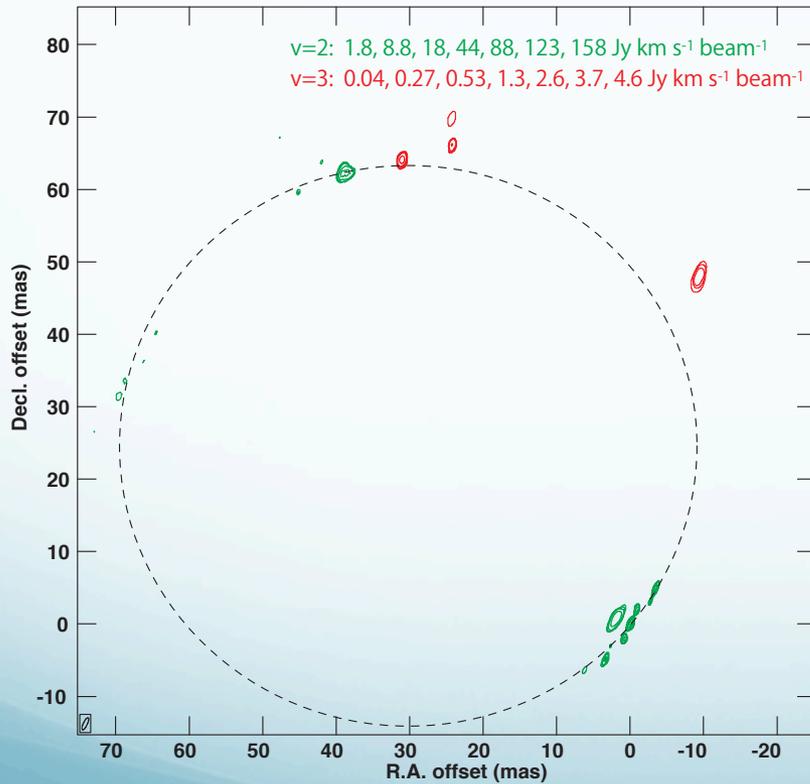
Results & Discussion

- W Hya

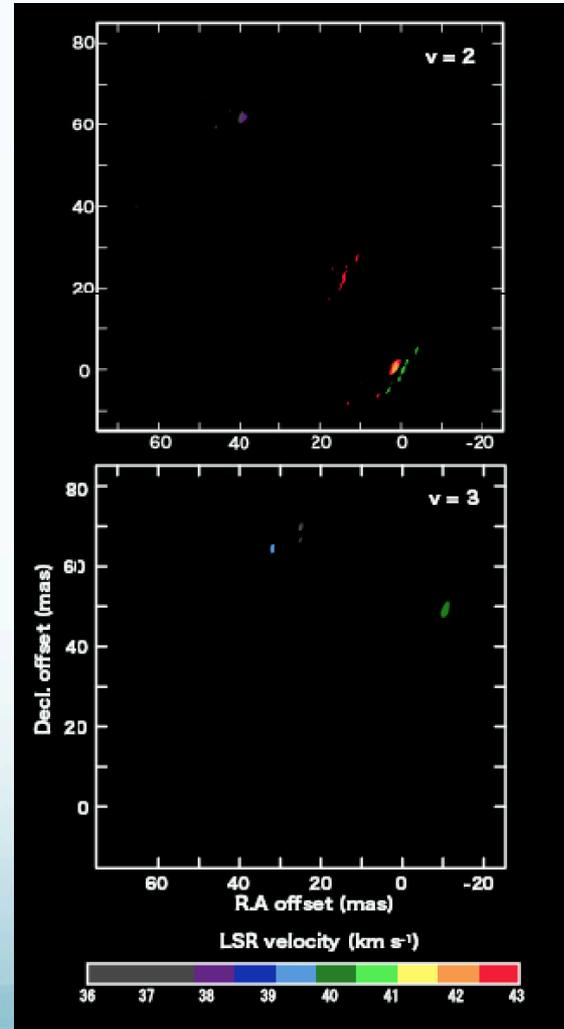
Line of sight velocity

W Hya

green: $v=2$
red: $v=3$



$v=2$



$v=3$

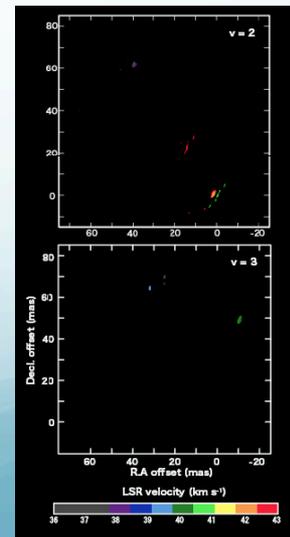
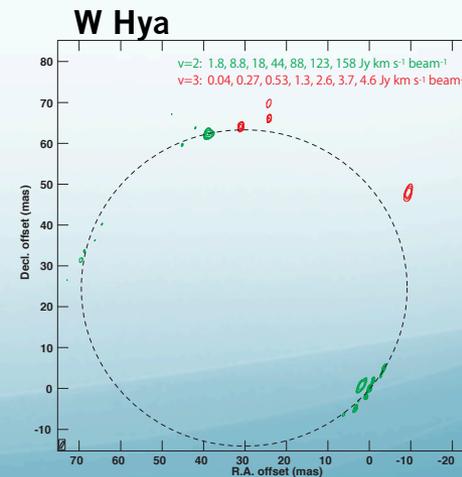
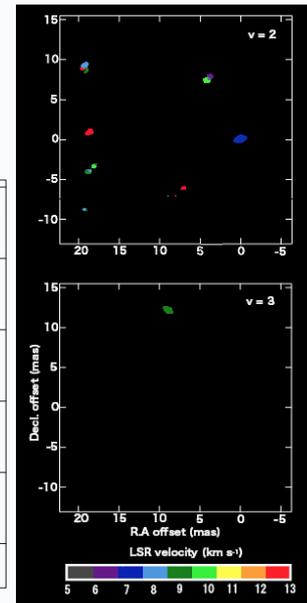
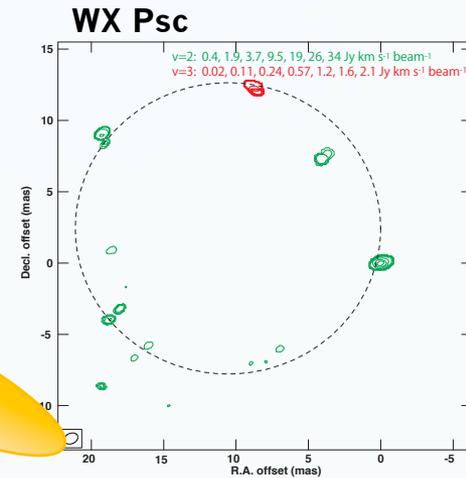
Results & Discussion

- WX Psc and W Hya
 - $v=3$ maser spot region is clearly different from $v=2$ region.
 - No correlation in spatial and velocity distribution.

Collisional pumping

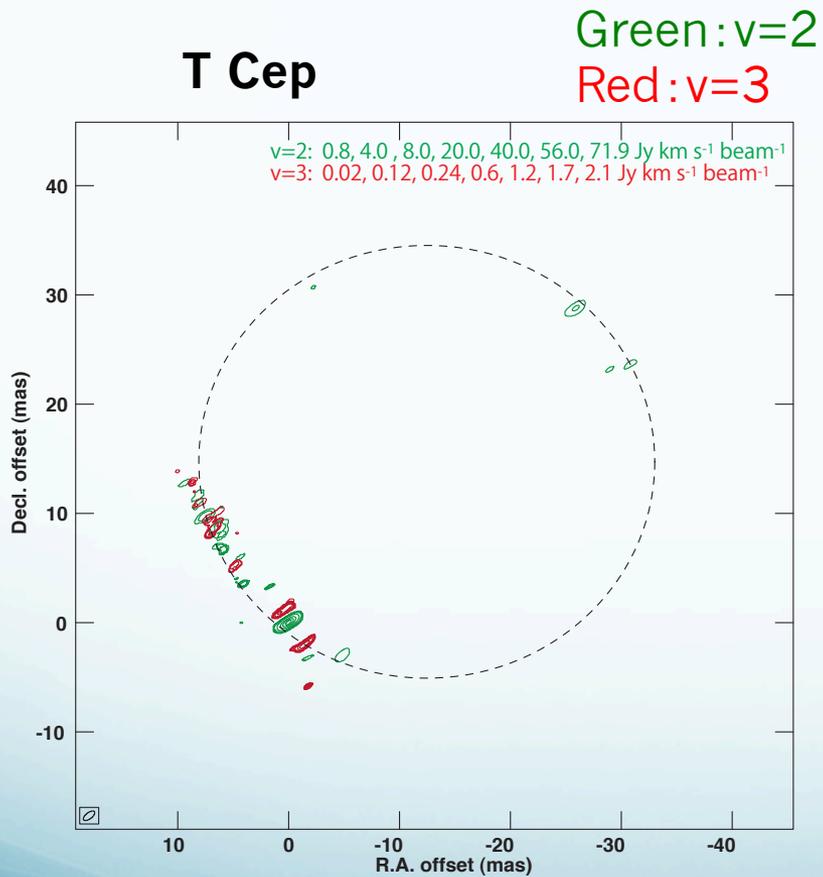
Dominant

- Previous observation of W Hya: $v=3$ maser exist inward from $v=2$ region
- WX Psc: $v=3$ exists same radius region from star
- W Hya: $v=3$ exists outward
 - Because of local gas flow

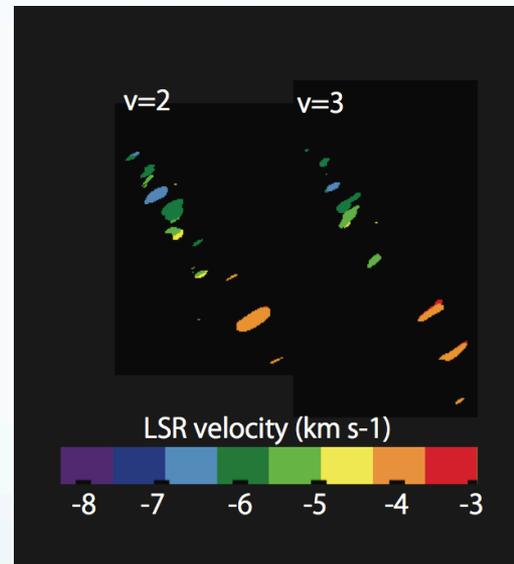


Results & Discussion

- T Cep



Line of sight velocity
 $v=2$ $v=3$



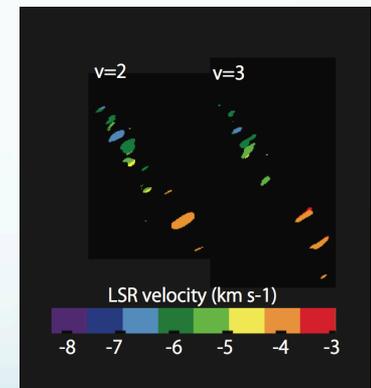
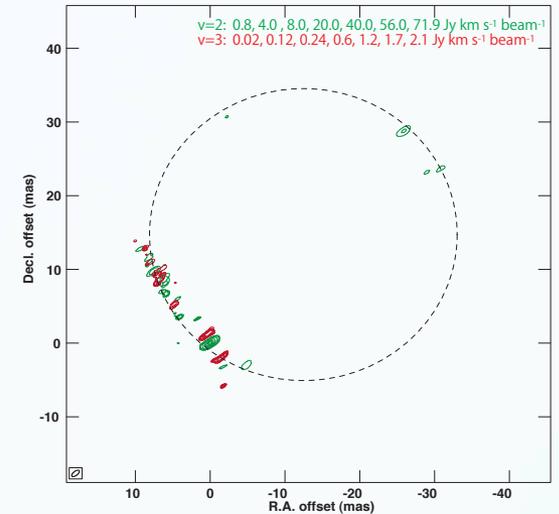
Results & Discussion

- T Cep
 - v=2 and v=3 maser spots exist in common region.
 - v=3 maser spots are correlated with v=2 in spatial and velocity distribution.

H₂O-SiO line overlapping

Dominant

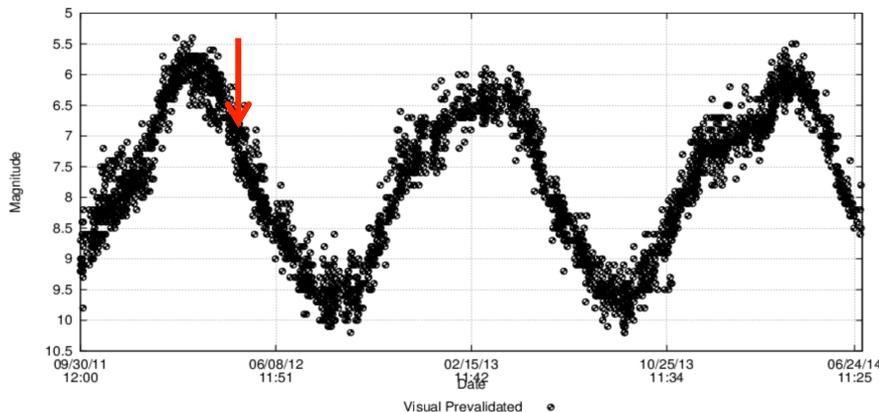
T Cep



Correlation between variable pulsation phase and SiO masers distribution

T Cep

2012/5/21 Line overlapping?



Mid-infrared radiation peak shifts $\phi \sim 0.2$ from visible peak.

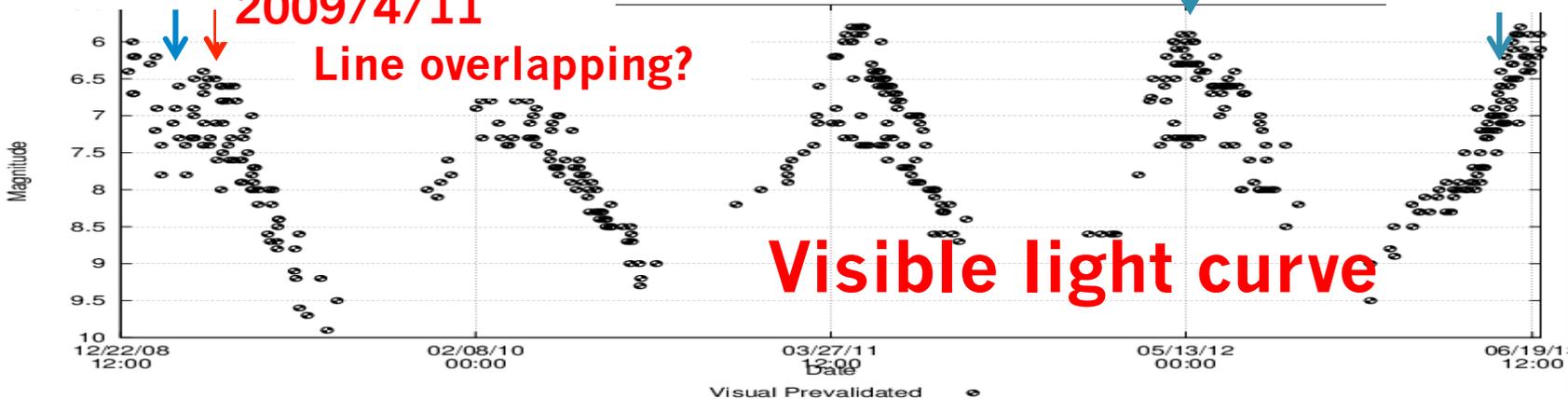
W Hya

Collisional?

2009/2/27

2009/4/11

Line overlapping?



Collisional?

2012/5/20

Collisional?
2013/5/8

Summary

- We observed SiO masers toward 12 O-rich stars. The $v=2$ and $v=3$ map registration was successful for 4 stars.
- There is a variety of $v=2/v=3$ maser distributions.
(Overlapping, displacement)
- We suggest that SiO maser pumping mechanism changes in stellar pulsation phase.
- When mid-infrared radiation brighten, line overlapping mechanism may become dominant.
- We need explanation of new finding that $v=3$ line emission region exits farther from central star than $v=2$ line.
- There are still few samples that can discuss relation between pumping mechanisms and pulsation phase.

Thank you for your attention