First VLBI detection of circumstellar SiO v=0 J=1→0 maser emission?

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Summary

We have made the first VLBI observations of v=0 (J=1→0) SiO (maser) emission toward a Mira variable R Cassiopeiae, together with v=1, 2 and 3 SiO maser emission that has been well mapped in VLBI observations, and faint ^{29}SiO v = 0 maser emission. All the five SiO lines were simultaneously observed in OCTAVE 4Gbps recording in the commissioning for developing the calibration scripts for the wide-band recording data. Because the v=0 emission is predominated by thermal one, the origin of the maser has been unclear in previous VLA observations with an insufficient angular resolution. We *marginally detected* this maser in VLBI, however failed to locate it in the image cubes because the maser components were completely resolved out. The ^{29}SiO v=0 maser emission was also in this case although this line was previosly detected in W Hya. We need retry detections of these v=0 lines on image cubes at different light curve phases.

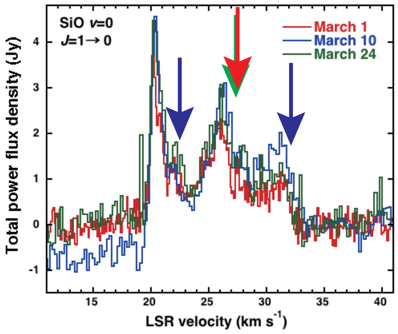

Figure 1 Total power spectra of the SiO v=0 J=1→0 line emission towards R Cas at three epochs in 2015 March. The spectra were taken with the NRO 45 m telescope on March 1 and four antennas of VERA on March 10 and 24. The colored arrows indicate 6-σ detection peaks in the VLBI image cubes on the individual epochs, but they do not mean true maser detections (at unbeliebaly far away from the star).

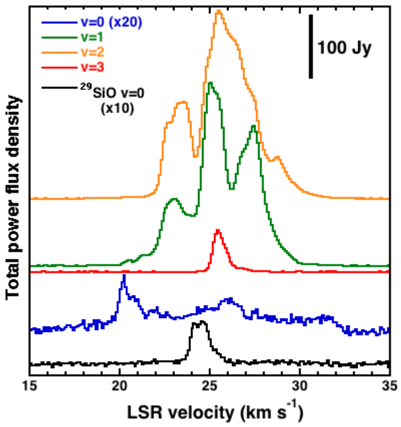

Figure 2 Total power spectra of the five SiO J=1→0 lines taken with the NRO 45 m telescope on March 1. The spectra of the v=0 lines are vertically enlarged with the factors described in the legend.

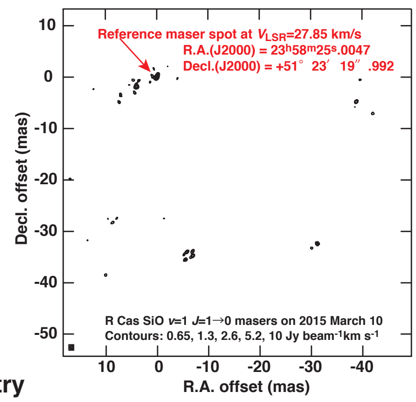

Figure 3 SiO v=1 J=1→0 masers taken on March 10. The absolute coodinates of the position/phase reference maser spot at the map origin were give through the astrometry using the data of J0006+5050.

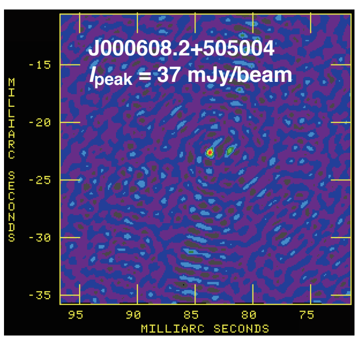

Figure 4 Inversely phase-referenced map of the reference source J0006+5050 taken on March 10. The position offset of the source indicates that of the phase-reference v=1 maser spot (-83.7, 22.6)[mas].

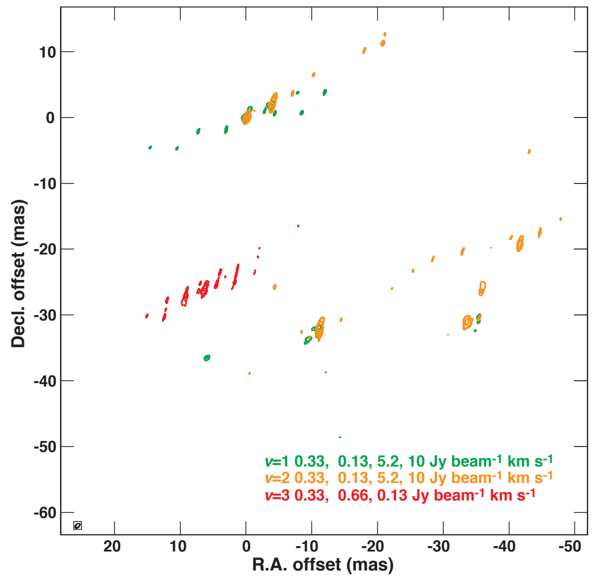

Figure 5 Relative locations of SiO v=1, 2, and 3 J=1→0 maser lines around R Cas taken in March 1. Thanks to the information of the absolute coordinates of the phase-reference v=1 maser spot (Figure 3, 4), the uncertainty of the relative positions was as small as ~0.3 mas. This uncertainty is predominated by the accuracy of registration of the v=2 and 3 maser maps created through self-calibration instead of those though phase-referencing. The former maps of the v=2 and 3 masers yielded better quality than the latter maps.

Observations

VERA+NRO 45m open-use observations with comissioning of OCTAVE 4 Gbps recording and Kashima 34 m operation at the 43 GHz band

r15060a (2015 March 1, VERA+NRO 45m+NiCT Kashima 34m)
- operation problem in Mizusawa, but the data still valid
- NRO data valid only for last two hours
- Data of v=0 and v=1 maser lines invalid from Kashima

r15066b (March 6, VERA only, missing data from Ishigaki)

r15069d (March 10, VERA only)
- problem of Tsys recording in Iriki
- Yielding successful inverse phase referencing (Figure 3, 4)

r15083b (March 24, VERA only)

r15132a (May 12, VERA+NRO 45m, waiting for correlation)

Baseband channel allocations for SiO maser lines

VERA 1Gbps (open use): for v=0 (43.42 GHz) and v=1 (43.12 GHz)
OCTAVE 4Gbps (VERA+NRO 45m+Kashima 34m):
from 42.46 to 43.48 GHz → v=3, 2, 1, 0 for SiO and v=0 for ^{29}SiO (42.52, 42.82, 42.88, 43.12, 43.42 GHz, respectively)
Velocity channel spacing: 512 channels in 8 MHz (about 0.1 km/s)
Velocity resolution in image cube synthesis: about 0.2 km/s

Results and discussion

Marginal detection of the v=0 lines

These lines were cleary detected in the total-power spectra (Figure 1, 2). The profile of the ^{28}SiO v=0 line had been stable within 24 days, and its maximum peak flux (~4 Jy) has persisted for a much longer scale (10 years? Boboltz & Claussen 2004). This line will be composed of thermal and maser components taking into account the temporal profile variation. On the VLBI image cubes, however, they were resolved out completely, just adding noise peaks at 6-σ levels (~0.42 Jy/beam), meaning *marginal detection*. Their locations were uncelar within the searched fields (1″.6×1″.6). Note that that ^{29}SiO v=0 maser line was detected in W Hya (Oyama et al. PASJ submitted) although this line was completely spatially resolved out in our observations.

Distributions of the v=1,2, and 3 maser lines

The v=3 maser distributions are quite different from those of the v=1 and 2 masers while the latters exhibit good spatial correlation (Figure 5). The mapping observation was made at the light curve phase of φ=0.23 (after the light maximum). This result is consistent with the suggestion that the v=3 masers will have good spatial correlation with other lines only at light maximum (Oyadomari et al. in preparation).

Future perspectives

Because of the marginal VLBI detection of the ^{28}SiO v=0 line, we will retry its detection. The data processing for r15132a is forthcoming.