A Progress Report on Maser Mapping of KaVA ESTEMA

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We observed water and SiO masers simultaneously towards 80 evolved stars in the KaVA ESTEMA program from 2015 to 2017. 64 out of the 80 stars (80%) have both water and SiO masers detected or some of them. We had completed image cube syntheses of water and SiO v=1 and v=2, J=1-0 masers for 50% of stars which have the detected masers. Y Cas, shown in figure 2, is a Mira type star and has 413 days period which is one of the candidate sources for the long monitoring observation in the 2nd stage of KaVA ESTEMA program from 2018 (ESTEMA=EAVN Synthesis of Stellar Maser Animations). The distributions of v=1 and v=2 masers around Y Cas have a ring-like shape, and the water masers extended more extensive than the SiO masers. In the case of UX Cyg, is a Mira type star and has 569 days period, the v=2 masers distribute in a ring-like shape, while it seems that v = 1 masers spread wider than v = 2 masers. We show the maser maps of a semiregular variable star and IR star in figure 4 and figure 6, respectively, which have various distributions of the masers.

Maser source (Type)	R.A. (J2000)	Dec. (J2000)	Fringe detection / mapping				
			H_2O	Q1	Q2	W	D
Y Cas (Mi*)	00 03 21.47	+55 40 51.8	Y/Y	Y/Y	Y/Y	Y/IP	N/–
V524 Cas (Mi*)	00 46 00.12	+69 10 53.4	N/–	Y/IP	Y/IP	N/–	N/–
o Cet (Mi*)	02 19 20.79	−02 58 37.4	N/–	N/–	N/–	N/–	N/–
RR Per (Mi*)	02 28 29.40	+51 16 17.3	N/–	Y/IP	Y/IP	N/–	N/–
BW Cam (Mi*)	05 19 52.56	+63 15 55.8	Y/IP	Y/IP	Y/IP	N/–	N/–
S Col (Mi*)	05 46 56.31	−31 41 28.4	N/–	N/–	N/–	N/–	N/–
U Ori (Mi*)	05 55 49.17	+20 10 30.7	N/–	Y/IP	Y/IP	N/–	N/–
AP Lyn (Mi*)	06 34 33.92	+60 56 26.2	Y/Y	Y/Y	Y/Y	Y/IP	N/–
U Lyn (Mi*)	06 40 46.49	+59 52 01.6	Y/Y	Y/Y	Y/N	N/–	N/–
GX Mon (Mi*)	06 52 47.04	+08 25 19.2	N/–	Y/IP	Y/IP	Y/IP	Y/IP
IRC−10151 (OH*)	07 07 49.38	−10 44 05.9	N/–	N/–	N/–	N/–	N/–
Z Pup (Mi*)	07 32 38.06	−20 39 29.1	N/–	Y/IP	N/–	N/–	N/–
OZ Gem(Mi*)	07 33 57.75	+30 30 37.8	Y/IP	Y/IP	Y/IP	Y/IP	N/–
QX Pup (pA*)	07 42 17.16	−14 42 49.9	N/–	N/–	N/–	N/–	N/–
V353 Pup (sr*)	07 46 34.15	−32 18 16.3	Y/Y	N/–	N/–	N/–	N/–
HU Pup (sr*)	07 55 40.16	−28 38 54.8	Y/Y	N/–	N/–	N/–	N/–
R Cnc (Mi*)	08 16 33.83	+11 43 34.6	N/–	Y/IP	Y/IP	N/–	N/–
X Hya (Mi*)	09 35 30.27	−14 41 28.6	N/–	Y/N	Y/N	N/–	N/–
IW Hya (Mi*)	09 45 15.24	−22 01 45.3	N/–	Y/Y	Y/IP	N/–	N/–
R Leo (Mi*)	09 47 33.49	+11 25 43.7	N/–	Y/IP	Y/IP	N/–	N/–
V Ant (Mi*)	10 21 09.11	−34 47 18.7	Y/Y	N/–	N/–	N/–	N/–
R UMa (Mi*)	10 44 38.47	+68 46 32.7	Y/Y	Y/N	Y/Y	N/–	N/–
VX UMa (Mi*)	10 55 39.88	+71 52 09.8	N/–	N/–	Y/N	N/–	N/–
R Crt (sr*)	11 00 33.85	−18 19 29.6	Y/Y	Y/Y	Y/Y	N/–	N/–
RT Vir (sr*)	13 02 37.98	+05 11 08.4	Y/Y	N/–	N/–	N/–	N/–
R Hya (Mi*)	13 29 42.78	−23 16 52.8	Y/Y	Y/Y	Y/N	N/–	N/–
RX Boo (sr*)	14 24 11.84	+25 42 21.1	Y/IP	N/–	Y/IP	N/–	N/–
RS Vir (Mi*)	14 27 16.39	+04 40 41.1	Y/IP	Y/IP	Y/IP	Y/IP	N/–
S CrB (Mi*)	15 21 23.93	+31 22 02.4	Y/IP	Y/IP	Y/IP	N/–	N/–
WX Ser (Mi*)	15 27 47.38	+19 33 42.9	N/–	Y/IP	Y/IP	N/–	N/–
U Her (Mi*)	16 25 47.47	+18 53 32.9	Y/IP	Y/IP	Y/IP	Y/IP	N/–
T Oph (Mi*)	16 33 43.54	−16 07 54.3	N/–	Y/IP	Y/IP	N/–	N/–
V446 Oph (sr*)	16 46 39.11	−11 38 53.1	N/–	Y/Y	N/–	N/–	N/–
AH Sco (SG)	17 11 17.02	−32 19 30.7	Y/IP	Y/IP	Y/IP	Y/IP	N/–
V2108 Oph (Mi*)	17 14 19.39	+08 56 02.6	N/–	Y/IP	Y/IP	N/–	N/–
RW Sco (Mi*)	17 14 51.68	−33 25 54.6	Y/IP	Y/IP	Y/IP	N/–	N/–
IRAS 17187−3750 (IR)	17 22 11.20	−37 53 13.0	N/–	N/–	N/–	N/–	N/–
IRAS17313−1531	17 34 10.80	−15 33 02.0	N/–	Y/N	Y/N	N/–	N/–
IRC−30308 (OH*)	17 38 40.49	−31 57 18.2	Y/IP	N/–	N/–	N/–	N/–
OH358.23+0.11 (OH*)	17 40 53.40	−30 23 09.0	Y/IP	N/–	N/–	N/–	N/–
MHSOM75	17 46 12.46	−28 07 05.3	N/–	N/–	N/–	N/–	N/–
MHSOM100	17 48 18.11	−28 07 38.9	N/–	N/–	N/–	N/–	N/–
V2211 Oph (Mi*)	17 51 09.95	−08 01 21.3	N/–	Y/Y	Y/N	N/–	N/–
V4201 Sgr (sr*)	17 53 18.80	−26 56 37.0	Y/IP	Y/IP	Y/IP	N/–	N/–
V4120 Sgr (Mi*)	18 03 56.54	−20 19 00.4	N/–	Y/IP	Y/IP	Y/IP	N/–
IRC−20427 (Mas)	18 05 35.49	−21 13 42.2	Y/Y	Y/Y	N/–	Y/IP	N/–
IRC−10395 (IR)	18 06 42.88	−08 13 12.0	N/–	Y/Y	Y/Y	Y/IP	N/–
OH16.1−0.3 (pA*)	18 21 06.44	−15 03 29.8	N/–	N/–	N/–	N/–	N/–
V2302 Oph (Mi*)	18 09 18.55	+09 12 15.6	N/–	N/–	N/–	N/–	N/–
V5102 Sgr (sr*)	18 16 26.03	−16 39 56.4	Y/IP	N/–	N/–	N/–	N/–
OH16.1−0.3 (pA*)	18 21 06.44	−15 03 29.8	N/–	N/–	N/–	N/–	N/–
UY Sct (sr*)	18 27 36.53	−12 27 58.9	Y/Y	Y/Y	Y/Y	N/–	N/–
OH24.7+0.2 (OH*)	18 35 29.20	−07 13 08.0	N/–	N/–	Y/Y	N/–	N/–
V1111 Oph (Mi*)	18 37 19.26	+10 25 42.2	Y/IP	Y/IP	Y/IP	Y/IP	Y/IP
V438 Sct (Mi*)	18 41 14.33	−06 15 00.7	Y/Y	Y/Y	Y/Y	N/–	N/–
IRC+00363 (Mi*)	18 41 25.00	−04 20 36.0	Y/IP	N/–	N/–	N/–	N/–
IRC+00364 (IR)	18 42 08.43	−02 45 15.4	Y/Y	N/–	N/–	N/–	N/–
V837 Her (Mi*)	18 43 36.47	+13 57 22.8	Y/Y	Y/Y	Y/Y	N/–	N/–
V1366 Aql (Mi*)	18 58 30.09	+06 42 57.8	Y/Y	Y/Y	Y/Y	N/–	N/–
OH38.10−0.13 (pA*)	19 01 20.05	+04 32 31.6	N/–	N/–	N/–	N/–	N/–
UV Cyg (sr*)	19 31 13.28	+43 38 13.6	Y/Y	N/–	N/–	N/–	N/–
RT Aql (Mi*)	19 38 01.60	+11 43 18.2	N/–	Y/IP	Y/IP	Y/IP	Y/IP
IRAS 19371+2855 (OH*)	19 39 07.77	+29 02 38.6	N/–	N/–	N/–	N/–	N/–
V391 Cyg (Mi*)	19 40 52.39	+48 47 41.5	Y/Y	N/–	N/–	N/–	N/–
V1415 Aql (Mi*)	19 43 45.29	+03 44 30.4	N/–	Y/IP	Y/IP	N/–	N/–
IRAS 19422+3506 (OH*)	19 44 07.00	+35 14 08.2	Y/IP	Y/IP	Y/IP	N/–	N/–
OH65.4+1.3 (OH*)	19 51 21.20	+29 13 01.3	N/–	N/–	N/–	N/–	N/–
V468 Cyg (Mi*)	19 55 38.15	+32 45 33.8	N/–	Y/Y	Y/N	N/–	N/–
V1828 Cyg (Mi*)	20 36 57.04	+37 52 33.9	N/–	N/–	Y/Y	N/–	N/–
IRAS 20381+5001 (Mi*)	20 39 39.60	+50 12 15.0	N/–	N/–	N/–	N/–	N/–
OH83.42−0.89 (OH*)	20 50 58.60	+42 48 11.0	N/–	N/–	Y/Y	N/–	N/–
UX Cyg (Mi*)	20 55 05.52	+30 24 52.1	Y/N	Y/Y	Y/Y	N/–	N/–
AM Cep (Mi*)	21 41 27.08	+76 23 11.3	Y/IP	Y/IP	Y/IP	N/–	N/–
IRC+60370 (Mi*)	22 49 59.20	+60 17 55.0	Y/Y	N/–	N/–	N/–	N/–
V386 Cep (sr*)	22 53 12.33	+61 17 00.4	Y/IP	Y/IP	N/–	N/–	N/–
MY Cep (SG)	22 54 31.71	+60 49 38.9	N/–	N/–	N/–	N/–	N/–
V627 Cas (Sy*)	22 57 40.99	+58 49 12.5	Y/N	Y/Y	Y/N	N/–	N/–
R Peg (Mi*)	23 06 39.17	+10 32 36.1	N/–	N/–	N/–	N/–	N/–
R Aqr (Sy*)	23 43 49.46	−15 17 04.1	N/–	Y/Y	Y/IP	Y/IP	N/–
R Cas (Mi*)	23 58 24.87	+51 23 19.7	N/–	Y/Y	Y/Y	Y/IP	N/–

Table 1 Results of VLBI fringe detections and maser source image cube synthesis for 80 evolved stars observed from 2015 to 2017. The frequency band codes Q1, Q2, W, and D correspond to the SiO masers of v=1 (J=1-0), v=2 (J=1-0), v=1 (J=2-1), and v=1 (J=3-2), respectively. The indexes of results mean below.

Y: VLBI fringes were detected or maser maps were created successfully.
N: VLBI fringes were not detected or maser maps were not created.
IP: In process of data reduction.

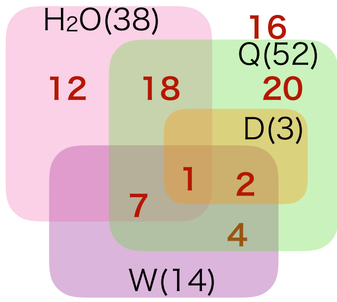

Figure 1 Venn diagram of VLBI fringe detections of water and SiO masers. 26 stars, correspond to 33% of observed stars, simultaneously detectable in H_2O and ^{28}SiO J=1→0 v=1 and v=2 masers.

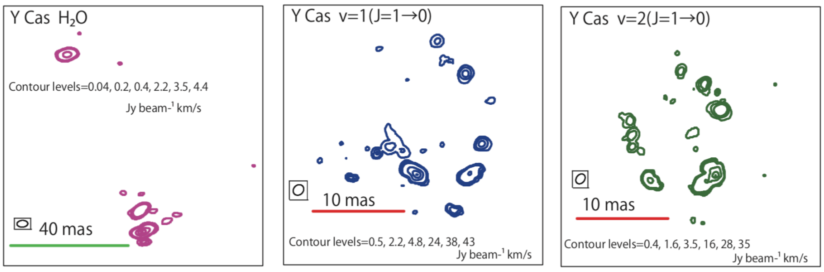

Figure 2 (Left panel) Distributions of water masers (left), SiO v=1 masers (middle), and v=2 masers(right) around Y Cas taken in the sessions r15355b and r15356b (at the light curve phase $\phi \sim 0.0$).

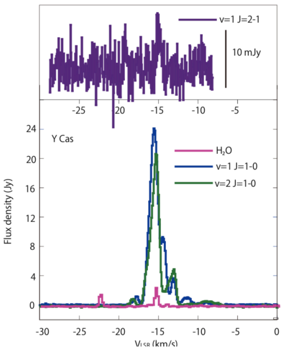

Figure 3 (Right panel) Cross-power spectra for Y Cas with a KVN baseline between YONSEI and ULSAN.

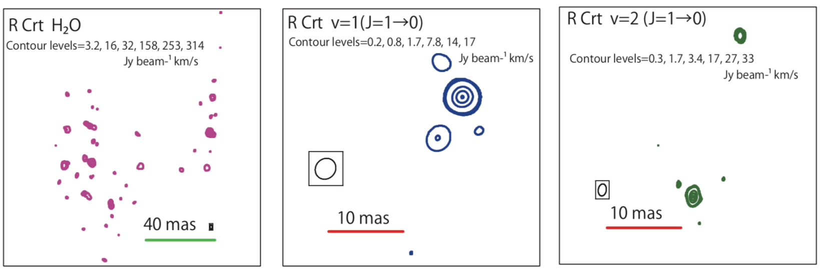

Figure 4 (Left panel) Same as figure 2 but around R Crt. The stellar light curve phase is unknown.

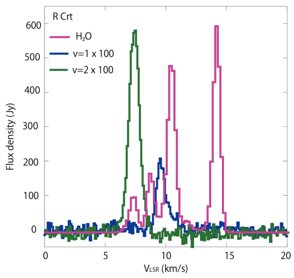

Figure 5 (Right panel) Same as figure 3 but for R Crt. The flux densities of SiO v=1 and v=2 J=1→0 are multiplied by 100 in the displayed spectra.

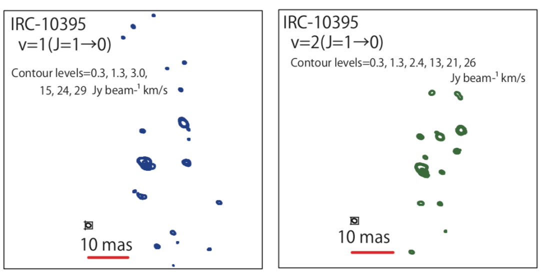

Figure 6 (Left panel) Distributions of SiO v=1 masers (left) and v=2 masers(right) around IRC-10395 taken in the sessions r16123a and r16124b. The stellar light curve phase is unknown.

Figure 7 (Right panel) Same as figure 6 but around UX Cyg taken in the sessions r16083a and r16184a (at the light curve phase $\phi \sim 0.8$).