KaVA ESTEMA and the Large Program on circumstellar masers

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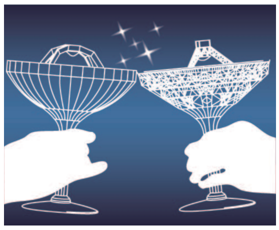


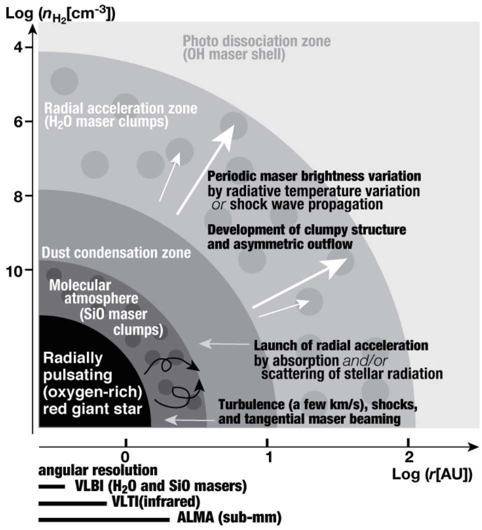
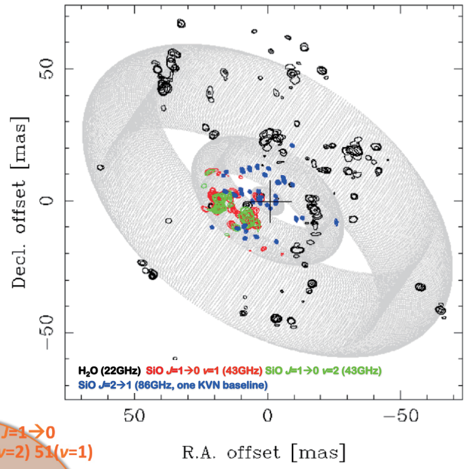


Figure 1
Schematic view of the structure of a circumstellar envelope around an O-rich long-period pulsating star and hosting SiO and H_2O masers. Gas ejected from the stellar surface forms molecules, then O-/Si-rich dust. The dust particles are transparent and accelerated by stellar radiative pressure received through scattering of stellar infrared radiation. The dust condensation, turbulence, and shock waves should be linked and explored in KaVA maser animation synthesis.

Figure 2
Composite map of H_2O and SiO (J=2→1 and 1→0) masers associated with the red supergiant S Persei, obtained in the KaVA (K/Q-bands)/ KVN (K/Q/W-band) commissioning observation (Asaki et al. in prep.).



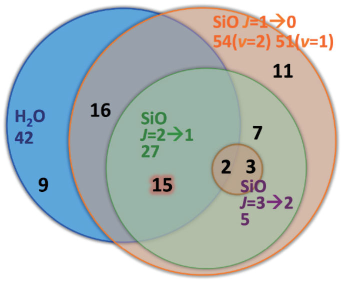


Figure 4
Venn diagram showing the overlap in occurrence of detections of maser emission in long-integration scalar-averaged spectra in KaVA ESTEMA.

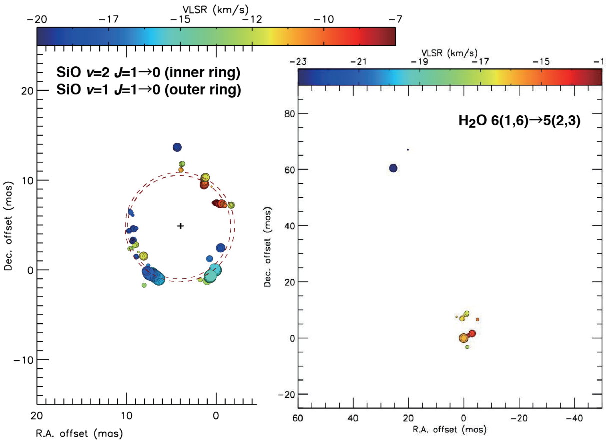


Figure 3
First images of H_2O and SiO masers around Y Cas observed in KaVA ESTEMA. Righ-shaped morphologies of the SiO masers are visible even in limited integration time (~2 hours). The H_2O masers exhibit a highly biased distribution, but such distribution is typically seen in circumstellar H_2O masers even in high sensitivity imaging (Imai et al. in preparation).

Table 1
Target maser and phase-reference/delay calibration sources in new ESTEMA

	Source name (order of priorit	reference	Coordinates (J2000) R.A. (hh:mm:ss.sss)			Decl. (±dd:mm:ss.ss)			*Approx. flux density (Jy/b)		Duration in total (hr)	Source category	Epochs per year	Span per epoch	Duration (year)	Total epochs
Target maser sources (order of priority)										P (days)						
1	omicron Cet	symbiotic star	02	19	20.7921	−02	58	39.496	4.7(K) / 1303 (Q)	333	300	A1	20	5	3	60
2	RS Vir	Mira	14	27	16.3900	04	40	41.143	39.1(K) / 12.4(Q)	353	300	A2	20	5	3	60
3	BX Cam	Mira	05	46	44.2900	69	58	24.200	78.4(K) / 77.1(Q)	486	260	B1	13	4	5	65
4	HU Pup	semiregular	07	55	40.1843	−28	38	54.689	10.2(K) / 15.2(Q)	820	335	C1	10	5	6.7	67
5	V438 Sct	OH/IR	18	41	14.3300	−06	15	0.700	14.2(K) / 7.6(Q)	1181	407.4	D1	7	6	9.7	67
6	NML Cyg	red supergiant	20	46	25.5444	40	6	59.383	45 (K) /3.4(Q)	~1000	325	D2	7	5	9	63
7	RT Vir	semiregular	13	02	37.9814	05	11	8.383	96.9(K) / 8.9(Q)	306	300	A3	20	5	3	60
8	RX Boo	semiregular	14	24	11.6266	25	42	13.409	20.5(K) / 10.8(Q)	372	300	A4	20	5	3	60
9	Y Cas	Mira	00	03	21.4700	55	40	51.800	3.9(K) / 17.2(Q)	414	260	B2	13	4	5	65
10	IW Hya	Mira or OH/IR	09	45	15.2400	−22	01	45.300	7.9(K) / 40.8(Q)	650	310	C2	10	5	6.2	62
Delay calibrator/phase-reference sources									(Jy/beam)	Sep. (deg)						
1	J0215−0222	VLBA Cal.	2	15	42.017291	−2	22	56.75238	0.14 at K band	1.08	108	Ref. A1	20	1.8	3	60
2	J1422+0414	Oyama in prep.	14	22	42.490502	4	14	39.12077	0.041 at Q-band	1.22	108	Ref. A2	20	1.8	3	60
3	J0524+7034	Oyama in prep.	5	24	13.433416	70	34	52.90621	0.16 at Q-band	1.99	97.5	Ref. B1	13	1.5	5	65
4	J0747−2919	Oyama in prep.	7	47	41.889632	−29	19	2.06148	0.09 at Q-band	1.87	120.6	Ref. C1	10	1.8	6.7	67
5	J1846−0651	Oyama in prep.	18	46	6.300263	−6	51	27.74616	0.05 at Q-band	1.35	154	Ref. D1	7	2.2	10	70
6	J2046+4106	Zhang et al. 2012	20	46	21.8414	41	6	1.107	0.017 at Q-band	1.00	113.4	Ref. D2	7	1.8	9	63
7	J1308+0401	Oyama in prep.	13	8	15.553075	4	1	9.35157	0.026 at K band	1.82	108	Ref. A3	20	1.8	3	60
8	J1419+2706	VERA	14	19	59.297073	27	6	25.55274	0.42 at K band	1.69	108	Ref. A4	20	1.8	3	60
9	J2353+5518	rfc_2017b	23	53	42.299696	55	18	40.66649	0.24 at X band	1.42	97.5	Ref. B2	13	1.5	5	65
10	J0921−2618	VLBA Cal.	9	21	29.353855	−26	18	43.38616	1.22 at X band	6.91	111.6	Ref. C2	10	1.8	6.2	62

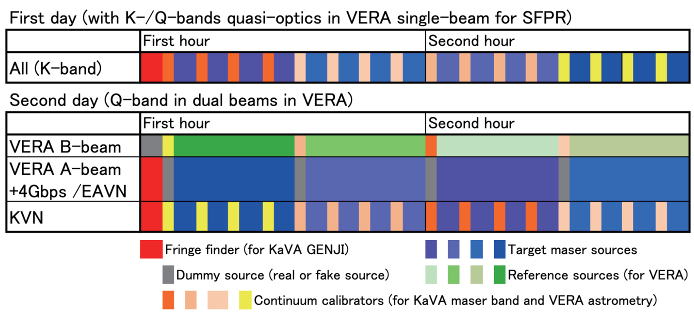


Figure 5 Scan patterns that will be adopted in the new ESTEMA sessions. Each session in one day suppose a block of 3—9 hours for 1—3 maser sources.

KaVA/EAVN Large Programs on circumstellar masers

Phase 1: KaVA ESTEMA (Extended Study on Stellar Masers)

2015 October —2017 March

Snapshot imaging of H_2O and SiO masers in circumstellar envelopes (Figure 1), around 80 stars. Using multi-frequency phase-referencing, composite maps will be produced (Figure 2). Image synthesis is ongoing (Figure 3), but we can find at least 15 stars suitable for the phase 2 project (Figure 4).

Phase 2: new ESTEMA (EAVN Synthesis of Stellar Maser Animations)

2018—2027, ~450 hours/year

10 pulsating stars (P=306—1433 days) monitoring SiO and H_2O masers in every 1/20 pulsation cycle over a few pulsation cycles for "stellar maser animation" synthesis. The new ESTEMA sessions will adopt the scan patterns (Figure 5), similar to those in KaVA ESTEMA. The time allocation model for the monitoring observations are considerd (Figure 6) for realistic monitoring program for a decade. K-/Q-band simultaneous observations shall be conducted in the whole KaVA. Tianma, Nanshan, Sejong, and Nobeyama will be added dependent on available setup, season, and time allocation rule.

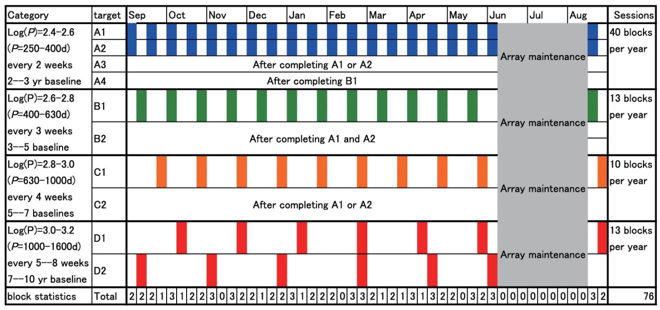


Figure 6 Model of session allocations for new ESTEMA.