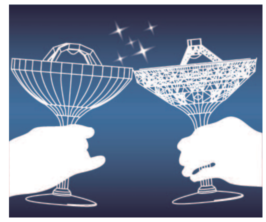
KaVA ESTEMA (Expanded Study on Stellar Masers)



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Time line and specification of the KaVA Large Programs on circumstellar masers

Phase 1: ESTEMA (approved)
during 2015 autumn—2016, 2 years ×120 hours
Snapshot imaging of H_2O and SiO masers in circumstellar envelopes (Figure 1)
around ~80 stars (source list in public)

- statistics of stellar masers
  - i. maser spot sizes and shapes
  - ii. distributions of H_2O masers with respect to locations of SiO masers
  - iii. correlation with kinematic parameters of circumstellar envelopes and stars
- yielding a larger sample of stars as targets of the Phase 2 project

Phase 2: Intensive monitoring campaign
during 2016—2024, 400—500 hours/year
16—20 pulsating stars (P=300—1600 days)
monitoring SiO and H_2O masers in every 1/20 pulsation cycle over a few pulsation cycles for "stellar maser movie" synthesis

- detecting (both or either)
  - i) propagation of pulsation-driven shock waves (Figure 2)
  - ii) periodic change in physical conditions affected by stellar radiation
- Comprehensive synergy with ALMA, VLTI, Nano-JASMINE

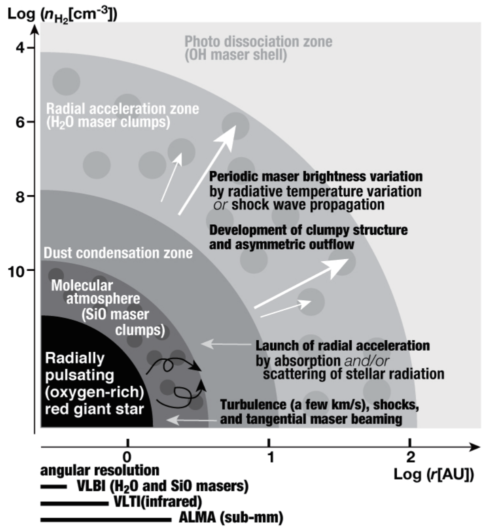

Figure 1
Schematic view of the spatial and density structure of a circumstellar envelope of an oxygen-rich (intermediate-mass) long-period pulsating star that hosts SiO and H_2O masers. Gas ejected from the stellar surface forms molecules, then oxygen/silicon-rich dust (e.g. silicate and olivine). The dust particles are accelerated by stellar radiative pressure received through scattering of stellar infrared radiation. The microscopic (dust condensation) and macroscopic (turbulence, shock waves) process should be linked and explored in the KaVA projects.

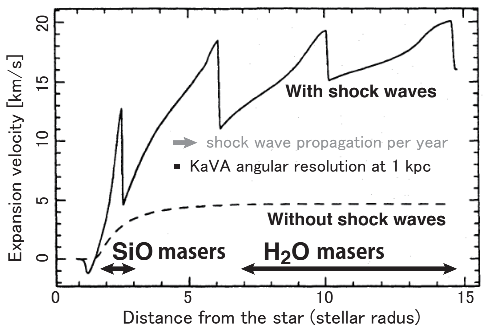

Figure 2
Schematic view of the radial velocity field of a circumstellar envelope of a pulsating star and the locations of the hosting SiO and H_2O masers. Pulsation driven shock waves will be detectable by directly finding the velocity field and its time variation in the intensive KaVA monitoring program over a few stellar pulsation cycles.

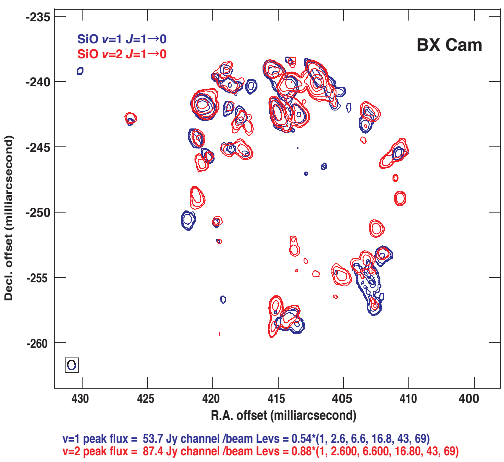

Figure 3 ESTEMA imaging demonstration resulted from the KaVA data of the SiO masers around BX Cam (including astrometric map registration).

ESTEMA operation design

Scan patterns in each session (Figure 3, 4)
Two-day pairs of blocks for K&Q-bands with VERA for K/Q/W/D bands with KVN
This yields a good (u,v) coverage
(~60 min + ~120 min integration with VERA and KVN, respectively)

Baseband channel allocation (Figure 5)
Covering 1 H_2O and 5 SiO (3, 1, 1 lines at Q-, W-, D-bands, respectively) lines

Data analysis mission for multiple scientific outcomes
1. KaVA snapshot images of 1 H_2O and 2 SiO (v=1 & J=1→0) maser lines
2. Astrometry (VERA dual beam & slow antenna nodding)
3. mm VLBI with KVN (SiO v=1 & J=2→1 and J=3→2 maser lines, with SFPR)

Data analysis processing (using AIPS/ParselTongue/Python)
a. ESTEMA ingest pipeline: amplitude calibration and data splitting for each mission
b. Standard data calibration pipelines for KaVA imaging and astrometry
c. Advanced data processing: SFPR
d. Data archiving: calibrated visibilities, image cubes, important plots, pipeline inputs

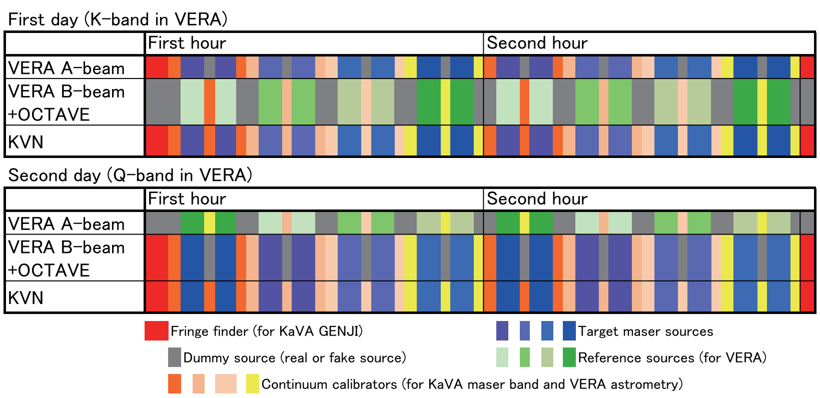

Figure 4 Scan patterns adopted in the KaVA ESTEMA sessions. The ESTEMA sessions suppose a block of 6 hours for 4 maser sources.

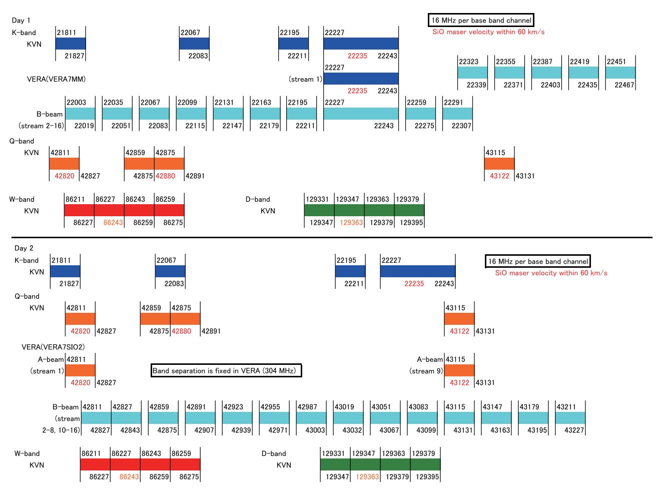

Figure 5 Baseband channel allocations for ESTEMA.