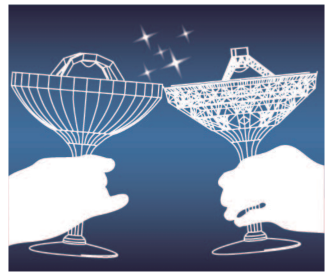
KaVA Large Programs of Circumstellar Masers



KaVA Evolved Stars sub-Working Group

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Specification of the Large Programs

Phase 1: ESTEMA

(Expanded Study on Stellar Masers)
during 2015—2016, ~200 hours
Snapshot imaging of H_2O and SiO masers in circumstellar envelopes (Figure 1) around ~80 stars

- statistics of stellar masers
  - i. maser spot sizes and phapes
  - 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

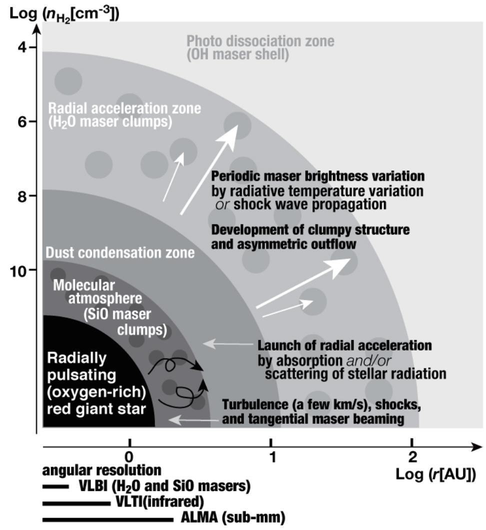


Figure 1

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.

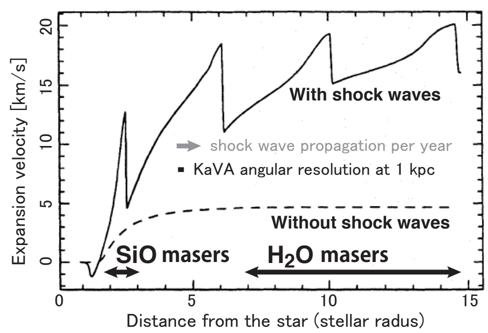


Figure 2

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.

Current progress towards the Large Programs

Imaging feasibility
image quality comparable to that with the VLBA (figure 3, 4)

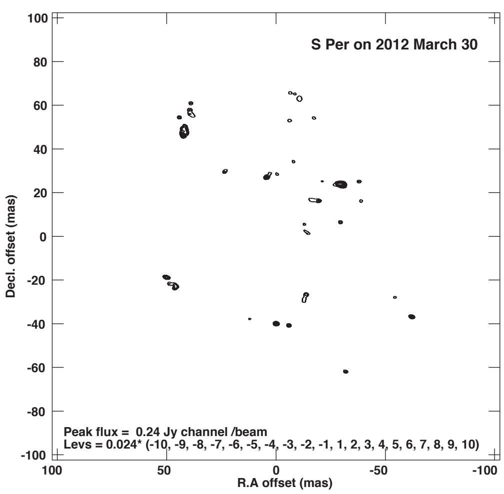
Snapshot imaging feasibility
Focused image in <2 hour integration time with a good (u,v) coverage

Feasibility of maser map registration onto a common coordinate system
Feasible in the source-frequency phase-referencing technique (Figure 5)
Now testing it in KaVA operation

Feasibility of maser source astrometry
feasible with VERA dual beam, testing in antenna fast-nodding mode

Scheduling of single observation session
testing hybrid operation (KaVA imaging + VERA astrometry + KVN SFPR)

Modeling of long-term campaign
Confirming the reality of biweekly-monthly monitoring operation, including scheduling, array operation, correlation, data processing, and archive



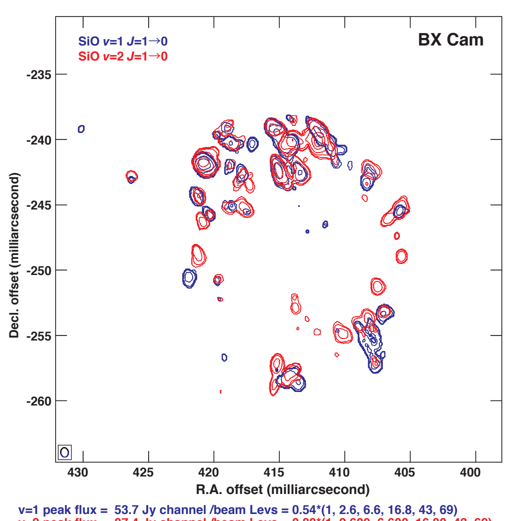


Figure 3 (top left) H_2O maser map in S Per taken with KaVA (by K. Kusuno, Y. Asaki)
Figure 4 (bottom left) SiO maser map in BX Cam taken with KaVA/KJCC (by H. Imai)

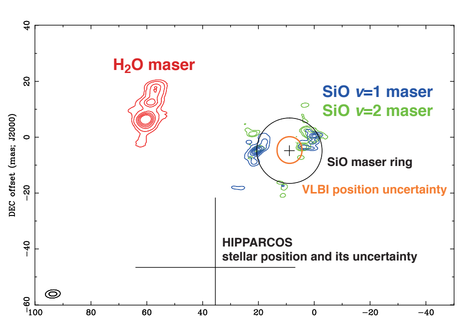


Figure 5

Demonstration of the source-frequency phase-referencing technique (SFPR) with KVN (Dodson et al. 2014). This technique will be adopted in the KaVA Large Programs. Note that this request high precision maser source astrometry as made with VERA as well.