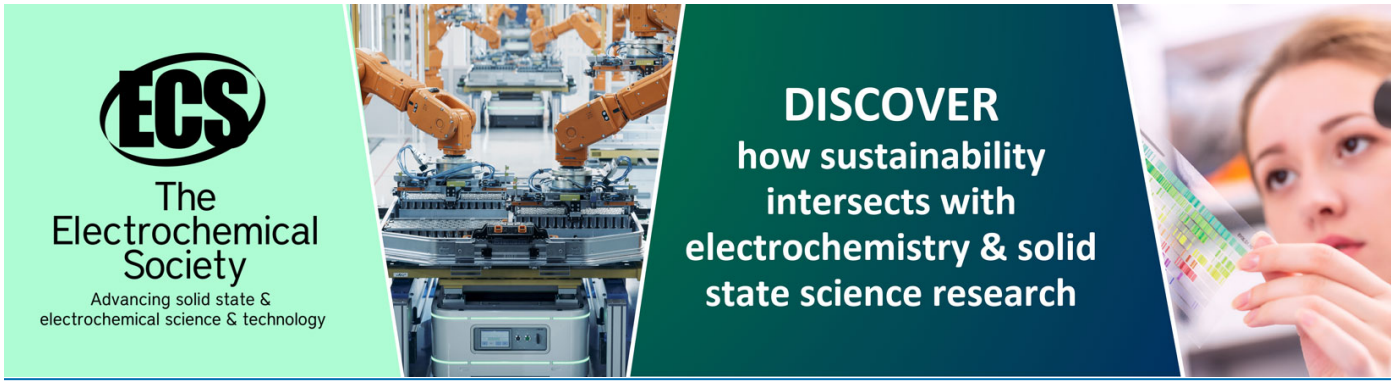
KaVA ESTEMA project



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Abstract. The ESTEMA (Expanded Study on Stellar Masers) project is one of three Large Programs of the KaVA (the combined array of the Korean VLBI Network and Japanese VLBI Exploration of Radio Astrometry), and conducted in 2015–2016. It aims to publish a database of the largest sample of VLBI images of circumstellar water (H_2O) and silicon-monoxide (SiO) maser sources towards circumstellar envelopes (CSEs) of 80 evolved stars in late AGB to early post-AGB phase. Here we present the specifications of the ESTEMA observations and the planned scientific goals in order to share the basic information of the ESTEMA with astronomical community and encourage future collaborations with the ESTEMA and future follow-up observations for the targeted stars.

Circumstellar maser sources are important tools of diagnostics of the dynamical and physical conditions of CSEs. These masers are spatially resolved into compact clumps of maser emission in VLBI, whose three-dimensional relative motions are also traceable though monitoring VLBI observations. Different species of maser lines are located at different distances from the central stars and, due to the maser actions, it is difficult to directly derive the physical parameters of the maser regions in CSEs without the knowledge of the maser properties. Therefore, simultaneous observations of these masers associated with common stars are crucial. Moreover, CSEs are affected by stellar pulsation and inhomogeneous mass loss; such performance of dynamic CSEs will be elucidated by monitoring VLBI observations.

Using the unique specifications of the Korean VLBI Network (KVN) and Japanese VLBI Exploration of Radio Astrometry (VERA), which enable, respectively, simultaneous observations of the masers at four frequency bands (around 22, 43, 86 and 129 GHz) and high-precision astrometry using the dual-beam receiving system, as well as the form of KaVA for high

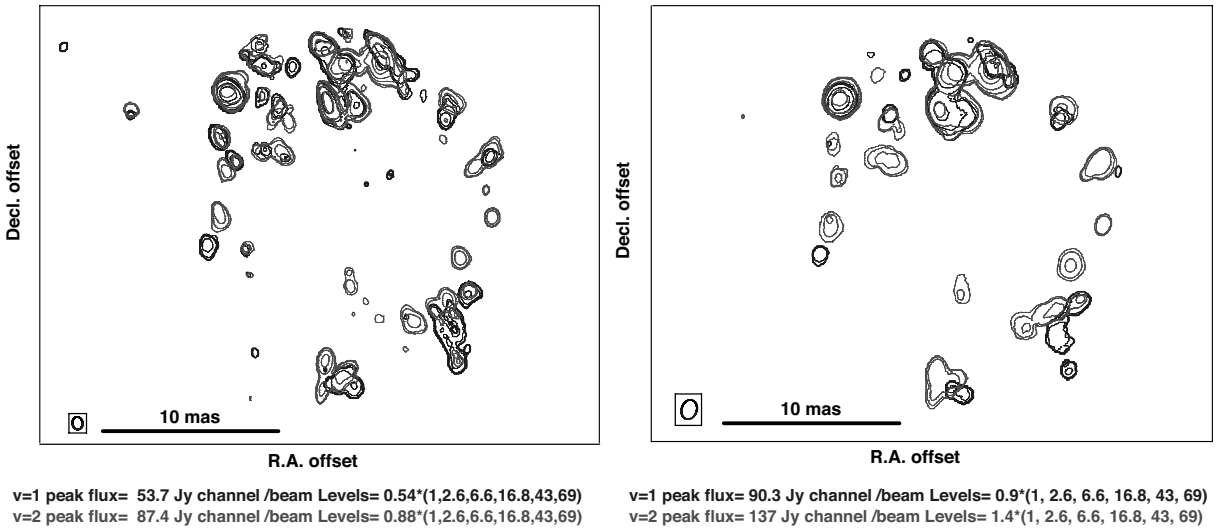

Figure 1. KaVA ESTEMA imaging demonstration for the SiO masers around BX Cam. The maser source was scanned in 17 times for 8 minutes each. The $v = 1$ and $v = 2$ $J = 1 \rightarrow$ masers brightness distributions are displayed in dark and light grey contours, respectively. *Left:* Map obtained by using all available visibility data of the KaVA observation. *Right:* Same as the left panel, but using the data expected to be obtained in an ESTEMA observation mode.

quality imaging [1], we have planned KaVA Large Projects to conduct more systematic legacy observations projects for circumstellar masers. We finally aims to monitor ∼20 stars in VLBI intensively (every 2–12 weeks depending on stellar pulsation period) throughout a few pulsation cycles (2–10 years). The first stage of the Large Projects named ESTEMA, whose name comes from Spanish "estema" (English "stemma", meaning "a family line"), will finally select such 20 stars from the snapshot imaging surveys for 80 stars (adding a few sources observed before the ESTEMA in KaVA commissioning [2]), whose large fraction of maser lines will be mapped through the whole stellar pulsation cycle. Using the whole ESTEMA maps, which are expected to be yielded as shown in Figure 1, it enables statistical analyses of the masers observed among different types of stars at a variety of pulsation phases, from microscopic (individual maser spots) to macroscopic (CSE) views. In the ESTEMA, for each star the relative locations and distributions of different maser lines are directly compared. Thus it enables us to analyze the dependence of maser pumping mechanisms on stellar type and pulsation phase, plus the evolution of asymmetric stellar mass loss found through biased H_2O maser spatio-kinematic structures in the CSE with respect to the SiO maser location, pinpointing the central star.

Because the ESTEMA is a risk-shared project, there are some problems in array operations and data processing in the observations. Nevertheless, a large fraction of the data will be yielded as planned, and the ESTEMA outputs will become a legacy reference for planning any long-term intensive monitoring campaigns of evolved stars exhibiting high mass loss rates, with current large and forthcoming radio astronomy facilities including KaVA and ALMA.

Acknowledgments

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References

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