Abstract

At the commissioning phase of KVN from 2009 to 2013, single dish survey performed toward about 1000 evolved stars and monitoring observations also toward about 60 relatively strong SiO and H$_2$O maser sources. Based on these single dish results and VLBI feasibility test observations at K/Q/W/D bands in 2014, KVN Key Science Project (KSP) centered on VLBI observations has started from 2015 and will be completed in 2019 as phase I. Here we report the overview of studies on evolved stars using KVN. In KSP phase I, we have focused on nine KSP sources which show a successful astrometrically registered maps of SiO and H$_2$O masers using the Source Frequency Phase Referencing (SFPR) method. We aim at investigating the spatial structure and dynamical effect from 43/42/86/129 GHz SiO to 22 GHz H$_2$O maser regions associated with a stellar pulsation and development of asymmetry in circumstellar envelopes.

Observational Results

- Successful SFPR maps of H$_2$O and SiO masers were obtained from KSP 9 stars: VX Sgr, VY CMa, IK Tau, R Crz, W Hya, V1111 Oph, V627 Cas, V5102 Sgr, WX Pac

Supergiant Star VX Sgr (PhD thesis of DH Yoon 2019)

43 GHz SiO maps of whole monitoring: 2014-2019A

VX Sgr: (Left) NE-SW transformations appeared from 2017 Feb, which shows the shortest period, 517 days (green box in the light curve). Probably caused by the variations of pulsation motion (Right) Variation of SiO ring radius with optical light curve. Ring radius of 129 GHz maser increases near optical max. Radiative pumping is dominant.

4 Band SFPR Maps (Movie) of H$_2$O and SiO Masers toward VY CMa

SH Cho et al. in prep., Movie by YJ Yun

VY CMa: (Left) Four band integrated intensity maps of H$_2$O and SiO masers. The SiO v=1, J=3-2 maser location is different from those of other SiO masers. (Right) The H$_2$O and SiO maser movies for 8 epochs. The SiO movies show an elliptical pulsation motions (NE-SW pulsation).

Semiregular b-Type Variable R Crz: P~160 days

Ring size of SiO v=1, J=2-1 maser in R Crz is smaller than that of v=1, J=1-0 different from known results (DJ Kim et al. 2018).

OH/IR star: WX Psc, V1111 Oph ► YJ Yun’s presentation

Symbiotic star: V627 Cas ► HY Yang’s pres.

OH/IR maser from WX Psc, near IR3

Discussion and Future Works

- What is the development process for changing from ring (elliptical)-like structure of SiO masers to highly asymmetric structure of H$_2$O maser via dust formation layer including the transformations of SiO ring-like structure ?
- Differences of pumping mechanism among SiO masers.
- Completion of movies and polarization obs.
- Hydrodynamical model combining SiO and H$_2$O maser propagation ► Gray et al. 2009

Observations Data Reduction

Target Sources for KVN Single Dish and VLBI Obs.

KVN Single Dish and VLBI Monitoring Obs.

- Single dish survey toward ~1000 stars from 2009 : SRs, Miras, SGs, OH/IR stars (252), Post-AGB stars (182), Symbiotic stars
- Single dish monitoring toward about 10-15 strong SiO and H$_2$O maser sources together with VLBI every 1-3 months regularly
- VLBI monitoring focused on 10 successful SFPR objects
- Obs. lines : H$_2$O 6$_{5,2}$-5$_{4,1}$, SiO v=1, 2, J=1-0, 2-1, and v=1, J=3-2
- Source Frequency Phase Referencing (SFPR) technique (Dodson et al. 2014) and SFPR pipeline (2019 YJ Yun) were adopted.

Observational Results

Summary of KVN Single Dish Observations

- Both SiO and H$_2$O masers are detected from a large number of AGB stars (SR, Mira, SG: 188-401, OH/IR: 92/22) at one epoch obs. Both H$_2$O & SiO masers are detected from known SiO-only and H$_2$O-only detected sources (Kim et al. 2010, 2013, Cho et al. 2012).
- Intensity variations of SiO and H$_2$O masers show similar patterns for several stars (Ref: H$_2$O maser maximum are scattered in the range of phase, 0.7-1.5, Shintani et al. 2008, Kim et al. 2014).
- SiO maser intensities are stronger than H$_2$O maser in most evolved stars and at most optical phases. However, peak intensities of H$_2$O are stronger than those of SiO around maximum phases in several stars (Kim et al. 2014).
- FW2P of SiO maser shows a similar value in both Mira variables and OH/IR stars, while FW2P of H$_2$O maser is large in OH/IR stars compared with that in Mira variables (Kim et al. 2012, 2014, Cho et al. 2017).
- One-way, double peaks of H$_2$O masers, and SiO v=2-0 only masers appear at late stage of AGB evolution and at post-AGB stage (Yoon et al. 2014, Cho et al. 2017).
- Different detection rates between SiO and H$_2$O masers at post-AGB stage (Yoon et al. 2014).

References

Cho et al. 2018, Proceedings IAU Sym. 336


Yoon et al. 2014, AJSP, 211, 15