

Dynamics of jet/outflow driven by high mass young stellar object revealed by KaVA 22 GHz water maser observations.

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COLLEAGUES: KAVA SCIENCE WORKING GROUP FOR STAR-
FORMING REGIONS

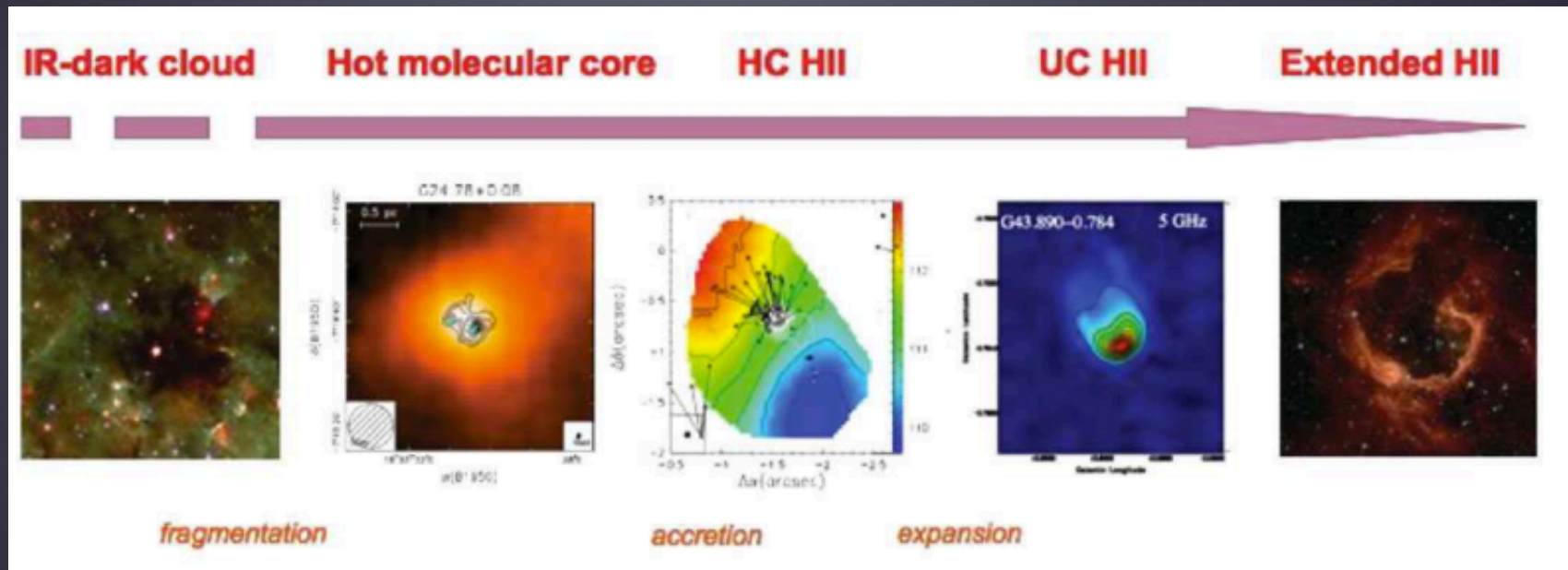
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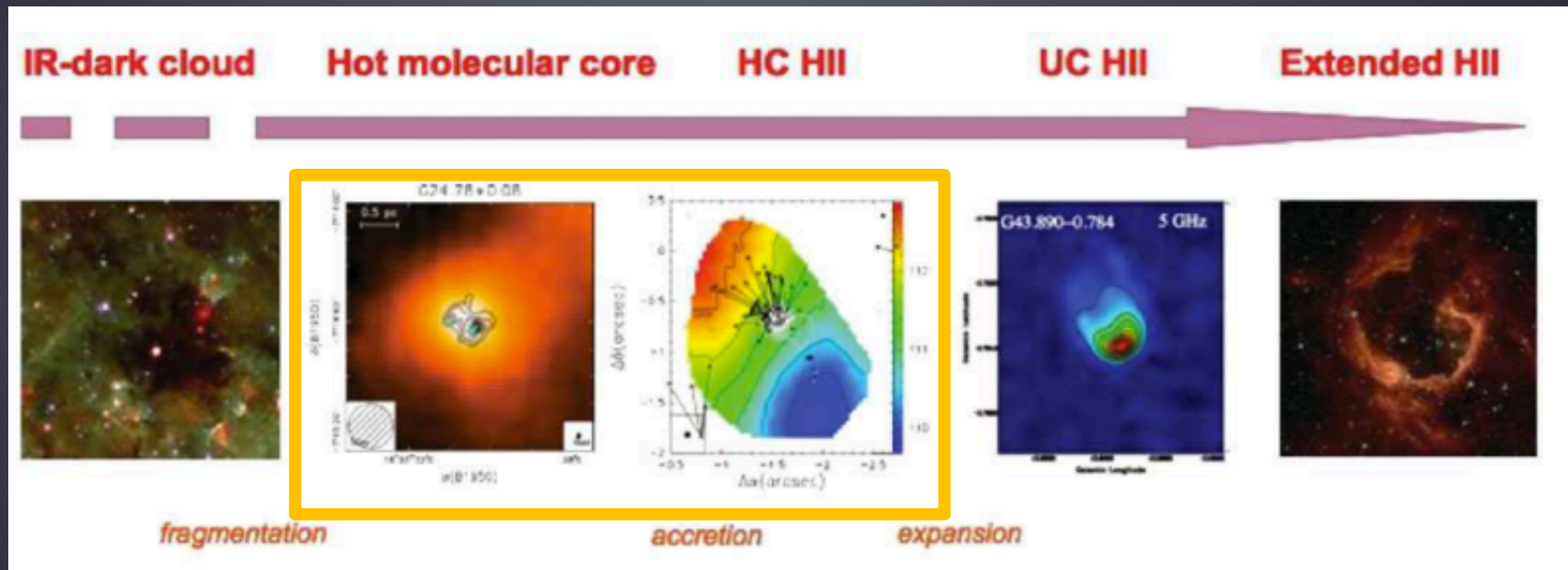
High-mass Star Formation

- ▶ High-mass star formation is still far from understanding **observationally**.
- ▶ Evolutionary Sequence of high-mass young stellar objects (HMYSOs)



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Astrophysical Masers

▶ Water (H₂O) masers at 22 GHz

- Tracing shocked gas associated with dynamical structures such as high velocity jets, outflows etc

▶ Methanol (CH₃OH) masers

- Class I at 44 GHz (Menten 1991)

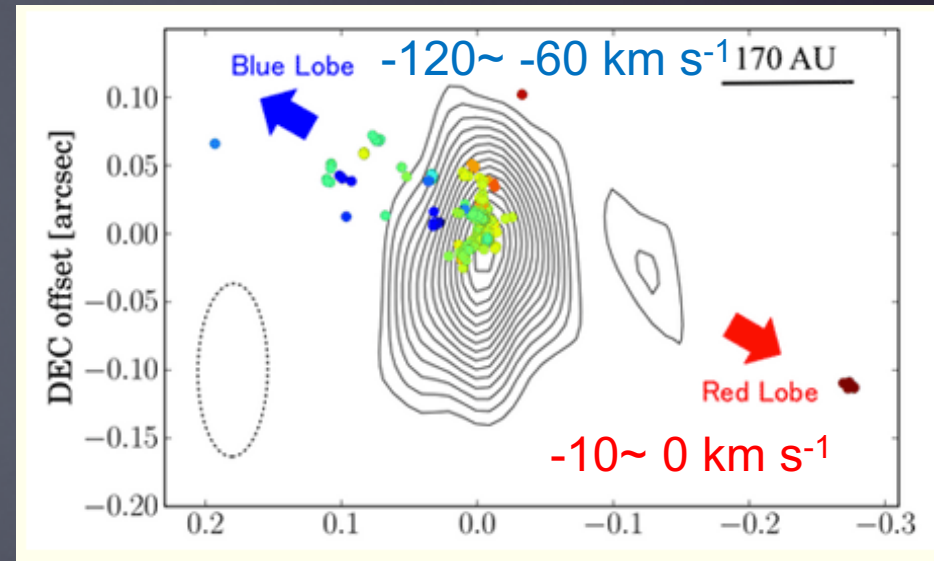
→ Low-velocity outflows

- Class II at 6.7 GHz (HMYSOs only?)

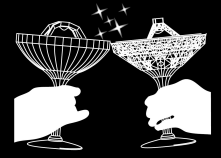
→ Rotating disks or outflows (under debating)

Masers are useful tracers of the dynamical signpost of HM star formation.

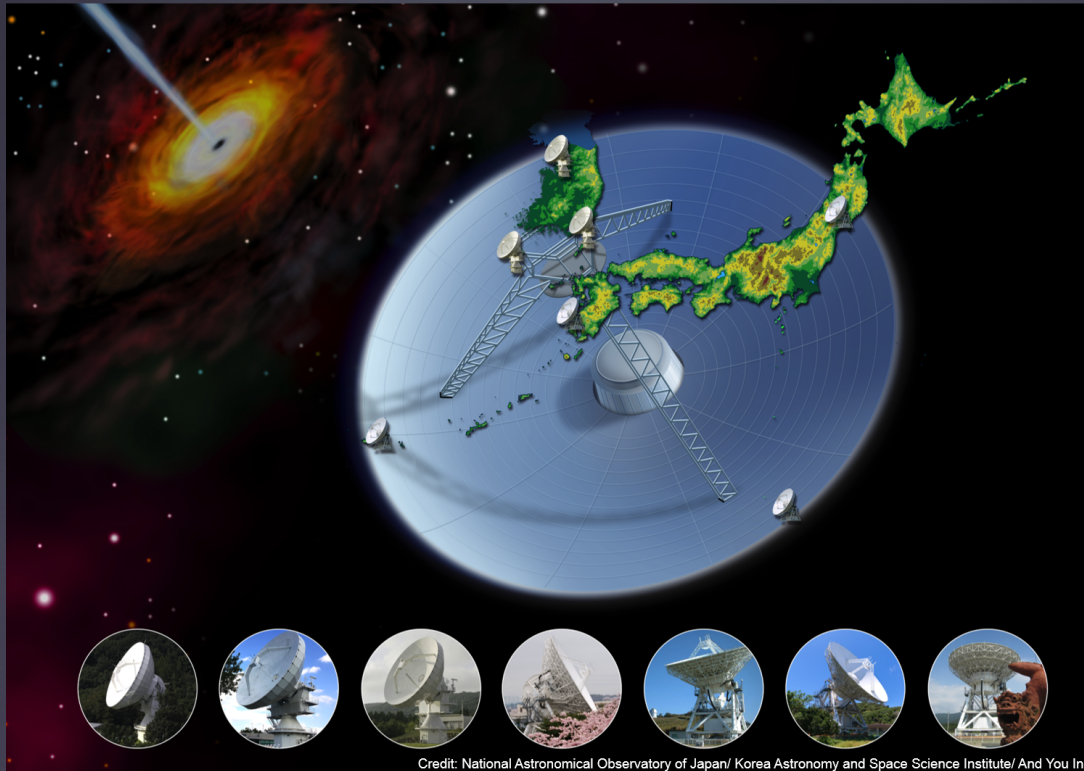
Motogi+2017



Bipolar jet from the G353.273+0.641



KaVA (KVN and VERA Array)



Credit: National Astronomical Observatory of Japan/ Korea Astronomy and Space Science Institute/ And You Inc.

Base line range:
200 km ~ 2300 km

Observable bands:
22 GHz and 44 GHz

- ▶ Combined VLBI array with **three** 21-m radio telescopes of **KVN** (Korean VLBI Network) and **four** 20-m radio telescopes of **VERA** (VLBI Exploration of Radio Astrometry)
- ▶ The highest angular resolution: ~ 1.2 mas @ 22 GHz

Motivations

- ▶ To establish an evolutionary scenario using different maser species enlarge samples of HMYSOs having VLBI image
- ▶ To investigate dynamics of jet/outflow+disk systems driven by HMYSOs by analyzing 3D velocity field and spatial structure of water masers
- ▶ To reveal their launching and mass accretion processes

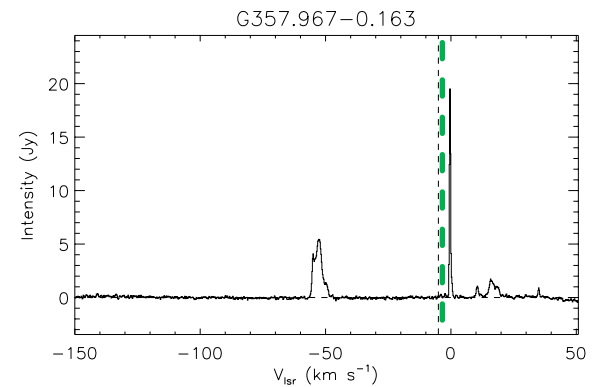
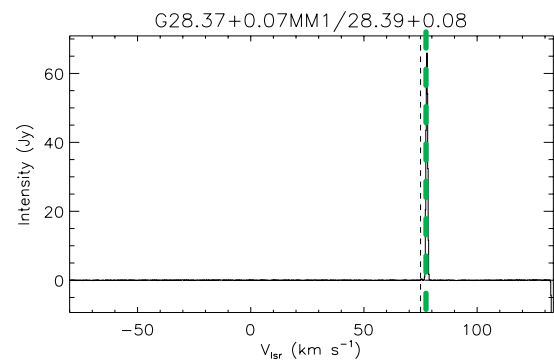
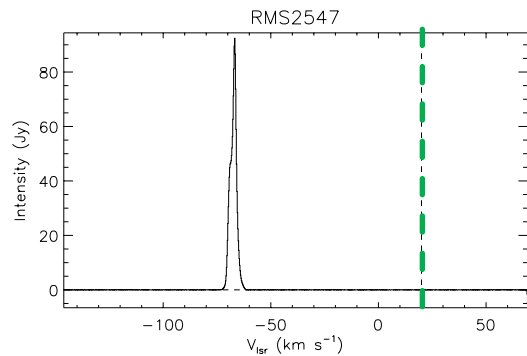
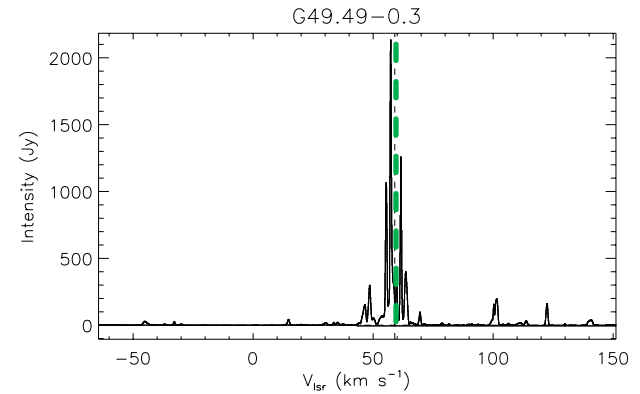
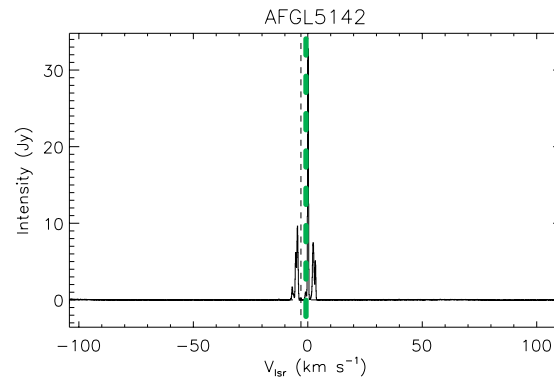
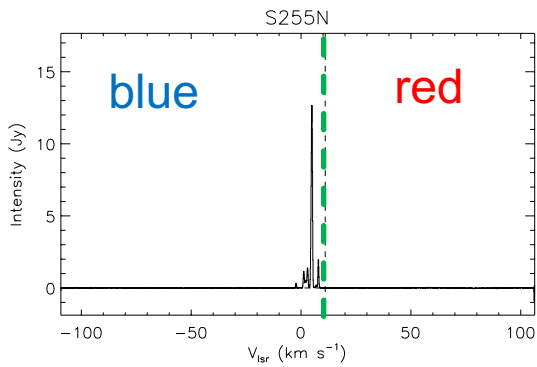


RESULTS

OVERALL SPECTRA

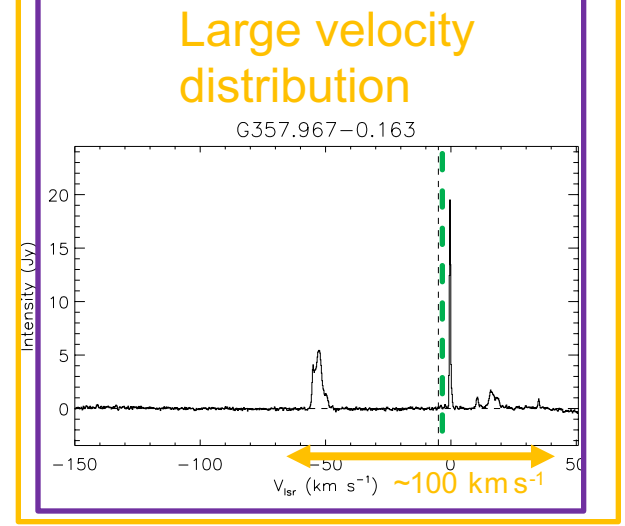
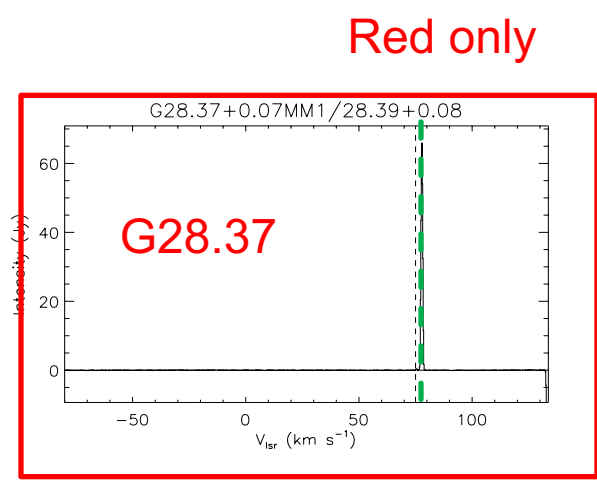
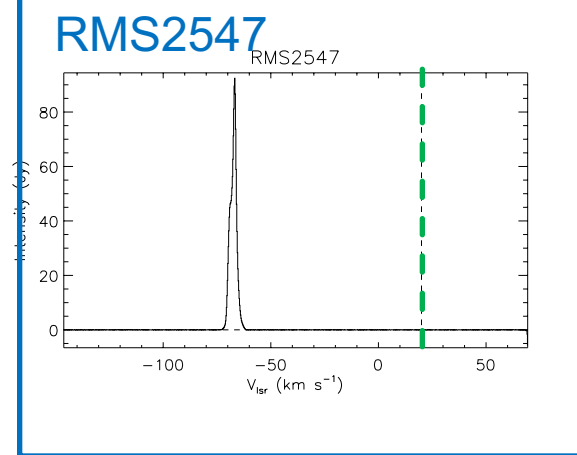
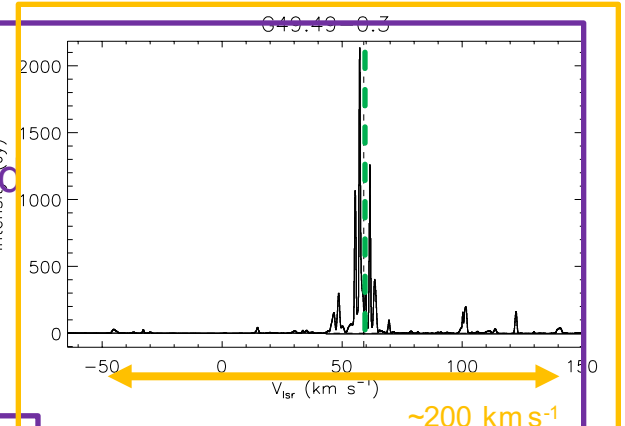
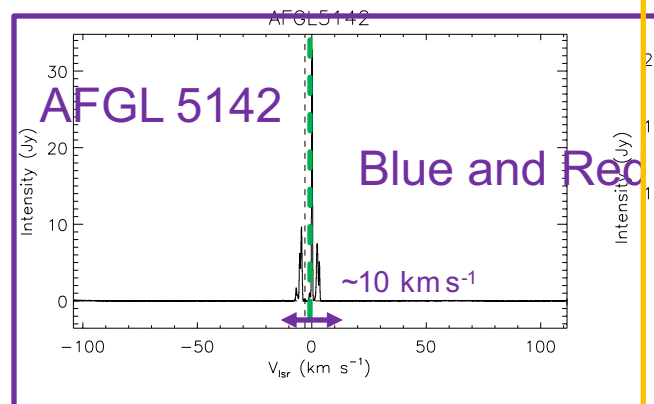
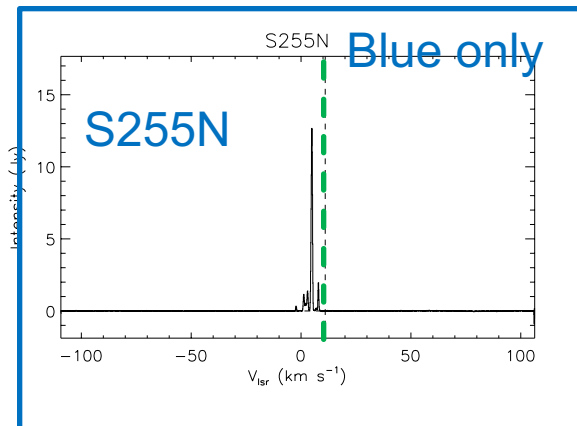
Results – Examples of Water maser Spectra

Dashed vertical lines indicate systemic velocities of each sources.



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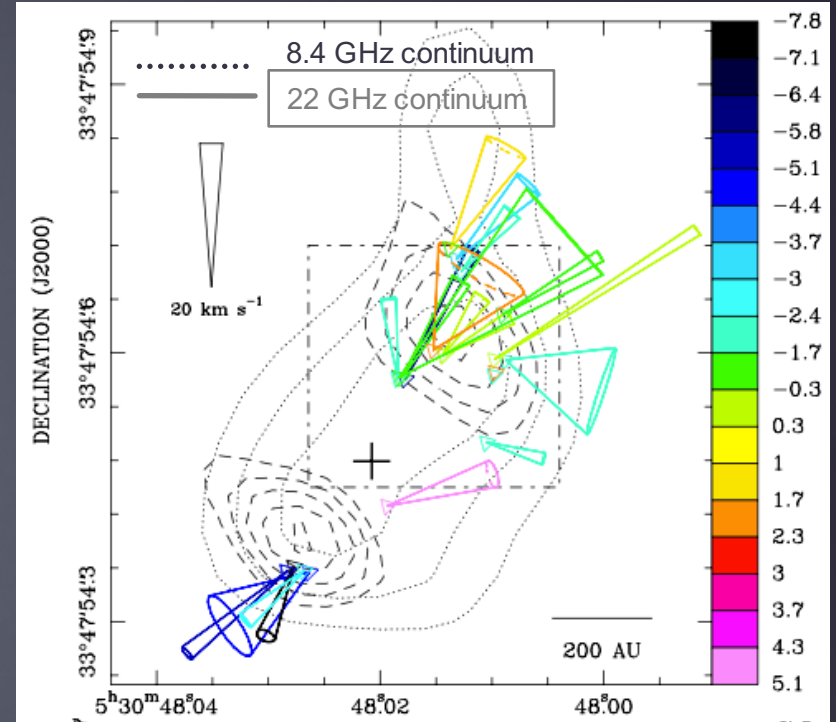
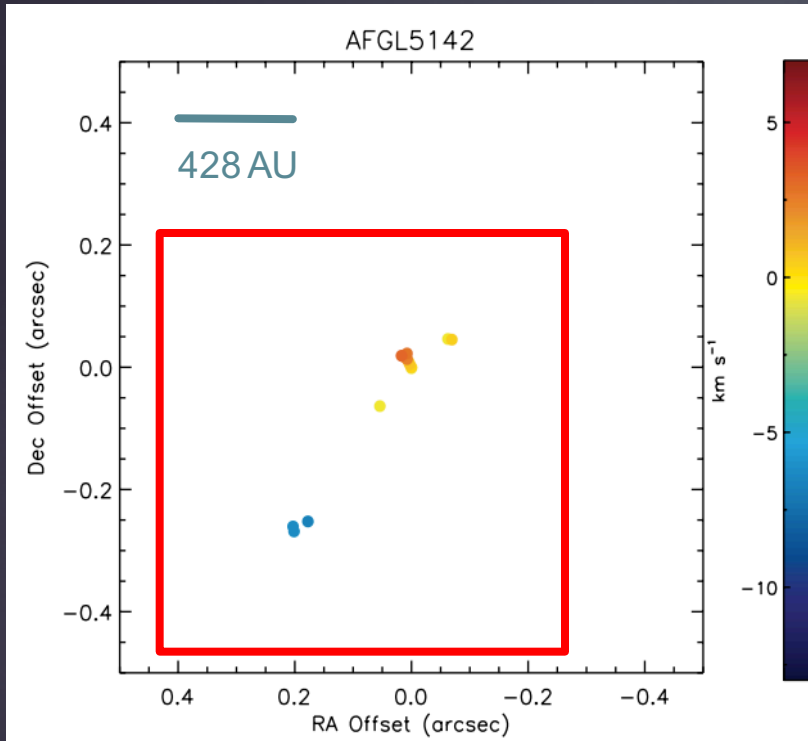




RESULTS

TOWARD INDIVIDUAL SOURCES

AFGL 5142



This study

Proper motion of water maser at 22 GHz
from Goddi, Moscadelli, and Sanna 2011

Similar distribution of water maser features is shown to that from
Goddi+2011 obtained with the VLBA.

AFGL 5142

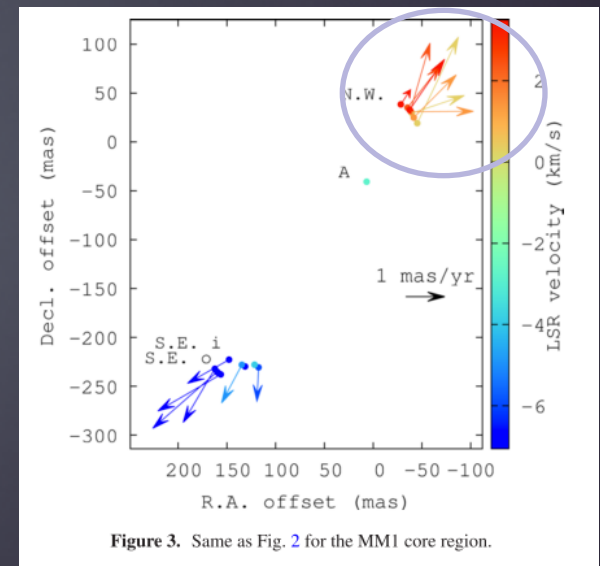
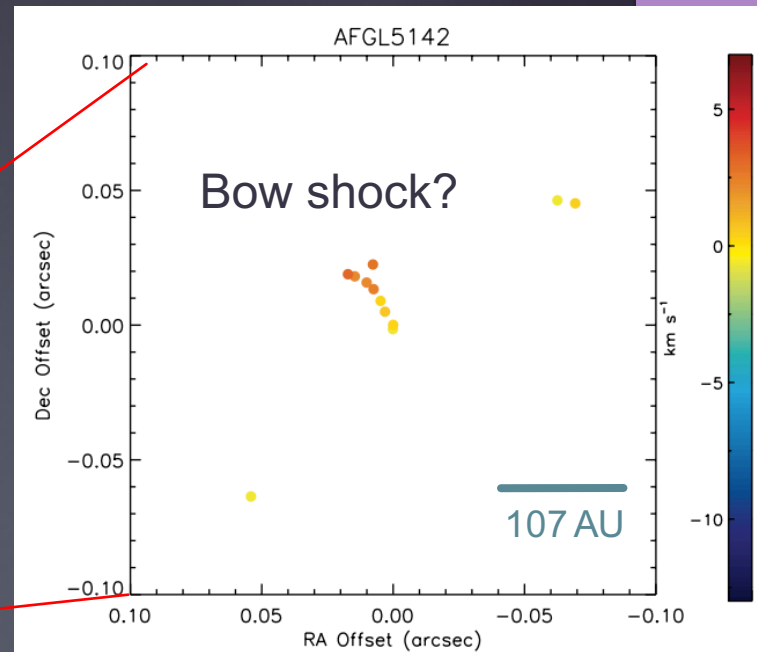
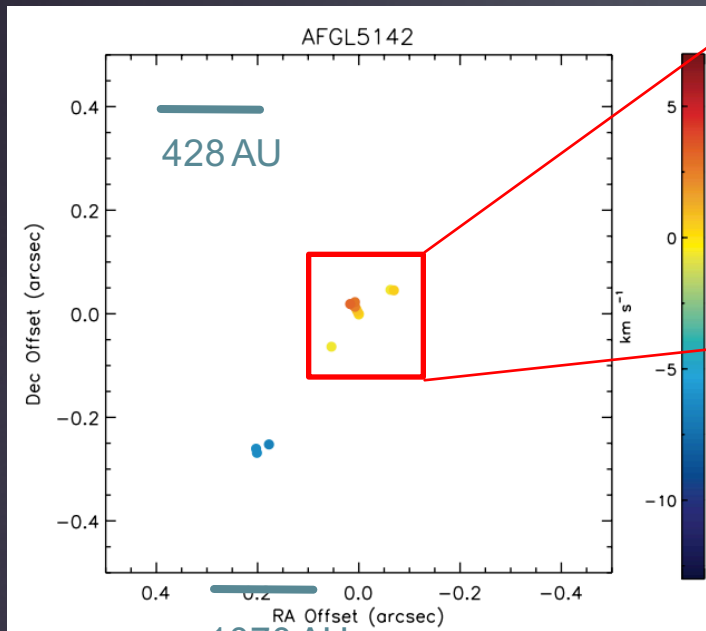
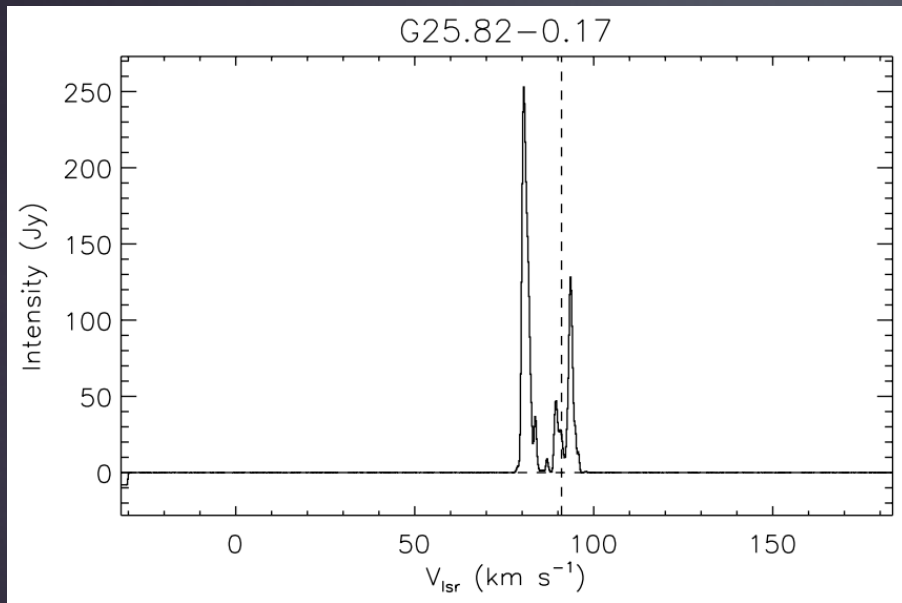


Figure 3. Same as Fig. 2 for the MMI core region.

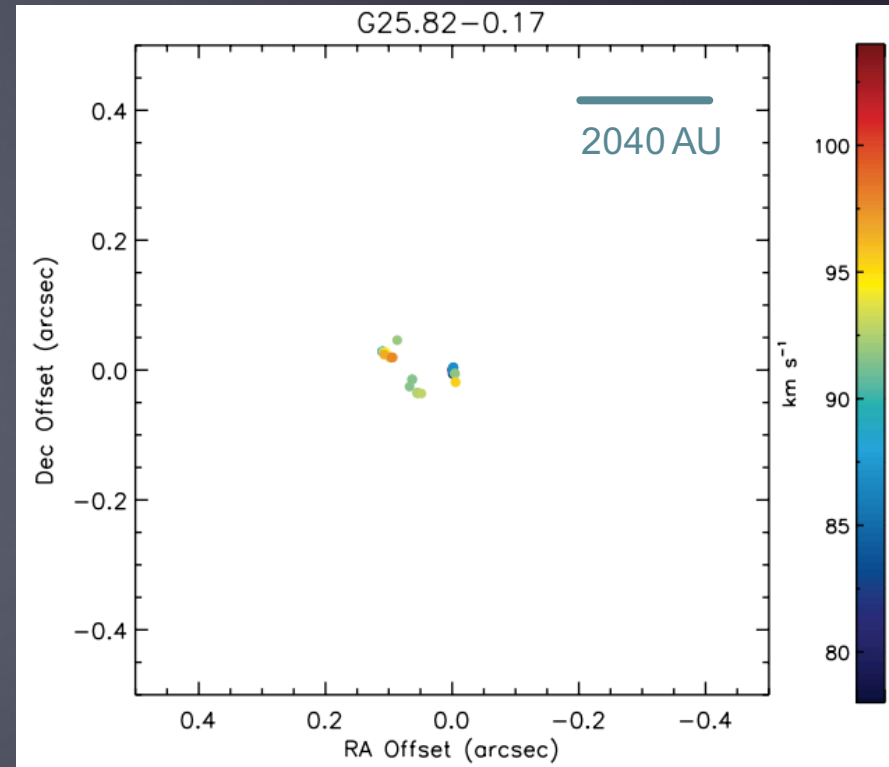
Magnified distribution maps of AFGL 5142
 - Red shifted spots at northwest of the center show arc-shaped feature with velocity gradient within the arc.

G25.82-0.17

D ~ 5.1 kpc (Green & McClure-Griffiths 2011)



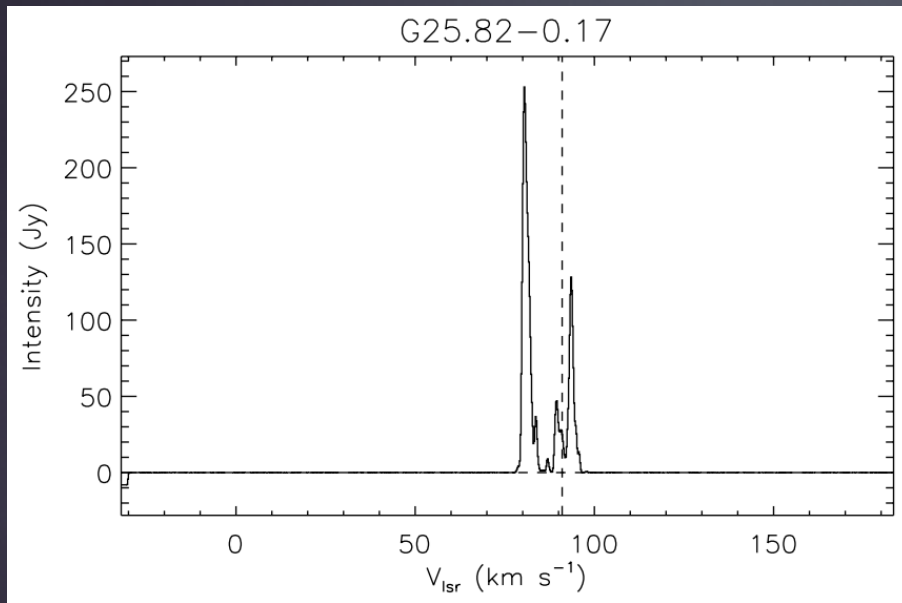
↑ Water maser spectrum at 22 GHz obtained with the KaVA.



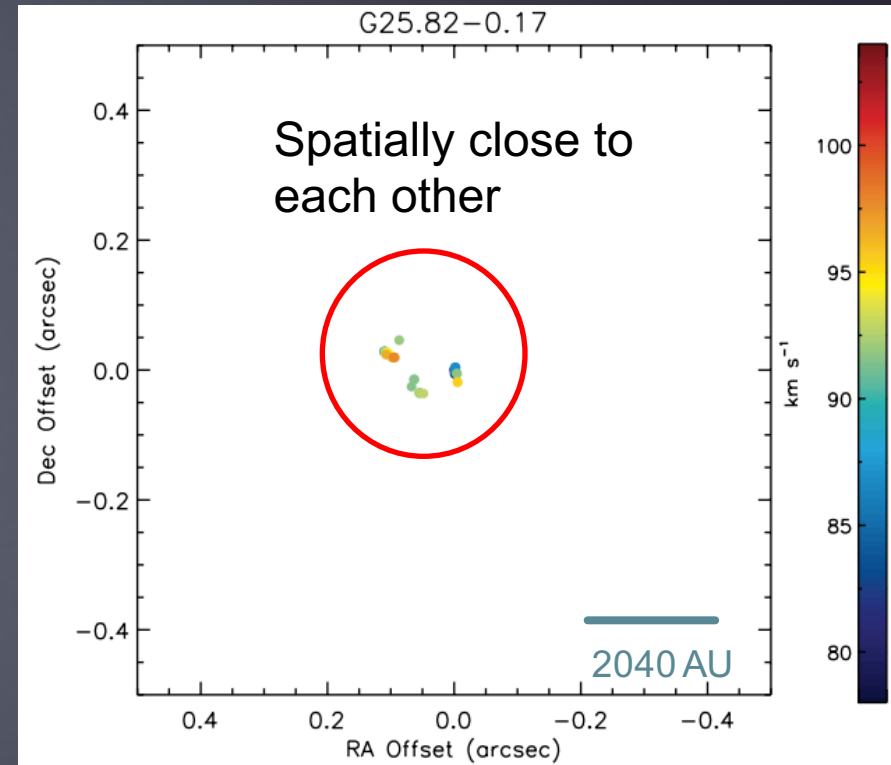
↑ Spatial distribution of water masers. (green: systemic velocity of 91 km s^{-1} ; shirley+2013)

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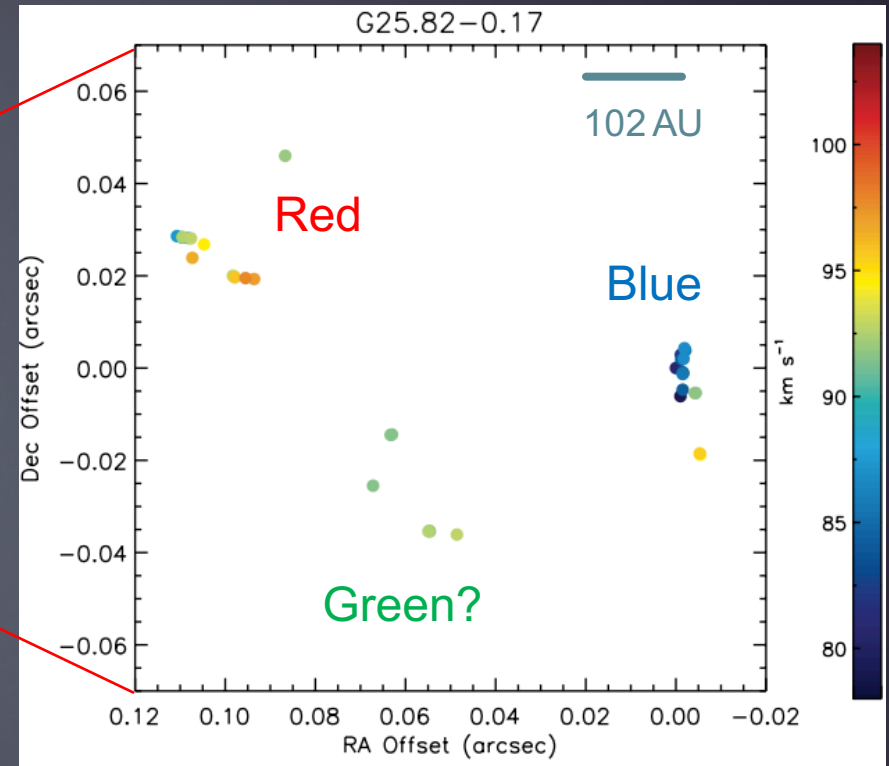
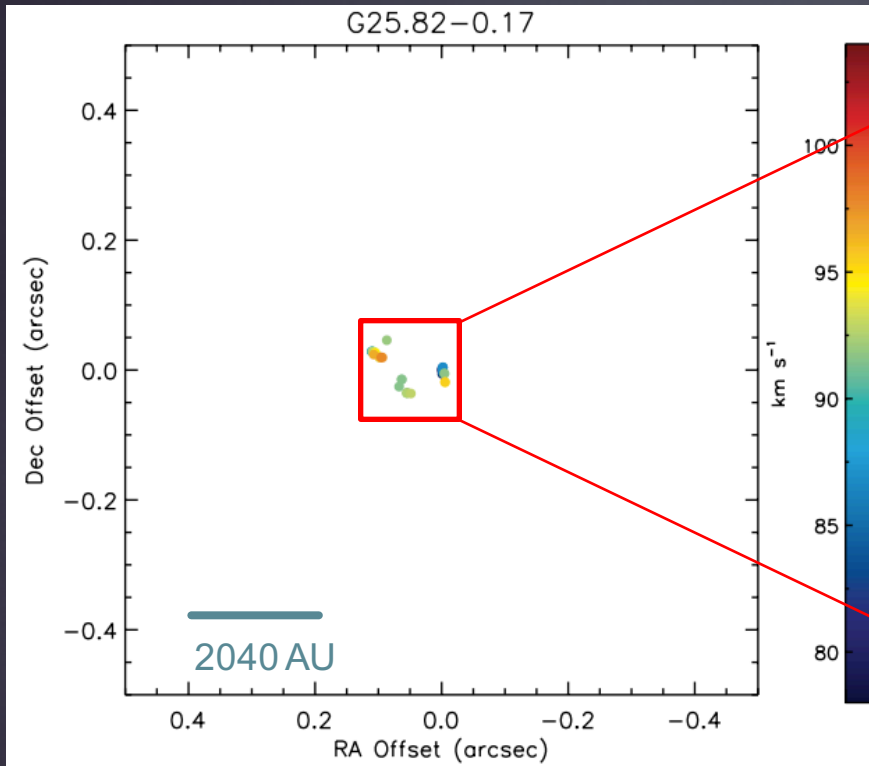


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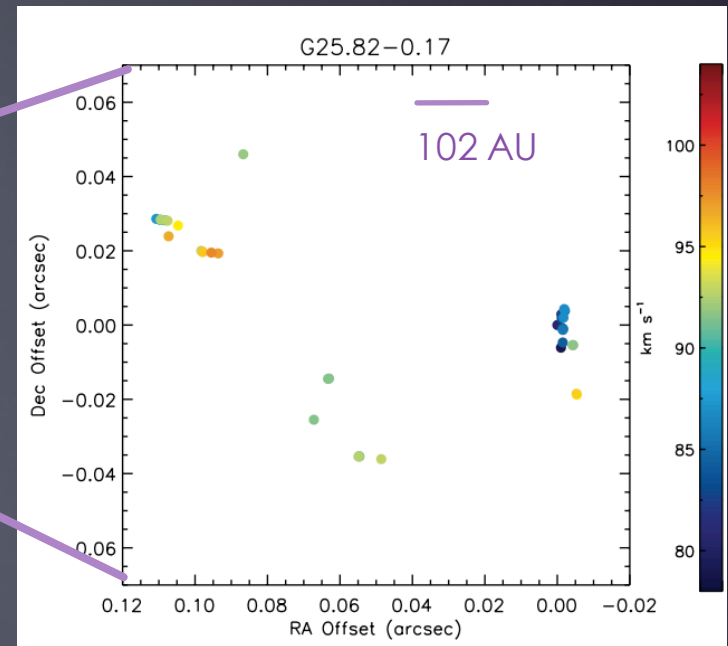
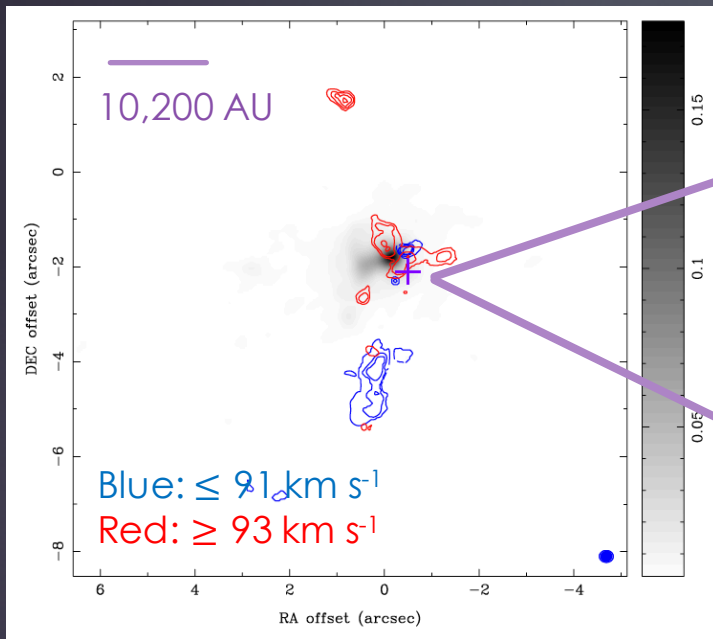


No 22 GHz water maser distribution map from the previous work.
-> **The first imaging** result at this position.



DISCUSSIONS & FUTURE WORKS

Preliminary results from ALMA cycle 3 observations (PI: Mikyong Kim, 2015.1.01571.S) at band 6 (239 GHz)



Integrated intensity map of SiO 5-4 overlaid onto dust continuum emission

Spatial distribution map of water maser features

The inner most part near HM-YSOs can be investigated by 3D velocity structure of water maser emission obtained with the KaVA.

Future works

- ▶ Target sources for the VLBI monitoring in the second year of KaVA LP is selected based on the first year results and further snap-shot imaging survey with KaVA and/or VERA (archival data).
- ▶ Dynamical properties of the water masers will be revealed by measuring proper motions with KaVA.
- ▶ Physical properties of the jets/outflows and their driving sources will be investigated by the follow-up observations such as ALMA.

Summary

- ▶ The first year project of water maser survey at 22 GHz using KaVA has been done.
- ▶ **Summarization of 22 GHz water maser observations** in the first year project is in progress in the same manner.
- ▶ **Both blue and red shifted components were apparently detected toward 9 sources** among 21 detected sources.
- ▶ Comparison with the previous work and verification of detectability have been done.
- ▶ Preliminary results from ALMA suggest that **measuring proper motion with KaVA is important to understand the innermost part of the jet/outflow+disk system.**