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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

High-mass Star Formation

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



Beltrán 2011

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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)
- \rightarrow Low-velocity outflows
- Class II at 6.7 GHz
- \rightarrow Rotating disks or outflows (under debating)

Motogi+2017



Bipolar jet from the G353.273+0.641

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

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



KaVA (KVN and VERA Array)





Base line range: 200 km ~ 2300 km

Observable bands: 22 GHz and 44 GHz

KaVA Large Program (LP) -Simultaneous observations at 22 and 44 GHz toward 87 sources from 2016 to now is in progress.

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

RESULTS

OVERALL SPECTRA

Results – Examples of Water maser Spectra

Dashed vertical lines indicate systemic velocities of each sources.



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Results – Examples of Water maser Spectra Dashed vertical lines included

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RESULTS

TOWARD INDIVIDUAL SOURCES

AFGL 5142

D ~ 2.14 kpc (Burn +2017)

-7.8

-7.1

-6.4

-5.8

-5.1 -4.4

-3.7

-3

-2.4

-1.7

-0.3 0.3

1

1.7 2.3 3

3.7 4.3

5.1



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



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





Burns+2017

G25.82-0.17

Case study for this source has not been done yet. D ~ 5.1 kpc (Green & McClure-Griffiths 2011)





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

 \uparrow Spatial distribution of water masers. (green: systemic velocity of 91 km s⁻¹ ; shirley+2013)

G25.82-0.17

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



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

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



Channel maps of CH₃OH 22₄-21₅ E overlaid onto continuum emission

The 1^{st} momentum map of CH₃OH 22₄-21₅ E (color) with the dust continuum emission (contours).

Preliminary results from ALMA cycle 3 observations at band 6

Channel maps of SiO J=5-4 overlaid onto continuum emission.



The distribution of SiO J=5-4 shows complicated structure.

Preliminary results from ALMA cycle 3 observations at band 6



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

The VLBI monitoring in the second year of KaVA LP will be done toward targets selected based on the first year results and 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 followup 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 almost done 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.