East-Asia ALMA Regional Meeting @ Deajeon 2017

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

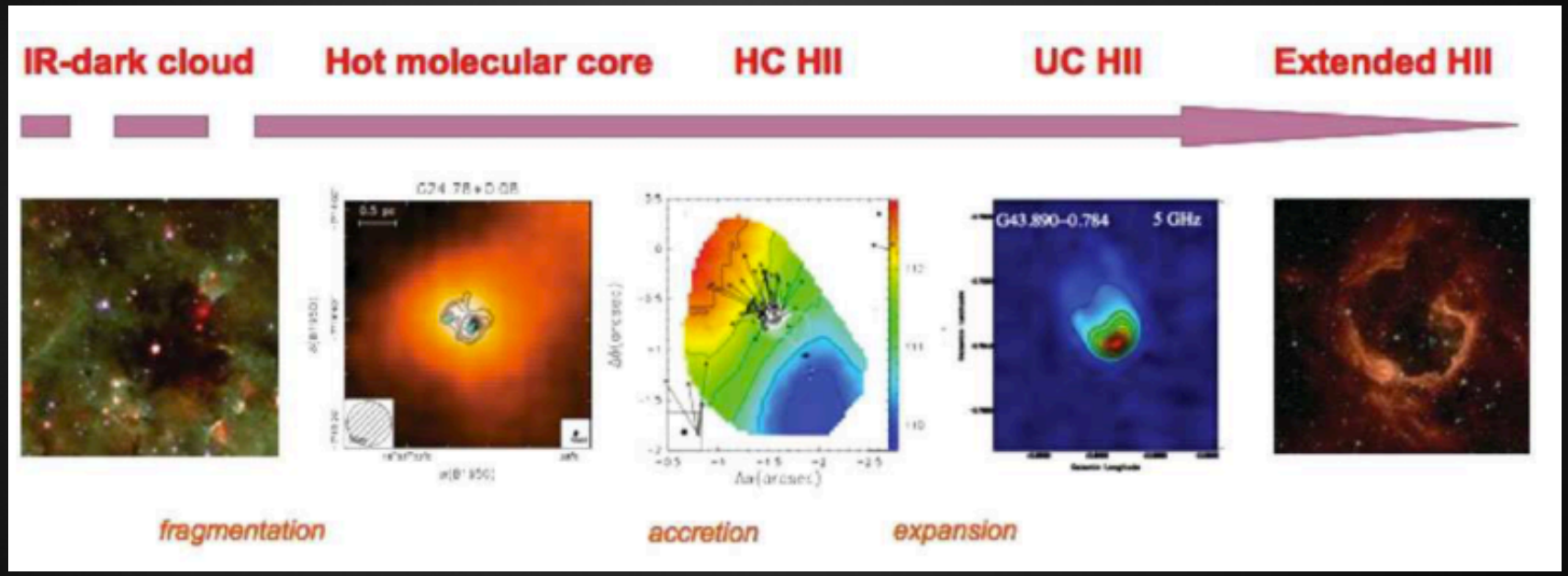
JUNGHA KIM (SOKENDAI, NAOJ)

SUPERVISORS: MAREKI HONMA (NAOJ), TOMOYA HIROTA (NAOJ), KATSUNORI SHIBATA (NAOJ)

COLLEAGUES: KAVA SCIENCE WORKING GROUP FOR STAR-FORMING REGIONS

High-mass Star Formation

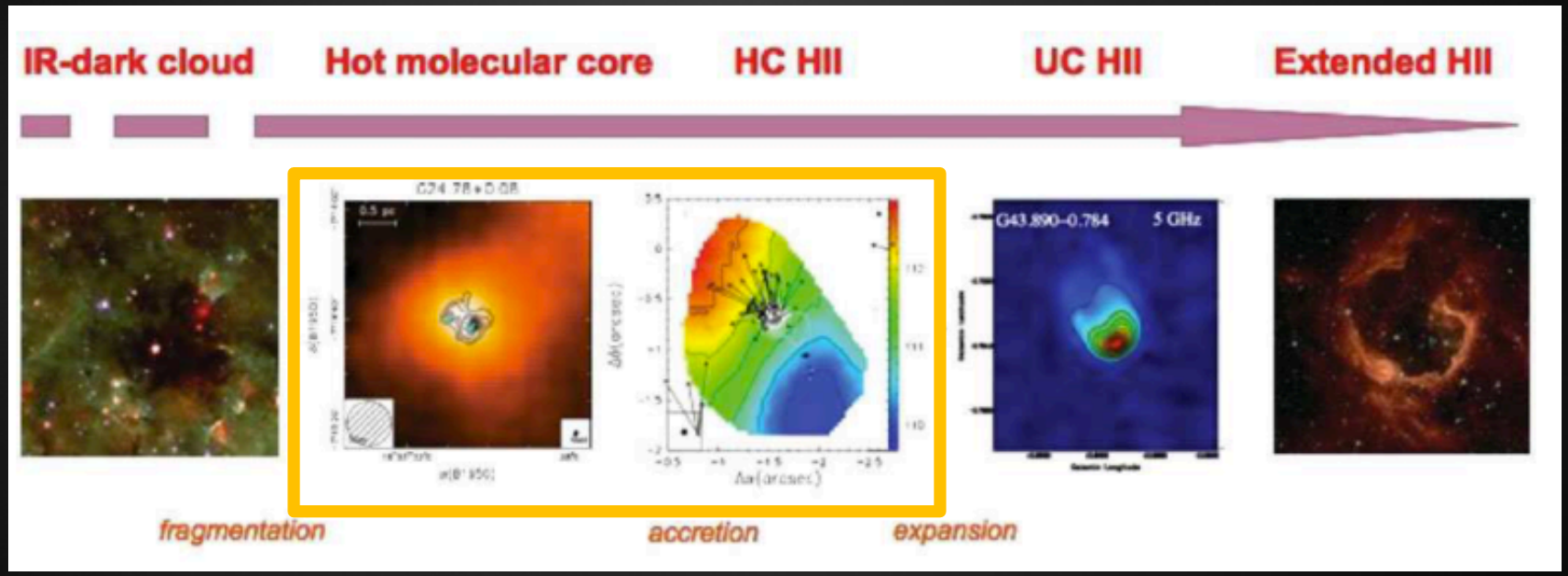
- High-mass star formation is still far from understanding observationally.
- Evolutionary Sequence of high-mass young stellar objects (HMYSOs)



Beltrán 2011

High-mass Star Formation

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



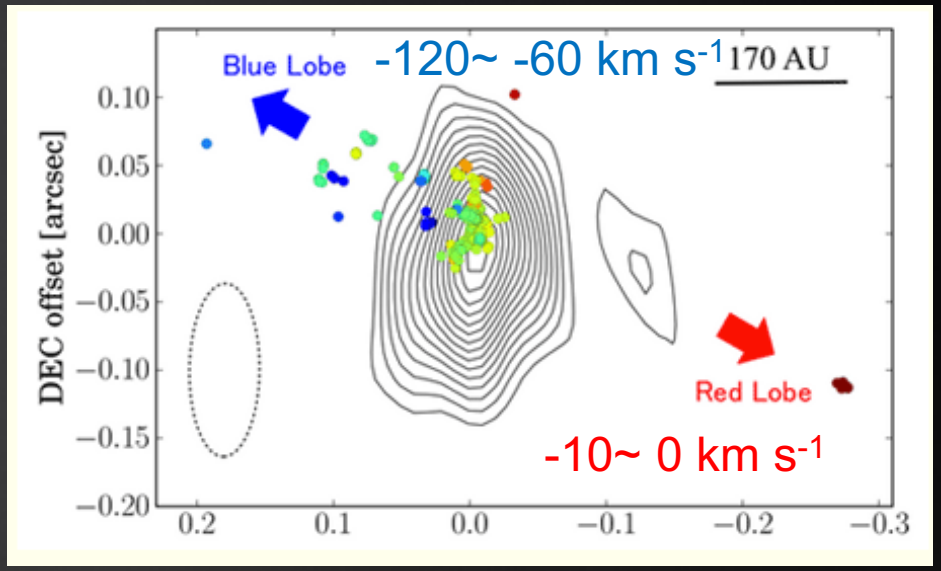
Beltrán 2011

Astrophysical Masers

- Water (H_2O) masers at 22 GHz

Motogi+2017

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



Bipolar jet from the G353.273+0.641

- Methanol (CH_3OH) masers

- Class I at 44 GHz (Menten 1991)

→ Low-velocity outflows

- Class II at 6.7 GHz

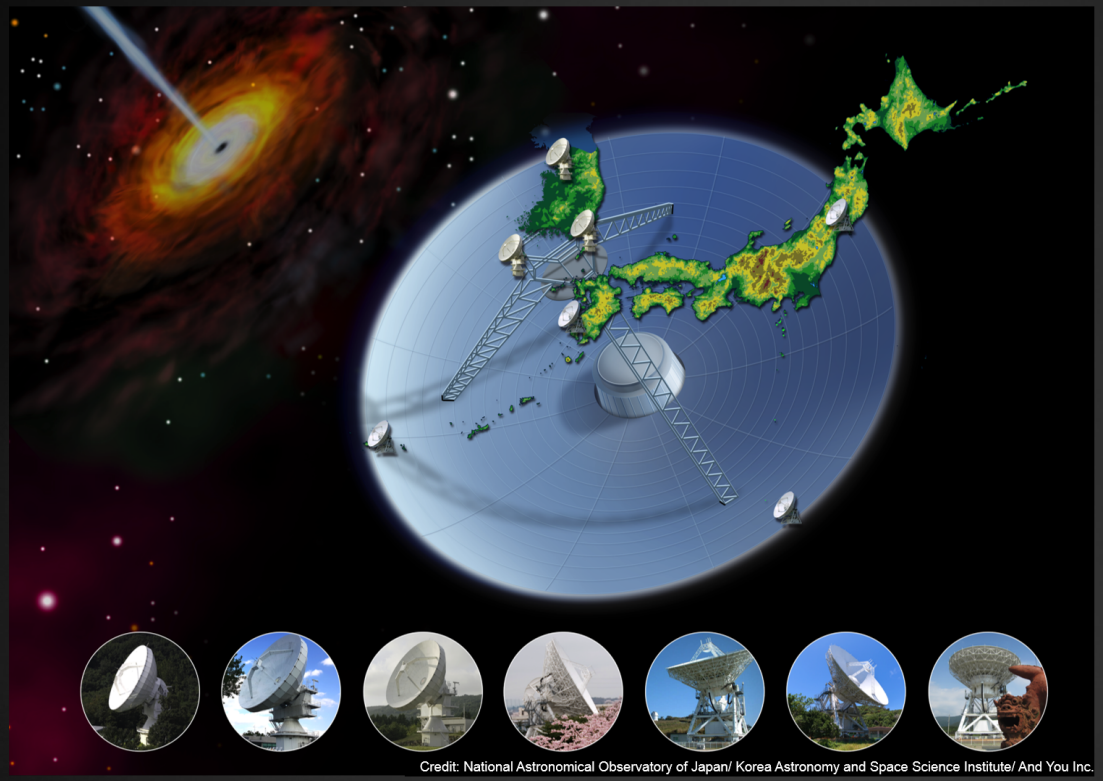
→ Rotating disks or outflows (under debating)

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
- To reveal their launching and mass accretion processes

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.

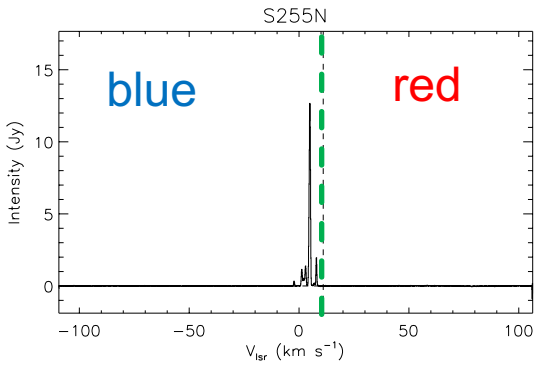
- Combined VLBI array with three 21-m radio telescopes of KVN (Korean VLBI Network) and four 20-m radio telescopes of VERA (VLBI Exploration of Radio Astrometry)
- The highest angular resolution: ~1.2 mas @ 22 GHz

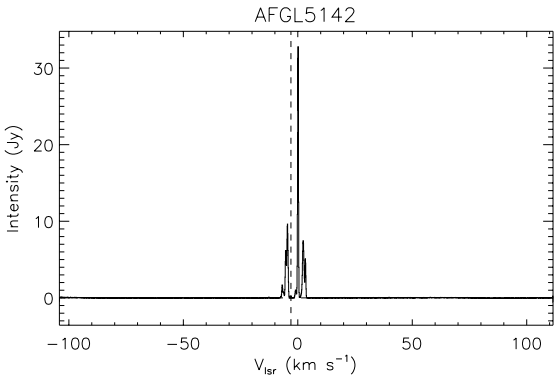
RESULTS

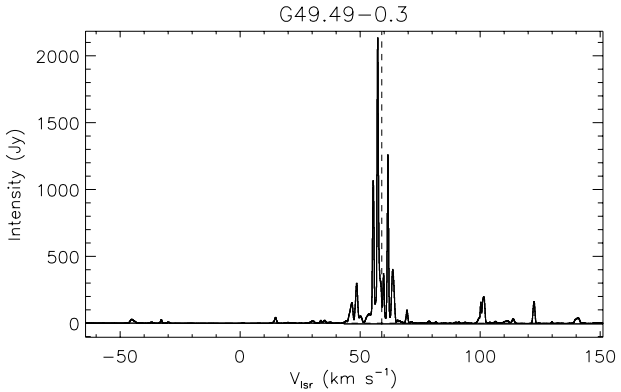
OVERALL SPECTRA

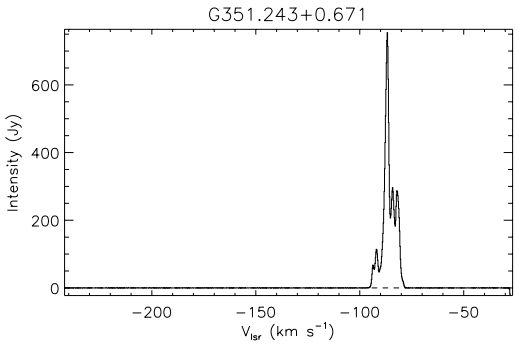
Results – Examples of Water maser Spectra

Dashed vertical lines indicate systemic velocities of each sources.

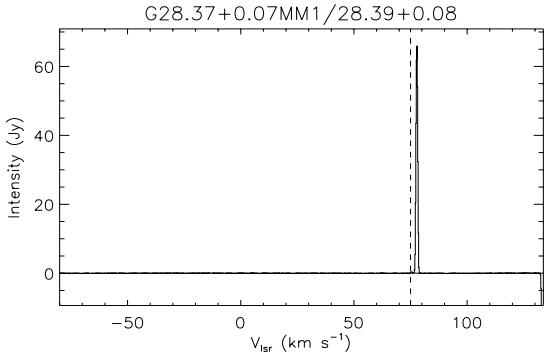


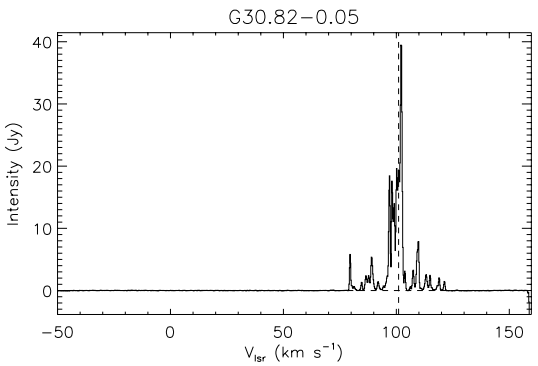






V_{sys} ~3 km s^{-1}



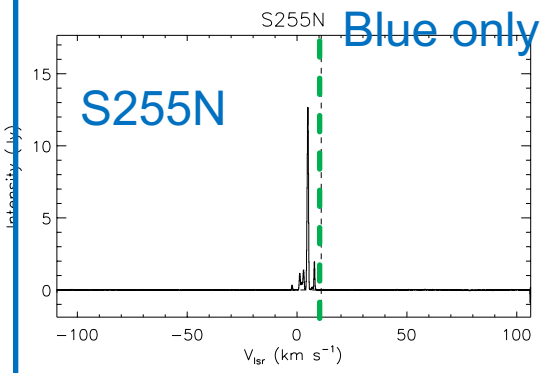


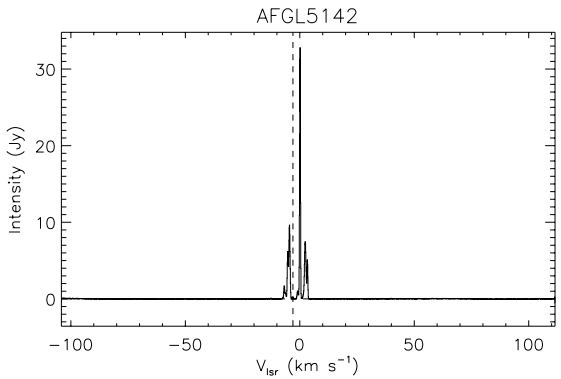
Results – Examples of Water maser Spectra

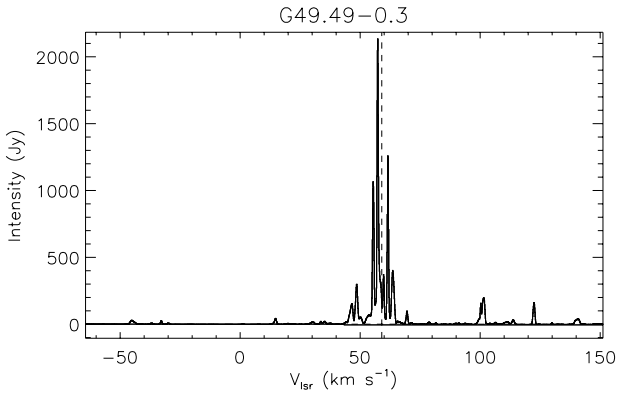
Dashed vertical lines indicate systemic velocities of each sources.

S255N Blue only

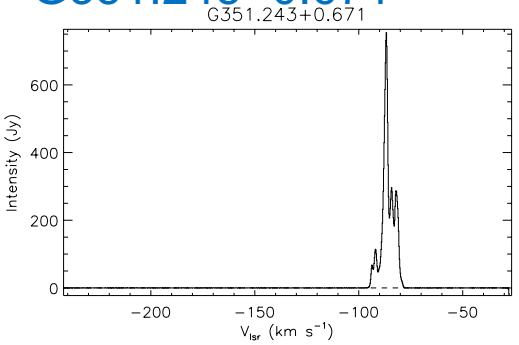
S255N



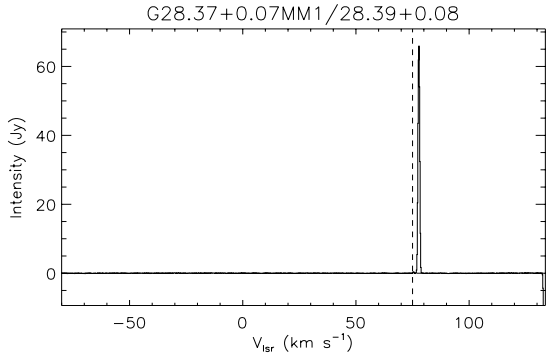


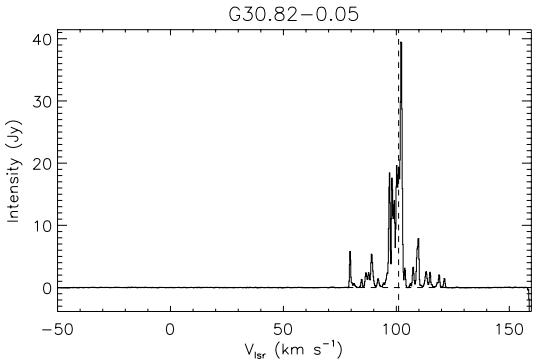


G351.245+0.671



V_{sys} ~3 km s^{-1}

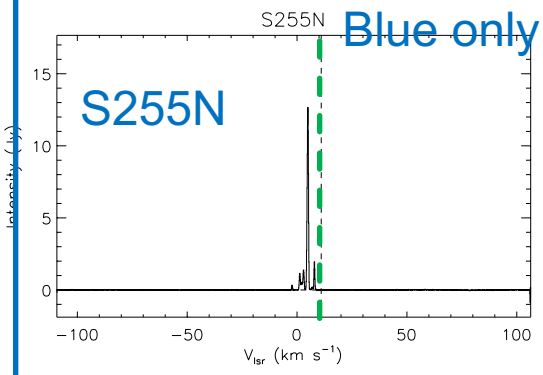


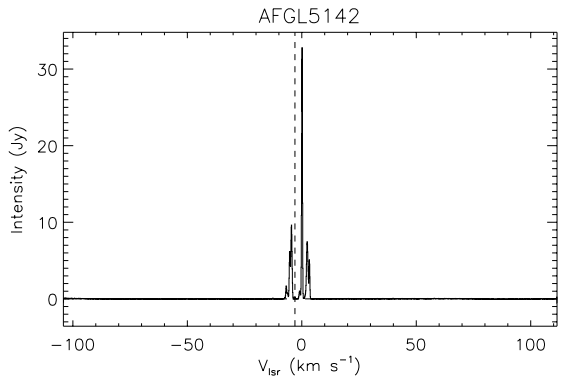


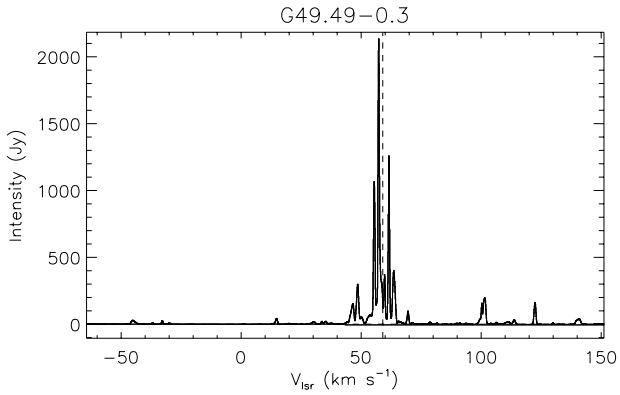
Results – Examples of Water maser Spectra

Dashed vertical lines indicate systemic velocities of each sources.

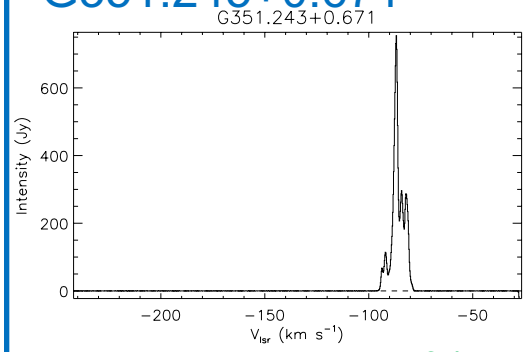
Blue only





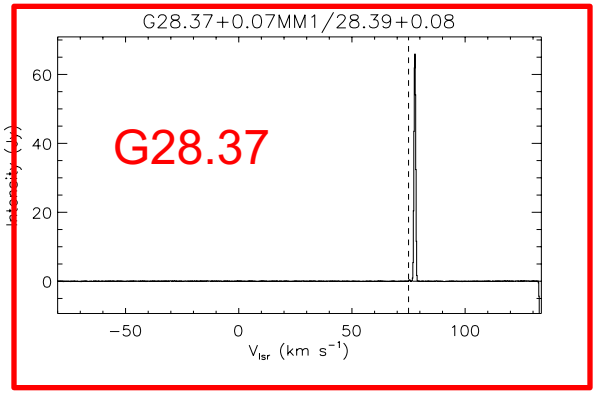


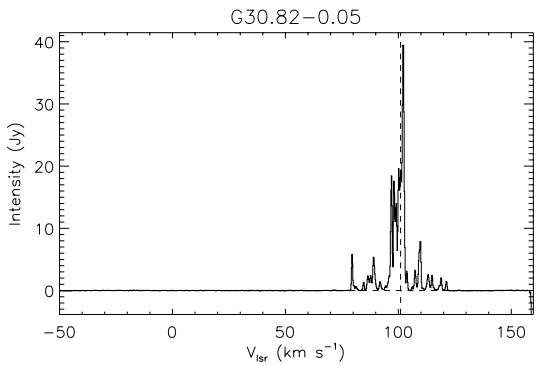
G351.245+0.671



V_{sys} ~3 km s^{-1}

Red only



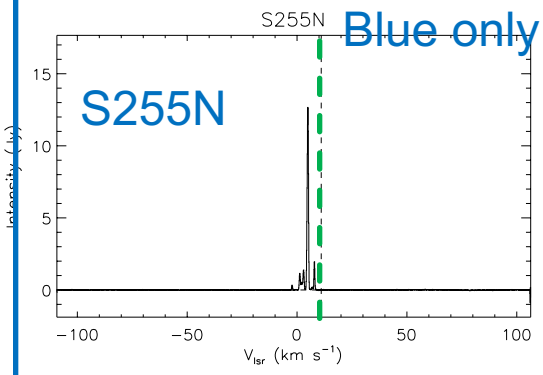


Results – Examples of Water maser Spectra

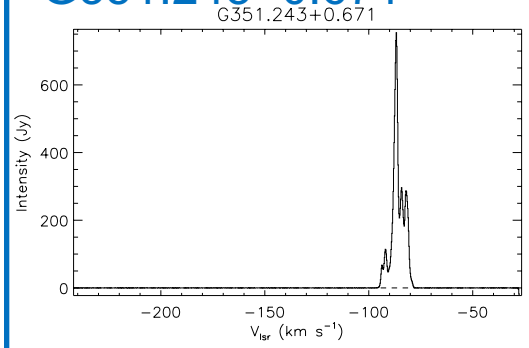
Dashed vertical lines indicate systemic velocities of each sources.

Blue only

S255N



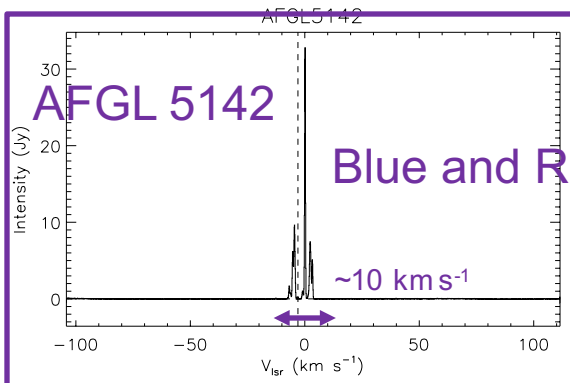
G351.243+0.671



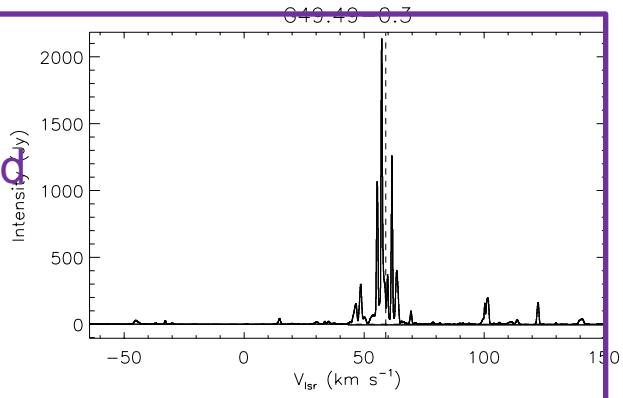
V_{sys} ~3 km s^{-1}

Blue and Red

AFGL 5142

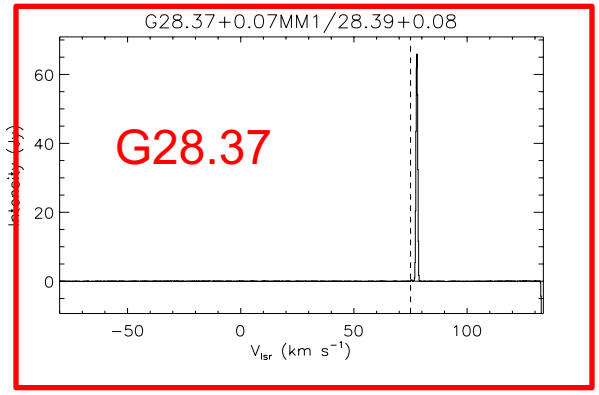


~10 km s^{-1}

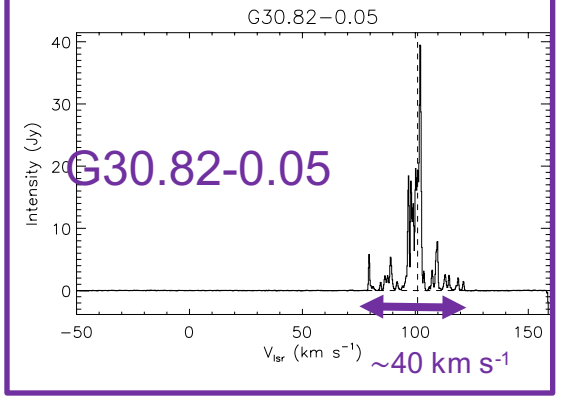


Red only

G28.37



G30.82-0.05

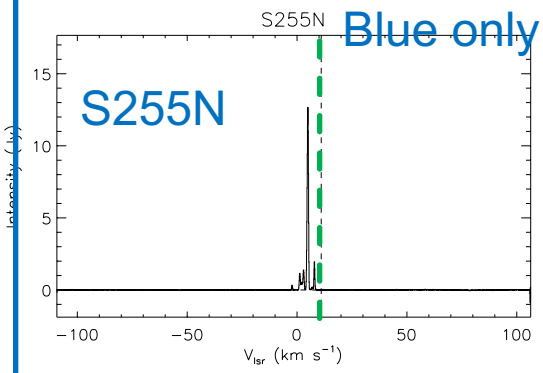


~40 km s^{-1}

Results – Examples of Water maser Spectra

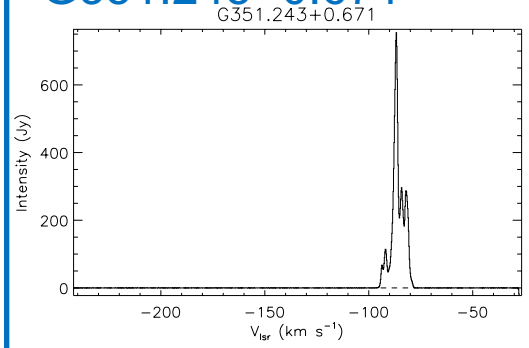
Dashed vertical lines indicate systemic velocities of each sources.

S255N Blue only



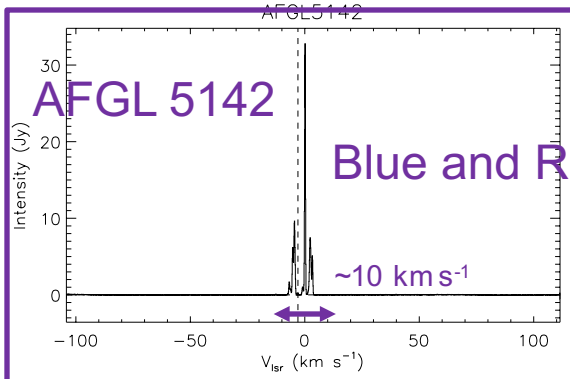
S255N

G351.245+0.671



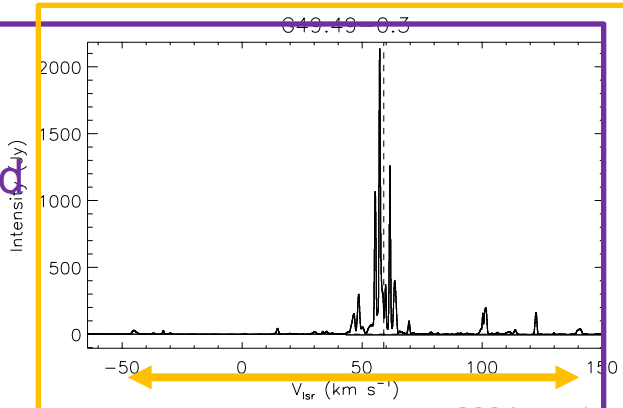
V_{sys} ~3 km s^{-1}

AFGL 5142 Blue and Red



~10 km s^{-1}

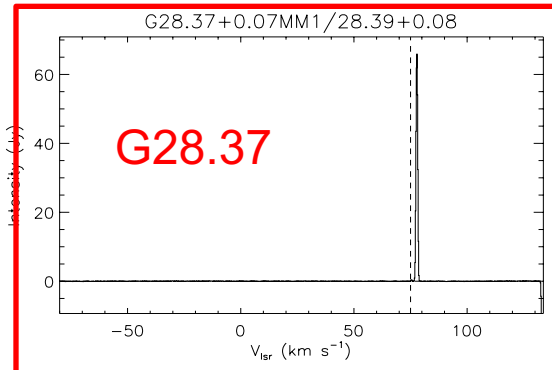
G49.49−0.3



~ 200 km s^{-1}

Red only

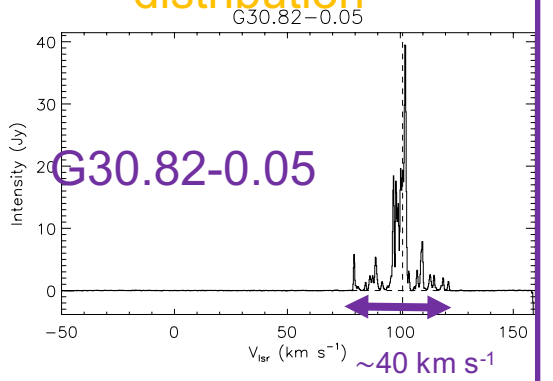
G28.37+0.07MM1/28.39+0.08



G28.37

Large velocity distribution

G30.82−0.05



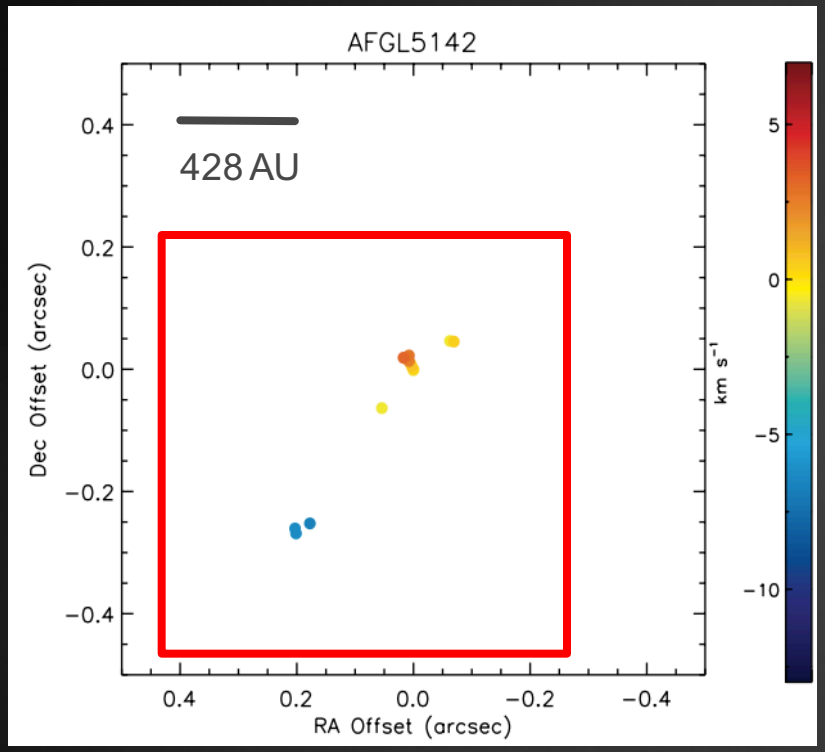
~40 km s^{-1}

RESULTS

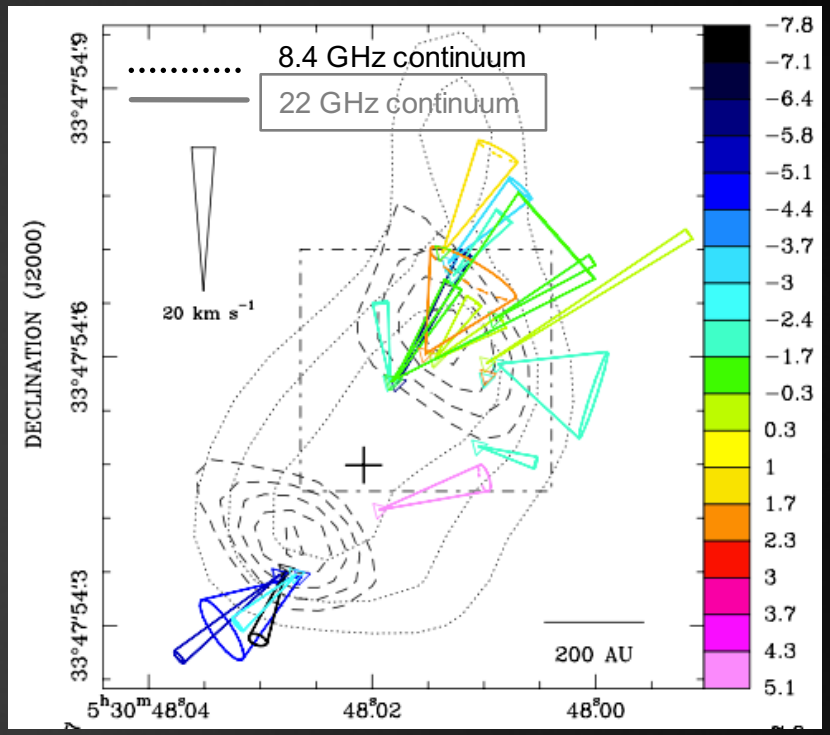
TOWARD INDIVIDUAL SOURCES

AFGL 5142

D ~ 2.14 kpc (Burn +2017)



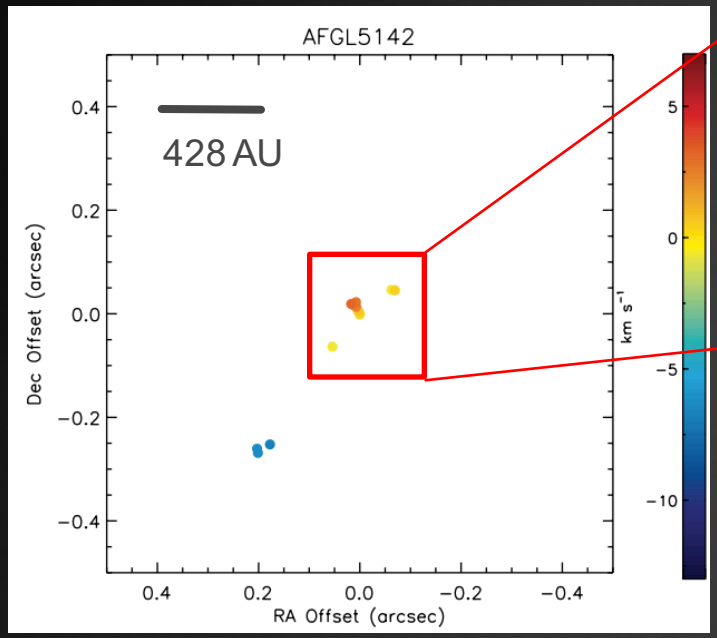
This study

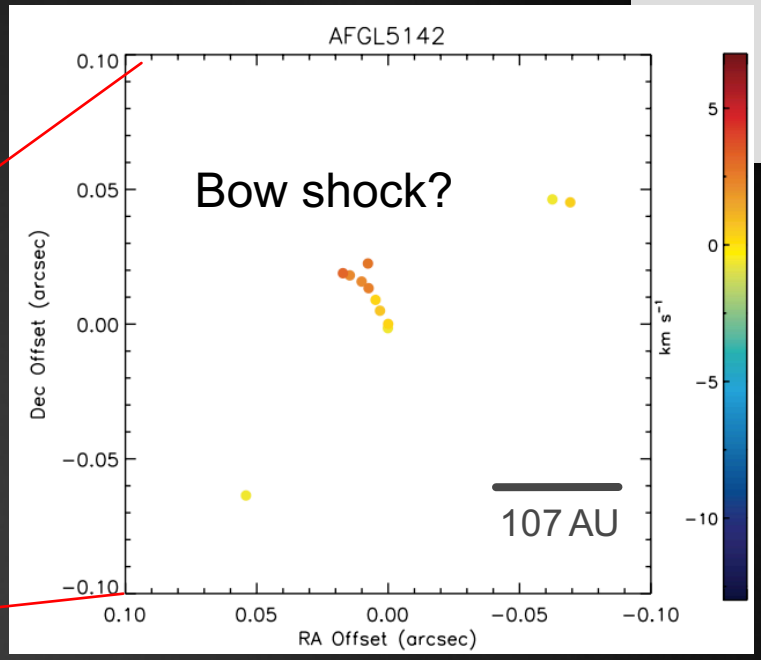


Proper motion of water maser at 22 GHz from Goddi, Moscadelli, and Sanna 2011

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

AFGL 5142





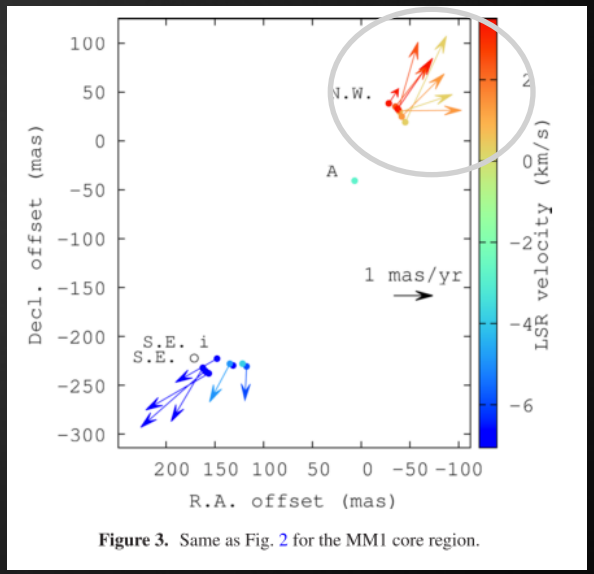


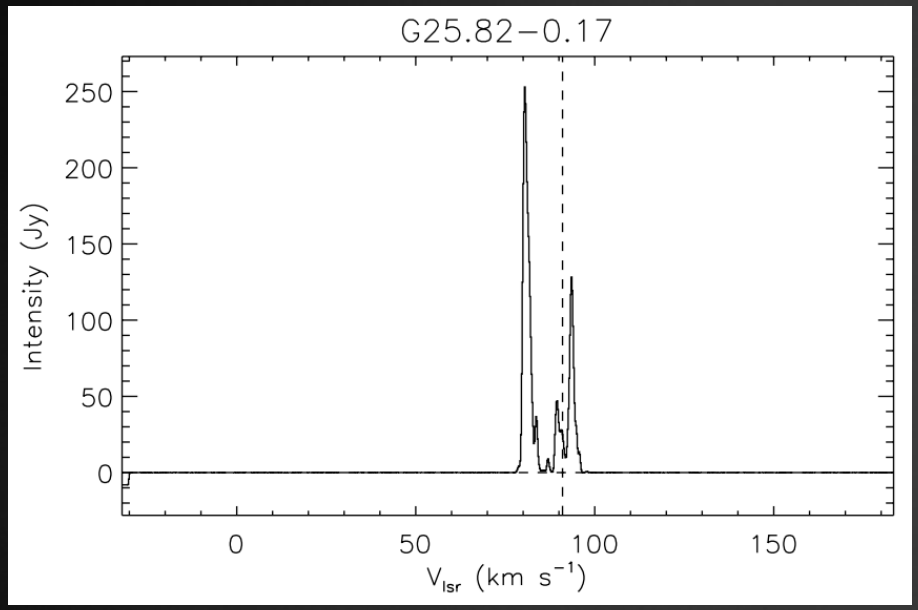
Figure 3. Same as Fig. 2 for the MM1 core region.

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

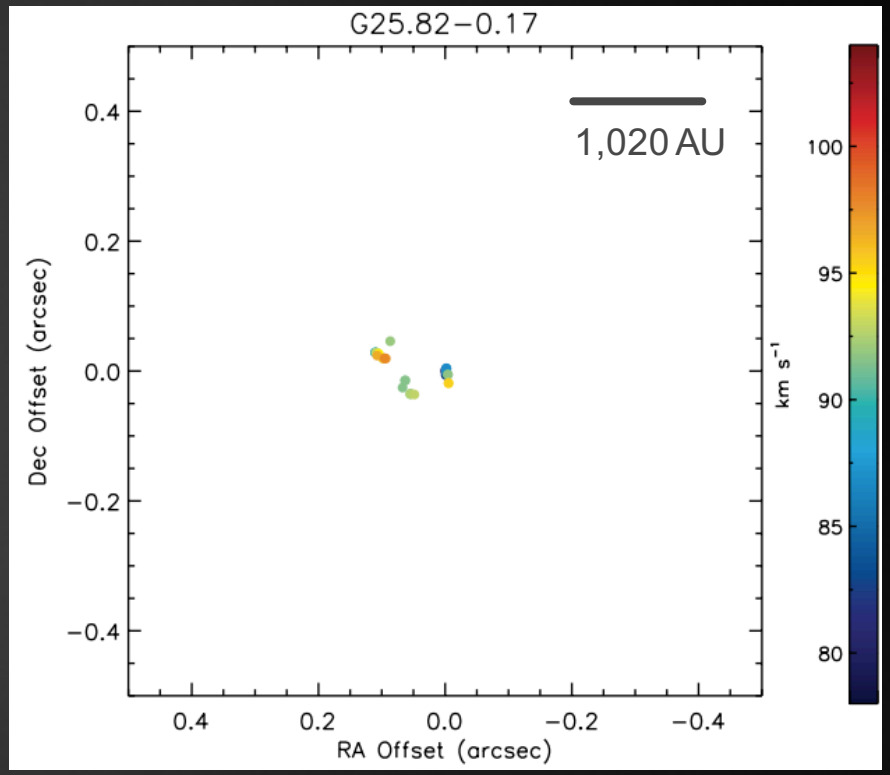
Burns+2017

G25.82-0.17

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



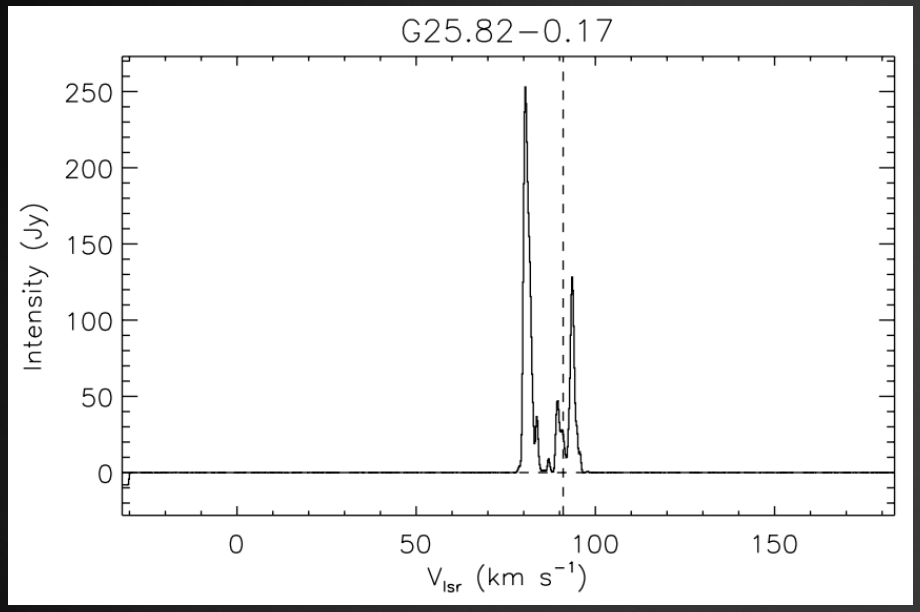
↑ Water maser spectrum at 22 GHz obtained with the KaVA.



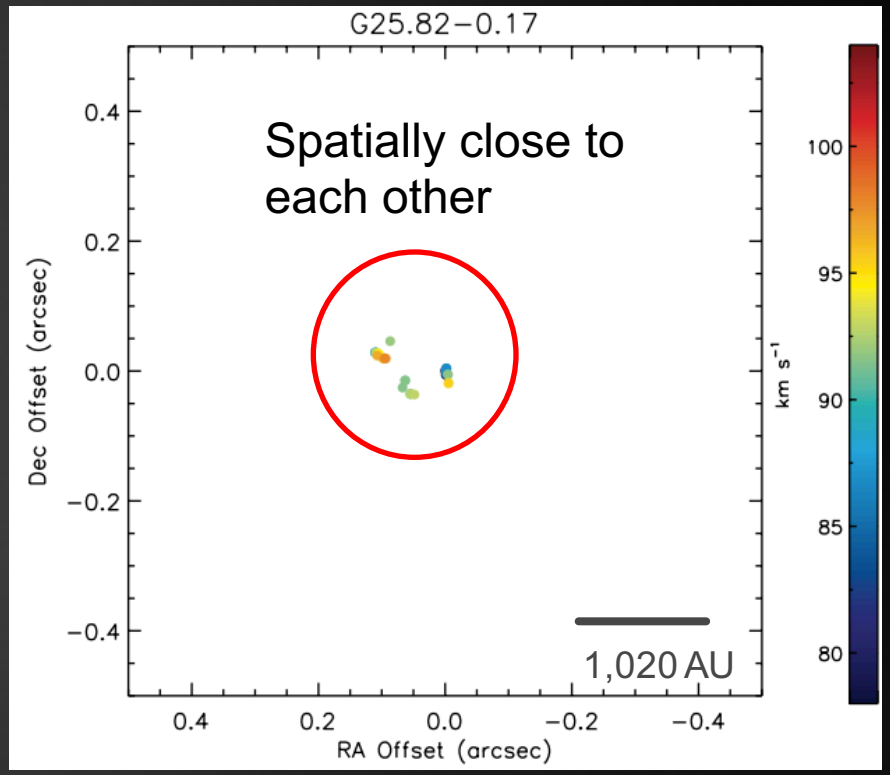
↑ Spatial distribution of water masers. (green: systemic velocity of 91 km s^{-1} ; shirley+2013)

G25.82-0.17

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

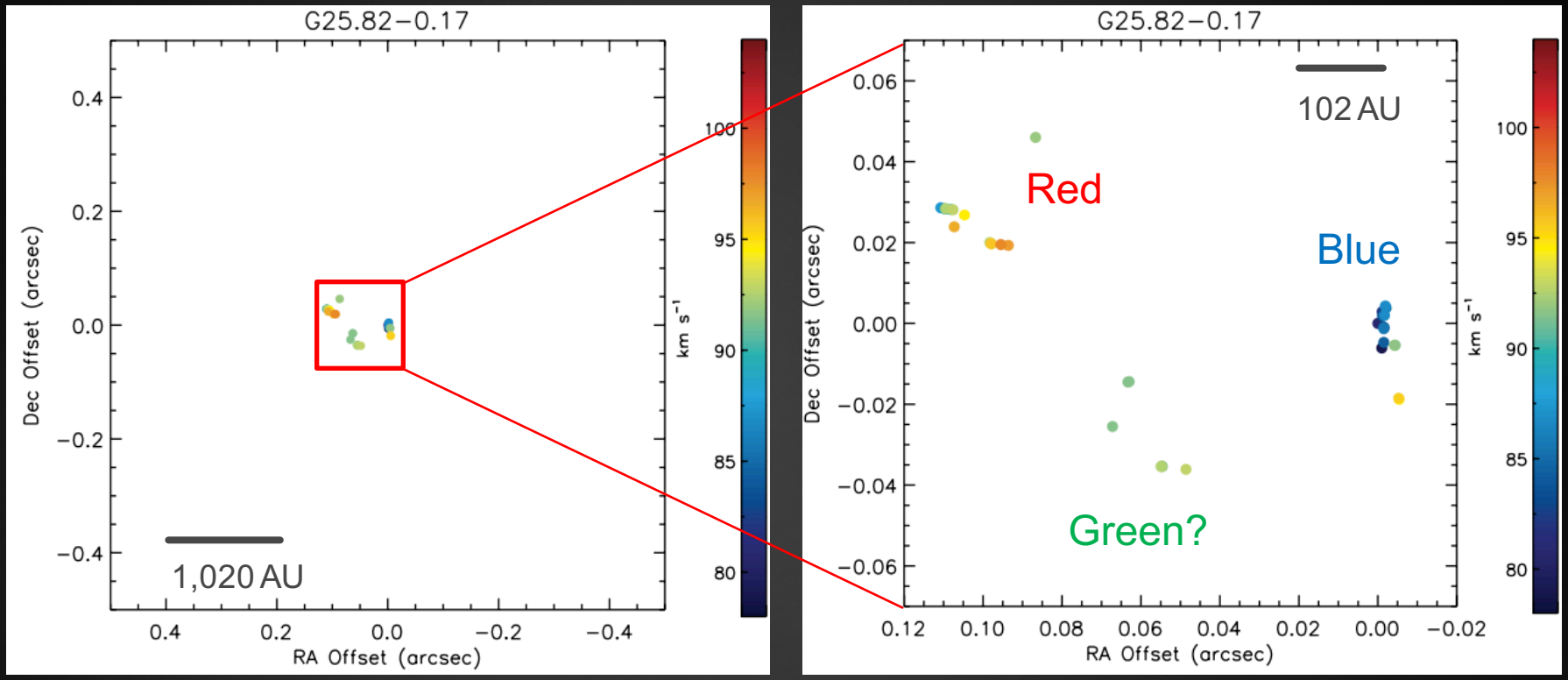


↑ Water maser spectrum at 22 GHz obtained with the KaVA.



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

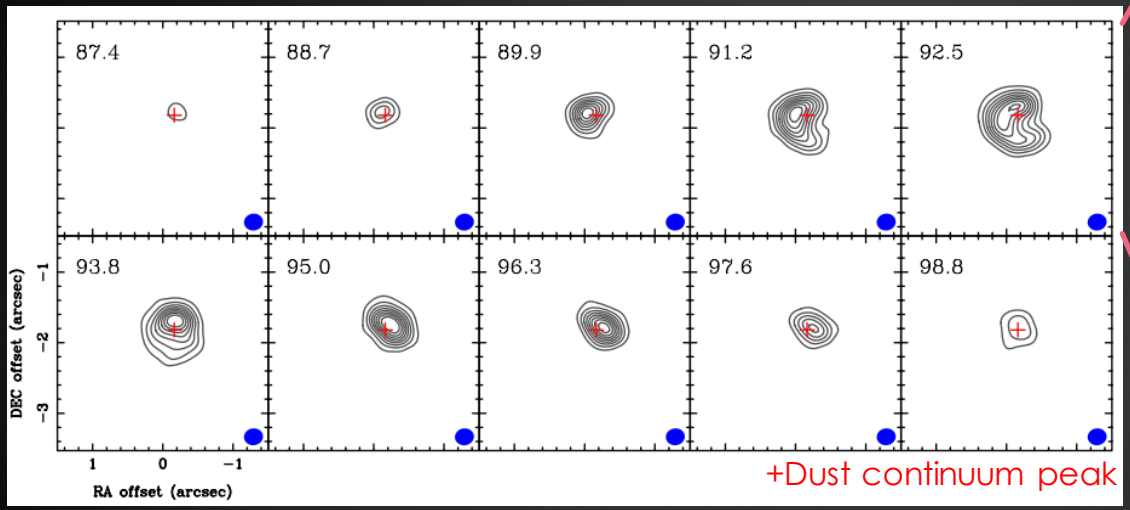
G25.82-0.17

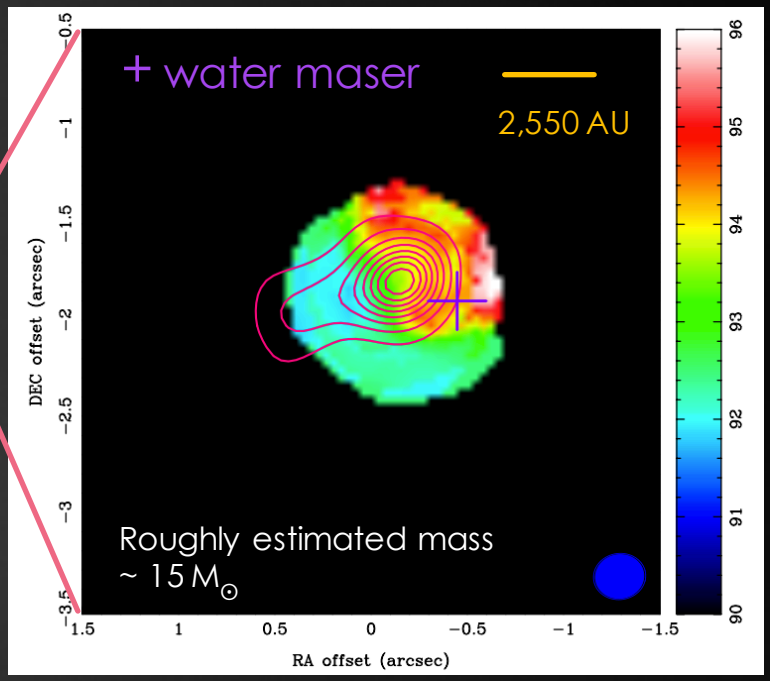


No 22 GHz water maser distribution map from the previous work.
-> The first imaging result at this position.

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

Clear velocity gradient is shown. → It is also shown in other molecular lines.



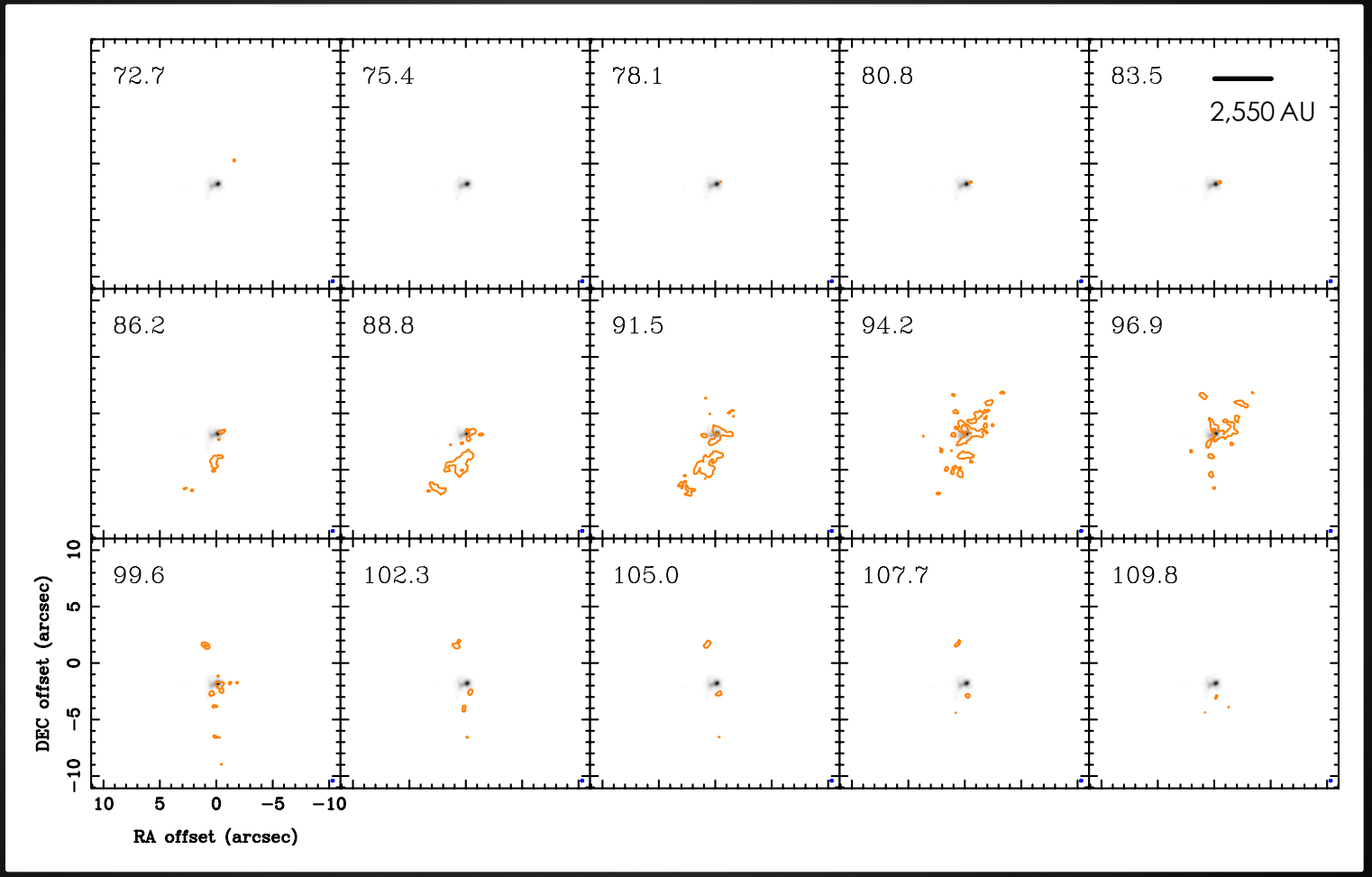


Channel maps of CH_3OH 22_4-21_5 E overlaid onto continuum emission

The 1st momentum map of CH_3OH 22_4-21_5 E (color) with the dust continuum emission (contours).

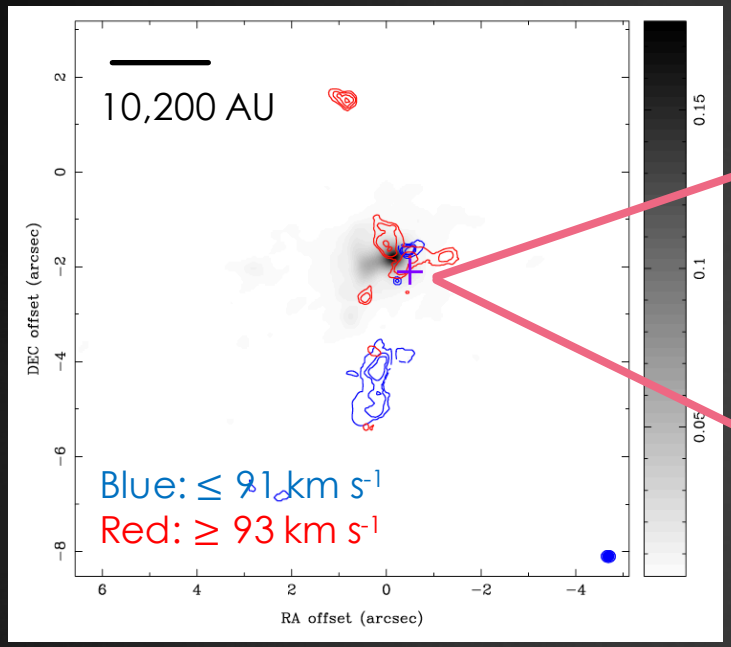
Preliminary results from ALMA cycle 3 observations at band 6

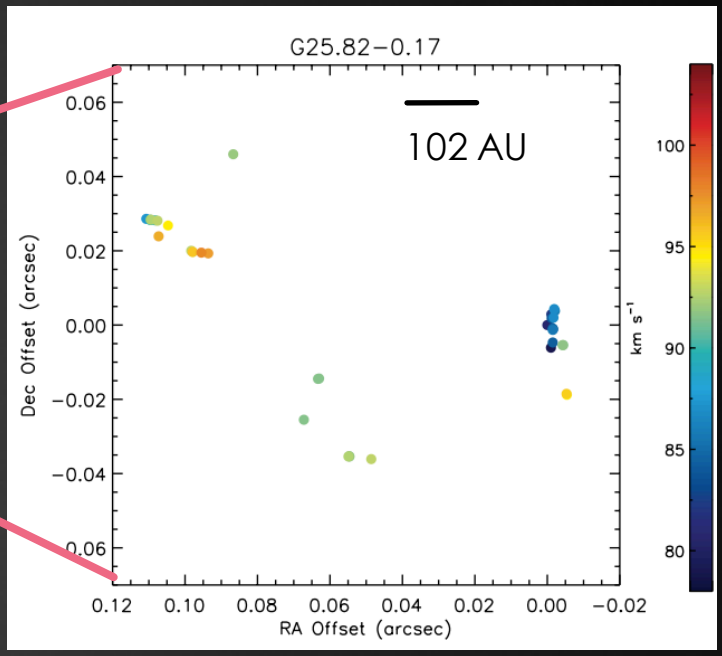
Channel maps of SiO J=5-4 overlaid onto continuum emission.



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 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 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.