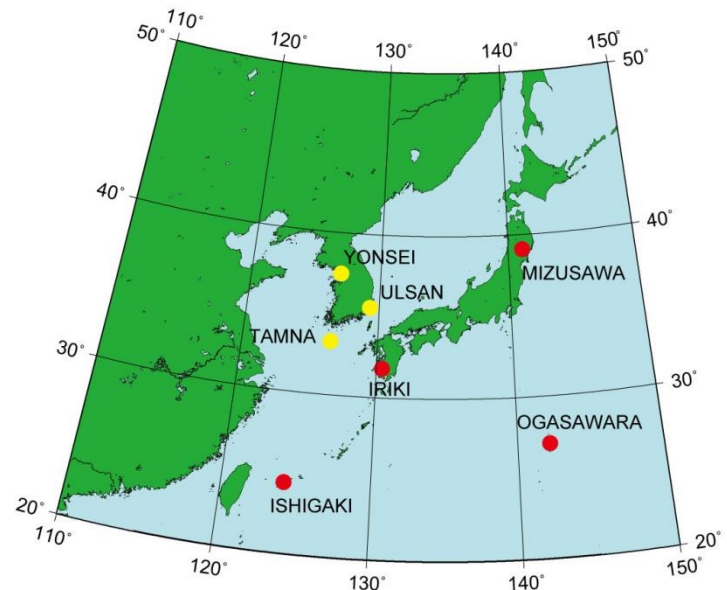


KaVA Large Proposal for Star-formation studies

Tomoya HIROTA (NAOJ)

KaVA large program (LP)

- KaVA: KVN and VERA Array
- Three LPs since 2015
 - AGN (Sohn and Kino)
 - Late-type stars (Cho and Imai)
 - SFR (K. T. Kim and Hirota)
- Allocation of ~200 hrs/yr
- Long-term program



KaVA SFRs LP

- “Understanding high-mass star formation through KaVA observations of water and methanol masers”
 - VLBI monitoring/survey to reveal 3D velocity and spatial structures of 22 GHz/44 GHz methanol maser lines in 87 high-mass YSOs (HM-YSOs)
 - Physical/dynamical properties of disk/jet/outflow
 - Evolution of disk/jet/outflow and maser chronology

KaVA SFRs LP organization

- 20 active members; new members are welcome!

Practical contributions!

PI; Hirota, K.T.Kim

New ideas!
More data!

Operation

Proposal

Planning proposal including second years and beyond

Leader
K.T.Kim or Hirota (TBD)
Member
Byun, Motogi, Sugiyama, others

Scheduling

Producing and checking VEX schedule production

Leader
Byun
Member
Chibueze, Hirota, J.S.Kim, M.K.Kim, Matsumoto, Sunada

Data analysis (DQ)

Data Quality (DQ) check of correlated data, feedback to observation and correlation

Leader
Oh
Member
Byun, Hirota, K.T.Kim, James, M.K.Kim, Matsumoto, Motogi, Oh, Sugiyama, Wu, (Liu, Sunada)

Data verification (PE)

Performance evaluation (PE) for test data of new mode (proposal for new test observations)

Leader
M.K.Kim
Member
Matsumoot, Wu, (Imai)

Science

Multiple masers

Full imaging, detailed analysis, discussion, publication

Leader
K.T. Kim & Sugiyama

High velocity jet

Full imaging, detailed analysis, discussion, publication

Leader
Motogi & Byun

Any other project?

Full imaging, detailed analysis, discussion, publication

TBD

Follow-up VERA

VERA astrometry/SD

Leader
Hirota

Follow-up JVN

JVN survey at 6.7 GHz

Leader
Sugiyama

Follow-up ALMA

ALMA cycle 3 project

Leader
M.K.Kim

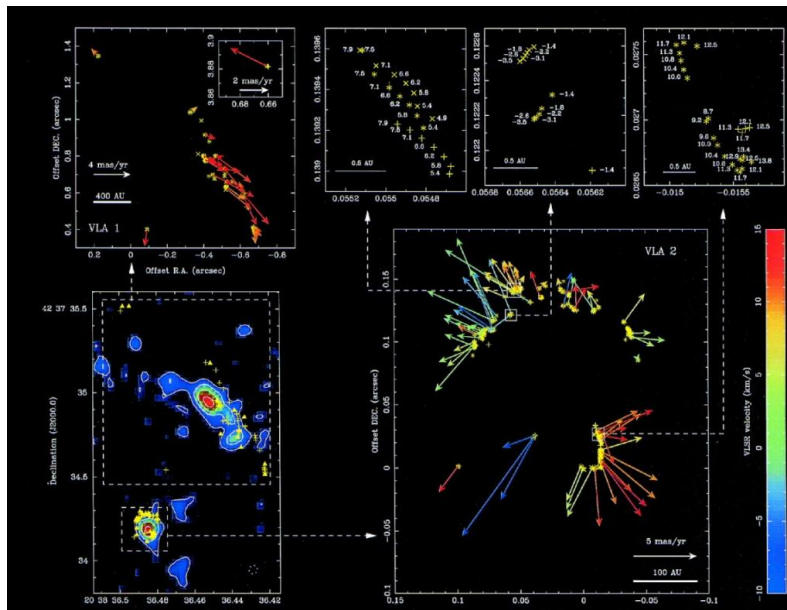
Follow-up SD/IF

Other common-use project

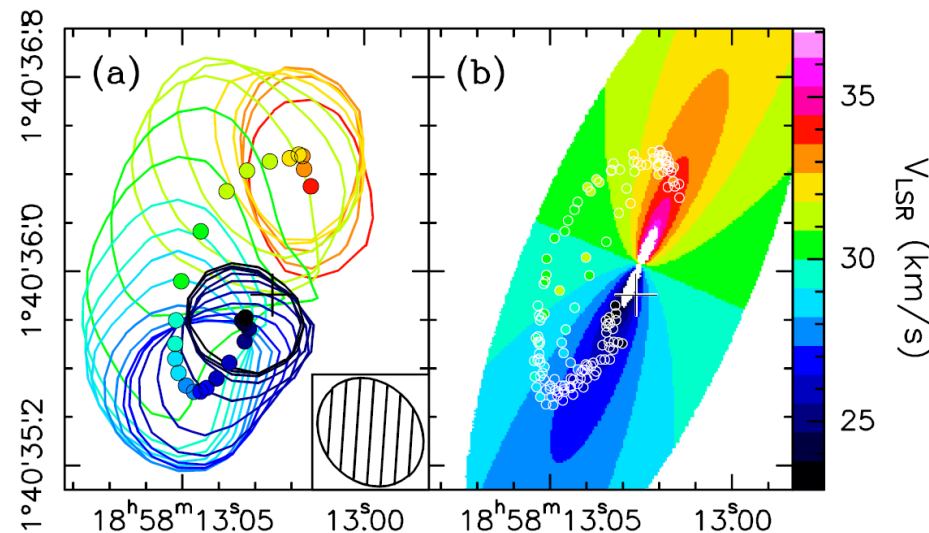
Leader
Liu

Mass accretion/ejection in HM-YSOs

- Evidence of outflow/disk system with $10-10^4$ AU
 - But spatial resolution is insufficient even with ALMA
 - 3D velocity is not available (except full ALMA)
 - Need systematic VLBI survey



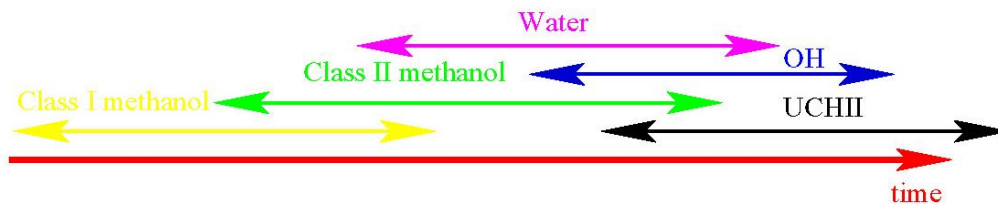
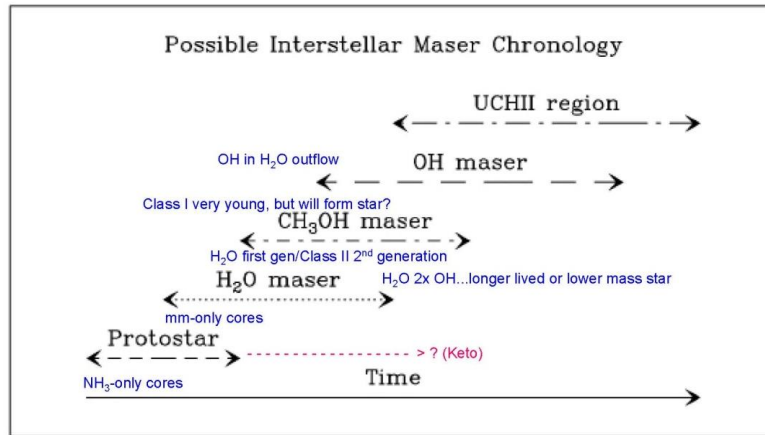
Torrelles et al. (2003)



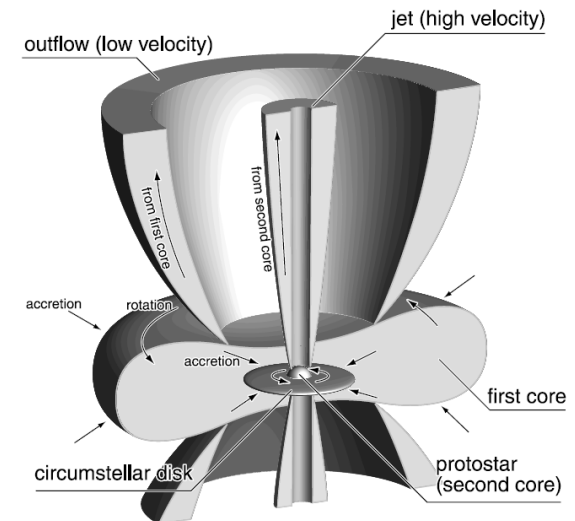
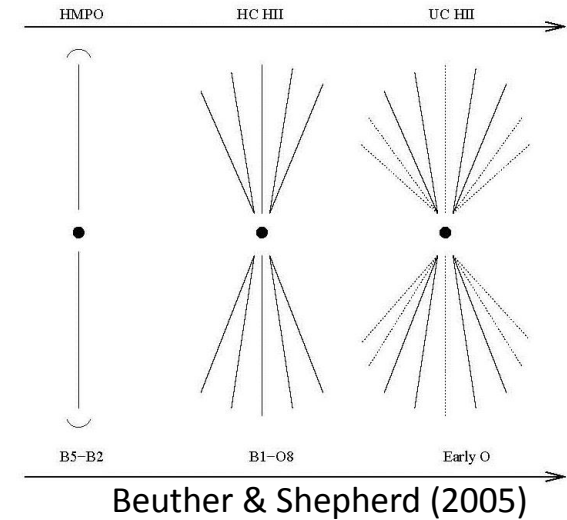
G35.20-0.74N (Sanchez-Monge et al. 2013)

Debate on evolutionary phase

- Need statistical studies
 - Evolution of outflow/jet?
 - Evolutionary phase of masers?



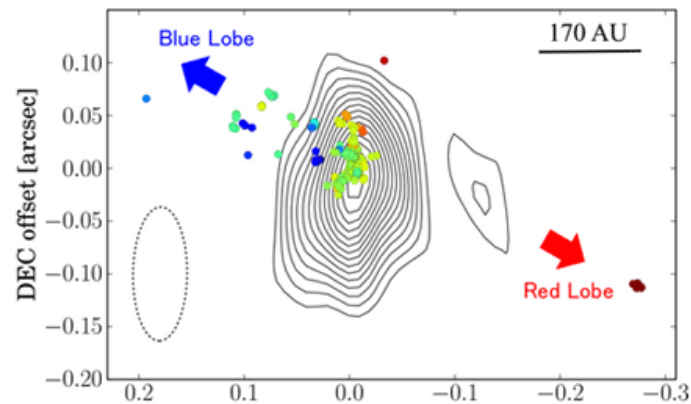
Reid (2007) vs Ellingsen (2007)
 Updated with slight modification but still controversial



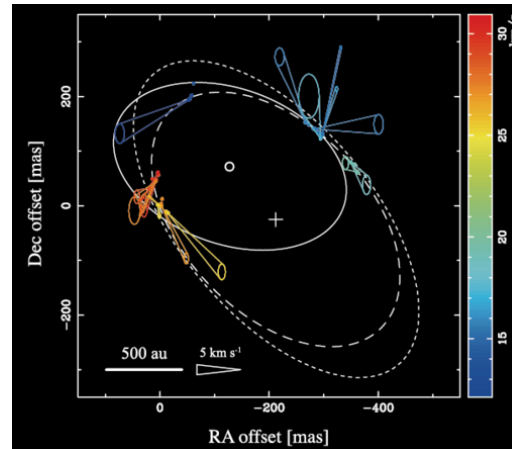
Machida et al. (2008, but for low-mass YSO)

Our tracers

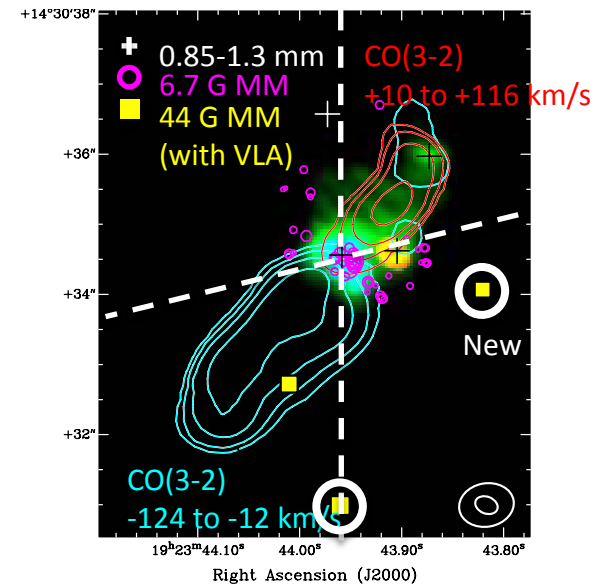
- Centimeter/millimeter maser lines
 - 22 GHz H₂O; high-velocity jet/outflow
 - 6.7 GHz CH₃OH; low-velocity outflow/disk
 - 44 GHz CH₃OH; low-velocity outflow



G353.273+0.641
(Motogi et al. 2015, in prep.);
H₂O masers trace high velocity
(~100 km/s) jet



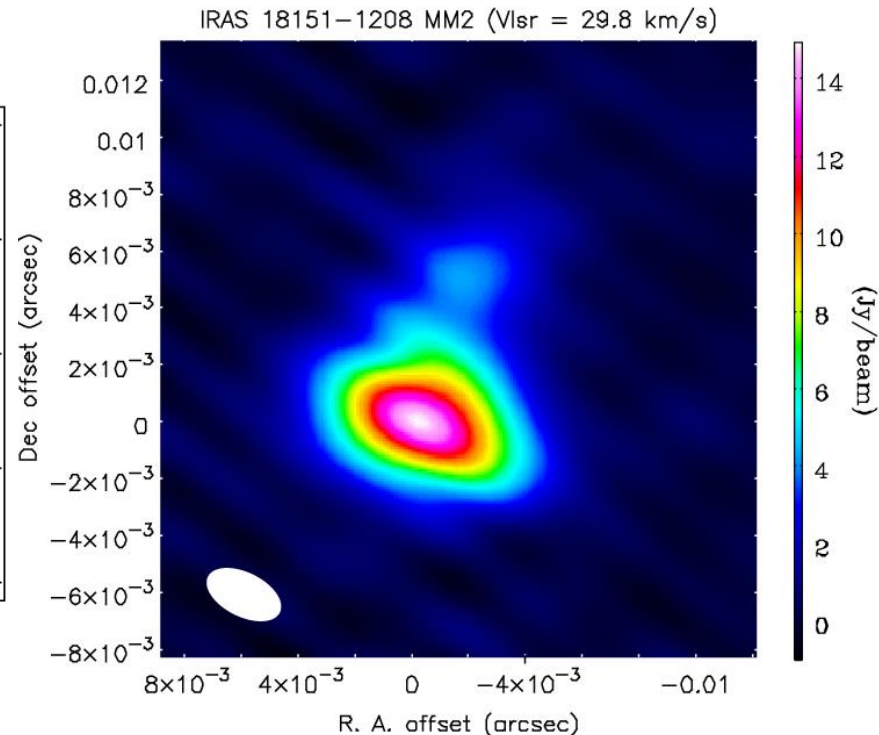
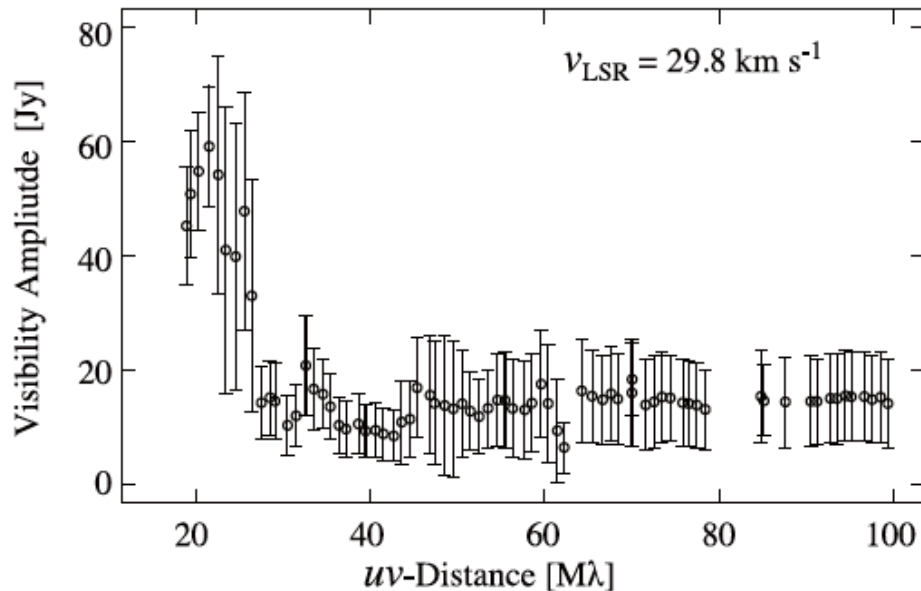
G6.79-0.25
(Sugiyama et al. 2015);
6.7 GHz CH₃OH masers
trace rotating disk



W51e2 (44GHz CH₃OH maser by Sugiyama
and SMA images by Shi et al. 2010)

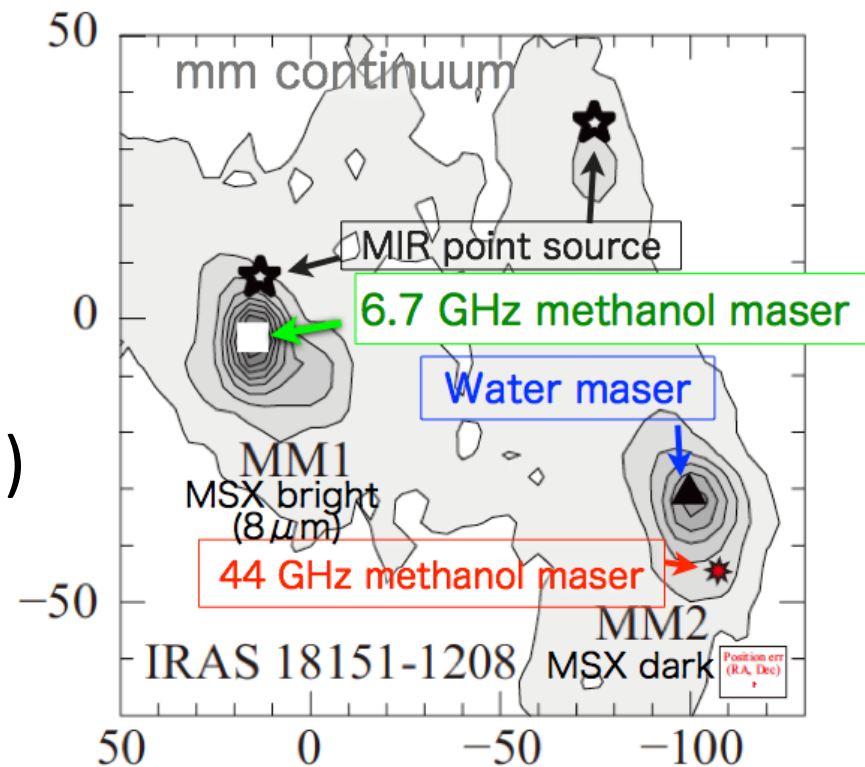
The first KaVA results

- First VLBI image of 44 GHz methanol maser (Matsumoto et al. 2014)
 - Advantage to obtain both extended structures and compact components

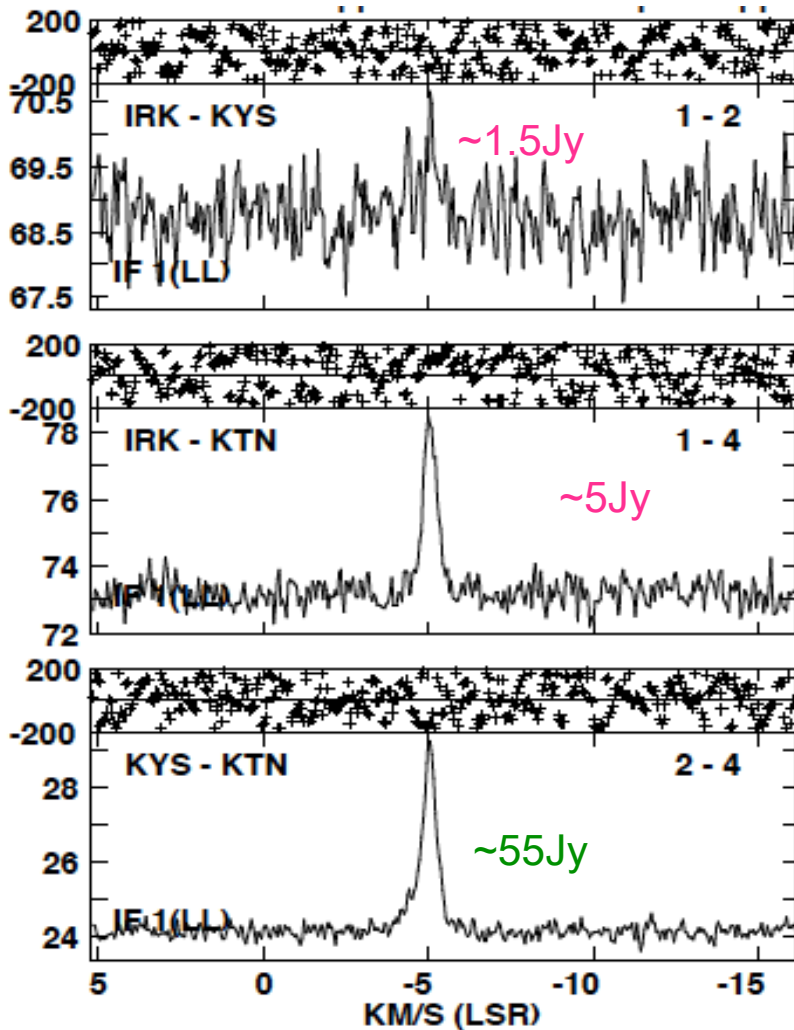


The first KaVA results

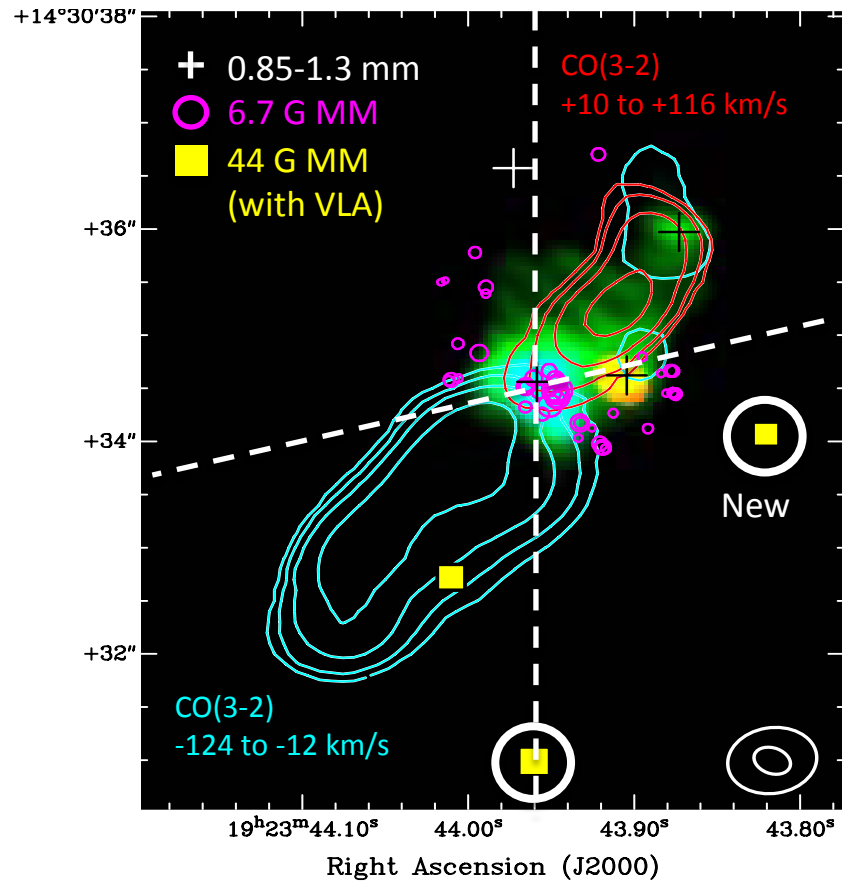
- First VLBI image of 44 GHz methanol maser in G18.34+1.78SW (Matsumoto et al. 2014)
 - Comparison with other maser species
 - Different HM-YSOs in different evolutionary phase (protostar to UCHII)
 - ALMA cycle 3 filler



Other examples



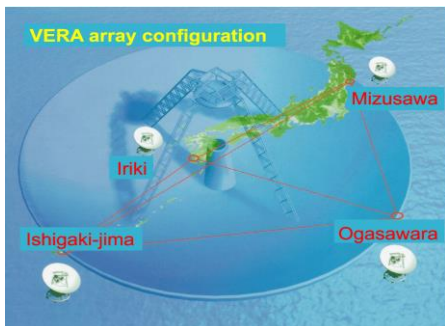
G357.96-0.16
(analyzed by Matsumoto)



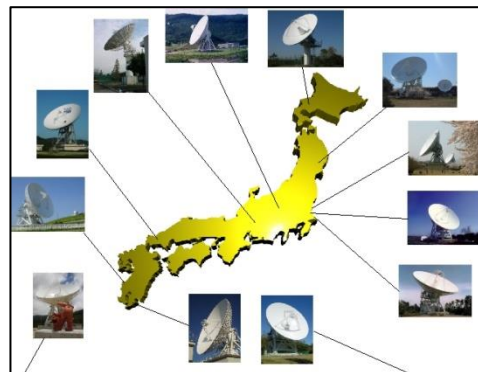
Superposed our 44GHz MM data on SMA images in W51e2 (Shi et al. 2010; Analyzed by Sugiyama)

Planned Observations

- VLBI survey/monitoring of sources; 87
 - Bright 22 GHz H₂O/44 GHz CH₃OH masers
 - Association of multiple masers, high velocity jets, ...
 - Statistics of HM-YSOs with uniform dataset
 - Possibly including multiple YSOs within fov
- Follow-up projects



Annual parallax



6.7GHz methanol masers



Thermal continuum/lines

Large-scale structure

Future and summary

- Timeline of KaVA SFRs LP
 - ~2017 Jun(1st yr); initial survey/snap-shot imaging
 - 2017 Aug ~(2nd yr); start of monitoring
- In parallel JVN (6.7 GHz), ALMA cycle 3, etc.
- SFRs LP will welcome new members at anytime!
- SFRs LP will welcome collaboration/new ideas with other instruments/theory!