KaVA Large Proposal for Star-formation studies

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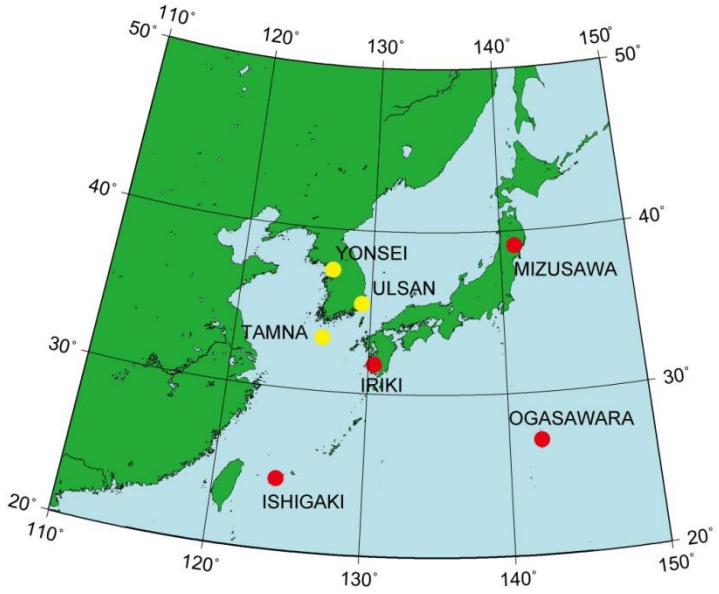
KaVA large program (LP)

- 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

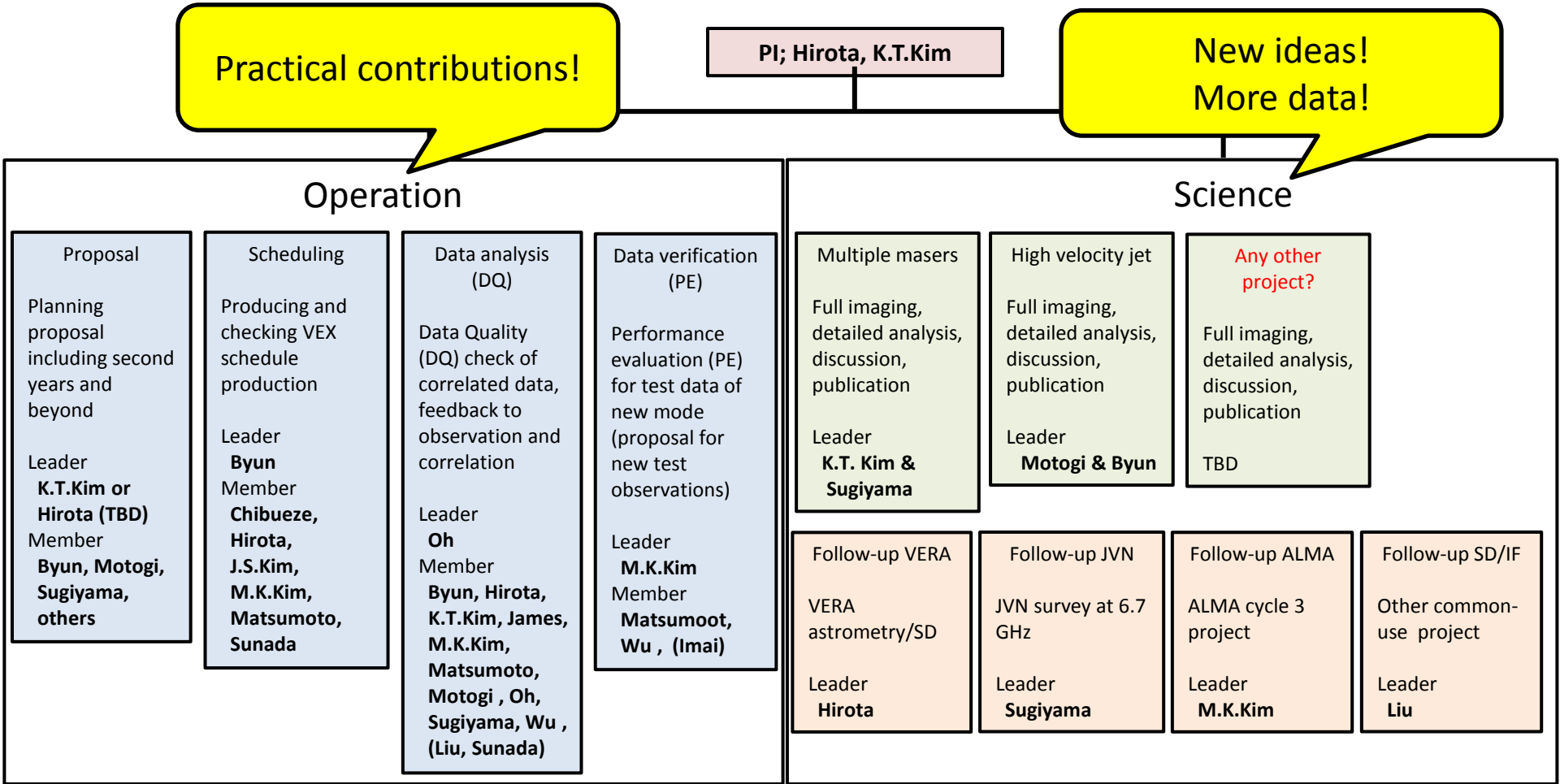


KaVA SFRs LP

- “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

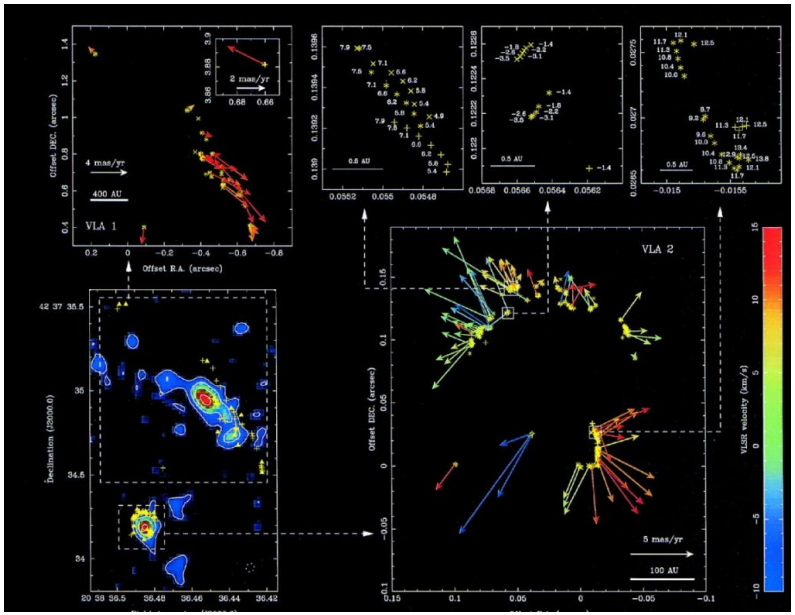
KaVA SFRs LP organization

- 20 active members; new members are welcome!

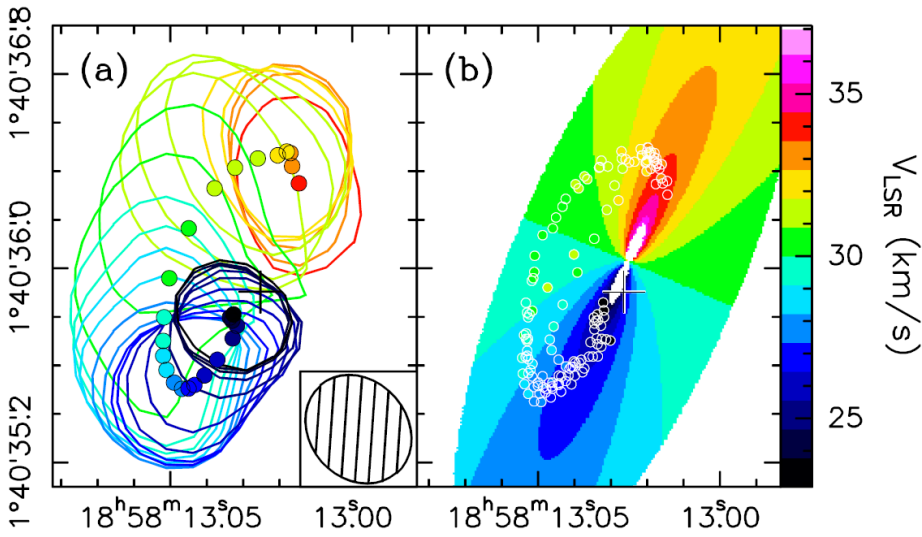


Mass accretion/ejection in HM-YSOs

- 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



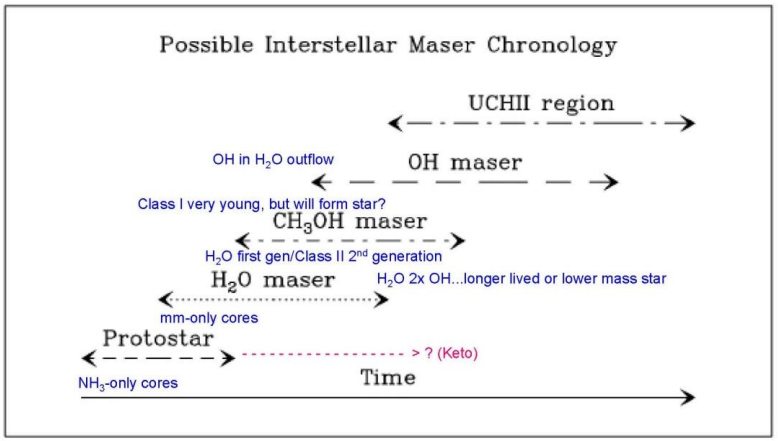
Torrelles et al. (2003)

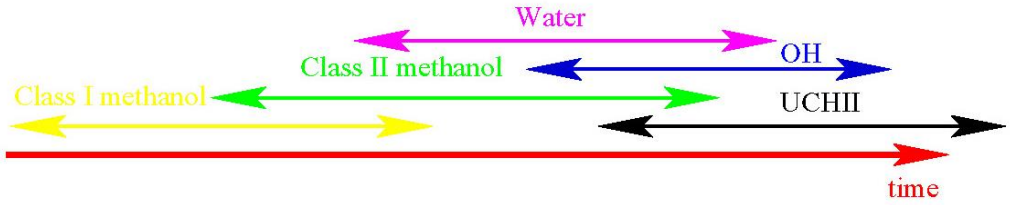


G35.20-0.74N (Sanchez-Monge et al. 2013)

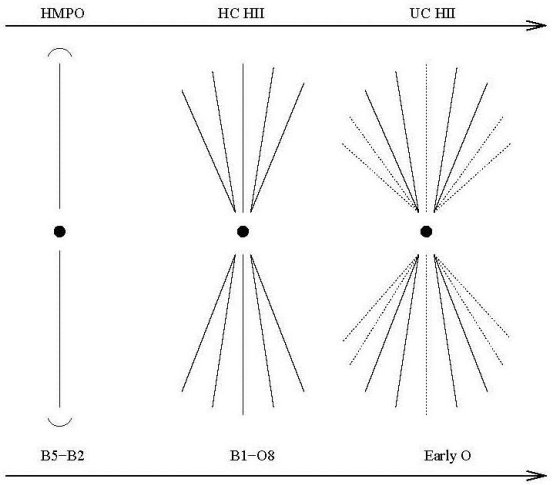
Debate on evolutionary phase

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

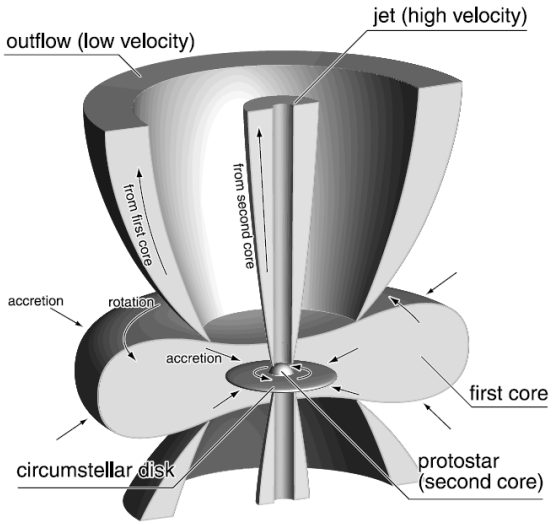




Reid (2007) vs Ellingsen (2007)
Updated with slight modification but still controversial



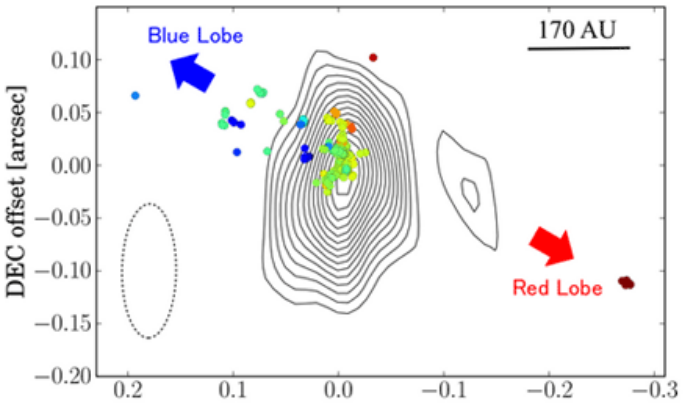
Beuther & Shepherd (2005)



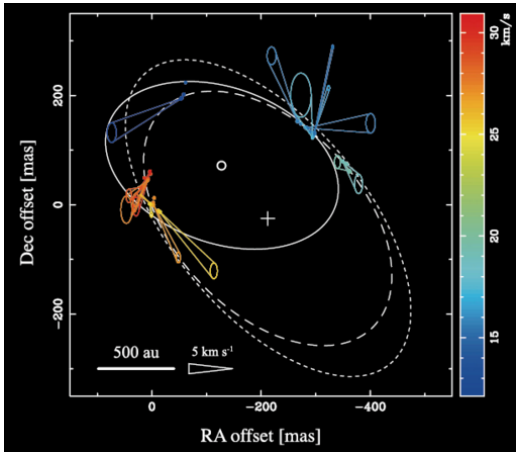
Machida et al. (2008, but for low-mass YSO)

Our tracers

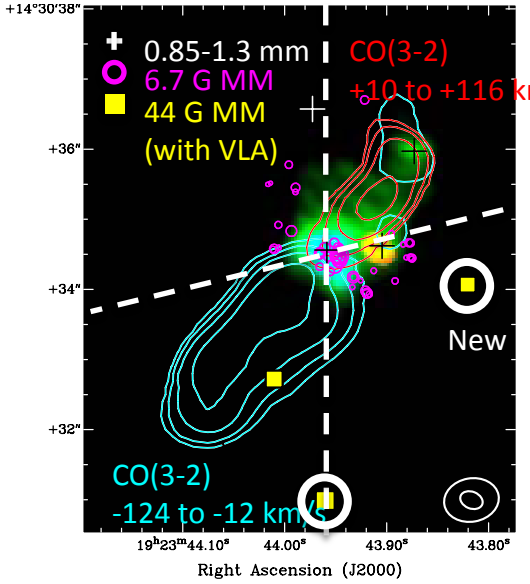
- Centimeter/millimeter maser lines
  - 22 GHz H2O; high-velocity jet/outflow
  - 6.7 GHz CH3OH; low-velocity outflow/disk
  - 44 GHz CH3OH; low-velocity outflow



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



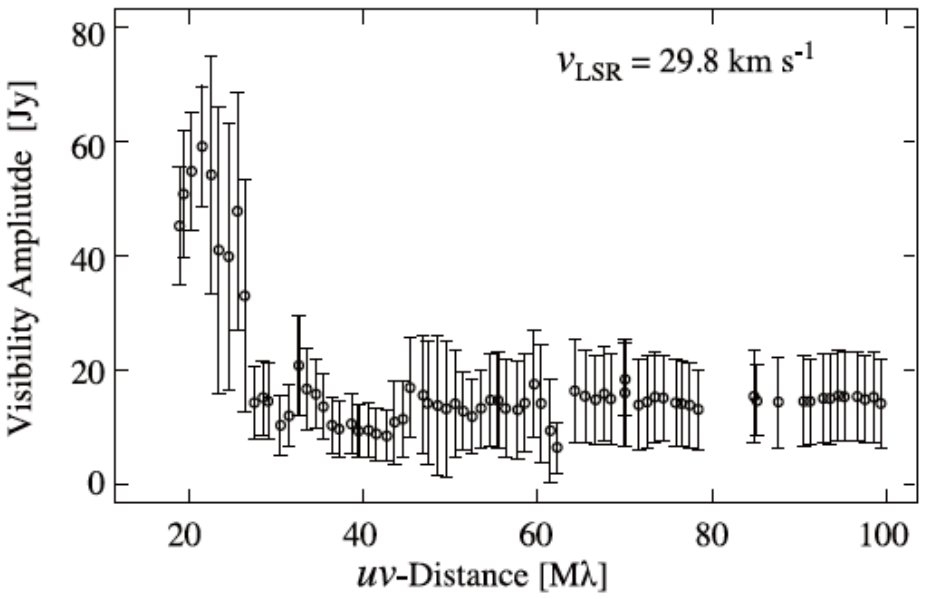
G6.79-0.25
(Sugiyama et al. 2015);
6.7 GHz CH3OH masers
trace rotating disk

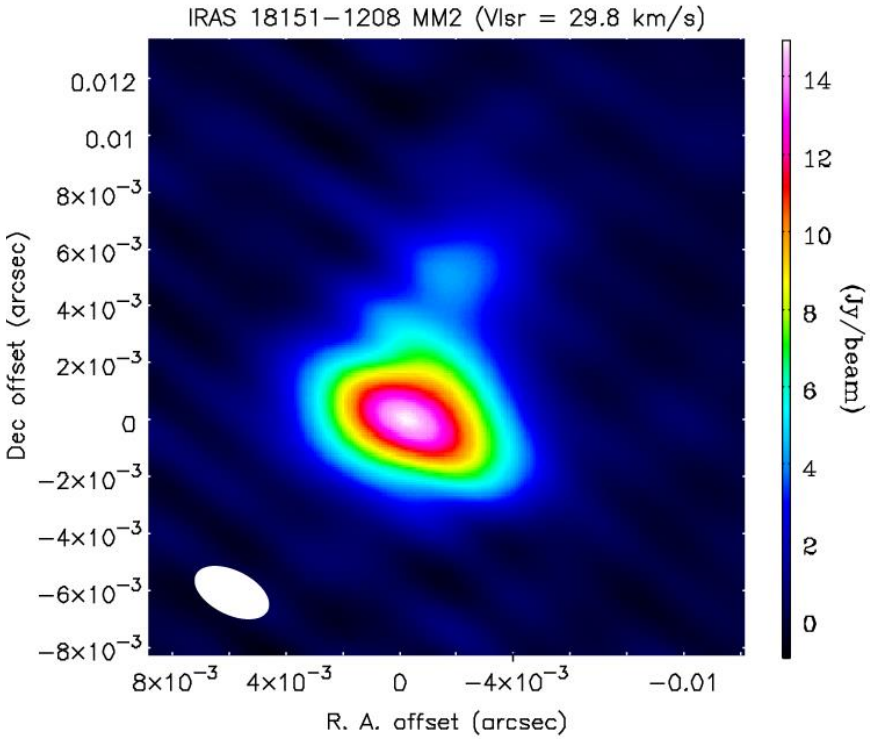


W51e2 (44GHz CH3OH maser by Sugiyama
and SMA images by Shi et al. 2010)

The first KaVA results

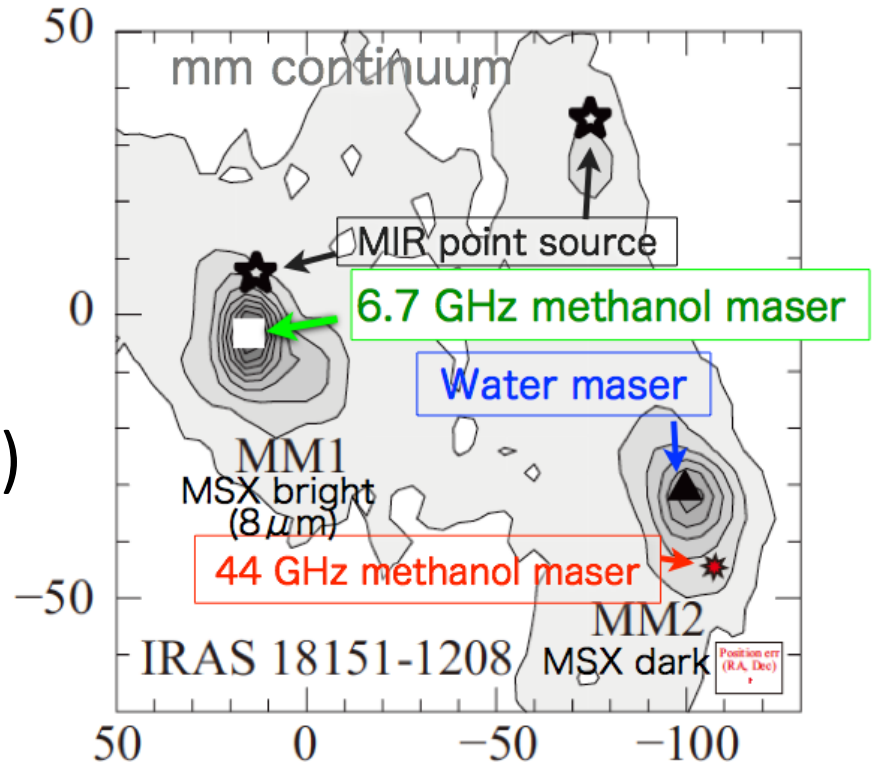
- First VLBI image of 44 GHz methanol maser (Matsumoto et al. 2014)
  - Advantage to obtain both extended structures and compact components





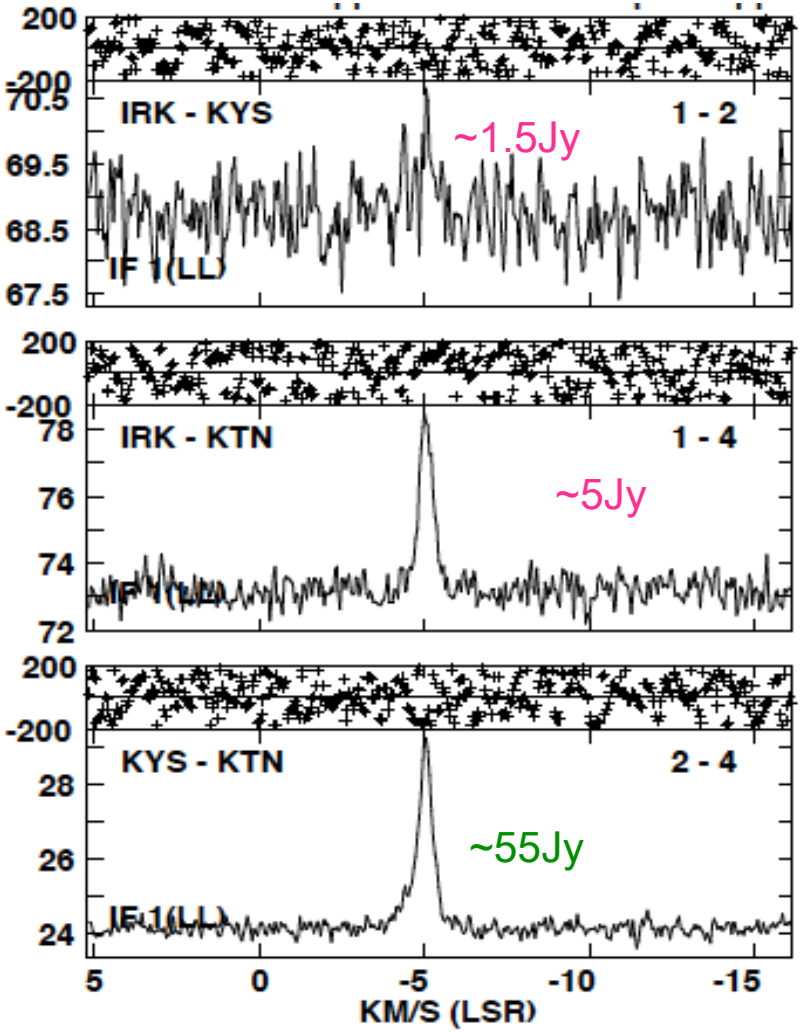
The first KaVA results

- 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

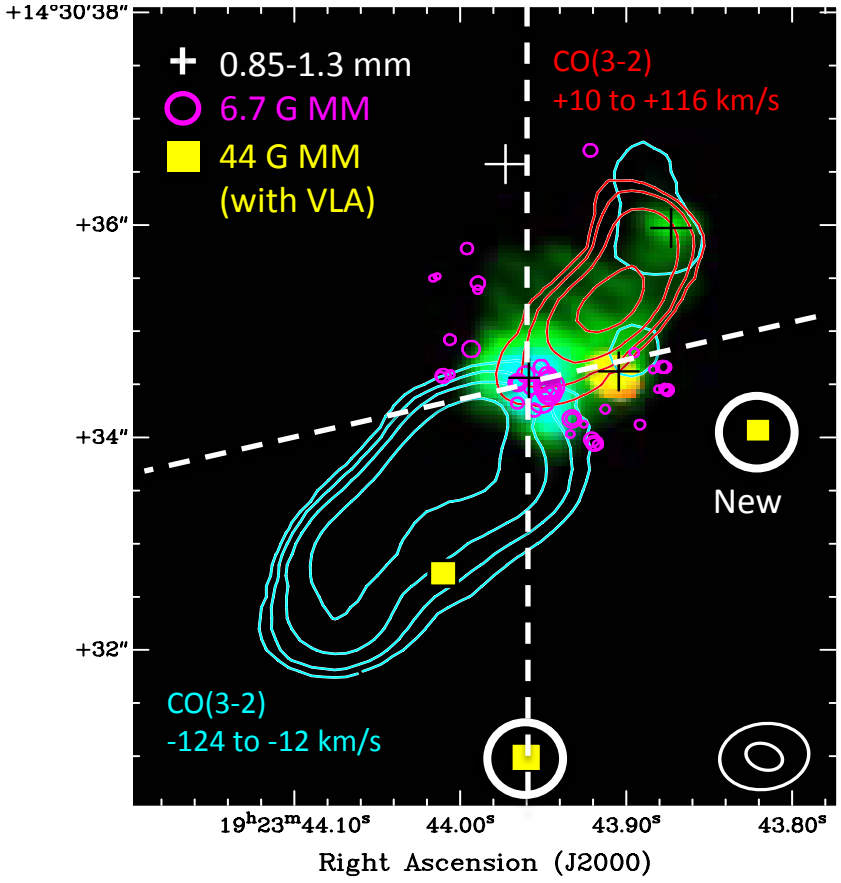


Marseille et al. (2008)

Other examples



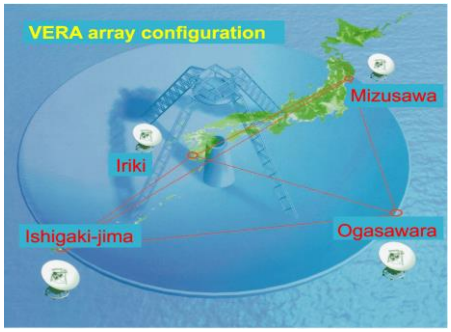
G357.96-0.16
(analyzed by Matsumoto)



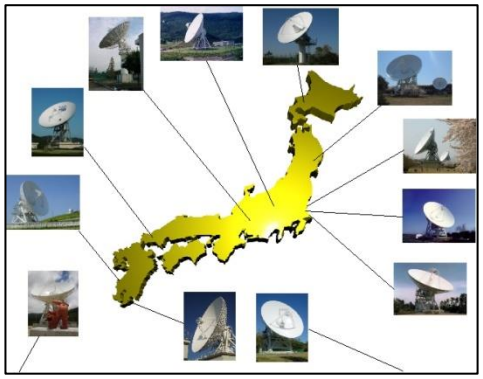
Superposed our 44GHz MM data on SMA images in W51e2 (Shi et al. 2010; Analyzed by Sugiyama)

Planned Observations

- VLBI survey/monitoring of sources; 87
  - Bright 22 GHz H_2O/44 GHz CH_3OH 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!