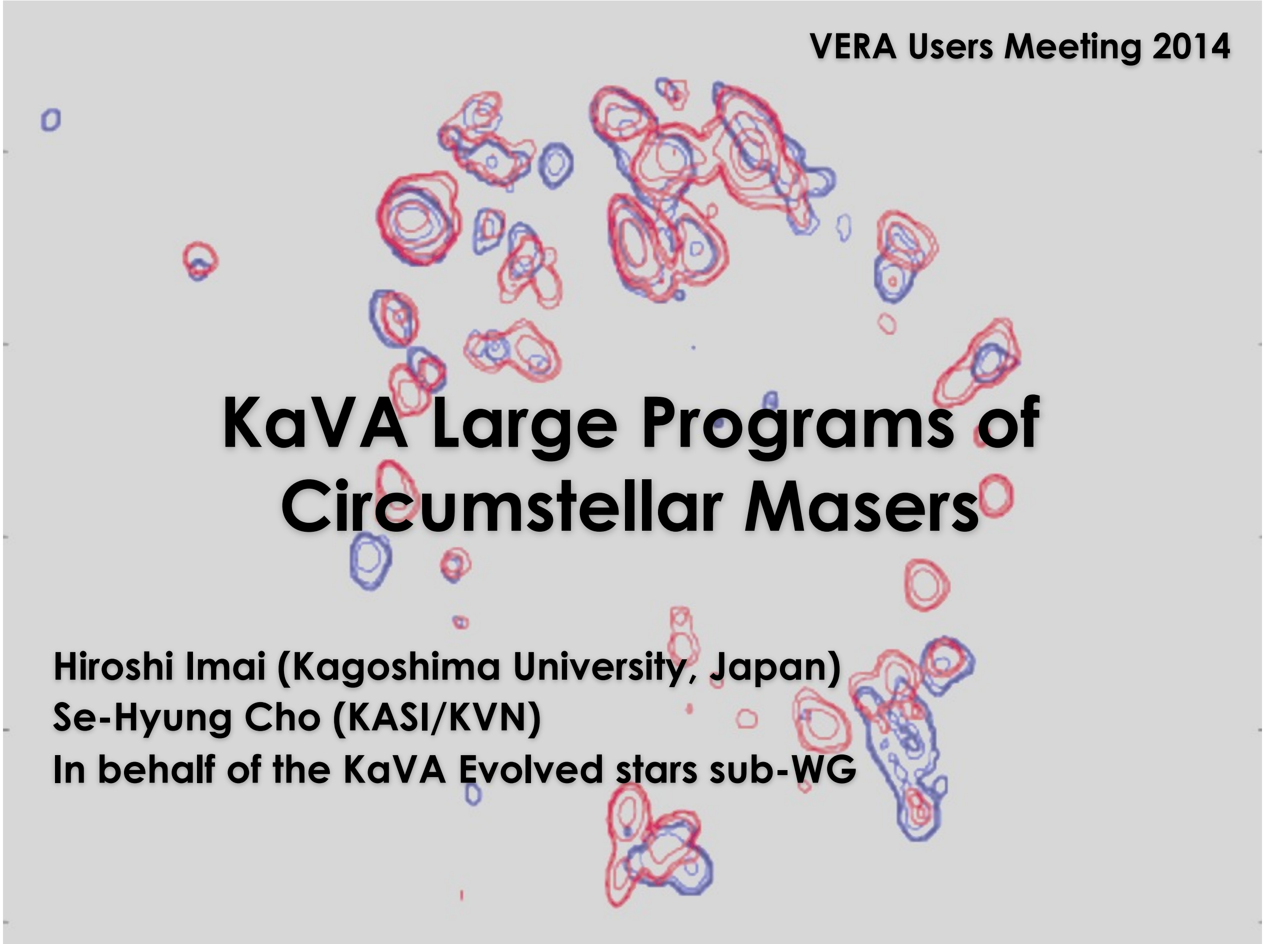


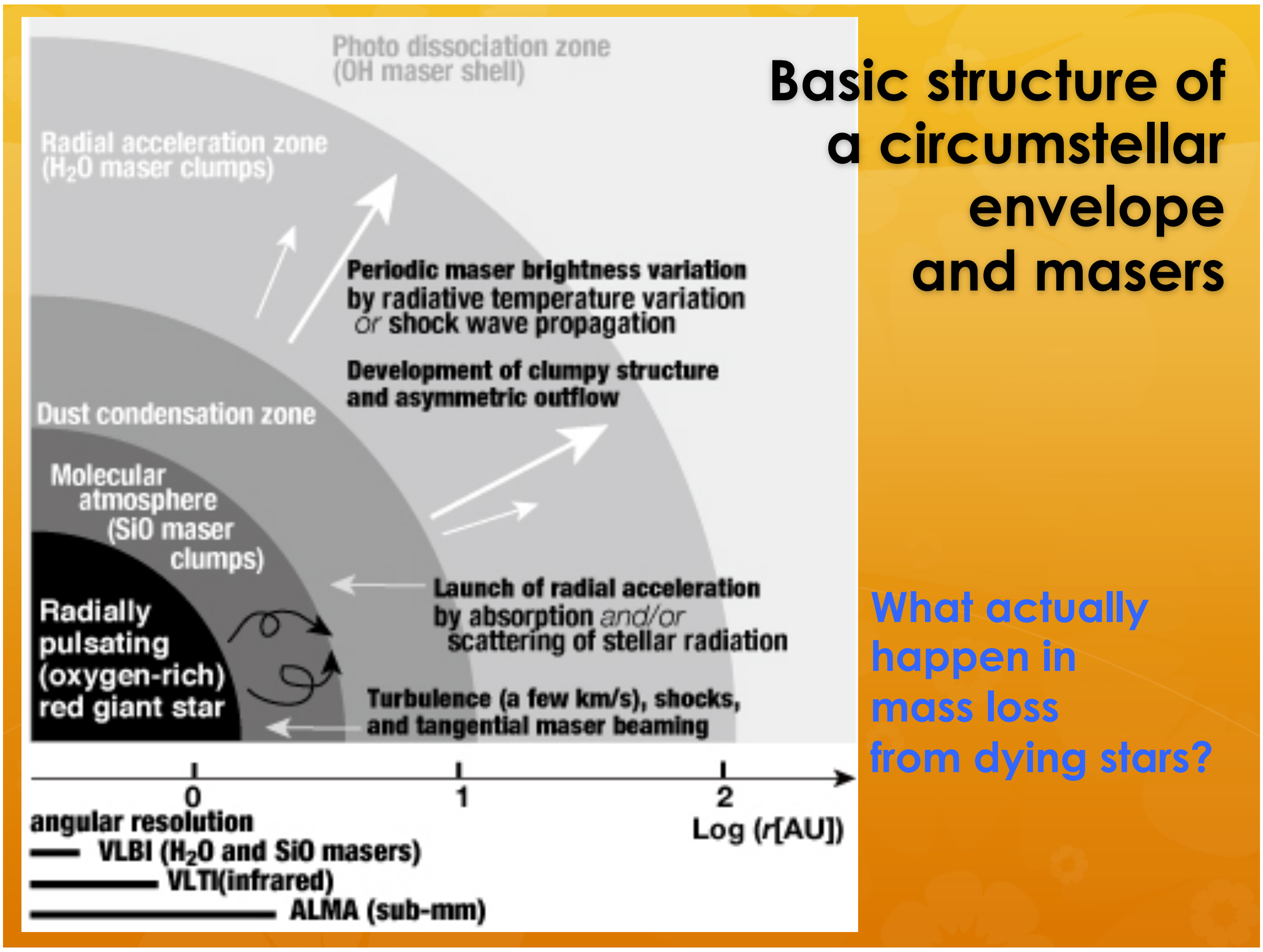
VERA Users Meeting 2014

KaVA Large Programs of Circumstellar Masers

Hiroshi Imai (Kagoshima University, Japan)
Se-Hyung Cho (KASI/KVN)
In behalf of the KaVA Evolved stars sub-WG

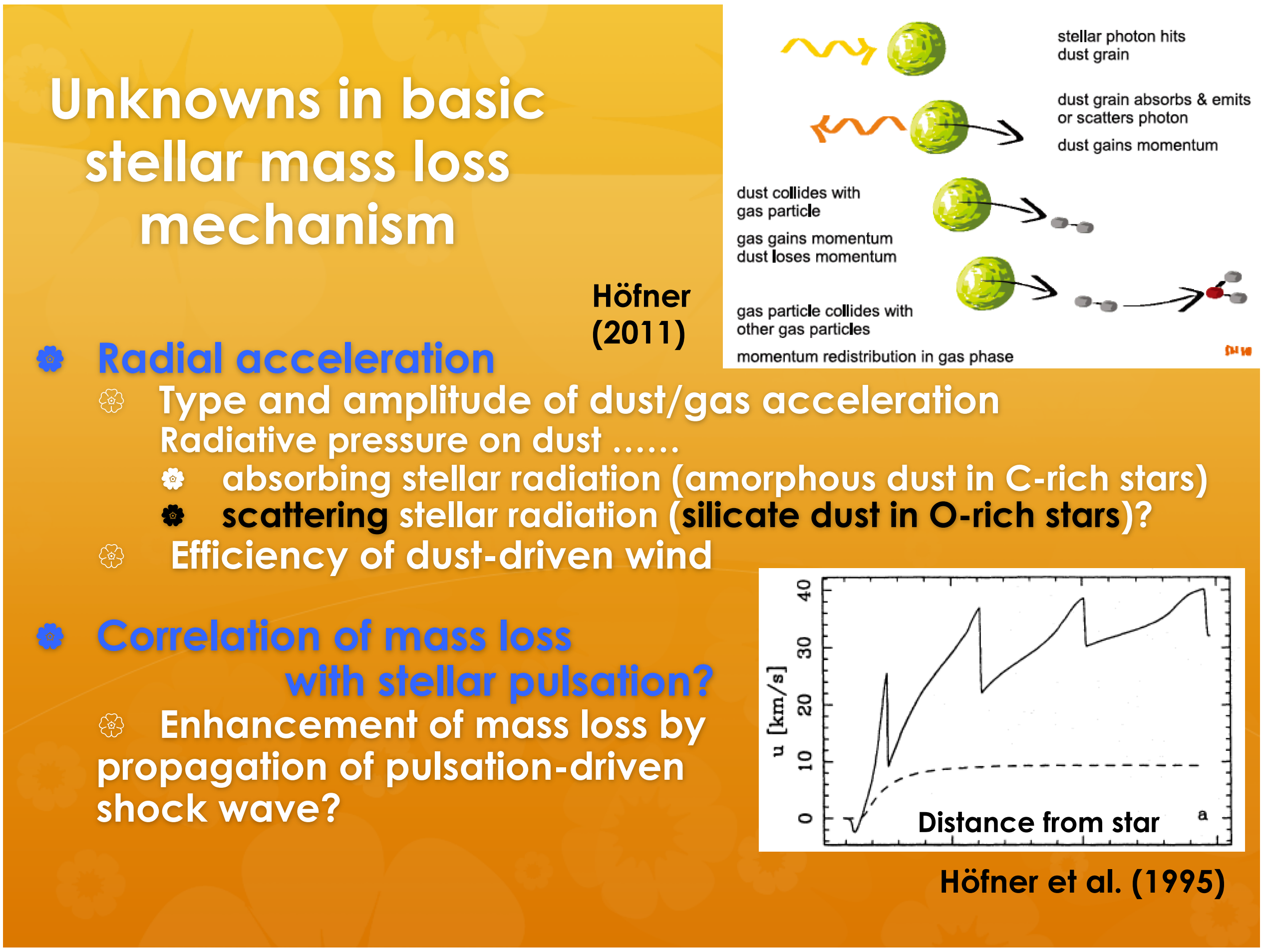
Draft proposal of KaVA Large Programs of Stellar Masers

- Scientific back ground of energetic mass loss in final stellar evolution and circumstellar maser excitation
- Scientific goals through intensive VLBI monitorings of stellar H_2O and SiO masers
- Specifications of the 10 year Large Programs
  - Phase 1 (2015A&B, ~200 hours):
    Large snapshot sampling of stellar masers
  - Phase 2 (2016A—2024, ~500 hours/year):
    Full monitorings of stellar masers
- Technical justification
  - Current progress of case studies



Basic structure of a circumstellar envelope and masers

What actually happen in mass loss from dying stars?



Unknowns in basic stellar mass loss mechanism

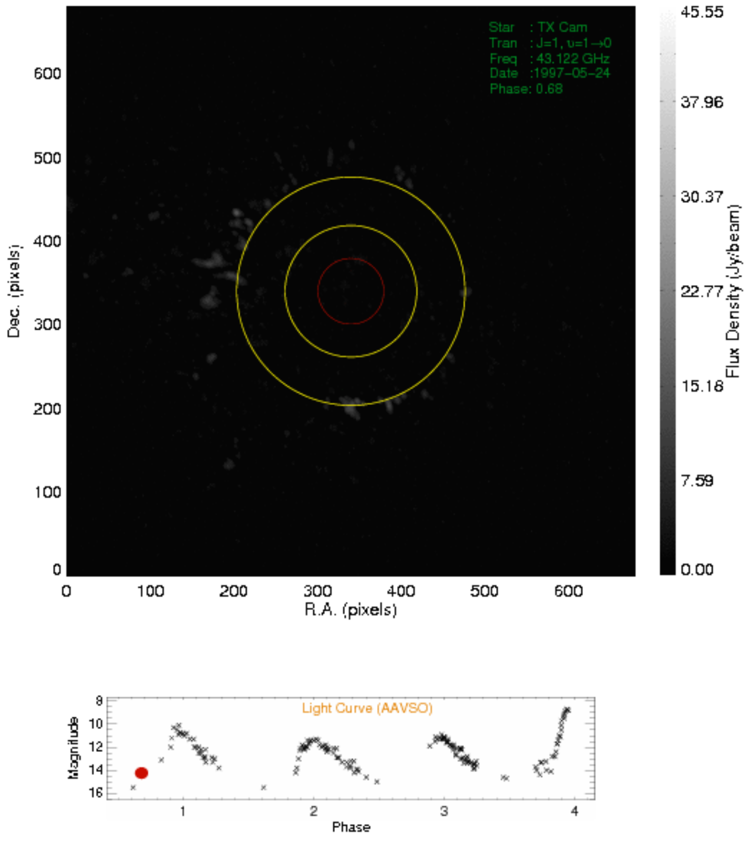
Höfner (2011)

- Radial acceleration
  - Type and amplitude of dust/gas acceleration
    Radiative pressure on dust ……
    - absorbing stellar radiation (amorphous dust in C-rich stars)
    - scattering stellar radiation (silicate dust in O-rich stars)?
  - Efficiency of dust-driven wind
- Correlation of mass loss with stellar pulsation?
  - Enhancement of mass loss by propagation of pulsation-driven shock wave?

Höfner et al. (1995)

Unknowns in circumstellar masers as sensitive probes of stellar mass loss

- Maser excitation mechanism (SiO masers nearby stars)
    - Collisional pumping (by shocks)
    - Line overlapping pumping (mid-IR radiation from H_2O)
- Origin of periodic and chaotic variation in masers
    - Not only in flux density!
    - but maser spot distribution as well?
    - By propagation of pulsation-driven shock waves?
    - By just change in physical parameters (*T*) in envelope?
- What is actually traced by maser emission?
    - Real Ballistic motions of material?
    - Just movement of "ghosts"
      (propagation of physical conditions)?

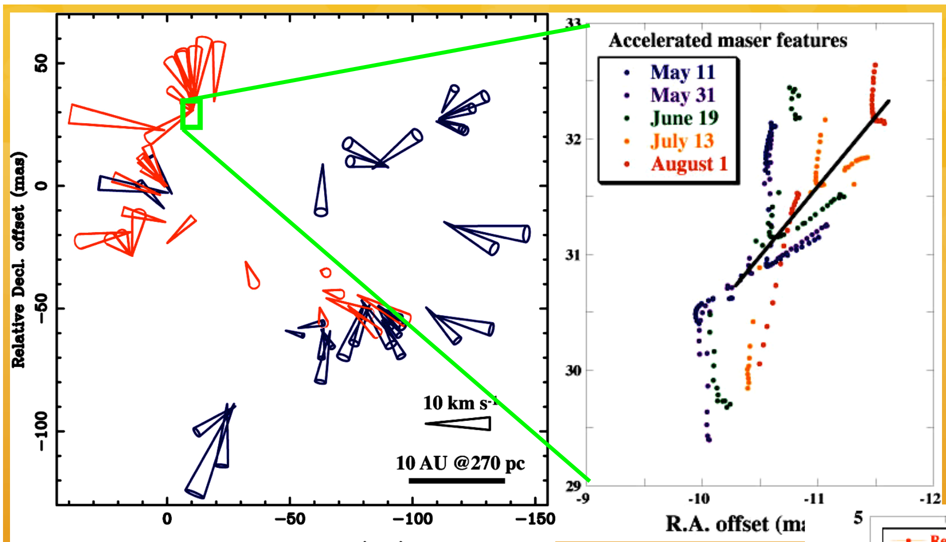


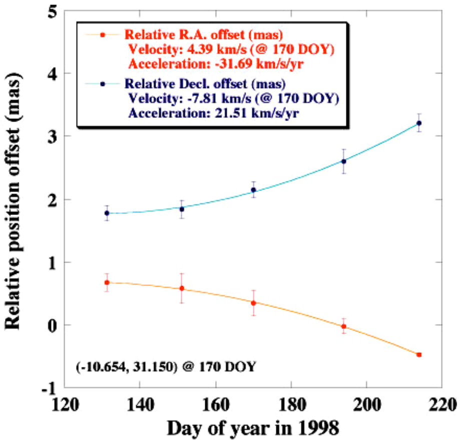
Unknowns will
still remain unknown
without intensive
maser monitoring.

Propagation of physical information (heating/shock) in SiO maser region?

We need new "colored" movies rather than "monochromatic" ones.

SiO masers in TX Cam
(Gonidakis et al. 2013)





We need H_2O maser movies as well!

(Rapid) acceleration up to H_2O maser region?

H_2O masers in RT Vir (Imai et al. 2003)

Planning the Large Programs (KaVA Evolved Stars sub-WG)

- Large-sample, intensive study of stellar H_2O and SiO masers for visualizing shock propagation and asymmetry in CSEs
  - AGB/post-AGB stars with long-period pulsations
    (100 d < P < 1600 d or 2.0 < log(P) < 3.2)

  Stellar pulsation dynamics in cirumstellar envelopes
  - Sub-samples of “exotic sources”: e.g. “water fountains”

  Evolution of asymmetric stellar mass loss

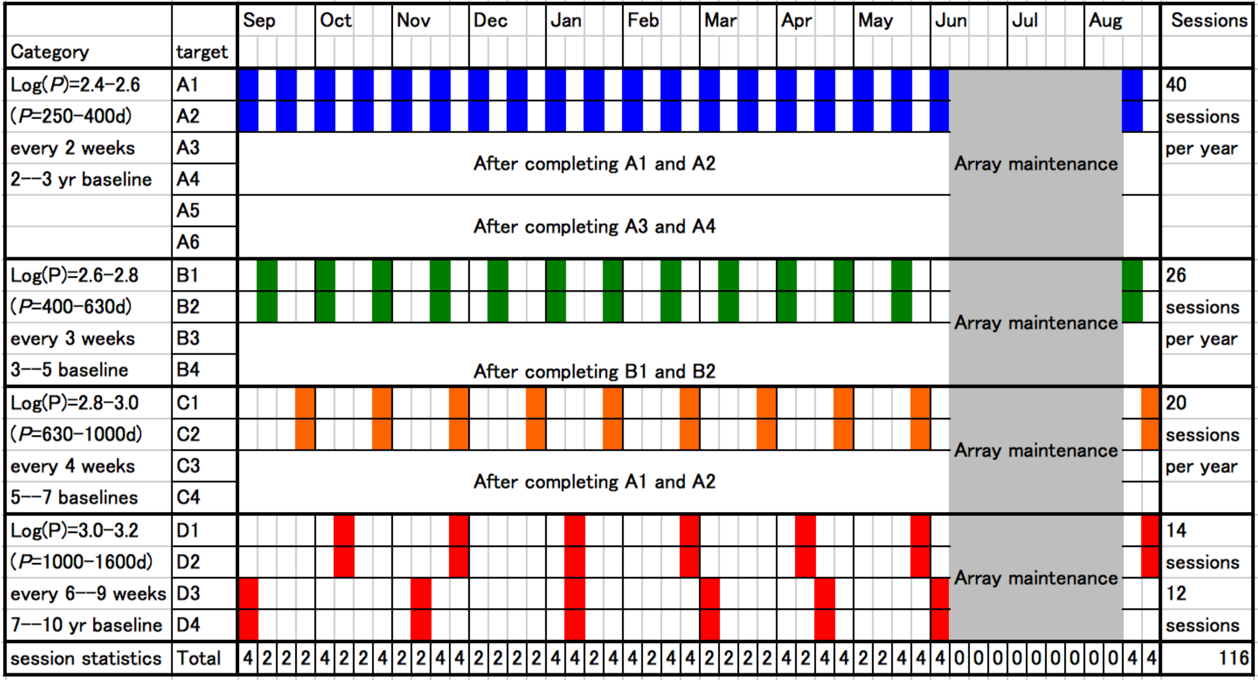
- Phase 1 (2015): Large snapshot sampling (~80 sources)
- Phase 2 (2016~2024): intensive monitoring for ~20 sources

  9 years ~ 3300 days > 2.0 P_{max}

Possible KaVA stellar maser monitoring program

Phase 2 (2016~2024), 18 stars, for 10 years, ~500 hours/year

Annual schedule block



Category	target	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sessions
Log(*P*)=2.4–2.6	A1													40
(*P*=250–400d)	A2													sessions
every 2 weeks	A3	After completing A1 and A2									Array maintenance			per year
2-–3 yr baseline	A4													
	A5	After completing A3 and A4												
	A6													
Log(P)=2.6–2.8	B1													26
(*P*=400–630d)	B2										Array maintenance			sessions
every 3 weeks	B3													per year
3-–5 baseline	B4	After completing B1 and B2												
Log(P)=2.8–3.0	C1													20
(*P*=630–1000d)	C2										Array maintenance			sessions
every 4 weeks	C3	After completing A1 and A2												per year
5-–7 baselines	C4													
Log(P)=3.0–3.2	D1													14
(*P*=1000–1600d)	D2													sessions
every 6-–9 weeks	D3										Array maintenance			12
7-–10 yr baseline	D4													sessions
session statistics	Total	4 2 2 2	4 2 2 4	2 2 4 4	2 2 2 2	4 4 2 4	4 2 4 4	2 2 2 2	4 2 4 4	2 2 4 4	4 0 0 0	0 0 0 0	0 0 4 4	116

1 session ~ 4 hours of observation

Phase 1 Large Program: ESTEMA

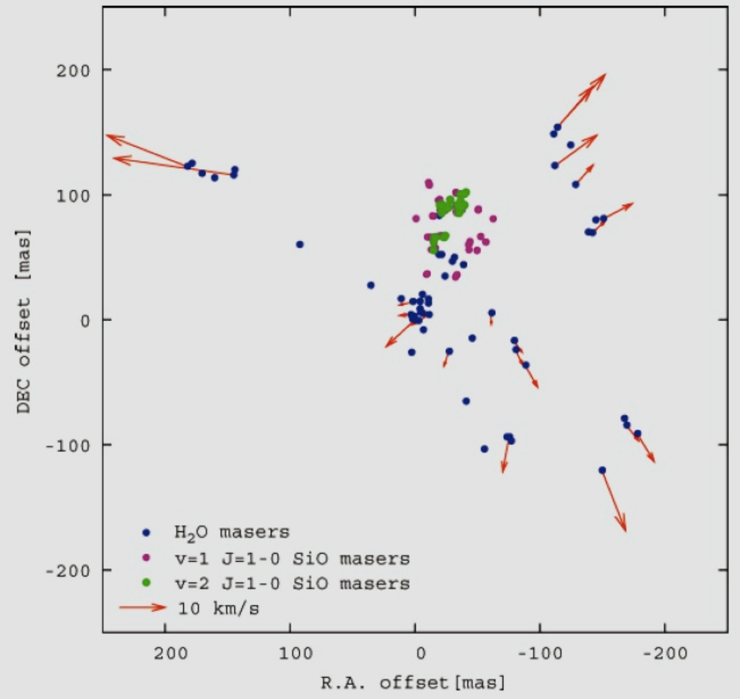
(Expanded Study on Stellar Masers)

- Snapshot imaging (~1.5 hours/source integration) of
  ~80 stellar 22 GHz H_2O and 43 GHz SiO masers
  ~200 hours in total (K/Q band observations) in 2015

- Expand the number of stellar masers as VLBI targets
  ※including water fountains, symbiotic stars
- List of ~50 new VLBI targets of stellar masers expected with ESTEMA (assuming ~75% fringe detection rate)
- Source selection for new decadal study with
  KaVA (Phase 2), ALMA and VLTI

- Microscopic (maser feature structure ~0.1 AU) to macroscopic (CSE diameter ~100 AU) view from the one-shot program

ESTEMA = maser imaging + astrometry
Finding the origin of asymmetric stellar mass loss

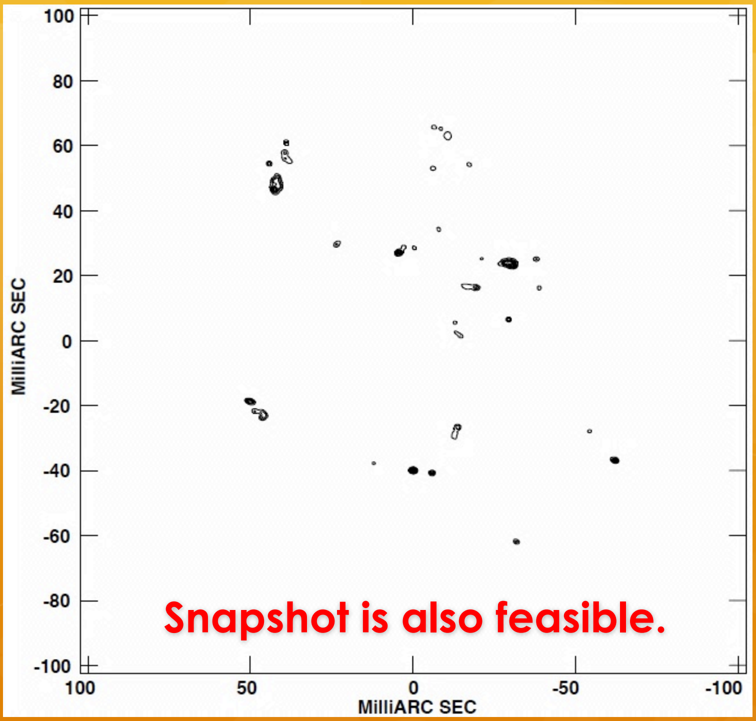


VY CMa (Choi et al. 2008)

- SiO masers pinpoint stellar positions in H_2O maser regions in CSE.
- Dynamical timescale of stellar outflow traced by H_2O masers
- Velocity field correlation between SiO and H_2O maser regions
- Asymmetry of stellar mass loss

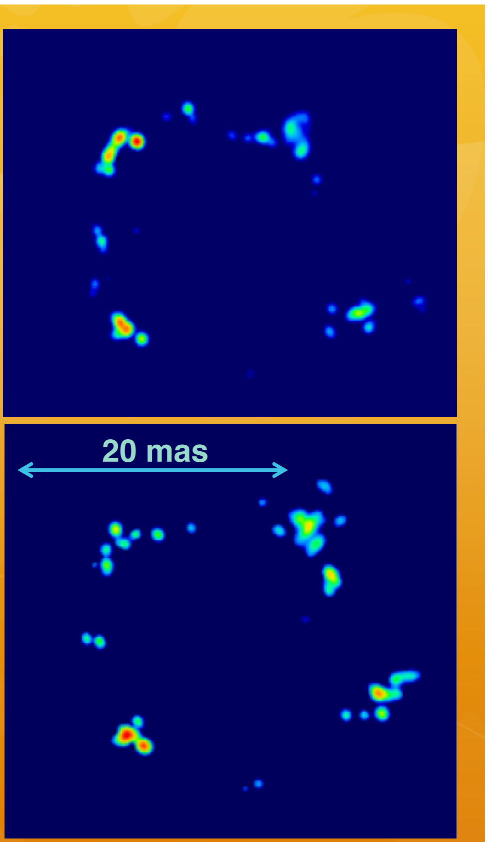
Multi frequency phase-referencing (KVN) or/and astrometry (VERA) are crucial.

Long exposure (>4 hours) with KaVA



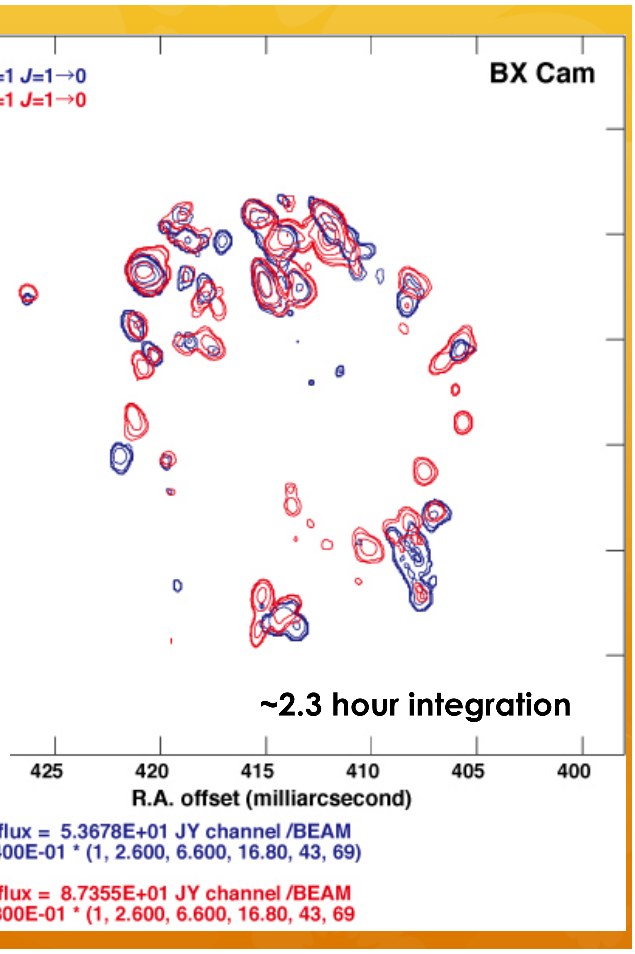
Snapshot is also feasible.

S Per H_2O (Kusuno et al.)



WX Psc SiO *v*=2 & *v*=1 *J*=1→0 (Yun et al.)

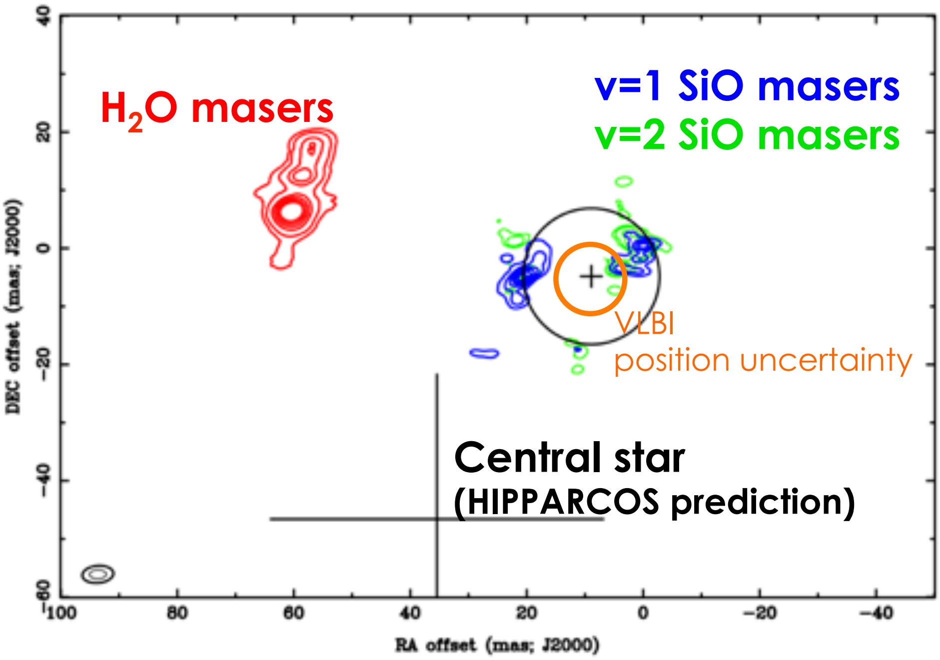
First maser images with KaVA data from Daejeon Correlator (KJCC processor)



BX Cam
(Imai et al., 2014 Sep.)

First successful multi frequency phase-referencing technique

R LMi (Dodson et al. 2014)



Summary

We are being ready for the Large Programs (phase 1 at least).

- Technical and operation issues have been fixed towards going ESTEMA (1st phase Large Program) including new Daejeon Correlator processing and user data processing in pipelines.
- Synergies with VLTI (imaging stars), ALMA (thermal/maser line and dust emission mapping) and Nano-JASMINE (Japanese space optical astrometry mission from 2015) become realistic.
- Astronomers who are interested in subsections of the Large Program science and further commissioning to (challenging) technical issues are always welcome to join the KaVA Evolved Stars sub-Working Group.