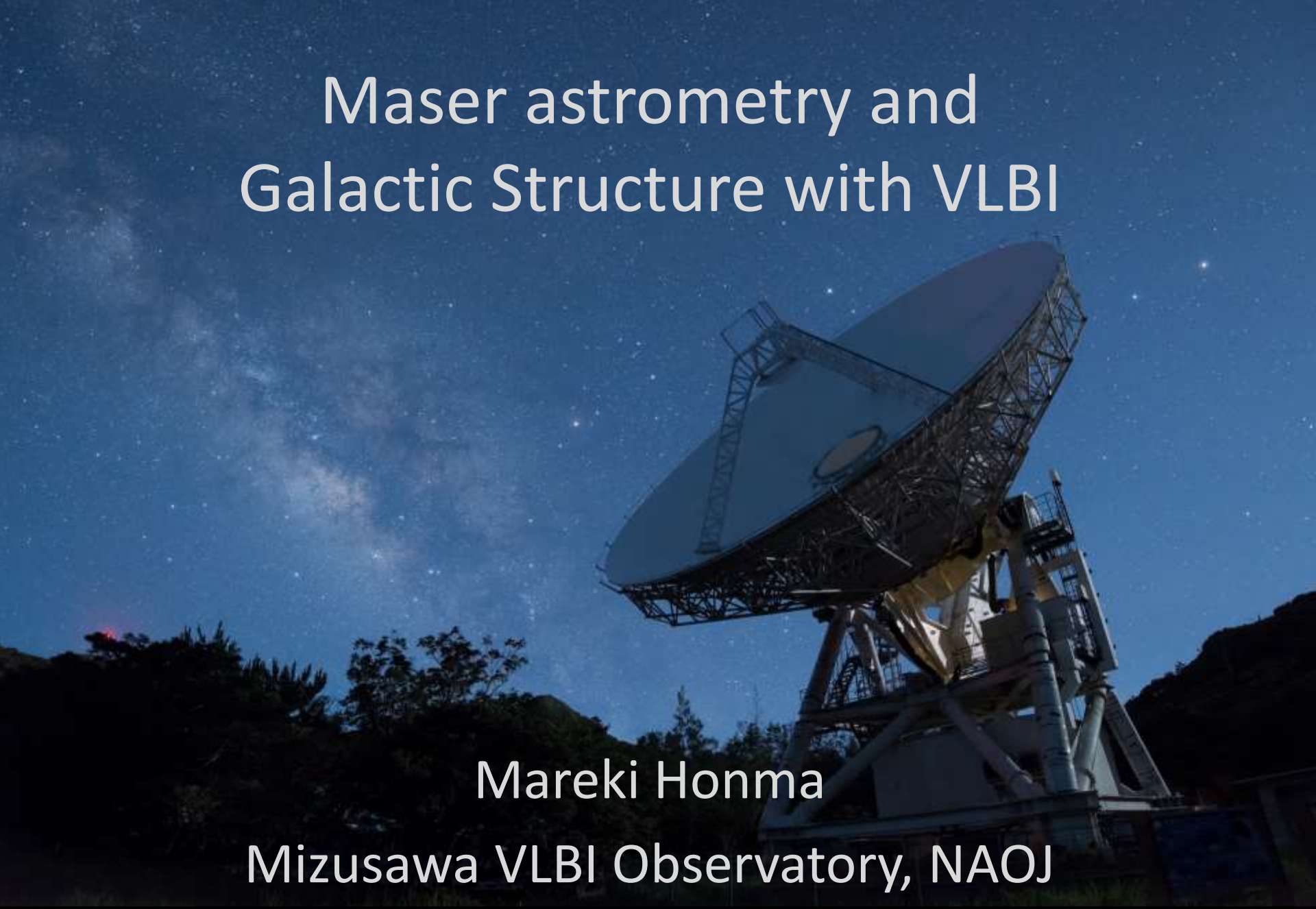
Maser astrometry and Galactic Structure with VLBI



Mareki Honma

Mizusawa VLBI Observatory, NAOJ

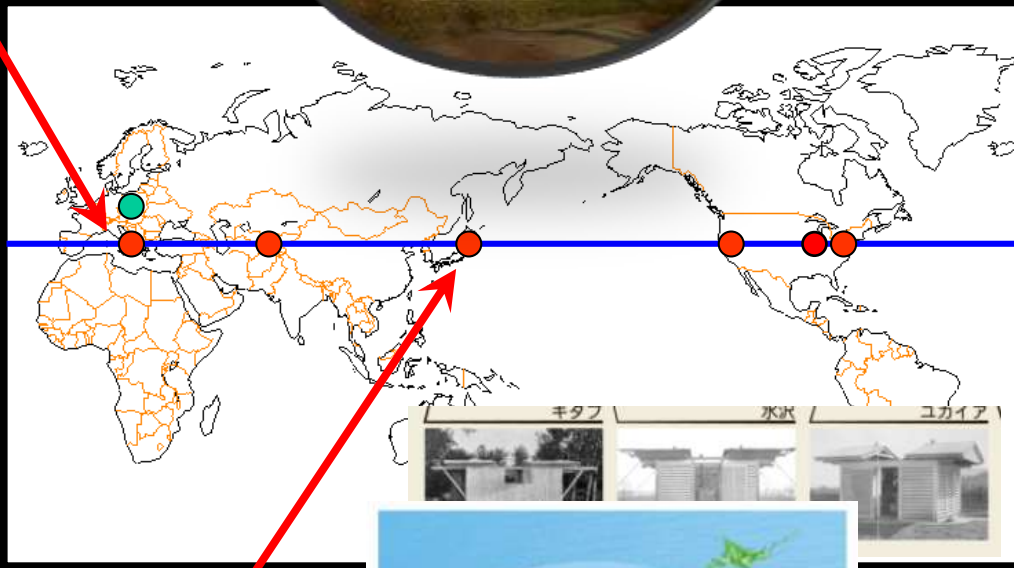
Milky Way & VERA Ogasawara station

120 years of research at Cagliari & Mizusawa

Internati… …bservatory (ILO), f…



Carlo Forte



ILO Mizusawa ->
Mizusawa VLBI Observatory, NAOJ

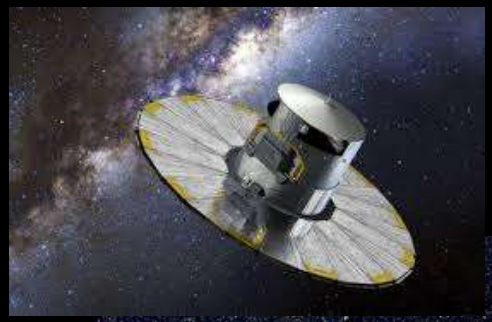
ILO Carlo Forte ->
Cagliari Astron. Observatory, INAF

Mizusawa

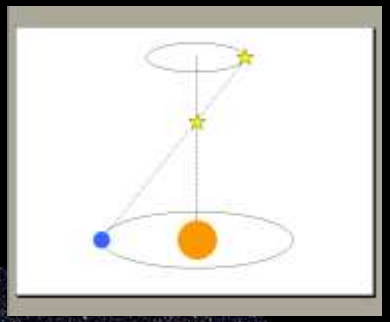


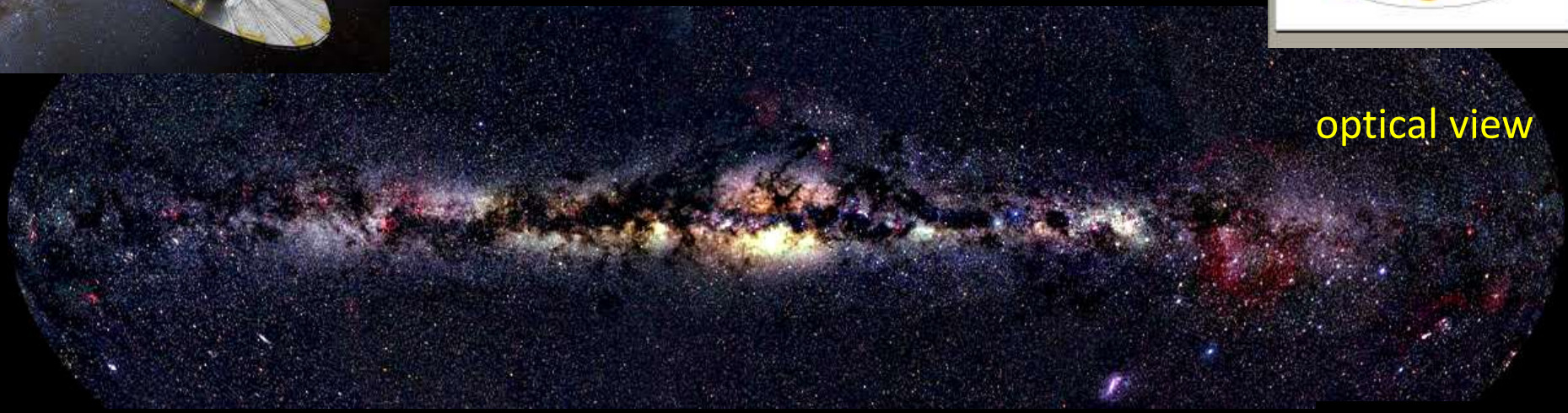
both working on radio/VLBI !!

Galactic astrometry



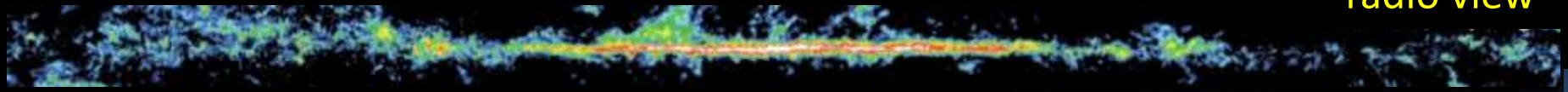
Parallax ~ 100 uas
for 10 kpc distance





optical view

radio view

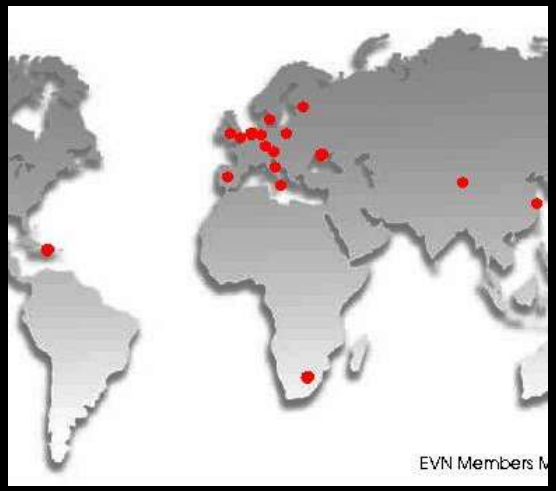


GAIA and VLBI are complementary
to each other



VLBI Arrays for Astrometry

- EVN, VLBA, VERA in the Northern hemisphere.





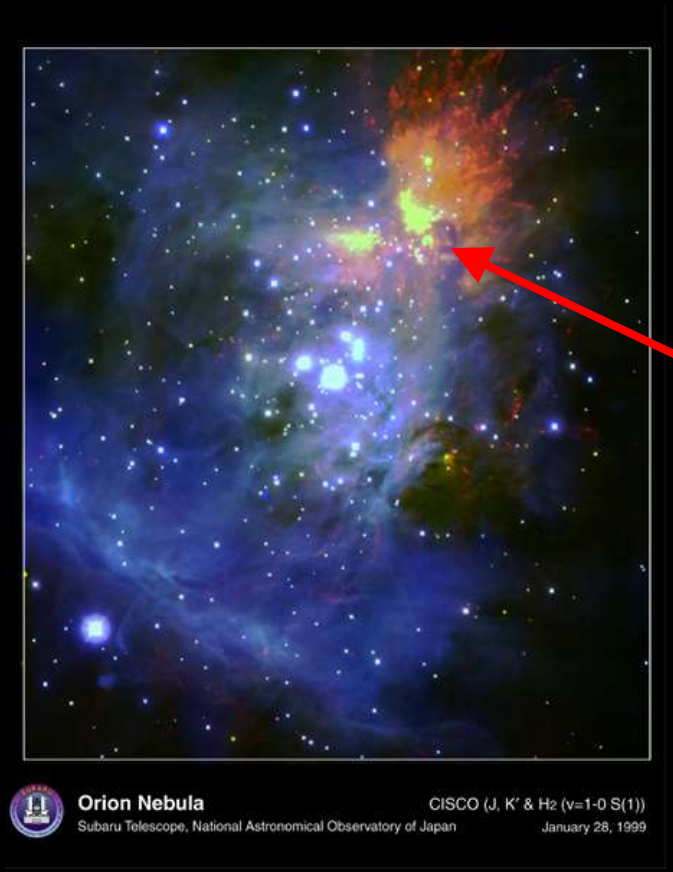


- LBA, in the Southern hemisphere



Example of VERA's initial result: Orion KL

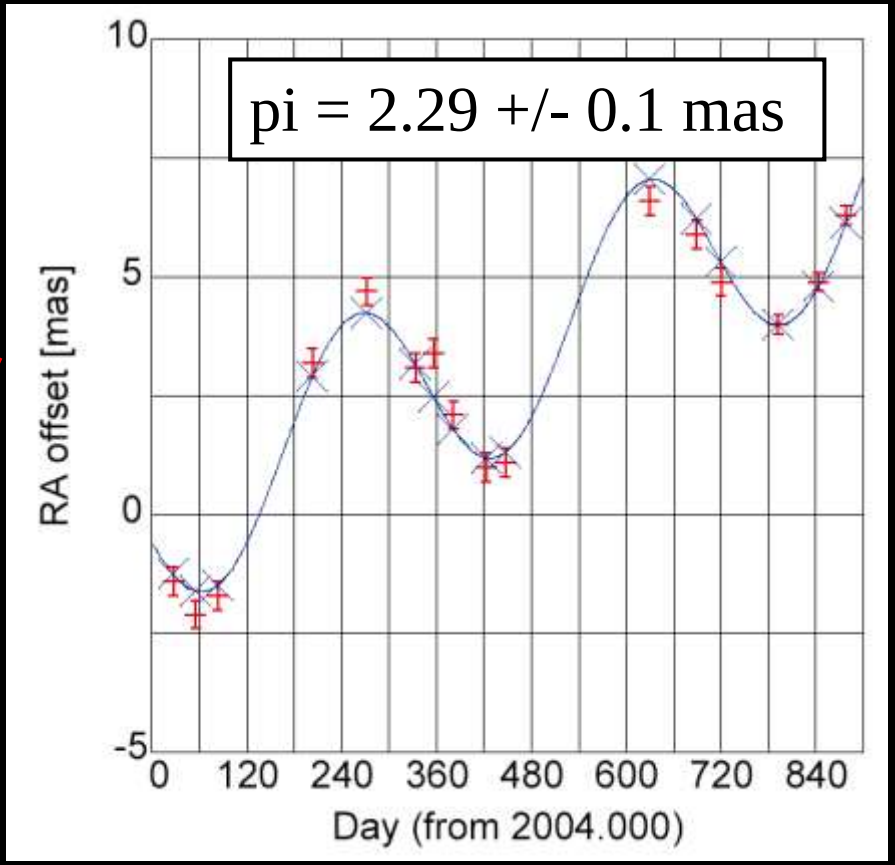
Astrometry of H2O masers in Orion KL



Orion nebula with Subaru

Hirota et al. (2007)

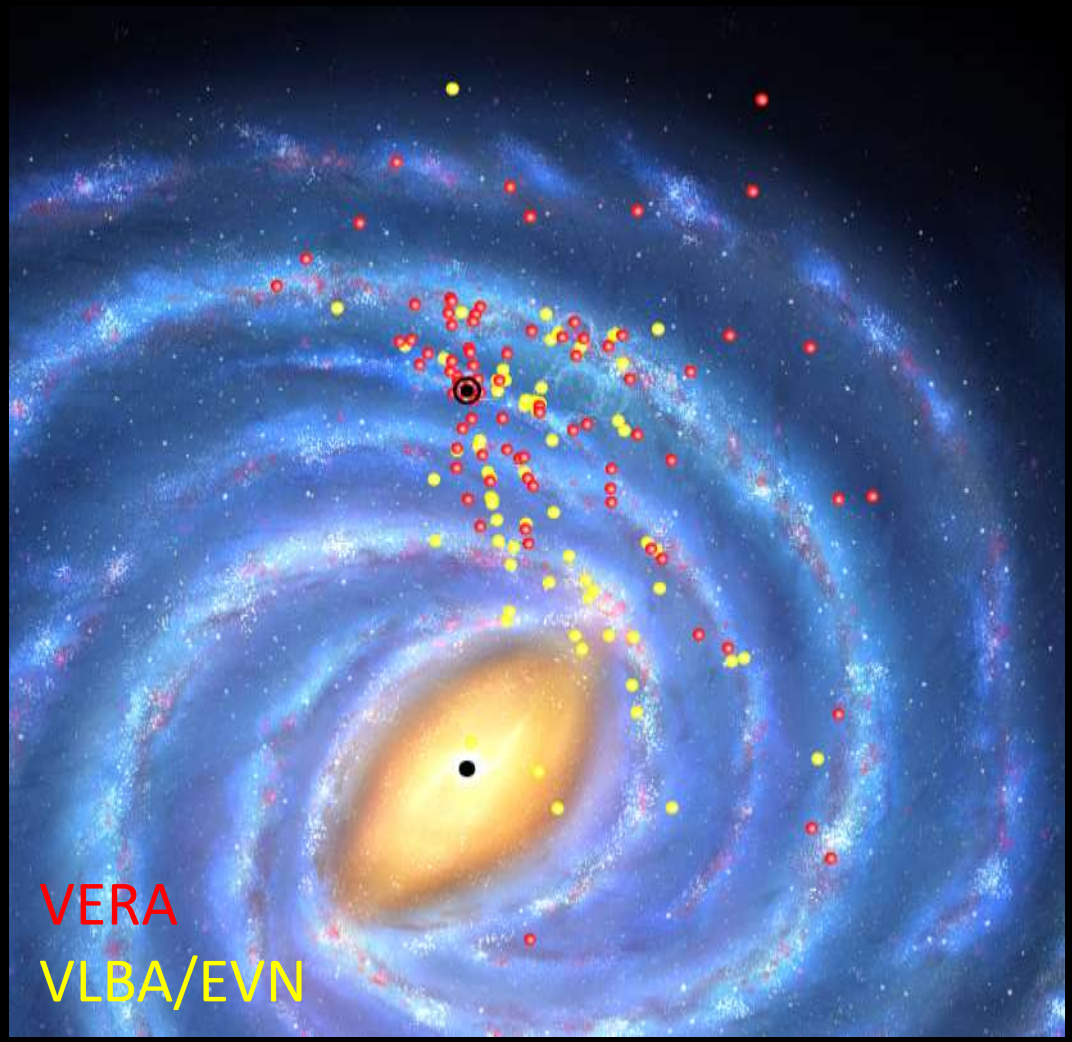
D = 437 +/- 19 pc



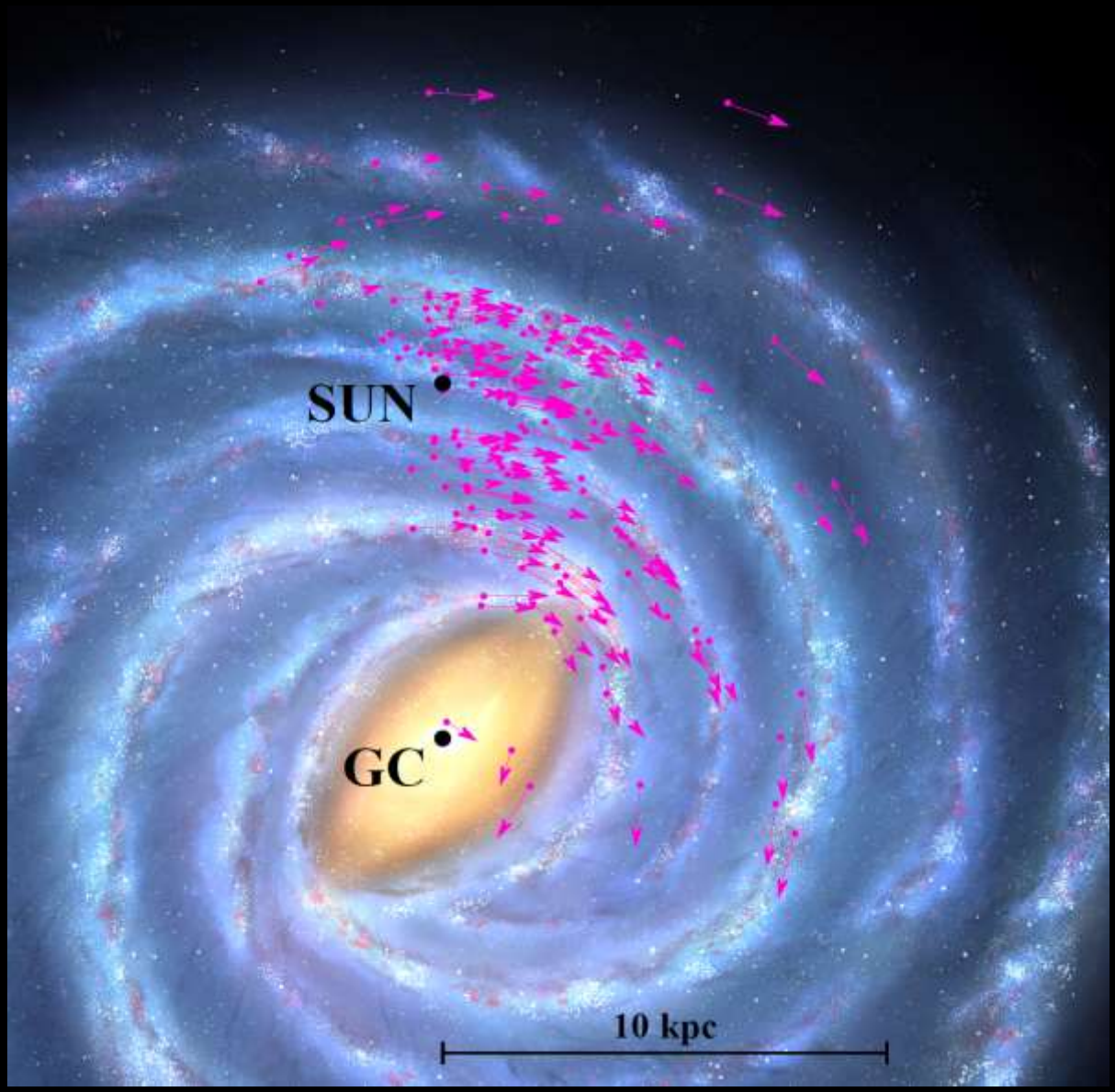
VERA results as of now

- Observed 180 src
- Parallax for 86 src
  - SFR 71 src
  - AGB 15 src
- VERA/VLBA/EVN
  - 159 sources

- a few tens of sources at 10kpc level distance



Galaxy rotation



VLBA/VERA/EVN

Galactic constants

As of 2017 (preliminary)

144 SFRs

$R_0 = 8.16 \pm 0.26$ kpc

$\Theta_0 = 237 \pm 8$ km/s

$\Omega_0 = 28.99 \pm 0.39$ km/s/kpc

Honma+ (2012)

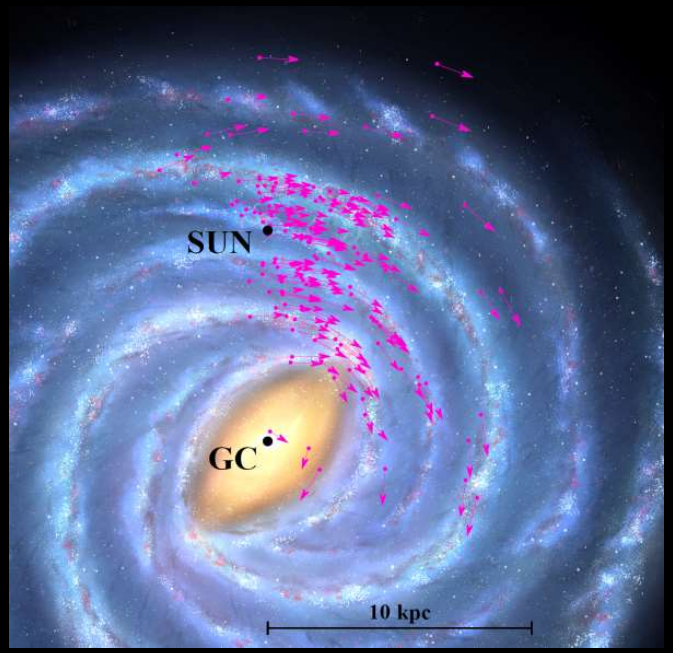
52 SFRs

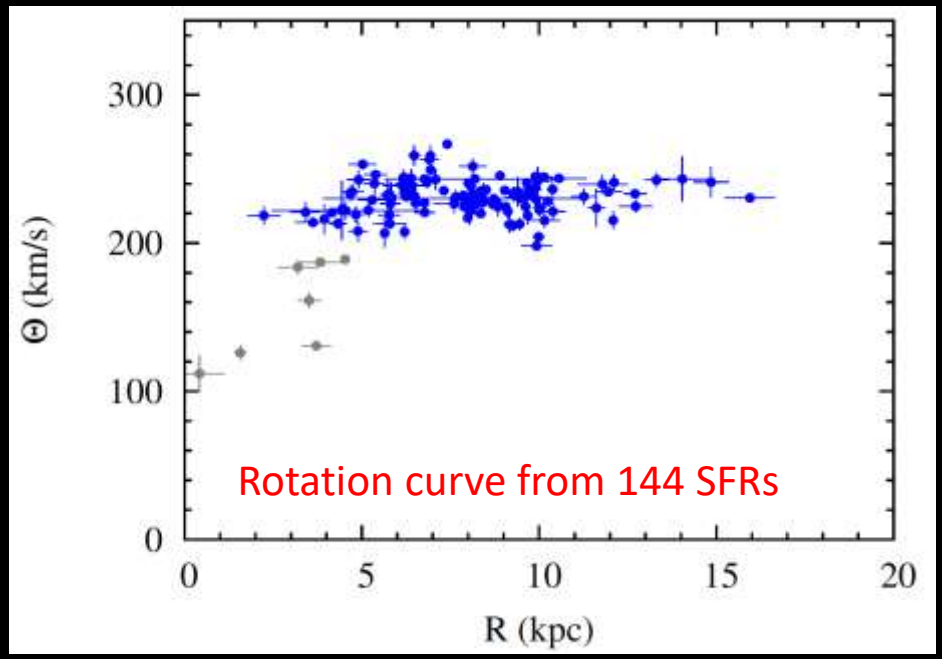
$R_0 = 8.05 \pm 0.45$ kpc

$\Theta_0 = 238 \pm 14$ km/s

$\Omega_0 = 29.57 \pm 0.78$ km/s/kpc

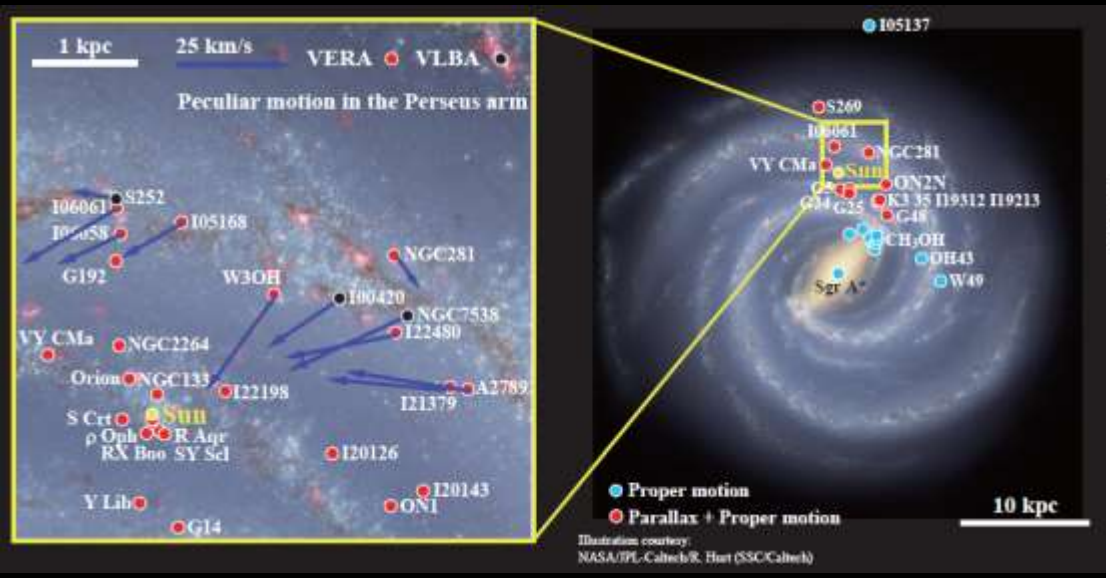
$(U_\odot, V_\odot, W_\odot) = (11.10, 12.24, 7.25)$ km/s (Schorich, Binney, Dehnen 2012) assumed

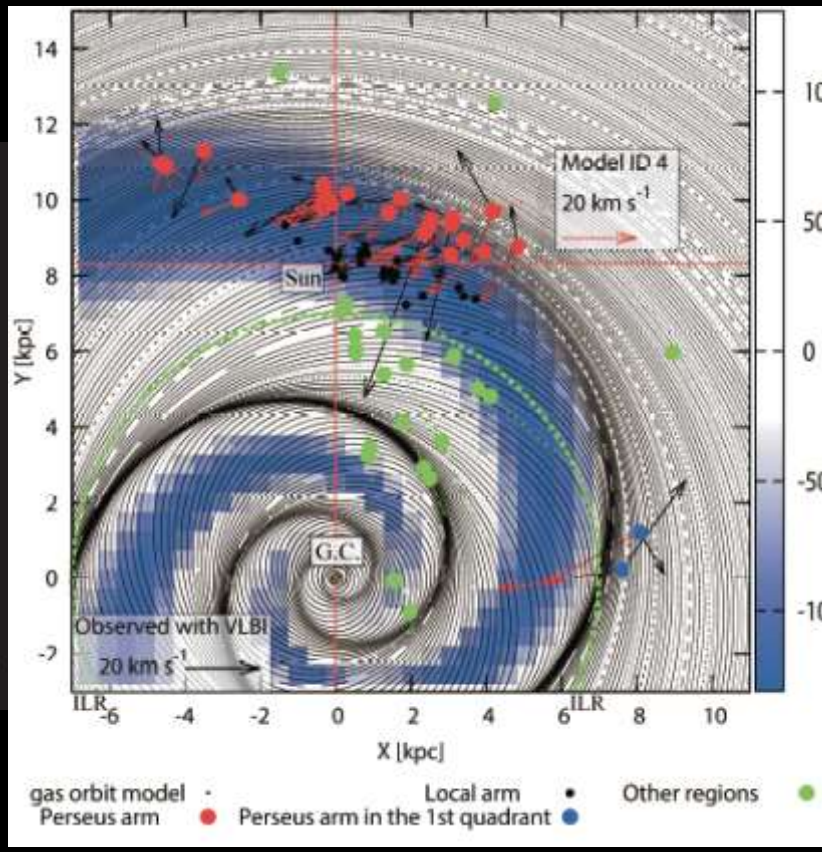




Spiral structure seen with VLBI astrometry

- Systematic deviation from circular rotation seen
- Lag behind the rotation + inward motion



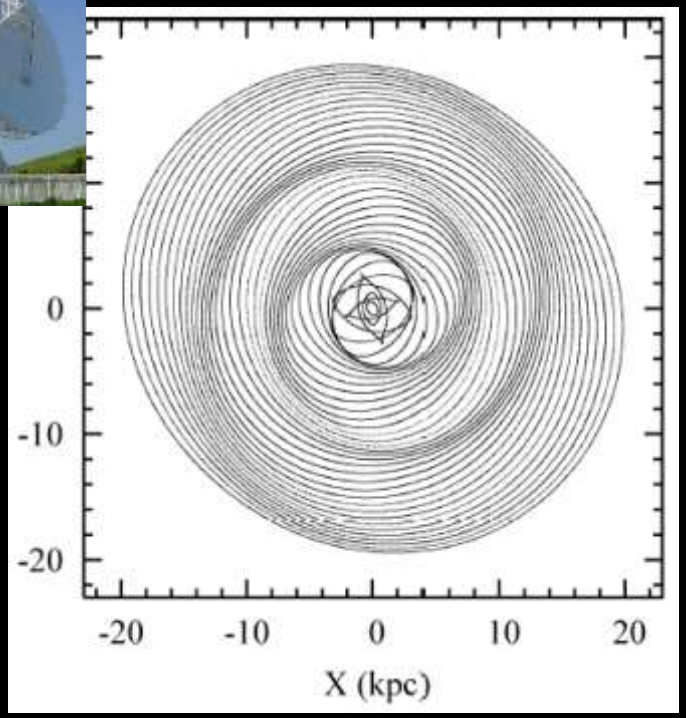


Comparison with theories will discriminate if the spiral arms are density wave or material wave (e.g., Sakai et al. 2015)

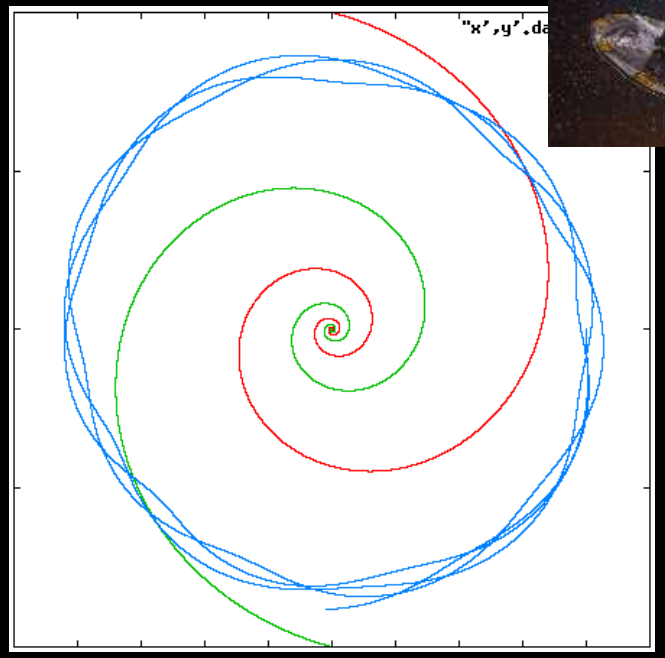
Galactic dynamics in GAIA era

- Tracing both gaseous and stellar components are fundamental (gas: collisional, star: collision-less)
- Also important is to compare with simulation





Collisional gas (closed orbit)

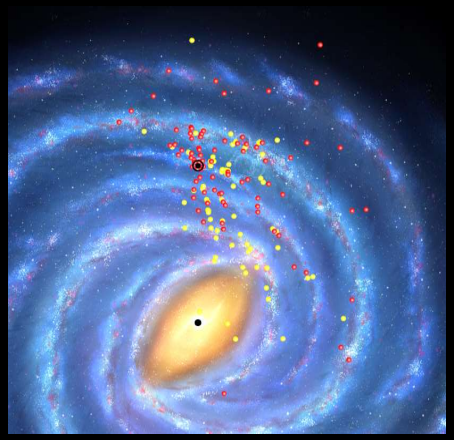


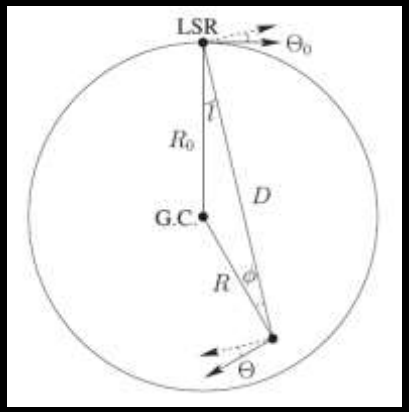
Collision-less stars (non-closed)



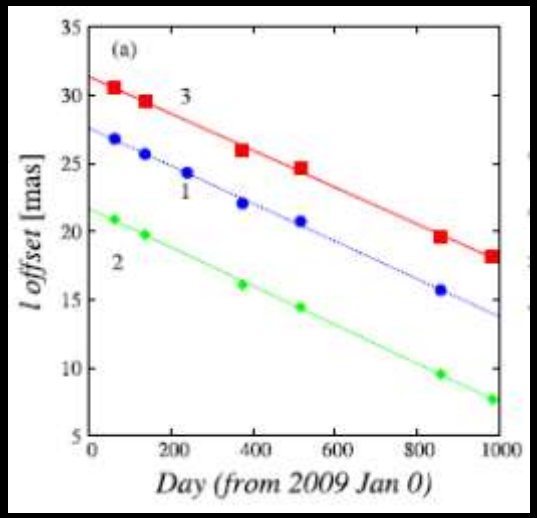
Kinematic distance beyond ~10 kpc

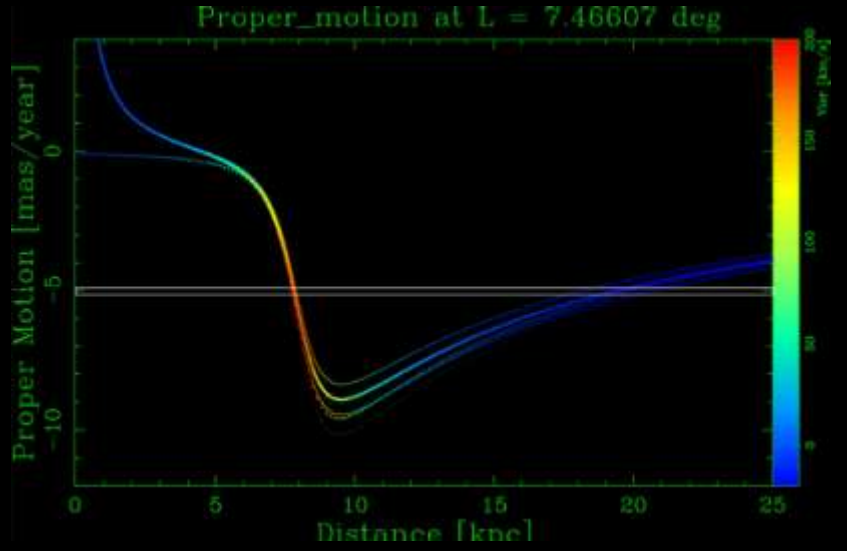
- Radial velocity and Proper motion can be used for estimate D





Proper motion for G7.47





Proper motion

Distance along LoS

Yamauchi+(2016) provided D_k=20+/-2 kpc
VLBA measured π and confirmed validity of the methods.

More VERA-related presentations

- Oral presentation

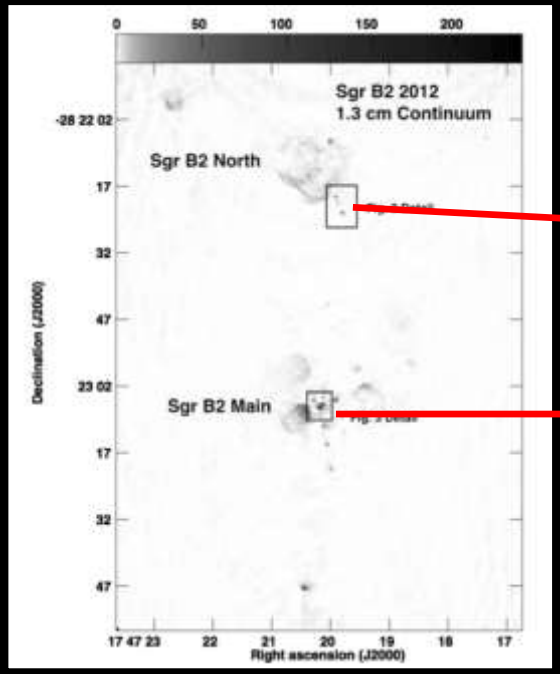
  SFR: Sugiyama, Motogi, Hirota

  AGB: Nakagawa, Imai

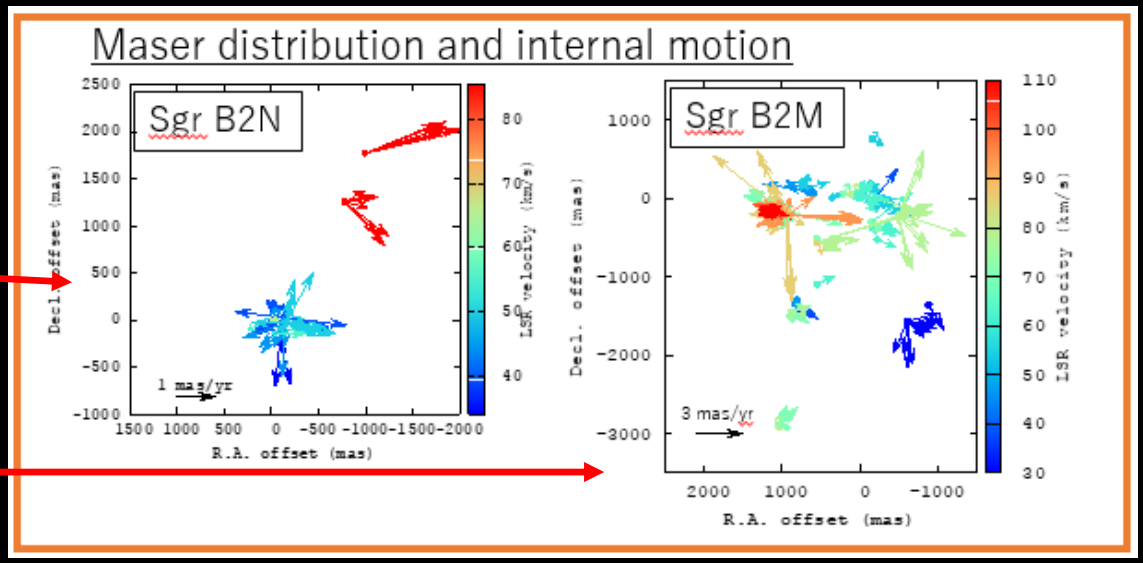
- Posters

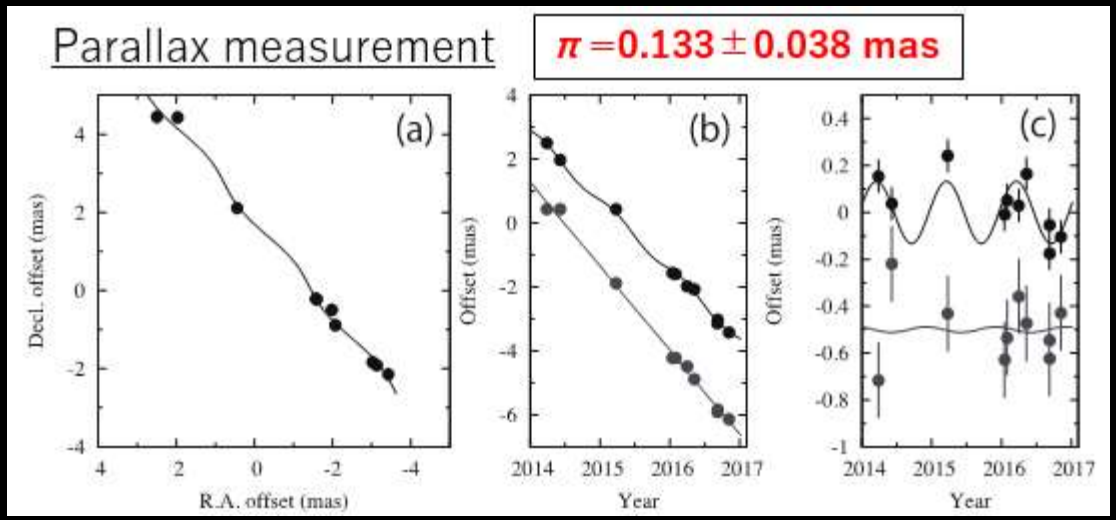
  Sakai, JH Kim, Sunada, Oyama …

VLBI astrometry of a water maser source in the Sgr B2 complex with VERA: P 10, Daisuke Sakai



Sgr B2N & B2M in continuum emission





The first simultaneous mapping of four 7 mm SiO maser lines using the OCTAVE system

P57 Tomoaki Oyama

- New broad band sampler for VERA: 2GHz bandwidth (OCTAVE-DAS)
- Four lines at the same time !
  SiO v=1, 2, 3, 29SiO v=1

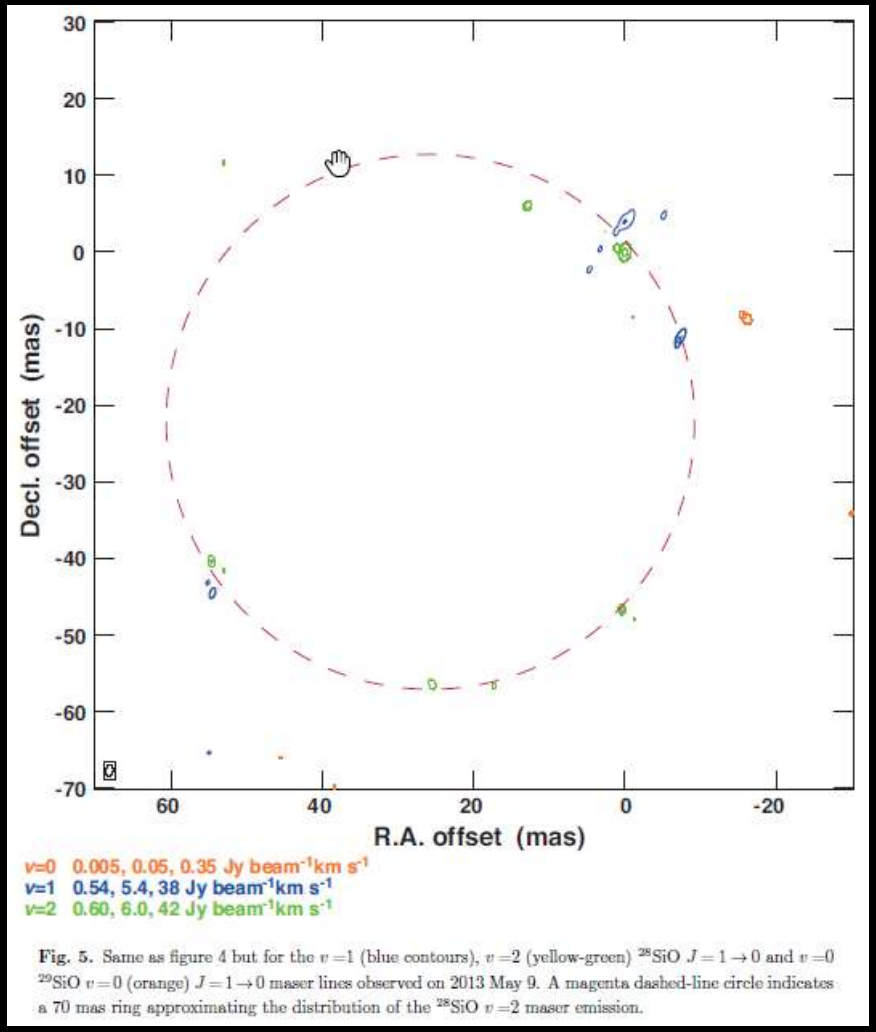
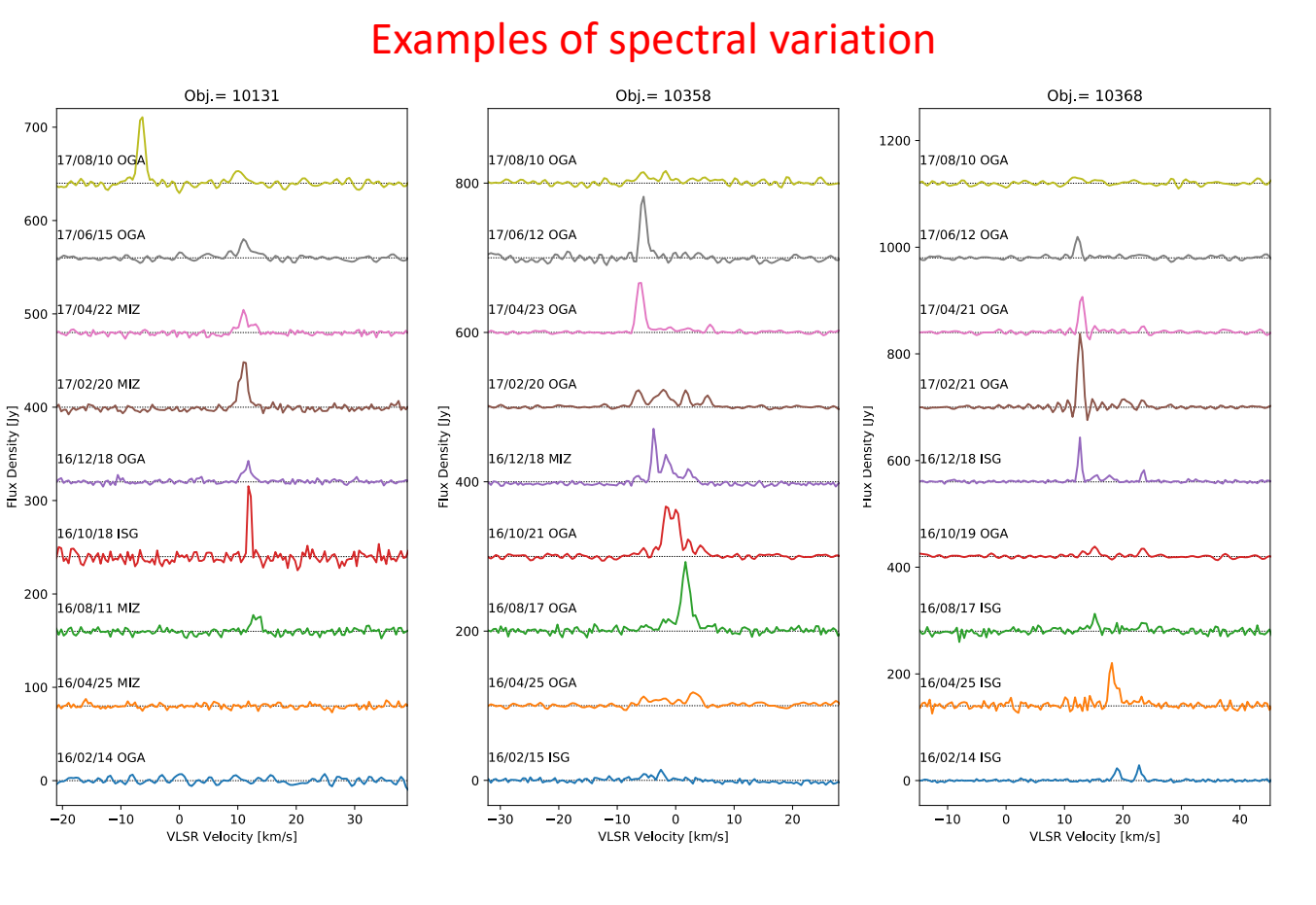


Fig. 5. Same as figure 4 but for the $v=1$ (blue contours), $v=2$ (yellow-green) ^{28}SiO $J=1\rightarrow0$ and $v=0$ ^{29}SiO $v=0$ (orange) $J=1\rightarrow0$ maser lines observed on 2013 May 9. A magenta dashed-line circle indicates a 70 mas ring approximating the distribution of the ^{28}SiO $v=2$ maser emission.

VERA single dish observation: P37, Kazuyoshi Sunada

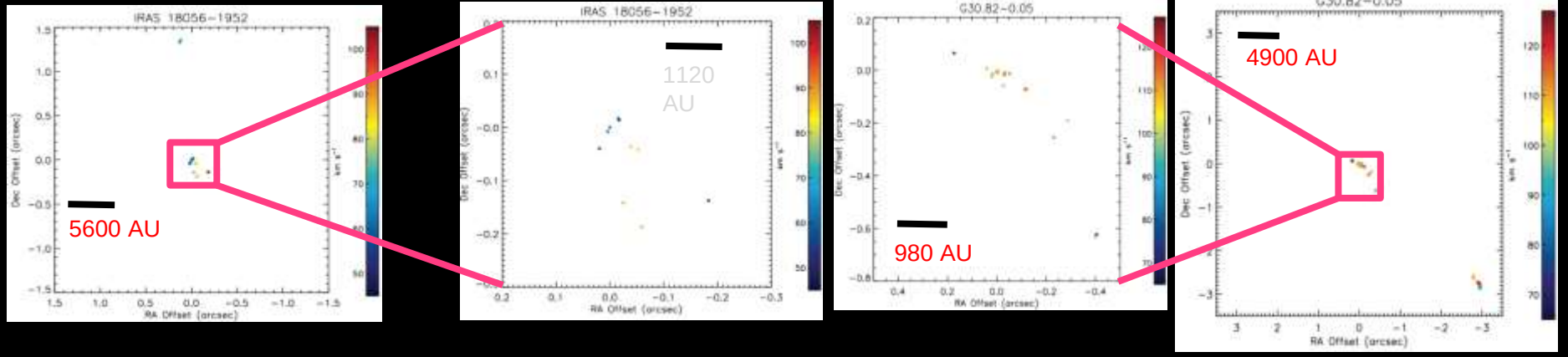
Monitoring program with VERA in single-dish mode
From Dec. 2015, 2 months interval 300 sources / year



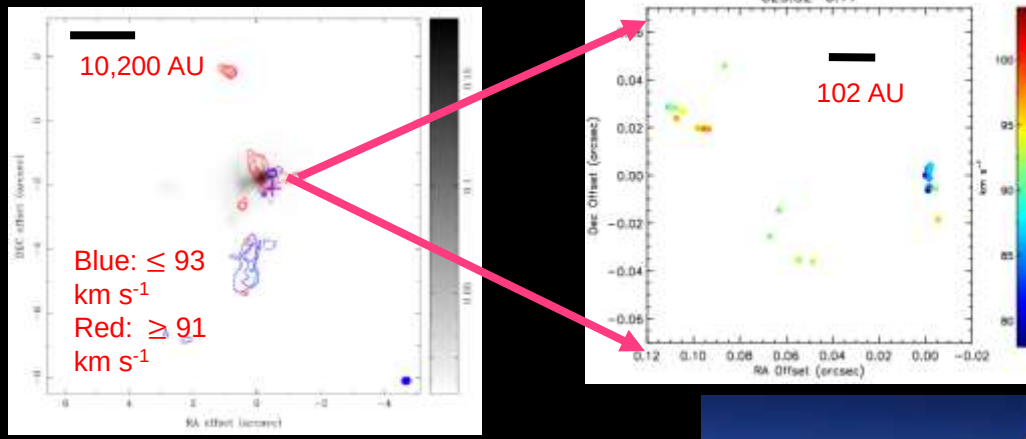
Useful not only for VERA astrometry but also for time-domain study

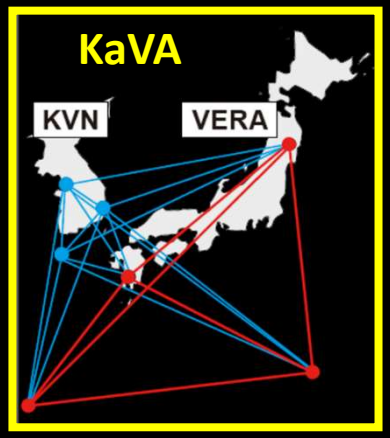
Dynamics of jet/outflow driven by high-mass young stellar object revealed by KaVA: P34, Jungha Kim

KaVA mapping of H2O masers toward massive SFR



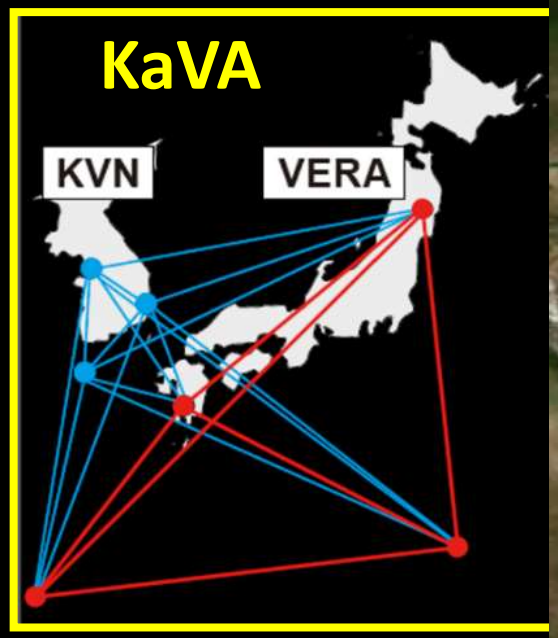
ALMA-KaVA comparison

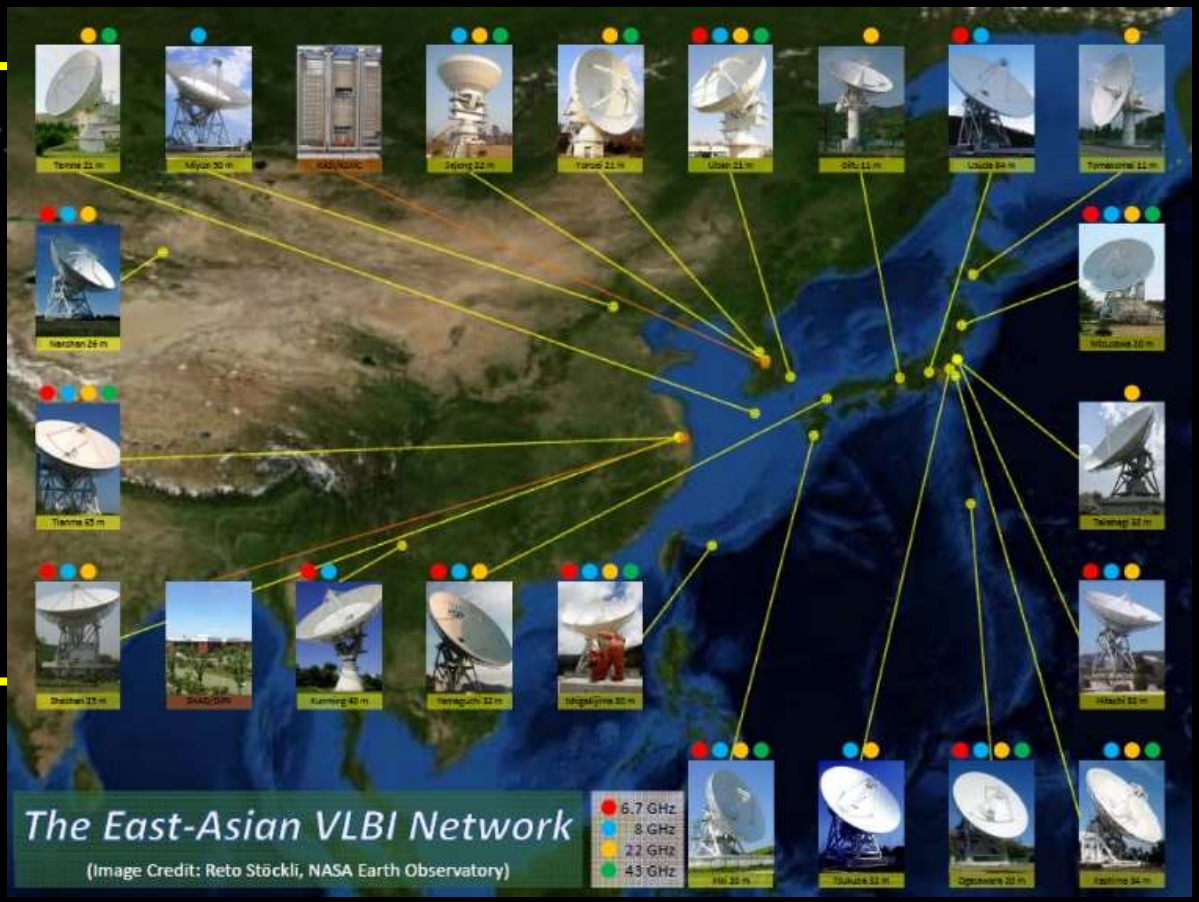






future





New big dishes:

- Shanghai 65m (in operation)
- Thai 40m (in 2020?)
- Qitai 110m (in 2025?)

Future(2): SKA and global VLBI





More collaborations,
Better science!

Future(3): Where to meet next?

