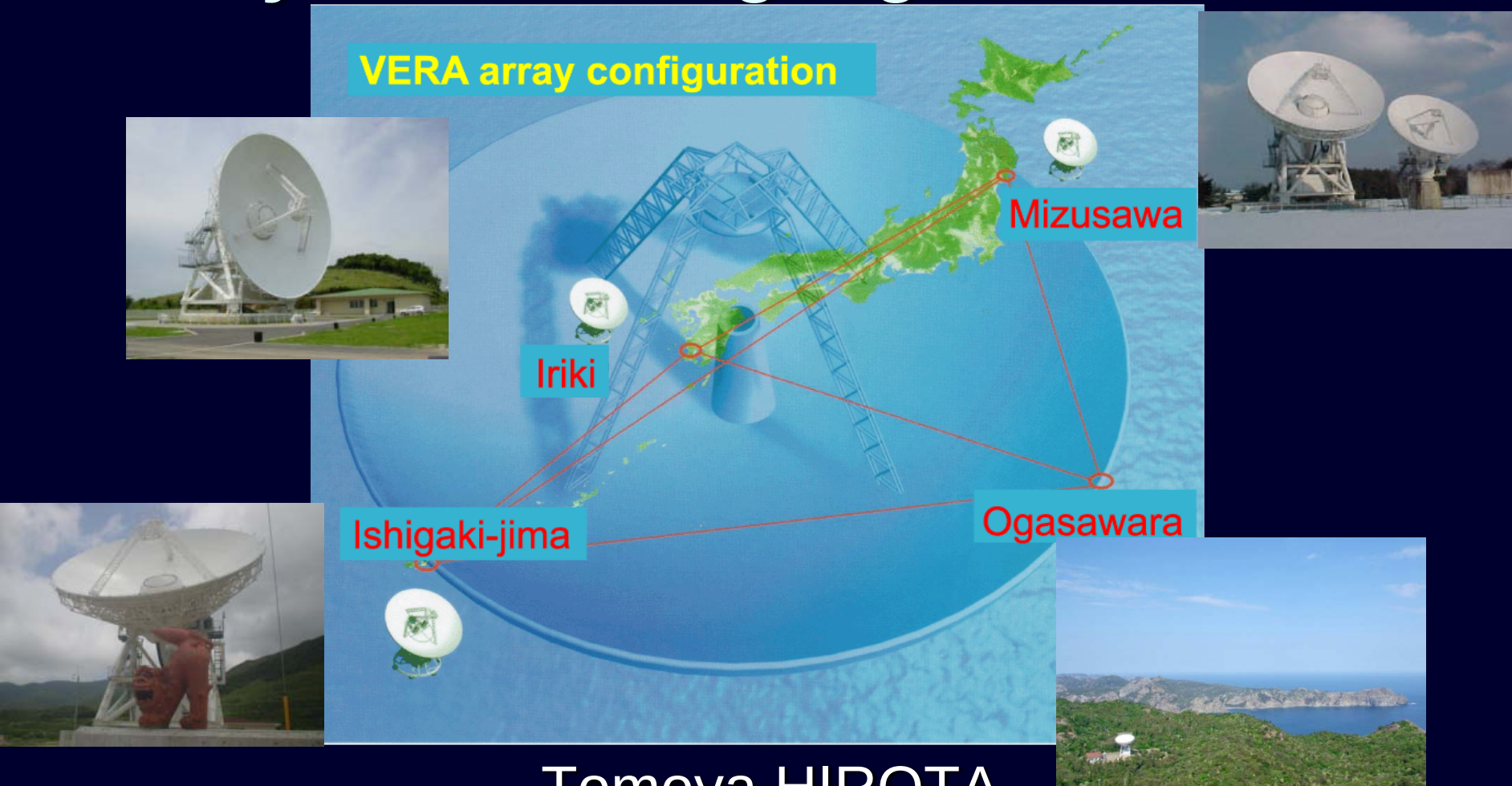


Astrometry of H₂O maser sources in nearby star-forming regions with VERA



Tomoya HIROTA
(Mizusawa-VLBI Observatory, NAOJ)

VERA:

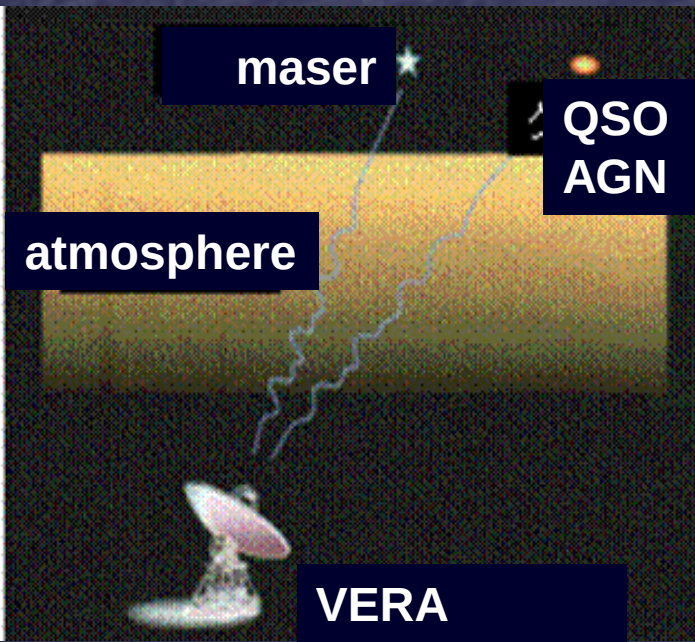
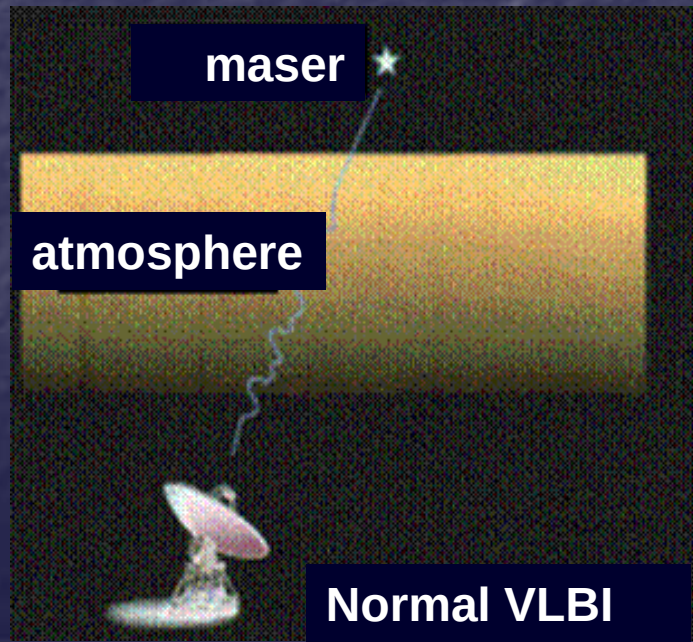
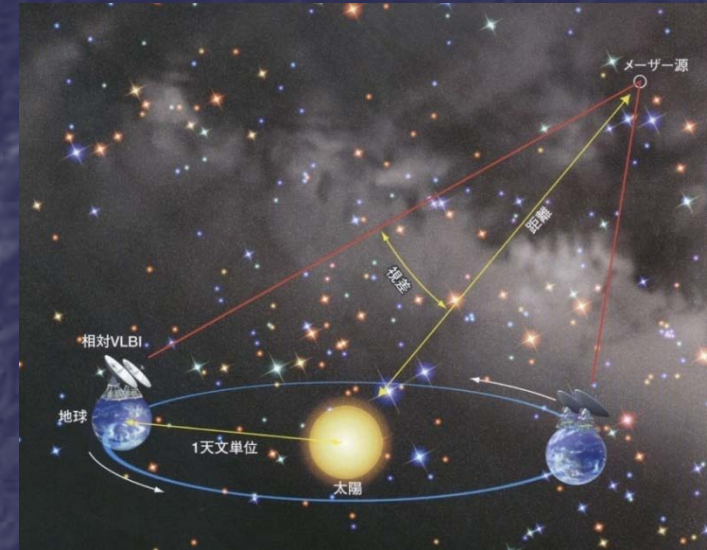
VLBI Exploration of Radio Astronomy

- Antenna diameter: 20m
- Frequency: S(2), C(6.7), X(8), K(22), Q(43)
- Baseline: 1000-2300 km
- Dual-beam system (K, Q)



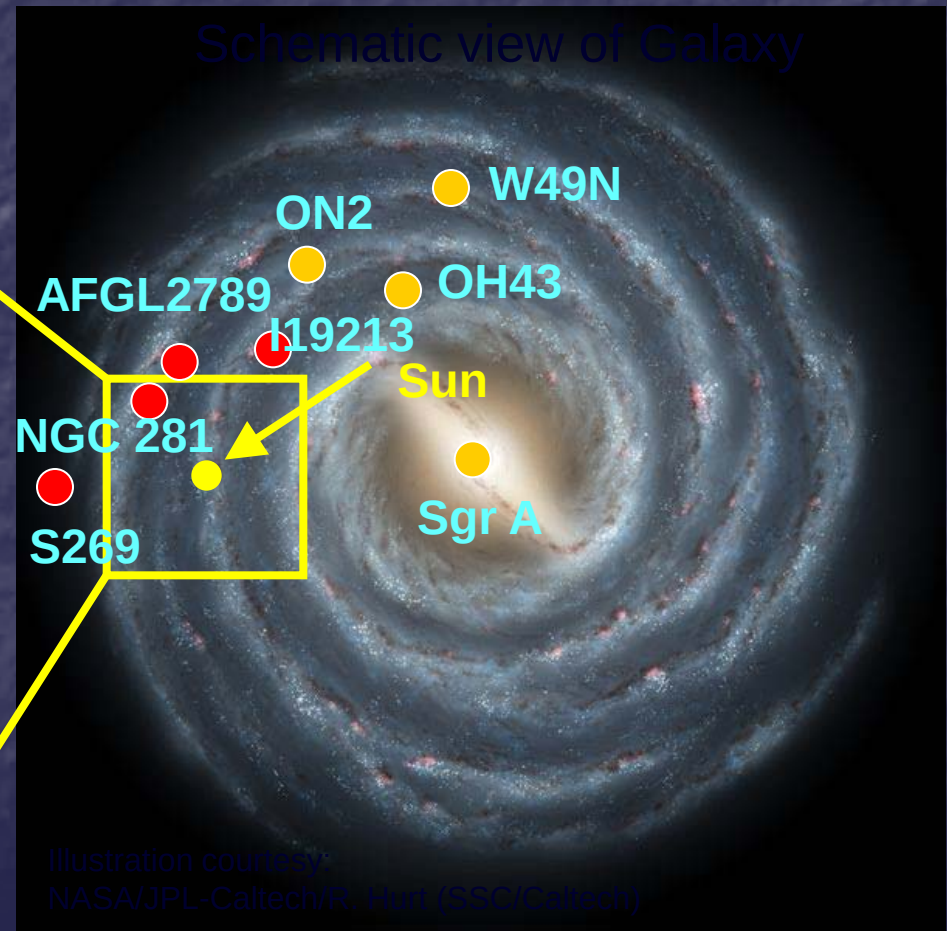
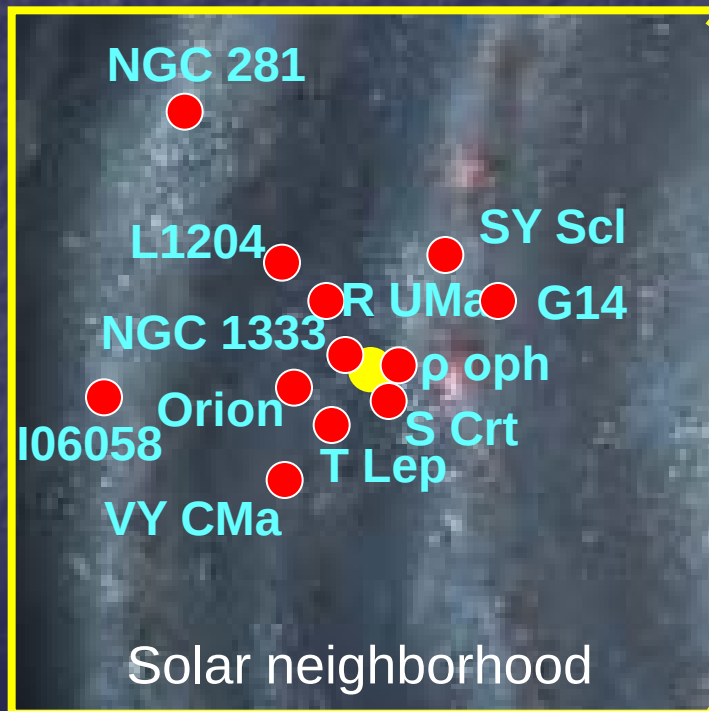
VERA

- Phase-referencing technique
 - Observation of target (maser) and reference sources simultaneously
 - Annual parallax measurements



Aim of VERA

- Distance/proper motion measurements for masers
 - Reveal 3-D structure of our Galaxy



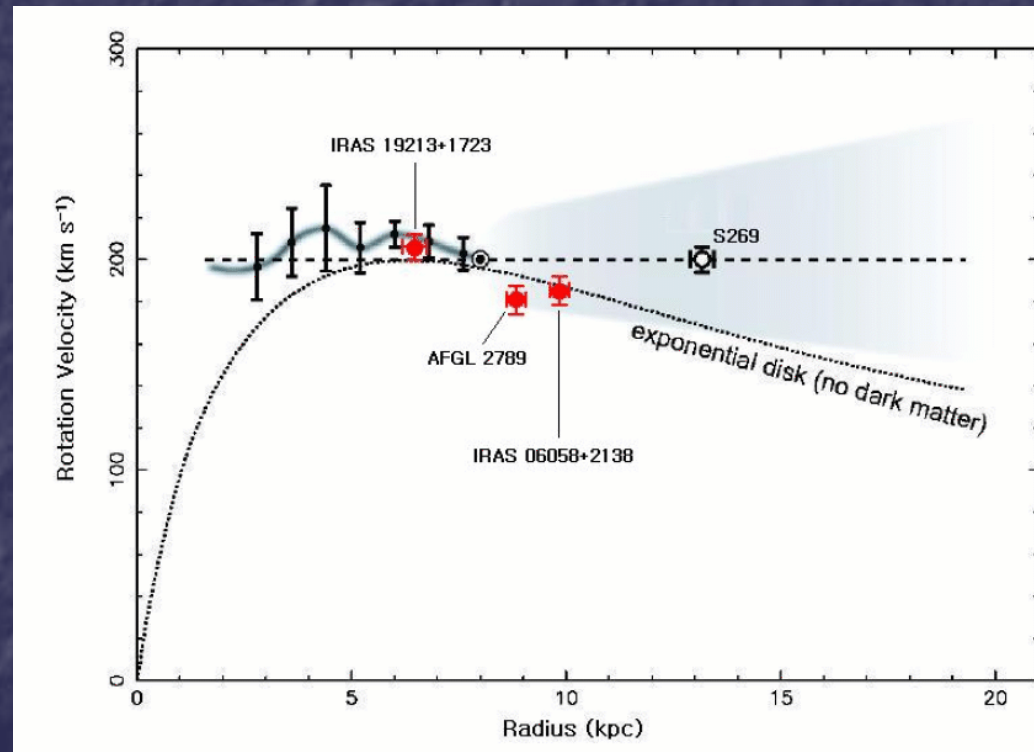
● Parallax + proper motion ● Proper motion

Rotation curve

- Honma et al. (2007) and Oh et al. (2009)

- S269
- IRAS19213+1723
- AFGL2789
- IRAS06058+2138
- $D = 2-5$ kpc

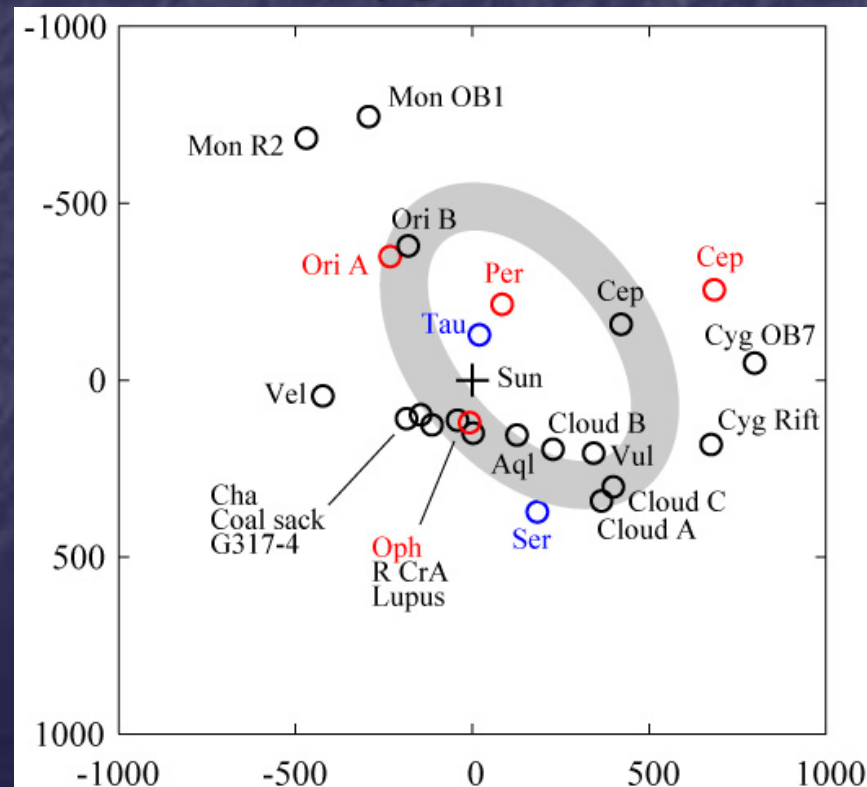
- Consistent with flat rotation curve, but a “dip” in Perseus arm



Nearby SFRs project

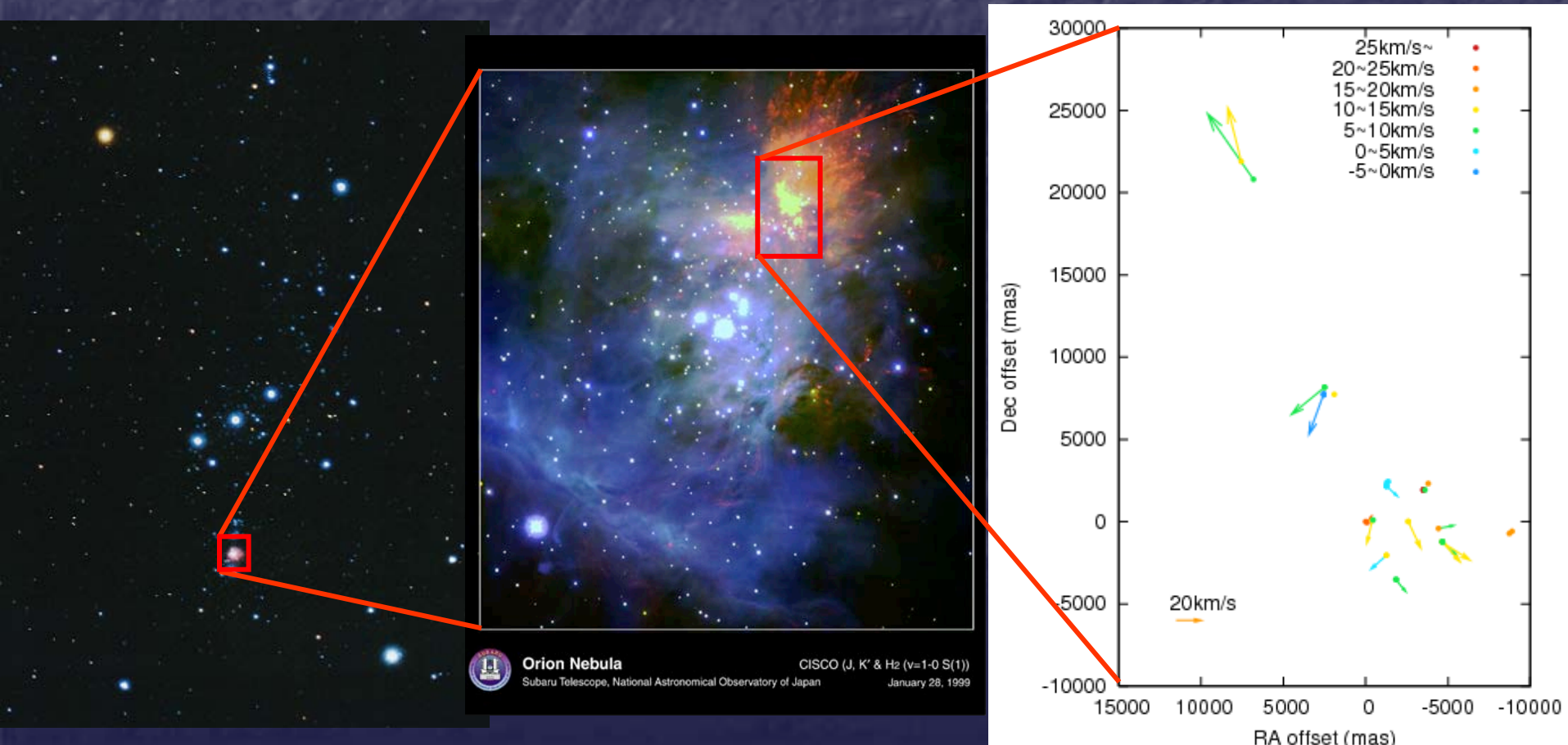
- Astrometry of H₂O masers in nearby SFRs (<1 kpc)
 - Orion (Orion A), Cepheus, Perseus
 - Taurus, Ophiuchus, Serpens, Monoceros, Cygnus ...
- Aim of this project
 - Fundamental database
 - Refine physical processes in star/planet-formation
 - Reveal 3-D structure of Gould belt and local bubble

Distribution of nearby SFRs
(based on Dame et al. 1987 and
Ward-Thompson et al. 2007)



Orion KL

- Famous H₂O maser source (e.g. Genzel et al. 1981)

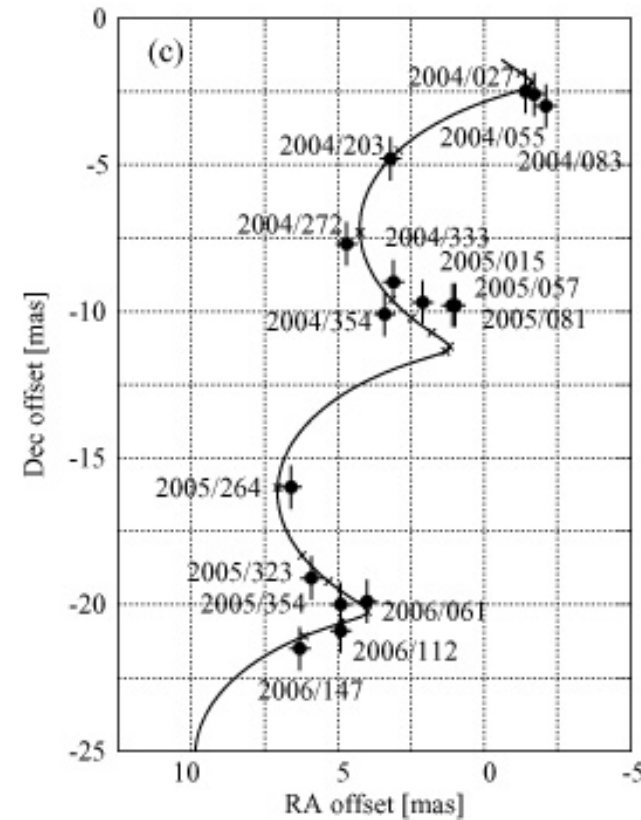
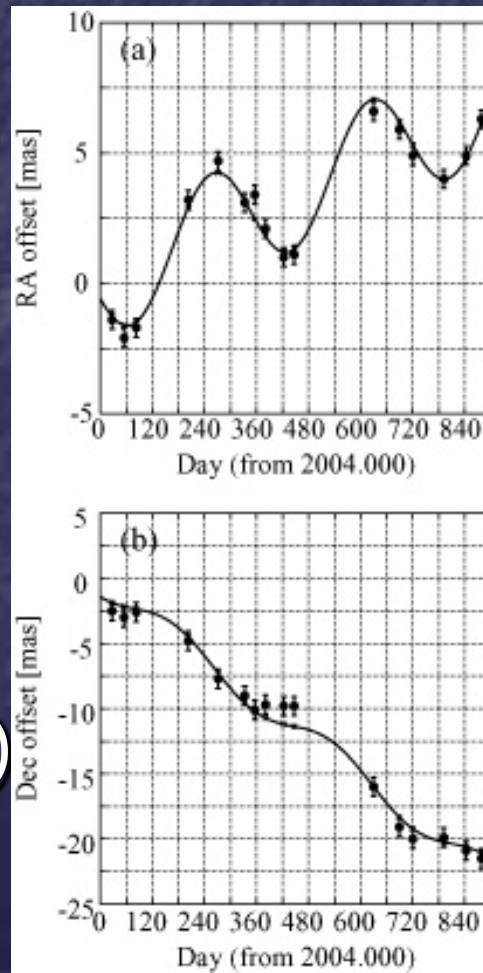


Distance to Orion KL

- The first result by Hirota et al. (2007)

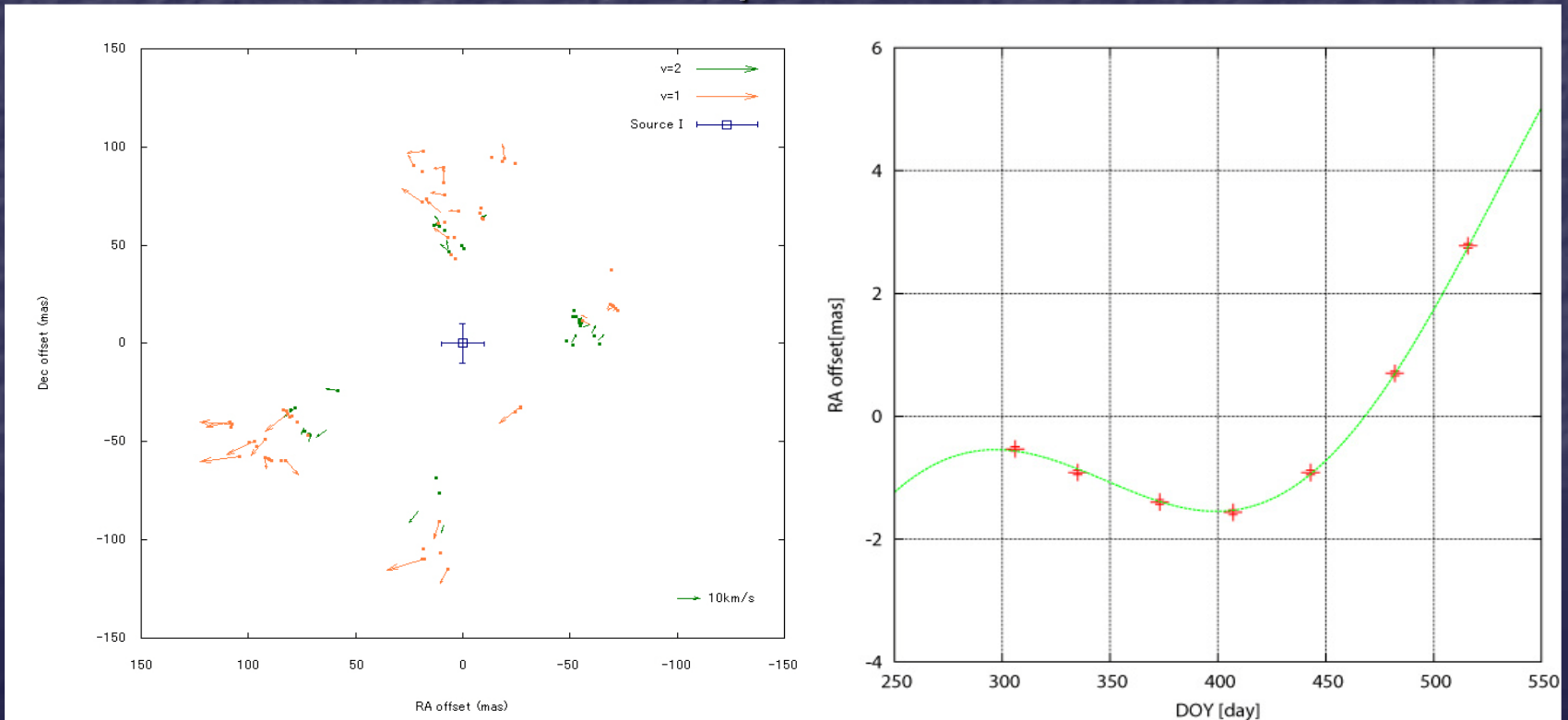
- Single H₂O maser
- 2.29 ± 0.10 mas = 437 ± 19 pc

- Smaller than well known value = 480 pc (Genzel et al. 1981)



Distance to Orion KL

- Refined by Kim et al. (2008)
 - Single SiO maser
 - 2.39 ± 0.03 mas = 418 ± 6 pc

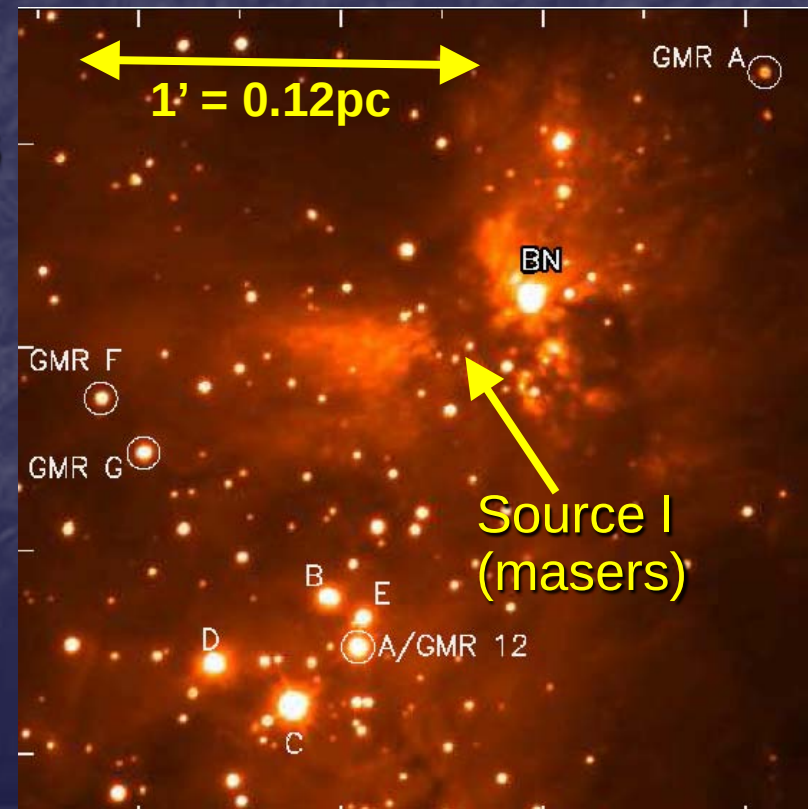


Orion Nebula

- VERA: H₂O and SiO masers in Orion KL
 - 437+/-19 pc (H₂O maser: Hirota et al. 2007)
 - 418+/-6 pc (SiO maser: Kim et al. 2008)

- VLBA: continuum from WTTSSs
 - 389 +24/-21 pc
(GMR-A: Sandstrom et al. 2007)
 - 414+/-7 pc
(4 WTTSSs: Menten et al. 2007)

(NIR image of ONC; Menten et al. 2007)

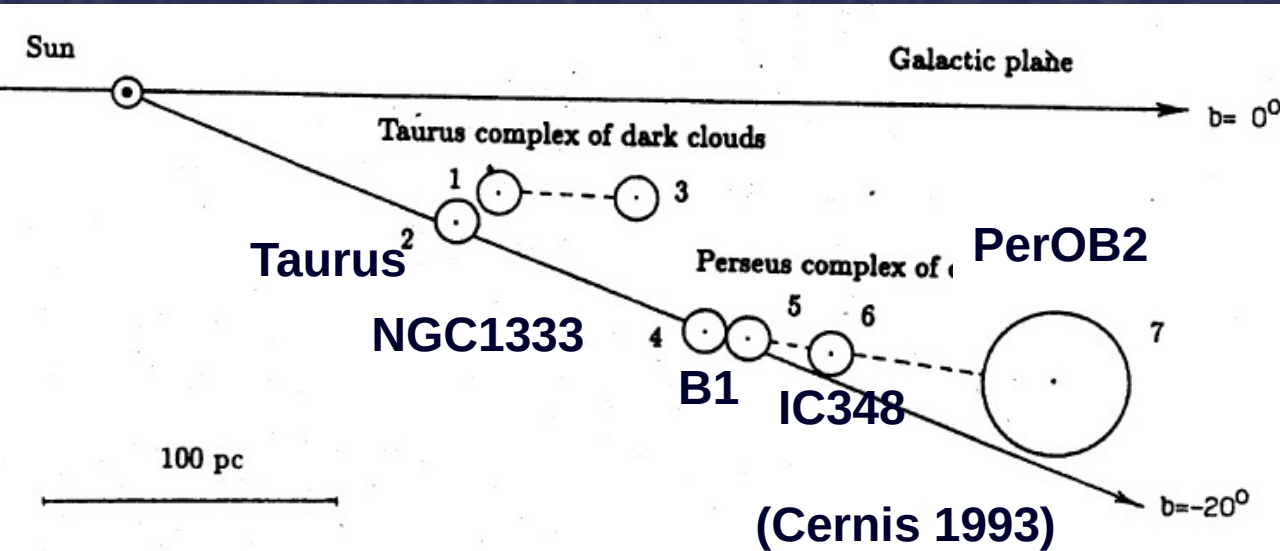


Perseus molecular cloud

- NGC1333 (Hirota et al. 2008): 235 ± 18 pc
- L1448C (Hirota et al. 2010): 232 ± 18 pc
 - Photometric distance: 220 pc (Cernis 1990)
 - HIPPARCOS: 318 pc for Per OB2 (de Zeeuw et al. 1999)
- Proper motions similar to VLA/HIPPARCOS results



Perseus molecular cloud



Suggested by previous photometric observations (Cernis 1993)



Other researches

- Ophuchus
 - VERA: 178^{+18}_{-37} (Imai et al. 2007)
 - VLBA: ~ 120 pc (Loinard et al. 2008)
- Cepheus
 - VERA: 764 ± 27 pc for L1204G (Hirota et al. 2008)
 - VLBA: 700 ± 40 pc for Cepheus A (Moscadelli et al. 2009)
- Consistent with each other
 - Small difference might be the depth of the cloud?
- Taurus, Serpens
 - VLBA (Loinard et al., Torres et al., Dzib et al.)

Current and future work

- Current --- Astrometry of H₂O masers
 - Orion-Monoceros, Perseus, Taurus: on-going
 - Ophiuchus and other regions: waiting for maser flare
- Future work
 - Wider-band backend (1G→4Gbps); continuum observations
 - East-asia VLBI (EAVN); powerful tool to study nearby YSOs
 - Collaboration with EVN and LBA; methanol masers
- VERA (and other VLBI arrays) will reveal 3-D structure of molecular clouds and local structure of Galaxy