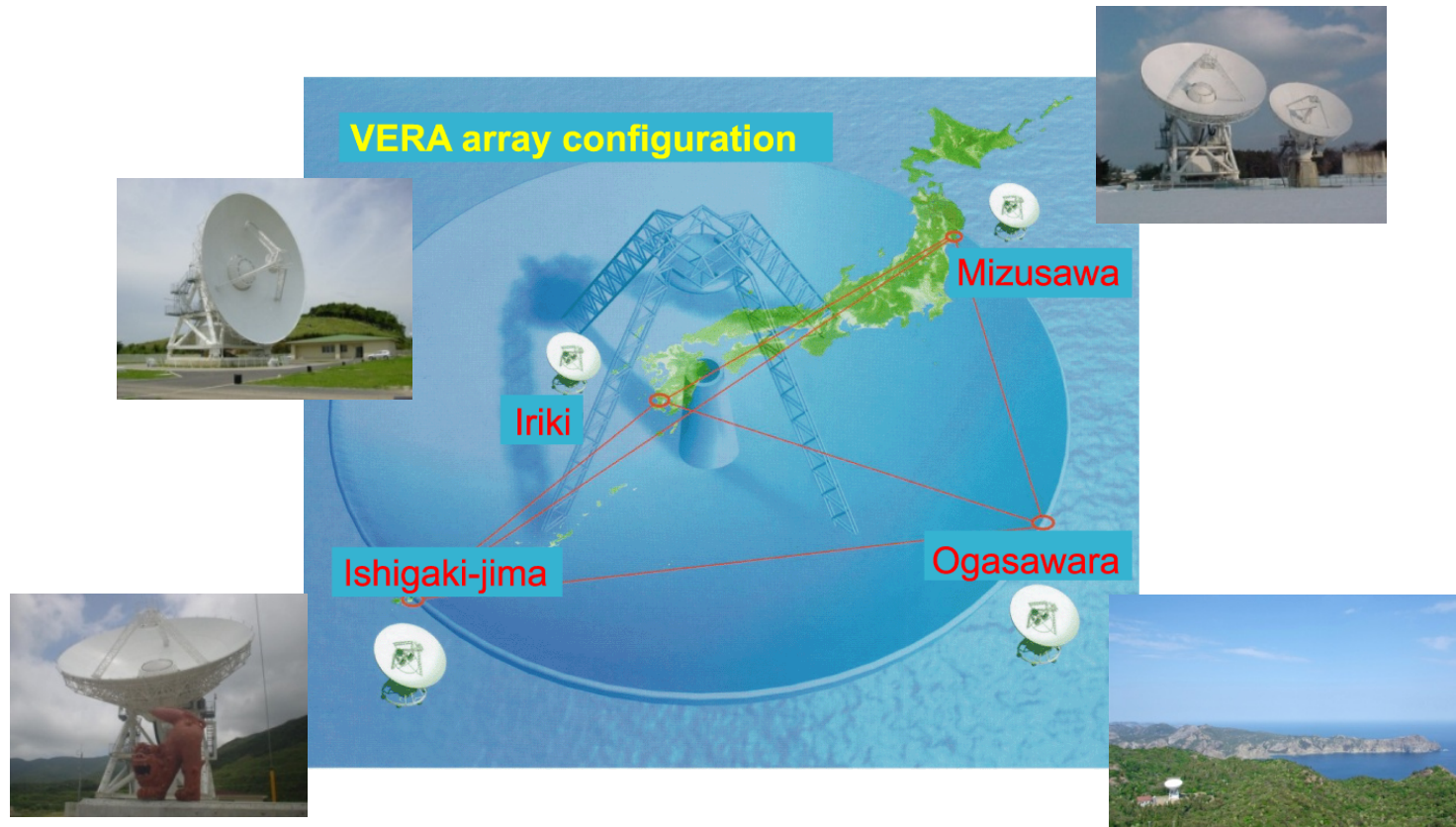


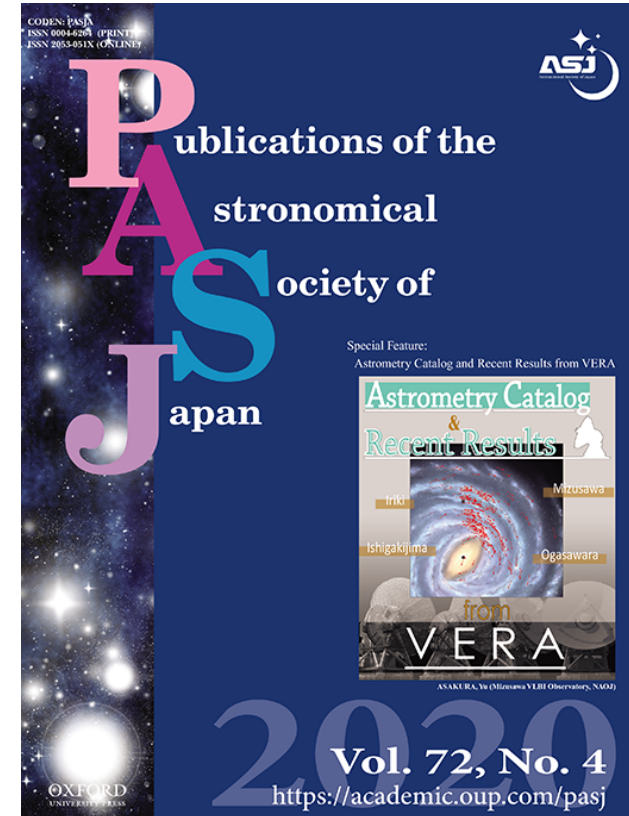
VERAの科学的成果の報告



VERA collaboration et al.,
Tomoya Hirota (NAOJ/SOKENDAI)

PASJ VERA special issue

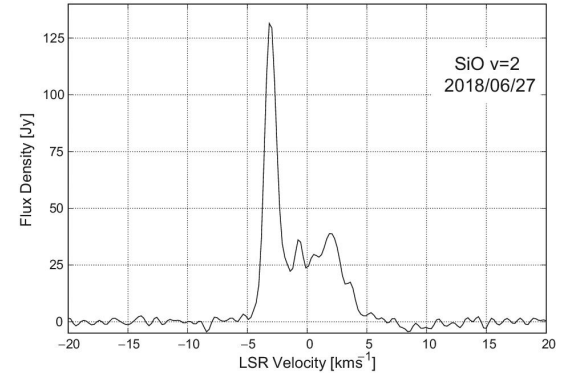
- Published in 2020 August
 - VERA collaboration et al.: 1st Catalog
 - Nagayama et al.: VEDA software
 - Nagayama et al.: Astrometry accuracy
 - Sakai et al.: Structure of outer disk
 - Chibueze et al.: High-mass SFR W48A
 - Omodaka et al.: Low-mass SFR L1482
 - Matsuno et al.: Mira variable BX Cam
 - Urago et al.: O-rich Mira OZ Gem
 - Imai et al.: Water fountain IRAS18286
 - Chibueze et al.: AGBs AP Lyn, V837 Her
- See other presentations and original papers!



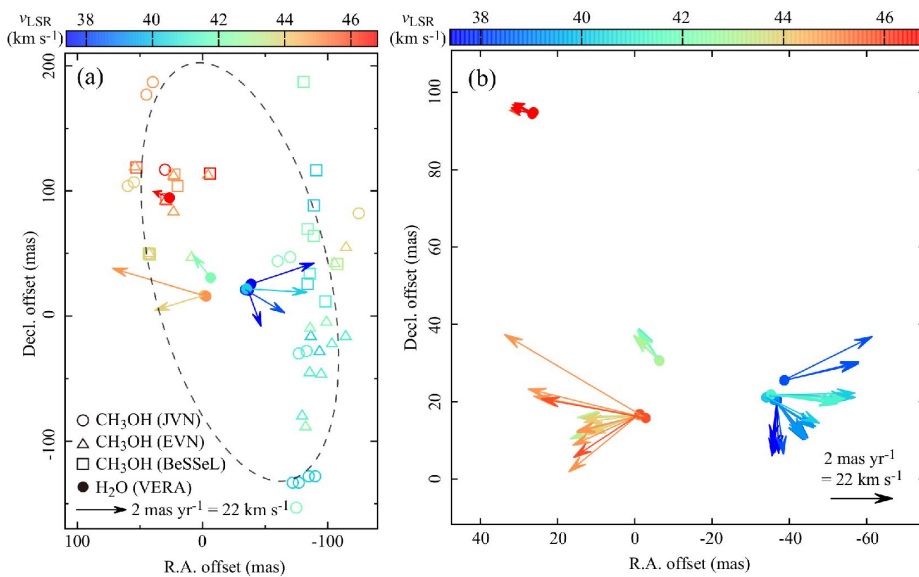
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Individual maser sciences

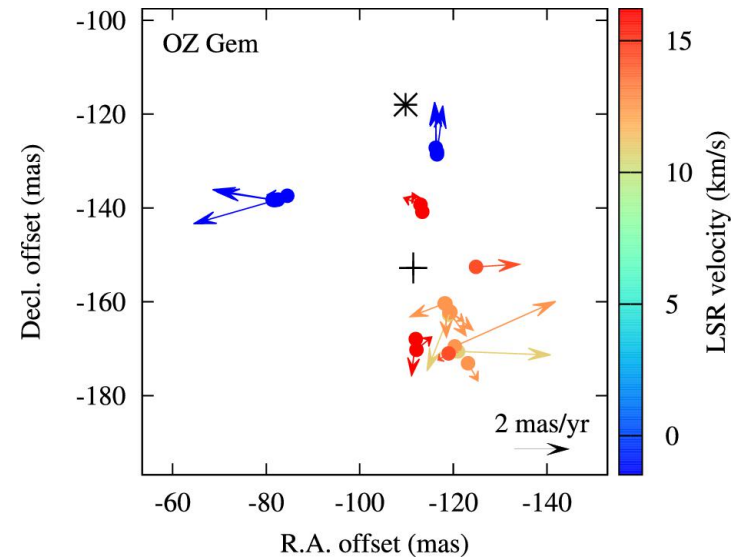
- AGBs and SFRs
 - Mainly by Kagoshima University group for their thesis works



SiO maser in AGB star BX Cam (Matsuno et al. 2020)



H₂O masers in SFR G35.20-01.74 (Chibueze et al. 2020)



H₂O masers in AGB star OZ Gem (Urago et al. 2020)

VERA catalog

- Total 99 VERA samples (including 21 new results)




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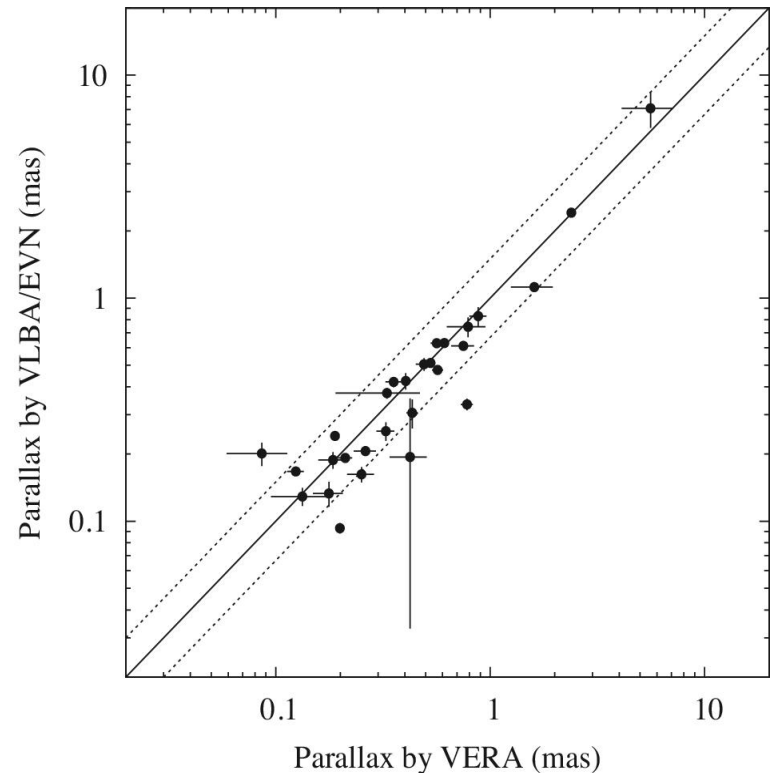
The First VERA Astrometry Catalog

VERA collaboration, Tomoya HIROTA,^{1,2,*} Takumi NAGAYAMA,³
Mareki HONMA,^{3,4,5} Yuuki ADACHI,³ Ross A. BURNS,¹ James O. CHIBUEZE,^{6,7}
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Toshihiro OMODAKA,¹⁰ Miyako OYADOMARI,¹³ Tomoaki OYAMA,³
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Ken TAKAHASHI,³ Yoshiaki TAMURA,^{3,4} Fumie TAZAKI,³ Yuji UENO,³ Yuri UNO,¹⁰
Riku URAGO,¹⁰ Koji WADA,¹⁰ Yuan Wei WU,¹⁹ Kazuyoshi YAMASHITA,³
Yuto YAMASHITA,¹⁰ Aya YAMAUCHI,³ and Akito YUDA¹⁰

VERA catalog

- Total 99 VERA samples (including 21 new results)
 - Comparison with VLBA/EVN and GAIA DR2 to verify astrometric accuracy (e.g. Nagayama et al. 2020)
 - Mostly consistent within $\Delta\pi/\sigma_\pi < 3$, but some are inconsistent with each other
 - Sometimes large differences between GAIA DR2/VLBA and VERA for nearby YSOs

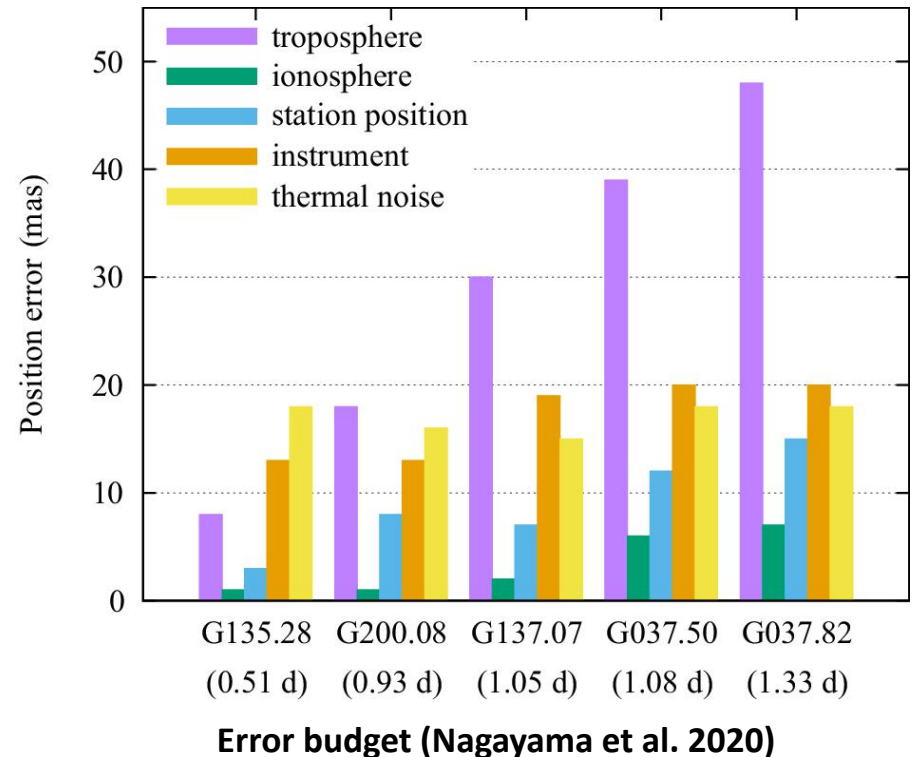
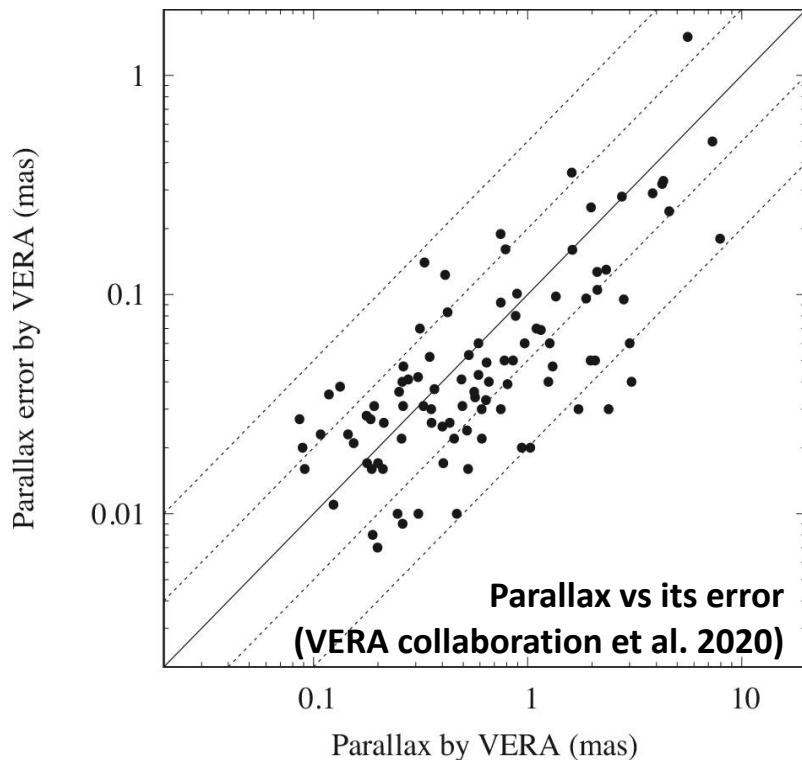
* Note that GAIA DR2 results are not always reliable due to binary motion and/or unknown error (e.g. Sudou et al. 2019, Matsuno et al. 2020)



**Maser parallax for VLBA/EVN vs VERA
(VERA collaboration et al. 2020)**

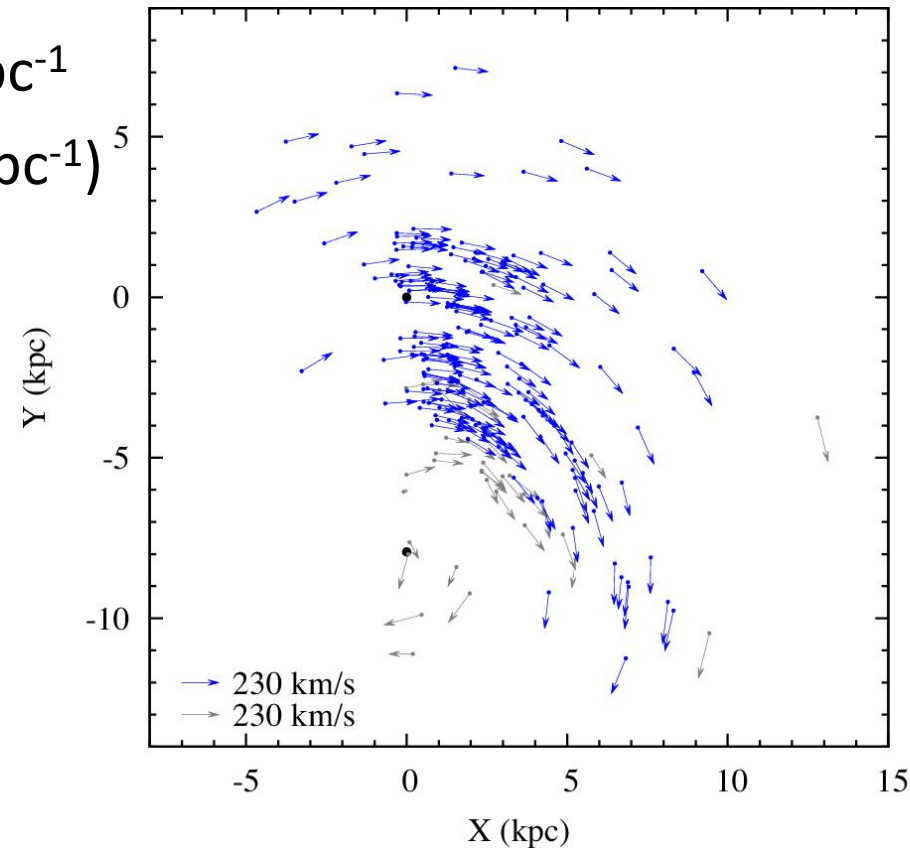
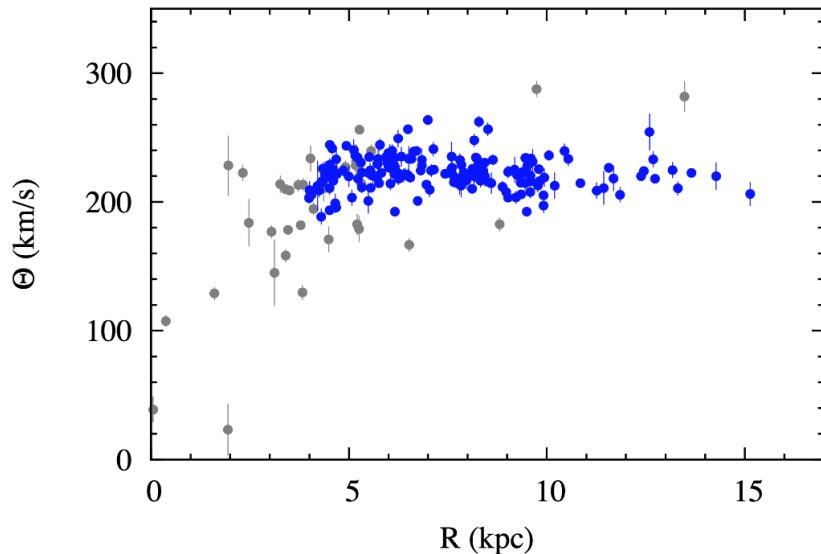
Possible error sources

- Errors not strongly dependent on parallax values
 - Large errors even for nearby targets (e.g. low-mass YSOs)
 - Caused by source structures, along with atmosphere (Nagayama et al. 2020 for more details)



Structure of Milky Way

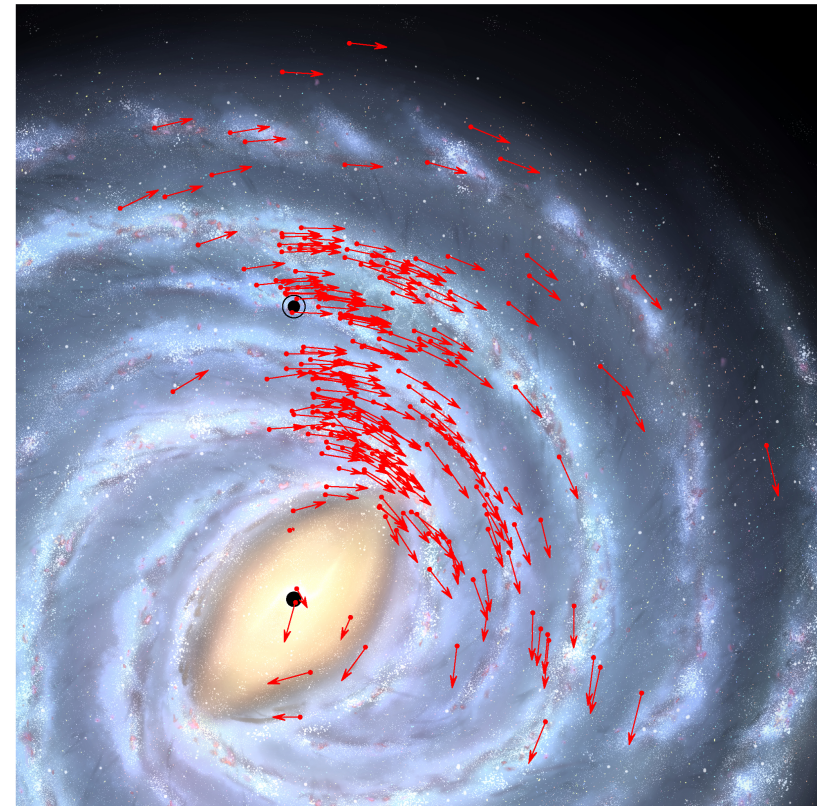
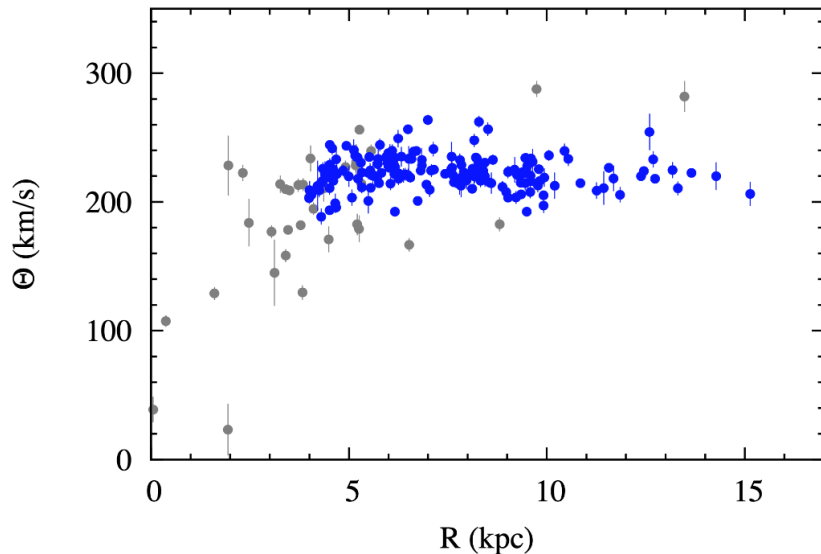
- Compiling all VLBI astrometry results of 189 sources
 - Up to >10 kpc (Nagayama et al. 2020, Sanna et al. 2017)
 - $R_0 = 7.92 \pm 0.16 \pm 0.3$ kpc
 - $\Omega_{\odot} = 30.17 \pm 0.27 \pm 0.3$ km s⁻¹ kpc⁻¹
($\Omega_0 = 28.63 \pm 0.26 \pm 1.7$ km s⁻¹ kpc⁻¹)⁵
 - $\Theta_0 = 227 \pm 11$ kms⁻¹



Galactic rotation observed with VLBI astrometry (VERA collaboration et al. 2020)

Structure of Milky Way

- Compiling all VLBI astrometry results of 189 sources
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Galactic rotation observed with VLBI astrometry (VERA collaboration et al. 2020)

Structure of Milky Way

- Consistent with other works but remaining systematic error
 - Caused by assumed Galactic rotation curve and Solar motion
 - Need to fill the gap not observed with VERA and northern VLBI
 - More distant sources extending toward far side of the Milky Way

Table 4. Comparison of Galactic center distance R_0 .

Method	Reference	R_0 (kpc)
VLBI astrometry of 189 maser sources	Present work	$7.92 \pm 0.16_{\text{stat.}} \pm 0.3_{\text{sys.}}$
VLBI astrometry of 147 maser sources	Reid et al. (2019)	8.15 ± 0.15
Orbital motion of S2 around Sgr A*	Gravity Collaboration (2019)	$8.178 \pm 0.013_{\text{stat.}} \pm 0.022_{\text{sys.}}$
Orbital motions of S0-2 around Sgr A*	Do et al. (2019)	$7.946 \pm 0.050_{\text{stat.}} \pm 0.032_{\text{sys.}}$

Table 5. Comparison of angular velocity of the Sun Ω_{\odot} .

Method	Reference	Ω_{\odot} ($\text{km s}^{-1} \text{kpc}^{-1}$)
VLBI astrometry of 189 maser sources	Present work	$30.17 \pm 0.27_{\text{stat.}} \pm 0.3_{\text{sys.}}$
VLBI astrometry of 147 maser sources	Reid et al. (2019)	30.32 ± 0.27
Proper motion of Sgr A*	Reid and Brunthaler (2020)	30.39 ± 0.04

Status of VERA scientific research

- Galactic astrometry project was terminated in FY2019
- Other selected sciences were approved as the NAOJ Leadership program in FY2020
 - Astrometry of Sgr A* with VERA
 - Astrometry of long period variables with VERA
 - AGN imaging with EAVN
 - And some others
- Figures are removed from the web version

Astrometry with VERA and beyond

- From VERA/EAVN to global VLBI and SKA
- Under discussion; see presentations in next sessions!

