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Proper Motion of Sagittarius A* with Atacama Large Millimeter/Submillimeter Array

Masato Tsuboi*(1), Takahiro Tsutsumi(2), Ryosuke Miyawaki(3), Makoto Miyoshi(4) and Atsushi Miyazaki(5)
(1) Institute of Space and Astronautical Science, Sagamihara, Japan; e-mail: tsuboi-masato@ttv.ne.jp
(2) National Radio Astronomy Observatory, Socorro, USA; e-mail: ttsutsum@nrao.edu
(3) J. F. Oberlin University, Machida, Japan; e-mail: miyawaki@obirin.ac.jp
(4) National Astronomical Observatory of Japan, Tokyo, Japan; e-mail: makoto.miyoshi@nao.ac.jp
(5) Japan Space Forum, Tokyo, Japan; e-mail: atsmiyazaki2@a-net.email.ne.jp

Atacama Large Millimeter/Submillimeter Array (ALMA) is promising to be a powerful tool for precision astrometry of the area around Sagittarius A* (Sgr A*) because it has the high angular resolution, high sensitivity, and wide field of view. We have observed the area at 230 GHz with ALMA in $t = 2017.773$ year. The angular resolution of the resultant image is achieved to be $0''.029 \times 0''.020, PA = 86^\circ$ in FWHM. Using 2-D Gaussian fitting, we determined the position of Sgr A* relative to a phase calibrator, J1744-3116, with the accuracy of $\sim 10\mu$arcsec. We also analyzed the similar high resolution ALMA data with slightly lower sensitivities obtained at 340 GHz and at 230 GHz, in $t = 2016.693$ year and $t = 2019.471$ year, respectively. The relative positions of Sgr A* to J1744-3116 at these epochs were determined. We derived the proper motion of Sgr A* by comparing these relative positions (see Fig.1). The proper motion in ICRS was $\frac{d\alpha}{dt} = -2.72 \pm 0.02$ mas year^{-1}, $\frac{d\delta}{dt} = -5.46 \pm 0.01$ mas year^{-1}. The annual parallax of Sgr A* is expected to be up to $1''/8000$ pc$= 0.125$ mas. Because the observations were performed only at three epochs, the annual parallax cannot be evaluated by them. However, the annual parallax is much smaller than the derived proper motion. Assuming the rotation angle between ICRS and Galactic coordinates of $\phi = 58.6^\circ$ at Sgr A*, the proper motion in ICRS is converted to be that in Galactic coordinates. The Galactic longitude component of the proper motion of Sgr A* is mainly caused by the Galactic rotation of Sun. On the other hand, the Galactic latitude component is caused by the mass distribution in the vicinity of Sgr A*. It is hard to depict the mass distribution by other methods. Therefore, it is important for such a study to derive the proper motion of Sgr A* in Galactic coordinates precisely. The derived components of the proper motion of Sgr A* were $\frac{dl}{dt} = -6.08 \pm 0.01$ mas year^{-1}, $\frac{db}{dt} = 0.53 \pm 0.02$ mas year^{-1}, which are consistent with those by the long-term VLBI observations of VLBA [1] and VERA[2]. The longitude component of the derived proper motion corresponds to the Galactic rotation velocity at Sun, $V \sim 230$ km s^{-1}.

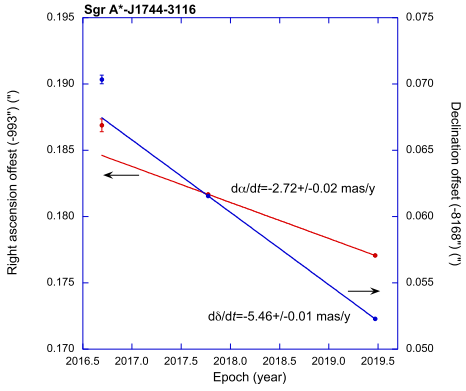

Figure 1. Measured relative positions of Sgr A* to a phase calibrator, J1744-3116, which is a distant quasar. The observation epochs were $t = 2016.693, 2017.773$, and 2019.471 year, respectively. Using linear-fit for these data points, the right ascension and declination components of the proper motion in ICRS were estimated to be $\frac{d\alpha}{dt} = -2.72 \pm 0.02$ mas year^{-1} and $\frac{d\delta}{dt} = -5.46 \pm 0.01$ mas year^{-1}, respectively.

References

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