Studying Black Holes with VERA

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In this paper we discuss the potential use of VERA (VLBI exploration of radio astrometry) to study black holes based on phase-referencing VLBI astrometry. First we present a brief overview of the project, from system design to scientific targets, and then we discuss the possibilities to investigate black holes and other high energy phenomena that are possibly linked to black holes.

§1. The VERA project

VERA[1),2)] (VLBI Exploration of Radio Astrometry) is a new VLBI array dedicated to phase-referencing astrometry, which consists of four 20m radio telescopes spread over Japan. All the telescopes at Mizusawa, Iriki, Ogasawara and Ishigaki-jima have a dual-beam system with which one can simultaneously observe a reference and a target radio source with a separation ranging from 0.3 to 2.2 degrees.[3)] With this dual-beam system, one can effectively cancel out tropospheric fluctuation,[4)] and high-precision relative astrometry can be carried out in the radio bands. VERA has two major receiving bands, 22 GHz and 43 GHz, for observing H_2O and SiO maser sources, which are mainly star forming regions and AGB variable stars in the Milky Way galaxy. By monitoring positions of maser sources with respect to extra-galactic QSOs, VERA will measure the proper motions and parallaxes of these maser sources, and establish the precise three-dimensional structure and dynamics of the Milky Way galaxy.[1),2)]

§2. Studying black holes with VERA

2.1. *Sgr A***

Based on the monitoring of the position with respect to reference extra-galactic QSOs, VERA will measure the proper motion and the direct distance to the galactic center radio source Sgr A*, which is thought to be a super massive black hole. In addition, the monitoring program of Sgr A* will be of great use for studying its variability and possible flare-up in the radio wavelength. Also, the motions of SiO maser sources (mostly AGB stars) with respect to Sgr A* can be used to trace the mass and the dynamics of the Milky Way's center.

2.2. *X-ray binaries*

Astrometry of X-ray binaries with VERA will provide information on the distance as well as orbital parameters of the binary systems, which are crucial for understanding the nature of compact stars in X-ray binaries. The motion of jets can be traced as well based on the monitoring observation with VERA.

2.3. *AGN monitoring*

In carrying out the astrometry of galactic maser sources, VERA will observe a large number of QSOs and radio galaxies as position reference sources. The data for reference radio sources are of great use in studying jet motion and activity variations in AGNs, providing a large number of AGN samples that are monitored with a time interval of around one month.

2.4. *Astrometric gravitational lensing*

VERA can observe a rather new type of gravitational lensing, namely astrometric gravitational lensing, in which an image position shift is used to detect the bending of light due to the source of gravity.[5)] This technique can be used to search for floating compact dark objects in the Milky Way, such as brown dwarfs, white dwarfs, neutron stars and black holes. Also, VERA's measurement of the gravitational bending of the light by the Sun will provide us one of the most precise tests of general relativity.

2.5. *Gamma ray bursts*

Some bright gamma ray bursts can be observed with VERA (for instance, GRB 030329 was in fact detected at 22 GHz band). The astrometry of gamma ray bursts will provide us a unique opportunity to test possible relativistic beaming in these phenomena.

References

1) T. Sasao, in Proc. 4th APT Workshop, ed. E. A. King (ATNF, Sydney, 1996), p. 94.
2) M. Honma, N. Kawaguchi and T. Sasao, in Proc. SPIE 4015, Radio Telescope, ed. H. R. Buthcer (SPIE, Washington, 2000), p. 624.
3) N. Kawaguchi, T. Sasao and S. Manabe, in Proc. SPIE 4015, Radio Telescope, ed. H. R. Buthcer (SPIE, Washington, 2000), p. 544.
4) M. Honma, T. Fujii, T. Hirota et al., Publ. Astron. Soc. Jpn. **55** (2003), L57.
5) M. Honma, Publ. Astron. Soc. Jpn. **53** (2001), 233.