IAU Colloquium 164: Radio Emission from Galactic and Extragalactic Compact Sources
ASP Conference Series, Vol. 144, 1998
J. A. Zensus, G. B. Taylor, & J. M. Wrobel (eds.)

Toward a Trigonometric Parallax of Sgr A*

M. J. Reid
Harvard-Smithsonian CfA, Cambridge, MA 02138, U.S.A.

A. C. S. Readhead & R. C. Vermeulen
Caltech, Pasadena, CA 91109, U.S.A.

R. N. Treuhaft
Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109, U.S.A.

Abstract. We initiated a project with the VLBA to measure directly the distance to the Galactic Center, R_0, via a trigonometric parallax. Here we describe the observing program and the first results–direct imaging of the effects of the Sun's orbit about the Galactic Center.

Balick & Brown (1974) first detected the source now called Sgr A*, using the Green Bank interferometer, and reported "intense sub-arcsecond structure" embedded in the complex and extended source Sgr A. VLBI observations (e. g.Lo et al., 1985) demonstrated that the cm-wavelength emission of Sgr A* originates from a region of order astronomical units or less in size. The similarity between the radio emission from weak AGNs and Sgr A*, and the location of Sgr A* very close to the suspected dynamical center of the Milky Way, lead to suggestions that Sgr A* was powered by a massive black hole.

In 1979, M. Reid and J. Moran submitted a "Proposal to Study the Feasibility of Detecting Proper Motion of the Galactic Center" to the US VLBI Network, outlining potentially observable components of the proper motion of Sgr A*: 1) a yearly oscillation owing to the Earth's orbital motion around the Sun (trigonometric parallax), which is sensitive to the distance to the Galactic Center, R_0; 2) a secular motion in the galactic plane toward $\ell = 90^\circ$ owing to the circular component of the Sun's orbit about the Galactic Center, Θ_0, which is sensitive to the angular rotation rate of the Milky Way (Θ_0/R_0); 3) a secular motion of approximately 20 km s^{-1} toward R.A.$\approx 18^h$ and Dec.$\approx 30^\circ$, owing to the deviation of the motion of the Sun from a circular orbit; and 4) a possible peculiar motion of the source Sgr A* itself, with respect to the dynamical center of the Milky Way. Preliminary VLBI observations at 2.8-cm failed to detect suitable background sources, owing to the weak nature of candidate sources and the effects of severe scatter-broadening of sources near the Galactic Center.

In 1991, with VLBA operation at 43 GHz becoming possible, we re-proposed a program to determine a trigonometric parallax to Sgr A*. A distance determined by trigonometric parallax techniques has almost no sources of systematic uncertainty and is of fundamental importance to astrophysics. Observations at a high frequency were necessary to minimize the effects of interstellar scattering. The first phase of the program involved locating background reference sources sufficiently compact and strong for detection with the VLBA. Candidate sources from several surveys were observed with the VLA at K-band in the C-configuration (proposal AR267) and with VLBI observations at X-band (proposal BR011). Two sources, 1745−283 and 1748−291 (J2000), from the catalog of Zoonematkermani et al. (1990) were found to be compact (< 10 mas) and strong enough ($S_{43GHz} > 10$ mJy) for our purposes. These sources each are separated from Sgr A* by about 0.7°, and they are two of the three sources used by Backer & Sramek (pers. comm.) to measure the apparent secular motion of Sgr A* using the VLA.

In 1995, we started observations to evaluate optimal observing strategies and to measure the change in position of Sgr A* with respect to the two background sources. Switching between Sgr A* and each of the background sources as rapidly as possible, with 15 seconds on each source, resulted in approximately 8 seconds of on-source time and achieved an optimal balance between duty cycle and coherence loss under good weather conditions. Observations in early 1996 and 1997 experienced acceptable phase coherence, typically exceeding 1 minute, allowing 1745–283 and 1748–291 to be calibrated using phases obtained on Sgr A*. We used Sgr A* as the *reference* source because it is stronger than either of the background sources. Fig. 1 shows images of 1745–283 at these two epochs, spaced by about 1 year, and referenced to Sgr A*. There is apparent motion toward the north-east, as expected from the reflex motion of Sgr A* of roughly 6 mas y^{-1} for standard values of R_0, Θ_0, and the solar motion. It is fascinating to consider that, although it takes about 200 million years for the Sun to orbit the Galactic Center, we can detect this motion in less than one month with the VLBA!

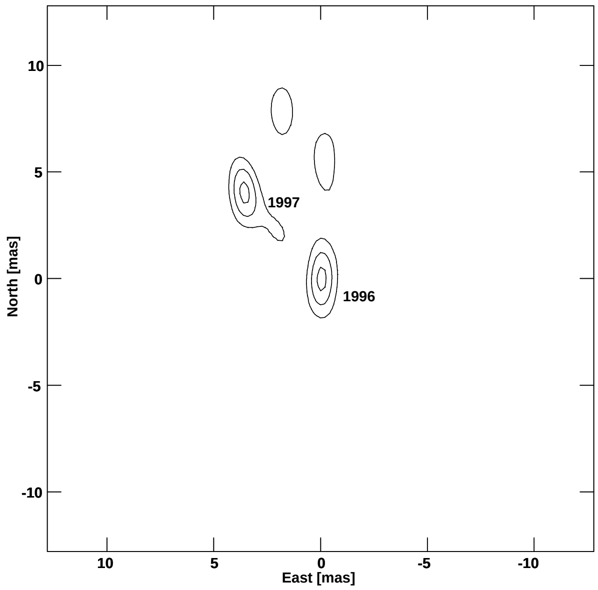

Figure 1. 1745–283 at 2 epochs, separated by ~ 1 year, referenced to Sgr A*.

Acknowledgments. The National Radio Astronomy Observatory is a facility of the NSF, operated under a cooperative agreement by Associated Universities, Inc.

References

Zoonematkermani, S. et al. 1990. *ApJS*, **74**, 181–224.