THE FIRST MEASUREMENT OF THE GALACTIC ABERRATION BY THE VLBI

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Abstract. This paper reports on the detection of the Galactic aberration in astrometric measurements of quasar positions by very long baseline radio interferometry (VLBI). The Galactic aberration effect shows up as a dipole component in the quasar proper motion field, oriented towards the Galactic center. The dipole amplitude is in good agreement with theoretical predictions.

Keywords: Astrometry, Techniques: interferometric, Galaxies: radio sources, Galaxies: active

The main component of the Solar System acceleration is due to its motion around the Galactic center. This acceleration produces a slight aberration of 5 to 6 milliseconds of arc per year (mas/yr) to the positions of distant bodies (e.g., Kovalevsky (2003)). This effect, known as secular aberration drift, was recently detected for the first time in geodetic and astrometric very long baseline interferometry (VLBI) measurements at 2 and 8 GHz by Titov, Lambert & Gontier (2011). This paper constitutes a summary of the former article which gives more technical details.

Fig. 1. Radio telescopes involved in 24 hour geodetic VLBI sessions since 1979 (`http://ivsopar.obspm.fr`).

Astrometric and geodetic VLBI is the cornerstone of highly accurate measurements of the time variable Earth's orientation and the establishment of terrestrial and celestial reference frames. Since 1979, the technique makes use of radio telescopes reparted worldwide (Figure 1). About thirty of these radio telescopes are regularly involved in 24-hour sessions scheduled bi-weekly for more than twenty years. Since 1998, the International VLBI Service for Geodesy and Astrometry (IVS, Schlüter & Behrend (2007)) coordinates astrometric and geodetic VLBI observations from scheduling to analysis (`http://ivscc.gsfc.nasa.gov`). The SYRTE department at

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the Paris Observatory hosts an IVS analysis center and an IVS data center (`http://ivsopar.obspm.fr`) whose jobs are to run operational analysis of the latest VLBI observations and to make publicly (and continuously) available the full VLBI observational data base together with analysis results.

The analysis of the full observational data base, consisting of about seven million delays at 2 and 8 GHz recorded over thirty years, allows one to obtain time series of absolute coordinates of hundreds of compact extragalactic radio sources with an accuracy better than 0.1 mas. Figure 2 displays two examples of these time series which reflect changes in the structure of the body.

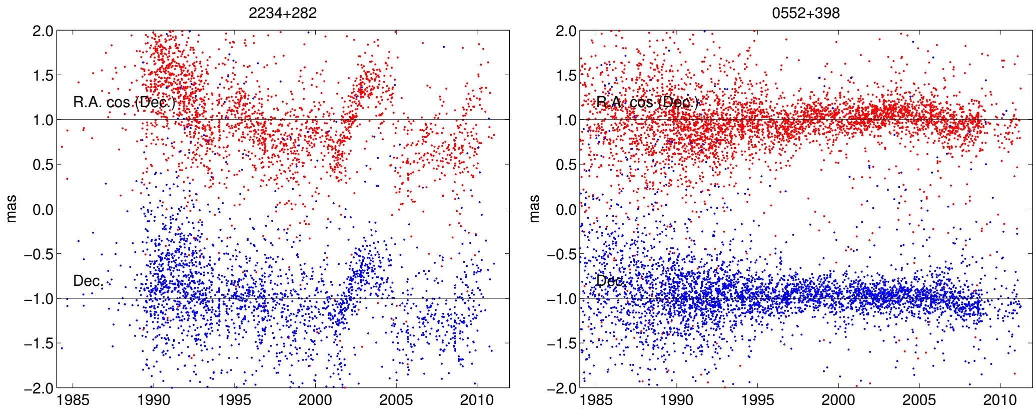

Fig. 2. Offsets of radio sources 2234+282 and 0552+398 to their respective ICRF2 positions.

The proper motion of the radio sources can then be computed as the slope of the series. However, this slope can be contaminated by reference frame effects if the analysis is done incorrectly. Indeed, during the analysis of delays, the analysts must impose minimal constraints of no-net rotation to avoid degeneracy of the system of equations, and to tie the radio sources to a reference frame (for instance the ICRF2 of Ma et al. (2009)). However, the constraint must be sufficiently loose to avoid masking the aberration effect. This point is the key point of the study. Previous studies that failed in finding the aberration used too tight constraints and obtained biased proper motions.

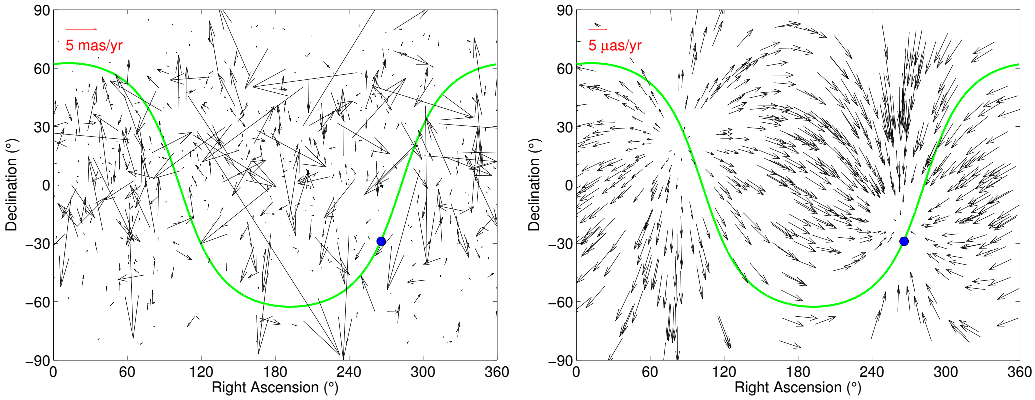

Fig. 3. Estimated proper motions of 555 radio sources (left) and adjusted dipole component (right). Note the drastic change in the scale.

The leftmost Fig. 3 displays the estimated proper motions of 555 radio sources fitted over 1990–2010. Through these proper motion we adjusted vector spherical harmonic coefficients of degree 2 (see for example Mignard & Morando (1990)) including a spheroidal (or dipolar) component, a toroidal (or global rotation) component, and a quadrupolar part. Before any adjustment, about 40 sources showing strong proper motion due to violent changes in the structure were removed from the sample. The quasar 2234+282 is among them. The dipole component is plotted in the right panel of Fig. 3.

The dipole of amplitude 6.4 ± 1.5 mas/yr is in good agreement with theoretical predictions and constitutes the first direct measurement of the Galactic aberration of distant bodies. It shows that VLBI has now accumulated accurate enough data to detect the Galactocentric acceleration through its effect on distant radio source positions. It turns out that the current definition of the celestial reference frame as epochless and based on the assumption that quasars have no detectable proper motions (Feissel & Mignard (1998)) should be mitigated. In the future, VLBI realizations of the celestial reference system should correct source coordinates for this effect, possibly by providing source positions, together with a corrective formula. The origin of the quadrupole remains unclear at this stage. It is certainly affected by Sun-atmosphere interactions along the ecliptic and needs more observations to identify systematics. It is especially interesting because the quadrupole amplitude is linked to the energy density of gravitational waves of period larger than 30 years Gwinn et al. (1997). The marginal quadrupolar amplitude found in our study is 6.4 ± 3.6 mas/yr and allows us to say that the upper limit of the gravitational wave energy density is $0.0042h^{-2}$.

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