ANALYSIS OF TIME SERIES OF THE EOP AND THE ICRF SOURCE COORDINATES

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ABSTRACT. Software ARIADNA was used for estimation of the Earth orientation parameters (EOP) for period 1984–2012. Simultaneously the time series of the coordinates of the ICRF radio sources were calculated. The least-squares method with constraints is applied. It is shown that most radio sources (including defining sources) are characterized by significant apparent motions.

1. INTRODUCTION

Very Long Baseline Interferometry (VLBI) technique is used by the International Earth Rotation Service and Reference System Service (IERS) for production of the Earth orientation parameters (EOP). They are required to study Earth orientation variations. Besides they are necessary to link the International Celestial Reference System (ICRS) and the International Terrestrial Reference System (ITRS).

The first of them is realized by the precise coordinates of extragalactic radio sources. A catalog of coordinates for 608 radio sources (Ma et al., 1998) was compiled using VLBI observations from 1975 to 1995 and is the first realization of the International Celestial Reference Frame (ICRF). In accordance with resolution B3 of the 27th General IAU Assembly, the new realization of the frame (ICRF-2) is based on two catalogs (Ma et al., 2009). The first one is the main catalog, while the second is supplementary. In total, both catalogs include 3414 sources, and 2197 objects were observed only one–two times.

The rotational stability of the frame is based on the assumption that some chosen sources have no proper motion and it means that there is no global rotation of the universe. One assumes that coordinates of them are known as precise as possible. These sources are unresolved with VLBI baselines comparable to the Earth diameter, and it was assumed that variations of their coordinates are negligible. The ICRF catalog contains 212 so called "defining" radio sources, while the ICRF-2 catalog contains 295 defining sources.

But analysis of time series of coordinates of the ICRF radio sources shows that many of them including the defining sources have significant apparent motion (Zharov et al., 2009). It is explained by motion of an emission region that is called by the ICRF source inside the jet of a quasar.

Software ARIADNA was used for estimation of the Earth orientation parameters (EOP) for period 1984–2012. In our previous work (Zharov et al., 2009) solution (EOP and the sources positions and velocities) was obtained for the first catalog of the ICRF sources (Ma et al.,1998).

New solution (EOP and the sources positions and velocities) was obtained for catalog ICRF-2 (Ma et al.,2009).

We show that

- many of new defining sources show significant apparent motion;
- small rotation of ICRF is transformed into long-term variations of the EOP.

To obtain the time series of the EOP and the ICRF sources coordinates the ARIADNA software was used. Solution "sai2013a.eops" was based on accepted positions of the sources ICRF2, precession-nutation model IAU2006. The terrestrial reference frame was fixed by the VTRF2008 coordinates and velocities of stations. Solution "sai2013b.eops" differs from previous one by adding the velocities of sources.

Secular variations of the EOP can be calculated by subtracting of two solutions "a" and "b".

2. SOLUTION DESCRIPTION

In the linear regression model under consideration, the estimated parameters can be subdivided into two different groups containing global and local parameters (Voronkov, Zharov, 2013). The former one includes the coordinates and velocities of telescopes, as well as the coordinates and apparent motions of radio sources that are estimated during the entire period of observation. Local parameters, including the Earths rotation, the dry and wet tropospheric delays of the signal, and the station clocks model, are calculated individually for each session.

Station clocks are estimated w.r.t. combined clock by a 2^{nd} order polynomial according equation:

$$\sum_j [C_0^j + C_1^j t + C_2^j t^2] = 0.$$

The zenith wet delay is parameterized by polynomial function too but order of it can be chosen as 3 or more in 2 h intervals.

In addition, the coordinates and apparent motions of the sources should satisfy the condition of the absence of the global rotation of the celestial frame of reference (no net rotation – NNR). As well, this condition is applied for the coordinates of telescopes (in the terrestrial frame of reference).

For all of these solutions a priori EOP are taken from IERS final products. Displacement of reference points, tidal variations in the Earth's rotation, transformation between the ITRF and ICRF are calculated according the IERS Conventions (2010) (IERS TN35, 2010). Atmospheric pressure loading have been applied according model developed in paper (Zharov, 2004).

3. RESULTS

The proposed method was applied for estimating the apparent motions of extragalactic radio sources. We processed more than 3200 daily sessions of the VLBI observations from 1984 to 2012. The solution was obtained with allowance for restrictions in corrections to the coordinates and apparent motions of the sources, and corrections to the coordinates and velocities of telescopes. The coordinates and apparent motions of the sources satisfy the condition of the no-net-rotation of the celestial frame of reference.

Figure 1 shows the distribution of the apparent motions of radio sources. In the southern hemisphere, the number of the sources is considerably lower than in the northern hemisphere. This is due to the insufficient number of observation stations in the southern part of the planet.

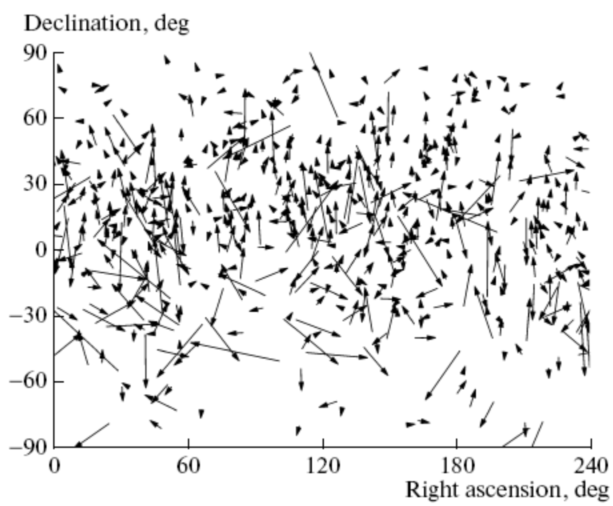

Figure 1: The apparent motions of radio sources depending in right ascension and declination.

As we can see from the histograms (Fig. 2 and Fig. 3), a great number of the sources have considerable apparent motions. More than half of them have apparent motions exceeding 50 microarcsecond per year.

Thus, we can assume that this phenomenon is not accidental and confirms previous conclusions based on the analysis of temporal series (Zharov et al., 2009). As was said, the main purpose in selecting defining sources is the creation of a stable frame of reference with fixed coordinate axes in space. Since the direction of the axes is determined by the coordinates of defining sources, the lack of apparent motions of these sources determines the stability of the system.

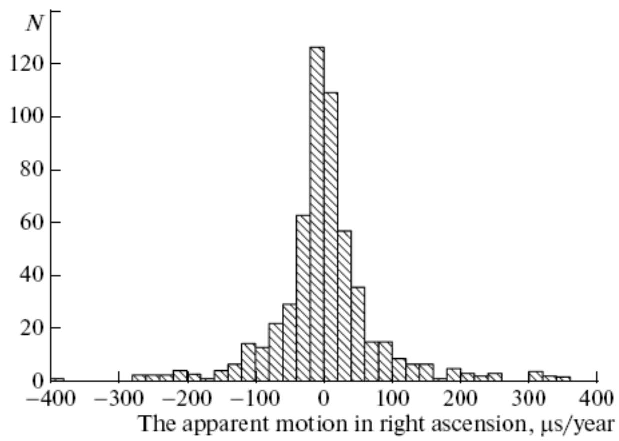

Figure 2: The apparent motion distribution histogram in right ascension.

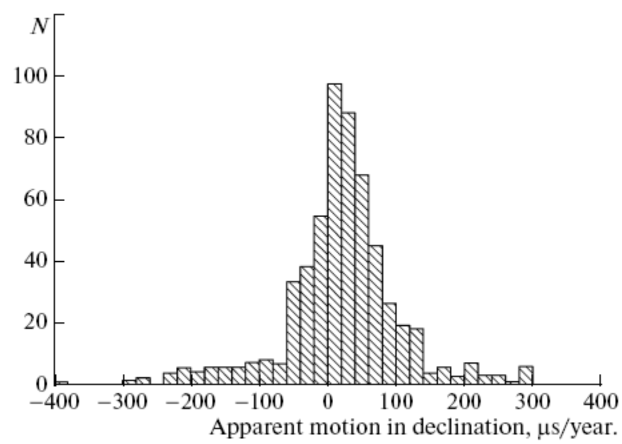

Figure 3: The apparent motion distribution histogram in declination.

The values of velocities of defining sources can reach a few microarcseconds per year. The variation of the ICRF source coordinates leads to small rotation of reference frame. To estimate the stability of the frame three small angles θ_1, θ_2, θ_3, which describe small rotation were calculated:

$$\mathbf{s}(t) = \begin{pmatrix} 1 & -\theta_3 & \theta_2 \\ \theta_3 & 1 & -\theta_1 \\ -\theta_2 & \theta_1 & 1 \end{pmatrix} \mathbf{s}(t_0)$$

where $\mathbf{s}(t)$, $\mathbf{s}(t_0)$ are unit vectors of a defining source at moments t and $t_0 = J2000.0$. Obviously, that variations of angles θ_1, θ_2, θ_3 are connected with motion of the defining sources and NNR condition. Stability of the ICRF (or constancy of θ_1, θ_2, θ_3) can be improved by correct choice of the defining source or extension of their number.

Rotation of the ICRF is due to the motions of sources. Variations of angles θ_1, θ_2, θ_3 are connected with the EOP or the effect of the source apparent motion has an impact on the determination of the EOP.

To calculate this effect two solutions "sai2013a.eops" and "sai2013b.eops" were obtained. From difference of solutions linear trend in x-coordinate of pole equal to $-2.77 \pm 0.22\,\mu$as/year, in y-coordinate of pole equal to $1.60 \pm 0.15\,\mu$as/year were found. Variations of nutation in longitude and obliquity are $0.47 \pm 0.46\,\mu$as/year, $-0.54 \pm 0.15\,\mu$as/year respectively, and UT is $0.144 \pm 0.007\,\mu$s/year.

Motion of extragalatic radio source can be decomposed on systematic and stochastic parts. The first of them can be explained by secular aberration drift of the extragalatic radio source motions caused by the rotation of the Solar System barycenter around the Galactic center (Titov et al., 2011). The dipole component of the velocity field is defined by the velocity of the Solar System barycenter and galactic coordinates of the radio source and can be estimated. Other regular part of the extragalatic radio source motions can be caused by the errors of the precession constants. It is planned to estimate this effect from our solutions.

4. CONCLUSIONS

New time series of the EOP and the ICRF sources coordinates were obtained. The ARIADNA software was used for this. Solutions were based on accepted positions of the sources ICRF2, precession-nutation model IAU2006.

It was shown that small rotation of the ICRF is due to the motions of sources. The effect of the source apparent motion has an impact on the determination of the EOP.

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