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Correction to the precession constant from optical observations of extragalactic sources

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Abstract. The rediscussion of the precession constant was performed by optical observations of the counterparts of extragalactic radio sources with longer observational intervals. After a reduction of the optical catalogue systems, the fictitious 'proper motions' of extragalactic radio sources were obtained in the FK5 system. On the assumption that these fictitious 'proper motions' of extragalactic sources are the reflection of an incorrcet value of the precession constant, then the correction of precession constant can be estimated. The corrections are $-2.60 \pm 1.35\,\mathrm{mas\,yr^{-1}}$ for 43 sources and $-3.35 \pm 1.62\,\mathrm{mas\,yr^{-1}}$ for 24 sources, respectively. If the improvement of the 18.6-year nutation term is considered in the data processing, the corrections of the precession constant are $-2.91\pm1.38\,\mathrm{mas\,yr^{-1}}$ and $-3.52\pm1.68\,\mathrm{mas\,yr^{-1}}$, respectively. The results were also compared with those from VLBI.

Key words: astrometry – reference systems – radio continuum: galaxies

1. Introduction

Theoretically speaking, the extragalactic sources exhibit no measurable proper motions. But an incorrect value of precession will induce fictitious apparent motions of extragalactic objects presented in observational positions referring to a common reference system at different epochs. In this paper some common objects with longer observational intervals were selected from optical catalogues containing optical counterparts of extragalactic radio sources. On the assemption that these 'proper motions' of the extragalactic sources are the reflection of an incorrect value of the precession constant, a correction of the precession constant has been derived.

However, the 18.6-year nutation term will affect the results of the observational positions. In the processing, the influence of the incorrect 18.6-year nutation term has also been estimated. These results are compared with those from VLBI.

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2. Observational materials

The optical positions of the counterparts of extragalactic radio sources used here have been taken from the observational catalogues listed in Table 1.

The reference catalogues used in these observational catalogues are FK4 and Perth70, respectively. 43 common sources, appearing at least in two catalogues, were selected. The observational intervals of these are more than 12 years. These sources are listed in Table 2, in which columns 1 and 3 give the names of sources, and columns 2 and 4 are the serial numbers listed in Table 1. Among these, there are 24 sources that cover more than 20 years and are labelled with an asterisk in Table 2.

3. Data processing

In this analysis, the positions of sources referring to the mean equator of date were reduced to the mean equator of J2000.0 using the method of Aoki et al. (1983). The systematic differences (FK5-reference catalogues) were added to the observational values according to the reference catalogue used in the observations, with the aim of reducing the systems of the observational catalogues to the FK5 system. The systematic differences (FK5-FK4) were taken from the FK5 catalogue (Fricke et al.,1988). The systematic differences (FK5-Perth70) were calculated with the method of Bien et al. (1978), and the results are described in detail by Lu et al. (1994).

On the assumption that the extragalactic objects are fixed in inertial space, if an incorrect value of precession constant is adopted in the data processing, apparent motions of the extragalactic objects will appear in the observational positions obtained at different epochs and processed to a common reference system. As a first approximation:

$$\begin{aligned} \alpha_t &= \alpha_{t_0} + \Delta p(\cos\varepsilon + \sin\varepsilon\sin\alpha\tan\delta)(t - t_0) \\ \delta_t &= \delta_{t_0} + \qquad \Delta p \sin\varepsilon\cos\alpha(t - t_0), \end{aligned} \tag{1}$$

where α_t, δ_t denote the right ascension and declination of the source at observational epoch t, α_{t_0},δ_{t_0} are the right ascension and the declination of the source at the common epoch, i.e. J2000.0 in this paper, ε is the obliquity of the ecliptic at J2000.0,

Table 1. Information of the observational catalogues

No.	Author	Internal precision	Reference catalogue	Observational epoch
1	Assafin et al. (1992)	$0''.21 - 0''.23$	Perth70	1988
2	Costa et al. (1983)	$0''.2$	Perth70	1980
3	Costa et al. (1992)	$0''.5$	Perth70	1975–86
4	de Vegt et al. (1978)	$0''.1$	FK4	1975–76
5	de Vegt et al. (1981)	$0''.04$	FK4	1980
6	Harrington et al. (1983)	$0''.05$	FK4	1978–80
7	Harvey et al. (1992)	$0''.19 - 0''.21$	Perth70	1975–77
8	Murray et al. (1971)	$0''.15 - 0''.20$	FK4	1967.5
9	Russell et al. (1992)	$0''.20$	Perth70	1988–90
10	Torres et al. (1984)	$0''.03 - 0''.08$	FK4	1979
11	Walter et al. (1986)	$0''.12$	Perth70	1980–82
12	West et al. (1981)	$0''.2$	Perth70	1955-76
13	White et al. (1990)	$0''.16$	Perth70	1955–77
14	White et al. (1991)	$0''.19$	Perth70	1973–76
15	Wroblewski et al. (1981)	$0''.17 - 0''.19$	Perth70	1972–79

Table 2. Sources selected for the analysis

IAU designation	Reference	IAU designation	Reference
0008−264	3, 11	1144−379*	1, 3,11,13
0104−408	3, 11	1148−001	2,11,12
0111+021*	3, 11	1222+037*	3,11
0113−118*	3, 11	1226+023*	4,5,6,12,15
0150−334	2,11,12	1224−255	3,11
0208−512	3, 7,14	1253−055*	2,11,12
0237−027*	10,12	1430−178	2,11,12
0332−403	1,10,11,12	1510−089*	6,11,12,15
0336−019*	10,11,12	1555+001*	10,11,12
0402−362	1,2,10,11,12	1641+399	4,6,8
0420−015*	11,12,13,15	1656+053*	3,11
0430+052*	3,10,11,12	1730−130*	10,11,12
0440−003*	11,13,15	1741−038*	2,11,12
0451−282	3,11	1933−400	1,2,11,12
0537−441	1,10,11,12	2008−159*	2,12
0605−085*	3,11	2134+004*	2,11,12
0607−157*	10,11,12	2155−152*	3,9,11
0637−752	1,3,7	2223−052	12,15
0736+017	12,15	2320−035*	3,11
0920−397	3,13	2326−477	1,3,7
1055+018*	2,3,11,12	2345−167*	2,12
1127−145	2,11,12		

and Δp the correction of precession. According to formula (1), similar to that described by Walter et al. (1994), the difference of position at two observational epochs t_i,t_j, avoiding repetitions, is formed for each source, or we can write the following equation:

$$\begin{aligned} \alpha_{t_i} - \alpha_{t_j} &= \Delta p(\cos\varepsilon + \sin\varepsilon\sin\alpha\tan\delta)(t_i - t_j) \\ \delta_{t_i} - \delta_{t_j} &= \Delta p\sin\varepsilon\cos\alpha(t_i - t_j) \end{aligned} \quad (2)$$

Then the Δp can be estimated by the least squares method.

Before the year 1984, Woolard's nutation theory was adopted. Since 1984, the IAU 1980 nutation has been used. With the differences (IAU 1980 nutation-Woolard's nutation) of the 18.6-year nutation term in Table 2 of appendix 3 of the Monitor Earth Rotation and Intercompare Techniques (MERIT) Standards(1983), then the corrections $\Delta\psi_1$ and $\Delta\varepsilon_1$ of the 18.6-year nutation term for Woolard's nutation in longitude and obliquity can be taken. But VLBI observations show that there are some small improvements to the IAU 1980 nutation (Sovers 1990; Herring et al. 1991). According to the Table 3.224-1 and the formula (3.224-1) of the Explanatory Supplement to the Astronomical Almanac (1992), the corrections $\Delta\psi_c$ and $\Delta\varepsilon_c$ of the 18.6-year nutation term for the IAU 1980 nutation in longitude and obliquity are calculated by

$$\begin{aligned} \Delta\psi_c &= -0''.00725\sin\Omega + 0''.00417\cos\Omega \\ \Delta\varepsilon_c &= 0''.00213\cos\Omega + 0''.00224\sin\Omega \end{aligned} \quad (3)$$

where Ω indicates the mean longitude of the ascending node of the lunar orbit on the ecliptic measured from the mean equinox of date.

For the observational catalogues whose observational epochs are after 1984, the total corrections of the 18.6-year nutation term are

$$\begin{aligned} \Delta\psi &= \Delta\psi_c \\ \Delta\varepsilon &= \Delta\varepsilon_c, \end{aligned} \quad (4)$$

while for others, the total corrections are

$$\begin{aligned} \Delta\psi &= \Delta\psi_1 + \Delta\psi_c \\ \Delta\varepsilon &= \Delta\varepsilon_1 + \Delta\varepsilon_c. \end{aligned} \quad (5)$$

It is well known that the relation between the nutation and the correction of a celestial position $\Delta\alpha$ and $\Delta\delta$ is:

$$\begin{aligned} \Delta\alpha &= (\cos\varepsilon + \sin\varepsilon\sin\alpha\tan\delta)\Delta\psi - \cos\alpha\tan\delta\Delta\varepsilon \\ \Delta\delta &= \sin\varepsilon\cos\alpha\Delta\psi + \sin\alpha\Delta\varepsilon. \end{aligned} \quad (6)$$

Table 3. Corrections to the IAU 1976 precession(unit:mas/yr)

	Source number	Δ p α Solutions	δ Solutions	α+δ Solutions	
(I)	43	−2.51±2.00	−3.10±1.80	−2.60±1.35	Without improvement
	24	−3.20±2.38	−3.85±2.20	−3.35±1.62	of 18.6-year nutation term
(II)	43	−2.75±2.12	−3.60±1.82	−2.91±1.38	With improvement
	24	−3.31±2.48	−4.18±2.40	−3.52±1.68	of 18.6-year nutation term

Table 4. Comparison between corrections of the precession constant (unit: mas/yr)

Δp	Author	Technique	Note
-2.39 ± 0.13	Herring et al. (1986)	VLBI	
-3.76 ± 0.47	Zhu et al. (1990)	VLBI	
-2.70 ± 0.4	Williams et al. (1991)	LLR	
-3.59 ± 1.14	Walter, Ma (1994)	VLBI	
-3.84 ± 1.16	Walter, Ma (1994)	VLBI	
-2.60 ± 1.35	Authors	Optical	Without improvement
-3.35 ± 1.62			of 18.6-year nutation term
-2.91 ± 1.38		Optical	With improvement
-3.52 ± 1.68			of 18.6-year nutation term

According to (6), the influence of an incorrect 18.6-year nutation term on the position will be considered. Then the correction of the precession constant can be determined from formula (2).

4. Results

For determining the correction of the precession constant Δp with the observational values α_t,δ_t of all 43 sources listed in Table 2, formula (2) has been applied with the weights assigned according to the accuracies of the right ascension α and declination δ. In the solutions of formula (2), there are two groups: group 1 containing all 43 sources and group 2 containing only 24 sources. In each case, an individual solution obtained from α or δ and a combined solution have been made. The weighted means are given in part (I) of Table 3. If the correction of the 18.6-year nutation term is considered, the corresponding results are given in part (II) of Table 3.

5. Comparison and conclusion

In recent years, there has been a variety of corrections of the precession constant performed with the different techniques. In Table 4, we give the comparison between some of these and our results.

The comparisons show that our results coincide with other corrections produced by different methods. The differences between the results of part (II) of Table 3 and those of other methods are smaller than the differences between those of part (I) of Table 3 and others. It shows that the influence of the imperfect nutation theory should be taken into account. As the accuracies of the optical observations are generally in the range from 0.04 to 0.2 arcsec this may introduce a larger source of uncertainty for the correction of the precession constant.

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