CORRECTIONS TO THE LUNI-SOLAR PRECESSION FROM RADIO POSITIONS OF EXTRAGALACTIC OBJECTS

H. G. WALTER
Astronomisches Rechen-Institut
Moenchhofstr. 12-14
D-6900 Heidelberg
Fed. Rep. of Germany

ABSTRACT. In an attempt of a realization of the radio reference frame a compilation catalogue of positions is derived from independent observation catalogues of extragalactic objects the coordinates of which had been determined by means of Very Long Baseline Interferometry. The compilation catalogue comprises 209 objects which are divided into a core consisting of 50 objects having mean positional accuracies of 0.5 milliseconds of arc (mas) and an extension with positional accuracies better than 2 mas. Comparison of this catalogue with an independent compilation catalogue led to confidence limits at the 1 mas level. - The compilation catalogue is supposed to represent a static reference frame of fixed extragalactic points. As the epochs of the contributing observations span nearly 10 years it was tried to interpret the apparent motion of the fixed points recognizable in the observation catalogues as an effect of luni-solar precession. The pilot study points at a reduction of the conventional value of about 2 mas per year.

1. INTRODUCTION

In recent years Very Long Baseline Interferometry (VLBI) has given rise to a steadily increasing number of observation catalogues of positions at the level of a few milliarcseconds (mas). The accumulated material suggests the establishment of a compilation catalogue (CC) constituting a radio reference frame of extraglactic objects. Assuming an isotropic model of the universe these objects, at cosmological distances, are not affected by proper motions and, thus, approximate a static reference frame. Tentatively, this frame may play the role of a reference for comparing observation catalogues of different origins. It may also be instrumental to the detection and interpretation of apparent motions of the extragalactic objects.

Below the construction of the compilation catalogue is outlined and compared with the independently derived catalogue of extragalactic radio sources of IERS (Arias et al., 1988 a). Another application of

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the CC concentrates on the apparent motions which are manifest in the observation catalogues. Stimulated by the findings of Fanselow et al. (1984) and, likewise, of Sovers and Edwards (1988) about a possible inconsistency of the IAU 1976 model of precession it is attempted to interpret these apparent motions as an effect of luni-solar precession. The observation equations are set up accordingly, and solved by a least squares fit. Several case studies are performed corroberating the hypothesis of a slightly too large value of precession.

2. CONSTRUCTION OF THE COMPILATION CATALOGUE

A catalogue of positions of extragalactic radio sources has been compiled from individual observation catalogues obtained during the last decade by the Goddard Space Flight Centre (GSFC), the Jet Propulsion Laboratory (JPL) and the U.S. National Geodetic Survey (NGS). In a previous paper (Walter, 1989 a) the method of catalogue construction is treated followed by a preliminary version of the catalogue. On setting up the system of the compilation catalogue, the line of thought was pursued that it is defined as the weighted mean of the instrumental systems of the observation catalogues, i.e. the coordinate determination is constrained to

$$\sum_{i=1}^{n} w_i \, \Delta c_i = 0, \qquad (1)$$

and the observation equations read

$$\Delta b + \Delta c_i = b_i - b_o, \qquad i = 1, \ldots, n. \qquad (2)$$

The meaning of the notation is:

Δb: correction to some approximate position b_o
Δc_i: systematic correction of the i-th catalogue
w_i: weight of the i-th observation catalogue
n : number of observation catalogues containing the respective radio source.

Eqs. (1) and (2) form a system of linear equations which is solved for the unknowns Δb and Δc_i.

With the advent of substantial new observations since 1988 an up-dated version of the compilation catalogue has been set up subdivided into a core and an extension (Walter, 1989 b). Account has been taken of the following observation catalogues: Fanselow et al. (1984) - Q17; Ma et al. (1986) - Q19; Robertson et al. (1986) - Q20; Sovers et al. (1988) - Q22; Ma (1988) - Q23; Carter et al. (1988) - Q26. The core consists of 50 objects the positions of which are determined from at least 4 observation catalogues, and the extension is comprised of 159 objects. The extension arises simply by applying the mean systematic corrections found in the core solution to the coordinates of the respective observation catalogues. Subsequently, weighted mean positions are calculated from these modified positions of the observation catalogues for all those objects which are not treated in the core. Table 1 summarizes the properties of the two sets and their union.

TABLE 1. Properties of the compilation catalogue: Core, extension and core + extension

	Average internal accuracy (mas) RA	Dec	Number of objects	Range of declination (degree)
Core	0.34	0.52	50	-30, +74
Extension	1.6	1.79	159	-45, +85
Core + Extension	1.30	1.49	209	-45, +85

It is intended to use the compilation catalogue as a basis for comparing not only the observation catalogues having contributed to the CC but also any other existing or forthcoming catalogues irrespective of their nature of being an observation or compilation catalogue. Furthermore, the basis is suitable for studying long-term effects in the context with astronomical constants such as precession. The sections below exemplify the usage of this basis for comparing compilation catalogues and studying the luni-solar precession.

3. COMPARISON OF TWO COMPILATION CATALOGUES

By mere coincidence of activities Arias et al. (1988 b) and Walter (1987) have set up compilation catalogues along different lines of thought. It is interesting to compare these catalogues, i.e. CC1 (Arias et al., 1988 a) and CC2 (Walter, 1989), in order to get some feeling for the external accuracy.

A total of 200 objects is common to both catalogues. Their right ascension and declination differences have been plotted versus RA and Dec. Typical for the differences in RA is a shift of about 1 mas. The differences in Dec with respect to RA (see Fig. 1) are dominated by a distinct sinusoidal function of 24 hours period with an amplitude of 3 mas, whereas the declination differences with respect to declination seem to be balanced showing the customary pattern of decreasing accuracy around declination zero.

When the comparison is limited to either the 50 core objects or the 159 objects of the extension the basic features of the above plots remain unaltered, only the error budget changes. Table 2 presents the weighted mean coordinate differences, their standard deviations, the weighted RMS differences, and the number of objects subjected to each comparison.

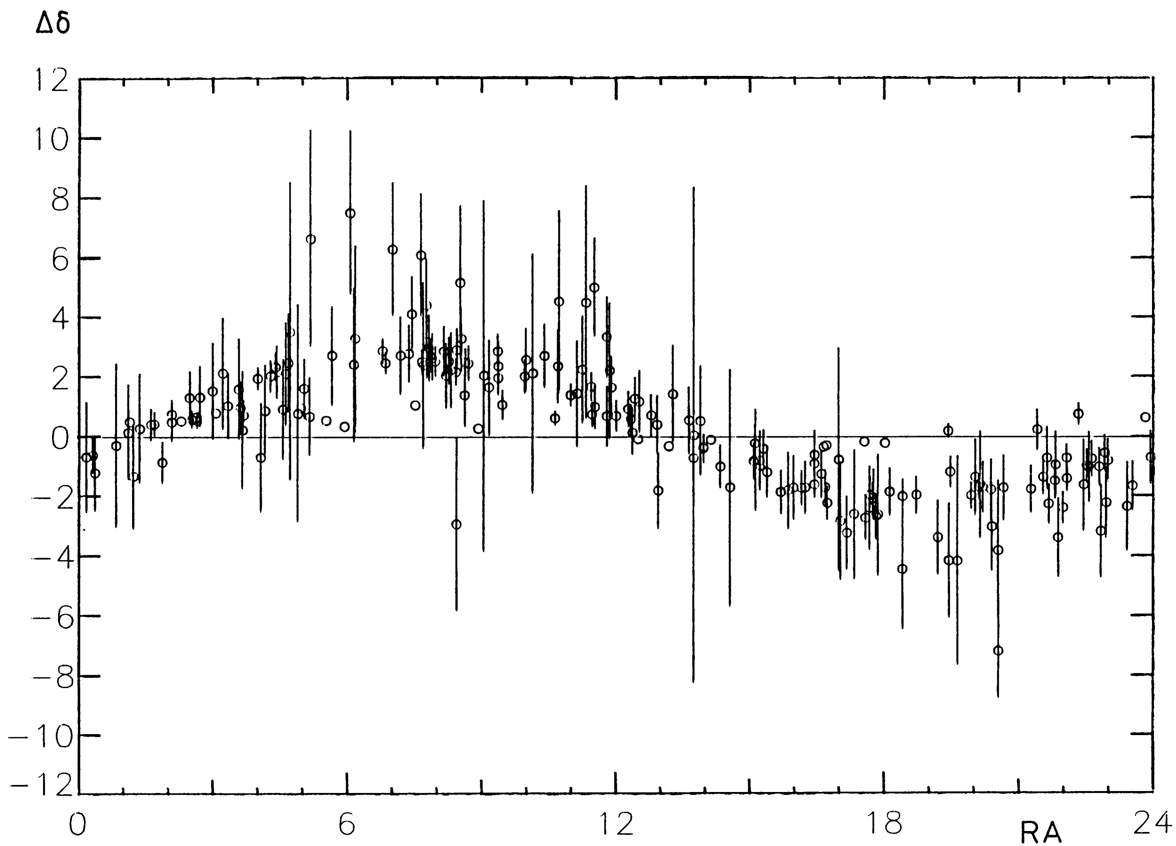

Fig. 1. CC1-CC2: Declination differences versus right ascension, units: 0.001 arcsec, hours

TABLE 2. Error budget of catalogue comparisons:
CC1 (Arias et al., 1988 a) minus CC2 (Walter, 1989 b)

	Weighted mean differences (mas) RA	Dec	RMS differences (mas) RA	Dec	Number of common objects
Entire CC2	0.57 ± 0.04	0.26 ± 0.08	0.81	1.13	200
Core	0.53 ± 0.07	0.36 ± 0.10	0.70	0.80	50
Extension	0.65 ± 0.06	0.12 ± 0.12	0.98	1.45	150

Using a 5 % significance number the significance test of the differences between CC1 and the entire CC2 yields 19 (10 %) rejections in RA and 12 (6 %) in Dec of the hypothesis of equal mean values. If the test is restricted to the core the figures become 12 (24 %) and 4 (8 %), respectively; for the extension one gets 6 (4 %) and 8 (5 %).

At present the offsets between the two compilation catalogues are not fully understood. One reason may be ascribed to the employed methods or to the selection of observation catalogues which is not exactly identical for CC1 and CC2. Another reason could be a statistical effect to the extent that 4 or 5 observation catalogues are insufficient for setting up a mean system.

4. A PILOT STUDY INTO THE POSITION DIFFERENCES

Since extragalactic objects are assumed fixed in inertial space one would expect that position differences between observation catalogues uniformly referred to J2000.0 are randomly distributed due to accidental errors. If, however, the value of precession employed to reduce a position at observation epoch to the fundamental epoch J2000.0 would be in error, a secular effect should be manifested in these differences.

TABLE 3. Variation of general precession in Dec (Δn_α, Δn_δ), and corrections $\Delta\psi$ of the luni-solar precession derived from Δn_α and Δn_δ. Units: 0.001 arcsec/y = 1 mas/y.

Origin of selected observations	Number of observations	Δn_α	$\Delta\psi$	Δn_δ	$\Delta\psi$
Qn $\cap$ Core					
1) n = 17,19B 22A,23,26	217	-0.39 ±0.14	-0.98 ±0.35	-0.43 ±0.09	-1.11 ±0.22
2) n = 17,22A, 26	124	-1.10 ±0.29	-2.77 ±0.72	-0.83 ±0.15	-2.12 ±0.39

Reportedly the IAU 1976 value of precession has been rigorously applied to reduce the data in deriving the observation catalogues. Therefore, also CC2 is marked by this precession value. The difference between the position in each observation catalogue and CC2 is formed for each object. Bearing in mind that these position differences are associated with the differences between the observation epoch and the mean epoch of observation in CC2 one can write the observation equations below for all sources in the observation catalogues which are represented in CC2. The following designations are used:

t	-	epoch of observation
$\bar{t}$	-	mean epoch of observation in CC2
T	-	fundamental epoch (J2000.0)
p_α , p_δ	-	variation in RA (α) and Dec (δ) due to general precession, i.e. $p_\alpha = m + n \sin \alpha \tan \delta$ $p_\delta = n \cos \alpha$ m - general precession in RA n - general precession in Dec.

To first approximation the object coordinates α, δ at observation epoch corrected by a precessional term are equal to the coordinates $\bar{\alpha}$, $\bar{\delta}$ in CC2 at mean epoch also corrected by a precessional term, i.e.

$$\alpha(t,T) + \Delta p_\alpha(T-t) = \bar{\alpha}(\bar{t},T) + \Delta p_\alpha(T-\bar{t}), \tag{3}$$
$$\delta(t,T) + \Delta p_\delta(T-t) = \bar{\delta}(\bar{t},T) + \Delta p_\delta(T-\bar{t}), \tag{4}$$

or, formulated as observation equations,

$$(\Delta m + \Delta n_\alpha \sin \alpha \tan \delta)\ (t-\bar{t}) = \alpha - \bar{\alpha} \tag{5}$$
$$\Delta n_\delta \cos \alpha\ (t-\bar{t}) = \delta - \bar{\delta}, \tag{6}$$

where the right-hand sides are supplied by the observation catalogues and CC2.

Since right ascensions are not measured directly but, instead, right ascension differences are given with respect to the reference source 3C273B, eq. (5) undergoes a modification. It has the effect that the coefficient of Δm vanishes and a correction term is added due to the precessional variations of the reference source. After some arithmetic eq. (5) becomes

$$\Delta n_\alpha \left[(-\sin \alpha_R \tan \delta_R) + \sin \alpha \tan \delta\right] (t-\bar{t}) = \alpha - \bar{\alpha} \tag{5a}$$

where the coordinates of 3C273B are denoted α_R, δ_R.

The unknowns Δn_α and Δn_δ are solved by weighted least squares fits applied to eqs. (5a) and (6), and to a variety of observational data. Surprisingly consistent results in RA and Dec have been found for the data sets treated. For two of them the possible corrections of the precessional values are listed in Table 3.

5. CONCLUSIONS

From present day VLBI observation catalogues of extragalactic radio sources it is possible to build a compilation catalogue having internal position accuracies better than 0.7 mas for the core with objects of at least four observations, and better than 2.5 mas for the extension with objects of not more than three observations. Its external error is assessed by comparison with an independently constructed compilation catalogue giving 0.1 mas for the error of the weighted mean differences of position, which lies well within the limits of the average standard deviations. An offset of about 1 mas is found in right ascension on top of which a periodic variation of 24 hours with an amplitude of 3 mas is added. The significance test for the two catalogues yields notable values only for the core.

The catalogues agree at the level of 1 mas. Since they avail of almost the same observational data any deviations seem to be related to the mode of compilation rather than to source structure and baseline configuration.

From analysing right ascension and declination residuals follow corrections $\Delta\psi$ of the luni-solar precession ranging from -1.1 ± 0.2 mas/y to -2.8 ± 0.7 mas/y depending on the selected data.

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Discussion

MURRAY: (1) Can you be sure that all the catalogues which you used have been reduced with the same set of precessional constants?

(2) The declination differences between your compilation catalogues and IERS could show a secular change of obliquity if the epochs were different.

WALTER: (1) The forewords to the catalogues used here state that the reductions proceeded along the lines recommended by IAU or by the MERIT standards.

(2) As both compilation catalogues are set up from almost the same observation catalogues, the mean catalogue epochs should not differ more than 1 or 2 years, which seems too short for explaining the 24 hours' periodicity of the declination differences.

VITYAZEV: Have you found any evidence of the equinox motion by evaluating Δn from RA and from declination?

WALTER: So far the goal of the analysis was to show that a secular effect in terms of Δn is detectable in the residuals of RA and Dec. A more refined study will have to demonstrate whether Δn contains a component which should be ascribed to the equinox motion.

YATSKIV: We have constructed a compilation catalogue of extragalactic objects using 16 primary sources (See the paper by Yatskiv and Kuryakova in this volume). It seems to me that our results agree with those of Walter.

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