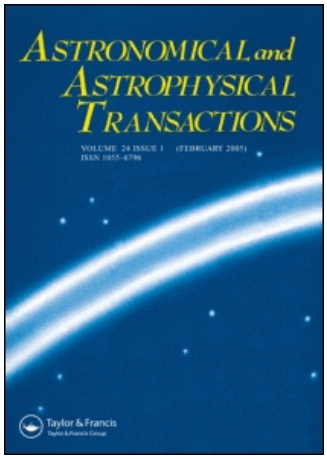

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Jinling Li [a]; Wenjing Jin [a]
[a] Shanghai Observatory, Shanghai, China

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A NEW APPROACH TO THE COMPILATION OF COMBINED EXTRAGALACTIC RADIO SOURCE CATALOGUES

JINLING LI and WENJING JIN

Shanghai Observatory, Shanghai 200030, China

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An attempt at the compilation of combined extragalactic radio source catalogues based on individual catalogues is undertaken. With reference to the ideas of other authors, a new approach is used. It includes the arc-length difference method in the selection of primary sources and the common primary source method in the maintenance of orientation. Our tests show that the stability of orientation of the combined catalogues with the new approach is better than 0.1 mas.

KEY WORDS Astrometry, reference system, catalogues, analytical methods

1 INTRODUCTION

To construct radio celestial reference frames based on individual catalogues of extragalactic radio sources, it is important to solve reasonably and effectively the following two problems:

(1) How can the relative deformations among individual catalogues be identified and removed? If this problem is overcome, a set of primary sources which constitue the reference frame will result.

(2) How can the orientation stability of the reference frame be maintained? An effective maintenance method of orientation is the essential prerequisite to improve the frame by applying newly available observations.

The whole process of solving the two problems constitutes the main work of the compilation of combined extragalactic radio source catalogues. Several independent compilation methods have been proposed by different authors (Walter, 1989; Arias *et al.*, 1988; Yatskiv and Kuryanova, 1990). Based on these works, we introduce in this paper a new compilation approach, which includes the selection of primary sources based on arc-length differences and the maintenance of the orientation of frame based on common primary sources of catalogues. The effectiveness

of this compilation method was tested through data analysis and some results are discussed.

2 SELECTING PRIMARY SOURCES BASED ON ARC-LENGTH DIFFERENCES

If there are relative rotations between individual catalogues, then the coordinates of the common sources will be different. If the consistency among coordinates of some sources is relatively high, i.e. regional deformations are very small, the lengths of common arcs connecting the sources should be approximately equal to each other in spite of the existence of relative rotations between frames. If relative deformations exist among coordinates of some sources, these deformations should be reflected to some extent on the length differences of common arcs. Therefore, by comparing the lengths of the common arcs, we can detect local relative deformations between catalogues without the influence of the different orientations, and so we can select the sources with relatively high consistency of coordinates to define the reference frame. We name this method selection of primary sources of the arc-length difference (ALD) selection method. Extensive tests have been conducted on the selection method (Li and Jin, 1995).

3 MAINTAINING THE ORIENTATION OF FRAME BASED ON COMMON PRIMARY SOURCES

In the recommendations of the IAU Reference Frame Working Group, the orientation maintenance of the frame was especially emphasized. It is pointed out that when adjustment (such as deletion, substitution or increase) is performed to a set of radio sources with respect to a reference frame, the orientation of the frame should be assured with no change. Therefore, when we compile a catalogue based on newly available observations, we must align the orientation of this catalogue to its preceding one by a proper maintenance method.

If the orientation of a specified combined catalogue is to be aligned to its preceding one by using all the primary sources, among which some are non-primary sources of the preceding catalogue with relatively low coordinate precision (even with systematic deviation), such alignment should decrease the precision of the orientation. If this alignment is performed based only on Common Primary Sources (CPS), the effect of non-primary sources on the alignment can therefore be avoided. Through this alignment, not only can the common parts of the two catalogues be certainly free from relative rotation, but we can also extend the number of radio sources in the frame by using newly available observations. Tests show that the CPS maintenance method is feasible if the common primary sources are numerous enough (Li *et al.*, 1994).

4 THE COMBINATION CATALOGUES

As an application, six combined catalogues from 1988 to 1993 are compiled based on individual catalogues in Table 1. The compilation process includes the following steps.

Table 1. A description of the definition catalogues (n: number of sources; s: rms formal uncertainties; d: declination interval; R: references)

Year	*Frame*	n	s (*mas*)	$d(°)$	R
1988	RSC(GSFC) 88 R 01	56	0.4–1.7	–30,+80	Arias *et al.*, 1988
	RSC(JPL) 88 R 02	142	1.8–4.2	–45,+85	Arias *et al.*, 1988
1989	RSC(GSFC) 89 R 01	64	0.2–0.8	–30,+81	IERS, 1989
	RSC(JPL) 89 R 02	189	2.5–2.7	–45,+85	IERS, 1989
1990	RSC(GSFC) 90 R 01	70	0.2–3.7	–30,+82	IERS, 1990
	RSC(JPL) 90 R 02	197	0.7–2.6	–45,+85	IERS, 1990
1991	RSC(GSFC) 91 R 04	334	0.2–2.5	–84,+85	IERS, 1991
	RSC(JPL) 91 R 01	241	0.5–1.8	–45,+85	IERS, 1991
1992	RSC(GSFC) 92 R 01	357	0.2–2.1	–82,+85	IERS, 1992
	RSC(JPL) 92 R 01	282	0.3–1.6	–45,+85	IERS, 1992
1993	RSC(GSFC) 93 R 05	449	0.4–3.7	–82,+86	IERS, 1993
	RSC(JPL) 92 R 02	333	0.6–1.8	–45,+85	IERS, 1993

4.1 Determine the Initial Coordinates of Primary Sources in Each Combined Catalogue and the Rotations from Definition Catalogues to the Combined One

Take the individual catalogues of a specified year (in Table 1) as the definition catalogues and select the primary sources by the ALD method. Find the initial coordinates (α_{cj}, δ_{cj}) of the jth primary source in the combined catalogue and the rotations ($A_1(i)$, $A_2(i)$, $A_3(i)$) from the ith definition catalogue to the combined one by using a weighted least squares adjustment from the following equation:

$$\begin{aligned} A_1(i)\cos\alpha_{ij}\tan\delta_{ij} + A_2(i)\sin\alpha_{ij}\tan\delta_{ij} - A_3(i) + \alpha_{cj} &= \alpha_{ij}, \\ -A_1(i)\sin\alpha_{ij} + A_2(i)\cos\alpha_{ij} + \delta_{cj} &= \delta_{ij}, \\ A_k(CSFC) + A_k(JPL) &= 0, \quad k = 1,2,3, \end{aligned} \tag{1}$$

where (α_{ij}, δ_{ij}) are the coordinates of the jth primary source in the ith definition catalogue. The equations are weighted according to formal uncertainties in the individual catalogues. We call α_{cj} and δ_{cj} the initial coordinates because the orientation of the combined catalogue will be adjusted afterwards.

4.2 Densify the Combined Catalogues

After the orientations of the definition catalogues are adjusted with equation (1), each combined catalogue is densified by taking sources common to its definition cat-

alogues which are not in the list of primary sources as the secondary sources, while taking those belonging to only one of its definition catalogues as complementary sources.

4.3 Align the Orientations of Combined Catalogues

The orientation of the 1988 combined catalogue is specified by the initial coordinates of its primary sources and it is taken as the original definition of the frame orientation. The orientation of a specified combined catalogue (1989–1993) is aligned to its preceding one by the CPS maintenance method.

Table 2. A description of the ALD-series combined catalogues

Label	*Primary*		*Secondary*		*Complementary*		$d(°)$
	n	s (*mas*)	n	s (*mas*)	n	s (*mas*)	
RSC(ALD) 88 C 01	20	0.63	17	0.85	124	4.04	−45,+85
RSC(ALD) 89 C 01	37	0.40	11	0.52	157	4.03	−45,+85
RSC(ALD) 90 C 01	40	0.36	13	0.65	163	2.69	−45,+85
RSC(ALD) 91 C 01	94	0.37	85	0.82	217	2.02	−84,+85
RSC(ALD) 92 C 01	116	0.29	101	0.79	205	1.58	−82,+85
RSC(ALD) 93 C 01	139	0.23	141	0.77	222	2.10	−82,+86

These combined catalogues are denoted as ALD-series catalogues, e.g. RSC (ALD) 88 C 01, RSC(ALD) 89 C 01, and so on. They are described in Table 2, where n, s and d mean respectively the number of sources, the rms formal uncertainties and the declination interval. Rotations between every two of these combined catalogues are listed in Table 3, from which it is clear that all the angles are smaller than 0.1 mas. Therefore, the orientation maintenance of the ALD-series combined catalogues is successful.

In addition, since the orientations of every two successive combined catalogues are aligned together by comparing coordinates of the common primary sources, the coordinate differences of these sources must be in a random distribution of zero mean. The standard deviation of this distribution can reflect, to some extent, the maintenance precision of the frame orientation. If the number of sources used to align the catalogues is N, and the number of parameters of orientation is M, then the standard deviation (σ) of the coordinate differences can be calculated as follows:

$$\sigma = (\Sigma(\Delta\delta_i^2 + \Delta\alpha_i^2 \cos^2 \delta_i)/2N/(2N - M))^{1/2} \tag{2}$$

where $\Delta\delta_i$ and $\Delta\alpha_i$ are the coordinate differences of the ith source which is used to align the two catalogues; δ_i is the declination of this source. The deviations about the ALD-series combined catalogues are calculated by equation (2) as follows:

$$\begin{aligned} &\sigma_{89-88} = 0.06 \text{ mas}, \quad \sigma_{90-89} = 0.03 \text{ mas}, \\ &\sigma_{91-90} = 0.03 \text{ mas}, \quad \sigma_{92-91} = 0.01 \text{ mas}, \\ &\sigma_{93-92} = 0.02 \text{ mas}. \end{aligned} \tag{3}$$

Table 3. Relative rotations between every two of the ALD-series combined catalogues (Pair: pair of catalogues compared; N: number of common primary sources). Unit: 1 mas

Pair	N	A_1	A_2	A_3
88–89	19	0.00 ± 0.15	0.00 ± 0.15	0.00 ± 0.09
89–90	30	0.00 ± 0.08	0.00 ± 0.08	0.00 ± 0.06
90–91	38	0.00 ± 0.07	0.00 ± 0.07	0.00 ± 0.05
91–92	79	0.00 ± 0.04	0.00 ± 0.04	0.00 ± 0.04
92–93	87	0.00 ± 0.04	0.00 ± 0.03	0.00 ± 0.03
88–90	18	0.01 ± 0.15	0.08 ± 0.14	0.10 ± 0.10
89–91	30	0.01 ± 0.07	-0.02 ± 0.07	-0.02 ± 0.06
90–92	36	-0.04 ± 0.06	-0.03 ± 0.06	-0.01 ± 0.05
91–93	72	0.03 ± 0.04	-0.03 ± 0.04	-0.01 ± 0.04
88–91	19	0.05 ± 0.14	0.04 ± 0.14	0.09 ± 0.09
89–92	29	-0.03 ± 0.07	-0.04 ± 0.07	-0.04 ± 0.06
90–93	36	0.04 ± 0.06	-0.02 ± 0.06	-0.04 ± 0.05
88–92	18	0.04 ± 0.14	0.08 ± 0.14	-0.03 ± 0.09
89–93	28	0.01 ± 0.07	-0.06 ± 0.07	-0.07 ± 0.06
88–93	18	0.01 ± 0.14	0.01 ± 0.13	0.09 ± 0.09

From these figures it is concluded again that the precision of orientation maintenance of the ALD-series combined catalogues is better than 0.1 mas.

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