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Optical positions of 55 radio stars from astrolabe observations from the Yunnan Observatory

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Abstract. The observations by the photoelectric astrolabe at Yunnan Observatory relative to the Hipparcos Catalogue and the optical positions of 55 radio stars were obtained from observations between 1991 and 2000. They all resulted from processing the photon counts obtained by means of the astrolabe after the automation of the instrument. There are 46 stars in common with the Hipparcos Catalogue*.

Key words. astrometry – radio continuum: stars

1. Introduction

The photoelectric astrolabe of the Yunnan Observatory was installed at the site and put into operation in 1980. The instrument took part in the determination of the Earth Rotation Parameters and joined the Main Campaign of Project MERIT (a program of international collaboration to monitor earth rotation and compare techniques of observation and analysis; Melbourne et al. 1983). Owing to its high observation accuracy the instrument also took part in compiling the General Catalogue of Photoelectric Astrolabes stars (Working group of GCPA 1983) and afterwards in the Chinese Geodetical Stars Catalogue (Working group of CGSC 1991). Upon S. Débarbat's (1986) call for intensive observations of radio stars by optical astrometry, 50 radio stars have been selected and observed since 1986. The instrument was automated and equipped with a photon counting detector in the later eighties. It can be operated automatically to observe stars as faint as magnitude 11.0 (Xu et al. 1993). The objects contained in the astrometric catalogue of radio stars by Walter et al. (1990) have all been included in the program to contribute to the linking of the optical reference frame to the VLBI reference frame based on extragalactic objects (Walter & Sovers 2000). Despite the rainy period lasting nearly half a year in Kunming we succeeded by the end of the year 2000 in deriving the optical positions of 55 radio stars from two transits each between 1991 and 2000. These observations resulted from the data acquired by the photon counting detector after the automation of the instrument.

2. Observation and reduction

The radio stars were inserted in the program of 16 basic groups. Each basic group lasts 1.5 hours and involves 40 stars, among which more than 32 stars are related to the FK5 (All FK5 stars are part of the Hipparcos Catalogue). The parameters, U (clock error), Y (latitude correction) and Z (correction of zenith distance for the instrument) are estimated using the FK5 stars in a basic group in which a radio star is inserted. Then the residual is calculated from the following expression:

$$V = 15 \sin A \cos \varphi_0 (T - T_0 + U) + B_z + Y \cos A - Z \quad (1)$$

(Débarbat & Guinot 1970; Li et al. 1983), where T is the recorded time of transit and T_0 is the calculated time of transit of a star. B_z accounts for the vacuum correction of the instrument tube and the acceleration correction of the instrument during observation. φ_0 is the adopted latitude of the observing site. A is the transit azimuth of a star, reckoning from north to east, in the range of 0° to 360°.

Assuming that V_e and V_w are the mean residuals at east and west transits, respectively, the position corrections of the radio stars in right ascension and declination are determined from double transits by the formulas

$$\Delta\alpha = \frac{V_e - V_w}{30 \cos \varphi_0 |\sin A|} \quad (2)$$

and

$$\Delta\delta = \frac{V_e + V_w - 2K}{2 \cos q}. \quad (3)$$

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* Tables 1 and 2 are also available in electronic form at the CDS via anonymous ftp cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/383/1062

Table 1. 55 radio star positions (Mean epoch of observations; equator and equinox J2000).

Name	RSC	HIC	Mg.	α	m_α	δ	m_δ	N_e	N_w	Epoch −1900
				h m s	s	° ′ ″	″			
UU Psc A	1004	1196	6.02	0 14 58.819	0.001	8 49 15.48	0.02	32	30	96.30
13 Cet		2762	5.20	0 35 14.786	0.002	−3 35 34.00	0.01	22	50	96.51
39 Cet	1010	5951	5.42	1 16 36.303	0.002	−2 30 01.14	0.01	43	31	96.03
HD 8634	1014	6669	6.18	1 25 35.664	0.001			38	25	93.83
o Cet		10826	6.47	2 19 20.795	0.004	−2 58 38.65	0.02	38	37	96.24
92 Cet	1025	14135	2.54	3 02 16.773	0.001	4 05 23.26	0.01	36	35	97.78
β Per	1026	14576	2.09	3 08 10.129	0.001	40 57 20.23	0.02	25	34	93.90
UX Ari	1028	16042	6.47	3 26 35.377	0.001			42	36	95.58
HR 1099 A	1029	16846	5.82	3 36 47.292	0.001	0 35 16.27	0.01	25	38	98.08
HD 22403	2654		8.30	3 37 10.707	0.003			28	22	94.30
HD 30455	1044	22349	6.95	4 48 42.112	0.001	18 42 34.86	0.03	47	41	97.58
α Aur		24608	0.08	5 16 41.335	0.002	45 59 54.05	0.02	43	56	97.06
R Aur			6.50	5 17 17.856	0.014	53 35 09.87	0.05	39	31	94.88
δ Ori A	2113	25930	2.25	5 32 00.395	0.001	−0 17 56.60	0.01	68	50	97.37
ζ OriA		26727	1.74	5 40 45.517	0.002	−1 56 33.24	0.02	38	32	93.91
HD 37806	1061		8.00	5 41 02.296	0.002	−2 43 00.67	0.01	31	25	95.85
54 Ori	2123	27913	4.39	5 54 23.012	0.001			49	42	96.93
π Ori		28404	4.30	5 59 56.092	0.001	45 56 12.25	0.01	38	36	95.82
CQ Aur	2129	26715	9.04	6 03 53.637	0.003			29	32	94.06
RY Gem	2166		8.69	7 27 24.152	0.002	15 39 35.21	0.08	32	40	93.87
σ Gem	1084	37629	4.23	7 43 18.709	0.001			43	33	96.72
RZ Cne	2183		8.67	8 39 08.546	0.002			32	42	93.66
RW UMa	1118		10.30	11 40 46.407	0.002	51 59 53.48	0.02	32	31	93.28
RS CVn	1137	64293	8.07	13 10 36.926	0.001			34	26	94.82
59 Vir	2256	64792	5.19	13 16 46.620	0.001	9 25 26.24	0.01	37	21	95.69
FK Com	1140	65915	8.15	13 30 46.813	0.004			34	32	94.62
BH CVn	1143	66257	4.91	13 34 47.777	0.001			49	33	95.22
ZZ Boo	1147	68064	6.78	13 56 09.550	0.001			30	29	95.78
CU Vir	2270	69389	4.99	14 12 15.820	0.002	2 24 34.14	0.02	32	33	94.97
26 Boo	2608	71115	5.91	14 32 32.578	0.001			45	35	96.05
44 Cen		73695	4.83	15 03 47.589	0.001	47 39 14.43	0.01	28	33	93.67
RW CrB	2298		10.22	15 39 15.243	0.002			27	30	93.35
σ CrB A	1172	79607	5.23	16 14 40.958	0.002			38	30	94.95
U Her		80488	8.31	16 25 47.484	0.001	18 53 33.12	0.03	42	21	93.32
V729 Her	2340	84014	8.08	17 10 25.609	0.004	48 57 56.24	0.04	24	25	93.30
Z Her	1189	87965	7.24	17 58 06.994	0.001	15 08 21.55	0.04	30	28	94.75
59 Ser	2373	90441	5.20	18 27 12.518	0.001	0 11 46.10	0.01	25	38	96.76
β Lyr	1201	92420	3.52	18 50 04.792	0.001			35	30	97.10
HD 178208	2613		7.60	19 05 09.849	0.001	49 55 23.26	0.01	42	27	93.69
HD 179094	1207	94013	5.88	19 08 25.832	0.003	52 25 32.72	0.01	23	39	95.66
U Sge A	2614	94910	6.50	19 18 48.405	0.001			30	42	96.60
χ Cyg		97629	7.91	19 50 33.934	0.004			21	27	93.93
		100013	6.57	20 17 25.181	0.001	39 35 36.61	0.04	33	35	97.55
ρ Cyg		100044	4.77	20 17 47.203	0.001			31	35	96.95
V444 Cyg	2442	100214	7.93	20 19 32.435	0.001	38 43 53.95	0.04	21	30	93.55
V1687 Cyg	1225	100287	6.78	20 20 27.984	0.001	43 51 16.10	0.02	33	34	97.74
ER Vul	2460	103833	7.33	21 02 25.893	0.001			29	39	97.38
HN Peg	2475	107350	5.96	21 44 31.297	0.001	14 46 19.39	0.02	41	40	97.62
RT Lac	1246	108728	8.93	22 01 30.716	0.003	43 53 25.58	0.06	21	23	94.08
IM Peg	1257	112997	5.86	22 53 02.279	0.001	16 50 28.25	0.04	31	45	98.65
RZ And	2615		10.30	23 09 30.043	0.017	53 02 39.98	0.08	29	27	94.83
SZ Psc	1263	114639	7.40	23 13 23.794	0.004	2 40 31.66	0.04	37	31	95.97
λ And	1265	116584	3.81	23 37 33.748	0.001	46 27 31.88	0.02	28	34	93.77
HD 223460	1271	117503	5.86	23 49 40.958	0.001			37	41	95.87
II Peg	1272	117915	7.51	23 55 03.862	0.002			21	42	95.88

Table 2. The external accuracy of the 55 radio star positions.

				HIC-YPA		BORD-YPA		USNO-YPA	
Name	RSC	HIC	Mg.	Da	Db	Da	Db	Da	Db
						(0.01″)			
UU Psc A	1004	1196	6.02	−6	7	−1	6	−3	2
13 Cet		2762	5.20	−3	−12				
39 Cet	1010	5951	5.42	17	7	17	−13	17	9
HD 8634	1014	6669	6.18	−1		2		5	
o Cet		10826	6.47	−7	3				
92 Cet	1025	14135	2.54	1	−3	7	−5		
β Per	1026	14576	2.09	2	10	−6	9		
UX Ari	1028	16042	6.47	−3		−11		−10	
HR 1099 A	1029	16846	5.82	3	−3	6	−8	4	2
HD 22403	2654		8.30	2		20			
HD 30455	1044	22349	6.95	−8	1	−9	−4	−2	−1
α Aur		24608	0.08	4	−2				
R Aur			6.50	−5	4				
δ Ori A	2113	25930	2.25	8	−12	3	−17		
ζ OriA		26727	1.74	13	−3				
HD 37806	1061		8.00	−13	−8	4	−19	−5	1
54 Ori	2123	27913	4.39	7		15		−2	
π Ori		28404	4.30	11	2	8	−11	4	1
CQ Aur	2129	26715	9.04	19		17		18	
RY Gem	2166		8.69	−2	−21				
σ Gem	1084	37629	4.23	4		−1		−4	
RZ Cne	2183		8.67	10		−1		0	
RW UMa	1118		10.30	5	−15	−17	−14	−13	6
RS CVn	1137	64293	8.07	4		4		12	
59 Vir	2256	64792	5.19	−9	−9	−4	−20	−6	−14
FK Com	1140	65915	8.15	17		23		16	
BH CVn	1143	66257	4.91	−4		−7		−3	
						(0.01″)			
ZZ Boo	1147	68064	6.78	−2		1		9	
CU Vir	2270	69389	4.99	−1	−4	5	−11	5	−7
26 Boo	2608	71115	5.91			1		9	
44 Cen		73695	4.83	−18	6				
RW CrB	2298		10.22	19		−1		−17	
σ CrB A	1172	79607	5.23	5		3		−14	
U Her		80488	8.31	−7	−19	7	−22	−13	−18
V729 Her	2340	84014	8.08	−14	19	−17	13	−11	10
Z Her	1189	87965	7.24	−7	−3	−3	−7	−10	3
59 Ser	2373	90441	5.20	14	8	13	−7		
β Lyr	1201	92420	3.52	4		4			
HD 178208	2613		7.60	15	4	−12	13	−3	4
HD 179094	1207	94013	5.88	6	15	8	11	0	21
U Sge A	2614	94910	6.50	4		6		7	
χ Cyg		97629	7.91	−1		11		−10	
		100013	6.57	−6	13	−14	22		
ρ Cyg		100044	4.77			−1			
V444 Cyg	2442	100214	7.93	−17	3	−14	6		
V1687 Cyg	1225	100287	6.78	−10	18	−8	17	−2	17
ER Vul	2460	103833	7.33	−4		0		0	
HN Peg	2475	107350	5.96	−6	−14	−5	−17	1	−27
RT Lac	1246	108728	8.93	−10	−6	−4	−7		

Table 2. continued.

				HIC-YPA		BORD-YPA		USNO-YPA	
Name	RSC	HIC	Mg.	Da	Db	Da	Db	Da	Db
IM Peg	1257	112997	5.86	−16	8	−7	12	−12	8
RZ And	2615		10.30	−3	−6	−9	−13	−8	−18
SZ Psc	1263	114639	7.40	−19	−18	−12	−18	−19	−16
λ And	1265	116584	3.81	−1	9	6	−4		
HD 223460	1271	117503	5.86	3		5			
II Peg	1272	117915	7.51	16		23		16	
Error	budget,	unit	0.001″:						
Mean	difference			−4	8	11	−40	−12	−9
Standard	deviation of	the mean	difference	14	19	15	25	17	29
Standard	deviation	of the	difference	95	103	101	128	99	127

Here q denotes the parallactic angle. We used the stars with $|\cos q| < 0.3$ to calculate $2K$ from the following expression

$$2K = \frac{\sum P_i (V_\mathrm{e} + V_\mathrm{w})_i}{\sum P_i} \tag{4}$$

$$P_i = -\frac{0.1}{m_\mathrm{e}^2 + m_\mathrm{w}^2} \tag{5}$$

where m_e and m_w are mean errors of V_e and V_w, respectively. In this catalogue there are 36 stars, from which one obtains $2K = 0.0045$. Since for $|\cos q| < 0.3$ the declinations are obtained by the astrolabe with a rather low precision, they are not given in the catalogue.

Since the Hipparcos Catalogue is the primary realization of the ICRS at optical wavelengths (IAU, 1998), the stellar data of the basic groups have all been adopted from the Hipparcos Catalogue and all the observations have been rereduced since 1986.

3. Results

The optical positions of the 55 radio stars are presented in Table 1. The mean number of observations of each star is about 33. The mean precisions are $\pm 0^{\mathrm{s}}.0021$ and $\pm 0''.026$, respectively. The mean epoch of observations is 1995.52.

To test the external accuracy of the positions given in Table 1 and denoted YPA we made the following three comparisons:

a) HIC-YPA. The difference between the positions of the Hipparcos Catalogue and YPA for the stars in Table 1.

b) BORD-YPA. The positions of stars determined by the Bordeaux meridian circle minus YPA. The Bordeaux results are quoted from the report of Requième & Mazurier (1991).

c) USNO-YPA. The positions of stars determined by the Flagstaff Astrometric Scanning Transit Telescope of the US Naval Observatory (Stone 1997) minus YPA.

For the comparisons, the positions of stars were reduced to the same epoch by means of the proper motions taken from the Hipparcos Catalogue or from Walter et al. (1990, 1997) before computing differences. The differences are given in Table 2. We also made a statistical analysis of the differences and the results are given in last four rows of Table 2. It can be seen that these quantities all are very small. Therefore YPA's external accuracy is very good.

4. Explanation of Tables 1 and 2

Table 1:

Column 1: name of star.

Column 2: the RSC denotes the number in the astrometric catalogue of radio stars.

Column 3: the number in the Hipparcos Catalogue.

Column 4: observed mean visual magnitude.

Columns 5 and 7: right ascension and declination for equator and equinox J2000.0 and epoch of observation.

Columns 6 and 8: mean errors of right ascension and declination.

Columns 9 and 10: the number of the observed transits in east and west, respectively.

Column 11: mean epoch of observations minus 1900.00.

Table 2:

Column 1: name of star.

Column 2: the RSC denotes the number in the astrometric catalogue of radio stars.

Column 3: the number in the Hipparcos Catalogue.

Column 4: observed mean visual magnitude.

Columns 5 and 6: the differences HIC-YPA in right ascension and declination, respectively. Definition of Da: $\mathrm{Da} = [\alpha(\mathrm{HIC}) - \alpha(\mathrm{YPA})]\cos\delta$. The unit of Da and Db is 0.01″.

Columns 7 and 8: the differences BORD-YPA in right ascension and declination, respectively. The unit of Da and Db is 0.01″.

Columns 9 and 10: the differences USNO-YPA in right ascension and declination, respectively. The unit of Da and Db is 0.01″.

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