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# The photoelectric astrolabe catalogue of Yunnan Observatory (YPAC)*

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**Abstract.** — The positions of 53 FK5, 70 FK5 Extension and 486 GC stars are given for the equator and equinox J2000.0 and for the mean observation epoch of each star. They are determined with the photoelectric astrolabe of Yunnan Observatory. The internal mean errors in right ascension and declination are $\pm0.''046$ and $\pm0.''059$, respectively. The mean observation epoch is 1989.51.

**Key words:** astrometry, catalogue

## 1. Introduction

The photoelectric astrolabe of Yunnan observatory was installed in 1975 and put into operation since the end of 1975. It was moved to the formal site in 1980, and took part in the determination of the Earth Rotation Parameters and joined the Main Campaign of Project MERIT (Melbourne et al. 1983). It also took part first in GCPA (The General Catalogue of Stars with System of Photoelectric Astrolabes in China) (Working group of GCPA 1983) and afterwards in CGSC (The Chinese Geodetical Stars Catalogue) (Working group of CGSC 1991) due to its high accuracy observations. Since 1986 it began to observe the radio stars selected from the list for the link of optical reference frames and the VLBI reference frame based on extragalactic objects (Walter et al. 1990).

The YPAC is compiled with the data observed from 1987 to 1992. It includes all observed stars with two transits except radio stars during the period. Their magnitudes are from 0.06 to 7.0 and the declination range is from $-3°45'$ to $53°24'$. The mean observation epoch is 1989.51. The internal mean errors in right ascension and declination are $\pm0.^{s}0031$ and $\pm0.''059$, respectively.

## 2. Observation schedule

For determining a lot of star positions of non-Fifth Fundamental Catalogue we used the fundamental and catalogue groups which consist of FK5 stars and non-FK5 stars, respectively, and each group lasts 1.5 hours. The two kinds of group were alternately observed, the fundamental groups were observed both before and after a catalogue group each night. The parameters, $U$ (clock error), $Y$ (latitude correction) and $Z$ (the correction of zenith distance for the instrument) are solved from two fundamental groups, respectively, then the residuals of the stars of the catalogue group are calculated from the mean values of the two group parameters.

## 3. The reduction procedure

The basic equation of the astrolabe catalog is given as (Guinot 1955; Débarbat & Guinot 1970; see also Li Dongming et al. 1983):

$$\begin{aligned} &-15\,\cos\phi_0\,\sin A\Delta\alpha+\cos q\Delta\delta \\ &=-\bar{V}-15\,\cos\phi_0\,\sin A\xi+\cos A\eta+\zeta \end{aligned} \qquad (1)$$

Here $\phi_0$ is the adopted value of latitude at the observing site. A is the transit azimuth of a star, reckoning from north to east, in the range of 0° to 360°. $\Delta\alpha$ and $\Delta\delta$ are star position corrections of the working catalog relative to the ideal catalog; $\bar{V}$ is the mean residual; $\xi$, $\eta$ and $\zeta$ are unknown constants related to the working catalog, observing site and the selected fundamental stars.

Applying Eq. (1) to the stars with two transits, and denoting mean residuals at east and west transits by $\bar{V}_{\rm e}$ and $\bar{V}_{\rm w}$, respectively, we can obtain the following formulae for computing star position corrections (Débarbat & Guinot 1970):

$$\Delta\alpha=\frac{\bar{V}_{\rm e}-\bar{V}_{\rm w}}{30\,|\sin A|\,\cos\phi_0}+\xi \qquad (2)$$

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*Table 1 is only available in electronic form at the CDS via anonymous ftp 130.79.128.5

**Table 2.** The group Corrections of $t$, $\phi$, d$z$

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $t$ (0.1ms) | −5 | 22 | 15 | 35 | 6 | 10 | −4 | −13 | −5 | −48 | −22 | −2 | −12 | −10 | 19 | 12 |
| $\phi$ (″.001) | 1 | 13 | 4 | −8 | 51 | 22 | 14 | −59 | 29 | 28 | −68 | −94 | 14 | 57 | −39 | 34 |
| d$z$ (″.001) | −64 | −58 | −22 | −18 | −1 | 8 | 14 | 51 | 23 | 1 | 4 | 42 | −25 | 19 | 30 | −5 |

**Table 3.** The group differences with their closing errors of $\Delta t$, $\Delta\phi$ and $\Delta$d$z$

| Group | $\Delta t$ | $\sigma_{\Delta t}$ | $N$ | $\Delta\phi$ | $\sigma_{\Delta\phi}$ | $N$ | $\Delta$d$z$ | $\sigma_{\Delta dz}$ | $N$ |
|---|---|---|---|---|---|---|---|---|---|
| 01.5−00.0 | 0.0029 | 0.0009 | 39 | 0.012 | 0.002 | 55 | 0.002 | 0.010 | 37 |
| 03.0−01.5 | −0.0005 | 0.0012 | 22 | −0.010 | 0.006 | 61 | 0.031 | 0.005 | 22 |
| 04.5−03.0 | 0.0022 | 0.0018 | 18 | −0.013 | 0.002 | 29 | −0.000 | 0.010 | 29 |
| 06.0−04.5 | −0.0028 | 0.0011 | 15 | 0.059 | 0.006 | 66 | 0.012 | 0.006 | 81 |
| 07.5−06.0 | 0.0007 | 0.0007 | 60 | −0.030 | 0.004 | 55 | 0.005 | 0.007 | 70 |
| 09.0−07.5 | −0.0013 | 0.0010 | 36 | −0.008 | 0.008 | 36 | 0.002 | 0.001 | 36 |
| 10.5−09.0 | −0.0006 | 0.0014 | 30 | −0.074 | 0.001 | 33 | 0.032 | 0.005 | 24 |
| 12.0−10.5 | 0.0010 | 0.0012 | 45 | 0.088 | 0.008 | 36 | −0.032 | 0.003 | 36 |
| 13.5−12.0 | −0.0041 | 0.0009 | 46 | −0.002 | 0.009 | 42 | −0.026 | 0.004 | 47 |
| 15.0−13.5 | 0.0029 | 0.0010 | 53 | −0.097 | 0.008 | 53 | −0.002 | 0.001 | 53 |
| 16.5−15.0 | 0.0022 | 0.0015 | 26 | −0.026 | 0.008 | 26 | 0.034 | 0.010 | 16 |
| 18.0−16.5 | −0.0008 | 0.0002 | 20 | 0.107 | 0.005 | 20 | −0.071 | 0.004 | 20 |
| 19.5−18.0 | 0.0004 | 0.0002 | 25 | 0.043 | 0.003 | 25 | 0.039 | 0.006 | 25 |
| 21.0−19.5 | 0.0030 | 0.0011 | 28 | −0.096 | 0.006 | 28 | 0.007 | 0.003 | 28 |
| 22.5−21.0 | −0.0005 | 0.0007 | 34 | 0.072 | 0.013 | 34 | −0.039 | 0.010 | 34 |
| 00.0−22.5 | −0.0014 | 0.0010 | 37 | −0.034 | 0.009 | 37 | −0.064 | 0.006 | 24 |
| $\sum$ | 0ˢ.0033±0ˢ.0021 | | | −0″.009±0″.061 | | | −0″.070±0″.034 | | |

$$\Delta\delta = \frac{\bar{V}_{\mathrm{e}} + \bar{V}_{\mathrm{w}}}{-2\cos q} - \frac{\eta\cos A - \zeta}{\cos q} \tag{3}$$

In Eq. (3) $q$ denotes the parallactic angle. When $\cos q = 0$ the following relation between $\eta$ and $\zeta$ can be obtained from (3) (Noël 1994):

$$\zeta = \eta\cos A_0 + \left(\bar{V}_{0\mathrm{e}} + \bar{V}_{0\mathrm{w}}\right)/2 \tag{4}$$

where $A_0$ is the azimuth for those stars for which $\cos q = 0$ and $\bar{V}_{0\mathrm{e}}$ and $\bar{V}_{0\mathrm{w}}$ are their east and west mean residuals respectively.

Let $2k = \bar{V}_{0\mathrm{e}} + \bar{V}_{0\mathrm{w}}$ and replacing $\zeta$ according to (4) in (3) one has:

$$\Delta\delta = \frac{\bar{V}_{\mathrm{e}} + \bar{V}_{\mathrm{w}} - 2k}{-2\cos q} - \frac{\eta\left(\cos A - \cos A_0\right)}{\cos q} \tag{5}$$

The calculation of $2k$, strictly speaking, should be made using the stars of $\cos q = 0$, that is $q = 90°$. But these stars are very few. So we adopted the stars of FK5 of $|\cos q| < 0.3$ to calculate $2k$ (in this catalogue there are 36 stars). Its calculation formulae is

$$2k = \sum_i^n P_i\left(\bar{V}_{\mathrm{e}} + \bar{V}_{\mathrm{w}}\right)_i / \sum P_i \tag{6}$$

$$P = -\frac{0.1}{m_{\mathrm{e}}^2 + m_{\mathrm{w}}^2} \tag{7}$$

where $m_{\mathrm{e}}$ and $m_{\mathrm{w}}$ are mean errors of $\bar{V}_{\mathrm{e}}$ and $\bar{V}_{\mathrm{w}}$, respectively, thereby $2k = 0''.0254$. Since in the range of $|\cos q| < 0.3$ the declinations are obtained with a rather low precision with the astrolabe, they are not given in the catalogue.

The second terms in the right-hand side of Eqs. (2) and (5) were ignored in our calculation, which implies that the given positions of the stars are to the equator and equinox in FK5 system.

In Eq. (1) the mean residual values are reduced to the standard groups, applying group corrections in time, latitude and zenith distance. These group corrections were obtained by the chain method from their group differences observed from 1981 to 1986. The group corrections used in this catalogue are given in Table 2. The group differences with their closing errors are given in Table 3. The photoelectric astrolabe catalogue of Yunnan Observatory (YPAC) is given in Table 1.

## 4. Precision estimate

For testing external accuracy of YPAC we calculate the difference between the positions of YPAC and FK5 or CMC (Carlsberg Meridian Catalogue) for each star. Since some stars in YPAC are FK5 and CMC stars, the external accuracy can only be calculated from these stars. The results are also given in Table 1. The mean, standard error of mean, standard deviation of the results are $-0\overset{s}{.}001$, $0\overset{s}{.}001$, $0\overset{s}{.}013$ for right ascension and $-0''05$, $0''02$, $0''26$ for declination, respectively.

## 5. Explanation of the Catalogue

The resulting J2000 positions of the astrolabe catalogue are presented in Table 1.

*Column 1*: the number in YPAC.

*Column 2*: the catalogue's name: FK5-Fifth Fundamental Catalogue; EXT-FK5 Extension; GC–Boss General Catalogue.

*Column 3*: the number in above catalogues.

*Column 4*: the visual magnitude from above catalogue.

*Columns 5 and 6*: the right ascension and declination, respectively, for equator and equinox J2000.0 and mean epoch of observation of the star.

*Columns 7 and 8*: the internal precision of $\alpha$ and $\delta$. Its units are, respectively, $0\overset{s}{.}001$ and $0\overset{''}{.}01$.

*Column 9*: the mean epoch of observations minus 1900.00.

*Columns 10 and 11*: differences YPAC-FK5 or YPAC-CMC in right ascension and declination, respectively. Their units are, respectively, in $0\overset{s}{.}001$ and $0\overset{''}{.}01$.

*Column 12*: the number of FK5 or CMC, larger than 10000 is that of the CMC. These stars are used to calculate the external accuracy of YPAC.

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