ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

JULY **1997**, PAGE 153

*Astron. Astrophys. Suppl. Ser.* **124,** 153-155 (1997)

# Systematic differences Astrolabe-FK5 derived from observations at 60° zenith distance

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Received October 23; accepted November 18, 1996

**Abstract.** After instrumental modifications, series of FK5 stars were observed at 60° zenith distance with the astrolabe of Santiago, Chile, during the period 1990-1994. The mean residuals in zenith distance for each star were obtained with an average mean error of $\pm 0.077''$. Analyzing the zenith distance residuals according to the star azimuths, systematic differences Astrolabe-FK5 (J1991.9) in alpha and delta as a function of delta are derived for the zone between $-70°$ and $+20°$ in declination. The average mean errors are $\varepsilon_{\Delta\alpha\cos\delta} = \pm 0.003$ s and $\varepsilon_{\Delta\delta} = \pm 0.05''$ for the systematic differences in right ascension and in declination respectively. A comparison of the astrolabe results with similar ones obtained with an automatic meridian circle, is discussed.

**Key words:** astrometry — reference systems

## 1. Introduction

The Danjon astrolabe at Santiago, Chile, was modified in 1989 by Chollet & Noël (1993) (Noël & Chollet 1990). The classical transparent prism was replaced by two CERVIT reflecting prisms which now permit observations at 30° and 60° zenith distances. Both prisms can be interchanged in a few minutes without further adjustment of the optical system. The modifications introduced in the astrolabe permit also observations of the Sun. For solar observations a filter made of transparent CERVIT with a chrome-nickel layer of density close to 5, is installed in front of the objective. A program of astrometric observations of the Sun at 30° and 60° zenith distances is in progress since 1990 (Chollet & Noël 1993; Noël 1993, 1994, 1995).

A narrow observing zone of less than 60° wide in declination, and spurious variations of the instrumental zenith distance due to thermal deformations of the transparent prism, were some of the drawbacks of the classic Danjon astrolabe. Both drawbacks have been diminished with the modifications introduced in the astrolabe of Santiago. A zone of about 115° wide in declination can now be observed at 60° zenit distance, and the rather low thermal coefficient of CERVIT provide a more stable instrumental reference. On the other hand, some disturbing effects inherent to astrolabes with transparent prism, do not exist in an astrolabe with reflecting prisms (Kovalevski 1990).

Series of fundamental stars were observed at 60° between 1990 and 1994 in order to obtain the instantaneous local latitude and UT0 for the reduction of the solar observations in the FK5 system. As a test of the results obtained at 60° zenith distance with the modified astrolabe and as a contribution to the research of the Fundamental Reference System, we present here an evaluation of systematic differences in the sense Astrolabe-FK5. These differences are compared with similar ones obtained with the photoelectric meridian circle of the U.S. Naval Observatory at Black Bierch, New Zealand (Corbin 1991).

## 2. Observations and reductions

According to the latitude of the astrolabe ($-33.4°$), a zone comprised between $-86°$ and $+24°$ in declination can be observed at 60° zenith distance from Santiago. A zone around the southern celestial pole of about 4° wide in declination is not observable since in this zone the small declination circles of the stars do not intercept the 60° almucantar. The observational program at 60° zenith distance consists of eleven groups of 28 stars each one. The star distribution in azimuth in each group is as uniform as possible. The eleven groups comprise 166 FK5 and 103 FK5 Extension stars. Of these 269 stars, 39 are observed in double transit. The observations were reduced following the IAU76/82 resolutions on fundamental constant and apparent places computation (Kaplan 1981; Chollet 1984). At 60° zenith distance the stars images as observed with the astrolabe, show permanently a rather strong agitation due to atmospheric effects. The effect of the image agitation on the results is clearly reflected in the precision of the mean zenith distance residuals of the stars. They were obtained with an average mean error of $\pm 0.077''$, which

**Table 1.** Systematic differences in right ascension and declination as a function of declination: Astrolabe-FK5, J1991.9

| NN | $\delta(°)$ | Right ascension(s) | | Declination($''$) | | $^*e$ | $^*w$ | NN |
|---|---|---|---|---|---|---|---|---|
| 01 | +20.1 | +0.003 | ± 0.0033 | −0.10 | ± 0.024 | 32 | 27 | 01 |
| 02 | +15.6 | +0.002 | 0.0026 | −0.02 | 0.026 | 36 | 35 | 02 |
| 03 | +06.4 | −0.002 | 0.0024 | +0.09 | 0.036 | 23 | 29 | 03 |
| 04 | −02.0 | −0.003 | 0.0025 | +0.15 | 0.047 | 24 | 24 | 04 |
| 05 | −10.1 | 0.000 | 0.0024 | +0.17 | 0.055 | 29 | 21 | 05 |
| 06 | −17.9 | +0.004 | 0.0019 | +0.12 | 0.049 | 27 | 21 | 06 |
| 07 | −26.0 | +0.003 | 0.0020 | 0.00 | 0.057 | 21 | 21 | 07 |
| 08 | −33.7 | +0.002 | 0.0028 | −0.07 | 0.086 | 20 | 20 | 08 |
| 09 | −41.9 | −0.001 | 0.0031 | +0.01 | 0.097 | 18 | 21 | 09 |
| 10 | −51.2 | −0.003 | 0.0032 | — | — | 20 | 23 | 10 |
| 11 | −60.6 | +0.002 | 0.0036 | — | — | 23 | 25 | 11 |
| 12 | −70.0 | +0.005 | 0.0062 | — | — | 20 | 23 | 12 |

is more or less twice the average mean error obtained at Santiago from observations at 30° zenith distance (Noël & Débarbat 1990).

### 3. Systematic differences astrolabe-FK5

The systematic differences Astrolabe-FK5 of type $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ are derived from an analysis of the zenith distance residuals according to the star azimuth. The stars are separated into azimuth intervals which correspond to zones of 17 degrees wide in declination with an overlap of 8.5 degrees approximately. For the stars in each interval, the average mean zenith distance residual R.M. and the mean declination $\delta$ are computed. If A is the mean azimuth of the stars in the interval, R.M.(E) and R.M.(W), the mean residuals for azimuth intervals at the east and west respectively, and if $\Phi$ is the adopted latitude of the astrolabe, it can be shown (Guinot 1955; Noël & Débarbat 1990) that for each pair of azimuth intervals (east and west) one has:

$$\Delta\alpha_\delta \quad (\text{Astrolabe} - \text{FK5}) = \frac{\text{R.M.(E)} - \text{R.M.(W)}}{30 \sin A \cos \Phi}, \quad (1)$$

$$\Delta\delta_\delta \quad (\text{Astrolabe} - \text{FK5}) = \frac{\text{R.M.(E)} + \text{R.M.(W)}}{2 \cos S}, \quad (2)$$

where $A$ and $S$ are the averages of the azimuth and paralactic angle respectively of the stars in the azimuth intervals. The results obtained with expressions (1) and (2) are given in Table 1, and in Fig. 1 they are plotted with similar results obtained with the automatic meridian circle of the U.S. Naval Observatory Station at Black Bierch, New Zealand (Corbin 1991). In Table 1, $\delta$ is the mean declination of the stars comprised in each declination zone designated by NN, and $^*e$ and $^*w$ are the number of stars at the corresponding east and west azimuth intervals respectively, involved in the computation of the systematic differences Astrolabe-FK5. According to the principles of the method of equal altitudes (Débarbat & Guinot 1970), systematic differences in declination are given only for those zones where the absolute value of the cosine of the paralactic angle is greater than 0.3. The systematic differences in right ascension as well as their mean errors given in Table 1 and Fig. 1 are multiplied by $\cos\delta$.

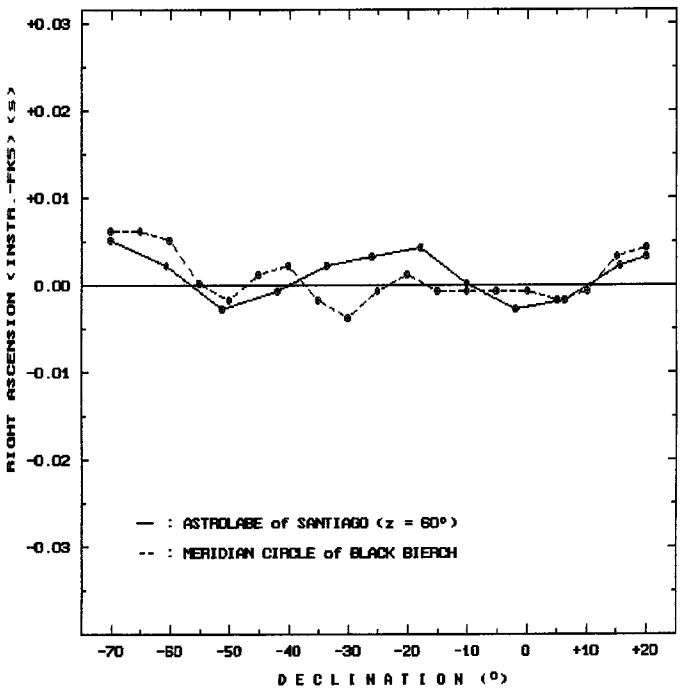


**Fig. 1.** Systematic differences in right ascension as a function of declination: Instrument-FK5

## 4. Conclusions

The differences in right ascension plotted in Fig. 1 as a function of declination show a clear agreement between the astrolabe results obtained at 60° zenith distance at Santiago and those obtained at Black Bierch, New Zealand, with the automatic meridian circle of the U.S. Naval Observatory (Corbin 1991). Since it is rather improbable that both instrumental systems defined by quite different astrometric techniques could be affected by similar systematic errors, one can conclude that the shapes of the curves in Fig. 1 are not due to instrumental artifacts, but they are representing a systematic error in right ascension of FK5 which varies as a function of declination.

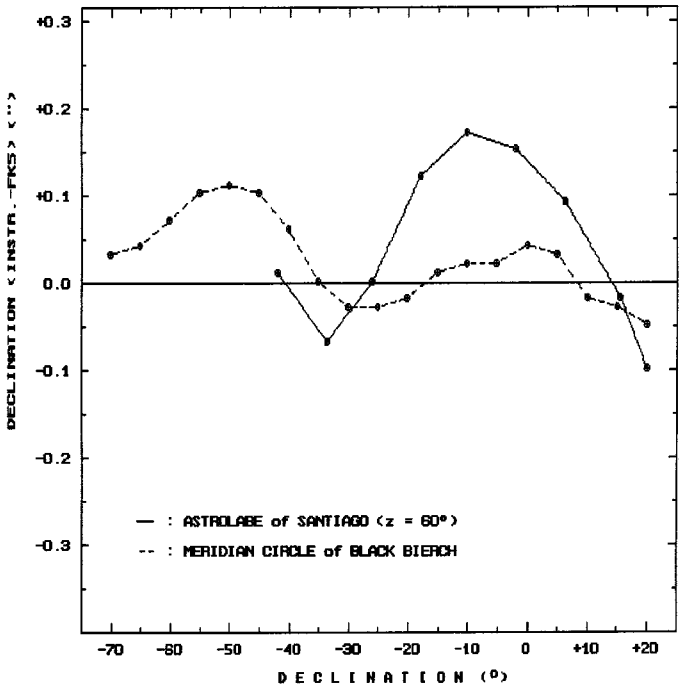


**Fig. 2.** Systematic differences in declination as a function of declination: Instrument-FK5

With respect to the systematic differences in declination which are given in Table 1 and are plotted in Fig. 2, the astrolabe and meridian observations show a similar general trend; however, it is exagerated in the astrolabe results. We think that the declination results of the astrolabe could be strongly affected by spurious effects of refraction which are quite prevalent at large zenith distance as in this case. If these effects are introducing distortions of the star zenith distance residuals which are similar at the east and west observations, then, according to Eqs. (1) and (2) they will be canceled when computing the right ascension results, but they should have a strong effect in the results in declination, as it is apparent if one compares the results given in Figs. 1 and 2.

To conclude, one can say that according to the results presented in this paper and in spite of a rather large zenith distance of observation, the astrolabe is still a reliable instrument to disclose systematic errors in right ascension of star catalogues which vary as a function of declination. However, the results obtained to research systematic errors in declination should be considered more cautiously.

*Acknowledgements.* This work was partially financed by Fondo Nacional de Ciencia y Tecnología (FONDECYT), Santiago, Chile, under research project 1940414. The program of the astrolabe at Santiago is a joint collaboration research project in astrometry at the southern hemisphere between the European Southern Observatory (ESO) and Universidad de Chile.

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