THE CONTRIBUTION OF THE DANJON ASTROLABE TO THE IMPROVEMENT OF THE FUNDAMENTAL REFERENCE SYSTEM AT THE SOUTHERN HEMISPHERE

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ABSTRACT. An historic review is made of the observation programs with Danjon astrolabes which were carried out or are in progress at the southern hemisphere. The consistency of their results in the research of systematic errors of the FK4 Fundamental System, largely confirmed by other observation techniques, is shown. The Cape and Santiago astrolabe catalogues, the largest ones derived so far for southern stars, are briefly reviewed.

Introduction

During the fiftieth it was shown that in spite of some limitations, the Danjon astrolabe is a reliable instrument to determine relative star positions with high accuracy and specially to disclose systematic errors of star catalogues (Guinot 1955, 1958; Guinot et al. 1961).

In this context it was clear that astrolabe observation programs of fundamental stars at the southern hemisphere should be of the greatest interest for the research of the FK4 introduced in 1963. Considering that south of -30° the fundamental system was principally defined by the Cape transit circle (Fricke and Kopff, 1963), any systematic error of this instrument must have strongly influenced the southern part of the FK4 (Eichhorn 1974).

In 1973 G. Billaud and S. Débarbat (1974) discussed the potentialities of the astrolabe observations at the southern hemisphere for improving the fundamental reference system. At that time several programs of astrolabe observations were in progress at the southern hemisphere. Furthermore, a demonstration of the existence of the now well known systematic error of type $\Delta\alpha_\delta$ of the FK4 had been published four years before. This demonstration was based, as we shall see, on the results obtained from meridian and astrolabe observations (Anguita and Noël 1969).

S. Débarbat et al. (eds.), Mapping the Sky, 359–367.

Astrolabe Observations at the Southern Hemisphere

As far as we know, it seems that the first astrolabe observations at the southern hemisphere were those of the astrolabe program of Tananarive, Madagascar, started in 1957. This program was in progress in 1958 during the International Geophysical Year, and lasted until January, 1959 (Lefebvre and Guinot 1966).

With the U.S. National Science Foundation and UNESCO supports and the scientific assistance of the Paris Observatory, the Escuela Politécnica Nacional commenced during 1963 a program of astrolabe observations at the Astronomical Observatory of Quito, Ecuador (Sheepmaker 1967).

In 1964 the Danjon astrolabe of the Royal Greenwich Observatory at Herstmonceux was transfered to the (then) Royal Observatory of Cape of Good Hope. The observations commenced in 1965 (Thomas and Morrison 1982).

Under an agreement between Universidad de Chile at Santiago and the European Southern Observatory (ESO) for a joint research project in astrometry at the southern hemisphere, a Danjon astrolabe was installed at the National Astronomical Observatory of Cerro Calán, Santiago. Regular observations begun in November 1965 with the assistance of the Paris Observatory (Noël 1968).

During 1965 the Instituto Astronômico e Geofísico of Sao Paulo, Brazil, initiated a program of astrolabe observations (Clauzet 1976). On the other hand, in 1968 a Danjon astrolabe was installed by the National University of Cuyo at "Félix Aguilar" Astronomical Observatory at San Juan, Argentina. The observations commenced during July of that year (Manrique et al. 1976).

In the following years astrolabe programs were started at San Martin, Argentina, and at Rio de Janeiro, Brazil. During 1983 a Danjon astrolabe of the Royal Greenwich Observatory, kindly lent to the National Astronomical Observatory of Rio de Janeiro, was installed at Natal, Brazil, by the Universidad Federal do Rio Grande do Norte. Regular observations commenced during 1984 (Takagi and Da Silva 1986).

We would like to mention specially the Danjon astrolabe of Rio Grande at the Argentinean "Fireland", which was put into operation in March 1979 (Mondinalli et al. 1985). We hope that in spite of the difficulties of many kinds of those regions, this station may keep a regular observations program. Considering its high southern latitude ($-53\overset{\circ}{.}8$), the results of the program should be of particular interest for the research of the fundamental system close to the southern polar cap.

Disclosing Systematic Errors of the FK4.

It seems that the first preliminary evidence of systematic errors of $\Delta\alpha_\delta$ type in the FK4 arose from the results of the observations made with a Repsold meridian circle and a transit instrument at Santiago (Anguita et al. 1963). The first results of the Santiago astrolabe, which could be used for a similar evaluation, were available only in 1967 (Noël 1968). They show a fairly similar effect in the FK4 as that shown by the meridian observations. This coincidence demonstrated at least that the observed effect could not be atributed to the instrumental systems. However, the results were still controversial, since one could assume that a local refractional effect could account for the distortion observed on the right ascensions of the FK4 south of -35° (Stock 1967).

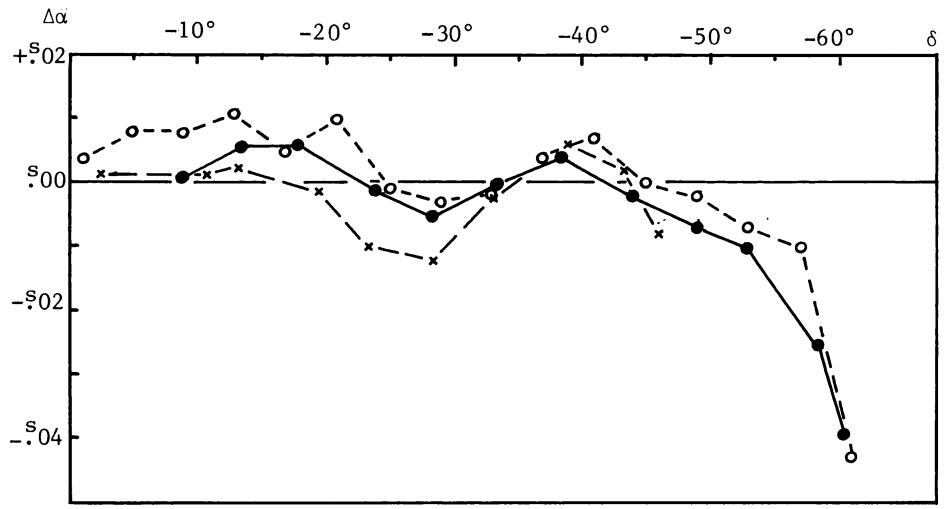

Figure 1. The first evidences of the $\Delta\alpha_\delta$ systematic error of FK4 obtained from astrolabe observations at Santiago (-●-) and Tananarive (-x-), and from meridian observations at Santiago (-o-).

Fortunately at that time the results of the astrolabe of Tananarive had been recently published including the individual corrections (Astr.-FK4) for 113 fundamental stars (Lefebvre and Guinot 1966). Using these corrections a curve was obtained for $\Delta\alpha_\delta$ which at the common zone was quite similar to the results of Santiago, as we can see in figure 1 (Anguita and Noël 1969). We think that these results, based on observations made at different places and with different techniques, may be considered as the first definitive demonstration of the existence of the now well known error of the FK4 south of -35° (Fricke 1972).

The curves of Santiago in figure 1 have been derived from the

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meridian catalogues SPF1, SPF2 and SP2 (Anguita 1974), and from the first astrolabe catalogue of Santiago (Noël et al. 1974). The curve for Tananarive was obtained by a slightly different smoothing of the data. This is the reason why they look somewhat different as the curves in the paper of Anguita and Noël (1969), which were based on the data available at that time.

Later on, these results had been largely confirmed by the other southern astrolabes as we can see in figure 2, where we present also the curves obtained for the systematic differences Astrolabe-FK4 of type $\Delta\delta_\delta$.

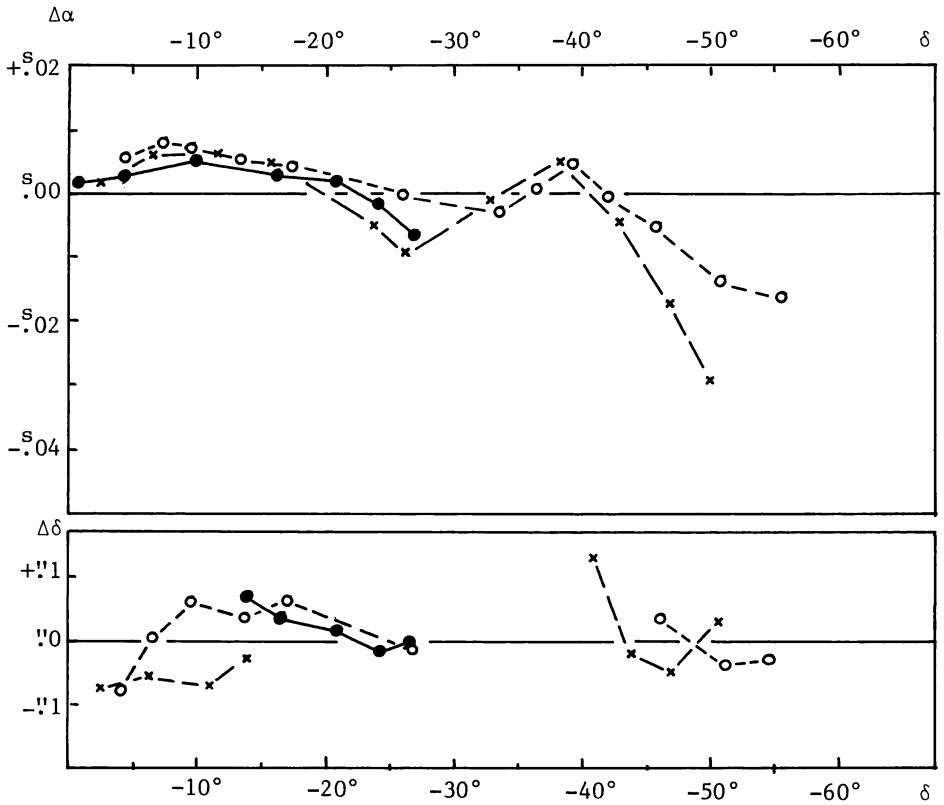

Figure 2. Systematic differences $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ Astrolabe-FK4 for Quito (-●-), San Juan (-o-) and Sao Paulo (-x-).

Southern Astrolabe Star Catalogues

In 1978 G. Billaud and his associates published the General Astrolabe Catalogue (Billaud et al 1978), which is one of the catalogues

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used in the compilation of the FK5 (Schwan 1986). Five southern astrolabe catalogues are included in the general catalogue of Billaud: Quito (Sheepmaker 1967), Tananarive (Lefebvre and Guinot 1966), Sao Paulo (Clauzet 1976), San Juan (Manrique 1976), Santiago (Noël et al. 1974) and Cape (Thomas and Morrison 1982).

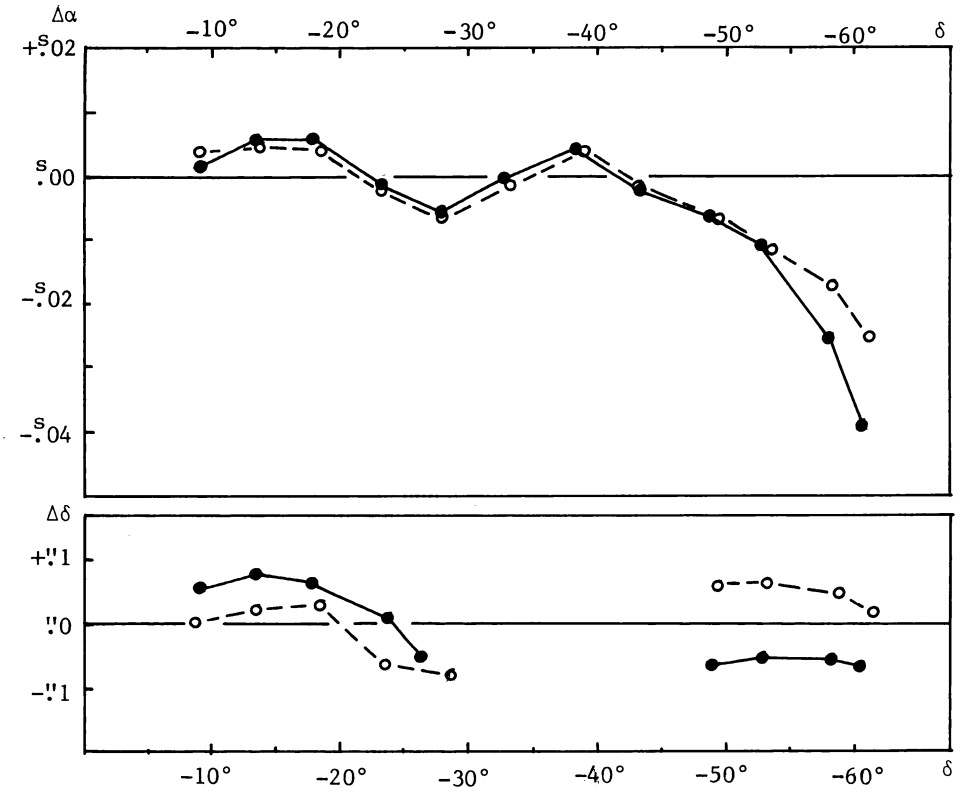

Figure 3. The $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ errors of FK4 as obtained by the astrolabes of Santiago (-●-) and Cape (-o-) (1967.3).

As it is well known the observations with Danjon astrolabes are limited to a zone of little less than 60° wide in declination. On the other hand, stars fainter than magnitude 6 are difficult to observe. These drawbacks and the fact that observations of both transits, east and west, are necessary to obtain star positions, make it rather difficult to construct astrolabe catalogues with a large number of stars. The catalogue of the Paris astrolabe with 571 northern fundamental stars is the largest astrolabe catalogue published so far (Guinot et al. 1961).

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The largest astrolabe catalogues of southern stars at present, are those of Cape Town with 416 fundamental stars and the first astrolabe catalogue of Santiago with 325 FK4 and 215 FK4 Suppl. stars.

Since the latitudes of Cape and Santiago are very similar, -33°.9 and -33°.4 respectively, the star coordinates have similar precision at a certain declination (Débarbat and Guinot 1970). On the other hand, both catalogues have a relative large number of common stars: 246. Therefore, a comparison of the systematic errors of the FK4 derived from these catalogues, should give an idea about the precision of the astrolabe to reproduce these kind of results. In figure 3 are presented the curves given by both astrolabes, Cape and Santiago, for the systematic errors $\Delta\alpha_\delta$ and $\Delta\delta_\delta$. It can be seen from this figure and also from figure 2 that the results in right ascension look more consistent than those in declination. This is an effect that should be expected if one remind that the right ascension is obtained from the difference of the east and west zenith distance residuals and the declination is obtained from the sum of these residuals (Débarbat and Guinot 1970). Any systematic error, which affect in the same sense both residuals, such as personal equations, will be cancelled in the results in right ascension but will strongly affect the declinations.

Conclusions

According to what we have shown in this paper, we think that the contribution of the Danjon astrolabe to the improvement of the fundamental reference system at the southern hemisphere has been of significant importance, principally in the investigation of systematic errors, specially of right ascension. For these kind of investigations and for individual determinations of right ascensions the precision of the astrolabe is remarkable. Instrumental modifications such as the full automatization of the observations (Billaud 1986), should improve the results in declination. The automatization and observations at larger zenith distances will increase the number of stars that could be included in an observing program. Some of the implemented modifications also allow observations of the Sun (Chollet and Laclare 1977).

Another important aspect is the coordination of the different programs. In this concern the first approach was made by initiative of Brazillian astrometrists during the IV Latinamerican Regional Astronomical Meeting of 1984 at Rio de Janeiro. There was agreement on the following points: a) Coordination of the observing programs in order to have a convenient number of common stars. b) Homogeneity of reduction and analysis methods. c) A future joint publication of an astrolabe southern general catalogue (Clauzet 1986).

The introduction of space and radioastrometry is compelling optical ground based astrometry to strongly improve its efficiency and precision in order to give worthy results. The importance of the future contribution of the southern astrolabes to astrometry of this hemisphere

will depend closely on the instrumental improvements which should be implemented during the next years, and on a careful coordination of their work.

Finally, we would like to mention the kind collaboration of the French astrolabes staff to the astrolabe programs of South America. Their scientific assistance and constant encouragement to our work was decisive for obtaining the results which we have reviewed in this paper. Our sincere acknowledgements to Drs. B. Guinot, S. Débarbat, G. Billaud, the late L. Arbey, F. Chollet and others.

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Discussion:

CORBIN Will you add the FK5 extension to your observing program? The faint fundamentals in particular need observations in the southern hemisphere.
NOEL The observation programs of the South American astrolabes have included so far FK4 and FK4 Supp. stars. If the magnitude of some FK5 extension stars fit the astrolabe capabilities, we shall include them in the future programs.

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