MAPPING THE SKY WITH THE CARLSBERG AUTOMATIC MERIDIAN CIRCLE

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ABSTRACT: The contribution of the Carlsberg Automatic Meridian Circle to the improvement of the stellar reference frame is reviewed.

1. INTRODUCTION

The establishment of a non-rotating, global reference frame has occupied astrometrists for a long time. To some extent this was inevitable because proper motions had to be measured over long time intervals and they had to be freed from rotational components, such as precession and the zero point of right ascension. Besides these rotations of the global system, there were problems with systematic errors varying with right ascension and declination which led to warping of the reference frame.

These problems are still with us, of course. In the mid-1990s, the HIPPARCOS catalogue, linked to the FK5 or extragalactic frame, will provide a rigid, non-rotating frame at the level of $0''.001$ per year with a density of 2 stars per 1^{o} x 1^{o}, down to 9th magnitude. However, much remains to be done by Earth-based instruments before and after HIPPARCOS. An important contribution is being made by automated Meridian Circles of which there are at least 5 in operation. In this article I review the contribution being made by the Carlsberg Automatic Meridian Circle (CAMC), with which the authors are associated.

2. AUTOMATIC TELESCOPE

The CAMC was automated at Copenhagen University Observatory (CUO) in the period 1975-81. After being tested successfully at CUO during 1981-83, it was moved to the Observatorio del Roque de los Muchachos on La Palma, Islas Canarias, where it began operation in May 1984. It is operated jointly by CUO, Royal Greenwich Observatory and the Instituto y Observatorio de Marina, San Fernando.

S. Débarbat et al. (eds.), Mapping the Sky, 369–374.

The CAMC incorporates an automatic setting system, with scanning slit micrometers for the telescope, collimator and circle-reading system. An HP1000 mini-computer controls all the movements of the telescope, including the scanning micrometers, and collects the data from the detectors, light switches and other sensors for on-line reduction by a second mini-computer.

The stars to be observed are held in a large disc file containing about 300000 stars, which comprises mainly the AGK3 and SAO (above -52^{o}), and lists of fainter stars whose positions are either requested by customers or are selected for special investigations. Stars are selected automatically from this file, depending on a weighting factor which is a combination of priority, slew angle and time from the previous observation. The telescope is set automatically and the stars are scanned as they transit the focal plane. Normally 8 scans are made, 4 forward and 4 reverse, each scan taking about 2s; the number of scans is increased for fainter stars, up to a maximum of 32 scans. The limiting magnitude is $m_V \sim 13.0$. The detector output from the slits and the circle-reading scanners is analysed on-line to give an instrumental right ascension and declination. About 700 stars are observed in a night. Instrumental variations are removed by observing calibration sources hourly (nadir pool and azimuth marks) and by fitting each night's observations of about 90 bright stars to the FK5. A fuller description of the observational process can be found in Helmer & Morrison (1985).

3. CAMC Catalogues (La Palma)

The following table sets out the numbers of positions, magnitudes and proper motions, and positions of planets and minor planets published in the first three annual catalogues covering the period May 1984 to December 1986.

Carlsberg Meridian Catalogue Number	Year	Stars	Planets
1	1984	5292	857
2	1985	10718	1785
3	1986	~20000	~3000

The instrument probably reached its peak efficiency in 1986 and the annual increase will not continue to rise geometrically! Each star has generally between 4 and 6 observations.

4. ACCURACY

The accuracy of the CAMC positions of FK4 stars observed during the test period at Brorfelde, Denmark, is shown in Figure 1. The CAMC is compared with two catalogues observed visually - Third Herstmonceux 1950.0. (Hx3/50) and Fifth Washington 1950.0 (W5/50). [Taken from Bien (1987)] The catalogues Hx3/50 and W5/50 are absolute catalogues, whereas Bror 5 (CAMC) is quasi-absolute. So, even though all the catalogues were reduced to the FK4 system before comparison

https://doi.org/10.1017/S007418090013983X Published online by Cambridge University Press

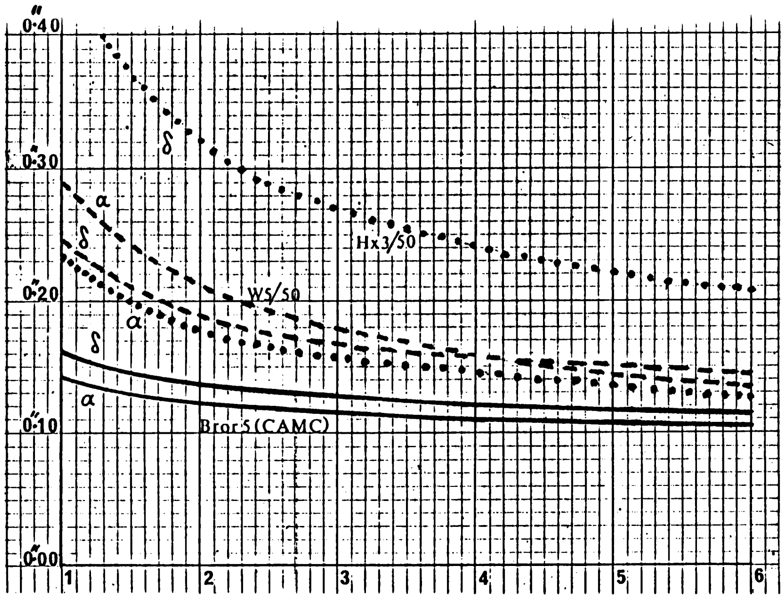

Fig. 1: Mean errors in α and δ as a function of number of observations.

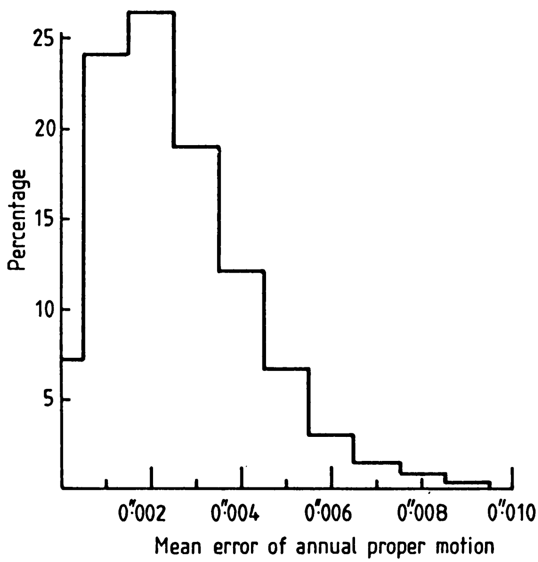

Fig. 2: Percentage of mean errors of annual proper motion in intervals of 0".001.

of their accuracies, the absolute catalogues may still stand off more from the FK4 than Bror5(CAMC) which is partly differential in its formation. Thus the comparison in accuracy may not be quite so favourable to the photoelectric technique as implied by Figure 1.

The asymptotic value of the mean error for the CAMC is near 0".10. Positions of this accuracy, combined with AGK2 (~1930) or Yale (~1940), give proper motions with mean errors in the range 0".0027 to 0".0050 per year. Figure 2 shows the distribution of the mean errors in proper motion in Carlsberg Meridian Catalogue Number 2. About 30% of the proper motions have mean errors less than 0".002 per year.

5. FK4/FK5

The improvement in the accuracy of the FK5 over the FK4 can be seen readily in Figure 3 which shows the differences in declination for individual stars observed by the CAMC in 1986. The tightness of the CAMC-FK5 residuals is good enough to reveal the presence of a flexure term in the CAMC observations varying as sin 2z, where z is the zenith distance.

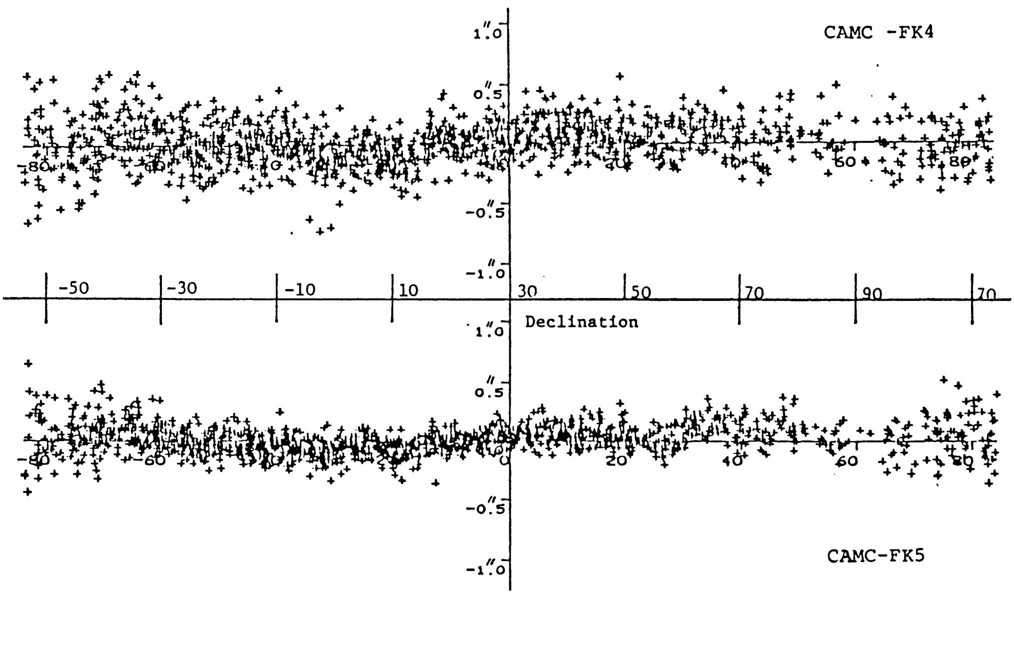

Fig. 3: Difference in declination between CAMC and FK4 and FK5.

https://doi.org/10.1017/S007418090013983X Published online by Cambridge University Press

INTERNATIONAL REFERENCE STARS (IRS)

From the latitude of La Palma (+29°) the CAMC is able to observe the northern hemisphere (AGK3R) and southern hemisphere (SRS) of the IRS as far south as -45° without losing too much in accuracy. By the end of 1986 the CAMC had completed 17000 IRS with 6 observations each, which is about half of the IRS stars available north of -45°. These observations will be used in the revision of the NIRS.

7. FAINT REFERENCE STARS

There is an obvious need to extend the FK5/IRS system to fainter magnitudes, say $11.0 < m_V < 12.0$. Work has started on selecting suitable stars from the Carte du Ciel in 1° x 1° fields which do not already contain a faint AGK3 star. The faint HIPPARCOS stars will also be included in this list.

8. CONCLUSIONS

Impersonal, automatic Meridian Circles are capable of high productivity (20000 stars per year) at relatively low operational cost, and can approach an accuracy of 0".10 by repeated observation. With this accuracy, proper motions with an average accuracy of 0".003 per year can be obtained for many stars in the AGK and Yale surveys.

The improvement of the FK5 and its extension, and the revision of the IRS are useful objectives prior to the publication of the HIPPARCOS catalogue in the mid-1990s. In the post-HIPPARCOS era, the most important task for automatic Meridian Circles will be the extension of the stellar reference frame to fainter magnitudes. Continued observation of the four inner planets with Meridian Circles is probably of limited value (Standish et al., 1986); but observations of the asteroids and outer planets (or their satellites) will continue to be of value.

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Standish, E. M., Newhall, X. X., Williams, J. G. and Dickey, J. O.; 1986. The Reference Frame of the Ephemerides, in IAU Symposium No. 128 The Earth's Rotation and Reference Frames for Geodesy and Geodynamics.

Discussion:

JOHNSTON What criteria do you use to select quasars for relating the optical to the radio reference frame?

MORRISON Our quasar list is usually that of the working group of IAU Commission 24 issued at Patras.

HEMENWAY In how large an area around the quasars are the reference stars included?

MORRISON About 1 degree square.

WAYMAN Would the slight variation $\Delta\delta_\delta$ be caused by the adopted refraction at the high-altitude site of La Palma?

MORRISON The integrated refraction has been calculated for the high altitude and would not account for that variation.

LASKER Please describe the magnitude distribution of your program objects.

MORRISON Most of the program objects are in the IRS, so the magnitude distribution follows the IRS where about 50% are between 7.5 and 8.5. The next largest group are 6000 reference stars in quasar fields which are in the range 11-12.

MONET What is the magnitude dependence of the errors?

MORRISON Six observations are needed of 0"1 accuracy at m = 12.