Polar Motion: Historical and Scientific Problems
ASP Conference Series, Vol. 208, 2000
S. Dick, D. McCarthy, and B. Luzum, eds.

The TOCAMM Project

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Abstract. The TOCAMM (TOrino CAgliari Measuring Machine) project undertaken jointly between Torino and Cagliari Astronomical Observatories aimed to convert the old measuring machine ASCORECORD into an automatic and impersonal one. This program is intended to contribute to the link of the HIPPARCOS Catalogue to the ICRS through the determination of precise position of optical counterparts of 80 extragalactic radiosources taken from the IERS list and to investigate the astrometric accuracy of the Guide Star Catalog (version 1 and 2). The calibration test phase, carried out first at the Astronomical Observatory of Torino and after at Cagliari Observatory, where the machine has been now installed, indicate that the available positional accuracy is about 0.5 microns in both x and y coordinates.

1. Introduction

About 12 years ago, the Torino Observatory started a program aimed at the determination of precise optical positions of extragalactic radio-sources. The scientific goal of this program was to contribute to the problem of the realization of an absolute reference system by linking the high accuracy VLBI observations to the optical ones. With the publication of the HIPPARCOS and Tycho Catalogues (ESA 1997), this problem has been extensively reviewed in order to tie the coordinate frame provided by the HIPPARCOS data to the International Celestial Reference System (ICRS) recently approved by IAU as the reference system. However, the link between the radio and optical reference frames is still a problem far from a conclusive solution, due both to the constant increase of ground based optical positions and the large number of observed targets.

Thus, a new and independent investigation of this problem seemed to be useful in several respects, and as Cagliari Astronomical Observatory expressed

https://doi.org/10.1017/S0252921100061431 Published online by Cambridge University Press

its interest in this research, the whole project was reorganized as a joint collaboration between the two institutes.

Until now we collected more than 350 plates, a small sample of which was already measured in the past (Chiumiento *et al.* 1991a, 1991b). The basic reduction methods outlined there are still valid however, in particular the use of the Carlsberg Automatic Meridian Circle Catalogue (in its final version) as primary reference system, as well as the use of a secondary reference frame transferred from large field photographic refractor plates to the astrometric reflector ones. The above papers also contain relevant information about the telescopes used to take the plates. Most of the target sources were observed with the Torino astrometric reflector REOSC and photographic refractor Morais, whereas for some fainter and/or southern objects the 1.5m Ritchey-Chretien of Loiano and the 1m JKT at La Palma telescopes were used. In addition to photographic plates, CCD images were taken to evaluate internal consistency.

The sky distribution of observed radio sources is shown in Figure 1. Their magnitude and declination is up to $B = 20$ and $\delta = -20°$, respectively.

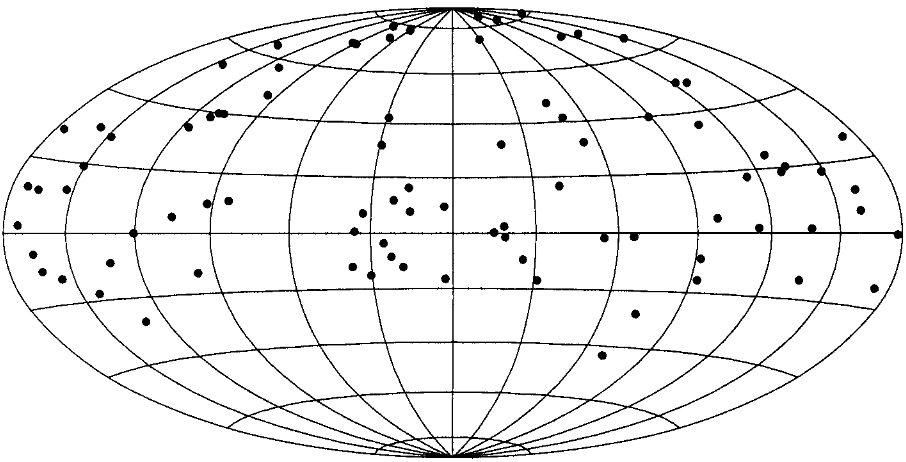

Figure 1. Sky distribution of observed radio sources (Aitoff projection).

The measurement of our plates with the old manual measuring machines used in our previous work was not deemed adequate for this project, therefore we decided to update our old machine to improve our accuracy and efficiency.

2. The TOCAMM measuring machine

The measuring machine we wanted to upgrade for the measurement of the accumulated plate material was built by the German firm Jenoptik (the well known Ascorecord model). It was used in the past in its original configuration, but, due to both the slowness and lack of accuracy of manual operations, it became obsolete. Consequently it was decided to undertake a project to convert this machine into an automatic and impersonal one, with the aim to obtain a device having performances comparable with the most modern ones available today.

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The basic mechanical and optical structure, considering stiffness and accurate construction, were retained.

The modifications introduced were:

- we replaced the original glass scales (read off by the very time consuming "spiral micrometer") with two high accuracy Heidenhain optical rulers, with RS 232 computer interface;
- we substituted the visual binocular head with a CCD camera, the CCD itself being now the reference "crosshair" for the measures;
- we introduced a motorized computer controlled stage for the plate carriage displacement.

The measuring principle, after having put on and centered the plate on the plate-holder, can follow one of the two possible strategies:

a) Pointed mode: the plate is moved until the selected star is centered in the CCD camera field of view, then (within a few seconds of delay after the motor came to a stop) the optical rulers are read off and a CCD frame is taken and stored as a FITS file with the plate coordinates written within the FITS header; in this mode an input list containing the stars to be measured must be prepared in advance.

b) Scan mode: the plate is moved step by step in a raster mode, the displacement between two steps is less than the CCD camera field of view and at each step a CCD frame is taken and stored as before with the associate optical ruler readings; in this mode the whole plate can be measured.

For the radio source program, as we already know in advance approximate positions of the objects to be measured (reference stars and radio source images) the pointed mode is used, because it simplifies the reduction procedure.

The CCD camera is equipped with a Kodak Kaf 260 detector of 512 by 512 pixels, covering a field of view on the plate of 2.8 by 2.8 mm, quite large enough to measure the largest star images of astrometric interest. The plate sampling is 5.5 micron/px. This is far larger than really necessary for a good plate sampling; therefore, the CCD frames are stored with some degree of binning.

Table 1. Plate sampling at different binning rates

binning rate	plate sampling $\mu m/px$
2×2	11.0
3×3	16.5
4×4	22.0

The binning rate is chosen according to the emulsion grains and star image dimension, ranging for the present program from 2×2 to 4×4 with the corresponding plate sampling given in Table 1.

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During operations the CCD temperature is controlled by a Peltier cell and kept stable within 0.5° degrees at -2°C, this had been proved to be adequate, due to the short exposure time required. Indeed, we are not at all limited by the detector performance, but the limiting accuracy is set by the optical rulers, read off at 1 micron resolution, a part — of course — of the intrinsic accuracy of photographic plates, for which the grain noise is much larger than the CCD's noise.

3. Tests and first results

The TOCAMM machine, after some preliminary tests carried out at Torino Astronomical Observatory, was moved to Cagliari Astronomical Observatory where it now is installed in a temperature-controlled room. In order to check possible temperature effects, 4 temperature sensors are mounted on the machine (one on each optical ruler, one on the CCD's mounting head and one on the machine environment) and the reading stored in the header FITS at each CCD exposure. The instrument stability, has proved even better than expected, showing no detectable temperature drift for a 12 hour measuring session.

As the final star position is a combination of the coordinates read off from optical rulers and of the image position on the CCD field of view, the first step is the calibration of the CCD scale in terms of the length scale set by the optical rulers. For this aim, a very simple procedure was devised, providing the CCD scale value in both coordinates with high accuracy. The resulting accuracy in a star position is (rms) of 0.5 micron in X and 0.6 in Y. The slightly worse value for the Y-axis is probably caused by the mechanical structure of the plate carriage guiding system, that is more sensitive to flexures along Y. Several accuracy tests made measuring the same plate in four different orientations (after rotation of the plate by 90, 180, and 270 degrees) indicate that the positions obtained by this machine should be accurate and stable at the 0.5 micron level in both coordinates, *i.e.* the intrinsic limit of the presently available optical rulers.

It is expected that this work will be completed in two years.

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