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FIRST RESULTS OF THE CMASF CCD OBSERVATIONS IN ARGENTINA

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RESUMEN

El círculo meridiano CCD de San Fernando (CMASF) está instalado en el observatorio Carlos U. Cesco en S. Juan (Argentina). Es explotado conjuntamente por el Real Instituto y Observatorio de la Armada (ROA) y el Observatorio Astronómico Félix Aguilar (OAFA). En diciembre de 1999, se le instaló una cámara CCD y desde entonces se observa la banda del cielo comprendida entre las declinaciones $+3°$ y $-55°$, para publicar un catálogo con posiciones y magnitudes de estrellas más brillantes que V=16. En esta comunicación se muestran los primeros resultados en forma de un catálogo preliminar con las estrellas de la banda $+3°$ a $-15°$.

ABSTRACT

The CCD meridian circle of San Fernando (CMASF) is installed in the Carlos U. Cesco observatory in San Juan (Argentina) at 69° W, 31° S and 2300 m of altitude. It is operated jointly by the Real Instituto y Observatorio de la Armada (ROA) and the Observatorio Astronómico Félix Aguilar (OAFA). In December 1999, a CCD camera was installed in the instrument. Since then, the sky band with declinations between $+3°$ and $-55°$ has been observed in order to publish a catalogue of positions and magnitudes of the stars brighter than V=16. In this paper, the first results of a preliminar catalogue with the stars in the band $+3°$ to $-15°$ are shown.

Key Words: **ASTROMETRY — STARS: CATALOGUES — SURVEYS**

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1. THE INSTRUMENT

The CMASF is an old meridian circle manufactured by the GrubbParsons company in 1950. Between 1987 and 1995, it underwent a complete automatization. The old objective and the declination circle were replaced by new, more modern ones, with better performances. The objective has a 168-mm effective aperture and 2664-mm focal length. The declination circle has markings every $5'$ and is read by means of six microscopes provided with CCTV cameras separated by 60°. The readoutof the circle is carried out by a PC which automatically determines its position by means of a video signal multiplexor card; ther is also a frame-grabber digitalizing the images of the portion of the circle seen in each camera, as well as the appropriate digital image treatment software. The readout precision is of the order of $0.''02$, and the time of one reading using the six cameras is approximately 2 sec. In December 1999, it was provided with a 9μ 1552×1332 pixels CCD camera observing in the continuous scanning mode (Gehrels et al. 1986; Stone 1993). Combining the cameras dimensions with the focal length yields a $0.69''$/pixel scale. When observing in the continuous scanning mode, the camera takes images of an $18'$ declination strip of the sky parallel to the equator, and up to 2.75 hours in right ascension. The automatization system is managed by a series of PCs: the TCC controlling the motion of the eyeglass and opening and closing the dome; the CCC controlling the CCD camera; and the PCC carrying out the automatic readout of the circle. In addition, another PC operating in Linux is in charge of intercommunicating the whole system and connecting it with the outside world via Internet.

2. THE OBSERVATIONS

The CMASF is a completely robotized instrument that operates without the presence of an observer. The totality of its functions can be carried out by remote control via Internet. The mission of an observer during the day following the observation night is to verify that the observations have been carried out successfully, to carry out the preliminary reductions of the observations performed, to prepare the list of observations for the following night, and to give ‘green light’ for observing. From that moment on, the automatized system takes over, carrying out the observation between sunset and sunrise, unless meteorological conditions (wind > 11m/s, humidity > 92%, or rain) prevent it. In that case, the system closes the dome, stops the observation and waits until meteorological conditions allow it to resume observations. If that happens before morning

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twilight, the dome is opened automatically and the observation continues.

3. PRELIMINARY REDUCTION

At the end of the observation, the images of the sky strips observed are copied automatically from the CCC to Linux. When this PC detects that the copying has concluded it enters a digital image processing program that analyzes the observed strips. It searches them for images of the observed stars and for each strip generates a series of files. There, the coordinates of the photocenters of the stars images found, the received light intensity, and the information on the quality of the images (ellipticity, inclination of the major axis of the eclipse, etc.) are stored. Information on sky quality during the observation of the strip and the intensity of the sky background are also stored there.

3.1. *Astrometric Reduction*

For the astrometric reduction Tycho2 catalogue is used as reference. Firstly, the stars that should be present in the strip according to declination of the center, the time of the beginning of the exposure and the duration of the strip, are identified in Tycho2. Then, the median positions J2000.0 are transformed to median positions at the observation date by applying proper motions. With these positions, the *calculated* cartesian coordinates relative to the center of the strip are determined. The coordinates of the stars present in the strip are transformed to the median of the date and are identified with the Tycho2 stars really present in it. This identification is carried out in two steps. In the first one, a 200-pixel radius is used and a star is considered identified when the distance of the photocenter of the observed image and the calculated one using Tycho2 positions is less than that radius. In a second step, using the different pairs of identified stars, the corrections to positions of the theoretical center of the strip and to the nominal scales in the directions of right ascension and declination are calculated by means of least squares, using a system of four parameters. With the corrections thus determined, an improvement in the positions of all the stars observed is achieved. Next, another identification of Tycho2 stars is made, using in this case a 20-pixel search radius. Having identified the pairs, the calculation by least squares is repeated, now with a system of six parameters. The latter are applied to the observed positions by which the preliminary median J2000.0 right ascensions and declinations observed of the date are obtained.

3.2. *Photometric reduction*

The observed magnitude for each star of the strip is calculated by means of the classic formula,

$$m = m_0 - 2.5 \times \log I$$

where I is the integrated total intensity received from the star in question. To this value, a Gaussian correction is applied, of the type,

$$\Delta m = \frac{A}{w\sqrt{\pi/2}} \times exp[-2(m - m_c)/w]^2$$

necessary to compensate the lack of linearity in the CCD response for low illumination conditions. The values of the A, w y m_c constants were calculated by comparing the observed magnitudes of the stars common to the CMSF and the Stone calibration regions (Stone 1999). For each strip, a correction for the atmospheres transparency during the observation is calculated; the latter in its turn is calculated using the differences between the observed magnitudes and those of the catalogue for all Tycho2 stars present in the strip.

The results of the preliminary reduction are kept in a filing system, waiting for the final reduction.

4. FINAL REDUCTION

When a band of a sky has been entirely covered by observed strips, and before a catalogue can be compiled with the stellar positions and magnitudes found in them, it is necessary to carry out a final reduction of all the strips. The purpose of this reduction is to eliminate atmospheric fluctuations produced during the exposition of each strip and to reduce the positions to a median atmosphere free of fluctuations. There are several methods to do this. In our case, we use partial overlapping (Evans et al. 2002).

4.1. *Partial overlapping*

In this method, the band to be observed is divided into $10'$ sub-bands in declination, and all the sub-bands are covered with the observed strips. As the width of CCD in the declination direction is $18'$, each strip has $8'$ in common with the strips of the sub-bands, both superior and inferior. For the final reduction of each strip, that strip and the six correlative ones with decreasing declinations have been used. Using the differences in right ascension and declination of the common stars in the overlapping $8'$ between each two consecutive strips, the respective *transfer functions* for *'transforming'* the positions of the reference stars (Tycho2) from the inferior to the superior strip are calculated, using cubic

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tracers. Once this operation is carried out for the six pairs of strips, the right ascensions and declinations of the reference stars are transferred, by successive application of the pairs of the transfer functions, from the sixth to the fifth, from the sixth and fifth to the fourth, from the sixth, fifth and fourth to the third, and so on, until all of them are transferred to the strip under reduction. Starting from here, the $O-C$ differences in right ascension and declination of the stars in question are formed and, as it can be then assumed that there already exist a sufficient number of stars for the calculations to be accurate, two *calibration functions*, one for each coordinate, are determined, also by using cubic tracers. These functions are applied to the coordinates of all the stars of the strip in question, making them, therefore, free of fluctuations.

Even if this method may seem somewhat clumsy, its advantage is that it is sufficient to cover each sub-band with valid observations just once; it saves observation time and permits to obtain 25-30 mas precisions for magnitudes fainter than $V = 14$.

5. CONSTRUCTION OF THE CATALOGUE

Once all the bands of the sky necessary to cover the zone with the $8'$ overlappings have been observed, the method explained in the previous paragraph is applied. The positions thus obtained are stored in a single file. The next step is to arrange the files by right ascension after which they are checked in order to determine those stars for which there is more than one observation. They comprise not only those of the $8'$ overlappings in declination, but also some overlappings in right ascension that result from the selection of the strips for covering the zone. The positions of stars observed more than once are calculated from a weighted mean of their different observations, their weights being a function of the fitting errors of the strip in which they were observed to Tycho2, and to the limiting magnitude observed in the said strip.

6. RESULTS

In Fig. 1, the average quadratic errors in right ascension, declination, and magnitude as a function of the latter, are shown. They were calculated from the data of the stars with more than one observation, for a subcatalogue of 10^6 objects with declinations between $+3°$ and $-15°$. As it can be seen, the results are very promising, and it is estimated that sometime during 2006 this subcatalogue will be made available to the public. Also, its precision is expected to improve by means of refining the reduction process.

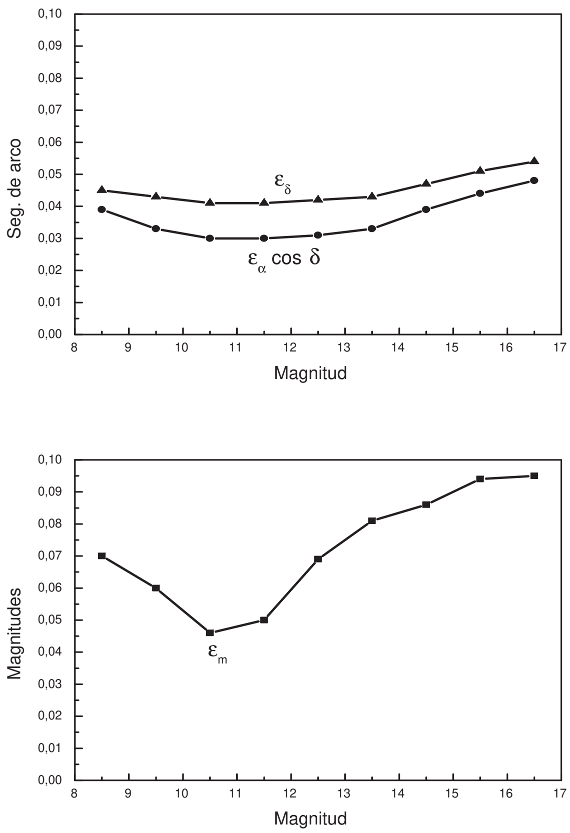

Fig. 1. Dependence on the average quadratic on magnitude.

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