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CDC-SF: PROPER MOTION CATALOGUE FROM *CARTE DU CIEL* PLATES, SAN FERNANDO ZONE

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RESUMEN

Presentamos un catálogo astrométrico de posiciones y movimientos propios, obtenido con las placas *Carte du Ciel* de la zona de San Fernando, material fotográfico de época media 1901.4 y magnitud límite V∼15. Se ha utilizado un escáner comercial de sobremesa para la digitalización de las placas. Ha sido necesario desarrollar técnicas especiales para el tratamiento del material y corregir la amplia distorsión que introduce el escáner. Las coordenadas ecuatoriales están en el sistema ICRS mediante Tycho-2 que es usado como referencia. Los errores externos comparados con Tycho-2 son de 0.″2. Para obtener movimientos propios se ha usado el catálogo UCAC2 como segunda época, obteniendo una incertidumbre de 1.2 mas/año, para las estrellas de V≤14.

ABSTRACT

We present an astrometric catalogue of positions and proper motions derived from the *Carte du Ciel* plates of the San Fernando zone, photographic material with a mean epoch 1901.4 with a limiting magnitude V∼15. Digitization has been made using a conventional flatbed scanner. Special techniques have been developed to handle the combination of plate material and the large distortion introduced by the scanner. A variety of post-scan corrections are shown to be necessary. The equatorial coordinates are on the ICRS system defined by Tycho-2. Comparison with the reference catalog indicates external errors of 0.″2. The UCAC2 Catalogue was used as second-epoch positions to derive proper motions with a mean accuracy of 1.2 mas/year for the proper motions for well-measure stars.

Key Words: astrometry — catalogs — reference systems — stars: kinematics — techniques: image processing

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1. INTRODUCTION

The *Carte du Ciel* project was established at the Astrophysical Congress held in Paris in 1887 and had a twofold objective: the construction of a complete catalogue to V∼11, the *Astrographic Catalog (AC)*, and to map the sky to V∼14, the *Carte du Ciel (CdC)*. A total of twenty observatories around the world were assigned the task of taking the photographic plates. This plate material constitutes the first observational full-sky record, currently with 100 years of antiquity in most cases. As such, it presents a valuable resource for wide-area proper motion determinations and, thus, kinematic studies of the Galaxy. The *AC* objective was successfully completed, culminating in the recent AC2000 Catalogue (Urban et al. 1998) on the Hipparcos system. However, only a few observatories completed their assigned declination zones for the *CdC* project.

2. MEASUREMENT OF THE PLATES

The Real Instituto y Observatorio de la Armada in San Fernando (Spain) was assigned the area between −2° and −10° declination, and this collection of 1260 *Carte du Ciel* plates has not been exploited up to now. Each plate covers a field of 2° × 2° and observations were planned in a full overlapping strategy.

Digitization has been done with a flatbed commercial scanner (Agfa DuoScan f40) that allows us to use the original plates. The residual mean errors, after correction for distortion, are similar to those obtained with specialized plate-measuring machines for this type of material.

The most important characteristics of the plates that complicate the determination of precise astrometry include: (1) the merging of the triple-exposure images on the odd-numbered declination plates, (2) the blending and confusion of stars that fall on the superposed *réseau* grid lines, (3) the false detections due to plate flaws, spurious dust and degradations that have accumulated during storage, and (4) typical effects in photographic material caused by optical aberrations. All of these are successfully treated.

The centering of the positions is made using a bivariant Gaussian fitting method, developed at Yale for use with their PDS machine (Lee & van Altena 1983), choosing the UCAC2 catalogue (Zacharias et

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al. 2004) as an input list of approximate positions of star images to be centered. A loss of up to 15% of stars can be expected due to interferences with the grid lines and spurious flaws as well as the blending of the triple exposures.

After the variety of post-scan corrections is made, the finale single-measurement internal error estimate per exposure is 3 μm for single-exposures plates, and 5 μm for triple-exposures ones. Details of the procedures are given in Vicente et al. (2007).

3. ASTROMETRIC REDUCTION OF THE PLATES

The transformation from (x, y) coordinates into celestial coordinates (α, δ) was performed by the block-adjustment technique (Stock 1981) including a determination of the field distortion (Abad 1993). The Tycho-2 Catalogue (Høg et al. 2000) was used as a reference catalogue at the epoch of the plates, due to its proper motions having an accuracy of 2.5 mas/year. It also has a sufficient density of stars and a magnitude limit of V$\sim$11.5.

Residuals are obtained as differences between individual positions and their average, if the star is not in the reference catalogue. If the star is identified as reference, we calculate also the residual difference between the average position and the catalogue position. The pattern found from the stacked residuals is used as a representation of the systematic field distortion remaining in the plates. This function is then applied to the positions and a new iteration of the astrometrical reduction is performed. Different correction masks are derived by binning stars into one-magnitude wide intervals to determine the magnitude dependence of the systematic errors. The distortion is found to be more pronounced at bright magnitudes.

An estimated internal error for each star in the catalogue is derived based on the rms of the positional differences of each image in the overlapping plates to the average position. Then mean values of these uncertainties are $(\sigma_{\alpha\cos\delta}, \sigma_\delta) = (0''.21, 0''.19)$ for the entire sample, and for stars brighter than 14, the mean values are $(\sigma_{\alpha\cos\delta}, \sigma_\delta) = (0''.12, 0''.11)$.

4. DETERMINATION OF THE PROPER MOTIONS

The early-epoch Carte du Ciel positions are combined with modern positions from the UCAC2 catalogue to derive proper motions. The proper motions are placed on the ICRS system via a direct comparison to Hipparcos proper motions for stars in common with our catalogue, correcting for systematic effects. A handful of open clusters allow us to estimate the the prope-motion errors and confirm that magnitude equation is not present. Internal error is about 1.2 mas/yr for stars with V$\leq$14 as is shown in Figure 1.

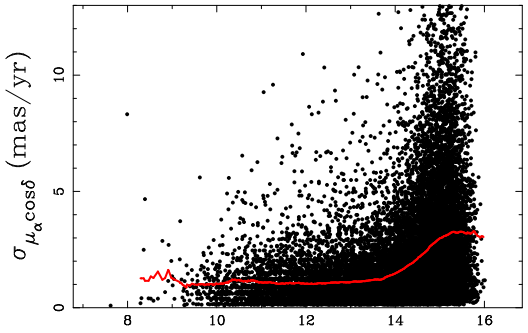

Fig. 1. Proper-motion uncertainties as a function of magnitude. Each point represents 25 stars and the red line indicates a moving mean. σ_{μ_δ} shows a similar behavior.

TABLE 1

CDC-SF CATALOGUE

mean epoch	1901.4
system	ICRS
area covered	$\sim$1080 degrees^2
position range in α	$06^h \leq \alpha \leq 14^h$
position range in δ	$-10.5^\circ \leq \delta \leq -2.5^\circ$
magnitude range	$6 \leq V \leq 16.3$
completeness	$V \simeq 15.1$
number of stars	503769
Hipparcos stars	701
Tycho-2 stars	40548
measuring error	3 $\mu m \sim 0''.18$
positional error	$(0''.21, 0''.19)$
(V<14)	$(0''.12, 0''.11)$
μ error (mas/yr)	(2.0,1.9)
(V<14)	(1.2,1.1)

A summary of the main properties of the CdC-SF Catalogue is given in Table 1.

Future versions of the CdC-SF Catalogue with expanded coverage to the full 24h of right ascension will be derived by applying the techniques presented here to the remainder of the digitized plate material.

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