

## A BRIEF OVERVIEW OF THE ABSOLUTE PROPER MOTIONS OUTSIDE THE PLANE CATALOG (APOP)

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### RESUMEN

APOP es la primera versión de un catálogo de movimientos propios absolutos que hace uso de las placas Schmidt del Digitized Sky Survey, fuera del plano galáctico ( $|b| \geq 27^\circ$ ). El error global del punto cero resultante es menor a  $0.6 \text{ msa año}^{-1}$  y la precisión mejor que  $4.0 \text{ msa año}^{-1}$  para objetos más brillantes que  $R_F = 18.5$ , subiendo a  $9.0 \text{ msa año}^{-1}$  para magnitudes en el rango  $18.5 < R_F < 20.0$ . La incertidumbre promedio en la posición es de alrededor de  $150 \text{ msa}$  (por coordenada) con una desviación sistemática del ICRS alrededor de  $0.2 \text{ msa}$ . El catálogo cubre  $22,525$  grados cuadrados y contiene  $100,777,385$  objetos hasta la magnitud límite  $R_F \sim 20.8$ . Aunque la misión GAIA impondrá nuevos estándares en los catálogos astronómicos, los métodos y procedimientos utilizados por APOP serán útiles en otras reducciones para corregir los errores sistemáticos astrométricos dependientes de la magnitud y el color de la próxima generación de sondeos desde la superficie terrestre.

### ABSTRACT

APOP is the first version of an absolute proper motion catalog achieved using the Digitized Sky Survey Schmidt plate material outside the galactic plane ( $|b| \geq 27^\circ$ ). The resulting global zero point error is less than  $0.6 \text{ mas/yr}$ , and the precision better than  $4.0 \text{ mas/yr}$  for objects brighter than  $R_F = 18.5$ , rising to  $9.0 \text{ mas/yr}$  for objects with magnitude in the range  $18.5 < R_F < 20.0$ . The average position accuracy is about  $150 \text{ mas}$  (per coordinate) with a systematic deviation from the ICRS around  $0.2 \text{ mas}$ . The catalog covers  $22,525$  square degrees and lists  $100,777,385$  objects to the limiting magnitude of  $R_F \sim 20.8$ . Although the Gaia mission is poised to set the new standard in catalog astronomy, the methods and procedures used for APOP will be useful in other reductions to dispel astrometric magnitude- and color-dependent systematic errors from the next generation of ground-based surveys.

*Key Words:* astrometry — astronomical data bases: miscellaneous — catalogs — proper motions

### 1. PLATE DATA

In this paper we concentrate on the calibration of the proper motions based on observational data that come from the STScI Catalog of Objects and Measured Parameters from All-Sky Surveys (COMPASS) archive of the GSC-II project (Lasker et al. 2008). The databases contain the measured astro-

metric, photometric and geometric parameters for all detections on the digitized scans of 7000+ all-sky survey Schmidt photographic plates used to build the Guide Star catalogs and the Digitized Sky Survey.

Due to increasing interstellar extinction as we approach the galactic plane, the number of observable (genuine) galaxies drops to zero. In the end, our reductions only addressed the parts of the celestial sphere with galactic latitudes  $|b| \geq 27^\circ$ , see Fig. 1.

### 2. PRINCIPLE OF CALIBRATION

Under the hypothesis that objects (stars and galaxies) physically close on a photographic plate and with similar magnitudes/colors have similar systematic errors, and that the absolute proper motions of galaxies are always zero, i.e. not dependent on their plate position, magnitude or color, we can rely on the galaxies present on each plate for the calibration of magnitude- and color- dependent errors

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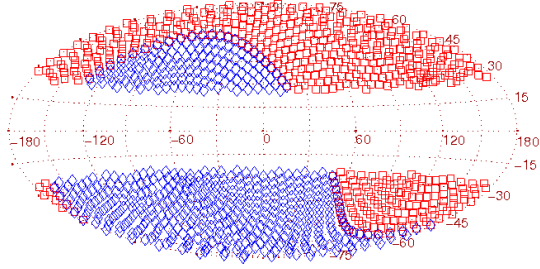


Fig. 1. The sky distribution of the Schmidt plates used in the APOP catalog. There are 4239 plates used in the reductions. The total area covered by this catalog is 22,525 deg<sup>2</sup>. The figure represents the celestial sphere in Galactic coordinates. The blue diamonds represent plates with  $\delta < 0^\circ$  and the red squares those with  $\delta \geq 0^\circ$ .

(Mde and Cde, respectively) in the plate-to-plate transformation.

In synthesis, the major plate-based calibration steps are:

- Remove the PdE with a moving-mean filter using stellar objects with good image quality;
- Select galaxies from non-stars via their pseudo (common) motion relative to the reference stars;
- Calibrate the Mde, Cde and the residual PdE of all objects with reference to the galaxies.
- Finally, absolute proper motions are calculated from all of the detections at the different plate epochs.

### 3. QUALITY ASSURANCE

For each object, we could obtain the calibrated absolute proper motions and positions by fitting an equation to all its measures at different epochs. Meanwhile, we could also get the formal errors of the calibrated parameters ( $\mu_{\alpha*} = \mu_\alpha \times \cos(\delta)$ ,  $\mu_\delta$ ,  $\alpha$ ,  $\delta$ ), which can be used as an internal check of the qualities of the catalog APOP. Figure 2 displays the statistics.

Quasi-stellar objects (QSOs) have star-like images and since they are extragalactic, they do not exhibit any time-dependent displacement. Thus, we can use the mean and dispersion of their measured motions to evaluate the zero point and overall precision of stellar proper motions. Here we use QSOs as an independent and direct determination of the APOP catalog quality. The Gaia Initial QSO Catalog (GIQC) (Andrei et al. 2012) is chosen as the source list for known QSOs. Figures 3, show the proper motions of the GIQC QSOs and indicate that there is a very good agreement between the external and theoretical error estimates of proper motions for the magnitude range  $R_F < 20.5$ .

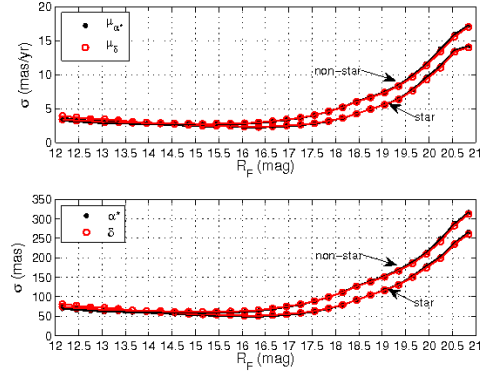


Fig. 2. Mean formal errors of APOP absolute proper motions ( $\mu_{\alpha*}$ ,  $\mu_\delta$ ) and positions ( $\alpha, \delta$ ) of stars and non-stars as a function of  $R_F$  magnitude. The magnitude is binned in 0.3 mag bins, with at least 100,000 objects per bin. The marker \* in the  $\mu_\alpha$  indicates multiplication by  $\cos(\delta)$ . **Top:** the formal errors of absolute proper motions in mas/yr; **bottom:** the formal errors of positions in mas.

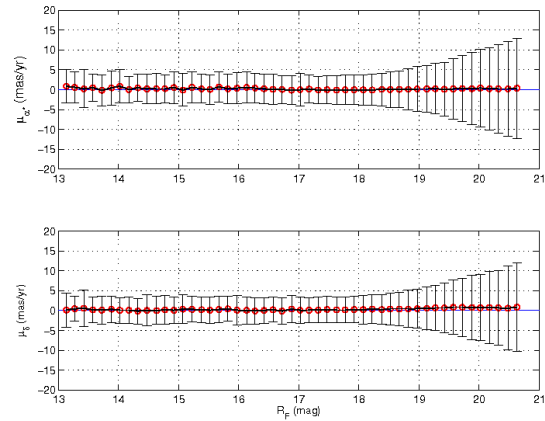


Fig. 3. The distribution of absolute proper motions ( $\mu_{\alpha*}$ ,  $\mu_\delta$ ) of QSOs as a function of magnitude. The red circles indicate the mean of  $\mu_{\alpha*}$  and  $\mu_\delta$  in that magnitude bin and the error-bar shows their standard deviation, which, following the assumption that QSO should have zero proper motions, are indicative of the proper motion random errors.

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