PLACING SCHMIDT ASTROMETRY ON THE ICRS

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1. Overview

The sky-limited, large-area photographic surveys which are being used for the construction of the second generation Guide Star Catalog (GSC-II) will be for many years to come the largest astronomical database available. The survey plates are typically placed on a 5-degree grid, with each plate area of about 42 square degrees, for a total of more than 1700 plates covering the whole sky. The expected data volume is about 2 Tbytes per bandpass. The final product will consist of an all-sky catalog of positions, proper motions, magnitudes and at least one color to a minimum of V=18. Among the scientific motivations behind such an endeavor let us mention operation of ground-based telescopes and future space missions, observation planning, statistical investigations (see, e.g., Lasker et al. 1995, Cannon 1997)

To fully exploit the astrophysical content of this database, both astrometric and photometric properties of the photographic plates must be calibrated with high precision. In particular, the very important task of placing GSC-II astrometry into the ICRS reference system has to be tackled.

Is is well known that Schmidt plates are astrometrically difficult to treat, essentially because metric distortions increase rapidly at a radius of 2.7° from the plate center outward. Therefore, a classical parametric approach to the plate solution, e.g., using simple polynomials, results in systematic errors of the order of 1 arcsecond or more at the plate edges. Characterization of these systematics deals with plate-holder driven mechanical stresses, asymmetry of image growth, focus-vignetting interactions, filter ghosts, diffraction spikes, etc. While improved understanding of these effects does not obviously provide us with a good modelling, the fact that the bulk of the error is stable within a set of similar plates allows it to be removed by subtracting a **mask** (Taff et al. 1990). The remainder of the error, specific to individual plates, can be removed by the use of a small-scale ($\sim 0.2°$) spatial filter against suitable reference stars. Another important finding is a magnitude dependent effect which has been discovered in the GSC-I catalog (Morrison et al. 1996), and which is typical of Schmidt photographic plates (Irwin et al. 1997). This effect has not yet been thoroughly explained, although it is clear that it stems from the performance of the centroiding algorithm on relatively bright objects. The systematic error increases with magnitude separation from the reference stars and radial distance from the plate centers; Morrison et al. (1996) showed that it can be efficiently removed by subtracting a tabular function of Δm, $\mathbf{r}$.

2. New Resources for GSC-II

From the experience gained with the astrometric re-reduction of the first Guide Star Catalog (Taff et al. 1990, Lattanzi and Bucciarelli 1991, Bucciarelli et al. 1994, Bucciarelli et al. 1995), we know that a very accurate and dense set of reference stars is essential to probe the small scale systematics characteristic of Schmidt plates. To this end, the newly released HIPPARCOS and Tycho catalogs are undoubtedly powerful resources.

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Although the HIPPARCOS average density is only 3 stars per square degree, its unprecedented accuracy (2 milliarcseconds in positions *and* proper motions) makes it unique for investigating plate-dependent systematic error toward the bright end of the photographic magnitude range of both recent and old-epoch surveys.

The density of the Tycho catalog is 25/sq degree, which is very good, with a typical magnitude of ~ 11, and a magnitude limit of 12. Tycho will contribute to the calibration of photometric zero-points errors across the plate, although its limited magnitude range cannot address the problem of magnitude effect. On the other end, the combination of its density and high positional precision will support a detailed investigation of plate-based systematics as function of different parameters (sky region, zenith distance, filters, etc.) at the mean magnitude of Tycho.

It has to be noted however that, because of large proper motion errors, Tycho will be best suited to reduce recent plates (POSS-II and SES surveys), but could not support the reduction of first epoch plates. For these we will need to use a combination of Tycho and the Astrographic Catalogue (AC) as proposed by Röser and Høg (1993). In such a way, it is intended to reduce the proper motion errors of the Tycho Catalogue to a few mas per year, making it possible then to use it successfully to reduce the first epoch plates. A new version of the AC (AC2000), reduced against the Astrographic Catalog Reference Stars (ACRS) and then tied to the HIPPARCOS system, has been announced at this IAU (Urban et al. 1997). Also, the USNO has recently completed the task of combining the AC2000 with Tycho to produce the ACT which is already available on a personal basis. Therefore, the choice of the reference catalog for the first epoch plates is no longer a matter of concern.

Auxiliary catalogs will also be essential for error control and determination of masks and magnitude effects. The most useful ones are the *Carlsberg Meridian Catalogue* (1997) series, which consist of about 1.4×10^5 objects north of $-40°$, with a significant number in the magnitude range $12 - 15$. In this context it is worth mentioning the availability of a special catalog of stars along the equator, observed with the *Carlsberg Meridian Telescope* in La Palma between 1994 and 1995, as part of the 'Faint Reference Star' observation program. This contains about 10 000 stars uniformly covering a strip along the equator of about 12 hours in right ascension and 12 degrees in declination. A first attempt to reduce POSS-II plates against Tycho and using this CAMC special catalog as external comparison produced very encouraging results, and is presented elsewhere in these proceedings (Bucciarelli et al. 1997).

Another very interesting catalog is FIRST, which is a VLA survey of about 10 000 square degrees about the North Galactic Pole, with magnitude fainter than 18 (White 1997). The FIRST catalog contains about 90 sources per square degree; most of these are optically faint, but about 15 per square degree have counterparts on the POSS plates ($V < 20$). Most of these objects are faint quasars or nearly unresolved galaxies. They make an ideal reference grid for studying residual astrometric errors: they are faint, they have accurate external positions from the FIRST catalog (which has both good precision and systematic errors smaller than 0.1 arcsec), and they are practically all extragalactic objects (so they have no proper motions).

3. Plans for GSC-II astrometry

With the reference catalog material at our disposal, a careful investigation of the systematic errors will be carried out in order to chose the 'optimal' strategy for GSC-II astrometry. In the following we summarize the general approach which will be adopted, based on our previous experience with Schmidt plate astrometry:

- Apply spherical (Schmidt) projection to x,y measurements and compute the refraction correction using the best available code; then fit a quadratic model to the data using Tycho as the reference catalog;
- For each recent-epoch survey, use the ensemble of Tycho reductions to construct mask(s) at mean magnitude of Tycho;
- Use available auxiliary data to map magnitude effects;
- After applying mask and magnitude equation, determine spatial scale of residual systematics and apply a local filtering technique with that scale.

With this technique, the expected adherence to the reference frame to be $\sim 0.15''$, averaged over all the plates. This means that the systematics will be mostly removed, and the astrometric

residuals will reflect essentially the plate measuring errors. Of course, this 'recipe' cannot be applied to first epoch plates; in this case either TRC or a less direct method will have to be used. Another concern is the fact that, with the material at hand, knowledge of magnitude effects in the range 13 to 18 is unsatisfactory. Therefore, the use of short-exposure plates and other indirect methods is indeed required. A lot of testing has still to be done in this respect, but we are confident of succeeding in bridging this gap. In conclusion, high quality GSC-II astrometry is a challenge which can be successfully tackled, thanks especially to the first class astrometric catalogs now available.

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References

Bucciarelli, B., Doggett, J.B., Sturch C.R., Lasker, B.M., Lattanzi, M.G., and Taff, L.G. (1995) GSC 1.2 - A Sub-plate Reduction of the GSC, Proceedings of *Astronomy from Wide Field Imaging*, IAU Symp. 161, 277

Bucciarelli, B., Sturch, C.R., Lasker, B.M., Lattanzi, M.G., Girard, T.M., Platais, I., and van Altena, W.F. (1995), A Test of the Astrometric Quality of the Southern Guide Star Catalogue 1.2, Proceedings of *Astronomical and Astrophysical Objectives of Sub-Milliarcseconds Optical Astrometry*, IAU Symp. 166, 375

Bucciarelli, B., Morrison, J.E., McLean, B.J., and Sturch, C.R., (1997), Astrometry of POSS-II plates using Tycho, these Proceedings

Cannon, R.D. (1997), Optical Reference Frame: high density requirements, these Proceedings

Irwin, M.J., Morrison, L.V., and Argyle, R.W. (1997) Transferring the Hipparcos frame to Schmidt Surveys, these Proceedings

Lasker, B.M., McLean, B.J., Jenkner, H., Lattanzi, M.G., and Spagna, A. (1995), Potential Applications of GSC-II for GAIA Operations, *Proceedings of the Workshop on Future Possibilities for Astrometry in Space, Cambridge, OK, 19-21 June 1995*

Lattanzi, M.G. and Bucciarelli B. (1991), A non-deterministic approach to Schmidt plate Astrometry, A&A, **250**, 565

Morrison, J.E., Röser, S., Lasker, B.M., Smart, R.L., and Taff, L.G. (1996) A Schmidt Plate Coma-Like Term, AJ, **111**, 1405

Röser, S., and Høg, E. (1993), Tycho Reference Catalogue (TRC): A catalogue of Positions and Proper Motions of 1 Million Stars, *Proceedings of a Workshop on Databases for Galactic Structure, Swaaathmore College, PA, May 17-19, 1993*

Taff, L.G., Lattanzi, M.G., and Bucciarelli, B. (1990) Two Successful techniques for Schmidt Plate Astrometry, ApJ **358**, 359

Urban, S.E., Corbin, T.E., and Wycoff, G.L. (1997) AC2000: The Astrographic Catalogue on the Hipparcos System, these Proceedings

White, R. (1997), private communication.