A Giant Step: from Milli- to Micro-arcsecond Astrometry
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Re-calibration of GSC2.3 with UCAC2

Z. H. Tang[1], Z. X. Qi[1,2], Y. Yu[1], R. L. Smart[3], B. Bucciarelli[3], M. G. Lattanzi[3] and A. Spagna[3]

[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China
email: zhtang@shao.ac.cn

[2]Graduate School of the Chinese Academy of Sciences, Beijing 100039, China

[3]INAF-Astronomical Observatory of Turin, Pino-Torinese 2010025, Italy

Abstract. To make GSC-II more accurate and useful, it is necessary to re-calibrate GSC-II when a better reference catalogue (UCAC2) is available. With UCAC2 as the reference, preliminary re-calibration of some sample plates from GSC2.3 were carried out with different methods, such as Global, Mask and Filter. The results indicate that a 7th-order polynomial is sufficient to account for the influence of Schmidt plate deformation on the measured coordinates of stars. The magnitude equation can be eliminated after correcting for a common magnitude equation. The RMS of the re-calibrated data is around ±0.2∼0.3 arcsec.

Keywords. astrometry, catalogs, surveys

1. Introduction

Over the last five decades, Schmidt telescopes have been frequently used as astrometric and astro-photometric survey instruments. And the surveys in various bandpass have already covered the entire sky several times in different epoch. The GSC-II is one of the largest all-sky astro-photometric catalog which is derived from the digitization of the Palomar and UK Schmidt survey plates today. The 2.3.2 version (about 1 billion objects) was released in October 2005, GSC-II is widely used in many fields. However, our research shows that there are some systematic residuals of position and magnitude equation still existing in this catalog. The main cause is that the plate reduction method did not account for the specific properties of plate which is bent during exposure. But sometimes the method we choose depends on the reference catalog. When GSC2.3 was calibrated, the unique and best choice of reference catalog was TYCHO-2, whose density is very low, magnitude range is narrow ($70\mathrm{deg}^{-2}$, V<11.5) and star images are over-exposure with large centroiding error in the plate. In 2003, the second version of USNO CCD Astrograph Catalog (UCAC2) was released, which is a high density ($1300\mathrm{deg}^{-2}$, R<16), high accurate astrometric catalog, and helping us to improve the GSC2.3 to a new level. In the following sections, we will talk about the property of former GSC2.3 and the results of re-calibration.

2. Astrometric property of GSC2.3

We use UCAC2 as the 'standard catalog' to inspect the systemic deformations related to location of the target on the plate, since its density, precision and accuracy of position and proper motion are enough for this purpose. To inspect magnitude equation, SDSS is an unique catalog to be used because of its accuracy and wide magnitude range which is around 10 to 21 mag. We can see from figure 1.1 that the plate deformation of the GSC2.3 still exists, and its bigger than 0.5 arc-sec near the plate edges. There is also a boundary whose radius is around 2.5° from the plate corner. The main reason for those

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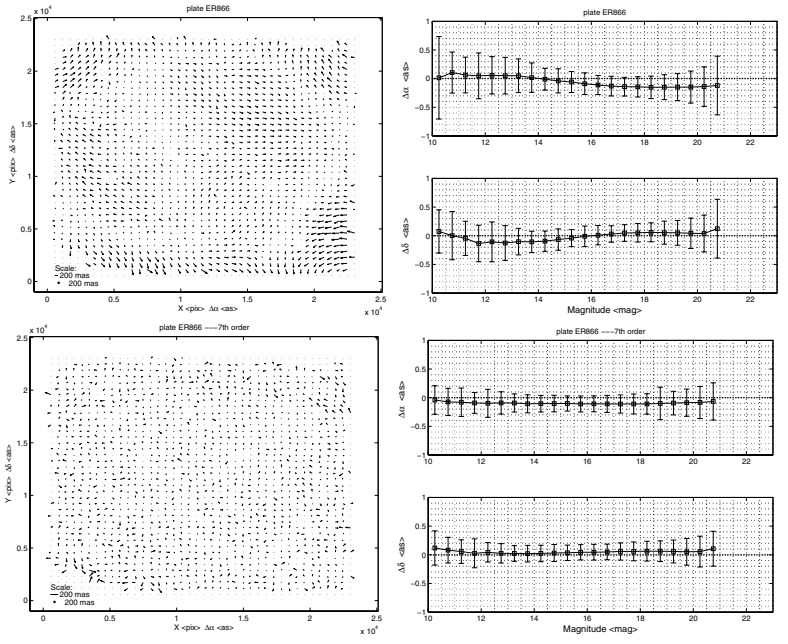

Figure 1. `Upper left`: Fig.1.1 Vector distribution of positional differences between GSC2.3 and UCAC2 on one plate. `Lower left`: Fig.1.3 Vector distribution of position differences between re-calibrated GSC2.3 and UCAC2 on the same plate. `Upper right`: Fig.1.2 Systematic and random errors of position differences between GSC2.3 and SDSS. `Lower right`: Fig.1.4 Systematic and random errors of position differences between the re-calibrated GSC2.3 and SDSS.

is the Schmidt plates are bent during exposure and expanded after exposure. But the former method of plate reduction, which is a second order polynomial, can not account for the specific properties. We can see from figure 1.2 that the well-known magnitude equation still exists, moreover it is nonlinear. The peak-to-peak amplitude is around 0.2 arc-sec. The possible physical factor of magnitude equation is the systematical influences of the mechanical and optical systems of telescopes on stars with different brightness.

3. Astrometric re-calibration of GSC2.3

3.1 The main processing pipelines of re-calibration with Global method are as follows:

- Equidistant projection
- 7th order plate model `(complete 7th order polynomial)`
- Magnitude equation correction

To account for the influence of Schmidt plate deformation on the measured coordinates of stars, after our study we find that a 7th order polynomial can be introduced when it is reduced against UCAC2. Figure 2.1 displays different order polynomial fitting to the standard coordinates as a function of measured coordinates for more than 100 plates, these plates are from Palomar and UK Schmidt telescopes with different sky cover, epoch, emulsion and filter. There are two inflection points, one is at the 5th order and the other is 7th. It is stable for both cases after the 7th order fitting. Figure 1.3 displays the vector distribution of position differences between re-calibrated GSC2.3 and UCAC2, we can find that the plate deformation is removed. We find that the tendency and the grade of the magnitude equation are similar for the plates in a same survey`(e.g. XP, XJ, XI, XO, ER, IS )` from the same telescope. Figure 2.2 displays the common magnitude

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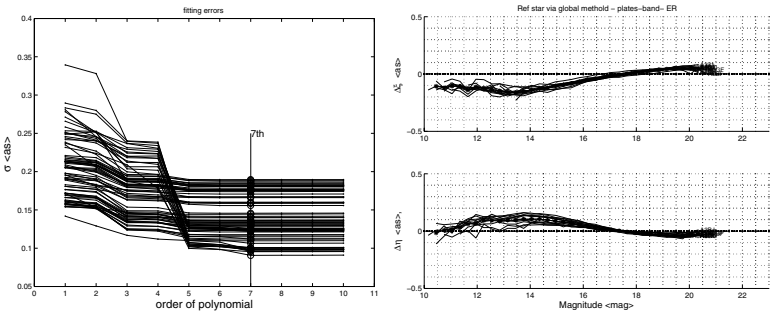

Figure 2. `Upper left`: Fig.2.1 Fitting error with different polynomial order for various plates. `Upper right`: Fig.2.2 Magnitude equation of ER plates, created from 13 plates of the UK Schmidt telescope ER survey.

equation of ER source(`ER surveys`), created from 13 ER plates, which is used to correct magnitude equation of ER plates. From Figure 1.4 we can find that the well-known magnitude equation has disappeared after correcting the common magnitude equation. And the off-set between the new GSC2.3 and SDSS is caused by the systemic error between the UCAC2 `(the reference catalog of the re-calibrated GSC2.3)` and SDSS.

3.2 The main processing pipelines of re-calibration with 'filter+mask' method (`double filter`) are as follows:

- Equidistant projection
- Obtain the mask from reference stars which has been filtered on the plate
- Filter the filed stars
- Apply the mask to the filed stars
- Magnitude equation correction

Just like using 7th order Global method, we can also remove the plate deformation via the 'double filter' method, but considering the speed and accuracy of these two methods we propose to use the Global method.

4. Conclusion

Preliminary tests show that the Schmidt plate deformation and magnitude equation can be nearly eliminated after re-calibration. The RMS of the re-calibrated data is around $\pm 0.2 \sim 0.3$ arc-sec for stars of different brightness. Some further tests are ongoing, which will help us to learn more about the factors in astrometric calibrations. After the tests, an astrometric re-calibration of the entire catalog will be performed and then the GSC-II should become more accurate.

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