A QUICK LOOK AT SOME NEW STAR CATALOGS

Herbert Raab[1,2]

[1] Astronomical Society of Linz, Sternwarteweg 5, A-4020 Linz, Austria
[2] Herbert Raab, Schönbergstr. 23/21, A-4020 Linz, Austria; herbert.raab@utanet.at

Some new astrometric star catalogs have recently become available, among them the Guide Star Catalog 2.2 (GSC 2), the USNO-B1.0, and the USNO CCD Astrograph Catalog 2 (UCAC 2). Both the GSC and the USNO-B are based on data collected from scanning photographic plates from the Palomar and Southern Sky Surveys. Positions in the UCAC, on the other hand, are derived from recent CCD observations, and proper motions are calculated from various earlier epoch data. A comparison of the features of these catalogs is presented, and results obtained with these catalogs on a few sample images are compared.

Introduction

In the past few years, most observers using CCDs for astrometric observations of minor planets and comets used the USNO-A2.0 star catalog [1, 2] (or the USNO-SA2.0, a subset of the former) as the primary source of reference star data. This catalog, however, is only the interim result from the efforts by the US Naval Observatory (USNO) to compile a star catalog that incorporates the information extracted from scanning the images of both the first and the second generation photographic sky surveys. The first version of the final result, the USNO-B1.0 catalog [3], is now available, effectively replacing the USNO-A2.0.
Contemporaneously, a second generation of the Guide Star Catalog (GSC), also based on scanned photographic plates from the sky surveys, is created at the Space Telescope Science Institute [4], and an intermediate release, the GSC 2.2, is already available online.
Finally, another star catalog, called USNO Astrograph CCD Catalog (UCAC) is under preparation at the USNO [5]. Contrary to the USNO-B and the GSC, this catalog is not based on scanned photographic images, as the positions are derived from current CCD observations. Although the observations are still under way, a second, intermediate release, the UCAC 2 [6], has recently become available.
We will first describe some basic properties of these new catalogs that are of interest for astrometric observers. The properties of the USNO-A2.0 are also described for comparison, as this catalog is well known.

USNO-A2.0

The USNO-A2.0 provides positions and magnitudes (in B and R) of 526,230,881 objects, based on digitized images from the first Palomar Observatory Sky Survey (POSS I) from the north celestial pole to a declination of -30°, and on the Science Research Council (SERC)-J survey as well as the European Southern Observatory (ESO)-R survey in the south. Only objects that were detected on both the blue and red plate were included in the catalog. The positions are good to ±0.25” at the plate epoch. For POSS I, the mean plate epoch is ~1957, and as the catalog does not include proper motions, some positional errors are can be expected for current epochs.

USNO-B1.0

In addition to the surveys plates used for the USNO-A catalog, the USNO-B also includes data from digitized photographic plates of the second Palomar Sky Survey (POSS II), the Anglo Australian Observatory (AAO)-R and the SERC-R surveys, as well as the SERC-I survey. This means that, for the sky north of -30° declination, five images (blue and red plates from POSS I, as well as blue, red and near-infrared plates from POSS II) at two epochs are available. In the south, four plates (the first generation ESO survey in red light, as well as the second generation blue, red and near-infrared images from the SERC and AAO surveys) were available. All objects detected on at least two of the available plates were included in the catalog, increasing the number of objects to 1,042,618,261.
With data from two separated epochs, it was also possible to calculate proper motions for the objects in the USNO-B catalog. The proper motions are relative, calculated for each plate so that the mean of the motions on the plate is zero. It should be noted that this results in small, systematic errors compared to proper motions that are measured against the fixed celestial reference frame.
The USNO-B is said to be complete to magnitude 21, but also includes information on many fainter stars. Positions are good to ±0.20” at current epochs. Besides positions and proper motions, the catalog lists magnitudes (separate for each survey, so there are up to two blue, two red and one infrared magnitude listed), stellar/nonstellar indicators, and other data for each object. Data for

brighter stars, which are heavily overexposed on the sky survey plates, are inserted from the Tycho 2 catalog.

GSC 2.2

Construction of the full GSC II catalog is still in progress, but an intermediate release, the GSC 2.2, is already available. It gives positions and magnitudes (in B and R) as well as stellar/nonstellar indicators for 455,851,237 objects. The data is based on digitized photographic images from the second generation sky surveys (that is, the POSS II north of -30° declination, and the SERC and AAO surveys in the south). A limiting magnitude of 18.5 in R and 19.5 in B has been set to ensure the photometric quality of the released data. Similar to the USNO-B, information for brighter stars are taken from the Tycho 2 catalog.

Positions are good to ±0.20” at the plate epoch. Although the GSC 2.2 does not include proper motions (except for the Tycho 2 stars), positional errors at current epochs should be smaller than for USNO-A due to the more recent epoch of the second generation surveys (~1993 for POSS II).

The final version, GSC 2.3, is expected to be released later in 2003. It will include information from the first generation sky surveys, as well as the Quick-V survey, and it will also contain proper motions. [7]

UCAC 2

Contrary to the catalogs described above, the UCAC is not based on digitized photographic images, but the positions are derived from recent CCD observations. Between 1998 and 2001, the 0.2m astrograph of the USNO, equipped with a 4k x 4k CCD camera, was set up at the Cerro Tollolo Interamerican Observatory (CITO) in Chile, imaging the southern sky. In late 2001, the instrument was relocated at the Naval Observatory Flagstaff Station (NOFS) in Arizona. Observations of the northern sky are still under way, and will probably be finished by the end of 2003.

The second, intermediate release, the UCAC 2, has recently become available. It includes data on about 50 million stars in the magnitude range between 8^{mag} and 16^{mag}, and covers the sky from the south celestial pole up to a declination of about +45°. Proper motions are calculated from older epoch data, including the AGK 2, AC 2000, and several other catalogs, as well as from digitized images from the photographic sky surveys for fainter stars. The positions are good to about ±0.02” for brighter stars, (10^{mag} to 14^{mag}) and to ±0.07” for stars at the catalogs limiting magnitude. Magnitudes, intended for identification purposes only, are given in a single, non-standard colour.

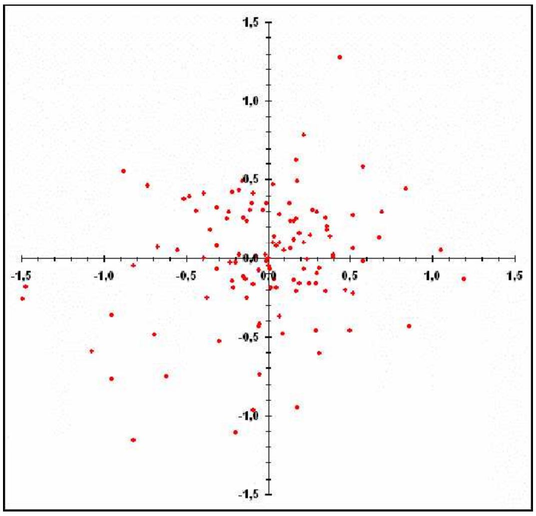
Observations

Observations of two fields around visible-light counterparts of sources in the International Celestial reference Frame (ICRF) [8] were performed with a SBIG ST-6 CCD camera at the 0.6m f/3.3 reflector of the Davidschlag Observatory near Linz, Austria (IAU Observatory Code 540). Astrometric data reduction of the images, using linear plate solutions for the 15’ x 20’ field, was done with the Astrometrica software, using each of the catalogs described above.

The first field was centered at the quasar ICRF J084205.0+183540. A total of ten images, each a 120 second integration taken on 2003 February 19, were measured, resulting in detections of the quasar with a peak SNR of about 40. The results of the reference star fits are summarized in Table 1: The number of reference stars found in the catalog is listed in the column “Total”. Stars with residuals larger than 1” in either Right Ascension or Declination were rejected by the software. The column “Used” lists the number of reference stars that were used in the final solution (i.e., having residuals less than 1” per coordinate). The mean residual for these reference stars in each coordinate is given in the last two columns of Table 1. The numbers shown here are the mean values from the ten available measurements.

Catalog	Total	Used	dRa	dDe
USNO-A2.0	123	109	0.28	0.28
USNO-B1.0	133	115	0.18	0.18
GSC 2.2	113	110	0.18	0.17
UCAC 2	17	17	0.06	0.08

Figure 1



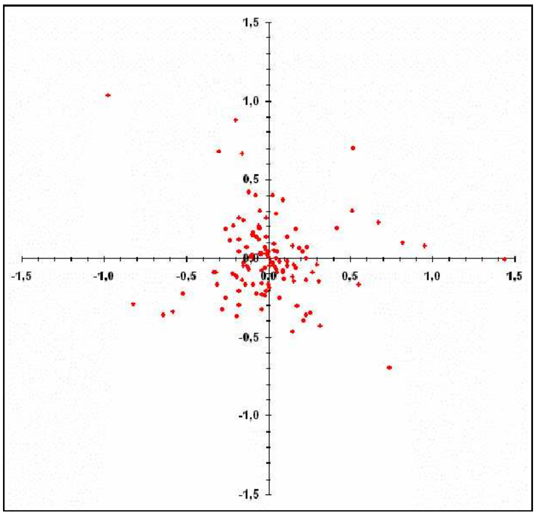


Figure 2

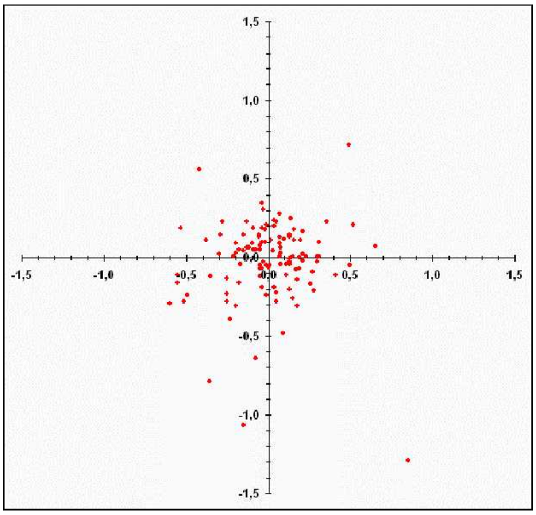


Figure 3

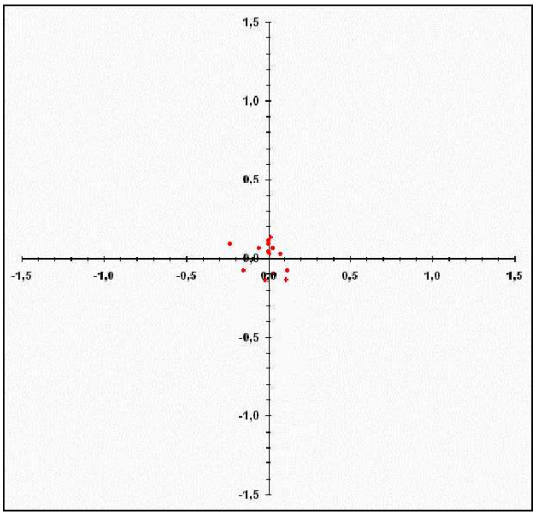


Figure 4

Plots showing the reference star residuals found in a typical image from the series are presented in *Figures 1 to 4*: The first figure shows the residuals from the USNO-A2.0 catalog, the second from the USNO-B1.0, the third from the GSC 2.2, and *Figure 4* shows the reference residuals from the data reduction with the UCAC 2. Obviously, the scatter in the reference star positions improves notable when switching from the USNO-A to the USNO-B or GSC II catalog. The UCAC does even better, although the comparable high limiting magnitude results in a rather small number of available reference stars.

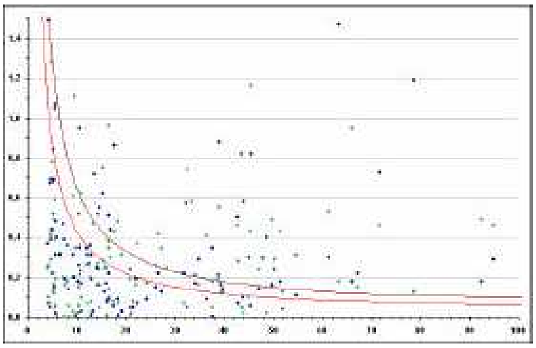


Figure 5

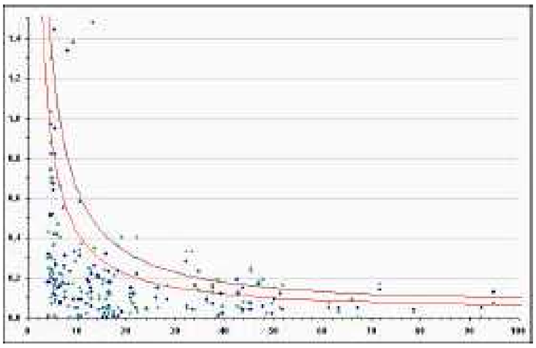


Figure 6

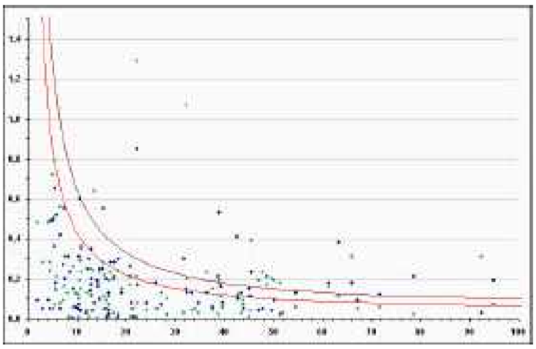


Figure 7

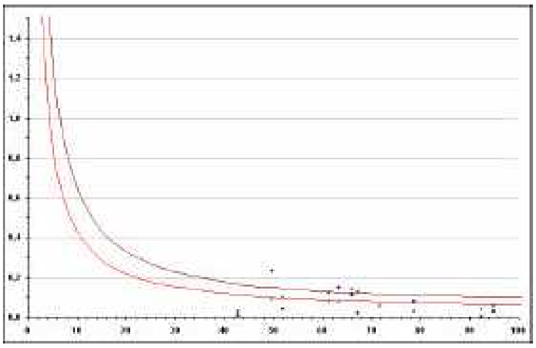


Figure 8

Figures 5 to 8 plot the reference star residuals for both for Right Ascension (blue) and Declination (green) against the peak SNR of the star. The red lines show the expected uncertainty in the measured position for the stars [9], where the light red line represents the two sigma, and the dark red line represents the three sigma error level. In *Figure 5*, which shows the data from the measurements using the USNO-A2.0 catalog, significant scatter can be seen even for very bright reference stars. In *Figure 6*, which shows the values found using the USNO-B1.0 catalog, the scatter in the reference star positions closely follows the expected uncertainties from the centroiding. *Figure 7*, showing the residuals from the data reduction with the GSC 2.2, is similar, with a few outliers, probably due to the missing proper motions in that catalog. *Figure 8* shows the same plot for the UCAC 2: While the faint stars, for which larger errors can be expected, are missing in that catalog, the available reference stars show residuals dominated by the predicted centroiding errors.

One should note, based on the reference star residuals, only conclusions about the internal precision of a catalog can be drawn. Any systematic errors will go unnoticed. For that reason, the position of the ICRF source in the centre of the filed has been measured, and compared with the position given in the ICRF catalog [10]. The results are summarized in *Figure 9*: The USNO-A2.0 shows the largest residuals, with a mean difference of about 0.44” between the position measured from the images, and the coordinates listed in the ICRF. Both the USNO-B1.0 and the GSC2.2 give comparable results, with a total residual of about 0.15”. The measurements based on the UCAC 2 have the smallest error, with an offset of only 0.09”. The error bars in *Figure 9* indicate the standard deviation from the mean position as found by measuring all ten available images.

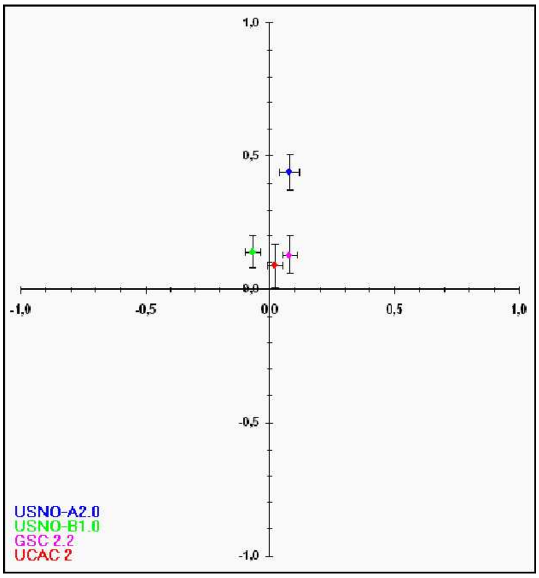


Figure 9

The second field was centered at the BL Lac object ICRF J082057.4-125859. A total of five images, each a 120 second integration taken on 2003 March 24, were measured, resulting in detections of the object with a peak SNR of about 20. The results of the reference star fits are summarized in Table 2 (where the columns have the same meaning as in Table 1). Again, the numbers shown in this table are the mean values from the five available measurements.

Catalog	Total	Used	dRa	dDe
USNO-A2.0	415	374	0.20	0.23
USNO-B1.0	474	384	0.17	0.21
GSC 2.2	440	406	0.14	0.18
UCAC 2	99	98	0.05	0.09

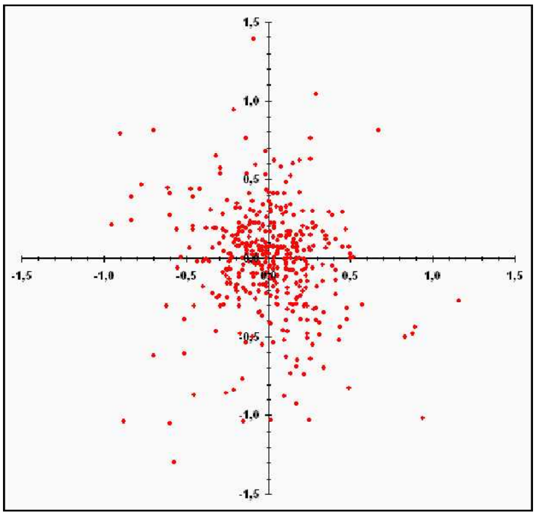


Figure 10

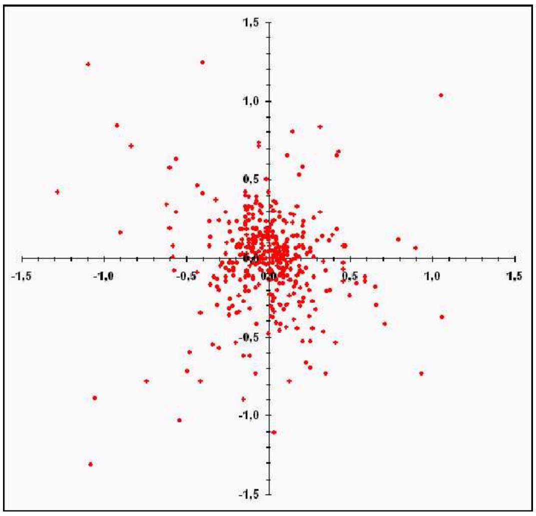


Figure 11

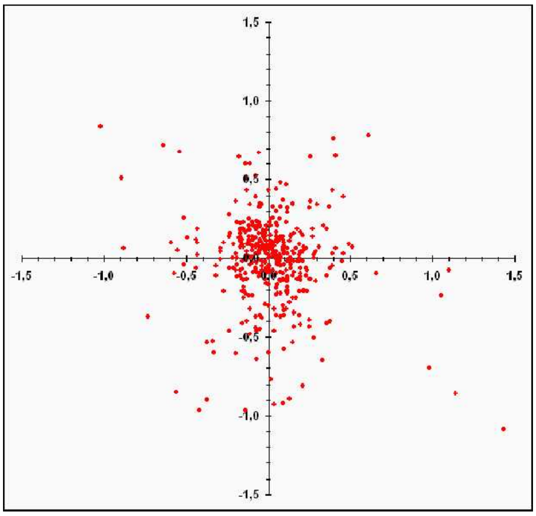


Figure 12

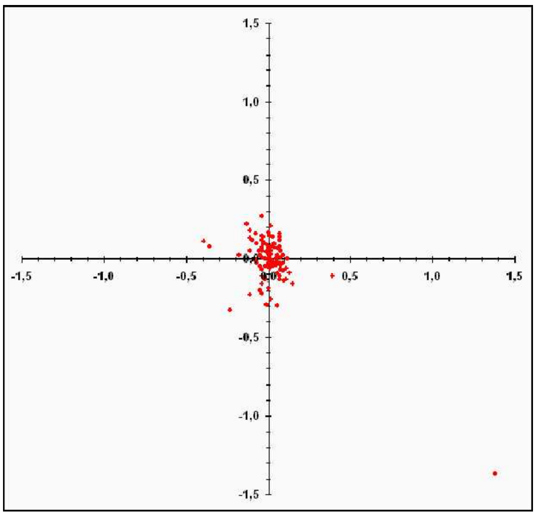


Figure 13

Plots showing the reference star residuals for this field are shown in *Figures 10 to 13*. While the improvement of the USNO-B and GSC II over the USNO-A is less obvious than in our first example, is it still noticeable. The UCAC 2 provides a sample of almost one hundred reference stars in that rich field, and the results are superior, again. The single outlier seen in this plot is a double star that was not resolved in the images used here.

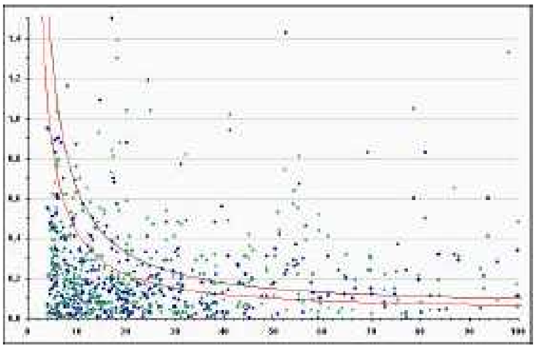


Figure 14

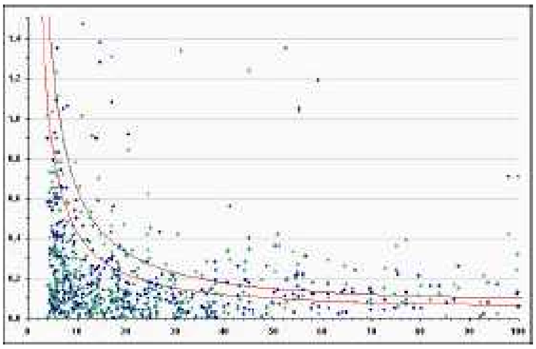


Figure 15

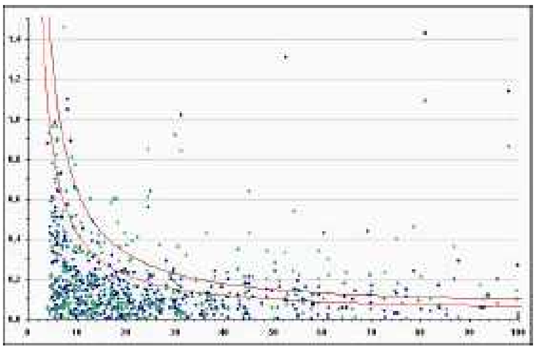


Figure 16

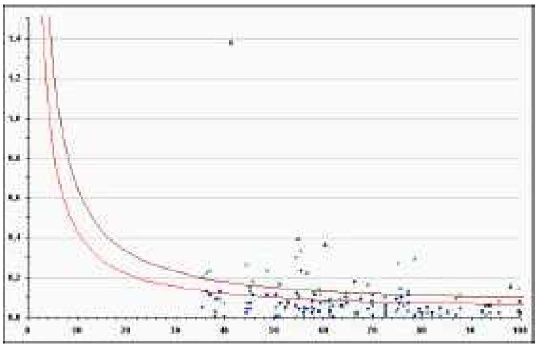


Figure 17

The plots of the reference star residuals versus the peak SNR for the second field are shown in *Figures 14 to 17*. They show much the same patterns as the corresponding plots for the first field.

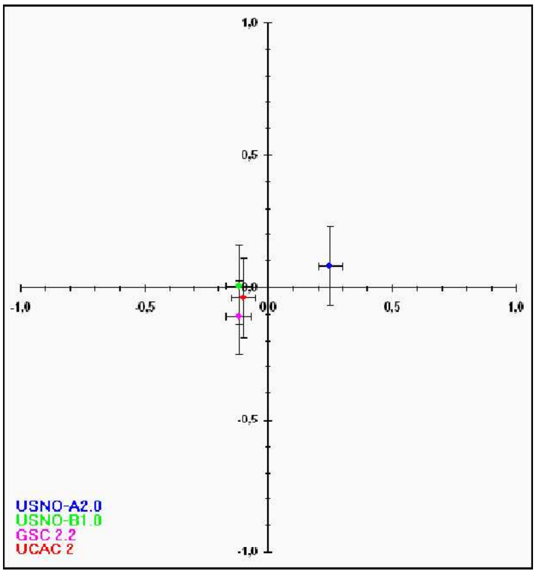


Figure 18

Figure 18 shows the offset from the measured position of the optical counterpart of the ICRF source from the position given in the ICRF. The situation is very similar to the results obtained for the first field: The position based on the USNO-A2.0 shows the largest offset with a total residual of 0.26". The USNO-B1.0 and GSC 2.2 give similar results, with total residuals of 0.16" and 0.12", respectively, and the position based on the UCAC 2 is off by 0.10" only. The error bars in *Figure 18* indicate the standard deviation from the mean position as found by measuring all five available images.

Availability

The full USNO-B catalog is not generally available, and there are currently no plans to produce CDs, DVDs or any other hardware media for distribution. Parts of the catalog, however, can be downloaded from the Integrated Image and Catalogue Archive Service provided by the USNO at http://www.nofs.navy.mil/data/FchPix/.

The GSC 2.2 is also only accessible trough the internet. The GSC online query is hosted by the STScI at http://www-gsss.stsci.edu/support/data_access.htm. According to information on the GSC II web site [7], options for mass distribution of the final version (GSC 2.3) on some media are considered.

The UCAC 2 is distributed by the USNO on three CD-ROMs. For more information, please visit the UCAC web page at http://ad.usno.navy.mil/ucac/.

Summary and Conclusions

Three new star catalogs that are of interest to astrometric observers have become available recently, namely the USNO-B1.0, GSC 2.2, and the UCAC 2. Two fields, containing objects used in the ICRF, have been observed, and astrometric data reduction has been performed using the three new catalogs, as well as the USNO-A2.0. Although comparison of only two fields is certainly not an extensive test by any means, the results obtained with the new catalogs seem to be very promising. Hopefully, the USNO-A2.0, which now seems to be obsolete, will soon be replaced by one of these new catalogs as the main source for astrometric standards used by most astrometric observers.

Acknowledgements – The author wants to thank Erich Meyer from the Davdischlag Observatory for taking the images of the two ICRF sources, and is grateful to Dr. Nobert Zacharias from the USNO for providing pre-release data from the UCAC 2 catalogue for these two fields.

References

[1] Monet, D. G.: "The 491,848,883 Sources in USNO-A1.0" American Astronomical Society, 188th AAS Meeting, #54.04 Bulletin of the American Astronomical Society, Vol. 28, p.905

[2] Monet, D. G.: "Astrometric Improvements for the USNO-A Catalog" American Astronomical Society, 191st AAS Meeting, #16.08 Bulletin of the American Astronomical Society, Vol. 29, p.1235

[3] Monet, D. G., et al.: "The USNO-B Catalog" The Astronomical Journal, Vol. 125, pp. 984-993

[4] Morrison, J. E.: "The Second Generation Guide Star Catalog"

American Astronomical Society, DDA meeting #32, #06.03

[5] Zacharias, N.; Rafferty, T. J.; Zacharias, M. I.: „The UCAC Astrometric Survey" Astronomical Data Analysis Software and Systems IX ASP Conference Proceedings, Vol. 216, p.427

[6] Zacharias, N.; Zacharias, M. I.; Urban, S. E.; Rafferty, T. J. : "UCAC2: a new high precision catalog of positions and proper motions" American Astronomical Society Meeting 199, #129.08

[7] Guide Star Catalog II Web page: http://www-gsss.stsci.edu/gsc/gsc2/GSC2home.htm

[8] Ma et al.: "The international celestial Reference Frame as realized by Very Long Baseline Interferometry" The Astronomical Journal, Vol. 116, pp. 516-546

[9] Raab, H.: "Detecting and Measuring faint Point Sources with a CCD" MACE 2002 Proceedings

[10] ICRF Web Page: http://rorf.usno.navy.mil/ICRF/