Significant radio-optical reference frame offsets from CTIO data

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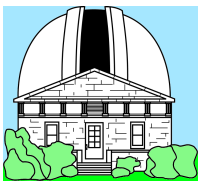


Abstract

We present results from the first application of UCAC3 data. A re-reduction of optical positions of extragalactic reference frame sources from CTIO 0.9m observing with UCAC3 gave consistent results with earlier reductions based on UCAC2. However, for many of the ICRF sources a significant offset in the order of 30 to 80 mas between the radio and optical positions is seen. Thus either the optical and radio centers of emission of some of these sources do not coincide, or the optical reference frame as represented by Tycho-2 and based on Hipparcos might have local deviations.

Astrograph reference stars

Wide-field images of ICRF source fields were taken with the USNO Twin Astrograph as part of the USNO CCD Astrograph Catalog (UCAC) project. These observations were contemporaneous to the NOAO observing runs. For each observing run an individual reference star catalog was constructed using Astrograph data and UCAC2 reduction procedures with Tycho-2 reference stars. For 1 observing run (runz) the reductions were repeated using the new UCAC3 reduction pipeline with improved systematic error control (runz3).

Deep frame observations

Deep frames were observed with the CTIO 0.9m telescope (Fig. 3). A customized filter was used to match the spectral bandpass of the USNO Twin Astrograph. At least 4 frames were taken per source. The sky distribution of the optical counterparts of ICRF sources of the all southern observing runs can be seen in Figure 2, whereby a faint optical source has a signal/noise ratio of 5 or less. For a potential problem source the (optical-radio) position difference is greater than 3-sigma of the total, estimated errors.

Deep frame reductions

Each deep CCD frame was reduced using a dedicated secondary reference star catalog from astrograph data. A field distortion pattern was derived from residuals and corrections applied. A linear plate model was adopted for the final adjustment. Thus optical positions of reference frame counterparts could be obtained on the HCRF.

Optical–radio results

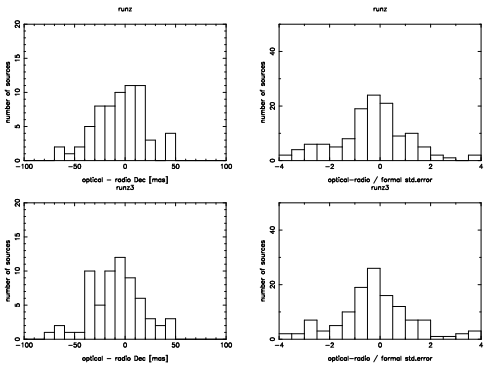
Table 1 shows results of "problem" sources from a single observing run, reduced with UCAC2 data (runz) and reduced with UCAC3 (runz3). Optical–radio position differences are given in mas per coordinate, as well as normalized by the corresponding standard errors.

		Opt-Radio (sigma)				Opt-Radio (mas)			
source	S/N	runz3		runz		runz3		runz	
0147−076	156	-2.5	6.5	-3.0	7.3	-50.8	131.8	-61.2	147.5
0215+015	27	-4.0	-0.6	-4.5	-0.5	-54.7	-8.0	-59.5	-7.2
0238−084	600	1.9	-7.3	2.2	-6.8	32.7	-123.5	36.6	-113.2
0405−123	927	-0.3	-4.8	-0.4	-3.7	-4.1	-57.5	-4.9	-44.5
2128−123	162	-4.9	-0.6	-9.4	-0.8	-27.2	-3.4	-51.2	-4.3
2216−038	46	-5.4	3.6	-4.3	3.5	-66.9	45.3	-53.7	44.1
2328+107	12	-3.1	-1.0	-2.9	-0.7	-103.0	-31.6	-97.0	-24.9
2335−027	17	0.2	-2.7	-0.9	-2.8	5.1	-60.9	-20.8	-64.1

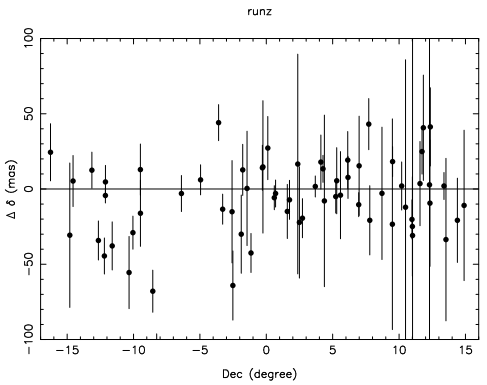
Table 2 puts together results of some "problem" sources as observed in more than 1 observing run.

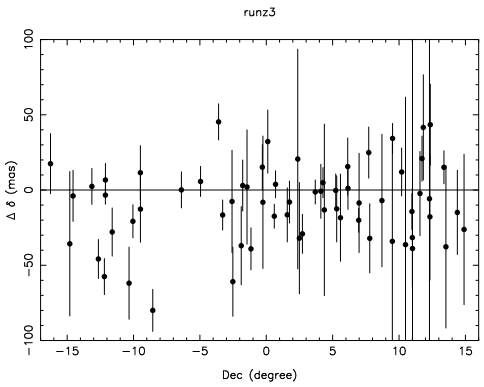
source	Opt-Radio (sigma)	Opt-Radio (mas)	run
0147−076	-3.1	-53.1	Sep 1999
	-0.6	-20.4	Dec 1999
	-3.0	-61.2	Sep 2000
0215+015	-7.2	-62.9	Dec 1999
	-4.5	-59.5	Sep 2000
0238−084	3.2	62.1	Sep 1999
	0.3	8.3	Dec 1999
	2.2	36.6	Sep 2000
0405−123	-0.6	-9.8	Sep 1999
	-1.3	-10.0	Dec 1999
	-0.4	-4.9	Sep 2000
2128−123	-4.3	-39.6	Jun 1999
	-5.7	-39.0	Sep 1999
	-9.4	-51.2	Sep 2000

The following histograms show the (optical-radio) position difference distribution and the distribution of total optical position errors.



The following plots display the optical–radio position differences in declination as function of declination for the 2 reductions, respectively.





Conclusions

The results from UCAC2 based and UCAC3 based data are very consistent. This indicates that even the old UCAC2 based results likely are correct on the 20 mas level. Optical position results of problem sources are also very consistent between observing runs, sometimes separated by several years.
Assuming the UCAC and deep CCD data are correct, the only explanation for the significant offsets between radio and optical position seen for more sources than can be explained by random errors is either a real physical offset between the centers of emission at radio and optical wavelengths, or a problem in the optical reference frame. Maybe we begin to see local, zonal errors in the Tycho-2 catalog.

References and Acronyms

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- Zacharias,M.I., Zacharias,N. "CTIO 0.9m observations of ICRF optical counterparts" in Proceedings IAU Symp. 248 (Shanghai, China, October 2007): A Giant Step: From Milli- to Micro- Arcsecond Astrometry eds. Wenjing Jin, Imants Platais, Michael A.C. Perryman Cambridge University Press, p.332-333, 2008
- UCAC3 available on DVD, request to ucac3@usno.navy.mil

CTIO = Cerro Tololo Interamerican Observatory
HCRF = Hipparcos Celestial Reference Frame
ICRF = International Celestial Reference Frame
KPNO = Kitt Peak National Observatory
NOAO = National Optical Astronomy Observatories
UCAC = USNO CCD Astrograph Catalog, http://ad.usno.navy.mil/ucac
USNO = U.S.Naval Observatory, Washington DC, USA

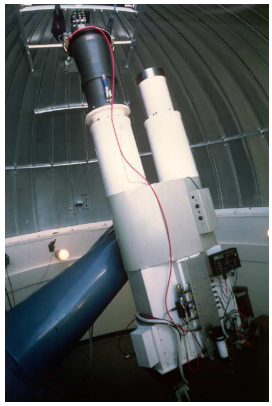

Figure 1. The U.S. Naval Observatory Twin Astrograph.

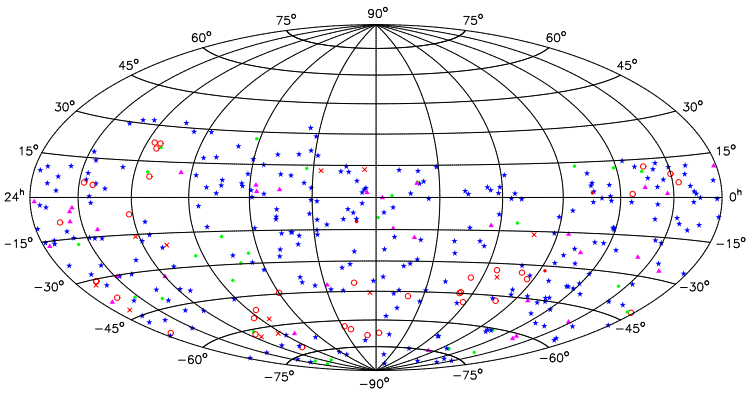

Figure 2. Sky distribution of optical counterparts of ICRF sources reduced so far; blue stars (270) = "good" sources, green dots (28) = optically faint, pink triangles (33) = potential problem sources (identification confirmed but position offset between 3 and 5 sigma), red cross (11) = problem source (with position difference (opt.-radio) greater than 5 sigma), red circles (36) = empty fields (no optical counterpart visible at the corresponding radio position or very faint with possible ID), and red dots (3) = no results, only observing attempt.

Figure 3. The CTIO 0.9 m telescope.