Radio-optical reference frame offsets from CTIO and UCAC4 data

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Abstract

CTIO 0.9m observations of ICRF counterparts were re-reduced with refernce stars observed by the USNO CCD astrograph of the same epoch, applying UCAC4-type reductions and systematic error corrections. Significant offsets between these optical and the ICRF radio positions are found for a number of sources and possible explanations are investigated.

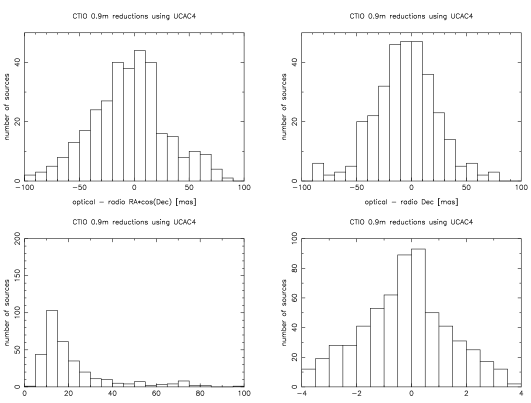
Data and data processing

Data from 6 observing runs at the CTIO 0.9m covering 220 sources were reduced with reference stars from the UCAC program using dedicated astrograph observations obtained at the same epoch as the deep 0.9m CCD images. Processing of the astrograph data followed the UCAC4-type of systematic error corrections and Tycho-2 (Høg et al. 2000) primary reference stars. For comparison a set of reference star positions based on UCAC2-type reductions was generated as well. The UCAC4 processing is based on new pixel data reductions and goes deeper than the UCAC2 based reference stars; however with larger random errors for additional faint stars in each field.

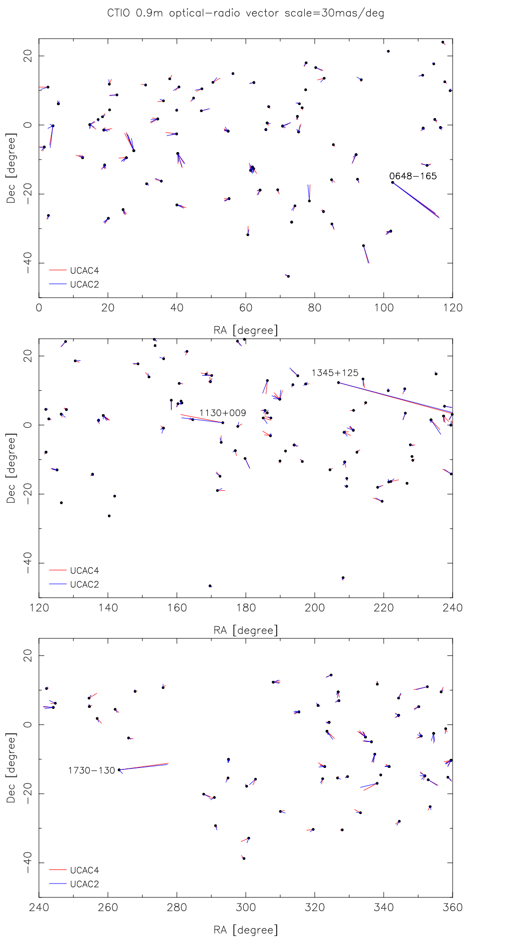
For each set, optical reference star positions were obtained from the 0.9m data which are compared to the almost error free radio positions taken from the ICRF catalog (Fey et al. 2009). Several sources were observed in more than one observing run.

Results

The following histograms show the distribution of the optical−radio position differences for the RA and Dec components (top row). Also shown are the distributions of formal standard errors and ratio of postion differences and formal errors. Most sources display a small formal error of about 10 to 30 mas per coordinate. However, the distribution of errors is non-Gaussian with larger than expected number of sources over 2 sigma optical−radio position differences.



The following three plots show the location of most of our sources on the sky (split by RA range) with optical−radio position differences indicated as vectors (scale 30 mas/degree). The red and blue vectors show results of UCAC4 and UCAC2-based reference stars, respectively. Some sources were observed in 2 observing runs.



Discussion

Sources observed in multiple observing runs have typically consistent optical−radio position differences, indicating the high precision of our data. In the RA = 300 to 360 deg area the vectors predominantly point to the left indicating additional local systematic errors coming from the reference stars.

Sources with largest vectors were looked at closer:

0648−165 was observed in 2 runs with 3 and 2 exposures, with 70 mas and 30 mas formal position errors per coordinate, respectively. The optical−radio offsets are 374, −271 mas (RA,Dec) and 402, −301 mas, respectively. In both cases the images on the exposures show no problem and we have an about 4 to 10 sigma outlayer.

1130+009 is relatively faint with a formal, total optical position error of 50 mas per coordinate but an offset of 365 mas along RA (6 sigma outlayer). This result is based on 1 observing run with 6 consistent exposures.

1345+125 is a radio galaxy (Seyfert 2) with visible host galaxy and 2 nuclei separated by 2 arcsec (O'Dea et al. 2000), which are mixed with the optical counterpart of the radio source in our about 1.5 arcsec resolution 0.9m data.

1730−130 was observed on 2 observing runs. The automatic processing from the first, poor seeing data resulted in the large optical−radio offset seen in the figure. The second set of observations taken under good seeing condition shows a double optical source separated by 2 arcsec. The deep 0.9m data of these were manually fitted by excluding pixels of the adjacent object resulting in the short, blue vector, revealing an optical position consistent with the radio position.

Conclusions

Our high precision optical positions of ICRF sources show systematic errors from at least 2 contributions: reference stars and blended optical images. Large outliers can easily be spotted but the question remains how much do closer, not easily detectable doubles (from forground stars or structure of the host galaxy) affect the optical positions of reference frame link sources.

References, further reading, and acronyms

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- Høg, E., et al. 2000, A&A, 355L, 27H
  "The Tycho-2 catalogue of the 2.5 million brightest stars"
- O'Dea, C.P. et al. 2000, AJ 119, 478
  "ASCA Observations of the Gigahertz-Peaked Spectrum Radio Galaxies 1345+125 and 2352+495"
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  "A Catalog of Faint reference Stars in 398 Fields of Extragalactic Radio Reference Frame Sources"
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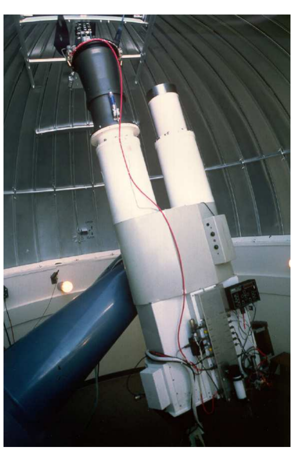
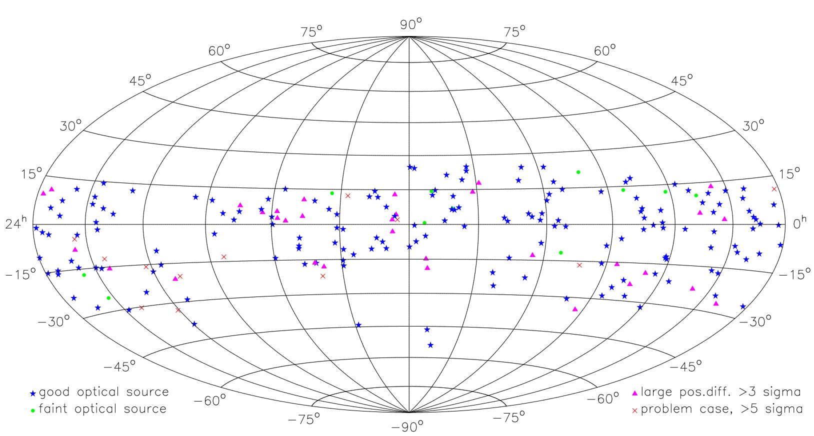
  "Optical Positions of ICRF Sources using UCAC reference stars"
- Zacharias,M.I., et al., JD16, IAU 2003, USNO, p.188-191, 2006
  "The USNO Extragalactic Reference Frame Link Program"
- Zacharias,N., et al. 2004, AJ, 127, 3043
  "The Second US Naval Observatory CCD Astrograph Catalog (UCAC2)"
- Zacharias,M.I. & Zacharias,N., ASP Conference Series 338, p.184, 2005
  "Radio-Optical Reference Frame Link: First results using dedicated astrograph reference stars"
- Fey, A.,L., et al., 2009, IERS Technical Note No. 35, ISBN 3-89888-918-6, 204 p.
  "The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry"
- Zacharias,N., et al. in preparation
  "The Fourth US Naval Observatory CCD Astrograph Catalog (UCAC4)"

CTIO = Cerro Tololo Interamerican Observatory
ICRF = International Celestial Reference Frame
UCAC = USNO CCD Astrograph Catalog, http://ad.usno.navy.mil/ucac
USNO = U.S.Naval Observatory, Washington DC, USA



The U.S. Naval Observatory Twin Astrograph.



Sky distribution of 220 optical counterparts of ICRF sources with one or more observation runs reduced with UCAC4 so far. There are 165 "good" and 11 "faint" sources. For 32 sources the offsets are between 3 and 5 sigma and 12 sources have a position difference (optical−radio) greater than 5 sigma.

The CTIO 0.9 m telescope.