The USNO CCD Astrograph Catalog (UCAC)

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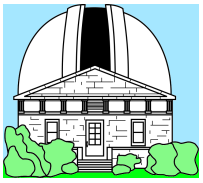
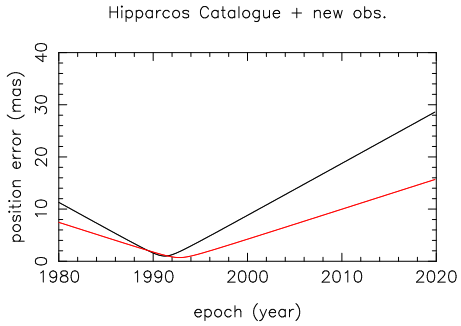


DoD relevance of this program

- accurate positions of bright stars for guiding and tracking
- accurate positions of faint stars for Space Situation Awareness and satellite orbit determination
- accurate celestial reference frame: link defining radio frame (VLBI) to optical frame (visual, infrared wavelengths) for consistent coordinate systems in the sky and on the ground
- build expertise and capitalize on software developments for future projects and missions like URAT and J-MAPS to address DoD requirements in star catalogs and reference frames

Stars do move!

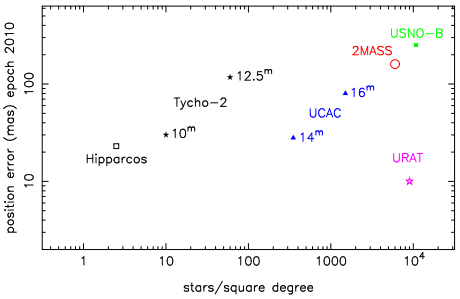
Stars slowly move on the sky (proper motion). Proper motions derived from astronomical observations are subject to random and systematic errors which lead to continuously increasing errors in position predictions over time. New observations are needed to reduce the errors on star positions and motions.



Important catalogs in comparison

name of catalog	ground space	proper motion	mag range	numb stars	pos.err (mas)	year
ICRF	G	QSO	radio	500	0.3	2000
Hipparcos	S	yes	<= 12	100 K	1.0	1997
Tycho-2	G/S	yes	<= 12	2.5 M	10..100	2000
UCAC2	G	yes	8..16	40 M	20.. 70	2003
2MASS	G	no	IR	500 M	90	2003
USNO-B	G	yes	12..21	1000 M	200	2003
PanSTARRS	G	yes	17..23	2000 M	30	2007
URAT	G	yes	14..21	1000 M	5..20	2009
J-MAPS	S	yes	2..15	40 M	0.5	2010
Gaia	S	yes	?..20	1000 M	0.02	2013
SIM	S	yes	0..20	20,000	0.004	2015

ICRF = International Celestial Reference Frame
2MASS = Two-micron All Sky Survey (Univ.Mass.)
PanSTARRS= sky survey project from Univ.Hawaii
USNO-B = all-sky catalog from photogr.plate scans
URAT = USNO Robotic Astrometric Telescope
J-MAPS = Joint Milli-Arcsecond Pathfinder Survey
Gaia = European Space Agency astrometric mission
SIM = Space Interferometry Mission / Planet-Quest



The optimum location in the above figure is at lower right (small position errors, and many stars). UCAC is a big step into that direction, building on the European Space Agency Hipparcos and Tycho catalogs. URAT is the USNO Robotic Astrometric Telescope (proposed project).

The USNO astrograph telescope

The USNO Twin Astrograph and camera (Fig. 1)

clear aperture	206 mm	number of pixels	4095 x 4095
focal length	2057 mm	field of view	61 x 61 arcmin
number of lens elements	5	pixel size	9.0 μm
usable flat field of view	$\approx$ 9 degree	pixel scale	0.9 "/pixel
active guiding with	ST4 at visual lens	spectral bandpass used	579–642 nm

UCAC project

- observing south: 1997 – 2000
- observing north: 2000 – 2004
- 100% complete all-sky coverage
- stars in magnitude range 8 to 16
- position errors 20 mas (10 to 14 mag)
- catalog includes proper motions
- final catalog reductions in progress (UCAC3)

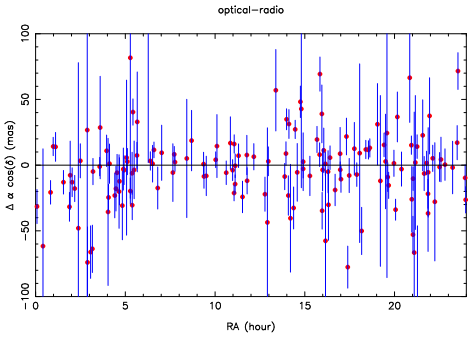
UCAC2 product

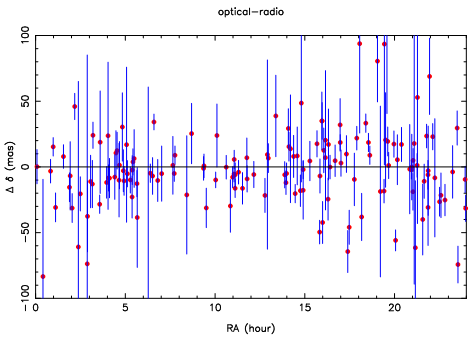
- second USNO CCD Astrograph Catalog released 2004
- over 40 million stars, about 80% of sky covered
- used by DoD, and astronomers worldwide
- 125 citations in scientific literature so far

Extragalactic link

- the accurate International Celestial Reference Frame (ICRF) is based on QSOs (quasars)
- observe these QSO counterparts at optical wavelengths
- tie astrograph data together with deep CCD observations

Results from the KPNO 2.1m (Fig.3) and CTIO 0.9m data are shown here, using dedicated astrograph observing for reference stars. The sky distribution of these 150 sources is displayed in Figure 2.





The difference in position optical (astrograph + deep CCD imaging) minus radio (ICRF) is plotted as a function of right ascension (RA) in the sky. The blue bars indicate the total, estimated, position errors (1 σ).

References and Acronyms

- de Vegt,C., et al. 2001, AJ, 121, 2815-2818 "A Catalog of Faint Reference Stars in 398 Fields of Extragalactic Radio Reference Frame Sources"
- Zacharias,M.I. & Zacharias,N., JD16, IAU 2003, (USNO publication)
- Zacharias,N., et al. 1999, AJ, 118, 2511-2525, "Accurate Optical Positions of Extragalactic Radio Reference Frame Sources"
- Zacharias,N., et al. 2004, AJ, 127, 3043 (UCAC2 paper)
- UCAC2 available on DVD upon request to nz@usno.navy.mil

mas	=	milliarcsecond = 1/1000 arcsecond = 4.8 nano-radian
IAU	=	International Astronomical Union
ICRF	=	International Celestial Reference Frame
J-MAPS	=	Joint Milli-Arcsecond Pathfinder Survey
KPNO	=	Kitt Peak National Observatory
NOAO	=	National Optical Astronomy Observatories
UCAC	=	USNO CCD Astrograph Catalog, http://ad.usno.navy.mil/ucac
URAT	=	USNO Robotoic Astrometric Telescope
USNO	=	U.S.Naval Observatory, Washington DC, USA
VLBI	=	Very-Long-Baseline Interferometry (linked radio telescopes)

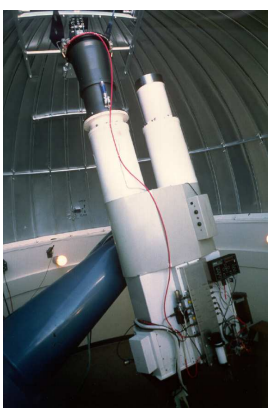


Figure 1. The U.S. Naval Observatory Twin Astrograph.

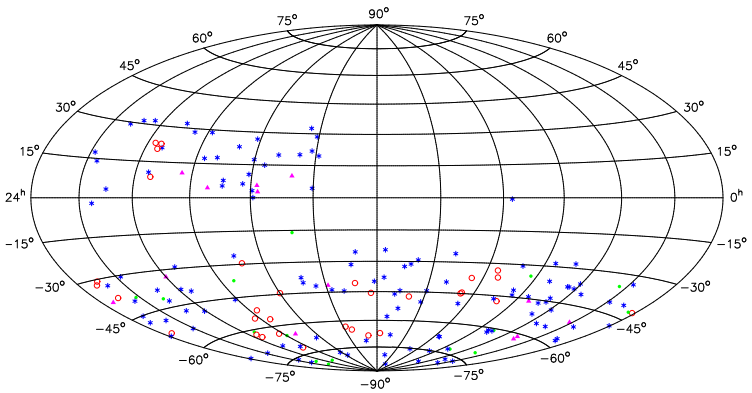


Figure 2. Sky distribution of optical counterparts of ICRF sources reduced so far; blue stars = "good" sources, green dots = optically faint, pink triangles = potential problem source (identification confirmed but position offset larger than expected), and red circles = empty fields (no optical counterpart visible at the corresponding radio position).

Figure 3. The KPNO 2.1 m telescope.