First parallax results from URAT data

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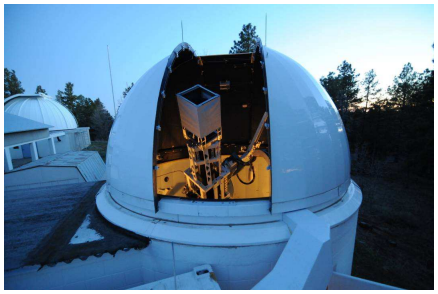
AAS, Kissimmee FL, 2016 Jan 04–08

Abstract:
The USNO Robotic Astrometric Telescope (URAT) performed a northern astrometric sky survey for stars in the about 3.5 to 18.5 mag range covering the about $\delta \geq -15^\circ$ area of sky with a single bandpass (680-760 nm) from its Flagstaff, AZ location. The full 3-year URAT North data (April 2012 to June 2015) is used here to find new nearby stars. Trigonometric parallax solutions with about 10 mas formal errors were obtained from an average of 25 observations per star. URAT parallaxes compare very well with Hipparcos Catalog and Yale Parallax Catalog values of stars in common. About 900 stars picked from photometric parallax data without yet published trigonometric parallax were found in URAT data to be within 25 pc, which is a substantial improvement over the know sample of about 2200 such stars.



Project:
The goal of the URAT project is to establish a deep (18+ mag), very accurate (10 mas level), optical reference frame based on the Hipparcos / ICRF system using UCAC4 reference stars, and to identify nearby stars unbiased by proper motion or other selection, before such data from Gaia becomes available.

Instrument:
The "redlens" of the USNO astrograph is fully utilized with its new, large focal plane of 286 mm diameter using a mosaic of STA1600 CCDs. A completely new tube structure was designed and built by the USNO instrument shop in Washington DC. Observations were performed at the Naval Observatory Flagstaff Station (NOFS) in Arizona. The clocked anti-blooming feature of the CCDs together with the use of an objective grating allows observation of stars as bright as 3rd magnitude. The astrograph is now relocated to Cerro Tololo, Chile to perform a quick, bright star survey.

telescope	USNO astrograph		
	aperture	203	mm
	focal length	2060	mm
	bandpass	680-760	nm
camera	4 CCDs, each	10.5k x 10.5k	pixels
	scale	0.905	arcsec/pixel
	single CCD field	2.65 x 2.65	deg^2
	total field of view	28	deg^2
guiding camera	3 CCDs, each	2k x 4k	pixels
	scale	0.8	arcsec/pixel
regular survey	2 exposures/field	60 & 240	sec
grating survey	2 exposures/field	10 & 30	sec

Observations:
Each observing night is split into 5 equal long periods during which a different set of 3 dither positions of a field are observed, thus providing good parallactic angle distribution. A 60 and a 240 sec exposure is taken at each individual telescope pointing. The entire pattern is repeated with 10 and 30 sec exposures with an objective grating near full moon.

First results from 2 years of operations were published in the URAT1 catalog of 228 million star positions (Zacharias et al. 2015). Data of all 3 years of operations at NOFS (April 2012 to June 2015) are used here for this parallax investigation.

Reductions:
An 8 parameter "plate" model was adopted for the astrometric reductions (linear + tilt terms) using UCAC4 reference stars (R = 8 to 16). The data are corrected for geometric field distortions (about 10 to 50 mas effect) and pixel phase errors (0 to 15 mas). Individual epoch positions (α, δ) of all stars were obtained on the ICRS. Depending on brightness and exposure time typical position errors of individual observations are 10 to 50 mas.

Our parallax pipeline utilizes JPL DE405 ephemeris for Earth position and algorithms based on RECONS parallax pipeline (Wei-Chun Jao, Phil Ianna and others). A least-squares fit for position differences (x, y), proper motion (μ_x, μ_y) and parallax (π) was performed for the observations as function of time (t),

$$x(t) = x(t_0) + \mu_x(t - t_0) + \pi P_\alpha \quad (1)$$
$$y(t) = y(t_0) + \mu_y(t - t_0) + \pi P_\delta \quad (2)$$

where P_α and P_δ are the parallax factors

$$P_\alpha = X \sin\alpha - Y \cos\alpha \quad (3)$$
$$P_\delta = X \cos\alpha \sin\delta + Y \sin\alpha \sin\delta - Z \cos\delta \quad (4)$$

All parallaxes investigated so far are relative to the set of UCAC4 reference stars (R = 8 to 16 mag) in a 2.65 by 2.65 deg field of view of a single URAT CCD. An example for the star Hip 30920 is given in Figure 1.

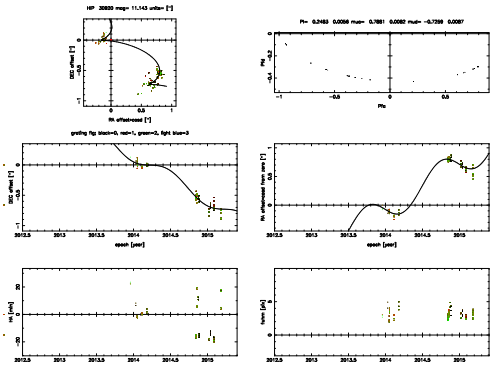


Figure 1: URAT reduction plots for the R=10 mag star GJ 234 (Hip 30920, π = 242 mas).

URAT parallax errors:
Distributions of the URAT relative parallax formal errors are shown in Fig. 2 for the YPC 25 pc sample and all Hipparcos stars with URAT parallax solution and $\delta \geq -10^\circ$, respectively. As expected, the error on URAT parallaxes largely depend on the epoch span and the number of observations (Fig. 3).

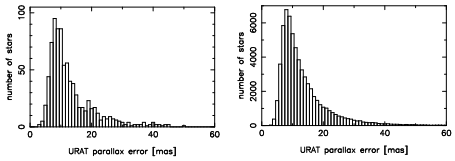


Figure 2: Histograms of URAT relative parallax errors for the 835 stars in the Hipparcos 25 pc sample with $\delta \geq -10^\circ$ (left), and for the total of 63609 Hip.stars in that area (right).

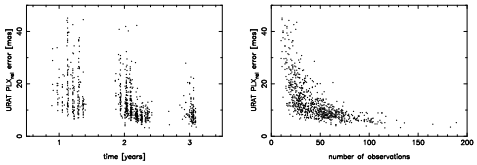


Figure 3: Relationship between URAT relative parallax errors and epoch span coverage (left) and number of observations (right).

Comparison to Hipparcos and YPC:

The URAT data recovers 65,524 out of 65,546 (99.96%) of Hipparcos stars with $\delta \geq -10^\circ$. Of these 696 stars are also in common with the Yale Parallax Catlog (YPC). Parallaxes are compared in Fig. 4. The diagonal line indicates perfect agreement, the others ± 20% deviations.

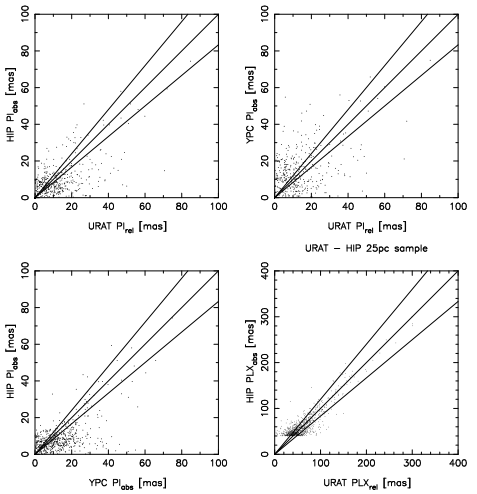


Figure 4: Comparison between URAT and Hipparcos (top left), URAT and YPC (top right), YPC and Hipparcos (bottom left) of stars in common to all 3 catalogs, and URAT and Hipparcos for the 25 pc sample (bottom right).

The algorithm was applied to all URAT North data. A list of potential nearby stars was compiled from various published photometric distances (e.g. Finch et al. 2014). About 900 stars from that list of stars without yet published trigonometric parallax were found in URAT data to be within 25 pc, which is a substantial improvement over the know sample of about 2200 such stars.

Acknowledgments:
We like to thank the entire URAT team including STA for continued support during URAT operations at NOFS.

References:
Finch,C.T. et al. 2014, AJ 148, 119 (nearby stars from UCAC4 photometry)
Zacharias, N. et al. 2015, AJ 150, 101 (URAT1 catalog)