URAT at CTIO

Norbert Zacharias (URAT team)

Wondering about the red shipping container sitting on top of Cerro Tololo? Between April 2012 and June 2015, the US Naval Observatory (USNO) Robotic Astrometric Telescope (URAT) conducted a three-year Northern Hemisphere observing program from its Naval Observatory Flagstaff Station site in Arizona. The URAT1 astrometric star catalog was derived from its first two years of operation, providing accurate positions at the 10–30 mas level for over 200 million stars between R = 3.5 and 19.

Unpacking the URAT container, from left to right: Norbert Zacharias, Esteban Parkes, Gary Wieder, The Red Lens (white box), Charlie Finch, Steve Heathcote, Chris Kilian, Marion Zacharias. (Image credit: Norbert Zacharias/USNO.)

Assembling of the new Ash dome for URAT. From left to right: Juan Andrade, Gary Wieder, Jorge Briones, Chris Kilian, Charlie Finch. (Image credit: Norbert Zacharias/USNO.)

In September 2015, URAT arrived at Cerro Tololo, and only a month later a Southern Hemisphere robotic survey was initiated. The URAT deployment was a joint effort between folks from USNO and CTIO. URAT moved into the 16-in telescope building—the previous home of the USNO CCD Astrograph Catalog (UCAC) project astrograph—next to the 0.9-m telescope dome on the top plateau. A new, automated Ash dome was acquired by USNO and shipped along with the mount, telescope, and camera, all in that red container, which now can be used for other purposes.

The USNO Robotic Astrometric Telescope. The white top box serves as dust protection and contains the motorized lens cover (206-mm entrance pupil aperture). The blue dewar contains four big CCDs (111 million pixels each) and has a 300 mm dewar window that also serves as the bandpass filter. Note the moving counterweight on the left arm, which is needed to balance the changing weight of LN2 fill of the dewar. (Image credit: Norbert Zacharias/USNO.)

This telescope uses the "redlens" of the all-sky UCAC project with a completely new tube assembly designed and constructed by the USNO instrument shop in Washington, DC. Contrary to the UCAC program, the 9-degree-diameter field-of-view (FOV) of this extraordinary lens is utilized with the "4-shooter" camera, consisting of 4 STA1600

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URAT at CTIO continued

CCDs with 10,560 by 10,560 pixels each plus three smaller guide/focus CCDs. In numbers of pixels this camera thus falls only a little short of the DECam at the 4-m telescope, covering 28 square degrees per exposure with 0.9"/px resolution.

The instrument is operated by a single Linux PC with multiple interfaces, many of which go through a Galil controller. A Boltwood cloud sensor provides environmental data for safe operations. A single command triggers start of operations for a given night. Progress control and override commands can be issued through a command line network connection. Raw data reductions and backups are performed during the daytime with a second Linux computer. A copy of the raw and processed pixel data (about 0.5–0.8 TB per night) is periodically shipped to Washington, DC, on external hard drives.

URAT North data mining to obtain parallaxes of nearby stars is in progress. The northern survey increased the average number of stars per square degree by a factor of four over UCAC with about four times higher positional precision. The southern survey is aiming mainly at the very bright stars where performance of the astrometric ESA Gaia space mission is unclear at the moment. The first Gaia data release, expected for mid-2016, will likely provide mas accurate positions for most stars in the ~5–20.5 mag range.

URAT observes all stars brighter than magnitude 4.5 individually in its single 680–760 nm bandpass using an objective grating and a neutral density (ND) spot filter on the dewar window, which also serves as the bandpass filter.

Accurate positions of these bright stars are obtained from measuring the centers of the first order diffraction images behind the ND spot filter with respect to the stars in the 2.65 x 2.65 degree FOV of a single CCD detector. In addition a shallow, quick, general sky survey is performed with URAT covering the southern sky up to a declination of about +25 deg. This general survey provides accurate positions for stars roughly in the 3.5–17 mag range. Initial astrometric reductions will be performed using UCAC4 reference stars while later reductions will use Gaia data.

A one-year observing program is envisioned for URAT at CTIO to obtain positions of these bright stars at about six different epochs with about 600 sec total integration time on each target star. A 5–10 mas positional accuracy at mean epoch is expected. This project is driven by DoD requirements to provide accurate positions of these bright stars at current epoch, a significant improvement over the Hipparcos Catalog data. The data will be made public for general use and should complement the Gaia data over the next few years.

We are grateful for the enthusiastic and knowledgeable support this project has received from CTIO through a contract with AURA.

CHIRON Data Reduction

F. M. Walter (Stony Brook University)

The CHIRON spectrograph (Tokovinin et al. 2013, PASP, 125, 1336) is a high throughput, highly stable fiber-fed echelle spectrograph mounted on the CTIO 1.5-m telescope. Operated by the SMARTS consortium, data are obtained following acquisition and delivered to investigators. The standard data reduction scheme, described by Tokovinin et al. (2011, *www.ctio.noao.edu/noao/sites/default/files/telescopes/smarts/tele15/chireduce.pdf*), is optimized for radial velocity searches for exoplanets. For the past three years I have been using CHIRON to study the temporal evolution of novae, which presents a different set of challenges.

Close examination of the standard data products for fiber-mode (R=28,000) observations show the following deficiencies (*note*: instrumental background is not subtracted; see also Figure 1):

- The tops of bright emission lines are often flagged as cosmic rays/bad pixels and removed (Figure 2).
- Flat-fielding retains the shape of the blaze function, which complicates continuum removal when the line widths are a significant fraction of the free spectral range.
- Orders 126-138, from 4080Å through 4600Å, are not extracted.
- Masking of the ends of the orders reduces spectral coverage beyond about 6500Å.

I have written a new set of extraction software, *ch reduce*, that ameliorates these issues. *Ch reduce* is written in the IDL language. It yields full spec-

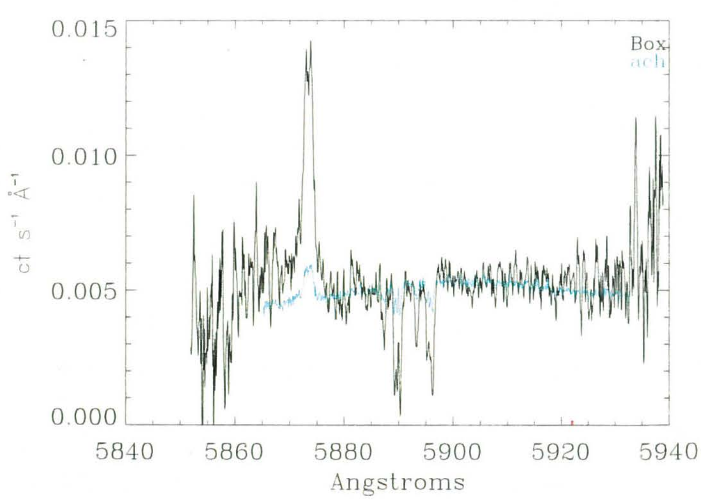

Figure 1: A comparison of the boxcar extraction (black) with the standard extraction (aqua) for the sodium D line region of Nova Sco 2015 (image chi150729.1124). The standard extraction is scaled so the medians match (units are counts/Å/s). Note that the line strengths are much weaker in the standard reduction, while the continuum S/N is higher, indicating that the background has not been subtracted. The emission line is He I λ5876Å. Multiple velocity components are visible in the Na D1 and D2 lines. The low velocity components are galactic foreground; the blue-shifted absorption lines are ejecta from the nova. On this date the V magnitude was about 15.0.

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