Annual RFO Research Report 2024

Overview

The goal of the Research Committee is to support docents and students as they learn how to do astronomical research using both the instruments available at RFO as well as instruments available for public use remotely. All areas of astronomical research are welcome and the committee meetings and observing sessions at the observatory are used to teach, learn, develop skills, increase understanding and, in some cases, to publish the results of the work that is being done.

During 2024, the Research Committee was able to:

- Improve the capability of the main science instrument at RFO, the Ritchey-Chretien 20-inch telescope (RC20), by installing two new cameras and upgrading the control computer.
- Train docents to operate the RC20 specifically for taking science and calibration images.
- Operate an online group to teach students how to do double star astrometry research.
- Support a high school Astronomy 101 variable star Research Friday initiative.
- Make observations of variable stars.
- Make observations of exoplanet transits.
- Analyze variable star observations with differential photometry and report findings to the AAVSO database.
- Upgrade the image repository software with feature improvements.
- Design an image calibration pipeline that is being implemented.
- Request and analyze images from AAVSO AstroNet telescopes.
- Deliver training on VPhot, the AAVSO differential photometry program, including basic Python programming and use of images from the RFO image repository.

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Observing for Research

Observation Target List

The number of science images taken during the year is an indication of research activity, and while not the only indicator, it was good to see that with over 3,000 images taken we quadrupled the activity of 2023. The Research Committee maintains a list of possible targets for regular observation to study variability. The list includes cataclysmic variables, R Coronae Borealis variables, Cepheid variables and other targets of interest. In addition, multiple exoplanet transits were observed in 2024. The top targets in 2024 were:

No Target (an unnamed exoplanet)	703
HIP 109754 (exoplanet)	623
HIP 18532 (exoplanet)	602
GCVS Z UMi (RCB)	189
GCVS TT Oph	120
GCVS Z Dra	110
GCVS5 V1226 Her	100
GCVS T CrB	97
GCVS EP Lyr	92
GCVS Z Aur	74
GCVS Z Cam	65
GCVS V0504 Per	56
GCVS AD Aur	53
GCVS5 NP Cam	51
GCVS SS Cyg	41
HIP 99571	39
GCVS V Vul	31
GCVS U Gem	17
HIP 78322	15
GCVS SW UMa	12

Remote observing at AAVSO AstroNet

AAVSO members can apply to have observations made on the telescopes of AstroNet that are privately maintained by other AAVSO members. During 2024 one target, Z UMi, was accepted as a target on AstroNet and some images during the dimmest part of the cycle that Z UMi is in were taken and provided to an RFO researcher. Since images are dropped off in the user's

VPhot account fully calibrated, it is likely that more of these requests will be created by RFO researchers in 2025.

Differential Photometry

Calibration Analysis

- Gordon Spear completed work on creating Master Bias, Master Dark and Master Flat images for the Atik16000 images taken in 2023 and posted them to imagelib where they can be used by others doing photometry with 2023 images.
- Spear presented a paper on the calibration images at the March meeting.
    - A uniformly illuminated whiteboard was used for flats.
    - The flats revealed donuts (dust on the filter), cheerios (dust on Perseus mirror) and specks (dust on the imaging cover slip) in the optical path.
    - I filter images were calibrated with I filter flats and demonstrated that the ‘swoosh’ artifact was in the optical path and could be removed during calibration.
    - Spear created a master dark for V and I filters.
- Calibration images were taken throughout the year. Spear set up SkyX so that color camera calibration images were taken automatically and used to calibrate images taken during public events.
- A design for a calibration pipeline was written by George Loyer and reviewed by the Research Committee. The pipeline will build on the imagelib system created by Dave Kensiski and the goal is that all science images will be calibrated within 24 hours. Development work in Python will begin in 2025.
- Calibration frames were taken throughout the year as work to calibrate science images with the new monochrome camera were going on.

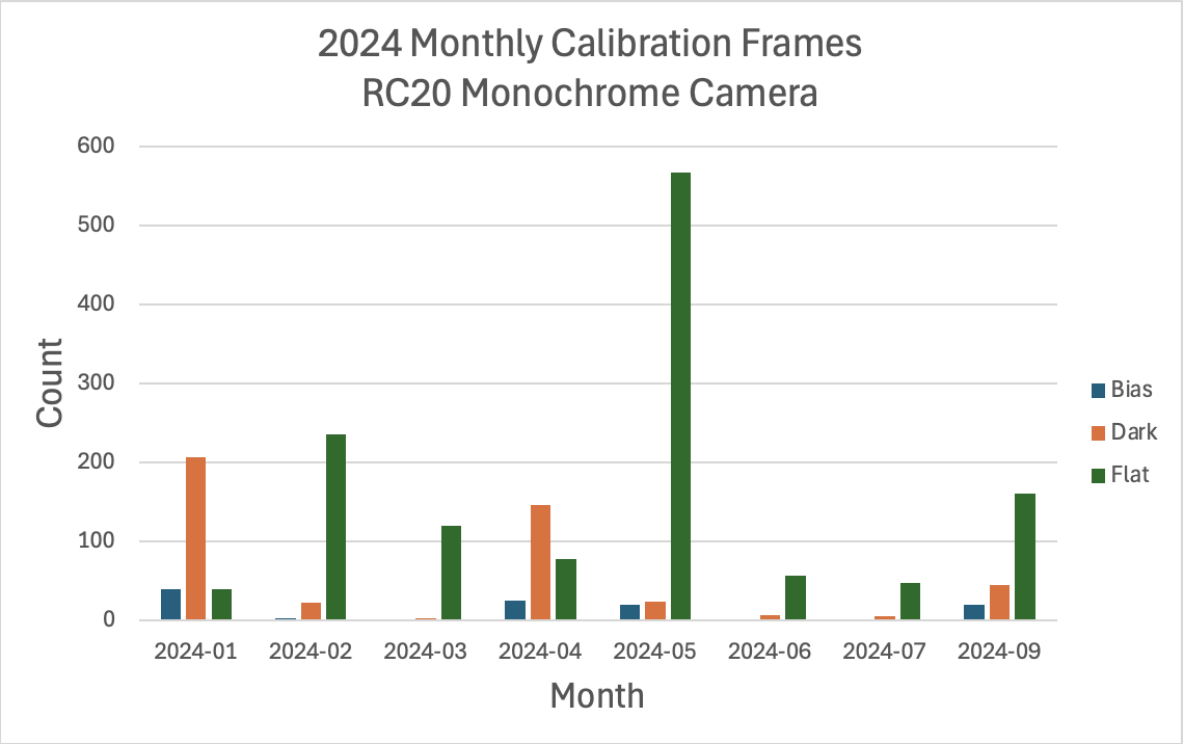

Figure 1. Monthly counts of calibration images taken with the RC20 monochrome camera.

Exoplanet Transits

During 2024 observers and analysts at RFO made their first image sequences of exoplanets in transit across their host stars. Judd Reed, George Loyer and Gordon Spear planned observations using the resources of the NASA Exoplanet Archive and the AAVSO. Reed and Spear then organized a series of campaigns of observing for nearly a full night to capture exoplanet transits for several objects, some more than once. While multiple campaigns failed due to weather, there were several successful campaigns that collected data for a full transit. Spear did the photometry and wrote up the analysis in a set of papers published on the RFO Research web page.

Predictions came from three different sources for the different campaigns. The NASA Exoplanet Archive, a Czech exoplanet predictions site, and a Swarthmore Transits program, (TAPIR), all web-based.

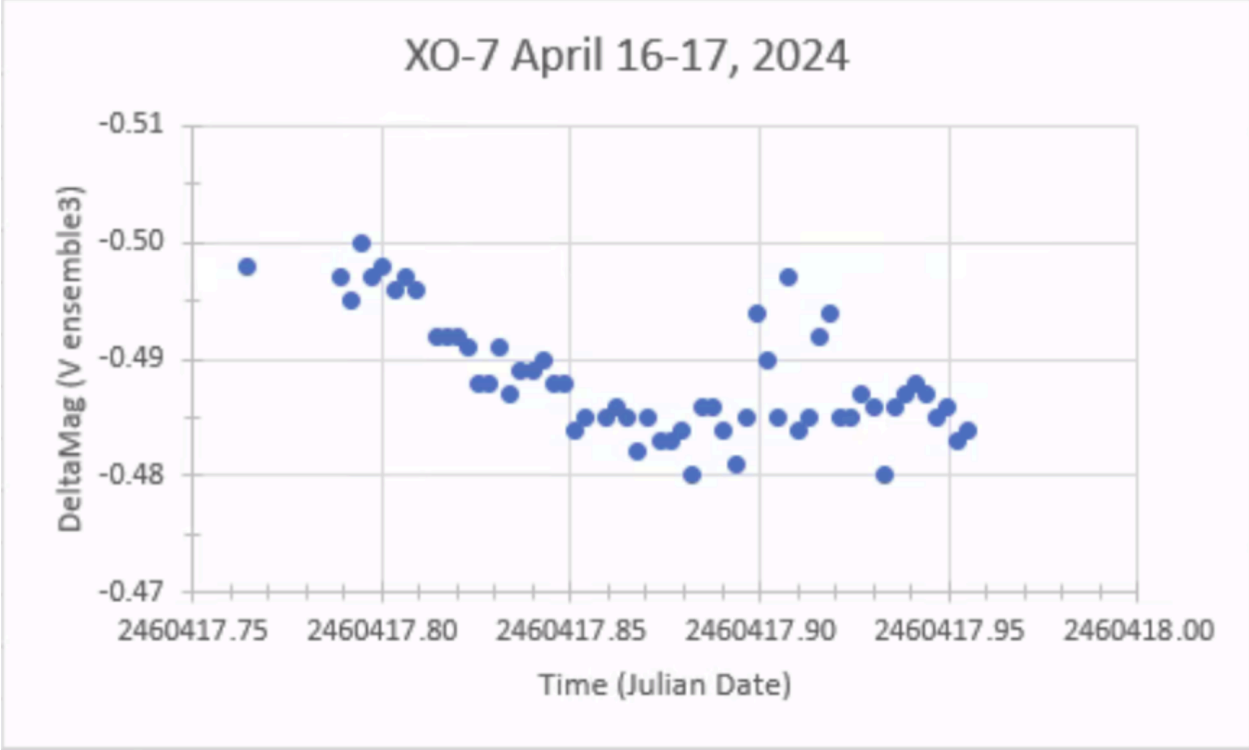

Figure 2. Exoplanet XO-7 transit on the night of April 16-17. Clouds caused significant noise during the session. Judd Reed, Gordon Spear

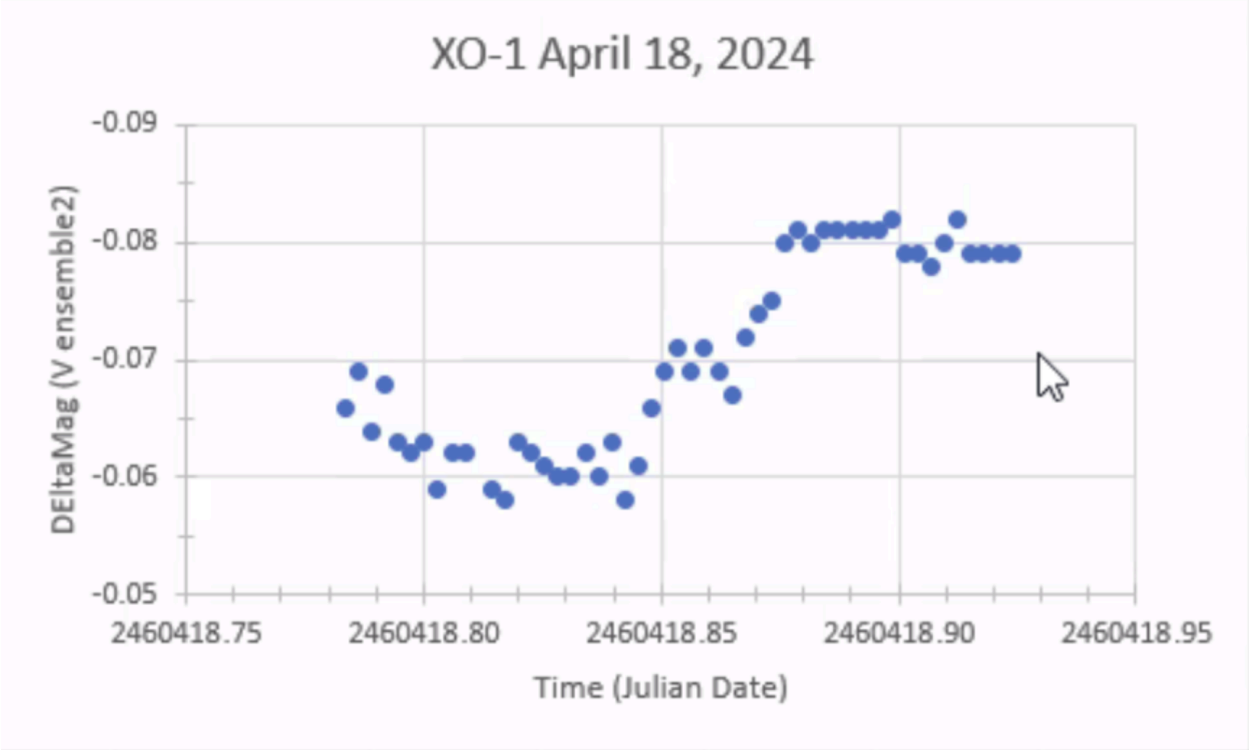

Figure 3. Exoplanet XO-1 transit on the night of April 18, Judd Reed.

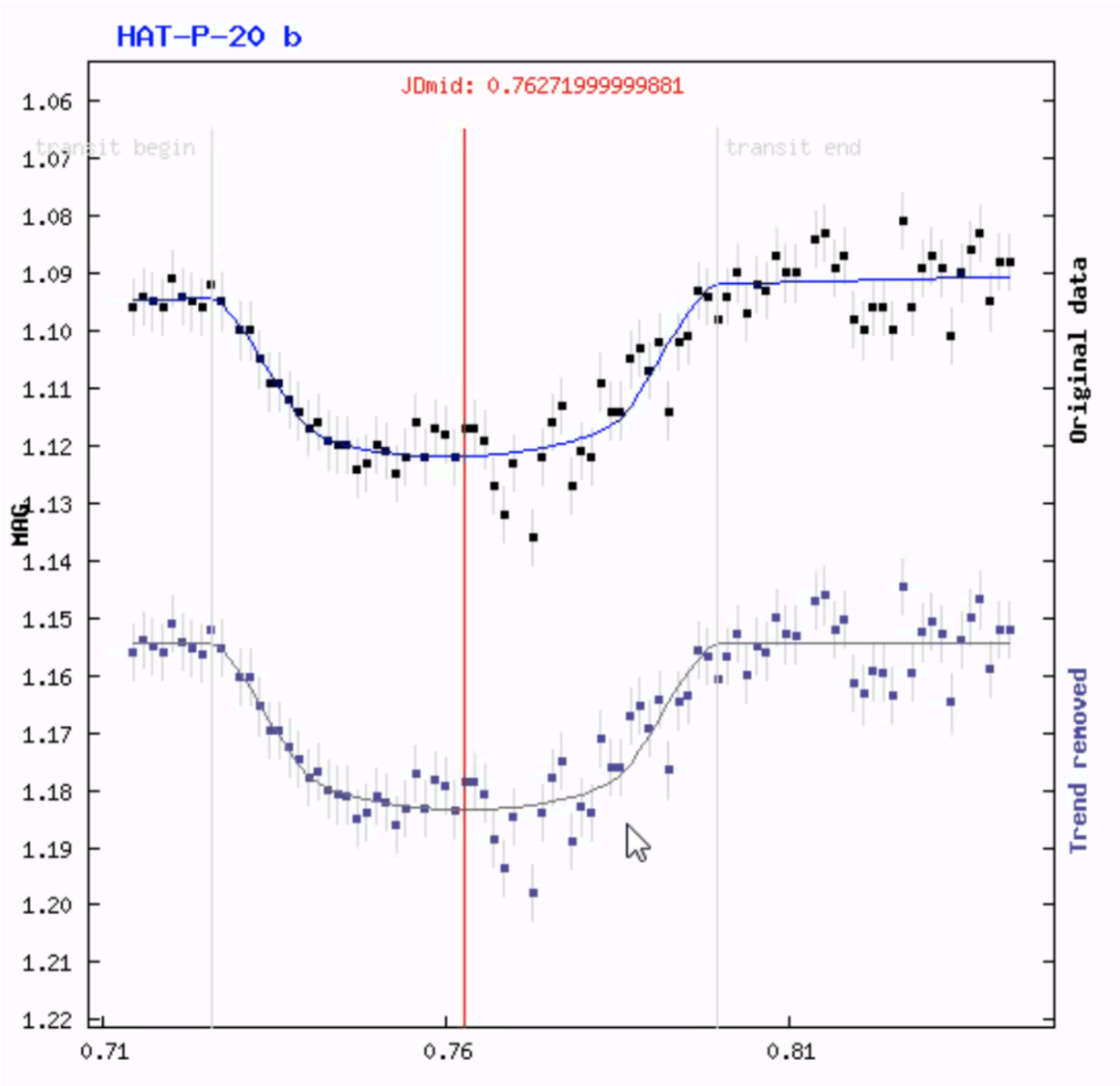

Figure 4. Exoplanet Hat-P-20b transit with raw data and data with Trend Removed to account for clouds during the session. Gordon Spear

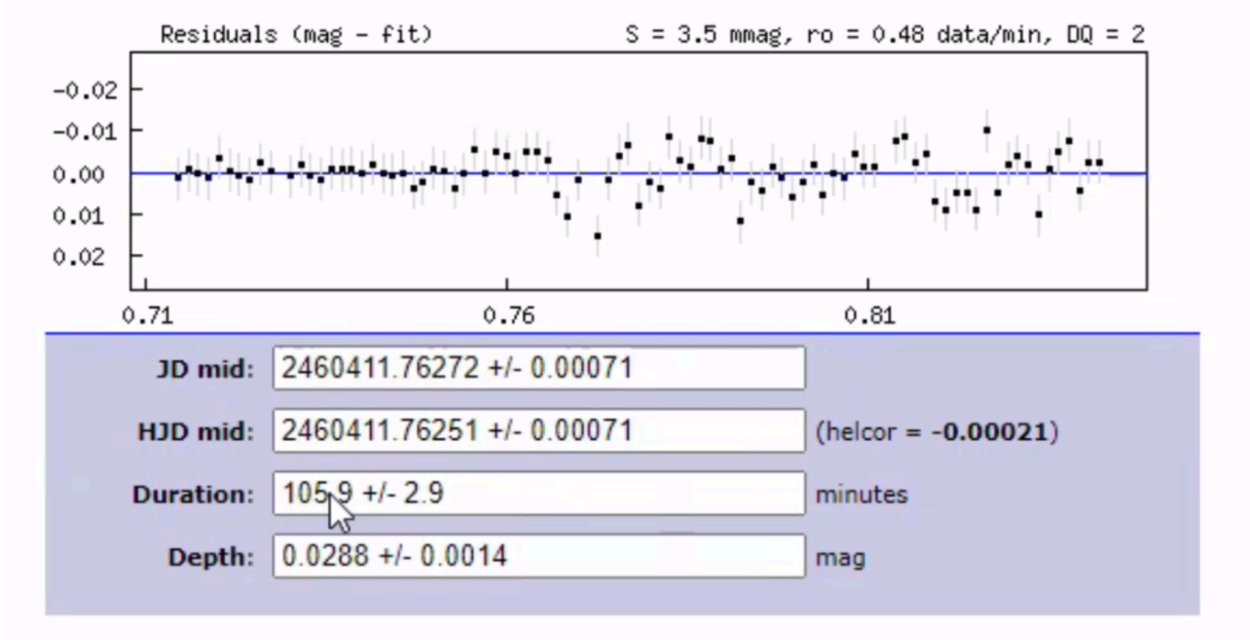

Figure 5. Data quality analysis of the aggregate of the exoplanet observations. Gordon Spear.

- Photometric analysis was done with AIP4WIN with uncalibrated images. Spear used three comp stars.
- The magnitude change for all three exoplanet transits was on the order of 0.02 magnitudes (millimag).
- He plotted the data points as a light curve, and provided a similar light curve that included error bars for each data point. The error bars made it clear where clouds got in the way on two of the exoplanets.
- XO7 transit did not end when expected, and other observations the next night showed that the star had still not returned to the expected brightness.
- XO1 had no clouds, but the light curve has a bump on the rise that shouldn't be there.

Z Draconis Light Curve

John Gregg reported doing observations throughout 2024 of Z Draconis and did differential photometry to create a light curve that captured an eclipse of this Algol eclipsing binary star. This work is continuing in 2025 so that he can compare the period of the eclipses to data he has gathered from an observer in 1912 to see if the period has changed.

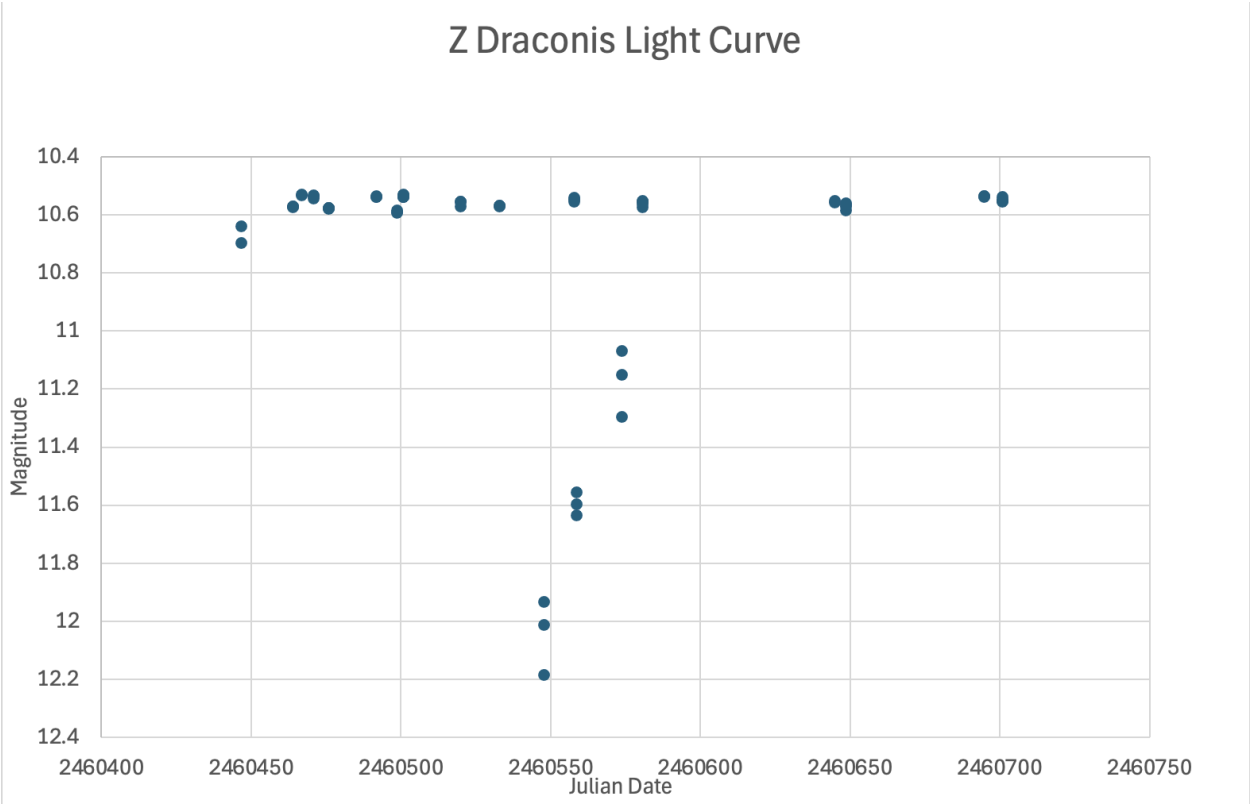

Figure 6. Z Draconis light curve during late 2024 campaign. Credit: John Gregg

Z Ursa Minoris Light Curve

Multiple observers at RFO took images of Z UMi in both V band and I band (infrared) filters throughout the year. In September of 2024 this R Coronae Borealis star began to drop in brightness and it was quickly clear that this would be the kind of event that marks this type of variable star where brightness drops 7 to 8 magnitudes in a relatively short period. Observers adjusted image exposures and the number of images taken as the event progressed to maintain a high enough signal to noise ratio (SNR) for reporting to the AAVSO. The full event was observed and continues to be observed as Z UMi reached a minimum in December 2024 and then began to brighten again. Observers are continuing to take data both at RFO and using AAVSOnet images.

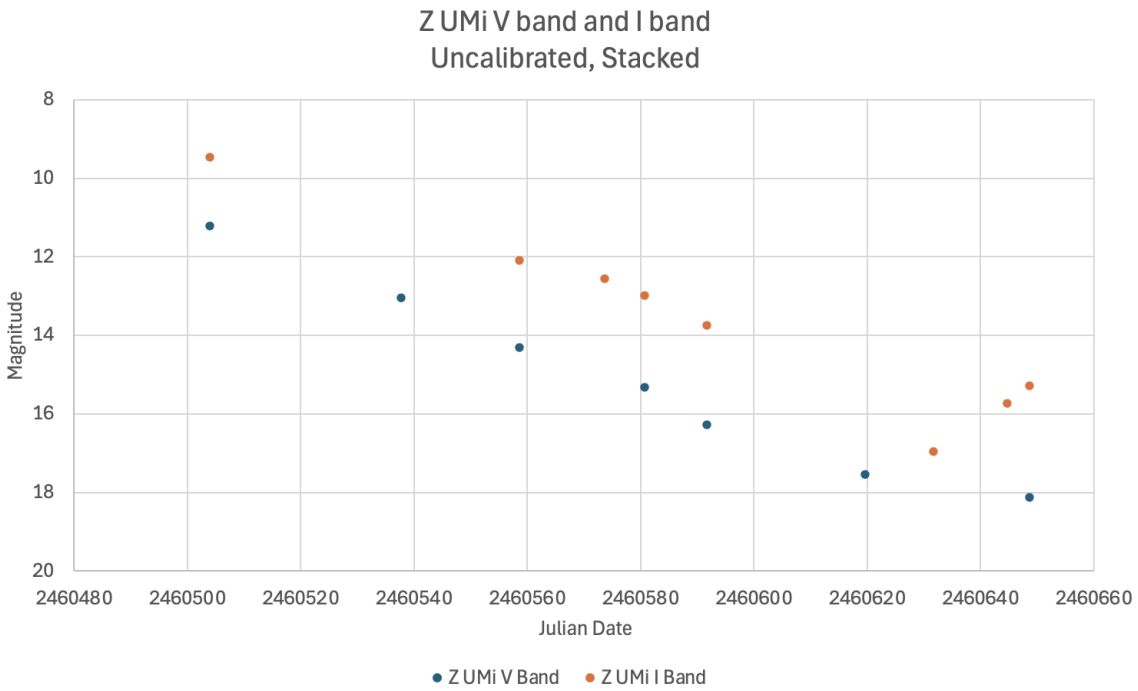

Figure 7. Z UMi light curve during 2024. Credit: George Loyer.

Comparing the V-I magnitude difference to the V filter data, the data showed that as the star got dimmer (to the left in the figure) the magnitude difference between I and V became greater. Another way of stating this finding is that the I filter dimmed less than the V filter brightness. This could be expected because the source of the dimming is an infrared-bright cloud of carbon dust surrounding the star.

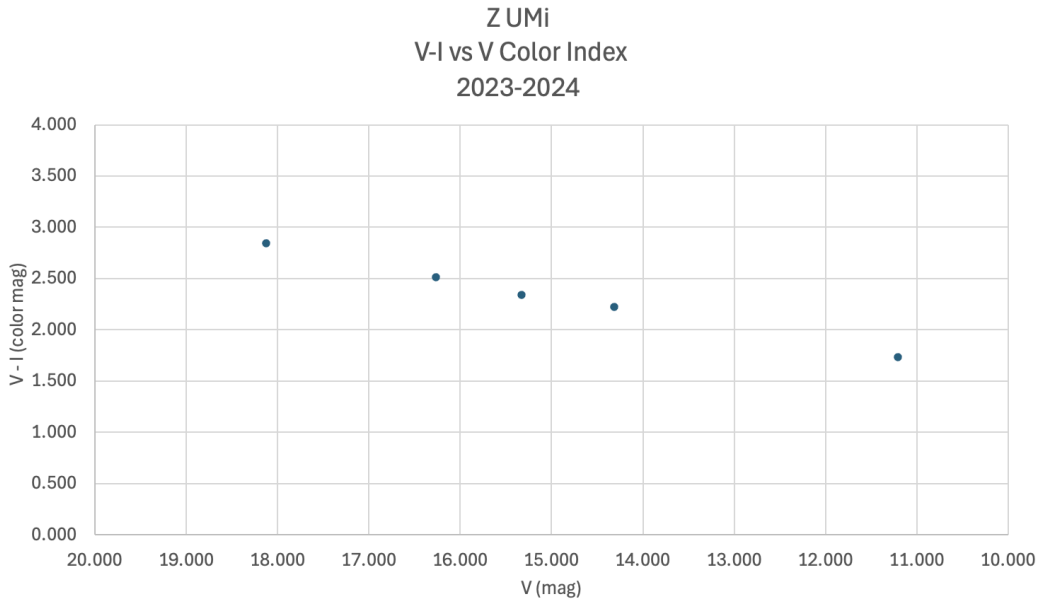

Figure 8. RFO data comparison of V and I difference over a range of magnitudes. Credit: George Loyer

Training: Differential Photometry

- Rachel Freed trained the Research Committee members on how to use AfterGlow software, available online, to do differential photometry.
    - While images can be analyzed without WCS coordinates (precise coordinates of the center of the image), the best results come from using plate-solved images. Since SkyX does not record WCS coordinates, RFO images need to be processed at astrometry.net.
    - The photometry from AfterGlow can be combined into a complete light curve with SkyNet.
- George Loyer trained interested Research Committee members on how to use VPhot, the AAVSO photometry software. Meeting the prerequisites prepared participants for submitting data to the AAVSO database by becoming AAVSO members and obtaining an Observer Code.

Research Instrumentation and Support

The work on the instrumentation in the Robert Ferguson Observatory can be divided into New Instrumentation, Maintenance and Troubleshooting and Support Work. Research is done only on the RC20 telescope in the East Wing of RFO, so the instrumentation work all refers to that telescope in the East wing of the observatory.

New Instrumentation

RC20 Upgrades

- The ZWO ASI294MC Pro Color Cooled Astronomy Camera, nicknamed CoCa or just the color camera, was installed in January and configured over the following three months to be parfocal with other instruments and to work with platesolve.
- The ZWO ASI2600 Pro USB3.0 Cooled Monochrome Camera, nicknamed MoCa or the monochrome camera, was installed in January, replacing the Atik16000 at the exit port of the filter wheel.
- Made switching between cameras much simpler.
- The Star Analyzer Grating 100 with associated prism to correct aberrations in the grating were checked for fit with the Atik16000 during the installation of MoCa. We got the critical measurements to have an adapter made. These gratings will allow us to take research spectra of low dispersion to identify specific stellar types by spectral type.
- Installed and configured the 64 Bit Version of SkyX. The 32 bit version is deprecated by support. Worked through multiple configuration issues to get it fully working with the RC20 hardware.
- Upgraded the control computer on the RC20 from an Eagle 4 to Eagle 5, with faster processor, increased memory and increased solid state disk.

Boltwood Weather Sensor

The Research Committee supported a grant request to acquire a new Boltwood Weather Sensor to replace the out-of-date unit that we currently have installed. The new system will be installed in 2025 and will be integrated into the observatory systems, moving us toward an automated observing system.

Maintenance and Troubleshooting

Infrared filter “swoosh” identified as intrinsic chip response to IR

Observers reported last year that images taken with the I (infrared) filter have an image artifact that looks like a “swoosh” of noise across the entire image. The filter was cleaned and dusted but it had no effect on the artifact. Calibration images were taken with the I filter and calibrating the images with the dark filter completely eliminated the artifact, indicating that it was caused by the difference in the way that the pixels on the imager reacted to the IR light.

Declination drive play reduced with worm gear adjustment

The maintenance team made adjustments to the worm gear engagement with the main gear that reduced the play without causing the drive gears to bind with each other.

RA tracking rate error

During exoplanet sessions that lasted 3-4 hours, Gordon and Judd reported a tracking error of 1 arc minute per hour in RA. After doing some research in the Astrophysics documentation, it was found that there is software that may or may not be already installed that allows the user to directly adjust the tracking rate to correct for this small error that is expected and is related to the latitude of the observatory.

RC20 Mirror Cleaning

During a May visit by Viavi professionals donating their time and expertise RFO team members learned how to clean mirrors with professional-level materials and methods. In addition to cleaning the 40-inch primary and secondary mirrors and the 8-inch objective lens, the primary and secondary mirrors of the RC20 were also cleaned. The cleaning was observed to remove many of the “donuts” from the uncalibrated images.

Control Computer Heat Shutdown

Operators of the RC20 experienced a self-initiated shutdown of the Eagle control computer when the temperature of the CPU exceeded a threshold on a very hot day on June 22. Attempts to reboot the computer failed both because it was still too hot and because unrelated disk equipment installed was preventing a clean reboot. While several methods to keep the East

wing cooler were discussed, in the end, operators simply shutdown the Eagle when hot weather threatened.

Filter Wheel Control Anomalies

Observers reported during an exoplanet campaign that the filter wheel seemed to be randomly restarting and moving during exposures. Troubleshooting the hardware and software turned up an intermittent USB cable. Once that was replaced and procedures were changed so that the filter wheel is not started up until the camera is powered up and online eliminated all of the unexpected restarts of the filter wheel system.

Focuser Reliability

Observers reported that the focuser was starting up with different values ranging from a number less than 10 and up to 20,000 as the position of the focus setting. Observers kept a log of the variations but troubleshooting didn't turn up any problem in the hardware or software. The problem stopped occurring after a month or so, but no one knows why.

ImageLib Feature Improvements

Dave Kensiski added a feature to the imagelib web page so that users can request just calibration images, just target images, or both. The page also allows the user to search for images by name and by date range.

Image Calibration Software Pipeline

Loyer published a design for a Python pipeline that would take raw science images and calibrate them with bias, flat and dark images within about 24 hours of the original image acquisition. Development work will start in 2025 on the software.

Outreach for Student Focused Research

Double Star Observations

Rachel Freed taught a Double Star Science class for high school students (Fall 2023) that was funded by the Astronomical Society of the Pacific. In 2024 their papers were published in the Journal of Double Stars (see Research Publications below). The class was repeated in the Fall of 2024 and a team of three students is in progress with writing their paper for publication (see Research Publications below).

Buckingham Charter School Astronomy Research Fridays

Multiple members of the Research Committee worked with teacher Robby Tabor at Buckingham Charter School to support his creation of an Astronomy 101 class for sophomores, juniors and

seniors. The class includes a series of 11 Research Fridays where the students will get hands-on experience with doing astronomical research. The Research Committee provided consulting on content, images acquired on the RC20 telescope, access to analysis software and in-person support for students during the Research Friday sessions.

Research Publications

RFO Research Web Page

The RFO Research page on the RFO website was completely revised with the latest research news from the RFO Research Committee by George Loyer. The page now has a short synopsis of research that has been performed and/or published, with links to the full papers for those who want to dig deeper. The new page has resulted in several new members of the Research Committee from members of the public who have become docents so that they could contribute to our research efforts.

Confirming RCB IR Excess with AllWISE and 2MASS

George Loyer and Adithya Vasudavan, IR Excess paper. Paper submitted to JAAVSO and peer reviewed, currently being revised.

Double Star Observations

A five person student team from Dr. Rachel Freed's Double Star class published their paper titled "Astrometric Measurements of WDS 22267+4433 ES 1346 AC". The paper from three local high school students from the Fall 2024 class is in preparation. Its title is:
New Astrometric Measurements of The Double Star WDS 04192+6135 and they expect it will be published in the April first Issue on the Journal of Double Star Observers website.

Z UMi

The R Corona Borealis (RCB) star, Z UMI, was observed during 2024 as noted above in Observations. Loyer submitted the uncalibrated data to AAVSO which was in agreement with observations made by other observers. Only RFO submitted data on the I (infrared) filter which showed an increasing difference between I and V filter magnitudes as the star dimmed.

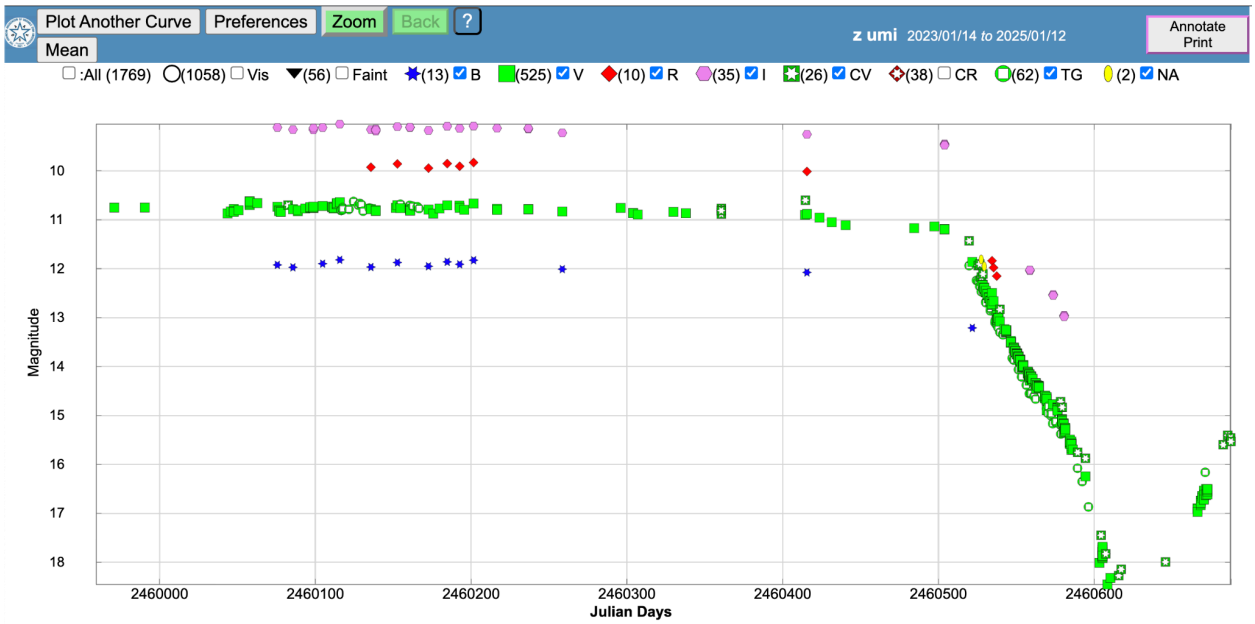

Figure 9. AAVSO light curve for Z UMi requested on 1/12/2025

Research Committee

The RFO Research Committee meets monthly via Zoom on the fourth Monday. In addition to meeting as a committee, there were frequent observatory sessions for observing, instrumentation changes, software installations and maintenance and training.

Active members of the Research Committee, in alphabetical order, are Joseph Byrnes, David Cranford, Byron Durkee, Rachel Freed, John Gregg, George Loyer, Brian Kellogg, Ryan McDaniel, Marek Mierzwinski, Jim Mirowski, Jud Reed, Gordon Spear, and Phil Sullivan.

George Loyer organized the Zoom call and the agenda for each meeting and recorded a report to the board from each meeting.

Annual Report submitted by George Loyer, committee chair.