# Exoplanet Detection with Small Telescopes at Deep Springs

Presentation to the Deep Springs Community
by Brian Hill
December 13th, 2019

# Exoplanet Detection with Small Telescopes at Deep Springs

I. Large Surveys and Small Telescopes

II. Saint Mary's College Milestones

III. Astronomy at Deep Springs College

# Large Surveys (SDSS)

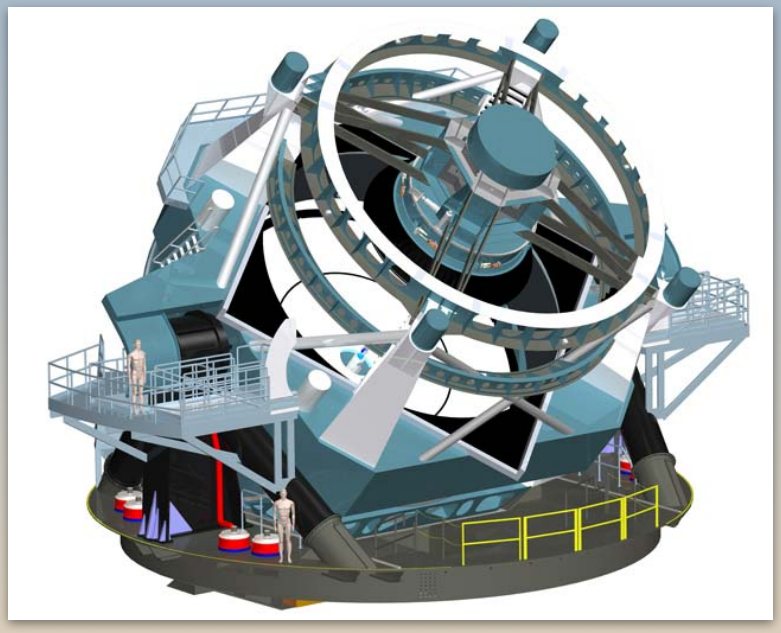
- Sloan Digital Sky Survey (SDSS)
  - Apache Point Observatory, New Mexico, 2788m (9,147')
  - 2.5m mirror, 30 4-Megapixel Cameras
  - 400,000,000 Objects (video with map of universe)
  - Spectroscopic Surveys of 3,000,000 Objects.
  - Survey IV: 2014-2020, infrared, more detail

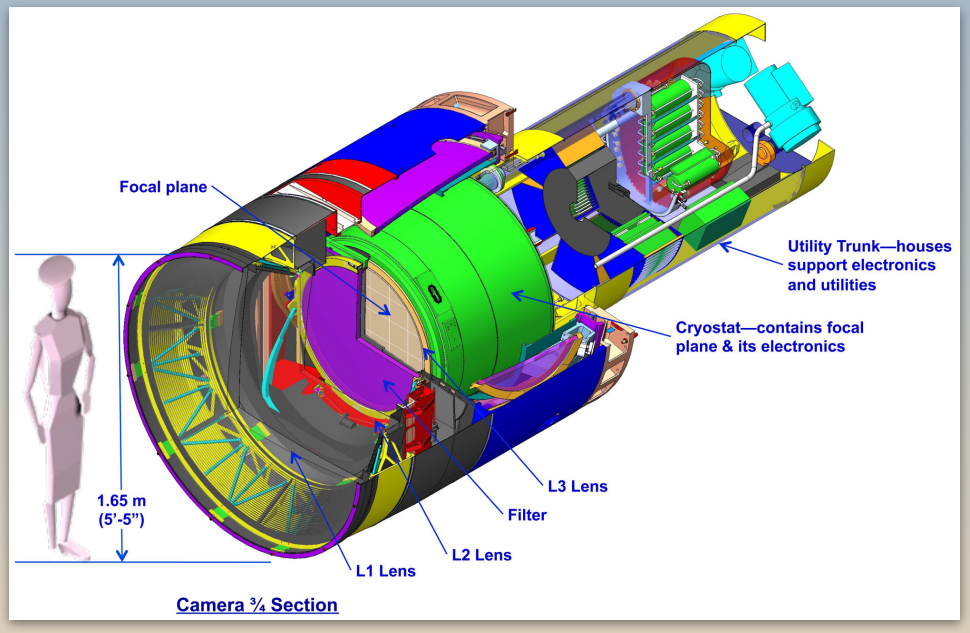
# Large Surveys (GAIA)

- GAIA Space Telescope
  - European Space Agency Satellite (orbiting L2)
  - 1 Billion Stars, 100,000,000 Radial Velocities (5-year mission begun 2013, extended through 2020)
  - Mapped in 3-D (video documenting data-taking process)
  - 10 Mirrors, 10nm Tolerances, 1 Gigapixel Camera (optics)
  - 5 Micro Arcsecond Ultimate Accuracy (science performance)

# Large Surveys (LSST)

- Large Synoptic Survey Telescope (LSST)
  - NSF/DOE, 2663m (8737') Elevation in Chile (site)
  - 8.4m (27') Mirror (optical design), 3.2 Gigapixel Sensor (camera)
  - Recording The Entire Sky Visible to the Telescope, 2x / week, for 10 years
  - Design and Funding Begun 2011, Primary Mirror Complete 2016, Dome and Summit Complete 2017, Project Complete 2022, Science Begins 2023 (schedule)

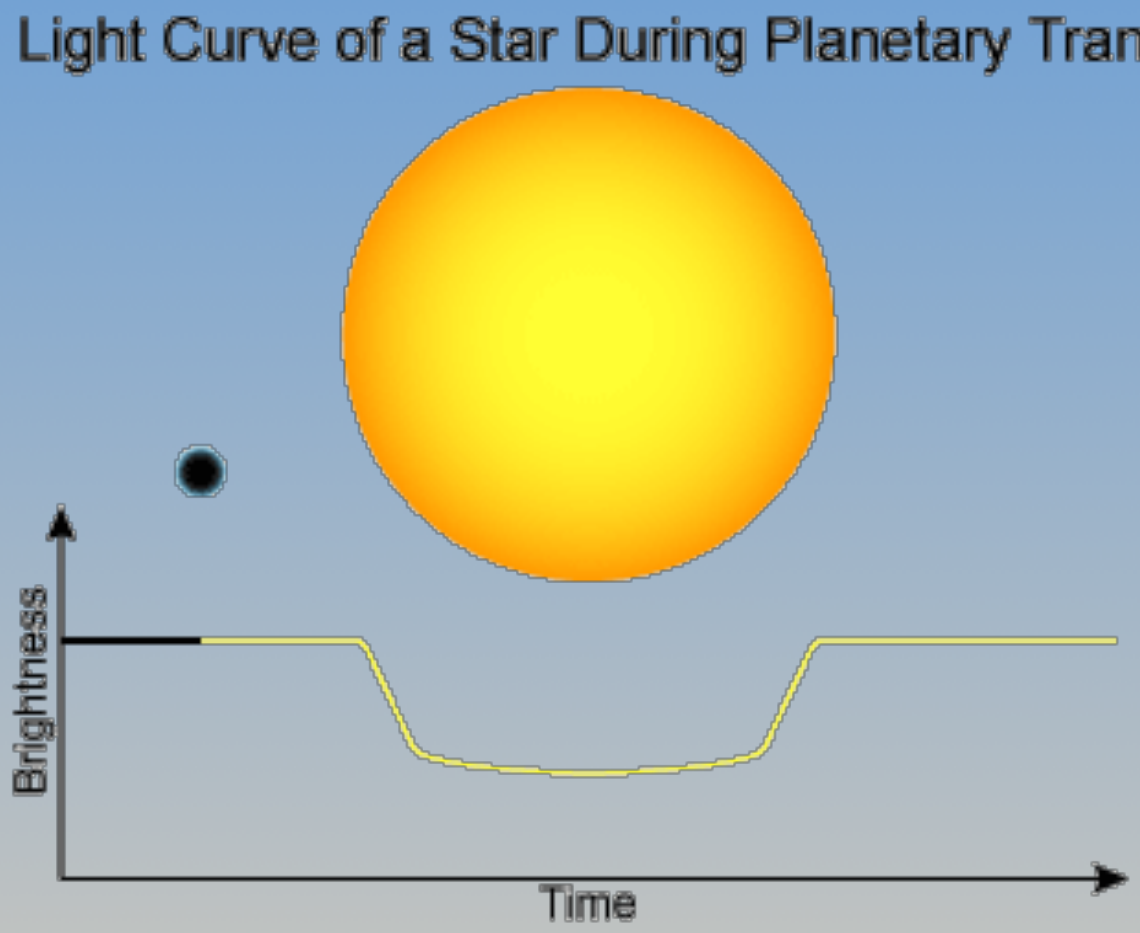




# Large Surveys and Small Telescopes

*Is there anything left for a small college to do?*

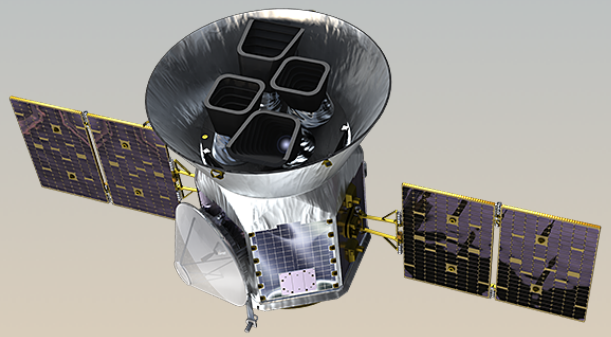
Yes! Exoplanet Transits (and other sources of variability)

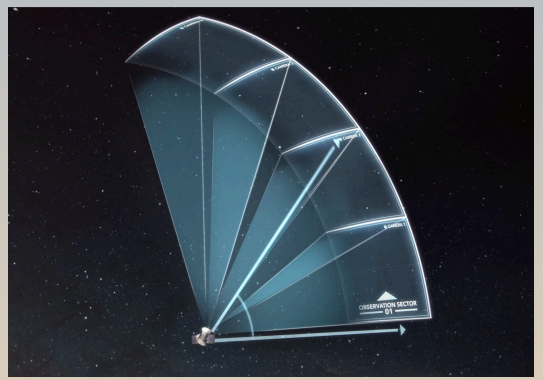


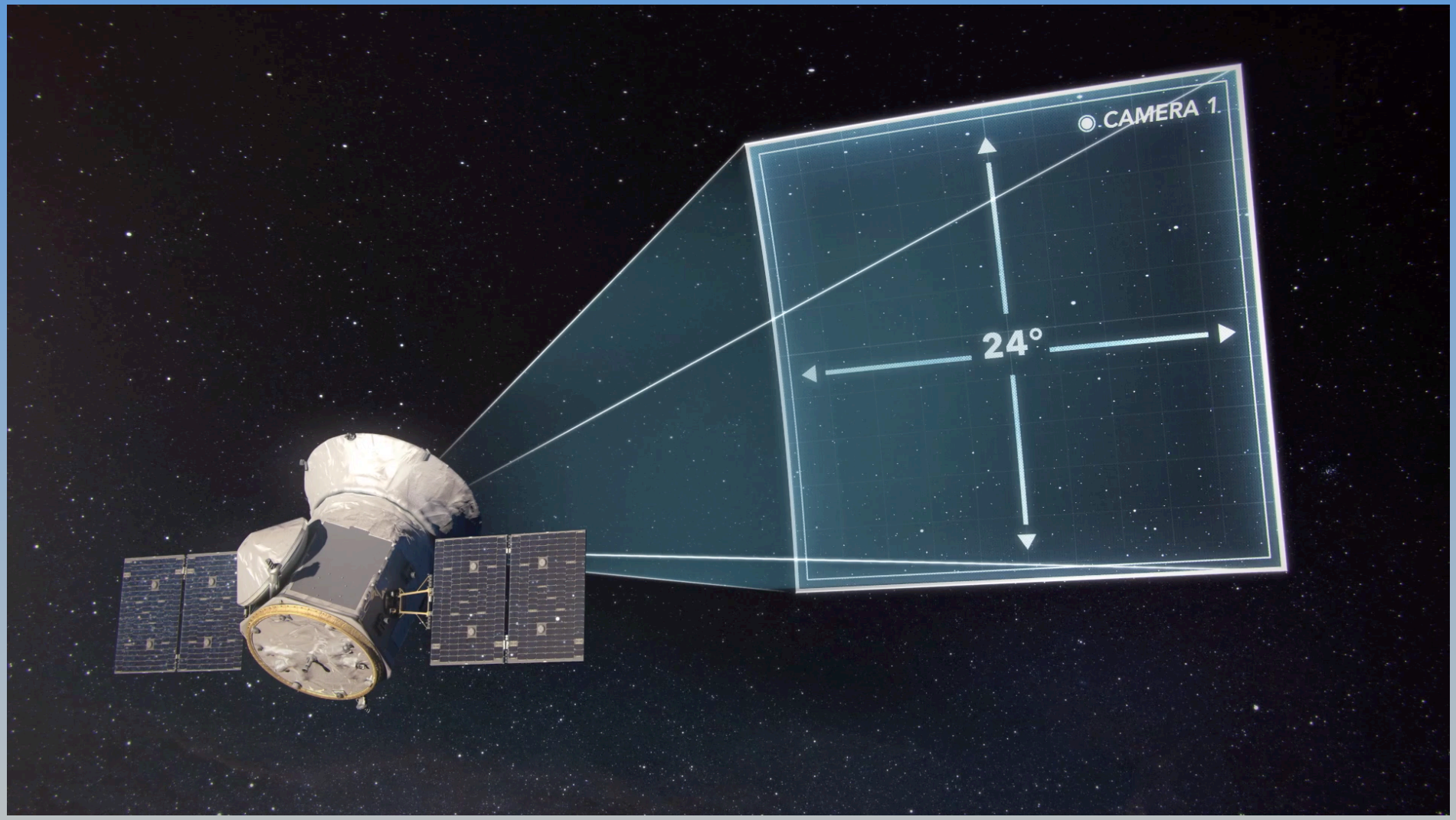

https://community.dur.ac.uk/physics.astrolab/exoplanets.html

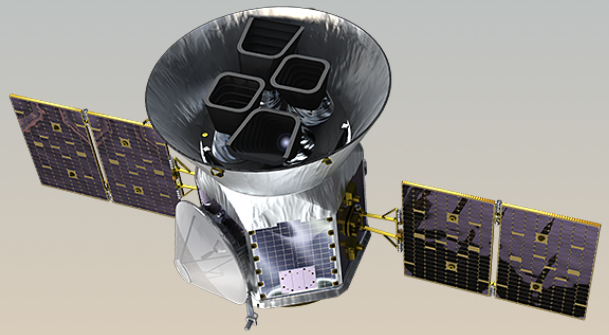
# Large Surveys (TESS)

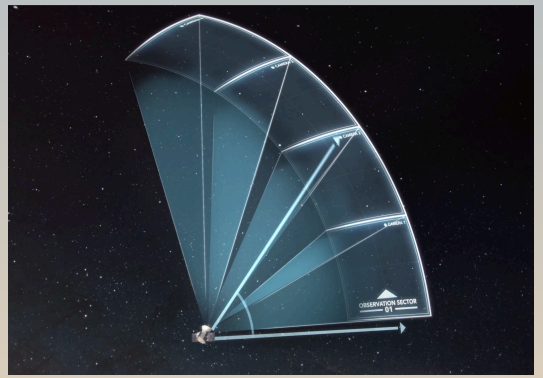
- Transiting Exoplanet Survey Satellite (TESS)
  - MIT/Harvard Center for Astrophysics/NASA (TESS website)
  - Launched April, 2018 (by SpaceX!)
  - Year 1: August 2018-July 2019, southern hemisphere
  - Year 2: August 2019-present, northern hemisphere
  - Four small telescopes, each imaging 24°x24° (NASA website)





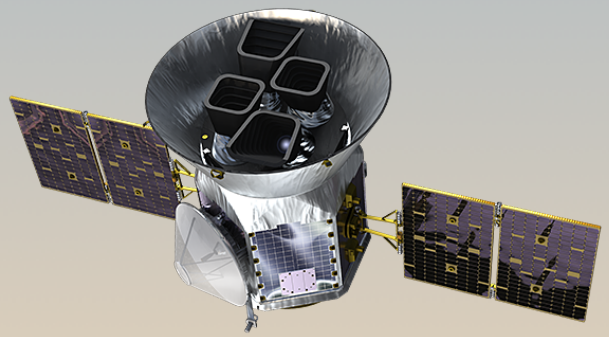

CAMERA 1
24°

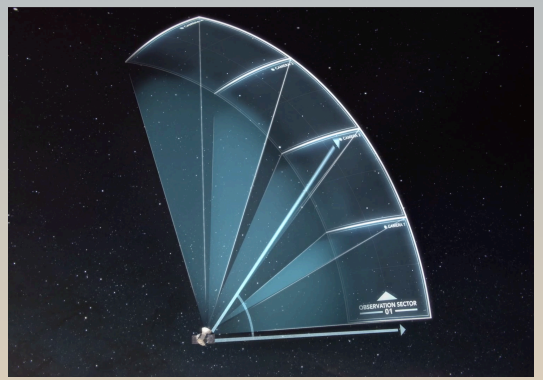




# Large Surveys (TESS)

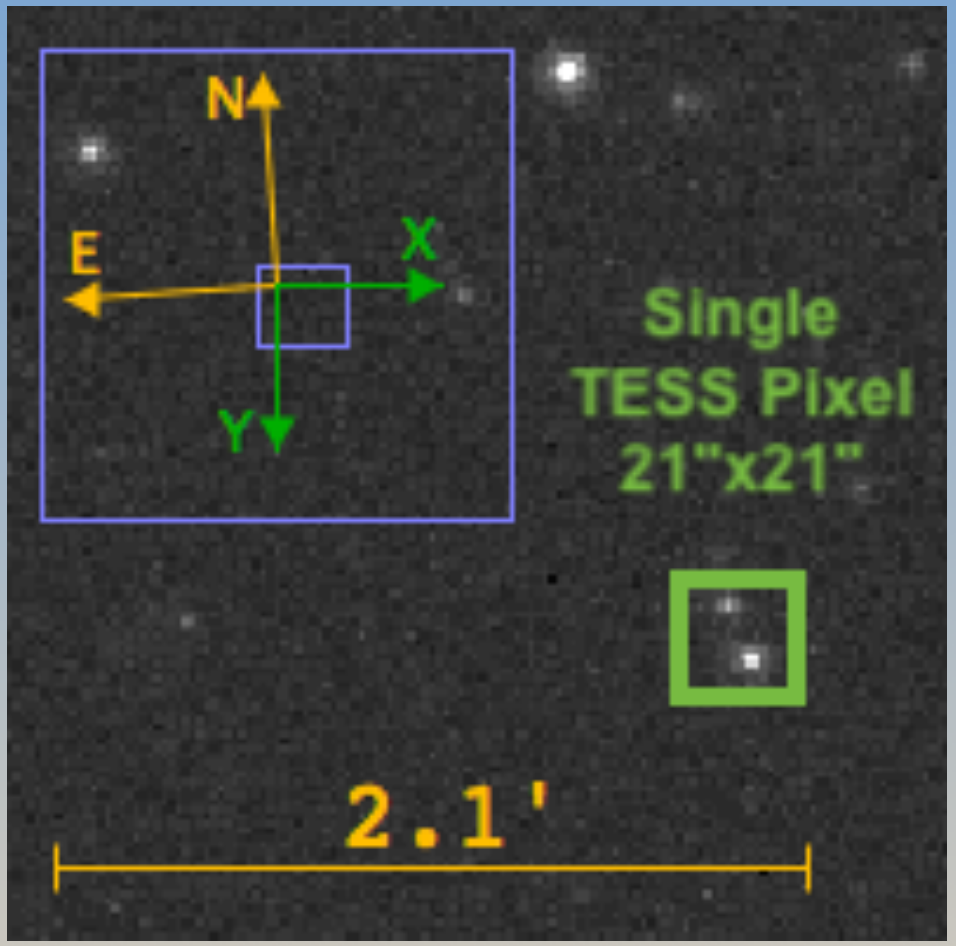
- Strong
  - Seeing: Space-borne
  - Coverage: very wide angle
- Moderate
  - Duratioon: 27 days on each sector
  - Cadence: every 30 minutes -- increasing to every 10 minutes in year 3
- Weak
  - Resolution: pixels are coarse 21"x21"



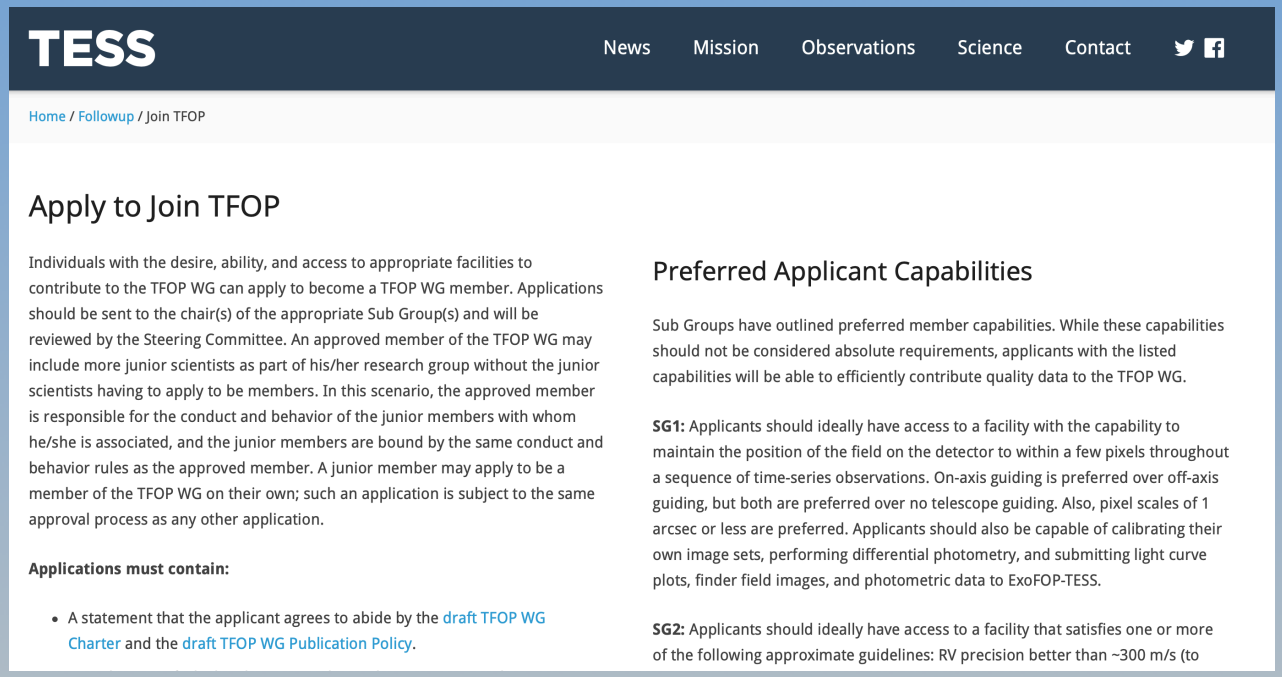


# TESS Pixels

- Single TESS Pixel is 21"x21" (arc seconds is a very small unit of angular size)
- Image taken with small telescope at Barcroft Field Station during seeing of 3 arc seconds
- For TESS, *everything* in the green square is a single shade of gray!



# TESS Follow-Up Observing Program (TFOP)



TESS

News Mission Observations Science Contact

Home / Followup / Join TFOP

## Apply to Join TFOP

Individuals with the desire, ability, and access to appropriate facilities to contribute to the TFOP WG can apply to become a TFOP WG member. Applications should be sent to the chair(s) of the appropriate Sub Group(s) and will be reviewed by the Steering Committee. An approved member of the TFOP WG may include more junior scientists as part of his/her research group without the junior scientists having to apply to be members. In this scenario, the approved member is responsible for the conduct and behavior of the junior members with whom he/she is associated, and the junior members are bound by the same conduct and behavior rules as the approved member. A junior member may apply to be a member of the TFOP WG on their own; such an application is subject to the same approval process as any other application.

**Applications must contain:**

- A statement that the applicant agrees to abide by the draft TFOP WG Charter and the draft TFOP WG Publication Policy.

### Preferred Applicant Capabilities

Sub Groups have outlined preferred member capabilities. While these capabilities should not be considered absolute requirements, applicants with the listed capabilities will be able to efficiently contribute quality data to the TFOP WG.

**SG1:** Applicants should ideally have access to a facility with the capability to maintain the position of the field on the detector to within a few pixels throughout a sequence of time-series observations. On-axis guiding is preferred over off-axis guiding, but both are preferred over no telescope guiding. Also, pixel scales of 1 arcsec or less are preferred. Applicants should also be capable of calibrating their own image sets, performing differential photometry, and submitting light curve plots, finder field images, and photometric data to ExoFOP-TESS.

**SG2:** Applicants should ideally have access to a facility that satisfies one or more of the following approximate guidelines: RV precision better than ~300 m/s (to

https://tess.mit.edu/followup/apply-join-tfop/

## Application Contents

- Statement of Abidance with Policies
- Sub Group Interest
- Background and Expected Contribution
- Instrument and Observatory Description
- Instrument Availability
- Local Team Availability

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# SMC Milestones

## AY 2017-18 and Summer 2018

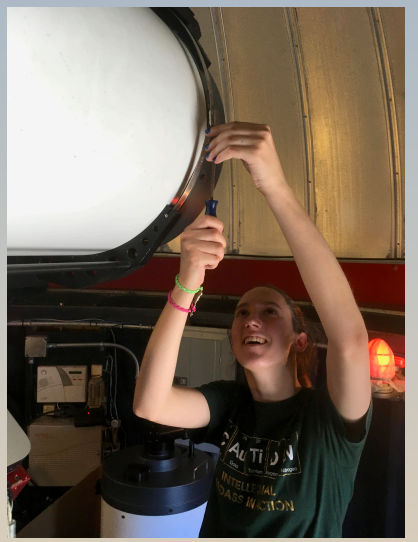
- **Mount Electronics Upgrade**
- **Imaging Train Upgrade**
- **Understand Hardware and Software**
- **First Exoplanet Transit Data**
- **Acceptance into TFOP!**
- **Barcroft Field Station**

## AY 2018-19 to Present

- **Nov. 2018 Presentation to AAVSO**
- **Telescope Overhaul**
- **Connor Martin TFOP Submission**
- **Weather Station On-Line**
- **Back to Barcroft**
- **Nov. 2019 AAVSO Course Leader**

# Mount Electronics Upgrade

Software Bisque Paramount ME MKS 5000 Control System



Good-bye RS-232.
Hello USB.

# Imaging Train Upgrade


Optec NGC 316 Reducer/Flattener


Starlight Xpress
Lodestar X2 Autoguider

ZWO ASI1600 MM-Cooled
CMOS Camera


Gerd-Neumann
D420 Aurora Flat-Field Panel

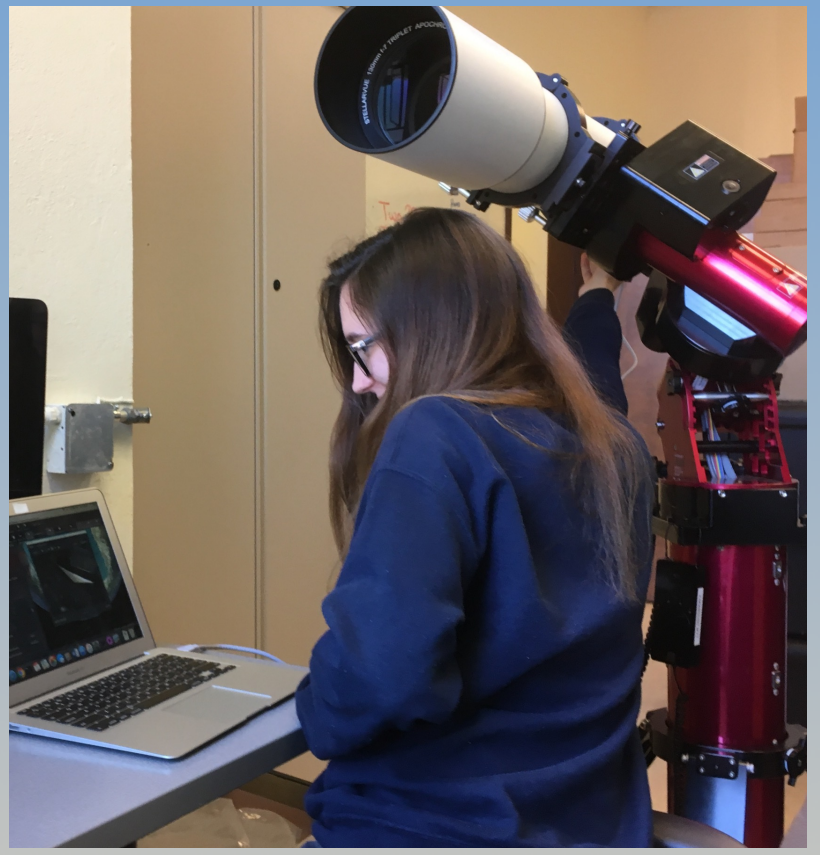

Optec TCF-S3i Temperature-Compensated Focuser

Starlight Xpress Mini USB Filter Wheel


Astrodon Clear Blue-Blocking
and Sloan g' r' i' and z' Filters

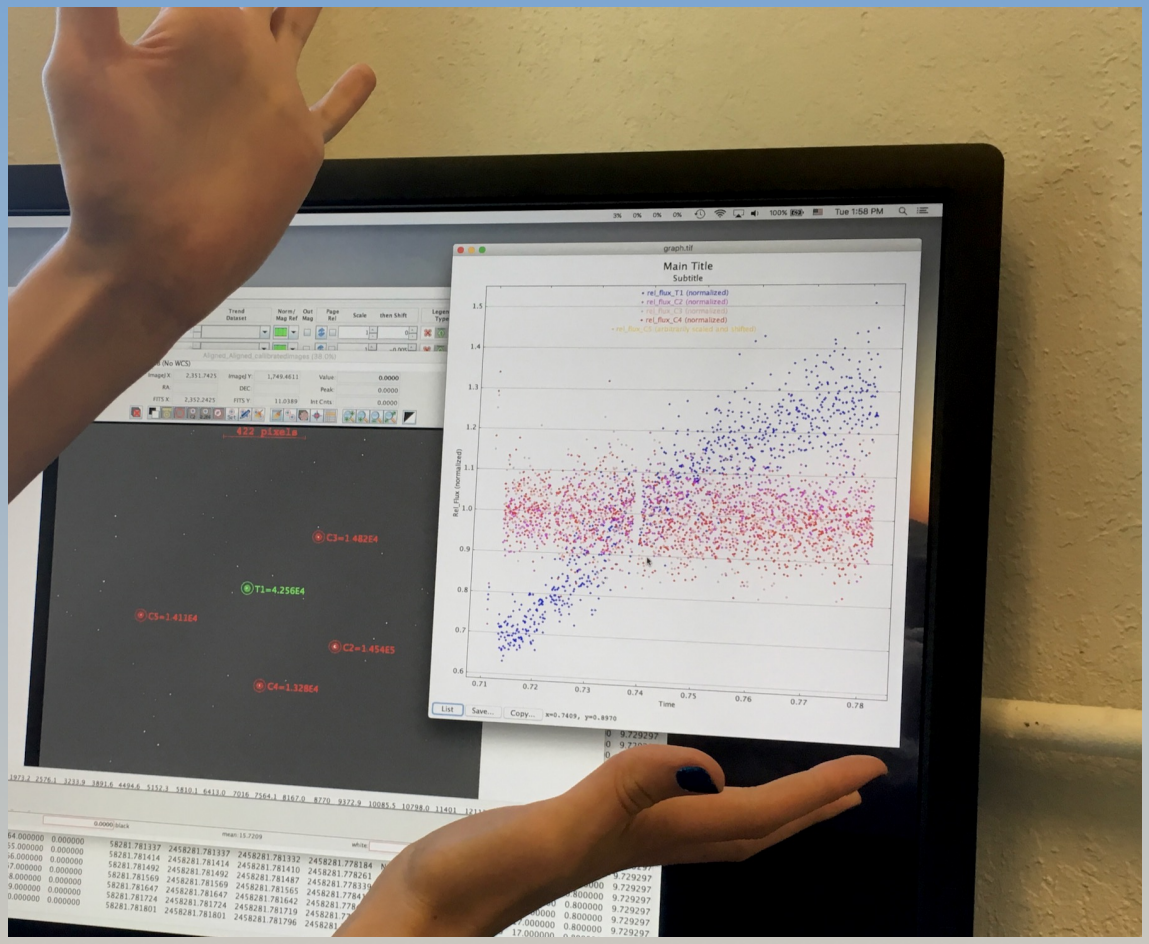
# Understand Hardware and Software

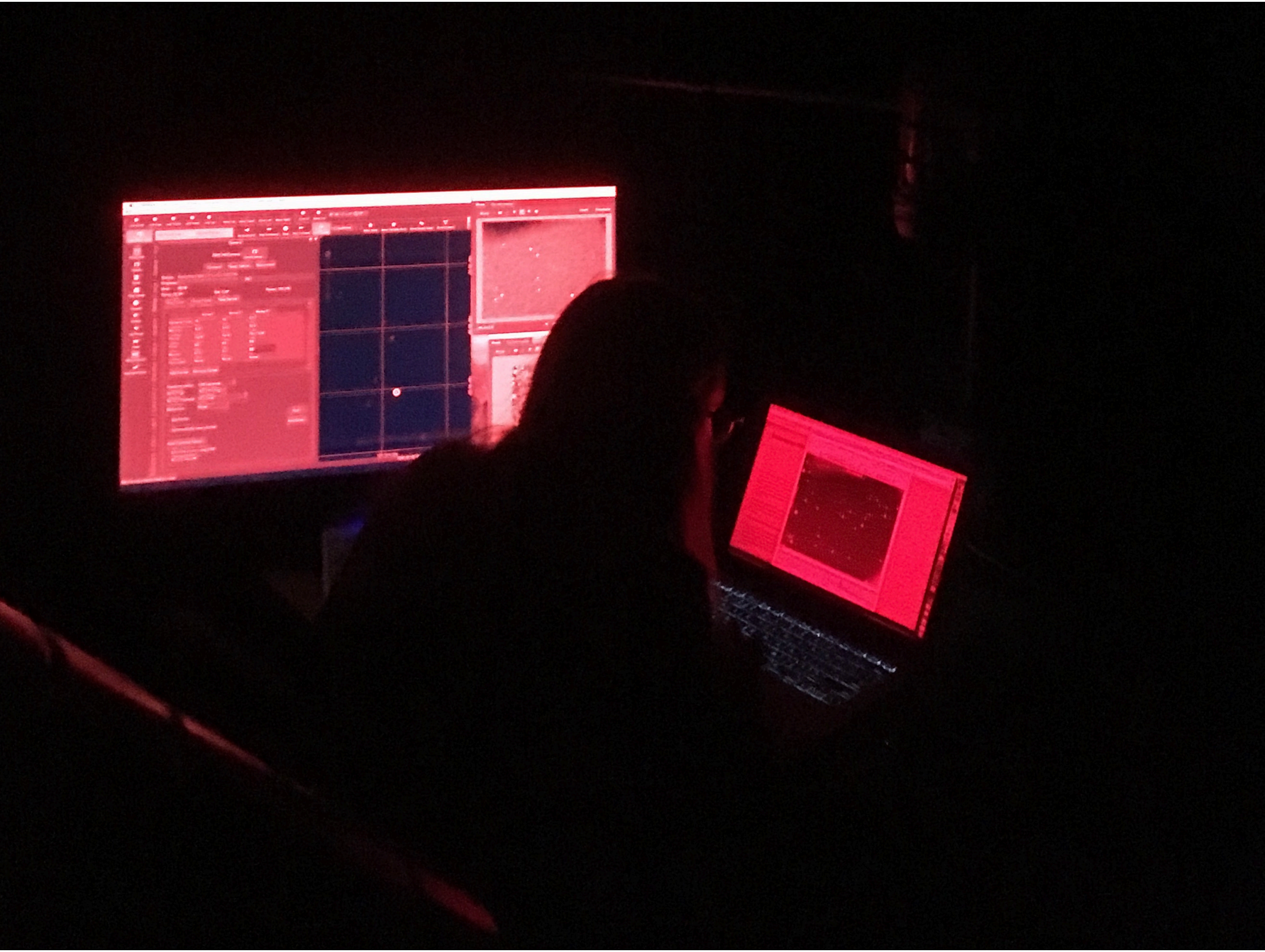
- Data Taking
  - Filters and Filter Wheel Control
  - Camera and Camera Control
  - Focuser and Automated Focusing
  - Mount and Mount Control



# Understand Hardware and Software

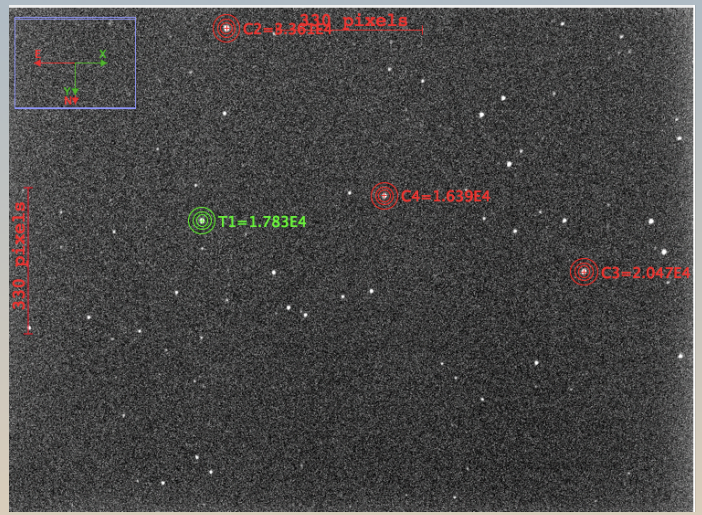
- Data Analysis
  - Image Calibration
  - Differential Photometry
  - Transit Fitting

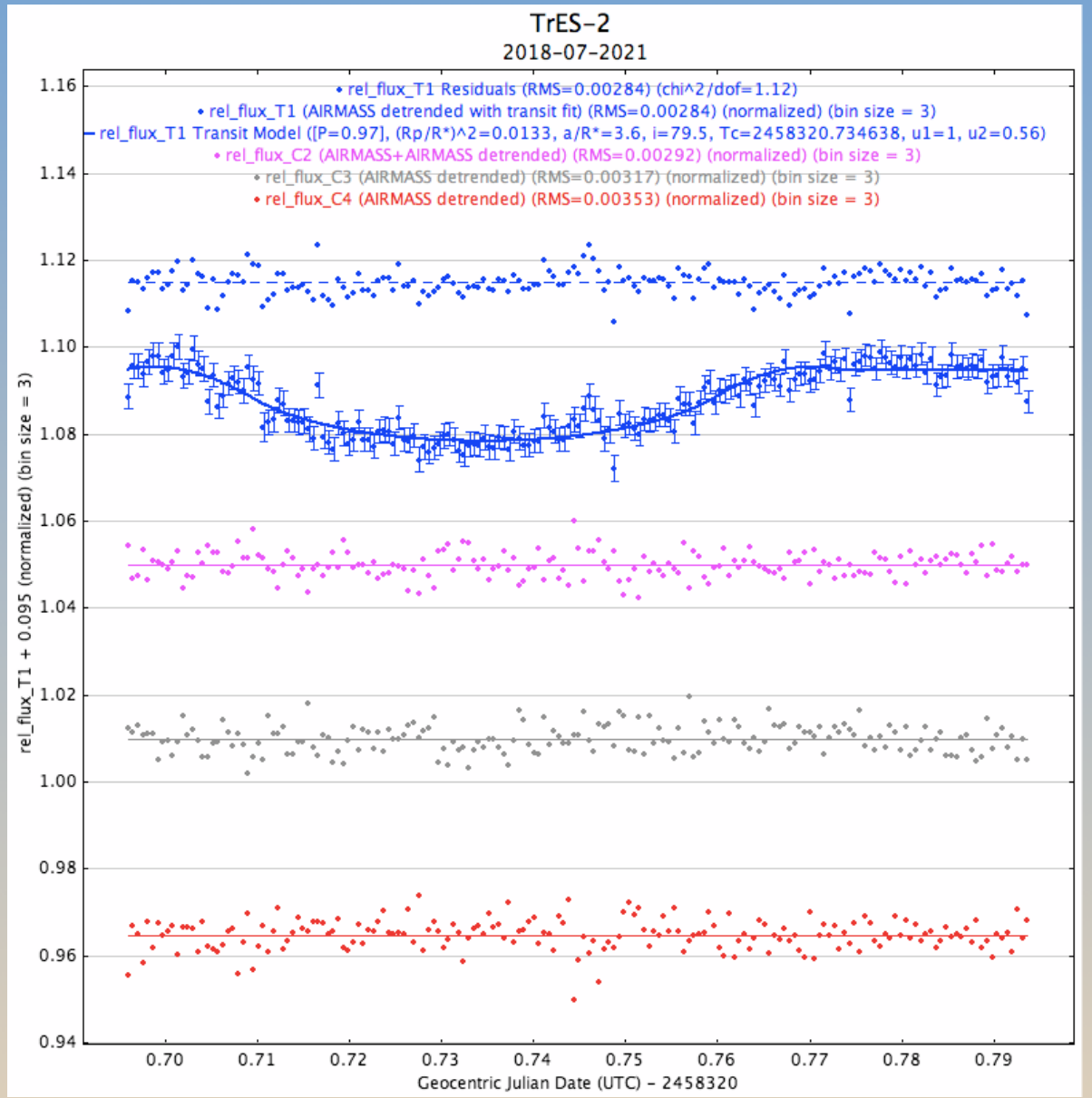




# Acceptance into TFOP

Below is one of the 541 images. The target TrES-2 is in green as T1. The comparison stars are in red as C2, C3, and C4. To the right is the light curve showing a 1.6% light drop at mid-eclipse.



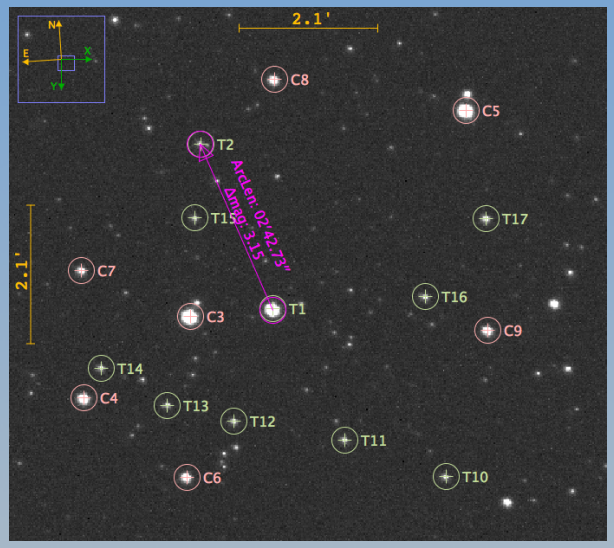



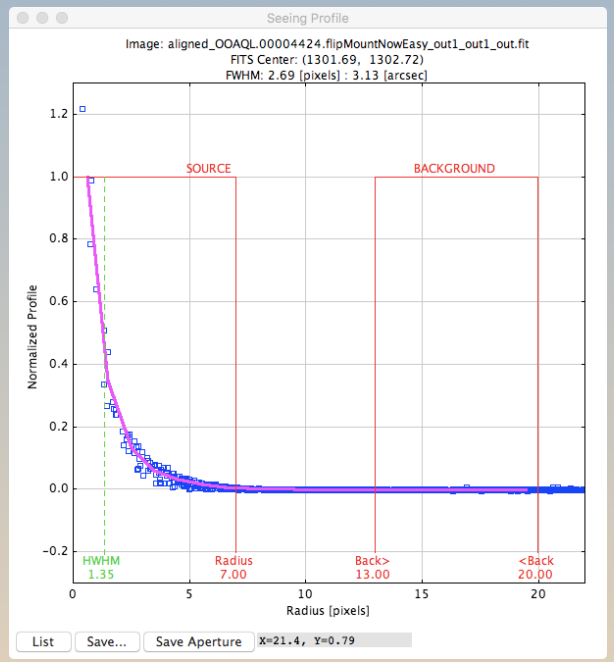
# Barcroft Field Station Trip

# First TFOP Submission

**9 Work Products For Each Submission**

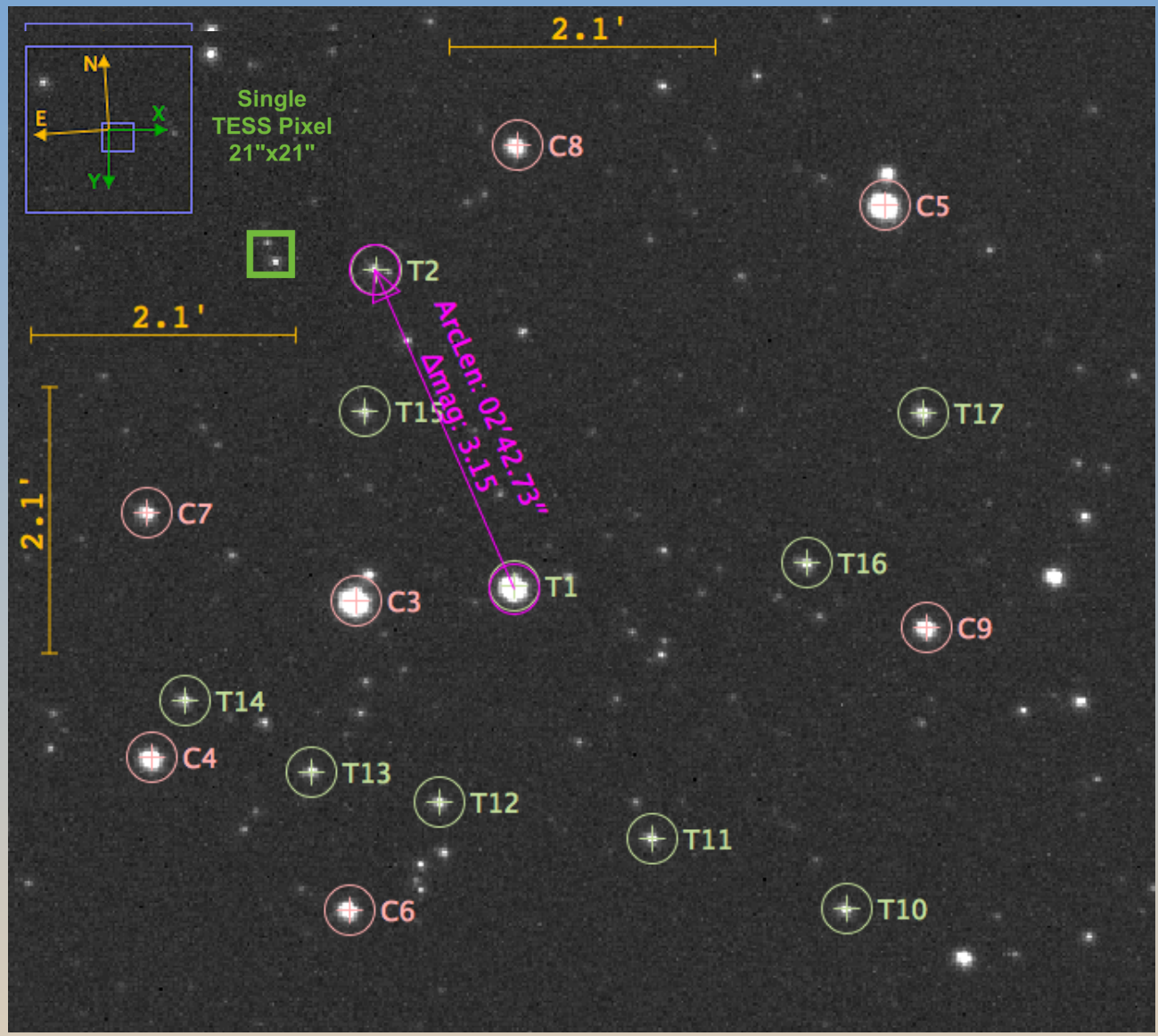
- Full Field (png or jpg)
- Zoomed-in Field *(shown at upper right)* (png or jpg)
- Seeing Profile *(shown at lower right)* (png or jpg)
- Plate-solved FITS file (fits)
- Apertures for Target and Comparison Stars (AstroImageJ format)
- Plot Configuration Used to Produce Final Light Curve (AstroImageJ format)
- Measurements File (xls)
- Light-Curve *(shown in subsequent slide)* (png)
- Observation Notes (txt)



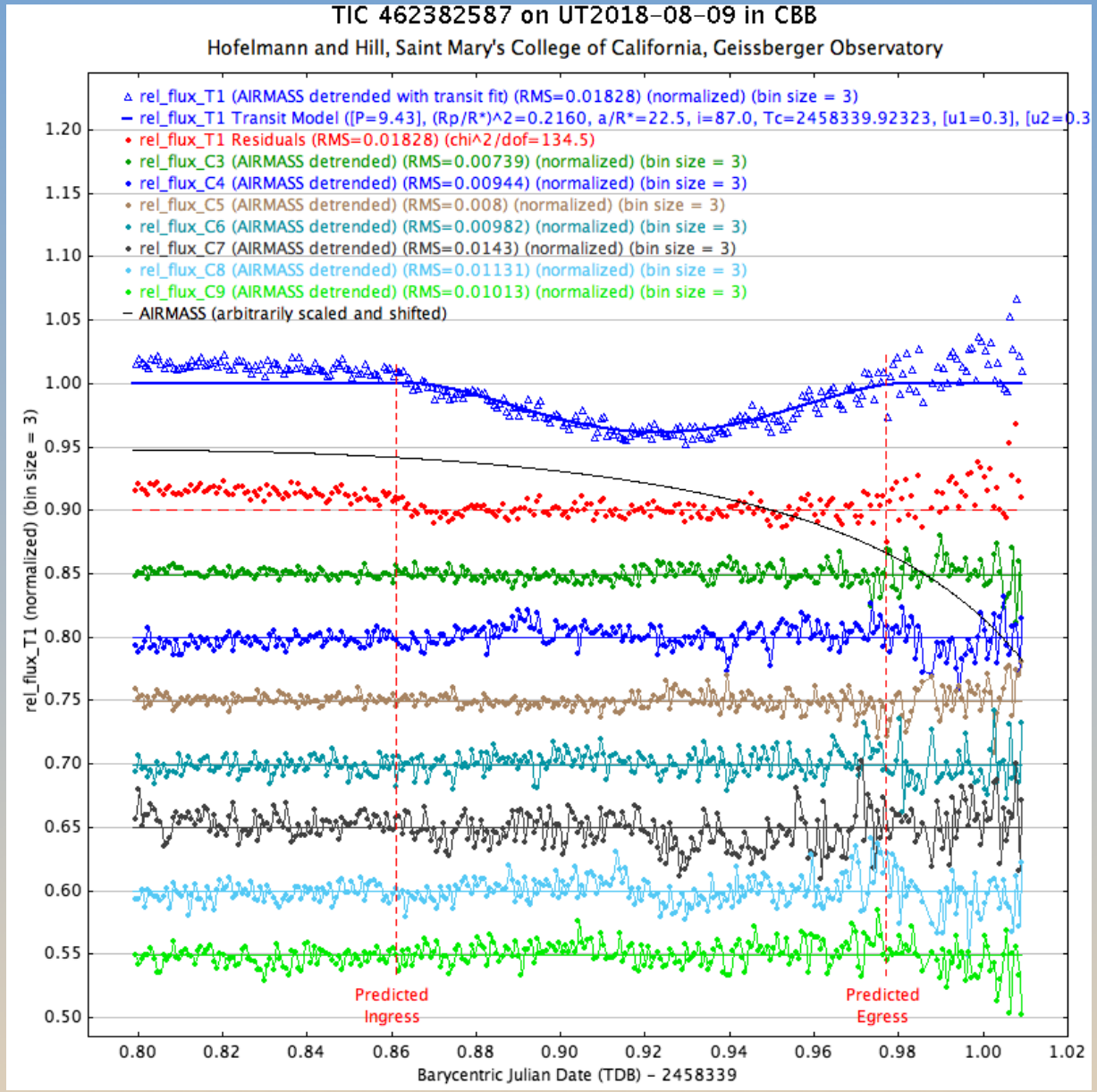

As a TFOP SG1 member, you will adhere to TFOP SG1 Observation Guidelines summarized and authored by Dennis Conti and reviewed by Karen Collins, TFOP SG1 Chair. This guide is designed to help all team members achieve uniform results.

# Field Near Target



# First TFOP Submission

- First of Two Priority 4 False Positive Submissions
- Usually Known False Positives from Kepler and KELT
- First two submissions are to demonstrate that your team is following a process that is uniform for all TFOP SG1 members.



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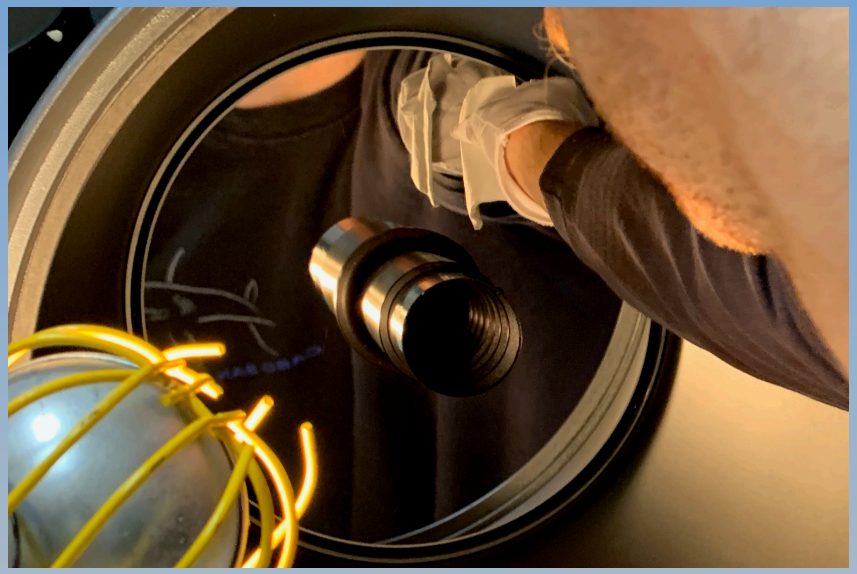
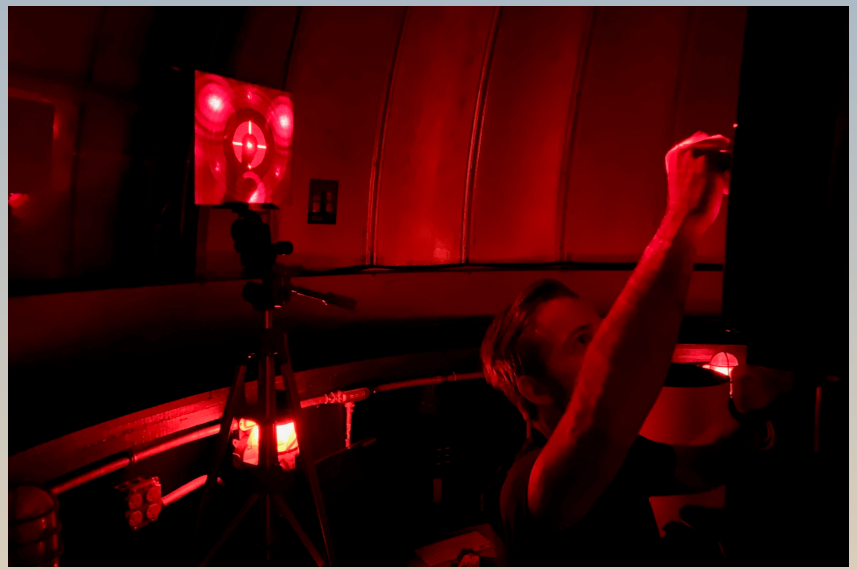
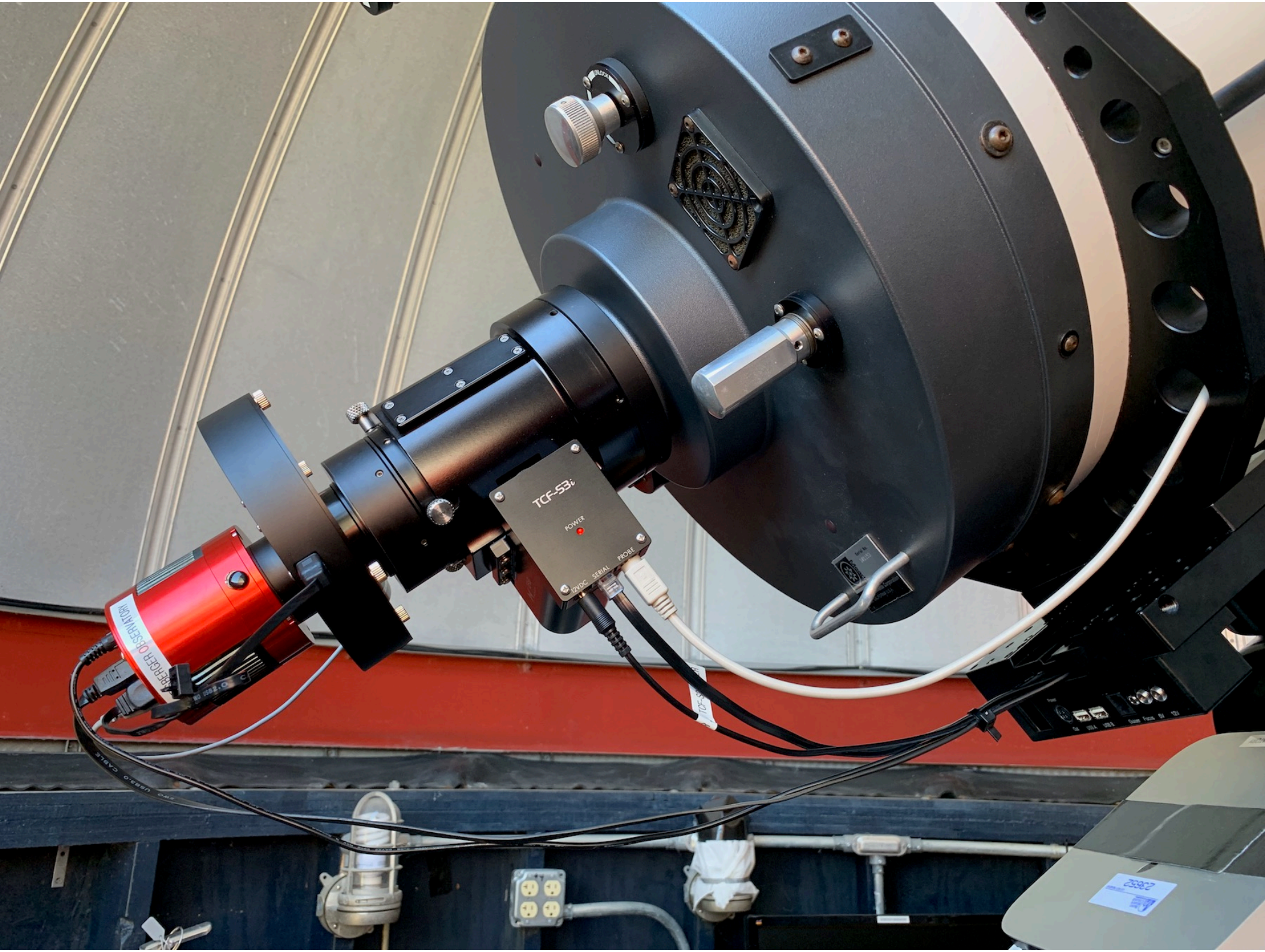
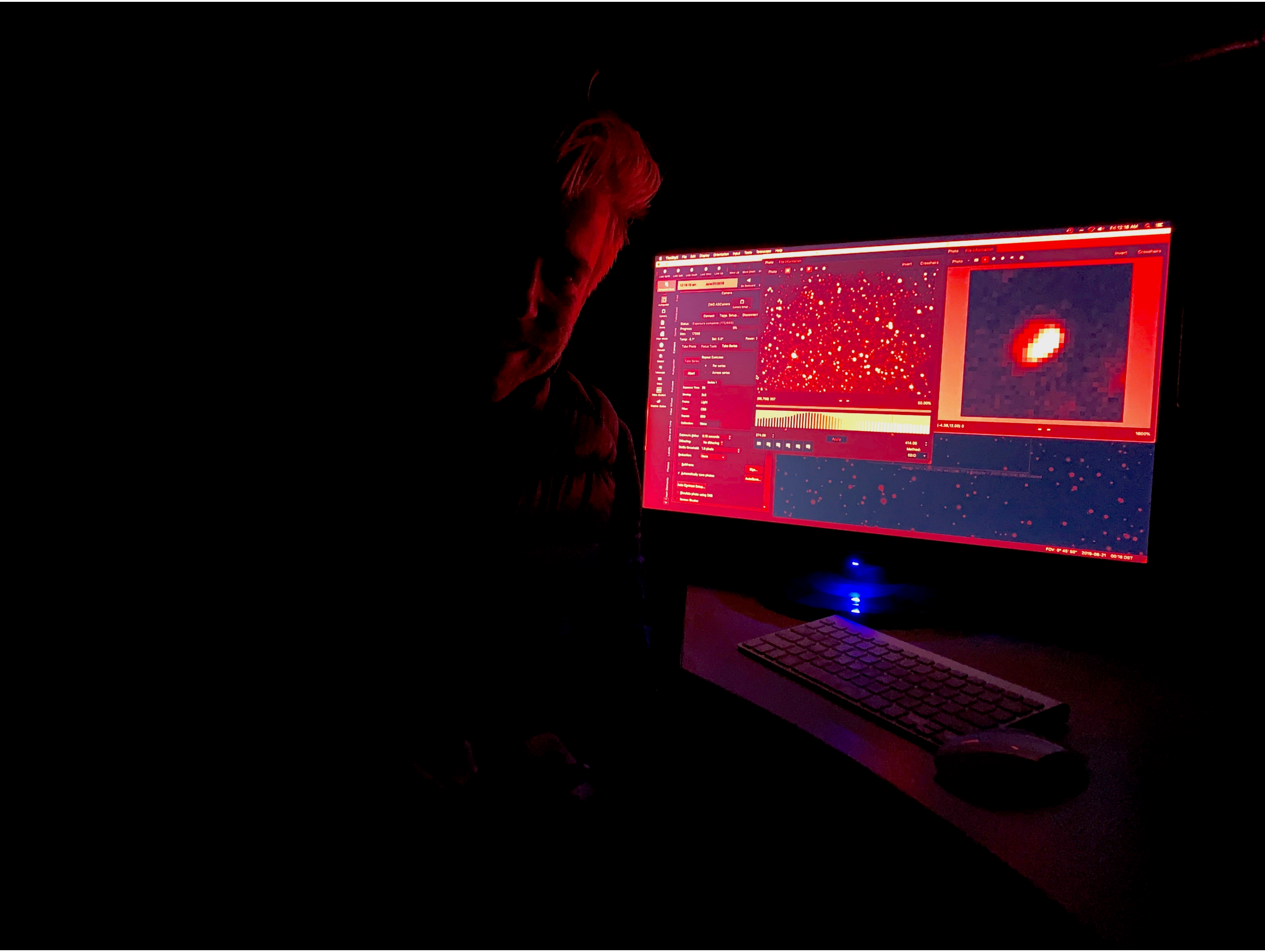
# Telescope Overhaul

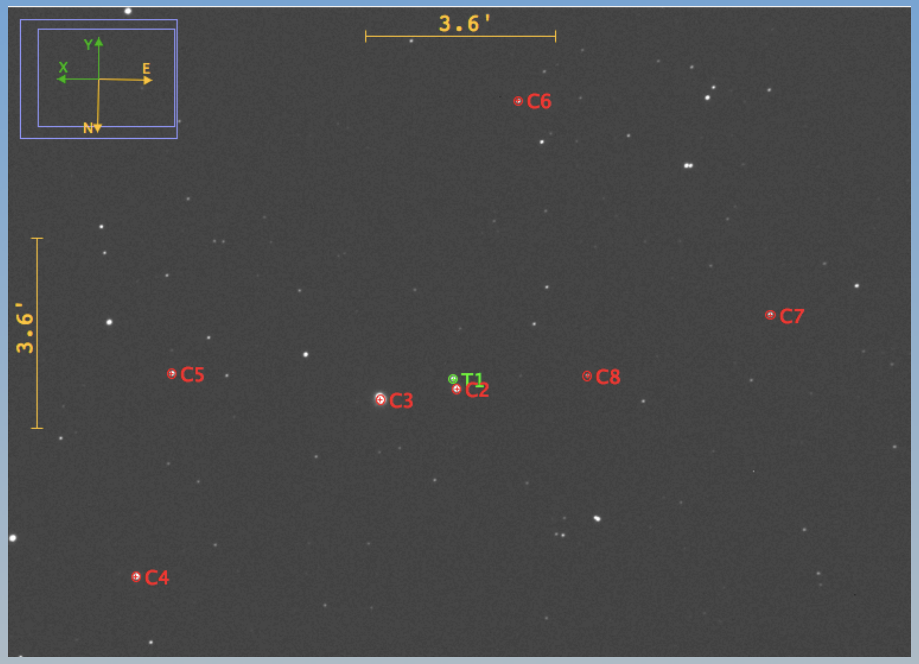


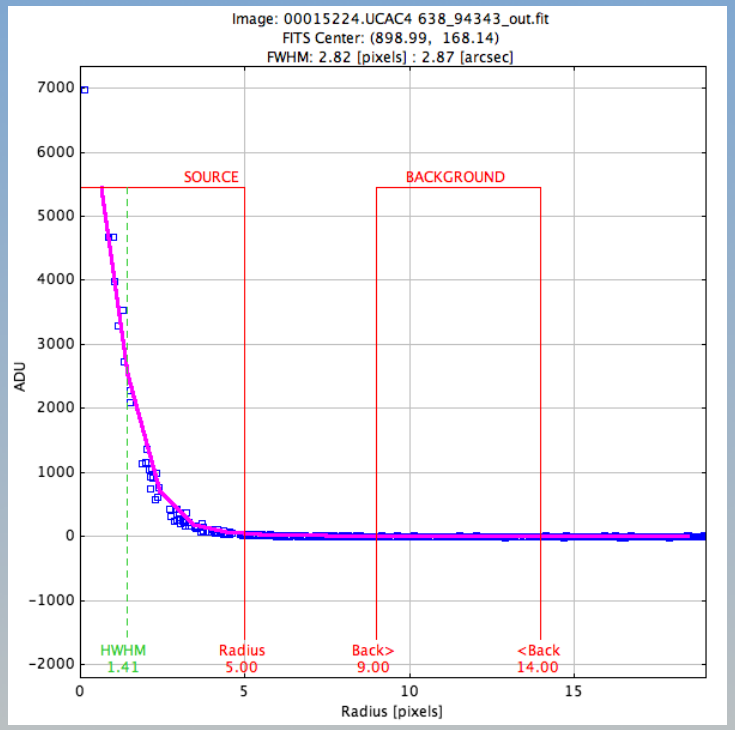


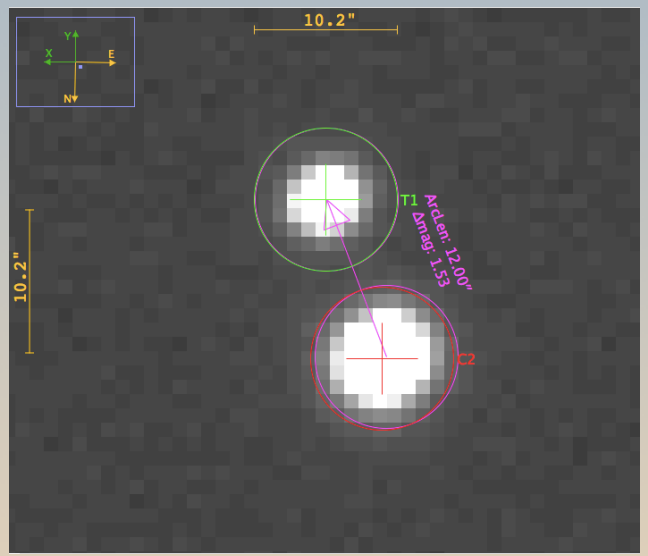

TCF-S3i
POWER
12VDC
SERIAL
PROBE



# Connor Martin TFOP Submission



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