Exoplanet Transits for Complete Noobs

...by an Almost Complete Noob

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Nightfall Imaging Conference
October 17, 2025

We Will Answer These Questions

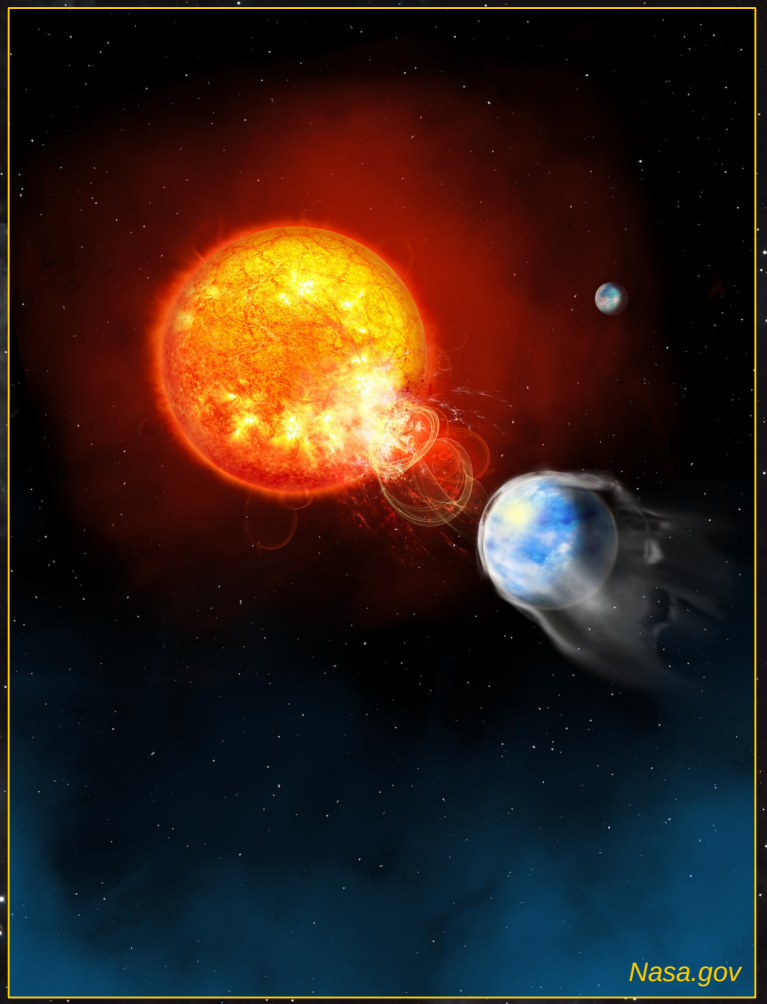
- What are exoplanets, and exoplanet transits?
- Can I really contribute useful data?
- How do I get started?
- What equipment do I need?
- What resources are available?
- What have I learned in my few months of imaging?

Outline

- Exoplanet discoveries – history, methods and current status
- Opportunities to contribute to exoplanet science
- Getting started With NASA Exoplanet Watch
- Ways to participate
- My exoplanet imaging setup and process
- Some initial transit curve results
- How to submit your analysis
- What I have learned so far
- Resources

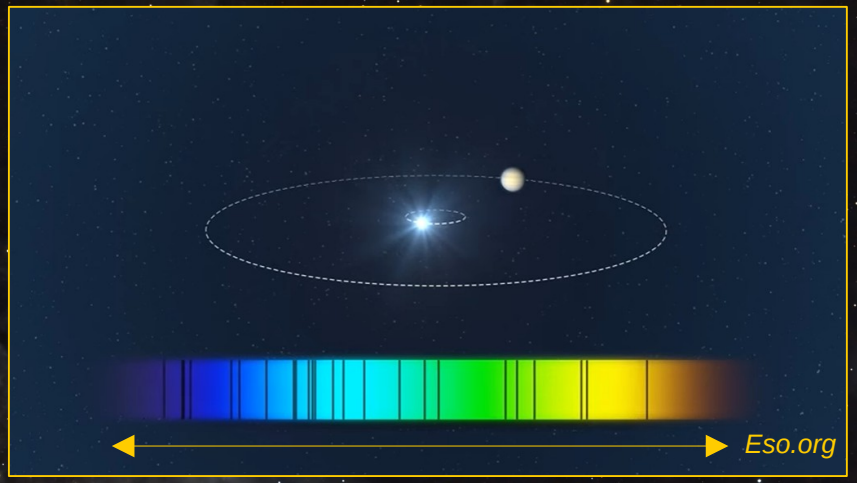
Exoplanets 101

- Extrasolar (exo) planets:
  - Objects below the limiting mass for thermonuclear fusion (i. e. not brown dwarfs)
  - Orbiting stars, brown dwarfs or stellar remnants beyond our sun
- First discoveries:
  - 1992: PSR B1257+12 b, c - Two planets orbiting a pulsar (Wolszczan, Frail)
  - 1995: 51 Pegasi b - planet orbiting sun-like star (Mayor, Queloz)

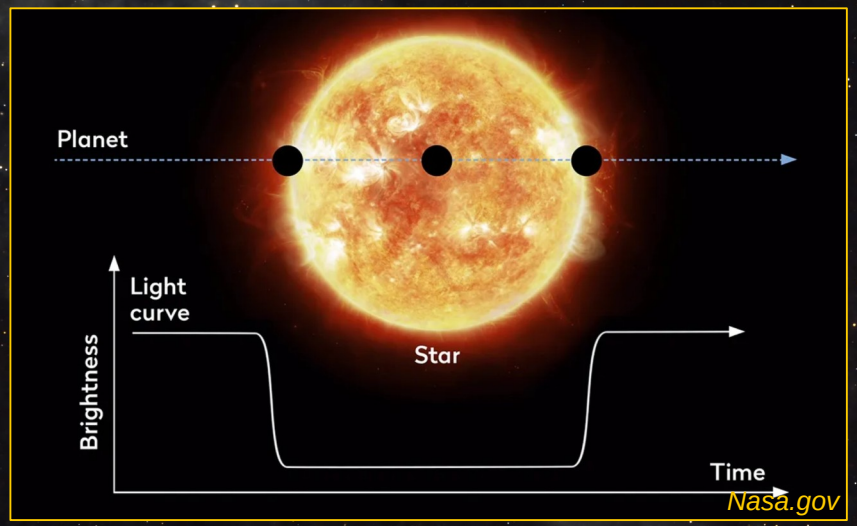


Exoplanet Detection Methods

- Radial Velocity (Doppler):
  - Detect variations in a star's radial velocity due to displacement of its spectral lines

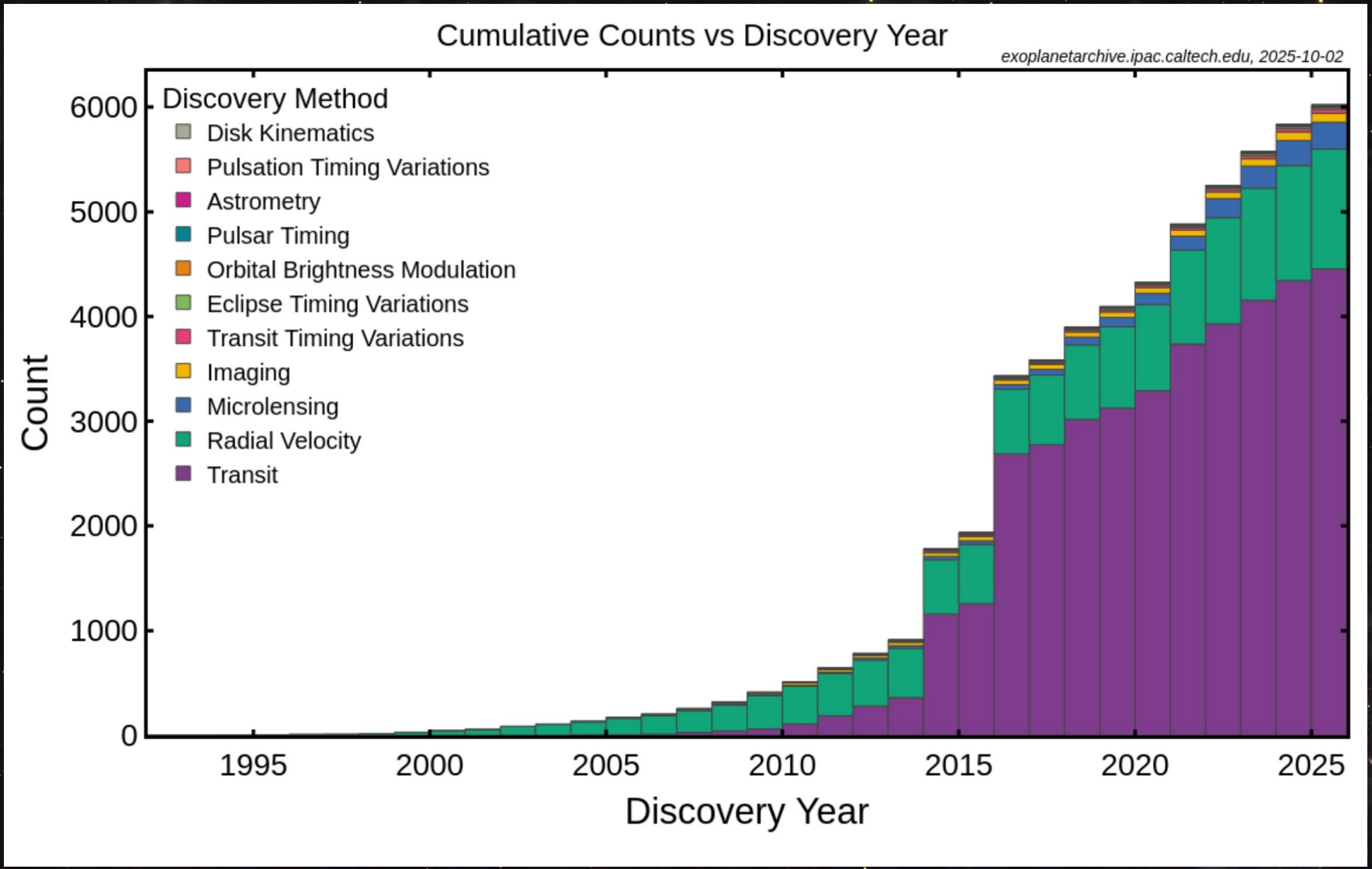


- Transit:
  - Detect dimming of a star due a planet passing in front
  - Responsible for most transit observations to date
  - Method most often used by amateur astronomers



- Other methods:
  - Pulsar timing,Gravitational Microlensing, Astrometry, Direct imaging, etc.

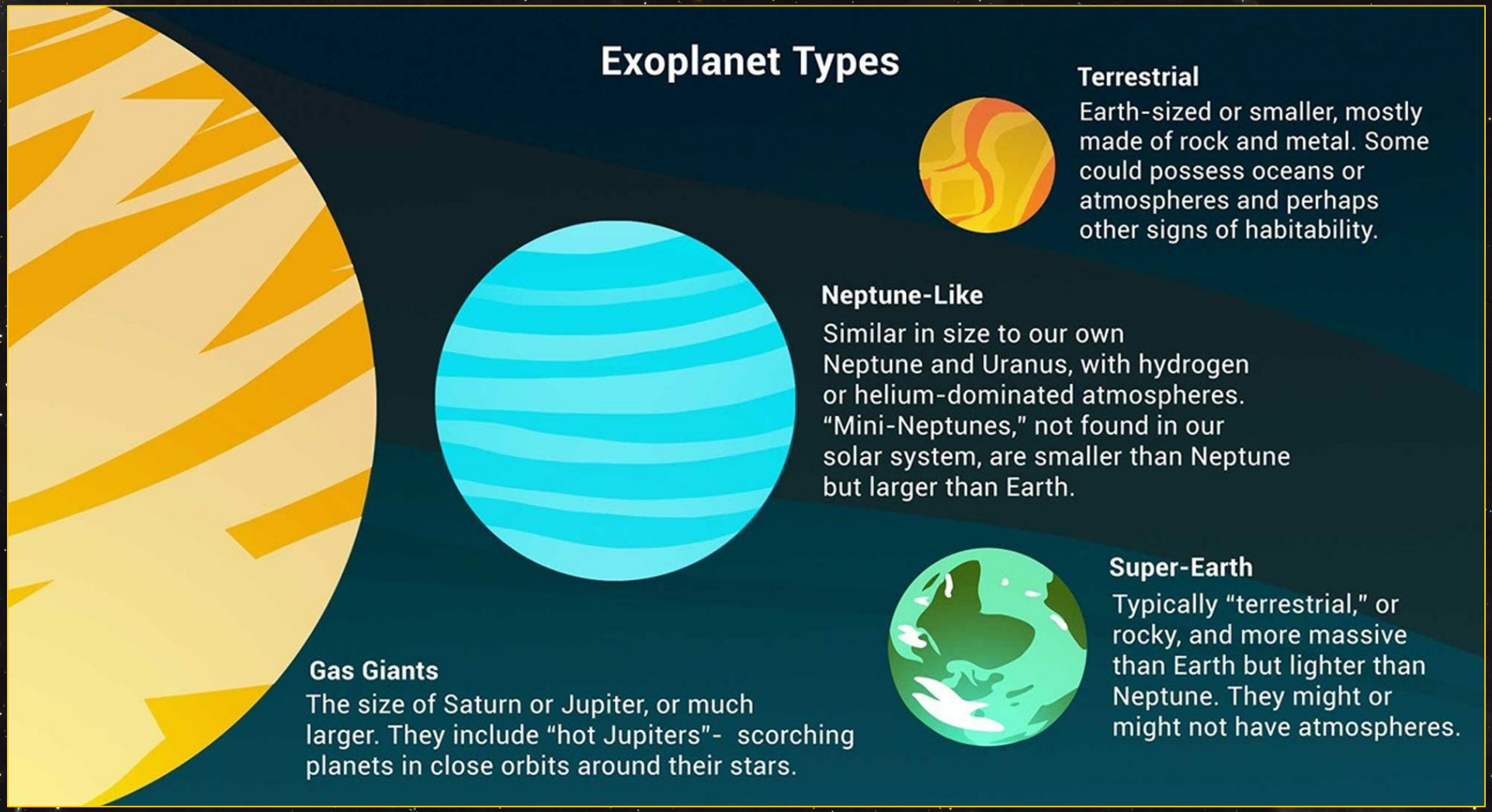
Exoplanet Discovery Progress



Over 6,000 exoplanets have been discovered to date!

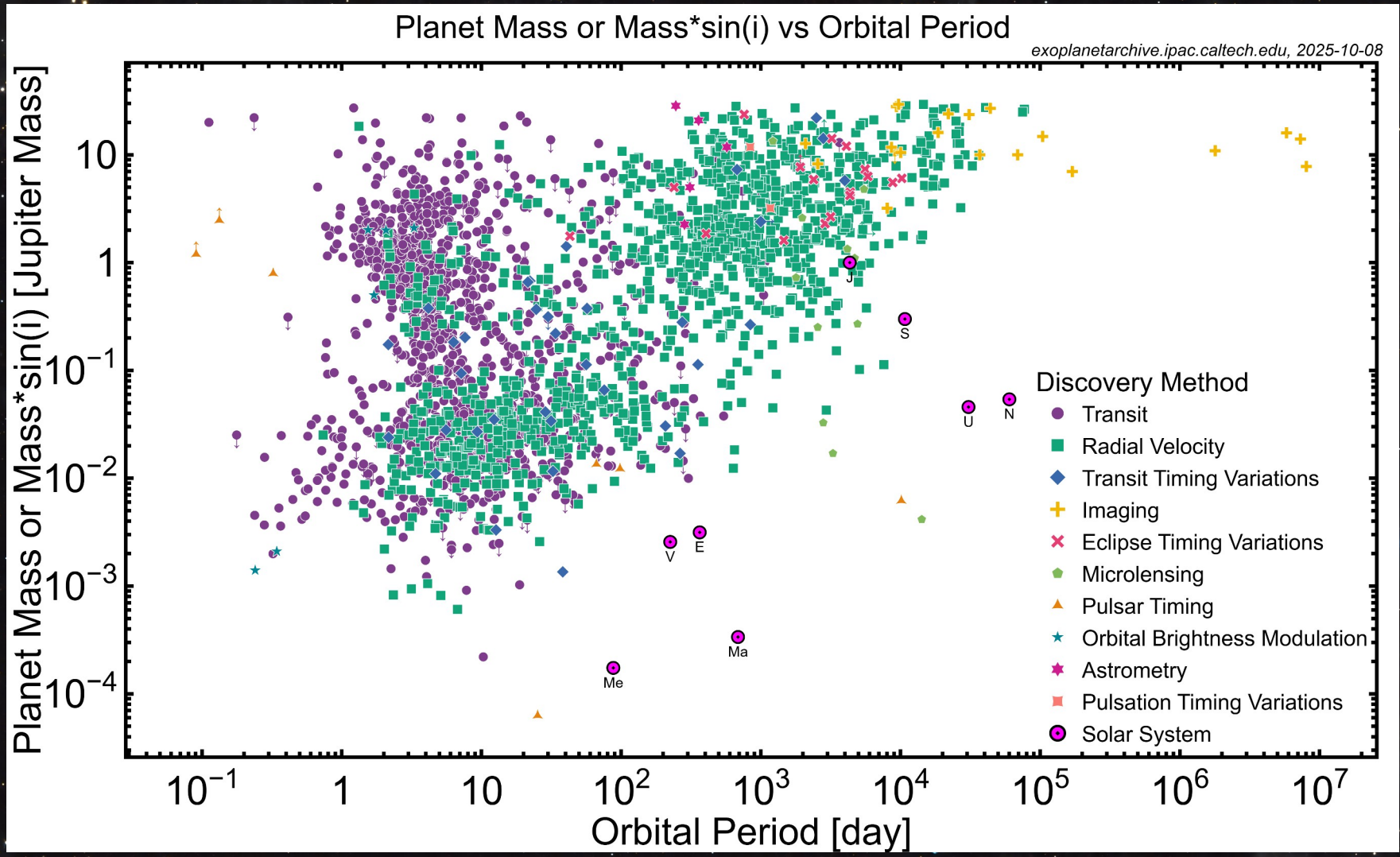
The majority by the transit method

Exoplanet Types



"Hot Jupiters" are the most common target for we amateurs

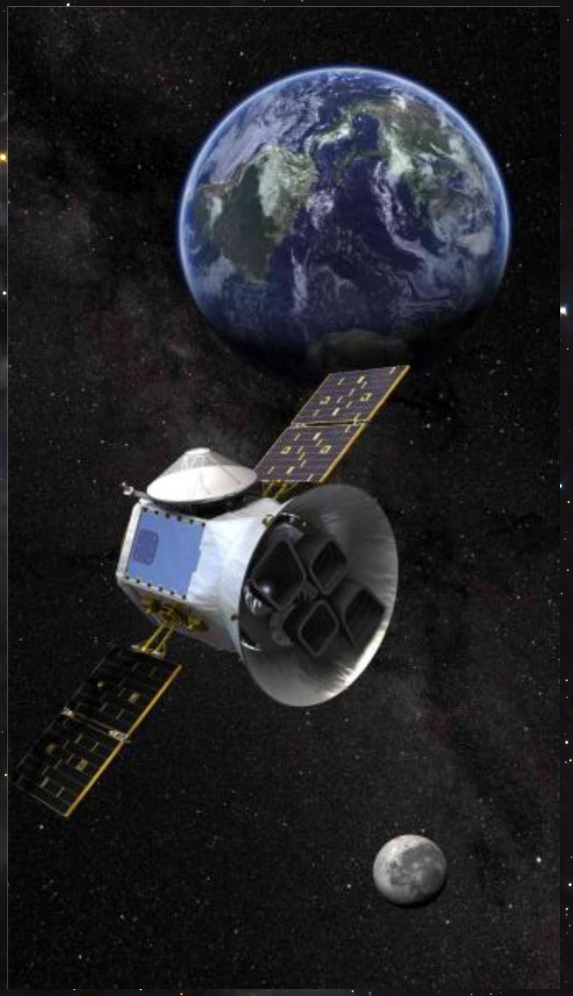
Exoplanet Discovery Progress



Transit observations are heavily biased toward short period orbits

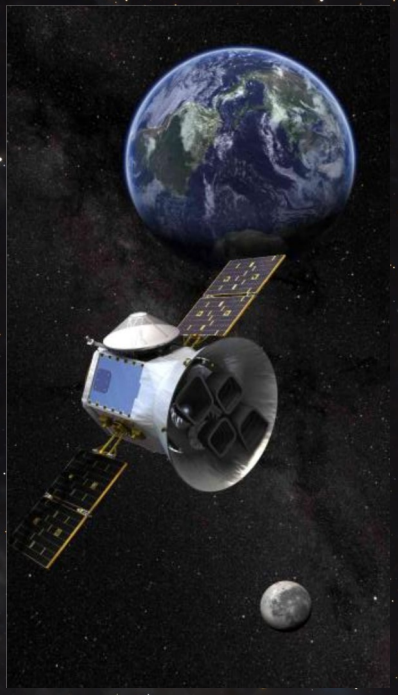
Opportunities to Contribute to Exoplanet Science

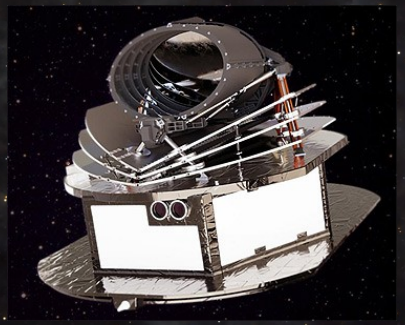
- Zooniverse (Adler Planetarium, Univ of Minnesota, Univ of Oxford)
  - Planet Hunters TESS
    - Inspect existing TESS light curves to find transits
    - Equipment: Computer, Internet Connection
  - Planet Patrol
    - Inspect TESS light curves to find false positive transits
    - Equipment: Computer, Internet Connection



Opportunities to Contribute to Exoplanet Science

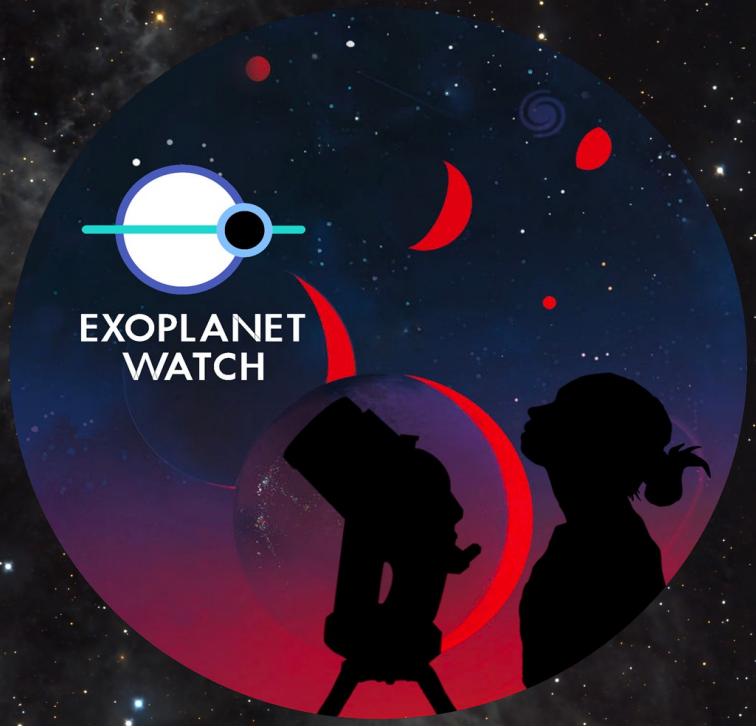
- TFOP - TESS Follow-up Observing Program (NASA, MIT, Harvard CfA)
  - Image TESS candidate exoplanets
  - Equipment: Telescope / Camera with < 1 arcsec pixel scale, precision guiding
  - Requires approved application
- ExoClock (ESA)
  - Monitor known transiting exoplanets in advance of ESA's ARIEL mission (2029 launch)
  - Equipment: Telescope / Camera
- Exoplanet Watch (NASA-JPL)...





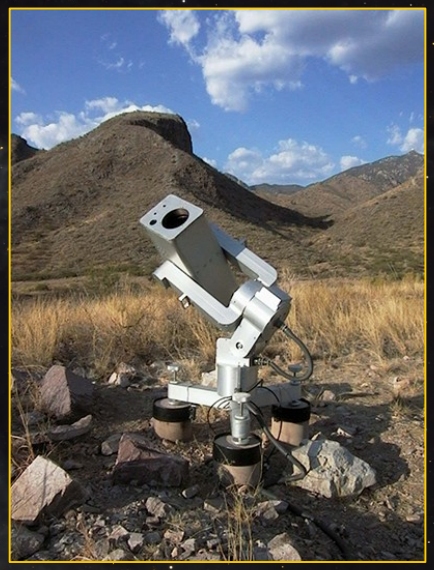
Exoplanet Watch - Objectives

- Refine transit event times for known exoplanets
  - Save imaging time on large for large space and ground-based telescopes
- Discover new exoplanets
  - Use transit timing variations to infer existence of an additional exoplanet around its host star
- Confirm new exoplanets
  - Make transit measurements of candidate exoplanets
- Monitor stellar variability
  - Brightness changes on exoplanet's host star caused by dark spots or light regions (plages)



Ways to Participate in Exoplanet Watch

- Process previously collected data on your computer
  - Request via email from Exoplanet Watch
- Use micro-observatory remote robotic telescopes
  - Select targets and control the telescope via the web
  - Download data and process on your computer
- Collect and process data from your own System
  - Polar-aligned mount / telescope
  - Cooled monochrome camera
  - Autoguide capability (strongly recommended)
  - Permanent observatory location makes life easier, not essential



MicroObservatory Telescope, Amado, Az

Leinz Observatory Mariposa, Ca.

Smithsonian Data Labs

DIY PLANET SEARCH

LOGIN

Community | Exoplanets | DIYTools | DIYTargets | Telescopes | Educator Resources

Your mission...

- Schedule Target
- Control Telescope
- Measure Brightness
- Interpret & Share
- Community Results

Schedule Target

Please choose a date and target for your telescope observations

Schedule Target Tutorial

October 2025

today

Sun	Mon	Tue	Wed	Thu	Fri	Sat
28	29	30	1	2	3	4
HATP-32 Observe	WASP-50 Observe	TRES-5 Observe	TRES-3 Observe		TRES-5 Observe	WASP-52 Observe
5	6	7	8	9	10	11
WASP-10 Observe	Qatar-1 Observe		WASP-10 Observe	TRES-5 Observe	WASP-35 Observe	WASP-52 Observe
12	13	**14**	15	16	17	18
TRES-5 Observe	Qatar-1 Observe		WASP-2 Observe			WASP-12 Observe WASP-52 Observe
19	20	21	22	23	24	25
HATP-10 Observe			TRES-2 Observe	Qatar-1 Observe	HATP-32 Observe	WASP-52 Observe
26	27	28	29	30	31	1
HATP-32 Observe	TRES-2 Observe	WASP-2 Observe	WASP-35 Observe		HATP-10 Observe	

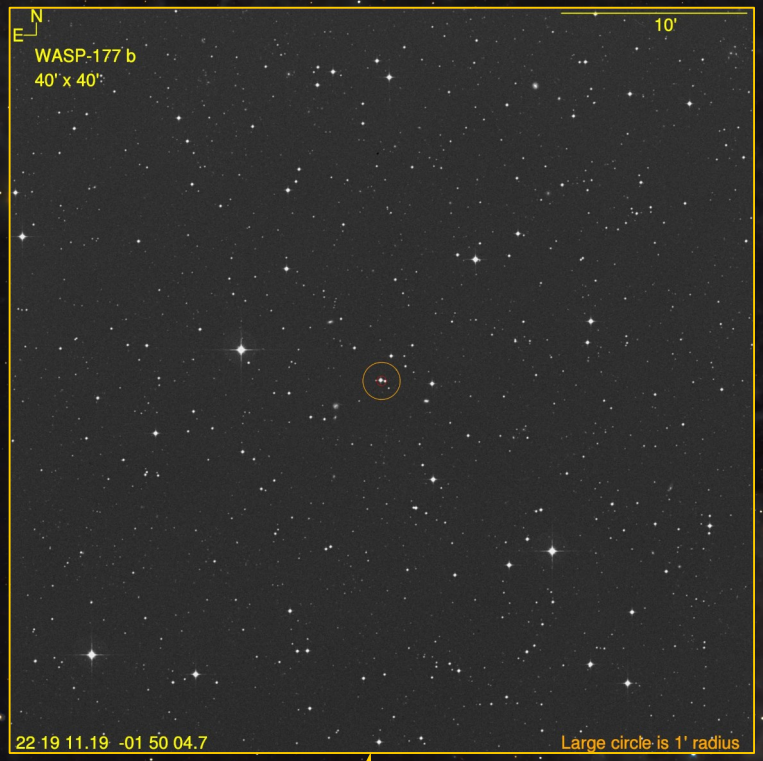
Transit Imaging Using Your Own Telescope/Camera (What I do)

- My System (Celestial Deep Observatory, Mariposa, Ca.):
  - Celestron RASA-11 telescope
  - Ioptron CEM120EC2 mount
  - Player One Zeus 455M full frame camera
  - NINA / PHD2 for imaging / guiding
  - Full remote operation capable via Home Assistant/Raspberry Pi
- NINA Setup
  - Exoplanets Plugin
    - Automatically loads selected exoplanet ephemeris in the Advanced Sequencer
    - I avoid using the Exoplanet Exposure Calculator (tends to give inconsistent results)
    - Instead take multiple ‘snapshots’ and manually adjust exposure
  - Set up a custom “Exoplanets” Profile
    - FITS File format
    - Target Name+ROI, Exposure time, Gain in filename


Celestial Deep Observatory Mariposa, Ca.


Celestial Deep Observatory Mariposa, Ca.

Select Target Via Swarthmore Transit Finder



- Developed and maintained by Swarthmore, PA College Department of Physics and Astronomy
- Greatly simplifies nightly target selection
- Highly customizable
  - Transit depth, duration, star magnitude, elevation, etc.
- Provides key transit information
  - Links to online databases, finder charts
  - NASA Exoplanet archive, Exoplanet Watch, TESS
- HTML and CSV output – best for export to spreadsheet
- Can setup custom URL with site information, preferences

447 targets match your constraints (on name, V mag, depth, etc.). Searching for observable transits over 1.0 days...

Upcoming events for the next 1 day from today; start/end given in timezone PST8PDT.

Night starts/ends at nautical twilight.

Results shown for Other Site latitude = 37 , longitude = -119

Colored text indicates a part of the transit that is during daylight, or a transit at elevation less than the user-specified limits, or that the Moon is relatively full and close to the target.

Click on column headers to sort the table by that column. Click again to reverse the sorting order. To sub-sort, first click one column (e.g. the left-hand one to sort by night), then *shift-click* another column to sort further within the first category. For example, to sort by priority within a given night (when multiple nights are displayed), first click the "Local evening date" header, then shift-click the "Priority" header. The highlighted column shows the current sorting.

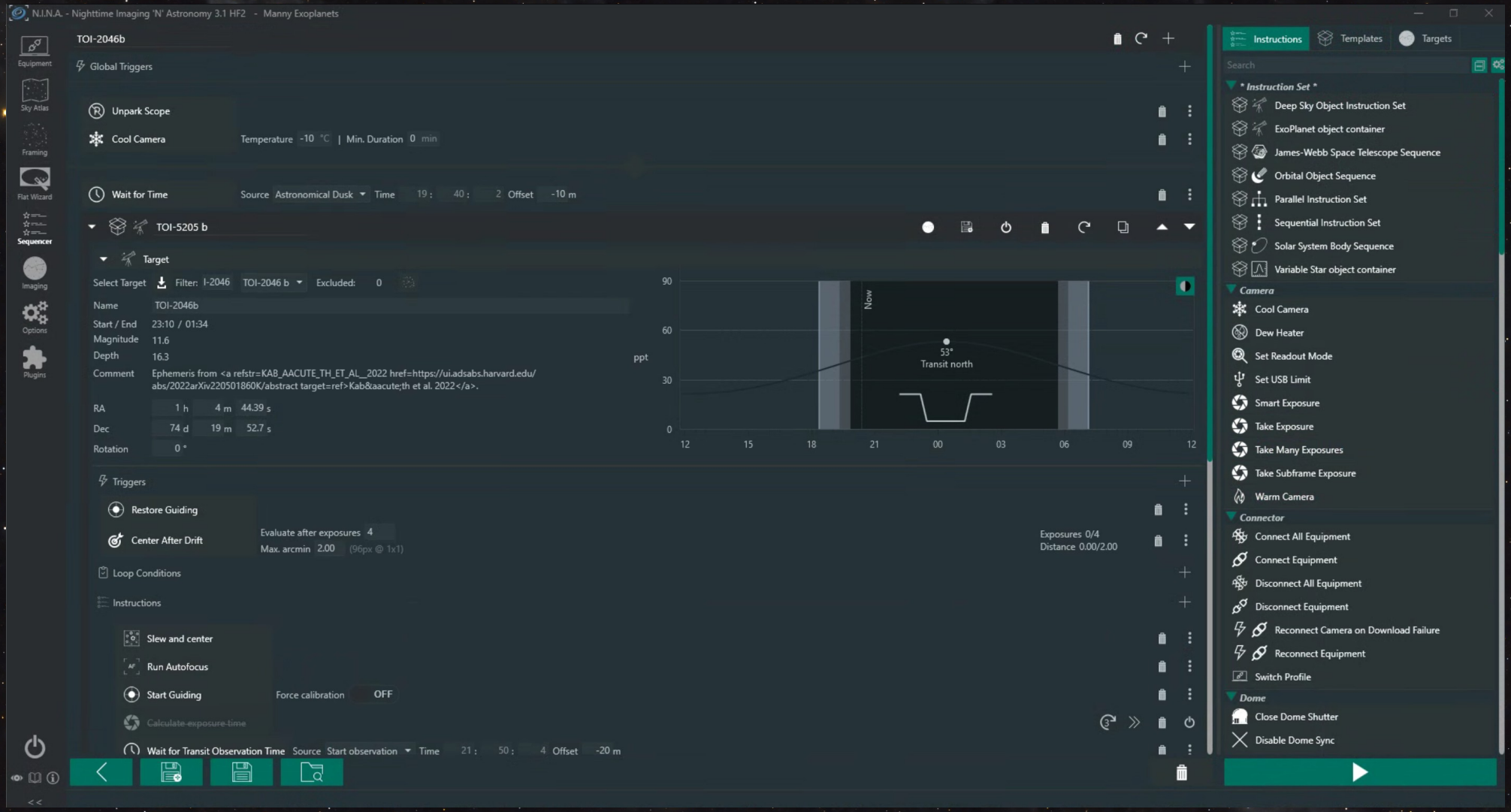
The buttons can be used to toggle the visibility of columns, and the column order can be rearranged by clicking and dragging the column header.

Column visibility | Reset column order | Show all columns | Disable tooltips

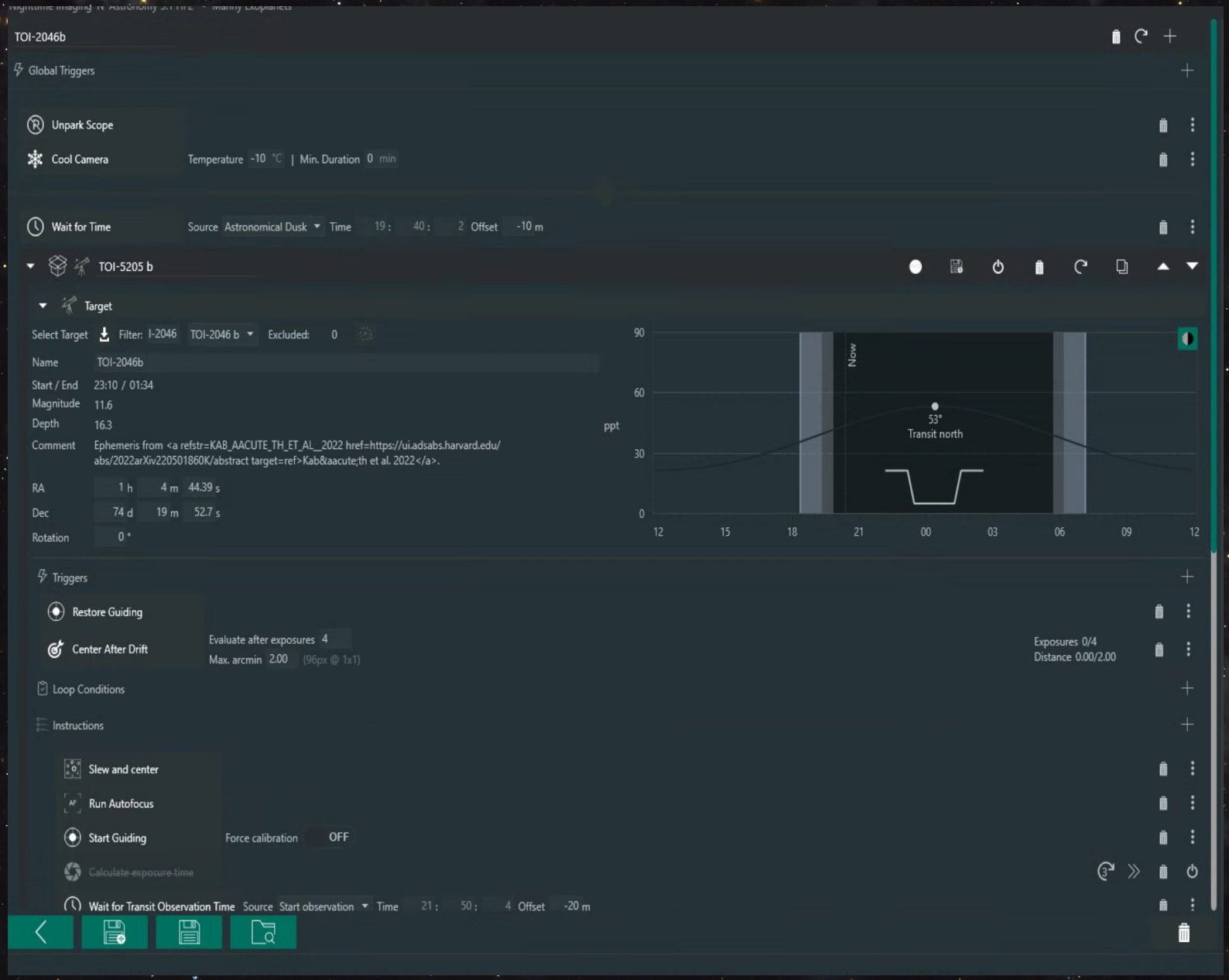
Search: Show if visible transit % + baseline % > 163 V_{max}: $Depth_{min}$: 0 ppt Overlap: 0 m. Other Site

Local evening date	Name	V or Gaia mag	Start—Mid—End	Duration	BJD_{TDB} start-mid-end	Elev. at start, mid, end ±1.0 hrs	% of transit (baseline) observable, Suggested obs. start, end	Az. at start, mid, end ±1.0 hrs	HA at start, mid, end ±1.0 hrs	RA & Dec (J2000)	Period (days)	Depth (ppt)	Comments
Wed. 2025-10-15: Nautical twilight 2025-10-15 19:18 — 2025-10-16 06:12 local time / 2025-10-16 02:18 — 2025-10-16 13:12 UTC													
Wed. 2025-10-15 Nautical twilight 19:18 – 06:12 (PST8PDT)	WASP-177 b Finding charts: Annotated, Aladin, SkyMap; Airmass plot, ACP plan Info: Exoplanet Archive, Simbad, Gaia, TIC	12.3 Moon 25% @164°	20:30 21:30—22:18—23:06 00:06 +0:01	1:37	10964.6921 10964.7256 10964.7592	48° 51°, 50°, 46° 38°	100% (89%) 20:29—23:54	153° 176°, 195°, 212° 229°	-1.2 -0.2, +0.6, +1.4 +2.4	22:19:11.28 -01:50:03.95	3.07	18.5	Ephemeris from Kokori et al. 2023.
Wed. 2025-10-15 Nautical twilight 19:18 – 06:12 (PST8PDT)	TOI-2046 Finding charts: Annotated, Aladin, SkyMap; Airmass plot, ACP plan Info: Exoplanet Archive, Simbad, Gaia, TIC	11.6 Moon 24% @86°	22:10 23:10—00:22—01:34 02:34 +0:11	2:25	10964.7598 10964.8100 10964.8602	50° 52°, 53°, 52° 50°	100% (100%) 21:59—02:45	13° 8°, 0°, 353° 347°	-2.3 -1.3, -0.1, +1.1 +2.1	01:04:44.39 +74:19:52.70	1.50	16.3	Ephemeris from Kabáth et al. 2022.

Image Target With NINA Advanced Sequencer



NINA Advanced Sequencer

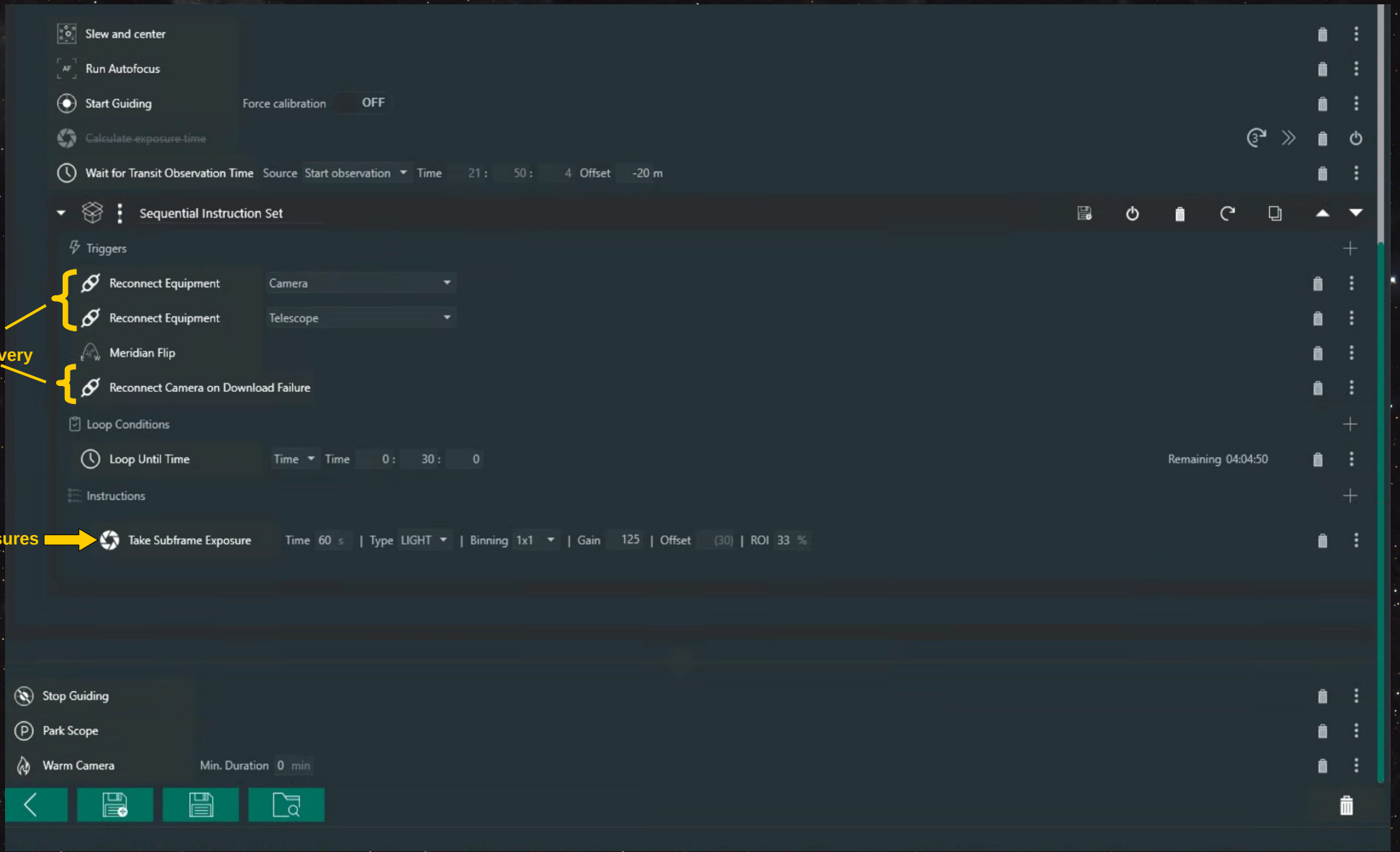


Exoplanet Object Container

Recenter Target

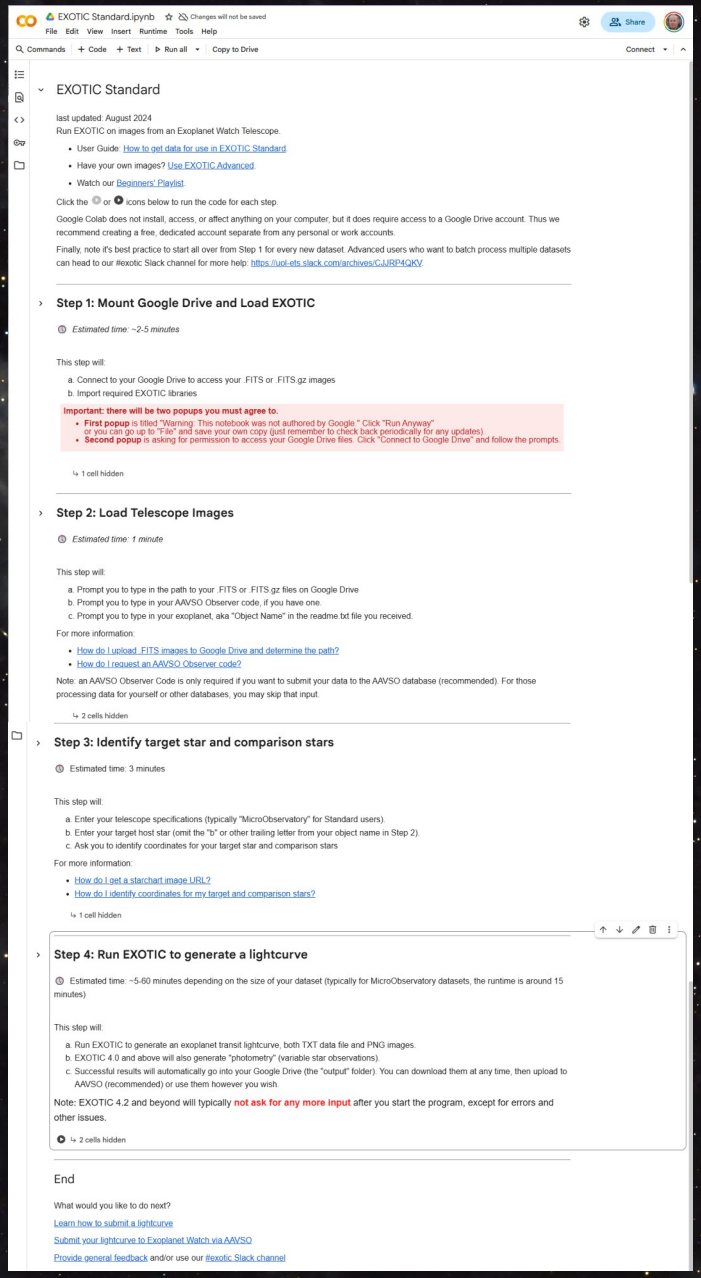
Wait

NINA Advanced Sequencer



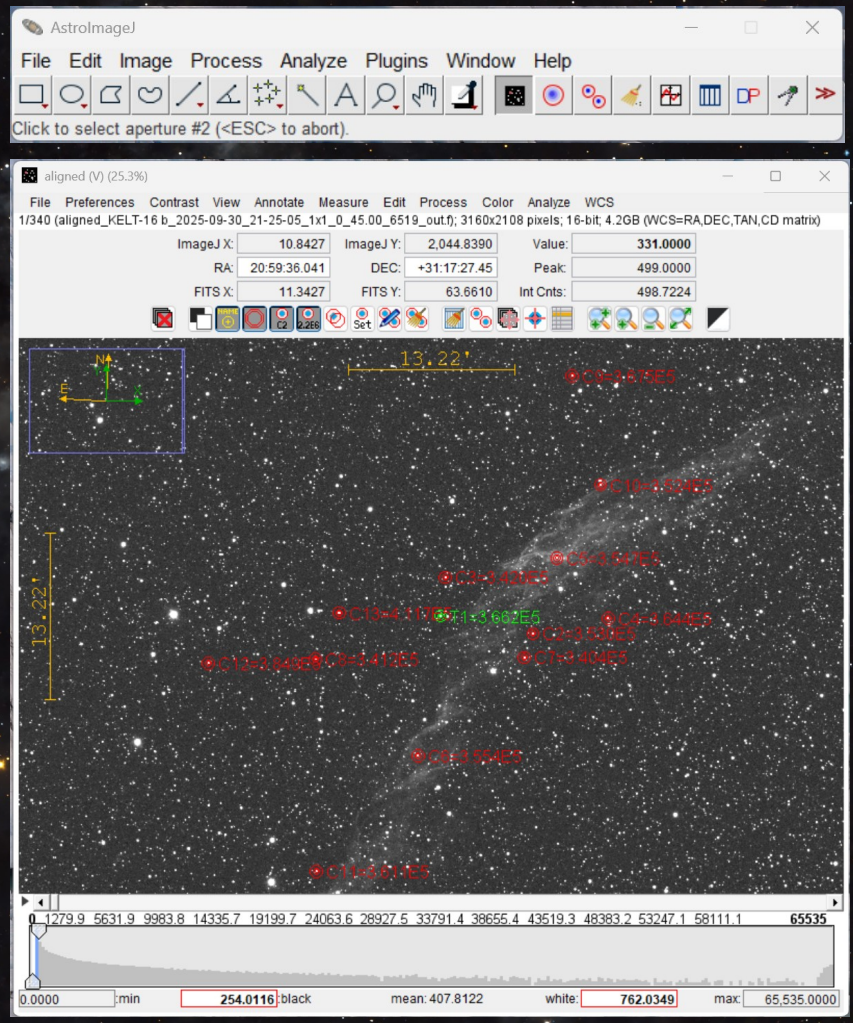
Transit Curve Processing Options

- EXOTIC (EXOplanet Transit Interpretation Code)
  - NASA-developed open source software
  - Runs locally or in Google Colab cloud environment using data stored on your Google Drive
    - Separate Google account highly recommended
  - Standard version for use with Exoplanet Watch telescope data
  - Advanced version for data collected with your own telescope/camera
  - Pros:
    - Relatively simple to use
    - Automatically computes/formats data for AAVSO upload
    - Online tutorials available to guide new users
  - Cons:
    - Free Google accounts limited to 15 GB – can quickly fill up with a limited number of transits!
    - Less flexibility than other processing options
    - Somewhat opaque – Not much visibility into what the code is doing, or why processing may have failed



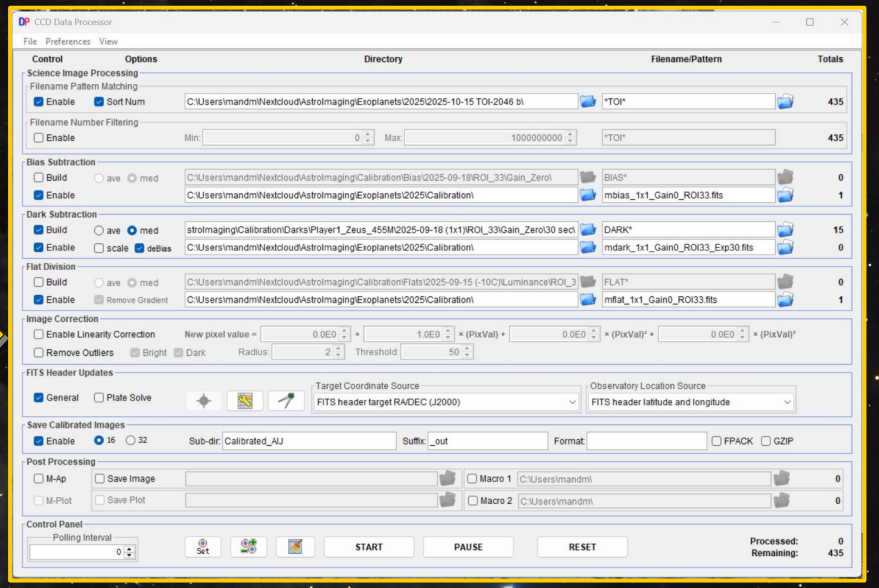
Transit Curve Processing Options

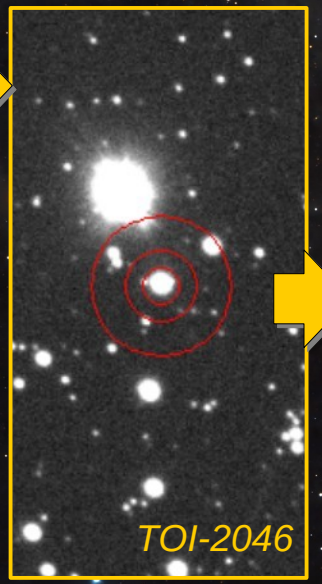
- AstroImageJ (AIJ)
  - NASA-developed software tool
  - Same tool used by professional astronomers
  - Fairly well documented manual available
  - Excellent introductory Youtube video by Patriot Astro
  - Pros:
    - Much more flexibility in choosing comparison stars, detrend parameters, plotting options, etc.
    - No need to upload data to the cloud
  - Cons:
    - Much more complicated to learn and use
    - Requires additional steps to generate AAVSO report: add parameters to measurement table, run macro

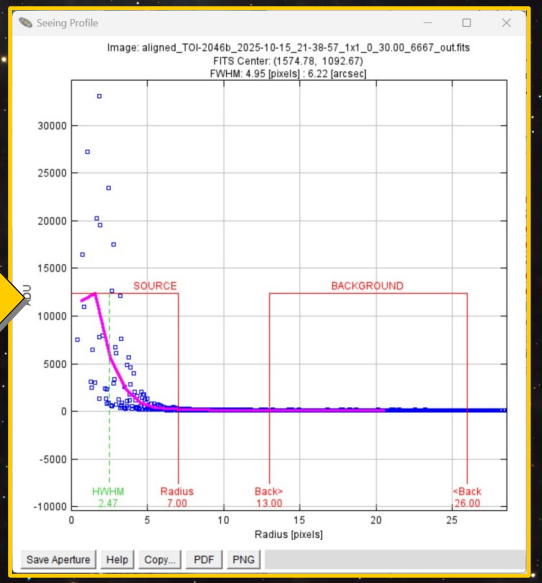


The Basics of Processing Transits With AIJ (What I do)

- Batch plate solve image stack - "slices"
  - Astrometric STAcking Program (ASTAP) is free and blazing fast!
- Calibrate – via bias, flats, darks
- Align image stack using ASTAP generated ephemerides
- Perform Multi-aperture photometry
  - Determine photometric aperture, inner and outer background annulus
  - Select comparison stars (automatic)
  - Run multi-aperture photometry
    - Generates measurements table, various analysis windows and transit curve

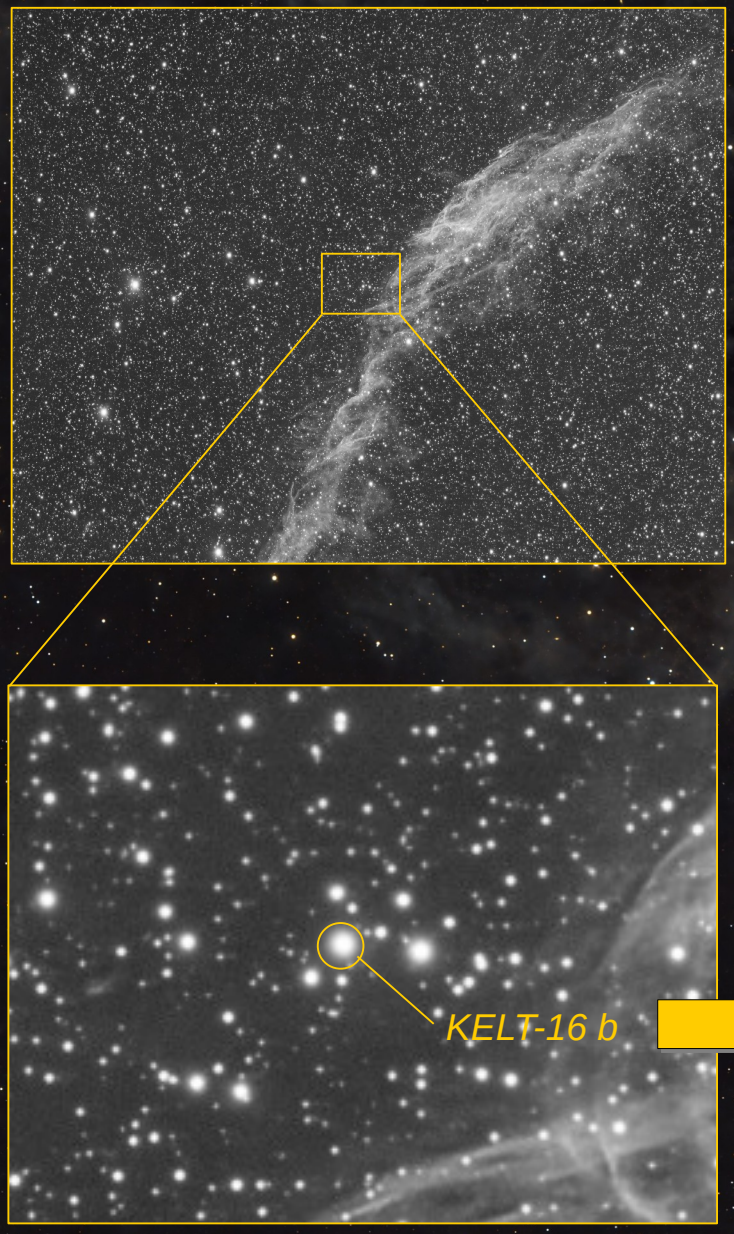




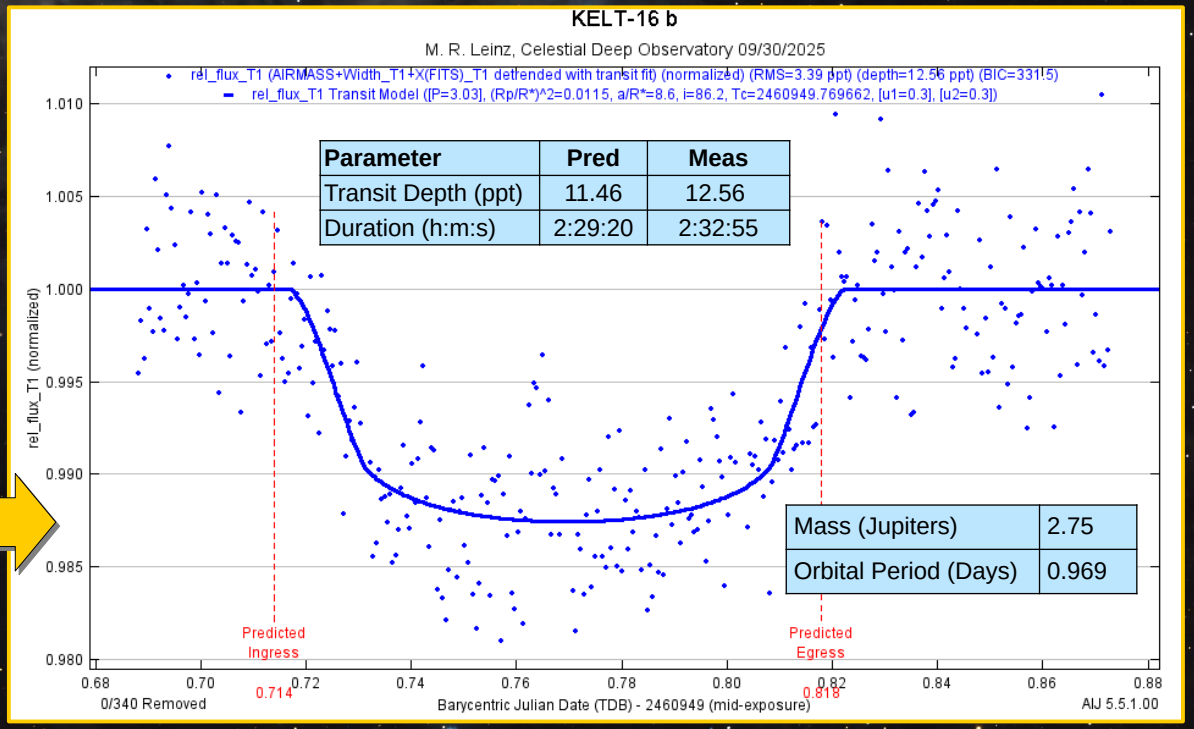


AIJ Exoplanet KELT-16 b Transit Results

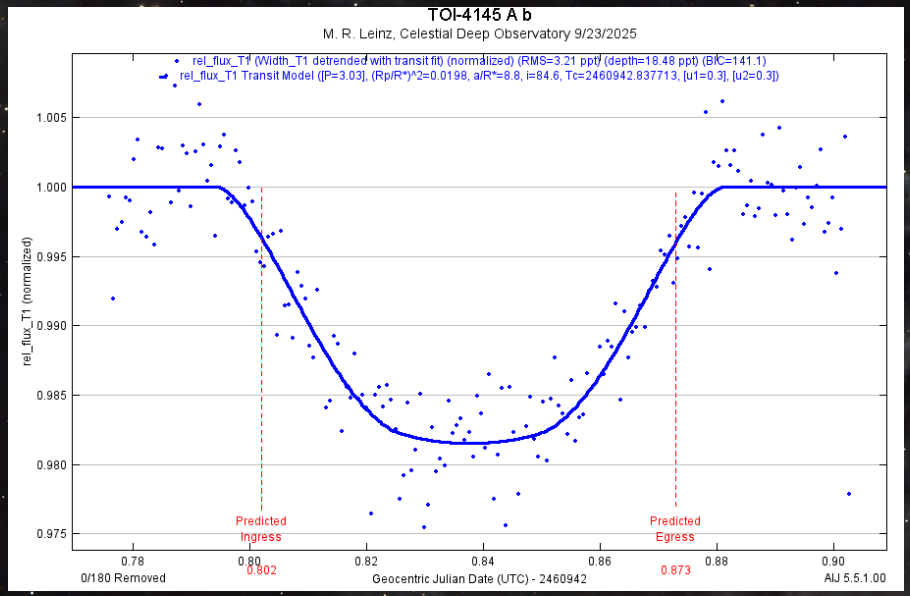
(Celestial Deep Observatory 9/30/2025)

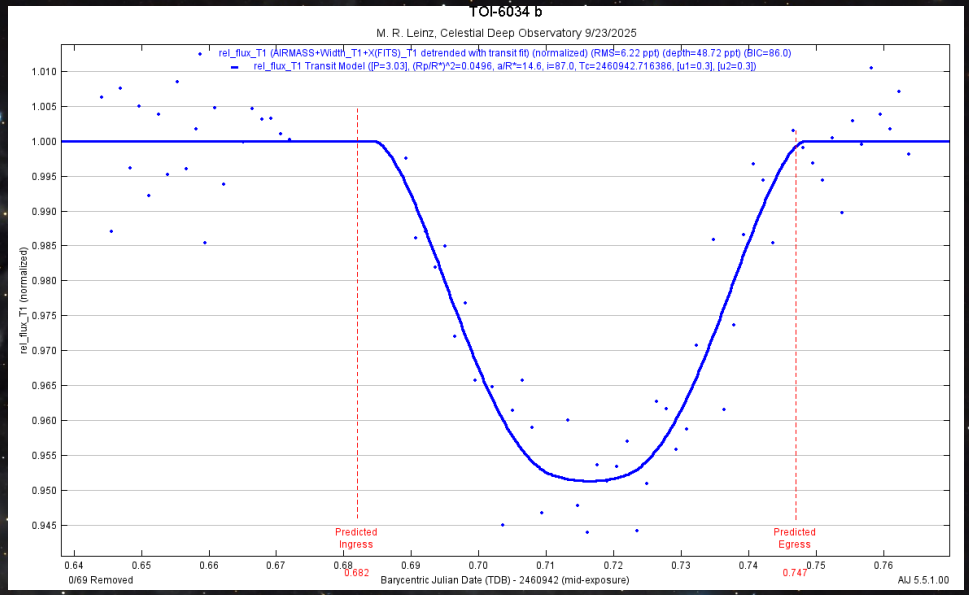


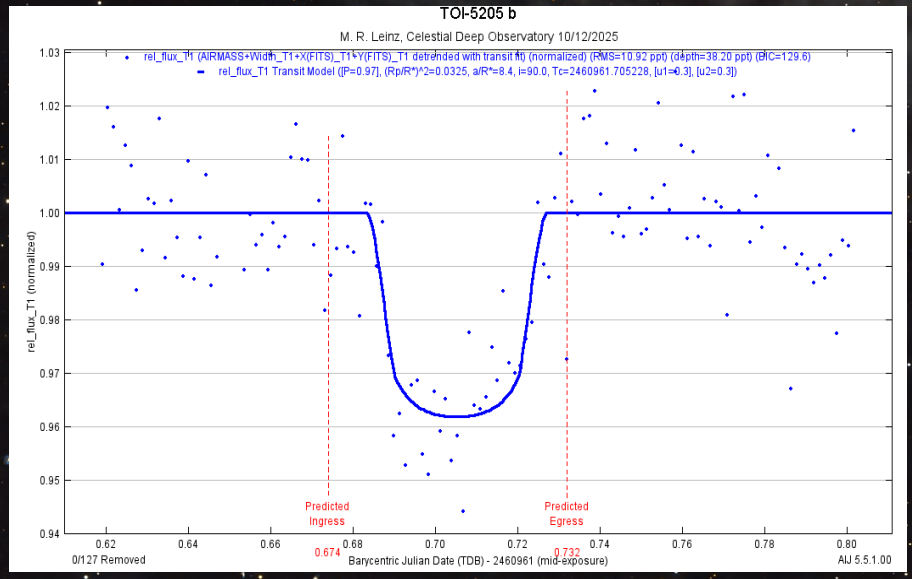
Telescope	Celestron RASA-11
Camera	PlayerOne Zeus 455M
Filter	Baader Luminance
Exposure	45 sec
Gain	0
ROI	33%
Total Frames	340

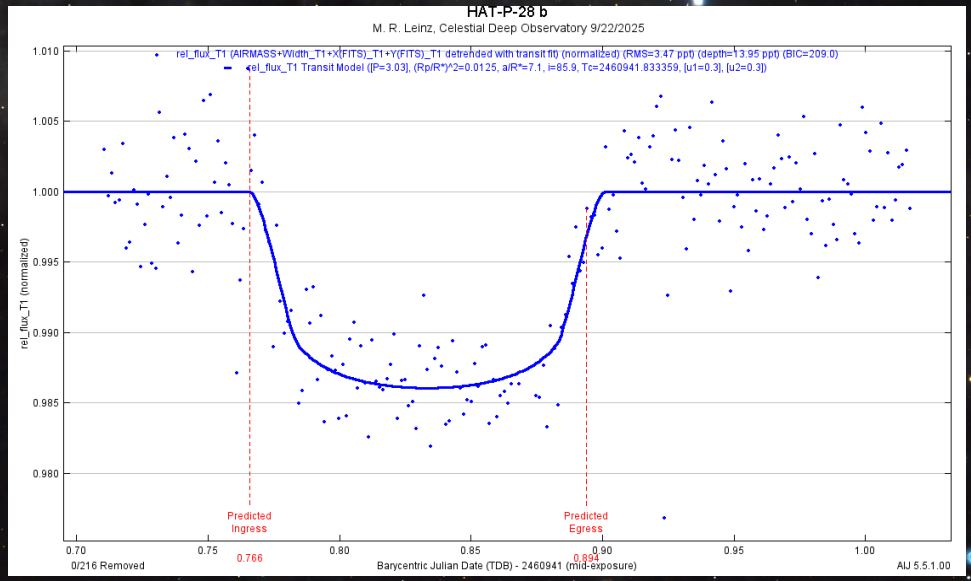


Preliminary Transit Light Curve Results

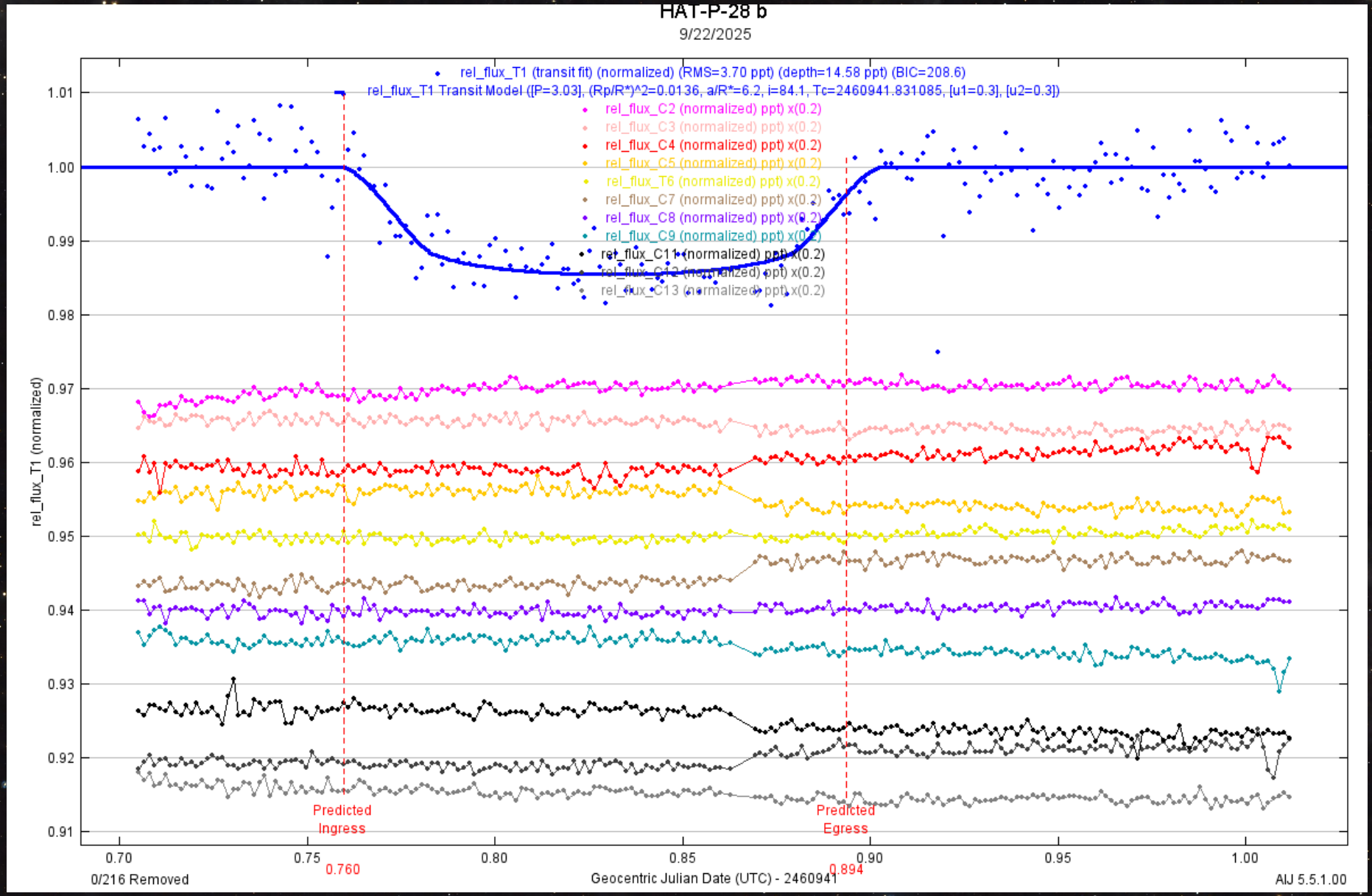








HAT P28 b Transit Curve Showing Comparison Stars



Uploading Data to AAVSO

- Setup a free AAVSO account and Observer Code
  - Edit your profile to specify site information and equipment
- Option 1 – Create report via EXOTIC
  - Complete transit analysis to obtain a satisfactory light curve
  - Automatically creates report in AAVSO format
- Option 2 – Create report via AstroImageJ
  - Complete transit analysis to obtain a satisfactory light curve
  - Add parameters to AIJ measurements table
    - BJD_TDB_B
    - rel_flux_T1_n
    - rel_flux_err_T1_n
  - Run macro within AIJ to create AAVSO Exoplanet Database formatted report

What I Have Learned So Far...

- Suitable transit opportunities exist practically every night
  - Select targets that you can image for at least 30-60 minutes before and after the transit time
  - Higher elevation angle is better – less atmosphere
  - Filter for stellar magnitude and transit depth that you can achieve with your equipment – this will come with practice
- Plan ahead:
  - You are going to need *lots* of calibration data
    - Different stellar magnitudes require different exposure / sensor gain settings
    - Separate dark, flat and bias libraries to match exposure, gain, ROI
    - Setup a sequence in NINA (or SGP, etc.) to automatically step gain, offset, ROI
    - *Be sure to indicate exposure, gain, ROI in calibration filenames!*
  - Disk space is a serious consideration
    - A single transit observation can generate multiple gigabytes of data
    - If you have a full frame sensor, use a 25-50% ROI – *trust me.*

What I Have Learned So Far…

- Maintain a balanced ‘cadence’ when selecting exposure times
  - Too short (< 30 sec.)
    - Mountains of data (i. e. disk space)
    - More susceptible to atmospheric scintillation
    - Potentially low target and comp star SNR → Noisy transit curve
  - Too long (> 3 min.)
    - Reduced transit timing measurement accuracy
    - Potential target and comp star saturation
  - Keep track of parameters used for each transit (I use a spreadsheet)
    - Simplifies determining proper exposure for subsequent transits
- Develop a workflow and document it
  - Streamlines future transit analyses, especially if you are using AIJ
  - I started with the Patriot Astro video and am continuously updating
  - I’m happy to share with anyone interested

Resources

- NASA Exoplanet Watch: *https://science.nasa.gov/citizen-science/exoplanet-watch/exoplanet-watch-overview/*
- Exoplanet Watch Beginner's Playlist: *https://www.youtube.com/playlist?list=PLQAvHoeWXY8k72xzA5Vhw4wBmik6Mf6Az*
- MicroObservatory Robotic Telescope Network: *https://mo-www.cfa.harvard.edu/OWN/index.html*
- Smithsonian Data Labs DIY Planet Search: *https://datalabs.cfa.harvard.edu/diy/index.php*
- NASA Exoplanet Archive: *https://exoplanetarchive.ipac.caltech.edu/index.html*
- Zooniverse Planet Patrol: *https://www.zooniverse.org/projects/marckuchner/planet-patrol*
- Zooniverse Planet Hunters TESS: *https://www.zooniverse.org/projects/nora-dot-eisner/planet-hunters-tess*
- TESS Follow-up Program (TFOP): *https://tess.mit.edu/followup/*
- ExoClock: *https://www.exoclock.space/*
- DIY Planet Search: *https://datalabs.cfa.harvard.edu/diy/index.php*
- ASTAP Download: *https://www.hnsky.org/astap.htm*
- Swarthmore Transit Finder: *https://astro.swarthmore.edu/transits/*
- AstroImageJ Download: *https://astroimagej.com/*
- Processing Exoplanet Transits with AstroImageJ (Patriot Astro): *https://www.youtube.com/watch?v=GW--rE5O-c8&t=2023s*
- A Practical Guide to Exoplanet Observing: *chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.astrodennis.com/Guide.pdf*
- American Association of Variable Star Observers: *https://www.aavso.org/*

If You'd Like to Get In Touch...

- Email: *celestialdeep55@gmail.com*
- Astrobin: *www.astrobin.com/users/Starrider55/*
- My website: *www.celestialdeep.space*

Comet C/2023 A3 (Tsuchinshan-ATLAS) Over Celestial Deep Observatory Mariposa, Ca. 10/28/2024


Questions?