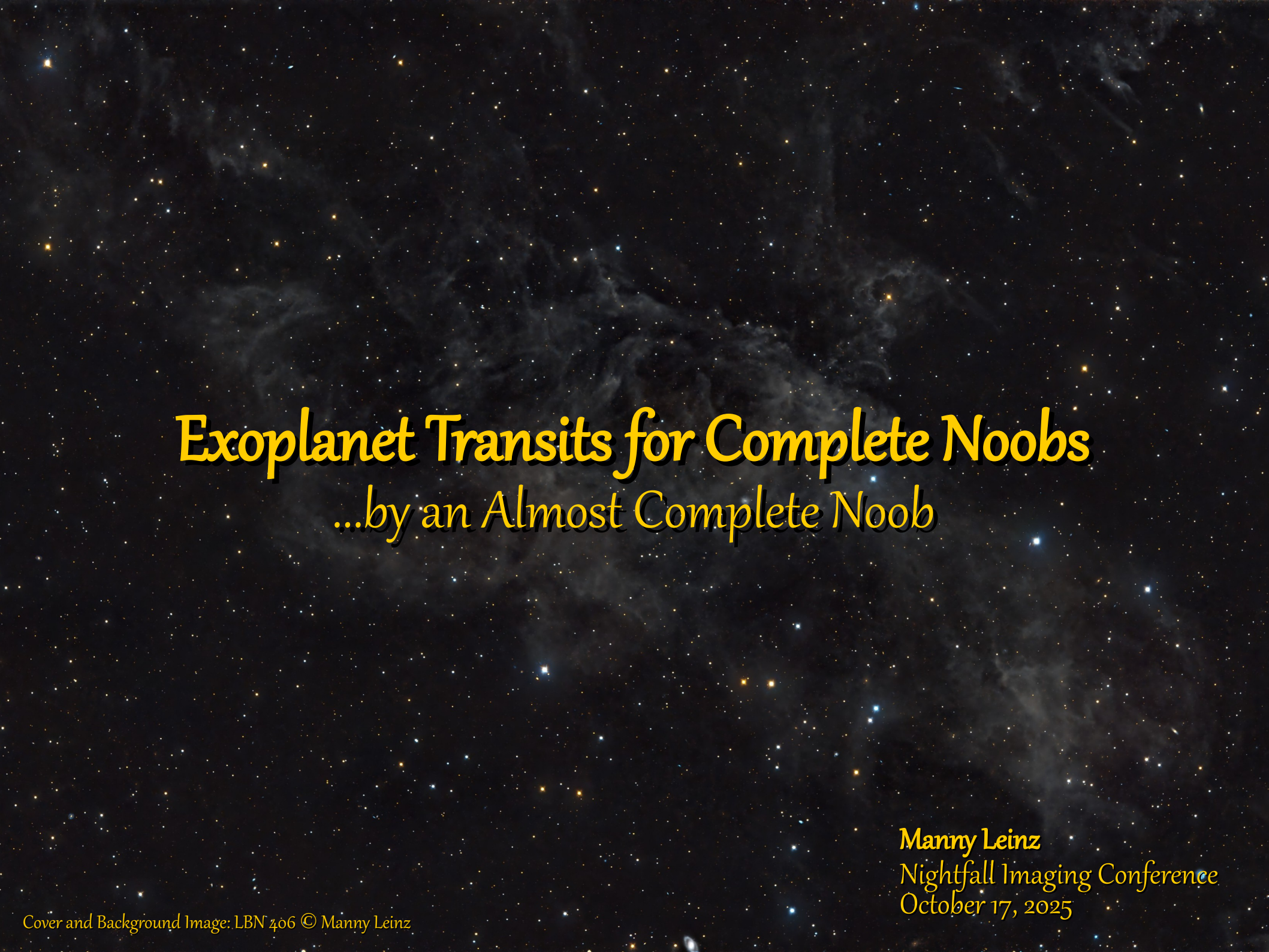




Exoplanet Transits for Complete Noobs

...by an Almost Complete Noob

Manny Leinz
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

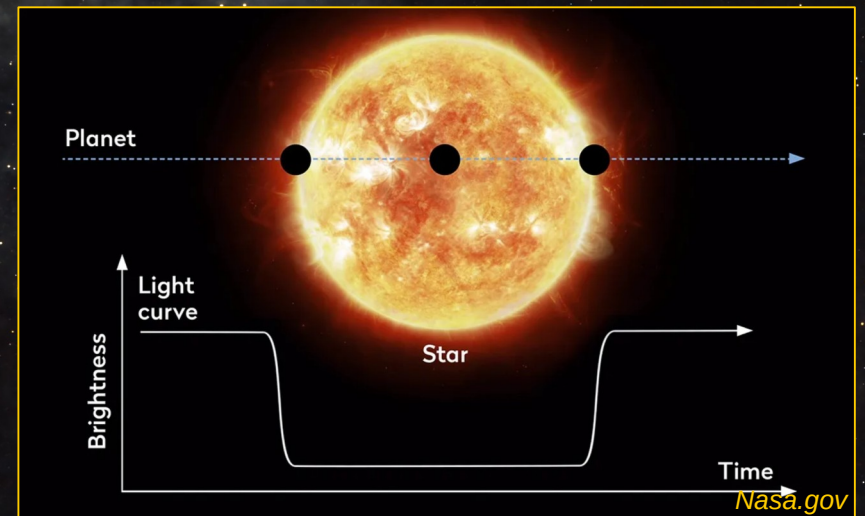
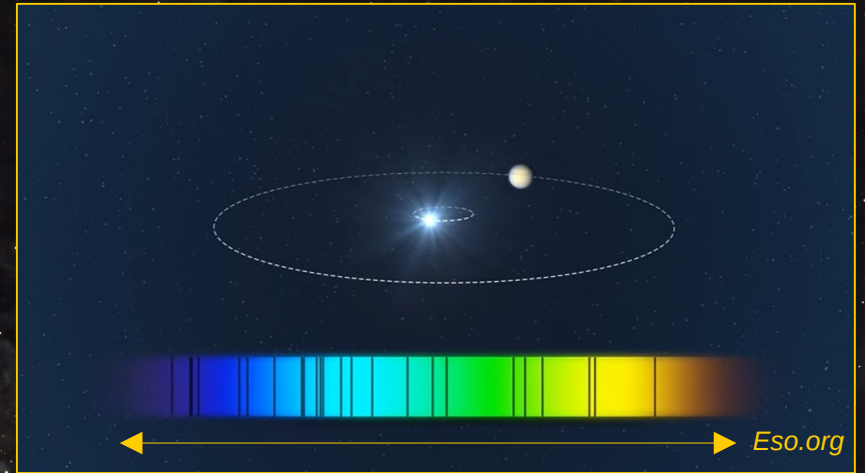
- Extrasolar (exo) planets:
 - Objects below the limiting mass for thermonuclear fusion (i. e. not brown dwarfs)
 - Orbiting stars, brown dwarfs or stellar remnants beyond our sun
- First discoveries:
 - 1992: PSR B1257+12 b, c - Two planets orbiting a pulsar (Wolszczan, Frail)
 - 1995: 51 Pegasi b -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



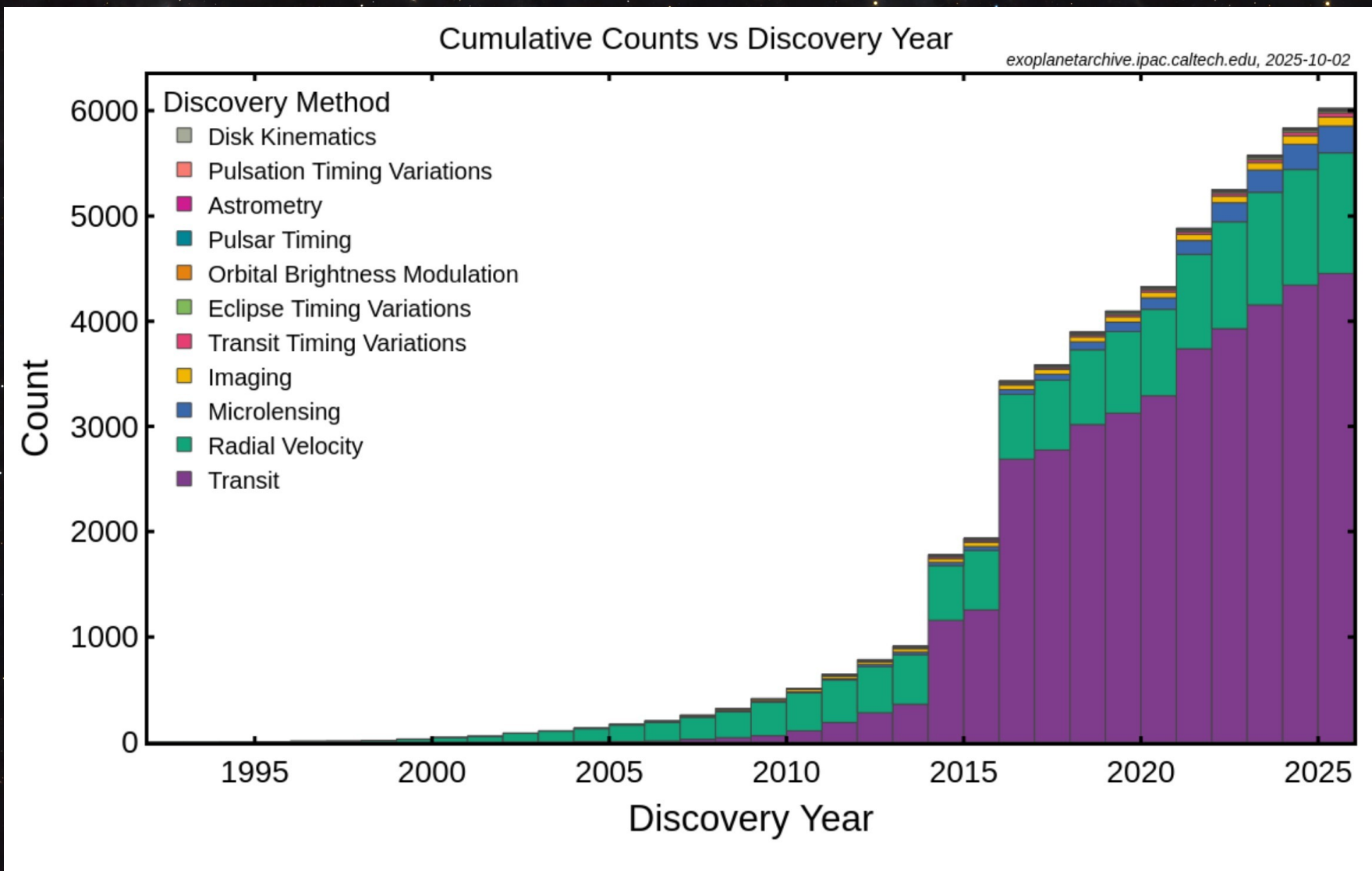
Nasa.gov

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

Exoplanet Types



Gas Giants

The size of Saturn or Jupiter, or much larger. They include "hot Jupiters"- scorching planets in close orbits around their stars.



Neptune-Like

Similar in size to our own Neptune and Uranus, with hydrogen or helium-dominated atmospheres. "Mini-Neptunes," not found in our solar system, are smaller than Neptune but larger than Earth.



Terrestrial

Earth-sized or smaller, mostly made of rock and metal. Some could possess oceans or atmospheres and perhaps other signs of habitability.

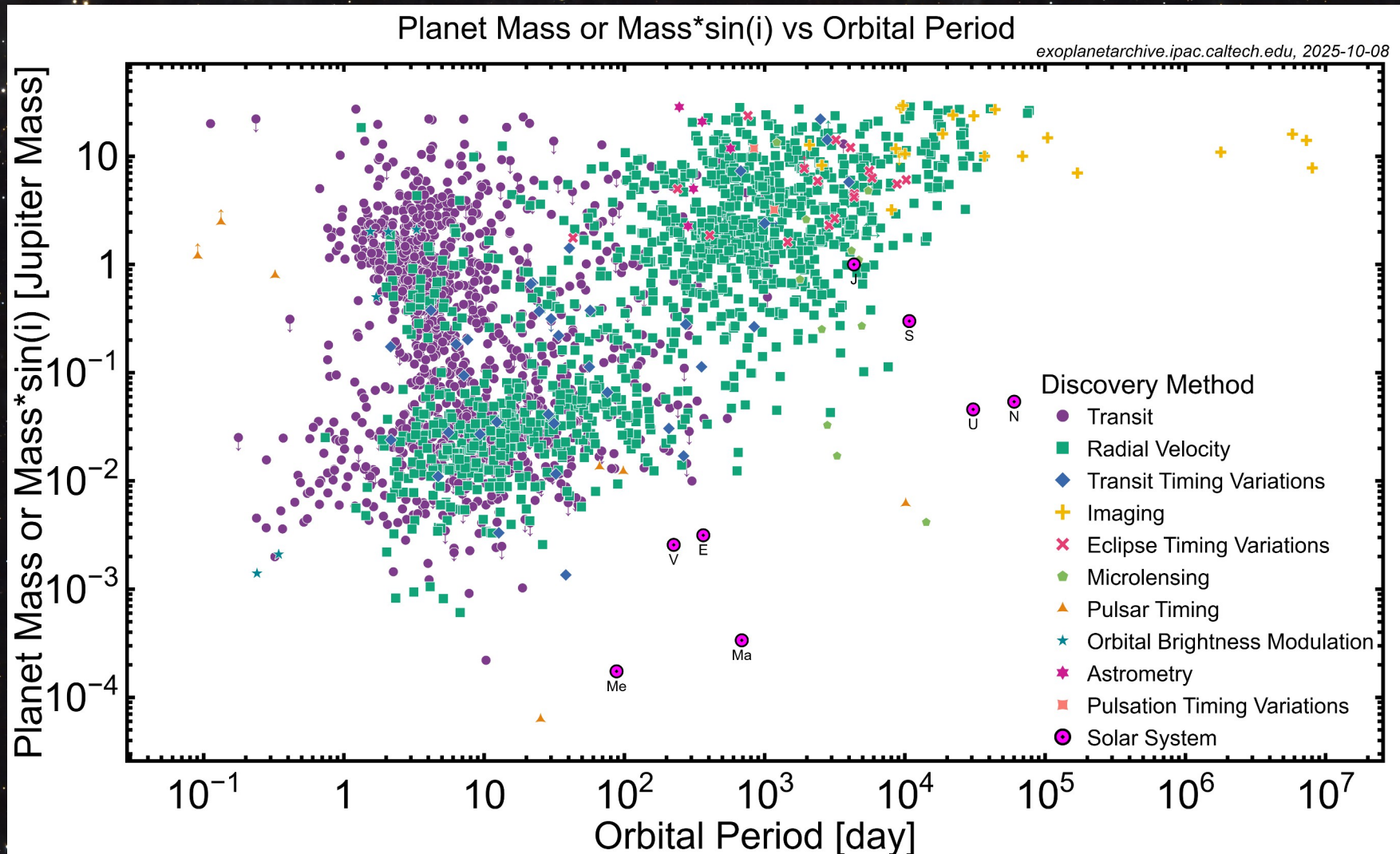


Super-Earth

Typically "terrestrial," or rocky, and more massive than Earth but lighter than Neptune. They might or might not have atmospheres.

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

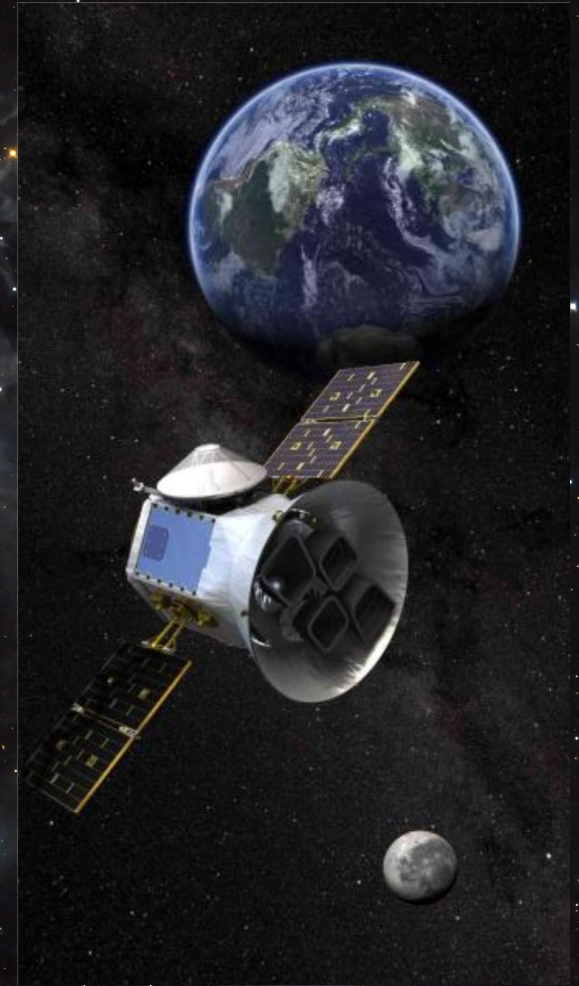
Exoplanet Discovery Progress



Transit observations are heavily biased toward short period orbits

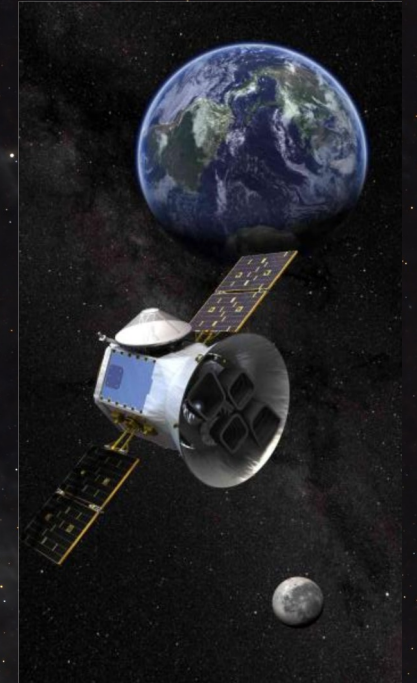
Opportunities to Contribute to Exoplanet Science

- 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



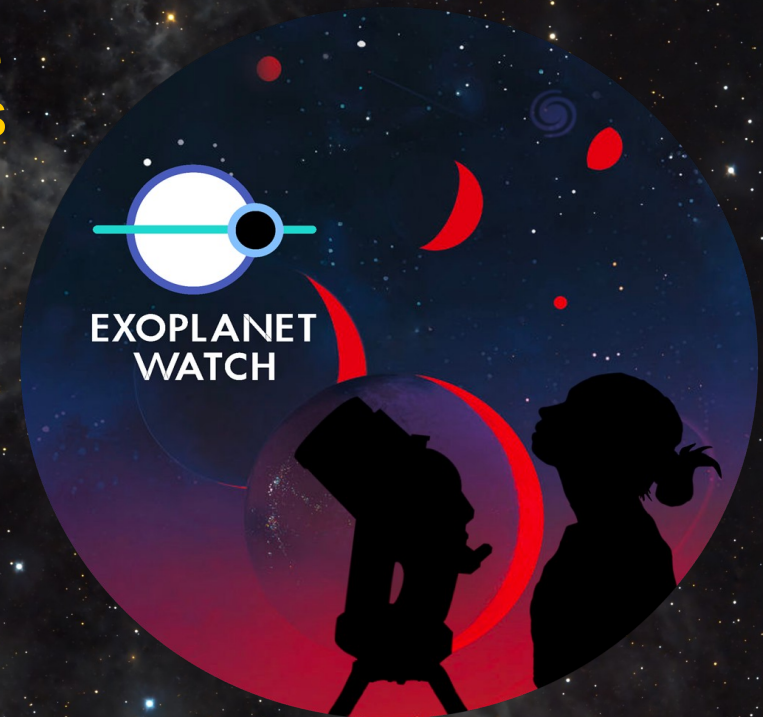
Opportunities to Contribute to Exoplanet Science

- 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)...



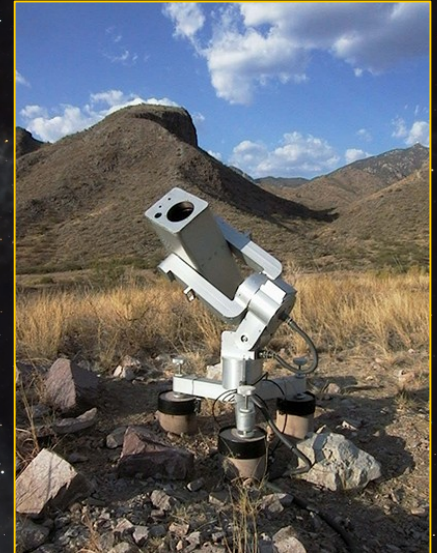
Exoplanet Watch - Objectives

- 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.



Schedule Target

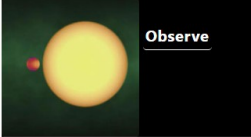
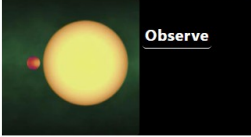
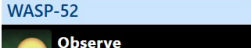
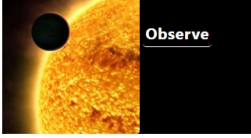
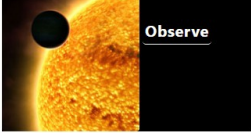
Please choose a date and target for your telescope observations

[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	

Your mission...



Schedule Target



Control Telescope



Measure Brightness



Interpret & Share



Community Results

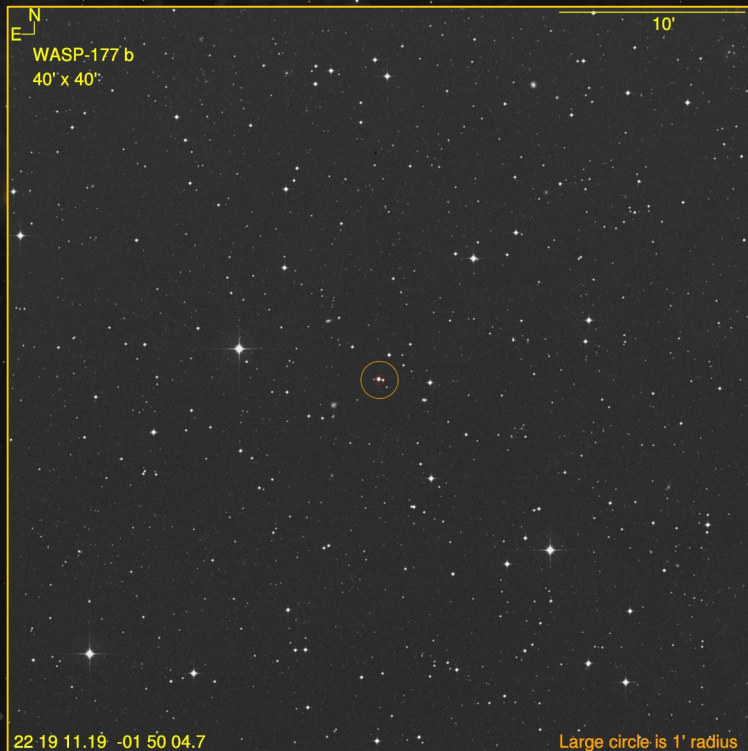
Transit Imaging Using Your Own Telescope/Camera

(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



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.

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

Column visibility Reset column order Show all columns Disable tooltips 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 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	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	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 Kabath et al. 2022

Image Target With NINA Advanced Sequencer

The screenshot displays the NINA Advanced Sequencer interface for configuring an observation of TOI-2046b. The interface is divided into several sections:

- Left Sidebar:** Contains icons for Equipment, Sky Atlas, Framing, Flat Wizard, Sequencer (active), Imaging, Options, and Plugins.
- Top Panel:** Shows the target name "TOI-2046b" and a "Global Triggers" section with options like "Unpark Scope", "Cool Camera" (Temperature: -10 °C, Min. Duration: 0 min), and "Wait for Time" (Source: Astronomical Dusk, Time: 19:40:02, Offset: -10 m).
- Target Configuration:** A section for "TOI-2046b" with fields for Name, Start/End (23:10 / 01:34), Magnitude (11.6), Depth (16.3), and a Comment. It also includes RA (1 h 4 m 44.39 s), Dec (74 d 19 m 52.7 s), and Rotation (0°).
- Graph:** A plot showing the position of the target (ppt) over time. The x-axis represents time from 12 to 12, and the y-axis represents position from 0 to 90. A vertical line marks the "Now" position. The graph shows a transit event labeled "Transit north" at 53°.
- Triggers:** A section for configuring triggers, including "Restore Guiding", "Center After Drift" (Evaluate after exposures: 4, Max. arcmin: 2.00), "Loop Conditions", and "Instructions" (Slew and center, Run Autofocus, Start Guiding, Calculate exposure time).
- Right Panel:** A sidebar with tabs for "Instructions", "Templates", and "Targets". It lists various instruction sets (e.g., Deep Sky Object, ExoPlanet, James-Webb Space Telescope) and camera settings (e.g., Cool Camera, Dew Heater, Set Readout Mode, Set USB Limit, Smart Exposure, Take Exposure, Take Many Exposures, Take Subframe Exposure, Warm Camera).
- Bottom Panel:** A section for "Wait for Transit Observation Time" (Source: Start observation, Time: 21:50:04, Offset: -20 m) and a large green play button.

NINA Advanced Sequencer

Exoplanet
Object
Container

Recenter
Target

Wait

The screenshot displays the NINA Advanced Sequencer interface, which is used for planning and executing astronomical observations. The interface is organized into several sections:

- Global Triggers:** A list of triggers that control the sequence. The visible triggers are:
 - Unpark Scope:** A trigger that unparks the telescope.
 - Cool Camera:** A trigger that cools the camera, with a temperature of -10°C and a minimum duration of 0 min.
 - Wait for Time:** A trigger that waits for a specific time, with a source of Astronomical Dusk, a time of 19:40:02, and an offset of -10 m.
- TOI-5205 b:** A section for the current target, TOI-5205 b. It includes a target selection interface and a graph showing the transit light curve. The graph plots the transit depth (ppt) against time (hours). The transit is labeled "Transit north" and shows a depth of 53%.
- Triggers:** A section for the sequence of triggers. The visible triggers are:
 - Restore Guiding:** A trigger that restores guiding.
 - Center After Drift:** A trigger that centers the target after drift, with a maximum arcmin of 2.00 (96px @ 1x1).
 - Loop Conditions:** A section for defining loop conditions.
 - Instructions:** A section for defining instructions, including:
 - Slew and center:** A trigger that slews and centers the target.
 - Run Autofocus:** A trigger that runs autofocus.
 - Start Guiding:** A trigger that starts guiding, with a force calibration of OFF.
 - Calculate exposure time:** A trigger that calculates the exposure time.
 - Wait for Transit Observation Time:** A trigger that waits for the transit observation time, with a source of Start observation, a time of 21:50:04, and an offset of -20 m.

The interface also includes a bottom bar with navigation icons and a right sidebar with additional controls.

NINA Advanced Sequencer

Error.
Recovery

Take
Exposures

The screenshot displays the NINA Advanced Sequencer interface, which is used for controlling astronomical imaging sequences. The interface is organized into several sections:

- Top Section:** Contains basic control buttons: "Slew and center", "Run Autofocus", "Start Guiding" (with a "Force calibration" toggle set to "OFF"), "Calculate exposure time", and "Wait for Transit Observation Time" (with fields for Source, Start observation, Time: 21:50:4, Offset: -20 m).
- Sequential Instruction Set:** A list of instructions to be executed in sequence, each with a trash icon and a menu icon on the right.
 - Triggers:** A section containing four triggers: "Reconnect Equipment" (Camera), "Reconnect Equipment" (Telescope), "Meridian Flip", and "Reconnect Camera on Download Failure".
 - Loop Conditions:** A section with a checked "Loop Conditions" checkbox and a "Loop Until Time" field set to "Time 0:30:0".
 - Instructions:** A section containing a "Take Subframe Exposure" instruction with parameters: Time 60 s, Type LIGHT, Binning 1x1, Gain 125, Offset (30), and ROI 33 %.
- Bottom Section:** Contains additional control buttons: "Stop Guiding", "Park Scope", and "Warm Camera" (with a "Min. Duration" field set to 0 min).
- Bottom Bar:** A navigation bar with icons for back, save, print, and search.

Annotations on the left side of the image point to specific elements:

- Error. Recovery:** Points to the "Reconnect Equipment" and "Reconnect Camera on Download Failure" triggers.
- Take Exposures:** Points to the "Take Subframe Exposure" instruction.

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

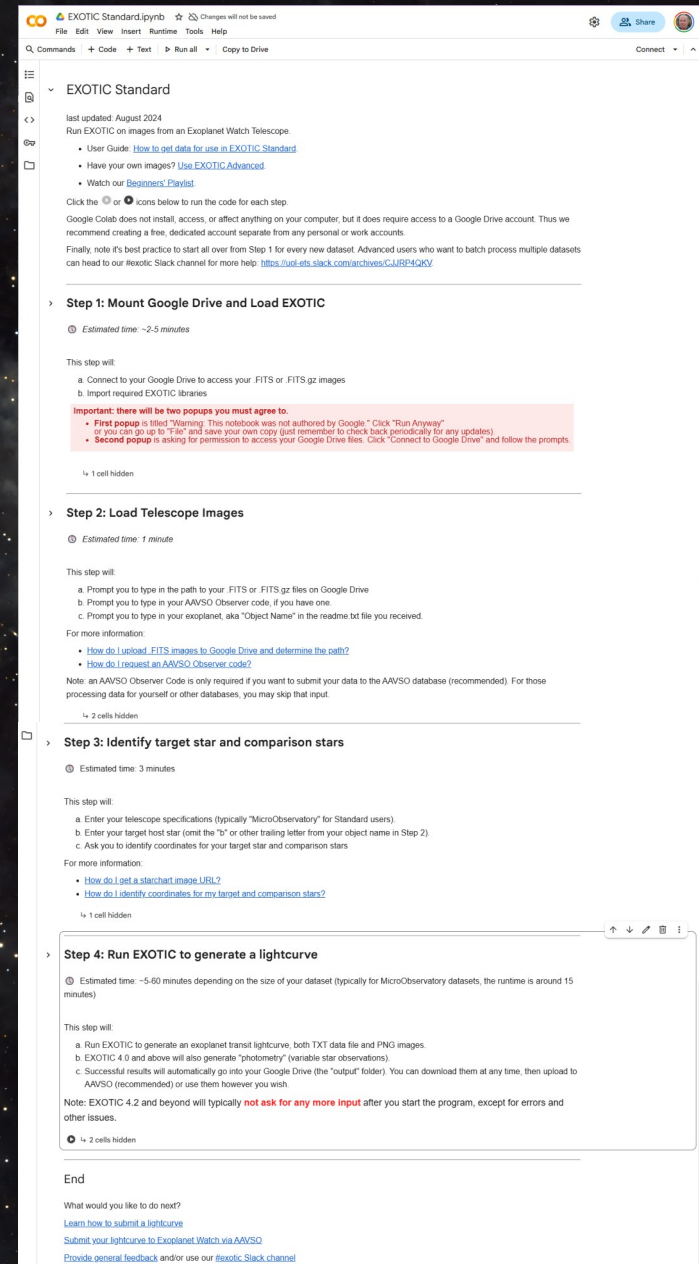
- Advanced version for data collected with your own telescope/camera

- **Pros:**

- Relatively simple to use
 - Automatically computes/formats data for AAVSO upload
 - Online tutorials available to guide new users

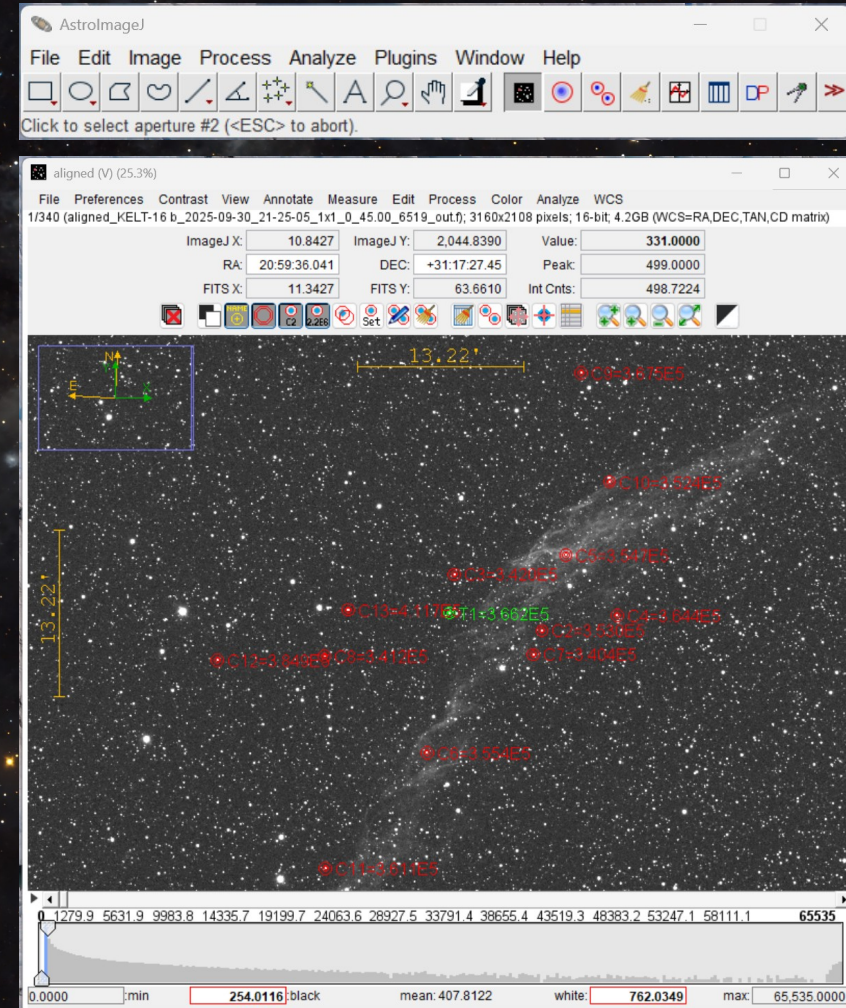
- **Cons:**

- 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



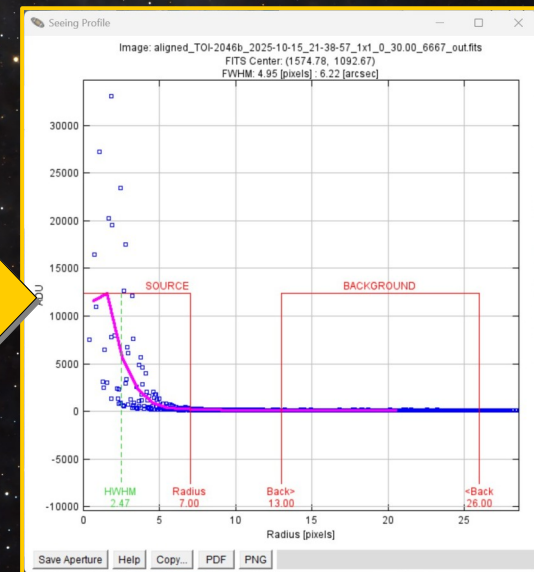
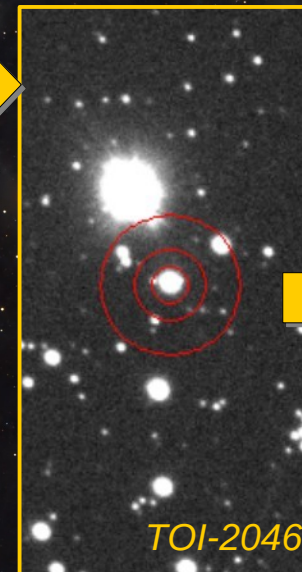
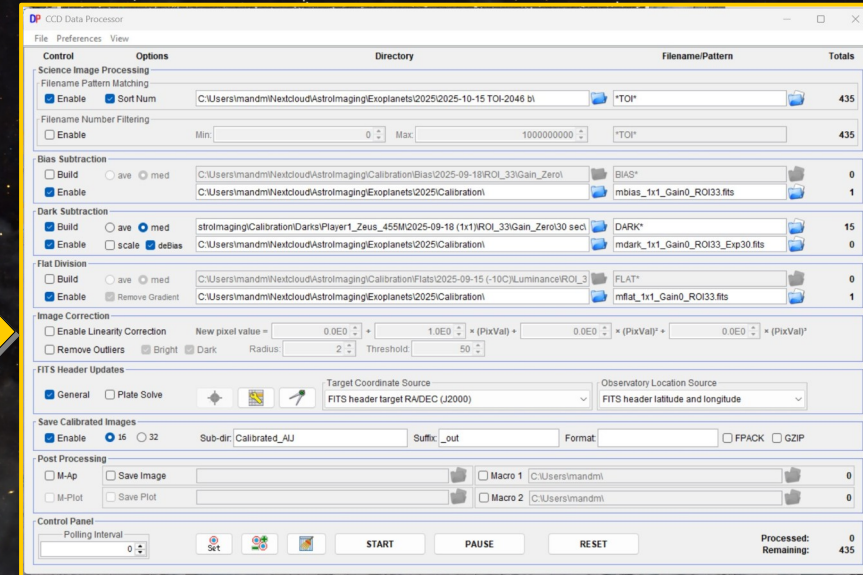
Transit Curve Processing Options

- AstrolImageJ (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



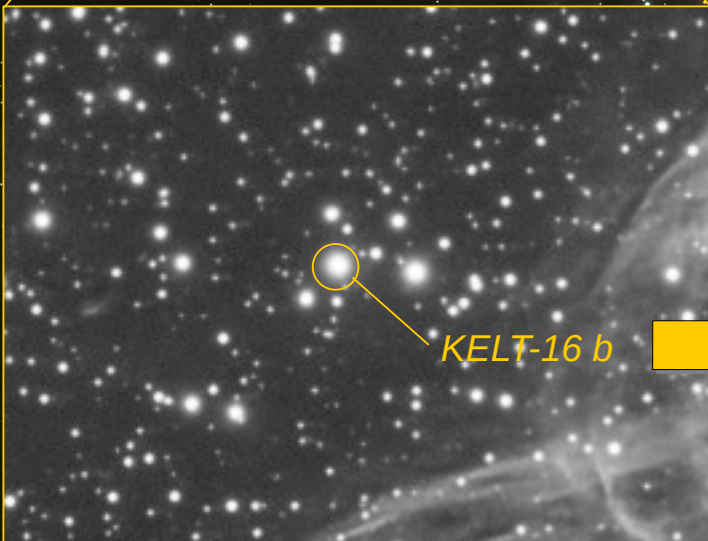
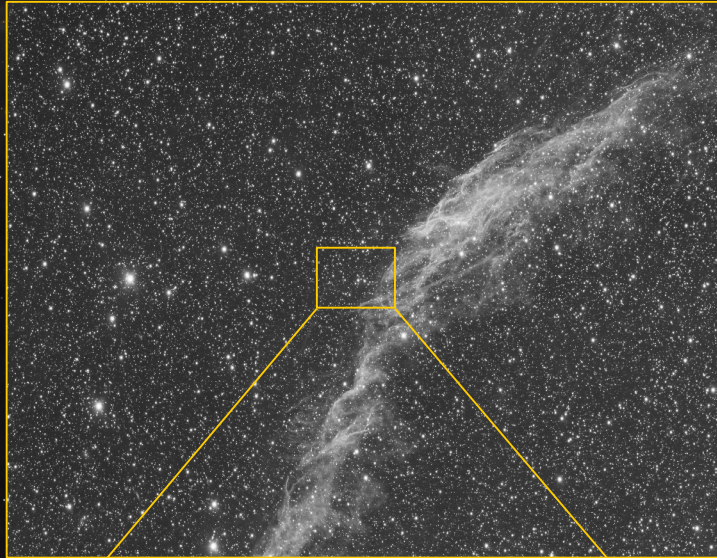
The Basics of Processing Transits With AIJ (What I do)

- 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

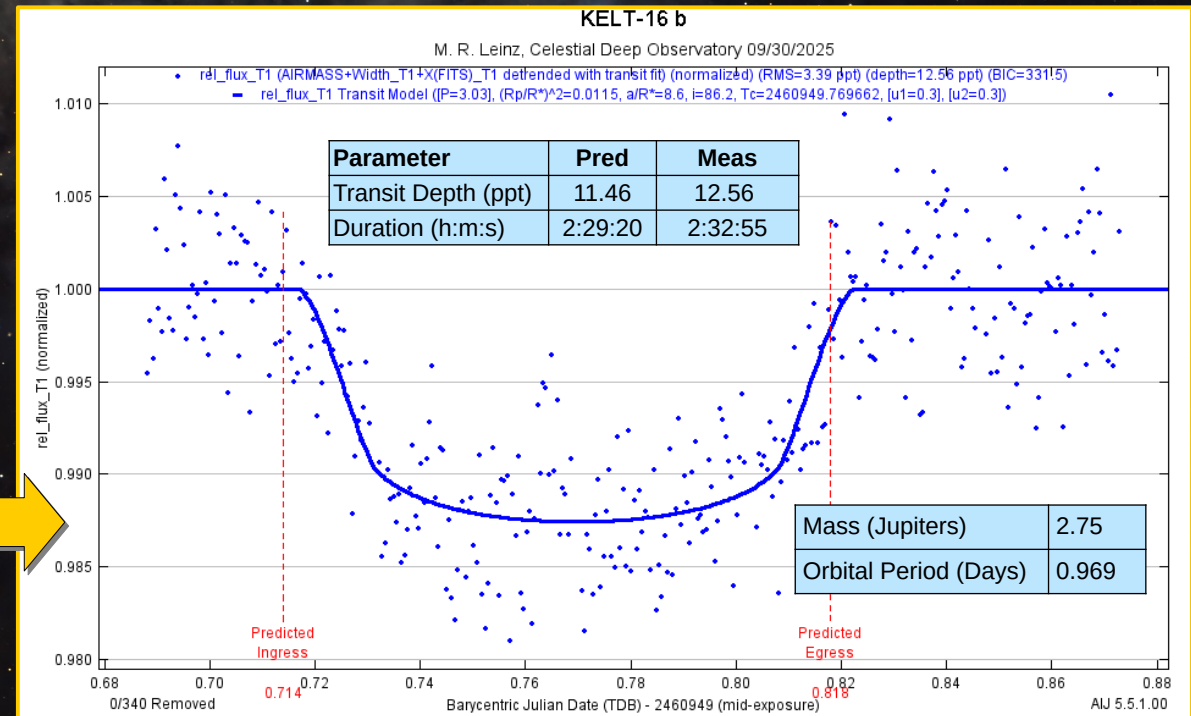


AJ Exoplanet KELT-16 b Transit Results

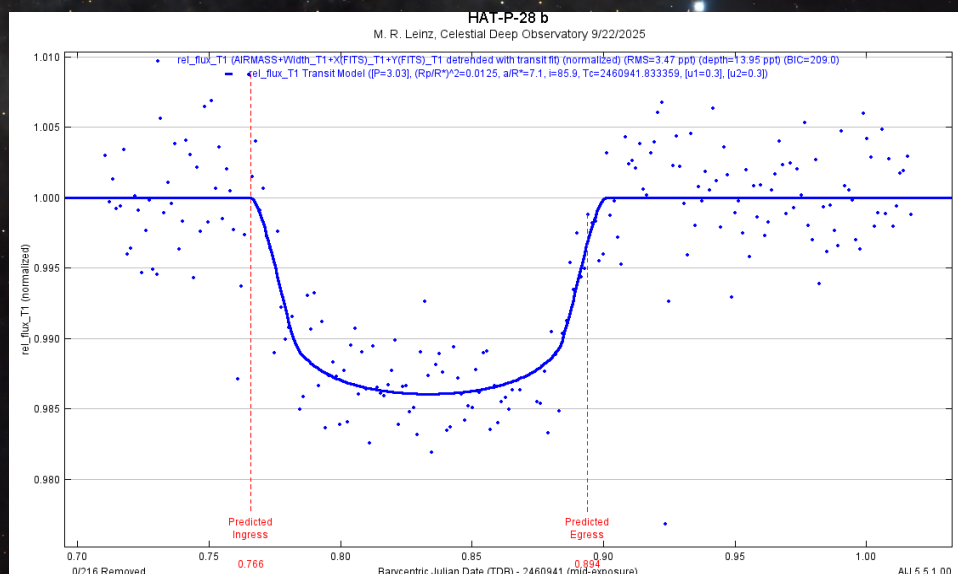
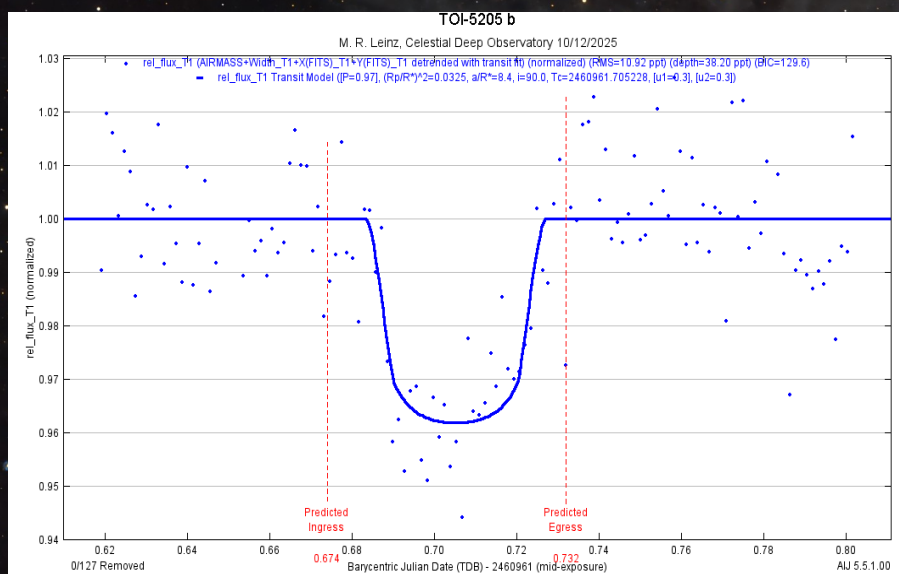
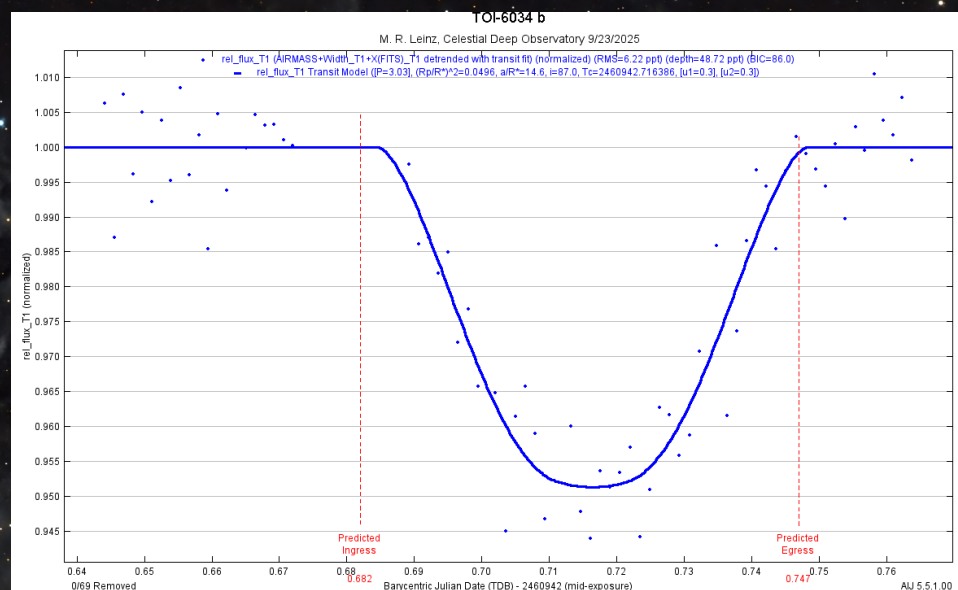
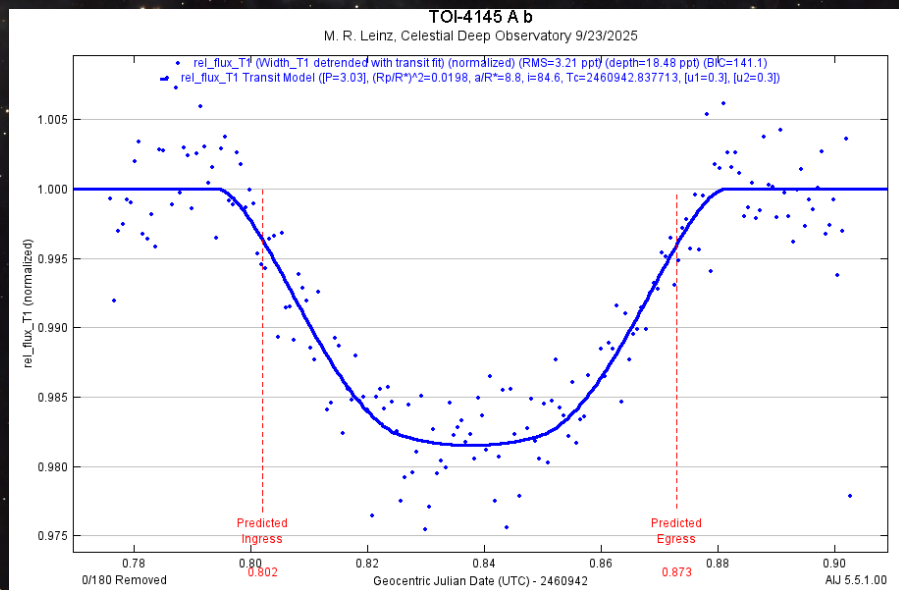
(Celestial Deep Observatory 9/30/2025)



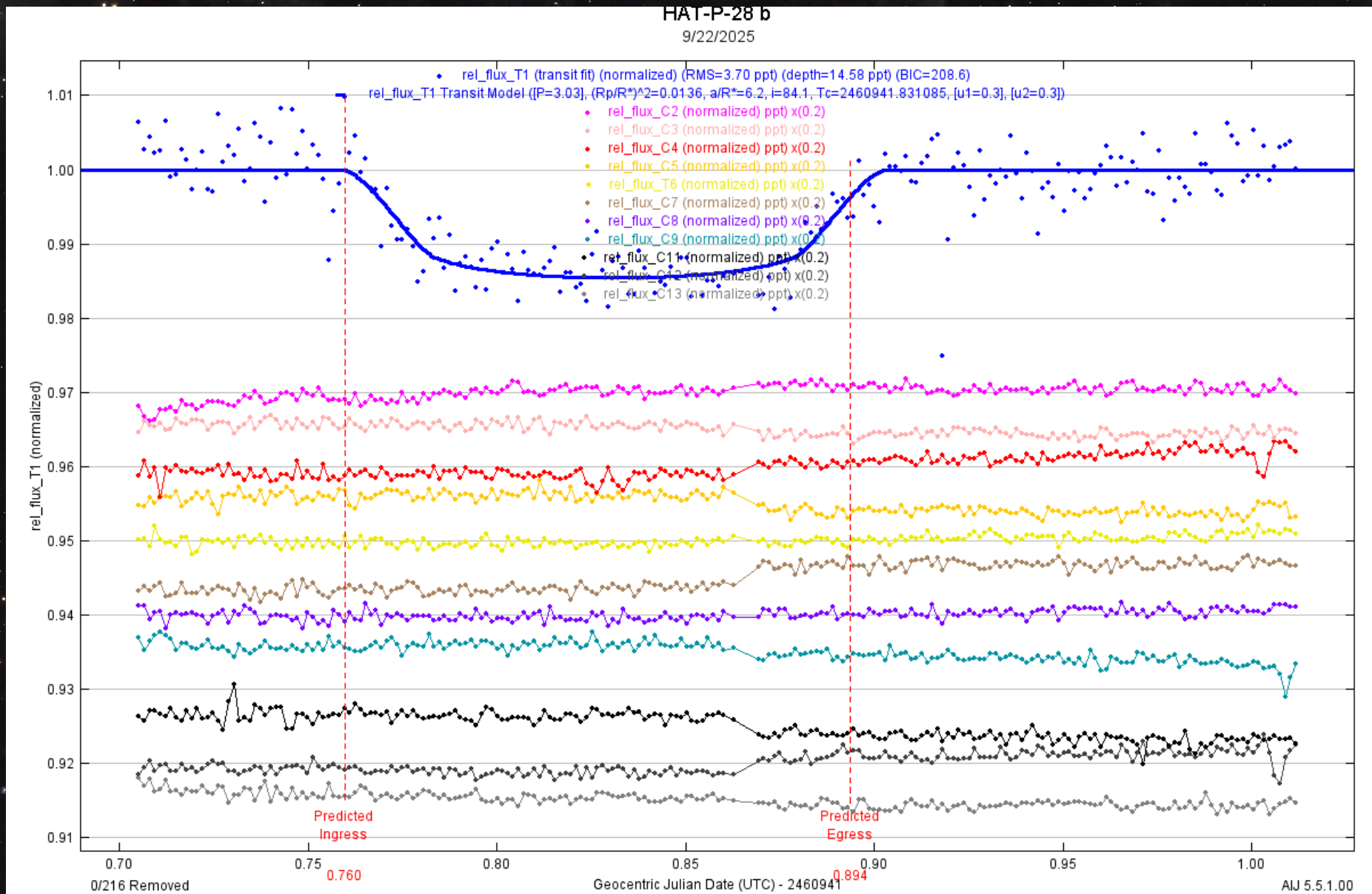
Telescope	Celestron RASA-11
Camera	PlayerOne Zeus 455M
Filter	Baader Luminance
Exposure	45 sec
Gain	0
ROI	33%
Total Frames	340



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 AstrolImageJ
 - 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.hnisky.org/astap.htm>
- Swarthmore Transit Finder: <https://astro.swarthmore.edu/transits/>
- AstrolmageJ Download: <https://astroimagej.com/>
- Processing Exoplanet Transits with AstrolmageJ (Patriot Astro): <https://www.youtube.com/watch?v=GW--rE5O-c8&t=2023s>
- A Practical Guide to Exoplanet Observing:
<chrome-extension://efaidnbmnnnibpcjpcglclefindmkaj/https://www.astrodennis.com/Guide.pdf>
- American Association of Variable Star Observers: <https://www.aavso.org/>

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

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Questions?