

The TESS Follow-Up Observing Program (TFOP)

An Opportunity for Citizen Astronomers to Contribute to
TESS Exoplanet Discoveries

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Astronomer

TESS Follow-up Lightcurve Lead (TFOP SG1)

Smithsonian Astrophysical Observatory

Center for Astrophysics | Harvard & Smithsonian

2025 September 06

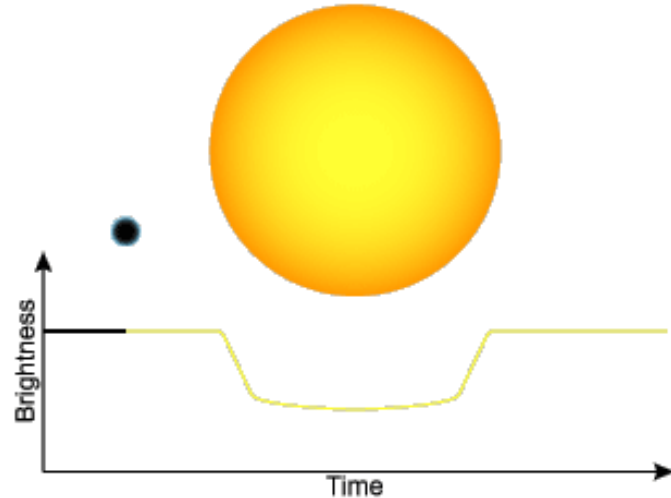
What is an Exoplanet?

- Planets orbiting stars outside our Solar System
- Nearly 6000 exoplanets to-date
- Earth-like to gas giants
- Studied to understand planet formation, evolution, demographics, atmospheres, and the possibility of habitability
- Brown dwarfs and low mass stellar companions are also interesting to scientists

Exoplanet Detection - Transit Method

- A planet passes ('transits') in front of its host star, causing a small, temporary dip in the star's brightness
- The depth and duration of the dimming reveals the planet's size (relative to the host star)
- Repeating transits reveal the orbital period

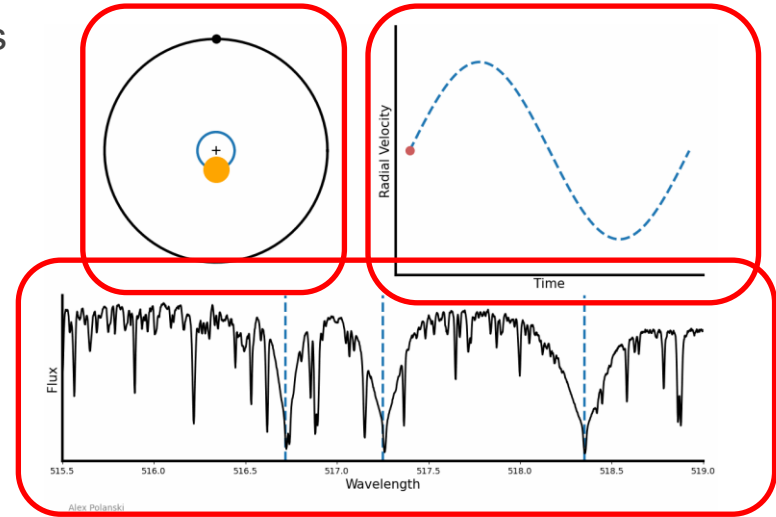
Light Curve of a Star During Planetary Transit



Exoplanet Detection - Radial Velocity Method

- Measures the star's "wobble" caused by the planet's gravity.
- Wobble appears as periodic Doppler shifts in the star's spectrum.
- Precise instruments can detect velocity changes smaller than a meter per second.

By combining transit data (for planet size) with radial velocity measurements (for mass), we determine the planet's density and derive constraints on its composition.



Ground and Space-Based Transit Surveys

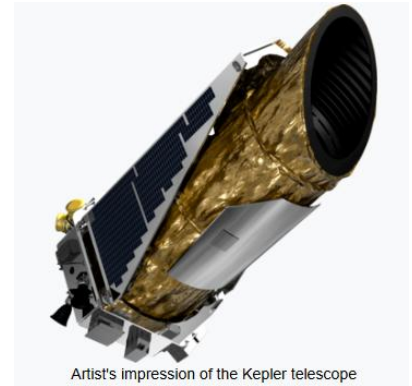
- **Ground-Based Transit Surveys:**

- Used/use networks of small-to-medium telescopes (e.g., HATNet, WASP, **KELT**, NGTS)
- Monitored wide fields for transit events across millions of stars
- Typically sensitive to larger/closer-in planets due to atmospheric limits

- **Space-Based Transit Surveys:**

- Satellites above the atmosphere (e.g., CoRoT, Kepler, TESS)
- Achieve higher photometric precision, no weather or day/night cycles
- Can detect smaller/longer-period planets
- Enables statistical studies of exoplanet populations

KELT “Telescope”



Artist's impression of the Kepler telescope

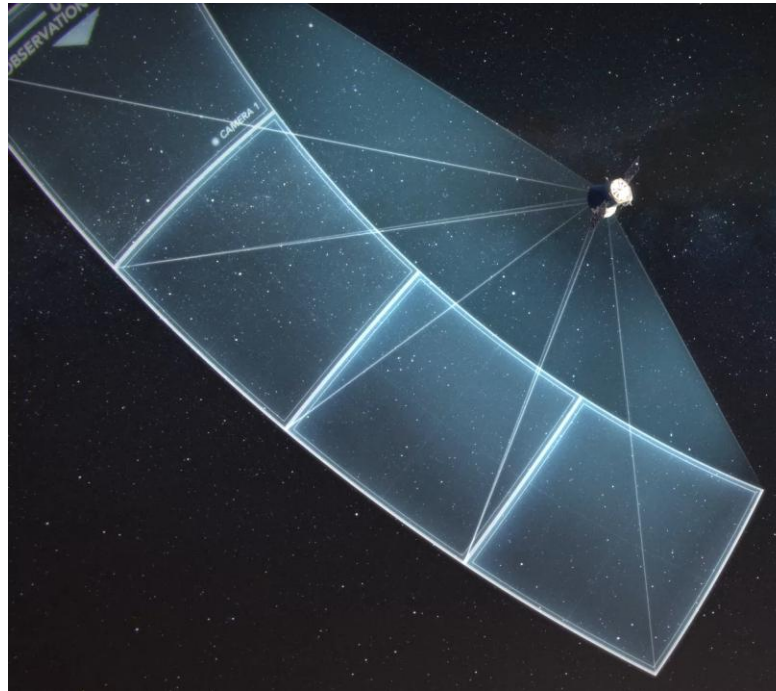
TESS Mission

- NASA's Transiting Exoplanet Survey Satellite, launched 2018
- Nearly all-sky survey to find planets around bright, nearby stars
- Starting its 8th year of observations (3rd Extended Mission) in October



TESS Observing Strategy

- Uses 4 wide-field cameras covering $24^\circ \times 96^\circ$ per pointing
- Continuously observes 27-day “sectors” to spot transit events
- Observes 13 sectors per year
- Has two continuous coverage zones

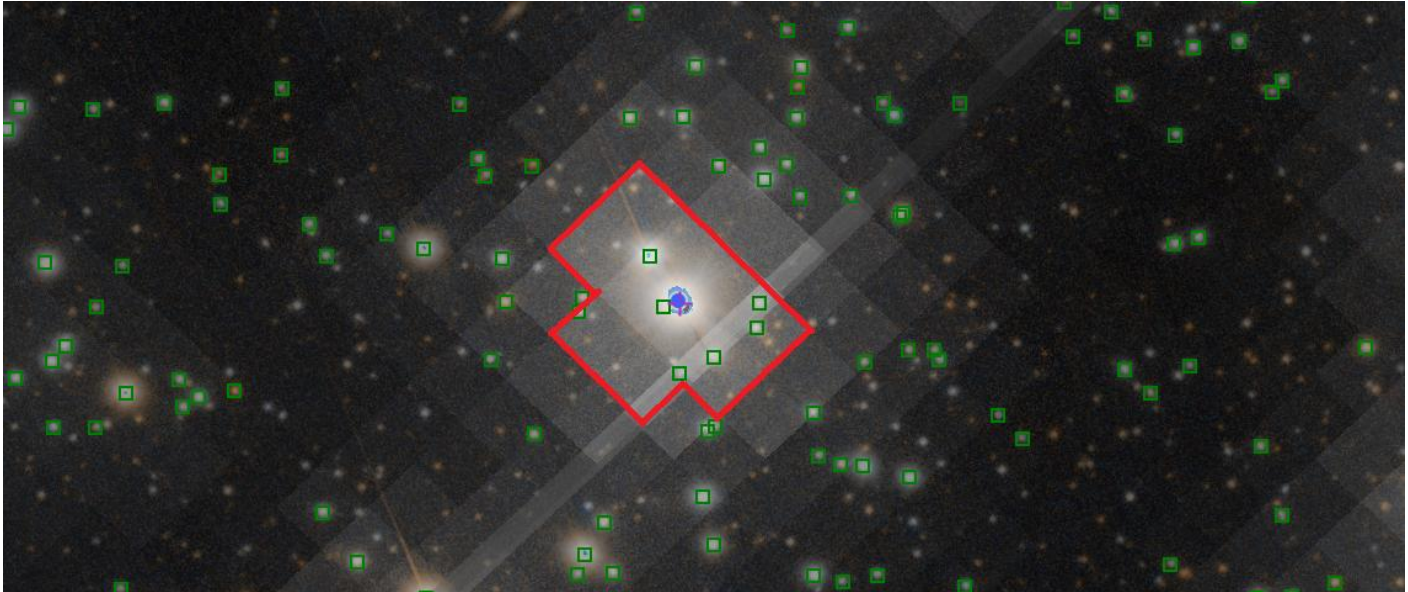


TESS Results So Far

- Over 7500 planet candidates (TESS Objects of Interest – TOIs)
- 687 published TESS planet discoveries
- 373 planets smaller than Neptune
- 80 planets smaller than 1.5 Earth radii
- 500 planets with mass measurements
- Prime targets for JWST atmospheric observations

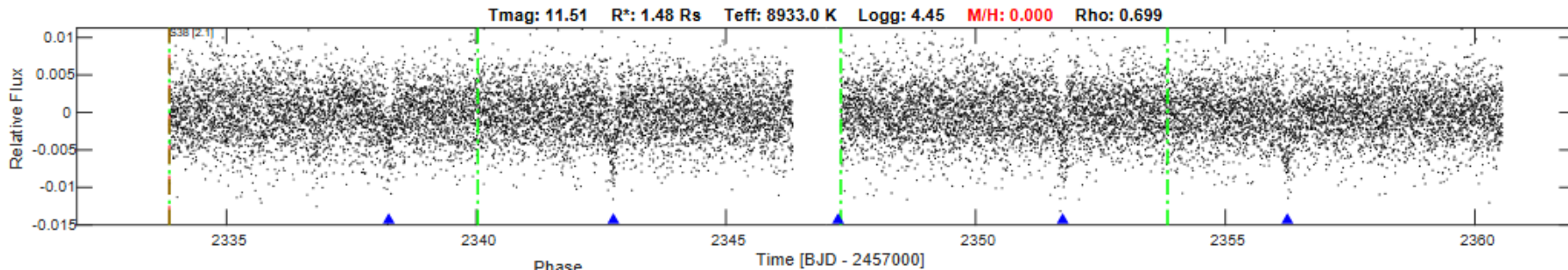
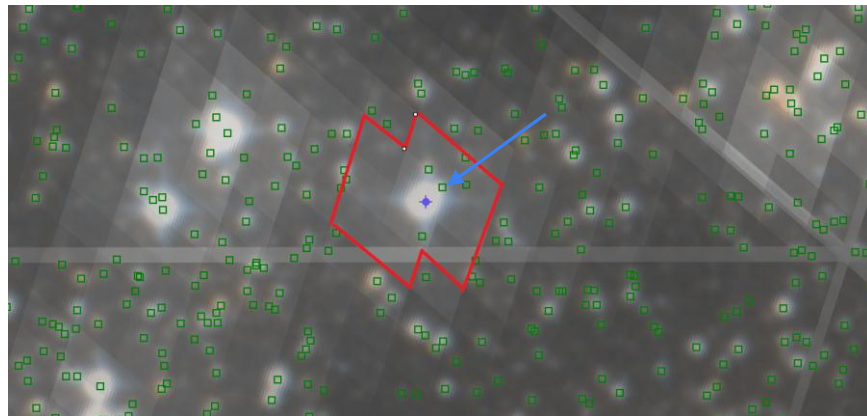
TESS Image Pixel Scale

- TESS Pixels are 21" x 21"
- TESS photometric apertures are roughly 60" x 60"
- Multiple stars are typically blended within the TESS photometric apertures



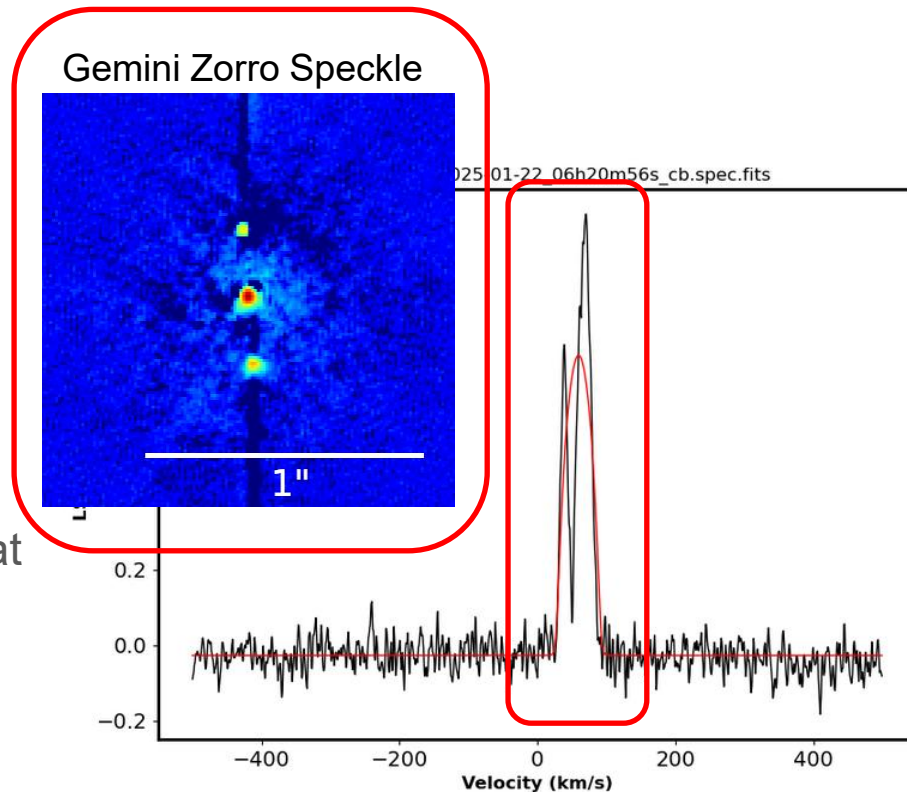
The need for ground-based follow-up

- TESS simply detects variations in a lightcurve of a ~ 60 arcsec region of the sky
- Higher spatial resolution ground-based lightcurves may be needed to determine the source of the dip in flux



The need for ground-based follow-up

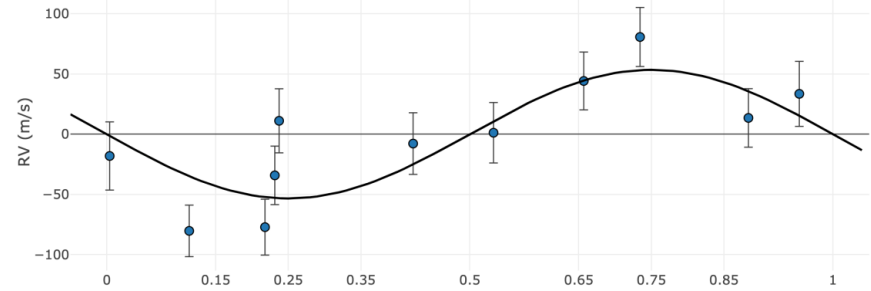
- Seeing limits may hide very close in stellar neighbor
- Adaptive optics and speckle high resolution imaging may reveal $< 1''$ neighbors
- Stellar spectroscopy may reveal even closer in “spectroscopic binaries” that are not otherwise resolved
- Stellar spectroscopy may also find that star is rotating too rapidly for precise radial velocity measurements



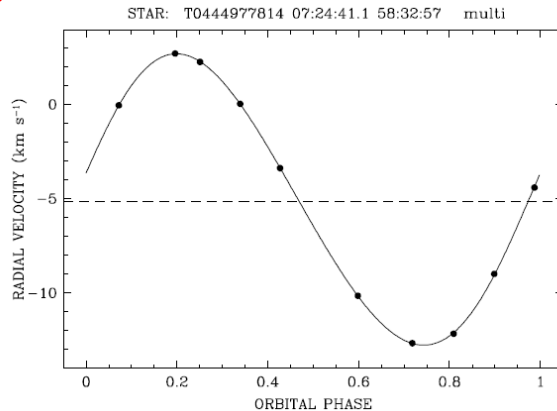
TRES Spectroscopy (LSD profile)

The need for ground-based follow-up

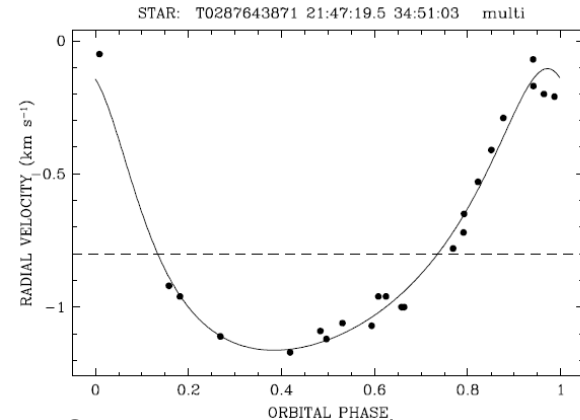
- Mass measurement with precise radial velocities (from spectroscopy)
 - Planet
 - or star
 - Eccentricity of orbit



TRES Planet Detection



TRES Binary Detection



TRES Binary Detection (eccentric orbit)

TESS Follow-up Observing Program (TFOP)

- Led by the Smithsonian Astrophysical Observatory (SAO) as part of the TESS Science Office
- Goal is to foster communication and coordination among the TESS Science Team members and the community:
 - Maximize scientific output
 - Minimize duplication of effort
- The TFOP is organized into five sub-groups (SGs):
 - **Ground-Based Lightcurve Photometry (SG1)** - Karen Collins (lead)
 - Recon Spectroscopy (SG2) - Sam Quinn (lead)
 - High-Resolution Imaging (SG3) - David Ciardi (lead)
 - Precise Radial Velocities (SG4) - David Latham (SG4 and overall TFOP lead)
 - Space-Based Photometry (SG5) - Diana Dragomir (lead; *Spitzer*, CHEOPS, NEOSAT)
- 700+ registered TFOP members worldwide
- 500+ registered SG1 members
280+ registered SG1 observatories (suitable for lightcurve follow-up)
- TFOP WG Charter and TFOP WG Publication Policy ensure coordinated publication efforts and intellectual property protections between TFOP members
 - Useful observations are included in TESS planet discovery papers
 - Observers are included as coauthors of planet discovery papers
- Observation results and final TOI dispositions are uploaded to ExoFOP (with a 12 month TFOP group proprietary period for uploaded files)

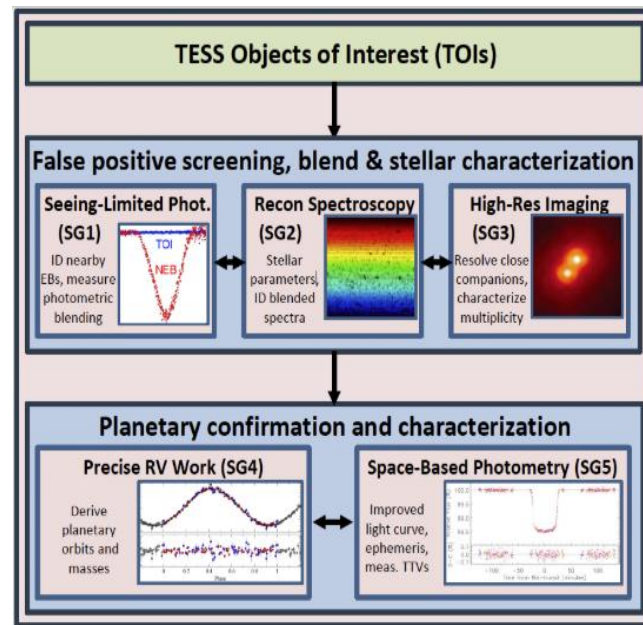


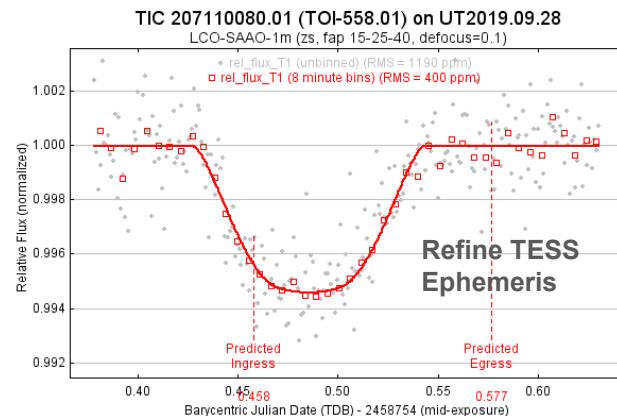
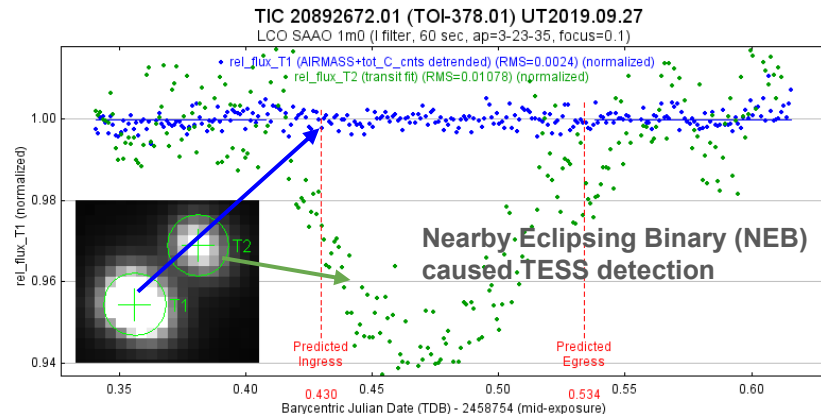
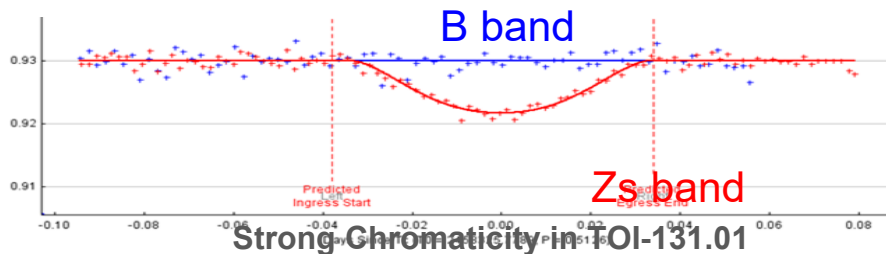
Image credits (clockwise from top left): KELT Survey, NOAO/AURA/NSF, Buchhave et al. (2011), Berta et al. (2012), Malavolta et al. (2016).

TFOP SG1 Overview

TFOP SG1 conducts ground-based lightcurve photometry

TFOP SG1 goals:

- Determine the true source the TESS transit detection (<1 arcsec px scale vs 21 arcsec TESS px scale)
- Refine the TESS transit ephemeris, depth, and duration
- Check for color dependent depth differences (chromaticity) across optical, IR, and NIR bands
- Conduct long-term TTV observations
- Track down the true orbital period of high uncertainty systems
 - a. TOIs with limited TESS time baseline coverage
 - b. Period from TESS Single Transit detections + RVs
- Determine the true orbital period of TESS “duo transits”



Duo Transits (Orbital Period Aliasing)

Generally a result of TESS data gaps

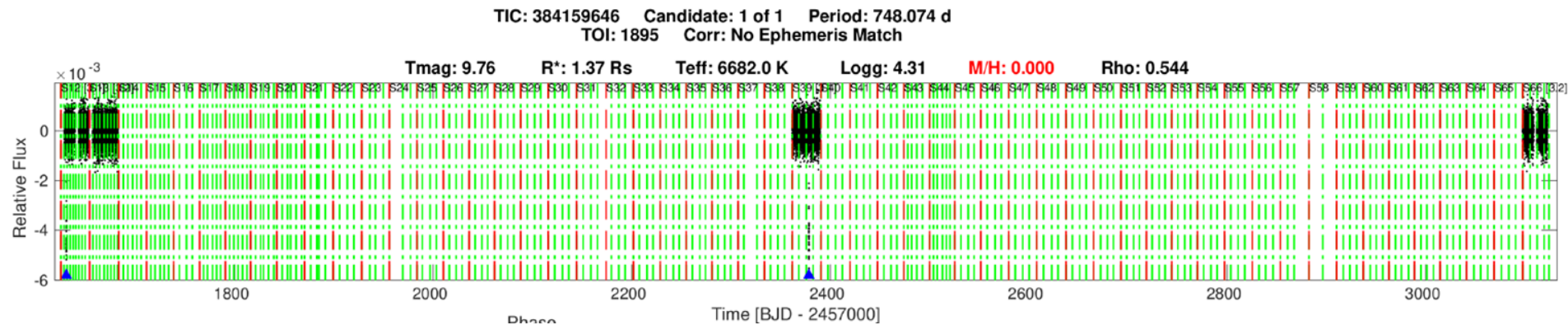
TESS detection is consistent with a family of orbital periods

Upper orbital period limit from two (or more) transit detections

Lower orbital period limit from TESS coverage with no transits

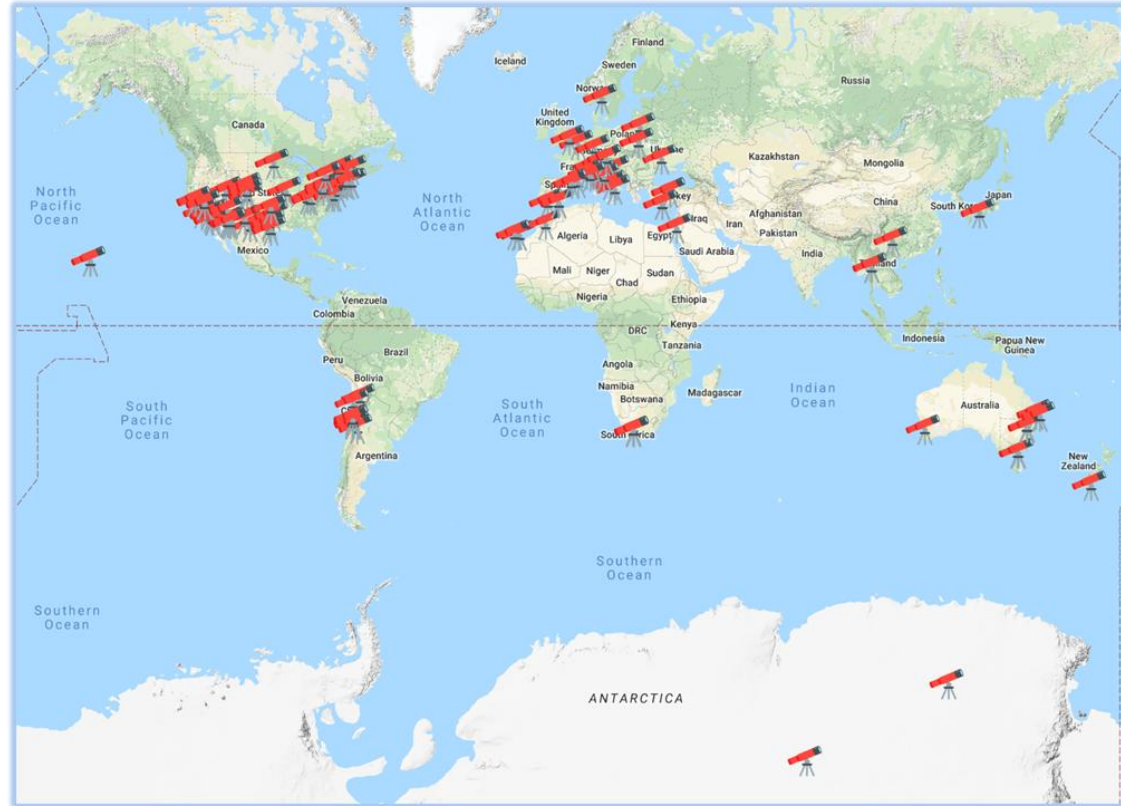
We parameterize as a maximum period and a set of valid alias integers “ I_N ”

$$P_N = P_{\text{MAX}} / I_N$$



TFOP SG1 Observatories

- 500+ members
- 280+ observatories
- Professional astronomers
- Student astronomers
- Citizen astronomers
- Ground-based surveys



Software Tools Provided to SG1 Team

- TESS Transit Finder (TTF)
(private to TFOP members)
- SG1 TOI List shared spreadsheet
(private to TFOP members)
- TESS Observations Coordinator (TOC)
(private to TFOP members)
- Field of view tool
- Gaia apertures tool
- ExoFOP (reduced data repository and sharing)
- AstrolmageJ (data reduction)

TESS Transit Finder (TTF)

Two methods for accessing TTF transit searches:

- User interface mode for interactive searches
- Scripted with output optionally available as csv file for easier parsing

Secure version including TESS alerts

Find TESS Candidate Transits


This form calculates observability of our 3561 current TESS transit candidates, and optionally 1446 candidates on hold (priority 4) and 3076 expired (priority 5).

Observatory:

Choose an observatory, or choose "manual coordinate entry" at end of list:

LCO Cerro Tololo Interamerican, 1m ☐ Use UTC / ☐ Use observatory's local time.

Date window:

Base date for transit list (mm-dd-yyyy or 'today'): 

From that date, show transits for the next days.

(Also include transits from the previous days.)

Constraints:

Elevation:

Only show transits with an elevation (in degrees) of at least:


at ingress:
at egress: Combine constraints with ☐ AND ☒ OR.

Unspecified elevation constraints default to 0. Constraints are evaluated *at night*, i.e. to be shown as observable an event has to meet that elevation constraint during nighttime hours.

TESS Transit Finder (TTF)

- Ephemeris prediction tool available to TFOP team for scheduling observations
- Transit predictions based on latest SG1 ephemerides, dispositions, priorities
- Provides feedback to observers:
 - Status of TOI
 - Observation history
 - Type of observation needed next

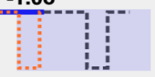
VPC VPC VRV? qlp-s49-219824470 Sectors:[16, 22, 23, 49] SG2:[TRES(18), Vrot=4] SG4:[Ariel, NEID-Yee]: TFOP determined this star (TIC 219824470) is the true source of TOI 1848.01 / TIC 219824469 which has been retired as off-target; Rick Schwarz/LCO-Teid-1m0 analyzed a full on 20240314 in zs and ruled out an on-time 3 ppt event on the original target, but detected an on-time 3 ppt in this star. **No more observations needed, except for a high precision (<1.0 ppt/10 min) full transit in a blue (U, u', B, g') filter to check chromaticity. High-precision (<1.0 ppt/10 min) multi-band observations even better.**

Local evening date	Name	V mag	T mag	% of transit (baseline) observable, Suggested obs. start, end	Start—Mid—End	Priority	Period (days)	Depth (ppt)	Duration	R _{planet} (R _⊕)	Comments and followup status
Fri. 2026-05-01: Nautical twilight 2026-05-01 21:30 — 2026-05-02 06:15 local time / 2026-05-02 02:30 — 2026-05-02 11:15 UTC											
Fri. 2026-05-01 (local date) Nautical twilight 02:30 — 11:15 (UTC)	<input type="checkbox"/> TIC 219824470.01 (TOI 6972.01) <input type="button" value="Add to TOC"/> Finding charts: Annotated , Aladin , Info: ExoFOP , Simbad , Gaia , TIC , VSX , ALL apertures, Vizier phot., Airmass , ACP plan	11.07	10.39	 100% (55%) 04:19—10:29 65°—36°	04:19 05:43— 08:11 —10:38 12:02 ±0:09	3	5.48	2.237	4:55 ±0:36	8.4	VPC VPC VRV? qlp-s49-219824470 Sectors:[16, 22, 23, 49] SG2:[TRES(18), Vrot=4] SG4:[Ariel, NEID-Yee]: TFOP determined this star (TIC 219824470) is the true source of TOI 1848.01 / TIC 219824469 which has been retired as off-target; Rick Schwarz/LCO-Teid-1m0 analyzed a full on 20240314 in zs and ruled out an on-time 3 ppt event on the original target, but detected an on-time 3 ppt in this star. No more observations needed, except for a high precision (<1.0 ppt/10 min) full transit in a blue (U, u', B, g') filter to check chromaticity. High-precision (<1.0 ppt/10 min) multi-band observations even better.

(coming soon)

TTF handling of high ephemeris uncertainty systems

- Typical ephemeris prediction tools require a nominal ingress or egress to be observable
- New TTF version will consider ephemeris uncertainty when listing observable transits

Local evening date	Name	Start—Mid—End	Elev. at start, mid, end ± 2 hrs	Duration	% of transit (baseline) observable, Suggested obs. start, end
Tue. 2025-08-05: Nautical twilight 2025-08-05 19:51 — 2025-08-06 05:10 local time / 2025-08-06 05:51 —					
<div><div>+</div><div>Tue. 2025-08-05 (local date)</div><div>Nautical twilight 05:51 — 15:10 (UTC)</div></div>	<div><div><input type="checkbox"/> TIC 277329402.01 (TOI 5851.01) <div>Add to TOC</div></div><div>Finding charts: Annotated, Aladin; Info: ExoFOP, Simbad, Gaia, TIC, VSX, AIJ apertures, Vizier phot.; Airmass, ACP plan</div></div>	<div>08:19 18:21 — 19:32 — 20:43 06:45 $\pm 8:02$</div>	<div>78° -40°, -51°, -57° 58°</div>	<div>2:22 $\pm 0:18$</div>	<div><div><div>-1.0σ</div><div>100% (86%) 08:19—13:26 78°—25°</div></div></div>

SG1 TOI List

A shared google sheet listing data and status for all public and custom TOIs

TESS Transit Finder (TTF) reads data from SG1 sheet

Maintained by SG1 leads and trained volunteers

AR	AS	AT	AU	AV	AW	BC	BD	BE	BF	BG	BH	BI	BK	BL	BM	BN	BO	BP		
Pipe- line	Sec- tor	Prio- rity	Master Disposi- tion	Phot Disposi- tion	Spec Dispo- sition	Tc_BTJD	Tc_Err	P	P_Err	Dura- tion (hrs)	Depth (ppm)	Rp (R_earth h)	Cur Eph Unc (min)	Dur Unc (min)	Delta Tc (min)	N Obs	Owner/Interest/ Publication Status	Comments		
CTOI	S49	3	VPC	VPC	VRV?	2661.0743	0.0025	5.4809114	0.0000215	4.91	2237	8.4	8	36	0	0		TFOP determined this star (TIC 219824470) is the true source of TOI 1848.01 / TIC 219824469 which has been retired as off-target; Rick Schwarz/LCO-Teid-1m0 analyzed a full on 20240314 in zs and ruled out an on-time 3 ppt event on the original target, but detected an on-time 3 ppt in this star. No more observations needed, except for a high precision (<1.0 ppt/10 min) full transit in a blue (U, u', B, g') filter to check chromaticity. High-precision (<1.0 ppt/10 min) multi-band observations even better.		
Pipe- line	Sec- tor	Prio- rity	Master Disposi- tion	Phot Disposi- tion	Spec Dispo- sition	Tc_BTJD	Tc_Err	P	P_Err	Dura- tion (hrs)	Depth (ppm)	Rp (R_earth h)	Cur Eph Unc (min)	Dur Unc (min)	Delta Tc (min)	N Obs	Owner/Interest/ Publication Status	Comments		TOI List Eph Unc
SPOC	S78	4	VPC+	VPC+		3434.6862	0.0053	3.0499550	0.0000100	1.82	23466	11.2	8	14	-295	7		[P=3.0513298] no centroid information; slightly v-shaped; Update from AIJ-s24+s78. [P=3.0498798] Ferran Grau/ Gemma Domènech/ Kike Herrero/ Jordi Lopesino/ TJO-0m8/ analyzed a full on 20250305 in rp and detected an ~11 min (1.4σ) late, ~20 min longer duration, ~23.0 ppt event using an uncontaminated 4.9" target aperture. [P=3.0499550] Dur => 1.82 hr. K. Barkaoui/LCO-Teid-1.0m analyzed a full on 20250425 in gp and detected a ~23 ppt event on target using an uncontaminated 3.5" aperture. ChrisS/LCO-SAAO-1m0 analyzed a full on 20250425 in gp and detected a 5 min (0.6σ) early, 8 min (0.5σ) longer, 22 ppt [(Rp/R*)²: 23.6 ppt] event using an uncontaminated 4.7" target aperture. MuSCAT2 Team observed a nominal full on 20250619 in gp, rp, ip, zs and detected a ~6 min. early 24.4, 24.84, 22.97, 21.22 ppt events using an uncontaminated 5.7" target apertures. No more SG1 observations needed at this time.		299

TFOP SG1 Process Overview

Public and Custom TFOP TOIs

SG1 TOI List

TESS Transit Finder

Observe

Reduce Data

Submit to
tfopsg1@gmail.com
and ExoFOP-TESS

Update TOI Obs. Request
on SG1 Sheet / TTF

Update TOI Disposition on
SG1 List/ TTF / ExoFOP

SG1 Leads
Interpret Result

TOI status and observation request

Comments

[P=4.0863647] v-shaped; ChrisS/ Hwd observed a full on 20241008 in R and detected an ~on-time ~4.3 ppt [(Rp/R*)²: 5.9 ppt] event using an uncontaminated 5.5" target aperture and cleared the neighbors over the window. Bob Massey/ LCO-CTIO-0m35/ analyzed a full on 20241029 in ip and detected a ~0-10 min (2.5σ) early ~3.2 ppt [(Rp/R*)²=4.2] event using an uncontaminated 5.9" target aperture. This observation checks the depth in a red band. FrancisWilkin/ KarenC/ LCO-CTIO-0m35 on 20250705 in gp an ingress+80% (intended full cut short by weather) and detected a ~17 min early, 4 ppt ingress on target in an uncontaminated 6.0" aperture.
[P=4.0862946] **No more observations needed, except for a high precision (<1.0 ppt/10 min) full transit in a blue (U, u', B, g') filter to check chromaticity and refine the timing. High-precision (<1.0 ppt/10 min) multi-band observations even better.**

SG1 List Dispositions

Prio rity	Master Dispo sition	Phot Dispo sition	Spec Dispo sition
4	VPC+	VPC+	VRV
3	VPC	VPC	
1	CPC	VPC?	RVD?
5	SEB1	PC	SEB1
5	NEB	NEB	





TESS Observations Coordinator (TOC)

- TTF Provides connection to TOC interface for posting planned observations
- The plans will show up in the TTF output to inform other potential observers
 - For events with planned observation, the priority cell is highlighted in yellow
 - Mouse over to see details
- Can help avoid duplication of observations

TESS Observations Coordinator

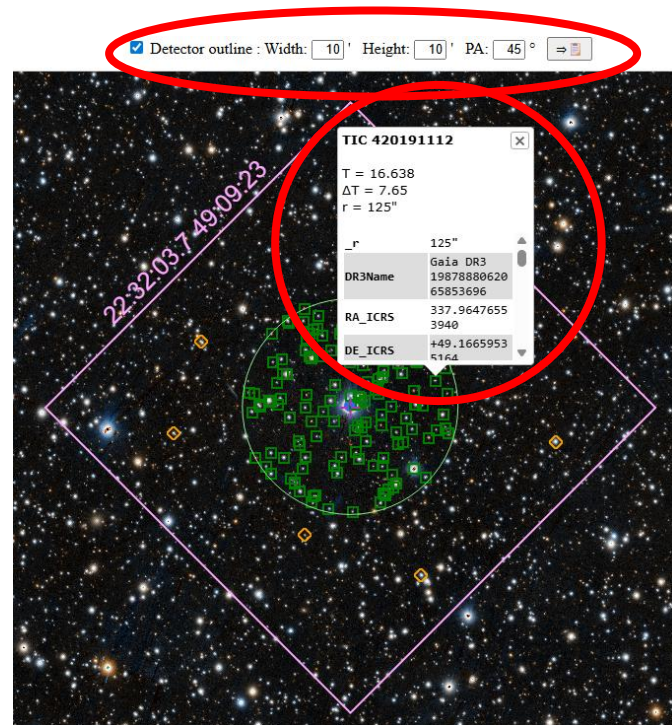
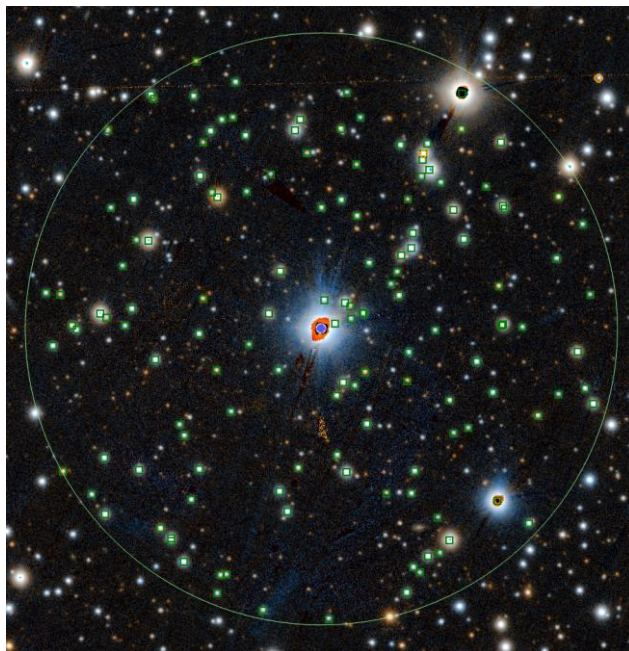
[Help](#)

Site LCO Cerro	Observer Your Name	Target ID TIC 28842161	When UTC 2025-06-08	Duration Full event
Estimate Success 50%	Filter 1 Open	Filter 2 None	Filter 3 None	Filter 4 None
New Entry Submit	Comment Your Text		Choose Satellite East Full C	View Weather Clouds
Selected Entry None	Update Selected Update	Delete Selected Delete	View Catalog ExoFOP	
View Latest Plan	From UTC 2025-06-06	To UTC 2025-06-10	Every UTC All Entries	Database Search

Sun. 2025-05-25: Nautical twilight 2025-05-25 18:47 — 2025-05-26 06:32 local time / 2025-05-25 22:47 — 2025-05-26 10:32 UTC												
Sun. 2025-05-25 (local date)	<input type="checkbox"/> TIC 288421619.01 (TOI 7166.01) Add to TOC	15.79	 Moon 1% @88°	13.12	 100% (100%) 07:20—11:52	2	12.92	8.7	1:36 ±0:13	07:20 08:48— 09:36 —10:24 11:52 ±0:13	10821.8682 10821.9015 10821.9349	2.1
Nautical twilight 22:47 — 10:32 (UTC)	Finding charts: Annotated, Aladin ; Info: ExoFOP , Simbad , Gaia , TIC , VSX , AIJ apertures, VizieR phot. , Airmass , ACP plan											
Sat. 2025-06-07: Nautical twilight 2025-06-07 18:45 — 2025-06-08 06:38 local time / 2025-06-07 22:45 — 2025-06-08 10:38 UTC												
Sat. 2025-06-07 (local date)	<input type="checkbox"/> TIC 288421619.01 (TOI 7166.01) Add to TOC	15.79	 Moon 91% @103°	13.12	 100% (100%) 05:23—09:57	2						
Nautical twilight 22:45 — 10:38 (UTC)	Finding charts: Annotated, Aladin ; Info: ExoFOP , Simbad , Gaia , TIC , VSX , AIJ apertures, VizieR phot. , Airmass , ACP plan											
Planned observations: Karen, LCO Cerro Tololo 1m; Filter: ip Full, Prob. 25%; LCO KEY2023B005 ID 2256006 IPP 1.16 0851 Karen, LCO McDonald 1m; Filter: ip Full, Prob. 25%; LCO KEY2023B005 ID 2256132 IPP 1.15 0851												

Field of View Tool

- Shows zoomable field of view using catalog imagery
- Identifies target star
- Green symbols identify all nearby Gaia stars bright enough to host TESS detected signal
- Field of view can be set to match your telescope
- Click symbol for catalog data on each star
- [Example field](#)



Gaia Apertures Tool

- Provides a list of star locations that should be checked for NEBs
- Star locations provided depend on transit depth
- Link to tool from TTF and SG1 sheet
- User interface auto-filled and bypassed when using TTF link
- Drag and drop file into AstrolmageJ

Find Gaia EDR3 Stars in Observed TESS Fields

[Help](#)

Observation UTC

2025-09-06

Right Ascension

hh:mm:ss.s

Declination

dd:mm:ss.s

Source of Coordinates

☐ Observation

Source of Coordinates

☐ Gaia 2016.0

Source of Coordinates

☒ TIC 2000.0

Magnitude



TESS

Transit Depth

PPT

Query Gaia

Submit

Sun. 2025-05-25: Nautical twilight 2025-05-25 18:47 — 2025-05-26 06:32 local time / 2025-05-25 22:47 — 2025-05-26 10:32 UTC											
Sun. 2025-05-25 (local date)	<input type="checkbox"/> TIC 288421619.01 (TOI 7166.01) Add to TOC Finding charts: Annotated , Aladin , Info , ExoFOP , Simbad , Gaia , TIC , VSX , All apertures , Vizier phot. , Airmass , ACP plan	15.79			2	12.92	8.7	1:36 ±0:13	07:20 08:48— 09:36 —10:24 11:52 ±0:13	10821.8682 10821.9015 10821.9349	2.1
Nautical twilight 22:47 — 10:32 (UTC)		Moon 1% @88°	13.12	100% (100%) 07:20—11:52							
Sat. 2025-06-07: Nautical twilight 2025-06-07 18:45 — 2025-06-08 06:38 local time / 2025-06-07 22:45 — 2025-06-08 10:38 UTC											
Sat. 2025-06-07 (local date)	<input type="checkbox"/> TIC 288421619.01 (TOI 7166.01) Add to TOC Finding charts: Annotated , Aladin , Info , ExoFOP , Simbad , Gaia , TIC , VSX , All apertures , Vizier phot. , Airmass , ACP plan	15.79			2				Planned observations: Karen, LCO Cerro Tololo 1m; Filter: lp Full, Prob. 25%; LCO KEY2023B005 ID 2256006 IPP 1.16 0851 Karen, LCO McDonald 1m; Filter: lp Full, Prob. 25%; LCO KEY2023B005 ID 2256132 IPP 1.15 0851		
Nautical twilight 22:45 — 10:38 (UTC)		Moon 91% @103°	13.12	100% (100%) 05:23—09:57							
									(Note planned obs)		

ExoFOP (Provided by NExSci at Caltech)

- Reduced data repository
- Provides list of all observations for each TIC / TOI number
- Hosts reduced data files, with optional 1 year proprietary period for TFOF members
- User interface or scriptable data uploads
- [Main Page](#)
- [TIC 288421619 Page](#)

Time Series Observations 98 [+ Add new](#)

Name	TOI	User	Telescope	Camera	Filter	Pixel scale (arcsec)	Estimated PSF (arcsec)	Photometric Aperture Radius (pixel)	Transit Coverage	Faintest Neighbor delta Mag	Observation date (UT)
TIC 288421619.01	TOI 7166.01	stockdale	LCO-Teid-1m0 (1.0 m)	SINISTRO	ip	0.389	1.55	8	Full		2025-06-09 05:08:31
TIC 288421619.01	TOI 7166.01	collins	LCO-CTIO-1m0 (1.0 m)	SINISTRO	rp	0.389	2.26	7	Egress		2025-07-04
TIC 288421619.01	TOI 7166.01	barkaoui	TRAPPIST-South (0.6 ...	FLI ProLine PL3041-BB	Rc	0.64	2.5	7	Full		2025-06-21
TIC 288421619.01	TOI 7166.01	barkaoui	SPECULOOS-South (1....	Andor ikon-L	zp	0.35	1.8	8	Full		2025-06-21
TIC 288421619.01	TOI 7166.01	schwarz	LCO-CTIO-1m0 (1.0 m)	SINISTRO	gp	0.389	2.26	15	Full		2025-06-21
TIC 288421619.01	TOI 7166.01	barkaoui	SPECULOOS-South (1....	Andor ikon-L	I+z	0.35	3.8	5	Full		2025-06-08
TIC 288421619.01	TOI 7166.01	barkaoui	LCO-McD-1.0m (1.0 m)	SINISTRO	ip	0.389	1.83	9	Full		2025-06-08

Files 98 [+ Add new](#)

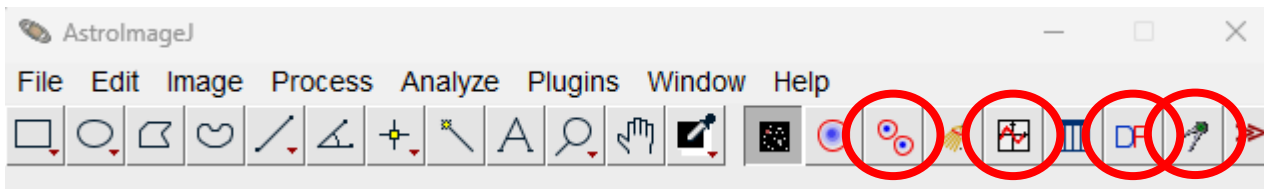
Name	TOI	Type	Filename	Description	Date	User
TIC 288421619.01	TOI 7166.01	Light_Curve	TOI-7166.01_20250608_SPECULOOS-South-1m0_LCO-McD-1m0_I+z_ip_lightcurves.pdf	T1 Light Curve	2025-06-09 05:08:31	barkaoui
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_Seeing-Profile.png	All Seeing Profile	2025-08-24 01:07:46	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_Platesolved-Image.fits.gz	All Sample Platesolved FITS Image	2025-08-24 01:07:46	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_Observation-Notes.txt	Observation Notes	2025-08-24 01:07:07	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements_dmagRMS-plot.png	All dMag RMS Plot	2025-08-24 01:07:07	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements_8px_NEbcheck.zip	All NEbCheck Plots	2025-08-24 01:07:06	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements_8px_NEb-table.txt	All NEbCheck Table	2025-08-24 01:07:04	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements.tbl	All Measurements Table	2025-08-24 01:07:03	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements.plotcfg	All Plot Configuration File	2025-08-24 01:06:57	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Measurements.apertures	All Aperture File	2025-08-24 01:06:53	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Lightcurve.png	All Lightcurve	2025-08-24 01:06:53	stockdale
TIC 288421619.01	TOI 7166.01	Light_Curve	TIC288421619-22_20250821_LCO-Teid-1m0_ip_8px_Field.png	All Field	2025-08-24 01:06:53	stockdale

AstrolImageJ

- General astronomical image and data analysis tool (based on ImageJ)
- Image calibration (bias, dark, and flat-fielding)
- Differential aperture photometry
- Lightcurve plotting (with automatic titling and legend capabilities)
- Lightcurve detrending and fitting
- Automatic comparison star selections
- Various aperture options (fixed, auto-fixed, variable size; circular, elliptical, arbitrary shape)
- Automated NEBcheck routine (written by AAVSO's Dennis Conti)
- Automatic optimization of comparison stars and detrend parameters
- Plate solving using astrometry.net (local solver capability on Microsoft Windows)
- Moving object tracking
- Image alignment (if needed)
- TESS image (e.g. TESScut) and SPOC lightcurve analysis

AstroImageJ Toolbar

- Provides access to Astronomy Tools (and underlying ImageJ tools)
- Data Processor (DP; data calibration)
- Multi-Aperture (MA; differential photometry)
- Multi-Plot and lightcurve fitting (MP; plotting facility)
- Coordinate Converter (CC; time format and coordinate conversion)



Data Processor (Image Calibration)

- Create master calibration files
- Bias subtract
- Dark Subtract
- Flat field
- Update FITS headers
- Plate Solve
- Save calibrated files
- Optional run photometry and plotting
- Run in realtime mode while observing to monitor live lightcurve

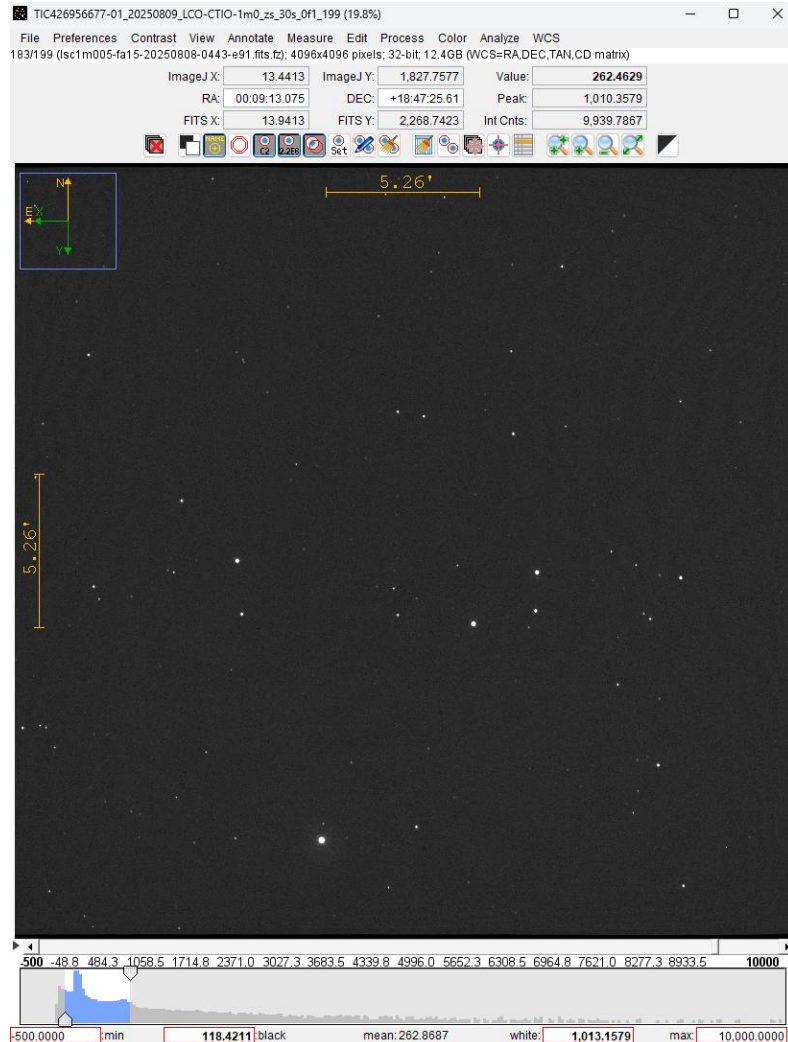
DP CCD Data Processor

File Preferences View

Control	Options	Directory	Filename/Pattern	Totals
Science Image Processing				
Filename Matching				
<input checked="" type="checkbox"/> Enable	<input checked="" type="checkbox"/> Sort Num	C:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter	WASP-12b_*.fits	134
Filename Number Filtering				
<input type="checkbox"/> Enable	Min: 0	Max: 1000000000	WASP-12b_*.fits	134
Bias Subtraction				
<input checked="" type="checkbox"/> Build	<input type="radio"/> ave <input checked="" type="radio"/> med	:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter\Bias	BIAS_*.fits	6
<input checked="" type="checkbox"/> Enable		:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter\Bias	mbias.fits	1
Dark Subtraction				
<input checked="" type="checkbox"/> Build	<input type="radio"/> ave <input checked="" type="radio"/> med	:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter\Dark	Dark_100s_*.fits	10
<input checked="" type="checkbox"/> Enable	<input checked="" type="checkbox"/> scale <input checked="" type="checkbox"/> deBias	:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter\Dark	mdark.fits	1
Flat Division				
<input type="checkbox"/> Build	<input type="radio"/> ave <input checked="" type="radio"/> med	C:\Users\Karen\Documents_Awaiting Reduction - TESS\Wingham\Calibration_Images\Flats 1x	*FLAT.FIT	0
<input checked="" type="checkbox"/> Enable	<input type="checkbox"/> Remove Gradient	C:\Users\karen\Documents\Observations\WASP-12b_qty-19\20091127_WASP-12b_r-filter	mflat.fits	1
Image Correction				
<input type="checkbox"/> Enable Linearity Correction	New pixel value = 0.0E0 + 1.0E0 * (PixVal) + 0.0E0 * (PixVal)^2 + 0.0E0 * (PixVal)^3			
<input type="checkbox"/> Remove Outliers	<input checked="" type="checkbox"/> Bright <input checked="" type="checkbox"/> Dark	Radius: 2	Threshold: 50	
FITS Header Updates				
<input checked="" type="checkbox"/> General	<input type="checkbox"/> Plate Solve	Target Coordinate Source FITS header target RA/DEC (J2000)		Observatory Location Source FITS header latitude and longitude
Save Calibrated Images				
<input checked="" type="checkbox"/> Enable	<input type="radio"/> 16 <input checked="" type="radio"/> 32	Sub-dir: .\pipelineout	Suffix: _out	Format: <input type="checkbox"/> FPACK <input type="checkbox"/> GZIP
Post Processing				
<input checked="" type="checkbox"/> M-Ap	<input type="checkbox"/> Save Image		<input type="checkbox"/> Macro 1 C:\Users\Karen\	0
<input checked="" type="checkbox"/> M-Plot	<input type="checkbox"/> Save Plot		<input type="checkbox"/> Macro 2 C:\Users\Karen\	0
Control Panel				
Polling Interval 3		START PAUSE RESET		
Processed: 0				Remaining: 134

Image Stack Display

- Zoom and pan image with mouse
- Adjust contrast
- Scroll through stack
- Photometer at mouse pointer
- X, Y, East, North, indicators
- Access to all AIJ settings and tools
 - Icons for common settings and tools
 - Menus for all others



Multi-Aperture

- Select aperture shape
- Select aperture size and size mode
- Select new or saved aperture mode
- Select aperture tracking modes
- Set up auto comp star mode
- Select runtime display options
- Select “Place Apertures” to interactively add, remove, or move apertures in image stack

Multi-Aperture Measurements

Aperture Shape:

First slice: Last slice:

Fixed/Base radius of photometric aperture:

Fixed/Base radius of inner background annulus:

Fixed/Base radius of outer background annulus:

☐ Fixed Apertures as selected above

☐ Auto Fixed Apertures from first image T1 radial profile

☒ Auto Fixed Apertures from multi-image T1 radial profiles

☐ Auto Variable Apertures from each image T1 radial profile

☐ Auto Variable Apertures from each image T1 FWHM

Normalized flux cutoff threshold: (0 < cutoff < 1; default = 0.010)

Normalized flux cutoff threshold: (0 < cutoff < 1; default = 0.010)

Normalized flux cutoff threshold: (0 < cutoff < 1; default = 0.010)

FWHM factor:

☐ Place all new apertures

☐ Place first previously used aperture

☐ Place 31 previously used apertures

☒ Place 1 imported apertures

☐ Use RA/Dec to locate aperture positions

☐ T1 is moving object

☐ Use single step mode (1-click to set first aperture location in each image)

☐ Allow aperture changes between slices in single step mode (right click to advance image)

☒ Auto comparison stars ☐ Enable log ☐ Show peaks

Smoothing Filter Radius: pixels

☒ Auto Thresholds

Max. Peak Value: Min. Peak Value:

Base Aperture: Max. Comp. Brightness %: Min. Comp. Brightness %:

Weight of Distance: vs Brightness

Max. Comp. Stars:

☒ Centroid apertures (initial setting) ☐ Halt processing on WCS or centroid error

☒ Remove stars from background ☐ Assume background is a plane

☐ Prompt to enter ref star apparent magnitude (required if target star apparent mag is desired)

☐ Update plot while running ☐ Show help panel during aperture selection

☐ Update image display while running

CLICK 'PLACE APERTURES' AND SELECT APERTURE LOCATIONS WITH LEFT CLICKS.
THEN RIGHT CLICK or <ENTER> TO BEGIN PROCESSING.
(to abort aperture selection or processing, press <ESC>)

Place Apertures Aperture Settings Cancel

Measurements Table Display

- Contains all data from multi-aperture run
- Interactive with plotted data
- Searchable
- Sortable
- Editable

Measurements in TIC393818343-01_20240702_LCO-CTIO-0m4p_5px_KC_measurements.tbl									
File Edit Font Results Filter									
	Label	slice	Saturated	J.D.-2400000	JD_UTC	BJD_TDB	ATDMACC	MMCHUMID	CCDATEMD
1	lsc0m476-sq34-20240701-0141-e91.fits.fz	1	0.0	60493.60185756395	2460493.601857564	2460493.601857564			
2	lsc0m476-sq34-20240701-0143-e91.fits.fz	2	0.0	60493.60233846679	2460493.602338467	2460493.602338467			
3	lsc0m476-sq34-20240701-0145-e91.fits.fz	3	0.0	60493.60281584505	2460493.602815845	2460493.602815845			
4	lsc0m476-sq34-20240701-0147-e91.fits.fz	4	0.0	60493.603305567056	2460493.603305567	2460493.603305567			
5	lsc0m476-sq34-20240701-0149-e91.fits.fz	5	0.0	60493.603779363446	2460493.603779363	2460493.603779363			
6	lsc0m476-sq34-20240701-0151-e91.fits.fz	6	0.0	60493.60424845526	2460493.604248455	2460493.604248455			
7	lsc0m476-sq34-20240701-0159-e91.fits.fz	10	0.0	60493.6061387267	2460493.606138726	2460493.606138726			
8	lsc0m476-sq34-20240701-0163-e91.fits.fz	12	0.0	60493.6070901854	2460493.607090185	2460493.607090185			
9	lsc0m476-sq34-20240701-0165-e91.fits.fz	13	0.0	60493.60756527772	2460493.607565277	2460493.607565277			
10	lsc0m476-sq34-20240701-0167-e91.fits.fz	14	0.0	60493.60803953698	2460493.608039537	2460493.608039537			
11	lsc0m476-sq34-20240701-0169-e91.fits.fz	15	0.0	60493.60851792246	2460493.608517922	2460493.608517922			
12	lsc0m476-sq34-20240701-0171-e91.fits.fz	16	0.0	60493.608991921414	2460493.608991921	2460493.608991921			
13	lsc0m476-sq34-20240701-0173-e91.fits.fz	17	0.0	60493.60946921911	2460493.609469219	2460493.609469219			
14	lsc0m476-sq34-20240701-0175-e91.fits.fz	18	0.0	60493.60994497128	2460493.609944971	2460493.609944971			
15	lsc0m476-sq34-20240701-0177-e91.fits.fz	19	0.0	60493.610423472244	2460493.610423472	2460493.610423472			
16	lsc0m476-sq34-20240701-0179-e91.fits.fz	20	0.0	60493.61090125609	2460493.610901256	2460493.610901256			
17	lsc0m476-sq34-20240701-0181-e91.fits.fz	21	0.0	60493.61137435166	2460493.611374351	2460493.611374351			
18	lsc0m476-sq34-20240701-0183-e91.fits.fz	22	0.0	60493.61184606468	2460493.611846064	2460493.611846064			
19	lsc0m476-sq34-20240701-0185-e91.fits.fz	23	0.0	60493.61237861728	2460493.612378617	2460493.612378617			
20	lsc0m476-sq34-20240701-0187-e91.fits.fz	24	0.0	60493.61285255244	2460493.612852552	2460493.612852552			
21	lsc0m476-sq34-20240701-0191-e91.fits.fz	26	0.0	60493.61385250604	2460493.613852506	2460493.613852506			
22	lsc0m476-sq34-20240701-0193-e91.fits.fz	27	0.0	60493.61432887195	2460493.614328872	2460493.614328872			
23	lsc0m476-sq34-20240701-0195-e91.fits.fz	28	0.0	60493.61480316566	2460493.614803165	2460493.614803165			
24	lsc0m476-sq34-20240701-0197-e91.fits.fz	29	0.0	60493.61527910316	2460493.615279103	2460493.615279103			
25	lsc0m476-sq34-20240701-0201-e91.fits.fz	31	0.0	60493.6162245255	2460493.616224525	2460493.616224525			
26	lsc0m476-sq34-20240701-0203-e91.fits.fz	32	0.0	60493.61669783015	2460493.616697830	2460493.616697830			
27	lsc0m476-sq34-20240701-0205-e91.fits.fz	33	0.0	60493.61716912035	2460493.617169120	2460493.617169120			
28	lsc0m476-sq34-20240701-0207-e91.fits.fz	34	0.0	60493.61764584482	2460493.617645844	2460493.617645844			
29	lsc0m476-sq34-20240701-0209-e91.fits.fz	35	0.0	60493.61812527198	2460493.618125272	2460493.618125272			
30	lsc0m476-sq34-20240701-0211-e91.fits.fz	36	0.0	60493.61860082764	2460493.618600827	2460493.618600827			
31	lsc0m476-sq34-20240701-0213-e91.fits.fz	37	0.0	60493.61907348968	2460493.619073489	2460493.619073489			
32	lsc0m476-sq34-20240701-0215-e91.fits.fz	38	0.0	60493.61954888329	2460493.619548883	2460493.619548883			
33	lsc0m476-sq34-20240701-0217-e91.fits.fz	39	0.0	60493.6200197977	2460493.620019797	2460493.620019797			
34	lsc0m476-sq34-20240701-0221-e91.fits.fz	41	0.0	60493.62096436927	2460493.620964369	2460493.620964369			
35	lsc0m476-sq34-20240701-0223-e91.fits.fz	42	0.0	60493.6214413424	2460493.621441342	2460493.621441342			
36	lsc0m476-sq34-20240701-0225-e91.fits.fz	43	0.0	60493.621919664554	2460493.621919664	2460493.621919664			
37	lsc0m476-sq34-20240701-0227-e91.fits.fz	44	0.0	60493.622391458135	2460493.622391458	2460493.622391458			
38	lsc0m476-sq34-20240701-0229-e91.fits.fz	45	0.0	60493.62286680564	2460493.622866805	2460493.622866805			
39	lsc0m476-sq34-20240701-0231-e91.fits.fz	46	0.0	60493.62334713573	2460493.623347135	2460493.623347135			
40	lsc0m476-sq34-20240701-0233-e91.fits.fz	47	0.0	60493.623822575435	2460493.623822575	2460493.623822575			
41	lsc0m476-sq34-20240701-0235-e91.fits.fz	48	0.0	60493.62430097815	2460493.624300978	2460493.624300978			
42	lsc0m476-sq34-20240701-0237-e91.fits.fz	49	0.0	60493.624772505835	2460493.624772506	2460493.624772506			

Multi-plot Main

- Controls related to overall plot
- Titling
- Axis labeling
- Axis Scaling
- Legend
- Plot size

Multi-plot Main

File Preferences Table X-axis Y-axis Style Help

Data (TIC393818343-01_20240702_LCO-CTIO-0m4p_ip_5px_KC_measurements.tbl)

Default X-data: BJD_TDB Y-datasets: 15 sets Detrend Vars: 10 Rel. Mag. Reference: 10 samples V. Marker 1: 0.6207 Copy V. Marker 2: 0.7936

Title
☐ None ☒ Text ☐ Programmable
 TIC 393818343.01 (TOI 6883.01) on UT 2024-07-02

Subtitle
☐ None ☒ Text ☐ Programmable
 LCO-CTIO-0m4p Telescope (ip-band, exp=14s, C-FA: 5-30--

Legend
 Align: ☐ Left ☒ Center ☐ Right
 Position: Top Middle Bottom

X-Axis Label
☐ None ☒ Column Label ☐ Custom Label
 X-axis custom label

Y-Axis Label
☐ None ☐ Column Label ☒ Custom Label
 Relative Flux

Trim Data Samples
 Head: 0 Tail: 0

X-Axis Scaling
☒ Auto X-range ☐ First X-value as min ☐ Custom X-range
 X-width: 0.251088 X-max: 2458823.803 X-min: 2458823.453912

Y-Axis Scaling
☐ Auto Y-range ☒ Custom Y-range
 Y-max: 1.016573 Y-min: 0.943377

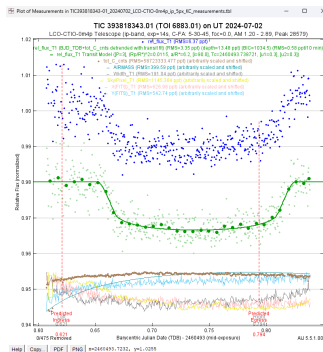
Plot Size
 Height: 800 Width: 800

Phase Folding
☒ Unphased ☐ Days Since Tc ☐ Hours Since Tc ☐ Phase
 T0 (Days): 2455873.679 Period (Days): 3.0196 Duration (Hours): 3 ☐ 2xP ☐ odd/even

Meridian Flip
 Show: ☐ Flip Time: 0.6

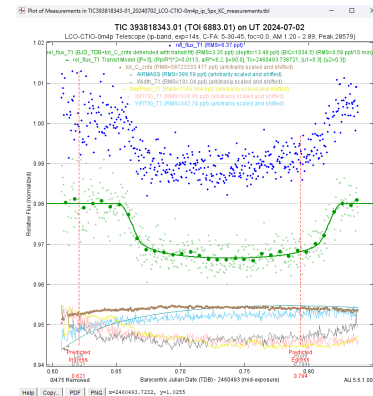
Fit and Normalize Region Selection
 Show: ☒ Left Trim: -0.01 Left: 0.6207 Right: 0.7936 Right Trim: 6.649275

Other Panels
 Redraw Plot Add Data
 Y-data Ref. Stars



Multi-plot Y-data

- Controls related to individual plotted datasets
- Color, symbol shape
- Fitting mode
- Data averaging and binning

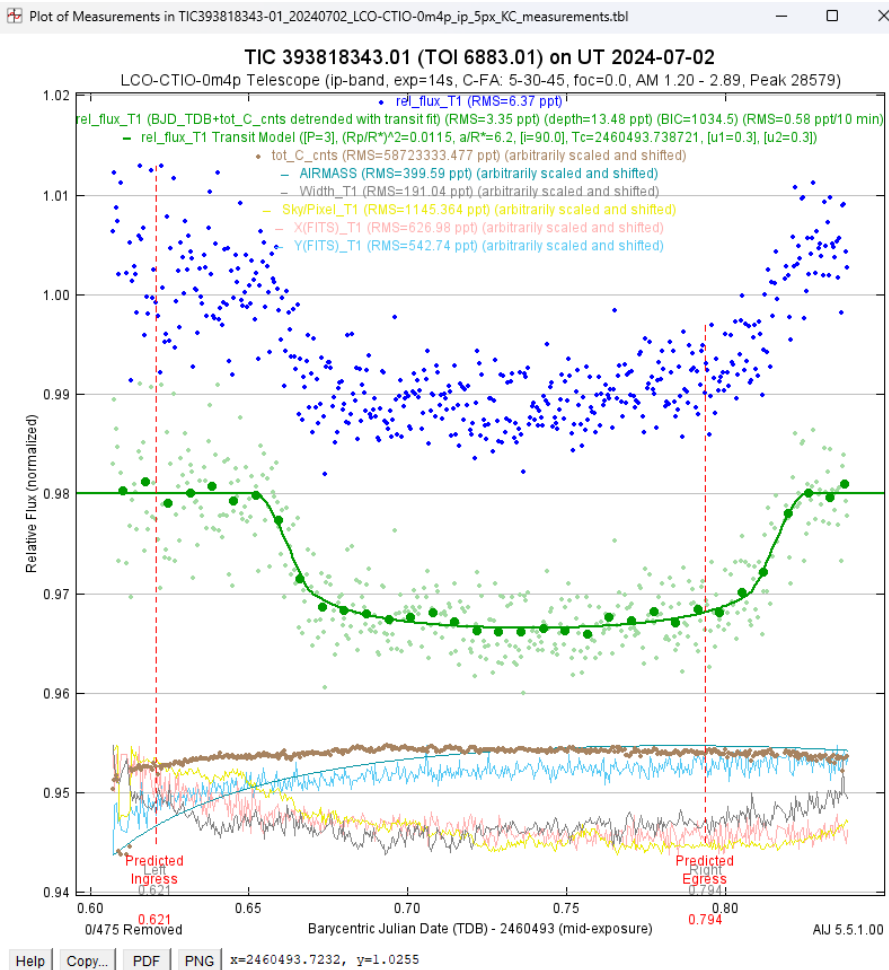


Multi-plot Y-data

Data Set	New Col	Plot	Auto Scale	X-data	Input in Mag	Y-data	Function	Y-operand	Show Error	Color	Symbol	Lines	Input Average	Spline Smooth	Fit Mode	Trend Select	Trend Coefficient	Trend Dataset	Norm/ Mag Ref	Out Mag	Page Rel	Scale	then Shift	Out Bin	BinSize (min)
1			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_T1	<input type="checkbox"/>		<input type="checkbox"/>	blue	dot	<input type="checkbox"/>	1			<input type="checkbox"/>	0.0000023			<input type="checkbox"/>		1	0	<input type="checkbox"/>	5
2			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_T1	<input type="checkbox"/>		<input type="checkbox"/>	red	box	<input type="checkbox"/>	5			<input type="checkbox"/>	0			<input type="checkbox"/>		1	-0.008	<input type="checkbox"/>	5
3			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_T1	<input type="checkbox"/>		<input type="checkbox"/>	dark green	dot	<input type="checkbox"/>	1			<input type="checkbox"/>	-0.0000000	tot_C_ents		<input type="checkbox"/>		1	-0.02	<input checked="" type="checkbox"/>	10
4			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C2	<input type="checkbox"/>		<input type="checkbox"/>	magenta	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	-0.0001225			<input type="checkbox"/>		1	-0.04	<input type="checkbox"/>	5
5			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C3	<input type="checkbox"/>		<input type="checkbox"/>	black	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0.0000094			<input type="checkbox"/>		1	-0.045	<input type="checkbox"/>	5
6			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C4	<input type="checkbox"/>		<input type="checkbox"/>	red	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	-0.000051			<input type="checkbox"/>		1	-0.05	<input type="checkbox"/>	5
7			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C5	<input type="checkbox"/>		<input type="checkbox"/>	purple	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	-0.001511			<input type="checkbox"/>		1	-0.055	<input type="checkbox"/>	5
8			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C6	<input type="checkbox"/>		<input type="checkbox"/>	light blue	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0.0000020			<input type="checkbox"/>		1	-0.06	<input type="checkbox"/>	5
9			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	rel_flux_C7	<input type="checkbox"/>		<input type="checkbox"/>	dark green	X	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0.0000997			<input type="checkbox"/>		1	-0.065	<input type="checkbox"/>	5
10			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	tot_C_ents	<input type="checkbox"/>		<input type="checkbox"/>	brown	dot	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		15	-42	<input type="checkbox"/>	5
11			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	AIRMASS	<input type="checkbox"/>		<input type="checkbox"/>	teal	line	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		-15	-42	<input type="checkbox"/>	5
12			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	Width_T1	<input type="checkbox"/>		<input type="checkbox"/>	gray	line	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		15	-42	<input type="checkbox"/>	5
13			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	Sky/Pixel_T1	<input type="checkbox"/>		<input type="checkbox"/>	yellow	line	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		15	-42	<input type="checkbox"/>	5
14			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	X(FITS)_T1	<input type="checkbox"/>		<input type="checkbox"/>	pink	line	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		15	-42	<input type="checkbox"/>	5
15			<input checked="" type="checkbox"/>	default	<input type="checkbox"/>	Y(FITS)_T1	<input type="checkbox"/>		<input type="checkbox"/>	light blue	line	<input type="checkbox"/>	1		off	<input type="checkbox"/>	0		off	<input type="checkbox"/>		15	-42	<input type="checkbox"/>	5

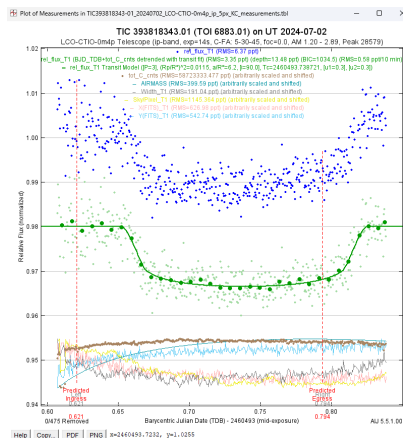
Plot Window

- Displays plotted dataset(s)
- Is interactive with mouse and data table
- Zoom and pan with mouse



Lightcurve Fitting Panel

- Set up initial fitting parameters
- View fitted values
- Manually select detrending
- Auto remove bad data points (“clean”)
- Auto optimize comparison stars
- Auto optimize detrending



File Auto Priors

rel_flux_T1

User Specified Parameters (not fitted)

Orbital Parameters

Period (days) Cr ☒ Ecc ω (deg)

Host Star Parameters (enter one)

Sp.T. Teff (K) J-K R^* (Rsun) M^* (Msun) ρ^* (cgs)

Transit Parameters

☒ Enable Transit Fit

☒ Auto Update Priors

Extract Prior Center Values From Light Curve, Orbit, and Fit Markers

Parameter	Best Fit	Lock	Prior Center	Use	Prior Width	Cust	StepSize	
Baseline Flux (Raw)	0.177981439	<input checked="" type="checkbox"/>	0.177516248	<input type="checkbox"/>	0.03550325	<input type="checkbox"/>	0.1	
$(R_p / R_*)^2$	0.011466227	<input checked="" type="checkbox"/>	0.010690118	<input type="checkbox"/>	0.005345059	<input type="checkbox"/>	0.010690118	
a / R_*	6.152852370	<input checked="" type="checkbox"/>	6.127483167	<input type="checkbox"/>	0.8	<input type="checkbox"/>	1.0	
T_c	2460493.738720952	<input checked="" type="checkbox"/>	2460493.70715	<input type="checkbox"/>	0.015	<input type="checkbox"/>	0.04	
Inclination (deg)	90.00000000	<input checked="" type="checkbox"/>	90.0	<input type="checkbox"/>	15.0	<input type="checkbox"/>	30.0	
Linear LD u1	0.300000000	<input checked="" type="checkbox"/>	0.3	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1	
Quad LD u2	0.300000000	<input checked="" type="checkbox"/>	0.3	<input type="checkbox"/>	0.2	<input type="checkbox"/>	0.1	
Calculated from model	13.48	<input type="checkbox"/>	0.000	<input type="checkbox"/>	0.000	<input type="checkbox"/>	0.000	
Depth (ppt)	b	<input type="checkbox"/>	t14 (d)	t14 (hrs)	t23 (d)	tau (d)	ρ^* (cgs)	Rp (Rjup)
		<input type="checkbox"/>	0.172761	04:08:47	0.139073	0.016844	0.4892	1.05

Detrend Parameters

Use	Parameter	Best Fit	Lock	Prior Center	Use	Prior Width	Cust	StepSize
<input type="checkbox"/>	AIRMASS		<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input checked="" type="checkbox"/>	BJD_TDB	0.003308716042	<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>	Width_T1		<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>	Sky/Pixel_T1		<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input checked="" type="checkbox"/>	tot_cnts	-0.000000002762	<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>	Y(FITS)_T1		<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>	X(FITS)_T1		<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>			<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>			<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>			<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1
<input type="checkbox"/>			<input checked="" type="checkbox"/>	0.0	<input type="checkbox"/>	1.0	<input type="checkbox"/>	0.1

Fit Statistics

RMS (ppt) χ^2/dof BIC dof χ^2

Fit Optimization

Outlier Removal: Clean

Comparison Star Selection: Quick Start Iter. Remaining:

Detrend Parameter Selection: Max Pars: Exhaustive BIC Thres: Iter. Remaining:

Plot Settings

☒ Show Model ☒ Show in legend ☐ Show Residuals ☐ Show Error

Line Color: Line Width: ☐ Log Optimization

Symbol: Symbol Color: Shift:

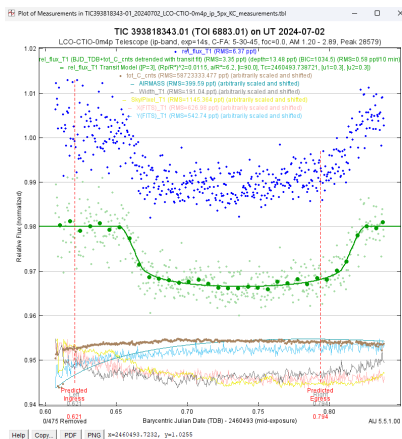
Fit Control

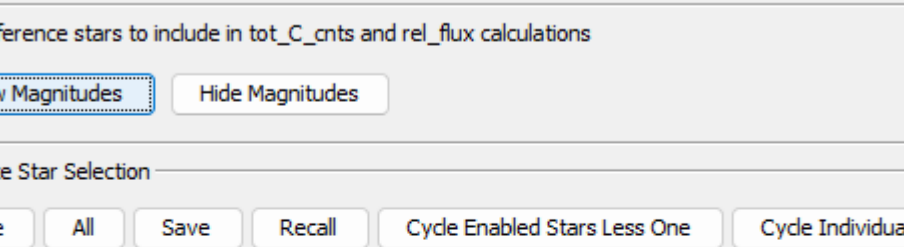
Fit Update Options: ☒ Auto Update Fit

Fit Tolerance: Max Allowed Steps: Steps Taken:

Reference Star Panel

- Interactively change comparison stars
- Add comp star magnitude data (optional)





Multi-plot Reference Star Settings

Select reference stars to include in tot_C_cnts and rel_flux calculations

Show Magnitudes Hide Magnitudes

Reference Star Selection

None All Save Recall Cycle Enabled Stars Less One Cycle Individual Stars

T1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Green checkbox border - aperture peak count under linearity limit
 Yellow checkbox border - aperture peak count over linearity limit
 Red checkbox border - aperture peak count over saturation limit

Save/Show Current Configuration

Save Table Save Apertures Send to Multi-aperture Show Apertures

Add Astronomical Data Panel

- Add calculated data to measurements table
- Examples are BJD_TDB, airmass, etc.
- Optionally runs automatically at end of each Multi-Aperture run

The screenshot shows a software window titled "Add astronomical data to table". It contains several configuration options for adding astronomical data to a table.

Input Time Format: Three radio buttons are present: ☒ JD (UTC), ☐ HJD (UTC), and ☐ BJD (TDB).

RA/Dec Source (J2000): Two radio buttons: ☐ Manual and ☒ Table.

Date/Time Column From Active Table: A dropdown menu showing "JD.UTC".

RA Column (hrs): A dropdown menu showing "RA_T1".

DEC Column (deg): A dropdown menu showing "DEC_T1".

Select data to add: A list of checkboxes with the following items: ☒ Airmass, ☐ Altitude, ☐ Azimuth, ☐ Hour Angle, ☐ Zenith Distance, ☐ JD.UTC, ☐ HJD.UTC, ☐ HJD Correction, ☒ BJD.TDB, ☐ BJD Correction, ☐ RA Now, ☐ Declination Now, ☐ RA J2000, and ☐ Declination J2000.

Enter table column name to add: A list of text boxes containing the following column names: AIRMASS2, ALTITUDE, AZIMUTH, HOUR_ANGLE, ZENITH_DIST, JD.UTC_MOBS, HJD.UTC_MOBS, HJD_CORR, BJD.TDB, BJD_CORR, RA_EOD, DEC_EOD, RA_J2000, and DEC_J2000.

Setup target and/or observatory parameters: A text box with the instruction "in 'MP Coordinate Converter' window, then press the 'Update Table' button."

Buttons: At the bottom right, there are three buttons: "Auto" (with a checked checkbox), "Update Table", and "Close".

Coordinate Converter Panel

- Convert between time formats
- Convert between coordinate formats
- Calculates observability parameters
- Includes leap second calculations
- Manual control or automatic control from:
 - Data Processor
 - Add Data panel

Coordinate Converter

File Preferences Network Help

Current UTC-based Time

UTC: 2025-09-05 11:07:57 Local: 2025-09-05 07:07:57 JD: 2460923.963858 LST: 05:23:57

SIMBAD Object ID (or SS Object) Time Zone Observatory ID

UTC offset: -4 LCO CTIO (Isr)

Target Proper Motion (mas/yr) Geographic Location of Observatory

pmRA: 0 pmDec: 0 Lon: -70.815000 Lat: -30.165000 Alt: 2215

Standard Coordinates

J2000 Equatorial J2000 Ecliptic

SIMBAD RA: 15.245316 Dec: -72.684825 Lon: 251.426781 Lat: -51.905055

Sky-Map B1950 Equatorial Galactic

RA: 15.158580 Dec: -72.498568 Lon: 313.219085 Lat: -12.740492

Epoch of Interest

UTC-based Time

Now UTC: 2020-01-10 08:21:24 UT 19:49 JD: 2458858.848194 LST: 10:55:28

Lock Local: 2020-01-10 03:21:24 03:52 HJD: 2458858.845428 dT: -00:03:59

Dynamical Time

Update Auto Leap-secs: 37.0 OSU/internal BJD: 2458858.846208 dT: -00:02:52

Equatorial Ecliptic

RA: 15.279270 Dec: -72.752073 Lon: 251.694040 Lat: -51.904368

Horizontal Direction - Hour Angle - Zenith Distance - Airmass

Alt: 35.961394 Az: 160.562732 Dir: S HA: -4.354841 ZD: 54.038606 AM: 1.6989

Phase - Altitude - Proximity

Moon 11.25 122.83 Down 59.05 Venus Down 78.94 Mars 19.53 52.50 Jupiter Down 56.77 Saturn Down 62.25 Uranus Down 118.28 Neptune Down 92.14 Pluto Down 61.50

Submit Your Results!

- . Use File => “Save All” to save reduced data files
- . Run NEBcheck (if still needed)
- . Upload reduced data to ExoFOP
- . Send summary email to SG1 lead
- . Select and observe your next target from the TTF!

Planet Publication Techniques

- Typical methods used for publishing transiting planet discoveries

- Statistical validation

- Typically uses TESS and ground-based lightcurves to show $<1\%$ chance of false positive
 - May also include spectroscopic stellar parameters, high resolution imaging, and Gaia magnitudes to strengthen results
 - Yields planet size, but not mass

- Radial velocity mass confirmation

- Models lightcurve data, precise radial velocities, stellar parameters, Gaia parallax and other catalog data to virtual push the chance of a false positive to near 0%
 - Yields planet size and mass, and thus bulk density and constraints on composition

- Transit timing variation confirmation

- Models many transit observations from TESS and ground to characterize TTVs
 - Yields planet size, and often planet mass, and pushes chance of false positive to near 0%

Publication Process

- TFOP lead authors request to post abstract of planet discovery on “TESS Wiki” protected website
- Lead author will review and select data from ExoFOP (SG1 leads will shadow to ensure proper data inclusion when practical)
- You may be asked to provide a short write describing your equipment and observation (SG1 leads attempt to help with this part when practical)
- When your data are useful for a publication, you will be nominated to join the paper as coauthor
- You will need to review the paper and agree to join as coauthor
- Lead author takes paper through peer review process
- Paper will appear in peer reviewed journal, including you as coauthor

Join the Fun!

- If you are new to transit observing, I highly recommend two training approaches
 - Go to [Dennis Conti's website](#) and work through his “[A Practical Guide to Exoplanet Observing](#)”
 - Attend an online AAVSO “**Introduction to Exoplanet Observing**” course, and possibly the more advanced course “**Advanced Use of AstrolmageJ for Exoplanet Observing**”
- Apply to join TFOP
 - Dennis Conti (AAVSO) offers a program to qualify AAVSO members to join TFOP
 - Experienced transit observers may opt to apply directly following instructions at <https://tess.mit.edu/followup/apply-join-tfop>
 - Send email to TFOP SG1 Lead (current me), answering bulleted questions
 - Read and agree to abide by the [TFOP WG Charter](#) (7 pages)
 - Read and agree to abide by the [TFOP WG Publication Policy](#) (3 pages)