

EXPLORE

exoplanet orbit research

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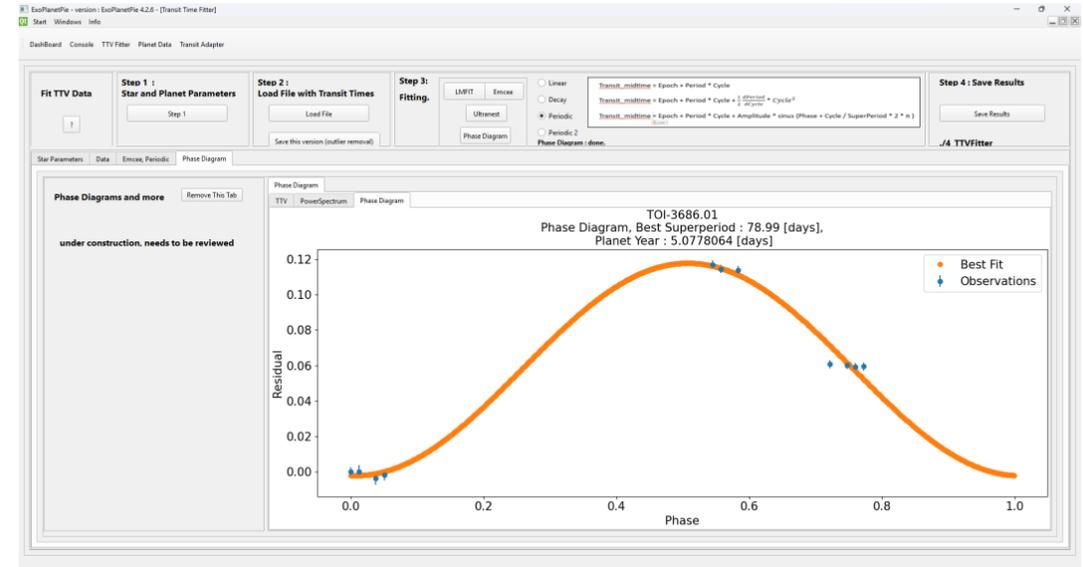
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Introduction



Citizen-science project
focused on Transit
Timing Variations
(TTVs)

Main goal: support
observations of
exoplanets with TTVs

Discovery of
multiplanet systems
using TTVs

**EXPLORE website
includes:**

- Target lists

- Observing guides & tutorials

- Links to software, papers & presentations

Working Group

- **Active members:**
 - • Rodney Buckland The open university, BAA
 - • Dennis Conti AAVSO
 - • Franky Dubois VVS
 - • Roger Dymock BAA
 - • Allan Schmitt Caltech
 - • Trifon Trifonov University of Heidelberg/Sofia
 - • Siegfried Vanaverbeke VVS, KUL
 - • Pieter Vuylsteke VVS, KUL



Objectives

Identify planets showing TTVs

- from ExoClock, TESS and other databases

Analyze TTV signals to constrain

- planetary & system parameters
- (Exoplanetpie, LcTools, PlanSim)

Determine possible causes of TTVs

- (extra planets, orbital decay, star-planet interaction, ...)

Follow-up promising candidates

- (new exoplanets, variable stars, etc.)

Observation and Analysis Process

Amateur contribution

Target list (mainly ExoClock + TESS...)

Observing guides

Observe & upload to ExoClock / AAVSO/exoFOP

Analysis & modeling

TTV detection (Exoplanetpie, LcTools, PlanSim)

Search for new systems in TESS data

Non-Keplerian effects(e. g. tidal decay in hot Jupiters)

EXOPLANETPIE SOFTWARE GUI

ExoPlanetPie - version : ExoPlanetPie 4.2.3 - [DashBoard]

Start Windows Info

DashBoard Console

ExoPlanetPie

?

STEP 1 : Get Data From Satellites

Get Satellite Data ? New: Find Transits

Here we will pick up data from the Tess and Kepler Satellites.

Star and Planet : The Data

Get Star and Planet Data ?

Several of these programs need some facts about the star and planet to be studied.
Here you can enter them, or upload them from the ExoClock database.

STEP 2 : Prepare Data

Prepare Files to fit ? Download and Prepare NASA Data ?

- Indicate where the midtimes of Transits are to be expected
- Creates for each transit a file that will be used for the actual fitting process, in Step 3.
- for NASA data : step 1 is not necessary

STEP 3 : Fit the Transits

Batman Fitter ?

- Fit the files created in step 2

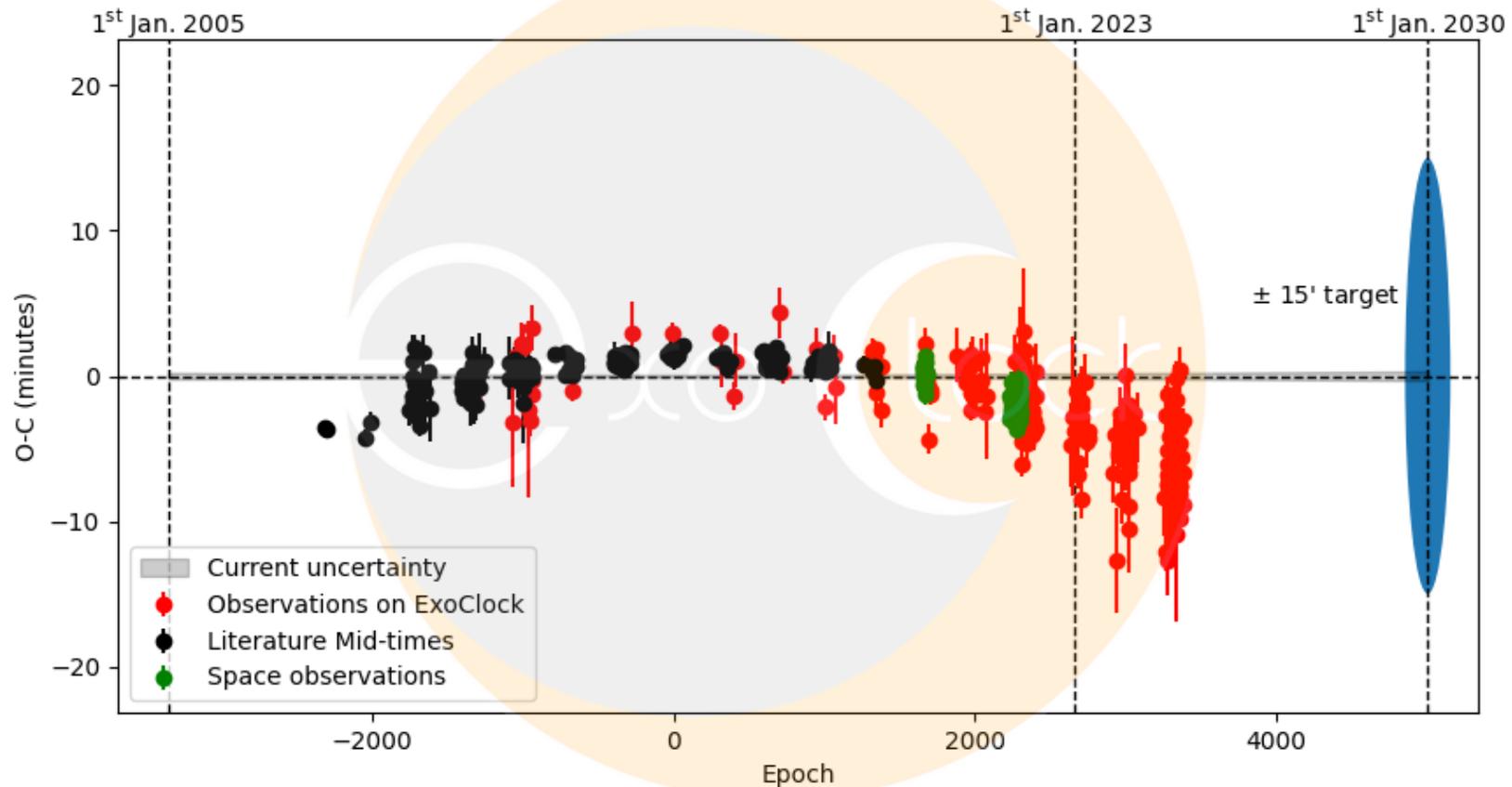
STEP 4 : Analyse Transit Time Variations

Analyse TTV ? Transit Merger

- Study the Transit Time Variations using data from ExoPlanetPie or Exoclock, or enter your own data

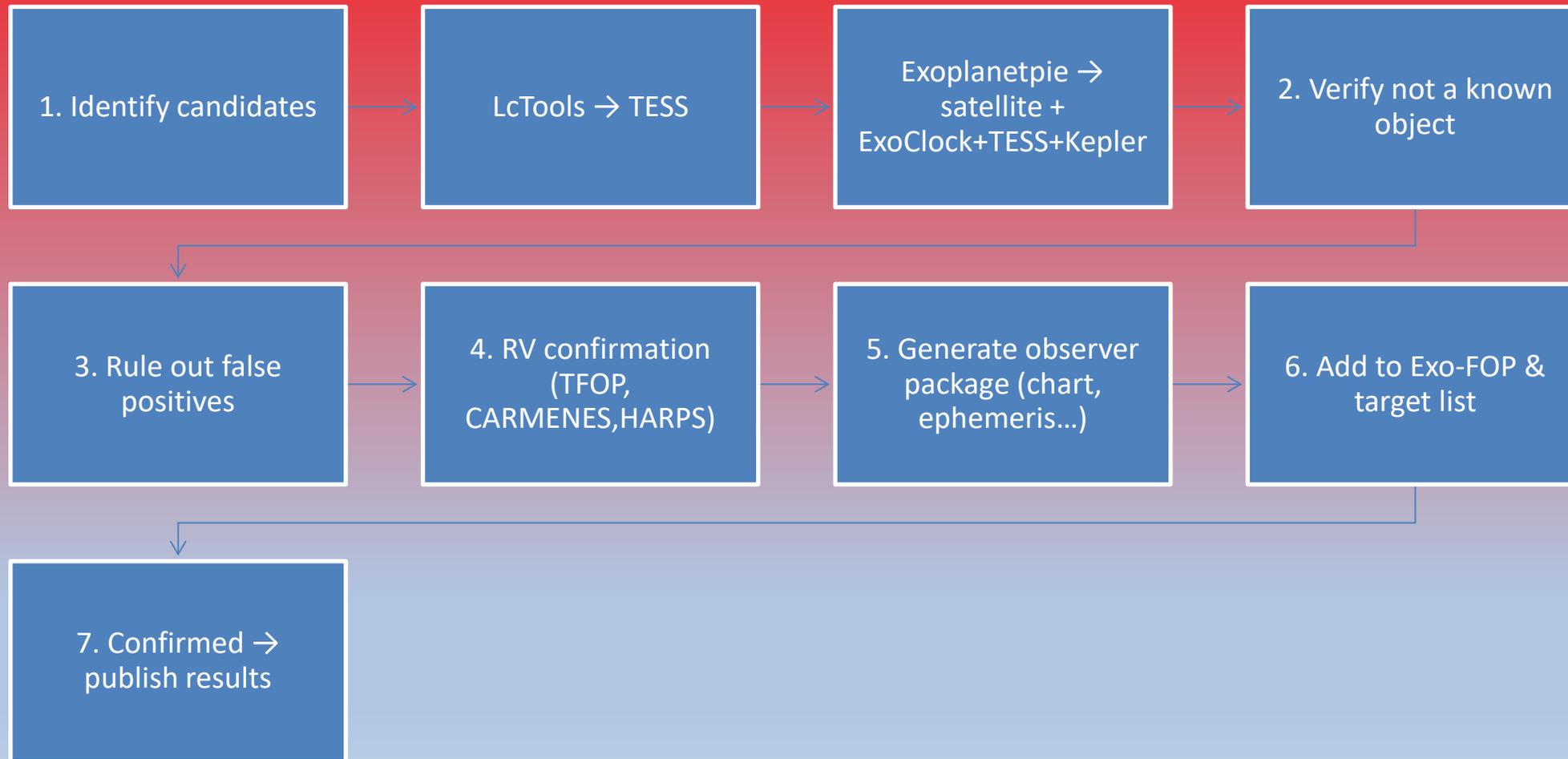
Visualizer

Visualizer ?



WASP 12b: TTV analysis using exoplanetPie

Discovery Process for new objects



TIC 229452949

The LcTools suite; LcGenerator, LcSignalFinder and LcViewer is being used to analyse TESS SPOC stars observed in multiple sectors. The data is downloaded from the LcTools website.

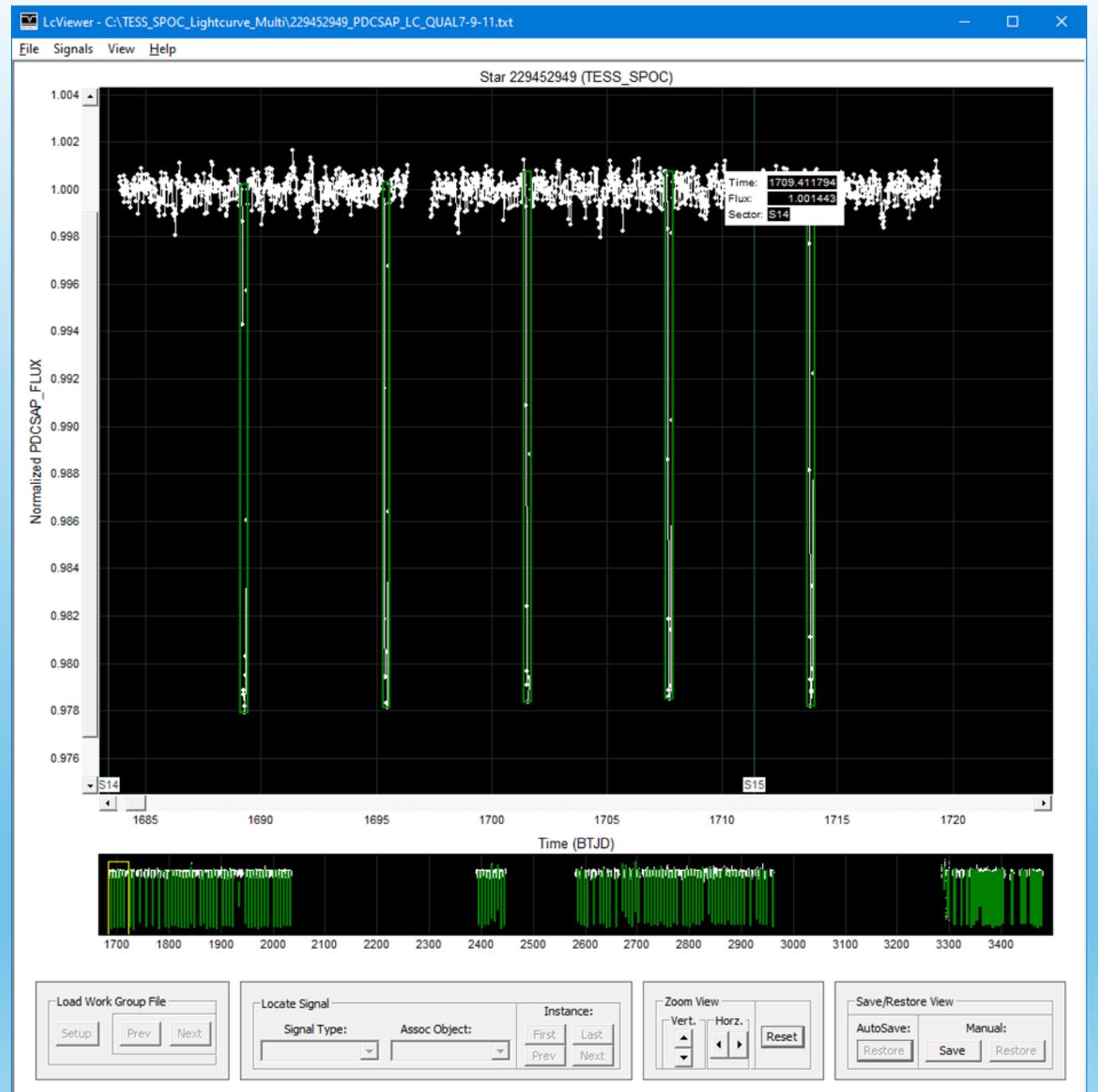
This plot shows multiple transits of possible exoplanet TIC 229452949

RA; 19 37 36.31, Dec; +63 51 22.1

Period; 6.1426970 days

Transit duration; 4.8 hrs

Transit depth; 22.9 mmag

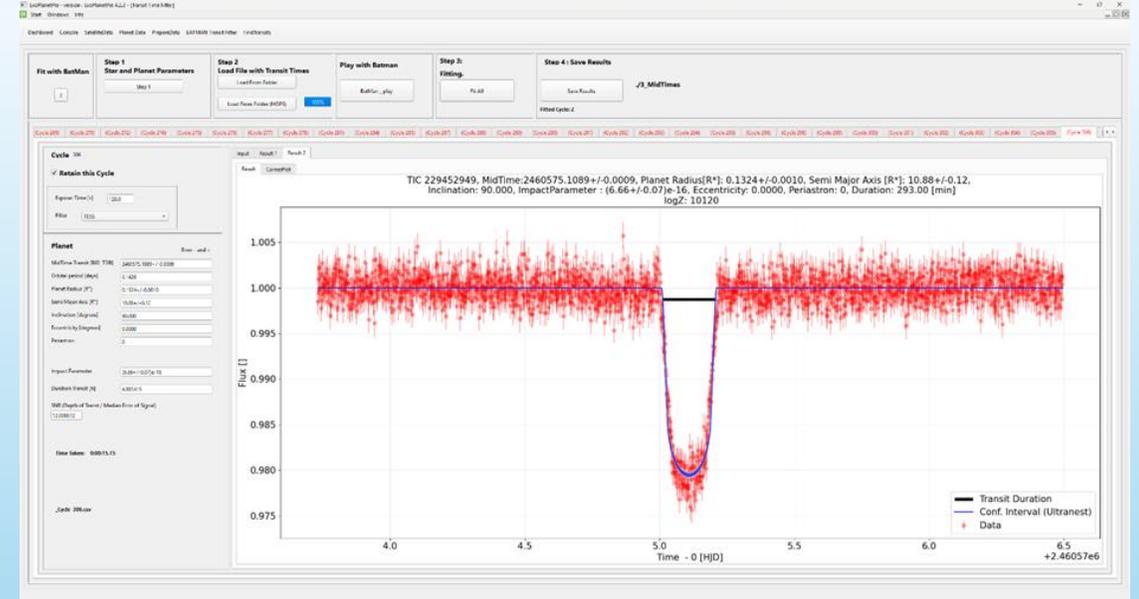


TIC 229452949



MAST

Additional data was obtained from MAST, Exoplanetpie and the Swarthmore Transit Finder.



Exoplanetpie

astro.swarthmore.edu/transits/print_transits.cgi?single_object=1&ra=19h37m36.32s&dec=+63d51m22.11s&epoch=2458689.2919380&period=6.1426970&duration=4.8&depth=22.9&target=T...

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

Local evening date	Name	V or Gala mag	Start—Mid—End	Duration	BJD _{TDB} start—mid—end	Elev. at start, mid, end ± 1 hrs	% of transit (baseline) observable, Suggested obs. start, end	Az. at start, mid, end ± 1 hrs	HA at start, mid, end ± 1 hrs	RA & Dec (J2000)	Period (days)	Depth (ppt)	Comments
Sun. 2025-12-07	TIC 229452949 Finding charts: Annotated , Aladin , SkyMap , Aimms plot , ACP plan Info: Exoplanet Archive , Simbad , Gaia , TIC	Moon 88% @92°	17:33—18:33—20:57 —23:21 00:21	4:48	11017.2741 11017.3741 11017.4741	63° 57° 42° 31° 28°	100% (100%) 17:33—00:21	316° 316° 324° 338° 344°	+3.0 +4.0 +6.4 +8.8 +9.8	19:37:36.32 +63:51:22.1	6.14	22.9	Manually-entered single object
Sat. 2025-12-13	TIC 229452949 Finding charts: Annotated , Aladin , SkyMap , Aimms plot , ACP plan Info: Exoplanet Archive , Simbad , Gaia , TIC	Moon 29% @103°	20:59—00:23 —02:47 03:47	4:48	11023.4168 11023.5168 11023.6168	40° 35° 27° 25° 26°	100% (100%) 20:59—03:47	326° 332° 347° 4° 12°	+6.8 +7.8 +10.2 -11.4 -10.4	19:37:36.32 +63:51:22.1	6.14	22.9	Manually-entered single object
Fri. 2025-12-19	TIC 229452949 Finding charts: Annotated , Aladin , SkyMap , Aimms plot , ACP plan Info: Exoplanet Archive , Simbad , Gaia , TIC	Moon 0% @95°	00:25—01:25—03:49 —06:13 07:13	4:48	11020.5595 11020.6595 11020.7595	26° 25° 27° 36° 41°	100% (74%) 00:25—06:41	350° 357° 15° 30° 35°	+10.6 +11.6 -10.0 -7.5 -6.5	19:37:36.32 +63:51:22.1	6.14	22.9	Manually-entered single object

Swarthmore Transit Finder

TIC 229452949

ExoFOP database entry for TIC 229452949 showing that it has not yet been identified as a TOI (target of interest)

The screenshot displays the ExoFOP database entry for TIC 229452949. The page is organized into several sections:

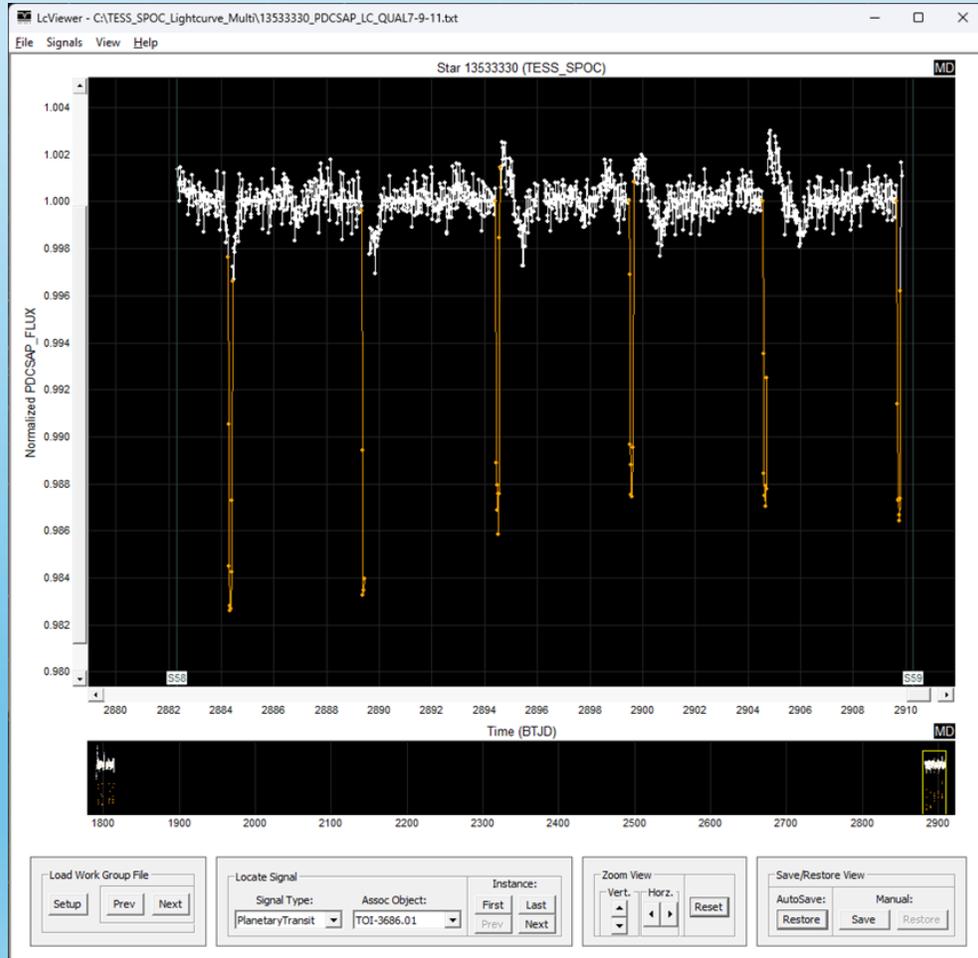
- Basic Information:** Star Name(s): TIC 229452949, 2MASS J19373633+6351220, APASS 58693216, Gaia DR2 2242253995467044864, Gaia DR3 2242253995467044608, TYC 4238-01787-1, UCAC4 770-047979, WISE J193736.32+635122.0. Confirmed Planet(s): N/A. TESS mag: 10.6918 ± 0.0073 | K mag: 9.932 ± 0.015. TIC Contamination Ratio: 0.00477.
- Coordinates:** RA/Dec (J2000, epoch 2015.5): 19:37:36.33 +63:51:22.03 (294.401392°63.856118°). Galactic Long/Lat: 95.70708 +19.32153. Ecliptic Long/Lat: 356.5184 +79.49211. Proper Motion (mas/yr): RA: 5.71571 ± 0.108312, Dec: -2.92077 ± 0.112353.
- Downloads:** Download 15 nearby TIC targets within 1 arcmin: csv · pipe · text · view. Download Gaia DR3 targets within 1 arcmin: JSON. Download this page: JSON. Download 0 Files: tar · zip · File List: csv · pipe.
- External Links:** NASA Exoplanet Archive: select. IRSA Finding Chart · Swarthmore Finding Chart · SIMBAD · MAST · KOA. Search the TESS EB Catalog · TESS Web Visibility Tool.

The main content area features several tabs, all of which are currently empty:

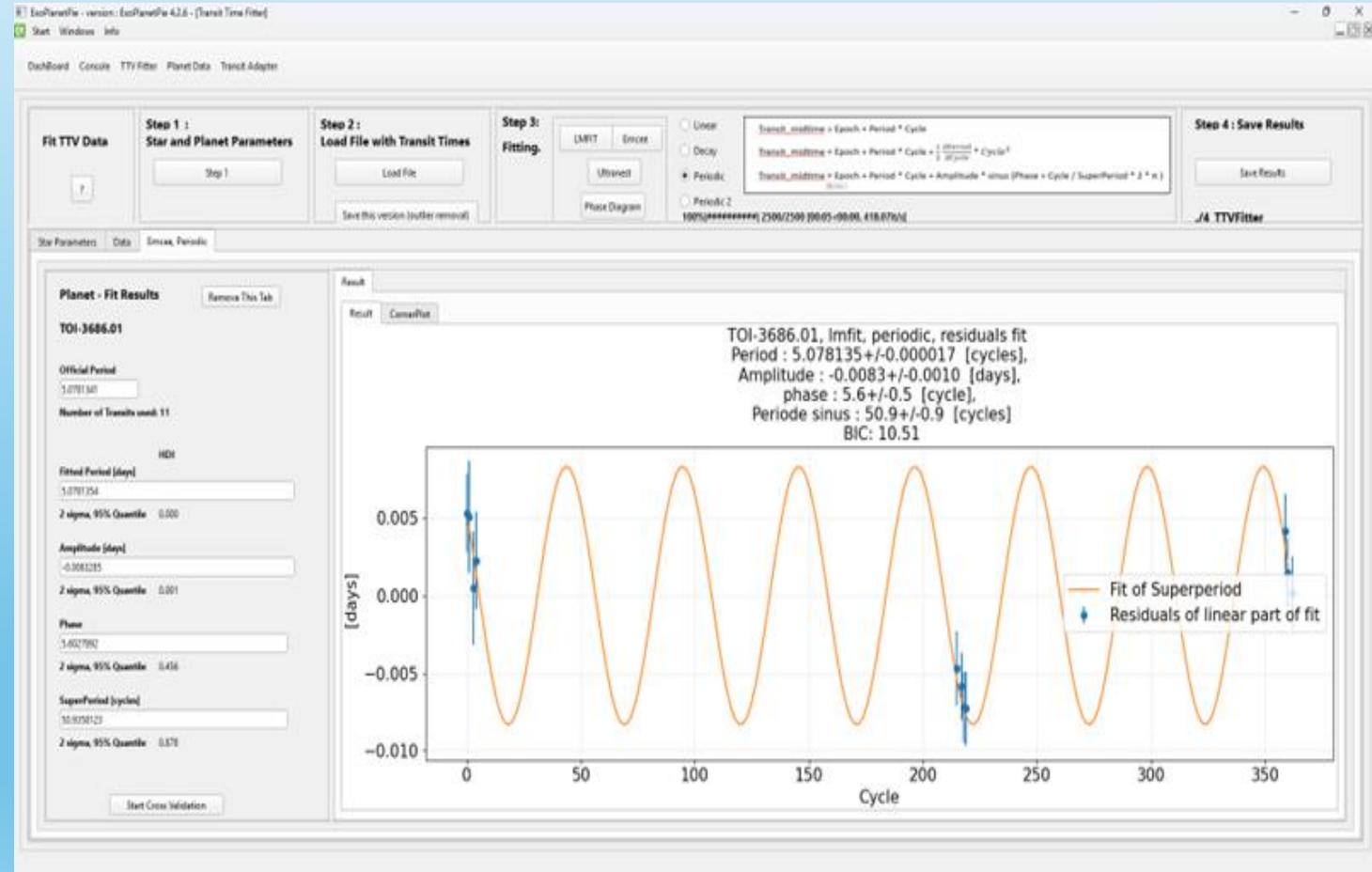
- TOIs:** No TOIs.
- Community Planet Candidates:** No Candidates.
- Planet Parameters:** No Planet Parameters.
- Stellar Parameters:** Shows data for TIC 229452949: Telescope: TESS, Instrument: Input Catalog, Spectral Type: 6378 ± 121.604, Teff (K): 3.88151 ± 0.0915469, log(g): 2.13886 ± 0.105897, Radius (R_Sun): 2.13886 ± 0.105897.
- Stellar Companions:** No data.

TOI-3686, TIC 13533330

This object exhibits a large TTV of 0.0083 days - 12 minutes. The LcTools data suggests that the variation is cyclical. Possible reasons are; starspots, change in orbital inclination, orbital precession, exomoons or orbital resonances.

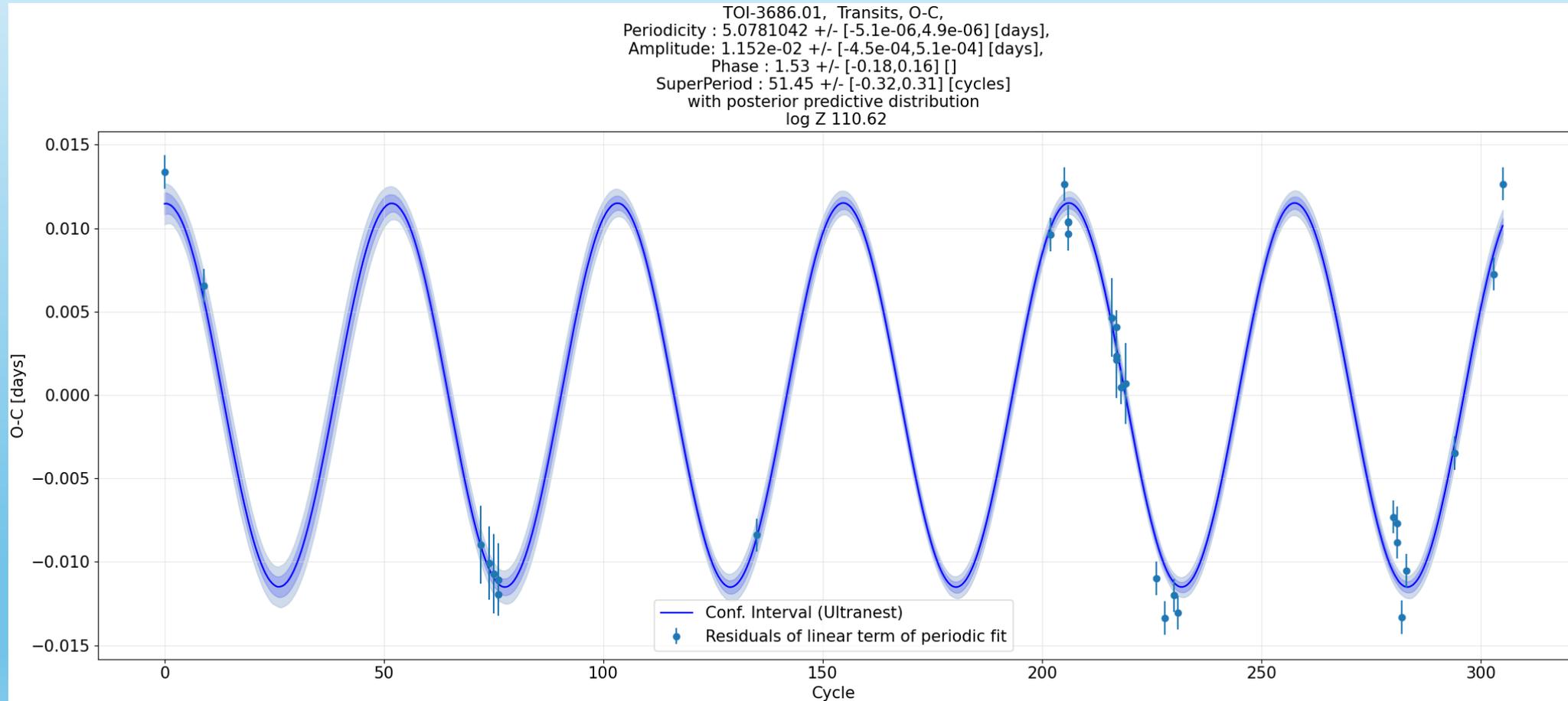


Lc Tools

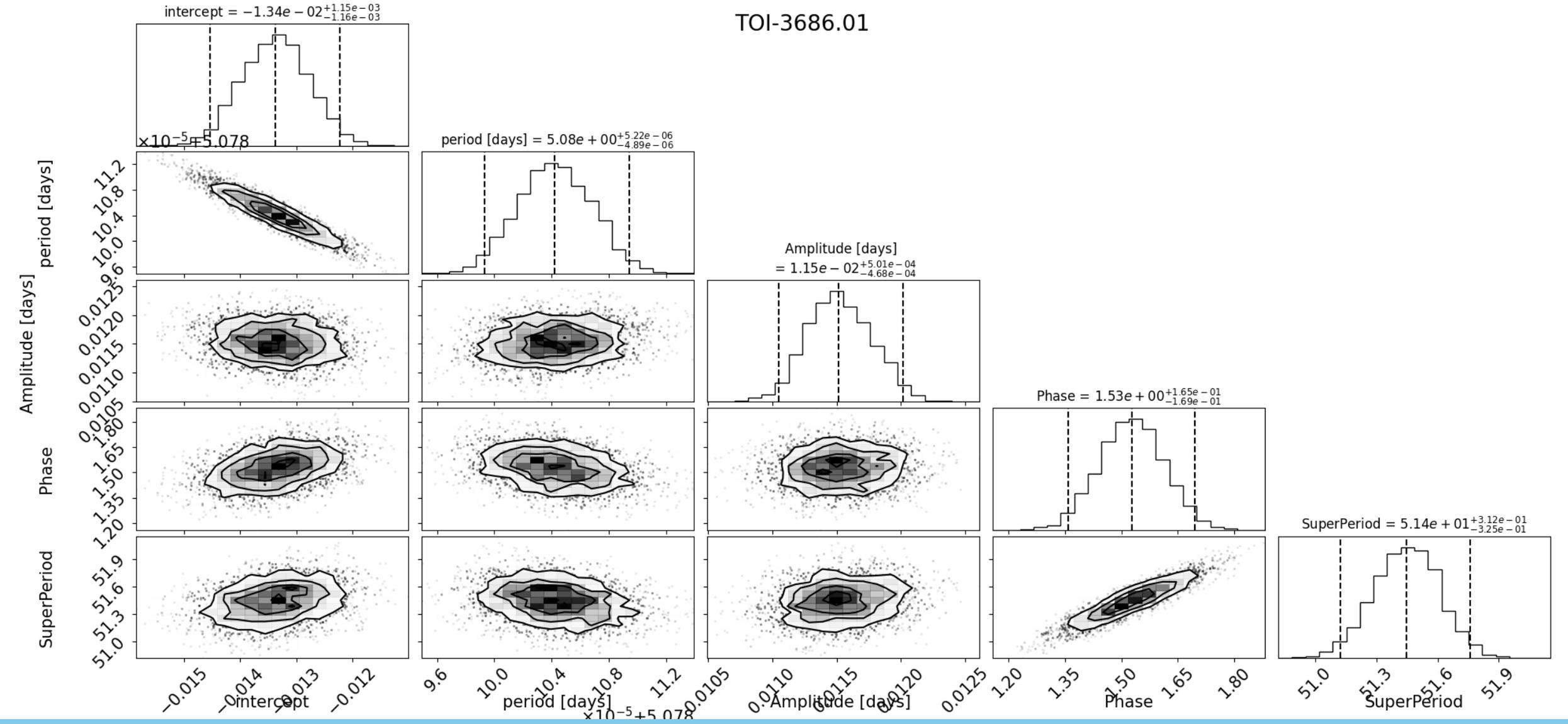


Exoplanetpie

TOI-3686, TIC 13533330

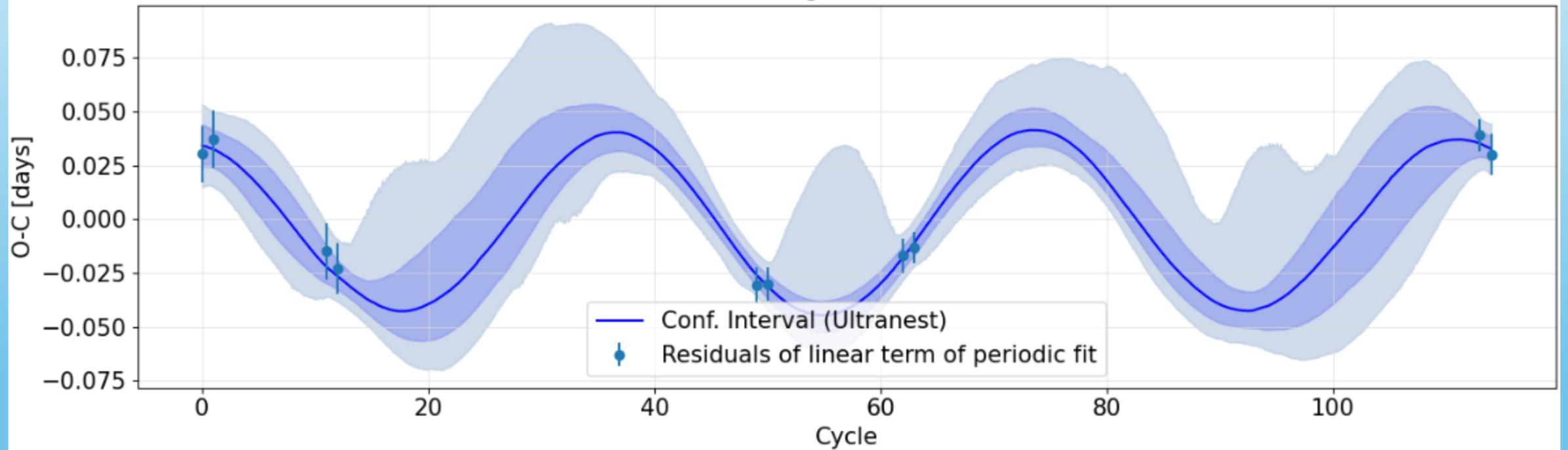


TOI-3686.01

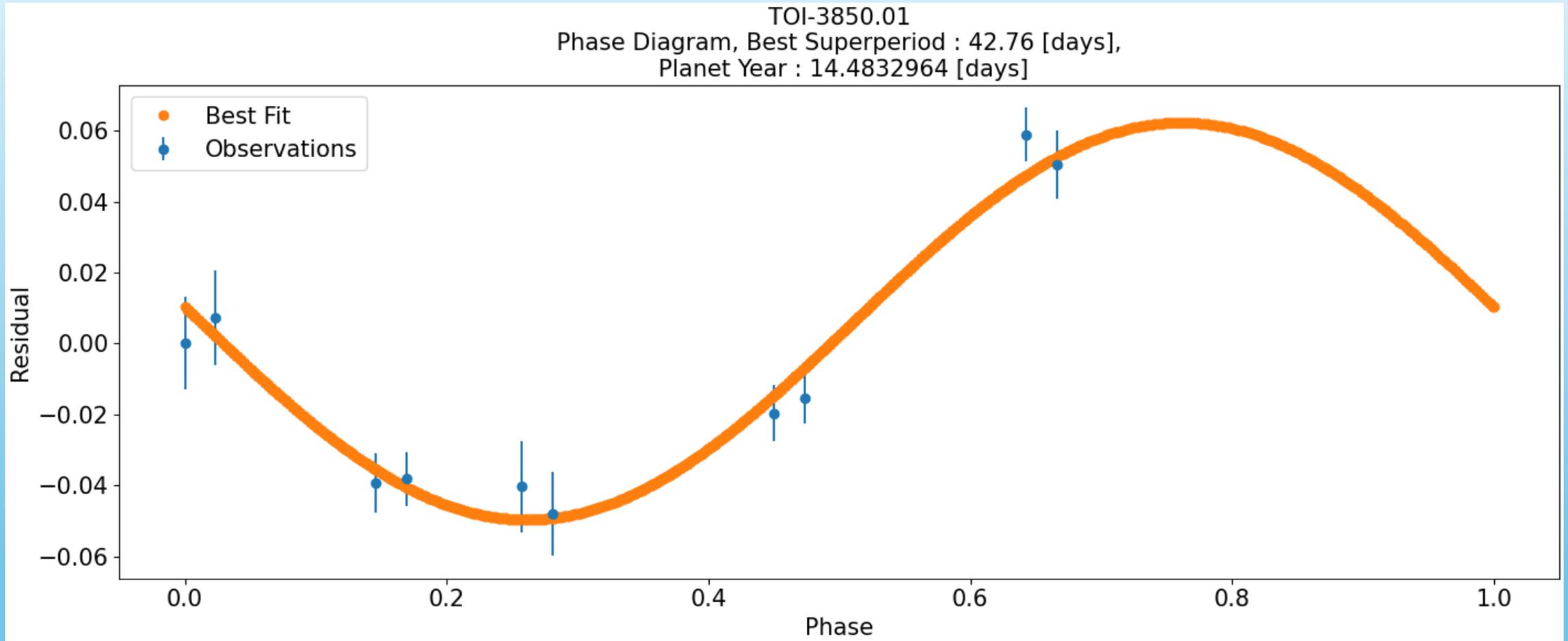


TOI-3850, TIC 143008050

TOI-3850.01, Transits, O-C,
Periodicity : $14.4837417 \pm [-4.4e-04, 3.7e-04]$ [days],
Amplitude: $4.531e-02 \pm [-1.6e-02, 1.8e-02]$ [days],
Phase : $1.87 \pm [-0.97, 1.29]$ [$^\circ$]
SuperPeriod : $37.17 \pm [-3.24, 7.05]$ [cycles]
with posterior predictive distribution
log Z 12.68



TOI-3850, TIC 143008050



Further Project Development & Collaboration

Project Development

- 1. Enhance PlanSim for unseen planet parameters
- 2. Use of exostriker(Trifonov) and jaxttv(Matsuda)
- 3. Contiguous (multi-longitude) campaigns
- 4. Future directions to be defined

Collaboration

- **Southern Hemisphere involvement(WINE survey) ?**

Warm vs Hot Jupiters

Warm Jupiters

- Period 10–200 days
- Large TTV signals → good for amateurs

Contiguous
campaigns/resonance
detection

Hot Jupiters

- Period typically < 10 days
- Small TTV amplitude

Typically long term
(tidal ?)
effects/companions
rare

Contiguous Observations (2026 basis)

**Focus: Warm Jupiters
(10–200 day periods)**

- with large TTV amplitudes

Challenges:

- • Uncertain predictions
- • Need multi-time-zone coverage

Planned:

- • Coordinated photometry
- • Radial velocity follow-up

Key contacts:

- • Trifon Trifonov (MPIA)
- • Siegfried Vanaverbeke (KU Leuven)