Beyond the Solar System: TESS's Journey into Exoplanetary Frontiers

Transit Method in Exoplanet Detection

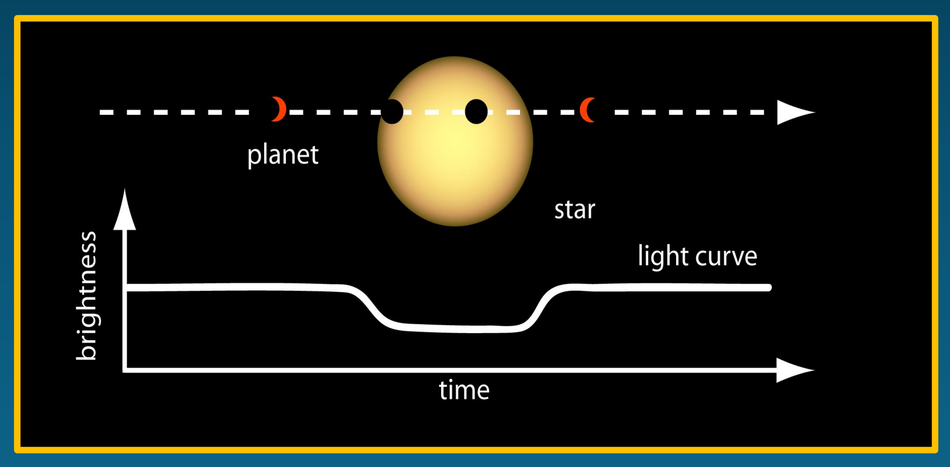
Dean Grant BSc Physics with Astrophysics
S/N: 40291098
dgrant12@qub.ac.uk

Abstract

NASA's Transiting Exoplanet Survey Satellite (TESS) has unveiled over 5,000 exoplanet candidates, revolutionizing the quest to understand the universe's myriad worlds. This poster presents my analysis leveraging ***TESS data and the Lightkurve Python toolkit***, highlighting the detection and study of these distant planets. I explored the application of advanced ***data analysis techniques*, including light curve normalization, outlier removal, and phase folding, enhancing my understanding of exoplanet characteristics and behaviours.** The work exemplifies the synergy between observational astronomy and computational analysis, shedding light on the diversity of planetary systems and contributing to the broader scientific endeavour of deciphering our cosmic context.

Illustration of a planet transiting its host star

Image Source:
Credit: NASA Ames



Extrasolar Planets

- Exoplanets, or planets located outside our own solar system, represent a vast array of celestial bodies.
- Most of these planets are in orbit around stars like our Sun. Even the nearest exoplanet to us, Proxima Centauri b, is situated a four light-years away.

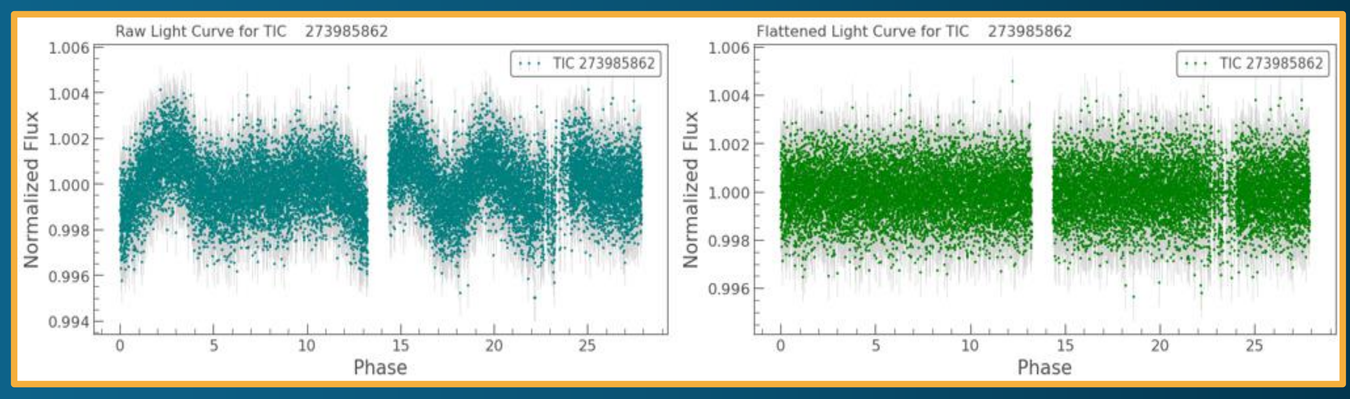
Lightkurve

A friendly package for Kepler & TESS time series analysis in Python.

(Lightkurve Collaboration, 2018):

- Streamlined and intuitive, it's designed to be user-friendly for both professional astronomers and citizen scientists.
- Efficiently handles light curves, making quick work of tasks like periodogram analysis to reveal the transiting exoplanets.

Removing Steller Variability



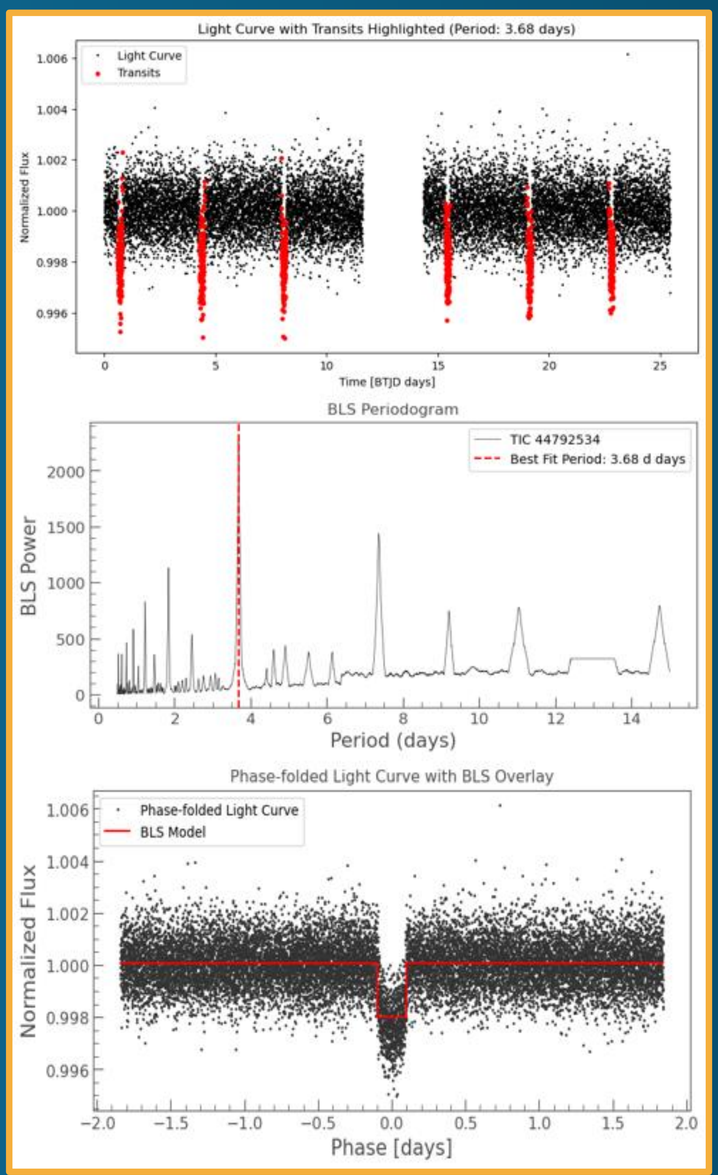
- ***Light Curve Processing for TIC 273985862.*** *On the left, the raw light curve data exhibiting the star's flux variability over time due to stellar activity and instrumental noise. On the right, the light curve is shown after applying a normalization and flattening process.* ***Normalization adjusts the flux values to centre around 1 , which allows for a consistent scale when comparing changes in brightness. Flattening is then performed to remove the effects of stellar variability and instrumental trends****, resulting in a cleaner signal that enhances the visibility of potential transit events.*

Methodology

$$\Delta F = \left(\frac{R_p}{R_s}\right)^2$$

- *The equation used to **determine the dip in brightness of a star** as a planet transits in front of it, given by where **ΔF** is the fractional change in flux, **Rp** is the radius of the planet, and **Rs** is the radius of the star.*

Data Acquisition and preprocessing
↓
Transit Detection with Lightkurve
↓
Analyse Target Signals (BLS)
↓
Verification and Interpretation
↓
Asteroseismology and Planet parameters



Results

Exoplanet Transit Detection for TIC 44972534

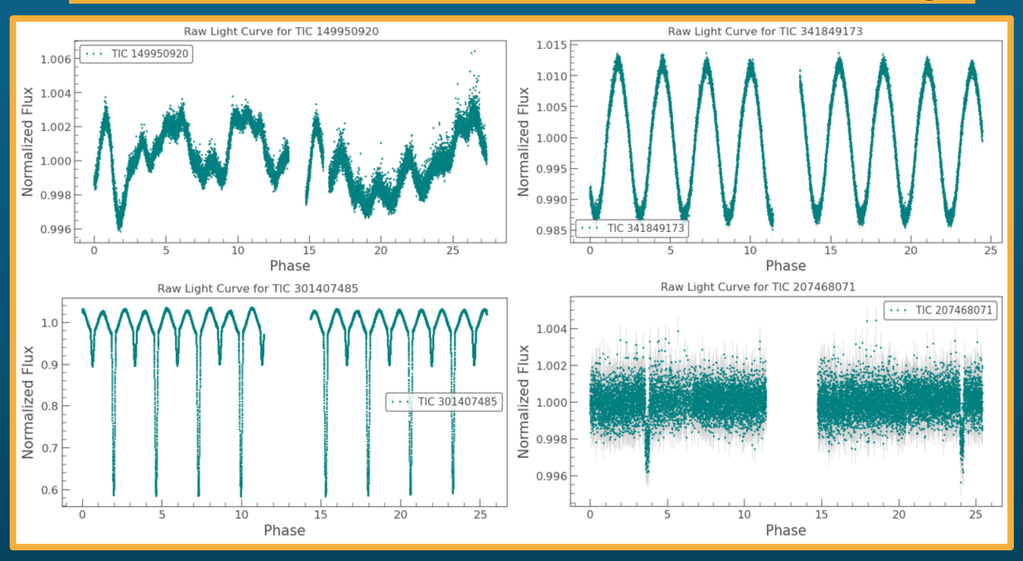
- ***The top panel*** Periodic dimming in the star's flux over time, marked in red, suggests an exoplanet orbits the star every 3.68 days.
- ***The middle panel*** The BLS periodogram, highlighting a peak at the same interval, corroborates the transit's periodic nature.
- ***The bottom panel*** A phase-folded light curve reveals consistent transit shapes, with the BLS model superimposed, validating the hypothesis of a transiting exoplanet and underscoring the events' repeatability.

Further analysis of Potential Planet and its Params:

Parameter	Value	Uncertainty(±)
Radius (Rj)	0.87472065	0.475658542
Equilibrium Temperature (K)	1777.262025	123.9800032
Period (days)	3.683648365	0.00132908
Transit Epoch (MJD)	0.697972255	0.004157481
Transit Duration (hours)	4.8	8.88E-16
Transit Depth (%)	0.002068228	0
Semi-major Axis (AU)	0.047141012	0.005784668

- Detected periodic transits indicating a potential exoplanet orbiting the star every **3.68 days**.
- The calculated equilibrium temperature of approximately **1777 K** suggests a substantial, warm planet, hinting at its unique atmospheric conditions.
- Errors were calculated using **bootstrap resampling, reflecting the 68% confidence intervals,** I have considered and ruled out common false positive scenarios such as eclipsing binaries and background stars through careful analysis of transit shape and depth variations.

Diverse Stellar Phenomena and Observational Challenges



- ***(Top Left)*** *Shows the light curve marked by the cyclic variation's indicative of rotational modulation due to stellar spots.* ***(Top Right)*** *Graph depicts the characteristic peaks of solar flares.* ***(Bottom Left)*** *Graph captures the light curve of an eclipsing binary system, evidenced by the regular deep dips as one star passes in front of the other.* ***(Bottom Right)*** *Highlights a gap in the observational data in Sector 23 corresponding to TESS's passage through Earth's shadow.*

Acknowledgements

This poster is based on a project carried out under the supervision of Senior Lecturer Meg Schwamb as part of the BSc degree in Queens University Belfast

References

- https://exo.mast.stsci.edu/ - MAST website
- https://exofop.ipac.caltech.edu/tess/search.php - Caltech Exofop
- https://heasarc.gsfc.nasa.gov/docs/tess/data_release_notes.html - NASA Data Release notes
- https://www.explore-exoplanets.eu/resource/tess/ - title photo source