Exoplanet Detection and Characterization Using NASA Kepler Data

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Abstract:
This research presents the detection and analysis of the exoplanet Kepler-10b using publicly available NASA Kepler data. In this research multiple parameter were used for identification and characterization such as the Box Least Squares (BLS) method was used for identification of the periodic dips in the host star's brightness, consistent with transiting behaviour. The folded light curve revealed the transits, from which the depth and duration were used to estimate the planetary radius (~6.85 Earth radii) and orbital period (~0.33 days). Orbital mechanics and radiative balance principles were used to calculate the semi-major axis (~0.0091 AU) and equilibrium temperature (~2676 K), which suggests it to be a hot Neptune-like exoplanet in close orbit. This study demonstrates how open-source datasets and Python based tools can enable a meaningful and scientific investigation by an independent student researcher.

Introduction:
The discovery of exoplanets has revolutionized our understanding of planetary systems beyond our own and one of the most reliable techniques of detecting exoplanets is the transit method, which includes observing periodic dips in a star's brightness, which can be caused by a planet crossing in front of it. NASA's Kepler Space Telescope has provided a wealth of such photometric data, enabling thousands of exoplanet discoveries.
This paper focuses on Kepler-10b, one of the first confirmed exoplanets. The goal of this study was to analyze the Kepler light curve of Kepler-10 to detect and characterize the exoplanet using open source data and Python tools.

Methodology:
1. Data Source: The Kepler light curve data for Kepler-10 was accessed via Lightkurve Python package, which directly interfaces with NASA Exoplanet Archive.
2. Transit Detection: The Box Least Squares (BLS) algorithm was used to identify periodic dips in the light curve. This method is ideal for detecting box shaped transit signatures of planets.
3. Light Curve Folding: After detecting a significant transit period (~0.33 days), the light curve was phase folded over the most suitable period to confirm the presence of consistent transit signals.
4. Parameter Estimation: From the folded light curve, the transit depth and duration were used to estimate the planet's radius. The semi major axis was derived using Kepler's Third Law, and equilibrium temperature was estimated based on stellar irradiance models.

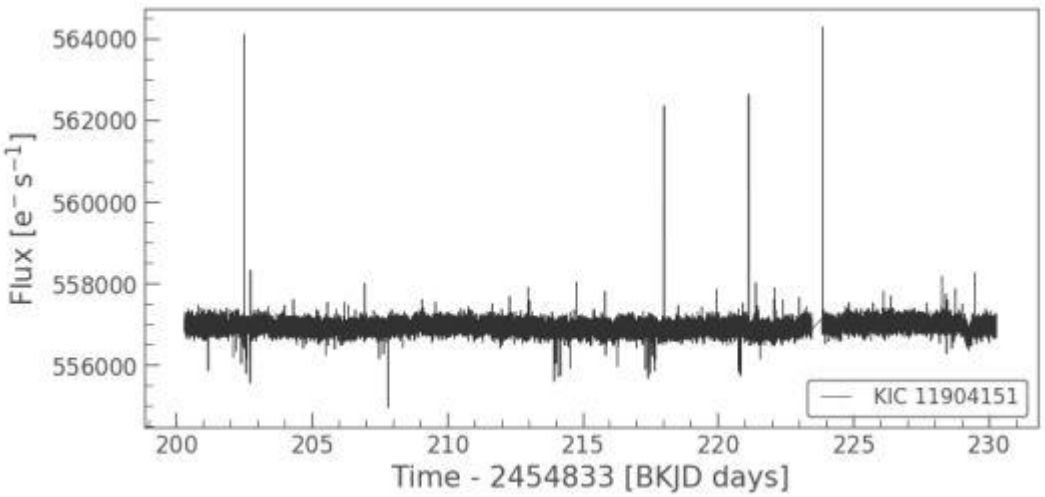

Fig. a: It is the raw light curve of KIC 119045151 obtained from NASA's Kepler mission. The X-axis represents time in Barycentric Kepler Julian Days (BKJD) and the Y-axis represents the flux (brightness) of the star in electrons per second. We can notice dips and spikes which may indicate potential data anomalies or transit events.

Results:

Parameter	**Value**
Orbital Period	0.33 days
Transit Depth	0.35%
Planet Radius	6.85 Earth radii
Semi-Major Axis	0.0091 AU
Equilibrium Temperature	2676 K

The results clearly indicate that Kepler-10b is a hot **Neptune sized planet** orbiting extremely close to its host star.

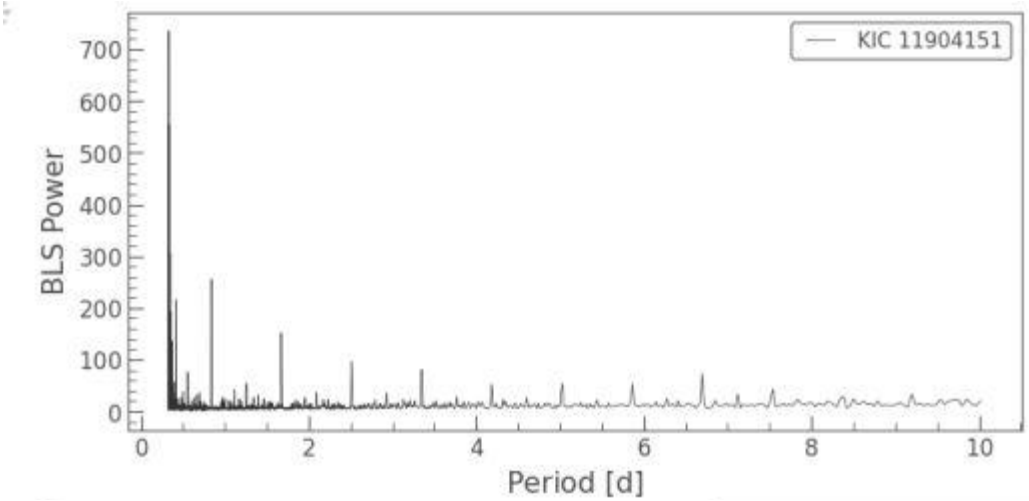

Fig. b: It is the BLS periodogram of KIC 11904151, showing transit detection power across a range of orbital periods. The peak at 0.33 days (approximately) indicates the most likely orbital period for a transiting exoplanet.

Discussion:

The high equilibrium temperature and short orbital period suggest that Kepler 10b is most likely to be tidally locked and not habitable. The BLS detection was successful in identifying the planet's signal with the least amount of noise. Python tools such as Lightkurve, NumPy and Matplotlib made the entire analysis accessible and replicable, even for independent researchers.

Conclusion:

This study demonstrates the effectiveness of publicly accessible space data and Python tools in conducting real astrophysical analysis. The detection and characterization of Kepler 10b validates the scientific potential of student-led research using publicly available resources.

Appendix- Code Availability:

The full Python code used in this research is publicly available at the following link
GitHub Repository: *https://github.com/sarthak-singh08/exoplanet-detection-kepler10b*

References:

1. NASA Exoplanet Archive (2024), Kepler 10b data: *https://exoplanetarchive.ipac.caltech.edu/docs/Kepler_Data_Products_Overview.html*
2. Lightkurve Collaboration (2023), Lightkurve, Kepler and TESS time series analysis in Python: *https://lightkurve.github.io/lightkurve/*