Department of Physics

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Class : M.Sc. Part 1 (2022-2023)

Course Name : Introduction to Astronomy & Astrophysics

Course Code : SPHY0804

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Project Topic : Identifying Exoplanet using lightcurve

Identifying Exoplanet using lightcurve

1.Abstract

Light curves are an important tool in astronomy that allows astronomers to study the properties and behaviour of celestial objects such as stars, planets, and galaxies. They are graphs that show how the brightness of an astronomical object changes over time. The study of light curves has been essential to the understanding of many astronomical phenomena, such as the rotation of stars, the discovery of exoplanets, the detection of supernovae and other transient events.

2.Aim of the project

Identifying exoplanet of a star by analysing the light curve of that star.

3.Introduction

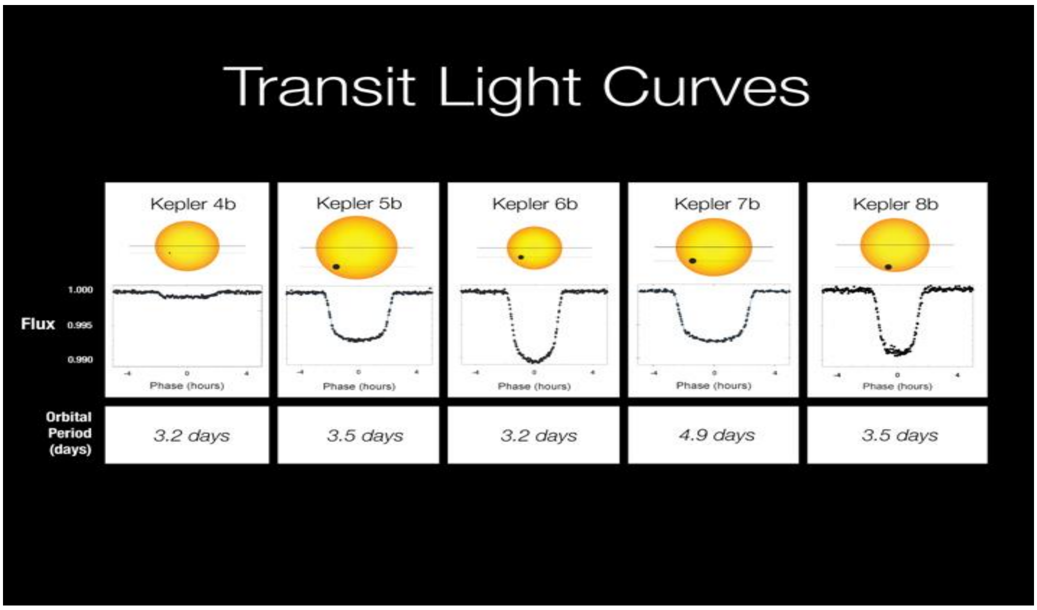
Exoplanets are planets that orbit stars other than our sun. They are difficult to detect directly because they are far away and dim compared to their host stars. However, astronomers can use indirect methods to find exoplanets, and one of the most successful methods is to observe changes in the brightness, or lightcurves, of stars.

When an exoplanet passes in front of its host star, it blocks some of the star's light, causing a dip in the star's brightness. This is called a transit. By measuring the depth and duration of the transit, astronomers can determine the size and orbital period of the exoplanet.

3.1.Light curves

In astronomy, a light curve is a graph of light intensity of a celestial object or region as a function of time, typically with the magnitude of light received on the y axis and with time on the x axis.

The light curves of different kinds of variable stars differ in the degree of change in magnitude (i.e., the amount of light flux observed). Variations in magnitude range from barely detectable for a star that is eclipsed by a planet in orbit around it to the billion-fold increase in brightness of a supernova, while periods vary from milliseconds for some pulsars to a supernova’s single explosion.



In This project we will take a look at **(KIC 6922244)** from **The Mikulski Archive for Space Telescopes (MAST)** which is a NASA-funded project that serves as a centralized archive for astronomical data from various space telescopes, including the Hubble Space Telescope, the Kepler/K2 Mission, the Transiting Exoplanet Survey Satellite (TESS), and more.

Below is the data obtained from MAST for KIC 6922244

KeplerLightCurve length=4116 LABEL="KIC 6922244" QUARTER=4 CAMPAIGN=None

time Time	flux electron / s float32	flux_err electron / s float32	centroid_col pix float64	centroid_row pix float64	cadenceno int32	quality int32
352.37632485035283	43689.1484375	6.631562232971191	682.6803253766153	190.0726135828141	11914	0
352.3967580484896	43698.078125	6.631830215454102	682.679939392134	190.0724388237138	11915	8192
352.4376244455707	43694.10546875	6.6317877769470215	682.6796255144184	190.07267575992847	11917	16
352.45805764463876	43698.31640625	6.631948947906494	682.6797879974883	190.07249571597706	11918	0
352.4784908439324	43687.6484375	6.631504535675049	682.6792868410989	190.07246464783114	11919	0
352.4989240434661	43686.4765625	6.6314263343811035	682.6797248240034	190.07284002730125	11920	0
352.5193572433491	43692.59375	6.631662845611572	682.6797061866289	190.07275265635383	11921	0
352.53979034345684	43712.01953125	6.6356940269470215	682.6787299772047	190.07316832254241	11922	128
352.56022364380624	43683.98046875	6.631390571594238	682.679365411703	190.0730725082332	11923	0
...	...	...	...	...	...	...
442.01959480413643	43153.08203125	6.599308490753174	682.5027122524675	190.28150665607106	16301	0
442.0400292694467	43162.8515625	6.5997772216796875	682.5029172042948	190.28117470942624	16302	0
442.0604635348791	43167.78125	6.600048065185547	682.5028434809847	190.28150709323504	16303	0
442.0808979004214	43156.33203125	6.599843978881836	682.5027064349352	190.2813695406399	16304	128
442.1013323661464	43164.0703125	6.599811553955078	682.5025883479478	190.28110702349872	16305	0
442.1217667319579	43160.6640625	6.599737167358398	682.5028468248179	190.28114515294416	16306	8192
442.1422009979142	43157.625	6.5994954109191895	682.5026386061921	190.28167292648035	16307	0
442.16263546398113	43155.80078125	6.599367618560791	682.5025609327599	190.2812354101034	16308	0
442.1830698302001	43148.46484375	6.599063873291016	682.502362185607	190.2815430315113	16309	0
442.20350409652747	43151.5625	6.599262714385986	682.5024686560814	190.28141944952384	16310	0

4.Methodology

1. Import necessary libraries such as numpy, matplotlib, lightkurve, etc and download the data from MAST

2. Convert the data from pixel to lightcurve and plot the lightcurve.

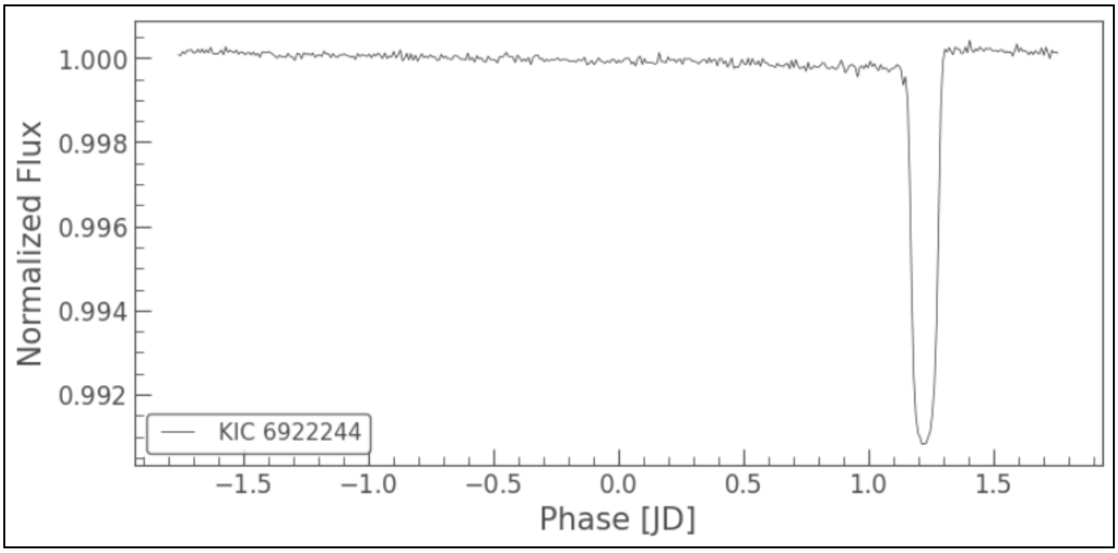
3. Normalize the data and compare the periodic brightness dips in the lightcurve.

4. Plot the periodic dip on each other and from the resultant graph determine whether the star has an exoplanet.

For this study we will be using the lightkure python package. Lightkurve is a Python package designed to provide easy access to Kepler and TESS data. It is an open-source library that provides a user-friendly interface to work with astronomical light curves. The package provides tools for downloading data from the Kepler and TESS archives, cleaning and detrending the light curves, and performing various types of analysis, including transit detection, periodogram analysis, and centroid motion analysis.

5.Results and Conclusion

After analysing the data we can see that there is a clear dip in the brightness of the star which indicates that there Is an exoplanet orbiting KIC 6922244.



From the graph we can see that the transit depth of the star is approximately 1 - 0.9908 which is 0.002.

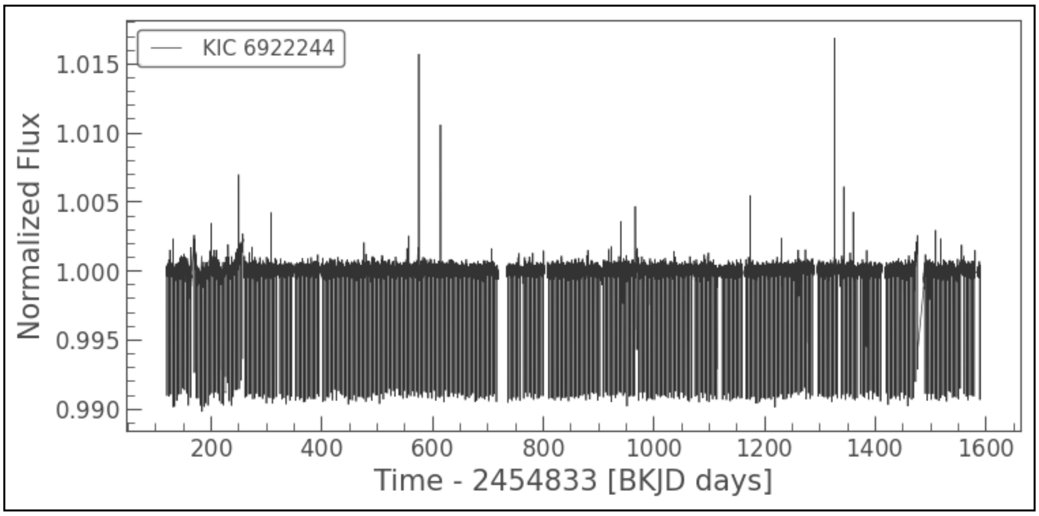
Hence we can determine

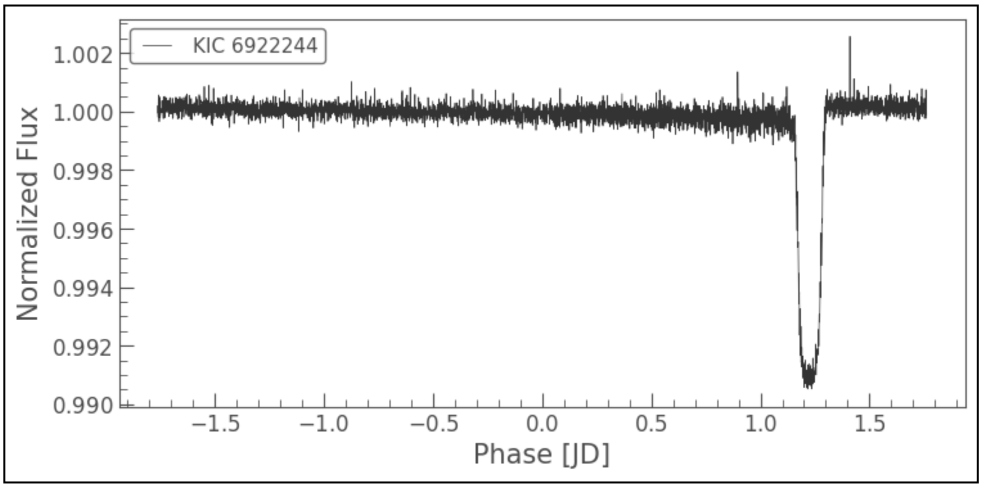
$$\text{Depth} = \left(\frac{R_p}{R_\star}\right)^2$$

the mass of the planet which comes out to be 0.10550829 times mass of sun OR 11.508462 times mass of earth.

Also the orbital period of the the exoplanet can be equated with the periodic dips in the brightness of the star hence the orbital period of the exoplanet will be approximately 3.522652 days.

The MAST data archive is responsible for collecting and curating data from various NASA space telescopes, including Kepler and TESS. To ensure that the data from these telescopes is used effectively by the scientific community, MAST releases the data in "quarters," which are typically 90-day periods. So when all the quarters were combined the resultant curve obtained was similar to a singe quarter which confrms that the star has an exoplanet orbiting around it.





Therefore by using the lightkurve lib we were able to analyse the data from KIC 6922244 and determine an exoplanet orbiting the star. Also from the transit curve we were able to find the period and mass of that exoplanet.

By plotting the graph for various quarters of the Kepler satellite and combining the data we able to confirm that dips in the brightness were indeed caused by a planet.

5. References

I. Lightkurve and its dependencies (https://docs.lightkurve.org/about/citing.html)

II. Kepler-91b: a planet at the end of its life J. Lillo-Box[1], D. Barrado[1,2], A. Moya[1], B. Montesinos[1], J. Montalbán[3], A. Bayo[4,5], M. Barbieri[6], C. Régulo[7,8], L. Mancini[4], H. Bouy[1] and T. Henning[4]

III. KEPLER-18b, c, AND d: A SYSTEM OF THREE PLANETS CONFIRMED BY TRANSIT TIMING VARIATIONS, LIGHT CURVE VALIDATION, *WARM-SPITZER* PHOTOMETRY, AND RADIAL VELOCITY MEASUREMENTS* William D. Cochran1, Daniel C. Fabrycky2, Guillermo Torres3, François Fressin3, Jean-Michel Désert3, Darin Ragozzine3, Dimitar Sasselov3, Jonathan J. Fortney2, Jason F. Rowe4, Erik J. Brugamyer5

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Python Code link