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Exoplanet Re-discovery from the CoRoT Space Mission

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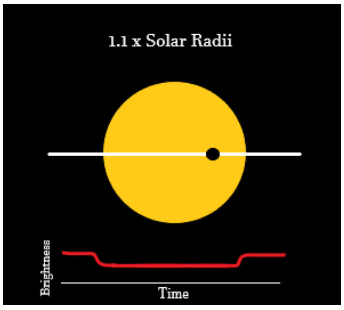
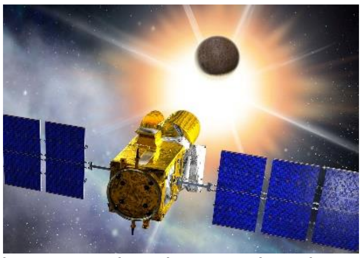
1. Introduction



Exoplanets are planets outside of the Solar System, which means they are in orbit around stars that are many light years away from us. The first exoplanets around sun-like stars were found in 1995 (Mayor & Queloz 1995). So far, 4.108 exoplanets have been confirmed[1] in the universe, most of which are relatively close to the sun within about 1000 light years. There are several methods to detect exoplanets. We have used the transit method to re-discover an exoplanet that was previously known to exist. The aim of our project was to learn the scientific methods to find exoplanets so that we can move on and search for new planets that have not been found before. If a planet crosses the star the observed (or "apparent") visual brightness of the star drops depending on a size of the planet. The larger the planet, the deeper the drop. The transit duration (T) depends on the orbital period of the planet but also on the so-called transit impact parameter, which is the apparent distance of the planet from the center of the stellar disk. A planet with a short orbital period will have a high orbital speed and therefore a short transit duration. On the other hand, a planet with a long orbital period and a low orbital speed can potentially transit the star very close to the limb of the stellar disk and therefore also cause a short transit duration. Generally speaking, the duration changes depending on how much time the exoplanet spends while tansiting. The mission we used the data from in the project is **CoRoT** (French: ***Co****nvection,* ***Ro****tation et* ***T****ransits planétaires*; English: **Co**nvection, **Ro**tation and planetary **T**ransits). CoRoT was a space telescope mission that operated from 2006 to 2013.



[1] NASA Exoplanet Archive (https://exoplanetarchive.ipac.caltech.edu) as of 30 January 2020.

2. Methods

2.1. Dependencies setup

First of all, in order to use the actual Transit Least Squares (TLS)[2]algorithm library which is an algorithm to detect planetary transits from time-series photometry, we installed the dependencies, but on that stage we encountered with a problem on Batman library because of C++ compiler error. As we both use computers which uses Windows as a operating system, we decide on setting up a TLS dedicated server which runs on RaspberryPi 3 Model B+ with an operating system Raspbian.

Currently, as we start using Linux-based operating system on RaspberryPi, we can use the Batman package without any extra effort.

Although we mostly use pip method for installing libraries, we couldn't manage to set some of them up with that method and as a result of it we ended up installing them manually by cloning it from github and installing them from "setup.py".

After the dependencies, we installed the TLS library with pip method and we made sure it's in the right location as the files of the server is not same with local libraries.

2.2. Connection Method

Because we decided to work on a Linux based server, we enabled VNC connection method in order to work on a server together as a team.

2.3 Observing K2-3 data

As we set all the libraries and connection methods, we followed the tutorials on the TLS github page and we successfully calculated the transits of the K2-3 star.

2.4 Observing CoRoT data

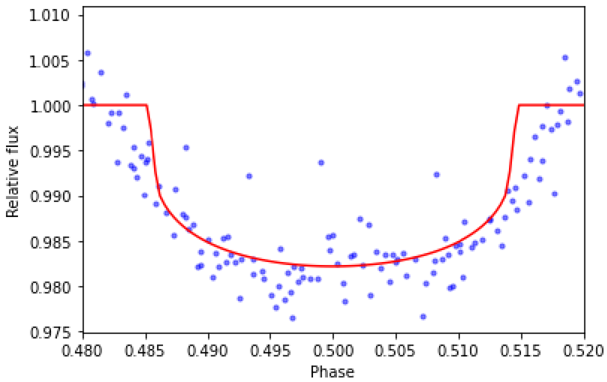
After the successful calculations, René Heller from Max Planck Institute provided us the light curves of the CoRoT-12 star for calculating the transits and compared them with the calculations which are already calculated by Gillon et al. (2010).

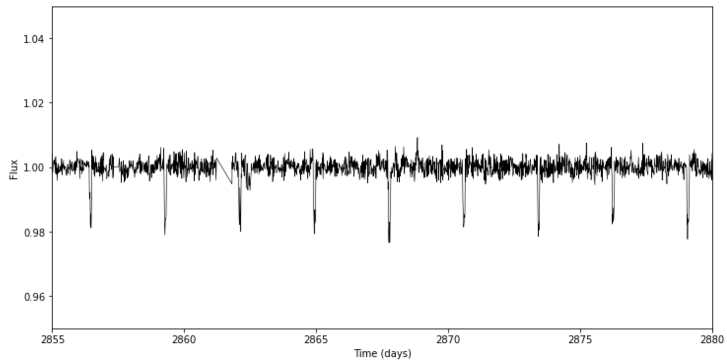
With the help of our advisor René Heller, we precisely calculated the transits with TLS algorithm by reading the curves from a plain/text format and then forwarding them to the algorithm.

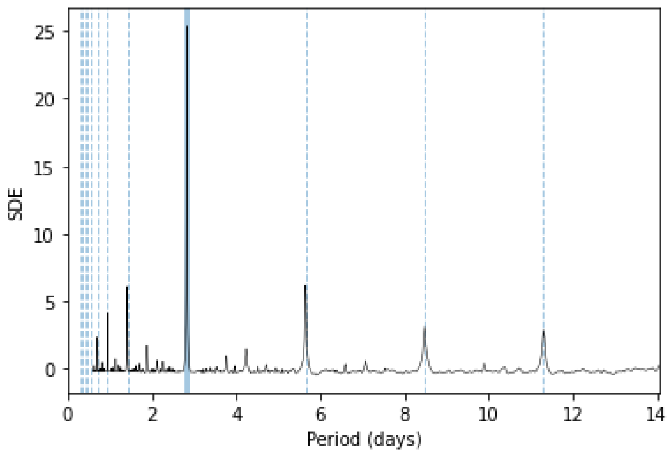
[2] Hippke & Heller 2019, https://github.com/hippke/tls

3. Results

With the help of the TLS algorithm we precisely calculated the transit light curves and parameterization of the planet.







The first graph gives a closer look at the transit light curve. The red line is the best fitting transit model. It shows the decrease of the star's brightness due to the planet.

For the second graph, the depth of these transits encode the size of the planet. It means the amount of the depth depends on how much light is blocked.

For the last graph, it says SDE on the y-axis that is the abbreviation of the signal detection efficiency. SDE tells how likely the signal is not a false positive

We calculated the distance between the star and the planet with using Kepler's Third Law. We assumed the planetary mass is much smaller than the stellar mass. Also assumed the solar mass for the star as 1.08 solar masses.

Keplers Third Law:

$$\frac{a^3}{T^2} = \frac{G(M+m)}{4\pi^2} \approx \frac{GM}{4\pi^2} \approx 7.496 \cdot 10^{-6} \left(\frac{\mathrm{AU}^3}{\mathrm{days}^2}\right) \text{ is constant}$$

Period (T) : 2.82774 x 24 x 60 x 60= 244316.736
π :3,1415
G : 6,67408 x 10 ^ -11
Mass of the star (M) : 1.08 x 1,989x10 ^ 30

a (semi-major axis): ?
= 0.0401558016300213480165

	Planet
Period (d)	2.82804
Transit Depth	0.01782
Distance (AU)	0.04016

4. Conclusion

We used a freely available computer code TLS to search for transits of extrasolar planets in the light curve of CoRoT-12b . We found the orbital period 2.82804 days and the transit depth 0.01782 . We found the distance 0.04016 AU between the star and the planet with using Keplers Third Law. The aim of this project was to learn the scientific methods to find exoplanets so that we can move on and search for new planets that have not been found before.

References

Gillon et al. (2010) Transiting exoplanets from the CoRoT space mission XII. CoRoT-12b: a short-period low-density planet transiting a solar analog star. *Astronomy & Astrophysics* Vol. 520, A97

Hippke, Heller (2019) Optimized transit detection algorithm to search for periodic transits of small planets. *Astronomy & Astrophysics* Vol. 623, A39

Mayor, Queloz (1995) A Jupiter-mass companion to a solar-type star. *Nature* Vol. **378**, pp. 355–359.

Acknowledgements

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