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Variability of Exoplanetary Secondary Eclipse

Wesley Sandidge

Boise State University

Brian Jackson

Boise State University

Steven Kreyche

Boise State University

Jennifer Briggs

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Variability of Exoplanetary Secondary Eclipse

Abstract

Phase curves and secondary eclipses of gaseous exoplanets are diagnostic of not only atmospheric composition and meteorology, but variations in the phase curves and eclipses over time may point to variability driven by atmospheric dynamics. The dataset from NASA's Kepler Mission has accurate photometric precision and spans a period of over 1,000 days, providing an ideal dataset to study Kepler-76 b. Kepler-76 b is a 2 Jupiter-mass gas giant, with an equilibrium temperature approaching 2,000 K, in a 1.5-day orbit around its star, and the data reveal Kepler-76 b's secondary eclipse - with a depth of 87 ± 6 parts-per-million (ppm), which corresponds to an effective temperature of 2,830 K. The data also reveals variations in the phase curve for Kepler 76-b secondary eclipse, with an average value of 50.5 ppm and values ranging from 35 ppm to 70 ppm over tens of days.

Introduction



Image Credit: NASA [6]

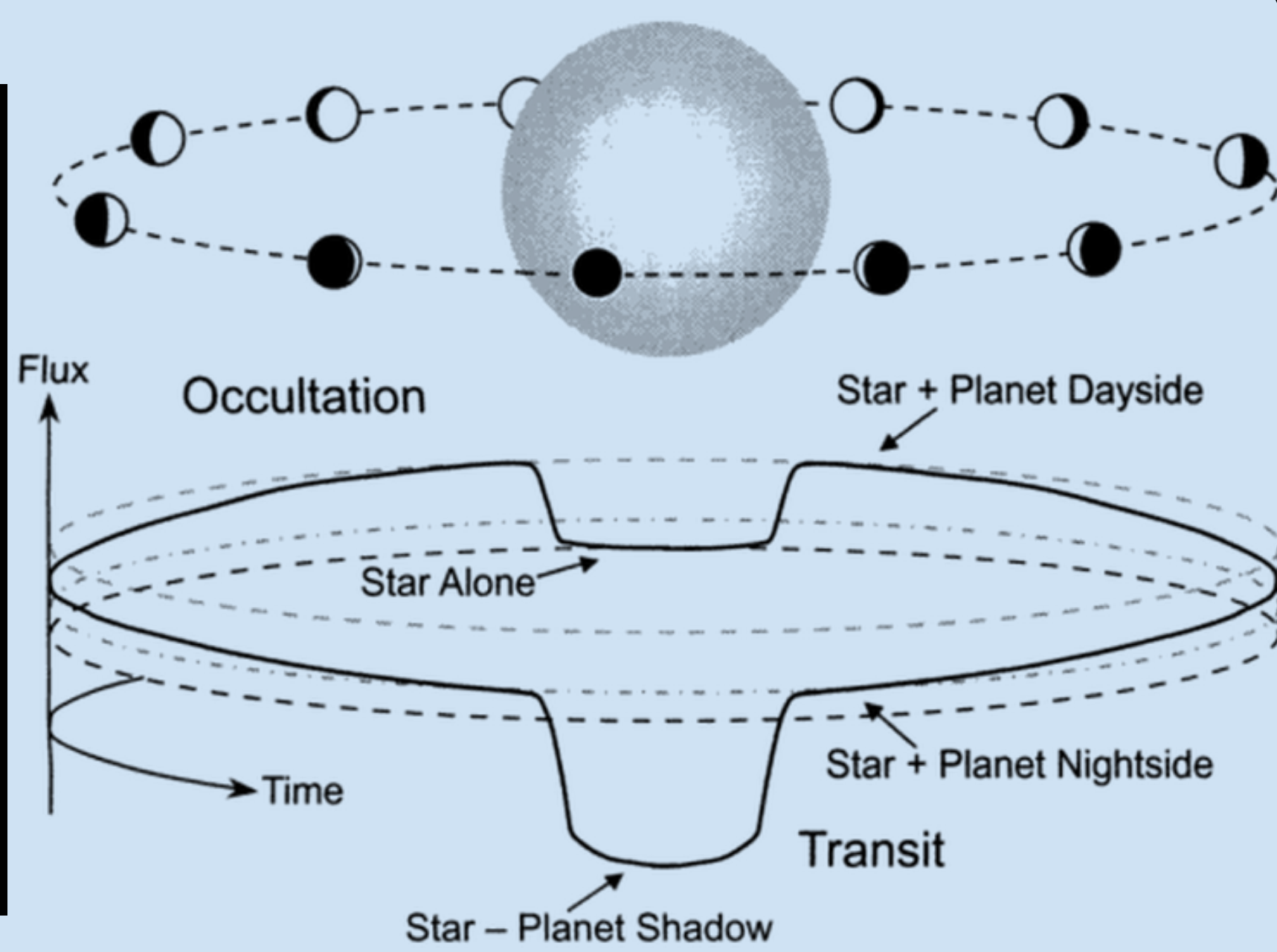


Figure 1. This cartoon provides a visual aid for the different phases of a transit. Including the primary transit which occurs when the planet passes in front of the star and the secondary eclipse which occurs when the planet passes behind the star. [1]

An exoplanet is a planet outside of our solar system orbiting a star other than our Sun. The most common way to detect exoplanets is to use the transit method. The transit method detects planets by observing the amount of light being emitted by a star over some period of time. If a planet is present in the system then a decrease in the amount of light may be observed over a regular interval.

In this poster I will discuss detecting the variability of the secondary eclipses of exoplanets. A secondary eclipse occurs as the planet orbits behind the star. As the planet is approaching the back of the star the amount of light observed will increase. This increase occurs because the planet's surface will reflect light contributing to the overall signal. Once the planet is being blocked by the star the amount of light observed will decrease. When observing this signal we have found variations in the amount of light being reflected between orbits.

Theory

The BEER curve algorithm allows for the analysis of the reflection of the planet by modeling the reflection curve and then fitting the data to the model or perhaps it is better to say fitting the model to the data. BEER stands for BEaming, Ellipsoidal, and Reflection. This algorithm provides a model for each signal and the graph of each of these signals can be seen in figure 2.

Doppler BEaming occurs when the star moves towards or away from the observer causing a change in brightness.

$$\text{Beaming Curve} = A_{\text{beam}} \sin(2\pi\phi)$$

Where A_{beam} is the amplitude of the beaming signal and ϕ is the orbital phase.

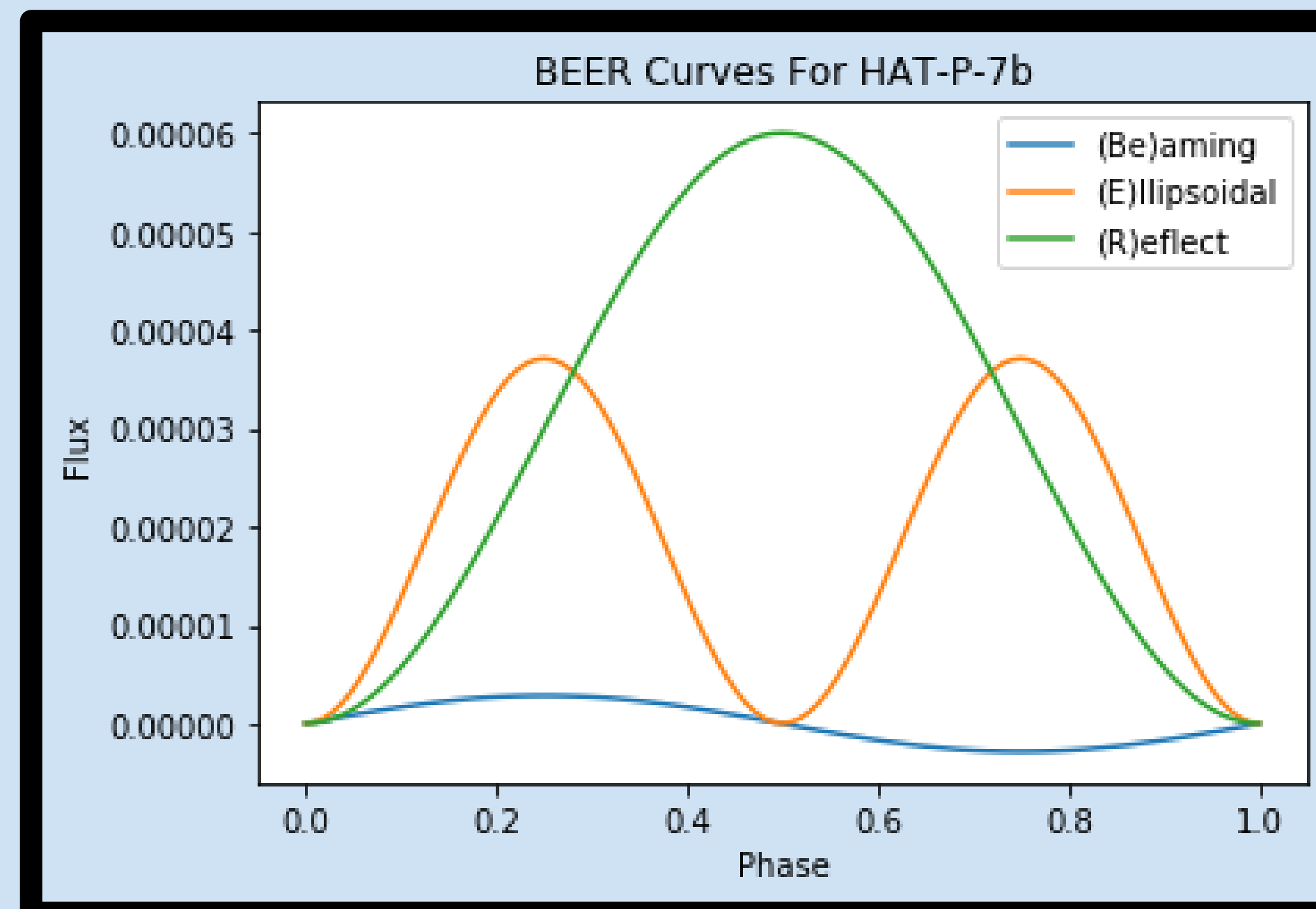


Figure 2.

Ellipsoidal distortions occur as the companion object orbits the star causing a bulge that will increase the brightness when on either side of the star.

$$\text{Ellipsoidal Curve} = -A_{\text{ellip}} \cos(4\pi\phi)$$

Where A_{ellip} is the amplitude of the ellipsoidal signal.

Reflection occurs when the companion object is orbiting the star and reflects light towards the observer causing an increase in brightness.

$$\text{Reflected Curve} = A_{\text{planet}} \cos(2\pi(\phi - \text{phase_shift}))$$

Where A_{planet} is the amplitude of the amplitude of the beaming signal.

Method

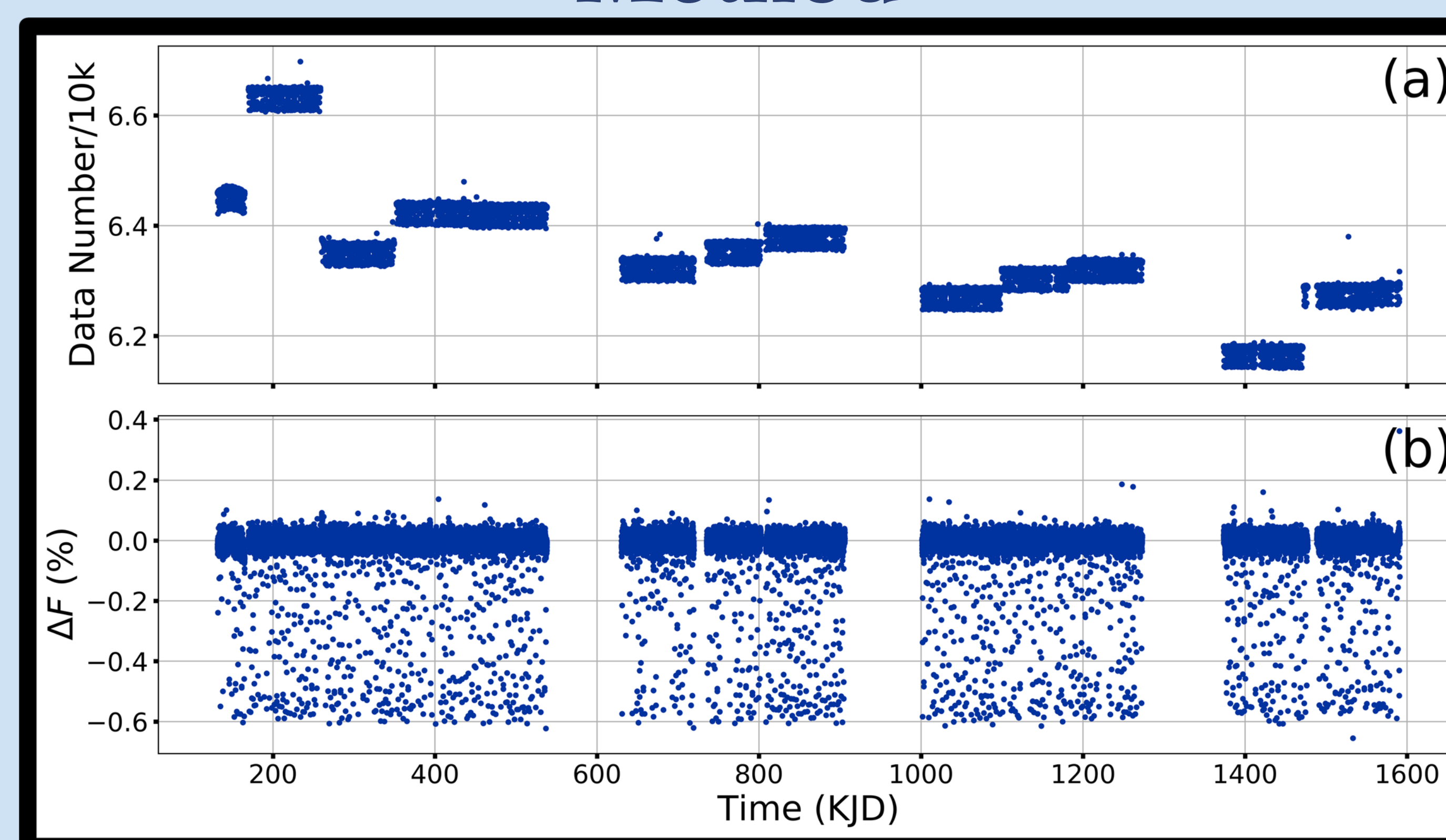


Figure 3.

Figure 3 above shows data in a more raw form from the Kepler Space Telescope. This is data for Kepler-76b. Figure 3 plot (b) shows the normalized signal. This process flattens the data and makes it easier to distinguish the transits of the planet. Where there are gaps in data there was no data sent from the telescope during that period.

Results

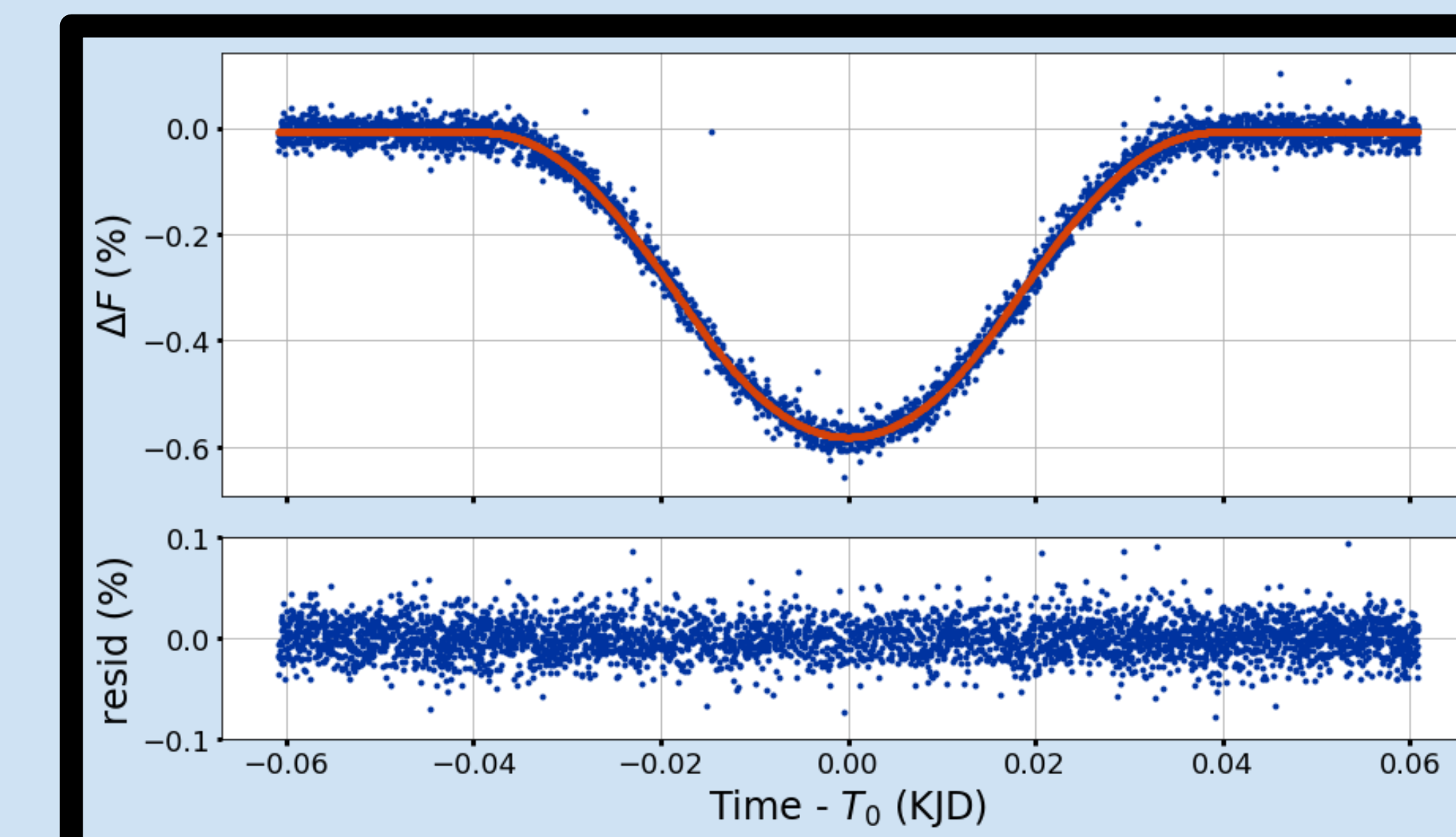


Figure 4.

After the data has been folded on top of itself this is the resulting lightcurve for the transit of Kepler-76b. On the right side of the data in figure 4 there is a very small decrease in light. This is the secondary eclipse being detected. The subplot underneath the transit plot shows the residual of the signal. For the model to be a good fit to the data the residual should be evenly distributed above and below the zero value of the x-axis.

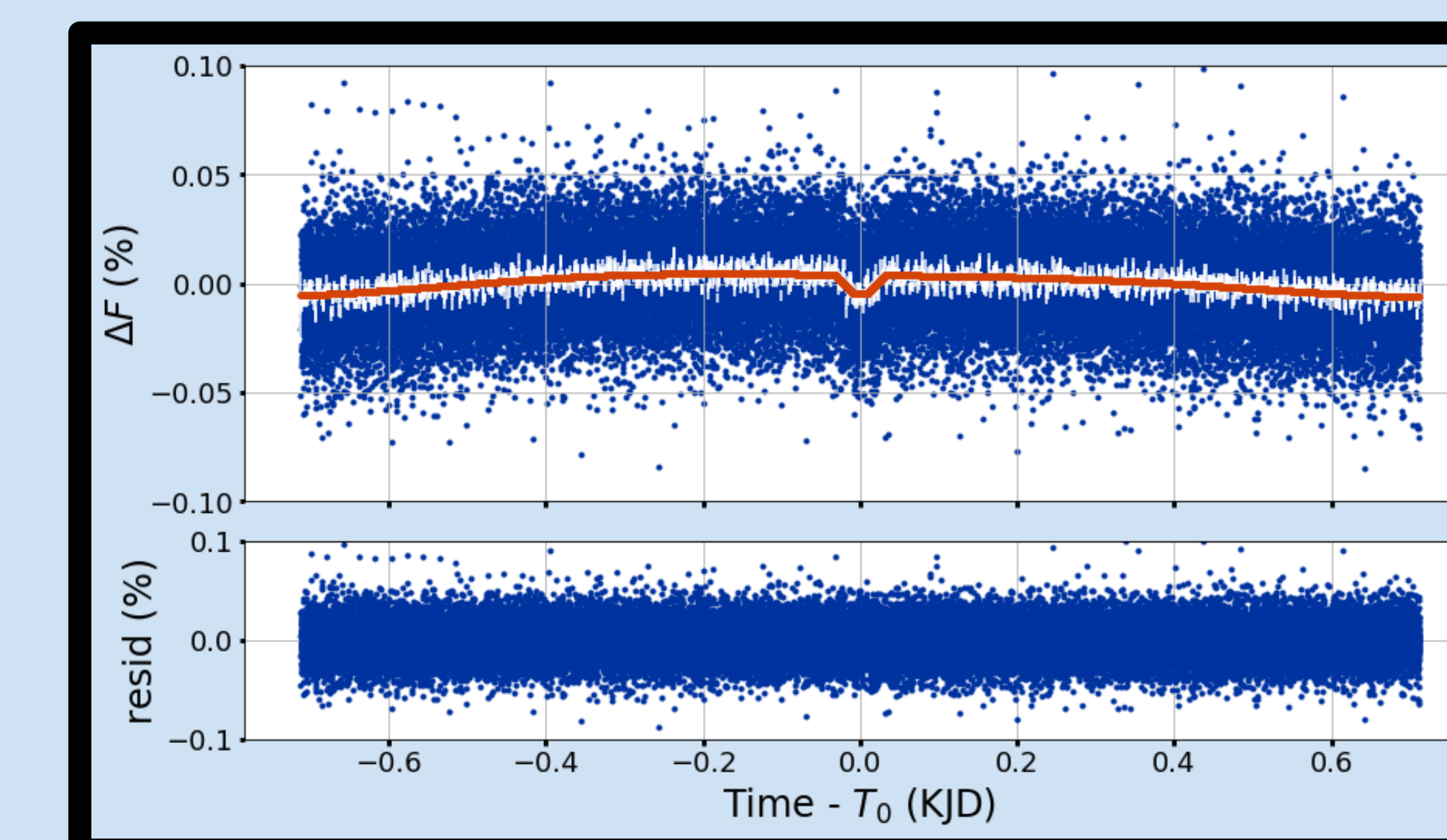


Figure 5.

Figure 5 now shows a zoomed in view of the secondary eclipse. The data has now been normalized and filtered to remove outliers and noise. It is now easier to distinguish that there is a clear and meaningful signal showing the presence of the secondary eclipse.

Discussion

Planet is tidally locked leading to differences in temperature between the dayside and the nightside of the planet would cause convection of atmospheric condensates in irregular amounts to the dayside of the planet. Going forward we will be looking for more planets that show this signal to better understand what the cause is. [2]

References

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