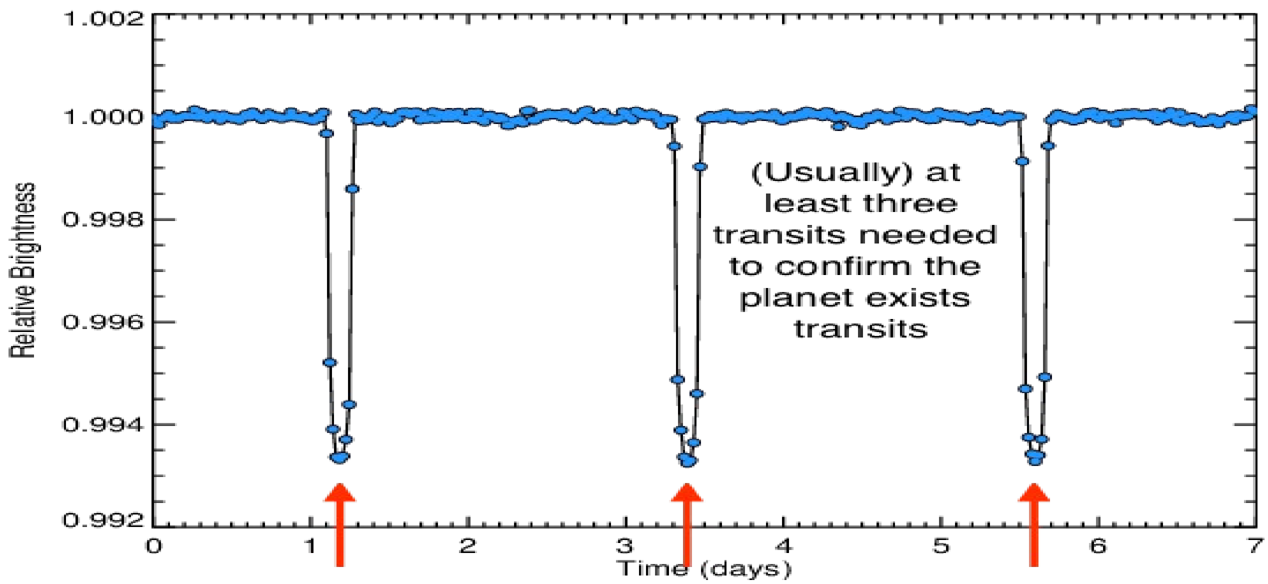
The Orrery Project Astr. 3800

Zade Alfalah

University of Colorado, Boulder



https://www.cfa.harvard.edu/~avanderb/tutorial/tutorial2.html

Abstract

In attempting to test the use of light curves and relative luminosity to find the size of orbiting planets it is found that either our current understanding is incorrect, or -more likely- experimental setup procedures must be more stringent in the measuring of said phenomena as a planet known to be 3.175 cm. is measured to be 5.049 ± 0.315 using current procedures.

$$R_p = R_\star \sqrt{\text{Depth}}$$

Eqn. 1

Introduction

The formula for calculating the size of a transiting planet based off of the apparent dip in light curves is well known (Eqn. 1). It has been used to great success in well known missions such as for Kepler's planet-hunting. In this paper we explore the experimental side of this relatively simple theoretical model by creating our own modeled planet and star and attempt to accurately determine the size of our planet based off of dips in our recorded light curve measured off of said model.

Observations

a) Technique

A Lego model of a 'planet' orbiting a 'star', called an orrery, was created with a styrofoam planet and a light bulb for our star. Fig. 1 shows a more detailed sketch of the setup. A separate group chose and measured the size of our foam planet and placed it upon our orrery, at which point the light was activated with the Lego motor, beginning the orbit of our planet around its sun. The light coming off of the sun was measured with a photometer set 45cm. away from the sun, which in turn was connected to our computer which ran Lab Quest to record the luminosity. We allowed for seven full orbits around our sun before ending measurements and disassembling our setup.

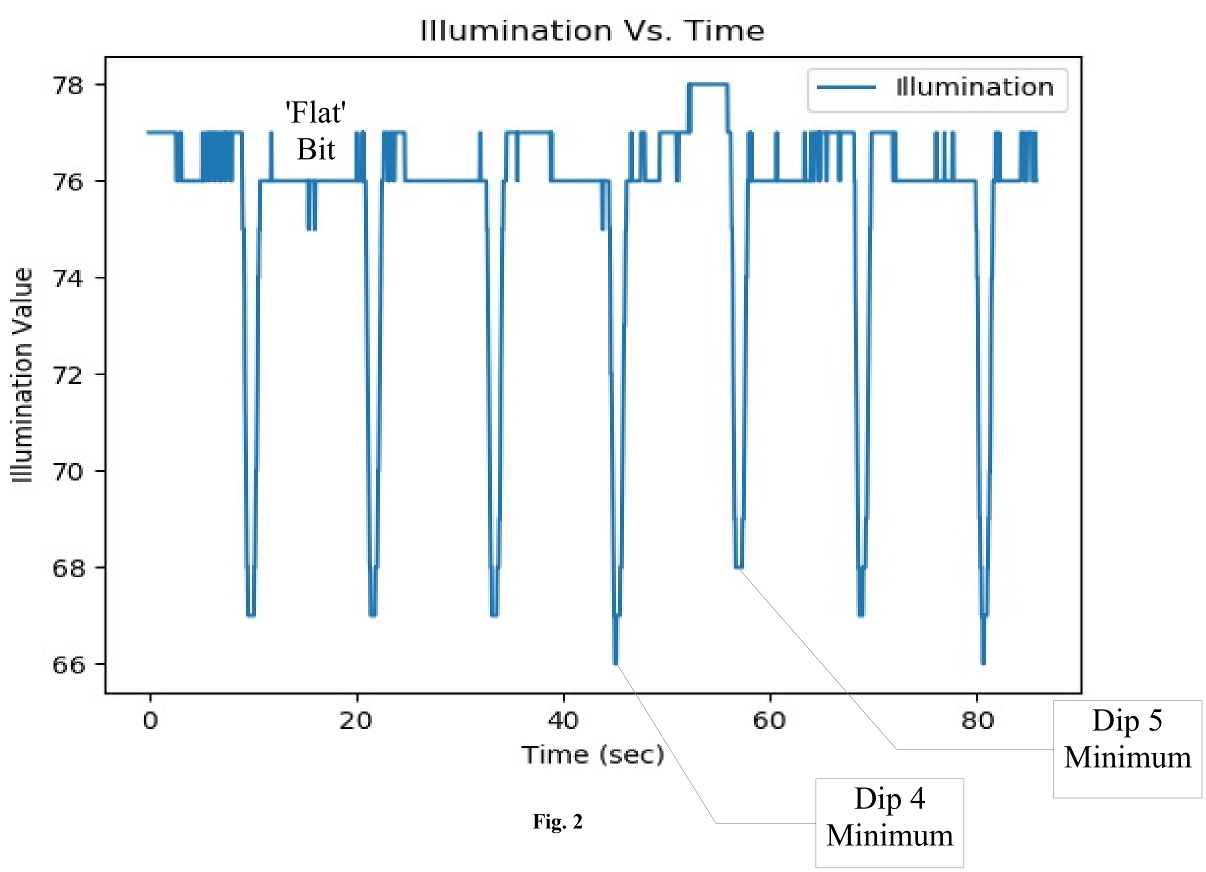


Fig. 2

$$\sigma_{rp/rs} = (½)\ \sigma_{dip}$$

Eqtn . 2

b) Results

Table 1, attached at the end of this report shows a sample of the measured 'illumination' values and their respective times of recording. A full data set is available on our Github page, but is excluded from this report due to its length. Even before the plotting of our data it is possible to pick out where the dips occur as they show significantly lower illumination values than the norm, going down in to the mid sixties. This data was then analyzed using Python, plots shown below in Fig. 2. A mean value of the 'non-dips' or 'flat' illumination was found to be 76.399 ± 0.591 by isolating the regions where the illumination was within 3 sigma of the overall mean value. Following this the minimum points in our dips were found then averaged to 66.857 ± 0.261 showing, a 12.489 ± 0.866% difference. Looking now at the ratio of our dip to the flat, our 12.489% value, we use Eqn. 1 and Eqn. 2 as well as a measured 'star' value of 5.3975cm (measured in inches, decimals from conversion). we get a measured planet radius of 5.049 ± 0.315cm. This is contrary to the value given to us by our partner group for our planet which was 3.175cm. This difference will be discussed in the following section.

Discussion

The large discrepancy with low error immediately calls into question the validity of the initial measurement of our planets size. Since it was not measured by this team and not peer-reviewed it is more than possible that there was a measuring error or miscommunication here. Regardless of this, there are a slew of other sources of error in our experimental setup. While we attempted to measure our 'illumination' values as accurately as possible, we were constrained by a number of factors including, but not limited to; people walking by casting shadows, people leaning in to look at our experiment, background light sources, reflection of light off of Legos, and absorption of light by our styrofoam. This errors, while they could be significant, are probably low in comparison to more serious errors that I believe could be cured more easily as well. These are caused by a low count rate on our detector and a misalignment of our photometer. The misalignment may not have caused much of a difference because we look at relative amounts of light, unless it was pointed slightly lower in which case it would have been measuring not just the light blocked from our planet but also the light blocked by the Lego arm supporting our planet, which would in turn lead to an exceptional overestimate of the planet size such as the one that we are seeing in our experiment. For further experimentation of this kind I would recommend it be redone in a dark room away from others, with a level to ensure that the photometer is pointed correctly and to increase the tick rates on the photometer itself. If time permits, an initial run without a planet to get a baseline for later subtraction would also benefit the accurate measuring of a planet. Other than these experimental setup failures we also see an interesting low dip followed by a high dip in dips 4 and 5 respectively which are shown on Fig. 2. These differ greatly from our other dips which were relatively uniform and should be investigated further for reproduceability.

Table 1

	Time	Illumination
0	0.00	77
1	0.05	77
2	0.10	77
3	0.15	77
4	0.20	77
5	0.25	77
6	0.30	77
7	0.35	77
8	0.40	77
9	0.45	77
10	0.50	77
11	0.55	77
12	0.60	77
13	0.65	77