Background

- First Few Exoplanets
  1. Planets around pulsars
  2. Pegasi 51b, discovered in 1997 using rotational velocity
  3. Use of Transiting
- Detection Methods
  1. How transiting works
  2. Rotational velocity
  3. Spectroscopy
  4. Gravitational Microlensing
- Moons
  1. Galilean Moons
  2. Enceladus and Titan
  3. Triton

- Three Body Problem
  1. Two body problem is solvable
  2. Three body problem is not solvable
  3. Recently new solutions have surfaced (Šuvakov, 2013)
  4. Can be approximated
- Exomoons
  1. TTV
  2. TDV
- Habitability

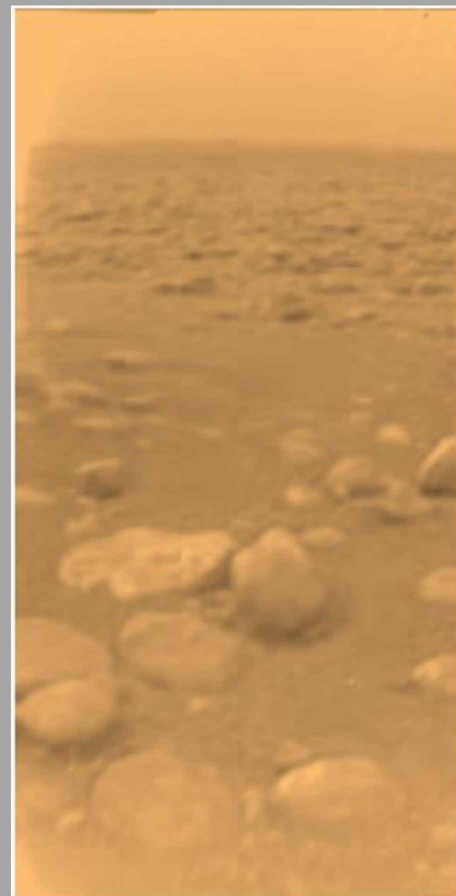


Figure 1. First colored view of Titan’s surface, by the Huygens lander (Williams, 2005). Thought to be a dried riverbed.

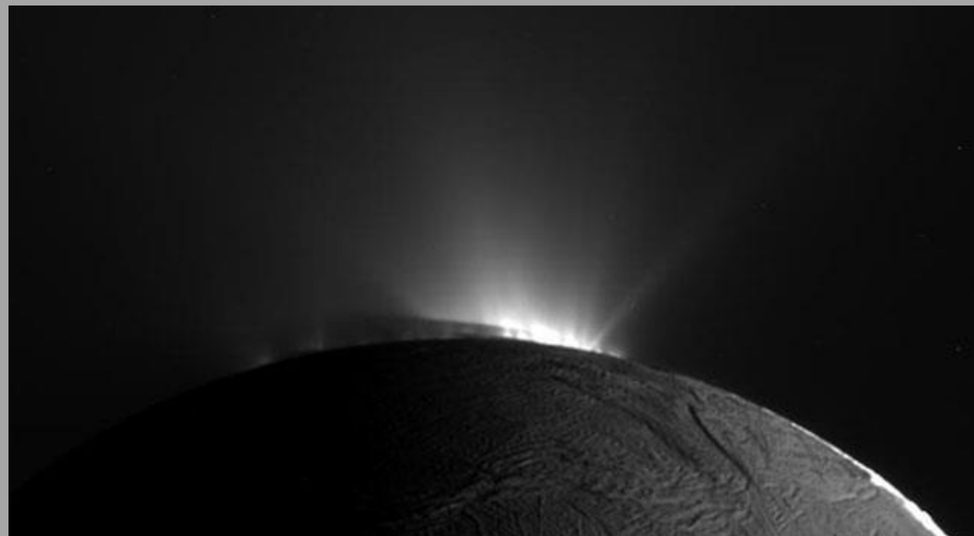


Figure 2: An image of Enceladus from the Cassini flybys. Shown here are jets of water caused by tidal resonance and heating (Cassini, 2010)

Research Question

How does the presence of an exomoon affect the light curve of a star in an n-body system?

Hypothesis

The changes in the TTV and TDVs of a light curve in a system containing an exomoon will be directly proportional to changes in the exomoon’s radius and mass.

Overall Aim

The overall aim of this project is to engineer a way to detect exomoons in a transit curve. The goal is to find a correlation between changes in the orbital parameters of an exomoon and the resulting TTV and TDVs of the system.

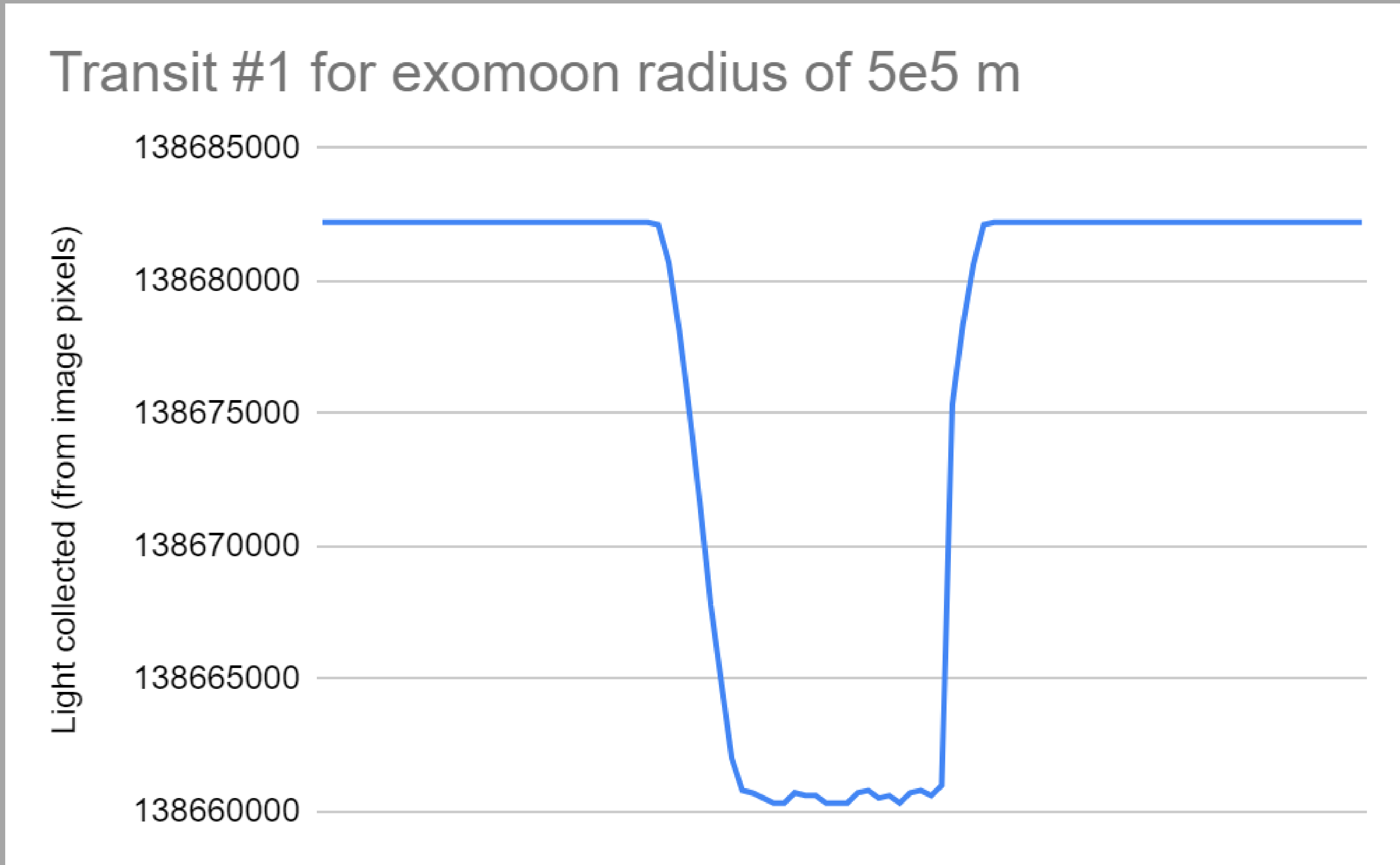


Figure 3. This figure illustrates the very first transit curve that is created when an exomoon of radius 0.3 $R_{☾}$ meters orbits an exoplanet of radius 100 $R_{\oplus}$. The exomoon has a mass 1 $M_{☾}$ and the exoplanet has a mass of 1 $M_{\oplus}$. The star has a radius of 10 $R_{\odot}$ and a mass of 1 $M_{\odot}$.

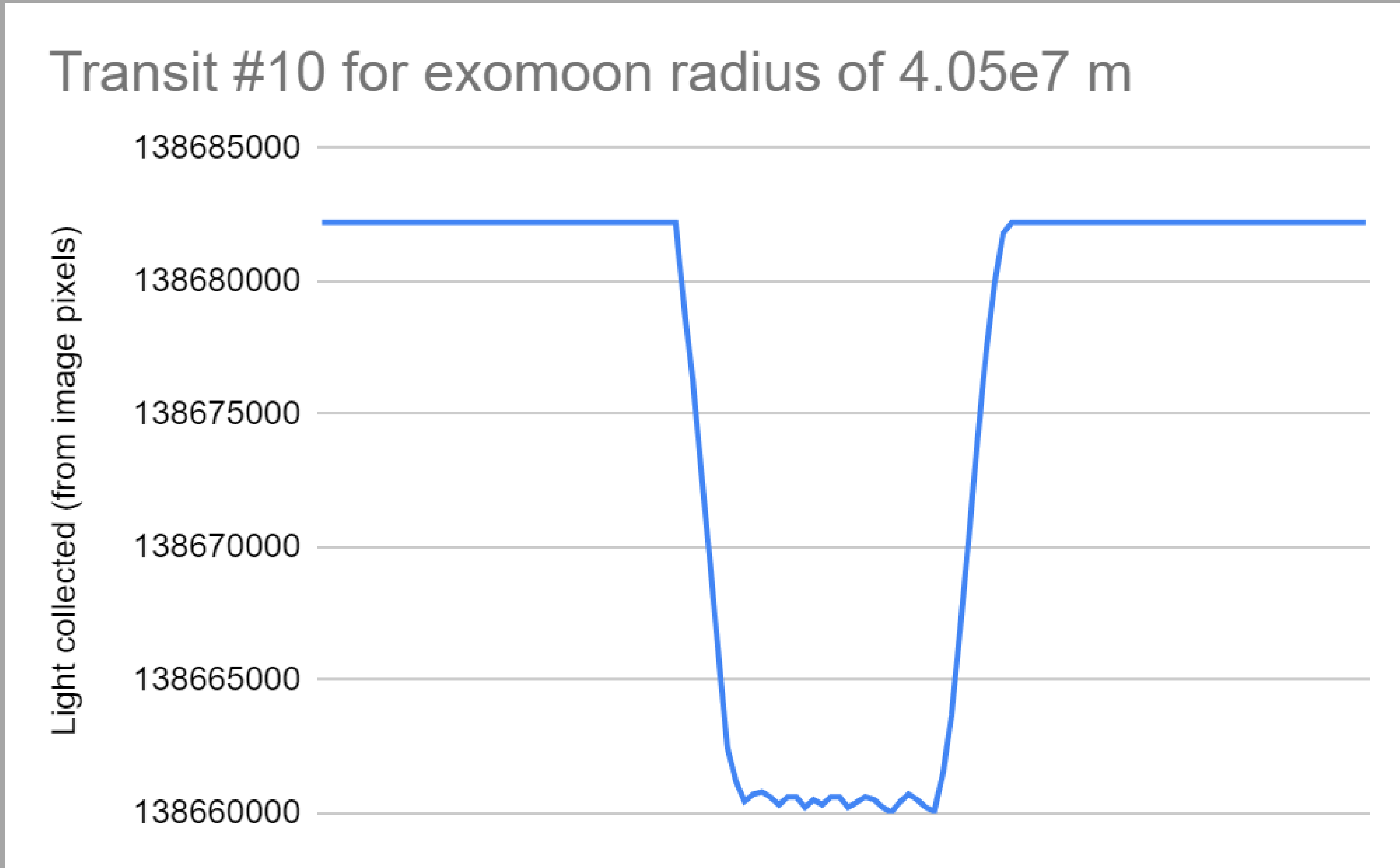


Figure 4. This figure illustrates the tenth transit curve that is created when an exomoon of radius 23 $R_☾$ meters orbits an exoplanet of radius 100 $R_\oplus$. The exomoon has a mass 1 $M_☾$ and the exoplanet has a mass of 1 $M_\oplus$. The star has a radius of 10 $R_\odot$ and a mass of 1 $M_\odot$.

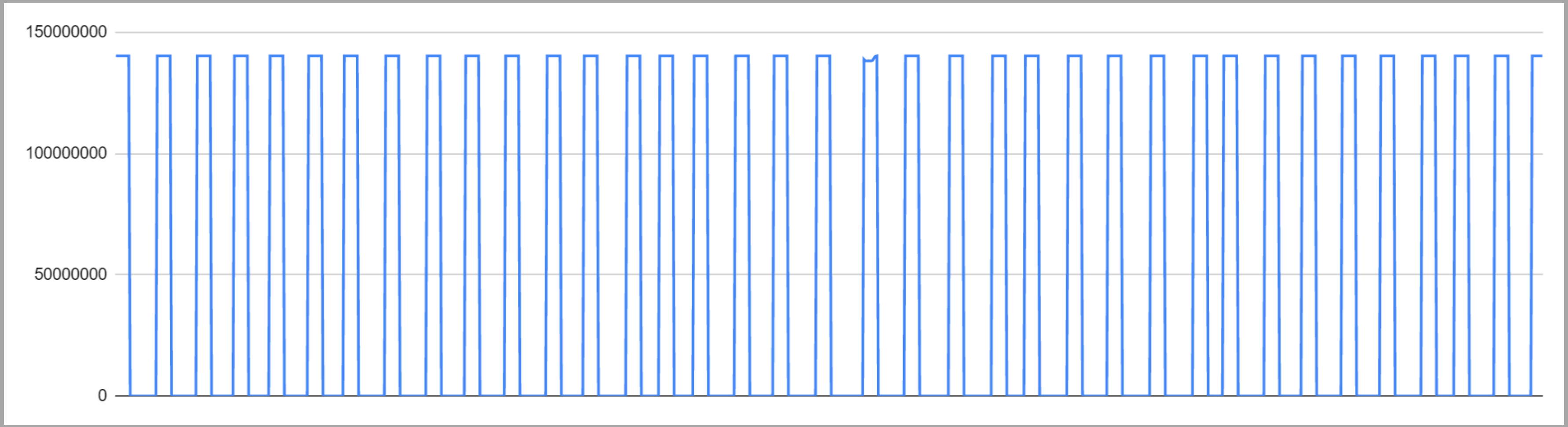


Figure 6. This figure illustrates the transit curve of some of my preliminary data from Iteration 4, in October. As you can see, the data is not continuous, as the frames did not manage to download continuously, due to the overload of files that were being downloaded at once. I later fixed this bug in my later iterations, and added a moon.

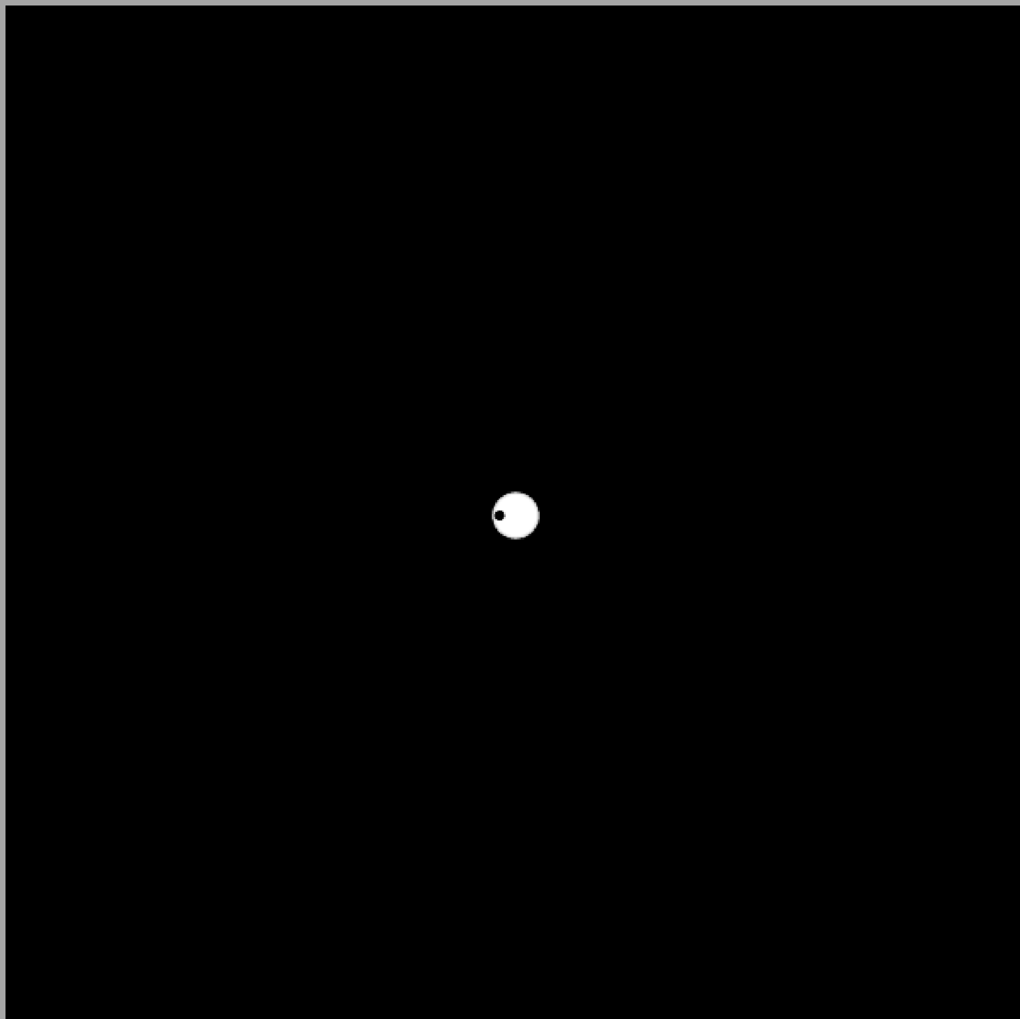


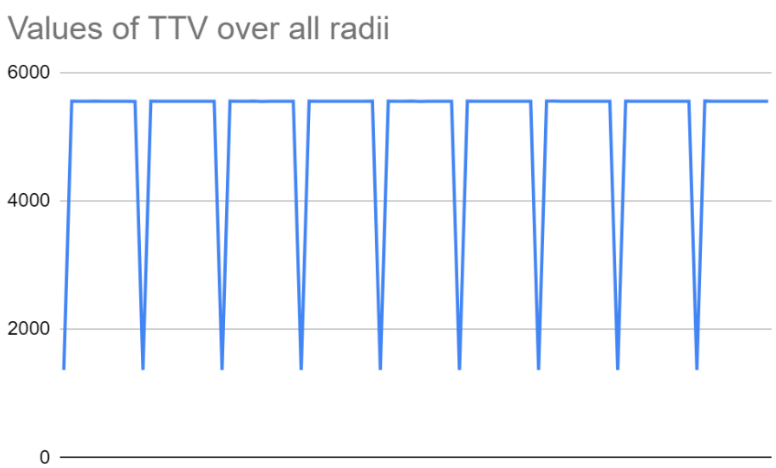
Figure 5. This is an illustration of what my program looks like when it is running. This is also what each individual frame looks like.

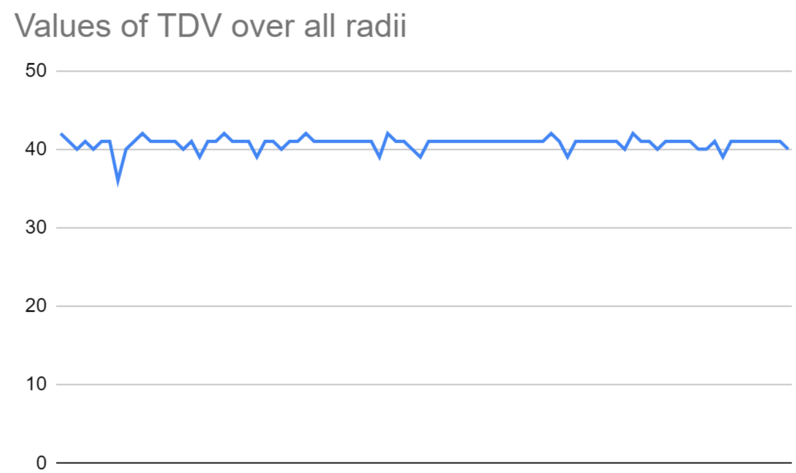
	Weight	Radius of Exomoon	Mass of Exomoon	Radius of Exoplanet	Mass of Exoplanet	Luminosity of the Star	Radius of the Star	Mass of the Star	Semi-major axis of Exomoon	Semi-major axis of Exoplanet	Presence of another planet	Presence of another moon	Tidal resonance of exomoon with other moon	Tidal locking of exomoon with Exoplanet	Trojans	Solar Flares/Solar Activity
Criteria	Max	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Easy to model	6	10	10	10	10	9	10	10	10	10	7	7	5	3	1	1
Changes TTV	10	6	8	1	5	1	1	3	10	2	8	10	5	8	10	10
Changes TDV	10	2	8	1	5	1	1	3	10	2	8	10	5	8	10	10
Not Easily Confused with Another Phenomenon	8	8	2	10	10	10	10	8	7	9	1	2	2	8	1	1
Reveals information about Exomoon	7	6	8	1	5	1	1	3	10	2	2	10	10	10	1	1
Easy to Isolate	8	8	2	10	8	10	10	10	10	6	1	1	5	1	1	1
	Scores	**310**	**308**	247	**339**	241	247	285	**466**	234	232	**336**	256	320	229	229

Figure 7. My decision matrix for choosing which variables to model for in my project. The five largest scores are bolded.

Analysis

- The bumps at the bottom of the transit
  - Number per transit
  - Largest difference in bump
  - Largest bump





Materials

- Functioning Computer
  1.Able to connect to internet
  2.Able to process relatively complex programs
- VPython and GlowScript
- Eclipse Java (2019-06)

Google Spreadsheets

Procedure

1. Create a working model of a star-planet-moon system using GlowScript and VPython.

2. Write a script that increments a certain variable a certain amount of times.
3. Download pngs of all frames when the planet is within a certain stretch.
4. Parse through these frames using Eclipse Java. Get a value for the total light emitted from each pixel per frame.
5. Graph these values in a continuous line graph in Google Spreadsheets.
6. Use Eclipse Java to run a program that analyses the TTVs and TDVs =f the data.
7. Graph these values in Google Spreadsheet as well.
8. Repeat for each variable.

Future Extensions

- Try to extrapolate variances in TTV and TDV for this data
- Analyze more variables
  - Mass of exomoon
  - Semi-major axis of exomoon
  - Decision Matrix
- Look at available exoplanet transit data
  - Amount of available data

Known Orbital Parameters

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