Binary Star Simulation

Zheyu Lu Rui Liu Shuqi Xu
University of California, Berkeley
{zheyulu, rui_liu, sqxu}@berkeley.edu

Abstract

The laws of physics lay the foundation of the orbital motions of the sun, the moon, and the Earth. These orbital motions together determine the phenomena people observed throughout the history which further determines the calendar and the time we experience. In this project, Imagine a new planetary system, we are interested in the new phenomenon presented there. Here we studied the motion in binary star system. We generated motional data of the two suns and the Earth, to validate the elliptical approximation of the Earth orbit under certain conditions. In addition, we generated the positions of the two suns and the moon from an Earth observer, as well as the lunar phase.

1 Introduction

Our data consists of two parts. The first part was obtained from the astrodynamics simulation, under the gravity law. It consists of the time and the position evolution of the two suns, the Earth and the moon, in the binary sun mass center coordinate system. The second part was obtained from SpaceEngine. We took screen shots from the three different positions on earth. Then we used trained model to extract useful information, including the coordinate information of the two suns and the moon in the spherical coordinate system.We also extracted the lunar eclipse phase and the time information.

The astrodynamics simulation data can serve for two purposes. First, it can validate the elliptical approximation of the Earth orbit in binary star system. Under this validation we can directly plug in the approximated elliptical orbit parameters in SpaceEngine. Second, it can serve as the output for machine learning. The data extracted from SpaceEngine are observations from local "people", thus can be seen as the input for machine learning. The two parts are closely related to each other. In theory, by doing some complicated math, i.e. coordinate transformation, one can establish the transformation between two datasets.

Our data is obtained from purely imagined universe, thus could potentially create interesting phenomenon that people can't observe in out universe. We hope that our data could provide some interesting results for those who like fictional universe.

2 Method

2.1 Numerical simulation of the orbital dynamics

The stable orbit of the Earth orbiting two suns only exist in several special cases, i.e. the sun-sun distance much greater (smaller) than the Earth-sun distance. If the aforementioned two quantities are at the same magnitude, the Earth orbit is likely not stable, thus the lifetime of the Earth is likely not long enough to bred lives. We tried to find a stable solution using Universe Sandbox, but we failed. If the sun-sun distance is much smaller than the Earth-sun distance, it's likely that the sun who has longer distance to the Earth would just become a super bright star, which does not present new

Preprint. Work in progress.

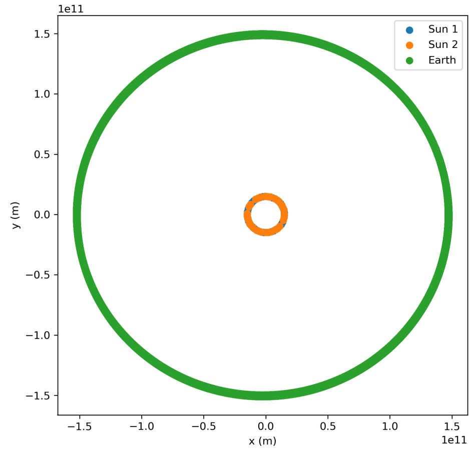

Figure 1: The astrodynamics of the Earth and the binary stars

interesting phenomenon. So we decide to simulate the dynamics under the condition that the sun-sun distance is much smaller than the Earth-sun distance. Considering a habitable Earth only exist in a small range of distance to the sun, we aimed to keep the Earth orbit in the new binary star system to be similar to the Earth orbit as much as possible, while observers can still distinguish the two suns on earth. Thus we set the sun-sun distance to be 0.2 au, and let each new sun has half of the mass of the true sun. To make things easier, we let two suns orbiting their mass center in a circle pattern. As for the Earth, we plugged in the real Earth data at Perihelion of the Solar System, including the velocity and the distance to the sun mass center. We didn't include the moon, since its orbit around the Earth is fairly stable in this case. Then we simulate the evolution of the whole system using Mathematica, as shown in Figure. 1. The simulated Earth orbit can be well approximated by a ellipse with eccentricity of 0.0166, which is close to the eccentricity of the true Earth orbit. And the revolution period is 364 days, which is 1.25 days less than the true period.

2.2 Simulate the binary star system using SpaceEngine

We set up our binary star system in SpaceEngine as shown in Figure 2. The two stars in our binary star system both have mass 0.5 $M_{\odot}$. They rotate with respect to each other in a circular orbit with radius 0.1 AU and period 0.0895 year. In subsection 2.1, we have already seen that in this case, the motion of the binary stars will not have a significant influence on our Earth's orbit and we can still treat the Earth's orbit as conic curves.

Since the mass of moon is not negligible, the mass center of the Earth-moon system is not exactly at the mass center of the Earth as shown in Figure 3. In our setup, we consider and include this effect.

2.3 Extract data from the image

SpaceEngine did not provide the user with direct API functions to extract the data but rather we are restricted to only create screenshots and extract the information we need from the pictures by ourselves. An example of the screen shot is shown in Figure 5.

We use the open source package pytesseract to extract texts from a given image based on which we can extract all the information we need including the position of the two suns and the moon in the observer's coordinate system and the phase of the moon.

Concretely speaking, we choose a box region in our image containing the relevant information we need and then pass it to the function from which we can get the text information. Finally, we can further process the data and store them in the .dat file which is listed on the github.

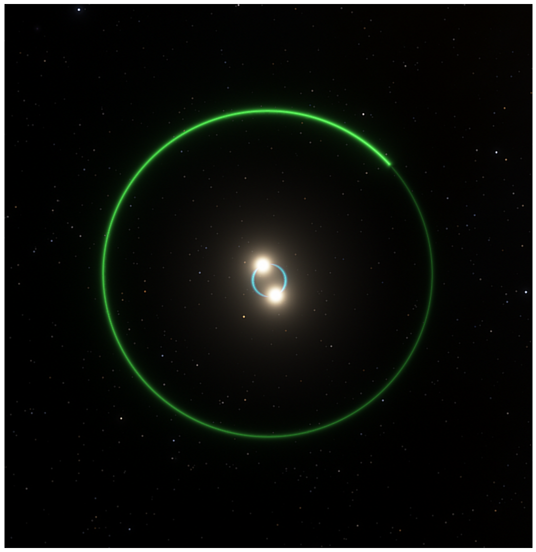

Figure 2: The binary star system in the universe.

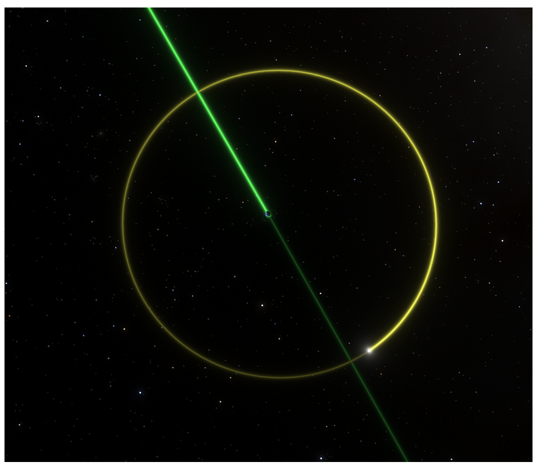

Figure 3: The Earth-moon system in the universe.

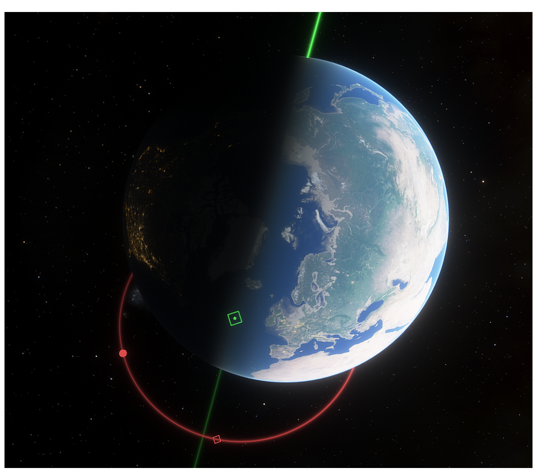

Figure 4: The Earth and the mass center of Earth-moon system.

Moon Bill I	
Class	Temperate airless miniterra
Distance	374443.25 km
Diameter	3472.48 km (0.27252 $D_\oplus$)
Mass	1 $M_☾$
ESI	0.604
Azimuth/height	172°39′27.27″ / 52°45′31.15″
Apparent mag	-7^m04
Phase	0.489
Apparent size	0°31′52.84″
Semimajor axis	362413.54 km
Orbital period	24.978 days
Rotation period	27.322 days (1:1)
Solar day	29.531 days
Axial tilt	0°06′48.53″
Age	$4.570 \cdot 10^9$ years
Gravity	0.16564 g
Temperature	47.978 °C

Figure 5: The raw image screenshot including the information of moon from SpaceEngine.

3 Results

From the direct simulation of the three-body motion by using mathematica, we verify the validity of using conic curves as the orbit of our Earth.

Then by constructing the binary star solar system with our Earth and moon in SpaceEngine, we can observe the position of the sun, both the phase and the position of the moon from different time and different positions on the Earth.

In our dataset, we choose three different locations on Earth, which are roughly located at North Europe, Brazil and China respectively where the three locations are across both northern and southern hemisphere and western and eastern hemisphere. Since the three observers are on totally different locations on the Earth, they will observe different astronomical phenomena in different seasons and years.

Furthermore, since we have two suns in our system, and its rotation period is much smaller than the revolution period of Earth, it is expected that we can observe more dramatic and complex eclipse and phase evolution phenomena which does not exist in our current solar system.

4 Conclusion

1. We analyze the orbit of Earth in our binary star solar system by directly solving the three-body differential equations of dynamics using mathematica and verify the validity of using conic curves as approximated orbit for our Earth.
2. We construct our fictional binary star solar system in SpaceEngine including two suns, one Earth and one moon.
3. We observe the position and phase data of the moon and the two suns at different time and locations on Earth.
4. Finally, we use open source package to extract the data from the raw image data.
5. The github link is:
   https://github.com/Leo-godel/Project-S-data-preparation/blob/main/README.md

References

[1] https://github.com/madmaze/pytesseract

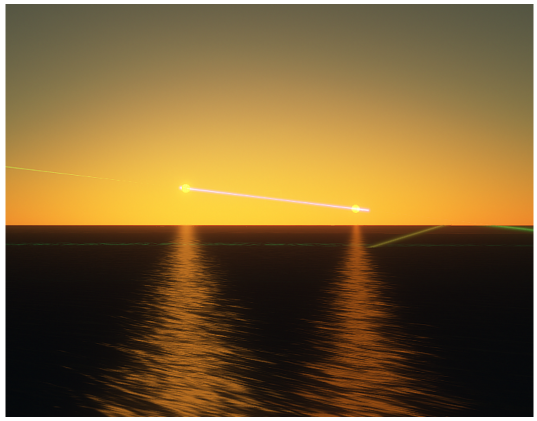

Figure 6: Sunset on Earth.

Figure 7: Observation of half moon on Earth.

[2] http://spaceengine.org/

[3] https://en.wikipedia.org/wiki/