The simulation of eclipsing binary system with variable star

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Abstract

The purposes of this research are to create a simulation of 3 target groups and show its light curve from the simulation. These target groups are (1) an eclipsing binary system, (2) a variable star, and (3) an eclipsing binary system with a variable star. The results show that the created program can display models of the eclipsing binary star systems with the variable star and reveal the determinant of a star system, the light curve, that is consistent with the physical properties of that star system.

Introduction

Variable stars are stars which brightness changes over time. The light curve of a variable star differs depending on its type. Furthermore, a binary star system is a star system in which two or more stars orbit around the center of mass of the system. A light curve is obtained when observing a binary star system in the period covers its orbital period, which can be used to predict the physical properties of the star system. The authors interested in creating a program to simulate an eclipsing binary star system with a variable star in one system and to determine the physical properties of the star system from the simulated light curve by using data from the All-Sky Automated Survey for Supernovae (ASAS-SN) database, and Python programming language for calculate and displaying the simulation.

Materials and Methods

PART 1: Simulate an eclipsing binary system and show the light curve.

1. Write a Python program, using Numpy to perform mathematical operations and Matplotlib to draw graphs. Using an equation as follows:

1.1 Newton's law of gravitation

$$\vec{F} = \frac{Gm_1m_2}{r^3}\vec{r} \qquad (1)$$

where $\vec{F}$ is the gravitational force between bodies, m is the masses of the bodies, $\vec{r}$ is the distance between their center of mass, and G is the universal gravitational constant.

1.2 Equation of position and velocity calculation for, "Leapfrog method"[7]

1.3 Calculate the luminosity and brightness to simulate the star's light curve. Using equations as follows:

$$L = A\varepsilon\sigma T^4 \qquad (2)$$

$$B = \frac{L}{4\pi d^2} \qquad (3)$$

where L is the luminosity, A is surface area, ε is the emissivity, σ is Stefan-Boltzmann constant, T is Absolute temperature, B is the Brightness, and d is the distant

PART 2: Simulate a variable star.

1. Plot a variable star's light curve by using a Python program, using ASAS-SN database to determine Phase Luminosity Absolute magnitude and Radius changed by Phase.

2. Simulate a variable star, showing its radius change over time according to Phase from step 1.

PART 3: Simulate an eclipsing binary system with a variable star.

1. Change one member of an eclipsing binary system in simulation to a variable star.

2. Create a light curve of the system.

Result

The result of PART 1 is shown in Fig 1. This simulation can display a binary star system orbiting around its center of mass with different inclination and shows the light curve of the system corresponding to their eclipse.
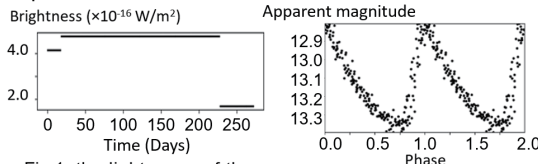

Fig 1: the light curve of the simulated eclipsing binary star system.

Fig 2: the created light curve.

Fig 3: the created light curve of the simulation of eclipsing binary system with variable star.

The result of PART 2 is shown in Fig 2. The creation of a light curve that is simulated from the simulation of variable star's collapse and expansion.
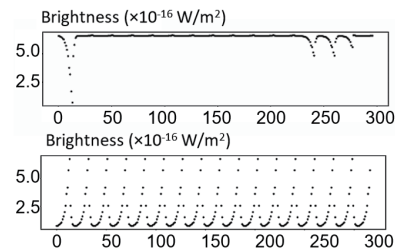
The result of PART 3 is shown in Fig 3. The light curve of the simulation of an eclipsing binary system with a variable star. The upper graph is observed at inclination 0°, while the lower graph is observed at inclination 90°.

Conclusions and Discussion.

The simulation of an eclipsing binary system can display the system with various inclination angles. The simulation uses initial conditions including mass, period, orbital velocity and their positions.

The simulation of a variable star can display the variable star with radius changed over time along with its phase and can display its light curve. In this study, the surface temperature of the star is set to be constant. As a result, the variable star radius is changed by its corresponding magnitude.

The simulation of an eclipsing binary system with a variable star can display the light curve that corresponds to characteristics of each type of star. The model of the eclipsing binary star system and the variable star model are combined in the same model. The created simulation does not account for the transfer of mass between the stars in the system. According to the upper graph in Fig 3, a variable star that collapses and expands is represented by the diminutive curve, and a pair of eclipses is represented by the dimmer. Furthermore, because they are not visible as the eclipsing binary system at a 90-degree inclination, the lower graph only displays the features of the variable star.

References

Lan Morison (2008). INTRODUCTION TO ASTRONOMY AND COSMOLOGY. A John Wiley and Sons, Ltd., Publication. United Kingdom.