Light curves of Near-Earth Asteroid 2018 GG observed with the Spacewatch 0.9m Telescope

The Spacewatch Project and USNA

Braden Larsen- blarsen@terpmail.umd.edu - SDU- PHYSICS

COLLEGE OF SCIENCE LUNAR & PLANETARY LABORATORY

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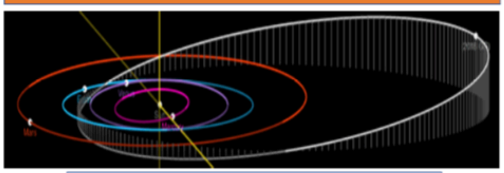
Research Question

What is the rotational period of a newly discovered 70m asteroid, 2018 GG?

Research context

The data that this part of the project focused on was for the asteroid 2018 GG, which was taken by Mike Read on April 10, 2018 on the Spacewatch 1.8-meter Telescope. The main problem with this data set was that it was taken over multiple intervals of several hours with gaps, one beginning at 7:37pm, 10:15pm, and 1:21am. As a result, the data reduction is separated into three different Photometry sessions that all must be fit to one rotational period. This 70m asteroid is now lost again, but it has a high probability of being recovered in its next apparition. Light curves are one of the most important ways to analyze images of Asteroids, since they are illuminated by the Sun. Most Asteroids are irregularly shaped and rotate, so there are variations in the amount of light that they reflect over time. These variations can be smaller than we can detect or up to 40% of the maximum light that is reflected (Harris, 2012). Using CCD images captured by small telescopes, the asteroid is observed as it rotates through several revolutions. As a result, the data reduction of these images produces light curves of flux v. time which are periodic. The rotational periods, captured in the periodic nature of these plots, are a fundamental property of these asteroids which are otherwise hard to measure.



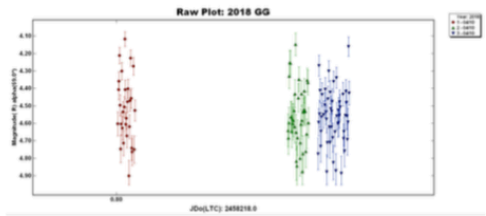
Methodology

The procedure for each asteroid involves: Image calibration (Darks and Flats) of data will occur using AstroimageJ (Collins, 2017), Calibrated Images will be reduced to light curves and rotational periods through use of Brian Warner's MPO Canopus, the Light curve data will be provided to the ALCDEF database

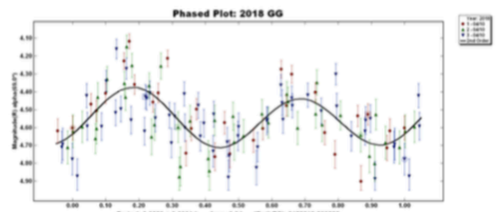
1. After opening the first image, I start a new photometry session and declared the target object to be 2018 GG. This declaration calculates the magnitude (brightness), distance, and phase of the asteroid.
2. Next, it was time for the primary astrometry solution, this solution is a mapping of cartesian coordinates on the image to Right Ascension, in units of time (15 degrees per hour), and Declination, measured in arc distance which has subunits of degrees, minutes, and seconds, on the sky. The astrometry solution will predict where the asteroid will be given a time and star configuration.
3. Once the astrometry solution is imported to MPO Canopus, I used light curve wizard to measure all of the images at once in a given light for location and flux. In order to start this process, I selected a reference star that verifies the orientation from image to image. Since we are measuring how much light that the asteroid will reflect from the Sun, I had to select a solar type star that was stable in luminosity over several hours.
4. In addition, since we are measuring brightness through differential photometry, I had to choose four other solar stars that are stable in luminosity as comparisons to our total light flux, as the variable flux that we measure will be the asteroid reflecting different amounts of light as it travels. I saved these comparisons as text for the reduction before selecting the target asteroid. This selection is made by choosing a later image and comparing it to the initial image to confirm what astronomical body is moving.
5. Then, I selected any stars on the asteroid's path of motion, as the overlap of these two bodies will remove the light of the star from the total flux. This is a problem as the variations in flux will be the rotational period of the asteroid, so any changes in flux must be limited to only be the rotation of the asteroid. I saved both images as PNGs and started the auto-measure tool, and I corrected any failure in orientation by selecting the reference star to reset it.
6. After it is completed measuring all images, we have the raw data to produce our light curve.

I had to use this process for three photometry secessions that covered the three intervals of time that the asteroid was measured, (cal001-cal030, cal101-cal140, and cal211-cal259) to receive the raw data of flux versus time that 2018 GG was measured, one beginning at 7:37pm, 10:15pm, and 1:21am.

Data



Data Analysis Conclusions

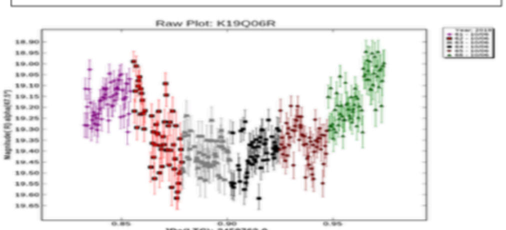


Since in physics, light is an electric-magnetic wave. Therefore, we can decompose the light reflected off the asteroid' surface into different wavelength or frequency waves. These wavelengths will repeat as the asteroids rotates. Therefore, I used a Fourier decomposition of the light emitted during the rotational period to produce the light curve. This Fourier decomposition must match the all three datasets simultaneously as the asteroid has the same rotational period in each set, therefore I must consider all three data sets in the Fourier decomposition. I was able to accomplish this by adjusting the parameters to a 2 order fit with 600 steps of 0.0001 hours. This reduction gave me a rotational period of 0.0223 hours with an error of 0.0001 hours

Future work and Limitations

The limitations of this project are mostly a result of the asteroid being currently lost. This means that the only data available is the set taken by Spacewatch. This means that I have no other dataset to compare my results with. In addition, once the data was complied, data set two and three were multiple magnitudes different then data set one. In order to the analysis necessary to find the rotational period, I had to use comp adjust to make the average light flux of each data set the same . Ideally, this would not have to be done, but since this is the only data set, it is necessary.

I completed the reduction of 2018 GG in preparation for a reduction of the 1991 VH asteroid, which is a candidate for the JANUS mission. This is good practice for the reduction of the 1991 VH, since that data is separated into multiple intervals. Before we get to that reduction, I will approach another binary asteroid to practice for that type of data. This asteroid is 2019QR6. I have the raw data displayed below, but this set is not refined.



Extensions

A light curve and the rotational period of an asteroid gives important information pertaining to the physical attributes and interactions that an asteroid faces as it revolves. Among the most important, if observed over different orientations of the Earth, Sun, and Asteroid, one can measure the direction of the rotation axis or approximate the size , shape, and volume of the asteroid. In addition, the need to deflect a near earth asteroid would require knowledge of the internal strength that holds it together. In Newtonian Physics, the Tensile Strength is equal to the mass of the asteroid multiplied by the acceleration of the asteroid, using our approximate volume and density to find mass:

FT=ma

If we assume that the asteroid is moving in uniform circular motion then:

FT=m(v2/r)

Where the rotational period of the asteroid to the velocity of the asteroid by,

v=2π r/T

As a result:

FT=m(4π2r/T2)

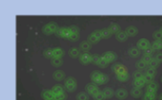
Interactions with other bodies in close flybys can be observed through changes in the rotational period of the asteroid, which displays information about the torque applied to the asteroid by said astronomical bodies. In a similar fashion, one can also follow the interaction of light and the mechanics that follow through the thermal properties of asteroids for example, the Yarkonsky-O'Keefe, Radziewski-Paddack (YORP) effect is a gradual change to the rotational period of an asteroid due to asymmetric cooling during their "nighttime". The cooling is a result of emissions in the form of IR Photons off the asteroid's surface, which carry momentum away gradually altering the asteroid's rotational period.

Charts and Photos

Spacewatch 1.8m Telescope

Reference Star and Orbit Prediction

Five Solar Comparison Stars



Light Curve Wizard Auto-Measure

Citations

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ON THE MAXIMUM AMPLITUDE OF HARMONICS OF AN ASTEROID LIGHTCURVE
-Alan Harris

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UNIVERSITY OF MARYLAND 1856

College Park scholars