Photometric Modeling of the Ultra-Fast Rotator 2014 GN1

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ABSTRACT

On April 2, 2014, the Mount Lemmon Sky Survey discovered the small near-Earth asteroid 2014 GN1 (GN1). The asteroid passed within 2.5 Lunar distances (0.0063 AU) on April 6, 2014, but is too small (absolute magnitude > 22) to be considered a Potentially Hazardous Asteroid (PHA). We observed GN1 on April 5 and 6, 2014, near it's closest Earth approach, and obtained two partial nights of Bessel R-band photometry. Applying standard Fourier techniques on the time-resolved photometry (converted to flux units) revealed the rotational period of the object to be 16.548 +/- 0.012 minutes. The short period reveals it is a monolithic ultra-fast rotator. We then plotted a solar phase corrected light curve assuming our measured rotational period. I developed a two-dimensional photometric model that obtains the light curve of convex shapes at any solar phase angle in order to try and put constraints on the shape of GN1. I plotted the light curve of a given shape, calculated the amplitude and the maximum-to-maximum separation of the curve and tried to match those values with those from the real data.

1 Introduction

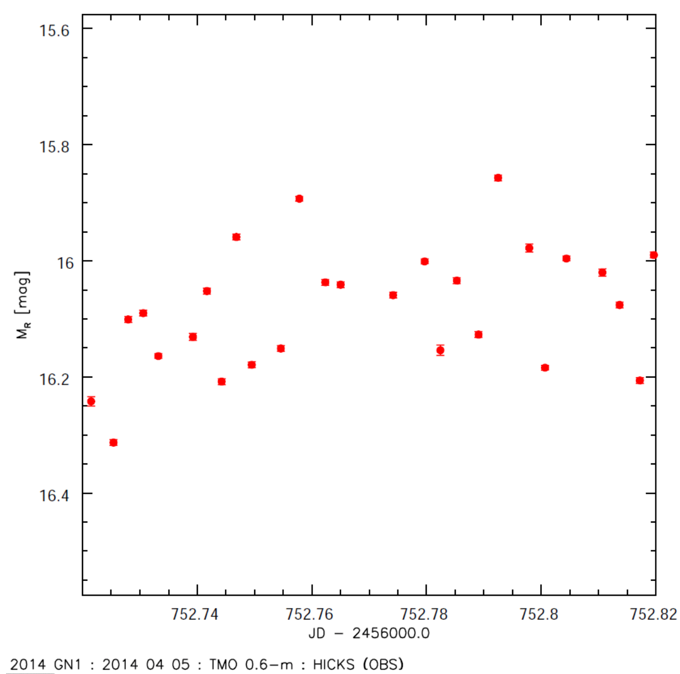
Studying asteroids and comets gives us an avenue to study the conditions and matter present in the early solar system and gain a more complete understanding of how those conditions led to the present solar system, where the only confirmed life exists. Of particular interest are Near Earth Objects (NEOs), asteroids or comets with a perihelion less than 1.3 AU, and Potentially Hazardous Asteroids (PHAs), NEOs with a minimum orbital intersection distance (MOID) of less than 0.05 AU and an absolute magnitude of less than 22, which corresponds approximately to at least a 100-meter diameter. It is a good idea to focus on the objects near to Earth so they can be observed more easily and in more detail, and because of the potential disaster they could cause if one of them impacted Earth. We observe using JPL's Table Mountain Facility 0.6-meter telescope (TMO), using a Spectral Instruments 2K CCD camera. In order to be able to do broadband photometry, we observe in Bessel BVRI filters.

2 Methods

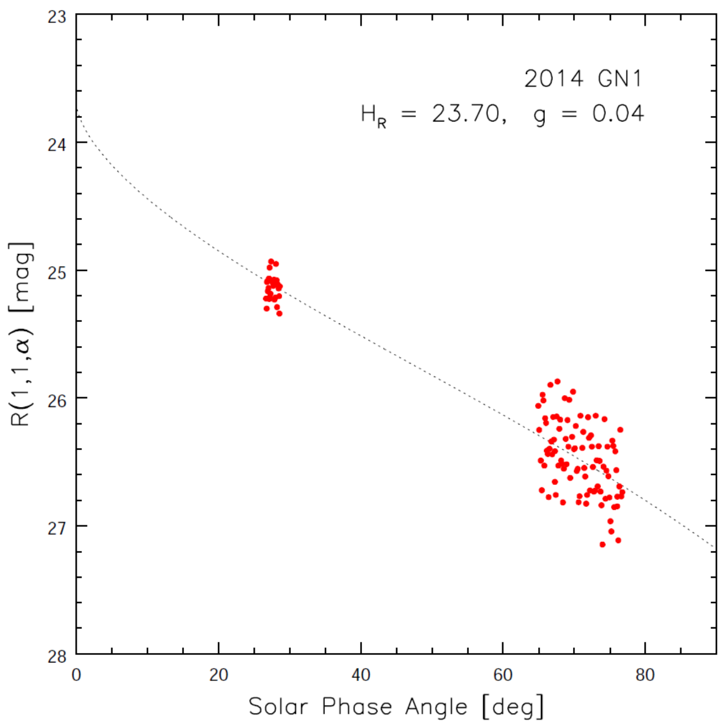
2.1 Observing Model

Using an observing model developed by Dr. Michael Hicks, the images from an observing night are analyzed to extract information. At the start of each observation session, Bias frames are taken that show the thermally generated noise in the CCD chip. Then, flat fields of a evenly illuminated source, such as the sky just after sunset or the inside of the dome, are taken so we can remove the noise from optical imperfections in the mirror, dust in the telescope, and other built-in sources. The flat fields and biases are subtracted from the images of the object to remove the noise. Now that the noise is removed, photometry can be done by plotting the magnitude of the object as a function of time, which generates a light curve.

GN1 rotates so fast that each data point on the light curve is a significant portion of the rotation period ahead of the previous data point. For many asteroids, the light curve is much smoother as each data point is only a small fraction of a rotation period ahead of the previous one. To ascertain the rotation period from the photometric data, standard Fourier techniques are applied, revealing the rotation period of GN1 to be 16.548 +/- 0.012 minutes. This rotation period shows GN1 is a monolithic ultra-fast rotator; it must be a single, solid object, because the fast rotation would cause any separate pieces or dust to fly apart. Plotting the observed magnitude of the object as a function of solar phase angle, determined using GN1's trajectory and the Earth-Sun-Object geometry, yields the solar phase curve, which shows how the brightness changes with solar phase. The steepness of this curve implies a relatively low albedo, and allows the absolute magnitude of the object to be found for each data point. Using the measured rotation period, we can then find the rotational light curve of GN1.



Figures: Photometric Data from April 5 and 6



Solar Phase Curve: the first group of points is first night of observing, the second group is the next night. The large phase difference in only one night shows the object is moving fast and is close to Earth.

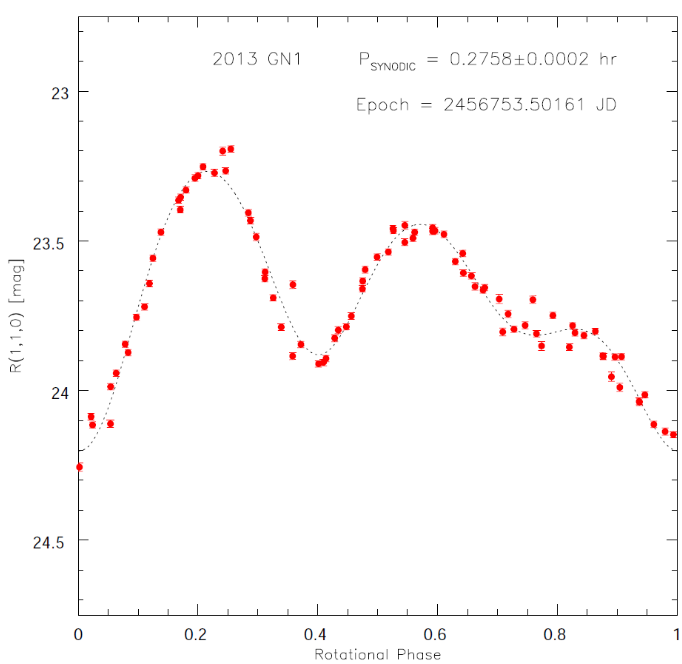
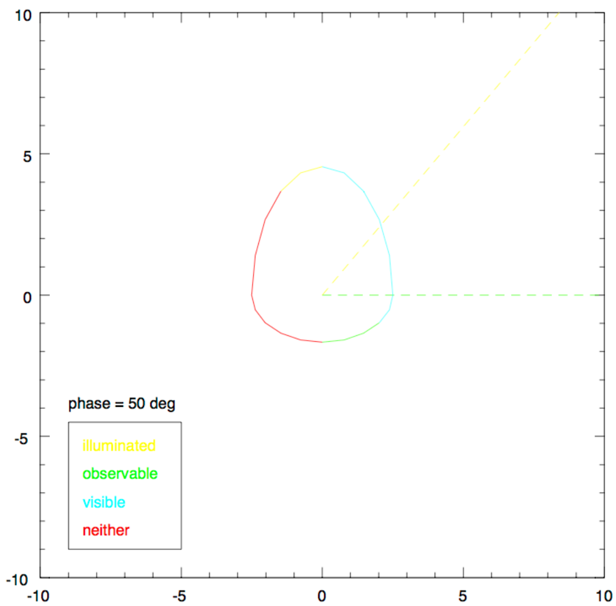


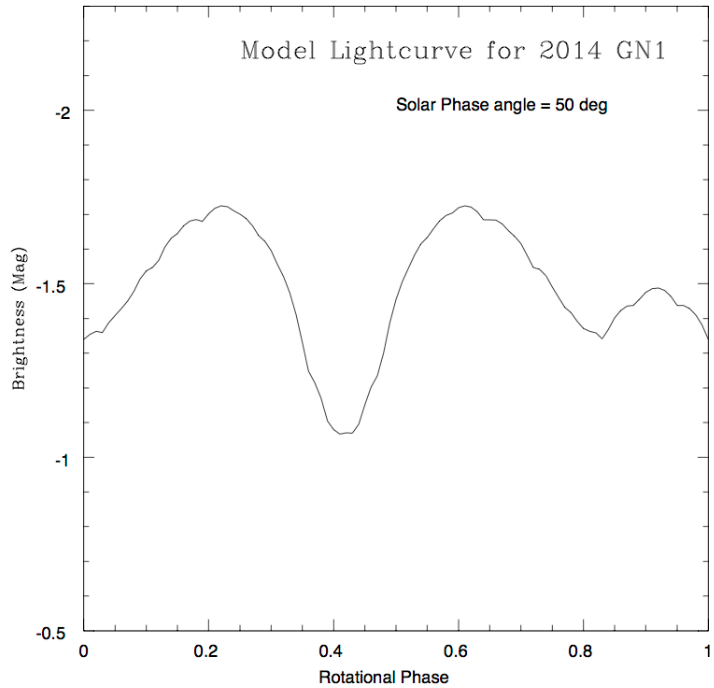
Figure shows light curve of 2014 GN1, a plot of absolute magnitude versus rotational phase.

2.2 Photometric Shape Model

To put some constraint on the shape of GN1, a photometric model was developed, with an objective of generating model light curves of two-dimensional convex shape models at arbitrary viewing geometries and compare them with real photometric light curves. The entire model consists of C++ programs and text files, and the plots were created using SuperMongo (SM). In order to get a somewhat accurate shape, the model light curve must be compared to the real light curve using some parameter that characterizes the shape of the curve. The model uses the amplitude, defined here as the separation from the initial maximum to the next minimum, and the peak-to-peak separation, which is the rotational separation between the two large maximums; two prominent maximums and potentially a smaller third peak would also indicate a partially accurate shape. The model defines a convex two-dimensional n-sided shape, light source and observer, then, using the Lommel-Seeliger scattering law, calculates the flux of the light reflected off of the shape and reaching the observer. The model calculates the flux for each of the line segments that form the shape and sums them up to get a total observed flux, then rotates the object a small amount and getting another observed flux. This is repeated until the shape has rotated 360 degrees. After converting the observed flux into magnitudes, the model plots the magnitude over time as the objects starts and completes a rotation.



Shape model that developed the best light curve matching the parameters for 2014 GN1.



Model light curve produced by the shape model.

3 Results and Discussion

The model shape had an amplitude of 0.66 magnitude, while GN1's light curve has an amplitude of 0.67, the peak to peak separation is 0.39 for the model and 0.37 for the real data, and finally the general structure matches the general structure of the real light curve, with two large peaks and a much smaller third peak. The model suggests GN1 is an asymmetrically elongated, candy corn shape, with one of the two closer corners protruding more than the other. Future developments on this model should include more customization tools to stretch and modify custom shapes, to avoid point-by-point manual modification, and expansion into three dimensions.

Acknowledgments

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