The lightcurve of an asteroid

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SCIENTIFIC JUSTIFICATION

Asteroids appear frequently in the inner Solar System and have been studied intensively by astronomers through the years. Properties of asteroids such as orbital characteristics, composition, age, rotation, color, mass and size are interesting to study. This information can be used in various fields of astronomical research. For example, asteroids can provide a lot of information about the forming and development of planetary system [1]. Also collisions between asteroids and their consequences can be important in planetary formation. Therefore asteroids may even hold the clue about the origin of life on earth [12]. While asteroids can be the key to understanding the origin of life, there is also a chance they will destroy life. Some asteroids cross Earth's orbit and are called near-earth asteroids. They have a probability to strike Earth and cause serious damage [3]. For this reason, it is important to know as much as possible about these objects.

Our mission is to observe the light curve of an asteroid and using this to determine the rotational period. Of course, the period of one asteroid will not be of significant importance: what could we possibly derive from one observation? However, knowing the rotational period of multiple asteroids can help answer a very interesting bigger question, namely how our solar system has been formed and how it evolves. Observing the light curve of one asteroid will be another step towards the solution of this puzzle. A more direct reason why asteroid light curves are important is that in the end, it can help determine possible correlations between asteroids rotational period, size, taxonomic class, location in the asteroid belt and even more properties. It can also help determine the shapes and pole orientations of the asteroids.
In particular it is interesting to try to find asteroids with a period under 2.2h. There appears to be a barrier to rotation rates faster then 2.2h [11]. This is the rate below which centrifugal force would cause a rubble pile to fly apart against it's own gravity, even for small asteroids. So an asteroid that does have such a short rotation period, would almost certainly be of solid composition, which would undermine the idea of the possible rubble pile structure of asteroids. It is a real mystery that not many of them have been found yet. On the other hand, there also exists a class of extremely slow rotating asteroids with periods of several days up to 2 months. The origin of the slow rotator population is unclear, and more data is needed to explain why some asteroids have such long rotation periods [11].

So it is important to observe the light curve and determine the period of asteroids. But how can the light curve tell us something about the rotational period? This can be done because most asteroids do not have a symmetrical shape or a constant albedo. This results in a fluctuation of the magnitude of the asteroid while it is rotating. Because the rotation is periodic this results in a periodic magnitude difference. Thus the rotational period can be determined from measuring the light curve and fitting the best period.

To determine the light curve we need to determine the apparent magnitude of the asteroid at many moments in time. First we will aim the telescope at the part of the sky where the asteroid is positioned. The view should not be too small, because we also need to be able to see some cataloged stars in the pictures. We can use these stars as calibration for the magnitude, because they have a known magnitude in a given filter range. If we take our pictures in one of the commonly used filters, for example the V-filter, we can relate the CCD asteroid flux to an apparent magnitude by comparison with the CCD flux of the reference stars. Therefore, after taking a lot of pictures over a certain period, we can determine the apparent magnitude of the asteroid at multiple moments in time. Thus we can determine the light curve. Finally, because of the limited observational time we do need to lay some restrictions on what asteroid to choose. We will need to observe an asteroid with a short rotational period, otherwise we can only measure a small part of the light curve which makes it harder to fit a period. Also, for a well defined light curve we need as many data points as possible. This means we need to take as many shots as possible so the exposure time must be very short. This means the object must be bright as well. So the ideal asteroid is a short rotator and a bright one.

TECHNICAL JUSTIFICATION

The asteroids we want to study are selected on the following criteria: short rotational period (so we can observe a complete light curve during our observation time), apparent magnitude (so we can use an integration time less than one minute) and position at the sky at the time of observation (so that the asteroid is visible during the night and is not too close to the moon). The asteroid we considered most suitable is Liberia 1816. Furthermore, the asteroid Gotha 1346 is a good alternative. We have found these asteroids using the Ephemerids Generator of www.minorplanet.info. Liberia is visible during the whole week on La Palma. It is also visible during the night, because the object will almost reach the zenith around midnight [9].

Because the rotational period of Liberia is only about three hours [10], it is possible to observe the entire light curve in one night. Ideally, we want three hours of observation time or even more, but we can also achieve a confident solution if we have 80 percent coverage of the light curve. So we would need at least 2.5 hours of observing time [8]. Because Liberia is visible the whole night and for every night we are on La Palma, the timing of our observations is not crucial. But because asteroids are moving objects, we will need to know beforehand when we will get time to observe, because we need to make a finding chart for the right night (see figure 2). However, the timing of the data sampling is crucial, in the sense that we want to avoid taking pictures at regular intervals. Using regular time intervals for our sampling might cause us to get the wrong rotational period, because we would be introducing an extra "period" manually. Thus, we need to take pictures at irregular intervals. We do not need to have an excellent seeing. If the seeing is bad, the point sources will spread out, but we are only interested in the flux, which will remain the same. Also because of the altitude of Liberia in the night sky, we will already have a good air mass ratio to start with. Transparency will mainly diminish the amount of light we get, so we just need to increase the exposure time. Again, because we are looking at point sources they will not quickly drown in the light of the sky itself. The moon will not be a problem, it is sufficiently far away from Liberia in the sky (see figure 1).

We want to use a filter that is commonly used by other astronomers, because then we can compare our data to the data from other research. Also, other researchers could use our data to compare theirs to. Because the night sky is mainly blue, we want to avoid using a filter that is mainly transparent for blue light. We have chosen to use a V-filter, because a lot of asteroid research has already been done in the visible spectrum [5], and it will also be easy to find magnitudes of our calibration stars in this band. There are two V-filters available for the WFC [7]. We want to use ING Filter number 192 (see figure 3), because it has a broader wavelength range and transmission then the other filter and we want to measure as much light as possible. However, if the weather conditions are very good the week we are on La Palma, we might get some more observing time. In that case, we also want to observe in a red filter, because then we can look at color variations of Liberia. The filter we will use if this is the case is the ING Filter number 193, a broad filter in the R-band. The apparent magnitude of the asteroid is important regarding the integration time, signal-to-noise ratio (S/N) and saturation of the detector. For the V-filter, Liberia 1816 has an apparent magnitude of $m = 15.1$ [10]. We expect a variation of ± 0.2 in the magnitude of the asteroid [5]. Using the INT wide-field camera (WHTWFC detector) and expecting a bright sky, an exposure time of 25 seconds yields a signal from the object of max. $31.2 \cdot 10^3$ photons per pixel with $S/N \approx 600$ at $m = 15.1$ (calculated with the Exposure Time Calculator for ING [6]: see figure 4). Since a signal greater than $40 \cdot 10^3$ photons [6] per pixel can cause saturation of the detector, an integration time of 25 seconds is preferred [6]. Also, because of the magnitude variation of approximately 1.3% this S/N ratio is accurate enough ($S/N \approx 600$ has an accuracy of approximately 0.4%). For our purposes only the relative flux is important. We are only interested in the shape of the light curve and therefore we do not need to determine the absolute magnitude.

The position of the asteroid will change during the week (see table I). See for example the finding chart for one of the nights (see figure 2). The magnitude of the asteroid will be around +15.1 [10]. We will only use one of the four mosaic elements of the INT wide-field camera, because correcting for multiple chips is much harder than correcting for one chip. Each element has a field of view of about 10 by 10 arc minutes. The image at the edges of the chip is slightly more prone to distortions, so we want a very small field of view, but with enough reference stars. As reference stars we can use a number of stars of the same magnitude as the asteroid that are very close to the asteroid. These stars have been found with the Keck Finding Chart Tool [4] and the USNOB10 catalog. The Keck has a much smaller field of view than the INT, but this is good, because the closer the stars are to the center of the chip, the smaller the distortion of the image. All of these stars are within one arc minute of the asteroid, which will be at the center of the chip. Again, this depends on the time of observation.

FIGURES

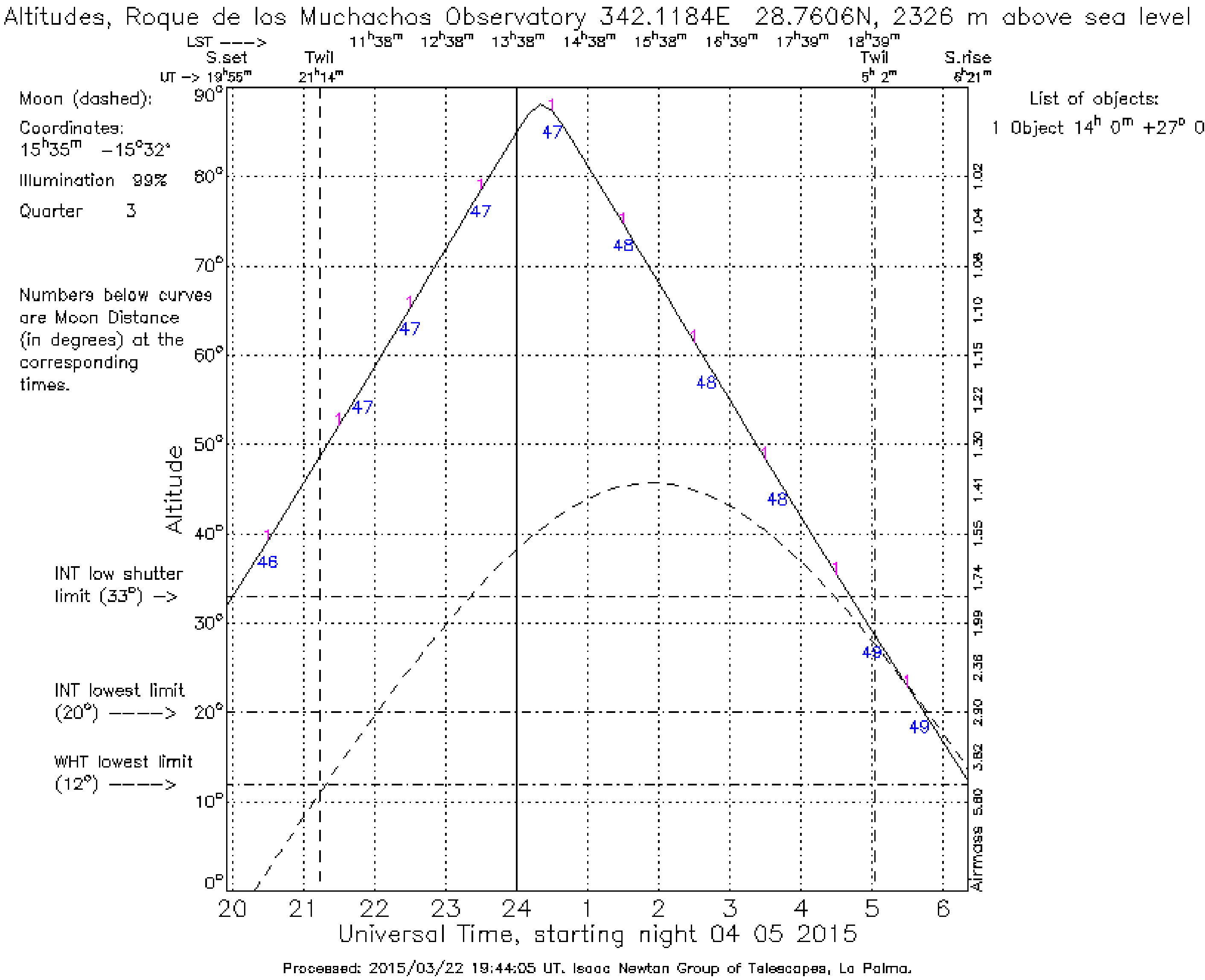

FIG. 1: Altitude of Liberia in the sky during the night of 04/05/2015 at La Palma. As you can see Liberia reaches almost zenith around midnight. The altitude of the moon is also plotted in the figure. The distance between the moon an Liberia is sufficiently large, namely more then 10 degrees. [9]

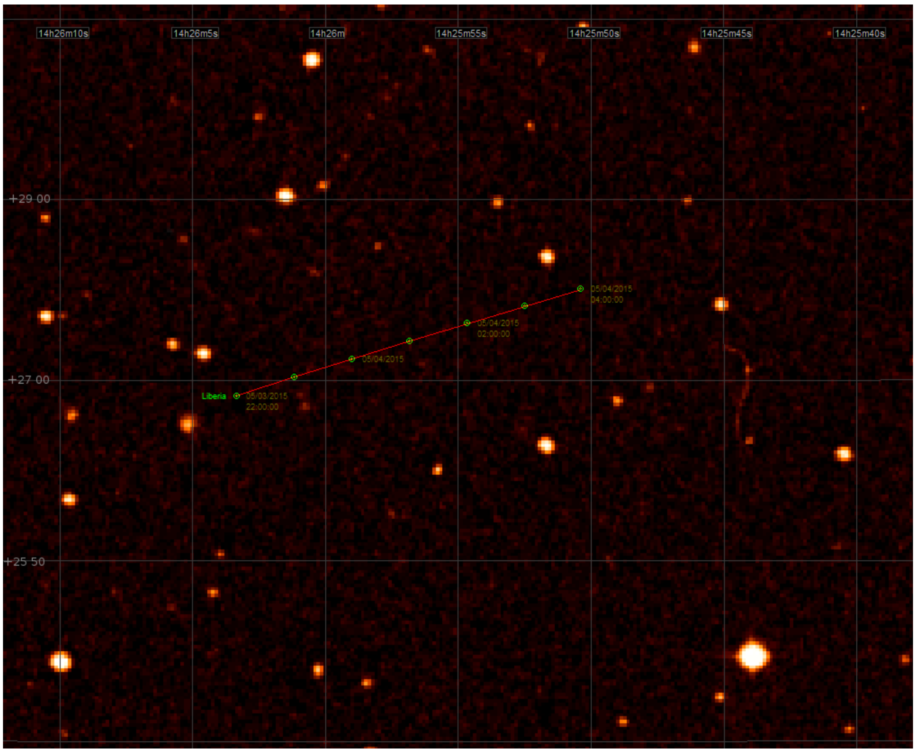

FIG. 2: Position of Liberia during the night of 03/05/2015-04/05/2015. The line corresponds with the orbit of Liberia projected in the sky. The time between two dots on the line is exactly 1 hour. The R.A. is on the x-axis and the declination on the y-axis. The finding chart is made using C2A planetarium software. [2]

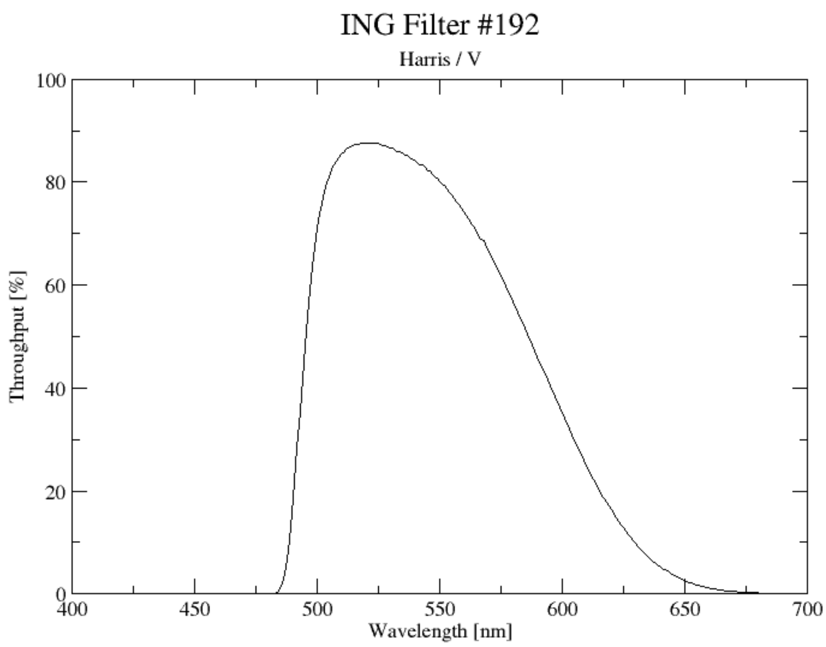

FIG. 3: The transmission profile of the V-filter we will use in La Palma. It is one of the commonly used filters and therefore great for comparing results with other researchers.

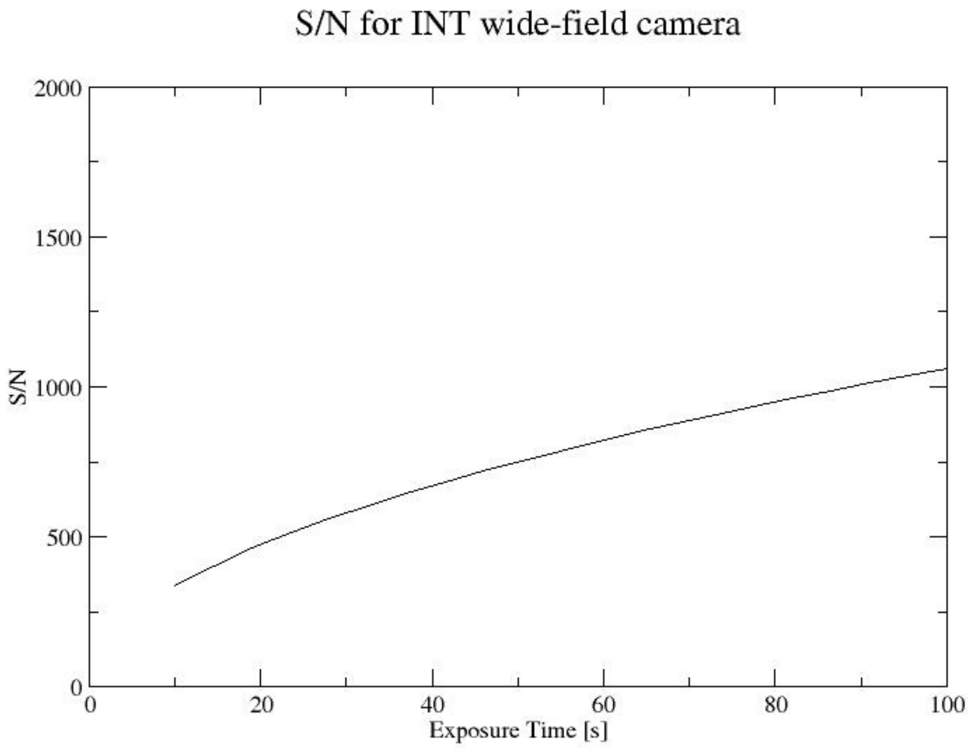

FIG. 4: Signal noise ratio versus exposure time for the telescope on La Palma for Liberia. As you can see the S/N ratio gets better and better the longer the exposure time. However, because of saturation the maximum exposure is around 25 seconds. [6]

Date	*RA*	δ
01/05/2015	$14^h28^m31.5^s$	$+27°44'00"$
02/05/2015	$14^h27^m40.0^s$	$+27°48'57"$
03/05/2015	$14^h26^m49.0^s$	$+27°53'23"$
04/05/2015	$14^h25^m58.5^s$	$+27°57'17"$
05/05/2015	$14^h25^m08.7^s$	$+28°00'40"$
06/05/2015	$14^h24^m19.5^s$	$+28°03'32"$
07/05/2015	$14^h23^m31.1^s$	$+28°05'53"$
08/05/2015	$14^h22^m43.5^s$	$+28°07'44"$

TABLE I: Table with positions of Liberia during the time in La Palma. The time is 00:00 for all days.

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