Serendipitous Photometric Observations of the October 2004 Lunar Eclipse

Shawn Dvorak
1643 Nightfall Drive, Clermont, FL 34711

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Abstract Analysis of data from a series of CCD observations of the eclipsing binary QQ Cas collected during the 27–28 October 2004 total lunar eclipse also captured a record of the lunar event. Analysis of sky brightness measurements from the CCD images yielded a time of minimum lunar brightness in good agreement with the predicted time of mid-eclipse.

1. Introduction

The Rolling Hills Observatory (RHO), a private observatory in Central Florida, has active eclipsing binary and RR Lyrae CCD observation programs. An observation run of the under-observed eclipsing binary QQ Cassiopeiae (R.A. 23^{h} 45^{m} 36.7^{s}, Dec. +59° 54' 22" (2000)) was undertaken during the October 27, 2004, total lunar eclipse to take advantage of the dark sky during the eclipse. Subsequent data reduction revealed evidence of the lunar eclipse, recorded in the sky background measurements from the CCD images.

2. Observations

An 8.5-hour series of CCD images was collected of QQ Cas, from 23:42 UT to 08:14. Each 75-second image was dark-subtracted and a twilight sky flat applied. Normal data reduction procedures at RHO include an analysis of the sky background trend, measured by calculating the average ADU value (count per pixel) of each image, to detect images that may have been affected by passing clouds. Background stars were not eliminated from the images from which the average ADU was calculated. The CCD's autoguider capability was used, which ensured that the star field stayed constant throughout the run. With the exception of the target variable the flux from the stars would be essentially constant, and the variable's changed brightness would only have a negligible effect when averaged against the 260,000 pixels on the images. When this data set was plotted a pattern was readily visible: the sky background showed an obvious symmetric drop by a factor of 5, and then a subsequent recovery (see Figure 1).

3. Analysis

Figure 1 shows the background sky brightness during the entire 8.5-hour run, which covers the entire duration of the eclipse. Based on data from the *Astronomical Almanac* for 2004, the stages of the lunar eclipse are shown in Table 1.

The curve in Figure 1 is rather asymmetric, especially during the penumbral phases. The increasing sky brightness at the start of penumbral phase at 00:05 UT occurred because the moon was still rising, being only 18 degrees above the horizon at the beginning of the data set, so its illumination of the sky was still increasing. Around 00:35 UT the increasing portion of the moon's disk within the earth's shadow started to overwhelm this effect, and the sky brightness began dropping. The sky brightness started increasing again as the moon exited the umbra and progressed into the brighter outer region of the penumbra. The brightness continued to increase after the eclipse ended, due to the decreasing altitude of the star field. The suburban observatory is located near sea level in a subtropical climate, and sky brightness typically increases markedly below 40 degrees elevation due to aerosol scattering of natural and artificial light pollution.

Interestingly there is no noticeable change in the slope of the light curve when the moon enters the much darker umbra. This is understandable, however, since the transition between penumbra and umbra is quite indistinct, and the effect on the moon's brightness is therefore gradual. This is consistent with results from a direct photometric study (Schmude *et al.* 1999) of the January 2000 total lunar eclipse.

Figure 2 shows a plot of the sky brightness during the umbral phase of the eclipse. This portion of the curve is reasonably symmetric, and even resembles that of a totally eclipsing binary star. With this in mind the 150 ADU values obtained during the umbral phase were analyzed with the Kwee and van Woerden algorithm in AVE (Barbera 1999) to determine the time of minimum light. This time should closely correspond to the time of maximum eclipse. AVE yielded a time of 03:05.9 UT ± 1.0 min, in reasonable agreement with the mid-eclipse value of 03:04.0 UT from the *Astronomical Almanac*.

The agreement between the time of mid-eclipse from and the time of minimum sky brightness from the CCD data is remarkably good, given the many variables involved. The changing altitude of the moon and of the target field had a large effect on the background brightness, as can be seen from the penumbral and post-eclipse portion of the curve in Figure 1. There is also no particular reason to expect the light curve of the moon to be symmetric during the eclipse, even when measured directly. The moon's brightness in eclipse is strongly dependent on the atmospheric conditions over large regions of the earth (Karkoschka 1996), and it is reasonable to assume that these conditions are likely to be very uneven, resulting in an uneven light distribution within the earth's shadow. Additionally, the amount of scattered moonlight is sensitive to localized weather conditions, varying as thin clouds and atmospheric moisture changes. The post-eclipse portion of the light curve in Figure 1 shows some small irregularities that are probably due to this effect.

4. Conclusions

Modern ephemerides predict the timings of events such as lunar eclipses with great accuracy, so the timing of the time of maximum eclipse depth is of little value. Photometry of lunar eclipses can reveal details about the earth's global atmospheric conditions and help distinguish between different models (see Schmude *et al.* 1999). Indirect photometry, such as done in this study, are susceptible to a number of effects that are difficult to quantify, including local weather conditions and the effects of changing moon and target field altitude. Better results presumably could be obtained from darker, high-altitude sites. Additionally, stopping the telescope drive to keep it fixed in position would mitigate the effect of changing target field altitude.

References

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Table 1. Predicted times for eclipse stages (from U.S. Naval Obs. 2004)

Stage of Eclipse	*Time (UT)*
Moon enters penumbra	00:05.5
Moon enters umbra	01:14.3
Moon enters totality	02:23.4
Middle of eclipse	03:04.0
Moon leaves totality	03:44.6
Moon leaves umbra	04:53.7
Moon leaves penumbra	06:02.7

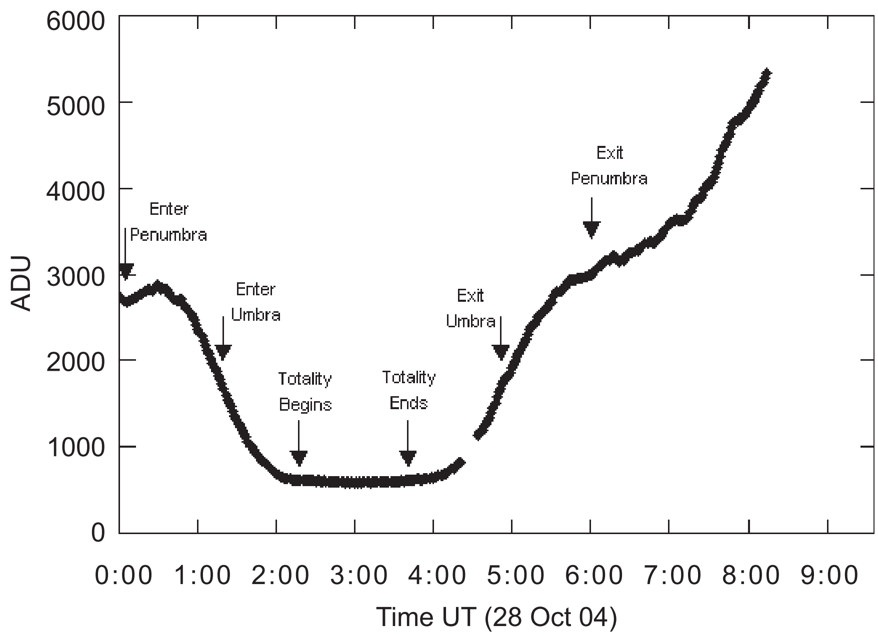

Figure 1. Sky brightness light curve during the entire QQ Cas observation run made during the October 2004 total lunar eclipse.

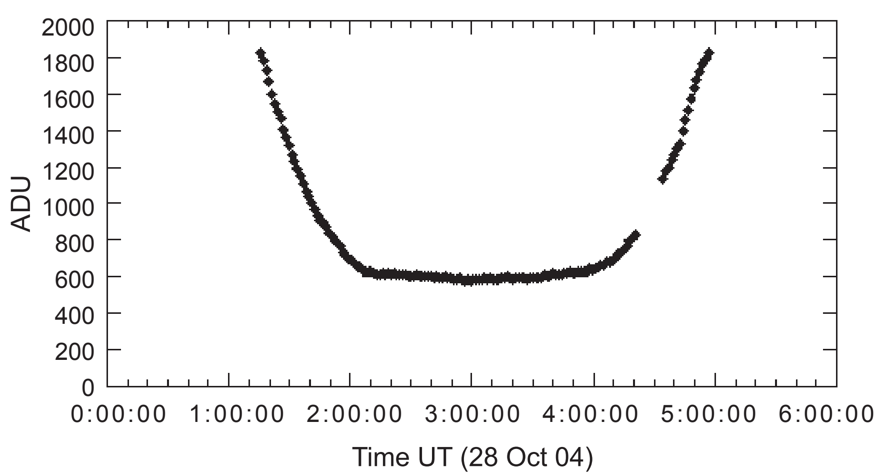

Figure 2. Sky brightness during the umbral phase of the lunar eclipse.