Unique observations of a partial eclipse of an asteroid: 2012 XE54

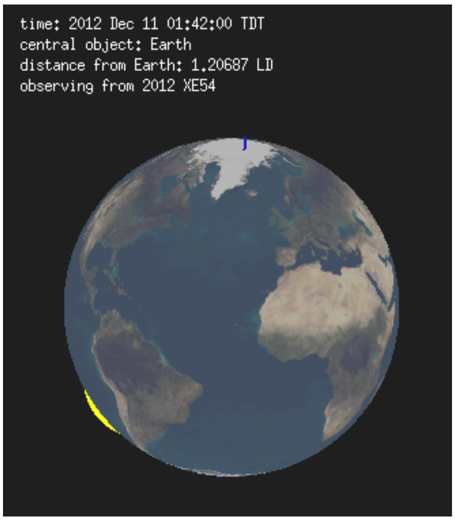

Figure 1. The eclipsed Sun as seen from 2012 XE54 during mid-eclipse *(courtesy P. Tricarico).*

Discovered on 2012 Dec 9 by the Catalina Sky Survey using the 0.68m f/1.9 Schmidt telescope on Mount Bigelow, Arizona, 2012 XE54, a near-Earth asteroid (NEA) some 15–40 metres in size, was promptly predicted by Pasquale Tricarico of the Planetary Science Institute, Tucson, to undergo a partial eclipse by the Earth's shadow – observation of which would be a unique event. See MPEC 2012-X37 and Pasquale's webpage at **http://orbit.psi.edu/~tricaric/2012XE54.html**.

Pasquale's prediction, based on early astrometry, was for mid-eclipse to occur at about 01:41 UT on December 11 some 460,000km from the Earth's centre. Closest approach would follow at around 10:10 UT the same day at a distance of 230,000km, *i.e.* a little over half the Earth–Moon distance. The accompanying image of the dark side of the Earth (Figure 1) shows the appearance of the Sun as seen from the asteroid at the time of maximum eclipse. Figure 2, the lightcurve plotted by Pasquale based on observations made on December 9, clearly shows the expected dramatic increase in brightness as the object buzzes past our planet at a relative velocity of 13 km/s.

The first case of an asteroid being observed as it approached being eclipsed by the Earth's shadow was that of 2008 TC3 on its way to entering the atmosphere over Sudan in 2008. To my knowledge, until 2012 XE54 made its appearance, no asteroid had been observed to pass through the Earth's shadow and re-appear the other side during a close fly-by of our planet. On hand were several amateur astronomers to record the event, including Elia Cozzi of the New Millennium Observatory in Italy, Luca Buzzi of the G. V. Schiaparelli Observatory (also in Italy), Gary Hug of Sandlot Observatory in the USA, and our own Peter Birtwhistle of Great Shefford Observatory in the UK.

As the object approached the Earth, its apparent motion accelerated as it brightened to reach almost 13th magnitude before it started to enter the Earth's penumbra about 01:17 UT. Maximum eclipse occurred at 01:37 UT as the trajectory of the object took it within about 100km of the Earth's umbra and the calculated depth of the eclipse reached 5.3 magnitudes. It left the penumbra at 01:56 UT. (Note that these calculations, which I have made with the help of information on the JPL *Horizons* website, do not take into account the effect of Earth's atmosphere on the size of the umbra at the distance of the asteroid.)

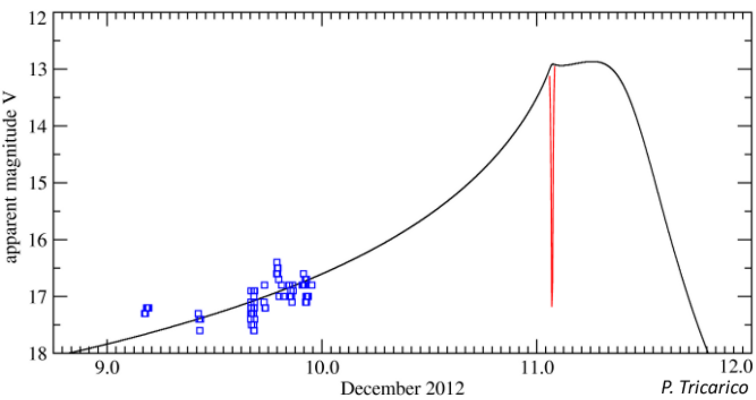

Figure 2. The predicted lightcurve of 2012 XE54 as it approached the Earth, based on early observations on December 9. *(P. Tricarico).*

Some observers took relatively long exposures to reveal the celestial visitor as a long streak. Luca Buzzi's sequence (Figure 3) clearly shows the streak of light of this particular passer-by fading dramatically between 01:23 UT and 01:34 UT as it plunged deeper into the penumbral shadow of the Earth.

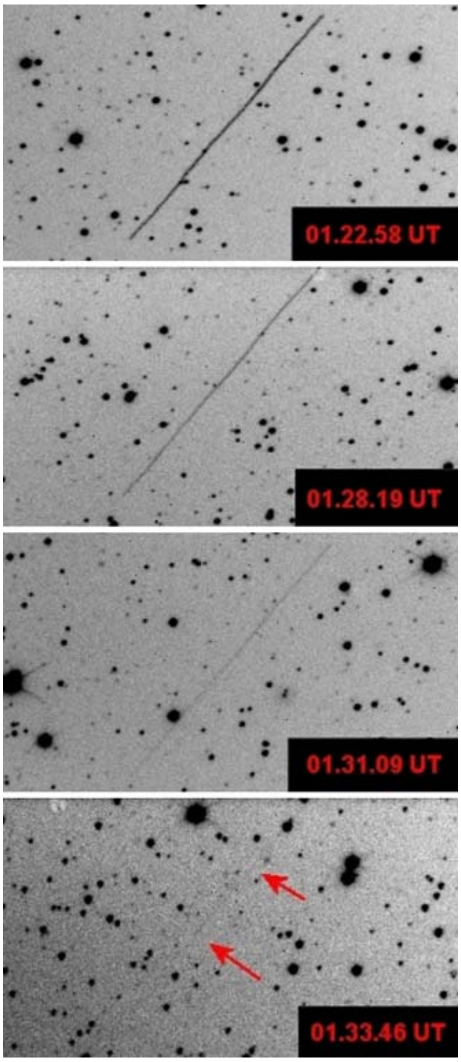

Figure 3. 2012 XE54 entering the Earth's shadow early in the morning of 2012 Dec 11. 120 sec exposures, 380mm f/6.8 reflector + CCD. *(Luca Buzzi, MPC 204, Italy).*

Peter Birtwhistle dedicated a long time-series of more than 1200 images using his 0.4m Schmidt–Cassegrain telescope, starting at 21:34 UT and finishing at 04:44 UT. This was a very difficult exercise as Peter had to move his scope some 62 times to keep the object in the field of view. Towards the end of the observing run, the object was streaking across the sky at a rate of motion in excess of 300 arcsec/min. He used relatively short exposures, and some results of

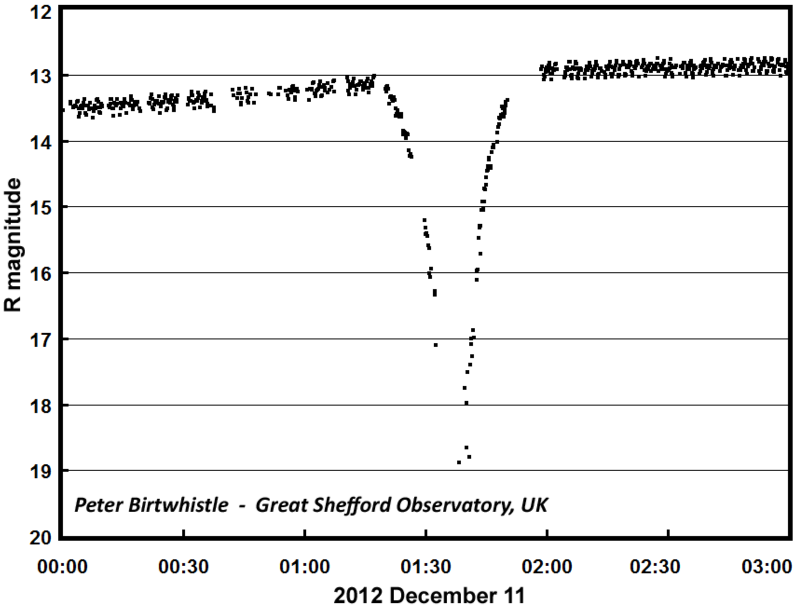

Figure 4. Lightcurve of the penumbral eclipse of near-Earth asteroid 2012 XE54.

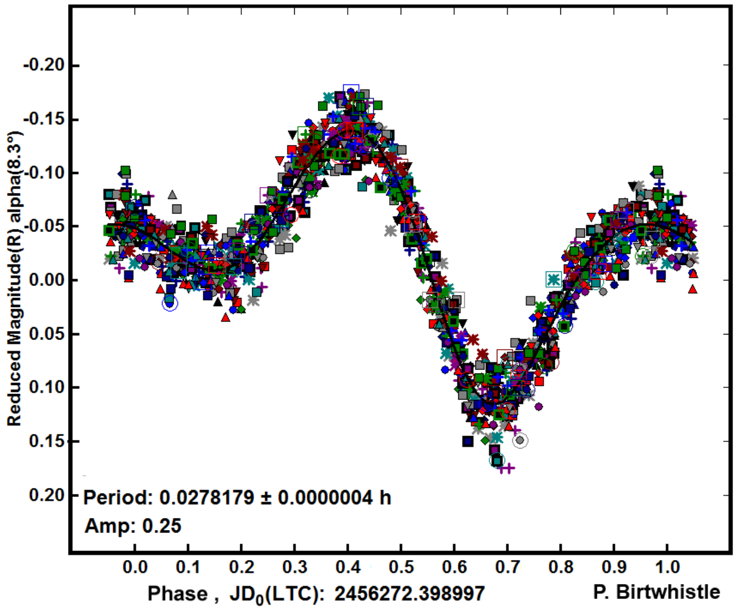

Figure 5. Rotational lightcurve of 2012 XE54. ***P. Birtwhistle.***

his photometric analysis of the images are shown in Figure 4.

The partial eclipse is very apparent and shows a drop in brightness amounting to close on 5.7 magnitudes: the extra fade of 0.4 mag, or about 45% over that predicted, was probably caused by the additional light lost by absorption of sunlight during its tangential transmission through the Earth's atmosphere. If visual observers had been able to witness the event they would no doubt have seen the asteroid take on a reddish hue as it approached minimum light. Peter's timing for mid-eclipse, taken from his estimates of the start and end times, was 01:36:25 UT, in full agreement with predictions.

Two other interesting results were found when Peter studied the extensive amount of photometric data he had obtained. One was that this particular NEA was a very fast rotator, exhibiting a double-peak composite lightcurve when the measured magnitudes were adjusted for distance and phase angle and folded on a rotation period of 0.027818 hours or 100.1 seconds (Figure 5). The second finding was that there seemed to be a longer-term regular fluctuation in brightness superimposed on the main 100s period. This much slower modulation in the reflected light seemed to have a period of some 8.7 hours and an amplitude of at least 0.16 magnitudes. In other words, 2012 XE54 appears to wobble as it spins, rather like a spinning top precessing around in a secondary direction or non-principal axis of rotation, possibly indicative of its origin as a fragment produced in some collision which may have occurred billions of years ago.

Thanks and congratulations are due to Peter for this valuable piece of work and unique contribution. Here we have another good example of the important rôle played by the skilful amateur in capturing a rare astronomical event of this kind. Well done to all the observers!

Richard Miles, *Director, Asteroids & Remote Planets Section*