ASTROMETRY AND PHOTOMETRY OF 2008 TC3

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ABSTRACT

2008 TC3 was an asteroid of about two meters in diameter which entered Earth' atmosphere and burned up over northern Sudan on October 7, 2008, at 02:46 UTC (5:46 a.m. local time). It was the first time that a celestial object was detected prior to entering Earth's atmosphere. 2008 TC3 was tracked by La Sagra Sky Survey (LSSS) with telescopes located at the Observatorio Astronomico de La Sagra (MPC observatory code J75) in Andalusia, and from Observatorio Astronomico de Mallorca (MPC observatory code 620), Balearic Islands, Spain. When the object entered Earth's shadow at 01:46 UT, two telescopes at LSSS have detected and recorded this rare event independently. With a total amount of 1500 images LSSS continuously tracked the object for about 7 hours until it entered the umbra and became invisible to optical detectors.

INTRODUCTION

2008 TC3 was a two meter sized object discovered on October 7, 2008 by the Mt. Lemmon Survey (MPC observatory code G96) about 21 hours before impact. It entered Earth's atmosphere and burned up over northern Sudan on October 7, 2008, at 02:46 UTC (5:46 a.m. local time). It was notably the first asteroid that has been detected before it entered Earth's atmosphere. The object was tracked by 27 amateur and professional stations until it entered Earth' shadow on October 07, 2008, at 01:49 UT. In less than 19 hours 586 astrometrical measurements were reported to the Minor Planet Center. The entry into Earth's atmosphere was detected by U.S. government satellites and ground-based very low frequency infrasound measurements [1], Meteosat 8 satellite [2] and KLM-592 captain Ron de Poorter and co-pilot Coen van Uden flying over Chad [3].

La Sagra Sky Survey (LSSS)

Observatorio Astronomico de La Sagra is located in the mountains of Andalusia in Southern Spain near the village Puebla de Don Fadrique. It is operated by the Observatorio Astronomico de Mallorca. The main activities at La Sagra Observatory are astrometric and photometric observations of Small Solar System Bodies. The first discoveries have been scored in August 2006. By improving our search methods and data reduction techniques, today we are able to detect several hundred new asteroids per month and monitor tens of thousands of known ones. The Fig. 1 shows the discovery statistics from La Sagra Observatory where the most productive month until now was Aug. 2008 with 524 designated discoveries.

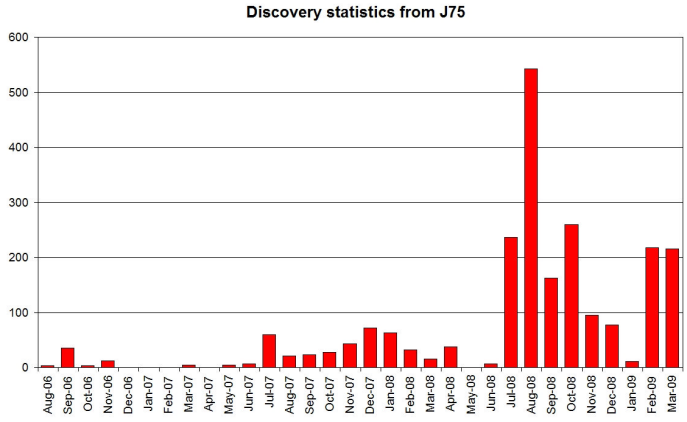

Fig. 1. Discovery statistics from La Sagra Observatory. Designated discoveries in the period August 2006 to March 2009.

The current instrumentation we use to scan the sky consists of three 0.45-m f/2.8 telescopes located at La Sagra Observatory. Follow-up of new objects is done with dedicated tracking telescopes at La Sagra Observatory and Observatorio Astronomico de Mallorca. Data acquisition and data reduction at LSSS is done entirely remotely via the Internet, by staff members located in Spain, Germany and Switzerland. Since August 18, 2008 LSSS is officially classified as a survey by the MPC.

ASTROMETRIC OBSERVATIONS OF 2008 TC3

Our first observations of 2008 TC3 were done with a remotely-controlled 0.30-m telescope at Observatorio Astronomico de Mallorca on 2008 Oct. 06 at 18:50 UT. However due to incoming clouds the observations had to be stopped at 21:09 UT. That resulted in an observed orbital arc of 2h 19min. Already while doing the observations at Mallorca, we sent two 0.45-m f/2.8 and one 0.40-m f/10 telescope at Observatorio Astronomico de La Sagra to track 2008 TC3 and they have done so until it entered into Earth's shadow, at 01:46 UT [5]. Fig. 2 is a small section from one image that shows 2008 TC3 entering the umbra and becoming invisible until atmospheric impact over Sudan one hour later.

Fig. 2. The image is a small section from a much larger image, exposed while asteroid 2008 TC3 entered Earth' shadow about one hour before atmospheric impact over northern Sudan. The image was made with one of La Sagra Sky Survey's (LSSS) 0.45-m f/2.8 telescopes. It is a six minute exposure tracked at siderial rate. Exposure start time was 2008 Oct. 07, 01:45:23 UT. The section shows a field which is half a degree wide. The asteroid moved from west (right) to east (left). At start of exposure it was at a distance of 29600 kilometers, approaching at a speed of 7.61 kilometers per second. Long before the exposure ended, the trail got dimmer and completely invisible, confirming the predicted time of entry into Earth' shadow.

With a total amount of over 1500 images collected at Observatorio Astronomico de Mallorca and Observatorio Astronomico de La Sagra we continuously tracked the object for 6.93 hours, which is longer than any other observatory did. In order to not bias the orbital calculation by reporting too many astrometric positions from one station, we decided to report just one position approximately every five minutes. This resulted in a total of 69 measurements (15 from 620, and 54 from J75) reported to the Minor Planet Center, which were published in a total of seven Minor Planet Electronic Circulars (M.P.E.C.) along with the astrometry done simultaneously by the other tracking stations around the World. Fig. 3. shows the residuals of our measurements compared to the residuals of all other measurements done by professional and amateur observatories on this object.

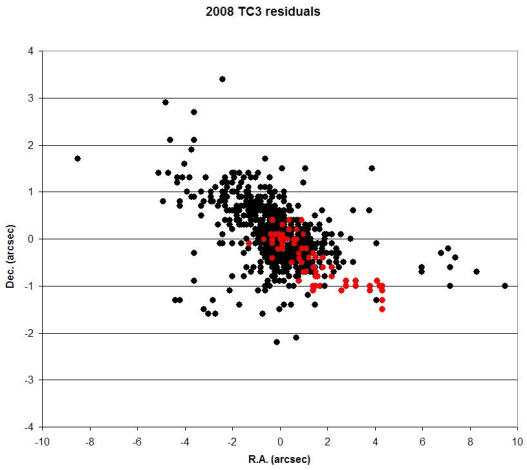

Fig. 3. Residuals of all published observations of 2008 TC3. Red dots are the residuals of our observations. Black dots are the residuals of observations done by others. The group of higher residuals in our set, to the lower right part of the plot is of those observations done near the end of visibility, when the object was moving already very fast. They are caused by timing inaccuracies in the tenths of second range.

PHOTOMETRIC OBSERVATIONS OF 2008 TC3

For the purpose of lightcurve work we tracked 2008 TC3 with a 0.40-m telescope for about 2h. To prevent the fast-moving asteroid from trailing, the exposure time had to be limited from 10s (at the start of the session) all the way down to 1s (at the end of the session). The exposures were grouped in six sessions, because the telescope had to change the field of view to keep track of the asteroid. The results of the photometric reduction are six individual lightcurves, of which only three showed periodic sequences (Fig. 4, 5 & 6). The largest amplitudes in the lightcurves are between 0.8 and 1.0 magnitudes. The errors of the measurements, estimated with the help of the reference stars) are +/-0.5 magnitudes. The shape of the periodic sequences varies between the individual lightcurves, a result of the tumbling rotation of 2008 TC3 [4]. Our lightcurves are cumulative, showing the sum of two real periods around two rotational axes. Due to lack of data we have not been able to apply the method described by Pravec et al. [4].

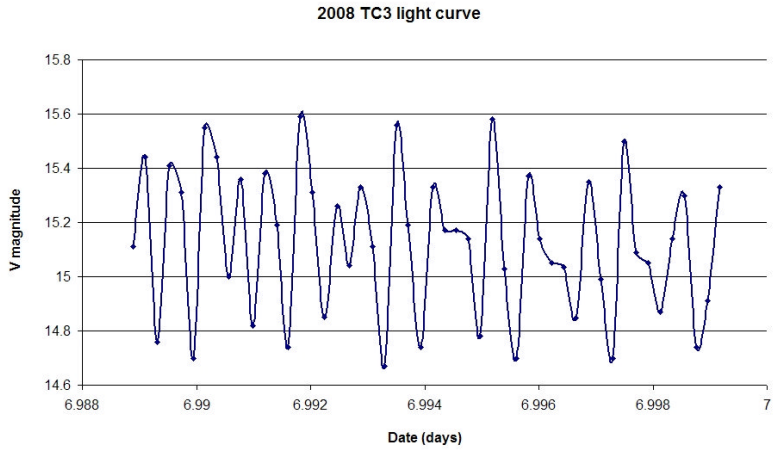

Fig. 4. Lightcurve of 2008 TC3 on 2008-10-06 between 23:44 and 23:59 UT. It contains 50 measurements. The lightcurve changed significantly during the session. The estimated period of the "periodic sequences" in the light curve is about 145 seconds.

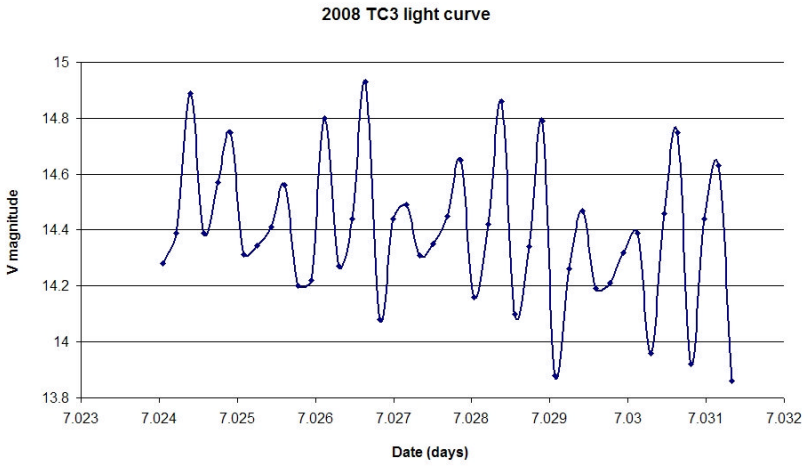

Fig. 5. Lightcurve of 2008 TC3 on 2008-10-07 between 00:34 and 00:45 UT. It contains 43 measurements and the estimated period of the periodic sequences is about 194 seconds.

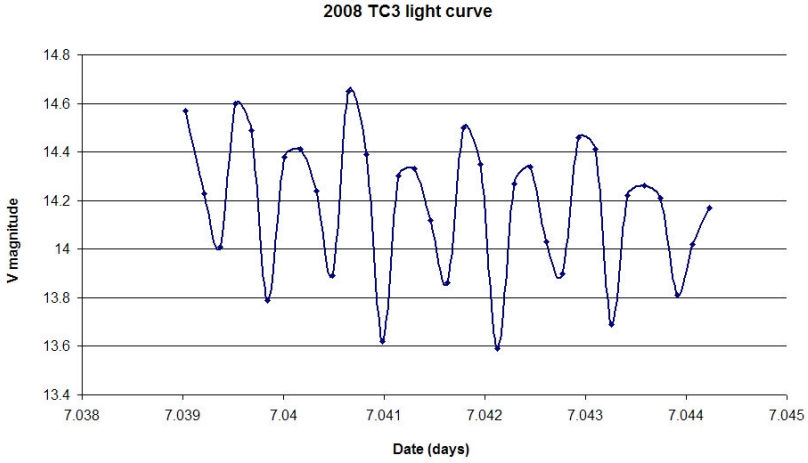

Fig 6. Lightcurve of 2008 TC3 on 2008-10-07 between 00:56 and 01:04 UT. It contains 33 measurements and the estimated period of the periodic sequences is about 97 seconds.

CONCLUSION

The atmospheric impact of an object such as 2008 TC3 is not a very rare and special event. Asteroids of this size are getting into Earth's atmosphere many times a year, and their bolides get detected. Unusually in the case of 2008 TC3 was the detection prior to atmospheric collision. The world's asteroid community (the professional and amateur astronomers, the Minor Planet Center, NEODyS and JPL) have perfectly worked together. They have proven to be able to track such an object and predict within hours after discovery where and when the object will impact.

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