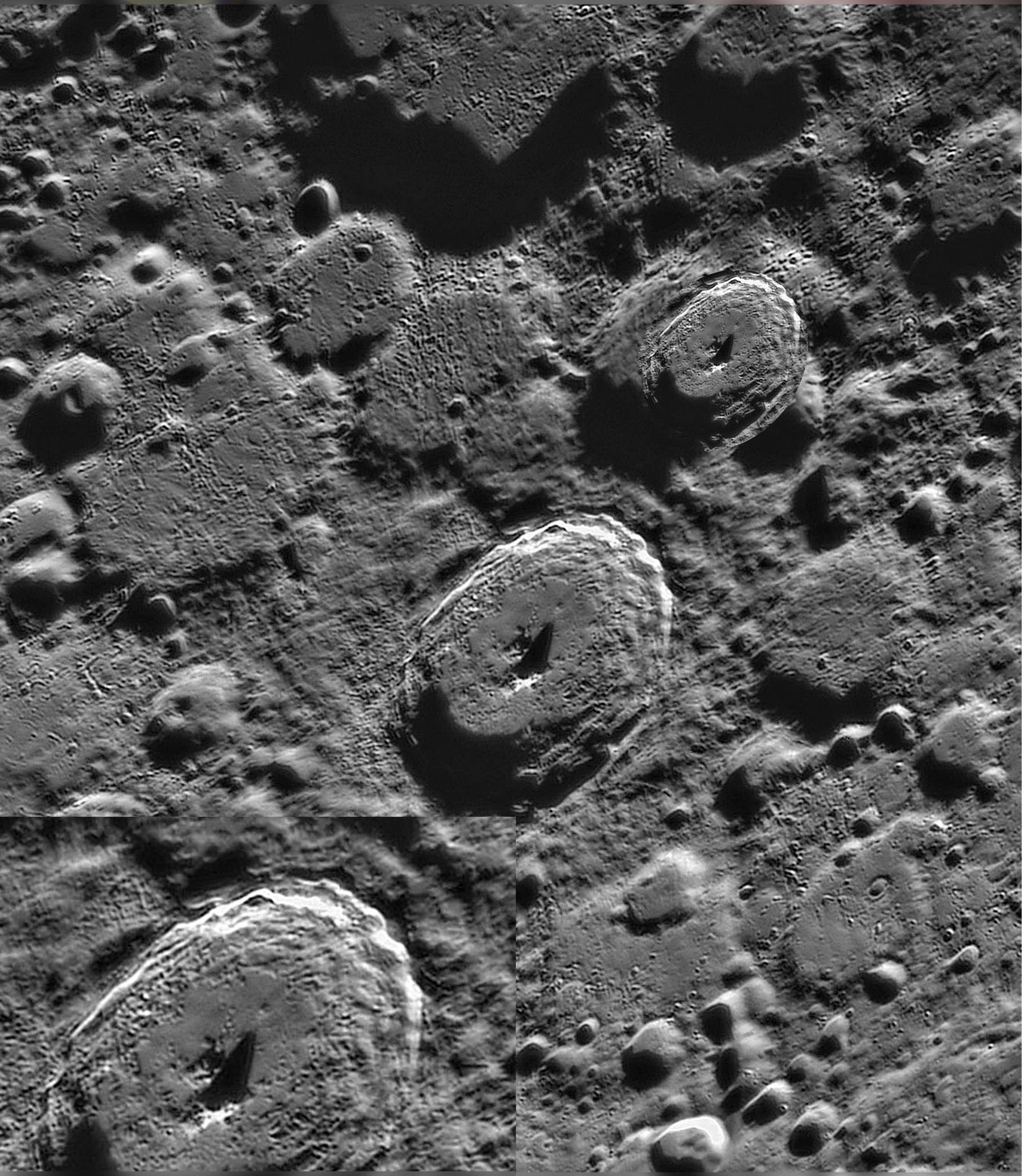
Selenology Today

ISSUE # 33, 2013



AUGUST 2013

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Selenology Today is under a reorganization, so that further comments sent to us will help for the new structure. So please doesn't exit to contact us for any ideas and suggestion about the Journal. Comments and suggestions can be sent to Raffaello Lena editor in chief :

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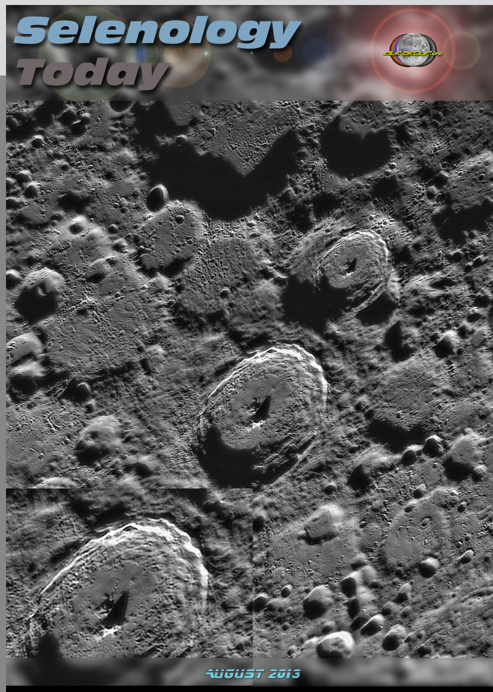

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Detection of a probable small meteoroidal impact on the Moon

By Raffaello Lena (GLR group- Roma, Italy), Andrea Manna (Cugnasco, Switzerland), Stefano Sposetti (Gnosca, Switzerland)

Abstract

In the course of our monitoring of the lunar surface during post-full Moon of August 2013, we could detect a small light flash. The flash was simultaneously recorded by four telescopes and videocams placed in Italy and Switzerland. The recorded flash was quite brief. We argue this flash is originated by meteoroidal impact. In addition the mass of the impactor for the flash occurred on August 1, 2013 at 02:21:55 UT is estimated using a nominal model with conversion efficiency from kinetic to optical energy of 2×10^{-3} and 2×10^{-2}. The results show that the meteoroid, probably attributable to the α-Capricornids shower, is to range in size from about 6 to 12 cm in diameter producing a crater of about 3-7 m in diameter.

1. Instruments and observing methods

Our observing procedure was presented and discussed in preceding articles (cf. Sposetti et al., 2011; Lena et al., 2011) published in Selenology Today N. 22, 23, 24 and 25.

During our survey we have observed from three locations with four different telescopes:

- a 130 mm refractor equipped with a Mintron MTV-12V1C-EX, located in Rome, Italy;
- a 150mm refractor and a 280mm reflector both equipped with Watec 902H2 Ultimate, located in Gnosca, Switzerland;
- a 200 mm reflector equipped with a Watec 120N+, located in Cugnasco, Switzerland.

The two observatories in Switzerland are at a distance of 10.0 km. The observatory in Italy (Rome) is at a distance of 558 km from Gnosca. Time synchronicity of the various files is assured by using a GPS time inserters (KIWI-OSD) and an Atomic Clock Synchronization protocol.

2. Detection

Table 1 shows the information about the apparent topocentric positions of the Moon, as seen from Rome. Table 2 shows the information about the impact flash detection. Figure 1 displays the lunar phase on August 1, 2013, while Fig. 2 and 3 show the location on the Moon of the detected flash.

Excluding cosmic rays:
We exclude cosmic rays because of the very low probability that they appear simultaneously in four sensors at the same lunar coordinates, and from distant observatories.

Excluding artificial satellite glints:
Specular reflection of sunlight from artificial satellites could cause very brief flashes. However, the lack of a trail and the absence of another flash in the same frame or in other frames indicate that the feature is not likely to be due to a satellite.
We used Calsky© (http://www.calsky.com/) to search for artificial satellites in the line of-sight. No known satellites within a circle of 3° diameter were found.

3. Selenographic Coordinates of the metoroidal impact

We used Photoshop in order to have a superimposition between our images by using the layers applied on resized frames.
The matching between the position of the flash in our three images is identical (cf. Fig. 3).

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The selenographic coordinates were computed using the image shown in Fig. 3, displaying several lunar features that were of very low contrast on the dark limb of the imaged lunar surface. After alignment with the edge of the lunar disk, computation of the libration, and overlay of the rotated Moon's surface matching the image, a coordinate map was superimposed on the flash image. This procedure was performed using the LTVT software package by Mosher and Bondo (2006) and the VMA software package by Legrand and Chevalley (2012). The coordinates of the flash were determined to 73° ± 4° E and 27° ± 3° N, in the region near the crater Seneca C (Fig. 4).

Observatory coordinates (GPS):
Lat. 41.94156° N and Long. 12.56089° (H=30 m).

Horizon: Azim: 90°50' Alt: +29°47'
Visibility: Rise 01:27, Set 16:26 UT August, 1, 2013
Transit time: 08:54 UT
Moon angular diameter: 00°29'87''
Moon distance: 400009 km
Lunation: 23.80 days
Illumination: 27.8%
Colongitude: 202.4°
Libration in Latitude: +03°07'
Libration in Longitude: +04°25'
Sub-solar latitude: -1.5°
Air Mass: 2.01

Table 1:
Moon data, at the moment of the detection, as seen from Raffaello Lena's observatory (Rome, Italy)

	Rome	Gnosca	Cugnasco
Observer	Lena	Sposetti	Manna
UT Time (hh:mm:ss.s)	02:21:55.7	02:21:55.7	02:21:55.7
Duration (s)	0.04 (=2 fields)	0.08 (=4 fields)[a] 0.04 (=2 fields)[b]	0.04 (=2 fields)
Max Magnitude (V)		8.3 ± 0.7 mag	

Table 2 .
Information about the flash occurred on August 1, 2013.
(a) Telescope 280mm reflector (b) Telescope 150mm refractor

Figure 1.
August 1, 2013 lunar phase. Image taken by Lena with a 130mm refractor at 03:20:10 UT. North is to the left and West to the bottom.

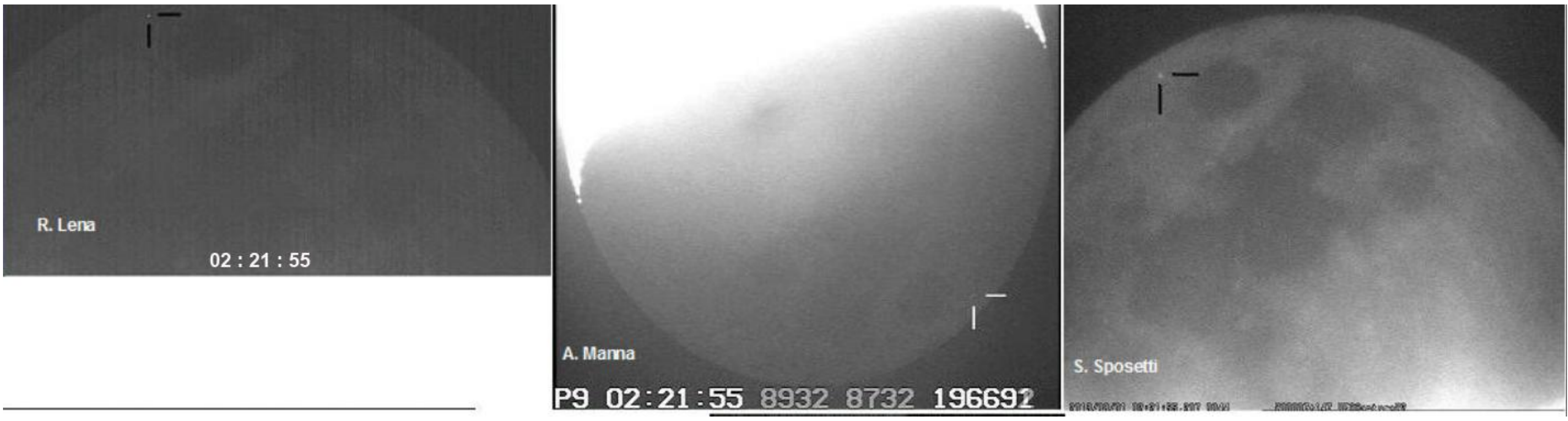
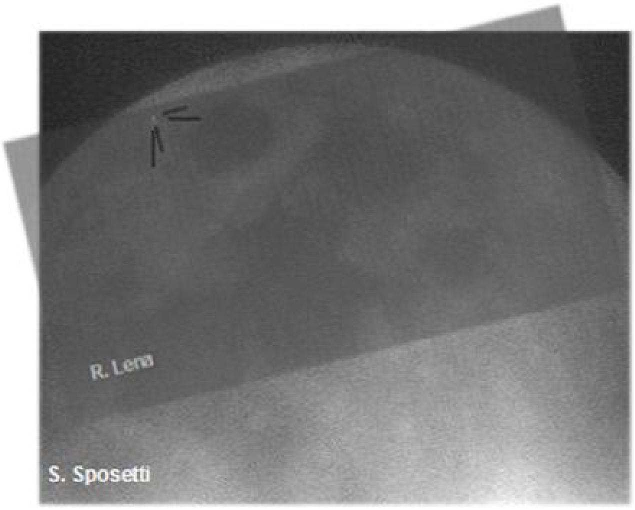


Figure 2. Detection of the impact flash (August, 1, 2013 at 02:21:55 UT) recorded simultaneously by Lena (left image) with a 130mm refractor, Manna (middle image) with a 200mm reflector and Sposetti (right image) with a 150mm refractor

Flash located in the same position (layers superimposed of the frame by Sposetti and Lena)



Flash detection

Inverted Image

Figure 3. Corresponding image composed by the superimposition method, described in the text. The matching between the position of the flash in the analyzed images is identical. North is to the left and West (lunar coordinate versus Oceanus Procellarum) to the bottom.

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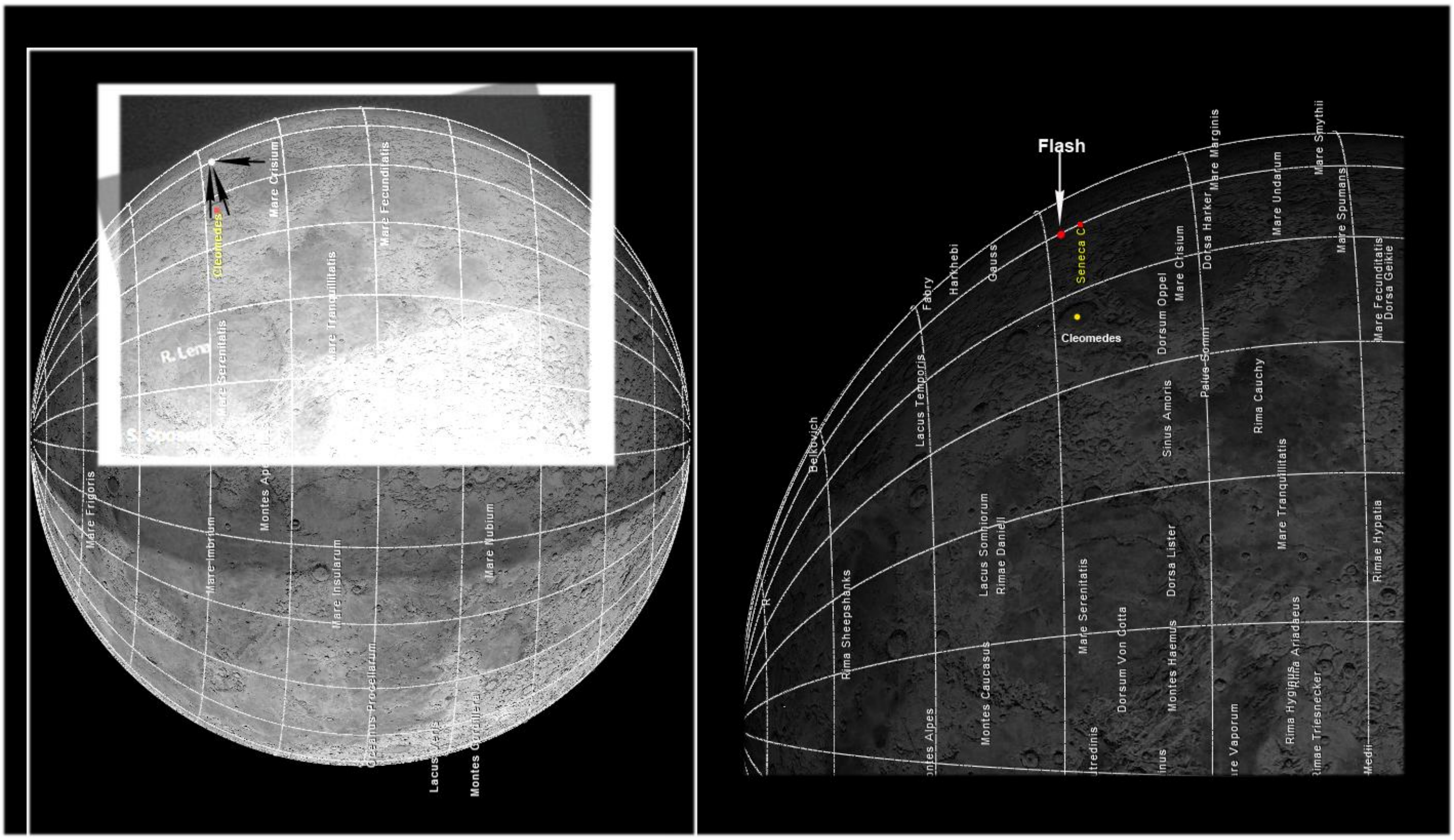

Figure 4. Selenographic Coordinates of the impact event. Lunar map and the region in which the lunar flash was detected. North is to the left and West (lunar coordinate versus Oceanus Procellarum) to the bottom.

4. Determining the brightness of the flash

We performed the method of aperture photometry and used v.1.3.0.409 of Tangra© software by Hristo Pavlov (http://www.hristopavlov.net/Tangra). This software yields "signal minus background" values. The corresponding light curve for this event is shown in Fig. 5. The whole duration of the flash corresponds to 0.08s in the Sposetti's video (Gnosca, air mass 2.33) made with the 280mm reflector, while using the refractor the flash has a shorter duration of 0.04s, lasting 2 video fields (1 field = 20ms). The flash reached a peak brightness of 8.3 ± 0.7 mag. The photometry was estimated using the star SAO 93833 (Sp.Type: F8, 9.3 mag) inside the field of view at about 02:11:32 UT.

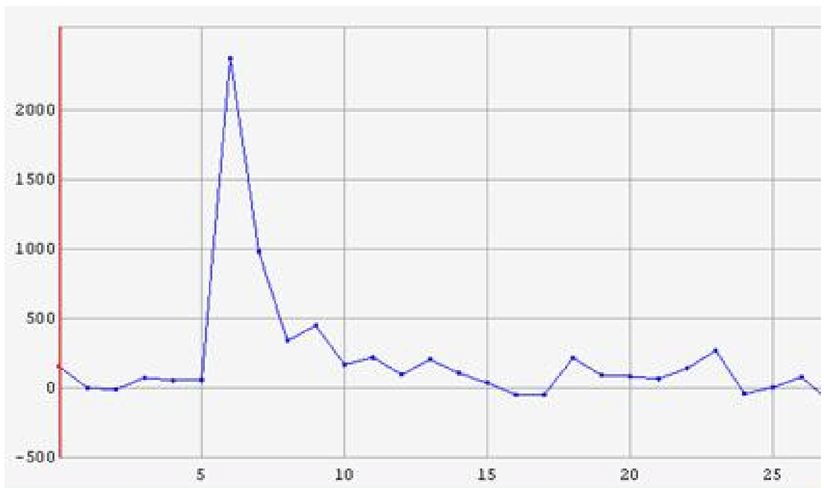

Figure 5. Light curve of the flash from the Sposetti's video made with a 280mm reflector telescope (1 interval time = 1 field = 20ms).

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5. Considerations on meteor showers

The agreement among the times and positions of the lunar flash detected by three observatories (and four telescopes) indicates that it must have been a lunar phenomena.
According to the International Meteor Organization when the flash happened, two meteor showers were active: the α-Capricornids and the Perseids (http://www.imo.net/files/data/calendar/cal2013.pdf)
However, the α-Capricornids had a predicted maximum on July 30, so that our impact can be likely attributable to the α-Capricornids shower ($V\infty$ = 23 km/s).

6. Luminous efficiencies of the impactors and initial mass estimates

According to Ortiz et al. (2006) the mass of the impactor is estimated using a nominal model with conversion efficiency from kinetic to optical energy of 2×10^{-3} and 2×10^{-2}. The parameters used in the calculation are the projectile density (2000 kg m^{-3}), the target density (2000 kg m^{-3}) and the impact velocity. Using the luminous efficiency $\eta = 2 \times 10^{-3}$ (the nominal value determined from Leonid impact flashes, e.g., Bellot Rubio et al., 2000; Ortiz et al., 2002) and the speed of the α-Capricornids (23 km/s), the mass of the impactor would be 1.88 kg. Based on the above data and assuming a spherical projectile, the diameter of the impactor was inferred to be approximately of about 12 cm. This impactor would strike the target with an energy of 5.45 x 108 Joules (0.13 x 10^{-6} MegaTons). A luminous efficiency of 2 x 10^{-2} yields a mass of the impactor and the impact energy considerably less than the preceding inferred value by a factor of 10. Using Gault's scaling law in regolith for crater sizes (Melosh, 1989; Melosh and Beyer, 1999), the size of the lunar impact crater was computed to be 6.6 m. Using the luminous efficiency $\eta = 2 \times 10^{-2}$ the mass of the impactor would be 0.188 kg with an impact crater estimated of about 3.3 m.
It should be noted, however, that these values are "nominal", since the results includes uncertainties in the projectile density, meteoroid mass and luminous efficiency.
Based on a modelling analysis the meteoroid is likely to range in size from about 6 to 12 cm in diameters and produced a crater of about 3-7 m in diameter.

7. Summary and conclusion

In this study we have described a most probably meteoroidal lunar impact detected simultaneously from four independent video recordings. The Observatories are placed in Italy (Rome) and Switzerland (Gnosca and Cugnasco). The meteoroidal impact occurred on August, 1, 2013 at 02:21:55.7 UT . The duration of the flash correspond to 0.08s in Sposetti's video. It reached a peak brightness of 8.3 ± 0.7 mag. The selenographic coordinates of the lunar impact flash are determined to 73° ± 4° E and 27° ± 3° N. The mass of the impactor is estimated to have been 1.88 kg based on a nominal model with conversion efficiency from kinetic to optical energy of 2x 10^{-3}. The results show that the meteoroid is likely to range in size from about 6 to 12 cm in diameter and produced a crater of about 3-7 m in diameter. The examined impact flash probably corresponds to a α-Capricornids shower exhibiting favourable impact geometry on the impact date.
Based on a modelling analysis, the mass of the impactor is estimated to 0.188 kg assuming a luminous efficiency of 2×10^{-2}.
Future high-resolution orbital data, e.g., from LRO spacecraft (NAC images) could allow the detection of this small crater.
The collisions of meteoroids on the Moon give rise to a wealth of phenomena that can be detected. Furthermore these studies could be used to derive properties of the meteoroids as well as properties of the soil at the impact sites. Therefore our team is planning future systematic search for shower and sporadic impact events using simultaneous ground based observations.

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