Detection of a Meteoroidal Impact on the Moon near the crater Seneca C. R. Lena[1], A. Manna[2], S. Sposetti[3] - [1]Geologic Lunar Research (GLR) Group, Via Cartesio 144, sc. D, 00137 Rome, Italy; r.lena@sanita.it; [2]Società Astronomica Ticinese Observatory Cugnasco, via alla Motta 34, 6516 Cugnasco (Switzerland), andreamanna@sunrise.ch; [3] In Fun I Vign 7, CH-6525 Gnosca, Switzerland, stefano@sposetti.ch

Introduction: On November 18, 1999, the first confirmed lunar meteoritic impacts were recorded in the form of flashes that resulted from the collision of the Moon with debris within the Leonid meteoroid stream [1]. Since these initial successes, other meteor swarms have been shown to produce lunar impacts [2-5]. NASA's Meteoroid Environment Office is conducting a survey of meteoroids striking the lunar surface. Rates and distribution of impactors, shower and sporadic, have been discussed by Cooke et al. in [6].

We carried out a survey on August 1, 2013 from 3 observatories (2 in Switzerland and 1 in Italy). At 02:21:55 UT, an impact was simultaneously recorded by 4 telescopes located in the 3 observatories. The two swiss observatories are at a distance of 10.0 km. The observatory in Italy (Rome) is at a distance of 558 km from Gnosca.

Methods and instruments: Time synchronicity of the various files is assured by using GPS time inserters (KIWI-OSD and IOTA-VTI) and an Atomic Clock Synchronization protocol. The selenographic coordinates of the flash were computed using our images displaying several lunar features that were of very low contrast on the dark limb of the imaged lunar surface. The photometry of the flash was estimated using the star SAO 93833 (Sp.Type F8; 9.3 magV) inside the field of view at about 02:11:32 UT. We performed the method of aperture photometry using the software *Tangra*® which delivers "signal minus background" values.

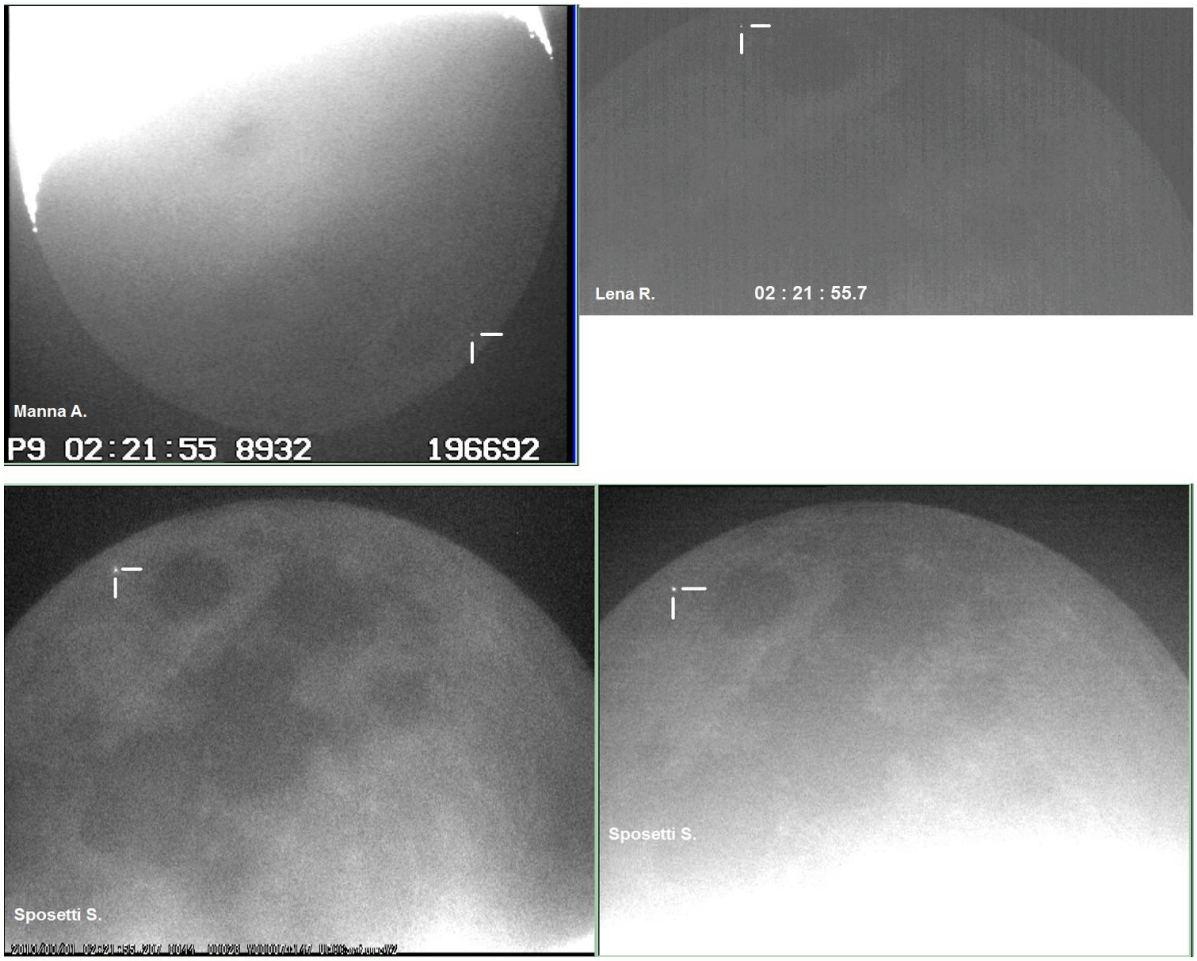

Fig. 1: Flash detected on August, 1, 2013 at 02:21:55.7 UT. Top left: 200 mm reflector equipped with a Watec 120N+, Cugnasco, Switzerland. Top right: 130 mm refractor equipped with a Mintron MTV-12V1C-EX, Rome, Italy. Bottom: 150 mm refractor (left) and 280 mm reflector (right) both equipped with Watec 902H2 Ultimate, Gnosca, Switzerland. Two observatories in Switzerland are separated by 10 km, while the observatory in Rome is 558 km from Gnosca.

Analysis: The flash reached a peak brightness of 8.3 ± 0.7 mag (airmass 2.33). The whole duration of the flash corresponds to about 0.08s in the Sposetti's video (Gnosca) made with the 280 mm reflector, while using smaller telescopes the flash has a shorter duration of 0.04s, lasting 2 video fields (1 field = 20ms). The coordinates of the flash were determined to 73° ± 4° E and 27° ± 3° N, in the region near the crater Seneca C (Fig. 3).

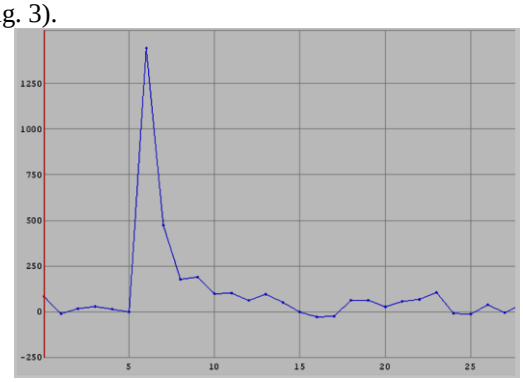

Fig. 2: Light curve of the flash from the Sposetti's video made with a 280mm reflector telescope (1 interval time = 1 field = 20ms). Photometry carried out using the software *Tangra®* by Pavlov (www.hristopavlov.net/Tangra).

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. 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.

According to the International Meteor Organization [8] when the flash happened, two meteor showers were active: the α-Capricornids and the Perseids. The α-Capricornids had a predicted maximum on July 30, so our impact could be likely attributable to this shower ($V_\infty = 23$ km/s). The mass of the impactor is estimated to be 1.8 kg based on a nominal model with conversion efficiency from kinetic to optical energy of $2x\ 10^{-3}$.

A luminous efficiency of 2×10^{-2} yields a mass of the impactor considerably less than the preceding inferred value by a factor of 10 [7]. 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 (Gault's scaling law in regolith for crater sizes) the meteoroid is likely to range in size from about 6 to 12 cm in diameters and produced a crater of about 2-10 m in diameter [9].

References: [1] Cudnik et al. (2003) *Earth, Moon and Planets 93*, 145-161; [2] Yanagisawa et al. (2006) *Icarus 182*, 489–495; [3] Ortiz et al. (2000) *Nature 405*, 921-923; [4] Ortiz et al. (2002) *Astrophys. J. 576*, 567–573; [5] Cooke et al. (2006) *LPSC XXXVII*, Abstract #1731 [6] Cooke et al. (2007) *LPSC XXXVIII*, Abstract #1986; [7] Ortiz et al. (2006) *Icarus 184*, 319-326; [8] http://www.imo.net/files/data/calendar/cal2013.pdf; [9] Melosh (1989). *Impact Cratering: A Geologic Process.* Oxford Univ. Press, New York

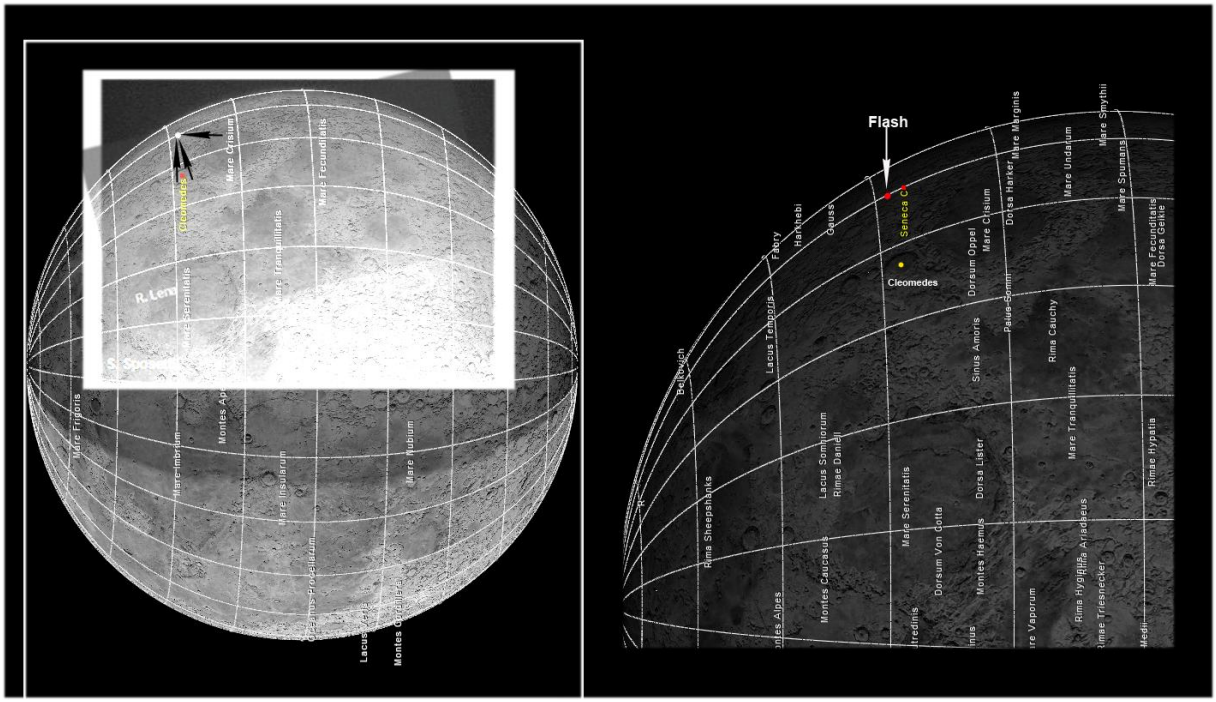

Fig. 3: Selenographic Coordinates of the impact event. Lunar map and the region in which the lunar flash was detected. North is to the left and West (lunar coordinate versus Oceanus Procellarum) to the bottom.