Selenology Today

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Selenology Today

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This is last issue of ST where I am the editor. I will work for the BAA as lunar domes project coordinator. As last editor i will thank you readers of the last years and the editors Jim Phillips, George Tarsoudis and Maria Teresa Bregante for last issues developed.

Thanks to Chuck Wood that mentioned this journal many times with a lot of LPODS! His comments are appreciated.

Raffaello Lena
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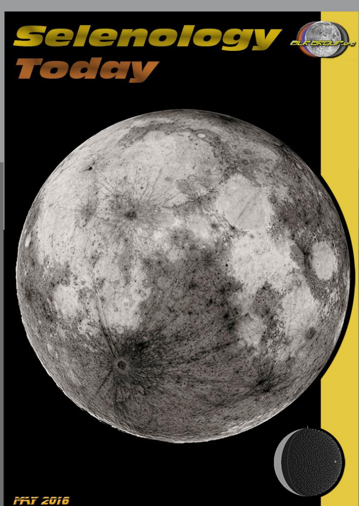
COVER

Blue Moon of August 02th 2012



by George Tarsoudis

ISSUE # 39, 2016

Selenology Today

Six probable meteoroidal impacts on the Moon detected in 2015

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Abstract

We report the detection of six luminous events probably generated by meteoroidal impacts on the lunar surface during year 2015. Such flashes were recorded by telescopes equipped with videocams.

1. Instruments and observing methods

Our equipment and observing procedure was presented and discussed in preceding reports published in [1] [2] [3] [4] [5].

The telescopes and the locations from we observed were:

- a 125 mm refractor located in Gordola, Switzerland
- a 280 mm reflector located in Gnosca, Switzerland
- a 200 mm reflector located in Locarno, Switzerland

All instruments were equipped with Watec 902H2 Ultimate working in CCIR mode. GPS time inserters (KIWI-OSD and IOTA-VTI) printed the Universal Time with millisecond precision in the video frames. Time synchronicity of the recorded files was assured.

2. Detections

Table 1 shows all important informations about the detections. Some of them were calculated using the software TheSkySix ®.

2.1. Artificial satellites

We checked for artificial satellites in the field of views with www.calsky.com © in order to check for possible sunlight glints on their surfaces.

For the event N.1 no satellites were along the line of sight in a 3° diameter circle centred on the Moon at the specified time.

For the event N.2 the nearest satellite was Picard (36598 2010-028-A) at an angular distance of 53 arcmin from the Moon center.

For the event N.3 the nearest satellite was DSP F21 Rocket Part 3 (26883 2001-033-D) at an angular distance of 47 arcmin from the Moon center.

For the event N.4 the nearest satellite was SL-12 R/B (36407 2010-007-H) at an angular distance of 19 arcmin from the Moon center.

For the event N.5 the nearest satellite was USA 153/DSCS 3B-11 (26575 2000-065-A) at an angular distance of 44 arcmin from the Moon center.

For the event N.6 the nearest satellite was CZ-3B DEB (40192 2011-077-R) at an angular distance of 1.1 arcdeg from the Moon center.

We exclude that these events were caused by sunlight reflections of these satellites.

2.2. Luminosity

We could evaluate the maximum luminosity (during the 20 ms field integration time) of flashes N. 2 and N. 4, because the star HIP 56941 (Sp.Type A8/9V D, 6.90 magV) was in the field of view at about 04:42 UT. The flash N. 2 reached a peak brightness of 8 magV, the flash N. 4 a peak brightness of 9 magV. During the flash N. 3 some thin clouds covered the target of view. Informations about the star were extracted from http://cdsweb.u-strasbg.fr/ ©. All lightcurves were produced with the software Limovie ®

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	Event N. 1	Event N. 2	Event N. 3	Event N. 4	Event N. 5	Event N. 6
Date	25 January 2015	07 November 2015	07 November 2015	07 November 2015	08 November 2015	15 November 2015
UTC Time (hh:mm:ss)	18:29:13	03:31:26	04:14:07	05:06:45	05:14:09	18:13:57
Duration (s)	0.06	0.06	0.06	0.06	0.06	0.04
N. Fields	3	3	3	3	3	2
Magnitude (V)	not measured	~ 8	not measured	~ 9	not measured	not measured
Selenographic Coordinates	54.2° E ; 19.3° N	50.9° E ; 24.0° N	48.8° E ; 0.7° S	62.4° E ; 4.9° S	28.4° E ; 7.3° S	52.2° W ; 11.2° N
Lunar region	South West from Schiapparelli crater	North edge of Mare Crisium, West of Eimmart crater	Mare Fecunditatis, North East of Messier crater	Mare Fecunditatis, North of Langrenus crater	South of Torricelli crater	Near Marius crater
Probable type of meteoroid	SPO	ORI, NTA, STA, SPO	ORI, NTA, STA, SPO	ORI, NTA, STA, SPO	ORI, NTA, STA, SPO	NTA, STA, SPO
Captured in	2 telescopes	1 telescope	1 telescope	1 telescope	1 telescope	1 telescope
Moon Coordinates (Eq. 2000.0)	RA:01 02 DE:+05 38	RA:11 40 DE:+01 13	RA:11 40 DE:+01 07	RA:11 42 DE:+00 59	RA:12 27 DE:-02 46	RA:18 37 DE:-18 51
Moon Horizon Coordinates	Az:228 11 Alt:+39 14	Az:106 07 Alt:+16 25	Az:114 38 Alt:+23 05	Az:126 20 Alt:+30 39	Az:120 57 Alt:+22 42	Az:233 32 Alt:+06 48
Moon Phase (%)	34.4	18.0	17.8	17.6	11.0	15.2
Air Mass	1.58	3.52	2.55	1.96	2.59	7.99
Moon angular diameter (arcmin)	32.2	29.5	29.5	29.5	29.5	30.8
Observing Site 1 (S. Sposetti)	Gnosca	Gnosca	Gnosca	Gnosca	Gnosca	Locarno
Telescope Site 1	280mm reflector	280mm reflector	280mm reflector	280mm reflector	280mm reflector	200mm reflector
Videocamera Site 1 (CCIR mode)	Watec 902H2Ult	Watec 902H2Ult	Watec 902H2Ult	Watec 902H2Ult	Watec 902H2Ult	Watec 902H2Ult
Observing Site 2 (M. Iten)	Gordola	-	-	-	-	-
Telescope Site 2	125mm refractor	-	-	-	-	-
Videocamera Site 2 (CCIR mode)	Watec 902H2Ult	-	-	-	-	-

Table 1. Informations about the events, the Moon and the observing sites.

3. Active Meteor Showers

Accordingly to the predictions of the software Lunarscan © no meteor showers were active around 2015 Jan 25. The images 1 and 2 show the meteor showers around 2015 Nov 07/08 accordingly to Lunarscan ©. The image 3 shows the meteor showers around 2015 Nov 15.

We can infer that:
- the impact flash N.1 was probably caused by a sporadic meteoroid.
- the impact flash N.2 was probably caused by a ORI, NTA, STA or a sporadic meteoroid.
- the impact flash N.3 was probably caused by a ORI, NTA, STA or a sporadic meteoroid.
- the impact flash N.4 was probably caused by a ORI, NTA, STA or a sporadic meteoroid.
- the impact flash N.5 was probably caused by a ORI, NTA, STA or a sporadic meteoroid.
- the impact flash N.6 was probably caused by a NTA, a STA or a sporadic meteoroid.

4. Size of the probable impactors and of their produced craters

According to Ortiz et al. (2000) 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 (2700 kg m^{-3}), the target density (2000 kg m^{-3}) and the impact velocity.

In this study the same formalism and equations as in the works by Bellot Rubio et al. (2000), Ortiz et al. (2000), Ortiz et al. (2002), and Carbognani (2000) was followed, including the kinetic energy that is translated into impactor mass assuming a typical sporadic impactor speed. According to the statistics of a large meteoroid orbit database (Steel, 1996) this speed is approximately 20.2 km s^{-1} on Earth and 16.9 km s^{-1} on the Moon, after correcting for the different escape velocities of the Earth and the Moon.
Moreover a short routine provided by Melosh and Beyer (1999) was used to evaluate the scaling equations to determine the diameter of a crater given details on the nature of the projectile, conditions of impact, and state of the target. The transient crater diameter is evaluated by three independent methods, yield scaling, pi-scaling and Gault's semi-empirical relations supplemented by rules on how crater size depends on gravity and angle of impact.
The parameters used in the calculation for flash 2 are the projectile density, the target density (2700 kg m^{-3}), the impact velocity (16.9 km s^{-1}), the peak brightness

(8.0 MagV) and the duration of 0.06 seconds. 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), the mass of the impactor would be 0.031 kg. Based on the above data and assuming a spherical projectile, the diameter of the impactor was inferred to be approximately between 3 and about 6 cm considering a bulk density ranging between 0.3 g cm^{-3} (soft cometary material) to 3.7 g cm^{-3} (corresponding to ordinary chondrites). If the meteorid is associated as a sporadic source, the impact angle is unknown. We have used the most likely angle of 45° to estimate the size of the crater produced by the impact.

Using the Pi-scaled law for transient craters, the final crater would be a simple crater with a rim-to-rim diameter of about 2-5 m.
The parameters used in the calculation for flash 4 are the projectile density, the target density (2700 kg m^{-3}), the impact velocity (16.9 km s^{-1}), the peak brightness (9.0 MagV) and the duration of 0.06 seconds. 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), the mass of the impactor would be 0.013 kg. Based on the above data and assuming a spherical projectile, the diameter of the impactor was inferred to be approximately between 2 and about 5 cm considering a bulk density ranging between 0.3 g cm^{-3} (soft cometary material) to 3.7 g cm^{-3} (corresponding to ordinary chondrites). If the meteorid is associated as a sporadic source, the impact angle is unknown. We have used the most likely angle of 45° to estimate the size of the crater produced by the impact.

Using the Pi-scaled law for transient craters, the final crater would be a simple crater with a rim-to-rim diameter of about 2-4 m, according to average values estimated for our previous impacts. It should be noted, however, that these values are “nominal”, since the results includes uncertainties in the projectile density, meteoroid mass, and luminous efficiency.

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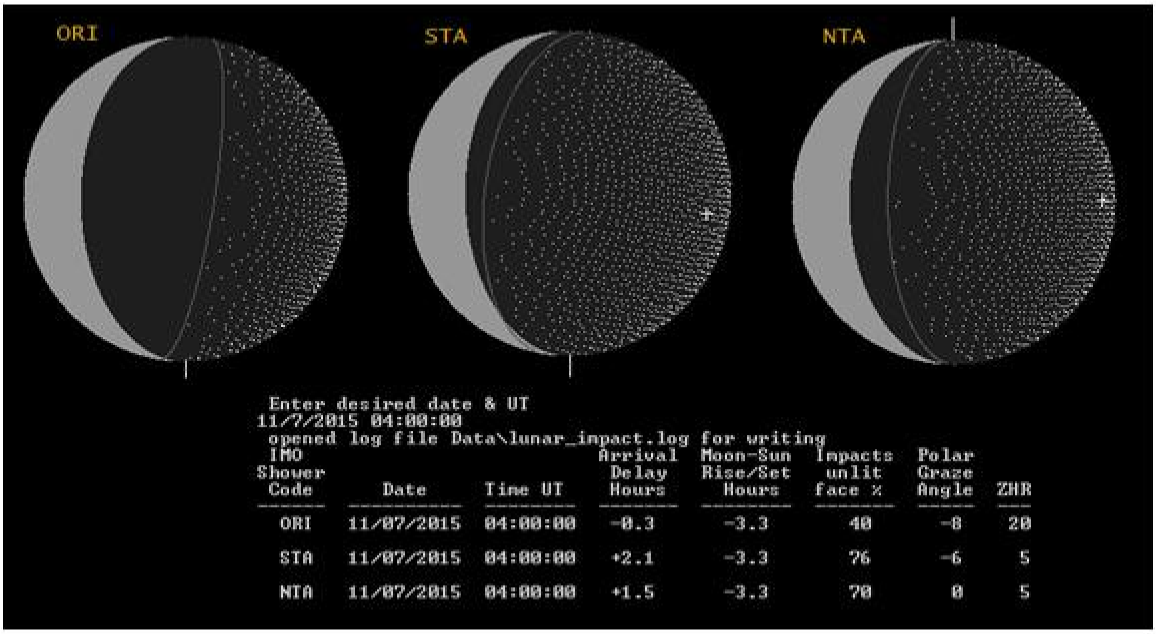

Image 1. Impact geometries of the active meteor showers when flashes N. 2, 3 and 4 happened.

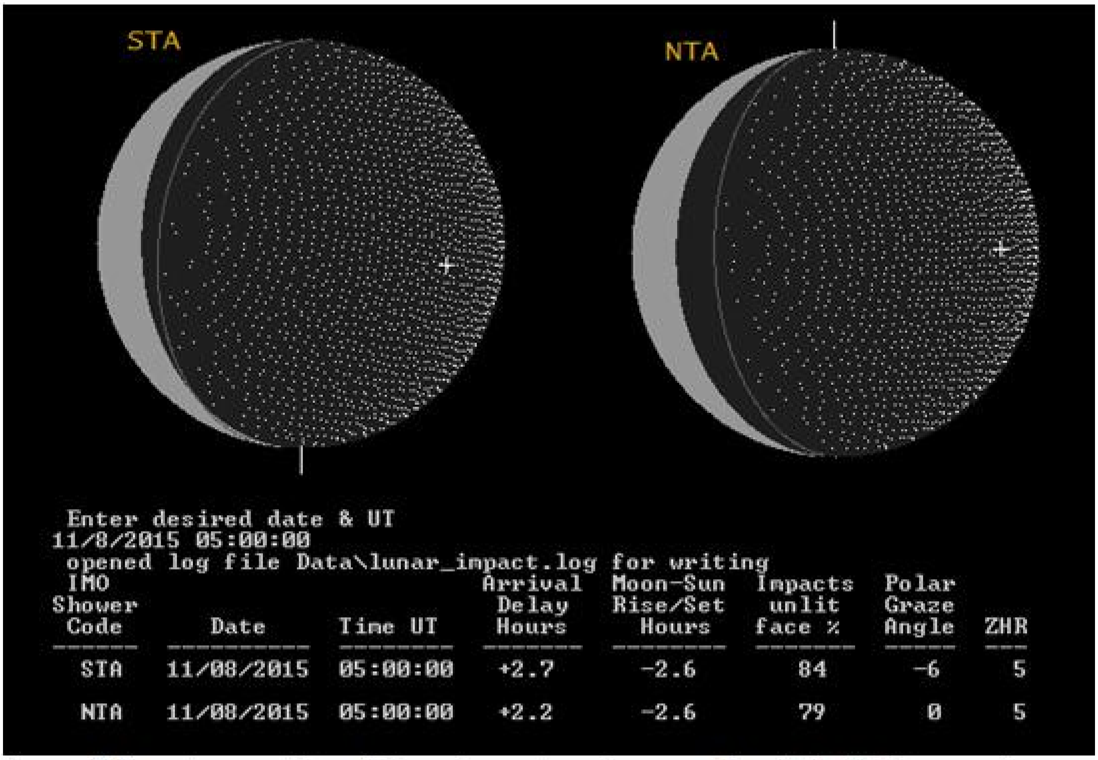

Image 2. Impact geometries of the active meteor showers when flash N. 5 happened.

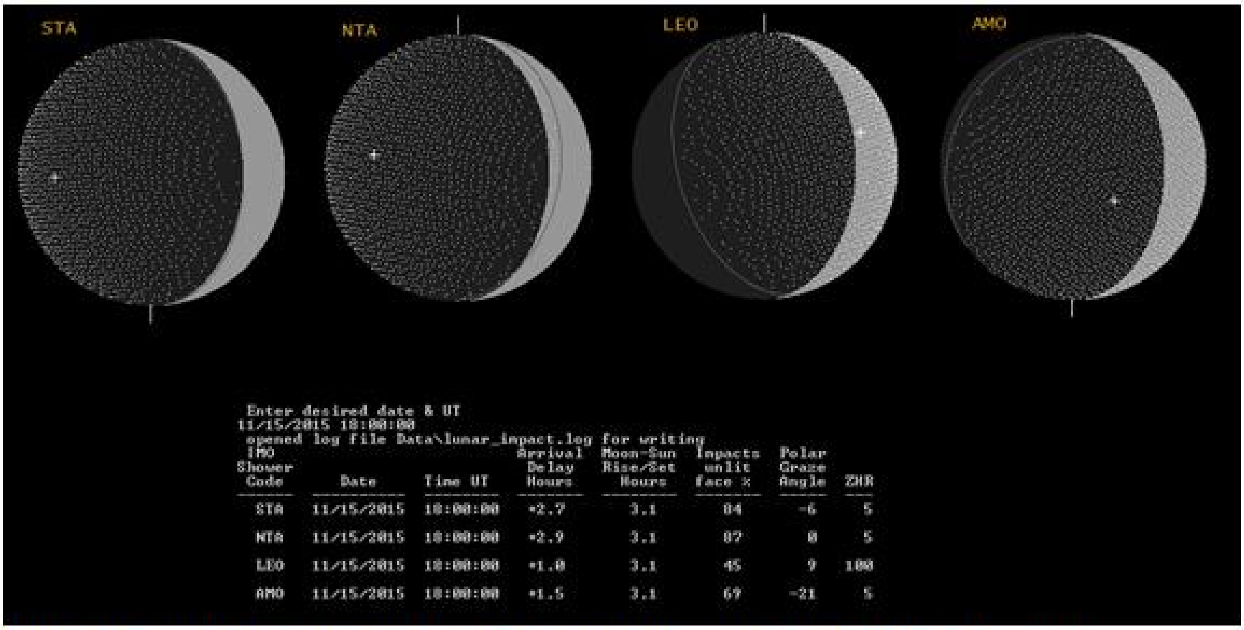

Image 3. Impact geometries of the active meteor showers when flash N. 6 happened.

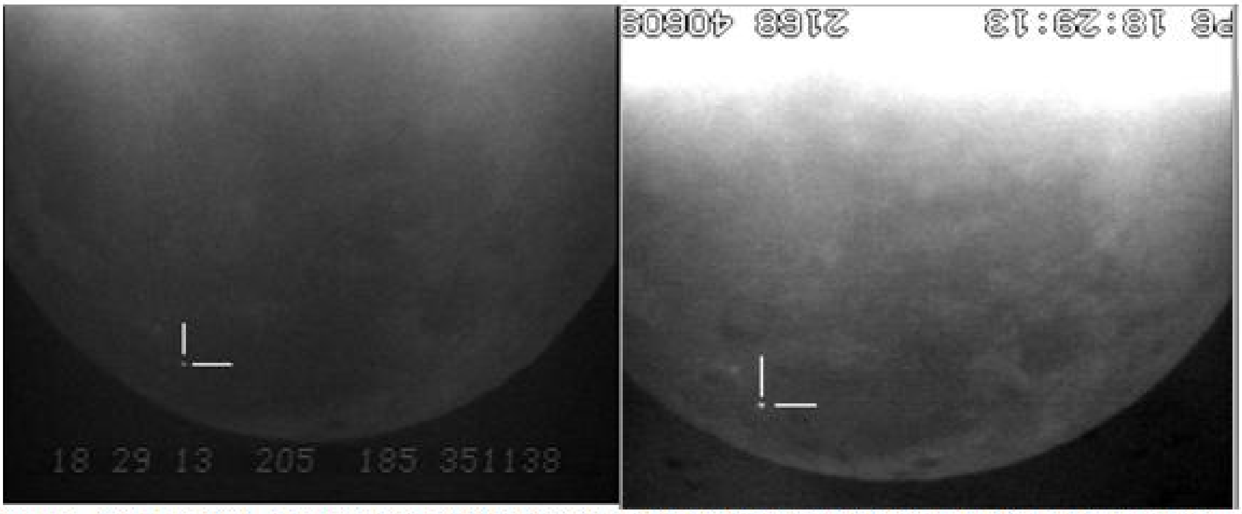

Image 4. Flash N. 1, occurred the 2015 Jan 25 at 18:29:13 UT in M. Iten (left) and S. Sposetti (right) recordings.

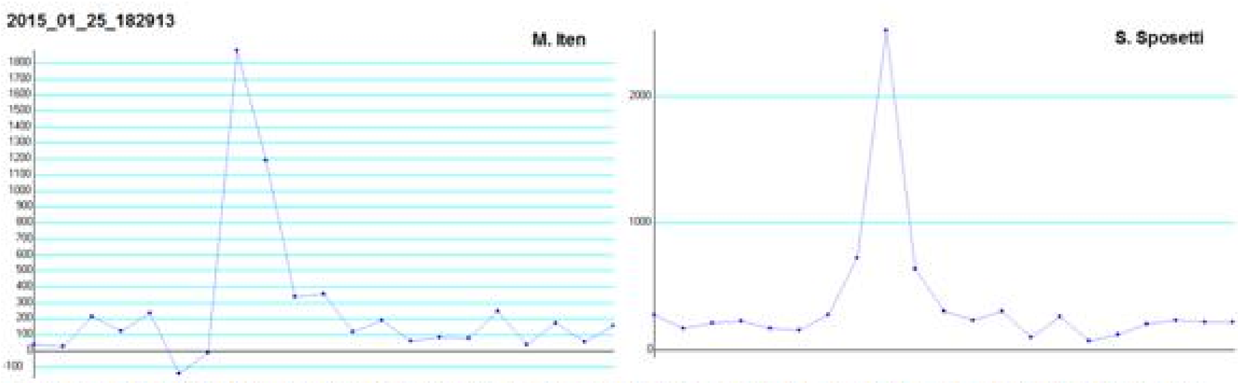

Image 5. Lightcurves plotting the intensity versus time of the flash N.1 in Iten and Sposetti's recording. Every dot represents one field, ie. 20 ms.

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Image 6. Flash N. 2, occurred the 2015 Nov 7 at 03:31:26 UT in S. Sposetti recording.

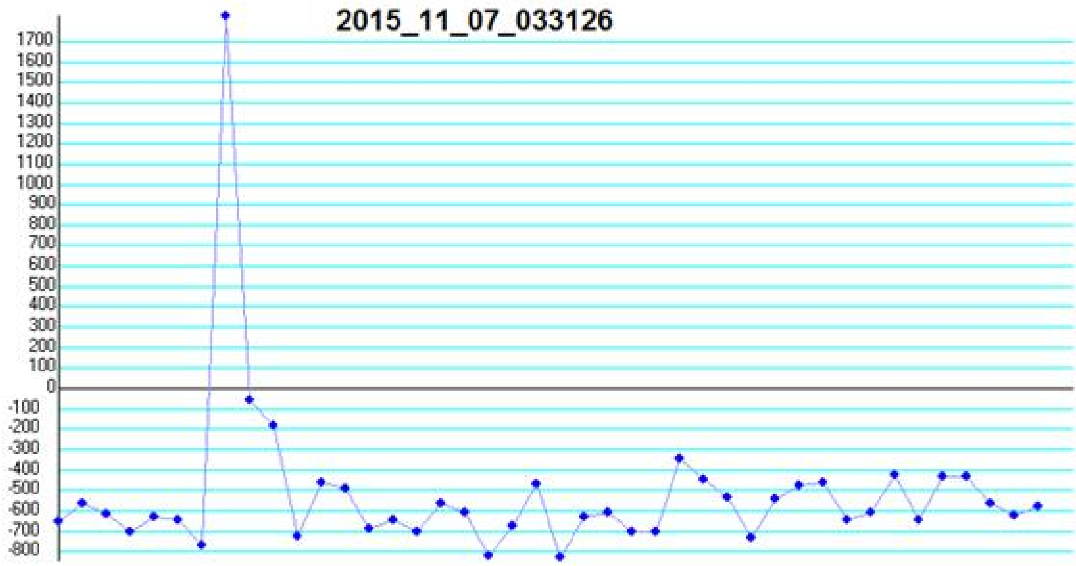

Image 7. Light intensity versus time of the flash N. 2. Every dot represents one field, ie. 20 ms.

Image 8. Flash N. 3, occurred the 2015 Nov 7 at 04:14:07 UT in S. Sposetti recording. Some thin clouds covered the Moon.

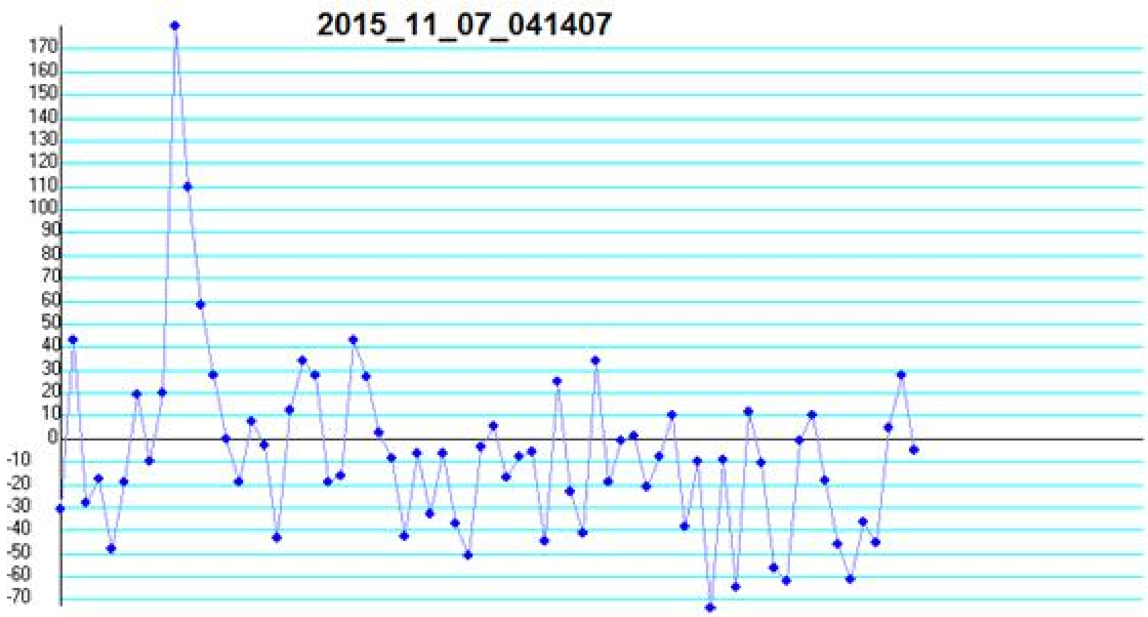

Image 9. Light intensity versus time of the flash N. 3. Every dot represents one field, ie. 20 ms.

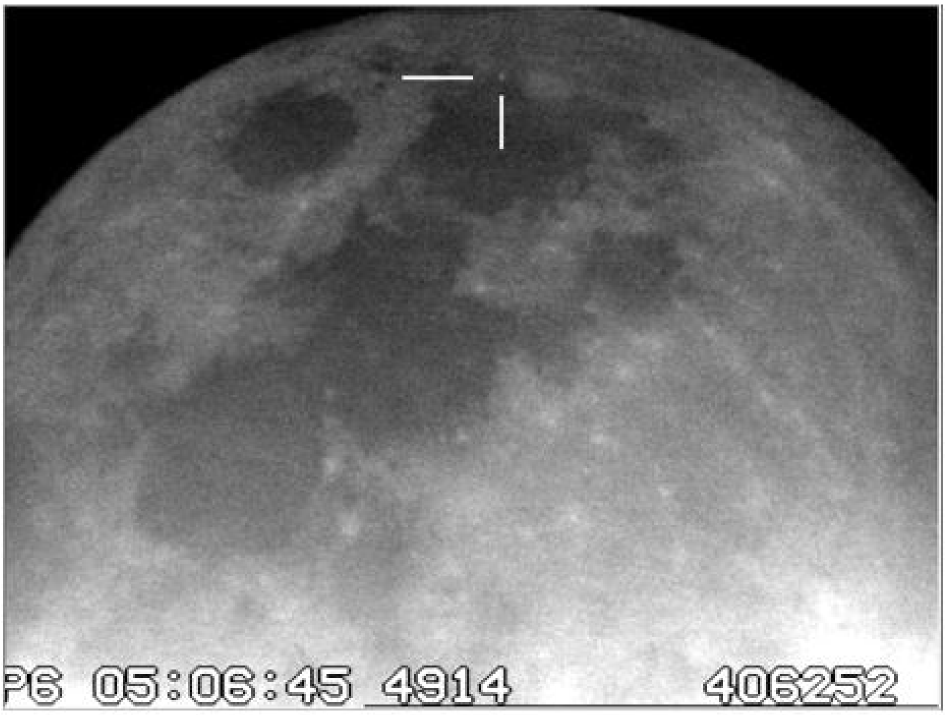

Image 10. Flash N. 4, occurred the 2015 Nov 7 at 05:06:45 UT in S. Sposetti recording.

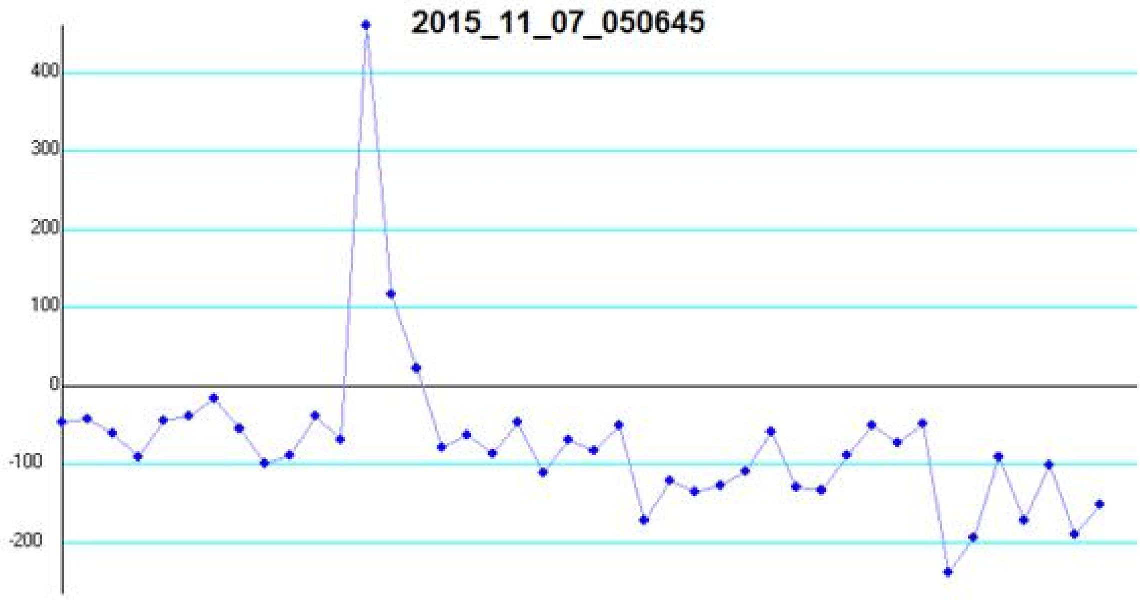

Image 11. Light intensity versus time of the flash N. 4. Every dot represents one field, ie. 20 ms.

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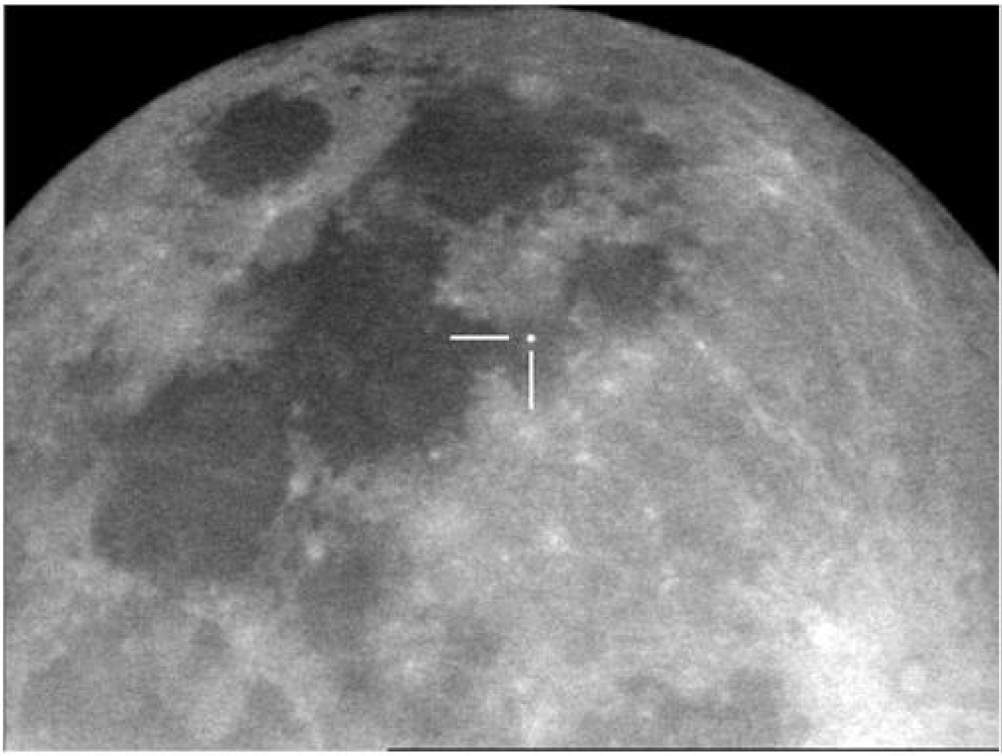

Image 12. Flash N. 5, occurred the 2015 Nov 8 at 05:14:09 UT in S. Sposetti recording.

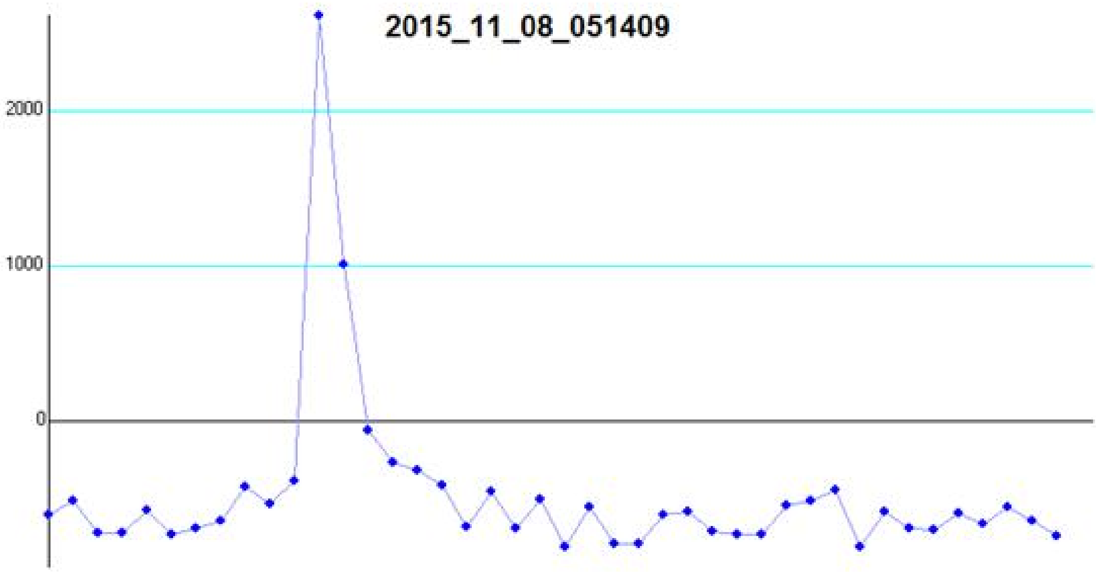

Image 13. Light intensity versus time of the flash N. 5. Every dot represents one field, ie. 20 ms.

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Image 14. Flash N. 6, occurred the 2015 Nov 15 at 18:13:57 UT in S. Sposetti recording. Some turbulence affected the quality of the images. The airmass was about 8.

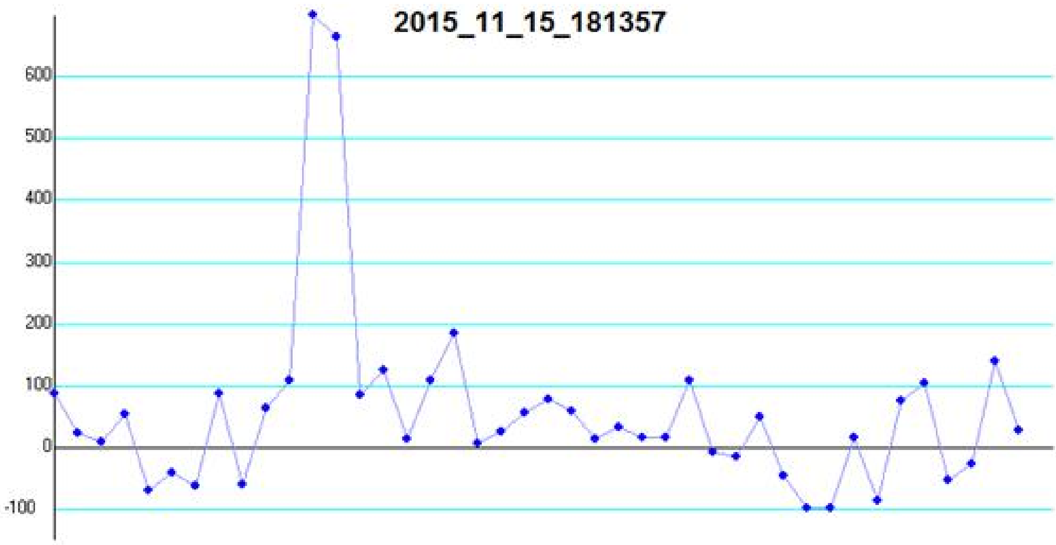

Image 15. Light intensity versus time of the flash N. 6. Every dot represents one field, ie. 20 ms.

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[2] Lena, R., Iten, M., Sposetti, S., 2011. Detection of three meteoroidal impact on the Moon. Selenology Today 24, 12-29.
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[11] Melosh, H.J., and Beyer, R. A. 1999. Computing Crater Size from Projectile Diameter.

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Results of the detection of meteoroidal impacts on the Moon in 2014

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(b) BAA Lunar Section
(c) Gnosca Observatory

Abstract

We report the detection of two luminous events probably generated by meteoroidal impacts on the lunar surface during post-new Moon periods in 2014. Such flashes were simultaneously recorded by two telescopes equipped with videocams. The instruments were separated by some kilometers.

1. Instruments and observing methods

Our equipment and observing procedure was presented and discussed in preceding reports published in Selenology Today [1] [2] [3] [4] [5] [6].

We observe with different telescopes from different locations:

- a 125 mm refractor, located in Gordola, Switzerland.
- a 280 mm reflector located in Gnosca, Switzerland.

The instruments are equipped with Watec 902H2 Ultimate videocameras. GPS time inserters (KIWI-OSD and IOTA-VTI) print the Universal Time with millisecond precision in the video frames. Time synchronicity of the recorded files is therefore assured.

2. Detections

Table 1 shows all important informations about the detections. Some of them were calculated using TheSkySix (R) software. We could evaluate the maximum luminosity only of one event.

We checked for artificial satellites in the field of views with www.calsky.com © . No satellites were on the line of sight in a 3° diameter circle centred on the Moon at the specified times.

3. Active Meteor Showers

No very active meteor shower was present in the dates of the events N.1, N.2.
Images N. 1 and 2 show the active showers accordingly to the predictions of the Lunarscan © software.
Delta-Cancrids (DCA) and Coma Berenicids (COM) were present the 2014 Jan 7.
Because of the low ZHR of the two mentioned showers we think that the nature of the meteoroid is sporadic.
Delta-Leonids (DLE), Gamma-Normids (GNO) and Virginids (VIR) were present the 2014 Mar 6.
The nature of the probably impacted meteoroid can be either GNO or sporadic.

4. Size of the probable impactors and of their produced craters

According to Ortiz et al. (2000) 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 (2700 kg m $^{-3}$), the target density (2000 kg m $^{-3}$) and the impact velocity.

In this study the same formalism and equations as in the works by Bellot Rubio et al. (2000), Ortiz et al. (2000), Ortiz et al. (2002), and Carbognani (2000) was followed, including the kinetic energy that is translated into impactor mass assuming a typical sporadic impactor speed. According to the statistics of a large meteoroid orbit database (Steel, 1996) this speed is approximately 20.2 km s^{-1} on Earth and 16.9 km s^{-1} on the Moon, after correcting for the different escape velocities of the

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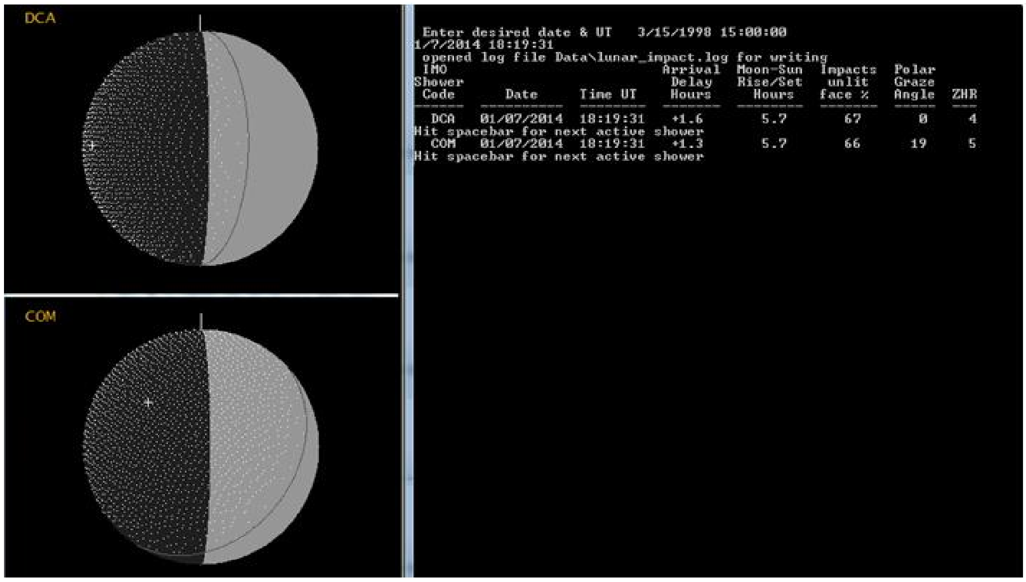

Image 1. Impact geometries of the active meteor showers when flash N.1 happened.

Earth and the Moon.

Moreover a short routine provided by Melosh and Beyer (1999) was used to evaluate the scaling equations to determine the diameter of a crater given details on the nature of the projectile, conditions of impact, and state of the target. The transient crater diameter is evaluated by three independent methods, yield scaling, pi-scaling and Gault's semi-empirical relations supplemented by rules on how crater size depends on gravity and angle of impact.

The parameters used in the calculation are the projectile density, the target density (2700 kg m^{-3}), the impact velocity (16.9 km s^{-1}), the peak brightness (9.0 MagV) and the duration of 0.04 seconds. 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), the mass of the impactor would be 0.083 kg. Based on the above data and assuming a spherical projectile, the diameter of the impactor was inferred to be approximately between 2 and about 4 cm considering a bulk density ranging between 0.3 g cm^{-3} (soft cometary material) to 3.7 g cm^{-3} (corresponding to ordinary chondrites). If the meteorid is associated as a sporadic source, the impact angle is unknown. We have used the most likely angle of 45° to estimate the size of the crater produced by the impact.

Using the Pi-scaled law for transient craters, the final crater would be a simple crater with a rim-to-rim diameter of about 2-4 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.

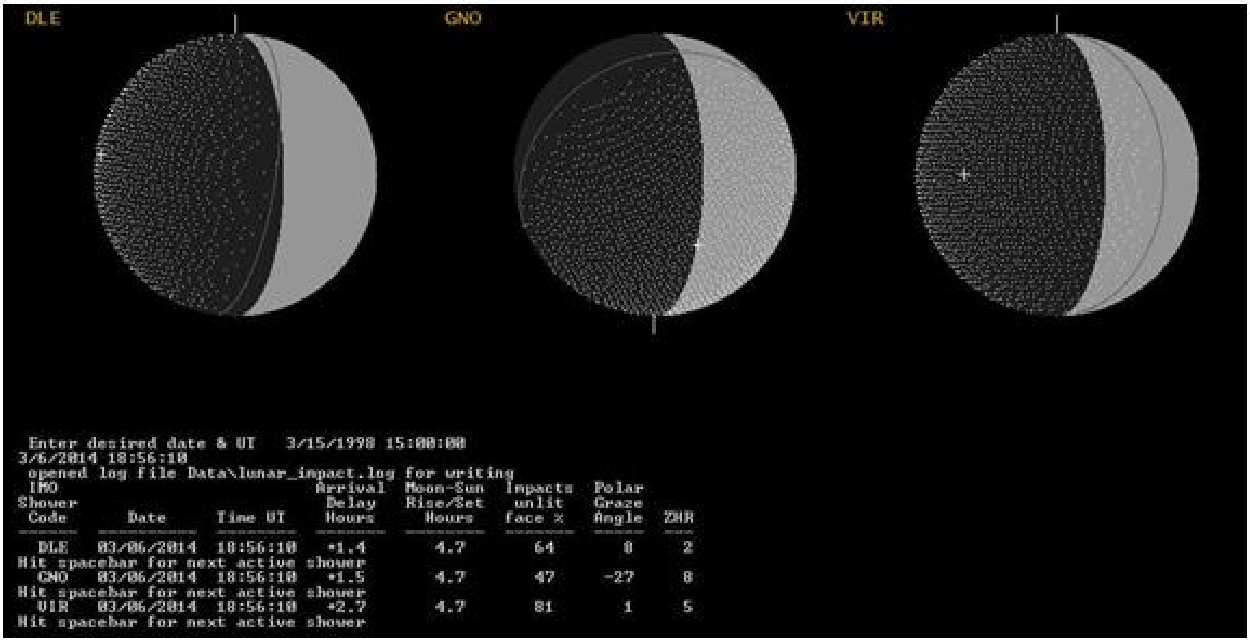

Image 2. Impact geometries of the active meteor showers when flash N.2 happened.

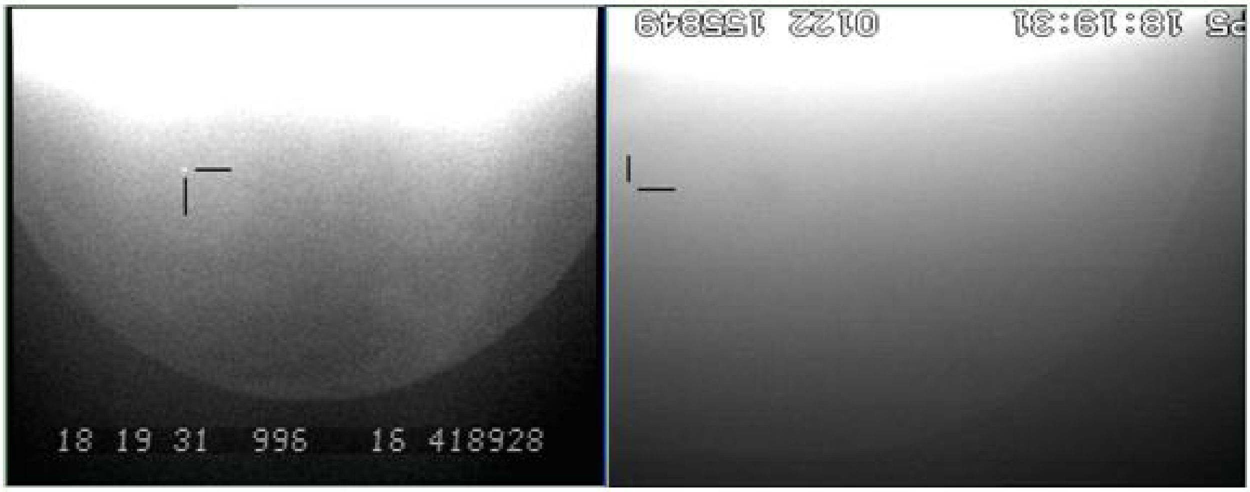

Image 3. Flash N.1, occurred the 2014 Jan 7 at 18:19:31 UT in M. Iten (left) and S. Sposetti (right) recordings.

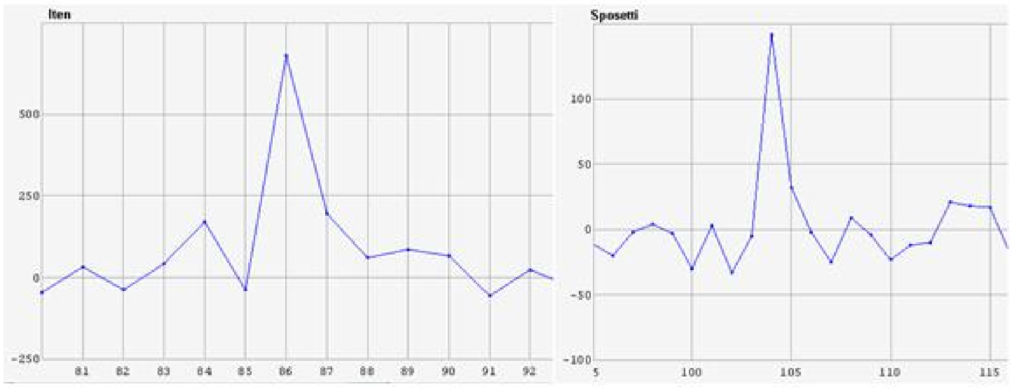

Image 4. Lightcurve plotting the intensity versus time of the flash N.1. Every dot represents one field, ie. 20 ms.

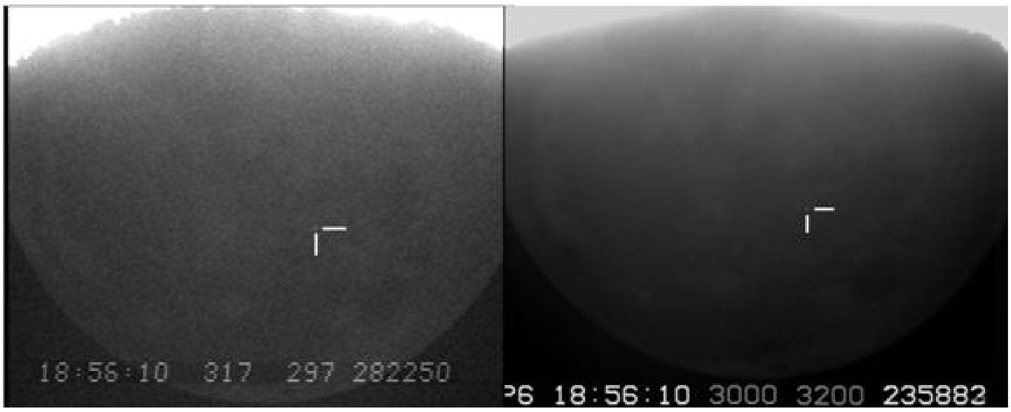

Image 5. Flash N.2, occurred the 2014 Mar 6 at 18:56:10 UT in M. Iten (left) and S. Sposetti (right) recordings.

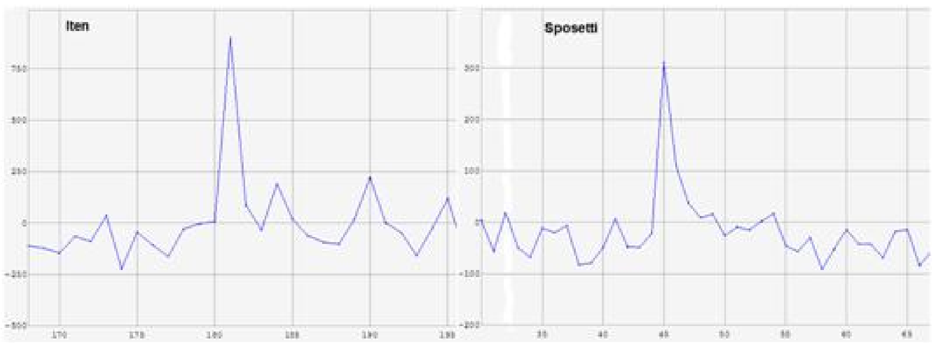

Image 6. Light intensity versus time of the flash N.2. Every dot represents one field, ie. 20 ms.

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	Event N. 1	Event N. 2
Date	07 January 2014	06 March 2014
UTC Time (hh:mm:ss)	18:19:31	18:56:10
Duration (s)	0.04	0.04
N. Fields	2	2
Magnitude (V)	not measured	9.0 ± 0.3
Selenographic Coordinates	15.5° W ; 19.5° N	20° W ; 8.5° S
Remarks	Sporadic	Gamma Normid ?
Captured in	2 telescopes	2 telescopes
Moon Coordinates (Eq. 2000.0)	RA: 00 42 De: +06 03.5	RA:03 34.1 DE:+16 25.3
Moon Horizon Coordinates	Az: 210 11 Alt: +46 10	Az: 245 22 Alt: +43 08.5
Phase (%)	46.0	32.9
Air Mass	1.39	1.46
Moon angular diameter (arcmin)	31.3	30.6
Observing Site 1 (M. Iten)	Gordola	Gordola
Telescope Site 1	125mm refractor	125mm refractor
Videocamera Site 1 (CCIR mode)	Watec 902H2Ult	Watec 902H2Ult
Observing Site 2 (S. Sposetti)	Gnosca	Gnosca
Telescope Site 2	280mm reflector	280mm reflector
Videocamera Site 2 (CCIR mode)	Watec 902H2Ult	Watec 902H2Ult

Table 1. Informations about the events, the Moon and the observing sites

References

[1] Sposetti, S., Iten, M., Lena, R. 2011. Detection of a meteoroidal impact on the Moon. Selenology Today 23, 1-32.

[2] Lena, R., Iten, M., Sposetti, S., 2011. Detection of three meteoroidal impact on the Moon. Selenology Today 24, 12-29.

[3] Lena, R., Iten, M., Sposetti, S., 2011. Detection of two probable meteoroidal impacts on the Moon. Selenology Today 25, 60-65.

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