The Southwestern Europe Meteor Network: remarkable bolides recorded from March to May 2022

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Some of the remarkable bolides spotted in the framework of the Southwestern Europe Meteor Network from March to May 2022 are described here. These have been observed from the Iberian Peninsula. Their absolute magnitude ranges from –8 to –15. The emission spectrum of one of them is also analyzed. Bright meteors included in this report were linked to different sources: the sporadic background, major meteoroid streams, and poorly-known streams.

1 Introduction

Our team is performing since 2006 a systematic monitoring of meteor activity in the framework of the SMART project (Spectroscopy of Meteoroids by means of Robotic Technologies), which started operation in 2006 to obtain new clues about the properties of meteoroids that penetrate our planet's atmosphere (Madiedo, 2014; Madiedo, 2017). This includes chemical data derived from the emission spectra of meteors generated by these particles of interplanetary matter. This survey is being conducted in the framework of the Southwestern Europe Meteor Network (SWEMN) and employs an array of automated spectrographs deployed at a series of meteor-observing stations in Spain. In this way we can derive the atmospheric path of meteors and the orbit of the meteoroids that generate them, but also study the evolution of the conditions in meteor plasmas from the emission spectrum produced by these events (Madiedo, 2017). Besides SMART provides key data for our MIDAS project, which is being conducted at the Institute of Astrophysics of Andalusia (IAA-CSIC) to study lunar impact flashes produced when large meteoroids collide with the Moon's surface (Madiedo et al., 2015a,b; Ortiz et al., 2015).

In this report we focus on the preliminary analysis of seven fireballs recorded by the SWEMN network. The emission spectrum of one of them is also described. This work has been fully written by AIMIE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) from the records included in the SWEMN fireball database (Madiedo et al., 2021; Madiedo et al., 2022).

2 Equipment and methods

The events analyzed here have been recorded by employing Watec 902H2 and Watec 902 Ultimate cameras. Their field of view ranges from 62 × 50 degrees to 14 × 11 degrees. To record meteor spectra we have attached holographic diffraction gratings (1000 lines/mm) to the lens of some of these cameras. we have also employed digital CMOS color cameras (models Sony A7S and A7SII) operating in HD video mode (1920 × 1080 pixels). These cover a field of view of around 70 × 40 degrees. A detailed description of this hardware and the way it operates was given in previous works (Madiedo, 2017). Besides digital CMOS cameras manufactured by ZWO, model ASI185MC were used. The atmospheric paths of the events were triangulated by employing the SAMIA software, developed by J. M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987). The emission spectrum was analyzed with the CHIMET software (Madiedo, 2014).

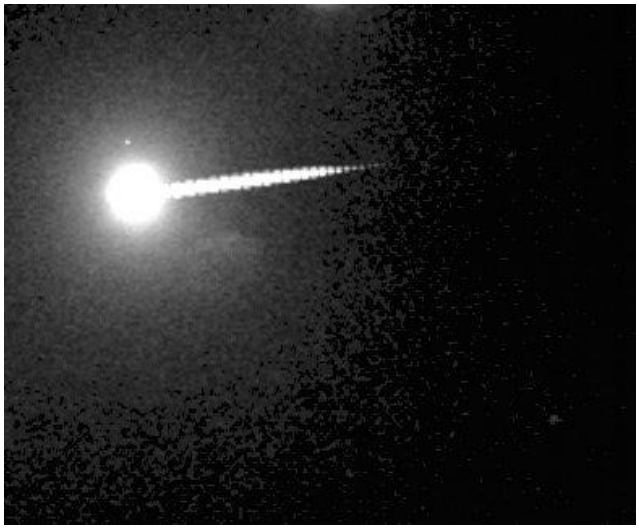

Figure 1 – Stacked image of the SWEMN20220309_030144 fireball as recorded from La Hita.

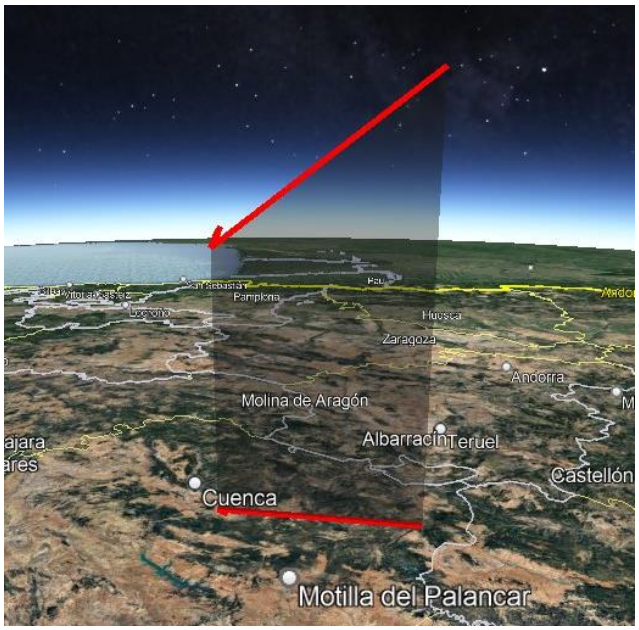

Figure 2 – Atmospheric path and projection on the ground of the SWEMN20220309_030144 fireball.

3 The 2022 March 9 meteor

This striking event was recorded on 2022 March 9, at $3^h01^m44.0 \pm 0.1^s$ UT (*Figure 1*). The fireball, that displayed a bright flare at the terminal stage of its trajectory in the atmosphere, it had a peak absolute magnitude of –11.0 ± 0.5. This flare occurred as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the code SWEMN20220309_030144. A video about this fireball can be viewed on YouTube[14].

Atmospheric trajectory, radiant and orbit

It was obtained from the calculation of the path in the atmosphere of the event that the bright meteor overflew the province of Cuenca (Spain). Its initial altitude was H_b = 121.9 ± 0.5 km. The bolide penetrated the atmosphere till a final height H_e = 76.6 ± 0.5 km. The equatorial coordinates of the apparent radiant yield α = 259.89º, δ = +11.25º. Besides, we inferred that the meteoroid hit the atmosphere with a velocity v_∞ = 64.0 ± 0.3 km/s. The trajectory in our atmosphere of the event is shown in *Figure 2*. *Figure 3* shows the orbit in the Solar System of the meteoroid.

Table 1 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20220309_030144 fireball before its encounter with our planet.

a (AU)	13.3 ± 4.6	ω (º)	179.75 ± 00.03
e	0.92 ± 0.02	Ω (º)	348.216394 ± 10-5
q (AU)	0.99277 ± 0.0	i (º)	122.0 ± 0.1

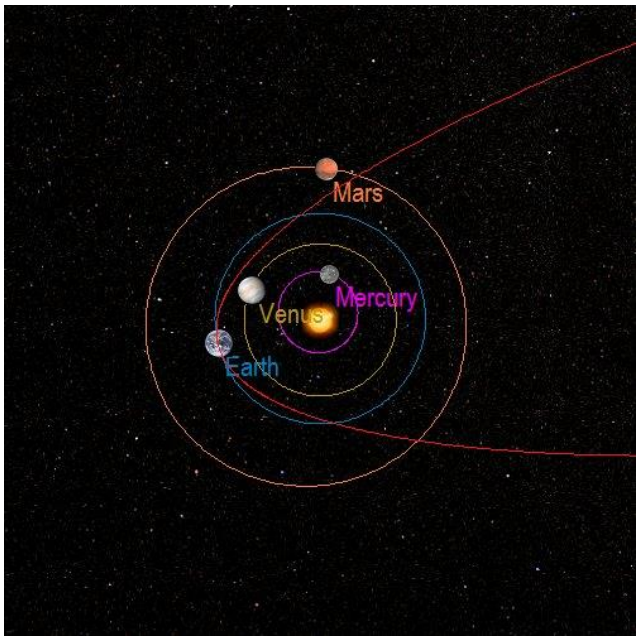

Figure 3 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20220309_030144 event.

The name given to the event was “Villar del Saz de Arcas”, since the fireball overflew this locality in the province of Cuenca during its final phase. The parameters of the

[14] https://youtu.be/MPmthzpUWDw

heliocentric orbit of the parent meteoroid before its encounter with our planet have been listed in *Table 1*. The geocentric velocity of the meteoroid was $v_g = 62.8 \pm 0.3$ km/s. From the value estimated for the Tisserand parameter with respect to Jupiter ($T_J = -0.25$), we found that the meteoroid followed a cometary (Halley-type, HTC) orbit before hitting the Earth's atmosphere. These values and the calculated radiant confirm the sporadic nature of the bolide.

4 Description of the 2022 April 26 bolide

This bright fireball was spotted by SWEMN cameras at $1^h39^m03.0 \pm 0.1^s$ UT on 2022 April 26 (*Figure 4*). The peak luminosity of the bright meteor was equivalent to an absolute magnitude of -8.0 ± 0.5. The code given to the event in the SWEMN meteor database is SWEMN20220426_013903. A video containing images of the bolide and its trajectory in the atmosphere was uploaded to YouTube[15].

Figure 4 – Stacked image of the SWEMN20220426_013903 bolide as recorded from Sevilla.

Figure 5 – Atmospheric path and projection on the ground of the SWEMN20220426_013903 event.

Atmospheric path, radiant and orbit

By analyzing the trajectory in the atmosphere of the event it was inferred that the bright meteor overflew the province of Huelva (southwest of Spain). The luminous event began at an altitude $H_b = 86.3 \pm 0.5$ km. The bolide penetrated the atmosphere till a final height $H_e = 50.5 \pm 0.5$ km. From the analysis of the atmospheric path, we also inferred that the apparent radiant was located at the position $\alpha = 201.36^o$, $\delta = -11.80^o$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 20.8 \pm 0.5$ km/s. The trajectory in our atmosphere of the bright meteor is shown in *Figure 5*. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

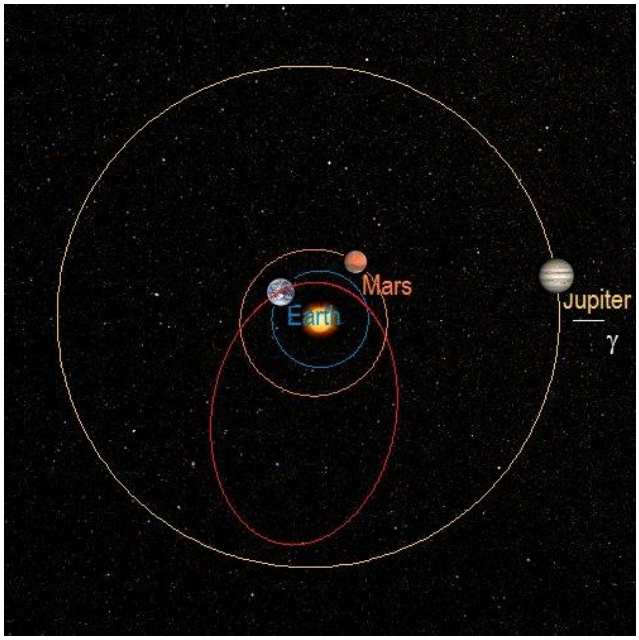

Figure 6 – Projection on the ecliptic plane of the orbit of the of the progenitor meteoroid of the SWEMN20220426_013903 meteor.

This fireball was named "Nerva", because the event was located near the zenith of this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet have been listed in *Table 2*. The geocentric velocity of the meteoroid was $v_g = 17.9 \pm 0.6$ km/s. The value estimated for the Tisserand parameter with respect to Jupiter ($T_J = 2.90$) suggests that the particle was moving on a cometary (JFC) orbit before entering our planet's atmosphere. By taking into account this orbit and the radiant position, the event was produced by the h Virginids (IAU shower code HVI#0343) (Jenniskens et al., 2016).

Table 2 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20220426_013903 event before its encounter with our planet.

a (AU)	2.7 ± 0.2	ω (º)	63.7 ± 00.2
e	0.71 ± 0.02	Ω (º)	215.539582 ± 10-5
q (AU)	0.771 ± 0.006	i (º)	4.39 ± 0.03

[15] https://youtu.be/mgtwL6LHwfs

5 Analysis of the 2022 May 7 fireball

On 2022 May 7, at $4^h09^m01.0 \pm 0.1^s$ UT, our meteor stations recorded this bright event (*Figure 7*). Its maximum luminosity was equivalent to an absolute magnitude of –10.0 ± 1.0. It displayed a bright flare at the final phase of its atmospheric trajectory as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the code SWEMN20220507_040901. The bright meteor can be viewed on this YouTube video[16].

Figure 7 – Stacked image of the SWEMN20220507_040901 fireball as recorded from La Hita.

Atmospheric path, radiant and orbit

We concluded as a result of the analysis of the luminous path of the event that the fireball overflew the province of Cuenca (Spain). The ablation process of the meteoroid began at a height H_b = 108.0 ± 0.5 km, with the terminal point of the luminous phase located at a height H_e = 74.2 ± 0.5 km. The position inferred for the apparent radiant correspond to the equatorial coordinates α = 247.02°, δ = –3.27º. The entry velocity in the atmosphere found for the parent meteoroid was v_∞ = 38.5 ± 0.4 km/s. The path in the atmosphere of the bright meteor is shown in *Figure 8*. The heliocentric orbit of the parent meteoroid is drawn in *Figure 9*.

The event was named "Algarra", because the bolide overflew this locality during its final phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet have been listed in *Table 3*. The geocentric velocity obtained for the particle yields v_g = 37.1 ± 0.4 km/s. The Tisserand parameter referred to Jupiter (T_J = 1.64) suggests that before impacting the atmosphere the particle was moving on a cometary (HTC) orbit. According to these parameters and the calculated radiant, this bright meteor was generated by the sporadic component.

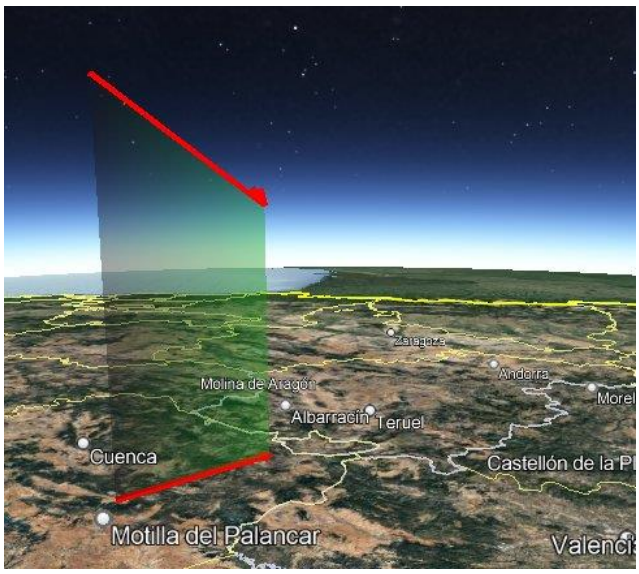

Figure 8 – Atmospheric path and projection on the ground of the SWEMN20220507_040901 event.

Table 3 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	4.7 ± 0.5	ω (º)	300.2 ± 00.1
e	0.943 ± 0.007	Ω (º)	46.292749 ± 10-5
q (AU)	0.272 ± 0.002	i (º)	30.3 ± 0.4

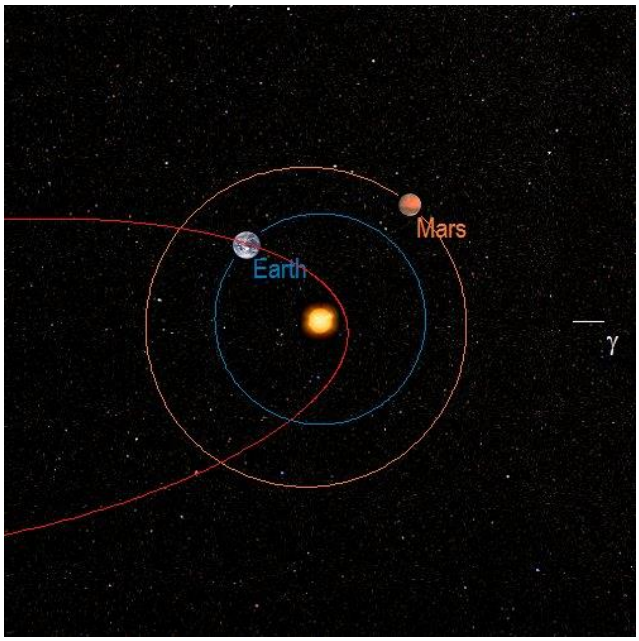

Figure 9 – Projection on the ecliptic plane of the orbit of the SWEMN20220507_040901 event.

6 Description of the 2022 May 8 event

We captured this bright event from the meteor-observing stations located at La Hita, El Guijo, and Coruña. The bolide was spotted on 2022 May 8, at $4^h18^m40.0 \pm 0.1^s$ UT. The peak luminosity the fireball was equivalent to an

[16] https://youtu.be/8OH15MBYKwA

absolute magnitude of –9.0 ± 0.5. It was listed in the SWEMN meteor database with the code SWEMN20220508_041840. A video about this fireball can be viewed on YouTube[17]. The bolide is shown in *Figure 10*.

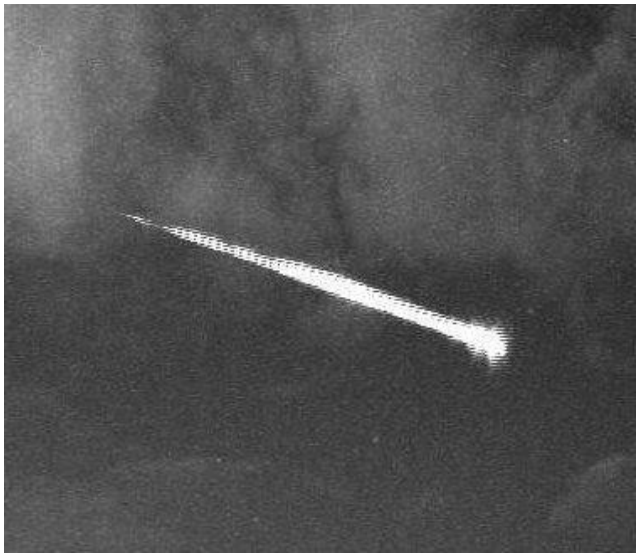

Figure 10 – Stacked image of the SWEMN20220508_041840 meteor as recorded from Coruña.

Atmospheric path, radiant and orbit

The fireball overflew the Atlantic Ocean. The ablation process of the meteoroid began at a height H_b = 114.9 ± 0.5 km, with the terminal point of the luminous phase located at a height H_e = 85.3 ± 0.5 km. The apparent radiant was located at the equatorial coordinates α = 338.90º, δ = +0.39º. The meteoroid collided with the atmosphere with an initial velocity v_∞ = 66.7 ± 0.4 km/s. The atmospheric trajectory of the event is shown in *Figure 11*.

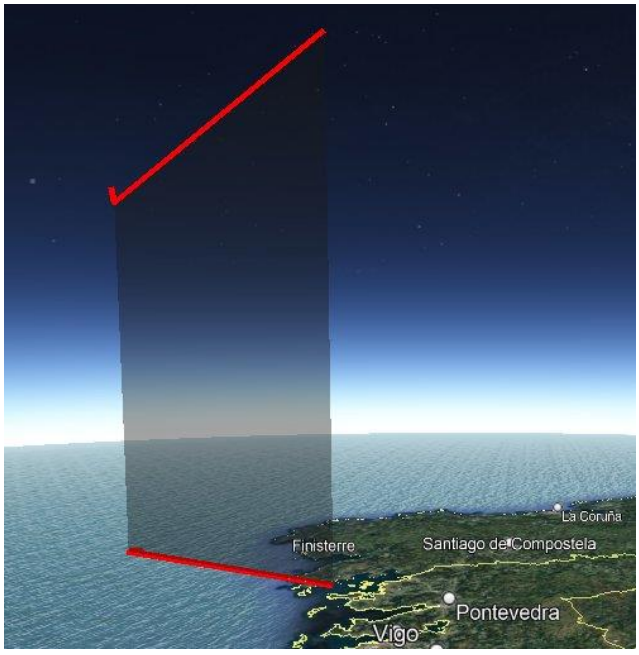

Figure 11 – Atmospheric path and projection on the ground of the SWEMN20220508_041840 meteor.

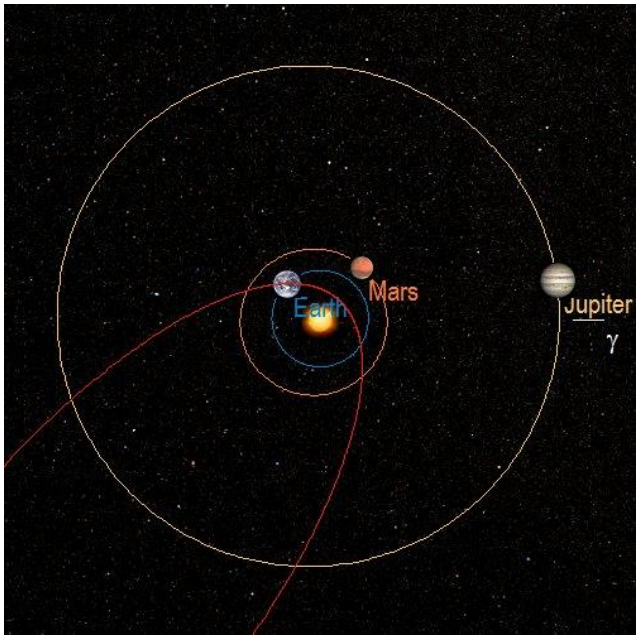

Figure 12 – Projection on the ecliptic plane of the orbit of the SWEMN20220508_041840 event.

Table 4 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	8.9 ± 2.8	ω (º)	97.8 ± 01.4
e	0.93 ± 0.01	Ω (º)	47.277521 ± 10-5
q (AU)	0.587 ± 0.007	i (º)	162.81 ± 0.08

The heliocentric orbit of the meteoroid is drawn in *Figure 12*. The parameters of this orbit are contained in *Table 4*. The geocentric velocity of the meteoroid was v_g = 65.5 ± 0.4 km/s. The value found for the Tisserand parameter referred to Jupiter (T_J = –0.31) indicates that the particle followed a cometary (HTC) orbit before impacting our atmosphere. By considering this orbit and the radiant position, the bolide was associated with the η-Aquariids (IAU code ETA#0031). The proposed parent body of this shower is Comet 1P/Halley (Jenniskens et al., 2016.).

7 The 2022 May 15 bolide

On 2022 May 15, at $4^h08^m06.0 \pm 0.1^s$ UT, SWEMN cameras spotted this striking fireball. It had a peak absolute magnitude of –11.0 ± 0.0 (*Figure 13*). The code given to the bolide in the SWEMN meteor database is SWEMN20220515_040806. The bright meteor can be viewed on YouTube[18].

Atmospheric path, radiant and orbit

The event overflew the provinces of Córdoba and Granada (south of Spain). It began at an altitude H_b = 127.8 ± 0.5 km, and the terminal point of the luminous path was located at a height H_e = 82.0 ± 0.5 km. The equatorial coordinates of the apparent radiant yield α = 334.69º, δ = –8.36º. The meteoroid stroke the atmosphere with an initial velocity v_∞ = 71.2 ± 0.3 km/s. The luminous path of this bright meteor is shown in

[17] https://youtu.be/SN8EGfxS_HE

[18] https://youtu.be/BaDZ7_un0fk

Figure 14. *Figure 15* shows the orbit in the Solar System of the meteoroid.

Figure 13 – Stacked image of the SWEMN20220515_040806 event as recorded from Sierra Nevada.

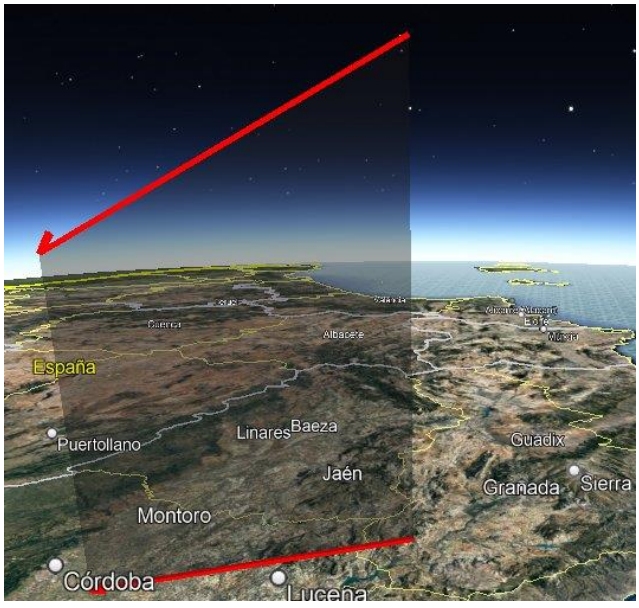

Figure 14 – Atmospheric path and projection on the ground of the SWEMN20220515_040806 fireball.

The parameters of the orbit of the progenitor meteoroid before its encounter with our planet can be found in *Table 5*. The geocentric velocity of the meteoroid was v_g = 70.1 ± 0.3 km/s. The value found for the Tisserand parameter with respect to Jupiter (T_J = –0.90) shows that the meteoroid followed a cometary (HTC) orbit before hitting the atmosphere. These values and the derived radiant confirm the sporadic nature of the fireball.

Table 5 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	18.6 ± 9.7	ω (º)	147.0 ± 00.8
e	0.95 ± 0.02	Ω (º)	54.072283 ± 10-5
q (AU)	0.931 ± 0.003	i (º)	177.0 ± 0.1

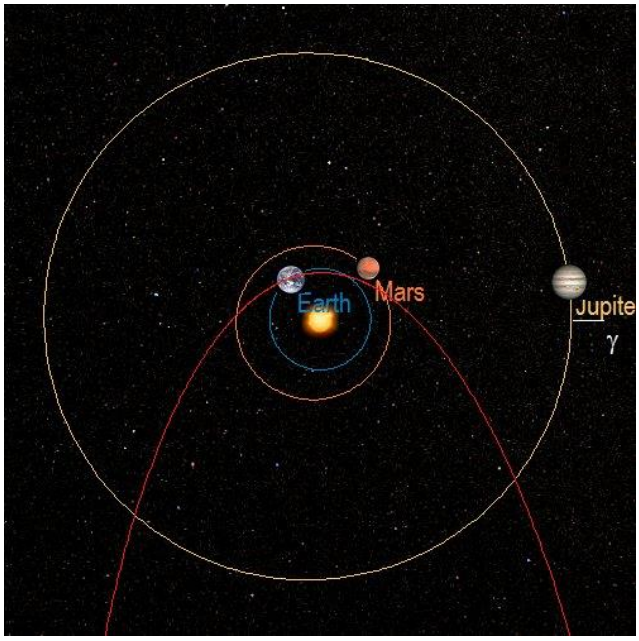

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20220515_040806 fireball.

8 The 2022 May 19 fireball

This bolide was captured by SWEMN meteor stations at $2^h00^m02.0 \pm 0.1^s$ UT on 2022 May 19 (*Figure 16*). The maximum brightness of this bright meteor, that displayed a bright flare at the ending phase of its trajectory in our atmosphere, was equivalent to an absolute magnitude of –10.0 ± 0.0. This flare took place as a consequence of the sudden disruption of the meteoroid. The code assigned to the bolide in the SWEMN meteor database is SWEMN20220519_020002.

Figure 16 – Stacked image of the SWEMN20220519_020002 event as recorded from Olocau.

Atmospheric path, radiant and orbit

The fireball overflew the region of Murcia (southeast of Spain). The luminous event began at an altitude H_b = 123.1 ± 0.5 km. It penetrated the atmosphere till a final height H_e = 85.8 ± 0.5 km. The equatorial coordinates obtained for the apparent radiant are α = 310.57º, δ = +16.95º. Besides, we inferred that the meteoroid collided with the atmosphere with a velocity v_∞ =63.1 ± 0.0 km/s. The trajectory in the Earth's atmosphere of the bolide is shown in *Figure 17*.

Table 6 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	16.15325 ± 0.0	ω (º)	203.96585 ± 00.0
e	0.93999 ± 0.0	Ω (º)	57.796443 ± 10-5
q (AU)	0.96937 ± 0.0	i (º)	121.81741 ± 0.0

The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 18*. We named this fireball "Los Zancarrones", because the bright meteor was located over this locality during its initial phase. The parameters of the orbit of the meteoroid before its encounter with our planet have been included in *Table 6*. The geocentric velocity obtained for the particle yields v_g = 61.9 ± 0.0 km/s. From the value derived for the Tisserand parameter referred to Jupiter (T_J = –0.31), we found that the particle was moving on a cometary (HTC) orbit before colliding with our atmosphere. These parameters and the calculated radiant confirm that the bright meteor was linked to the γ-Aquilids (IAU code GAQ#0531). The proposed progenitor body of this shower, which peaks on May 5, is Comet C/1853G1 (Schweizer) (Jenniskens et al., 2016.).

Figure 17 – Atmospheric path and projection on the ground of the SWEMN20220519_020002 "Los Zancarrones" event.

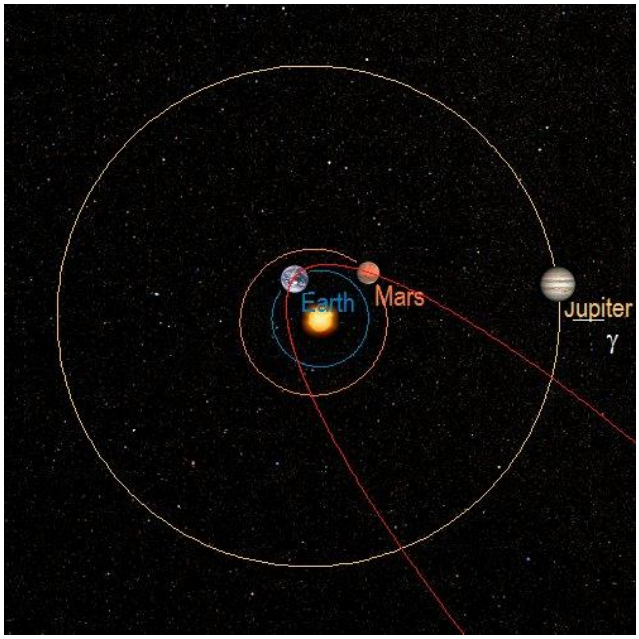

Figure 18 – Projection on the ecliptic plane of the orbit of the SWEMN20220519_020002 fireball.

Emission spectrum

The emission spectrum of the bolide was also recorded with the video spectrographs operated by the SWEMN network. This emission spectrum was calibrated in wavelength by taking into consideration typical lines appearing in meteor spectra, and then corrected by taking into account the sensitivity of the recording device. The resulting calibrated signal is shown in *Figure 19*. This plot also shows the most relevant contributions identified in the emission spectrum. These contributions correspond to Na I-1 (588.9 nm), Mg I-2 (516.7 nm), Fe I-15, and Fe I-4 (385.6 nm). In addition, the emissions from N2, O I and N I have been identified.

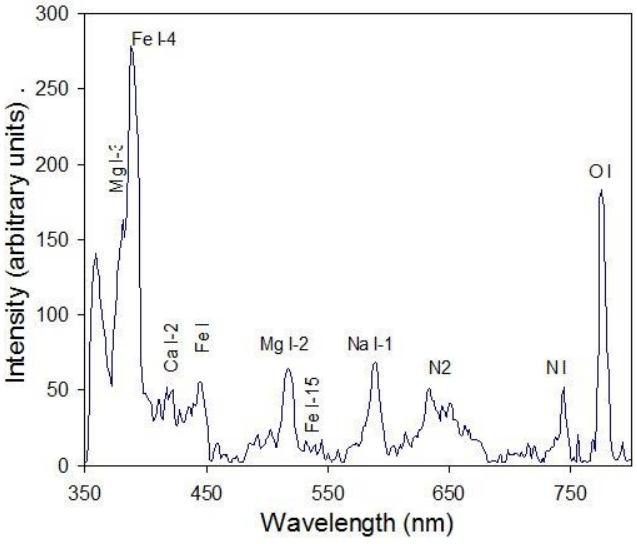

Figure 19 – Emission spectrum of the SWEMN20220519_020002 "Los Zancarrones" fireball.

9 The 2022 May 23 fireball

This extraordinary bolide was captured on 2022 May 23 at $0^h42^m49.0 \pm 0.1^s$ UT from the meteor-observing stations located at Ayora, La Hita, CAHA, Olocau, and OSN (*Figure 20*). The bright meteor had a peak absolute magnitude of –15.0 ± 1.0. It was listed in the SWEMN meteor database with the code SWEMN20220523_004249.

Figure 20 – Stacked image of the SWEMN20220523_004249 event as recorded from Olocau.

Atmospheric path, radiant and orbit

It was found as a result of the analysis of the trajectory in the atmosphere of the event that this bright meteor overflew the province of Barcelona (northeast of Spain). It began at an altitude H_b = 35.6 ± 0.5 km, and the event penetrated the atmosphere till a final height H_e = 27.9 ± 0.5 km. The apparent radiant was located at the equatorial coordinates α = 223.47º, δ = –8.03º. The entry velocity in the atmosphere inferred for the parent meteoroid was v_∞ = 17.3 ± 0.2 km/s. *Figure 21* shows the atmospheric path of the bolide.

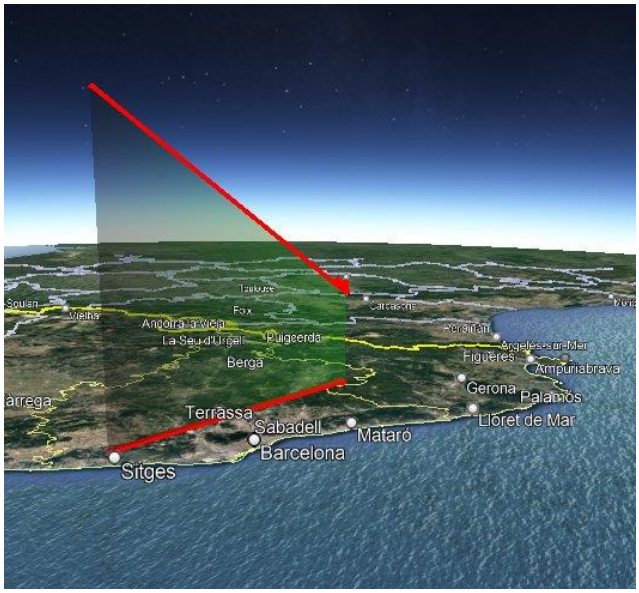

Figure 21 – Atmospheric path and projection on the ground of the SWEMN20220523_004249 event.

This bright meteor was named "Vilanova de Sau", since the event was located over this locality during its final phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 7*. The geocentric velocity of the meteoroid was v_g = 13.4 ± 0.3 km/s. From the value estimated for the Tisserand parameter with respect to Jupiter (T_J = 3.58), we found that the particle followed an asteroidal orbit before impacting the Earth's atmosphere. Radiant and orbital data do not match any of the meteoroid streams listed in the IAU meteor database. So, we concluded that this bolide was produced by the sporadic background.

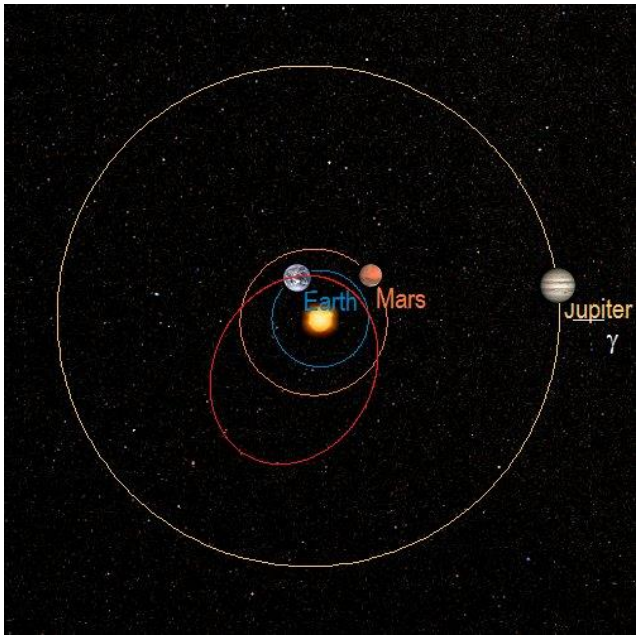

Figure 22 – Projection on the ecliptic plane of the orbit of the SWEMN20220523_004249 fireball.

Table 7 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.02 ± 0.05	ω (º)	236.57 ± 00.07
e	0.57 ± 0.01	Ω (º)	60.240703 ± 10-5
q (AU)	0.852 ± 0.002	i (º)	0.10 ± 0.09

10 Conclusions

Some of the brightest meteors recorded by SWEMN from March to May 2022 have been described here. They had a peak luminosity ranging from mag. –8 to mag. –15.

The "Villar del Saz de Arcas" bolide was recorded on March 9. Its peak magnitude was –11.0. The fireball was produced by a sporadic meteoroid and overflew the province of Cuenca (Spain). Before hitting the Earth's atmosphere, the meteoroid was moving on a cometary (HTC) orbit.

The second bolide analyzed here was an event recorded on April 26 and named "Nerva". It reached a peak absolute magnitude of –8.0, and belonged to the poorly known meteoroid stream of the h Virginids (HVI#0343). This meteor event overflew the province of Nerva (southwest of

Spain). Before striking the atmosphere, the progenitor meteoroid was moving on a cometary (JFC) orbit.

The next bolide analyzed here was the "Algarra" event. This was recorded on May 7. The peak magnitude of this sporadic meteor, which also overflew the province of Cuenca (Spain), was –10.0. Before colliding with the Earth's atmosphere, the progenitor meteoroid was moving on a cometary (HTC) orbit.

The fourth bright meteor analyzed here was an event recorded on May 7. It belonged to the η-Aquariids (ETA#0031). Its peak magnitude was –9.0 and overflew the Atlantic Ocean. The progenitor particle was a meteoroid from Comet 1P/Halley.

Next we have presented a bright meteor recorded on May 15. Its peak magnitude was –11.0. The fireball was produced by a sporadic meteoroid and overflew the provinces of Córdoba and Granada (south of Spain). The meteoroid followed a cometary (HTC) orbit before colliding with the Earth's atmosphere.

The next bolide in this report was the "Los Zancarrones" fireball. This was recorded on May 19. The peak magnitude of this γ-Aquilid (GAQ#0531), which overflew the region of Murcia (southeast of Spain), was –10.0. The parent meteoroid was moving on a cometary (HTC) orbit before striking the atmosphere. The analysis of the emission spectrum of this fireball was also performed, and revealed the contributions corresponding to Na I-1, Mg I-2, Mg I-3, Ca I-2, Fe I-4, Fe I-15, and N2. In addition, the emissions from O I and N I have been also found.

The last analyzed here was the "Vilanova de Sau" fireball, that was recorded on May 23. It reached a peak absolute magnitude of –15.0 and belonged to the sporadic background. This bolide overflew the province of Barcelona (northeast of Spain). Before entering our planet's atmosphere, the parent meteoroid was moving on an asteroidal orbit. This deep-penetrating meteor event reached a terminal altitude of about 27 km.

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