Remarkable fireballs spotted in the framework of the Southwestern Europe Meteor Network along August and September 2022

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Some of the bright bolides observed in the framework of the Southwestern Europe Meteor Network between August and September 2022 are described in this work. These have been spotted from the Iberian Peninsula. Their maximum luminosity ranges from mag. –7 to mag. –12. One of these bolides gave rise to a meteorite.

1 Introduction

Our meteor network performs 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 analyze the properties of meteoroids ablating in our planet's atmosphere. This includes chemical data derived from the emission spectra of meteors generated by these particles of interplanetary matter. This survey, which is being conducted in the framework of the Southwestern Europe Meteor Network (SWEMN), employs an array of automated spectrographs deployed at meteor-observing stations in Spain (Madiedo, 2014; Madiedo, 2017). This allows to derive the luminous path of meteors and the orbit of their progenitor meteoroids, and also to study the evolution of meteor plasmas from the emission spectrum produced by these events (Madiedo, 2015a,b). SMART also provides important information for our MIDAS project, which is being conducted by the Institute of Astrophysics of Andalusia (IAA-CSIC) to study lunar impact flashes produced when large meteoroids impact the Moon (Madiedo et al., 2015; Madiedo et al., 2018; Madiedo et al. 2019; Ortiz et al., 2015).

In this work we focus on the preliminary analysis of seven fireballs recorded by the SWEMN network between August and September 2022. One of them was a meteorite-producing bolide that overflew the Mediterranean Sea. 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

To record the events presented in this work we have used Watec 902H2 and Watec 902 Ultimate CCD cameras. Their field of view ranges from around 62 × 50 degrees to about 14 × 11 degrees. 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).

Figure 1 – Stacked image of the SWEMN20220803_001420 meteor as recorded from Calar Alto.

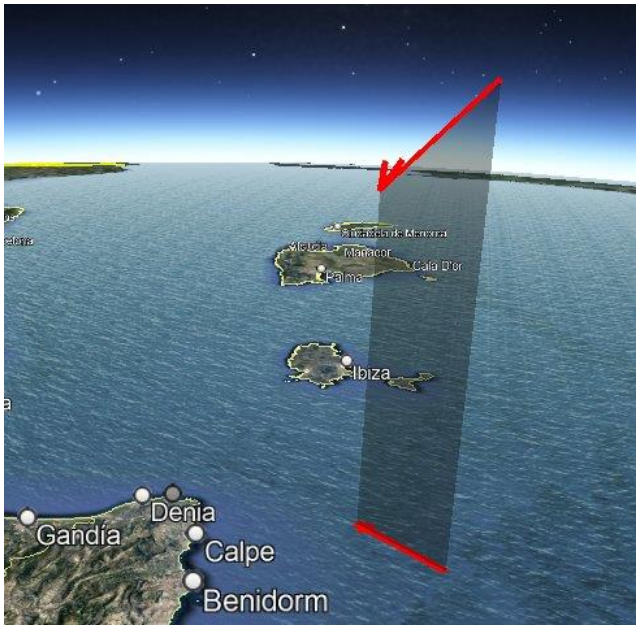

Figure 2 – Atmospheric path of the SWEMN20220803_001420 fireball, and its projection on the ground.

3 The 2022 August 3 event

We spotted this bright bolide from the meteor-observing stations located at Ayora, Huelva, La Hita, CAHA, OSN, La Sagra, and Sevilla. The bright meteor was captured on 2022 August 3, at $0^h14^m20.0 \pm 0.1^s$ UT. The peak brightness the event, which exhibited a bright flare at the final phase of its atmospheric trajectory, was equivalent to an absolute magnitude of –9.0 ± 1.0 (*Figure 1*). This flare occurred as a consequence of the sudden break-up of the meteoroid. It was added to the SWEMN meteor database with the code SWEMN20220803_001420. A video about this bolide was uploaded to YouTube[28].

Atmospheric trajectory, radiant and orbit

It was concluded according to the analysis of the atmospheric path of the meteor that this bolide overflew the Mediterranean Sea. Its initial altitude was $H_b = 106.7 \pm 0.5$ km. The fireball penetrated the atmosphere till a final height $H_e = 81.1 \pm 0.5$ km. The equatorial coordinates found for the apparent radiant are $\alpha = 307.82º$, $\delta = –7.43º$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 24.2 \pm 0.3$ km/s. *Figure 2* shows the obtained projection on the ground of the trajectory in our atmosphere of the event. *Figure 3* shows the orbit in the Solar System of its progenitor meteoroid.

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

a (AU)	2.8 ± 0.1	ω (º)	261.29 ± 00.03
e	0.77 ± 0.01	Ω (º)	130.348137 ± 10^{-5}
q (AU)	0.638 ± 0.003	i (º)	6.0 ± 0.1

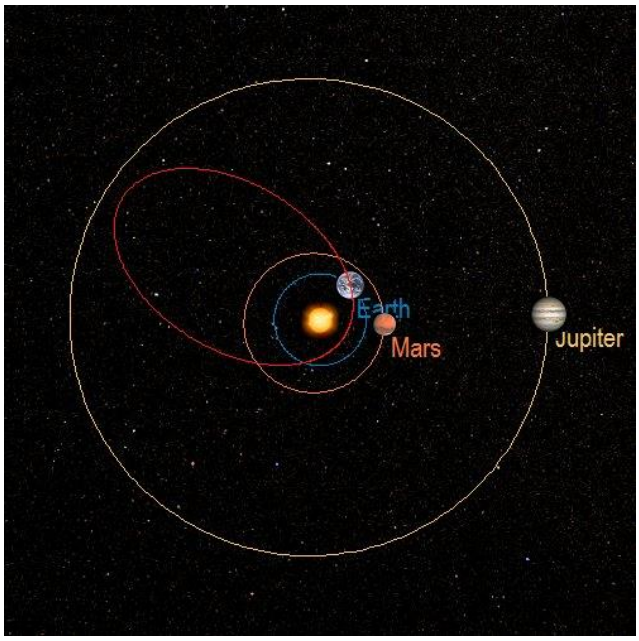

Figure 3 – Projection on the ecliptic plane of the orbit of the SWEMN20220803_001420 fireball.

The parameters of the orbit of the progenitor meteoroid

[28] https://youtu.be/5gNGIOsfUDI

before its encounter with our planet have been included in *Table 1*, and the geocentric velocity yields v_g = 21.6 ± 0.3 km/s. The value found for the Tisserand parameter referred to Jupiter (T_J = 2.75) indicates that the meteoroid followed a cometary (JFC) orbit before entering our atmosphere. These values and the derived radiant confirm that the fireball was linked to the α-Capricornids (IAU meteor shower code CAP#0001). The proposed progenitor body of this shower, which peaks around August 1, is Comet 169P/NEAT (= 2002 EX12) (Jenniskens et al., 2016).

Figure 4 – Stacked image of the SWEMN20220805_002528 event as recorded from Calar Alto.

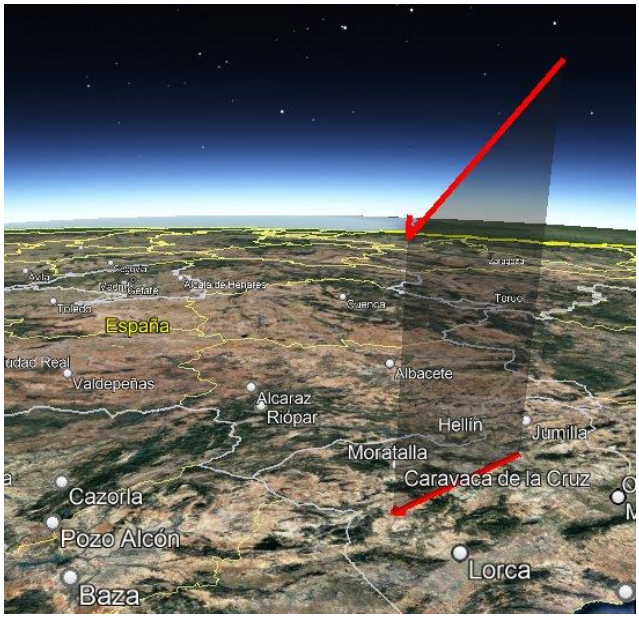

Figure 5 – Atmospheric path of the SWEMN20220805_002528 event, and its projection on the ground.

4 Description of the 2022 August 5 meteor

This gorgeous event was spotted on 2022 August 5 at $0^h25^m28.0 \pm 0.1^s$ UT from the meteor-observing stations located at La Hita, CAHA, OSN, La Sagra, and Sevilla. The bolide, which presented a bright flare at the terminal stage of its atmospheric path, had a peak absolute magnitude of –11.0 ± 1.0 (*Figure 4*). This flare arose as a consequence of the sudden disruption of the meteoroid. It was included in the SWEMN meteor database with the code SWEMN20220805_002528.

Atmospheric path, radiant and orbit

The calculation of the atmospheric path of the fireball allowed to conclude that this event overflew Murcia (Spain). The luminous event began at an altitude H_b = 124.3 ± 0.5 km. The bolide penetrated the atmosphere till a final height H_e = 79.6 ± 0.5 km. The equatorial coordinates of the apparent radiant yield α = 38.72º, δ = +54.76º. Besides, we concluded that the meteoroid impacted the atmosphere with a velocity v_∞ = 60.9 ± 0.5 km/s. The obtained luminous path of the fireball is shown in *Figure 5*. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

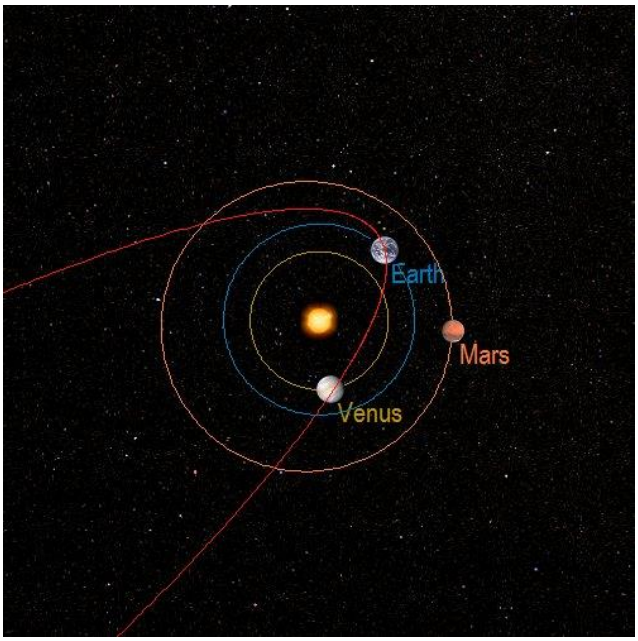

Figure 6 – Projection on the ecliptic plane of the orbit of the SWEMN20220805_002528 bolide.

This event was named “Don Gonzalo”, because the bright meteor overflew this locality during its final phase. The parameters of the orbit of the progenitor meteoroid before its encounter with our planet are included in *Table 2*. The geocentric velocity obtained for the particle yields v_g = 59.7 ± 0.5 km/s. The value derived for the Tisserand parameter with respect to Jupiter (T_J = –0.24) indicates that before hitting our planet’s atmosphere the particle was moving on a cometary (HTC) orbit. By taking into account this orbit and the radiant position, the fireball was produced by the Perseid meteoroid stream (IAU code PER#0007), whose parent is Comet 109P/Swift-Tuttle (Jenniskens et al., 2016).

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

a (AU)	20.2 ± 17.	ω (º)	148.9 ± 00.7
e	0.95 ± 0.03	Ω (º)	132.292253 ± 10-5
q (AU)	0.943 ± 0.001	i (º)	114.9 ± 0.3

5 The 2022 August 11 meteor

This bright fireball was recorded by the systems operated by the SWEMN network at $4^h08^m35.0 \pm 0.1^s$ UT on 2022 August 11. The event, which exhibited a bright flare at the final phase of its path in the atmosphere, had a peak absolute magnitude of –9.0 ± 1.0 (*Figure 7*). This flare appeared as a consequence of the sudden disruption of the meteoroid. Its code in the SWEMN meteor database is SWEMN20220811_040835. The bright meteor can be viewed on this YouTube video[29].

Figure 7 – Stacked image of the SWEMN20220811_040835 meteor as recorded from Sierra Nevada.

Atmospheric path, radiant and orbit

This fireball overflew Jaén and Córdoba (Spain). Its initial altitude was H_b = 113.3 ± 0.5 km. The bolide penetrated the atmosphere till a final height H_e = 74.9 ± 0.5 km. The apparent radiant was located at the equatorial coordinates α = 48.63º, δ = +56.28º. The meteoroid hit the atmosphere with an initial velocity v_∞ = 60.8 ± 0.4 km/s. *Figure 8* shows the obtained path in the atmosphere of the bright meteor. The heliocentric orbit of the meteoroid is drawn in *Figure 9*.

The name given to the fireball was "Los Noguerones", since the bolide passed near the zenith of this locality during its initial phase. The orbital parameters of the parent meteoroid before its encounter with our planet have been listed in *Table 3*. The geocentric velocity of the meteoroid was v_g = 59.7 ± 0.4 km/s. From the value derived for the Tisserand parameter referred to Jupiter (T_J = –0.22), we found that the meteoroid followed a cometary (HTC) orbit before entering the atmosphere. These values and the derived radiant confirm that this bolide was also linked to the Perseids (IAU code PER#0007). The proposed progenitor body of this shower is Comet 109P/Swift-Tuttle (Jenniskens et al., 2016).

Figure 8 – Atmospheric path of the SWEMN20220811_040835 bolide, and its projection on the ground.

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

a (AU)	18.3 ± 11.	ω (º)	147.0 ± 00.6
e	0.94 ± 0.03	Ω (º)	138.190897 ± 10-5
q (AU)	0.934 ± 0.001	i (º)	115.0 ± 0.2

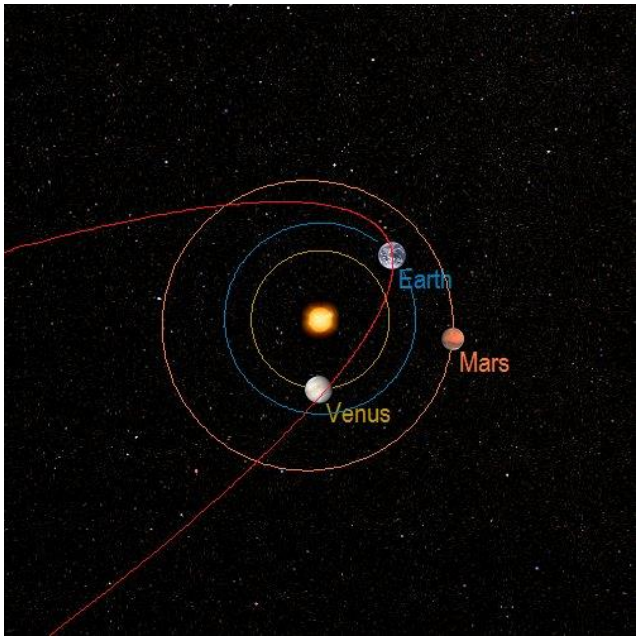

Figure 9 – Projection on the ecliptic plane of the orbit of the SWEMN20220811_040835 event.

[29] https://youtu.be/h79yEPYIB1k

6 Description of the 2022 August 17 meteor

This bright event was captured by the systems operated by the SWEMN network at $21^h18^m55.0 \pm 0.1^s$ UT on 2022 August 17 (*Figure 10*). It had a peak absolute magnitude of –9.0 ± 0.5. The code assigned to the event in the SWEMN meteor database is SWEMN20220817_211855. A video about this fireball can be viewed on YouTube[30]. Casual observers saw the bolide crossing the sky and reported the event on social networks.

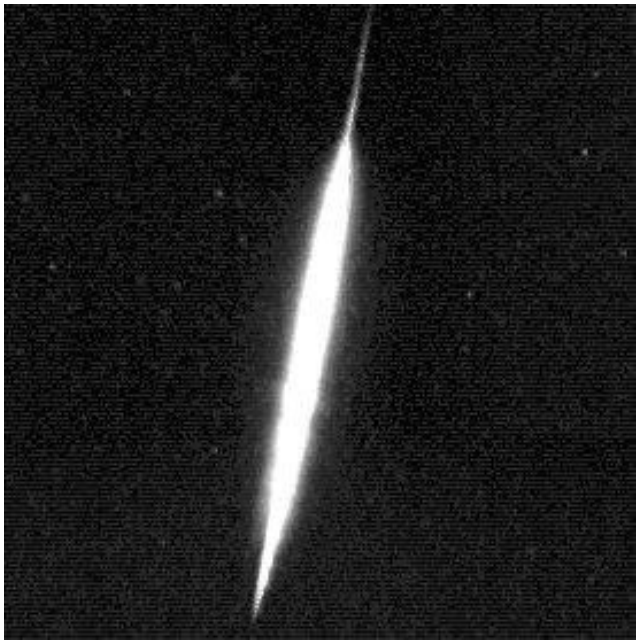

Figure 10 – Stacked image of the SWEMN20220817_211855 bolide.

Figure 11 – Atmospheric path of the SWEMN20220817_211855 event, and its projection on the ground.

Atmospheric path, radiant and orbit

The calculation of the atmospheric path of the fireball led to the conclusion that this bolide overflew the Mediterranean Sea. The luminous event began at an altitude $H_b = 82.3 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 23.4 \pm 0.5$ km. The equatorial coordinates obtained for the apparent radiant are $\alpha = 256.37^o$, $\delta = +27.68^o$. The meteoroid hit the atmosphere with an initial velocity $v_\infty = 15.1 \pm 0.3$ km/s. *Figure 11* shows the calculated trajectory in the atmosphere of the fireball.

Figure 12 shows the orbit in the Solar System of the parent meteoroid, and *Table 4* shows the corresponding orbital parameters. The geocentric velocity of the meteoroid was $v_g = 10.5 \pm 0.4$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 3.14$) suggests that before colliding with our atmosphere the particle was moving on an asteroidal orbit. These values and the calculated radiant confirm the sporadic nature of the bolide.

From the calculation of the trajectory in our atmosphere it was inferred that the meteoroid was not completely ablated in the atmosphere. Thus, a part of it survived and reached the ground as a meteorite. The full circumstances of this fall are still under analysis.

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

a (AU)	2.5 ± 0.1	ω (º)	185.0 ± 00.1
e	0.60 ± 0.02	Ω (º)	144.631242 ± 10-5
q (AU)	1.0109 ± 0.0001	i (º)	11.6 ± 0.4

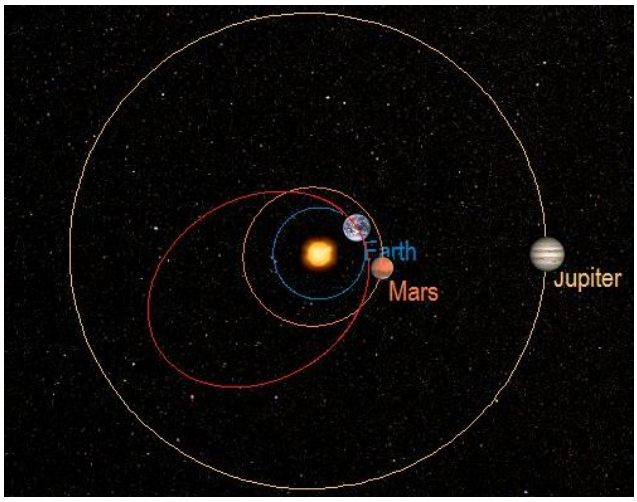

Figure 12 – Projection on the ecliptic plane of the orbit of the SWEMN20220817_211855 meteor.

Figure 13 – Stacked image of the SWEMN20220817_214643 event.

[30] https://youtu.be/IiFAVbL5sdw

7 The 2022 August 17 event

This bright fireball was recorded on 2022 August 17, at $21^h46^m43.0 \pm 0.1^s$ UT (*Figure 13*). The maximum luminosity the bright meteor, that showed a series of flares along its atmospheric trajectory, was equivalent to an absolute magnitude of –10.0 ± 1.0. These flares appeared as a consequence of the sudden disruption of the meteoroid. The code given to the fireball in the SWEMN meteor database is SWEMN20220817_214643. A video about this bright meteor was uploaded to YouTube[31]. The event could also be observed by a wide number of causal eyewitnesses. that reported the event on social networks.

Figure 14 – Atmospheric path of the SWEMN20220817_214643 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

This event overflew Spain and the Mediterranean Sea. Its initial altitude was $H_b = 103.7 \pm 0.5$ km. The fireball penetrated the atmosphere till a final height $H_e = 68.2 \pm 0.5$ km. From the analysis of the atmospheric path, we also inferred that the apparent radiant was located at the position $\alpha = 316.96^o$, $\delta = -10.70^o$. Besides, we obtained that the meteoroid impacted the atmosphere with a velocity $v_\infty = 24.2 \pm 0.3$ km/s. The calculated atmospheric trajectory of the bright meteor is shown in *Figure 14*. The orbit in the Solar System of the meteoroid is shown in *Figure 15*.

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

a (AU)	4.2 ± 0.3	ω (º)	253.34 ± 00.03
e	0.83 ± 0.01	Ω (º)	144.597323 ± 10-5
q (AU)	0.683 ± 0.002	i (º)	1.61 ± 0.08

The name given to the bright meteor was “Las Matanzas”, since the event was located over this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are listed in *Table 5*. The geocentric velocity of the meteoroid was $v_g = 21.4 \pm 0.3$ km/s. The value obtained for the Tisserand parameter with respect to Jupiter ($T_J = 2.20$) shows that before colliding with our planet’s atmosphere the meteoroid was moving on a cometary (JFC) orbit. These parameters and the calculated radiant confirm that the event was associated with the August ν-Aquariids (IAU code ANA#0467). The proposed progenitor body of this shower, which peaks around August 12, is Comet 72P/Denning-Fujikawa (Kornos et al., 2014).

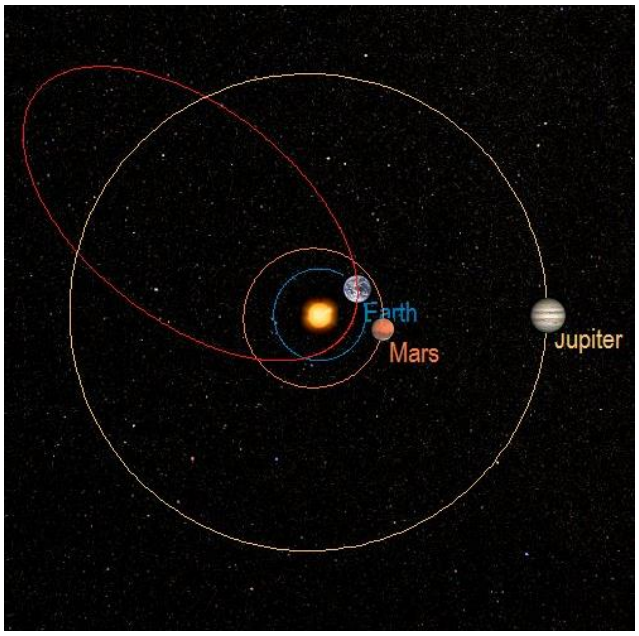

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20220817_214643 fireball.

8 Description of the 2022 September 3 event

Figure 16 – Stacked image of the SWEMN20220903_033415 event.

This notable bolide was spotted on 2022 September 3, at $3^h34^m15.0 \pm 0.1^s$ UT (*Figure 16*). The maximum luminosity the fireball, that presented various flares along its trajectory in the atmosphere, was equivalent to an absolute magnitude of –12.0 ± 1.0. These flares took place as a consequence of the sudden disruption of the meteoroid. Its code in the

[31] https://youtu.be/e_AjJItElUA

SWEMN meteor database is SWEMN20220903_033415. A video about this fireball can be viewed on YouTube[32].

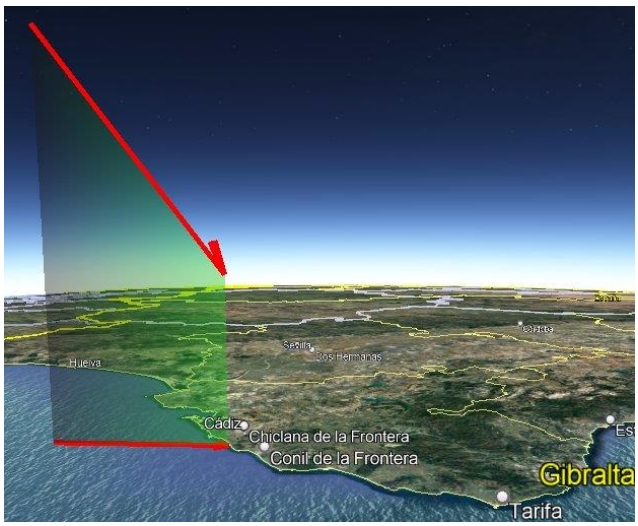

Figure 17 – Atmospheric path of the SWEMN20220903_033415 event, and its projection on the ground.

Atmospheric path, radiant and orbit

By calculating the trajectory in our atmosphere of the bolide it was concluded that this event overflew the Gulf of Cádiz. Its initial altitude was $H_b = 93.3 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 38.5 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 325.84^o$, $\delta = +51.18^o$. The meteoroid stroke the atmosphere with an initial velocity $v_\infty = 15.7 \pm 0.3$ km/s. The calculated luminous path of the event is shown in *Figure 17*. The orbit in the Solar System of the meteoroid is shown in *Figure 18*.

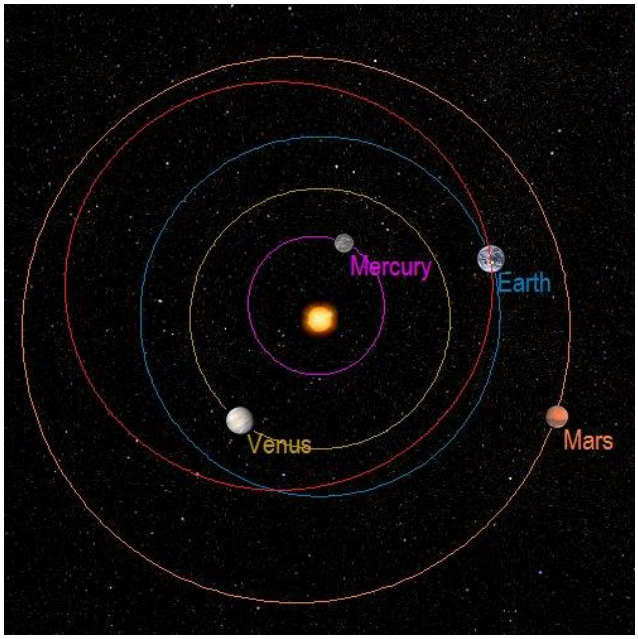

Figure 18 – Projection on the ecliptic plane of the orbit of the SWEMN20220903_033415 fireball.

Table 6 shows the orbital parameters of the parent meteoroid before its encounter with our planet., and the geocentric velocity yields $v_g = 11.4 \pm 0.4$ km/s. The value obtained for the Tisserand parameter referred to Jupiter ($T_J = 5.18$) reveals that the meteoroid was moving on an asteroidal orbit before colliding with our planet's atmosphere. By taking into account these orbital data and the radiant position, it was inferred that the fireball was generated by a sporadic meteoroid.

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

a (AU)	1.211 ± 0.007	ω (º)	240.0 ± 00.5
e	0.250 ± 0.007	Ω (º)	160.324857 ± 10-5
q (AU)	0.907 ± 0.004	i (º)	18.3 ± 0.6

Figure 19 – Stacked image of the SWEMN20220926_004442 event.

9 Analysis of the 2022 September 26 bolide

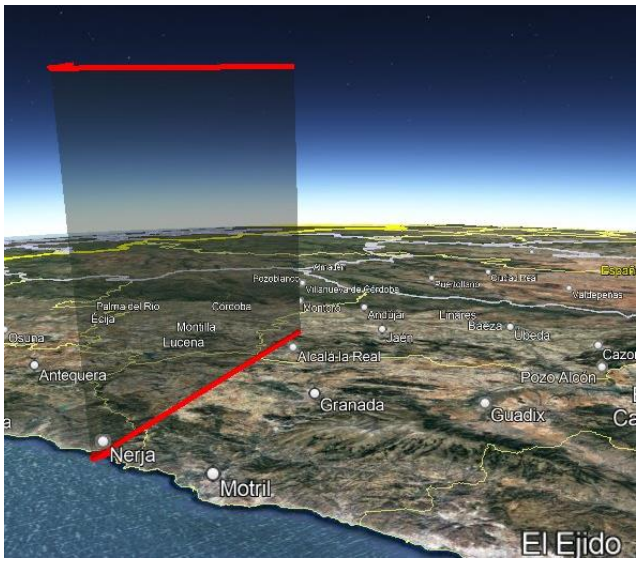

Figure 20 – Atmospheric path of the SWEMN20220926_004442 meteor, and its projection on the ground.

This bright event was captured on 2022 September 26 at $0^h44^m42.6 \pm 0.1^s$ UT from the SWEMN meteor-observing stations located at Huelva, La Hita, CAHA, OSN, La Sagra,

[32] https://youtu.be/HpgANm_vT_w

and Sevilla. The fireball was an Earth-grazer that had a peak absolute magnitude of –7.0 ± 0.5 (*Figure 19*). The code given to the bright meteor in the SWEMN meteor database is SWEMN20220926_004442. A video with images of the fireball and its trajectory in our atmosphere was uploaded to YouTube[33].

Atmospheric path, radiant and orbit

This bolide overflew the provinces of Jaén and Granada (south of Spain). The luminous event began at an altitude H_b = 88.1 ± 0.5 km. The bright meteor penetrated the atmosphere till a final height H_e = 78.8 ± 0.5 km. The equatorial coordinates of the apparent radiant yield α = 211.93º, δ = +55.77º. Besides, we concluded that the meteoroid collided with the atmosphere with a velocity v_∞ = 16.5 ± 0.2 km/s. *Figure 20* shows the calculated atmospheric trajectory of the fireball. The orbit in the Solar System of the meteoroid is shown in *Figure 21*.

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

a (AU)	1.277 ± 0.008	ω (º)	118.1 ± 00.1
e	0.314 ± 0.005	Ω (º)	182.616433 ± 10-5
q (AU)	0.876 ± 0.001	i (º)	16.5 ± 0.4

The bolide was named "Tocón", because the event was located over this locality during its final phase. *Table 7* shows the orbital parameters of the progenitor meteoroid before its encounter with our planet., and the geocentric velocity derived in this case was v_g = 12.3 ± 0.3 km/s. From the value derived for the Tisserand parameter with respect to Jupiter (T_J = 4.98), we found that the particle followed an asteroidal orbit before entering the atmosphere. By taking into account this orbit and the radiant position, the bright meteor was linked to the sporadic background.

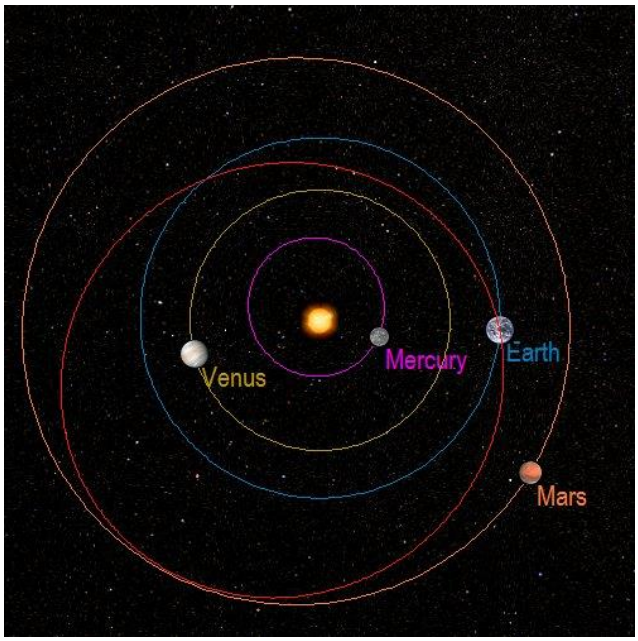

Figure 21 – Projection on the ecliptic plane of the orbit of the SWEMN20220926_004442 fireball.

10 Conclusions

We have analyzed in this work some of the most remarkable meteors recorded by our meteor-observing stations from August to September 2022. Their peak absolute brightness ranges from mag. –7 to mag. –12.

The first bolide described in this paper was recorded on August 3. It reached a peak absolute magnitude of –9.0, and was associated with the α-Capricornids (CAP#0001). This meteor overflew the Mediterranean Sea. The particle was moving on a cometary (JFC) orbit before hitting our atmosphere and exhibited the typical final flare of bright members of this shower.

The second fireball analyzed here was the "Don Gonzalo" event, which was recorded on August 5. Its peak magnitude was –11.0. The bolide was produced by a Perseid meteoroid and overflew Murcia (Spain). The progenitor body of this meteoroid stream is Comet 109P/Swift-Tuttle.

The next bright meteor described here was the "Los Noguerones" bolide. This was recorded on August 11. It also belonged to the Perseids (PER#0007). Its peak magnitude was –9.0 and overflew the provinces of Jaén and Córdoba (south of Spain).

The fourth fireball analyzed here was a bolide recorded on August 17. It was associated with the sporadic component. Its peak absolute magnitude was –9.0 and overflew the Mediterranean Sea. The meteoroid followed an asteroidal orbit before impacting our atmosphere. The ending altitude of this deep-penetrating meteor event was of about 23 km. From the analysis of the ending point of the luminous path of the event we concluded that this bolide was a meteorite-producer.

Next, we have analyzed the "Las Matanzas" event, which was recorded on August 17. It belonged to the August ν-Aquariids (ANA#0467). Its peak magnitude was –10.0 and it overflew Spain and the Mediterranean Sea. The meteoroid was moving on a cometary (JFC) orbit before colliding with our planet's atmosphere.

The next event analyzed here was a bolide recorded on September 3. The peak magnitude of this sporadic, which overflew the Gulf of Cádiz, was –12.0. The meteoroid was moving on an asteroidal orbit before striking our planet's atmosphere. The terminal altitude of this deep-penetrating meteor event was of about 38 km.

And the last fireball presented here was the "Tocón" fireball, which was recorded on September 26. This Earth-grazer was generated by a meteoroid belonging to the sporadic background. Its peak magnitude was –7.0 and it overflew the provinces of Jaén and Granada (south of Spain). Before hitting our planet's atmosphere the meteoroid was moving on an asteroidal orbit.

[33] https://youtu.be/HRGpknv-YVU

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