Analysis of bright bolides recorded between October and November 2022 by the Southwestern Europe Meteor Network

J.M. Madiedo[1], J.L. Ortiz[1], J. Izquierdo[2], P. Santos-Sanz[1], J. Aceituno[3], E. de Guindos[3], P. Yanguas[4], J. Palacián[4], A. San Segundo[5], D. Ávila[6], B. Tosar[7], A. Gómez-Hernández[8], Juan Gómez-Martínez[8], Antonio García[9], and A.I. Aimee[10]

[1] **Departamento de Sistema Solar, Instituto de Astrofísica de Andalucía (IAA-CSIC), 18080 Granada, Spain**
madiedo@cica.es, ortiz@iaa.es, psantos@iaa.es

[2] **Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, 28040 Madrid, Spain**
jizquierdo9@gmail.com

[3] **Observatorio Astronómico de Calar Alto (CAHA), E-04004, Almería, Spain**
aceitun@caha.es, guindos@caha.es

[4] **Departamento de Estadística, Informática y Matemáticas e Institute for Advanced Materials and Mathematics, Universidad Pública de Navarra, 31006 Pamplona, Navarra, Spain**
yanguas@unavarra.es, palacian@unavarra.es

[5] **Observatorio El Guijo (MPC J27), Galapagar, Madrid, Spain**
mpcj27@outlook.es

[6] **Estación de Meteoros de Ayora, Ayora, Valencia, Spain**
David_ayora007@hotmail.com

[7] **Casa das Ciencias. Museos Científicos Coruñeses. A Coruña, Spain**
borjatosar@gmail.com

[8] **Estación de Registro La Lloma, Olocau, Valencia, Spain**
curso88@gmail.com

[9] **Estación de Meteoros de Cullera (Faro de Cullera), Valencia, Spain**
antonio.garcia88@joseantoniogarcia.com

[10] **Southwestern Europe Meteor Network, 41012 Sevilla, Spain**
swemn.server@gmail.com

We present in this work the analysis of some of the bright fireballs spotted in the framework of the Southwestern Europe Meteor Network (SWEMN) between October and November 2022. They have been observed from the Iberian Peninsula and had a maximum brightness ranging from mag. –7 to mag. –15. Most meteors included in this report were linked to the sporadic background and also to the Southern Taurids.

1 Introduction

The Southwestern Europe Meteor Network (SWEMN) conducts the SMART project (Spectroscopy of Meteoroids by means of Robotic Technologies), which started operation in 2006 to analyze the physical and chemical properties of meteoroids ablating in the Earth's atmosphere. For this purpose we employ an array of automated cameras and spectrographs deployed at meteor-observing stations in Spain (Madiedo, 2014; 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; 2015b). 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).

Here we report a preliminary analysis of a series of remarkable fireballs recorded over Spain, France, and Portugal in the framework of the SWEMN network along October and November 2022. One of them was an Earth-grazer that ended over the Atlantic Ocean. This work has been fully written by AIMEE (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 path of the events were triangulated by means of the SAMIA software, developed by J.M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987).

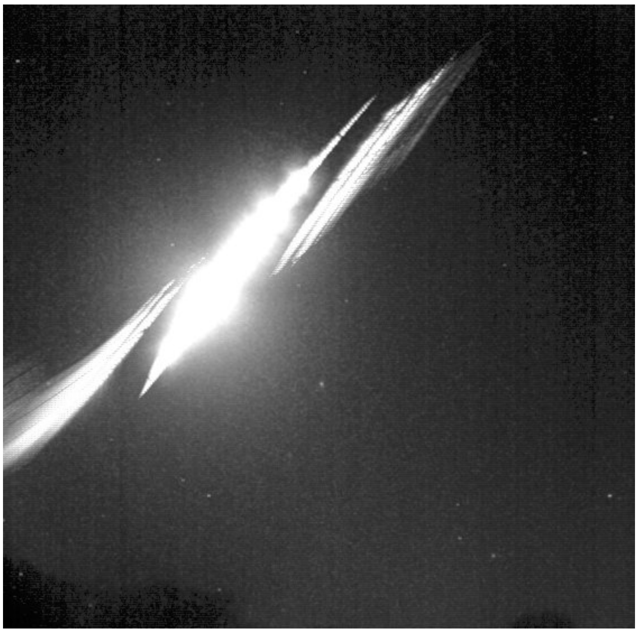

Figure 1 – Stacked image of the SWEMN20221005_221937 "Palomares del Campo" meteor as recorded from La Hita.

Figure 2 – Projection on the ground of the trajectory of the SWEMN20221005_221937 "Palomares del Campo" event.

3 Analysis of the 2022 October 5 event

This stunning bolide was recorded by our cameras at $22^h19^m37.0 \pm 0.1^s$ UT on 2022 October 5. The bright meteor, that exhibited a series of flares along its atmospheric trajectory, had a peak absolute magnitude of -12.0 ± 1.0 (*Figure 1*). These flares took place as a consequence of the sudden break-up of the meteoroid. The code assigned to the bolide in the SWEMN meteor database is SWEMN20221005_221937. A video showing this bolide was uploaded to YouTube[7].

Atmospheric trajectory, radiant and orbit

Having analyzed the atmospheric trajectory of the event it was deduced that this fireball overflew the province of Cuenca (Spain). The luminous event began at an altitude $H_b = 89.0 \pm 0.5$ km. The bolide penetrated the atmosphere till a final height $H_e = 67.6 \pm 0.5$ km. The equatorial coordinates found for the apparent radiant are $\alpha = 1.78°$, $\delta = +20.35°$. The pre-atmospheric velocity deduced for the meteoroid yields $v_\infty = 23.4 \pm 0.3$ km/s. *Figure 2* shows the calculated projection on the ground of the trajectory in the Earth's atmosphere of the fireball. *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)	2.35 ± 0.09	ω (°)	260.33 ± 00.07
e	0.72 ± 0.01	Ω (°)	192.348786 ± 10^{-5}
q (AU)	0.650 ± 0.003	i (°)	10.8 ± 0.2

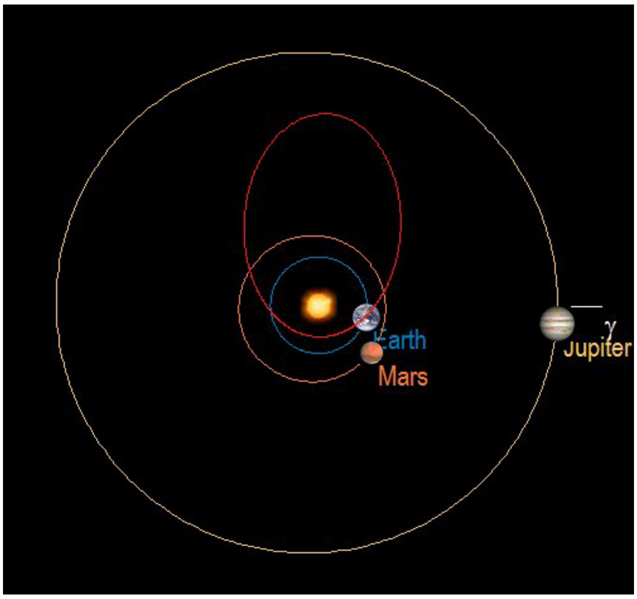

Figure 3 – Orbit of the SWEMN20221005_221937 "Palomares del Campo" fireball.

The bolide was named "Palomares del Campo", because the bright meteor was located over this locality during its initial phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet can be found in *Table 1*. The geocentric velocity obtained for the particle yields $v_g = 20.5 \pm 0.3$ km/s.

According to the value obtained for the Tisserand parameter referred to Jupiter ($T_J = 3.12$), before striking our planet's atmosphere the meteoroid was moving on an asteroidal

[7] https://youtu.be/qULk3ayDBu0

orbit. These data and the calculated radiant do not match any of the streams listed in the IAU meteor database. Consequently, it was concluded that the bright meteor was linked to the sporadic background.

Figure 4 – Stacked image of the SWEMN20221009_022441 event as recorded from CAHA.

Figure 5 – Atmospheric path of the SWEMN20221009_022441 fireball, and its projection on the ground.

4 Analysis of the 2022 October 9 meteor

We captured this bright event from the meteor-observing stations located at La Hita (Toledo), Calar Alto, Sierra Nevada, and La Sagra (Granada). The fireball was spotted on 2022 October 9, at $2^h24^m41.0 \pm 0.1^s$ UT. It had a peak absolute magnitude of -9.0 ± 1.0 (*Figure 4*), and showed various flares along its trajectory in the Earth's atmosphere as a consequence of the sudden disruption of the meteoroid. The code assigned to the fireball in the SWEMN meteor database is SWEMN20221009_022441.

Atmospheric path, radiant and orbit

It was deduced from the calculation of the trajectory in the Earth's atmosphere of the event that this fireball overflew the province of Valencia (Spain). The meteoroid started ablating at a height $H_b = 92.2 \pm 0.5$ km, and the terminal point of the luminous path was located at a height $H_e = 77.1 \pm 0.5$ km. From the analysis of the atmospheric path, we also deduced that the apparent radiant was located at the position $\alpha = 150.57°$, $\delta = +79.92°$. Besides, we inferred that the meteoroid stroke the atmosphere with a velocity $v_\infty = 23.7 \pm 0.2$ km/s. *Figure 5* shows the obtained atmospheric trajectory of the fireball. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

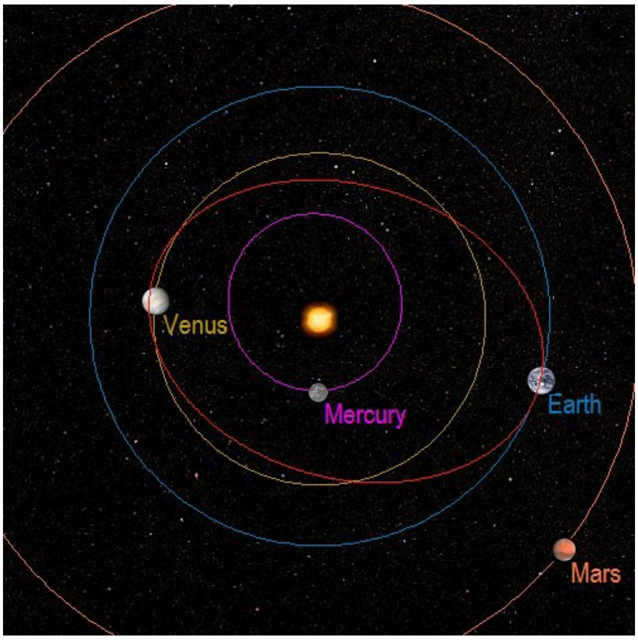

Figure 6 – Projection on the ecliptic plane of the orbit of the SWEMN20221009_022441 event.

The event was named "Gavarda", since 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 listed in *Table 2*. The value calculated for the geocentric velocity was $v_g = 20.9 \pm 0.2$ km/s. From the value estimated for the Tisserand parameter referred to Jupiter ($T_J = 6.56$), we found that the meteoroid was moving on an asteroidal orbit before hitting the Earth's atmosphere. These parameters and the derived radiant do not match any of the streams listed in the IAU meteor database. Consequently, it was concluded that the bright meteor was linked to the sporadic background.

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

a (AU)	0.872 ± 0.002	*ω* (°)	9.4 ± 00.2
e	0.147 ± 0.003	Ω (°)	195.473854 ± 10^{-5}
q (AU)	0.743 ± 0.004	*i* (°)	42.2 ± 0.4

5 The 2022 October 12 event

This stunning bolide was recorded by the systems operated by the SWEMN network at $4^h50^m43.0 \pm 0.1^s$ UT on 2022 October 12 (*Figure 7*). Its maximum luminosity was equivalent to an absolute magnitude of -15.0 ± 1.0. It showed a series of flares along its luminous path as a consequence of the sudden break-up of the meteoroid. The code given to the event in the SWEMN meteor database is SWEMN20221012_045043. It can be viewed on this YouTube video[8].

Figure 7 – Stacked image of the SWEMN20221012_045043 bolide as recorded from CAHA.

Atmospheric path, radiant and orbit

It was deduced by calculating the luminous path of the fireball that this event overflew the province of Jaén (Spain). The initial altitude of the meteor yields $H_b = 80.5 \pm 0.5$ km, with the terminal point of the luminous phase located at a height $H_e = 75.2 \pm 0.5$ km. The equatorial coordinates concluded for the apparent radiant are $\alpha = 8.09^o$, $\delta = +9.48^o$. The entry velocity in the atmosphere inferred for the parent meteoroid was $v_\infty = 18.9 \pm 0.1$ km/s. *Figure 8* shows the obtained trajectory in the atmosphere of the fireball.

Figure 8 – Atmospheric path of the SWEMN20221012_045043 event, and its projection on the ground.

We named this fireball “Reculo”, since the bright meteor passed near the zenith of this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet can be found in *Table 3*, and the geocentric velocity derived in this case was $v_g = 15.7 \pm 0.1$ km/s. From the value calculated for the Tisserand parameter referred to Jupiter ($T_J = 2.99$), we found that the meteoroid followed a cometary (JFC) orbit before entering the Earth’s atmosphere. These parameters and the derived radiant do not match any of the streams listed in the IAU meteor database. Consequently, it was concluded that this bolide was also linked to the sporadic background.

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

a (AU)	2.64 ± 0.03	ω (º)	239.5 ± 00.2
e	0.699 ± 0.005	Ω (º)	198.582920 ± 10^{-5}
q (AU)	0.795 ± 0.002	i (º)	1.21 ± 0.02

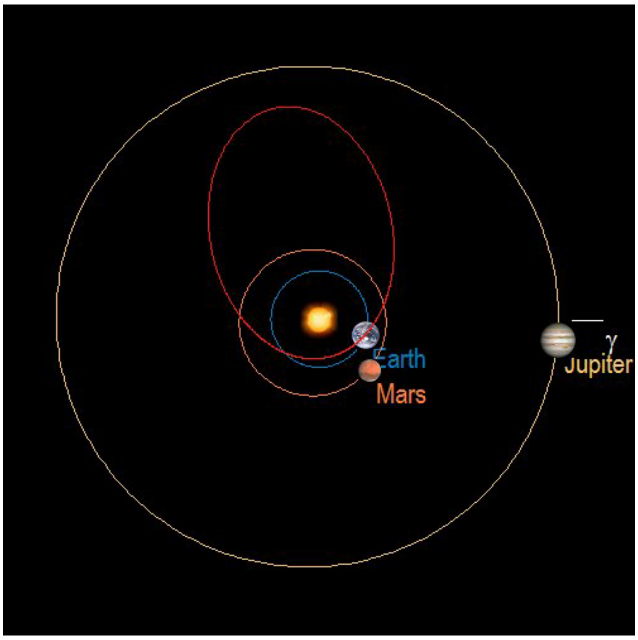

Figure 9 – Projection on the ecliptic plane of the orbit of the SWEMN20221012_045043 meteor.

6 Description of the 2022 October 16 meteor

We captured this bright event from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), Sevilla, and El Aljarafe (Sevilla). The fireball was spotted on 2022 October 16, at $2^h46^m41.0 \pm 0.1^s$ UT. Its maximum brightness was equivalent to an absolute magnitude of –9.0 ± 1.0 (*Figure 10*). It displayed a bright flare at the terminal stage of its atmospheric trajectory as a consequence of the sudden disruption of the meteoroid. The code given to the event in the SWEMN meteor database is SWEMN20221016_024641.

Atmospheric path, radiant and orbit

From the calculation of the atmospheric trajectory of the bright meteor it was found that this bolide overflew the province of Ciudad Real (Spain). The meteoroid started ablating at a height $H_b = 105.5 \pm 0.5$ km, and the terminal

[8] https://youtu.be/Sr_H9TZtiCg

point of the luminous path was located at a height $H_e = 59.2 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 43.84°$, $\delta = +13.25°$. Besides, we inferred that the meteoroid entered the atmosphere with a velocity $v_\infty = 39.9 \pm 0.2$ km/s. The obtained atmospheric path of the bolide is shown in *Figure 11*.

Figure 10 – Stacked image of the SWEMN20221016_024641 event as recorded from CAHA.

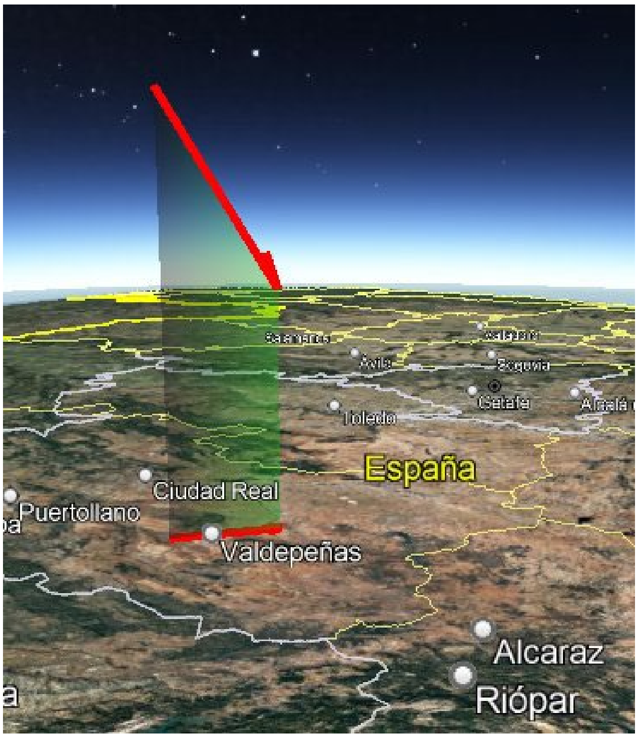

Figure 11 – Atmospheric path of the SWEMN20221016_024641 event, and its projection on the ground.

Figure 12 shows the orbit in the Solar System of the parent meteoroid, and *Table 4* shows the corresponding orbital parameters. The bolide was named "La Solana", because the bright meteor passed near the zenith of this locality during its final phase. *Table 4* shows the orbital parameters of the progenitor meteoroid before its encounter with our planet, and the geocentric velocity yields $v_g = 38.5 \pm 0.2$ km/s. From the value calculated for the Tisserand parameter referred to Jupiter ($T_J = 1.67$), we found that the particle followed a cometary (HTC) orbit before impacting our atmosphere. According to these parameters and the derived radiant, the event was produced by the sigma Arietids (IAU shower code SSA#0237), which peak around October 15 (Molau and Rendtel, 2009). So, the fireball was recorded near the activity peak of this meteor shower.

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

a (AU)	4.3 ± 0.2	ω (°)	137.1 ± 00.3
e	0.965 ± 0.002	Ω (°)	22.406612 ± 10^{-5}
q (AU)	0.148 ± 0.002	i (°)	8.6 ± 0.1

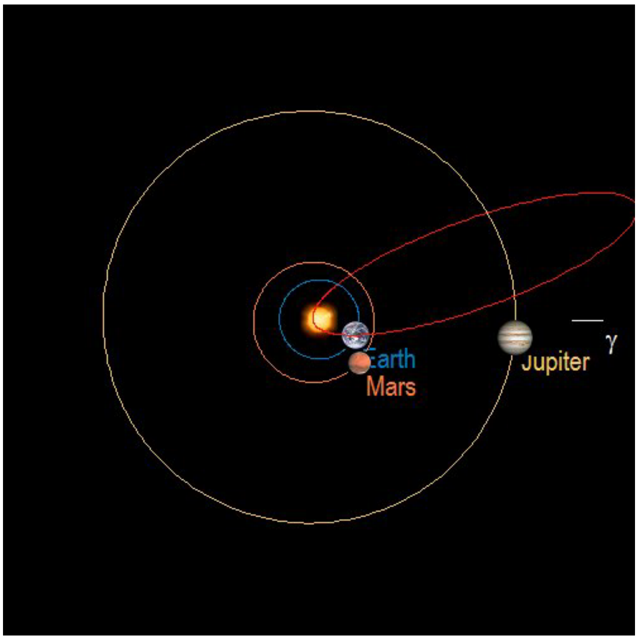

Figure 12 – Projection on the ecliptic plane of the orbit of the SWEMN20221016_024641 bolide.

7 Another fireball on 2022 October 16

This bright event was also captured on 2022 October 16, at $3^h00^m32.0 \pm 0.1^s$ UT (*Figure 13*). Its peak brightness was equivalent to an absolute magnitude of –7.0 ± 1.0. The code assigned to this fireball in the SWEMN meteor database is SWEMN20221016_030032.

Atmospheric path, radiant and orbit

By analyzing the trajectory in the Earth's atmosphere of the fireball it was deduced that this bright meteor was an Earth-grazer that overflew the north of Spain and the Atlantic Ocean. The luminous event began at an altitude $H_b = 128.7 \pm 0.5$ km over Spain. The bolide penetrated the atmosphere till a final height $H_e = 101.3 \pm 0.5$ km over the Atlantic. The position deduced for the apparent radiant correspond to the equatorial coordinates $\alpha = 138.67°$, $\delta = –10.62°$. The pre-atmospheric velocity concluded for the meteoroid yields $v_\infty = 61.1 \pm 0.2$ km/s. *Figure 14* shows the obtained atmospheric path of the meteor, which traveled a total distance in the atmosphere of around 311 km. The orbit in the Solar System of the meteoroid is shown in *Figure 15*.

Figure 13 – Stacked image of the SWEMN20221016_030032 meteor as recorded from El Guijo.

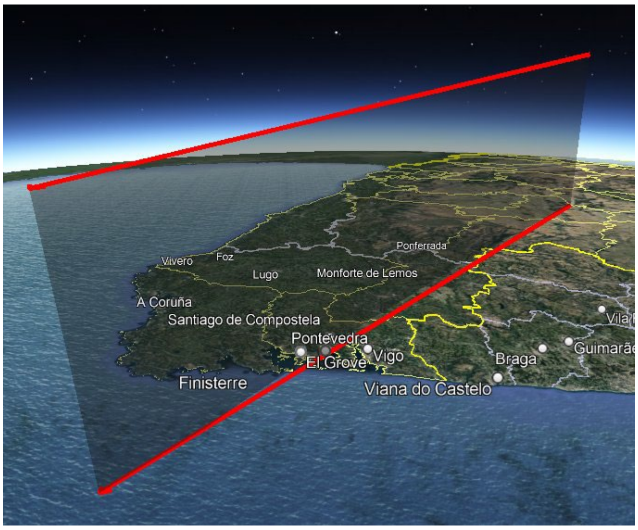

Figure 14 – Atmospheric path of the SWEMN20221016_030032 event, and its projection on the ground.

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

a (AU)	16.4 ± 4.5	*ω* (°)	271.6 ± 00.6
e	0.968 ± 0.008	Ω (°)	22.424283 ± 10^{-5}
q (AU)	0.520 ± 0.003	*i* (°)	120.7 ± 0.1

This fireball was named “Arquillinos”, because the bolide was located over this locality during its initial phase. *Table 5* shows the orbital parameters of the parent meteoroid before its encounter with our planet, and the geocentric velocity yields $v_g = 59.8 \pm 0.2$ km/s. The Tisserand parameter with respect to Jupiter ($T_J = -0.14$) indicates that before striking our planet’s atmosphere the meteoroid was moving on a cometary (HTC) orbit. These parameters and the derived radiant do not match any of the meteoroid streams in the IAU meteor database. So, it was concluded that the bright meteor was produced by a sporadic meteoroid.

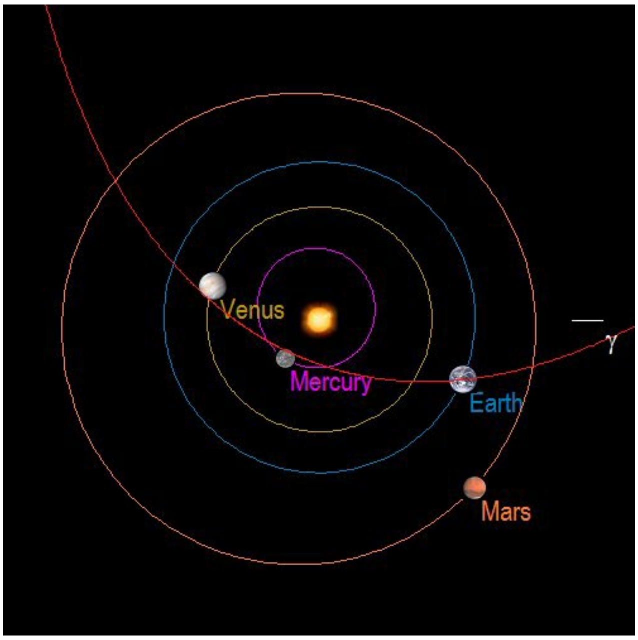

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20221016_030032 event.

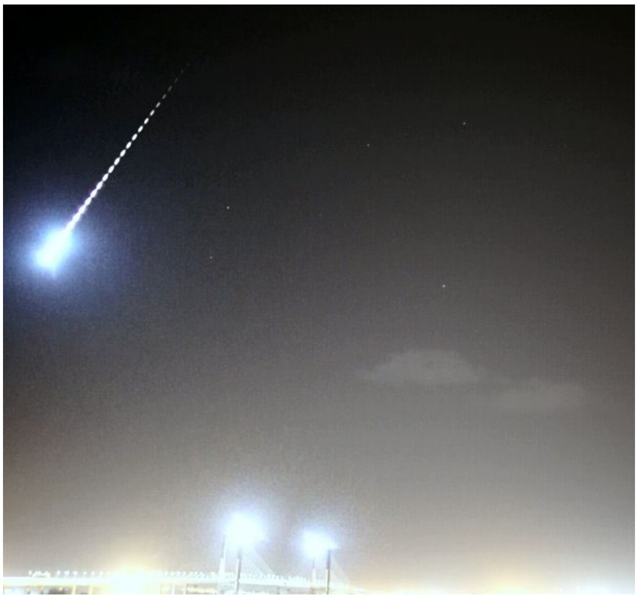

Figure 16 – Stacked image of the SWEMN20221027_045555 bolide as recorded from Sevilla.

8 Description of the 2022 October 27 bolide

This notable bright meteor was recorded on 2022 October 27 at $4^h55^m55.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 16*). Its maximum brightness was equivalent to an absolute magnitude of –12.0 ± 1.0. It exhibited a series of flares along its trajectory in the atmosphere as a consequence of the sudden disruption of the meteoroid. The code assigned to the bright meteor in the SWEMN meteor database is SWEMN20221027_045555. A video about this fireball can be viewed on YouTube[9].

[9] https://youtu.be/aHE0UKlwHhc

Figure 17 – Atmospheric path of the SWEMN20221027_045555 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

Following the analysis for the trajectory in the atmosphere of the event it was concluded that this bolide overflew Portugal. The luminous event began at an altitude $H_b = 135.8 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 82.2 \pm 0.5$ km. The equatorial coordinates inferred for the apparent radiant are $\alpha = 164.97°$, $\delta = +47.00°$. The entry velocity in the atmosphere concluded for the progenitor meteoroid was $v_\infty = 60.3 \pm 0.4$ km/s. *Figure 17* shows the calculated trajectory in our atmosphere of the bolide. The orbit in the Solar System of the meteoroid is shown in *Figure 18*.

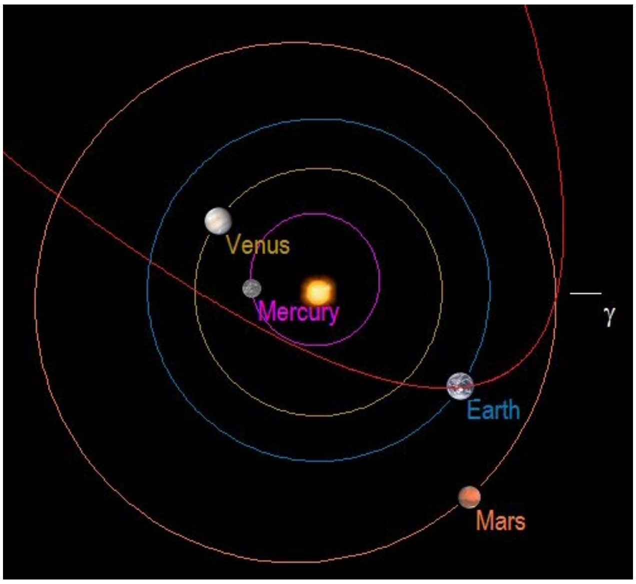

Figure 18 – Projection on the ecliptic plane of the orbit of the SWEMN20221027_045555 meteor.

The fireball was named "Nave do Barao", because the event was located over this locality during its final phase. *Table 6* shows the orbital parameters of the progenitor meteoroid before its encounter with our planet, and the geocentric velocity yields $v_g = 59.1 \pm 0.4$ km/s. From the value estimated for the Tisserand parameter referred to Jupiter ($T_J = -0.18$), we found that the meteoroid was moving on a cometary (HTC) orbit before entering our planet's atmosphere. By taking into account this orbit and the radiant position, the bright meteor was associated with the lambda Ursae Majorids (IAU meteor shower code LUM#0524). Since the lambda Ursae Majorids peak on October 28 (Jenniskens et al., 2016), the fireball was spotted during this activity peak.

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

a (AU)	23.7 ± 18.	ω (°)	131.2 ± 00.8
e	0.96 ± 0.02	Ω (°)	213.442207 ± 10^{-5}
q (AU)	0.827 ± 0.002	i (°)	111.1 ± 0.2

Figure 19 – Stacked image of the SWEMN20221102_224238 meteor as recorded from Sevilla.

9 Analysis of the 2022 November 2 meteor

This striking event was spotted on 2022 November 2 at $22^h42^m38.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), Sevilla, and El Aljarafe (Sevilla). The peak brightness of the bright meteor, which displayed a bright flare at the ending phase of its trajectory in the Earth's atmosphere, was equivalent to an absolute magnitude of –11.0 ± 1.0 (*Figure 19*). This flare appeared as a consequence of the sudden disruption of the meteoroid. The code given to the event in the SWEMN meteor database is SWEMN20221102_224238. A wide number of casual observers saw how the bolide crossed the sky, and reported the event on social networks. A video with images of the fireball and its trajectory in the atmosphere was uploaded to YouTube[10].

[10] https://youtu.be/_Yu2JfyZDwE

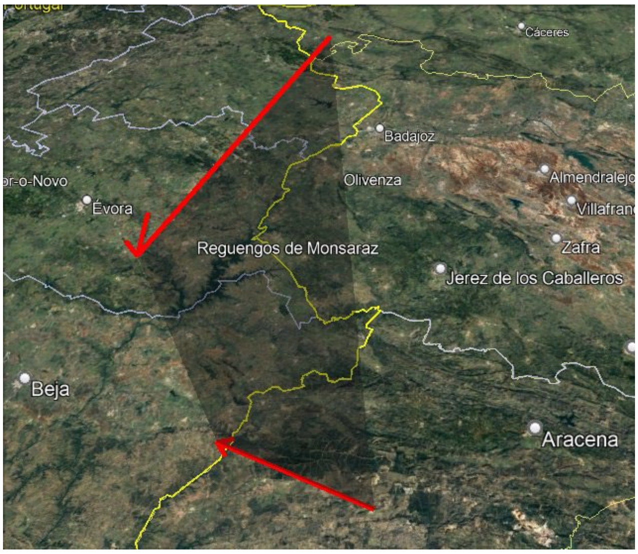

Figure 20 – Atmospheric path of the SWEMN20221102_224238 bolide, and its projection on the ground.

Atmospheric path, radiant and orbit

By analyzing the trajectory in the Earth's atmosphere of the event it was found that this fireball overflew Spain and Portugal. The initial altitude of the meteor yields $H_b = 98.6 \pm 0.5$ km over the south of Spain, and the bright meteor penetrated the atmosphere till a final height $H_e = 57.0 \pm 0.5$ km over the south of Portugal. The equatorial coordinates of the apparent radiant yield $\alpha = 54.00°$, $\delta = +14.32°$. Besides, we found that the meteoroid collided with the atmosphere with a velocity $v_\infty = 30.1 \pm 0.3$ km/s. *Figure 20* shows the calculated atmospheric trajectory of the bolide. The orbit in the Solar System of the meteoroid is shown in *Figure 21*.

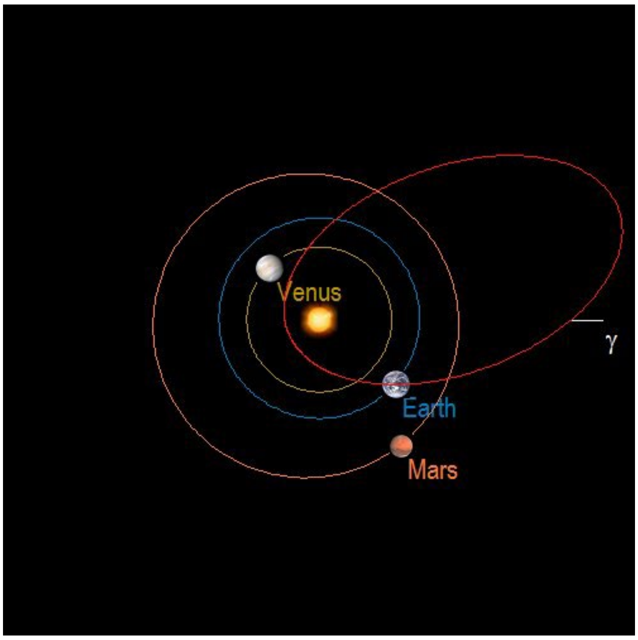

Figure 21 – Projection on the ecliptic plane of the orbit of the SWEMN20221102_224238 bolide.

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

a (AU)	1.76 ± 0.04	*ω* (°)	118.88 ± 00.03
e	0.811 ± 0.007	Ω (°)	40.163103 ± 10^{-5}
q (AU)	0.333 ± 0.003	*i* (°)	6.80 ± 0.07

The name given to the fireball was "El Cerro de Andévalo", since the bright meteor was located over this locality during its initial phase. The orbital parameters of the parent meteoroid before its encounter with our planet have been included in *Table 7*, and the geocentric velocity derived in this case was $v_g = 27.8 \pm 0.3$ km/s. These parameters and the derived radiant confirm that the bolide was associated with the Southern Taurids (IAU meteor shower code STA#0002). The proposed parent body of this shower, which peaks around November 6, is Comet 2P/Encke (Jenniskens et al., 2016).

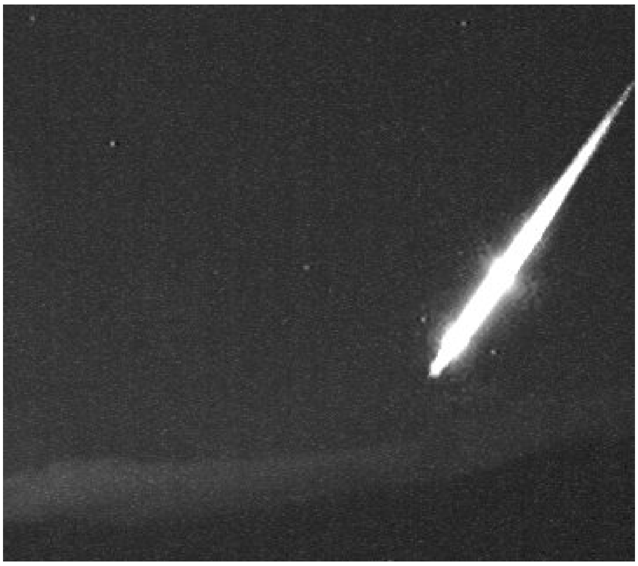

Figure 22 – Stacked image of the SWEMN20221103_205819 bolide as recorded from La Sagra.

10 The 2022 November 3 meteor

This bright event was captured on 2022 November 3 at $20^h58^m19.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), Sevilla, and El Aljarafe (Sevilla) (*Figure 22*). The peak luminosity of the fireball, that presented a series of flares along its trajectory in the atmosphere, was equivalent to an absolute magnitude of –9.0 ± 1.0. These flares took place as a consequence of the sudden break-up of the meteoroid. The code given to the bolide in the SWEMN meteor database is SWEMN20221103_205819. The event could also be observed by a wide number of causal eyewitnesses that reported the event on social networks. A video with images of the fireball and its trajectory in the atmosphere was uploaded to YouTube[11].

[11] https://youtu.be/Nh7H8LnNUow

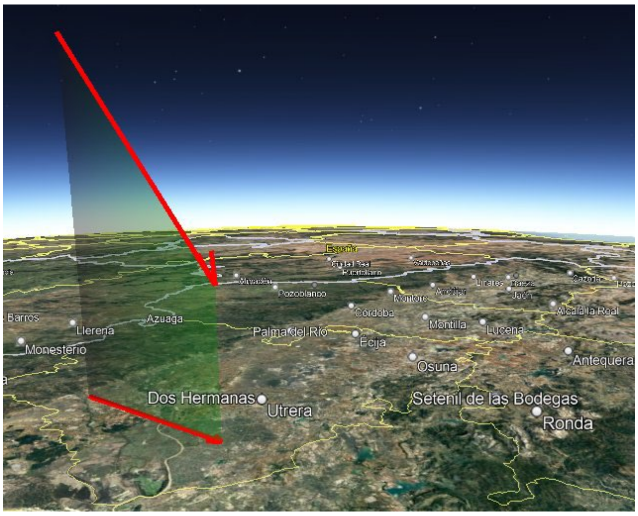

Figure 23 – Atmospheric path of the SWEMN20221103_205819 bolide, and its projection on the ground.

Atmospheric path, radiant and orbit

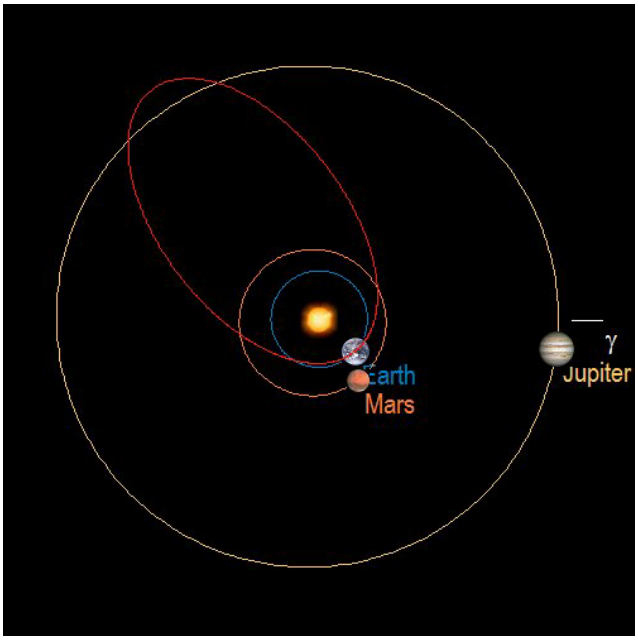

Figure 24 – Projection on the ecliptic plane of the orbit of the SWEMN20221103_205819 event.

By calculating the trajectory in the atmosphere of the bright meteor it was obtained that this fireball overflew the province of Sevilla (Spain). The ablation process of the meteoroid began at a height $H_b = 99.3 \pm 0.5$ km, and ended at a height $H_e = 77.5 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 306.31°$, $\delta = +71.81°$. The meteoroid collided with the atmosphere with an initial velocity $v_\infty = 27.3 \pm 0.3$ km/s. The obtained luminous path of the event is shown in *Figure 23*. The orbit in the Solar System of the meteoroid is shown in *Figure 24*.

Table 8 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	3.4 ± 0.2	ω (°)	198.9 ± 00.5
e	0.72 ± 0.02	Ω (°)	221.110431 ± 10^{-5}
q (AU)	0.969 ± 0.001	i (°)	39.2 ± 0.3

The name given to the fireball was "San Leandro", because the bolide overflew this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are included in *Table 8*. The geocentric velocity of the meteoroid was $v_g = 25.0 \pm 0.3$ km/s. From the value found for the Tisserand parameter with respect to Jupiter ($T_J = 2.37$), we found that before entering our planet's atmosphere the meteoroid was moving on a cometary (JFC) orbit. According to these values and the calculated radiant, the bright meteor was generated by the sporadic component.

11 The 2022 November 5 bolide

This striking event was recorded by the systems operated by the SWEMN network at $0^h00^m20.0 \pm 0.1^s$ UT on 2022 November 5. The fireball had a peak absolute magnitude of –12.0 ± 0.0 (*Figure 25*). The event was included in our meteor database with the code SWEMN20221105_000020. A video with images of the fireball and its trajectory in the atmosphere was uploaded to YouTube[12].

Figure 25 – Stacked image of the SWEMN20221105_000020 event.

Atmospheric path, radiant and orbit

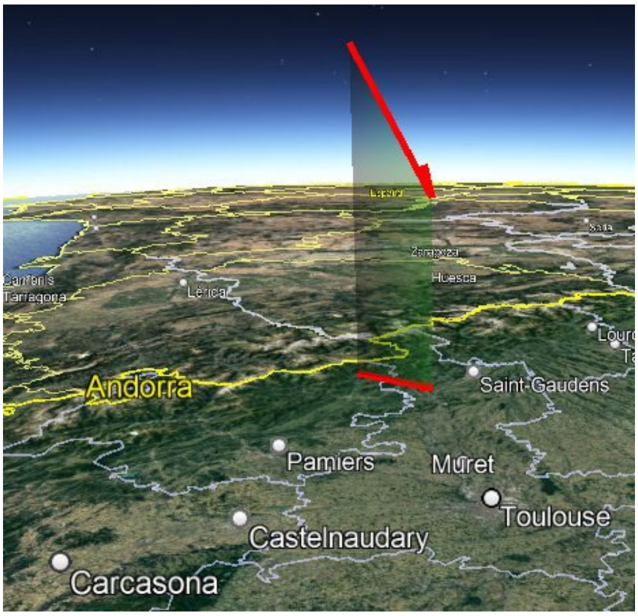

Figure 26 – Atmospheric path of the SWEMN20221105_000020 fireball, and its projection on the ground.

From the analysis of the atmospheric trajectory of the

[12] https://youtu.be/_aAcmNixt8I

fireball it was concluded that this event overflew the south of France. The luminous event began at an altitude $H_b = 95.0 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 54.6 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 54.19°$, $\delta = +12.41°$. Besides, we concluded that the meteoroid hit the atmosphere with a velocity $v_\infty = 30.8 \pm 0.3$ km/s. The obtained luminous path of the fireball is shown in *Figure 26*. The orbit in the Solar System of the meteoroid is shown in *Figure 27*.

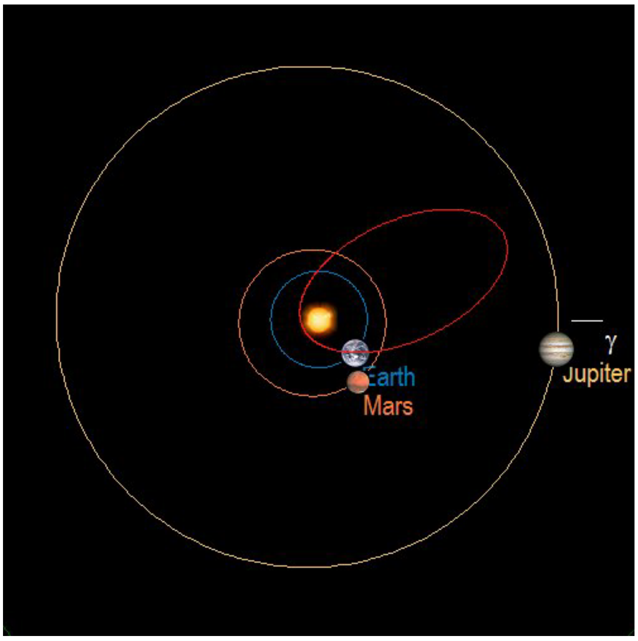

Figure 27 – Projection on the ecliptic plane of the orbit of the SWEMN20221105_000020 event.

Table 9 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.32 ± 0.09	*ω* (°)	112.36 ± 00.03
e	0.842 ± 0.007	Ω (°)	42.223828 ± 10^{-5}
q (AU)	0.365 ± 0.003	*i* (°)	8.95 ± 0.09

The name given to the bright meteor was "Bonac-Irazein", since the event was located over this locality during its initial phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet have been listed in *Table 9*, and the geocentric velocity derived in this case was $v_g = 28.7 \pm 0.3$ km/s. From the value found for the Tisserand parameter with respect to Jupiter ($T_J = 2.95$), we found that before impacting the atmosphere the particle was moving on a cometary (JFC) orbit. By taking into account this orbit and the radiant position, the event was produced by the Southern Taurids (IAU code STA#0002). Since the Southern Taurids reach their peak around November 6, this bright meteor was captured during this activity peak. The parent body of this shower is Comet 2P/Encke (Jenniskens et al., 2016).

12 Description of the 2022 November 7 bolide

This bright meteor was captured on 2022 November 7, at $0^h53^m40.0 \pm 0.1^s$ UT (*Figure 28*). The fireball, which displayed different flares along its trajectory in the atmosphere, had a peak absolute magnitude of –9.0 ± 1.0. These flares arose as a consequence of the sudden disruption of the meteoroid. The code given to the bolide in the SWEMN meteor database is SWEMN20221107_005340. A video with images of the fireball and its trajectory in the atmosphere can be found on YouTube[13].

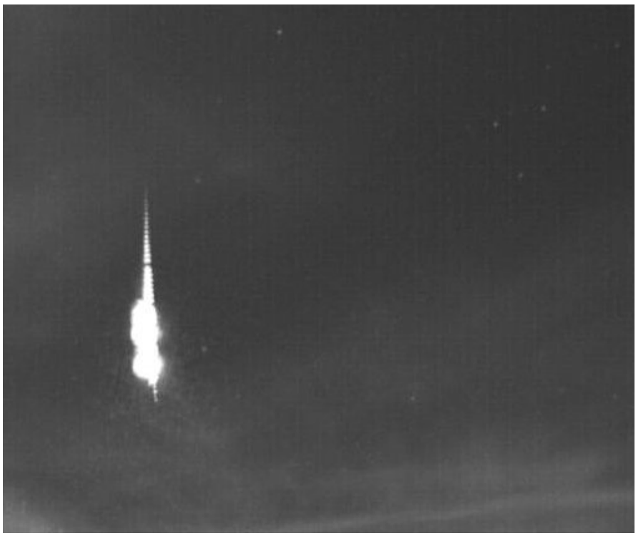

Figure 28 – Stacked image of the SWEMN20221107_005340 event as recorded from El Guijo.

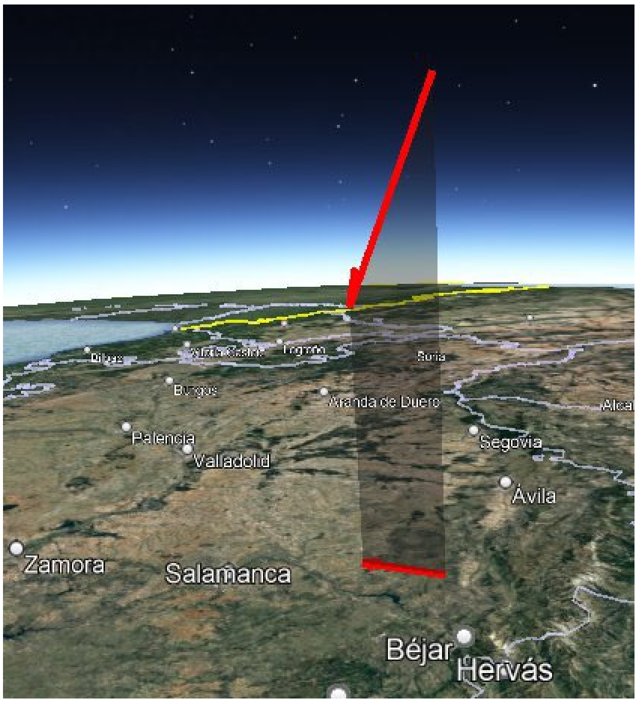

Figure 29 – Atmospheric path of the SWEMN20221107_005340 fireball, and its projection on the ground.

[13] https://youtu.be/a0Kttxhm494

Atmospheric path, radiant and orbit

Following the analysis of the trajectory in the atmosphere of the event it was obtained that this bolide overflew the provinces of Avila and Salamanca (Spain). The luminous event began at an altitude H_b = 113.0 ± 0.5 km over Avila. The bright meteor penetrated the atmosphere till a final height H_e = 63.5 ± 0.5 km over Salamanca. The equatorial coordinates of the apparent radiant yield α = 55.08º, δ = +16.70º. The pre-atmospheric velocity concluded for the meteoroid yields v_∞ = 30.3 ± 0.3 km/s. *Figure 29* shows the obtained trajectory in the Earth's atmosphere of the fireball. The orbit in the Solar System of the meteoroid is shown in *Figure 30*.

Table 10 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.31 ± 0.08	ω (º)	111.79 ± 00.06
e	0.840 ± 0.007	Ω (º)	44.248643 ± 10^{-5}
q (AU)	0.370 ± 0.003	i (º)	3.91 ± 0.03

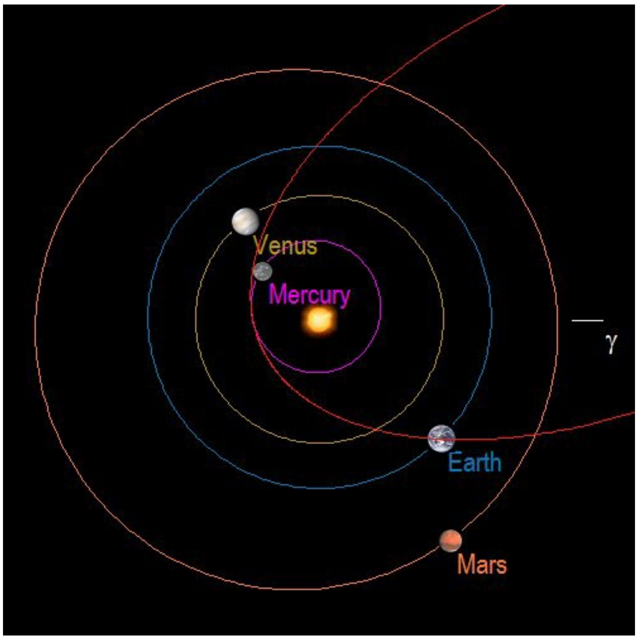

Figure 30 – Projection on the ecliptic plane of the orbit of the SWEMN20221107_005340 fireball.

This event was named "Carabias", since the fireball overflew this locality during its final phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet are listed in *Table 10*, and the geocentric velocity yields v_g = 28.3 ± 0.3 km/s. The value found for the Tisserand parameter with respect to Jupiter (T_J = 2.97) shows that the meteoroid followed a cometary (JFC) orbit before striking our atmosphere. These parameters and the derived radiant confirm that the bolide was also associated with the Southern Taurids (IAU meteor shower code STA#0002) (Jenniskens et al., 2016).

Figure 31 – Stacked image of the SWEMN20221112_001150 event as recorded from Sevilla.

13 The 2022 November 9 fireball

On 2022 November 12, at $0^h11^m50.0 \pm 0.1^s$ UT, the systems operated by the SWEMN network captured this bright event (*Figure 31*). The maximum luminosity of the bolide, that exhibited various flares along its trajectory in our atmosphere, was equivalent to an absolute magnitude of –9.0 ± 1.0. These flares arose as a consequence of the sudden disruption of the meteoroid. The bright meteor was included in our meteor database with the code SWEMN20221112_001150. A video with images of the fireball and its trajectory in the atmosphere was uploaded to YouTube[14].

Figure 32 – Atmospheric path of the SWEMN20221112_001150 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

This bright meteor overflew the Atlantic Ocean. The luminous event began at an altitude H_b = 116.4 ± 0.5 km. The event penetrated the atmosphere till a final height H_e = 62.6 ± 0.5 km. From the analysis of the atmospheric path, we also obtained that the apparent radiant was located at the position α = 55.81º, δ = +15.32º. The entry velocity in the atmosphere inferred for the parent meteoroid was

[14] https://youtu.be/Gm18KORg2as

$v_\infty = 28.4 \pm 0.3$ km/s. *Figure 32* shows the calculated trajectory in the Earth's atmosphere of the bright meteor. The orbit in the Solar System of the meteoroid is shown in *Figure 33*.

Table 11 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.5 ± 0.1	ω (º)	101.57 ± 00.04
e	0.820 ± 0.009	Ω (º)	49.244600 ± 10^{-5}
q (AU)	0.454 ± 0.003	i (º)	4.74 ± 0.04

Table 11 shows the orbital parameters of the progenitor meteoroid before its encounter with our planet. The geocentric velocity obtained for the particle yields $v_g = 26.2 \pm 0.3$ km/s. The value estimated for the Tisserand parameter with respect to Jupiter ($T_J = 2.85$) reveals that the particle followed a cometary (JFC) orbit before striking our atmosphere. According to these parameters and the derived radiant, this bolide was also generated by the Southern Taurids (IAU meteor shower code STA#0002).

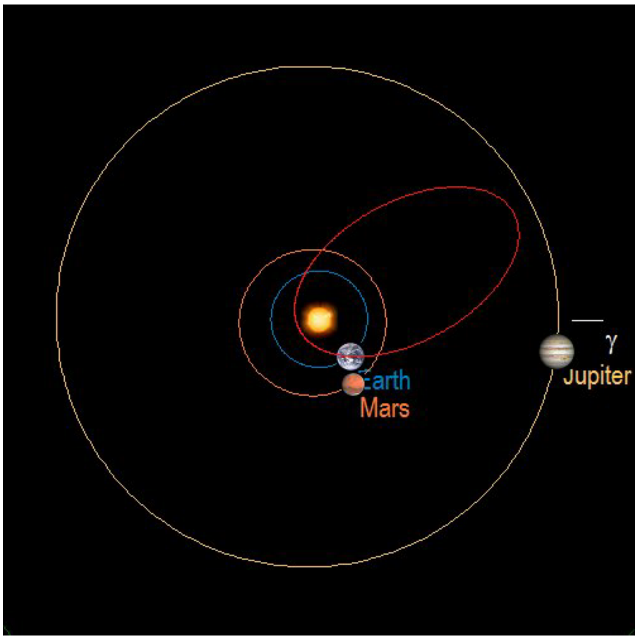

Figure 33 – Projection on the ecliptic plane of the orbit of the SWEMN20221112_001150 fireball.

14 Analysis of the 2022 November 13 event

On 2022 November 13, at $1^h42^m11.0 \pm 0.1^s$ UT, our meteor stations recorded this stunning bolide (*Figure 34*). It had a peak absolute magnitude of –11.0 ± 1.0, and exhibited a bright flare at the ending phase of its atmospheric path as a consequence of the sudden disruption of the meteoroid. The code given to the bright meteor in the SWEMN meteor database is SWEMN20221113_014211. A video describing the main features of the fireball and its trajectory in the atmosphere was uploaded to YouTube[15].

Figure 34 – Stacked image of the SWEMN20221113_014211 event as recorded from CAHA.

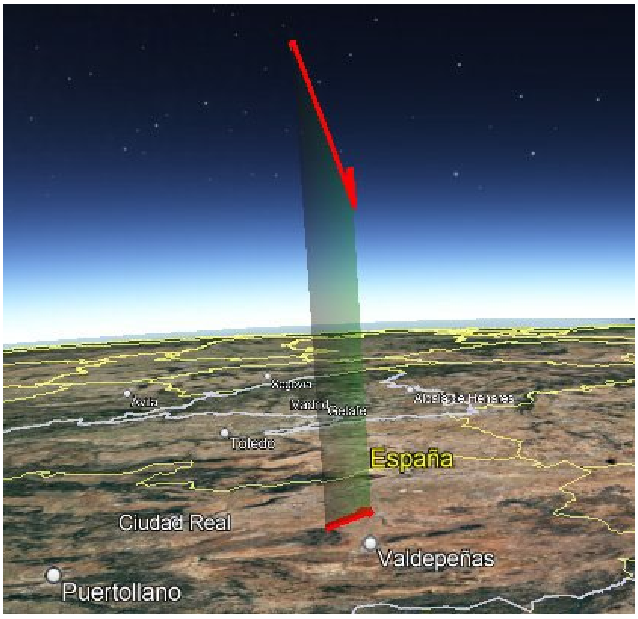

Figure 35 – Atmospheric path of the SWEMN20221113_014211 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

It was concluded by calculating the atmospheric path of the event that this bright meteor overflew the province of Ciudad Real (Spain). The meteoroid started ablating at a height $H_b = 109.5 \pm 0.5$ km, and ended at a height $H_e = 68.0 \pm 0.5$ km. The position concluded for the apparent radiant correspond to the equatorial coordinates $\alpha = 58.96$º, $\delta = +18.66$º. The pre-atmospheric velocity deduced for the meteoroid yields $v_\infty = 29.1 \pm 0.3$ km/s. *Figure 35* shows the obtained path in the atmosphere of the fireball. The orbit in the Solar System of the meteoroid is shown in *Figure 36*.

Table 12 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.37 ± 0.09	ω (º)	106.71 ± 00.07
e	0.826 ± 0.008	Ω (º)	50.286116 ± 10^{-5}
q (AU)	0.413 ± 0.003	i (º)	2.40 ± 0.02

[15] https://youtu.be/azjpzyP7Ncc

The bright meteor was named “Llanos del Caudillo”, because the event was located near the zenith of this locality during its final phase. The parameters of the orbit of the parent meteoroid before its encounter with our planet are listed in *Table 12*, and the geocentric velocity yields $v_g = 27.0 \pm 0.3$ km/s. From the value derived for the Tisserand parameter with respect to Jupiter ($T_J = 2.95$), we found that the meteoroid was moving on a cometary (JFC) orbit before entering the atmosphere. According to these data and the calculated radiant, the bolide was linked to the Southern Taurids (IAU shower code STA#0002).

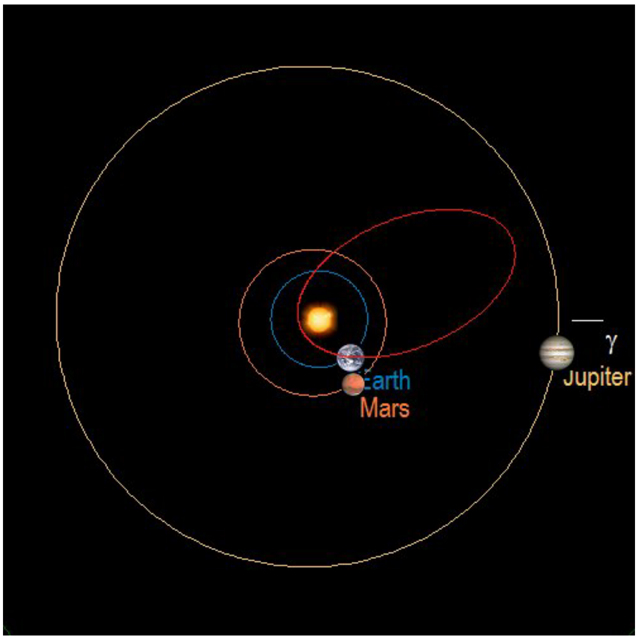

Figure 36 – Projection on the ecliptic plane of the orbit of the SWEMN20221113_014211 bolide.

15 Conclusions

Some of the most notable fireballs recorded by SWEMN from October to November 2022 have been described in this report. Their maximum absolute luminosity ranges from mag. –7 to mag. –15. Most of them were linked to the Southern Taurids and the sporadic component.

The “Palomares del Campo” event was recorded on October 5. The peak magnitude of this sporadic bolide, which overflew the province of Cuenca (Spain), was –12.0. The particle followed an asteroidal orbit before colliding with the atmosphere.

The second bright meteor presented here was the “Gavarda” fireball. This was recorded on October 9. The peak absolute magnitude of this sporadic, which overflew the province of Valencia (Spain), was –9.0. Its parent meteoroid followed an asteroidal orbit before impacting the Earth’s atmosphere.

The third event in this report was the “Reculo” bolide, which was recorded on October 12. This sporadic meteor had a peak absolute magnitude of –15.0 and overflew the province of Jaén (Spain). The meteoroid followed a cometary (JFC) orbit before striking the Earth’s atmosphere.

The fourth bolide presented in this work was named “La Solana”. It was recorded on October 16 and reached a peak absolute magnitude of –9.0. This fireball was associated with the sigma Arietids (SSA#0237) and overflew the province of Ciudad Real (Spain). Before entering the atmosphere the meteoroid was moving on a cometary (HTC) orbit.

Next, we have analyzed an Earth-grazer bolide recorded on October 16 and named “Arquillinos”. It reached a peak absolute magnitude of –7.0, and belonged to the sporadic background. This meteor overflew Spain and the Atlantic Ocean. The meteoroid followed a cometary (HTC) orbit before hitting our atmosphere.

The bright meteor recorded on October 27, which was named “Nave do Barao”, belonged to the lambda Ursae Majorids (LUM#0524) and reached a peak absolute magnitude of –12.0. This fireball overflew Portugal and the parent meteoroid was also moving on a cometary (HTC) orbit before entering the atmosphere.

The “El Cerro de Andévalo” bolide, recorded on November 2, was produced by the Southern Taurids (STA#0002). It overflew Spain and Portugal with a peak absolute magnitude of –11.0.

A sporadic meteoroid moving on a cometary (JFC) orbit gave rise to the “San Leandro” bright meteor, which was recorded on November 3. It reached a peak absolute magnitude of –9.0 and overflew the province of Sevilla (Spain).

The next bright event presented here was a fireball recorded on November 5 named “Bonac-Irazein”. This Southern Taurid (STA#0002) meteor had a peak absolute magnitude of –12.0 and overflew the south of France.

The “Carabias” fireball, which was generated by a meteoroid moving on a JFC orbit, was recorded on November 7. It belonged to the Southern Taurids (STA#0002). Its peak magnitude was –9.0 and overflew the provinces of Avila and Salamanca (Spain).

The next fireball analyzed here was a bolide recorded on November 12. It was also associated with the Southern Taurids (STA#0002). Its peak magnitude was –9.0 and overflew the Atlantic Ocean.

And the last bolide discussed in this work was the “Llanos del Caudillo” bolide, which was recorded on November 13. Its peak absolute magnitude was –11.0. The fireball was also a Southern Taurid (STA#0002) and overflew the province of Ciudad Real (Spain).

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