

Observation of three twilight bolides in August, 2013 from Galicia, NW of Spain. J. A. Docobo¹, P. P. Campo¹, J. M. Madiedo^{2, 3} and J. M. Trigo-Rodríguez⁴, ¹Observatorio Astronómico Ramón María Aller (OARMA). Universidade de Santiago de Compostela, Avenida das Ciencias, Campus Vida. Santiago de Compostela, Spain, joseangel.docobo@usc.es. ²Facultad de Ciencias Experimentales. University of Huelva. Avda de las Fuerzas Armadas S/N, 21071 Huelva, Spain, madiedo@uhu.es. ³Departamento de Física Atómica, Molecular y Nuclear. Universidad de Sevilla. 41012 Sevilla, Spain. ⁴Institute of Space Sciences (CSIC-IEEC). Campus UAB, Facultat de Ciències, Torre C5-p2. 08193 Bellaterra, Spain, trigo@ieec.uab.es.

Introduction: The Spanish Meteor Network (SPMN) is dedicated to the study of fireballs and bolides which may cause meteorite falls on our planet. These meteorites allow us a better understanding of other bodies from the Solar System and that is why we operate 25 meteor observing stations to monitor the night sky.

During the month of August 2013, three bright bolides were observed from the northwest of the Iberian Peninsula, on days 14, 22, and 30. The first one was recorded by the camera from the R. M. Aller Astronomical Observatory (OARMA). There were numerous visual witnesses that could account for them and the atmospheric path of one the bolides was reconstructed from the observation provided by them and the images of the camera.

In this work we present the data provided by the witnesses (for all three cases) and a preliminary analysis of one of these events (day 14).

Observational data: On August 14, 2013, at 19 h 53 min 41±1 s UTC, a bright fireball was observed over northwest of Spain. One of the cameras installed in the OARMA in Santiago de Compostela captured it. Besides, there were numerous visual witnesses and these were interviewed by a team belonging to OARMA. No sounds related to the bolide were heard, but there was a persistent trail associated with it. We estimate that its absolute magnitude was -9 ± 1 . Several fulgurations were observed during the final part of its atmospheric trajectory, before fading in the twilight sky (Sunset took place at 19 h 38 min UTC).

Eight days later, on August 22, a few people saw another fireball at 20 h 12±1 min UTC. This one was not recorded by the Santiago camera due to the local weather conditions. Finally, on August 30, yet another one was reported to the SPMN from diverse locations of the Iberian Peninsula. The bolide was observed at 19 h 32±1 min UTC, which unfortunately occurred when the cameras were not operating. Most of the witnesses described it as having a brightness close to or even superior to the Full Moon. We estimate an absolute magnitude of -12 ± 3 .

As in previous studies [1, 2, 3], visual witnesses were interviewed and precise visual measurements

were performed with a theodolite at the same locations where the fireball was observed. This allowed us to determine the positions of the initial and final points of the apparent luminous trajectory for the first bolide. The reports for the three cases are summarized in Table 1 (azimuths were measured from the North). In some cases, however, these initial or final coordinates corresponded to the position of an object (house, tree, hill, etc.) that occulted the fireball.

Preliminary results: The AMALTHEA software [4, 5, 6] employs the planes intersection method [7] to determine the luminous trajectory and radiant. According to the calculations made by using this tool, the beginning point for the first case was located at $\phi = 42.874^\circ$, $\lambda = -8.556^\circ$, $H = 92.3$ km, with the terminal point at $\phi = 43.085^\circ$, $\lambda = -9.211^\circ$, $H = 20.2$ km. The coordinates of the apparent radiant are R.A = 289.6°, Dec = 21.2°. The projection on the ground of this luminous trajectory is shown in red in Figure 1. The low height of the terminal point indicates a possible meteorite fall. However, the meteorite would have landed in the Atlantic Ocean. This bolide seems to be sporadic in nature, not associated with any known stream. The orbit has not been computed yet.

Conclusions: We have analyzed a very bright twilight bolide witnessed over the northwest of Spain on August 14, 2013 and determined its luminous phase on the basis of the information provided by witnesses and the images obtained by one of our cameras. The calculations reveal that this could have been a meteorite-producing fireball. However, fragments surviving the ablation process would have landed on the Atlantic Ocean. We also present the observations of other two events that took place on August 22 and 30. The provisional projections on the ground of these last trajectories are shown in Figure 1 in yellow.

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Obs #	Coordinates		Initial point		Final Point	
	ϕ (°)	λ (°)	A (°)	h (°)	A (°)	h (°)
August 14						
1	+43°22'41"	-8°24'28"	80	40	242.7	17
2	+43°20'57"3	-8°24'12"3	193.3	59.1	246.2	11.7
3	+43°19'28"	-8°21'3"8	155.7	71.8	216.3	49.2
4	+43°16'55"	-8°38'49"	226.4	46.2	265.8	11.7
5	+43°9'32"3	-8°46'44"6	232.4	45.7	259.6	31.8
6	+42°58'11"4	-8°24'57"3	273.6	23.6	273.6	19.4
7	+42°56'23"5	-9°13'54"6	20	20	0	10
8	+42°53'11"6	-8°30'51"3	292.9	35.7	286	8.4
9	+42°52'7"	-8°37'52"	306.8	32	289.3	17.3
10	+42°51'8"9	-8°36'44"6	357.2	51.8	288.2	14
11	+42°39'13"0	-9°1'49"2	370.8	44.3	359.7	37.8
12	+42°27'59"6	-8°37'13"2	17.3	45.4	328.8	16.5
13	+42°17'51"3	-8°39'15"4	0	35	325	15
14	+42°10'27"1	-8°48'50"2	60	50	28	20
15	+41°56'46"3	-8°46'36"8	50	45	0	10
August 22						
1	+42°57'2"2	-9°11'4"4	330	33	10	28.9
2	+42°40'24"	-8°49'10"	288	45	308	30
3	+42°35'22"	-9°2'40"	266	44.8	344	27.7
4	+42°17'37"	-8°35'24"	307.7	15.6	322.4	14
August 30						
1	+43°46'19"3	-7°40'38"8	126.5	40	100	30
2	+43°32'3"4	-6°7'9"1	235	30	90	25
3	+43°12'40"6	-7°3'6"6	130	35	97	25
4	+43°10'22"	-4°52'09"	160	40	150	35
5	+42°42'51"	-1°31'17"	200	40	270	20
6	+42°24'56"9	-6°58'26"5	83	45	73	35
7	+40°48'24"	-5°51'13"	35	50	22	6
8	+39°18'40"	-6°30'39"	35	30	35	15

Table 1. Geographical coordinates of the visual witnesses, along with the corresponding observed azimuth (A) and altitude (h) of the initial and final points of the fireball analyzed in this work. Azimuths were measured from the North.

References: [1] Docobo J.A. et al. (1998) *Meteorit. Planet. Sci.* 33, 57–64. [2] Docobo, J. A. et al (1999) *Astron. Astrophys. Suppl. Ser.* 138, 1–9. [3] Docobo, J. A. et al. (2009) *EMP* 102, 537–542. [4] Trigo-Rodriguez J.M. et al. (2009) *MNRAS* 394, 569–576. [5] J.M. Madiedo et al. (2011), *EPSC-DPS Joint Meeting 2011*, Abstract #Vol. 6, EPSC-DPS2011-67. [6] Madiedo J.M. et al. (2011), *NASA/CP-2011-216469*, 330. [7] Ceplecha, Z. (1987) *Bull. Astron. Inst. Cz.* 38, 222-234.



Figure 1. Projection on the ground of the luminous trajectory of the day 14 fireball (red), and the preliminary trajectories for the other two (yellow). S14: starting point, day 14. E14: ending point, day 14. S22: starting point, day 22. E22: ending point, day 22. S30: starting point, day 30. E30: ending point, day 30.