PRELIMINARY SPECTROSCOPIC AND DYNAMICAL ANALYSIS OF AN EARTH-GRAZER FIREBALL OBSERVED ON DECEMBER 24, 2014. A. Moreno[1], J.M. Madiedo[2], J. Zamorano[3], R. Goncalves[4], F. Espartero[3,5], J.M. Trigo-Rodríguez[6], J.L. Ortiz[7], J. Lacruz[8], J. Aceituno[9], E. de Guindos[9], J. Izquierdo[3], J. Alonso-Azcárate[10], A. Sánchez de Miguel[3], F. Ocaña[3] and E. Blanch[11]. [1]Facultad de Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain. [2]Dpto. de Física Atómica, Molecular y Nuclear, Facultad de Física, Universidad de Sevilla, 41012 Sevilla, Spain. [3]Dpto. de Astrofísica y CC. de la Atmósfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, 28040 Madrid, Spain. [4]Unidade Departamental de Matemática e Fisica, Instituto Politecnico de Tomar, 2300-313 Tomar , Portugal. [5]Observatorio Astronómico de Andalucía, 23688 La Pedriza, Alcalá la Real, Jaén, Spain. [6]Institute of Space Sciences (CSIC-IEEC). Campus UAB, Facultat de Ciències, Torre C5-p2. 08193 Bellaterra, Spain. [7]Instituto de Astrofísica de Andalucía, CSIC, Apt. 3004, Camino Bajo de Huetor 50, 18080 Granada, Spain. [8]La Cañada Observatory (MPC J87), Ávila, Spain. [9]Centro Astronómico Hispano-Alemán, Calar Alto (CSIC-MPG), E-04004 Almería, Spain. [10]Universidad de Castilla-La Mancha, Campus Fábrica de Armas, 45071 Toledo, Spain. [11]Observatori de l'Ebre, 43520 Roquetes, Tarragona, Spain.

Introduction: Most meteoroids entering the Earth's atmosphere are completely destroyed as a consequence of the ablation process. In some special cases, however, they can reach the ground and survive as meteorites. But meteoroid survival is also possible when these particles enter the atmosphere almost tangentially and only a portion of their mass is destroyed by ablation. Then, the meteoroid can leave the atmosphere and follow a modified orbit. Since this happens in very rare cases, these Earth-grazing events are not abundant in the scientific literature [1-5]. Here we present the results obtained from the preliminary analysis of a mag. -7±1 Earth-grazing fireball observed over Algeria, Spain and Portugal on Dec. 24, 2014.

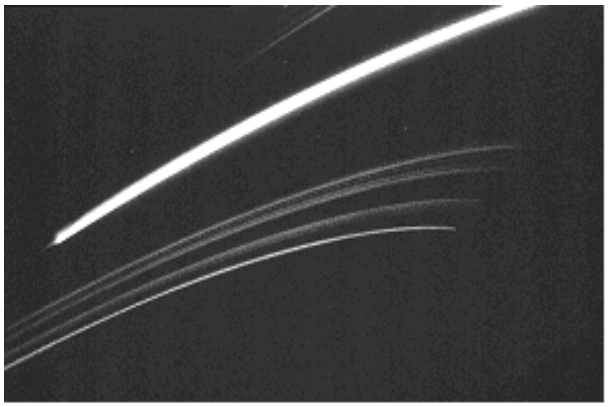

Figure 1. Composite image of the SPMN241214 Earth-grazing fireball as imaged from La Hita Astronomical Observatory (Toledo, Spain). The first order emission spectrum is also shown.

Instrumentation and methods: The fireball discussed here was recorded from several meteor observing stations operating in the framework of the Spanish Meteor Network (SPMN). Most of these employ an array of low-lux CCD video cameras manufactured by Watec Corporation (models 902H and 902H2 Ultimate). These devices monitor the night sky and some of them operate in a fully autonomous way by means of software developed by the second author [6]. For meteor spectroscopy we have employed transmission diffraction gratings attached to the objective lens of some of these cameras. The bolide was also imaged from a meteor station located in Tomar (Portugal), which employs five low-lux CCD video cameras (models Mintron 12V6HC-EX/12V1C-EX and Watec 902H2 Ultimate) named TEMPLAR1 to TEMPLAR5 and controlled by the MetRec Software [7]. The atmospheric trajectory and orbital data were obtained with the Amalthea software [8]. The CHIMET software [6] was employed to analyze the emission spectrum of the bolide.

The Dec. 24, 2014 event: A slow-moving fireball (Figure 1) was imaged on Christmas Eve at 20h06m00±1s UTC from 12 meteor observing stations located in Spain, and also from one station in Portugal. The bolide, which was included in our fireball database under code SPMN241214, was also witnessed by numerous casual observers along the Iberian Peninsula. Excluding the initial and ending phases, the luminosity of the event was practically constant along its atmospheric path. The photometric analysis of the imagery recorded for this fireball show that its maximum brightness was equivalent to an absolute magnitude of -7±1. Its total duration was of about 60 seconds.

H_b (km)	H_e (km)	H_{min} (km)	α_G (º)	δ_G (º)	V_∞ (km/s)	V_G (km/s)
105	102	75	102.2	-39.0	19	16

Table 1. Geocentric radiant (J2000) and atmospheric trajectory data.

Preliminary results: The analysis of the atmospheric trajectory reveals that the luminous phase started at H_b=105 km above the sea level over the North of Africa. Thus, the meteoroid stroke the atmosphere with a velocity V_∞ of about 19 km/s next to the zenith of Tiaret (Algeria), and with a zenith angle of

around 86º. The apparent radiant was located at the equatorial coordinates α=93.4º, δ=-30.9º. The calculated geocentric velocity was V_G = 16 km/s. The height of the bolide decreased slowly till a minimum value H_{min} of about 75 km (the perigee position). At this stage it was located next to the zenith of Ciudad Real (Spain). Then, its height increased slowly as the event overflew Ciudad Rodrigo (Salamanca, Spain) and the North of Portugal. Finally, the fireball left Portugal and overflew the Southwest of Galicia (Spain), and ended over the Atlantic Ocean at around 100 km from the coast of Galicia. At that point, when it was located at a height H_e of around 102 km above the sea level, ablation ceased. Then, the meteoroid left the atmosphere and followed a modified orbit.

a (AU)	e	q (AU)	i (º)	ω (º)	Ω (º)	T_J
1.15	0.266	0.844	26.3	71.0	97.726	5.3

Table 2. Orbital data (J2000) of the meteoroid before impacting our planet.

Figure 2. Projection on the ground of the atmospheric trajectory of the SPMN241214 event.

The total length traveled by the fireball in the atmosphere was of about 1,200 km. The projection on the ground of the atmospheric trajectory is shown in Figure 2, and the main parameters of this path are listed in Table 1. The parameters of the heliocentric orbit followed by the meteoroid before its encounter with our planet are shown in Table 2. These data confirm the sporadic nature of the event. The value of the Tisserand parameter with respect to Jupiter (T_J =5.3) indicates that the meteoroid was following an asteroidal orbit.

The emission spectrum of the bolide at the perigee, once calibrated in wavelengths and corrected for the instrumental efficiency, is shown in Figure 3. The most significant contributions have been highlighted on this plot. As can be noticed, the spectrum is dominated by the emissions from different Fe I multiplets, the Na I-1 doublet and the Mg I-2 triplet. The contribution from FeO orange-arc emission was also identified. Additional analysis will be performed in order to obtain information about the chemical nature of the progenitor meteoroid from this signal.

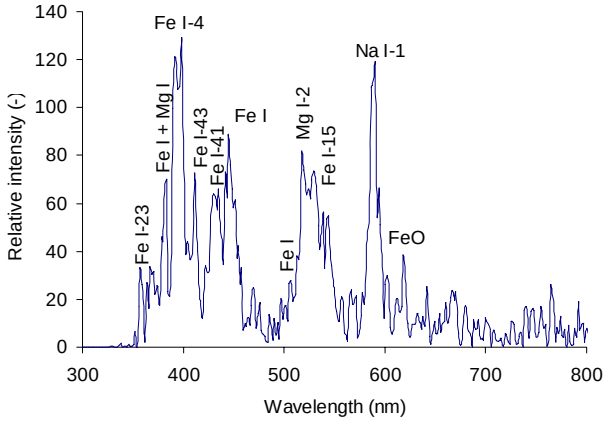

Figure 3. Calibrated emission spectrum of the SPMN241214 Earth-grazing fireball at the perigee position.

Conclusions: We have presented the results obtained from the preliminary analysis of a sporadic mag. -7±1 Earth-grazing fireball observed over the Iberian Peninsula on Dec. 24, 2014. The event started over the North of Africa and reached a minimum height of about 75 km above the ground level when it was located next to the zenith of Ciudad Real (Spain). The fireball ended over the Atlantic Ocean, at about 100 km from the coast of Galicia (Spain), after crossing the North of Portugal. At that point the meteoroid left the atmosphere and continued its path around the Sun on a modified orbit. The emission spectrum of this event and the final orbit of the meteoroid are currently under analysis.

References: [1] Jacchia L.G. (1974), S&T, 48, 4. [2] Ceplecha Z. (1979), Bull. Astron. Inst. Czechosl.,30, 349. [3] Borovicka J. & Ceplecha Z. (1992), A&A, 257, 323. [4] Ceplecha Z. (1994), A&A, 283, 287. [5] Abe et al. (2006), EPSC 2006, p.486. [6] Madiedo J.M. (2014), Earth, Planets & Space, 66, 70. [7] Molau S. (1999) Proc. of the International Meteor Conference, Stara Lesna 20-23 August 1998, Eds.: Arlt, R., Knoefel, A., International Meteor Organization, p.9. [8] Madiedo J.M. et al. (2011), NASA/CP-2011-216469, 330.