

PHYSICO-CHEMICAL PROPERTIES OF 109P/SWIFT-TUTTLE DEBRIS. F. Ocaña¹, J.M. Madiedo^{2,3}, J.M. Trigo-Rodríguez⁴, J. Zamorano¹, J. Izquierdo¹ and A. Sánchez de Miguel¹. ¹Dpto. de Astrofísica y CC. de la Atmósfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, 28040 Madrid, Spain, jzamorano@fis.ucm.es. ²Facultad de Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain, madiedo@uhu.es. ³Dpto. de Física Atómica, Molecular y Nuclear, Facultad de Física, Universidad de Sevilla, 41012 Sevilla, Spain, ⁴Institute of Space Sciences (CSIC-IEEC). Campus UAB, Facultat de Ciències, Torre C5-p2. 08193 Bellaterra, Spain, trigo@ice.csic.es.

Introduction: Dust ejecta of comet 109P/Swift-Tuttle produces one of the most relevant annual meteor showers: the Perseids (PER). This display of meteors is active between July 17 and August 24, peaking on August 12 [1]. As a result of good weather conditions that generally predominate in most of Spain during summer time, the video observing stations operated by the Spanish Meteor Network (SPMN) have registered a huge amount of multi-station meteor and fireballs events since they started operation in 2006. As a result of our continuous spectroscopic campaign, emission spectra of Perseids brighter than mag. -4/-5 have also been recorded. As an example, we present here a preliminary analysis of some relevant multi-station PER fireball events recorded during 2011 and 2012.

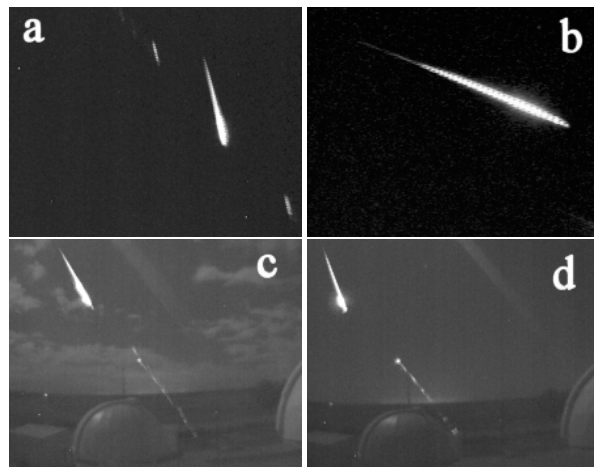


Figure 1. Composite images of the Perseid fireballs listed in Table 1: a) 020811; b) 110811; c) 060812; d) 070812.

SPMN Code	Date	Time (UT) ±0.1 s	Abs. mag.
020811	Aug. 2, 2011	02:27:43.8	-7±1
110811	Aug. 11, 2011	01:46:43.5	-7±1
060812	Aug. 6, 2012	01:23:17.2	-8±1
070812	Aug. 7, 2012	02:44:04.3	-7±1

Table 1. Perseid fireballs analyzed in this work.

Instrumentation: Our video meteor observing stations are based on an array of low-lux CCD video cameras manufactured by Wattec Corporation (models 902H and 902H Ultimate). These devices monitor the night sky and some of them operate in a fully auto-

nous way thanks to software developed by us [2, 3, 4]. For meteor spectroscopy we have employed transmission diffraction gratings attached to the objective lens of some of these cameras.

Preliminary results: Table 1 contains the absolute magnitude and the recording date and time of the fireballs analyzed in this work. Their atmospheric trajectory and apparent radiant position were determined by means of the planes intersection method [5]. These calculations were performed with our AMALTHEA software [4]. The preatmospheric velocity (V_{∞}), inferred from the velocities measured at the beginning of the meteor trails, can be found in Table 3, together with the position of the geocentric radiant and the beginning (H_b) and terminal (H_e) heights of the luminous atmospheric path. The orbital parameters, also calculated with AMALTHEA, are shown in Table 3.

SPMN Code	H_b (km) ±0.5	H_e (km) ±0.5	α_G (°) ±0.3	δ_G (°) ±0.2	V_{∞} (km/s) ±0.3	V_G (km/s) ±0.3
020811	110.8	79.6	39.4	54.6	60.9	59.7
110811	113.1	86.7	42.0	59.2	59.8	58.6
060812	107.5	74.9	32.5	53.8	61.6	60.5
070812	110.3	77.4	44.9	66.4	55.2	53.9

Table 2. Radiant (J2000) and trajectory data for the PER fireballs listed in Table 1.

SPMN Code	a (AU) ±0.02	e ±0.02	q (AU)	i (°) ±0.03	Ω (°)	Ω (°) ±10 ⁻⁴
020811	78±3	0.98	0.908±0.001	114.4	142.1±0.5	129.3281
110811	70±4	0.98	0.966±0.004	110.2	154.9±0.5	137.9219
060812	73±4	0.98	0.995±0.001	115.8	164.3±0.5	133.8266
070812	86±6	0.98	0.917±0.002	97.4	143.8±0.6	134.8380

Table 3. Orbital data (J2000) for the Perseid bolides analyzed here.

The emission spectra, once calibrated in wavelengths and corrected for the instrumental efficiency, are shown in Figure 2. As can be noticed, the contribution of atmospheric N_2 in the red part of the spectrum is very significant. In the infrared, the O I triplet at 777.4 nm is also very prominent. Several Fe I multiplets have been identified and the bright ionized calcium H and K lines appear blended with the contribution from Fe I-4 (386 nm) and Mg I-3 (382.9 nm) multiplets. The emissions from Mg I-2 (516.7 nm) and Na I-1 (588.9 nm) are also seen. Due to the aggregate na-

ture of mm-sized cometary meteoroids significant mineralogical differences should be found between these particles. The heterogeneity in their forming components is clearly shown in a qualitative way by comparing the significant differences in the Ca, Mg, and Na contents. In a similar way that the rock-forming materials of 81P/Wild 2 comet studied in Stardust particles, 109P/Swift-Tuttle materials should contain chondrules and refractory inclusions capable to explain the observed bulk chemistry differences [6, 7].

Conclusions: We have analyzed here four Perseid fireballs imaged during our continuous meteor and fireball monitoring campaign. Their atmospheric trajectory and radiant was determined, together with the orbit of the meteoroids producing these events that demonstrate their association with comet 109P/Swift-Tuttle. The emission spectra recorded by our video spectrographs have provided clues on the chemical composition of these grains. The noticed differences suggest important heterogeneity among the different particles as they were formed by aggregates with different amounts of chondrules, CAI and matrix components. These differences occur naturally for mm-sized meteoroids due to be aggregates with different proportions of grains [8]. We also found that the contribution of atmospheric nitrogen in the spectrum is very significant, and can be easily distinguished from the meteoroid chemistry. In general, Perseid spectra are dominated by the emission from H and K lines of ionized calcium, and by the O I triplet at 777.4 nm in the infrared.

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References: [1] Jenniskens, P. (2006) *Meteor Showers and their Parent Comets*. Cambridge University Press. [2] Madiedo J.M. and Trigo-Rodríguez J.M. (2007) *EMP* 102, 133-139. [3] Madiedo J.M. et al. (2010) *Adv.in Astron.* 2010, 1-5. [4] Trigo-Rodríguez, et al. (2009) *MNRAS*. 392, 367-375. [5] Cepelch, Z. (1987) *Bull. Astron. Inst. Cz.* 38, 222-234. [6] Brownlee et al. (2006) *Science*, 314, 1711. [7] Nakamura T. et al. (2008) *Science* 321, 1664. [8] Rietmeijer, F.J.M (1998) *Planetary Materials, Reviews in Mineralogy* 36, 1-95.

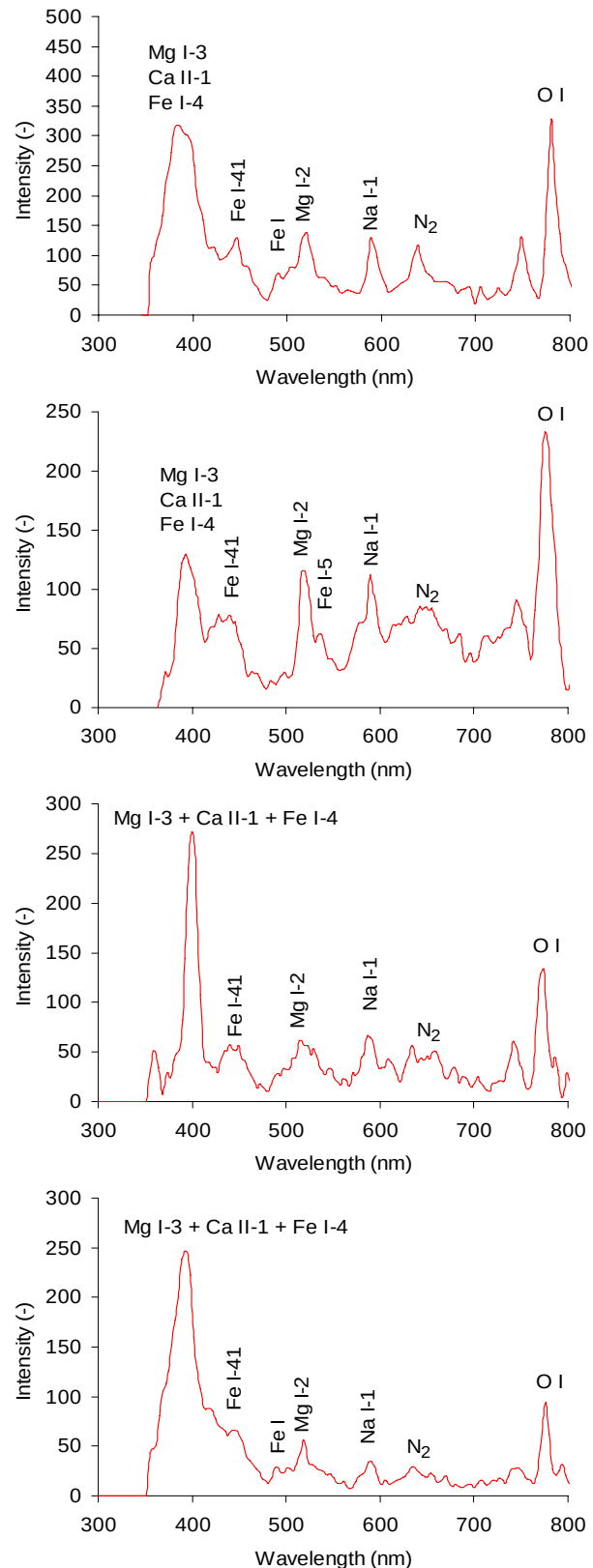


Figure 2. From top to bottom, calibrated emission spectra of the Perseid bolides with SPMN code 020811, 110811, 060812 and 070812.