EVIDENCE FOR HYDRATED 109P/SWIFT-TUTTLE METEOROIDS FROM METEOR SPECTROSCOPY. J.M. Trigo-Rodríguez[1], A.J. Castro-Tirado[2] and J. Llorca[3,4]. [1]Institute of Geophysics & Planetary Physics, University of California Los Angeles (UCLA), Los Angeles CA 90095-1567, USA (jtrigor@ucla.edu); [2]Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain (ajct@iaa.es); [3]Dept. Quimica Inorganica, Universitat de Barcelona, Spain (jordi.llorca@qi.ub.es); [4]Institut d'Estudis Espacials de Catalunya, Spain.

Introduction: Evidence for the possible presence of water in meteoroids released from comet 109P/Swift-Tuttle is presented. The absence of chondritic principal components [1] supports the idea that the structure of the meteoroids from this comet follows the dustball model [2] where mineral grains can exhibit aqueous alteration as recently proposed [3]. A study of the Fe and Mg chemical abundances for five photographic Perseid meteoroids is presented. We also include the first results of a Perseid fireball spectrum obtained during the 2004 campaign of this meteoroid stream from the Spanish Meteor Network (SPMN). The spectrum shows O and H lines produced during flares associated with the fragmentation of the meteoroid, consistent with the presence of water in the mineral components of the meteoroid.

Methods: We present data on five photographic Perseid spectra obtained with fixed cameras (focal length 360 mm, focal ratio 1:4.5) equipped with prism (resolution 130 Å mm^{-1} at 4000 Å to 550 Å mm^{-1} at 6000 Å) and registered on 18×24 cm plates (Agfa 100 and Orwo NP27) at the Ondrejov Observatory, Czech Republic. Data reduction and the relative chemical compositions of the meteoroids were obtained using the procedure developed by Borovicka [4]. Basically, to deduce the relative chemical composition of meteoroids, we considered the radiating volume as a prism with a square base and elongated in the direction of the meteor flight. Assuming thermal equilibrium, we computed the brightness of the spectral lines by adjusting four parameters: temperature (T), the column density of atoms (N), the damping constant (Γ) and the surface area (P) [4, 5]. The procedure consisted of the reconstruction of a synthetic spectrum that allowed the determination of these four parameters from the observed brightness of lines. This was done by the least-squares method. As most lines in the spectrum are of neutral iron, Fe I is taken as a reference element to adjust the intensity of lines and temperature. To obtain chemical abundances, we considered the degree of ionization of different elements, taking into account the ratio of neutral, singly and doubly ionized atoms given by the Saha equation as previously explained in [4, 5].

On August 12, 2004 at 01h14m UTC we obtained a detailed Perseid meteor spectrum (SPMN-PER01) using a CCD ST8E camera and a f2.8/50mm lens. A diffraction grating of 1200 grooves/mm was placed in front of the lens. The instrument was placed at the BOOTES-2 station at the La Mayora Research Station in Málaga, South Spain [6]. This spectrograph provides a field of 16°×11° allowing a resolution of ~3 Å pix^{-1}. The spectrum covers the range ~4700 to 6750 Å. The brightest lines are the Mg I-2 (the multiplet number is given after the excitation degree), Na I-1, Si II-2, and several lines associated with volatile elements like H, O and N_2. In this grating spectrum the wavelength scale is almost linear, and the wavelength calibration has been performed by matching known lines like the sodium doublet (Na I-2) at 6890 and 6896 Å, the Si II-2 at 6347 Å and the bright Fe I-268 at 6678 Å. Detailed calibration and determination of chemical abundances for this high-resolution spectrum will be given in a future work. However, we discuss here the identification of lines of N_2, O and H I associated with the main fragmentation of the meteoroid.

Results and discussion: We obtained for the five photographic Perseid meteors the relative chemical abundances of Na, Mg, Ca, Si, Ti, Cr, Mn, Fe, Co and Ni [5]. We focus here our attention on the relative chemical abundance of Fe and Mg in these meteoroids because both elements can be present in oxidized form or within clay minerals. Fe lines are omnipresent in meteor spectra while main Mg lines are visible from Mg I-2 located at 5184 Å and Mg II-4 located at 4481 Å. Fe and Mg abundance were obtained for several segments in each fireball and averaged [5], the errors were estimated from the dispersion of the abundances in all analyzed segments. In Figure 1 we have arranged Fe/Si as a function of Mg/Si. For the sake of comparison the typical abundances in IDPs, 1P/Halley dust [8] and CI and CM carbonaceous chondrites [9] are plotted. It is quite significant that particles produced by comets: 109P/Swift-Tuttle comet (PER1 to PER5) and 55P/Tempel Tuttle (LEO) have Fe and Mg abundance close to the IDP and chondritic values. The chemical composition of 1P/Halley dust measured from the Giotto spacecraft is far off the composition estimated for the analyzed meteoroids [5]. Unfortunately Perseid photographic spectra had a resolution lower than that required to study volatile elements, covering only the visible part of the electromagnetic spectrum.

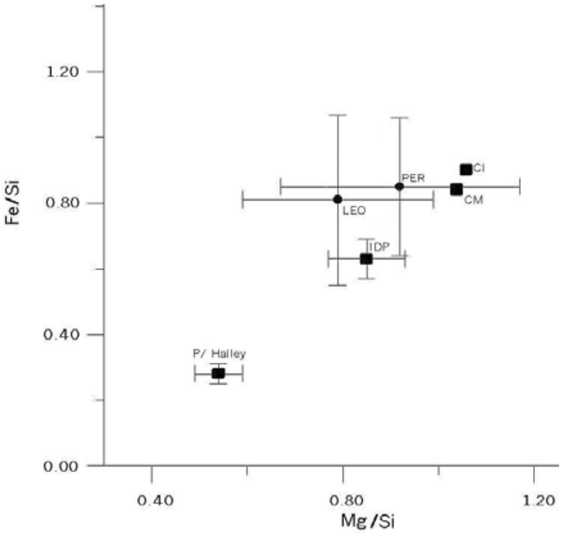

Figure 1. Fe and Mg abundance for five Perseid spectra and one Leonid analyzed in [5].

The SPMN-PER01 spectrum recorded during the 2004 Perseid campaign has more resolution and ranges to the near infrared. As a consequence, this spectrum allows us to study several lines of astrobiological significance. Between them, the Hα line at 6563 Å, the OI-2 line at 6727 Å and others one associated with the complex N_2 molecular band. We include here a preliminary discussion of the main lines of volatile elements visible in the spectrum. N_2 first-positive band radiation is a major contributor to this meteor spectra. The N_2 first-positive band radiation is visible between 6650 and 6720 Å including the sequence of bright lines predicted in wavelengths 6772, 6689 and 6608 Å by [10] (Fig. 2). The OI-2 line in ~6727 Å is distinguished from the background even in the faintest segments. Fe I multiplets 111 and 268 are also blended to the N_2 1P band in this region of the spectrum producing two bright lines (Fig. 3). Prior to the main fragmentation, the Hα line and the OI-2 lines are clearly visible. At the typical meteor plasma temperature for a Perseid meteor (4500±500 K), water is effectively dissociated into H and OH, and again OH is expected to be dissociated into O and H, given sufficient time. As a consequence of this decomposition into radicals, we would observe H, O or OH contributions in meteor spectra [11]. Although a part of the contribution of O can come directly from the Earth's atmosphere, the highest intensity of the oxygen line during the first instants of fragmentation, together with the appearance at the same time of the Hα line, suggest that during massive breakups the meteoroid exposed hydrated minerals which were then ablated. To confirm this hypothesis a detailed study of the column densities and chemical abundance is in progress.

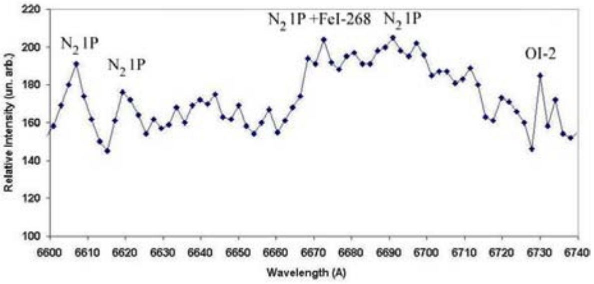

Figure 2. Line profile for the box on Figure 3.

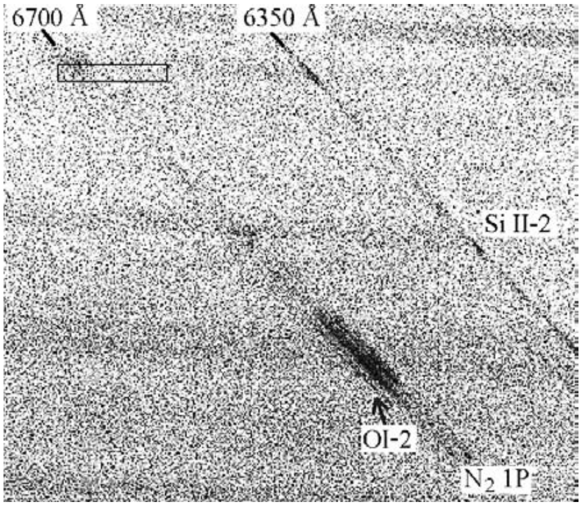

Figure 3. Near-IR region of the SPMN-PER01 spectrum. The fireball's movement was from the bottom right to the top left.

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