LOW-VELOCITY COMETARY METEOROID STREAMS ENCOUNTERING THE EARTH: CLUES ON THE FRAGMENTATION OF COMETARY AGGREGATES AND IMPLICATIONS FOR INTERPLANETARY DUST PARTICLES.

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Introduction: Since 2005, the SPanish Fireball and Meteor Network (SPMN) is continuously monitoring meteor activity by using all-sky CCD and medium-field video cameras up to +3 to +4 meteor limiting magnitude [1,2]. One important goal of our network is the study of the meteoroid physico-chemical properties from multiple station data, together with meteor spectra. It is well known that the ablation behavior of meteors in the Earth's atmosphere shows photometric patterns that are reflecting important properties of the incoming meteoroids [3], but we are not yet fully understanding such patterns. Besides, we are also trying to identify the main sources of large bolides to the Earth. As a consequence of the SPMN monitoring effort, valuable trajectory and orbital data of meteors and fireballs is being obtained [4-6]. During 2007 several poorly-known meteoroid streams associated with comets were crossed by the Earth. We describe here unexpected fireball activity, but focusing in low-velocity cometary streams. Particularly, we describe some meteor outbursts and fireball events recorded by the SPMN during 2006-2007 that would be important delivery sources of Interplanetary Dust Particles (IDPs). We try to encourage setting up future IDP campaigns for collecting cometary particles in the upper atmosphere. By knowing the most important and favourable sources of cometary particles, and the dates of the encounters with dense dust trails, such missions would be prepared in time for being successful.

Methods: The different instrumentation that we are using for continuous monitoring of meteor and fireball activity over Spain and bordering countries has been already described in full detail in recent papers [4,5]. In essence, we employ all-sky CCD and high-sensitivity video cameras operated from several stations and dotted of holographic diffraction gratings of 600 or 1200 grooves/mm for obtaining meteor spectra. The signal obtained in each spectrum is corrected by taking into account the instrumental efficiency, and calibrated in wavelengths by using typical metal lines (Ca, Fe, Mg, and Na multiplets). On the other hand, CCD and video images of multiple-station meteors are astrometrically reduced by measuring the position of the stars and meteors in the images. The astrometric measurements are then introduced into our recently developed *Amalthea* software that has been tested with *Network* software, which provides the equatorial coordinates of the meteors with a typical astrometric accuracy of 0.01° [2]. By the method of the intersection of planes we reconstruct the trajectory and length of the meteor in the Earth's atmosphere. Time information needed for the calculation of the initial velocity, average velocity and deceleration is directly obtained from the video sequences or from the breaks produced by the rotating shutter contained into the all-sky CCD devices. From such time marks, the velocity of the meteoroid in different points of the trajectory is also derived. The backward projection of the atmospheric trajectory in the sky provides the radiant. The preatmospheric velocity V_∞ is also measured when the deceleration is noticeable. In the last step, we determine orbital elements from the measured radiant and velocity.

Results and discussion: The photometric behavior of Draconid and κ-Cygnid fireballs show typically flares along the atomspheric trajectories, and in many cases are characterized by very bright (maximum) ending flares. Such behavior is consequence of catastrophic disruption of the meteoroid, probably composed by a fluffy aggregate of μm-sized grains. We think that the progressive or catastrophic disruption of such fragile meteoroids can produce small fragments that would be collected as IDPs in the atmosphere. The energy released during fragmentation would be able to make these particles escape to the heating associated with the front thermal wave, but perhaps some thermal metamorphism or collapse of the pore spaces would be observed [7].

There are certainly important flight opportunities during the next years for testing our hypothesis. For example, we have noticed an important increase in the fireball activity of τ-Herculids meteor shower. This stream is produced by comet 73P/Schwassman-Wachmann 3, which has been experiencing continuous break-ups since the 1995 return to perihelion. The activity of bright fireballs has increased in 2006 and 2007 as a consequence of the interception of a largest number of fragments of this comet. It is likely that the spatial density of cm-sized meteoroids will increase in the next years, getting important in 2022. Other important recovery opportunity will take place on Oct. 8, 2011, when we expect that the Earth will cross a dense dust trail of 21P/ Giacobini-Zinner.

Meteoroid stream	V_g (km/s)	Comet
June Bootids	14.1	7P/Pons-Winnecke
κ-Cygnids	23.5	Unknown comet
October Draconids	20.4	21P/Giacobinni-Zinner
τ-Herculids	15.0	73P/Schwassman-Wachmann 3

Table 1. Likely sources of IDPs discussed here, and respective geocentric velocities (V_g). For more details on future encounters see the text, and [8].

Another good example of relative dense cometary debris crossed by the Earth under low-velocity geometric circumstances is the June Bootids stream. This one is associated with comet 7P/Pons-Winnecke, and experienced on June 27, 1998 a strong outburst. During the last years we have been recording very bright bolides during the last days of June. This shower has a low level of visual activity, but exhibits a remarkable background of very bright fireballs.

During August, 2007 our cameras identified an outburst of κ-Cygnid fireballs [9]. This meteoroid stream was first identified by F. Whipple [10] who pointed out its likely cometary origin as deduced from its extended activity period and orbit. We are already computing the orbits of the meteoroids that produced the 2007 outburst. Such information would be valuable for identifying the parent comet of this stream, among the different candidates [11]. The meteoroids of this stream are characterized by a rapid progression of break up, and atmospheric deceleration [12]. In fact, the average particle density derived for the meteoroids of this stream is as low as 0.16 g/cm^3 [13], clearly indicative of highly porous particles [14, 15]. Figure 1 exemplifies the photometric behavior of a κ-Cygnid fireball during atmospheric entry, with a bright ending flare that reveals catastrophic disruption of the particle. By studying this pattern, together with the evolution of the spectral lines in the spectrum (Fig. 2) it is possible to get clues on the nature, structure and composition of cometary meteoroids, as pointed out in our early work [16].

The example given here corresponds to a bright fireball appeared on August 23, 2007 at 22h11m18.5±0.1s UTC over Sevilla province. This event reached an absolute magnitude of -9±1 during its ending flare. The incoming meteoroid had an estimated photometric mass of about 500 g, and was recorded from one all-sky CCD camera and one video camera that were monitoring the sky from Sevilla and Cerro Negro SPMN stations. From the astrometric reduction of the double station images of the bolide we have estimated an apparent radiant of RA= 292° and Dec=+56°, confirming its association with the κ-Cygnid stream [8].

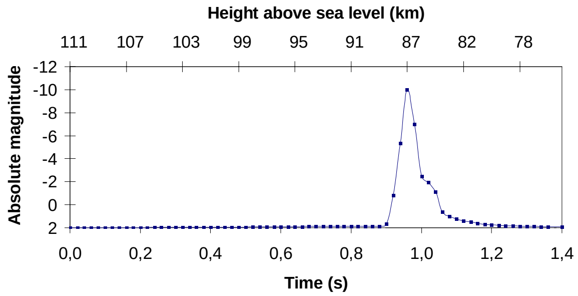

Figure 1. Photometric curve of a Kappa Cygnid fireball registered on August 23, 2007.

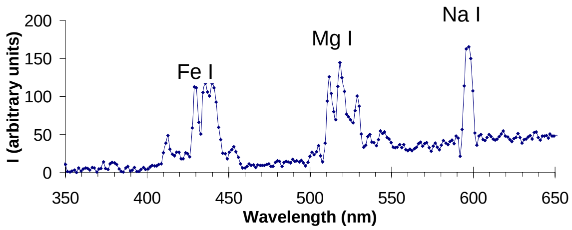

Figure 2. Spectrum corresponding to the final flare of a Kappa Cygnid fireball registered on August 23, 2007.

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