Detection of spectral UV of meteor from a nanosatellite

Nicolas Rambaux[1,2], Dimitri Galayko[1,3], Jean-François Mariscal[4], Michel-Andres Breton[1,2], Jérémie Vaubaillon[2], Mirel Birlan[2], François Colas[2] and Thierry Fouchet[5]

[1] **University Pierre et Marie Curie – Paris 06, Paris, France**
Nicolas.Rambaux@imcce.fr

[2] **Institut de Mécanique Céleste et Calcul des Ephémérides, Observatory of Paris, CNRS UMR8028,**

77 Avenue Denfert-Rocherau, 75014 Paris
Breton@obspm.fr, Vaubaillon@imcce.fr, Birlan@imcce.fr, Colas@imcce.fr

[3] **Lip6, 4, place Jussieu, 75252 Paris Cedex France**
dimitri.galayko@lip6.fr

[4] **LATMOS, Quartier des Garennes, 11 boulevard d'Alembert 78280, Guyancourt, France**
jean-francois.mariscal@latmos.ipsl.fr

[5] **LESIA, Observatory of Paris**
Thierry.Fouchet@obspm.fr

Here, we present a cubesat space mission concept devoted to the UV detection of meteors from space. Space observations have the advantages to continuously observe meteors independently of weather conditions on large portions of the atmosphere and, specifically, to perform ultra-violet light measurement as it is above the ozone layer. The UV spectrum is interesting for the detection of elements such as Iron, Carbon and Hydroxide that can yield a signature of elements present during the solar system formation.

1 Introduction

The atmosphere is constantly colliding with extraterrestrial particles that give rise to the luminous phenomenon of meteors. Such an event is very short (0.2-5 seconds), it results from the heating of a particle called a meteoroid (see Ceplecha et al., 1998). The meteoroids come from comets or asteroids and each year the flux of meteoroids is estimated with a great uncertainty between 30 and 200 ktons (Bland et al., 1996). Consequently, the Earth atmosphere can be seen as a giant detector of these primordial objects.

At present, the meteors are mainly observed ground based from the Earth by imagery, spectroscopy, and radar detection. The two first methods are limited in space coverage, depend on the weather conditions, and on the absorption band of the atmosphere. A space mission offers a unique possibility to measure continuously meteors and to assess the flux of meteoroids that collides with the Earth. In addition, the vantage point of a space mission allows exploring the UV spectrum to characterize the meteor. Until now only two space detections of meteors in the UV spectrum have been reported in literature (e.g. Jenniskens et al., 2002). That paper highlights the signature of Carbon and Hydroxide, two prebiotic constituents.

Here we present the development of a nanosatellite that could reach the objective to characterize meteors. Such a mission will consist of two instruments namely a visible camera and a UV spectrometer. The main objectives of this mission are (1) to measure the luminous spectrum of a meteor and to determine the composition of the meteoroid, (2) to analyze the light curve and to quantify the physical process acting during the entry in the atmosphere and (3) to contribute into determining the meteoroid's trajectory by combining these observations with ground-based data on Earth. Secondary objectives are to enable the study of transient luminous phenomenon, the study of Earth UV spectrum, and the detection of artificial debris during the mission.

2 Why a nanosatellite?

A nanosatellite is a small satellite where the mass varies between 1 and 10 kg. Here, we use the cubesat norm developed by California Polytechnic State University at San Luis Obispo and by the University of Stanford. The cubesat is a cube of 10 cm edge, a volume of 1 liter, a mass of 1 kilogram and a power of 1 Watt (in average). Such satellite offers all the vital functions of a normal satellite plus either a technological package to test a Technology Merit Level, to test the resistance for radiation, or a small sensor or a camera to perform science investigation.

We schedule to develop a three units cubesat (3 cubes, 3U), which will contain a scientific payload composed by a visible camera and a UV spectrometer. In addition to the scientific objectives the nanosatellite offers hands-on experience to aerospace engineering for students in all the development of the project (design, development, test, and qualification of a real spacecraft).

3 Science investigation

The main objective of the mission is to detect and record the UV spectrum of a meteor. The UV spectrum is useful to detect chemical elements such as Iron, Carbon, and Hydroxide (Jenniskens et al., 2002; Carbary et al., 2004). In particular, Carbon and Hydroxide radicals are tracers of physical and chemical conditions in the primordial solar nebulae and their study gives information on the solar system formation and to the contribution of prebiotic materials on the Earth. The main knowledge on meteoroids comes from the short time of their interaction with the Earth atmosphere (Ceplecha et al., 1998). Several methods, on the Earth or airborne, have been expended since years in order to accurately measure meteors such as imagery, spectroscopy, and radar detection to determine the flux and origin of primitive material brought by meteoroids (see e.g. Ceplecha et al., 1998). The collection of meteorites and micro-meteorites on the ground is crucial to bring back samples into the laboratory and to perform thorough studies.

However, very few space missions have been dedicated to the detection of meteors. Only two missions, Argos and MSX, have detected meteors from space. The first one (ARGOS) is the observation of an American military satellite in far-UV while the second one, MSX explored a large spectrum band with the instrument UVISI (Jenniskens et al., 2002). The UVIS instrument has recorded the presence of Carbon and Hydroxide in the UV spectrum illustrating the strong potential of detection from space in UV. *Figure 1* presents a meteor synthetic spectrum reconstruction using as input the observations of Jenniskens et al. (2002) and the database of laboratory spectra for a given number of chemical elements and compounds. This synthetic spectrum is used to determine the technical specification of the nanosatellite. The objective of the nanosatellite is to reach a range of detection in the 200-400 nm spectral window with a spatial resolution below 1.5 nm in order to distinguish between the Carbon and Iron bands.

In addition, the recording of meteors with the camera brings information on the physical interaction of meteoroids with the atmosphere. Notably, it will significantly improve the statistics for global studies. Indeed, the position of the nanosatellite (scheduled at an altitude of 500-600 km) allows observing a broad surface on the Earth and is independent of the meteorological conditions. The increase of statistics on these data is crucial to improve the ablation models of meteoroids (Gritsevich and Koschny, 2011; Campbell-Brown and Koschny, 2004).

At the altitude of 500 km and pointing at the nadir, a meteor with a magnitude between 0 and -5 should be detected with an irradiance of 78-7800 photons/s/cm^2/Å. If the measurement is done at the limb, a meteor at 2 400 km, with magnitude 0 and -5, produces an irradiance of 1.3-130 photons/ s/cm^2/Å. During the meteor shower, the number of meteors can reach 50-100 per hour (detected from the ground) while the rate of sporadic detections can reach 12 meteors per hour for a high-quality camera such as SPOSH (Oberst et al., 2011; Bouquet et al., 2014).

The determination of the trajectory is crucial to track the origin of the parent body (Rudawska et al., 2012). Here the objective is to combine space observations with ground-based observations obtained by survey networks such as FRIPON (Colas et al., 2012). This requires an accurate follow-up of the nanosatellite and attitude determination of the spacecraft.

4 Scientific instruments and cubesats

The project is at the beginning and we schedule 3U cubesat in order to include a UV spectrometer, a visible camera, and an altitude control system that are the three larger parts of the payload. The orbit will be

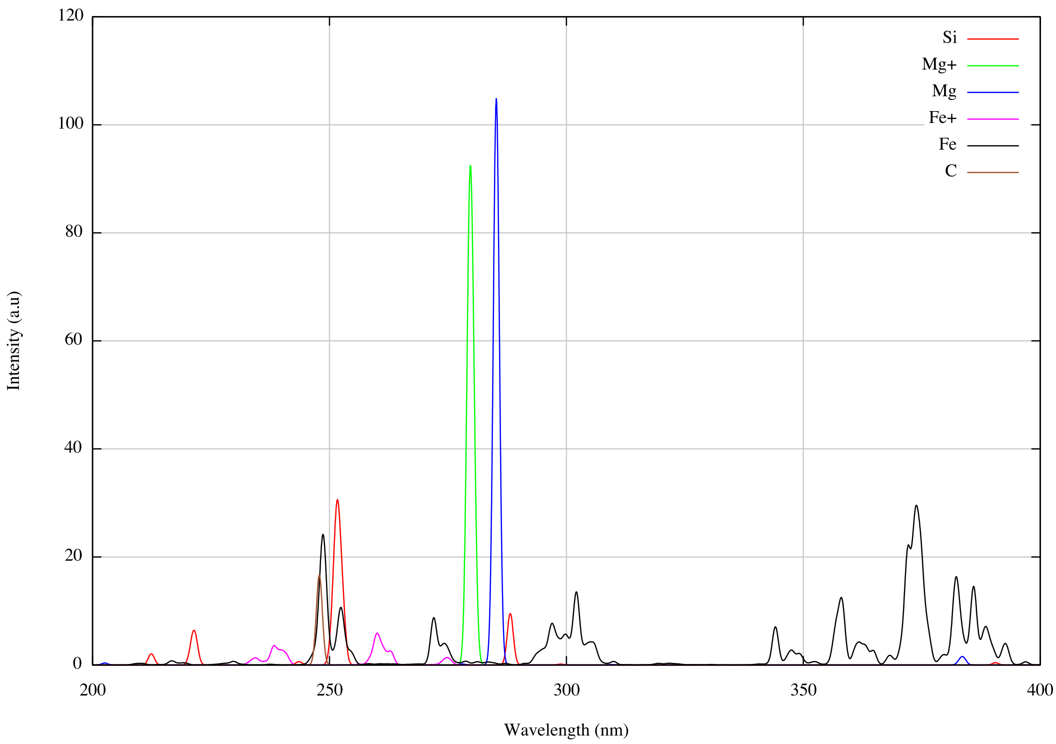

Figure 1 – Synthetic spectrum of a meteor. This example is build from detection of a Lenoids by Jenniskens et. al (2002).

heliosynchronous with an ascending node at 10^h30^m to allow recharging the battery of the nanosatellite. In addition, the meteors are observed during the night. In order to detect faint magnitude meteors and to stay in orbit at least one year, the cubesat will stay at an altitude of 500-600 km and will respects the LOS (re-entry in the atmosphere in less than 25 years).

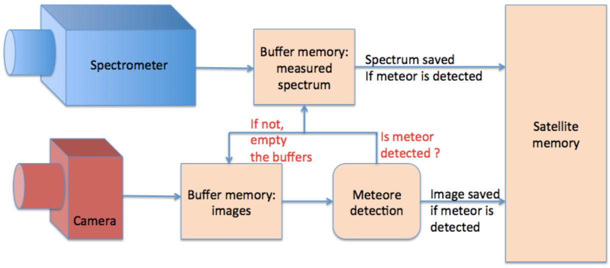

Figure 2 – Diagram illustrating the meteor detection and spectrum measurement.

The most important challenge related to the meteor spectrometry is a transient character of the light emission by the meteors (<0.5 s duration), coupled to the ambiguous location of the upcoming phenomenon in the field of view of the instrument. Obviously, the nanosatellite should be a fully autonomous meteor observatory. This challenge will be addressed in the following way (*Figure 2*): both camera and spectrometer have the same orientation and capture the image of the same area. They permanently register the visible data (images and spectra) in the buffer memory, so that the buffer memory has permanently the full data of last N seconds (the exact duration is to be defined). In parallel, the buffer memory of the camera is processed by an onboard computing unit, and if a meteor is detected, the last data registered from the spectrometer is archived as the data about the phenomenon of interest. Otherwise, both the camera and spectrometer buffers are erased.

The meteor detection software package is challenging and it should inspect a video data stream in real time and determine the time of appearance of meteors.

Technical key challenges are:

- the altitude control system (the camera should be stabilized at a known, predictable altitude)
- The telemetry of a large amount of data: the estimated required rate is 3.8 Mbits/second during the communication with the ground station; S-band and X-band telemetry solutions are being explored.
- The camera and spectrometer raw video data output, this should be pre-processed, in order to reduce the quantity of data to be transmitted toward the ground station.

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