GRAAL project: in situ optical detection of dust concentration from the Earth's orbit

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Abstract

We present here a new concept of instrument, based of optical aerosols counter, to better estimate the concentration and size distribution of incoming interplanetary material in the Earth's atmosphere. This concept, called GRAAL, could be in the Earth's orbit onboard a micro-satellite or within the International Space Station.

1. Introduction

The amount of interplanetary dust impacting the Earth atmosphere is still not well estimated, in terms of total mass, size distribution and concentration of the particles [1]. These particles come mainly from Jupiter family comets; they could have various structures and compositions as shown by results of the Rosetta mission on dust particles [2]. Even if the amount of such particles is small in the Earth atmosphere, their presence could be non-negligible, and their detection from local measurements inside the atmosphere could be confused with particles coming from the Earth surface. Also, such solid particles inside the middle and the upper atmosphere could skew the remote sensing observations of events in the troposphere (like pollution) from satellite instruments. We propose to apply the counting technique used in routine in the Earth's atmosphere for determining the concentration of liquid and solid aerosols, to the detection of these interplanetary particles. The main differences with the atmospheric measurements are the very low concentrations, the high speed of the particles in respect with the instrument (at least several km/s) and the space conditions.

2. Aerosol counter LOAC

We have developed recently an innovative design of aerosols counter, called LOAC (Light Optical Aerosols Counter), which provides the concentrations for 19 size classes of solid and liquid particles in the 0.2-100 micrometers size range [3]. LOAC provides also an estimate of the typology of the particles from their light absorbing properties (transparent, semi-transparent, absorbing). The particles are injected through a laser beam via a pumping system, and two photodiodes record the light scattered. This instrument combines the measurements at two different scattering angles. The first is around 15°, being insensitive to the refractive index and porosity of the particles, to retrieve the size of the particles; the second one is around 60°, being very sensitive to the nature of the particles, to estimate the typology. LOAC is designed mainly to detect the optical size (or equivalent diameter) of the irregular shaped particles. LOAC has been ~~is~~ used in routine for 6 years on the ground and from all kinds of balloons to study the events in the troposphere like urban pollution and for the stratospheric aerosols monitoring.

3. GRAAL concept

An updated version of LOAC is in development for space applications, essentially for in situ measurements of planetary atmospheres (telluric and giants planets). LOAC can also be modified for the detection of high velocity particles from Earth's orbit, using fast electronics and a light source of several cm long instead of a laser beam. This is the GRAAL project, "GRains Above the Atmosphere with Light optical aerosols counter", dedicated to the determination of the size and concentration of ~~the~~ incoming materials to the Earth's atmosphere. This instrument could perform measurements from a micro-satellite, or even better from the International Space Station, while always facing Earth. No pump is needed since the particles will cross an open cell oriented towards Earth's surface. Figure 1 presents the instrumental design. We expect to detect particles from about 1 micrometer to several hundreds of micrometers, as those detected by the Rosetta mission in the inner coma of comet 67P. Using two photodiodes as for LOAC "balloon" could provide an estimate of the typology of the detected particles.

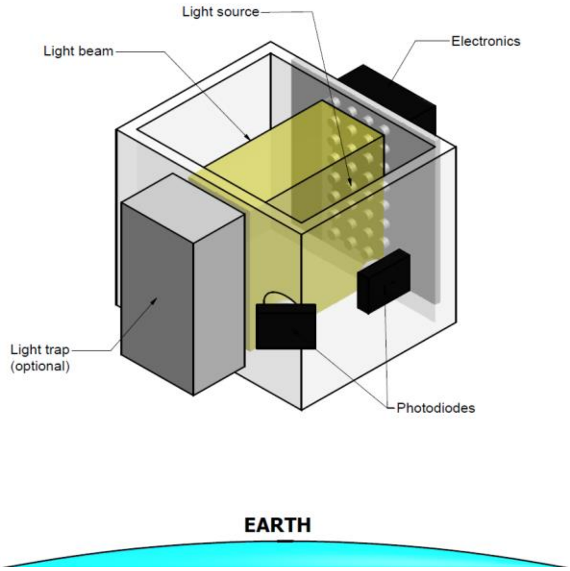

Figure 1: GRAAL concept.

4. Expected measurements

The expected mean velocity of the incoming interplanetary particles could be of about 15 km/s [4,5]; a secondary mode is expected at a few km/s, coming from space debris contamination. Considering the proposed geometry of measurements, we expect to detect several particles per day greater than 1 micrometer in background condition, up to several tens of particles during major–shooting stars events. This estimate is based on the 30 years-old data of the impact measurements from MIR station and LDEF experiment [6], as shown in Figure 2.

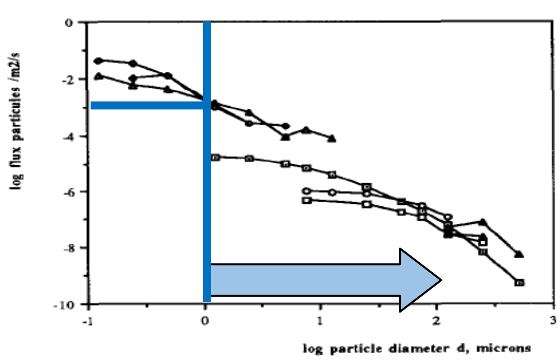

Figure 2: Expected size distribution detected by GRAAL (blue arrow), based on Mendeville (1991) concentrations

5. Summary and Conclusions

The GRAAL concept is an innovative approach to better characterize the incoming material in Earth atmosphere, in complement with traditional techniques as ground-based collection, atmospheric collections, optical and radar meteor counting. GRAAL project has been recently proposed to the French space agency CNES. Depending of funding and launching opportunities, the instrument could be realized in about 3 years.

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