EPSC Abstracts,
Vol. 4, EPSC2009-798, 2009
European Planetary Science Congress,

A light aerosol counter for the detection of aerosols in planetary atmospheres

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Abstract

Liquid and solid aerosols can be found from ground to upper atmosphere in several objects of the solar system (Venus, Earth, Mars, Titan). Among the physical properties of aerosols, the size distribution, the concentration (number per cm^{-3}) and their main nature (liquid, solid) can be retrieved from their optical properties.

Usual aerosol counters provide the concentration and the size distribution of aerosols. Nevertheless, they cannot be able to distinguish between the various families of particulates. The air is collected by a pumping system and crosses a light beam; the light scattered by the aerosols in then detected with a photodiode at a scattering angle usually around 90°. Counting the number of pulses by time unit and volume allow us to retrieve the total concentration of aerosols, at least having a size in a size range depending on the intensity of the light source and on the sensitivity of the detector. The minimum size detected by aerosol counters is around 0.3 mm. The maximum size depends on the dynamic of the detector; some counters have an upper limit at a few mm, some other can reach tens of mm.

The intensity of the scattered light is dependant on the size but also on the nature of the particulates. Assuming or expected the nature of the particulates, the size distribution can be retrieved using theoretical calculations. This approach works well for liquid aerosols, but not for solid aerosols; particulates having different size and different refractive indexes can produce the same amount of scattered light at some measurement angles. Also, black and absorbing particulates can be difficult to detect.

A new approach of aerosol detection has been developed recently for air quality monitoring on Earth, in the frame of a research contract between the LPC2E-CNRS laboratory and the "Environnement-SA" company. This new instrument is called "CPM" (Continuous Particulate Monitoring). The measurements are conducted at low scattering angle (below 20°), where the light scattered is more dependent on the size on the aerosols than on their nature. All solid aerosols greater than 0.5 mm are detected and classified in different size ranges, even if they are black and strongly absorbing. The instrument can be calibrated using glass or latex beads having a well-known size but also using real solid particulates that can be found in the air and be selected by size-filters. Then, the concentration and the size distribution can be determined unambiguously. A simultaneous measurement is conducted at a scattering angle around 60° (Figure 1). At such angle, the light scattered by the aerosols is strongly dependant on their nature. The ratio of the light scattered at 60° by the light scattered at 15° differs upon the nature of the aerosols. Thus this ratio can be use to determine the aerosol main nature by comparison with a reference data base. These reference values are determined in laboratory using well known particulates that are expected to be found in the studied air sample, but can be completed if necessary with particulates of different composition.

The stray-light contamination is a strong problem at the low scattering angle. An electronic system has been developed in order

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to evaluate and to correct the stray light in real time. Also, no lenses are used in the instrument so there is no critical mechanical constraint and no need of accurate optical alignment.

A lighter version of this instrument (~1 kg) is under development. This new version, at one angle or two angles depending of the objectives (counting, or counting + determination the nature of the aerosols), will be mounted onboard sounding atmospheric balloons, but also will be easily implanted everywhere at ground. The aim is to be able to perform aerosols measurements in routine for scientific purpose and for air quality monitoring and meteorology, as done at present for example for ozone, temperature and humidity.

It could be proposed to perform detection of aerosols in other planetary atmospheres, or even at ground in the case of Mars, using the same principle of measurement. This instrument can allow to evaluate the concentration of aerosols and their size distribution, to determine the width of the aerosols layers and their links with dynamical processes (as in the Earth atmosphere), and to give indication of the nature of the particulates.

The concept and performance of the instrument will be tested under various temperatures and pressures encountered in the lower and middle Earth atmosphere. There is no critical part on this instrument: no lenses are needed, photodiodes are use since long time in pace conditions, as well as light sources (laser or LED), so this concept could be "easily" adapted to space measurements.

The instrument can be used during the descent of a spacecraft; in this case, no pumping system is needed. It can be also mounted onboard a balloon in a planetary atmosphere or on ground meteorological station or on a rover.

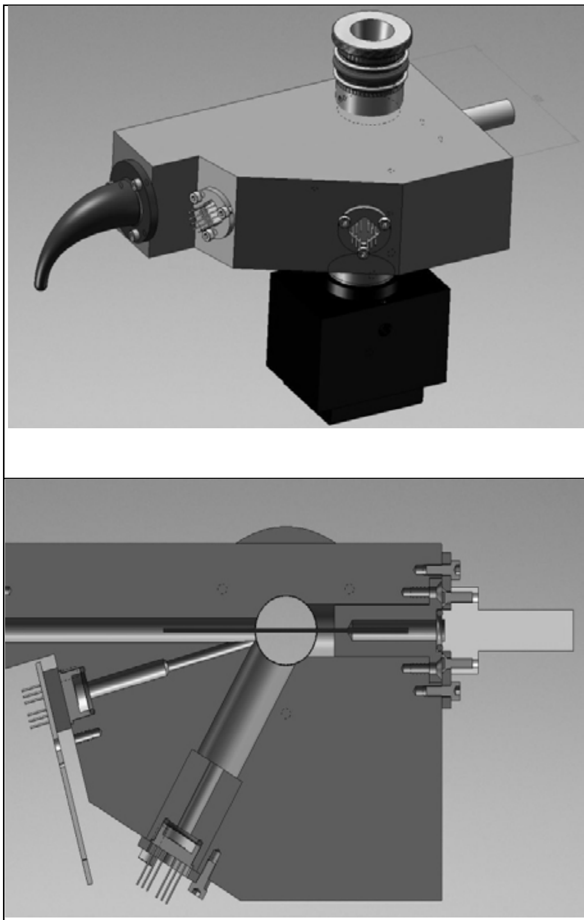

Figure 1: Principle of measurement at two scattering angles (adapted from the CPM instrument by Environnement-SA company and LPC2E-CNRS laboratory).