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MicroMED: an optical particle counter for the direct in situ measurement of abundance and size distribution of dust suspended in the atmosphere of Mars

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Abstract

The MicroMED experiment has been developed for the characterization of airborne dust close to the surface of Mars and is suitable to be accommodated on Martian landers or rovers. It is an optical particle counter, analyzing light scattered from single dust particles to measure their size and abundance. An Elegant Breadboard of the instrument has been realized and successfully tested in a Martian simulated environment. Test results demonstrate the expected functionality and performances of the experiment.

1. Introduction

Monitoring of airborne dust is very important in planetary climatology. Indeed, dust absorbs and scatter solar and thermal radiation, severely affecting atmospheric thermal structure, balance and dynamics (in terms of circulations). Wind-driven blowing of sand and dust is also responsible for shaping planetary surfaces through the formation of sand dunes and ripples, the erosion of rocks, and the creation and transport of soil particles.
Dust is permanently present in the atmosphere of Mars and its amount varies with seasons. During regional or global dust storms, more than 80% of the incoming sunlight is absorbed by dust causing an intense atmospheric heating. Airborne dust is therefore a crucial climate component on Mars which impacts atmospheric circulations at all scales. Main dust parameters influencing the atmosphere heating are size distribution, abundance, albedo, single scattering phase function, imaginary part of the index of refraction. Moreover, major improvements of Mars climate models require, in addition to the standard meteorological parameters, quantitative information about dust lifting, transport and removal mechanisms. In this context, two major quantities need to be measured for the dust source to be understood: surface flux and granulometry. While many observations have constrained the size distribution of the dust haze seen from the orbit, it is still not known what the primary airborne dust (e.g. the recently lifted dust) is made of, size-wise.
MicroMED has been designed to fill this gap. It will measure the abundance and size distribution of dust, not in the atmospheric column, but close to the surface, where dust is lifted, so to be able to monitor dust injection into the atmosphere. This has never been performed in Mars and other planets exploration.

2. MicroMED experiment

MicroMED is a miniaturization of the instrument MEDUSA, developed for the Humboldt payload of the ExoMars mission.
It is able to measure the size of single dust grains entering into the instrument from 0.2 to 10 μm radius, giving as products the dust size distribution and abundance. It is an Optical Particle Counter, analyzing light scattered from single dust particles. A pump is used to sample the Martian atmosphere, generating a flux of gas and dust across the instrument trough the inlet. When the dust grains reach the Optical Sensor (OS), they cross a collimated IR laser beam emitted by a laser diode. The light scattered by the grains is detect-ed by a photodiode, which is amplified by the Proximity Electronics (PE).

3. Performances

MicroMED acquires the intensity of the light scattered by single dust grains entering into the instrument. This is related to grain size via scattering models. The run duration has been tuned in order to acquire about 400-2000 particles depending on dust concentration. This will allow to obtain enough statistics to sample the dust size distribution. The system has been designed in order to work up to particle concentrations of several hundreds cm^{-3} before coincidence effects become significant. The estimated fraction of coincidences goes from 0.01% (constant haze) to < 4% (dust devil).

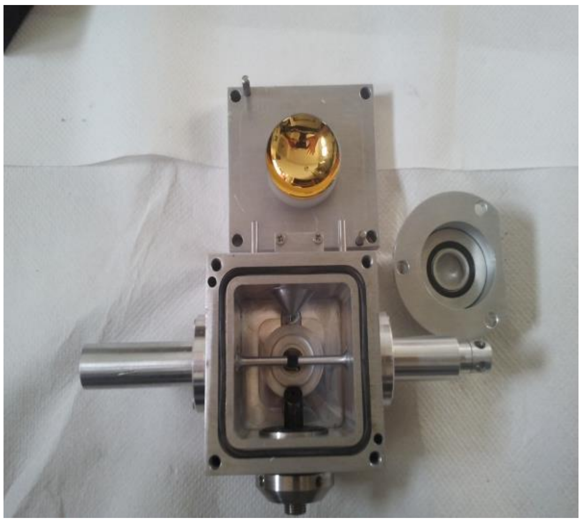
Figure 1: MicroMED Breadboard.

The minimum detectable current from the photodiode is < 5 nA. Using Mie scattering theory evaluation, this implies an expected minimum detectable grain radius of < 0.2 µm (see theoretical curve in Figure 2). The maximum detectable size is related to fluid dynamics constraints inside the instrument and is around 20-30 µm, in the range of expected suspended grain size (radius ~10 µm). Dust abundance will be computed starting from size measurements and sampled volume (fixed by pump flux and run duration). The mentioned performances have been verified with the MicroMED breadboard.

Monodisperse particles with calibrated size have been injected in the Martian simulation chamber where the MicroMED instrument was placed. Results are shown in Figure 2. MicroMED output current, generated by the photodiode as a response of the detection of light scattered by the grains, perfectly corresponds to the values predicted using Mie's theory.

Performed tests clearly show that the instrument satisfies technical and scientific requirements and perfectly reproduces the results obtained during the simulations that drove its design.

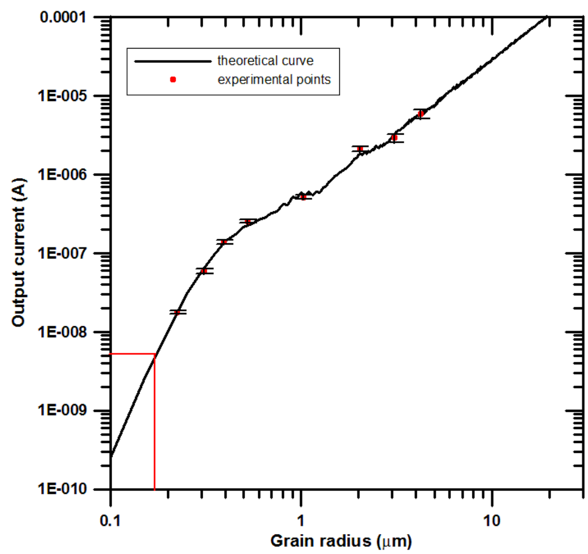

Figure 2: MicroMED performances.

MicroMED has a mass < 500 g and a power consumption of < 3 W.