VISTA INSTRUMENT: A μ-THERMOGRAVIMETER TO CHARACTERIZE THE LUNAR DUST CHARGING AND THE PHYSICAL PROCESSES CONCERNING VOLATILES COMPOUND AROUND LUNAR SOUTH POLE. E.Palomba[1], F. Dirri[1], A. Longobardo[1], D. Biondi[1], A. Galiano[1], A. Boccaccini, E. Zampetti[2], B. Saggin[3], D. Scaccabarozzi[3], [1]INAF (National Institute for Astrophysics), Via Fosso del Cavaliere, 100, Rome, Italy (ernesto.palomba@inaf.it; fabrizio.dirri@inaf.it), [2]CNR-IIA, Via Salaria km. 29.300, 00016, Montelibretti, Rome, Italy; [3]Politecnico di Milano, Polo Territoriale di Lecco, Via G. Previati, 1/c, 23900, Lecco, Italy.

Introduction: The study and characterization of the lunar dust charging and levitation has significant implications both from the scientific point of view and for enabling future long-duration human lunar missions. During the Apollo missions it was noted that lunar dust (with diameter less than 20 mm) easily entered the cabin after astronauts Extra Vehicular Activity: this dust created several problems both to crew safety and instrumentation [1].

The measurement of water and organic rich materials is extremely important to understand the resources available on the Moon to humans and the processes originating and/or destroying Lunar volatiles. In particular, due to lunar surface bombardments by solar wind particles and meteoroids [2], the processes connected to water ice particles relocation/re-condensation in the areas around the Lunar South Pole will be crucial to understand the sustainability of water-rich lunar permafrost (local spots with high content of H-bearing volatiles, presumably water ice [2]).

Scientific contest and instrument objectives: The presence of water ice at the lunar poles was proposed by [3] and [4] while direct detection of volatile concentrations in this area was reported by [5] on the basis of orbital neutron spectroscopy. On the Moon, [6] found that some areas in the lunar south pole with maximum surface temperatures below ∼100K and consistent with the presence of water ice using multispectral UV data from Lyman Alpha Mapping Project (LAMP) instrument aboard the Lunar Reconnaissance Orbiter (LRO) [7]. Evidence of surface water ice was confirmed by reflectance measurement from the Lunar Orbiter Laser Altimeter and temperature measurement from Diviner Lunar Radiometer Experiment: the reflectance increase close to the South Pole at decreasing temperature (i.e., 110K), is consistent with the presence of water ice, while, the reflectance measured for temperatures of 200K and 300K is consistent with the presence of organics or sulphur [8]. In the framework of the next human mission to the Moon (Artemis Programme), it will be extremely important to know what kind of resources can be used by the crews and the sustainability of water-rich lunar permafrost. At the same time the study and the characterization of Lunar dust (charging and levitation) will be fundamental to ensure the safety of instrumentations and astronauts.

In this framework, VISTA can accomplish the following scientific objectives:

- measure the properties of lunar dust, the dust grain mass and the processes of charging and levitation. Since the charge-to-mass ratio depends on the grain size, information about granulometry can be inferred;
- measure the volatiles content in the regolith (water ice and light organics up to 403K);
- measure the water ice abundance in the Lunar South Pole.

Working principle and instrument concept: VISTA is based on micro-oscillators whose detecting part is made up of piezoelectric crystals with a conductive electrode that acts as a collector of micron and submicron size particles. Piezoelectric Crystal Microbalances (PCM) are one of the most widely used chemical sensors in gas/particle sensing for Space and in environmental and biological applications. These sensors convert mass changes into fundamental resonance frequency variations. They have been widely applied in space to monitor dust flux and volatile outgassing [9,10]. Microbalances are made up of a piezoelectric foil with metallic electrodes deposited on both sides. The fundamental transduction equation according to Sauerbrey equation [11] is:

$$\Delta f \propto \frac{f_0^2}{A} \Delta m$$

which states that the change in resonance frequency Δf of a thin quartz crystal is proportional to the additional mass Δm deposited on it, f_0 being the resonance frequency of the uncovered quartz and A the sensitive area.

The PCM temperature can be increased in order to allow the most volatile component of the analysed sample to desorb. This process, known as μ-Thermogravimetric analysis (TGA), allows to infer the abundance of the desorbed volatile compound (from the mass variation) and its composition (by measuring its sublimation temperature and its enthalpy of sublimation) [12].

VISTA is composed by the electronic box (*Unit 1*) and two subsystem: *Unit 2*, a Thermal-PCM (T-PCM), for measurements of volatile content in the regolith and water ice detection; *Unit 3*, an Electric Field-PCM (EF-PCM) coupled with an electric field generator for measurements of electric properties of the dust.

An important challenge of **VISTA** (*Unit 2*) is the presence of a built-in heater (0.5W are used to perform a ΔT of 210 K, only) and a built-in thermistor integrated onto the crystal. This special design dramatically reduces the total mass and the power required to perform thermal cycles. The TRL is 6 and an Engineering Model is currently available.

Another innovation introduced by **VISTA** (*Unit 3*) consists in the development of a new generation of microbalances able to attract charged dust grain by means of a variable Electric Field (EF), generated locally by the instrument itself. The application of this EF will break the equilibrium between the Electric and the Gravity Fields on the Moon (predicted by Levitation model [13]), allowing the electrically charged dust grains to be attracted toward the microbalance. In principle, by varying the local EF it is possible to attract grain with different size and electric charge. The electronics will be designed to optimize the configuration of a capacitors cascade in order to measure the electric charge accumulated onto the sensor. The TRL of this *Unit* is 3.

Technical characteristics and heritage: VISTA *Unit 2* and *Unit 3* requires low mass, low size and is low power-consuming. Instead, the *Unit 1* can be shared with other instruments. Its technical characteristics are summarized in Table 1.

Mass	<500g
Volume	< 300 cm^3
Average data rate	0.5 kbps
Average required power	< 2 W

Table 1: VISTA technical characteristics

The technical concepts of **VISTA** for Moon application benefit of developments already performed in previous projects for ESA ITT Call and ESA Cosmic Vision 2015-2025 proposed mission:

- *Marco Polo* and *Marco Polo – R* (selected for Phase A): cometary-like activity of asteroids, water and organic content in the asteroid regolith, touchdown operations monitoring and contamination assessing;
- *Penetrator for JUICE (JUpiter ICy moon Explorer)* [14]: organics and clathrate hydrates detection, composition of non-ice materials of the Europa and Ganymede surfaces;
- *CAM (Contamination Assessment Microbalance)*, a ITT-ESA funded study for the development of a quartz crystal microbalance to measure contamination in space [15];
- *CAMLAB (Contamination Assessment Microbalance for LABoratory)*, a ITT-ESA funded study for the development of a quartz crystal microbalance to measure contamination in laboratory environments.

The technology of VISTA is mature for different planetary scenarios. The new improvements, consisting in measuring electric charge by capacitor discharge and in capturing charged particle by means of a controlled Electric Field, are demonstrated in their basic principles. Their performances should be evaluated experimentally.

References:

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