SUDA: A DUST MASS SPECTROMETER FOR COMPOSITIONAL SURFACE MAPPING FOR A MISSION TO EUROPA. S. Kempf[1], N. Altobelli[2], C. Briois[3], E. Grün[1], K. Hand[4], M. Horányi[1], M. Gutipati[4], F. Postberg[5], J. Schmidt[6], R. Srama[5], Z. Sternovsky[1], G. Tobie[10], J. Young, and M. Zolotov[12], [1] LASP, CU Boulder, USA, [2]ESA, ESAC, Spain, [3]LPC2E, Orléans, France, [4]JPL, Caltech, Pasadena, USA, [5]IRS, Universität Stuttgart, Germany, [6]University of Oulu, Finland, [7]Arizona State University, Tempe, USA.

Introduction: We developed a dust mass spectrometer to measure the composition of ballistic dust particles populating the thin exospheres that were detected around each of the Galilean moons. Since these grains are direct samples from the moons' icy surfaces, unique composition data will be obtained that will help to define and constrain the geological activities on and below the moons' surface. The proposed instrument will make a vital contribution to NASA's planned mission to Europa and provide key answers to its main scientific questions about the surface composition, habitability, the icy crust, and exchange processes with the deeper interior of the Jovian icy moon Europa.

The SUrface Dust Aanalyser (SUDA) is a time-of-flight, reflectron-type impact mass spectrometer, optimised for a high mass resolution which only weakly depends on the impact location. The small size (268×250×171 mm^3), low mass (< 4 kg) and large sensitive area (220 cm^2) makes the instrument well suited for the challenging demands of mission to Europa. A full-size prototype SUDA instrument was built in order to demonstrate its performance through calibration experiments at the dust accelerator at NASA's IMPACT institute at Boulder, CO, with a variety of cosmo-chemically relevant dust analogues. The effective mass resolution of $m/\Delta m$ of 150-200 is achieved for mass range of interest m = 1-150.

Dust Exoclouds: The basic idea of compositional mapping [1], [2] is that moons without an atmosphere are ensgulfed in clouds of dust particles released from their surfaces by meteoroid bombardment. The ejecta cloud particles can be detected and their composition analyzed from orbit or during a spacecraft flyby. The ejecta production process is very efficient: a typical interplanetary 10^{-8} kg micrometeoroid impact on a Jovian moon produces a large number of ejecta particles whith a total mass on the order of a few thousand times of that of the impactor [3]. These ejecta particles move on ballistic trajectories and most of them re-collide with the satellite due to the lower initial speed. As a consequence, an almost isotropic dust exosphere is present around the moon [4] [5].

In 1999, the Galileo dust instrument measured the density profiles of the tenuous dust exospheres around the Galilean satellites Callisto, Ganymede, and Europa [6]. The cloud density decreases asymptotically with radial distance as $r^{-5/2}$, i.e. the cloud extent is only of a few moon radii. However, a spacecraft in close orbit around Europa will detect a substantial number of ejecta particles. The initial speed of most ejecta particles is smaller than the escape velocity, which in turn is much smaller than the speed of an orbiting spacecraft. The ejecta particles thus hit the dust detector with the velocity of the spacecraft and arrive from the apex direction. The dynamic properties of the particles forming the ejecta cloud are unique and can be clearly distinguished from any other kind of cosmic dust likely to be detected in the vicinity of the satellite.

Surface Composition of Europa: For planetary scientists, the Galilean moon Europa is amongst the most interesting bodies in the solar system. Their surface composition is revealing the past and recent geophysical processes both on and below the surface, and a dust mass analyzer of a Europa mission will allow us to acquire this invaluable knowledge. In particular, hydrated forms of minerals such as sodium carbonates and magnesium sulfates present in the ice surface probably represent deposits of materials from below the ice crust [8].

Ejecta particles from Europa will mostly consist of water ice with traces of hydrated minerals such as sodium carbonates and magnesium sulphates, hydrated sodium chloride, and of organic materials. The spectra of Enceladus plume particles and E ring grains obtained by the Cassini dust detector CDA [8], [9], [10] detected at low impact speeds are, thus, be similar to mass spectra of cloud particles of Europa. Impact spectra of slow water ice particles are dominated by positive water cluster ions $(H_2O)_nH^+$. Traces of hydrated minerals embedded in the grains' ice matrix will manifest themselves as positive cluster ions formed from their metallic component and water such as $(H2O)_n(MgOH)^+$ [11]. During a flyby at Europa the dust mass spectrometer will mostly record mass spectra with the mass range up to 150 amu densely filled with mass lines. Thus, a surface composition analyzer for Europa must be able to resolve adjacent mass lines in this range, i.e. its resolving powers should be beyond 150.

It is important to note that the interpretation of impact mass spectra of surface ice ejecta particles is a well-developed technique aided by laboratory calibration measurements and yields clear composition analy-

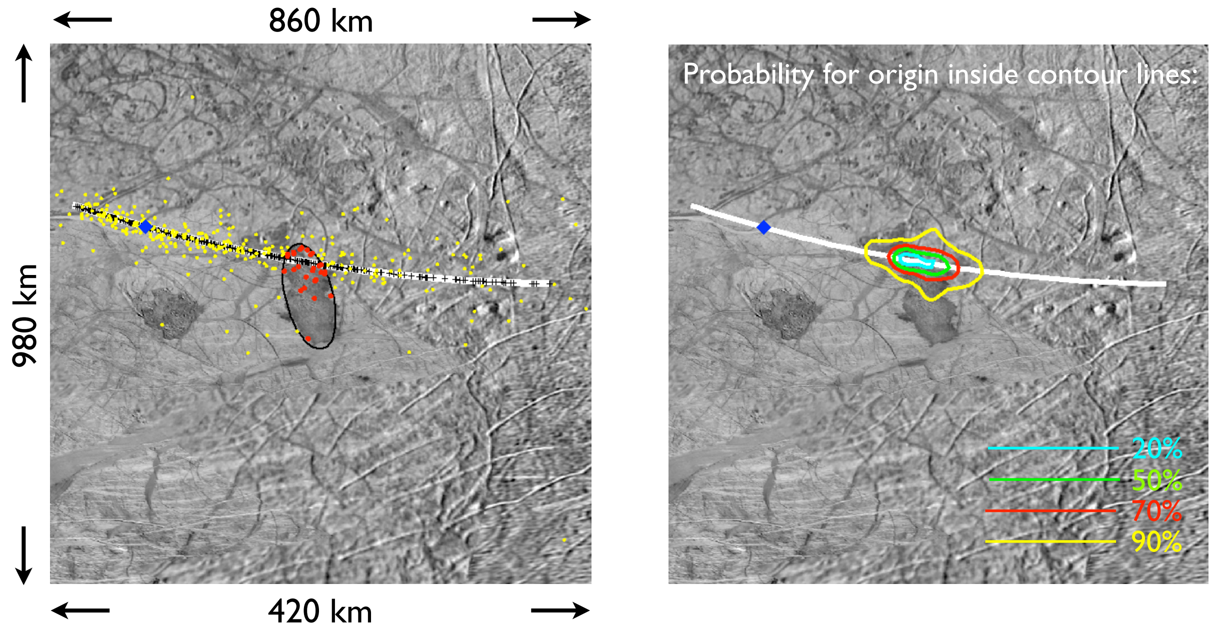

Fig. 1 Monte Carlo simulations demonstrate that compositionally distinct features in excess of 30 km on the surface can be resolved. The example shows the compositional mapping of the dark lobated feature Thrace Macula (140 km diameter) on Europa during a 25 km flyby. *Left:* SUDA detections (black crosses, rate 4.1 s^{-1} along the spacecraft groundtrack (white) of randomly launched ejecta > 500 nm from inside (red dots) and outside (yellow) the feature. *Right:* Resulting probability map for the origin of the detected particles from the dark feature on (red dots in left plot) if identified by their unique composition.

sis, at least when compared to the more ambiguous IR spectrometry of ejected surface ice is less ambiguous

than by IR spectrometry. This is because the high mass

resolution allows to constrain the nature of the molecule by its mass.

Compositional Mapping: SUDA observations will provide the chemical composition of the individual ejected dust particles from low altitude flybys on Europa. These measurements provide a direct link of the grains' composition to their origin on the surface, hence enabling the compositional mapping of Europa.

When an in-situ mass spectrometer detects a particle in the vicinity of a satellite it is possible to constrain the location of origin of that particle on the surface. This enables SUDA to relate the measured composition of the grain to geologic patterns and features on the moon. Such a backtracking is constrained by: (a) the known position and velocity of the spacecraft; (b) the measurement of the impact speed; and (c) employing probabilistic models [4, 5] specifying the likelihood of possible impact directions (Fig. 1).

Instrument description: The SUrface Dust Analyser (SUDA) is a reflectron-type, time-of-flight impact mass spectrometer, which has heritage from the Cassini CDA and the Stardust CIDA instruments (Fig. 1). The main challenge for the design of a dust mass spectro-meter is to achieve simultaneously a high mass resolution, a sufficiently large sensitive area, and a compact design. The plasma ions produced by the hypervelocity impact may have a broad energy distributions of up to 100 eV, which limits the mass resolution of linear TOF dust spectrometer of reasonable size to about m/Δm = 50. The effect of the initial energy spread on the mass resolution is significantly reduced by employing a so-called reflectron acting as an electrostatic mirror [12].

The ion optics of large area reflectron mass spectrometers can be designed using optimization methods to ensure simultaneously the good spatial and time focusing of ions. The combination of a plane target, a set of ring electrodes and an hemispherical reflectron grid yields a good performance instruments (Fig. 1, 2). The SUDA mass spectrometer is a scaled-down ver sion of the Large Area Mass Analyser LAMA [13]. However, there are significant differences between the design of LAMA and SUDA, which does not have a field-free drift region between the acceleration grid and the reflectron unit and employes a larger number of ring electrodes (see Fig. 2). The instrument size is 268×250×171 mm^3 and the weight of the laboratory prototype is 5 kg.

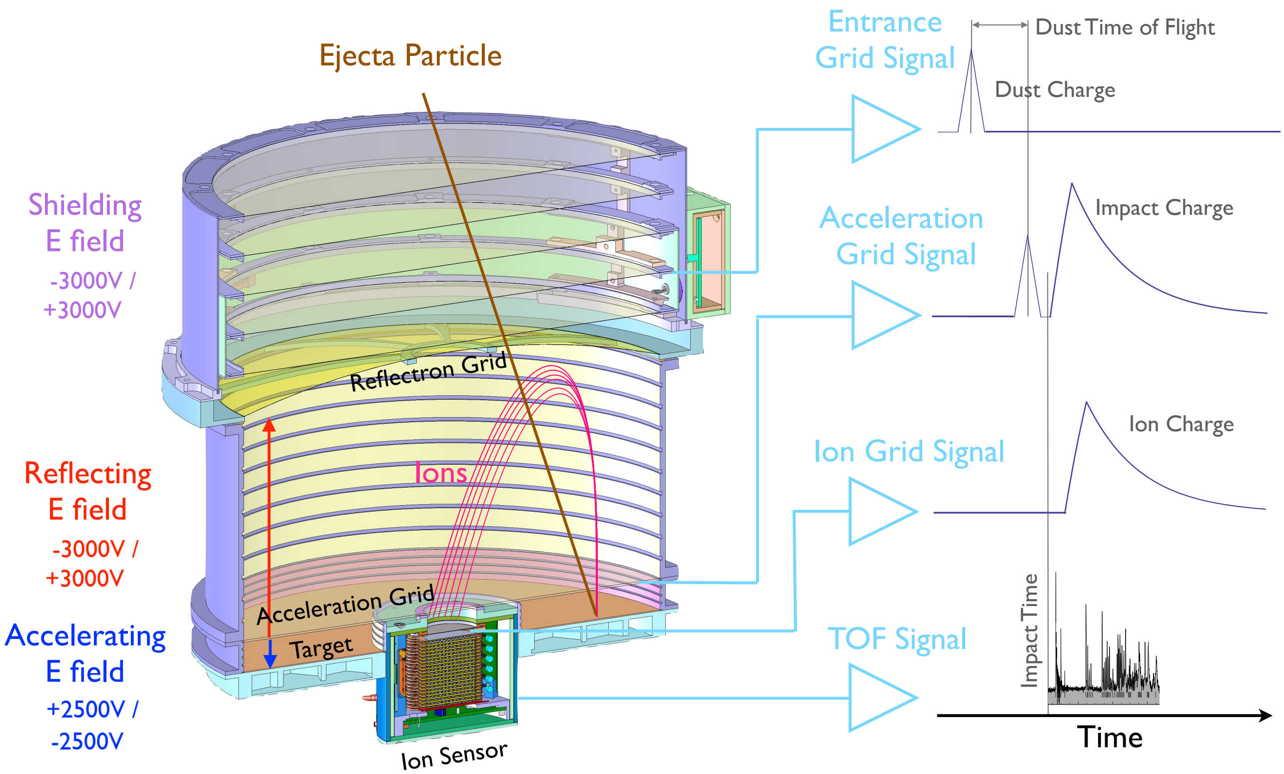

Fig. 1 Function principle oft he SUDA impact mass spectrometer.

Dust particles enter the aperture and fly through a set of shielding grids and reflectron grid before impacting on the planar, ring shaped target (Fig. 2). Even a relatively slow dust impact of typically 4 km/s generates a sufficient amount amount of atomic and molecular ions for the in-situ mass analysis of the grain's material. A strong electric field generated by the 2.5 kV bias potential on the target accelerates the ions toward the ions detector, where they are detected in a time-of-flight fashion focusing by the reflectron.

The acquisiton of the mass spectra is triggered by the impact generated charge pulse detected by the charge sensitive electronics connected to the target. The retarding field of the reflectron was optimized to achieve the best spatial and time focusing at the ion detector area in the center of the instrument.

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