CHEMICAL IN-SITU ANALYSIS OF INTERPLANETARY AND INTERSTELLAR METEOROIDS. M. Landgraf, *ESA/ESOC, 64293 Darmstadt, Germany, (Markus.Landgraf@esa.int)*, E. Grün, *Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu HI 96822, USA.*

1 Introduction

In-situ measurements of cosmic dust grains (meteoroids) have given us a wealth of information about dynamic processes in- and outside the Solar System (Morfill and Grün, 1979; Grün et al., 1985; Landgraf et al., 1999). Central issues regarding the make-up of interstellar as well as interplanetary dust are less well established. For example unknown what fraction of the interplanetary dust population at Earth originates from comets and what from asteroids (Liou et al., 1995, 1999; Dermott et al., 2002).

Much work has been done on the isotopic and chemical composition of certain, identifiable, phases of interplanetary dust grains (IDPs) (e.g. Zolensky et al. (2000); Stadermann (2001); Messenger et al. (2003)). The chemical composition of the dust grains is indicative of their origin, but cannot unambiguously determine whether an individual dust grain originates from a comet, an asteroid, or from interstellar space. In order to establish a dust grain's source the simultaneous knowledge about its state of motion and its chemical make-up is required.

For that purpose a dedicated space mission has been proposed (Grün et al., 2001). It is intended to carry a set of dust detection instruments to a disturbance-free, near-Earth position, like one of the co-linear Lagrange points, $1.5 \times 10^6\ km$ from Earth. The instrument set is comprised of a trajectory sensor, a large-area mass analyser, and auxiliary payload such as a plasma monitor. The total sensitive area of the dust detectors is $0.1\ m^2$, one order of magnitude larger than current instruments. The spacecraft is three-axis stabilised and is able to point the instrument array in any direction with a relatively low precision requirement of 1°. The proposed name for the mission is DUNE, for DUst Near Earth.

While the characteristics of the trajectory sensor are discussed in accompanying work (E. Grün, this issue), we focus here on the large area mass analyser (LAMA), the purpose of which is to find the elementary composition of interplanetary and interstellar dust grains by means of time-of-flight mass spectrometry.

2 Measurement Technique

LAMA makes use of impact ionisation, a process during which ions are formed from a solid impactor on a well-defined target surface Auer and Sitte (1968). In this process most ions are singly ionised. The instruments accelerates the ions with a uniform electrical field, which gives them approximately the same kinetic energy. The ion's velocities are the acceleration are thus proportional to the square root of their mass. One can therefore measure a mass spectrum by recording the time-resolved signal of an ion detector placed at a given distance in the direction of the ion's drift. In order to increase the mass resolution, LAMA is designed as a reflectron-type mass spectrometer. It utilises a second electro-static field in order to reverse the ion's direction of motion. This compensates the limiting effects of the initial energy distribution, because ions of the same mass but higher kinetic energy are sent on a longer flight-path. Using this technique, a mass resolution of $m/\Delta m$ greater than 300 is envisaged for LAMA.

Initial efforts for the development of LAMA are under way. It is essential to find an efficient and thorough method for the calibration of the instruments. Impact analysis instruments are usually calibrated at dust acceleration facilities (Grün et al., 1992). The variation of the total ion charge produced with these accelerator experiments is however limited to less than one order of magnitude. While accelerator calibration will be performed with LAMA, we propose to use impact simulation by laser desorption (Kissel and Krüger, 1987; Austin et al., 2002). With this technique it is possible to vary the produced ion charge over more than 5 decades by changing the laser intensity.

3 Model Prediction of Impactor Flux

In order to predict the amount of science return expected from the analysis of the interplanetary and interstellar dust environment of the Earth with LAMA, we rely on a model Dikarev et al. (2002) that is based on earlier in-situ measurements of the Galileo and Ulysses space probes Grün et al. (1997); Landgraf et al. (2003) as well as observations of radar meteoroids Galligan and Baggaley (2002). Here we assume that the sensor is located at the position of the Earth and moves around the Sun with the same velocity. This is a good approximation, because the planned orbit around one of the co-linear Lagrange points of the Sun-Earth system is located on the Sun-Earth line less than $0.01\ AU$ away from the Earth, and the structure of the interstellar dust stream and the interplanetary dust cloud are homogeneous on scales of $1\ AU$.

Figure 1 shows the number of expected impacts of interplanetary dust grains larger than $10\ \mu m$ as predicted by the Dikarev et al. (2002) model. The situation around the autumn equinox is shown. For this prediction we assume a field of view of the sensor of 70°. The highest rate of more than 20 large dust impacts per year can be found when the sensor is pointed into the direction of motion of the Earth. Especially impacts by these relatively large dust grains require the calibration of the instrument with the laser desorption method.

In addition to interplanetary dust, LAMA will analyse the elementary composition of interstellar dust grains. The first detection of these grains was achieved by the dust detector on board Ulysses Grün et al. (1993). Assuming the mass and directional distribution of the dust stream discovered with the Ulysses instrument, we expect to find a directional distribution

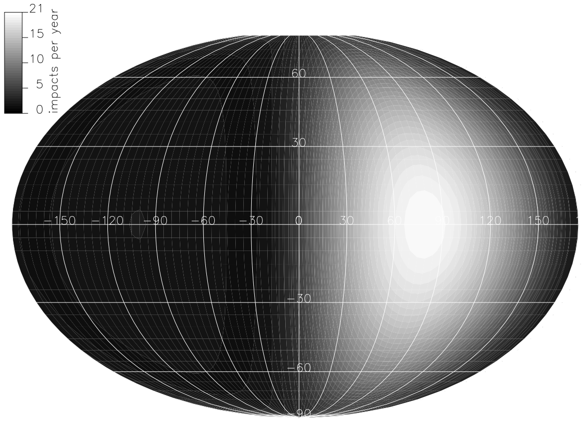

Figure 1: Sky map of impacts of interplanetary dust grains larger than 10 μm onto the LAMA sensor in ecliptic coordinates.

as shown in figure 2. Again the situation around the autumn equinox is shown. While the upstream direction of the dust stream was determined from the Ulysses data to coincide with the upstream direction of interstellar neutral gas, which is 259° ecliptic longitude and 8° ecliptic latitude, in autumn the grains appear to come from an ecliptic longitude of 170° for an observer co-moving with the Earth. This is because the orbital velocity of the Earth ($\approx 29\ km\ s^{-1}$) is similar to the velocity of the interstellar dust stream ($\approx 26\ km\ s^{-1}$). With a field of view of 70° LAMA will measure more than 30 interstellar dust grains larger than 1 μm per year.

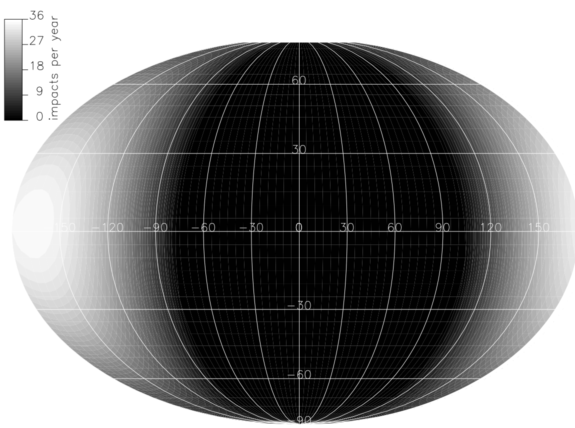

Figure 2: Sky map of impacts of interstellar dust grains larger than 1 μm onto the LAMA sensor in ecliptic coordinates.

4 Conclusion

We have presented the benefits of simultaneous in-situ measurement of the kinetic and chemical properties of interstellar and interplanetary dust grains. Such measurements can be the Rosetta stone that helps to decipher even more of the information contained in the IDP collection. Putting a large area mass analyser instrument for in-situ time-of-flight mass spectrometry on a dedicated spacecraft that stays in the Earth's vicinity will allow us to analyse tens of large ($> 10\,\mu m$) interplanetary and interstellar dust grains, as well as thousands of smaller ones.

References

S. Auer and K. Sitte. *Earth and Planetary Science Letters*, 4: 178–179, 1968.

D. E. Austin et al. In *Proceedings of the XXXIIIrd Lunar and Planetary Science Conference*, number 1939, 2002.

S. F. Dermott et al. In *ESA SP-500: Asteroids, Comets, and Meteors: ACM 2002*, pages 319–320, 2002.

V. Dikarev et al. *Astronomy & Astrophysics*, 383:302–308, 2002.

D. P. Galligan and W. J. Baggaley. In *ESA SP-500: Asteroids, Comets, and Meteors: ACM 2002*, pages 225–226, November 2002.

E. Grün et al. *Icarus*, 62:244–272, 1985.

E. Grün et al. *Space Science Reviews*, 60:317–340, 1992.

E. Grün et al. *Nature*, 362:428–430, 1993.

E. Grün et al. *Icarus*, 129:270–289, 1997.

E. Grün et al. *Astronomy and Astrophysics*, 377:1098–1118, 2001.

J. Kissel and F. Krüger. *Applied Physics A*, 42:69–85, 1987.

M. Landgraf et al. *Science*, 286:2319–2322, 1999.

M. Landgraf et al. *Journal of Geophysical Research (Space Physics)*, 108(A10):5–1, 2003.

J. C. Liou et al. *Planetary and Space Science*, 43:717–722, 1995.

J.-C. Liou et al. *Icarus*, 141:13–28, 1999.

S. Messenger et al. *Science*, 300:105–108, 2003.

G. E. Morfill and E. Grün. *Planetary and Space Science*, 27: 1269 – 1282, 1979.

F. J. Stadermann. In *Proceedings of the XXXIInd Lunar and Planetary Science Conference*, pages 1792–1793, 2001.

M. E. Zolensky et al. *Meteoritics and Planetary Science*, 35: 9–29, 2000.