

Introduction

Scientific Motivation

- Micron sized slow moving (1 – 100 m/s) particles on lunar surface (ejecta, electro static lofting dust)
- Detection methods utilizing momentum transfer or impact ionization are not applicable due to slow speed
- ELDA uses the charge on dust grains for detection

ELDA Instrument

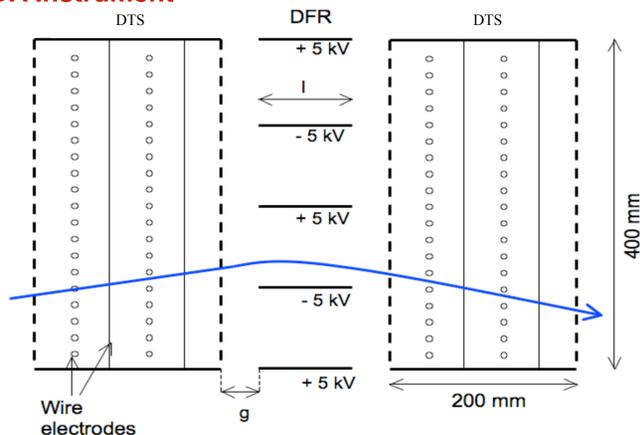


Fig. 1. The operation principle of ELDA: Two Dust Trajectory Sensors (DTS) measure the dust particle velocity vector before and after passing through an electrostatic deflection field region (DFR). The mass is derived from the deflection and charge.

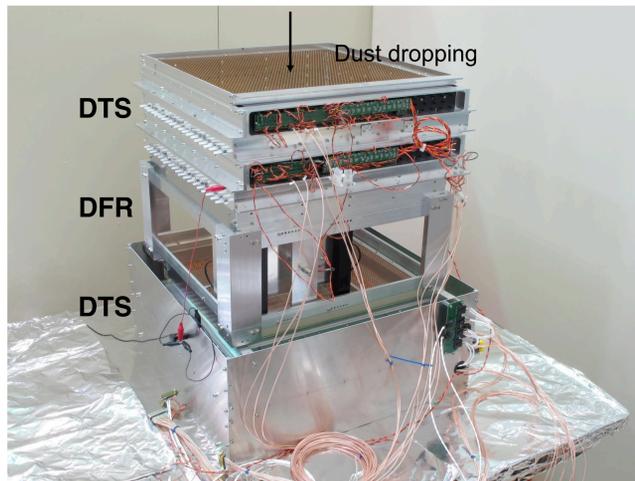


Fig. 2. The complete version of ELDA in lab that measures the charge, velocity vector, and mass of individual dust grains. It has a size 450X450X600 mm³.

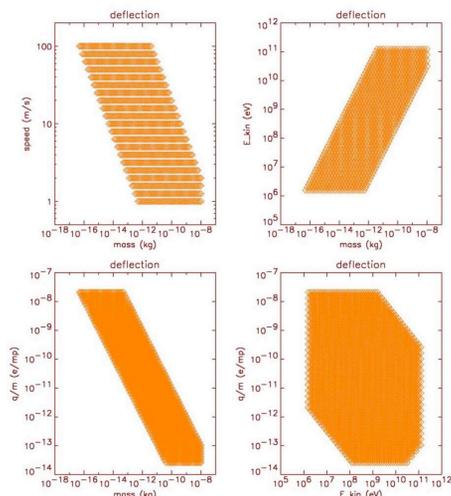


Fig. 3. This figure shows the parameter range where the deflection is significant and measurable, i.e. between 0.1 and 100mm.

Radius(micron)	1000	100	1
Mass(kg)	9.8E-6	9.8E-9	9.8E-15

Table 1. Mass vs. size for sphere dust particle of SiO₂.

Dust Trajectory Sensor (DTS)

The DTS is a critical part of the ELDA instrument. DTS measures the velocity vector of the dust particle by detecting the dust charge on an array of wire electrodes. The wires are arranged in four planes with alternating wire and each electrode is connected to a separate charge sensitive amplifier (CSA).

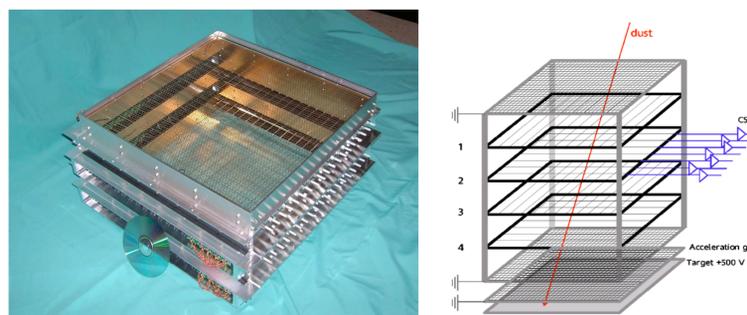


Fig. 4. Left is the laboratory prototype of the DTS. The figure on the right illustrates the method of measurement.

DTS Signal Simulation

The simulated charge signals on each wire in the DTS are calculated electrostatically by using Coulomb software as a function of time as the particle is passing through.

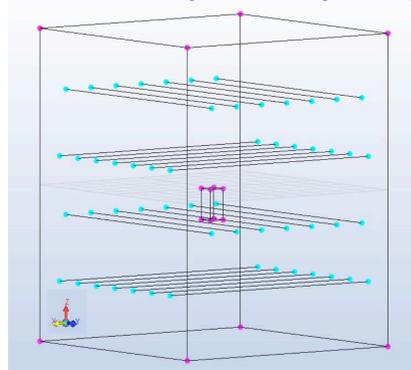


Fig. 5. The simplified model setup is a 160*160*200 mm box containing four wire planes with seven electrodes in each. The dust particle is simulated as a 5 micron sphere. The solutions to this simplified model can be extended for a larger instrument with more wire electrodes and planes.

Analysis of Experimental Data of DTS

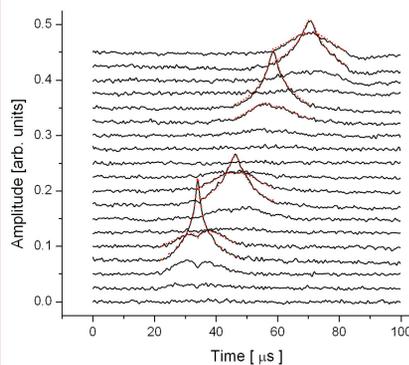


Fig. 6. Experimental DTS data from a 3.5 km/s dust particle. The red curves are from the fitting procedure.

Algorithm

1. The first estimate of the particle's charge and trajectory is determined
2. Monte Carlo optimization process is used to find the best match between the measurements and data simulations.
3. Narrow the parameter range using the results from 2.
4. Repeat 2 and 3 until the desired agreement is obtained

For more details, see Ref. 2.

Accuracy analysis

Artificial signals at different dust charge to noise (QNR) levels are used to study the accuracy of the algorithm.

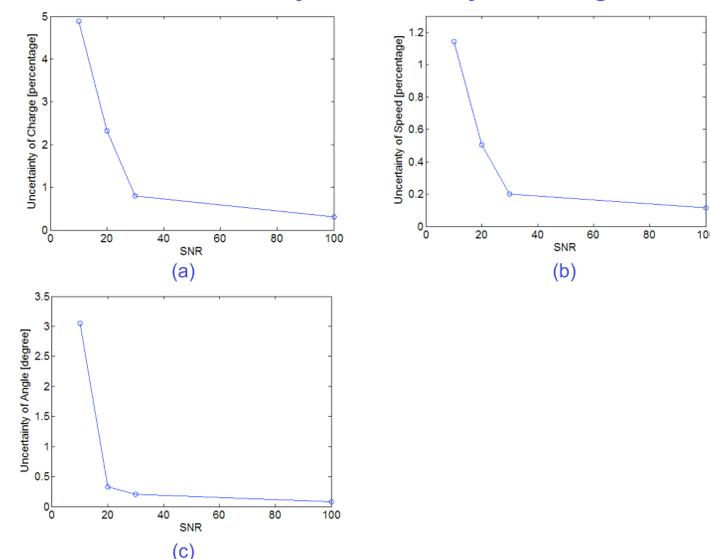


Fig. 7. Fig. 10. Uncertainty of the analysis at different SNR level. (a). Charge (b). Speed (c). Angle.

Effect of Gravity

The data analysis in previous part supposes that no acceleration, the dust particle passes through the DTS with constant speed and in straight line. The new algorithm considers the known gravity.

Laboratory Testing

The experiment is done in a vacuum chamber. Charged dust particles are dropped from about 0.8 m into the instrument. See Fig. 2.

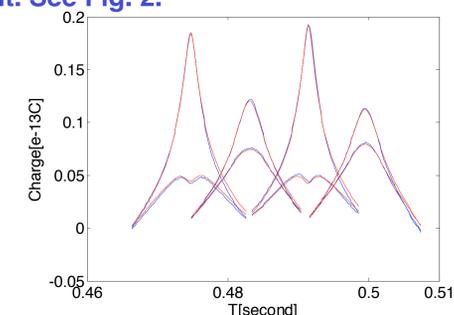


Fig. 8. A set of data of the second DTS recorded with the HV off. $Q = 3.9 \cdot 10^{-12}$ C. Because of the gravity, the dust particle accelerated in the DTS. $v_{in} = 4.6$ m/s and $v_{out} = 5.0$ m/s.

Current Work

- Numerical model of the deflection field region (DFR) to calculate the E-field distribution
- Develop algorithm for trajectory-mass-fitting to find the mass of the particle in the conditions limited by the trajectory information provided by the two DTS

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References:

1. N. Duncan *et al*, Planet. Space Sci. **59**, 1446 (2011).
2. J. Xie *et al*, Rev. Sci. Instrum. **82**, 105104 (2011).