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Dust Astronomy with the DESTINY$^+$ Dust Analyser

Ralf Srama (1), Masanori Kobayashi (2), Harald Krüger (3), Heiko Strack (1), Hartmut Henkel (4), Georg Moragas-Klostermeyer (1), Jonas Simolka (1), Thomas Albin (1), Jan Gläser (1), Ariane Exle (1), Yanwei Li (1), Stephan Ingerl (1), Takayuki Hirai (2), Tomoko Arai (2), Frank Postberg (5), Jessica Agarwal (3), Nicolas Altobelli (6), Thomas Henning (7), Jon K. Hillier (5), Sean Hsu (8), Mihaly Horanyi (8), Sascha Kempf (8), Nozair Khawaja (5), Anna Mocker (1), Michael Lengowski (1), Tomoki Nakamura (9), Ernesto Palomba (10), Jürgen Schmidt (11), Rachel Soja (1), Zoltan Sternovsky (8), Peter Strub (3), Thomas Stephan (12), Veerle Sterken (13), Shogo Tachibana (14), Mario Trieloff (5), Hikaru Yabuta (15), Jamey R. Szalay (16), Eberhard Grün (17), Sabine Klinkner (1)

(1) Institute for Space Systems, University Stuttgart, Ger, (srama@irs.uni-stuttgart.de)
(2) Planetary Exploration Research Center, Chiba Institute of Technology, Narashino, JPN
(3) MPI for Solar System Research, Göttingen, Ger
(4) von Hoerner & Sulger, Schwetzingen, Ger
(5) University Heidelberg, Ger
(6) ESA-ESAC, Madrid, ESP
(7) MPI Astronomy, Heidelberg, Ger
(8) University of Colorado, LASP, Boulder, USA
(9) Tohoku University, Sendai, JPN
(10) INAF, Rome, I
(11) University Oulu, FIN
(12) University of Chicago, USA
(13) Astronomical Institute, University of Bern, Switzerland
(14) University of Tokyo, JPN
(15) Hiroshima University, JPN
(16) Department of Astrophysical Sciences, Princeton University, USA
(17) MPI Nuclear Physics, Heidelberg, Ger

Abstract

DESTINY$^+$ is an interplanetary mission by JAXA/ISAS to the inner Solar System with a flyby at the active asteroid 3200 Phaethon in the year 2026. The science payload includes the new Dust Telescope “DESTINY+ Dust Analyser” (DDA), which is optimised to perform compositional measurements of individual micrometeoroid impacts. Mass spectrometry of the impact plasma is combined with particle trajectory information. This paper summarises the characteristics of the DESTINY$^+$ Dust Analyser and describes its science goals in context to earlier Cassini results.

Scientific Goals

Galactic interstellar dust represents the solid material from which stars and planetary systems form. Interplanetary dust from comets and asteroids represent remnant material from small bodies of objects from the early Solar System. DESTINY$^+$ studies compositional differences between the solid material of the interstellar medium and of material from primitive planetary objects in the inner Solar System. The results promise deeper insight into the physical conditions during our Solar System formation and DESTINY$^+$ forms a bridge between planetary science and astrophysics.

The discovery of interstellar dust in the outer and inner solar system in recent decades has enabled a new innovative approach to the characterisation of galactic cosmic dust. DESTINY$^+$ will address major questions like (1) What is the origin and nature of the dust particles that constantly fall onto the earth? (2) What is the fraction and composition of organic material in interplanetary and interstellar matter? (3) How do active asteroids work?

The in-situ methods of Dust Astronomy complement and extend the results achieved so far. DESTINY$^+$ is the next logical step after the successful missions of Stardust, Rosetta and Cassini. In particular, the following questions are addressed:

- In-situ analysis of the elementary and isotopic composition of individual cosmic dust particles including their organic constituents

- Characterisation of dust emission of the active asteroid 3200 Phaethon

- Determination of the size distribution of interstellar dust

- Characterisation of the interaction of interstellar matter with the heliosphere

- Determination and criteria for cometary and asteroidal interplanetary dust particles

- Improvement of meteoroid models for the inner solar system

DESTINY+ Dust Analyser

The DESTINY+ Dust Analyser (DDA) determines the particle density, composition (m/dm>150, mass range 1-1000 amu), electric charge (>0.15 fC) and mass (10e-19 kg to 10e-12 kg) of the smallest dust particles. Dust impact rates are measured for rates as low as 1/week up to 20/sec. DDA consists of two sensor heads, a 2-axis gimbal mechanism and an electronics box. The measuring principle is based on impact ionization, time-of-flight mass spectrometry and charge induction. The sensitivity (particle size, trace elements) and mass resolution has been improved up to a factor of 10 compared to the Cassini dust instrument. The properties of DDA are similar to the SUDA instrument onboard the Europa mission. The fast flyby at Phaethon with a speed of 33 km/s allows compositional analysis of nanograins as small as 50 nm radius. Its combined sensitive area (2 head) is 310 cm^2. For the first time, a dust sensor head allows the simultaneous operation of two spectrometers. Different spectrometer voltages will analyse cations and anions during all phases of the mission without the need to switch voltages. The measurement of anions is mandatory for the understanding of organic dust components in the mass spectra. The instrument is currently undergoing a Phase A study.

Open questions after Cassini

The Cosmic Dust Analyzer (CDA) onboard the Cassini mission measured the properties of micron sized dust particles in the planetary system. The instrument was operated during the cruise phase starting in 1999 and remained switched on until Saturn Orbit Insertion. Between 2004 and 2017 CDA performed successfully measurements in the Saturnian system and made many exciting discoveries and measurements: Dust streams from the inner and outer ring system, dust grain potentials, dust grain composition of ring particles, dust size and density distributions in the outer ring system, the G ring detection, the Enceladus dust plumes and significant dust fluxes outside the known E ring. Dedicated measurement campaigns were attributed to icy satellite flybys, interstellar dust observations and nanograin-magnetosphere interactions. Finally, the ring rain of between the main ring system and Saturn was characterised.

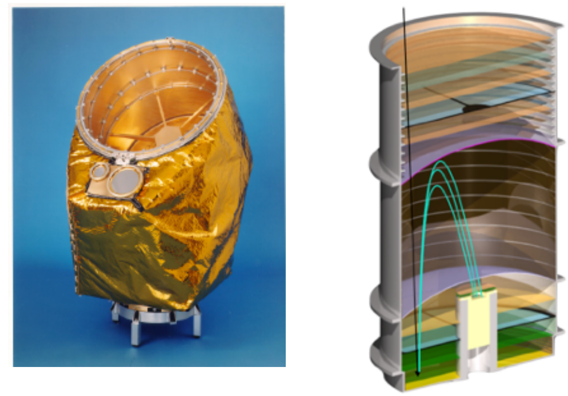

Fig. 1 The Cassini Cosmic Dust Analyser (left) and cross section of DDA (right). The instrument contains a ring shaped target (green) and a reflectron-type TOF mass spectrometer. Charge induction grids allow a dust trajectory determination. The cross section shows one sensor head. The gimbal, the instrument cover and the electronics box is not shown.

Interstellar dust was even measured twice: first, in the early cruise phase at 1 AU, and second, at Saturn during an almost one year long integration campaign. The second campaign succeeded to measure, for the first time, the composition of interstellar dust grains by an in-situ TOF mass spectrometer in space. The interstellar dust particles were identified and analysed. However, the mass spectrometer resolution was not high enough to clearly separate all elemental isotopes. DDA will fill this knowledge gap. Furthermore, the analysis of interplanetary dust particles by Cassini was compromised during cruise and during the Saturn tour. During cruise, the pointing profile was insufficient to measure a significant number of interplanetary dust grains. DESTINY+ promises the analysis of a statistical meaningful sample of interplanetary dust particles.

Acknowledgements

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