DESTINY$^+$ Dust Analyzer. M. Masanori[1], Ralf Srama[2], H. Krüger[3],T. Arai[1] and H. Kimura[1], [1]Planetary Exploration Research Center, Chiba Institute of Technology, [2]Institut für Raumfahrtsysteme, Stuttgart University. [3]Max Planck Institute for Solar System Research.

Introduction: DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage for Phaethon fLyby and dUSt analysis) is a deep space exploration technology experimental mission by the Japanese space agency JAXA. Its mission concept is "Advanced technology as the key for future deep space exploration". DESTINY$^+$ aims to realize a compact, high-performance deep space probe with mission payload of > 50 kg for explorations beyond the Earth orbit.

DESTINY$^+$ is currently planned to be launched in 2022 and to perform a close fly-by at 3200 Phaethon after a cruise phase of about two years in interplanetary space. During the Phaethon encounter with a relative speed of approximately 25 km/s, DESTINY+ will perform remote sensing and in-situ observations. A multiband camera will track the small body environment and a new dust telescope called Destiny+ Dust Analyzer (DDA) performs compositional analysis of micronsized dust grains along the track.

The close observations of a rock-comet like object like Phaethon are essential to resolve questions related to the evolution of our inner Solar System, especially the heating process of small bodies. Phaethon is believed to be the parent body of the Gemini meteor shower at Earth and it is considered to be a Comet-Asteroid Transition Object. Such objects play a major role for the material transport to the Earth [1]. Before arriving at Phaethon, DDA will characterize the interplanetary and interstellar dust environment at solar distances between 0.9 and 1.1 AU during the cruise phase. The mission will shed new light on the interaction between the heliosphere and the interstellar dust particles as component of the interstellar medium. This paper describes the mission goals, the Destiny+ probe and its instrumentation.

Dust Analyzer for DESTINY$^+$ mission: The sensor part of DDA consists of a trajectory sensor and a mass spectrometer. The trajectory sensor is placed on the front of the mass spectrometer part as shown in figure 1. The trajectory sensor measures the arrival direction of incident dust particles with the precision of < 10º and also measures the incident speed with the precision of < 10 %.

The mass spectrometer is a time-of-flight, reflectron-type impact mass spectrometer. The concept of the mass spectrometer part of DDA is the same as the one of SUDA [2] proposed for the Europa Clipper mission, which has heritage from the Cassini Cosmic Dust Analyzer (CDA) [3]. The DDA mass spectrometer has an improved mass resolution of M/dM >150.

With the DDA mass spectrometer, either anions or cations are measurable depending on the applied bias voltage for the acceleration of impact plasma in the TOF part of the instrument. In previous instruments flown in space the mass spectrometer was set to cation mode because many elements and molecules produce preferentially positive ions. For DDA, two sensor heads are planned, one for anion and cation mode, respectively, if the DESTINY$^+$ spacecraft resources are sufficient. If the anion mode is realized, O and C can be measured with a much higher sensitivity as well as S, P, SO_4, PO_4, CO_3.

The sensor head(s) will be mounted on a two-axes gimbal (elevation and azimuth). Owing to the gimbal, the boresight of sensor head(s) can be pointed to the arrival direction of individual dust populations, and also sunlight can be avoided from entering the DDA sensor(s) FOV.

The design of the DDA system is now under study to be optimized in terms of its function and performance. Table 1 shows the performance of DDA presently considered for development.

Interesting Dust Particle Populations as Observation Targets of DDA: It has a great opportunity of observing interstellar and interplanetary dust particles during the cruising phase after DESTINY$^+$ is left from the Earth around which in-situ dust observation is affected by artificial debris causing overwhelming background events.

Interstellar dust. CDA on board Cassini measured the arrival (inflow) direction of interstellar dust, its velocity, and the composition of its main elements when Cassini war in orbit about Saturn. DDA improves its performance, with having a better mass resolution and better angular resolution in the direction of arrival, and increasing its detection area, perhaps, adding anion mode. We expect further understanding of interstellar dust from DDA observation with those improvements of performance.

Best periods for interstellar observation in orbit is a half of year around the vernal equinox; the relative speed of interstellar dust v.r.t. the spacecraft is larger than the other half where the relative speed of interstellar dust to the spacecraft ranges between 26 km/s and 60 km/s [4]. The sensor head(s) of DDA has to be pointed into the upstream of the interstellar dust using the gimbal.

Interplanetary dust. In-situ observation of interplanetary dust in orbit around the Sun has been performed in many previous missions. However, no data on in-situ compositional measurements of interplanetary dust exists except for the two particles measured by the Cassini Cosmic Dust Analyzer on its way to Jupiter [5]. DDA observation will provide us with the chemical composition and the orbital elements of individual interplanetary dust particles for a better understanding of the significance of the asteroidal and cometary dust sources.

Dust particles ambient Phaethon. During the Phaethon fly-by, we aim to indirectly obtain Phaethon's compositional information by elemental/mass analysis of dust around Phaethon. There are two sources of dust particles around Phaethon, its own activity, ~~namely cometary activity~~ and impact ejecta by meteoroid bombardment.

A former study based on optical ground-based observations when Phaethon was at a heliocentric distance of 1.6 AU estimates the dust production rate of 0.01 kg/s as the upper limit [6]. Under some assumptions of escape process of dust particles from Phaethon, it corresponds to 8×10^{12} particles/s for a particle size of 0.5 micron and a bulk density of 2500 kg/m^3. This implies that up to 1700 dust particles may be detected by a single DDA sensor during the DESTINY+ fly-by of Phaethon at the closet distance of 500 km/s from the object. Phaethon approached to 0.12 AU of Earth on December 10, 2017, and many astronomers observed Phaethon from the ground under the best conditions ever. These latest results may update the dust production rate around Phaethon at a heliocentric distance of 1 AU.

Even if there is no cometary activity of Phaethon at all, dust particles around Phaethon must exist as impact ejecta of meteoroid bombardment, called dust cloud, which exists permanently around airless bodies in interplanetary space [7]. It is difficult to estimate the production rate of impact ejecta because the surface condition of Phaethon is unknown, however, several dust particles from the impact ejecta may be detected by the DDA sensor during the Phaethon fly-by.

References: [1] Arai et al. (2018) *LPS IL, in this issue*. [2] Kempf et al. (2014) *EPSC Abstracts 9*, EPSC2014-229. [3] Srama et al., (2004) *SSR* 114: 465–518. [4] Krüger et al., (2017) *EPSC Abstract*, 11, EPSC2017-204. [5] Hiller et al. (2007) *Icarus* 190, 643–654. [6] Hsieh and Jewitt (2005) *ApJ* 624, 1093-1096. [7] Krüger et al. (1999) *Nature* 399, 558-560.

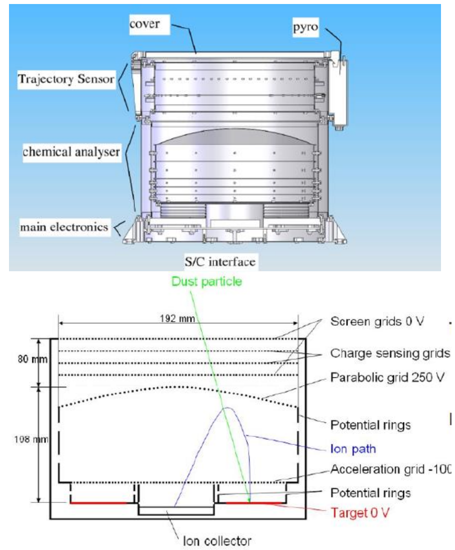

Figure 1. Concept of DDA. The cross-sectional view of the whole structure of DDA sensor (upper) and the mass spectrometer part (bottom).

Table 1. Performance of DDA

Item		Values
Measurement items		Mass, speed, charge, flux, composition
Mass range for dust measurement		10^{-16} g $\sim$ 10^{-6} g
Sensitive area (one sensor head)		$0.011 m^2$
Precision	Arrival direction	<10°
	Speed	<10%
Mass resolution		M/dM >150
FOV		45° (half cone)