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iDUST: A mission concept for the 'dust tomography' of the heliosphere

M. Horányi (1) , E. Grün (1), Z. Sternovsky (1), S. Kempf (1), R. Srama (2), F. Postberg (2), S. Auer (3)
(1) LASP, U. of Colorado, Boulder, USA, (2) MPI-K, Heidelberg, Germany, (3) A&M Associates, Basye, VA, USA
(contact: horanyi@colorado.edu).

Abstract

The observations of the inward transport of interstellar dust and the outflow of near-solar dust provide a unique opportunity to explore dusty plasma processes throughout the heliosphere. The flux, direction, and size-distribution of interstellar dust can be used to test our models about the large-scale structure of the heliospheric magnetic field, and its temporal variability with solar cycle. The measurements of the speed, composition and size distribution of the recently discovered, solar wind-entrained nano-dust particles hold the key to understand their effects on the dynamics and composition of the solar wind plasma. Both the inflowing interstellar grains and the out-flowing nano-dust particles can be measured on-board a near Earth spacecraft at 1 AU, using recently developed dust detection techniques. This talk will summarize our current understanding, the outstanding issues, and the science and measurements requirements for a mission dedicated to dust observations. We will also discuss the technical readiness of the required instrumentation, and the possible implementation of the ***iDUST*** mission.

1. Introduction

Dust is an important component of the heliospheric plasma environment. Dust carries significant mass, momentum and energy, yet the processes responsible for coupling it to the solar wind plasma flow remain largely unexplored. The nano-dust particles generated near the Sun and accelerated by the out-flowing solar wind, and the interstellar dust particles traversing the heliosphere can be measured at 1 AU, providing a 'tomographic image' of our heliosphere through dust measurements. Recently developed dust instrumentation enables the precise measurement of the mass, charge, velocity vector, and the chemical and isotopic composition of the dust particles. Hence, a mission dedicated to dust measurements is now timely, and could provide a new window into our cosmic environment.

1.1 Interstellar dust

After its fly-by of Jupiter, the dust detector onboard the Ulysses spacecraft detected impacts of particles in the mass range of 10^{-14} to 10^{-11} g, predominantly from a direction that was opposite to the expected impact direction of interplanetary dust grains. In addition, the impact velocities exceeded the local solar system escape velocity [1]. Subsequent analysis showed that the motion of the interstellar grains through the solar system was parallel to the flow of neutral interstellar hydrogen and helium gas (Figure 1), both traveling at a speed of 26 km/s.

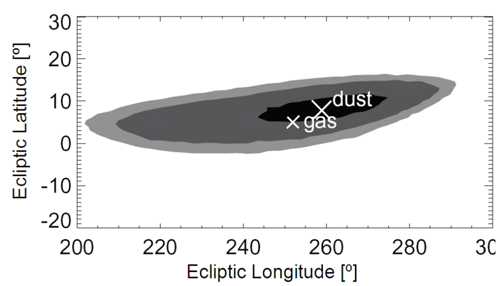

Figure 1: The upstream direction of the interstellar dust flux observed by Ulysses is λ=259±20° and θ=8±10° ecliptic longitude and latitude, respectively. The contour plot shows 1σ, 2σ, and 3σ confidence levels as black, dark grey, and light grey. The helium upstream direction is λ=254°, θ=5.6° [2].

1.1 Interplanetary dust

Early dust instruments onboard Pioneer 8 and 9 and Helios spacecraft detected a flow of submicron sized dust particles arriving from the solar direction. It was concluded that these particles originate in the inner solar system from mutual collisions among meteoroids and move on hyperbolic orbits that leave the Solar System under the prevailing radiation pressure force. As of to date little more has been learned since more sensitive dust could not face the solar direction because of severe interferences caused by solar UV radiation and solar wind entering the instruments. Only the dust instrument onboard the Ulysses spacecraft observed escaping dust particles high above the solar poles, which confirms the supposition that charged nanometer sized dust grains are carried to high heliographic latitudes by electromagnetic interactions with the IMF. Recently, the STEREO WAVES instruments recorded a large number of intense voltage signals in the ecliptic plane at 1 AU, which were interpreted as impact ionization signals of streams of nanometer sized particles striking the spacecraft at velocities of about solar wind speed (Figure 2). High fluxes of nanometer sized dust grains at low heliographic latitudes, as well as strong spatial and temporal fluctuations of dust streams uncorrelated with solar wind properties pose a mystery. The nano-dust, if real, represents a significant mass flux, which would require that the total collisional meteoroid debris inside 1 AU is cast in nanometer sized fragments.

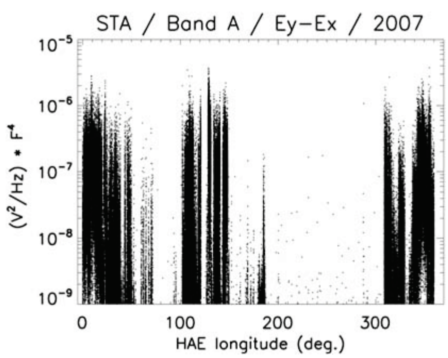

Figure 2. Average power observed by the STEREO/WAVES low frequency receiver on STEREO A as a function of ecliptic longitude during the whole 2007 orbit. The periods of high amplitudes could be caused by high-speed nano-dust striking the spacecraft [3].

2. Dust telescope

The ***iDUST*** Dust Telescope (DT) is a combination of the Dust Trajectory Sensor (DTS) and the Large Area Mass Analyser (LAMA) shown in Figure 3. DTS measures the velocity, direction, and charge of the dust particles. After passing through DTS, the particles impact the target plate of LAMA. The total amount of impact charge generated provides a measure of the grain's mass. The elemental composition is obtained by measuring the Time- of-Flight (ToF) spectrum of the impact-generated ions.

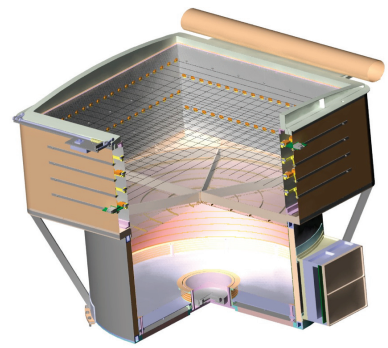

Figure 3: A Dust Telescope (DT). The top section is a Dust Trajectory Sensor (DTS) to measure the charge, and the velocity vector of the impacting dust particles. The bottom section is the Large Area Mass Analyser (LAMA) to measure the chemical and isotopic composition of the dust grains using a time-of-flight mass spectroscopy.

References

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