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Interstellar Dust Measurements with the Interstellar Probe

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Interstellar dust (ISD) particles are messengers from the remote sites where they formed and from the environment that they traversed during their journey through space and time. They are born as stardust and take their initial elemental and isotopic signatures from the cool atmospheres of giant stars or from stellar explosions. Ultraviolet (UV) irradiation, interstellar shock waves, and mutual collisions modify and deplete particles in the interstellar medium (ISM). In dense molecular clouds particles grow by agglomeration and accretion. But interstellar particles are also found in our neighbourhood. The Sun and the heliosphere are surrounded by a local dense warm cloud of gas and dust, the Local Interstellar Cloud (LIC). About 1 % of the mass of this cloud is ISD. The motion of the heliosphere with respect to this cloud causes an inflow of the ISD into the heliosphere from a direction of 259° ecliptic longitude, and +8° ecliptic latitude. The relative velocity of the ISD in the heliosphere was determined to be approximately 26 km s^{-1} and a subsequent analysis showed, that the ISD particle motion through the solar system was parallel to the flow of neutral interstellar hydrogen and helium gas.

ISD plays a crucial role in regulating the thermal energy in the ISM, in catalysing chemical reactions in molecular clouds, and in providing the basic building blocks for the formation of planetesimals in protoplanetary disks around main-sequence stars. In our Galaxy, the presence of dust grains is primarily inferred from their interaction with electromagnetic radiation, which gives rise to absorption, scattering, and polarisation of Galactic starlight; infrared, submillimetre, and microwave emission, including the broad solid-state emission and absorption features; and the production of scattering halos around x-ray sources.

More direct information can be achieved by in-situ measurements inside and outside of the heliosphere. After the discovery of ISD in the our Solar System by the missions Galileo and Ulysses, it was found, that ISD is penetrating deep into the heliosphere even reaching the Earth orbit. Probes like IMAP or DESTINY+ will study ISD at the Earth environment in the near future (*Krüger et al, 2018*). However, only a small fraction of ISD particles will reach solar distances of 1 AU. Due to the Sun radiation pressure and Lorentz forces of the IMF, the heliosphere acts like a huge time dependent filter for certain ISD particle masses. How does the ISD composition and mass distribution varies with solar distance and time? How does it look like outside of the heliosphere?

With the interstellar probe, we have a chance to directly sample the interstellar dust particles in the ISM even before they enter the heliosphere. The interstellar probe should determine spatial, time and compositional variations along its way out of the solar system.

In-situ dust measurements of an interstellar probe will address the following science objectives:

- What is the distribution of the condensed (dust) in our galactic neighbourhood and its relation to the chemical diversity of our Solar System?
- How is the ISD filtered by the heliosphere? How do the particles change in mass and composition with solar distance?
- What is the nature of carbonaceous dust and of organic precursor molecules for life?
- What is the composition of silicate grains? Can we identify SiC in ISD particles and where is the iron?
- What are the sizes of compositionally different grains? Do we find nano-diamonds?
- What is the metallicity of the local interstellar medium?
- Can destruction and formation processes (coagulation, condensation) be identified in the composition and size-distribution of ISD?
- Do we find multi-component grains? Are silicates mixed-in with carbonaceous material?
- Can we distinguish original stardust grains from dust grains that have been homogenised through processing in the ISM?
- What is the shape and density of interstellar dust? Can we confirm the core-mantle model of the grains? Do we find fluffy particles? What are the optical properties of the grains?

An interstellar probe is the only method to answer the scientific questions. Instrumentation is available to characterize the mass, directionality and composition of individual ISD impacts for grain sizes larger than a few nm depending on the relative impact speed.