FM10
Nano Dust in Space and Astrophysics

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Nano dust in space and astrophysics

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Abstract. The theme of this focus meeting is related to the detection, characterization and modeling of nano particles — cosmic dust of sizes of roughly 1 to 100 nm — in space environments like the interstellar medium, planetary debris disks, the heliosphere, the vicinity of the Sun and planetary atmospheres, and the space near Earth. Discussions focus on nano dust that forms from condensations and collisions and from planetary objects, as well as its interactions with space plasmas like the solar and stellar winds, atmospheres and magnetospheres. A particular goal is to bring together space scientists, astronomers, astrophysicists, and laboratory experimentalists and combine their knowledge to reach cross fertilization of different disciplines.

Nano dust particles are intermediate between molecules and bulk matter. Because of their finite small size and large surface-to-volume ratio, the physical properties of nano grains are often peculiar, being qualitatively different from those of bulk materials. Different behavior is found, e.g., in heat capacity, melting temperature, surface energy, diffusion coefficient, and optical properties. Especially, clusters of $\sim$ 1–10 nm are expected to reveal strongly variable size-dependent properties such as electronic structure, binding energy and dielectric function which determine how they interact with gas particles and the electromagnetic radiation. Larger clusters, with many thousands of atoms and diameters in the range of 10 nm and more, have a behavior smoothly varying with size and approaching bulk properties as size increases.

While the exact role of nano dust is not fully understood yet, those nanoclusters should play an important role, since, because of their large surface area (relative to their small mass), they interact more efficiently with particles and fields. Interstellar nano dust grains dominate the far ultraviolet extinction as well as the near- and mid-infrared emission of the interstellar medium (ISM) of the Milky Way and external galaxies. The heating of the interstellar gas and the surface layers of protoplanetary disks are dominated by nano grains through the photoelectrons provided by them. The presence of charged nano dust likewise influences other space plasma, also leading to dusty plasma effects, like waves and instabilities. Nano-sized (or smaller) polycyclic aromatic hydrocarbon (PAH) molecules, C60, diamonds reveal their presence in astrophysical regions through their characteristic vibrational spectral features. Nanodiamonds and nano TiC crystals have also been identified as presolar grains in primitive meteorites through their isotope anomalies. Their path from formation in the late stages of stellar evolution to identification in the laboratory is sketched in Figure 1.

For many years nano dust has been detected with in-situ instruments from spacecraft in different regions of the solar system. In the inner heliosphere of our solar system, nano dust forms from the dust-dust collisions in the zodiacal cloud and from sun-grazing

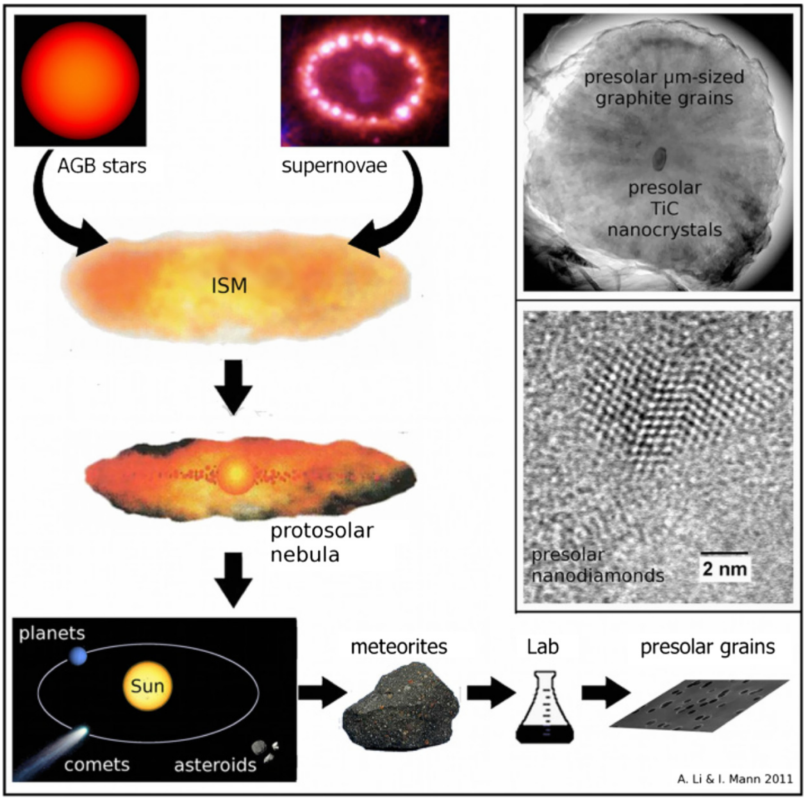

Figure 1. Schematic illustration of the history of cosmic dust grains, from their condensation in stellar winds of asymptotic giant branch (AGB) stars or in supernova ejecta, to their injection into the ISM, and subsequent incorporation into the dense molecular cloud from which our solar system formed (i.e., protosolar nebula). These grains survived all the violent processes occurring in the ISM (e.g., sputtering by shock waves) and in the early stages of solar system formation and were incorporated into meteorite parent bodies. Finally, they were collisionally liberated from their parent bodies and entered the Earth atmosphere, making them available for experimental studies in terrestrial laboratories, and therefore allowing one to separate them from the meteorite or interplanetary dust material in which they are embedded. Inserted are the TEM (*Transmission Electron Microscopy*) images of presolar nanodiamond grains and a presolar TiC nanocrystal within a micrometer-sized presolar graphite spherule. Taken from A. Li & I. Mann (2012, in Astrophys. Space Sci. Library, Vol. 385, *Nanodust in the Solar System: Discoveries and Interpretations*, ed. I. Mann, N. Meyer-Vernet, & A. Czechowski, Berlin, Springer-Verlag, 5).

comets. A notable recent finding is that nano dust in the heliosphere is deflected and accelerated in the solar wind. Astronomical observations suggest the presence of nano dust also in circum-stellar debris disks around main-sequence stars under conditions similar to the inner heliosphere. In-situ measurements from sounding rockets detect nano dust in the Earth's upper atmosphere (mesosphere), where it forms from the re-condensation of metallic compounds produced from ablating meteoroids. This dust — termed meteoric smoke — provides condensation nuclei for noctilucent clouds (first reported in 1886, and almost certainly a harbinger of climate change in the upper atmosphere). Meteoric smoke is also implicated in the formation and freezing of stratospheric clouds (which cause polar ozone depletion) and in the chemistry of clouds and atmospheres of, e.g., Mars, Venus, and Titan. Nano dust is probably also observed in comets. Planetary vulcanic plumes and impacts on planetary objects are sources of interplanetary nano dust as, e.g., observed near the surface of the Moon.

Nanodust interacts efficiently with particles and fields and in plasmas. The vast majority of our universe is plasma in which the heavy chemical elements are often contained in small solid dust particles that carry electric surface charge. A large fraction of the plasma is therefore dusty plasma, where dust participates in and gives rise to charge collective effects. Examples for dusty plasma are the ISM, the Earth's ionosphere, the ring systems of planets as well as the surface layers of moons and in general of solar system objects that are not surrounded by an atmosphere. Although dusty plasma is extensively studied, only a few observations in space are fully described with existing theory.

The research on the dynamics of nano dust in the heliosphere at present progresses motivated by the detection with space instruments on several different spacecraft. We expect a wealth of new observations in the near future. NASA has launched the *Parker Solar Probe* in August 2018 and ESA will soon launch the *Solar Orbiter*. Both spacecraft explore the most inner heliosphere and plasma in the vicinity of the Sun, including a region where we expect nanodust is being formed. Observing the near- and mid-infrared emission of the ISM which is dominated by nano dust is one focus of *JWST* which will be launched in 2021. Laboratory astrophysics is today a well-established field and in recent years further progress on dust studies was made with sample returns, from which the knowledge, often referring to larger dust, still provides information on nano dust.

During the General Assembly in Vienna, the Focus Meeting "*Nano Dust in Space and Astrophysics*" (FM10) on 28–29 August 2018 has brought together space physicists who study nano dust in the heliosphere and specialists from physics, astrophysics, as well as atmospheric research to make progress in understanding nano dust particles by combining their knowledge on dust under a wide range of space conditions. Knowledge on nano dust is also gained from studies of larger particles that progressed through laboratory astrophysics and analysis of returned samples.

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