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Editorial: Cosmic dust—its formation, processing, and destruction

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Editorial on the Research Topic
Cosmic dust—its formation, processing, and destruction

In this editorial we summarize the main outcomes of our article Research Topic that includes four articles, of which three are original research paper and one is a review.

The review by Herrero et al. provides a comprehensive review of the current understanding of carbonaceous dust in the interstellar medium, focusing on its composition, formation, and physico-chemical properties. Carbonaceous dust grains are primarily composed of hydrogenated amorphous carbon, exhibiting a range of sizes, hydrogen content, and proportions of aliphatic and aromatic structures. Other minor carbon forms, such as nanodiamonds and fullerenes, are also present. The most relevant spectral features of carbonaceous dust include a UV bump at 217.5 nm and a series of infrared absorption and emission bands. Laboratory dust analogs have successfully reproduced these observed spectral features, providing valuable insights into the nature of interstellar dust. Carbonaceous dust is thought to originate in the inner envelopes of carbon-rich AGB stars and can grow in the cold interstellar medium. Interactions with H atoms, VUV photons, and cosmic rays significantly influence the properties and evolution of dust grains, such as the formation of an aliphatic mantle. The paper also discusses recent experiments that demonstrate the release of small molecules and large polycyclic aromatic hydrocarbons or fullerenes from dust grains under the influence of VUV photons and cosmic rays. This top-down chemistry could help explain the rich molecular inventory observed in the diffuse medium, particularly in photon-dominated regions at the edges of dense clouds. Several unresolved issues and open questions are raised, highlighting the importance of continued experimental work in this field. While recreating exact interstellar or circumstellar conditions in the laboratory is impossible, simulating relevant physicochemical conditions remains critical for interpreting astrophysical observations and advancing our understanding of carbonaceous dust in the interstellar medium.

Polycyclic aromatic hydrocarbons (PAHs) are accountable for the family of infrared emission features noticed in diverse astrophysical environments. This group of molecules could contain approximately 20% of the galactic carbon. It plays a vital role in maintaining

the physics and chemistry of the Interstellar medium. Some PAHs like indene and cyanonapthalene isomers were recently identified in Taurus Molecular Cloud 1. In their contribution, Hashemi et al. deduced the energy-resolved rate constants for the photodissociation of Indene over an energy range of 8–25 eV. They used the RRK-Marcus (RRKM) theory based on electronic structure and Molecular dynamic simulations using Reax force field (ReaxFF). Both methods complement each other at the lower energy, but for the higher energy, MD simulations give a larger value than RRKM. The difference between the results could be attributed to several reasons, including using different potentials and non-statistical effects. Compared to their RRKM and MD simulation results, Allain et al. (1996b), with the RRK expression, obtained a higher rate constant between the 8–25 eV. Hashemi et al. suggested using their obtained photoionization rates to estimate a realistic PAH abundance.

Along the journey of cosmic grains from stellar outflows to interstellar space and eventually proto-planetary disks, an important role is occupied by silicon carbide (SiC) clusters. Several SiC species have been detected in the envelopes of carbon-rich AGB stars and as inclusions in carbonaceous chondrites, establishing the importance of small SiC clusters as an intermediate step in dust formation. Unfortunately, remote detections of small SiC dust precursors have proven difficult due to a lack of spectroscopic data. Sehring et al. studied nine isomers of the tetra-atomic species C_4, SiC_3, Si_2C_2, Si_3C, and Si_4 using high-level coupled cluster theory. They utilize quartic force field methods to generate rovibrational transitions and spectral data for each species. This way, Sehring et al. were able to identify several strong vibrational modes, such as the 1339.4 cm^{-1}/7.5 μm mode of d-SiC_3 and the 988.1 cm^{-1}/10.1 μm mode of r-Si_2C_2, which could be targeted with the James Webb Space Telescope's MIRI instrument. A highlight of this ensemble study is that the addition of silicon atoms to carbon clusters has the effect of shifting their vibrational transitions to lower frequencies. This general insight may lead to a better identification of unknown silicon-bearing species in stellar atmospheres or nebulae in the future.

Andersson et al. revisited the longstanding problem of astrophysical silicate formation from gas phase molecules predominantly SiO. The authors calculated rate coefficients for oxidation and clustering reactions of SiO, Si_2O_2 and Si_2O_3 using high-level density functional theory calculations. They found that oxidations by OH are faster and more efficient than those by the more abundant H_2O molecules. Instead, reactions with H_2O can lead to hydroxylated silicon oxide species under certain conditions. Phyisco-chemical models of circumstellar envelopes of oxygen-rich evolved stars that include the derived rate coefficients, however, show that only small concentrations of SiO_2 and Si_2O_2 are formed and that most of the silicon remains as molecular SiO.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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