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Understanding of the properties of cosmic organic dust based on combined approaches among astronomical observations, experiments and numerical simulations

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At least a part of the Organic dust in space is believed to be formed by condensing the stellar wind containing nucleo-synthesized heavy elements. So far, experiments have been conducted to synthesize materials simulating the organic dust in space by generating plasma gas using hydrocarbon dust and nitrogen gas with a 2.45 GHz microwave and rapidly cooling and condensing it. These experiments successfully synthesized Quenched Nitrogen-included carbonaceous composite (QNCC) that replicate the characteristics of unidentified infrared bands observed around novae (Endo et al. 2021; see upper panel of the Figure). This experiment qualitatively simulates the process of organic dust formation in novae where the N-rich nova wind interact with the pre-existing hydrocarbon dust. Analysis results reveal that QNCC contains about 3-5% N/C ratio and contains nitrogen in the form of amines within the material (Endo et al. 2021). Additionally, the infrared and X-ray analysis of QNCC material collected after one year of exposure in orbit using the ExHAM facility on the International Space Station (ISS) '*Kibo*' module showed striking similarities to the insoluble organic matter (IOM) in carbonaceous meteorites (Sakon et al. in preparation), suggesting QNCC's importance in investigating the origin of primordial organic matter in the solar system. On the other hand, with support from the program "Understanding the Process of Nitrogen-Inclusive Chemical Bond Formation in Cosmic Organic Dust" (PI. Itsuki Sakon) selected as part of the 2022 NINS Cross-Disciplinary Joint Research Project, an experiment was conducted at the Large Helical Device (LHD) of the National Institute for Fusion Science, irradiating hydrocarbon dust with a relatively low-energy plasma at the outer edge of the LHD plasma (Cycle 24 experiment). Preliminary analysis revealed changes that reproduce the characteristics of peculiar unidentified infrared bands observed in galaxies with weak active galactic nuclei (Smith et al. 2007) and in elliptical galaxies (Bregman et al. 2008; Kaneda et al. 2005), characterized by the absence of the 6-9μm bands corresponding to stretching modes of aromatic C-C bonds and the presence of only the 11-14μm bands corresponding to out-of-plane bending modes of aromatic C-H bonds (see bottom panel of Figure). While the polycyclic aromatic hydrocarbons (PAHs) hypothesis is widely accepted in astronomy as the carrier of these bands, the exact understanding of their nature is incomplete. Thus, the identification of the carrier responsible for these bands and the determination of the physical factors giving rise to their characteristics remain unresolved for galaxies with weak active galactic nuclei and elliptical galaxies. In this presentation, I will report the latest progress in research aimed at understanding the properties of interstellar organic matter, based on an integrated approach involving astronomical observations, experimental astrophysics, and molecular dynamics simulations.

References

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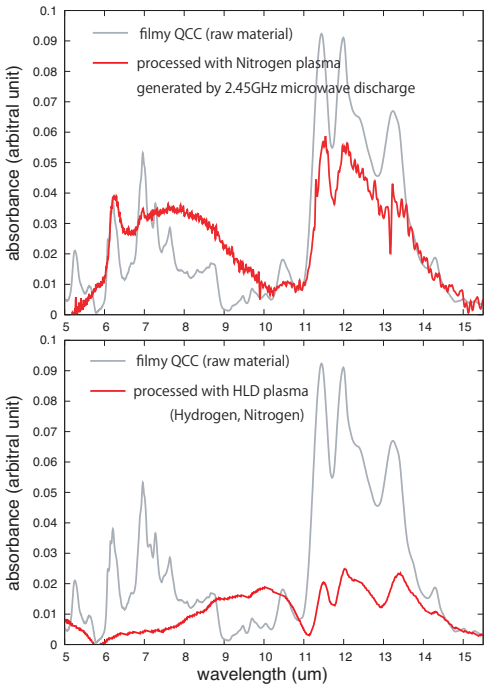

Figure 1. (top) Infrared ATR spectrum of organic dust named QNCC (Endo et al. 2021) synthesized by irradiating nitrogen plasma generated by 2.45 GHz microwave discharge to filmy QCC. (bottom) Infrared ATR spectrum of organic dust synthesized by irradiating LHD plasma made of hydrogen and Nitrogen to filmy QCC. The infrared ATR spectrum of unprocessed filmy QCC is shown with gray in both panel.