Dust evolution in photon-dominated regions

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Dust plays a crucial role in numerous physical and chemical processes in the interstellar medium (ISM). Variations of physical conditions in the ISM (i.e. particle density and radiation field) trigger evolution of the dust properties (i.e optical properties, abundances, size distribution, composition) which strongly impact the gas [1]. It is therefore important to understand how dust evolves with the local environment.

We study dust evolution, through its emission and scattering properties, in nearby photon-dominated regions (PDRs) where the physical conditions vary widely but can be spatially resolved. We focus on the Horsehead Nebula, IC63, and the Orion Bar, three well-known PDRs which have been extensively studied. Observations from the Herschel Space Observatory together with those from the Spitzer Space Telescope are available and provide us with a wealth of spatial and spectral informations of dust and gas emission from the mid-IR to the submillimeter spectral ranges. To model the dust emission and scattering across these PDRs, we use the THEMIS dust model [2][3], included in the dust physics numerical tool DustEM [4]. A 3D continuum radiative transfer code, SOC [5], is then used to assess dust emission and scattering at different positions inside these PDRs. Considering first dust populations from the diffuse interstellar medium with fixed abundances across the cloud we show that the short and long wavelength dust emission cannot be simultaneously matched.

We constrain dust properties in the Horsehead [6], IC63 and the Orion Bar [7] and we find that regardless of the PDR, the nano-grains are depleted and that their minimum size is larger than in the diffuse ISM, which suggests that the mechanisms that lead nano-grains to be photo-destroyed are very efficient below a given critical size limit. The evolution of the nano-grain dust-to-gas mass ratio with both the intensity and temperature of illuminating stars indicates a competition between the nano-grain formation through the fragmentation of larger grains and the nano-grain photo-destruction. We model dust collisions driven by radiative pressure with a classical 1D approach to show that this is a viable scenario to explain the nano-grain formation through fragmentation and therefore the variation in nano-grain dust-to-gas mass ratio from one PDR to another.

Références

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