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Orion Bar as a window to evolution of small carbonaceous dust grains

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The Orion Bar is one of the most well-known photodissociation regions. An enormous volume of observational data in various spectral ranges makes it a versatile tool for checking theoretical ideas. Specifically, it allows studying small carbonaceous grains, which reveal themselves through mid-infrared (IR) emission bands. Their lifecycle strongly depends on external conditions that vary dramatically within this object. Thus, it is possible to trace the evolutionary changes of dust at different conditions within a single object.

We use the archival photometric and spectroscopic observations in the mid-IR range from several telescopes: UKIRT, Spitzer, ISO, SOFIA. Fluxes in bands at 3.3, 3.4, 6.4, 6.6, 7.7, 11.2 μm are measured. These IR-bands are usually associated with vibrations of polycyclic aromatic hydrocarbons (PAHs). Ratios between band fluxes indicate variations in dust size ($F_{3.3}/F_{11.2}$), ionization stage ($F_{6.4}/F_{11.2}$, $F_{7.7}/F_{3.3}$, $F_{7.7}/F_{11.2}$), and fraction of grains with aliphatic bonds ($F_{3.4}/F_{3.3}$). We have found that in the Orion Bar the band ratios change with the distance from the Trapezium Cluster (TC). The ratio $F_{3.3}/F_{11.2}$ increases with the distance from the TC indicating growing abundance of small PAHs relative to larger ones. The ratios $F_{6.4}/F_{11.2}$, $F_{7.7}/F_{3.3}$, $F_{7.7}/F_{11.2}$ decrease toward the molecular cloud, implying that abundance of positively charged PAHs drops relative to abundance of neutral PAHs. The ratio $F_{3.4}/F_{3.3}$ has a minimum approximately at the ionisation front and increases toward the molecular cloud, which likely characterises the increasing contribution of hydrogenated grains whether they are PAHs or small amorphous carbons.

We have fitted the spectrum of the Orion Bar by PAHs' spectra from the NASA Ames PAH IR database presented by Bauschlicher *et al.* (2018). The spectrum is well fitted by the PAH-mixture of ≈ 50 species. Most of them are large (number of carbon atoms $N_{\rm C} > 80$) pericondensed neutral species and cations, medium ($40 < N_{\rm C} < 80$), and small ($N_{\rm C} < 40$) dehydrogenated pericondensed neutral species and cations, and also small hydrogenated PAHs like hydrogenated coronene.

We have modelled the evolution of PAHs at the conditions of the Orion Bar using our dust evolution model described in the work of Murga *et al.* (2016). We have obtained the results which are generally consistent with observations but with some exceptions. Specifically, it was found that there should be large cations and neutral PAHs at the ionization front, and the small fraction of medium dehydrogenated PAHs can exist also, but the model cannot predict the the presence of small PAHs, neither hydrogenated nor dehydrogenated. We assume that such small PAHs can be result of destruction of PAH clusters or restructuring of amorphous carbonaceous grains from H-rich to H-poor state.

References

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