

Unidentified Infrared Emission Features

Christine Joblin^{1,2}

¹Université de Toulouse; UPS-OMP; IRAP; Toulouse, France

²CNRS; IRAP; 9 Av. Colonel Roche, BP 44346, F-31028 Toulouse cedex 4, France
email: christine.joblin@irap.omp.eu

Abstract. When referring to unidentified infrared emission features, one has in mind the series of aromatic IR bands (AIBs) between 3.3 and 15 μm that are observed in emission in many environments where UV photons irradiate interstellar matter. These bands are now used by astronomers to classify objects and characterize local physical conditions. However, a deep analysis cannot proceed without understanding the properties of the band carriers. Large polycyclic aromatic hydrocarbon molecules are attractive candidates but interstellar species are still poorly characterized. Various studies emphasize the need for tackling the link between molecular aromatic species, aliphatic material and very small carbonaceous grains. Other unidentified emission features such as the 6.9, 21 and 30 μm bands could be involved in the evolutionary scenario.

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1. AIBs as a tool for astronomers

The AIBs at 3.3, 6.2, 7.7, 8.6, 11.3 and 12.7 μm are major features in the cycle of dust in the Milky Way, from evolved stars (planetary nebulae), to the diffuse interstellar medium (ISM) and bright photodissociation region (PDRs) associated to molecular clouds and to the circumstellar environment of young stars including their disks. They are also well observed in external galaxies including luminous IR galaxies (e.g. Smith *et al.* 2007; Fadda *et al.* 2010). The observed spectra exhibit variations in band positions, profiles and relative intensities and also differ in their satellite features. Peeters *et al.* (2002) and van Dienenhoven *et al.* (2004) have performed spectral classification as a function of object type and Smith *et al.* (2007) have published the spectral decomposition tool PAHFIT that provides a band by band analysis. Galliano *et al.* (2008) have derived an empirical law between the 6.2 over 11.3 μm band intensity ratio and the ionisation parameter $\gamma = G_0 \sqrt{T}/n_e$ where G_0 is the UV field intensity, T the gas temperature and n_e the electron density. Further spectral analysis requires a better understanding of the nature of the AIB carriers and their physical and chemical evolution due to environmental conditions. In a series of papers (Rapacioli *et al.* 2005; Berné *et al.* 2007; Joblin *et al.* 2008; Berné *et al.* 2009), we have shown that the AIB spectrum can be decomposed into four template spectra, the various mixtures of which create the observed spectral variations in most UV-irradiated environments. Three of the spectra carry only band emission and are assigned to PAH cations, PAH neutrals and large ionized PAHs. The other spectrum has band and continuum emission and it is assigned to evaporating very small grains (eVSGs) by the authors (see discussion in Pilleri *et al.* 2012). A drop of the eVSG emission is observed at the UV irradiated surface of clouds and is correlated with an increase in the PAH emission, strongly suggesting that free PAHs are produced by destruction of eVSGs under UV irradiation. The fitting tool PAHTAT includes the four template spectra described above. It is publicly available and can be used to derive local physical parameters such as G_0 or the extinction along the line of sight (Pilleri *et al.* 2012; <http://userpages.irap.omp.eu/~cjoblin/PAHTAT>).

2. Which carriers for the AIBs

The best carriers for the AIBs are polycyclic aromatic hydrocarbon (PAH) molecules. The emission mechanism following excitation by single UV photons can account for the observational constraints such as the broadness and profile of the bands, without requiring a (too) large diversity of species (Pech *et al.* 2002). The evolution of relative band intensities with the ionisation parameter is consistent with the molecular properties of PAHs (e.g., Ricca *et al.* 2012 and references therein). The recent identification of C₆₀ (see conference by J. Cami) supports the presence of large carbon molecules in space. Yet, there has been no identification of a single PAH in space. The mid-IR range reflects mainly chemical bonds and, therefore, provides information on the composition and some trends about the size and structure, but is not well suited to identify individual species. Still, some bands are challenging to be accounted for by pure PAHs (e.g. the presence of N heteroatoms has been proposed by Hudgins *et al.* 2005 to account for the 6.2 μm band). To better characterise interstellar PAHs, one has therefore to progress in the understanding on how these species are formed in the envelopes of evolved stars. At the protoplanetary nebula stage, gas-phase hydrocarbon photochemistry (Cernicharo *et al.* 2001) is observed as well as signatures of hydrogenated amorphous carbon grains (e.g., Chiar *et al.* 1998), aromatics and aliphatics in molecular form and/or in the form of pristine/hot small grains (Kwok *et al.* 1999; Peeters *et al.* 2002). Irradiation by UV photons in more advanced evolutionary stage of the central star leads to destruction of the fragile aliphatic bonds and further aromatisation of the material, although the involved species and the mechanisms leading to the formation of PAHs have still to be clarified. For instance it has been proposed that PAHs are generated by photodestruction of carbonaceous grains by UV photons and possibly shocks from the central star (Kwok *et al.* 2001; Joblin *et al.* 2008; García-Hernández *et al.* 2011), but this has still to be proven. In solving this evolutionary scenario it is important to consider other emission features than AIBs, such as the 3.4 and 6.9 μm bands due to aliphatics, the broad 8 and 12 μm bands, as well as the 21 and 30 μm features (see conference by K. Volk).

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