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Some insights on the dust properties of nearby galaxies, as seen with *Herschel*

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ABSTRACT

Nearby galaxies are particularly relevant laboratories to study dust evolution due to the diversity of physical conditions they harbor and to the wealth of data at our disposal. In this paper, we review several recent advances in this field, mainly based on *Herschel* observations. We first discuss the problems linked with our ignorance of grain emissivities, and show that it can be constrained in some cases. New models are starting to incorporate these constraints. We then present methodological issues encountered when fitting spectral energy distributions, leading to biases in derived dust properties, and some attempts to solve them. Subsequently, we review studies scrutinizing dust evolution: (i) from a global point of view, inferring long term cosmic dust evolution; (ii) from a local point of view, looking for indices of dust processing in the ISM.

1. Introduction

Although only accouting for 1% of the interstellar medium (ISM) mass, dust plays a crucial role in galactic physics. It re-radiates in the infrared (IR) about 30% of the stellar power in normal disk galaxies, and up to 99% in ultraluminous IR galaxies (Clements et al., 1996, *e.g.*). It is a catalyst for numerous chemical reactions, including H_2 formation (*e.g.* Bron et al., 2014). The photoelectrons it releases in photodissociation regions (PDR) are one of the main heating sources of the gas (*e.g.* Kimura, 2016). However, the detailed microscopic properties of the dust – its chemical composition, size distribution, abundance, *etc.* – are poorly known and are evidenced to vary strongly from one environment to the other. As a consequence, we are left with large uncertainties on the physics of the ISM, and on galaxy evolution.

In theory, we could infer dust properties by modelling its evolution from its formation in stellar ejecta and dense ISM, to its processing by shock and UV radiation and its recycling in star formation (Fig. 1; *e.g.* Zhukovska, 2014). However, the efficiency of each individual process is not accurately enough known to provide reliable grain properties, purely based on theory. We therefore have to rely on observations to constrain the grain properties in different environments.

Nearby galaxies are particularly suitable environments to conduct such studies, as they harbor a wide diversity of physical conditions (star formation activity, metallicity, *etc.*). In addition, a wealth of data is available for them, with good spatial resolution and sensitivity. The Milky Way itself is an important laboratory, but it spans a rather narrow range of metallicity and does not contain very massive star forming regions.

2. The dust SED of nearby galaxies

2.1. A typical galactic SED

The spectral energy distribution (SED; Fig. 2) of a typical galaxy is dominated by several processes.

Stars. Young OB stars are strong UV emitters, while older stellar populations dominate the visible/near-IR range. The weights of these two main components depend on the star formation history of the galaxy. The fraction of light absorbed by dust is represented by the hatched area on Fig. 2.

Gas. Atomic and molecular lines are numerous, but the gas also emits continuum radiation (Fig. 2): (i) thermal continuum in the form of free-bound and free-free emission; and (ii) non-thermal continuum, mainly synchrotron.

Dust. Dust radiates thermally over the whole IR domain. Several molecular and solid state features can be seen, mainly in the mid-IR. Fig. 2 represents the aromatic feature emission believed to be carried

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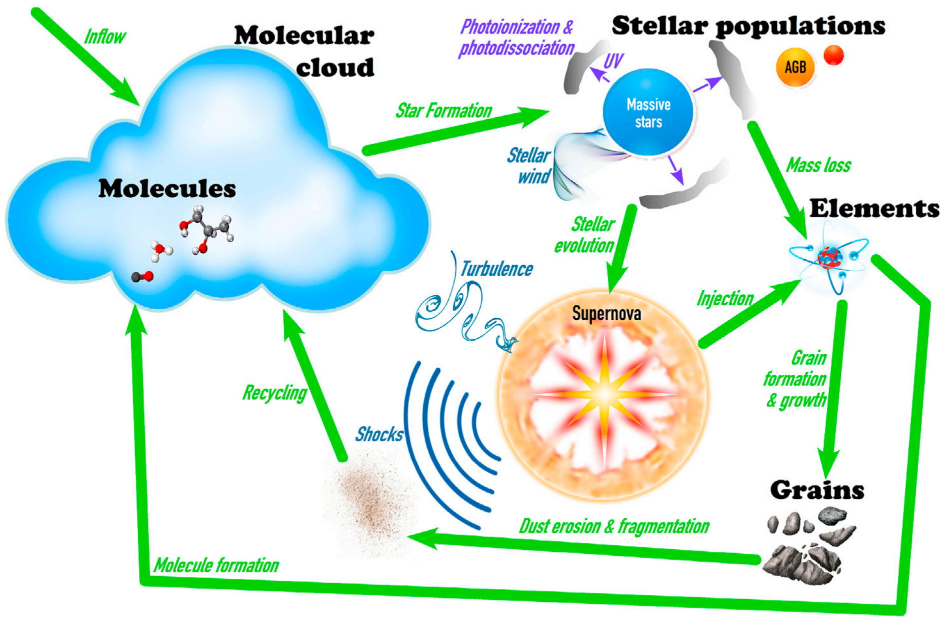

Fig. 1. Schematic view of the interstellar lifecycle.

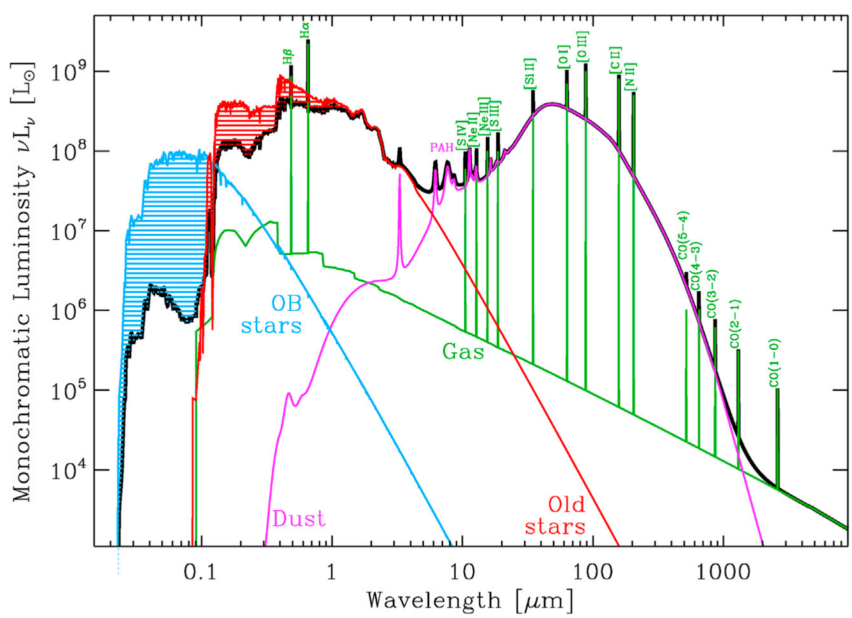

Fig. 2. Typical SED of a star forming galaxy. It is based on the model of NGC 1569 by Galliano et al. (2008), with the addition of a typical gas contribution, modelled with Cloudy (Ferland et al., 2013). Only the most widely observed gas lines have been shown. The hatched areas in the stellar spectra represent the fraction of light that has been absorbed by the ISM (mainly the dust). This absorbed light is re-emitted by the dust component.

by polycyclic aromatic hydrocarbons (PAH). The whole power emitted by the dust equals the absorbed stellar power (hatched areas of Fig. 2).

2.2. The large-scale distribution of dust in nearby galaxies

Dust and stars are not uniformly mixed. Knowing which stellar population is responsible for the dust heating in a given regime can be observationnally inferred. For instance, Bendo et al. (2015) studied a sample of 24 face-on galaxies. Comparing select far-IR *Herschel* band ratios to tracers of the stellar populations (young: 24 μm and Hα; old: 3.6 μm), they could show that the transition between dust heated by young stars and dust heated by old stars happens between 160 and 350 μm, in most cases. It appears that dust grains are on average hotter when heated by young stars, and colder when heated by older populations. The picture is different in more extreme objects, like low-metallicity dwarf galaxies, where the young stellar population can dominate the whole emission (*e.g.* Rémy-Ruyer et al., 2015). For example, in the LMC, the massive star forming region 30 Doradus accounts for ≃20% of the total IR luminosity (Aguirre et al., 2003), and a dozen of the brightest regions account for 40% of the total (Rubin et al., 2009). In the extreme case of SBS 0 335-052 ($Z = 1/35 Z_\odot$), six star forming regions can account for 65% of the total galaxy power (Thuan et al., 1997; Galliano et al., 2008). Combined with the lower dust screening resulting from the lower heavy element abundance, the whole galactic dust can be heated by a few massive star forming regions.

A more comprehensive approach to this problem is provided by panchromatic radiative transfer models. Such codes can solve the