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Dust-to-gas ratio and metallicity gradients in DustPedia galaxies

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Abstract. Far-infrared photometric observations from the *Herschel* Space Observatory offer the opportunity to study the dust-to-gas ratio at a resolved scale in nearby galaxies. The amount, and gradient, of solid-phase metals can thus be compared with metallicity measurements in the gas phase. We describe our preliminary work on the topic with data from the DustPedia project.

Keywords. dust, extinction, galaxies: ISM, galaxies: abundances, galaxies: structure

1. Introduction

A considerable fraction of the heavy elements in the ISM is locked-up in dust: for the local medium, the observed depletions show that half of the total metal mass is in the gas, half in grains (with a dust-to-metal ratio, DTM$\approx$0.5; see, e.g., Clark et al. 2016). The dust-to-gas mass ratio (DGR) can thus be used as a tracer of the solid-phase metallicity. For galaxies, it is tempting to use the DGR also as a proxy of the gas-phase metallicity, assuming the constant DTM derived in the local MW ISM. A direct association of DGR and metallicity (typically the O/H ratio) is however prevented by several uncertainties. For instance, the estimate of the dust mass depends on the opacity cross sections: the mass can vary by a factor of three or more, depending on the assumed dust-grain model (Casasola *et al.* 2017); also, the derivation of the DGR requires an estimate of the gas molecular component, which is usually derived indirectly from CO. Thus, the uncertainties in the DGR are not significantly different from those on metallicity, i.e. the usually-quoted 0.7-dex spread due to the use of different metallicity calibrators. The possible dependence of some of the factors (e.g. DTM and the CO-to-H_2 conversion factor, α_{CO}) on metallicity itself also affects the comparison between DGR and metallicity gradients. With these caveats, we nevertheless attempted a few study on the subject for some of the galaxies in the DustPedia sample.

2. The DustPedia database

DustPedia - A definitive study of Cosmic Dust in the local Universe (Davies *et al.* 2017; http://www.dustpedia.com) is a collaborative-focused project supported by the EU FP7 grant 606847. Its goal is to perform a complete characterisation of dust in local galaxies including: its composition and physical properties in different galactic environments; its origin and evolution; its relation to other ISM components; its effects on stellar radiation; the connection between SF indicators and dust emission; the contribution of local galaxies to the cosmic far-IR background. The research is carried out on a sample of 875 objects, i.e. almost all the large (D25>1') and nearby (z<0.01) galaxies observed by the *Herschel* Space Observatory. A legacy database was constructed from *Herschel* and other UV-to-microwave observations, containing multi-wavelength imagery and aperture-matched photometry in up to 42 bands (Clark *et al.* 2018; data are publicly available at http://dustpedia.astro.noa.gr/). Eventually, the database will include data on the atomic and molecular gas from the literature (Casasola, see this volume) and on metallicity from literature and public MUSE observations (De Vis *et al.* 2019). Homogeneously-derived metallicities are available for over 10000 position across about 500 galaxies, for seven different calibrators. Characteristic (global) metallicities at $0.4R_{25}$ have been derived using Bayesian gradient estimates. They are currently being analysed in the framework of dust/metallicity evolutionary models (see, e.g. De Vis *et al.* 2017) About 70 galaxies have low-uncertainty estimates of the metallicity gradient.

3. The DGR as a tracer of metallicity

In Magrini *et al.* (2011) we studied the DGR and O/H gradients in four galaxies of the *Herschel* Virgo Cluster Survey (Davies *et al.* 2012), a precursor to the DustPedia project. Maps of the dust surface density were obtained by pixel-to-pixel fitting of the far-infrared/submm spectral energy distribution (SED); the DGR was derived with different choices of α_{CO}; it was converted into the same scale as O/H observations, assuming a MW DTM; and its gradient compared to that of the metallicity. We found that an α_{CO} lower than the value used for the MW provide a better match between the gradients, supporting a dependence of the factor on metallicity. We plan to extend the work to the largest DustPedia galaxies, for which Casasola *et al.* (2017) found that radial gradients in the dust surface density are flatter than the stellar, and intermediate between those of the molecular and gas components.

Conversely, for a given α_{CO} and constant DTM, one can derive the dust mass from the metallicity, and compare it with the value obtained using standard SED fitting methods. The comparison yields an estimate for the dust absorption cross-section, independently of a dust-grain model. Such measurements have been made at a global scale, using integrated galactic properties (see, e.g. Clark *et al.* 2016) and are now being attempted at a resolved scale for a few large DustPedia galaxies (Clark *et al.* 2019). Preliminary results for M83 show an increase of the cross section at 500μm with galactocentric distance, with values encompassing those of current state-of-the-art dust models and ranging over more than 1-dex. The results could be due to real changes in the dust properties with radius, or depend on the assumption of a constant DTM ratio. In fact, a DGR steeper than the metallicity gradient, and thus a variation of DTM with radius, is predicted when most of the dust mass is due to accretion of atoms onto seed-grains in the ISM; this has been verified on observations of M31 (Mattsson *et al.* 2014). Also, a super-linear dependence of DGR on the metallicity has been found also for M101 (Chiang *et al.* 2018) and for the MW (Giannetti *et al.* 2017). We are currently investigating the impact of DTM gradients in our analysis of DustPedia galaxies.

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