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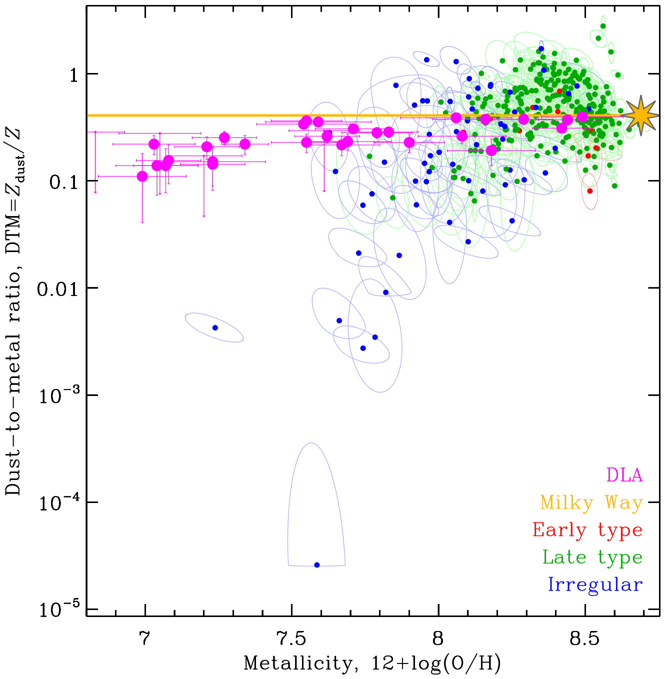

Fig. 10. Comparison to DLAs. This figure shows the relation between the metallicity and the dust-to-metal mass ratio, for the reference run (Sect. 3.2). This figure is very similar to panel d of Fig. 8: the only difference is that the *y*-axis has been divided by *Z* (related to the *x*-axis through Eq. (1)). We have overlaid in magenta the DLA measures from Table 6 of De Cia et al. (2016). The horizontal yellow line corresponds to the Galactic dust-to-metal mass ratio. The Bayesian correlation coefficient of the nearby galaxy sample is $\rho = 0.636^{+0.021}_{-0.023}$, with $\mathrm{CR}_{95\%}(\rho) = [0.59, 0.68]$.

a potential issue for our nearby galaxy sample. This is particularly important for low-metallicity, dwarf galaxies, where the IR-emitting region is usually small compared to the whole H I halo (e.g., Walter et al. 2007; Begum et al. 2008). For instance, Draine et al. (2007) hinted that the trend between Z and Z_{dust} was close to linear, when the gas mass used to estimate Z_{dust} was integrated in the same region as the dust mass. They only had nine galaxies below $12 + \log(\mathrm{O/H}) < 8.1$. We have addressed this issue by adopting the interferometric $[\mathrm{H\,I}]_{21\,\mathrm{cm}}$ observations of 20 of the lowest metallicity galaxies in our sample, including the lowest metallicity system, I Zw 18 (Roychowdhury et al., in prep.; Sect. 2.2.3). We have integrated the gas mass within the photometric aperture for these 20 objects. I Zw 18 still lies two orders of magnitude below the Galactic DTM, despite this correction. On the contrary, it is possible that the DTM of UGCA 20, the lowest SUE in Fig. 10, has been underestimated, as it has not been resolved in H I. We have to admit that there is still room for improvement as several of the ELMGs are barely resolved in the IR. Thus, although we corrected for a large fraction of the H I halo, there might still be residual gas not associated with the star forming region within our aperture. We might therefore be underestimating the dustiness of our ELMGs. This will have consequences in Sect. 5. The amplitude of this underestimation is not quantifiable as these sources are not resolved in the far-IR. It is however difficult to imagine that there would still be 99% of gas not associated with IR emission within our aperture. Indeed, for the most extreme case, I Zw 18, our aperture is only 1.5 times the optical radius (Rémy-Ruyer et al. 2013), which should be comparable to the IR radius. The overall rising DTM with $12 + \log(\mathrm{O/H})$ of Fig. 10 is therefore unlikely due to an improper correction of the H I envelopes of ELMGs.

Variation of the grain opacities. We have noted in Sect. 3.1.3 that our dust mass estimates depend on the rather arbitrary grain opacity we have adopted. This grain opacity has been designed to account for the emission, extinction, and depletions of the diffuse Galactic ISM (cf. Sect. 3.1.1). A systematic variation of the overall grain opacity with metallicity could change the slope of the trend in Fig. 10. In order to move I Zw 18 up to the Galactic DTM, we would need to adopt a grain emissivity diminished by about two orders of magnitude[19]. Qualitatively, the ISM of an ELMG, such as I Zw 18, is (e.g., Cormier et al. 2019): (i) permeated by hard UV photons; (ii) very clumpy with a low cloud filling factor. With more UV photons to evaporate the mantles and less clouds to grow them back, we could assume that the grains in such a system would be reduced to their cores (cf. Fig. 16 of Jones et al. 2013). Demantled, crystalline, compact grains are indeed among the least emissive grains. However, to our knowledge, there are no interstellar dust analogs having a far-IR opacity two orders of magnitude lower than those used in the `THEMIS` model. The Draine & Li (2007) mixture, which resembles compact bare grains, is only a factor of ≃2 less emissive than `THEMIS` (e.g., Fig. 4 of Galliano et al. 2018). We could also imagine that the composition of the dust mixture itself changes. In particular, the fraction of silicates could be higher in ELMGs, as C/O and O/H are correlated (Garnett et al. 1995). This would have a limited effect, since: (i) a decrease of the large a-C(:H) abundance by 50% would decrease the global emissivity of `THEMIS` in the SPIRE bands by 15−30%; (ii) a variation of the forsterite-to-enstatite ratio would change the emissivity by less than 30%. It is therefore very unlikely that the dependence of DTM with metallicity is artificially induced by our grain opacity assumption.

Variation of the size distribution. Another factor that could affect the trend of Fig. 10 is that we have fixed the size distribution of the large grains. In principle, relaxing this assumption and allowing the size distribution to be dominated by very small grains (VSG) in low-metallicity sources, would raise the DTM of objects such as I Zw 18. Indeed, VSGs are stochastically heated. They spend most of their time at very low temperatures between successive photon absorptions. Their excursion at $T \gtrsim 20\,\mathrm{K}$ will span only a fraction of their time. A mixture of VSGs would thus appear less emissive than a larger grain at an equilibrium temperature close to the high end of their temperature distribution. We have demonstrated this effect in Fig. 11. We have simulated a VSG-dominated SED mimicking a typical ELMG, peaking around $\lambda \simeq 40\,\mu\mathrm{m}$, and with very weak aromatic feature emission (Fig. 11; panel b; blue curve). The size distribution needed to produce such a SED is made almost exclusively of $a \simeq 1.5\,\mathrm{nm}$ radius grains (Fig. 11; panel a; blue curve). We have fit this synthetic SED with our reference model (Sect. 3.1.2), keeping the large grain size distribution fixed (Fig. 11; panel a; red curve), but varying the ISRF distribution. This model reproduces very well the photometric fluxes (Fig. 11; panel b; red circles), but requires a total dust mass a factor of ≃3 lower than the VSG model. This effect goes in the right direction but is not enough to explain the two orders of magnitude required to account for a constant DTM in Fig. 10. We could further decrease the emissivity of the VSG model by lowering the size of the grains. However, it would result in a SED peaking shortward

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[19] For I Zw 18, $\mathrm{CR}_{95\%}(\mathrm{DTM}) = [2.3\times10^{-3}, 7.9\times10^{-3}]$, while $\mathrm{DTM}_{\odot} \simeq 0.5$.