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2.2.3. The gas mass

Neutral gas. The neutral hydrogen masses, derived from $[\mathrm{H\,I}]_{21\,\mathrm{cm}}$, have been compiled by De Vis et al. (2019), for DustPedia, and Madden et al. (2013), for the DGS. Integrating the H I mass in the aperture used for the photometry is not always possible for the smallest sources, as they are not resolved by single dish observations. This is particularly important for dwarf galaxies, where the H I disk tends to be significantly larger than the optical and IR radius (e.g., Begum et al. 2008), as we discuss in Sect. 4.1.3. Roychowdhury et al. (in prep.) recently obtained interferometric, spatially-resolved $[\mathrm{H\,I}]_{21\,\mathrm{cm}}$ observations of 20 of the lowest-metallicity galaxies in our sample ($12+\log(\mathrm{O/H}) \leq 8.0$)[9]. They integrated these H I masses in the aperture used for the photometry in order to provide a better estimate of the gas mass associated with the dust emission. We have adopted these more accurate values, for these 20 objects. We have multiplied the H I mass of each galaxy by $1/(1-Y_\odot-Z) \simeq 1.35$ to account for helium (assumed independent of metallicity) and heavier elements. We use $M_{\mathrm{H\,I}}$ to denote the *total* atomic gas mass probed by $[\mathrm{H\,I}]_{21\,\mathrm{cm}}$.

Molecular gas. Casasola et al. (2020) compiled observations of ^{12}CO lines for 245 late-type DustPedia galaxies. They converted these observations in molecular masses, assuming a constant X_{CO} conversion factor (Bolatto et al. 2013), and corrected them for aperture effects. The uncertainties are the quadratic sum of the ^{12}CO line noise measurement and 30%, corresponding to the uncertainty on the X_{CO}. We adopt these values when available. For the other DustPedia and DGS galaxies, we infer the $\mathrm{H_2}$ mass, with the approximation used by De Vis et al. (2019, Eq. (7)). It uses the scaling relation between $M_{\mathrm{H\,I}}/M_\star$ and $M_{\mathrm{H_2}}/M_{\mathrm{H\,I}}$, derived by Casasola et al. (2020). The scatter of this relation is propagated and accounted for in the uncertainties. These molecular gas masses are also corrected for helium and heavy elements. We use $M_{\mathrm{H_2}}^{\mathrm{CO}}$ to denote the *total* molecular gas mass derived from actual ^{12}CO line observations, and $M_{\mathrm{H_2}}$, to denote the method-independent total molecular mass, either derived from ^{12}CO lines or from the De Vis et al. (2019) approximation.

2.2.4. The star formation rate

For DustPedia, the star formation rate (SFR), has been derived by Nersesian et al. (2019). The SFR was a free parameter of the SED fit they performed with `CIGALE`. For the DGS, we used the SFR estimated by Rémy-Ruyer et al. (2015), using a combination of the $\mathrm{H}\alpha_{656.3\,\mathrm{nm}}$ line and of the total infrared luminosity (TIR). Although the two estimators are different, we do not expect significant biases between DustPedia and the DGS. Indeed, both account for: (i) the escaping power from young ionizing stars, with the UV SED or the $\mathrm{H}\alpha_{656.3\,\mathrm{nm}}$ line; and (ii) the power reradiated by dust, with the IR SED or the TIR. In addition, both assume a Salpeter (1955) IMF, which, similarly to the stellar mass (Sect. 2.2.1), is the main source of uncertainty. We use SFR to denote the numerical value of the SFR, expressed in $M_\odot\,\mathrm{yr}^{-1}$ and, $\mathrm{sSFR} \equiv \mathrm{SFR}/M_\star$, to denote the specific SFR.

Table 2. Number of galaxies per ancillary data constraint.

Ancillary data	Parameter	Number of galaxies
Total gas mass	$\ln M_{\mathrm{gas}}$	518
Molecular fraction	$\ln f_{\mathrm{H_2}}^{\mathrm{CO}}$	179
Stellar mass	$\ln M_\star$	785
Star formation rate	$\ln \mathrm{SFR}$	749
Metallicity	$12+\log(\mathrm{O/H})$	376
Molecular fraction	$\ln f_{\mathrm{H_2}}$	514
Gas-to-star ratio	$\ln(M_{\mathrm{gas}}/M_\star)$	514
Gas fraction	$\ln f_{\mathrm{gas}}$	514
Specific SFR	$\ln \mathrm{sSFR}$	745

2.2.5. Uncertainties of the ancillary data

The SED analysis we present in Sect. 3.1 includes the ancillary data, as a prior. For that purpose, it is preferable to consider the logarithm of quantities that can span several orders of magnitude. The independent ancillary data parameters we use as a constraint are listed in the first five lines of Table 2. The total gas mass is $M_{\mathrm{gas}} = M_{\mathrm{H\,I}} + M_{\mathrm{H_2}}$ and the ^{12}CO-line-estimated molecular fraction, $f_{\mathrm{H_2}}^{\mathrm{CO}} = M_{\mathrm{H_2}}^{\mathrm{CO}}/M_{\mathrm{gas}}$. We also list, in the second part of Table 2, parameters derived from these quantities, including the method-independent molecular fraction, $f_{\mathrm{H_2}} = M_{\mathrm{H_2}}/M_{\mathrm{gas}}$. All the extensive quantities (masses and SFR) have been homogenized to the distances adopted in Sect. 2.1.

We assume that the uncertainty of the five independent ancillary parameters (first part of Table 2) follows a split-normal distribution (G18, Sect. 3.2.3). We propagate the uncertainties and their correlations in the derived parameters (second part of Table 2).

3. The SED modeling approach

We now describe our modeling approach, as well as the consistency tests we have performed to assess the robustness of our results.

3.1. Our in-house hierarchical Bayesian SED model

`HerBIE` (HiERarchical Bayesian Inference for dust Emission; G18) is a hierarchical Bayesian model aimed at inferring the probability density functions (PDF) of dust parameters (dust mass, etc.), from their SED, rigorously accounting for the different sources of uncertainties. As any Bayesian model, `HerBIE` computes a posterior PDF as the product of a classical likelihood and a prior PDF. What makes this model hierarchical is that the prior depends on a set of hyperparameters. These hyperparameters are: (i) the average of each physical parameter; and (ii) their covariance matrix. The hyperparameters are inferred, together with the parameters of each individual galaxy. We are therefore sampling a single, large-dimension[10], joint PDF. Since the shape of the prior is inferred from the data, the information of the whole sample is used, in this process, to refine our knowledge of each individual galaxy. In particular, it is relevant to keep in our sample even poorly-constrained SEDs, with upper limits or missing fluxes. Such a model is also efficient at suppressing the

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[9] Those are: UGC 00300, NGC 625, ESO 358−060, NGC 1569, UGC 04305, UGC 04483, UGC 05139, UGC 05373, PGC 029653, IC 3105, IC 3355, NGC 4656, PGC 044532, UGC 08333, ESO 471−006, Mrk 209, NGC 2366, VII Zw 403, I Zw 18, and SBS 1415+437.

[10] The dimension of the parameter space is approximately the product of the number of galaxies and the number of model and ancillary parameters (G18, Sect. 3.3). In the present case, it has ≃798 × (7 + 5) ≃ 10 000 dimensions.