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multivariate Student's $t$ distribution controlled by hyperparameters, similar to the treatment in `HerBIE`. We have assumed wide log-normal priors for the three common tuning parameters. These priors are centered at $\ln 0.1$, $\ln 1000$, and $\ln 320\,M_\odot$ with standard-deviations, 0.8, 0.8, and 0.4, for $\delta_{\rm SN}$, $\epsilon_{\rm grow}$, and $m_{\rm gas}^{\rm dest}$, respectively. These priors were designed so that their $\pm 3\sigma$ range roughly corresponds to the extent of the values reported in the literature: $1\% \lesssim \delta_{\rm SN} \lesssim 100\%$, $100 \lesssim \epsilon_{\rm grow} \lesssim 10^4$, and $100\,M_\odot \lesssim m_{\rm gas}^{\rm dest} \lesssim 1000\,M_\odot$. It does not mean that these parameters can not exceed these limits, but it will be a priori improbable. The reason to adopt weakly informative priors is to avoid unrealistic degeneracies. For instance, there is a well-known degeneracy between grain growth and grain destruction (e.g., Mattsson & Andersen 2012; De Vis et al. 2017a; De Looze et al. 2020). Indeed, the ratio of the two timescales, $\tau_{\rm dest}(t)/\tau_{\rm grow}(t) \propto \epsilon_{\rm grow}/m_{\rm gas}^{\rm dest} \times (Z(t) - Z_{\rm dust}(t))$ is not constant, but the metallicity dependence is quite mild in the narrow range above the critical metallicity. This is enough to allow the MCMC to explore unrealistically high values of $\epsilon_{\rm grow}$ and $m_{\rm gas}^{\rm dest}$, if we assume a flat prior.

*HB run specifications.* Accounting for the missing ancillary data, we have a total of 1913 observational constraints, for our 556 sources. One may note that we are fitting a model with $5 \times 556 + 3 = 2783$ parameters and $5 + 5 + C_5^2 = 20$ hyperparameters. This is not an issue in the Bayesian approach (e.g., Hogg et al. 2010). Model parameters are rarely completely independent. Furthermore, the hyperprior is the dominant constraint for very scattered parameters (G18). Finally, by sampling the full joint PDF, a Bayesian model clearly delineates the various degeneracies, provided the MCMC has converged toward the stationary posterior. We have run 12 parallel MCMCs, starting from uniformly distributed random initial conditions within the parameter ranges in Table 6, in order to ensure the uniqueness of our posterior. The results discussed below are from a $10^5$ length MCMC, removing the first $10^4$ steps to account for burn-in. The longest integrated autocorrelation time is 6200.

### 5.2.3. The fitted dust evolution tracks

The four panels of Fig. 14 present the same relations as in Fig. 8, for the subsample of 556 sources. The posterior PDF of the dust evolution tracks is displayed as colored density contours, marginalizing over the SFH of individual galaxies.

*Qualitative inspection.* At first glance, we can see that the tracks of Fig. 14 reproduce the data quite well. Apart from a few outliers, there are however two notable systematic discrepancies. Firstly, the s$M_{\rm dust}$–sSFR trend of panel c is poorly reproduced. The initial rise of s$M_{\rm dust}$ at sSFR $\gtrsim 0.3\,{\rm Gyr}^{-1}$ undershoots several of the starbursting dwarf galaxies. Overall, this discrepancy is quite mild, as most of the SUEs in this area are less than $2\sigma$ away from the trend. The recent burst of star formation, that is not accounted for by the chemical evolution model, is likely responsible for the enhanced observed SFR. On the contrary, a starburst occuring in more evolved objects, on the left of this trend, might simply contribute to the general scatter of the relation and go unnoticed. Below sSFR $\lesssim 0.1\,{\rm Gyr}^{-1}$, there is a general decreasing trend of s$M_{\rm dust}$ with decreasing sSFR, but our model is essentially flat. This is the most troublesome discrepancy of our analysis. We discuss it fully below. Secondly, in panel a, several high-gas-fraction sources are undershot by the model, although most of them are only less than $2\sigma$ away from the tracks. Those are the irregular galaxies around the critical metallicity regime. They are in the stage where the dustiness changes rapidly, due to the increased contribution of grain growth. These outliers can be seen in panel b, around s$M_{\rm gas} \simeq 10$, in panel c, around sSFR $\simeq 3\,{\rm Gyr}^{-1}$, and in panel d, around $12 + \log({\rm O/H}) \simeq 8$. The model poorly reproduces the rapid dustiness rise around the critical metallicity, in panel d.

*On the sM$_{dust}$–sSFR relation.* The quasi-linear trend of s$M_{\rm dust}$ with sSFR, for sSFR $\lesssim 0.1\,{\rm Gyr}^{-1}$ (panel c of Fig. 14), is not accounted for by our model. N20 argue that outflows is responsible for this trend[24]. Indeed, outflow depletes the dust content proportionally to SFR, without affecting the stellar content. It seems like a natural explanation. The outflow rate, $\delta_{\rm out}$, is a free parameter in our model. However, it does not produce a linear s$M_{\rm dust}$–sSFR relation. Figure 15 shows the same data as in panel c of Fig. 14. We have overlaid several dust evolution tracks corresponding to our maximum a posteriori parameters, varying $\delta_{\rm out}$. This figure is similar to Fig. 6 of N20. We note the following. Firstly, we can see that no single track can reproduce the trend. It could be a satisfactory explanation if galaxies were rapidly evolving off the main trend, staying only a small fraction of their lifetime on the horizontal branch. However, looking at the top axis of Fig. 15, we realize that a galaxy should spend about half of its lifetime on the horizontal branch. If our model was correct, there should have been, statistically, a significant number of sources deviating from the main trend. Secondly, the range of $\delta_{\rm out}$ values that can account for most of the trend is quite narrow (Fig. 15). It would mean that the outflow has to be precisely regulated. It seems unlikely. Finally, if this trend was solely due to outflow, the specific gas mass would follow it closely, which is not the case. This point has also been discussed by Cortese et al. (2012). In summary, it appears our failure at reproducing the s$M_{\rm dust}$–sSFR relation is rather an incapacity of our model to produce a realistic trend, rather than a fitting issue. As we see in Sect. 5.3.3, this is not an IMF-related issue. Since the other trends are acceptably reproduced, the problem might lie in the only quantity represented in panel c of Fig. 14 not appearing in the other panels: the SFR. Our adopted SFH (Eq. (15)) and our inflow and outflow prescriptions might be too simplistic to account for the wealth of data we have here (cf. e.g., Leja et al. 2019, for a discussion on the limitations of the delayed SFH).

*The importance of fitting dust evolution models.* We stress the importance of actually fitting, in a consistent way, dust evolution models, rather than simply performing visual comparisons. Here, we have attempted to fit $M_\star$, $M_{\rm gas}$, $M_{\rm dust}$, $Z$, and SFR for each galaxy. This rigorous process highlights the model limitations. Most past studies have merely overlaid tracks on their data, producing a convincing but inconsistent interpretation. For instance, De Vis et al. (2017a), who used the same dust evolution model as we use, and compared it to a similar sample as ours, were able to produce tracks accounting for most of the observations in the panels a and d of our Fig. 14. However, two quantities of a given galaxy, such as the dust and stellar masses, were usually explained with different values of the dust evolution parameters, at different ages. On the contrary, our approach allows us to avoid mutually inconsistent explanations of different trends and correlations. Overall, performing a rigorous fit does not help getting better solutions, but it definitely helps avoiding bad ones.

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[24] We note that N20 do not have sources below s$M_{\rm dust} \lesssim 10^{-4}$, while it is where our fit gets the most problematic.