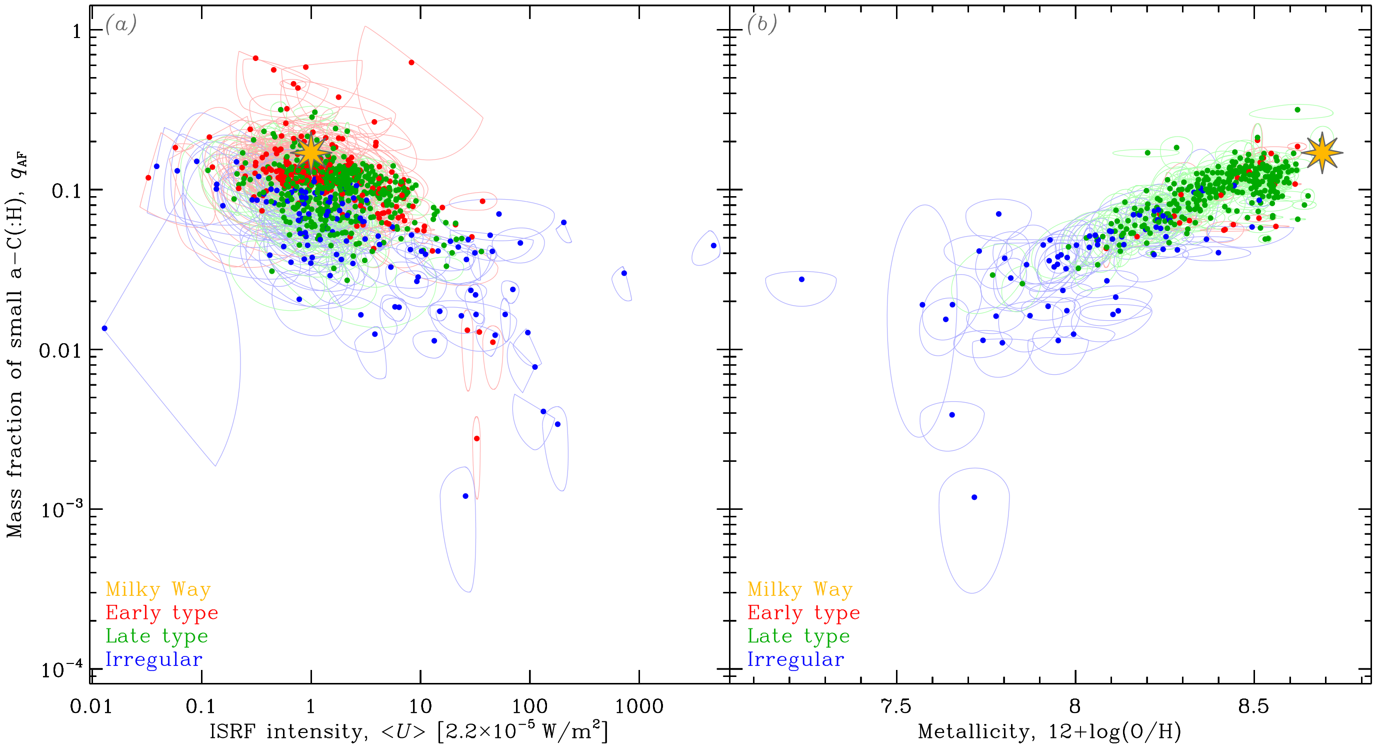

Fig. 12. Evolution of small a-C(:H) grains. The SUEs are color-coded according to the type of galaxy (cf. Sect. 3.3). The Milky Way is shown as a yellow star. There are fewer objects with metallicity measurements (376; Table 2), especially among ETGs (*panel b*).

A 4th degree polynomial fit of the dustiness-metallicity relation gives, posing $x = 12 + \log(\mathrm{O/H})$:

$$\log Z_{\mathrm{dust}} \simeq 11471.808 - 5669.5959x + 1045.9713x^2 - 85.434332x^3 + 2.6078774x^4. \tag{8}$$

This equation provides a good fit of our trend, for the metallicity range covered by our sources. However, it gives a rising dustiness trend with decreasing metallicity below I Zw 18. To improve this relation, we can assume that the dustiness will be proportional to 12 + log(O/H) at extremelly low-metallicity, as we show in Sect. 5.3 that dust evolution in this regime is dominated by SN II production. We therefore modify Eq. (8), as:

$$\log Z_{\mathrm{dust}} \simeq -13.230 + x \quad \text{for } x < 7.3. \tag{9}$$

This fit splits our data in two equal size samples above and below. To quantify its uncertainty, we can compute the envelopes corresponding to encompassing 68% and 95% of the sources, adding [−0.27, +0.29] and [−0.68, +0.70] respectively to the fit of $\log Z_{\mathrm{dust}}$.

In the case of q_{AF}, a 1st degree polynomial gives a satisfactory fit as a function of 12 + log(O/H):

$$\log q_{\mathrm{AF}} \simeq -9.001 + 0.9486x. \tag{10}$$

Its 68% and 95% envelopes are obtained adding [−0.13, +0.10] and [−0.36, +0.20], respectively.

5. Empirical quantification of key dust evolution processes

We now analyze the trends of Fig. 8, in a more quantitative way, with the help of a grain evolution model. The goal here is twofold: (i) by fitting theoretical tracks to our sample, we intend to test if it is possible to account for the variation of the main galaxy parameters, with only a few evolutionary processes; (ii) we aim to give a self-consistent empirical quantification of the main ad hoc tuning parameters controlling these evolutionary processes.

5.1. The cosmic dust evolution model

Cosmic dust evolution models compute the variation of the dust content[20] of a galaxy as a function of time. Dwek & Scalo (1980) presented the first model of this kind, developed as an extension of models computing the elemental enrichment of the ISM (Audouze & Tinsley 1976, for an early review). Subsequent attempts, with various degrees of complexity, followed (e.g., Dwek 1998; Lisenfeld & Ferrara 1998; Hirashita 1999; Morgan & Edmunds 2003; Inoue 2003; Dwek et al. 2007; Galliano et al. 2008b; Calura et al. 2008; Valiante et al. 2009; Mattsson & Andersen 2012; Asano et al. 2013; Zhukovska 2014; Feldmann 2015; De Looze et al. 2020; Nanni et al. 2020). Recently, such models have been used to post-process numerical simulations in order to provide a more comprehensive understanding of galaxy evolution (e.g., Aoyama et al. 2017).

5.1.1. Model hypotheses

We adopt the one-zone dust evolution model of Rowlands et al. (2014) updated by De Vis et al. (2017a)[21]. It solves the coupled

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[20] They can also eventually compute the variation of the grain size distribution and composition with time (e.g., Hirashita et al. 2015).

[21] We started from the public Python code provided by the authors at `https://github.com/zemogle/chemevol`. We have rewritten it in Fortran for numerical efficiency, since we needed to generate large grids of models. We have also implemented an adaptative temporal grid to ensure numerical precision at later stages of evolution.