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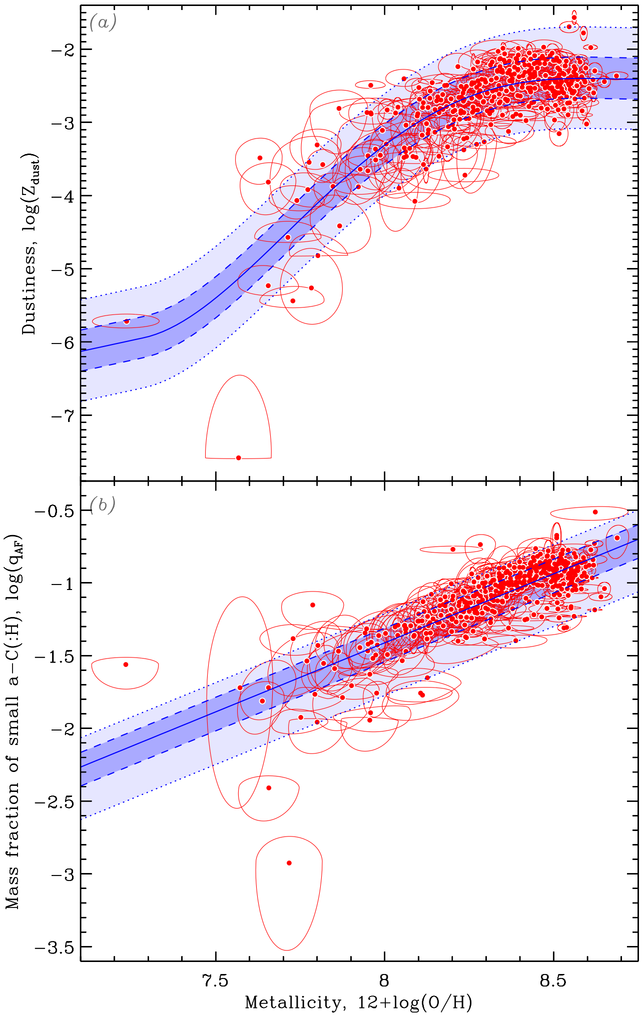

Fig. 13. Analytical fit of the scaling relations. The red SUEs show the data of panel d of Fig. 8 and panel b of Fig. 12. The blue curve in *panel a* shows the analytical fit of Eq. (8) modified by Eq. (9). The blue curve in *panel b* shows the analytical fit of Eq. (10). In both panels, the dashed lines display the envelope encompassing 68% of the sources, and the dotted lines, the envelope encompassing 95% of the sources. We show here the *decimal* logarithm of the $Z_{\rm dust}$ and $q_{\rm AF}$.

differential equations accounting for the time evolution of the mass of the four following quantities.

Stars are made out of the gas, which is partially returned to the ISM at the end of their lifetime. The model tracks their evolution as a function of their mass, which determines their lifetime and their elemental and dust yields. The role of this component therefore relies greatly on the form of the assumed IMF (e.g., Salpeter 1955; Chabrier 2003).

Gas is depleted by astration and outflow, and is replenished by stellar feedback and by inflow of metal- and dust-free gas.

Heavy elements are injected in the ISM by stars at the end of their lifetime. A fraction of them is recycled into stars through astration and lost via outflow.

Dust is produced by three main processes: (i) condensation in low- and intemediate-mass star (LIMS) ejecta ($m_\star < 8\,M_\odot$)[22]; (ii) condensation in SN II ejecta ($m_\star \geq 8\,M_\odot$); (iii) grain growth in the ISM, by accretion of elements onto grain seeds. Dust is removed from the ISM by: (i) destruction by SN II blast waves; (ii) outflow; (iii) astration.

Table 5. SN II dust yields.

Individual star mass, $m_\star$	Dust yield, $m_{\rm dust}^{\rm SN}$
$8.5\,M_\odot$	$0\,M_\odot \times \delta_{\rm SN}$
$9\,M_\odot$	$0.17\,M_\odot \times \delta_{\rm SN}$
$12\,M_\odot$	$0.2\,M_\odot \times \delta_{\rm SN}$
$15\,M_\odot$	$0.5\,M_\odot \times \delta_{\rm SN}$
$20\,M_\odot$	$0.5\,M_\odot \times \delta_{\rm SN}$
$22\,M_\odot$	$0.8\,M_\odot \times \delta_{\rm SN}$
$25\,M_\odot$	$1.0\,M_\odot \times \delta_{\rm SN}$
$30\,M_\odot$	$1.0\,M_\odot \times \delta_{\rm SN}$
$35\,M_\odot$	$0.6\,M_\odot \times \delta_{\rm SN}$
$40\,M_\odot$	$0.4\,M_\odot \times \delta_{\rm SN}$

Notes. These values are the Todini & Ferrara (2001) yields, compiled by Rowlands et al. (2014). They are multiplied by the tuning parameter $\delta_{\rm SN}$, used by De Vis et al. (2017a).

The drivers of the evolution of these quantities are: (i) the assumed SFH (i.e., the SFR as a function of time); (ii) the assumed inflow and outflow rates.

5.1.2. The tuning parameters

The efficiencies of individual dust evolution processes are poorly known (see reviews by Dwek 2005; Draine 2009; Jones 2016a,b,c; Galliano et al. 2018). From a theoretical point of view, these efficiencies depend on the most elusive detailed microscopic dust properties: chemical constitution, structure (crystalline, amorphous, aggregate, etc.), and size. Consequently, theoretical estimates usually span several orders of magnitude. From an observational point of view, unambiguous constraints of the evolution rates are also problematic, because it is nearly impossible to isolate a dust source or sink in a telescope beam. Dust evolution models therefore use simple parametric efficiencies controlled by tuning parameters.

Dust condensation in SN-II ejecta. Dust formed by massive stars ($m_\star \geq 8\,M_\odot$) is thought to dominate the dust production at early stages, below the critical metallicity (cf. Sect. 4.1.3). The dust evolution model we are using assumes the theoretical dust yields, $m_{\rm dust}^{\rm SN}$, of Todini & Ferrara (2001), modified by a general tuning parameter, $\delta_{\rm SN}$ (Table 5). These dust yields can also be integrated over the IMF, $\phi(m_\star)$:

$$\langle Y_{\rm SN}\rangle \equiv \frac{\displaystyle\int_{8\,M_\odot}^{40\,M_\odot} \phi(m_\star) \times m_{\rm dust}^{\rm SN}(m_\star)\,{\rm d}m_\star}{\displaystyle\int_{8\,M_\odot}^{40\,M_\odot} \phi(m_\star)\,{\rm d}m_\star}, \tag{11}$$

to provide a single averaged dust yield per SN II. For both Salpeter (1955) and Chabrier (2003) IMFs, it is: $\langle Y_{\rm SN}\rangle \simeq 0.35 \times \delta_{\rm SN}\,M_\odot/{\rm SN}$. The dust condensation timescale, $\tau_{\rm cond}$, can be expressed as a function of the SN II rate, $R_{\rm SN}$:

$$\frac{1}{\tau_{\rm cond}(t)} = \langle Y_{\rm SN}\rangle \frac{R_{\rm SN}(t)}{M_{\rm dust}(t)}. \tag{12}$$

Grain growth in the ISM. The dust build-up by accretion of gas atoms onto pre-existing dust seeds is a potentially dominant production process at late stages, above the critical metallicity

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[22] Following De Vis et al. (2017a), we assume that LIMSs condense 15% of their heavy elements into dust.