Overall dust input from core-collapse supernovae in the Galaxy

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○ Abstract There are increasing pieces of evidence that core-collapse supernovae (CCSNe) are efficient producers of dust particles; recent far-infrared observations as well as analyses of optical line emissions have revealed the presence of dust above 0.1 Msun in the ejecta of young supernova remnants such as SN 1987A and Cassiopeia A. However, some fraction of these newly formed dust grains would finally be destroyed by the passage of the reverse shocks (RSs). Furthermore, stripped-envelope CCSNe, which occupy half of the total number of CCSNe, are likely to be poor suppliers of interstellar dust. Here, by taking account into these effects suppressing dust inputs from CCSNe, we summarize the fundamental knowledge about the overall dust input (and relative contributions of dust masses) from asymptotic giant branch (AGB) stars and CCSNe, based on an extremely simple dust evolution model.

○ Contributions of dust mass from stellar sources

$$\frac{dM_{\mathrm{dust},i}(t)}{dt} = \int_{m_i}^{m_{i+1}} m_{\mathrm{dust}}(m,t)\phi(m)\psi(t-\tau_{\mathrm{m}})dm.$$

where $$m_{\mathrm{dust}}(m,t) = \begin{cases} 0 & \text{for } t-\tau_m < 0 \\ m_{\mathrm{d},i}(m) & \text{for } t-\tau_m \geq 0, \end{cases}$$

- **$m_{\mathrm{d,AGB}}$ (i=1): mass of dust injected per AGB star whose initial mass is between m_1 = 2 Msun and m_2 = 8 Msun**
- **$m_{\mathrm{d,SN}}$ (i=2): mass of dust injected per CCSN whose initial stellar mass is between m_2 = 8 Msun and m_3 = m_{SN}**
- **ψ(t): star formation rate**

- **φ(m) = Am$^{-\alpha}$: Salpeter initial mass function (IMF) with α=2.35**

normalization : $$1 = \int_{m_{\mathrm{low}}}^{m_{\mathrm{up}}} m\phi(m)dm,$$

m_{low} ($M_\odot$)	m_{up} ($M_\odot$)	A	$I_n(2,8)$ AGB	$I_n(8,m_{\mathrm{up}})$ CCSN	$I_n(8,m_{\mathrm{up}})/I_n(2,8)$ CCSN/AGB	$I_n(8,18)$ SNIIP	$I_n(8,18)/I_n(2,8)$ SNIIP/AGB
0.1	100	0.172	0.0422	0.00742	0.176	0.00511	0.121
0.1	60	0.175	0.0430	0.00731	0.170	0.00597	0.121
1	100	0.437	0.108	0.0189	0.176	0.0130	0.121
1	60	0.460	0.113	0.0192	0.170	0.0137	0.121

Table 1 – Relative numbers, $I_n(m_i, m_{i+1})$, of AGB stars and CCSNe for representative combinations of the lower mass limit (m_{low}) and upper mass limit (m_{up}) of stars in the Salpeter IMF, which are derived from the equation below. The (cumulative) number ratios of CCSNe to AGB stars are about 0.17, independent of the stellar mass range of IMF. Also is given the relative number of CCSNe in the case that the upper mass limit of the SNe is m_{SN} = 18 Msun.

$$I_n(m_i, m_{i+1}) = \int_{m_i}^{m_{i+1}} \phi(m)dm = \frac{A}{1-\alpha}(m_{i+1}^{1-\alpha} - m_i^{1-\alpha})$$

○ Dust yields per AGB star

- **Case 1 (AGB1)** $$m_{\mathrm{d,AGB1}} = f_{\mathrm{AGB}}(m - m_{\mathrm{WD}}) \ \ M_\odot.$$

  f_{AGB} = 0.01 and m_WD = 1.4 Msun

- **Case 2 (AGB2)** $$m_{\mathrm{d,AGB2}} = 6 \times 10^{-3} \ \ M_\odot.$$

  (e.g., Dell'Agli et al. 2017)

○ Dust yields per CCSN

- **Case 1 (SN1)** $$m_{\mathrm{d,SN1}} = f_{\mathrm{SN}}(m - m_{\mathrm{NS}}) \ \ M_\odot.$$

  f_{SN} = 0.01 and m_NS = 2.0 Msun

- **Case 2 (SN2)** $$m_{\mathrm{d,SN2}} = 0.5 \ \ M_\odot.$$ **(optimistic)**

  (e.g., Matsuura et al. 2011; De Looze et al. 2017)

- **Case 3 (SN3)** $$m_{\mathrm{d,SN3}} = 0.01 \ \ M_\odot.$$ **(after RSs)**

  (e.g., Bocchio et al. 2016; Nozawa et al. 2007)

- **Case 4 (SN4)** $$m_{\mathrm{d,SN4}} = 2 \times 10^{-4} \ \ M_\odot,$$ **(pessimistic)**

  (e.g., Kotak et al. 2009; Nozawa et al. 2010)

SNe II-P, likely major producers of dust, have the upper mass limit of m_{SN} = 18 Msun? (Smartt 2009) ➔ see dashed lines in figures

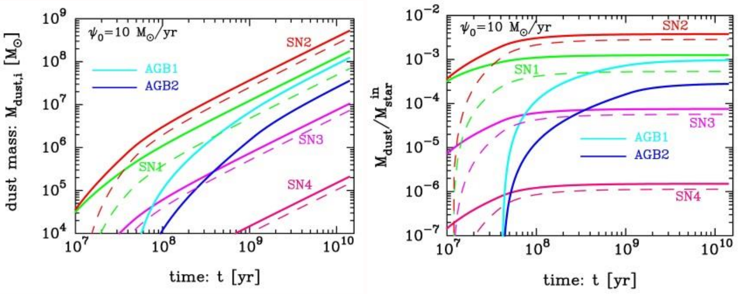

Fig. 1 – (Left panel) Time evolutions of dust masses that are injected by AGBs stars and CCSNe for a constant star formation rate of ψ(t) = ψ_0 = 10 Msun yr^{-1}. The mass range of stars is set to be from m_{low} = 0.1 Msun to m_{up} = 100 Msun. Colored lines discriminate the results for different dust yields per AGB star and per CCSN (see left). (Right panel) Time evolutions of dust masses relative to the cumulative stellar mass $M_{\mathrm{star}}^{\mathrm{in}}$, which equals to (t ψ_0). In both figures, dashed lines indicate the results in the case that the upper mass limit of CCSNe is m_{SN} = 18 Msun, which is considered to be the maximum mass of SNe II-P (Smartt 2009).

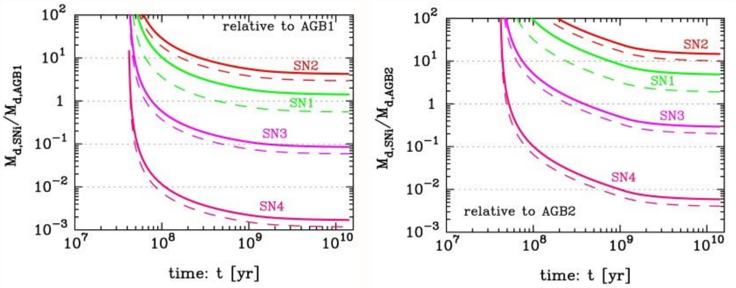

Fig. 2 – Time evolutions of the ratio of SN-dust mass to AGB-dust mass, corresponding to the results in Figure 1. The left panel shows the results for different SN-dust yields relative to AGB1 (a higher dust yield from AGB stars), while the right panel plots the results relative to AGB2 (a smaller dust yield from AGB stars). In both figures, dashed lines indicate the results in the case that the upper mass limit of CCSNe is m_{SN} = 18 Msun.

○ Results and Conclusions

- **If condensation efficiency of dust in AGB winds and SN ejecta is the same (0.01 in this study), the contributions of dust mass from AGB stars and CCSNe are comparable. (AGB1 and SN1)**
- **If CCSNe can eject 0.5 Msun (0.01 Msun) of dust, the mass of interstellar dust that originated from CCSNe is 3-20 times higher (lower) than that from AGB stars. (SN2 and SN3)**
- **If dust mass per CCSN is as low as 10^{-4} Msun, the abundance of SN-dust is less than 1% of AGB-dust, which seems consistent with the abundance of SN-dust in presolar grains. (SN4)**
- **Assuming the upper mass limit of CCSNe to be m_{SN} = 18 Msun reduces the mass of SN-origin dust by about a factor of 1.4.**

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