Origins of Large Amounts of Dust Grains and Unusual Extinction Curves in High-Redshift Dusty Quasars

NOZAWA, Takaya (NAOJ)
ASANO, Ryosuke S., TAKEUCHI, Tsutomu T. (Nagoya University)
HIRASHITA, Hiroyuki (ASIAA)

There are many pieces of evidence that the extinction curves of quasars beyond $z = 4$ are different from those of low-z quasars and that a huge amount of dust is present in their host galaxies. These indicate that the early interstellar medium (ISM) was rapidly enriched with dust grains whose properties were different than the nearby ones. The previous dust evolution models argued that, in addition to dust grains ejected from supernovae and asymptotic giant branch stars, grain growth via accretion of gaseous metals in the ISM is required to account for the observed dust mass. However, these models assumed a representative grain size or a specific grain size distribution throughout the galaxy evolution, and thus could not make any prediction on extinction curves.

Recently, we constructed an evolution model of size distribution of interstellar dust by taking into account the fundamental physical processes of formation and destruction of dust [1]. This model enables us to predict the extinction curves in galaxies as a function of time [2]. Based on this state-of-the-art dust evolution model, we investigate how the massive amounts of dust and the unusual extinction curves in high-z dusty quasars can be reproduced in a self-consistent manner.

First, we demonstrate that the Milky-Way extinction curve is reproduced by introducing a moderate fraction ($\simeq 0.2$) of dense molecular-cloud phases in the ISM for a graphite-silicate dust model. Then, we show that the peculier extinction curves in high-z quasars can be explained by taking a much higher molecular-cloud fraction (≥ 0.5) (Fig. 1), which leads to more efficient grain growth and coagulation. The large dust content in high-z quasar hosts is also found to be a natural consequence of the enhanced dust growth (Fig. 2). We also find that the major composition of carbonaceous dust in high-z dusty quasars is amorphous carbon rather than graphite. These results indicate the differences in the properties of carbonaceous dust and in the condition of the ISM between low-z and high-z galaxies.

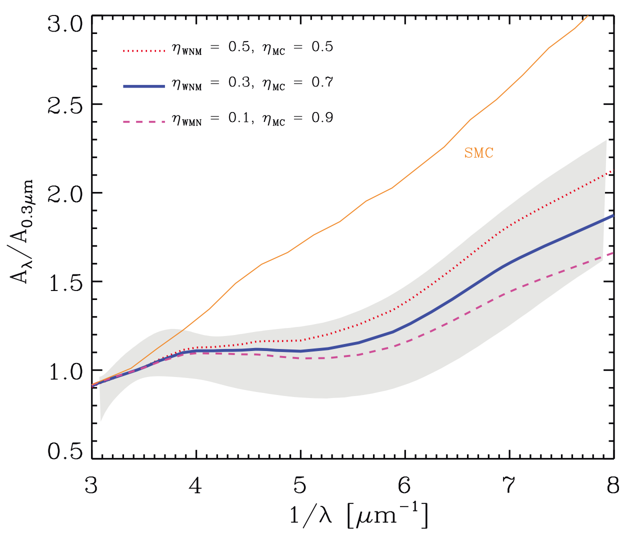

Figure 1: Calculated UV extinction curves at t = 1 Gyr. The dotted, thick solid, and dashed lines show the results for the mass fraction of the molecular-cloud phase of 0.5, 0.7, and 0.9, respectively. The hatched region draws the range of the extinction curve for the high-z quasar J1048+4637 at z = 6.2 [4]. For comparison, the SMC extinction curve is denoted by the thin solid line. The figure is taken from [3].

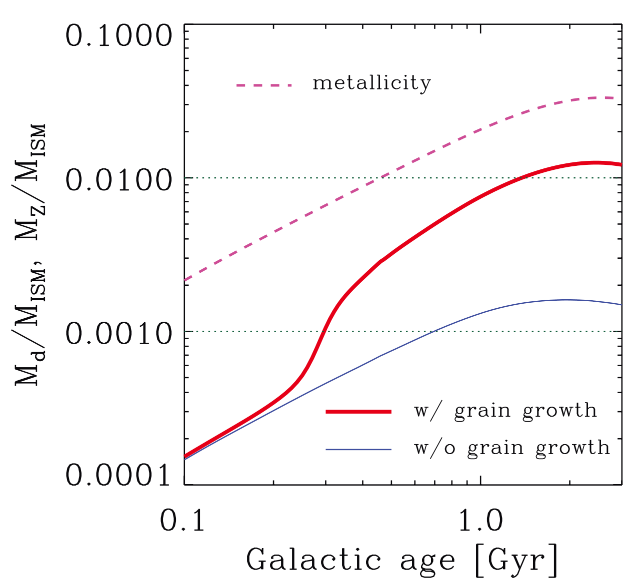

Figure 2: Time evolutions of dust-to-gas mass ratios (solid) and metallicity (dashed) obtained from the dust evolution model in a high-z quasar. The case with grain growth (red solid) can reach the observed high dust-to-gas mass ratio ($\simeq 0.01$), while the case without grain growth (blue solid) cannot. The figure is taken from [3].

References

[1] Asano, R. S., et al.: 2013, *MNRAS*, **432**, 637.
[2] Asano, R. S., et al.: 2014, *MNRAS*, **440**, 134.
[3] Nozawa, T., et al.: 2015, *MNRAS*, **447**, L16.
[4] Maiolino, R., et al.: 2004, *Nature*, **431**, 533.