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Dust at $z > 6$. Observations and theory

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Abstract. I shortly review the investigation of dust in the early universe. I discuss the possible evolution of the dust properties, as well as the possible dust production mechanisms at $z > 6$.

Keywords. Dust, galaxies: ISM, galaxies: active, early Universe

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Dust plays a crucial role in the early universe. It affects the formation of high mass stars, it allows the formation of low mass stars in low metallicity environments (Schenider *et al.* 2006), and it also greatly enhances the formation of molecules. However, according to the standard scenarios we expect little or no dust at $z > 6$. Indeed, in the local universe dust is mostly produced in the envelopes of evolved, low mass stars (mostly AGB stars) and, as a consequence, most of the dust is produced with a delay of ~ 1 Gyr with respect to the onset of star formation. At $z > 6$ the age of the universe is less than 1 Gyr, thus falling short of time to produce dust through AGBs.

Therefore, although other production mechanisms have been proposed, a strong decrease of the average dust mass in galaxies is expected at $z > 6$, just because the main dust contributor is missing. Currently there are only hints of this effect, observed in the IR data of high-z QSOs (e.g., Jiang *et al.* 2007) and in the optical-UV SEDs of star forming galaxies (e.g., Eyles *et al.* 2007).

The most sensitive tracer of the dust mass is its far-IR emission, which at $z > 6$ is observed in the submm-mm range. However, currently there are only a few submm-mm detections, of hyperluminous QSOs, at $z > 6$, preventing any meaningful investigation on the evolution of the dust mass at high-z. However, these observations reveal that in these few objects huge masses of dust ($\sim 10^8 M_\odot$) have already formed by $z = 6$ (Beelen *et al.* 2006). Such large masses cannot be accounted for by AGB stars at such early times in the Universe.

An alternative, rapid channel of dust production are the ejecta of type II SNe (Todini & Ferrara 2001). The dust properties inferred from the extinction curve in QSOs at $z > 6$ are consistent with the presence of SN dust (Maiolino *et al.* 2004). Whether dust production in SNe can be efficient enough to account for the whole dust mass observed in bright QSOs at $z > 6$ is still under debate. The constraints on the SN dust yield inferred from Galactic SNRs are not conclusive (*Spitzer* mid-IR observation only probe the warm component of dust, while sub-mm observations provide only loose upper limits). However, the recent *Spitzer* detection of dust forming in SN 2003gd (Sugerman *et al.* 2006) indicate a dust production efficiency which could account for the dust masses observed at $z > 6$.

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