The other side of the equation: Systematic effects in the determination of dust masses

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In recent years, major difficulties have emerged in attempts to reconcile observed interstellar dust reservoirs with the rates of dust production from known sources, both locally and in the early universe (e.g. Jones et al., 1996; Morgan & Edmunds, 2003); this has become known as the "dust-budget crisis". This is a particular problem for high-redshift submillimetre galaxies, as the youth of the universe prohibits AGB stars from contributing.

Previous attempts to tackle this issue have focussed on the sources of dust, invoking dust production by massive stars (0.1–$1\,M_{\odot}$ per supernova, Gall et al. (2011) and references therein) or dust formation in the interstellar medium itself (e.g. Jones et al., 2001; Michalowski et al., 2010, Krasnokutski et al., 2014) to explain the large observed dust masses. However, the systematic effects involved in determining dust masses from observations have been poorly studied. In particular, dust masses are measured in the far-IR and sub-mm, where observers must generally rely upon poorly-constrained extrapolations of mid-IR opacities, while dust production rates are usually measured in the mid-IR for AGB stars and supernovae. To alleviate this deficiency, we are exploring the effects of realistic ranges of the dust composition, emissivity, structure, temperature and size distributions on synthetic observations.

Dust masses are usually determined at (sub-)mm wavelengths, and therefore depend critically on the assumed dust properties in this range. However, the availability of good quality laboratory data is still limited, so many studies rely on dust models that extrapolate optical properties from shorter wavelengths. Laboratory studies have shown that these extrapolations perform rather poorly (e.g. Mennella et al., 1998, Coupeaud et al., 2011), and that the long-wavelength optical properties of interstellar dust analogues have a significant temperature dependence. Our study exploits these measurements as well as modern methods for determining dust cross-sections from optical constants which have been shown to provide more realistic output than compact spherical dust grains (Min et al., 2003, 2004).

Our preliminary results show that the mass-absorption coefficients typically used in astronomy may be underestimated by a factor $\gtrsim 4$, implying that interstellar dust masses are overestimated by a similar amount. Although this is significant, it is not by itself sufficient to eliminate the dust-budget problem in the early universe (Rowlands et al., 2014). Further work will consider the temperature dependence of the far-IR and sub-mm opacities. We will quantify any systematic biases in the dust mass determination by applying standard techniques to synthetic data.