Circumstellar Dust Around Massive Stars and Supernovae

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Evolved massive stars are efficient producers of dust, seen as strong IR emission from their dense and massive circumstellar shells, as well as the extinction and reddening they cause along our line of sight to the photosphere. While it is perhaps not so surprising that dust grains form in the slow, cool, and dense winds of massive RSG stars, the formation of dust around luminous hot stars (LBVs, B[e] stars, WR stars) is more puzzling. In hot stars, dust formation requires episodic (eruptive/explosive) mass loss, where grains form quickly in high-density shells. Interestingly, 8-10% of supernovae suffer violent precursor outbursts that eject massive dusty shells just before core-collapse.

Even more puzzling is the evidence for efficient dust formation in systems with very strong shock waves. We normally think of shocks as efficient ways to destroy dust, but in high-density shocks we see strong observational evidence that new dust is forming. Examples are the colliding winds of WC+O binary systems and similar dust formation in the colliding winds of Eta Carinae, as well as rapid grain formation in particular types of explosions where a supernova crashes into very dense CSM. Pre-existing dust is seen as an observed IR echo in supernovae, but the formation of new dust grains in the post-shock zone is also seen, revealed by increasing extinction and progressively blueshifted emission lines. Pre-existing dust in the CSM may play an important role, where incomplete destruction by the slow shock might allow the grains to re-grow rapidly in the post-shock cooling zone. Since the eruptive pre-SN mass loss that produces these shells is more common among high-mass stars and is not related to metallicity, this could provide very efficient dust formation from supernovae in the early universe.