Dust formation in dense CSM behind the shock: A study based on SN2010jl

Arkaprabha Sarangi & Eli Dwek
NASA Goddard Space Flight Center

Dust is known to form in the quiescent outflows of AGB stars and in the explosively ejected matter of core collapse supernovae (CCSNe). Recent optical and near-infrared (IR) observations of the light curve of the ultraluminous CCSN SN2010jl has shown evidence for the rapid rise of a thermal IR emission component from newly forming dust in its spectrum. The UV-optical light curve from the SN cannot be powered by the radioactivities in the ejecta, and is powered by the interaction of the SN blast wave with the ambient dense circumstellar (CSM) shell. Observations of the evolution of the broad H and He lines in the spectra show that the dust could not have formed in the SN ejecta, but must have formed in the CSM instead.

The supernova blast-wave traverses the CSM heating and ionizing the gas and destroying all pre-existing molecules and dust grains. The shocked CSM gas cools rapidly behind the shock to temperatures below the dust condensation temperatures. However, the radiation emanating from the shocked CSM plays a pivotal role in determining the earliest epoch after which seed nucleation centers can form and survive in the post-shock region. We use X-ray and UV-optical data from SN2010jl to follow the evolution of the shock through the CSM, and solve for the time-dependent temperature and density profile of the post-shock gas. Embedding a 10 Angstrom seed nucleation center in the dense cooling shell, we calculate its temperature, and the earliest epoch beyond which such grain can survive evaporation and rapidly grow to large submicron grains. Thereafter, we study the formation of possible dust species through nucleation of condensable elements, and trace their evolution in time through accretion and coagulation. The final dust mass yield has been calculated and compared with other known dust sources in the galaxy. Detection of the IR excess as early as 67 days post-explosion poses new challenges to our understanding of the dust scenario behind shocks. Our model, first of this kind, provides a complete picture of the formation of dust in such extreme astrophysical environments and the role of Type IIn supernova as sources of dust in galaxies.