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

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Overview

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 ultra-luminous CSM (SN2010jl) has shown evidence for the rapid rise of a thermal IR emission component attributed to the formation of new dust grains. 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 radiation emanating from the shocked CSM plays a pivotal role in determining the earliest epoch of which nucleosynthesis can form and survive in the post-shock region. 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 provides a complete picture of the formation of dust in such extreme astrophysical environment and its manifestation on the SN light curve.

1. Type IIn Supernovae and SN2010jl
a) Pre-pulse supernova behind the shock
b) Line of sight to the shock

c) Dust formation in dense CSM behind the shock

2. UVO & NIR observations: Traces of early dust formation?

1) IR excess dust to thermal emission from hot dust
2) Increased rate of fading of optical flux
3) Progressive blue-shift of emission lines (receding part of the object is blocked by dust)

3. The mystery and the challenges

1) New dust in dense shell/ShA-epochs within 100 days?
2) Early NIR due to echo from pre-existing dust?
3) How do the dust mass evolve?
4) What is heating the dust at later times?
5) What is the contribution of shocked-CDSM dust on SN-light curve?

4. What are the possible sites for the new and/or pre-existing dust

a) The pre-existing dust outside the evaporation radius, b) The cool dense shell, c) The shocked CDSM.

5. The constraints on physical parameters

The product of the n_e and L_0 of the CSM is constrained by the H-column densities determined from X-ray observations (Chandar + 2015)

6. The Hydrogen column densities are calculated & compared

H-column densities compared with data

7. The post-shock gas cools rapidly forming a dense shell

Post-shock temperature vs column densities

8. The highlights & probable scenarios

Dust formation in the dense shell is delayed until day 250 due to:
- Radiation from the hot gas behind the shock (Possible cause for the rise in NIR after day 250)
- The post-shock gas cools rapidly within 5-10 days, forming the dense shell (n_e > 10^8 cm^-3)
- The dense shell remains warm due to the radiative heating by the shock (Probable heating source for dust)
- Final dust mass varies from 4x10^2 to 3x10^3 M_☉, comprised of essentia silicates

Probable scenario that can explain NIR & progressive blue-shift of emission lines before day 250

(a) Echo from pre-existing dust
(b) Ejecta dust
(c) Clumpy CSM

9. Radiative heating: Dust cannot form in the dense shell until day 250!

Heating of dust by radiation

The Scenario

Past shock location

The shaded region represents the relative position of the dense shell

The dense shell at day 300

Past-shock dust & dust mass evolution

Dust temperature compared to dust fit

Dust properties in the dense shell

The drop in temperature of the dust is due to the ionized gas behind the shock (Plausible cause of the rise in NIR after day 250)