Modeling the Complex Spectra of Supernovae

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Abstract

We describe the difficulties in modeling the spectra and light curves of supernovae (SNe), and highlight how they differ from modeling stellar atmospheres. Supernovae evolve in time, and hence time-dependent radiation transfer is necessary. The densities are low, making non-LTE calculations absolutely essential, and at some epochs it is also necessary to include time-dependence in the kinetic equations. The abundances are non-solar and vary throughout the SN ejecta. Species often considered to be unimportant (e.g., cobalt, titanium) can be abundant and can have a crucial influence on spectra. Further, hydrogen and helium are often underabundant (or even absent), substantially reducing the continuum opacity. In Type Ia SNe, bound-bound processes dominate spectra formation and thermalization. Unfortunately, accurate atomic data for many ionization stages and species is lacking. The transport of gamma-rays arising from radioactive decay also needs to considered. These gamma-rays deposit energy, and give rise to non-thermal electrons which can both ionize and excite the gas. In some cases the SN interacts with an existing CSM, converting much of their kinetic energy to electromagnetic energy. Due to complex time-dependent dynamics, shock formation and non-monotonic velocities, spectra arising from such interactions are difficult to model. In reality, SNe are likely to be aspherical, necessitating 3D calculations. Other researchers have made significant progress towards 3D models of SNe using Monte-Carlo techniques.

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