Unlocking the Secrets of Supernovae Through their Spectra

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Abstract

Modern survey telescopes will discover thousands of supernovae (SNe). The discoveries will identify new SN classes, refine the statistics of SN occurrence as a function of class and host galaxy properties, allow the direct identification of SN progenitors, and identify SNe for which spectra can be obtained throughout the SN's temporal evolution. In this presentation we present and discuss results coming from a series of investigations on Type Ia, Ib, Ic, and Type II SNe. Using CMFGEN, we solve the non-LTE time-dependent radiative transfer equation at $\sim 10^5$ frequencies, from the far UV to the far-IR, yielding simultaneously the spectral evolution as well as the multi-band light curves from approximately 1 day after the explosion through the photospheric phase, and into the nebular phase. The calculations are fully non-LTE, allow for a multitude of atomic processes (bound-bound, bound-free, free-free, collisional, charge exchange, and Penning ionization) and include non-thermal excitation and ionization from non-thermal electrons created by the degradation in energy of high energy ($\sim$MeV) gamma-rays. The proper treatment of all these processes requires a vast amount of atomic data. Not all the atomic data

is available, and the quality of the available atomic data varies considerably. We have confirmed the results of Utrobin and Chugai (2005) that time dependent terms must be included in the statistical equilibrium equations in order to model the Hα evolution of SN 1987A, shown that time dependent terms influence other spectral features, and demonstrated that these conclusions also apply to the modeling of Type II SNe in general. The inclusion of non-thermal processes has allowed us to model Hα and He I line emission in Type II SNe into the nebular phase, and to model the HeI line emission in Type IIb/Ib SNe. Our calculations show that the apparent He deficiency in Ic SNe is unlikely to be real – instead the absence of He I lines in SN Ic spectra is more likely related to inefficient excitation of He I ions. Simply by varying the amount of mixing we are able to create SNe of Type Ib and Ic using the SAME progenitor model. We have also successfully applied CMFGEN to model Type Ia SNe, and are currently exploring the complex line formation and line-blanketing effects in these ejecta composed primarily of metals and intermediate-mass elements.