Hydrodynamical Models of Type II-P Supernova Light Curves

Melina C. Bersten[1], Omar Benvenuto[2], and Mario Hamuy[1]

melina@das.uchile.cl

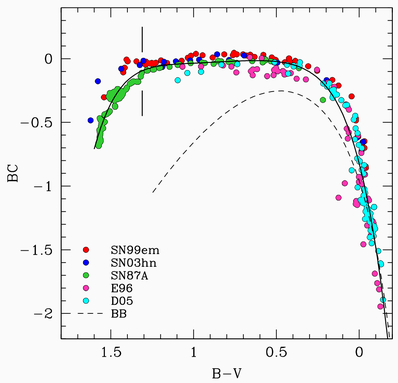
[1] Universidad de Chile
[2] Universidad Nacional de La Plata

Abstract

We present computations of bolometric light curves (LC) of type II plateau supernovae (SNe II-P) obtained using a newly developed, one-dimensional Lagrangian hydrodynamic code with flux-limited radiation diffusion. We derive a calibration for bolometric corrections (BC) from BVI photometry with the goal of comparing our models with a large database of high-quality BVI light curves of SNe II-P. The typical scatter of our calibration is 0.1 mag. As a first step, in our comparison we have determined the physical parameters (mass, radius and energy) of two very well observed supernovae, SN 1999em and SN 1987A. Despite the simplifications used in our code we obtain a remarkably good agreement with the observations and the parameters derived are in excellent concordance with previous studies of these objects.

Bolometric Correction

- Three well-observed supernovae: SN 1987A [5], SN 1999em [6], and SN 2003hn [7]
- Integration of all the available broadband data
- Estimation of the missing flux in UV and IR: blackbody (BB) fit **(right)**
- We also calculated BC for two atmosphere models: Eastman et al. [4] and Dessart & Hillier [3] (E96 and D05, respectively)



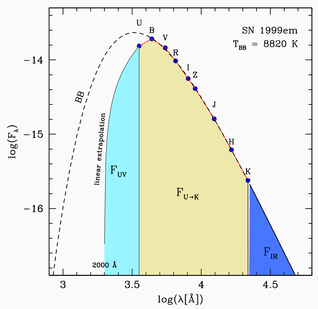


Figure 1:(left) BC for V band vs. $(B-V)$ for our calibrator SNe and the models of E96 and D05. The vertical lines indicate the approximate color at the end of the plateau phase and the dashed curve corresponds to the BC of a BB spectrum. The solid line shows our fit to the points with $rms = 0.1$ mag leading to an uncertainty of 0.04 dex in bolometric luminosity Bersten & Hamuy [2].

Sample of Supernovae

- 33 nearby SNe II-P: Calán/Tololo, SOIRS and CATS (1986-2003)
- High-quality, well-sampled $BVRI$ light curves and spectra
- The CSP is providing even more ($\sim$ 80 SNe II-P)
- We derived bolometric luminosities for our 33 SNe

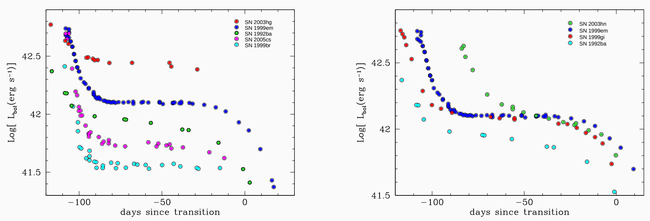


Figure 2: Bolometric LC for selected SNe from our sample. **(left)** There is 1 dex of differences in plateau luminosities. **(right)** The range of the plateau durations is 75–120 days.

Acknowledgments

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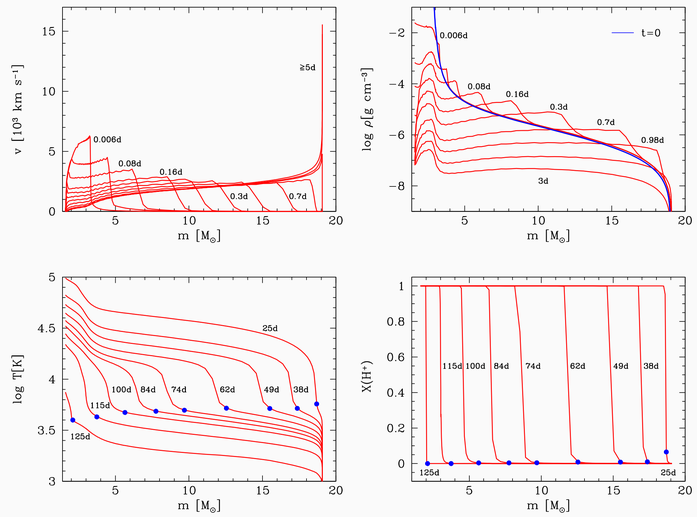

Figure 3: Profiles of different quantities as a function of interior mass for the same initial model of SN 1999em. **(Upper left)** velocity, **(upper right)** density, **(lower left)** temperature, and **(lower right)** fraction of ionized hydrogen. The time elapsed since the energy is injected is shown as reference for some of the curves. The photospheric position defined by $\tau = 2/3$ is indicated by a blue dot on each profile.

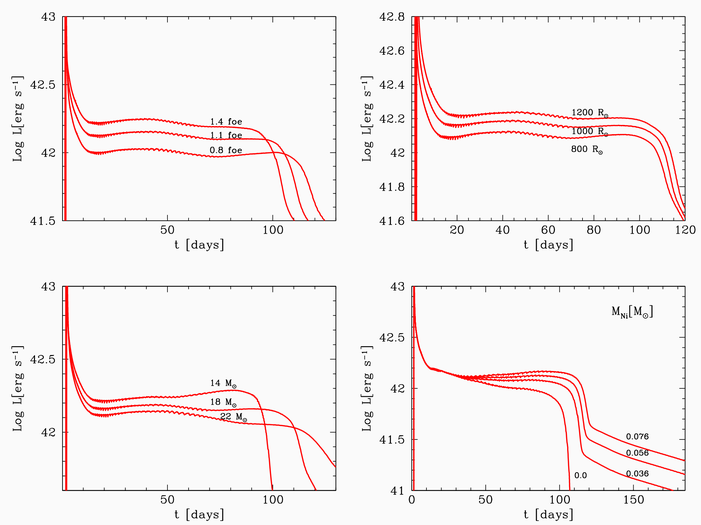

Figure 4: Bolometric LC for different **(upper right)** injected energies (E), **(upper left)** initial radius (R), **(lower left)** initial mass (M), and **(lower right)** ^{56}Ni mass. The shape of the LC, being sensitive to the hydrodynamics, is a useful tool to infer physical parameter of the SN progenitor.

Model

Theoretical light curves are obtained by numerical integration of the hydrodynamic equations plus radiation transport in a flux-limited diffusion approximation. The γ-ray transfer in grey approximation for any distribution of ^{56}Ni is also included in our code. We use the OPAL tables for the opacity and an equation of state with ionized H, He and pressure of degeneracy included. Double-polytropic models are used for the initial density profiles. The explosion itself is simulated by injecting a certain amount of energy near the center of the progenitor object [1].

Figure 3 shows how the profiles of different quantities change during the SN evolution. In Figure 4 we analyze the sensitivity of the model light curves to the variation of physical parameters. Finally, we compare our models with the observations of SN 1999em and SN 1987A (Figure 5).

Two Famous SNe

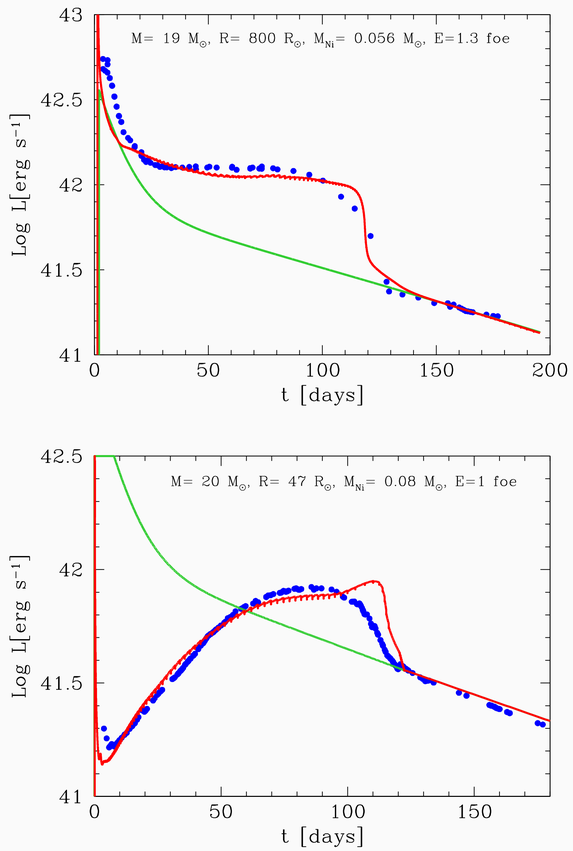

Figure 5: Comparison of the calculated bolometric LC (red line) with the observations (blue dots) for SN 1999em **(top)** and SN 1987A **(bottom)** as calculated using our BC calibration. The luminosity due to ^{56}Ni decay is shown with a green line. The physical parameters used in each model are shown. Note that the compact nature of progenitor of SN 1987A is retrieved.

References

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