THE LIGHT CURVE OF SN 1987 A

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Abstract. We use a semi-analytical model of supernova light curves that extends Arnett's scheme [1,2] to include the effect of recombination of hydrogen, helium and heavy elements in the expanding ejecta. Introducing in the model the physical parameters of Sanduleak –69 202, the salient characteristics of the light curve of SN 1987 A are reasonably reproduced over 100 days.

1. Relevant physical parameters.

The light curve is sensitive to several critical parameters. Those are mainly the mass M and radius R of the progenitor star and the energy E of the explosion. Other important parameters are the composition of the exploding star, on which depend the opacity and the details of recombination in the ejecta, the mass of ^{56}Ni ejected and the energy which can be injected by a newly born pulsar.

We have adopted $M = 15 M_\odot$, $R = 3\ 10^{12}$ cm and the energy E, expected to be of the order of 10^{51} erg, has been ajusted to fit the supernova luminosity in its plateau phase. The composition has been deduced from the supernova models of Woosley [3], assuming for Sk–69 202 a ZAMS mass of 20 $M_\odot$, which means that we suppose that about 5 $M_\odot$ of hydrogen–rich material have been lost during the stellar lifetime. We have also assumed a radioactive energy output corresponding to 0.01 $M_\odot$ of ^{56}Ni (the preferred value is however now 0.07 $M_\odot$ [4,5]) and no pulsar energy injection.

2. Results.

The results given by our semi-analytical model are illustrated in figures 1,2, 3 and 4. The explosion energy is E=1.2 10^{51} erg and the 0.01 $M_\odot$ of ^{56}Ni are located in the very inner region of the exploding star. The early light curve exhibits a first abrupt rise in the V band followed by a 10 day rather flat part. The bolometric luminosity is constant during that period. The gentle increase after ten days occurs because the photospheric temperature is then fixed at the recombination temperature, whereas the photospheric radius is still increasing. The second plateau at 50–100 days, is due to the progress of recombination in the expanding envelope that stabilizes the photosphere at a given radius and temperature. The prevailing contribution to the bolometric luminosity is, over most of the evolution, the initial energy imparted by the explosion. The recombination energy and the ^{56}Ni radioactivity however begin to play a significant role just before the drop of luminosity after about 100 days.

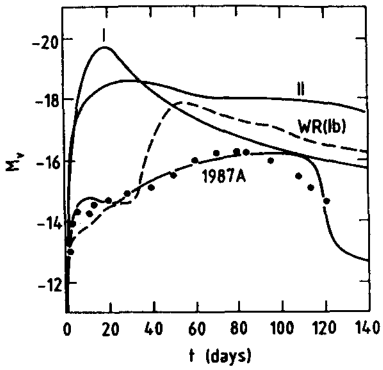

Figure 1: Visual light curve of SN 1987 A compared to typical SN I and SN II. The dashed line corresponds to the Wolf-Rayet supernova considered in [6] and the lower full line to the light curve computed with the Sk −69 202 parameters.

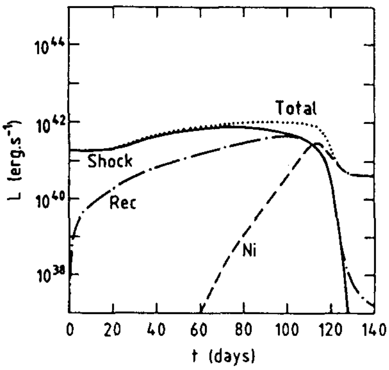

Figure 2: Bolometric light curve of SN 1987 A for the assumed parameters of Sk −69 202. The dots indicate the total luminosity, the full line the luminosity due to the shock energy, the dashed line the luminosity coming from the decay of ^{56}Ni and the dash-dotted line the recombination energy.

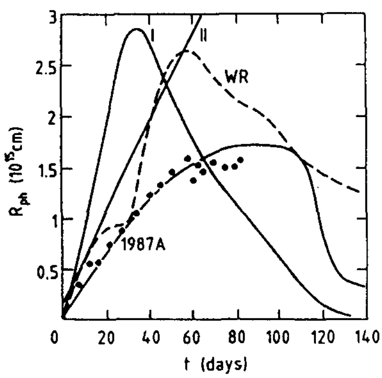

Figure 3: Photospheric radius for the different models considered in Fig.1, as compared to the observational data for SN 1987 A obtained by Dopita et al. [7].

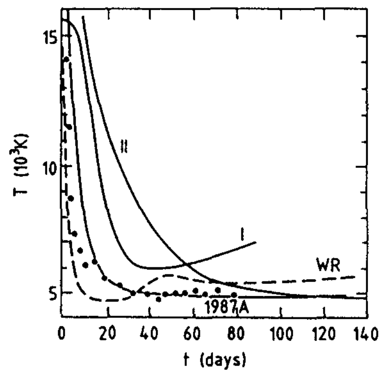

Figure 4: Effective temperature for the different models considered in Fig.1, as compared to the data for SN 1987 A of Dopita et al. [7].

References

[1] Arnett, W.D. : 1980, Astrophys. J. 237, 541

[2] Arnett, W.D. : 1982, Astrophys. J. 253, 785

[3] Woosley, S.E. : 1987, in 16^{th} Advanced Course of Saas-Fee, ed. B. Hauck, A. Maeder, G. Meynet, p. 127

[4] Nomoto, K. : 1987, this conference

[5] Woosley, S.E. : 1987, this conference

[6] Schaeffer, R., Cassé, M., Cahen, S. : 1987, Astrophys. J. 316, L31

[7] Dopita, M.A., Achilleos, N., Dawe, J.A., Flynn, C., Meatheringham, S. J. : 1987, to be published in Proc. Astron. Soc. Austr.