Light curves of Multiple Ejecta-circumstella Medium

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1 Introduciton

The interaction of the ejecta with the pre-existing CSM results in the formation of two shock waves: a forward shock (FS) propagating through the CSM and a reverse shock (RS) sweeping up the SN ejecta. The interaction provides a strong energy source by converting the kinetic energy to radiation.

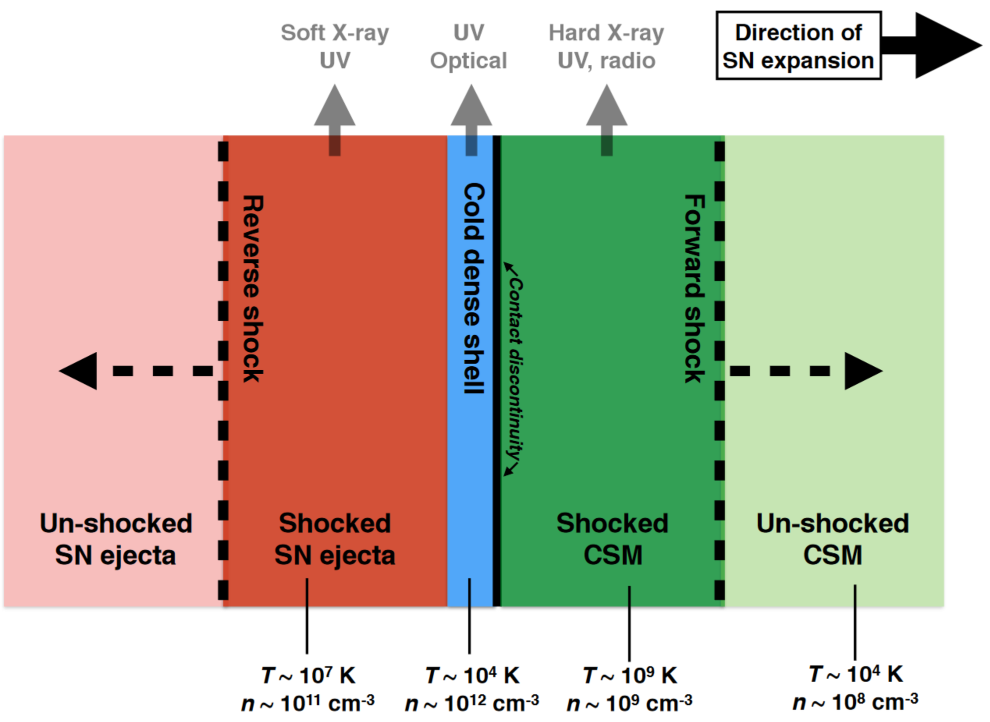

Figure 1. Illustration of the radiative shock structure during ejecta CSM interaction, with the different shock features labeled.

Massive stars could be unstable and experience mass losses in the form of eruptions in the final stage of their lives. Some complex light curve can be well modelled by successive interactions with multiple circumstellar medium.

2 Multiple Ejecta-CSM Interaction Model

Repeated episodes of eruptive mass occur, as for example in pulsational pair-instability supernovae, the CSM may consist of numerous spherical shells. If these CSM shells are well separated, iterative application of the formalism presented here may be used to analyze each shell interaction individually.

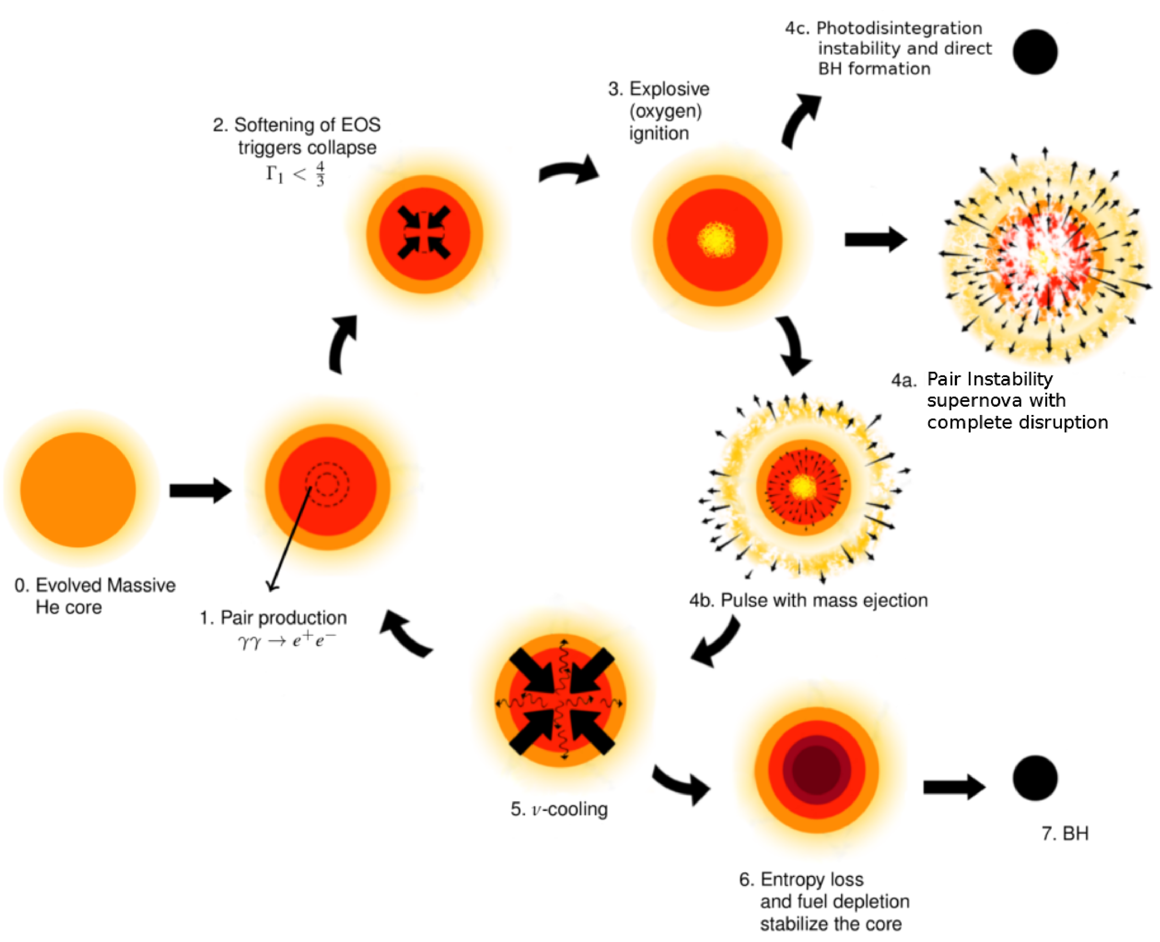

Figure 2. Evolution of a massive He core undergoing (pulsational) pair instability evolution [2].

In this multiple-interaction model, the total bolometric LC of N times interactions can be described as

$$L_{\rm tot}(t) = \sum_{i=1}^{N} L_{{\rm CSM},i}(t)$$

3 Modeling the Multiple Peaks Light Curves

3.1 iPTF 15esb

iPTP15esb is a superluminous supernova, its ate-time spectra show strong, broad Hα emission lines, indicating the interaction between the SN ejecta and the hydrogen-rich CSM shell surrounding the SN progenitor. Moreover, its LC has two peaks whose luminosities are approximately equal to each other ($L_{\rm peaks} \approx 4 \times 10^{43}$ erg s^{-1}) and a plateau lasting about 40 days. Its late-time LC decays as $L_{\rm bol} \propto t^{-2.5}$.

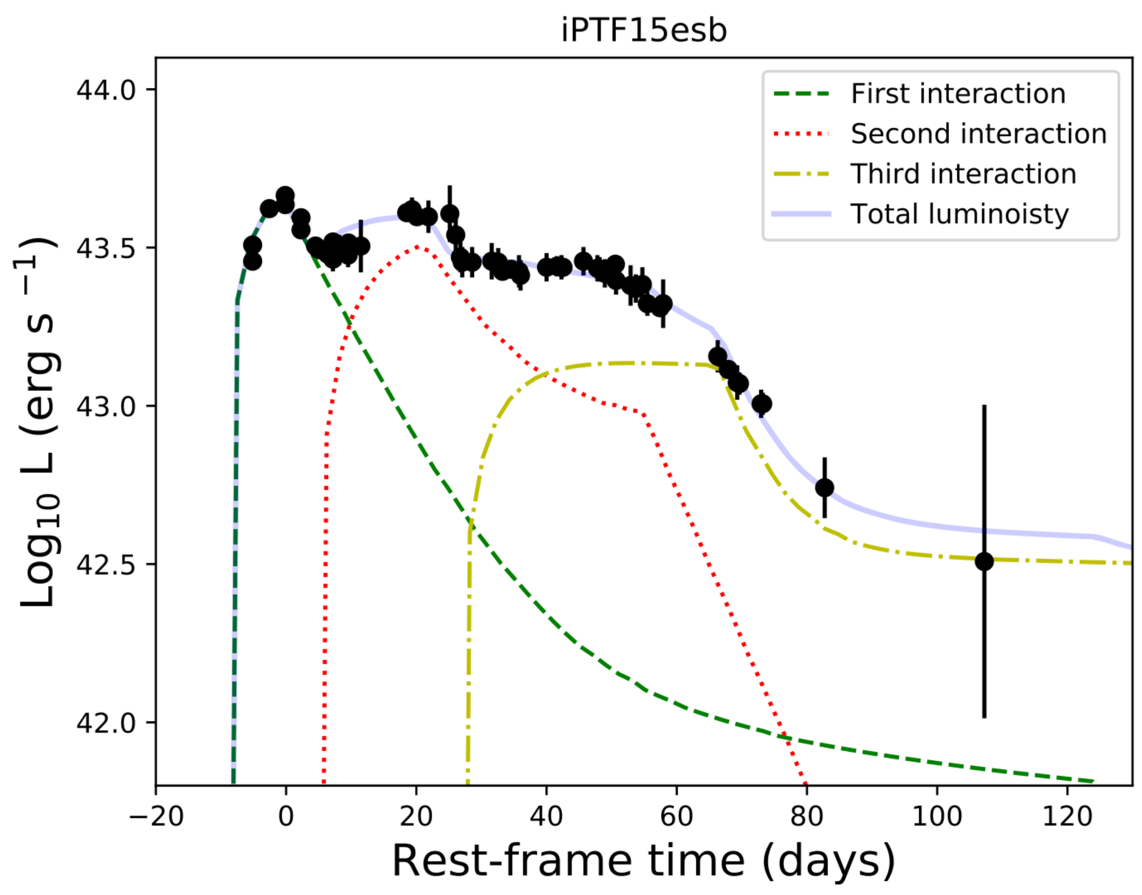

Figure 3. The fit to the bolometric LC of iPTF15esb using the multiple ejecta-CSM interaction model [1].

3.2 iPTF14hls

iPTF14hls is a luminous Type II SN with a bumpy light curve whose origin remains under debate. It maintains a roughly constant effective temperature and luminosity for about 600 days after discovery, followed by a slow decay. About ∼1000 days after discovery, the light curve transitions to a very steep decline.

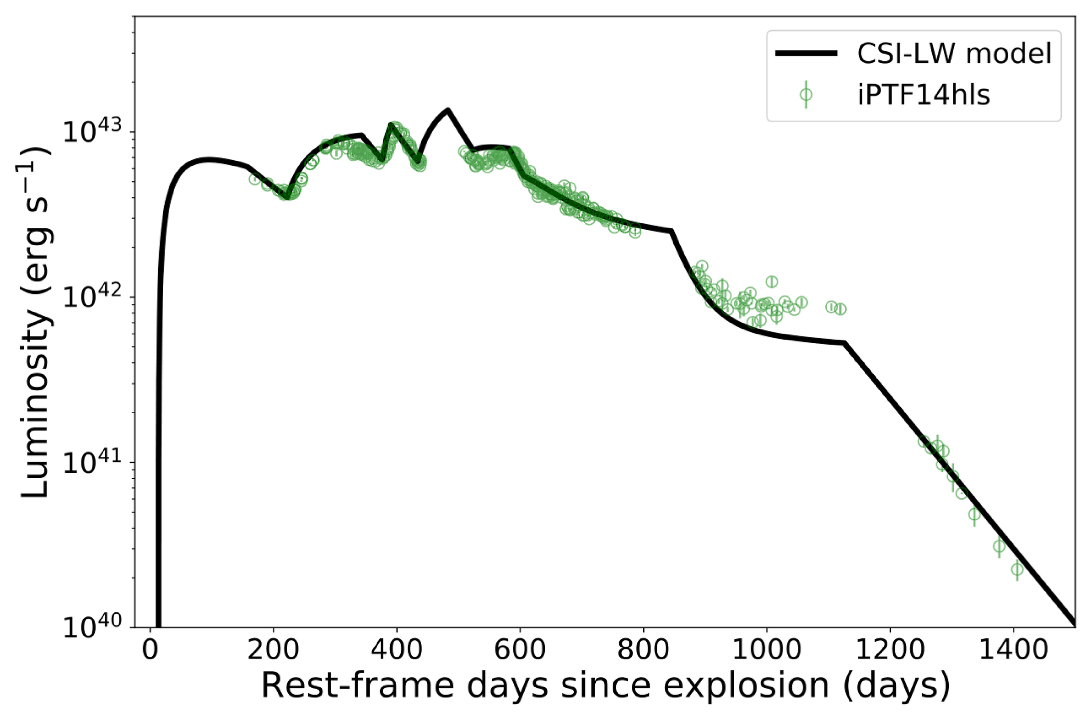

Figure 4. The fit to the bolometric luminosity of iPTF14hls by the multiple ejecta-CSM interaction model [3].

We explore the possibility of iPTF14hls as an interaction-powered SN. The light curve of iPTF14hls can be fitted with wind-like CSMs. Analytic modeling indicates that iPTF14hls may have undertaken six episodes of mass loss during the last ∼200 yr.

4 Conclusions

- The multiple interaction model can effectively explain why some supernovae have bumpy light curves.
- The inferred total mass of the ejecta and CSMs ($M_{\rm ej} + M_{\rm CSMs} \sim 250 M_\odot$) supports the idea that iPTF14hls may be a candidate for a (pulsational) pair-instability SN.
- Further investigations for SNe like iPTF15esb and iPTF14hls should shed light on the nature of the mass-loss histories of their progenitors.

Bibliography

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[3] Ling-Jun Wang, Liang-Duan Liu, Wei-Li Lin, Xiao-Feng Wang, Zi-Gao Dai, Bing Li, and Li-Ming Song. IPTF14hls in the Circumstellar Medium Interaction Model: A Promising Candidate for a Pulsational Pair-instability Supernova. *ApJ*, 933(1):102, 2022.