A Strong Interaction between The Ejecta of SN IIb 2013df and The CSM

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Type IIp supernovae are believed to be an explosion of a red supergiant, while type Ib/c supernovae (SNe Ib/c) are an outcome of an explosion of a star which has lost most of the hydrogen envelope before the explosion. They should represent different evolutionary paths, and thus a unified understanding of these phenomena is key to clarifying the unresolved nature of massive stellar evolution in the final centuries. SNe IIb retain a small but non-negligible amount of the hydrogen envelope at the time of the explosion, about the Solar mass or less, and thus they represent a link between SNe IIp and Ib/c. Their progenitors have diverse properties from a blue supergiant to a red supergiant, which are difficult to understand in the standard stellar evolution theory [1,2].

We have performed follow-up observations of SN IIb 2013df [3]. Especially surprising was a spectral feature at ~600 days after the explosion, obtained through the Subaru/FOCAS. At ~200 days, SN 2013df showed a spectrum similar to other SNe, characterized by forbidden lines of heavy elements. However, at ~600 days the spectrum showed a dramatic change, showing a strong Hα emission (Fig. 1). This transition is interpreted as follows: early on the SN was powered by radioactive decays of ^{56}Co, while later on the interaction between the expanding SN ejecta and circumstellar materials (CSM) became a dominant energy source. Such a transition has never been seen previously except for SN IIb 1993J.

This observational finding indicates that at least a fraction of SNe IIb have a large amount of CSM, namely they experience a huge mass loss in the last ~1000 years. On the other hand, for other SNe IIb the ejecta-CSM interaction have never been observed (Fig. 1) [4]. We have discovered that there is a relation between the mass loss rate and the radius of the progenitor (Fig. 2). A more extended progenitor is associated with a larger mass loss rate just before the explosion. It seems that SNe IIb from a more extended progenitor are the explosions during a strong binary interaction phase, while those from a less extended progenitor have a delay between the binary interaction and the explosion. A confirmation of the idea will require further studies, but in any case our discovery places a new and strong constraint on the unresolved nature of the final evolution of massive stars.

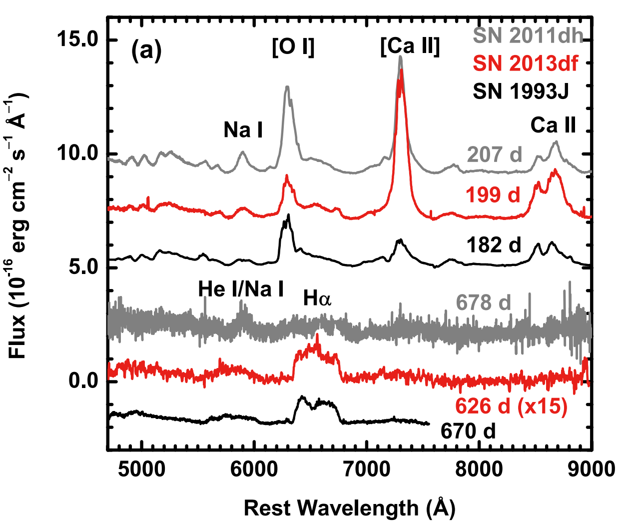

Figure 1: Late time spectra of SN 2013df as compared to those of SNe IIb 1993J and 2011dh at similar epochs [3].

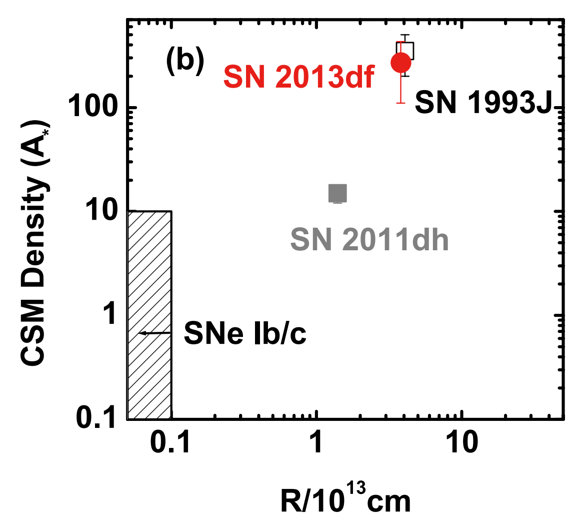

Figure 2: A relation between the progenitor radius and the CSM density (i.e., the mass loss rate) [3].

References

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