Ultraviolet-Bright Type IIP Supernovae from Massive Red Supergiants

Takashi Moriya

N. Tominaga, S. I. Blinnikov, P. V. Baklanov, E. I. Sorokina
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Ultraviolet-Bright Type IIP SN

SN 2009kf

spectra (Type IIP)

Botticella et al. (2010)
Why UV-Bright?

CSM interaction?
RSGs Exploded in Dense CSM?

- Extensive mass loss of RSGs
  - e.g., VY CMa (Smith+ ‘09)
    \[ 1 - 2 \times 10^{-3} \, M_\odot \, \text{yr}^{-1} \]

- Several suggested mechanisms
  - e.g., pulsation (Yoon+ ‘10)

Effect of dense CSM around RSGs on LCs? = the origin of SN 2009kf?
RSGs Exploded in Dense CSM

- 1D multi-group radiation hydrodynamics
- STELLA code (Blinnikov et al.)
Initial Conditions

- RSG inside: s13, s15, s18, s20 (Woosley+ '02)
- CSM (10 km/s)
- \( \rho \propto r^{-2} \)
- Mass-loss rate \((M_\odot \text{ yr}^{-1})\)
  - \(10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}\)
- Radius \((10^{15} \text{ cm})\)
  - 0.5, 1, 2, 3 (15, 30, 45, 60 yrs)

Example: s15, \(10^{-2} M_\odot \text{ yr}^{-1}\), 60 years \(\rightarrow 0.6M_\odot, 2 \times 10^{15}\text{ cm}\)
Effect on Light Curves

![Graph showing effect on light curves](image)

- **s15w2r20m3e3**
- **s15e3 (no CSM)**

**Axes:**
- **Y-axis:** Absolute bolometric magnitude
- **X-axis:** Days since the explosion (rest frame)
Effect on LCs

- **Black**: density
- **Red**: optical depth
- **Shock**
- **Photosphere**
- **SN ejecta**
- **CSM**

Graphs showing:
- Log density vs. log radius (cm)
- Absolute bolometric magnitude vs. days since the explosion (rest frame)
- Photospheric velocity (cm s⁻¹) vs. days since the explosion (rest frame)
Effect on Light Curves

The diagram illustrates the effect on light curves with and without CSM (circumstellar medium). The x-axis represents days since the explosion in the rest frame, while the y-axis shows the absolute bolometric magnitude. The graph shows the diffusion and shell effects, with distinct regions labeled for CSM and ejecta.
Effect on Light Curves

UV-Bright

Moriya et al. (2011)
SN 2009kf

Consistent with SN ejecta + CSM model

- Progenitor inside s15
- \(3 \times 10^{51}\) erg
- CSM \(\rho \propto r^{-2}\)
- \(2 \times 10^{15}\) cm
- \(10^{-2} M_\odot\) yr\(^{-1}\) (0.6\(M_\odot\))

Moriya et al. (2011)
SN 2009kf

A hybrid of Type IIln & IIP? c.f. SN 1987C (Schlegel+ ’98)
Implications

- SN 2009kf: high energy = massive RSGs? (Hamuy ‘03)
- RSGs at high-mass end experience extensive mass loss?
- A key for the RSG problem?
Summary

- UV-bright Type IIP SN 2009kf
- Progenitor: a RSG exploded in dense CSM
- SN 2009kf = very massive RSG?
- massive RSGs experience extensive mass loss?
- such mass loss mechanisms can determine the upper mass limit of Type IIP SN progenitors