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SN classification

thermonuclear

IIb

Ia

SiII

HeI

core collapse

II

IIP

Ib

Ic

Ib/c pec

IIIn

light curve

shape

strong ejecta−CSM interaction

hypernovae

Turrato 2003
SN Light Curves

Image of a graph showing light curves for different types of supernovae (Ia, Ib, II-P, II-L) over time (days after maximum light).
Extremely bright Type Ic SNe

Quasi-bolometric light curves (Young et al. 2010)
Extremely bright Type Ic SNe

R-band light curves (Young et al. 2010)
Extremely bright Type IIin SNe
Extremely bright Type IIn SNe

V-band (Drake et al. 2010)
Very bright Type Ib SNe with narrow lines

Type Ibn

Quasi-bolometric (optical+NIR) (Pastorello et al. 2008)
Very bright Type Ib SNe with narrow lines

Pastorello et al. 2008
Windy models for type Ic SNe

Ejecta: politropic mass distribution;
Wind: $\rho \sim r^{-p}$

Models (all masses $M$ and radii $R$ are in solar units)

<table>
<thead>
<tr>
<th>Model</th>
<th>$M_{ej}$</th>
<th>$R_{ej}$</th>
<th>$M_{Ni}$</th>
<th>$p$</th>
<th>$M_w$</th>
<th>$R_w$</th>
<th>$E$, foe</th>
</tr>
</thead>
<tbody>
<tr>
<td>shallowIb</td>
<td>1.0</td>
<td>10.0</td>
<td>0.0</td>
<td>2.5</td>
<td>2.9</td>
<td>$10^5$</td>
<td>3.0</td>
</tr>
<tr>
<td>standardIb</td>
<td>0.2</td>
<td>10.0</td>
<td>0.0</td>
<td>2.0</td>
<td>3.5</td>
<td>$8 \cdot 10^4$</td>
<td>3.0</td>
</tr>
<tr>
<td>brightIb</td>
<td>0.2</td>
<td>10.0</td>
<td>0.0</td>
<td>1.8</td>
<td>4.8</td>
<td>$9 \cdot 10^4$</td>
<td>1, 2, 4</td>
</tr>
</tbody>
</table>

Composition: uniform;
0.5 C + 0.5 O + 1% heavier elements of Solar abundance;
no $^{56}$Ni – to check the influence of the pure shock
Initial models

Samples of the density distribution

$p=1.8$ (black), $2.5$ (red)
Initial models

Samples of the density distribution

\[ p = 1.8 \text{(black)}, \ 2.5 \text{(red)}; \ M_{ej} = 0.2M_\odot \text{(black)}, \ 1M_\odot \text{(red)} \]
Light curves for different wind structure

\( p = 2.5, M_w = 2.9 M_\odot \)

\( p = 2, M_w = 3.5 M_\odot \)
Light curves for different explosion energies

\[ p = 1.8, \ M_w = 4.8M_\odot \]
$^{56}\text{Ni}$ vs. Shock wave heating
$M(^{56}\text{Ni}) = 1M_\odot$ in the ejecta
Best models for SN 2010gx

SN 2010gx and model
low $\kappa$ p=1.8 $R_4=9$ E=2

SN 2010gx and model
low $\kappa$ p=1.8 $R_4=9$ E=4
Expansion opacity enhanced

Opacity is taken as for $\frac{dv}{dr} = \frac{1}{t} = \frac{1}{1\text{day}}$
Evolution of model structure
Evolution of model structure
Evolution of model structure

The graph shows the evolution of model structure as a function of ejecta mass. The x-axis represents the ejecta mass in units of $M_r/M_\odot$, and the y-axis represents the log density in units of g/cm$^3$. Various lines with different colors and markers indicate different parameters, such as $v_g$, $\log L_{40}$, $\log T$, and $\tau_R$. The graph also includes annotations such as "out26p18z3e20" and "12 days."
Evolution of model structure

![Graph showing the evolution of model structure with parameters like density, ejecta mass, and time. The graph includes labels such as log \(\rho\), \(M_e/M_\odot\), and 22 days.](image-url)
Evolution of model structure
Evolution of model structure

![Graph showing the evolution of model structure with varying ejecta mass and density.](image-url)
Evolution of model structure
Evolution of model structure

![Graph showing the evolution of model structure with various parameters.]
Evolution of model structure
Evolution of model structure

![Graph showing the evolution of model structure](image-url)

- **Ejecta Mass, $M_r/M_\odot$**
- **Logarithm of density, $\log \rho_r$, g/cm$^3$**
- **Logarithm of luminosity, $\log L_40$**
- **Temperature, $T_R$**
- **Ejection velocity, $v_\theta$**
- **Duration, 102 days**
Evolution of model structure
Evolution of another model structure

![Graph showing evolutionary models](image)

- $\rho$, g/cm$^3$
- $v_\theta$
- $\log |L_{40}|$
- $\log T$
- $\tau_R$

**Graph Details**
- Ejecta Mass, $M_r/M_\odot$
- Log density ($\log \rho$) vs. Ejecta Mass
- Various evolutionary tracks indicated
- Notation: out23p25z3e40
- Annotations: 2 days
Evolution of another model structure

![Graph showing the evolution of various parameters over Ejecta Mass](image-url)
Evolution of another model structure
Evolution of another model structure
Evolution of another model structure
Evolution of another model structure

![Graph showing the evolution of a model structure with parameters such as density, ejecta mass, and time. The graph illustrates the changes over time, with key points labeled for understanding.]
Evolution of another model structure
Evolution of another model structure
The light curve for the last model

![Light curve graph](image)

- $L_{\text{bol}}$
- $L_{\text{XUV}}$
- $L_{\text{UBVRI}}$
- $L_{\text{farIR}}$

**Out23 p=2.5 E=4B**
The shock wave which runs through rather dense matter surrounding an exploding star can produce enough light to explain very luminous SN events. No $^{56}$Ni is needed in this case to explain the light curve near maximum light (some amount is of course needed to explain light curve tails).

We need the explosion energy of only 2-3 Bethe for the shell with $M = 3 - 5M_\odot$ and $R < 10^{16}$ cm.

The brightness and the duration of the light curve maximum strongly depends on the mass and structure of the envelope.
Conclusions

Questions on the latest phases of star evolution arise:

- Is it possible to form so big and dense envelopes? And how?
- Time scale for such a formation
- How far can the envelope extend?
- Density and temperature profiles inside the envelope right before the explosion

Question to observations: try to find traces of such shells for bright explosions. (There are spectral evidence of circumstellar shells for type IIln and Ibn SNe. Is it possible to find C–O envelopes as well?)
Conclusions

- Many technical problems in light curve calculations:
  - line opacities;
  - dimensionality: 3D is preferable, since the envelope can most probably be clumpy;
  - NLTE spectra