Core-Collapse
SN Progenitors

Schuyler Van Dyk (IPAC/Caltech)
Core-Collapse SNe: Classification

Thermonuclear SNe

<table>
<thead>
<tr>
<th>NO Hydrogen</th>
<th>Core Collapse SNe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si II lines</td>
<td>NO Si II lines</td>
</tr>
<tr>
<td>Ia</td>
<td>He</td>
</tr>
<tr>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Ic</td>
<td>Ib</td>
</tr>
<tr>
<td>(hypernovae,</td>
<td></td>
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<tr>
<td>Ic-bl, SN-GRB)</td>
<td></td>
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<tr>
<td></td>
<td>II/IIb hybrid</td>
</tr>
<tr>
<td></td>
<td>H lines disappear</td>
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<tr>
<td></td>
<td>in ~few weeks,</td>
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<tr>
<td></td>
<td>reappear in</td>
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<tr>
<td></td>
<td>nebular phase</td>
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<tr>
<td></td>
<td>II-L</td>
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<tr>
<td></td>
<td>II-P</td>
</tr>
<tr>
<td></td>
<td>Linear</td>
</tr>
<tr>
<td></td>
<td>Plateau</td>
</tr>
<tr>
<td></td>
<td>Narrow</td>
</tr>
<tr>
<td></td>
<td>IIln</td>
</tr>
<tr>
<td></td>
<td>H lines dominate</td>
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<tr>
<td></td>
<td>at all epochs</td>
</tr>
<tr>
<td></td>
<td>Envelope Stripping</td>
</tr>
</tbody>
</table>

(adapted from Turatto 2003)
Evolution of Massive Stars

What do theoretical stellar evolutionary tracks predict/explain?

Rotating, solar Z models
(Ekstrom et al. 2012)

Rotating models agree better with the revised Humphreys-Davidson Limit on RSGs at $\sim 25 \, M_\odot$
(Levesque et al. 2005, Crowther 2007)
Evolution of Massive Stars

What do theoretical stellar evolutionary tracks predict/explain?

- Departure from standardized Mass loss formulation
- Pulsationally-driven superwinds from RSGs, solar Z (Yoon & Cantiello 2010)
Direct Identification of
SN Progenitors

We have precious few (19 +/-) examples:
Mass Range (?) of SNe II-P Progenitors

Smartt et al. (2009)
SN II-P 2012aw in M95

Van Dyk et al. (2012, in revision)

$M_{\text{ini}} \approx 16-17 \, M_\odot$
SN II-L Progenitors

SN 2009kr in NGC 1832 (Elias-Rosa et al. 2010)

Yellow supergiant (!) with $M_{\text{ini}} = 18 - 24 \, M_{\odot}$

(also Fraser et al. 2010; $M_{\text{ini}} = 15^{+5}_{-4} \, M_{\odot}$)
SN IIb Progenitors

Maund et al. (2004), Maund & Smartt (2009)

Chevalier & Soderberg (2010): SNe IIb from *extended* (R ≈ 10^{13} cm) progenitors, e.g., SN 1993J, and from *compact* (R ≈ 10^{11} cm) progenitors, e.g., SN 2008ax & 2011dh
SN Ib Progenitors

SN Ib 2009jf in NGC 7479 (Van Dyk et al., in prep.)

Yoon, Woosley, & Langer (2010)
SN Ic Progenitors

SN Ic 2007gr in NGC 1058  (Crockett et al. 2008)

Not very restrictive limits, based on properties of star cluster may not be in the cluster after all

HST WFPC2 F555W from 2008
SN Ic Progenitors

e.g., SN Ic 2000ew in NGC 3810 (Van Dyk, Li, & Filippenko 2003a)

Also, SN 2003jg in NGC 2997, SN 2004cc in NGC 4568, SN 2005V in NGC 2146, etc.
(Elias-Rosa et al. in prep.) --- These are all highly extinguished
SN IIp Progenitors

SN 2005gl in NGC 266  \((d = 66 \text{ Mpc})\)
\((\text{Gal-Yam et al. 2007; Gal-Yam & Leonard 2009})\)

HST WFPC2 F\(_{547M}\)
\(M_V \approx -10.3 \text{ mag} \text{ (!!)}\)
Keck-II NIRC2 AO
HST WFPC2 F\(_{547M}\)
Provocative (?) Questions

- What is the lower mass limit for core collapse?
- Are stars at ~8 $M_\odot$ really undergoing core collapse?
- How much does the core care about the overlying layers?
- What influence does binary interaction (mass transfer) have on the core?
- What is the “transition” core mass dividing NS from BH as remnant? (And, is this sensitive to metallicity? rotation? B-field?)
- How to produce asymmetries in the explosion?
- Does the presence of a jet have an effect on core collapse? Is the jet’s presence necessary for core collapse?
- Does the core play a role in the late stage mass loss prior to explosion?
- Does the core play a role in pre-SN eruptions or outbursts?