Evaluating the Evidence for LBVs as Supernova Progenitors

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LBVs as SN Progenitors

Recently, there have been many papers proposing LBVs as progenitors of core-collapse SNe (2005gl, 2003bg, 2006gy, 2008iy, 2006tf, 2009ip ….).

But … stellar evolution theory suggests that LBVs do not explode but instead form WR stars.

So how many of the SN progenitors suggested to be LBVs have been shown to be Luminous, Blue **and** Variable?

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(2009ip??)

LBVs

- Luminosity - > 10^6 solar? (2005gl)
- Blue ???
- Variable – Hard to prove, so a general proxy seems to be high density (1997ab,2006gy, 2008iy, 2006tf, …..), especially for Type IIn SNe.
- Especially true for IIns, because they show very high X-ray and radio luminosity.
- The High density is then converted to a high-mass loss rate.
- But….. High Density Shell ≠ Eruption!

High Density could be due to clumps, or swept-up mass by wind shocks. A fast wind can seep up slower wind material into a high-density shell, *irrespective of the mass-loss rate*.

LBVs

- High Density ≠ High Mass-loss rate
- Are mass-loss rates determinations for these SNe reliable?
- In many cases, mass-loss rates determined by assuming

$$L = 0.5 \frac{\dot{M}}{v_w} v_s^3$$

- But …. This equation assumed a *steady wind with constant mass-loss parameters* . Often, the assumptions are inconsistent with the answers obtained (2006gy, 2008iy, 2006tf). Thus these mass-loss rates cannot be believed.

LBVs

- High Mass-loss rate ≠ LBV automatically.

e.g. Fox et al (2011, ApJ, 741, 7)

Deduce the mass-loss rate for several IIn SNe assuming dust-to-gas mass ratio 0.1, and find values > 10^{-3} Msun/yr.

→ LBV

How accurate are the mass-loss estimates, and how accurate are the dust mass estimates?

But .... yellow supergiants can show mass-loss rates > 10^{-3} Msun/yr. Are LBVs only option?

Yesterday, we learnt that many other stars can show eruptions.

Short WR phase

- In many cases, pulsatory or episodic mass-loss is automatically attributed to LBVs. If a star lost a large amount of mass before collapse ⇒ LBV.
- But it's possible that a star can go from LBV to WR for a short period before explosion:

i. Yoon and Cantiello (2010) – RSGs can have strong pulsation-driven superwinds, remove outer layers and become a WR star in last hundreds of years of evolution

ii. Case C mass-transfer can lead to explosive common envelope ejection, ejecting both H and He layers late in the evolution of star (Podsiadlowski 2007, 2010), resulting in a WR star with a lifetime < 10000 years.

iii. Binary Companion: Mass transfer could cause stars to enter the WR phase at a very low initial mass. The lowest mass WR stars will have very short WR lifetimes (Eldridge et al 2008).

Narrow-Line Velocities

- The narrow lines are assumed to signify the velocity of the ambient wind, aka LBV.
- What is the appropriate velocity range for LBV winds?
- Few 100 km/s attributed to LBVs – but BSGs also thought to have similar wind velocities (cf progenitor of SN 1987A)
- Narrow lines can be due to shocks driven in high-density clumps
- Contamination from HII regions, host galaxy?

Features resembling LBV Spectra

- Multiple absorption component P-Cygni profiles noted in SN 2005gj
- Resemble similar features in LBV spectra (Trundle et al 2008)
- However, overall 2005gj spectrum most closely resembles a Type Ia -> 2002ic!
- If Type Ia, how can it be LBV?
- If not Type Ia, then why close correspondence with 2002ic between days 26 and 84??

Quasi-periodic Modulations of Radio SN Light-curves

- 2001ig – Modulations of ~150d, 2 peaks with a probable third
- 2003 bg – modulations at 120, 300 and 600d
- Soderberg et al (2006) – Density enhancements of 1.8, 1.4 and 1.2 required to fit the light curve.
- Kotak & Vink – bistability jumps would work
- But ….

i. Can bistability jumps give such small density jumps??

ii. Even if so, why only LBVs, bistability jumps should work for all massive stars

iii. 2003bg – Classified as Ic initially. Why would LBV give rise to a SN with no H in spectrum?

Summary & Conclusions

- While there are many suggestions of features in SN spectra or light curves that resemble LBVs, none are compelling.
- In one case, 2005gl, luminous (blue?) star found in pre-explosion images. LBV??
- In other cases, alternative scenarios available (Dwarkadas 2011)