Supernova Spectral Diagnostics and Typing

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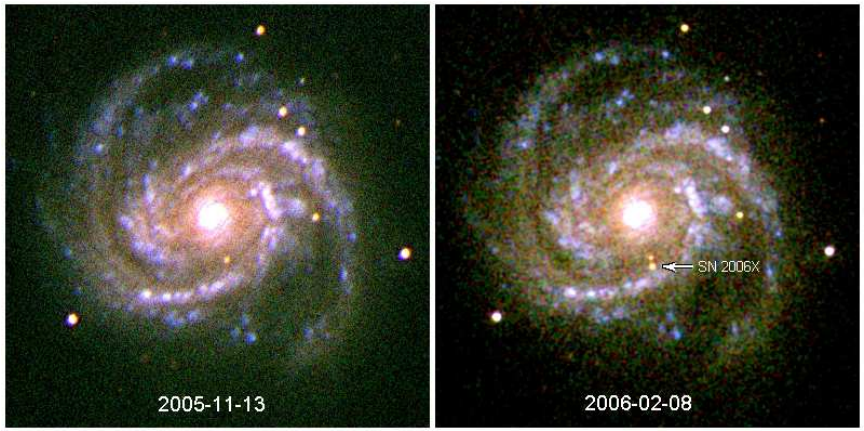

First identification of SN

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Type I & II SN

Basic dichotomy (Minkowski, 1941):

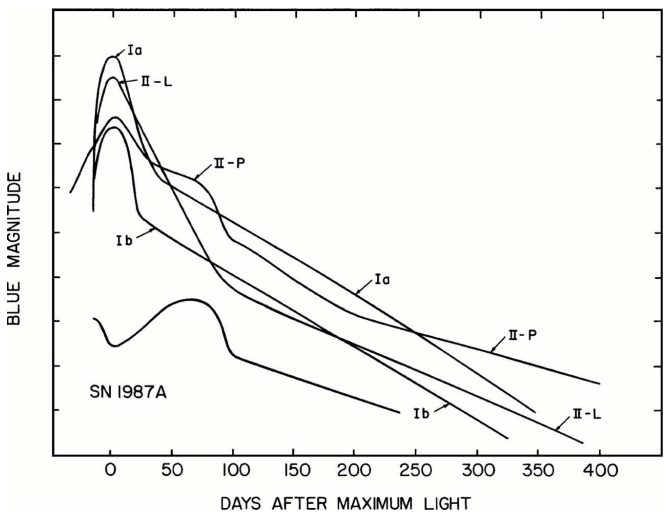
- Type I: Has no hydrogen lines
- Type II: Has hydrogen lines

Defunct classes: Type III, IV & V (Zwicky, 1964)

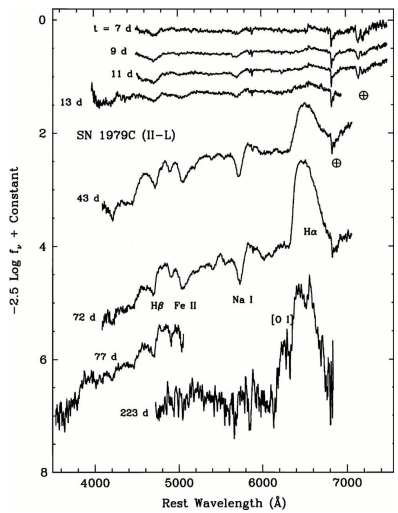
- Type III: Similar to (old) Type II, retains bright continuum for longer periods, wide hydrogen lines $\rightarrow$ modern IIP?
- Type IV: ???
- Type V: Strong Balmer, Fe II & He I. Similar to novae but no forbidden lines

Temporal Behaviour of Spectra

- Near maximum light: Strong blackbody continuum with $T_c \sim 10000K$
- $\sim$ weeks after max light: Dominated by blends of P-Cygni line profiles, photosphere gradually recedes through ejecta
- $\sim$ year after max light: Optically thin 'nebular phase', forbidden lines
- At late-times, generically powered by decay of ^{56}Ni / ^{56}Co



Cox (2000)



Filippenko (1997)

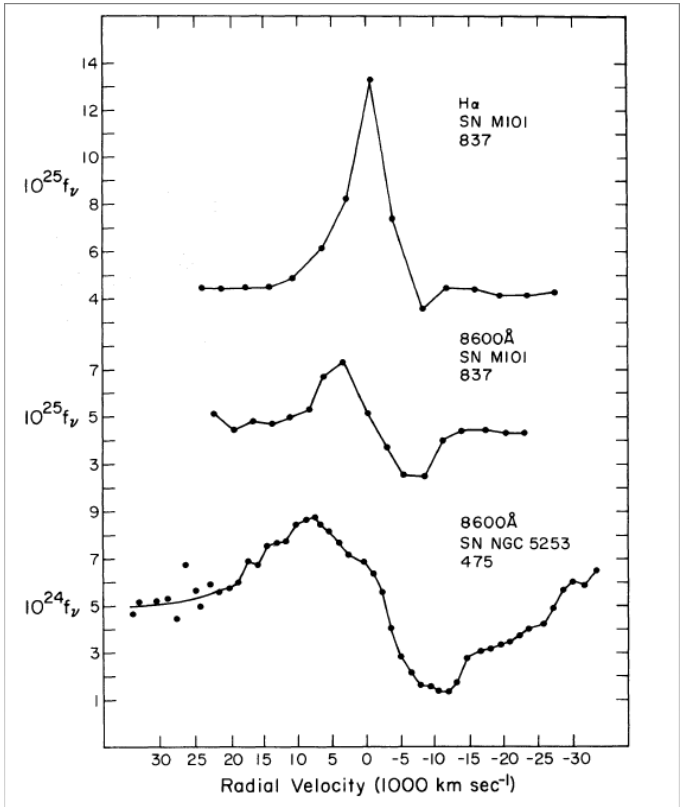
P-Cygni Line Profiles

Many SN lines have a distinct line profile:

- Blue-shifted absorption trough
- Red-shifted emission peak

Known as **P-Cygni line profile**

Can be symmetric or asymmetric



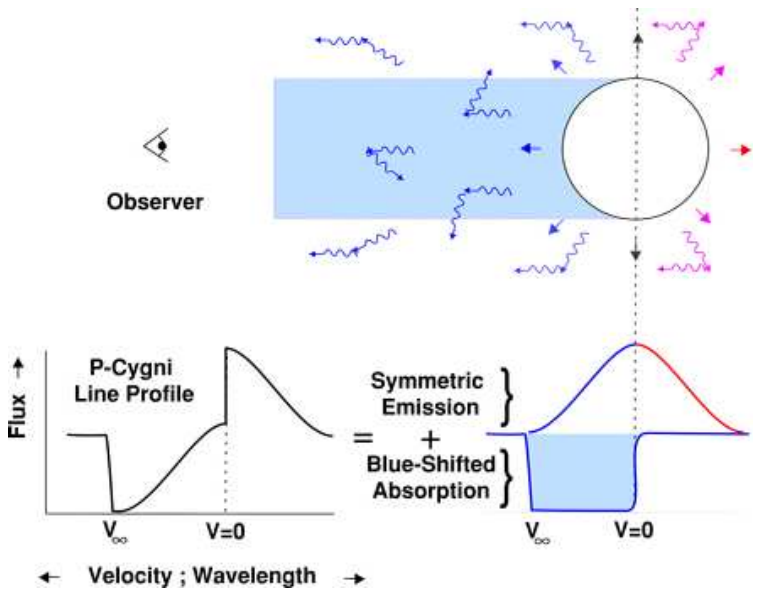
Kirshner et al. (1973)

Physical interpretation of P-Cygni Profile

Radiation emitted from photosphere:

- Blue-shifted absorption along LOS by material streaming towards observer
- Resonant scattering of both receding and advancing material causes symmetric emission profile

Line profile provides constraints on outflow velocities ($v \sim 5000 - 15000\ \mathrm{km\,s^{-1}}$ for SN)

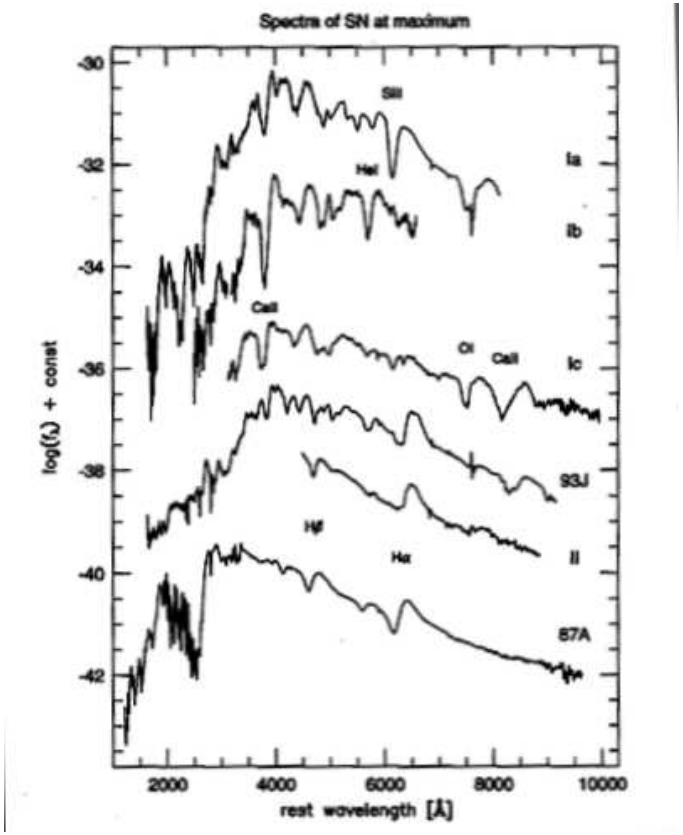


Encyclopedia of Astronomy & Astrophysics

Basic Spectral Classes

Type Ia seen in old stellar populations, while Ib, Ic & II seen in young populations $\rightarrow$ core-collapse from massive stars

- Type Ia: No H, Si II, λ6355 seen
- Type Ib: No H, He I, λ5876 seen
- Type Ic: No H, no He or Si
- Type II: H seen (e.g. Balmer Hα λ6563, Hβ λ4861 etc)



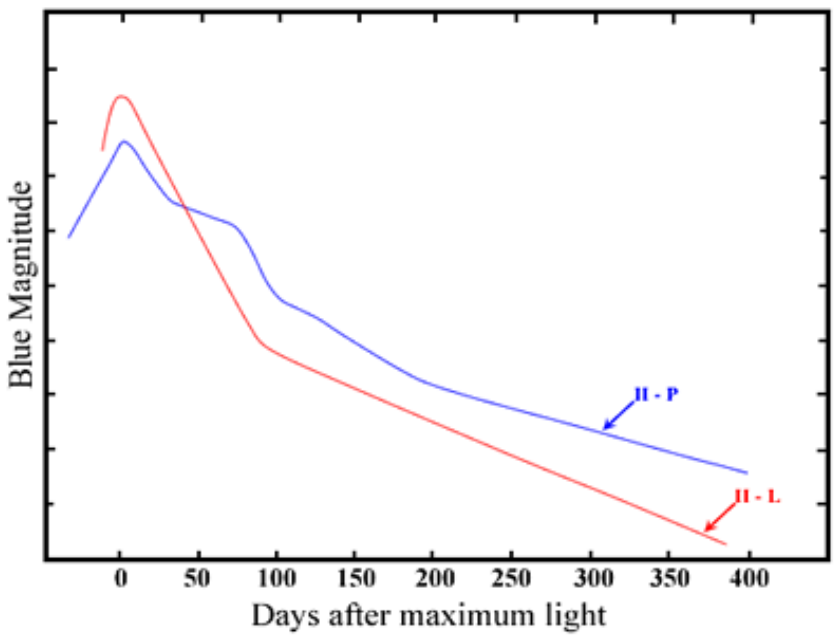
Cox (2000)

Type IIP & Type IIL

Type II exhibit 'plateau' and 'linear' light-curves

- SN blastwave ionizes H envelope of star, increasing opacity
- Optically thick as photosphere recedes through ejecta at ~constant T_c, '**plateau phase**'
- After photosphere becomes optically thin, luminosity powered by ^{56}Co decay

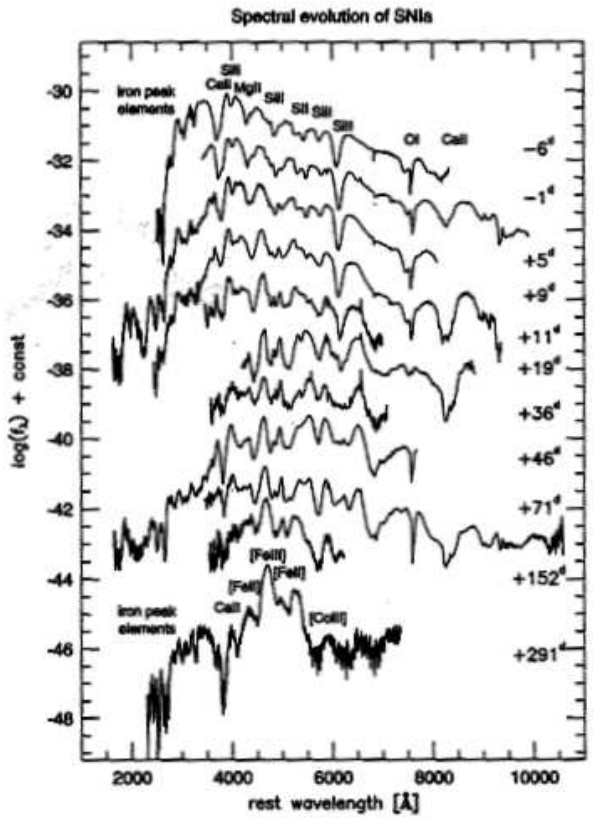
Type IIL: Smaller H envelopes?



http://astronomy.swin.edu.au/cms/astro/cosmos/

Type Ia

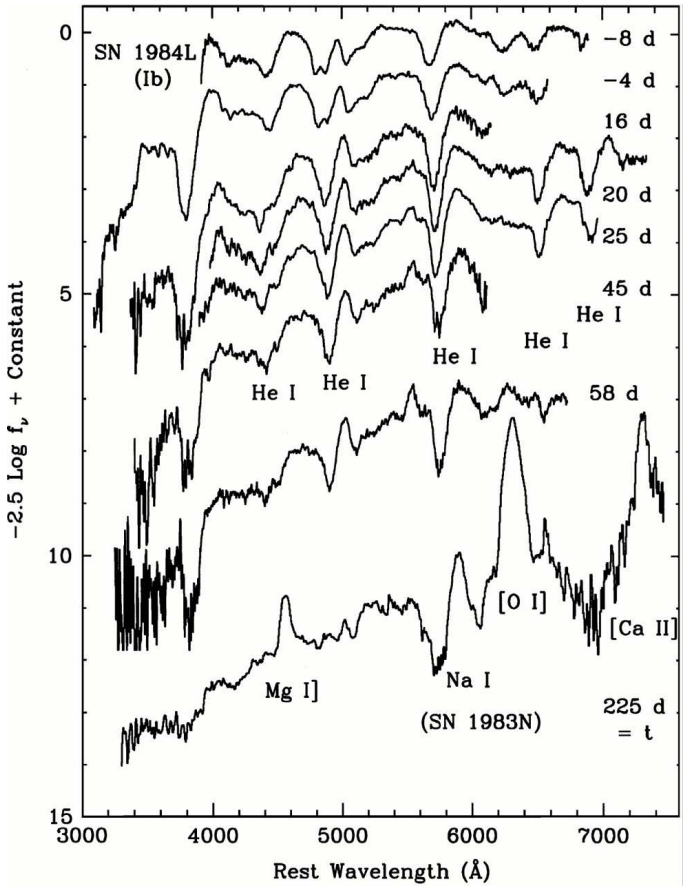
- The most intrisically luminous SN ($\langle M_V \rangle = -18.5$)
- Progenitor: CO white-dwarf undergoing thermonuclear flash
- No hydrogen lines, strong Si II (λ6355)
- As photosphere recedes into ejecta at t $\sim$ 2 weeks, see more iron-group elements
- Nebular phase: [FeII], [Fe III], [Co III]



Cox (2000)

Type Ib

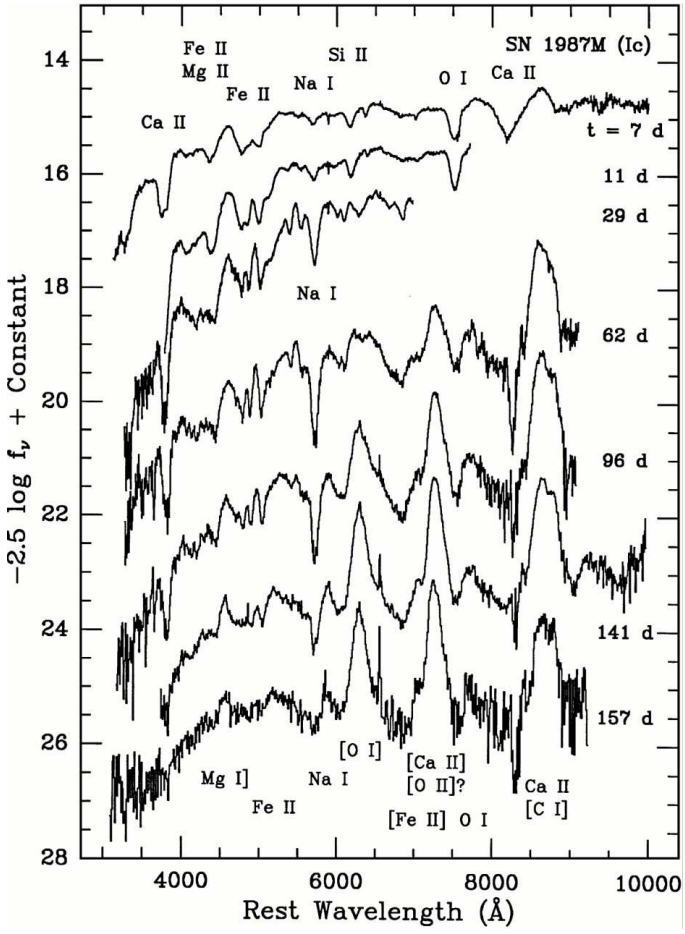
- Rarer than SNIa – only identified in ∼1985
- ∼ 1.5 mag less bright than SNeIa
- Velocities drop from $v \sim 18000\ \mathrm{km\,s^{-1}}$ at $t_{max} - 15$ days to $v \sim 10000\ \mathrm{km\,s^{-1}}$ at t_{max}
- Helium seen in He I λλ 4471, 5876, 6678, and 7065 few weeks after max light
- After ∼ 2 months, see nebular lines [O I] λλ 6300, 6364 and [O I] λ 5577



Filippenko (1997)

Type Ic

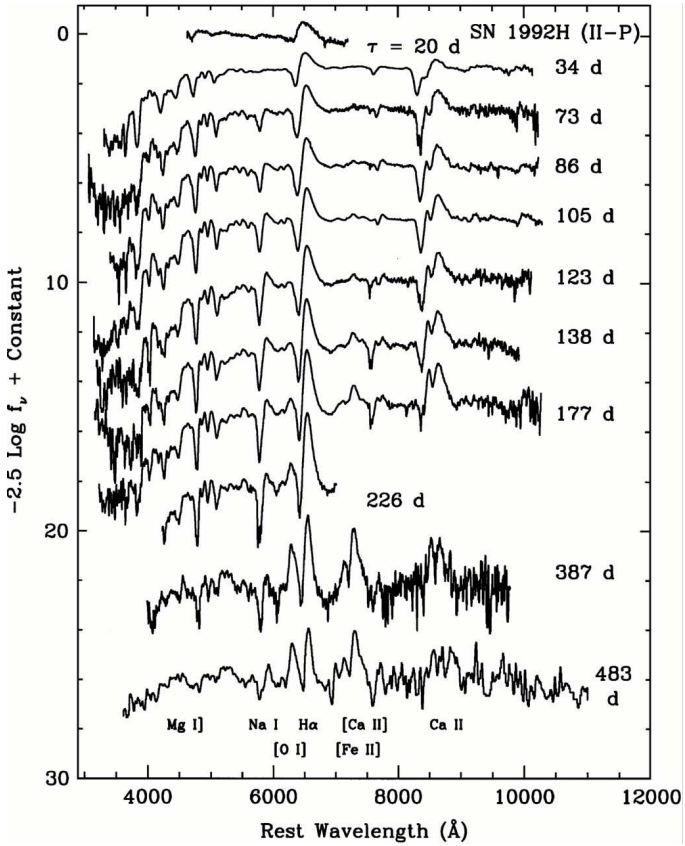
- Similar to Type Ib
- Luminosity declines faster than Ia or Ib
- No strong He lines
- Obvious lines: Ca II near-IR triplet, O I λ 7774 absorption, and Ca II H&K $\lambda\lambda$ 3933, 3968 absorption
- Some He detected in SNeIc, e.g. 1994I $\rightarrow$ is Ib/Ic dichotomy justified?
- Likely progenitors for Ib/Ic: massive stars (e.g. Wolf-Rayet) which had shed most of their envelopes



Filippenko (1997)

Type II

- Initially, very blue continuum ($T_c > 10000$ K)
- After few weeks, see decrease in line blueshifts/widths, $T_c \rightarrow 5000$ K – IIP plateaus at this point
- Strong hydrogen Balmer + He I λ5876 with P Cygni profile
- Nebular phase: Hα, Na D, [O I] $\lambda\lambda$ 6300, 6364, [Ca II] $\lambda\lambda$ 7291, 7323, Ca II IR triplet
- Little spectral difference between IIP & IIL (IIL has no Hα absorption?)

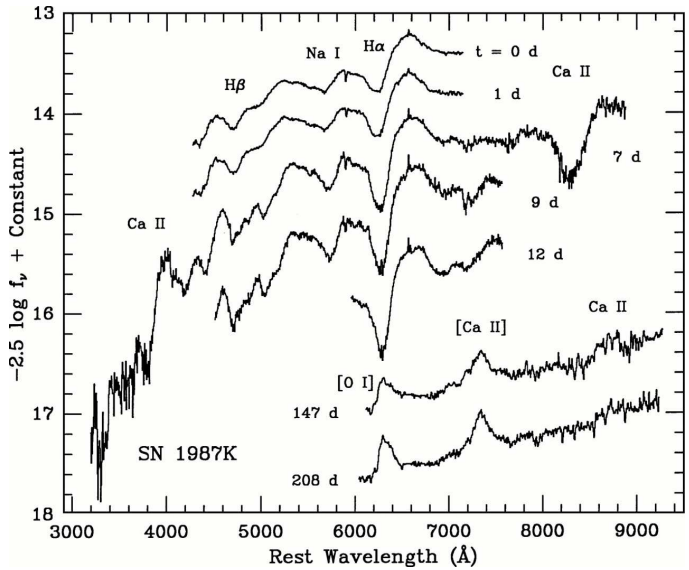


Filippenko (1997)

Type IIb

Combination of Type II and Type Ib

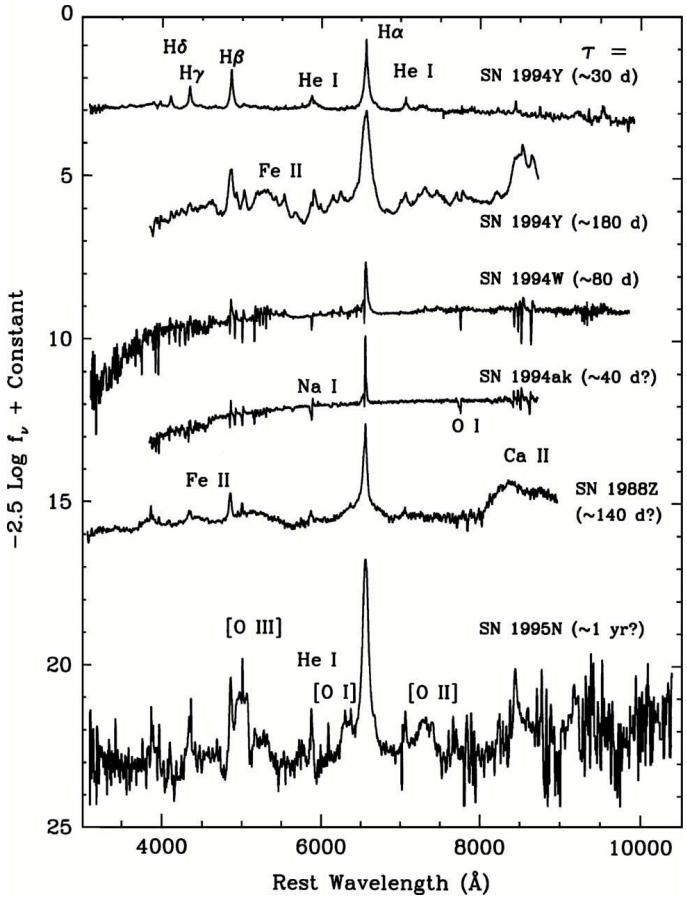
- Examples: SNe1987N, 1993J
- Initially has Type II spectrum
- At late times, Hα disappears $\rightarrow$ Type Ib spectrum
- Progenitors believed to have only a low-mass 'skin' of H – $\sim 0.1 - 0.6 M_{\odot}$ for 1993J



Filippenko (1997)

Type IIn

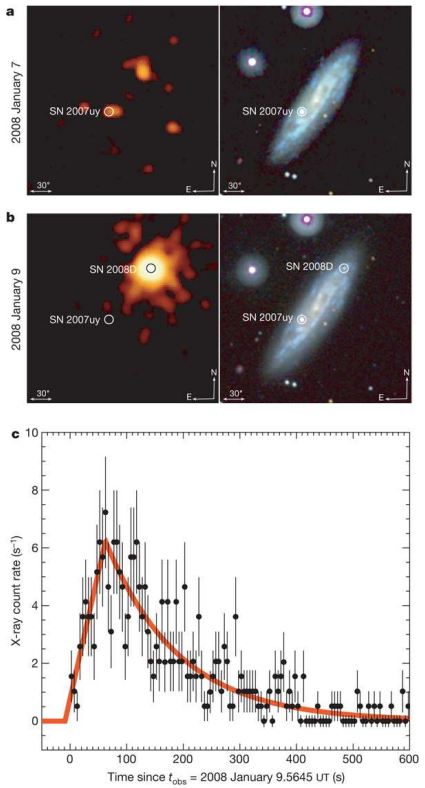
- Type II with 'narrow' lines
- Narrow Hα (FWHM $\lesssim 200\ \mathrm{km\,s^{-1}}$) emission on top of broader component
- Suppression of forbidden lines at late times denote dense material ($n > 10^{7-9}\ \mathrm{cm^{-3}}$)
- Caused by interaction of SN radiation & ejecta with dense circumstellar material



Filippenko (1997)

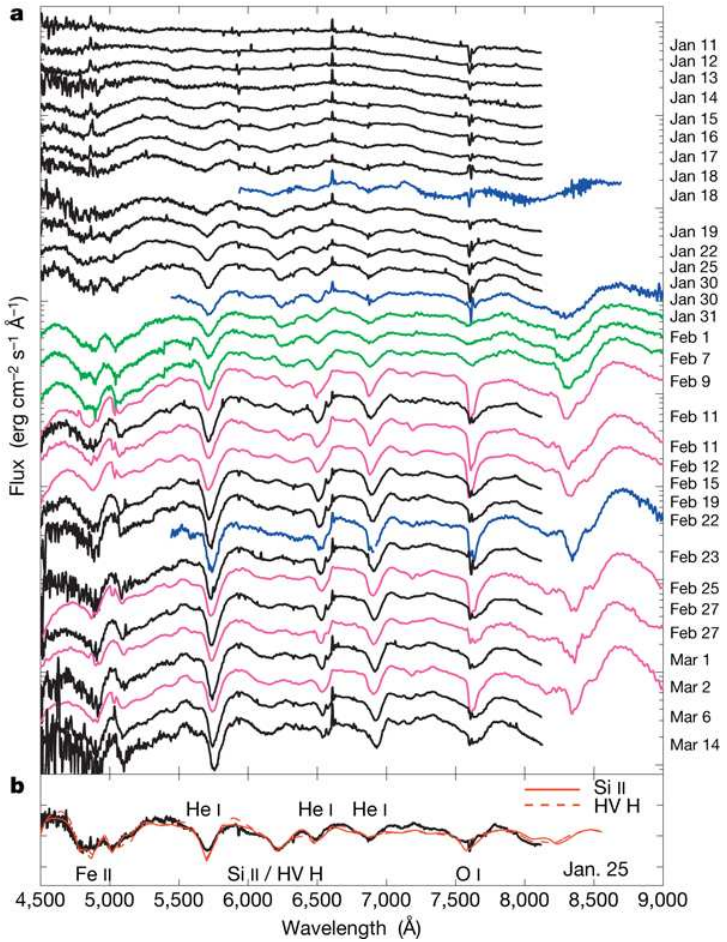
SN2008D

In Jan 9 2008, Alicia Soderberg discovered X-ray burst in NGC 2770, identified with UV/optical counterpart 1.4hrs later
$\longrightarrow$ Interpretation: X-ray burst from shock break-out of Type Ibc supernova



Soderberg et al. (2008)

SN2008D



Soderberg et al. (2008)

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