Photometric and Spectroscopic evolution of Type II-P Supernova SN 2004et

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Introduction

Classification of Supernovae

Based on spectroscopy near max. light

Hydrogen rich Type II

Hydrogen deficient Type I

Explosion mechanism

Core Collapse Supernovae
IIP -- IIL -- Ib -- Ic

Thermonuclear explosion Ia

Observational Importance of Supernovae:

Type Ia – *Ideal probe to be used as distance indicator.*

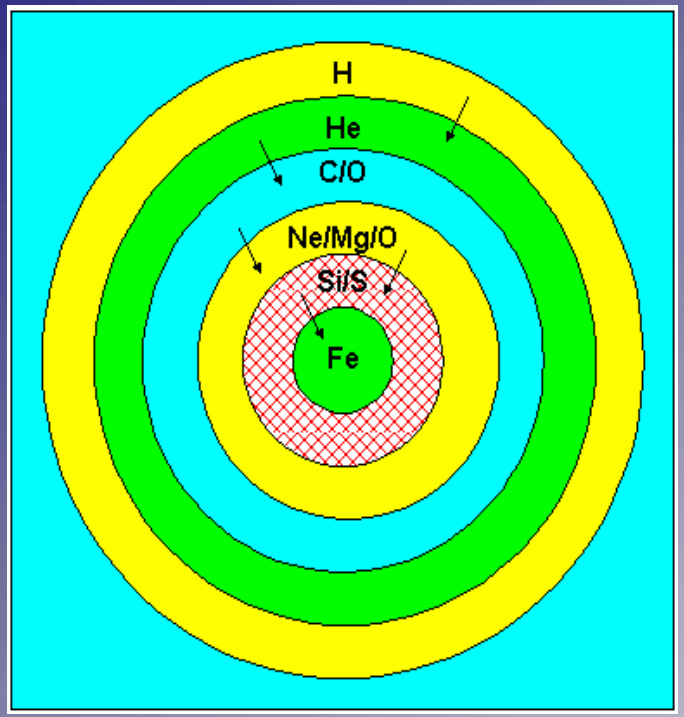
Type II - *Wide range in luminosity. Type IIP plateau luminosity is correlated with expansion velocity of ejecta.*

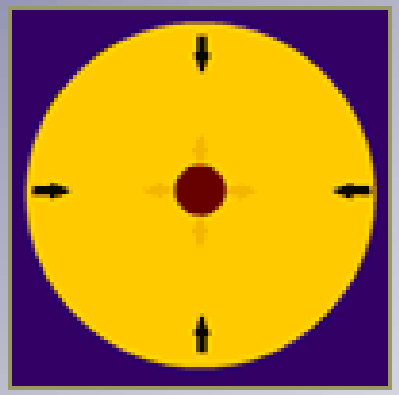
Advantages:

Well understood progenitors

Atmosphere is dominated by Hydrogen

Type II : Core Collapse Supernovae





Massive star: Fe is fusion endpoint

$\gamma + {}^{56}Fe \rightarrow 13\ {}^{4}He + 4n$

↓

Pressure drop

↓

Collapse

↓

Density increases

↓

$p^{+} + e^{-} \rightarrow n + \nu_e$

↓

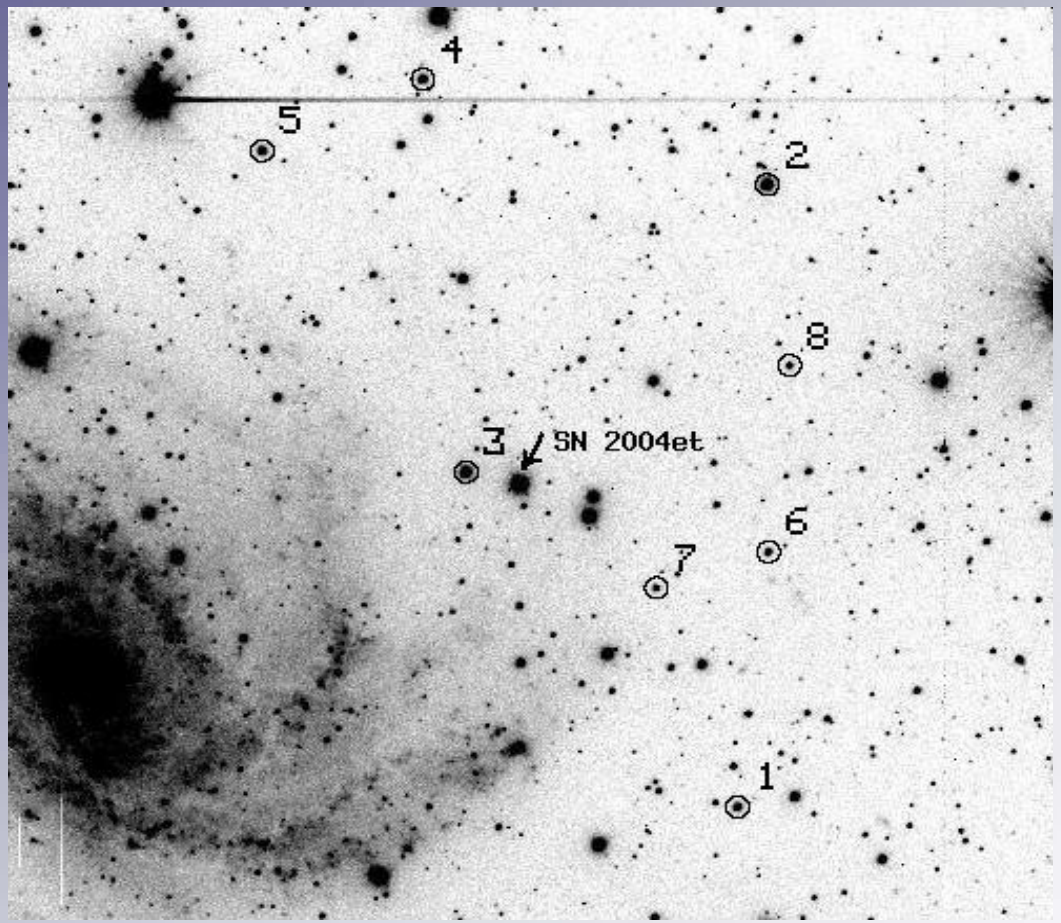
Core bounces back

↓

Shockwave ⇒heating ⇒expansion

SN 2004et

Host Galaxy - NGC 6946, already had produced 7 supernovae
Discovery – Sept. 27, 2004 (Moretti et al.)
Classification – II-P (Zwitter et al. & Filippenko et al. 2004)
Early detection in radio ==> presence of appreciable circumstellar material (Stockdale et al 2004)

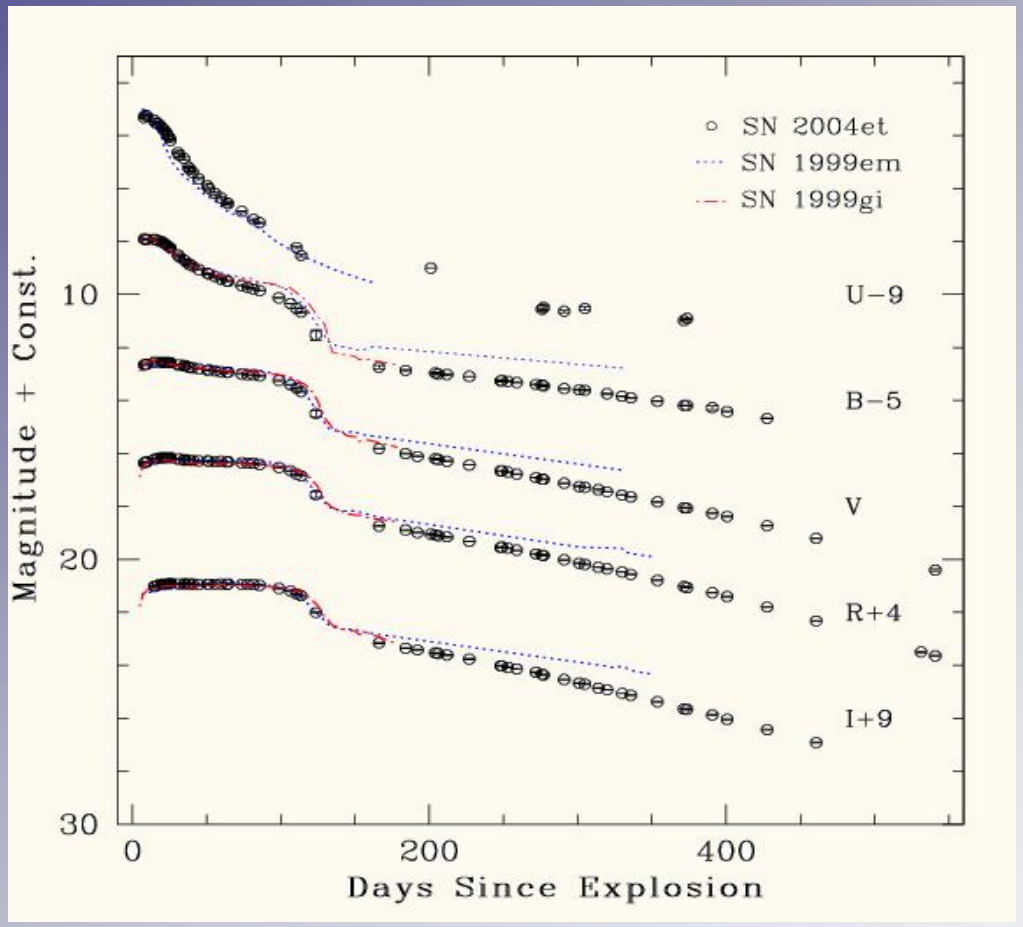


Numbered stars are the secondary standards

Observations

Photometry : Sept 29, 2004 to March 2006 (8 days to 540 days after explosion)

Spectroscopy: Oct. 16, 2004 to Dec. 2005 (25 days to 465 days after explosion)



Plateau in V, R and I bands - consequence of propagation of cooling and recombination wave

Date of explosion : Sept 22, 2004 (JD 2453270.5)

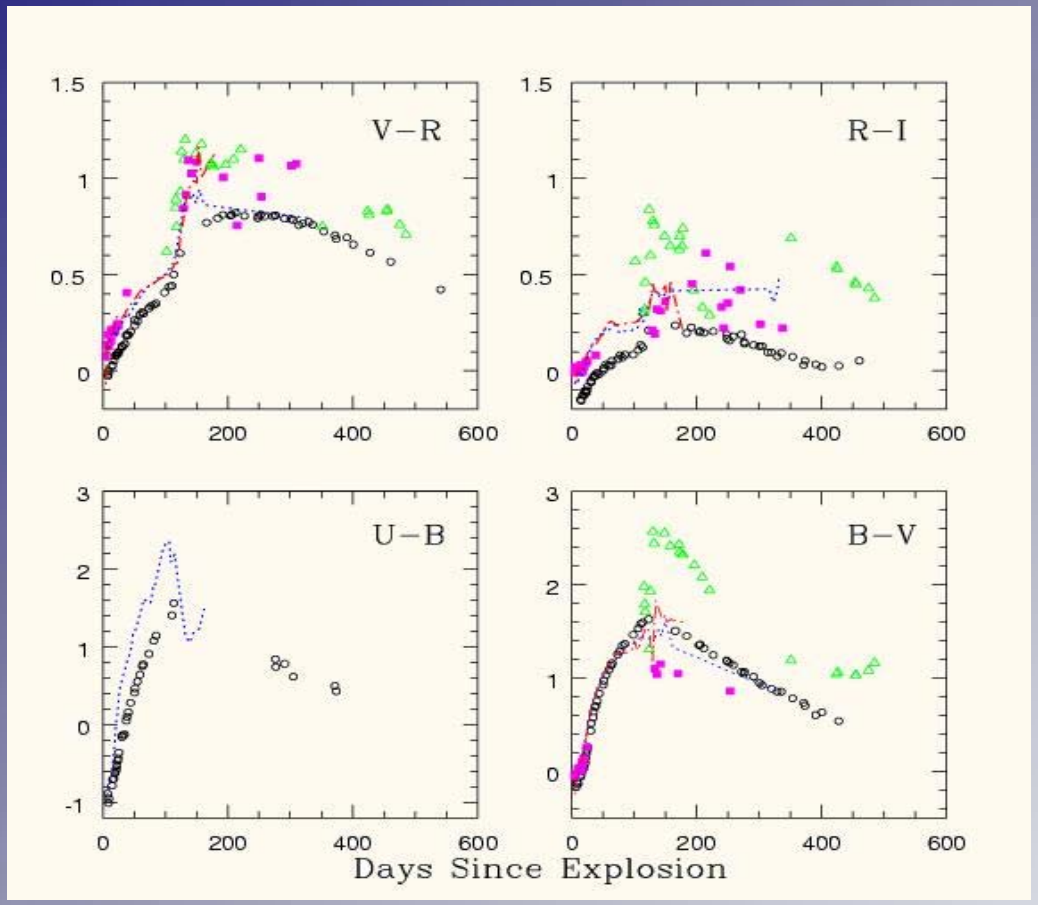
m_U(max) = 12.17±0.05 (JD 2453279.9)

m_B(max) = 12.89±0.02 (JD 2453280.7)

m_V(max) = 12.55±0.02 (JD 2453286.6)

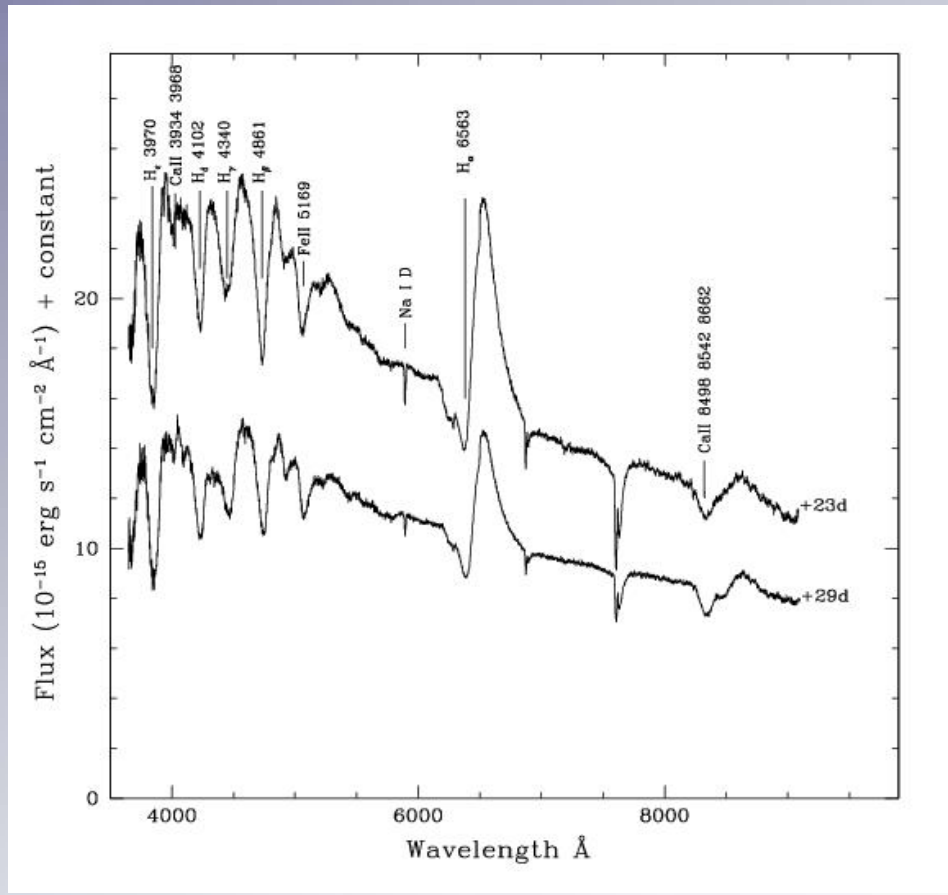
m_R(max) = 12.15±0.02 (JD

Colour Curve



Colour evolution of SN 2004et is different from SN 1999em, *U-B* and *B-V* colours of SN 2004et evolve slowly than those of SN 1999em

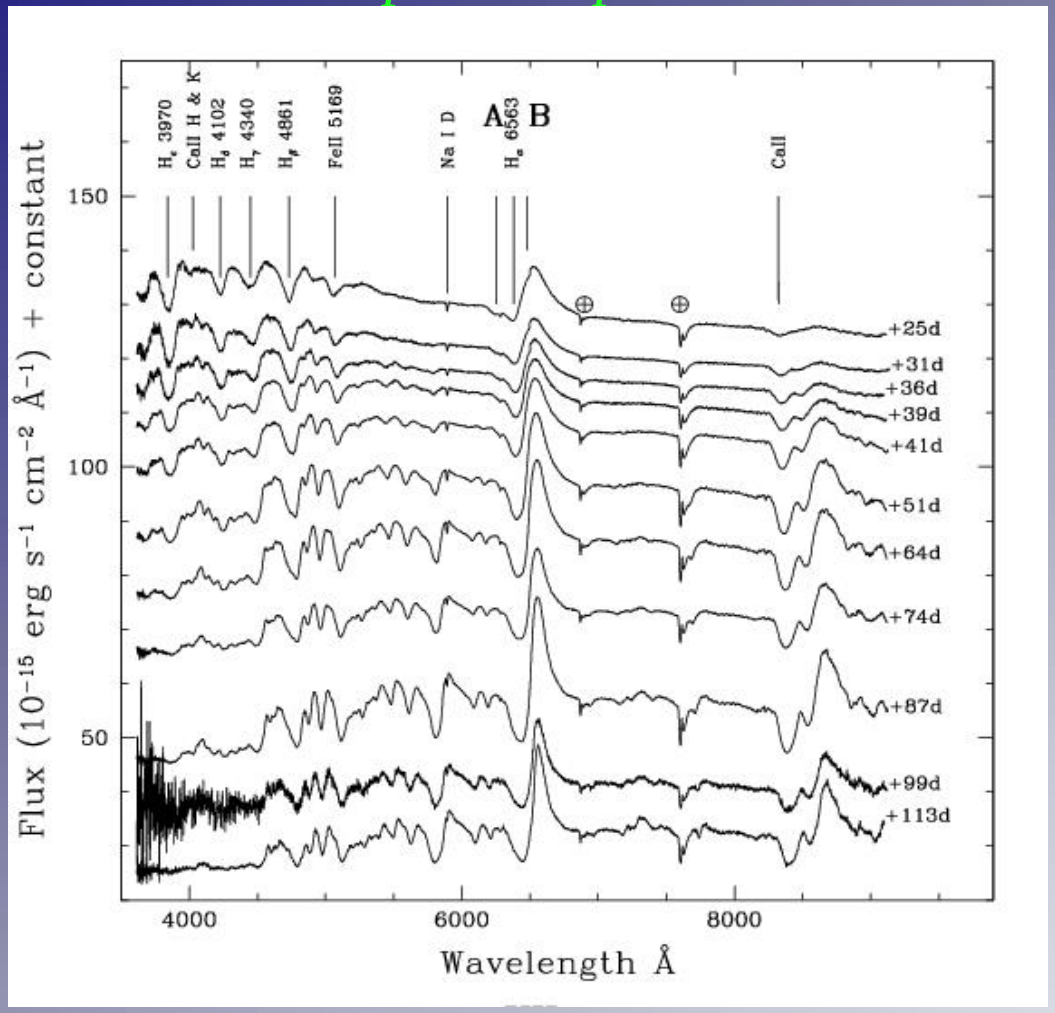
Reddening Estimate



Equiv. width of NaI D line 1.70Å
==> *E(B-V) = 0.44* (Munari & Zwitter).
High resolution spectroscopy
==> *E(B-V) = 0.41* (Zwitter et al.)

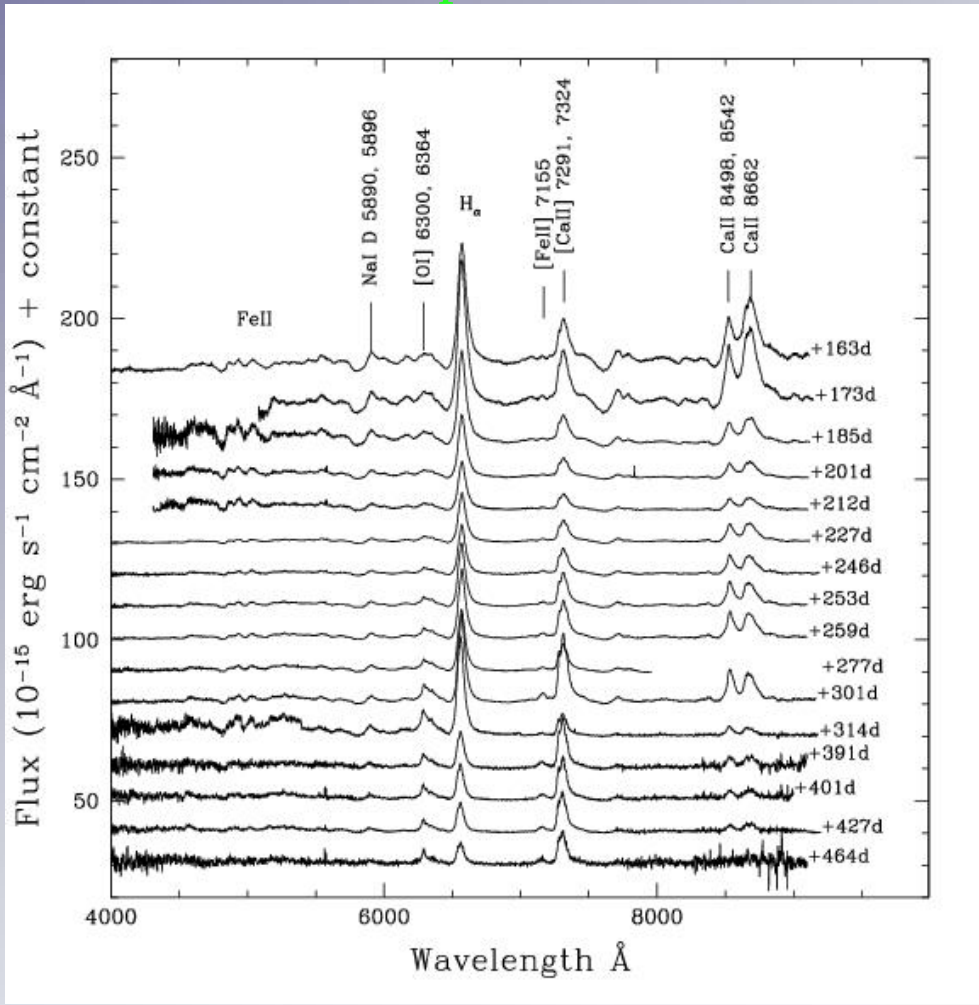
Spectroscopic evolution

Photospheric Spectra



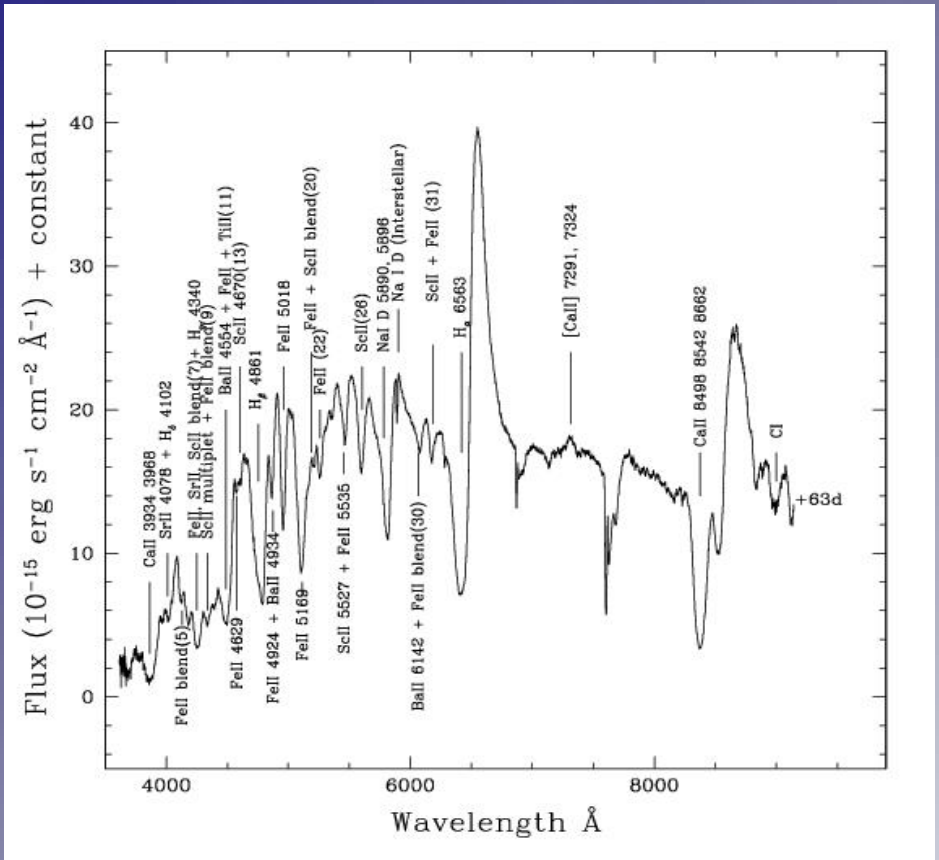
P-Cygni lines superimposed on photospheric continuum.
Two component P-Cygni profile.

Nebular Spectra

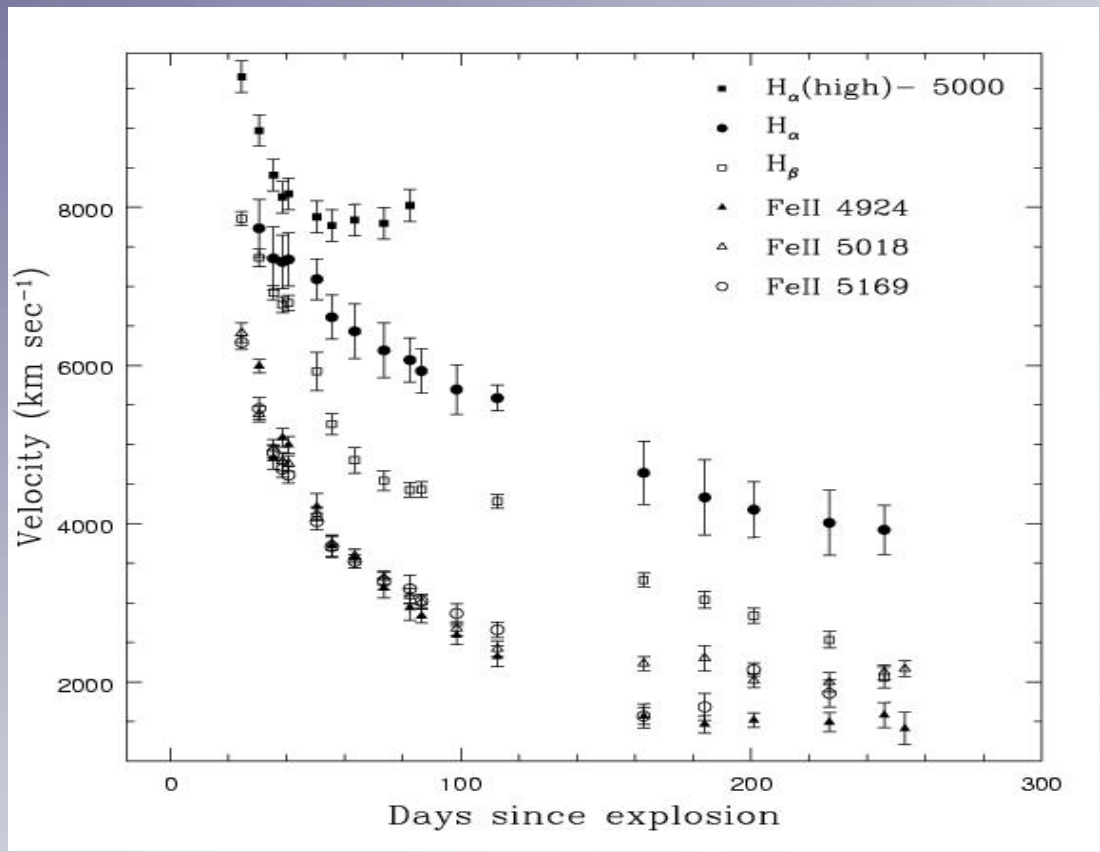


Emission dominated, nebular emission lines of [OI], [CaII] .

Line identification



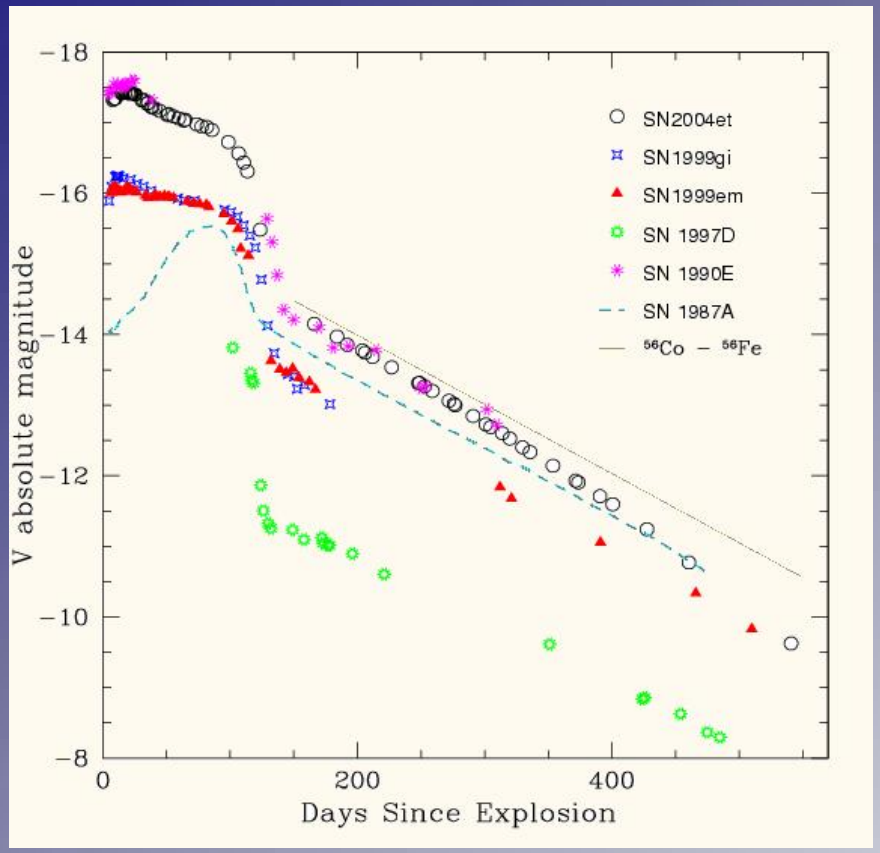
Expansion velocity



Photospheric velocity estimated using the absorption minima of FeII lines. H_alpha and H_beta gives always higher velocity.

SN 2004et has higher expansion velocity.

V absolute magnitude



Distance of SN 2004et using the Standard Candle Method (SCM) 4.8 Mpc

Expanding Photosphere Method (Schmidt et al. 1994) 5.7 Mpc
Other estimates 5.5 Mpc, 5.4 Mpc

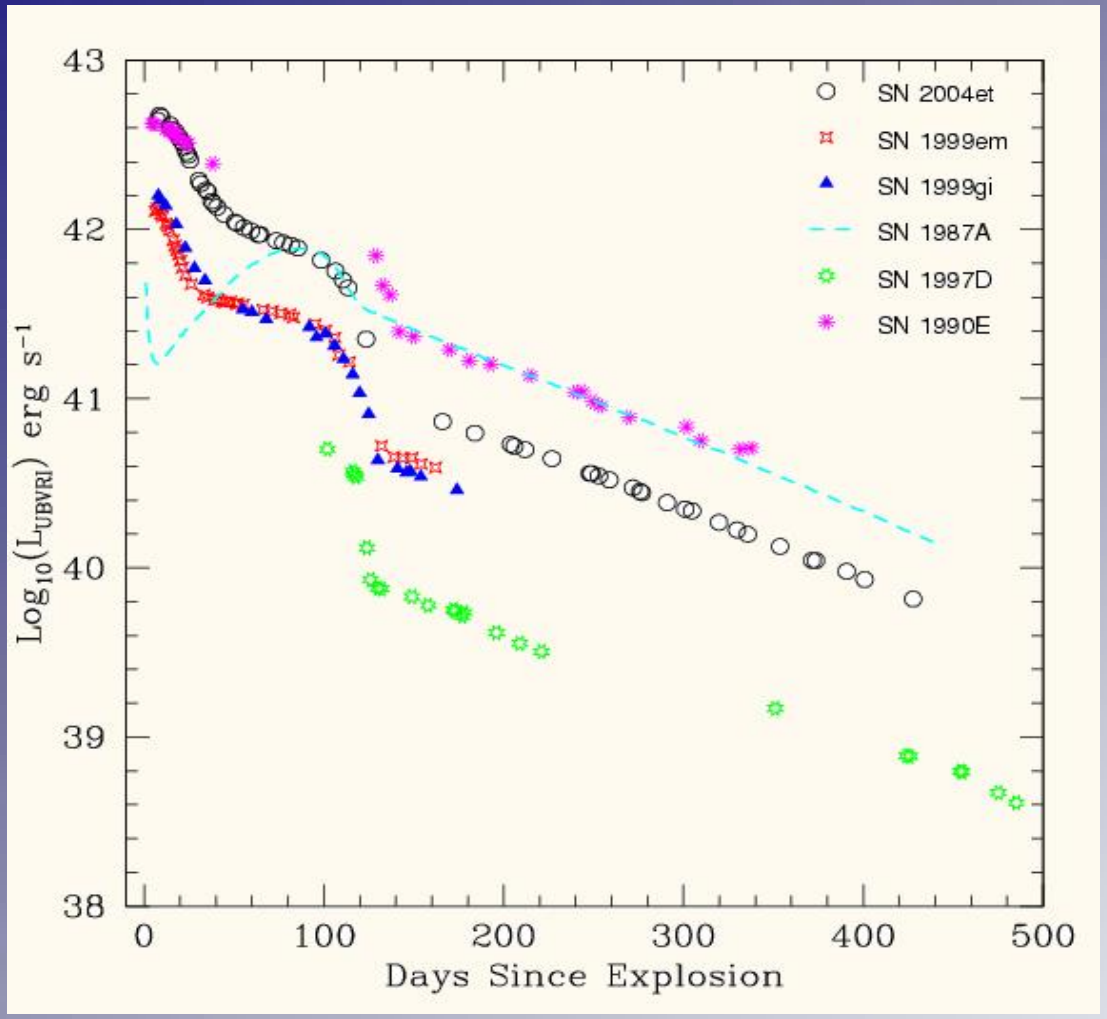
Distance used is 5.5 Mpc.

Average absolute magnitude for SN 2004et -17.10, SN 1999em -15.92 and SN 1999gi - 15.97

Light curve of SN 2004et and SN 1990E are similar.

Late time light curve is governed by $^{56}Co \longrightarrow {}^{56}Fe$ decay 0.98mag/100days
In the nebular phase the V band light curve deviates from the $^{56}Co \longrightarrow {}^{56}Fe$ decay ==> leakage of gamma-rays and/or dust formation in the ejecta

Bolometric light Curve



Optical magnitudes are converted into fluxes.

The *UBVRI* flux is integrated to get the bolometric flux

Mass of ^{56}Ni can be estimated from the late time bolometric curve

1. V magnitude in tail phase, correct for Av= 1.27 and convert V mag in bolometric luminosity

^{56} Ni mass = 0.059 ±0.02 *M_sun*

(Hamuy 2003)

2. Comparison of tail phase bolometric luminosity with that of SN 1987A, difference of log of bolometric luminosity is 0.198±0.02

^{56}Ni mass 0.048±0.01 *M_sun*

3. Photometric estimate of ^{56}Ni mass and maximum rate of decline in V band light curve from plateau to tail is anticorrelated.
(Elmhamdi et al. 2003)
Steepness parameter 0.062±0.02 ==> mass of ^{56}Ni 0.062±0.02 *M_sun*

Properties of progenitor :

Mass of the envelope thrown off *M*
radius of the star prior to the outburst *R*
energy of explosion *E*

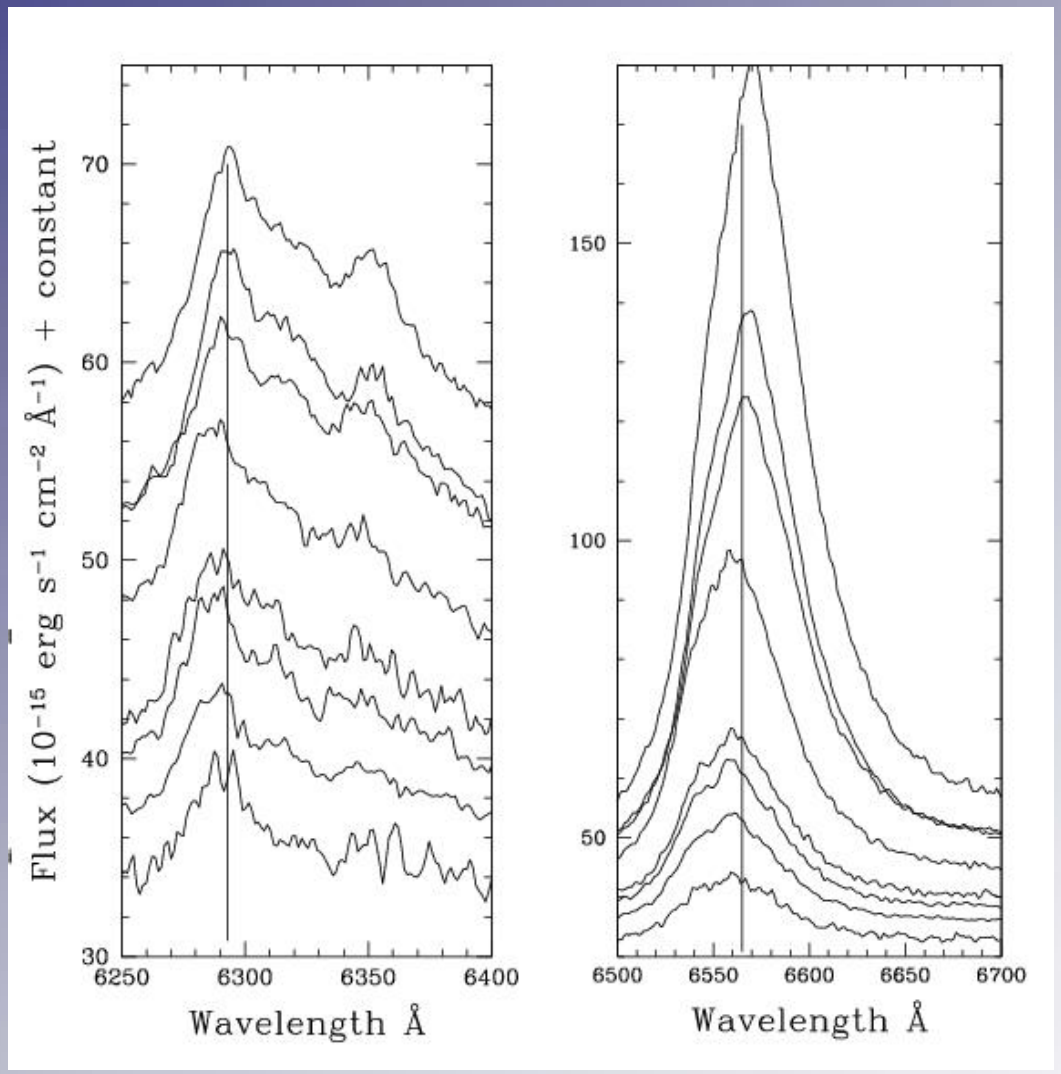
Observables – absolute magnitude *Mv* at the mid plateau,
velocity of photosphere at mid plateau and length of the plateau.
Plateau length 120±10 days;
photospheric velocity at mid plateau 3560±100 km/sec; *Mv* -17.10
Litvinova et al. (1985) relations gives

Explosion energy	1.20(±0.35) X 10^{51} *ergs*
Mass ejected during explosion	20±6 *M_sun*
Pre-supernova radius	496±80 *R_sun*
Mass of progenitor	~ 15 - 26 *M_sun*

Probable dust formation in the ejecta

Formation of dust in the supernova ejecta:

a. increases the rate of decline of light curve
b. shifts peak of optical emission lines towards blue



In SN 1987A and SN 1999em dust formation is seen ~ 400 days after explosion.

Steepening in the decline of the V band light curve ~320 days after explosion and blue shift in the emission lines indicate probable dust formation in the ejecta of SN 2004et.

Summary

1. Fast rise in the early part shows that it was caught young few days after the shock breakout.

2. Average mass of ^{56}Ni synthesized during the explosion is 0.061±0.02 *M_sun*

3. Mass ejected during the explosion ~ 20±6 *M_sun*,
   Explosion energy ~1.20(±0.35) X 10^{51} ergs
   Pre-supernova radius ~ 496±80 *R_sun*
   Mass of progenitor ~ 15 - 26 *M_sun*

4. Possible dust formation in the supernova ejecta