The Extremely Luminous Supernova 2006gy at late phases

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Introduction

SN 2006gy:

Eextremely luminous, M < -22 mag (Ofek+ 2007, Smith et al. 2007)

LC evolved very slowly (Fig 1)

Total radiation energy ~10^{51}ergs is comparable to kinetic energy of typical SNe

Suggested models:

- •Interaction between CSM and SN ejecta, analog with SNe IIn/IIa (Ofek+ 2007)
- •Radioactive decay of ^{56}Ni (> 10Msun) is primal heating source (e.g., Smith+ 2007)
  - •Pair-instability SN at extremely massive star (Smith+ 2007)
  - •Core-collapse SNe is more plausible (Umeda & Nomoto 2007)
  - •Shell collisions in pulsational pair-instability activity at massive stars (~90Msun) (Woosley+ 2007)

→ Explore this unusual SN by Subaru late, optically-thinner phase observation

Observation and Data Reduction

Subaru 8.2m telescope + FOCAS:

2006 Dec 25.4 (127 d) and 2007 Jan 24.4 (157 d)

R~3600 spectroscopy with VPH650 grism, 1200sec exp.

V- and R-band imaging photometry

2007 Sep 18.5 (394 d)

R~660 spectroscopy with B300 grism, 1200sec exp.

V- and R-band imaging photometry

This SN is close to bright nucleus (<1") of the host galaxy.

Underlying galaxy component is carefully subtracted.

Lightcurve Analysis

In Fig.1 we plot LC of SN 2006gy compared with bright type Ic SN 1998bw, SNe IIa 2002ic and 1999el (Patat+ 2001; Deng+ 2004; Di Carlo+ 2002)

Decline rate between 200d and 400d:

Faster than that of SN 2002ic and ^{56}Co decay line

Comparable to SN 1998bw

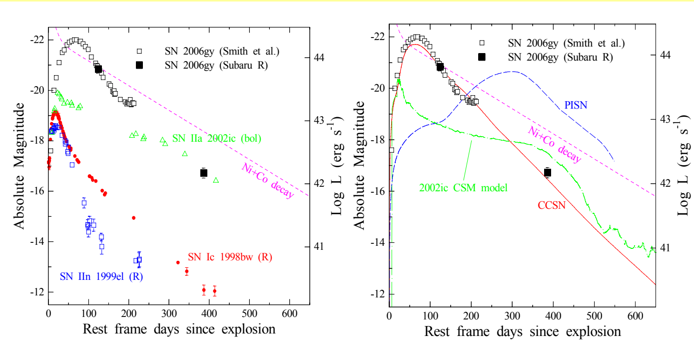


Fig 1. (Left) Absolute R-band light curve of SN 2006gy compared with various typs of SNe. (Right) Compared with core-collapse SN and pair-instability SN LC models.

Lightcurve Analysis (continued)

Decline rate at late phase (Fig 1, right panel). :

- •56Ni-56Co decay model with M_{ej}=53Msun, kinetic energy=64 × 10^{51}erg and M_{Ni}=15M_{sun} reasonably explains the LC including late phase (200-400d)
- •Woosely et al (2007) also gives a good agreement in LC with their model (see Introduction).
- •Diffusion model by Smith & McCray (2007) is inconsistent

→ Decline rate at late phase is consistent with the radioactive heating cases, but we cannot exclude some kinds of CSM interaction models like SNe IIa/IIn.

Spectral Analysis and Discussion

In Fig. 2a and Fig. 2b we plot the observe spectra.

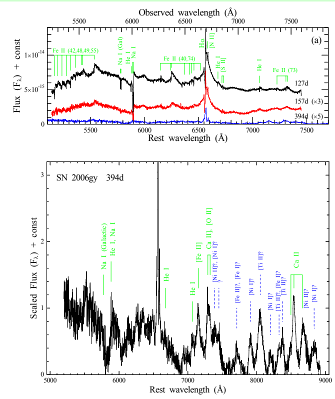
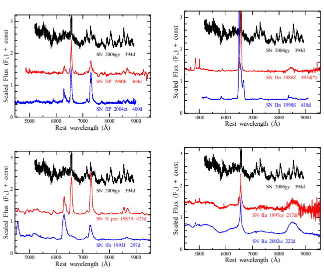


Fig 2a (upper): Higher resolution spectra on 127d an 157d.which is characterized by many lines with P Cyg type profiles. Fig 2b (lower): Late phase (394d) spectrum. There are some unidentified lines at 7000-9000A, some of them would be from Ni or Fe.

The early phase (127d, 157d) spectra are characterized by structured H-alpha emission line (accompanied with broad blue absorption ranging up to ~-3000 km s^{-1}) as well as FeII, He I and Na I D lines. Forbidden lines [N II] and [S II] appears between 96d and 127d. At 394d the H-alpha emission line has been narrowed (<500km s^{-1}). Na I D line still has a broad absorption with a Doppler shift of ~3000 km s^{-1}.



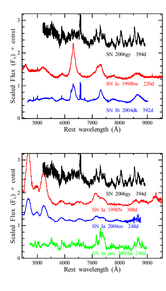


Fig 3a (upper left) Comparison with SNe IIP 1990E and 2004et and peculiar II 1987A and SN IIb 1993J (Gomez & Lopez 2000; Sahu+ 2006; Pun+ 1995; Barbon+ 1995). Fig 3b (upper tight) with SNe IIn 1988Z and 1998S and SNe IIa 1997cy and 2002ic (Turatto+ 1993; Pozzo+ 2004; Germany+ 2000; Turatto+ 2000). Fig 3c (lower) with SN Ic 1998bw and SN Ib 2004dk and SNe Ia 2004eo and 1998bu (Patat+ 2001; Maeda+ 2008; Deng+2004)

Figure 3a-3c we compare the late phase spectrum with various types of SNe. Unlike SNe IIP and SNe Ib/Ic, SN 2006gy does not show strong [O I] 6300, which is consistent with outer layer emitting SNe IIn.

In case that the SN is powered by decay of 56Ni, weakness/absence of [O I] suggests that the ejecta is less massive, which seems inconsistent with the decay model (needs large amount of ^{56}Ni; Umeda and Nomoto 2007) and slow evolution of LC (suggesting massive ejecta). Fe lines are not so strong.

→Favors CSM interaction model, but possible existence of narrow Fe and Ni lines would contradict to CSM model. Still misterious.