近傍に現れた特異なIa型超新星 SN 2019mujの可視・近赤外線観測

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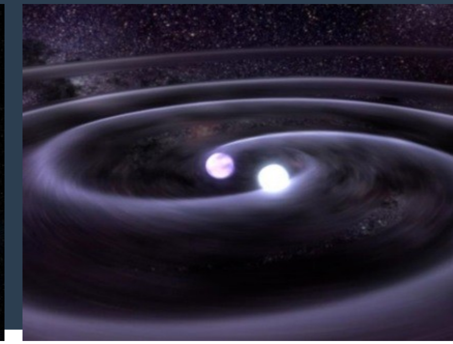
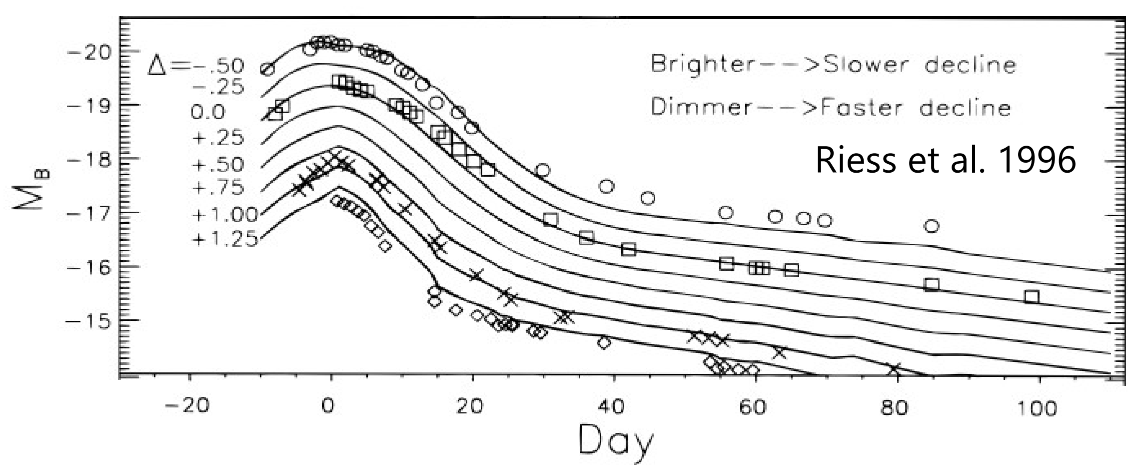
Type Ia Supernovae

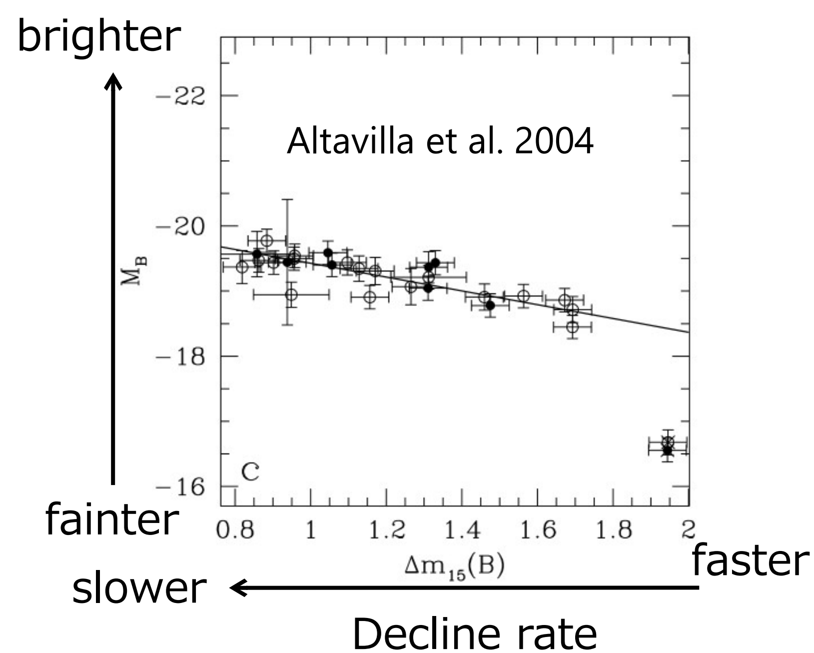


- When a white dwarf (WD) in a binary system gains mass and it approaches the Chandrasekhar limit mass (~1.4 M)
  → thermonuclear runaway

$$^{56}Ni \rightarrow {}^{56}Co \rightarrow {}^{56}Fe$$

γ線+陽電子　γ線+陽電子



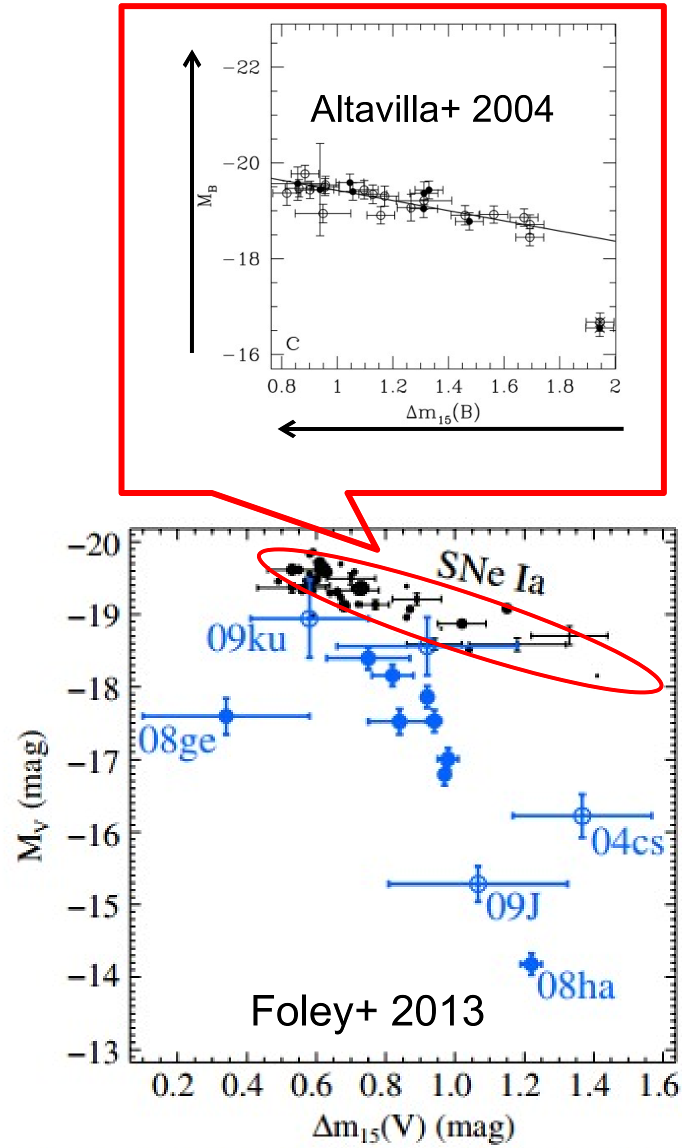


- Tight correlation between the peak luminosity and following decline rates.
  → Utilized for distance measurements of remote galaxies.

Type Iax Supernovae

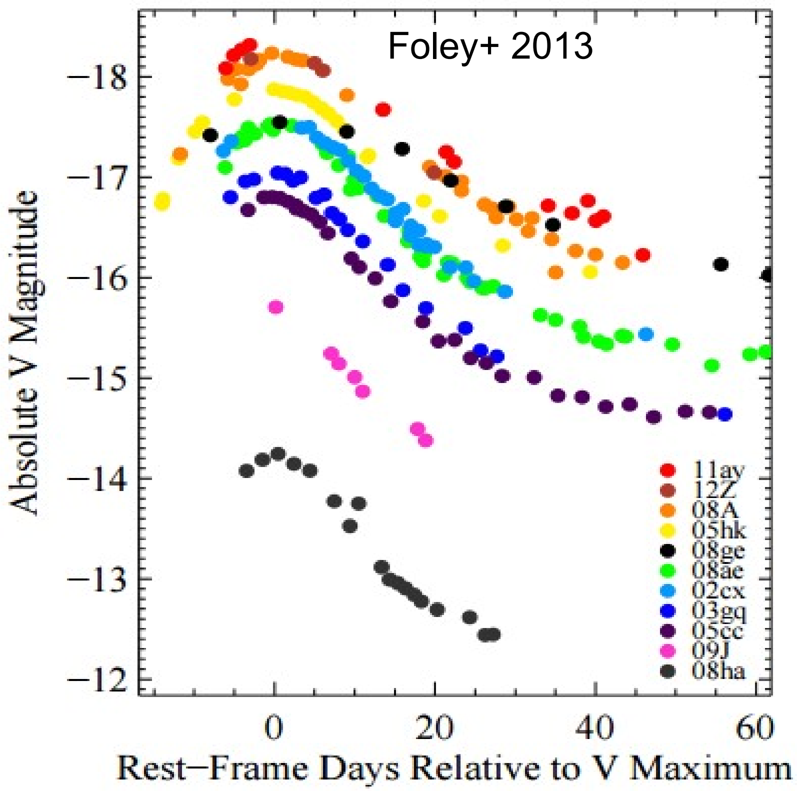
- For some SNe Ia, the decline rate
  is similar; while, the peak luminosity is
  too faint (>~1 mag)
  → SN 2002cx-like SNe, Type Iax Supernovae

- Other characteristics of SNe Iax
  Expansion velocity is slow
  → 2000 ~ 8000 km/s @ maximum
  Early phase spectra show blue continuum
  → higher temperature photosphere

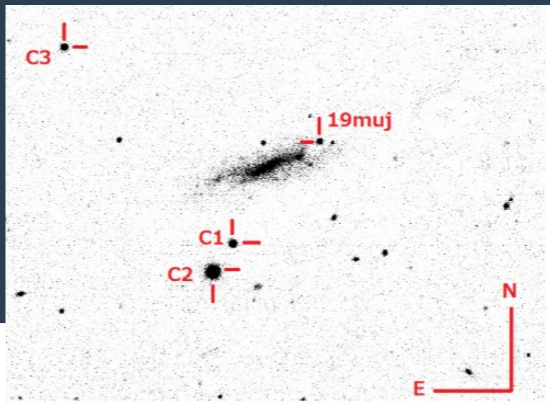


Type Iax Supernovae

- Some explosion models are suggested, and still under debate.
- Some varieties in Ni mass and explosion energy.
- Observation samples are still small, the understanding is delayed.
- Weak deflagration of a Chandrasekhar-mass WD → WD could not gain sufficient kinetic energy to exceed the binding energy, leaving a bound WD remnant after the explosion.



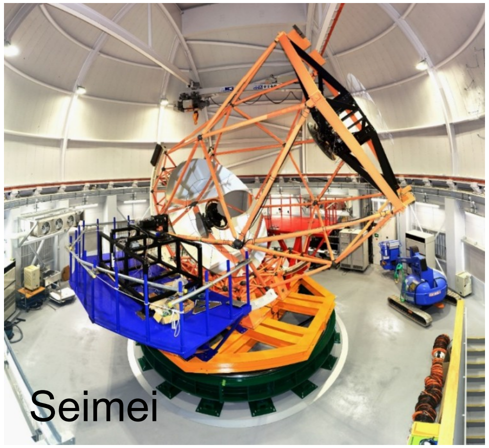
Observations

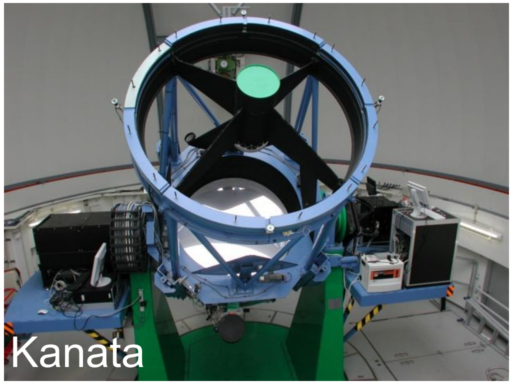


- Host galaxy : VV 525 (31.2Mpc)
- Discovery : 2019 Aug. 7.4 UT (Brimacombe et al. 2019)

- 3.8m Seimei telescope (Kyoto Univ.)
  Optical spectroscopy (4000 ~ 9000 Å,
  R = 500 @ 6000 Å)
- 1.5m Kanata telescope (Hiroshima Univ.)
  Optical / NIR Photometry (BVRIJHKs-bands)
  Optical spectroscopy (4500 ~ 9000 Å,
  R = 400 @ 6000 Å)
- Swift/UVOT
  UV/Optical Photometry

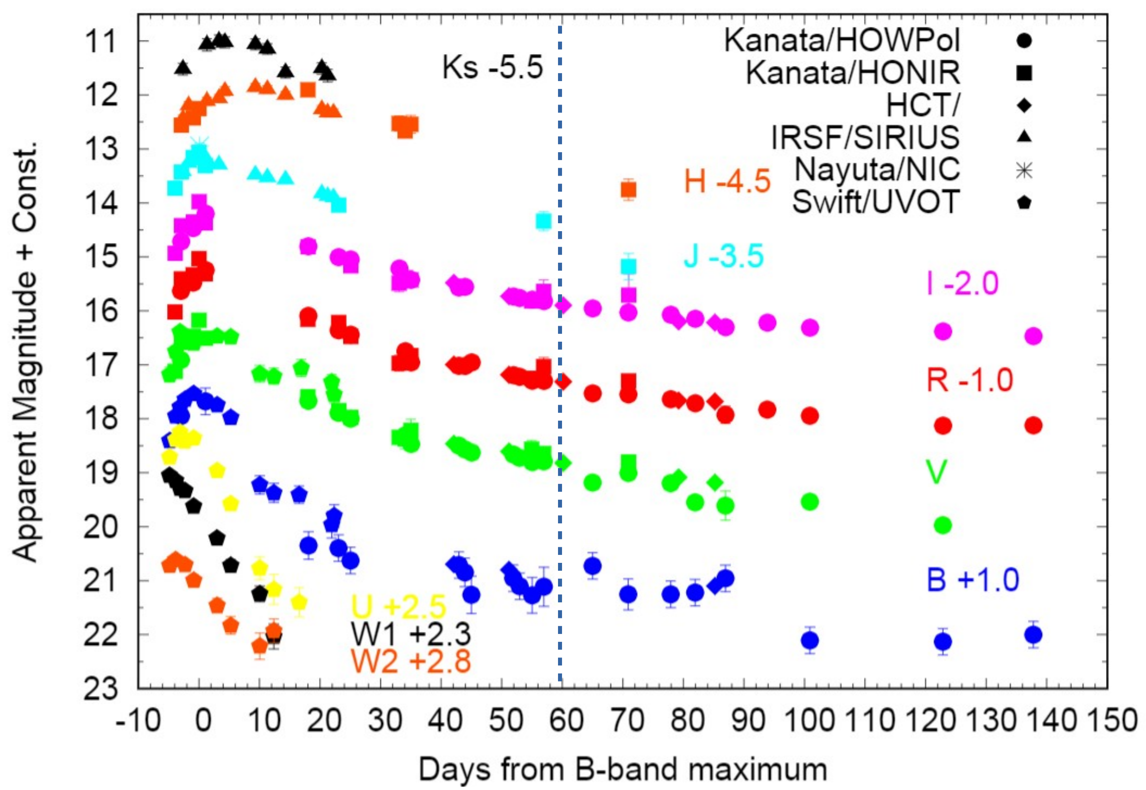
- OISTER ToO

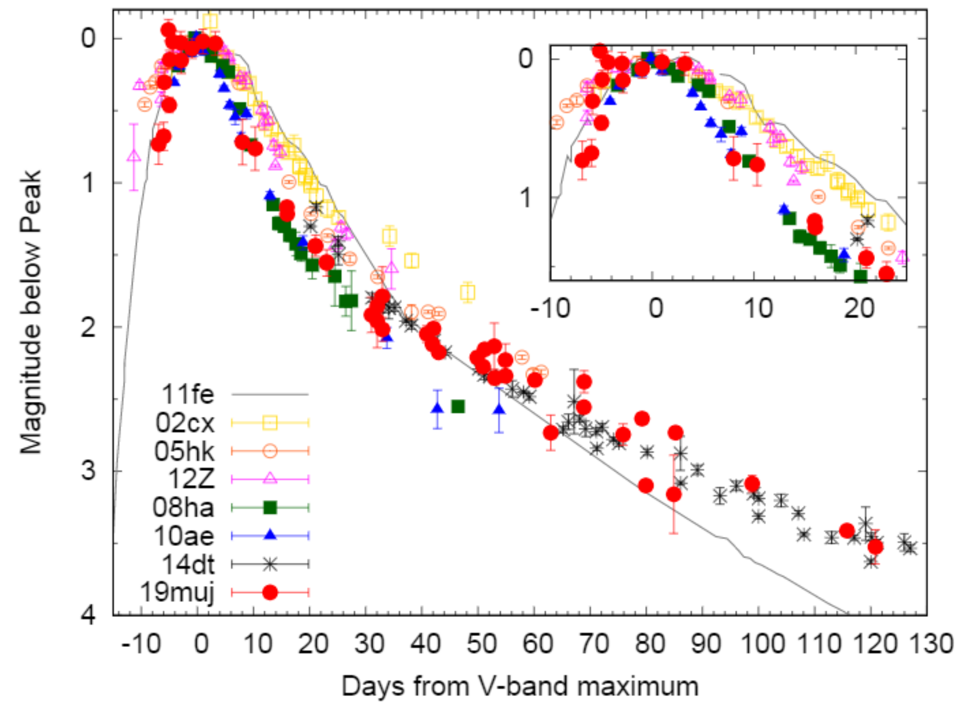




Light Curves

- Successfully obtained long-term light curves
- Early phase : faster light curve evolution
- Late phase : slow decline rate



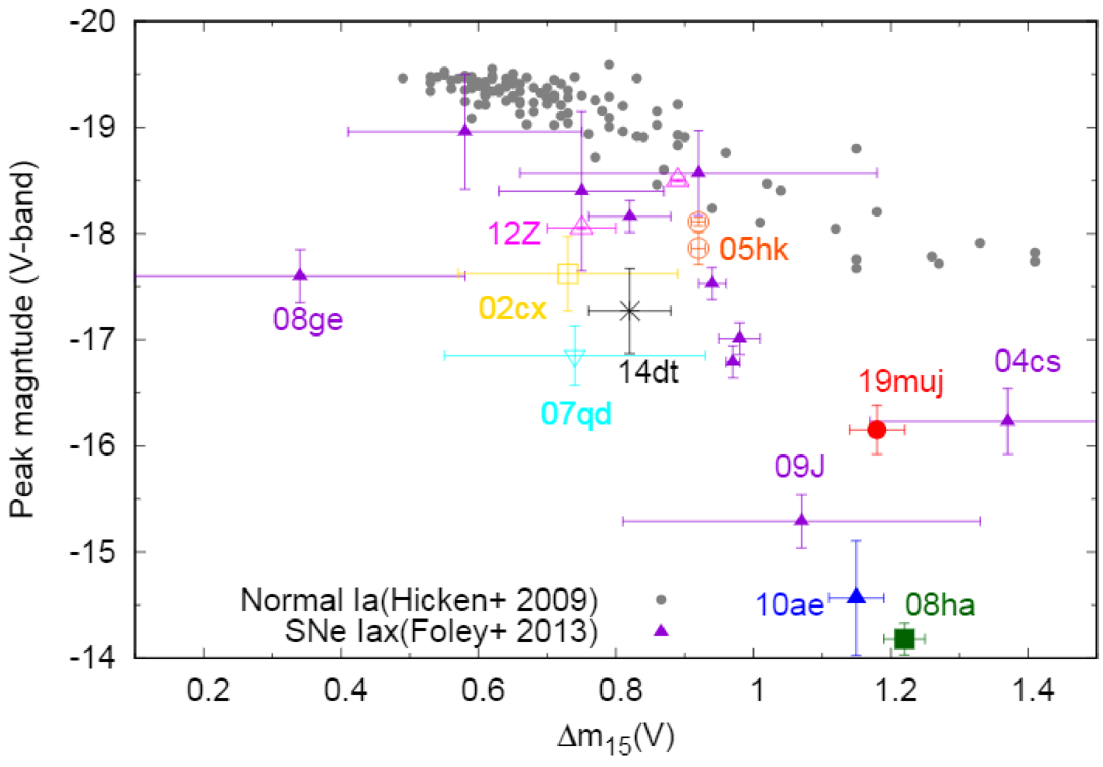


Light Curves

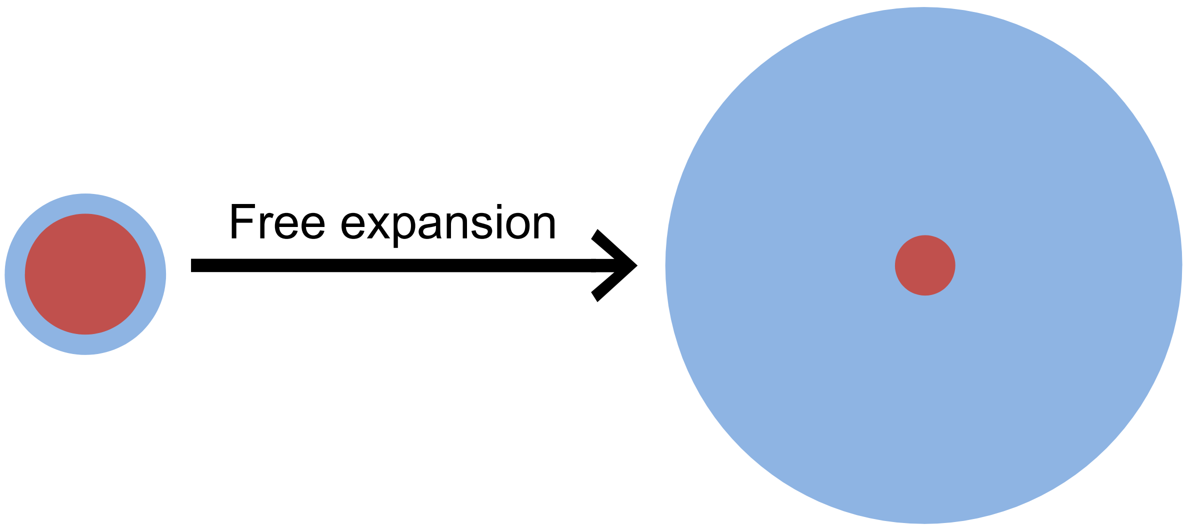
- Peak luminosity v.s. decline rate in the V-band

- SN 2019muj
  intermediate-luminosity SN Iax

- Bright SNe Iax (e.g., SN 2005hk)
- Faint SNe Iax (e.g., SN 2008ha)
  → single class?
  two distinct subclass?



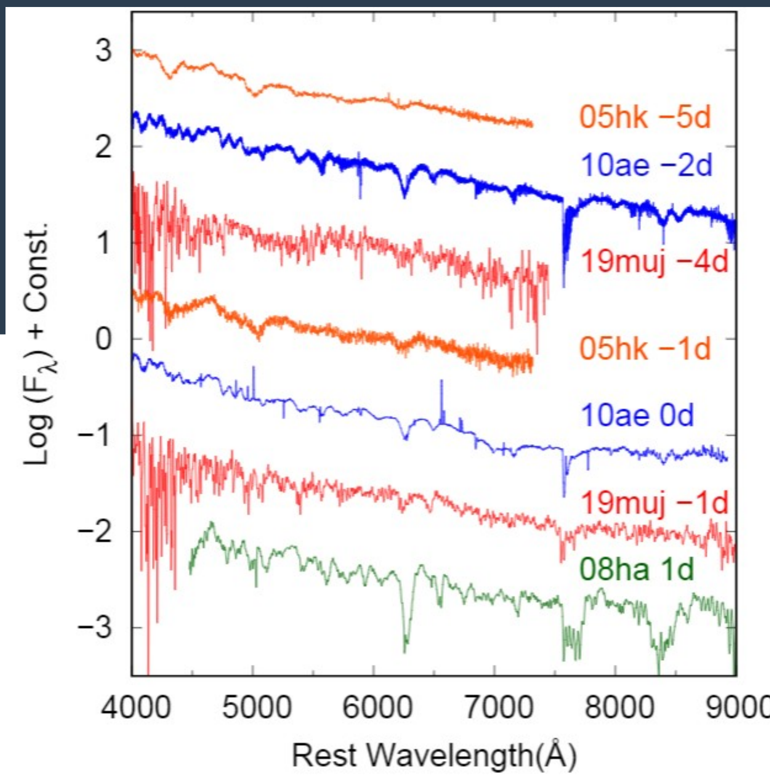
Spectral Evolution

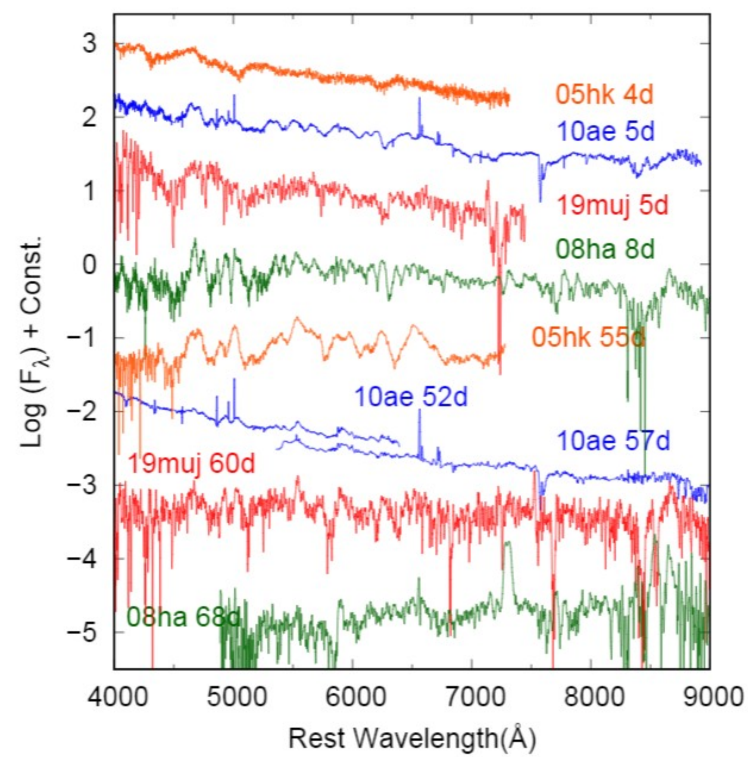


- Early phase
  Si II, S II, Fe II and Ca II IR triplet

- Si line : 4000 ~ 5000 km/s @ maximum

- Middle phase
  Na I D, Fe II, Fe III, Co II and Ca II IR triplet



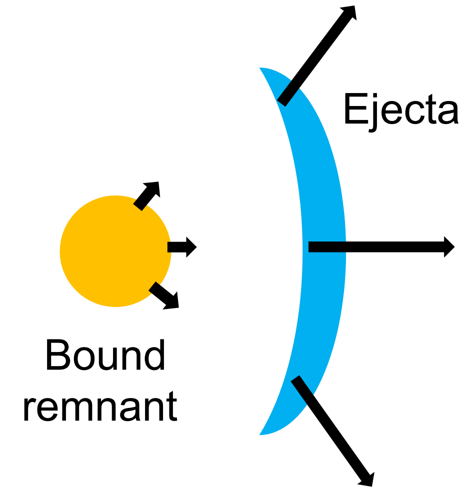


Bolometric Light Curve

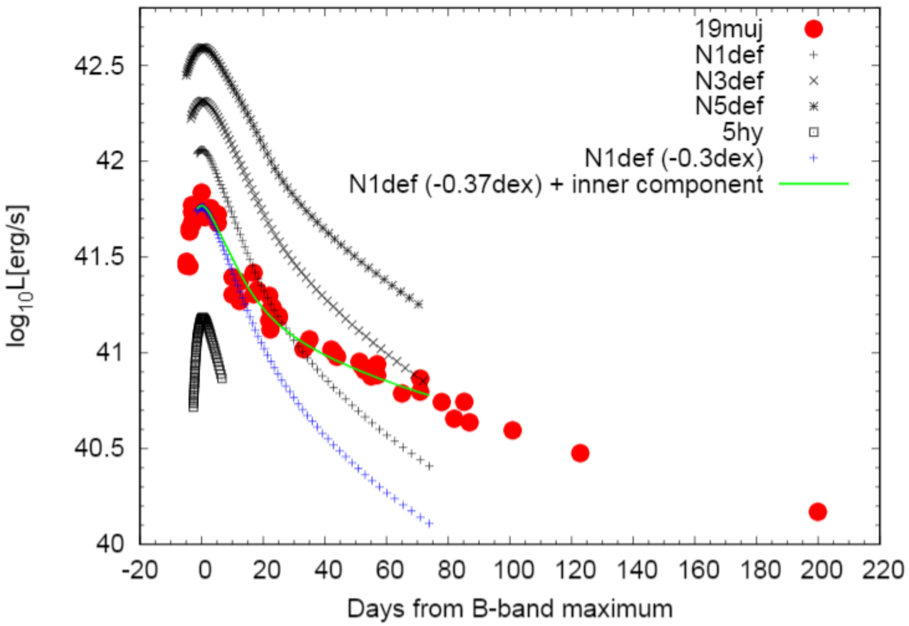
Fit a semi-analytic light curve model (two component model; Maeda+2010)
→ successfully reproduce the bolometric light curve from near maximum to ~130 days

$$L = M(^{56}Ni)e^{(-t_d/113\mathrm{d})}[\epsilon_\gamma(1-e^{-\tau})+\epsilon_{e^+}]$$

$$\tau = 1000 \times \frac{(M_{ej}/M_\odot)^2}{E_{51}} t_d^{-2}$$



- M_Ni : ~ 0.02 M
- E_kin : 0.2 – 0.12 * 10^50 erg
- M_ej : 0.2 – 0.62 M



Bound WD remnants in all SNe Iax?

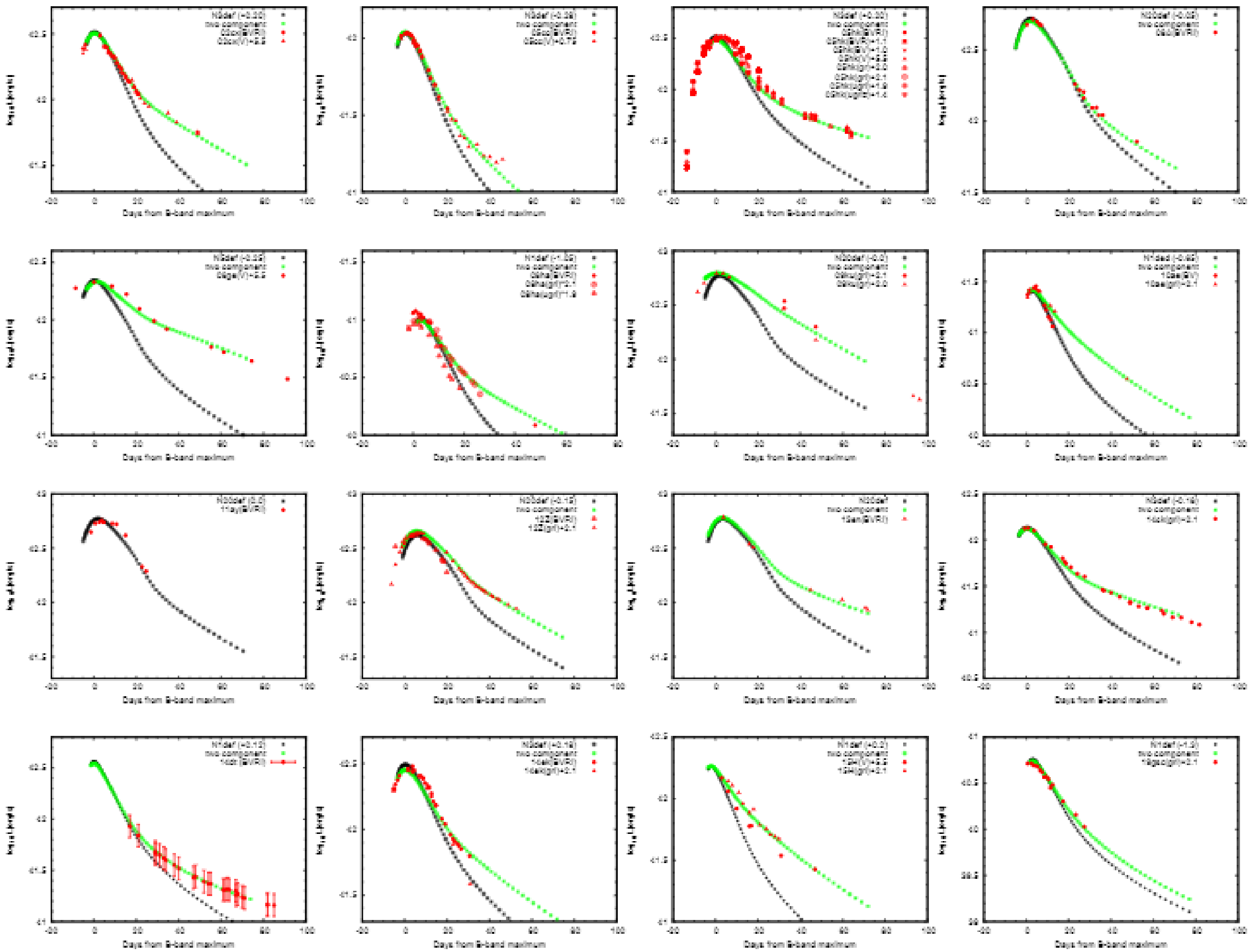


Fig. 13. Bolometric light curves of SNe Iax (red points). We compare the weak deflagration model light curve (black points; Fink et al. 2014). The black points are shifted to fit the peak luminosity of each SN Iax. The green points are the two-component model as the sum of the weak deflagration model and the simple radioactive-decay light curve model (see §4.3).

Summary

- Long-term observation of peculiar SN 2019muj up to 140 days after the maximum

- Fast decline in the early phase
- Slow expansion velocity
  → Intermediate-luminosity SN Iax

- Light curve analyses
  Successfully reproduce by two component model

- Low density component & high density component
  → Consistent with the predictions of the weak deflagration model,
  leaving a bound white dwarf remnant after the explosion.