Multicolor light curves of electron-capture supernovae

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Outline

- Introduction
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  - Electron-Capture Supernovae
- Theoretical light curves of ECSNe
  - Observable features
  - Pulsar contribution
- Comparisons with possible ECSNe
  - SN1054 (Crab SNR)
  - SN2008S

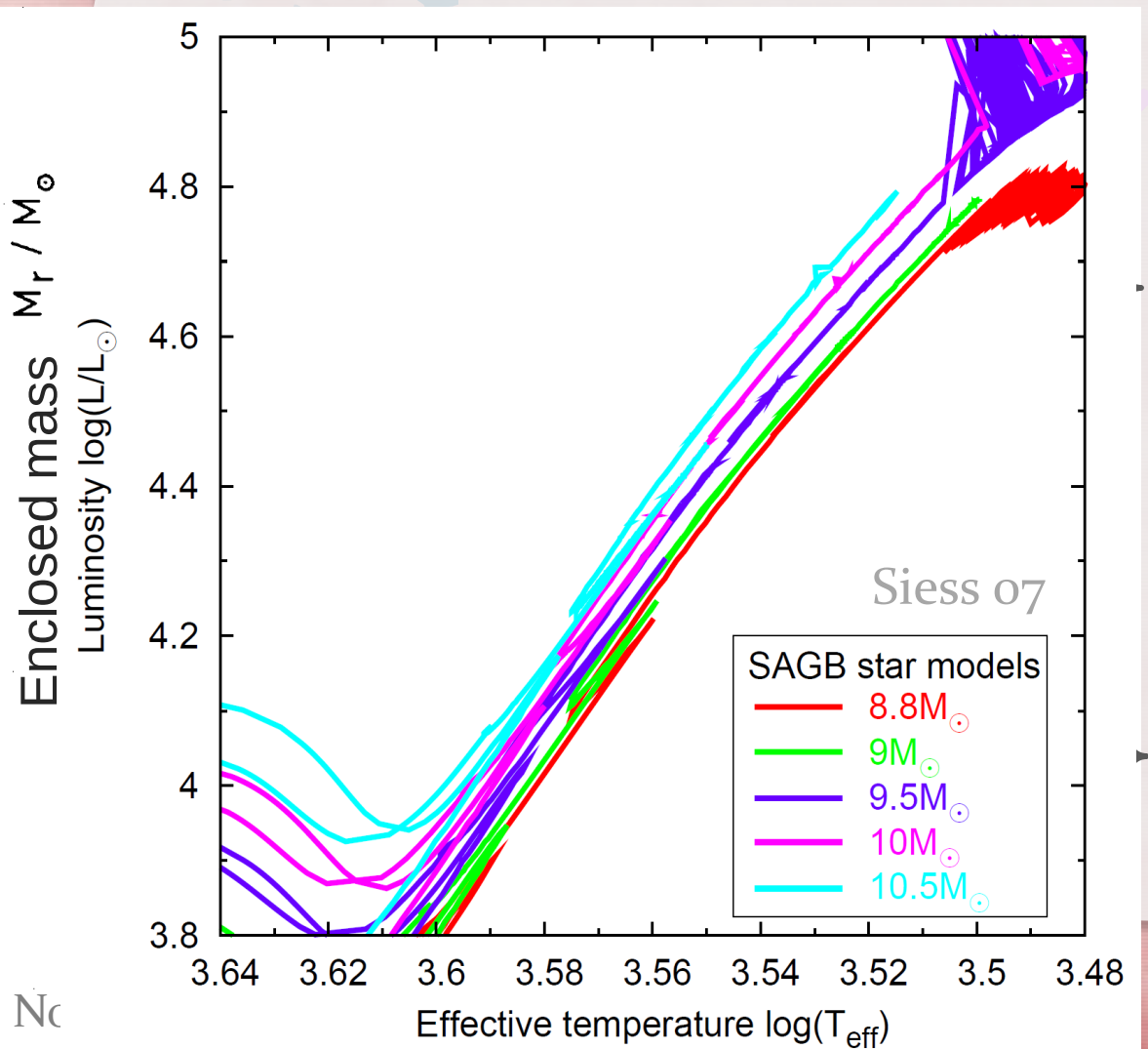
Introduction

Please refer Mr. Jones' talk, Mr.Takahashi's poster.

Super AGB star w/ ONeMg core

Typical mass range: ~8-10$M_\odot$

Siess 07
Poelarends+08
Jones+13
Takahashi+13



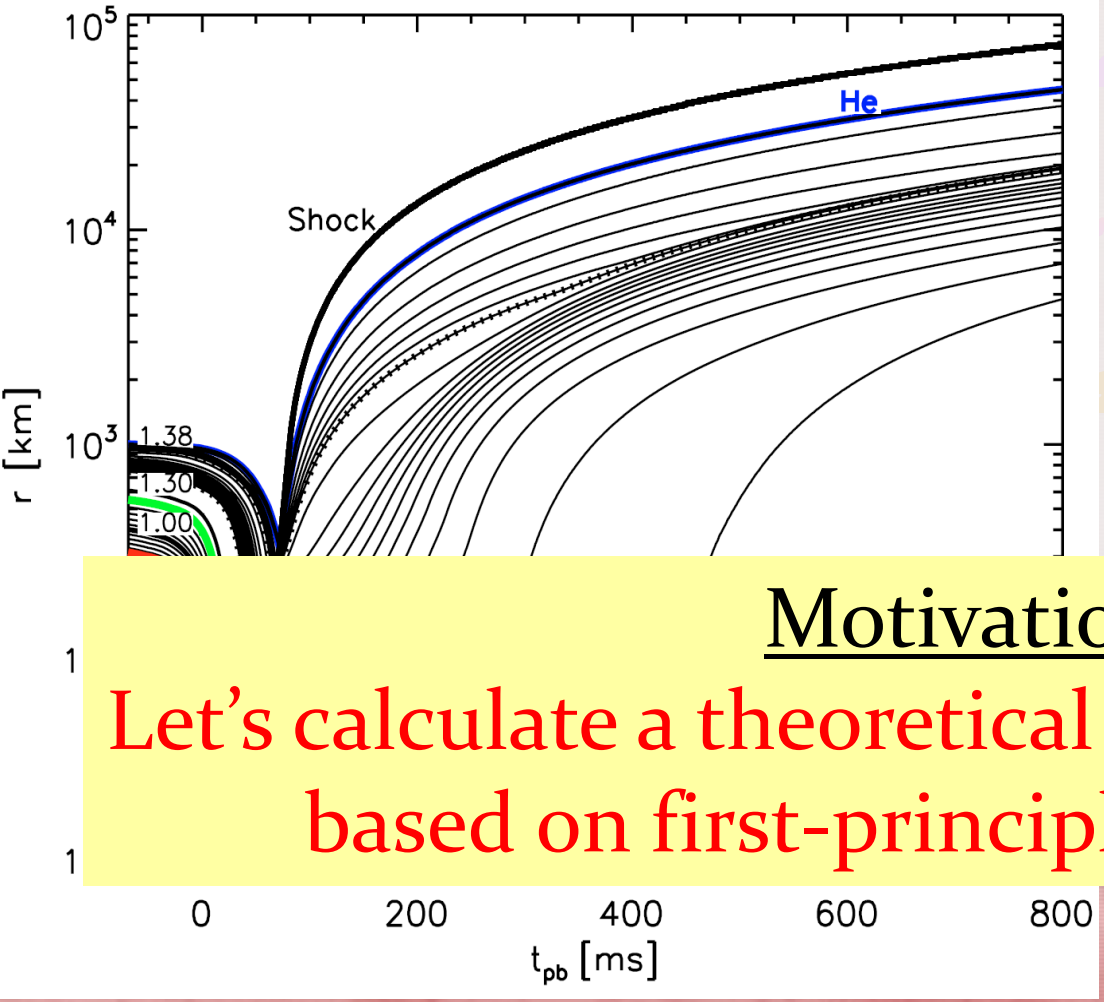
- He-rich envelope
  X(He)~0.8-0.7
- Strongly degenerated
  O+Ne+Mg core

Please refer Tuesday morning session.

Electron capture supernovae

Successful explosion in 1D!!

Kitaura + 06
Burrows+07
Janka + 08
Wanajo + 09,13a,b



Explosion properties

Low explosion energy

$E \sim 1.5 \times 10^{50}$erg

Neutron star

$M_B \sim 1.36 M_\odot$

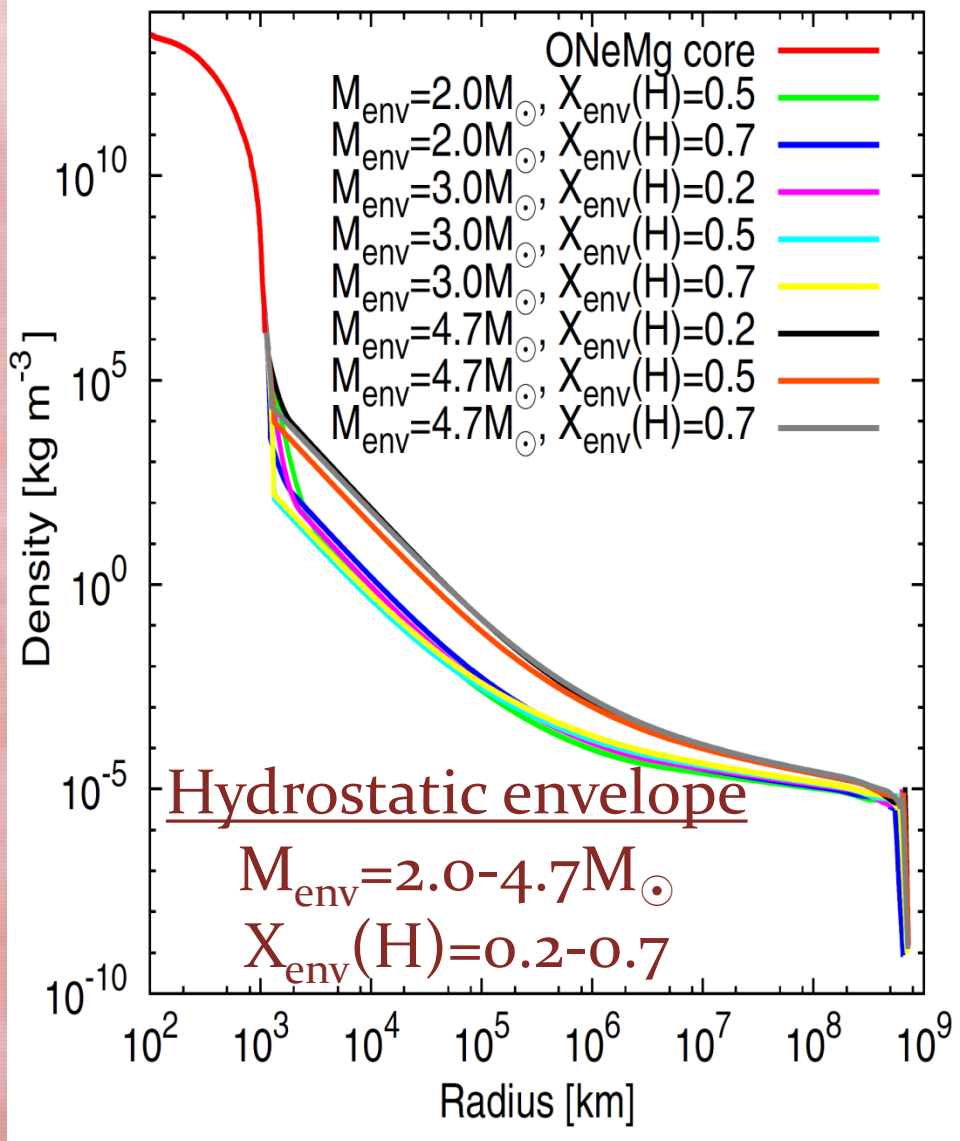
Motivation

Let's calculate a theoretical light curve of ECSN based on first-principle simulations.

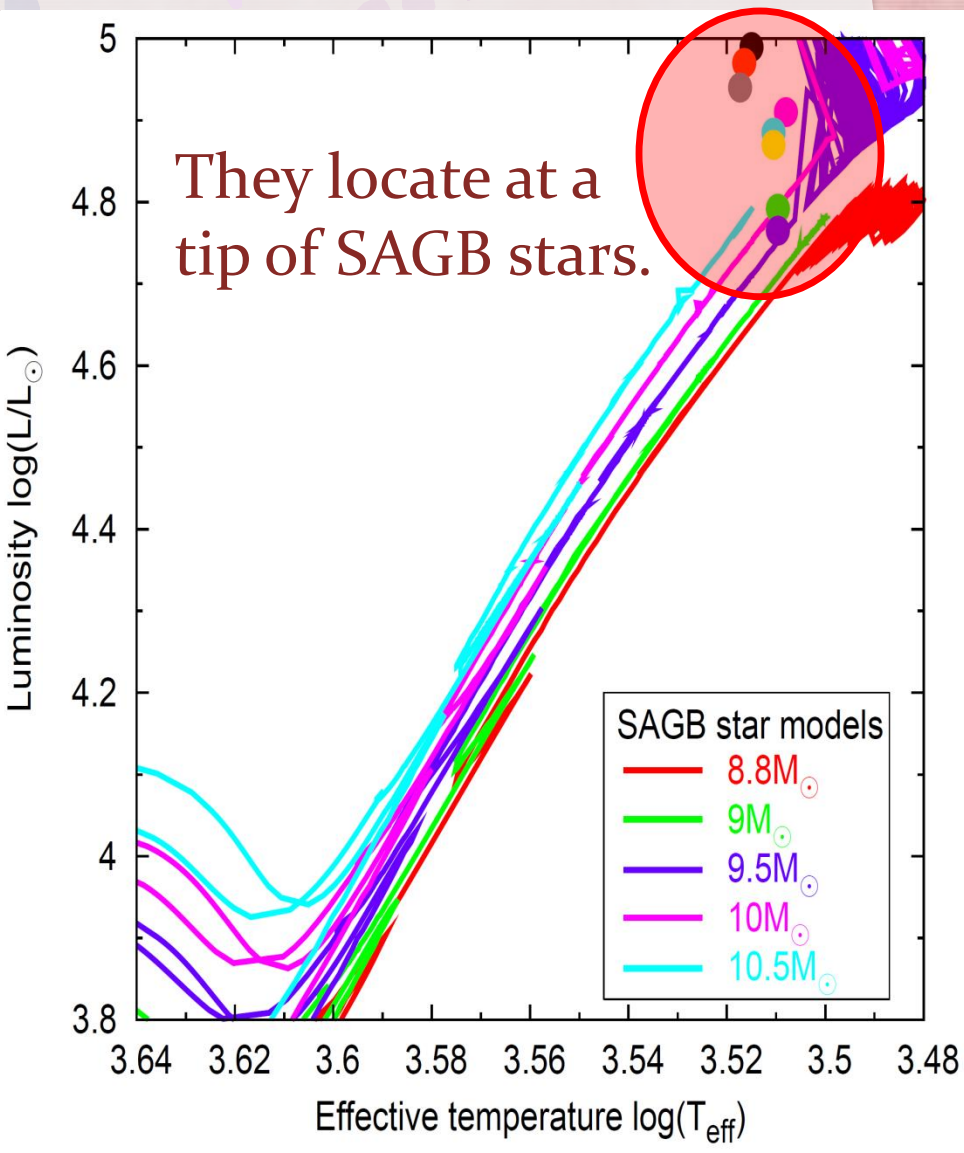
Theoretical light curves

Progenitor models

Density structure



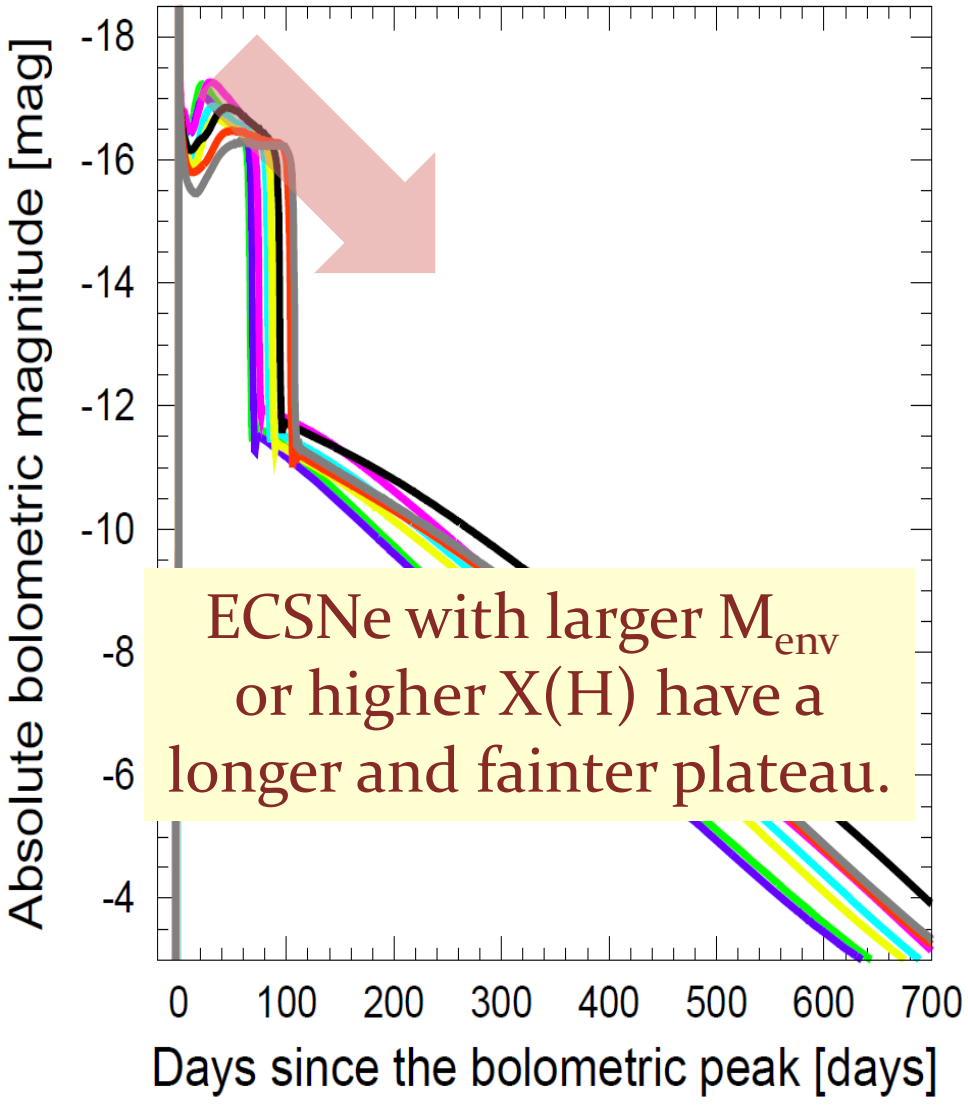
HR diagram



Light curves

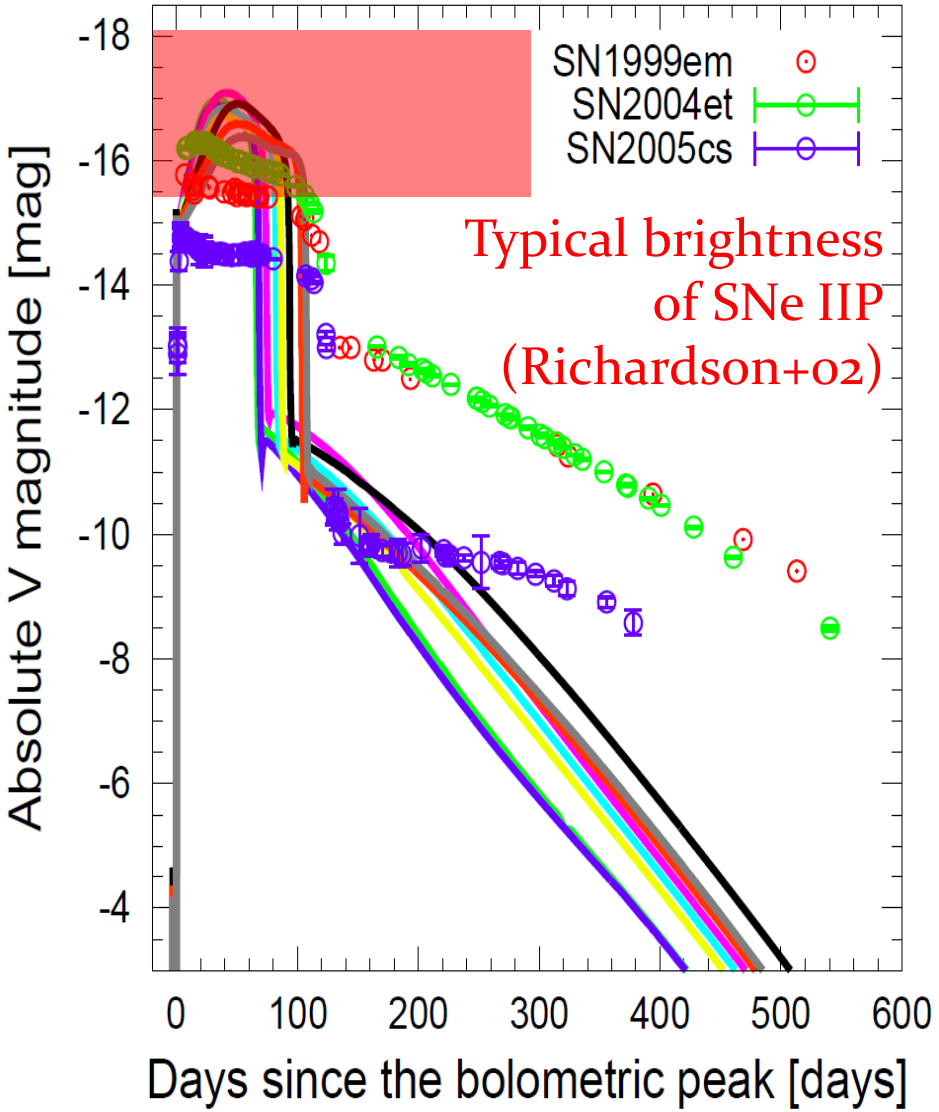
(adopted STELLA, Blinnikov+98,00,06)

Bolometric LCs



ECSNe with larger M_{env} or higher X(H) have a longer and fainter plateau.

V-band LCs



Observational features
-how to distinguish ECSNe from Fe-CCSNe-

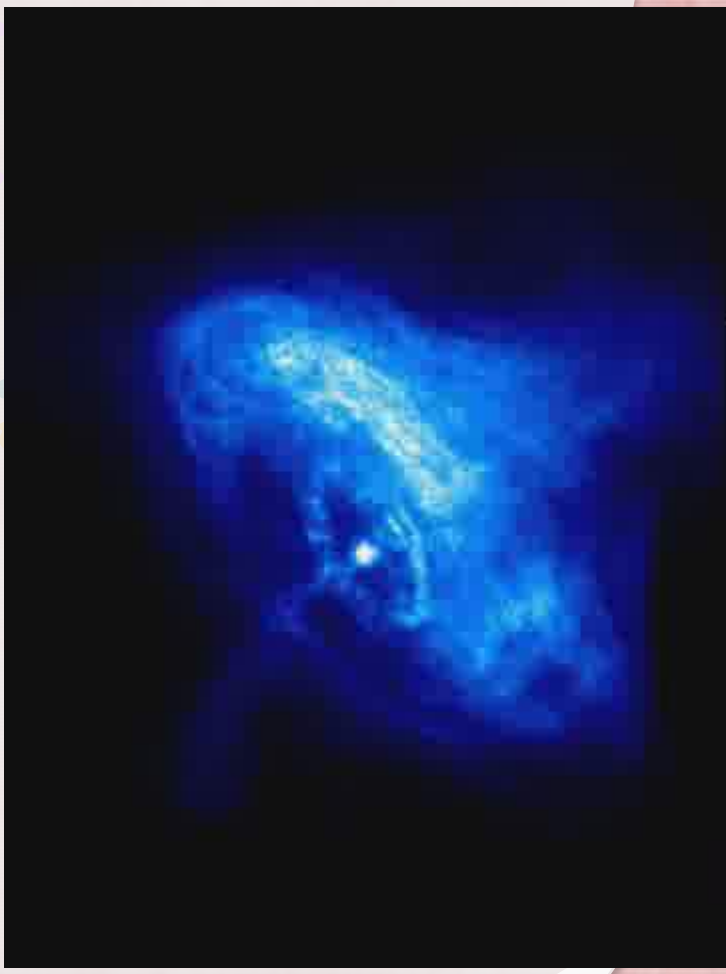
- Plateau
  - slightly short duration: 60-100 days (~100day)
  - slightly slower photospheric velocity:
    $3\text{-}4\times10^{3}$ km s^{-1} (~$3\text{-}6\times10^{3}$ km s^{-1})
    (faint Fe-CCSNe: ~$1\text{-}2\times10^{3}$ km s^{-1})
  - similar brightness: $L\sim10^{42}$ erg s^{-1}
- Tail
  - fainter: $M_{bol}\sim$ -11mag at the beginning (~13mag)
    Luminosity drops by ~4mag.

Pulsar contribution

- ECSN is a NS-forming SN.
- Crab pulsar (Hester 2008)
  - $L_{sd} \sim 5 \times 10^{38}$ erg s^{-1}
  - $\tau_{sd} \sim 700$ yr
  - $n_{sd} \sim 2.5$
- Initial spindown luminosity
  - $L_{sd,o} \sim 3.3 \times 10^{39}$ erg s^{-1}

The spin-down luminosity could contribute to the LC of ECSN.

Note: however, we do not know how efficiently the energy is deposited to the envelope just after the explosion.



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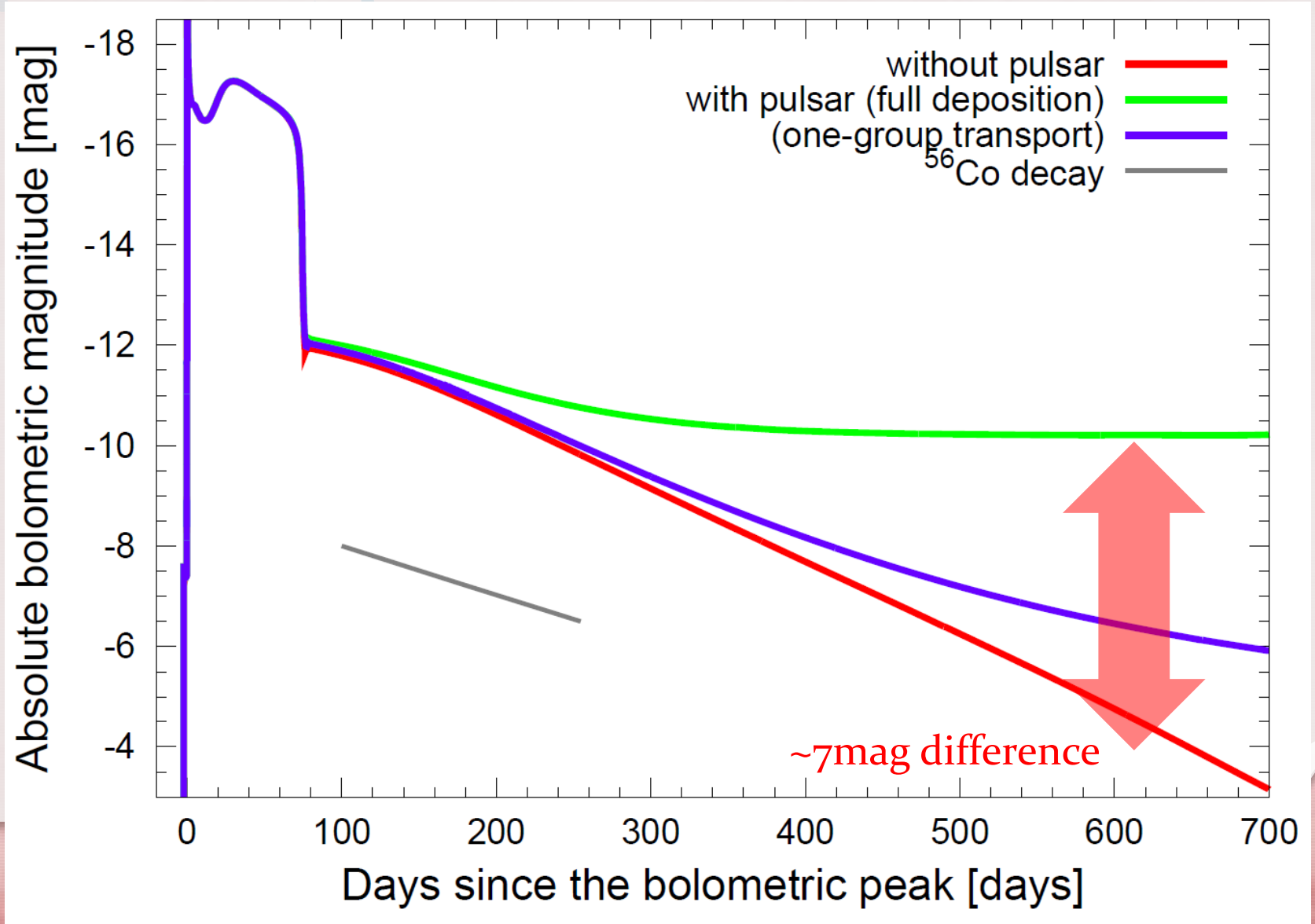
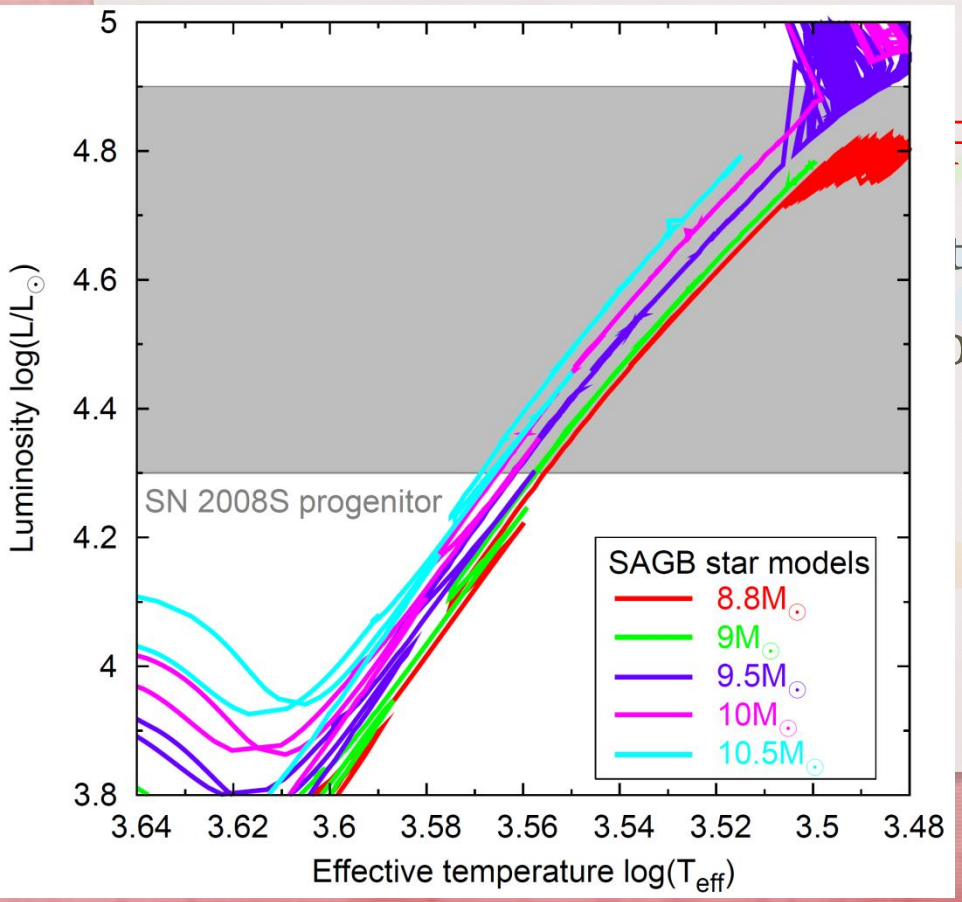
Pulsar contribution

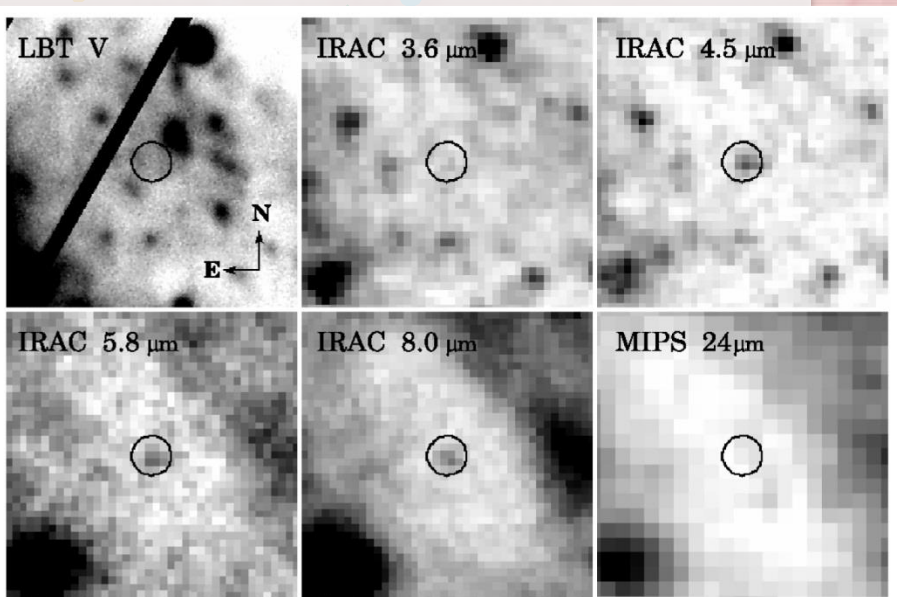


Comparisons with observations

Possible ECSNe

- SN1054 (→ Crab SNR) (Davidson + 82; Nomoto + 82)
  - small ejecta mass: $4.6 \pm 1.8 M_{\odot}$ (Fesen + 97)
  - low kinetic energy: $E \sim 3 \times 10^{49}$erg for $M_{ej}=1\text{-}2M_{\odot}$
  - 1.6<He/H<8 (Davidson 73)
  - Fe~0.76-4 (Henry 84)
  - ticella+09)
  - oge





Observations of SN1054

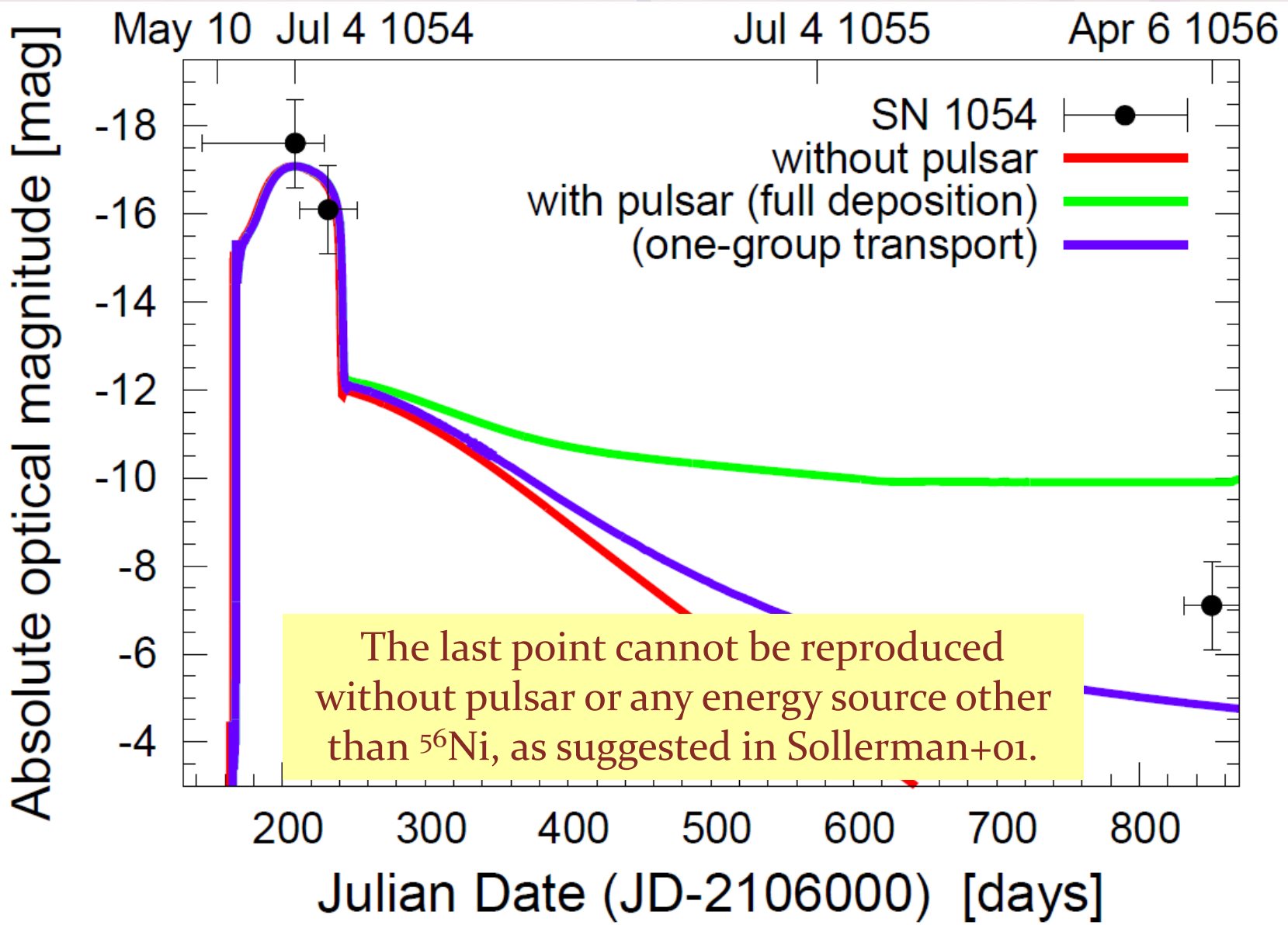
(Pskovskii 1985; Stephenson&Green 2002)

- They are enscrolled in historiographies.
- We take 3 points with large error bars.

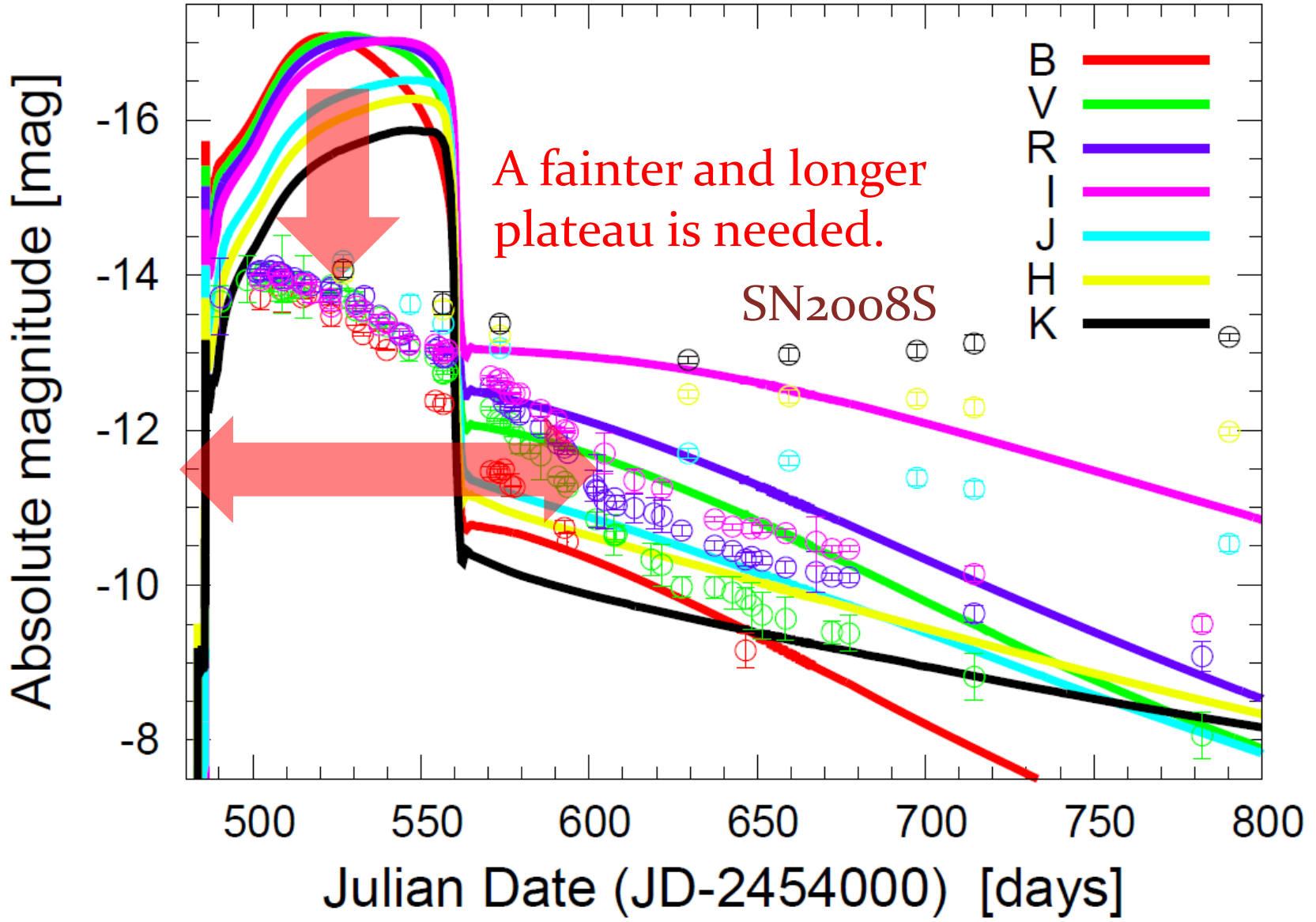
1. July 4, 1054 (possibly from May 10, 1054)
   as bright as Venus
   $m_{opt} \sim -3.5$ to -5
2. until July 27, 1054
   visible in the daytime
   $m_{opt} \sim -3$
3. April 6, 1056
   disappeared in the night
   $m_{opt} \sim 6$

Meigetsuki (明月記)
Teika Fujiwara (藤原定家)

Comparison with SN1054



Multicolor LCs of SN2008S



Analytic speculation for SN2008S

- Explosion energy
  - E~3.5x10^{48}erg
- Envelope mass
  - M_{env} ~ 3.4$M_\odot$

$$L_{\rm bol}({\rm plateau}) \approx 1.1 \times 10^{42} \left(\frac{R_0}{3.5 \times 10^{13}\ {\rm cm}}\right)^{2/3} \times \left(\frac{E}{10^{51}\ {\rm ergs}}\right)^{5/6} \left(\frac{T_{\rm rec}}{4500\ {\rm K}}\right)^{4/3} \left(\frac{M}{10\ M_\odot}\right)^{-1/2} \times \left(\frac{\kappa}{0.4\ {\rm cm^2\ g^{-1}}}\right)^{-1/3} {\rm ergs\ s^{-1}}\,, \quad (9)$$

$$t_p \approx 109 \left(\frac{R_0}{3.5 \times 10^{13}\ {\rm cm}}\right)^{1/6} \left(\frac{E}{10^{51}\ {\rm ergs}}\right)^{-1/6} \left(\frac{T_{\rm rec}}{4500\ {\rm K}}\right)^{-2/3} \times \left(\frac{M}{10\ M_\odot}\right)^{1/2} \left(\frac{\kappa}{0.4\ {\rm cm^2\ g^{-1}}}\right)^{1/6} {\rm days}\,, \quad (10)$$

Dependence of plateau (Eastman + 94)

- Shock breakout luminosity
  - L ~ 1.4x10^{42}erg s^{-1} (eq. in Matzner & McKee 99)
  - dust cavity with R_{cavity}~10^{11}km

(cf. R_{cavity}~3-10x10^{11}km for SN2008S, Botticella+09)

Summary

- We present first self-consistent multicolor light curves of ECSNe.
- ECSNe have
  - a plateau with L ~ 10^{42} erg s^{-1} and t ~ 60–100 days,
  - a faint tail (luminosity drops by ~4 mag), and
  - a photospheric velocity at plateau of 3-4x10^{3} km s^{-1}.
- Crab SNR is a remnant of ECSN SN1054.
- The model with 1.5 x 10^{50} erg is too energetic for SN2008S.

Can ECSNe explode with E~10^{48}erg?