Light Curve Models for Super-Chandrasekhar Candidate SN 2009dc (Kamiya+ ’10, in prep.)

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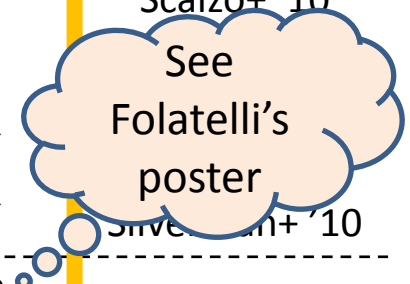
Extremely Luminous SNe Ia

ID	M_{peak} [mag]	C II lines	Reference
SN 2003fg	−19.94	?	Howell+ ’06
SN 2006gz	−19.74	✓	Hicken+ ’07
SN 2007if	−20.4	✓	Scalzo+ ’10
	−20.4	?	
SN 2009dc	−19.90	✓	
	−19.76	✓	Silve[illegible]n+ ’10
normal	−19.3	x?	



- Estimated M_{56Ni} are ≥1 $M_\odot$.
  - Theoretical models have <1 $M_\odot$ of ^{56}Ni (e.g. Iwamoto+ ’99)

➔ Super-Chandrasekhar mass WD ($M_{WD} > 1.4\ M_\odot$)?

  - Or … asymmetric explosion? (Hillebrandt+ ’07)
    - But … spherically symmetric (SN 2009dc; Tanaka+ ’10)

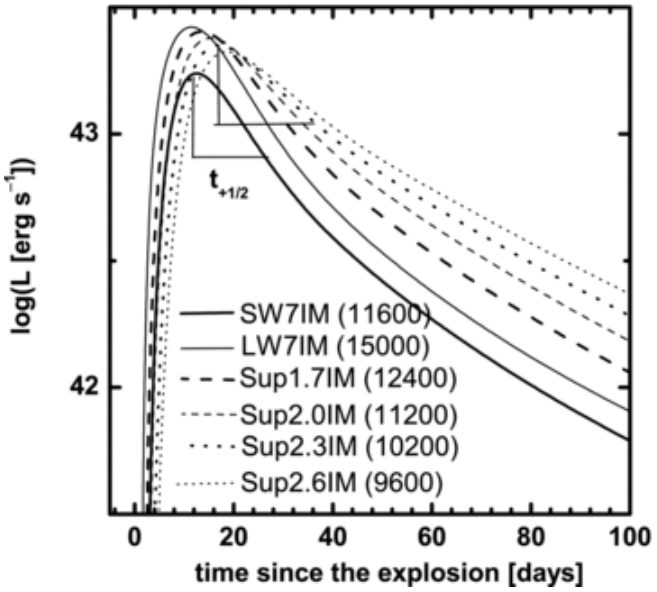
Super-Ch Mass WD Models

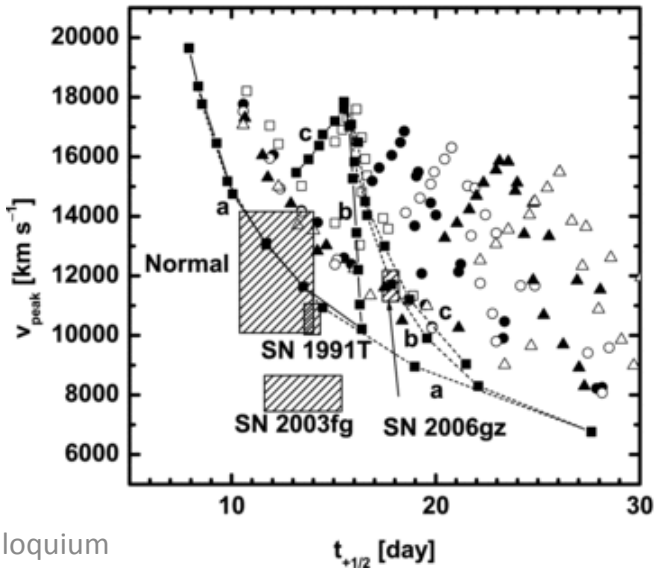
- Previous study
  - Maeda & Iwamoto '09
    - Simplified sup-Ch models
    - Bolometric LCs

    ➔ <u>SN 2006gz explainable by super-Ch models</u>

- This study

  + Multi-band LCs
    - <u>SN 2009dc explainable by super-Ch models?</u>
    - <u>Derive M_{WD}, M_{56Ni}, …</u>

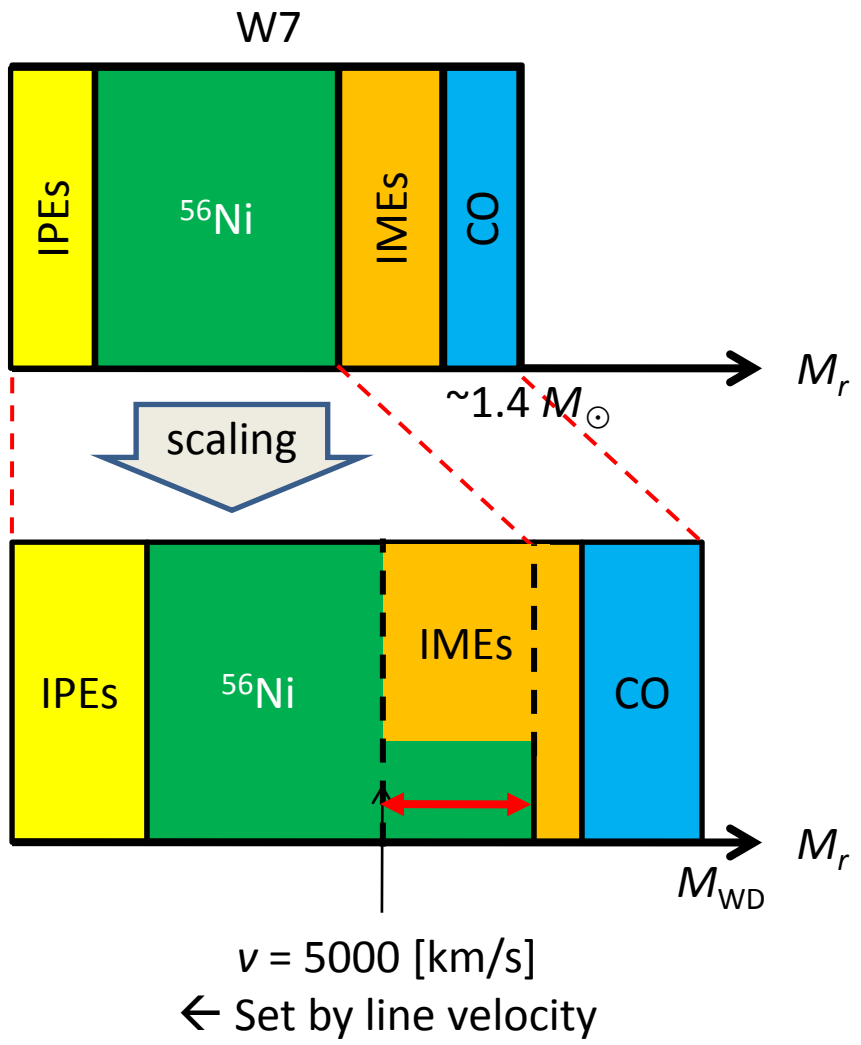




(Maeda & Iwamoto '09)

Model Construction

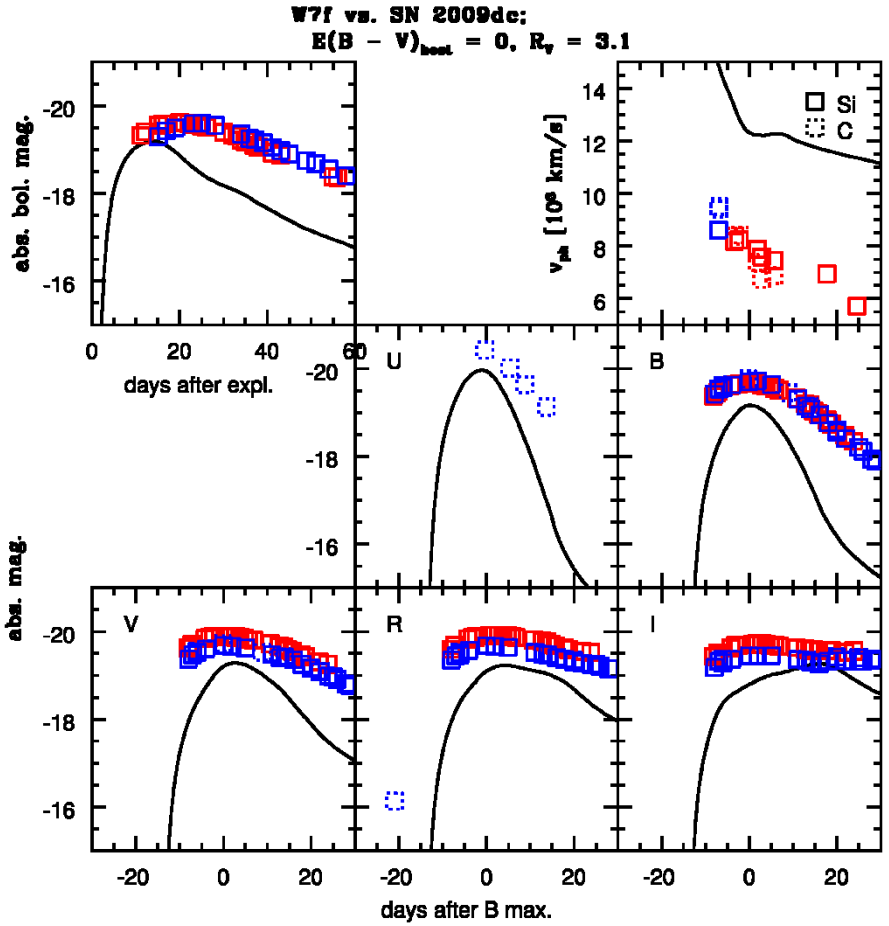
- Assumptions
  - 1D (spherical symmetry)
    ← 09dc polarimetry
  - Homologous expansion
- Parameters
  - M_{WD}, M_{IPE}, M_{56Ni}, M_{IME}, M_{CO}
    - $M_{IPE} + M_{56Ni} + M_{IME} + M_{CO} = M_{WD}$
- Procedure
  1. Determine parameters
  2. Calculate E_k (= $E_n - E_b$)
     - $E_n = (1.74\, M_{IPE} + 1.56\, M_{56Ni} + 1.24\, M_{IME}) \times 10^{51}$ [erg]
     - E_b by Yoon & Langer ('05; *extrapolated*)
  3. Scale the Ch mass WD model (W7; Nomoto+ '84) by
     - $\rho \propto \sqrt{(M_{WD}^5/E_K^3)}$, $v \propto \sqrt{(E_K/M_{WD})}$
  4. Determine abundance distribution
     - Locally mixed, considering low-velocity Si II lines were observed



LC Calculation

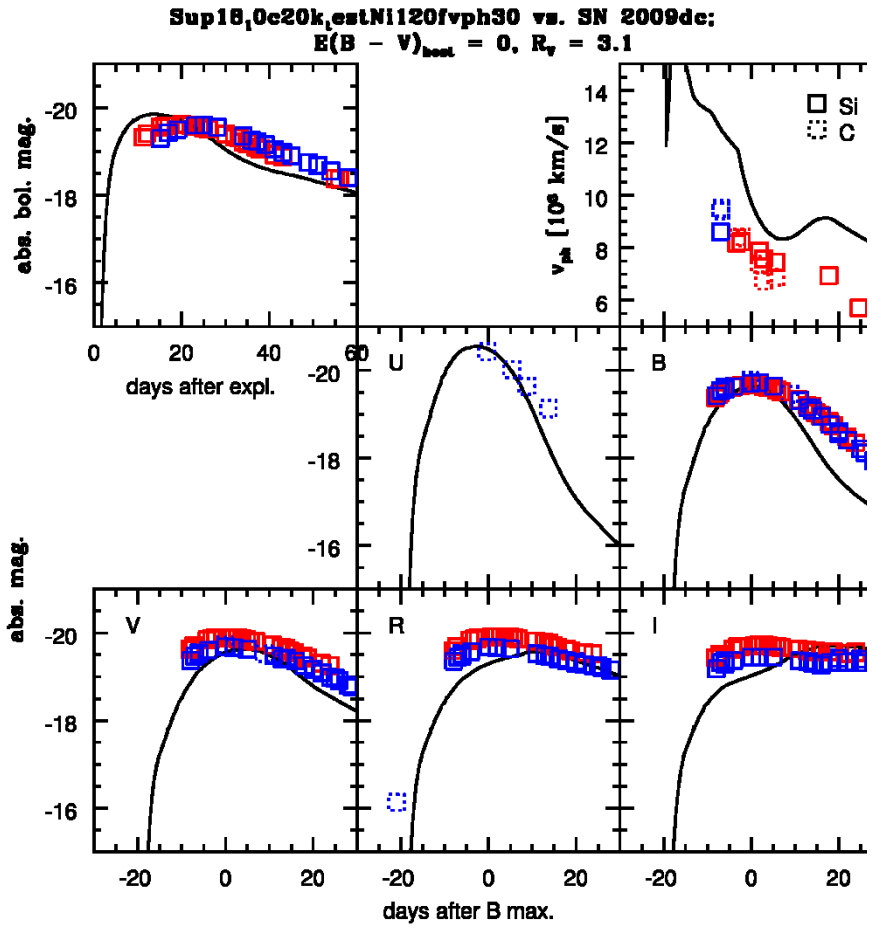
- Calculation code
  - STELLA (e.g. Blinnikov+ '9
    - Solves 1D radiation trans
    - Calculates bolometric & *UBVRI*-band LCs
- Parameter range for SN 2009dc
  - M_{WD} = 1.8, 2, …, 2.6 $M_\odot$
  - M_{56Ni} = 1.2 $M_\odot$
  - M_{IPE}/M_{WD} = 0.1, 0.2, …
  - M_{CO}/M_{WD} = 0.1, 0.2, …
    (➔ velocity & width)

- SN 2009dc vs. W7
  - (red) Yamanaka+ '10
  - (blue) Silverman+ '10

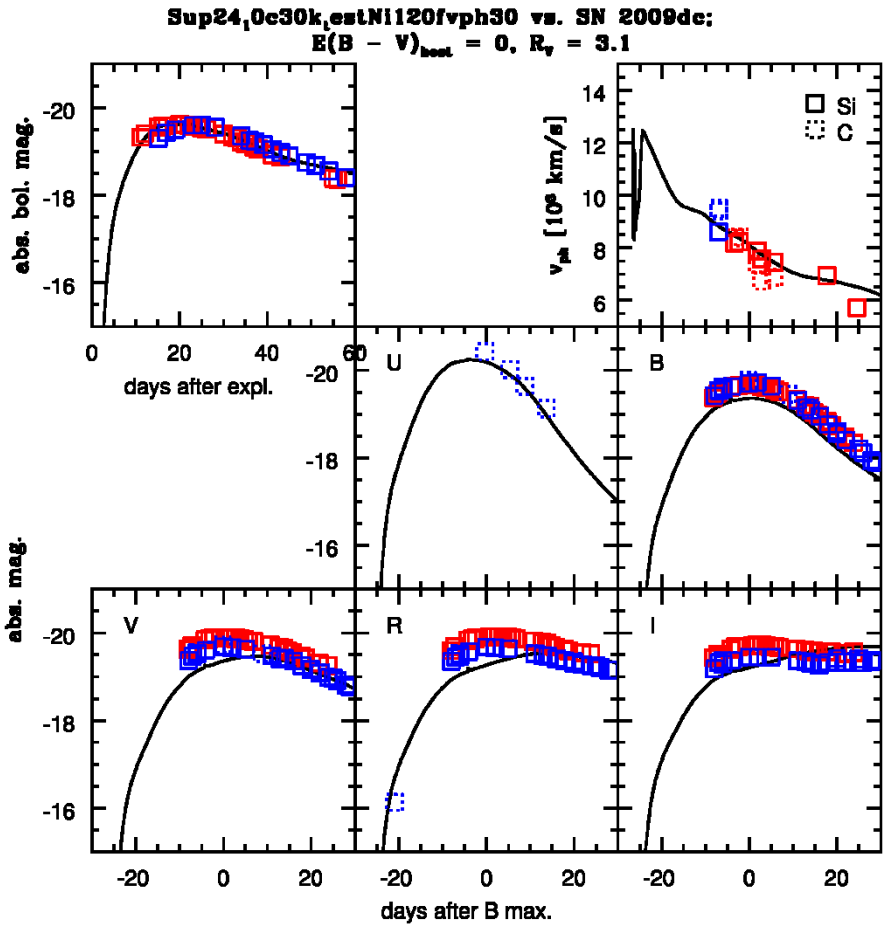


Comparisons: Examples

- $M_{WD} = 1.8\ M_{\odot}$

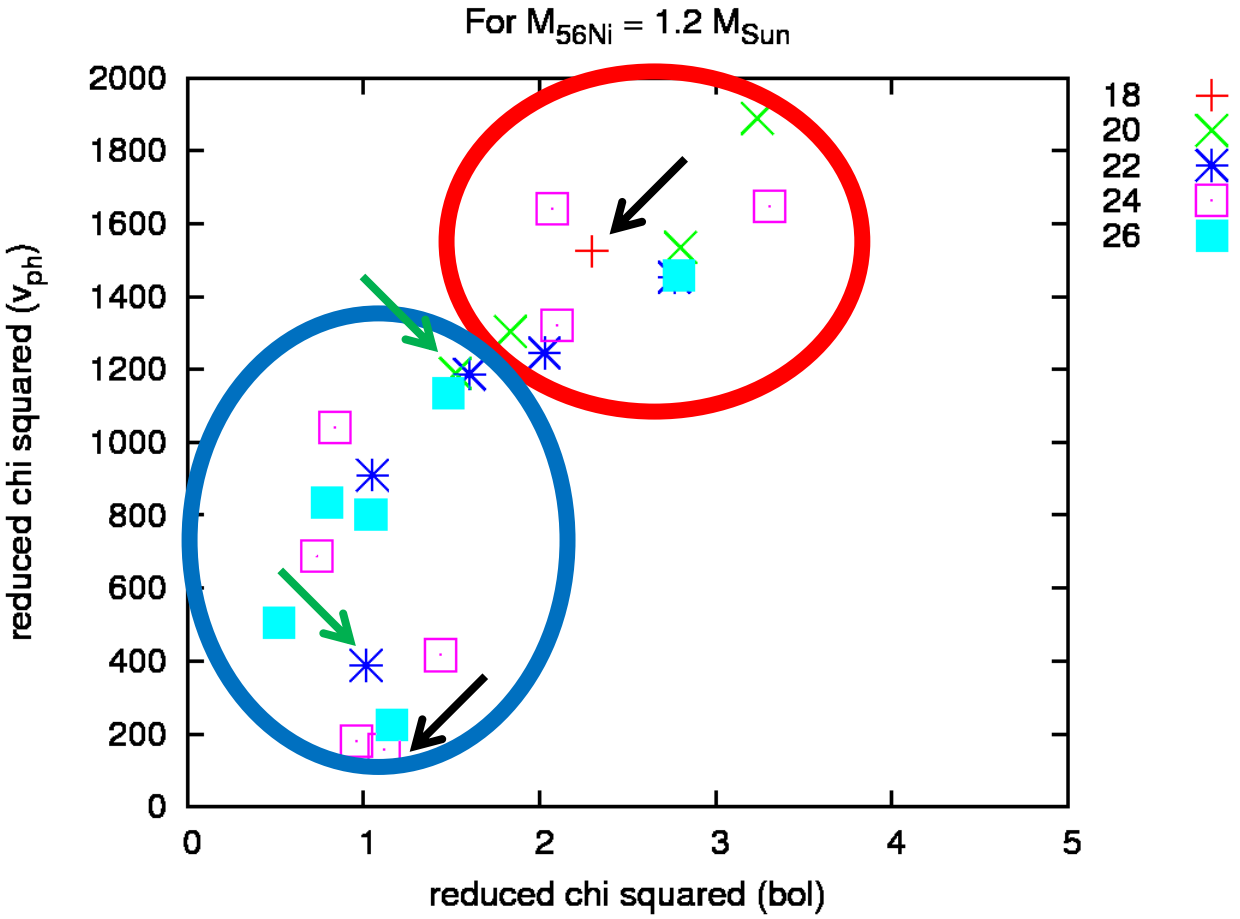


- $M_{WD} = 2.4\ M_{\odot}$



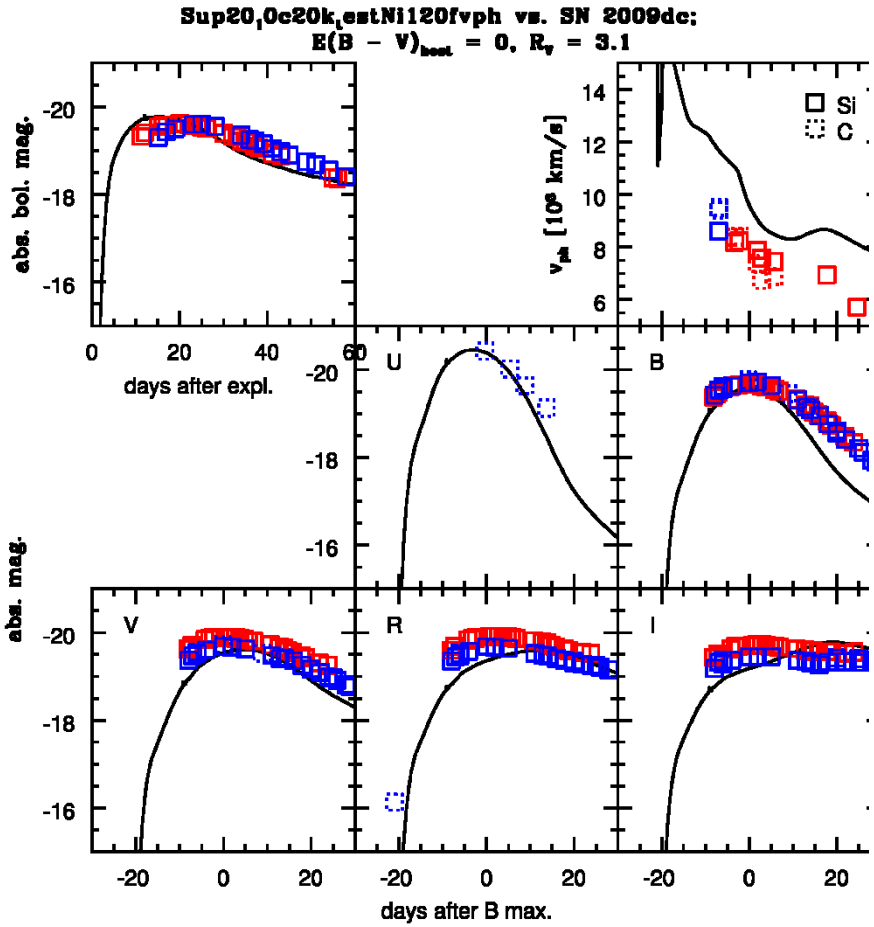
Comparisons: Reduced χ^2 (M_{bol} vs. v_{ph})

- M_{ZAMS} = 1.8–2.6 $M_{\odot}$

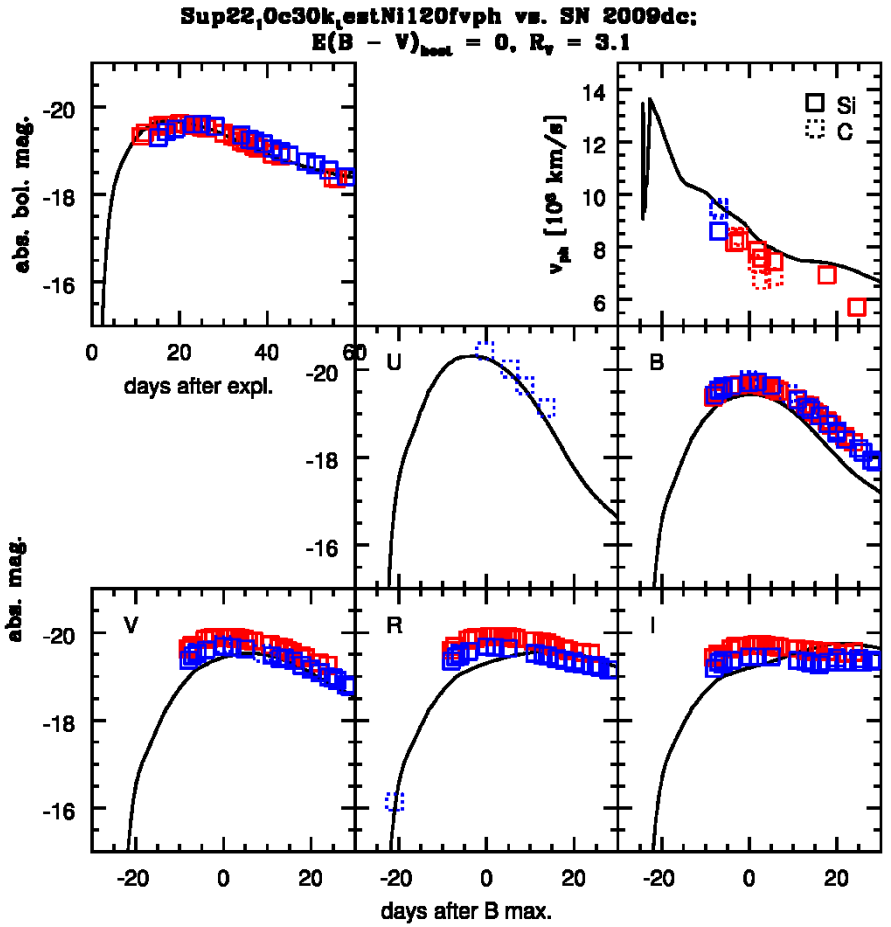


Comparisons: Marginals

- $M_{WD} = 2\ M_{\odot}$



- $M_{WD} = 2.2\ M_{\odot}$



Summary

- 4 extremely luminous Type Ia, so far
  - Too bright ➔ too much ^{56}Ni ➔ super-Ch WD?
- Derive progenitor properties from LC calculations
    - Construct simplified super-Ch models
    - Calculate bolometric and *UBVRI*-band LCs
    - Compare observations
  - SN2009dc
    - $M_{WD} \geq 2\ M_{\odot}$ and $M_{56Ni} = 1.2\ M_{\odot}$ w/ thick C+O layer
      - Marginal: $M_{WD} = 2, 2.2\ M_{\odot}$
      - Best fitted: $M_{WD} = 2.4\ M_{\odot}$
- <u>What about formations and thermonuclear explosions of super-Ch mass WDs?</u>