Simulations of Type Ia Supernova Explosions

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In collaboration with

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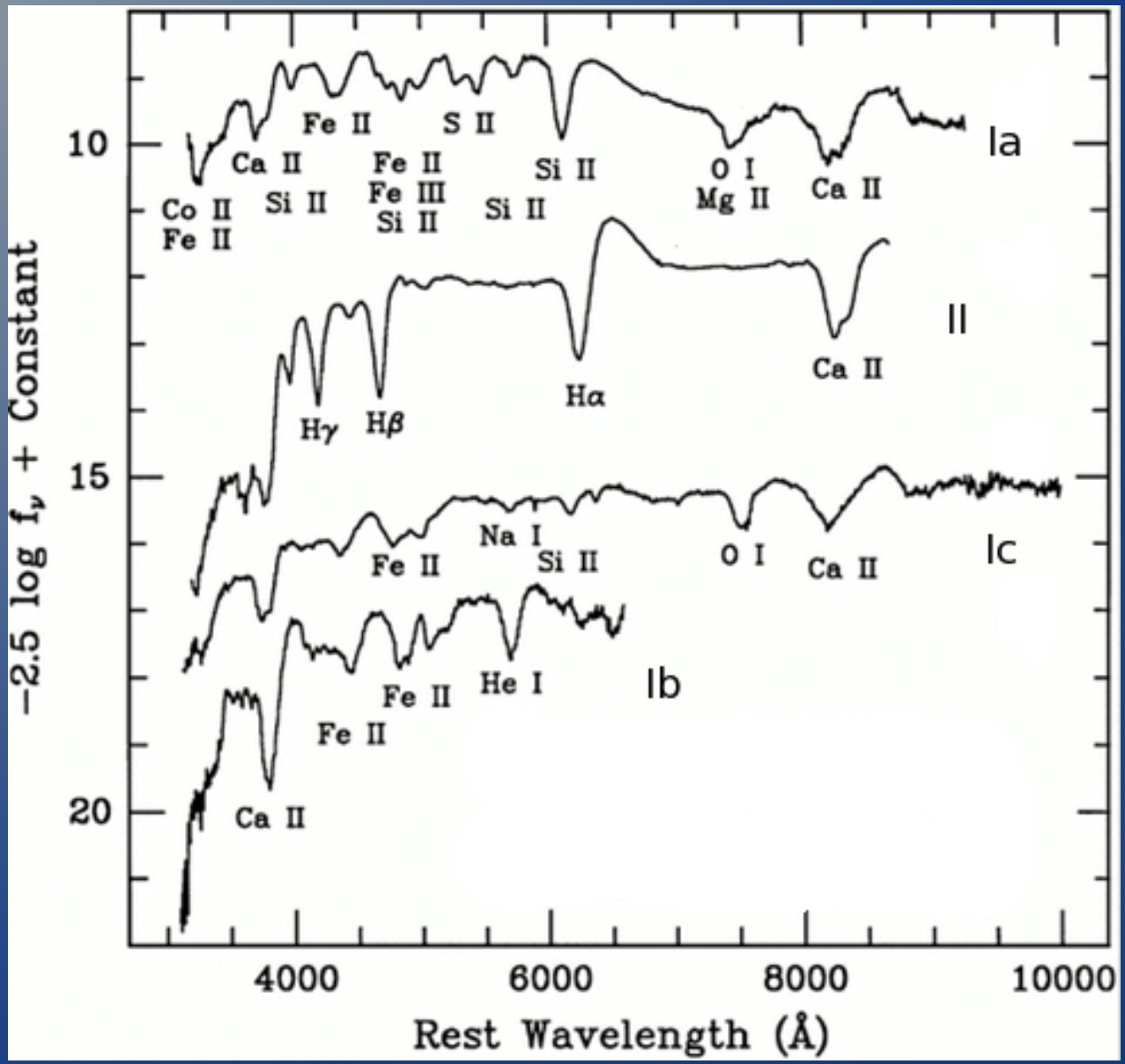
Outline

- Observational constraints on SNe Ia
- First principle explosion models
- Violent mergers in detail

SN 1994D

Credit:
Nasa/Esa Hubble

Supernova spectra



Fillipenko 1997

Type Ia Supernovae

- No Hydrogen/Helium
- Produce C/O/Si/Ni...
- About 0.1-1.0 $M_\odot$ ^{56}Ni > (6d) ^{56}Co > (77d) ^{56}Fe
- No compact remnant
- About a solar mass of ejecta
- Also old stellar systems

=> Thermonuclear explosion of CO-WD in binary system

The Problem

- What is the nature of the companion star?
- What causes the explosion?

Progenitor systems

Main sequence, red giant or He WD companion

stable accretion of H or He

CO WD or He WD Companion

Disruptive merger

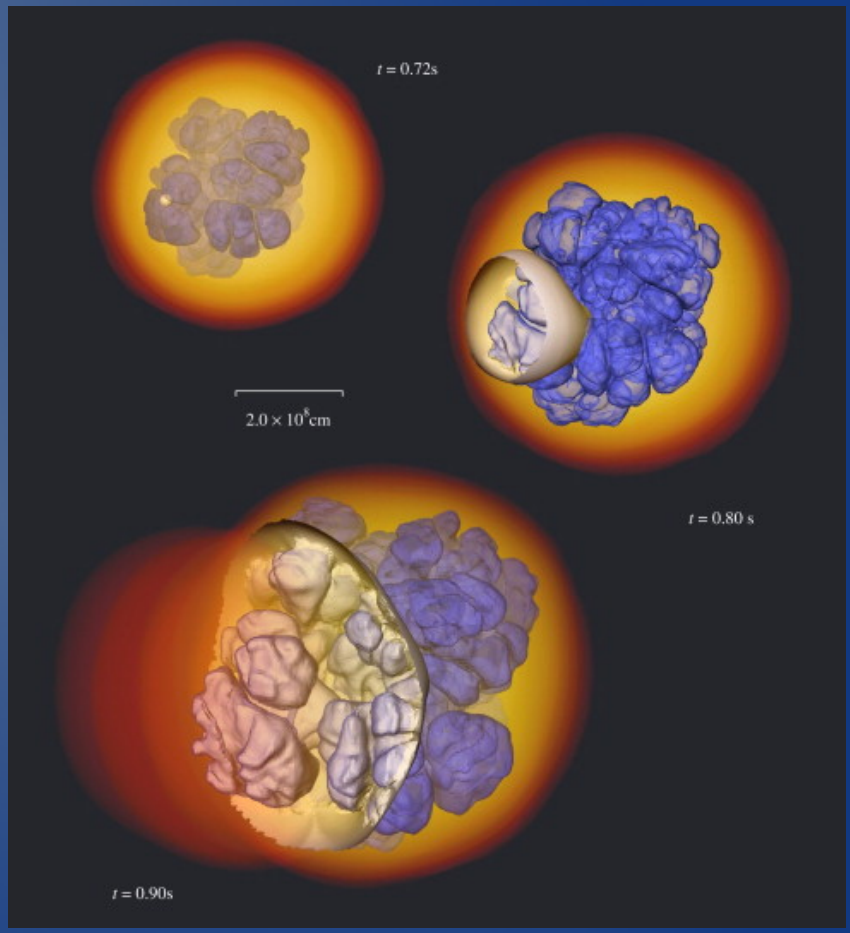
Bad Astronomy / Discover Magazin

Modelling a SN Ia

- Progenitor system
- 3D Hydrodynamics explosion model including nuclear burning
- Detailed nucleosynthesis
- Radiative transfer
- Comparison with observations

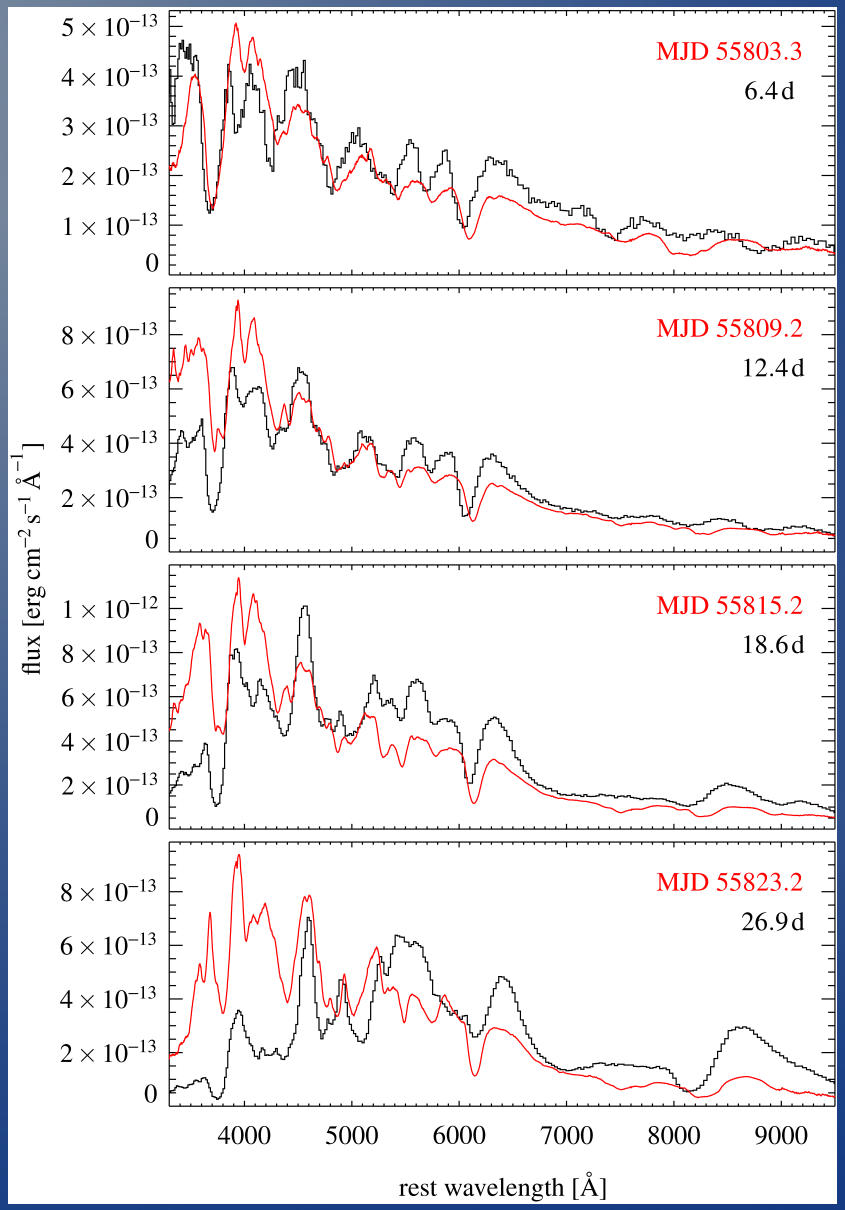
Explosions I: Chandrasekhar-mass

- H-rich accretion
- WD grows to M_{Ch}
- Ignition of deflagration
- Delayed detonation



Roepke et al. 2011

Delayed detonations

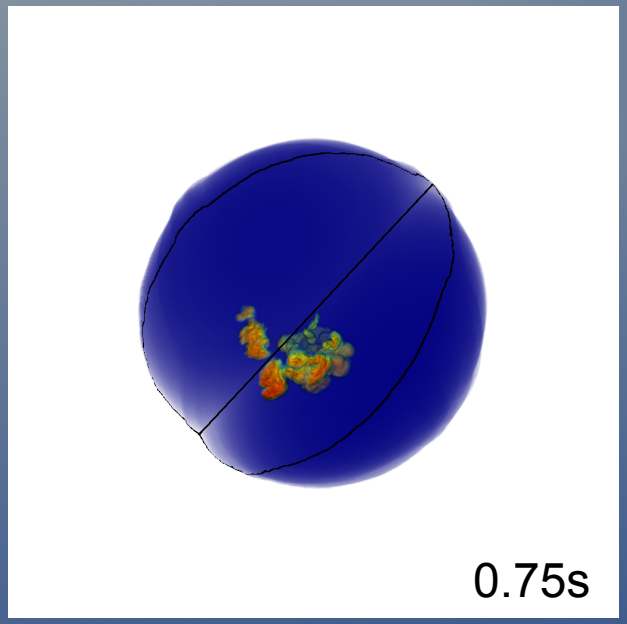


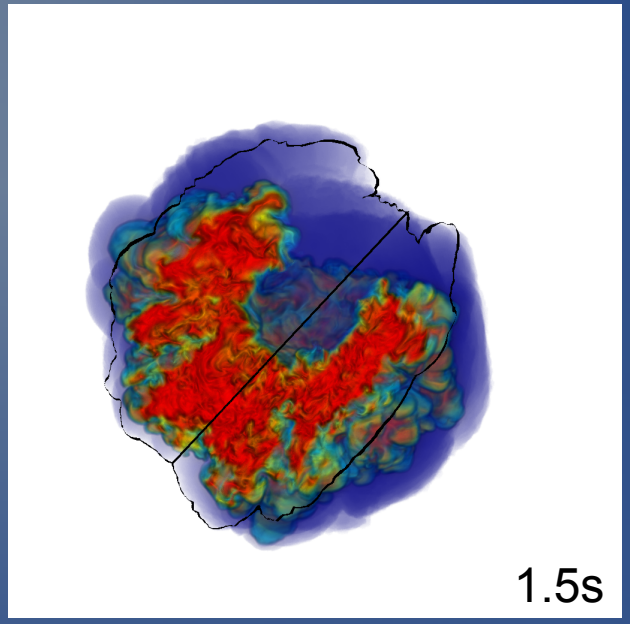
Roepke et al. 2012

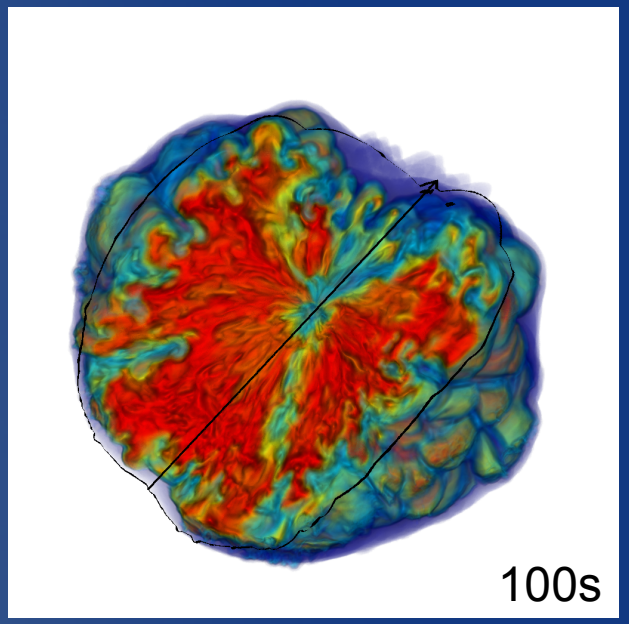
Delayed detonations

- ✗ Good agreement for spectra and lightcurves
- ✗ Details of ignition unknown
- ✗ Rates: possibly not enough systems
- ✗ No pre-explosion detections
- ✗ No sign (of interaction with) companion star
- ✗ No first parameter for brightness variations
- ✗ But: CSM interactions for some SNe Ia

Explosions II: M_{Ch} pure deflagrations





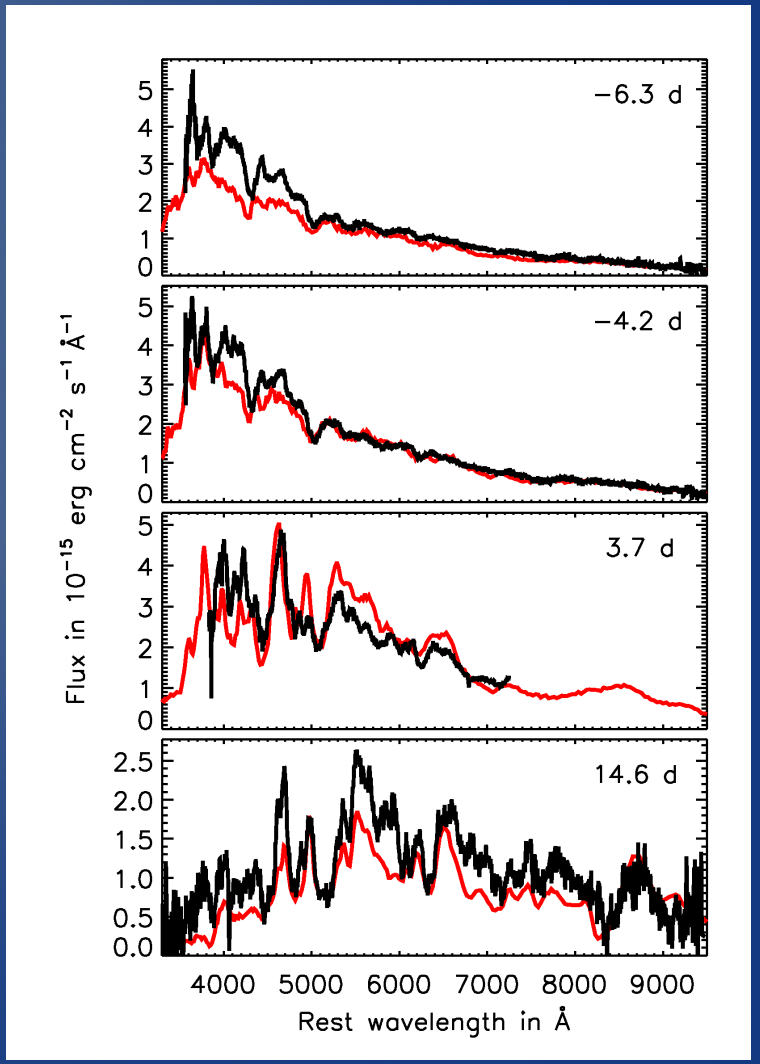


Kromer et al. 2012

- ✗ Pure deflagration
- ✗ Bound WD remnant
- ✗ $0.4M_{\odot}$ mixed ejecta

Explosions II: M_{Ch} pure deflagrations

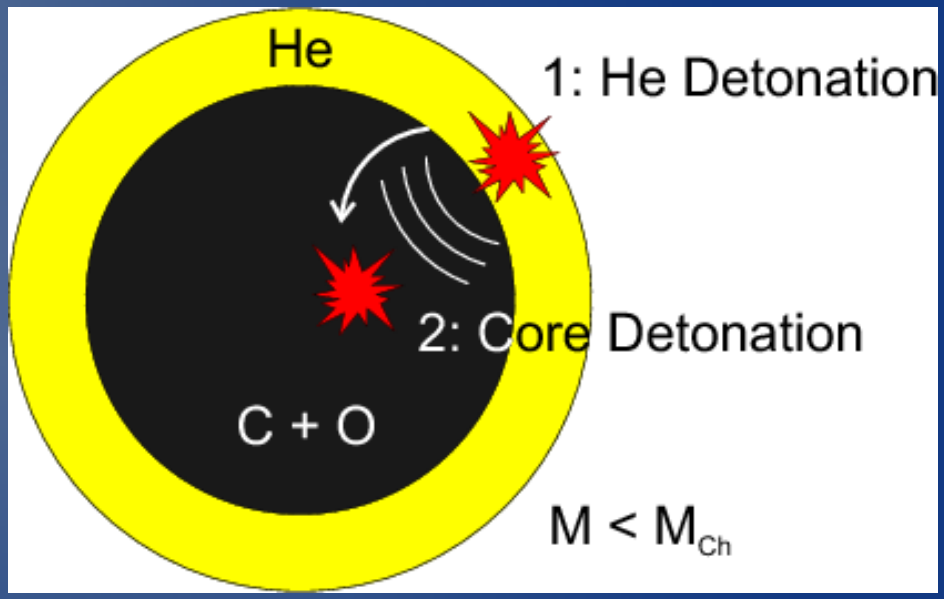
- ✗ Good agreement for spectra and lightcurves with subclass of 02cx-like objects
- ✗ Relative rates of model viable



05hk (black) vs. model (red)

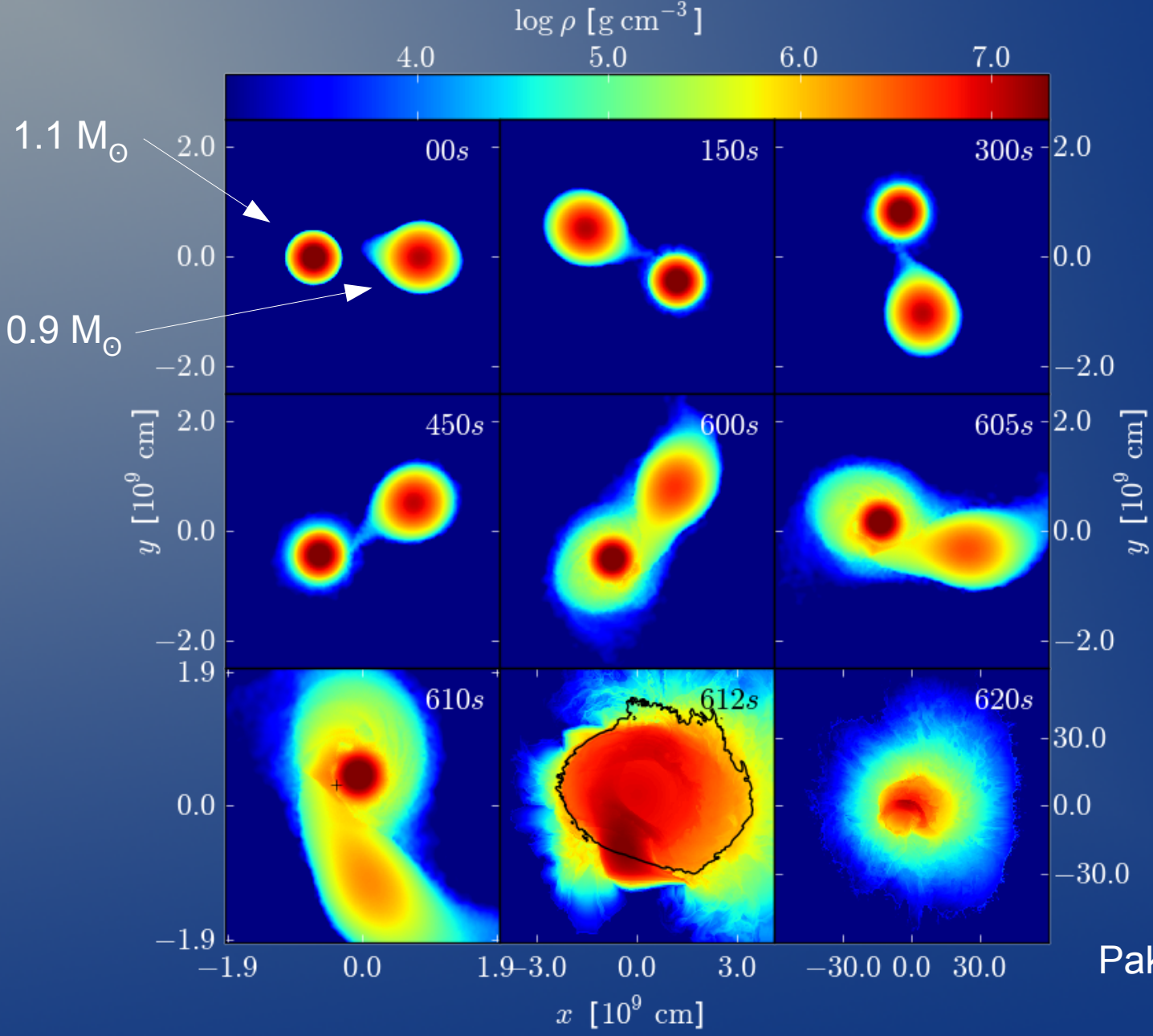
Explosions III: Double detonations

- He accretion on sub-Chandra CO WD
- He-shell accumulates and detonates
- CO-detonation follows
- Natural explanation of brightness range
- Problems with ashes of He-shell



Fink et al. 2008, 2010

Explosions IV: Violent WD mergers



Pakmor et al. 2012

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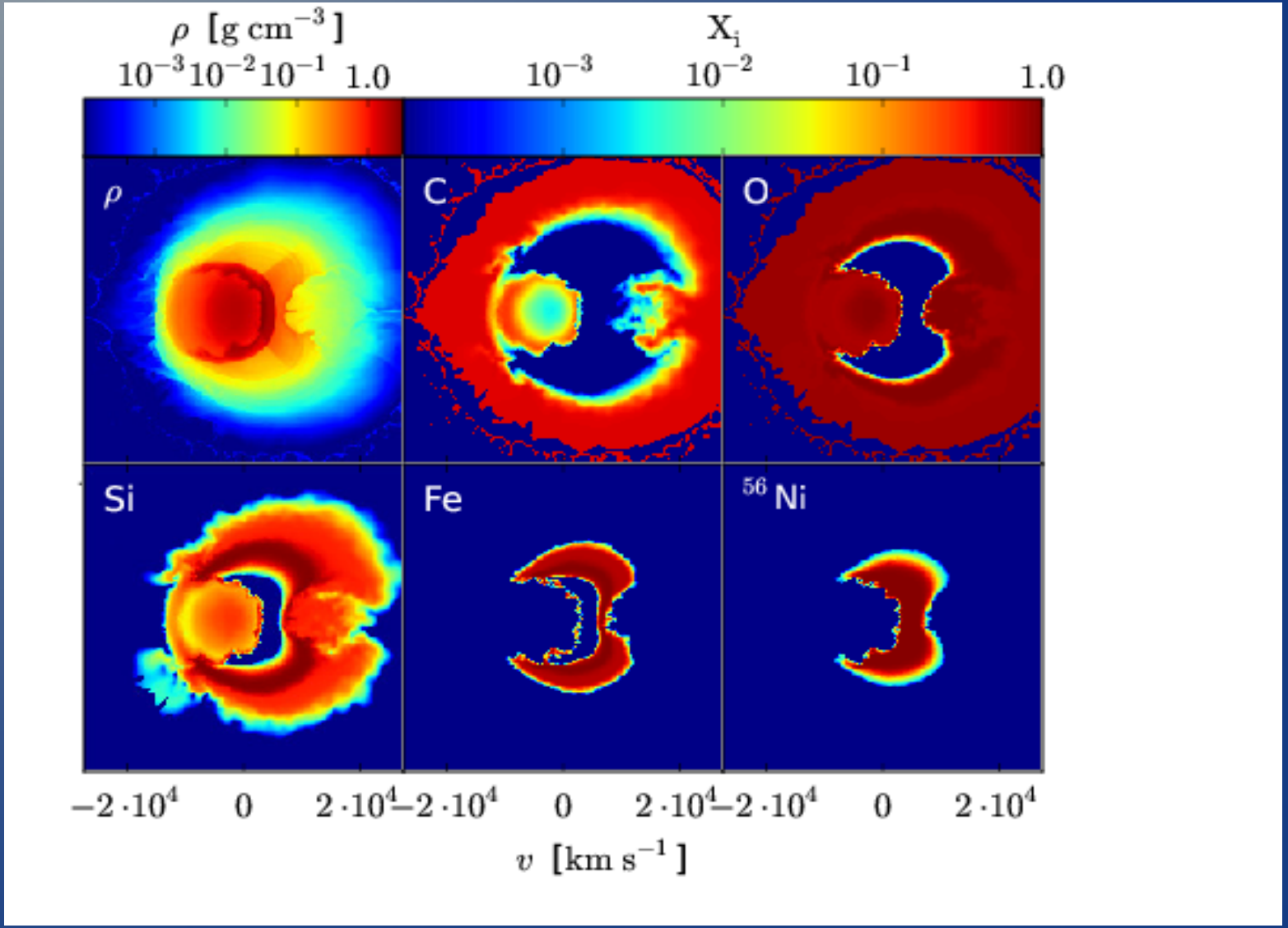

Pakmor et al. 2012

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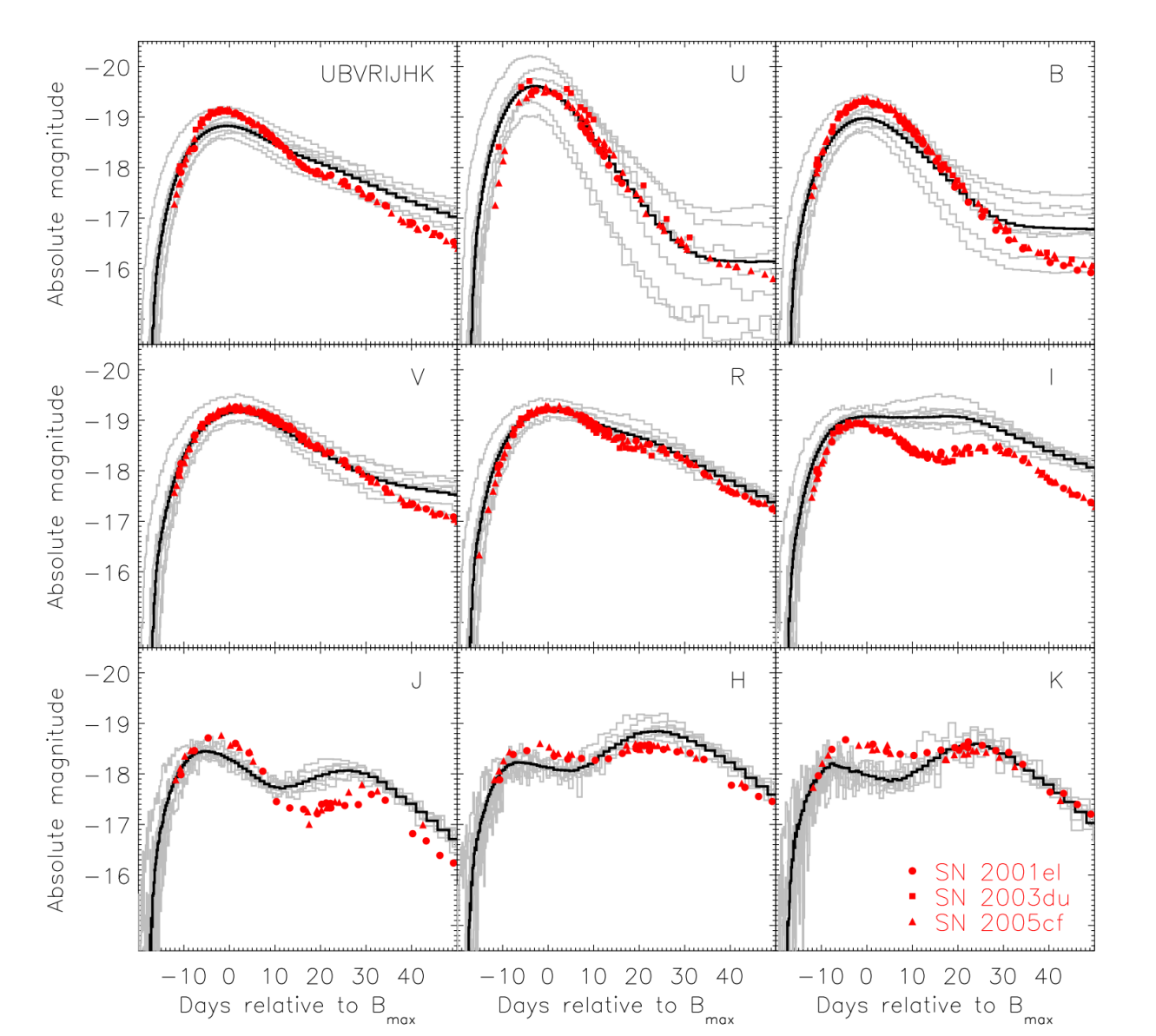
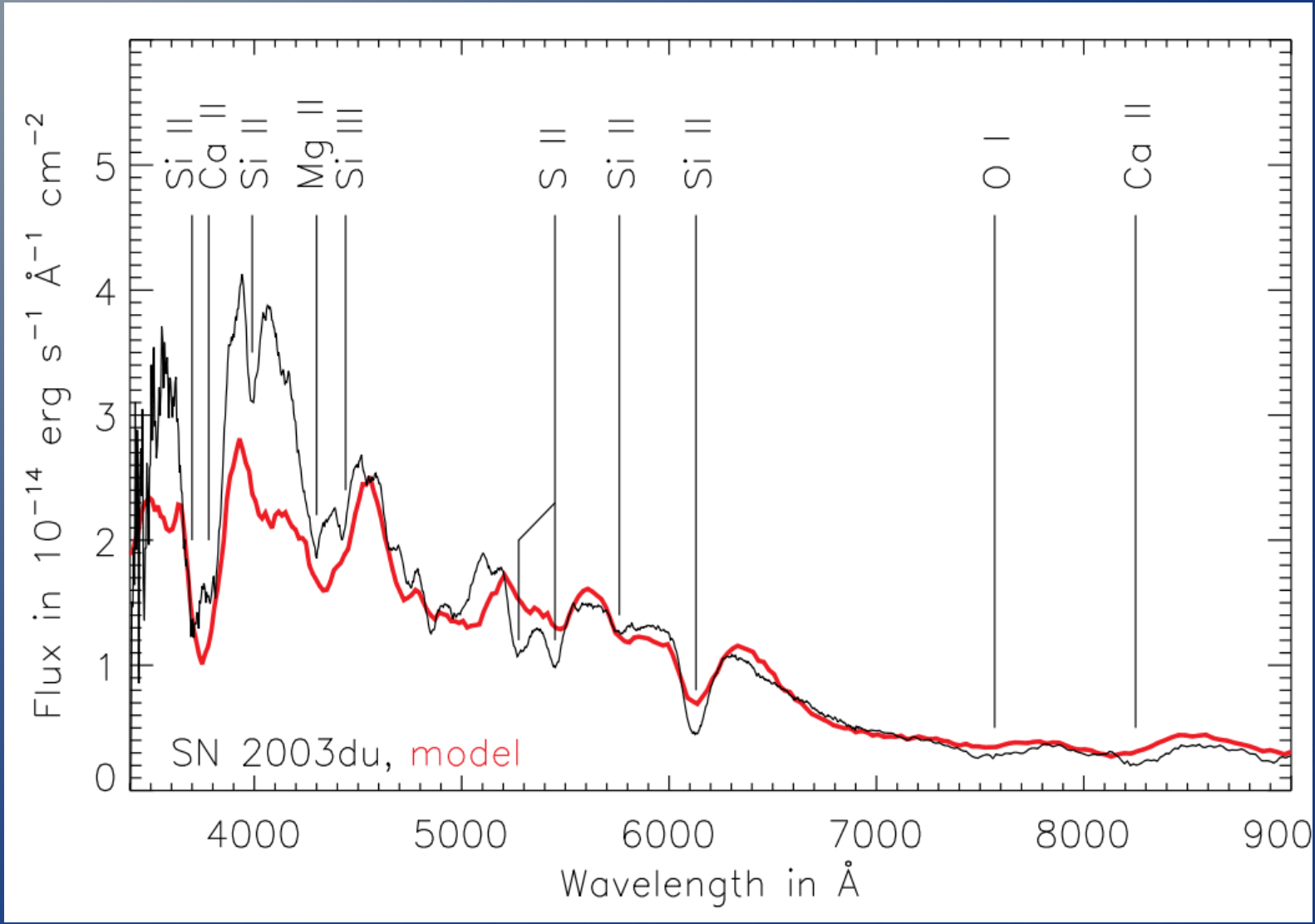


Pakmor et al. 2012

Explosions IV: Violent WD mergers

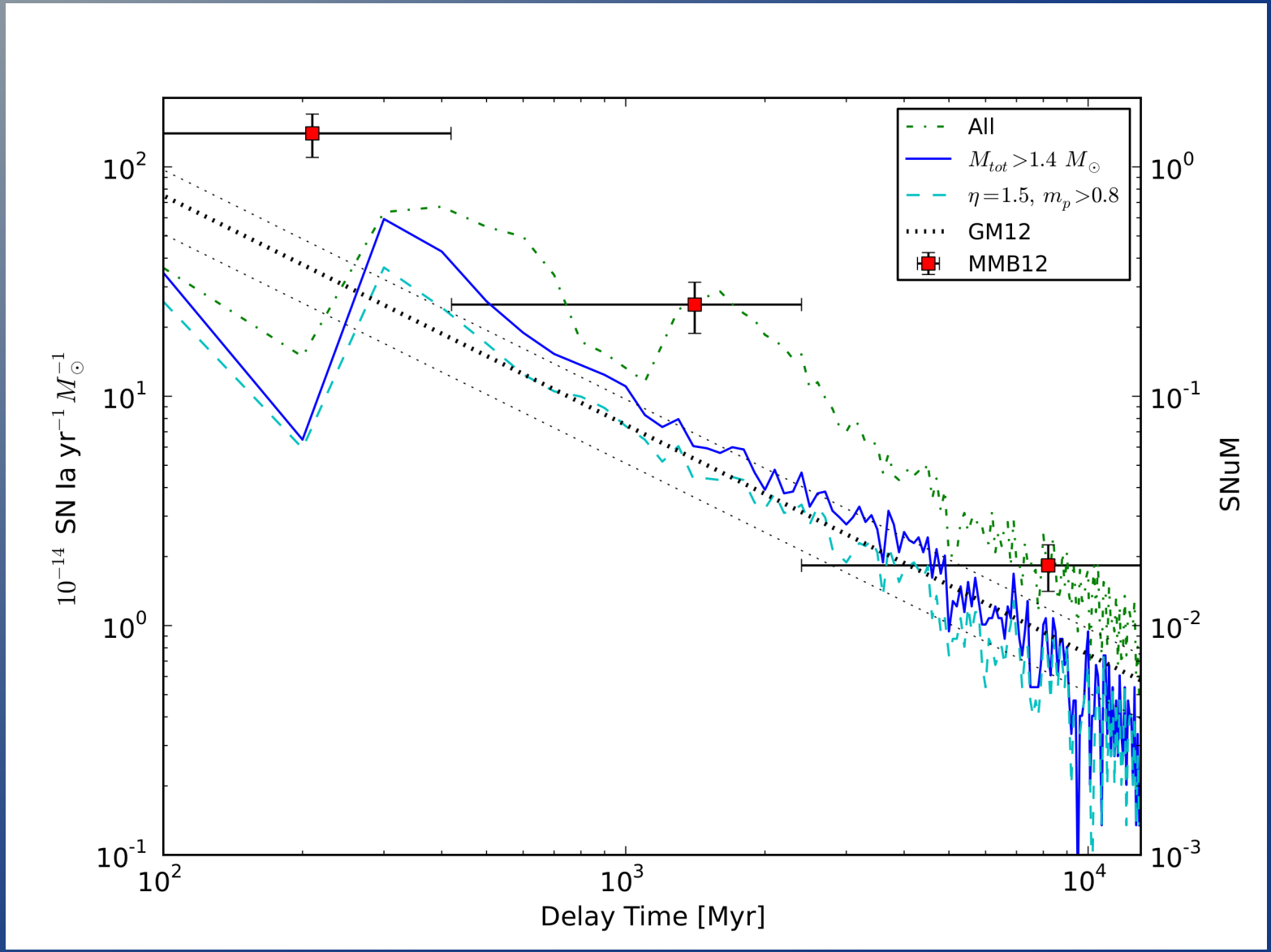


Pakmor et al. 2012

Explosions IV: Violent WD mergers

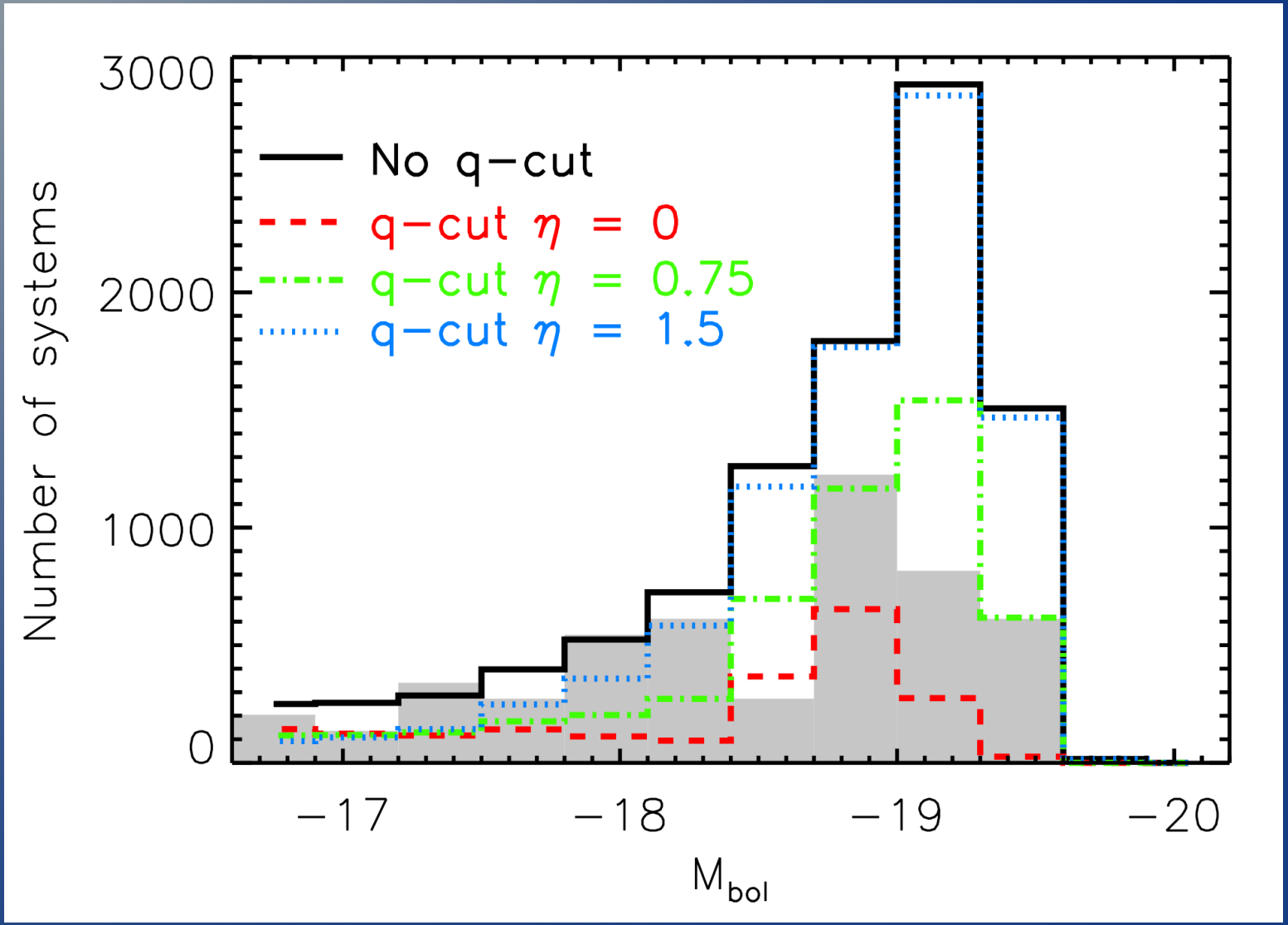
- ✗ Good agreement for spectra and lightcurves
- ✗ Details of ignition unknown
- ✗ Brightness given by mass of primary WD
- ✗ Rates?
- ✗ Ages?

White Dwarf mergers: Rates



Ruiter et al. 2012

White Dwarf mergers: Brightnesses



Ruiter et al. 2012

Summary

- We can now simulate SNe Ia in 3D from progenitors to observables!
- Probably different explosion scenarios realised in nature
- Mergers of two white dwarfs are a good candidate for bulk of normal SNe Ias
- Merger scenario still rather unexplored