Nuclei in the Cosmos XI

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Multi-dimensional models of Type Ia supernova explosions

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Modeling sequence

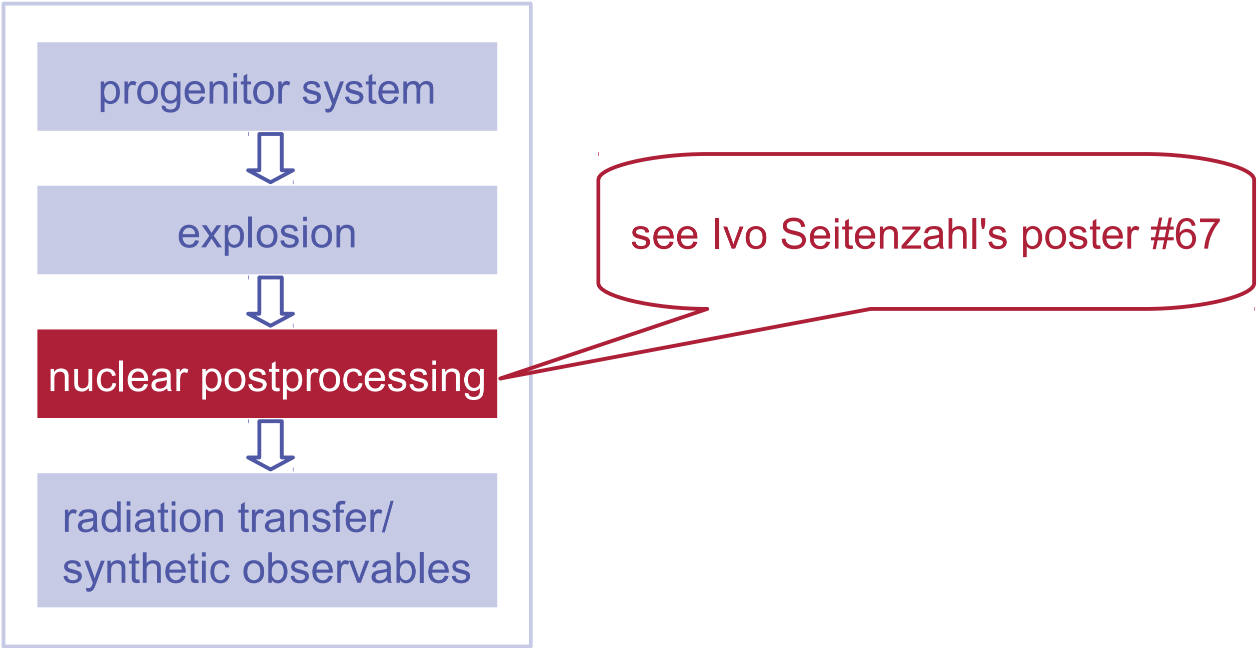
progenitor system

explosion

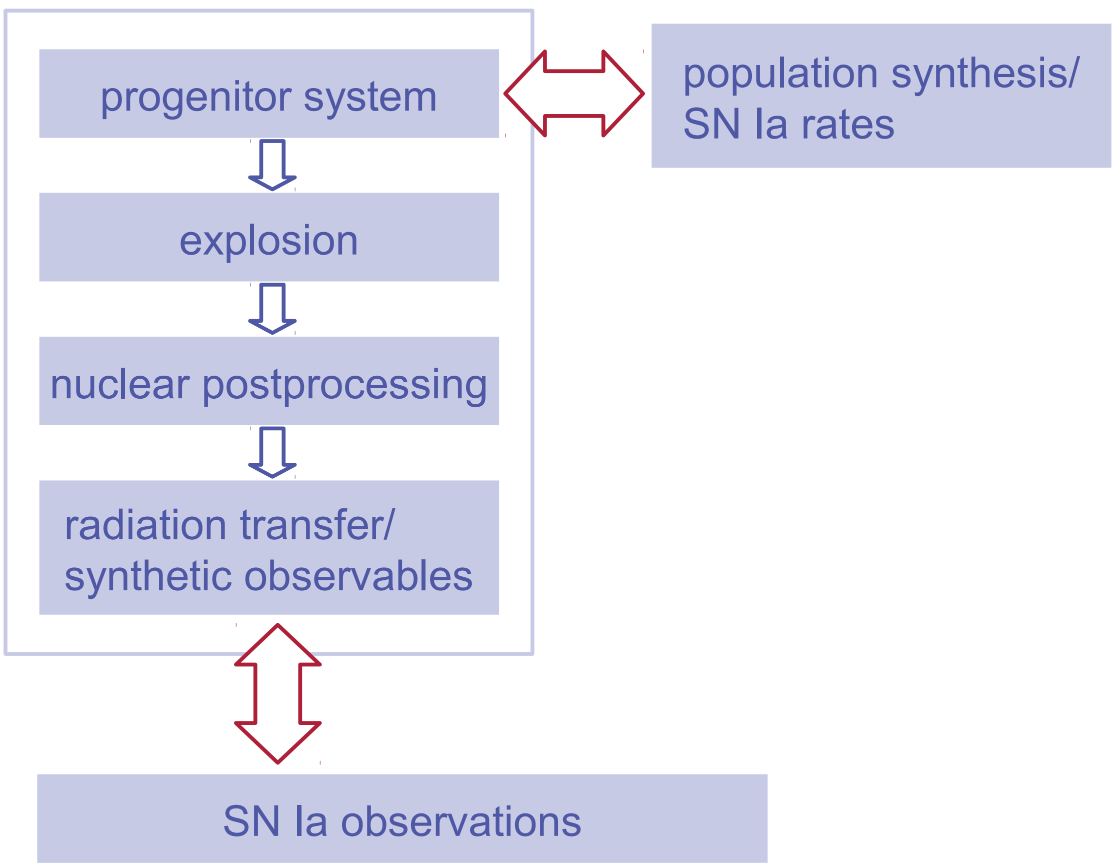
nuclear postprocessing

radiation transfer/
synthetic observables

Modeling sequence



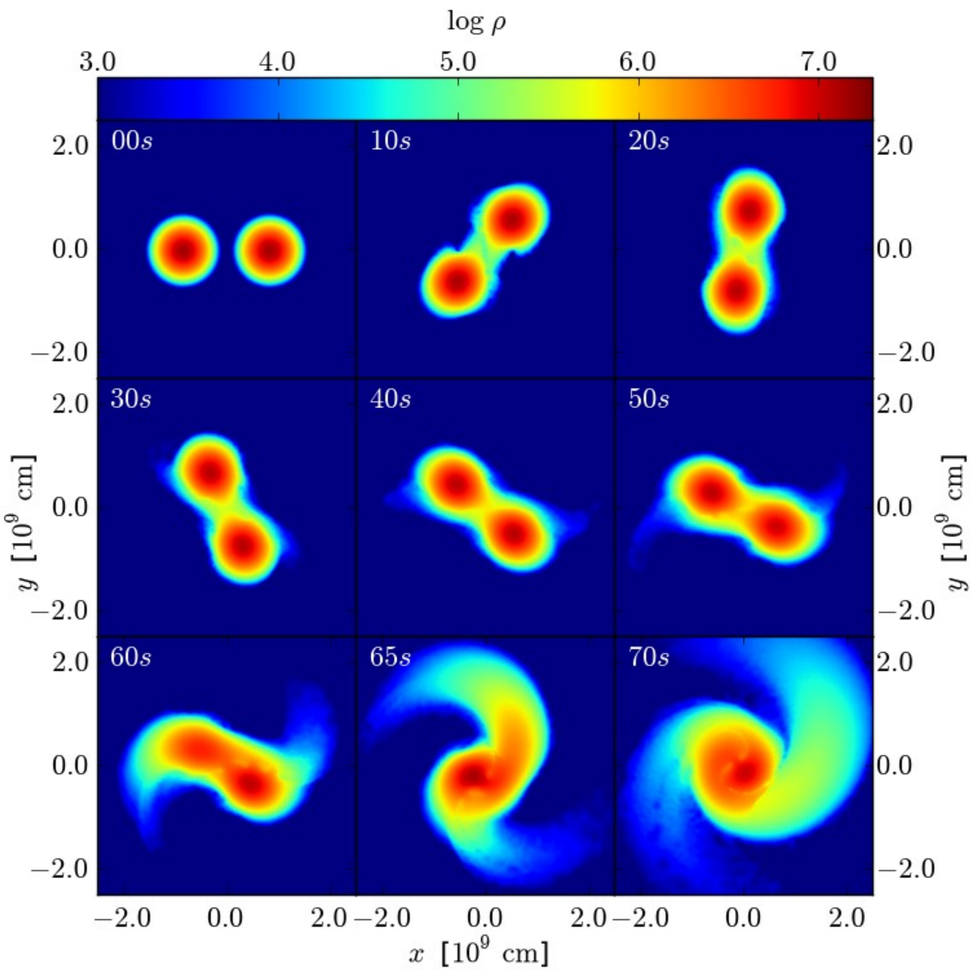
Modeling sequence



Violent WD-WD mergers

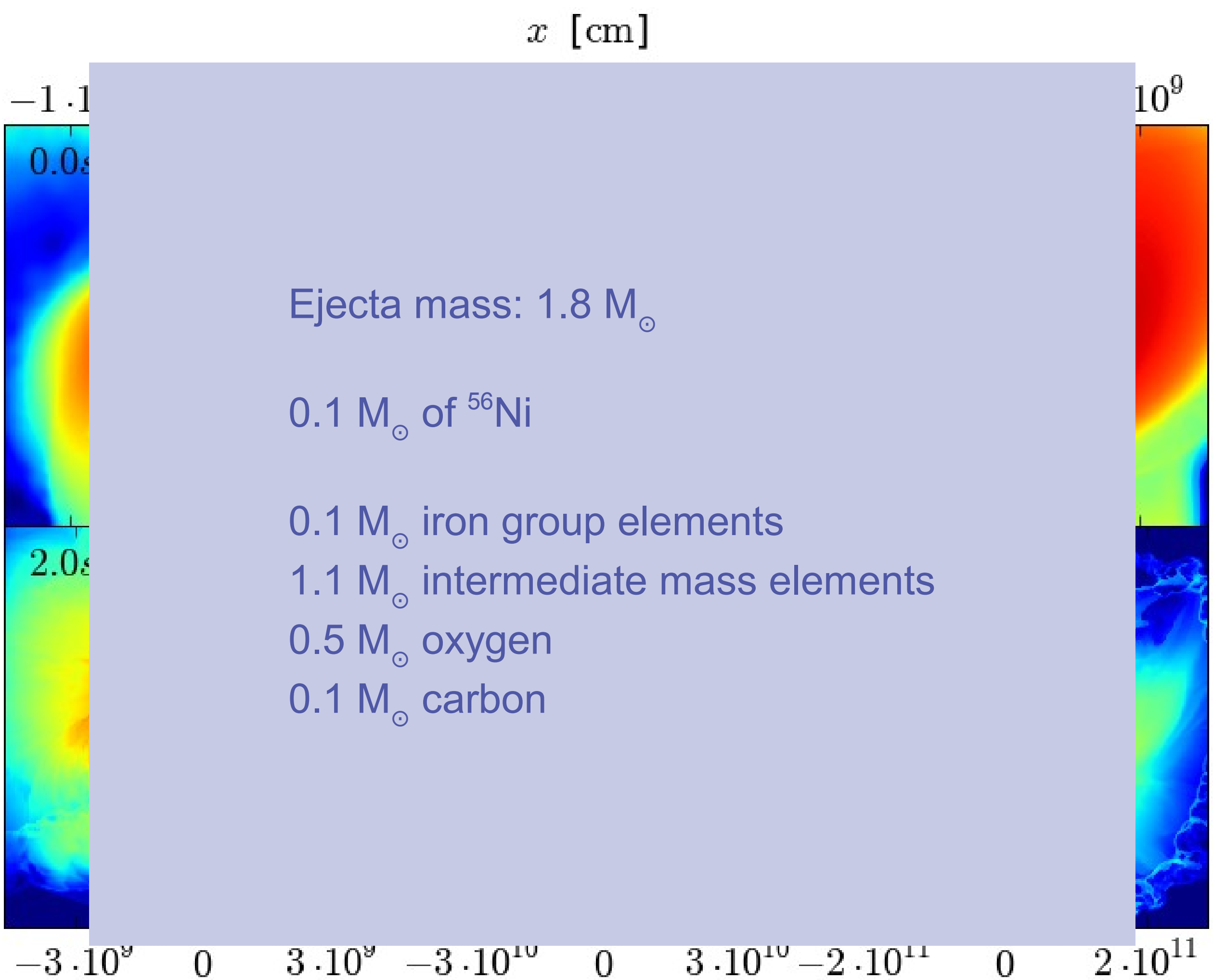
(Pakmor+, 2010)

- inspiral and merger: 3D SPH code (GADGET3)
- 2 WDs: $M_1 = M_2 = 0.9M_\odot$



Violent WD-WD mergers

- explosion: 3D MPA SN Ia code (LEAFS)
- detonation after T>2.8 GK reached @ $\rho = 3.8\ 10^6$ g/cm^3



Ejecta mass: 1.8 $M_\odot$

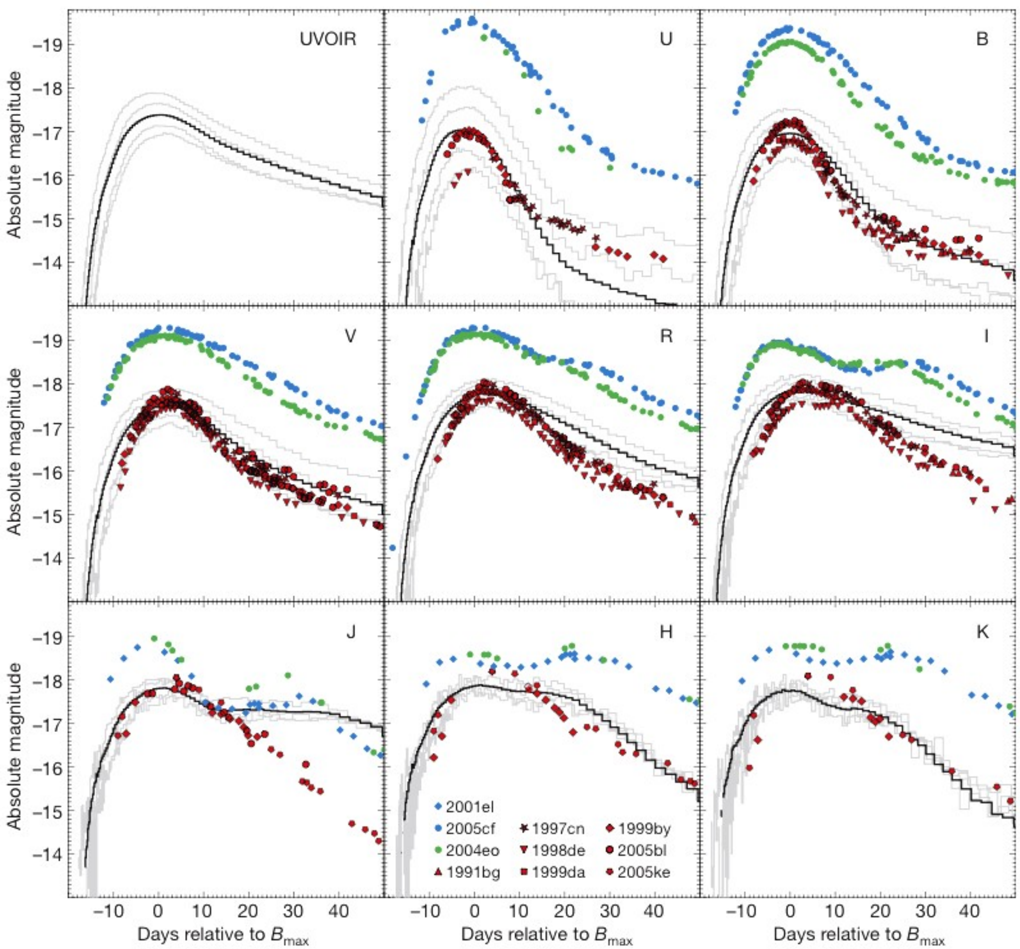
0.1 $M_\odot$ of ^{56}Ni

0.1 $M_\odot$ iron group elements
1.1 $M_\odot$ intermediate mass elements
0.5 $M_\odot$ oxygen
0.1 $M_\odot$ carbon

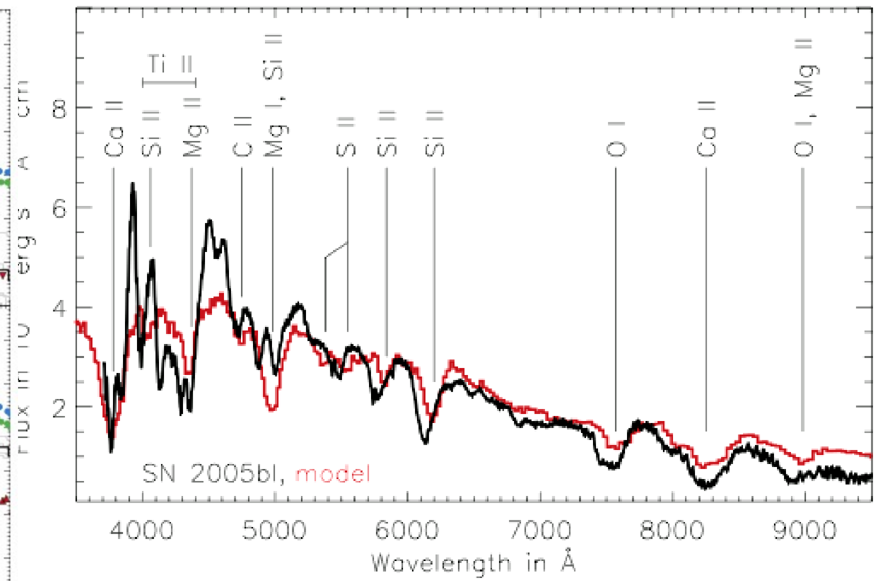
Violent WD-WD mergers

- radiation transfer: 3D monte carlo (ARTIS)

light curves



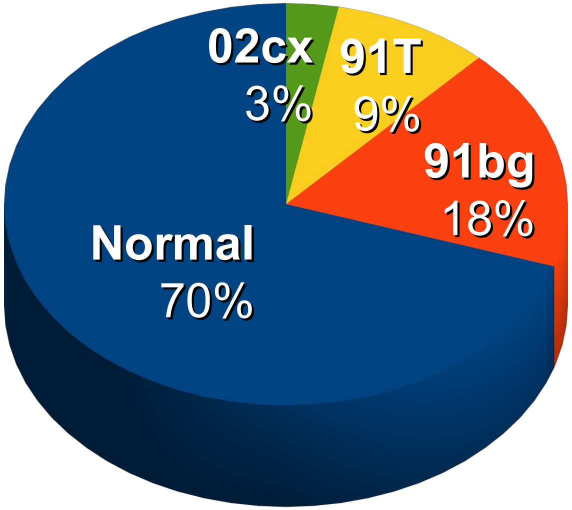
spectrum



good agreement with observed sub-luminous SNe Ia ("1991bg-like" objects)
also supported by population synthesis

SN Ia sub-classes and rates

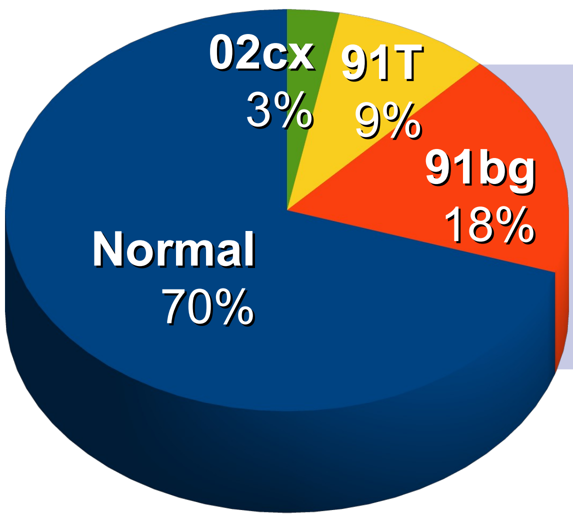
- volume-limited (Li+, 2010)



Friedrich Röpke, MPA

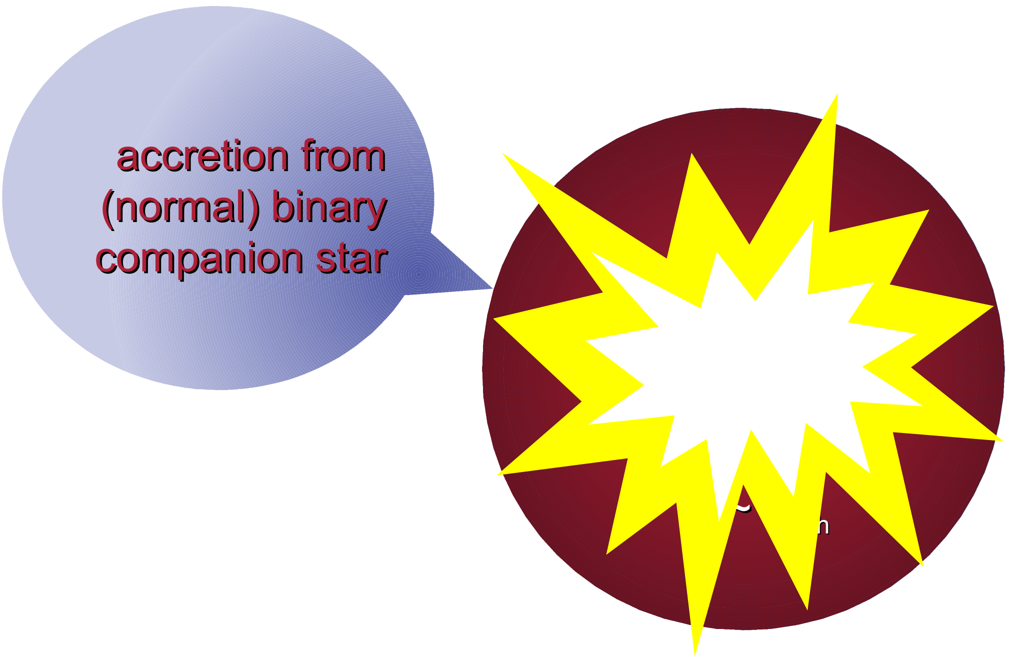
SN Ia sub-classes and rates

- volume-limited (Li+, 2010)



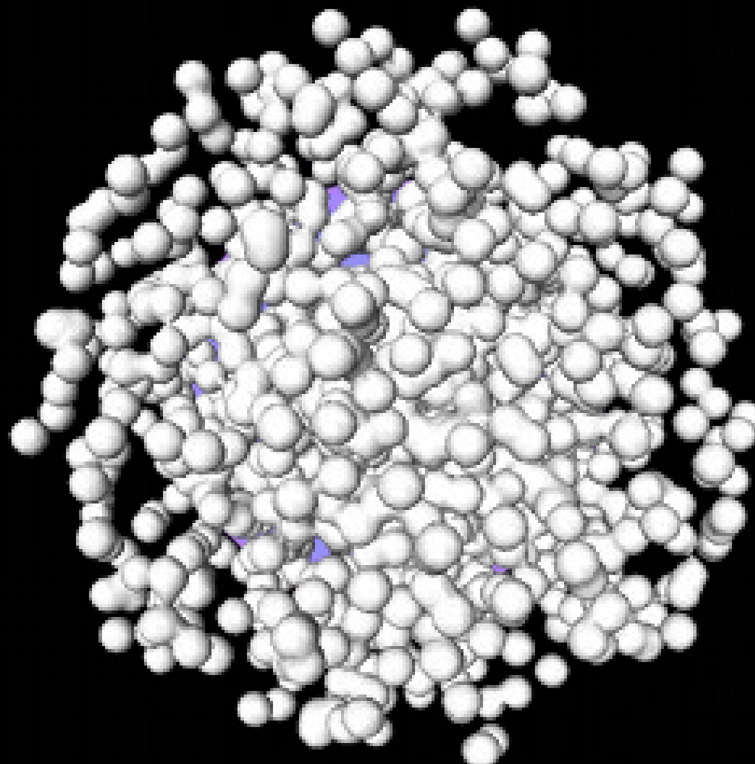
violent (q~1)
WD-WD mergers?

M_{Ch} model



Turbulent deflagrations

t = 0.025 sec

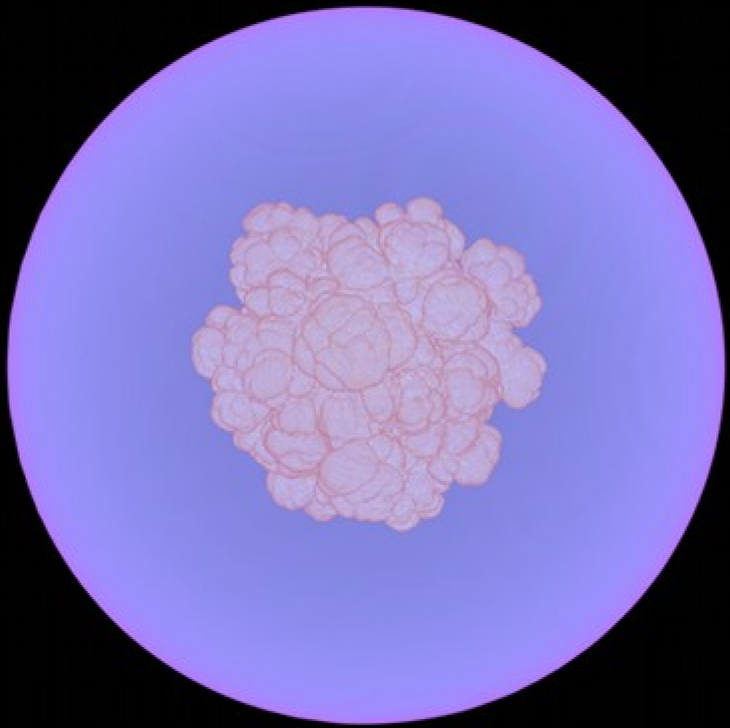


Turbulent deflagrations

t = 0.200 sec

Turbulent deflagrations

t = 0.600 sec

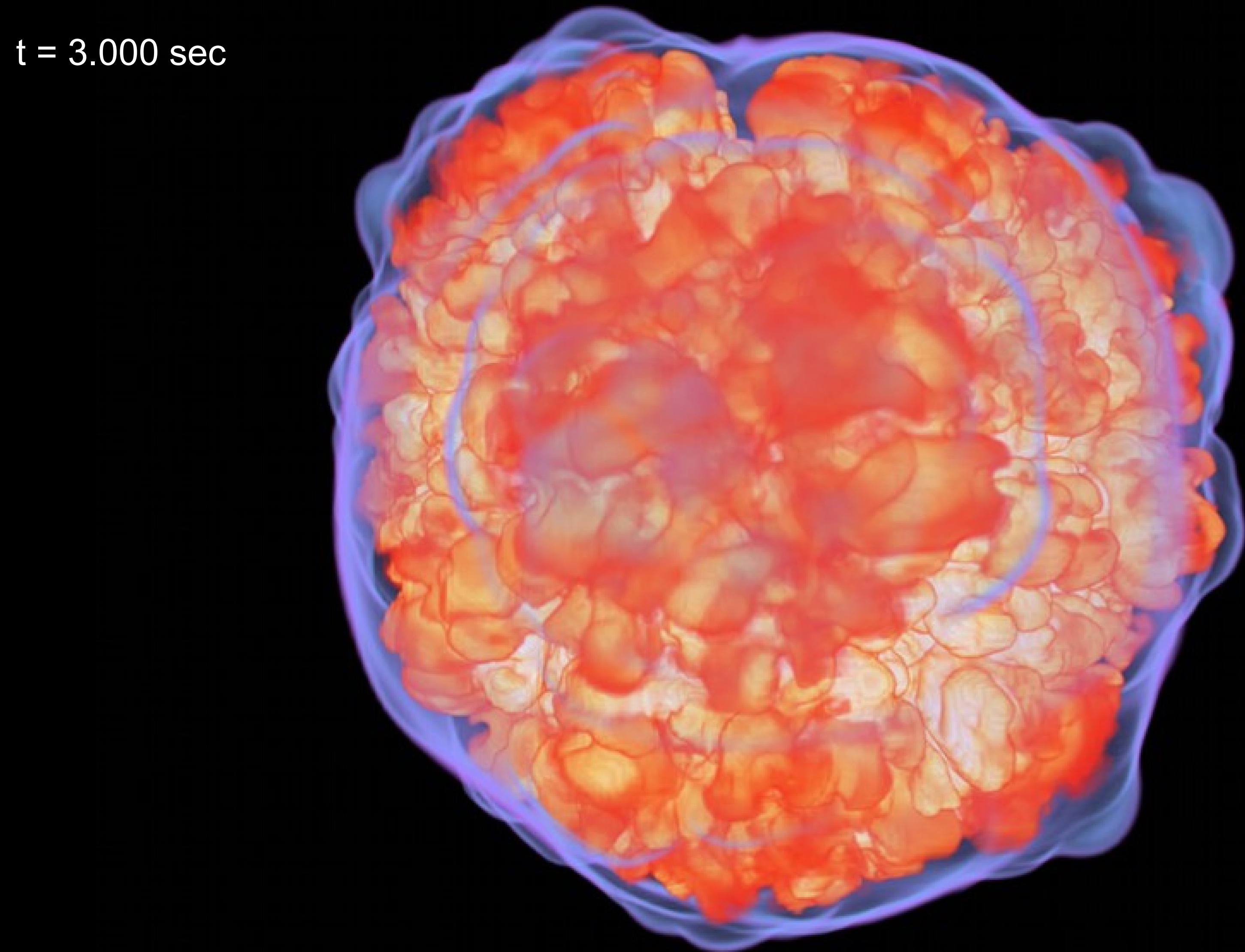


Turbulent deflagrations

t = 1.000 sec

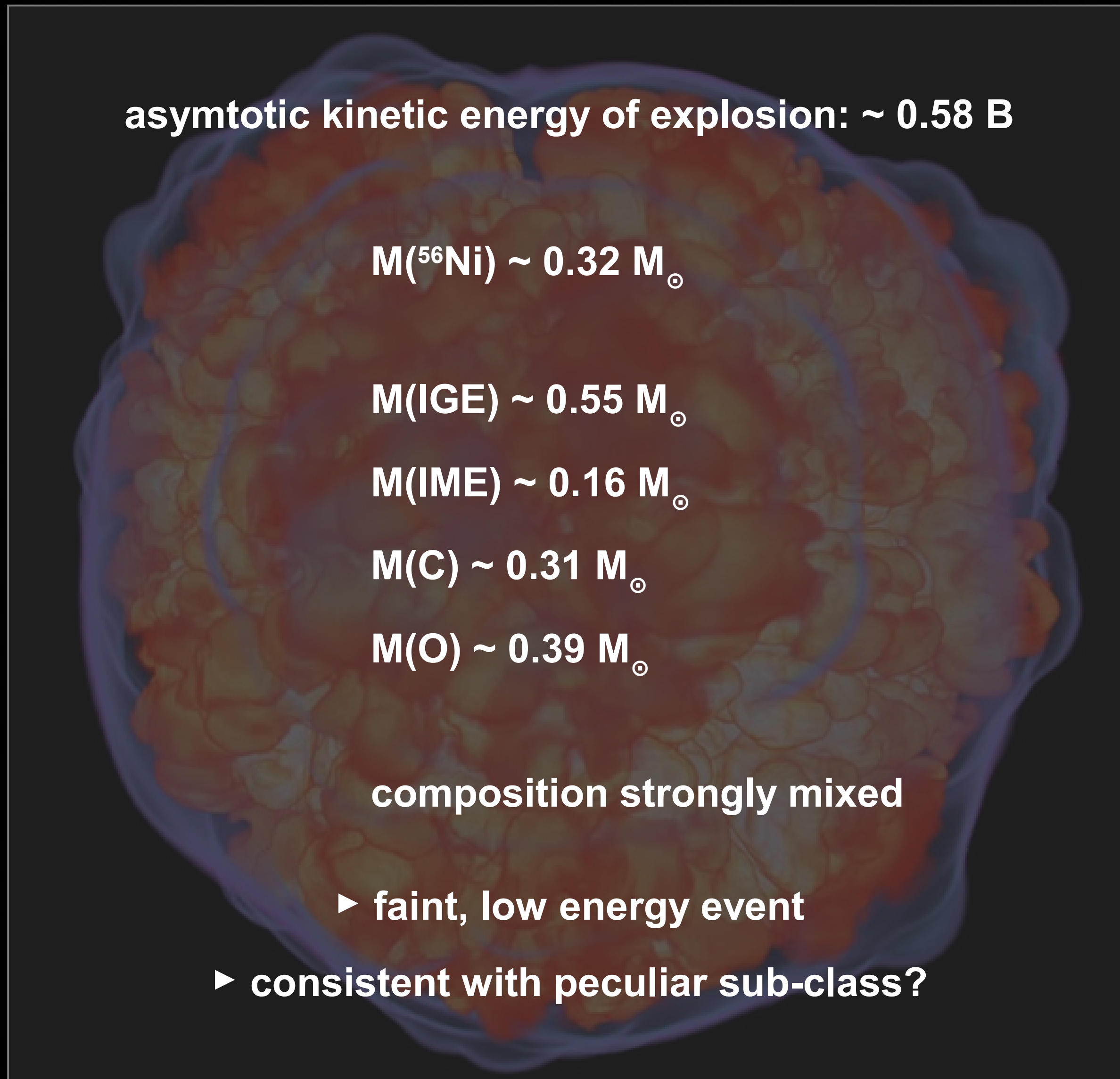
Turbulent deflagrations

Turbulent deflagrations



Turbulent deflagrations

t = 3.000 sec



asymtotic kinetic energy of explosion: ~ 0.58 B

M(^{56}Ni) ~ 0.32 $M_\odot$

M(IGE) ~ 0.55 $M_\odot$

M(IME) ~ 0.16 $M_\odot$

M(C) ~ 0.31 $M_\odot$

M(O) ~ 0.39 $M_\odot$

composition strongly mixed

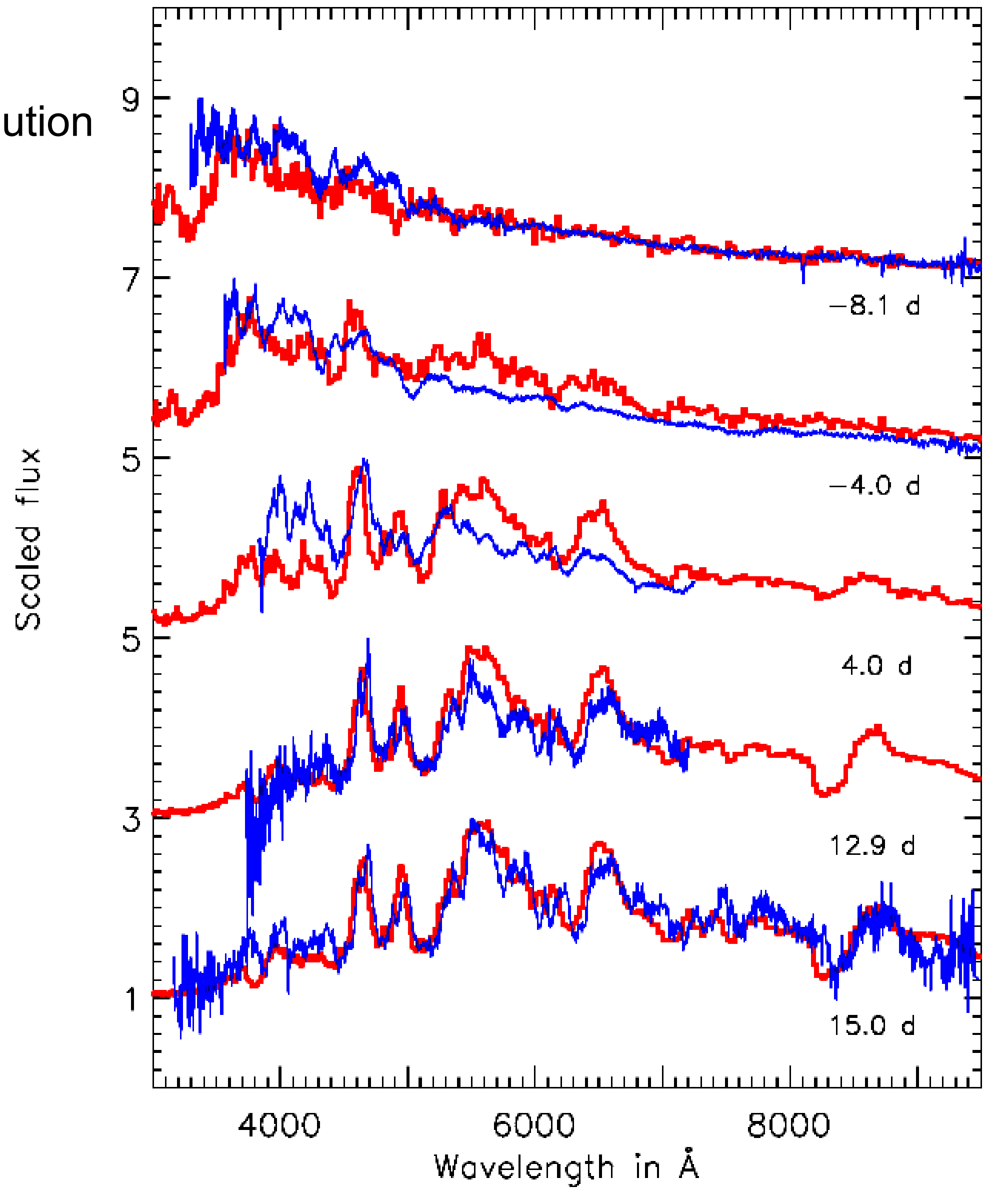
- ► **faint, low energy event**
- ► **consistent with peculiar sub-class?**

Turbulent deflagrations

- radiation transfer:

  preliminary, low resolution

  (Kromer & Sim)

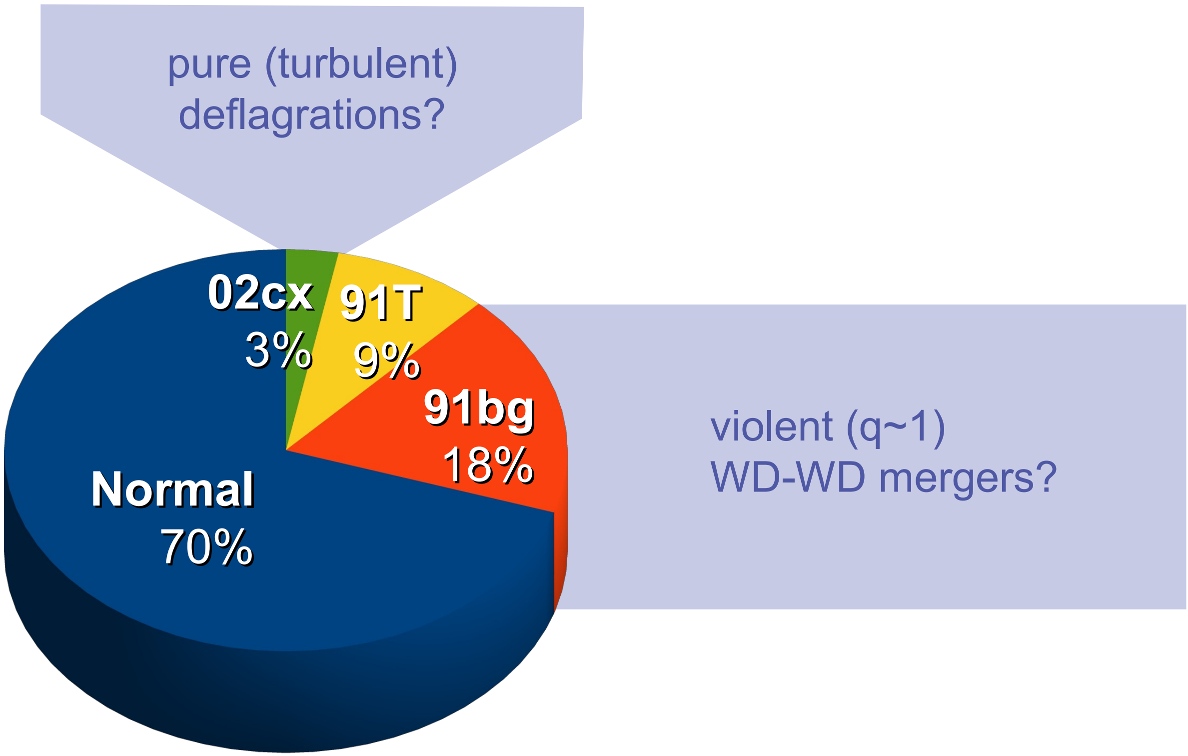


model spectrum (deflagration simulation)

SN 2005hk (observation)

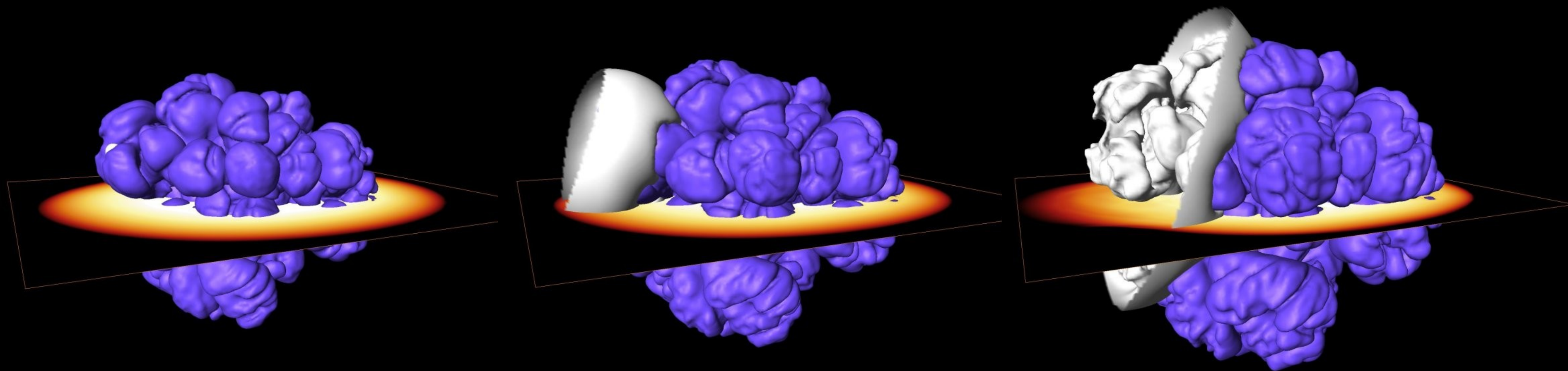
SN Ia sub-classes and rates

- volume-limited (Li+, 2010)



Delayed detonation model

- detonation of M_{Ch} WD after pre-expansion in initial deflagration phase (Khokhlov 1991)

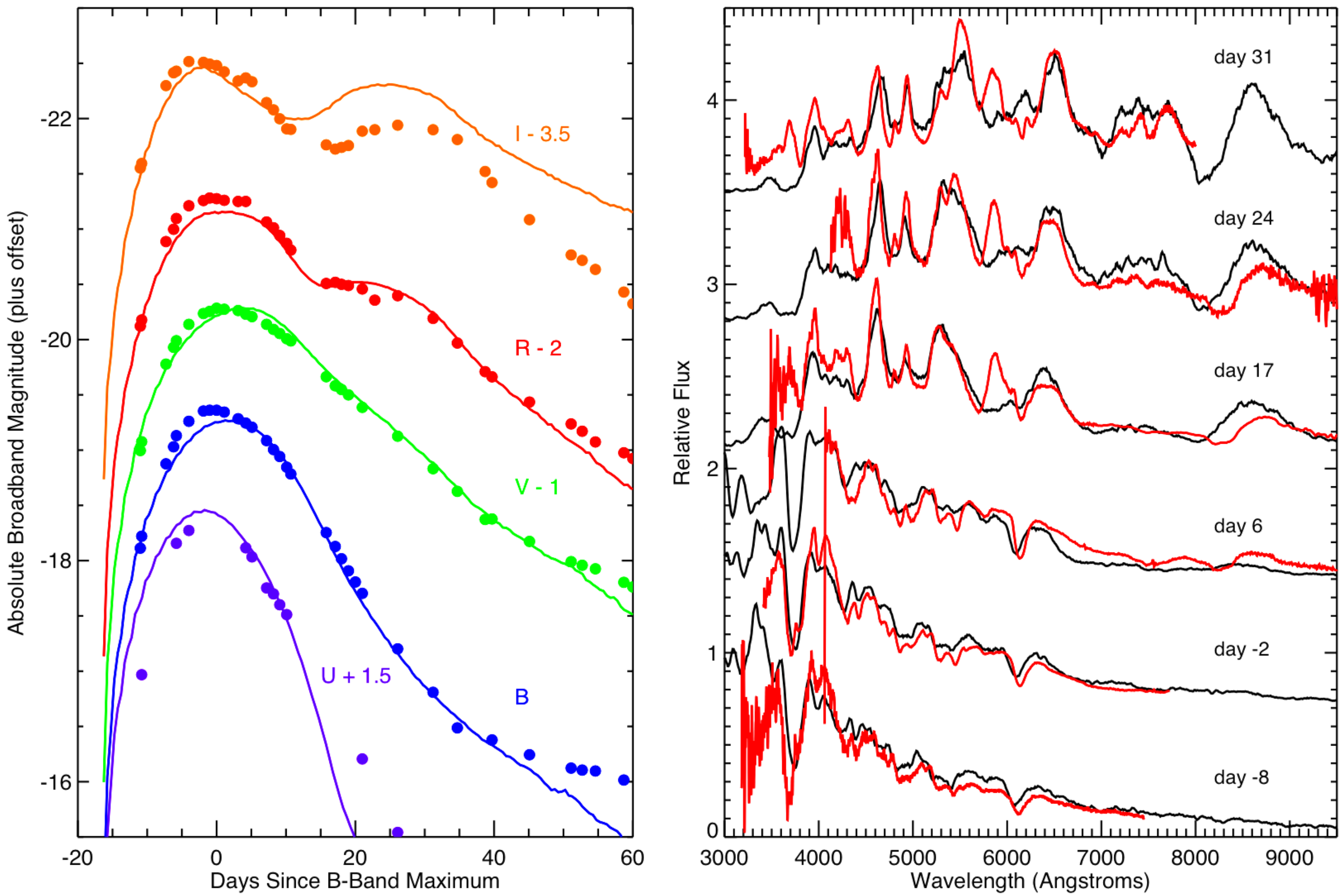


FR & Niemeyer, 2007
Mazzali et al., 2007

- requires deflagration-to-detonation transition (DDT) of flame
- probably possible at low densitites (late phase of explosion) if turbulence still strong enough (FR, 2007; Woosley 2007; Woosley+, 2009)

Synthetic observables

- radiation transfer for 44 2D explosion models (Kasen+, 2009) compared with SN 2003du



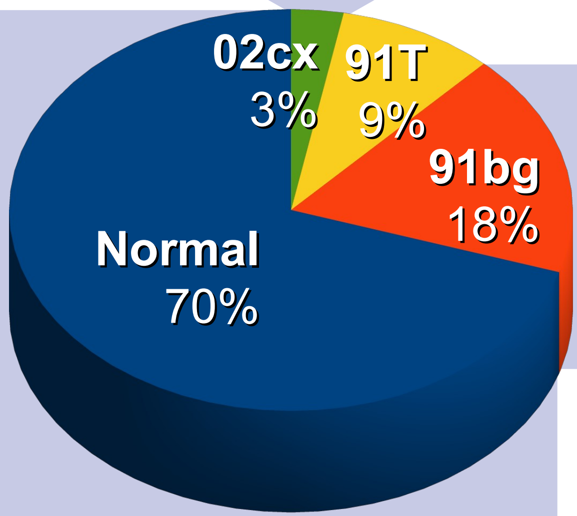
SN Ia sub-classes and rates

- volume-limited (Li+, 2010)

pure (turbulent)
deflagrations?

delayed
detonations?

not supported by
population
synthesis

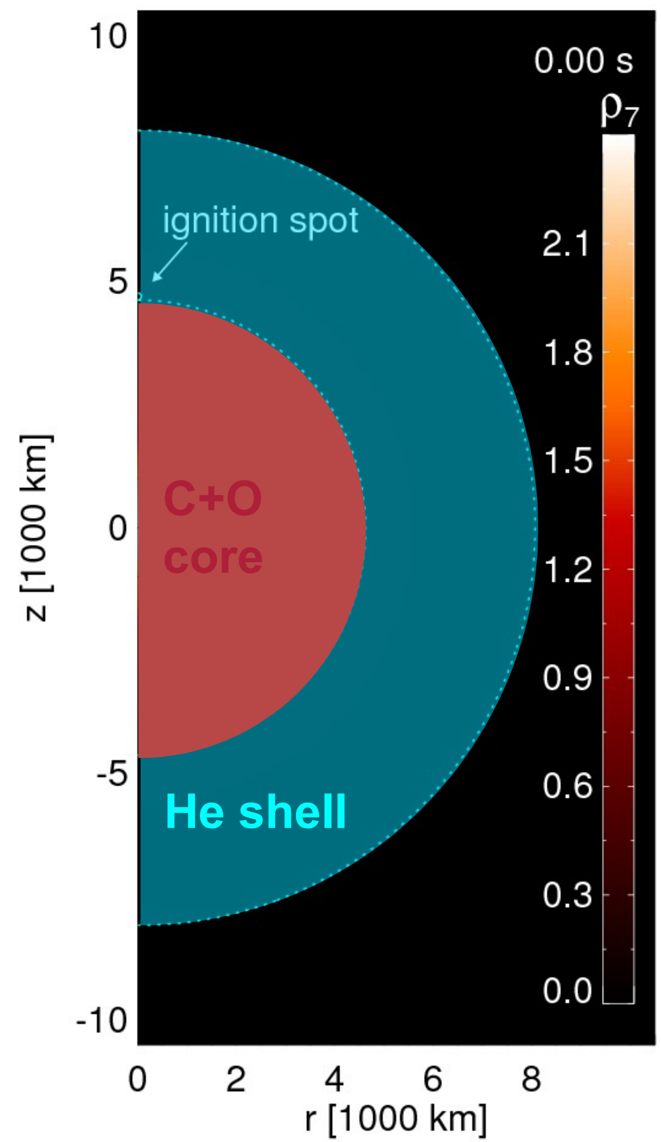


violent (q~1)
WD-WD mergers?

Sub-M_{Ch} explosions

- explosion simulation (Fink+, 2007, 2010)
- minimum He-shell masses (Bildsten+, 2007)

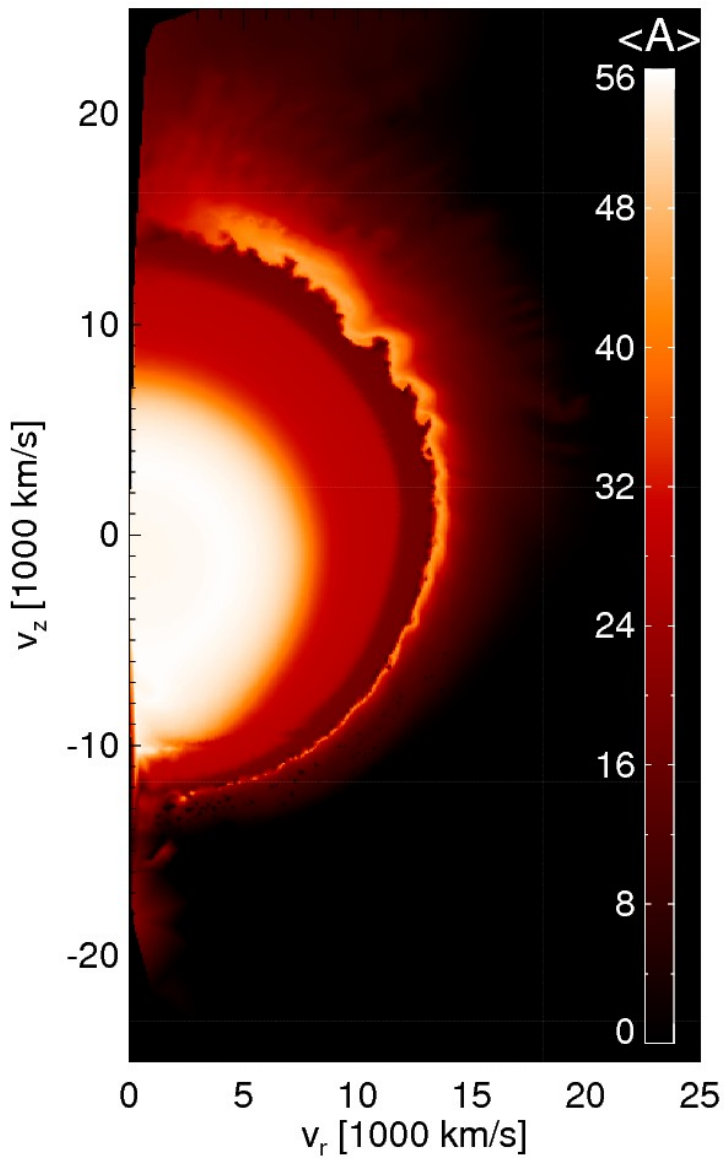
Model 2



Sub-M_{Ch} explosions

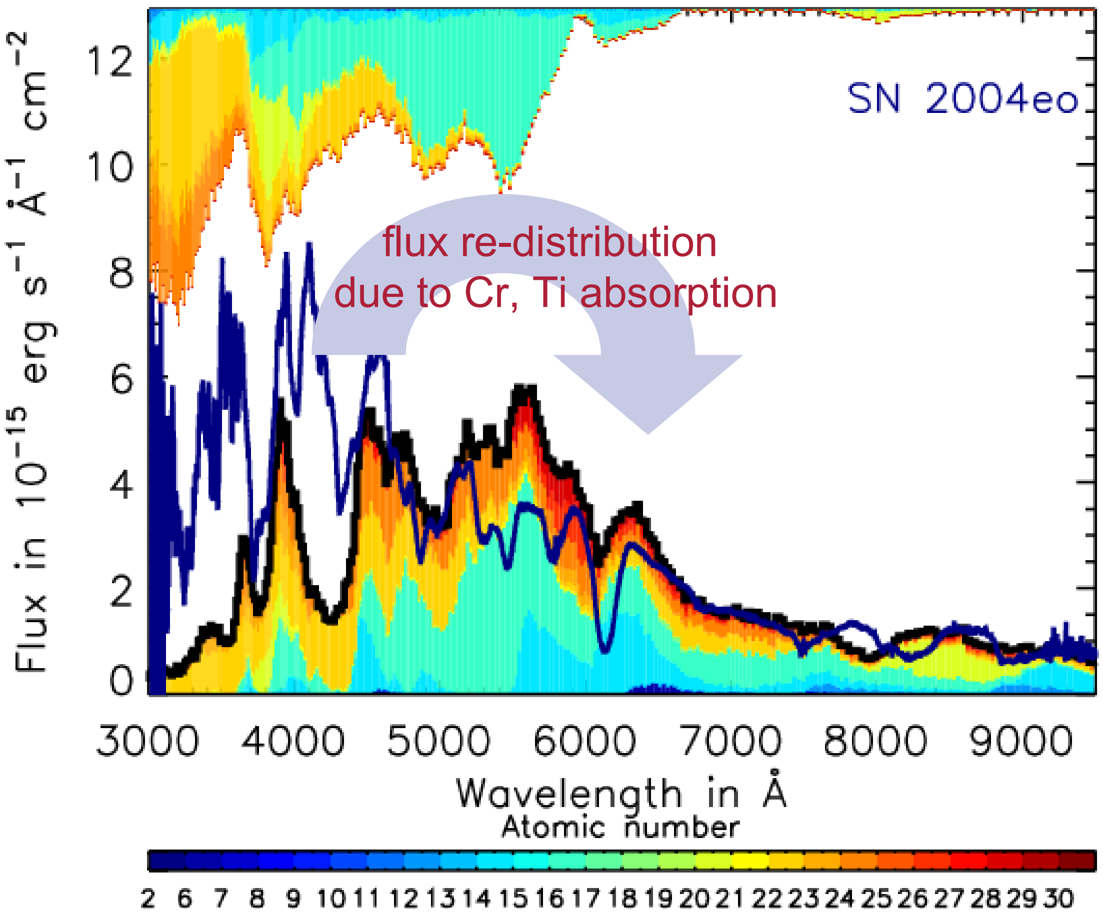
- explosion simulation: (Fink+, 2007, 2010)
- minimum He-shell masses (Bildsten+, 2007)
- C+O core detonation triggers robustly

Model 2



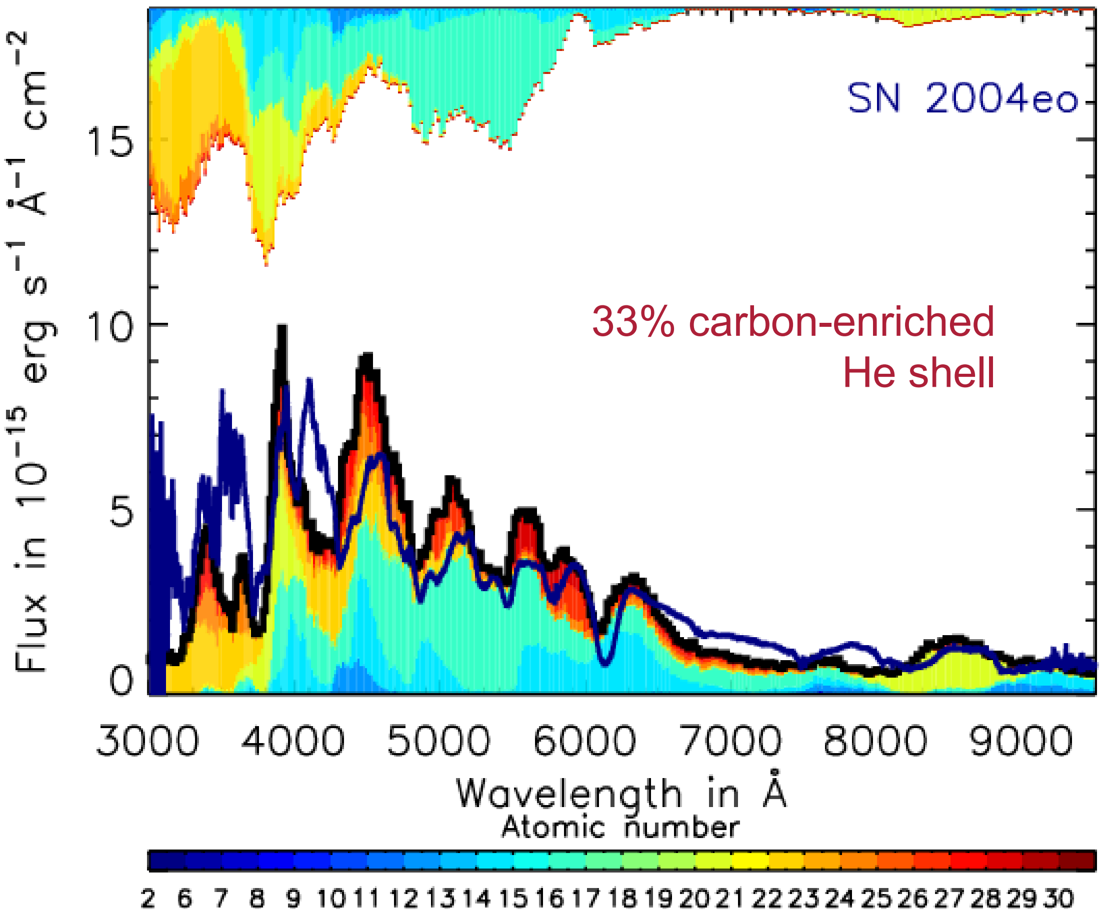
Sub-M_{Ch} explosions

- radiation transfer (Kromer+, 2010)
- iron group elements produced in He shell detonation (Ti, Cr, etc) may be problematic



Sub-M_{Ch} explosions

- changing C abundance in He shell may help (Kromer+, 2010)
- bare sub-M_{ch} detonations produce promising results (Sim+, 2010)



SN Ia sub-classes and rates

- volume-limited (Li+, 2010)

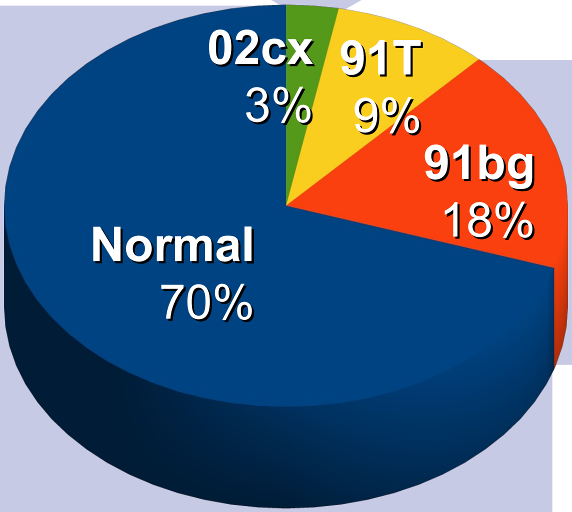
pure (turbulent)
deflagrations?

delayed
detonations?

or

sub-M_{Ch}
detonations?

(consistent with
population synthesis)



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