Type Ia Supernovae from mergers of white dwarfs

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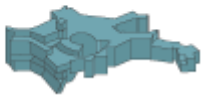


Modeling a merger in full 3D

- Inspiral & Merger (SPH: Gadget)
- Nuclear Burning & Explosion

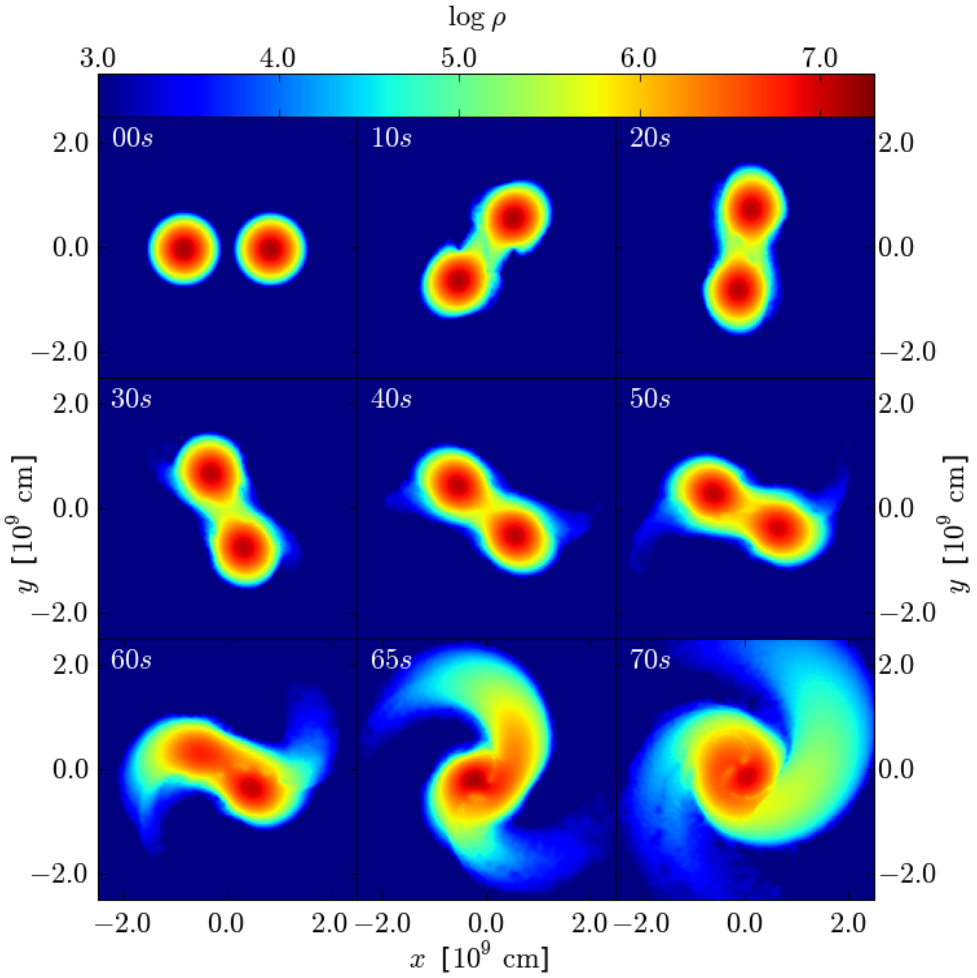
  (Grid: MPA SNIa code)
- Detailed Nucleosynthesis (Tracer particles)
- Radiative Transfer (Monte Carlo: ARTIS)

Initial conditions

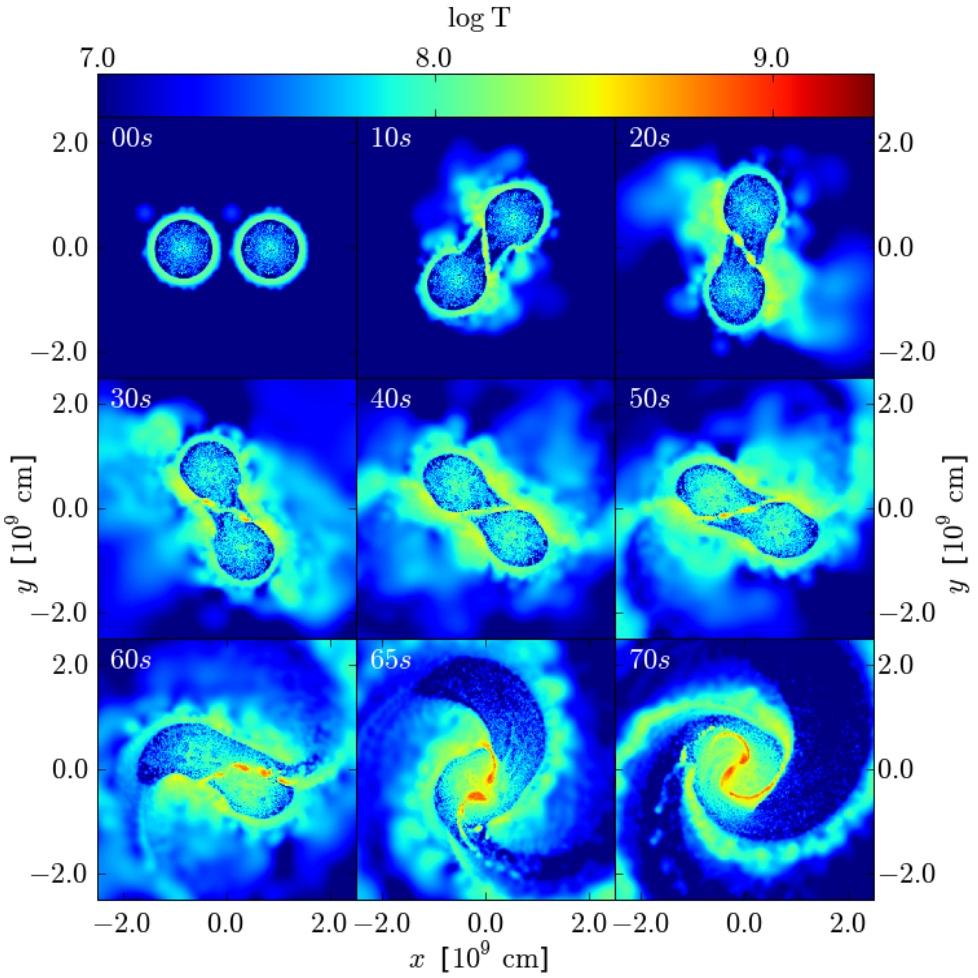
- 2 WDs of 0.9 $M_{\odot}$ $\longrightarrow$ q = 1
- Temperature 5 x 10^5 K
- Composition 1:1 C/O
- Initial period 28s
- WDs initially in hydrostatic equilibrium

Inspiral & Merger

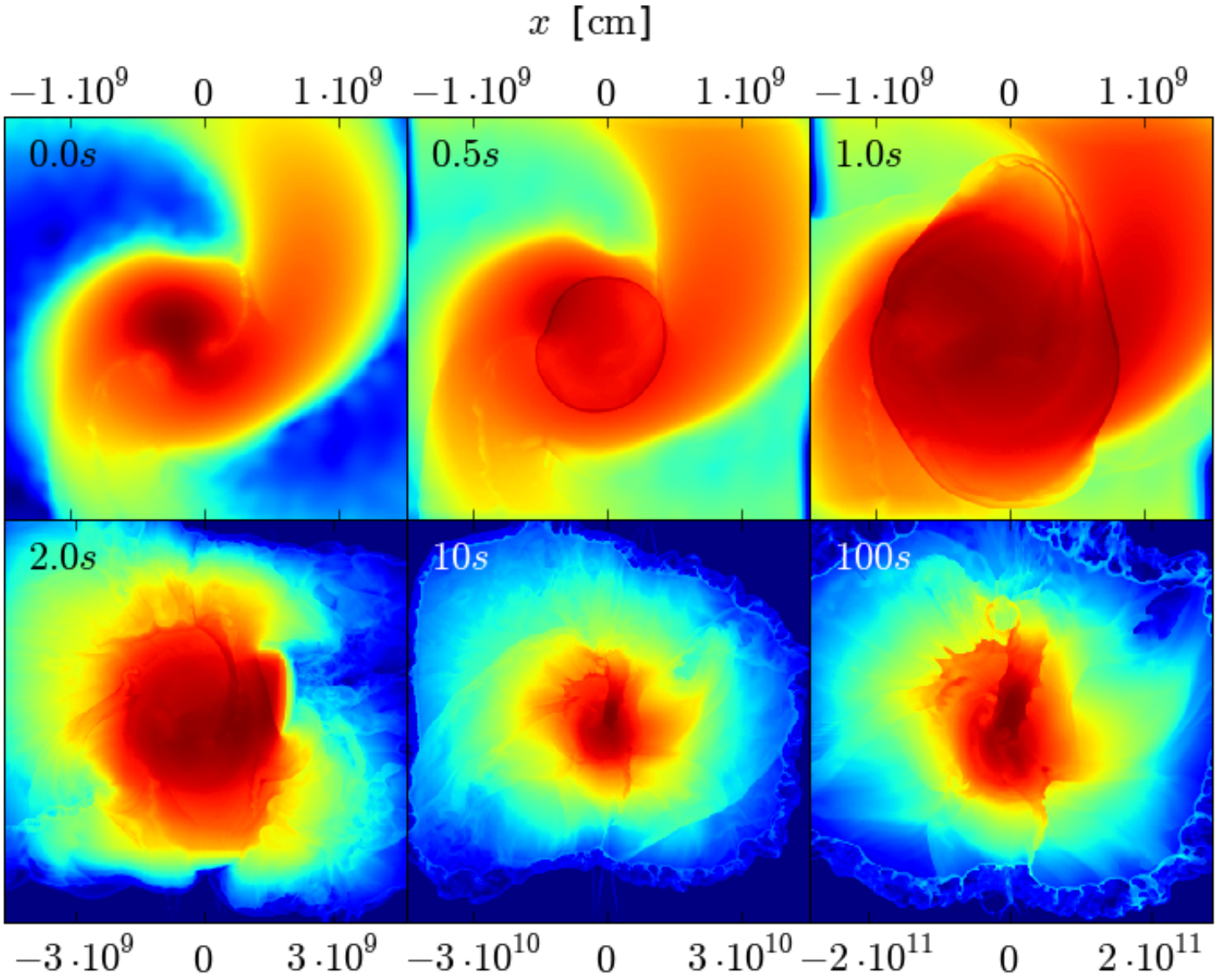
Density



Temperature

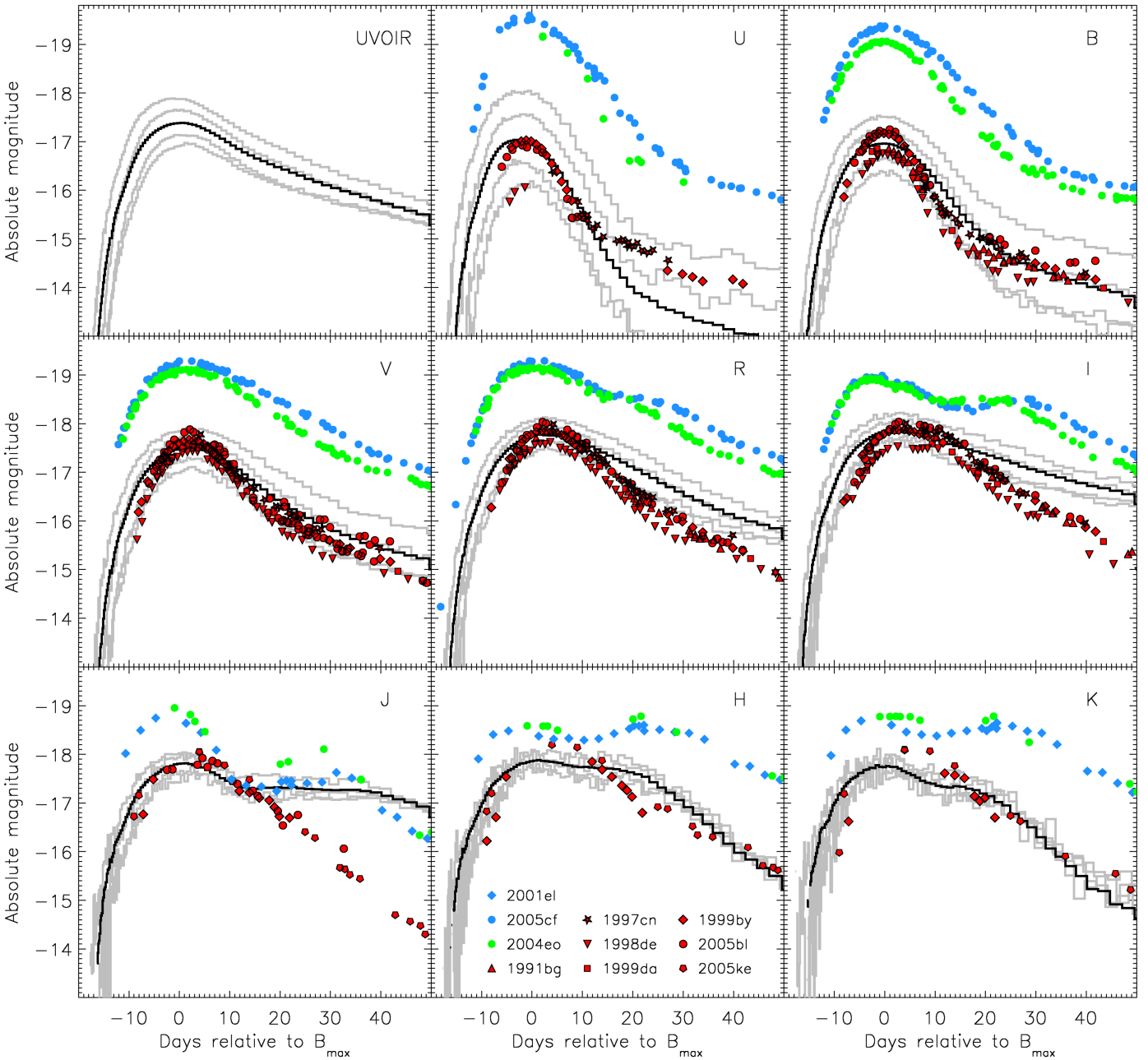


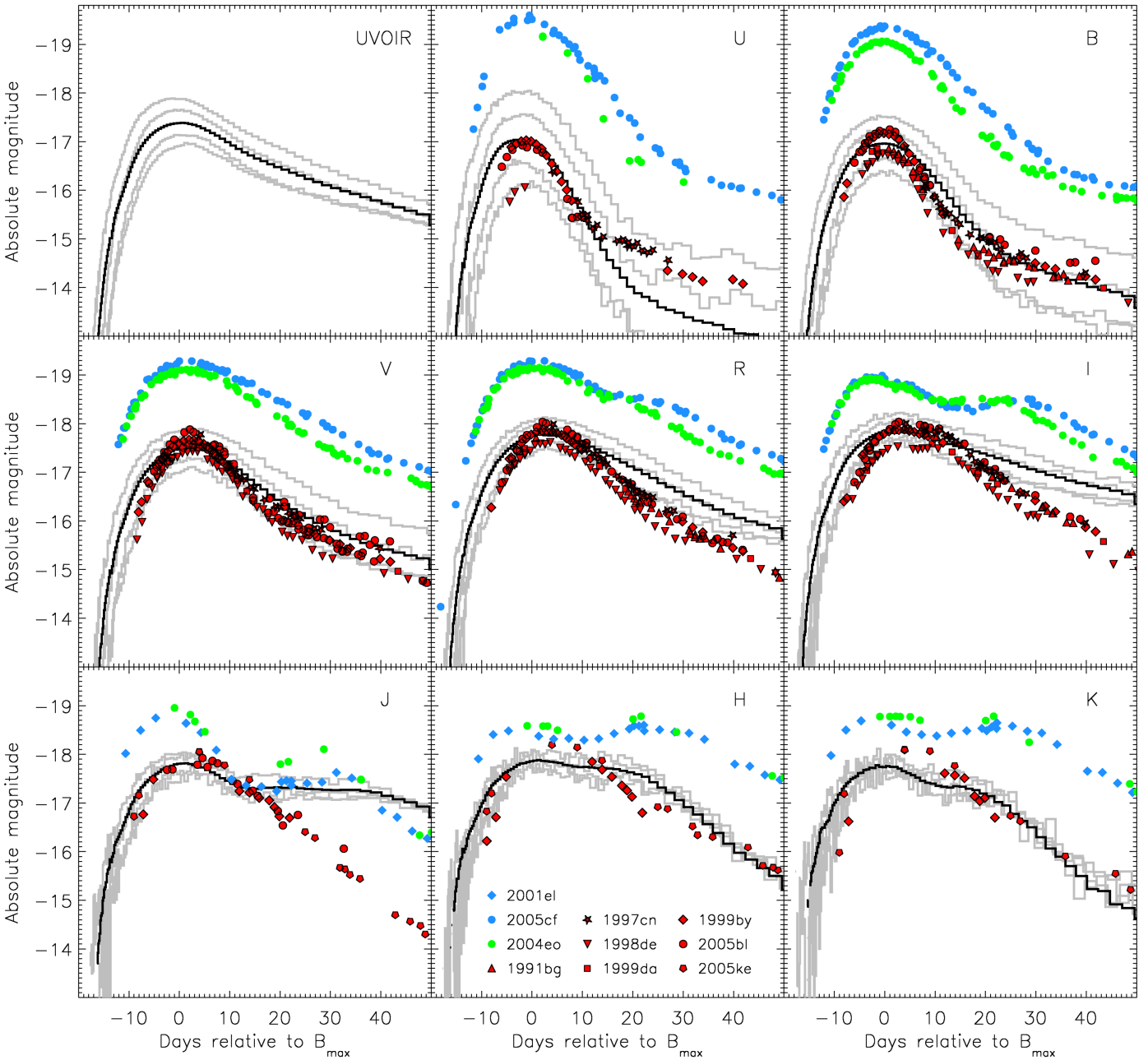
Explosion


x [cm]
$-1 \cdot 10^9$
0
$1 \cdot 10^9$
$-1 \cdot 10^9$
0
$1 \cdot 10^9$
$-1 \cdot 10^9$
0
$1 \cdot 10^9$
0.0s
0.5s
1.0s
2.0s
10s
100s
$-3 \cdot 10^9$
0
$3 \cdot 10^9$
$-3 \cdot 10^{10}$
0
$3 \cdot 10^{10}$
$-2 \cdot 10^{11}$
0
$2 \cdot 10^{11}$

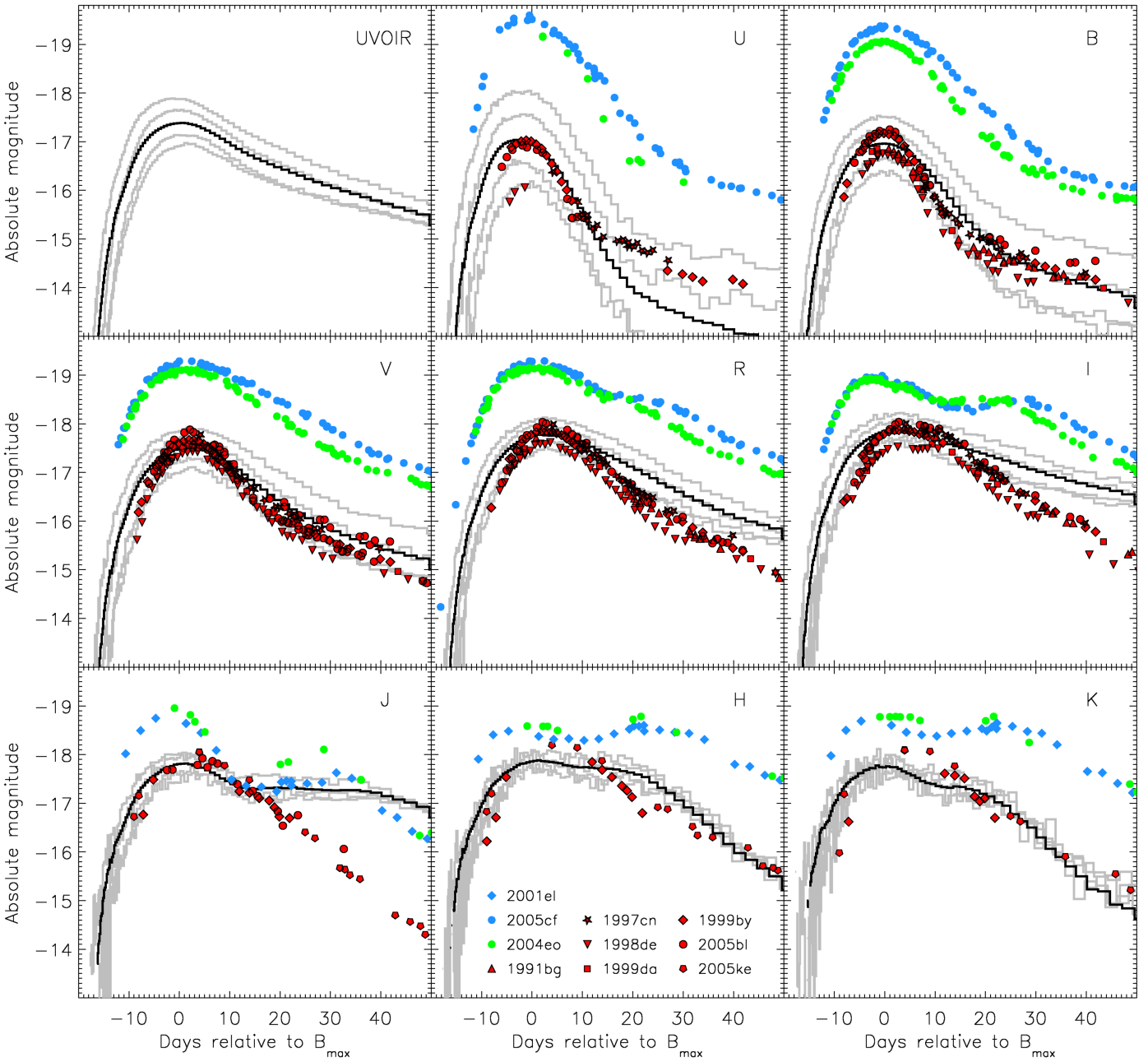
Explosion

- Complete disruption of the merged object
- Kinetic energy: 1.3 x 10^{51} erg
- Ejecta mass: 1.8 $M_{\odot}$ = 1.3 M_{Ch}
- Composition:
  - 0.1 $M_{\odot}$ Iron group elements
  - 1.1 $M_{\odot}$ Intermediate mass elements
  - 0.5 $M_{\odot}$ Oxygen
  - 0.1 $M_{\odot}$ Carbon


UVOIR
U
B
V
R
I
J
H
K
Absolute magnitude
−19
−18
−17
−16
−15
−14
−10
0
10
20
30
40
Days relative to B max
2001el
2005cf
2004eo
1991bg
1997cn
1998de
1999da
1999by
2005bl
2005ke

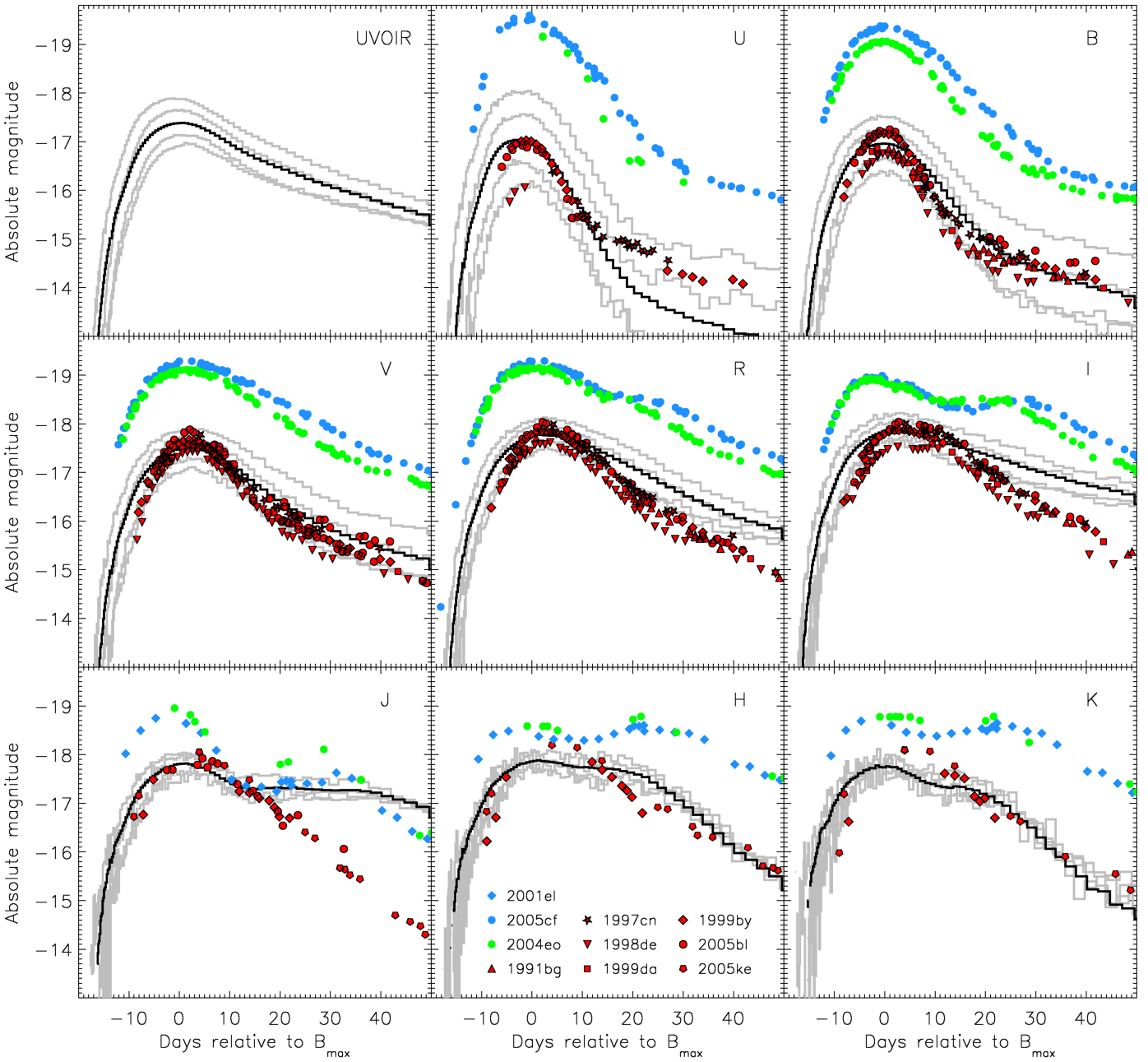


Low luminosity: B_{max} = -17 mag

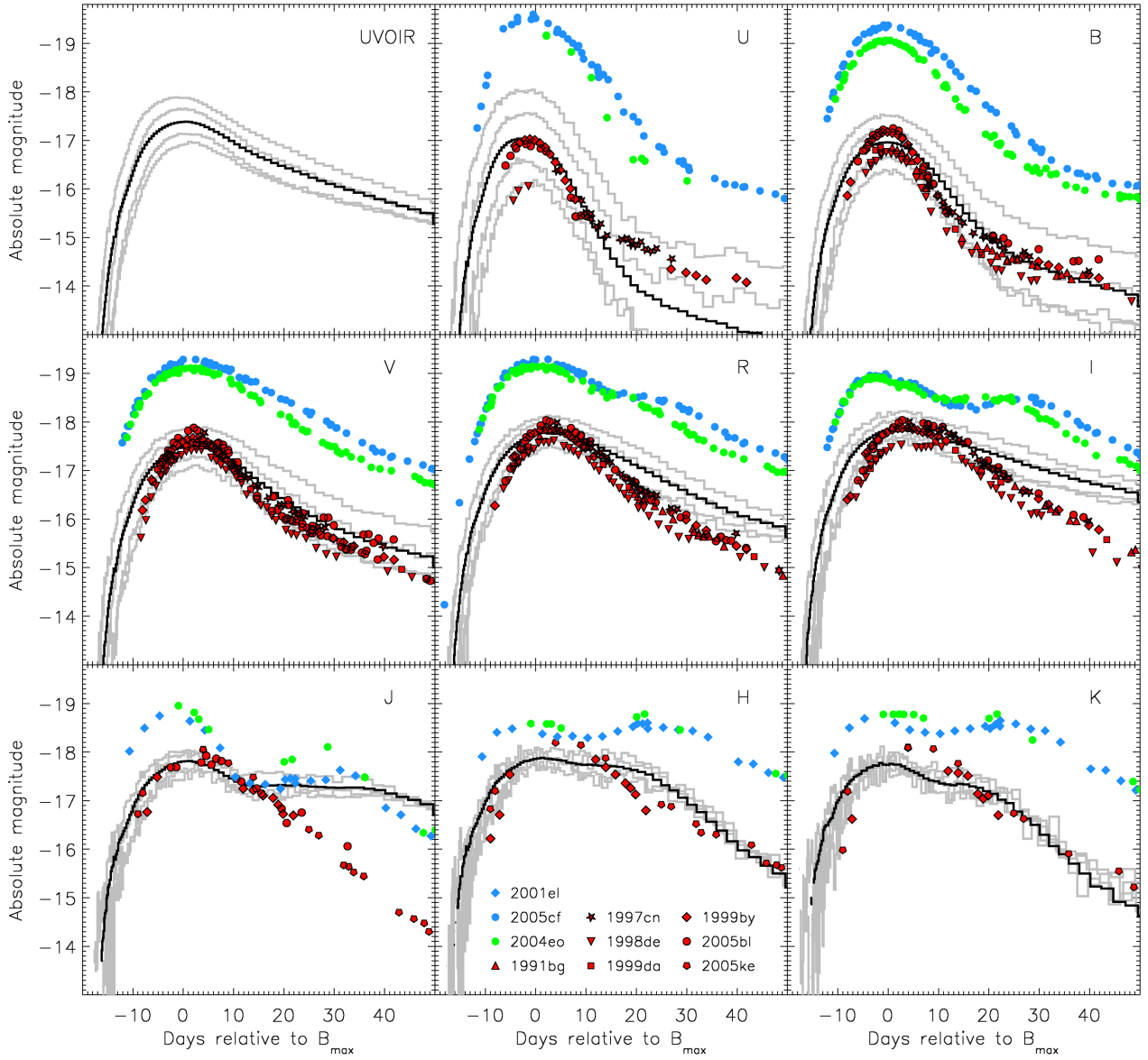


Narrow light curve: slightly too broad

$\Delta m_{15} = 1.4$ (observed: 1.9)



No secondary maxima in the near infrared bands (J,H,K)

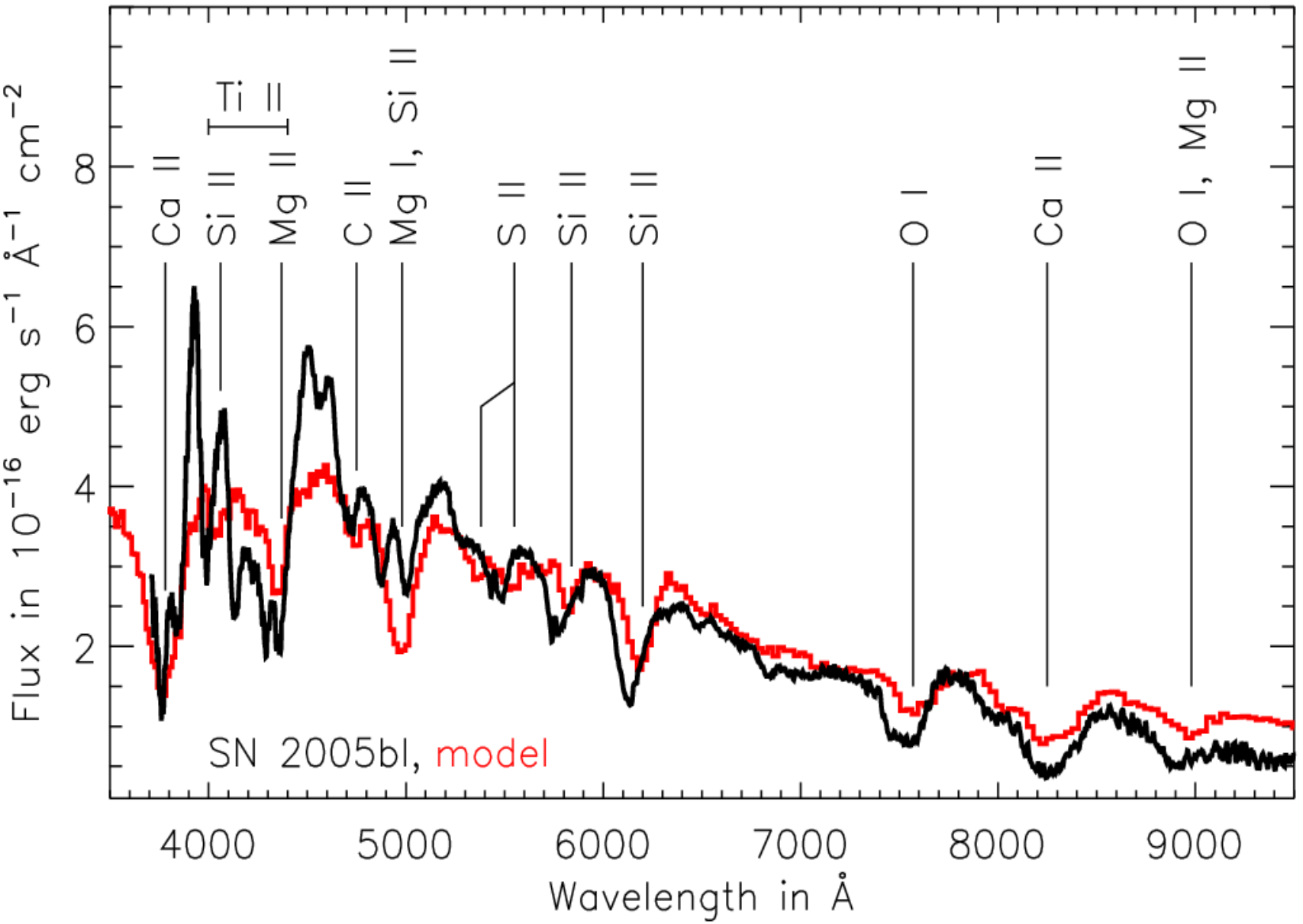


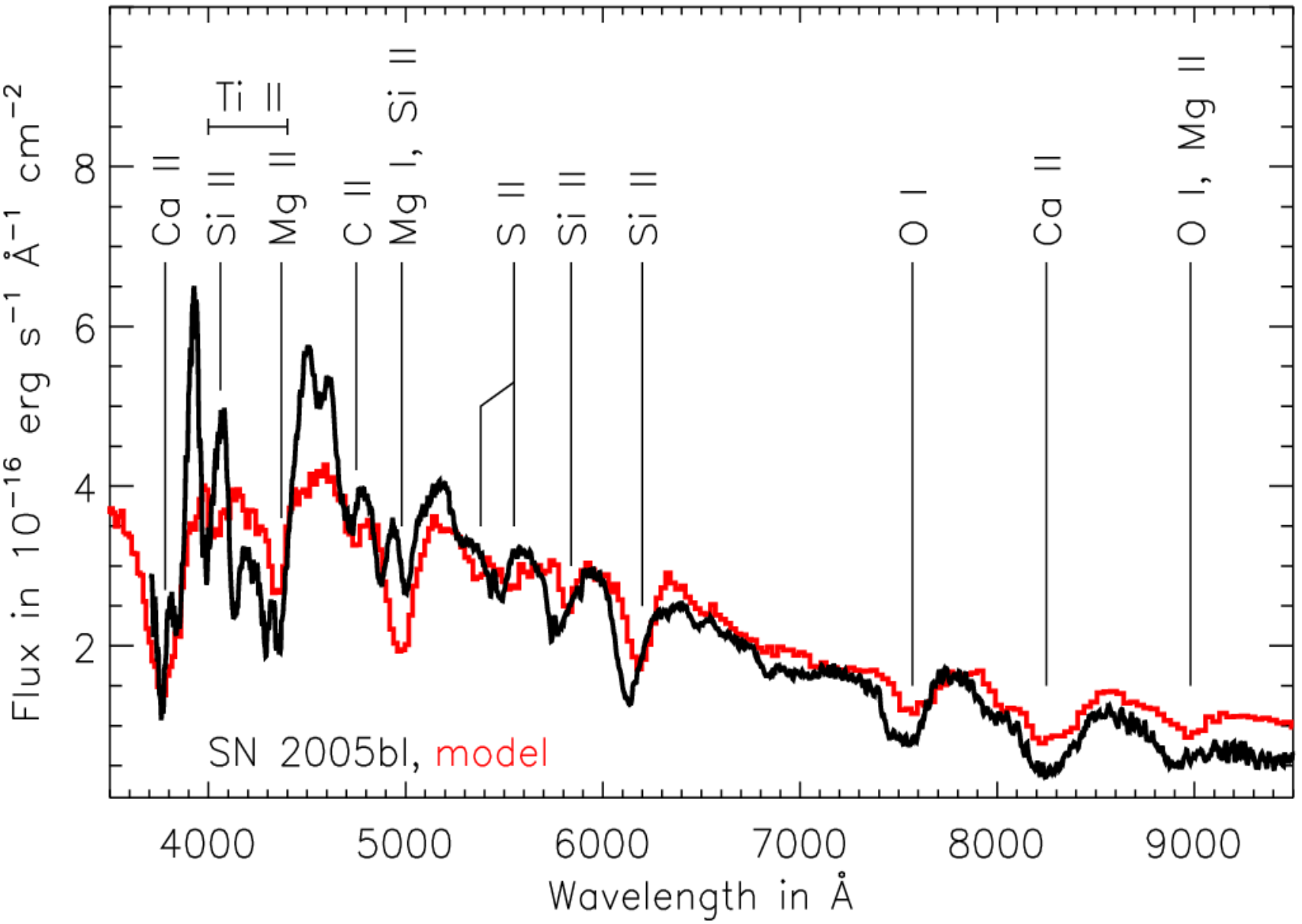
Colors:

simulation: B-V = 0.53, V-R = 0.27, V-I = 0.36

subluminous (05bl): B-V = 0.61, V-R = 0.21, V-I = 0.25

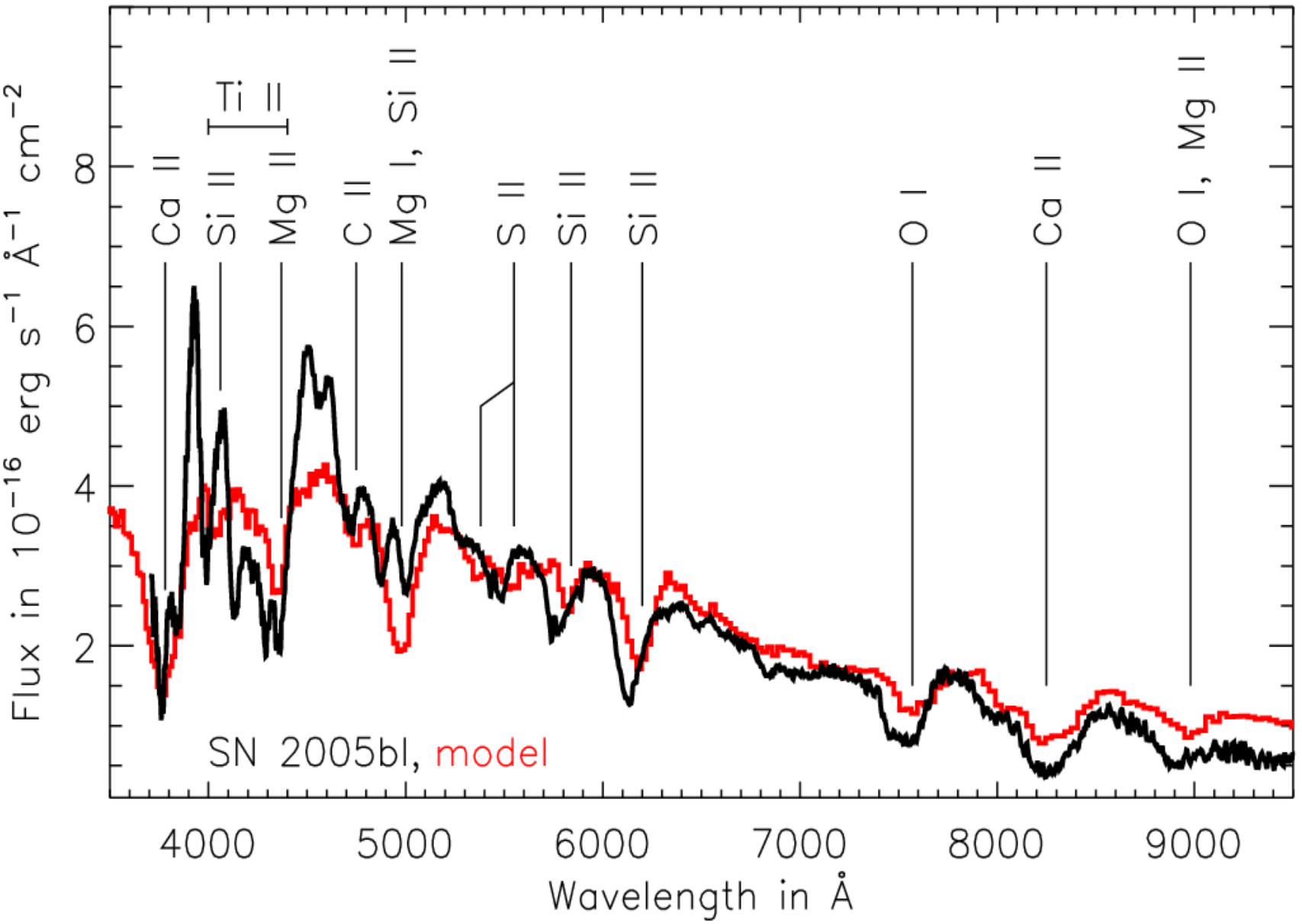
normal (04eo): B-V = 0.05, V-R = 0.06, V-I = -0.16


Ca II
Si II
Ti II
Mg II
C II
Mg I, Si II
S II
Si II
Si II
O I
Ca II
O I, Mg II
SN 2005bl, model
Flux in 10^{-16} erg s^{-1} Å^{-1} cm^{-2}
Wavelength in Å
2
4
6
8
4000
5000
6000
7000
8000
9000

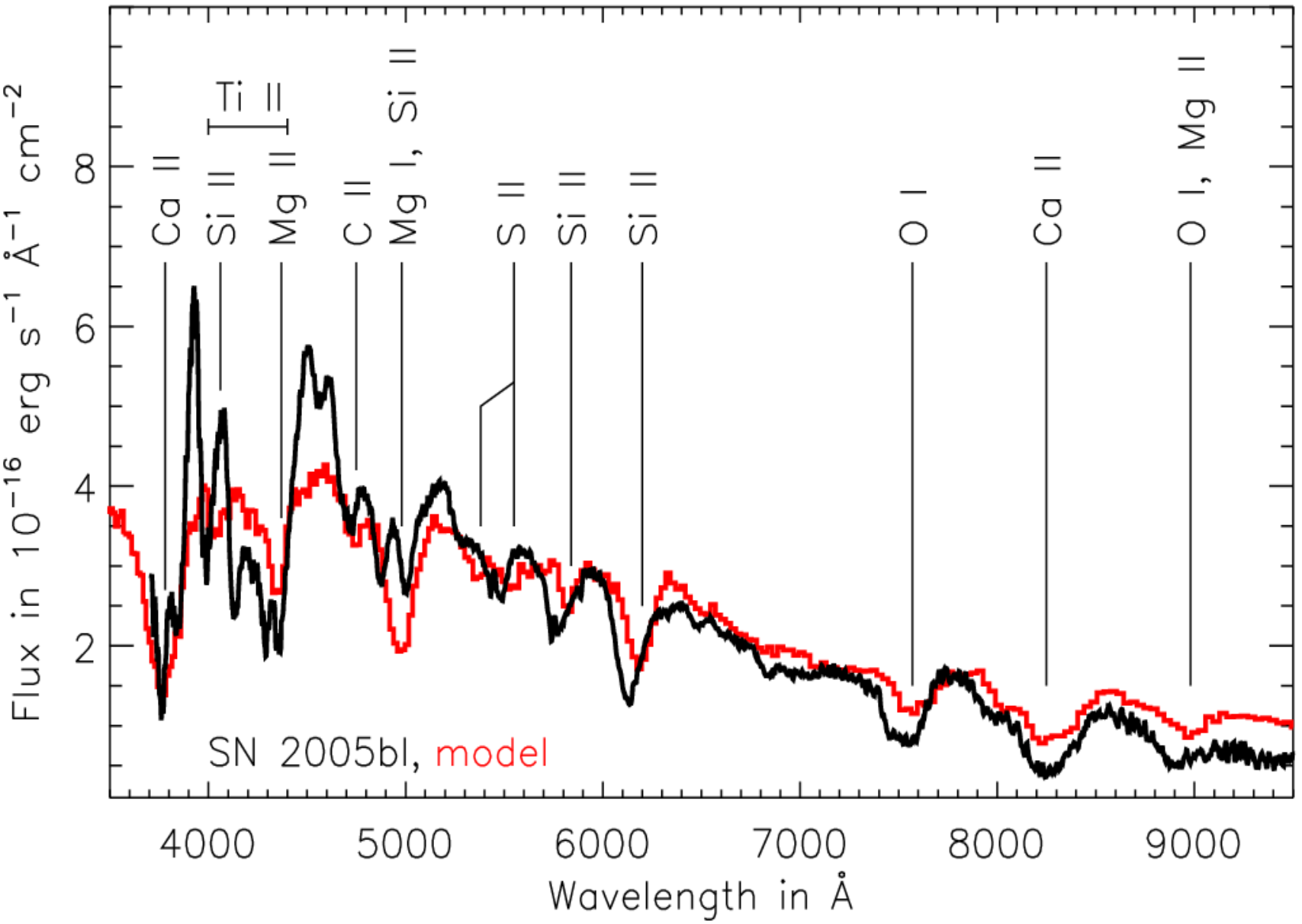


Low expansion velocities:

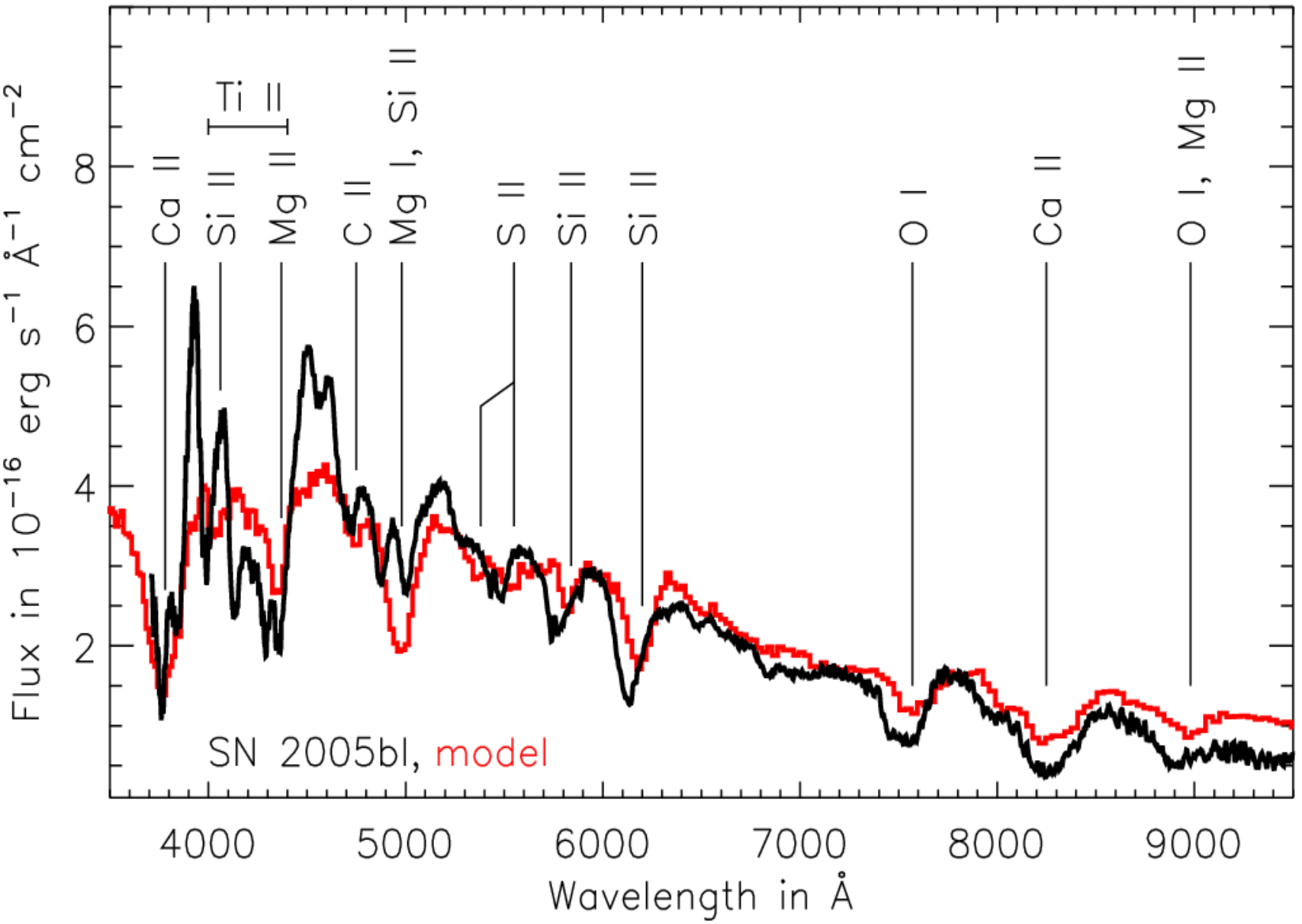
Velocities are slightly too low



Strong intermediate mass elements:
present



Strong O I features:
present



Ti II trough:

exists, but too weak

Summary

- Mergers of two white dwarfs can lead to Type Ia Supernovae
- The subclass of 1991bg-like SNe Ia can be explained with the merger model, possibly also other SNe Ia
- The crucial point of the scenario is whether a detonation forms