Modelling the spectral evolution of Supernovae (using the JEKYLL code)

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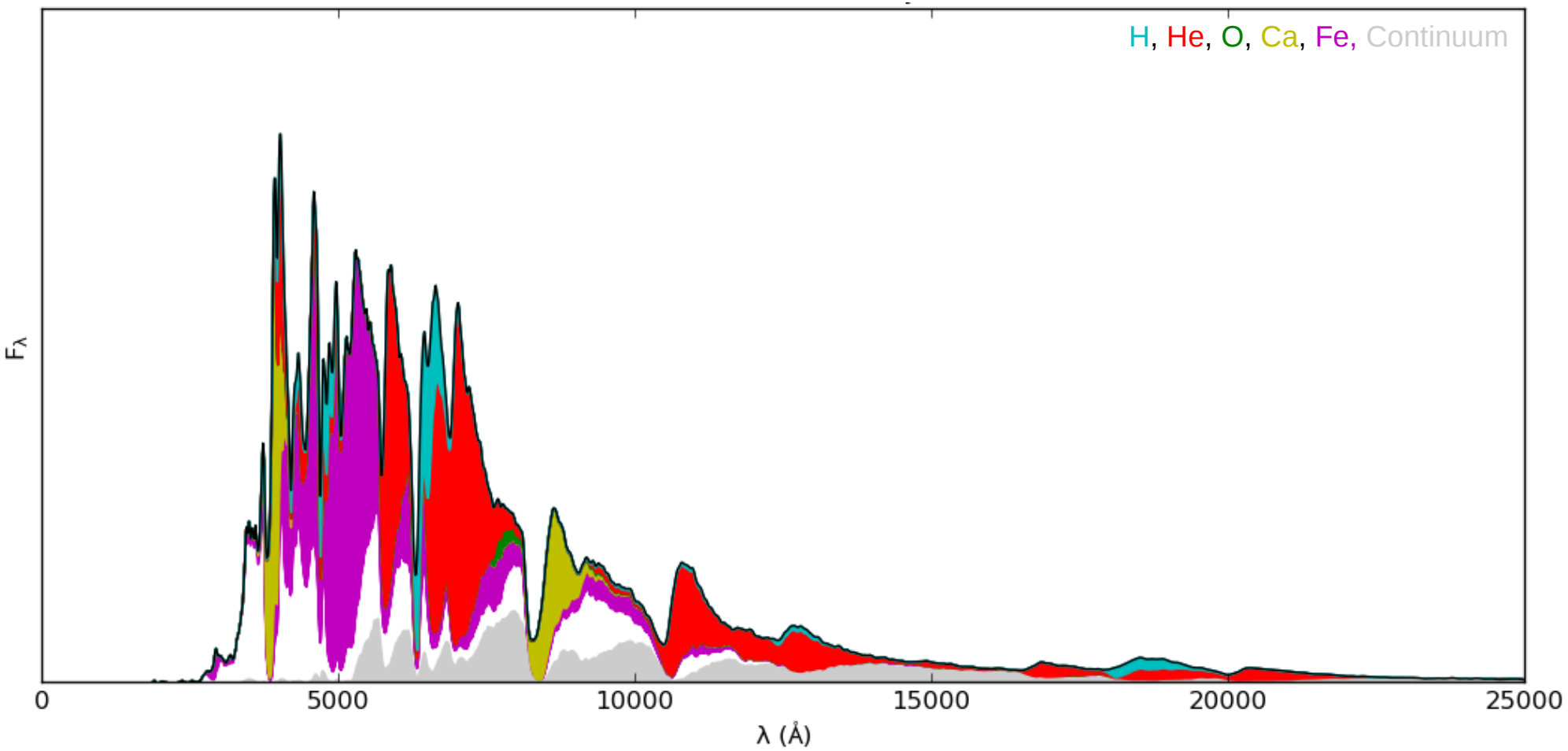
In collaboration with Claes Fransson, Anders Jerkstrand, Markus Kromer and Cecilia Kozma



The JEKYLL code

What: Realistic* simulations of the spectral evolution and lightcurves of SNe in the photospheric and nebular phase.

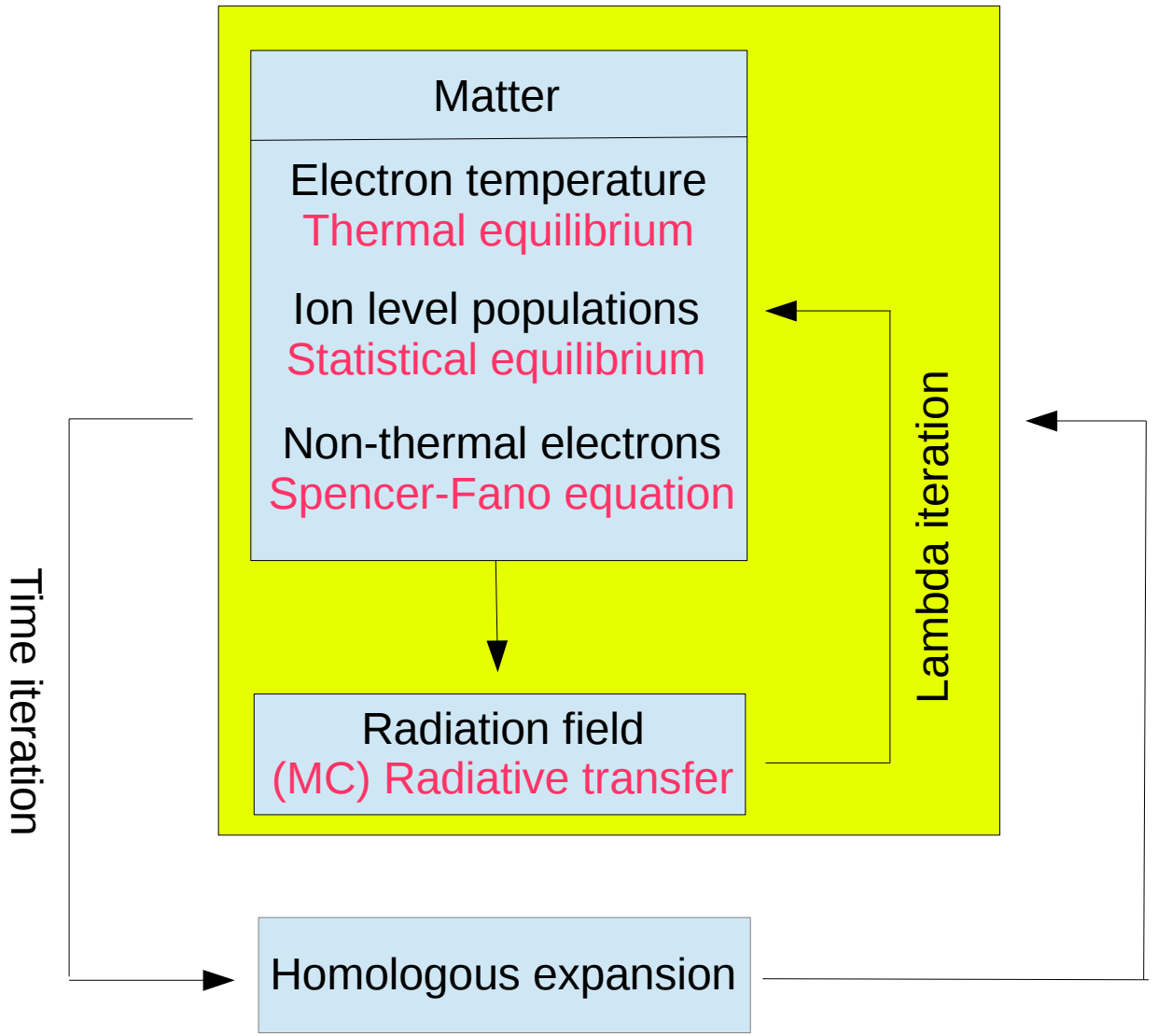
How: Full NLTE-solution for the matter and the radiation field, following (and extending) the MC method outlined by Leon Lucy (2002, 2003, 2005).

Key ingredients: Non-thermal electrons and macroscopic mixing.

* Restrictions:

Homologous expansion.
Spherical symmetry.
Steady-state for the matter.

Method outline



Other similar codes

SEDONA (Kasen et al. 2006)

Geometry: 3-D
NLTE: No
Non-thermal ionization/excitation: No
Time-dependence: Radiation field
Macroscopic mixing: Yes
Phase : Photospheric

SUMO (Jerkstrand et al. 2011)

Geometry: 1-D
NLTE: Full
Non-thermal ionization/excitation: Yes
Time-dependence: No
Macroscopic mixing: Yes
Phase: Nebular

JEKYLL (Ergon et al. In prep.)

Geometry: 1-D
NLTE: Full
Non-thermal ionization/excitation: Yes
Time-dependence: Radiation field
Macroscopic mixing: Yes
Phase: All

ARTIS (Kromer et al. 2009)

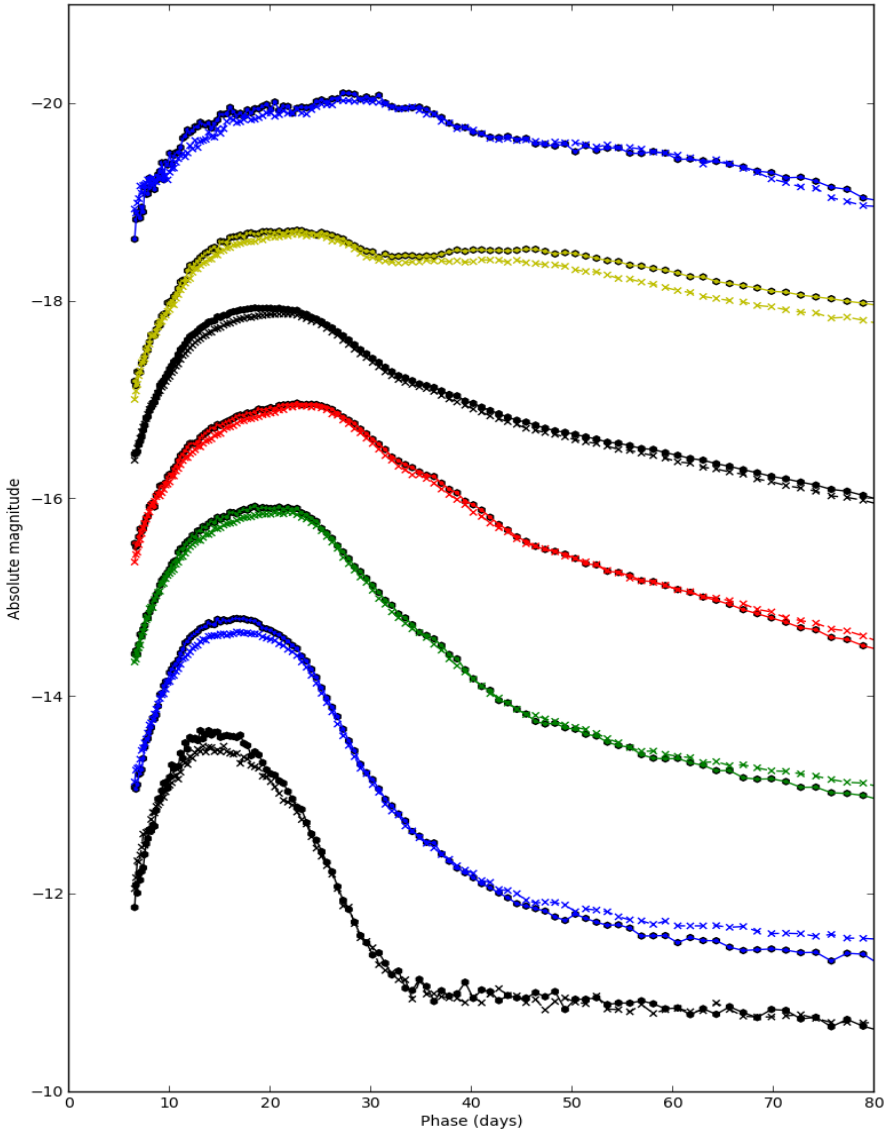
Geometry: 3-D
NLTE: Ionization
Non-thermal ionization/excitation: No
Time-dependence: Radiation field
Macroscopic mixing: Yes
Phase : Photospheric

CMFGEN (Hillier 1998)

Geometry: 1-D
NLTE: Full
Non-thermal ionization/excitation: Yes
Time-dependence: Full
Macroscopic mixing: No
Phase: All

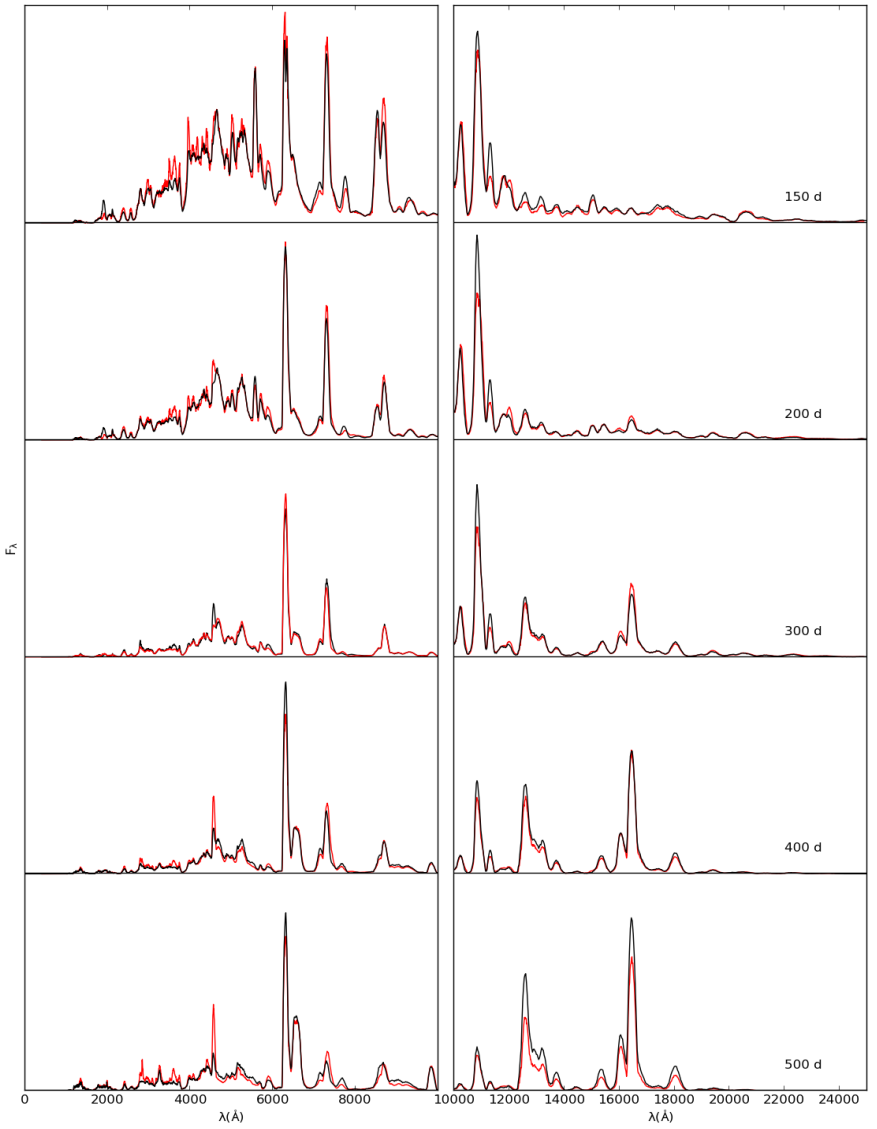
Comparisons

ARTIS



Early lightcurves for model 12C

SUMO

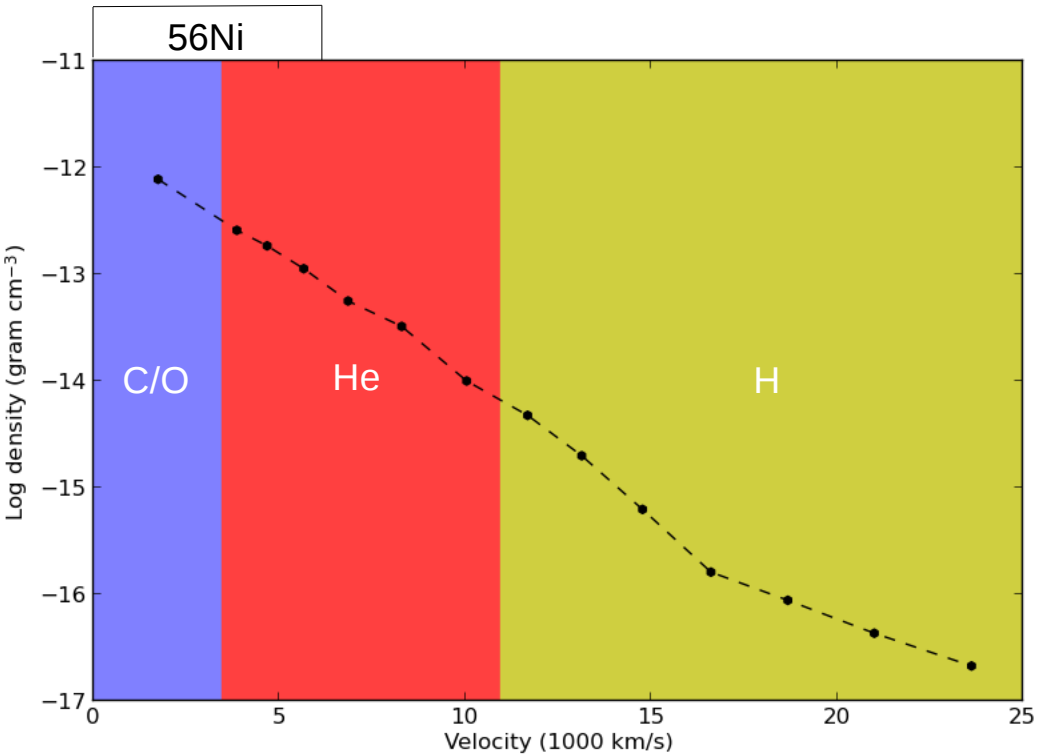


Nebular spectra model 13G

A model of the Type IIb SN 2011dh

Preferred model for SN 2011dh from Jerkstrand et al. (2015), where it was evolved through the nebular phase with SUMO.

Evolved through the early phase with JEKYLL in Ergon et al. (In prep.)



$M_{In} = 12\,M_{\odot}$

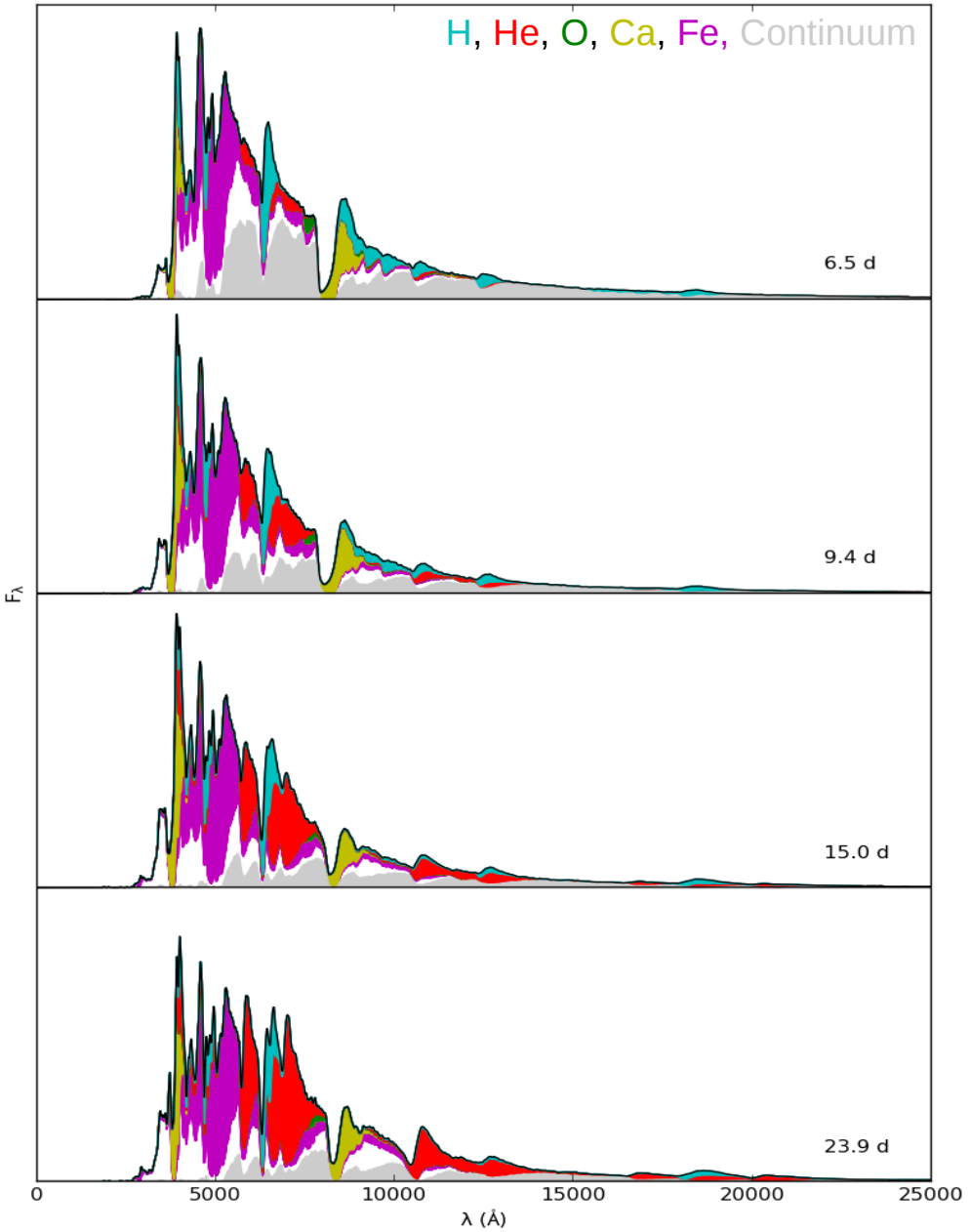
$M_{Ej} = 1.7\,M_{\odot}$

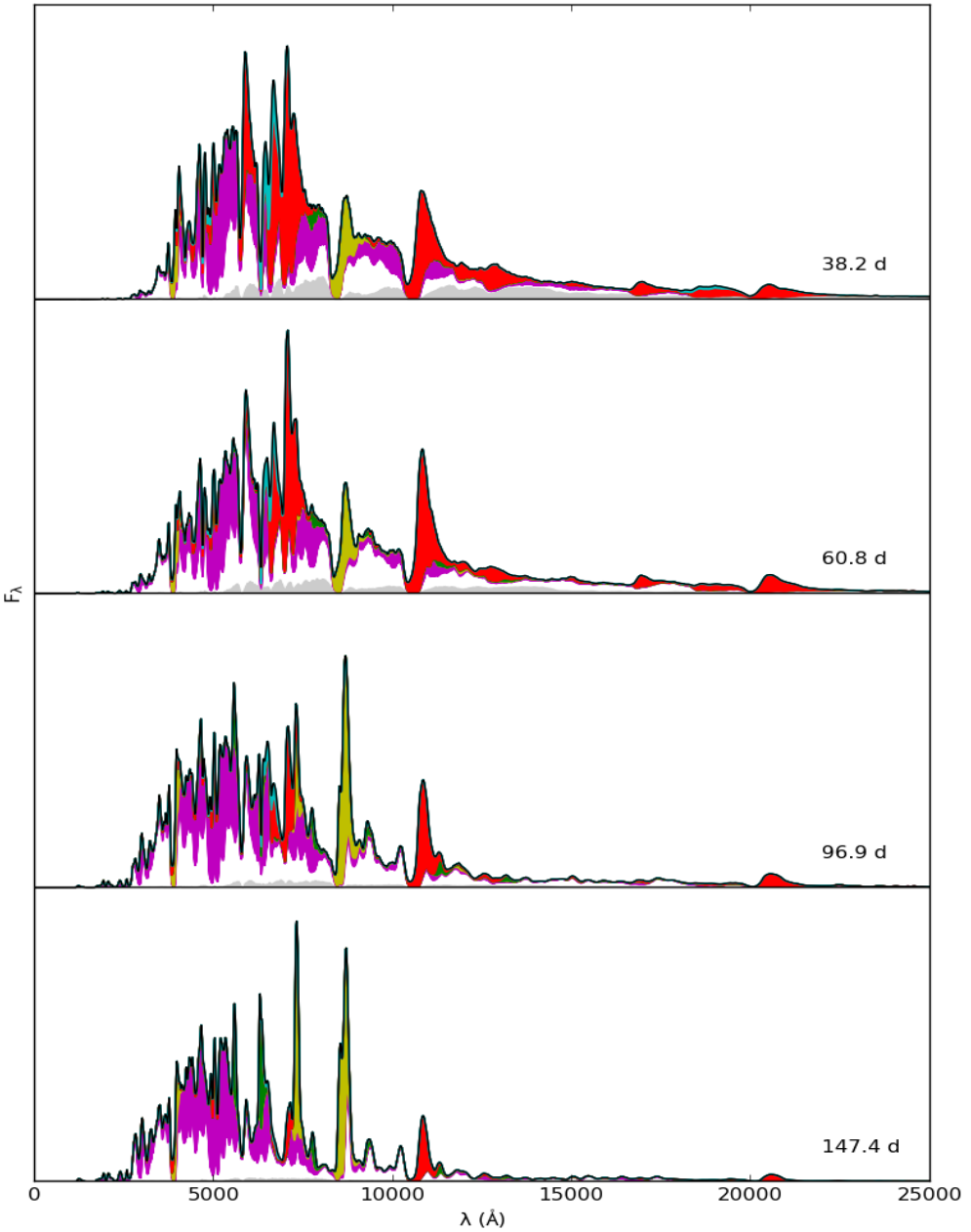
$M_{Ni} = 0.075\,M_{\odot}$

$E_K = 6.8 \times 10^{50}\,\mathrm{erg}$

Type IIb model: Spectral evolution

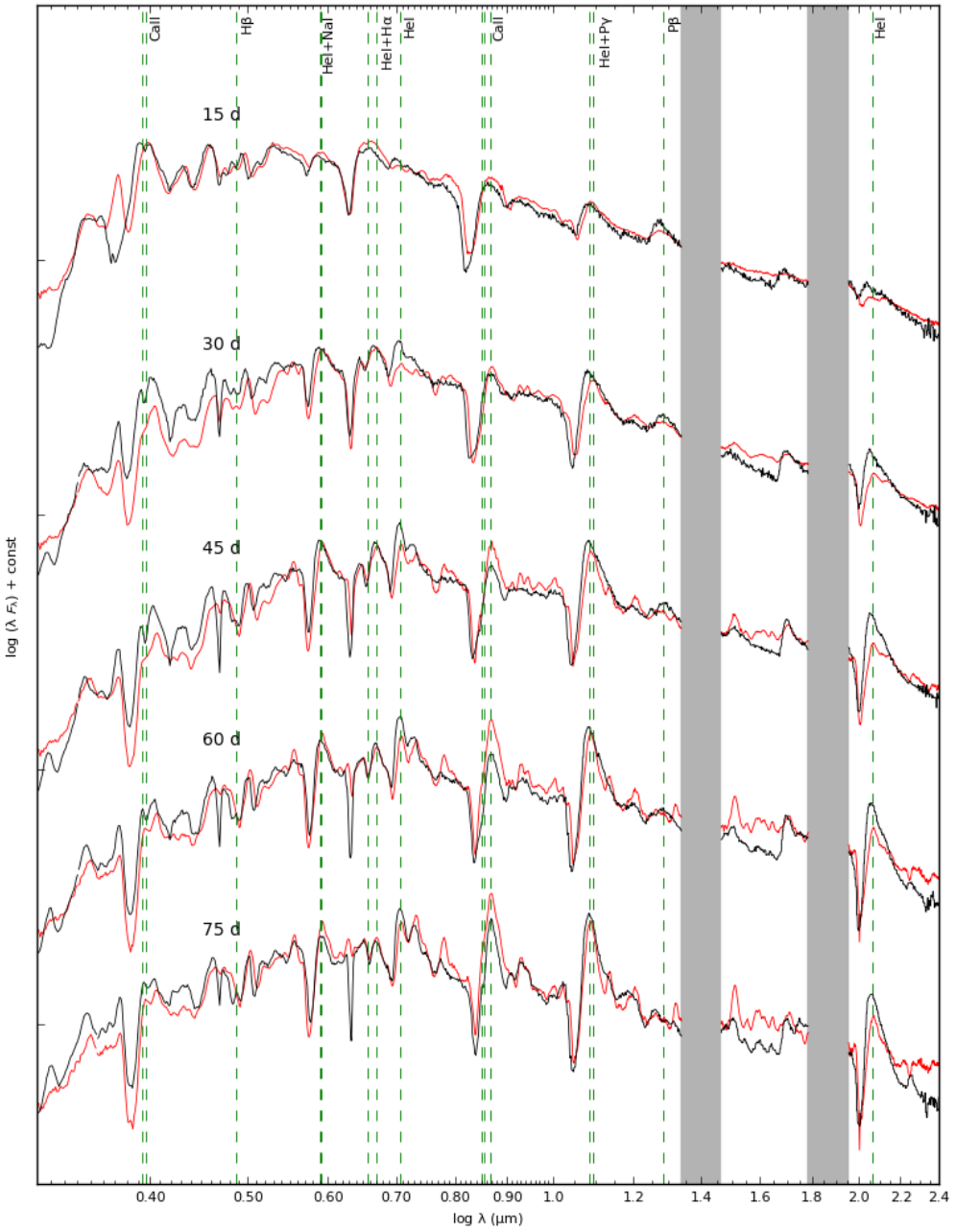
Model: Before 150 days

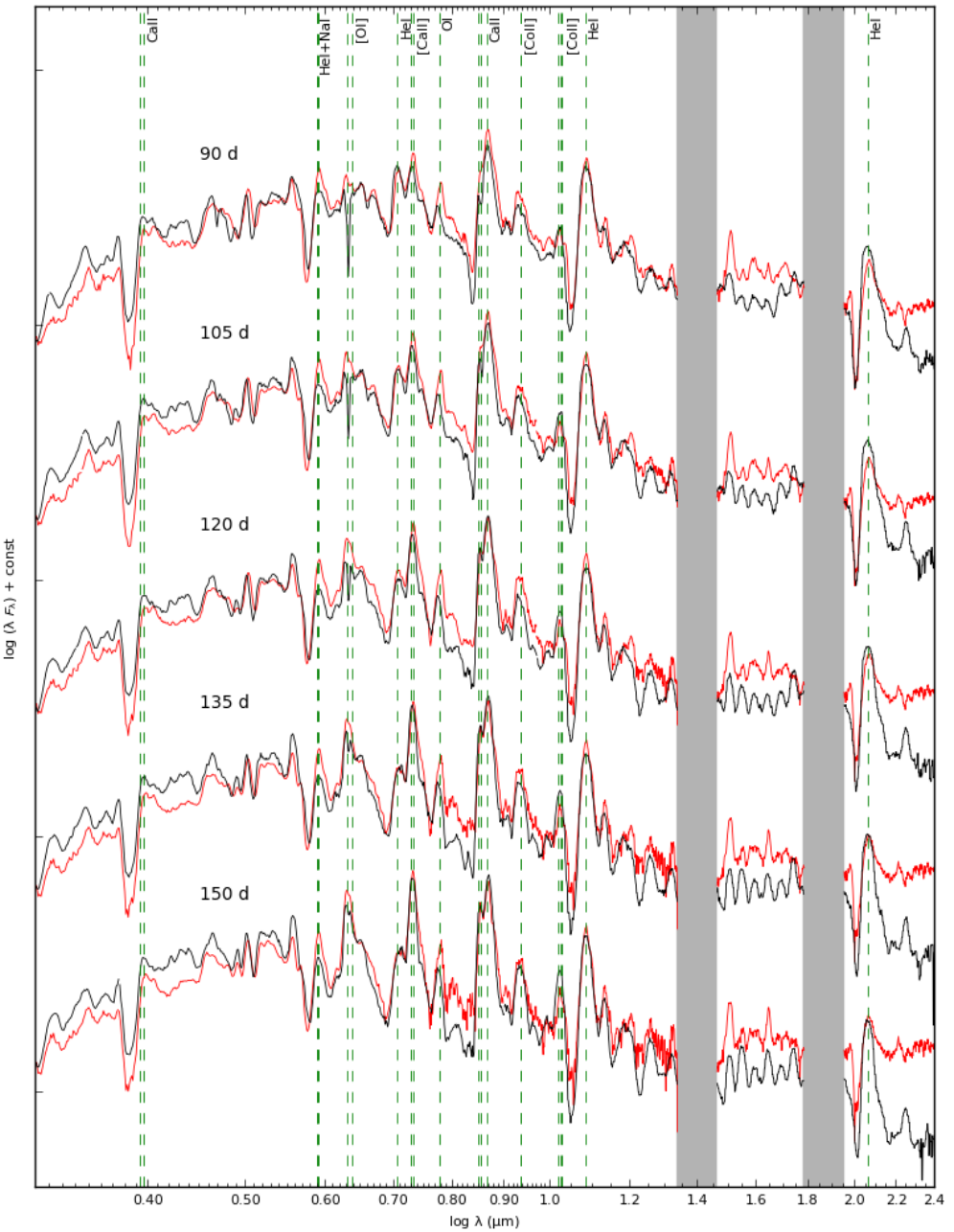




Comparison to SN 2011dh: Spectral evolution

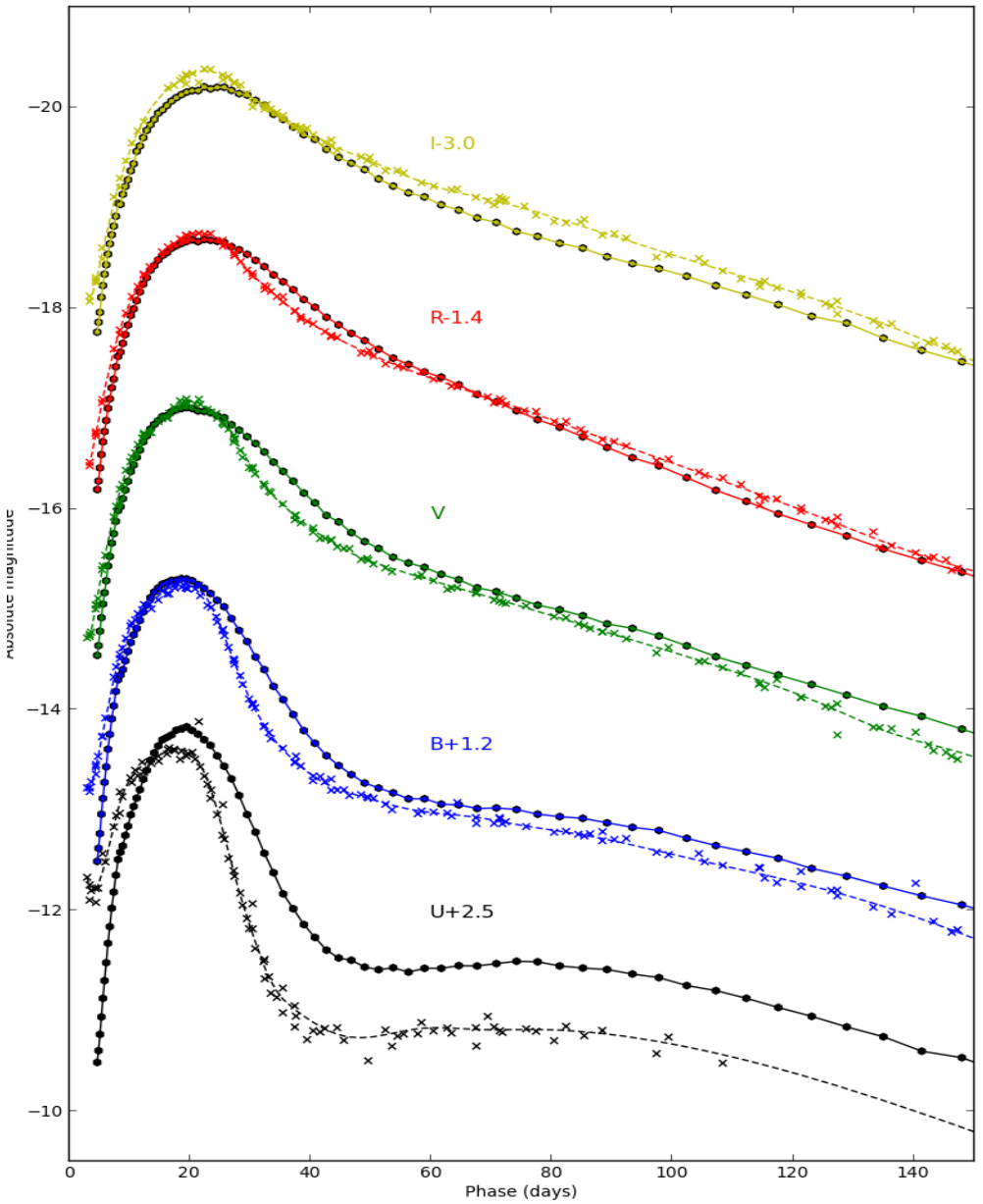
Model and SN 2011dh – Before 150 days

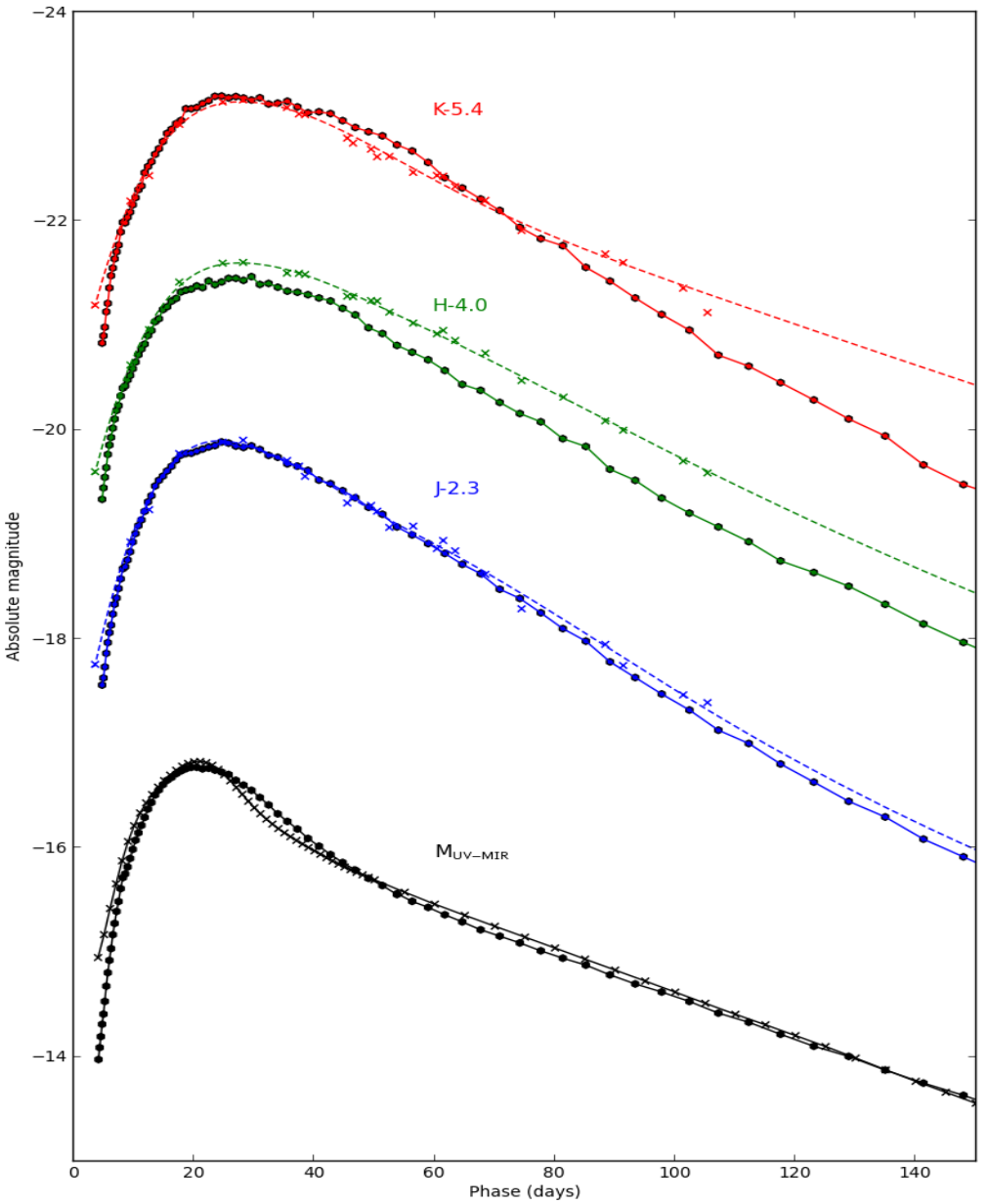




Comparison to SN 2011dh: Lightcurves

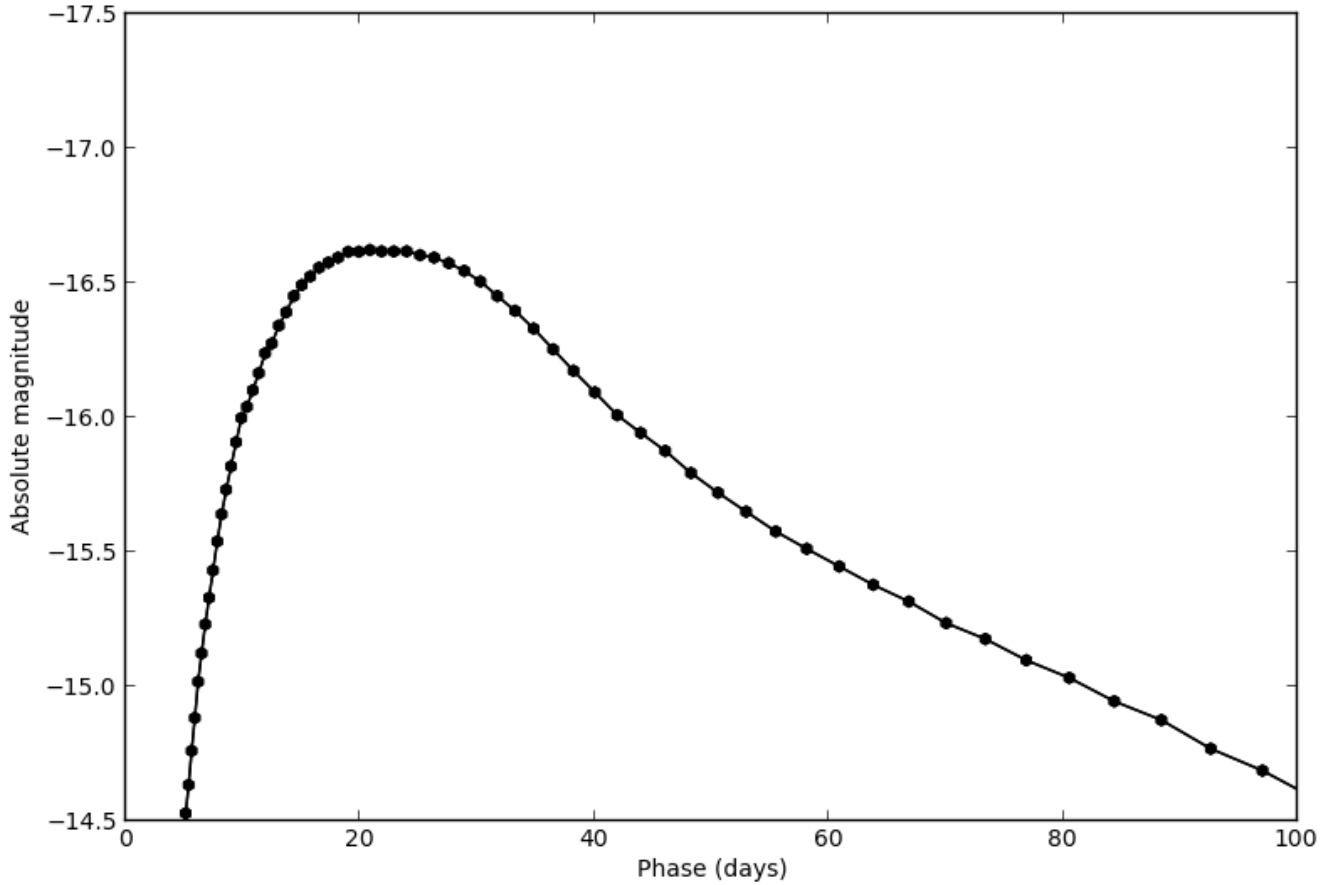
Model (circles) and SN 2011dh (crosses): Before 150 days





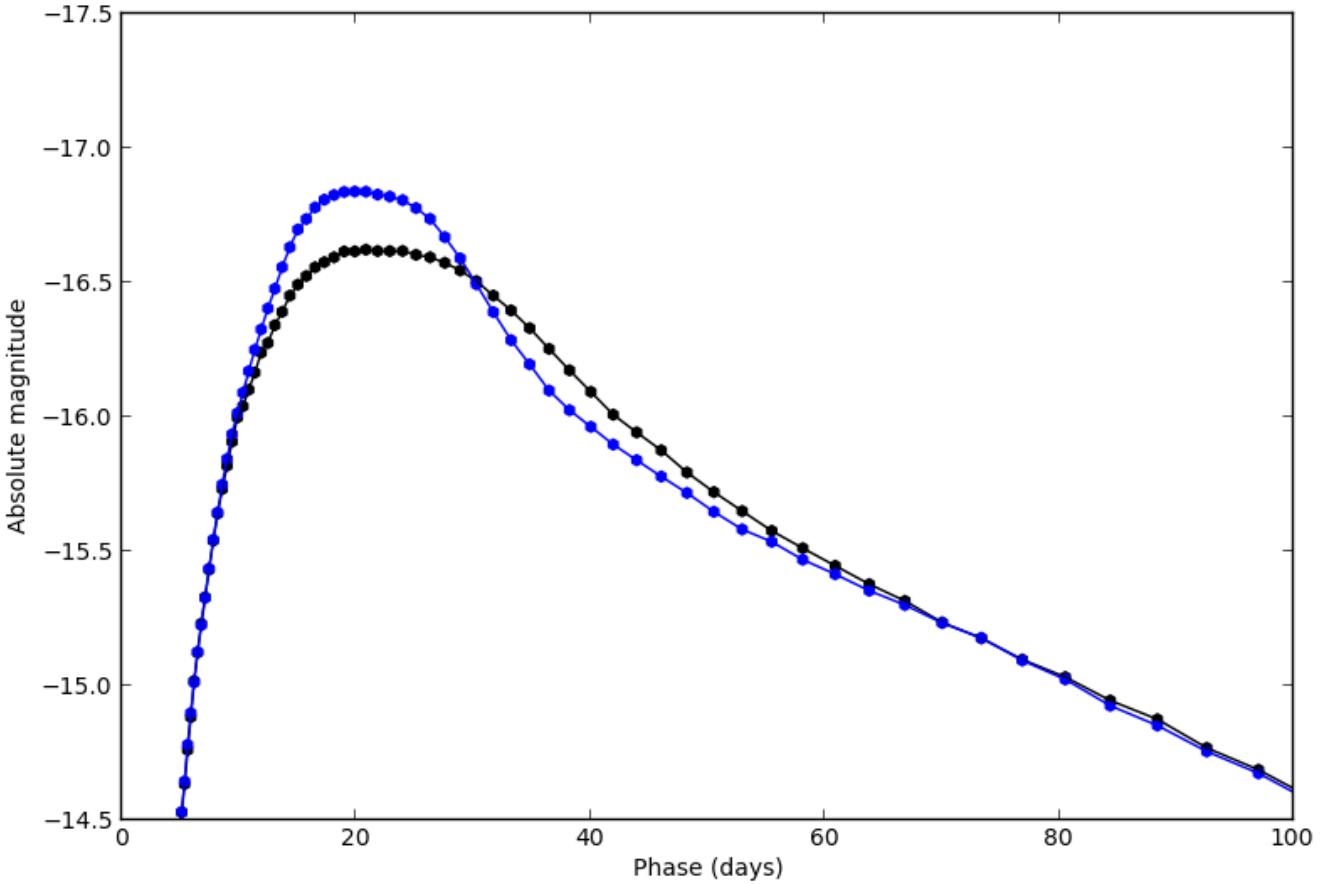
Effect of NLTE: Bolometric lightcurve

Model: Before 100 days



Effect of NLTE: Bolometric lightcurve

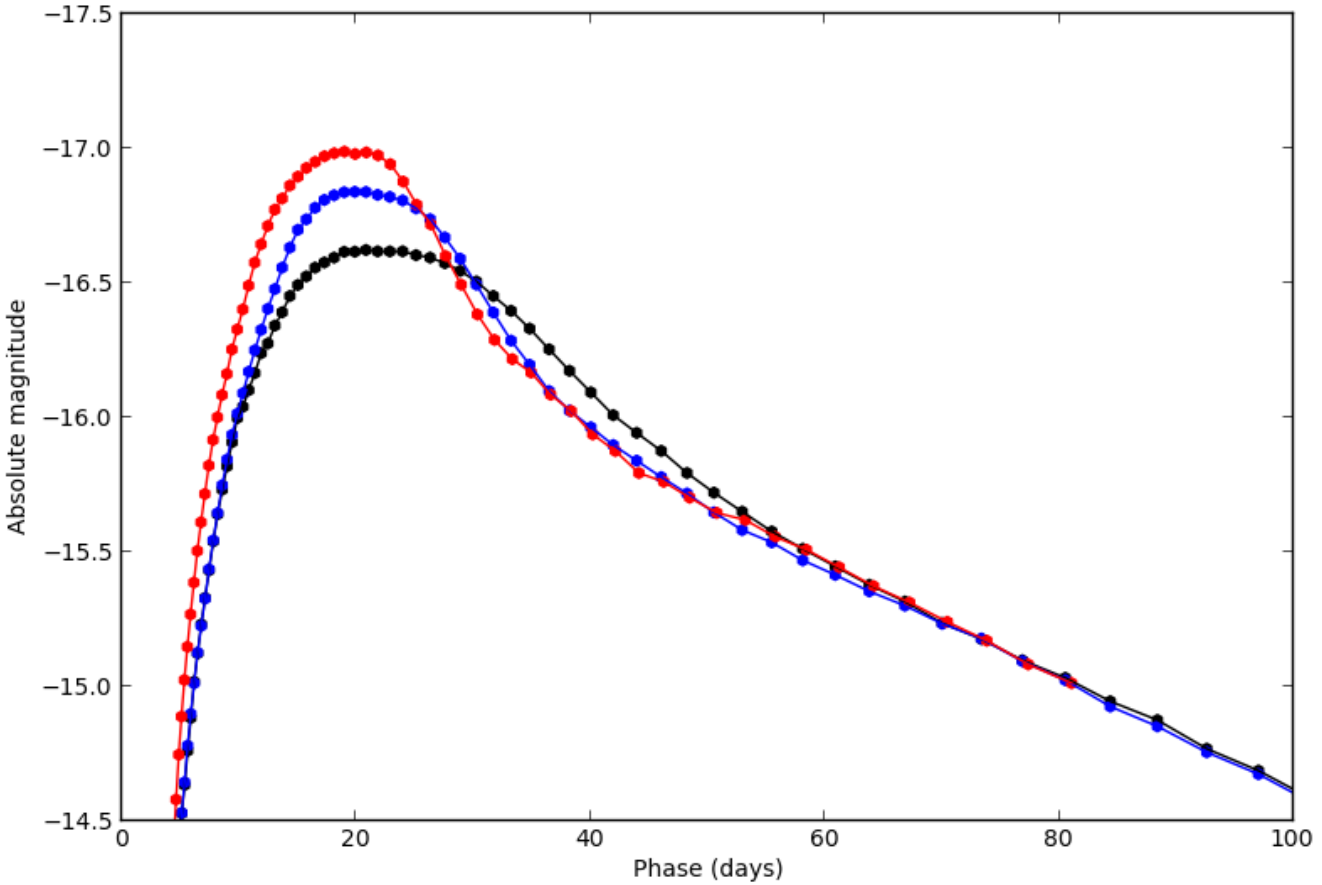
Model: Before 100 days



Non-thermal ionization/excitation - Off

Effect of NLTE: Bolometric lightcurve

Model: Before 100 days

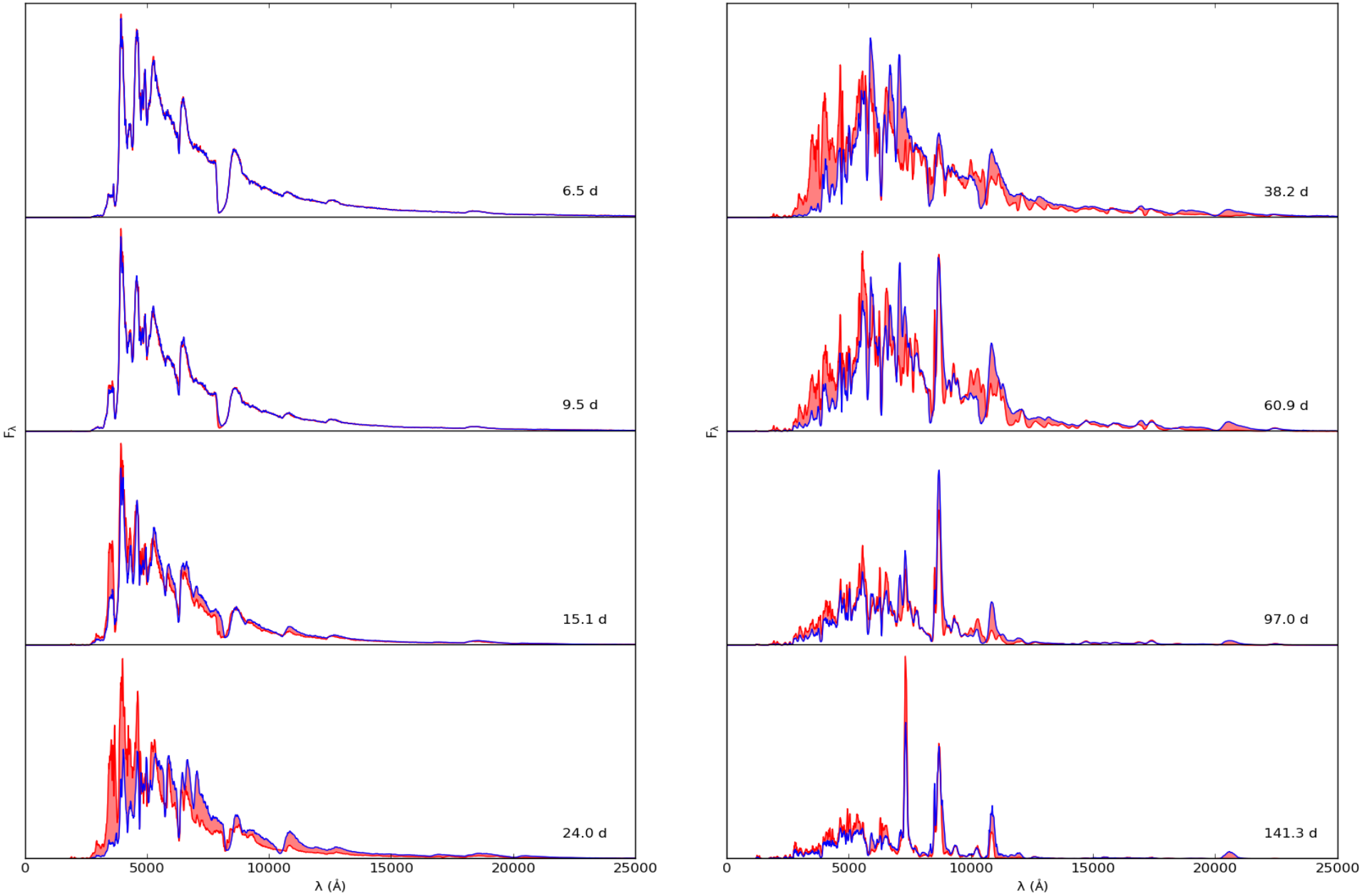


Non-thermal ionization/excitation - Off

NLTE excitation - Off

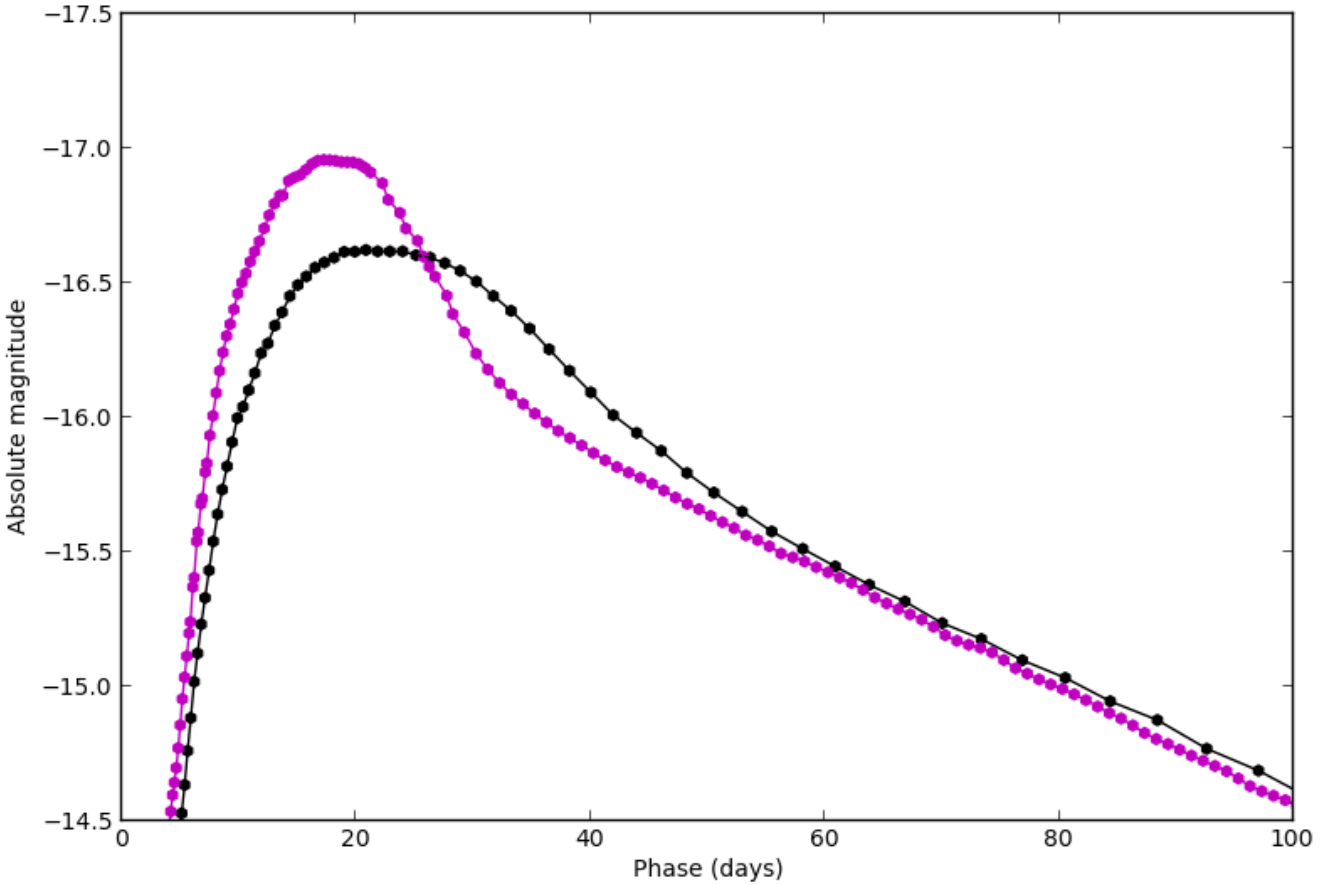
Effect of NLTE: Spectral evolution

Non-thermal ionization/excitation - On/Off



Effect of NLTE: Bolometric lightcurve

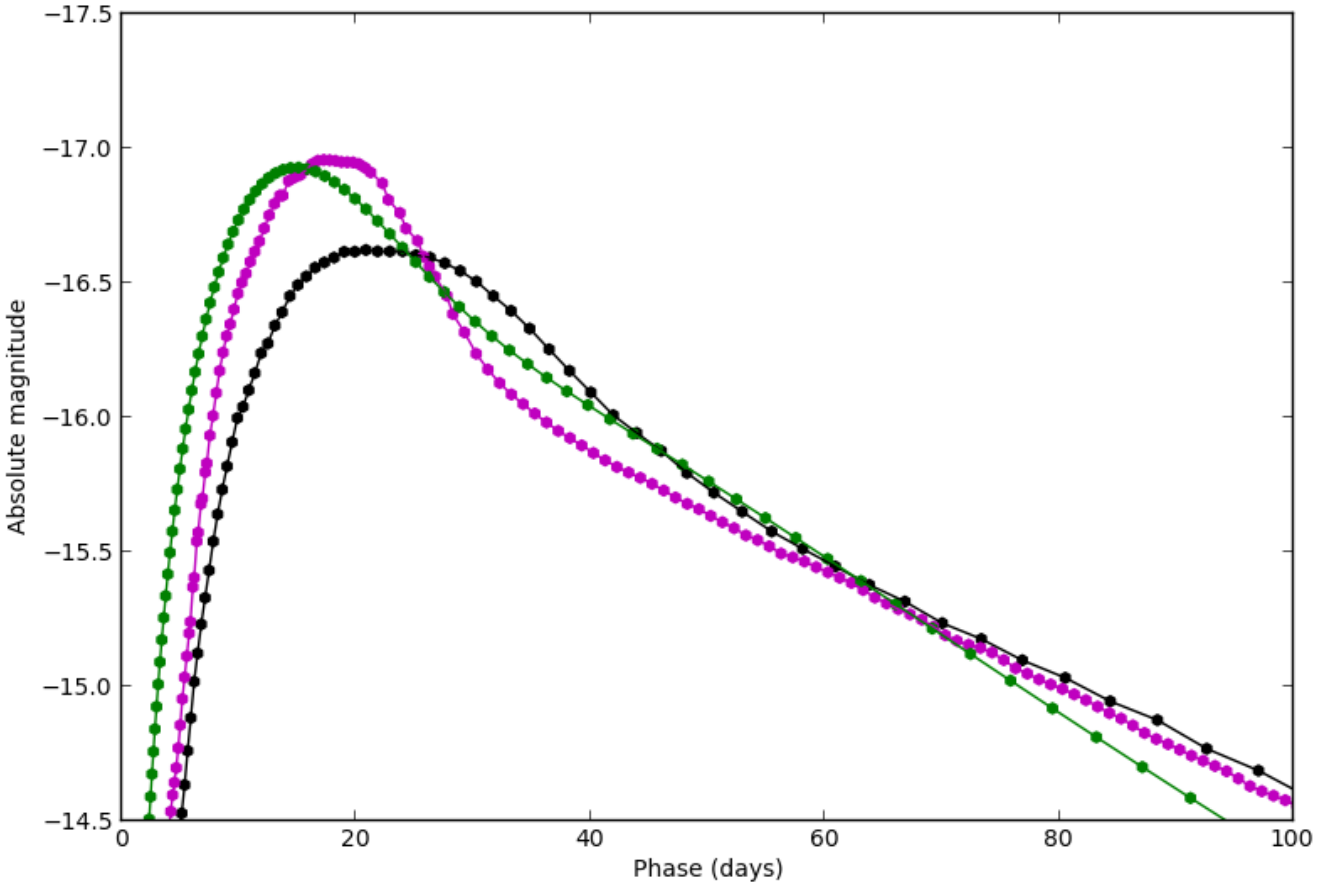
Model: Before 100 days



LTE + Opacity floor (HYDE)

Effect of NLTE: Bolometric lightcurve

Model: Before 100 days

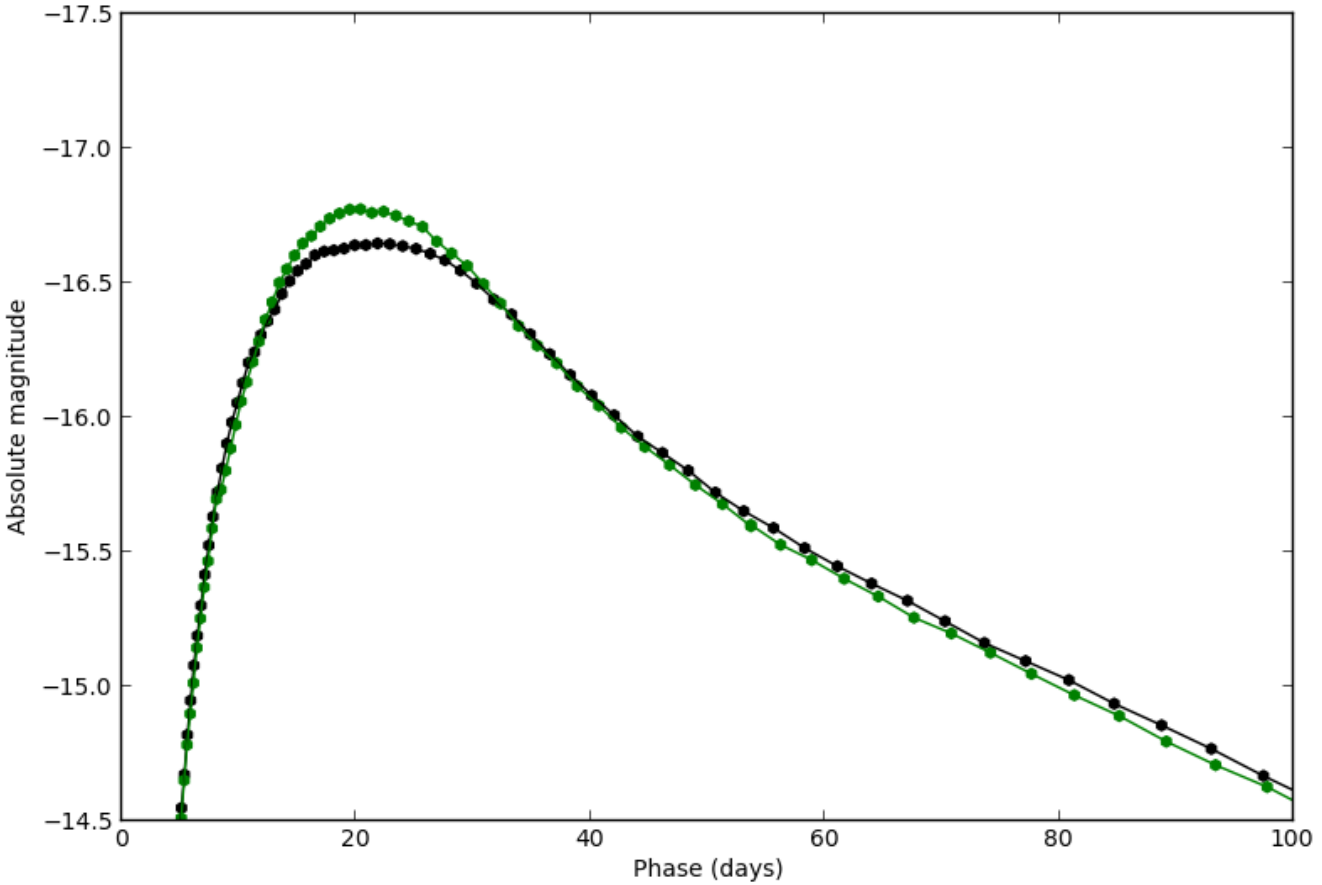


LTE + Opacity floor (HYDE)

Arnett (1982) + Popov (1991)

Effect of mixing: Bolometric lightcurve

Model: Before 100 days

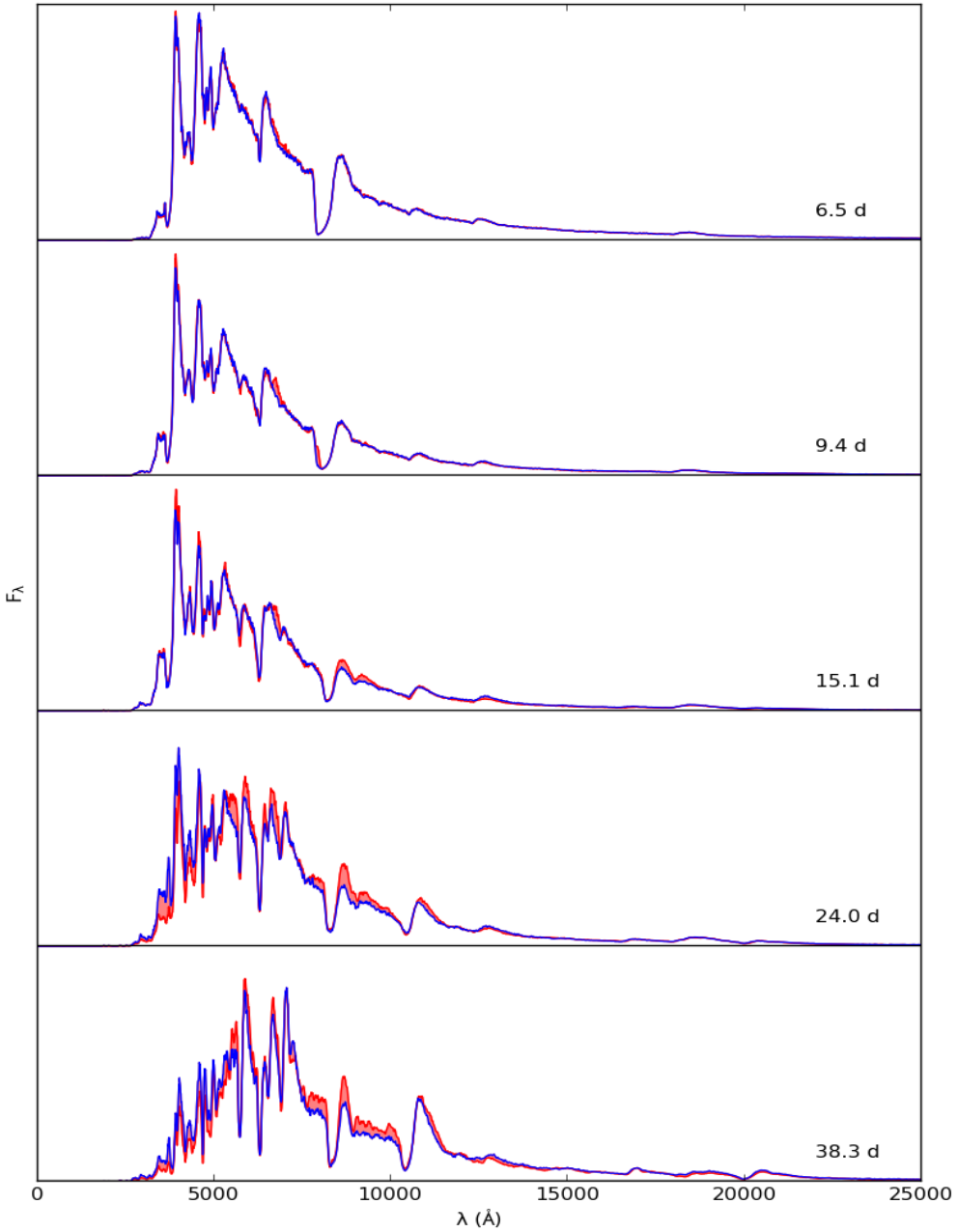


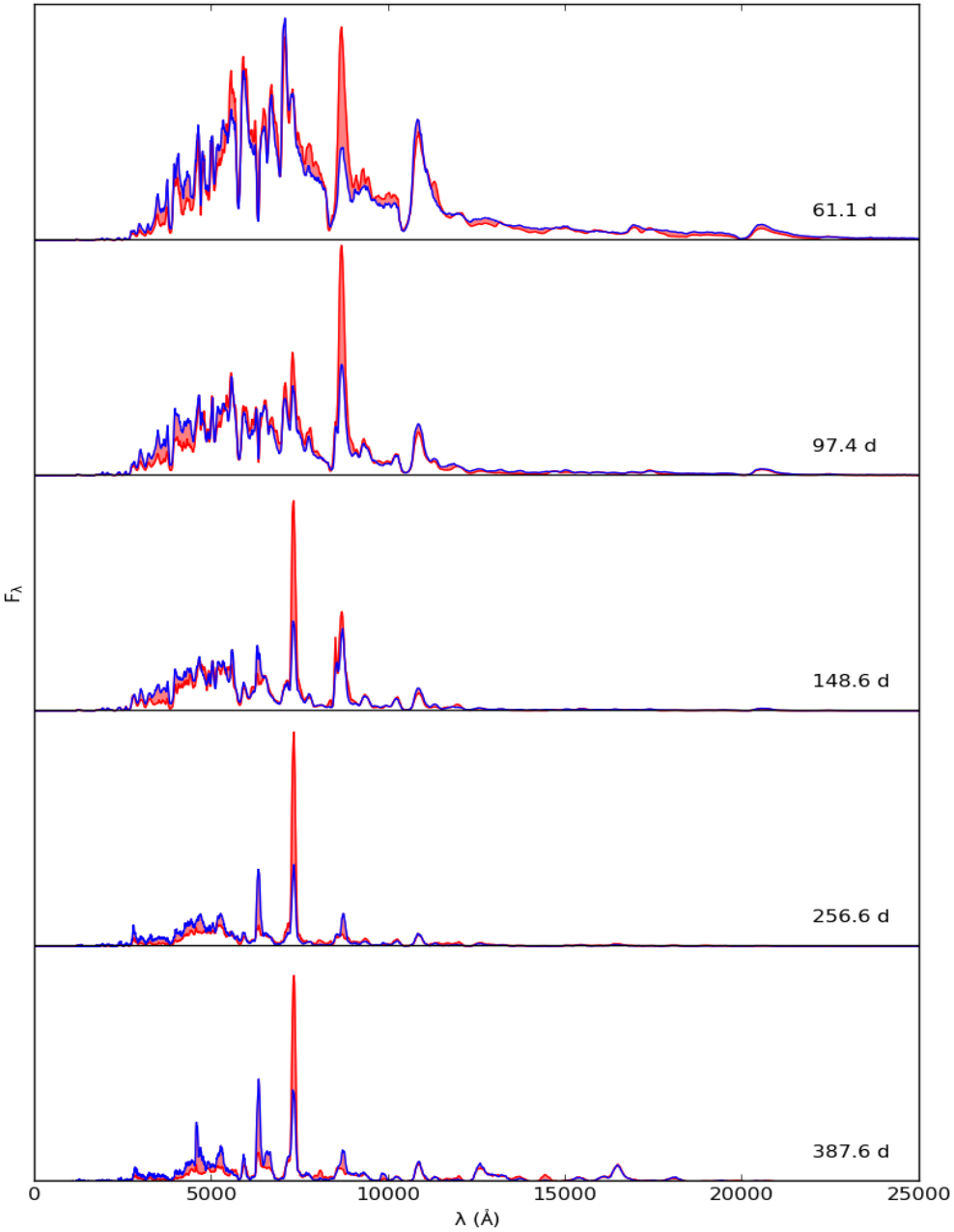
Microscopic Mixing

Macroscopic Mixing

Effect of mixing: Spectral evolution

Macroscopic mixing - On/Off





More to come ...