SN 2011fe: a modeller’s view

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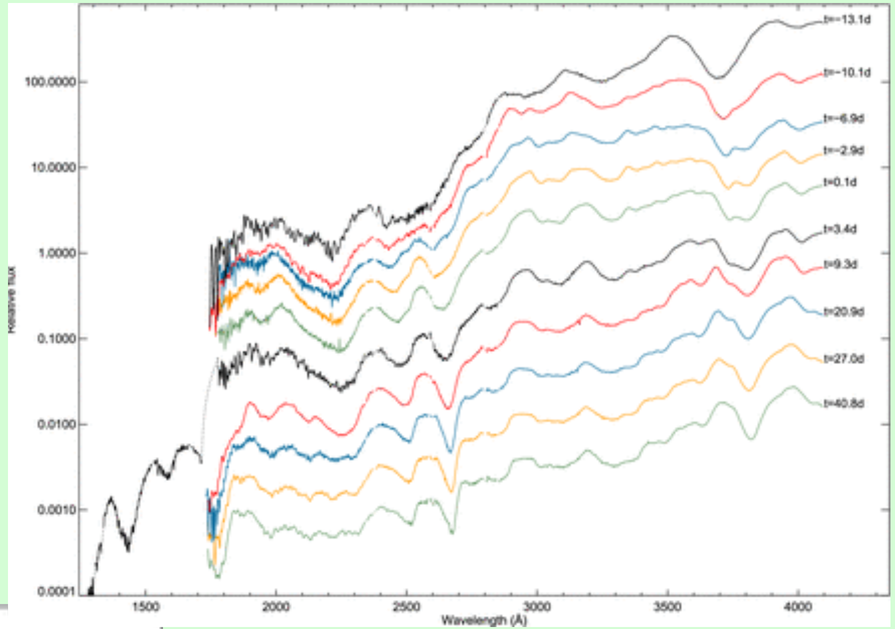
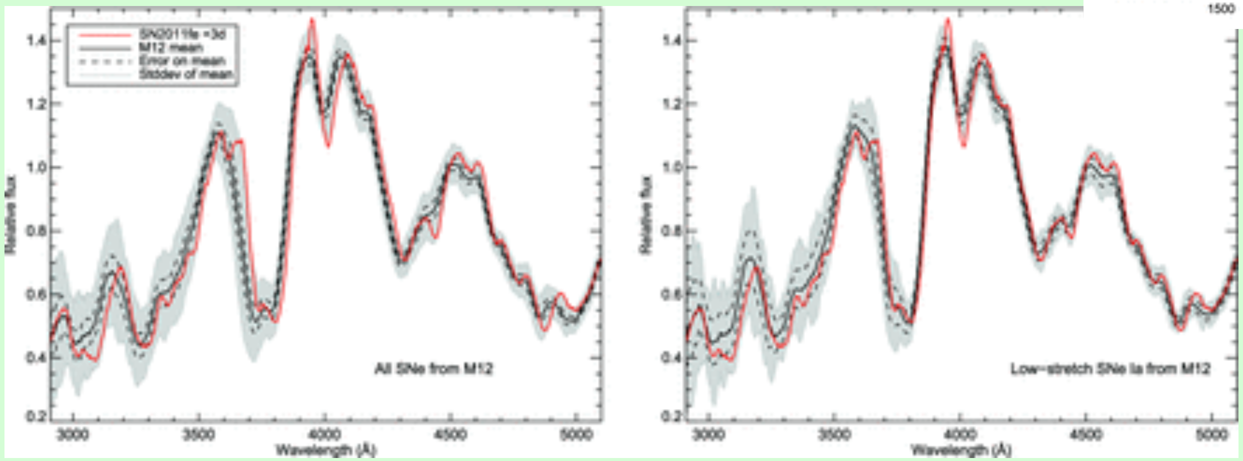
SN2011fe: one of the nearest recent SNe Ia

- Discovered very early (PTF11kly, Nugent et al 2012 etc)
- Normal SN Ia
- $\Delta m_{15}(B)$~1.1 mag
- HST coverage (UV)
- Perfect for tomography work

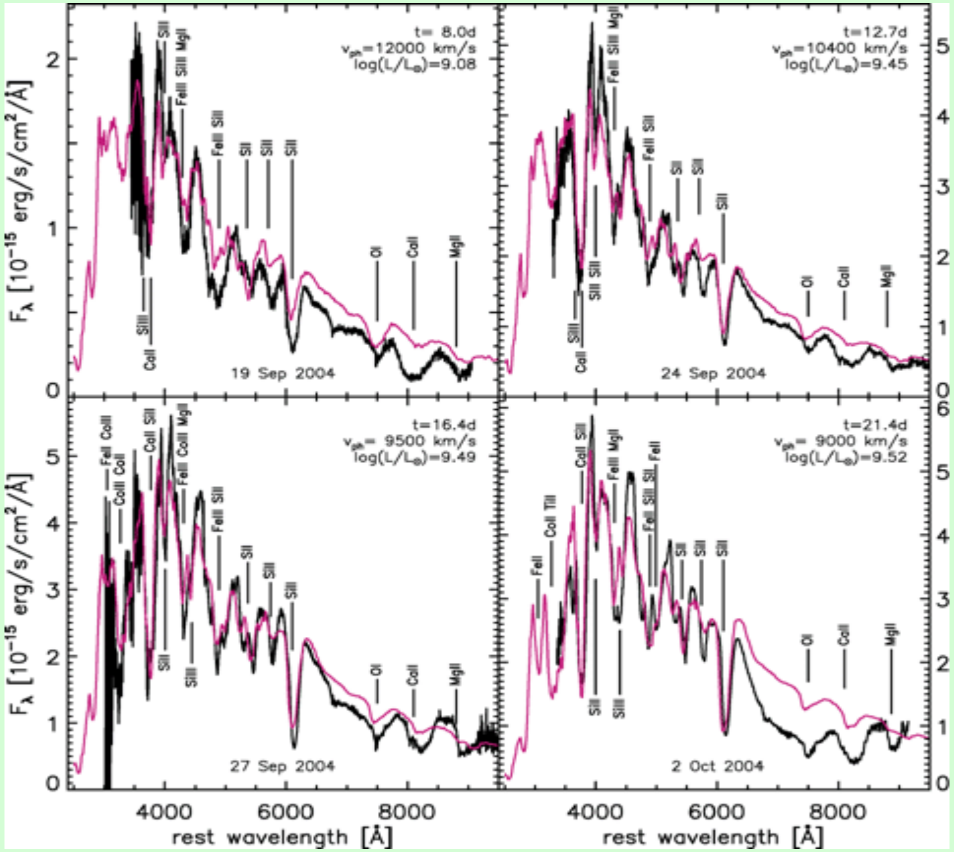




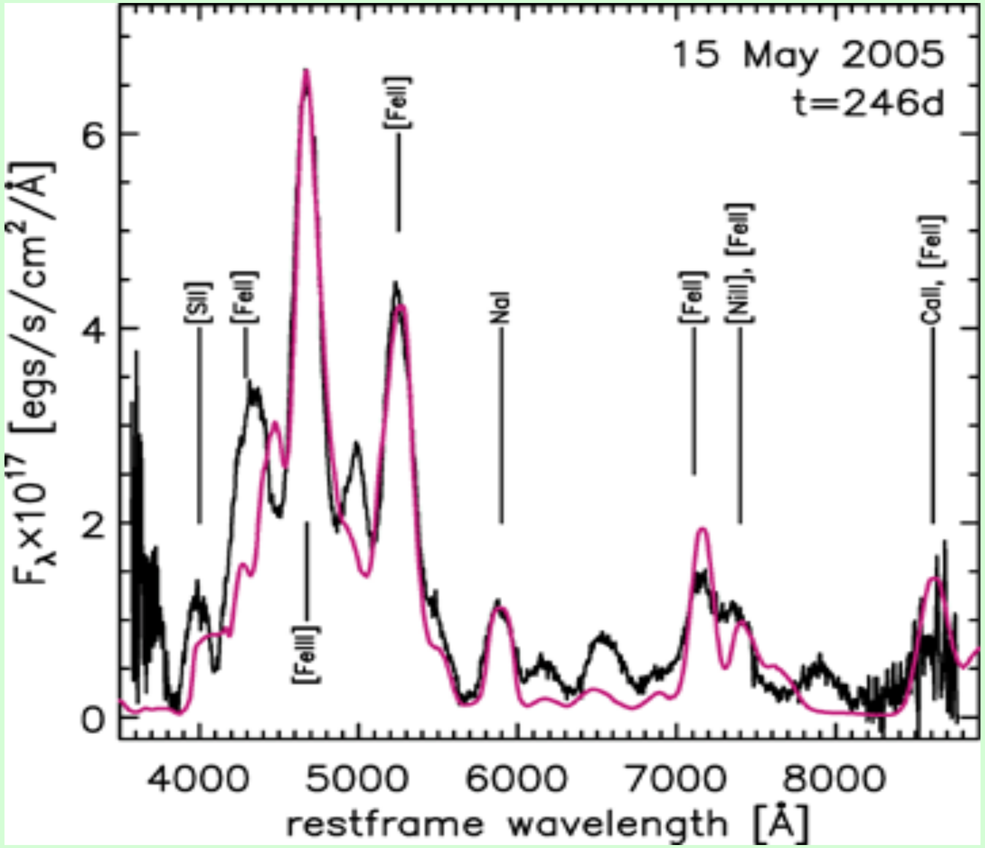
PM et al 2014

Tomography: modelling spectral time-series yields Abudances, Density

Early time



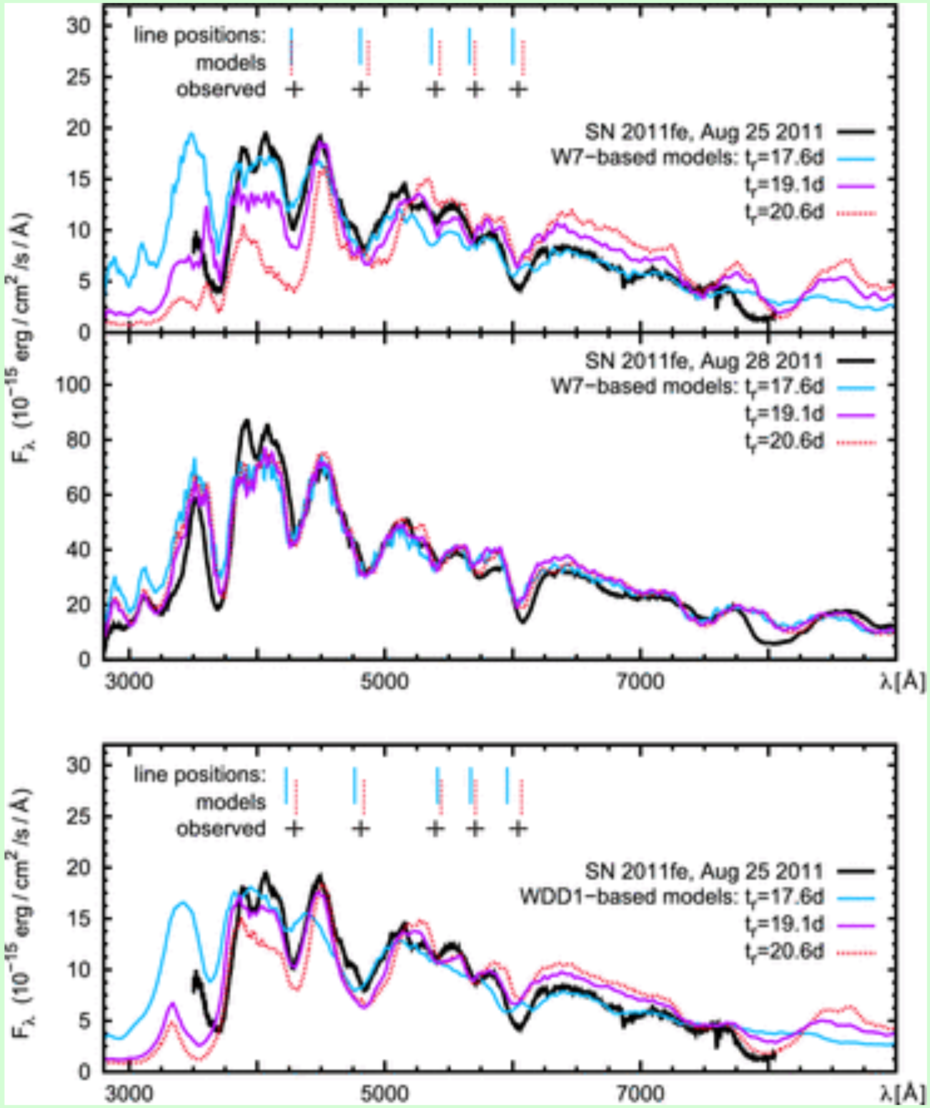
Late time



PM et al. 2007

Setting up the model: Risetime

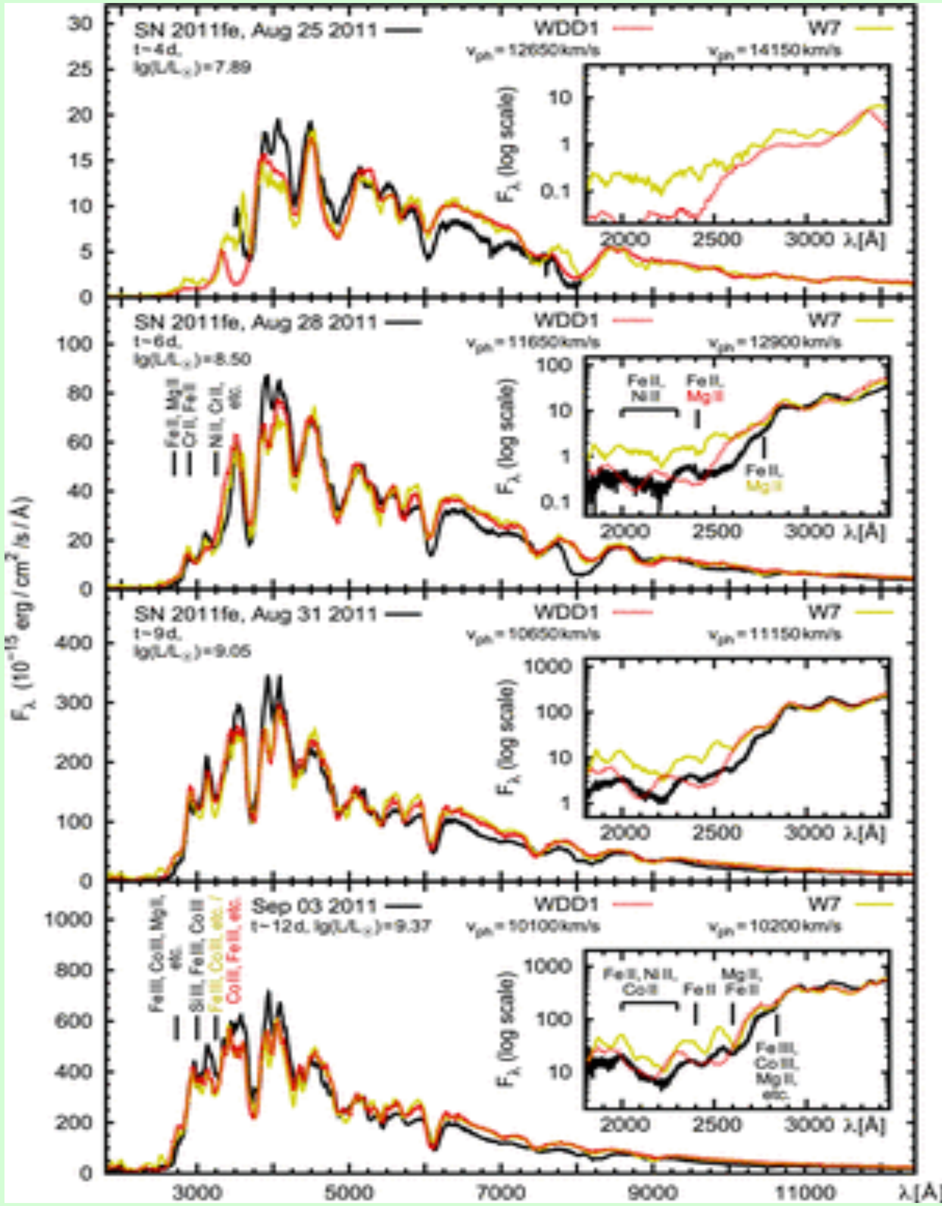
- This is important to estimate the radius of the progenitor
- and it is essential for spectral modelling
- models can be used to estimate t_r based on their success on the earliest spectra, where leverage of Δt is largest
- Using W7 suggests that
  t(Max) ~ 19 days
- This is larger than in N11 but in agreement with Piro&Nakar



Determining the best density structure

Test W7 (fast deflagration)
v. WDD1 (delayed detonation)

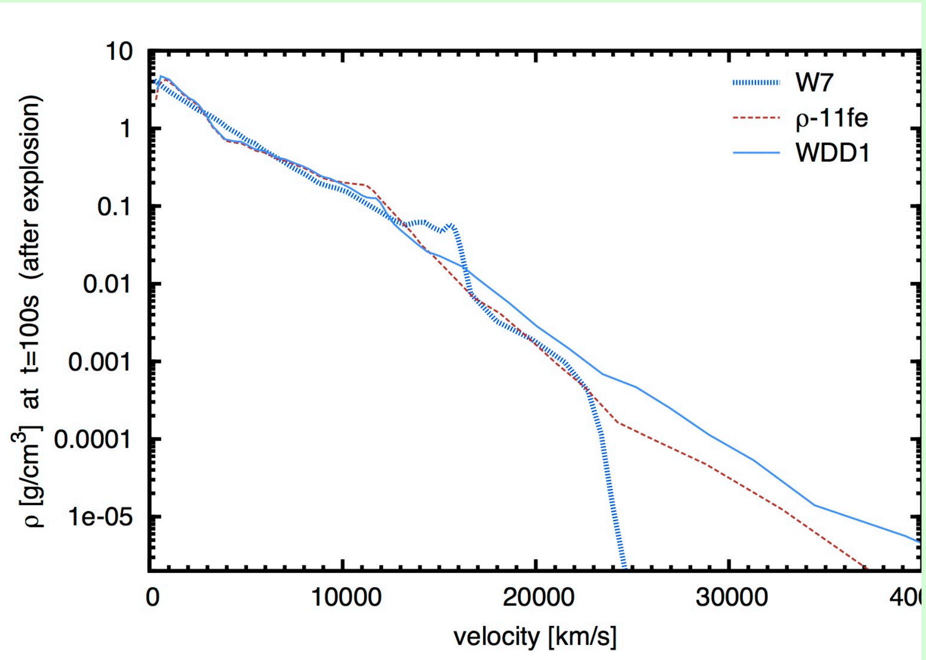
- Neither model is perfect, but WDD1 produces more line blocking in the NUV because of the larger mass of ejecta at high velocity
- Availability of an exquisite spectral database allows us to search for an optimal density profile

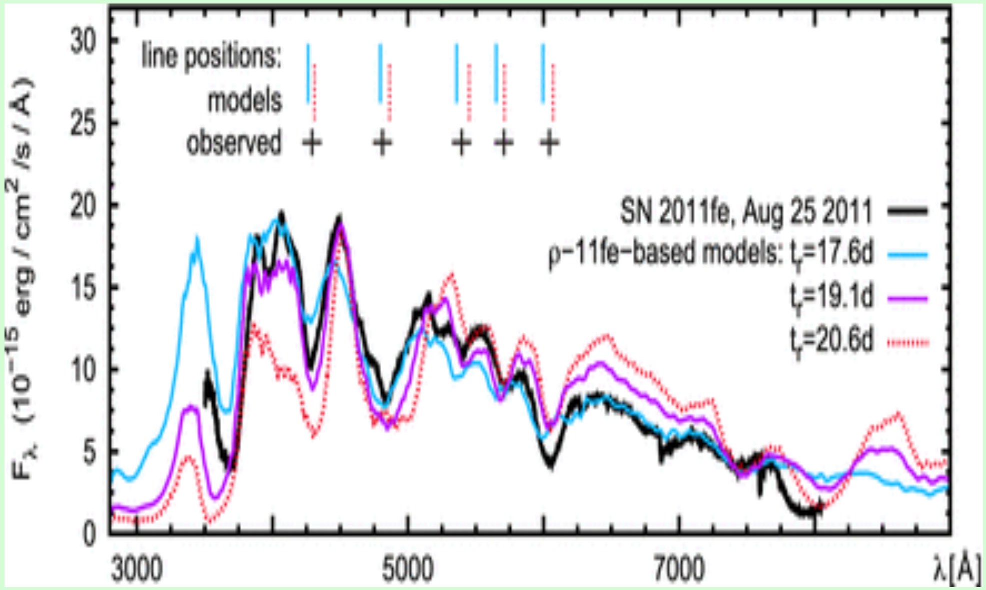


A custom-made model: “ρ-11fe”

- More mass at high velocity than W7, but less than WDD1
- $M = M_{Chandra}$
- $Ek = 1.2\ 10^{51}$ erg
- A low-energy delayed det?

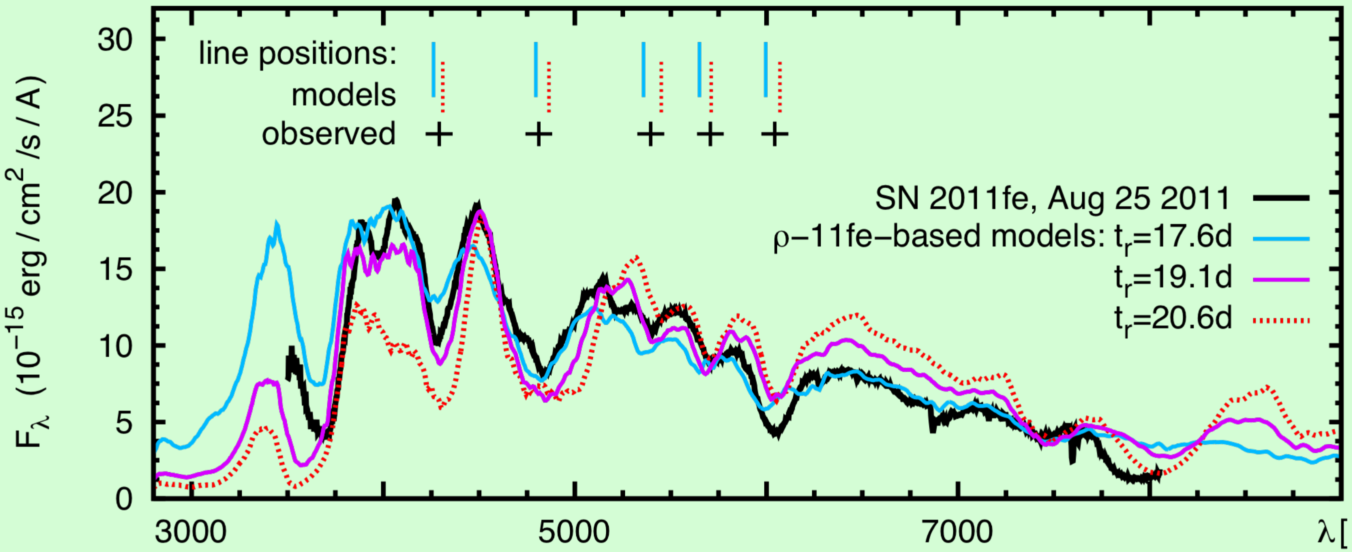
Risetime still ~ 19 days





How early was SN2011fe discovered?

- Nugent et al. (2011) suggest first detection was 11 hrs after explosion based on t^2 fit of early light curve
- This ignores photon diffusion time inside star
- Early spectra can be used to test t(rise): N2011:17.6d

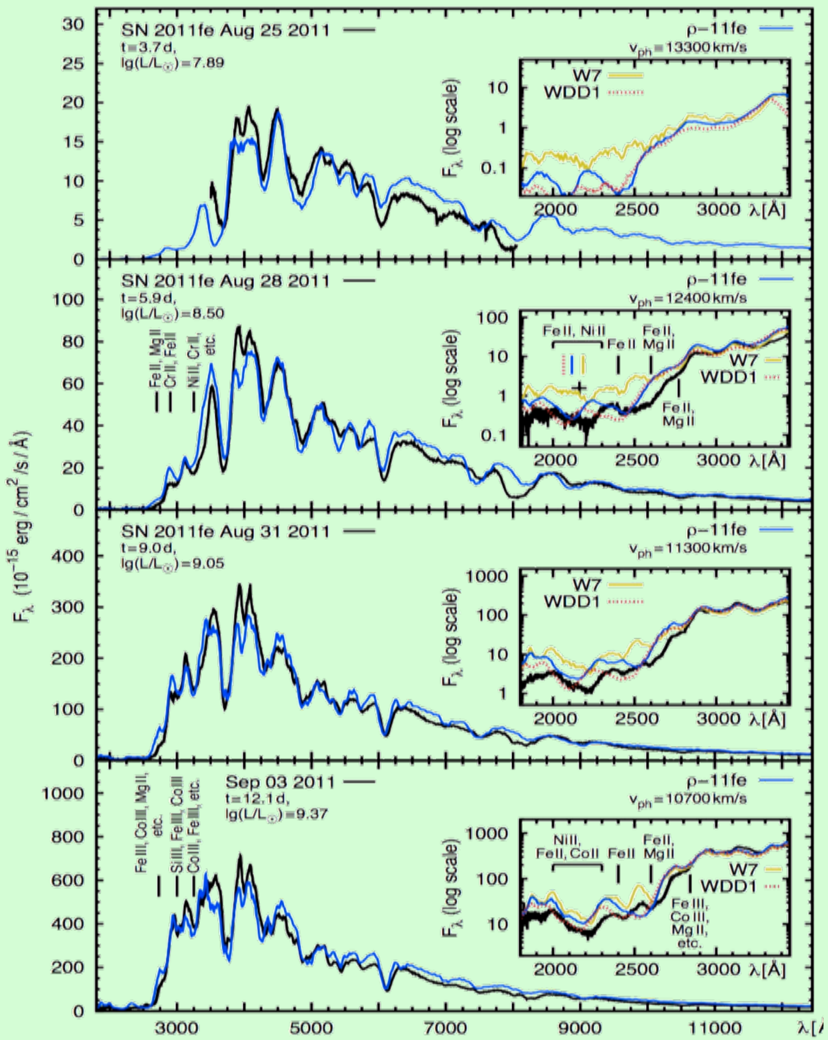


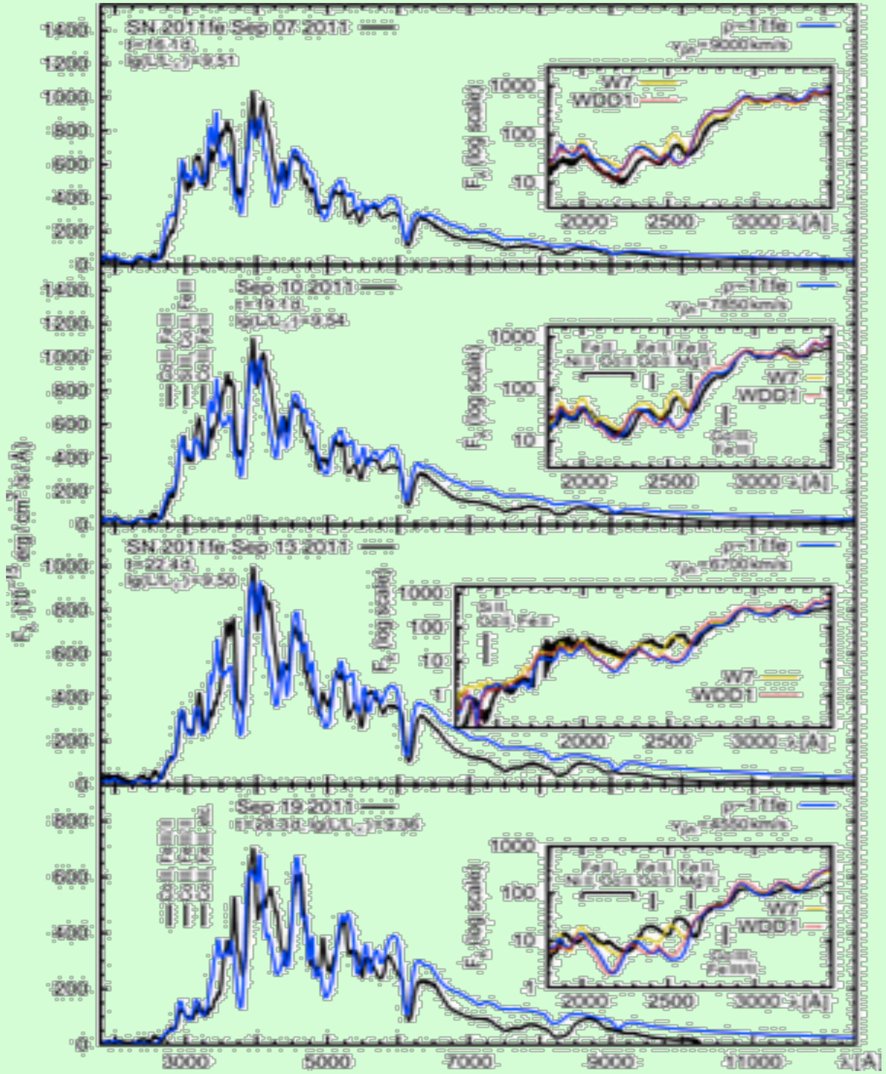
- Result: “dark epoch” > 1 day, t(Max)~19 d

(Mazzali et al 2013, cf also Piro & Nakar 2013)

Tomography

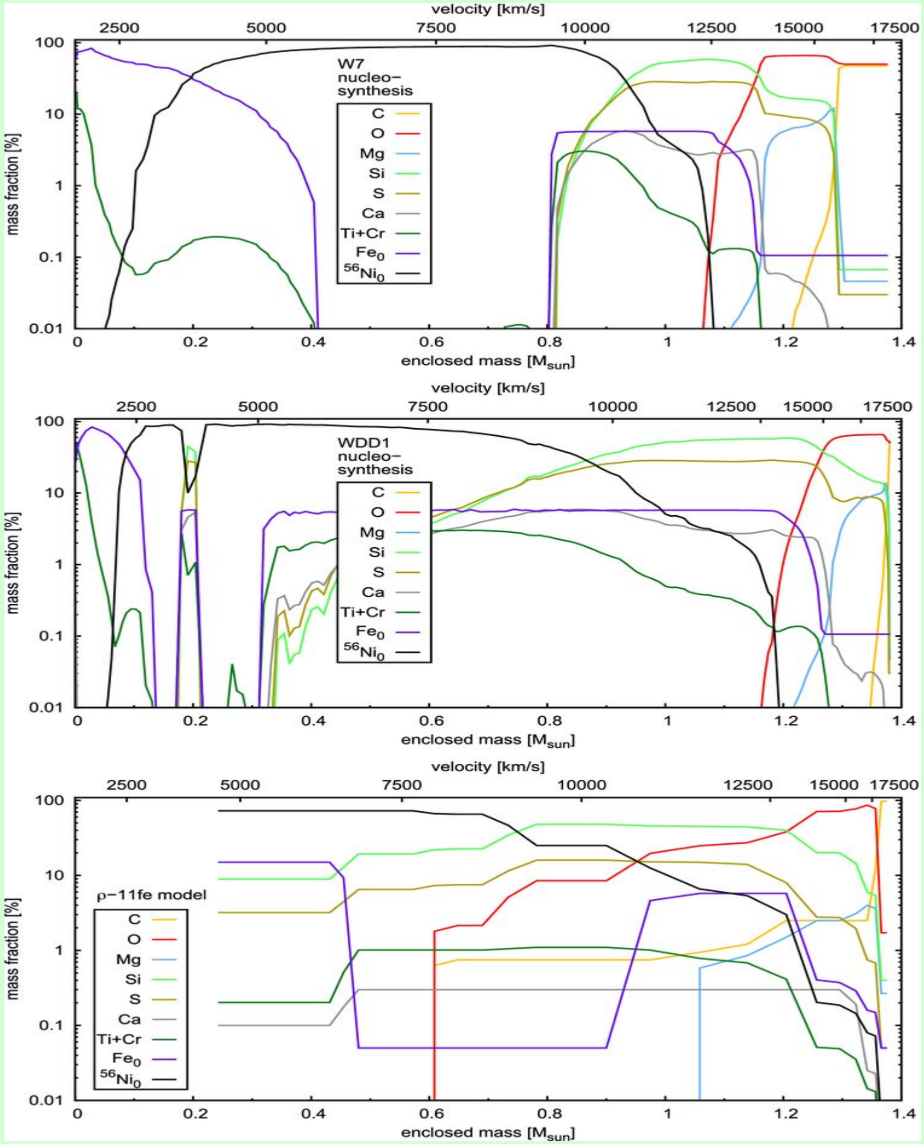
Pre-maximum | **Post-maximum**





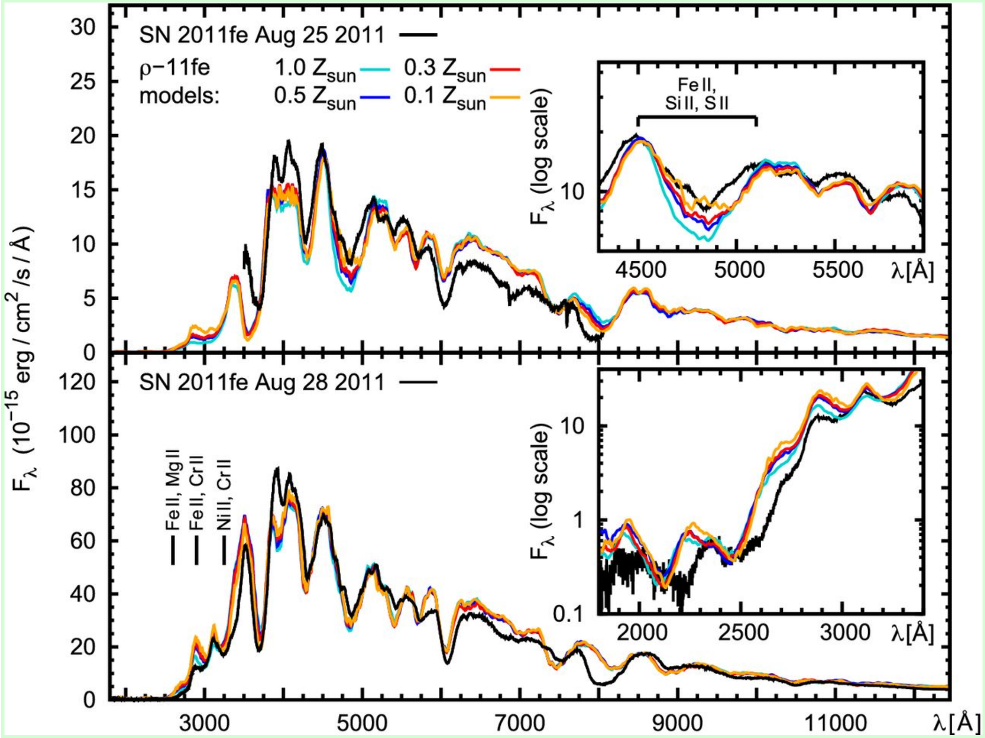
Result: composition of outer layers

- ^{56}Ni extends beyond 10000 km/s
- Stratification similar to WDD1
- Oxygen mixed downwards
- Cannot investigate inner layer with spectra near maximum



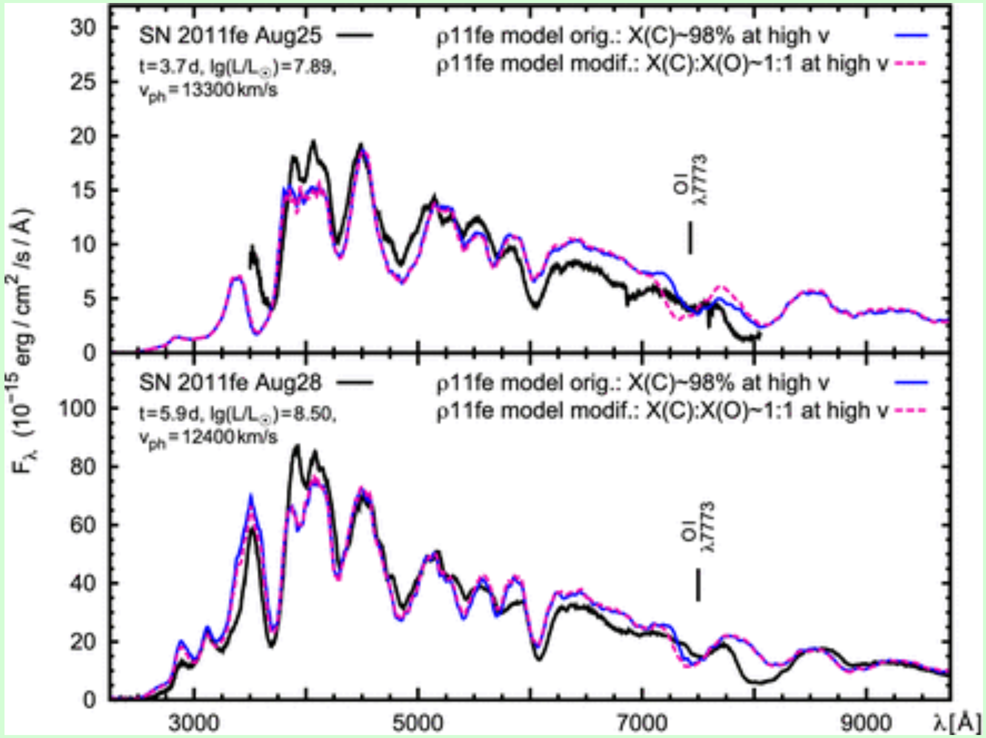
Some experiments…

Metal content of outer layers



Best fits for Z~1/3-1/2 solar

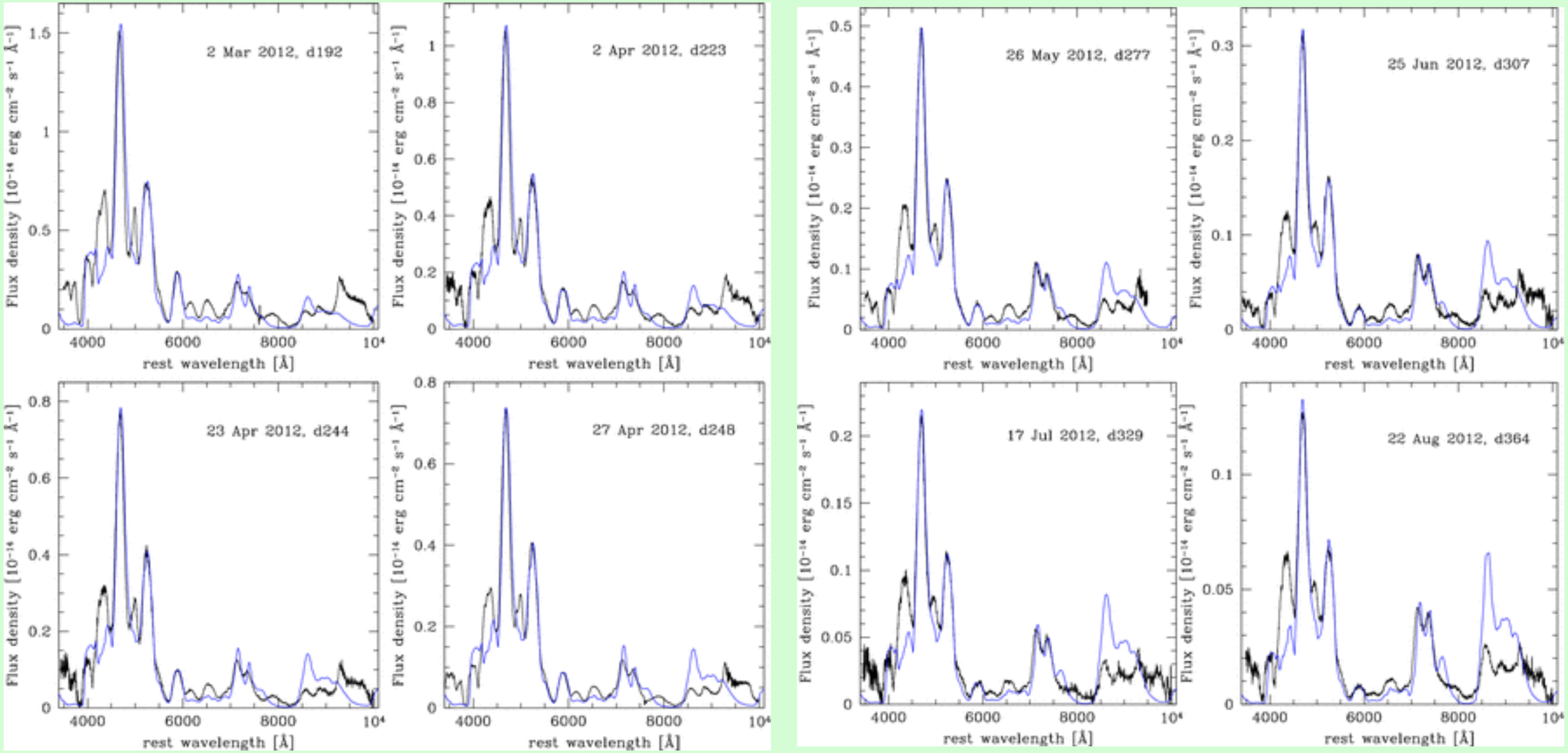
Unburned Carbon



Carbon dominates above 20000 km/s

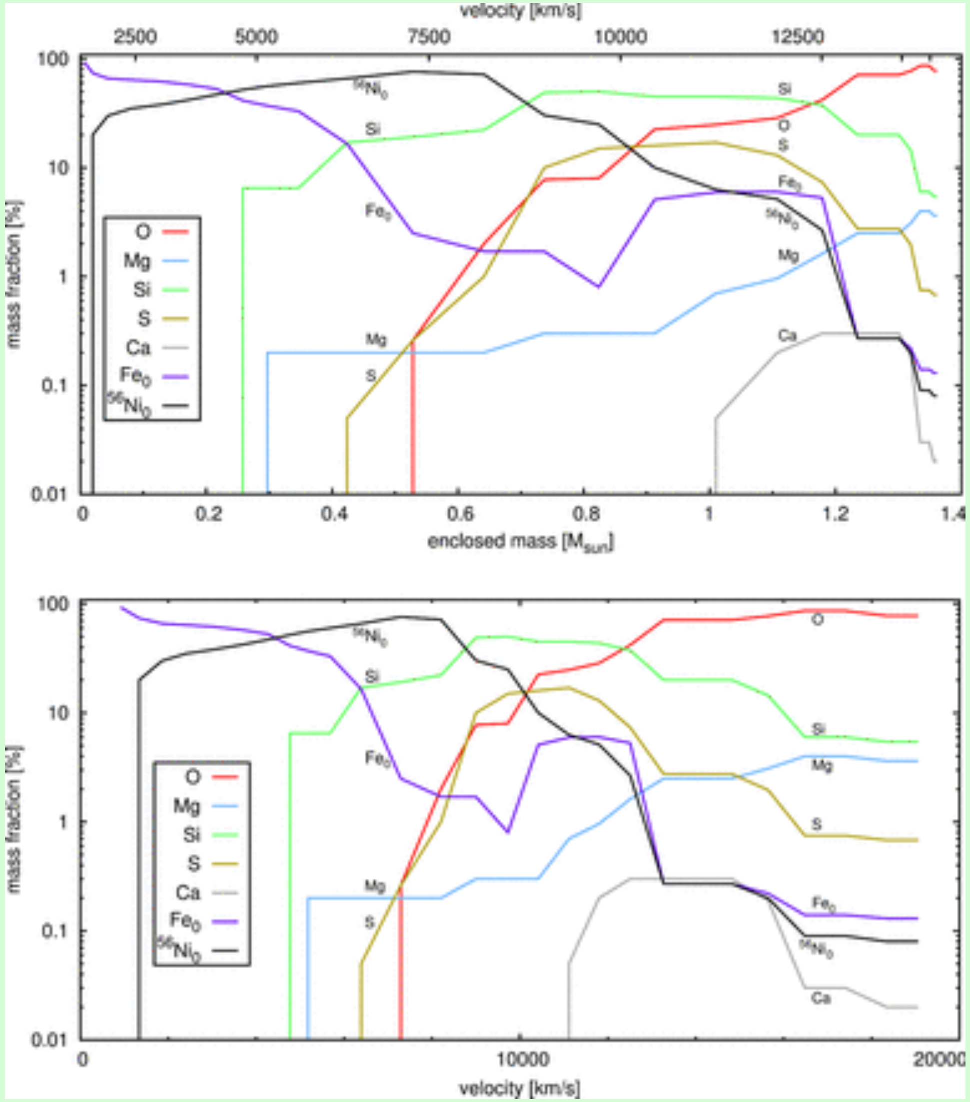
Adding nebular spectra with ρ11fe...

Very little evolution during first year or so



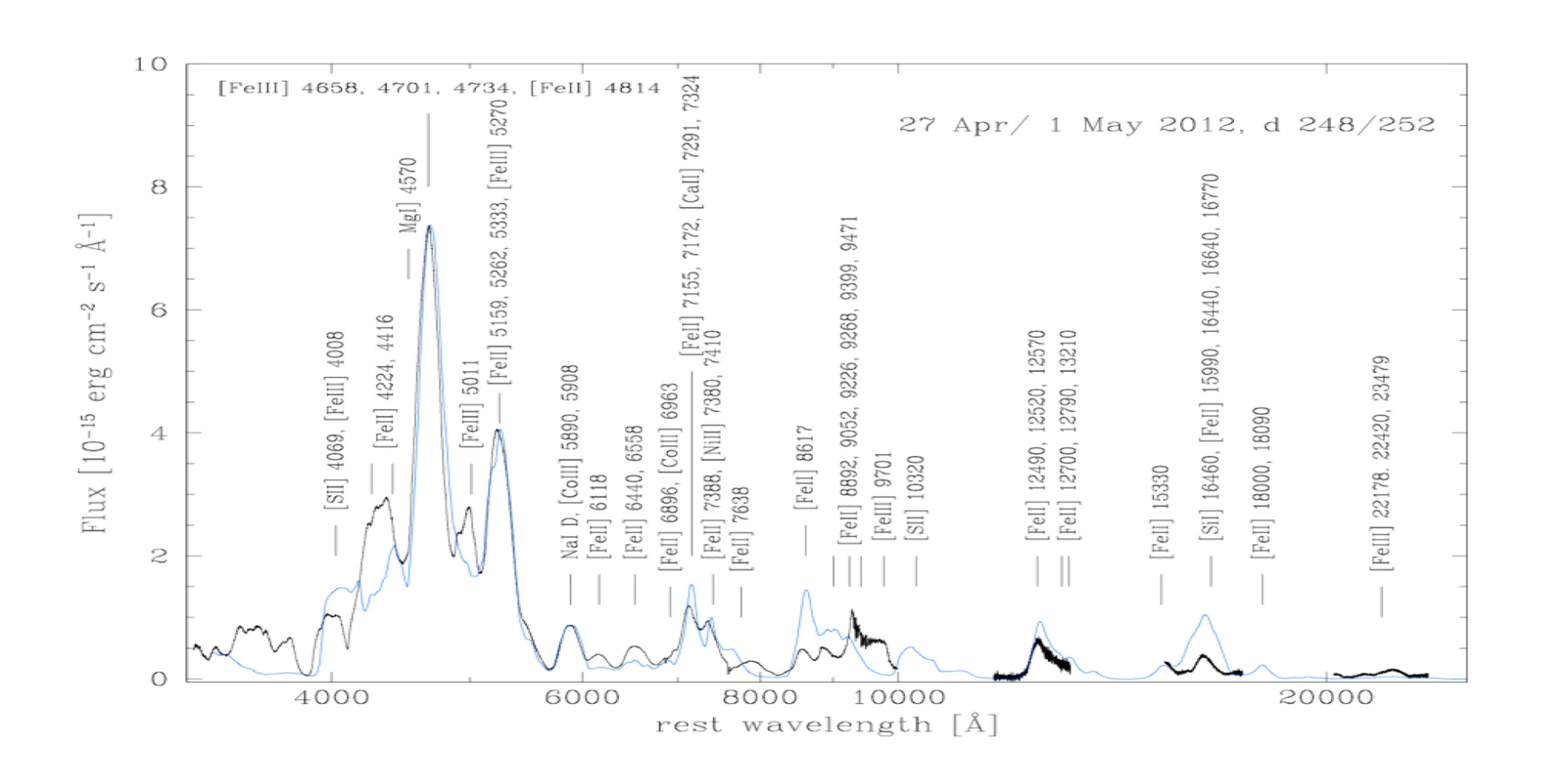
Results: Abundance distribution

- Inner layers dominated by ^{56}Ni and stable Fe-group elements
- M(^{56}Ni) = 0.47 ± 0.05 $M_{\odot}$
- M(stable NSE) ≅ 0.24±0.03$M_{\odot}$
- M(IME) ≅ 0.41 M
- M(C) ≅ 0.01; M(O) ≅ 0.24



Looking at the Near-Infrared

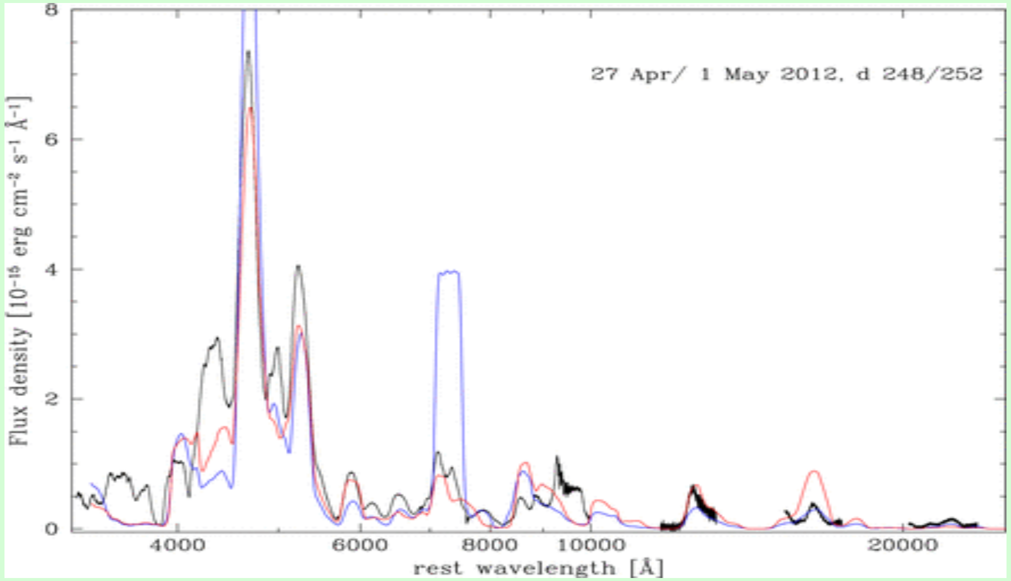
- Most emission lines are reproduced (Si, S)



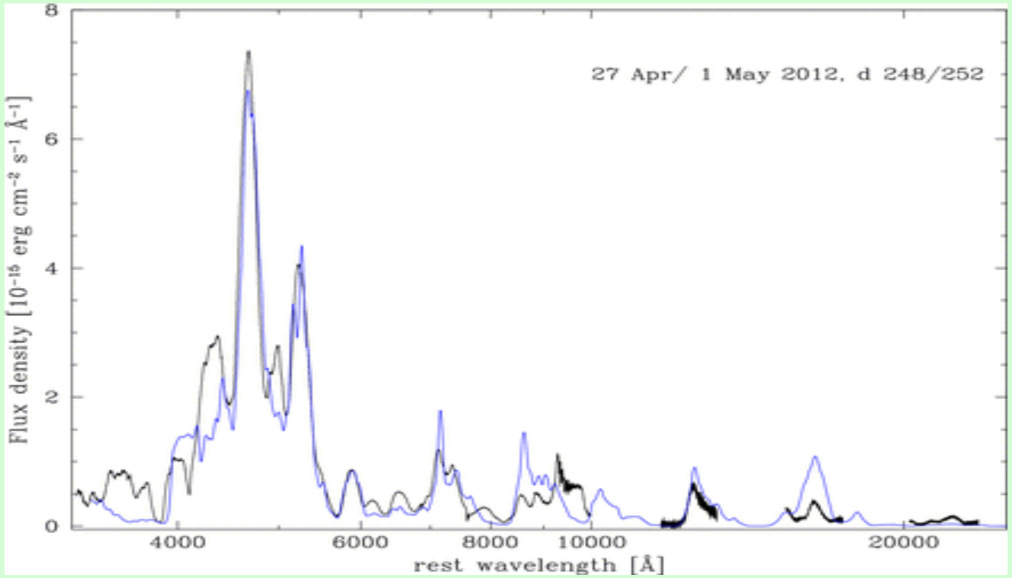
(PM et al 2015)

Some tests…..

- Sub-Chandra models
  (1.0, 1.2 $M_\odot$)
  - Lower inner density and lack of stable Fe lead to higher ionization degree

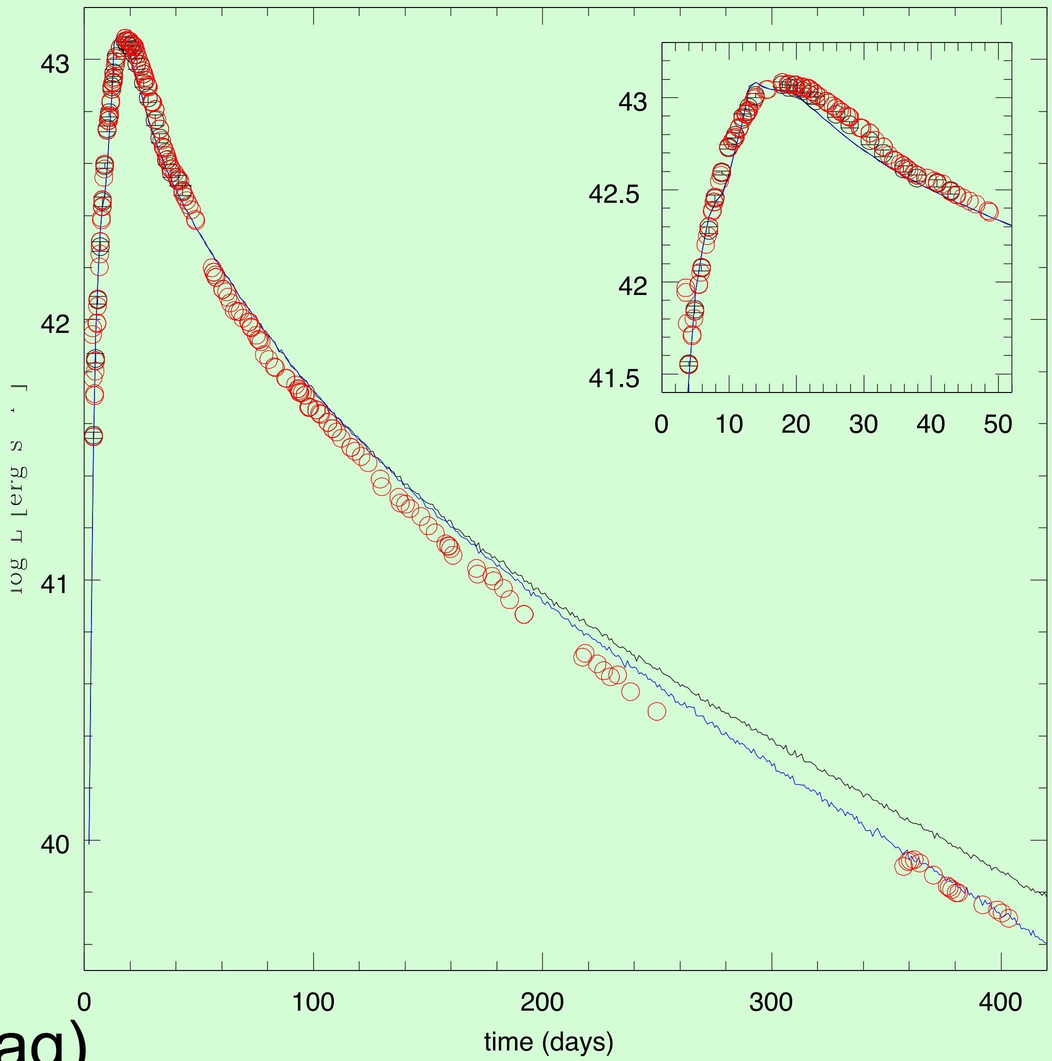


- Invert ^{56}Ni and stable Fe ("mock 3D model")
  - Fe lines become narrower
  - Ionization slightly lower



Test results with Light curve

- Use density and abundance distribution to compute synthetic bolometric LC with Montecarlo method
- Successful match confirms results:
  - Mass ~ M(Ch)
  - Ek ~ 1.25 10^^{51} erg
  - M(^{56}Ni) ~ 0.47 $M_{\odot}$
  - M(NSE) ~ 0.70 $M_{\odot}$
  - M(IME) ~ 0.42 $M_{\odot}$
  - M(CO) ~ 0.24 $M_{\odot}$
- Matches Zorro (ΔM_{15}≅1.1 mag)



Conclusions & questions

- 11fe matches a "1D low-Ek del-det"
- This appears to contradict other lines of evidence

Q. How can all this be reconciled?

- Why do 1D models look better than 1D ones?