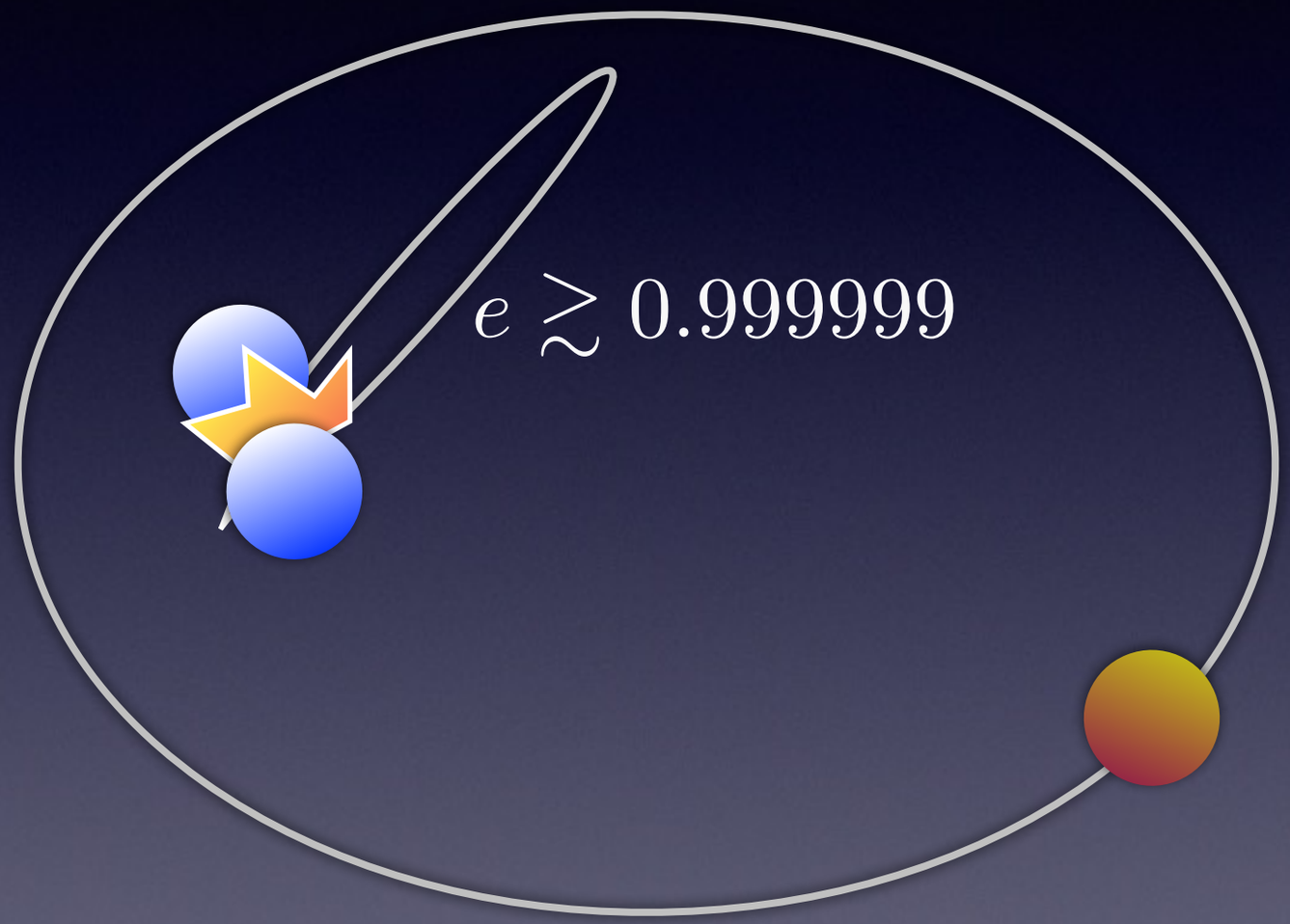
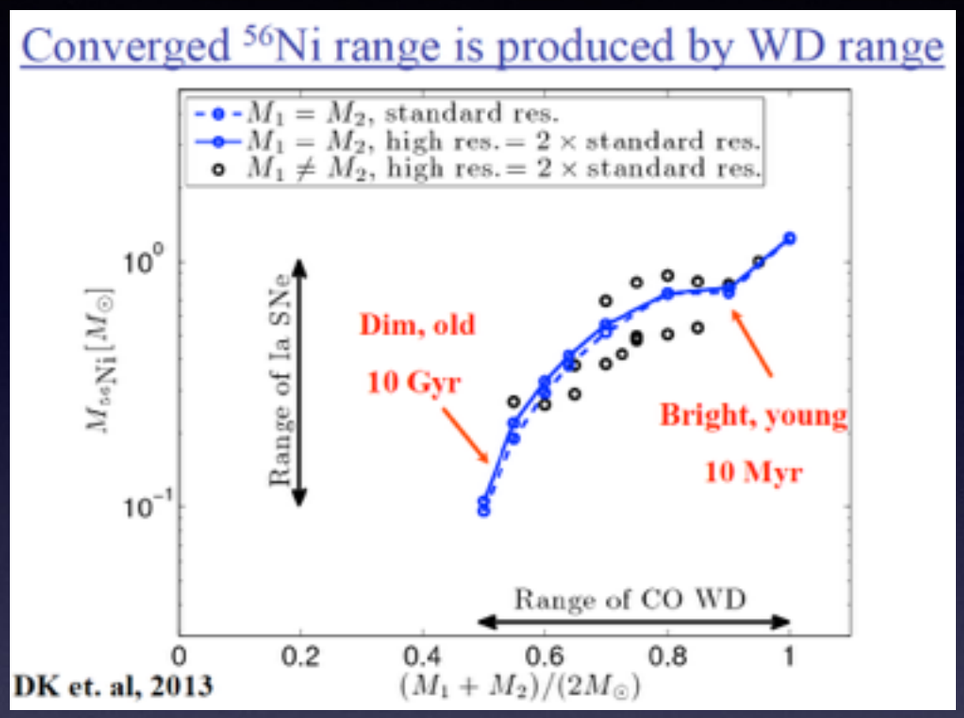
Type Ia are likely collisions

Boaz Katz, Doron Kushnir, Subo Dong

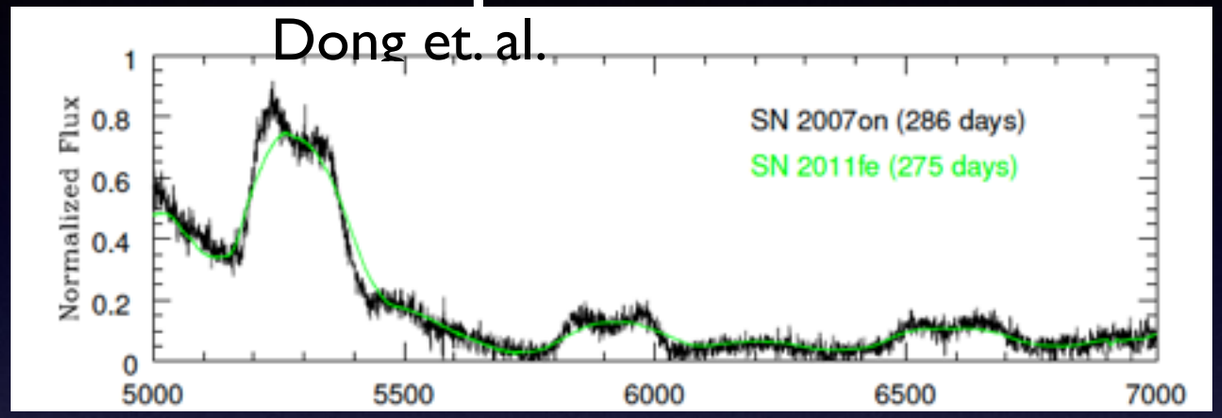


Evidence For Collisions

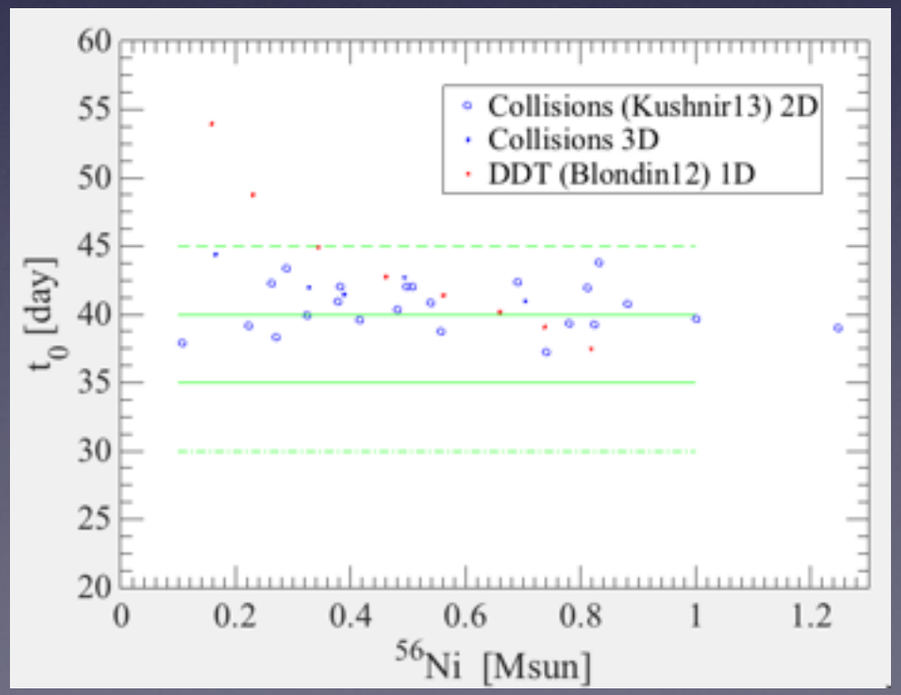


(~1/t DTD)

Double peak nebular lines



Correct bolometric properties



Main Challenge: enough relevant triples

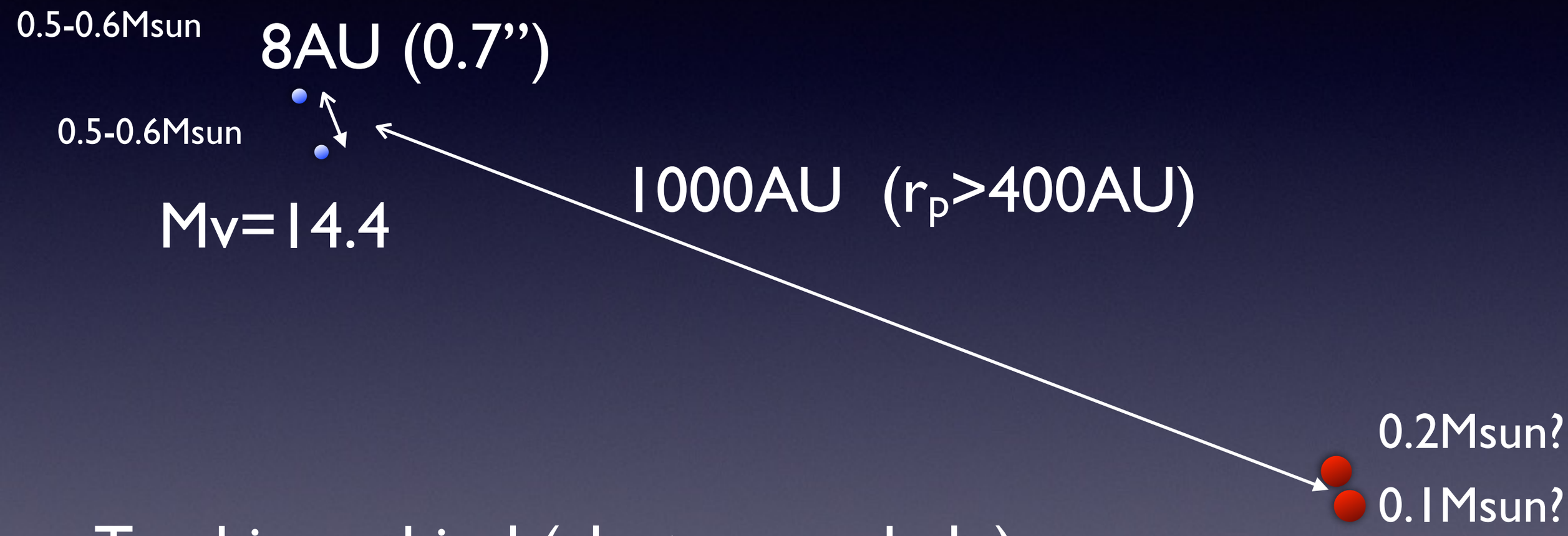
Need ~30% of WDs in relevant triples during their lifetime.

Better find at least few % now.

Some should be in 20pc sample (more than 100).

G107-70 (11pc away!) e.g. Harrington&Christy 81 :

Among the closest 20-30 WDs

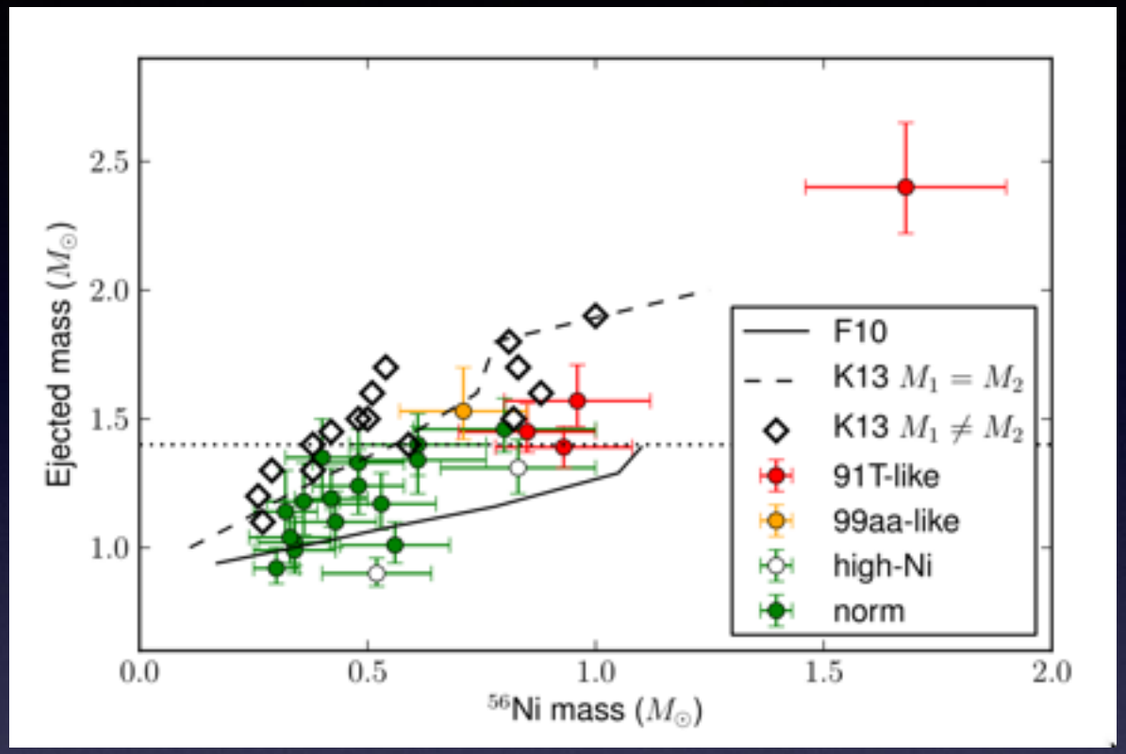


Too hierarchical (cluster may help)

This talk:
2 striking features of type Ia's

1. Jeffery's t_0 from L_{bol}:
   t_0=35-40 d for all Ia's
2. Double peak nebular lines
   (best: 5900A)

About Scalzo 14



rays from ^{56}Co decay. The code fits two parameters, a ^{56}Ni mass $M_{^{56}\mathrm{Ni}}$ and a fiducial time t_0 at which the optical depth to Compton scattering equals unity, using Arnett's rule (Arnett 1982) and the analytic treatment of Jeffery (1999). The ^{56}Ni mass is calculated

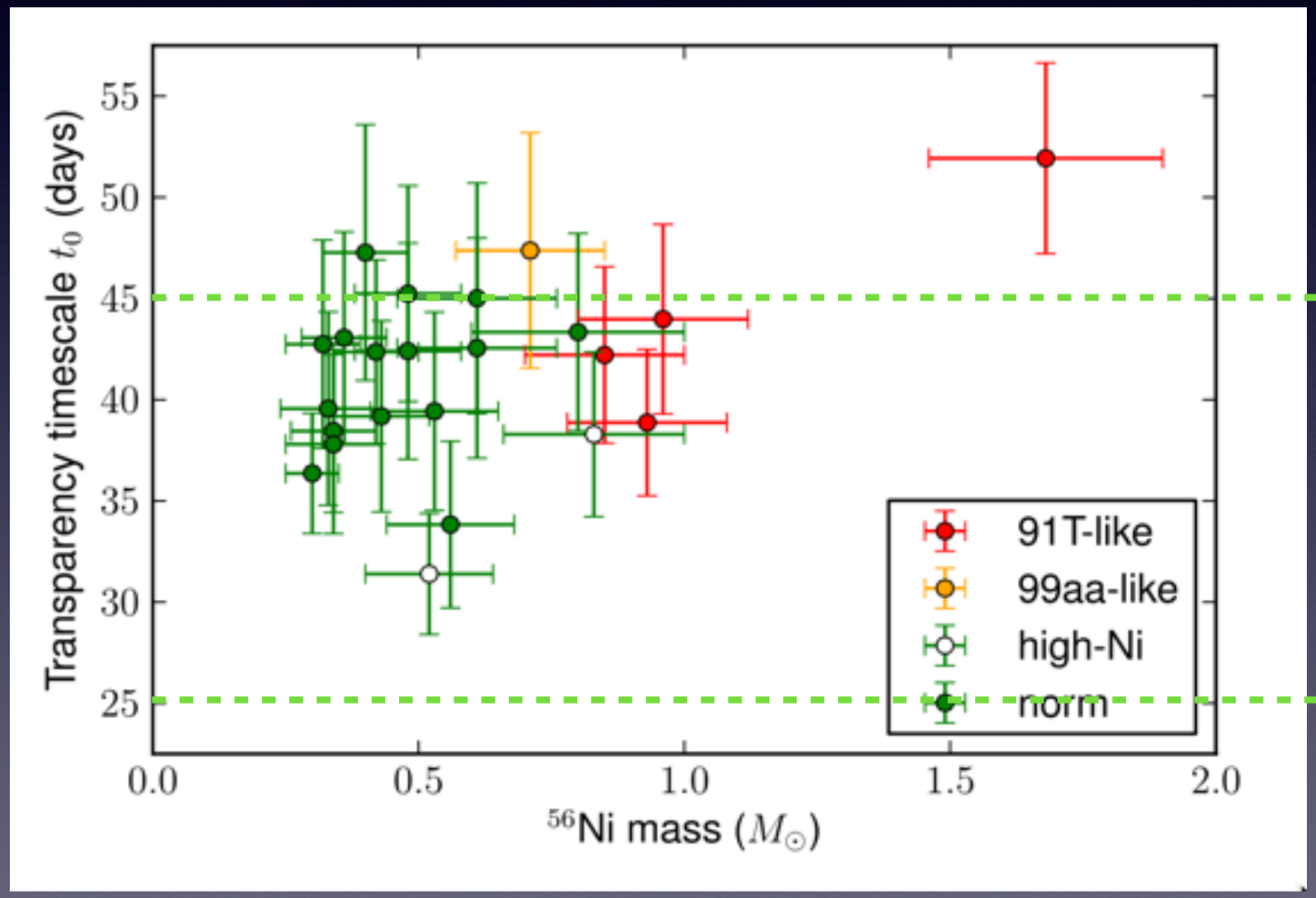
Mass - Bad

Column density - Good

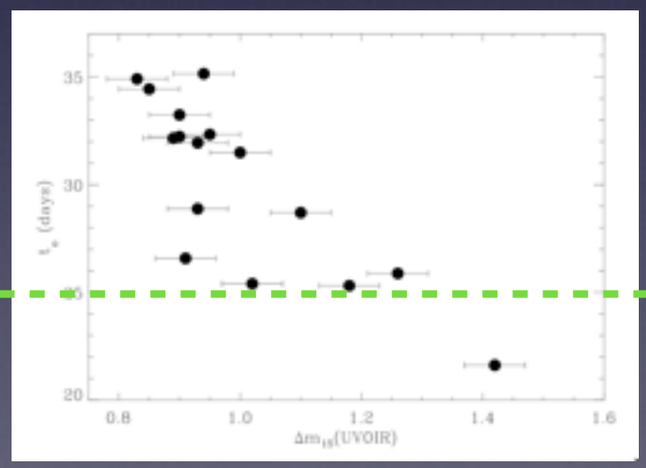
Column density (Jeffery 99):

t_0

Scalzo 14



Stritzinger 06



What is t_0 and why is it good?

t_0 sets the (global) energy deposition fraction to few percent accuracy:

$$Q_{\mathrm{deposition}}(t) = Q_{\mathrm{decay}}(t)(0.97 f_\gamma + 0.03)$$

e+ kinetic

late times (t>~60 days)

$$f_\gamma = \frac{t_0^2}{t^2}$$

early times (t<~20 days)

$$f_\gamma = 1$$

excellent interpolation

$$f_\gamma = 1 - e^{-t_0^2/t^2}$$

Why is deposition good?

- Q = L_{bol} at late times (>60 after explosion)
- Q is related to L_{bol} near maximum:

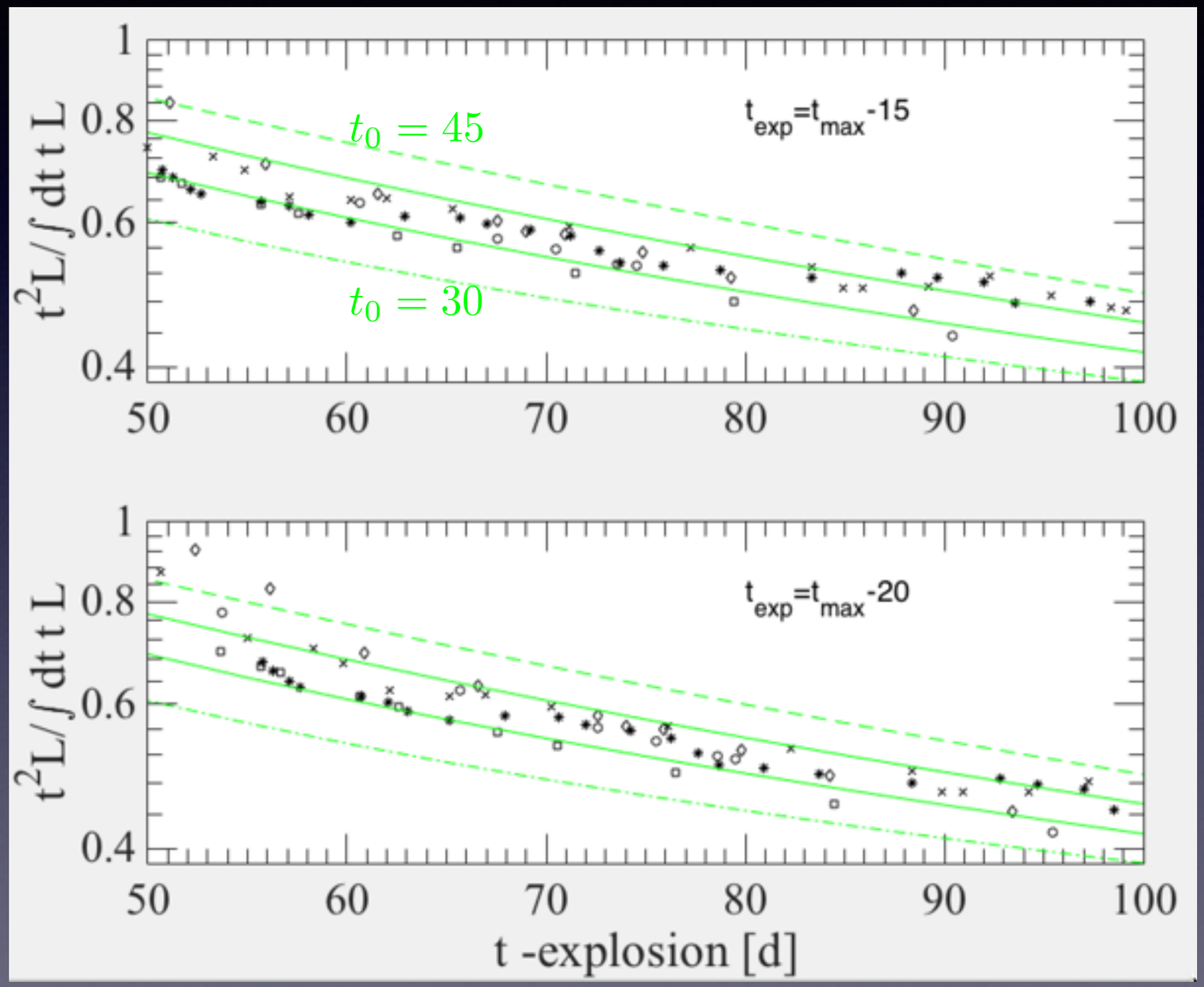
  old- Arnett: L_{bol}=Q at max

  new - $\int tLdt = \int tQdt$

Katz,Kushnir,Dong13

t_0, ^{56}Ni can be measured from L_{bol} and calculated from models without (optical) radiation transfer

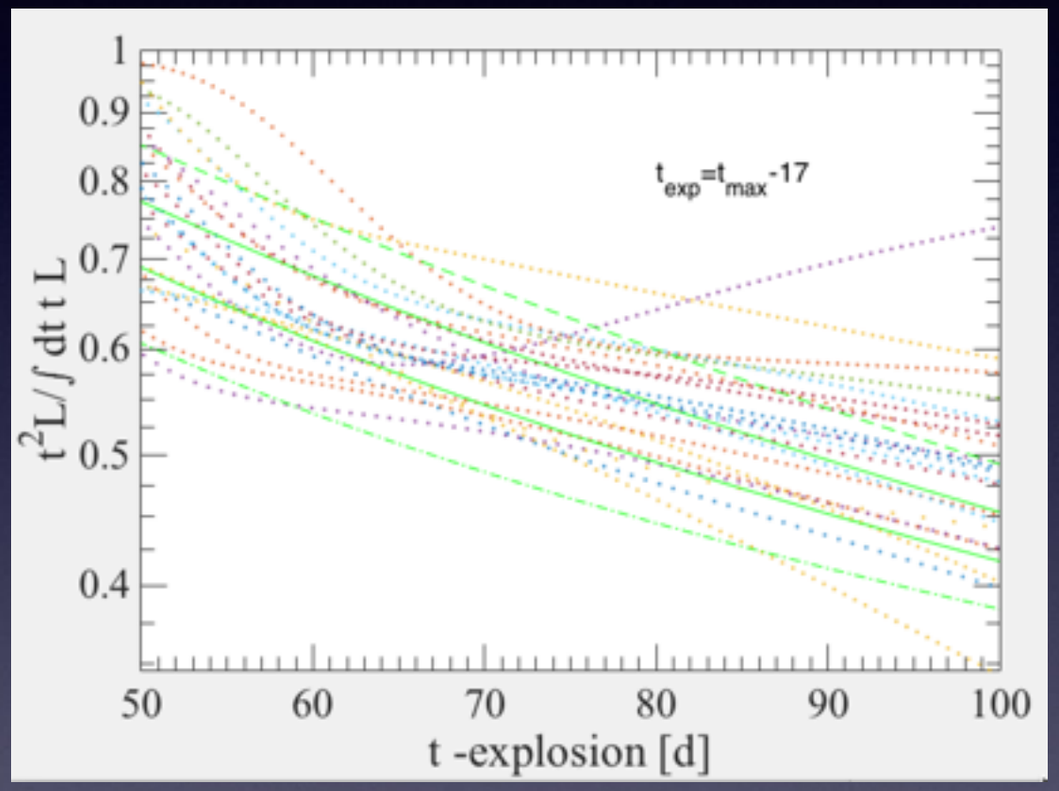
Column density (Jeffery 99): t_0=35-40 d for all type Ia

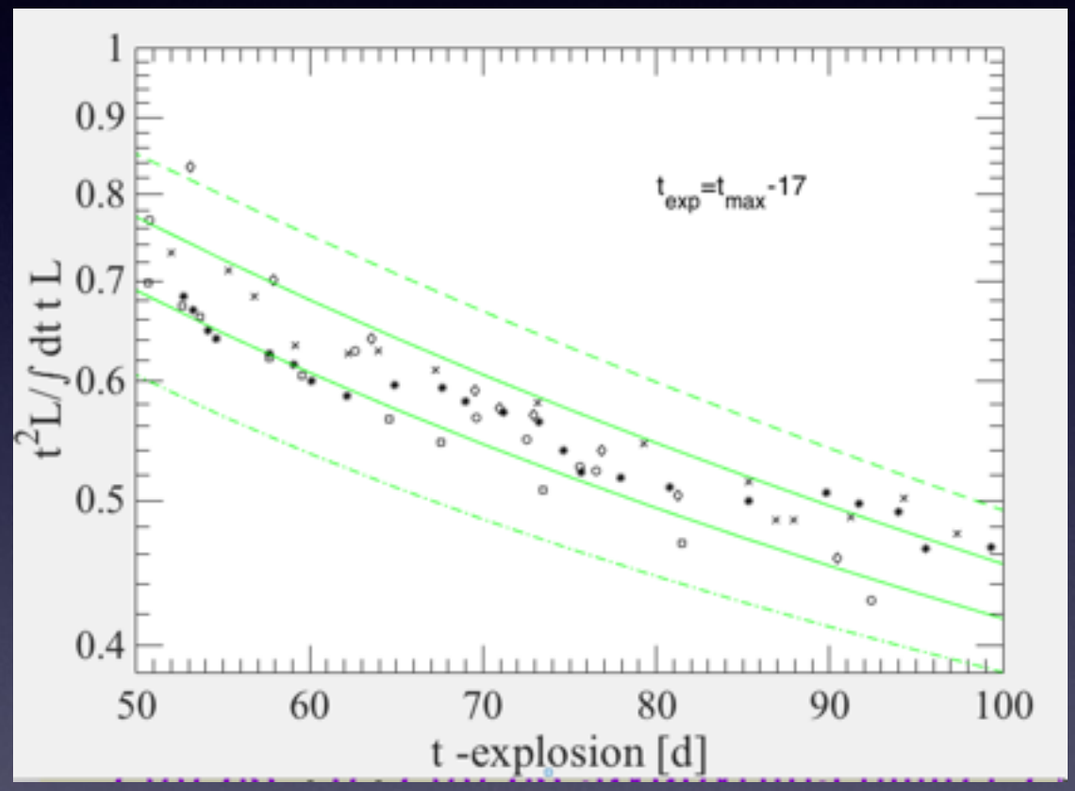


- 2005ke Phillips+12
- 2005cf Wang+09
- 2003du Stanishev+07
- 2007on Phillips+12
- 2011fe Mazzali+15
- t_0=45--,40-,35-,30-.-

Column density (Jeffery 99): t_0=35-40 d for all type Ia

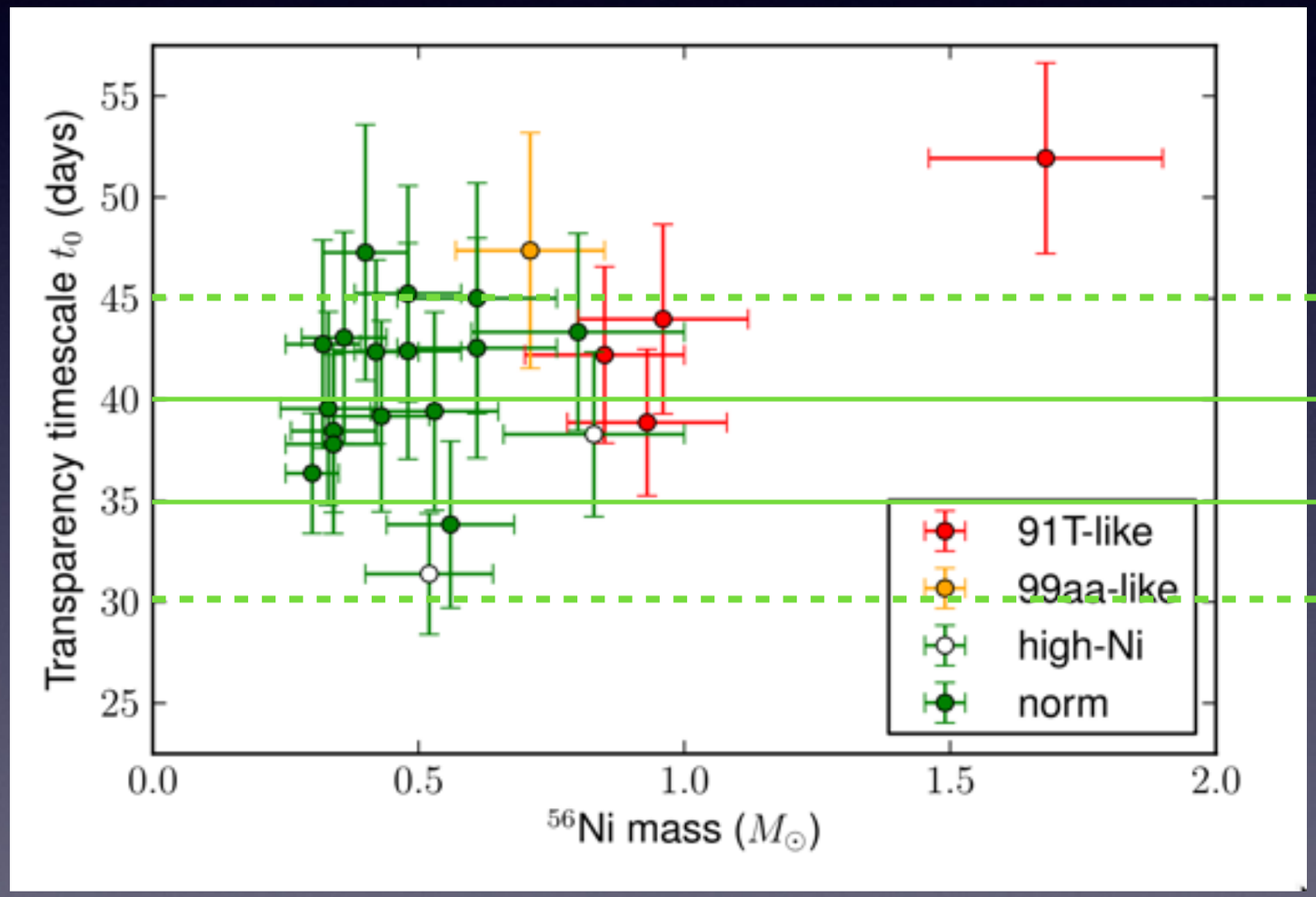
Stritzinger 06 bigger but no NIR



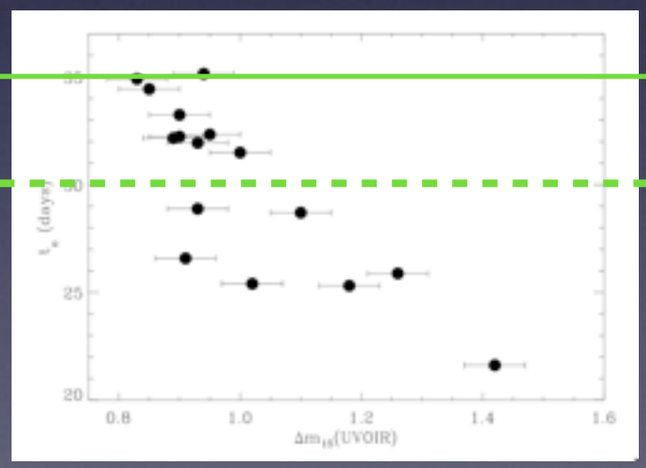


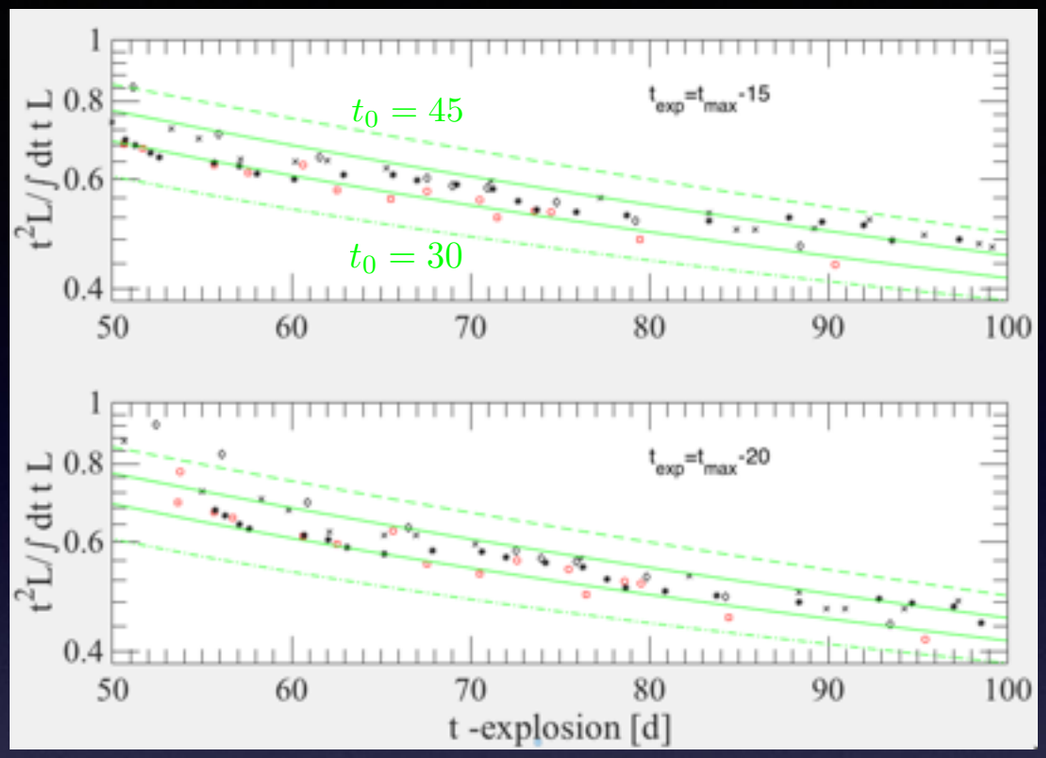
I want Scalzo's light curves…

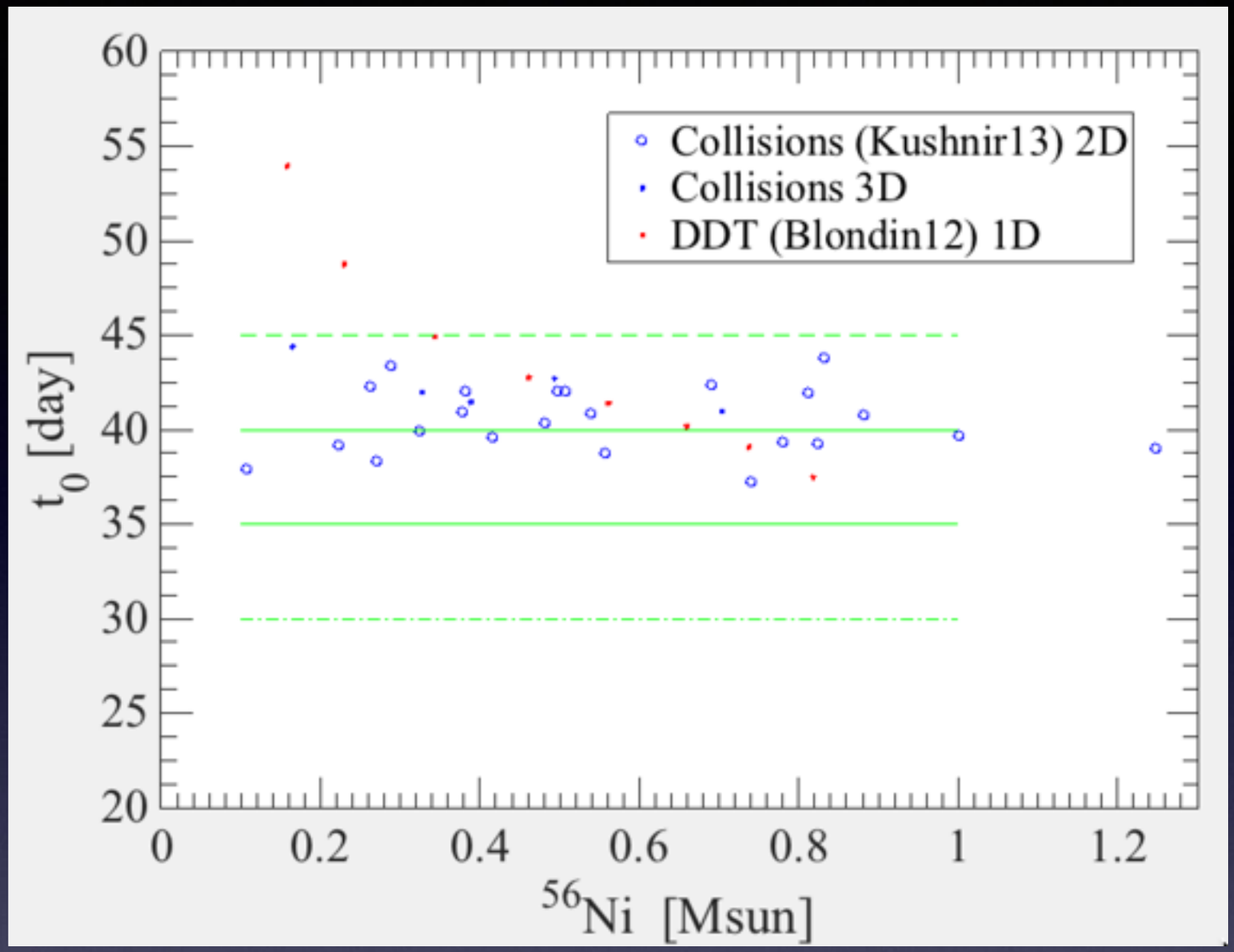
Scalzo 14

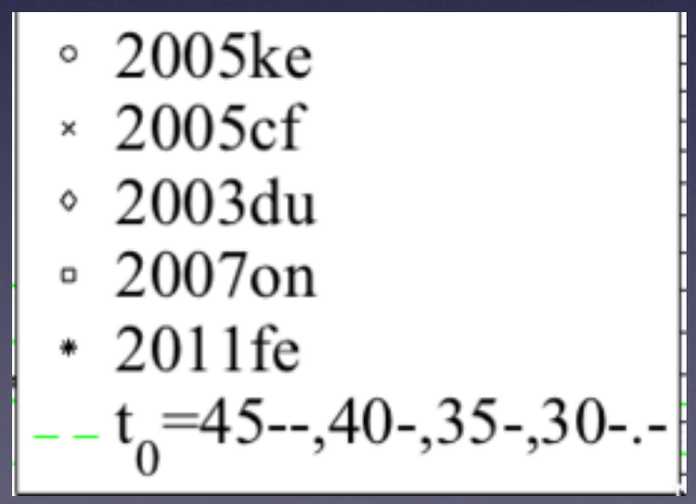


Stritzinger 06

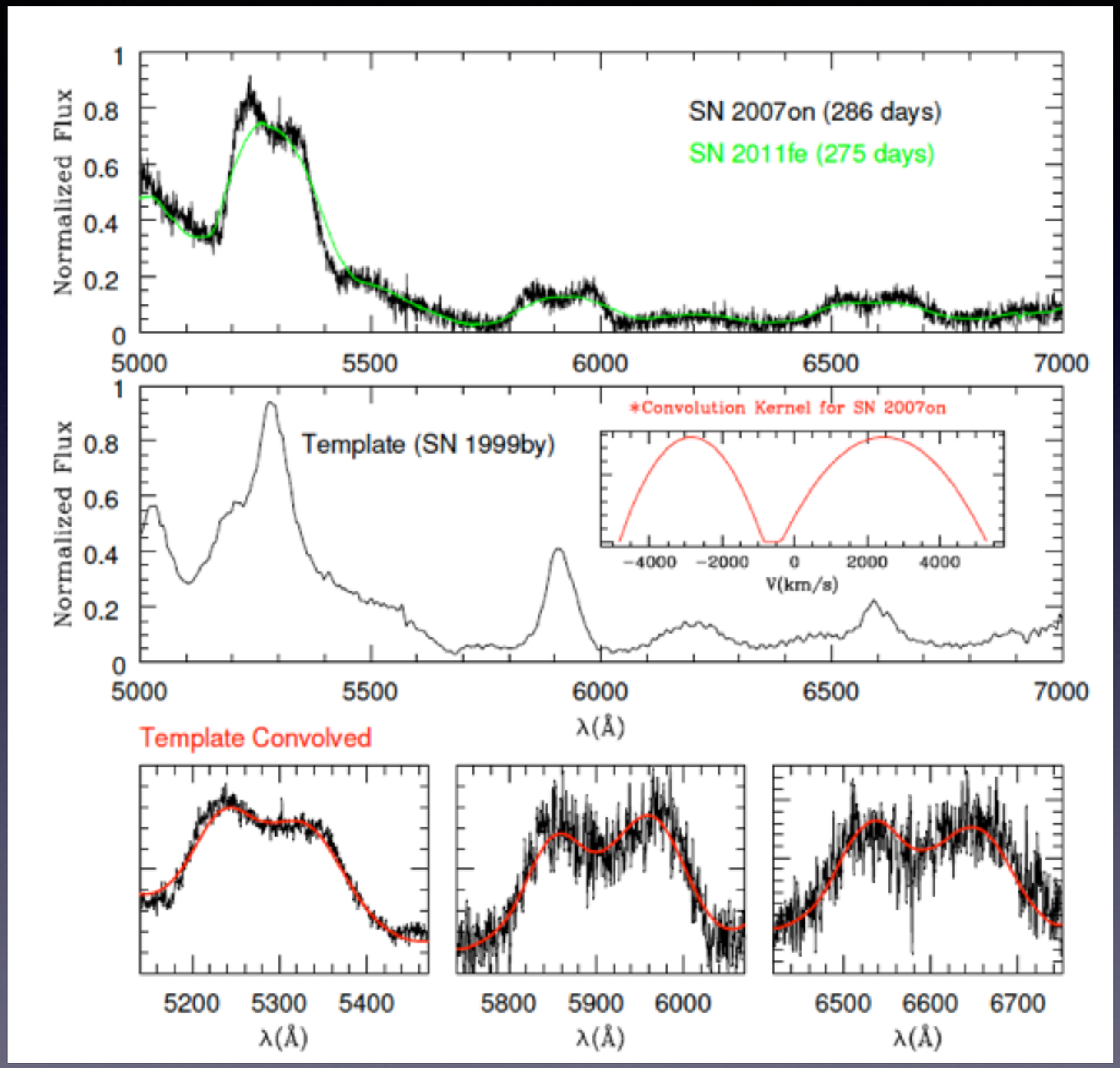



$t_0 = 45$
$t_0 = 30$
$t_{exp}=t_{max}$-15
$t_{exp}=t_{max}$-20
$t^2L/\int dt\, t\, L$
t -explosion [d]

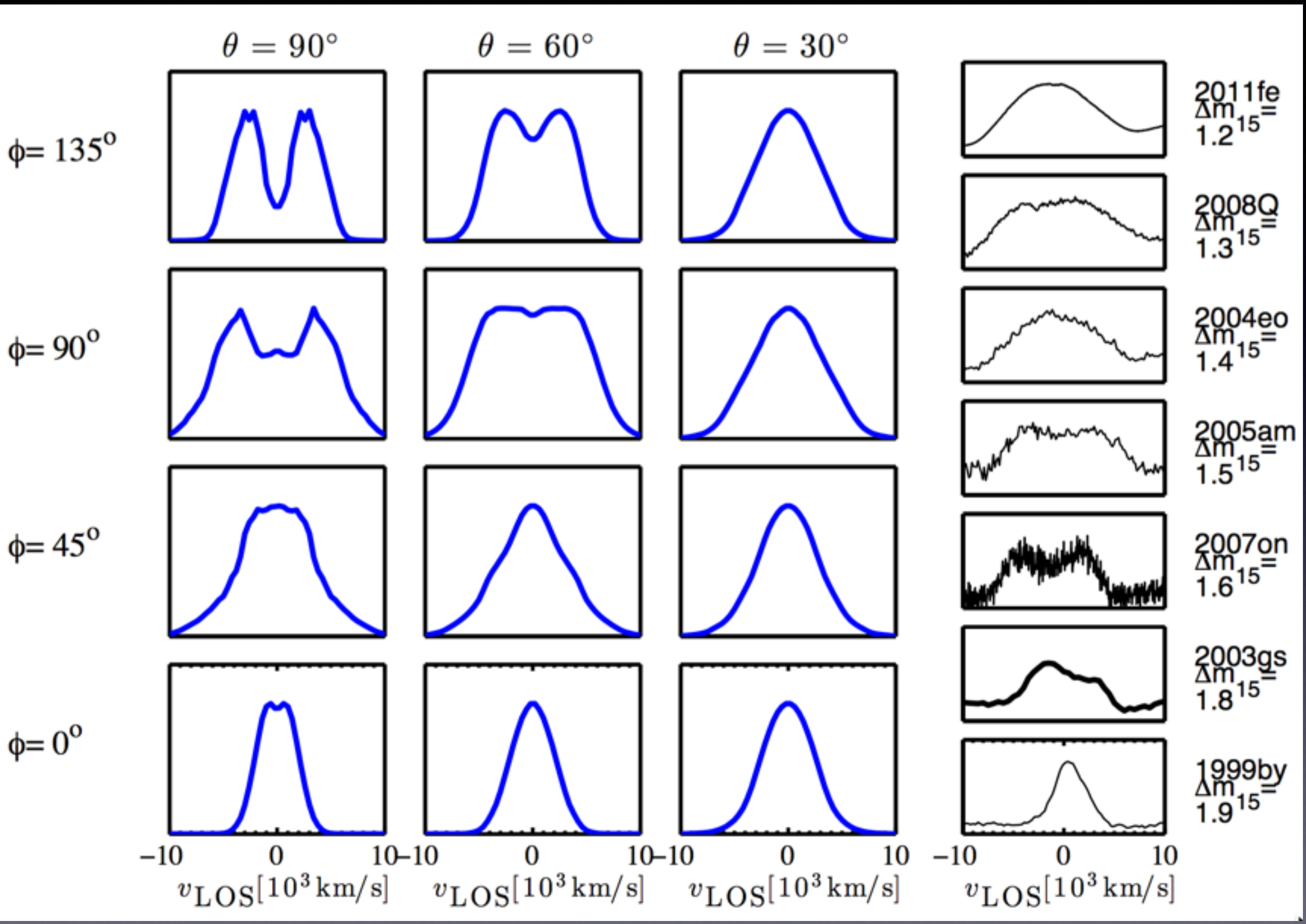

Collisions (Kushnir13) 2D
Collisions 3D
DDT (Blondin12) 1D
t_0 [day]
^{56}Ni [Msun]


2005ke
2005cf
2003du
2007on
2011fe
t_0=45--,40-,35-,30-.-

Nebular line profiles:

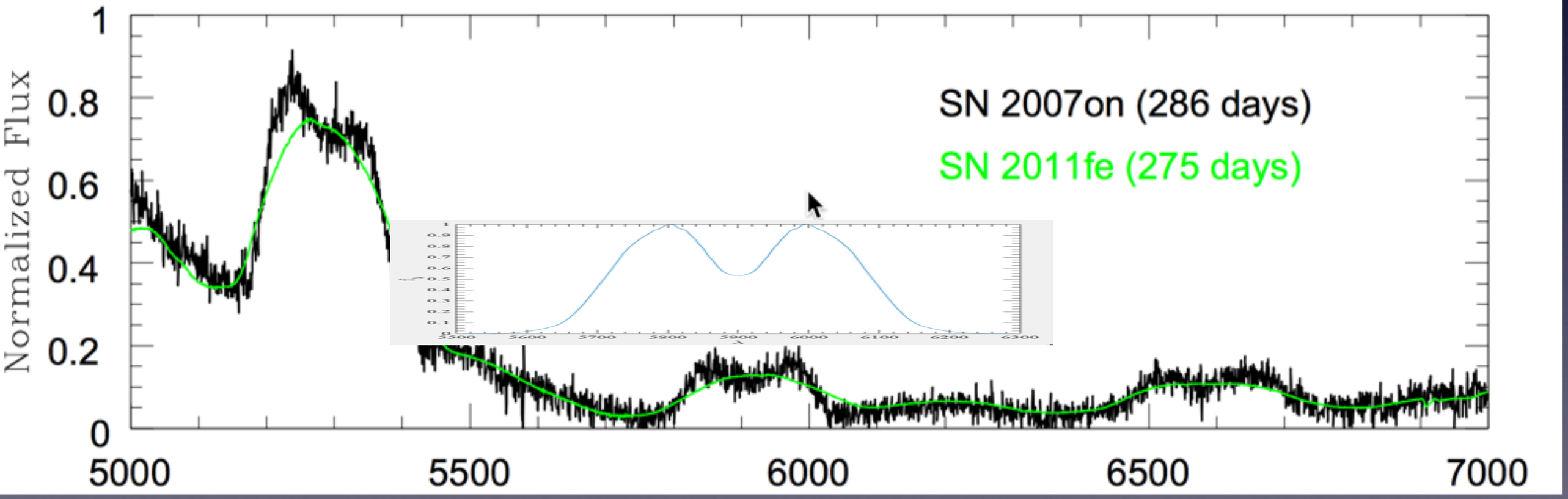


Dong +2014


θ = 90°
θ = 60°
θ = 30°
ϕ= 135°
ϕ= 90°
ϕ= 45°
ϕ= 0°
2011fe
Δm15= 1.2
2008Q
Δm15= 1.3
2004eo
Δm15= 1.4
2005am
Δm15= 1.5
2007on
Δm15= 1.6
2003gs
Δm15= 1.8
1999by
Δm15= 1.9
−10
0
10
vLOS[10³ km/s]

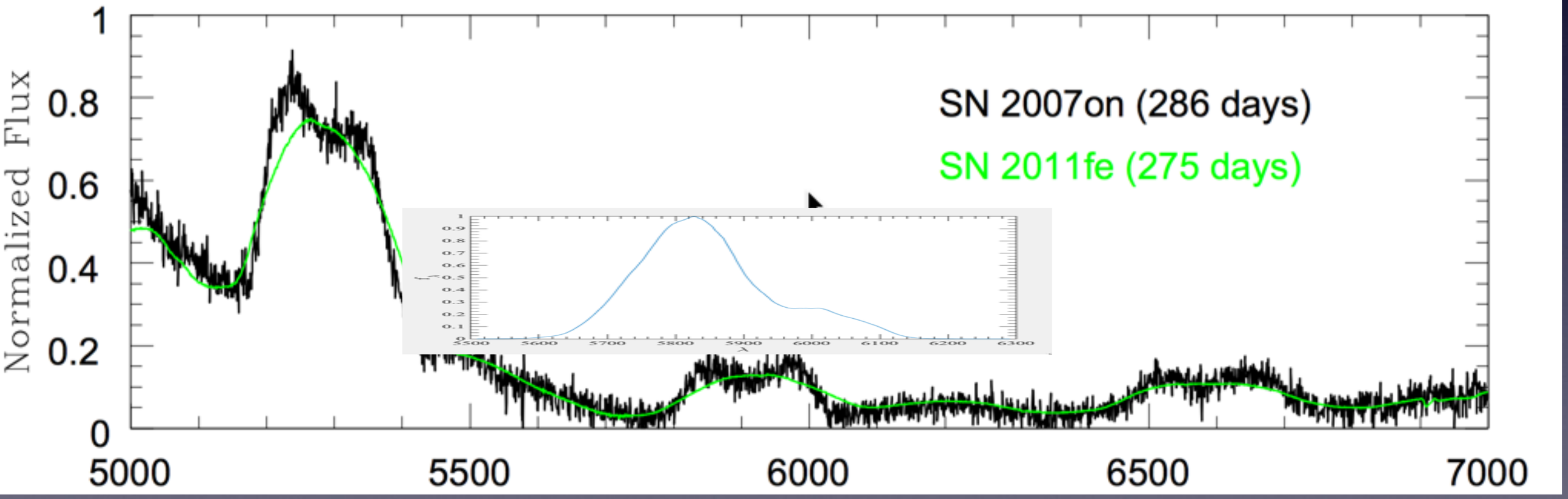
Dong +2014

Prediction I (Kushnir+)
Some bright Ia's with very large double peak



0.9 - 0.9 collision, b=0.5 RWD, >0.7 Msun Ni56

Prediction 2(Kushnir+) Some bright Ia's with very shifted peak



0.9 - 0.8 collision, b=0.5 RWD, >0.45 Msun Ni56

Questions:
What is t_0 of the different models?

How can we get ~100 nebular spectra?