Superluminous Supernovae

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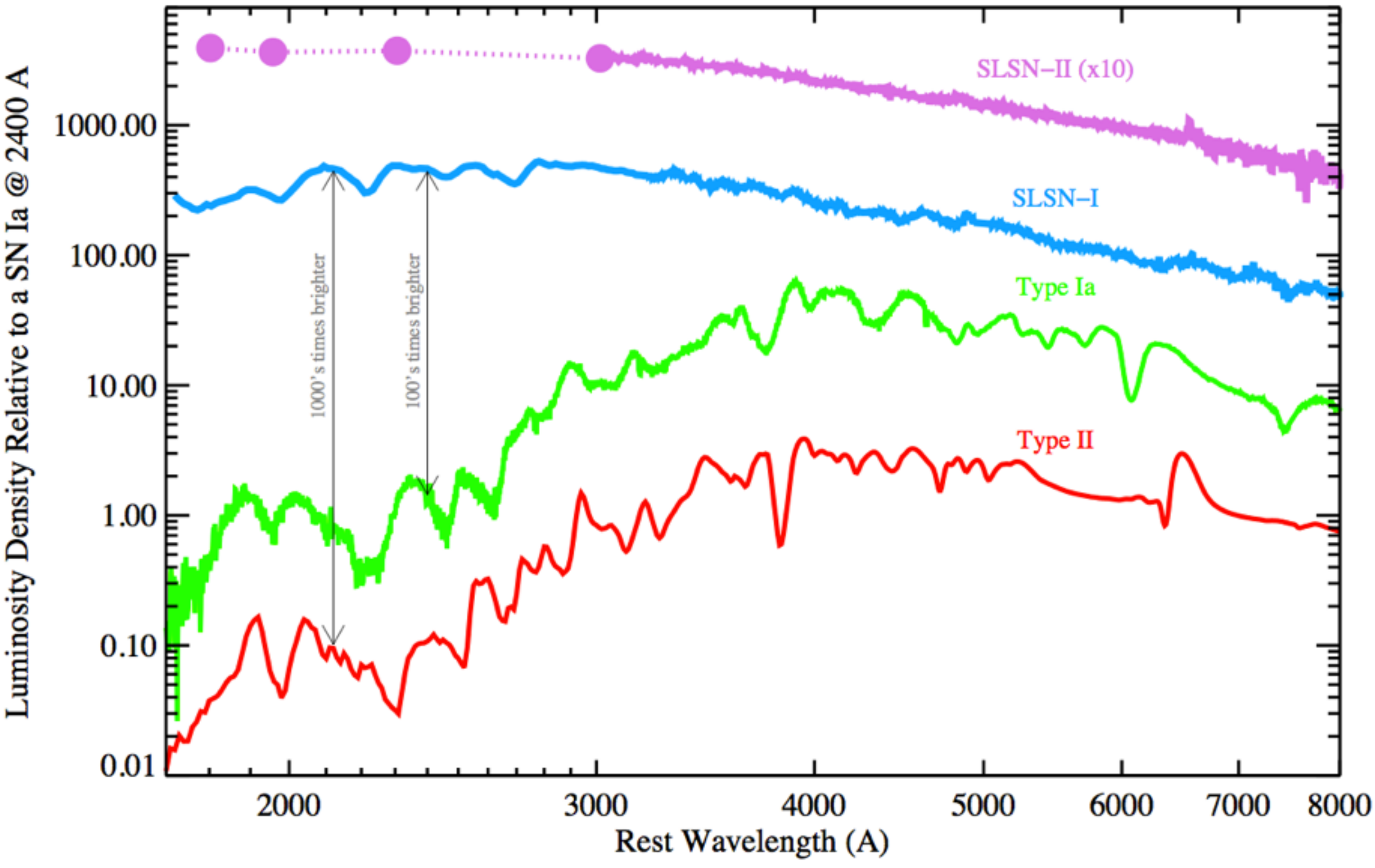
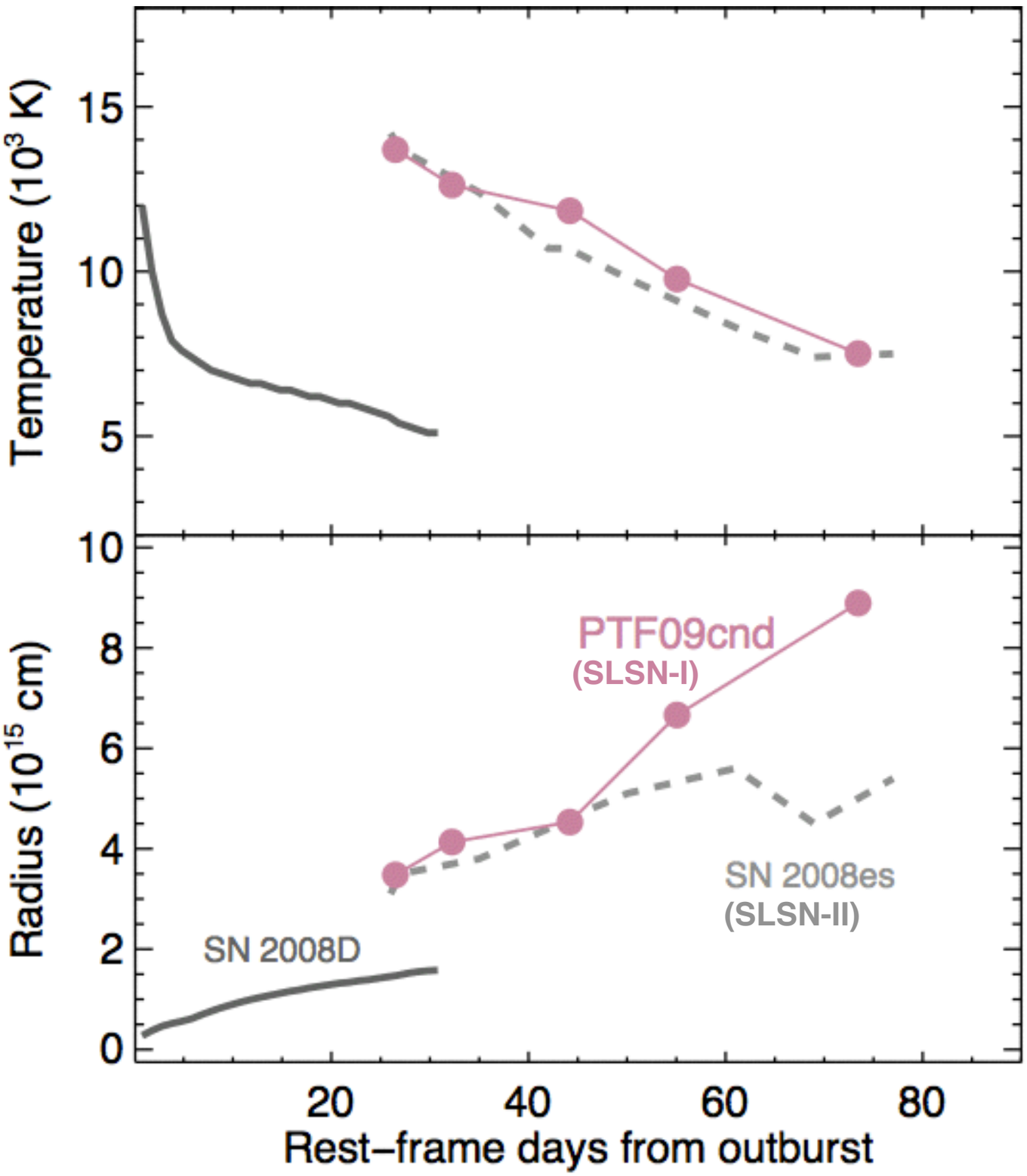
SLSN Spectra

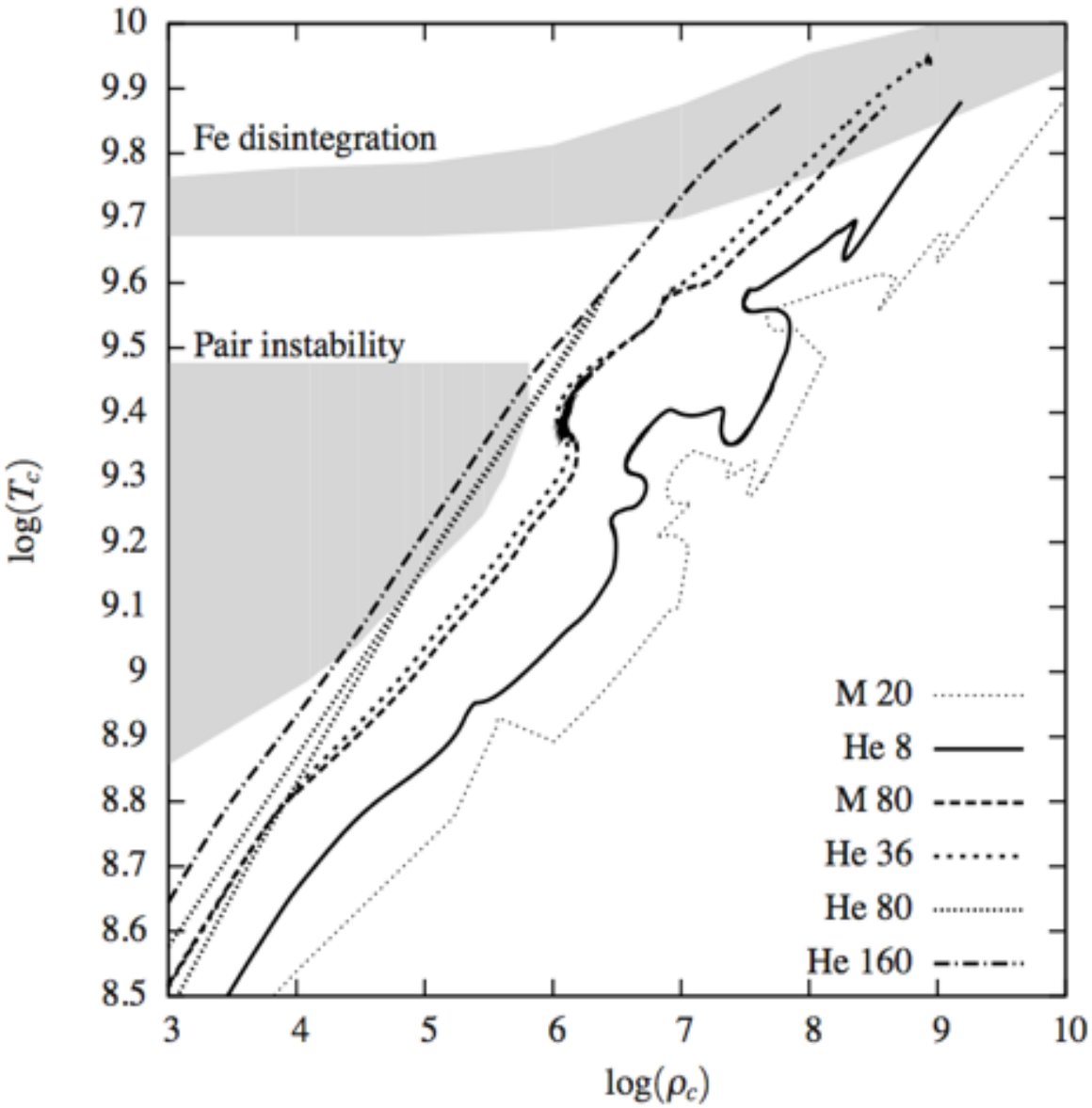


SLSN Stay Hot Longer



RQ et al. 2011

Are SLSNe: 1) Pair-Instability SNe?

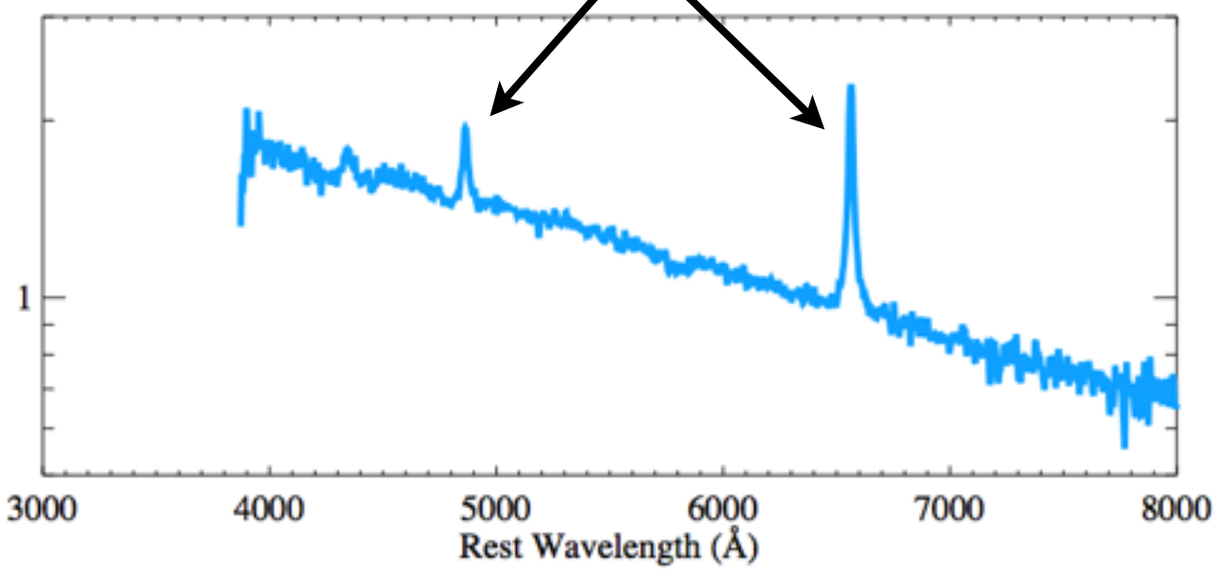


Waldman 2008

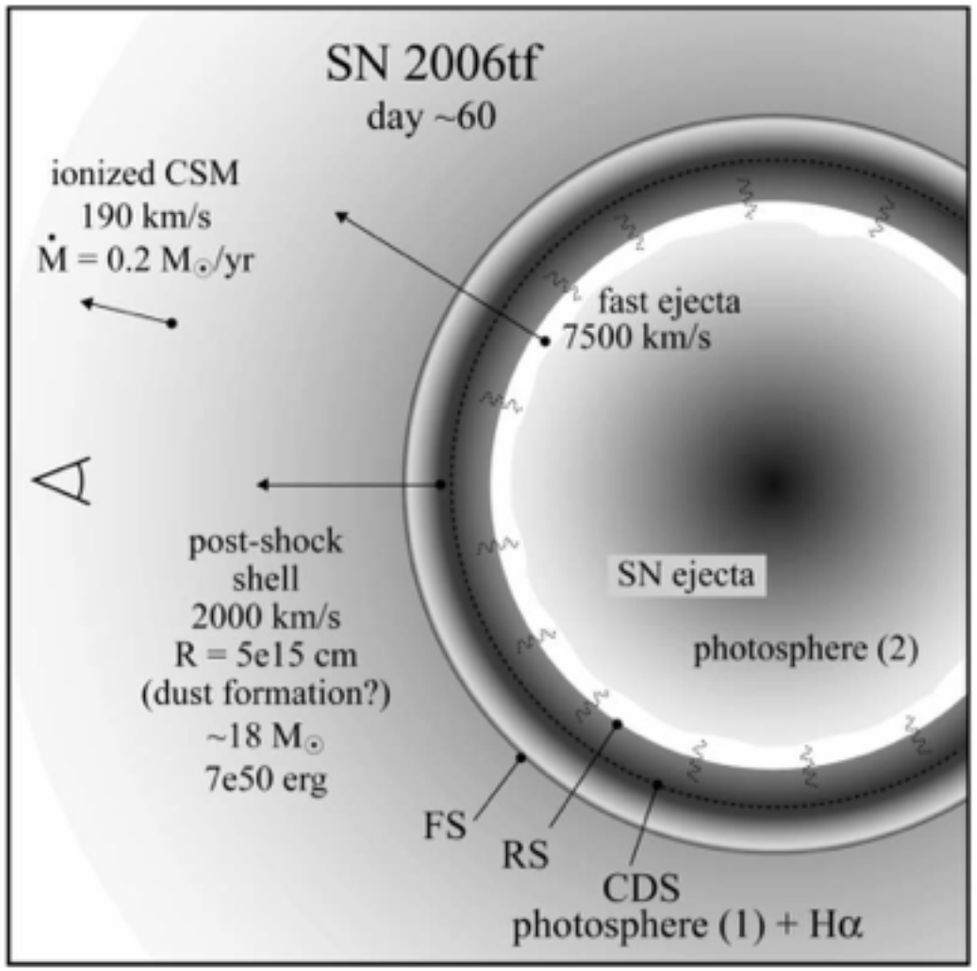
- First Proposed it the 1960's (Rakavy et al. 1967; Barkat et al. 1967)
- Massive stars are supported by radiation pressure
- At high temperatures, photons are created with E > e+e-
- Losses to pair production soften the EOS, and lead to instability
- Expected fate of the first (low metal, high mass) stars

2) Interaction Power?

Narrow emission lines indicate ejecta/wind interaction



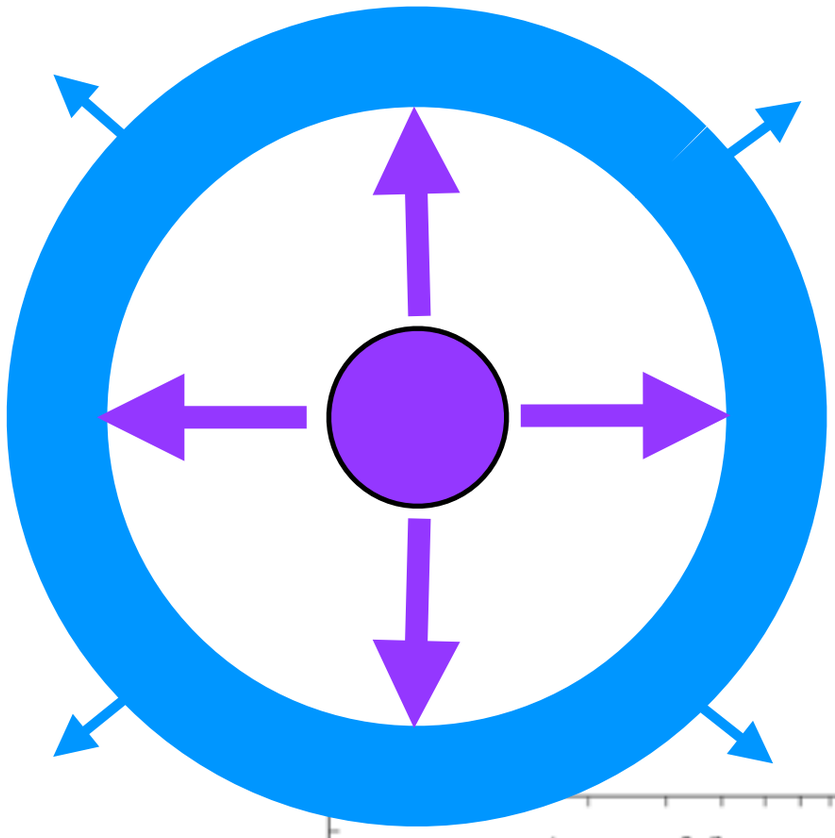
Ejecta run into surrounding material (progenitor wind, shells, etc.) and convert kinetic energy into luminosity



Smith et al. 2008

see also Smith & McCray 2007, Chevalier & Irwin 2011

3) Central Engine Power?

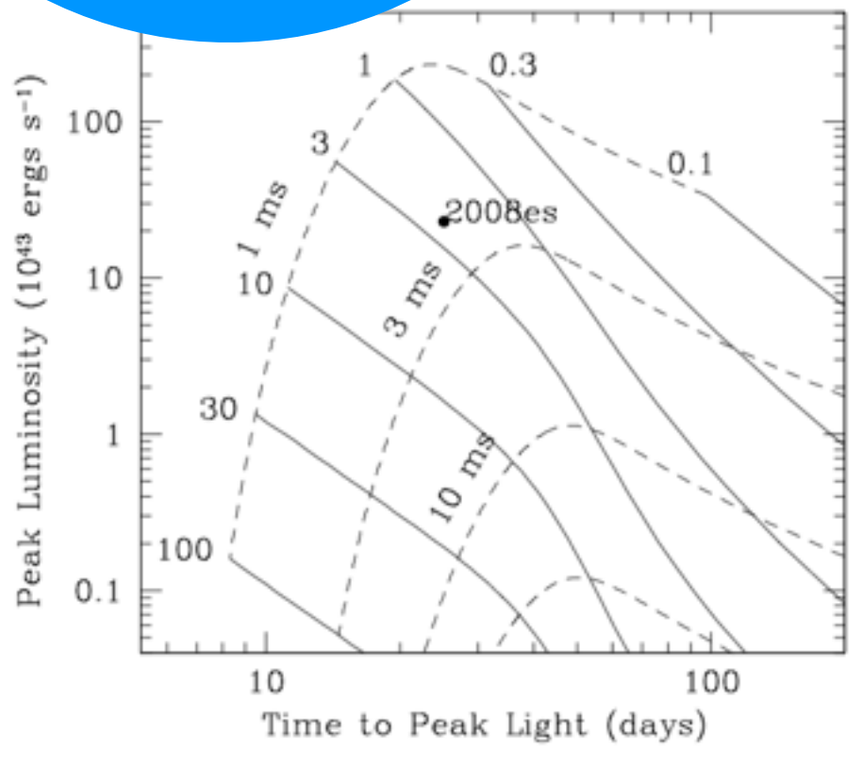


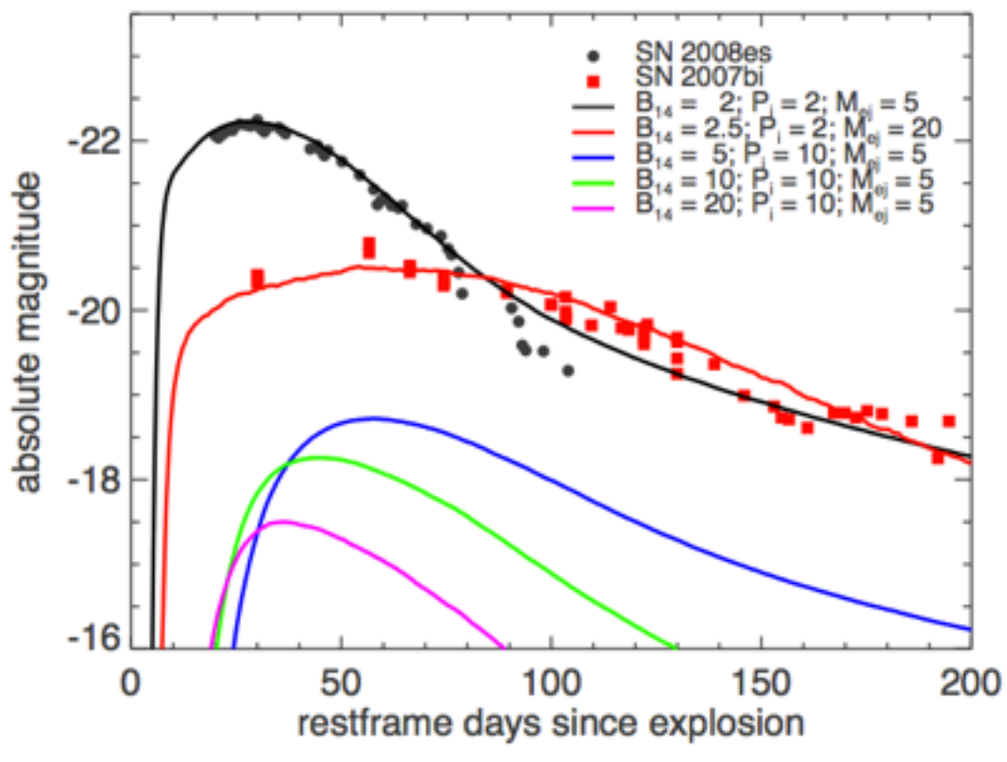
$$E_{\rm p} = \frac{I_{\rm ns}\Omega_{\rm i}^2}{2} = 2\times10^{50}P_{10}^{-2}\ {\rm ergs},$$

$$t_{\rm p} = \frac{6I_{\rm ns}c^3}{B^2R_{\rm ns}^6\Omega_{\rm i}^2} = 1.3B_{14}^{-2}P_{10}^2\ {\rm yr},$$

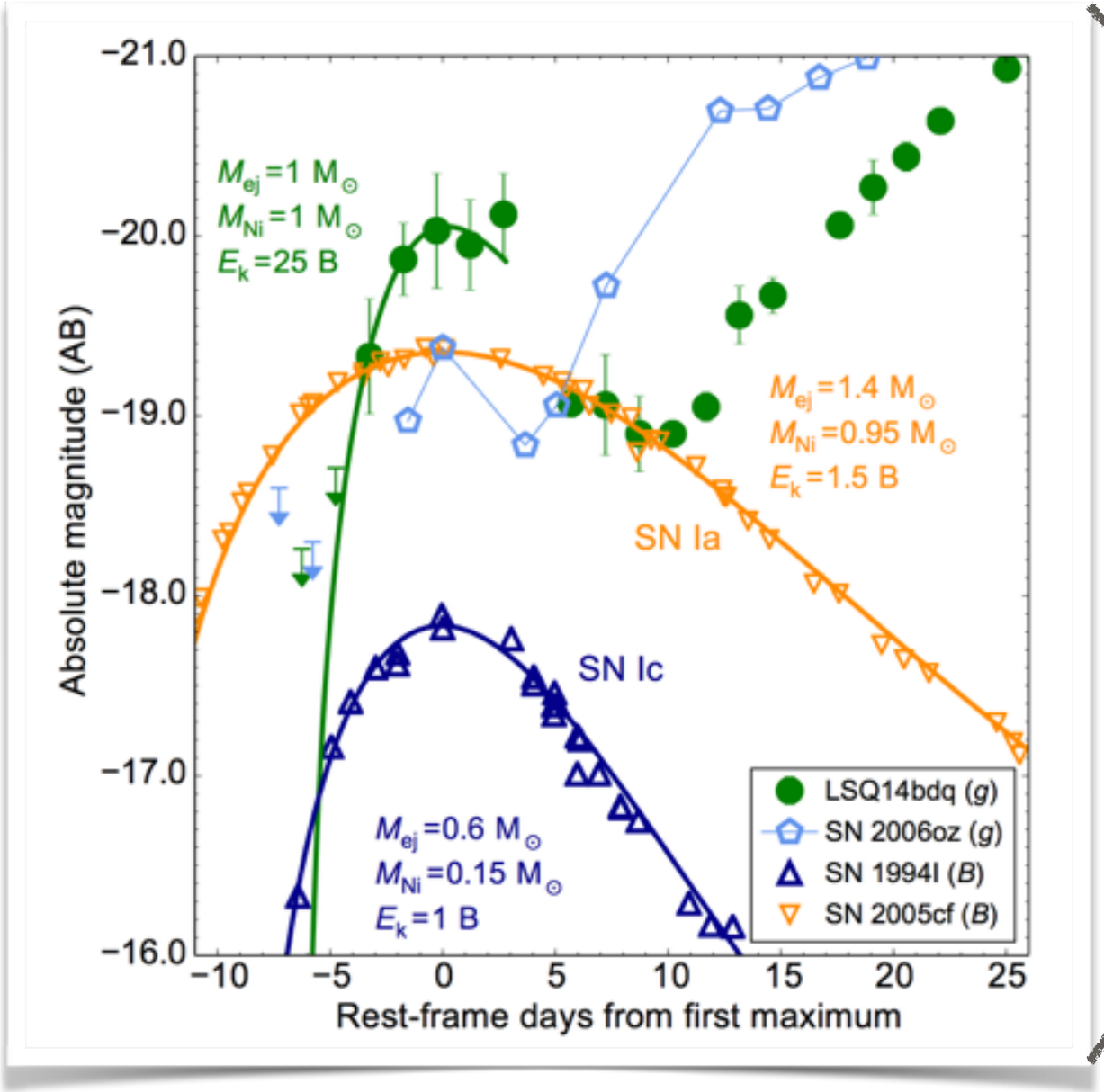
$$L_{\rm peak} \sim \frac{E_{\rm p}t_{\rm p}}{t_{\rm d}^2} \sim 5\times10^{43}B_{14}^{-2}\kappa_{\rm es}^{-1}M_5^{-3/2}E_{51}^{1/2}{\rm erg\ s^{-1}}$$

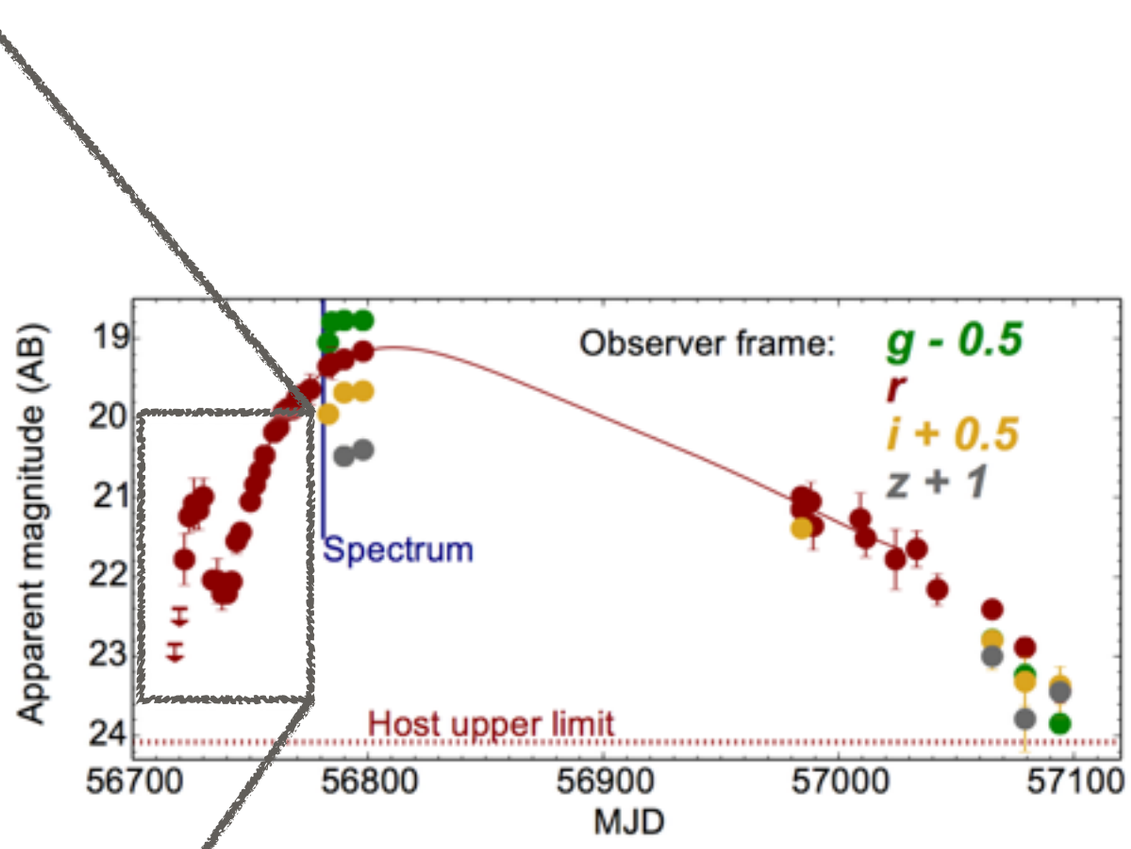
Kasen & Bildsten 2010; see also Woosley 2010





Double Peaked SLSN-I

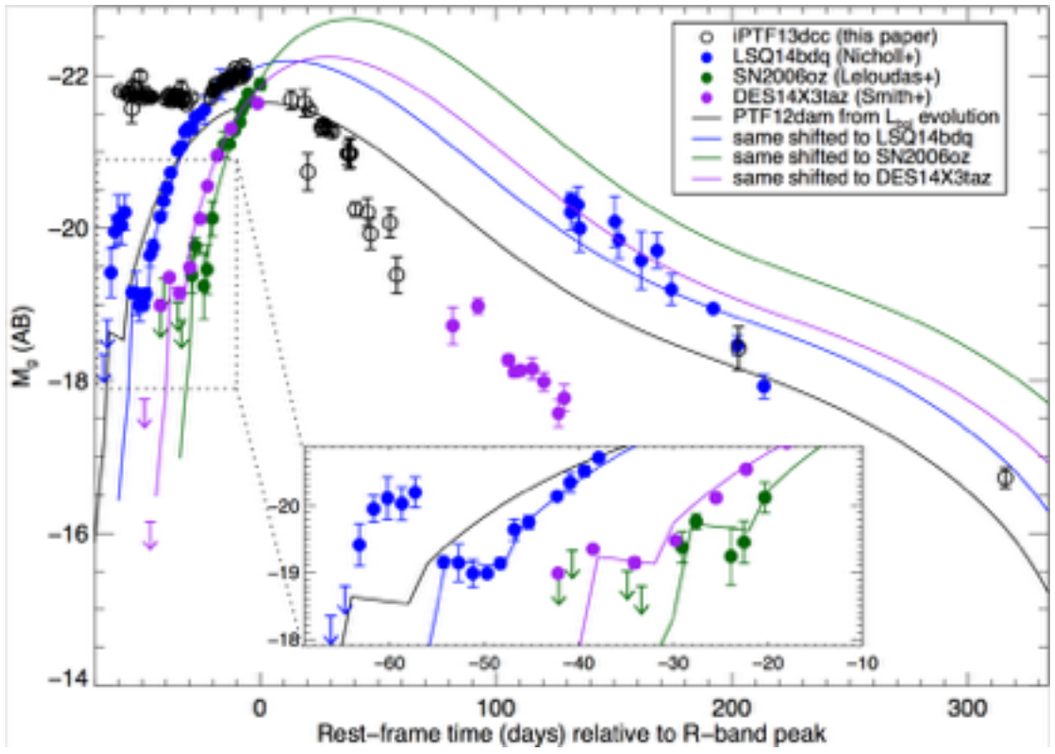




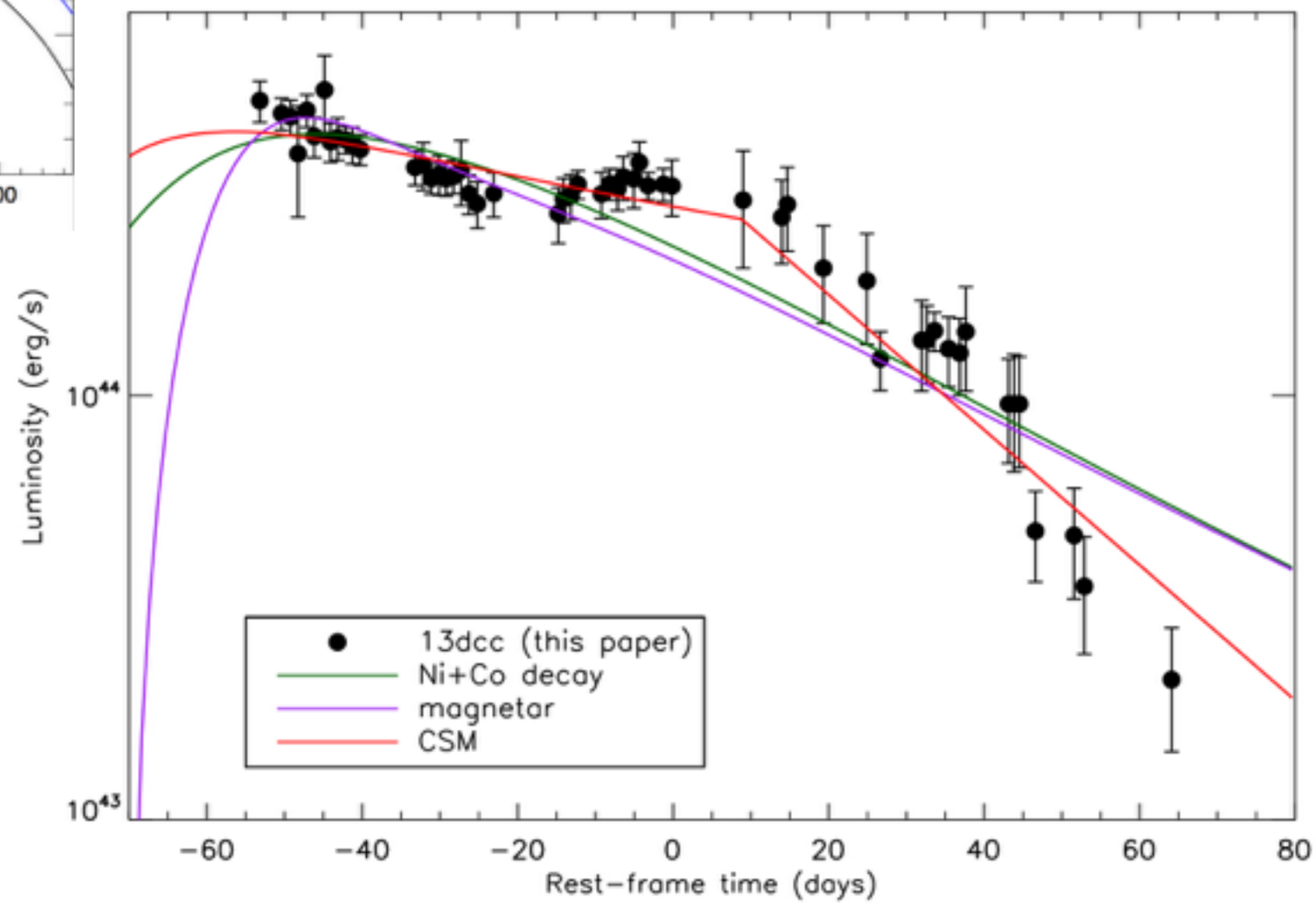
Nicholl et al. (2015)

See also Leloudas et al. 2012
Nicholl & Smartt 2016
Kasen et al. 2016

PTF13dcc

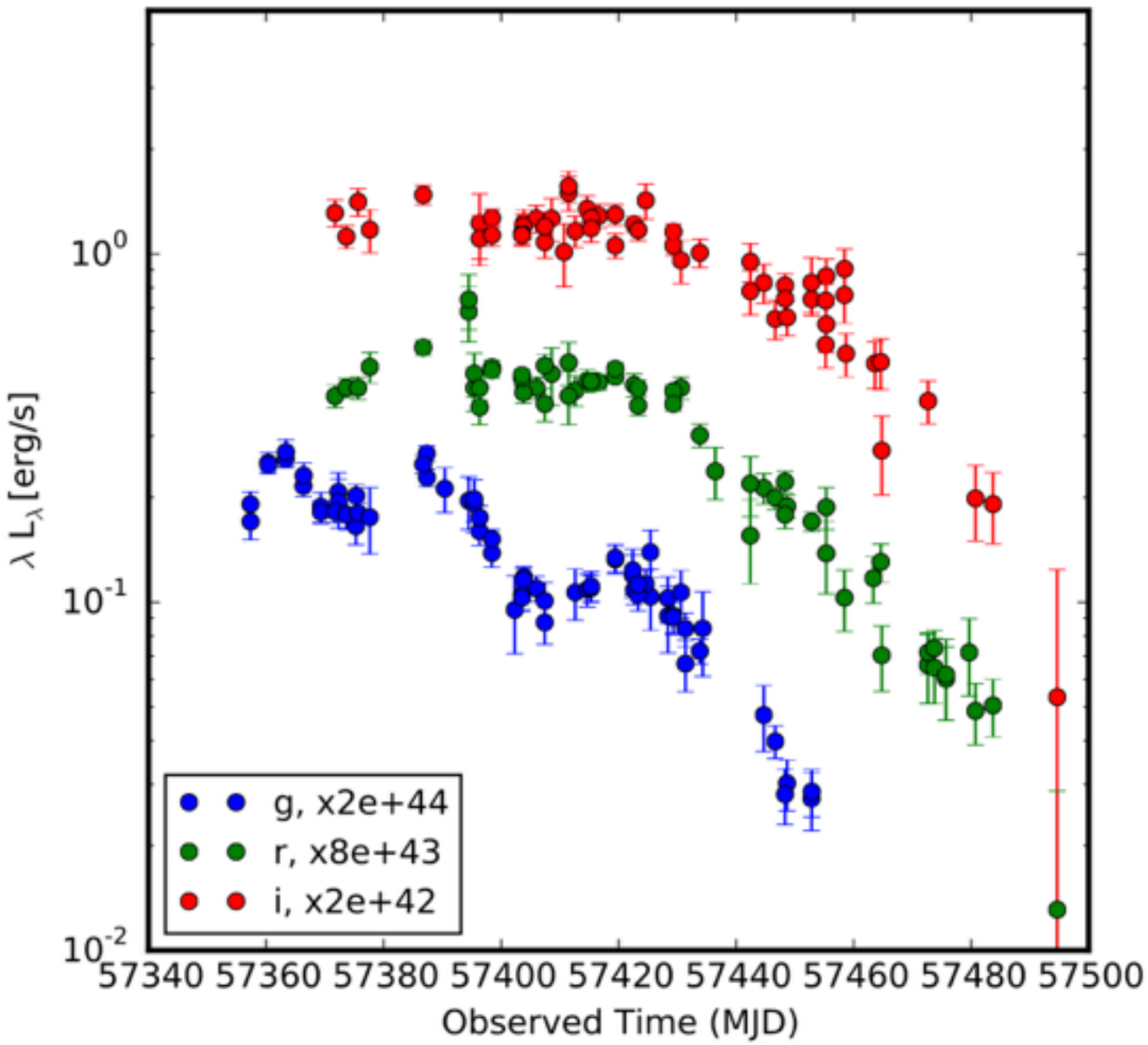


Vreeswijk et al. (in prep)

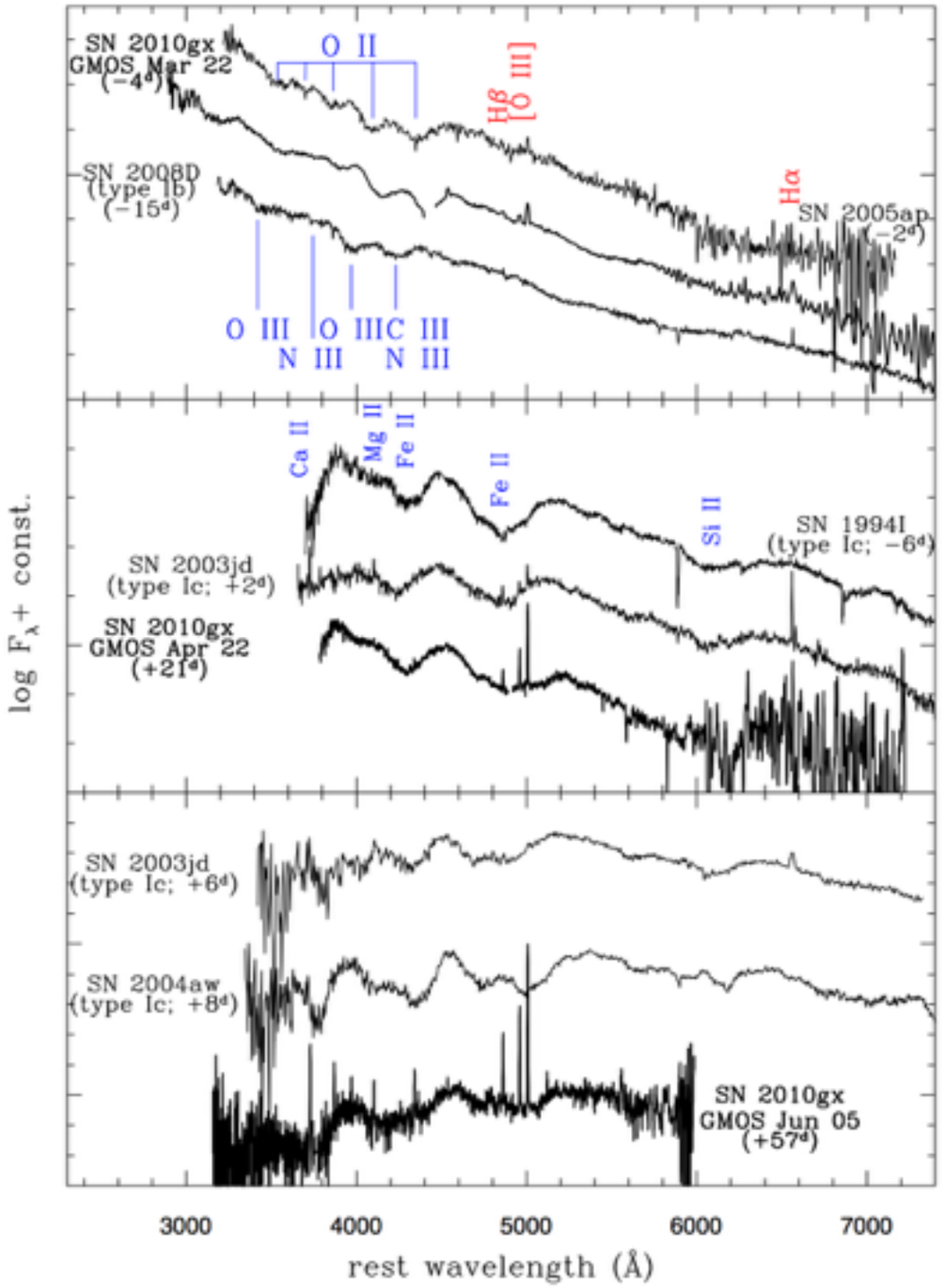


PTF15esb

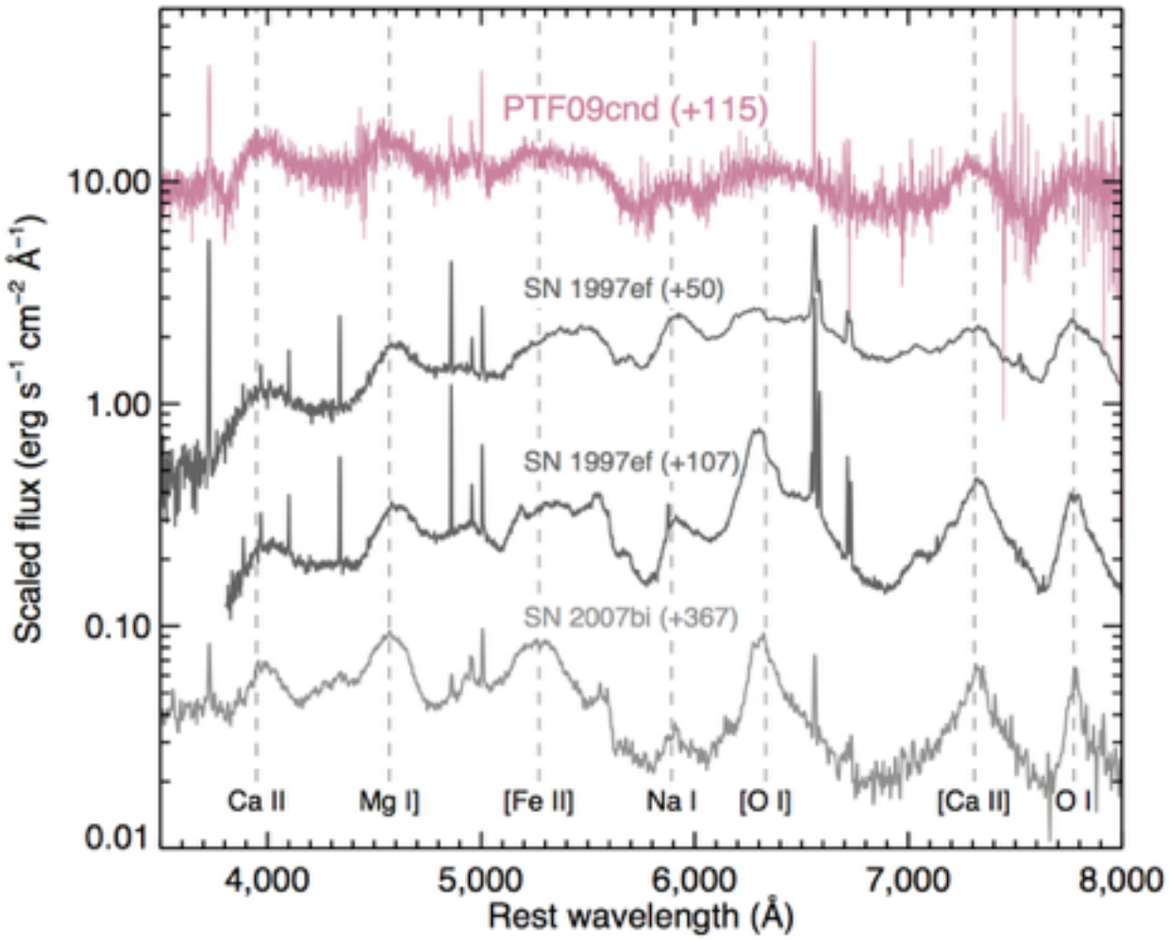
Yan et al. (in prep)



SLSN-I / SNIc "Connection"



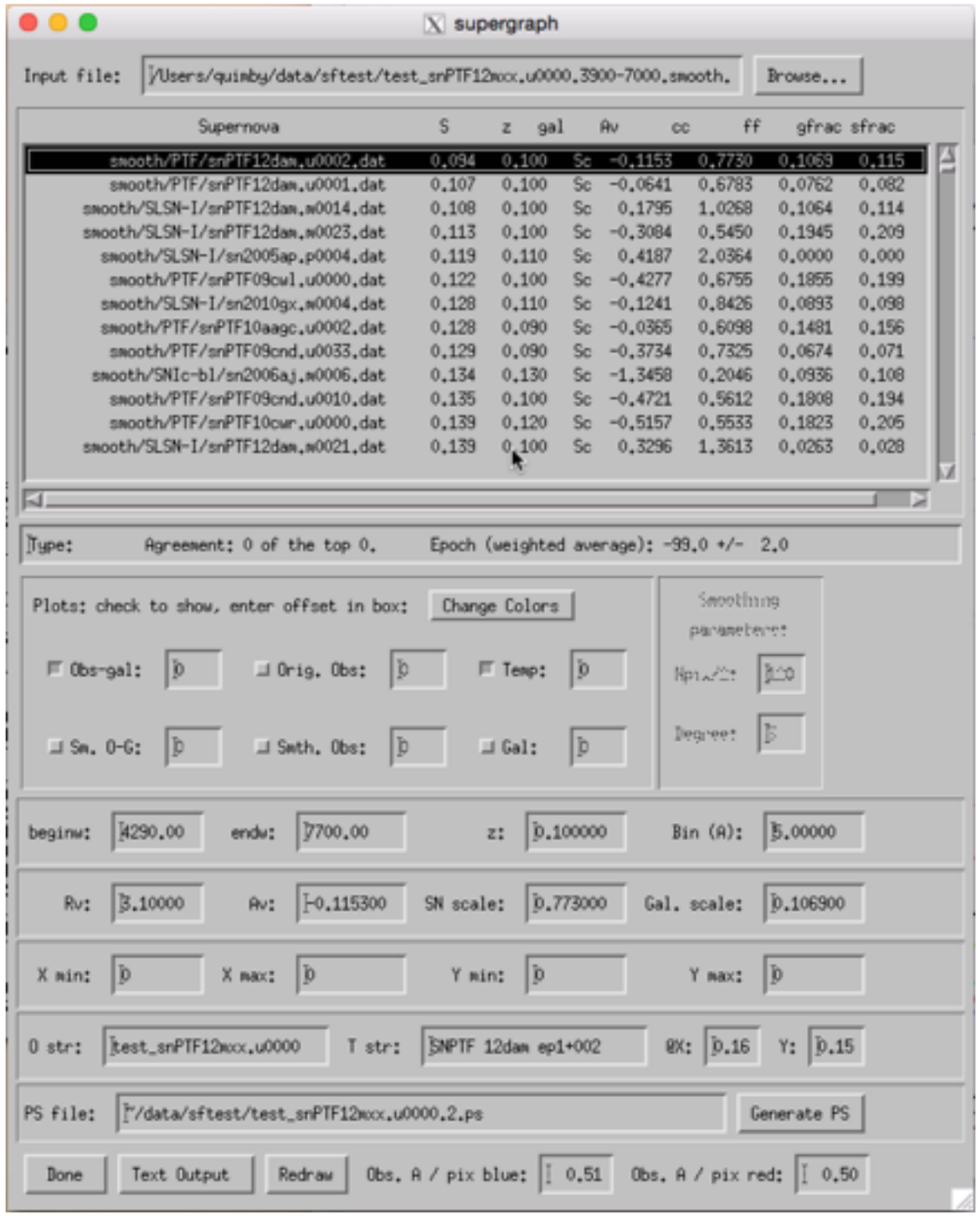
Pastorello et al. 2010

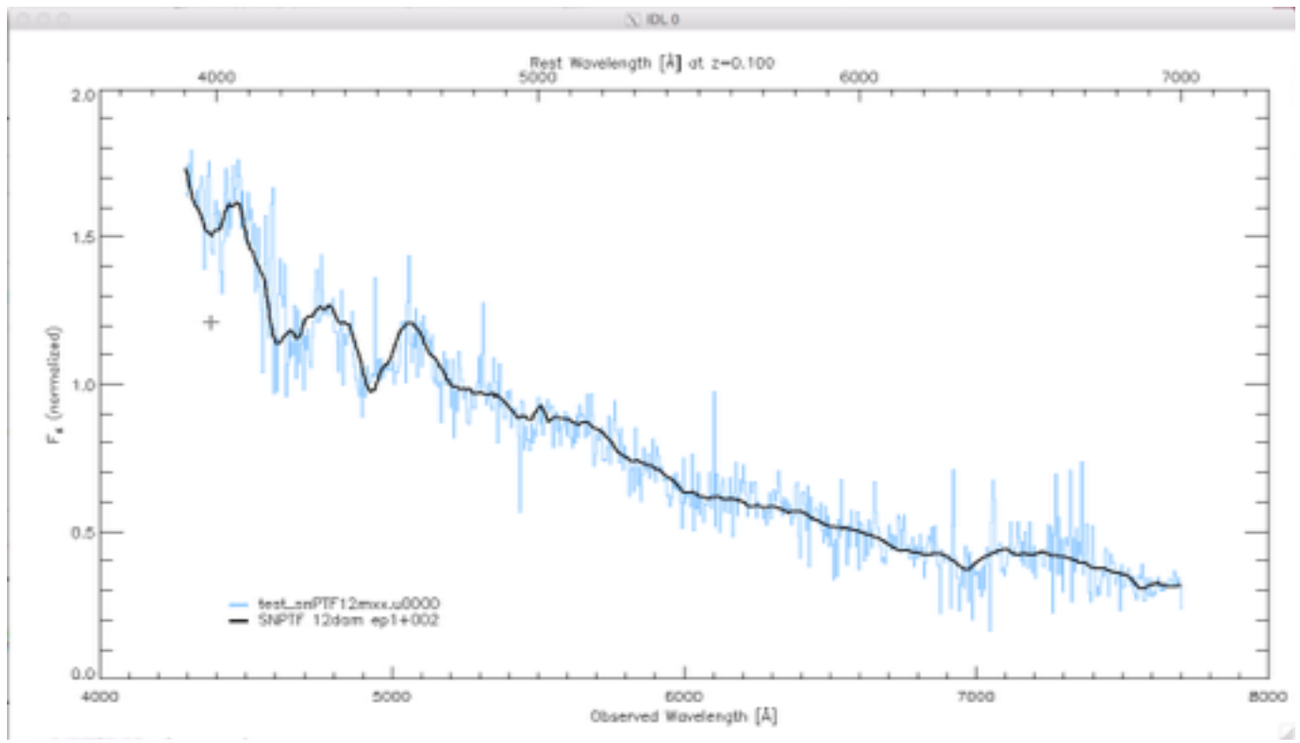


RQ et al. 2011

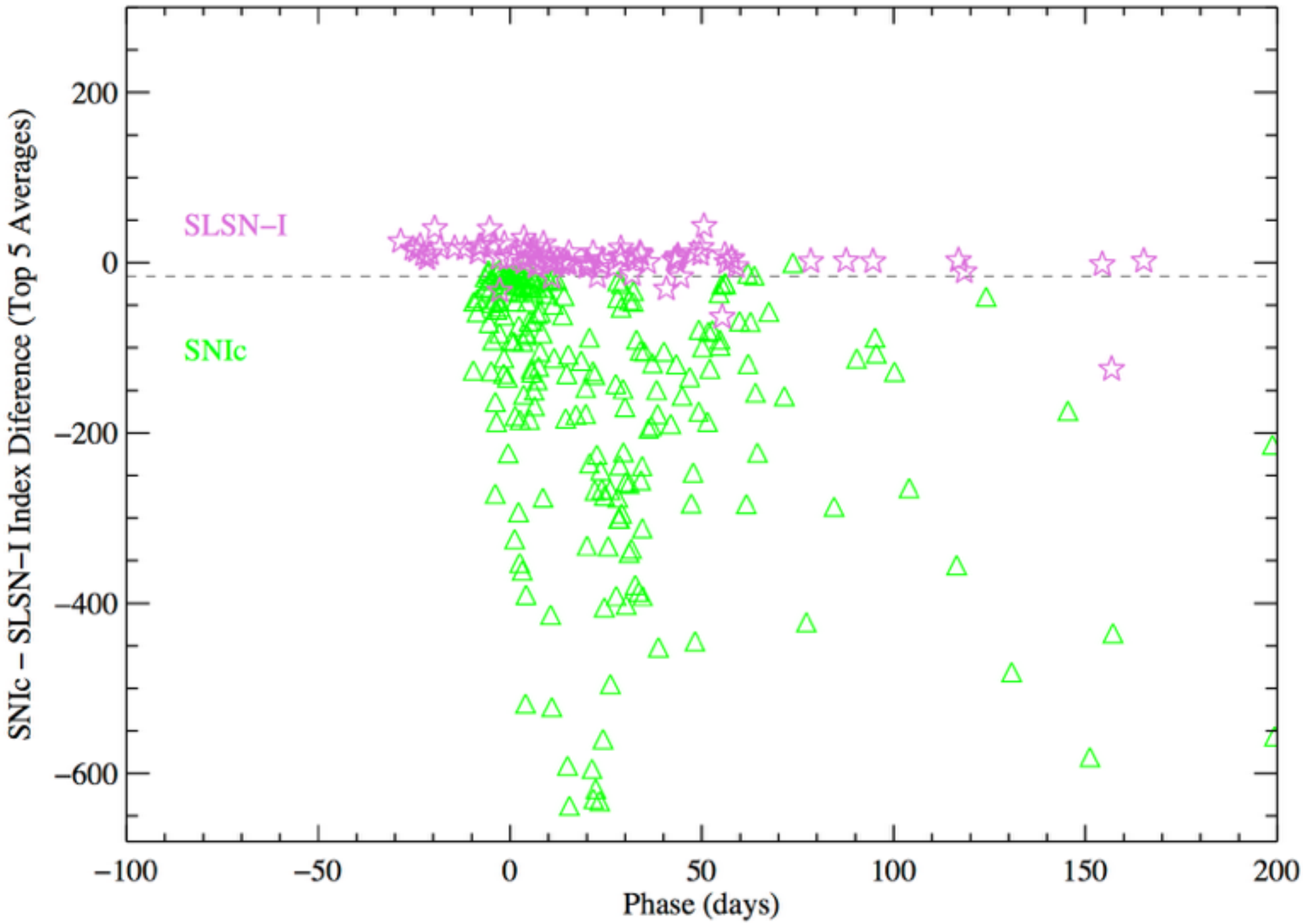
Superfit

Howell et al. 2006

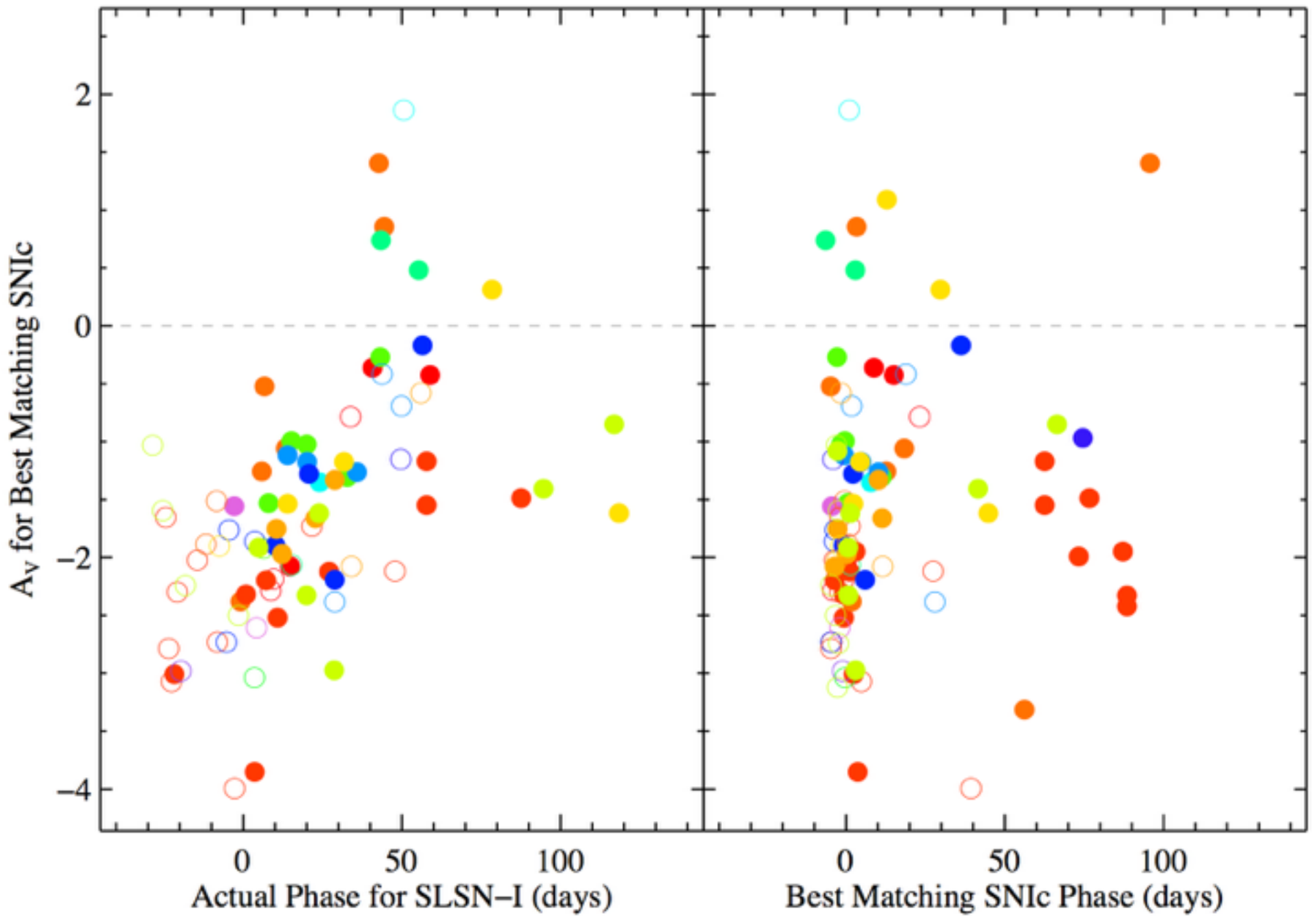




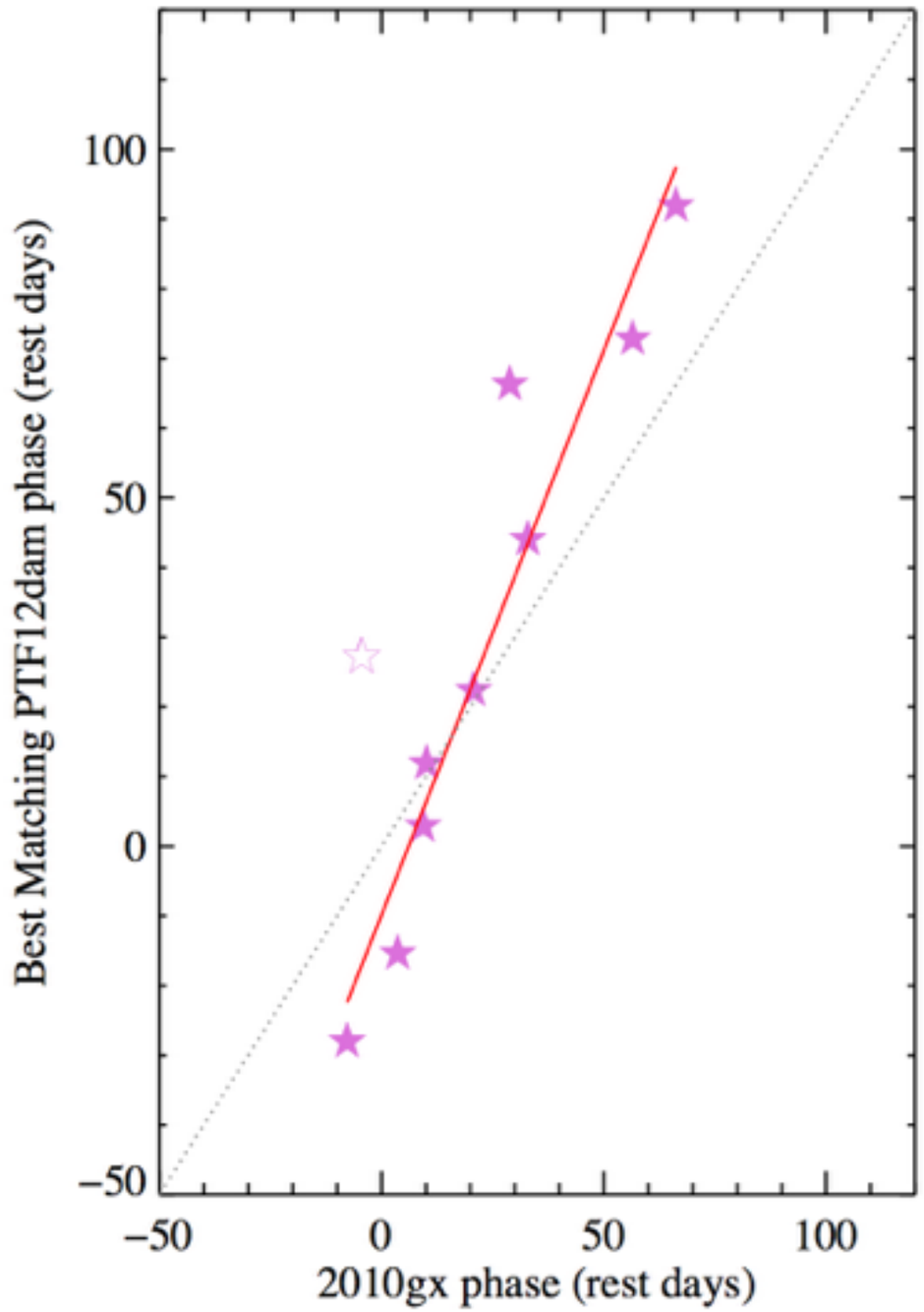
Are SLSN-I and SNIc Spectra The same?



SLSN-I are Bluer than SNIc

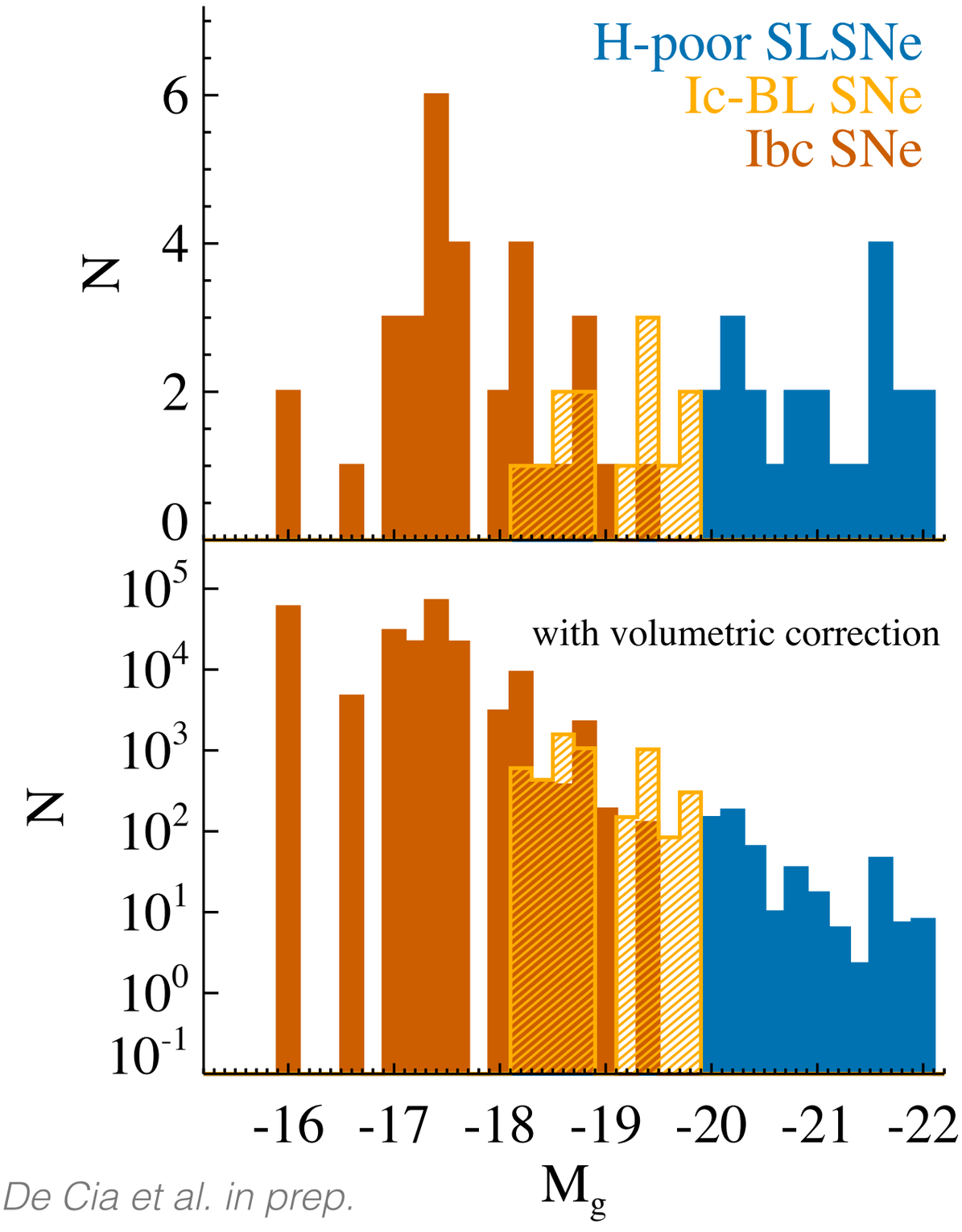


Some SLSN-I Evolve Faster (spectroscopically)

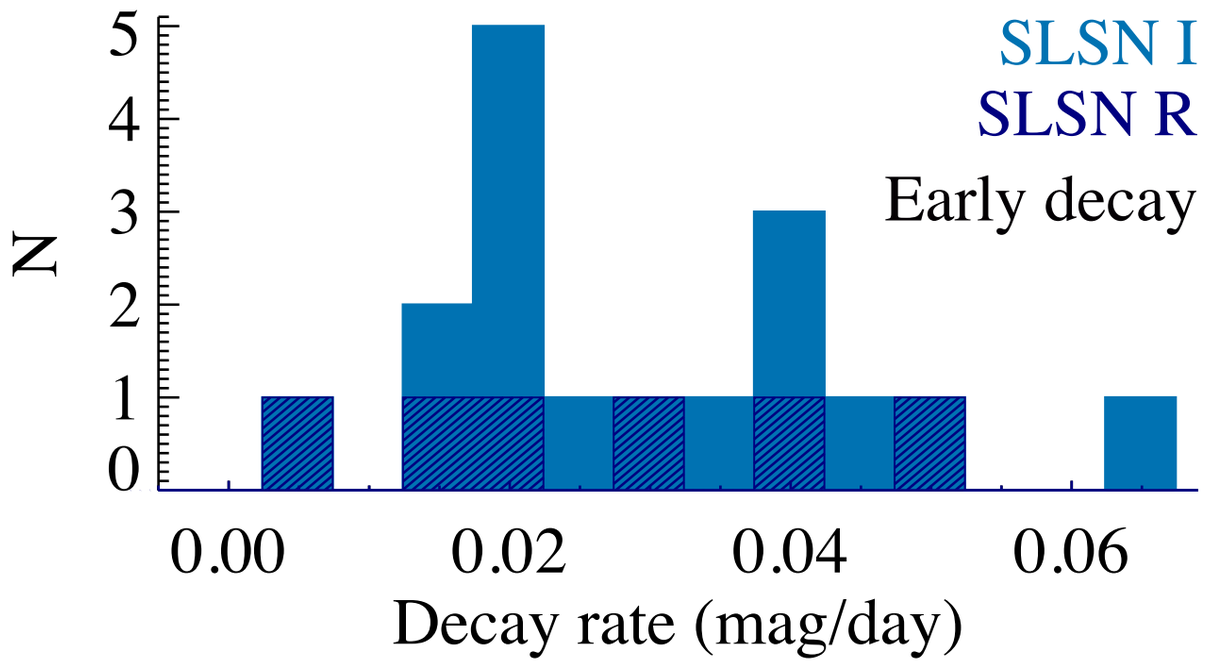


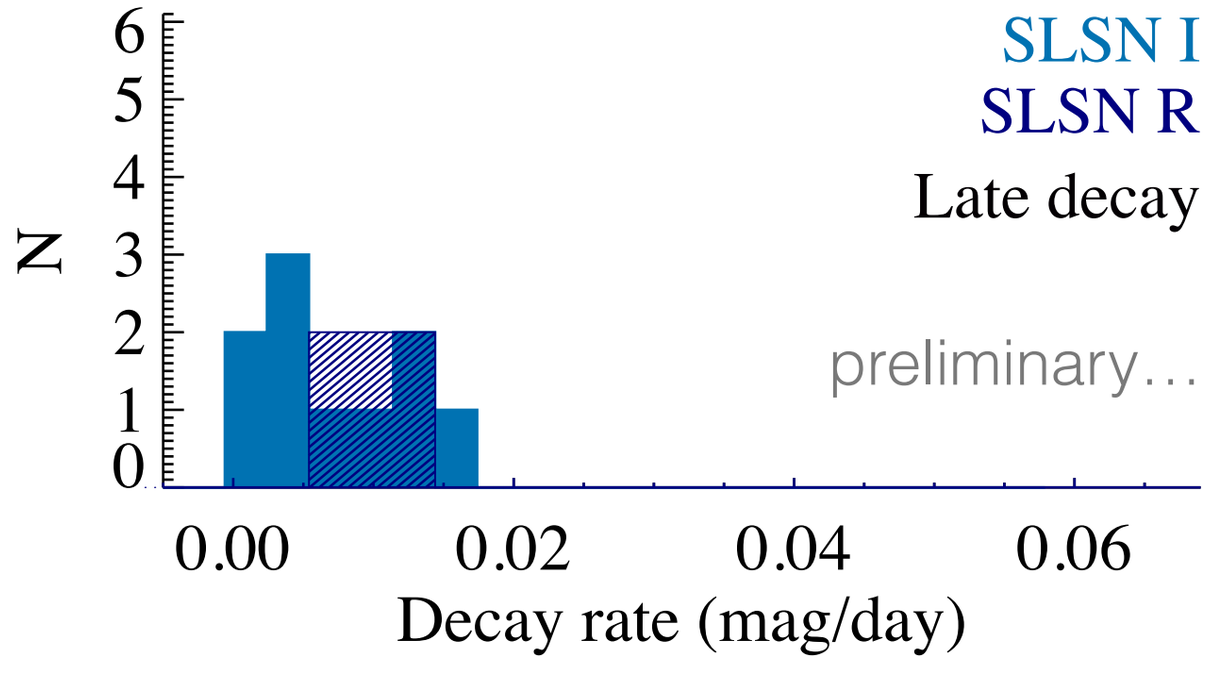
H-poor SLSNe and Ib/c SNe in PTF - light curve properties

PEAK MAG



DECAY RATE



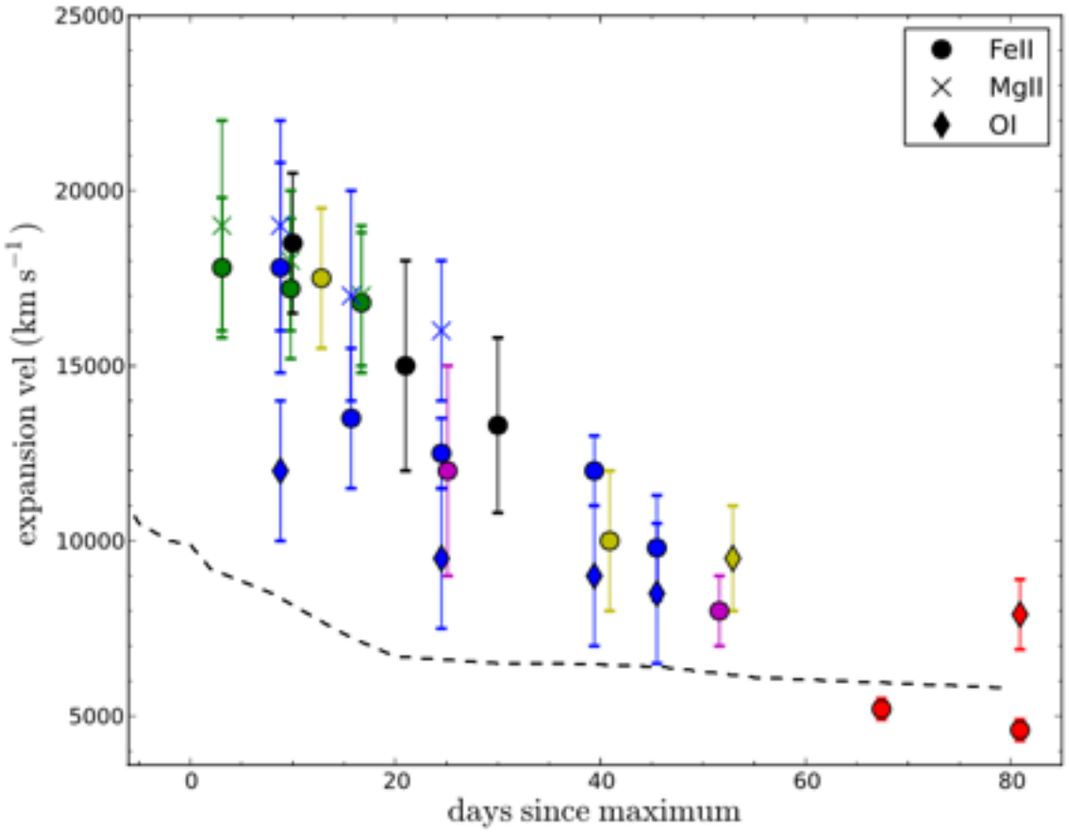


De Cia et al. in prep.

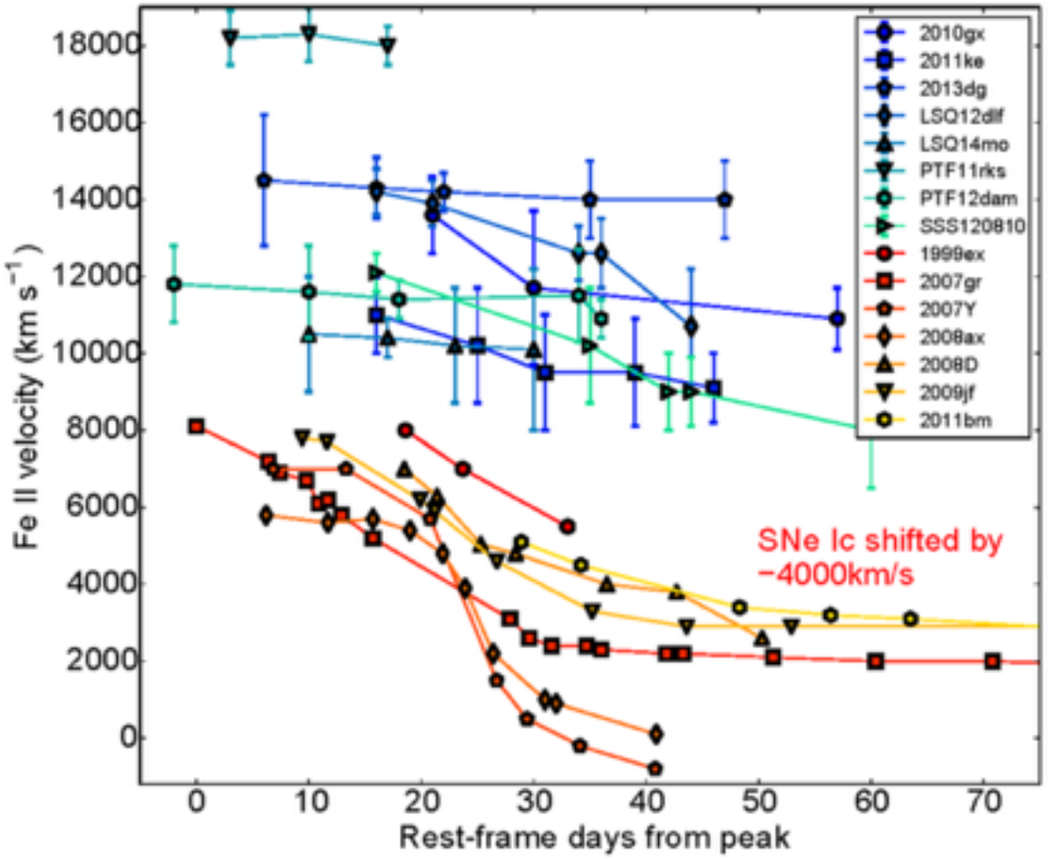
SLSN-I Spectroscopic Sequence

Line Velocities

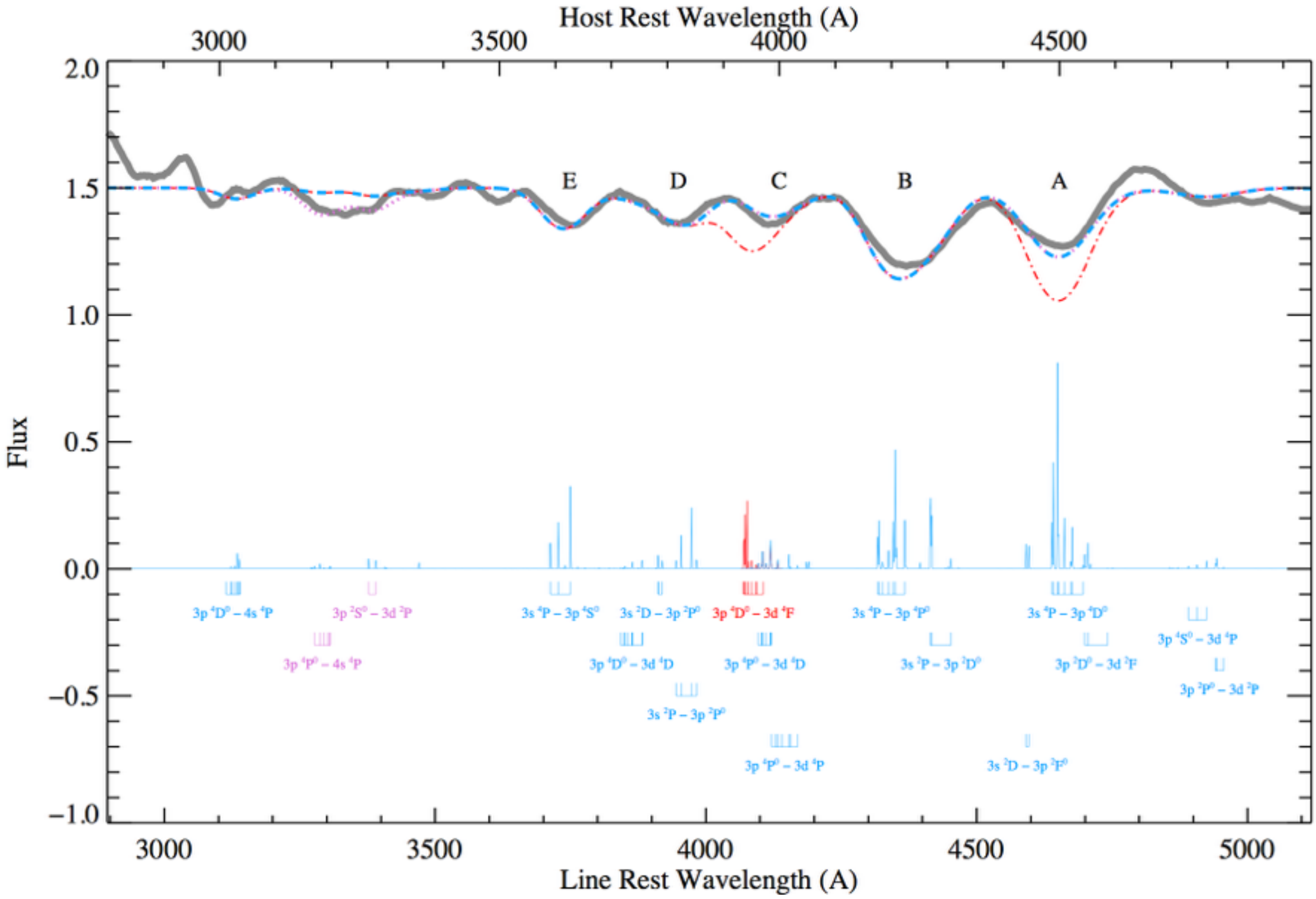
Inserra et al. 2013



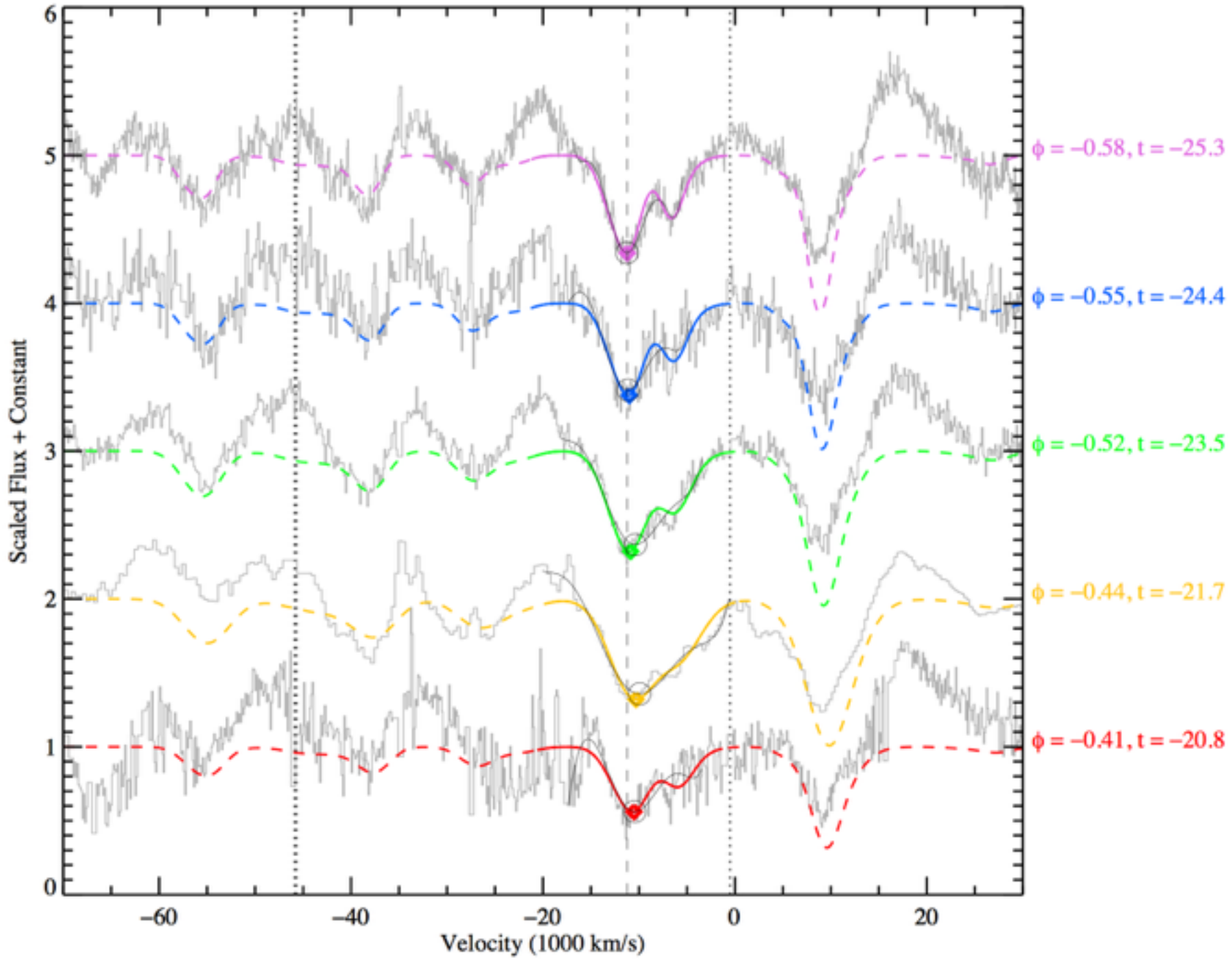
Nicholl et al. 2015



Oxygen Lines (OII)



PTF12dam (O II)



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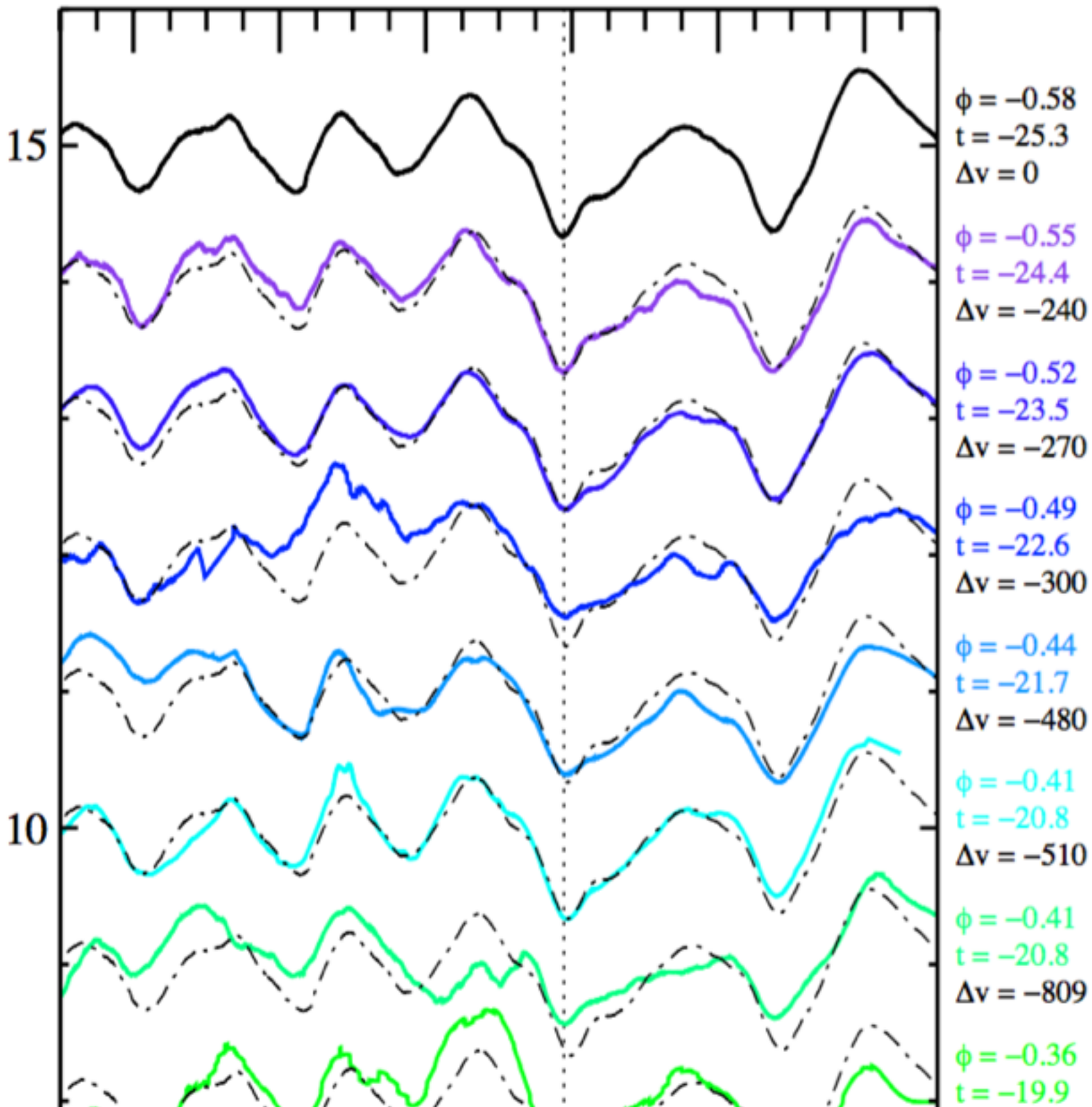
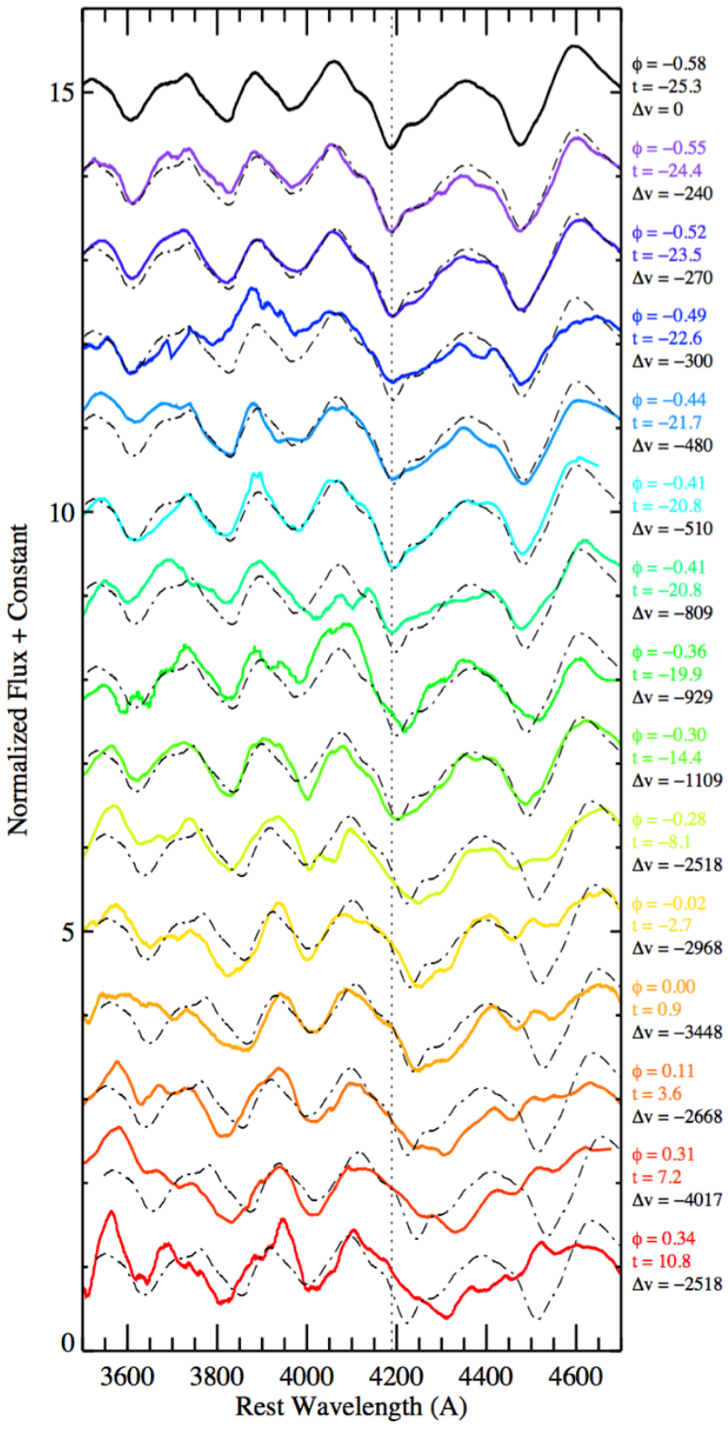
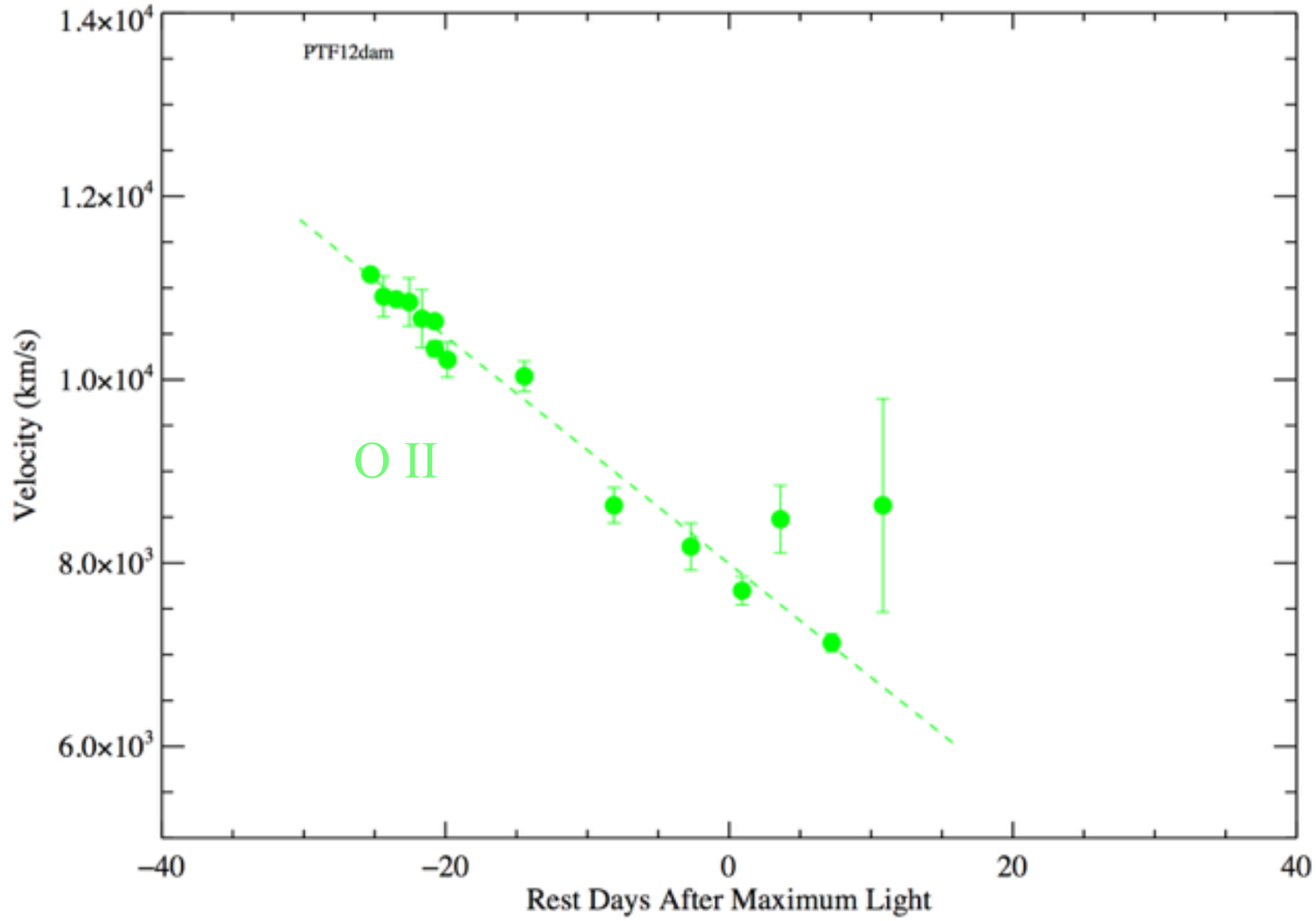
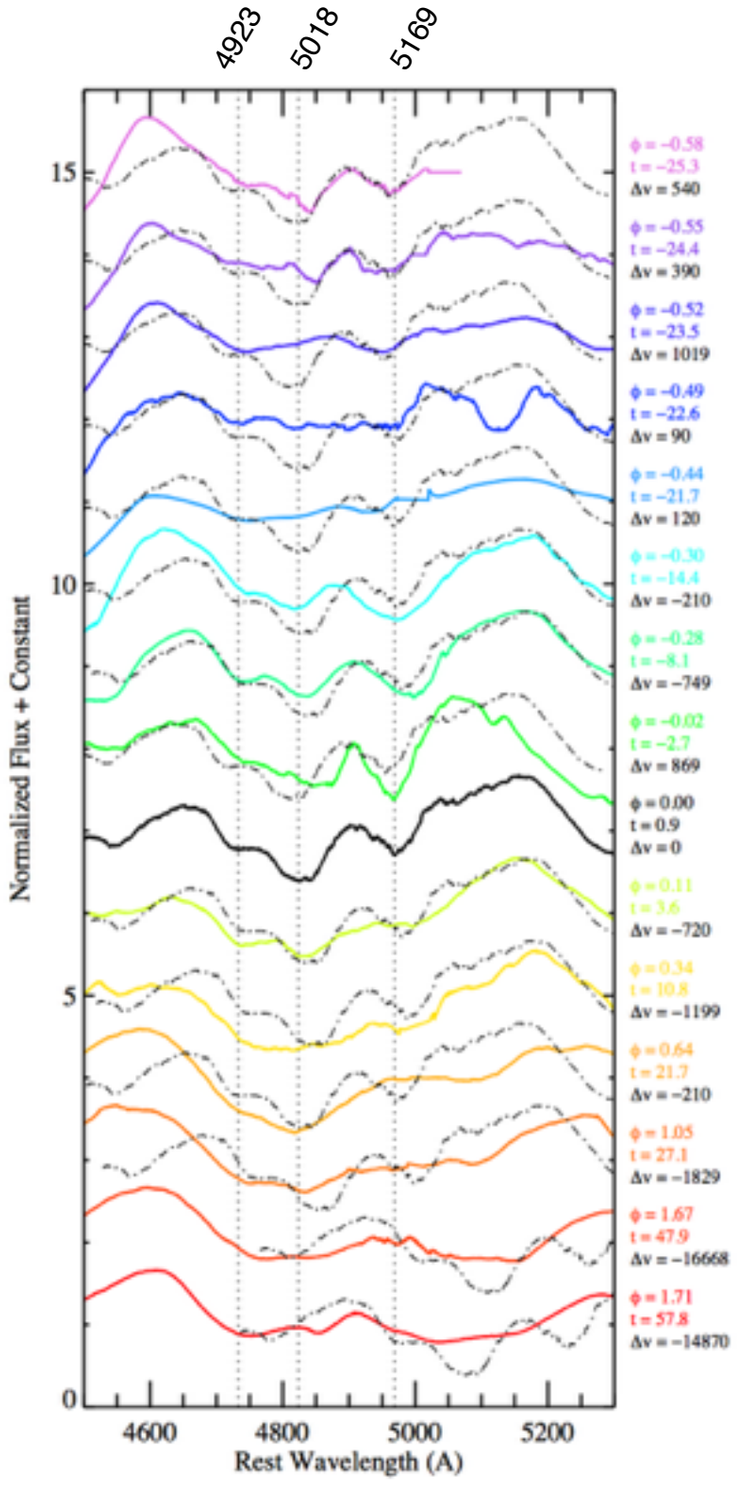


PTF12dam (O II)

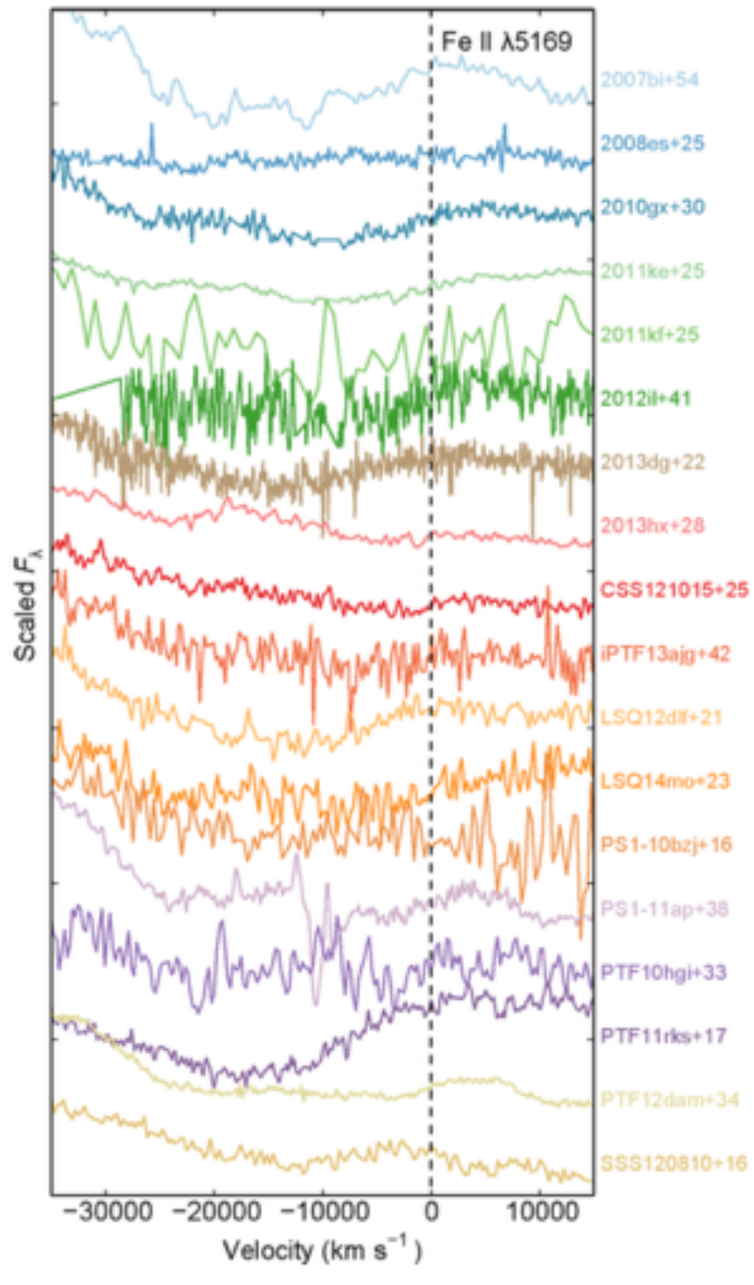




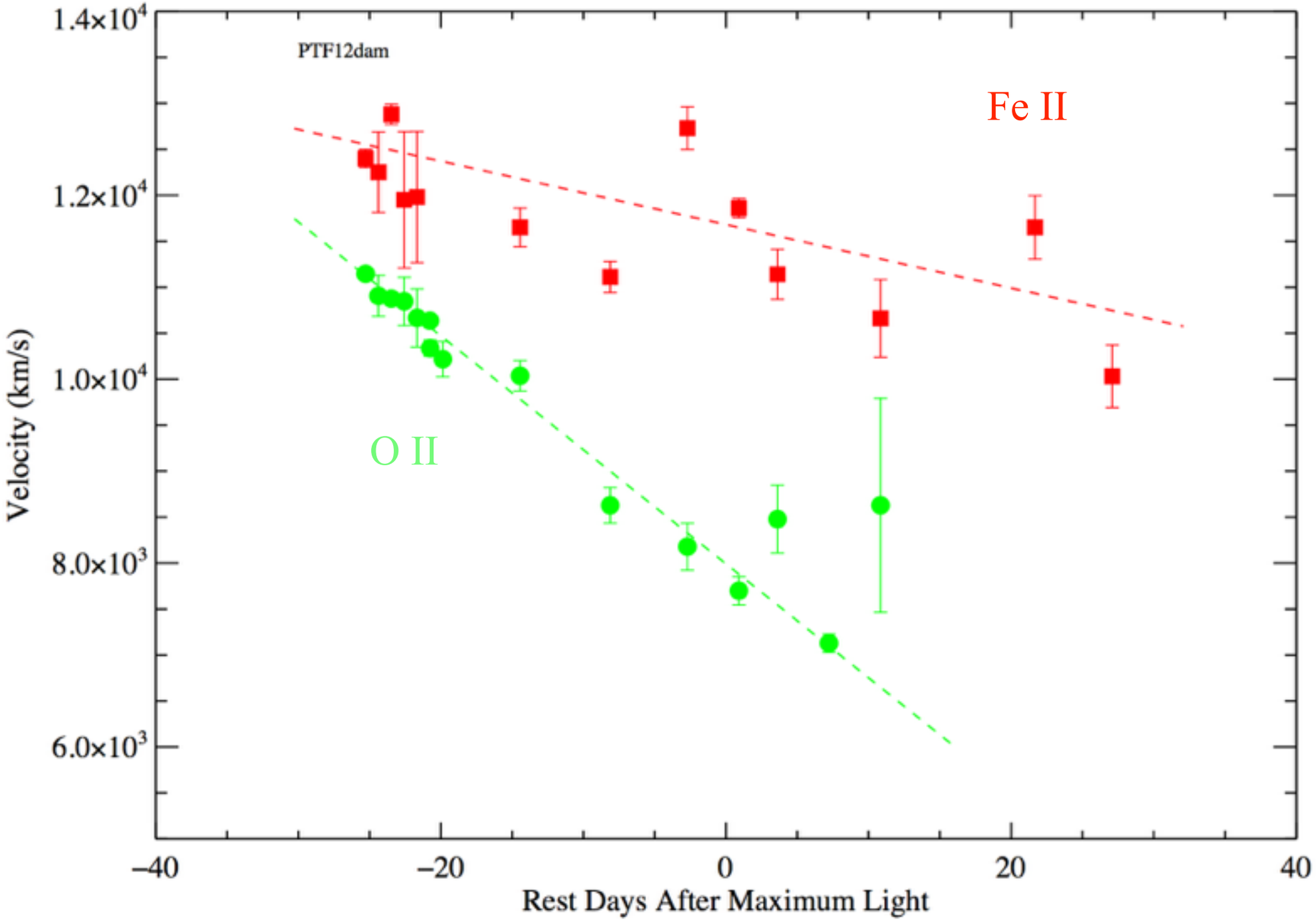
Fe II is Tough



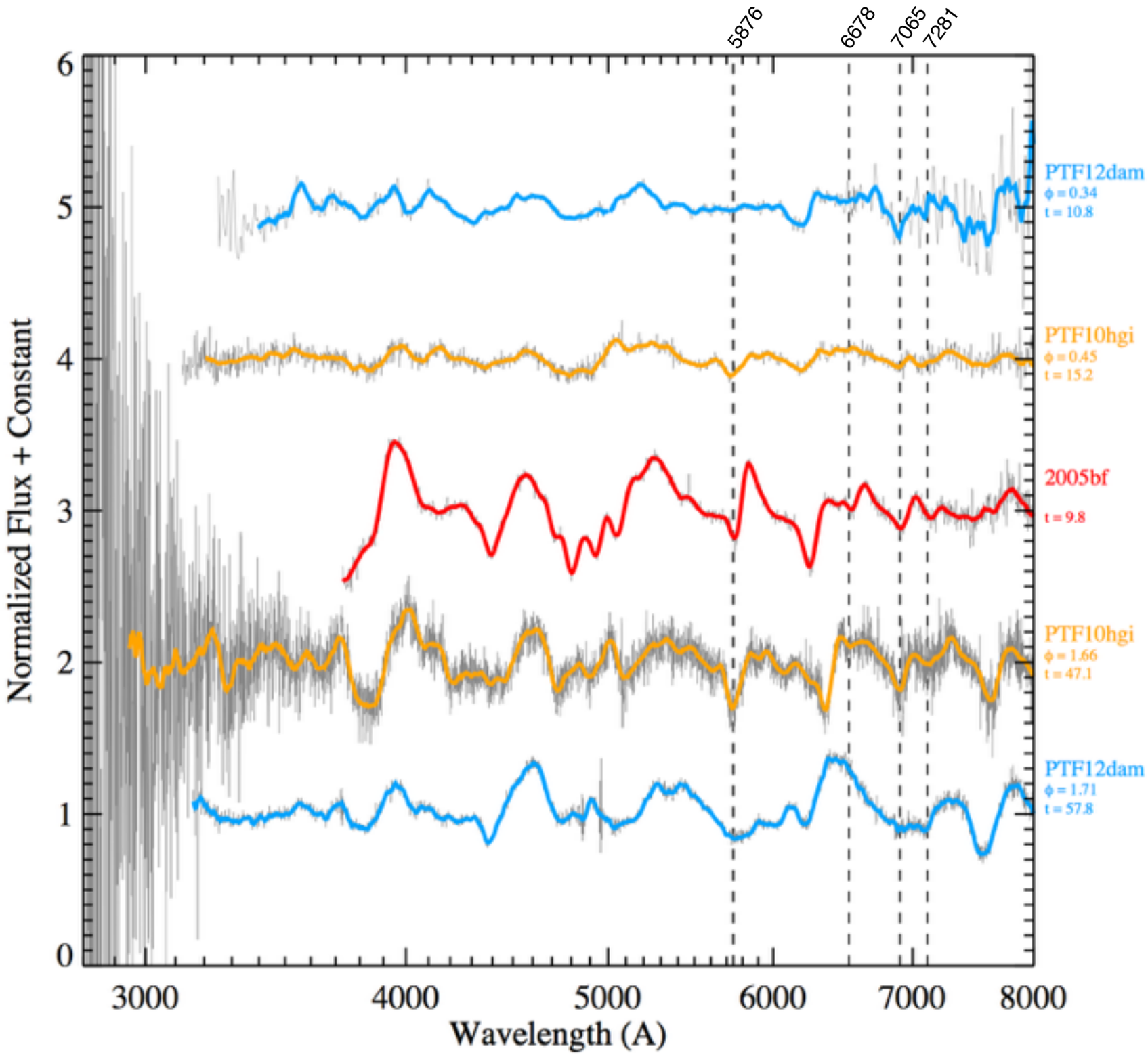
Nicholl et al. 2015



PTF12dam Line Velocities

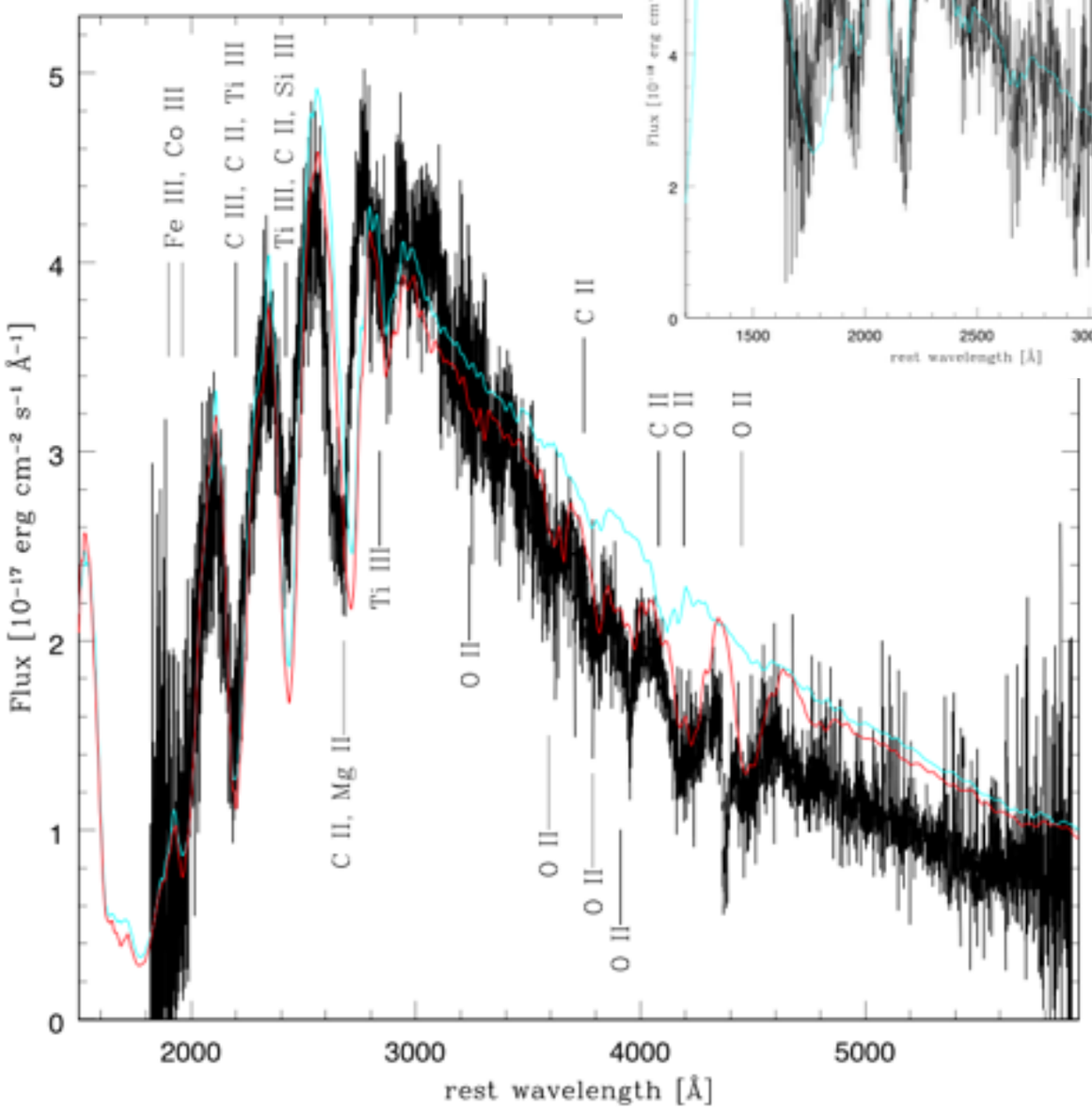


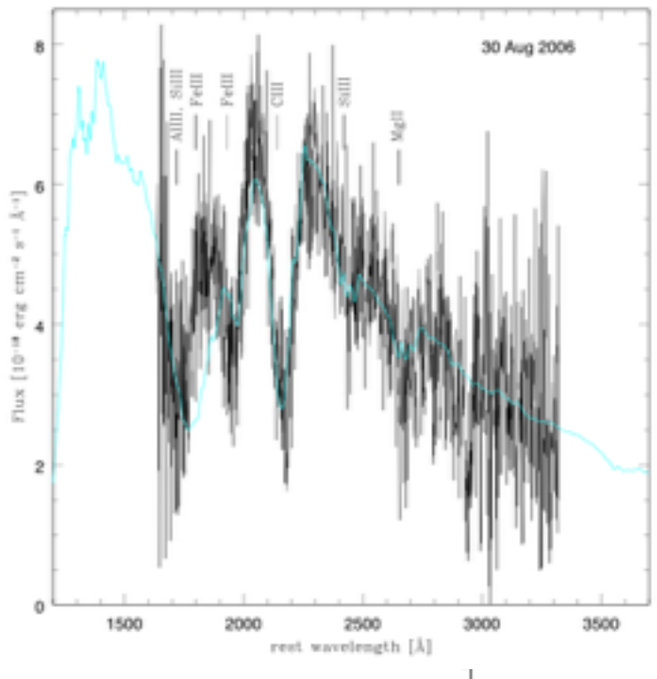
Helium?

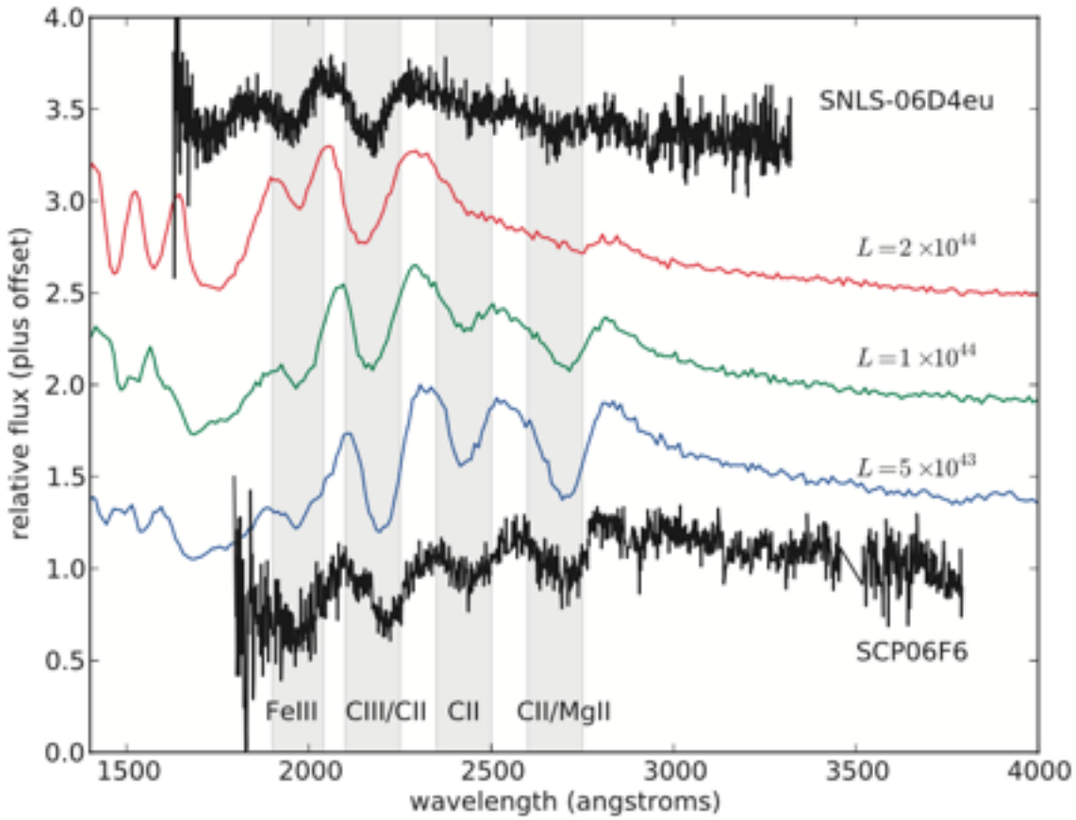

5876
6678
7065
7281
PTF12dam
ϕ = 0.34
t = 10.8
PTF10hgi
ϕ = 0.45
t = 15.2
2005bf
t = 9.8
PTF10hgi
ϕ = 1.66
t = 47.1
PTF12dam
ϕ = 1.71
t = 57.8
Normalized Flux + Constant
Wavelength (A)
0
1
2
3
4
5
6
3000
4000
5000
6000
7000
8000

Line Identifications

Mazzali et al. 2016

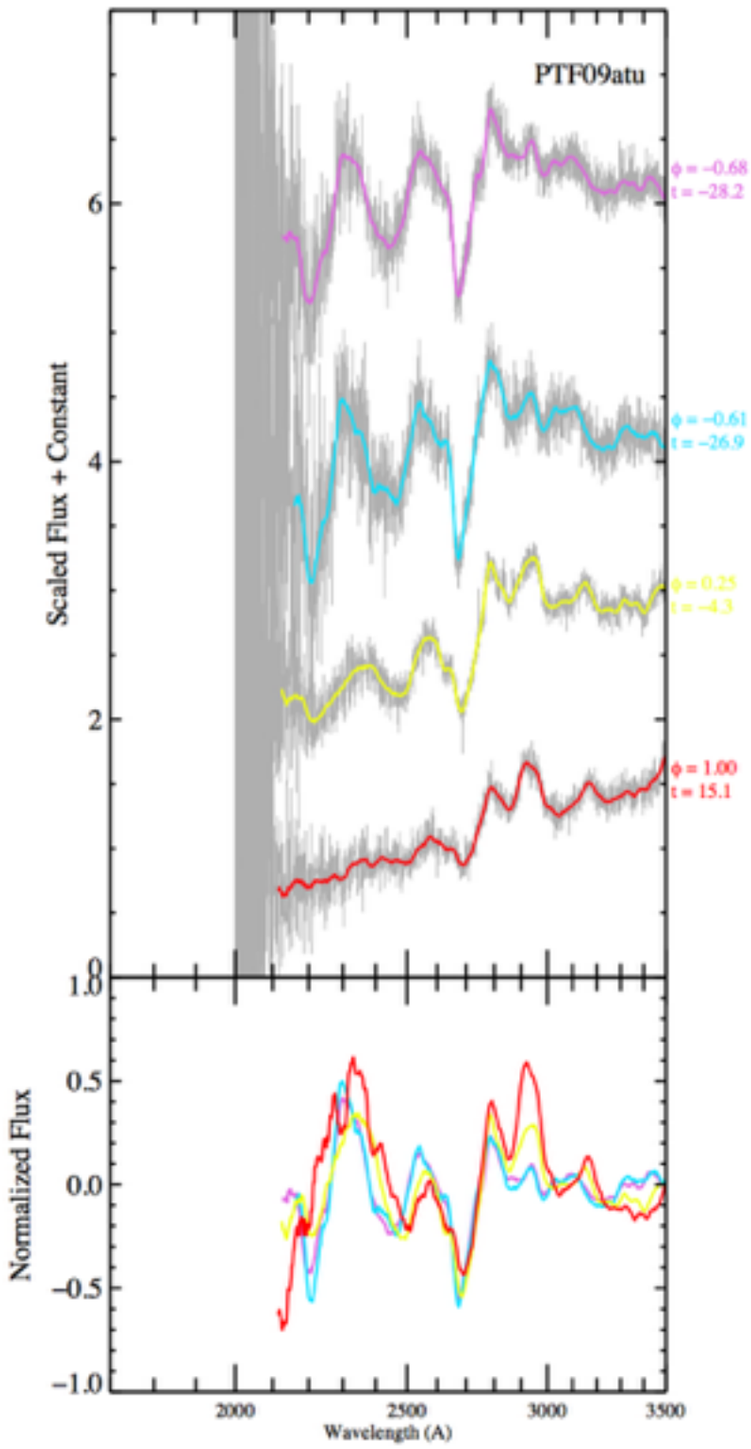


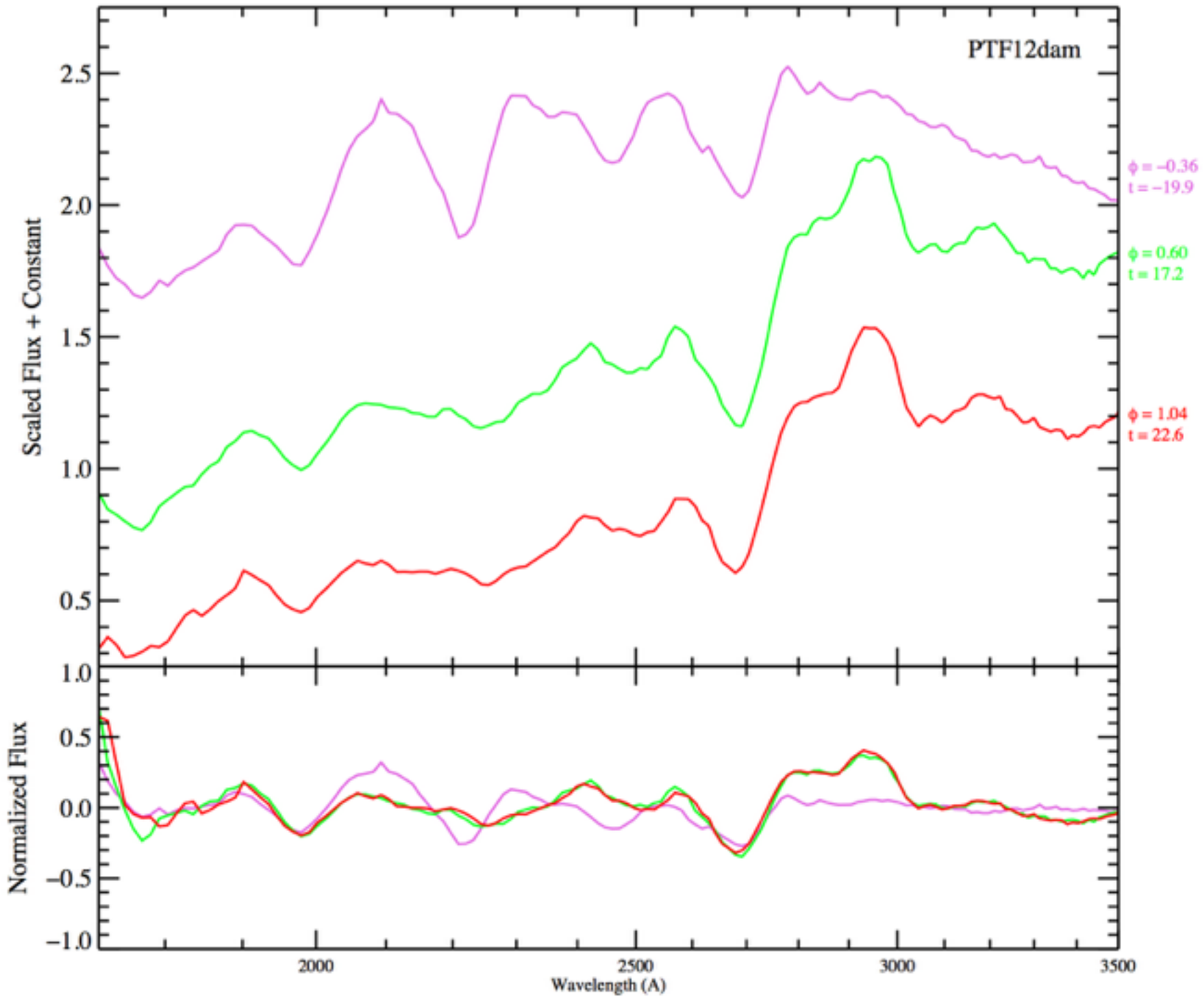




Howell et al. 2013

UV Features


PTF09atu
Scaled Flux + Constant
Normalized Flux
Wavelength (A)
ϕ = −0.68
t = −28.2
ϕ = −0.61
t = −26.9
ϕ = 0.25
t = −4.3
ϕ = 1.00
t = 15.1


PTF12dam
Scaled Flux + Constant
Normalized Flux
Wavelength (A)
ϕ = −0.36
t = −19.9
ϕ = 0.60
t = 17.2
ϕ = 1.04
t = 22.6

Synow Identifications