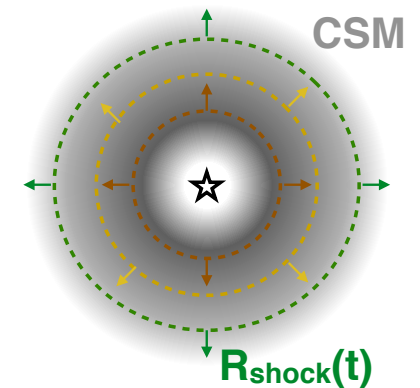
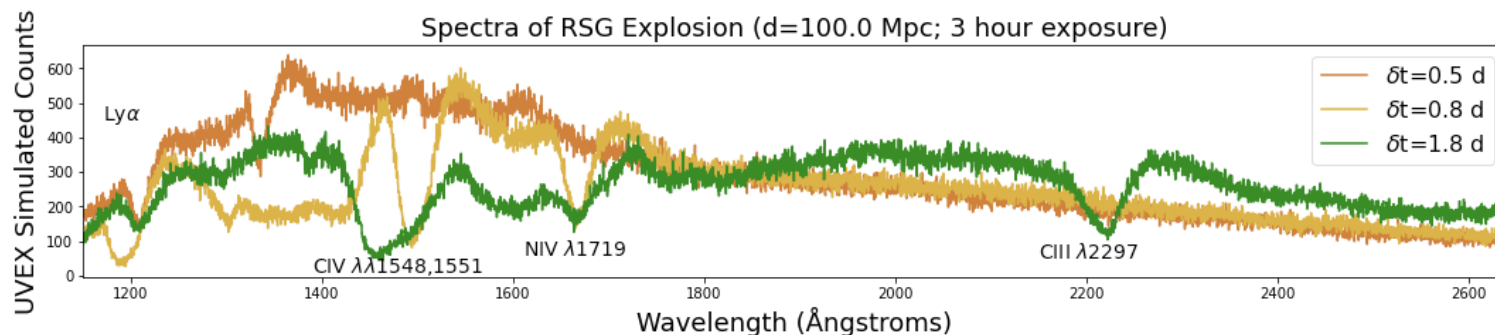


What can UVEX do for transient spectroscopy?

Ryan Chornock (UC Berkeley)



Why is UV spectroscopy so exciting?

Many more strong lines in the FUV!

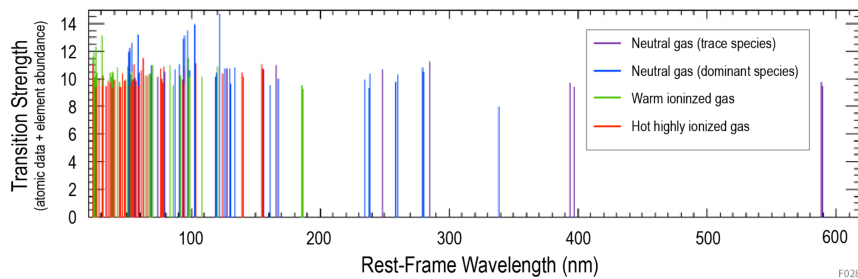
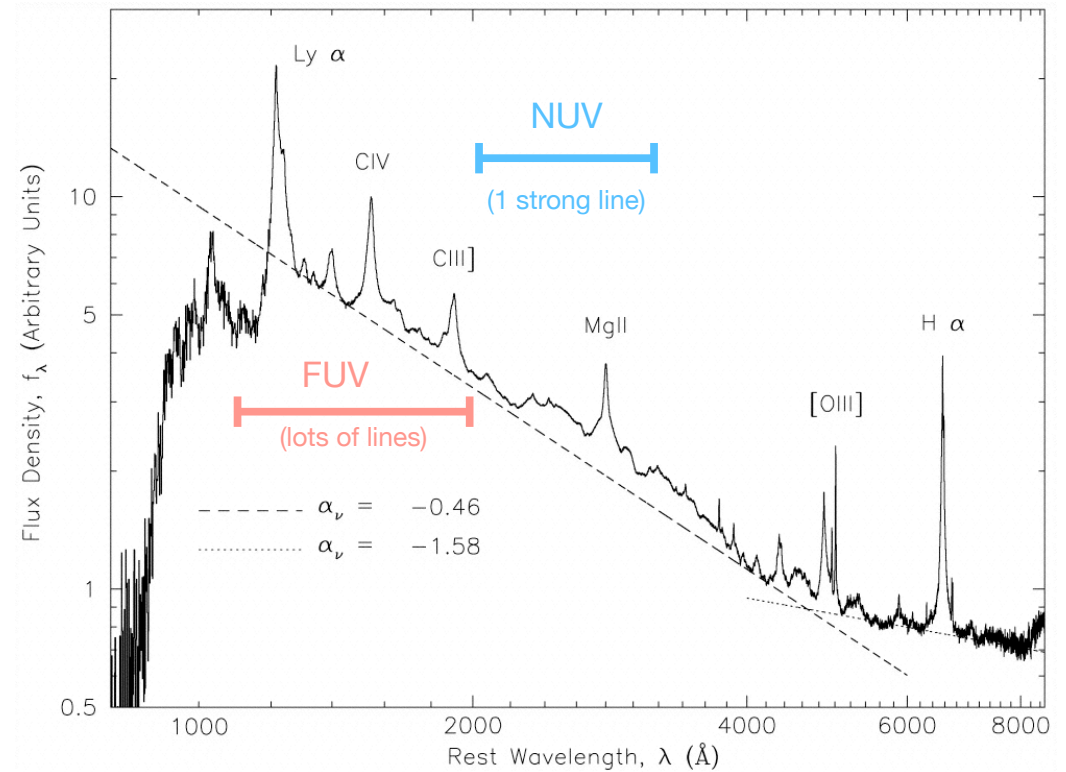


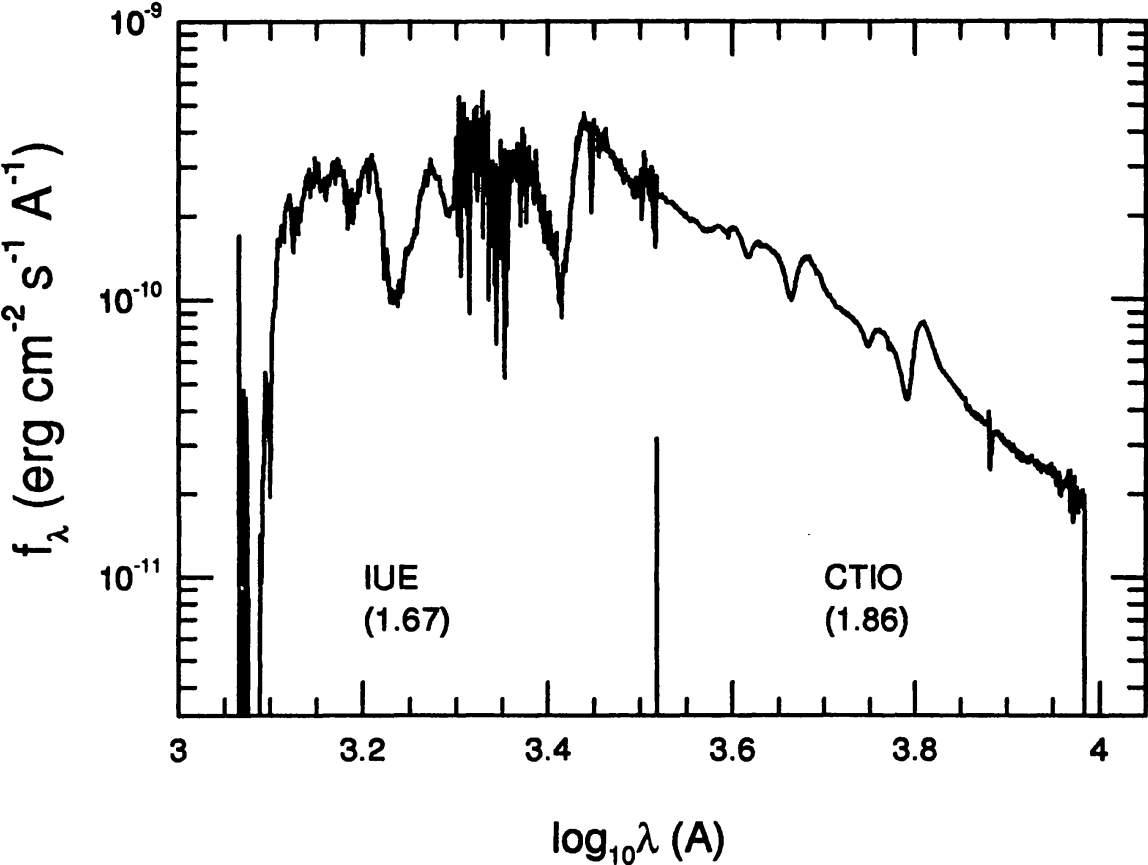
Figure 1. The strength (the product of the oscillator strength and the relative cosmic abundance) of resonance lines of elements (atoms, ions) as a function of rest wavelength. From Tripp (2019).

- Atomic physics dictates that many strong lines from ions are in the FUV
- Early-time SNe (and other transients) are hot! $T > 10^4$ K



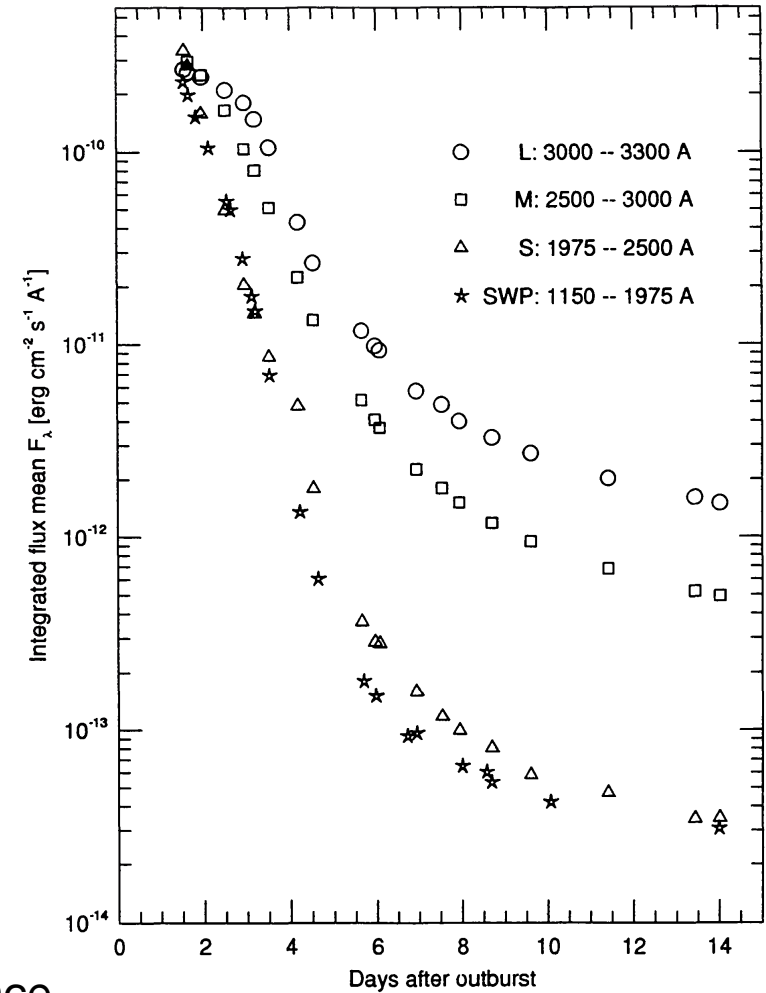
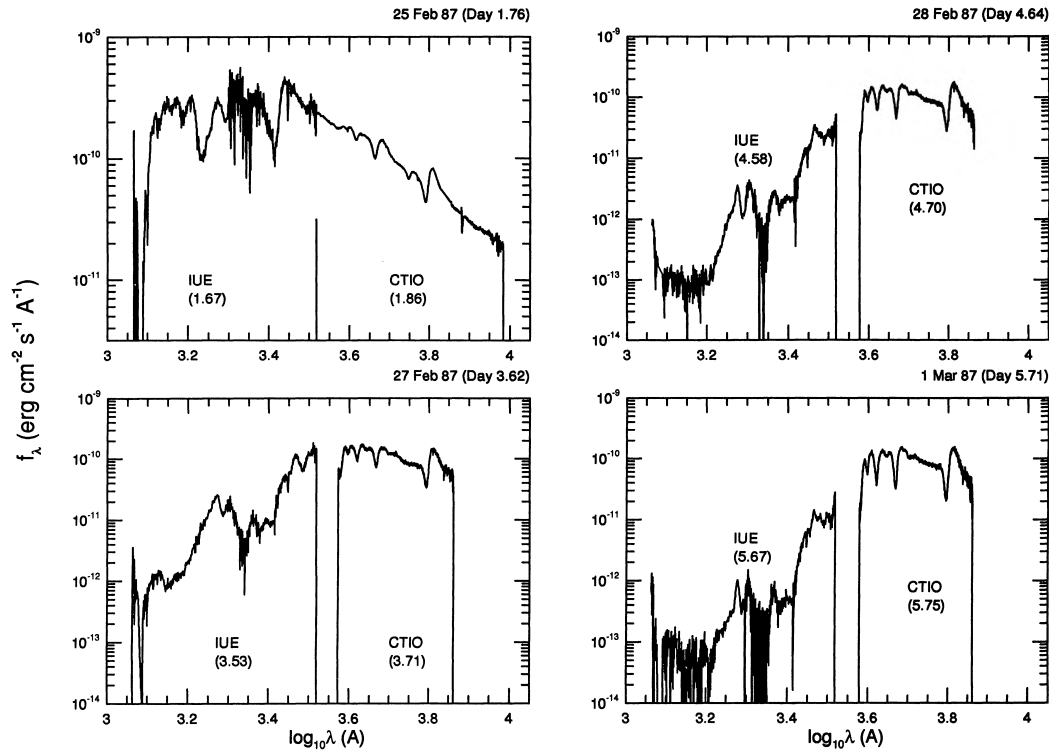
SN 1987A: The Earliest UV Supernova Spectrum

25 Feb 87 (Day 1.76)



Pun et al. 1995

SN 1987A

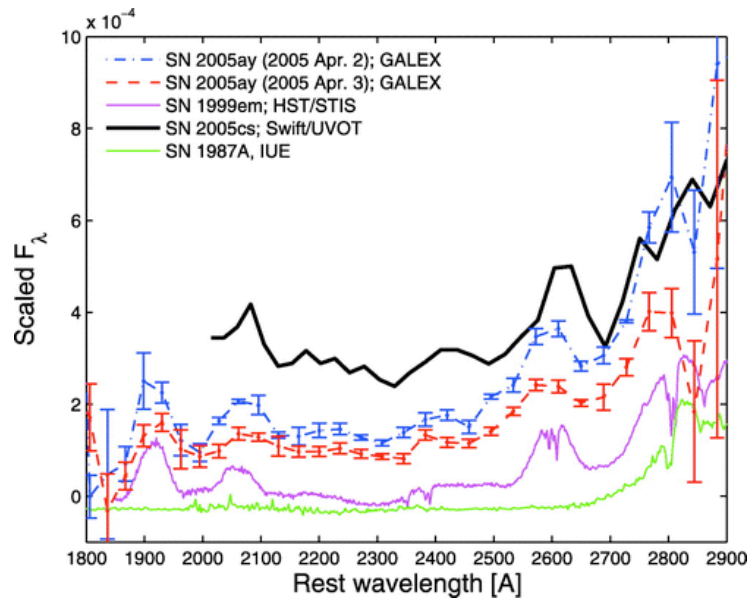


- The only SN with dense sampling of the UV spectral sequence
- Note how fast the UV (from *IUE*) fades relative to the optical

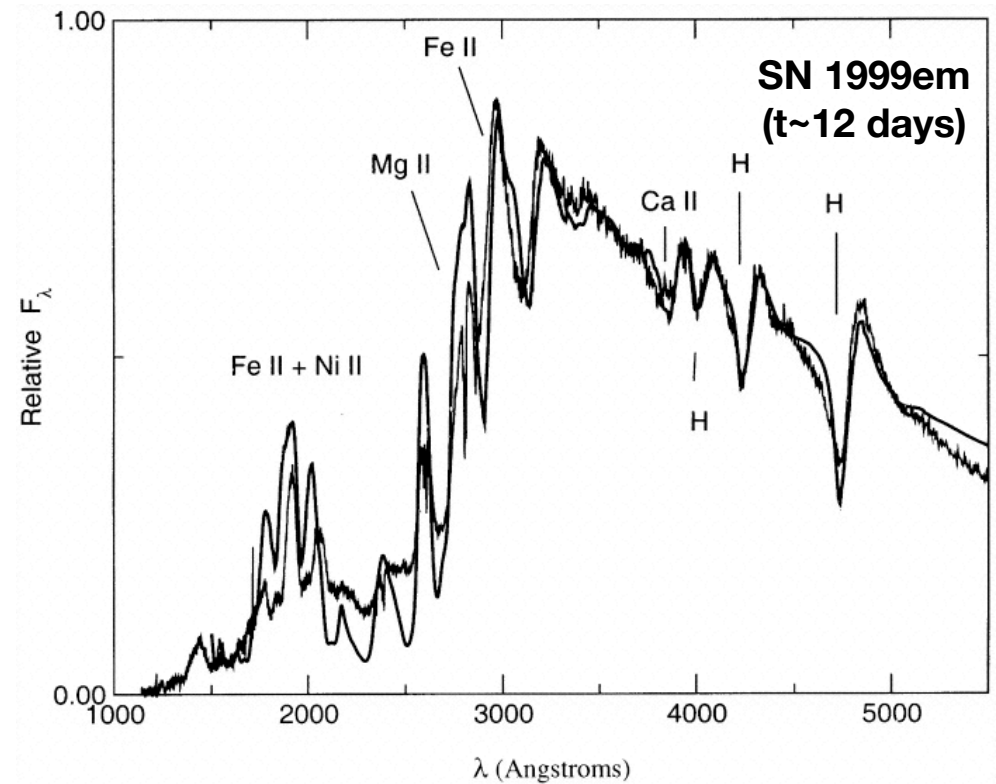
Pun et al. 1995

SNe IIP

- Explosions of Red Supergiants
- “Plainest” explosions possible
- Most UV spectra have been taken after the photosphere has cooled and line blanketing takes over



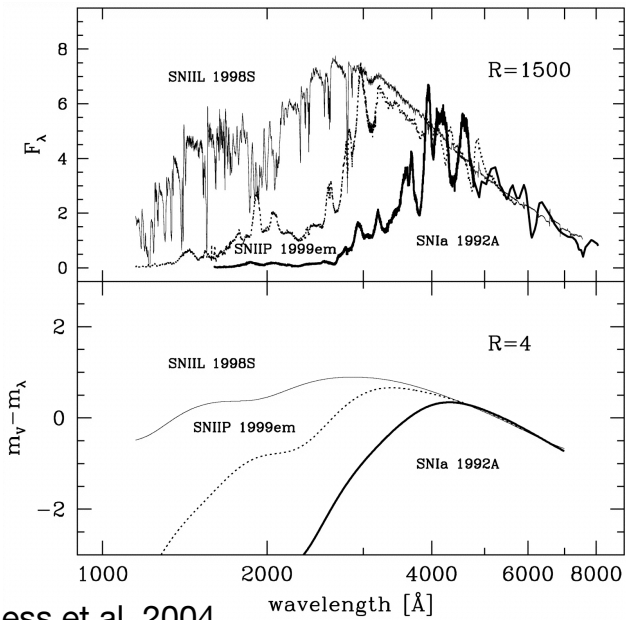
Gal-Yam et al. 2008



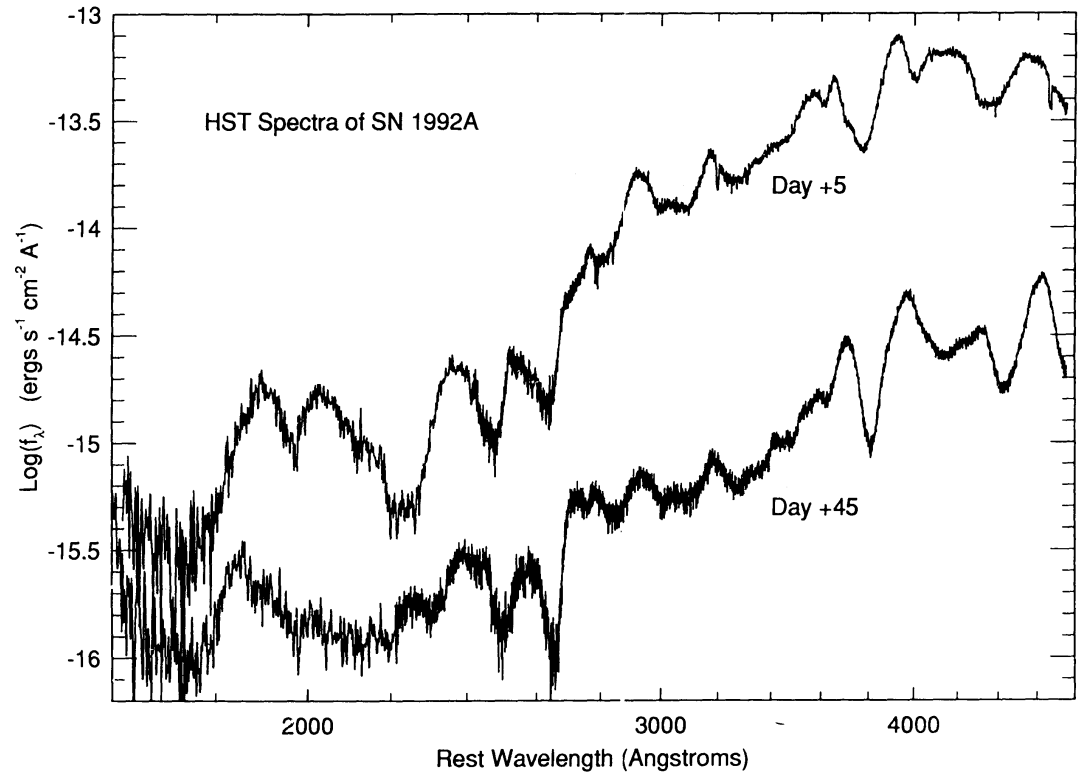
Baron et al. 2000

SNe Ia

- Copious line-blanketing from Fe-group elements suppresses the UV flux

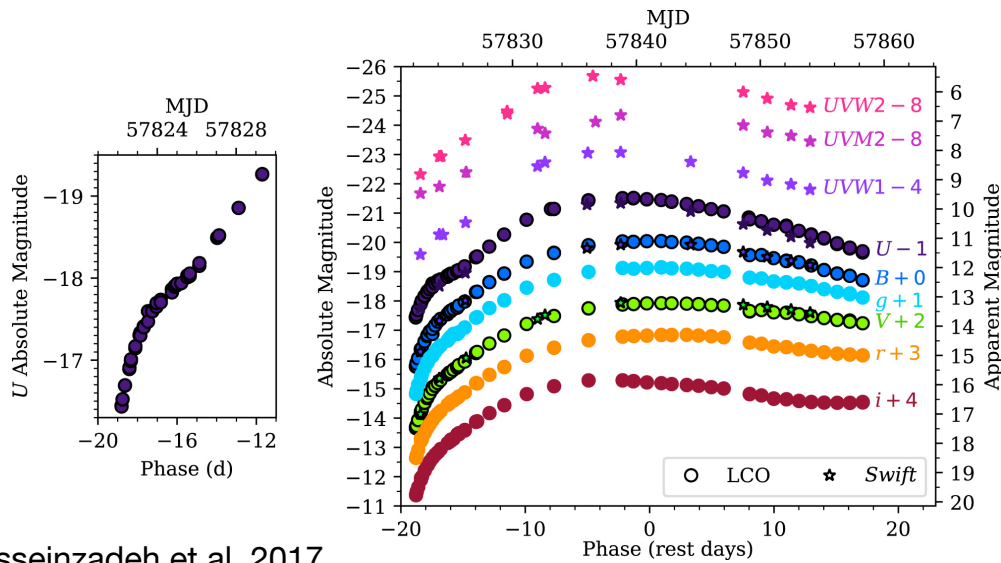


Riess et al. 2004

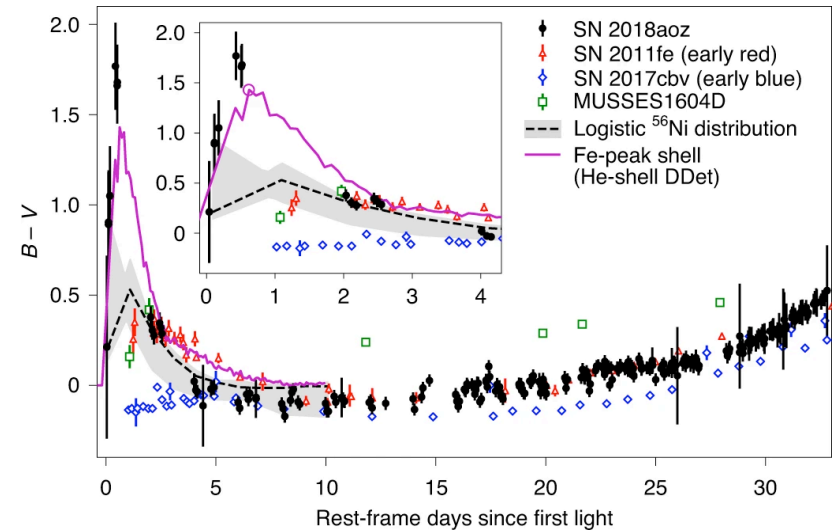


Kirshner et al. 1993

Early-time Bumps in SNe Ia



Hosseinzadeh et al. 2017



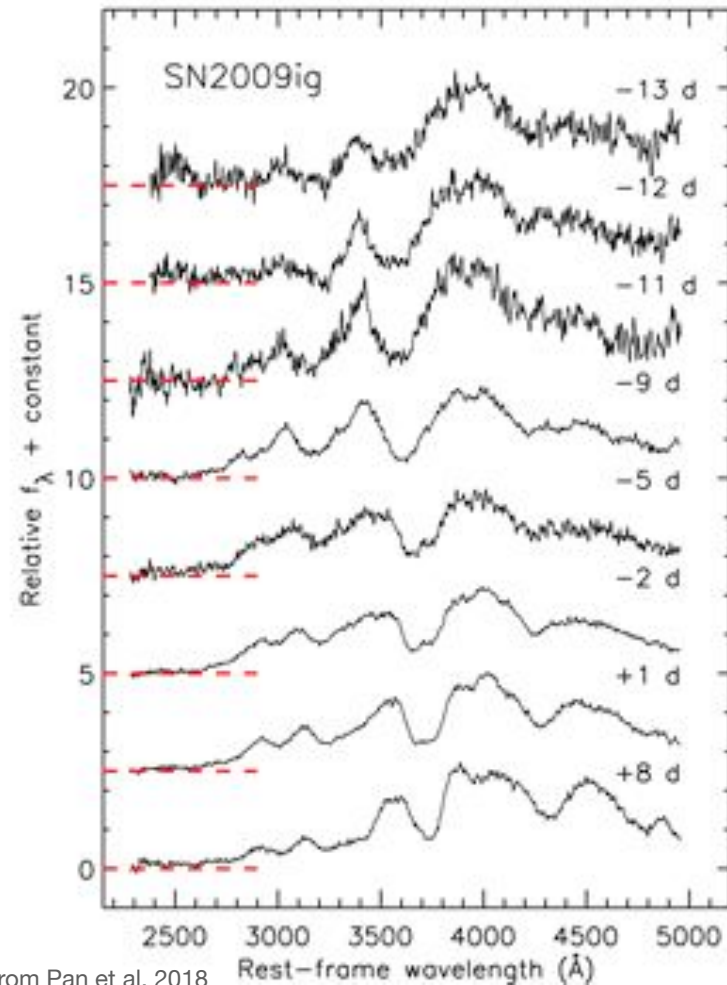
Ni et al. 2022

- Spectroscopy can disentangle the different models (UV spectra will be very sensitive to line blanketing due to Fe abundances)
- The problem is that they are so faint in the first few days!

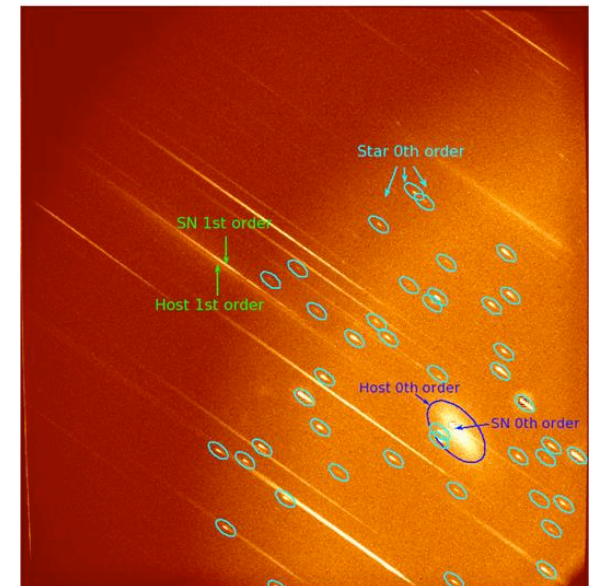
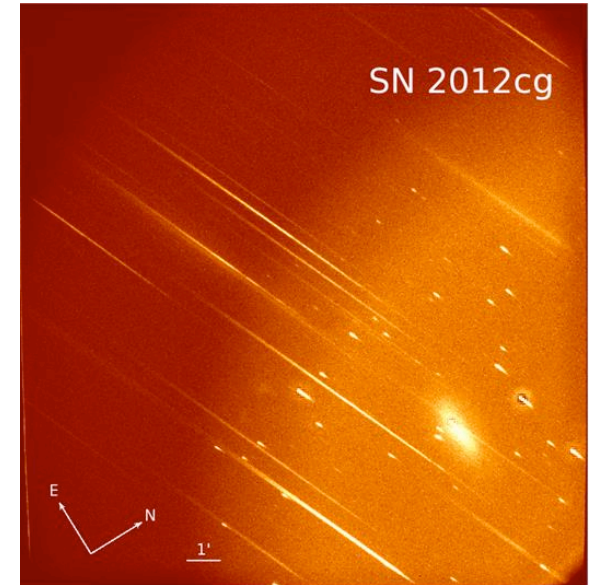
Limits of UVOT

Only rapid-response UV option right now is the UVOT grism

- Very limited sensitivity
- Data are very difficult
- Data don't go very far into the UV (no FUV)



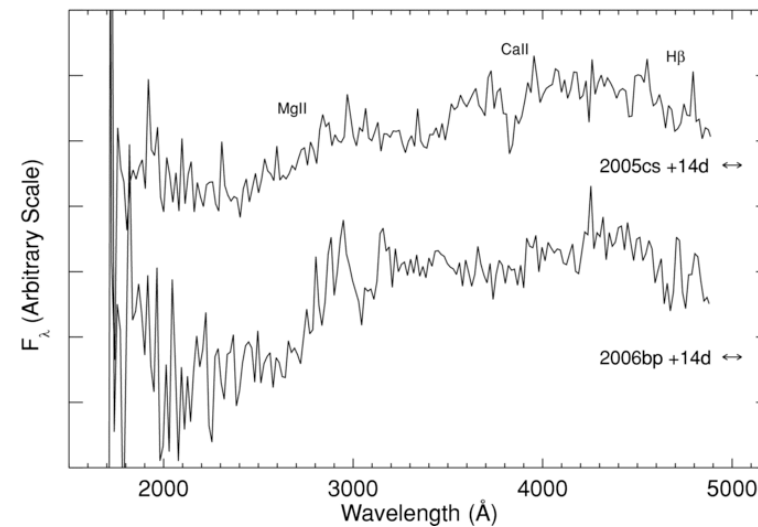
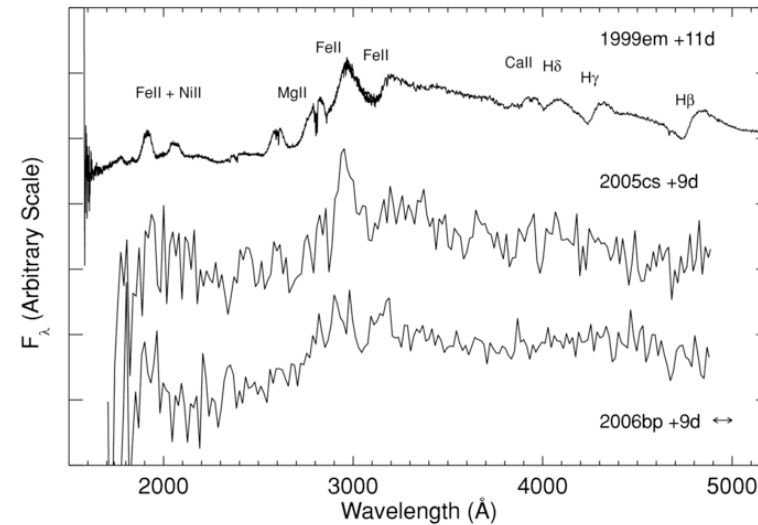
Figures from Pan et al. 2018



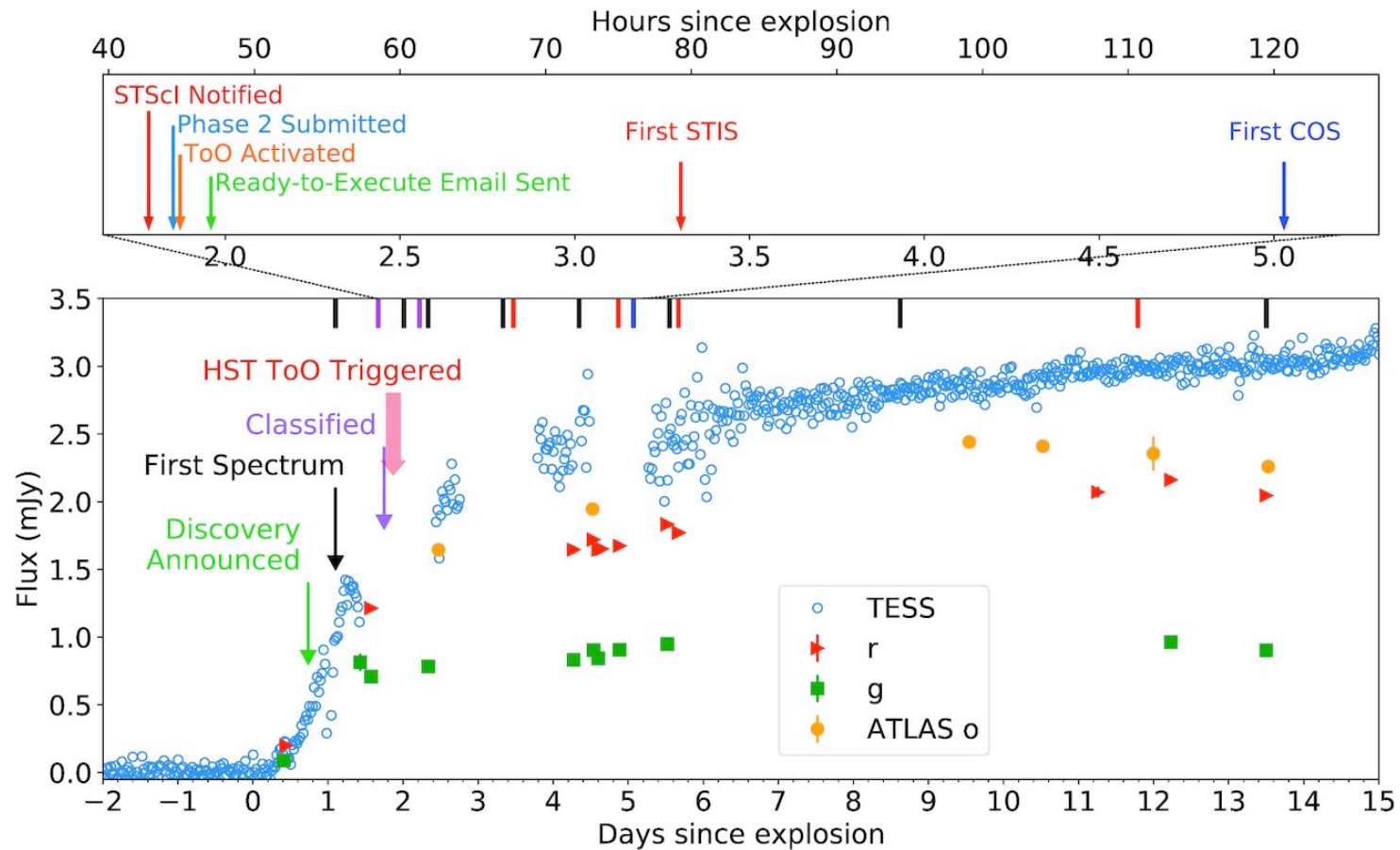
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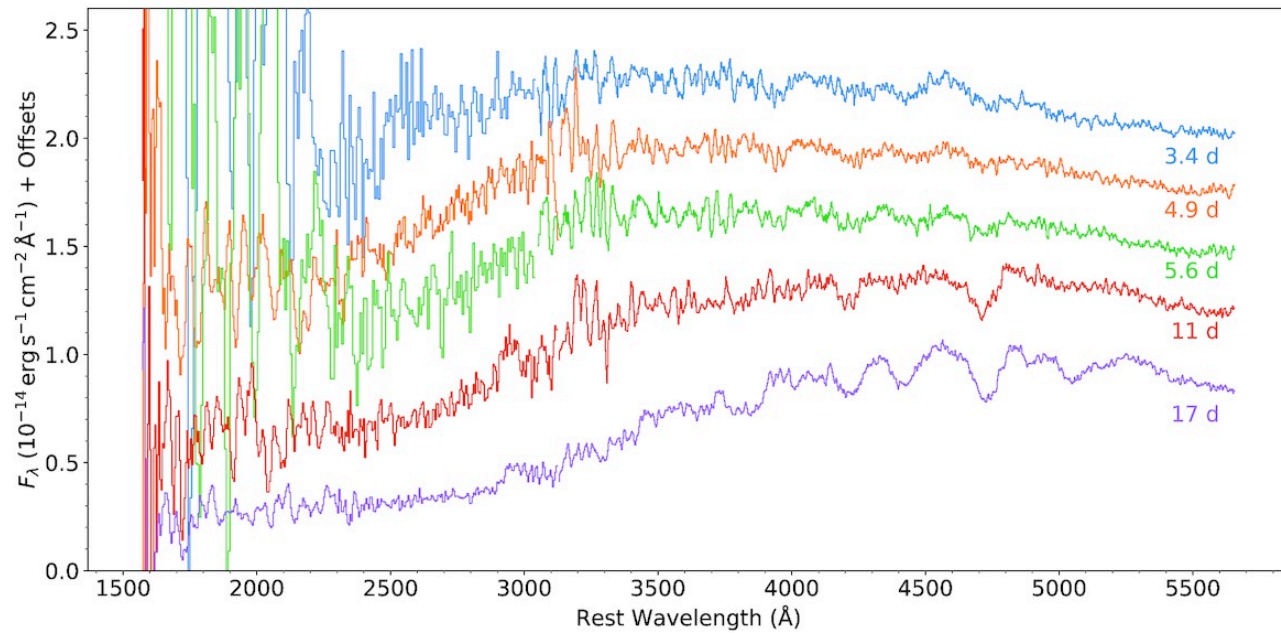
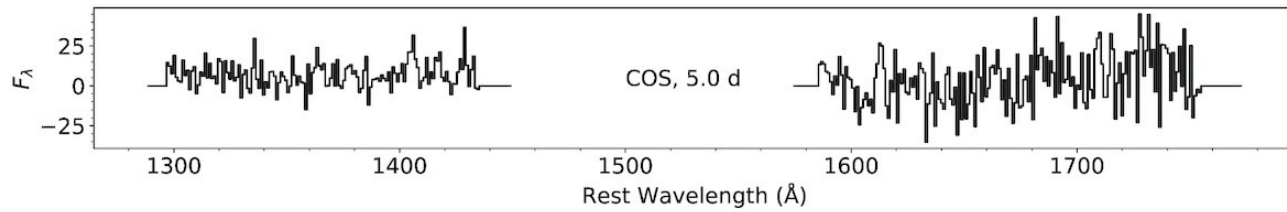
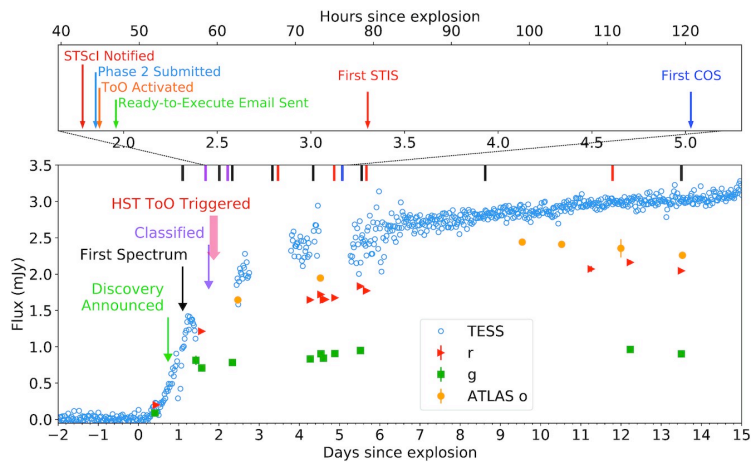


The State of the Art



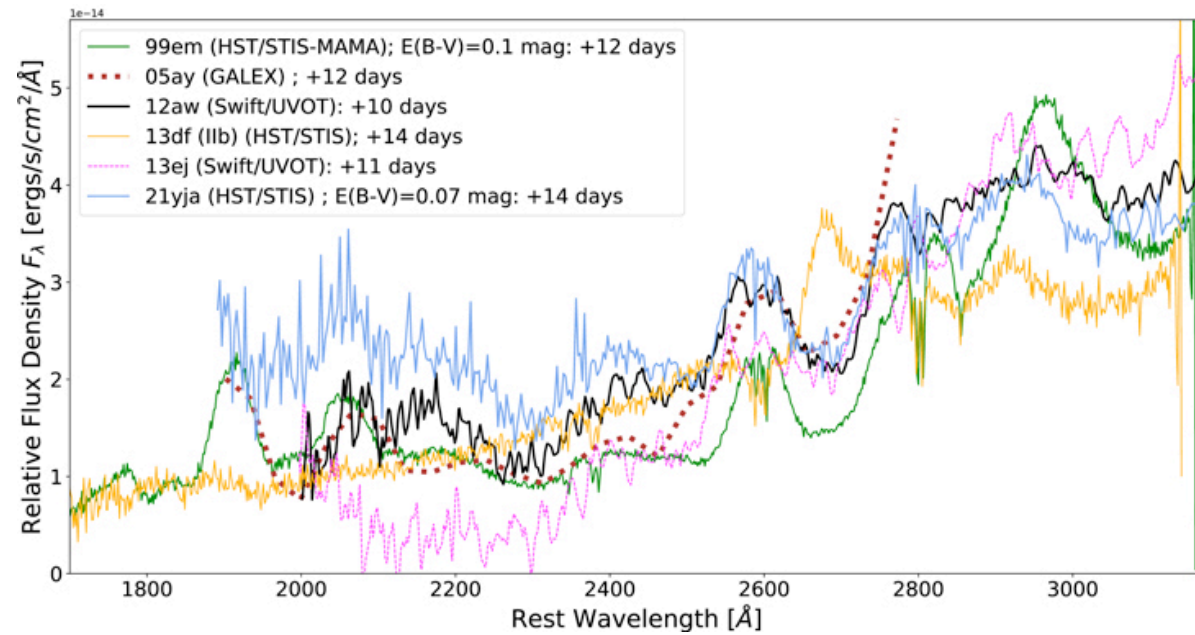
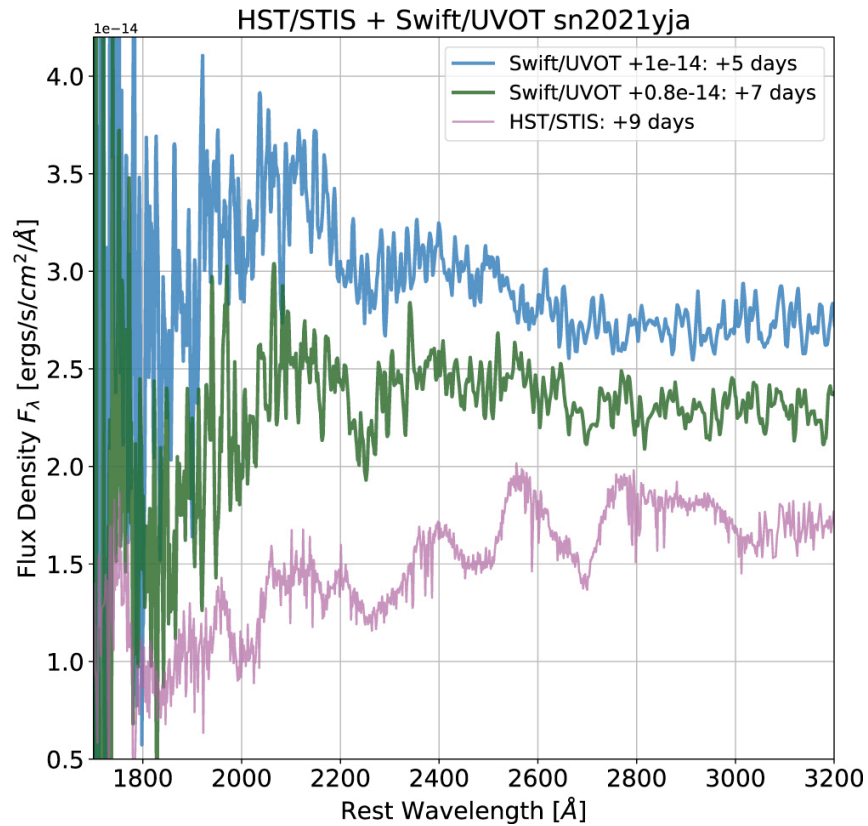
SN 2020fqv: Tinyanont et al. 2022

The State of the Art



SN 2020fqv: Tinyanont et al. 2022

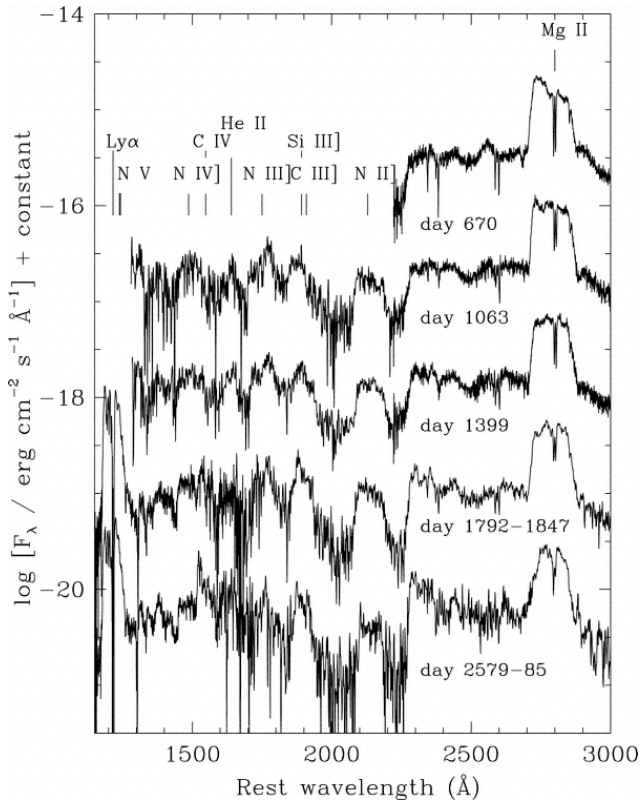
The State of the Art



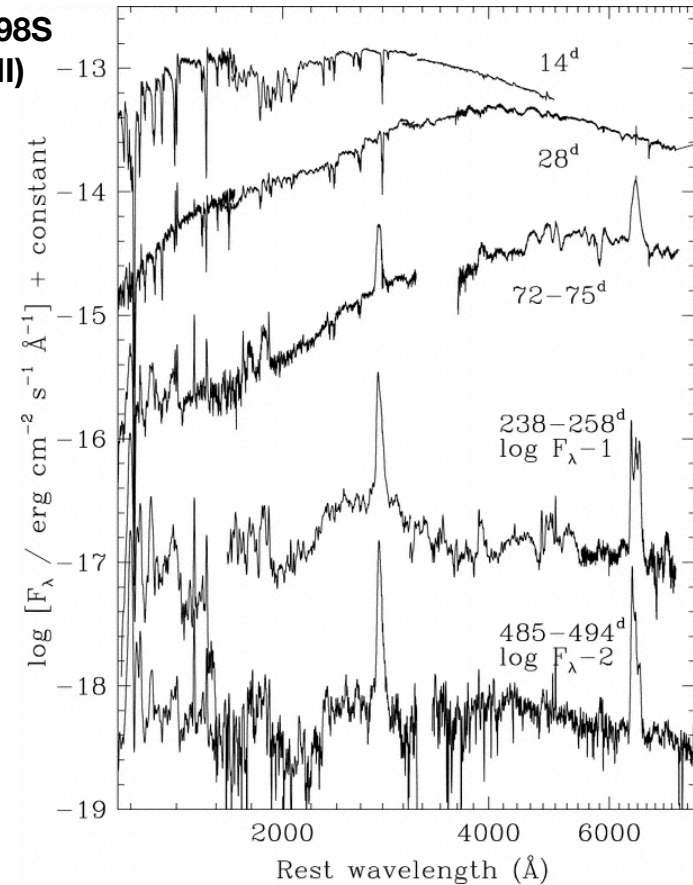
SN 2021yja: Vasylyev et al. 2022

Circumstellar Interaction

SN 1993J
(SN Ib)



SN 1998S
(SN II)

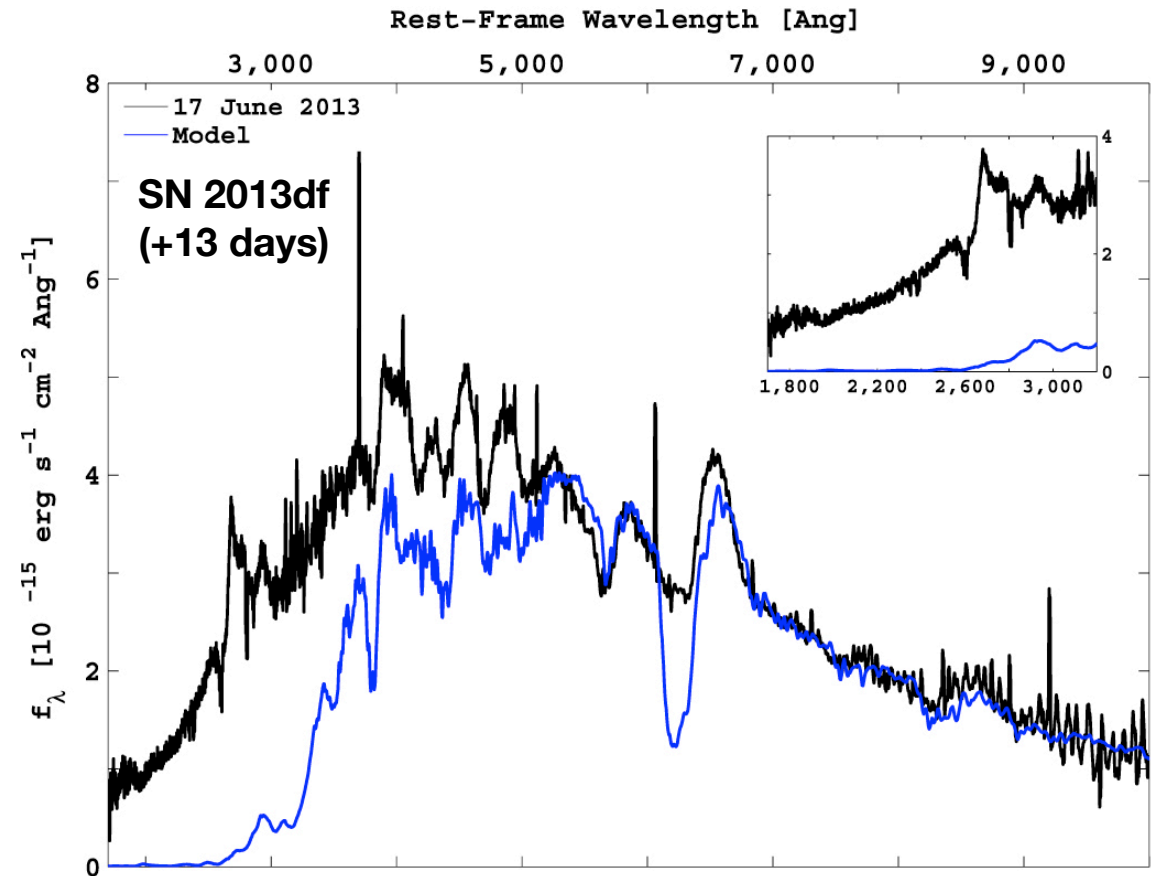


- CSM interaction prolongs UV emission from SNe to the point that HST can study them...

Fransson et al. 2005

Stripped-envelope SNe

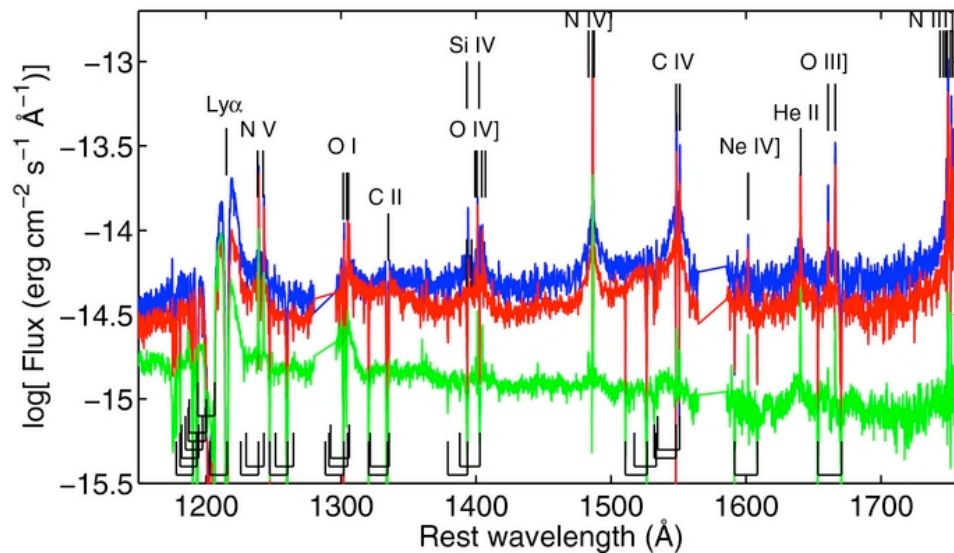
- In the SN IIb 2013df, there was an additional UV continuum source that did not exhibit line blanketing
- Ben-Ami et al. (2015) interpreted this as being due to CSM interaction
- Possibly also present in other SNe IIb (1993J, 2011dh)



Ben-Ami et al. 2015

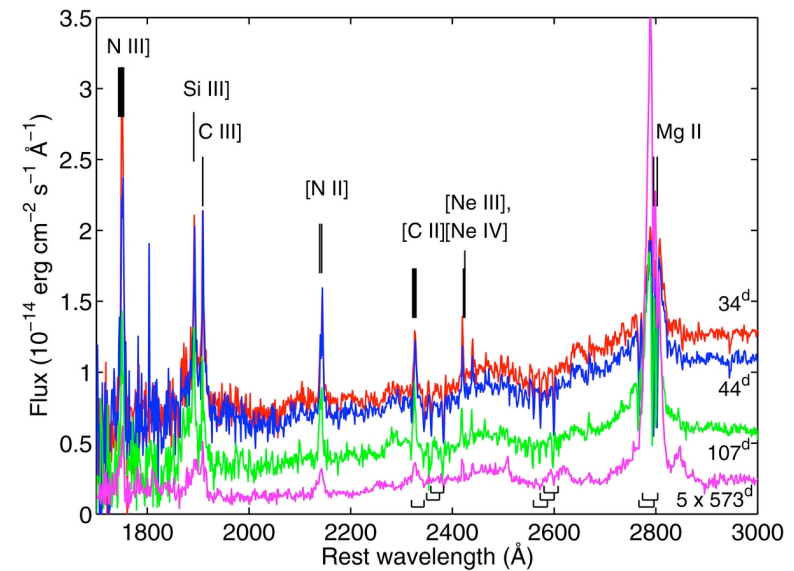
SN 2010jl (Fransson et al. 2014)

FUV (COS)



Lots of resonance lines in the FUV

NUV (STIS)



Note that many of these are narrow and forbidden

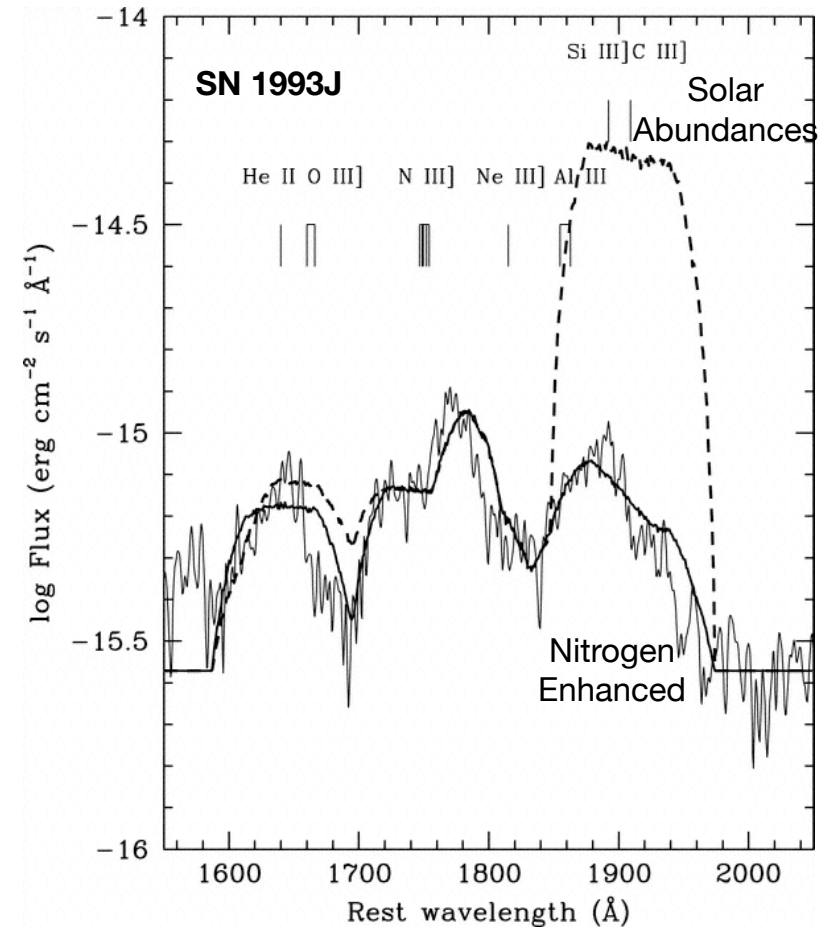
- Lots of diagnostics of CSM interaction in these lines (density, CNO abundances)

CNO Abundances

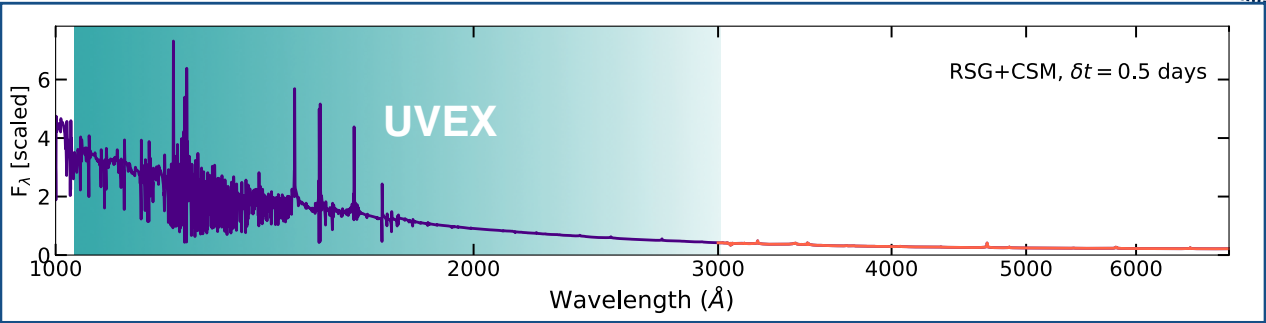
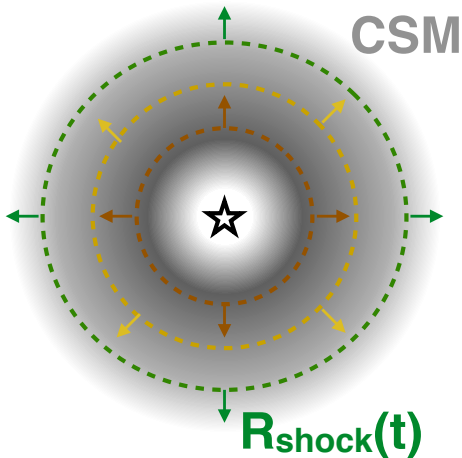
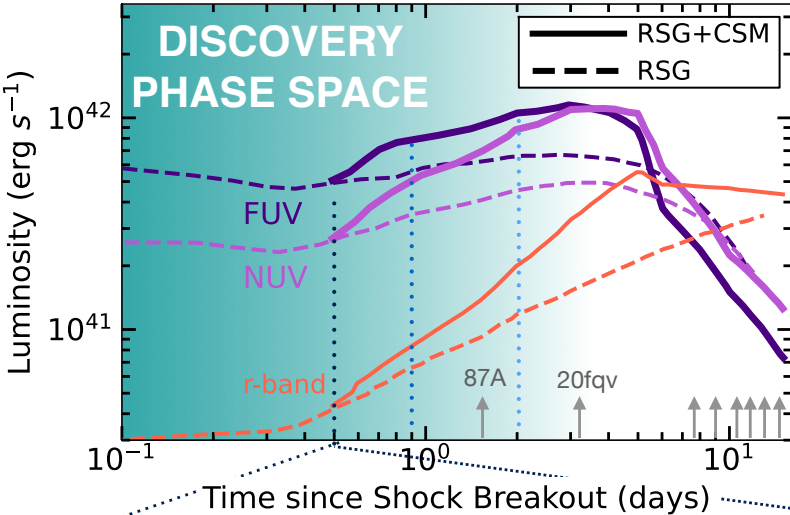
TABLE 7
SUMMARY OF CNO ABUNDANCES IN SNe II

Supernova	Type	Environment	N/C	N/O	Notes
SN 1979C	II-L	Ejecta	8	>2	...
SN 1987A	II-P	Circumstellar	7.8	1.6	Nebular analysis
	5.0	1.1	Photoionization model
SN 1993J.....	IIb	Ejecta	12.4	>0.8	...
SN 1995N.....	IIIn	Ejecta	3.8	0.2	Uncertain
SN 1998S.....	IIIn	Circumstellar	6.0	>1.4	...

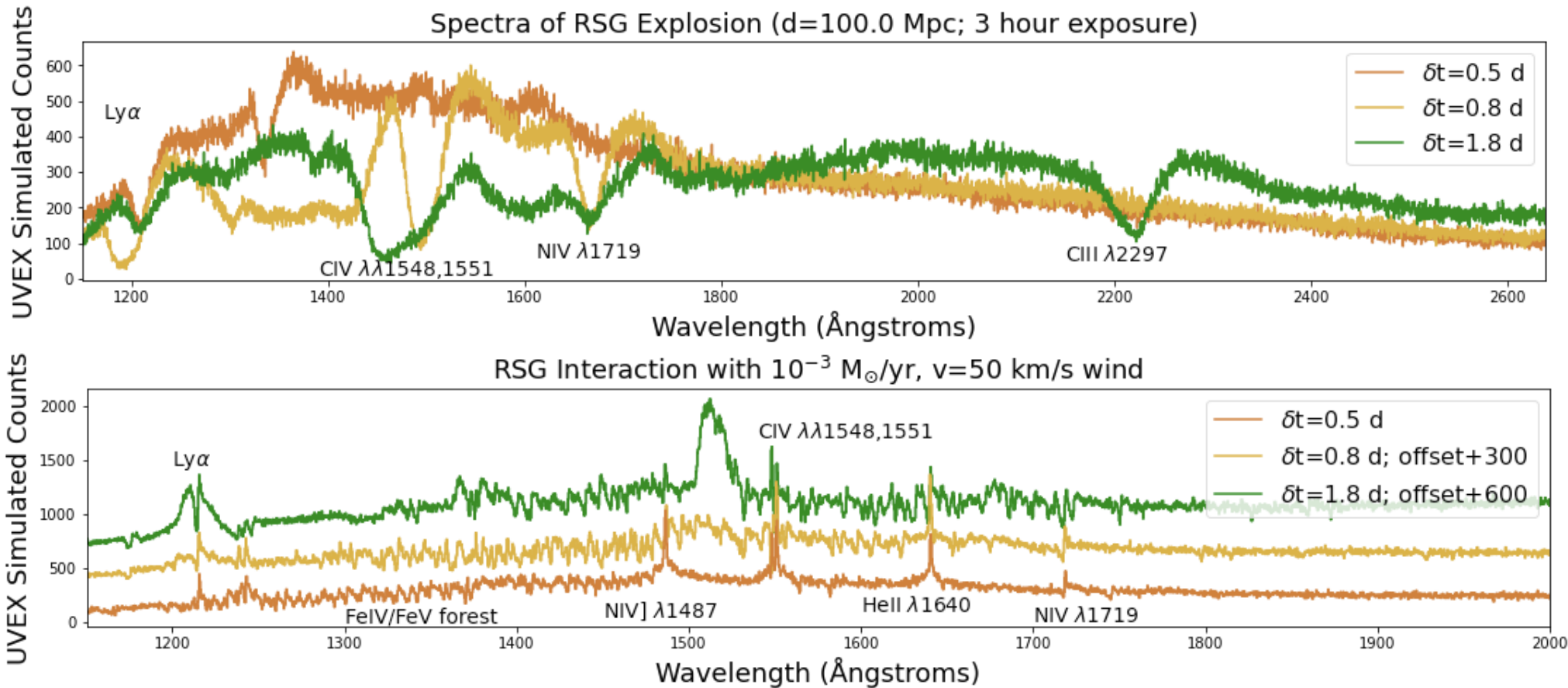
- Multiple ionization stages of CNO elements are present in the UV
- Ratios of N III/C III and N IV/C IV demonstrate that the CSM was formerly inside a massive star!



Core-collapse Supernovae

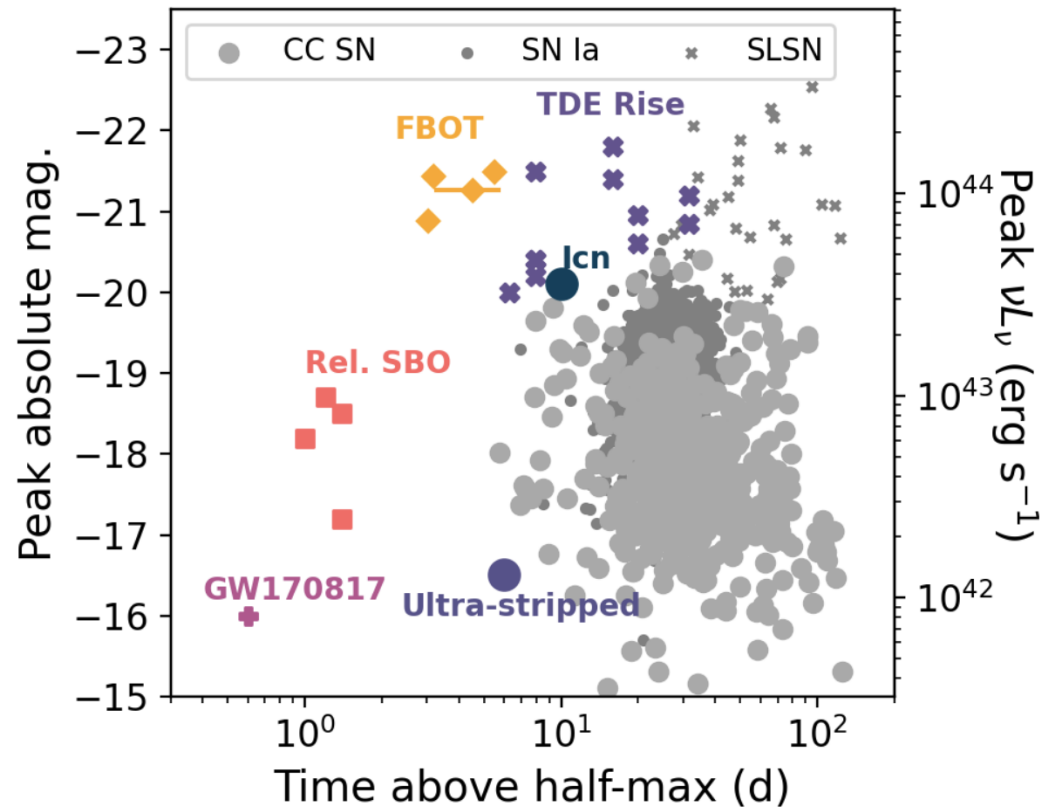


What can UVEX do?



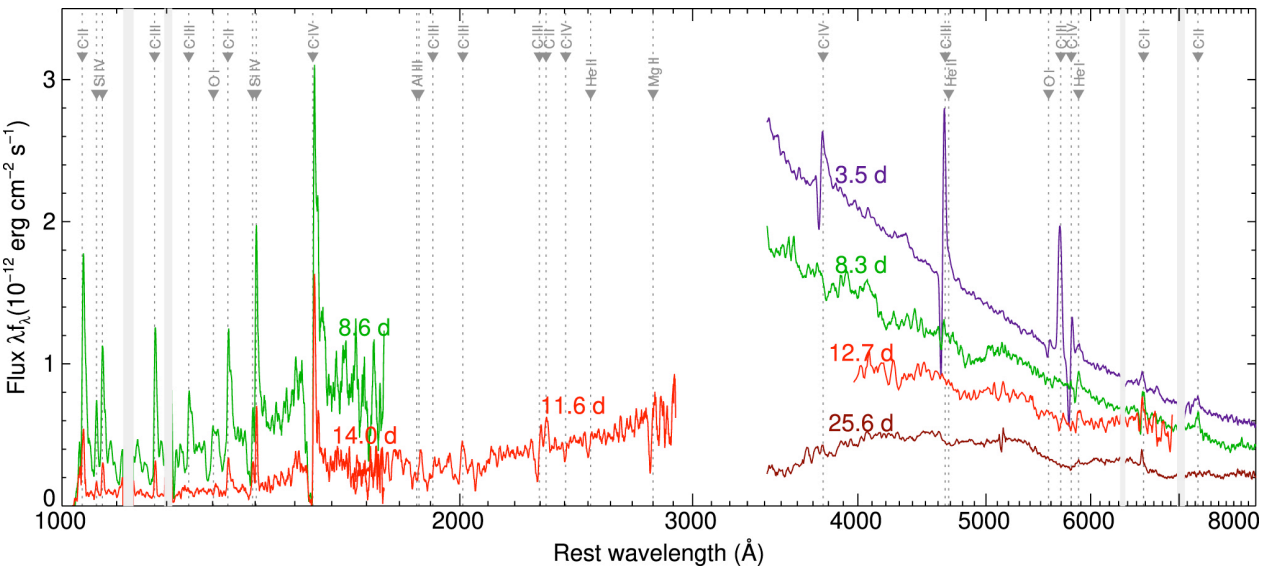
Models from L. Dessart

The frontier keeps moving to faster timescales...



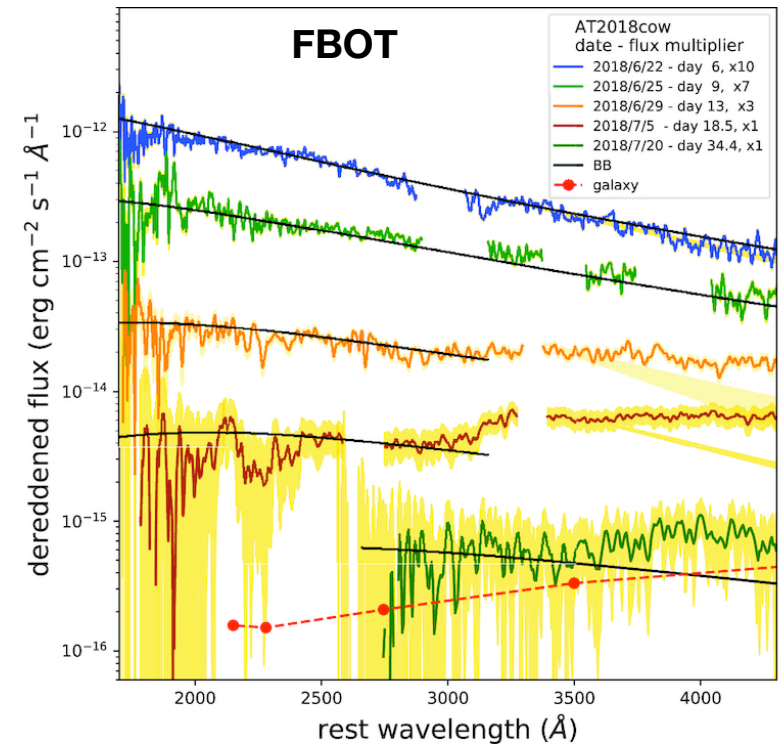
Fast is hard to do...

SN 2021csp (Icn)



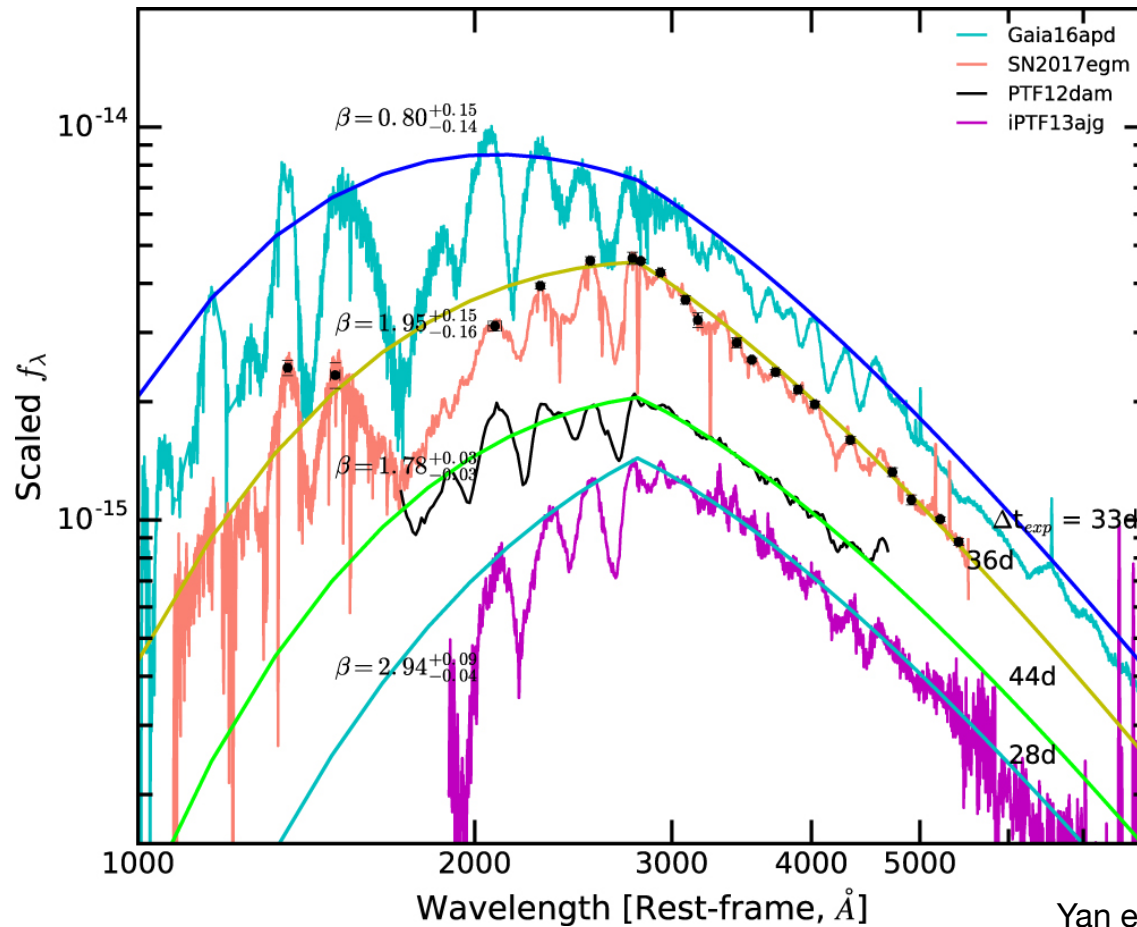
Perley et al. 2022

- The SN Icn has high-ionization lines in the UV
- The FBOT is pretty featureless...



Kuin et al. 2019

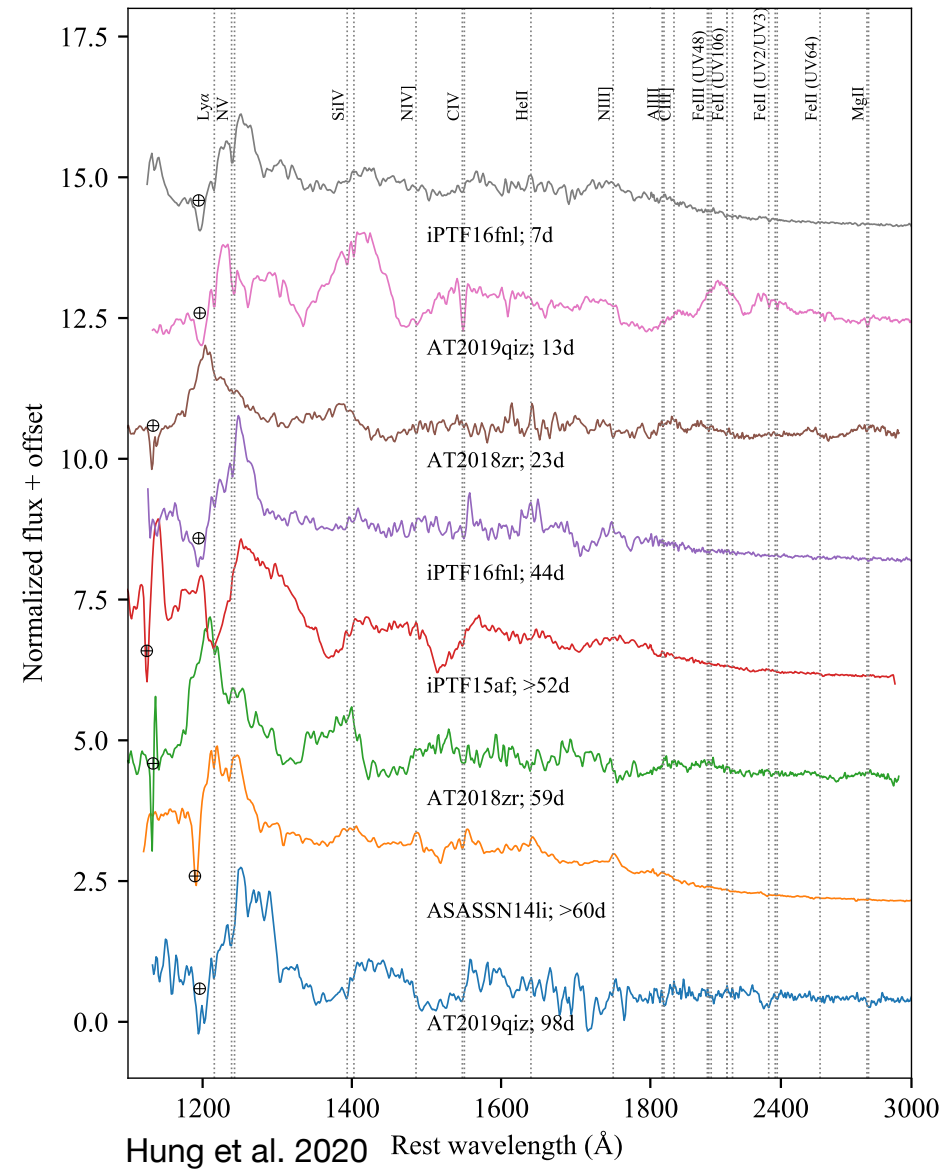
Superluminous Supernovae



- Slow light curves!
- Lots of UV flux!

Tidal Disruption Events

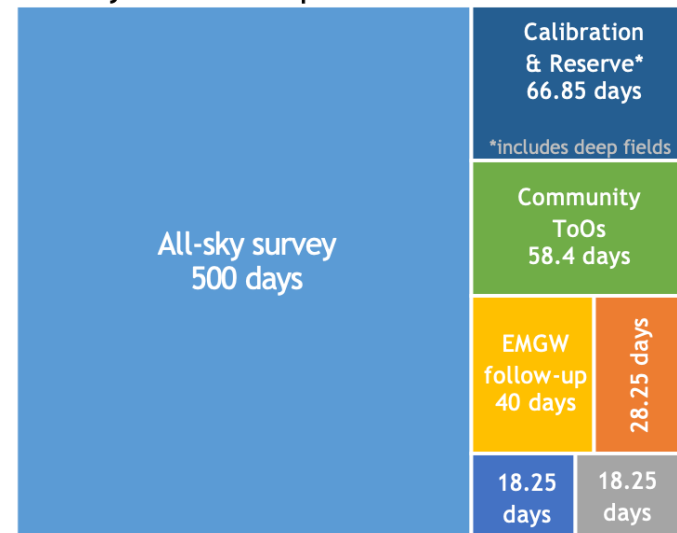
- Again, FUV has more info than NUV (note wavelength scale!)



Future with UVEX

- UVEX will devote ~8% of time to spectroscopic ToOs (~70 triggers)
- This is more than HST has been able to do in 30 years
- Rapid response means that spectra will be possible in the critical early days after explosion:
 - Abundances (Fe group, CNO)
 - Diagnostics of interaction
 - Both will diagnose the state of the progenitor star at the time of explosion

730 days of science operations



Low Metallicity Galaxies spectroscopy
Rapid CC SNe spectroscopy
LMC/SMC (imaging & spectroscopy)