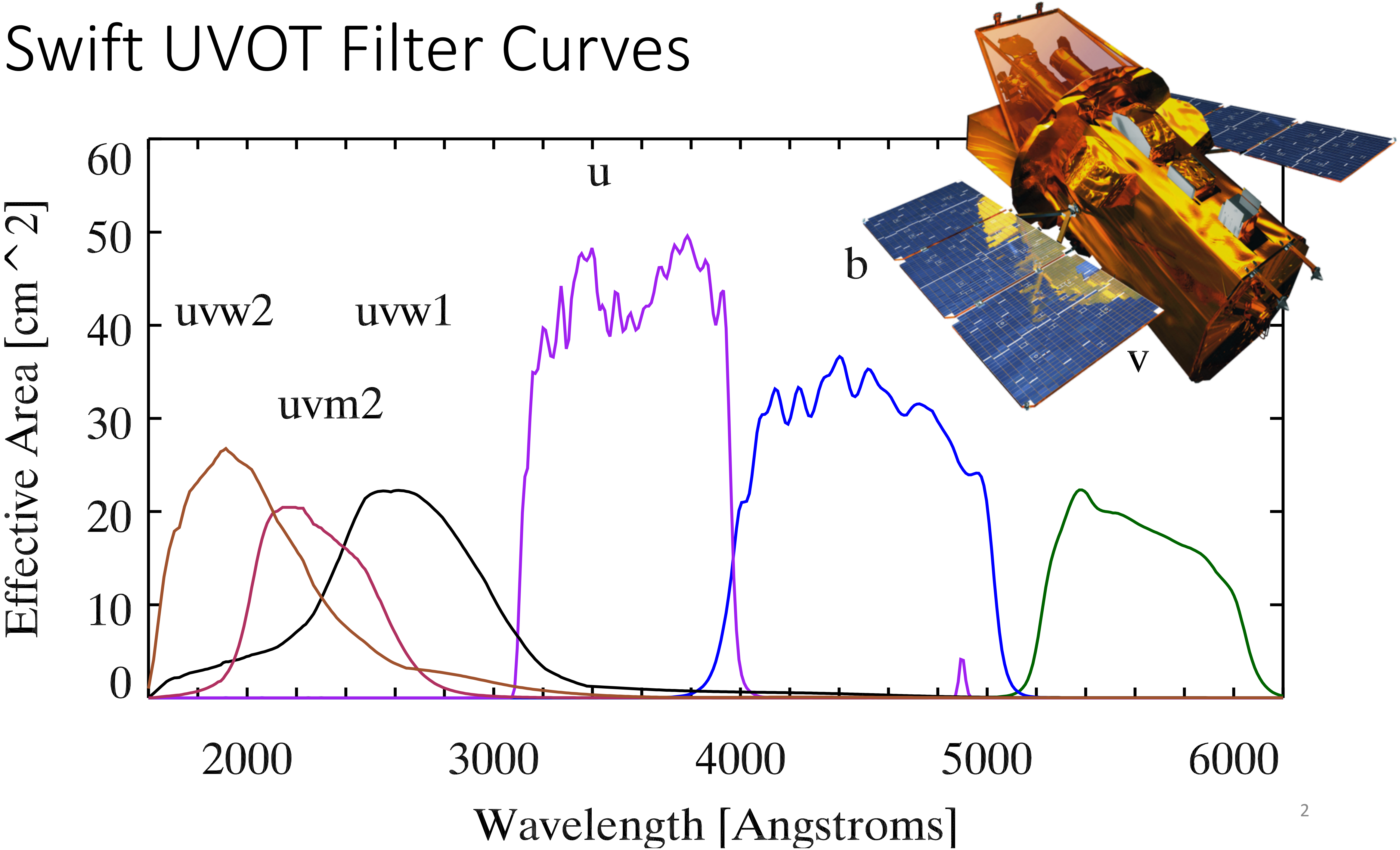
Ultraviolet Diversity of Supernovae: Complications for analysis and implications for Cosmology

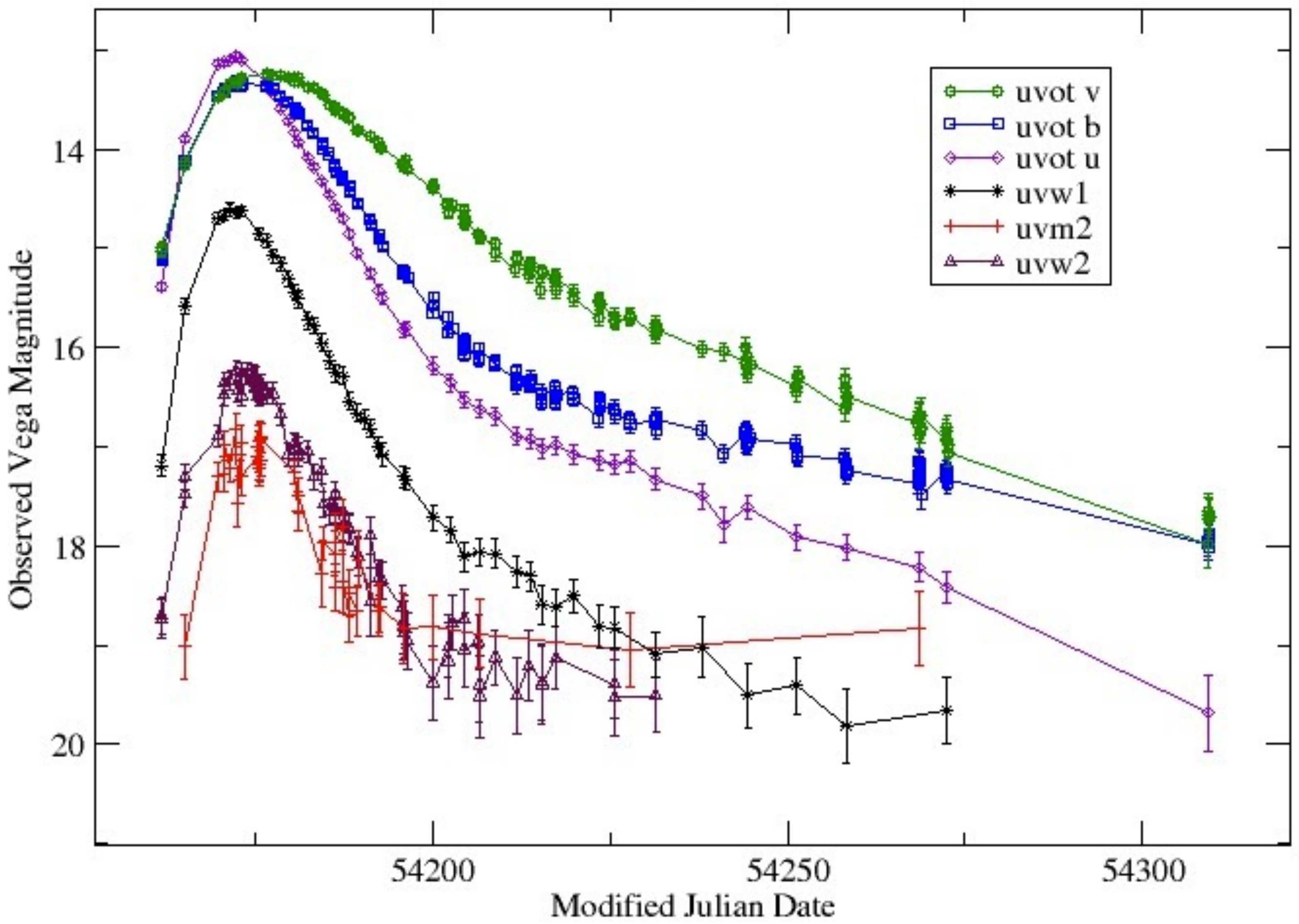
Dr. Peter J Brown

Texas A&M University

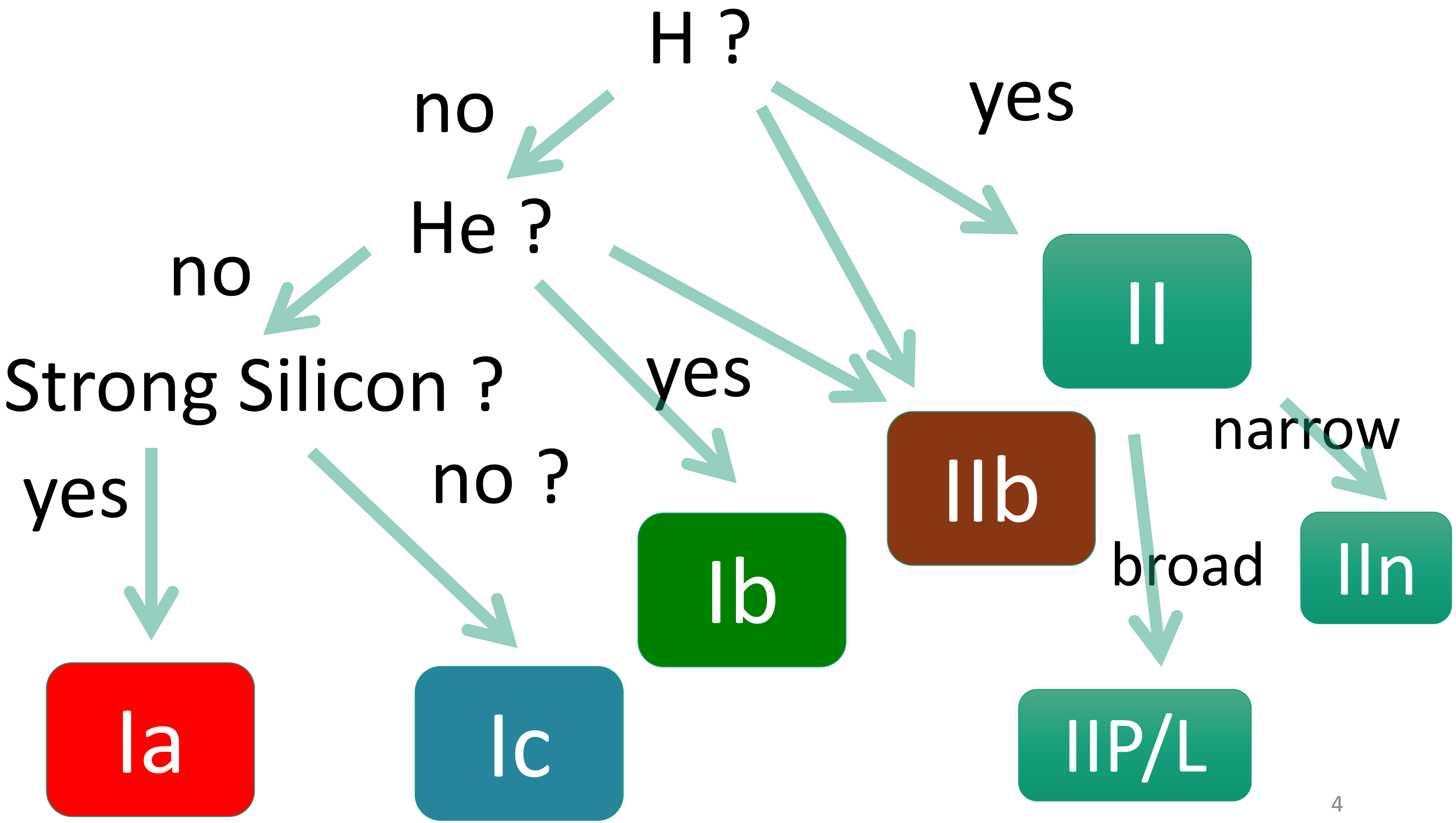
Swift UVOT Filter Curves

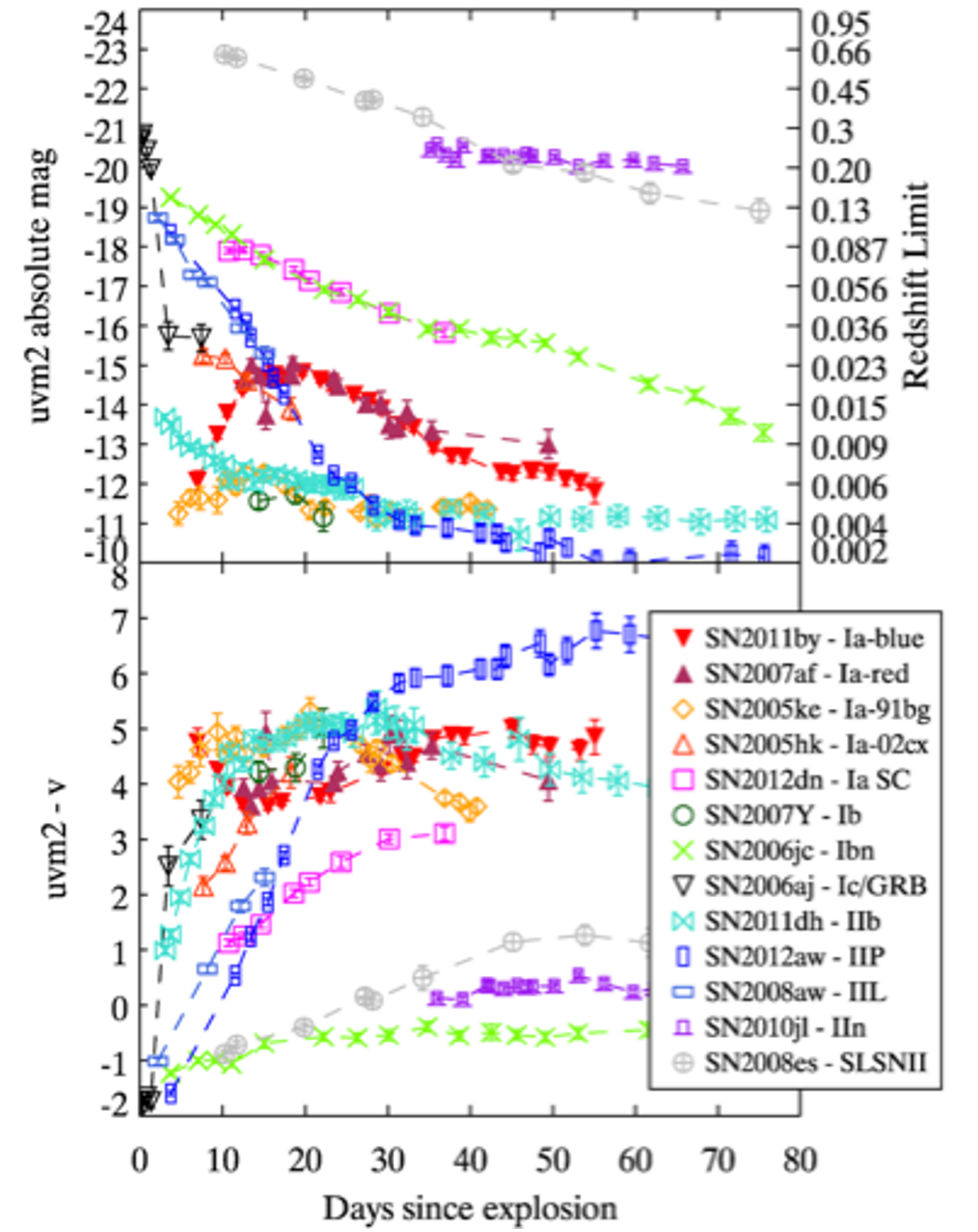


Example of 6-filter light curves of Type Ia SN2007af



We start by grouping supernovae based on elements in their spectra

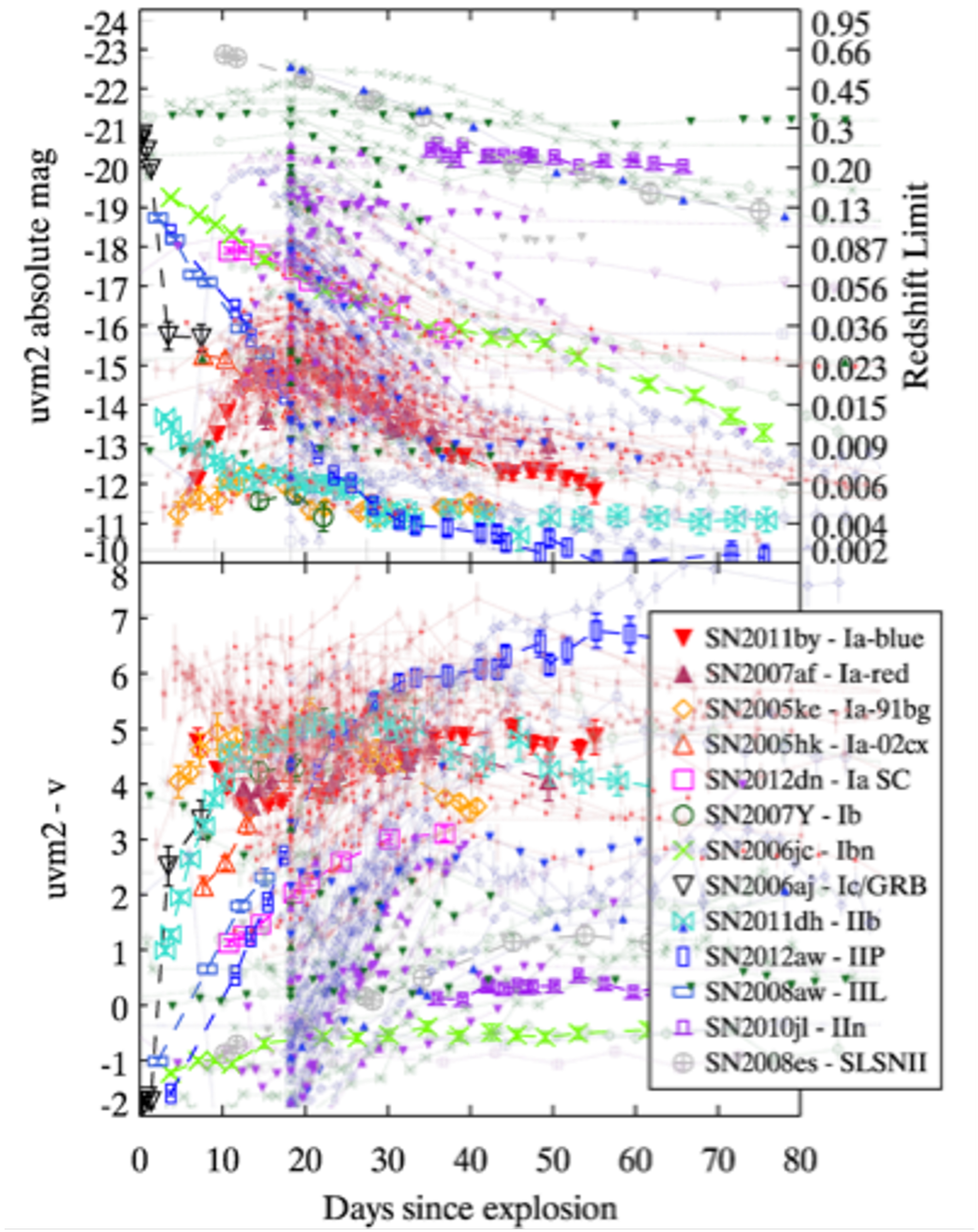




Swift has now observed all major classes and subtypes

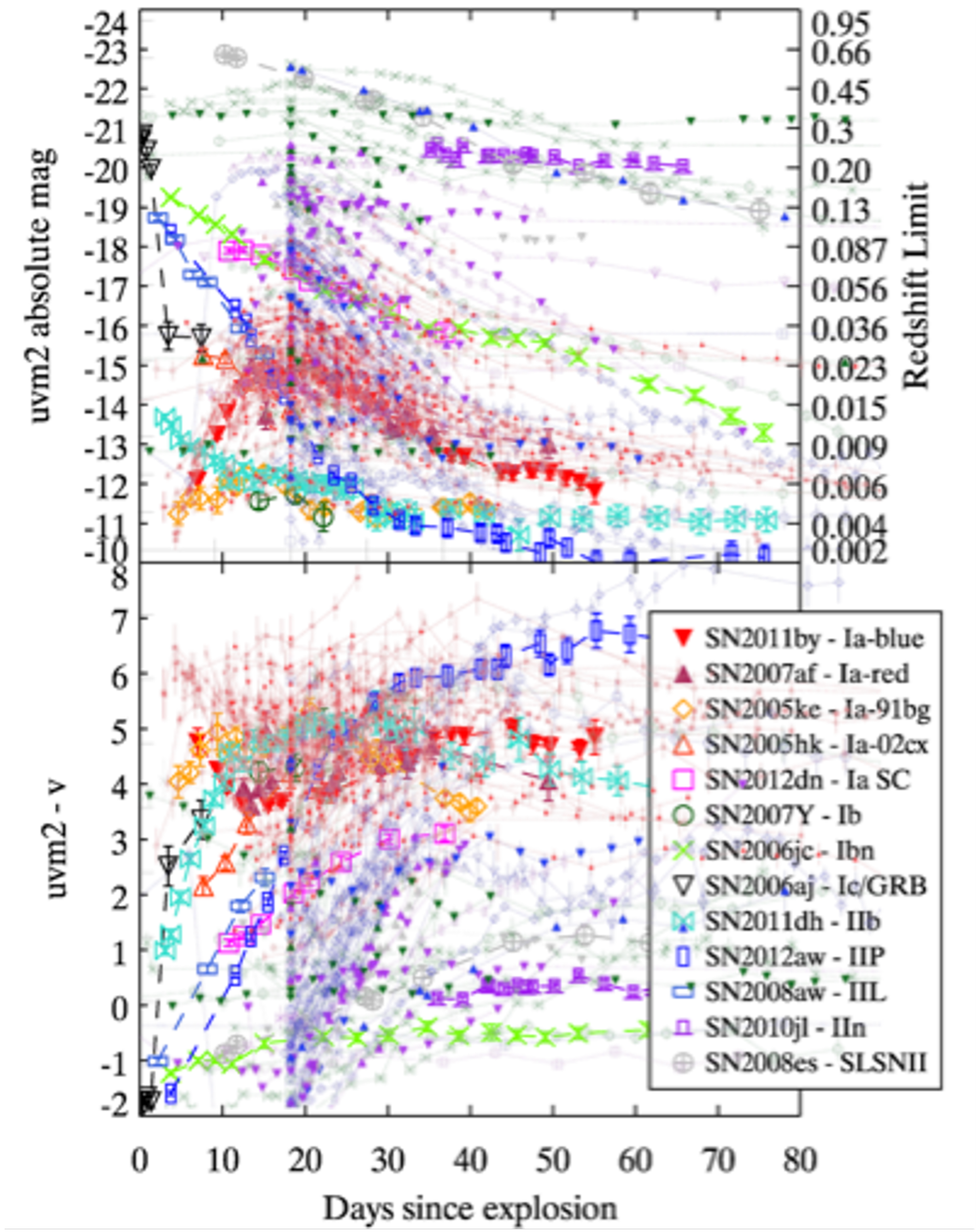
UV luminosity for different supernova types varies by x10,000

Brown et al. 2015
arXiv:1505.01368v1



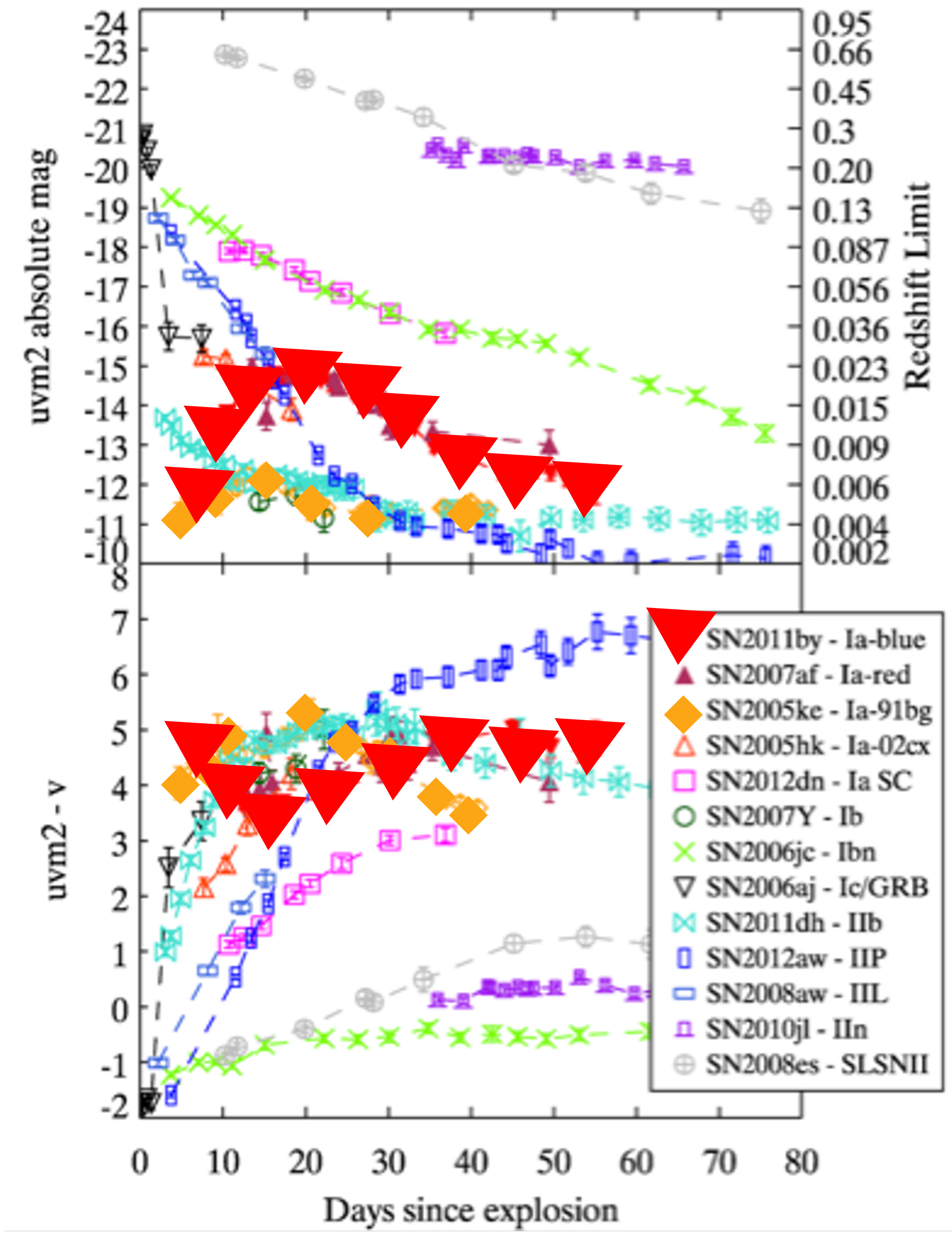
Swift has now observed all major classes and subtypes and many more

Swift
Optical
Ultraviolet
Supernova
Archive



Swift has now observed all major classes and subtypes and many more

Work now is focused on statistical comparisons within classes

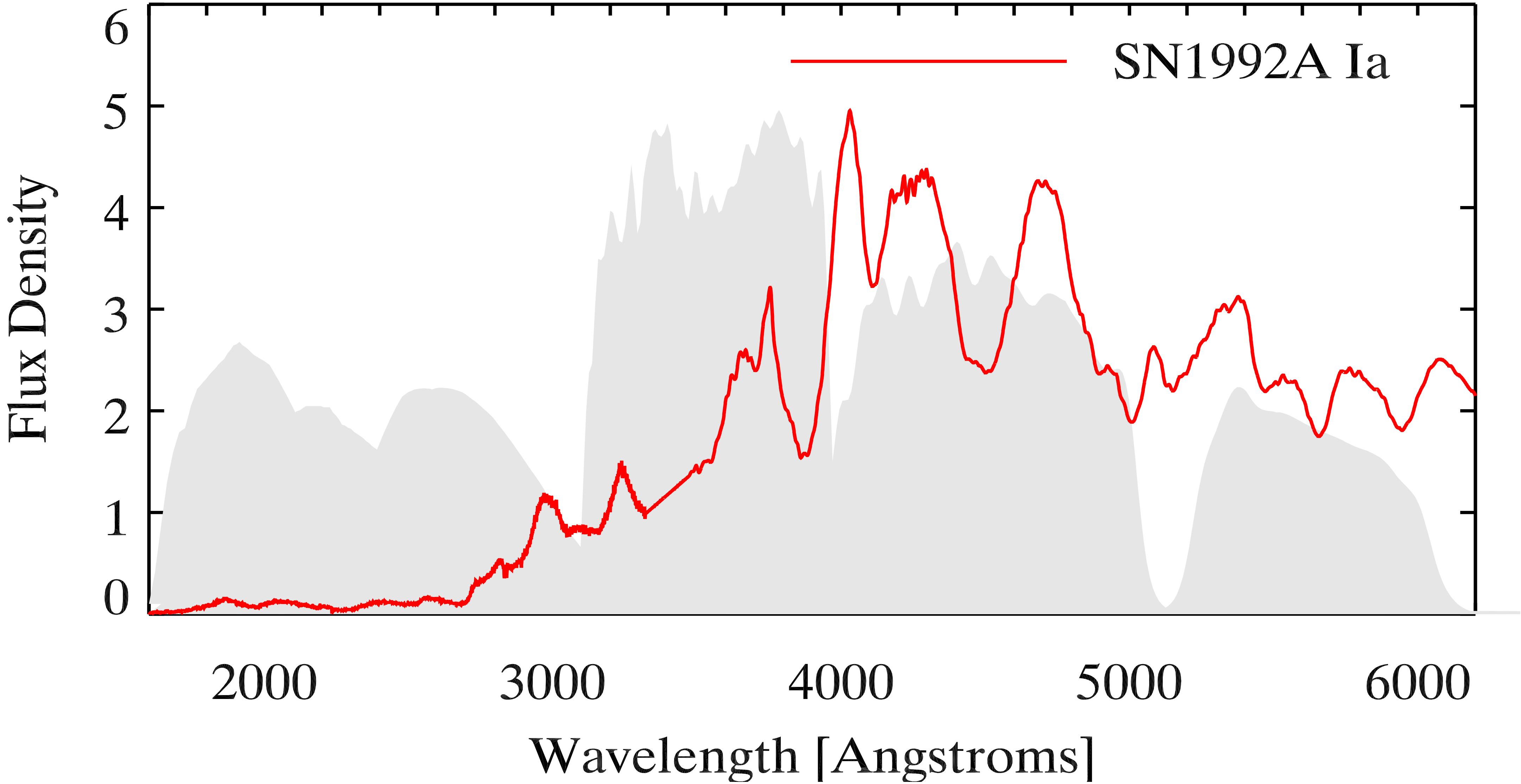


Thermonuclear Type Ia SNe

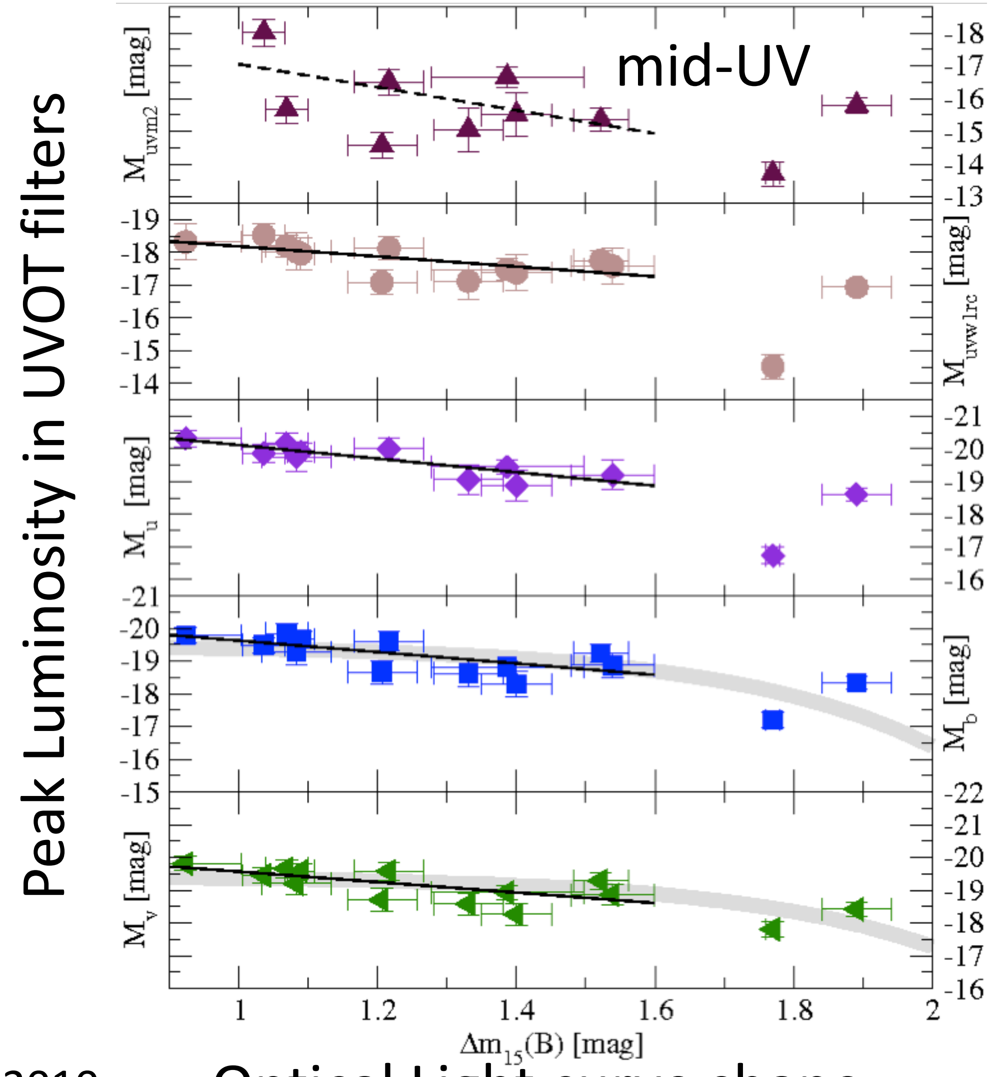
Radioactive decay powers light curve,
Line blanketing in the UV

Brown et al. 2015
arXiv:1505.01368v1

What does a SN Ia look like in the UV?

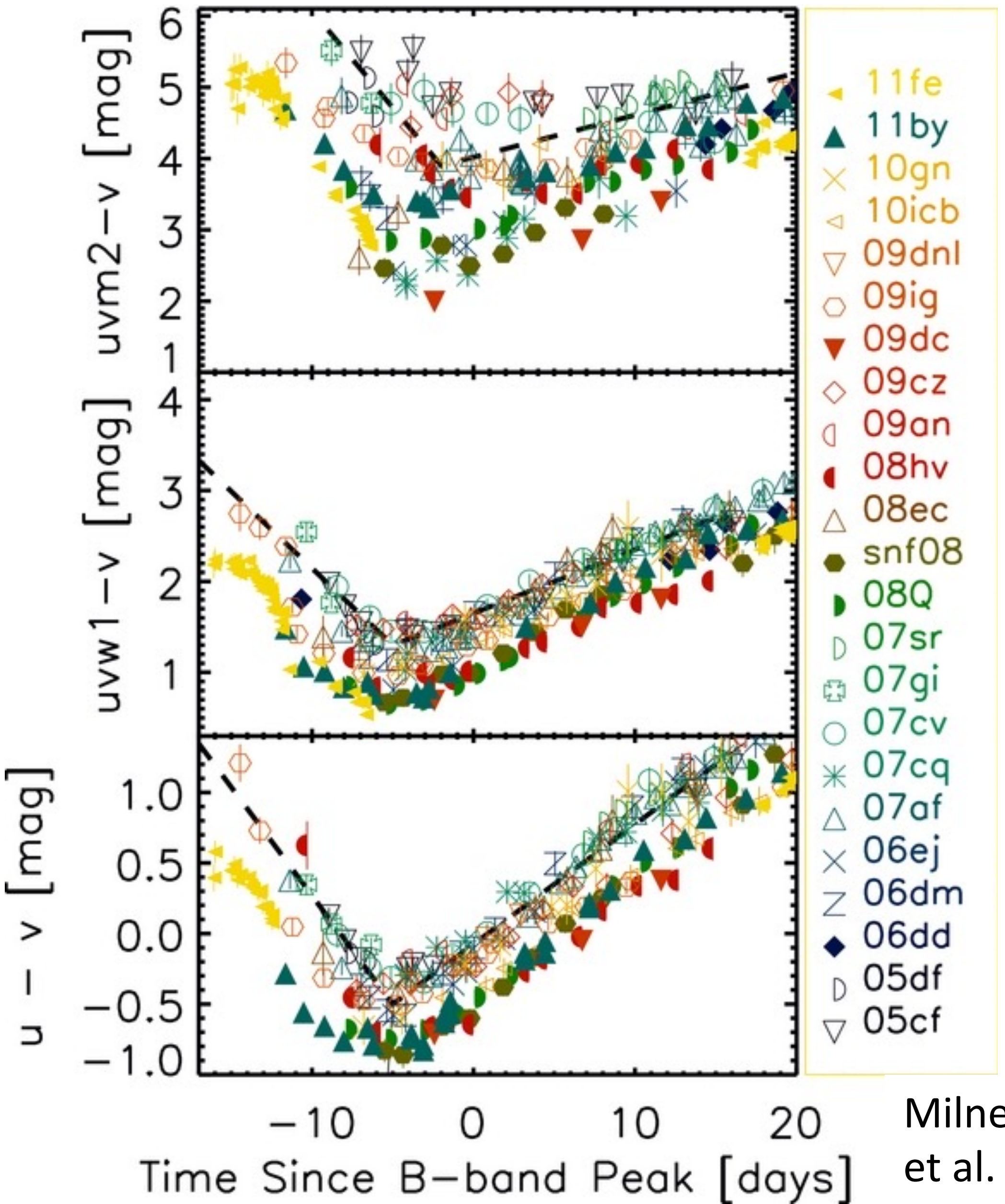


UV observations show nearby SNe Ia are not all the same



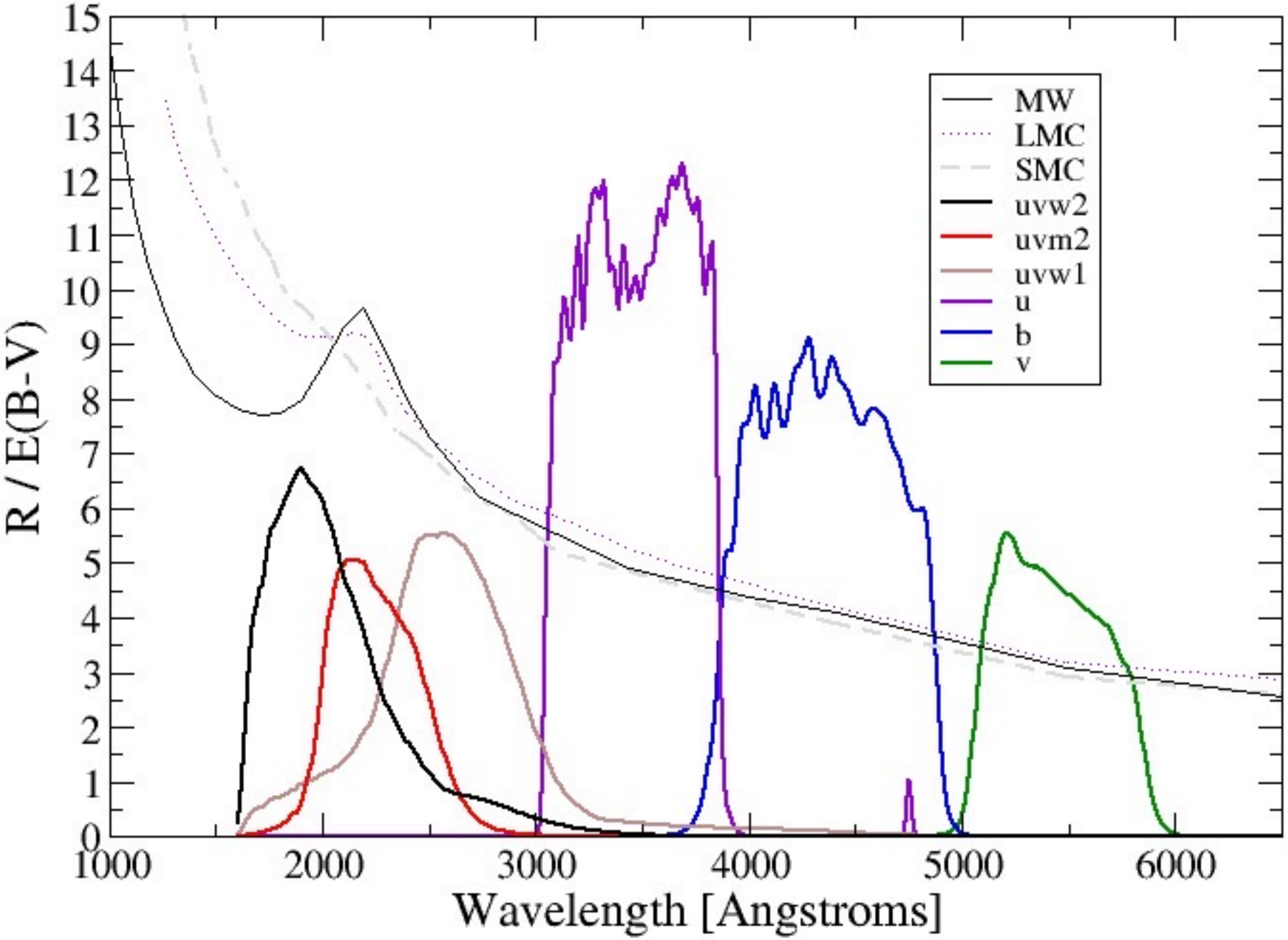
Brown, et al. 2010

Optical Light curve shape

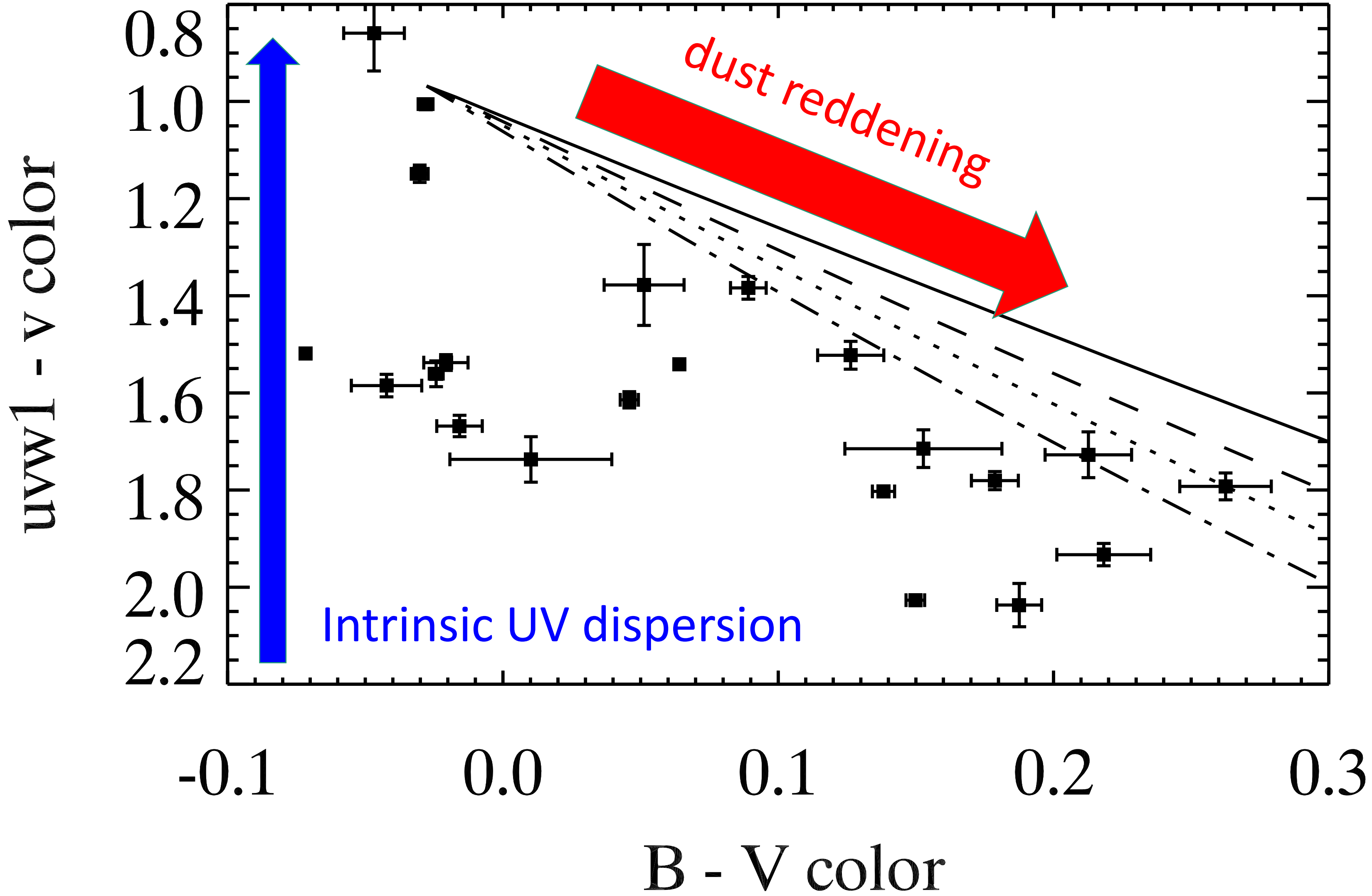


Milne, Brown, et al. 2013

Is it just reddening?

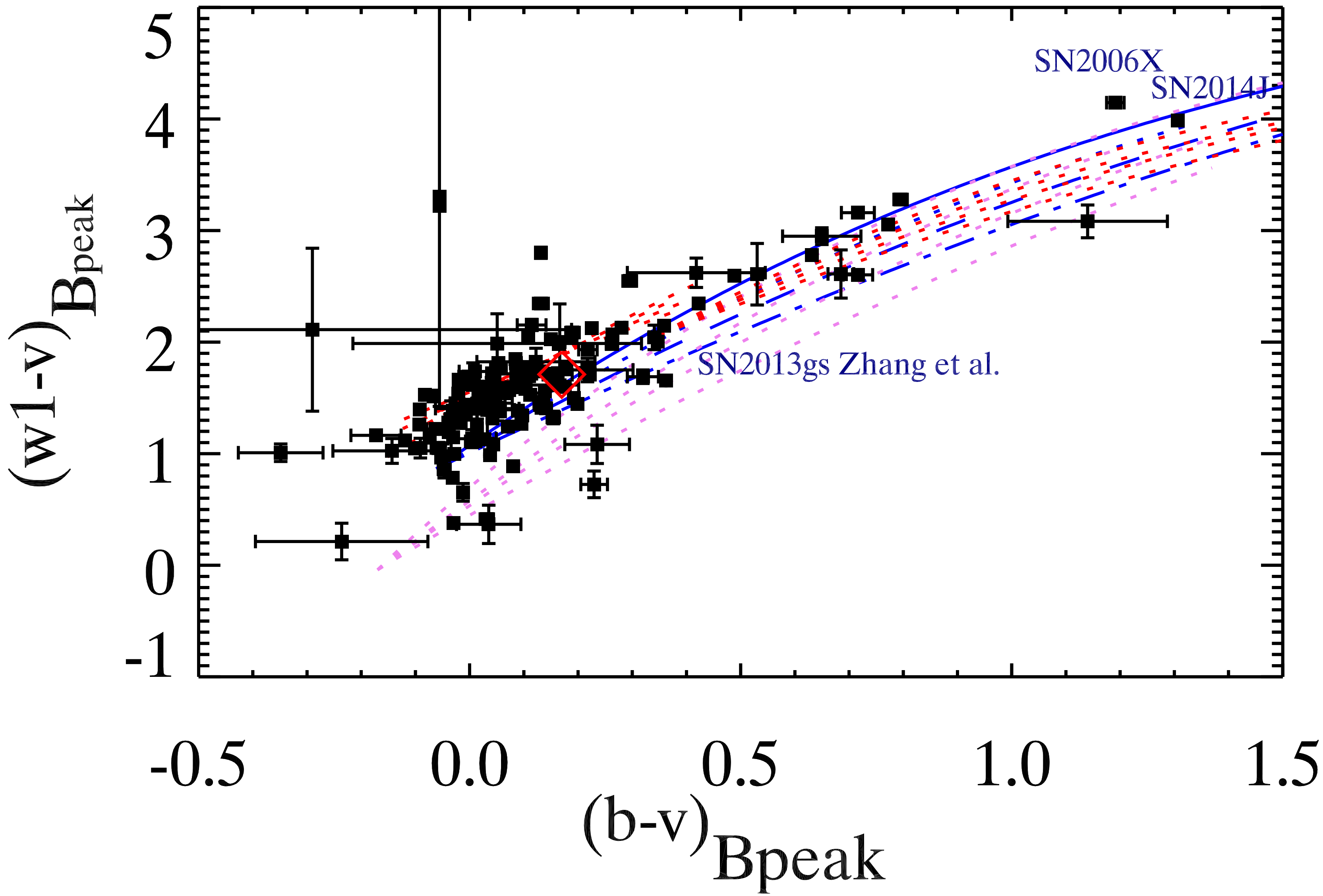


UV dispersion not all caused by dust

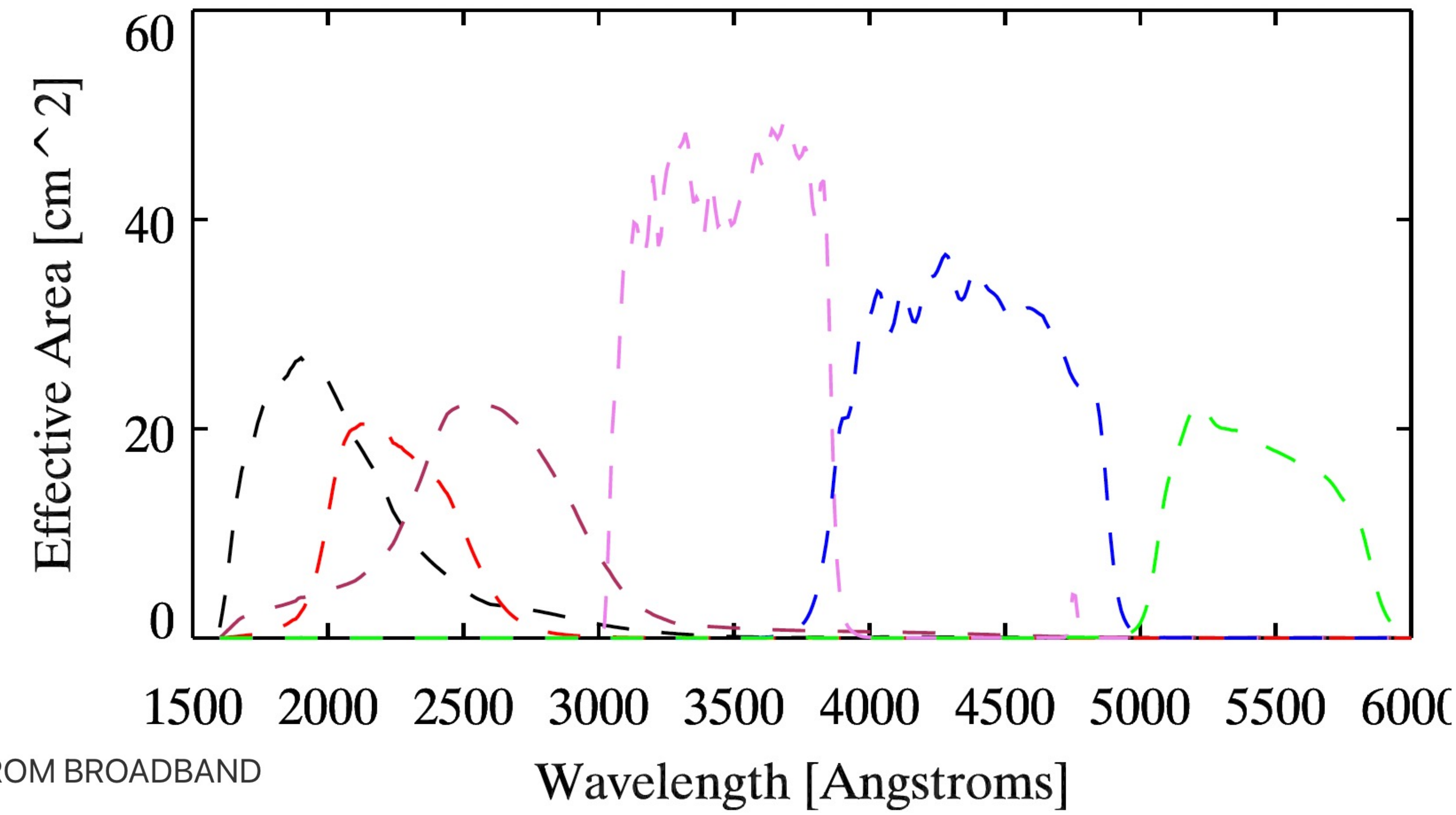


Brown et al. 2017 with undergrad Nancy Landez

Filter extinction coefficients are non-linear -- depend on spectral shape



Photometry is a measurement of flux through a finite-width filter



INTERPRETING FLUX FROM BROADBAND PHOTOMETRY

Peter J. Brown[1], Alice Breeveld[2], Peter W. A. Roming[3], and Michael Siegel[4]

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Fig 1

Here is a sample filter, uvw2, from Swift UVOT

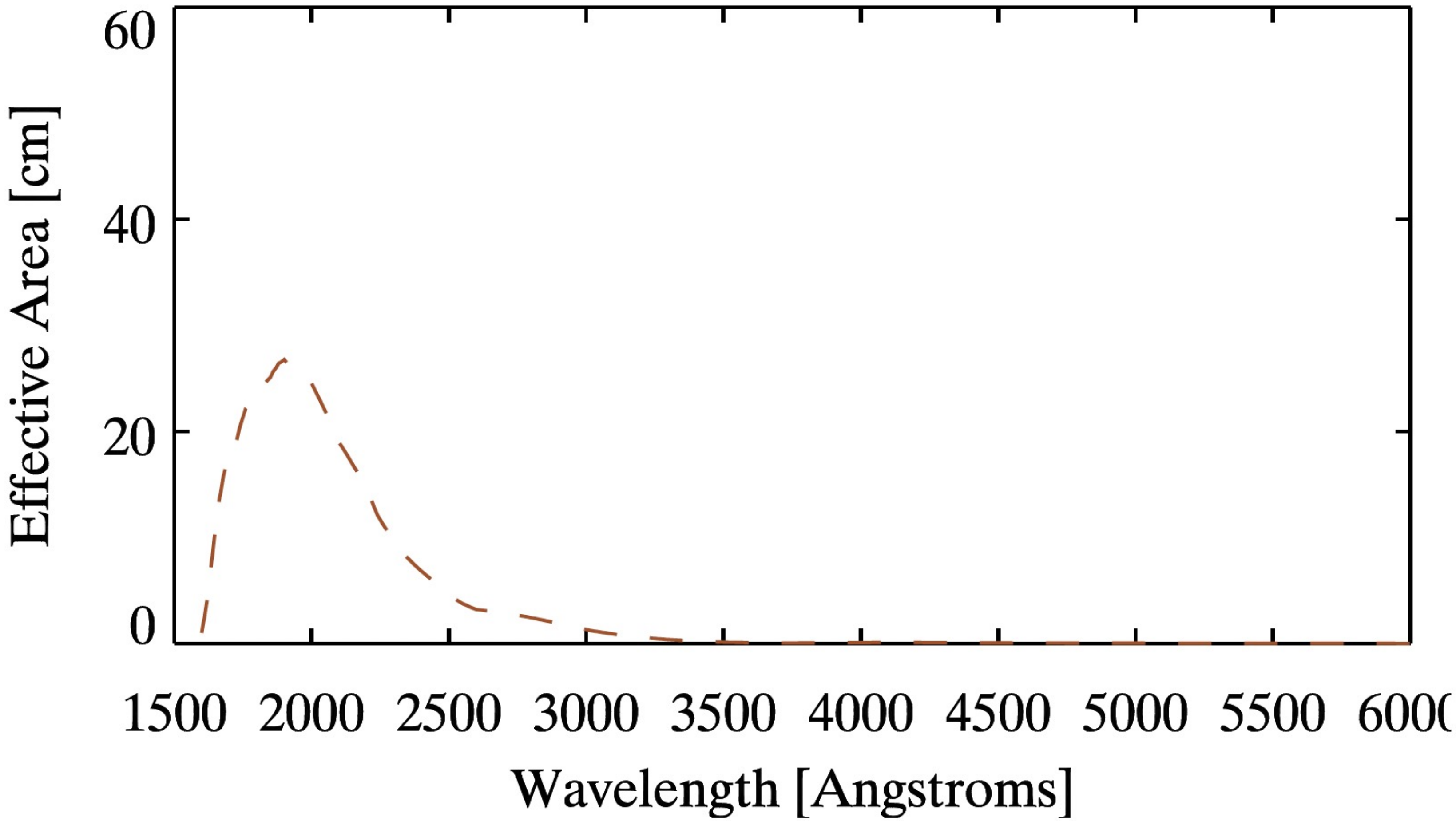


Fig 1

What is actually measured, however, is a total count rate

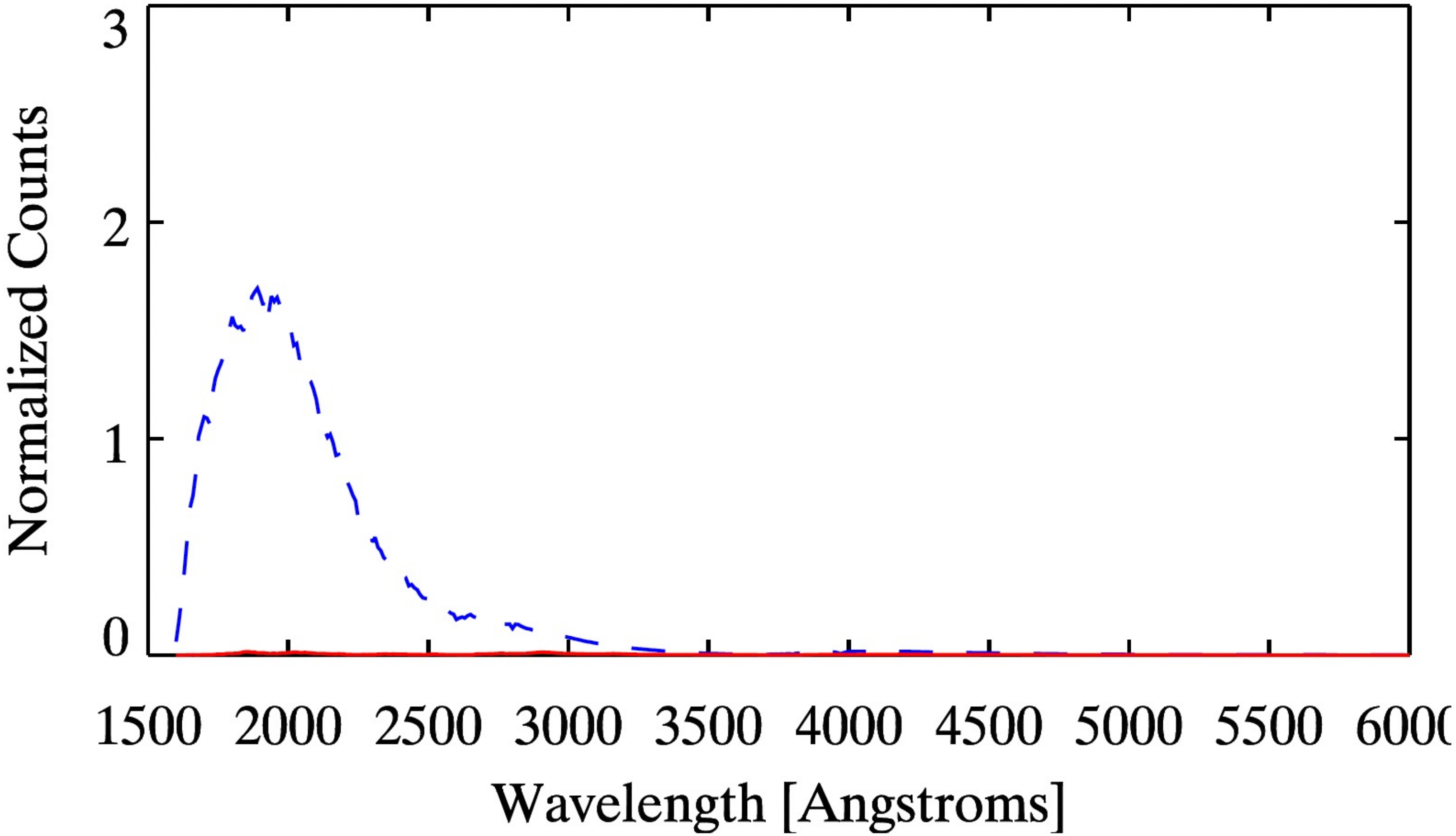


Fig 1

Observed count spectrum from Vega.

The energy of those counts depends on the spectral shape

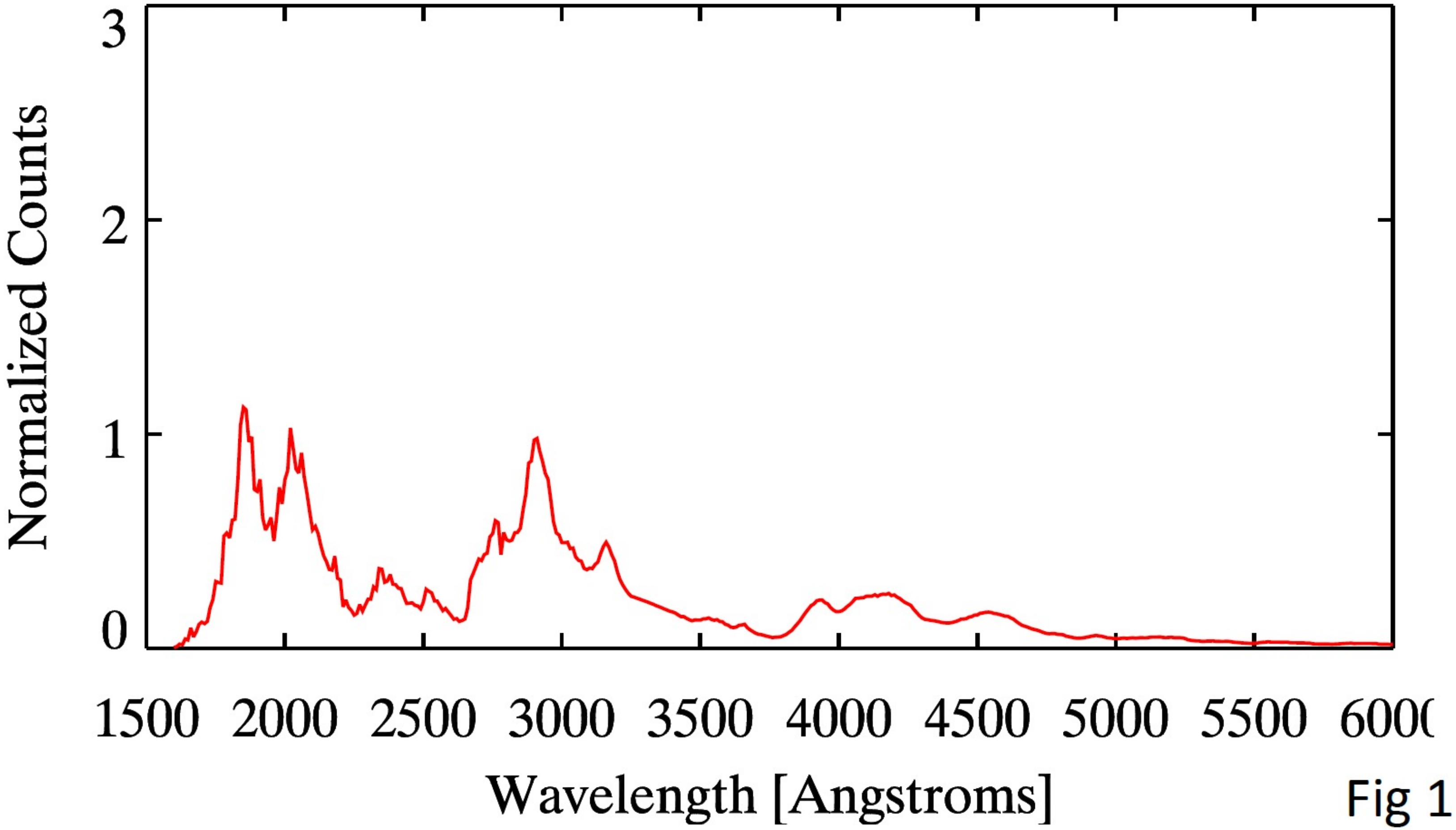


Fig 1

Observed count spectrum from Supernova Ia SN1992A.

The flux and the effective wavelength depends on the spectral shape

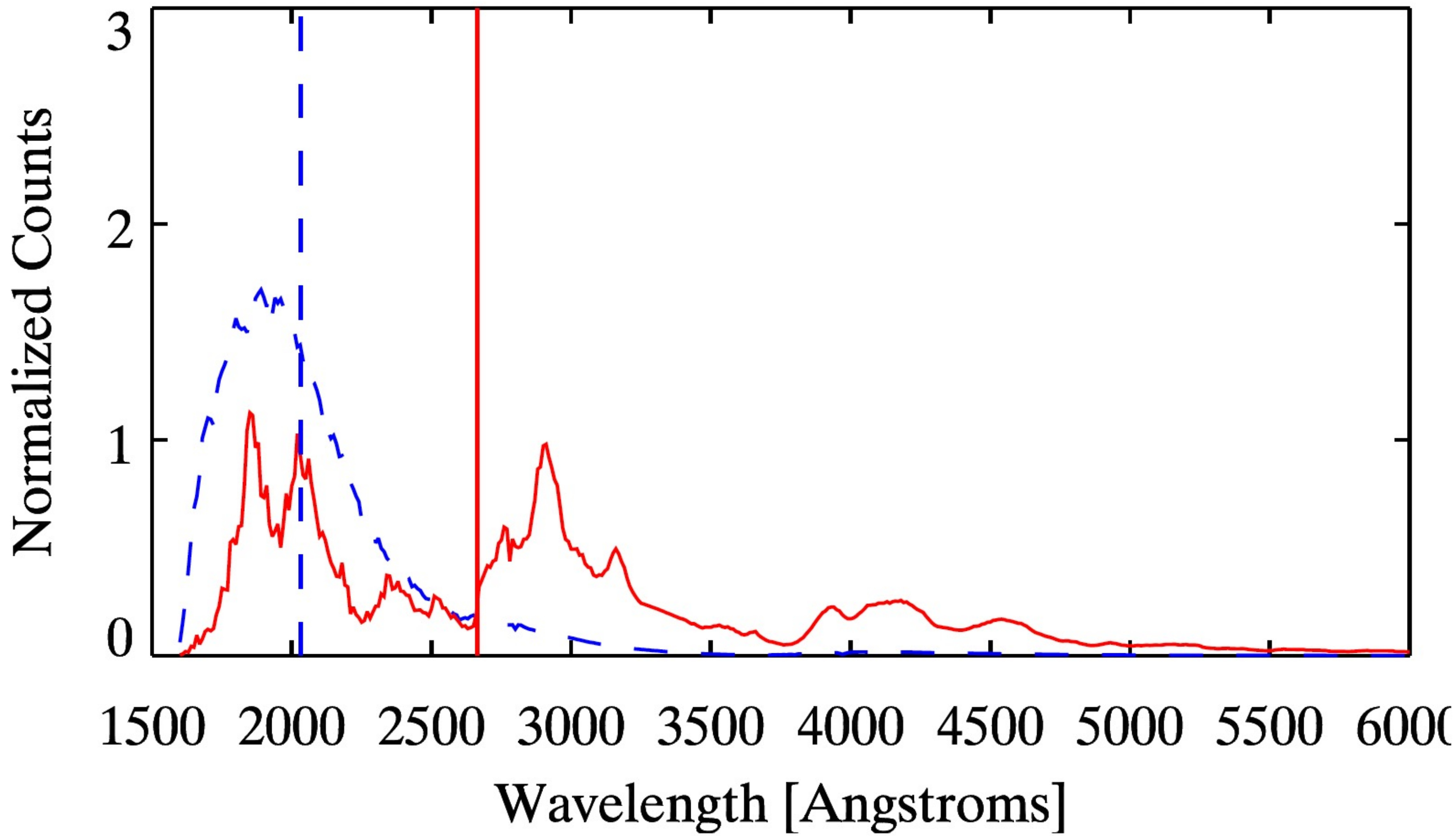


Fig 1

The ratio of integrated flux to integrated count rate varies greatly

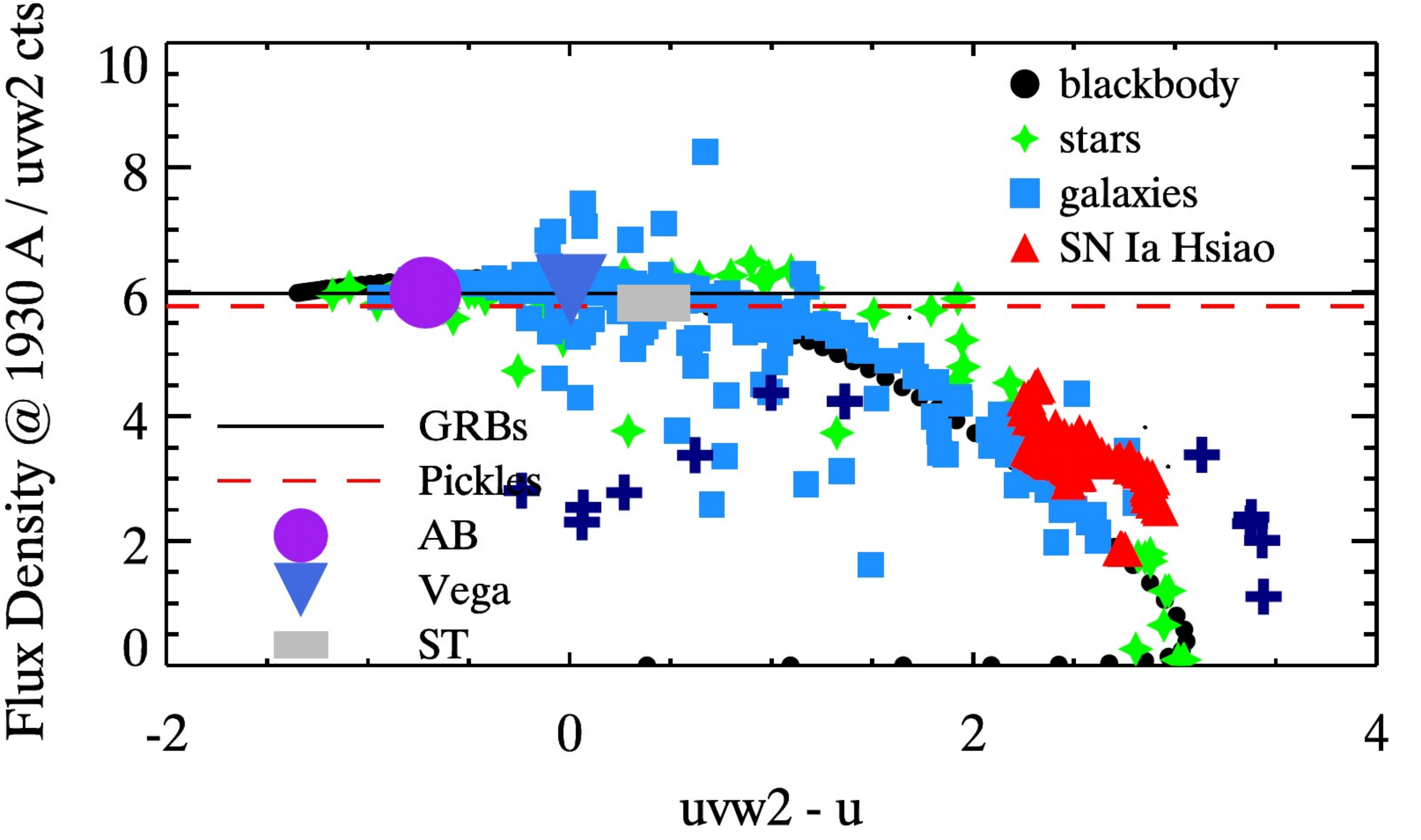


Fig 2

The flux and the effective wavelength depends on the spectral shape

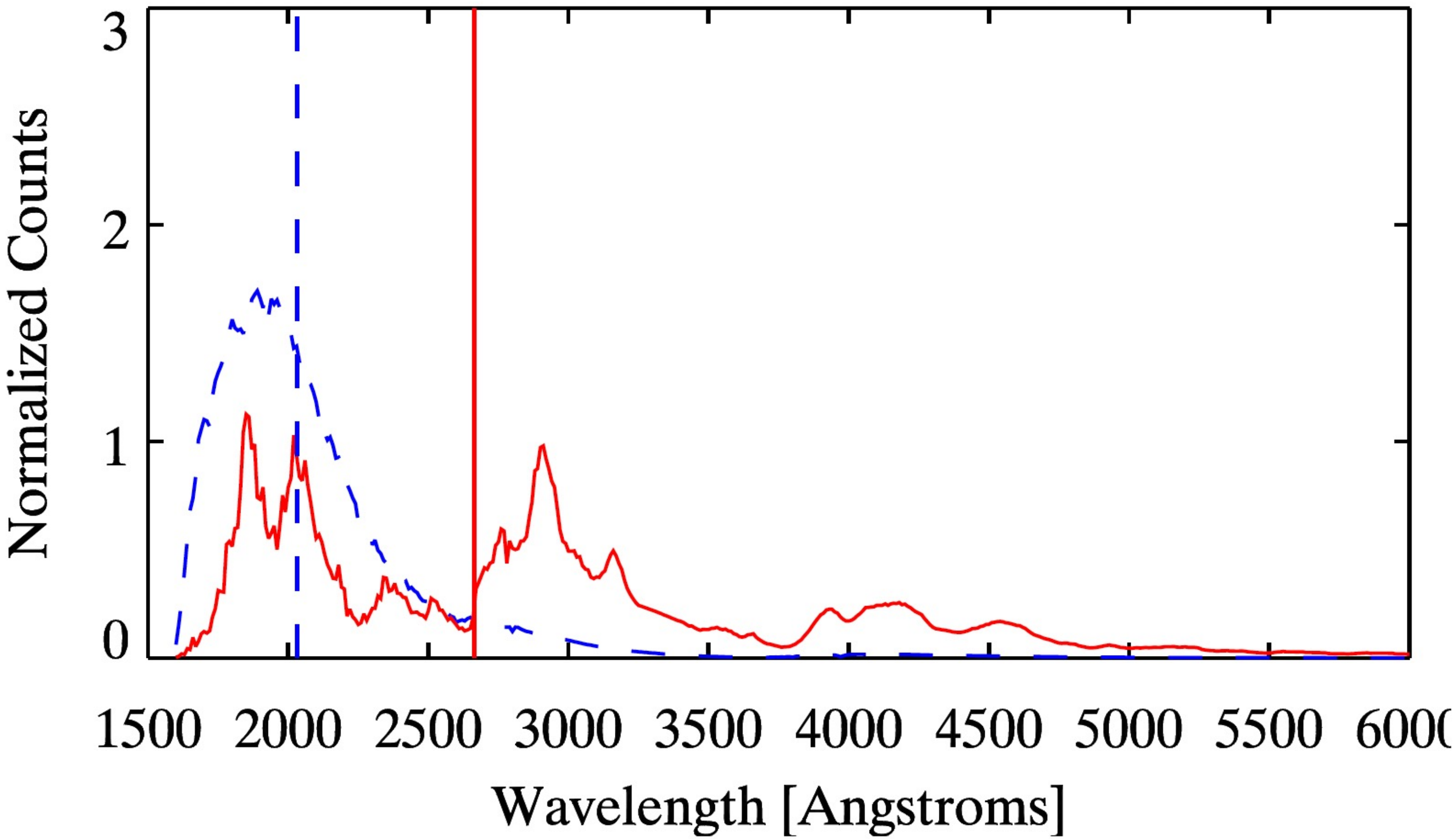
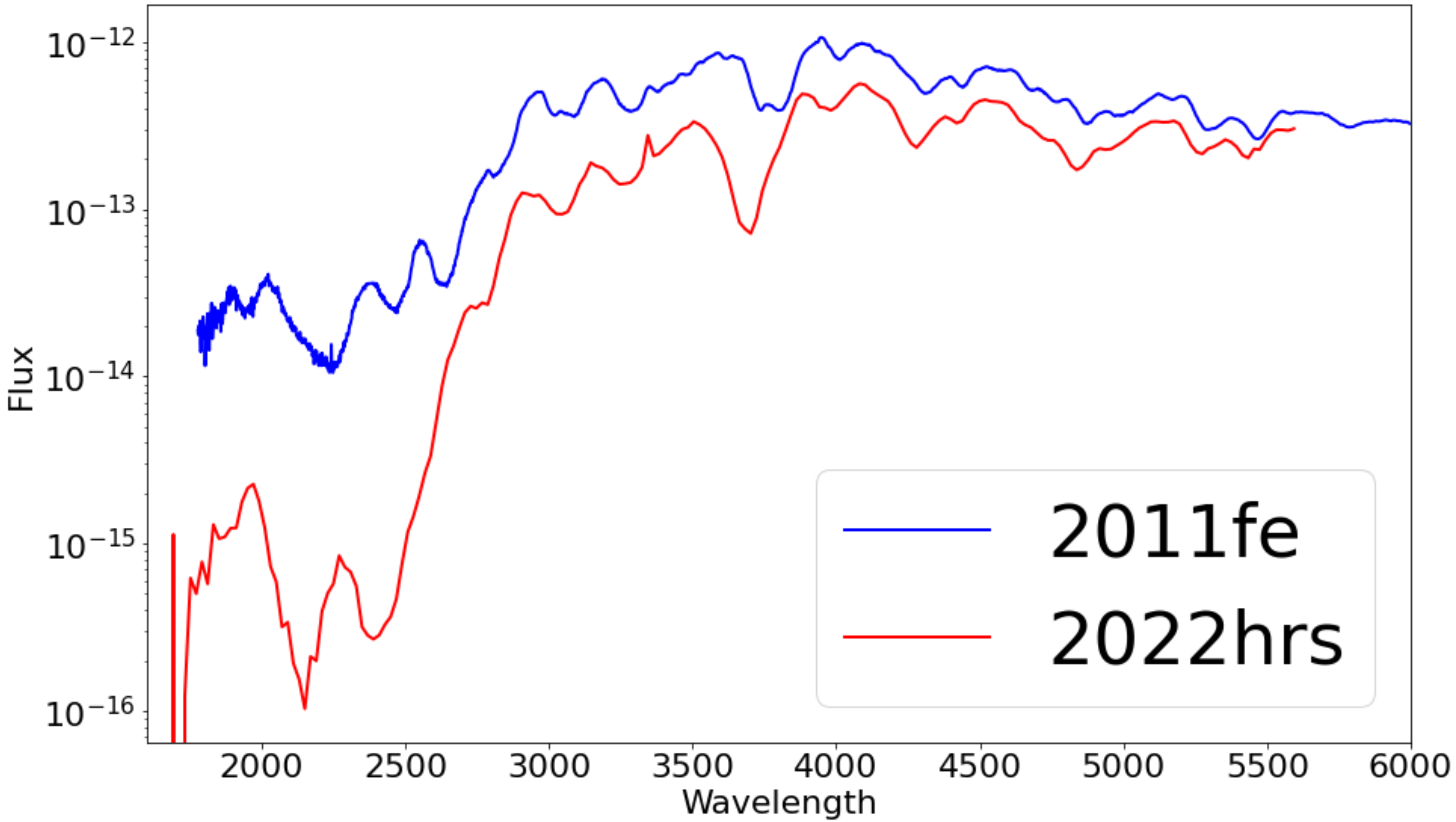
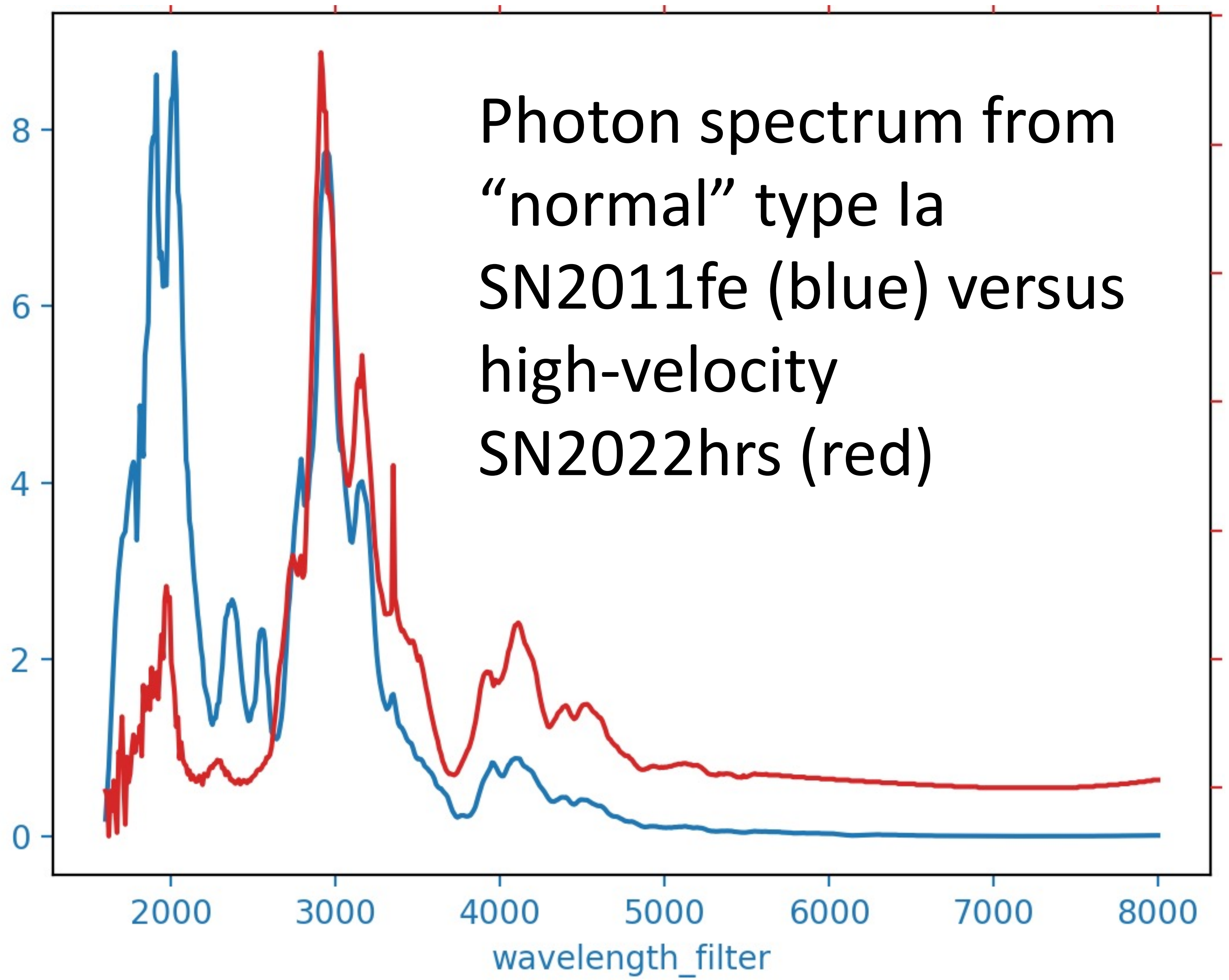
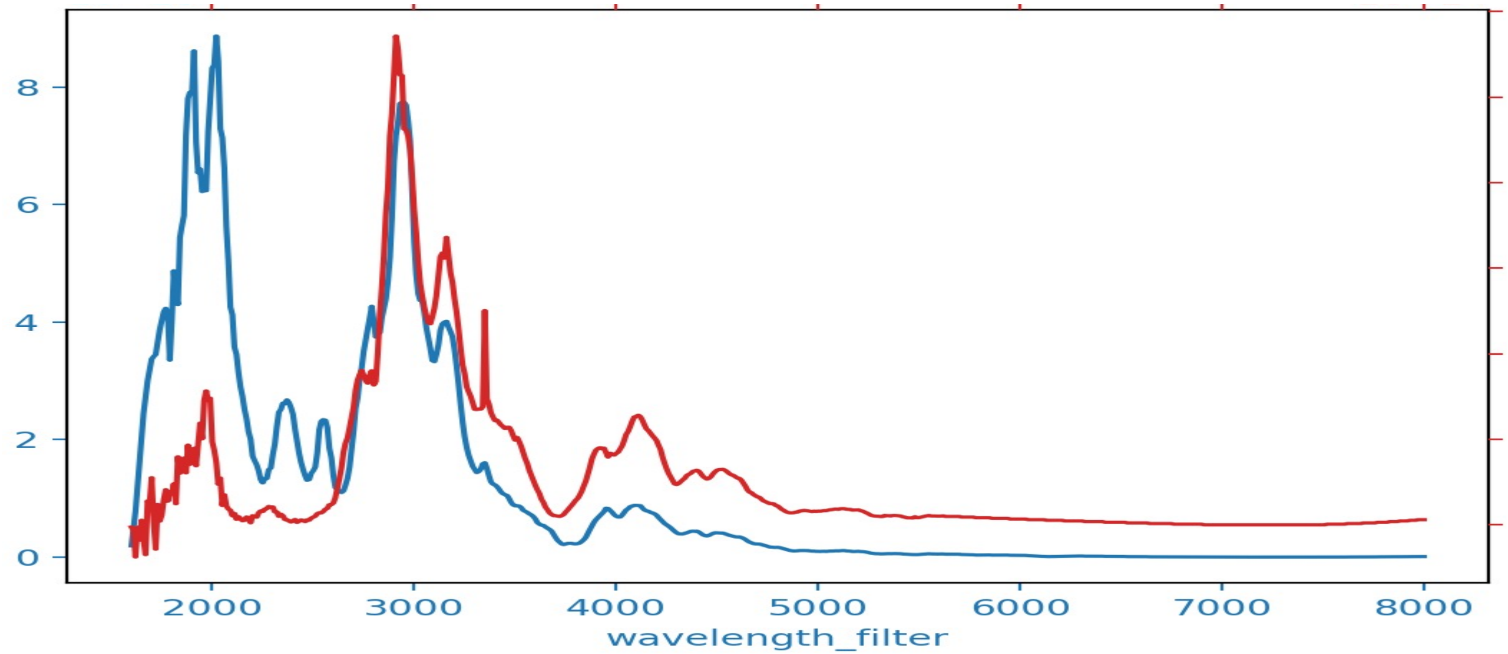


Fig 1

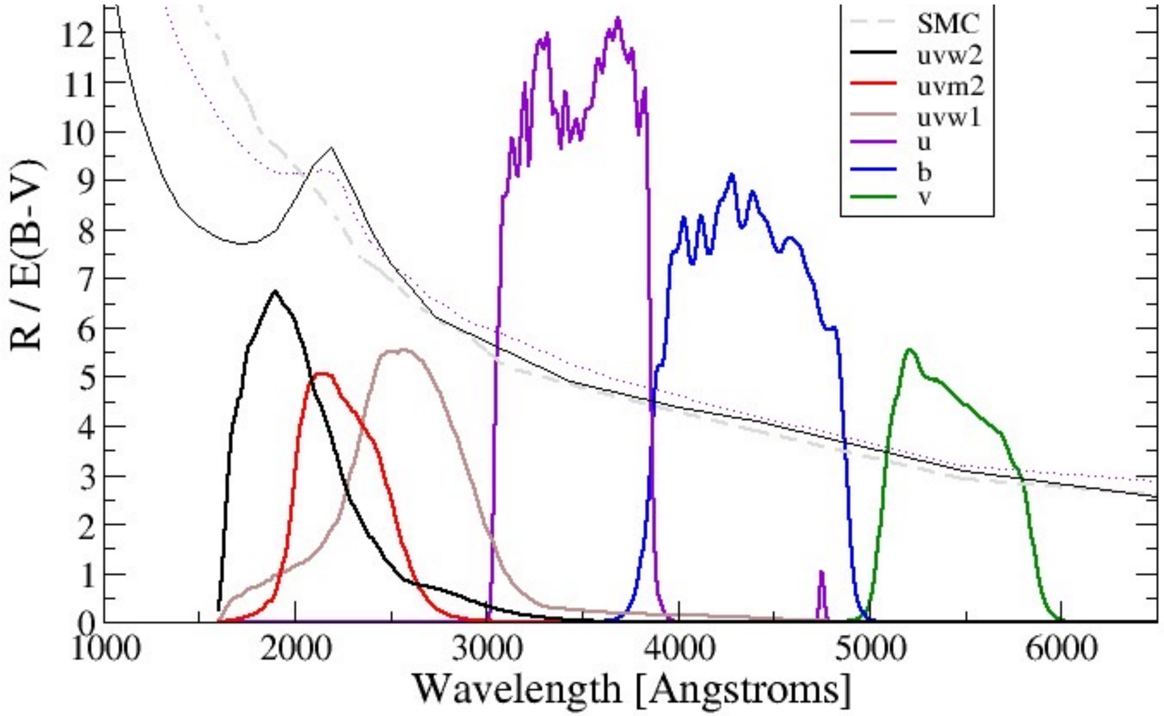


Flux
Wavelength
2011fe
2022hrs
2000
2500
3000
3500
4000
4500
5000
5500
6000


Photon spectrum from
“normal” type Ia
SN2011fe (blue) versus
high-velocity
SN2022hrs (red)
0
2
4
6
8
2000
3000
4000
5000
6000
7000
8000
wavelength_filter

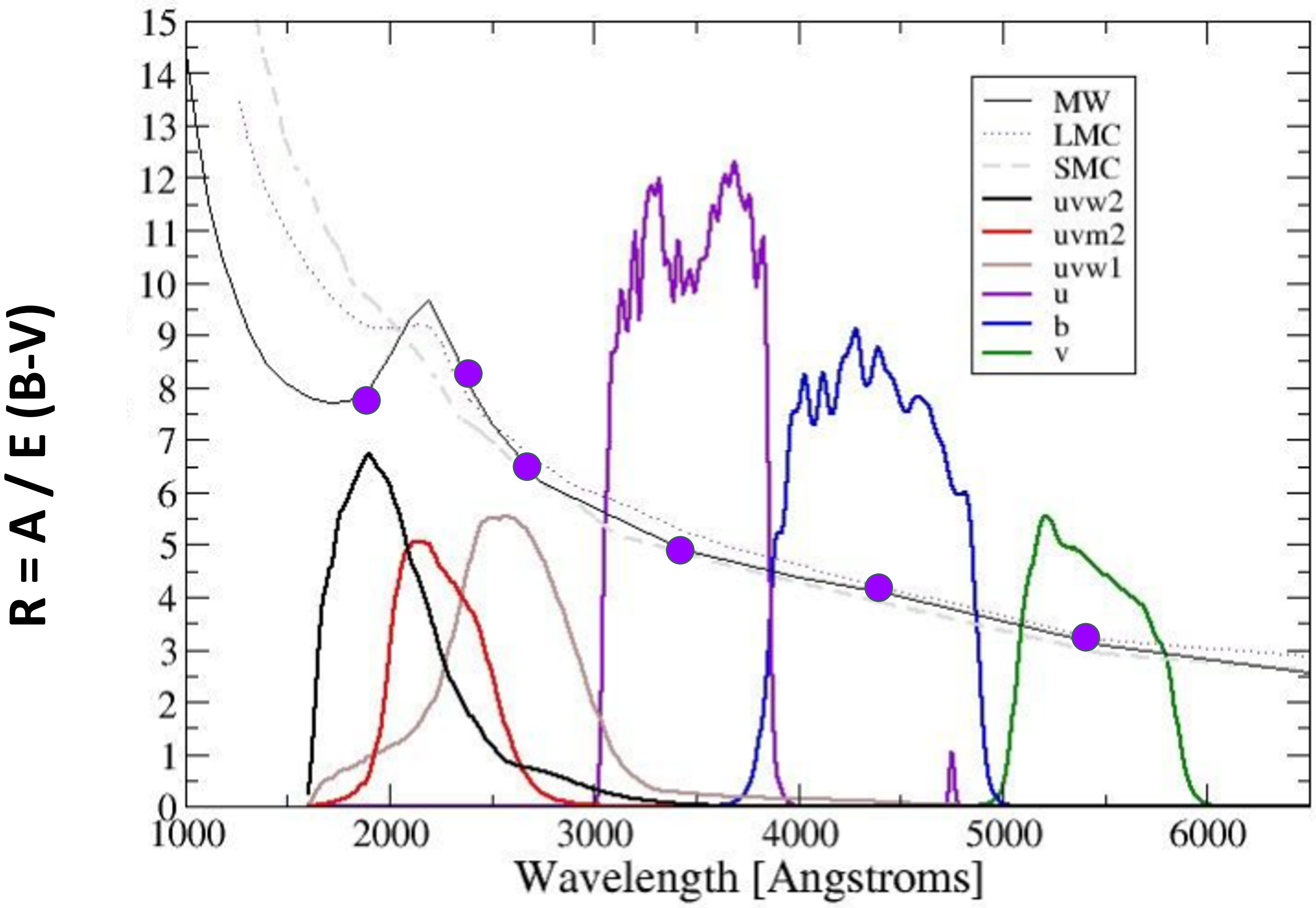


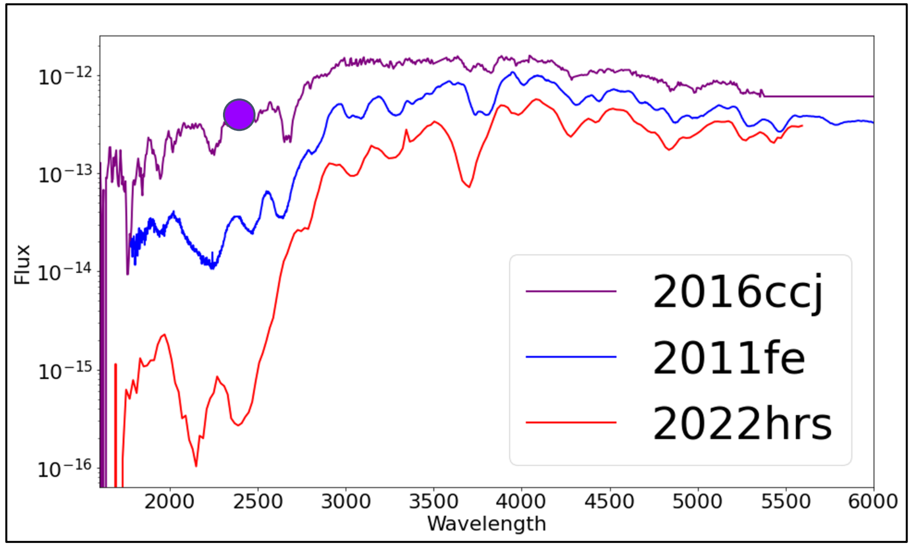
0
2
4
6
8
2000
3000
4000
5000
6000
7000
8000
wavelength_filter



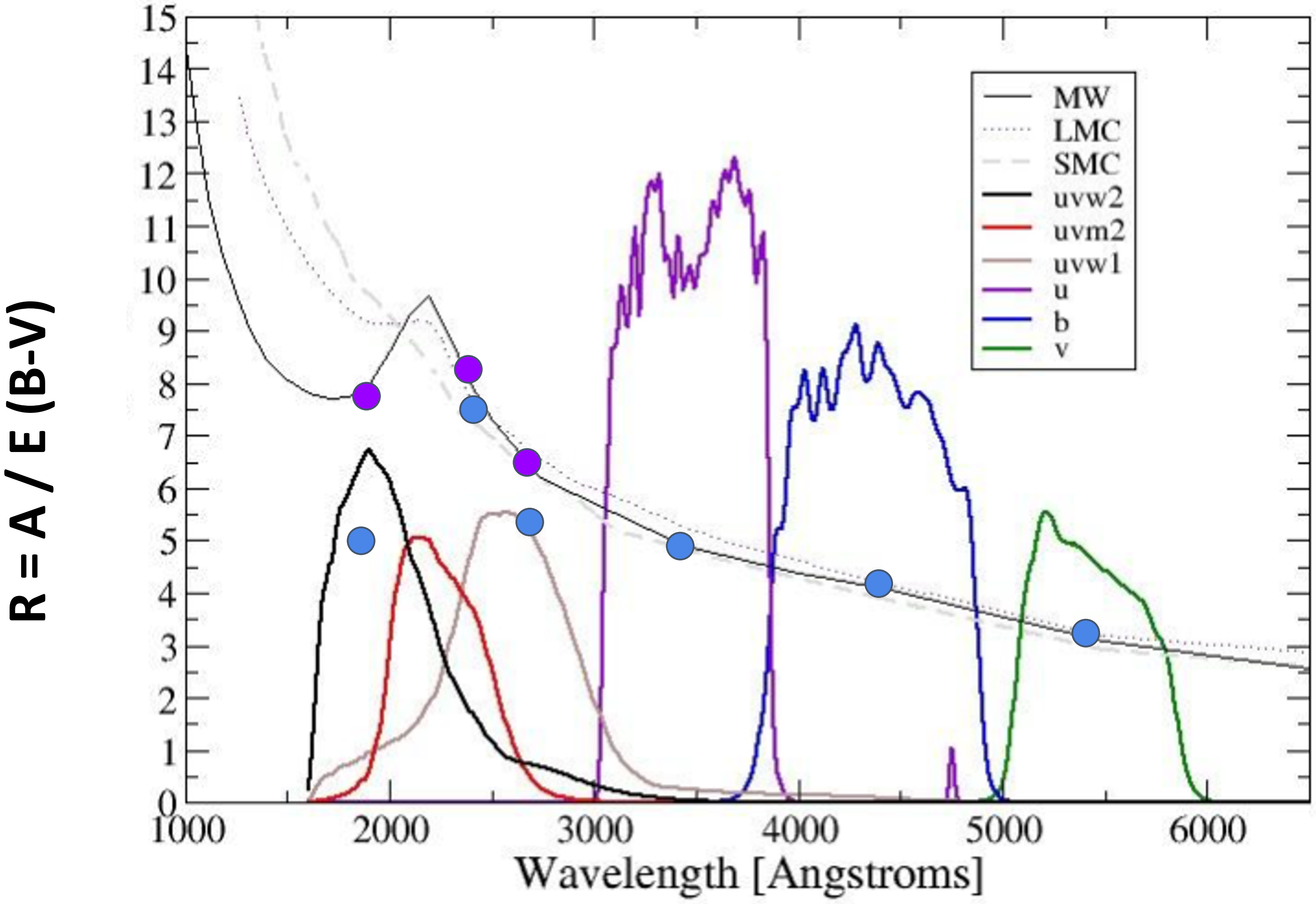
SMC
uvw2
uvm2
uvw1
u
b
v
R / E(B-V)
0
1
2
3
4
5
6
7
8
9
10
11
12
1000
2000
3000
4000
5000
6000
Wavelength [Angstroms]

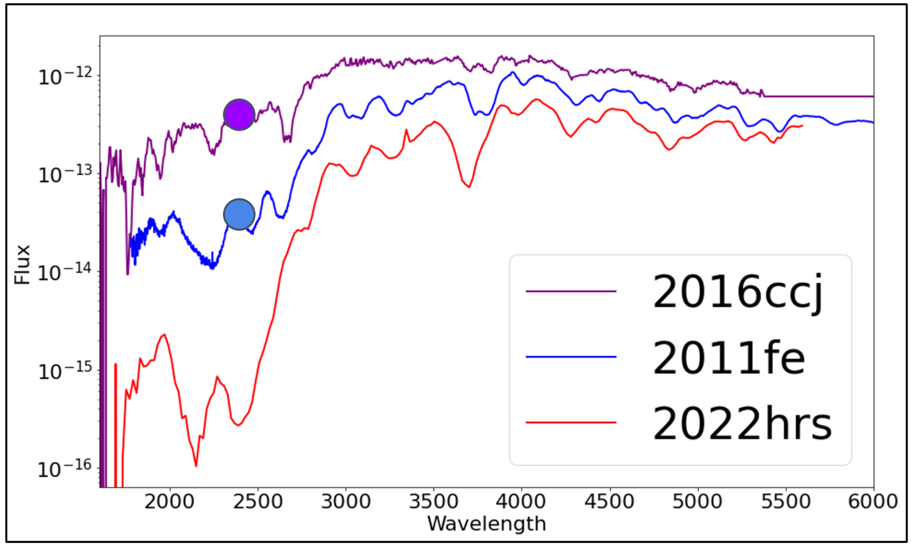
Extinction changes over the range of a broad filter





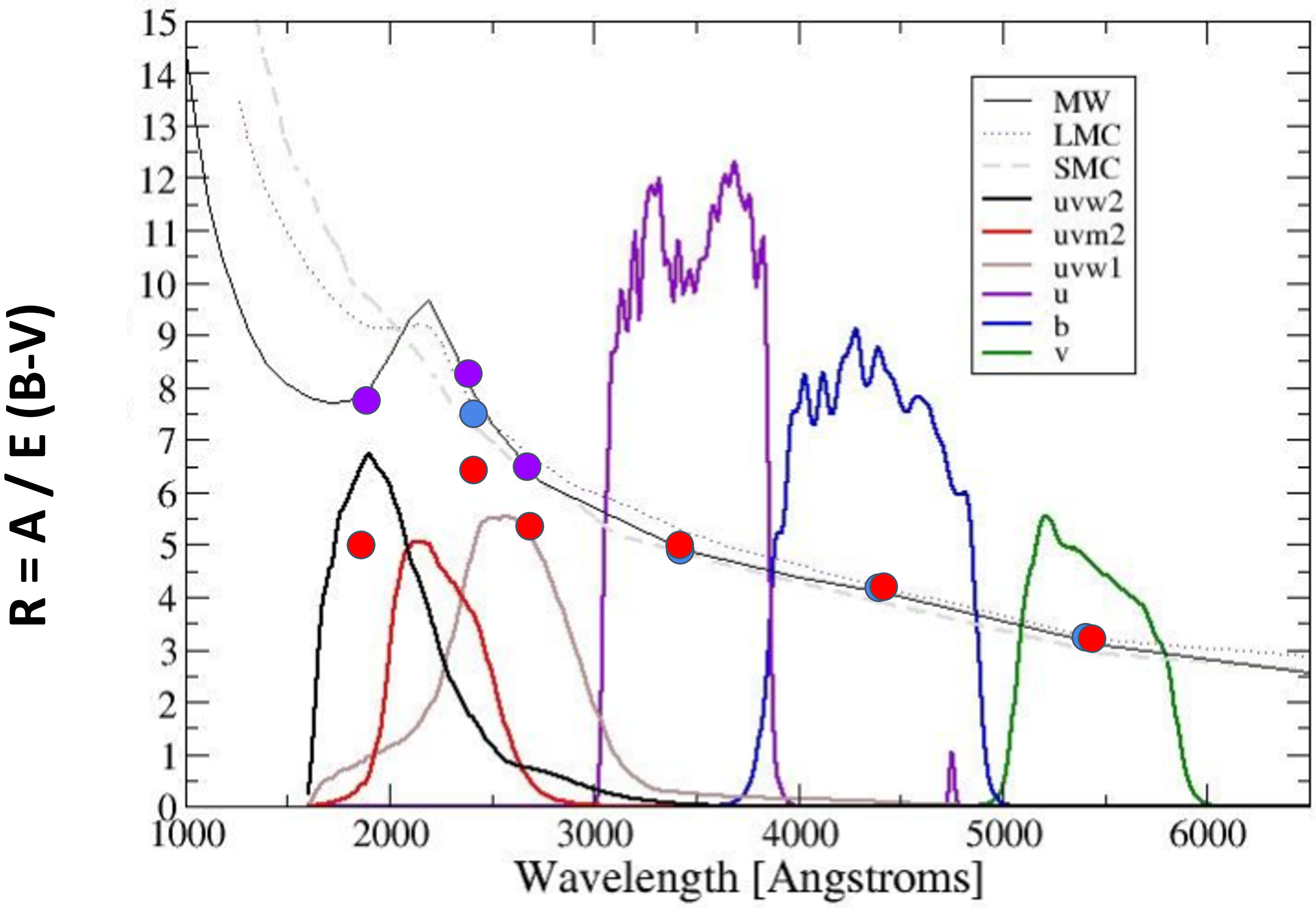
Extinction changes over the range of a broad filter

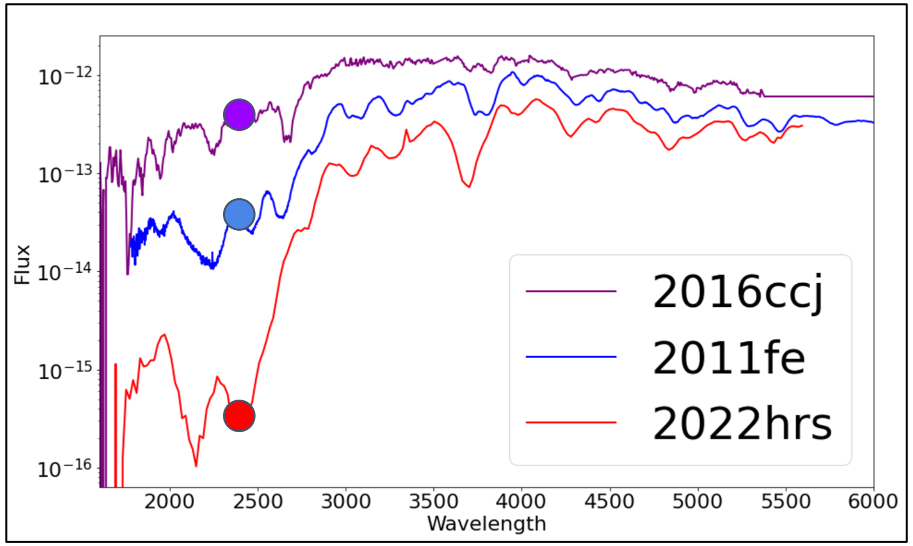




A redder spectrum has a lower extinction coefficient because the fraction of redder photons shifts

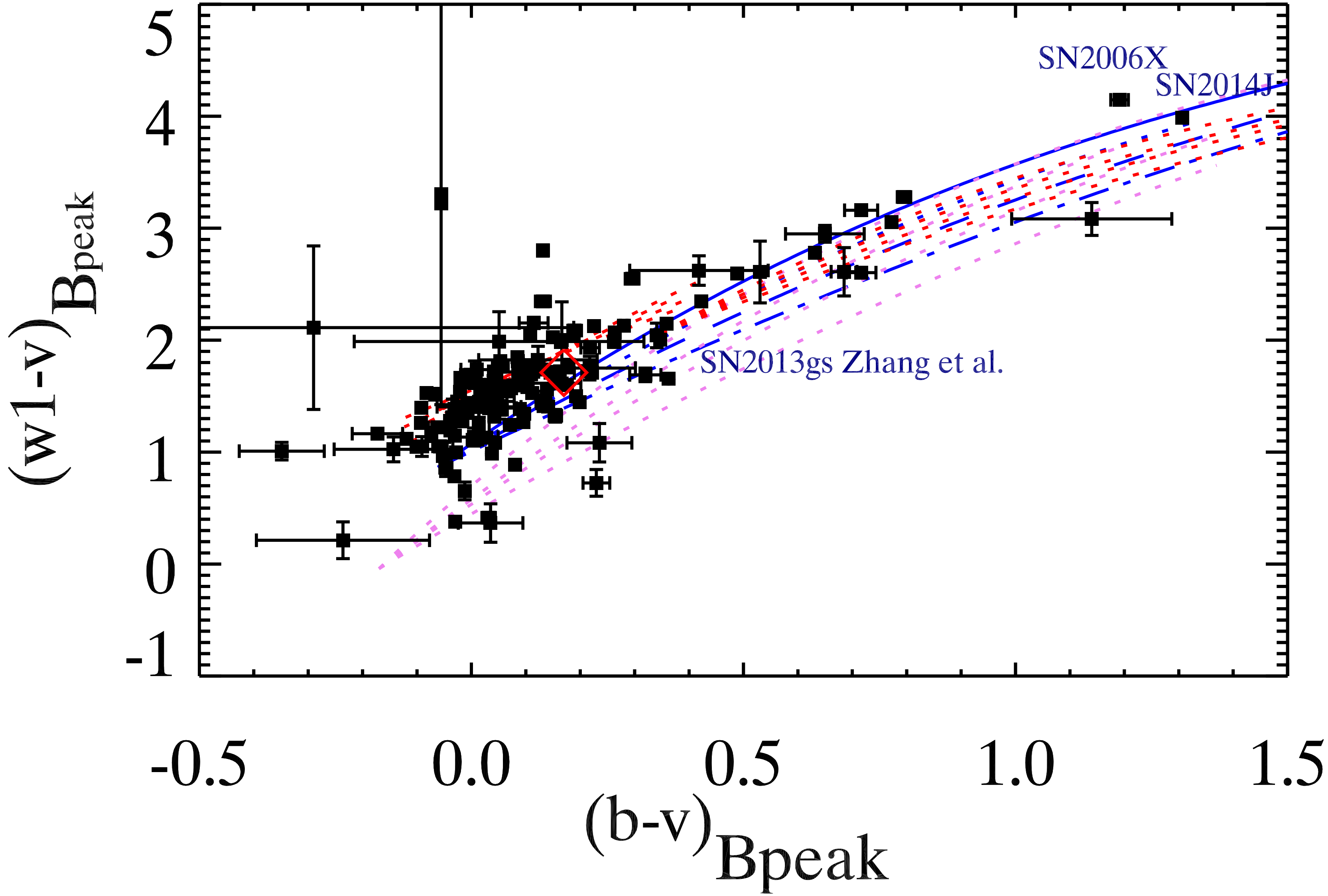
Extinction changes over the range of a broad filter





The effect is tiny in the optical, but up to 20% in the UV

Filter extinction coefficients, k corrections, s corrections depend on spectral shape



Solution:

Build a grid of SN spectra with all available UV spectra, different choices of reddening, and other empirical or theoretical functions

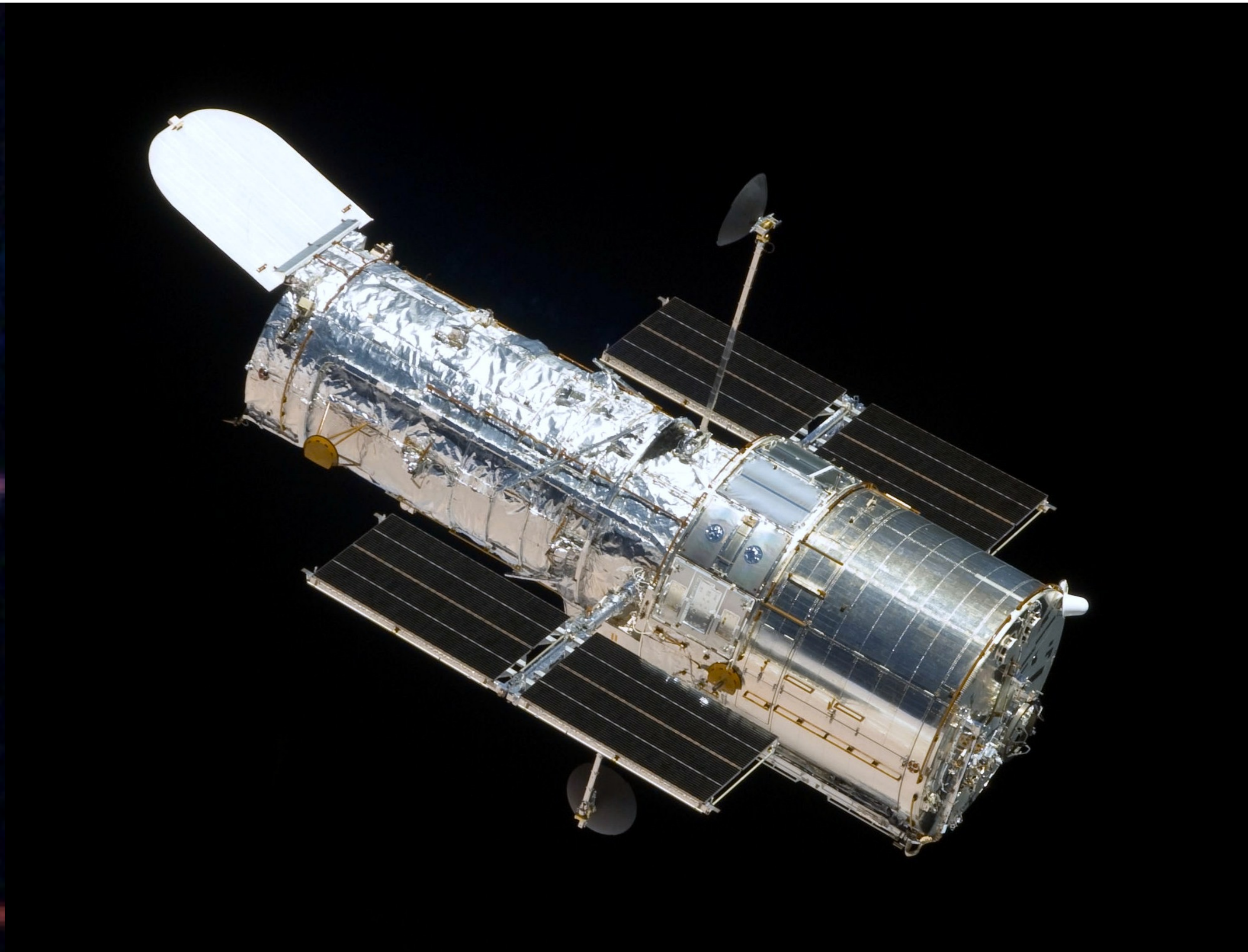
Find best matches to the photometry to compute average value and dispersion of spectrum-dependent values

What is the physical cause of the UV differences?

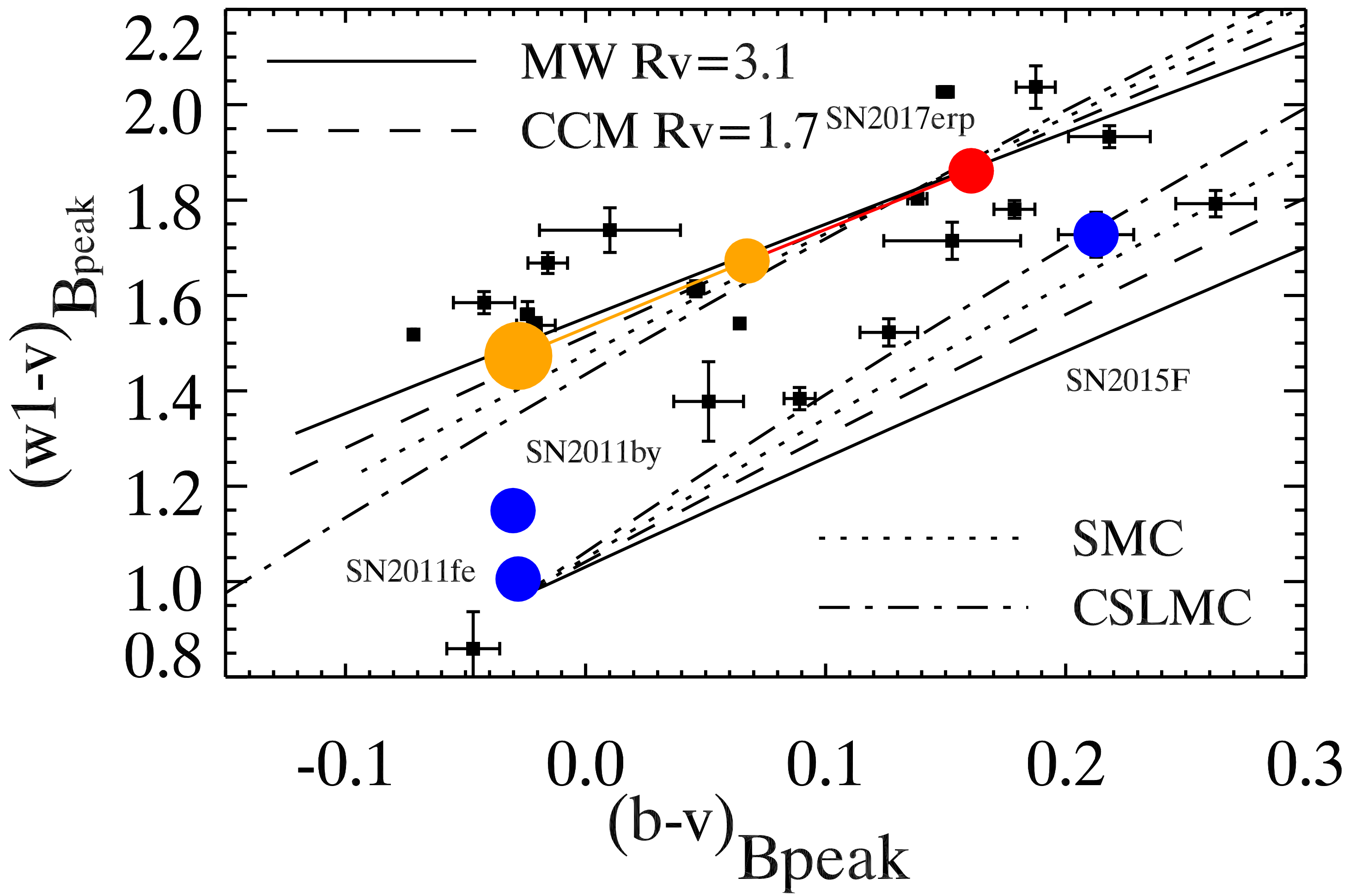
Does it change with redshift?

How much does it affect cosmological measurements?

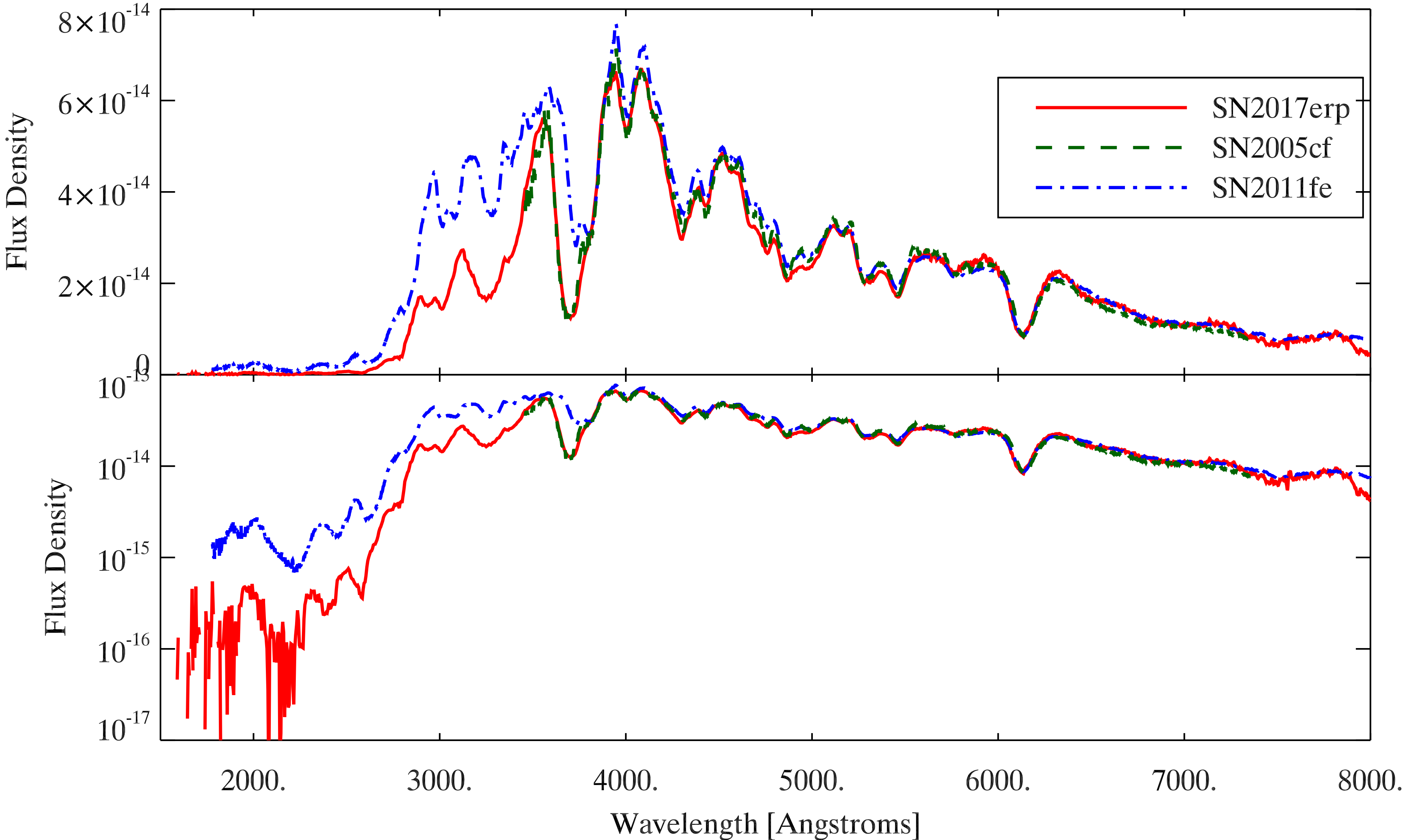
What insights can be gained from Ultraviolet spectroscopy?



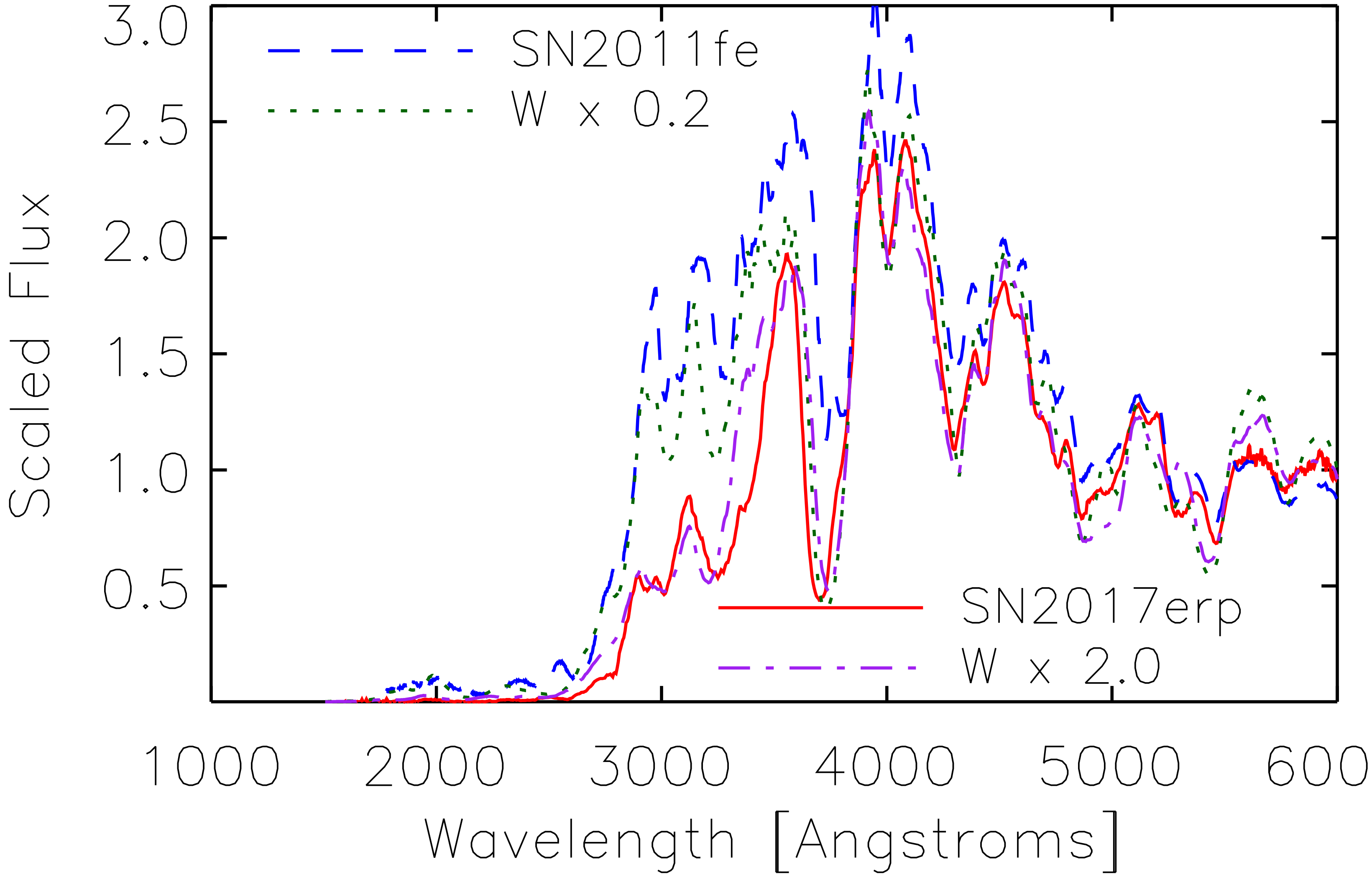
SN2017erp is very normal in optical but intrinsically red after correction for reddening by MW and host dust



Optically-normal spectra – difference is UV !



Metallicity is a possible explanation for difference in the near-UV (3000 A) features



What is the physical cause of the UV differences?

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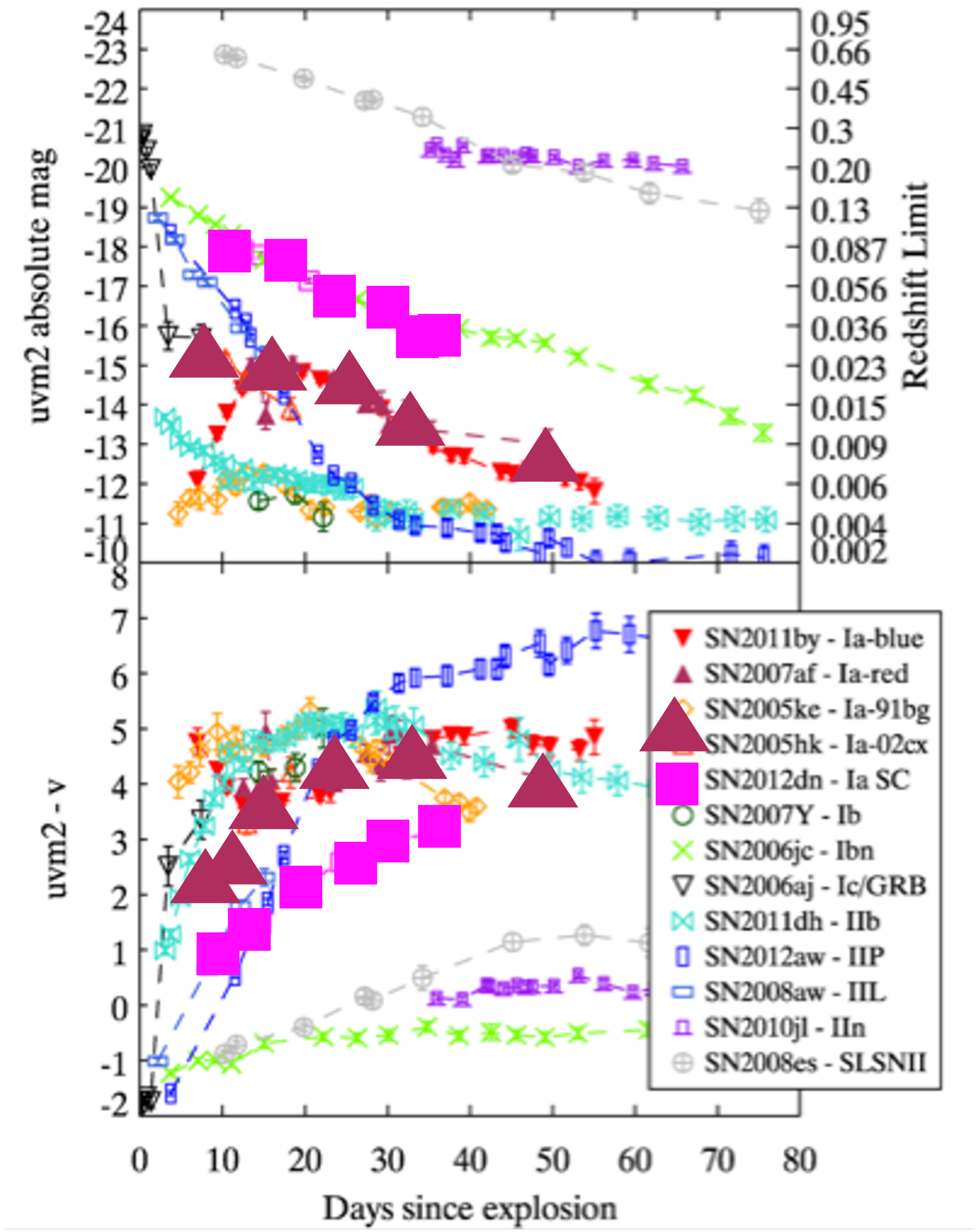
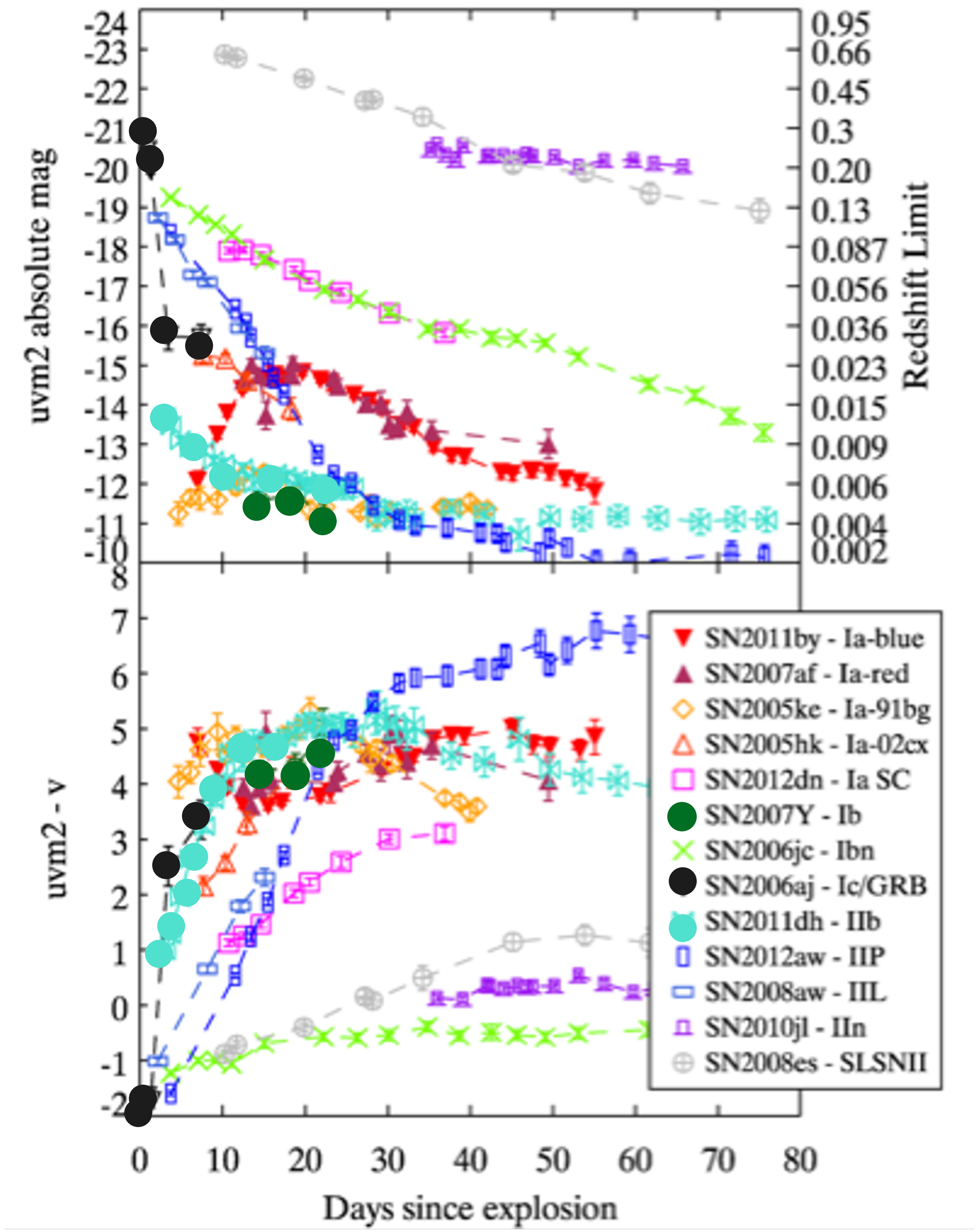


Thermonuclear Iax and SuperC SNe Ia

Hotter, more ionized explosion

Excess flux from H-poor interaction?

Brown et al. 2015
arXiv:1505.01368v1



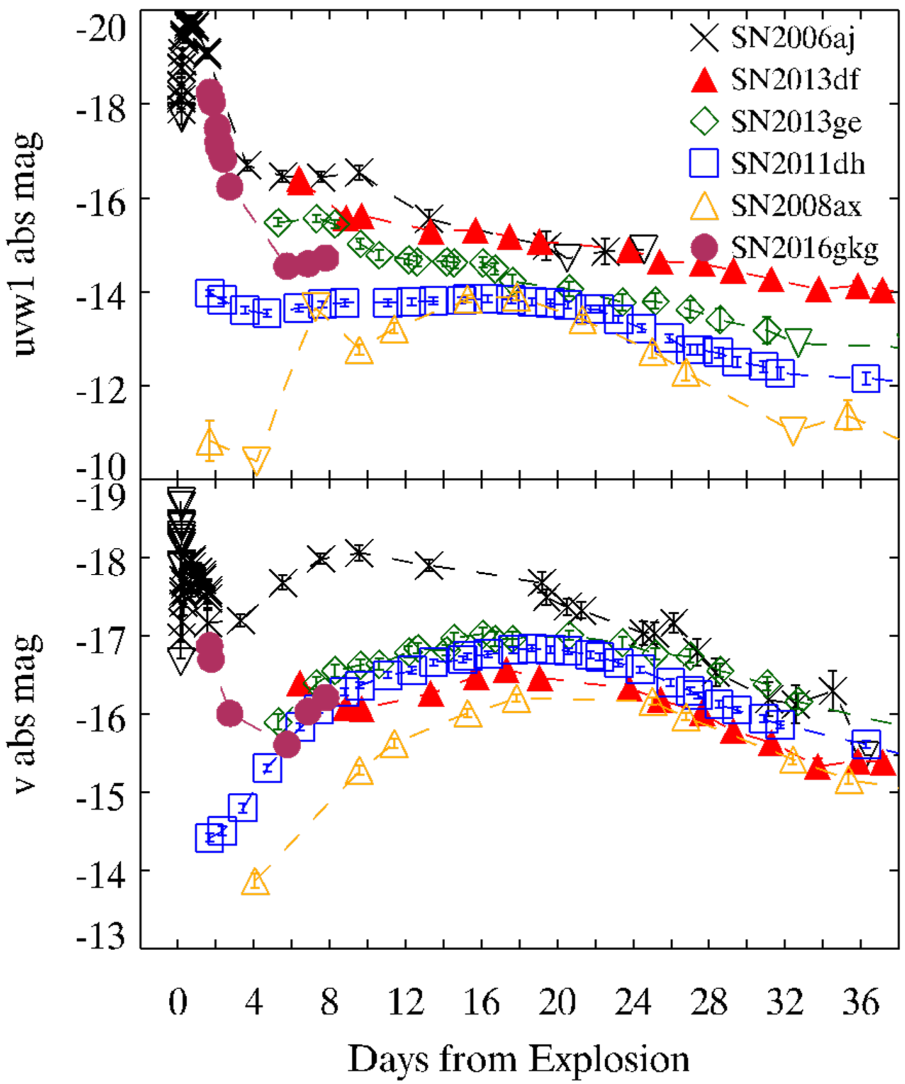
Stripped-envelope core-collapse SNe

Early, hot shock breakout

Radioactive peak

Brown et al. 2015
arXiv:1505.01368v1

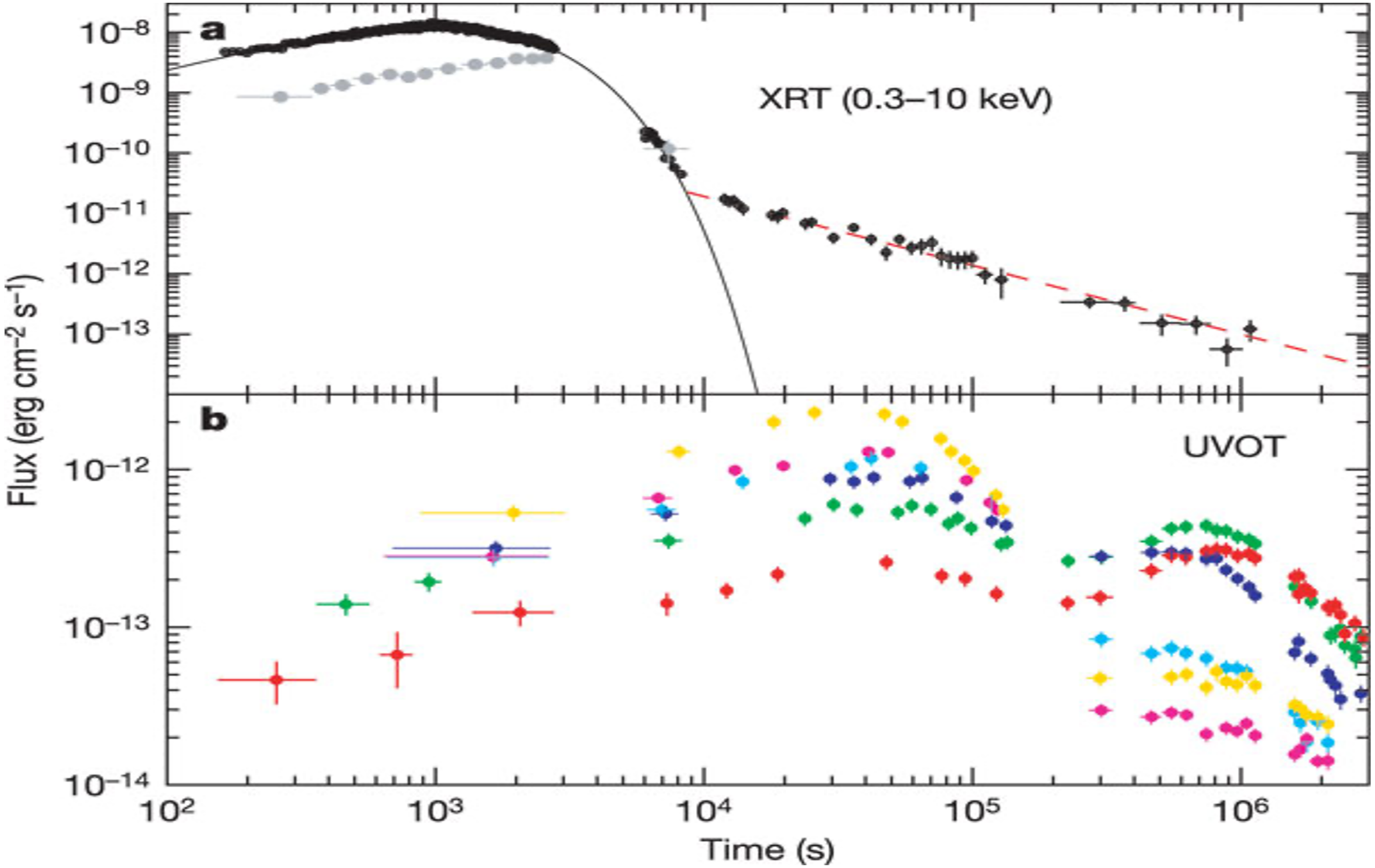
Stripped-Envelope Core-Collapse SNe



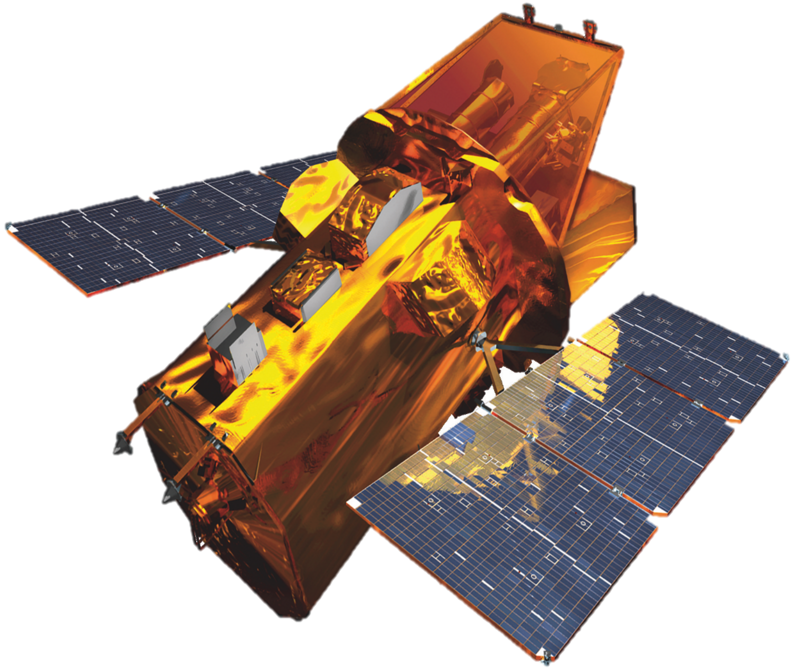
UV observations of the shock breakout constrain the temperature and size of photosphere

> size of progenitor

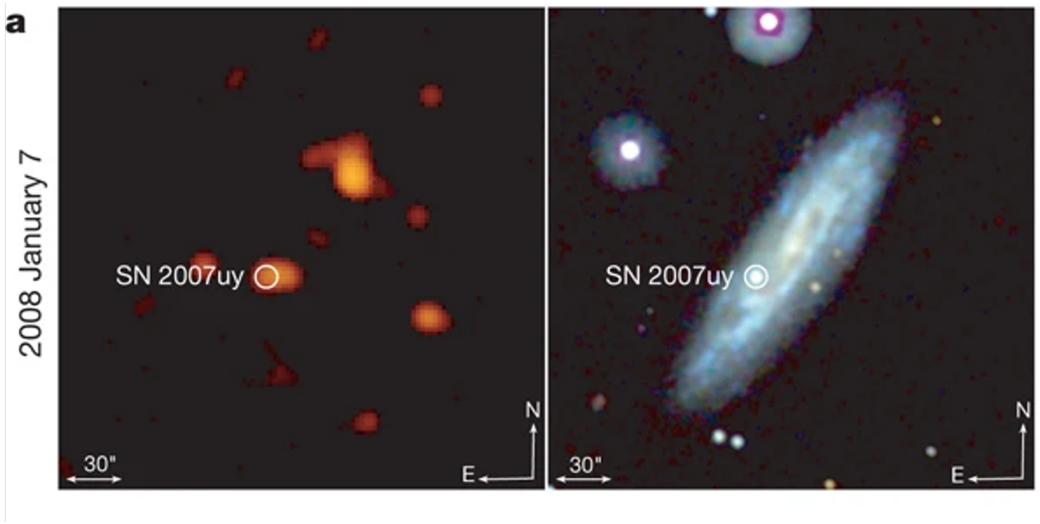
GRB060218 → SN2006aj



Campana et al. 2006

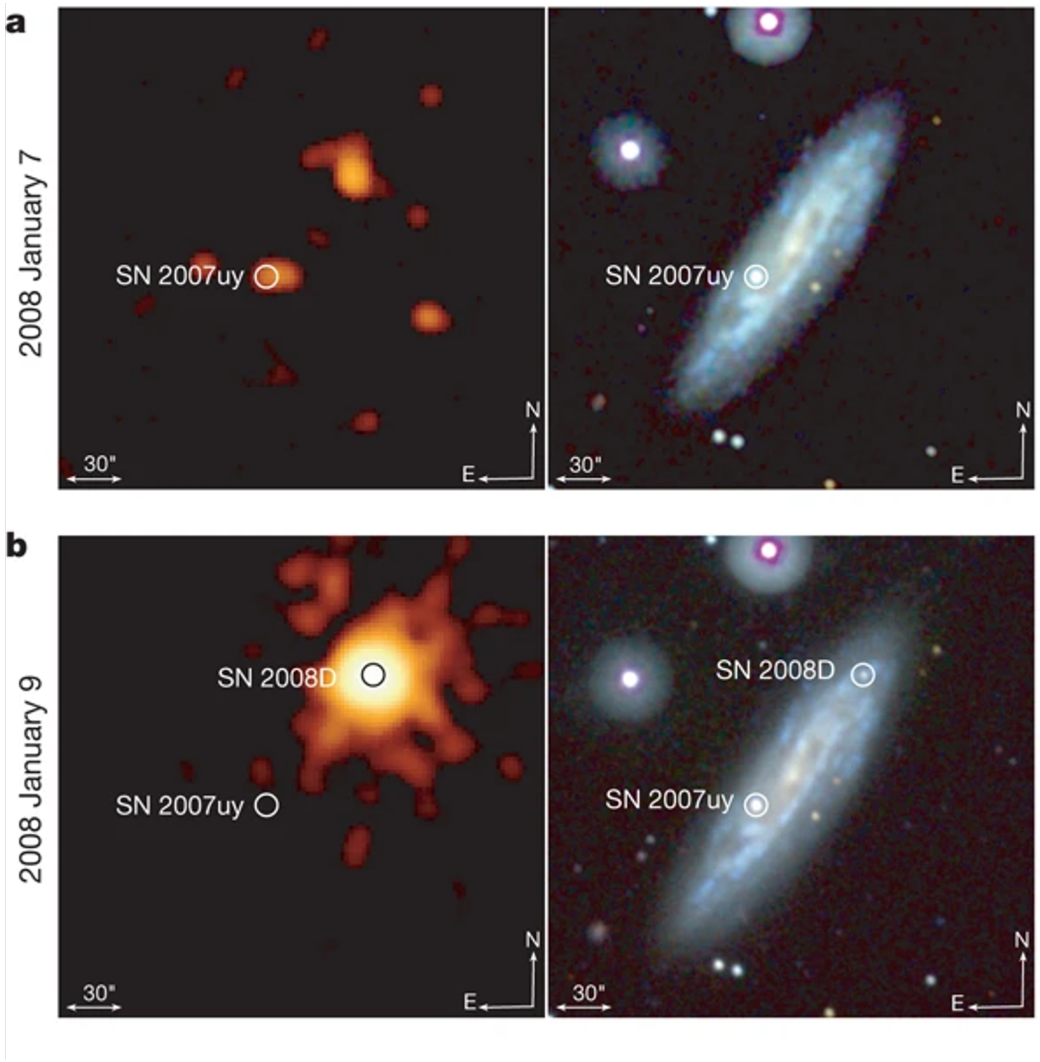


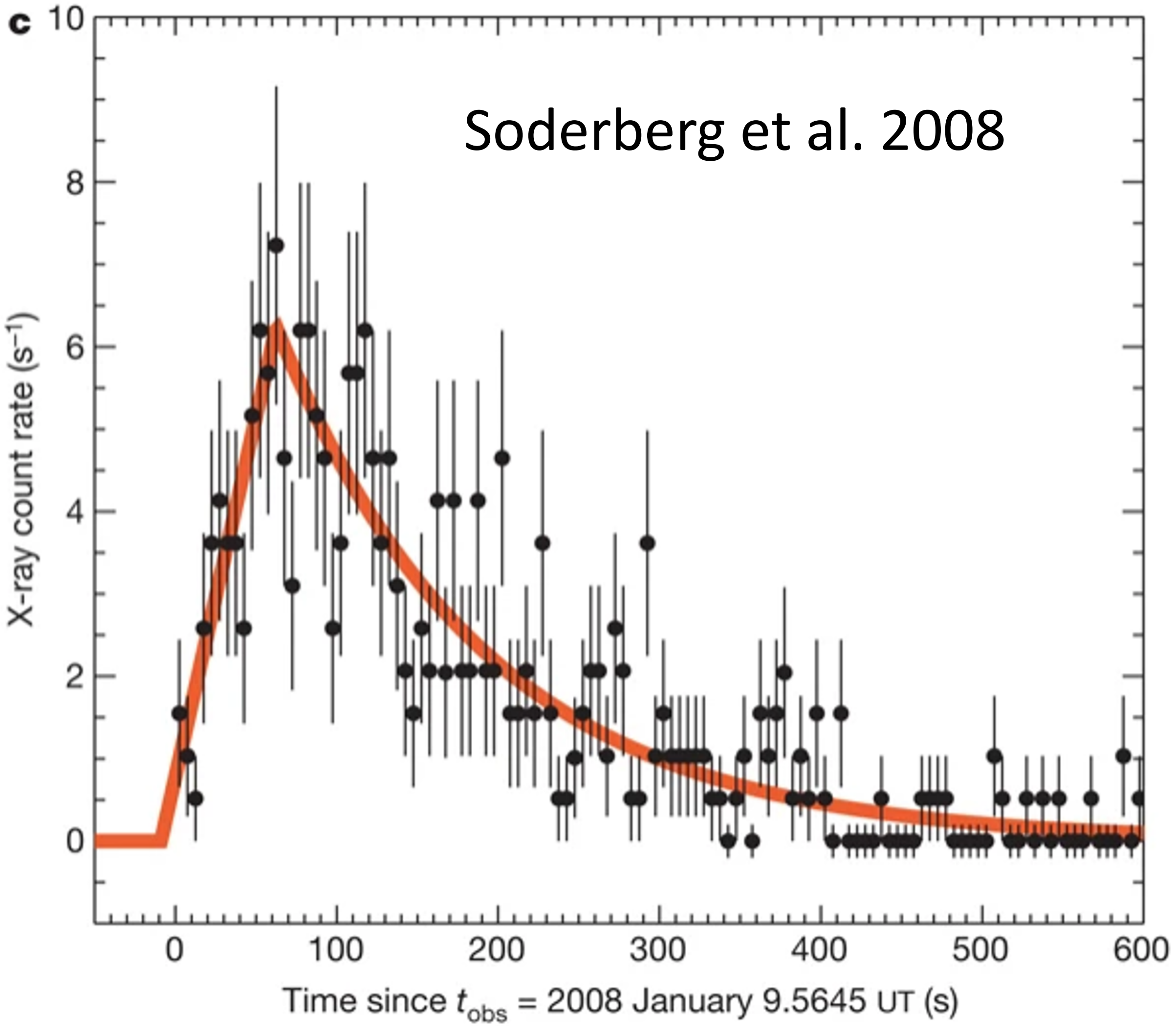
SN2007uy observations



Soderberg et al. 2008

SN2007uy observations serendipitously detect SN2008D

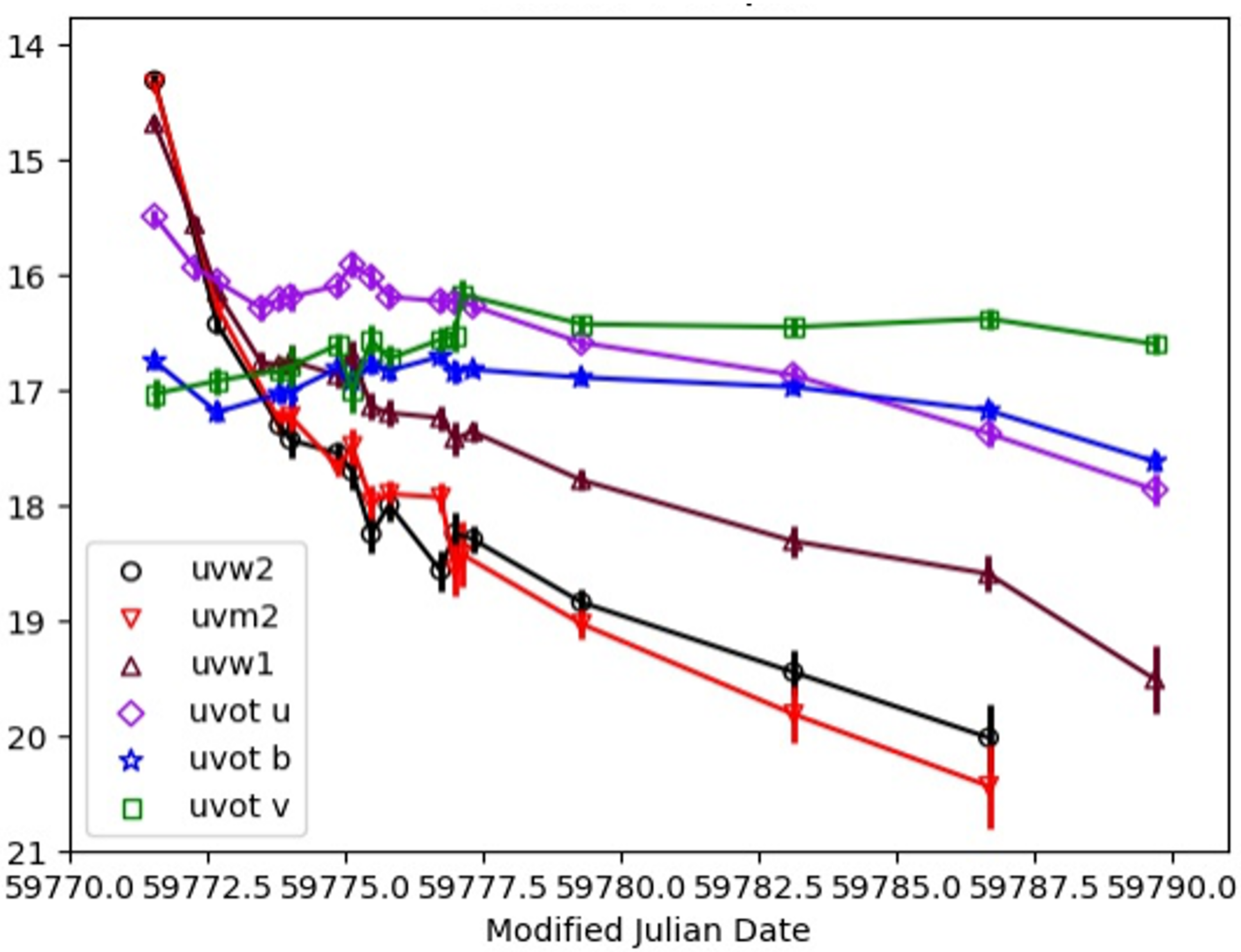


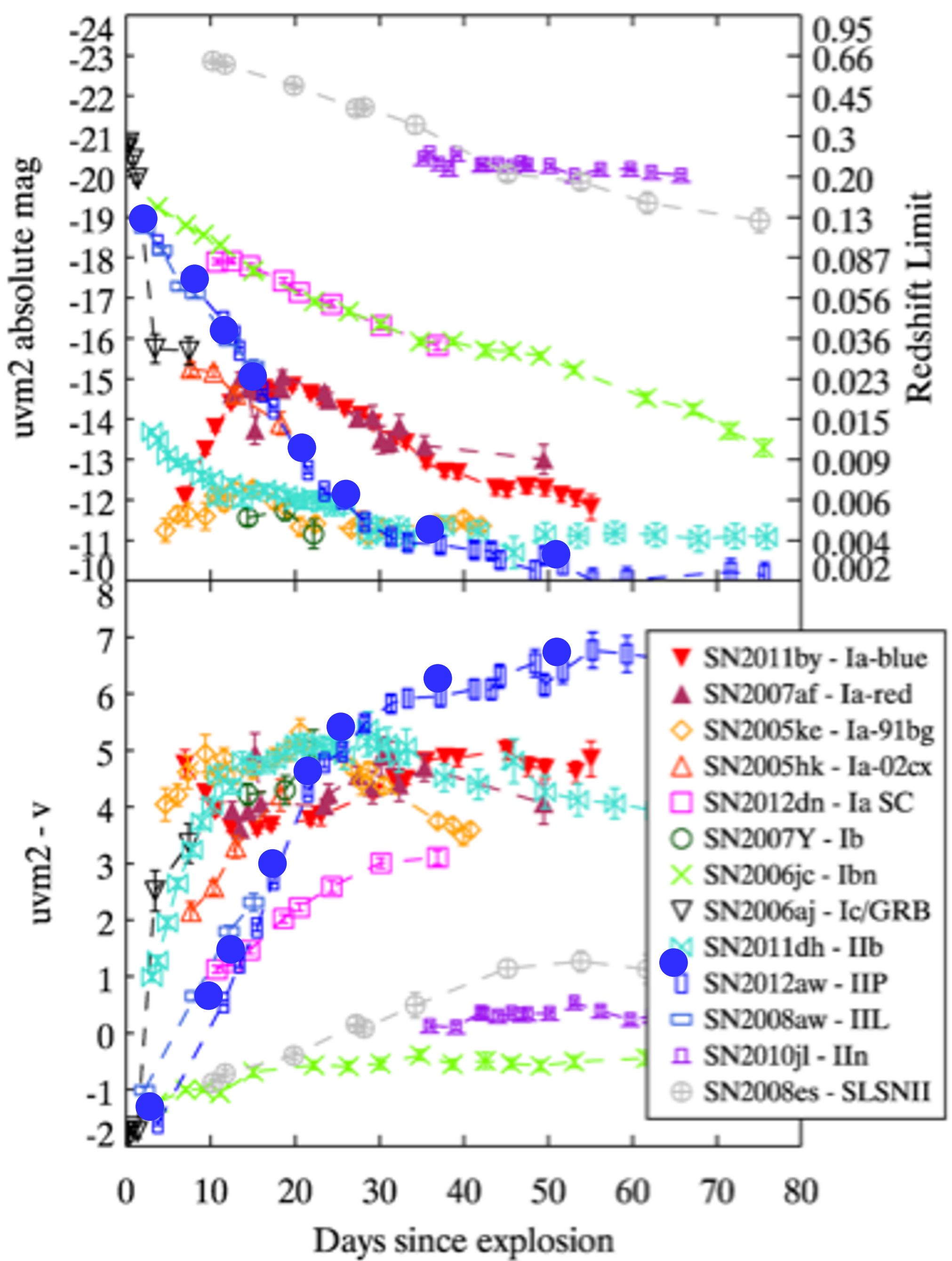


Soderberg et al. 2008

SN2022oqm found in high cadence ZTF data, promptly identified, requested and observed by Swift

see Irani et al. 2022

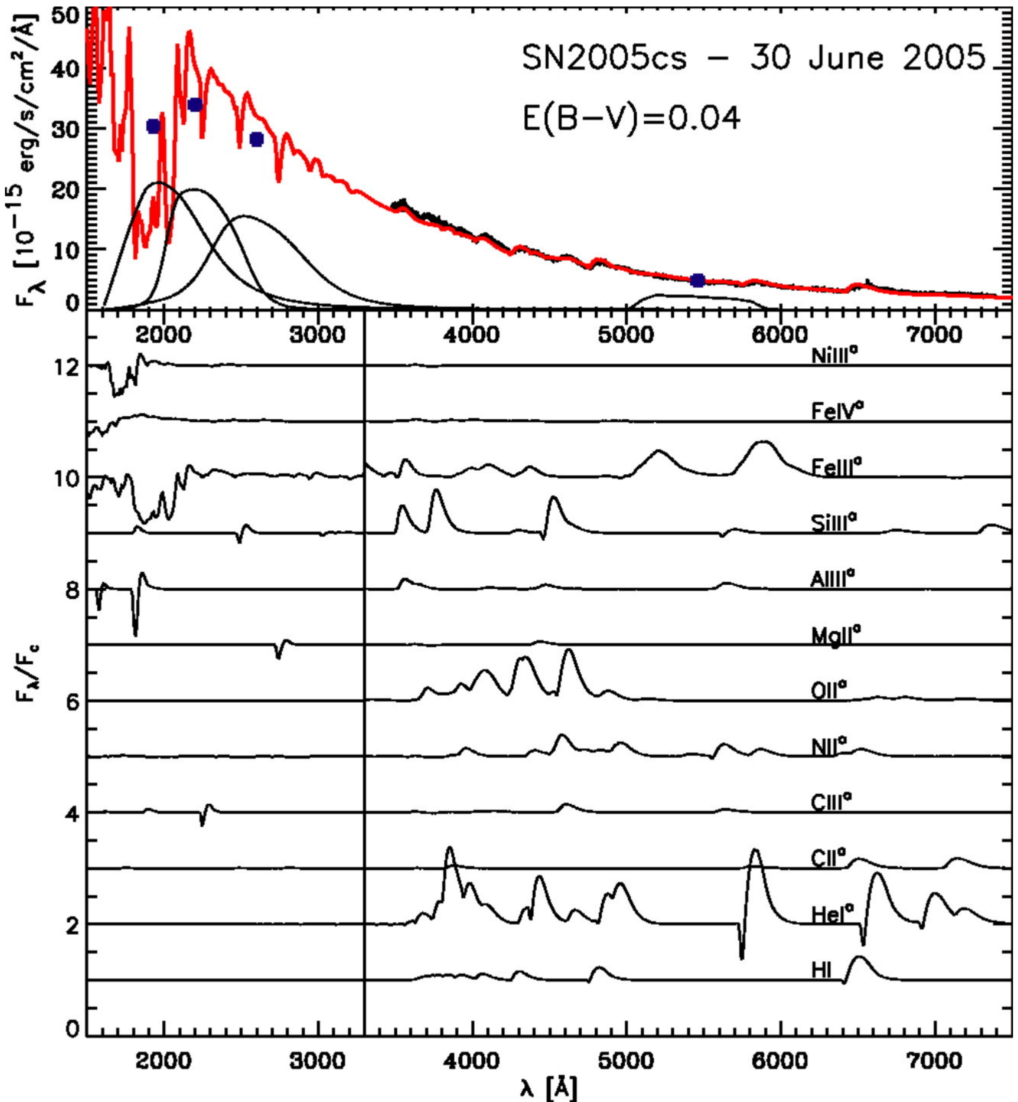


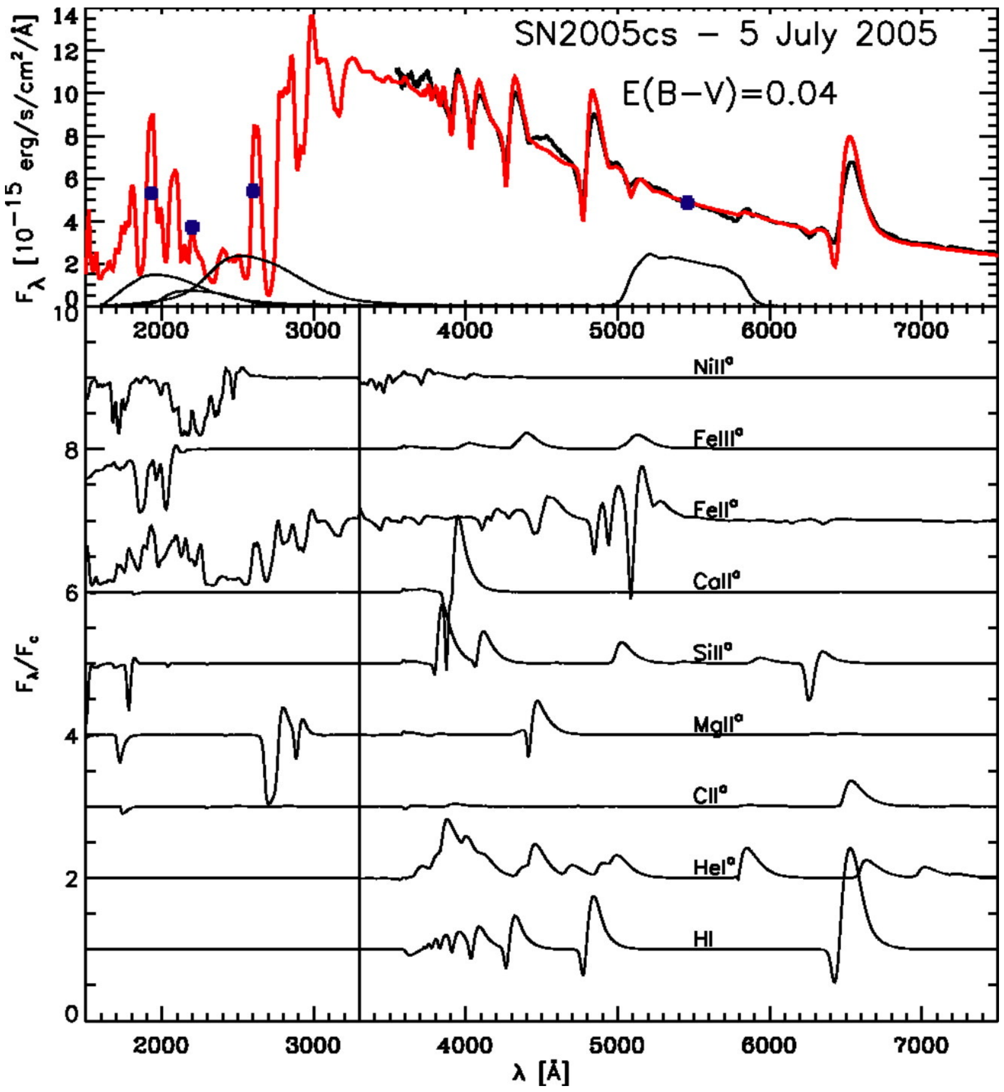


Explosions of red supergiants with lots of hydrogen
Type II

Brown et al. 2015
arXiv:1505.01368v1

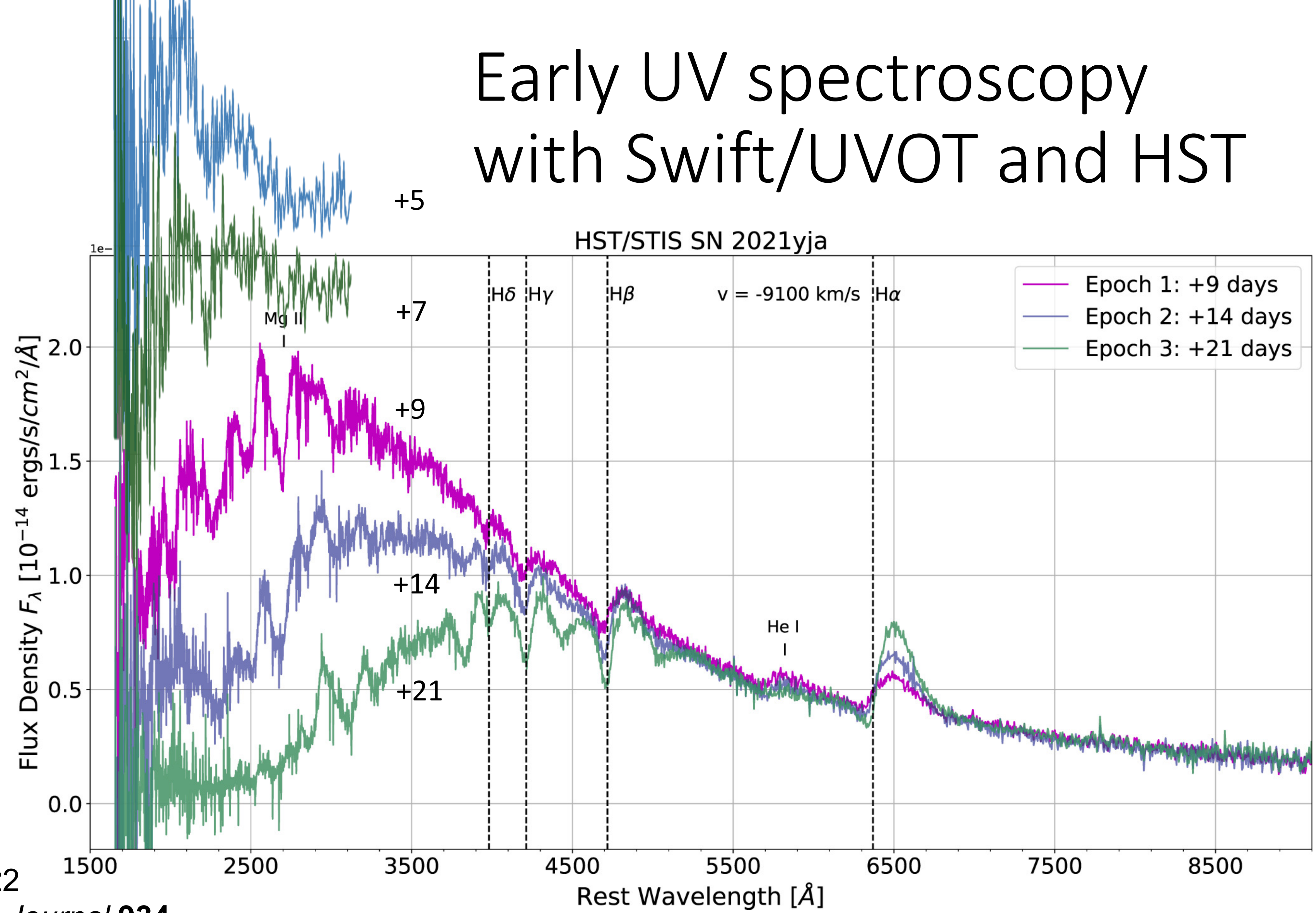
Rapid ionization changes in week after II explosion





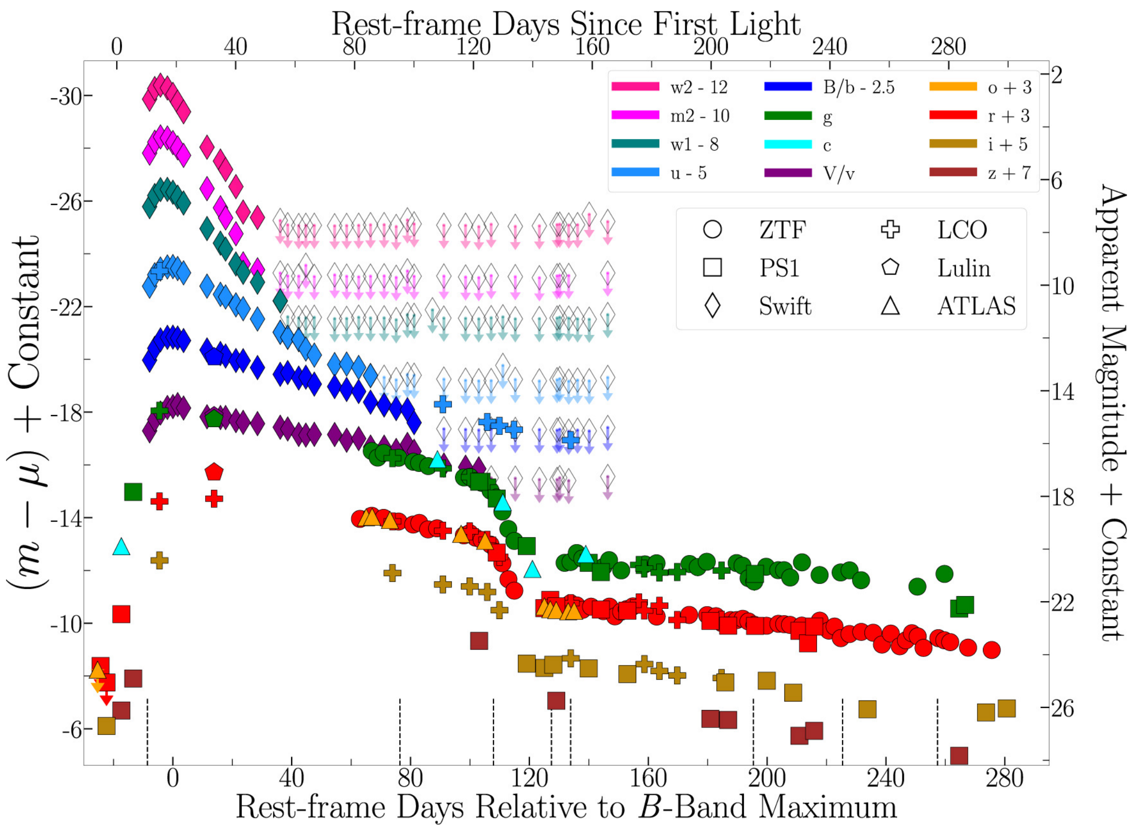
Brown et al. 2007 with models from Luc Dessart

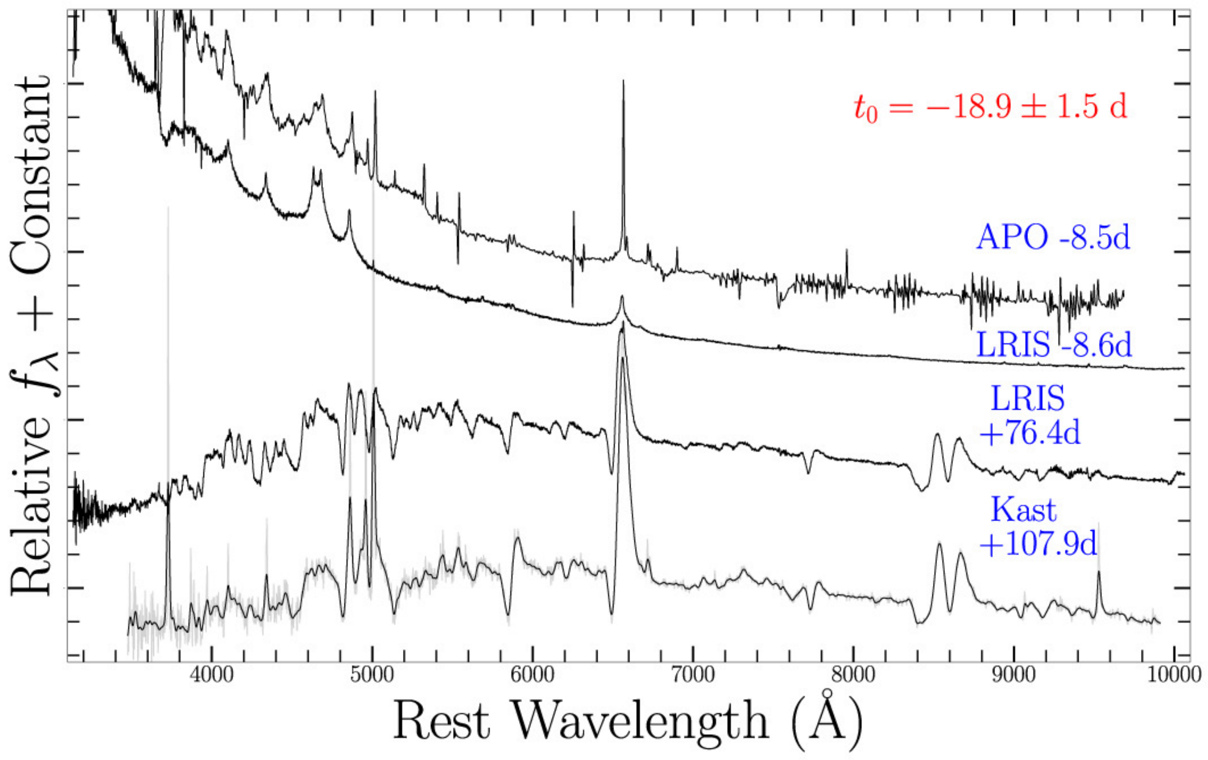
Early UV spectroscopy with Swift/UVOT and HST



Vasylyev et al 2022
The Astrophysical Journal **934**

Final Moments. I. Precursor Emission, Envelope Inflation, and Enhanced Mass Loss Preceding the Luminous Type II Supernova 2020tlf

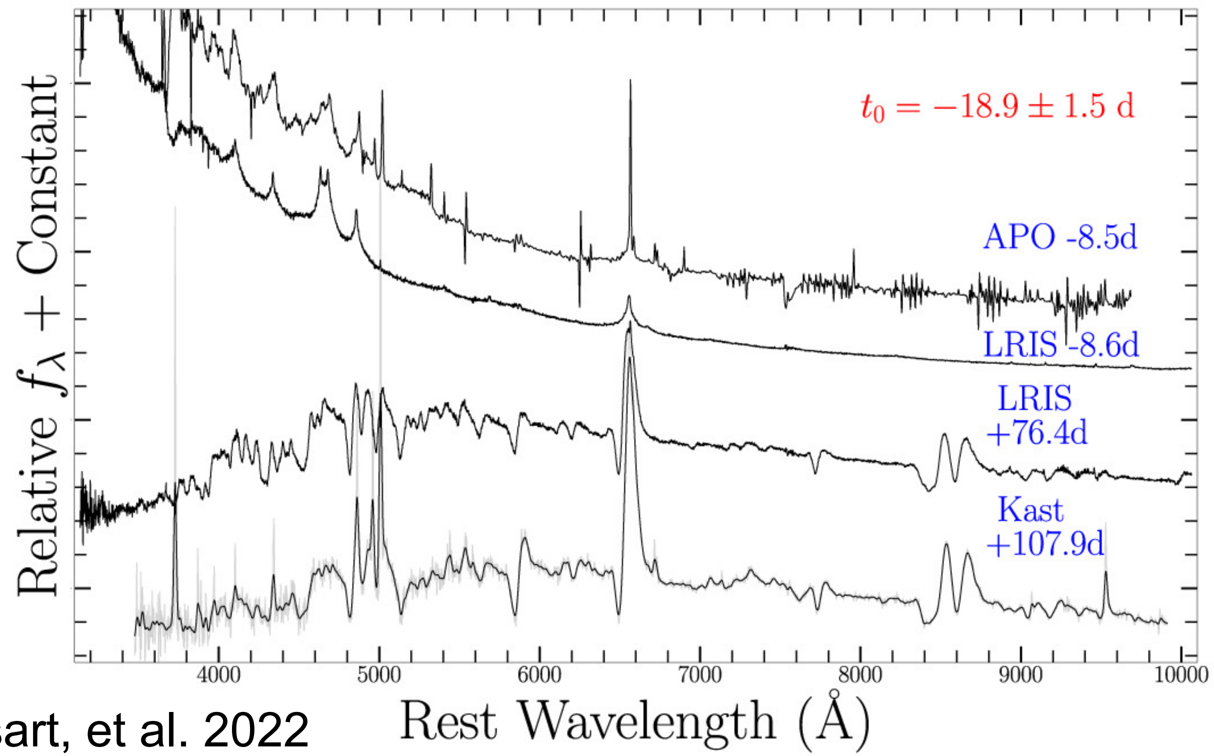




(a)

- W. V. Jacobson-Galán, L. Dessart, et al. 2022
- *The Astrophysical Journal* **924** 15

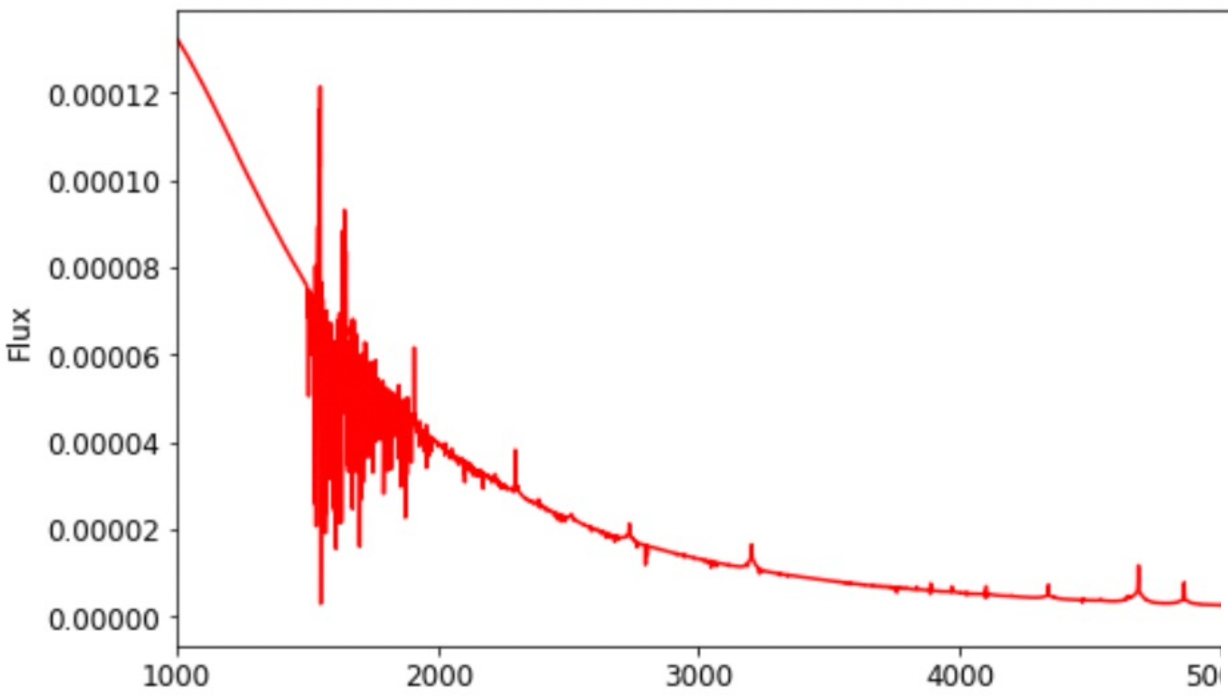
Flash Spectroscopy
rapid response to observe flash ionized material at the surface of or immediately surrounding the progenitor star

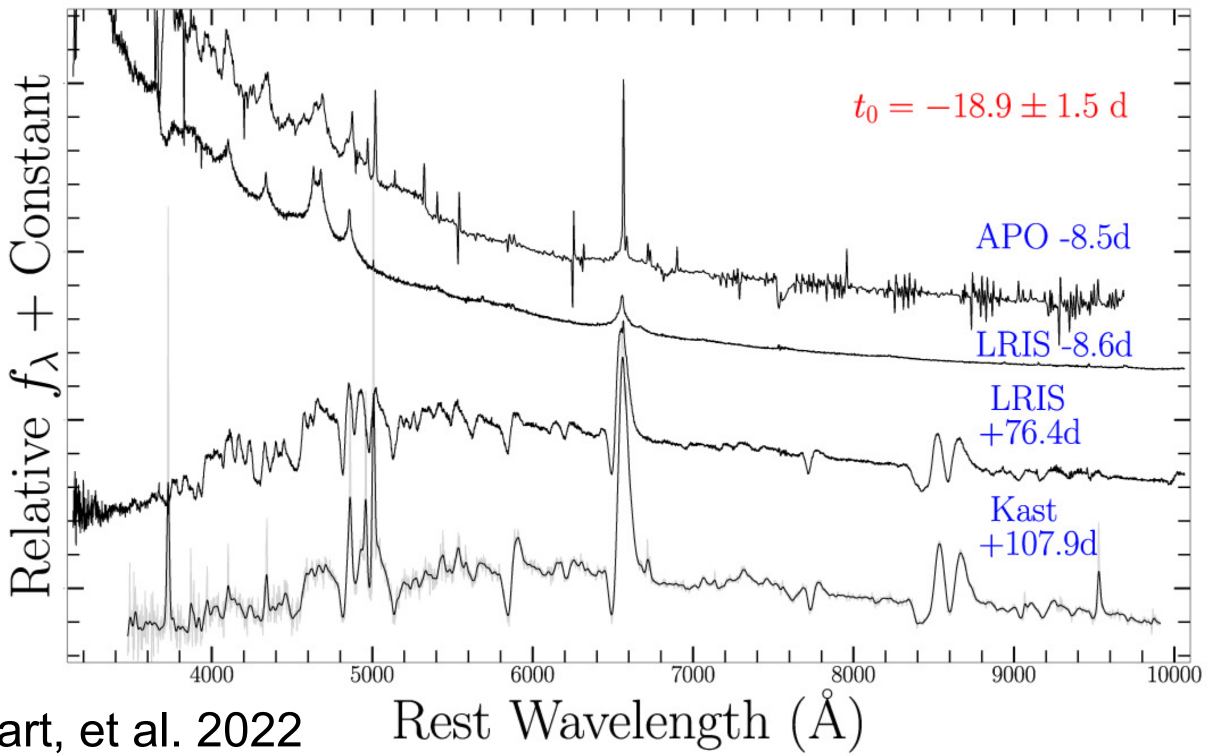


(a)

- W. V. Jacobson-Galán, L. Dessart, et al. 2022
- *The Astrophysical Journal* **924** 15

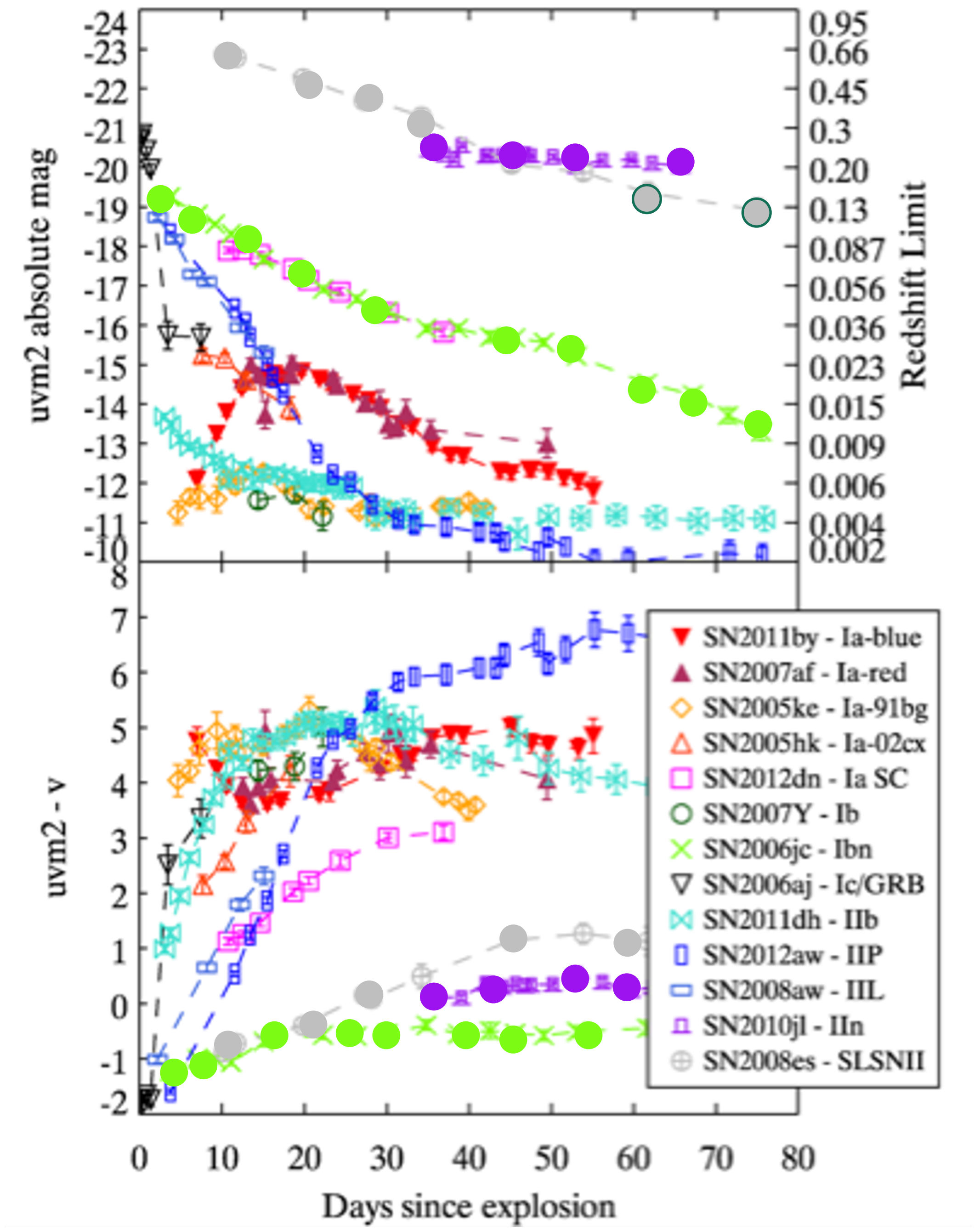
Theoretical model by Luc Dessart shows lots of UV structure





(a)

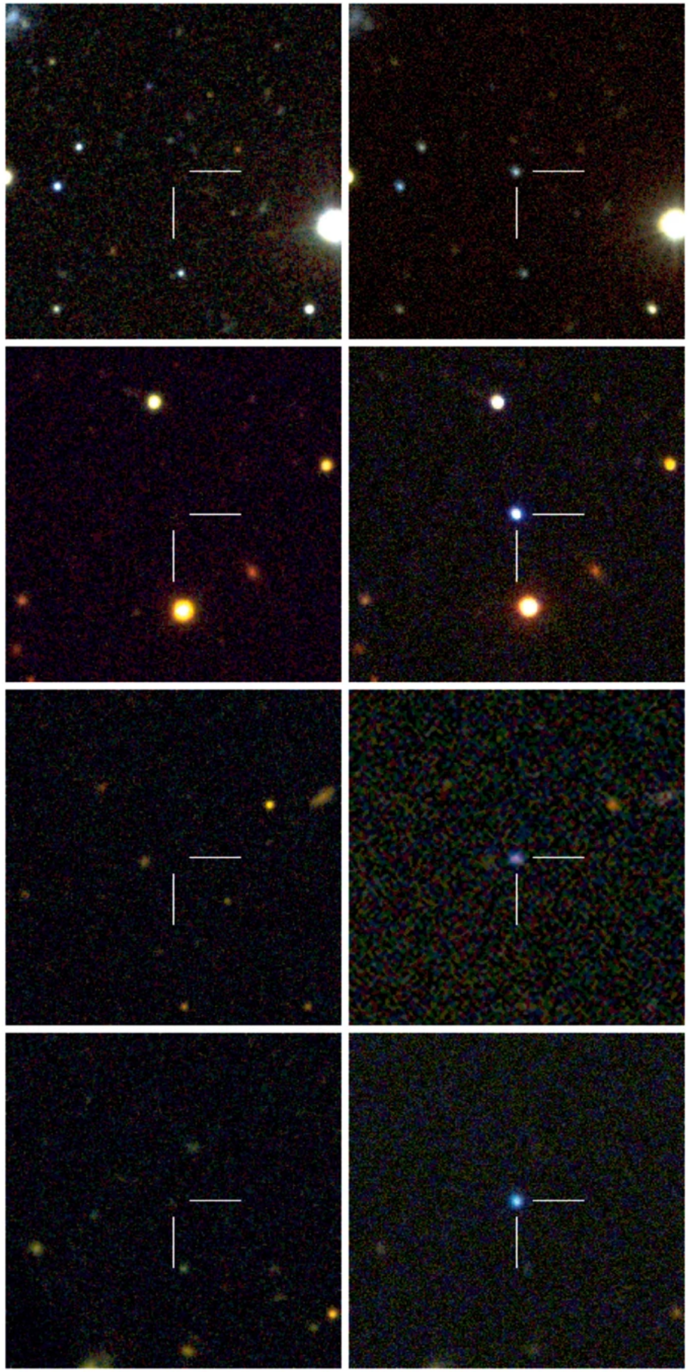
- W. V. Jacobson-Galán, L. Dessart, et al. 2022
- *The Astrophysical Journal* **924** 15

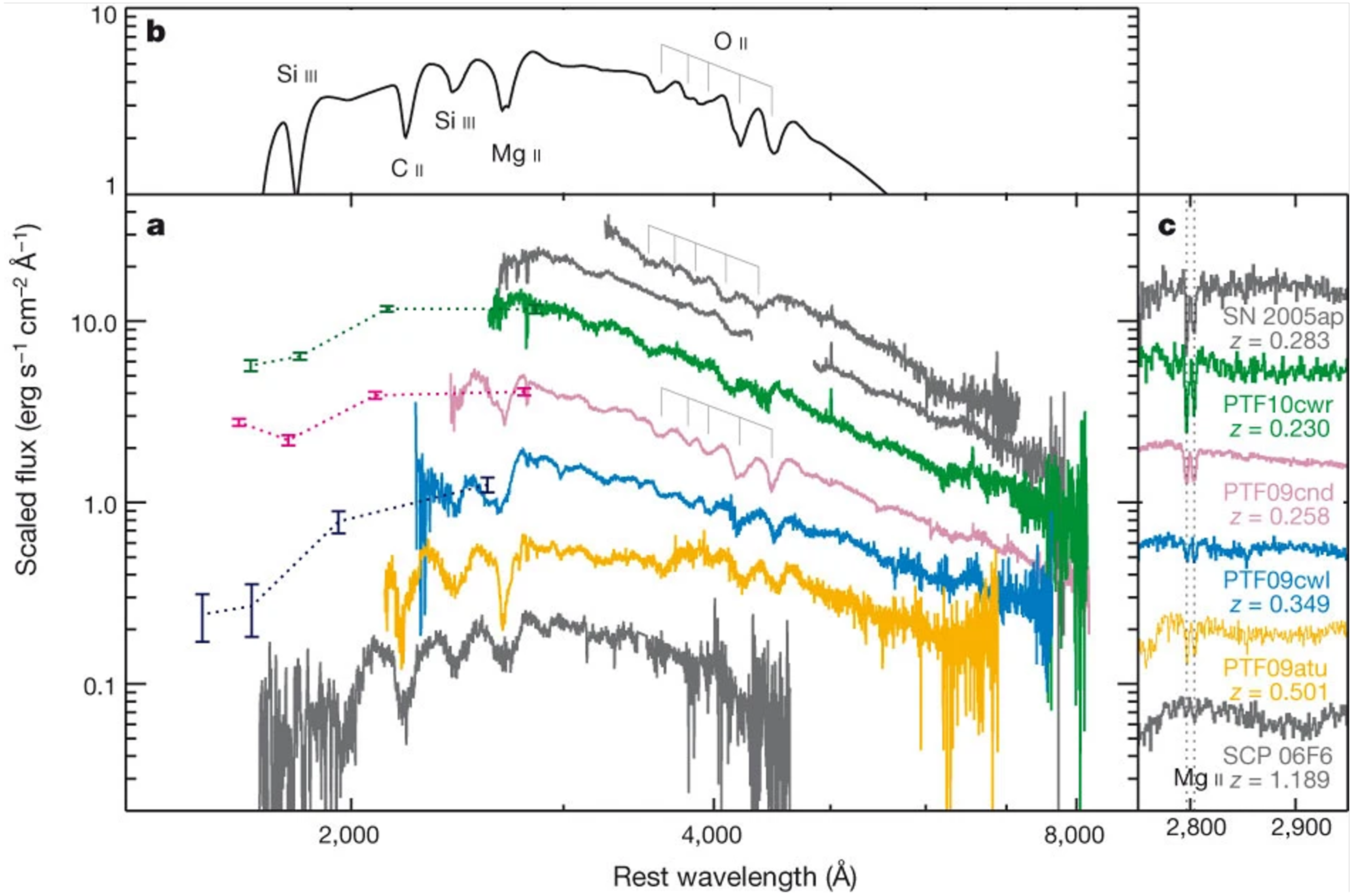


Interaction-powered SLSNe II, IIn, Ibn

Brown et al. 2015
arXiv:1505.01368v1

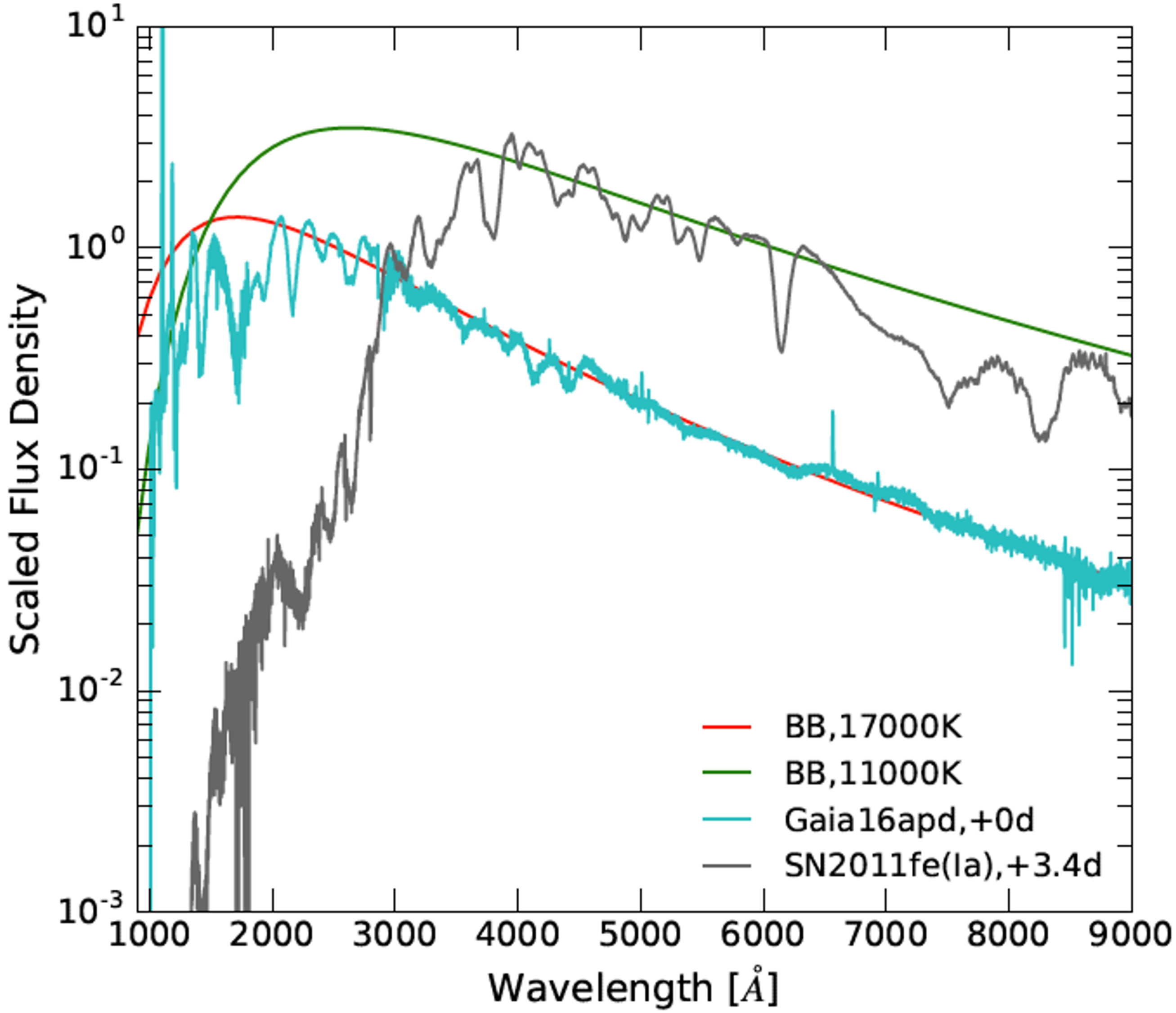
Superluminous Supernovae – magnetar powered





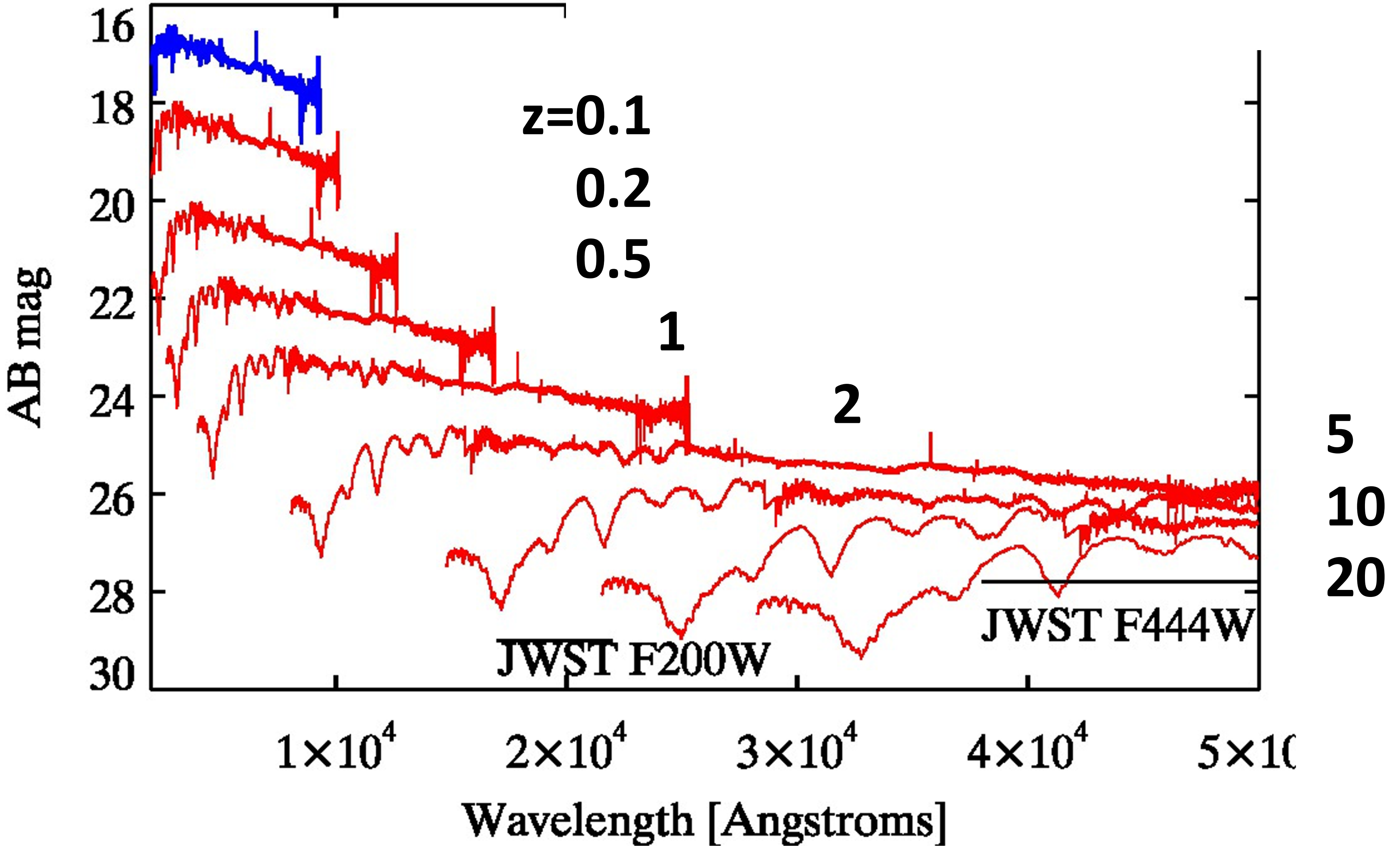
Quimby et al. 2011

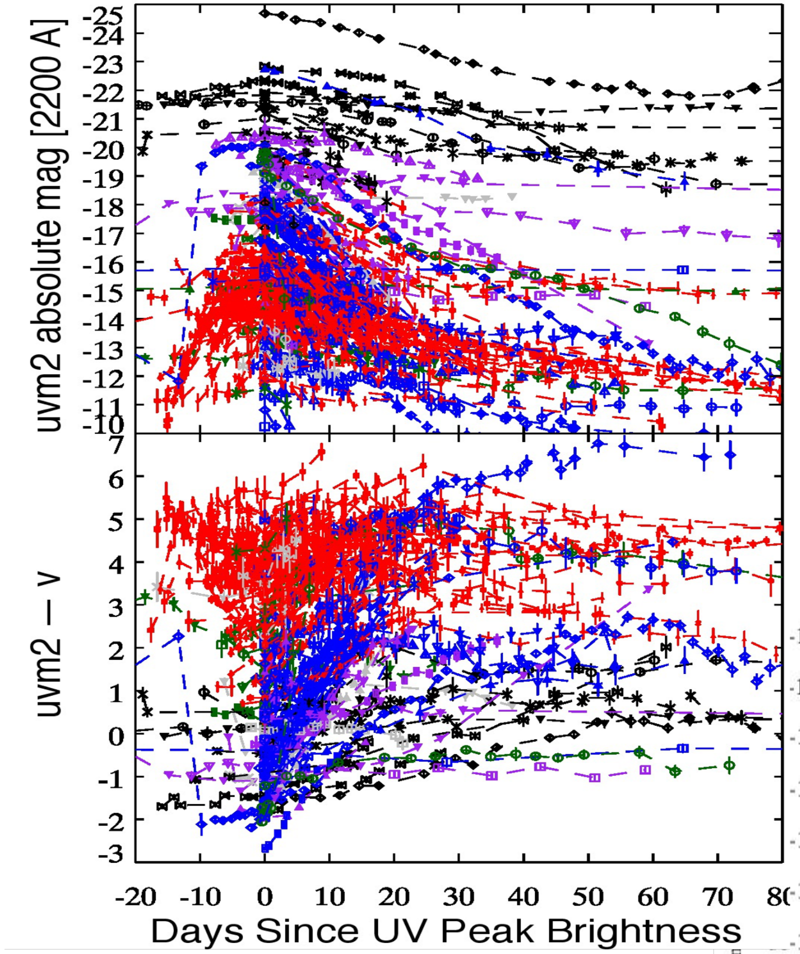
Superluminous Supernovae are much more luminous in the UV than SNe Ia



Yan et al. 2017 (inc PJB)

UV-bright Superluminous supernova redshifted across the universe!





AGGIENOVA TEMPLATES

Combine HST or model spectra with light curves to make time-series spectrophotometric templates