UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

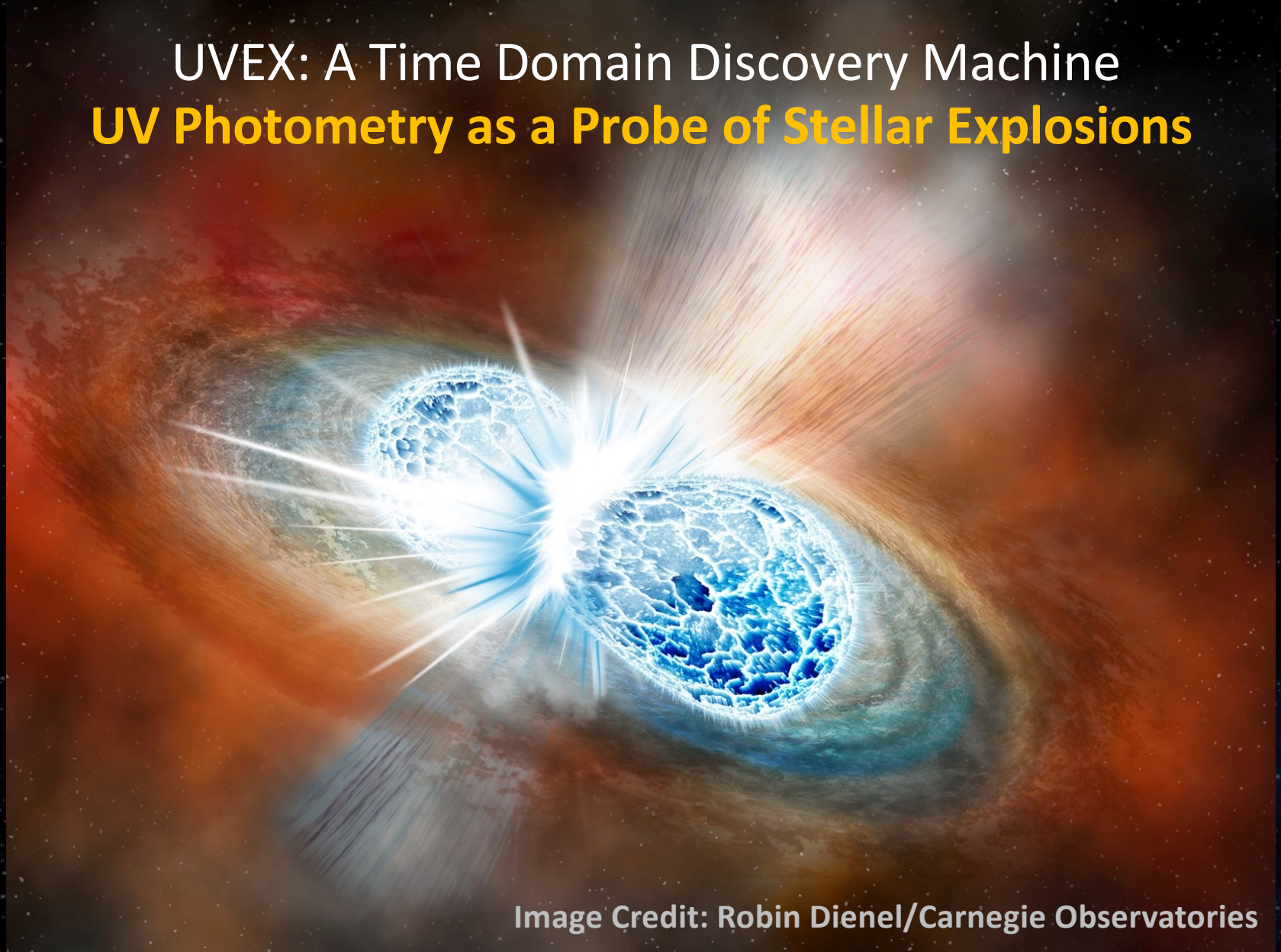
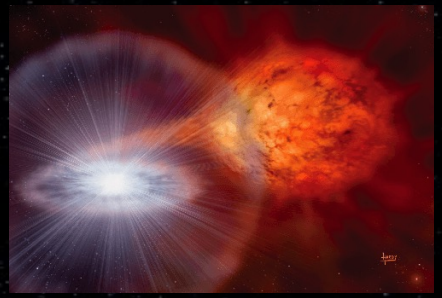


Image Credit: Robin Dienel/Carnegie Observatories

UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

Core-Collapse Supernova



Thermonuclear Supernova

Peculiar Transients

Why (broadly) the ultraviolet?

Stellar explosions often start hot and then rapidly cool

Why (broadly) the ultraviolet?

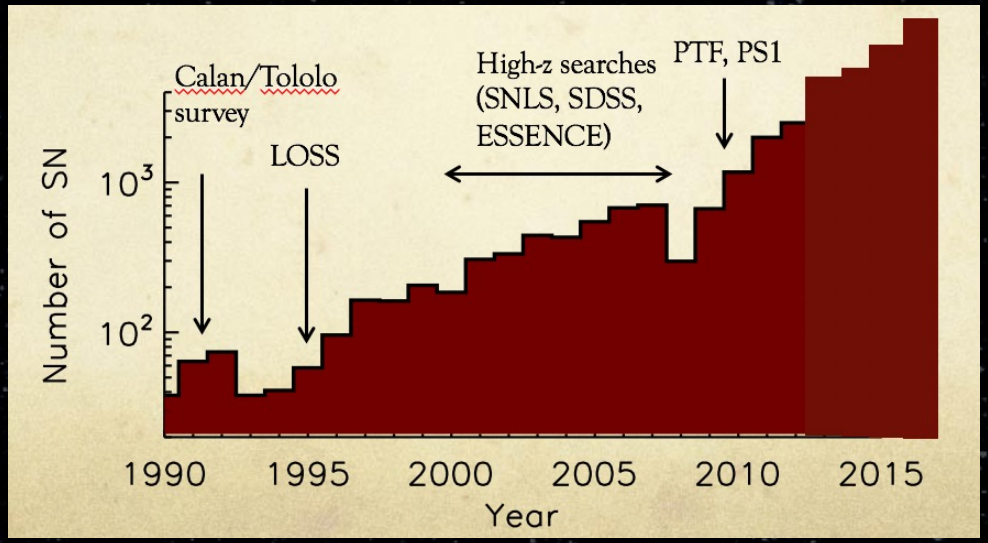
Stellar explosions often start hot and then rapidly cool

- UV is prime a prime wavelength to discover young transients

Why (broadly) the ultraviolet?

Stellar explosions often start hot and then rapidly cool

- UV is prime a prime wavelength to discover **young** transients

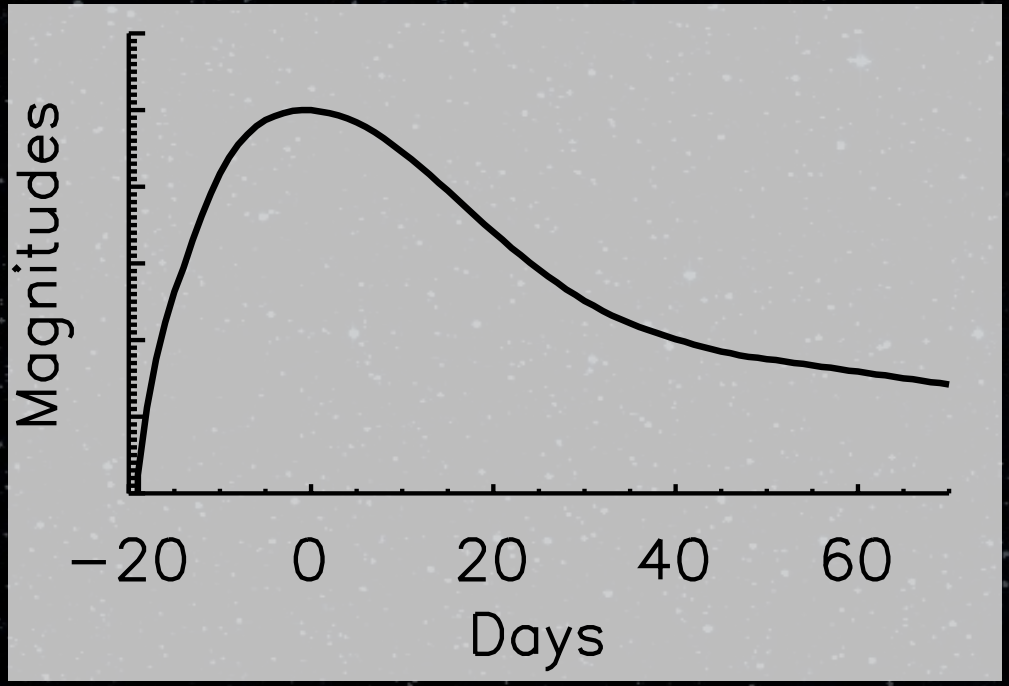


In current era of optical time domain supernova, the community discovers >20,000 explosive transients per year

Why (broadly) the ultraviolet?

Stellar explosions often start hot and then rapidly cool

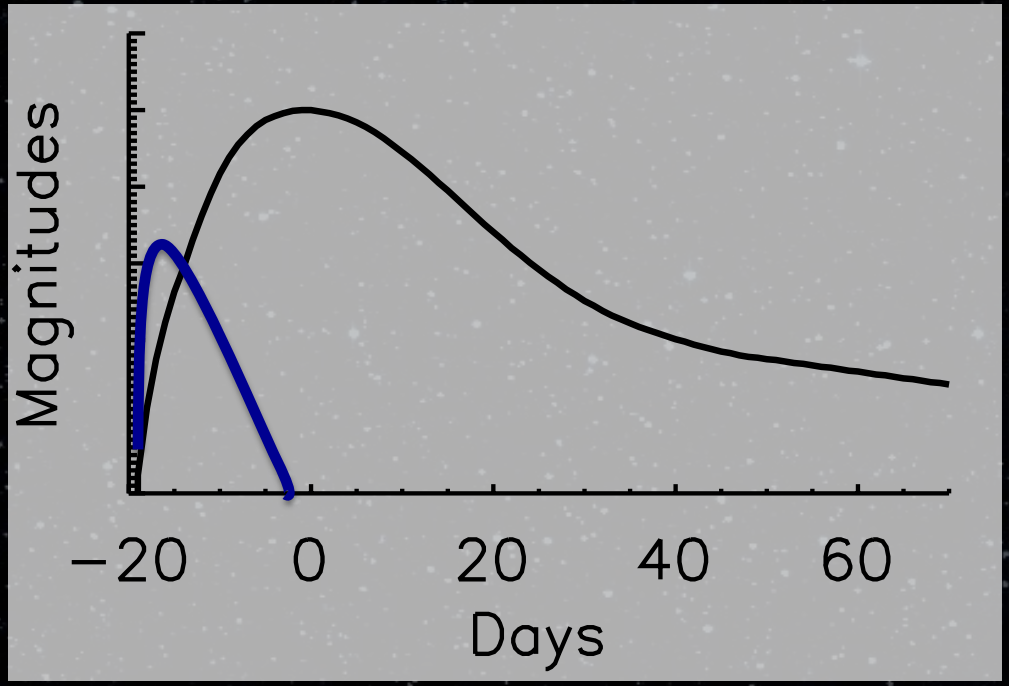
- UV is prime a prime wavelength to discover young transients
- Early UV emission can probe unique physics.



Why (broadly) the ultraviolet?

Stellar explosions often start hot and then rapidly cool

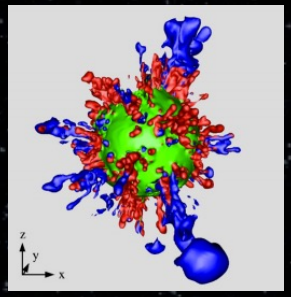
- UV is prime a prime wavelength to discover young transients
- Early UV emission can probe unique physics.

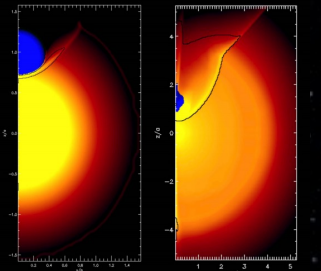


Why (broadly) the ultraviolet?

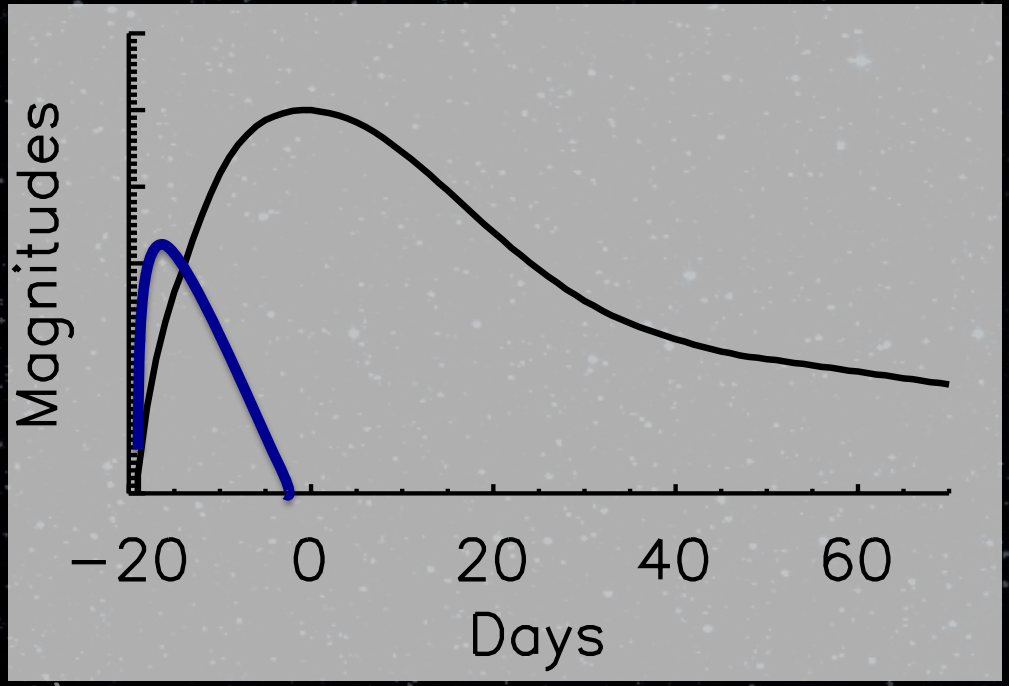
Stellar explosions often start hot and then rapidly cool

- UV is prime a prime wavelength to discover young transients
- Early UV emission can probe unique physics.





Kasen (2010)
Hammer+ (2010)



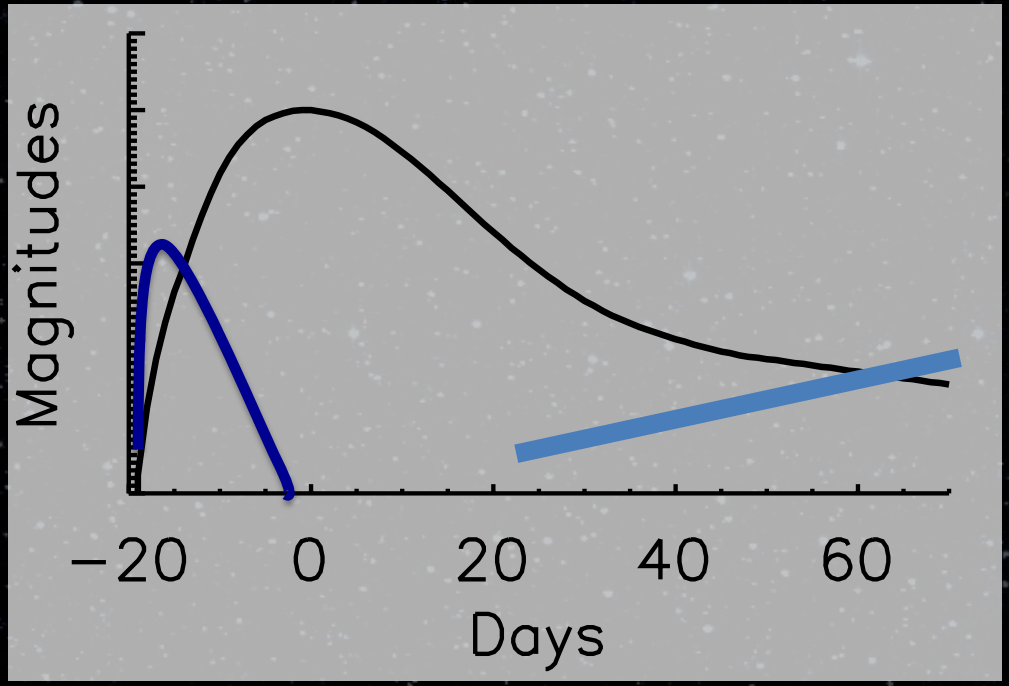
Early Emission from:

- Envelope cooling
- Collision with a companion star
- Mixing of radioactive material
- … etc.

Why (broadly) the ultraviolet?

Stellar explosions often start hot and then rapidly cool

- UV is prime a prime wavelength to discover young transients
- Early (and late!) UV emission can probe unique physics.

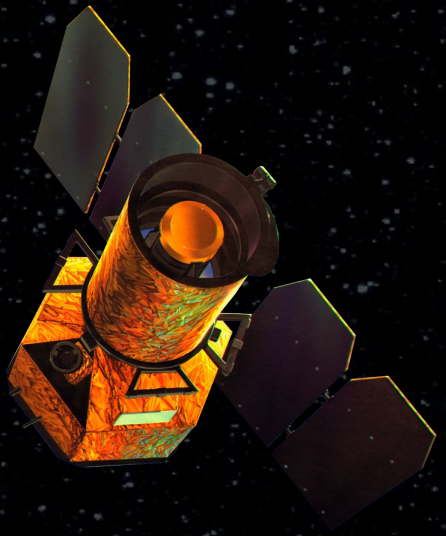


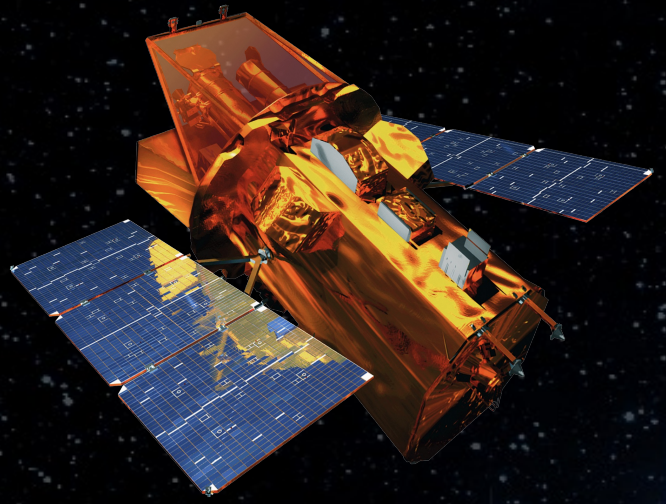
Late-time emission:

- Interaction with ambient material.
- Additional power from a compact object (accretion, PWN)

What is the current landscape?

Probing Early UV Emission of explosive transients requires wide-field monitoring and/or rapid-response capabilities



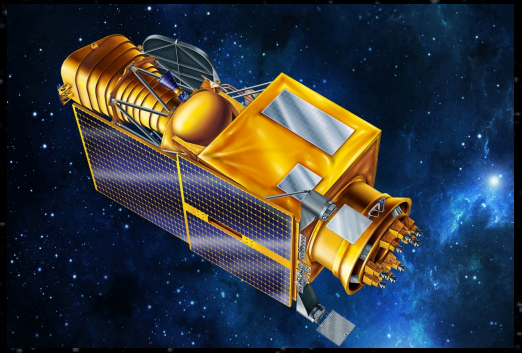


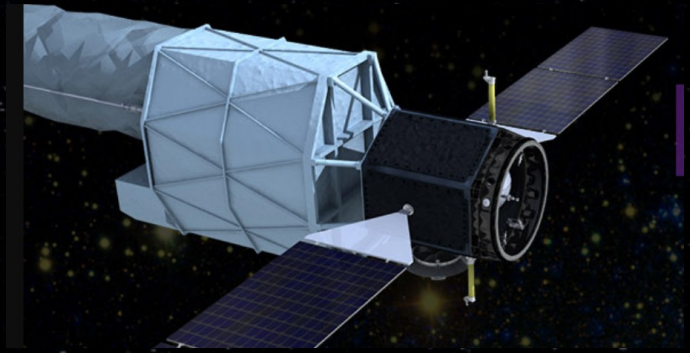
GALEX Time Domain Survey
40 deg^2, ~2 day cadence,
24 total epochs
(Gezari et al. 2013,2015a,b)

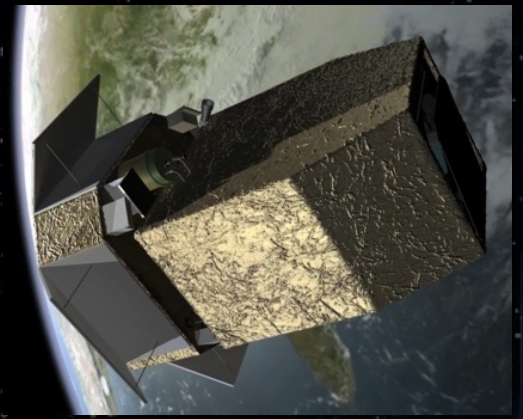
Swift-UVOT ToOs
Hundreds of SN light curves of date in response to external triggers

What is the current landscape?

Probing Early UV Emission of explosive transients requires wide-field monitoring and/or rapid-response capabilities





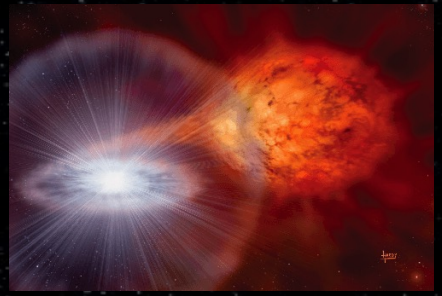


UltraSAT	UVEX	CASTOR
200 deg^2	10 deg^2	0.25 deg^2
8.3” FWHM	2.5” FWHM	0.15” FWHM
22.4 mag (900s)	24.5 mag (900s)	27.2 mag (900s)

UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

Core-Collapse Supernova



Thermonuclear Supernova

Peculiar Transients

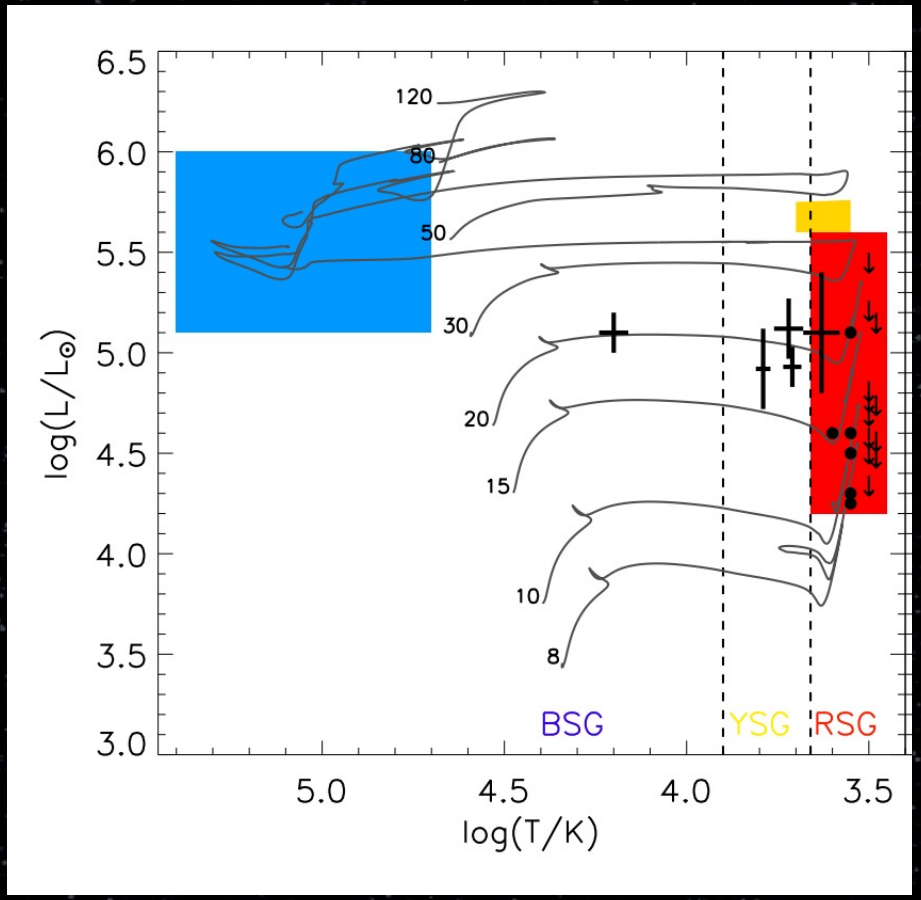
UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes

What are the progenitors to core-collapse supernova? What is their final structure and final behavior while evolving towards core-collapse?

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



Eldridge, et al. (2013)

Supernova studies have found progenitors we did not expect, a lack of progenitors that were anticipated, and pointed to classes of stars that we have yet to observationally identify.

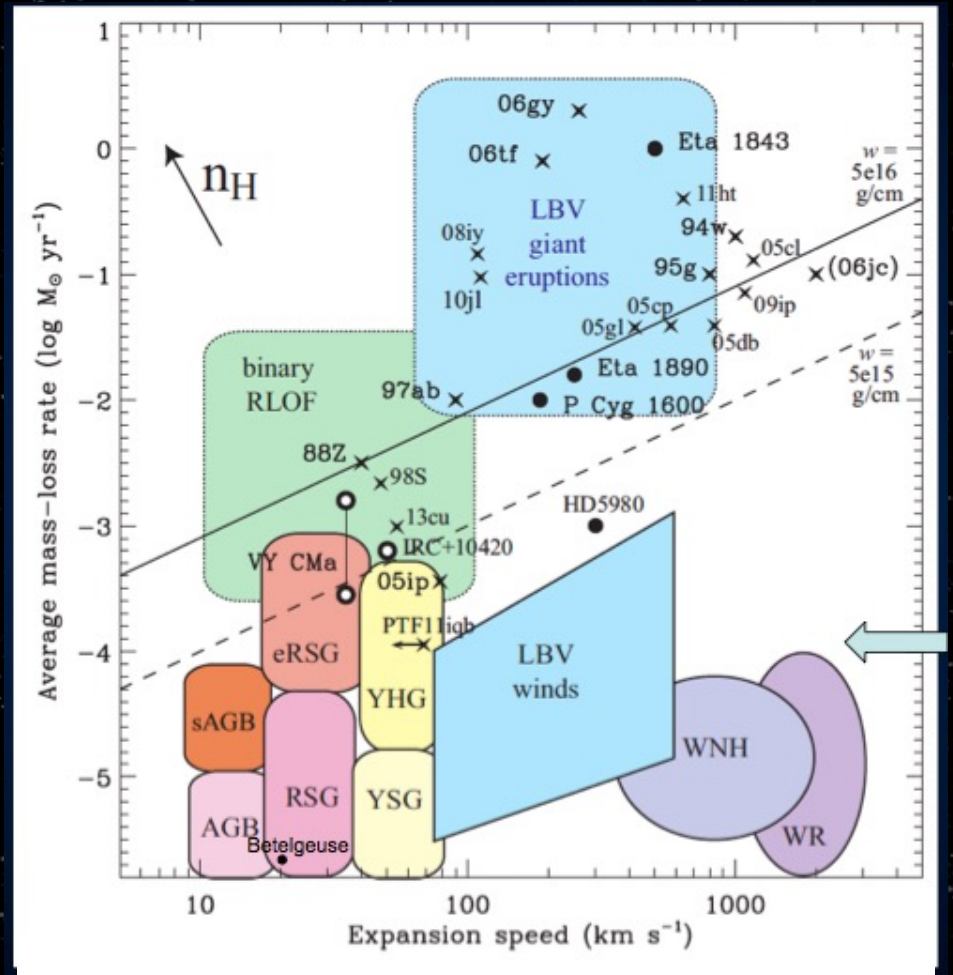
UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes

At this point, it is clear that many massive stars lead dynamic lives during their final years.

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



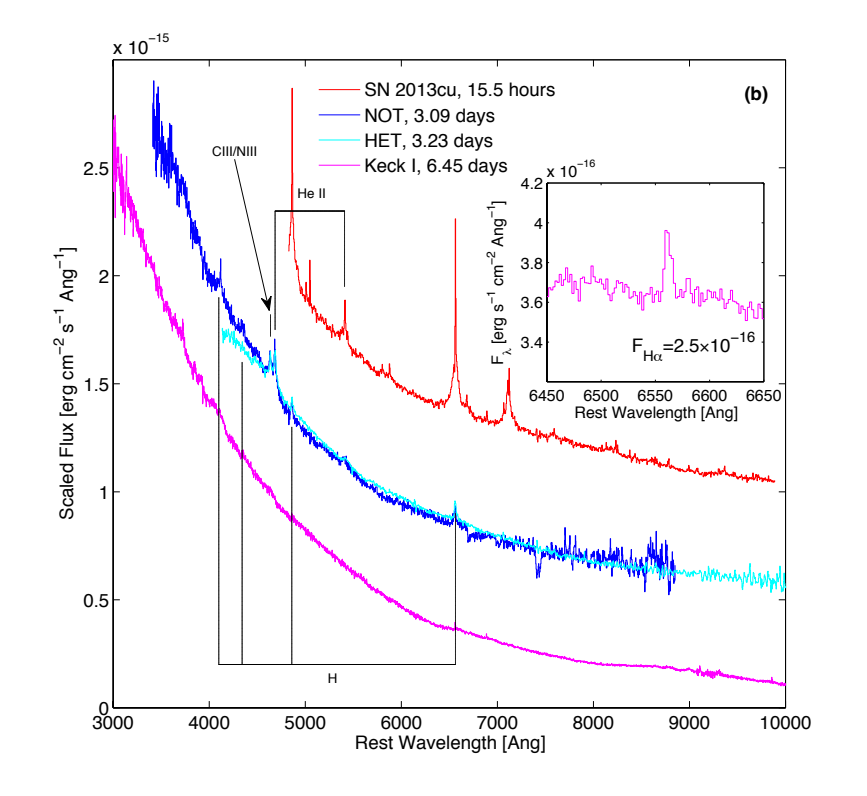
[Nathan Smith 2016, Supernova Handbook]

At this point, it is clear that many massive stars lead dynamic lives during their final years.

Exhibit A: Type IIn Supernovae

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



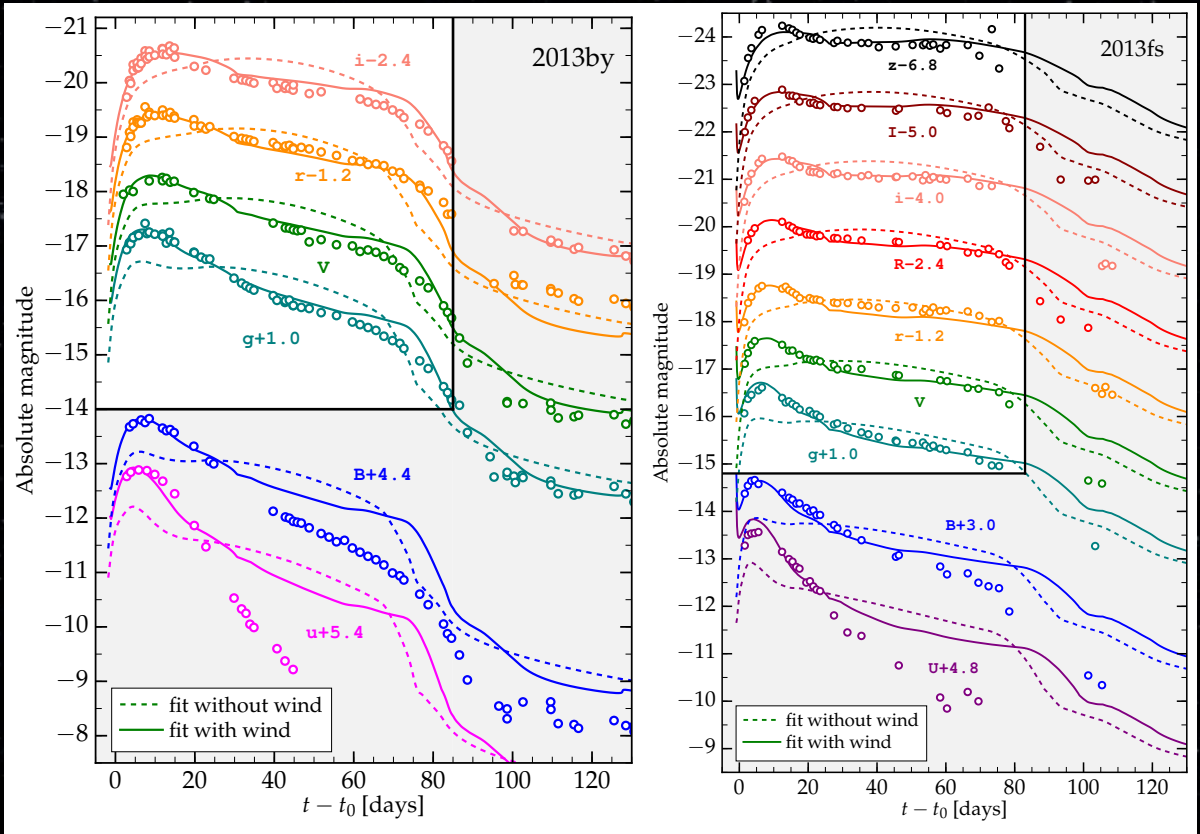
Gal-Yam et al. 2014.

At this point, it is clear that many massive stars lead dynamic lives during their final years.

Exhibit B: enhanced mass loss in “normal supernovae”

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



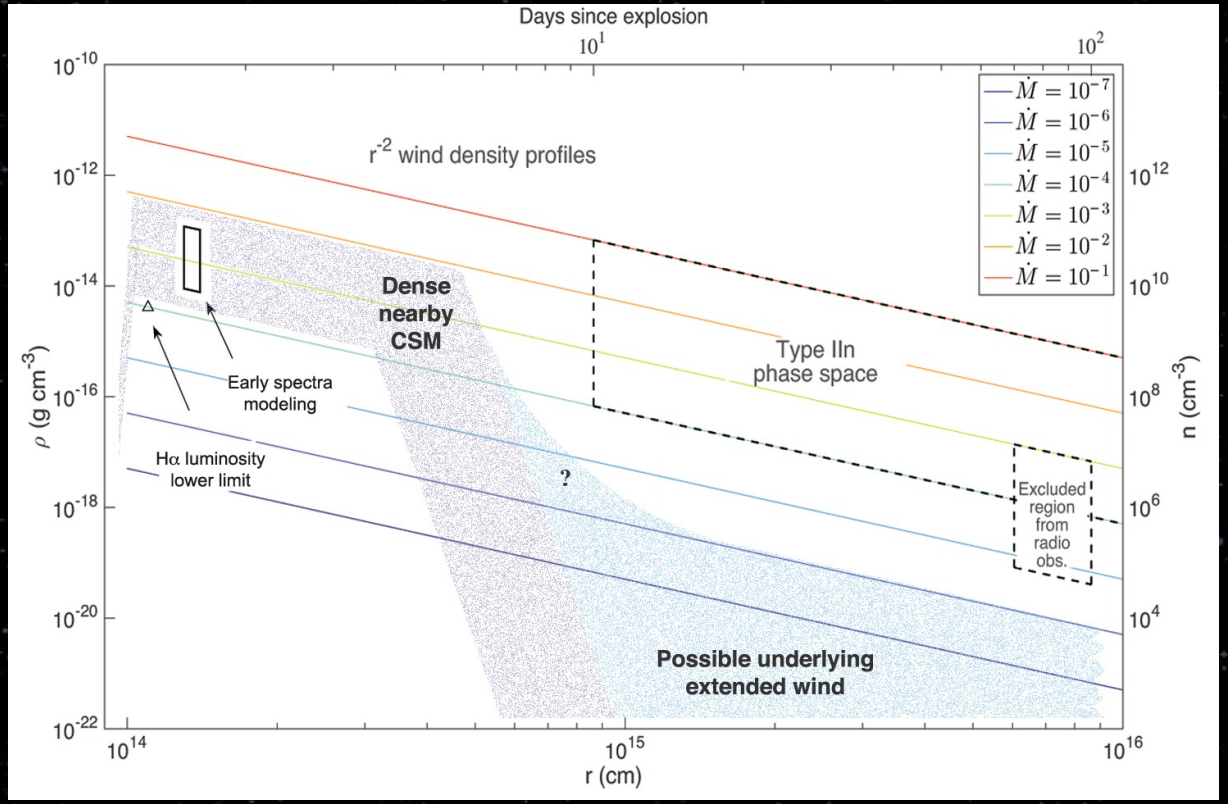
At this point, it is clear that many massive stars lead dynamic lives during their final years.

Exhibit B: enhanced mass loss in “normal supernovae”

Morozova, Piro, & Valenti 2017, 2018

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



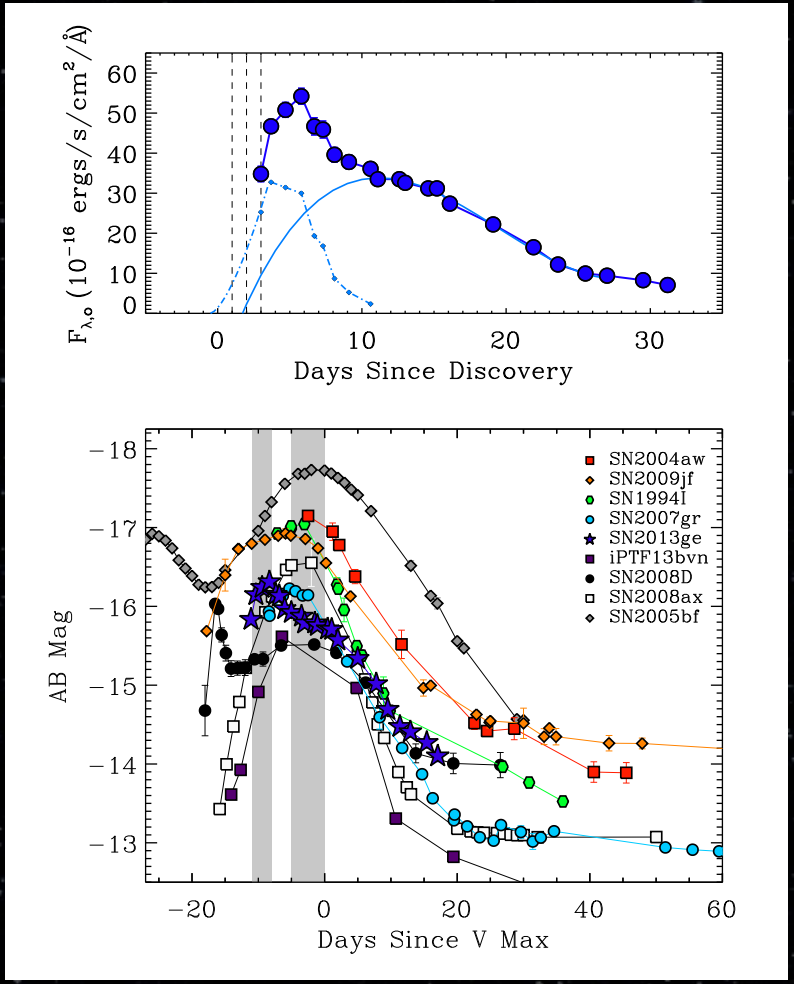
Yaron et al. 2017.

At this point, it is clear that many massive stars lead dynamic lives during their final years.

Exhibit B: enhanced mass loss in “normal supernovae”

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



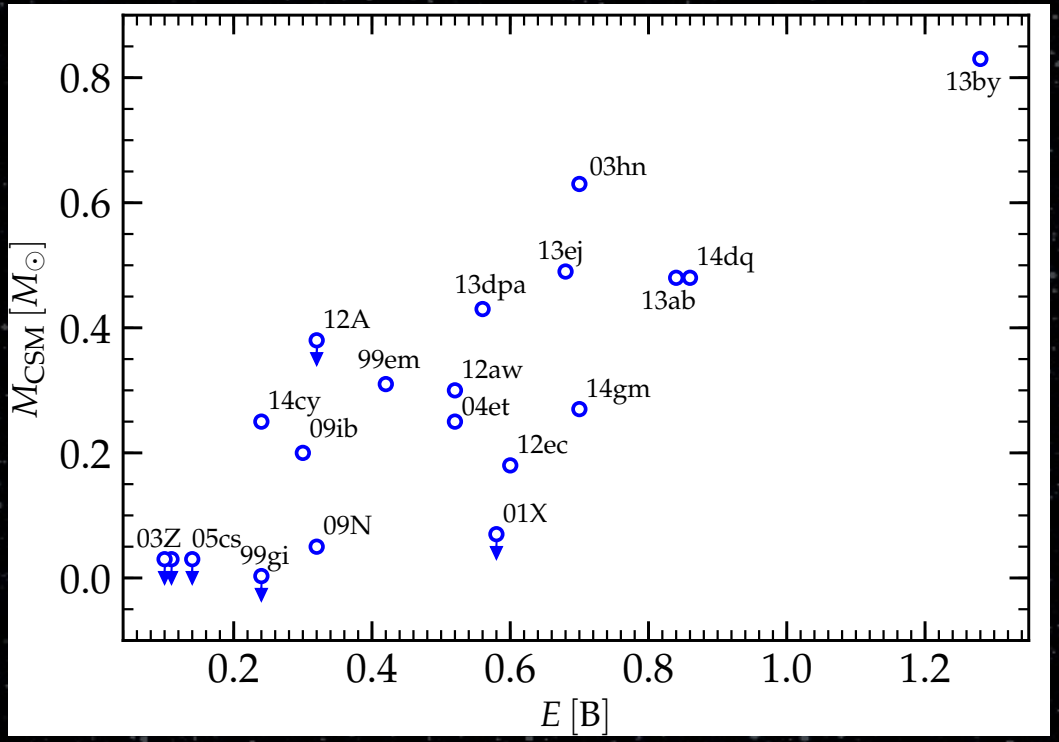
At this point, it is clear that many massive stars lead dynamic lives during their final years.

Exhibit C: This is not limited to hydrogen-rich supernovae

Drout et al. (2016); Asfari et al 2021

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



Morozova, Piro, & Valenti 2018
see also Kazov et al. 2016, Hozzeinzadeh et al. 2018

At this point, it is clear that many massive stars lead dynamic lives during their final years.

How common is this?

Current estimates range from 30-70%

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes

Fuller et al.

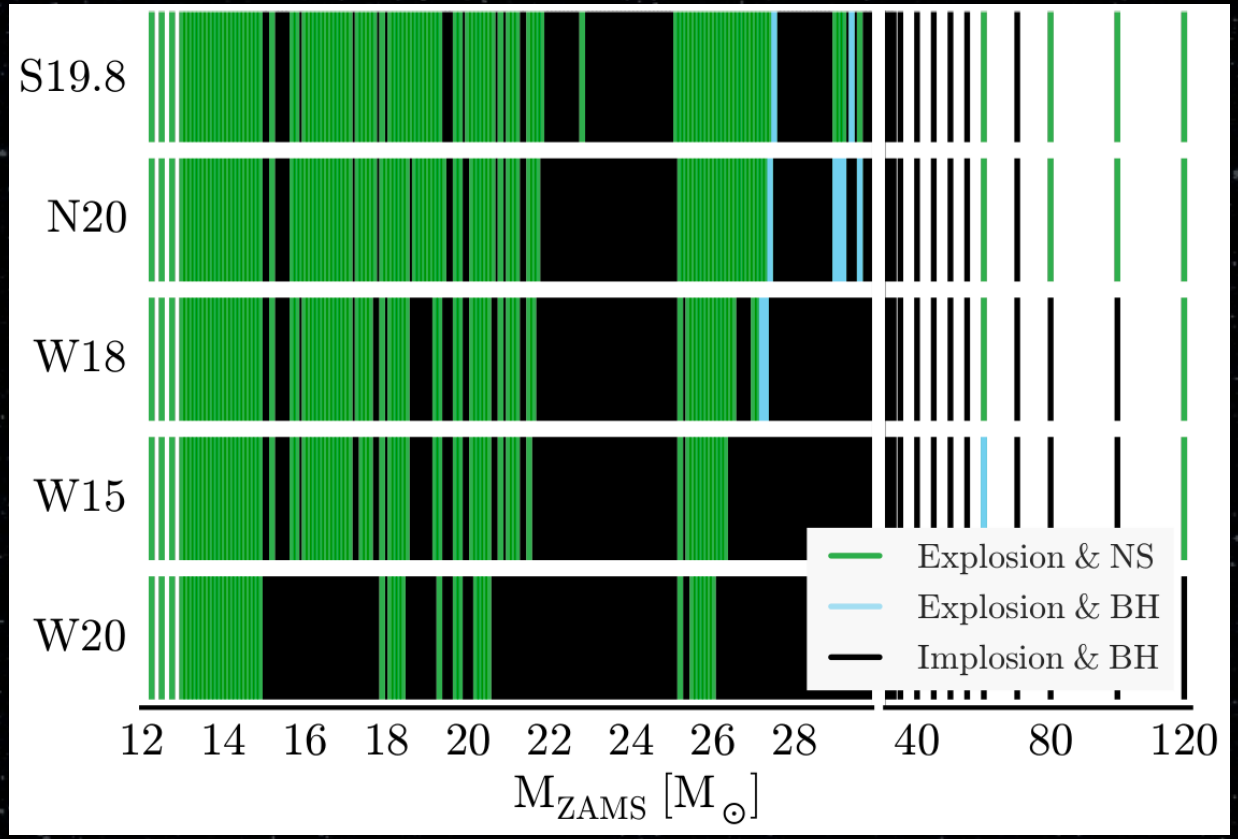
At this point, it is clear that many massive stars lead dynamic lives during their final years.

Why does this matter?

Can impact pre-explosion structure of the star and spin rate of the core

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: Science Themes



T. Sukhbold et al.

At this point, it is clear that many massive stars lead dynamic lives during their final years.

Why does this matter?

Can impact pre-explosion structure of the star and spin rate of the core

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: The Role of UV Data

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: The Role of UV Data

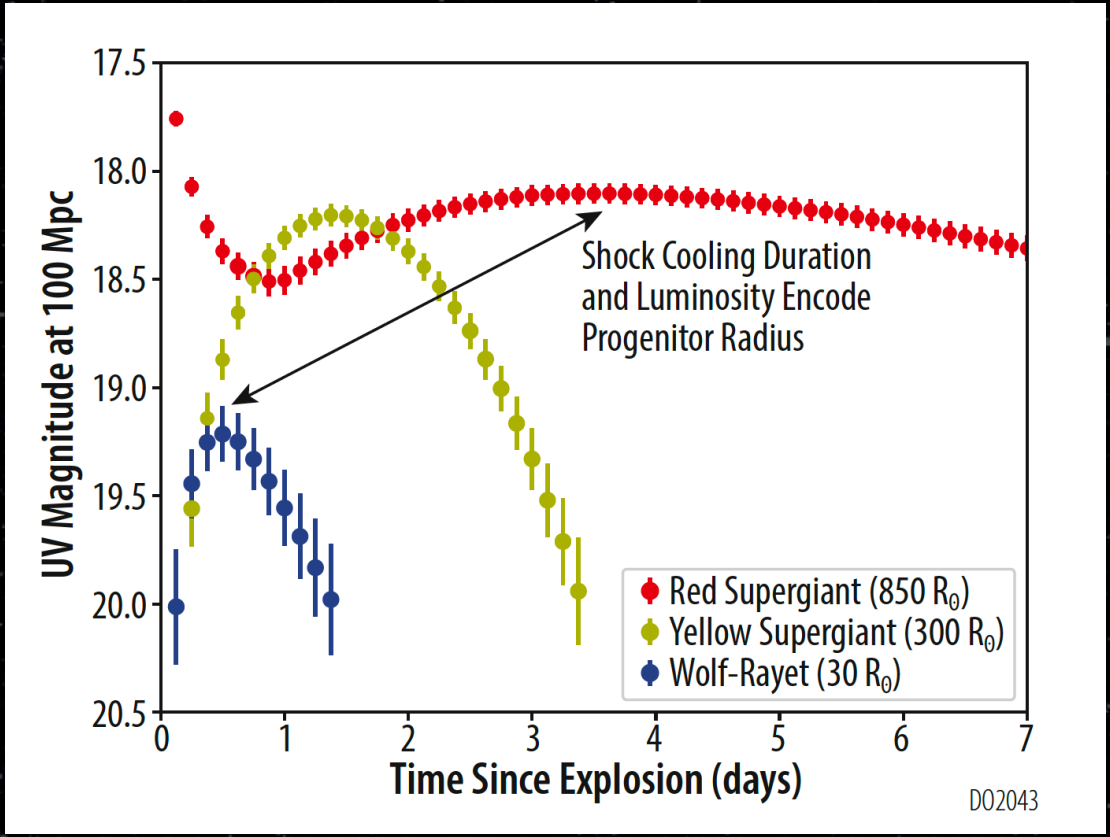


Figure: Piro, Cenko, Dorado team

Progenitior Radius Constraints from shock cooling emission.

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: The Role of UV Data

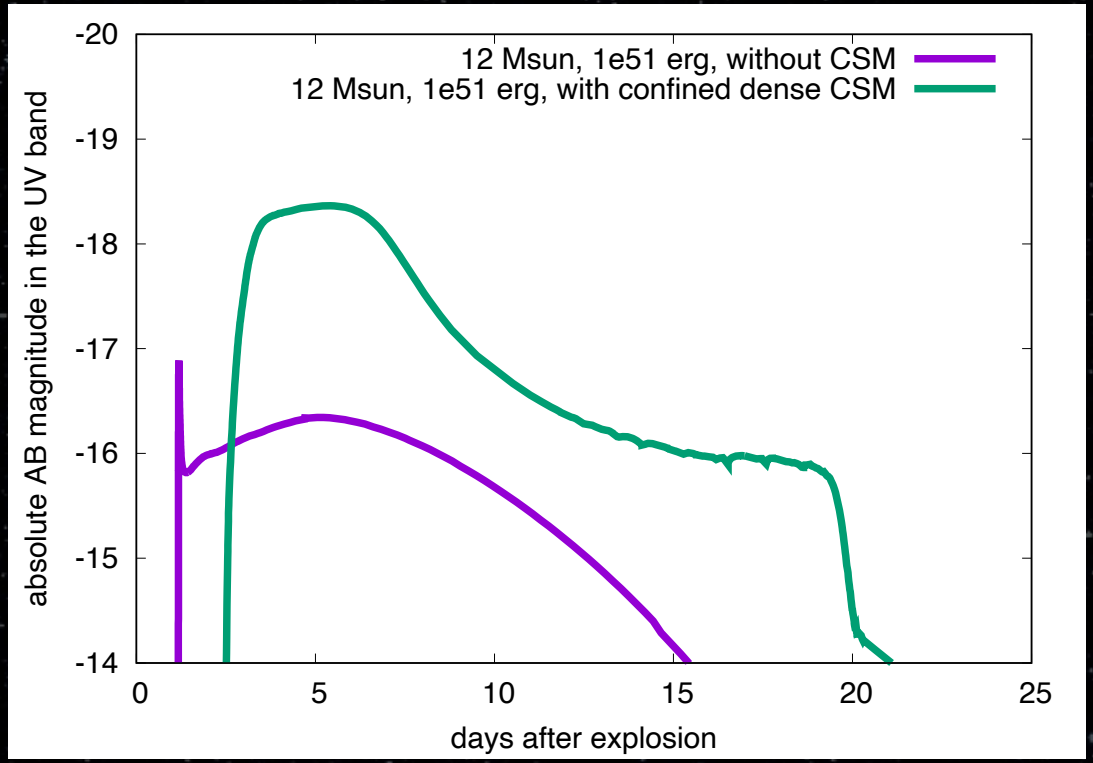


Figure: T. Moriya

Progenitior Radius Constraints from shock cooling emission.

Fraction of SN with enhanced pre-SN mass loss

UVEX: A Time Domain Discovery Machine

Core Collapse Supernovae: The Role of UV Data

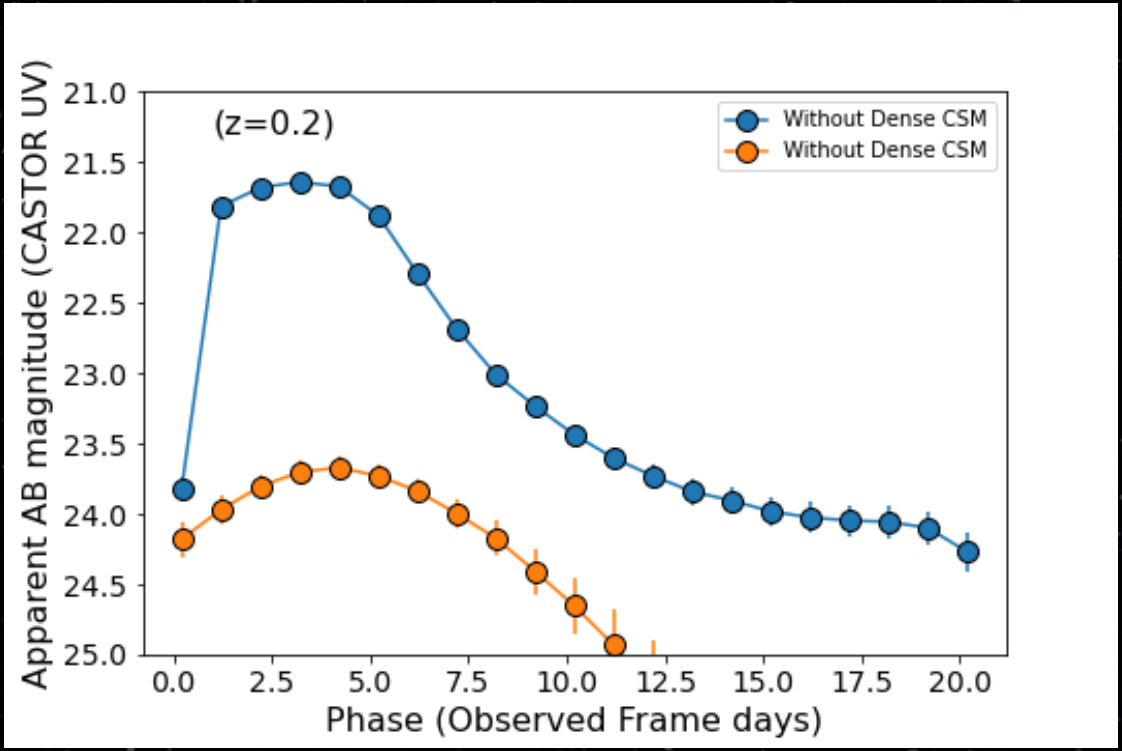


Figure: Drout, CASTOR team

Progenitior Radius Constraints from shock cooling emission.

Fraction of SN with enhanced pre-SN mass loss

UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

Core-Collapse Supernova

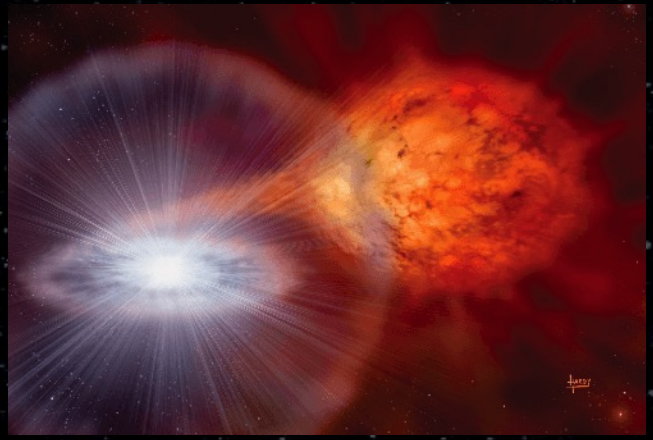
Thermonuclear Supernova

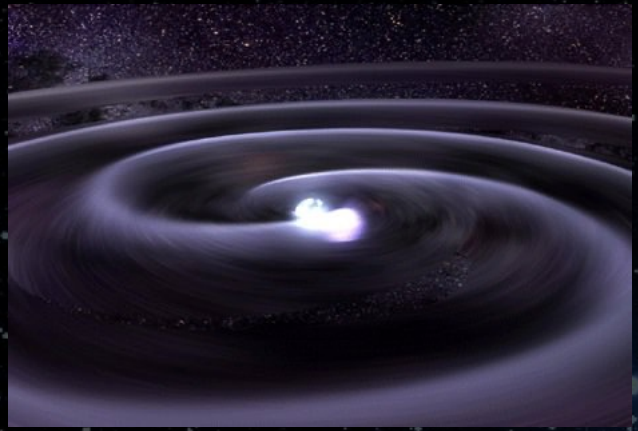
Peculiar Transients

UVEX: A Time Domain Discovery Machine

Thermonuclear Supernovae: Science Themes

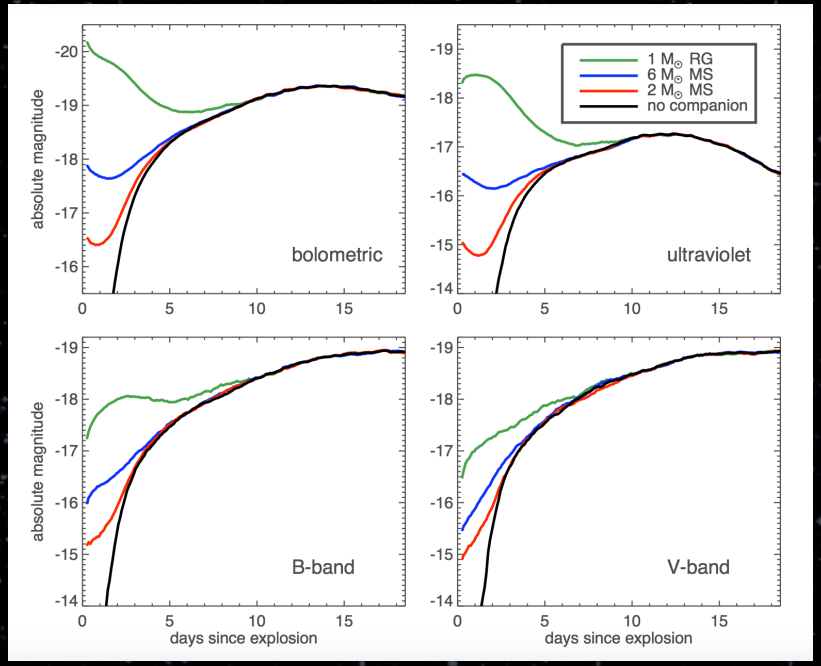
What is the nature of the binary system? What is the explosion mechanism



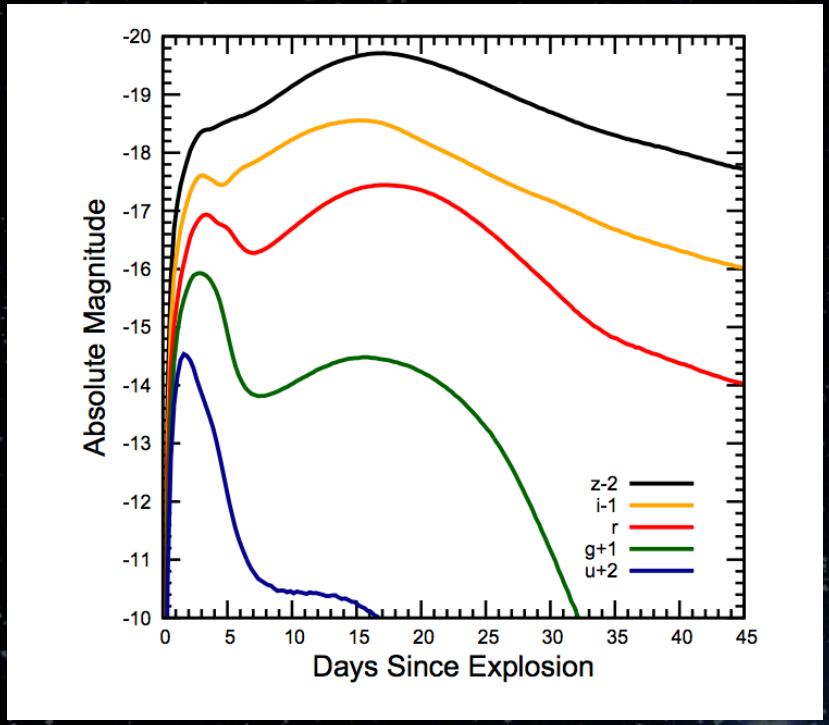


UVEX: A Time Domain Discovery Machine

Thermonuclear Supernovae: Science Themes



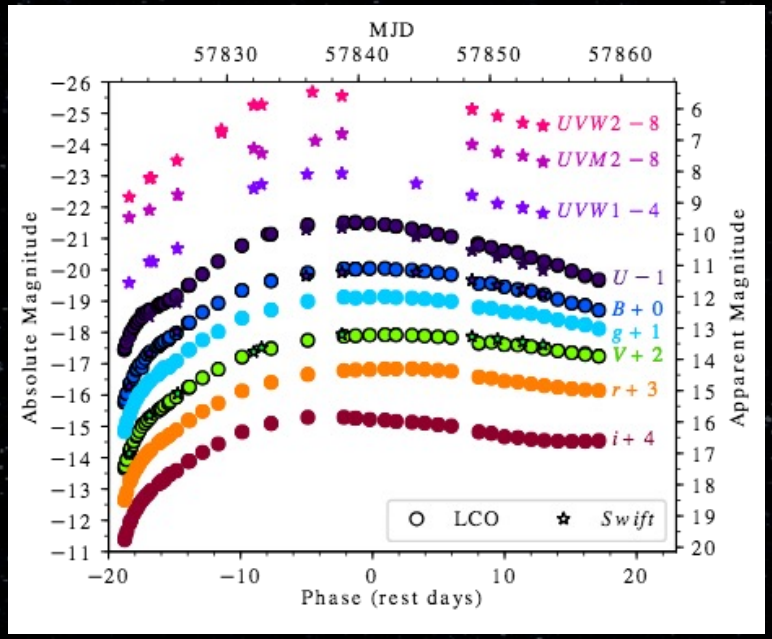
Kasen (2010) Collision with a companion



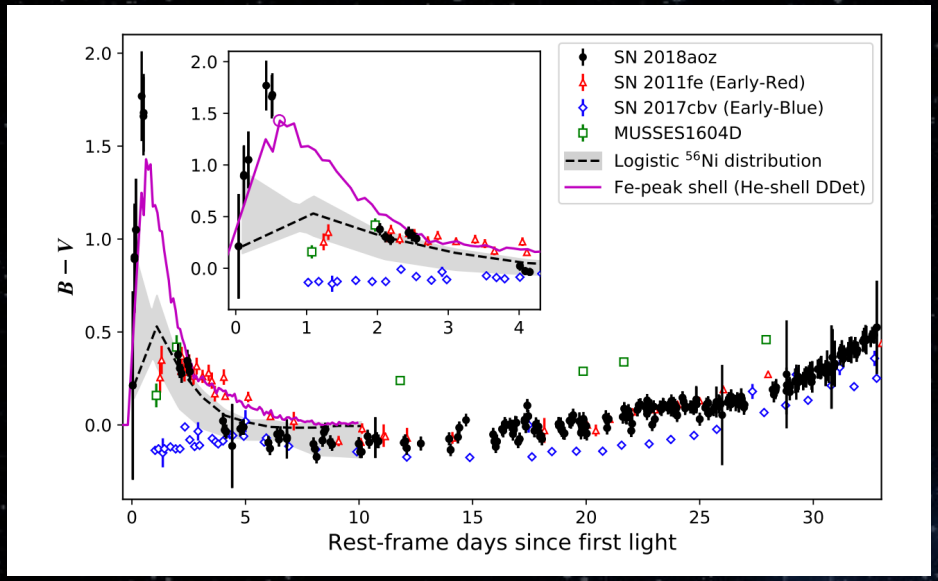
Polin+ (2019) Surface Radioactive decay due to a helium shell detonation

UVEX: A Time Domain Discovery Machine

Thermonuclear Supernovae: Science Themes



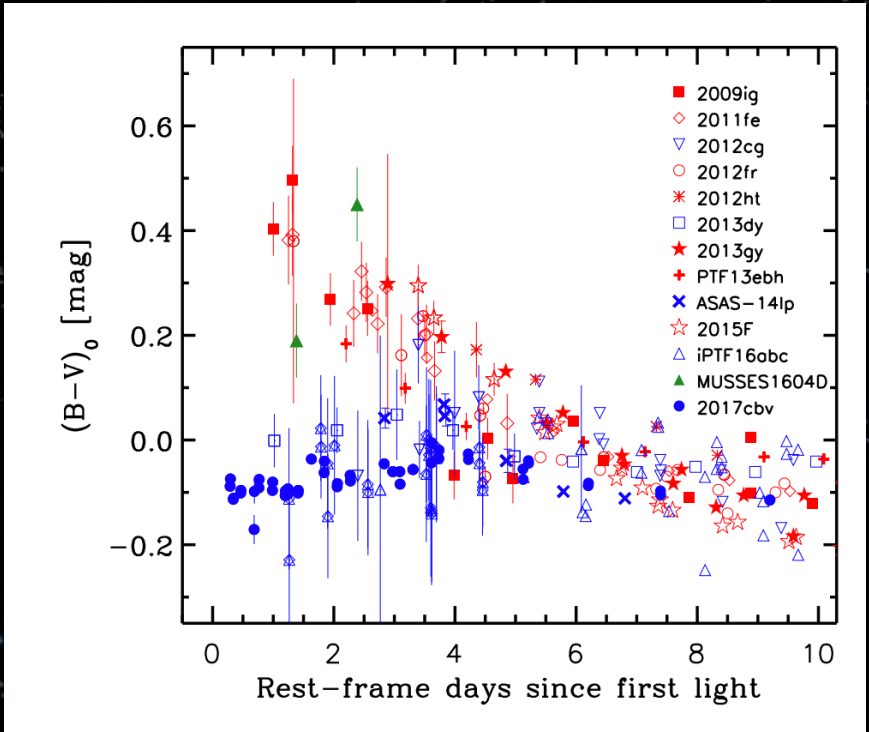
Hosseinzadeh et al (2017)
Type Ia with a blue bump



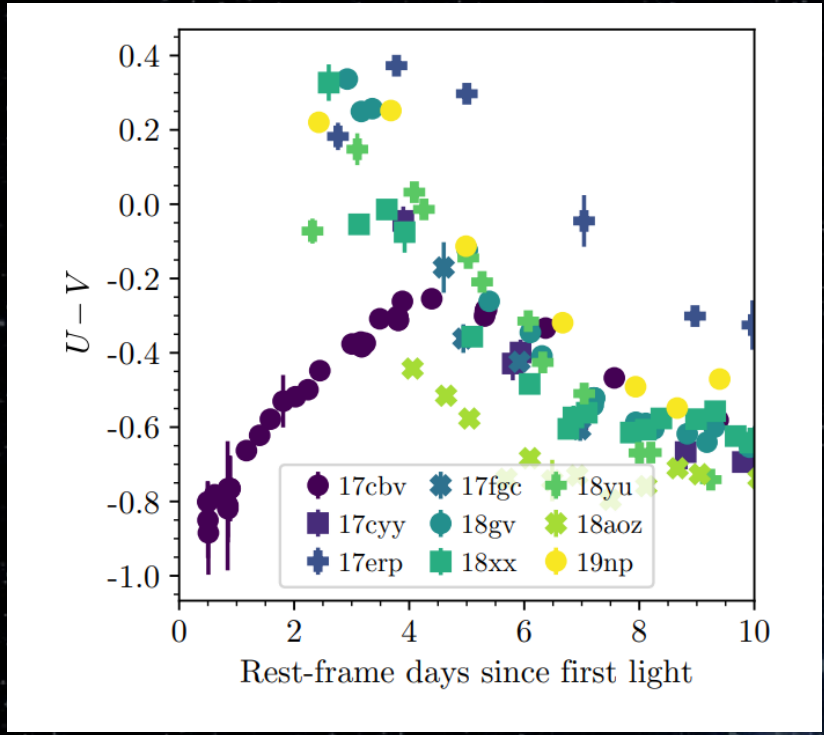
Ni, Moon, Drout et al+ (2022) Type Ia with early excess emission and reddening due to surface Nickel.

UVEX: A Time Domain Discovery Machine

Thermonuclear Supernovae: Science Themes



Stritzinger et al. 2018



Burke et a. (2022)

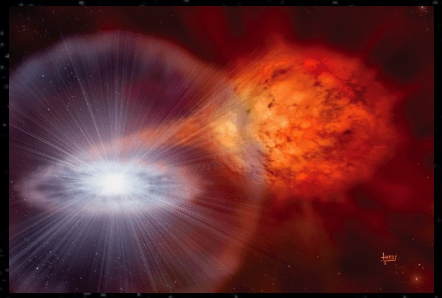
UVEX: A Time Domain Discovery Machine

Thermonuclear Supernovae: The Role of the UV

UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

Core-Collapse Supernova



Thermonuclear Supernova

Peculiar Transients

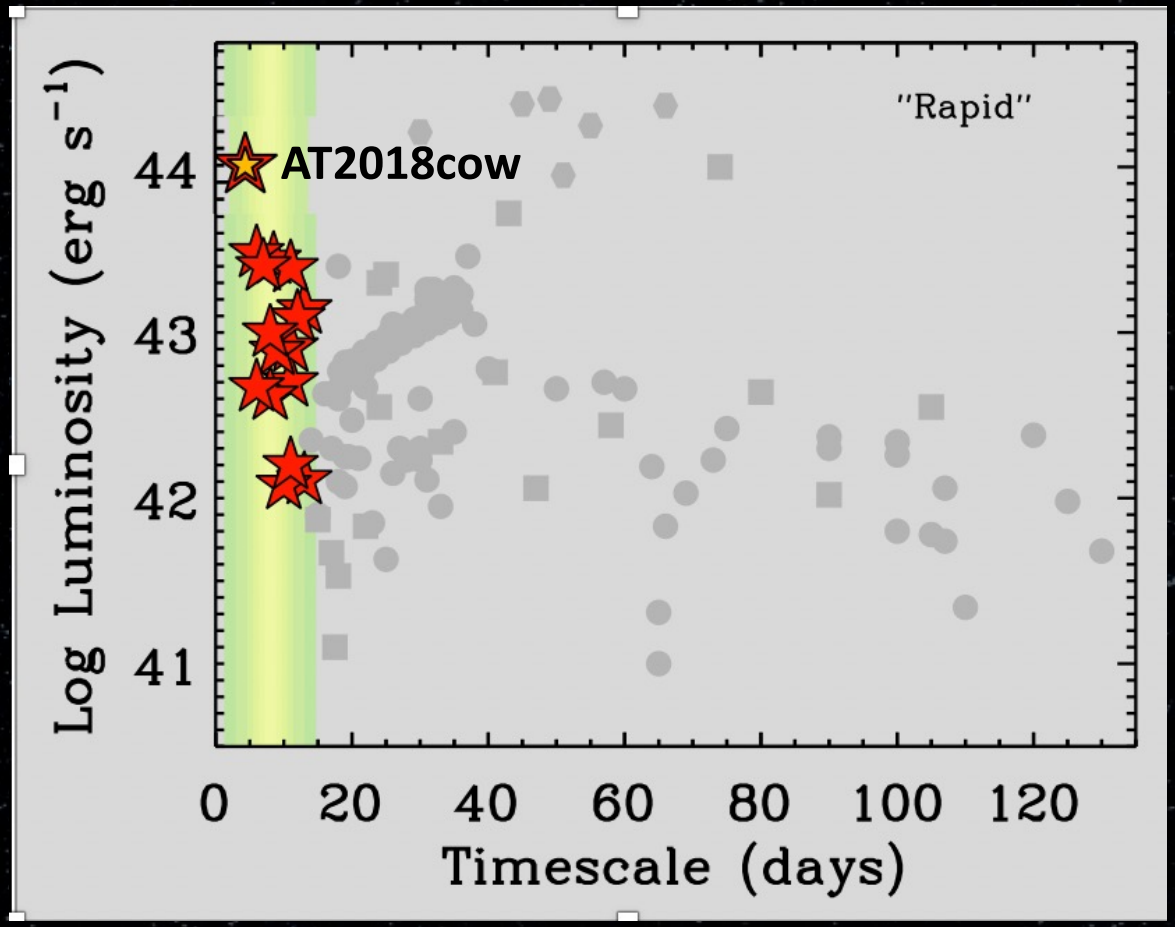
UVEX: A Time Domain Discovery Machine

Peculiar Transients: Science Themes

What is the origin of various classes of “peculiar” transients discovered in modern time domain surveys?

UVEX: A Time Domain Discovery Machine

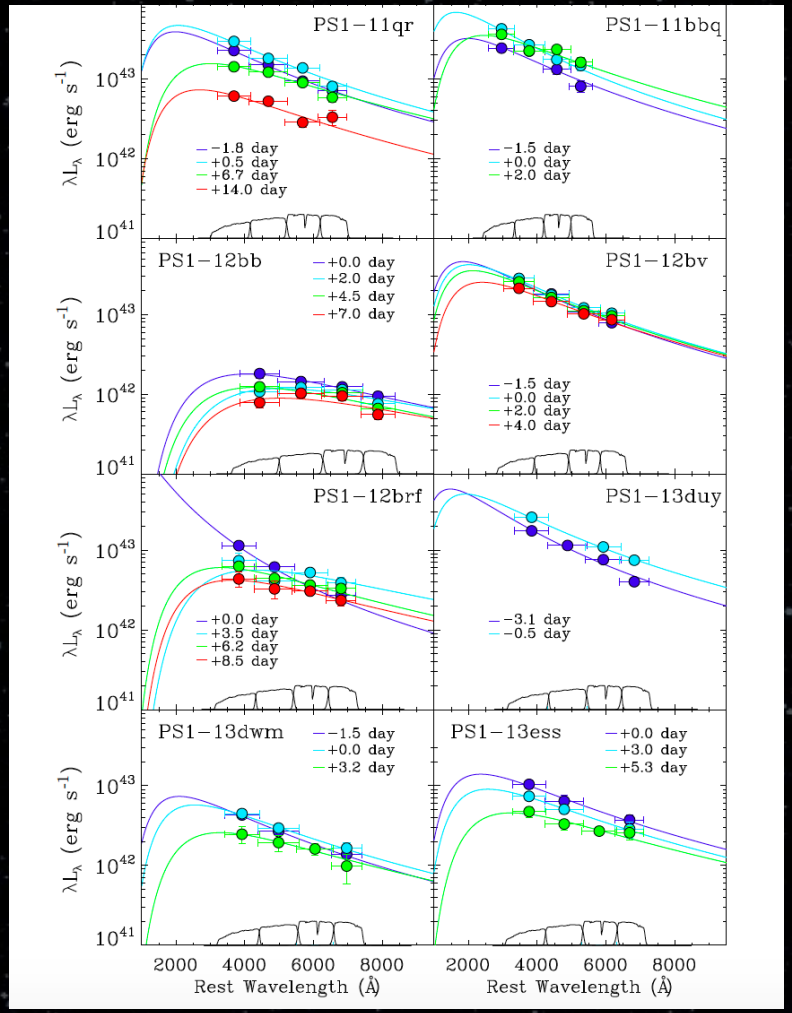
Peculiar Transients: Science Themes



Overall, their rates are not low (Drout+2014, Pursiainen+2018), but certain sub-populations are (Ho+2021)

UVEX: A Time Domain Discovery Machine

Peculiar Transients: Science Themes



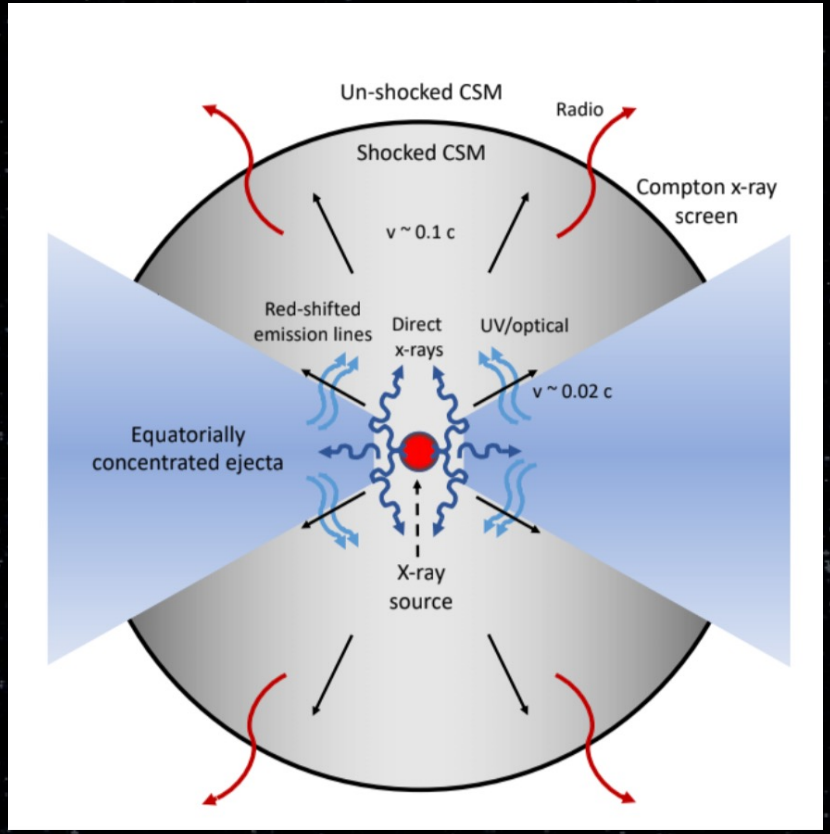
Many have:

hot temperatures and colors that peak in the UV at maximum

Timescales and luminosities inconsistent with being powered by radioactive decay

UVEX: A Time Domain Discovery Machine

Peculiar Transients: Science Themes



Margutii+2018

Some some: Evidence for central engine activity and/or circumstellar interaction

Theories include: Failed supernova, mergers, tidal disruption events, …

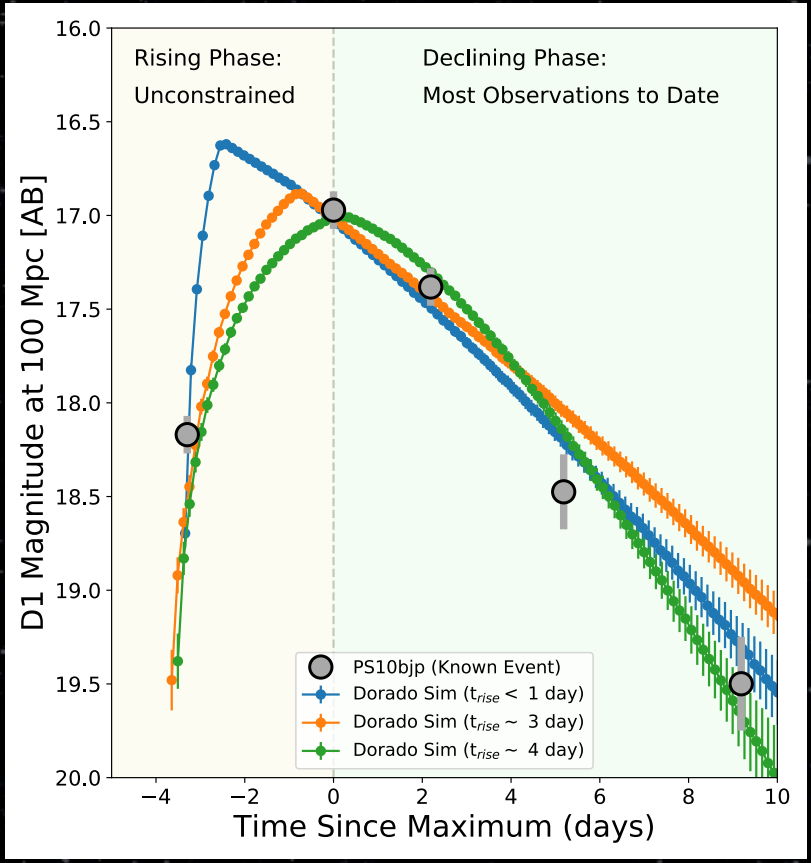
UVEX: A Time Domain Discovery Machine

Peculiar Transients: The Role and Potential of UV Data

1. Discovery

UVEX: A Time Domain Discovery Machine

Peculiar Transients: The Role and Potential of UV Data

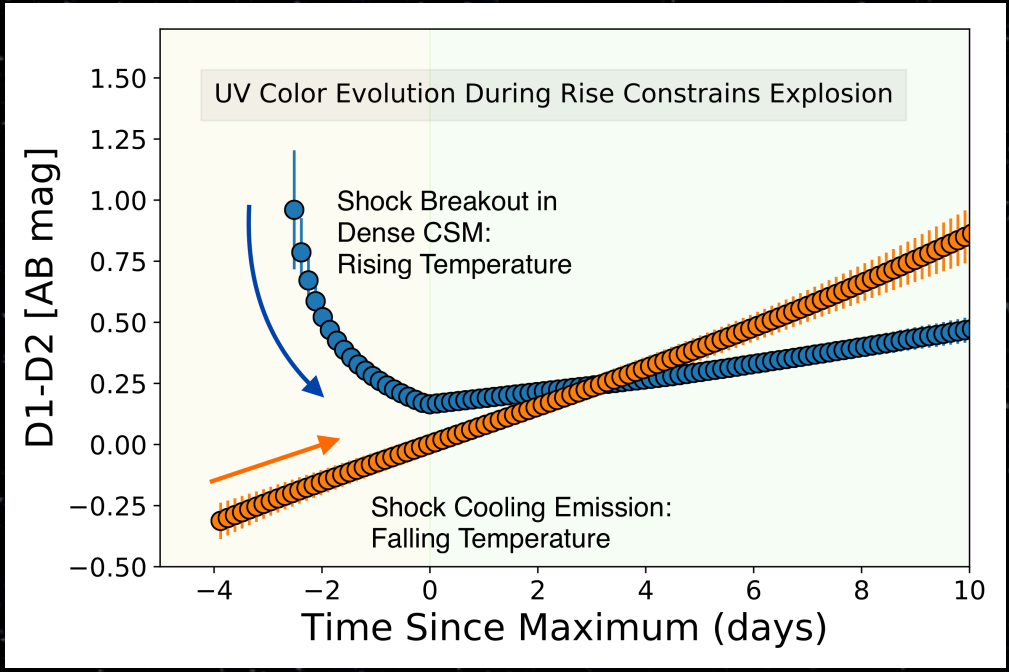


1. Discovery
2. Rise Time Measurements

UVEX: A Time Domain Discovery Machine

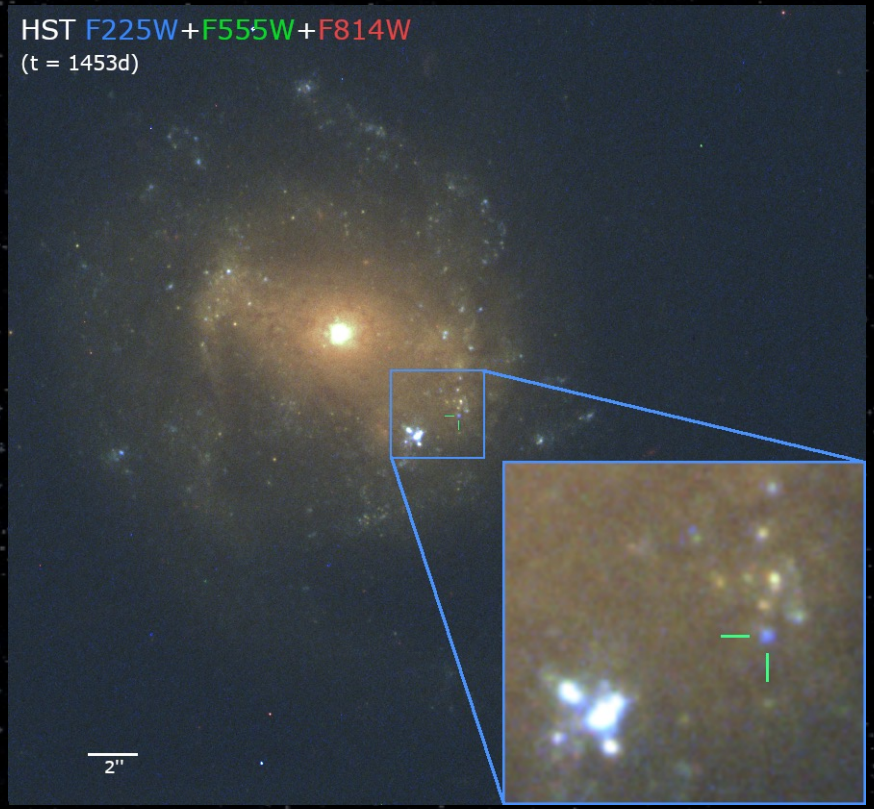
Peculiar Transients: The Role and Potential of UV Data

1. Discovery
2. Rise Time Measurements
3. Temperature Evolution on the rising phase



UVEX: A Time Domain Discovery Machine

Peculiar Transients: The Role and Potential of UV Data

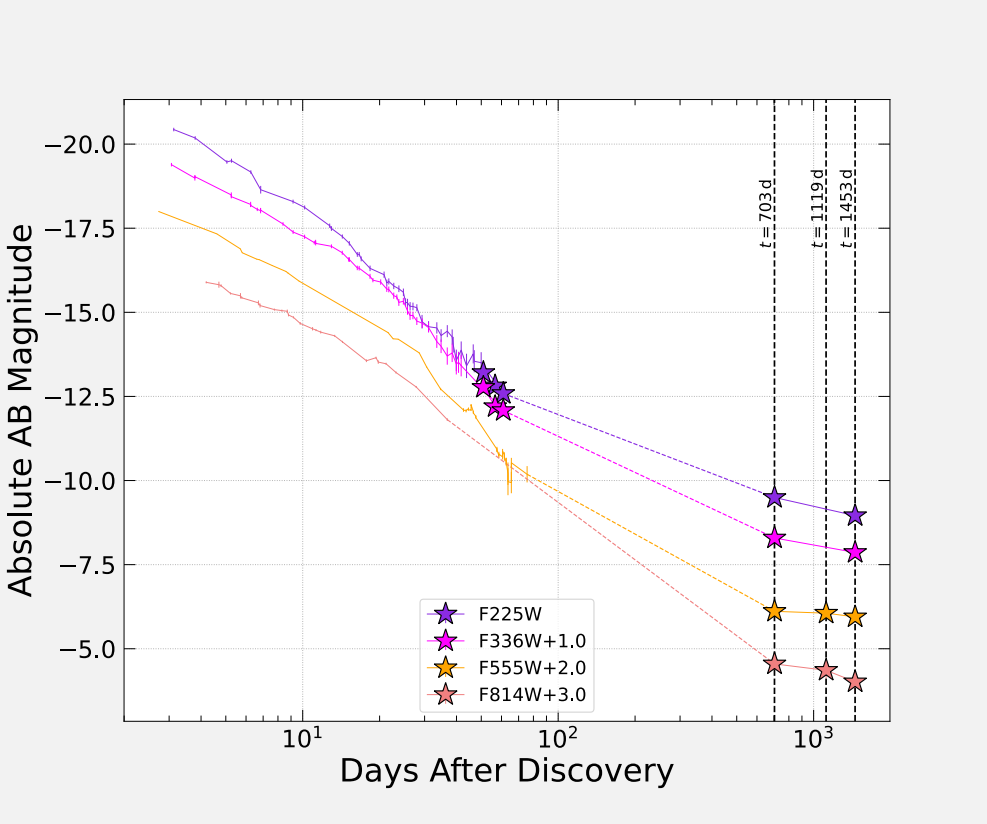


1. Discovery
2. Rise Time Measurements
3. Temperature Evolution on the rising phase
4. Probing the presence of a late-time time power source.

Chen, Drout, Piro et al. 2023b

UVEX: A Time Domain Discovery Machine

Peculiar Transients: The Role and Potential of UV Data

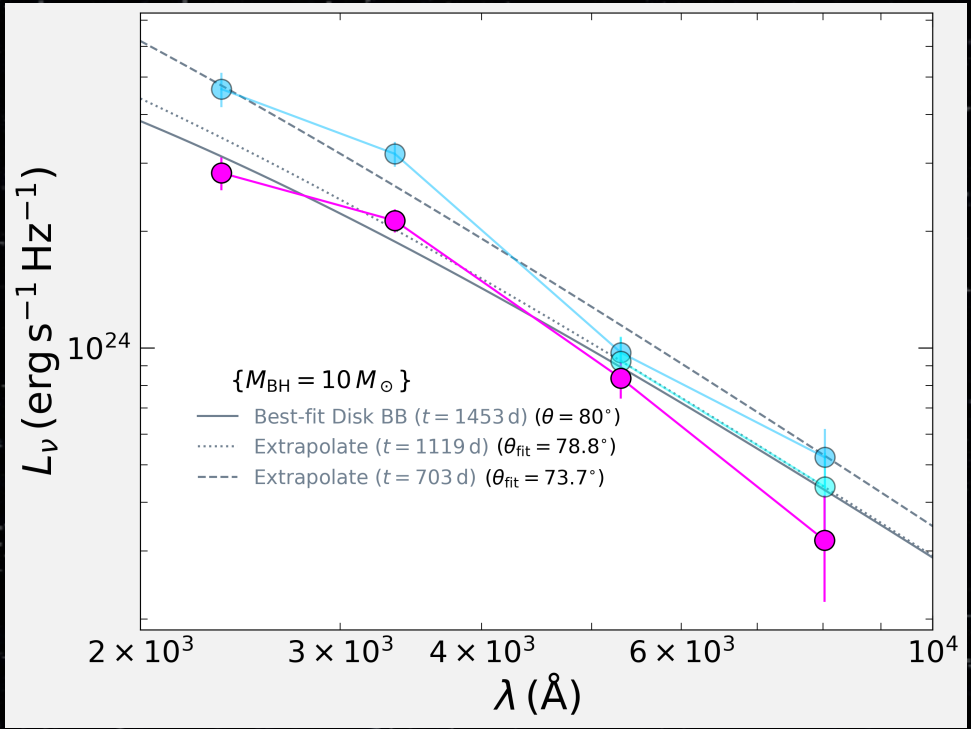


1. Discovery
2. Temperature Evolution on the rising phase
3. Probing the presence of a late-time time power source.

Chen, Drout, Piro et al. 2023b

UVEX: A Time Domain Discovery Machine

Peculiar Transients: The Role and Potential of UV Data



1. Discovery
2. Temperature Evolution on the rising phase
3. Probing the presence of a late-time time power source.

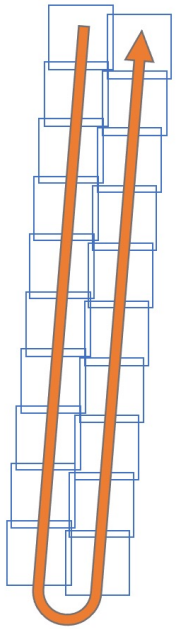
Chen, Drout, Piro et al. 2023b

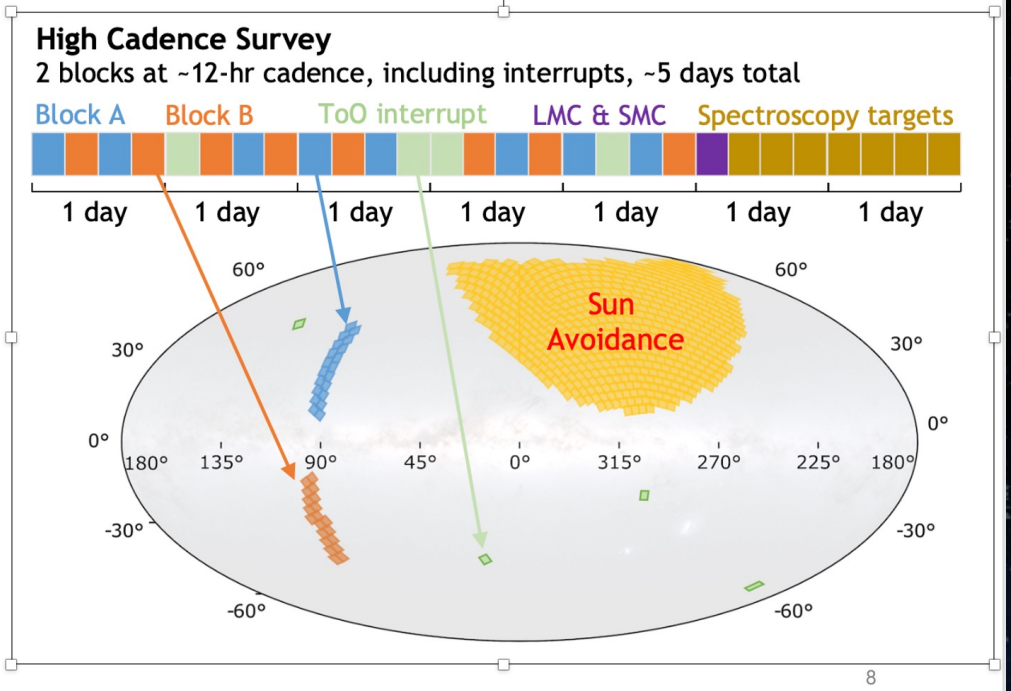
UVEX: A Time Domain Discovery Machine

Multiwavelength Coordination will be critical

One 6-hr Survey Block =
- 20 contiguous fields
- One dwell per field

One Dwell =
- 3 x NUV Images
- 1 x FUV Image
- 1 x LSS image
- All simultaneous w/overheads ≈ 930s

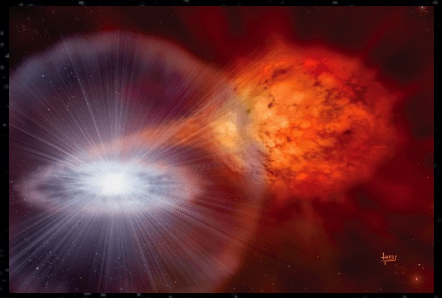




UVEX: A Time Domain Discovery Machine

UV Photometry as a Probe of Stellar Explosions

Core-Collapse Supernova



Thermonuclear Supernova

Peculiar Transients