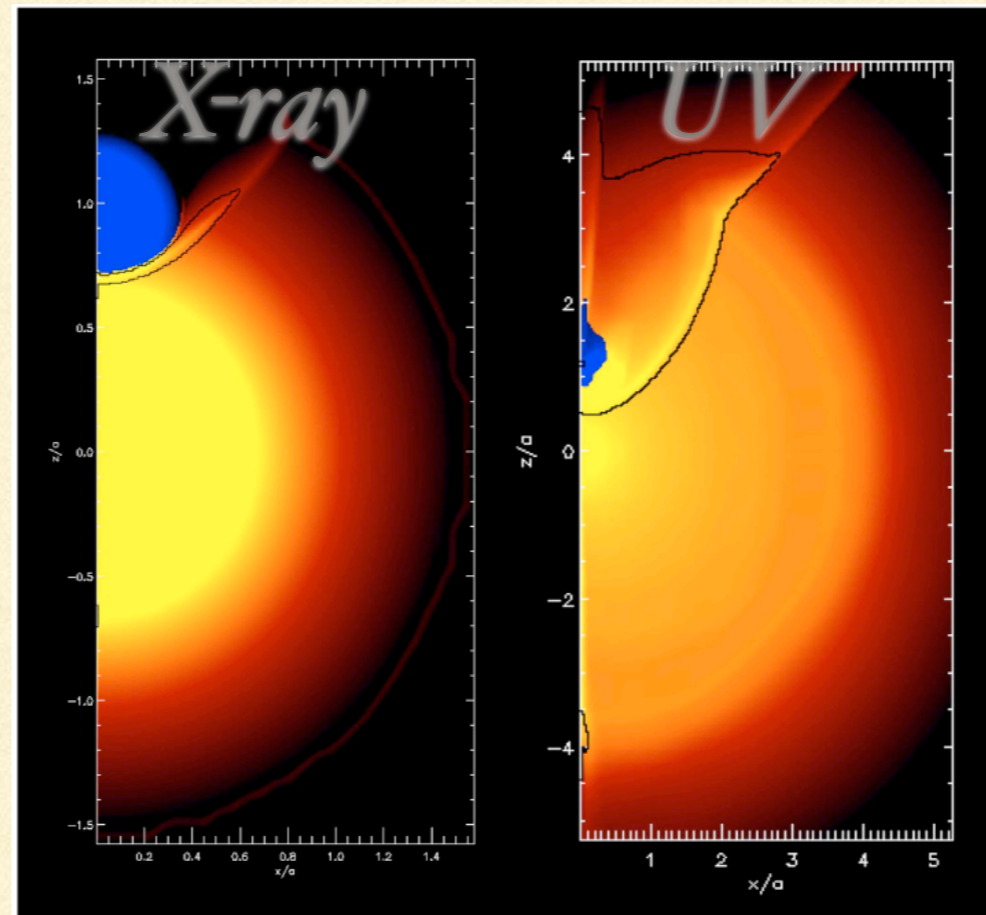
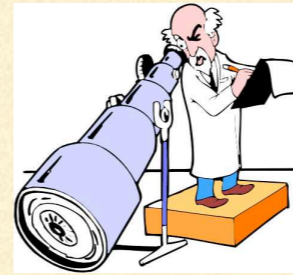




ULTRAVIOLET PULSE FROM TYPE IA SUPERNOVAE

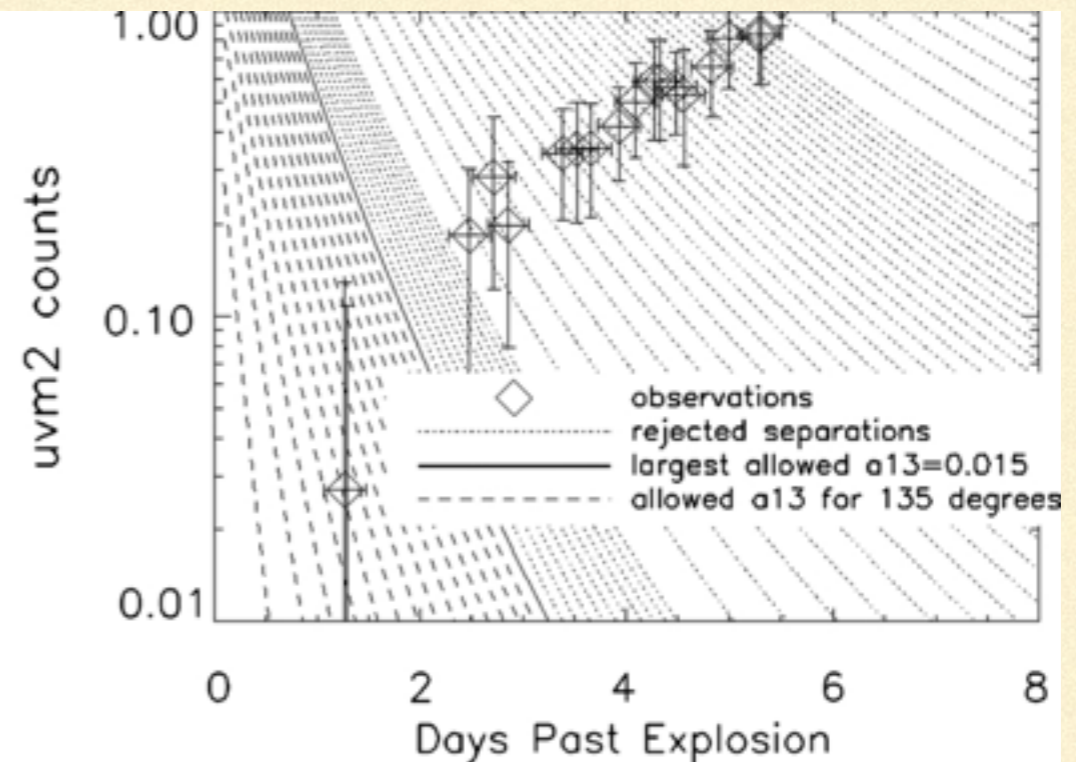
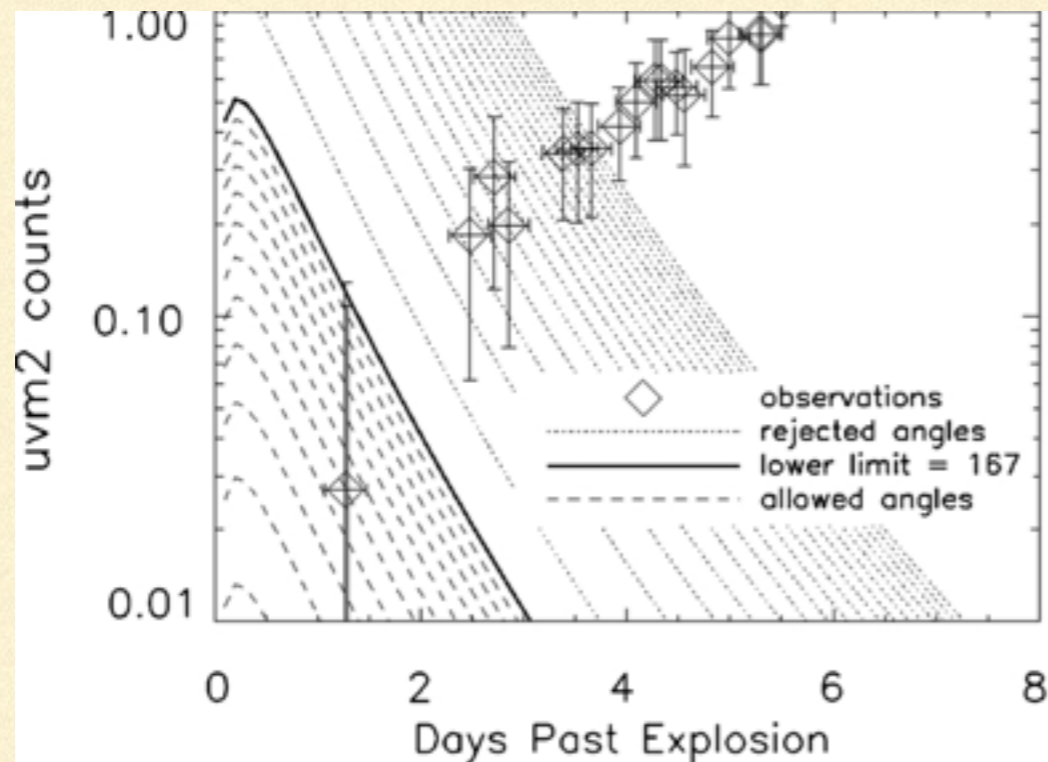
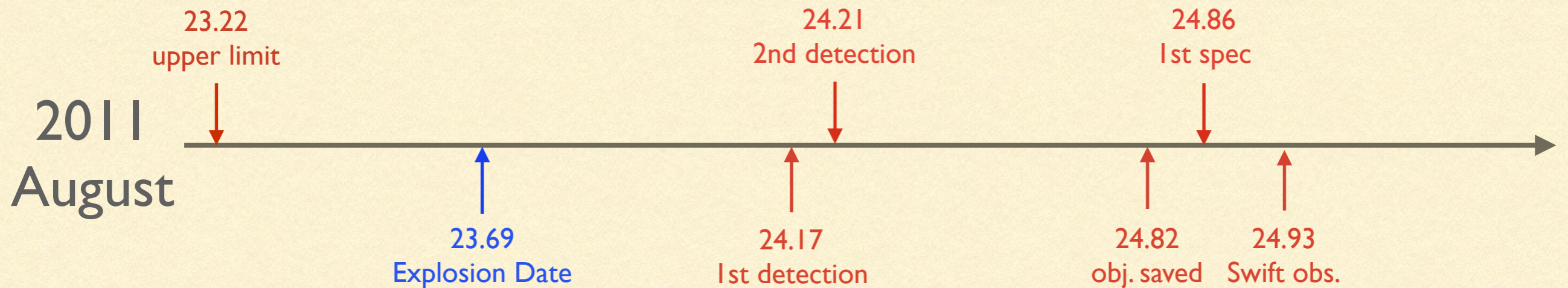
Yi Cao (Caltech)

Collaborators: S. R. Kulkarni (Advisor), P. E. Nugent, M. M. Kasliwal, A. Goobar, A. Gal-Yam, and the intermediate Palomar Transient Factory collaboration



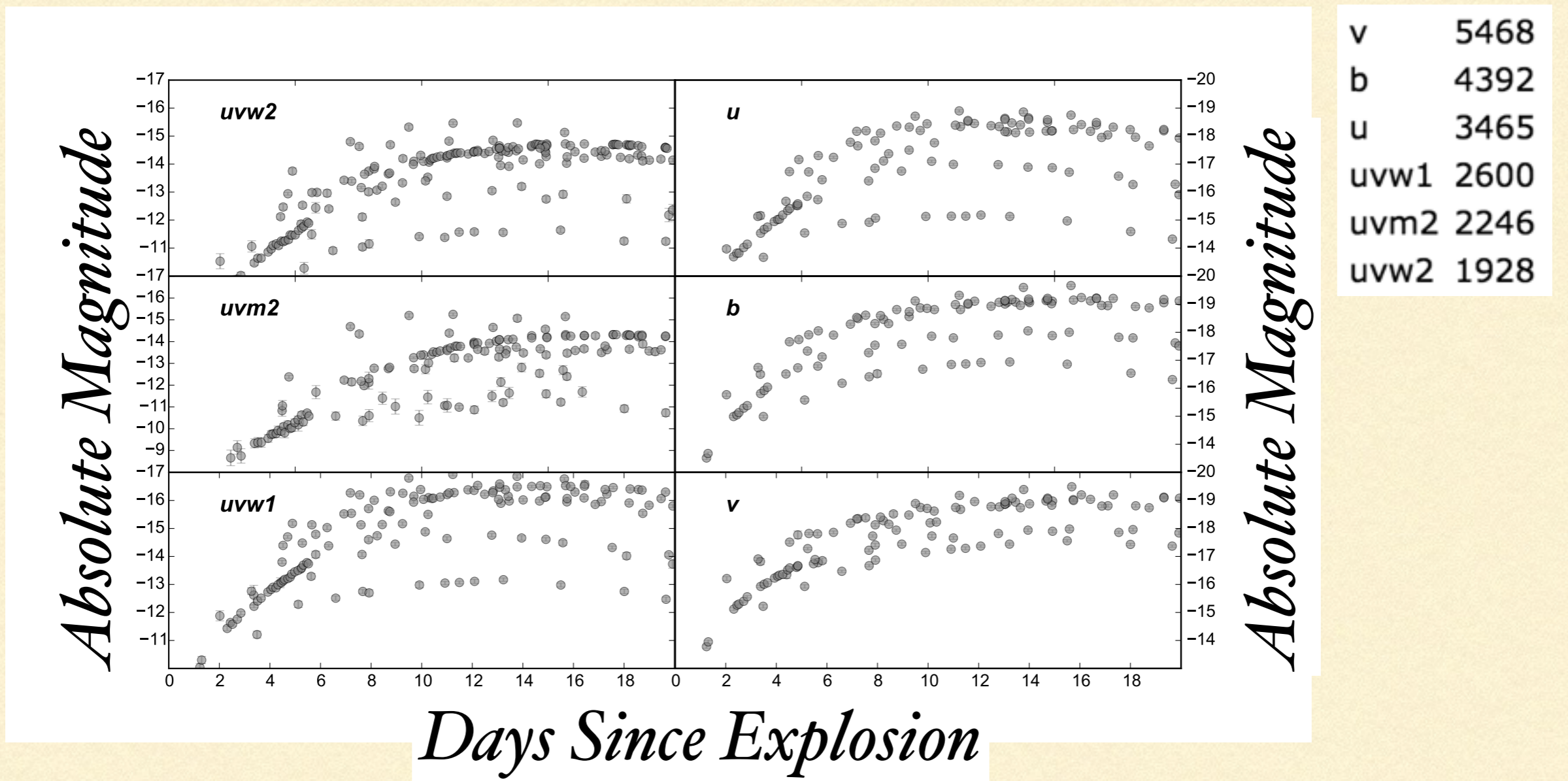
(Kasen 2010)

SWIFT OBSERVATIONS OF SN2011FE



(Nugent et al. 2011; Brown et al. 2012)

UV OBSERVATIONS OF SNE IA



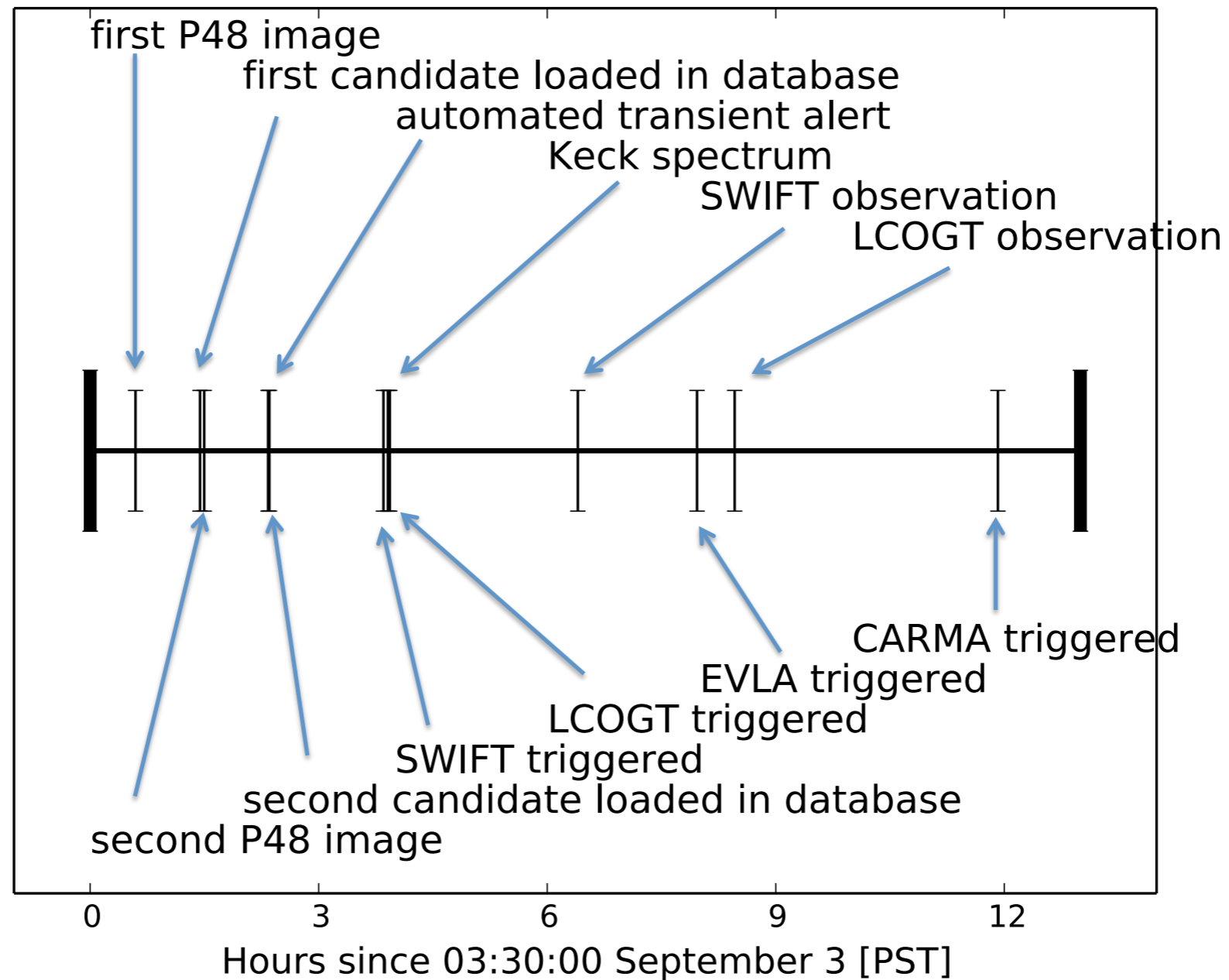
(Milne et al. 2010; Brown et al. 2012a, 2012b)

INTERMEDIATE PALOMAR TRANSIENT FACTORY

- Primary Science Goal: fast-cadence survey for young & fast transients
- Discovery Machine: 48-inch Telescope at Palomar
- Follow-up Machine: Palomar 60-inch (Phot.), Palomar 200-inch (Spec.), Keck (Spec.), Gemini-N (Spec.), NOT (Phot. & Spec.), Swift (UV)
- Transient Discovery in 15 minutes, Spectroscopy Classification in 1 hour, Swift Observation in a few hours

FAST & FURIOUS

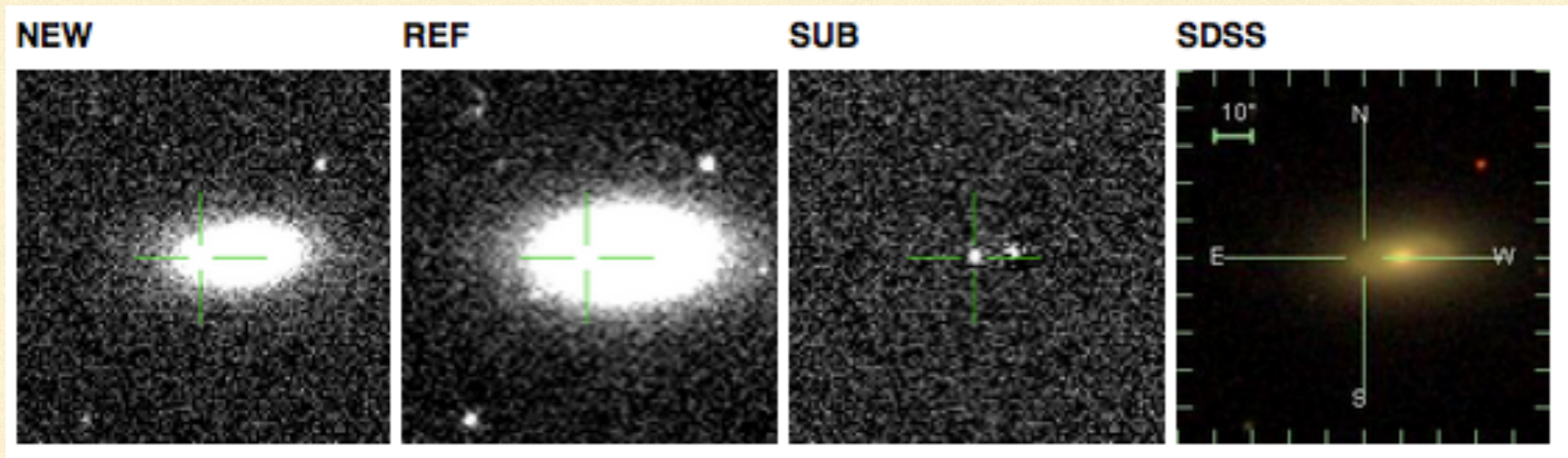
23
upper
2011
August



IPTF YOUNG SNE IA SAMPLE

- Selection criterion: fainter than -16.5 mag at discovery (within a week of explosion; $z < 0.07$)
- Sample: 38 young SNe Ia
 - two 91T-like; two 02es-like; two 02cx-like
 - Swift obs: three < 1 day, four < 2 days, 1 < 3 days

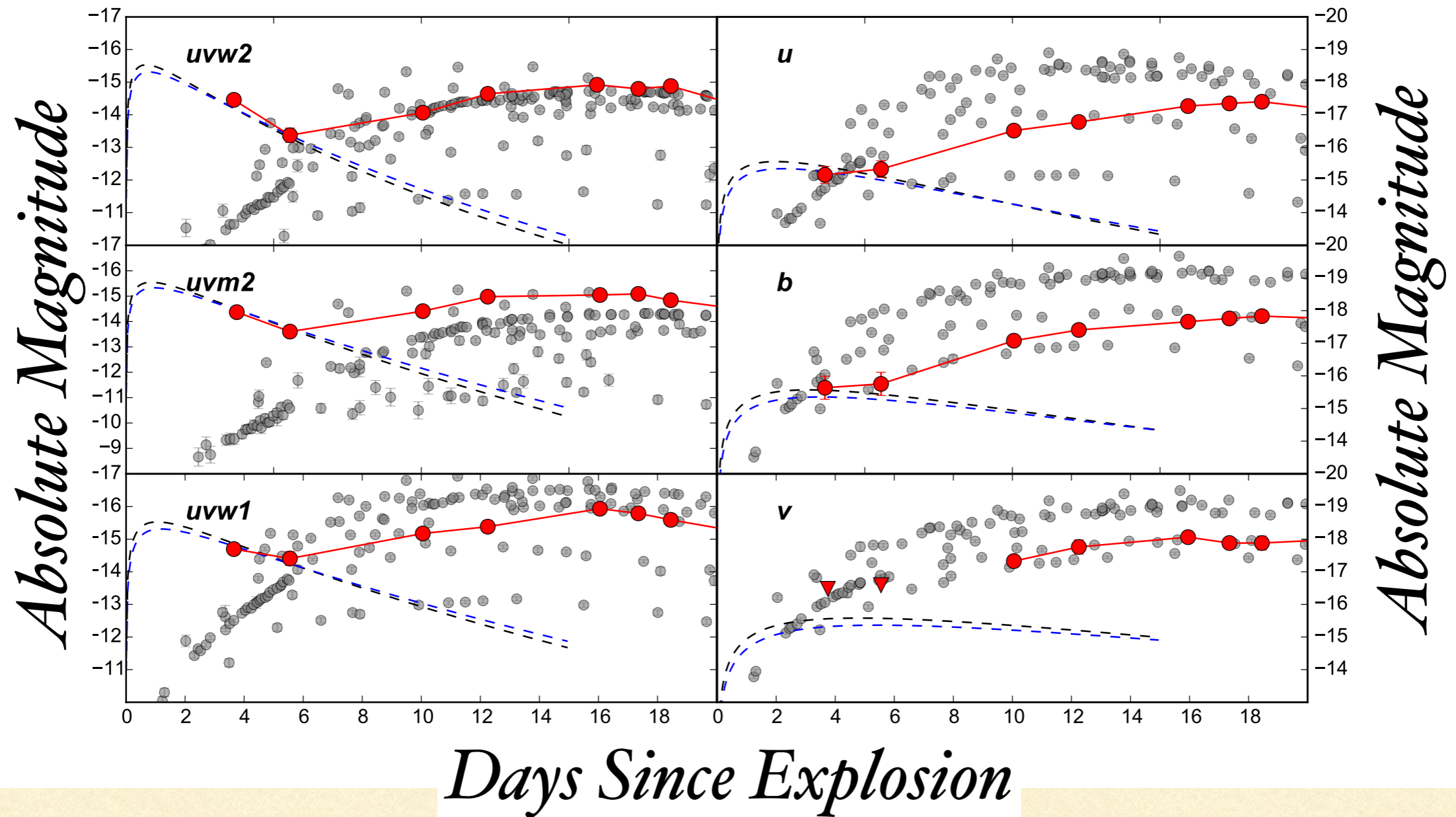
IPTF 14ATG: DISCOVERY



redshift: 0.021

(Cao et al. 2015 Nature)

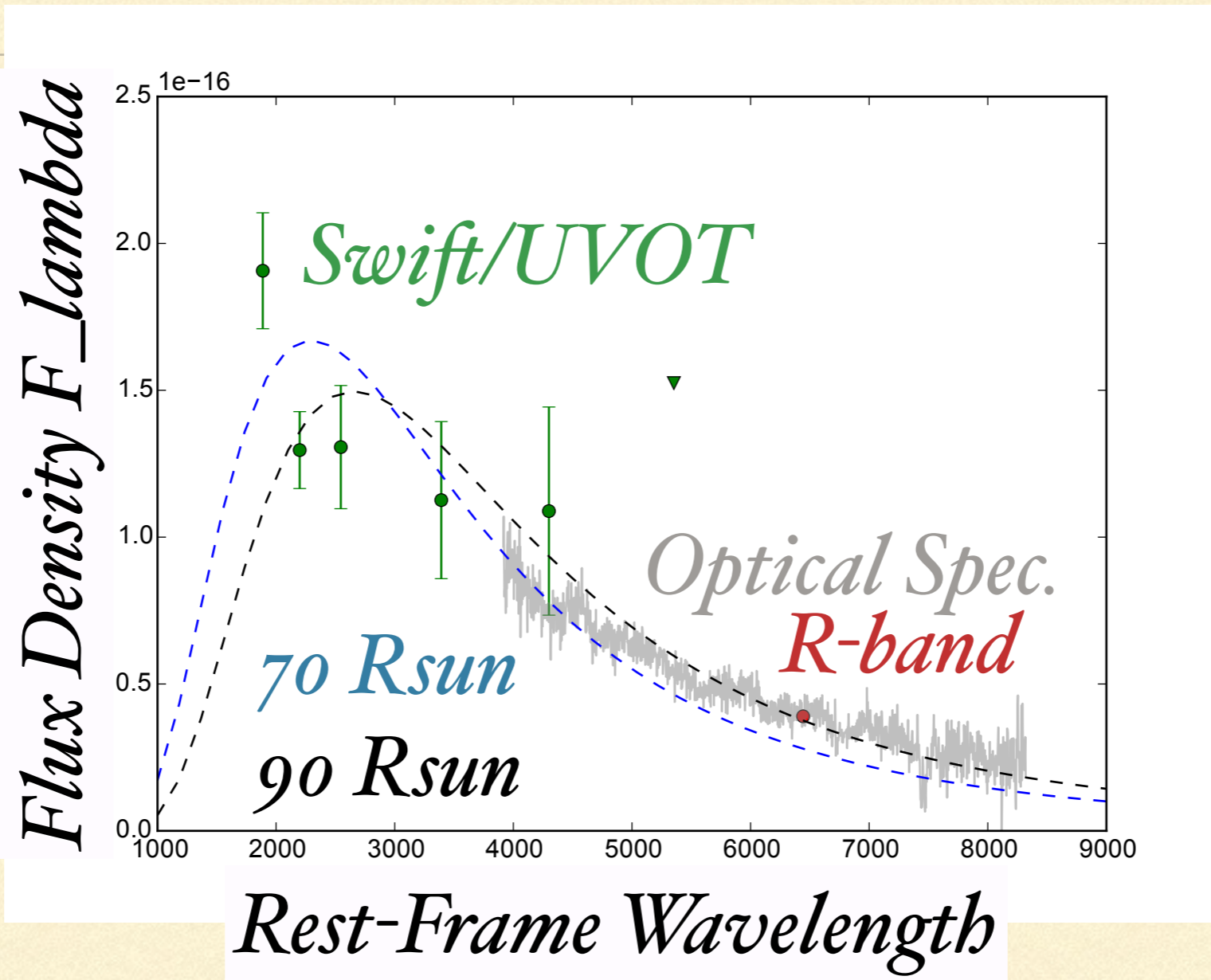
IPTF14ATG: SWIFT LIGHTCURVE



UV Luminosity: 3×10^{41} erg/s
Binary Separation: 70 or 90 R_{sun}

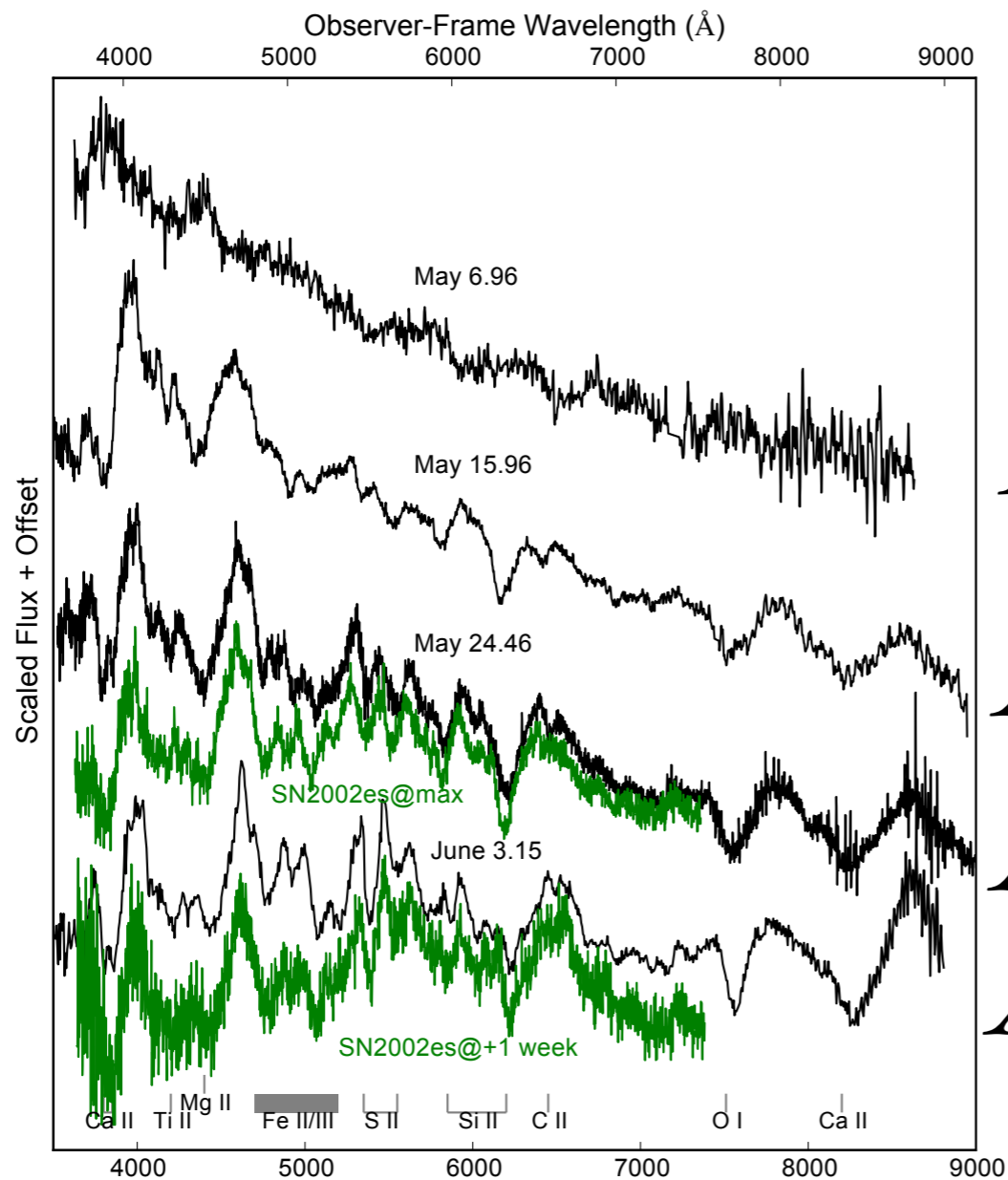
(Cao et al. 2015 Nature)

IPTF14ATG: SPECTRAL ENERGY DISTRIBUTION



(Cao et al. 2015 Nature)

IPTF14ATG: OPTICAL SPECTRA



Black: iPTF14atg

Green: SN2002es

During UV flare

About 10 days before max

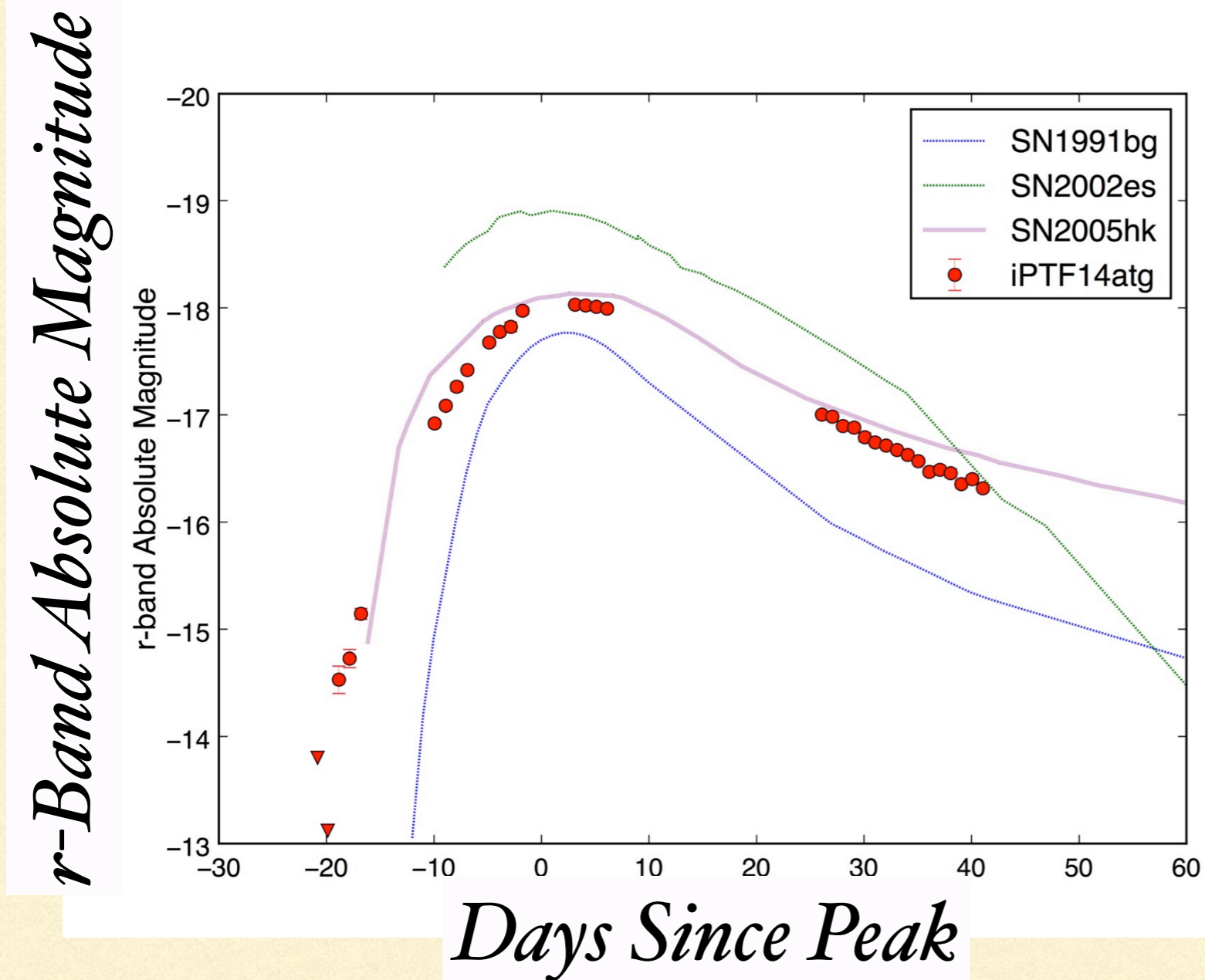
Around max

About a week after max

Rest-Frame Wavelength

(Cao et al. 2015 Nature)

IPTF14ATG: OPTICAL LIGHTCURVE

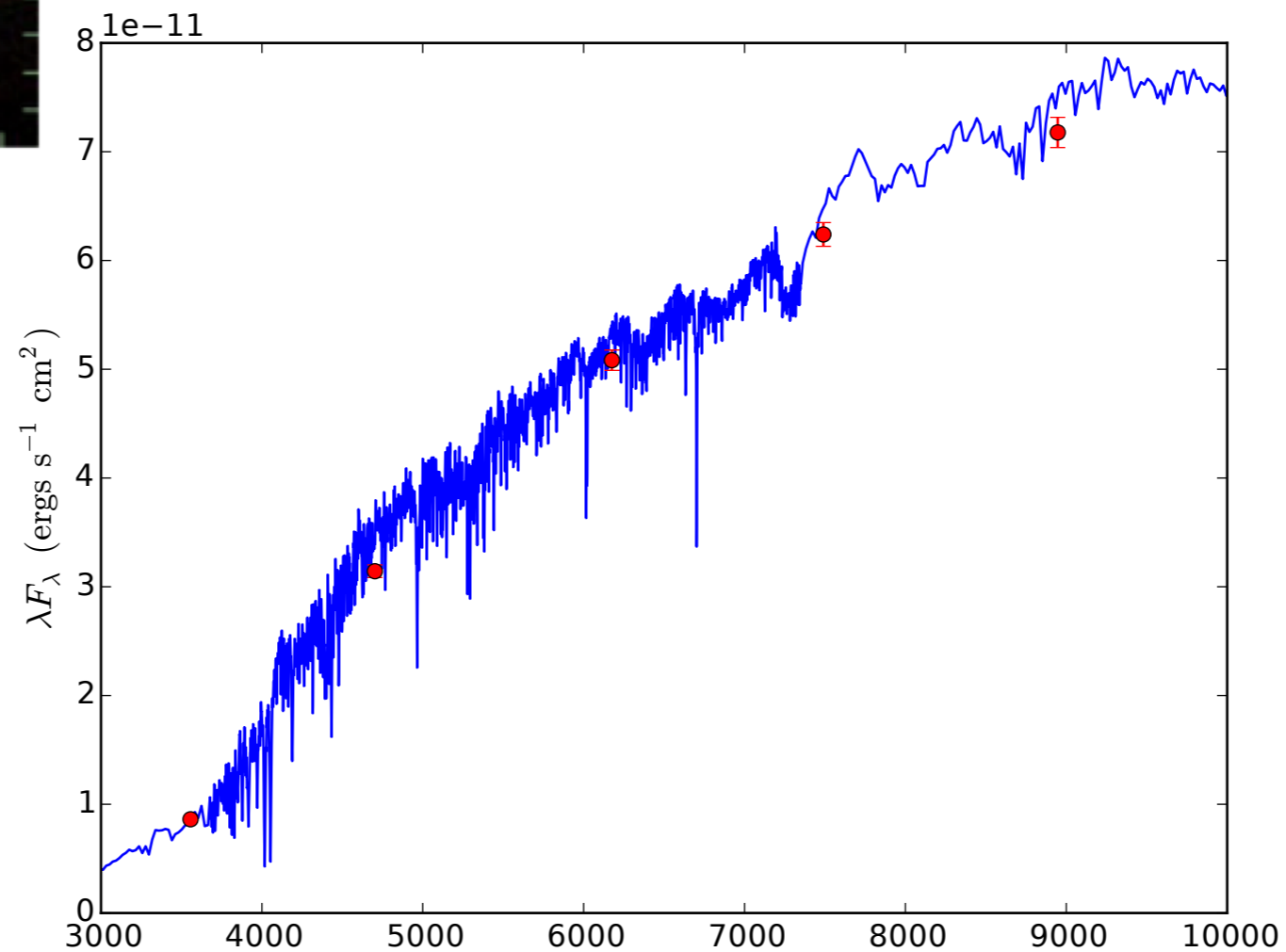


(SN1991bg: Filippenko et al. 1992;
SN2005hk: Phillips et al. 2007;
SN2002es: Ganeshalingam et al. 2012;
iPTF14atg: Cao et al. 2015 Nature)

IPTFI 4ATG: HOST GALAXY



*Stellar Mass: a few times $10^{10} M_{\text{sun}}$
No Star Formation*



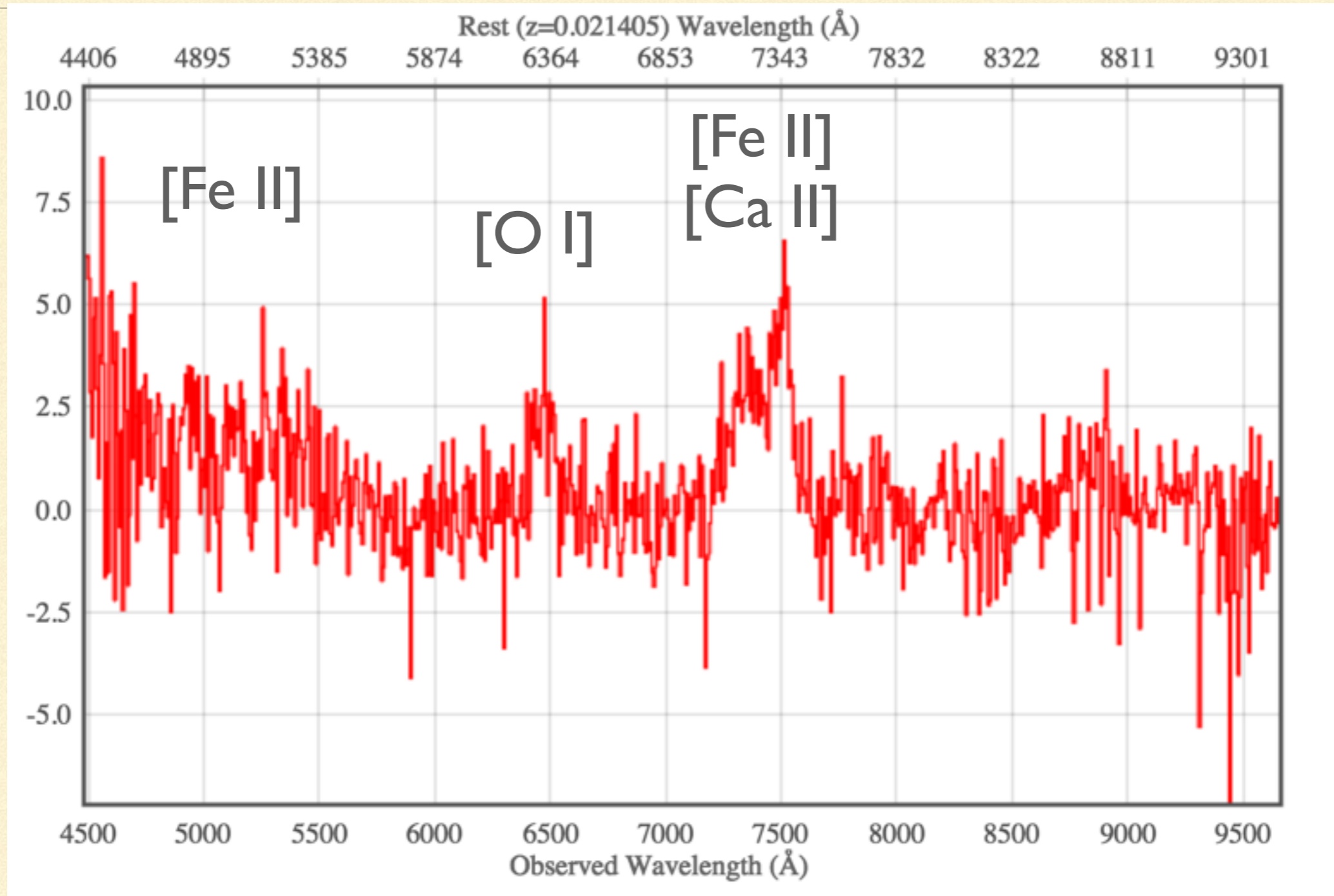
Observed Wavelength

SUMMARY OF IPTF14ATG

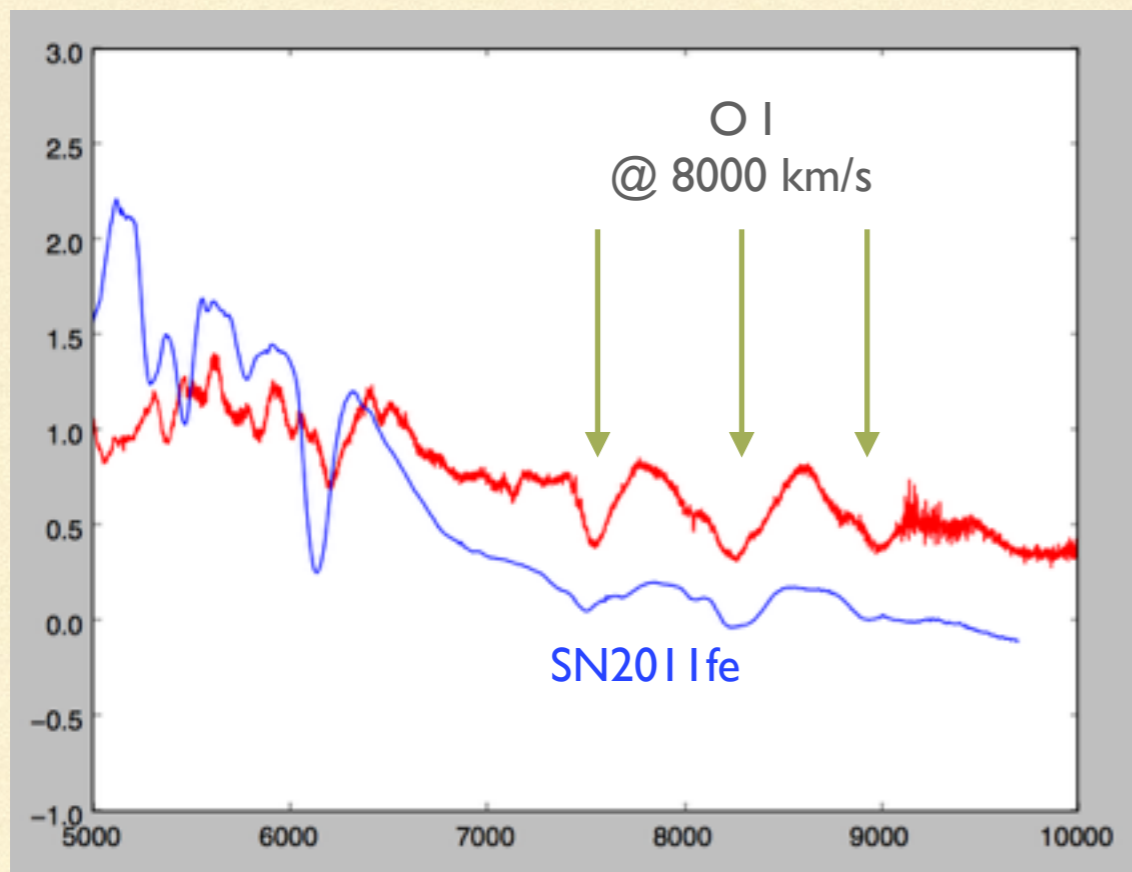
- iPTF14atg is a thermonuclear supernova.
- We observed a strong and declining UV flare in iPTF14atg within a few days of its explosion.
- This UV flare is consistent with the supernova-companion interaction signature. This observation is a strong evidence that a companion star exists.
- The observations of iPTF14atg together with other recent observations strongly suggest that thermonuclear supernovae have multiple origins.

IPTF 14ATG: NEBULAR SPECTRUM

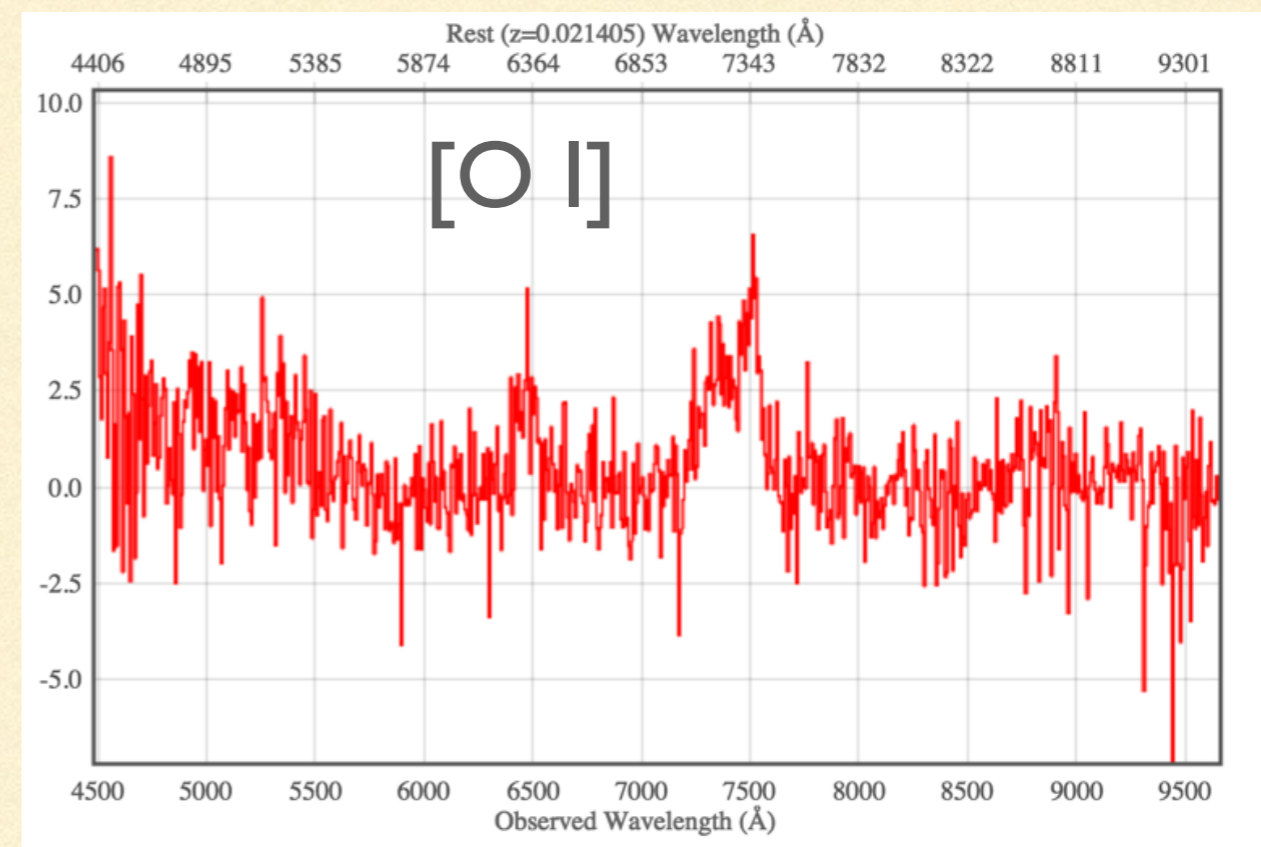
Phase:
+210 d



COMPANION COMPOSITION?

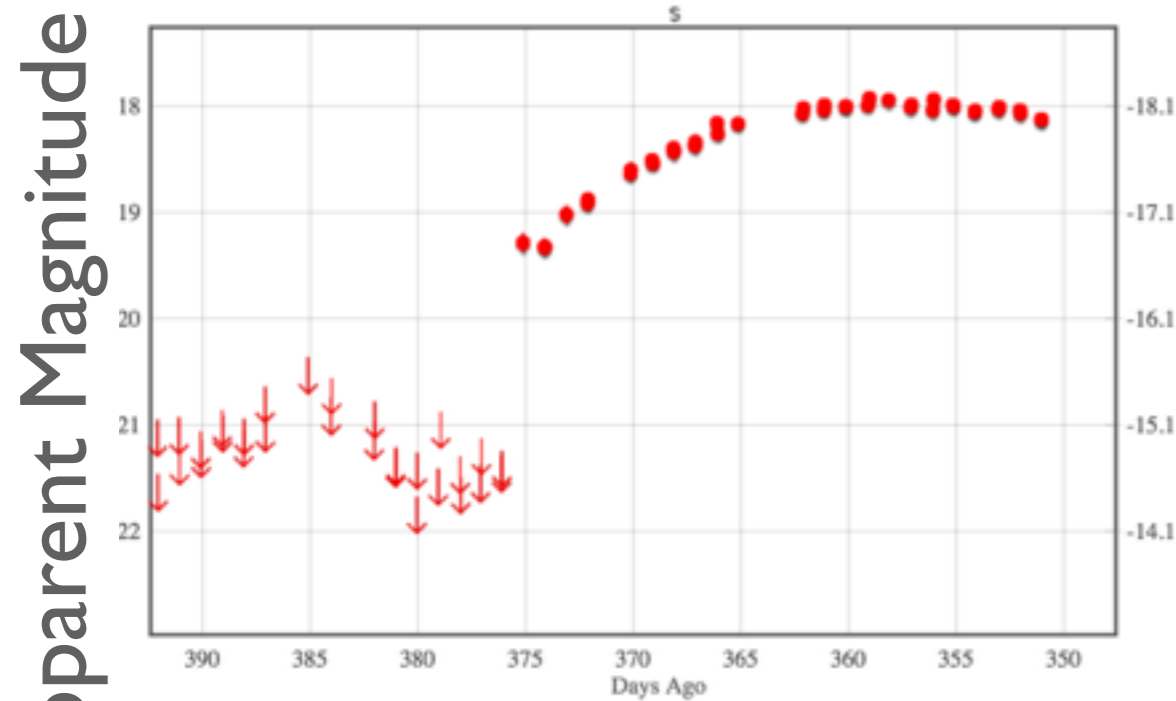


iPTF14atg around max

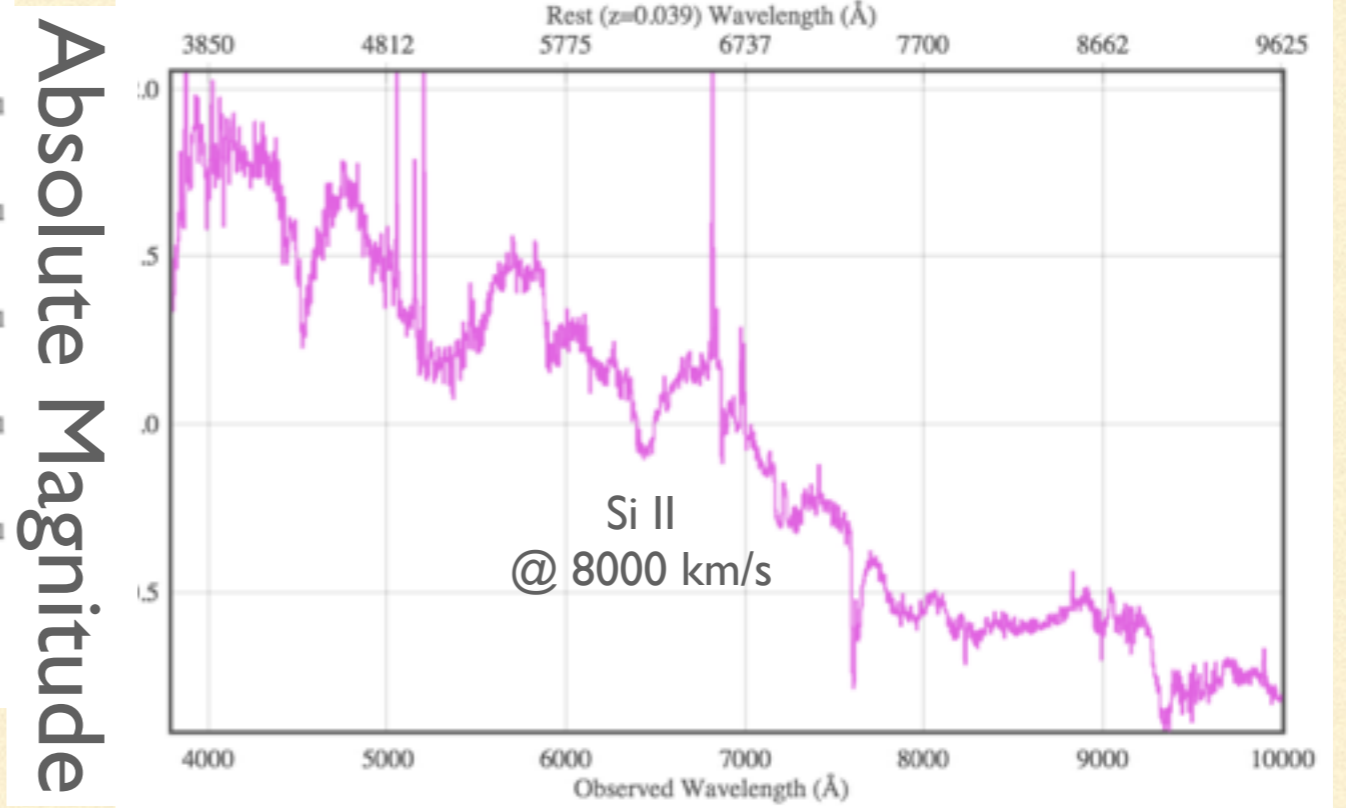


iPTF14atg @ 210 days

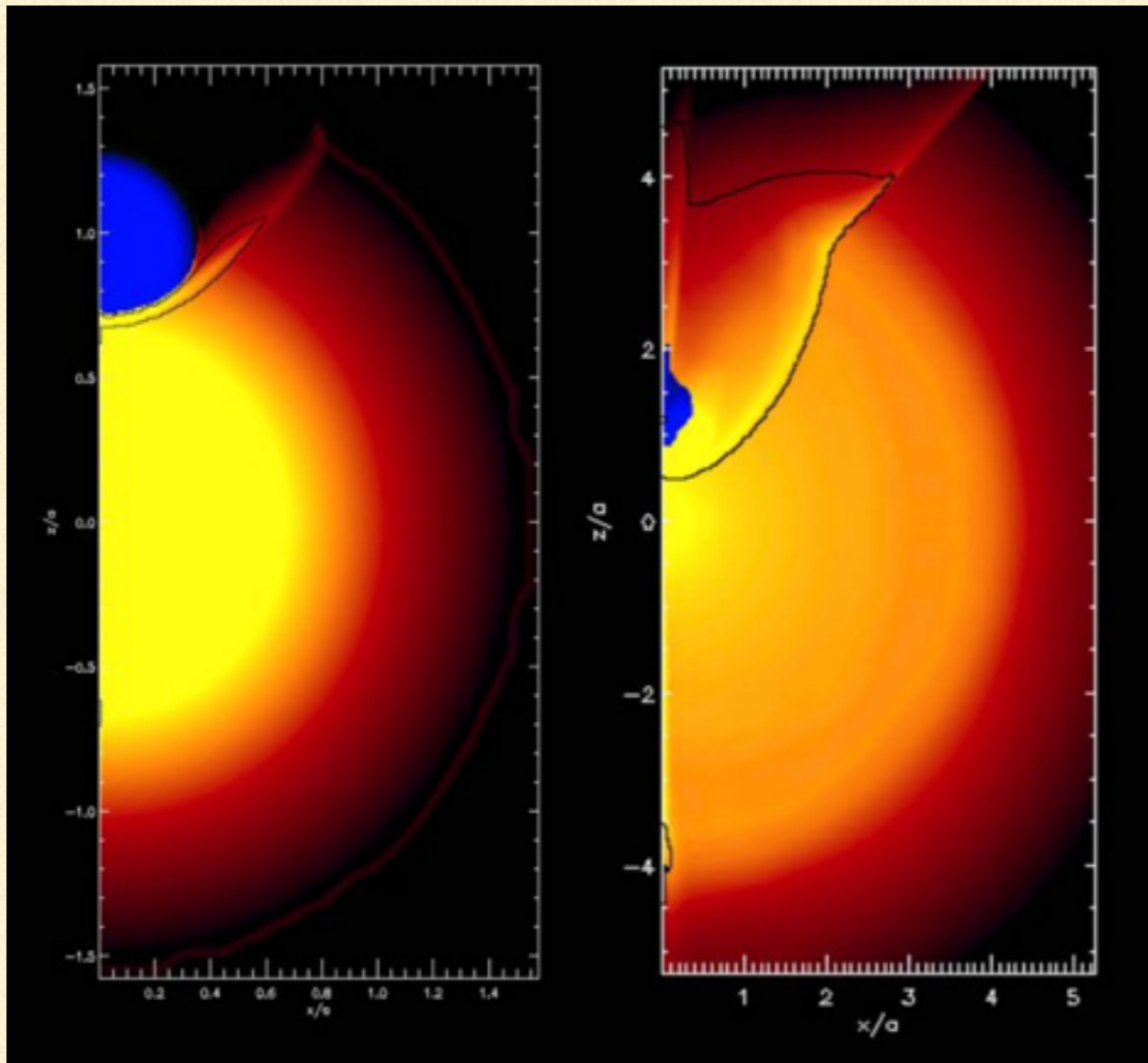
IPTF 14DPK: SN2002ES-LIKE EVENT



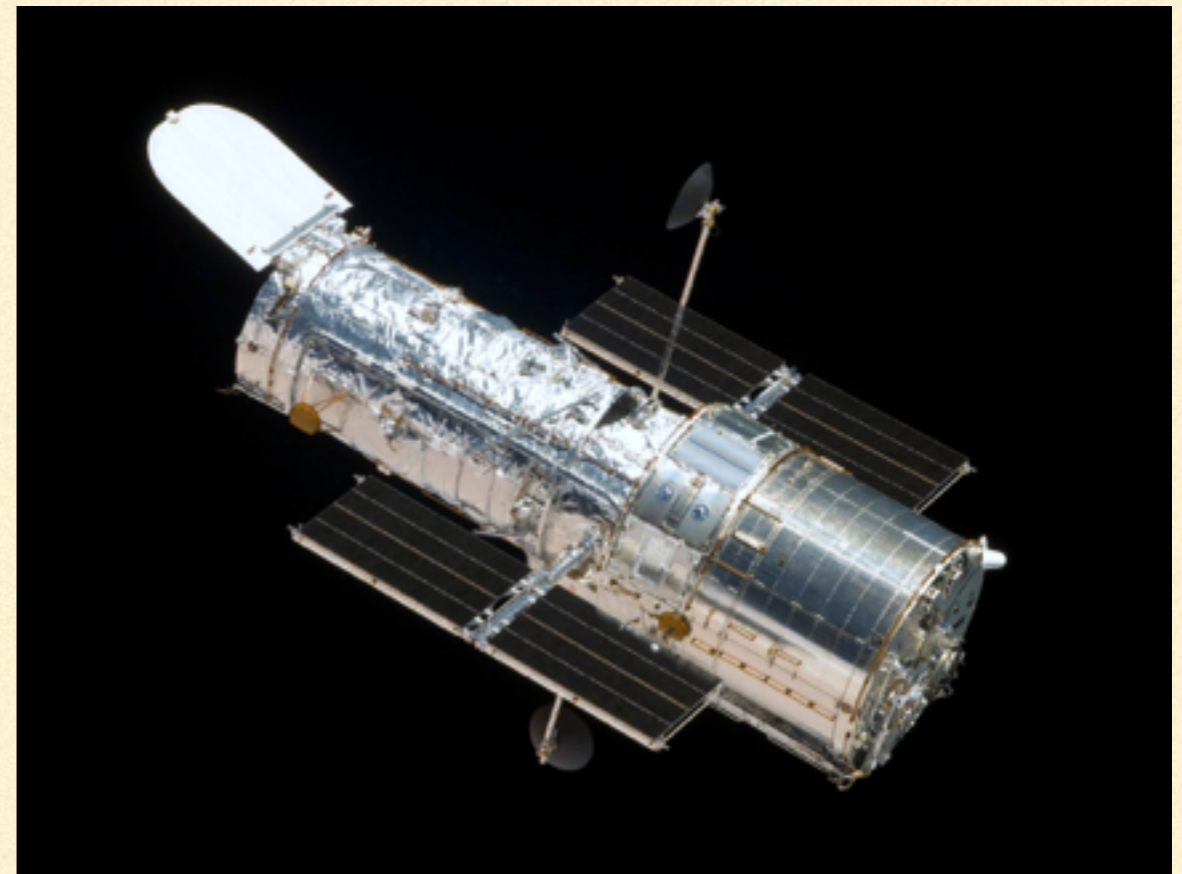
Look-back Time (days)



DETAILED SIMULATIONS ARE WARRANTED!



(Kasen 2010)



Cycle23: 3 orbits w/
HST STIS/NUV-MAMA

BRANCH FRACTIONS OF DIFFERENT CHANNELS

SN Ia_x

SN2002es-like

SN Ia-CSM

CV (maybe?)



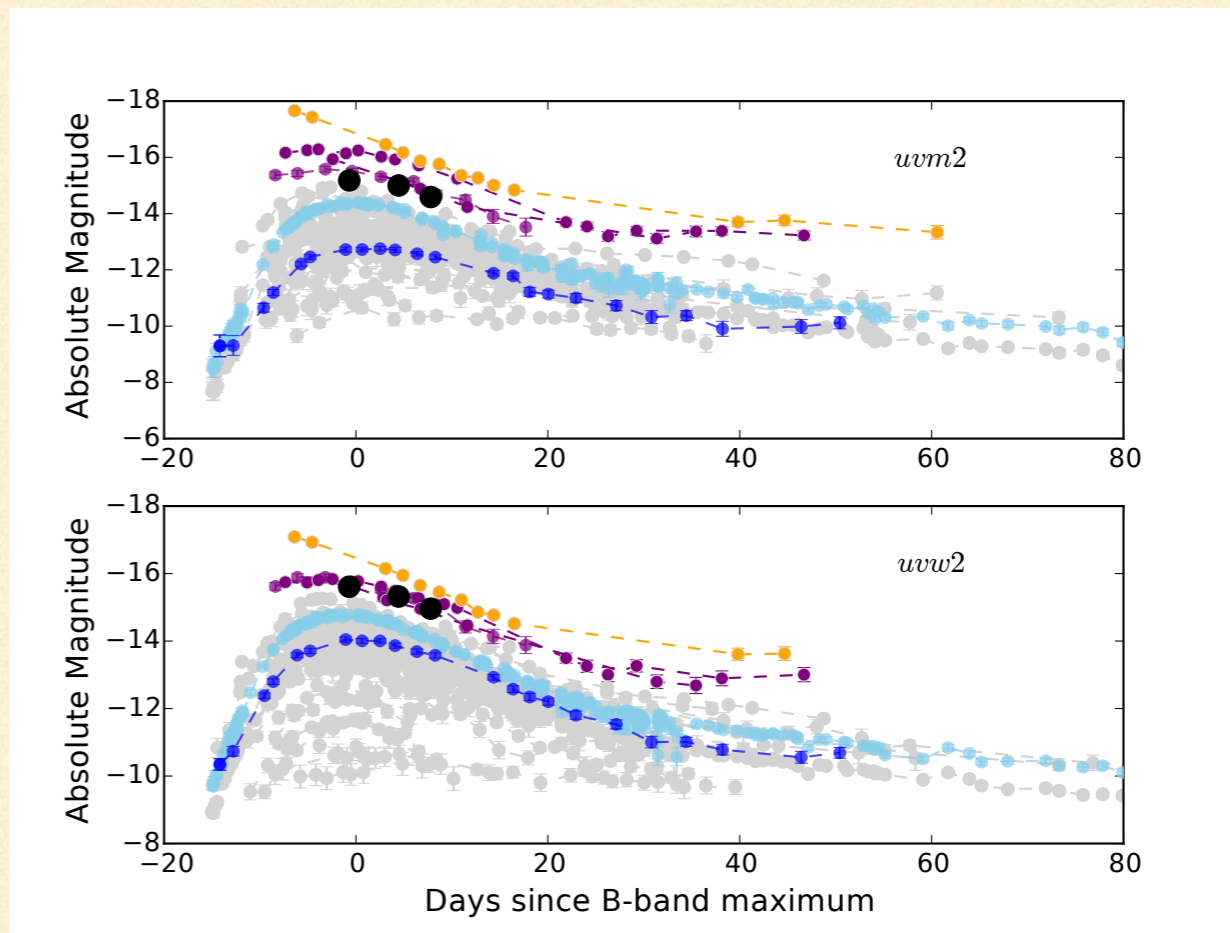
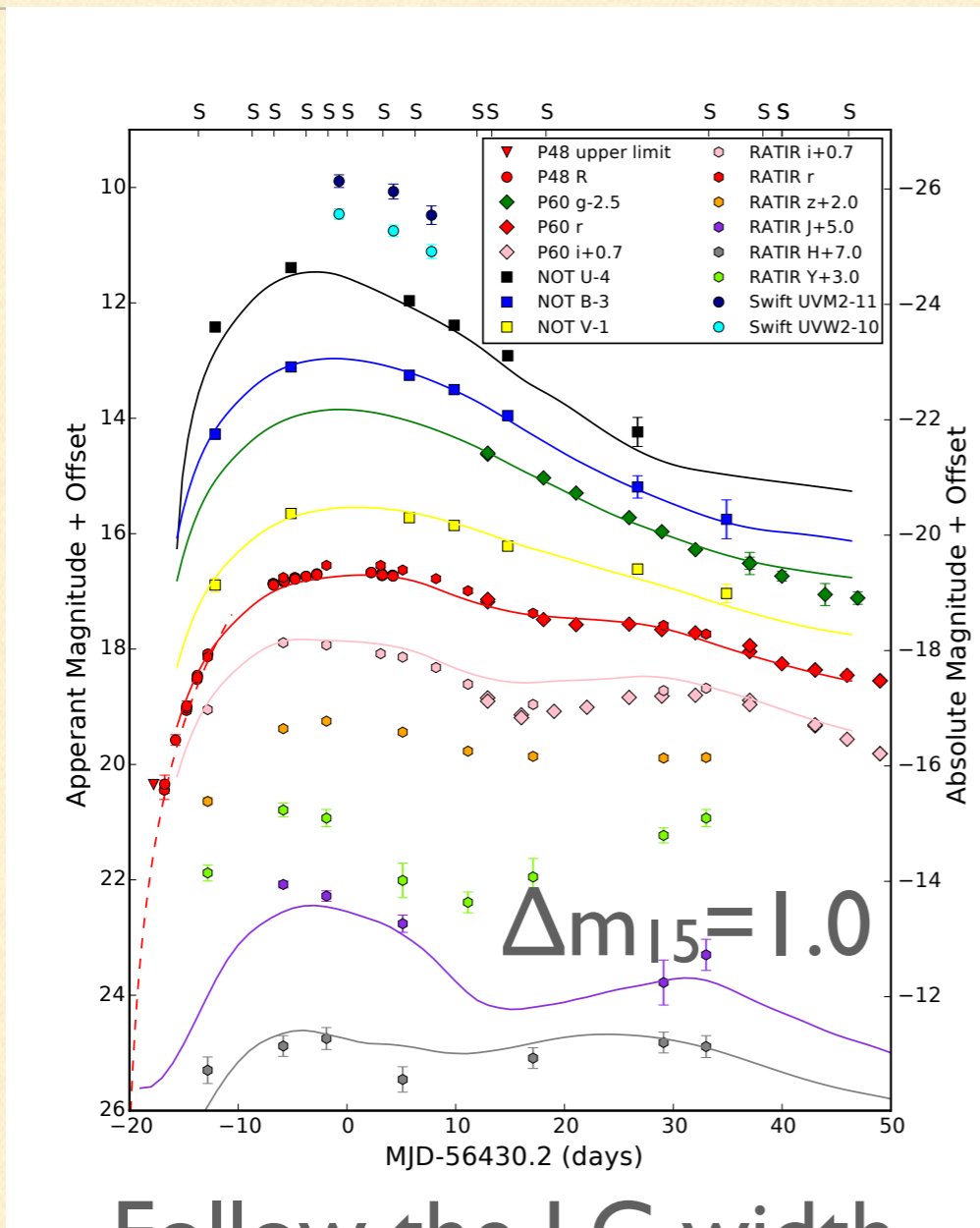
SNe Ia Luminosity Function = a SD + $(1-a)$ DD

Optical: understood well
UV: poorly constrained
(iPTF+Swift; ULTRASAT?)



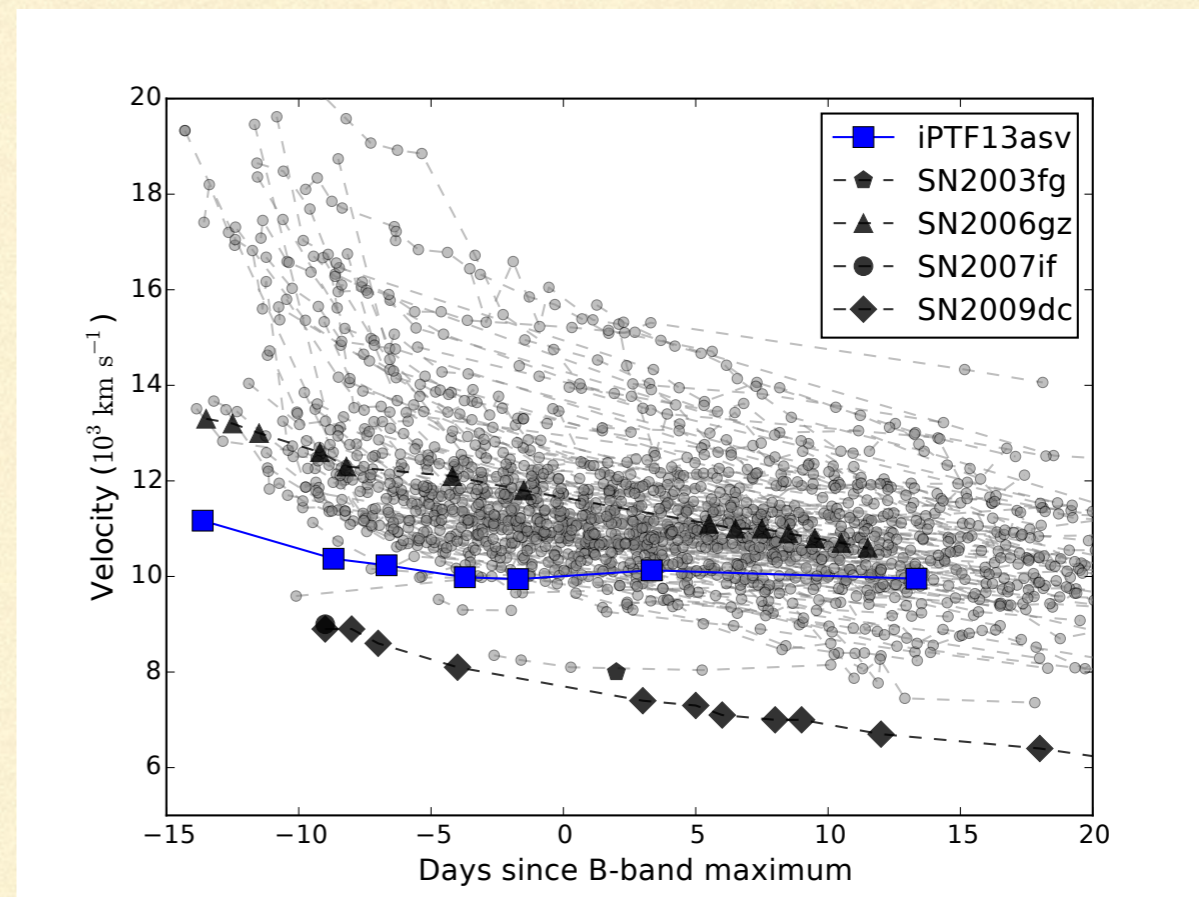
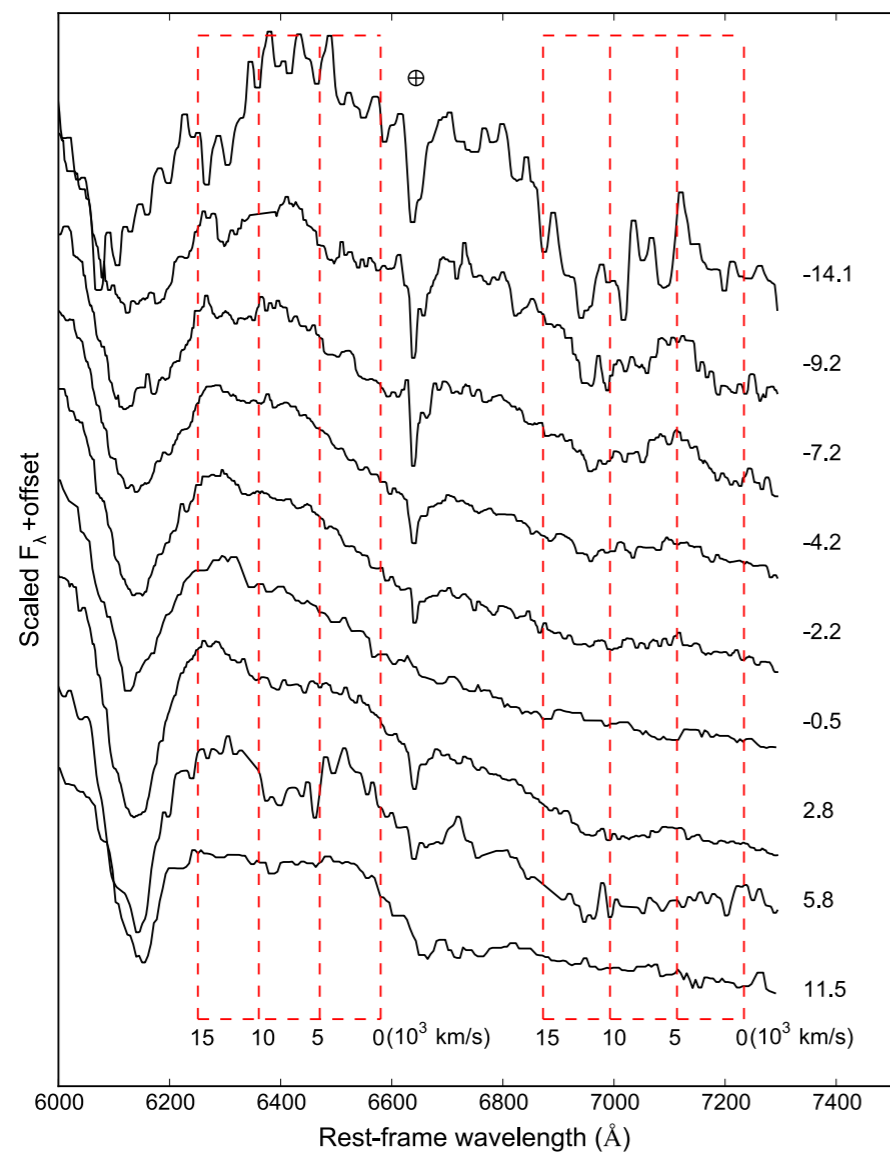
Super-C Events?
(luminosity, persistent carbon,
broad lightcurve, low velocity)

IPTFI 3ASV: A CONNECTION?



Follow the LC width -
 B-band magnitude - color relation

IPTF13ASV: A CONNECTION?



CONCLUSION

- The strong UV flare from iPTF14atg is probably from the supernova-companion collision.
- More observations and detailed modelings are both needed for better understanding the physics of supernova-companion collision, such as line emissions and viewing angle dependence.
- Type Ia supernovae probably have multiple channels.
- In order to determine branch fractions of different channels, better understanding to the luminosity functions of normal events, SD events and DD events is required.

QUESTIONS

- Does oxygen observed in iPTF14atg from its companion star? Does it tell us about the chemical abundance of the companion star?
- What is the physical difference between SNe Iax and SN2002es-like events? Different types of companion stars?
- How can we build the luminosity function from the double degenerate channel?