The early-time light curves of type II and type IIb supernovae from the ATLAS survey

Keila Ertini, Bastian Ayala (Joe Anderson, ESO Chile)

Explosive Transients @NAM 2025

Ayala+25, accepted

Astronomy & Astrophysics manuscript no. aanda ©ESO 2025
March 11, 2025

Early Light Curve Excess in Type IIb Supernovae Observed by the ATLAS Survey

Qualitative constraints on progenitor systems

Bastian Ayala[1,2,3★], Joseph P. Anderson[3,2], G. Pignata[2,4], Francisco Förster[5,2,6], S.J. Smartt[7,8], A. Rest[9,10], Martín Solar[11], Nicolas Erasmus[12,13], Raya Dastidar[1,2], Mauricio Ramirez[1,2], and Jonathan Pineda-García[1,2]

1 Instituto de Astrofí
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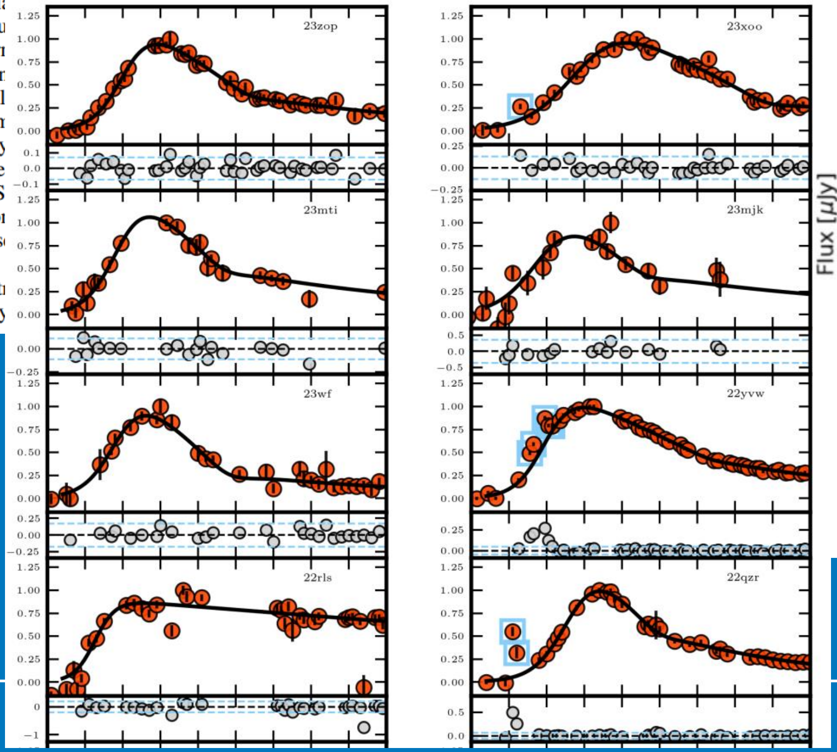

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July 7, 2025

Light-Curve and Spectral Properties of Type II Supernovae from the ATLAS survey

K.Ertini[1,2], J. P. Anderson[3], G. Folatelli[1,2,4], S. González-Gaitán[5,3], C. P. Gutierrez[6,7], and more

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Lisbon, Portugal
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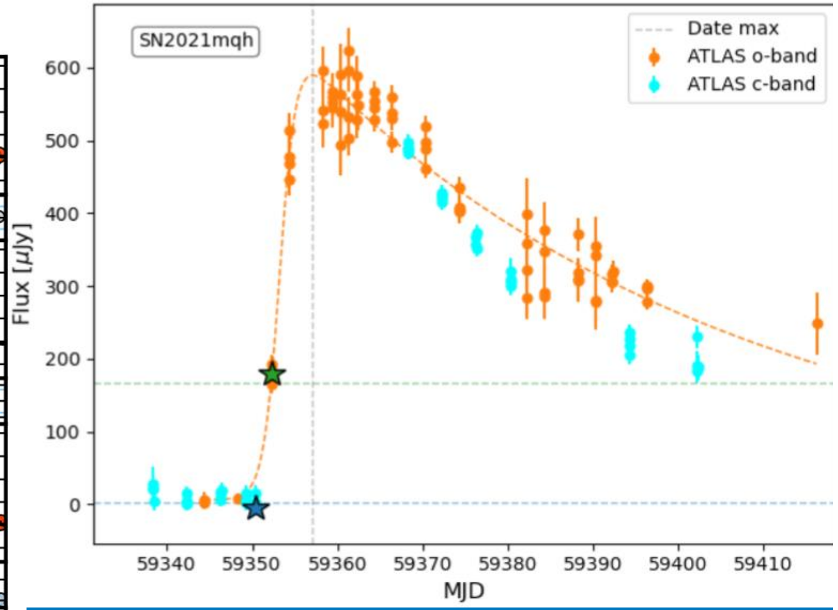
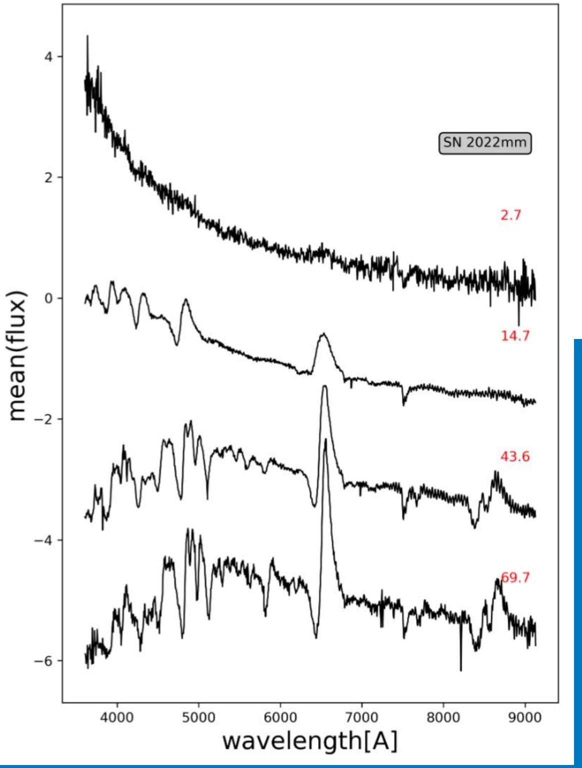
7 Institute of Space Sciences (ICE, CSIC), Campus UAB, Carrer d





Ertini+, in prep.

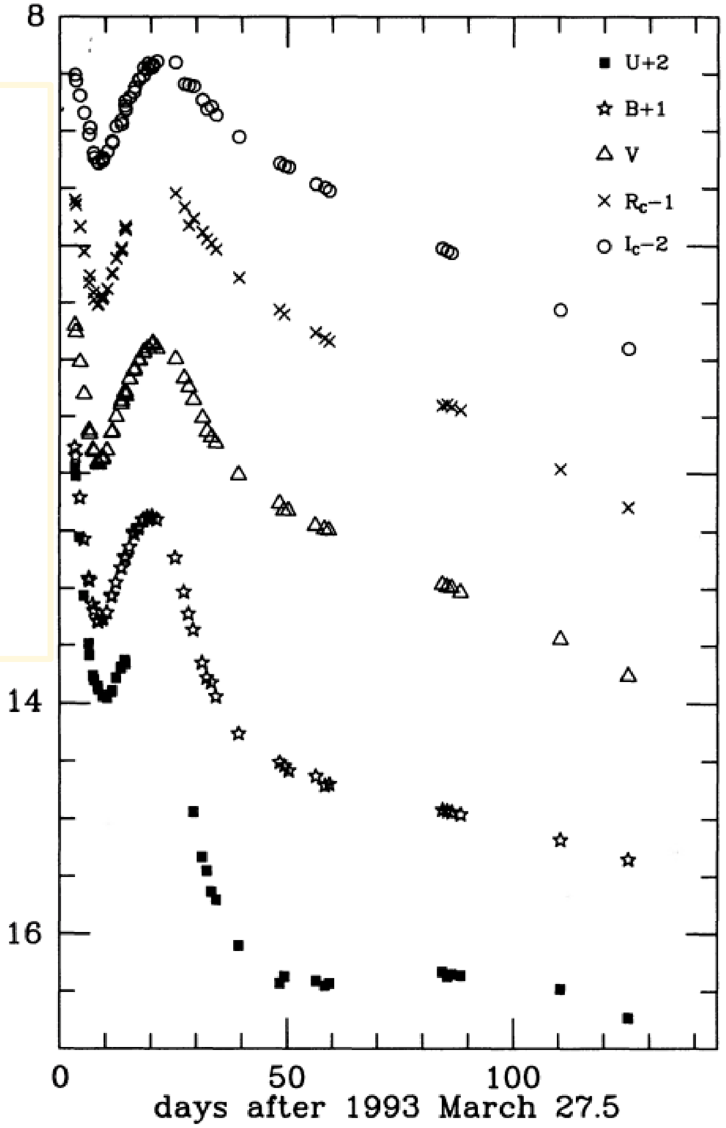
Type II and Type IIb supernovae

'Hydrogen-rich' and 'Hydrogen-poor' SNeII

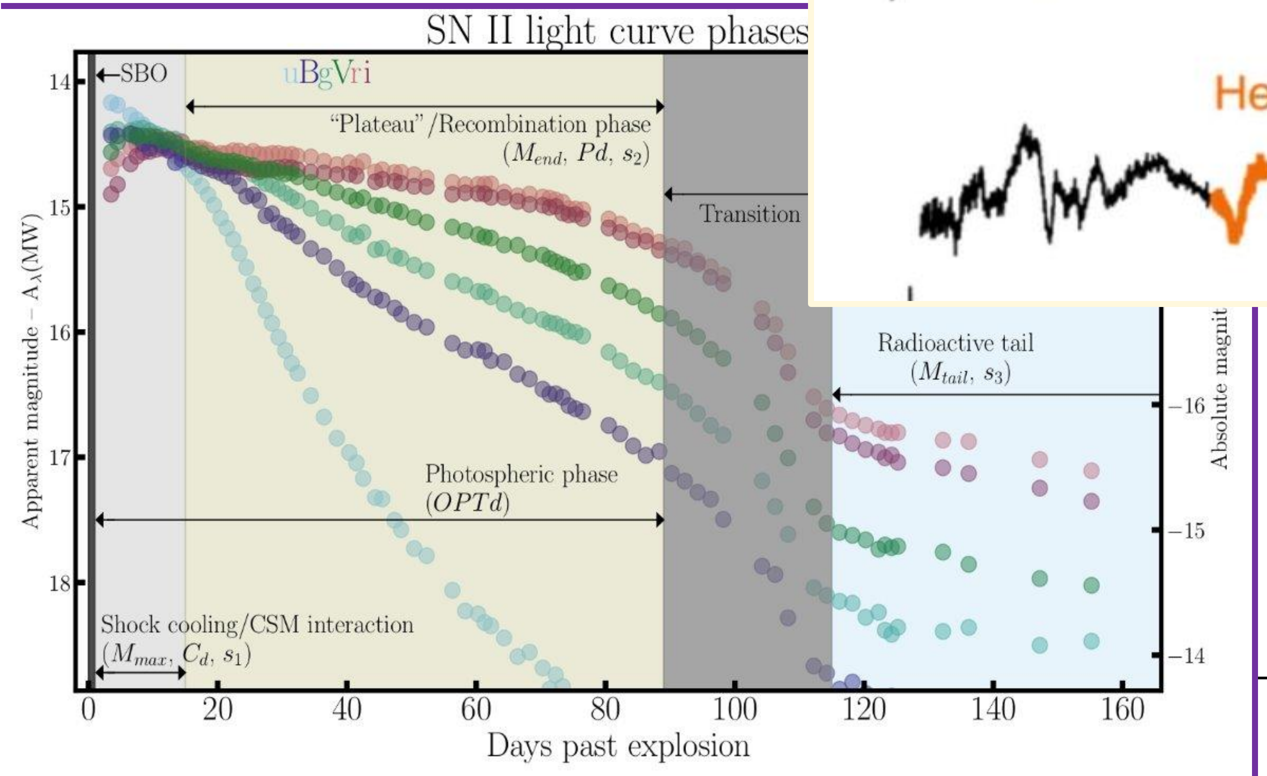
'Hydrogen rich' = IIP+fast decliners *('true' IILs don't exist...!)*

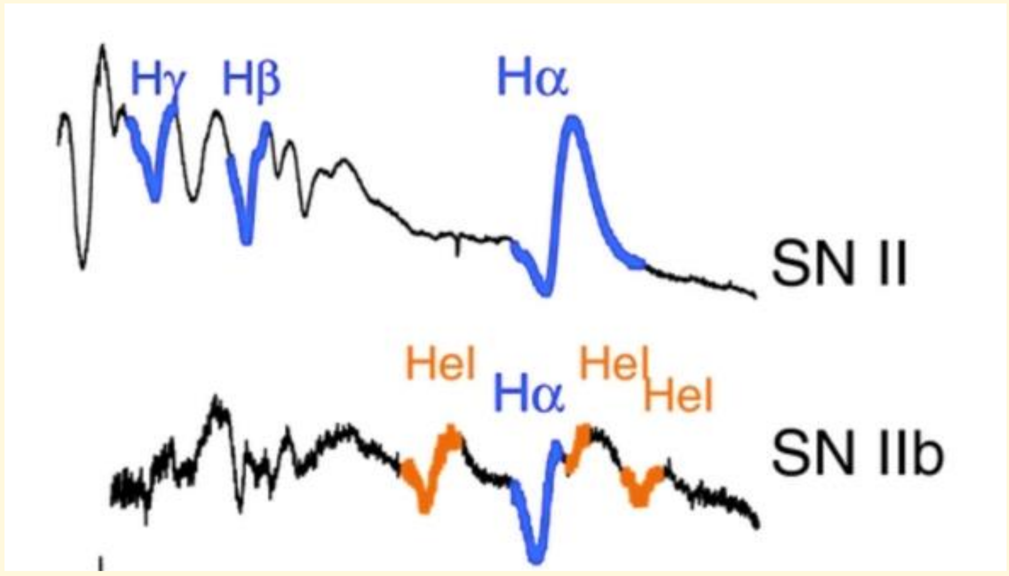
'Hydrogen poor' = IIb

Lewis+94



Anderson+24



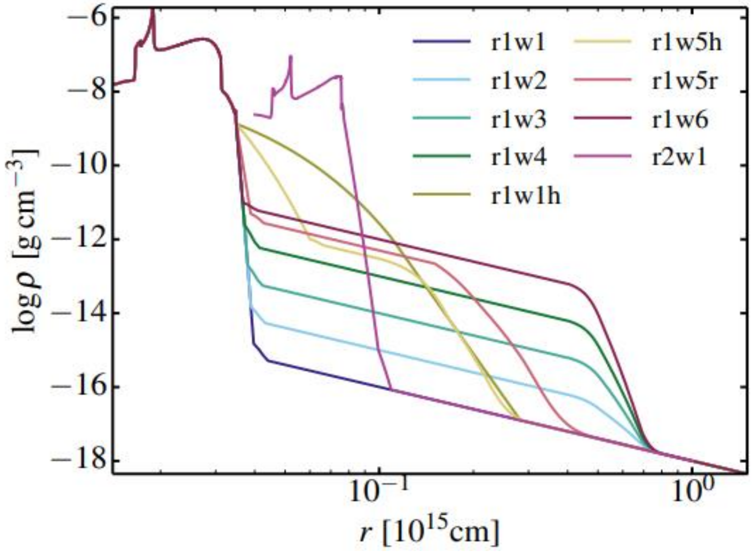


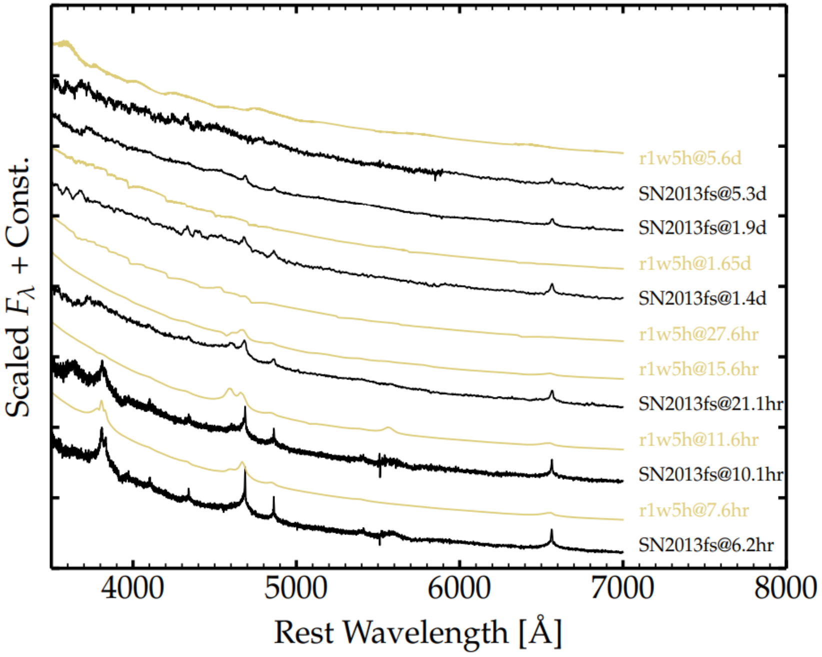
Modjaz

Early-time observations of supernovae

Constraining late-time stellar evolution and mass loss

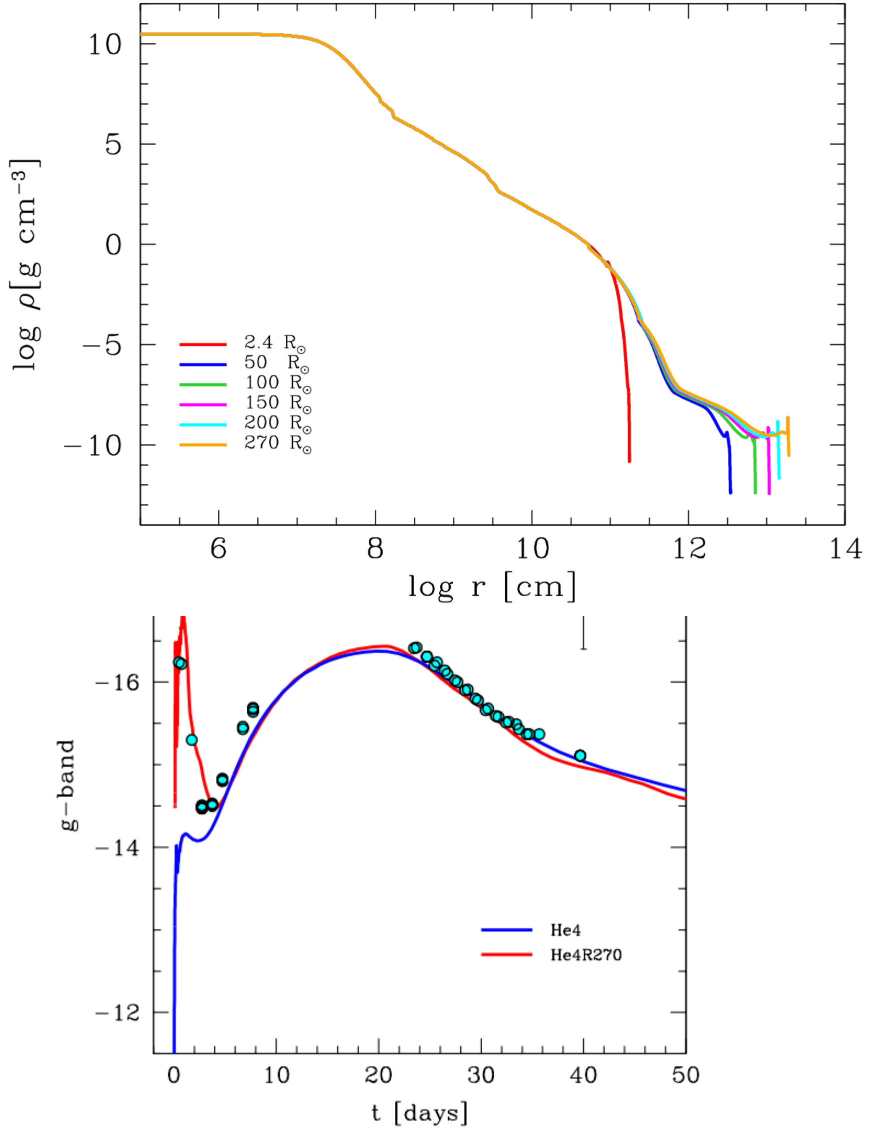
Relatively small changes in outer progenitor density profiles can have profound effect on early transient behaviour!





Dessart+17 – RSGs (SNeII) and CSM

Bersten+12, SN2011dh - IIb



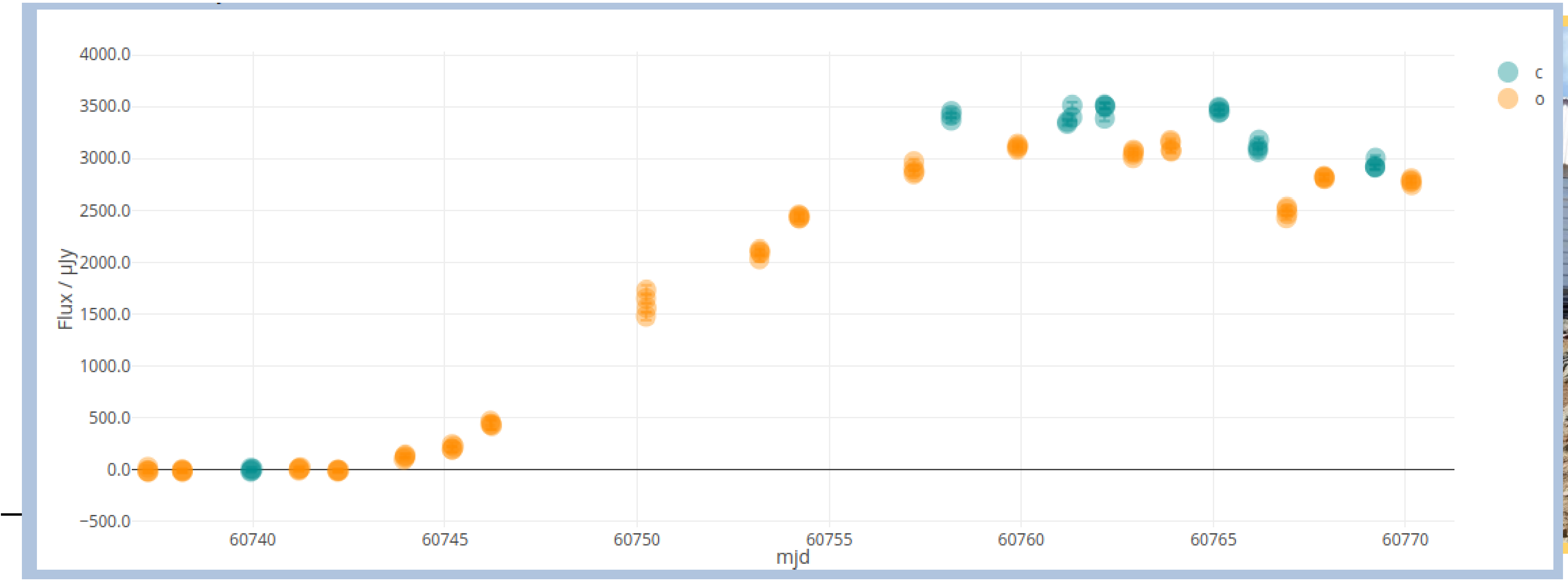
ATLAS:

The Asteroid Terrestrial-impact Last Alert System

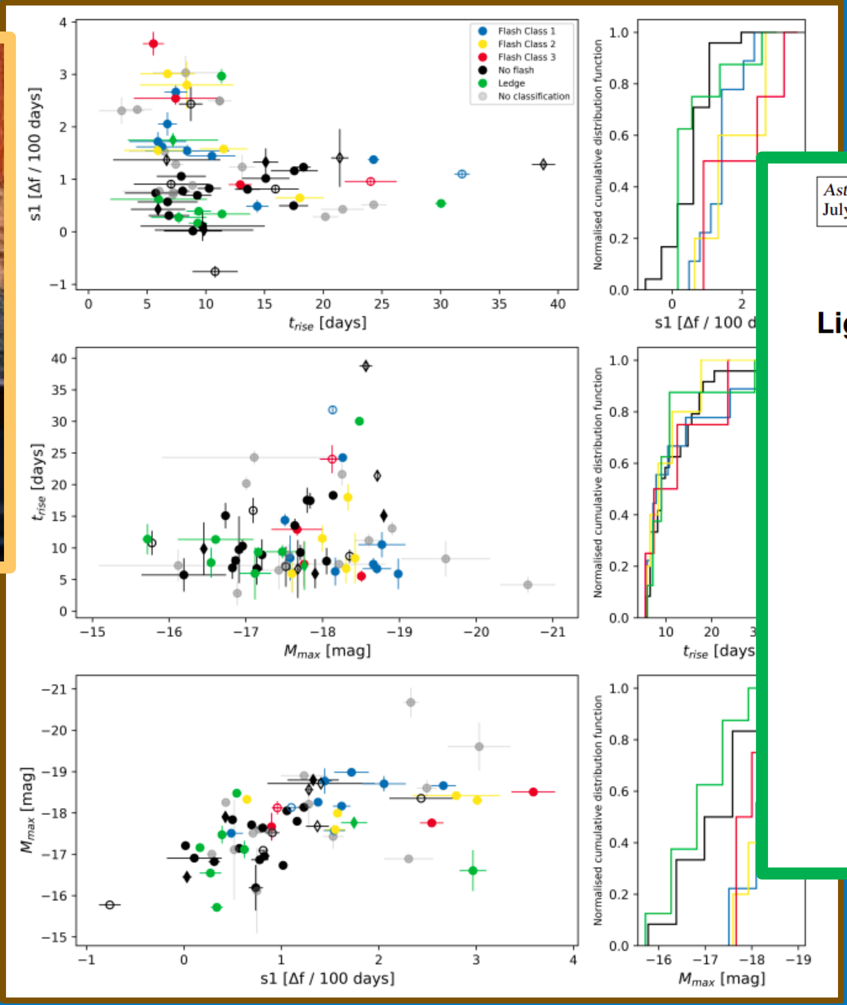
Designed for Earth-threatening asteroids... Perfect for finding and following nearby supernovae, particularly at early times!

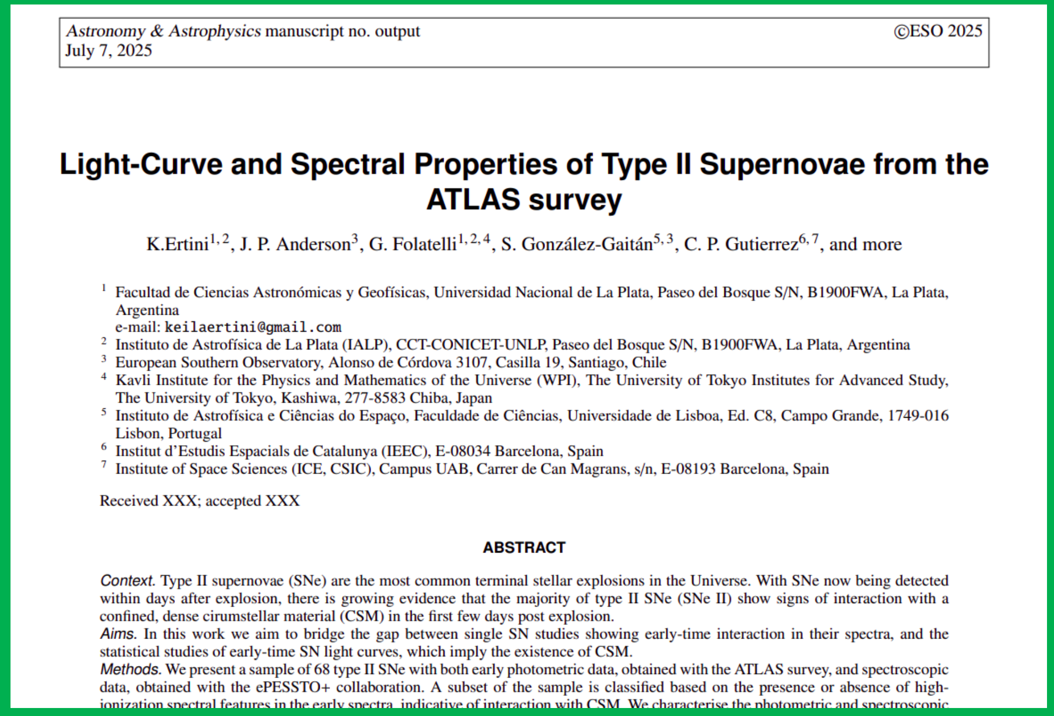
Four 0.5m telescopes: two in Hawaii, one in South Africa, **one in Chile**

- (weather permitting) full sky, down to ~19.5th mag (o-band) **every night**
- 'Optical' light curves for free ('c' and 'o' bands)



Light-curve and spectral properties of Type II supernovae from the ATLAS survey (Ertini+, in prep.)





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Light-Curve and Spectral Properties of Type II Supernovae from the ATLAS survey

K.Ertini[1,2], J. P. Anderson[3], G. Folatelli[1,2,4], S. González-Gaitán[5,3], C. P. Gutierrez[6,7], and more

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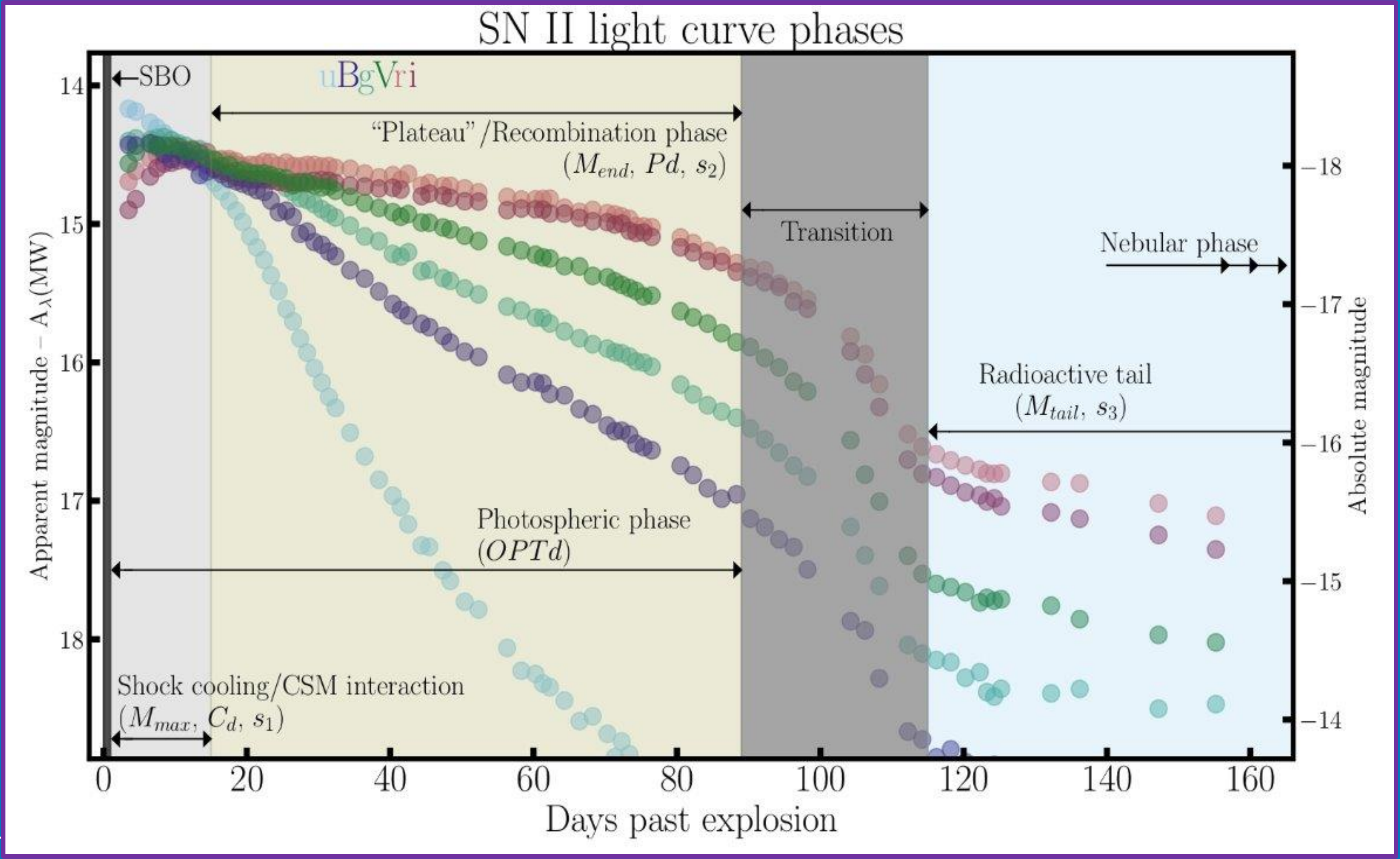
Received XXX; accepted XXX

ABSTRACT

Context. Type II supernovae (SNe) are the most common terminal stellar explosions in the Universe. With SNe now being detected within days after explosion, there is growing evidence that the majority of type II SNe (SNe II) show signs of interaction with a confined, dense cirumstellar material (CSM) in the first few days post explosion.
Aims. In this work we aim to bridge the gap between single SN studies showing early-time interaction in their spectra, and the statistical studies of early-time SN light curves, which imply the existence of CSM.
Methods. We present a sample of 68 type II SNe with both early photometric data, obtained with the ATLAS survey, and spectroscopic data, obtained with the ePESSTO+ collaboration. A subset of the sample is classified based on the presence or absence of high-ionization spectral features in the early spectra, indicative of interaction with CSM. We characterise the photometric and spectroscopic

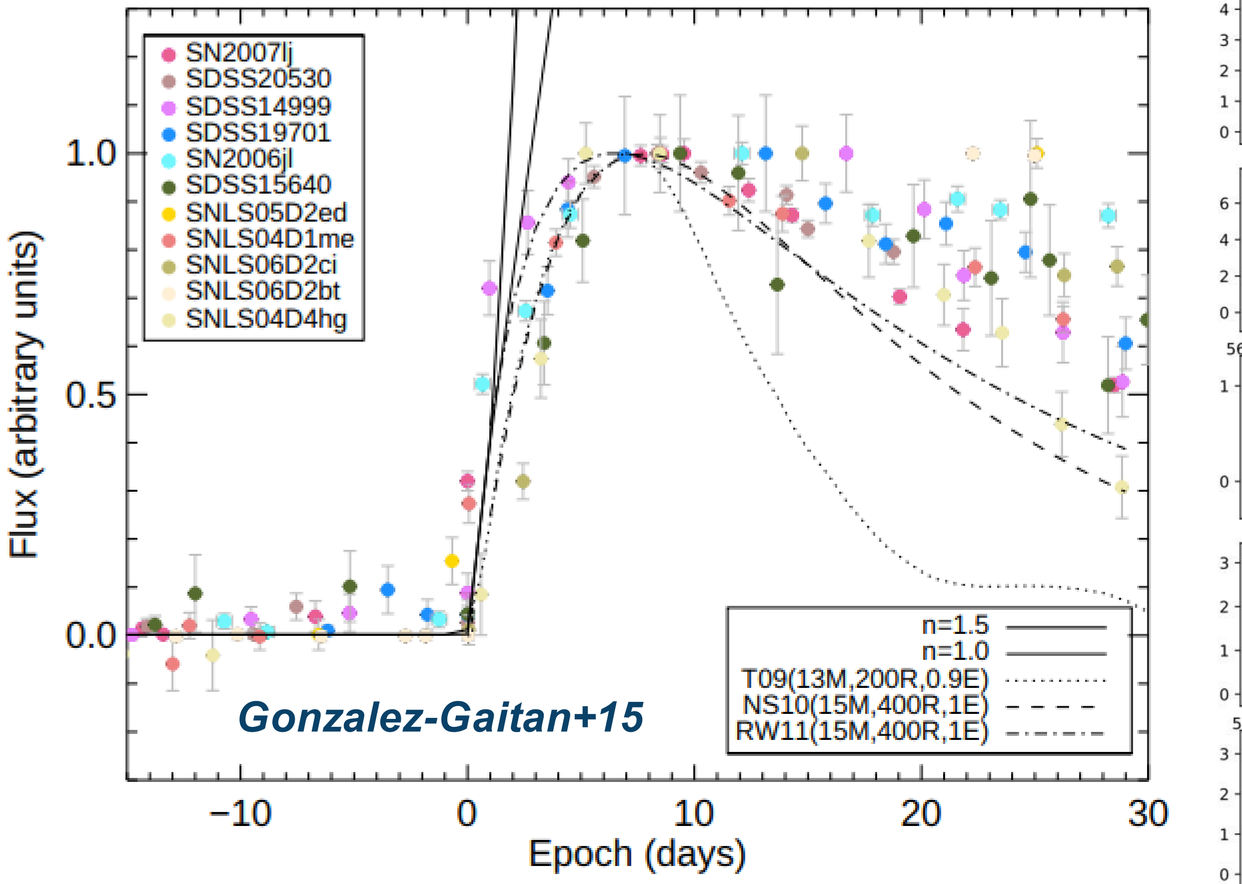
Hydrogen-rich SNeII



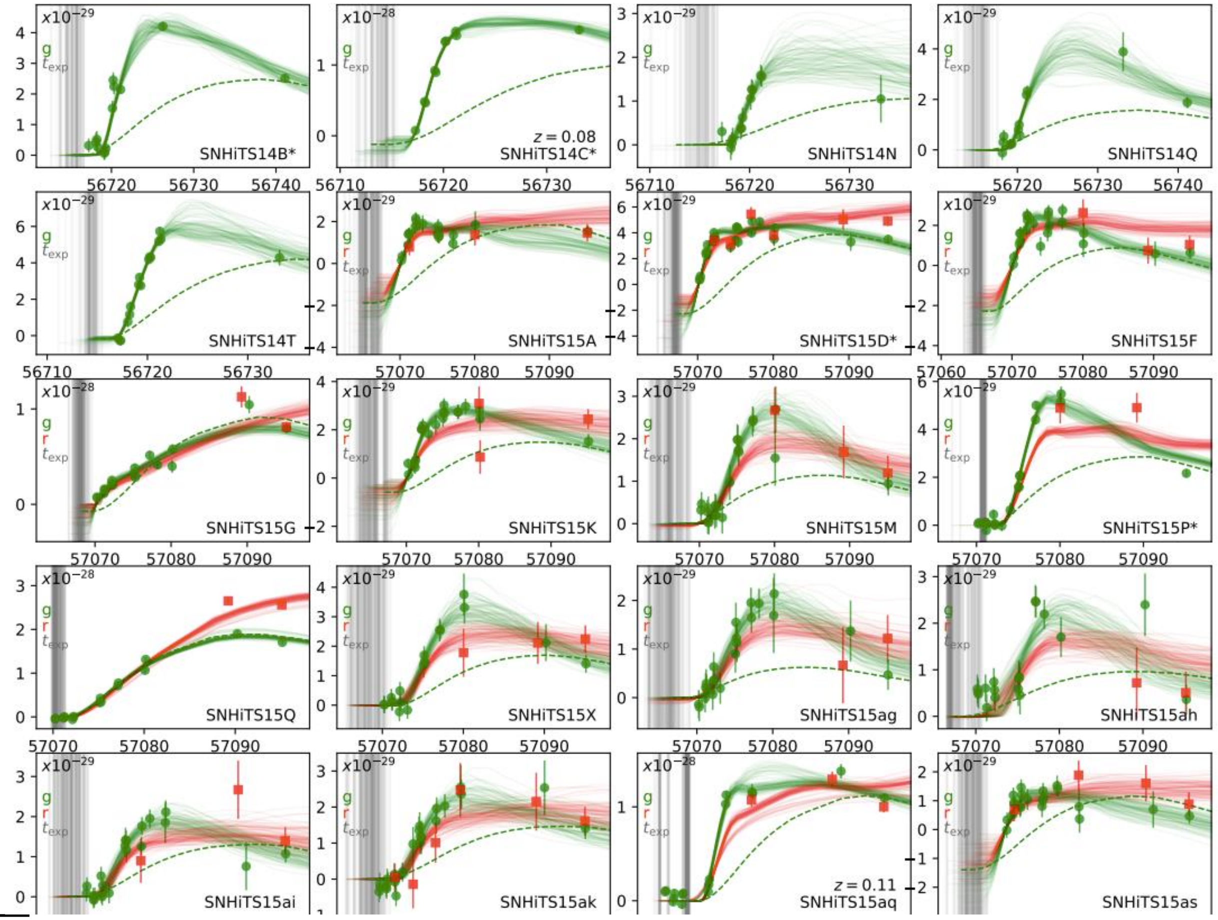
Anderson+24

SNII light curves require significant CSM!

SNII rise times are inconsistent with RSG progenitors exploding into 'clean' environment...



Forster+18

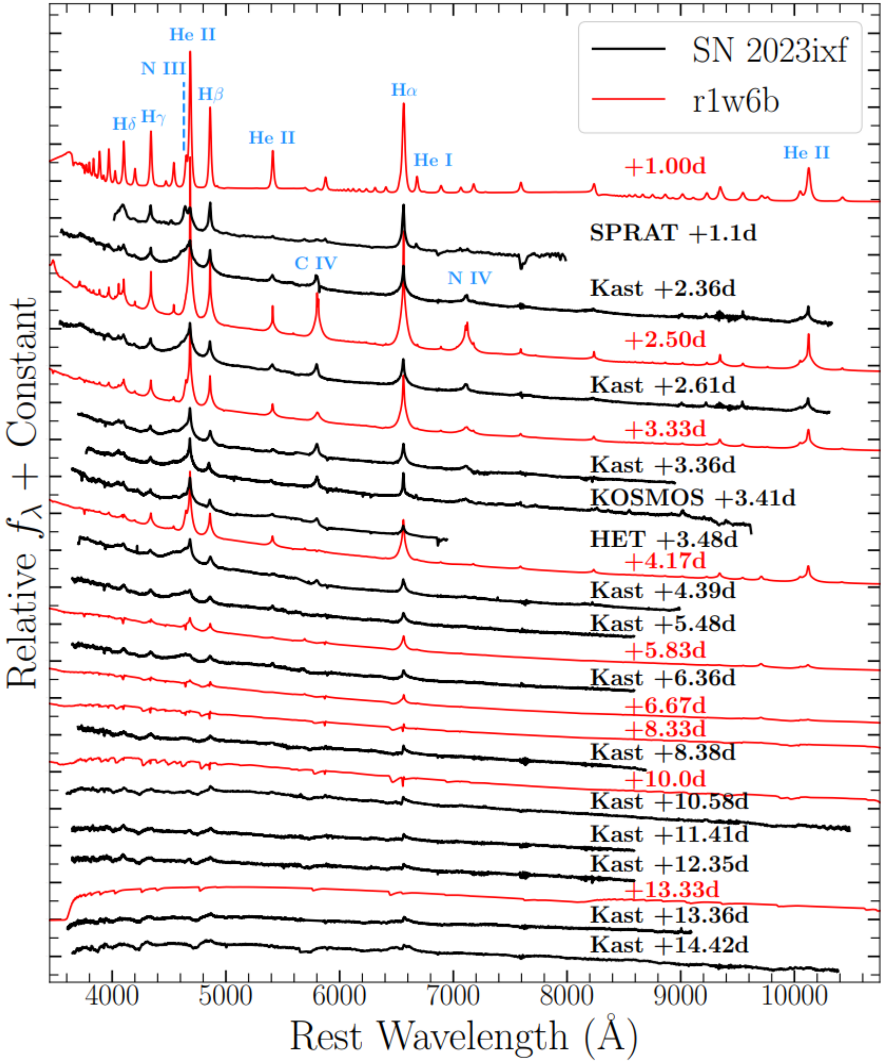


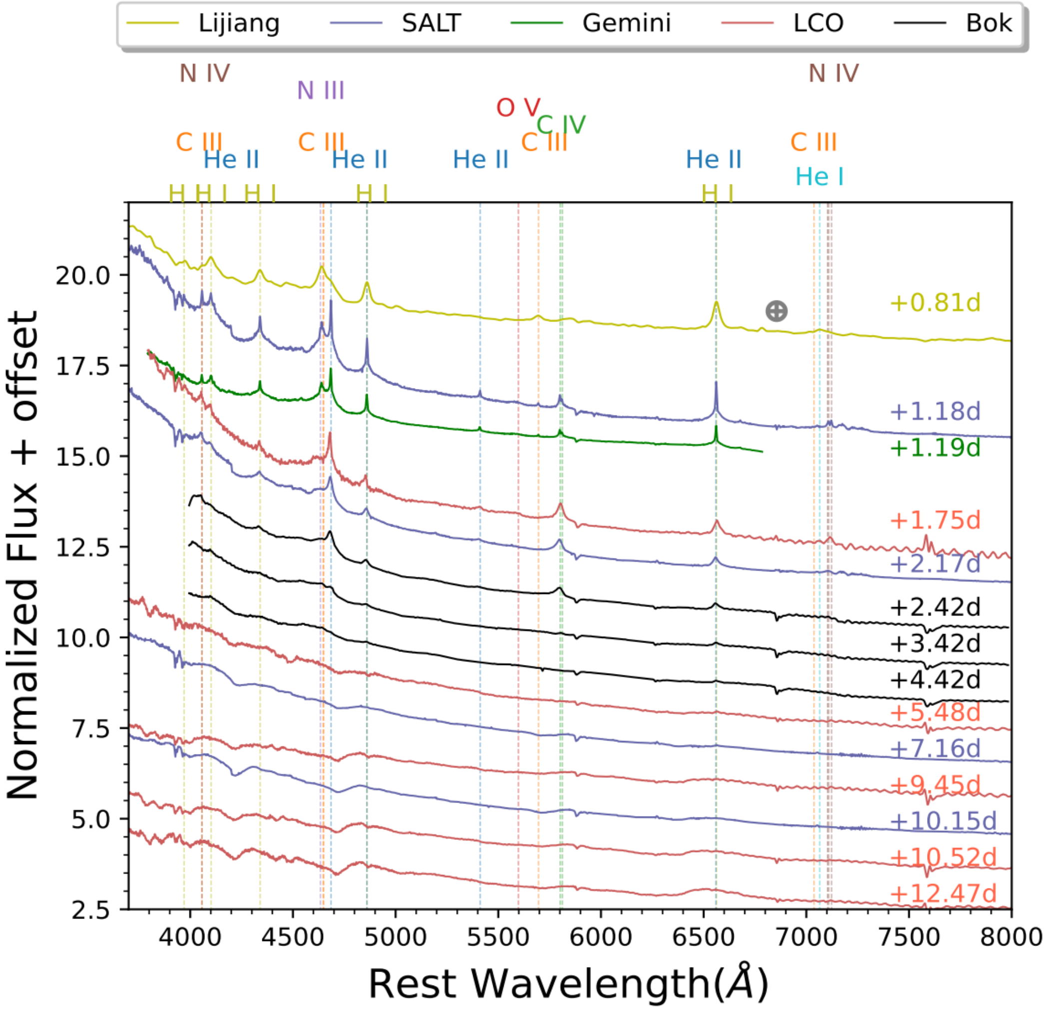
Early SNII spectra imply CSM interaction

'Flash spectroscopy' – the cases of 23ixf and 24ggi

(Also see e.g. Bruch+23 and Jacobson-Galan+24)

Jacobson-Galan+23





Shrestha+24

Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

Combining light curve statistics with spectral followup

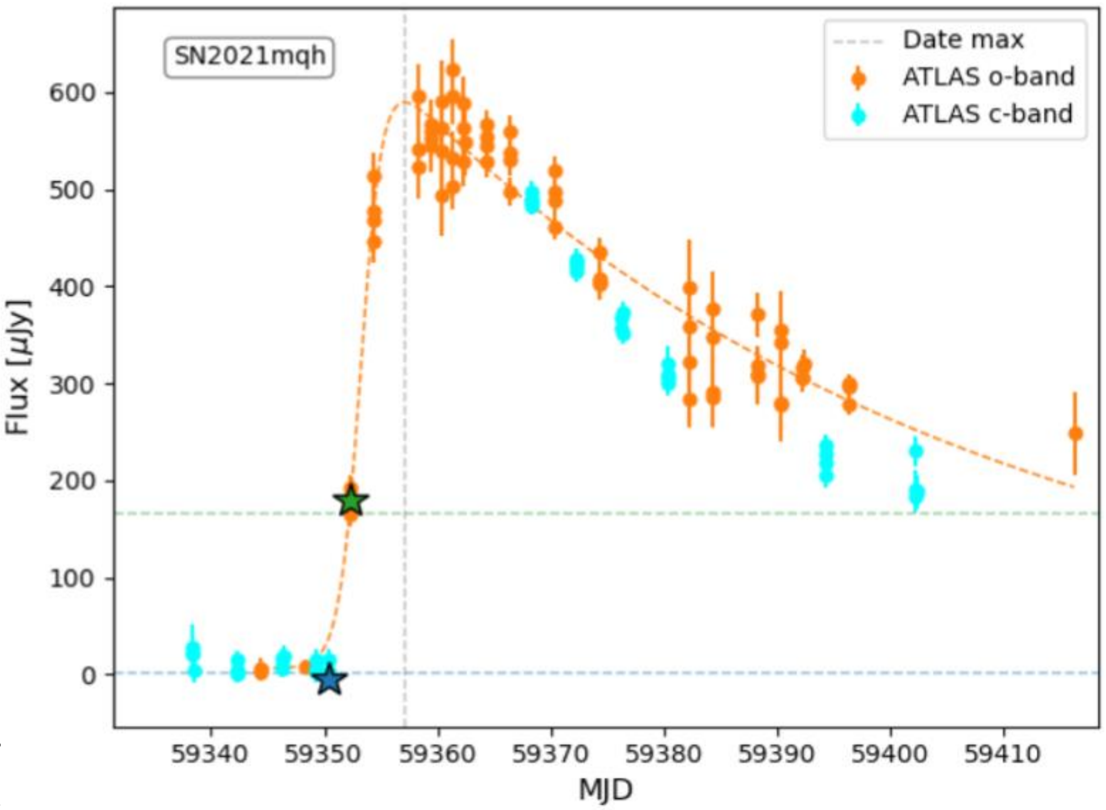
68 SNeII observed by ATLAS ('o' and 'c'-band), 56 with ePESSTO+ optical spectroscopy

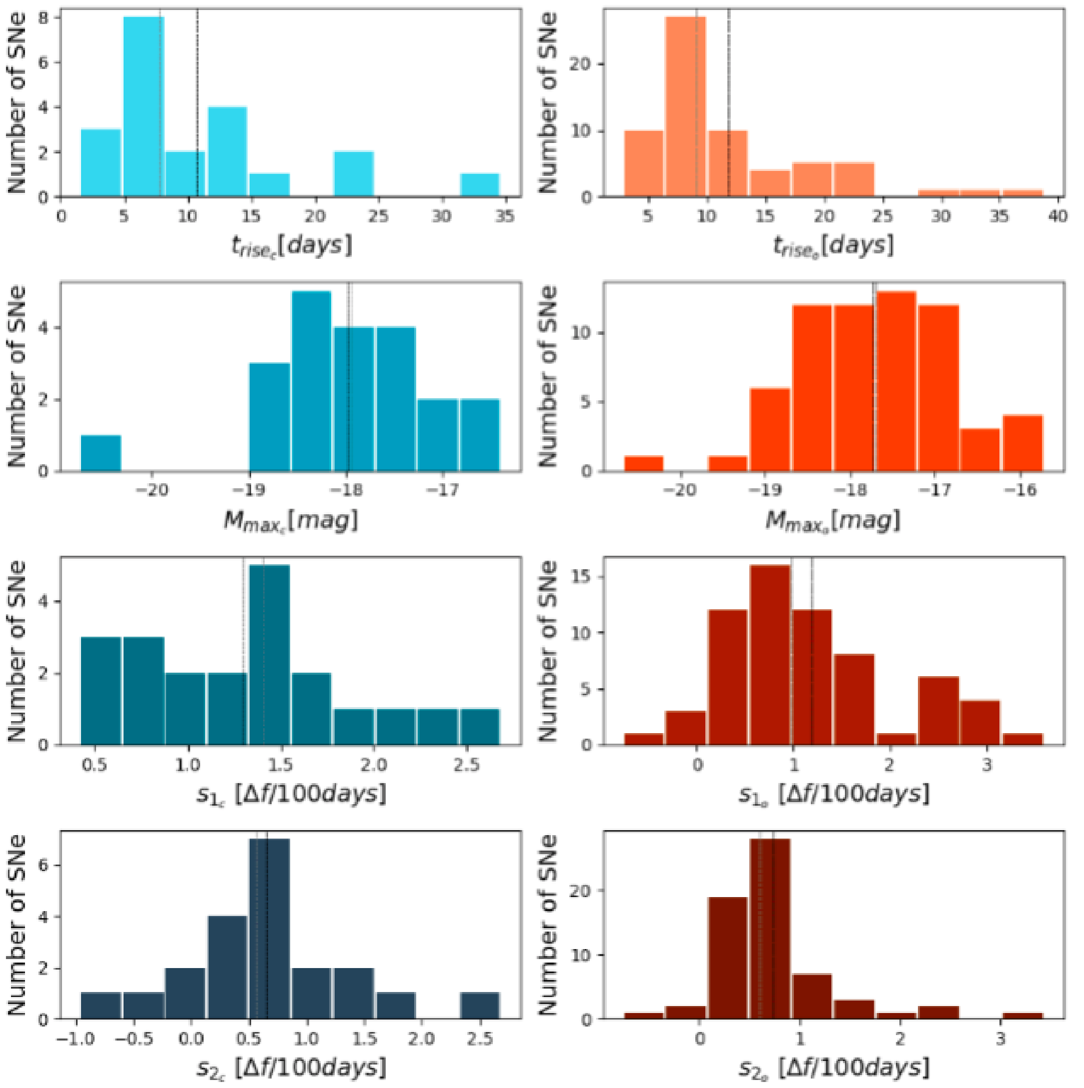
- **Light curve measurements:**
  - Rise time, peak magnitude, s_1 and s_2 decline rate
- **Spectral measurements**
  - Presence/absence of 'flash' features (spectra <6d post explosion)
  - Bulk and bluest velocities
  - a/e (absorption/emission pEW of Hα

Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

Rise times, peak magnitudes, decline rates

Spectral features, spectral evolution...

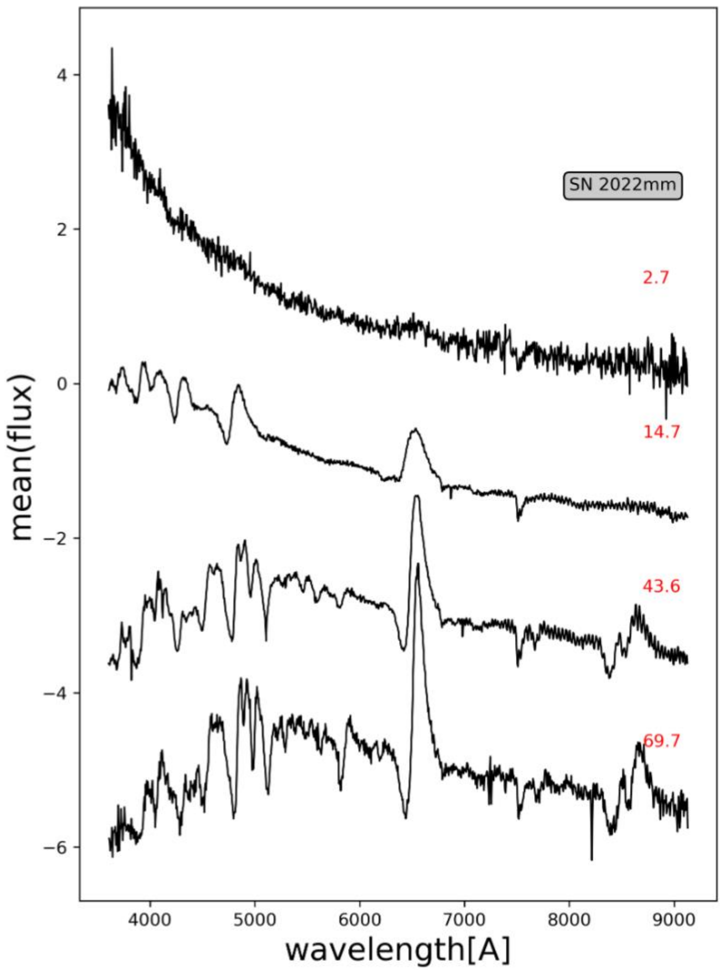


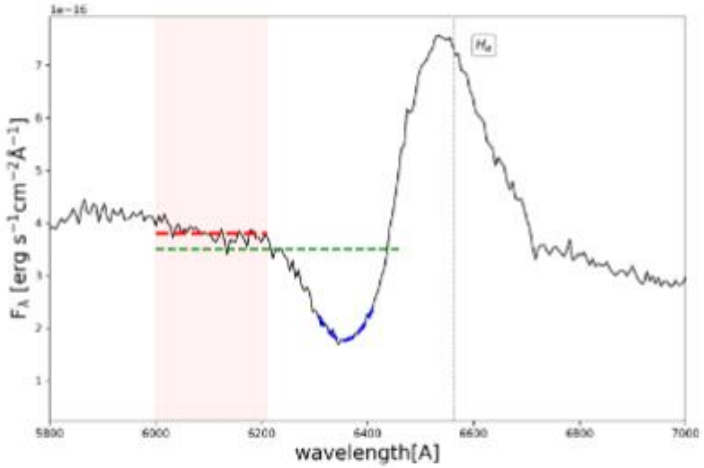


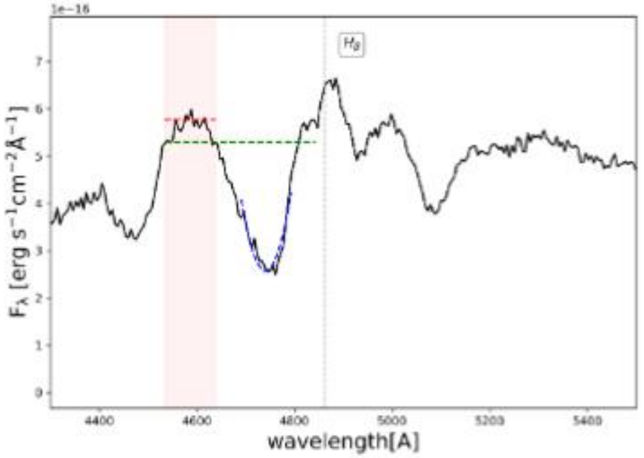
Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

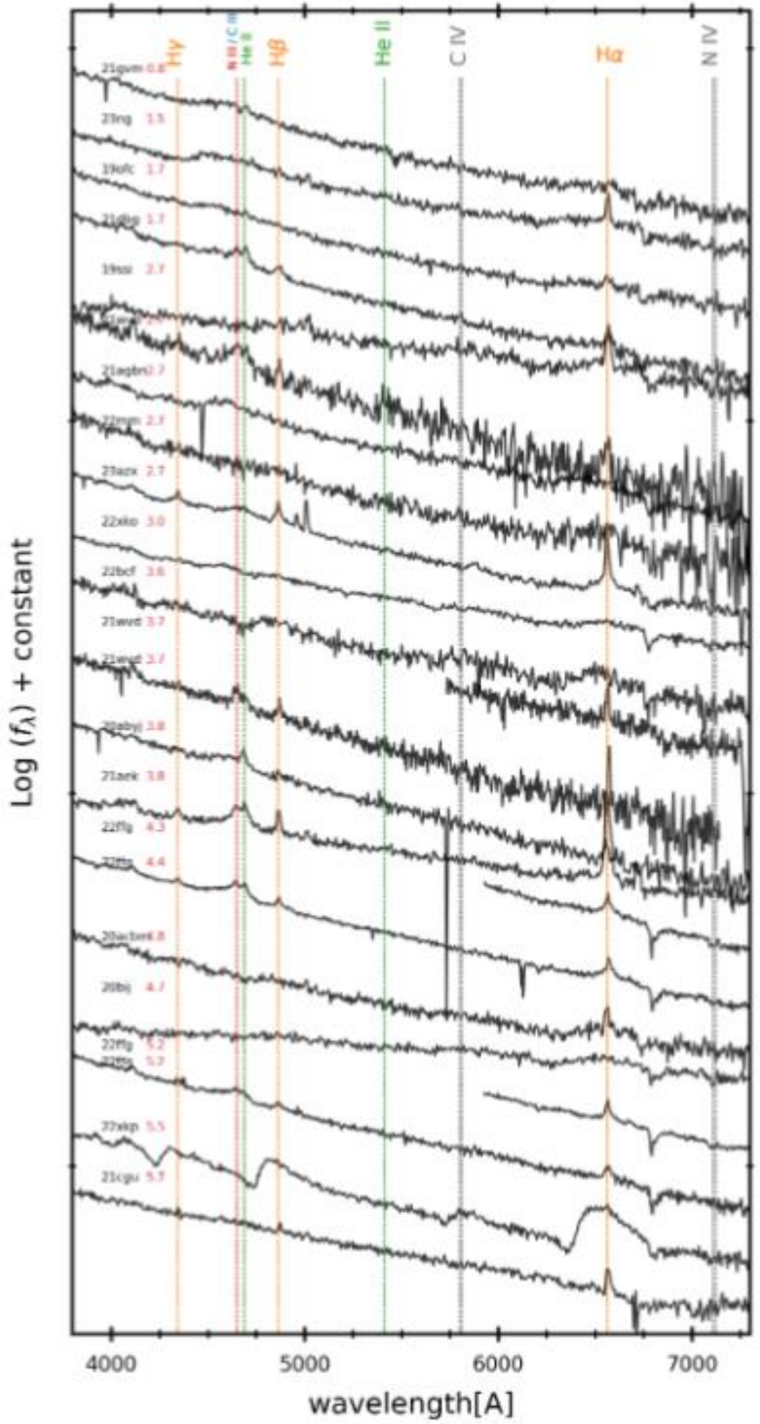
Rise times, peak magnitudes, decline rates

Spectral features, spectral evolution







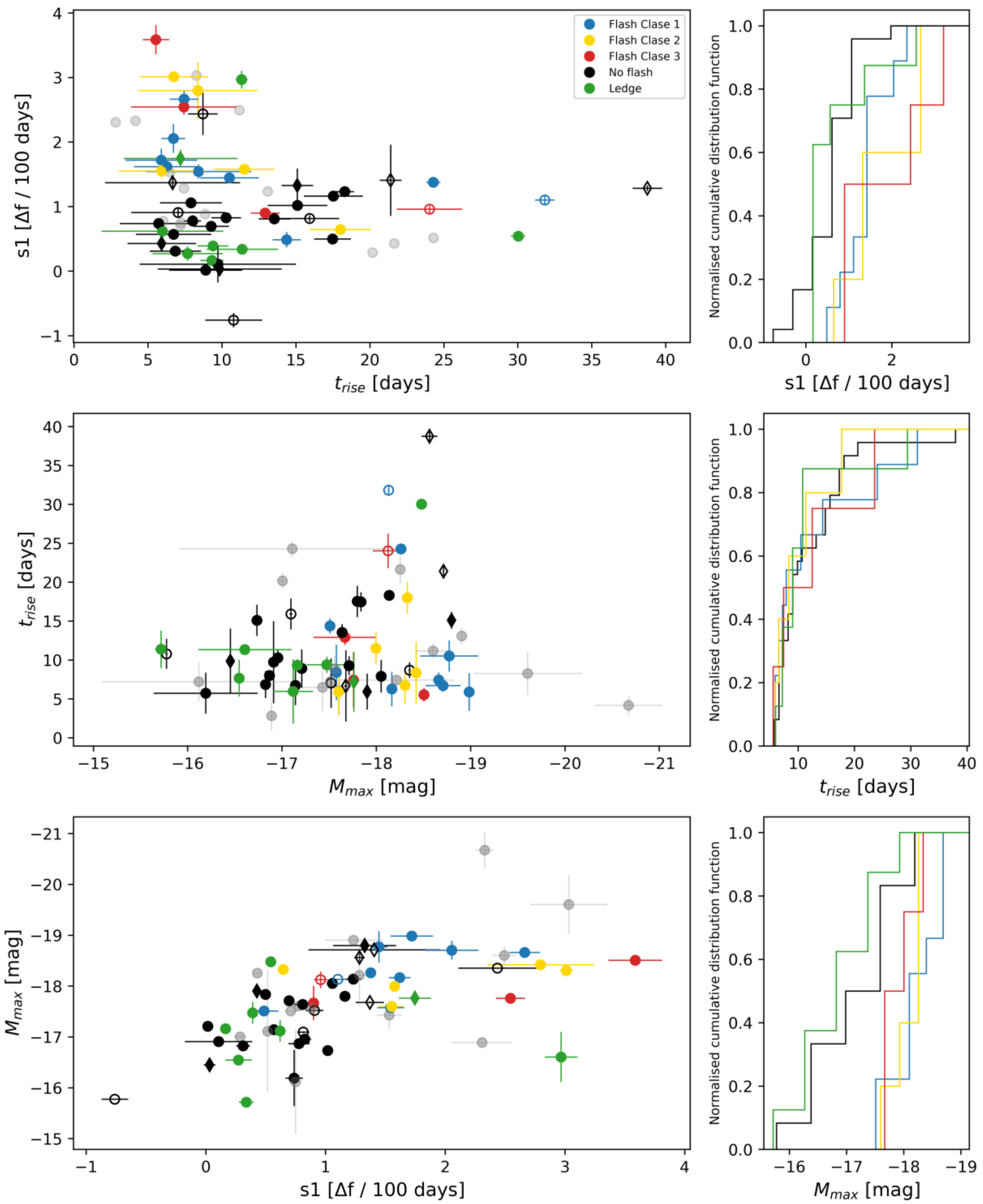


Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

SNeII with early 'flash' features, show different light curve properties

- SNeII with flash features compared to those without are:
  - Brighter
  - Faster declining
- ...But do not show distinct rise times

'Fast declining SNeII' (IIL in historic nomenclature) **are brighter and faster declining due to higher levels of ejecta – CSM interaction**

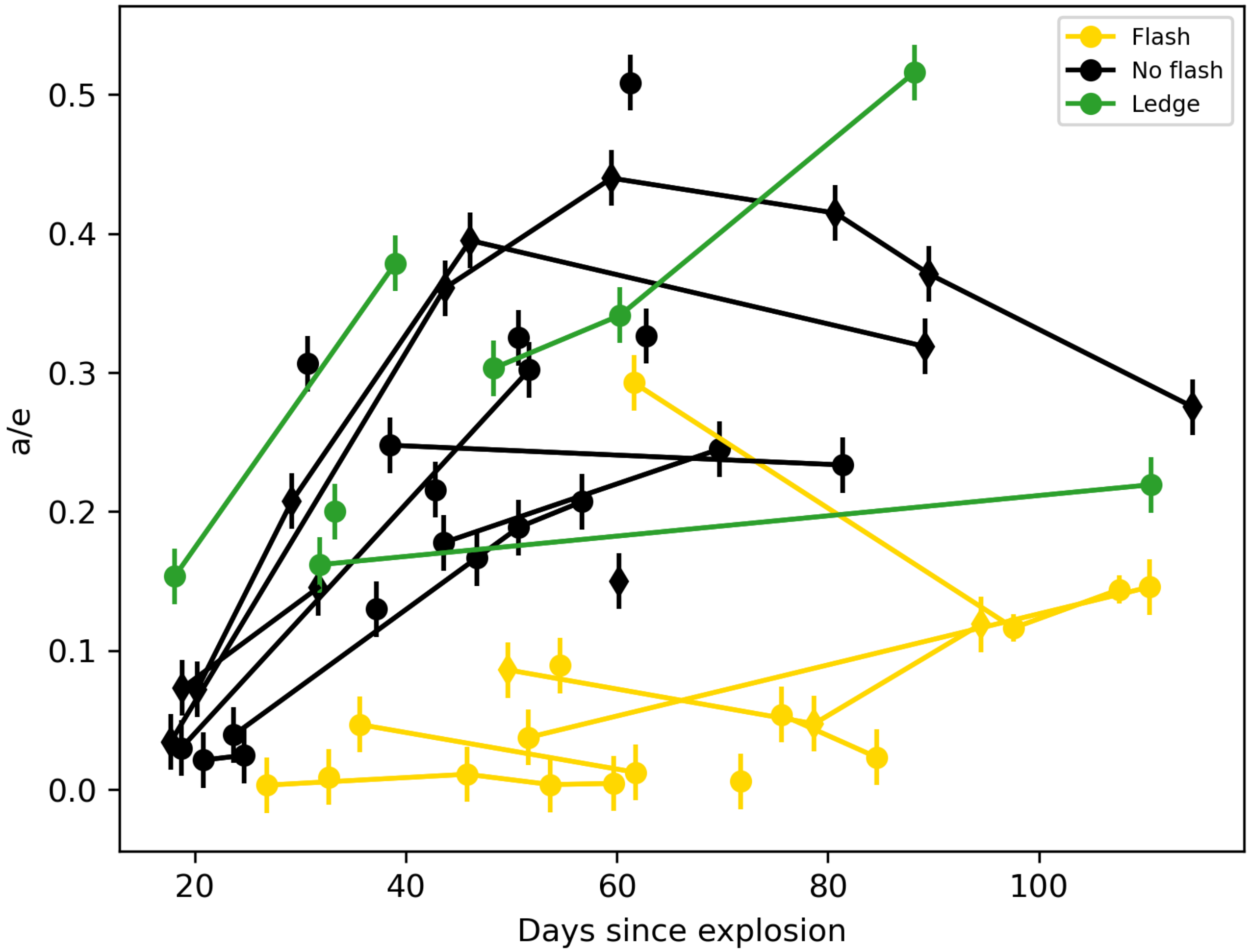


Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

SNeII with early 'flash' features also show effects of CSM interaction in their later Hα properties!

- SNeII with flash features show clearly distinct spectral properties (Hα) in their later 'plateau' phases
- (Velocities don't show any clear differences...)

Effects of early ejecta – CSM interaction imprints onto later SNII properties. a/e is a robust indicator of early interaction ('flash' features)



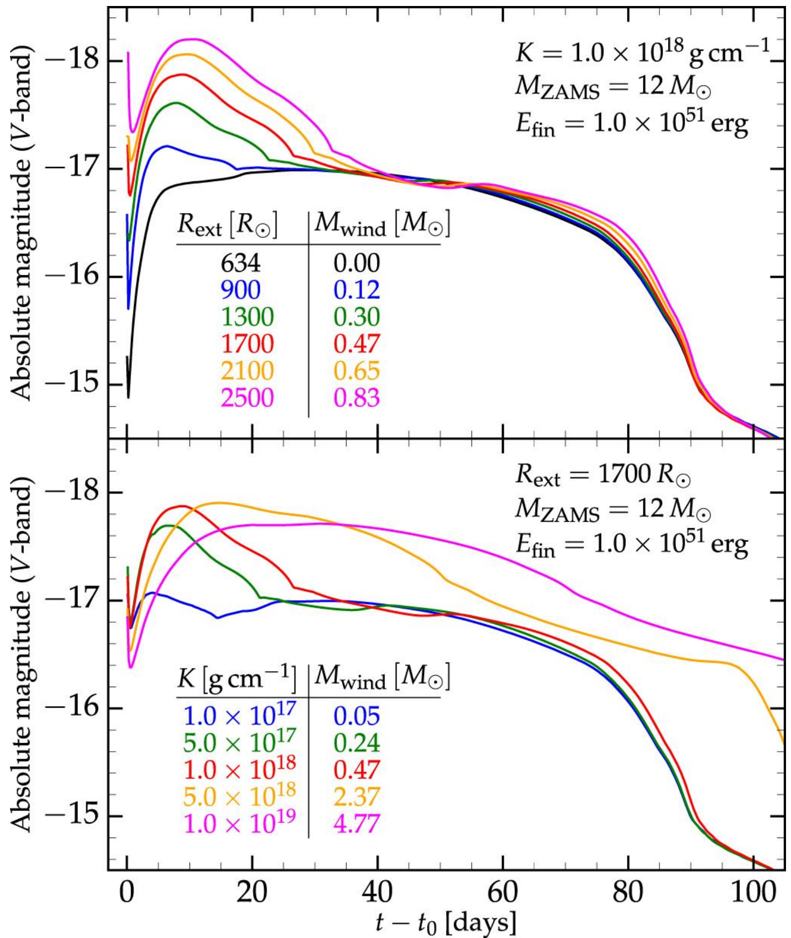
Light curve and spectral properties of type II supernovae from the ATLAS survey (Ertini+, in prep)

The combination of early-time light curves and spectral followup further constrains the presence and effects of ejecta – CSM interaction in 'normal' Hydrogen-rich SNeII

Significant, mounting evidence that many – probably the majority – SNII progenitors explode into significant, dense CSM, implying significantly higher mass loss(?) than those measured for RSGs (e.g. Gonzalez-Gaitan+15; Khazov+16; Morozova+17; Forster+18; Bruch+21,+23; Jacobson-Galan+24).

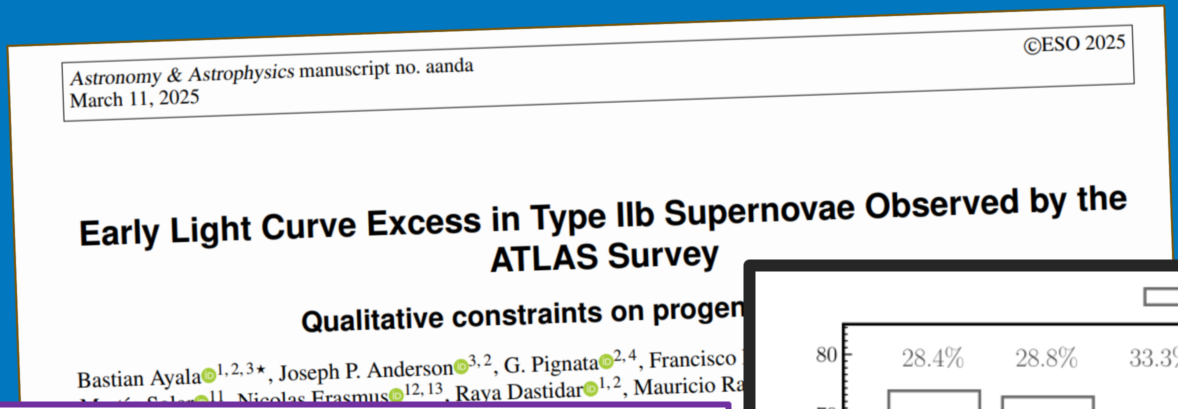
Fast-declining SNeII (...IIL) **show a significantly higher presence of early 'flash' features. Thus, significant early-time interaction may be the origin of the transient differences between fast and slow** (...IIP) **SNeII.**

Morozova+18



Early light curve excess in type IIb supernovae observed by the ATLAS survey

Qualitative constraints on progenitor systems (Ayala+, accepted)


Astronomy & Astrophysics manuscript no. aanda
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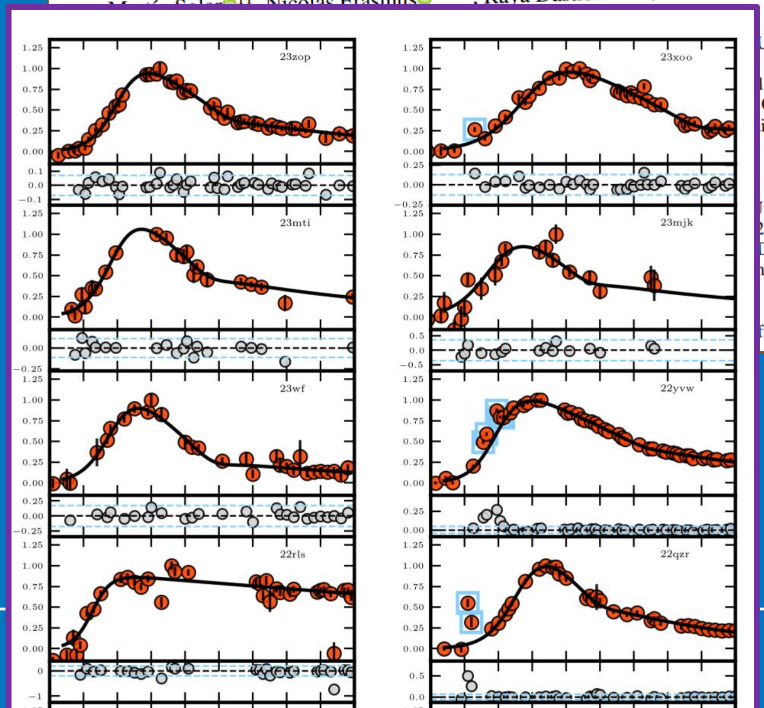
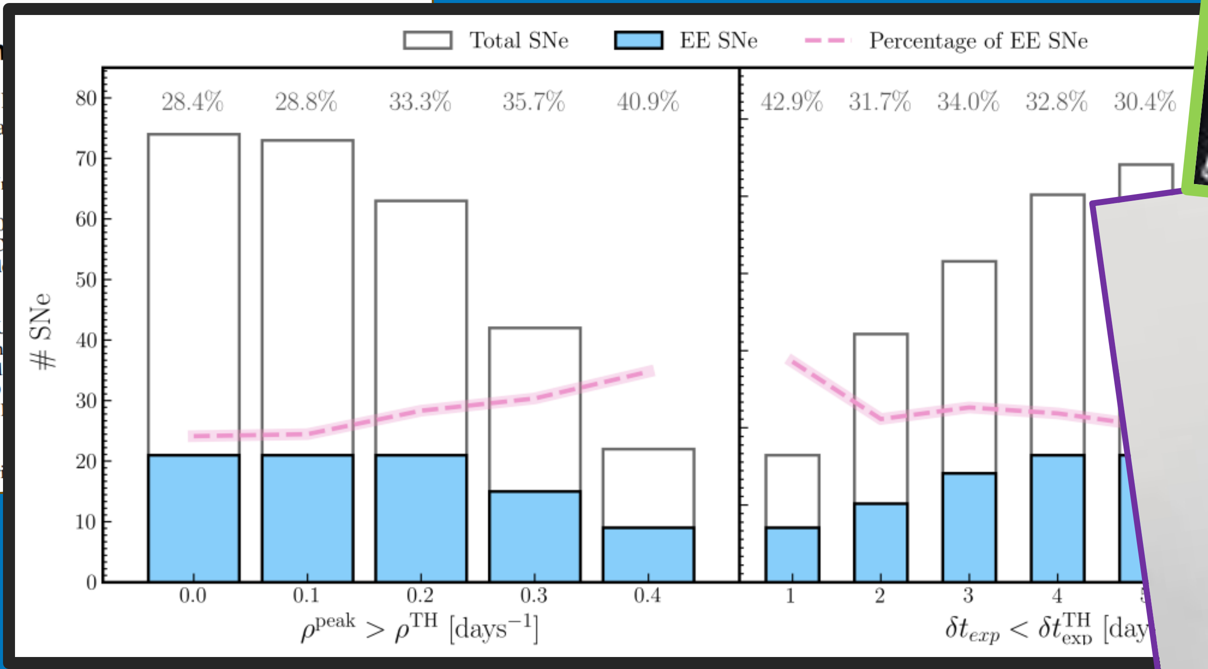
Early Light Curve Excess in Type IIb Supernovae Observed by the ATLAS Survey

Qualitative constraints on progen

Bastian Ayala[1,2,3]★, Joseph P. Anderson[3,2], G. Pignata[2,4], Francisco
Nicolas Erasmus[12,13], Raya Dastidar[1,2], Mauricio Ra



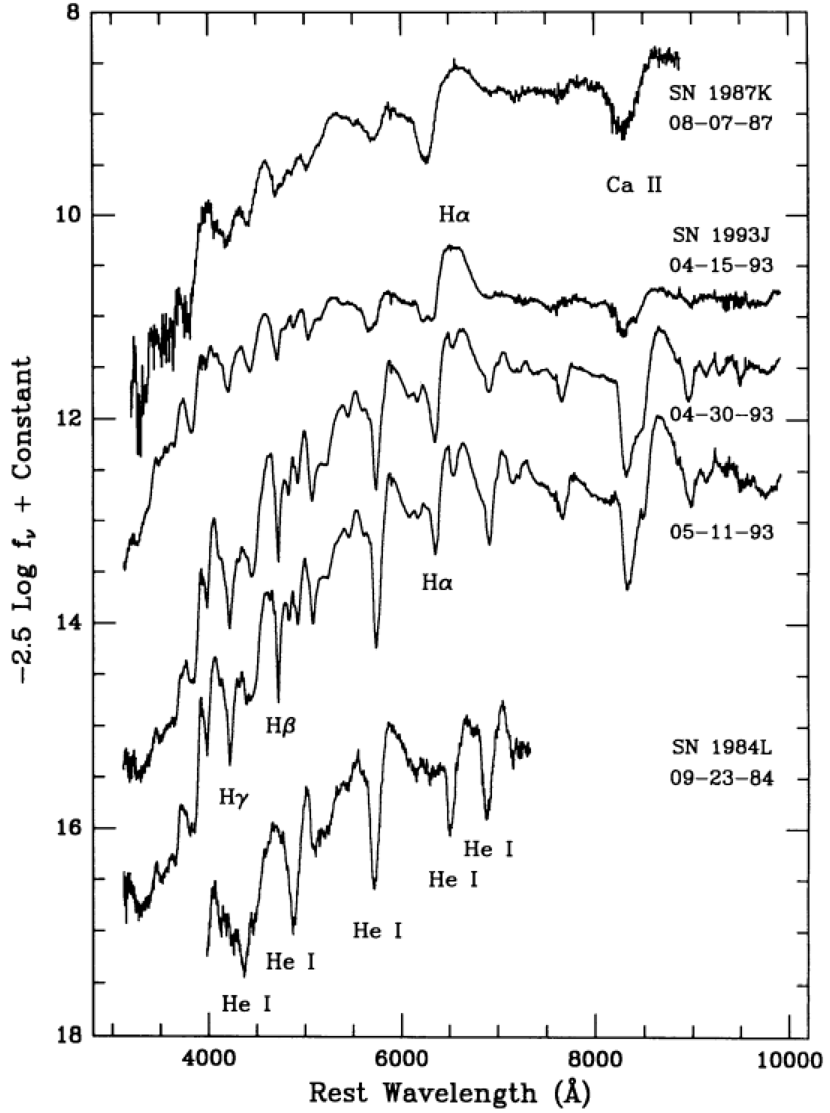


SNeIIb – transitional events from SNeII to SNeIb

(relatively weak) Hydrogen features at peak, then spectra become Helium dominated...

"Spectra of SN93J... ...prominent H-alpha emission line visible at early times became progressively weaker as... ...HeI gradually appeared; SN93J is therefore a hydrogen-poor, helium-rich 'SNIIb'. ...transferred most, but not all, of its hydrogen envelope to a physically bound companion" *(Filippenko+93)*

Filippenko+93

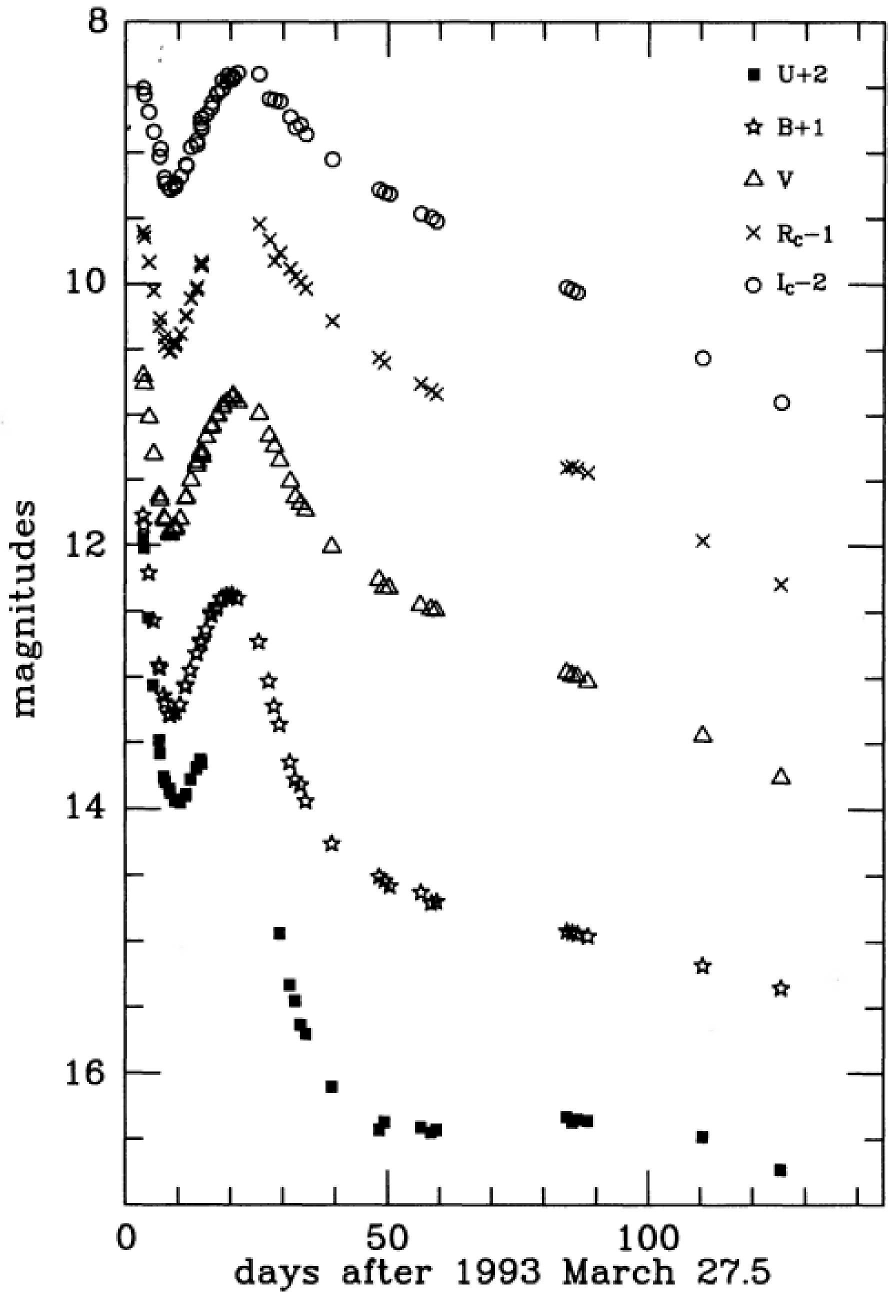


SN1993J

Prototypical SNIIb, long-duration shock cooling light curve

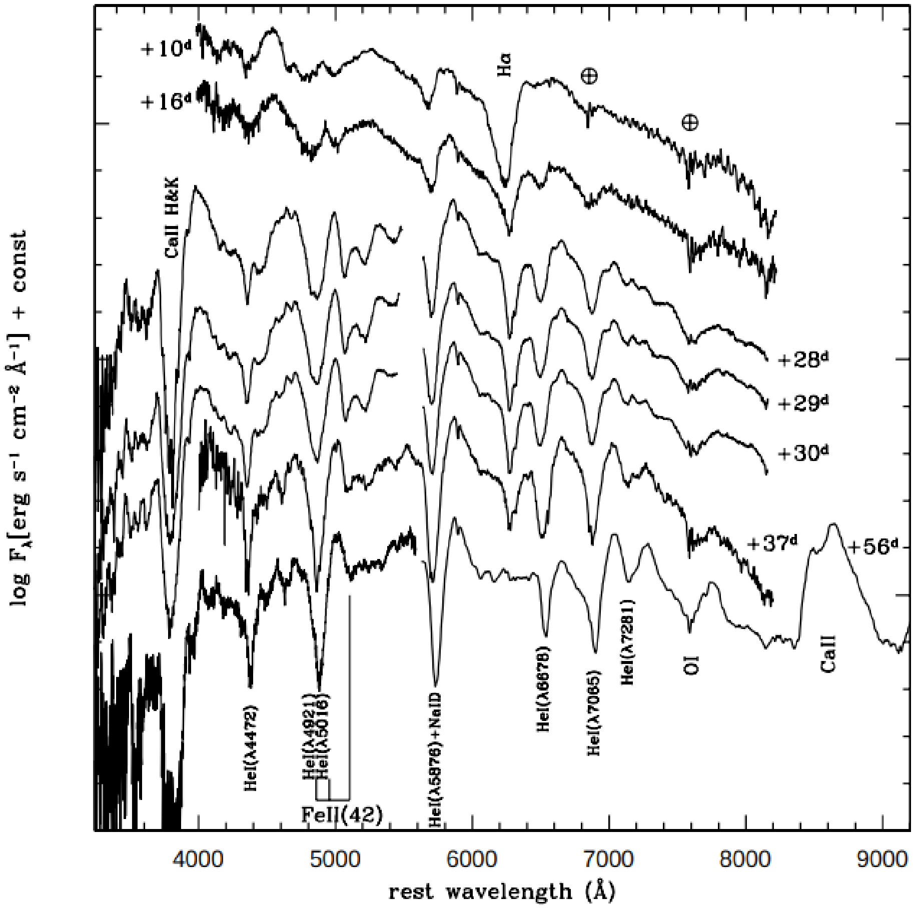
- Typical 'stripped-envelope' SN ^{56}Ni powered peak
- Additional 'early-excess' in light curve, from the shock-cooling of a (low mass) extended Hydrogen envelope
- But...

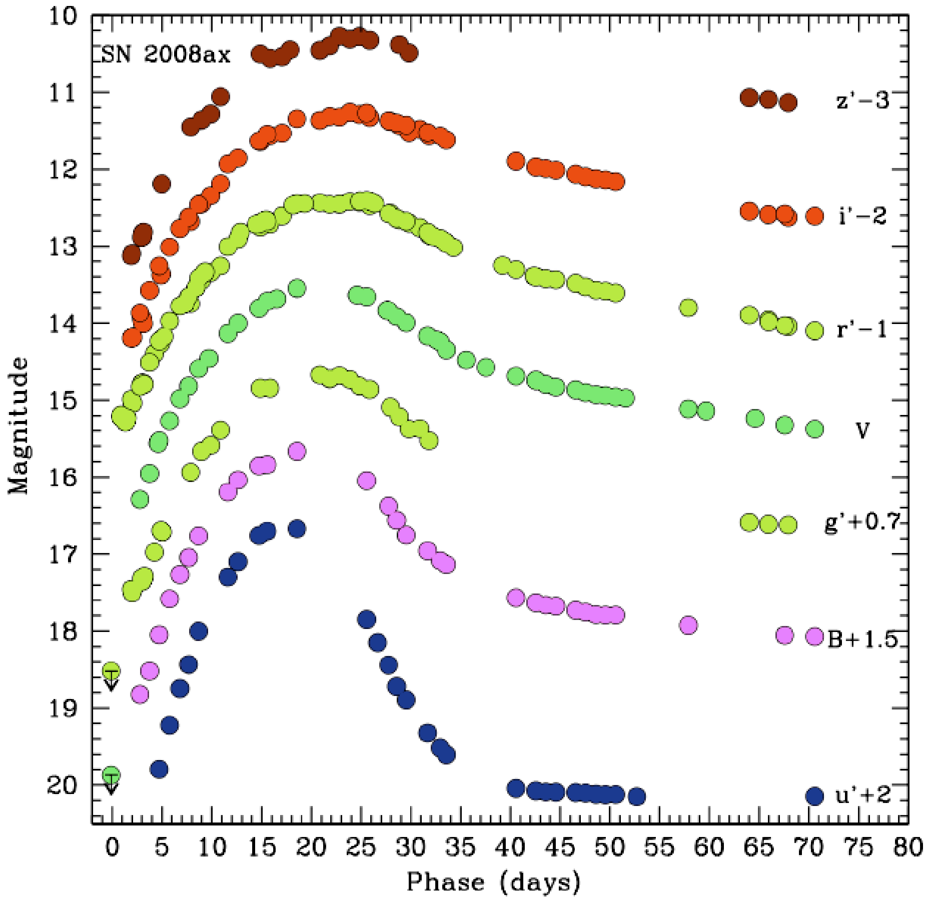
Lewis+94



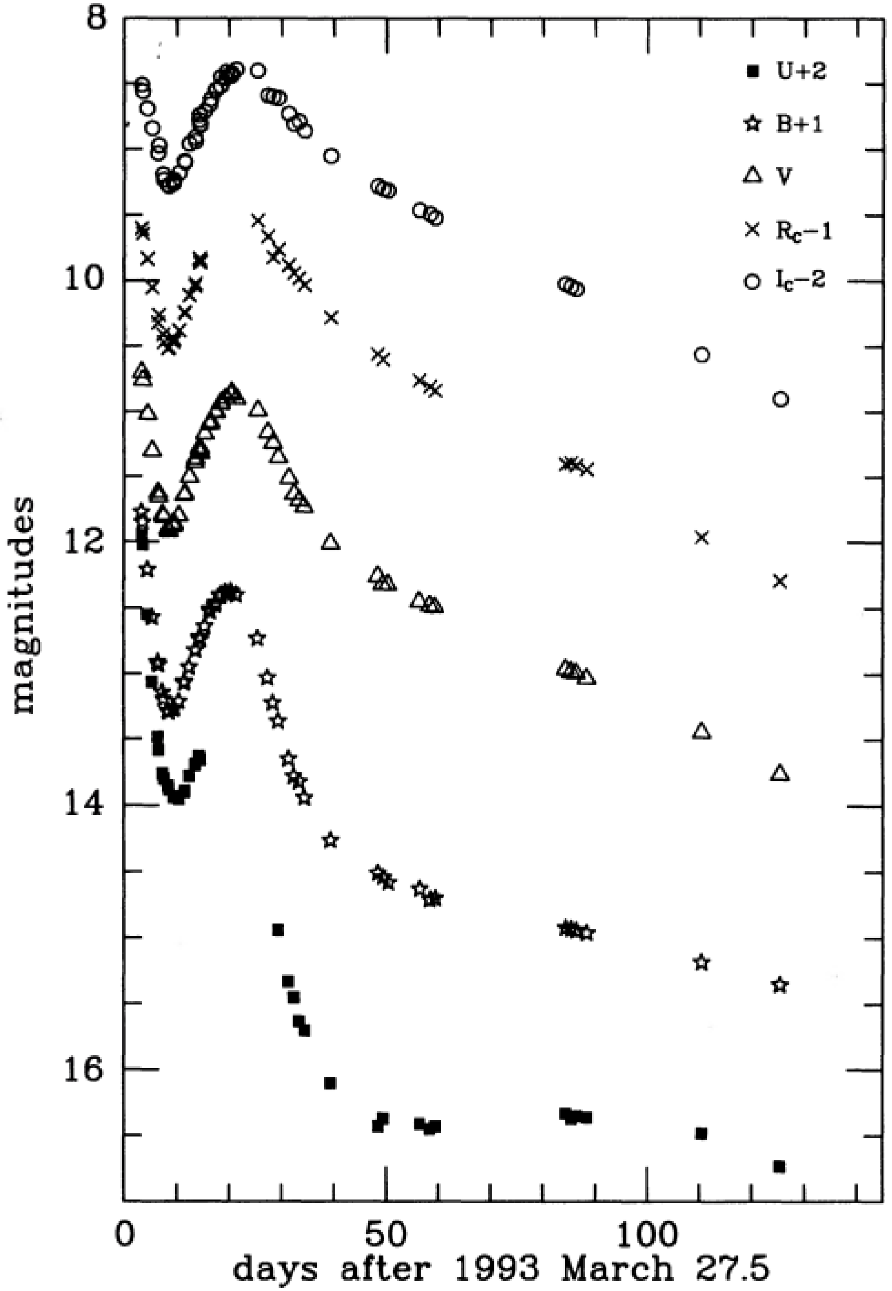
SN2008ax

Another well-observed SNIIb... no clear 'early excess' in the light curve



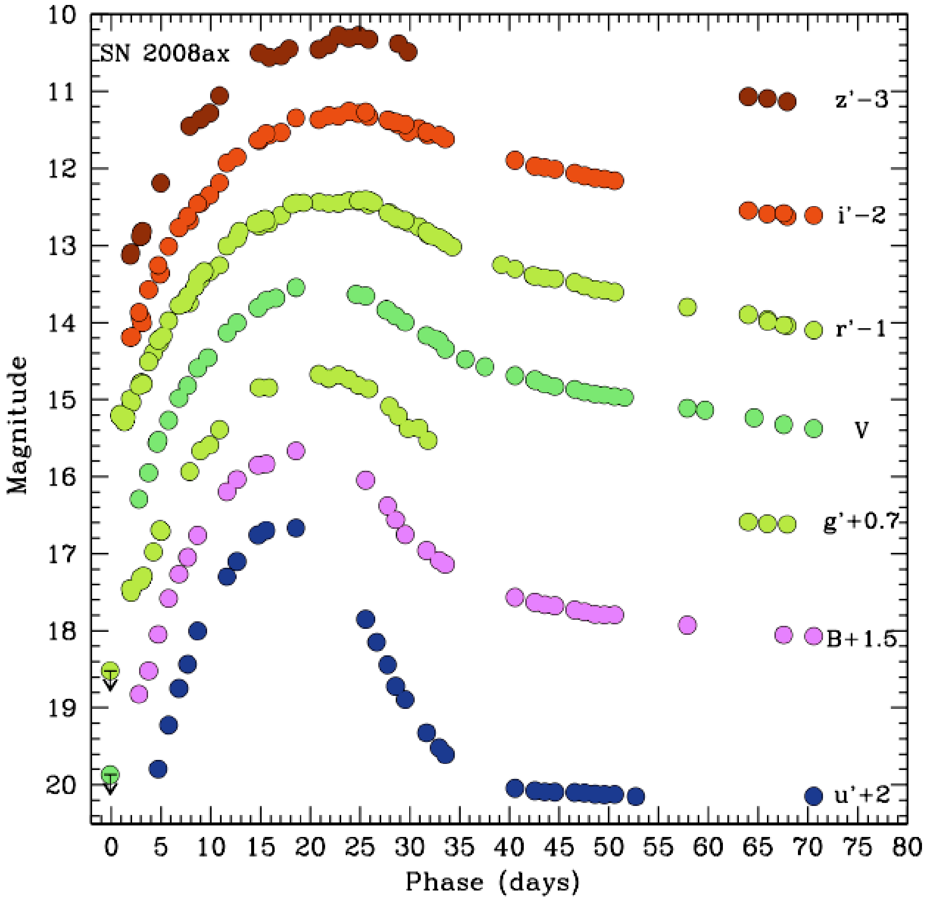


Pastorello+08



SNeIIb

What is the frequency of early-excess light curves, and what determines its presence?

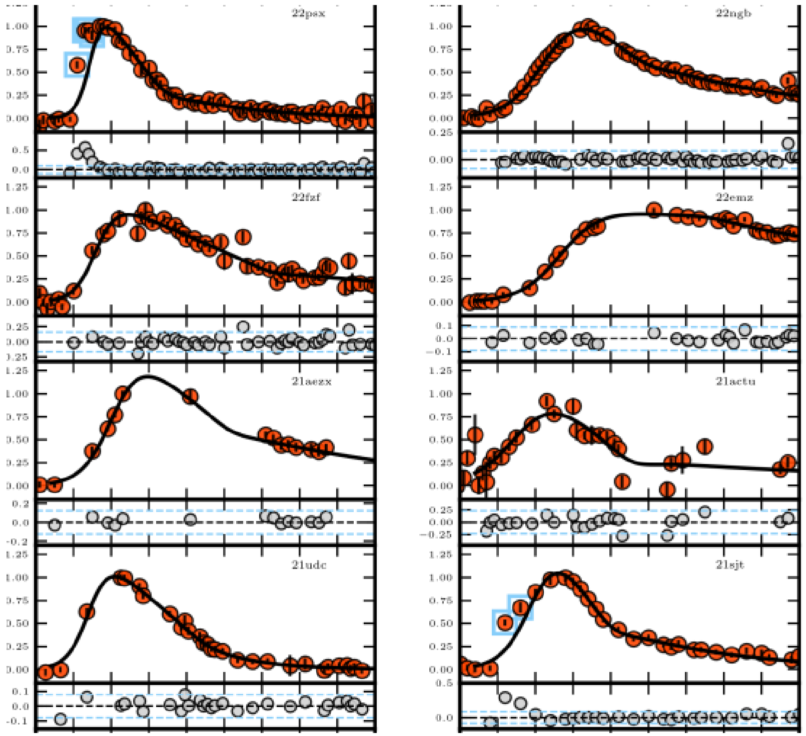


Early light curve excess in type IIb supernovae observed by the ATLAS survey (Ayala+25, accepted)

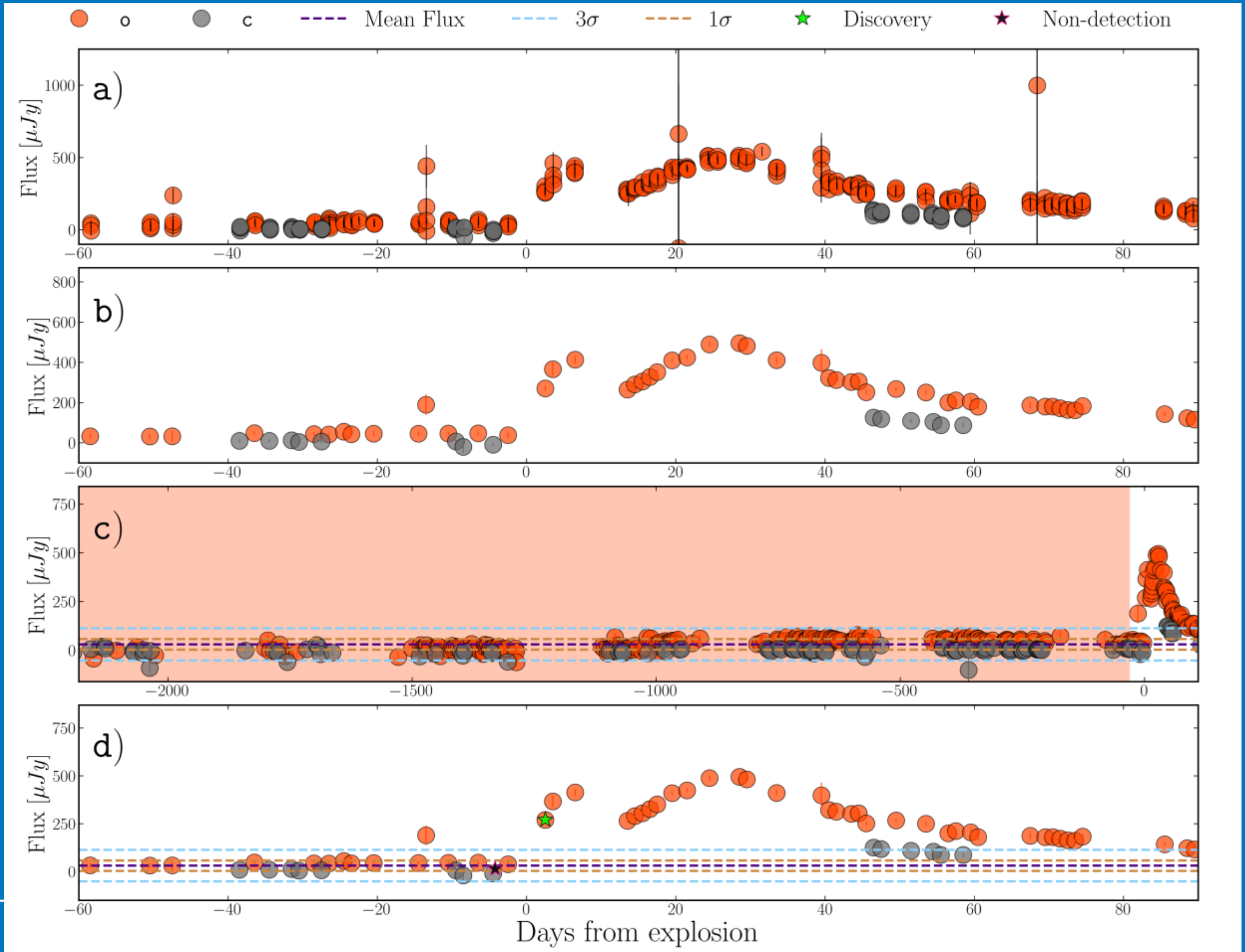
...determine the frequency of early-excess light curves in SNeIIb, assess its presence with progenitor properties...

As of 03/10/24, TNS contained 233 spectroscopically classified SNeIIb, 154 of which had been observed by ATLAS

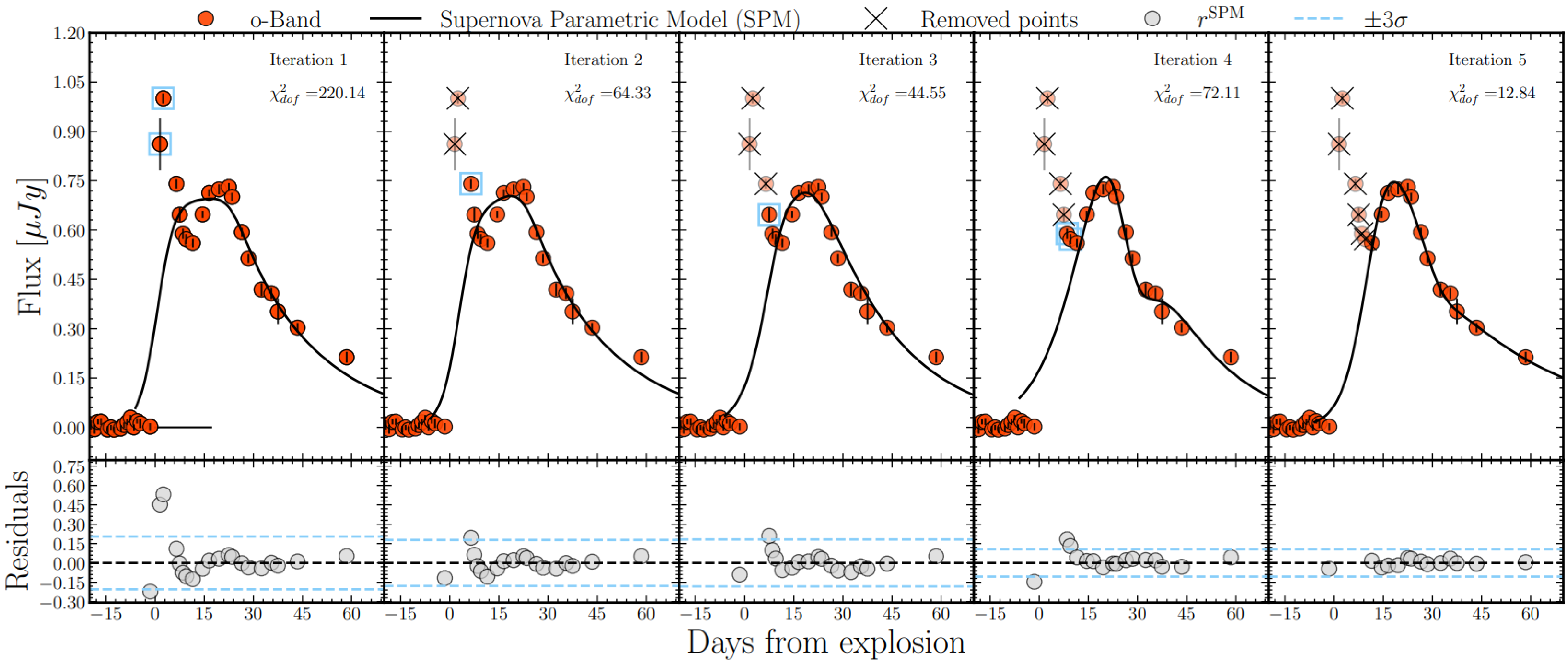
- 154 reduced to 66 SNeIIb when applying cuts/reclassifications
- ATLAS photometry cleaned using 'ATClean' (Rest+23,24)
- Robust non-detection and first detection photometry defined
- Light curves fit with 'Supernova Parametric Model' (SPM, Villar+19)
- Outliers from fit defined as early excess
- Frequency of early excess estimated
- Presence/absence of excess compared with other SN parameters



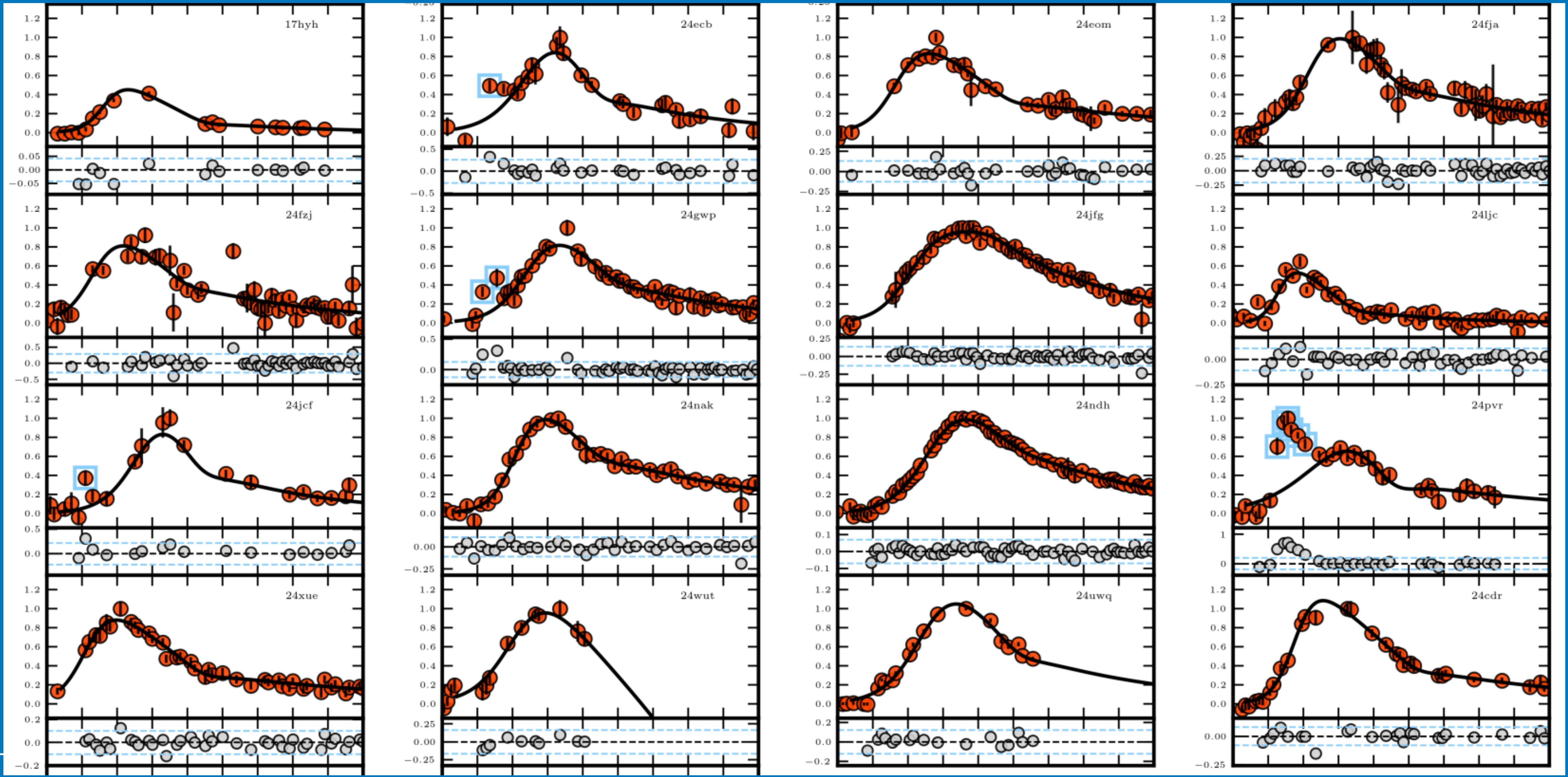
1) Light curve cleaning, explosion epoch estimation:



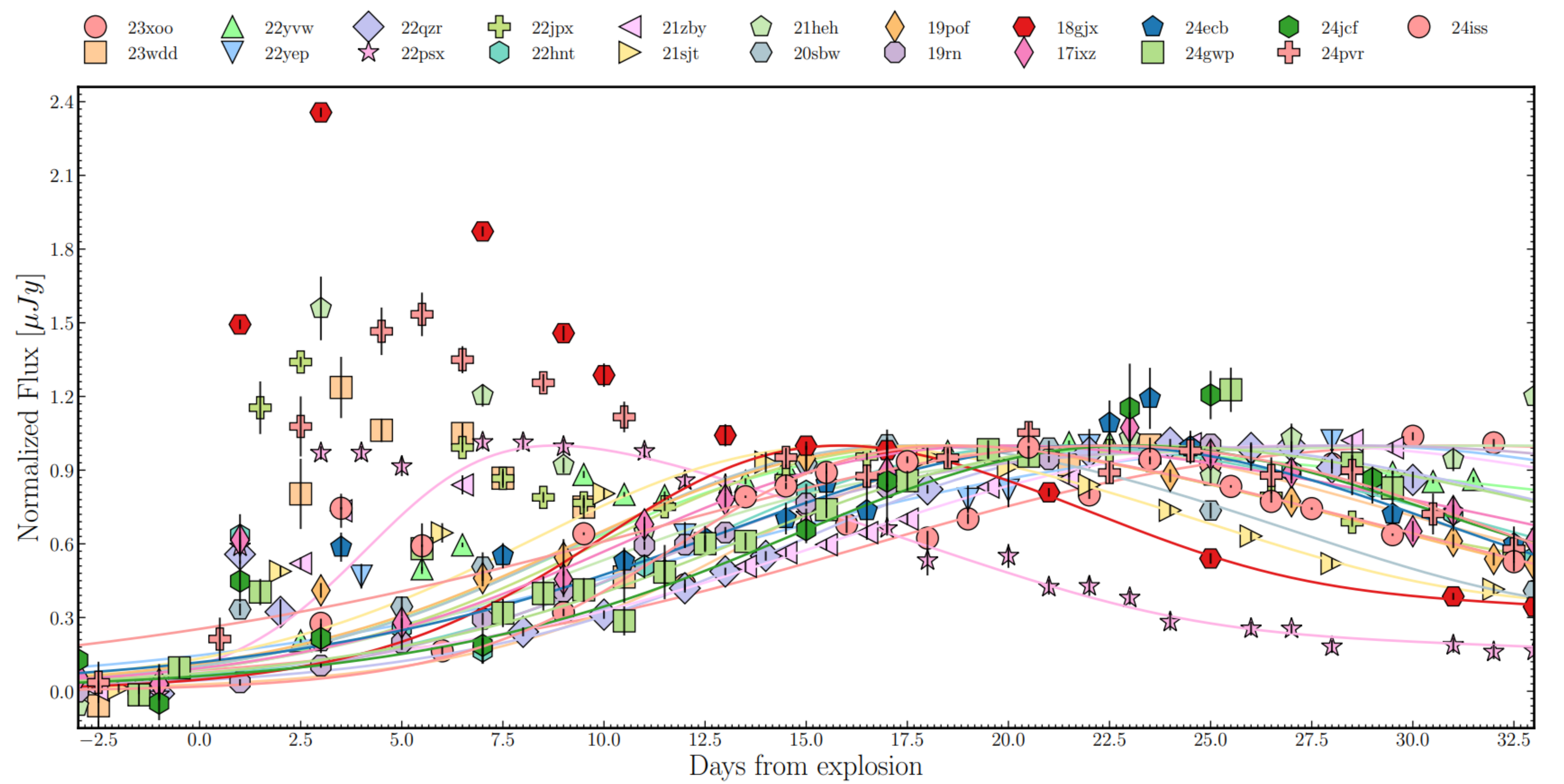
2) Light curve fitting, early-excess detection:



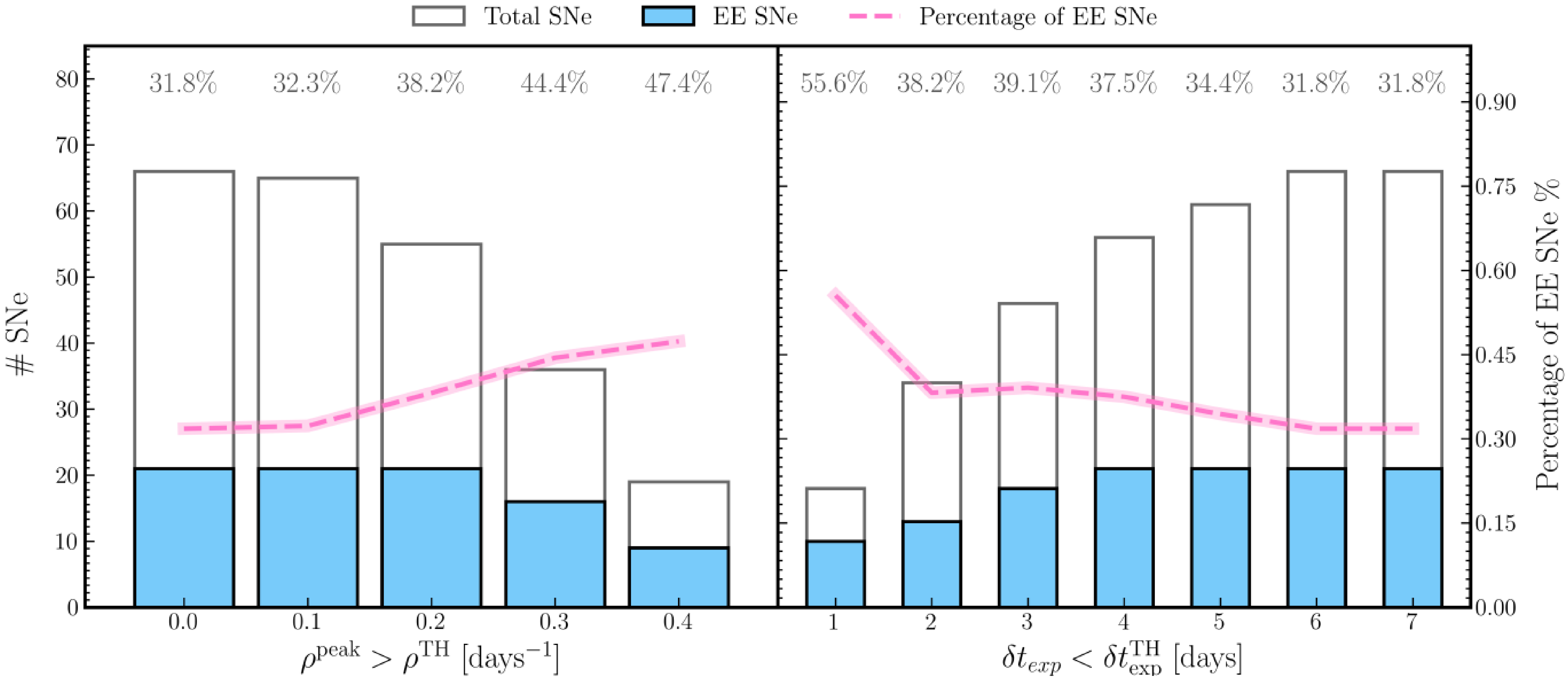
2) Light curve fitting, early-excess detection:



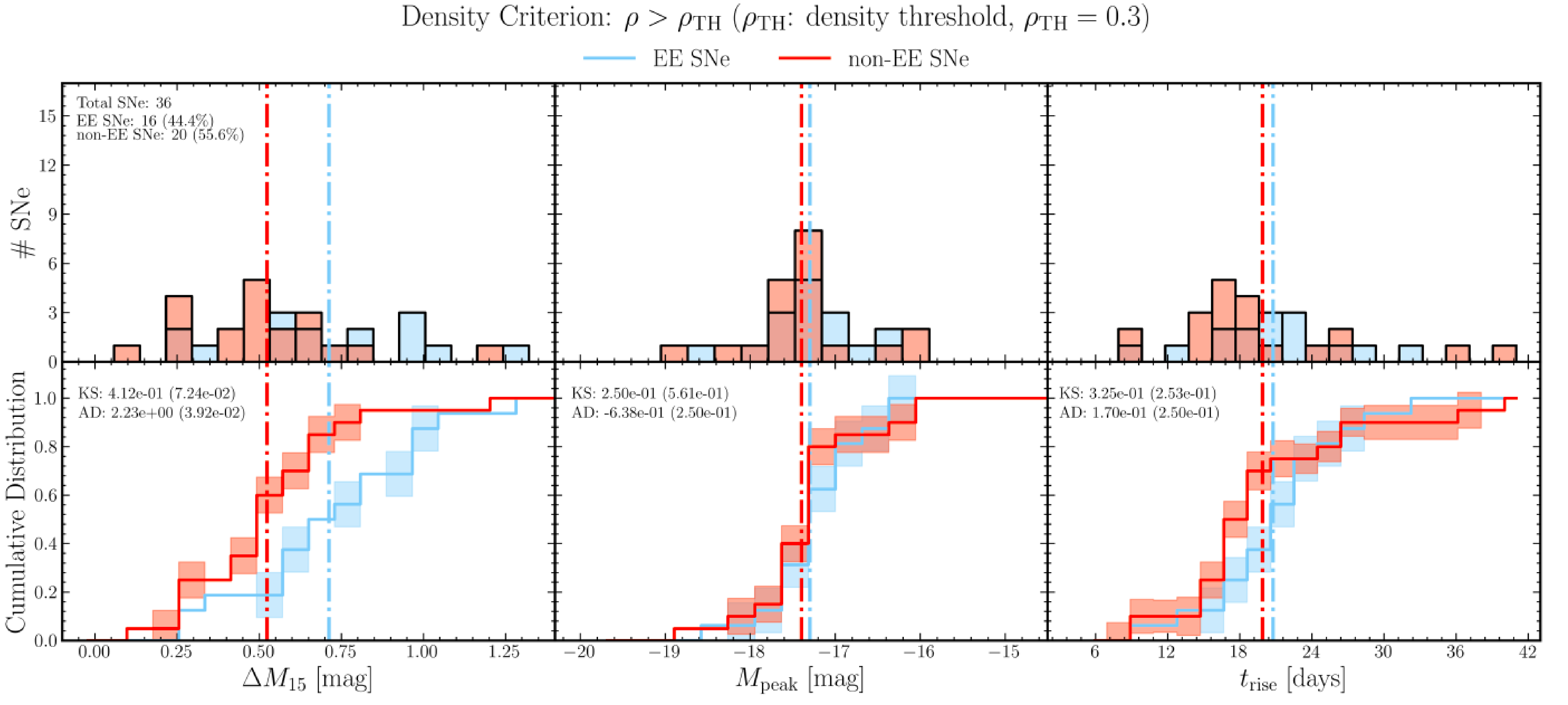
Early excess detected in 20 of full sample of 66 SNeIIb:



3) Frequency of early excess estimated (as a function of photometric density and explosion epoch error):



4) Are the ^{56}Ni-powered light curves of SNeIIb with early excess distinct from those without?



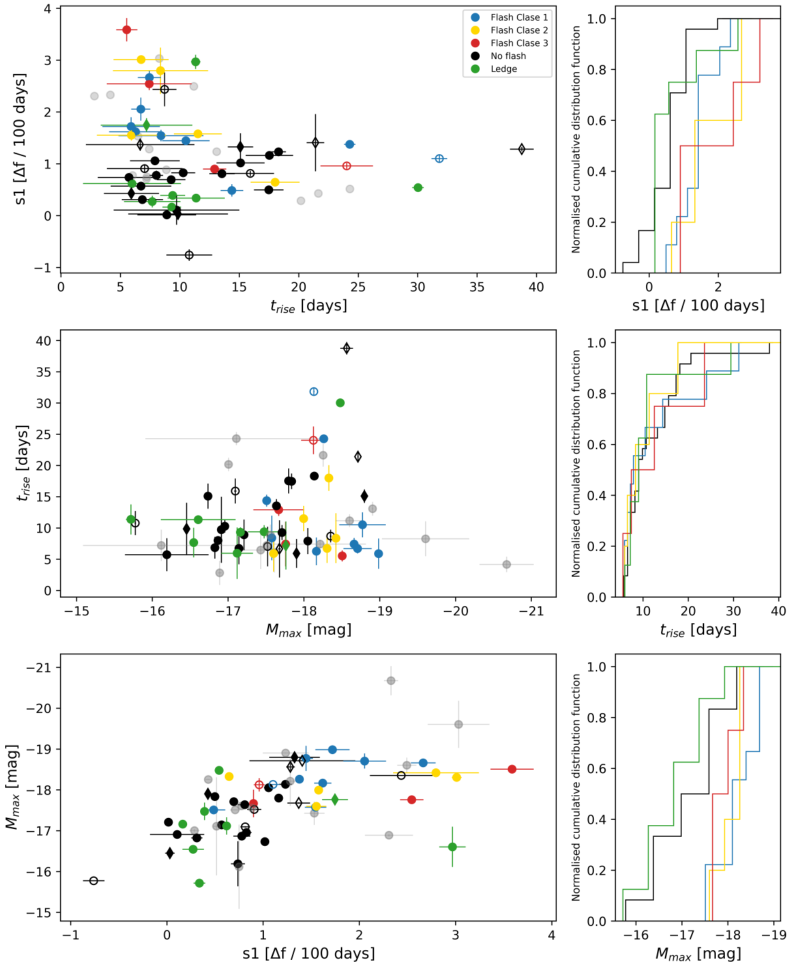
Early light curve excess in type IIb supernovae observed by the ATLAS survey (Ayala+, submitted)

Almost half of SNeIIb have an early-excess – probably related to an extended Hydrogen envelope. The presence of this envelope may be related to other progenitor properties...

- **SNeIIb show an early-excess rate of ~40%**
- The presence of an early-excess may be related to the width of the light curve (t_rise and dm15)
- Comparison with well-observed literature SNeIIb, suggest that this early-excess – in the majority of cases – is related to the shock cooling of an extended Hydrogen envelope
  - The duration of ATLAS SNeIIb early excess is consistent with those in the literature
  - The colour evolution of those SNeIIb (ATLAS and the literature) is consistent with shock cooling
- The frequency of shock-cooling light curves constrains the stellar evolutionary pathways leading to SNeIIb
- This may be consistent with binary evolution being the dominant parameter that determines whether Helium core explodes with an extended envelope or not...

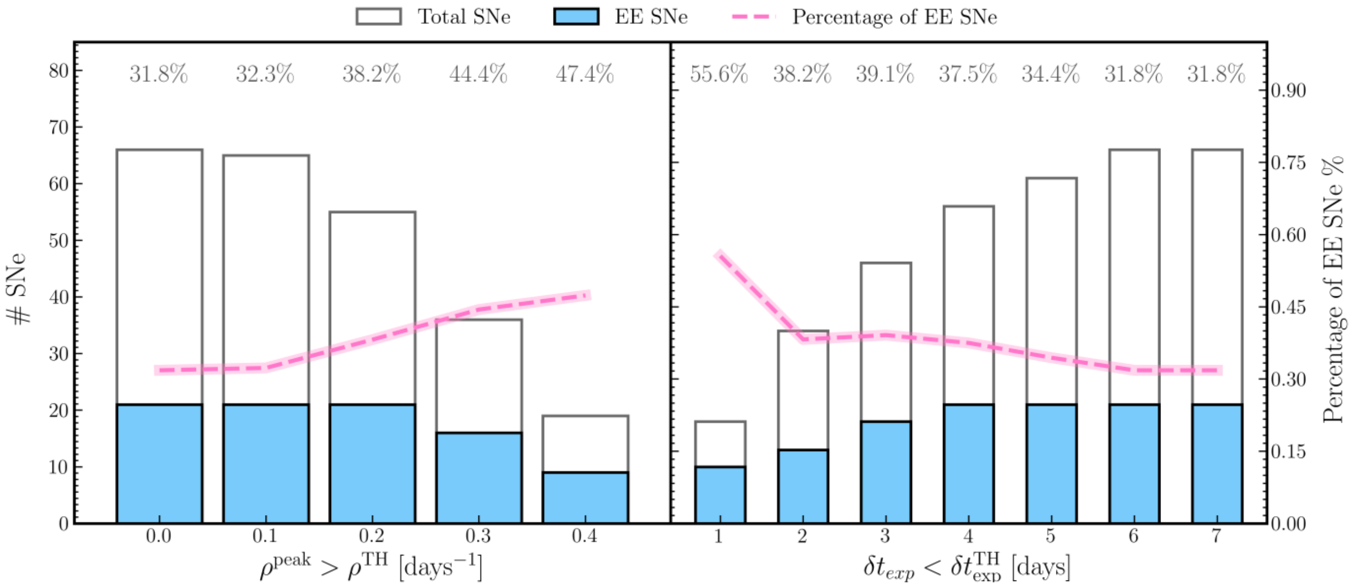
The early-time light curves of type II and type IIb supernovae from the ATLAS survey

Early observations are critical to constrain outer progenitor density profiles (here SNeII and IIb), constraining the later stages of stellar evolution



Early-phase CSM interaction may be dominant in producing Fast-declining SNeII (IIL) and thus SNII diversity

Extended Hydrogen envelopes are present in ~40% of SNeIIb progenitors. This presence may be related to higher mass progenitors, but the binary system configuration likely plays and important role



"Type II Supernovae:

The Chaotic Deaths of Supergiants and their Cosmic Implications"

An ESO-Chile workshop in 2026

Joe Anderson, Santiago Gonzalez-Gaitan, Thallis Pessi, Evgenia Koumpia, Geza Csörnyei, Aleksandar Cikota

- ~Early October 2026
- **In San Pedro de Atacama, Chile**
- *From stellar evolution -> mass loss -> progenitors -> explosion physics -> SNII observations from early to late times -> the use of SNeII to understand the Universe...*
- ***See official announcement in coming months!!!***