

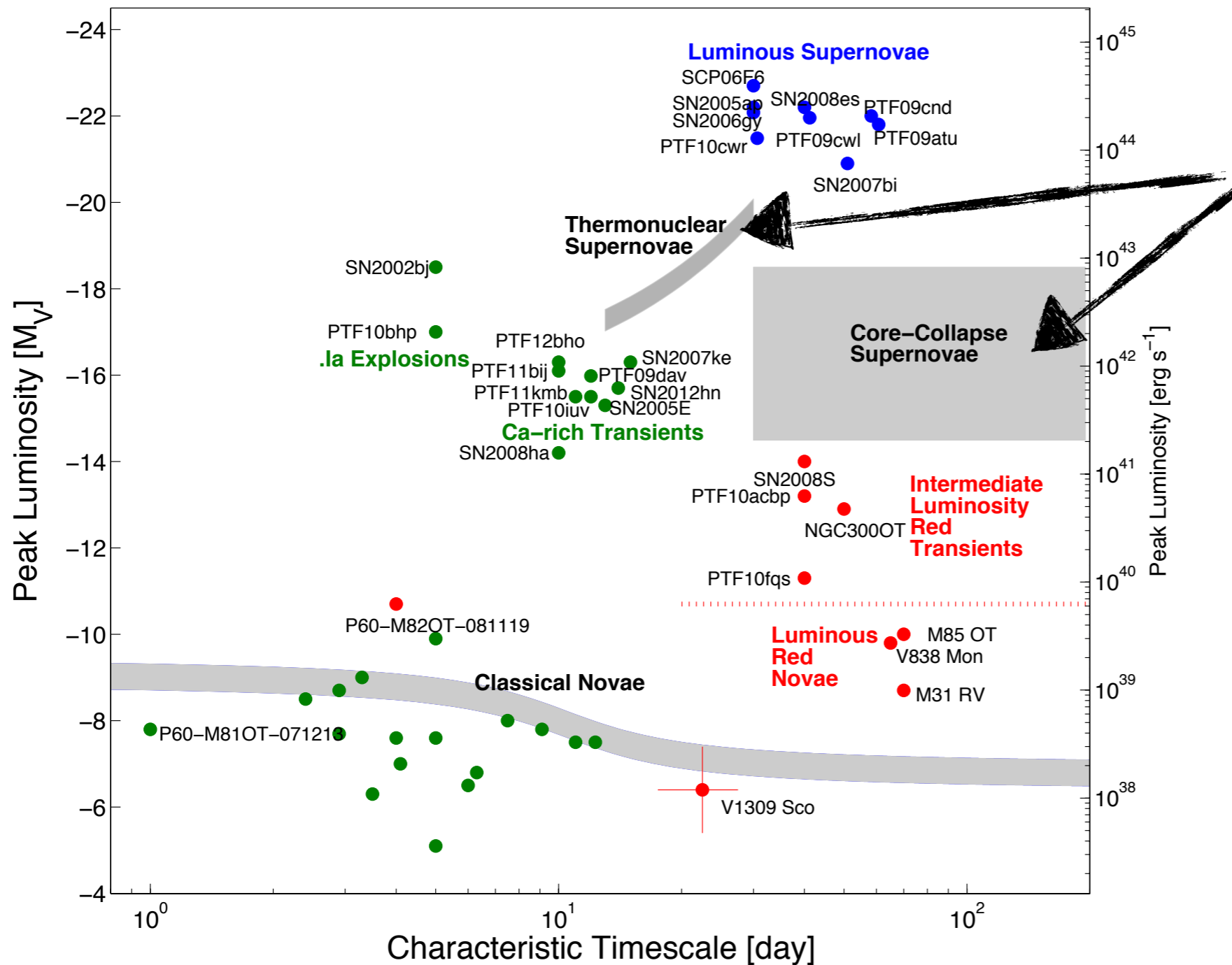
Physics of Supernovae and Relativistic Explosions Update

Dr. Ragnhild Lunnan
August 6, 2018

ZTF Team Meeting



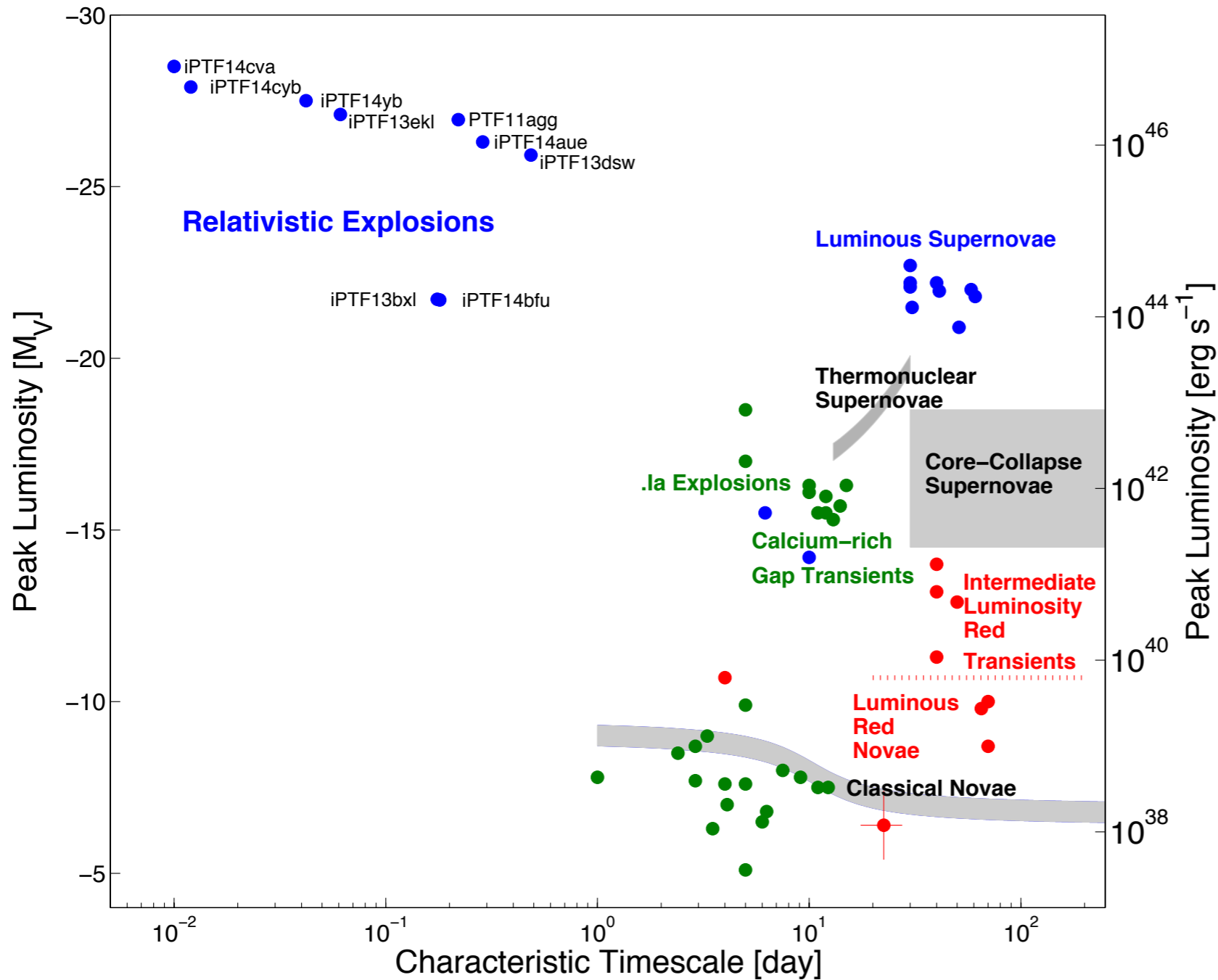
Major Goals



Understanding the progenitors and explosion mechanisms of “ordinary” supernovae.

Finding, characterizing and understanding rare transients like superluminous supernovae, fast and blue transients, Ca-rich transients, etc.

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Finding, characterizing and understanding rare transients like superluminous supernovae, fast and blue transients, Ca-rich transients, etc.

Exploring the diversity of relativistic explosions.

Key Advantages of ZTF

- High cadence in partnership fields allows for constraining rise times, finding young explosions, and gives sensitivity to rapidly evolving transients
- Large overall area allows for building up large samples and for finding intrinsically rare objects

Talk Outline

- Relativistic Explosions & Fast Transients
- Transients in the Local Universe
- Superluminous supernovae
- Infant supernovae and flash spectroscopy
- Core-collapse supernovae

Talk Outline

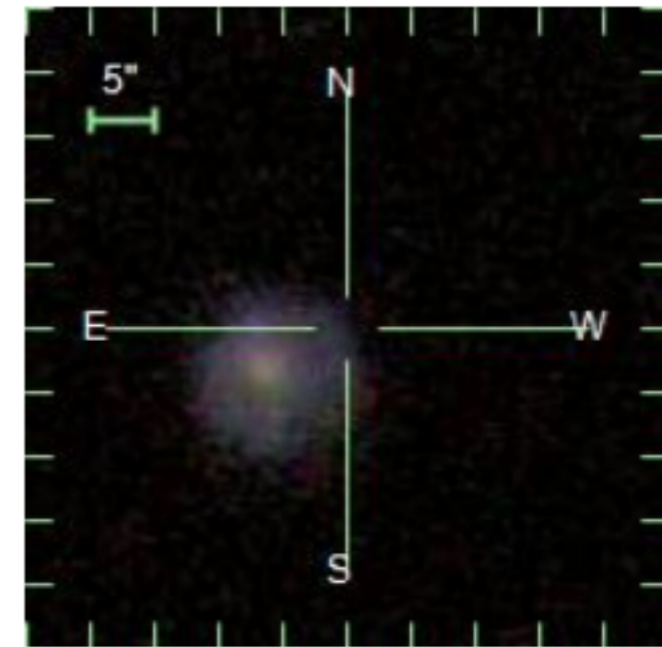
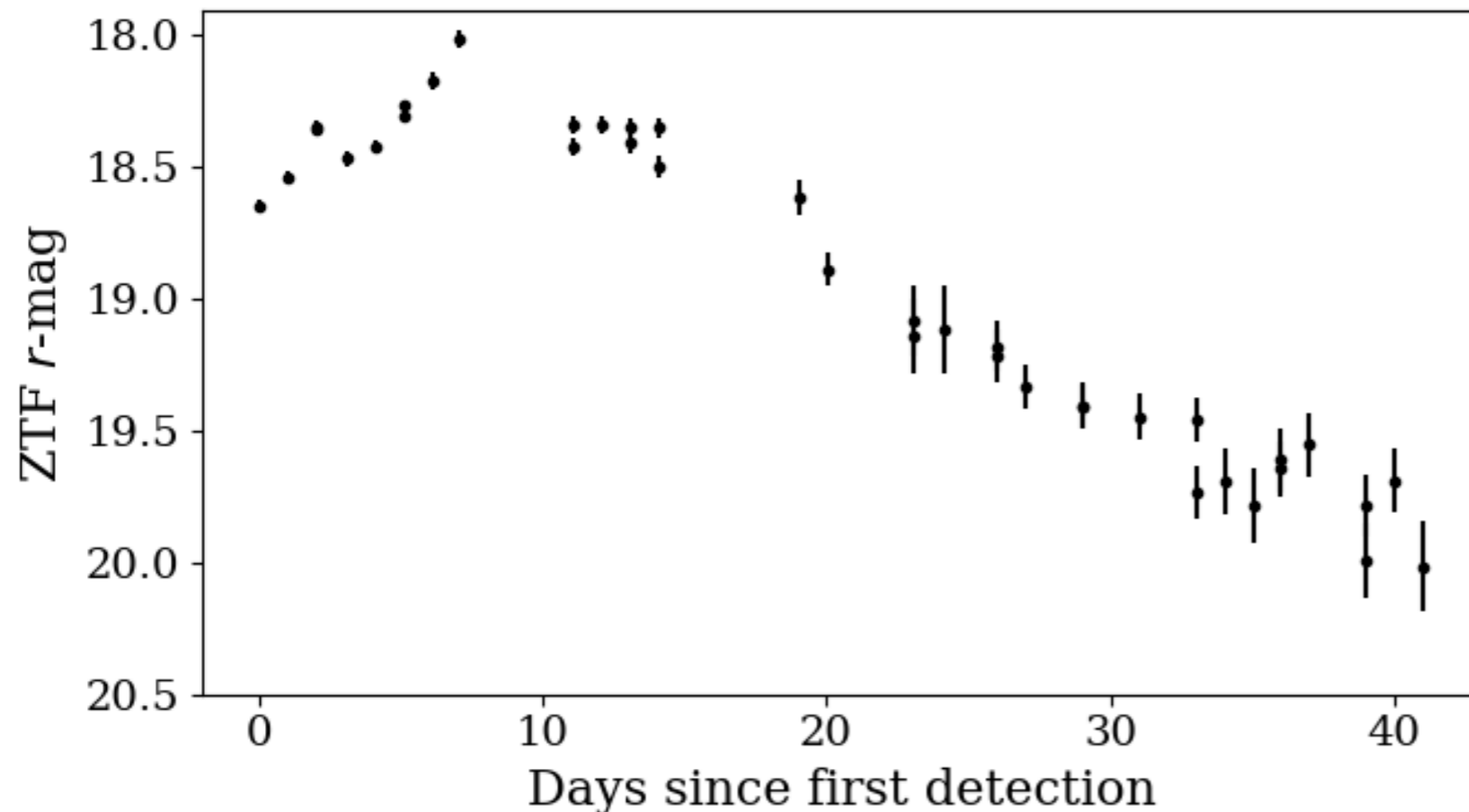
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An optically selected sample of relativistic explosions

- Search for GRB afterglows as rapidly fading sources, and compare to the population discovered by high-energy emission. Do “dirty fireballs” exist and how common are they?
- Follow up nearby ($z < 0.05$) SN Ic-BL in the radio to get meaningful constraints on any relativistic outflow (collaboration with Alessandra Corsi)

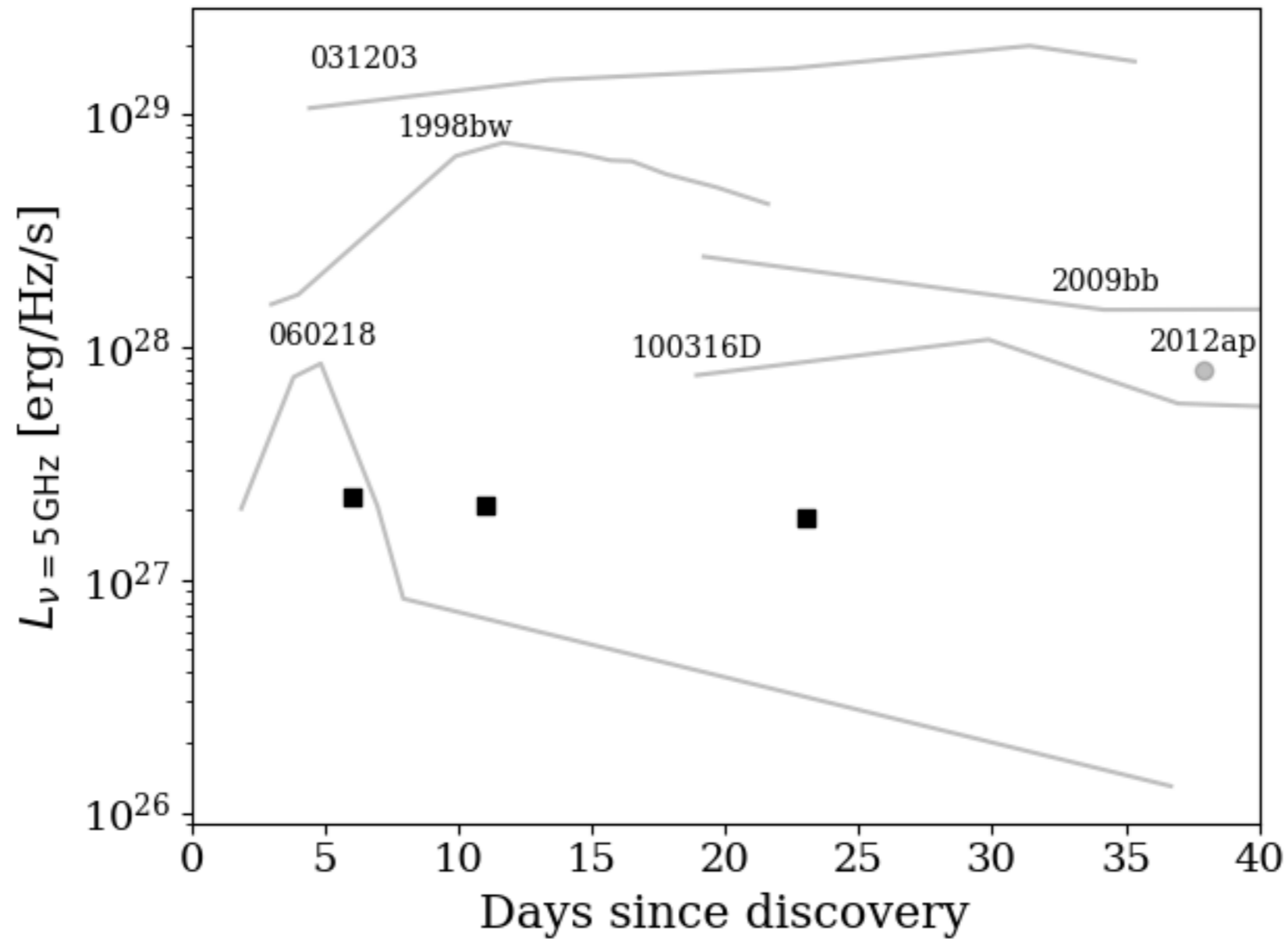
ZTF I 8aaqjovh: a SN Ic-BL at $z=0.05$ with radio emission

To date, ZTF has discovered 3 SN Ic-BL, 2 of which are at $z < 0.05$.
The expected rate is ~ 15 / year.



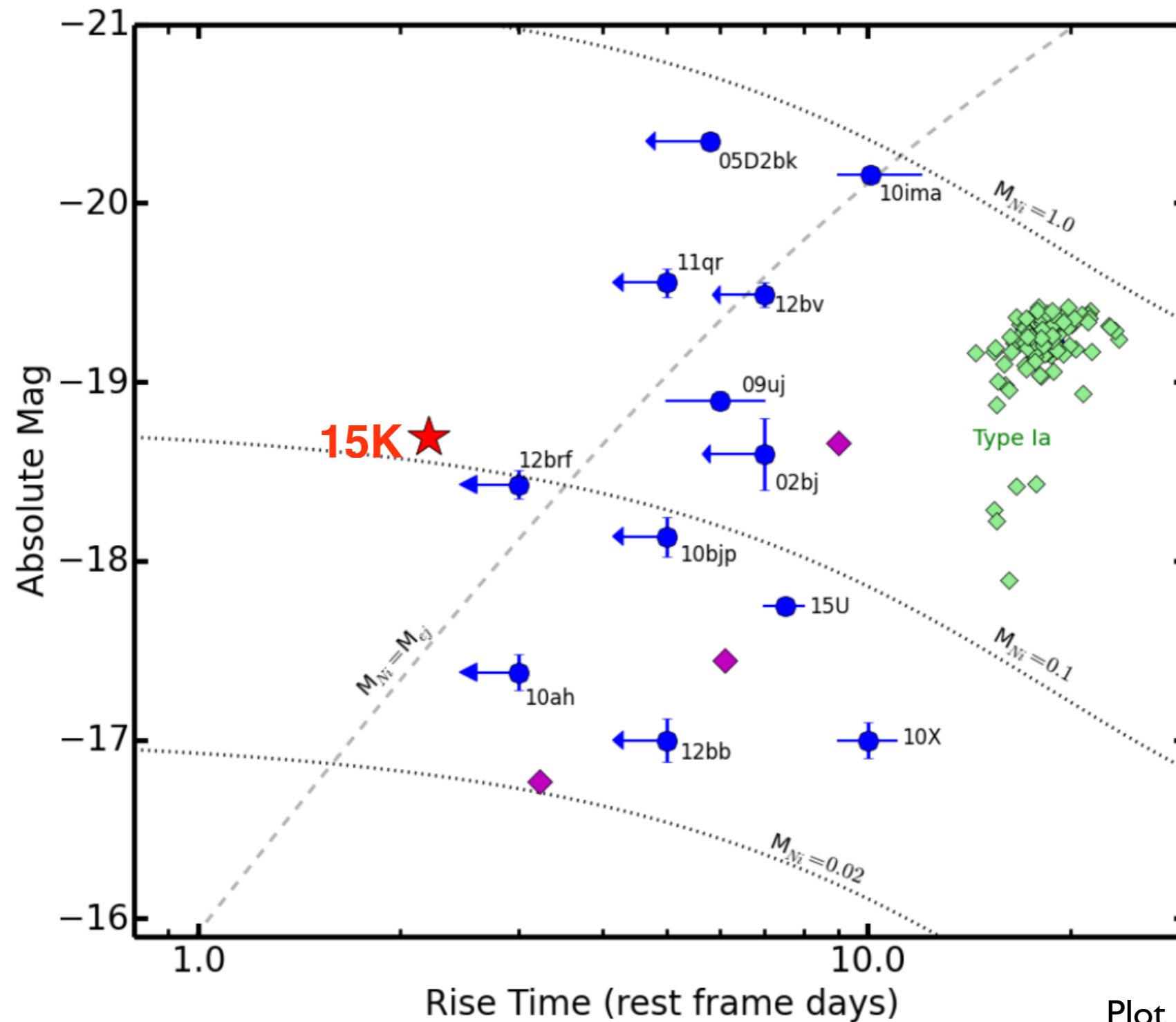
Ho et al., in prep.

ZTF18aaqjovh: a SN Ic-BL at $z=0.05$ with radio emission



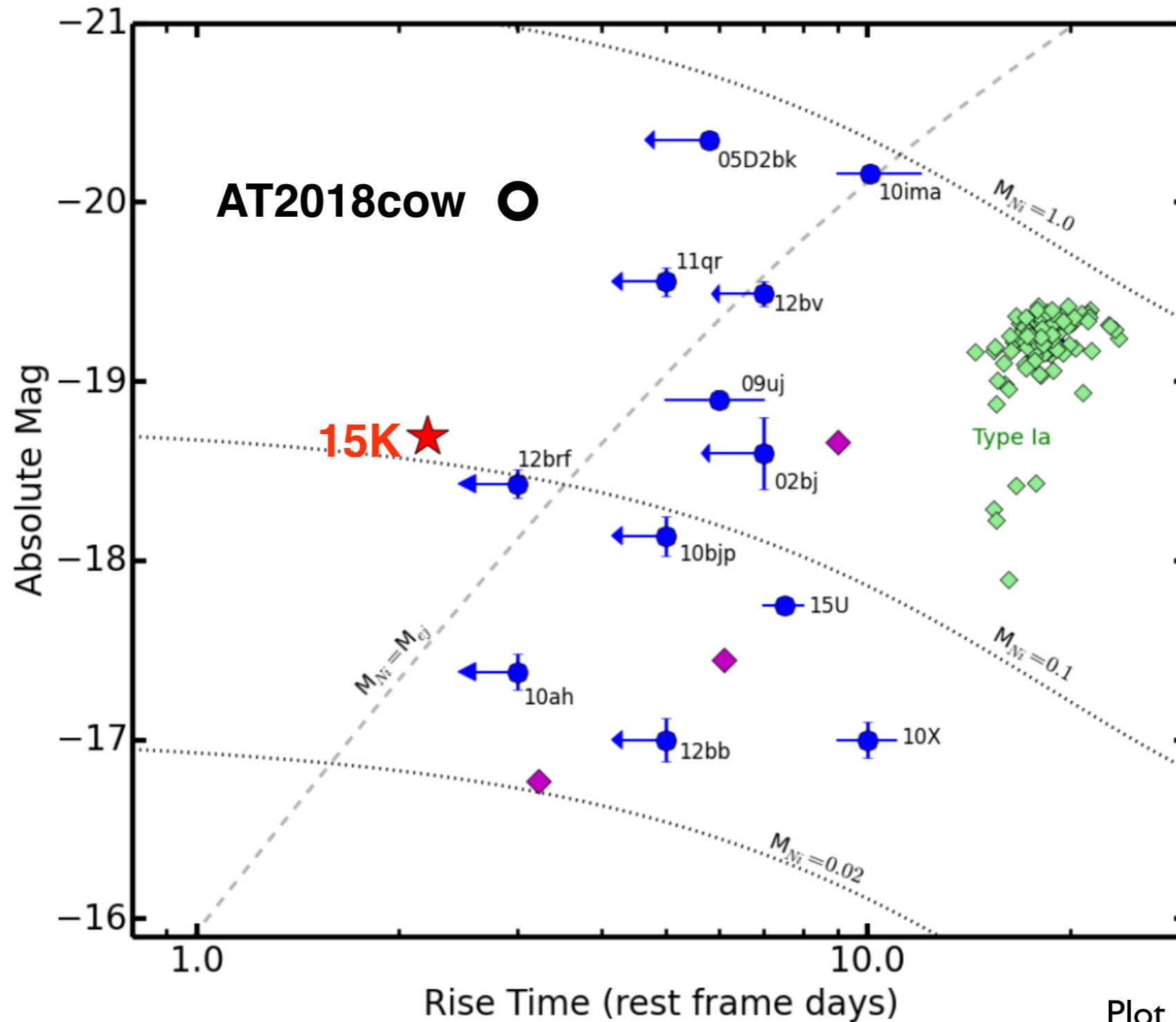
Ho et al., in prep.

Rapidly Rising Transients



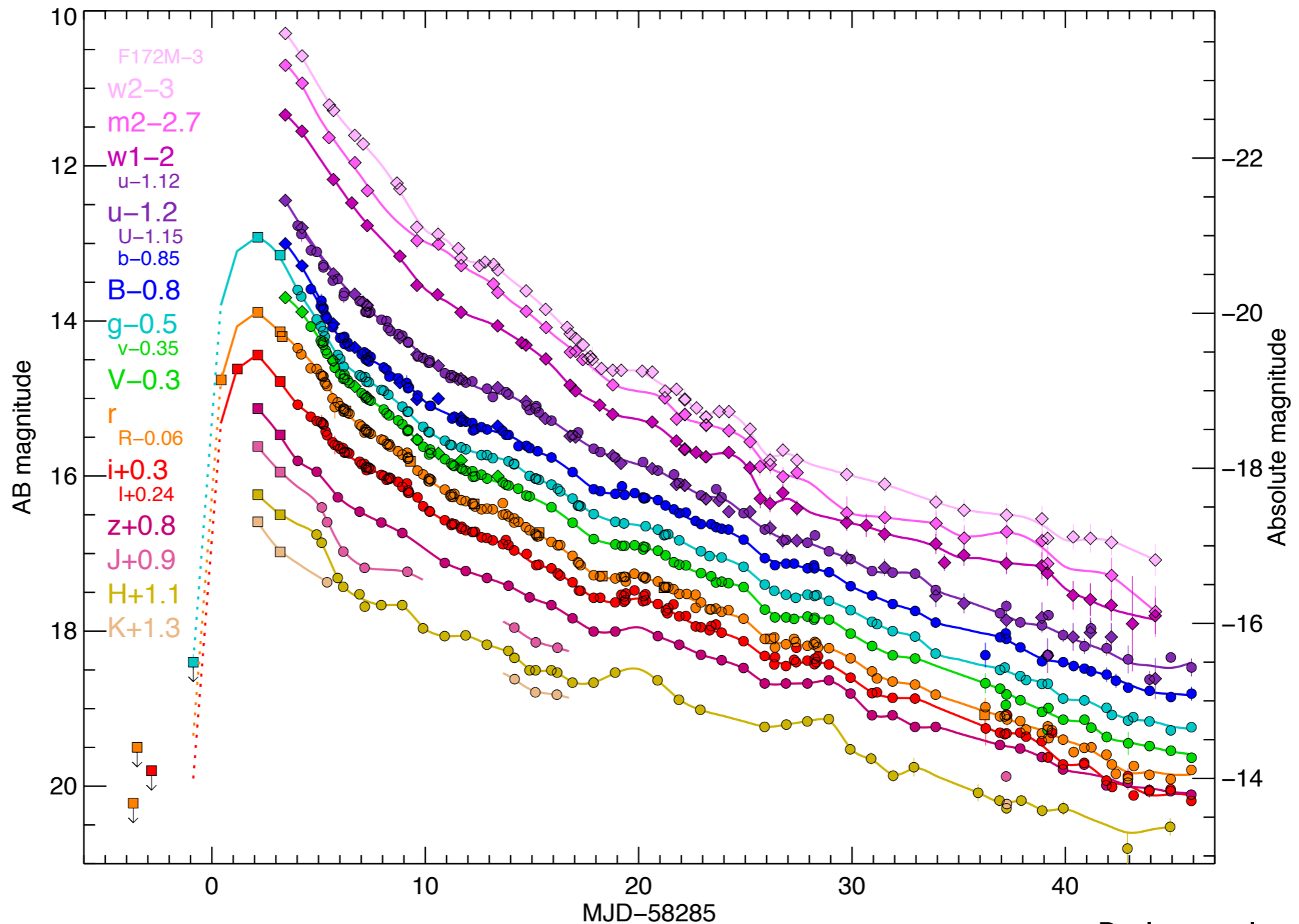
Plot adapted from Armin Rest

Rapidly Rising Transients: AT2018cow



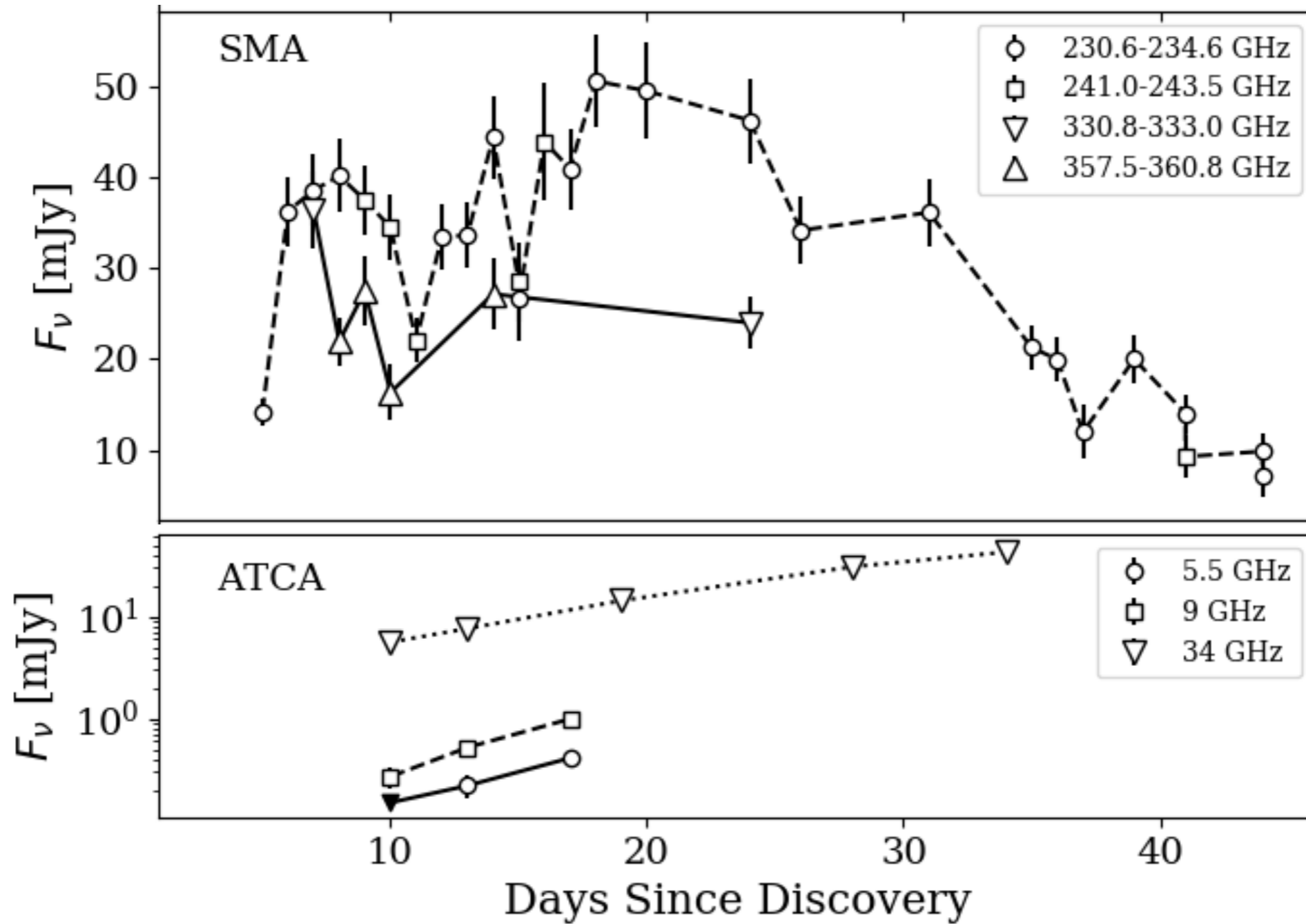
Plot adapted from Armin Rest

AT2018cow: Fast & persistently blue



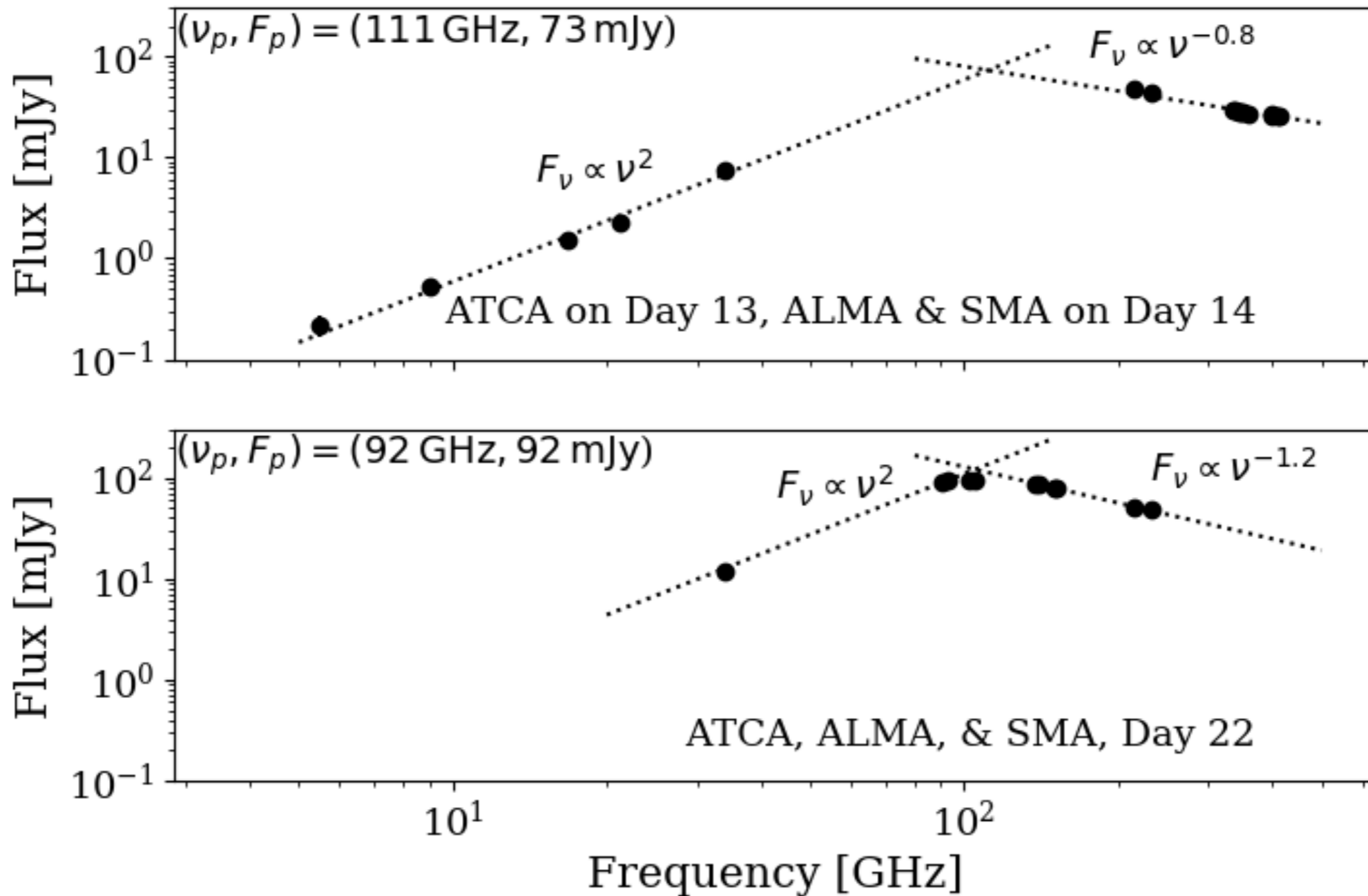
Perley et al., submitted

AT2018cow: Millimeter and Radio light curves



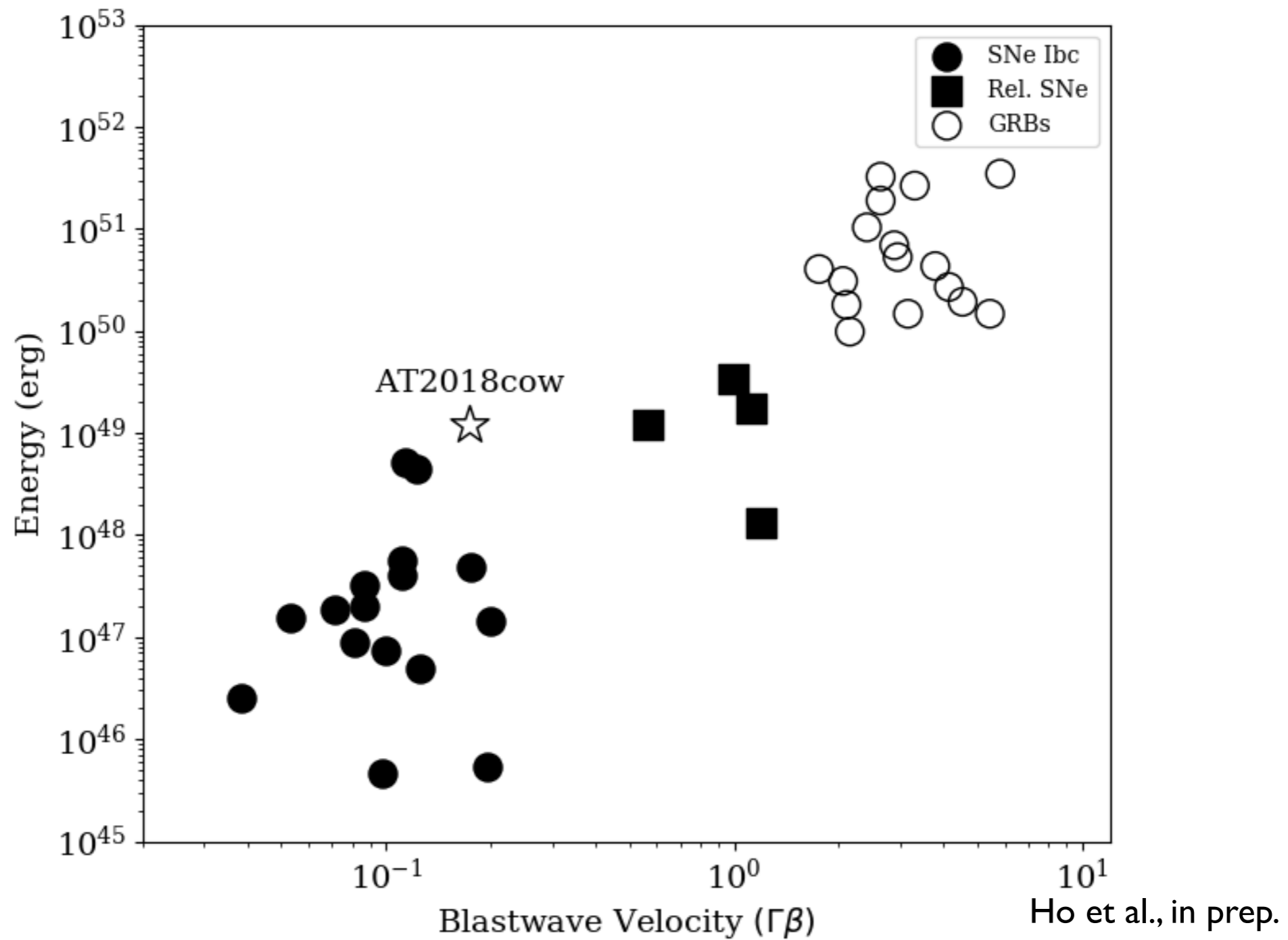
Ho et al., in prep.

AT2018cow: Radio SED



Ho et al., in prep.

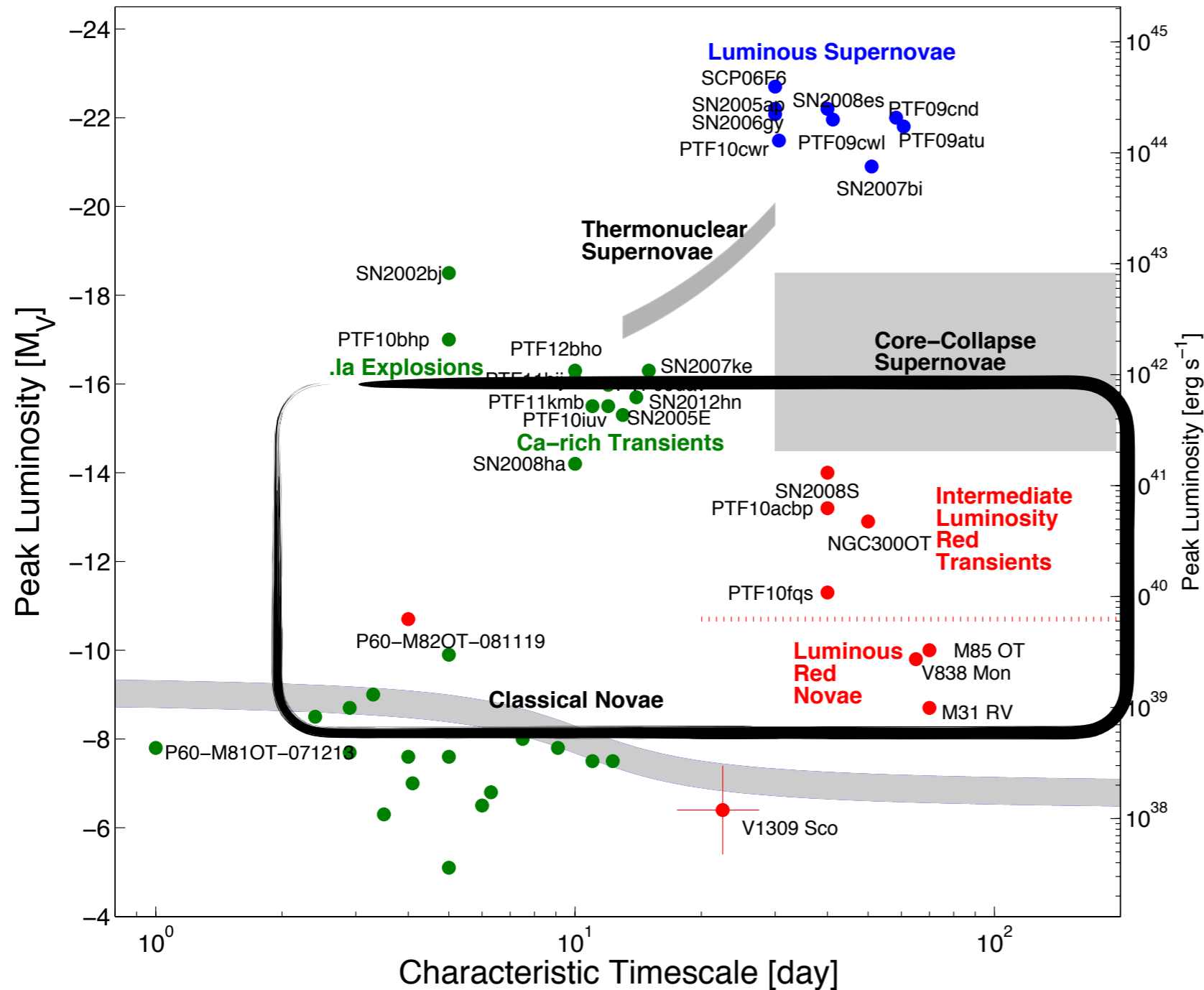
AT2018cow: Velocity and Energy



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CLU filter: galaxies within 200 Mpc

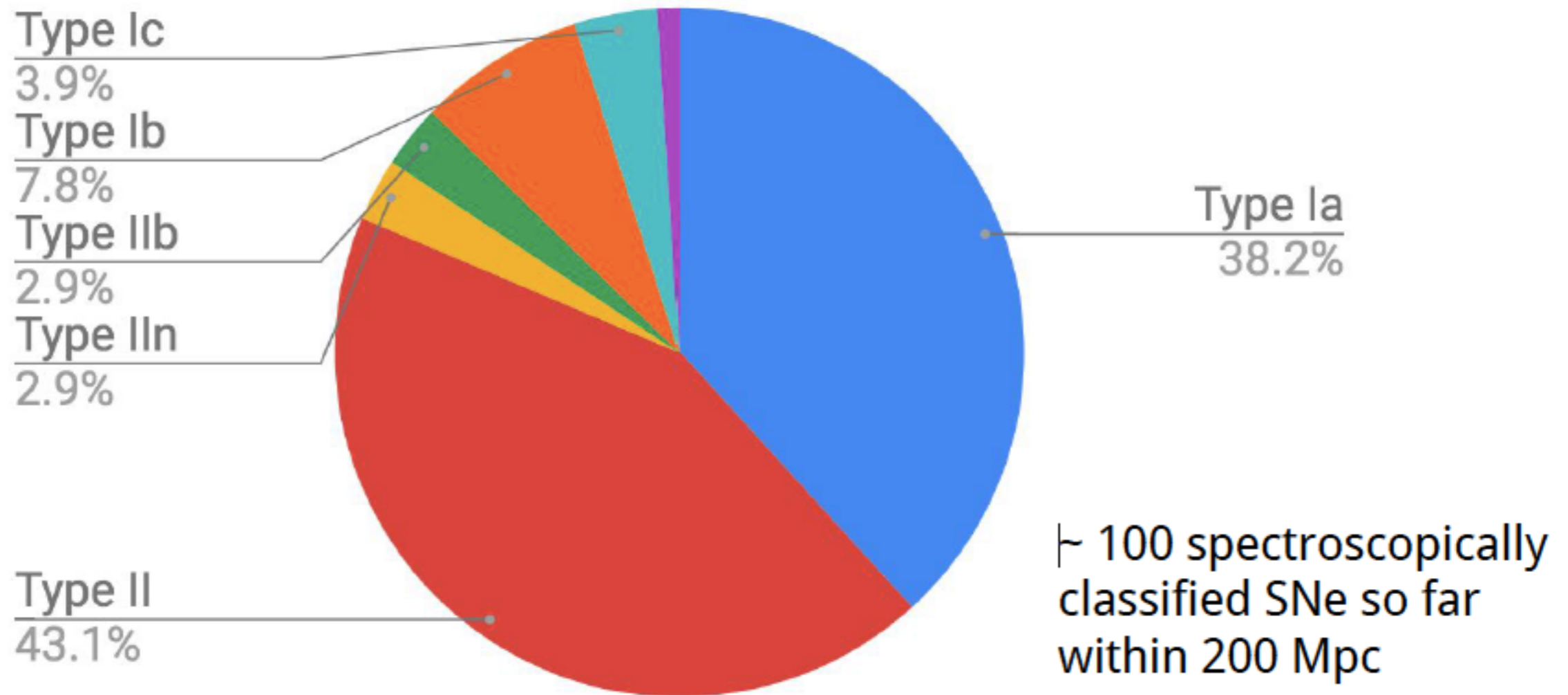


Constrain supernova rates the local universe by creating a volume-limited sample

Probing low-luminosity transients.

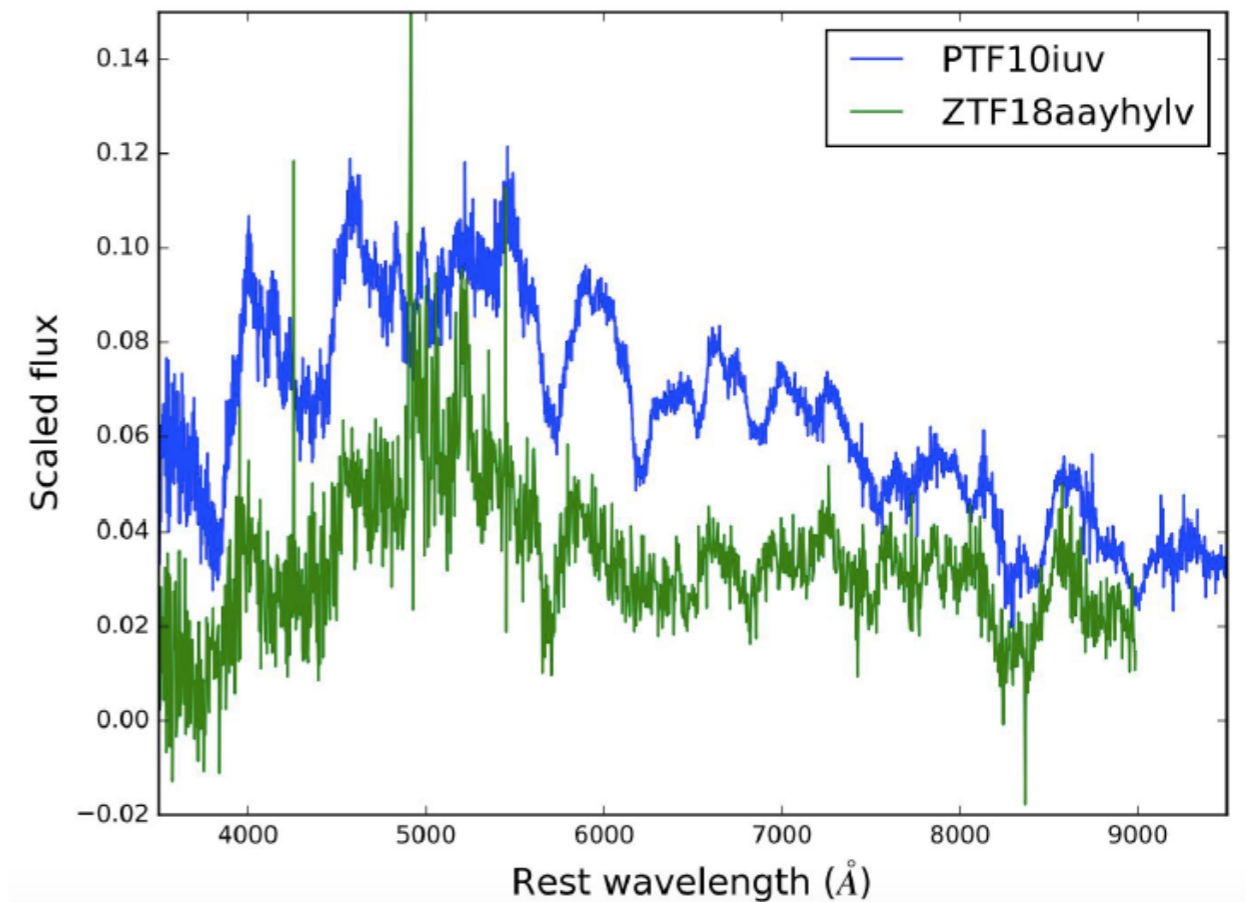
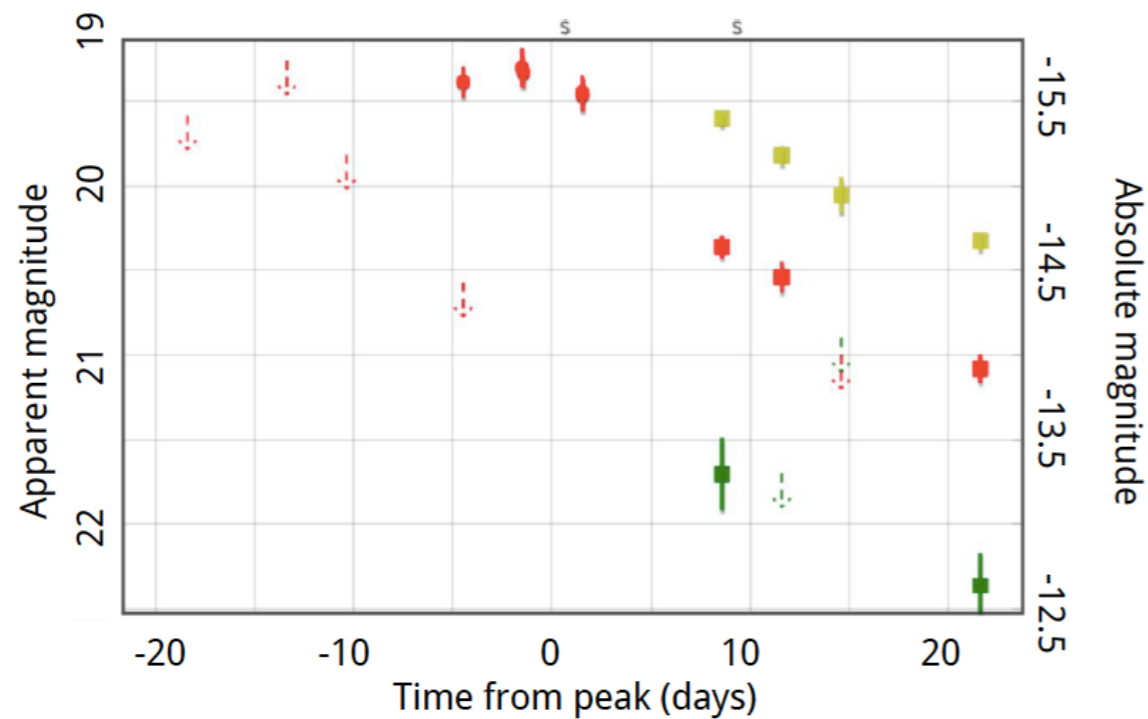
SN relative rates within 200 Mpc

Fraction by SN Type



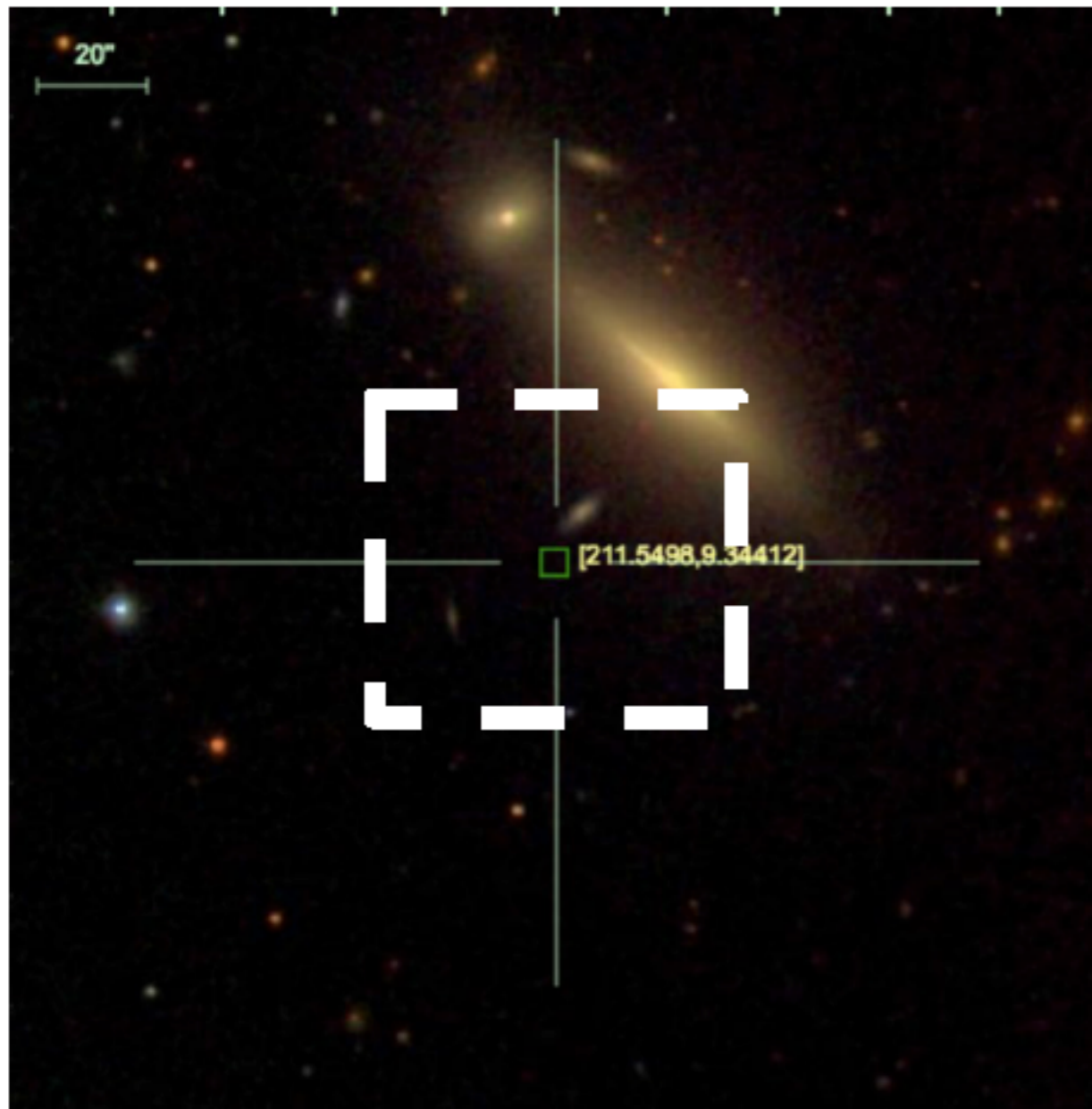
Slide from Kishalay De

Ca-rich Gap Transient candidate: ZTF18aayhylv



Slide from Kishalay De

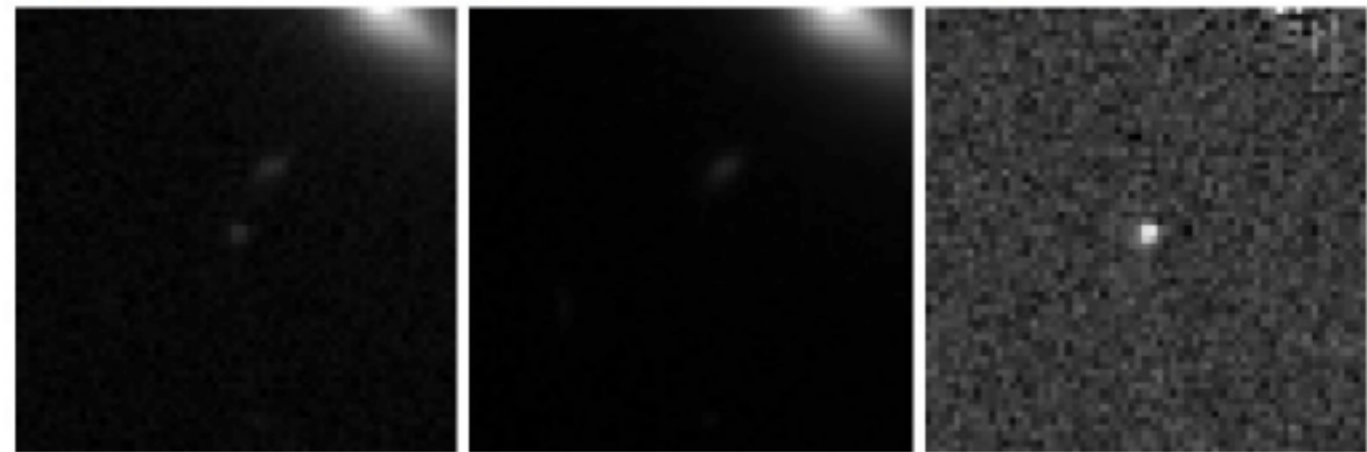
ZTF I 8aayhylv location



NEW

REF

SUB

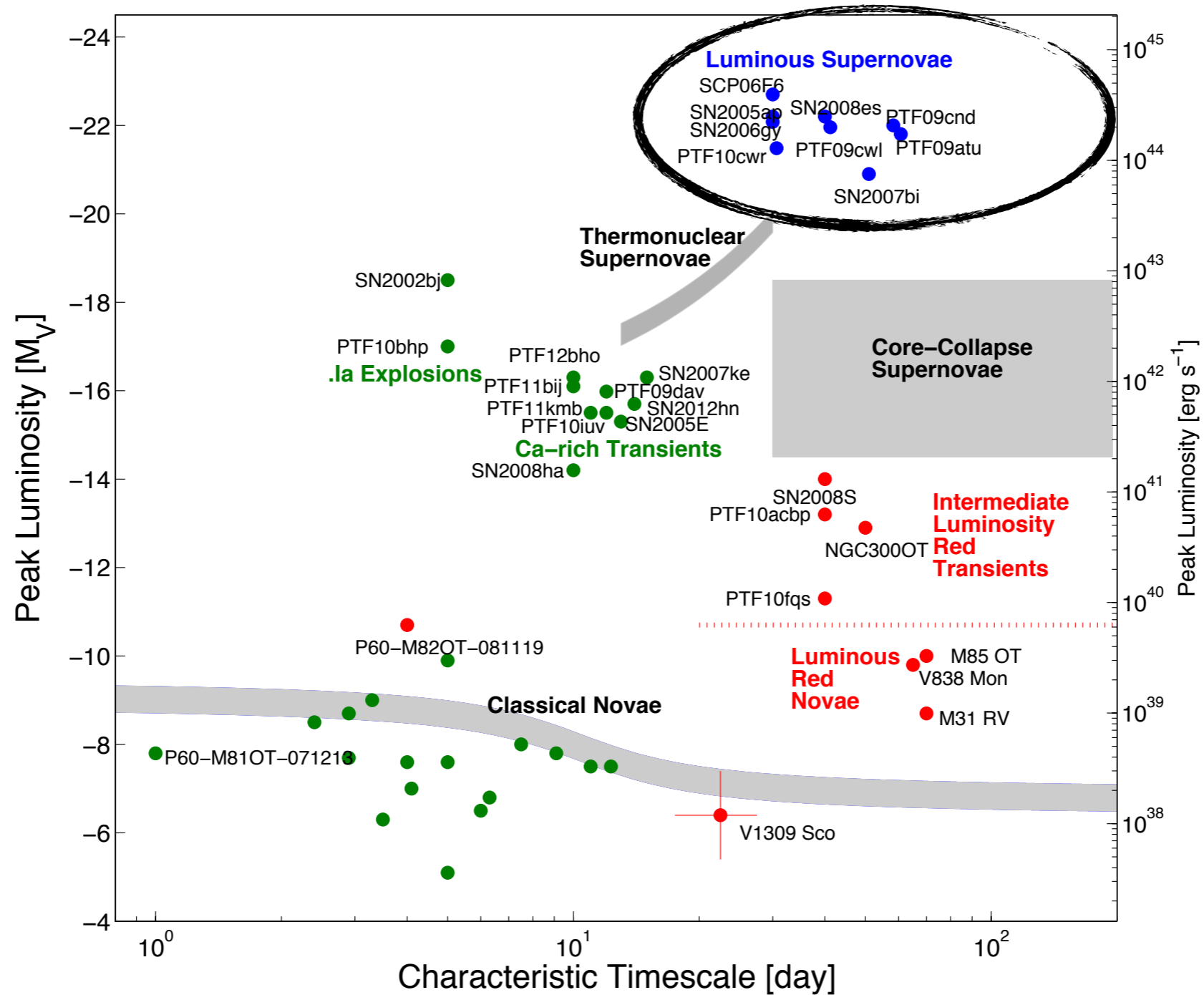


Slide from Kishalay De

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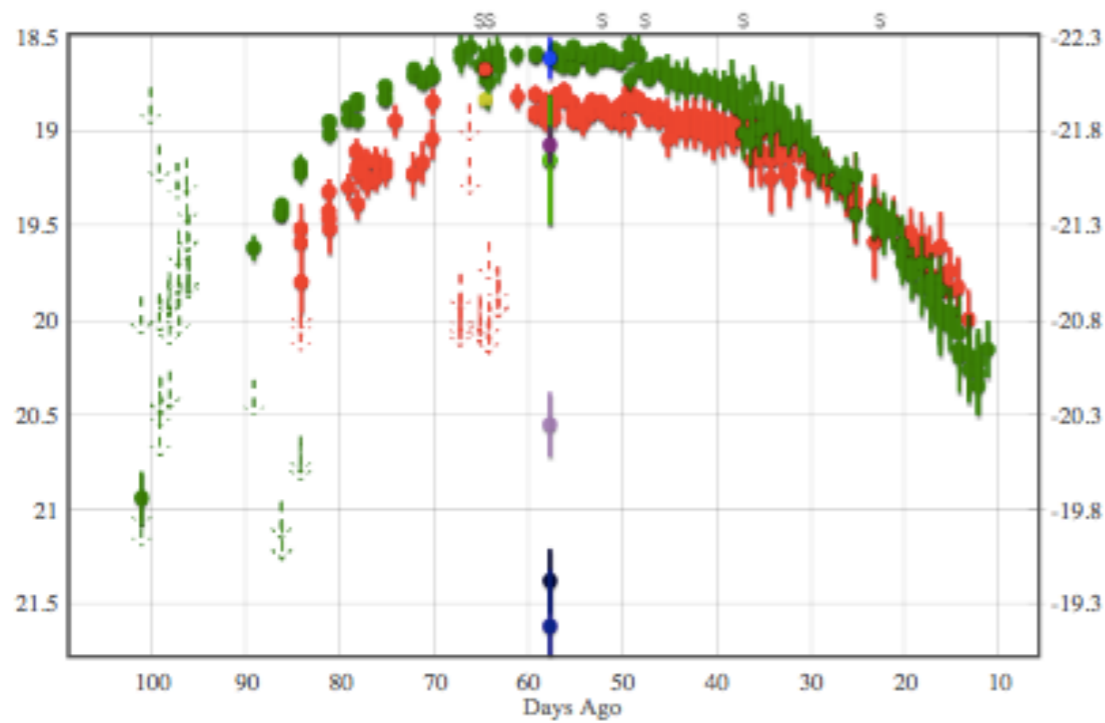
Superluminous Supernovae



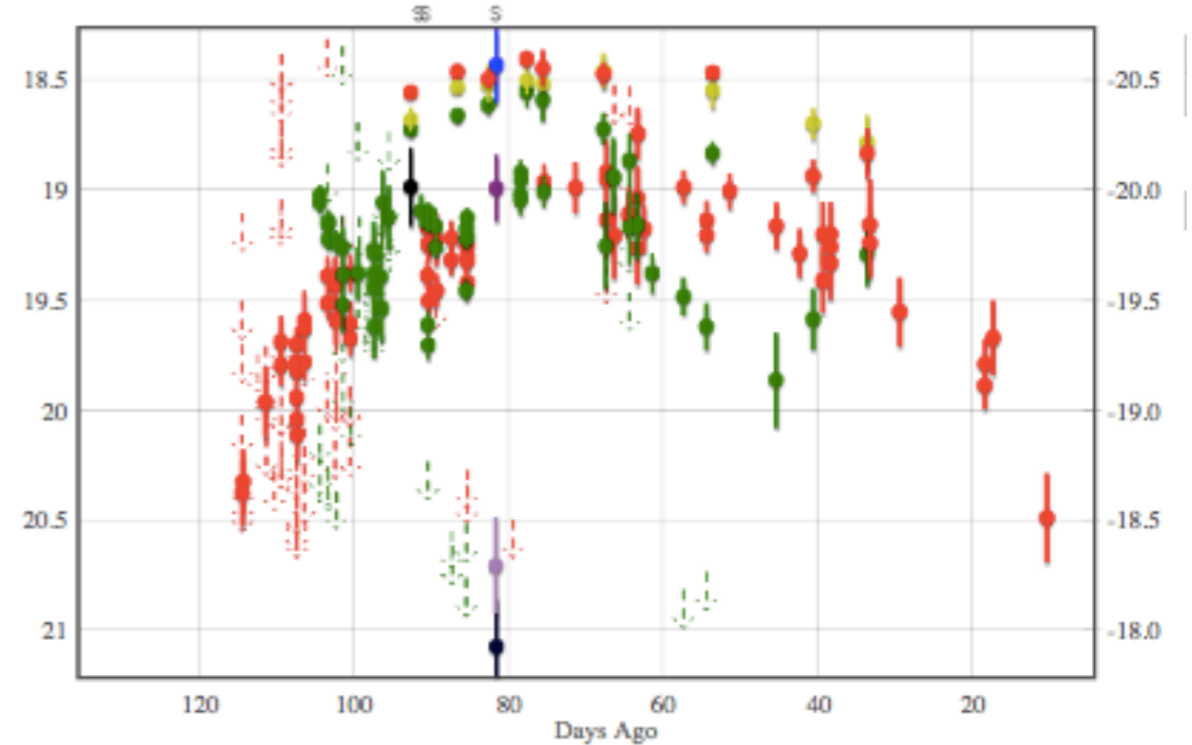
Superluminous Supernovae with ZTF

- SLSNe are *rare* — all-sky surveys like ZTF ideal for finding all the nearby objects
- Rates are currently very poorly constrained
- Many SLSNe in the literature show double-peaked light curves or other structure on the rise — ZTF can constrain how common this is & help probe physical origin

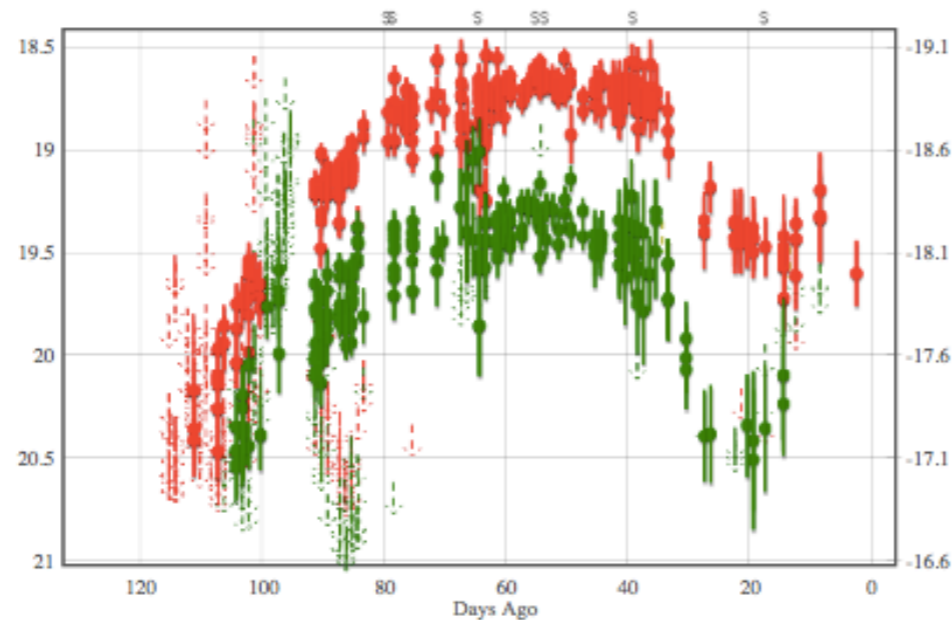
ZTF has found 5 H-poor SLSNe to date...



ZTF18aapgrxo ($z=0.274$)

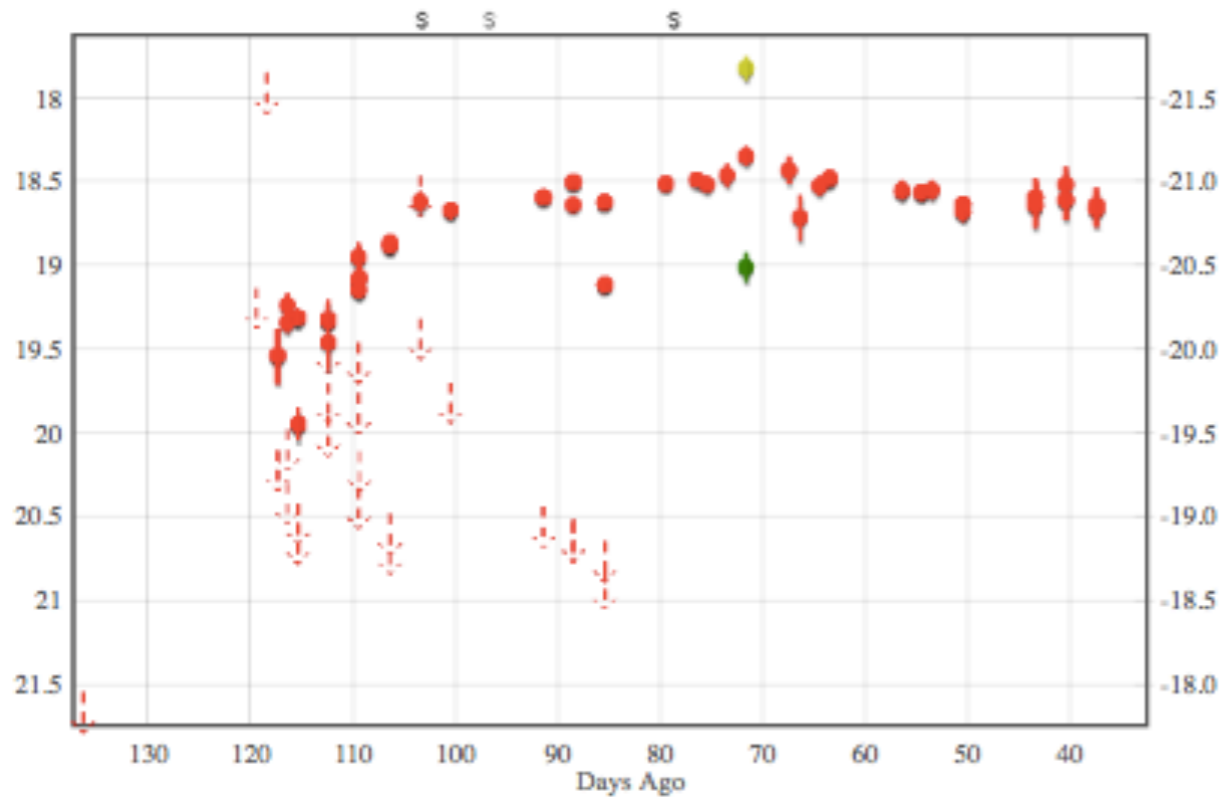


ZTF18aaisyyp ($z=0.132$)

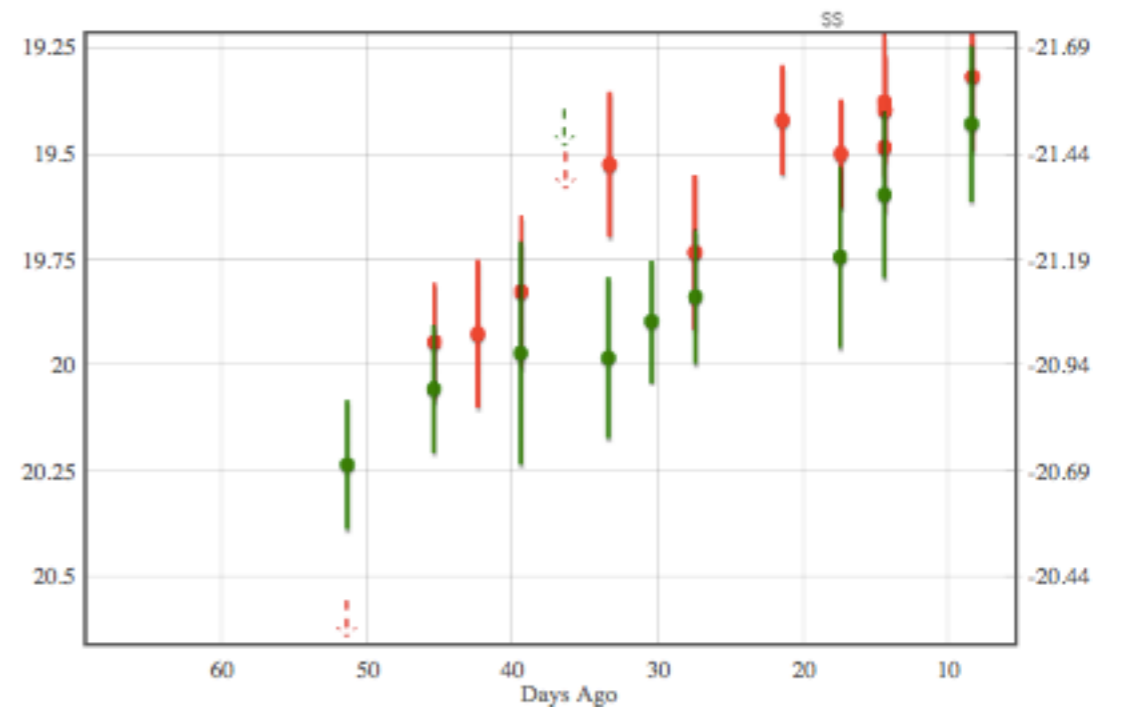


ZTF18aajqcue ($z=0.073$)

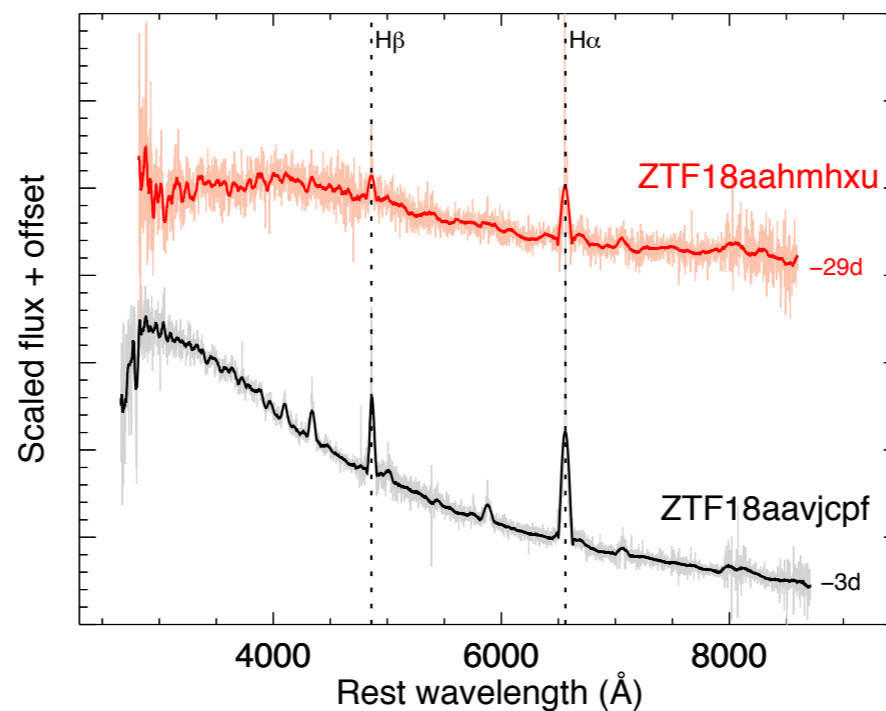
... and six H-rich SLSNe!



ZTF18aahmhxu (z=0.167)



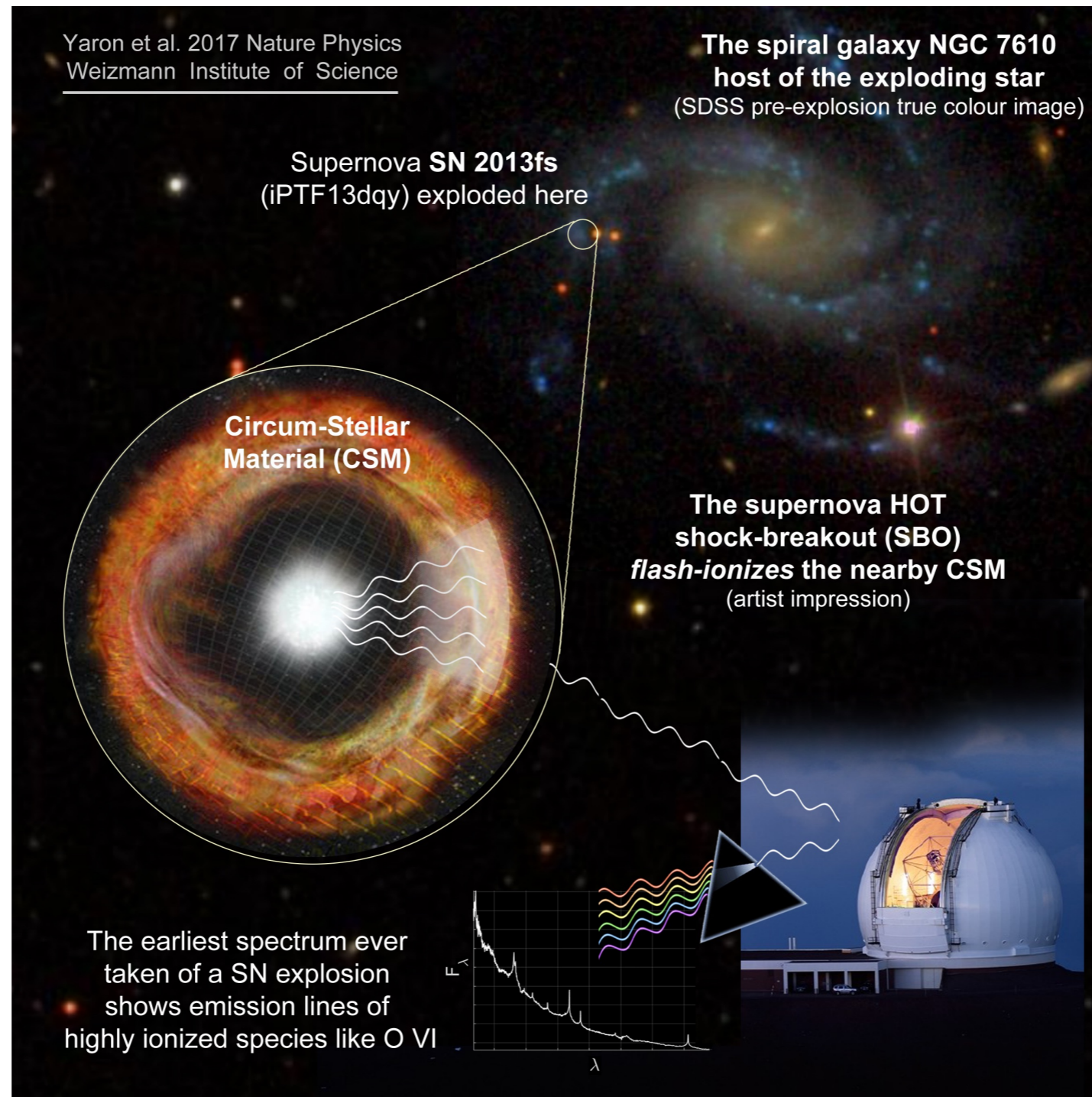
ZTF18aautopz (z=0.295)



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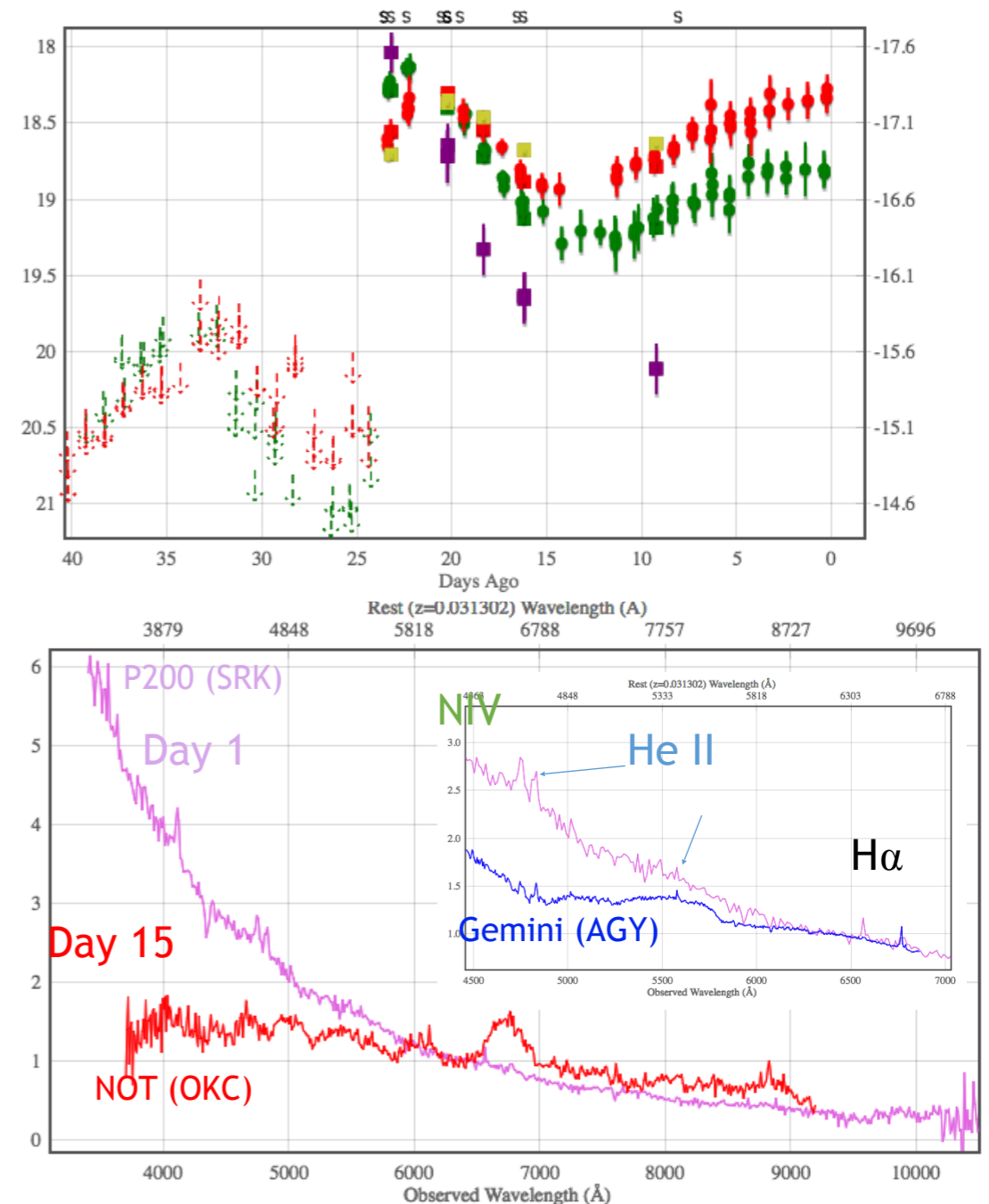
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Flash Spectroscopy



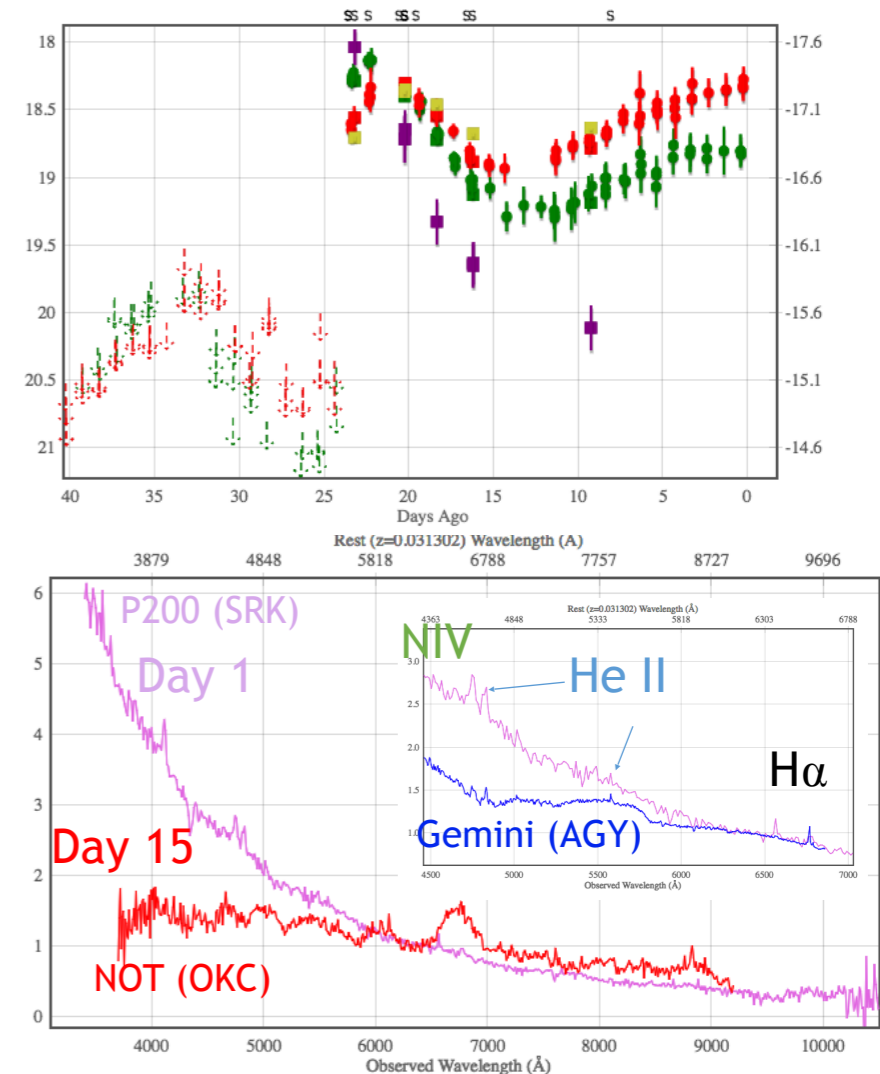
Finding Infant Supernovae with ZTF

- The infant SN filter has been running well for about 2 months
- Young events regularly saved; follow-up initiated, including same-night spectra
- Finds include core-collapse SNe (three with flash features in spectra from days 1-2); young SNe Ia, and an exciting “fast” transient with a same-night spectrum
- WIS maintains nightly scanning duty

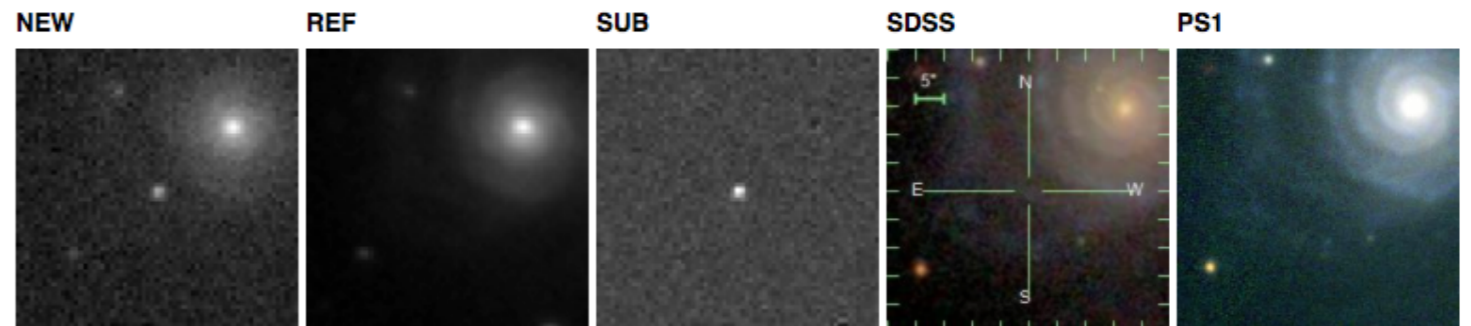


SN2018dfi / ZTF18abffyp

- Double-peaked IIb with well-measured rise in g and r, and multiple spectra during first peak.
- P60 u-band photometry decays from day 1
- Paper in prep. by Noam Ganot



SN 2018dfi
(ZTF18abffyp)
Saved by A. Ho



Optical+NUV allows for estimating progenitor properties

PTF12gnt Galex+PTF

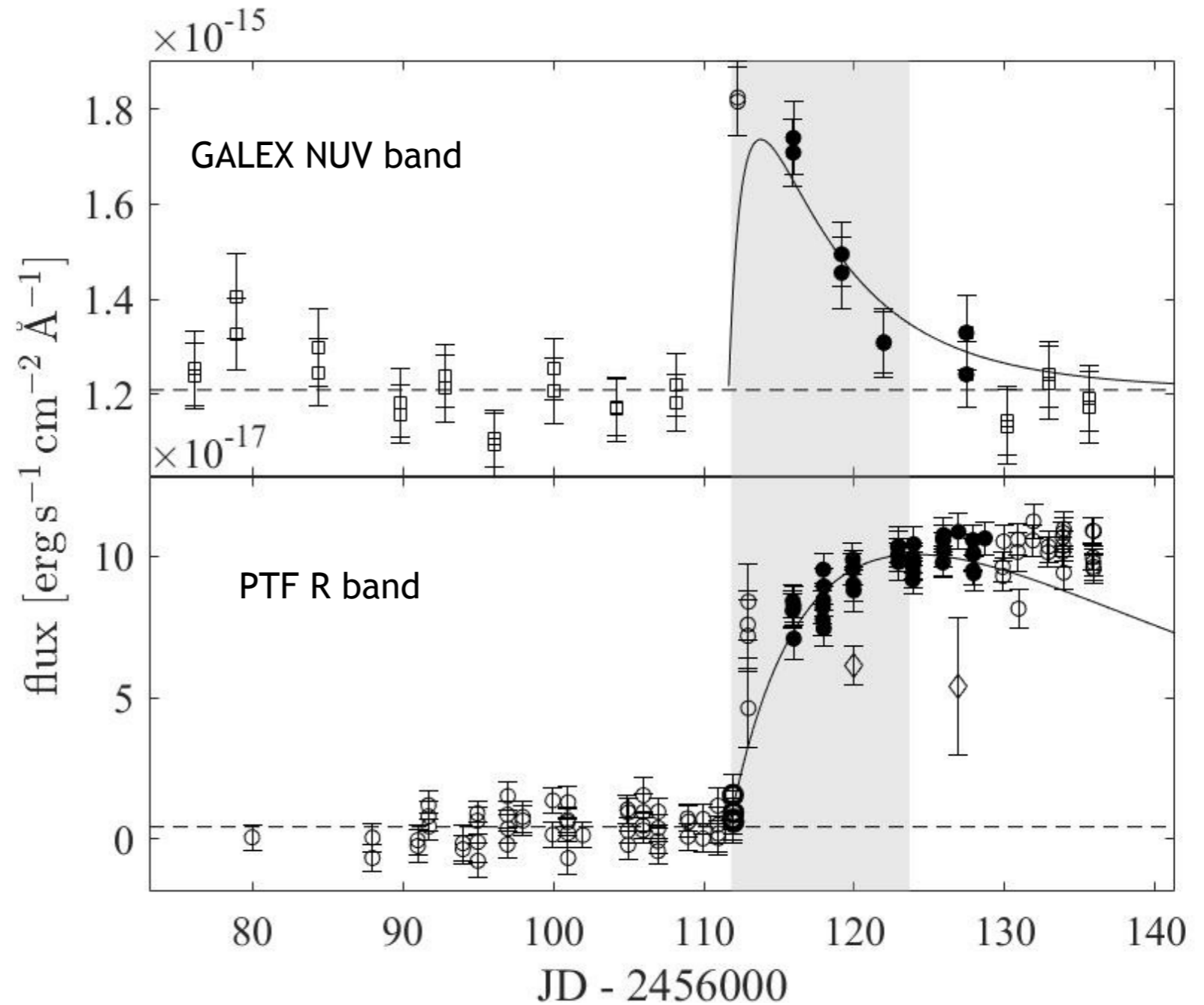
Sapir & Waxman 2016:

$R_* = 670 R_\odot$ $v_{s*,8.5} = 0.78$

$M_{ej} = 9 M_\odot$ $f_0 = 1$

- model valid data points
- model invalid data points
- points used to estimate NUV background
- ◇ outliers

Gray area – data points used for estimation.

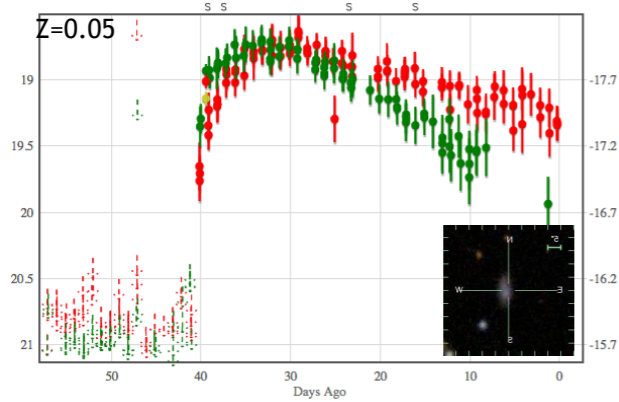


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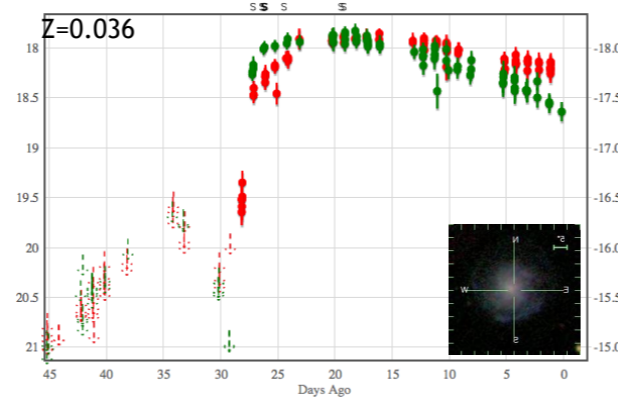
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Early light curves of Type II SNe

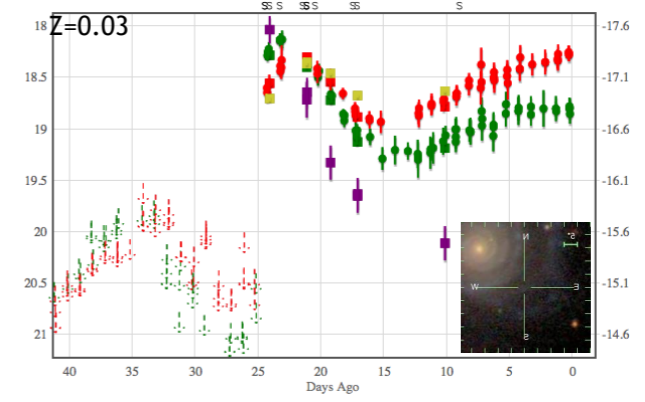
ZTF18abcptmt Type II 1-d lim Flash



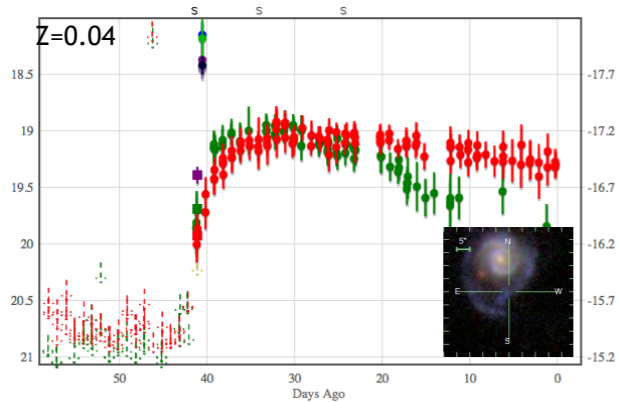
ZTF18abeajml Type II 1-d lim Flash



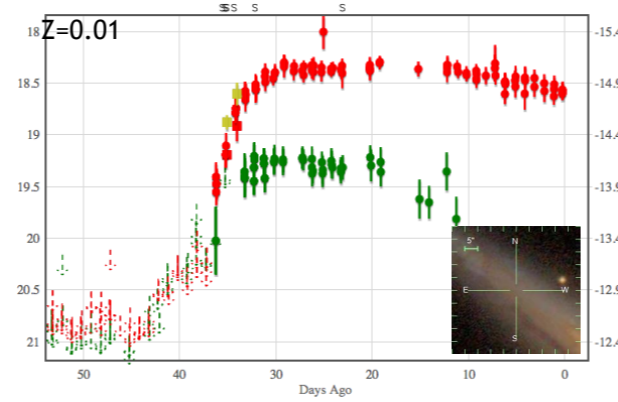
ZTF18abffyqp Type II 1-d lim Flash



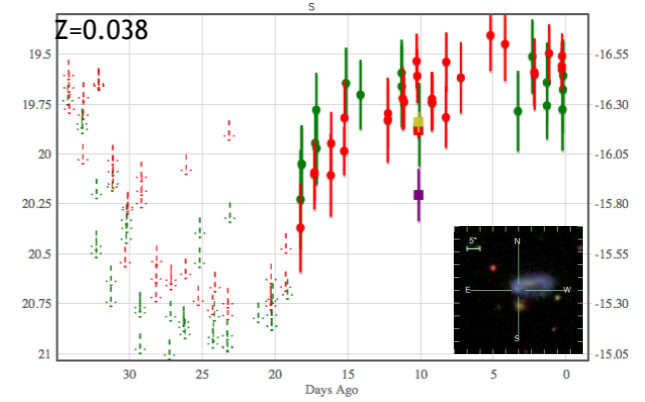
ZTF18abckutn Type II(P?) 1-d lim



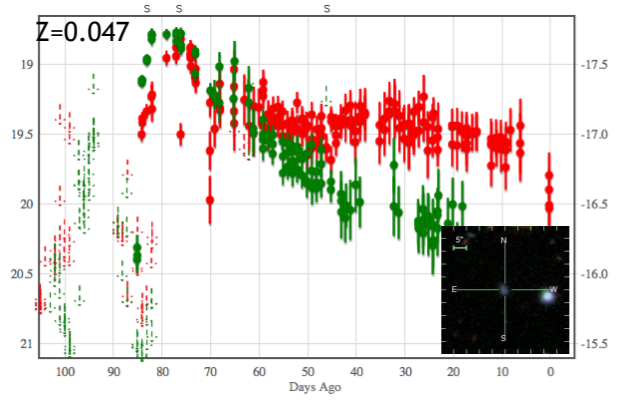
ZTF18abbysy Type II(P?) 1-d lim



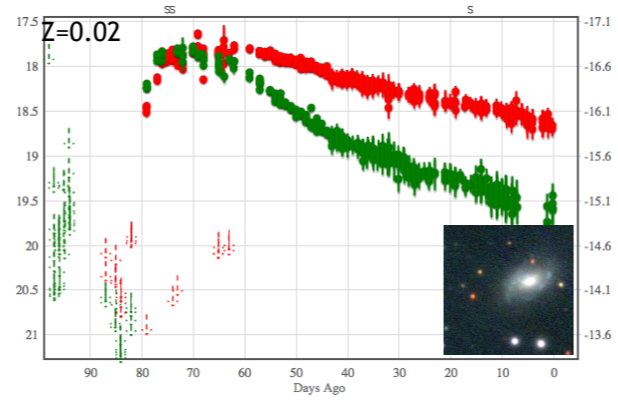
ZTF18abgqvww Type II 1-d lim



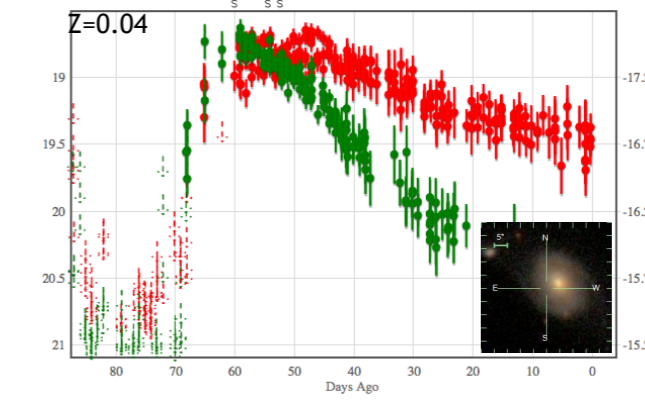
ZTF18aarpttw Type II 2-d lim



ZTF18aatyqds Type II(P?) 3-d lim



ZTF18aawyjjq Type II 1-d lim



Yaron et al., in prep.

ZTF survey of SN IIn: measuring asphericity around massive stars

Early multiband monitoring, including Swift UV and ZTF g+r during rising phase

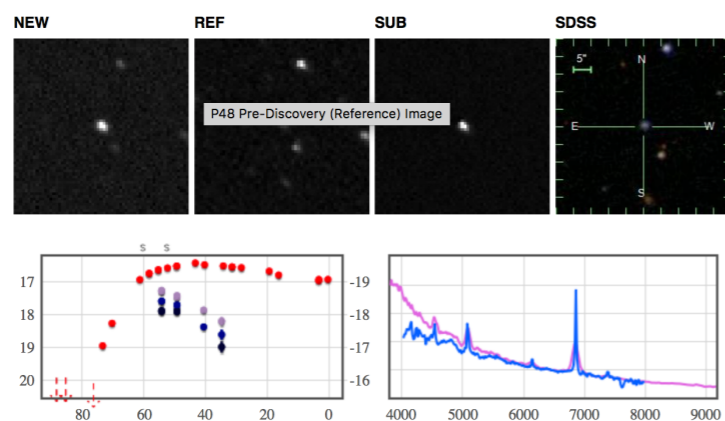


- Information about bolometric L, mass of the CSM, Progenitors
- Early evolution of the effective R and T gives information about the geometrical distribution of the CSM (Theoretical background in Soumagnac et al. 2018).

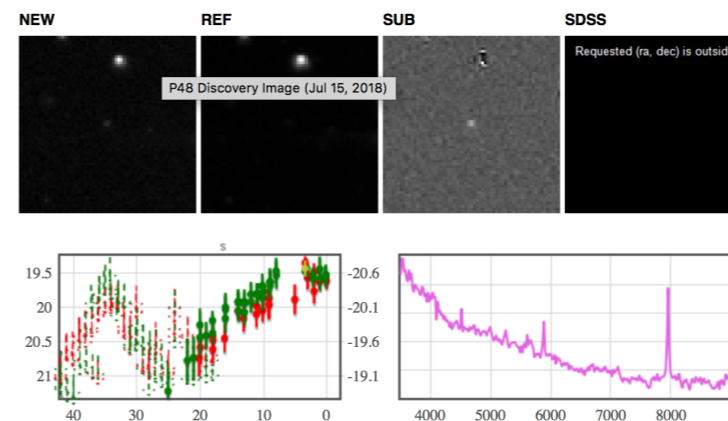


lower limit on the rate of type IIn events that show evidence for non-spherical CSM

Goal: ~10 objects in coming months ; Dedicated Marshal program (“Type IIn Supernovae”).



ZTF18aavskep



ZTF18abgrlpv

Soumagnac et al., in prep.

Stripped-envelope supernovae with ZTF

- Stripped-envelope SNe (Types IIb, Ib, Ic) have been stripped of the hydrogen (and sometimes helium envelope).
- Do they come from single (high-mass) stars, or binary (lower-mass) stars?
- ZTF enables building large sample of SESNe with well-defined rise times

Well-defined light curves probe ejecta mass and degree of Ni mixing

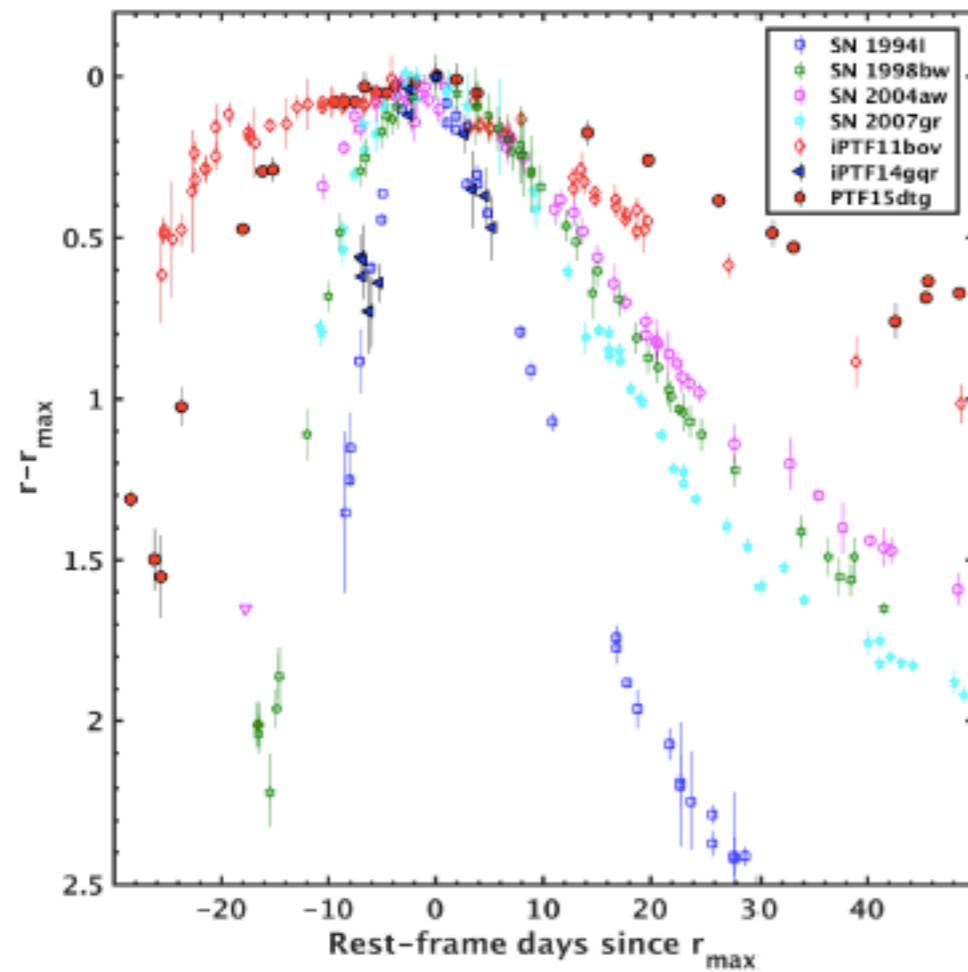
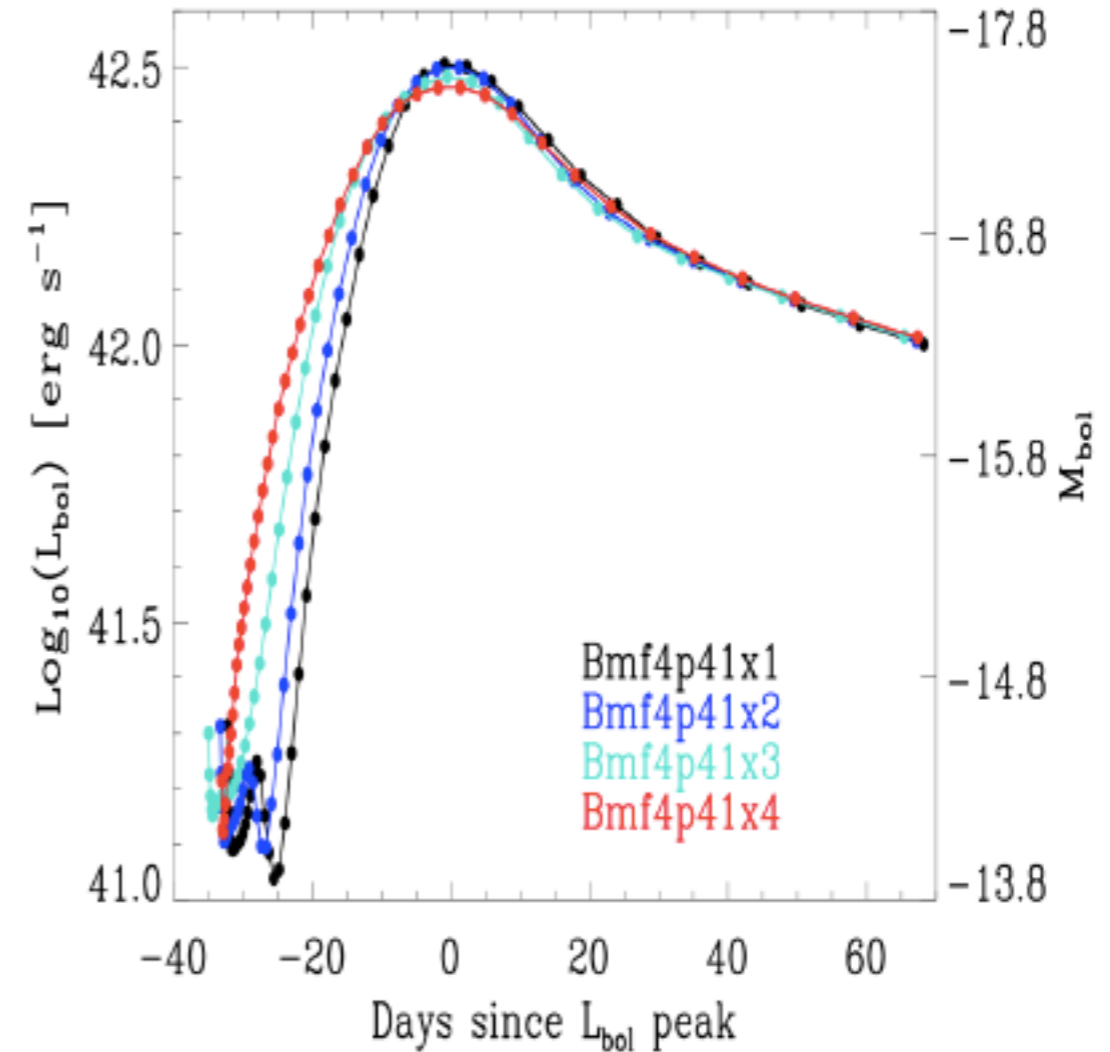
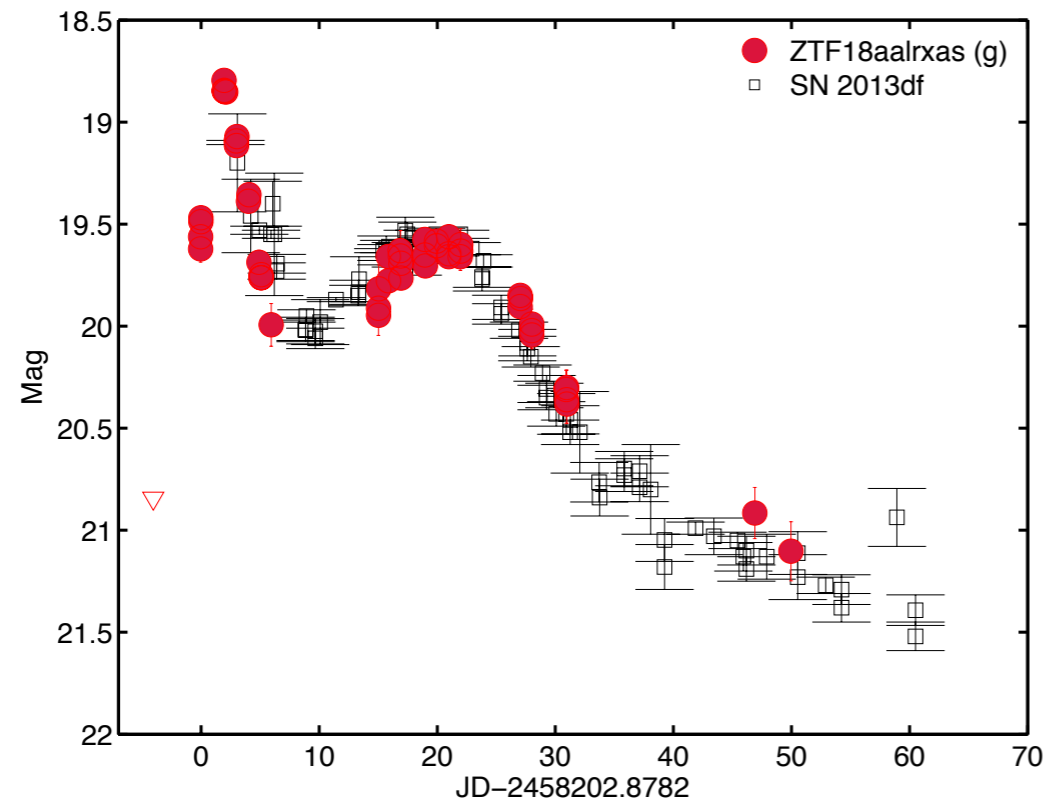


Figure: F. Taddia

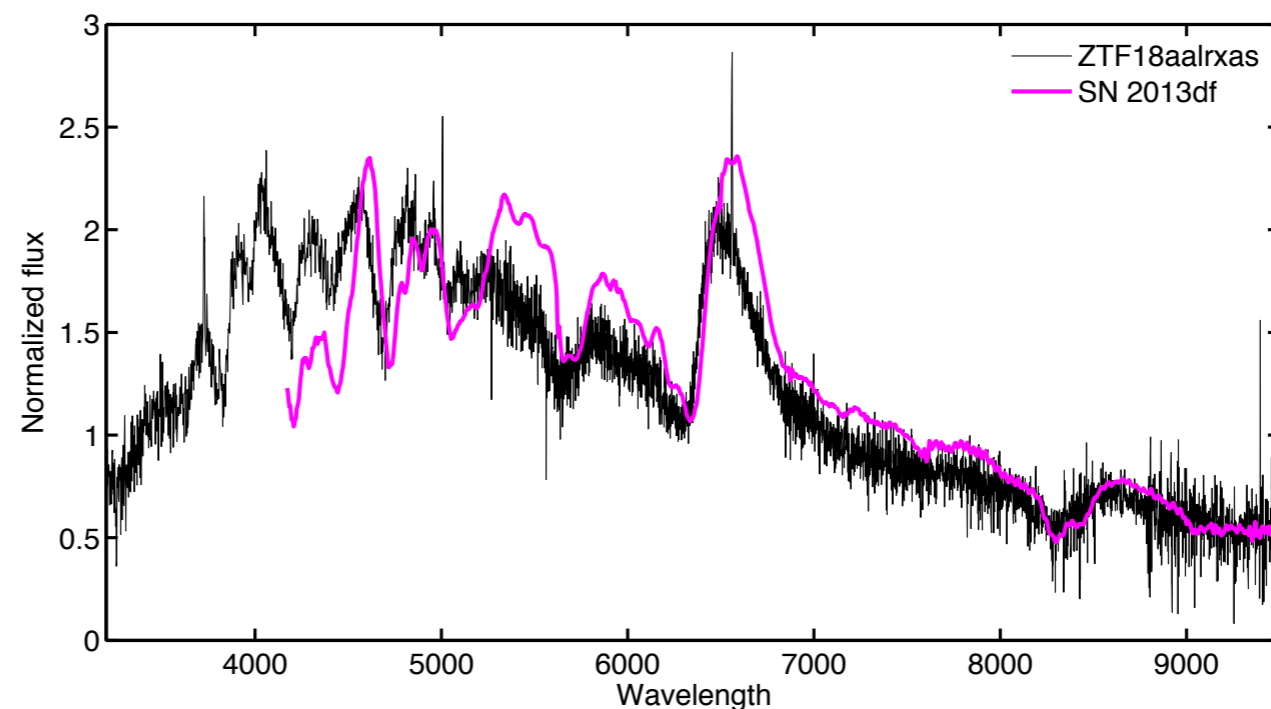


From Dessart+ 2012

ZTF18aalrxas: double-peaked SN IIb

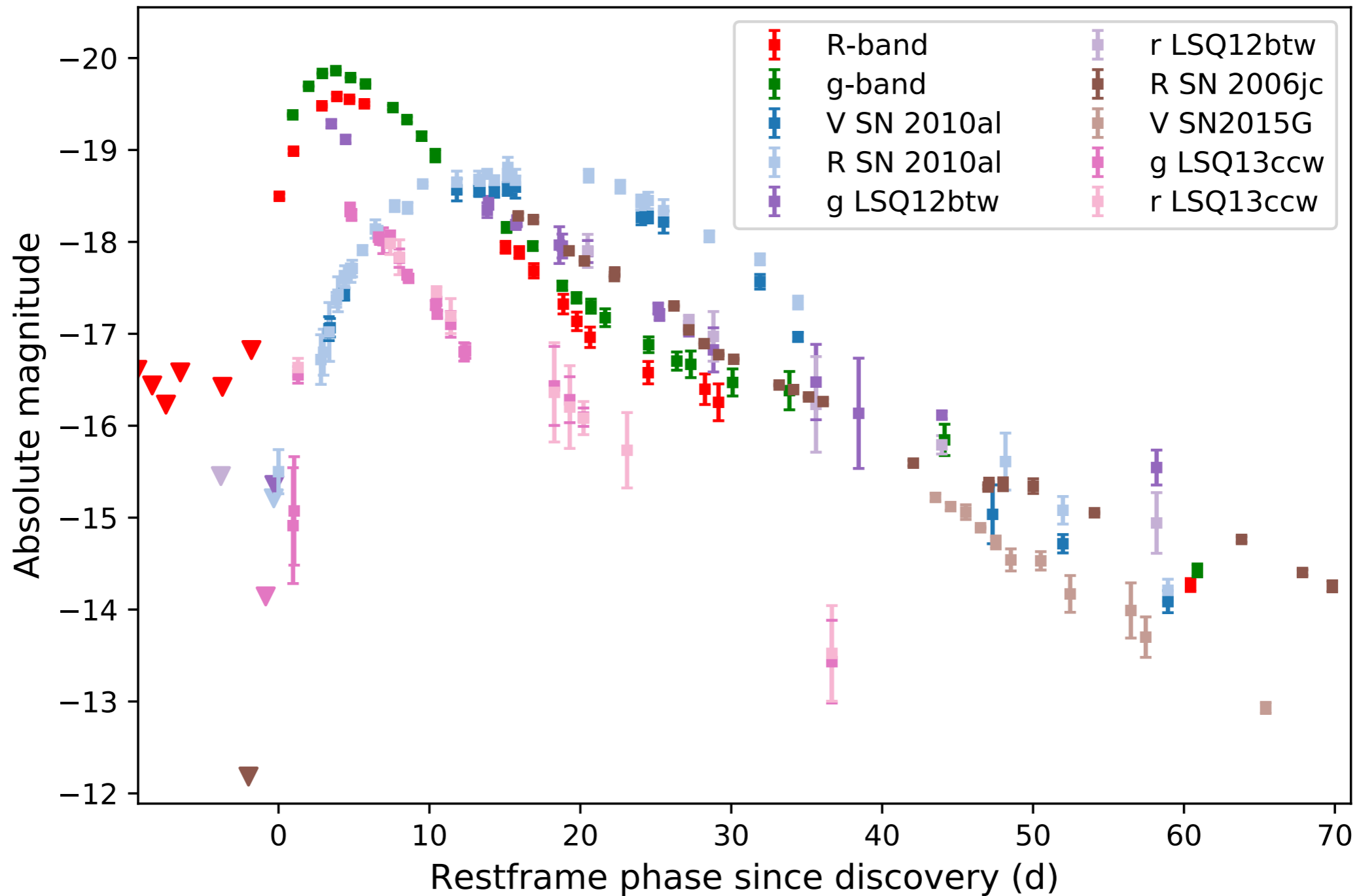


Many SN IIb show a double-peaked structure (first peak shock cooling of extended CSM); in ZTF18aalrxas we capture both the rise and the decline of the first peak.



Fremling et al., in prep.

SN2018bcc / ZTF18aakuewf: fast-rising and luminous SN Ibn



Karamehmetoglu et al., in prep.

Summary

- The combination of fast cadence and wide area coverage makes ZTF excellent for studying the physics of supernovae and relativistic explosions!
- We are detecting newborn supernovae and fast transients in real time
- Filters are working; several papers in prep based on individual objects
- Samples being built up for population studies

(Some) Challenges

- Completeness/efficiency ??
- Communication (name resolver; marshal; across groups)
- Coordination across programs (scanning & follow-up)