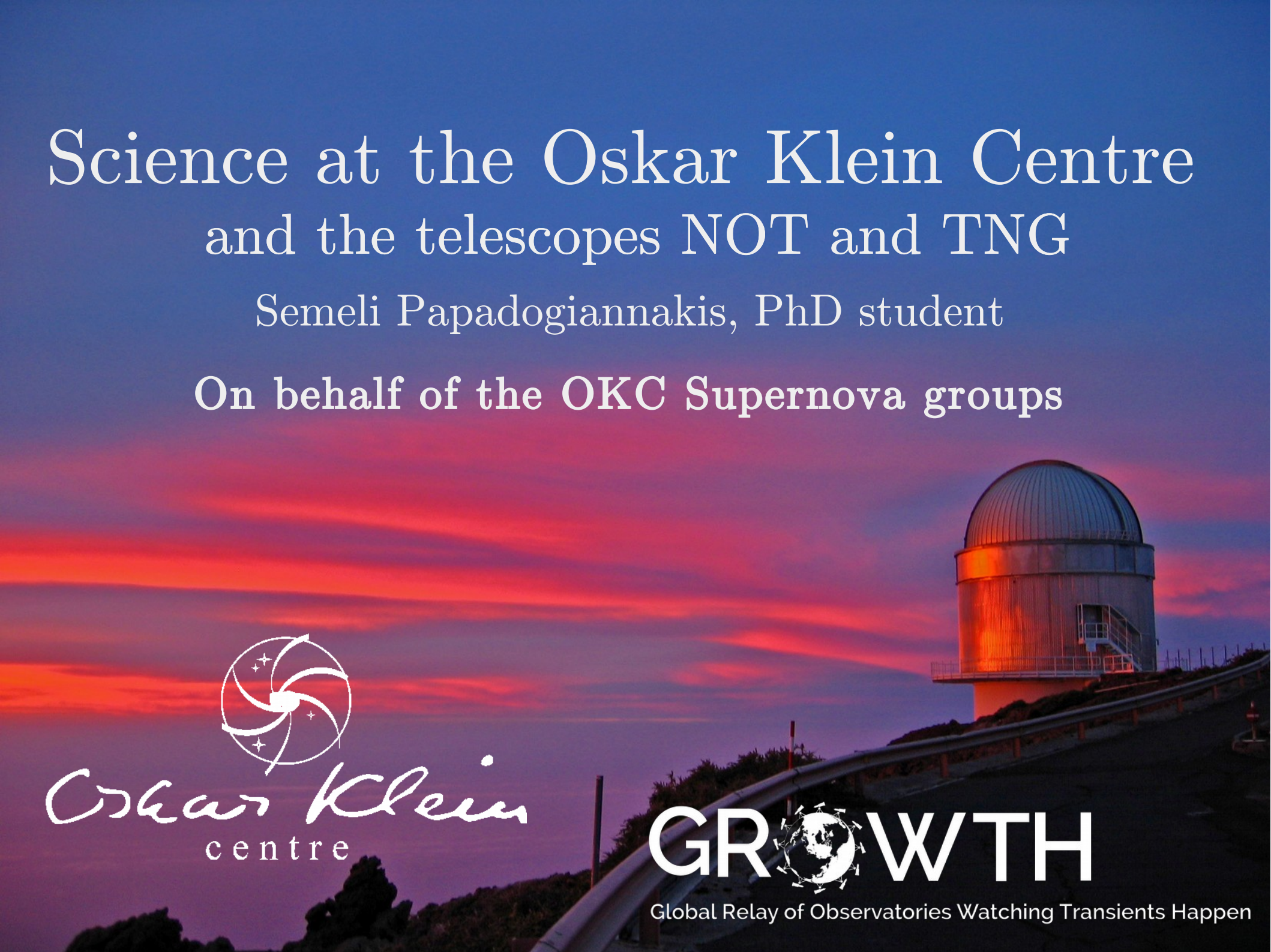
Science at the Oskar Klein Centre
and the telescopes NOT and TNG

Semeli Papadogiannakis, PhD student

On behalf of the OKC Supernova groups



GROWTH
Global Relay of Observatories Watching Transients Happen

Oskar Klein centre

Outline of this talk

- Presenting the OKC groups and their science goals in relation to GROWTH
- NOT & TNG telescopes
- Science example: Type Ia supernova with PTF/iPTF and how it will change with ZTF

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SN Ia group

Oskar Klein centre

Ariel Goobar

Rahman Amannulah

Ulrich Feindt

Markus Kromer

+ 2 new Postdocs starting this fall:

Suhail Dhawan

Mattia Bulla

Laura Hangard

Tanja Petrushevska

Raphael Ferretti

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What do we do?

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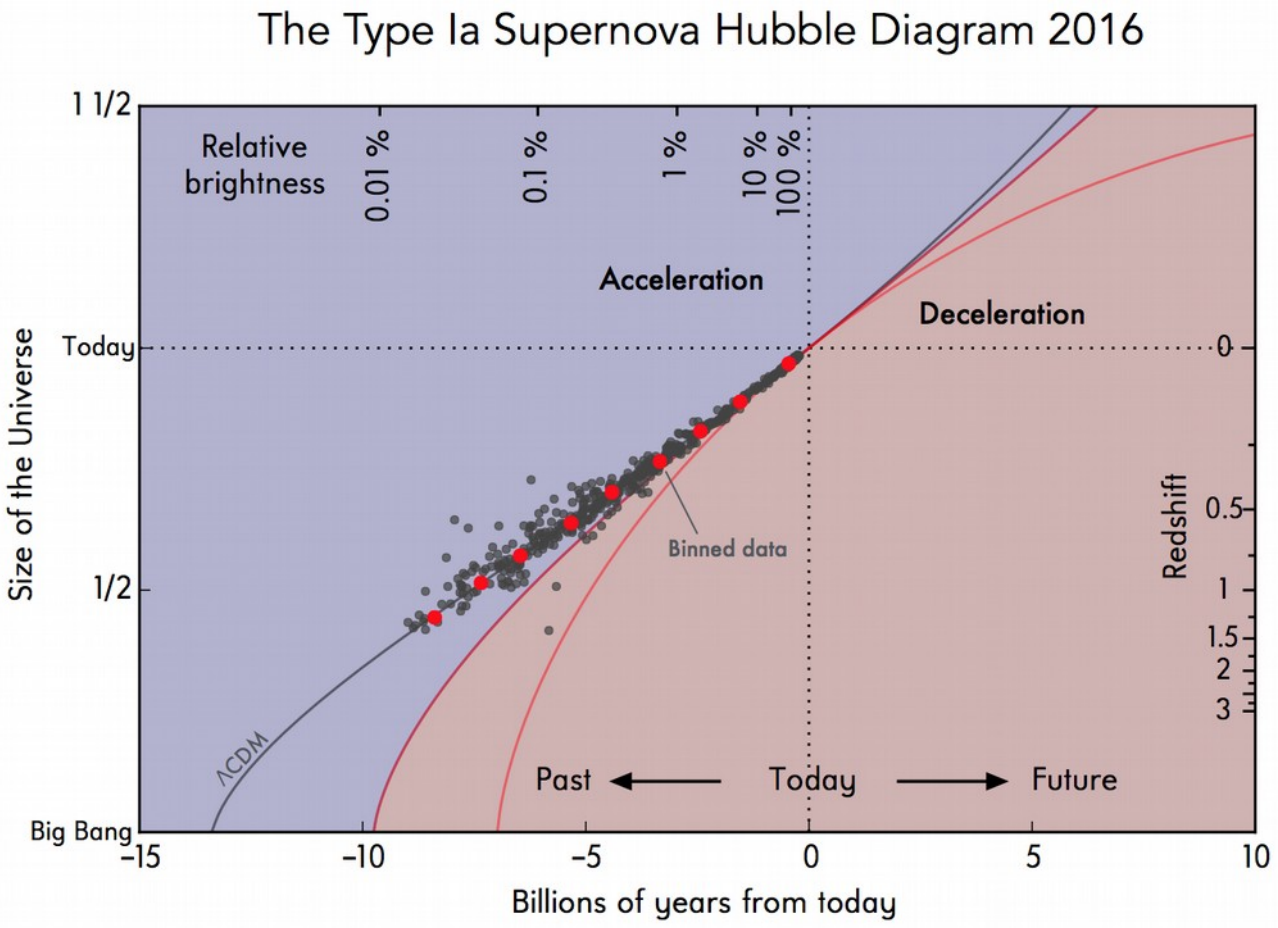
- Cosmological sample: new low-z anchoring set with ZTF
- Set uncertinty floor for LSST, WFIRST: Host galaxy environment dependencies, dust
- Local anisotropies measurement (Feindt+13, ...)
- Sample to trigger Near-IR SNIa Hubble diagram (Baron-Nugent+12, ...)
- Extragalactic extinction (Amanullah+14,15, Johansson+14)
- Interaction w. companion, CSM and surface radioactivity, dark phase of SNIa (first 4 days) (Nugent+11,Goobar+14,15,Cao+15, Kromer+16, ...)
- Late time lightcurves and spectra to understand nebular physics and interaction (¿100 d).
- High-resolution spectroscopy: CSM and ISM studies. (Maguire+14,Ferretti+16...)
- Diversity in SNIa properties (Maguire+14, ...)
- Lensed SNe behind galaxy clusters (Petrushevska+16)

What is the cause of the accelerated expansion of the universe?



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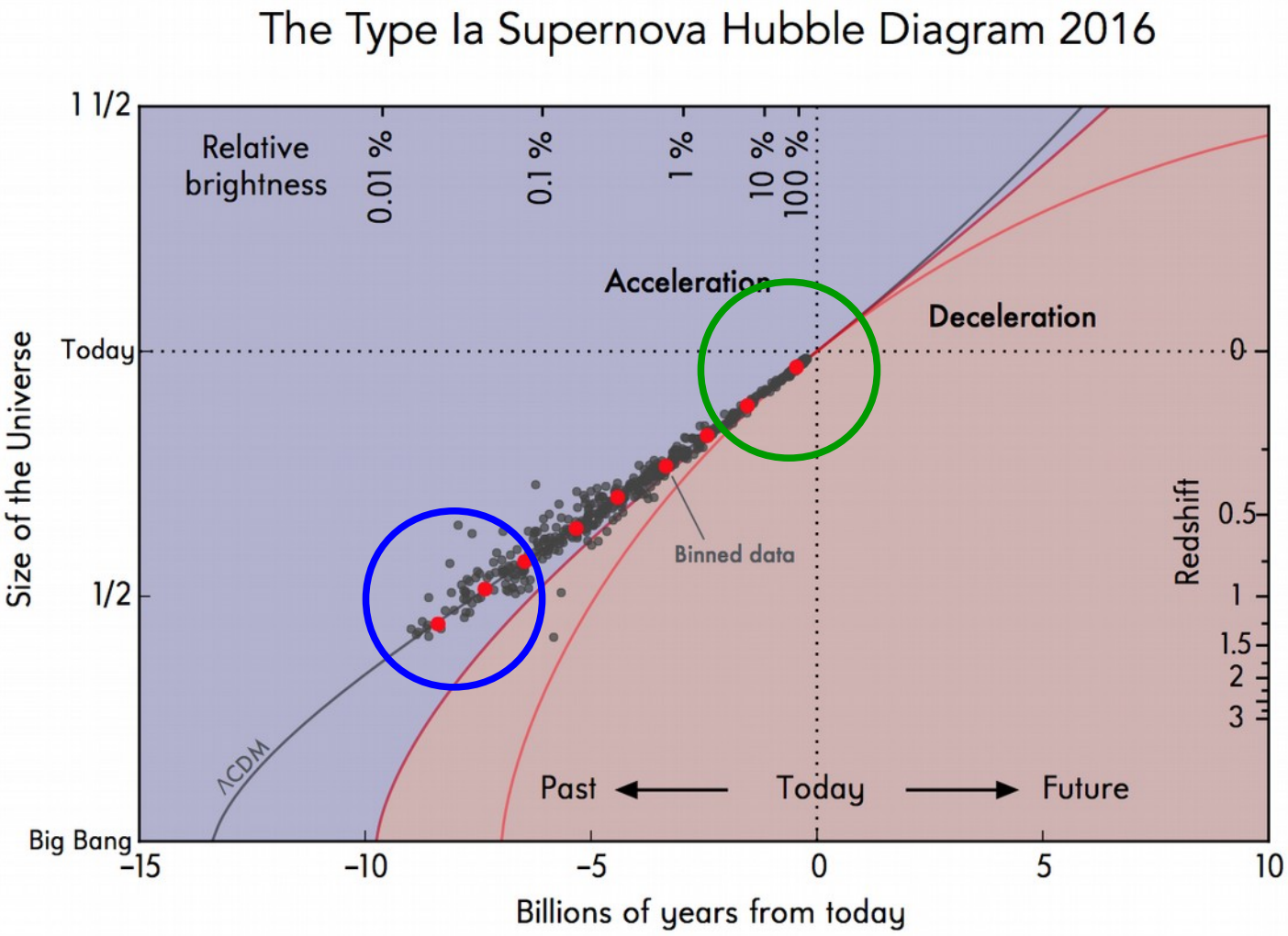
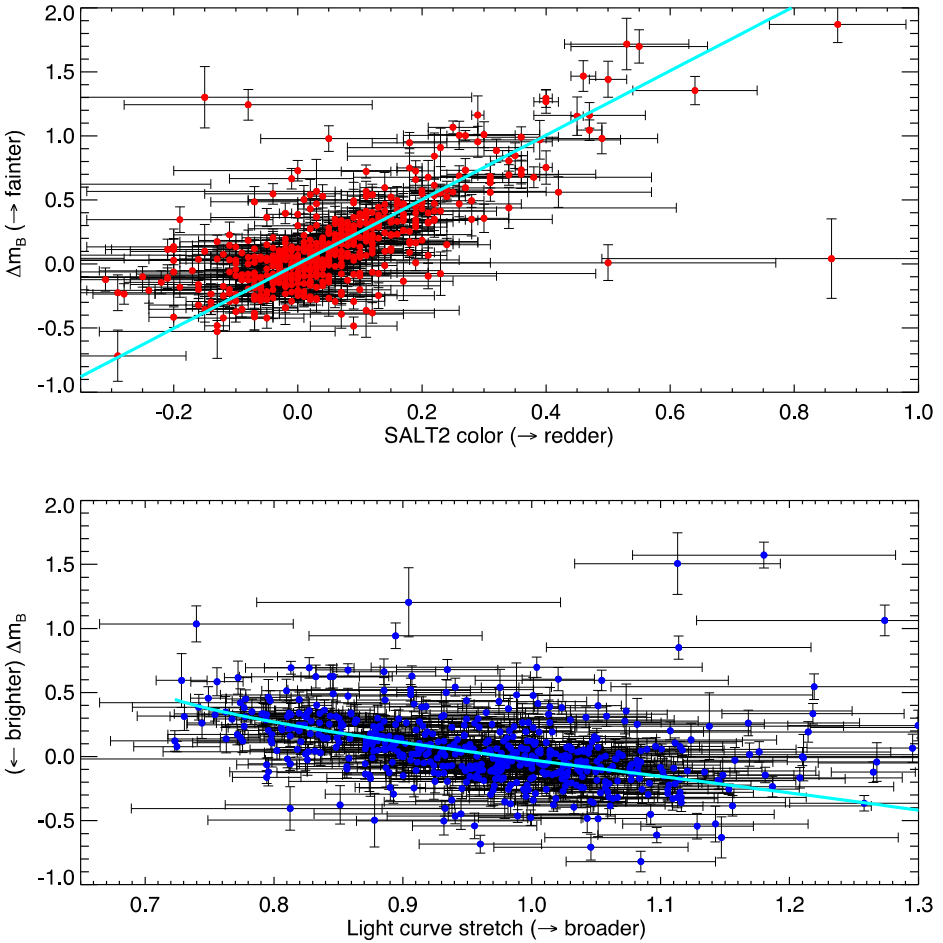
- **Cosmological constant** (Λ), consistent with existing data but is 10^{60}-10^{120} times lower than the expected vacuum energy density
- Completely new physics?
- ***Combined* studies of *low-* and *high*-redshift SNe provides the key for testing models for the cosmic acceleration: time-evolution**
- High-z, HST programs now; WFIRST in the future
- **ZTF:** can provide critical **low-z sample**



ZTF will be sensitive to cosmic acceleration with 2 photometric bands to correct for extinction.



Goobar & Leibengut 2011

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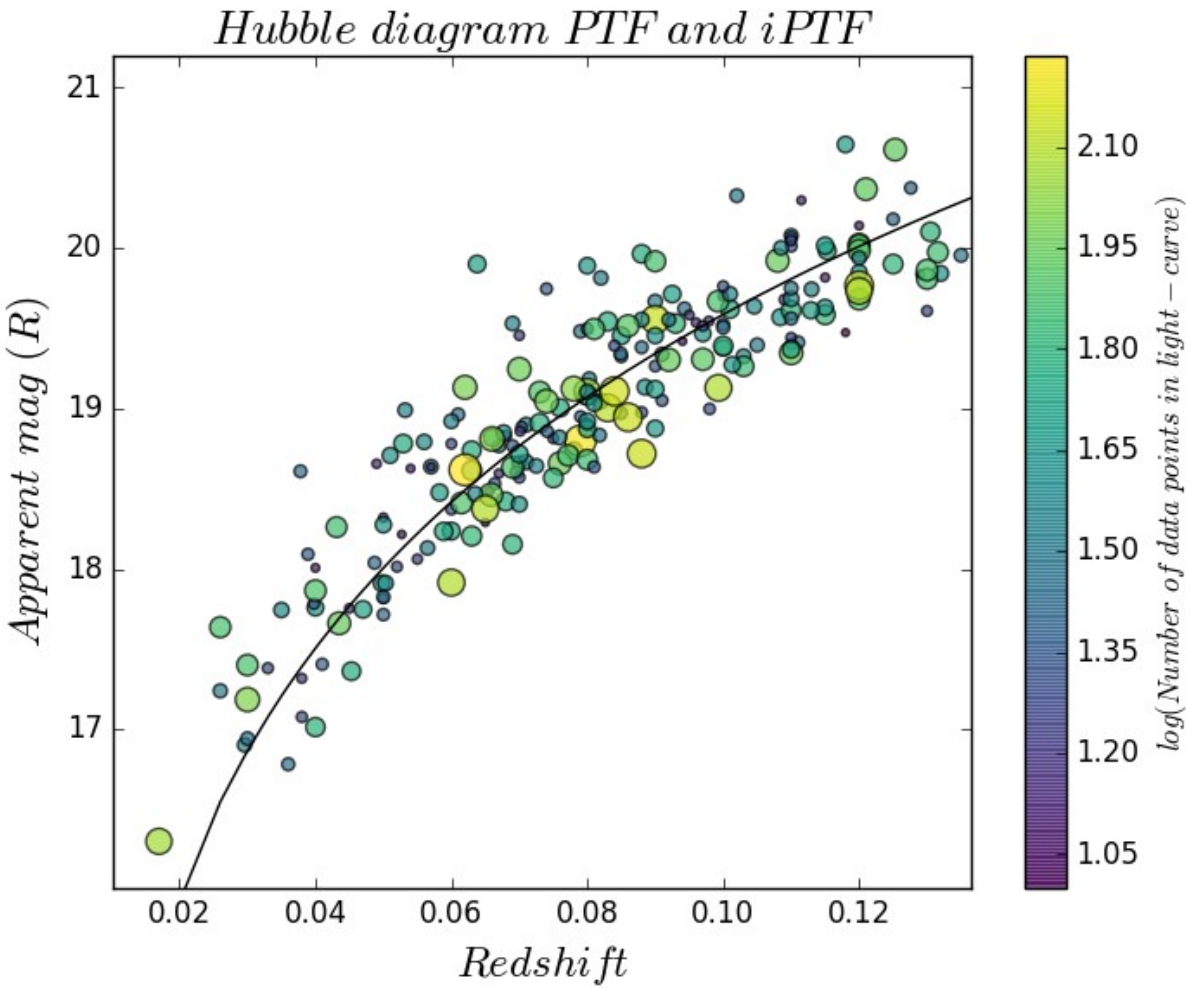
Cosmology accuracy improvement
with **color data+statistics:**
PTF ⟶ ZTF

$$\sigma_\mu(z)\,\mu\,\frac{\sigma_m}{\sqrt{N}} \approx \frac{1/3}{\sqrt{10}} \Rightarrow \frac{\sigma_\mu^{ZTF}}{\sigma_\mu^{PTF}} \sim 0.1$$

Single band
iPTF/PTF Hubble
has large scatter
(no color
corrections are
possible)

Discuss later
in this talk



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Diversity in the colour parameter?

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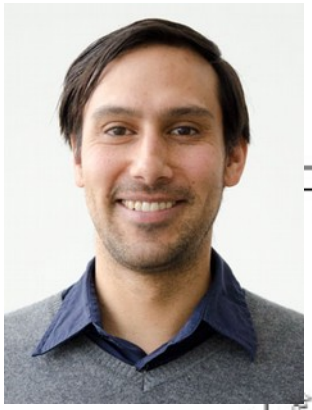
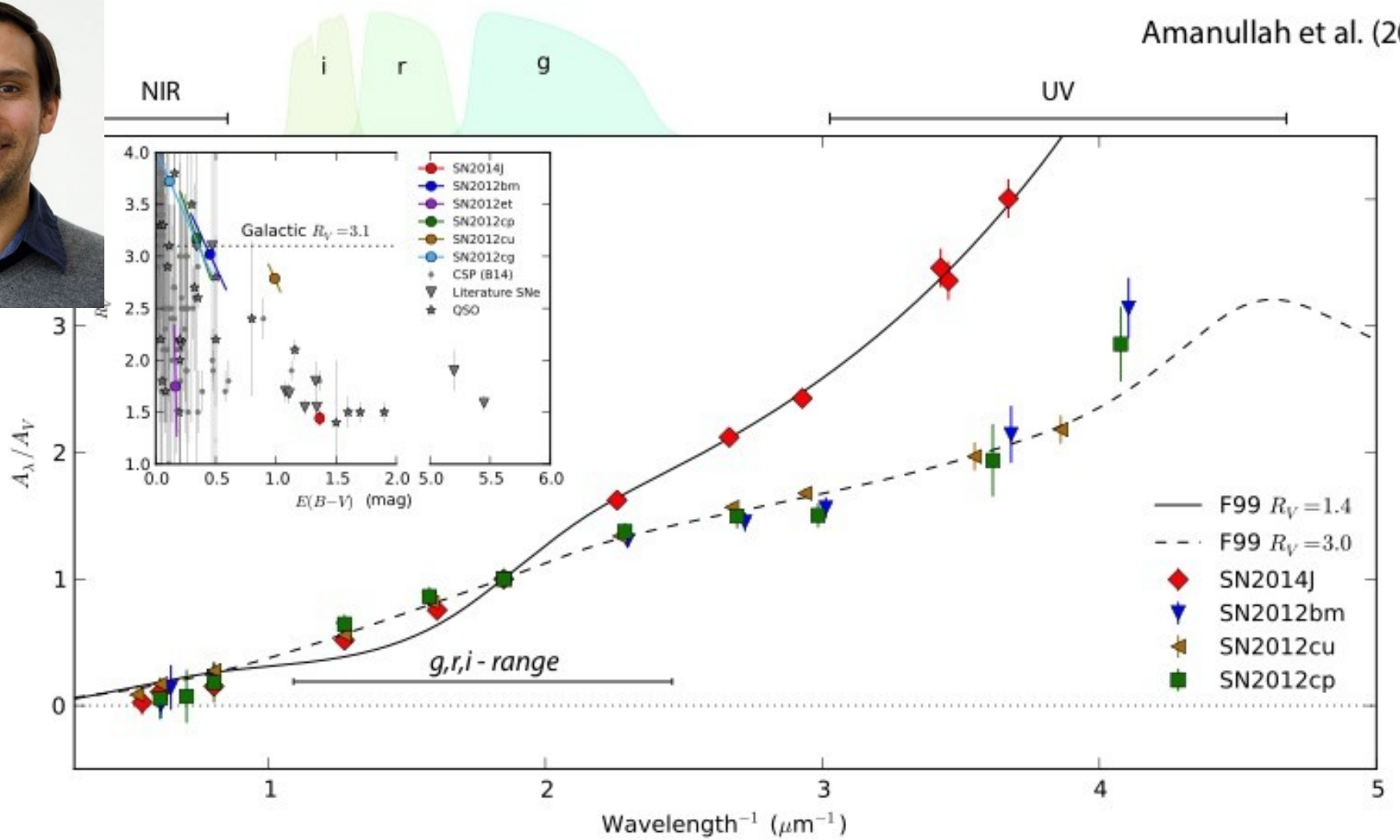


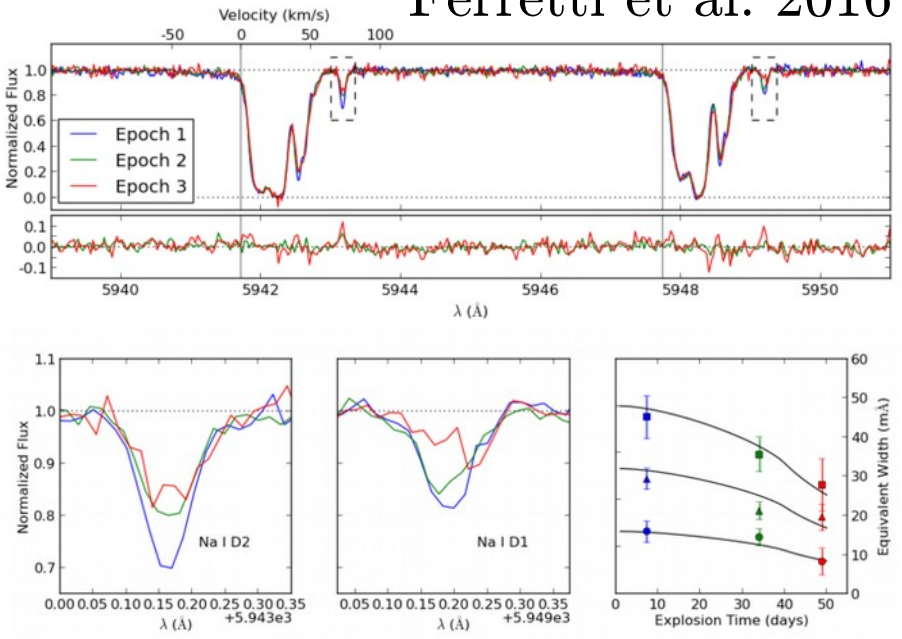
Amanullah et al. (2015)

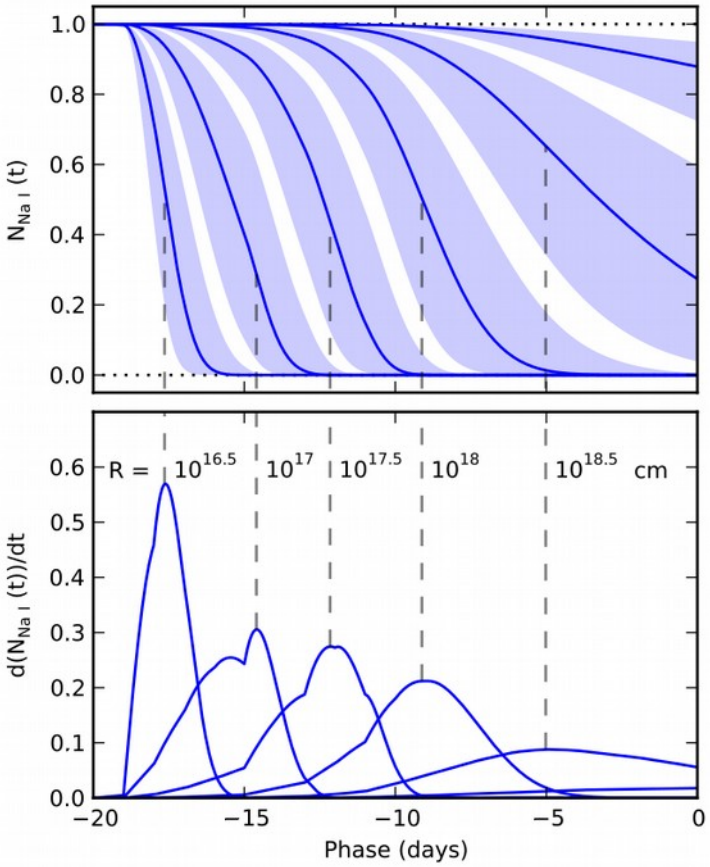


Circum stellar Dust?

Early detection and spectra is crucial to detect changes near SN

Ferretti et al. 2016



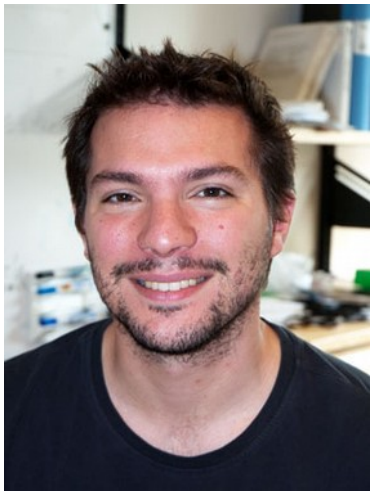


VLT proposal accepted for more high-resolution spectroscopy

CC group

Jesper Solleman

Rupak Roy



Fransesco Taddia

+ more member not involved in iPTF/ZTF

Christoffer Fremling

Anders Nyholm

Emir Karamehmetoglu

+ New postdocs this fall

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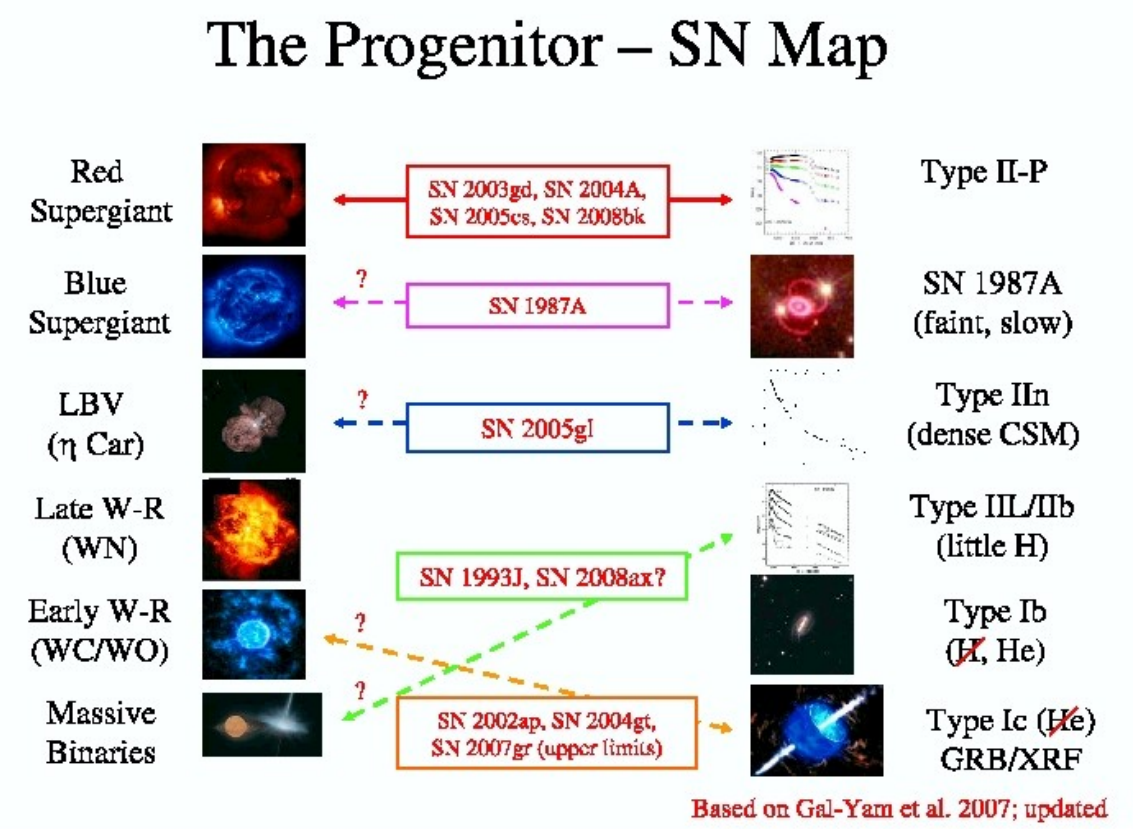
What kind of Core-collapse SNe are we interested in?

1) **Stripped-envelope core-collapse SNe**: Type Ibc/IIb. These supernovae lack hydrogen (sometimes even helium), which was stripped away from the progenitor star by either a companion star or strong winds.
2) **Circumstellar-interacting SNe** (Type Iin, Ibn, Ia-CSM). These are supernovae whose ejecta interact with the material ejected by the progenitor system before collapse.
3) Other **new or rare and peculiar SNe** events: e.g. 1987A-like supernovae

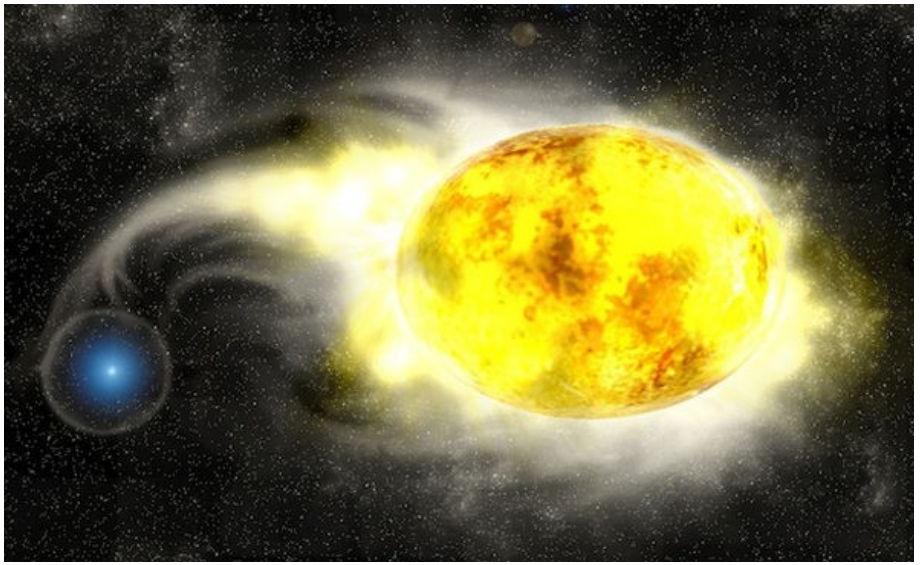
Which progenitor corresponds to which SN?

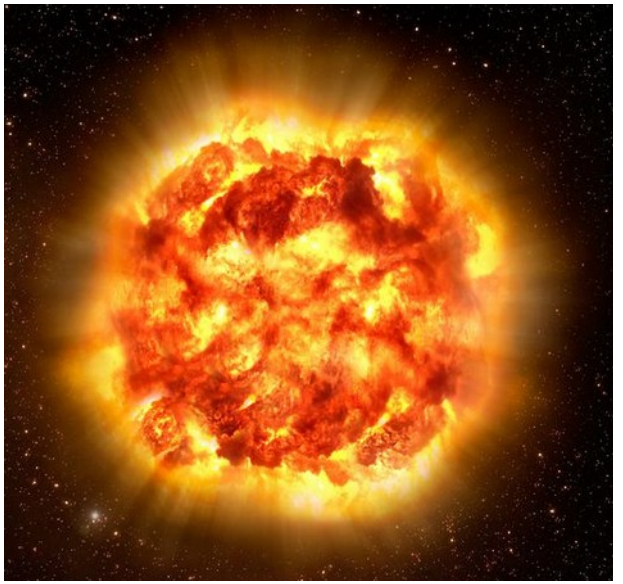


To answer this we study:

- Individual SN
- Large SN samples
- SN environments

Type Ib/c & IIb progenitors





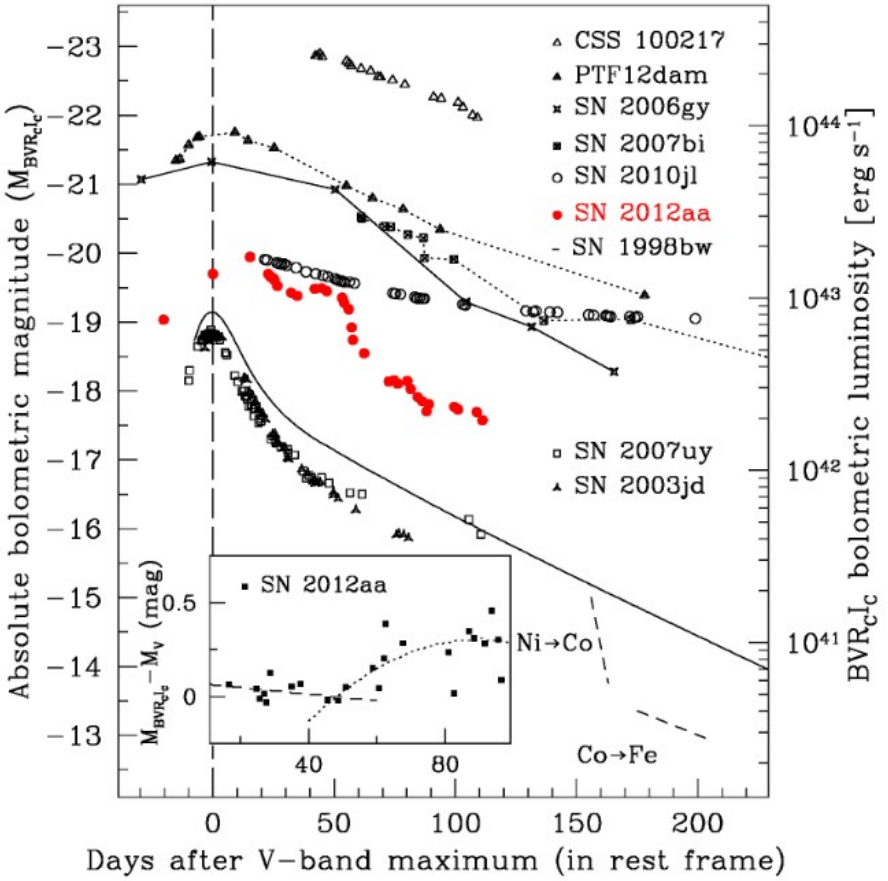
Low ejecta mass, low Oxygen mass, Most of them are probably from binaries?

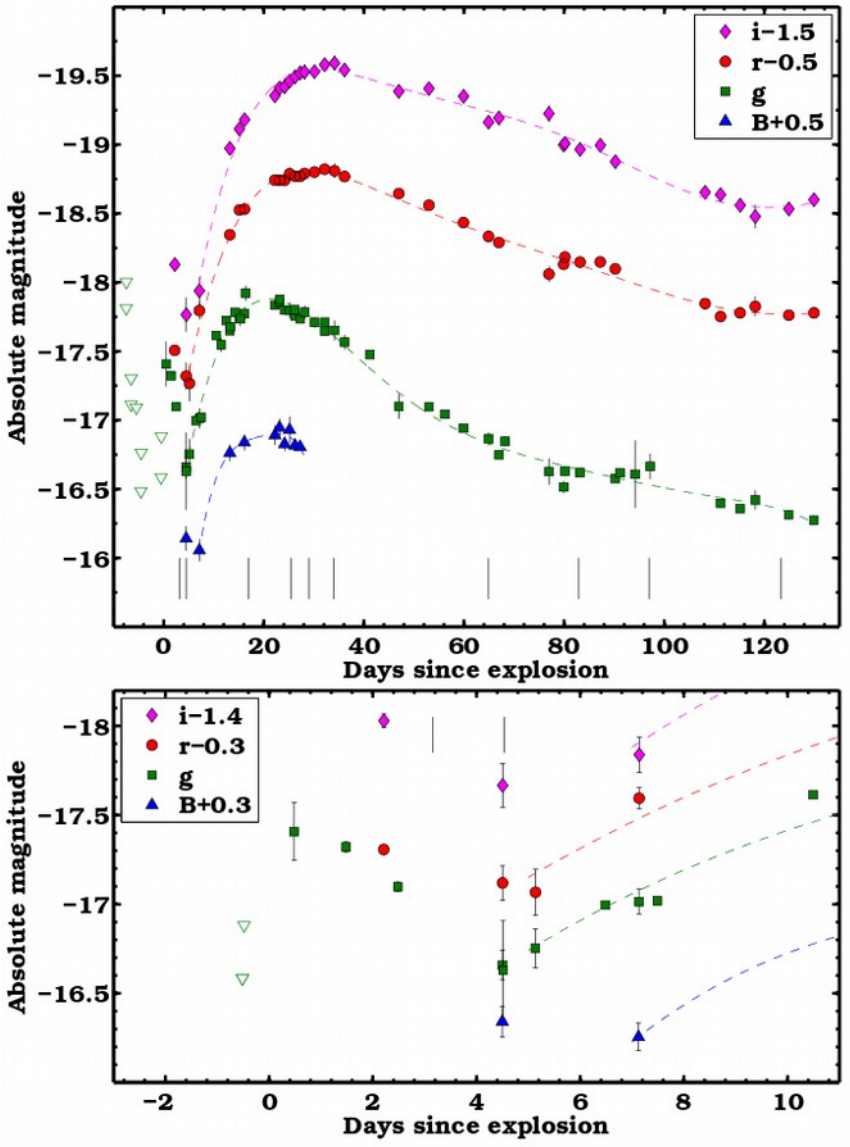
We now have some events that have broader light-curves or higher velocities, probably from single stars?

Type Ib/c & IIb progenitors

Roy et al. 2016 (submitted)

- Spectral properties and velocities consistent with normal SNe Ibc.
- Peak Mv ~20 mag
- Broad light-curve.
- CSM must play a significant part in the powering of this SN.

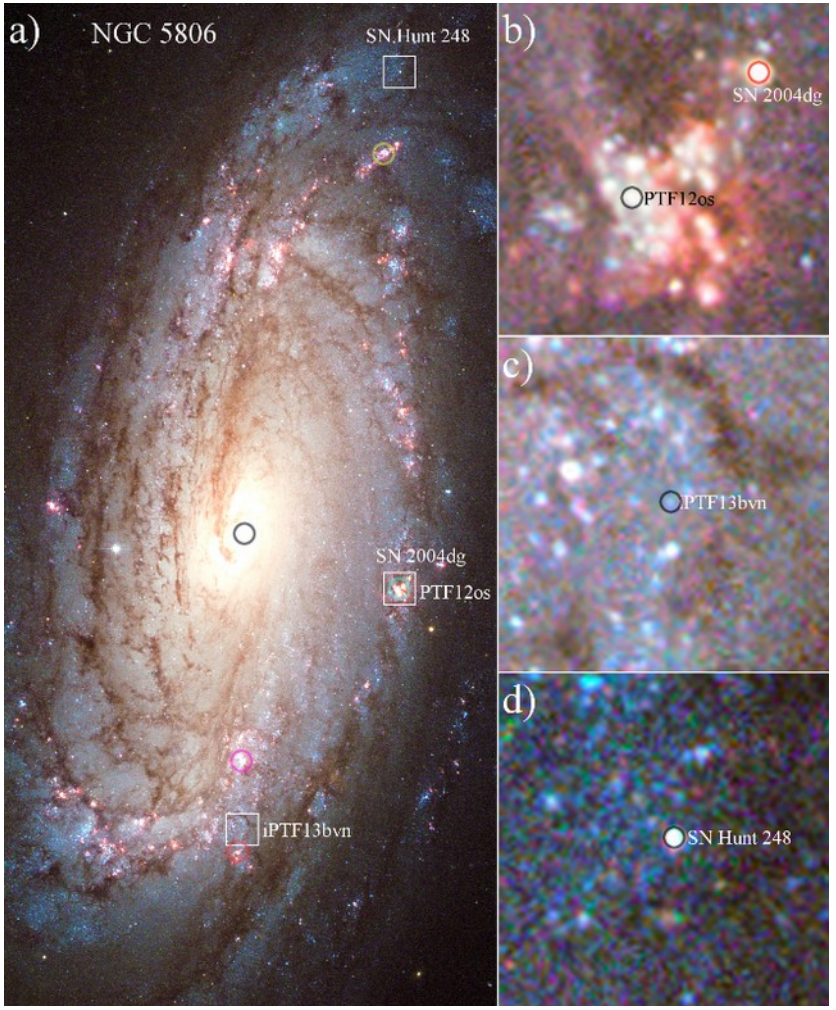




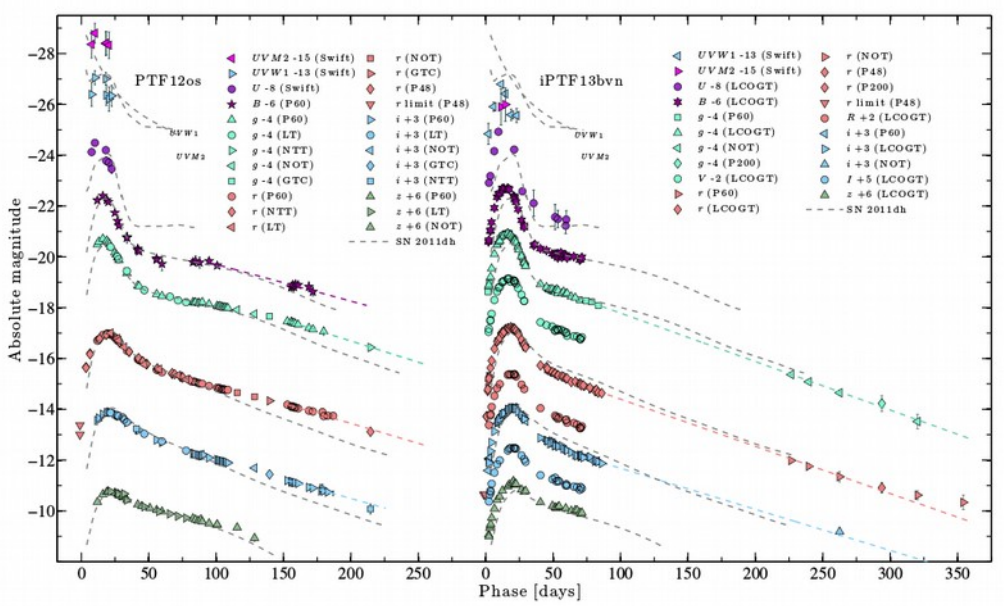
- The first spectroscopically normal SN Ic with a detected early cooling phase!
- Progenitor >35 M⊙ WR star suffering strong mass loss.

Taddia et al. 2016 (submitted)

Stripped-envelope SNe

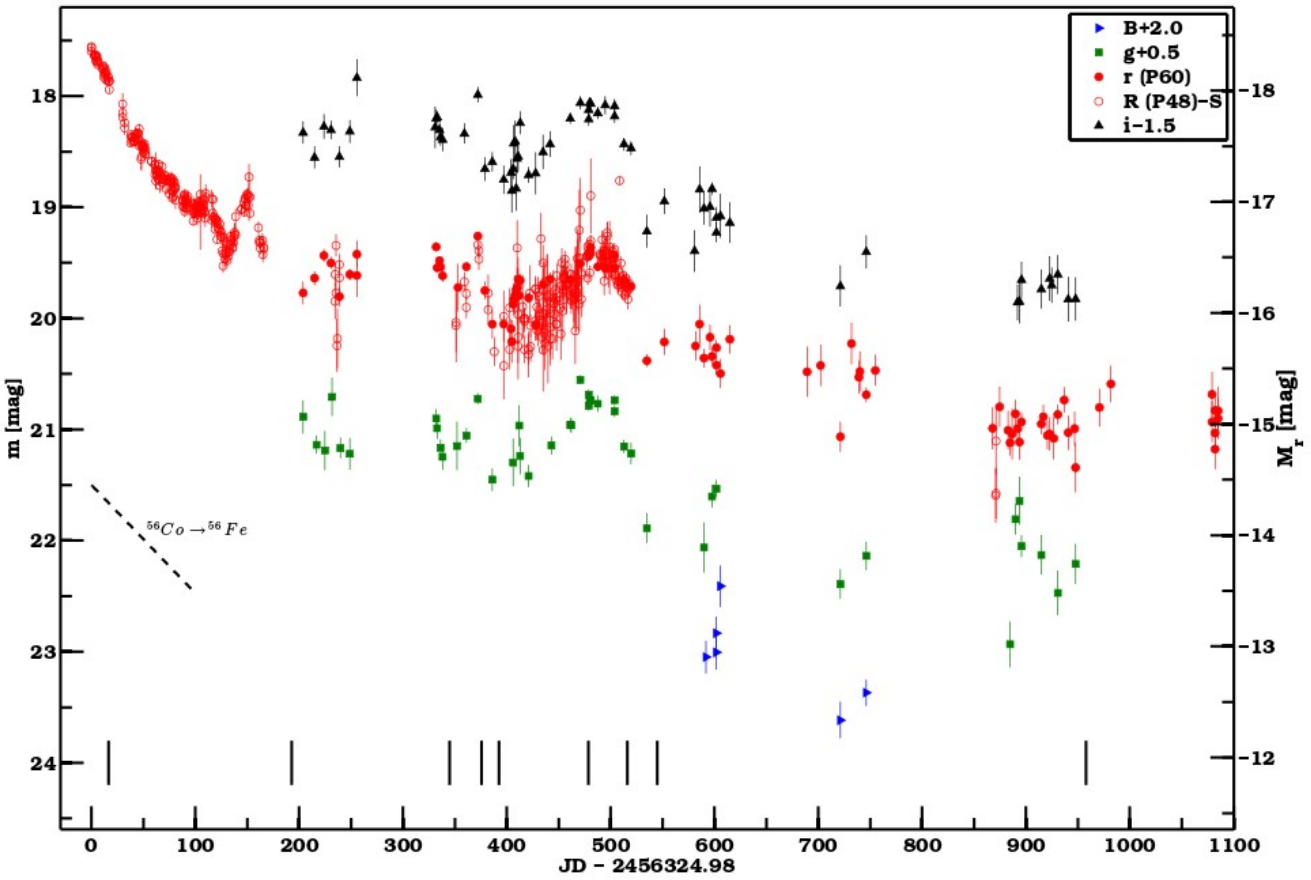


Fremling et al. 2016



2 SN with the same host, NGC 5806: PTF12os and iPTF13bvn

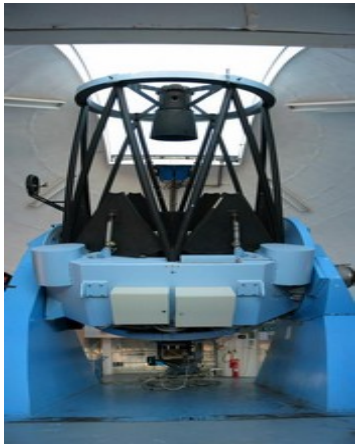
Peculiar SN IIn with bumpy light-curve



- Peak mag ~-18.3
- > 3 bumps from interraction with Circum stellar medium.

Nyholm et al. 2016 in prep.

Nordic Optical Telescope (NOT)



On La Palma,
diameter=2.56 m, 3300-9000 Å,
R~ 360.
We can perform spectroscopy and photometry, mainly with ALFOSC, via the following programs:

Supernova Target-of-Opportunity from the **iPalomar Transient Factory**.

10 nights each semester (April 1, 2015 --- **September 30, 2016**)
Time Allocation: 2x10x1.5h (HARD triggers) + 10x5x1h (SOFT triggers)

Submitted proposals:
Supernova Target-of-Opportunity from the **Zwicky Transient Facility**

10 nights each semester (**October 1, 2016 --- April 30, 2018**)
Time Allocation: 2x10x1.5h (HARD triggers) + 10x5x1h (SOFT triggers)

Telescopio Nazionale Galileo (TNG)

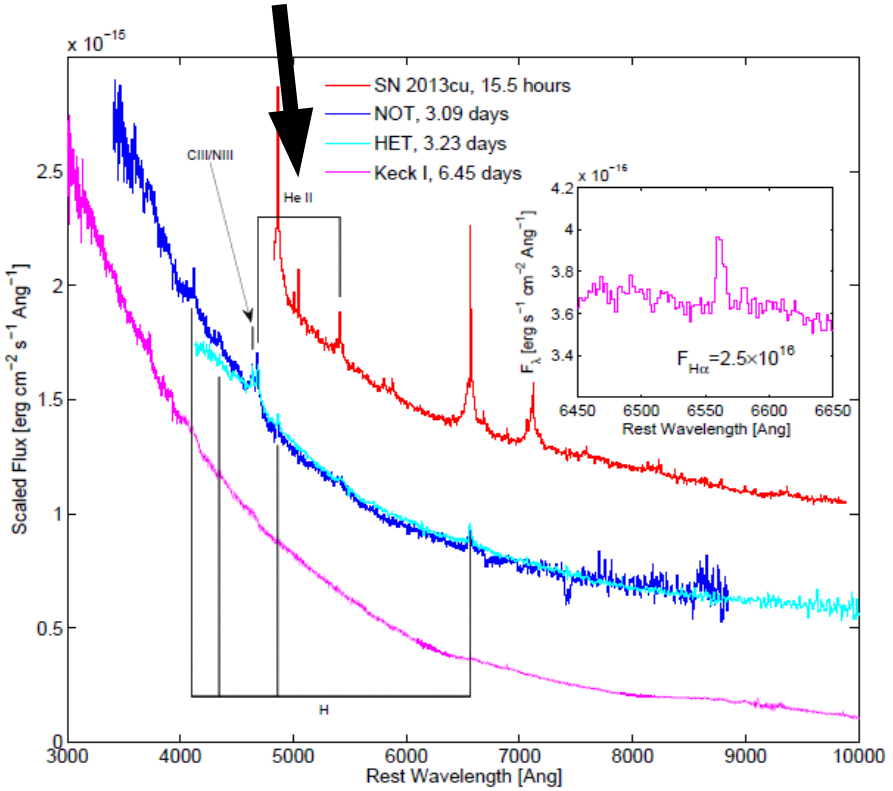
On La Palma,
Diameter=3.58 m.
3000-10000 Å, R~ 500.
We can perform spectroscopy and photometry with DOLORES, via the following program:

Observing core-collapse supernovae from the intermediate Palomar Transient Factory with the TNG. PIs: F. Taddia

30 hours (3 hours over 10 nights) each semester (September 1 2015 --- **August 31, 2016**). Will apply for the coming semesters.

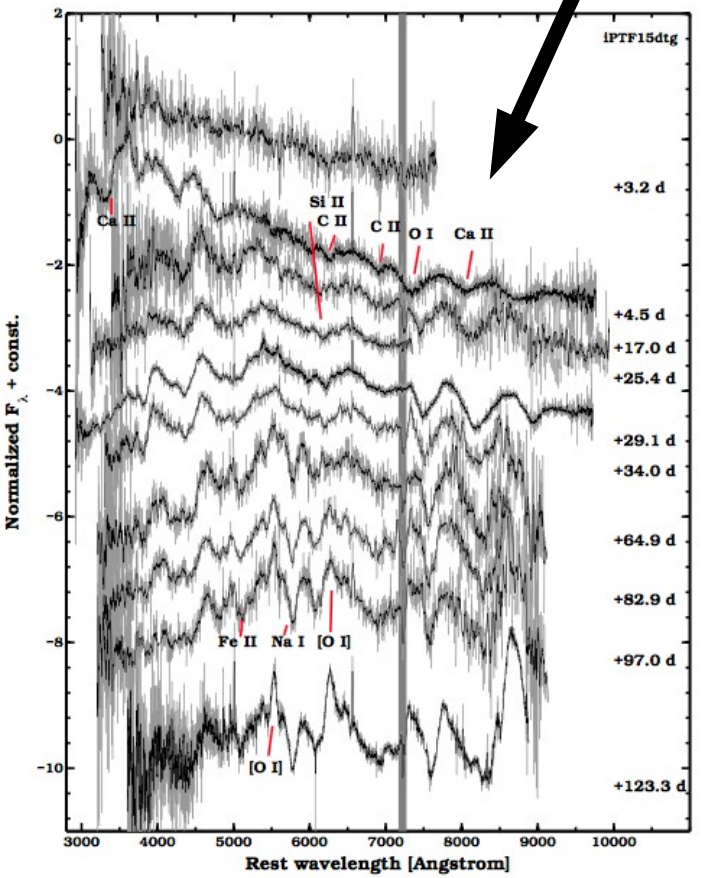
NOT+TNG strategy

NOT is perfect for fast ToO spectra when the SNe discovered by iPTF are very young.



Gal-Yam et al. 2014, Nature (iPTF13ast)

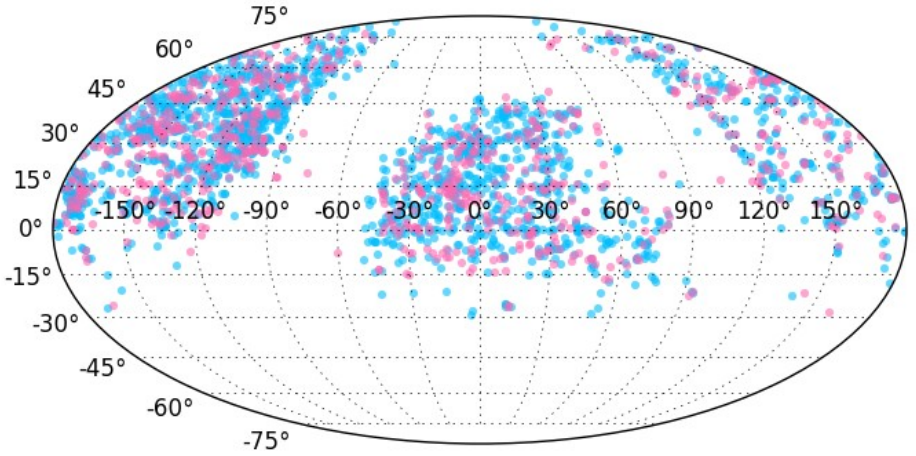
TNG, which is larger, provides useful follow-up observations when the SN is faint, at late epochs.

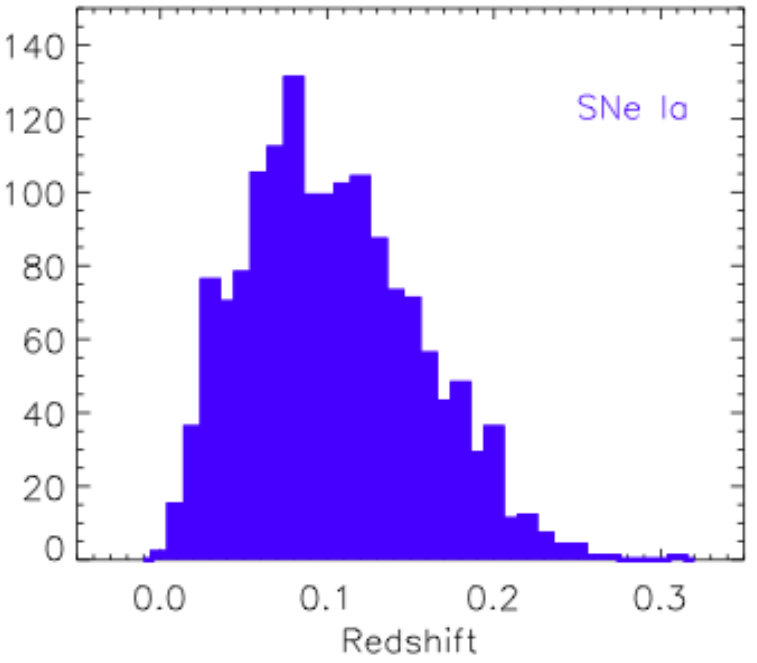


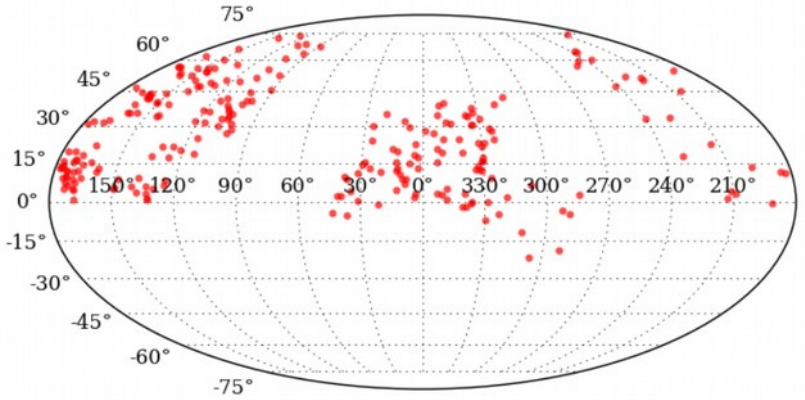
Taddia et al. 2016, A&A (iPTF15dtg)

PTF + iPTF SN sample

1870 SN Ia

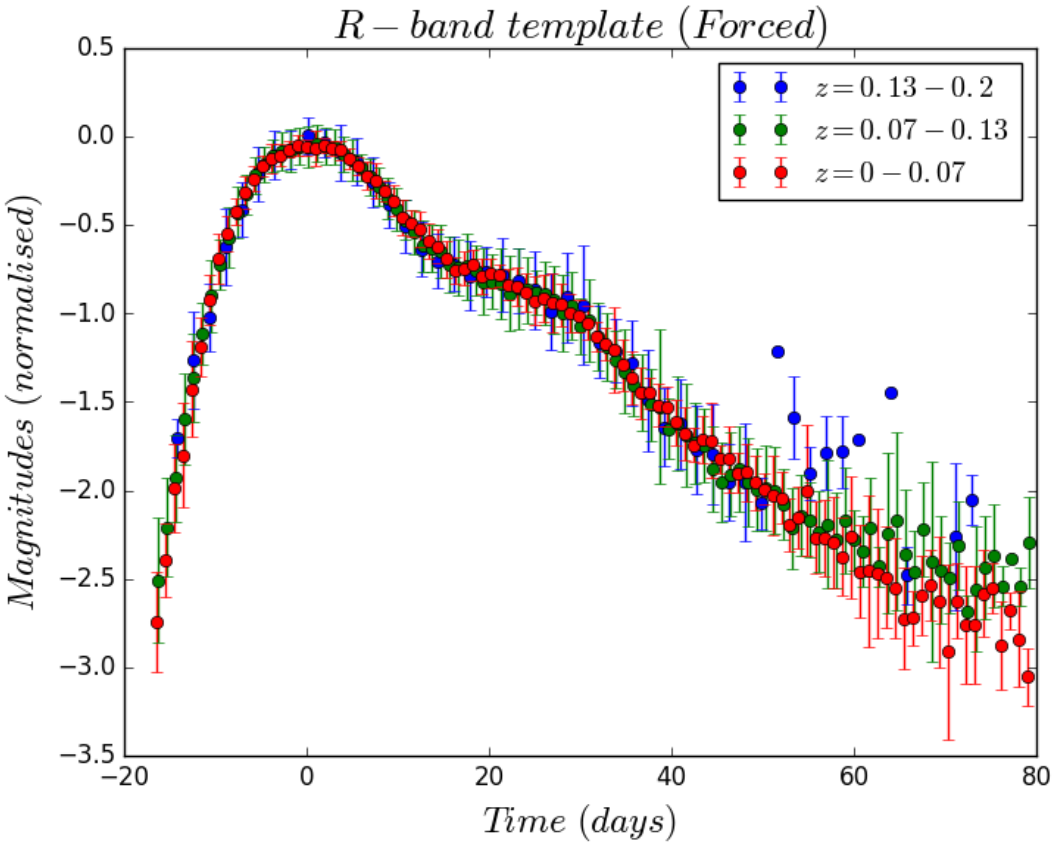






Papadogiannakis et al. In prep

- Picking the best sampled Supernovae in the R-band from PTF+iPTF
- Making a template
- Can we say something about the progenitor?



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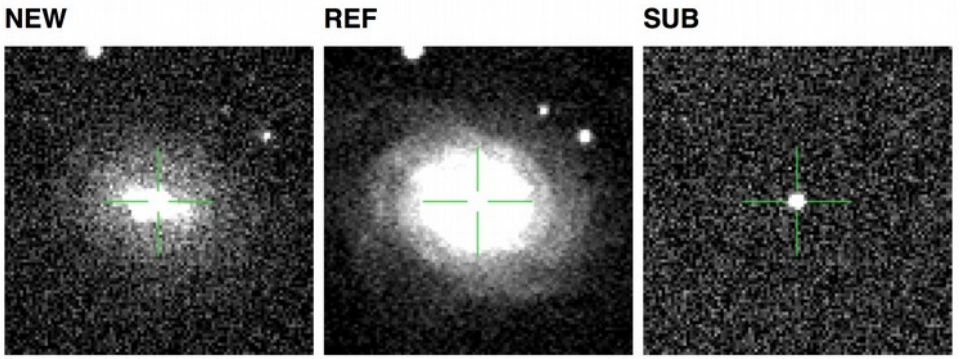
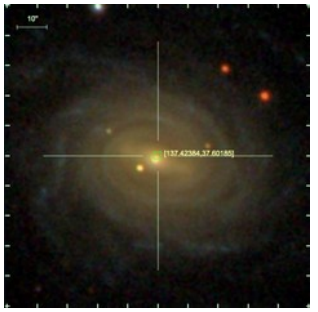
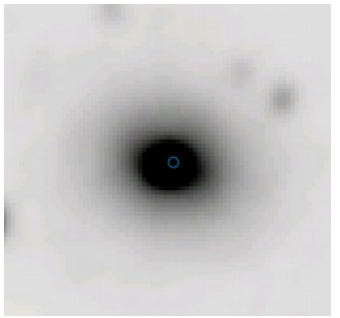
iPTF



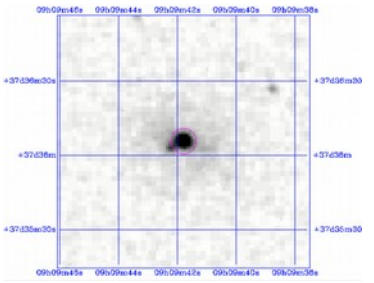
SDSS

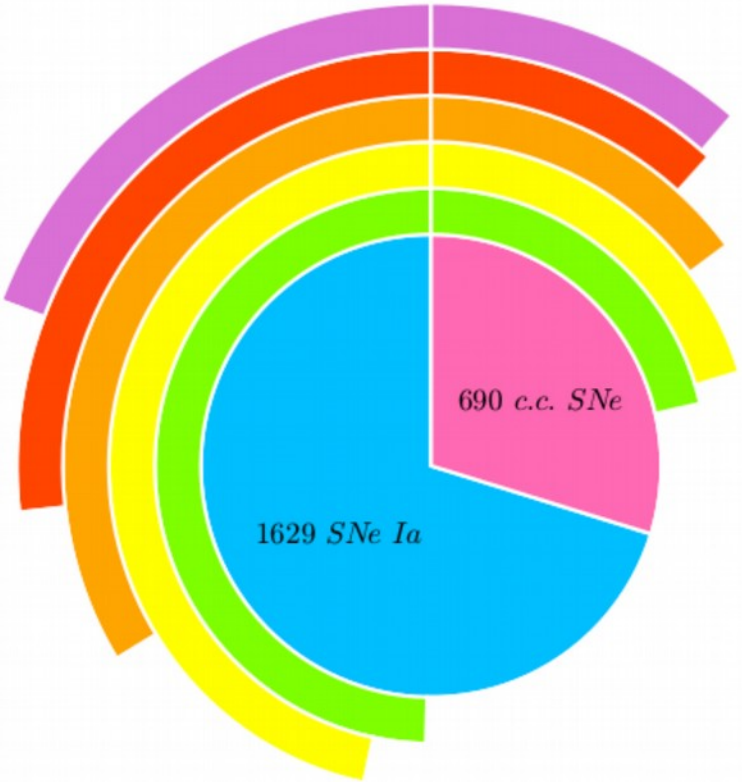


WISE



2MASS





- SNe Ia
- Core collapse SNe
- SDSS host galaxies
- WISE host galaxies
- FIRST host galaxies
- 2MASS host galaxies
- GALEX host galaxies

Hangard et al.
in prep

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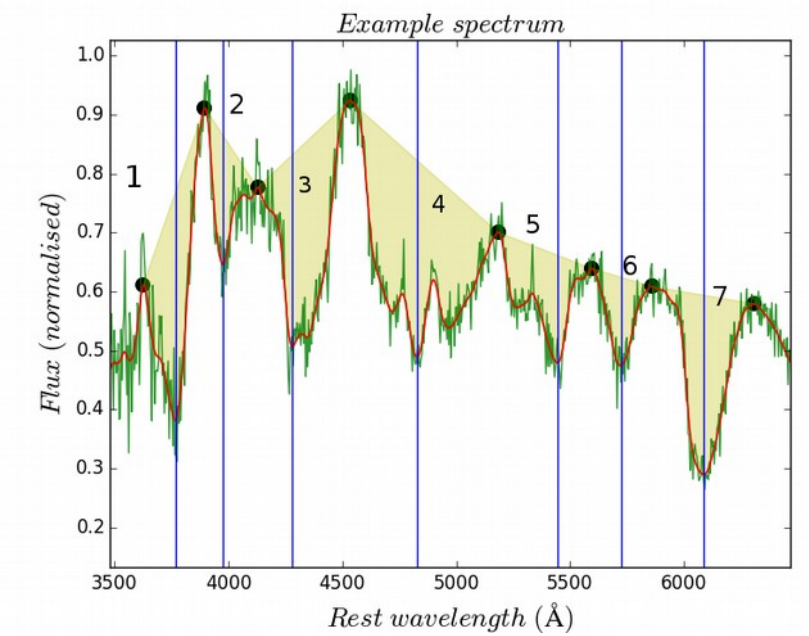
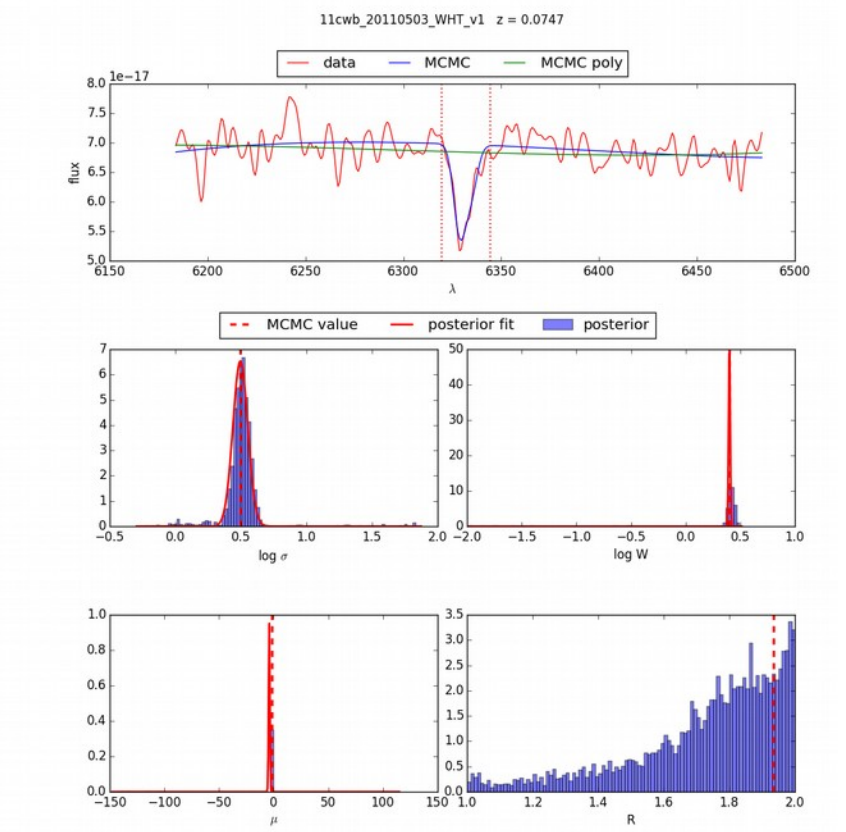
- Combine the host information, light-curve information and spectroscopy to look for correlations and classes → reduce Hubble residuals?
- Could this give any clues to the progenitor of Ia's?





Credit:T. Anson

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Summary:

- At OKC we work on both Type Ia SN (cosmology) and Core-collapse SN (Stripped-envelope core-collapse SNe, Circumstellar-interacting SNe, new or rare and peculiar SNe)
- Telescopes in the Canary Islands (NOT and TNG) and Chile (VLT) to which we have access are now part of the follow-up network of GROWTH
- Thanks to the NSF to have made the GROWTH network possible.

Extra slides

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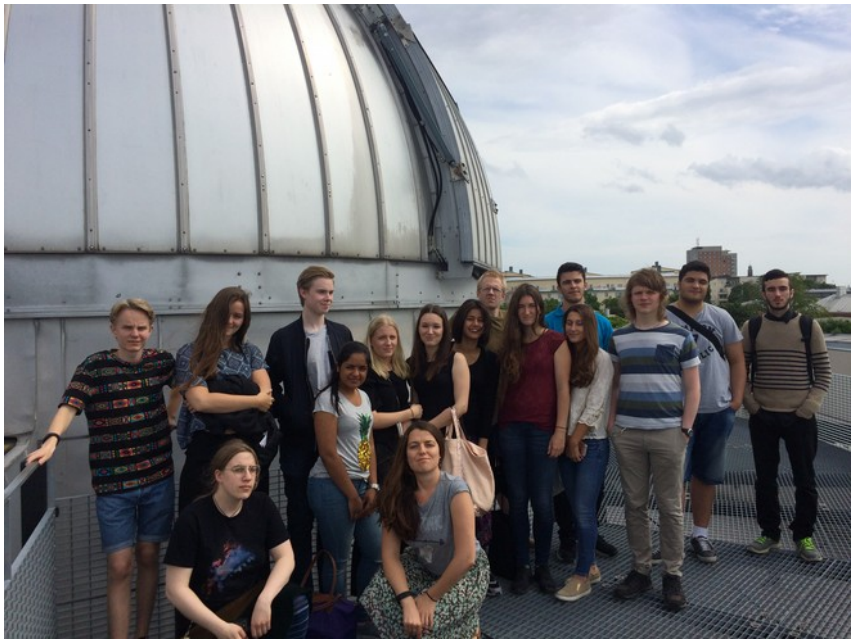
Outreach activities

Live-scanning from iPTF for Transients in the park!



Summer school for high-school students with PTF data