The Transient Sky in the LSST Era

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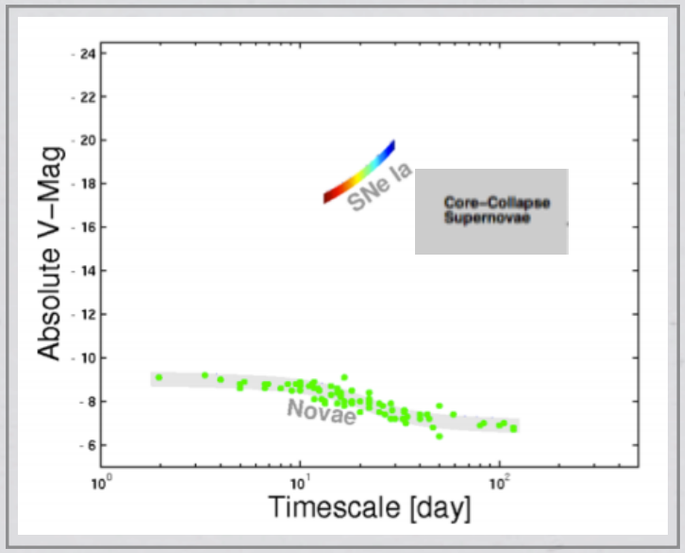
Roma, 14 Luglio 2016

New types of stellar transients

The transient sky in the past



Credits: S. Kulkarni

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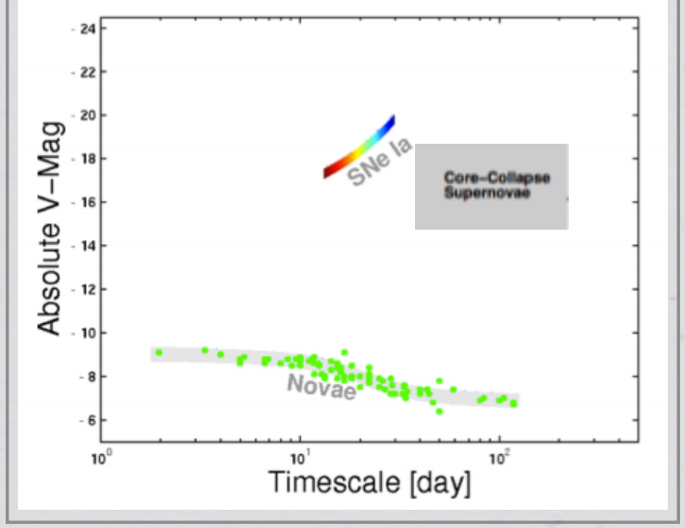

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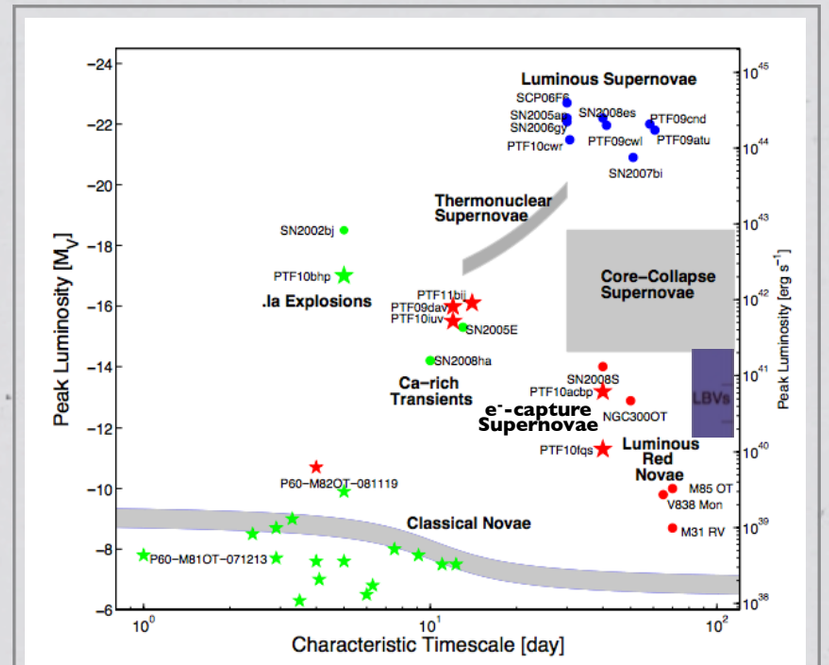
The current transient sky: new transients



New types of stellar transients

The transient sky in the past

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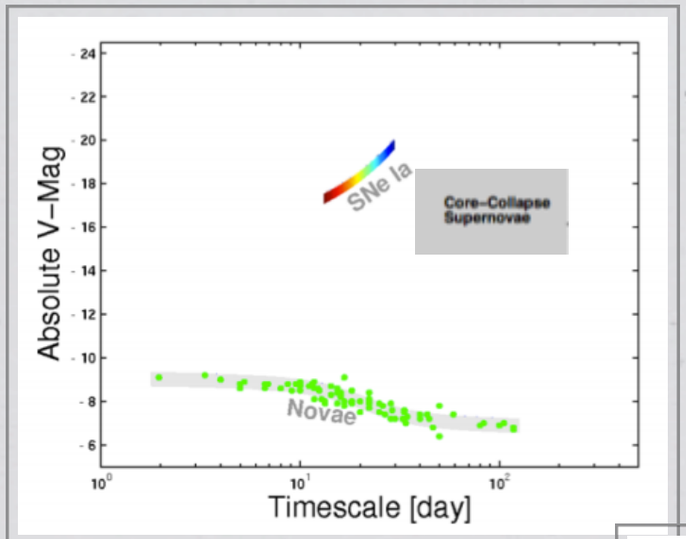

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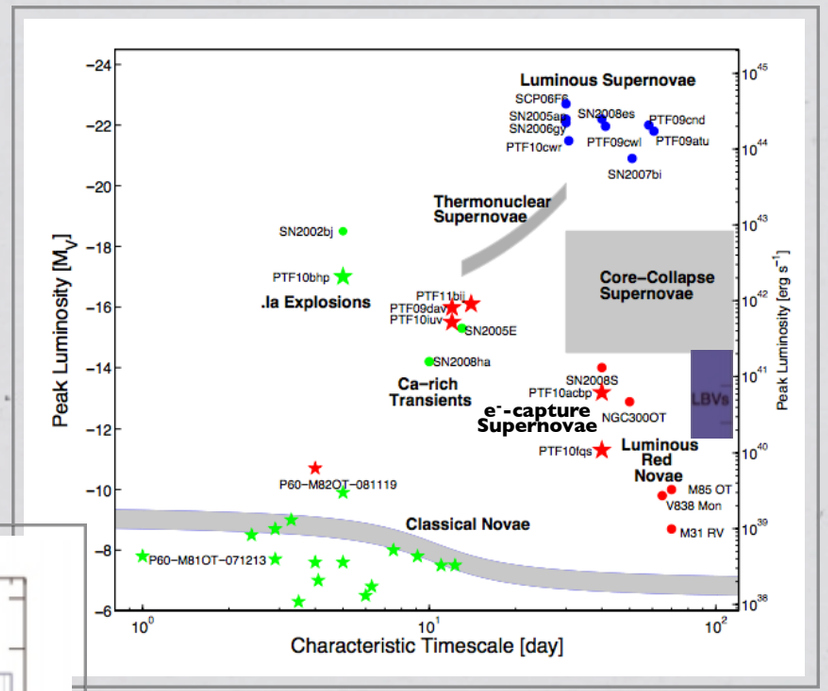
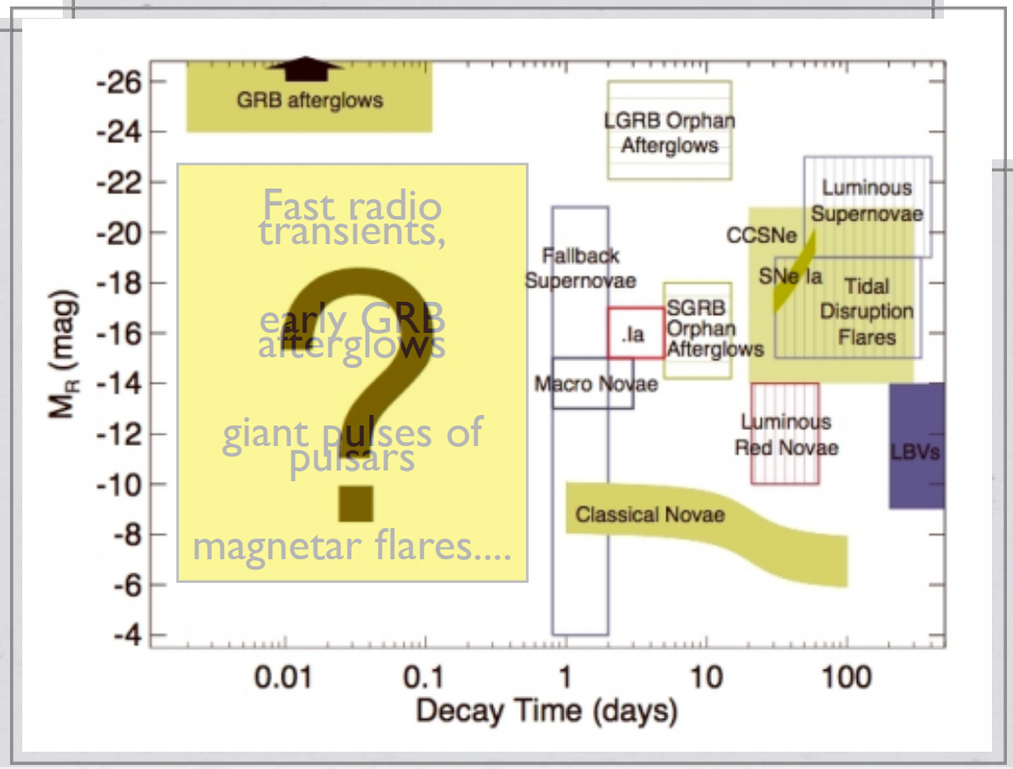




The transient sky in the LSST era: the unknown

From the LSST Science Book

The transient sky with LSST: main goals

* Improving characterization of classical stellar explosions (progenitors, environments, dependence of their properties with redshift - cosmology applications).

* New classes of stellar transients (about 10 classes): 5-30 newly discovered objects per type - insufficient statistics, incomplete observational follow-up; only preliminary models existing.

* Pair-instability SNe, dark/failed SNe; optical counterparts of GWs; macronovae: searches to down, 0-1 candidates per type.

* Fast-evolving transients: the unknown - the future…

LSST: strategies

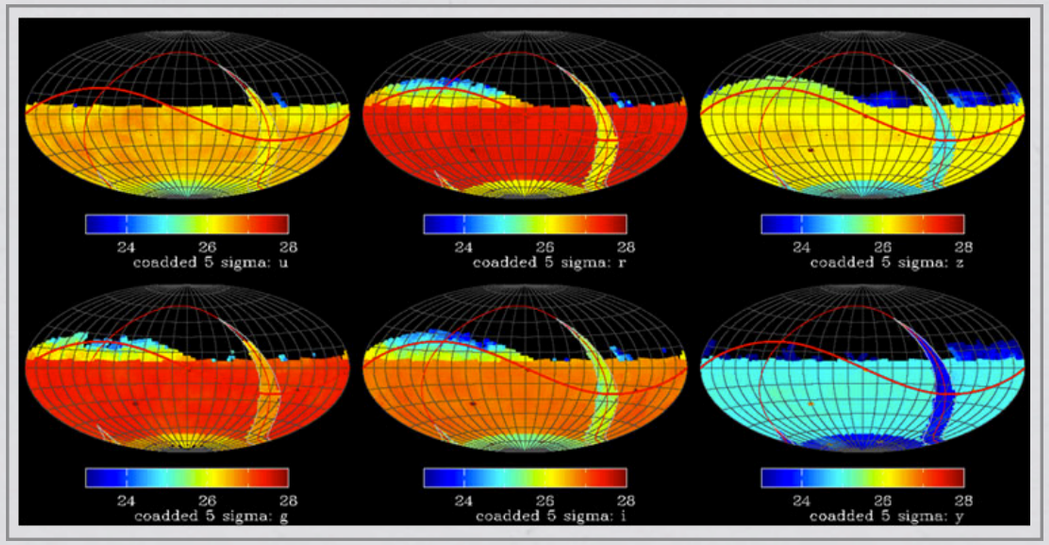
From single visits of the main survey:

* Search of transients
* Multi-band photometric follow-up of transient events

From high-cadence mini-surveys:

* SN shock breakout and GRB afterglow events
* Fast-evolving transients

LSST: strategies



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From high-cadence mini-surveys:

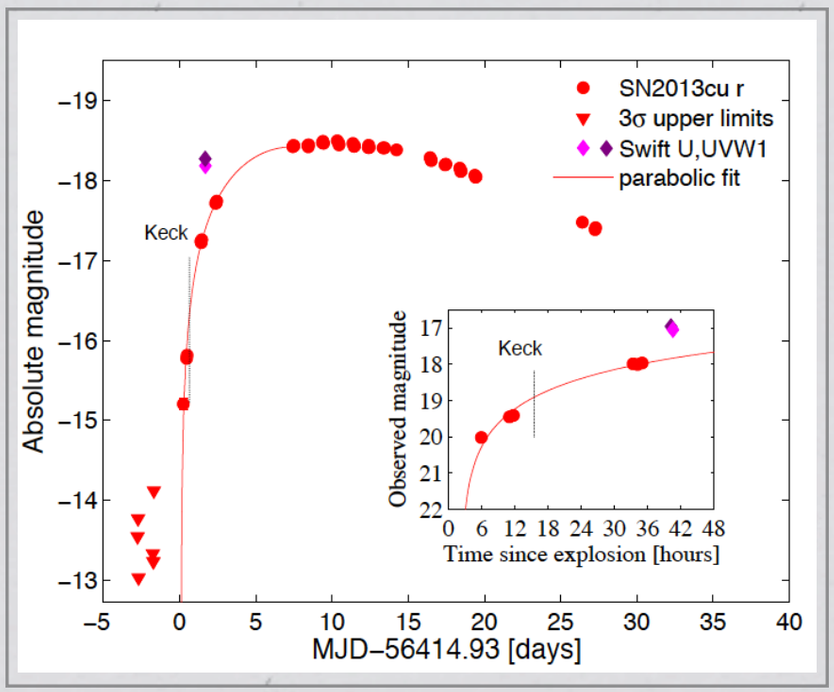
* SN shock breakout and GRB afterglow events
* Fast-evolving transients

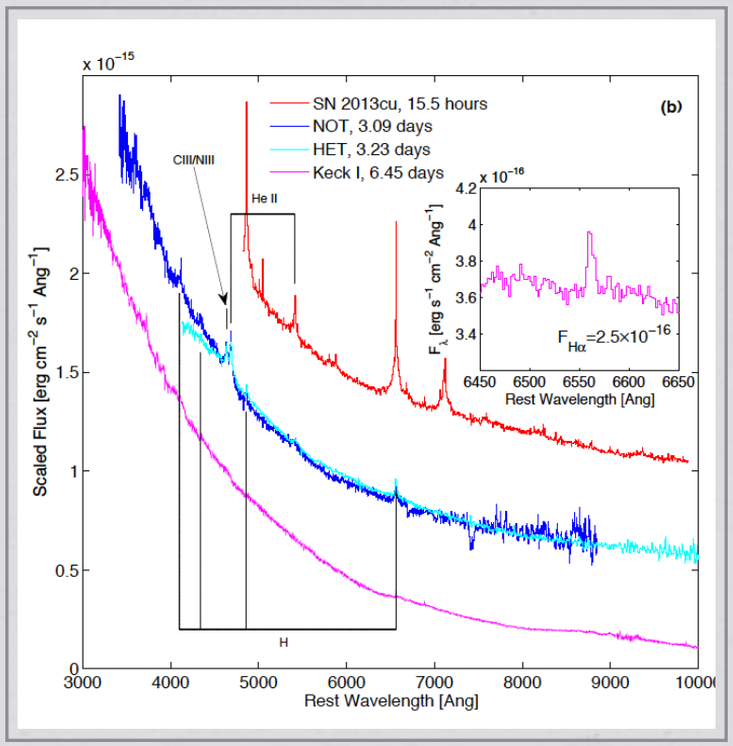
From co-added images

* Templates for the search of transients
* SN progenitors detection and their environment
* Failed supernovae detection
* Ultra-faint transients (or at very high z)

The transient sky with LSST: methods

- LSST transient alert
- Prompt spectroscopic classification => *insufficient, we need dedicated facilities!!!*
- Catching very early phases: *early photometric monitoring and flash spectroscopy*





Very rapid evolution during the first few hours

Gal-Yam+ 2014, Nature 509, 471

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SPECTROSCOPIC FACILITIES (SUCH AS **SOXS** AND **NTE**) ARE CRUCIAL FOR OUR RESEARCH!

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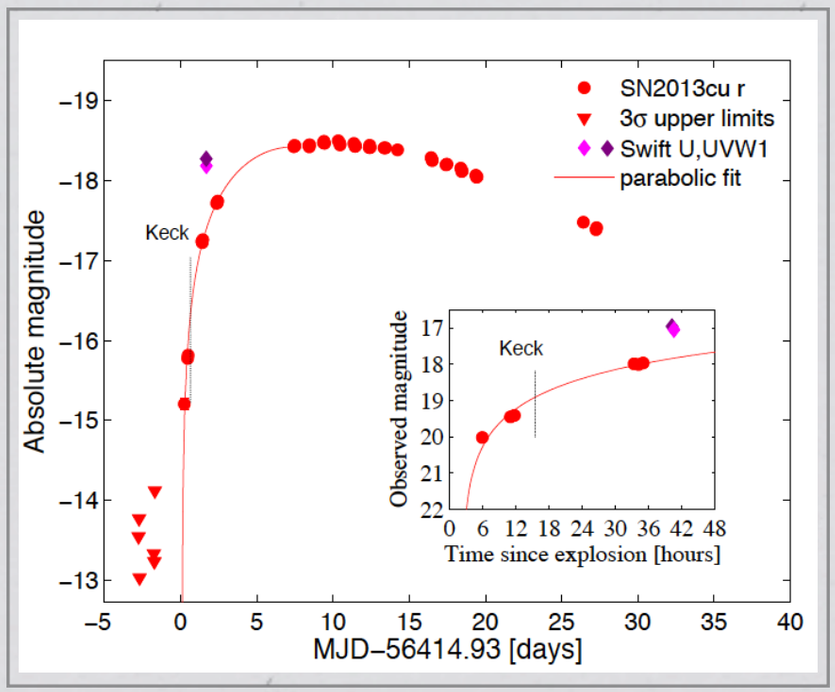
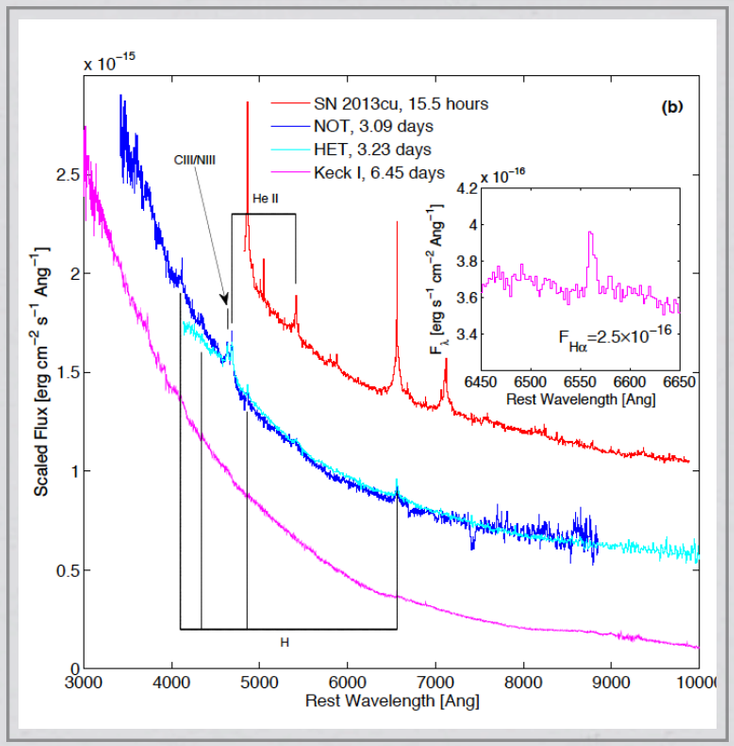


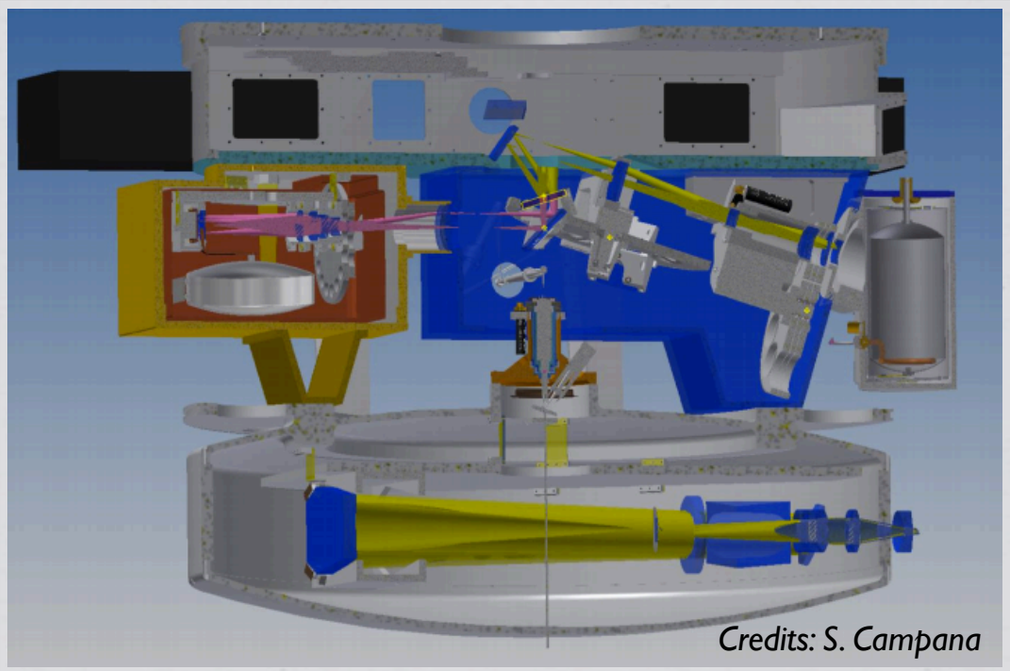


ESO-NTT with SOXS

(PI: S. Campana)

A dedicated, ESO-approved machine for typing and follow transients!

- Wide wavelength coverage via two-beam spectroscopy (350 to 1750 nm)
- Good spectral resolution (R=4500) to study e.g. stellar winds
- Fast reaction spectroscopy to survey alerts
- A twin (NTE) to be mounted at the 2.5m NOT



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* Cooperation with multi-messenger experiments; wide wavelength coverage

Multi-messenger astronomy

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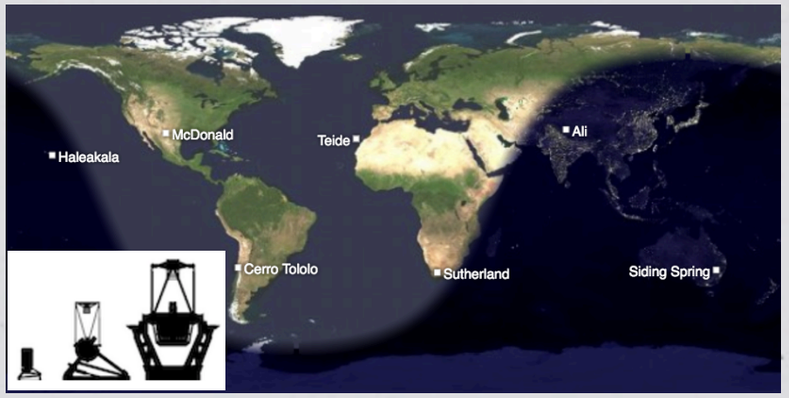
Multi-messenger astronomy



LCOGT is a network of 17 small (0.4-m, 1-m and 2-m) telescopes

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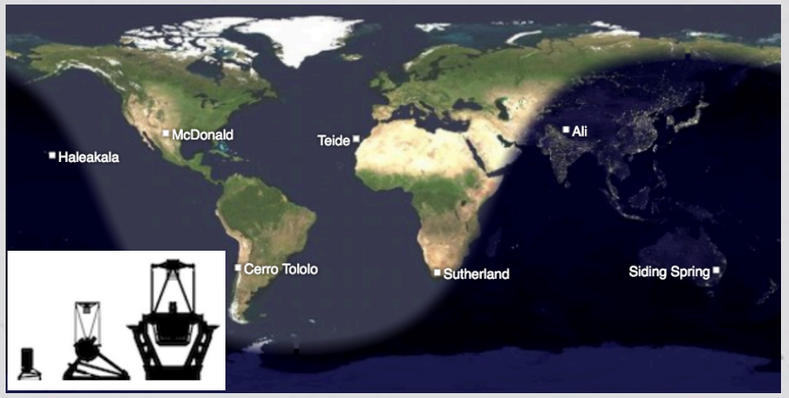
- Spectro-photometric sampling to the nebular phase => *LSST + different sized telescopes; differentiated strategy for fast transients (e.g. telescope rings like LCOGT)*
- Studying the progenitor stars and their environment => *very deep imaging , possibly high spatial resolution*
- Modeling the observational data with theoretical tools

Multi-messenger astronomy



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SCIENCE WITH LSST

HOT TOPICS

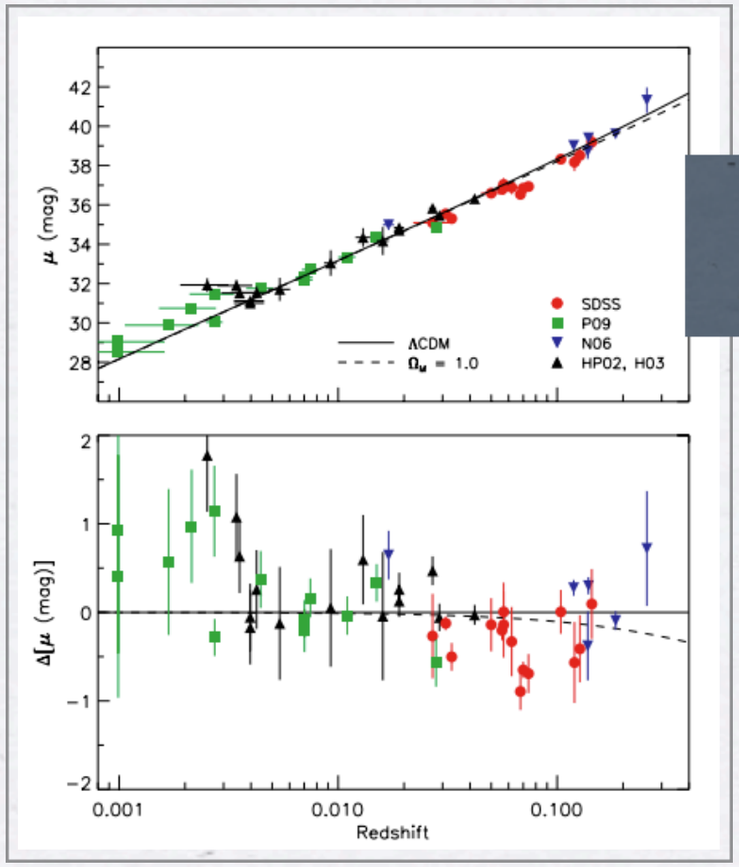
Properties of SNe II as a function of z

1. SNe IIP at higher z (> 0.3)

2. Rare intrinsically luminous SNe IIP

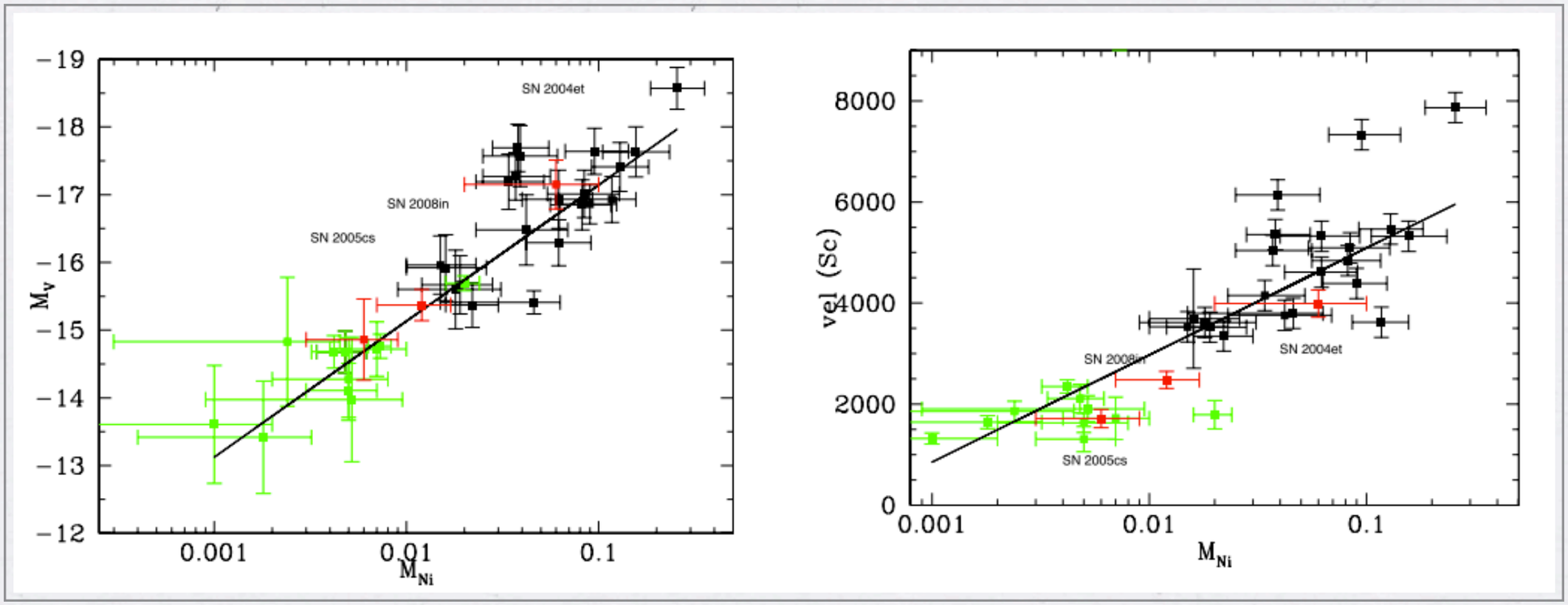
3. SNe IIP in metal-poor hosts

4. Stacked images for the detection of progenitor stars



z >>0.3

D'Andrea+ 2010, ApJ 708, 661

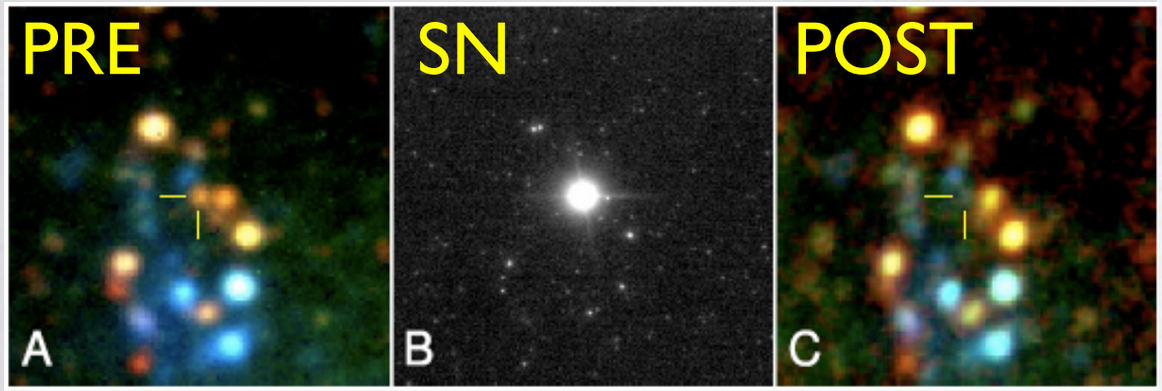


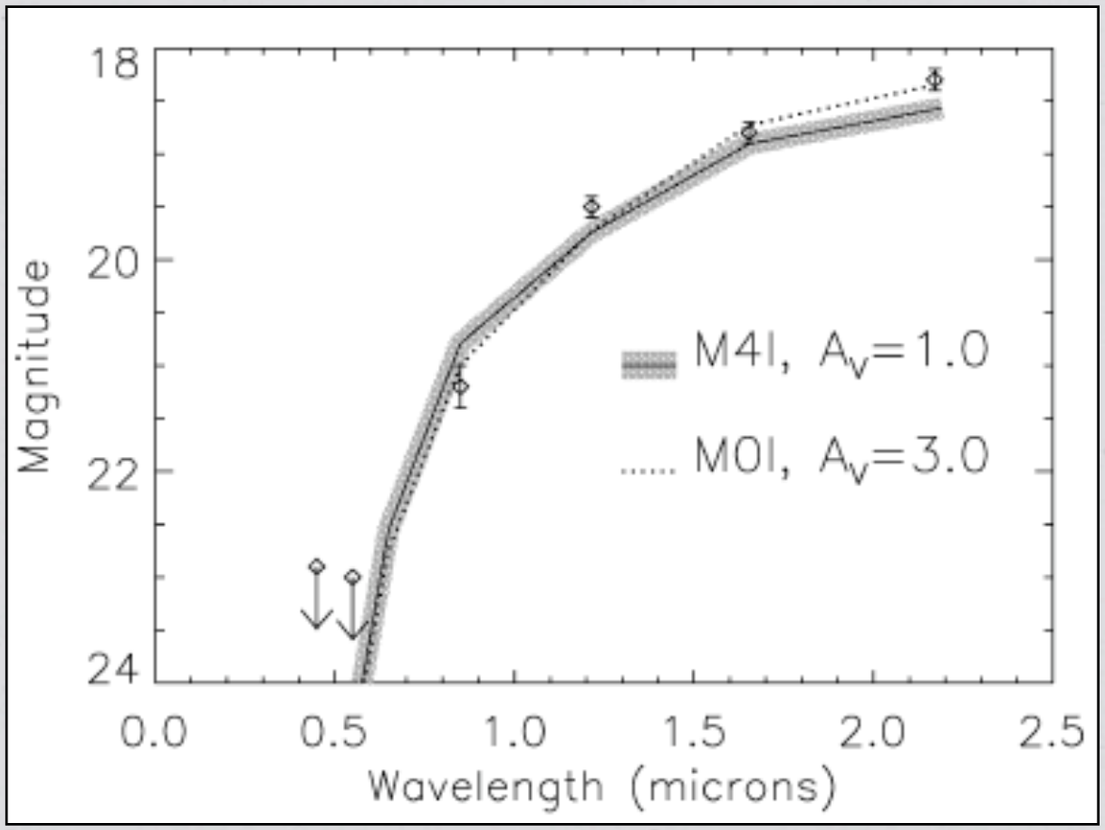
Spiro, Pastorello et al. 2014, MNRAS 438, 2873

Detecting massive stars before their death

- < 30 RSG progenitors of SNe IIP + 1 BSG progenitor of SN1987A identified so far
- A handful of YHG progenitors for SNe IIL/IIb
- About 15 progenitors of SNe IIn and SN impostors
- 1 stripped-envelope SN (dozens of non-detections)
- 3 intermediate-luminosity red transients (EC SNe?)

Maund+ 2014, MNRAS 438, 1577



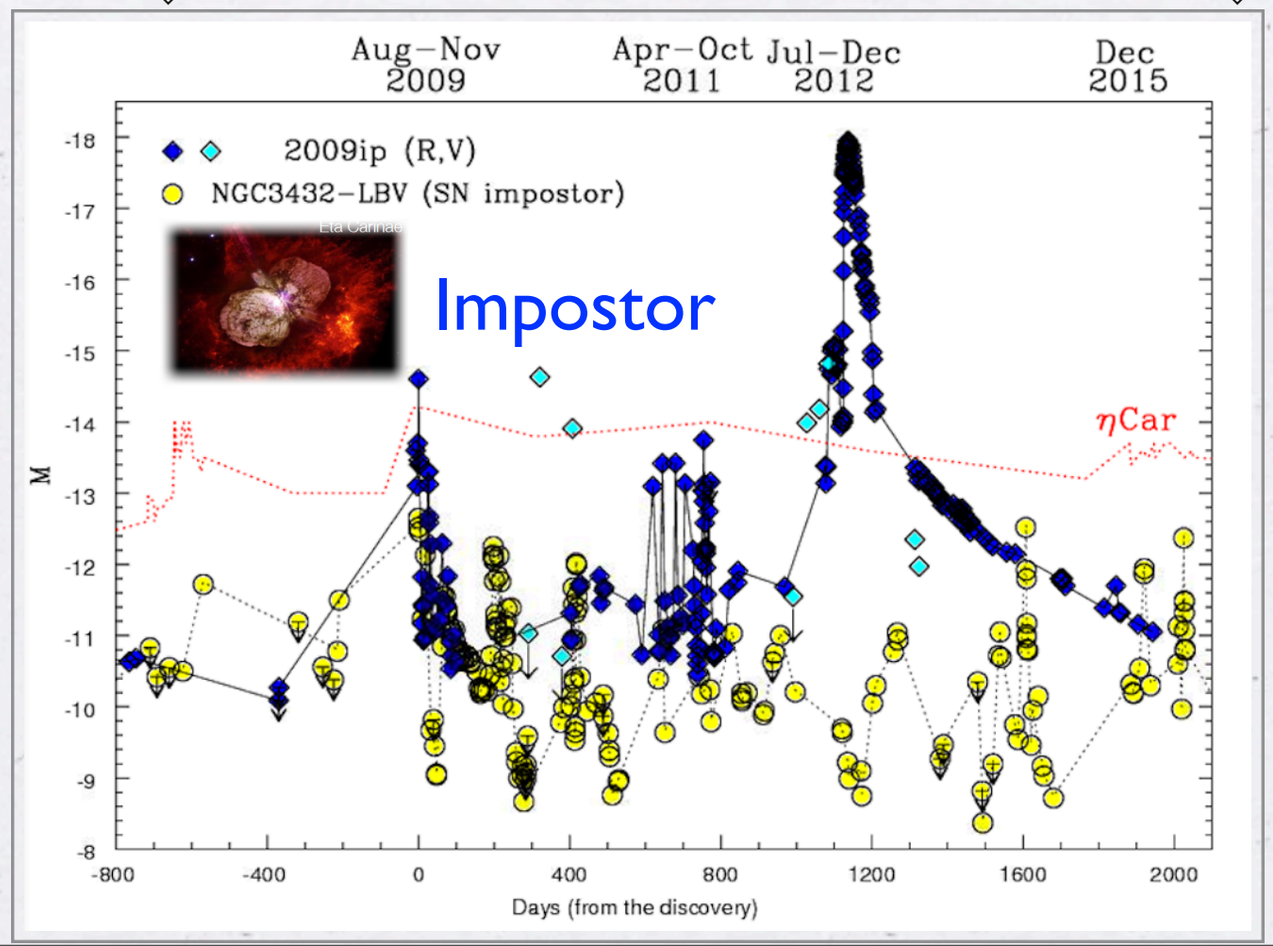


Pre-SN instabilities (SN impostors)

* < *Early 2012* => major LBV eruption

* *July 2012* => Type II SN explosion

* > *Late September 2012* => Strong ejecta-CSM interaction (SN IIn)



Adapted from
Pastorello+ 2012,
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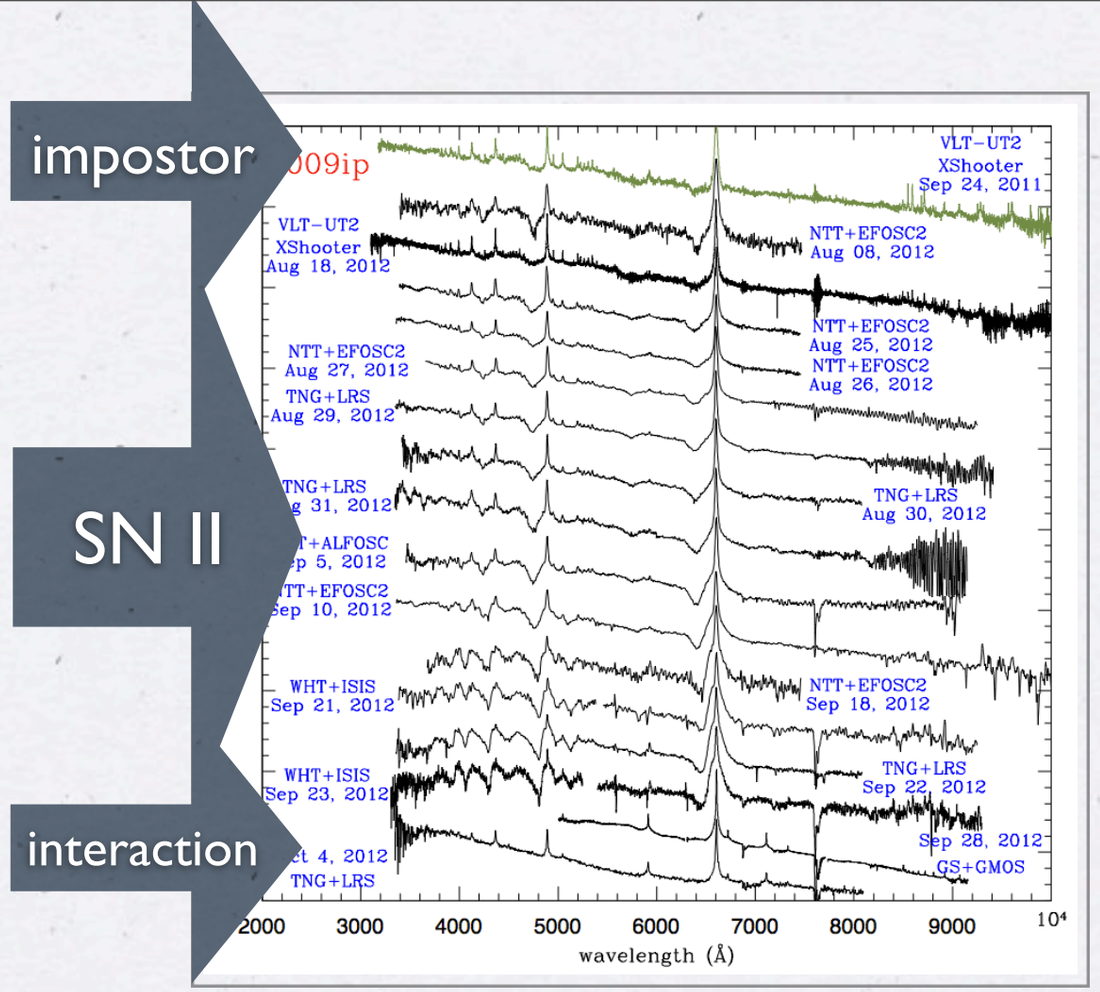

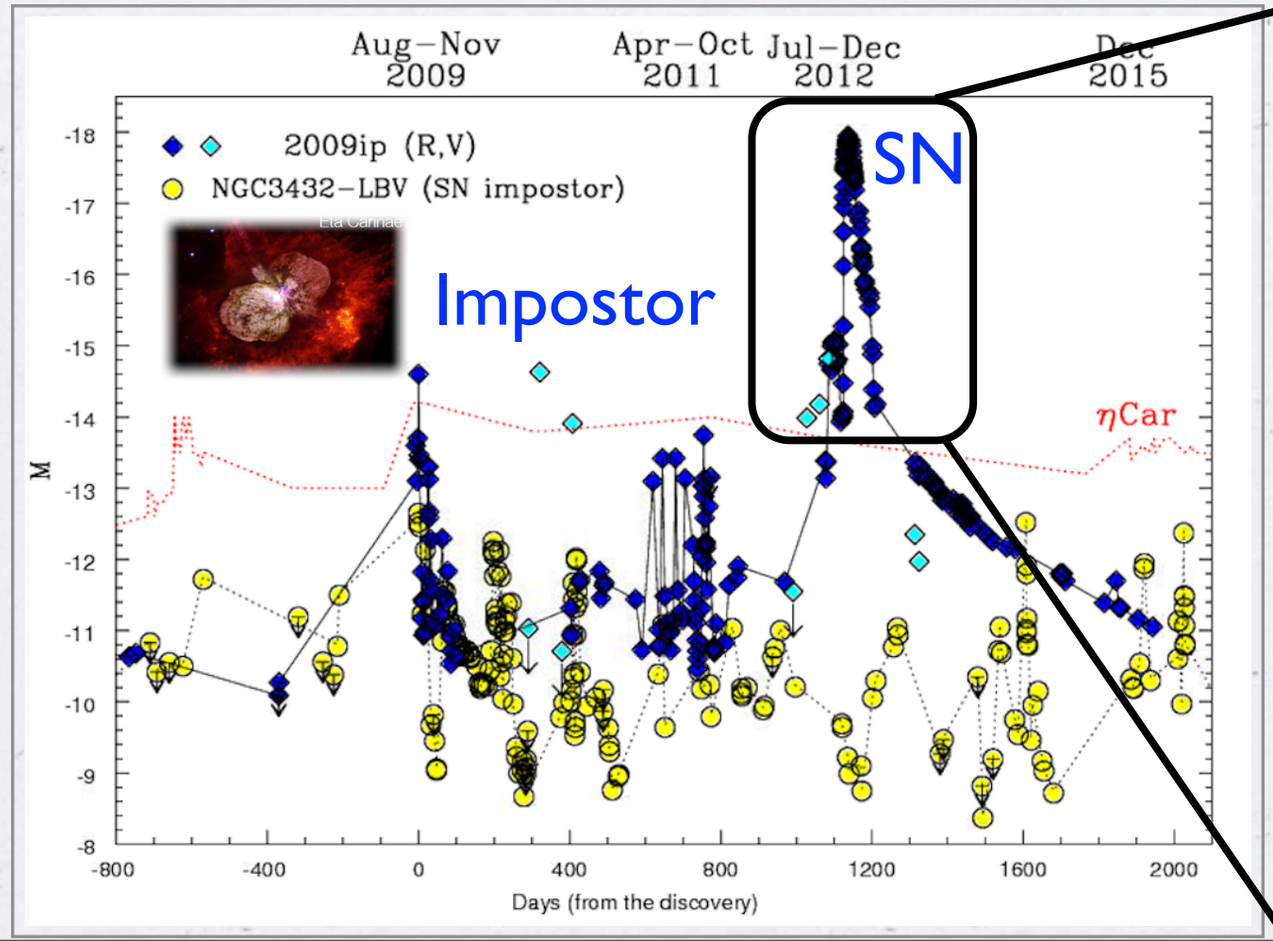

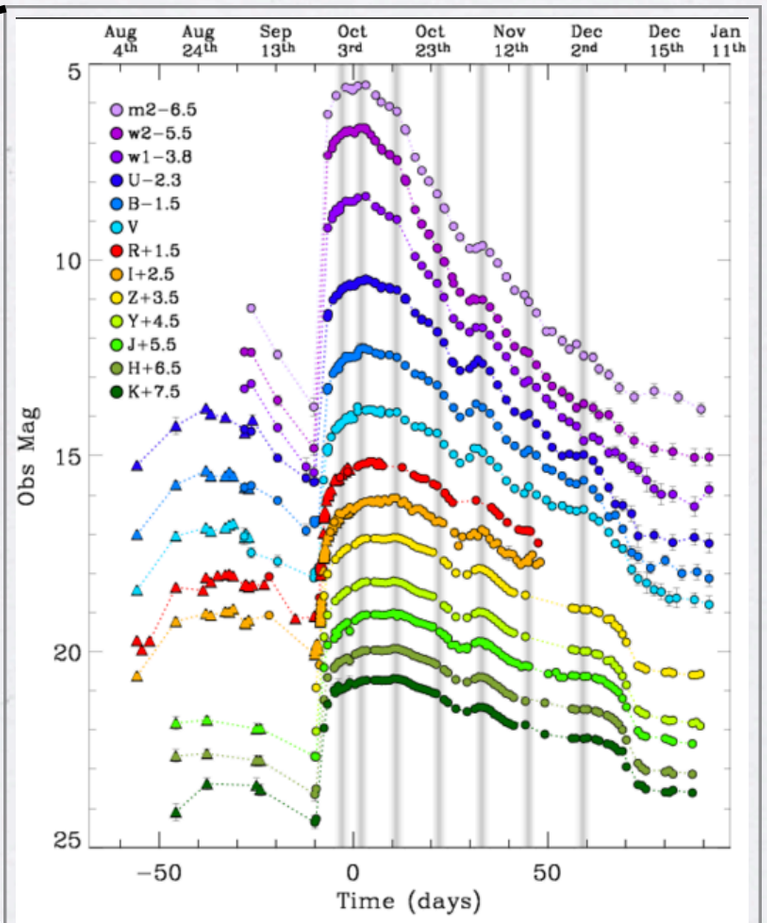

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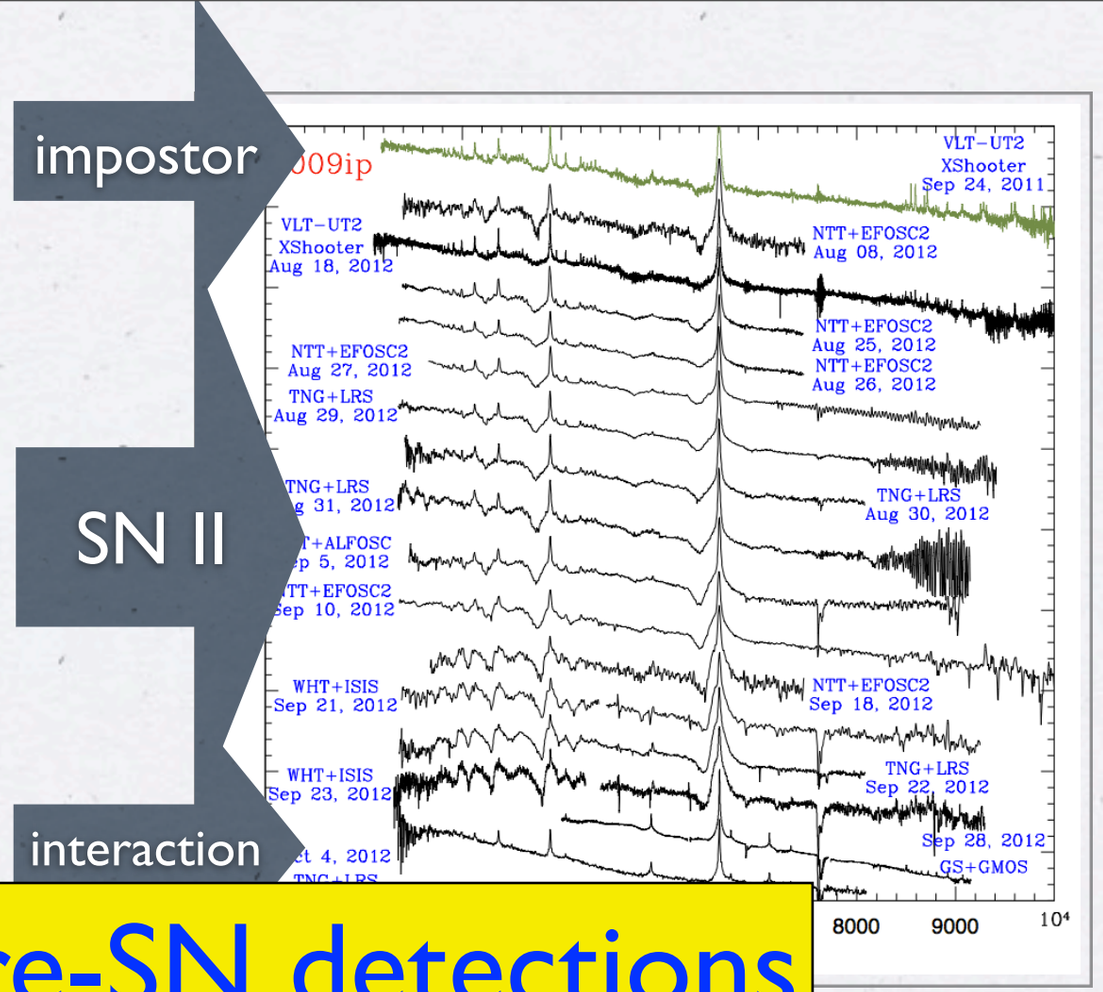
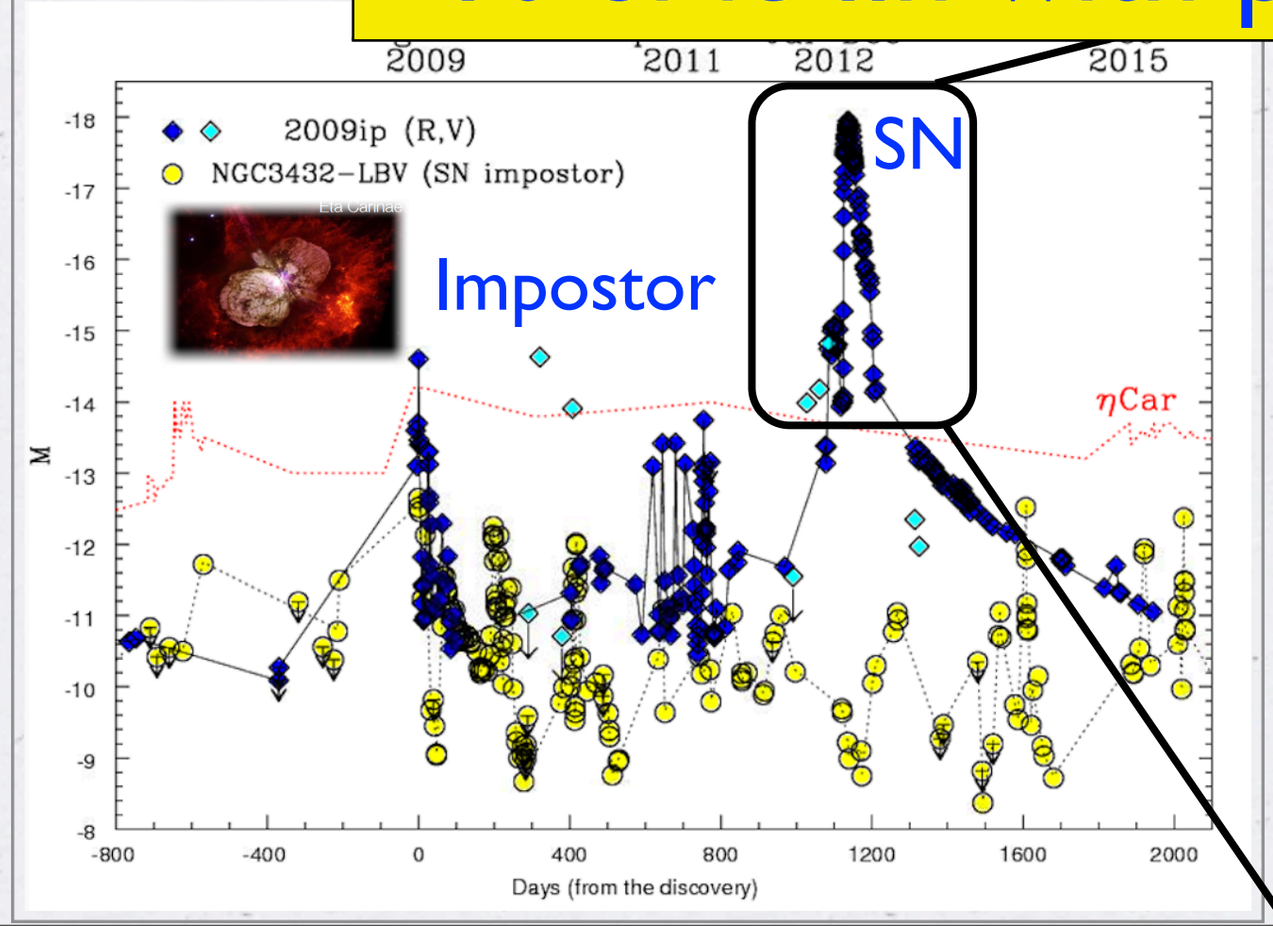
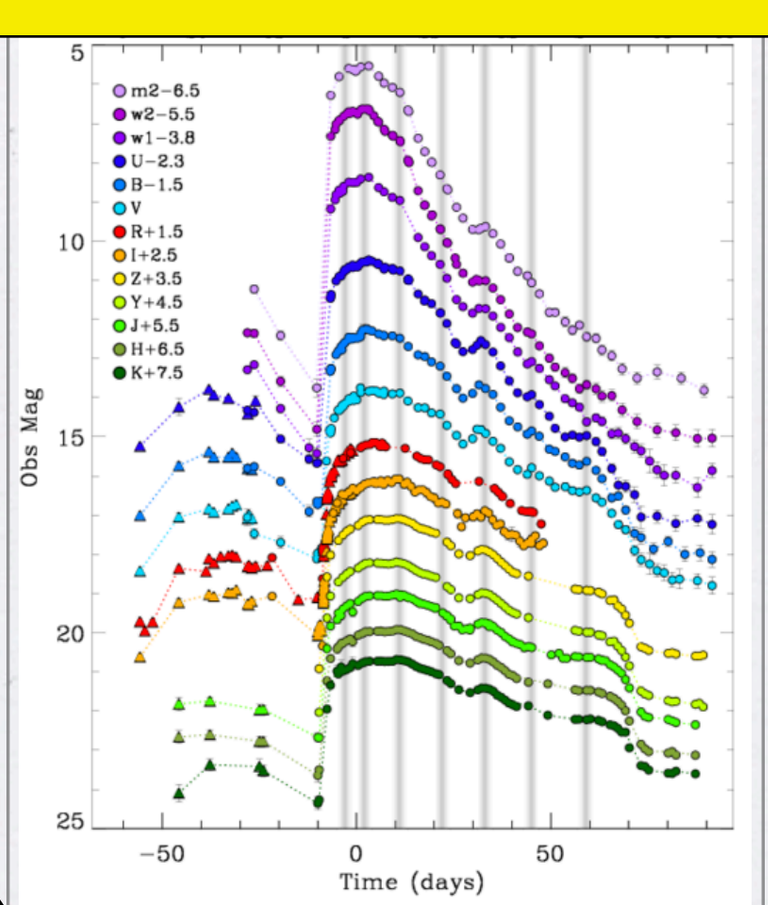


<10 SNe IIn with pre-SN detections





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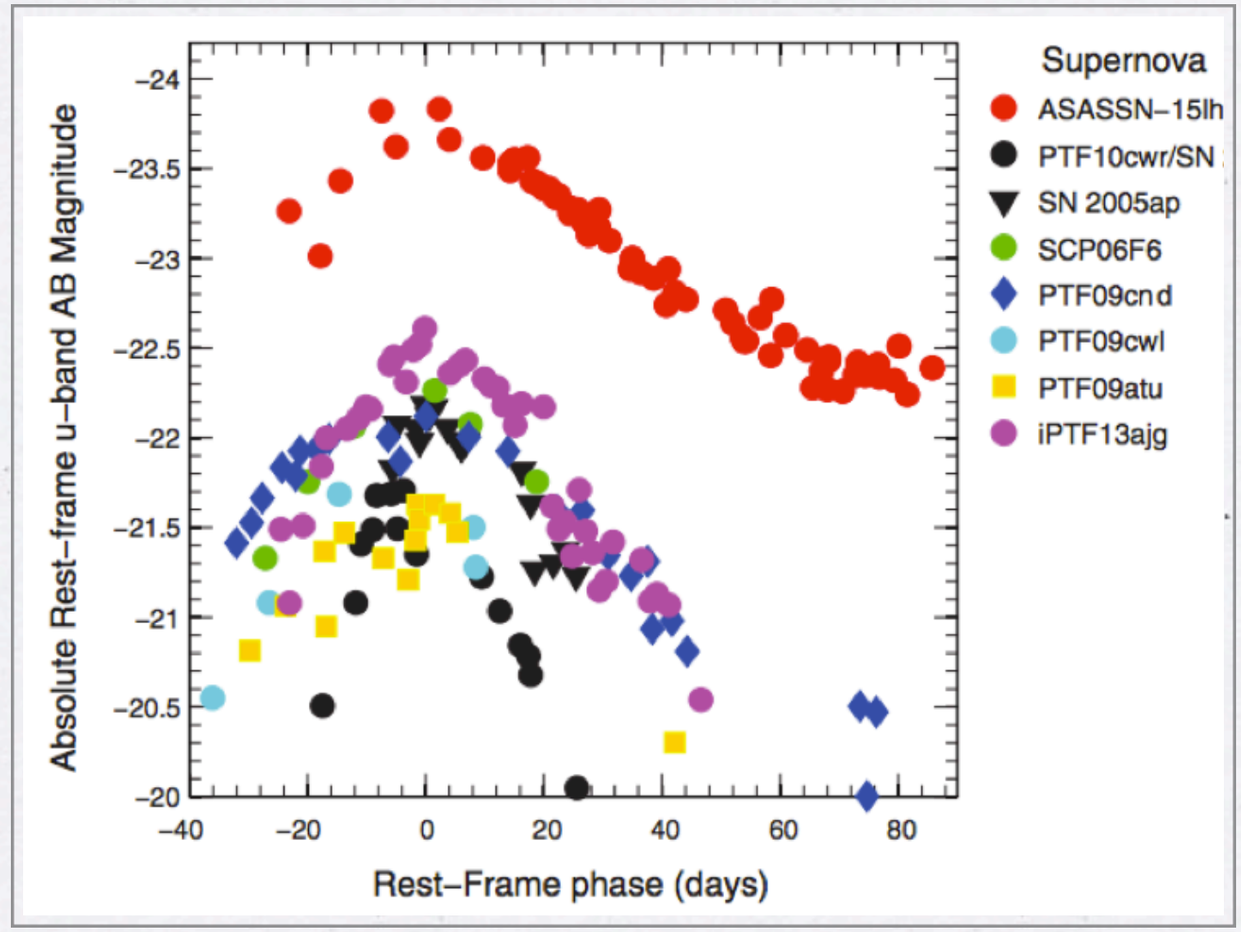
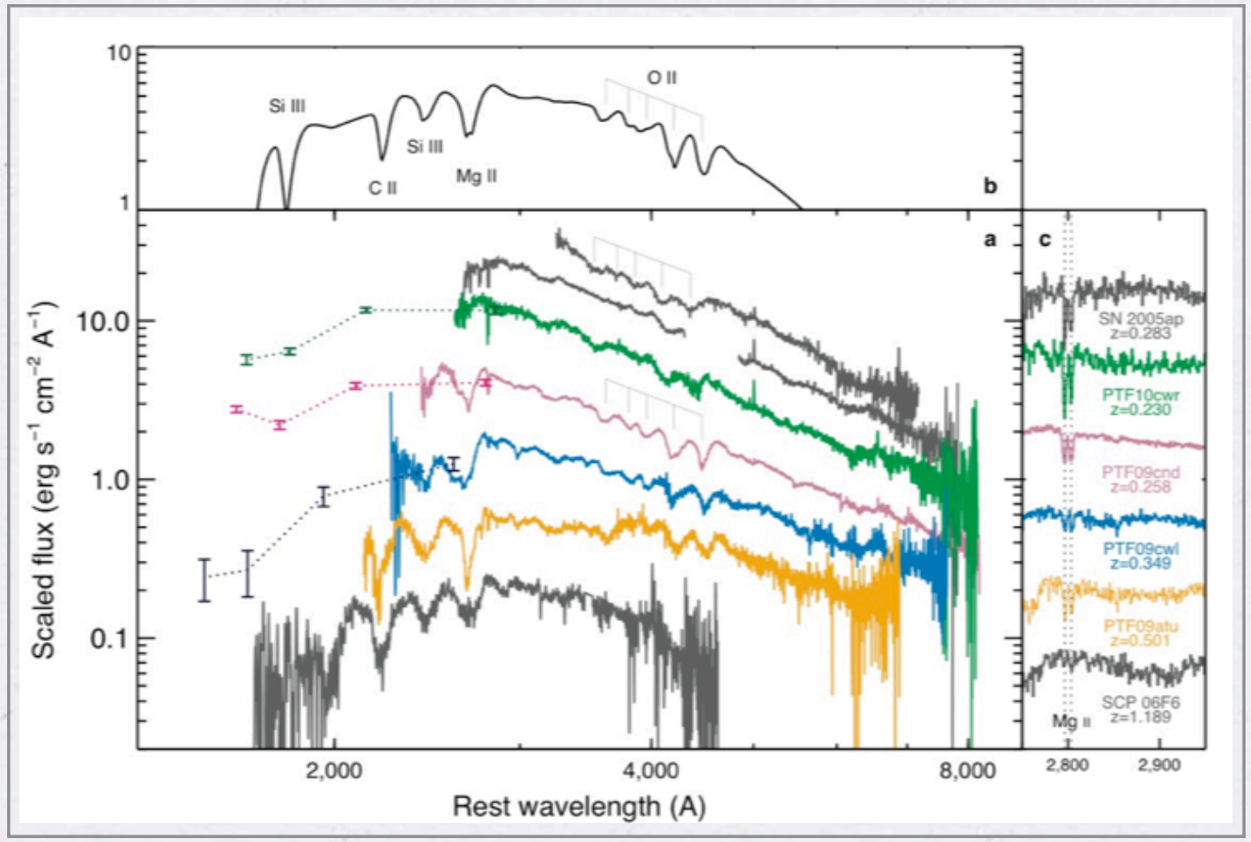
Super-luminous supernovae

1. ^{56}Ni-powered pair-production SN?
2. Pulsational pair-instability events?
3. Magnetar-powered CCSNe?
4. Ejecta-CSM interacting CCSNe?
5. A combination of above scenarios?





Quimby+ 2011, Nature, 474, 487; Dong+ 2016, Science, 351, 257

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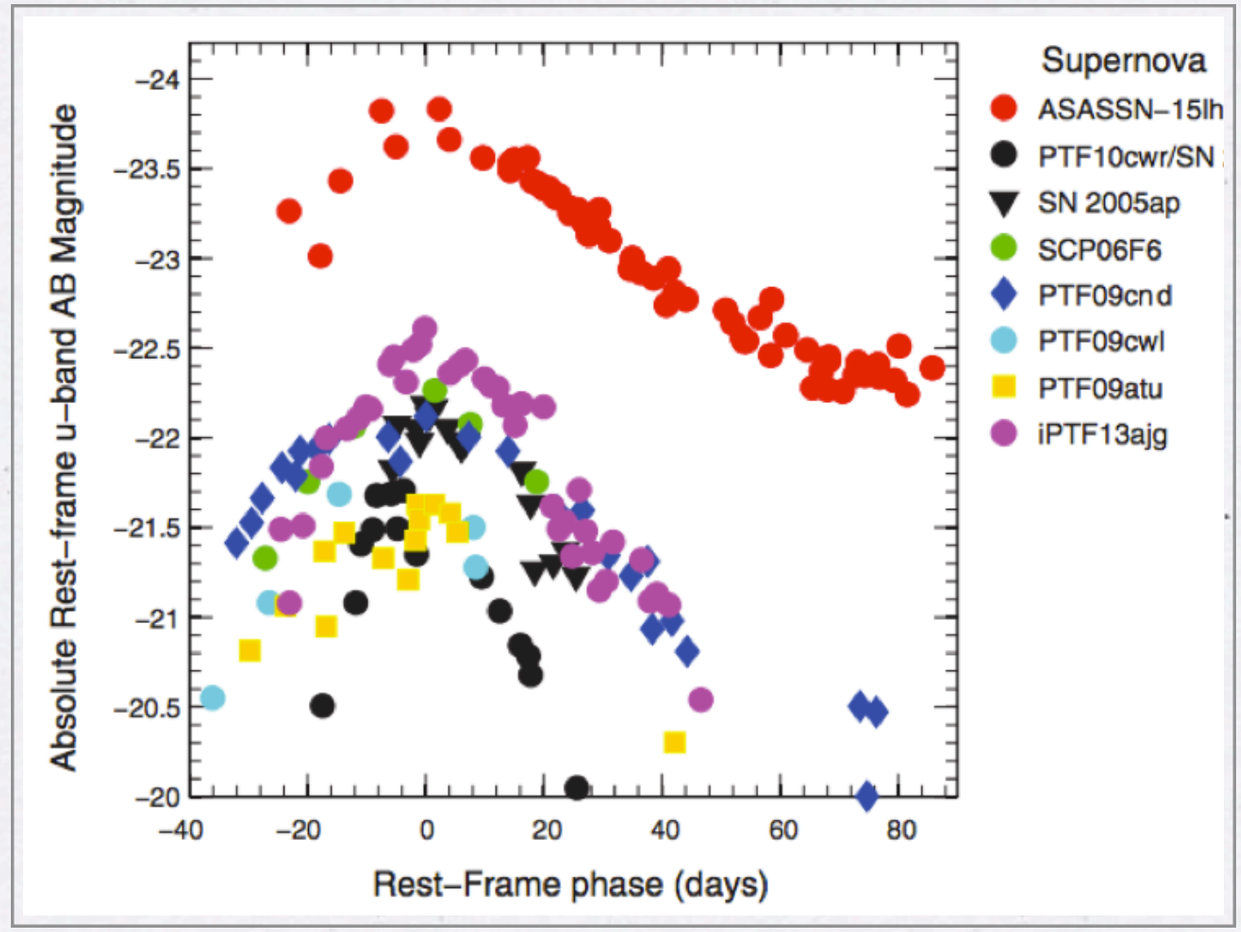

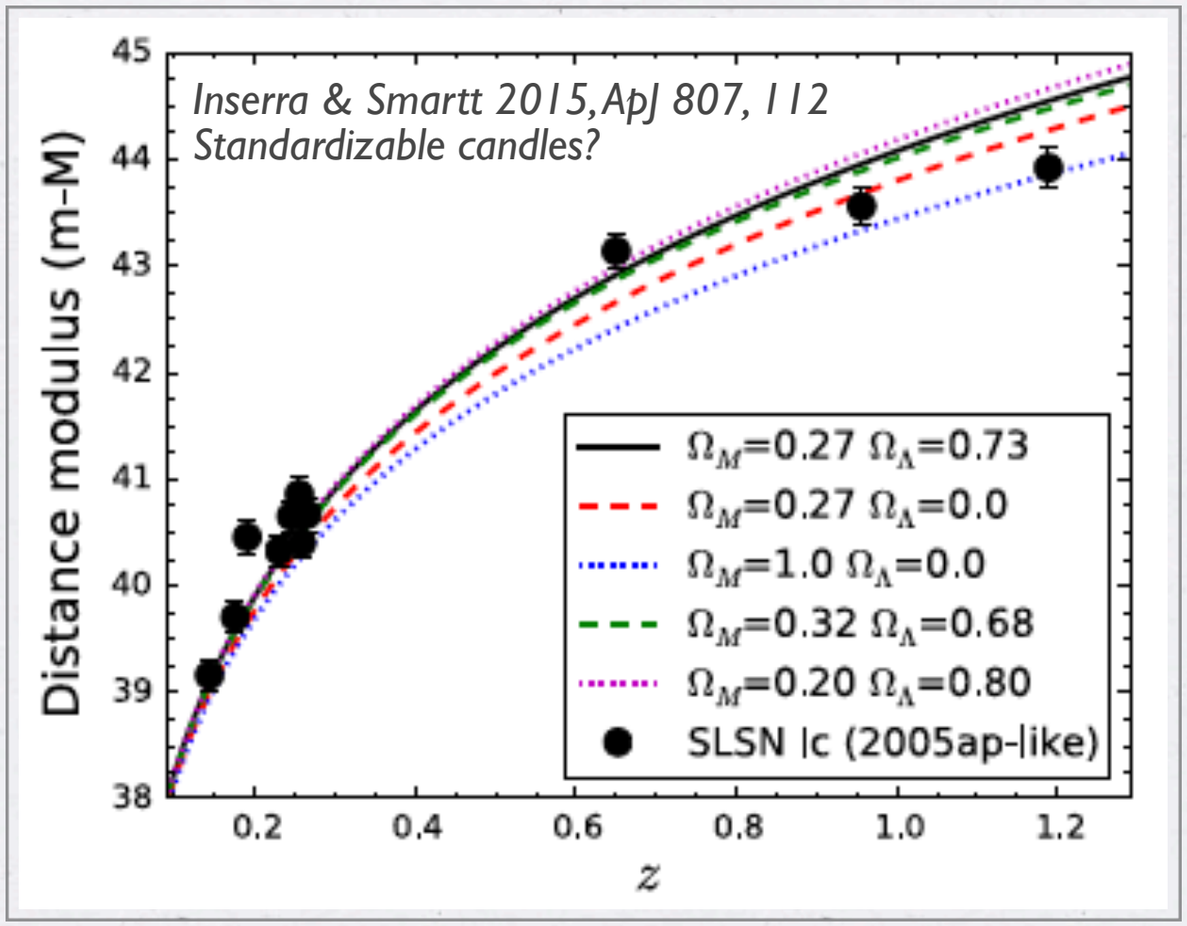

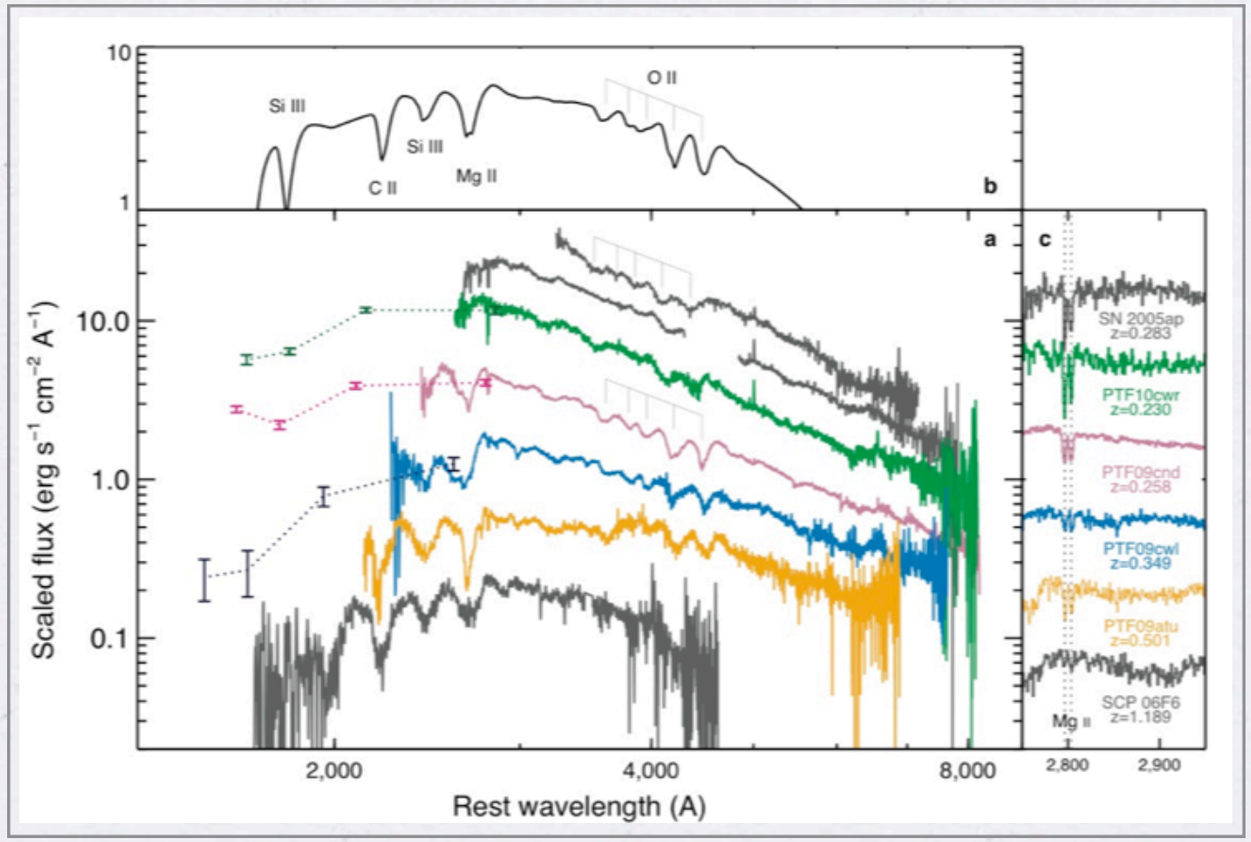

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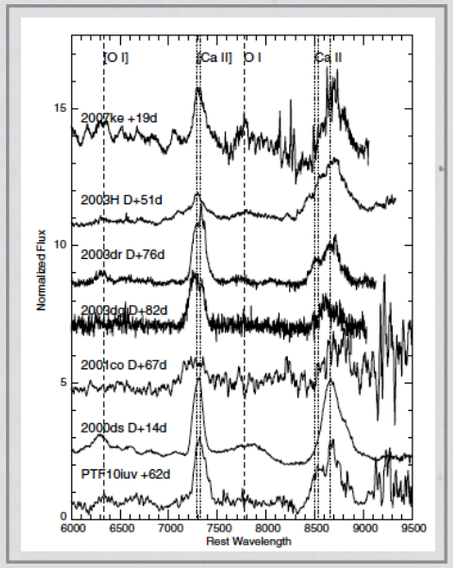
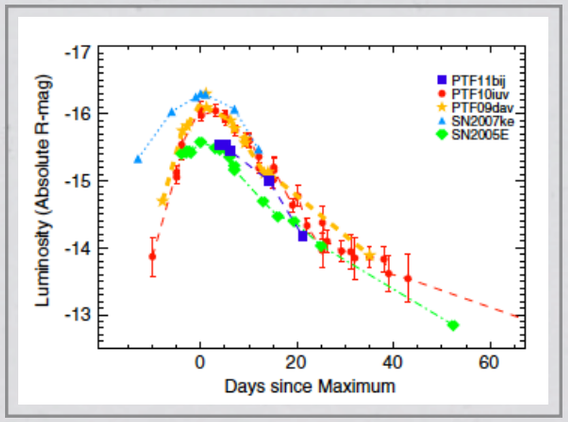
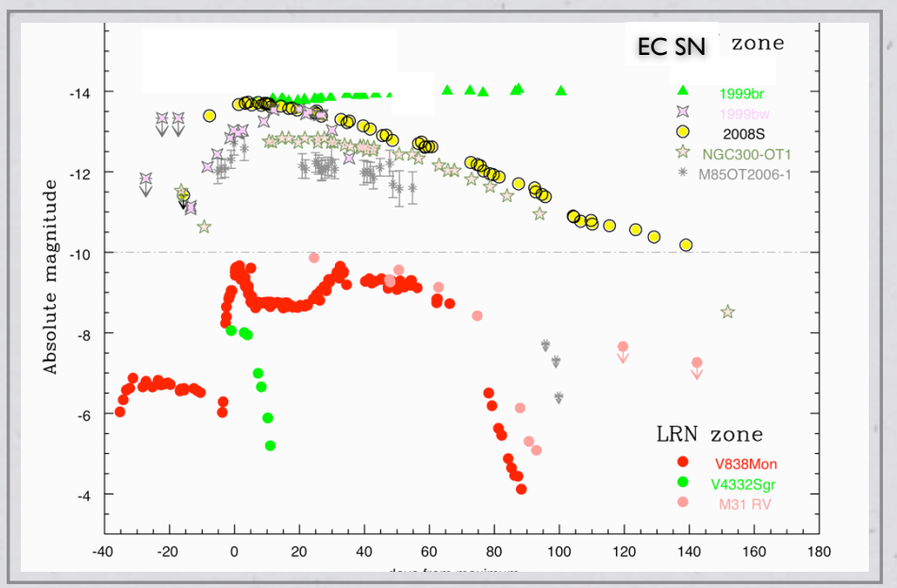
Intermediate luminosity optical transients



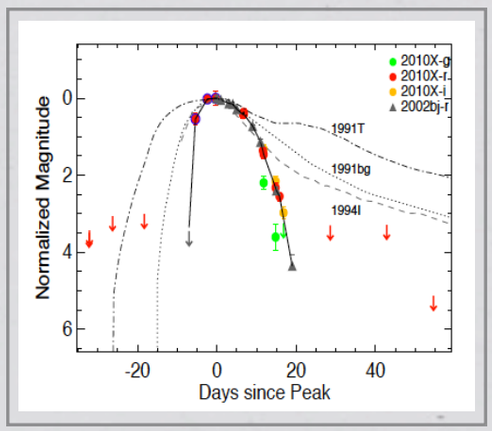


Kasliwal+ 2012



Pastorello 2012

* Ca-rich spectra, fast & faint, no star forming hosts: WD explosions or faint core-collapse?



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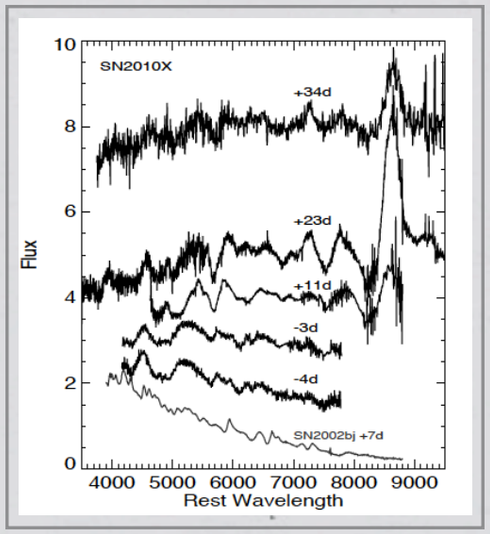


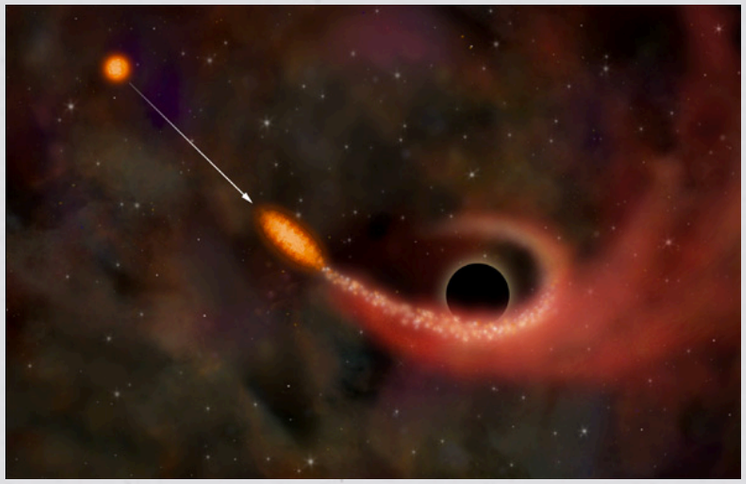
* Very fast SNe I: He shell detonation (.Ia SNe)?

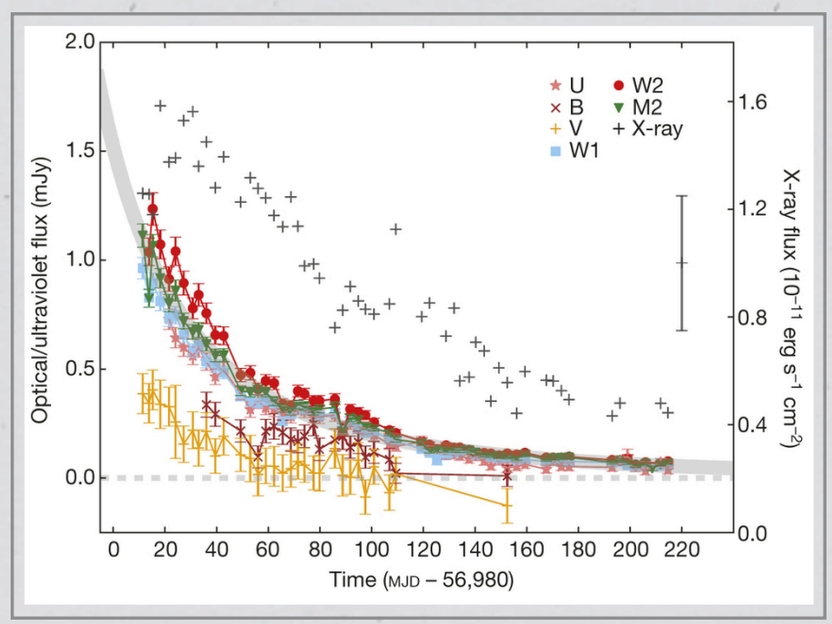
* Faint SNe IIn, with lightcurve decline consistent with the ^{56}Co decay and massive (dust-enshrouded) progenitors - probably EC-SNe (e.g. *Botticella+ 2010*)

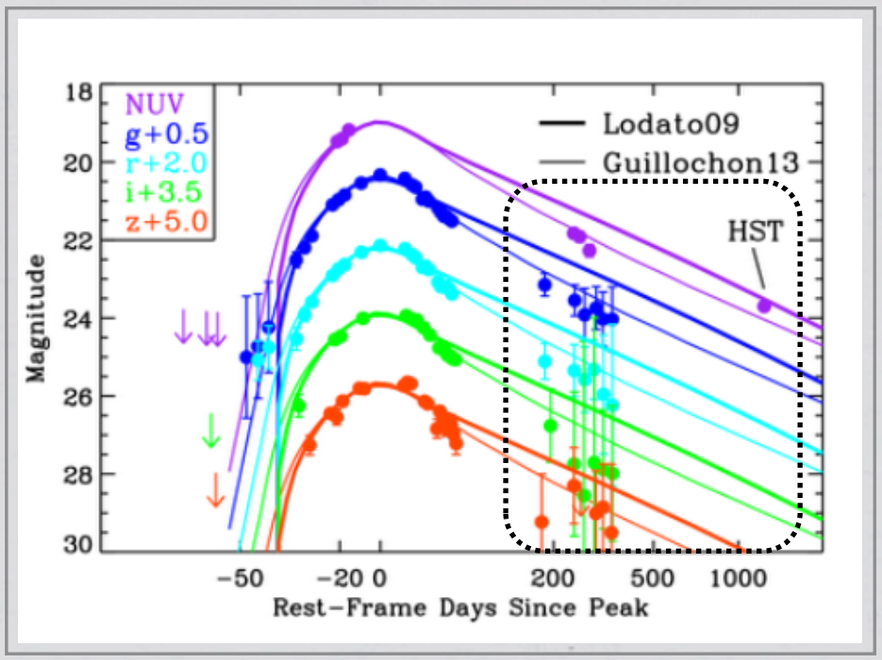
* Luminous Red Novae, with double-peaked lightcurves - probably mergers (e.g. V838 Mon, *Munari+ 2002*; NGC4490-2011OT, *Smith+ 2016*)

Tidal Disruption Events

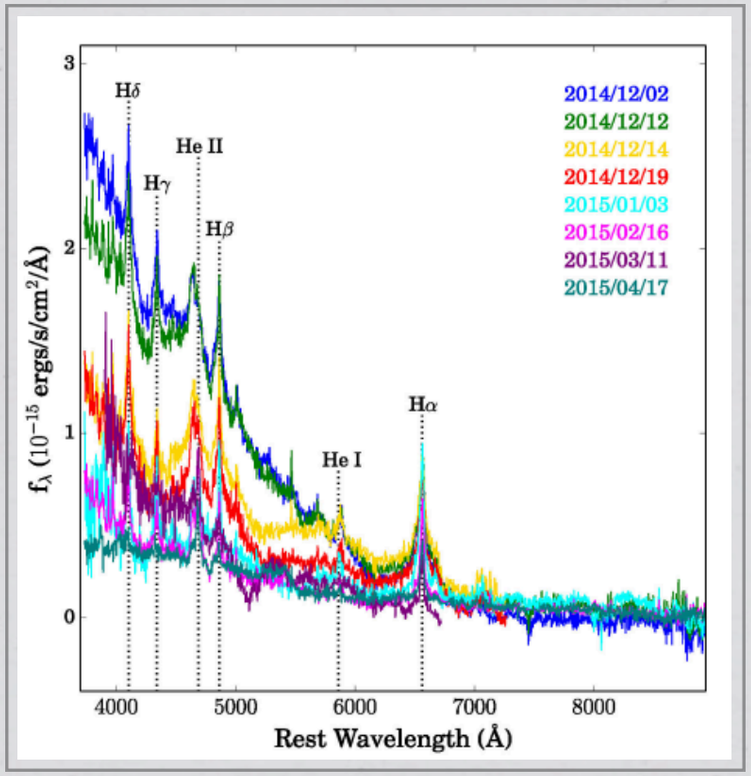
TDEs result from a violent stellar encounter with a massive BH





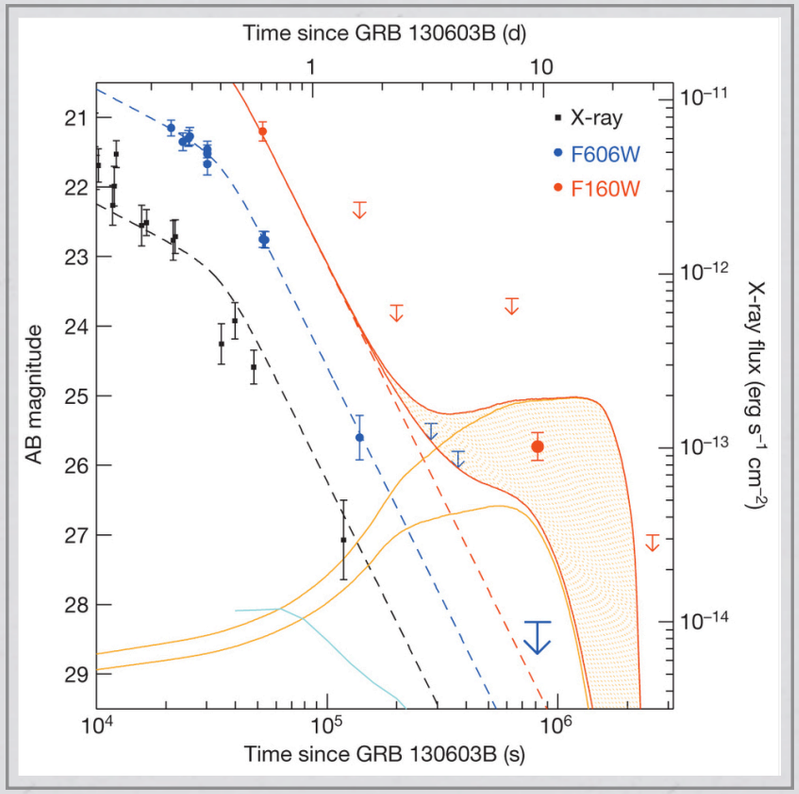


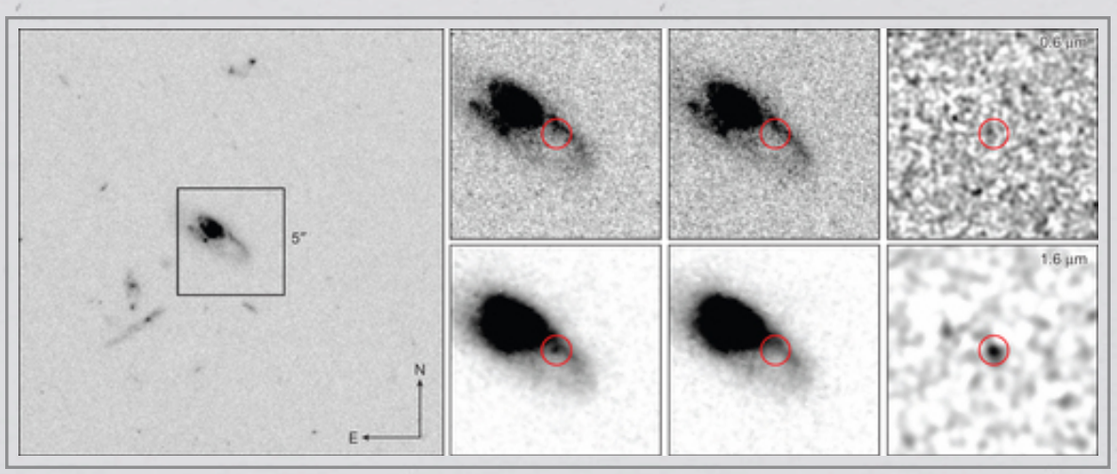
Late accretion! *Gezari+ 2015*



Miller+ 2015, Nature
Holoinen+ 2016, MNRAS

New frontieres with LSST

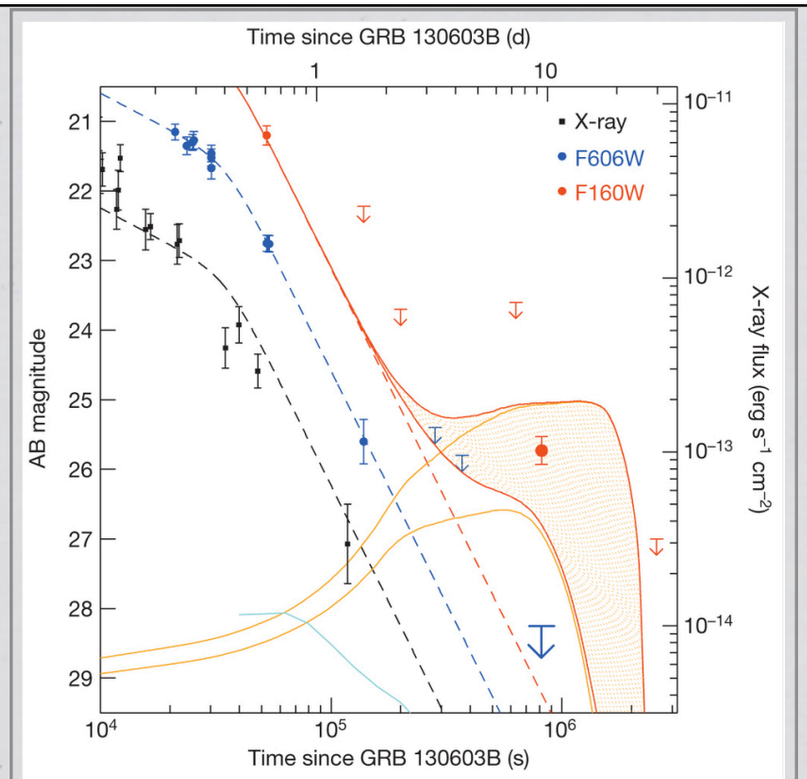


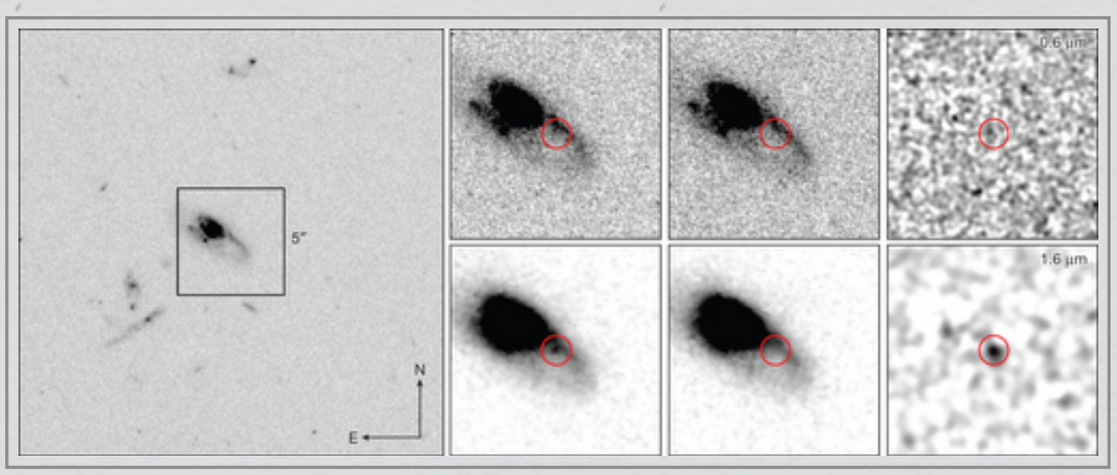


- Optical counterparts of gravitational waves (none so far, but hot topic)
- Dark SNe from massive stars (no solid detection; e.g. *Kochanek 2008, 2014; Gerke+ 2015*)
- Pair-production SNe from metal-free ultra-massive stars (no solid detection)
- Kilonovae /Macronovae in S-GRBs (a couple of claims; *Tanvir+ 2013, Nature 500, 547*)
- Ultra-fast transients: the unknown

New frontieres with LSST

SPECTROSCOPIC FACILITIES ARE ESSENTIAL FOR OUR GOALS!





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Summary

What I can offer

* I can invest 0.75 full-time equivalent to work on science based on LSST data
* Preparatory activity: characterization of the most important families of transients.
* Preparatory activity: database with comparison tools and for ingesting new data.
* I have access to low-to-mid size telescopes for photometric and spectroscopic follow-up of bright targets.

What I need

* A large FTE investment on LSST will limit my competitivity to financial resources through other research projects. For this reason, grants for man-power (e.g. post-doc personnel), hardware, mobility (to join meetings, conferences and observational runs) are necessary.
* I need spectroscopic facilities for classification and follow-up of relatively faint targets in the optical to NIR domains (e.g. SOXS) or LBT for very faint targets.