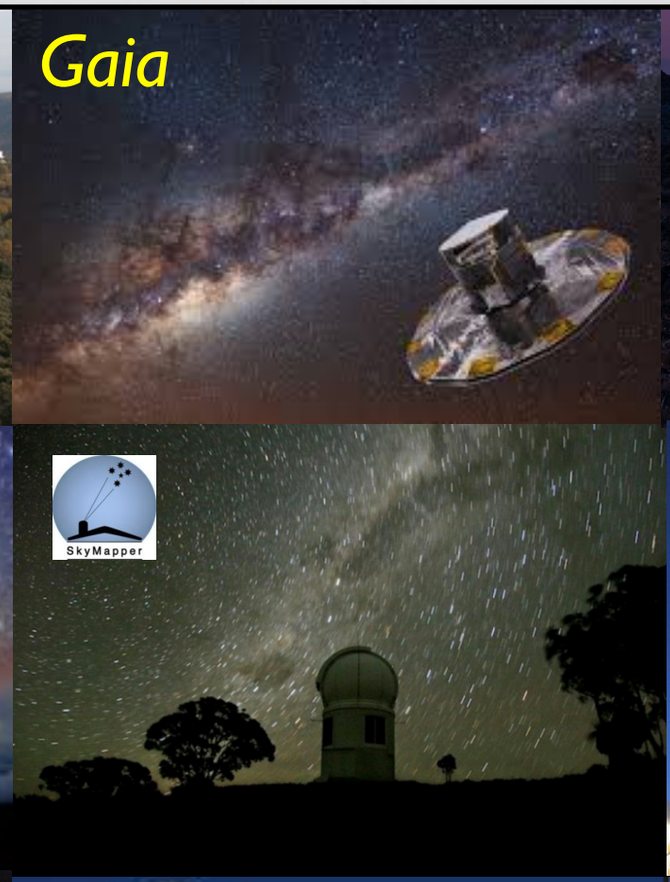
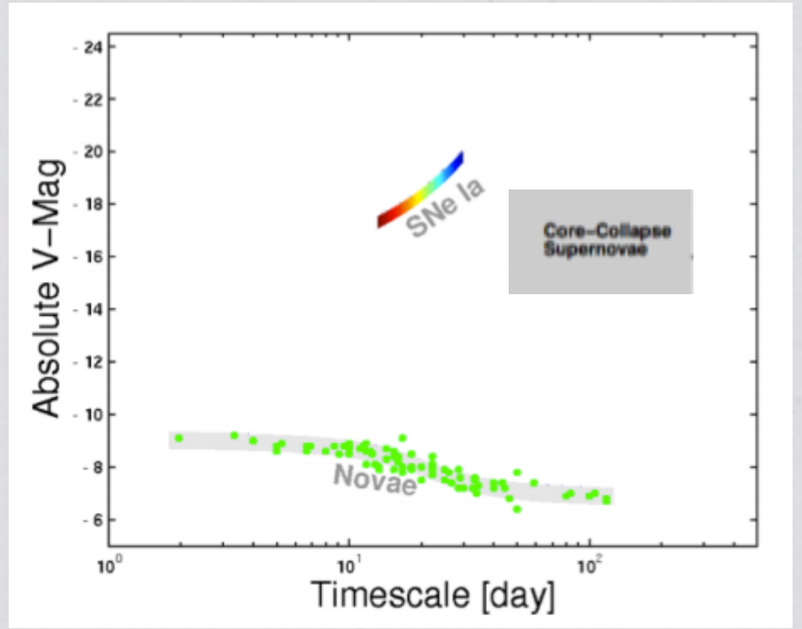
Multi-wavelength characterization of transients

ANDREA PASTORELLO (INAF-OAPd)

A golden age to study the transient sky
(mostly with small-to-mid size telescopes)



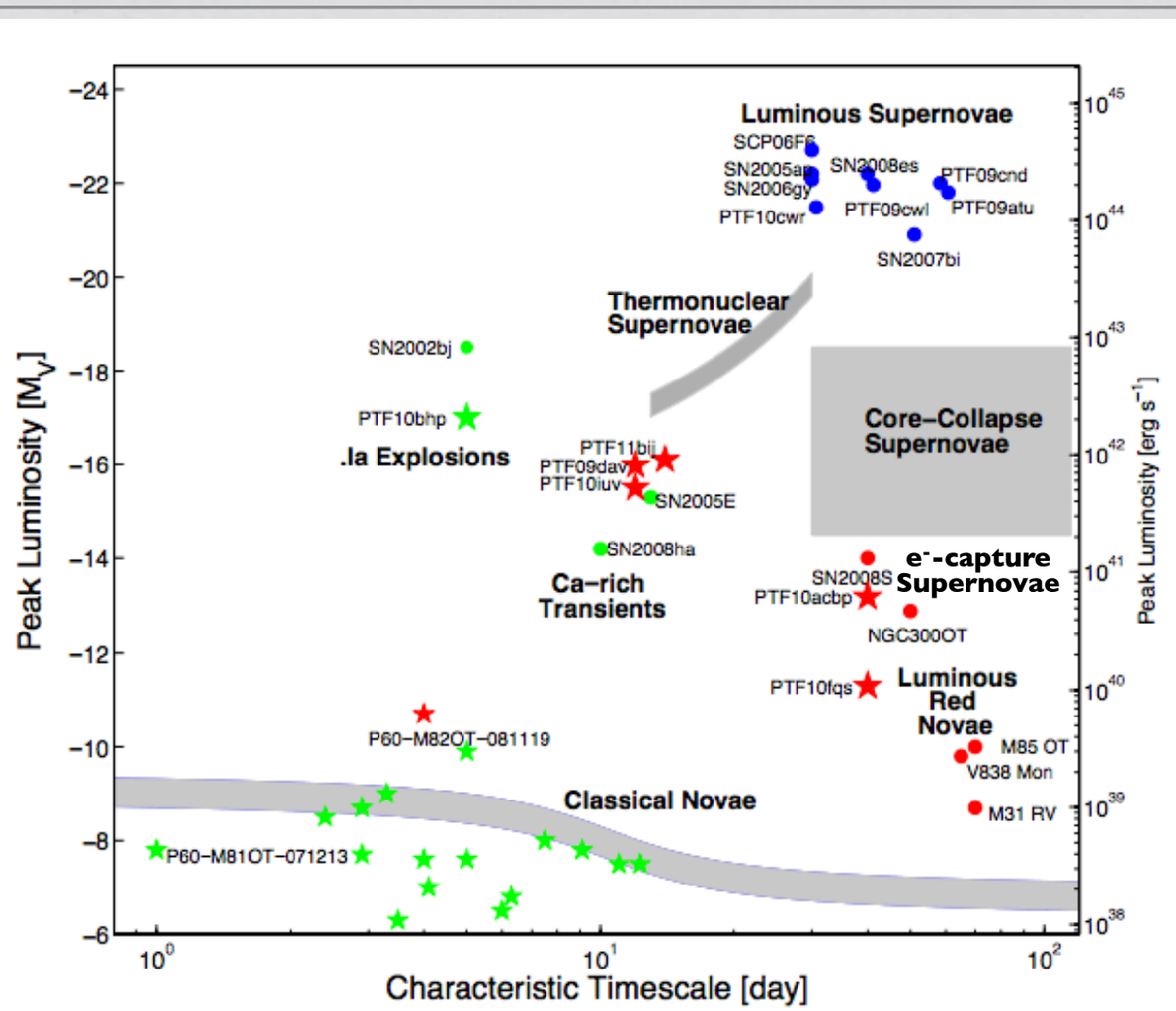
New types of stellar transients



Credits: S. Kulkarni's team

The current transient sky: populating the phase diagram with new stellar transients

The transient sky
(until a decade ago)



New types of stellar explosions

A challenge for the next decade!...

* 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.

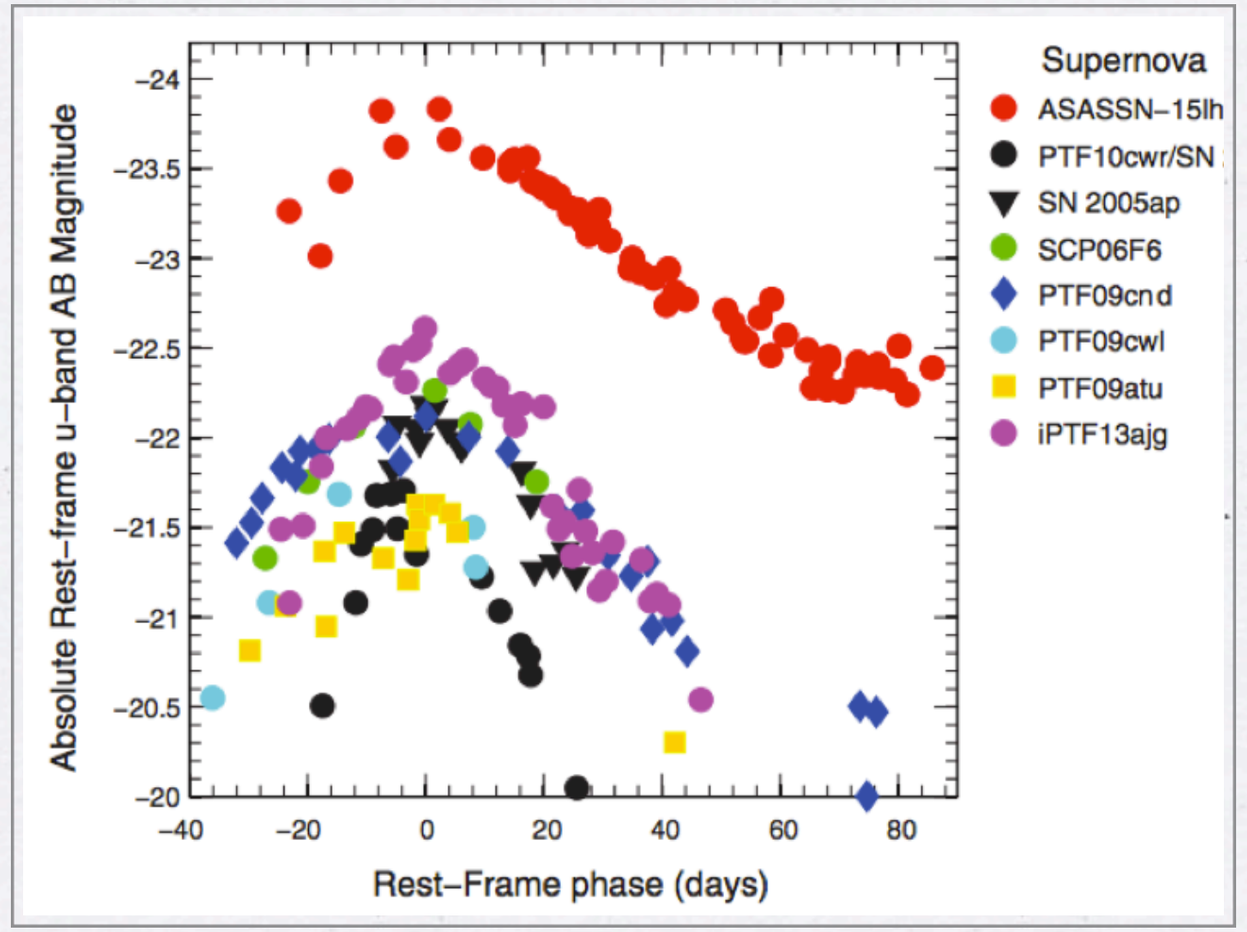
* Fast evolving transients in the high-frequency, optical and radio domains; dark/failed SNe; optical counterparts of GWs: searches to down, 0-1 candidate per type.

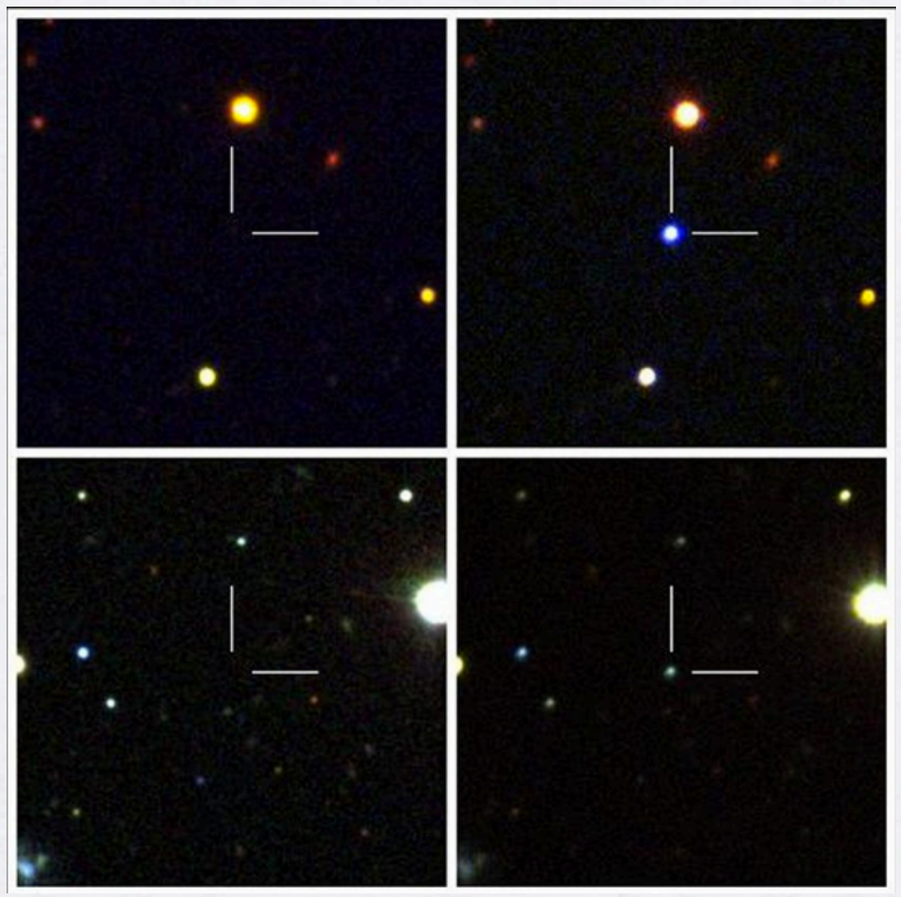
* Ultra-fast evolving transients: the unknown - the future...

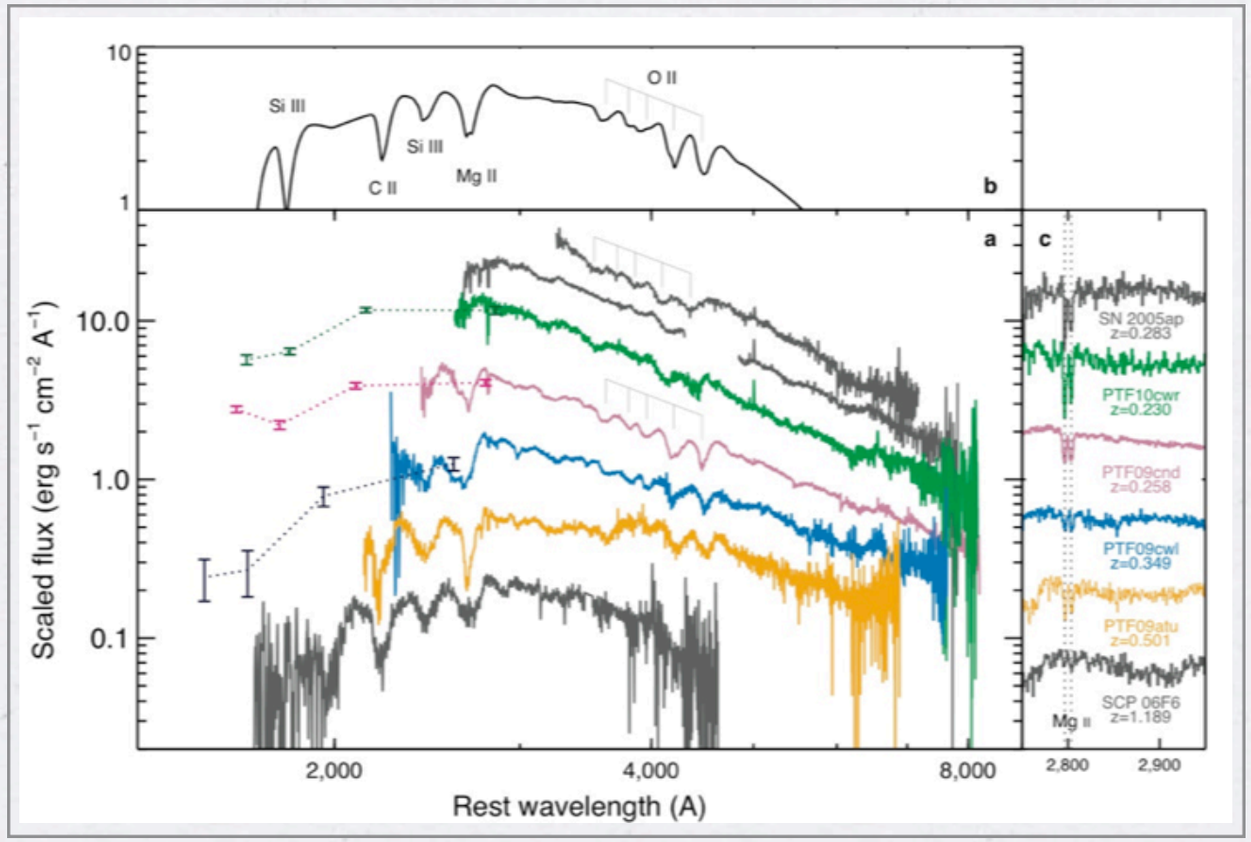
Super-luminous SNe

Uncertain explosion mechanism:

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







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

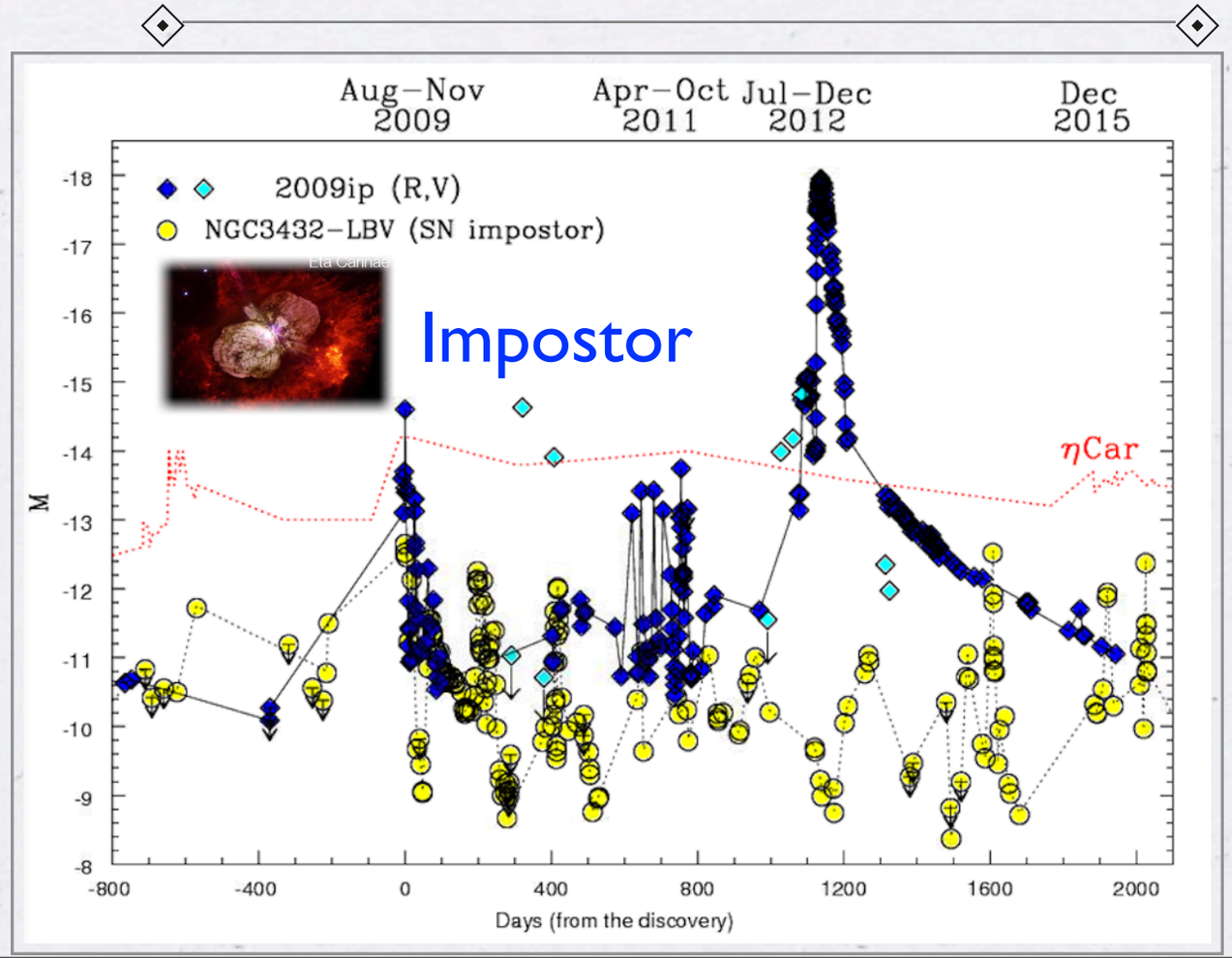
Pre-SN stellar instabilities

(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,
Fraser+ 2013,15;
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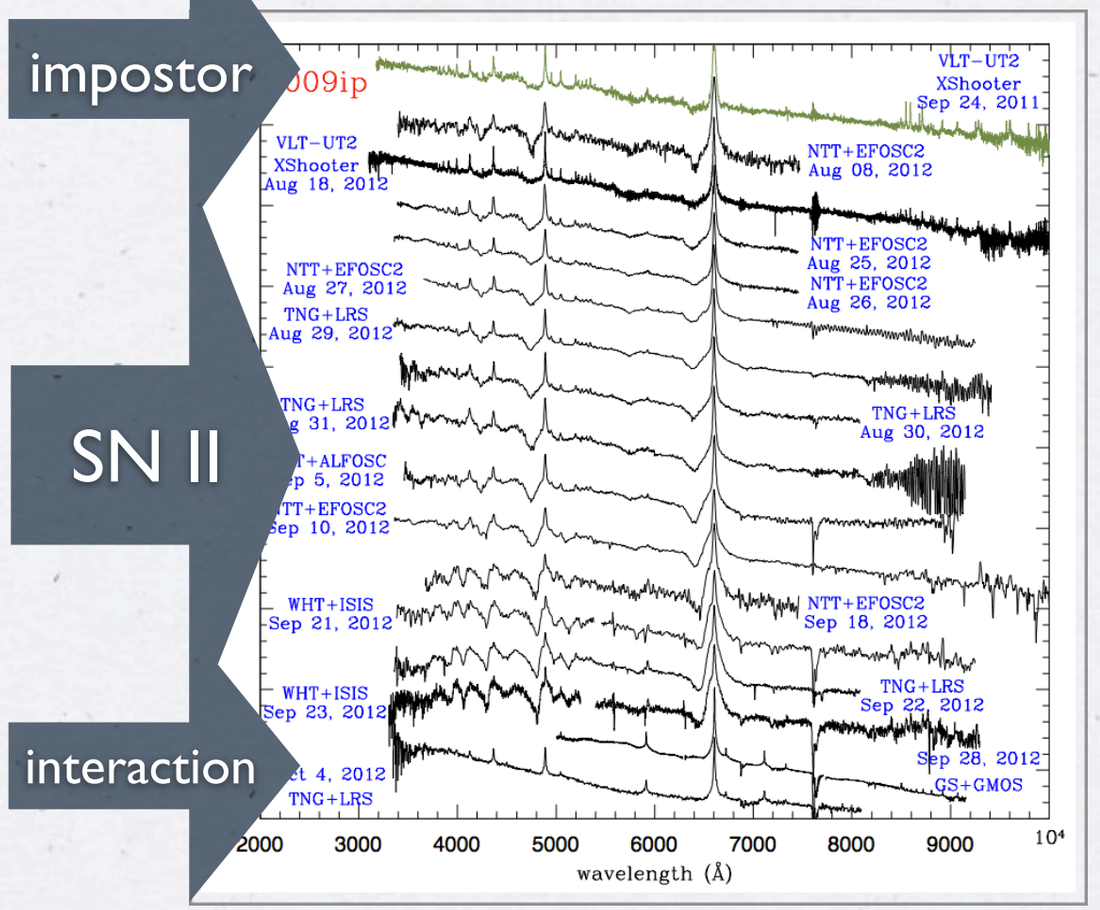

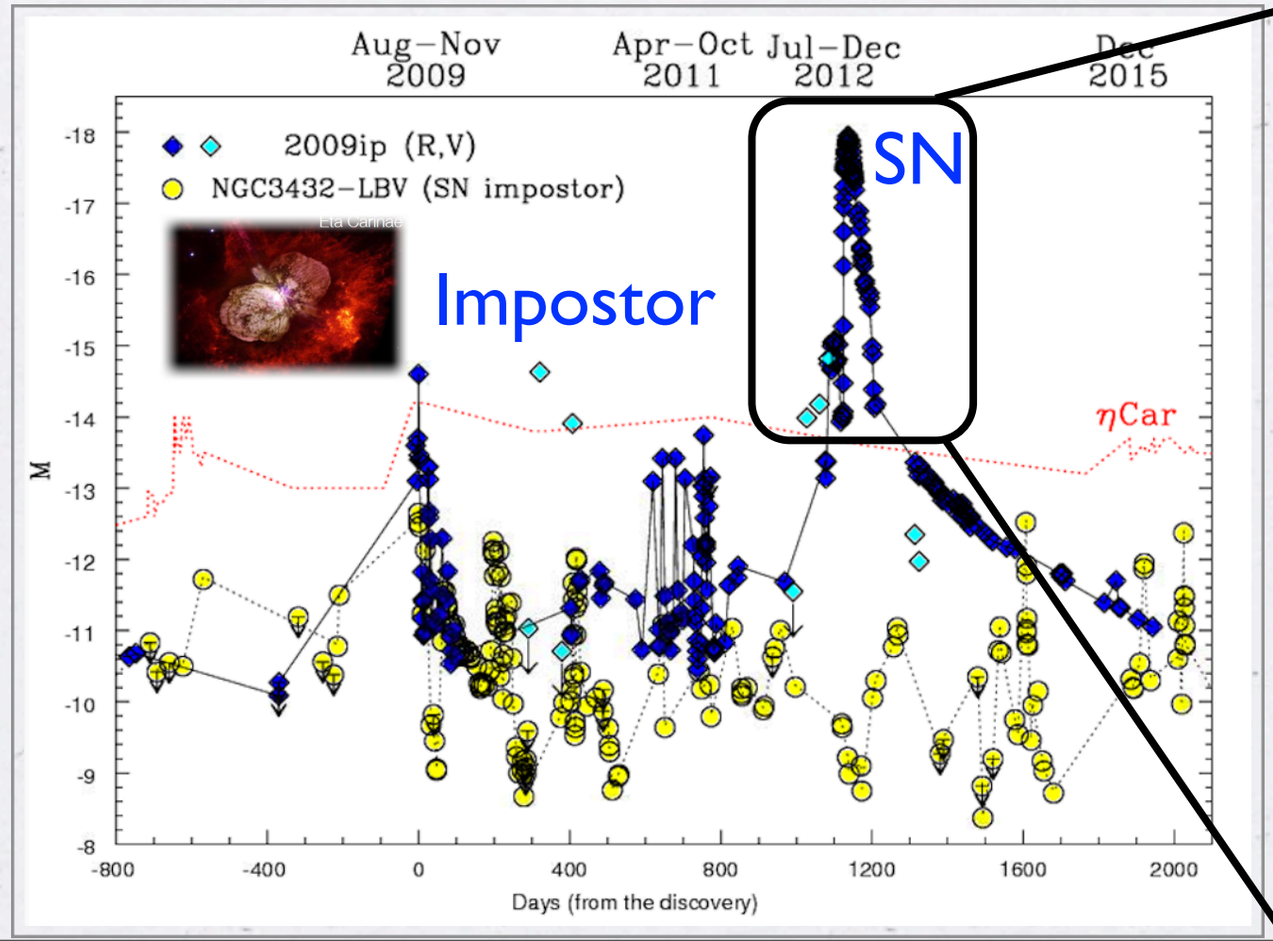

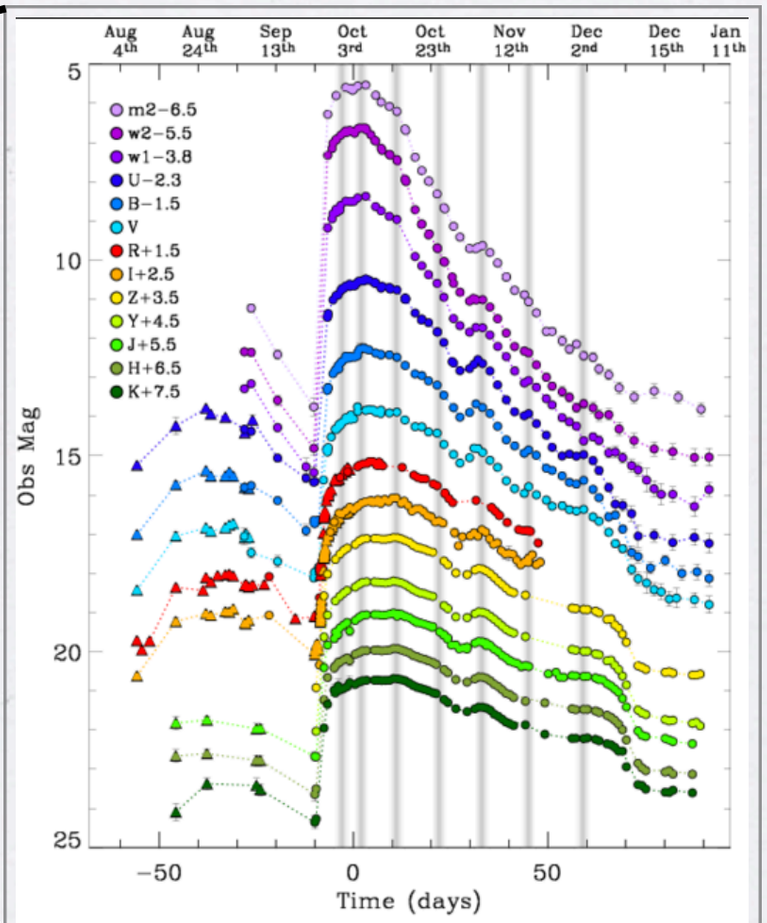

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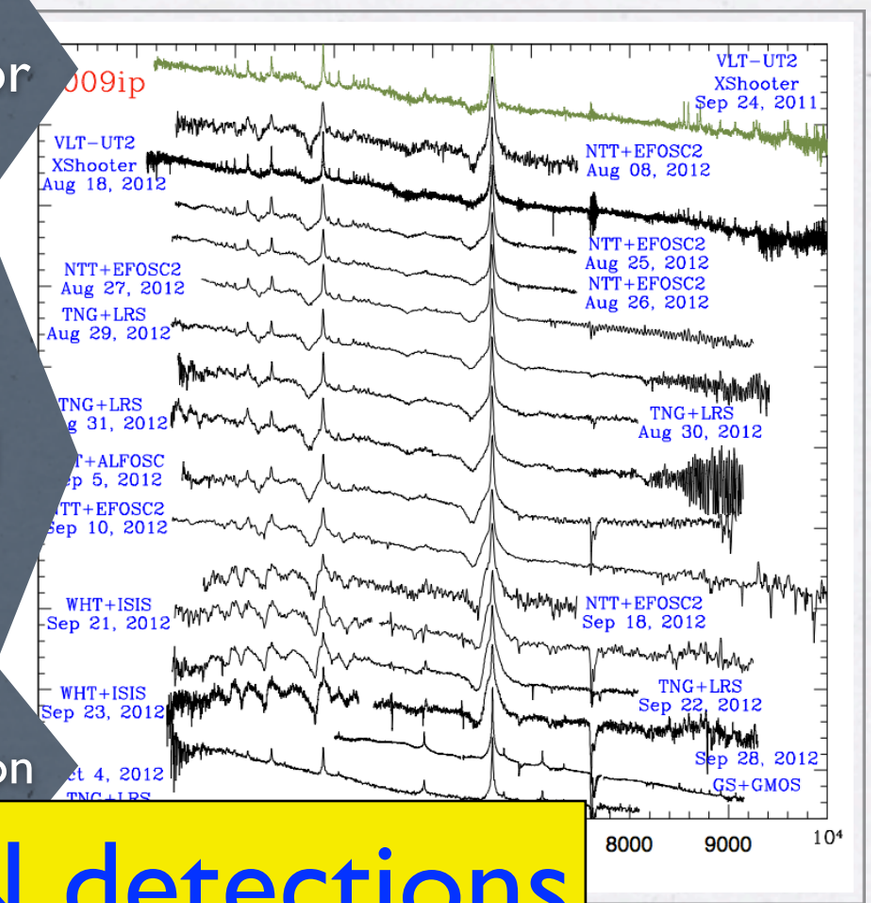
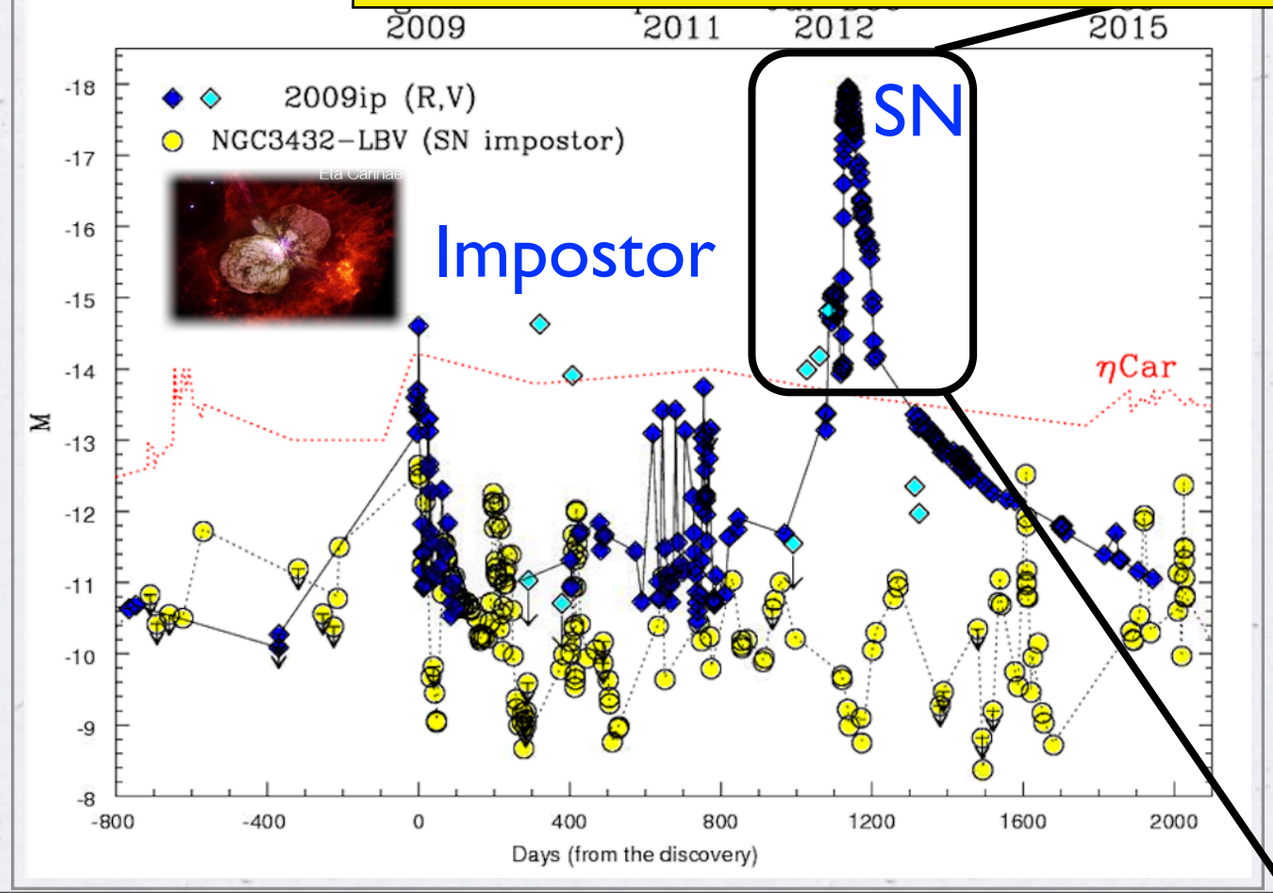
impostor

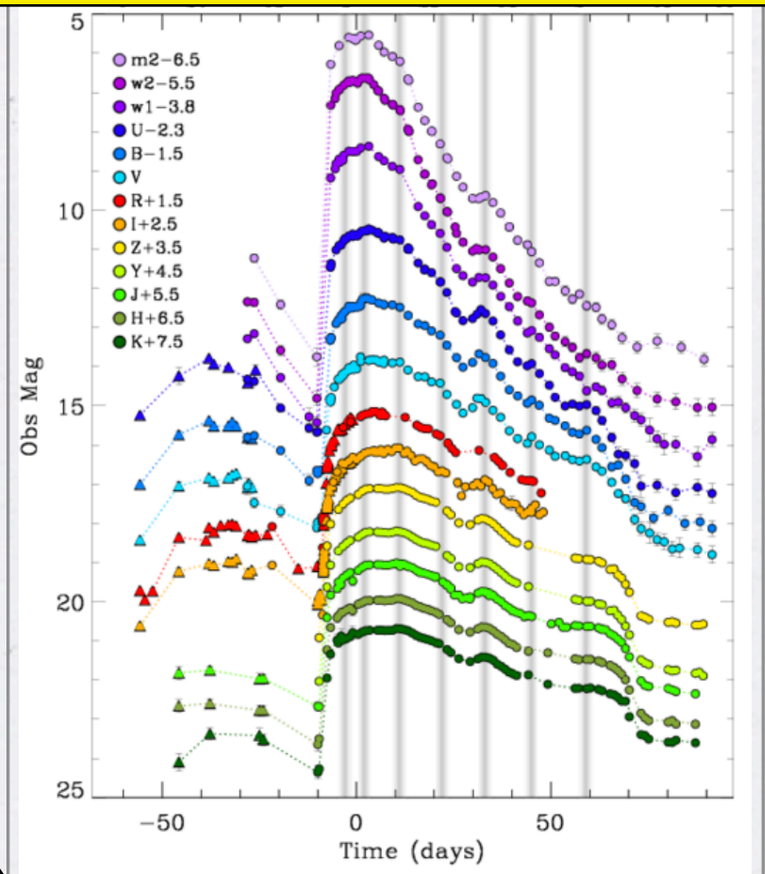
SN II

interaction



<10 SNe IIn with pre-SN detections





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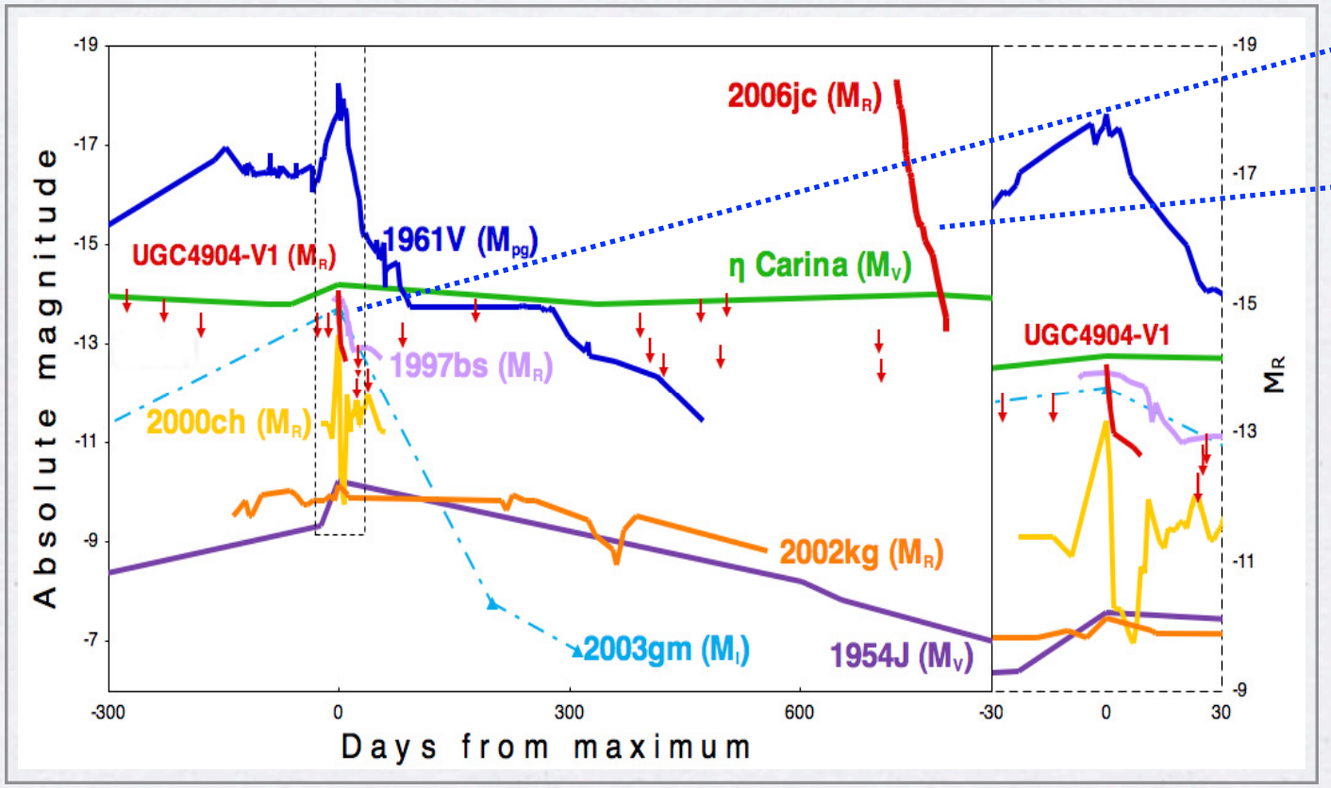
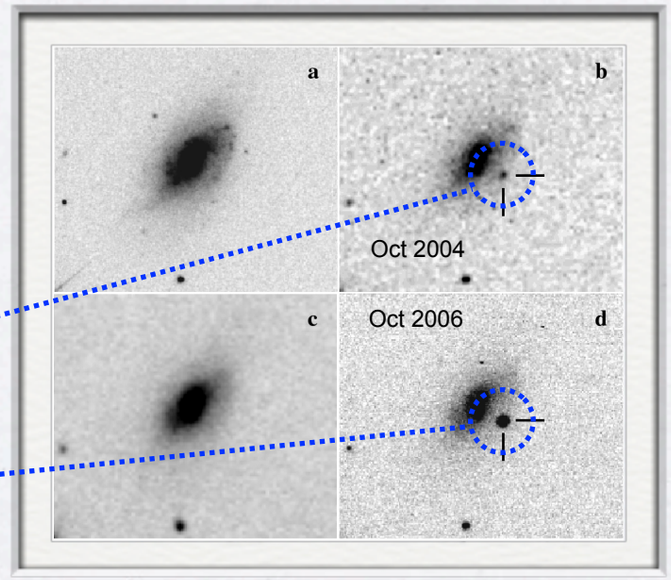
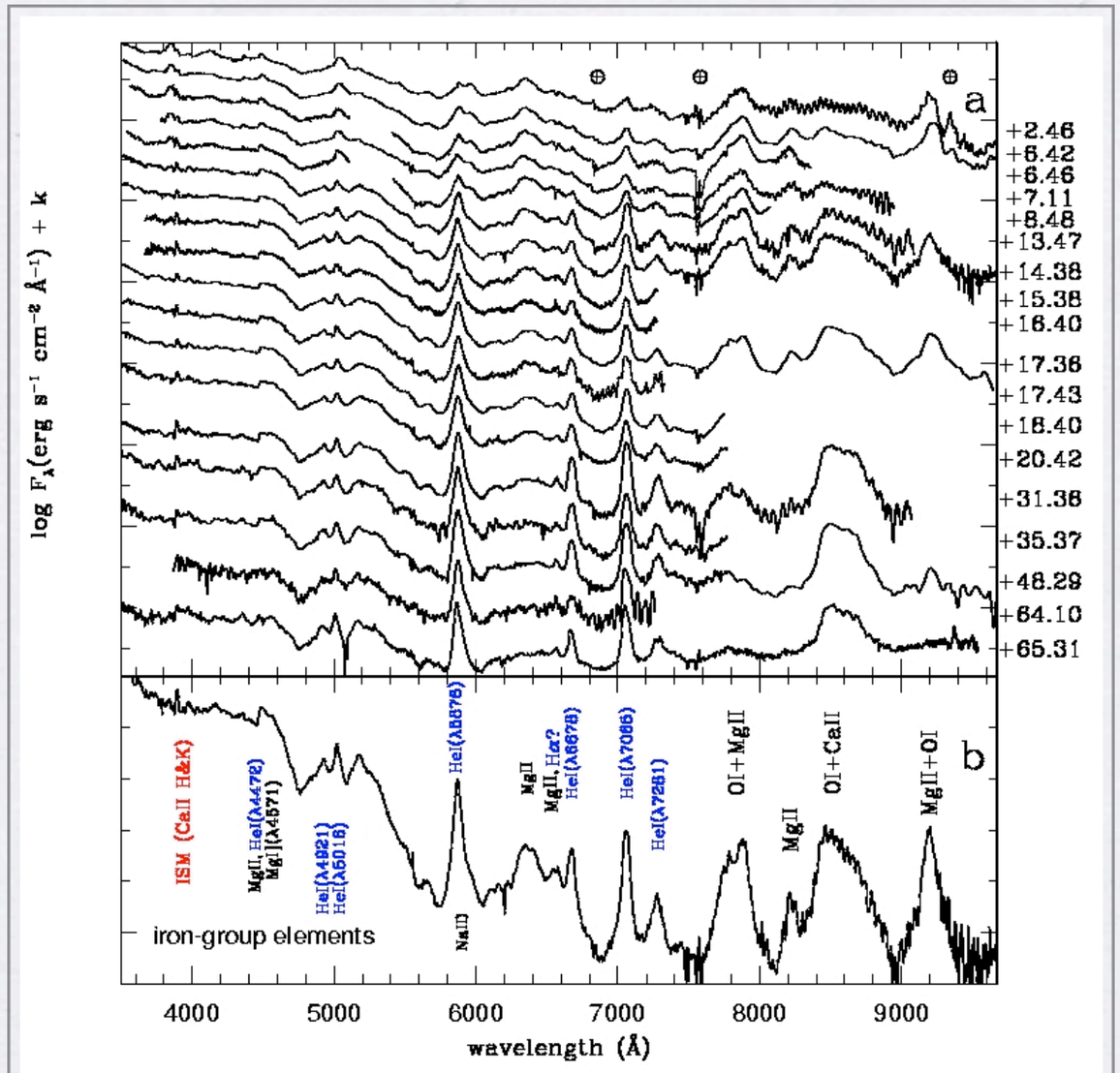


Pastorello+ 2007, Nature, 447, 829





2004 => outburst of a Wolf-Rayet (WN-type) star

2006 => SN explosion as SN Ib/c interacting with He-rich CSM

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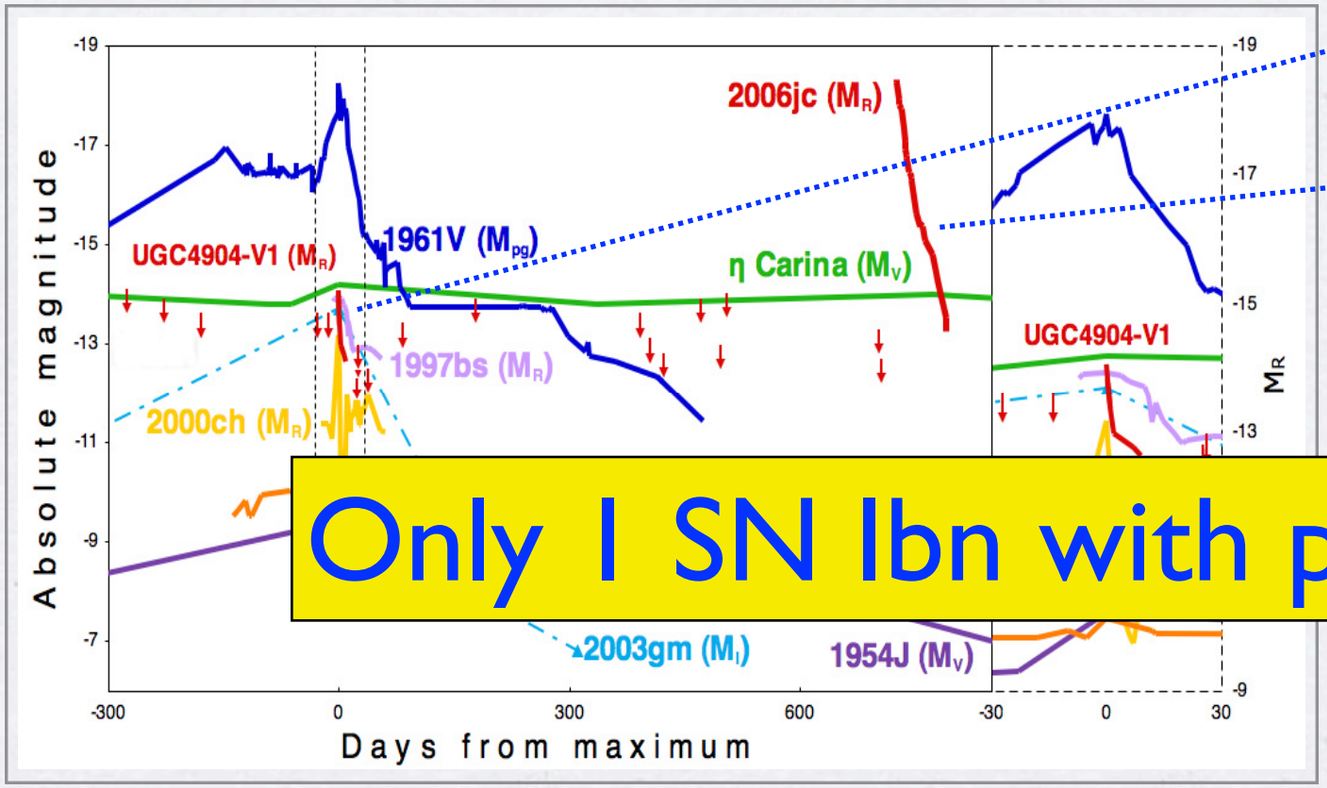
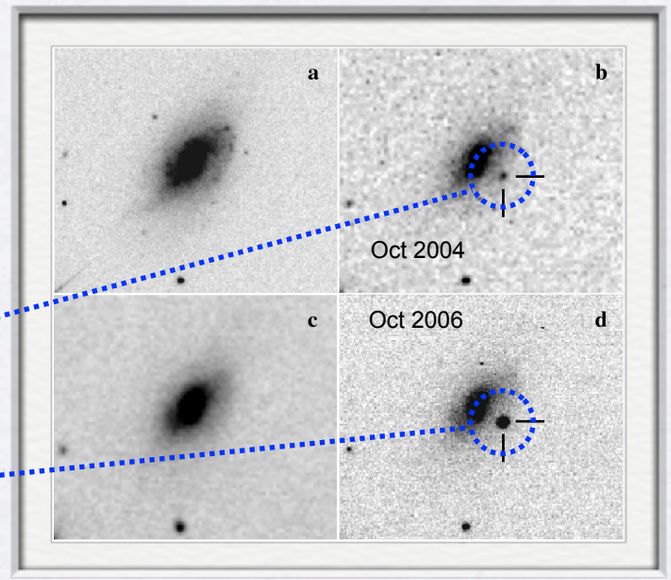
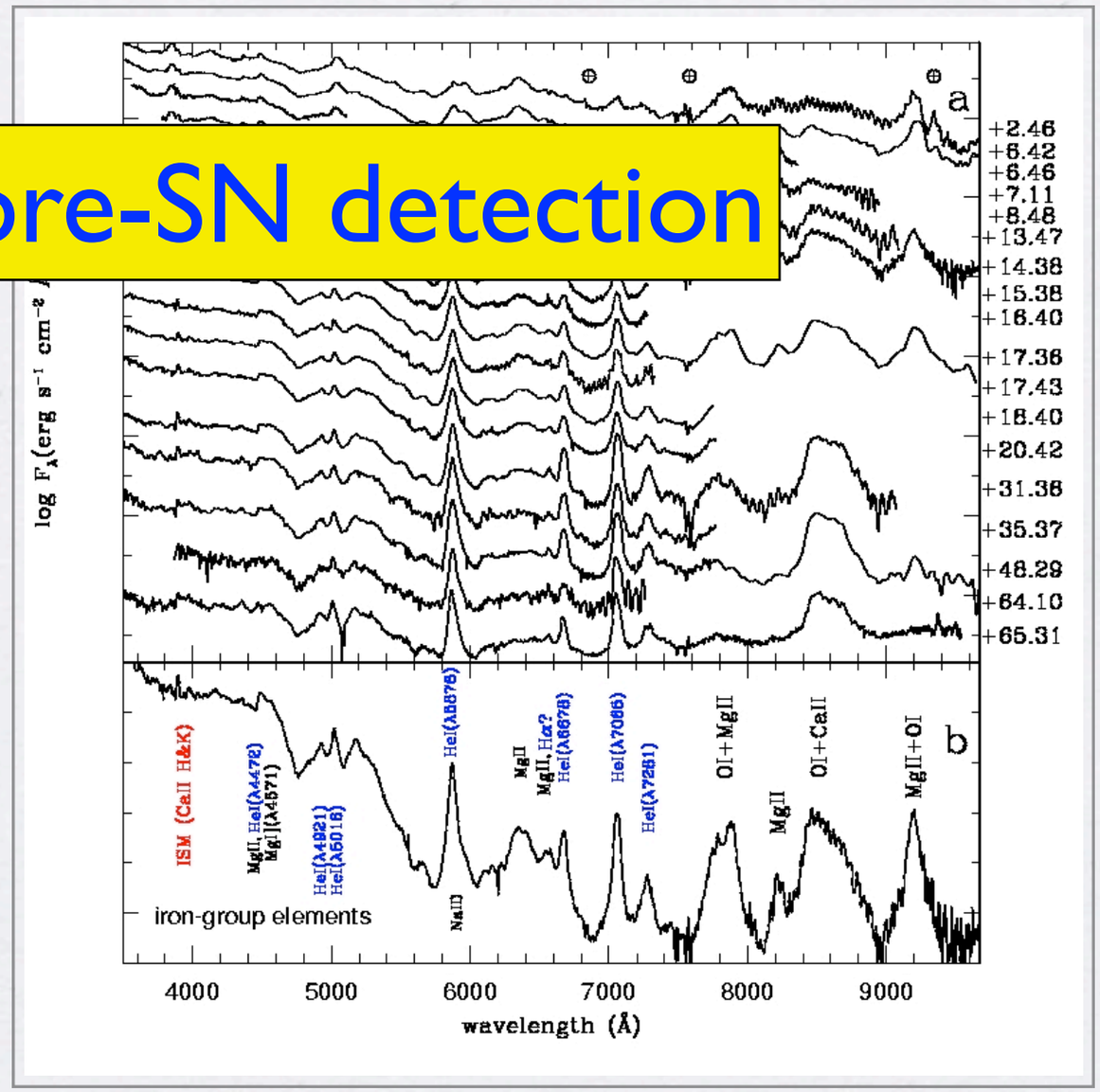




Only 1 SN Ibn with pre-SN detection



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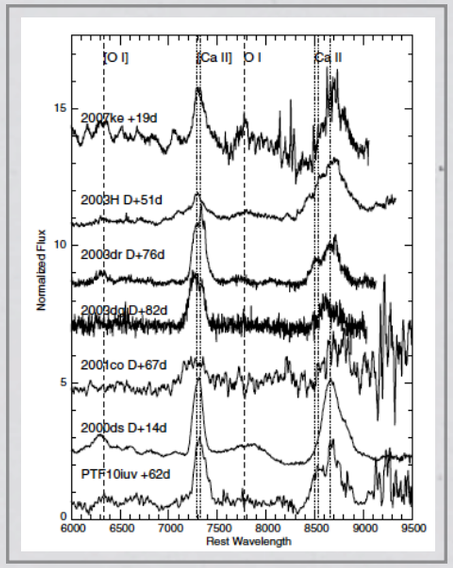
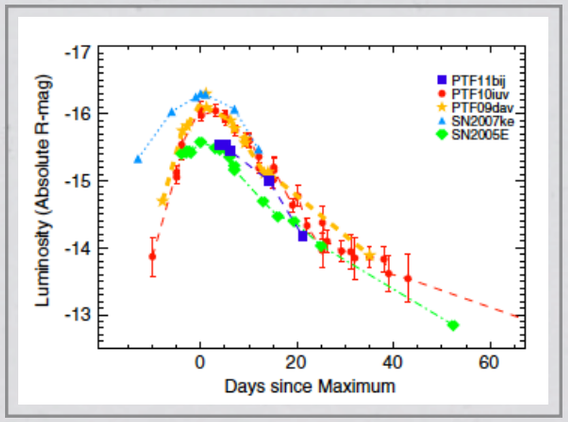
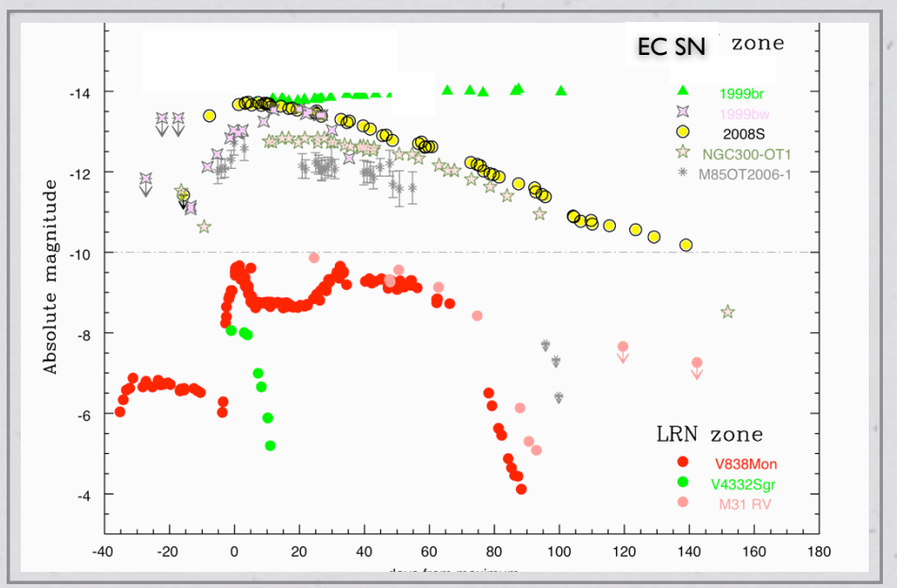
Intermediate luminosity optical transients



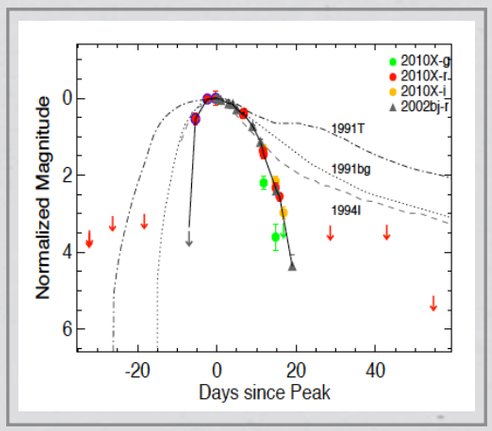


Kasliwal+ 2012



Pastorello 2012

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



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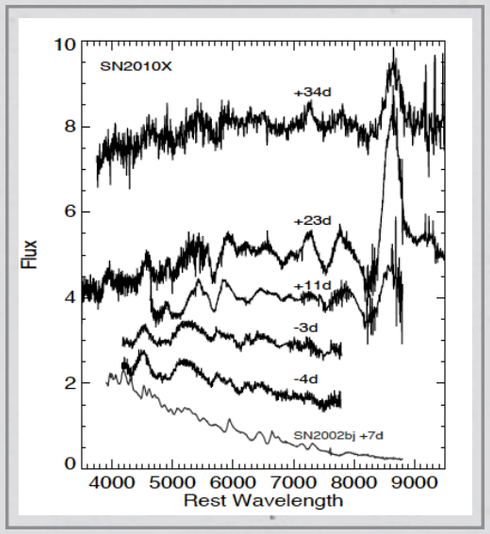


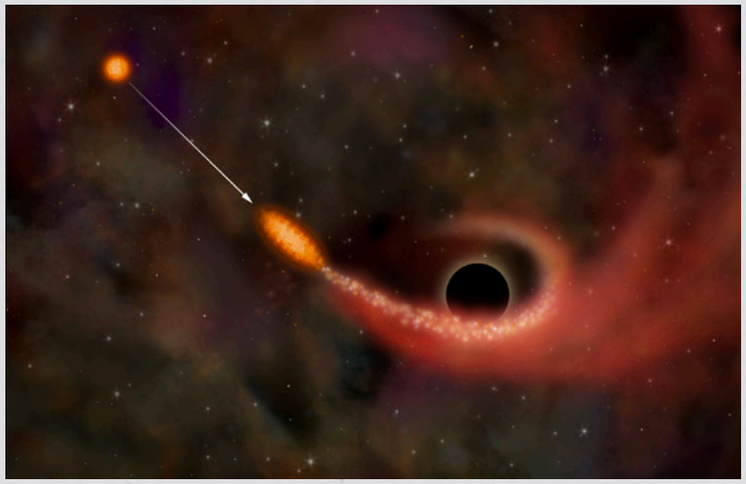
* Very fast SNe I: He shell detonation (.Ia SNe)?

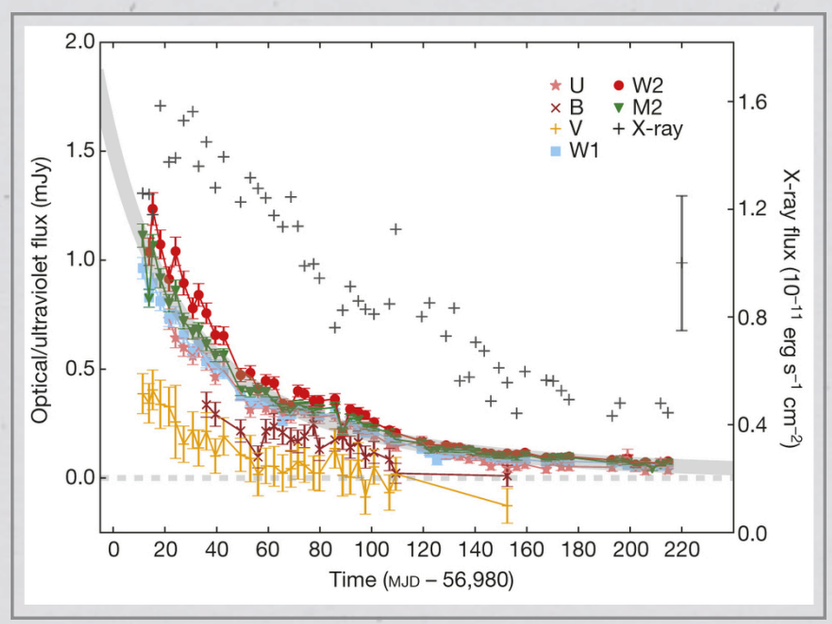
* Faint SNe IIn, with lightcurve decline consistent with the ^{56}Co decay and massive (dust-enshrouded) progenitors - probably EC-SNe (e.g. Botticella+ 2010)

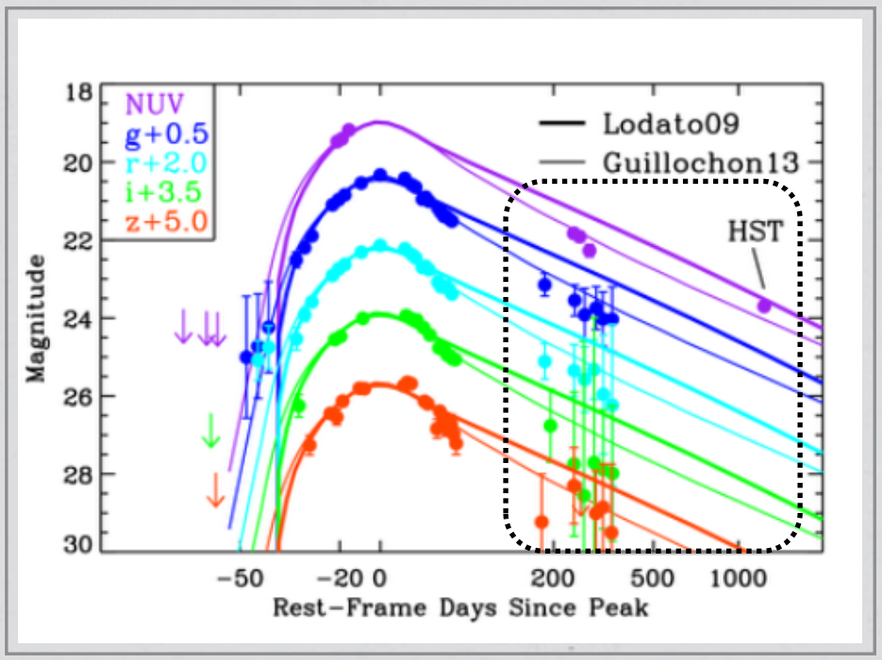
* Luminous Red Novae, with double-peaked lightcurves - probably mergers (e.g. V838 Mon, Munari+ 2002)

Tidal Disruption Events

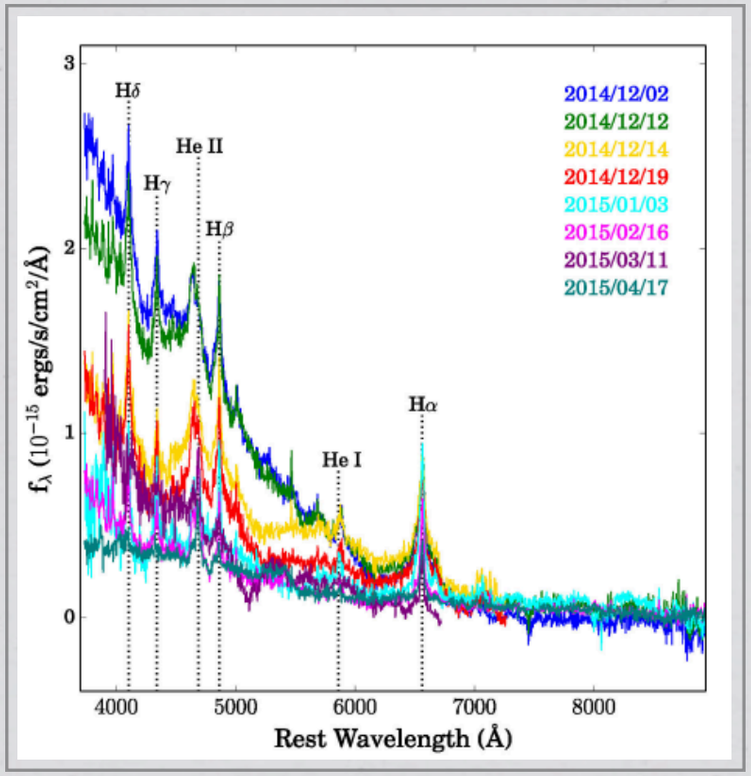
TDEs result from a violent stellar encounter with a massive BH





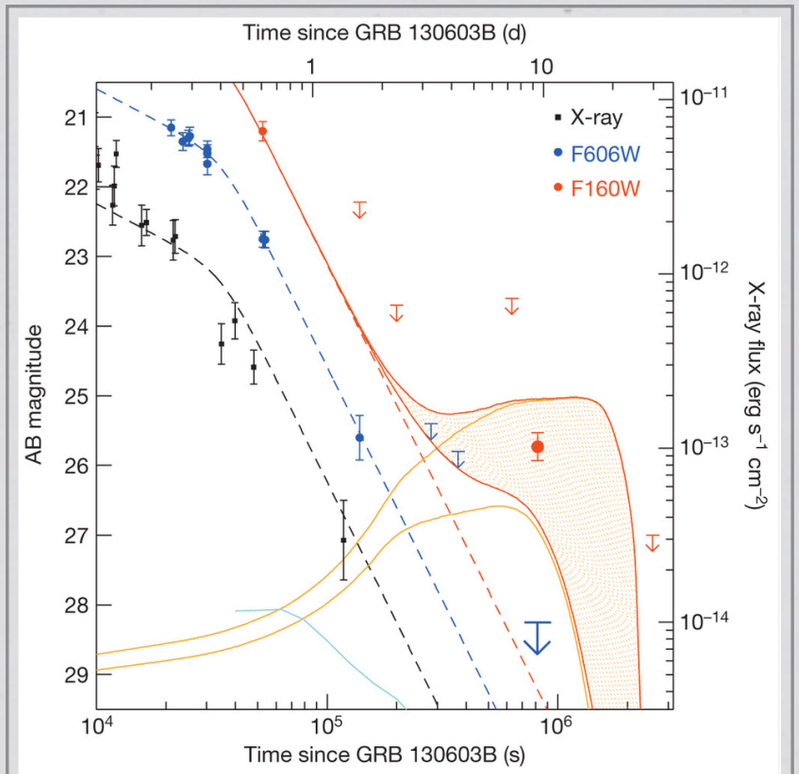


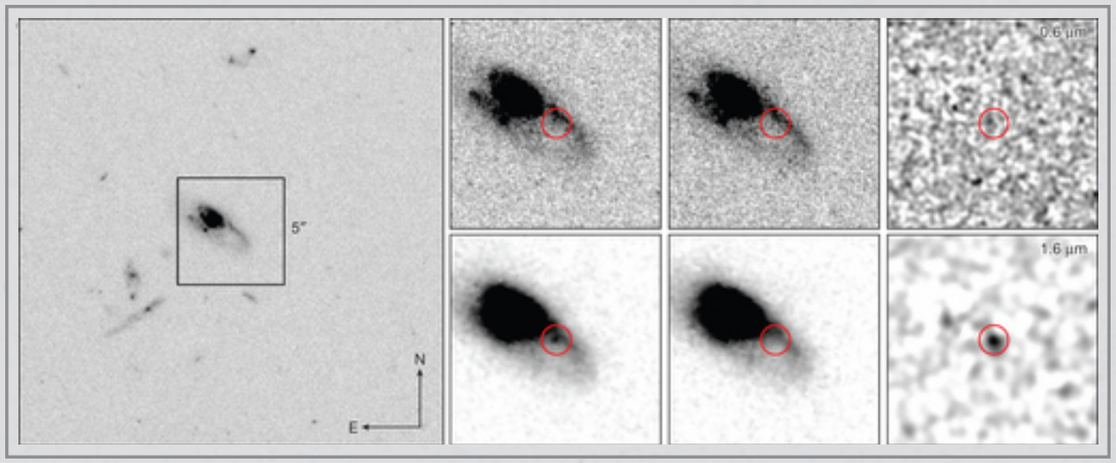
Late accretion! *Gezari+ 2015*



Miller+ 2015, Nature
Holoinen+ 2016, MNRAS

New frontieres





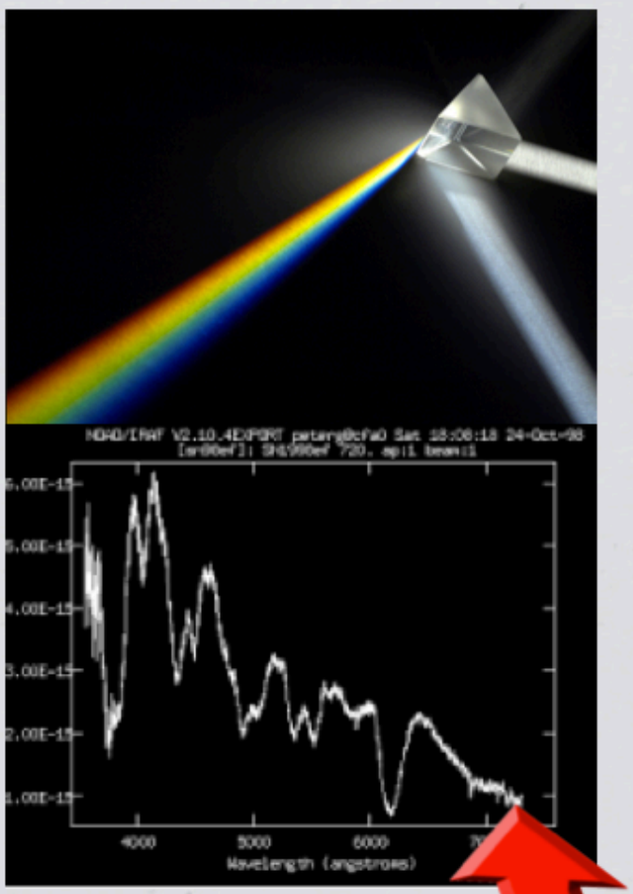
* Optical counterparts of gravitational waves (none so far, but hot topic)
* Dark SNe from massive stars (no solid detection; e.g. *Kochanek 2008, 2014; Gerke+ 2015*)
* Pair-production SNe from metal-free ultra-massive stars (no solid detection)
* Fast radio transients (*Keane+ 2016, Nature 530, 453*)
* Kilonovae /Macronovae in S-GRBs (a couple of claims; *Tanvir+ 2013, Nature 500, 547*)

Improving our knowledge of new transients

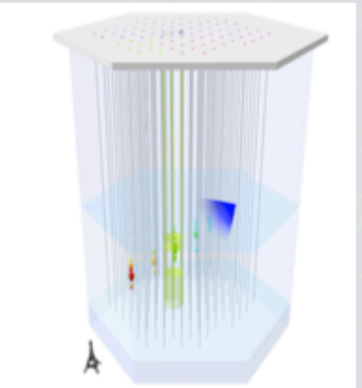
* Wavelength coverage & cooperation with neutrino & GW experiments => *Multi-messenger, including X-ray, UV, IR and radio facilities*

From multi-messenger triggers to classifications

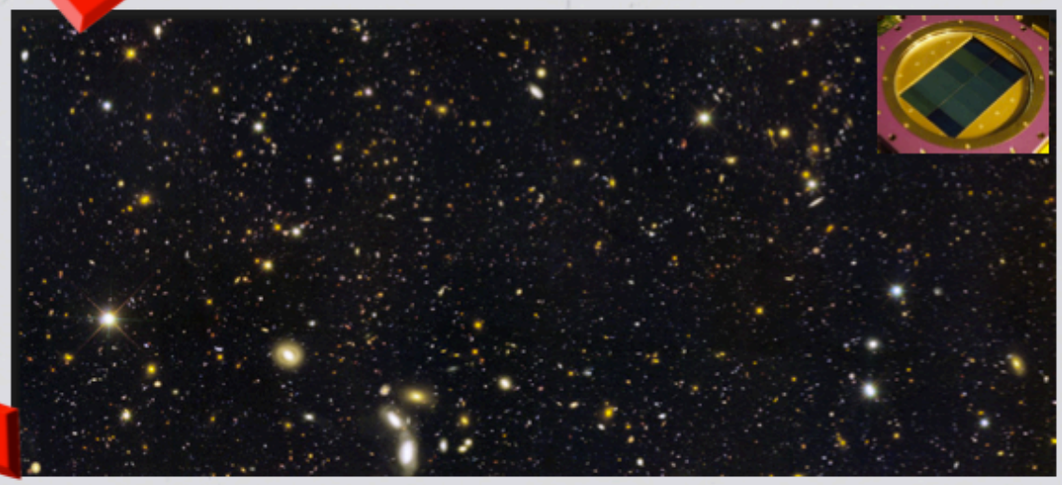
Spectroscopic classification



GW, neutrino, X-ray, gamma, radio alerts



ID of the optical counterpart candidate



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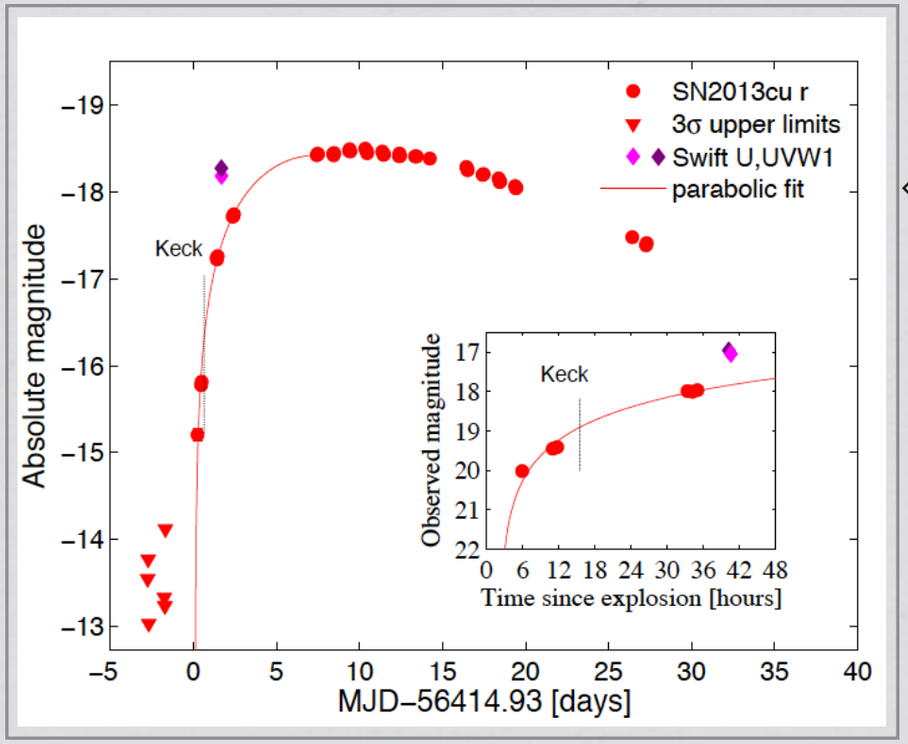
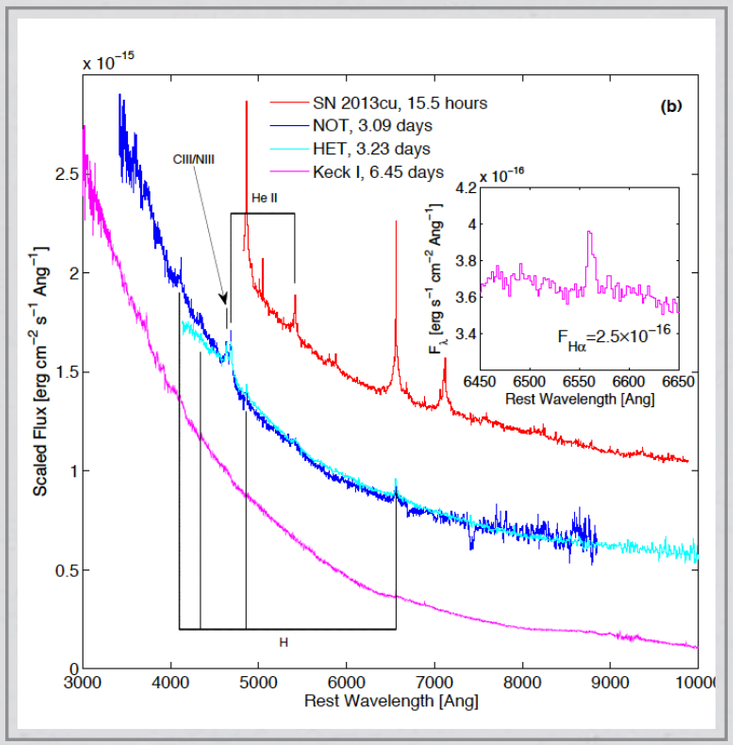
* Catching very early stage: *flash spectroscopy*



Very rapid evolution during the first few hours

Gal-Yam+ 2014, Nature 509, 471

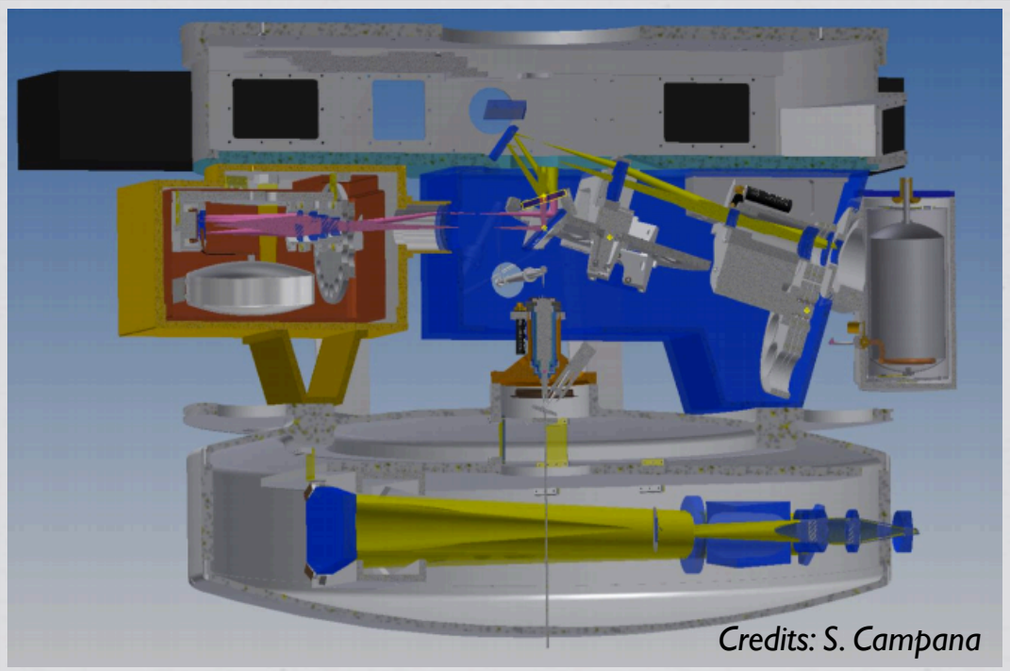


ESO-NTT with SOXS

(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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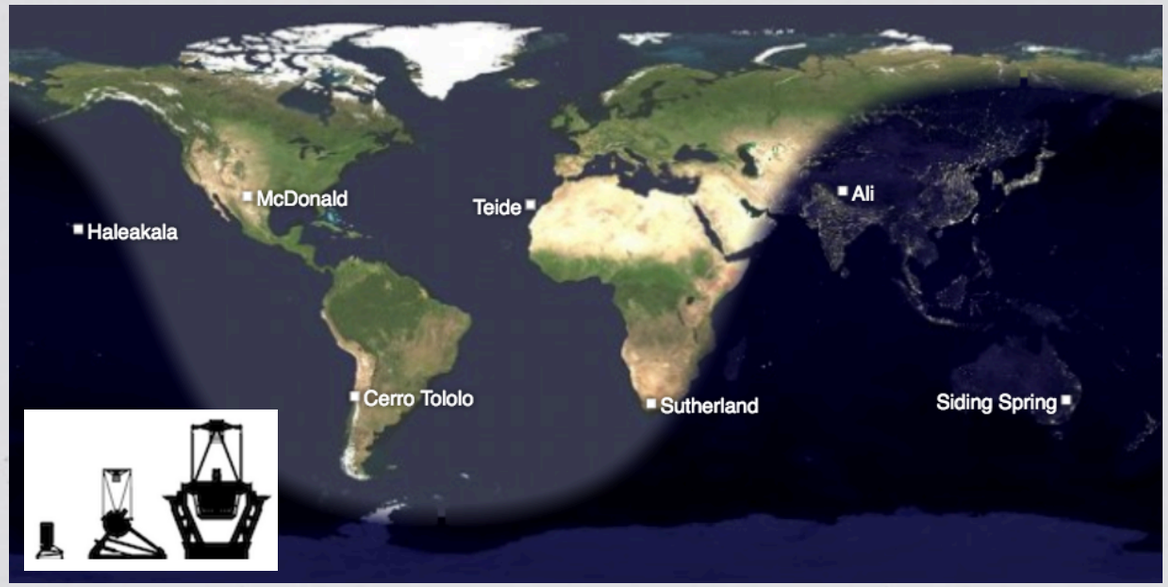

LCOGT is a network of 17 small (0.4-m, 1-m and 2-m) telescopes

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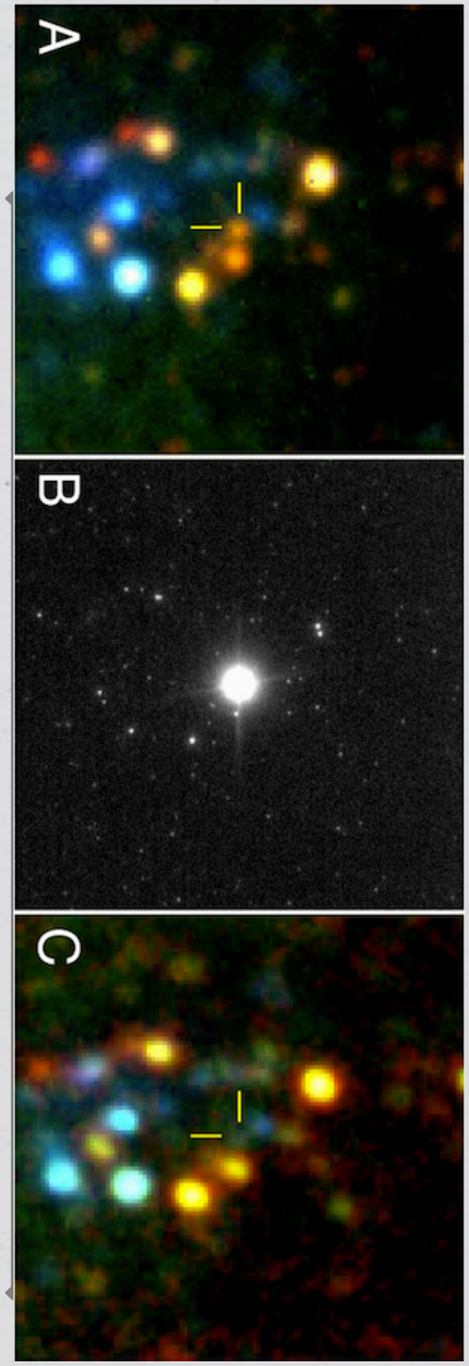
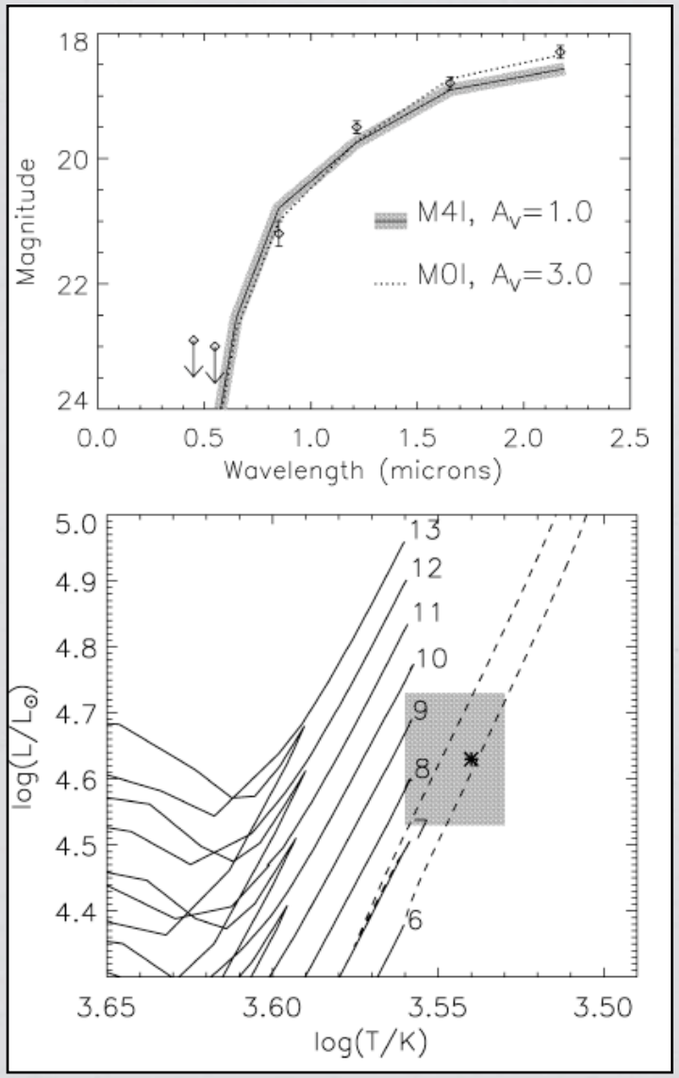
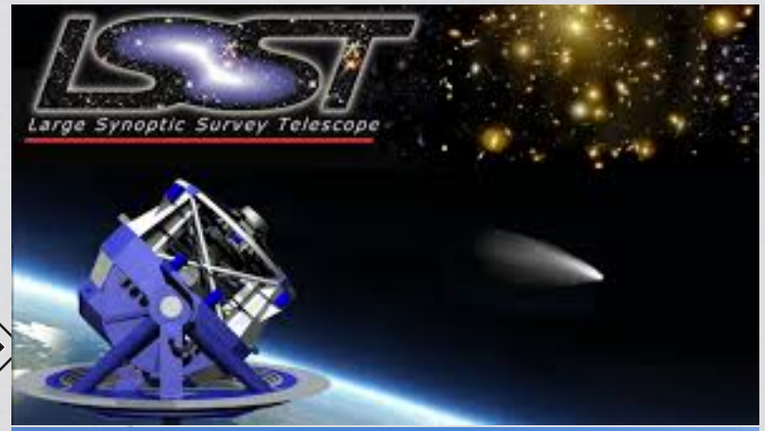
- Studying the progenitor stars and their environment => *deep imaging , high spatial resolution*

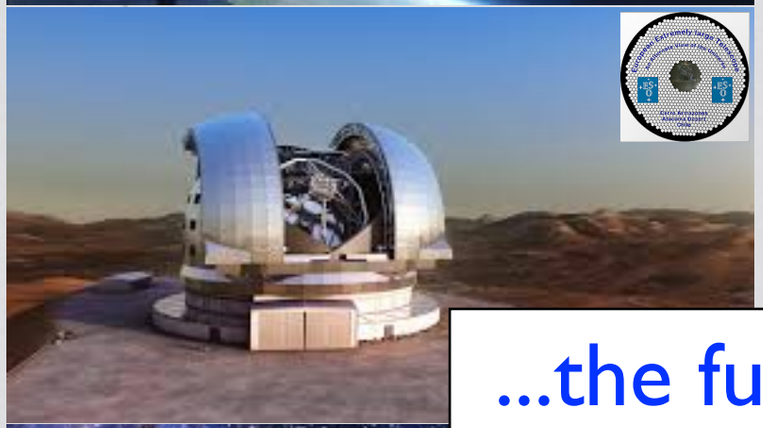




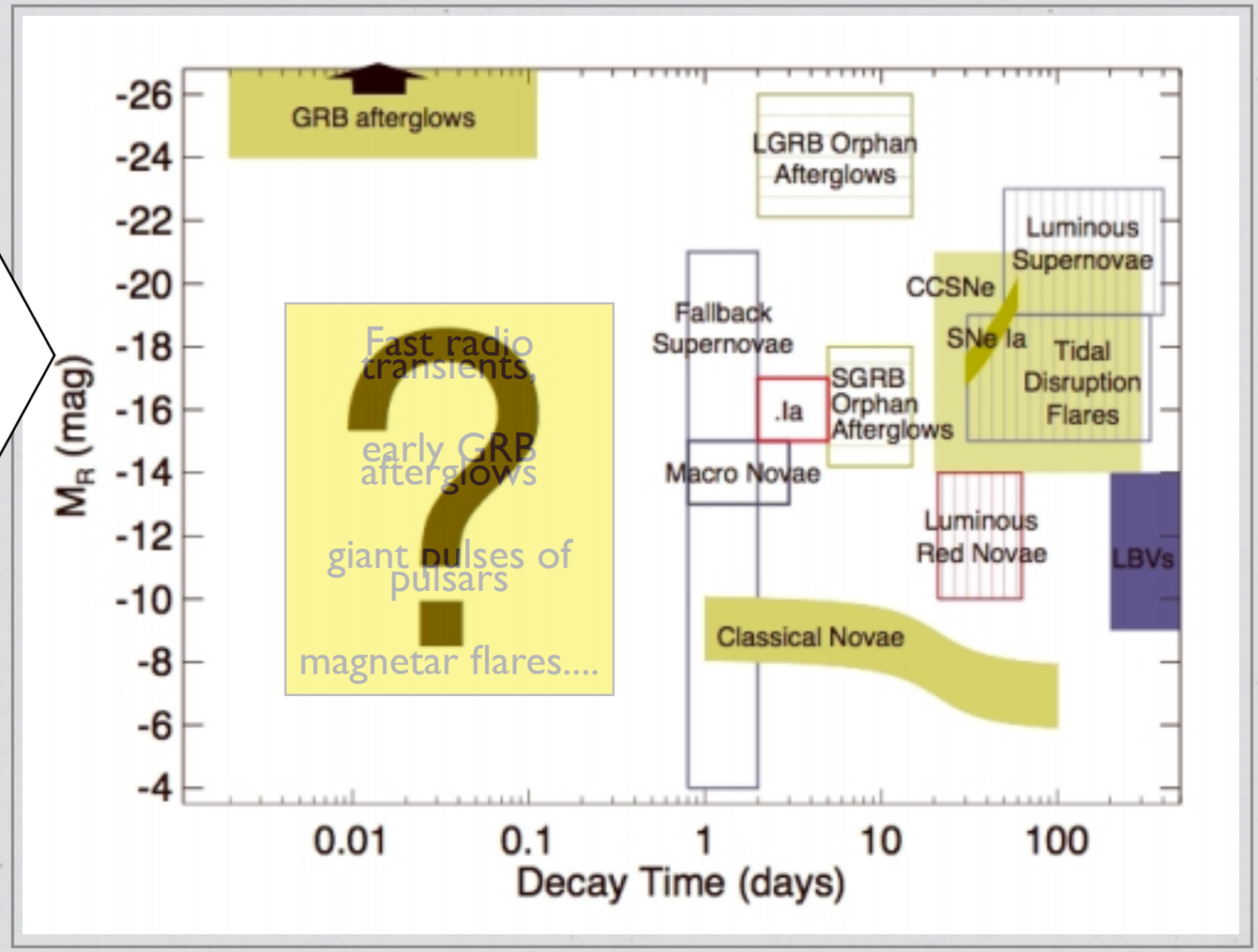
Mattila+ 2008,Van Dyk+ 2012; Maund+ 2013

The unknown





...the future



From the LSST Science Book