

Freaks and weirdos

A taxonomy of rare, peculiar
and puzzling supernovae

Morgan Fraser

Andrea Pastorello, Rubina Kotak,
Łukasz Wyrzykowski, Heather Campbell,
Seppo Mattila, Cosimo Inserra,
Gaia, PESSTO, OGLE,
and many more surveys and people...

GSAWG6

Rationale for this talk...

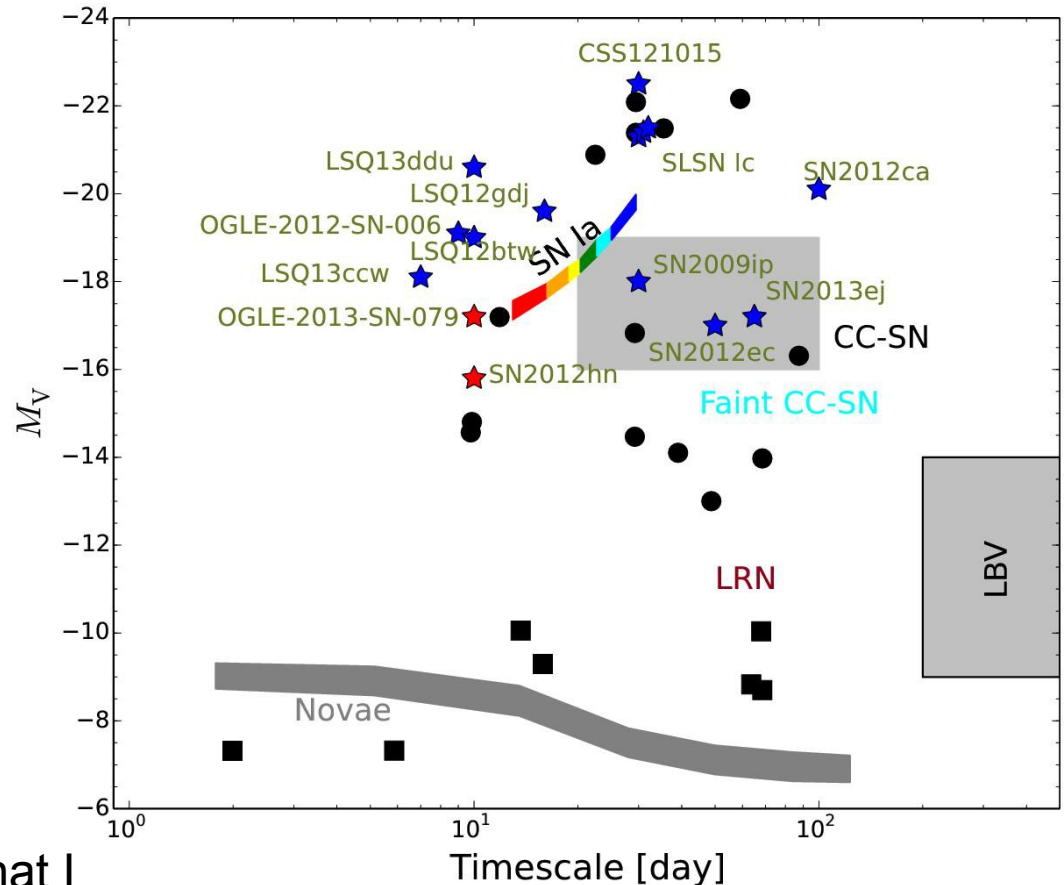
- Normal supernovae are boring¹!
- There are still objects we fundamentally do not understand, and parameter space which is unexplored.
- Science drivers must inform survey strategy (cf. Massimo's talk).
- ...detector / classification techniques (along with issues such as changing onboard detection parameters).
-and followup requirements.

¹Not a quote!

Overview

- Interacting transients
 - aka. LBV outbursts, SN impostors
- Ia-CSM
 - Thermonuclear SNe with circumstellar material
- Superluminous Supernovae

(There are many more classes of objects that I could mention here, .Ia SNe, Ibn, LRNe...)



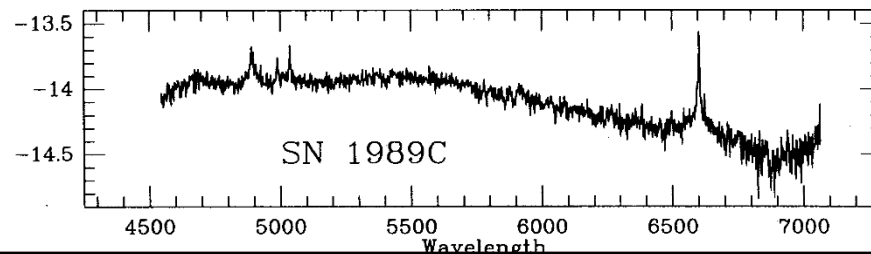
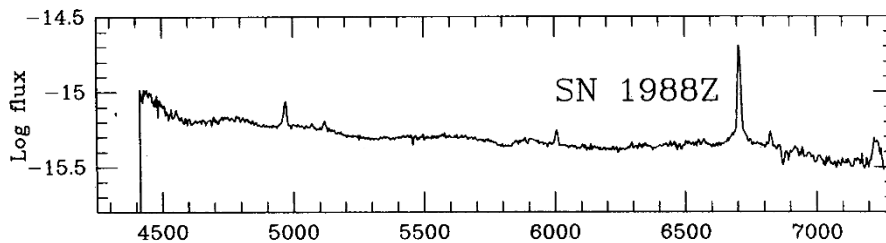
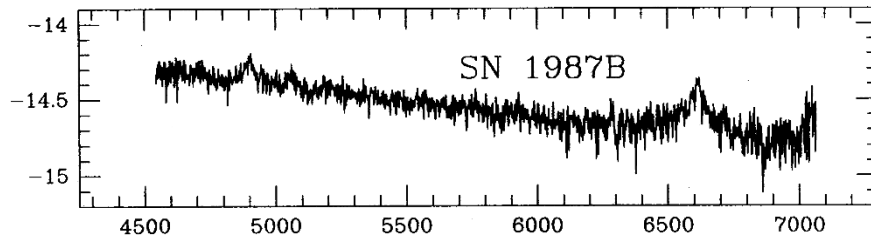
From Smartt, Valenti, MF+ 2015, based on Kulkarni & Kasliwal

Interacting transients

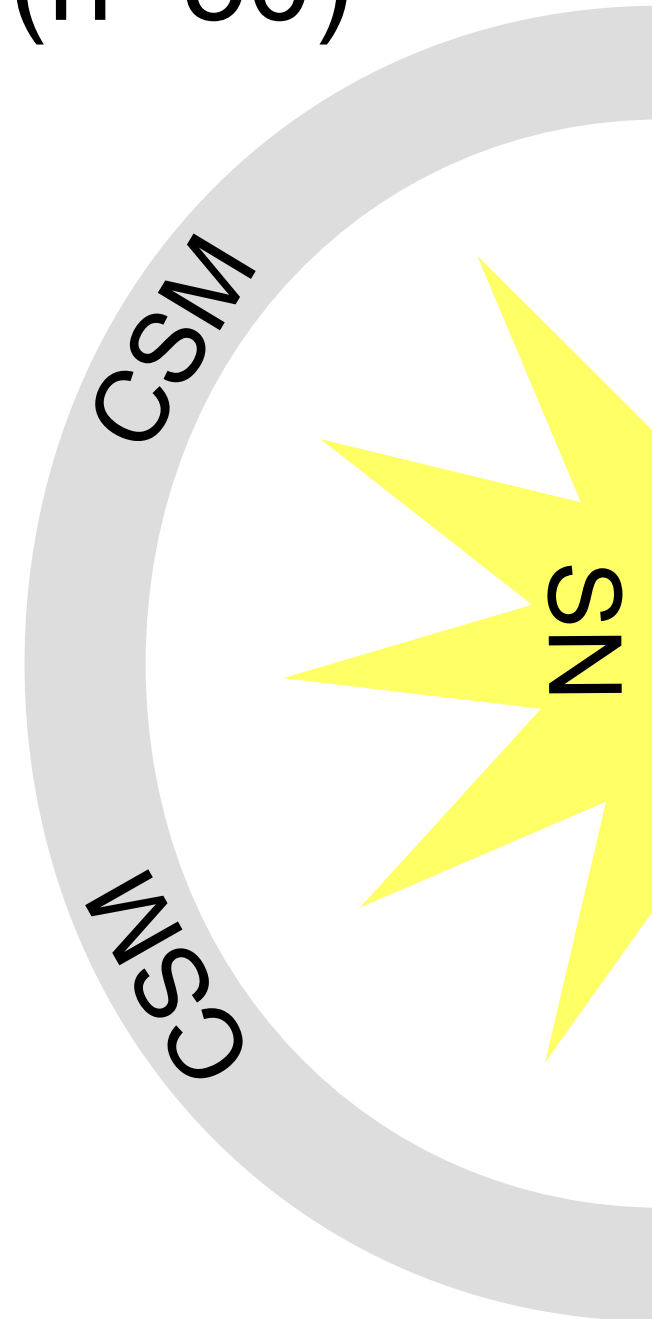
“Type IIn” supernovae (n~50)

A new subclass of Type II supernovae?

Eric M. Schlegel★



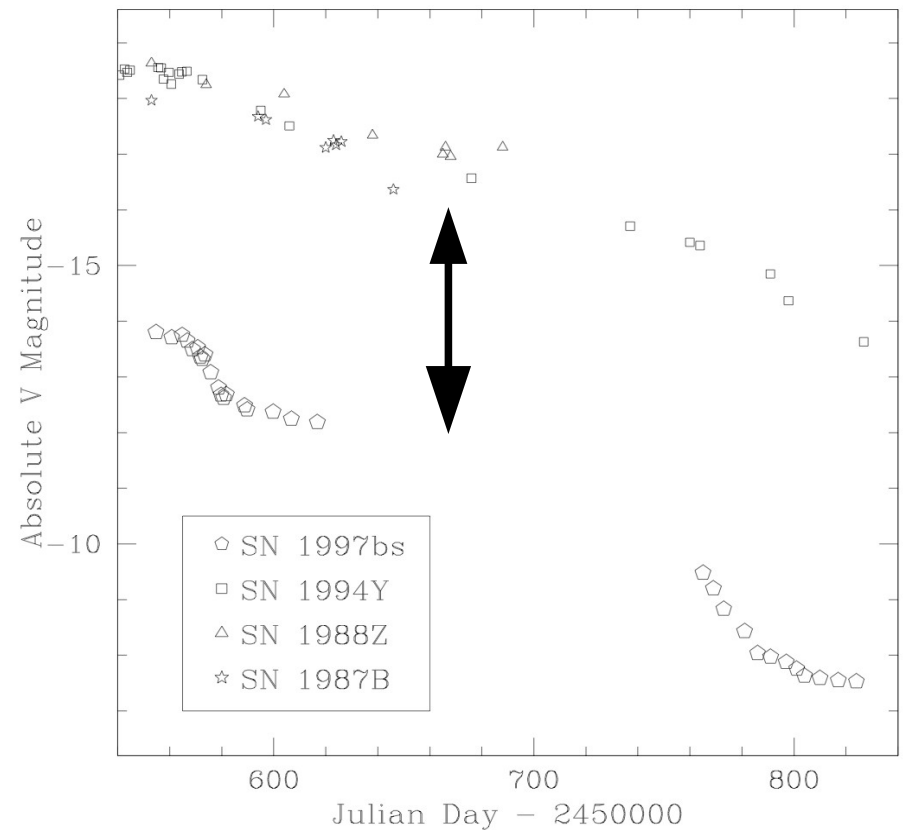
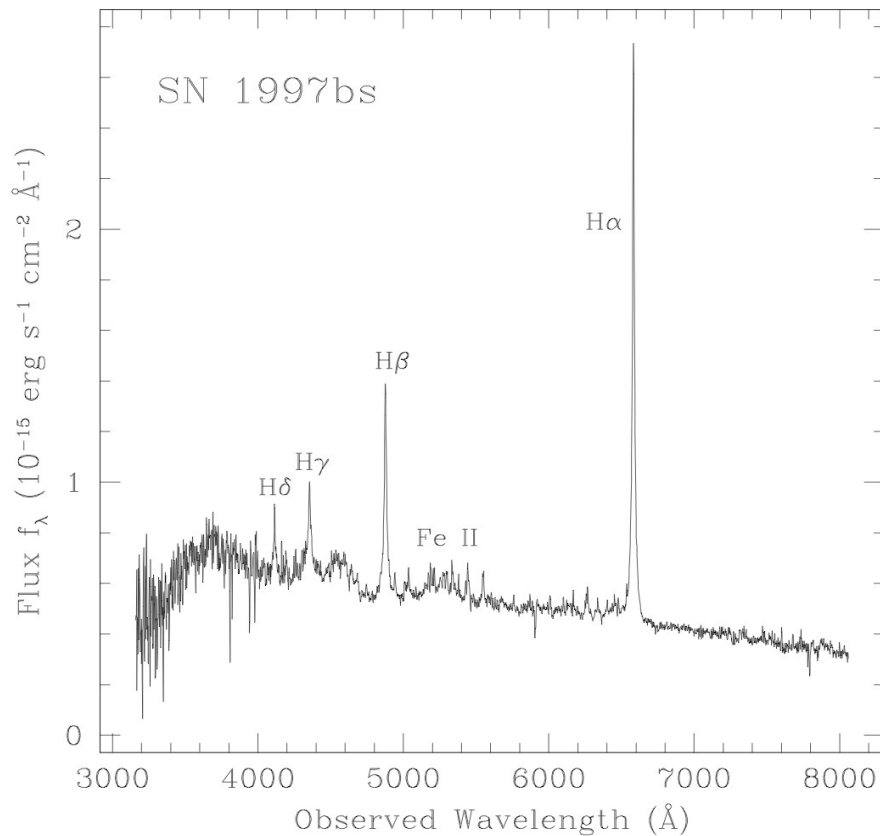
Can these spectra be interpreted by invoking ‘circum-stellar’ effects? The answer is not obvious. What can be said



“SN impostors” (n~30)

SN 1997bs in M66: Another Extragalactic η Carinae Analog?

SCHUYLER D. VAN DYK



a bona fide supernova. We believe that it is more likely a superoutburst of a very massive luminous blue variable star, analogous to η Carinae, and similar to SN 1961V in NGC 1058 (Filippenko et al. 1995 AJ, 110, 2261). SN 1954J (“V” + 11-12) in NGC 2442 (H. 11-12, 1954 PASP, 66, 1005) TL

Type IIn SNe and SN impostors

Type IIn SN

- *Terminal* core-collapse
- Ni-powered tail phase
- Ejects products of nucleosynthesis

SN impostor

- *Non-terminal* outburst
- No Ni-powered tail phase
- No products of nucleosynthesis in ejecta



What powers the eruptive mass loss?

Central Bureau for Astronomical Telegrams

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URL <http://www.cfa.harvard.edu/iau/cbat.html>

SUPERNOVA 2009ip IN NGC 7259

J. Maza, M. Hamuy, R. Antezana, L. Gonzalez, P. Gonzalez, P. Lopez, S. Silva, G. Folatelli, D. Iturra, R. Cartier, F. Forster, S. Marchi, and A. Rojas, Universidad de Chile; G. Pignata, Universidad Andres Bello; B. Conuel, Wesleyan University; and D. Reichart, K. Ivarsen, J. Haislip, A. Crain, D. Foster, M. Nysewander, and A. LaCluyze, University of North Carolina at Chapel Hill, on behalf of the CHASE project, report the discovery of an apparent supernova (mag approximately 17.9 \pm 0.3) on an unfiltered image taken on Aug. 26.11 UT with the 0.41-m 'PROMPT 3' telescope located at Cerro Tololo. The new object is located at R.A. = 22h23m08s.26 \pm -28o56'52".4 \pm 0".1 (equinox 2000.0), which is about 36".2 north of the center of the galaxy NGC 7259. Additional magnitudes: 2009ip: 2008 Oct. 7.09, [19.0; 2009 Aug. 21.14, [18.0; 24.0; 28.00; 17.0 \pm 0.3.

NOTE: These 'Central Bureau Electronic Telegrams' are sometimes superseded by text appearing later in the printed IAU

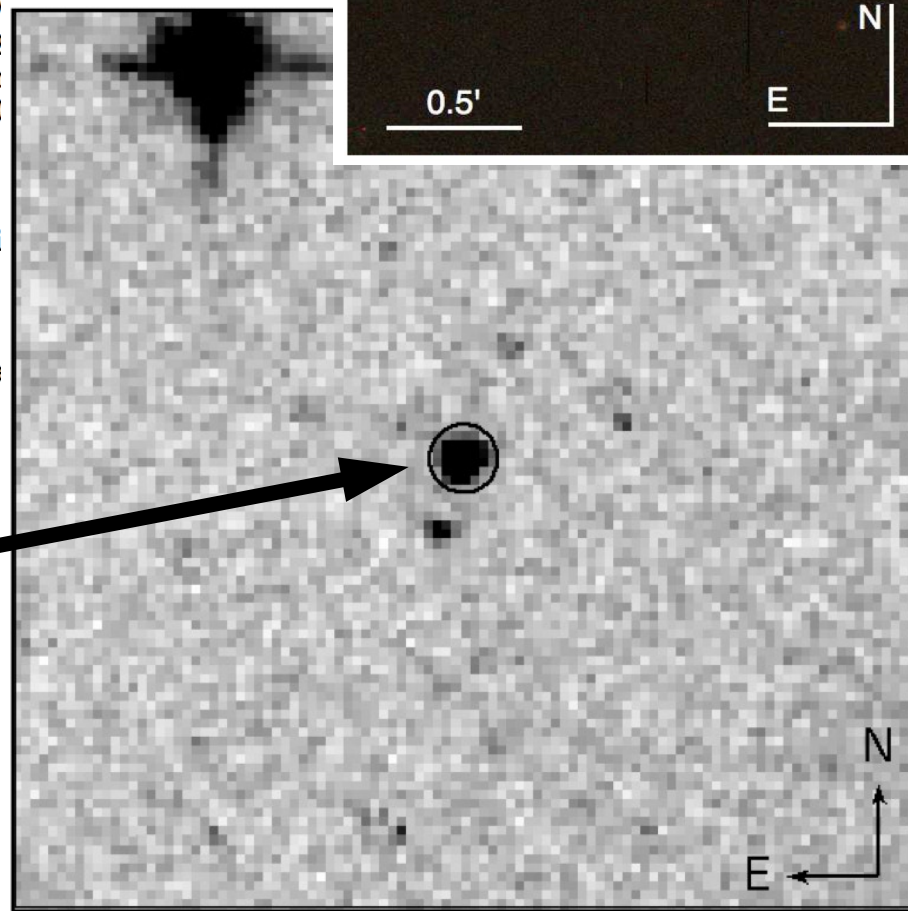
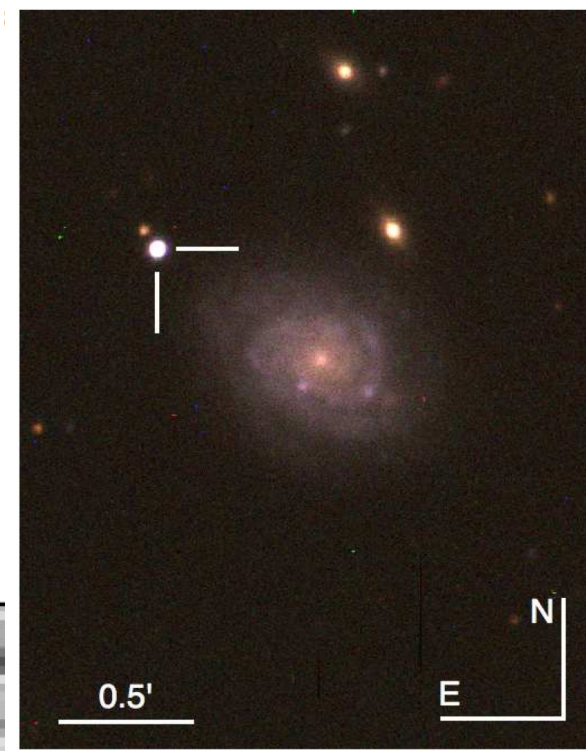
2009 August 29

(C) Copyright 2009 CBAT
(CBET 1928)

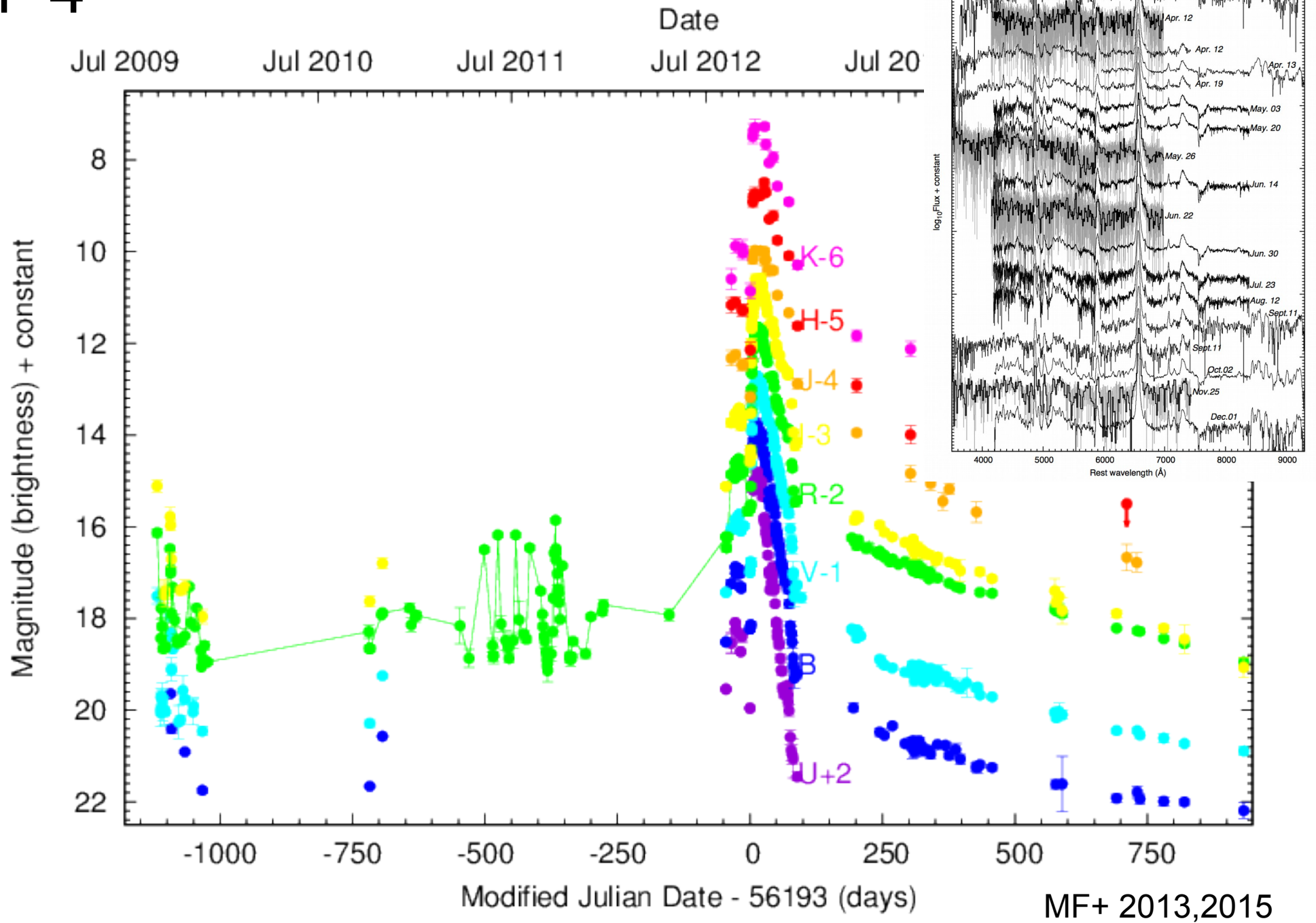
De

M_F606W = -10.3

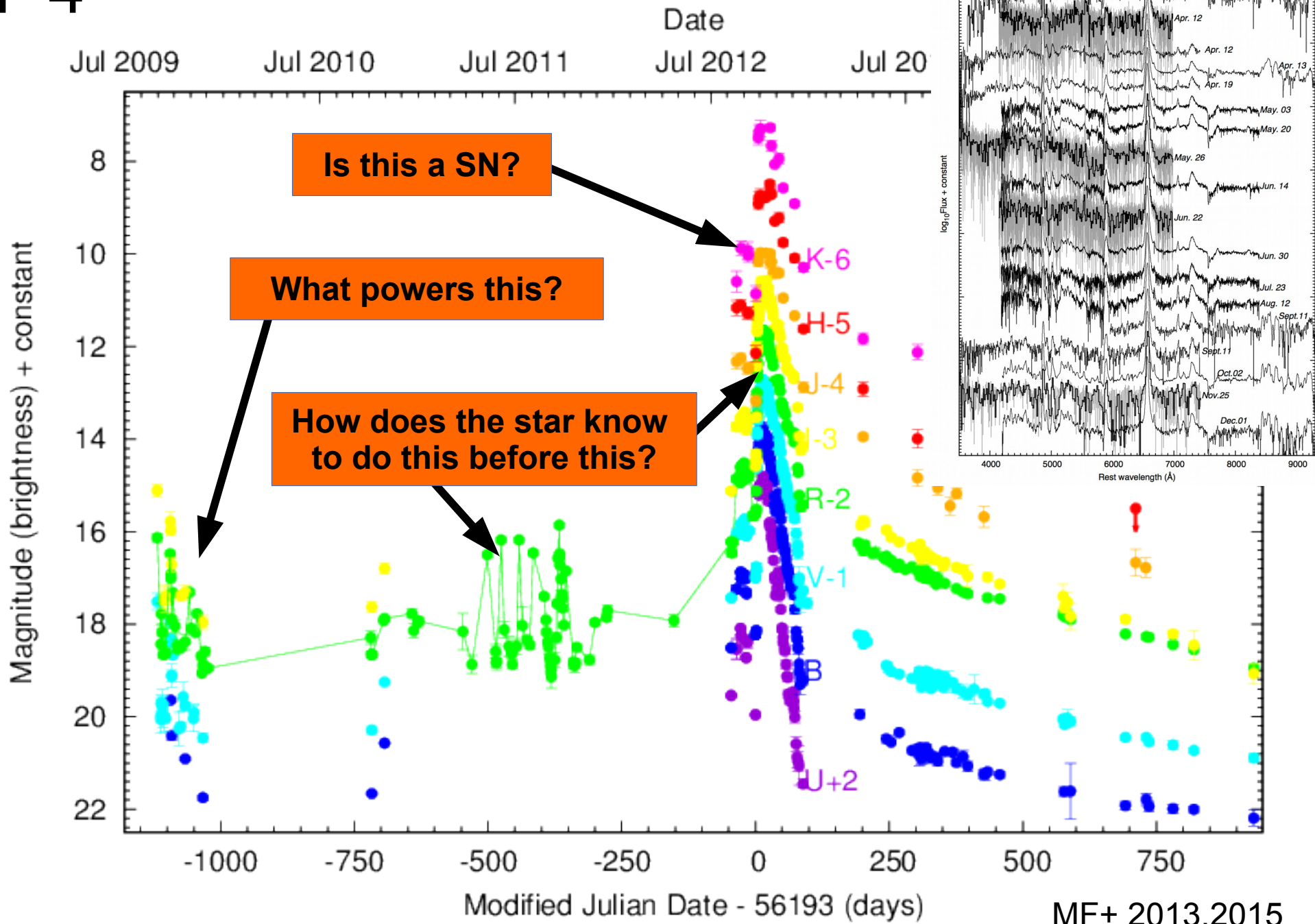
HST image of the
site of SN 2009ip
Foley et al. (2010)



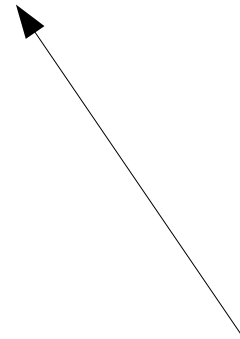
$n \sim 4$



$n \sim 4$



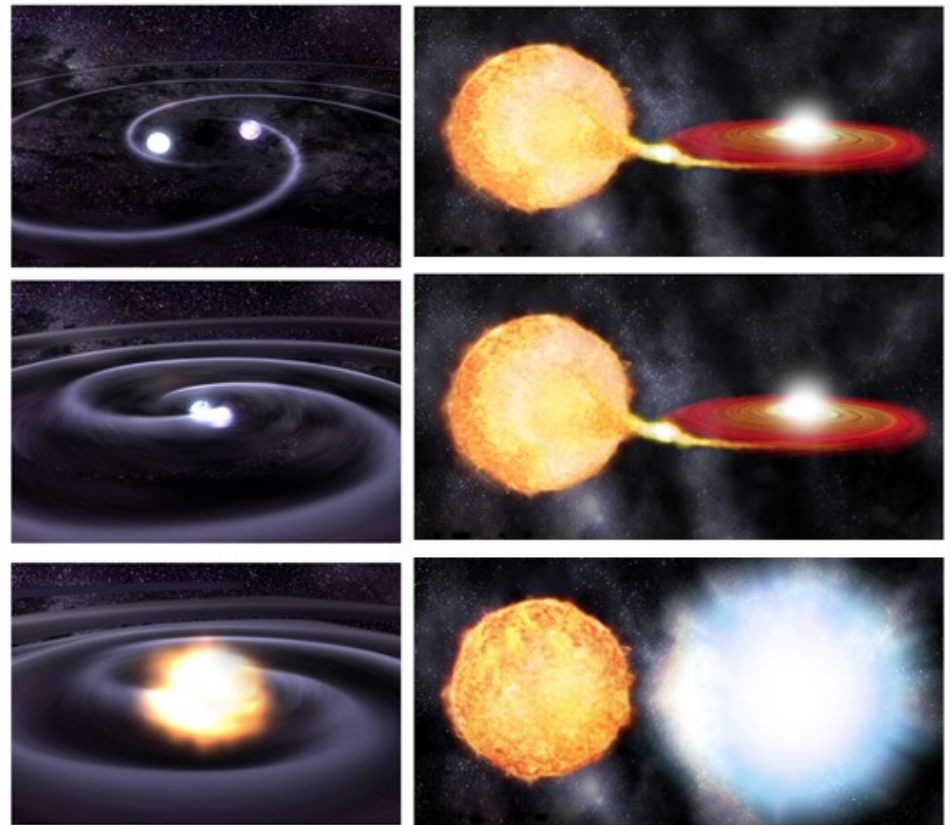
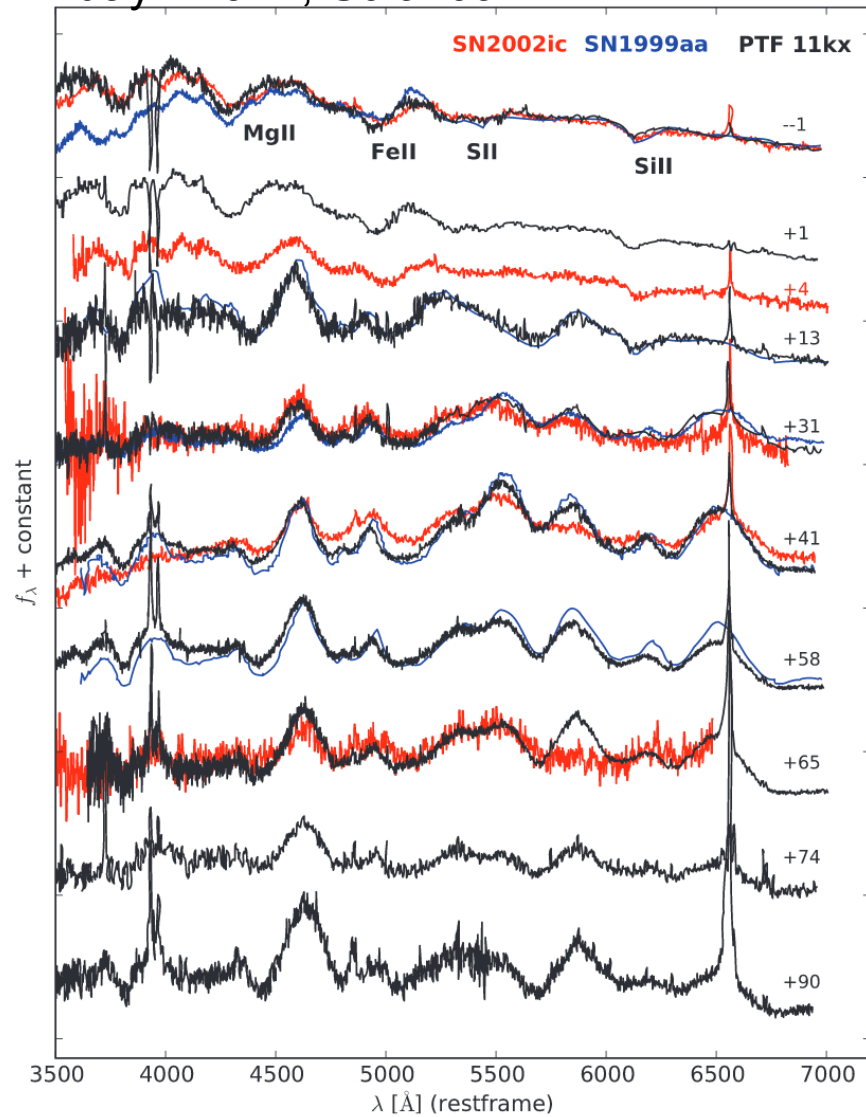
Ia-CSM



Circumstellar Medium

SNe Ia-CSM (n~15)

Dilday+ 2012, *Science*

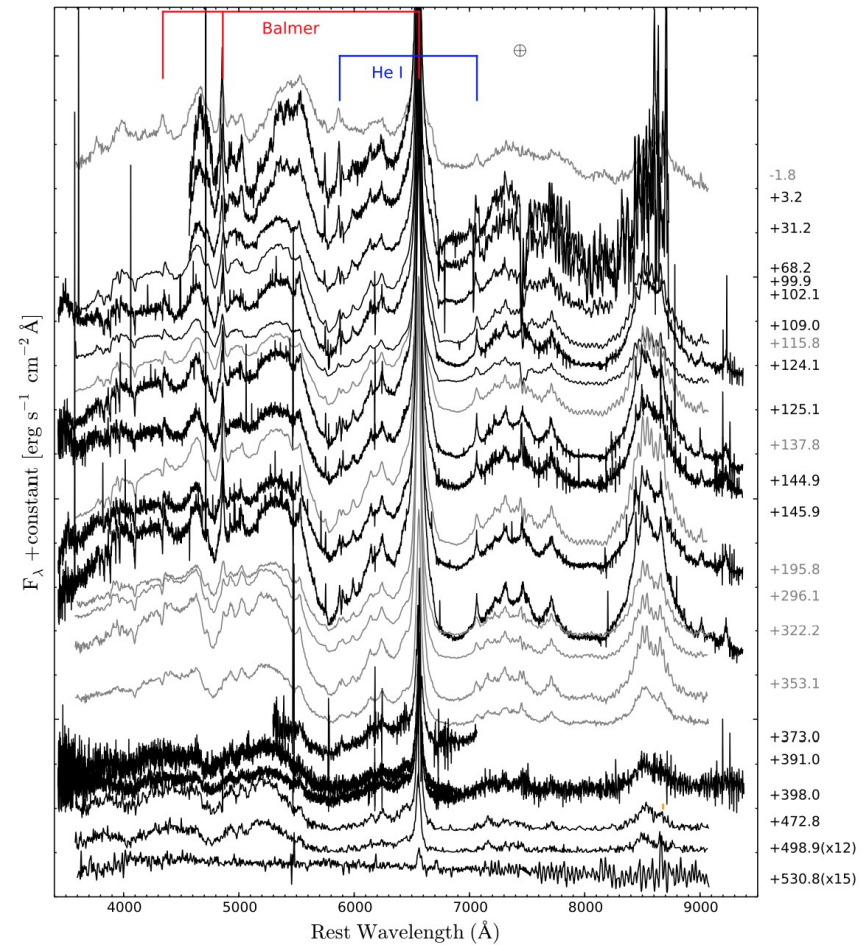
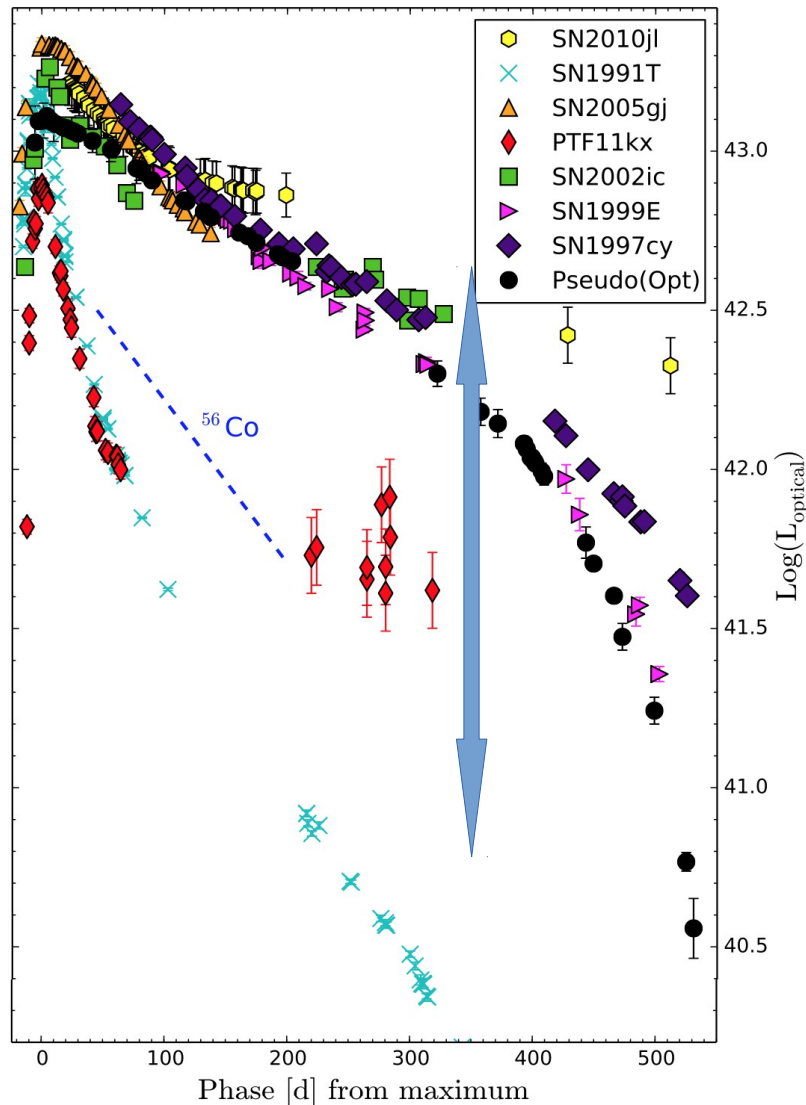


Blue spectra – “normal” SN Ia
Black spectra - interacting SN Ia

For some “Ia-CSM”, the energy requirements (intergrated bolometric LC) are uncomfortably high.

SNe Ia-CSM

Inserra, MF+ 2015

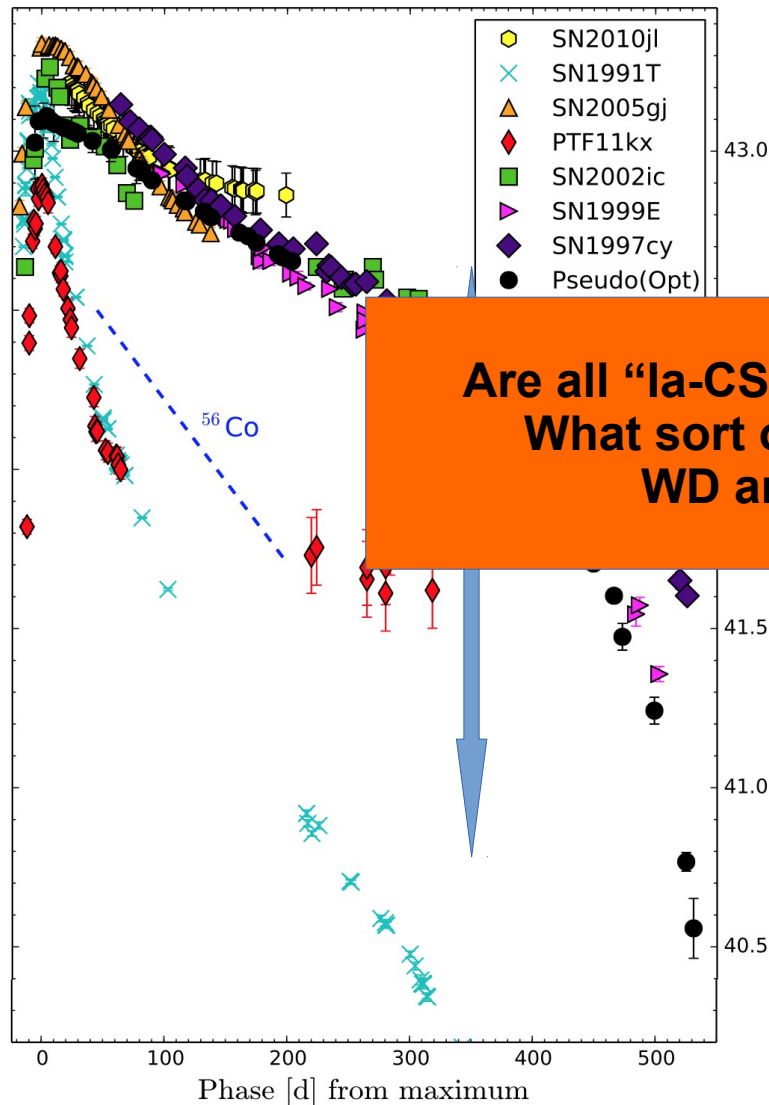


No change in spectra over ~ 1 yr, despite factor 100 change in relative flux contribution of underlying SN Ia

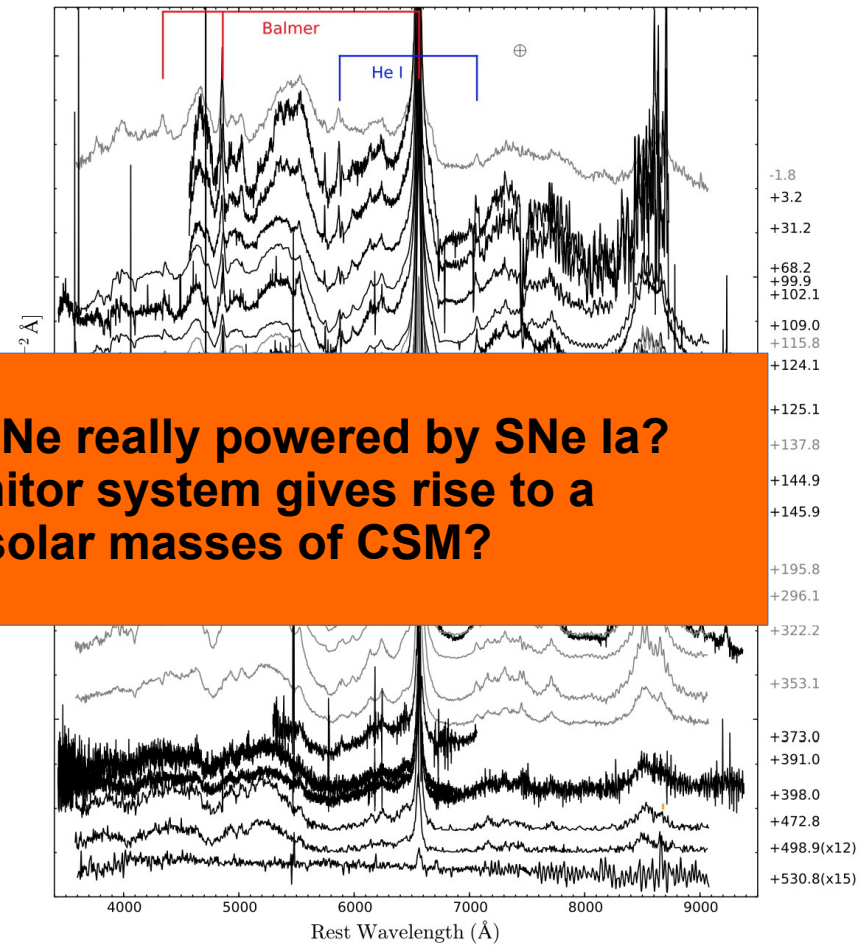
SNe Ia-CSM

For some “Ia-CSM”, the energy requirements (integrated bolometric LC) are uncomfortably high.

Inserra, MF+ 2015



**Are all “Ia-CSM-like” SNe really powered by SNe Ia?
What sort of progenitor system gives rise to a
WD and ~few solar masses of CSM?**

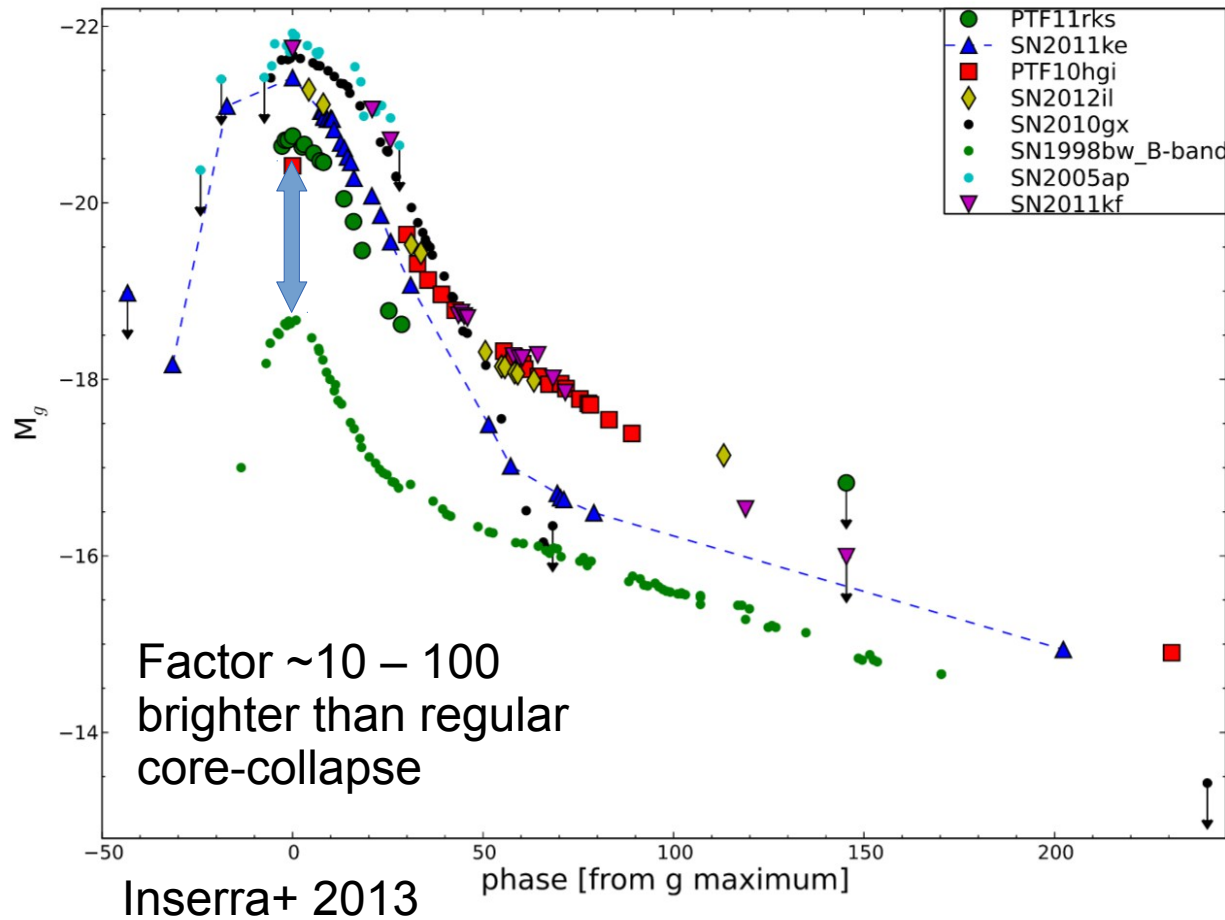


No change in spectra over ~1 yr, despite factor 100 change in relative flux contribution of underlying SN Ia

Super-Luminous SNe

(aka. SLSN-Ic, SLSNe, SN 2010gx-like...)

SLSNe (n~30)



Not powered by ^{56}Ni !
(cannot get self-consistent
Ni and ejecta masses)

If we could standardise them,
could they be used for
cosmology...?

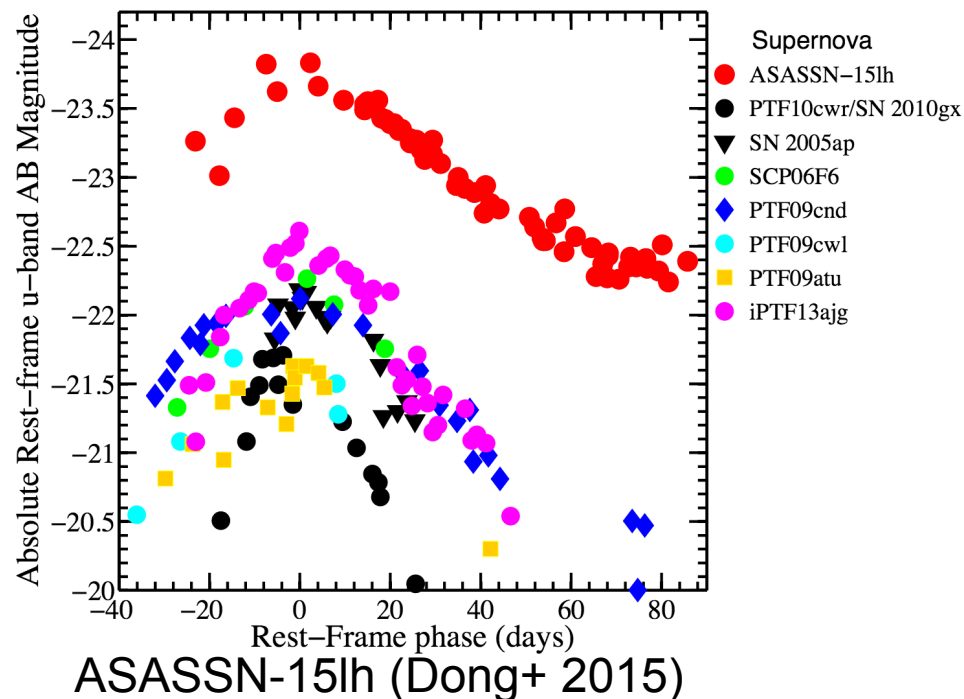
SLSNe

- Powered by energy input from spindown of young magnetar (but see recent result by ASASS-SN; Dong+ 2015)? CSM interaction? Something more exotic.
- Seem to prefer dwarf, low-Z, high sSFR hosts (but not exclusively) – also why not found earlier!

- Also other SLSNe classes, some interaction dominated, some claimed PISN Sne...

RARE!

(10^{-4} of SN rate by volume)



Some thoughts...

There is value in doing extragalactic transient surveys to find individual objects (and not just large samples)!

- General
 - Detectors need to be agnostic to types of transients (as far as possible).
- Impostors
 - Archival value of Gaia key – can go back and look for pre-outbursts, eruptions before a SN.
 - Require higher resolution (~ 100 km/s) spectroscopy. Is this a gap in our capabilities?
- Ia-CSM
 - Spectrophotometric coverage to late times. Need a large sample of SNe that have high S/N followup spectra (or monitoring) to find a few of these objects.
- SLSNe
 - Multi-season lightcurves for slowly evolving objects (have been missed by ground based surveys due to season effects)
 - Must make sure we are not biased against unusual environments.