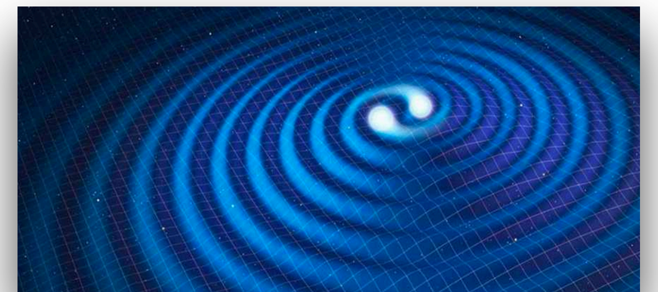
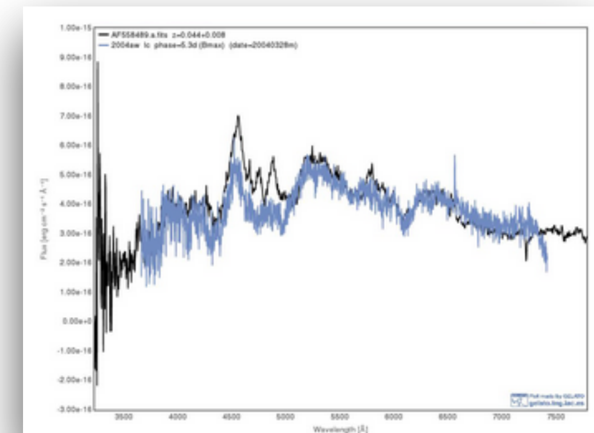
# Padova-Asiago Transient Group



**Enrico's talk**

SN searches

EM counterparts of GWs

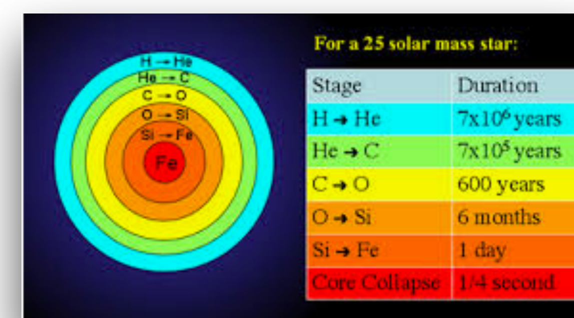


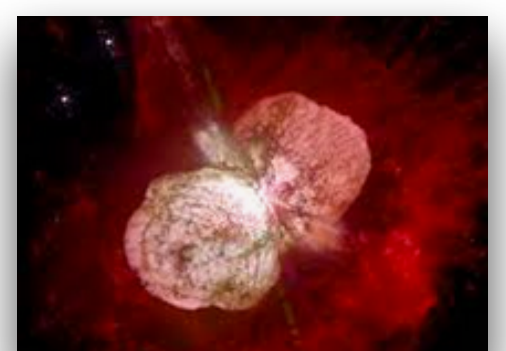
Asiago classification program

**Lina's talk**

Thermonuclear SNe
peculiar objects

Core-collapse
SN subtypes



Pre-SN outbursts

Stellar mergers

# Peculiar stellar transients


Andrea Pastorello

INAF-OAPd

Y.-Z. Cai, G. Valerin, P. Ochner (UniPd), A. Reguitti (Andres Bello Univ.), E. Mason (INAF-OATs), L. Tartaglia (Stockholm Univ.), N. Elias-Rosa (CSIC/IEEC).

Collaborators: T.-W. Chen (Stockholm Univ.), A. Morales-Garoffolo (Univ. of Cadiz), M. Fraser, E. Callis (Univ. College Dublin), R. Kotak, E. Kankare, T. Reynolds (Univ. of Turku), Z. Cano (IAA-CSIC), E. Barsukova (SAO,RAS), V. Goranskji (SAI), G. Pignata (Andres Bello Univ.), the Padova SN group.

# Collaborations & Facilities

- PESSTO/ePESSTO/ePESSTO+; PIs S.J. Smartt, C. Inserra. A wide collaboration currently composed by 228 researchers.
  - 90-100 nights/year with NTT (EFOSC2/SOFI)
  - 65 nights/semester with 1m-class telescopes of Las Cumbres Observatory

- The NOT Unbiased Transient Survey (NUTS/NUTS2); PIs: E. Kankare, A. Pastorello, M. Fraser, M. Stritzinger, P. Lundqvist. Collaboration of 28 researchers of 6 EU countries;
  - >180 hr in ToO/Service at the NOT (ALFOSC/NOTCam)
  - Additional time at Magellan with FSU (PI: E. Hsiao)
  - Photometric follow-up from the ASAS-SN collaboration
  - Asiago telescopes via the Padova SN group
  - Liverpool Telescope observations (PI: S. Prentice)

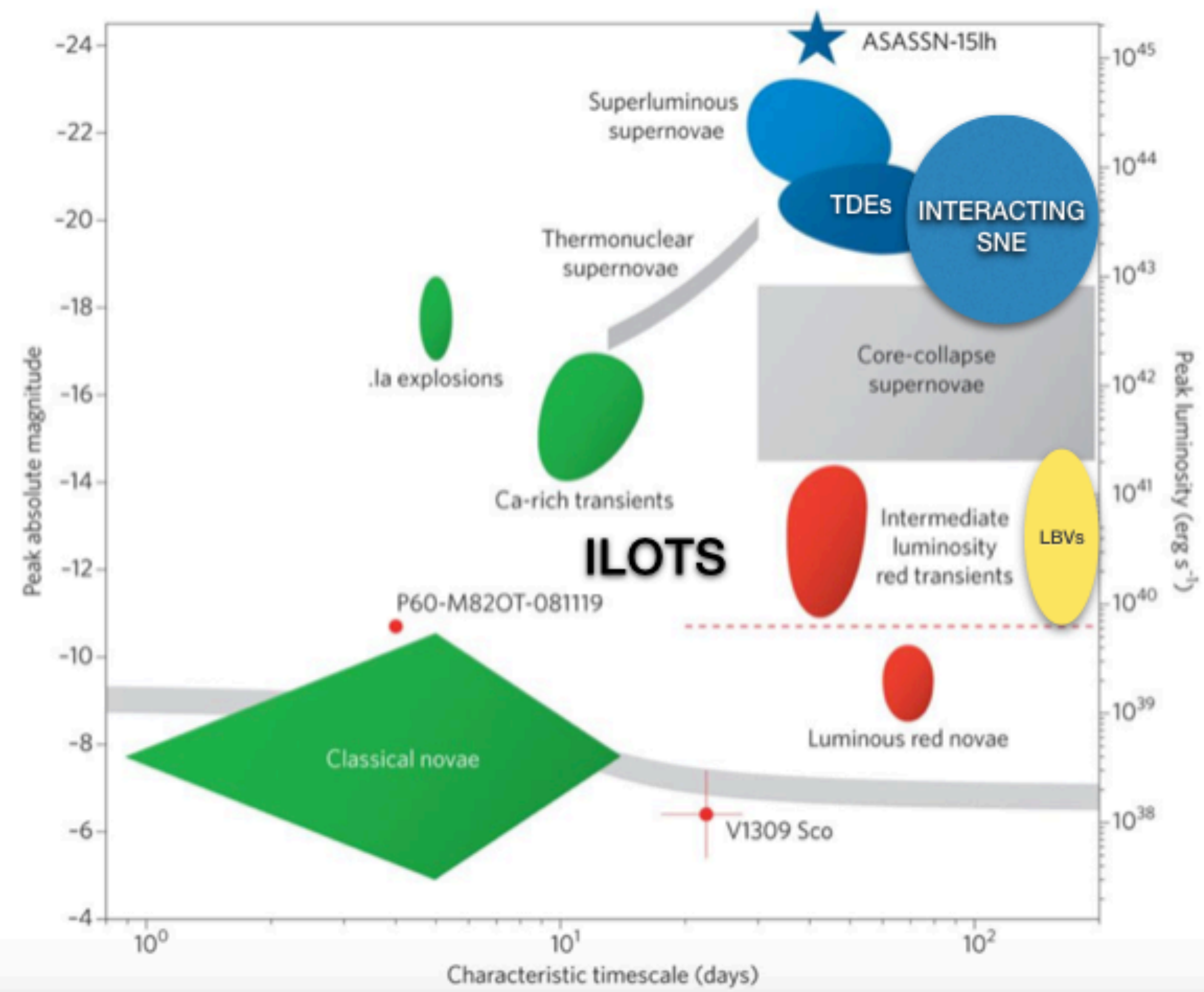
- The Fast and Dark Side of Transients experiment; PIs Gutierrez-Avendano/Inserra.
  - 26 hrs at the Liverpool Telescope with IO:O and SPRAT
  - 15% of available ToO time with 2.2m MPG/GROND

# Collaborations & Facilities

- The Global Supernova Network
  - Shared access to 1m-class telescopes for photometry
  - Shared access to 2m-class telescopes for spectroscopy
- GTC+Hipercam: 1.5hs per semester for high time resolution imaging (PI: N. Elias-Rosa); frequent DDTs with OSIRIS for spectroscopy of faint objects
- Liverpool Telescope: 25hrs per semester for optical and NIR imaging with IO:O and IO:I
- PROMPT telescopes for high-cadence optical imaging and CTIO 1.3m + ANDICAM for NIR imaging
- Additional hours with other facilities, incl. SALT and Russian telescopes

# Motivations

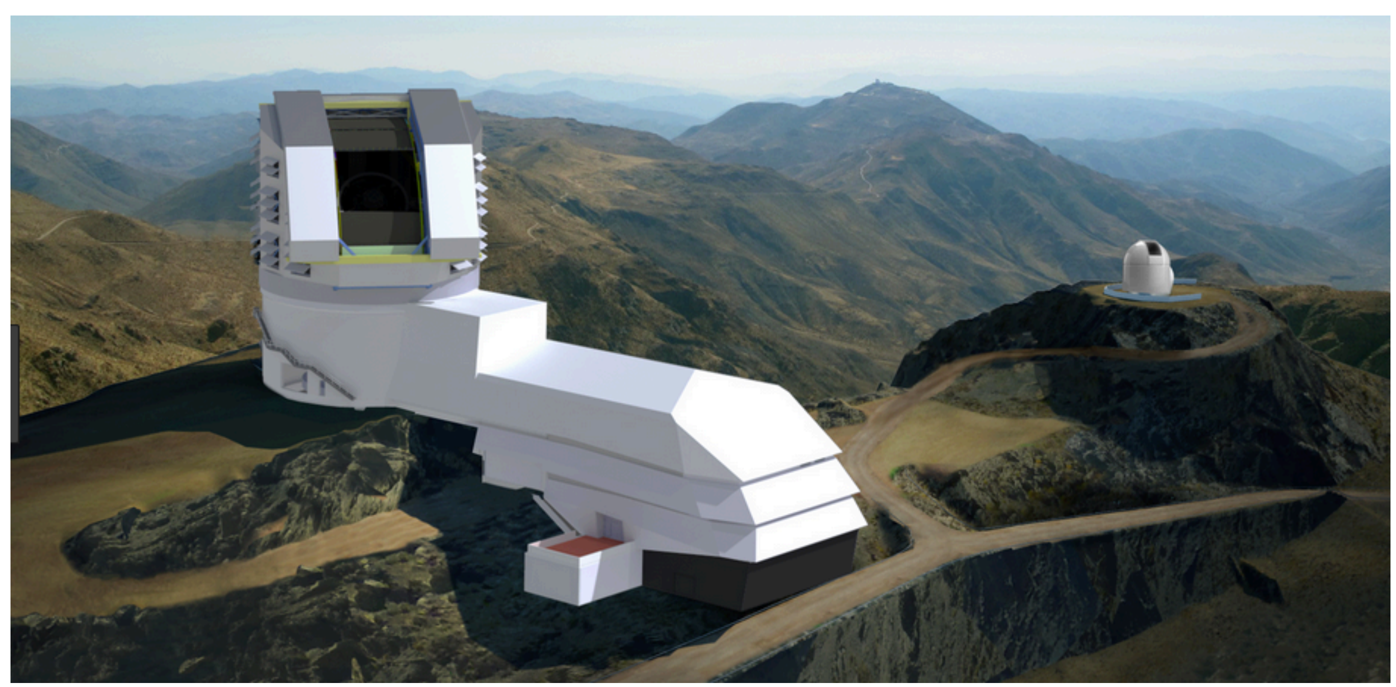
- <u>Characterizing rare species of stellar transients:</u>
  - Spectro-photometric monitoring and data modeling
  - Multi-messenger approach
  - Inspection of image archives to study the progenitors and their variability
  - The local environment and host galaxy parameters...



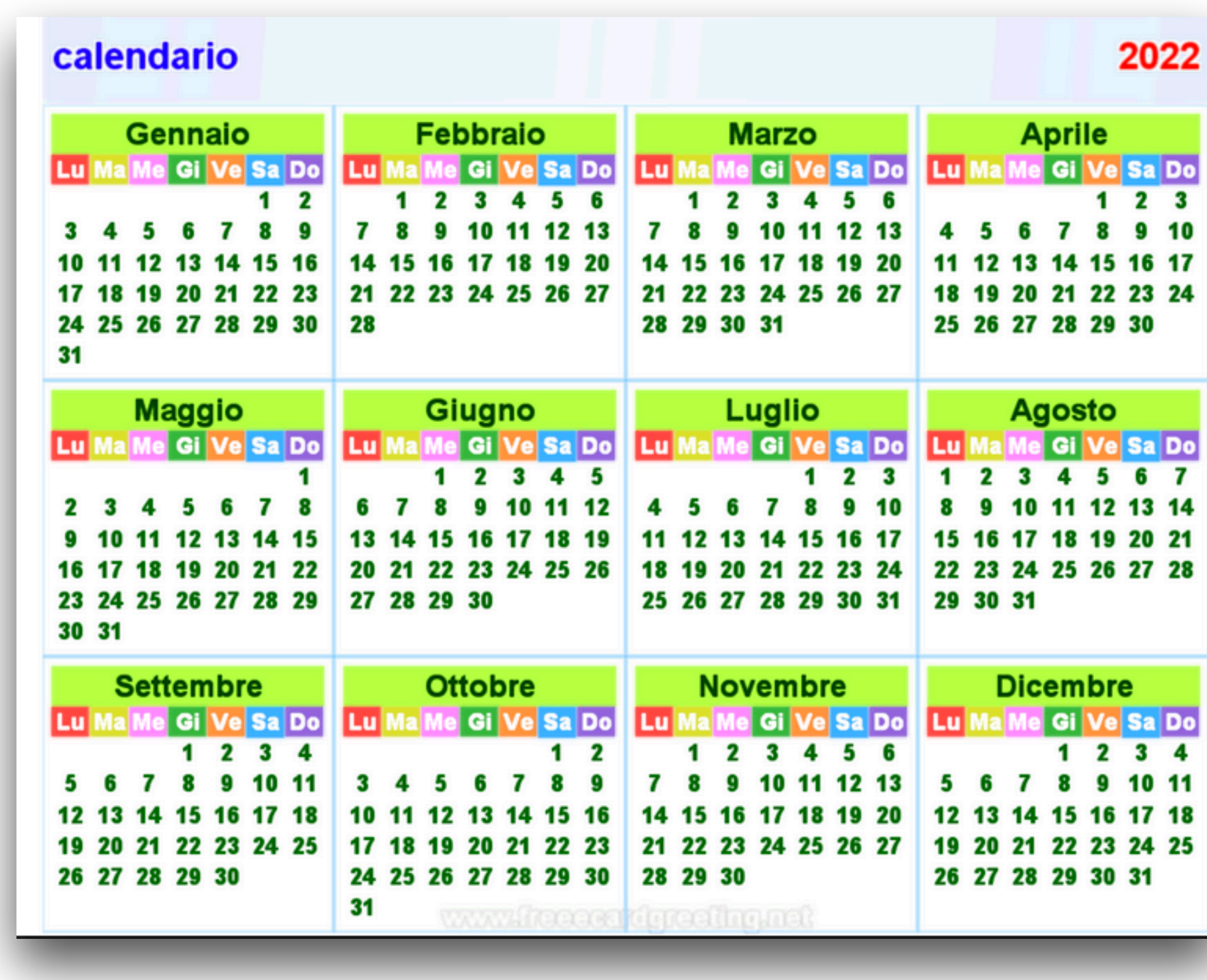

## Why?

- They are challenging our knowledge of stellar evolution
- They will likely produce NSs, BHs or degenerate binary remnants

- <u>LSST preparatory phase:</u>
  - Historical lightcurves of known LBVs
  - Complete database of ILOTs (Padova)
  - Templates for photometric classification (brokers)



# 2015-2022 Characterization of new species of stellar transients



# The “Gap Transients” zoo: taxonomy

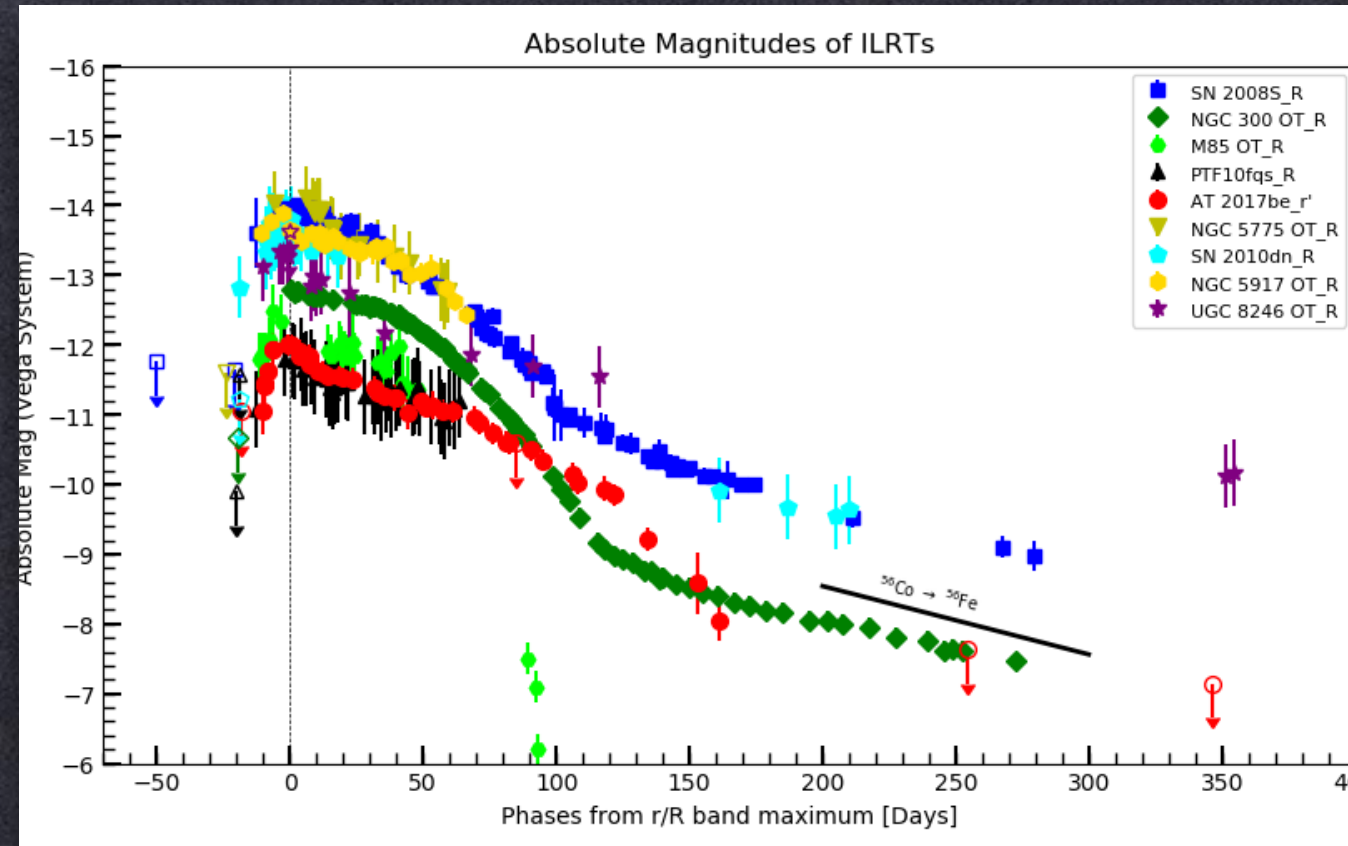
*Pastorello & Fraser 2019*

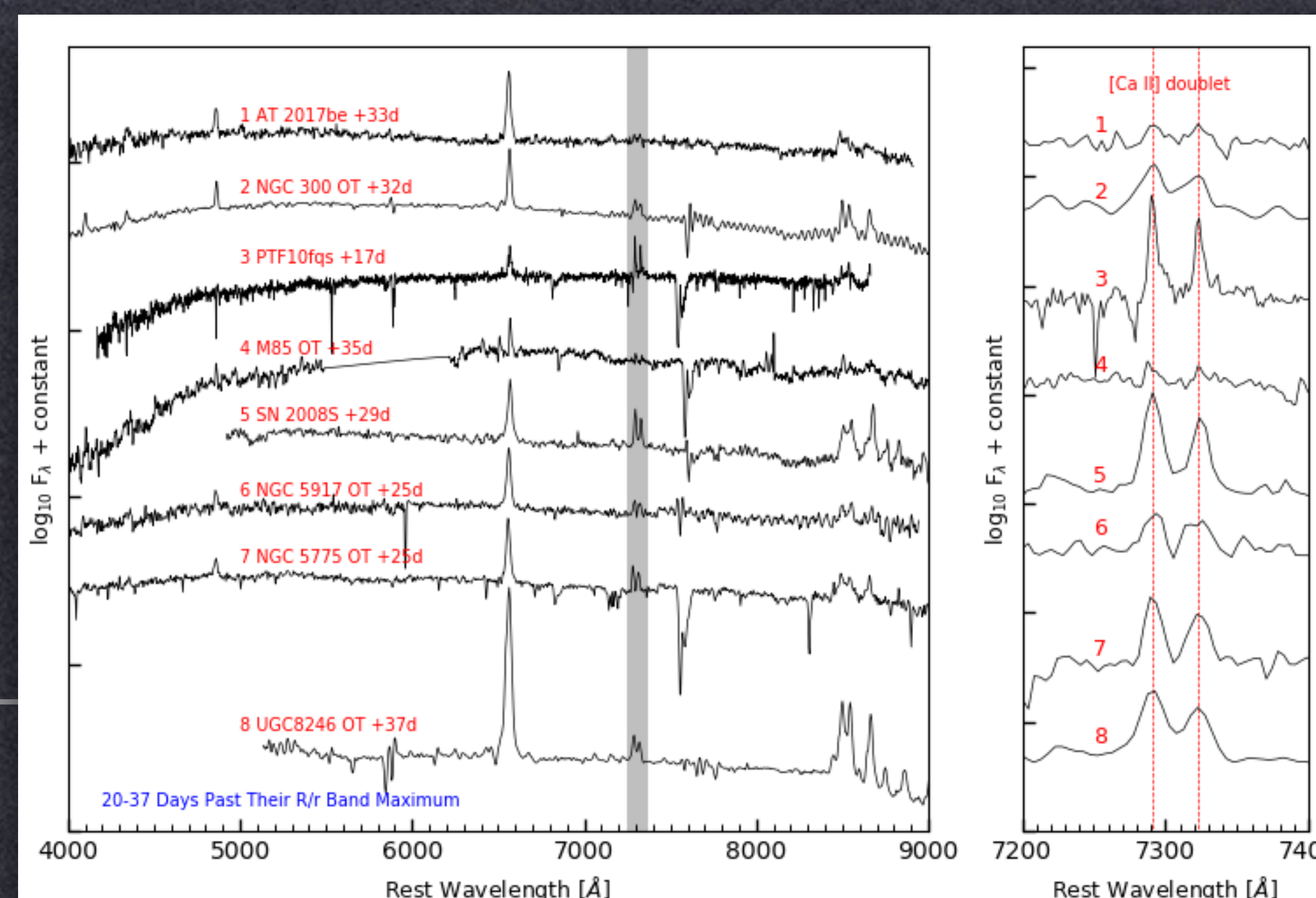
1. Luminous Red Novae (LRNe) - yellowish giant-to-hypergiant progenitors (with wide mass range), in close binaries. Mergers?
2. Intermediate-Luminosity Red Transients (ILRTs) Dust-embedded 8-15 $M_\odot$ progenitors. Electron-capture SNe or outbursts of E-AGB?
3. Major LBV eruptions (Eta-Car, SN 2000ch, SN 2009ip in 2009-2012) => erratic variability with multiple outbursts; $M_V$ ~ -11.5 to -14.5 mag
4. Major stellar outbursts / SN impostors - massive ($M_{ZAMS}$ > 40 $M_\odot$) progenitors (hypergiants, WRs), such as the precursor of SN 2006jc) => single outburst; $M_V$ ~ -13 to -14
5. Extreme S Dor variability (e.g. R71, M33 Var C, AE & AF And, UGC 2773-2009OT1) => heterogeneous $\triangle$M < 3 mag, $M_V$ > -11 mag
6. Faint type I SNe (.Ia, Ca-rich transients, fast & faint SNe) - failed thermonuclear explosions or faint core-collapse (fall-back SNe, EC SNe)
7. Faint type II SNe (1997D-like) - Fe core-collapse of 8-10 $M_\odot$ RSGs or fall-back SNe?

# Intermediate-Luminosity Red Transients (ILRTs)

- Peak absolute mag: -12 to -14
- Type IIP or IIL-like light curves
- Late-time decline consistent with $^{56}Co$
- Type IIn-like spectra
- [Ca II] near 7300 A <u>always</u> detected
- No molecular bands in the late optical spectra
- Quiescent progenitors seen in the mid-IR only; no detection in the optical or near-IR regions

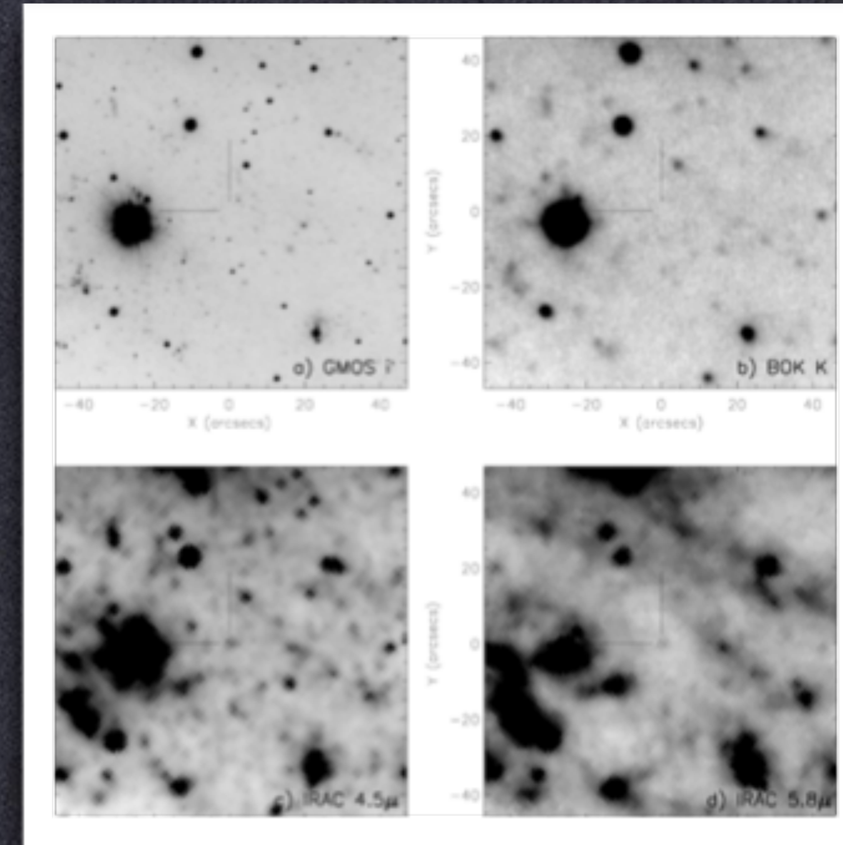
*Cai et al. 2018, MNRAS, 480, 3424*
*Cai et al. 2019a, A&A, to be subm.*
*Valerin MSc Thesis, in prep.*



## 8-15 M$_\odot$ STARS EMBEDDED IN DUSTY COCOONS

- ✴ Outbursts from low-mass LBVs or B[e] hypergiants in a dusty cocoon
- ✴ Outbursts due to binary interaction involving a S-AGB
- ✴ Electron-capture SNe from S-AGB stars (disappearance of the progenitors in the MIR)
- ✴ Outbursts of low-mass LBVs or B[e] hypergiants in a dusty cocoon
- ✴ Outbursts from binary interaction with a S-AGB
- ✴ <u>Electron-capture SNe</u>




Mon. Not. R. Astron. Soc. 000, 000–000 (0000) Printed 24 November 2015 (MN LaTeX style file v2.2)

### Almost Gone: SN 2008S and NGC 300 2008OT-1 are Fainter than their Progenitors

S. M. Adams[1,2], C. S. Kochanek[1,2], J. L. Prieto[3,4], X. Dai[5], B. J. Shappee[6,7,8], and K. Z. Stanek[1,2]

[1] Dept. of Astronomy, The Ohio State University, 140 W. 18th Ave., Columbus, OH 43210
[2] Center for Cosmology and AstroParticle Physics (CCAPP), The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210
[3] Núcleo de Astronomía de la Facultad de Ingeniería, Universidad Diego Portales, Av. Ejército 441, Santiago, Chile
[4] Millennium Institute of Astrophysics
[5] Department of Physics and Astronomy, University of Oklahoma, 440 W. Brooks St., Norman, OK 73019, USA
[6] Carnegie Observatories, 813 Santa Barbara Street, Pasadena, CA 91101, USA
[7] Carnegie-Princeton Fellow
[8] Hubble Fellow
E-mail: sadams@astronomy.ohio-state.edu

arXiv:1511.07393v1 [astro-ph.HE] 23 Nov 2015

24 November 2015

**ABSTRACT**

We present late-time *Hubble* and *Spitzer Space Telescope* imaging of SN 2008S and NGC 300 2008OT-1, the prototypes of a common class of stellar transients whose true nature is debated. Both objects are still fading and are now > 15 times fainter than the progenitors in the mid-IR and are undetected in the optical and near-IR. Data from the Large Binocular Telescope and Magellan show that neither source has been variable in the optical since fading in 2010. We present models of surviving sources obscured by dusty shells or winds and find that extreme dust models are needed for surviving stars to be successfully hidden by dust. Explaining these transients as supernovae explosions, such as the electron capture supernovae believed to be associated with extreme AGB stars, seems an equally viable solution. Though SN 2008S is not detected in *Chandra X-Ray Observatory* data taken in 2012, the flux limits allow the fading IR source to be powered solely by the shock interaction of ejecta with the circumstellar medium if the shock velocity at the time of the observation was $\gtrsim$ 20% slower than estimated from emission line widths while the transient was still optically bright. Continued *SST* monitoring and 10 – 20 $\mu$m observations with *JWST* can resolve any remaining ambiguities.

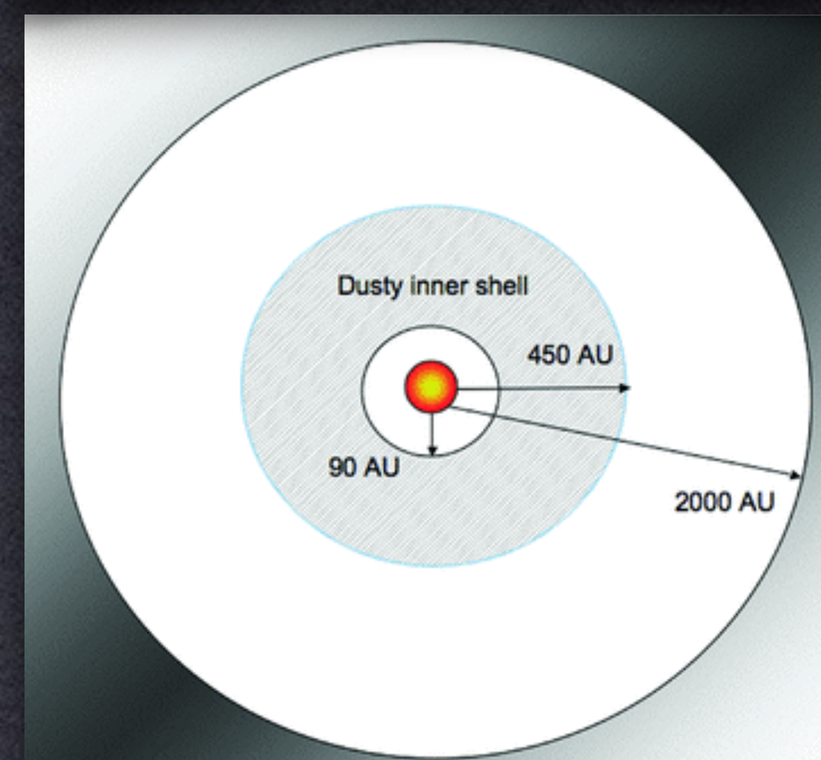
#### 1 INTRODUCTION

SN 2008S-like events are transients arising from heavily obscured extreme asymptotic branch stars (Prieto et al. 2008; Thompson et al. 2009). The spectra of the events are similar to Type IIn supernovae (SNe), but have lower ejecta velocities (~ 1000 km/s) and peak luminosities (~ −10 to −15 mag) than typical supernovae (e.g., Smith et al. 2011).

SN 2008S-like transients are not a rare, inconsequential phenomenon. Though few events have been detected due to their low luminosities, the rate of these transients is ~ 10 – 20% of the core-collapse supernova (ccSN) rate (Thompson et al. 2009). The obscured progenitors of these transients are very rare (even relative to massive stars; Thompson et al. 2009; Khan et al. 2010), which likely means that the dust-enshrouded phase is a relatively common but short-lived (< $10^4$ yr) phase (Thompson et al. 2009).

These transients are often considered to be a subclass of SN impostors. However, other SN impostors seem to arise from more massive stars (> 20 $M_\odot$) and are often considered to be eruptions of Luminous Blue Variables (see, e.g., Humphreys & Davidson 1994; Smith et al. 2011; Kochanek et al. 2012). While some events classified as SN impostors clearly are non-terminal, evidence is emerging that others are just as likely to be low-luminosity, core-collapse events (Kochanek et al. 2012; Adams & Kochanek 2015).

The two best prototypes of the SN 2008S class are SN 2008S itself (Arbour & Boles 2008) and the very similar NGC 300 2008OT-1 (Monard 2008, hereafter referred to as N300OT). The progenitor of SN 2008S was heavily obscured and undetected in the optical, but was identified as a mid-IR source with $L_* \simeq 10^{4.5}\ L_\odot$ and a blackbody temperature of $T_{bb} \simeq 440$ K (see Table 1; Prieto et al. 2008). The transient peaked at an absolute V-band magnitude of $-14.0 \pm 0.2$ (Botticella et al. 2009). Likewise, the dusty progenitor of N300OT had a luminosity of $10^{4.9}\ L_\odot$ and $T_{bb} \simeq 300$ K (see Table 2; Prieto 2008). The N300OT transient peaked at

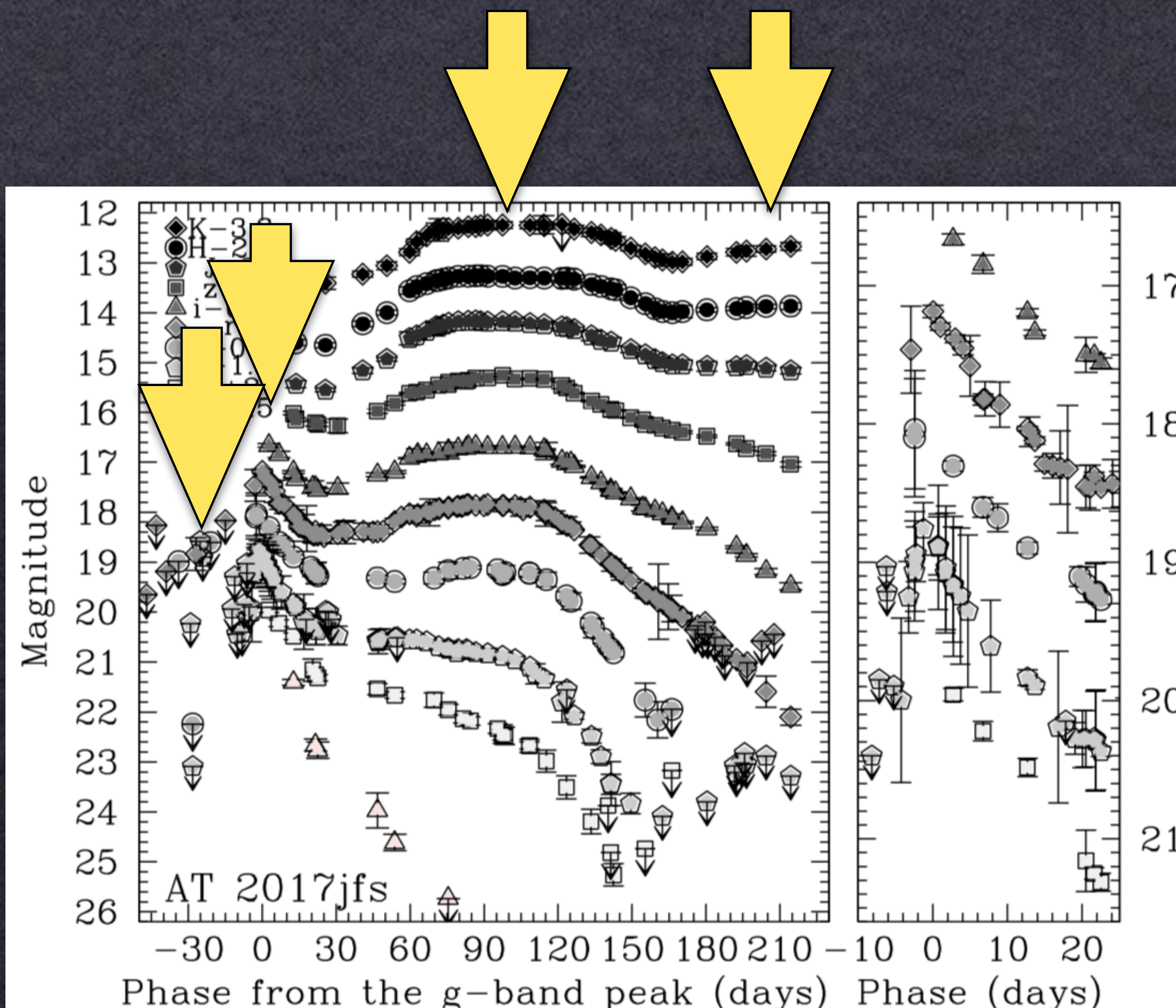


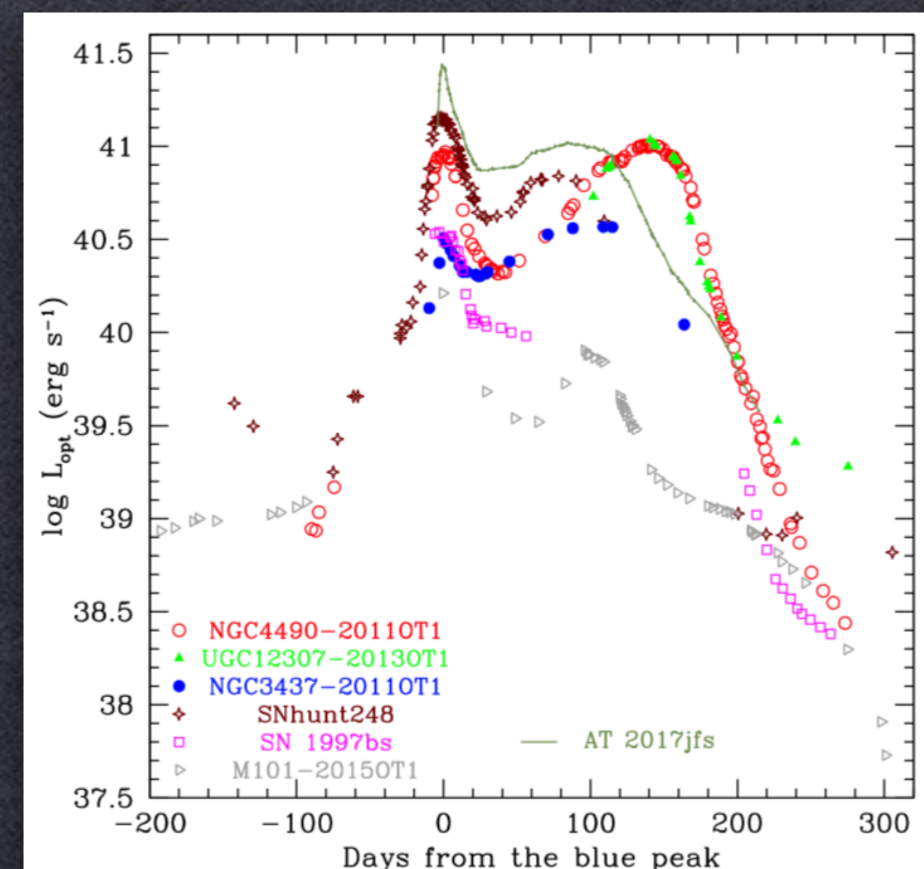

# Intermediate-Luminosity Red Transients (ILRTs)

*Botticella+ 2009, MNRAS, 398, 1041*
*This will be the subject of the PhD activity of Giorgio Valerin*

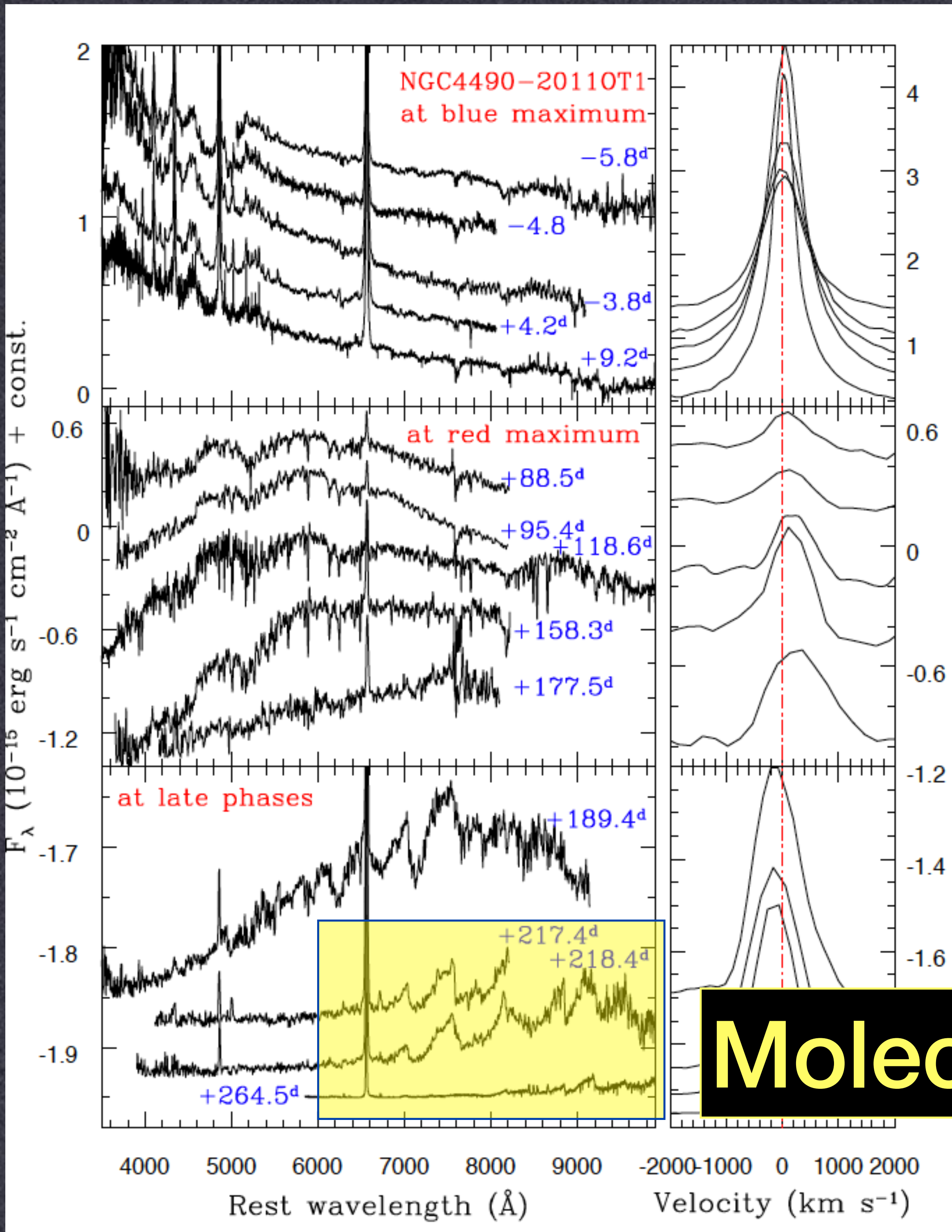
*Pastorello+ 2019a, A&A, 625, L8*
*Pastorello+ 2019b, A&A subm. (arXiv:1906,00812)*
*Cai et al. 2019b, A&A lett., in prep.*

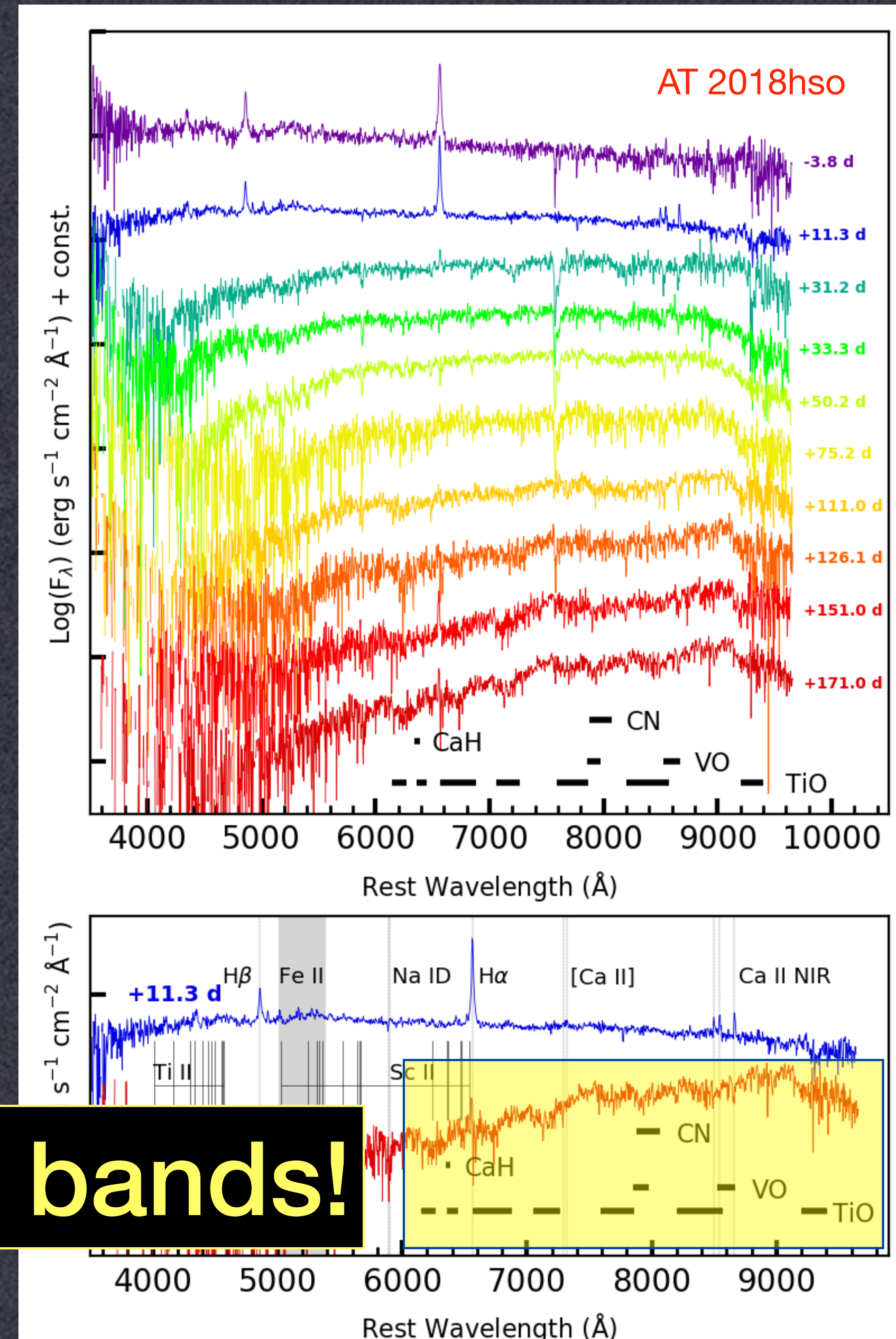
- ✳ Max absolute magnitudes:
  - RNe: $M_V$ < -10 (to -4) mag
  - LRNe: $M_V$ > -10 (to -15) mag
- ✳ Pre-outburst brightening
- ✳ First, short-duration blue peak
- ✳ Second, shallow red peak, or plateau
- ✳ Late-time infrared excess




# Luminous Red Novae



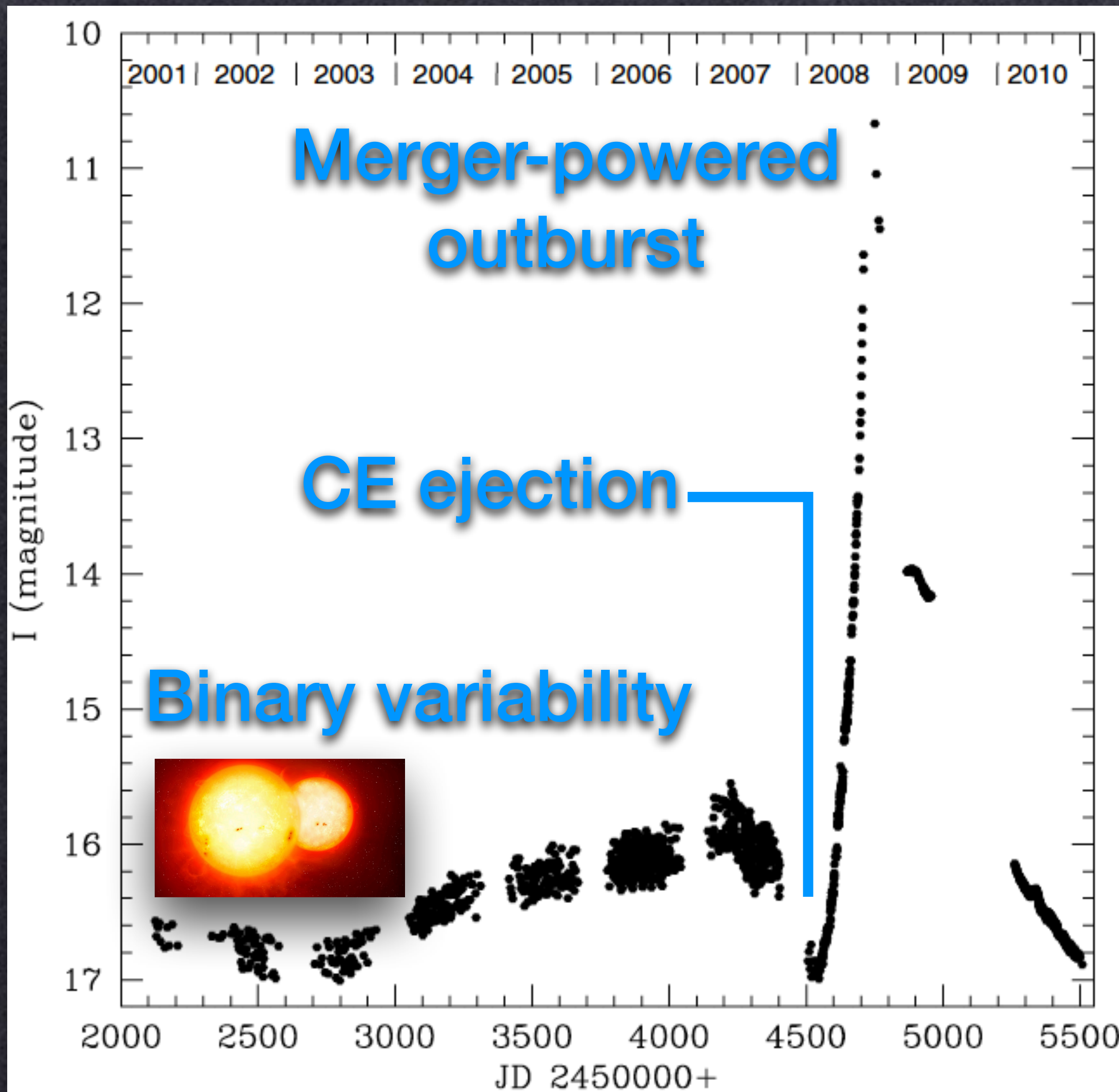

Molecular bands!

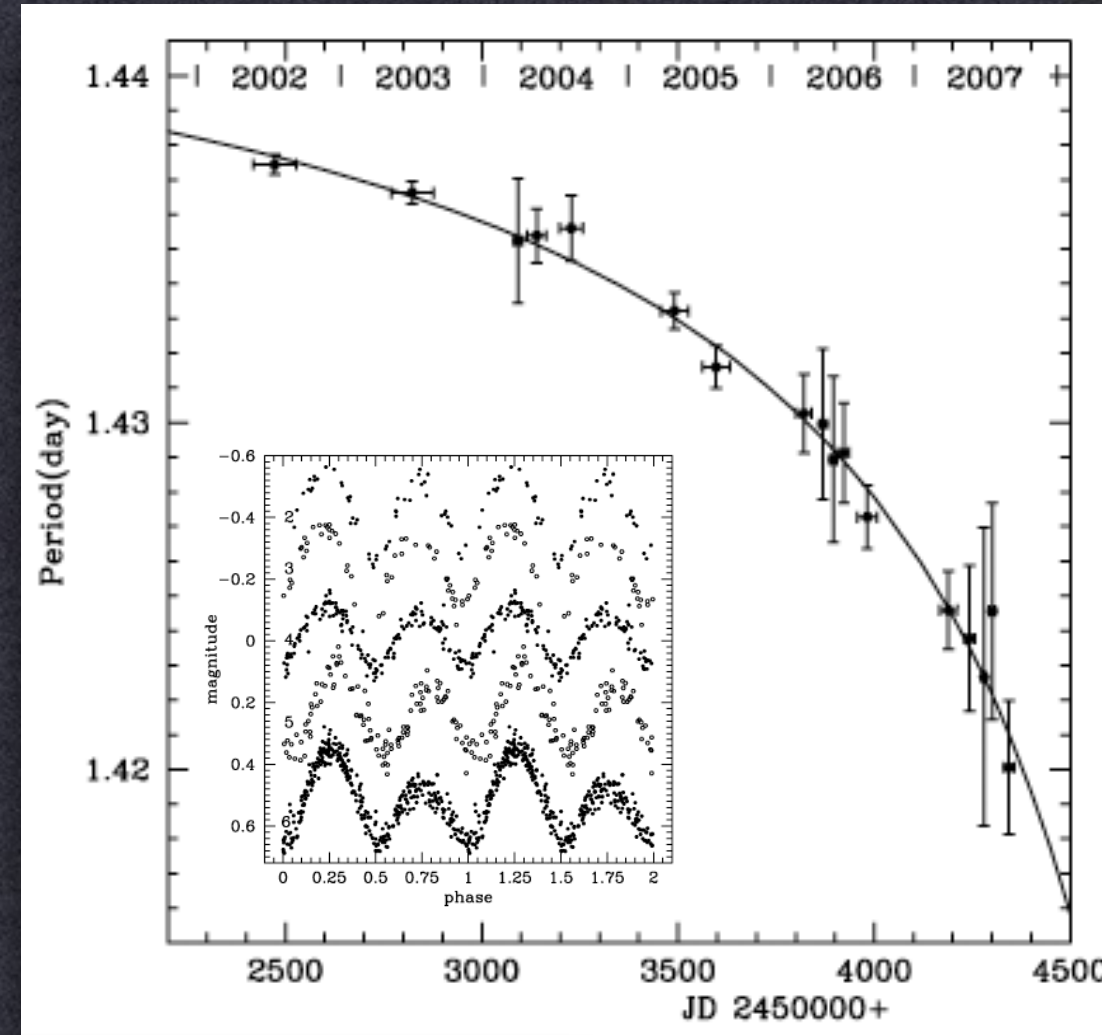
*Cai et al. 2019b, A&A lett., in prep.*

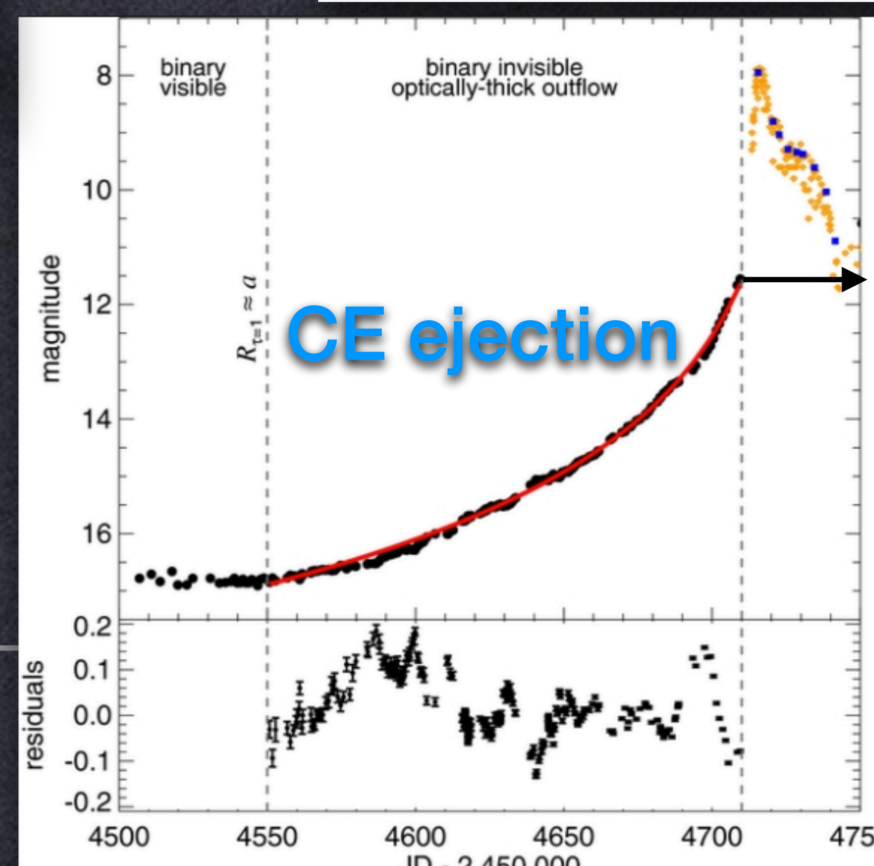
# Luminous Red Novae

# Red Novae

## V1309 Sco




Merger-powered outburst

G to M-type

*Tylenda et al. 2011*
*(see also Mason+ 2010)*

A. Red Novae

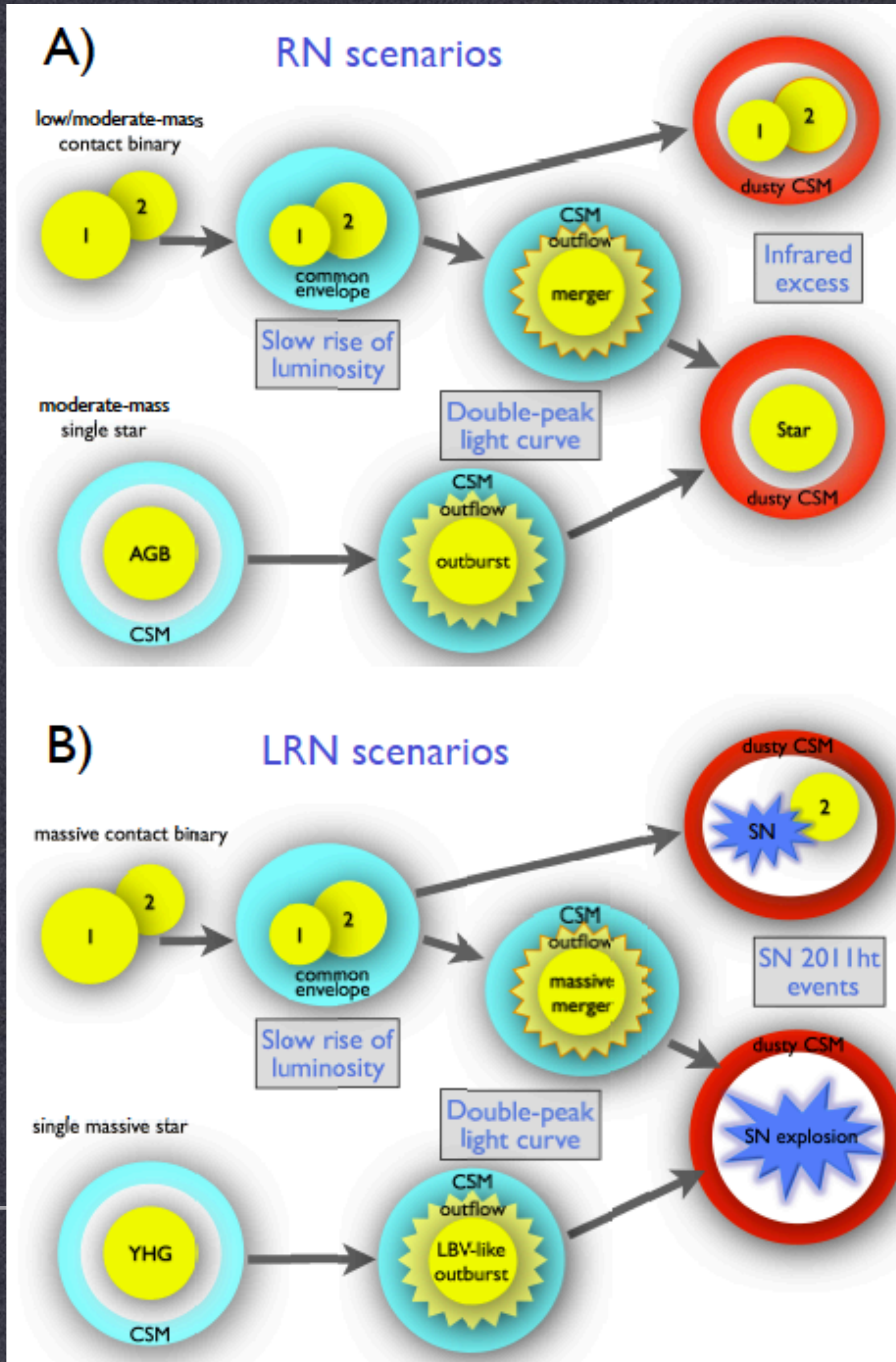
Low-mass binary

- CE & survived binary
- CE & merger
- AGB-like outburst

B. Luminous Red Novae

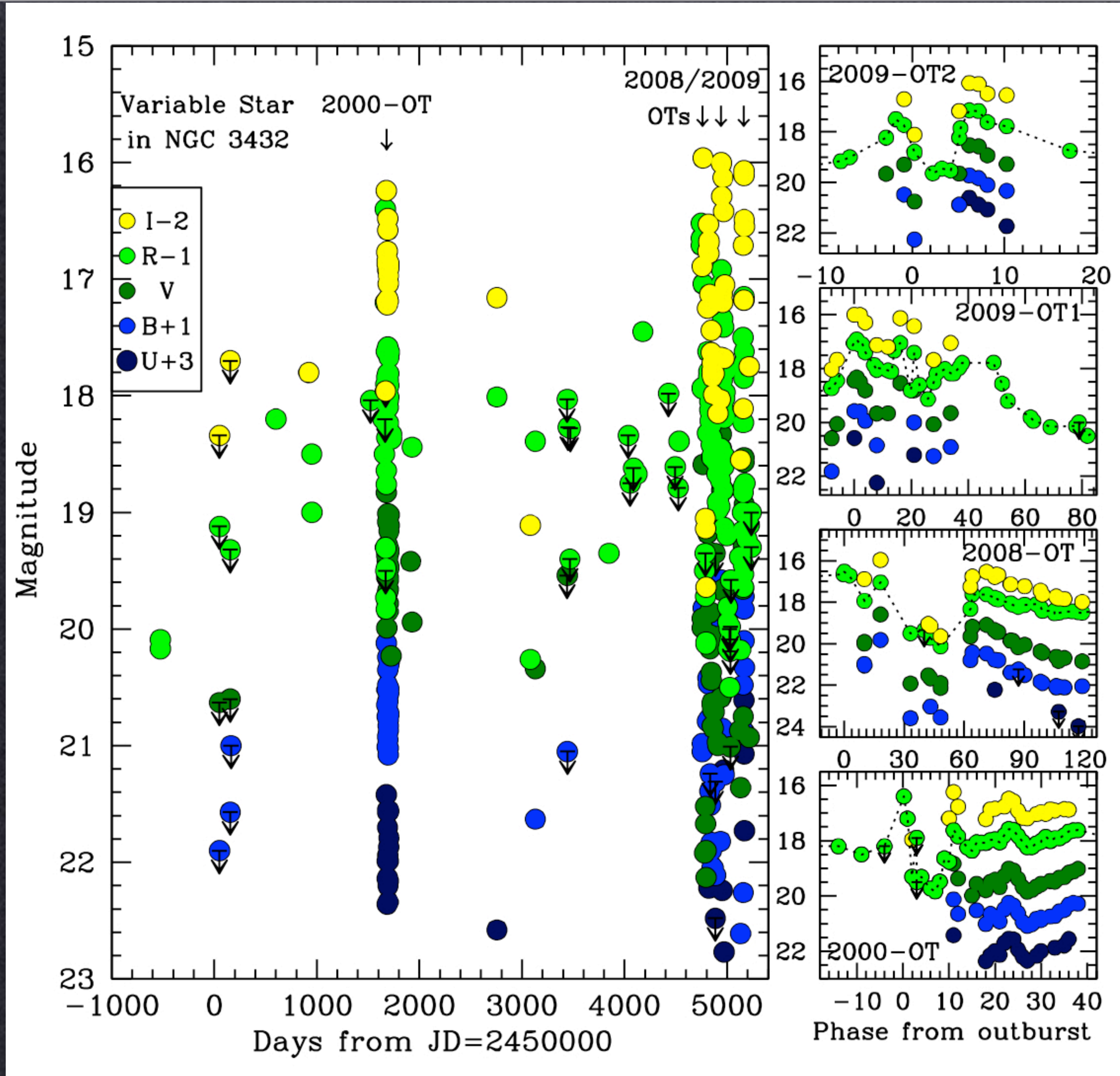
Massive binary

- CE & survived binary (with primary exploding as a SN)
- CE & massive merger (eventually going to SN)
- LBV-like outburst followed by a SN explosion

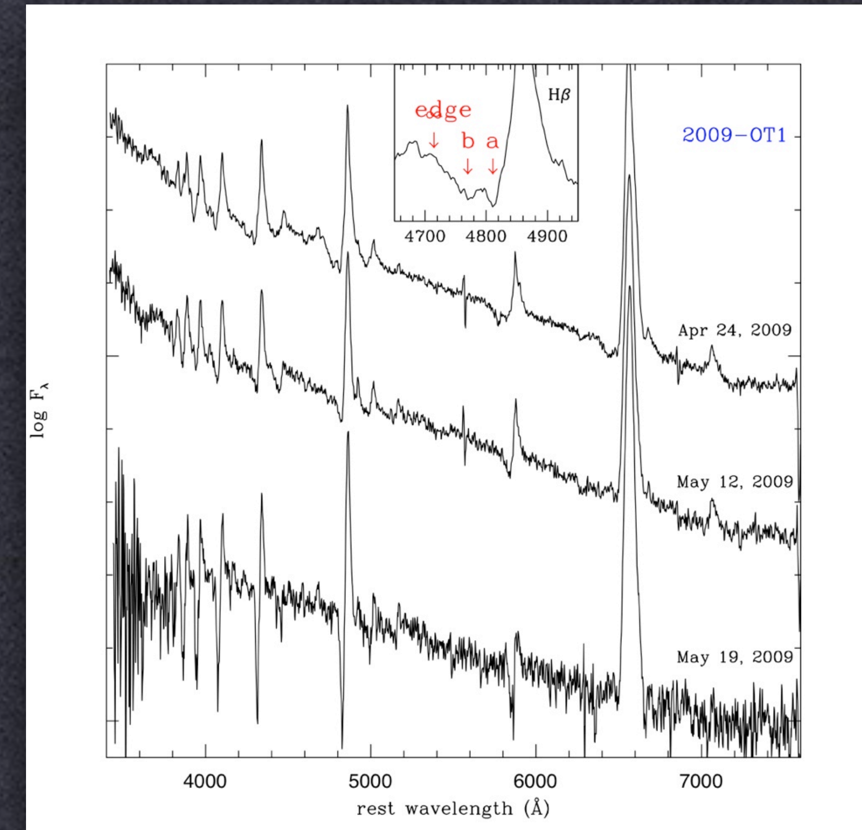



# RN/LRN Channels

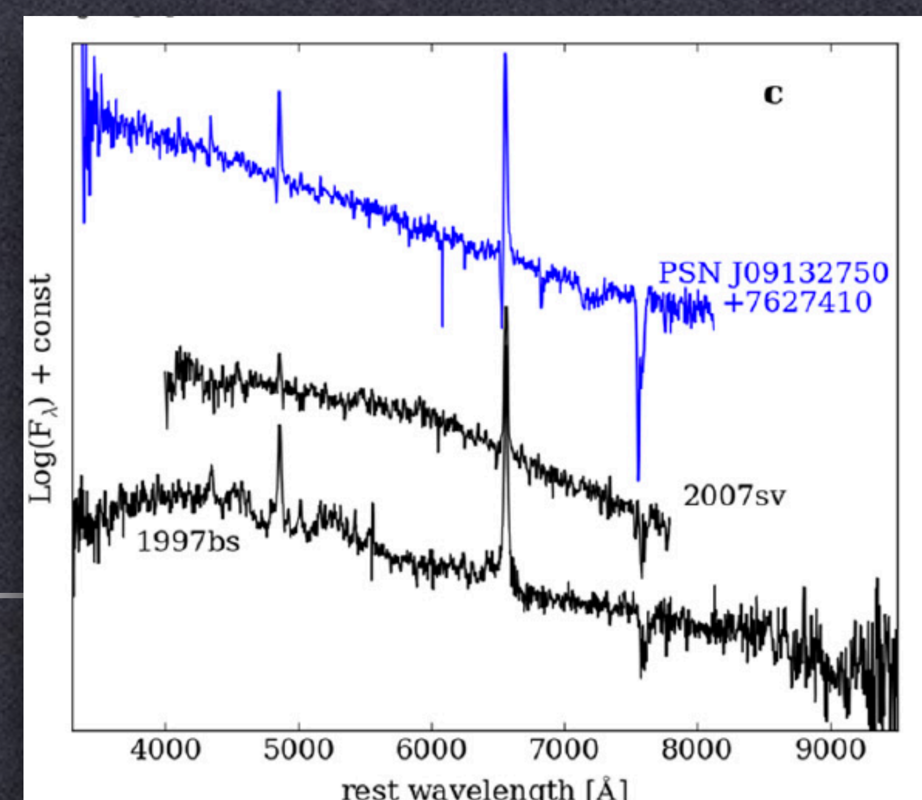
# SN impostors

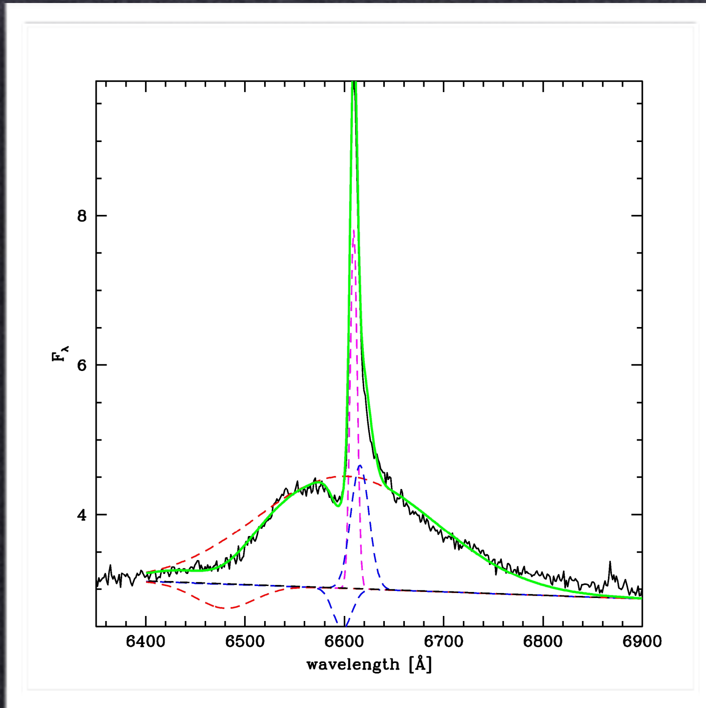



Impostors occasionally explode as genuine SNe!

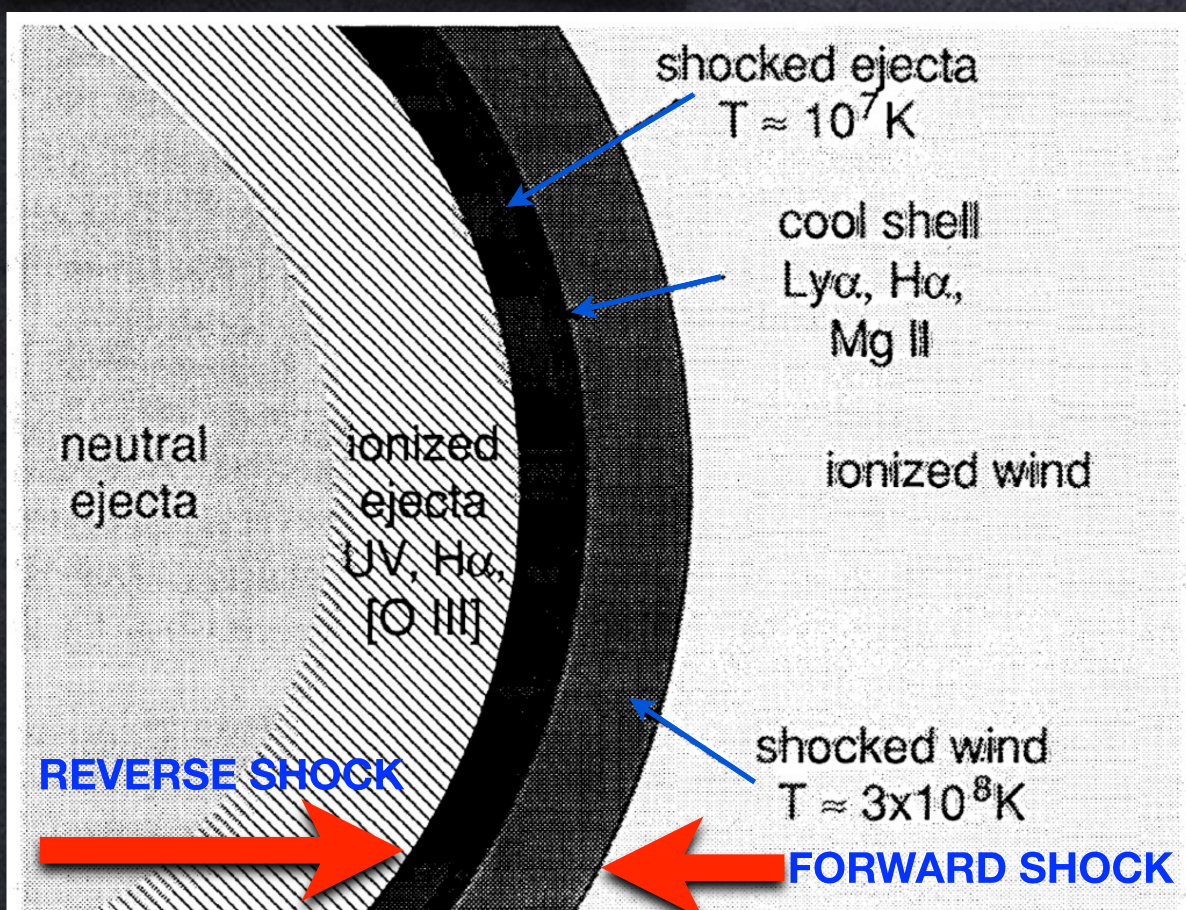



*Pastorello+ 2010, MNRAS, 408, 181*
*Tartaglia+ 2015, MNRAS, 447, 117*
*Tartaglia+ 2016, ApJ, 823, L23*

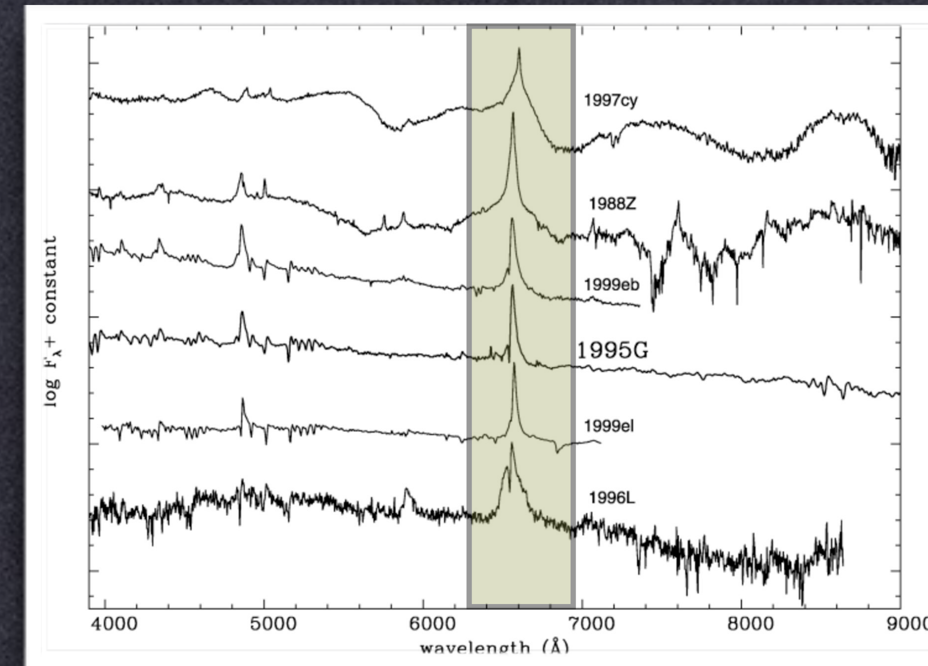




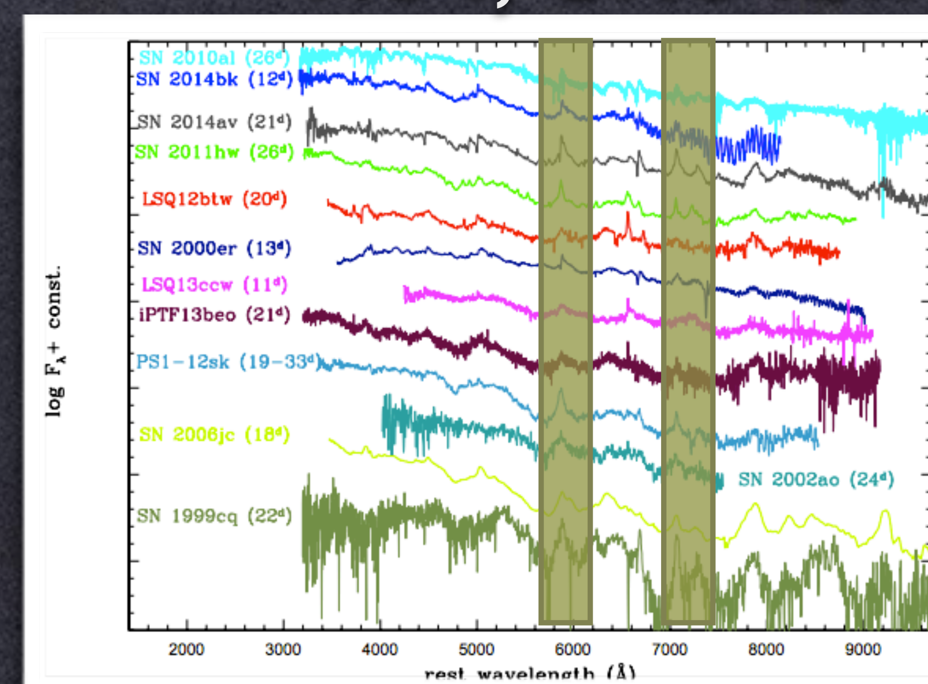

- Blue pseudo-continuum
- Multi-component H or He I lines
- Wind velocity of $10^2$ to $10^3$ km $s^{-1}$
- Slow-evolving, long-duration light curve



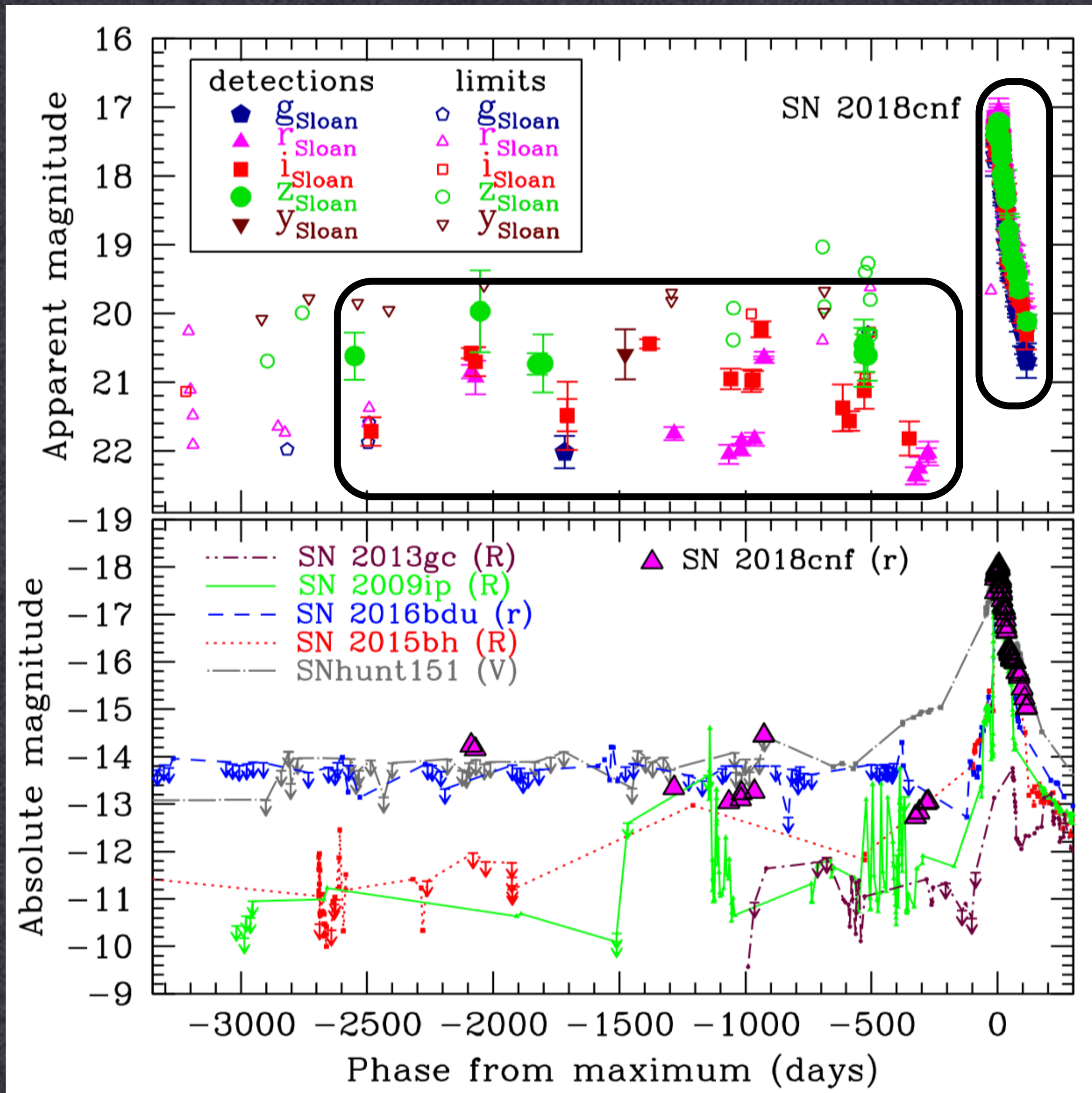

## H; SNe IIn



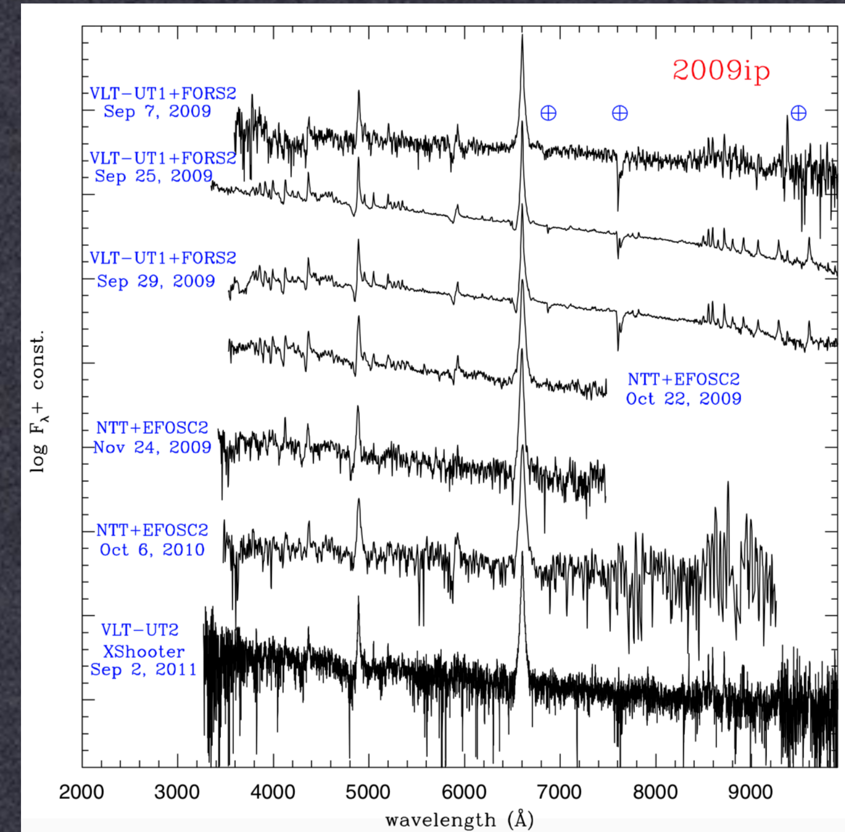

## He I; SNe Ibn



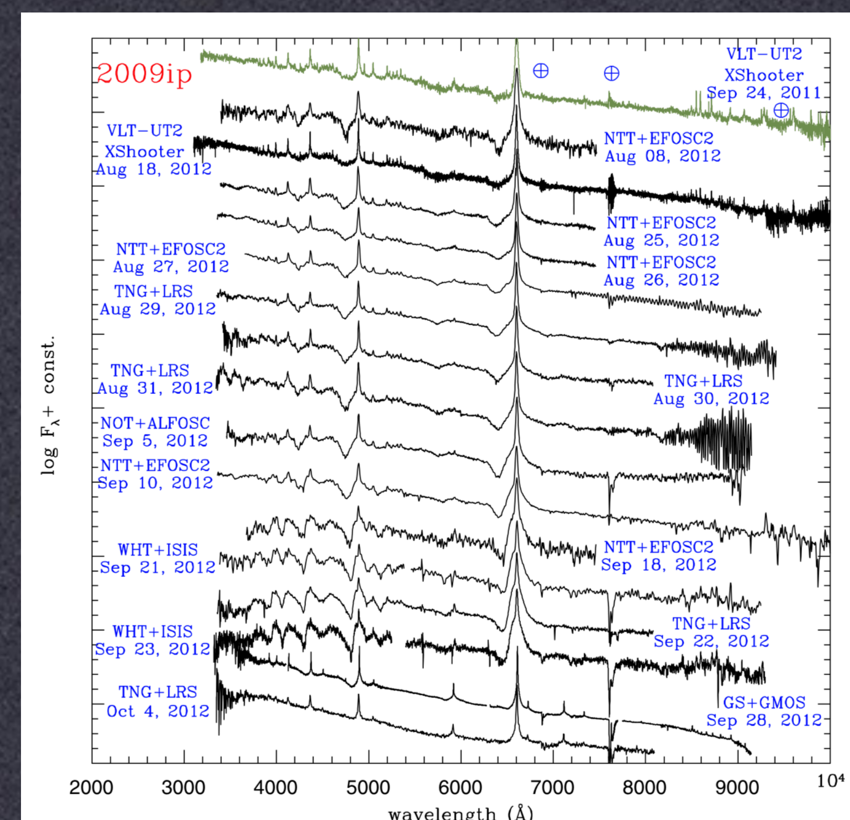

# Ejecta-CSM interacting Supernovae




*Pastorello+ 2019, A&A, arXiv:1906.00814*
*Reguitti+ 2019, MNRAS, 482, 2750*
*Pastorello+ 2018, MNRAS, 474, 197*
*Elias-Rosa et al. 2018, MNRAS, 475, 2614*
*Elias-Rosa et al. 2016, MNRAS, 463, 3894*
*Tartaglia+ 2016, MNRAS,459, 1039.....*



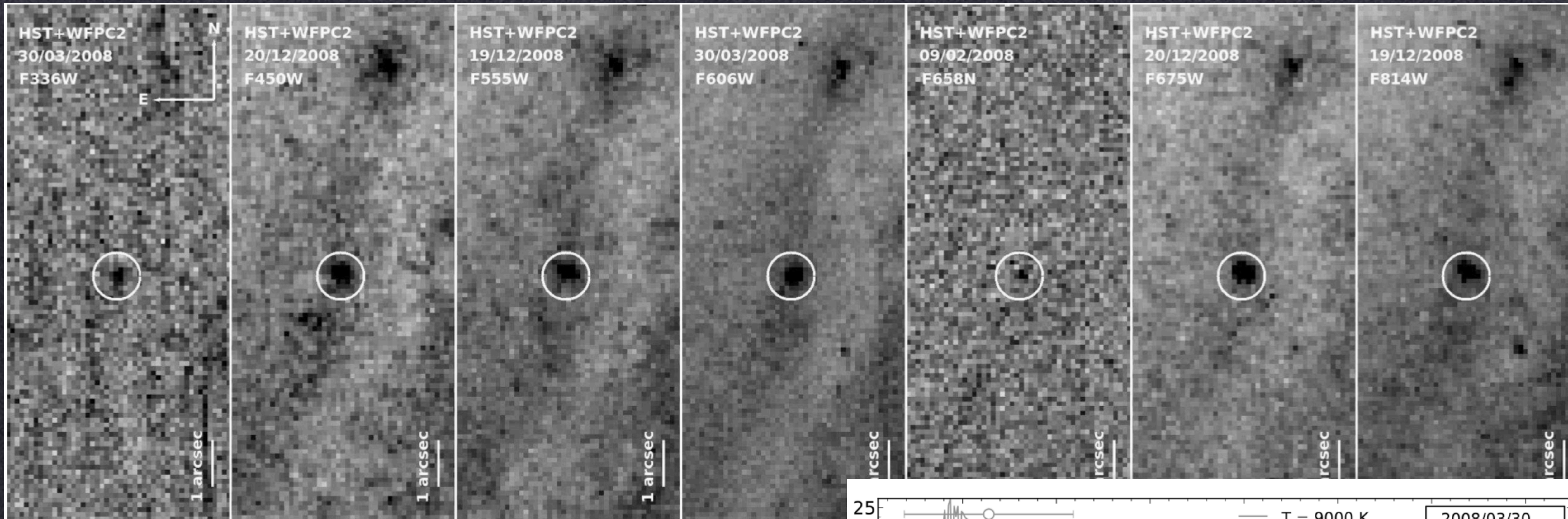

impostor

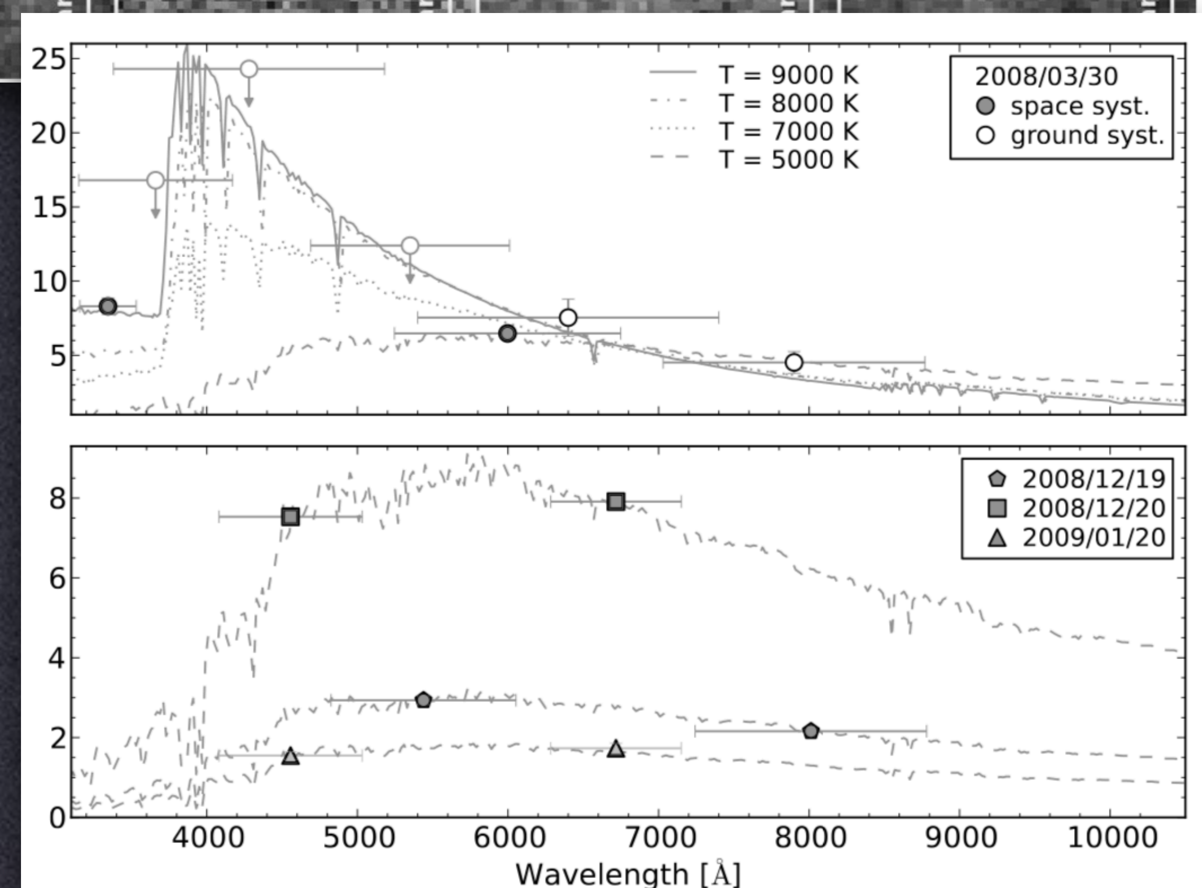



SN II

interaction

# From impostors to interacting SNe




The progenitors of impostors (and SNe IIn) are occasionally detected in "quiescence". They are massive (over $40M_{\odot}$) hypergiants or LBVs.

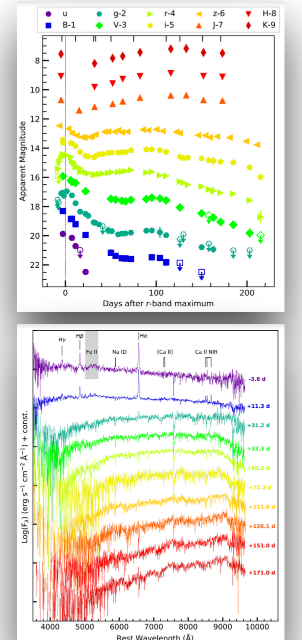
*Elias-Rosa et al. 2018, MNRAS, 475, 2614*

# From impostors to interacting SNe

# Our papers on gap transients and interacting SNe from 2015

- Reguitti, Pastorello, Smartt et al. 2019, A&A lett., submitted (shock breakout/SN IIn)
- Pastorello, Mason, et al. 2019, A&A, submitted, arXiv:1906.00812 (LRN sample)
- Pastorello, Reguitti et al. 2019, A&A, submitted, arXiv:1906.00814 (impostor+SN IIn)
- Pastorello, Chen, Cai et al. 2019, A&A, 625, L8 (LRN)
- Pastorello & Fraser, 2019, Nature Astr., in press
- Reguitti, Pastorello, Pignata et al. 2019, MNRAS, 482, 2750 (impostor+SN IIn)
- Cai, Pastorello, Fraser et al., 2018, MNRAS, 480, 3423 (ILRT)
- Chen, Inserra, Fraser et al., 2018, ApJ, L31 (SN IIn)
- Elias-Rosa, Benetti, Cappellaro et al. 2018, MNRAS, 475, 2614 (impostor+SN IIn)
- Pastorello, Kochanek, Fraser et al. 2018, MNRAS, 474, 197 (impostor+SN IIn)
- Kunkarayakti, Maeda et al. 2018, ApJ, 854, L14 (SN IIn)
- Hosseinzadeh, Arcavi, Valenti et al. 2017, ApJ, 836, 158 (SN Ibn)
- Blagorodnova, Kotak, Polshaw et al. 2017, ApJ, 834, 107 (LRN)
- Elias-Rosa, Pastorello, Benetti et al., 2016, MNRAS, 463, 3894 (impostor+SN IIn)
- Maund, Pastorello, Mattila et al. 2016, ApJ, 833, 128 (SN Ibn)
- Tartaglia, Pastorello, Sullivan et al. 2016, MNRAS, 459, 1039 (impostor+SN IIn)
- Tartaglia, Elias-Rosa, Pastorello et al. 2016, ApJ, 823, L23 (impostor)
- Pastorello, Wang, Ciabattari et al. 2016, MNRAS, 456, 853 (SN Ibn)
- Kangas, Mattila, Kankare et al. 2016, MNRAS, 456, 323 (IIn)
- Pastorello, Tartaglia, Elias-Rosa et al. 2015, MNRAS, 454, 4293 (Ibn)
- Fraser, Kotak, Pastorello et al. 2015, MNRAS, 453, 3886 (SN IIn)
- Pastorello, Prieto, Elias-Rosa et al. 2015, 453, 3649 (SN Ibn)
- Kankare, Kotak, Pastorello et al. 2015, A&A, 581, L4 (LRN)
- Taddia , Sollerman, Pastorello et al. 2015, A&A, 580, 131 (hosts of interacting transients)
- Pastorello, Hadjiyska, Rabinowitz et al. 2015, MNRAS, 449, 1954 (SN Ibn)
- Pastorello, Wyrzykowski, Valenti et al. 2015, MNRAS, 449, 1941 (SN Ibn)
- Pastorello, Benetti, Brown et al. 2015, MNRAS, 449, 1921(SN Ibn)
- Tartaglia, Pastorello, Taubenberger et al. 2015, MNRAS, 447, 117 (impostor)

# LSST preparatory phase



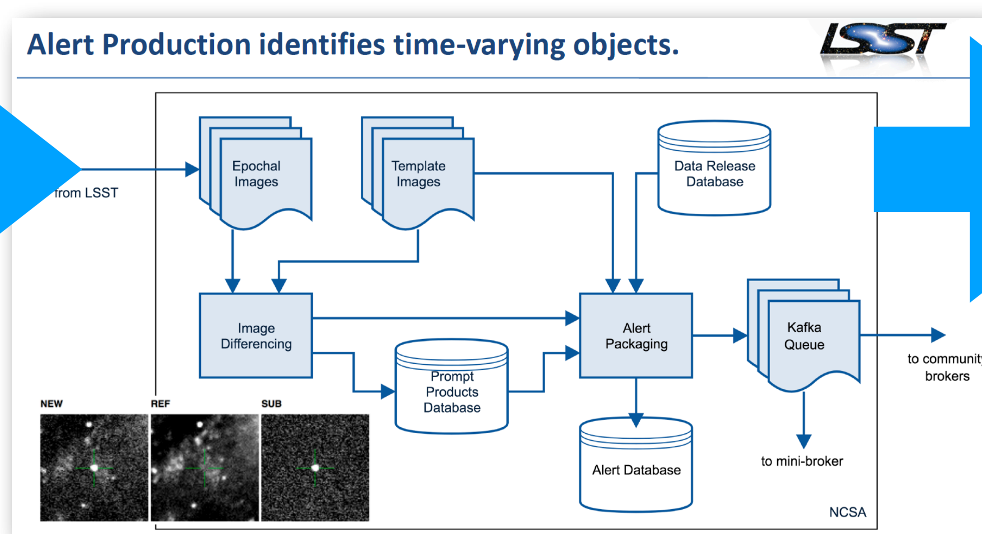
Pagina introduttiva: *http://sngroup.oapd.inaf.it/ilot.html*

Attualmente 50 oggetti inclusi di varie classi, dalla letteratura o non ancora pubblicati.
Altri 40 oggetti individuati, con curve di luce e spettri sotto analisi. Altri saranno aggiunti non appena scoperti.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ASASSN-15qi | Milky Way | 22:54:05.373 | +58:15:02.02 | 13.64 | 2015/10/03 | YSO | EXor/FUor | sdss | view |
| AT2017be | NGC 2537 | 08:13:13.380 | +45:59:29.54 | 18.5 | 2017/01/06 | ILRT | Sp | sdss | view |
| AT2017dau | UGC 09113 | 14:14:17.08 | +35:25:43.47 | 19.28 i | 2017/04/482 | Impostor? | S? | sdss | view |
| AT2017dha | UGC 10213 | 16:07:23.710 | +10:25:40.19 | 20.58 i | 2017/04/20 | Impostor | S? | sdss | view |
| CK-Vul | Milky Way | 19:47:38.0 | +27:18:48.0 | 3 V | 1670/06/20 | LRN/Nova | S2 | sdss | view |
| HFF14Spo-NW | anonymous | 04:16:09.256 | -24:04:11.78 | 29.30 | 2014/01/07 | Impostor/LRN | Mb | sdss | view |
| HFF14Spo-SE | anonymous | 04:16:09.360 | -24:04:12.87 | 27.98 | 2014/08/28 | Impostor/LRN | Mb | sdss | view |
| LMC-R71 | LMC | 05:02:07.394 | -71:20:13.12 | 7.1 | 2012/04/02 | LBV | S Dor | sdss | view |
| LSQ13zm | SDSS J102654.56+195254.8 | 10:26:54.591 | +19:52:54.91 | 17.2 | 2013/04/13 | Impostor?+SN | M?+IIn2 | sdss | view |
| M101-2015OT1 | M 101 | 14:02:16.78 | +54:26:20.5 | 16.5 | 2015/01/20 | LRN | S2 | sdss | view |
| M31-LRN2015 | M 31 | 00:42:07.99 | +40:55:01.1 | 19.0 | 2015/01/13 | LRN | S2 | sdss | view |
| M31-RV | M 31 | 00:43:02.433 | +41:12:56.17 | 14.9 I | 1988/09/03 | LRN | S2 | sdss | view |
| M85-2006OT1 | NGC 4382 | 12:25:23.80 | +18:10:56.0 | 14.0 | 2006/01/07 | ILRT/BLRN | Sp | sdss | view |
| NGC2363A-V1 | NGC 2366 | 07:28:43.37 | +69:11:23.95 | 17.88 | 1996/01/08 | Impostor | SI | sdss | view |
| NGC2403-V37 | NGC 2403 | 07:37:01.83 | +65:34:29.3 | 19.0 | 1916/02/03 | Impostor | S Dor / Mb | sdss | view |
| NGC2748-2015OT1 | NGC 2748 | 09:13:27.50 | +76:27:41.0 | 18.3 | 2015/02/10 | Impostor | S1 | sdss | view |
| NGC3437-2011OT1 | NGC 3437 | 10:52:34.53 | +22:56:05.2 | 18.4 | 2011/01/10 | BLRN | S2 | sdss | view |
| NGC4490-2011OT1 | NGC 4490 | 12:30:41.84 | +41:37:49.7 | 16.0 | 2011/08/16 | BLRN | S2 | sdss | view |
| NGC4656-2005OT1 | NGC 4656 | 12:43:45.84 | +32:06:15.0 | 18.5 | 2005/03/19 | Impostor | S1d? | sdss | view |
| NGC55-2014OT1 | NGC 55 | 00:15:08.75 | -39:12:50.1 | 16.7 | 2014/10/06 | Impostor/Nova | S1/Fe nova | sdss | view |
| NGC5806-2014OT1 | NGC 5806 | 14:59:59.47 | +01:54:26.6 | 20.3 | 2014/05/21 | BLRN | S2/S3 | sdss | view |
| NGC6509-2011OT1 | NGC 6509 | 17:59:22.995 | +06:17:26.56 | 18.5 | 2011/06/24 | ILRT: | S1d | sdss | view |
| OGLE-2002-BLG-360 | Milky Way | 17:57:38.97 | -29:46:04.8 | 15.92 I | 2002/10/09 | LRN | S2/S3 | sdss | view |
| PTF10fqs | M 99 | 12:18:50.16 | +14:26:39.2 | 20.1 | 2010/03/16 | ILRT/BLRN | Sp | sdss | view |
| SNhunt275 | NGC 2770 | 09:09:35.12 | +33:07:21.3 | 19.9 | 2015/02/07 | SNIIn | Mb+IIn2 | sdss | view |
| UGC12307-2013OT1 | UGC 12307 | 23:01:11.53 | +12:43:21.8 | 18.3 | 2013/06/08 | BLRN | S2: | sdss | view |
| UGC2773-2009OT1 | UGC 2773 | 03:32:07.24 | +47:47:39.6 | 17.6 | 2009/08/18 | Impostor | SI | sdss | view |
| V1309Sco | Milky Way | 17:57:32.94 | -30:43:10.0 | 9.5 | 2008/09/02 | LRN | S2 | sdss | view |
| V4332Sgr | Milky Way | 18:50:36.74 | -21:23:28.8 | 8.9 | 1994/02/24 | LRN | S2: | sdss | view |
| iPTF13z | SDSS J160200.05+211442.3 | 16:02:00.12 | +21:14:41.4 | 18 | 2013/02/01 | Impostor+SN | S?+IInM | sdss | view |

## Future rare transients

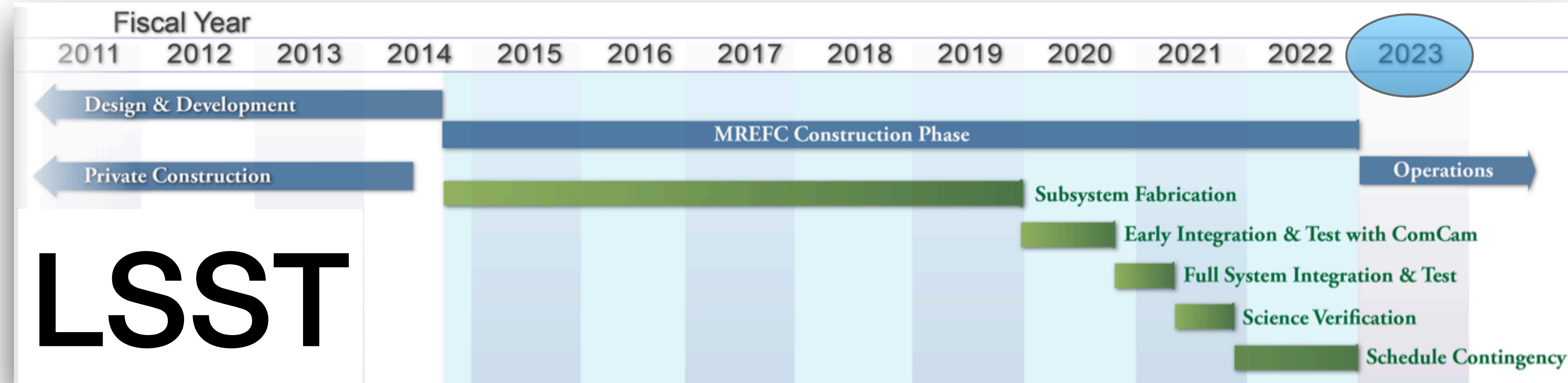
**Filters**




Showing results 0-138

| objectId | ramean | decmean | mjdmin | mjdmax | magrmin | latestrmag | sherlock_classification | score |
|---|---|---|---|---|---|---|---|---|
| ZTF18abnchro | 355.0482186666666 | 24.408041683333337 | 58346.349641200155 | 58437.215902800206 | None | None | NT | Not Near PS1 star |
| ZTF18absqkfg | 43.68501786666667 | 47.442790261111114 | 58367.425763899926 | 58462.270393500105 | None | None | NT | Not Near PS1 star |
| ZTF17aaarqox | 327.0434185123239 | 47.86675474401408 | 58280.455844900105 | 58457.16057869978 | 16.2591 | 18.4422 | NT | Not Near PS1 star |
| ZTF18acbxsge | 9.800914709999999 | -5.2007028 | 58423.24353010021 | 58456.185011600144 | 16.6615 | 18.43 | NT | Not Near PS1 star |
| ZTF18abmjuya | 75.32455640701755 | 46.86420921754386 | 58342.49126160005 | 58464.29006939987 | 16.6665 | 18.8811 | NT | Not Near PS1 star |
| ZTF18accnnyu | 142.62426130666665 | 16.34365577333334 | 58425.498124999925 | 58461.5225463002 | 16.9433 | 17.7337 | NT | Not Near PS1 star |
| ZTF18abuhyjv | 39.06520179047619 | -1.1996821190476192 | 58372.48464119993 | 58456.25726850005 | 17.2608 | 18.7595 | NT | Not Near PS1 star |
| ZTF18abugmrg | 351.505418772 | 38.14633266800001 | 58370.30142359994 | 58456.15363429999 | 17.3337 | 17.6203 | NT | Not Near PS1 star |
| ZTF18abtswjk | 38.29801417407407 | -1.3056561407407405 | 58369.47621530015 | 58462.274513899814 | 17.4162 | 17.5588 | NT | Not Near PS1 star |
| ZTF18aaklpdo | 177.45079423809526 | 25.650587876190478 | 58276.19857640006 | 58450.51827549981 | 17.4824 | 17.6624 | NT | Not Near PS1 star |
| ZTF18aaasgau | 124.86382430833332 | 22.638784966666666 | 58372.51559029985 | 58455.456747699995 | 17.5226 | 18.6124 | NT | Not Near PS1 star |
| ZTF18acrukpd | 84.85494625555556 | -6.150067966666667 | 58450.39837960014 | 58462.35304399999 | 17.5524 | 17.5524 | NT | Not Near PS1 star |
| ZTF18abmenfr | 346.8452078 | 43.60390094705882 | 58358.40563660022 | 5845 | | | | |
| ZTF18abvtcpk | 45.449476881818185 | 18.568137145454543 | 58374.4365393999 | 5846 | | | | |
| ZTF18abtpite | 349.64964474 | 41.13330549 | 58428.178391200025 | 5845 | | | | |
| ZTF18acauwik | 350.81365819 | 35.621342229999996 | 58423.22281249985 | 5845 | | | | |
| ZTF18acewwqf | 142.98697635714285 | 67.6147391 | 58434.465104199946 | 5845 | | | | |

# The Future: mapping the unknown




## Project timeline

Date to be operational on sky: late 2021

| | | |
|---|---|---|
| Preliminary design review | July 2017 | ✓ |
| Final design review | July 2018 | ✓ |
| End of Procurement | May 2020 | |
| AIT & Test in Europe | December 2020 | |
| Instrument in Chile | March 2021 | |
| End of Commissioning | September 2021 | |