

IAU Symposium 331 „SN 1987A - 30 years after“
Saint-Gilles-les-Bains, La Réunion, Feb. 20, 2017



Outbursts of massive stars: SN 2015bh and its relatives

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Thöne et al. *A&A* in press, astro.ph 1606.09025
see also Elias-Rosa et al. 2016

The hunt for telluric eruptions...

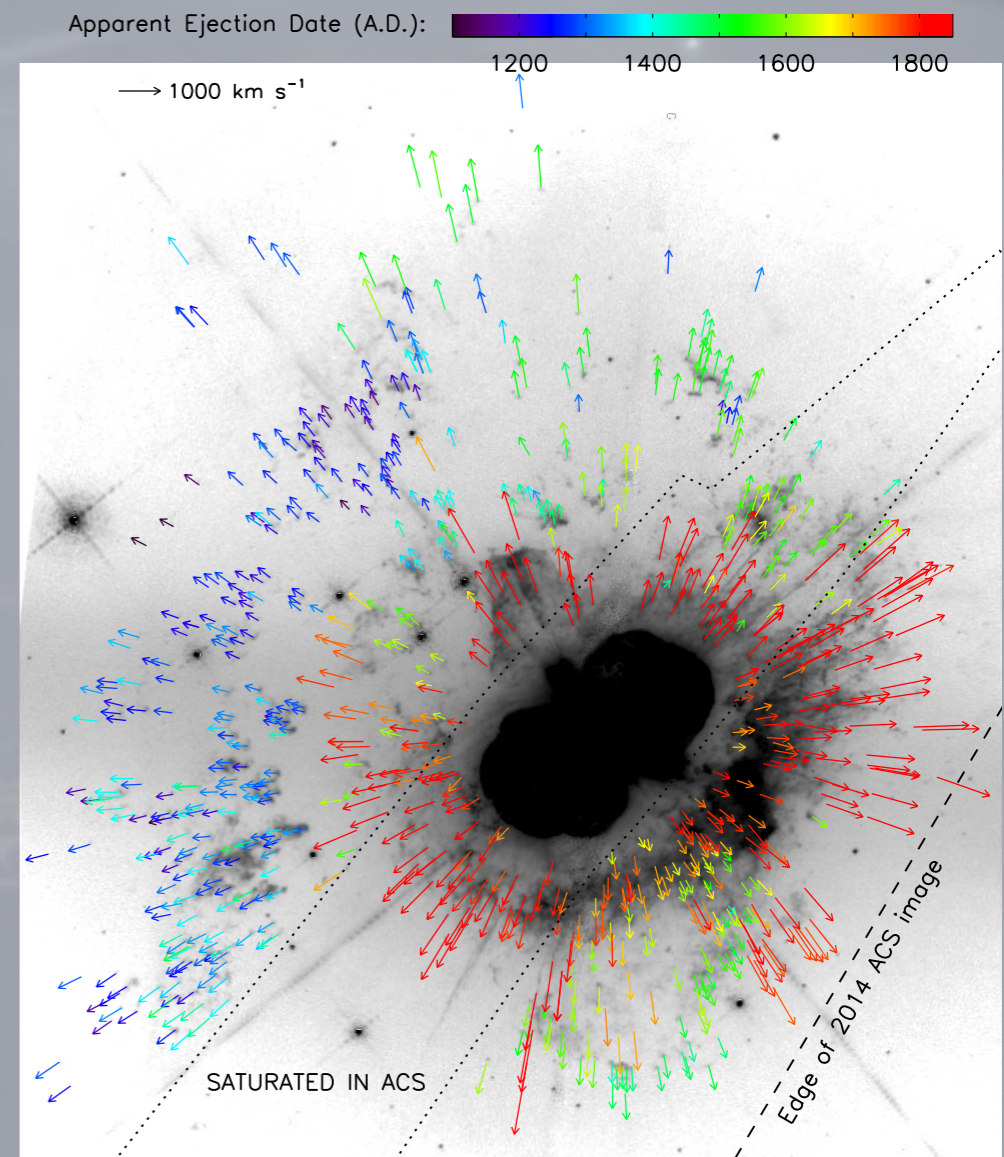
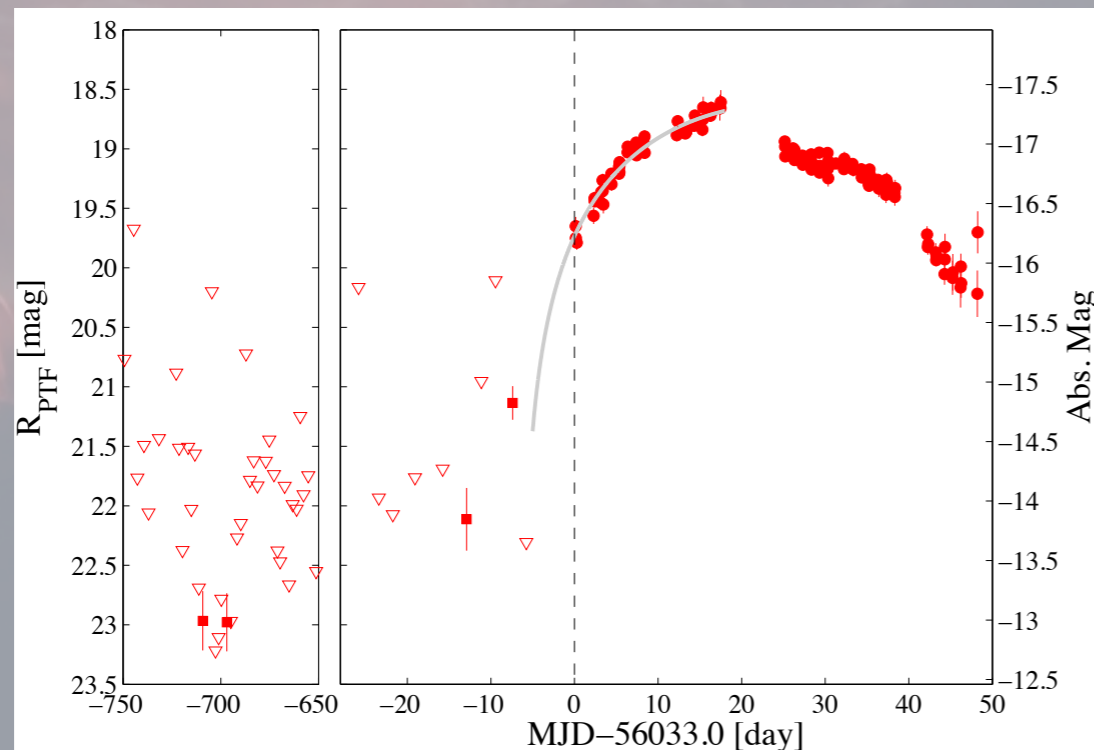
Piton de la Fournaise, Feb. 15, 2017!!!





Stellar eruptions

- Eta Car: outbursts every ~ 300 y?
- Precursors in IIc SNe are common, esp. in the year before SN (Ofek et al. 2014)
- Possibly in IIb (Strotjohann et al. 2015) and Ic (Corsi et al. 2013)?
- Narrow lines in early „flash-spectroscopy“ connected to CSM?

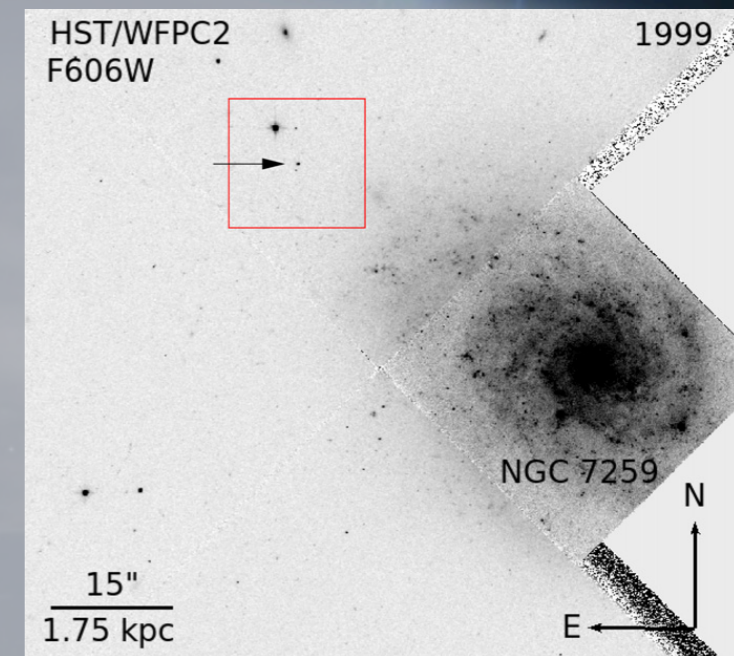


Kimiki et al. 2016

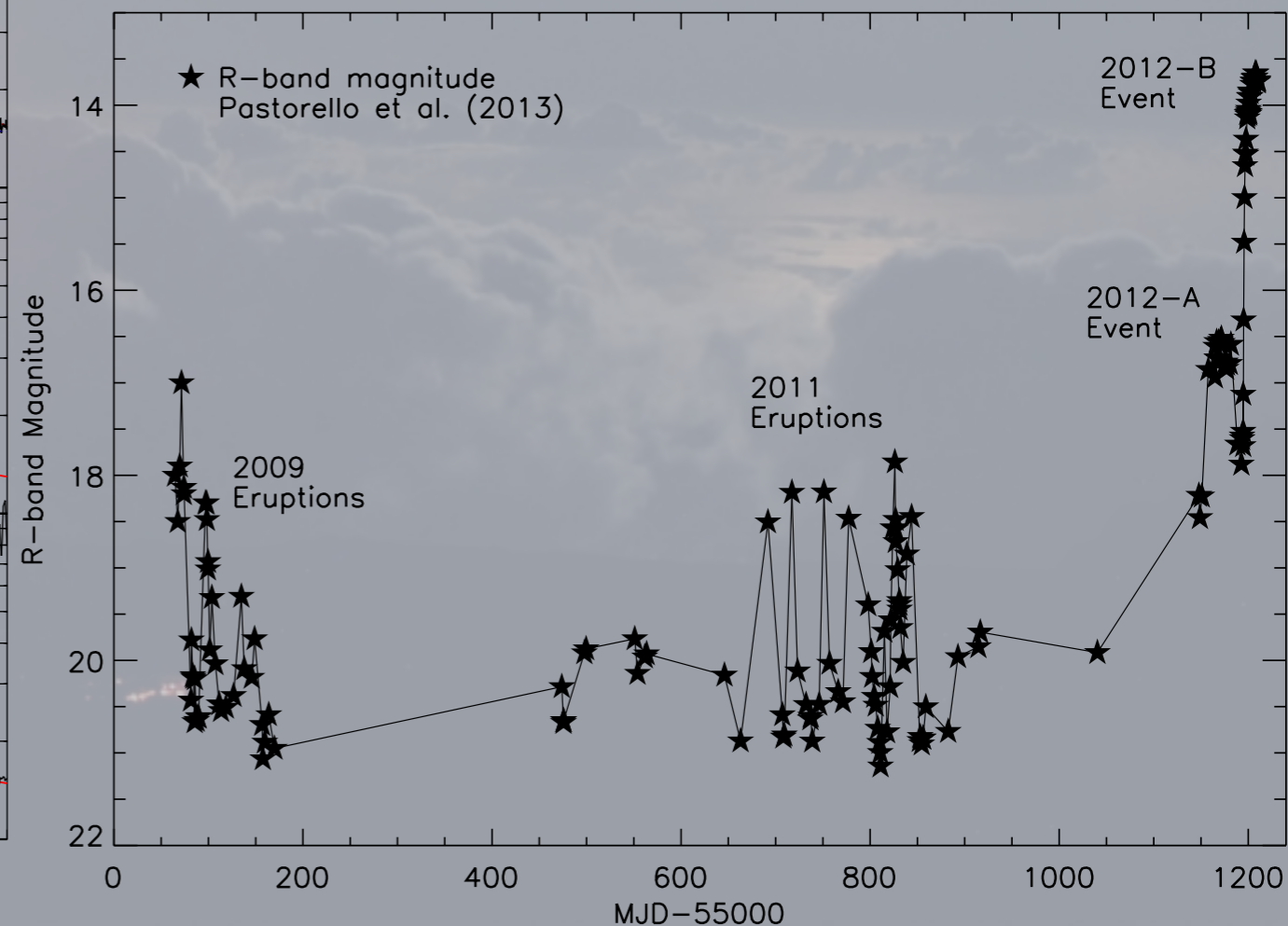
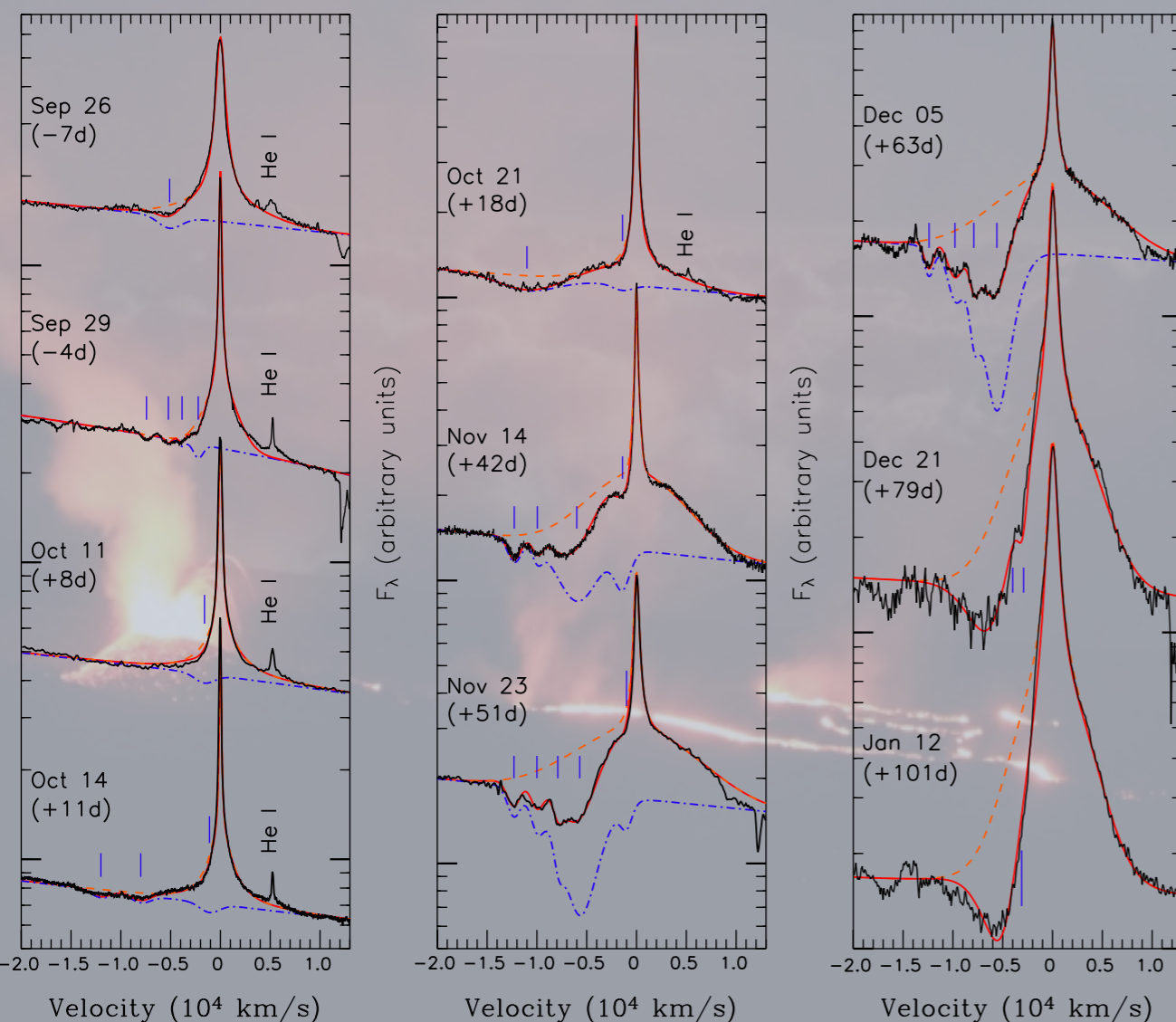
PTF12cxj
 (Ofek et al. 15)

Stellar eruptions: 2009ip

- Multiple outbursts 2009-2012
precursor + main event/explosion?
- SN far from the host
- Complex CSM (from pre-explosion outbursts?)

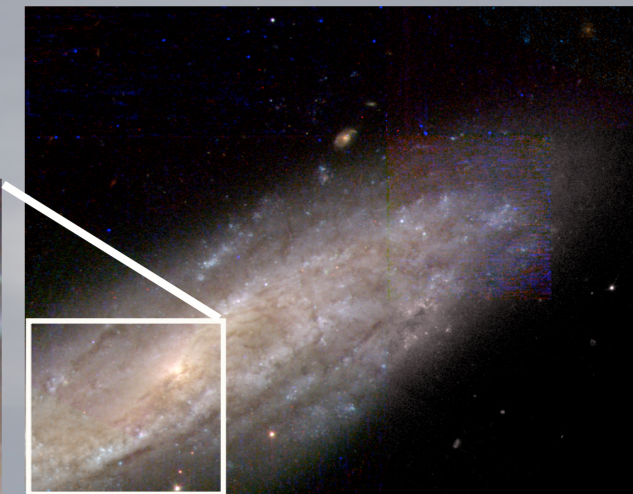
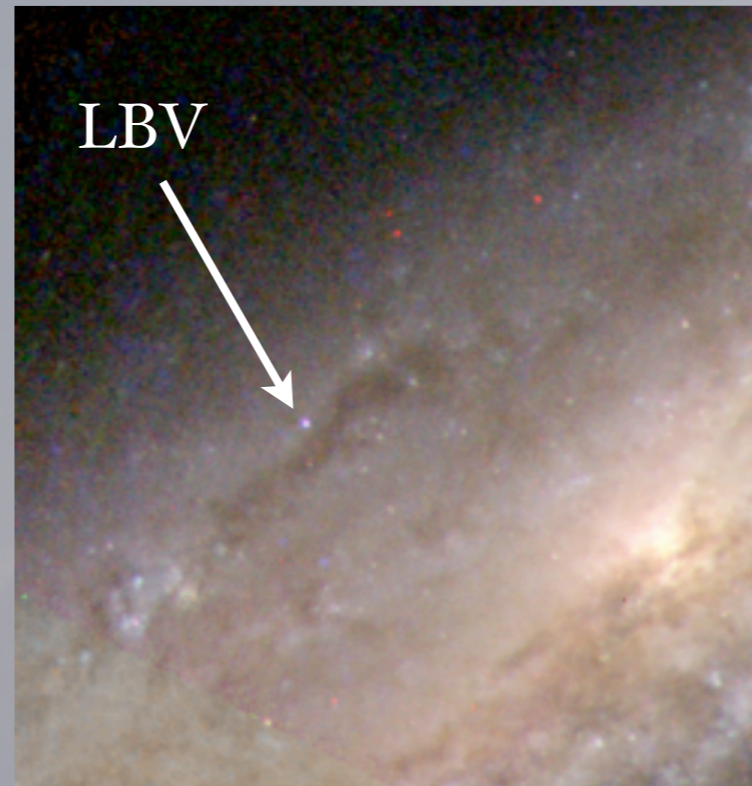


Margutti et al. 15
Fraser et al. 13

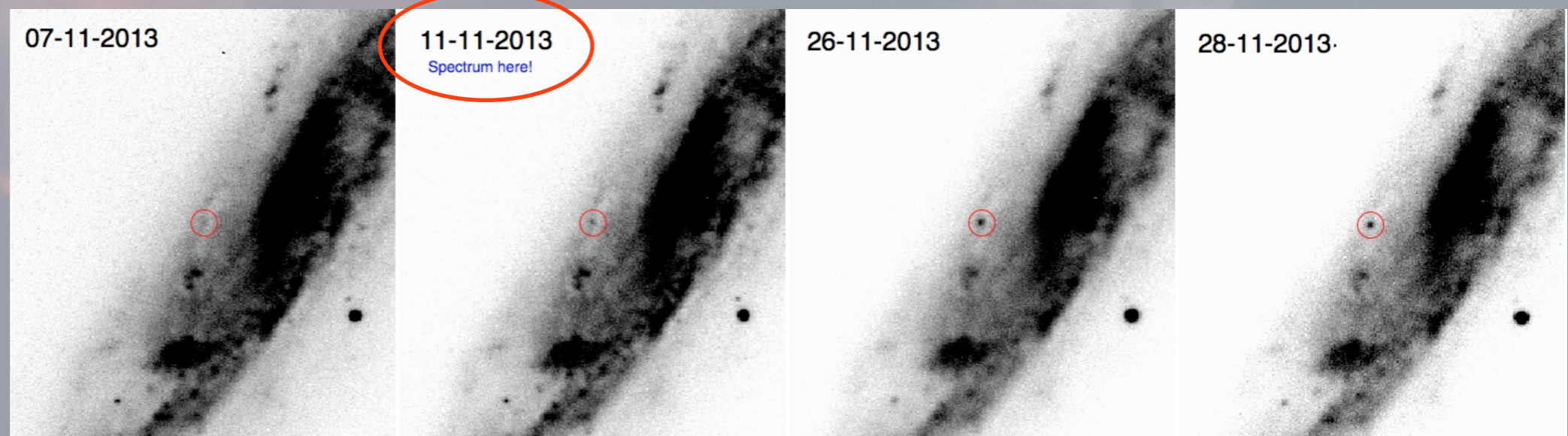


SN 2015bh (SNhunt 275/PTF13evf) in NGC 2770 (26 Mpc)

- LBV outburst discovered by PTF in Dec. 2013 unpublished!
→ serendipitous spectra from Nov. 2013!
- SN hunt reports transient in Feb. 2015 classified as IIn/impostor (ATEL Elias-Rosa et al.)
- Follow-up campaign by 0.9/1.5m OSN
- May 16, 2015:
Massive rebrightening



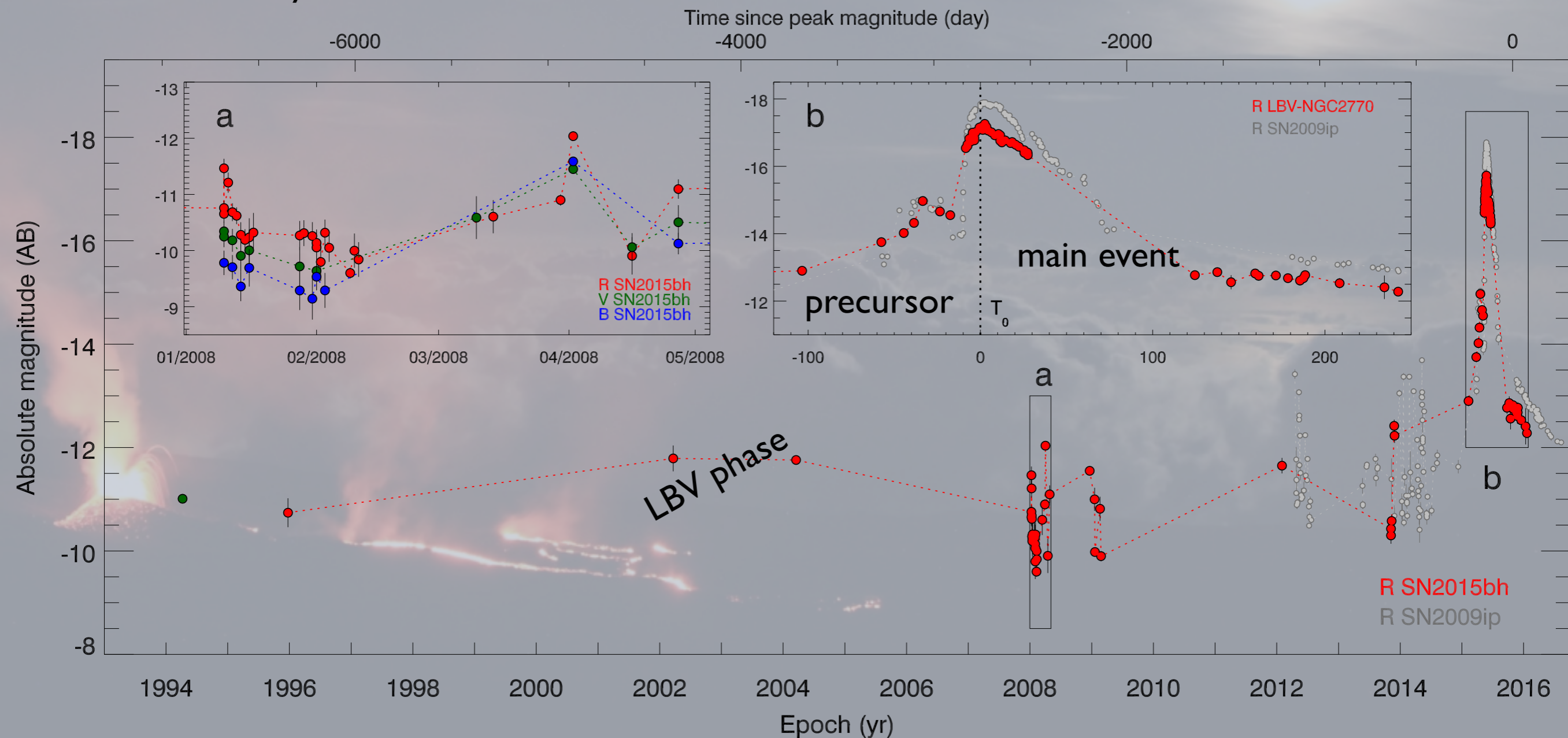
HST Jan. 2008



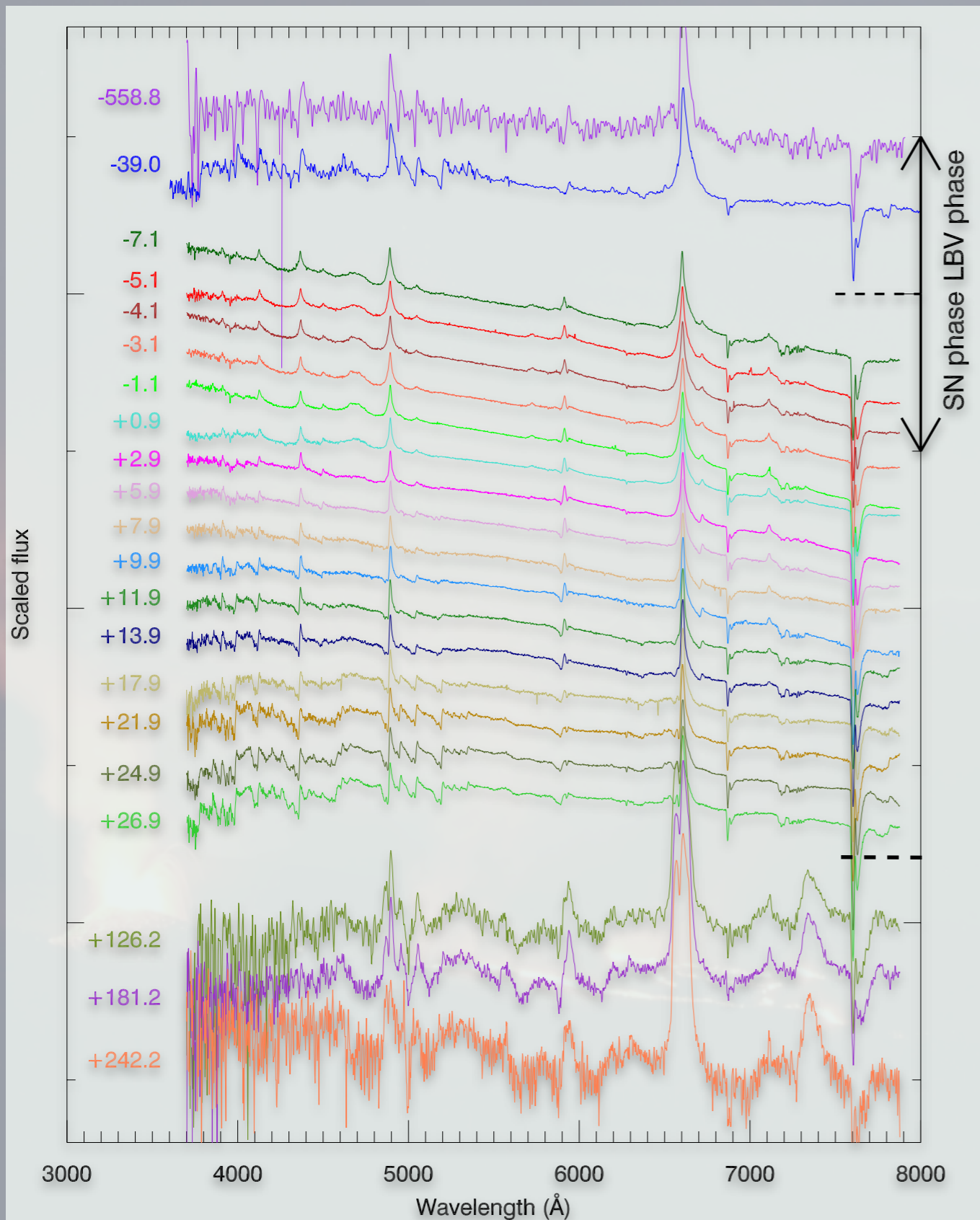
GTC
Nov. 2013

Light-curve

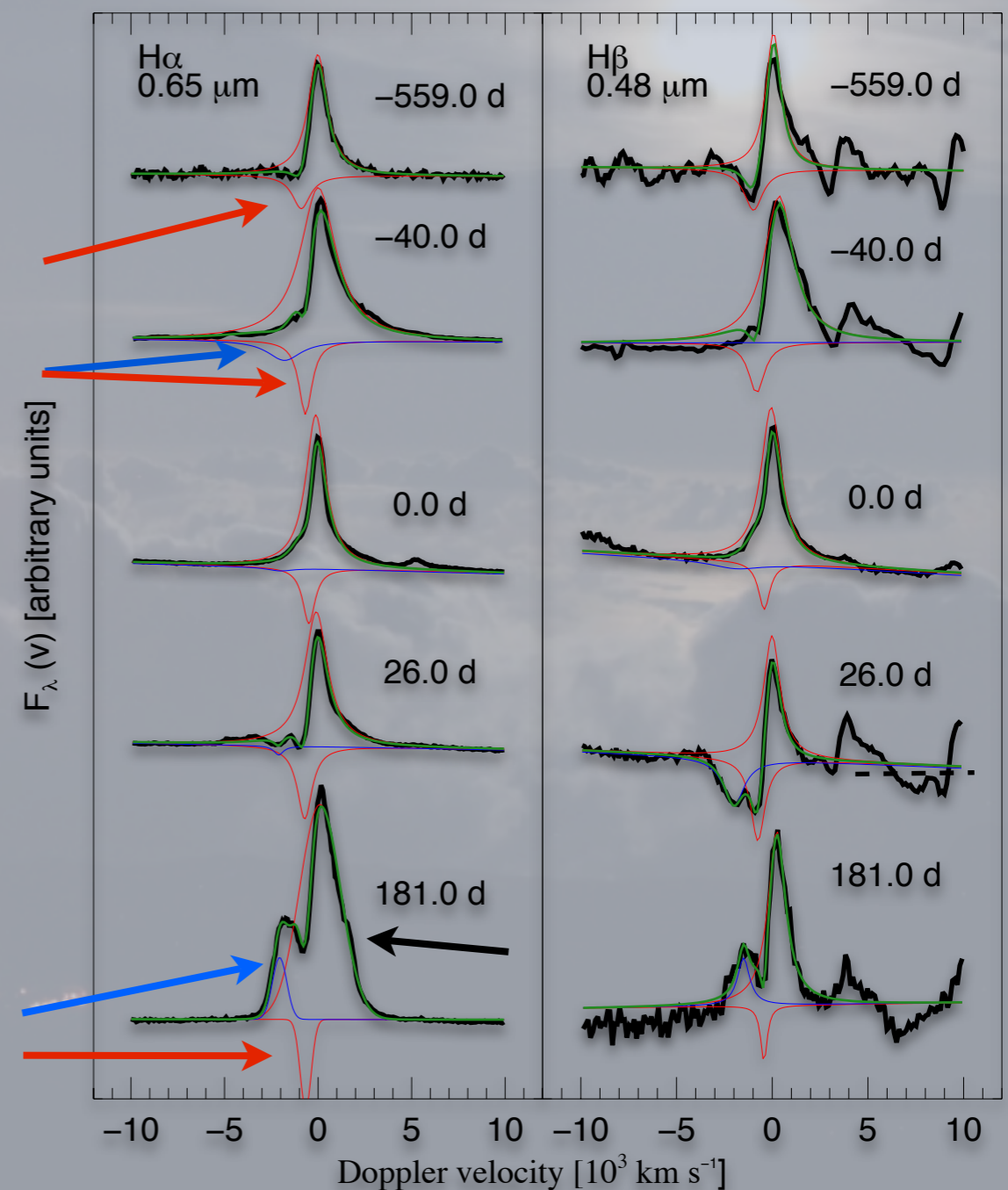
- Variable since at least 1994
- Precursor 40 days before the „main event“
- Standard SN lightcurve with linear decay, flattening > 100 days
- no X-rays or radio detection



Spectral evolution

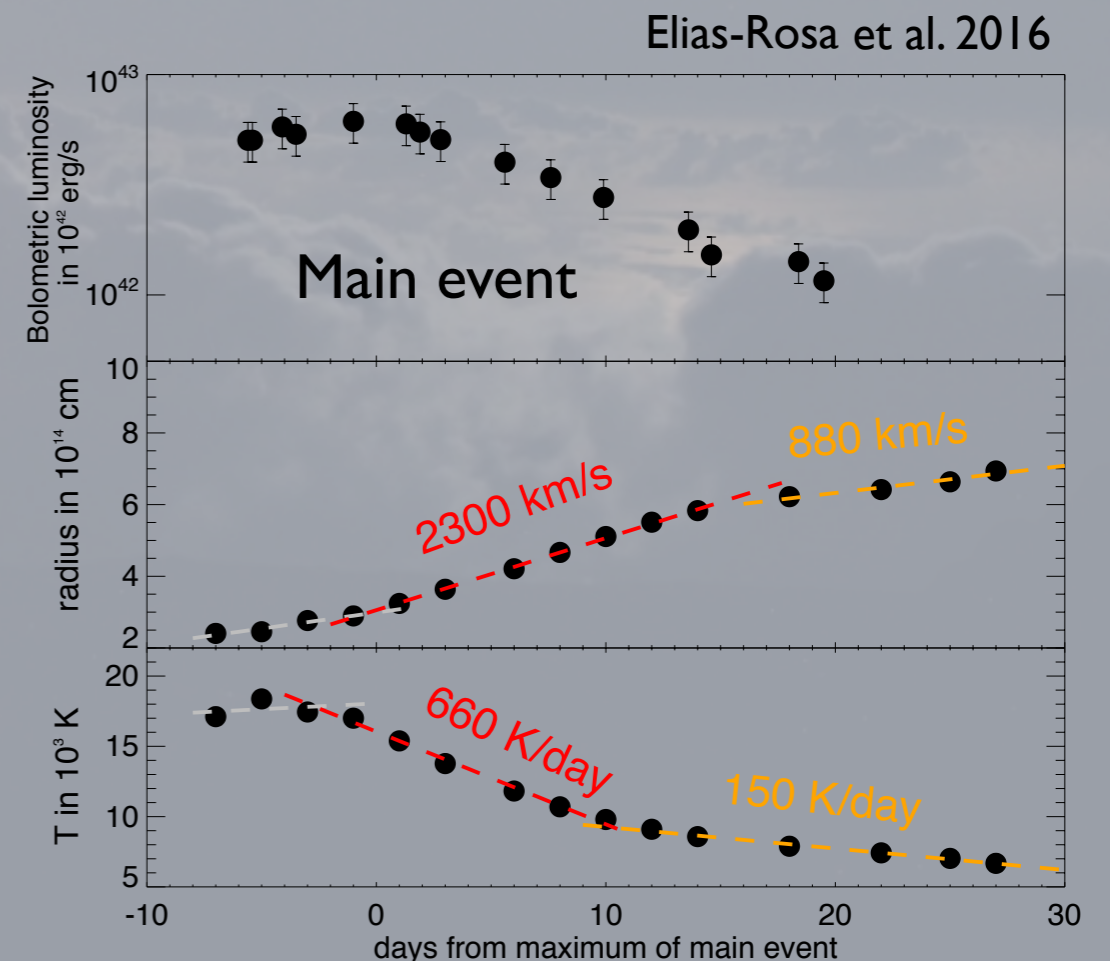
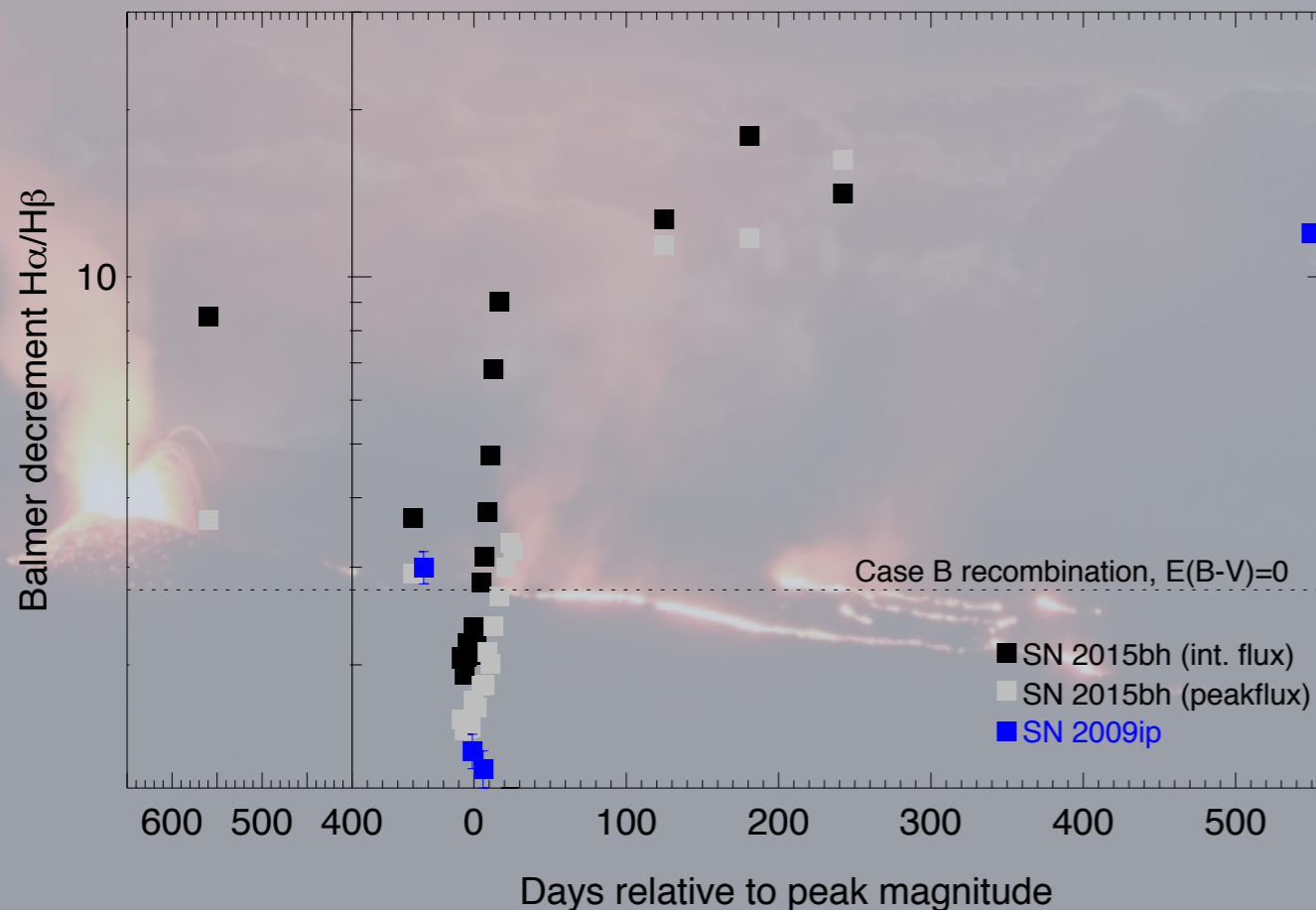
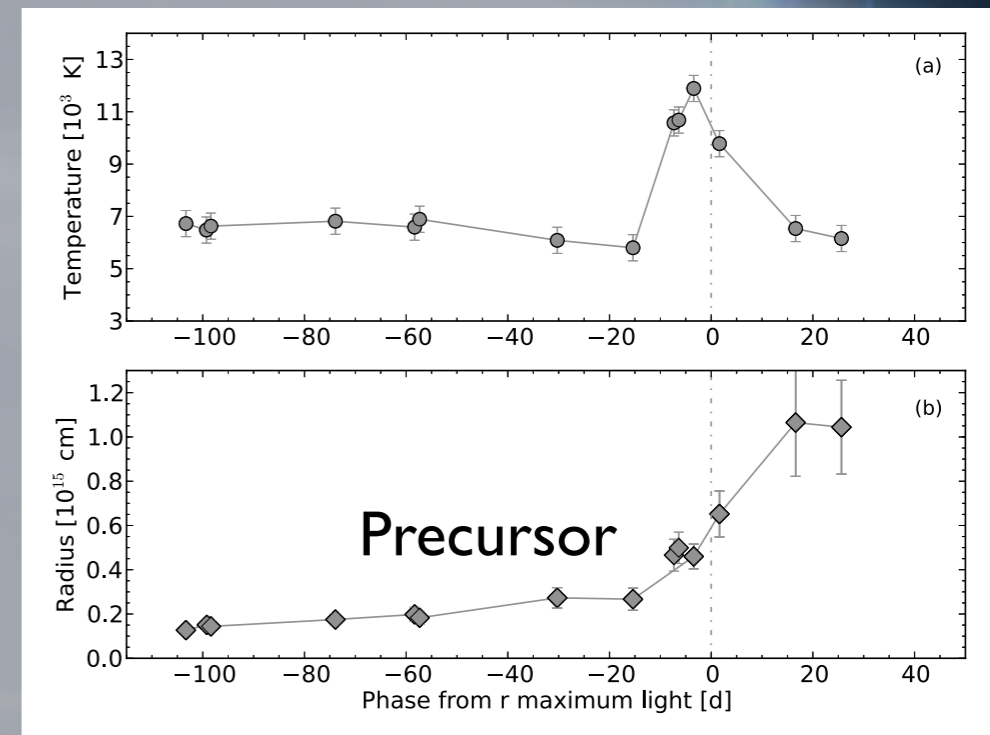


- Single P-Cygni during LBV phase
- Double profile since precursor
- In emission in nebular phase?

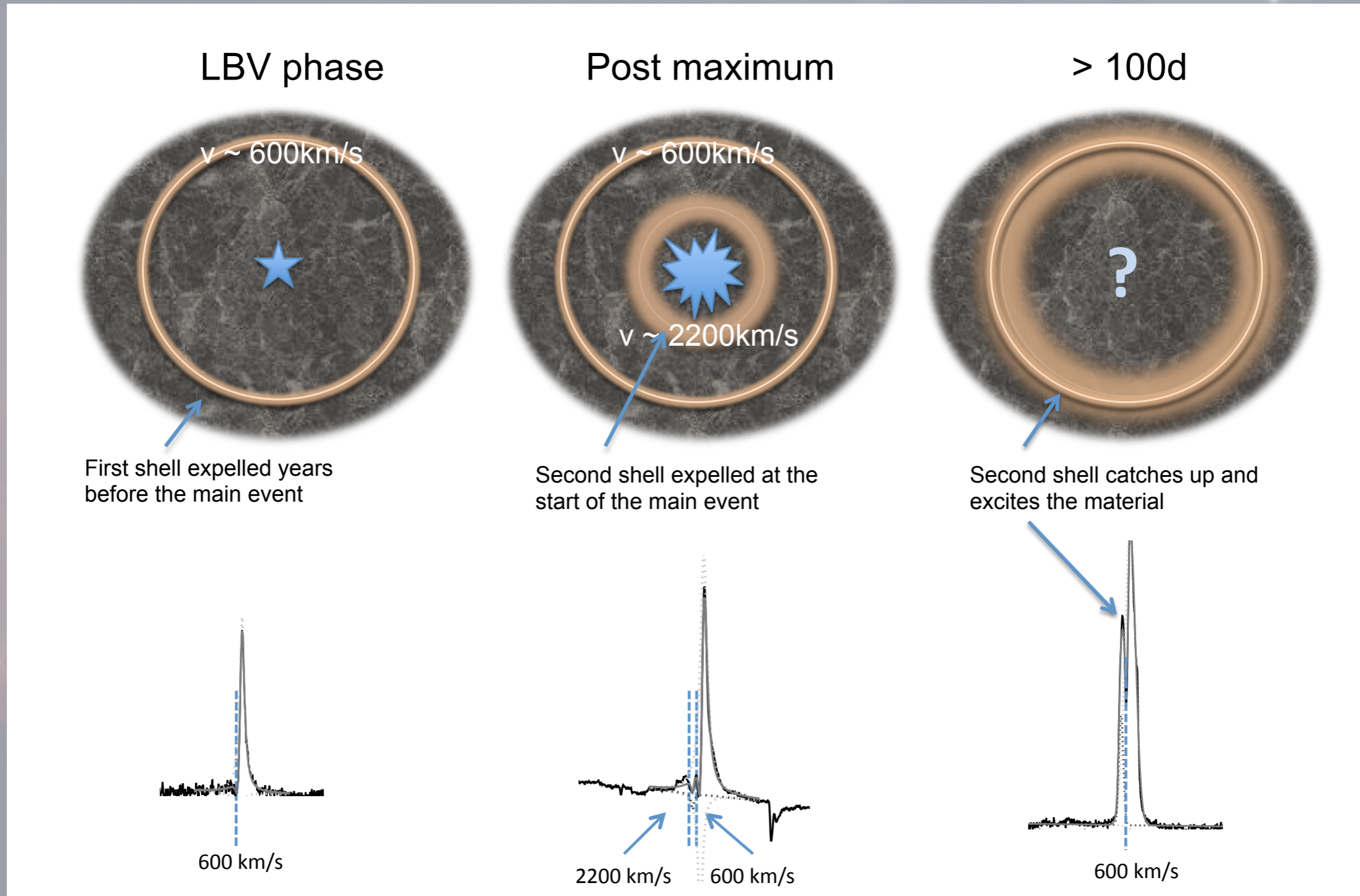


Properties of the ejecta

- Main event: $1.2-1.8 \times 10^{48}$ erg
- Late time flattening of LC, only $\sim 0.005 \text{ Ni}^{56}$ produced
- Balmer decrement below case B
 → dense plasma thermalizing emission?
 high during nebular phases
 → not extinction (no evidence in SN SED)

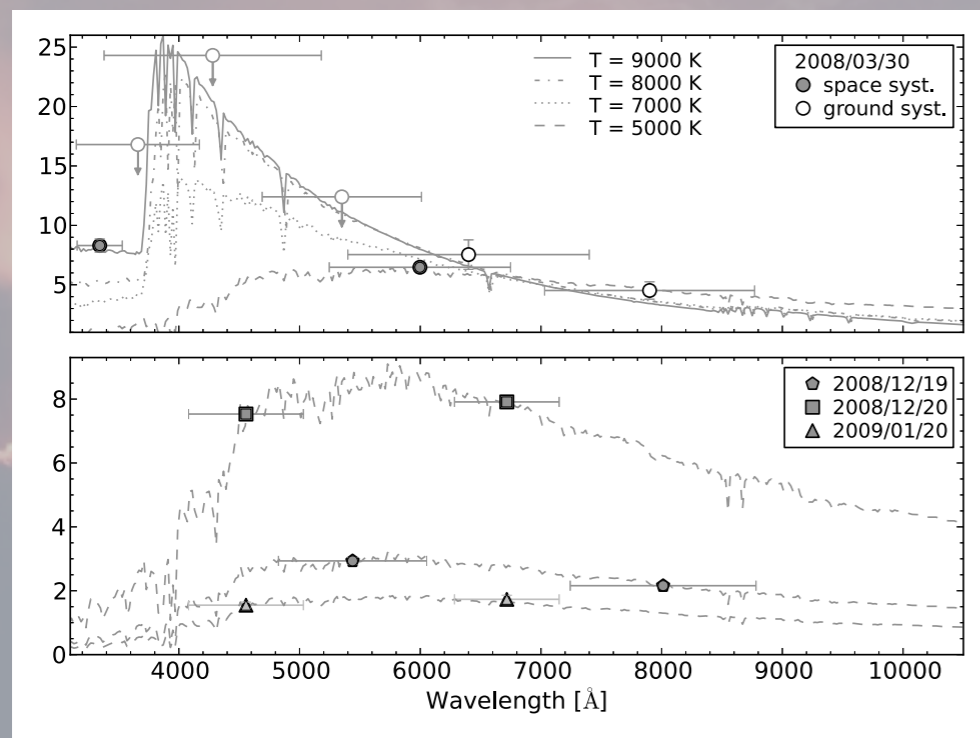
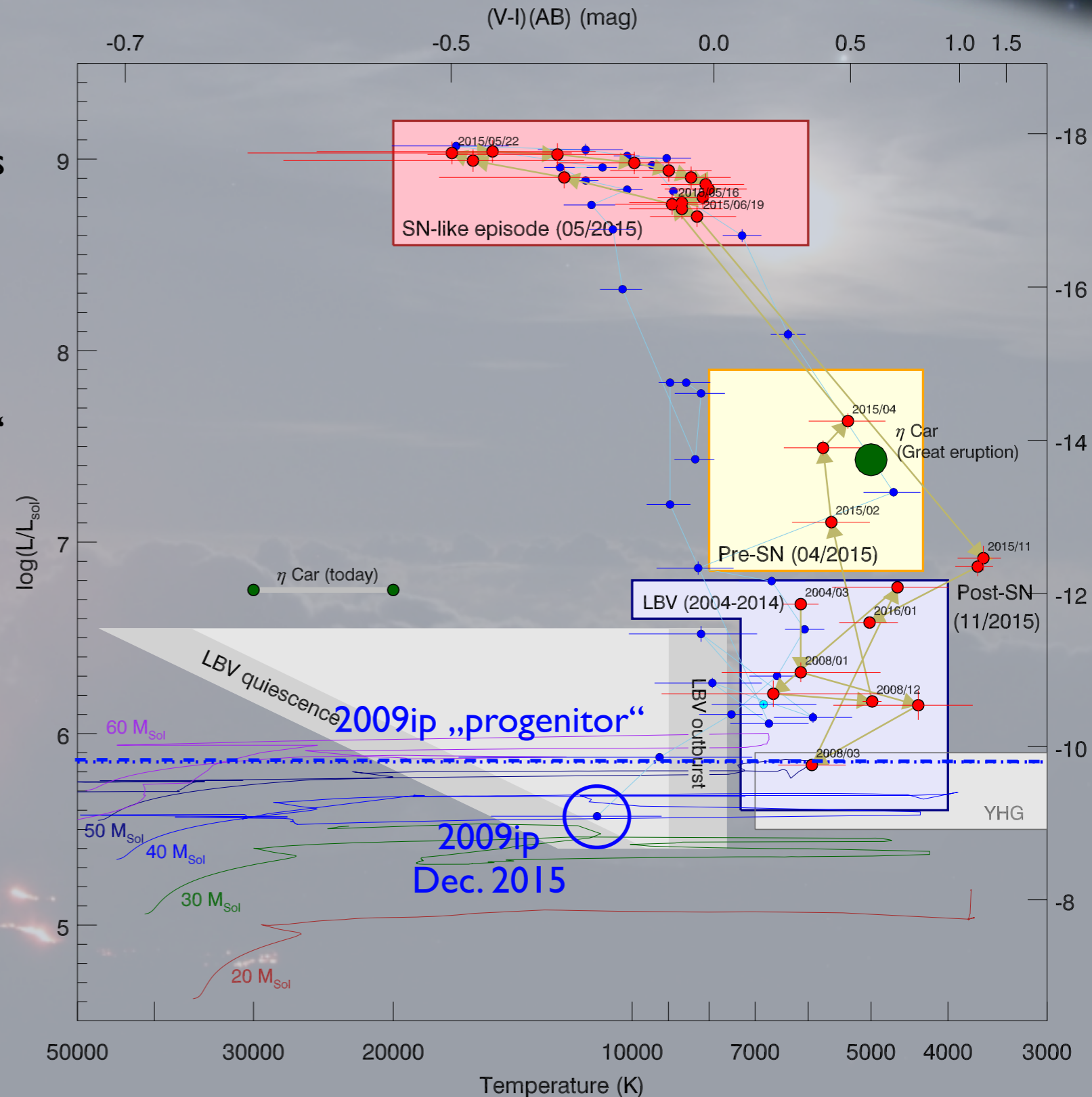


Possible geometry of the event



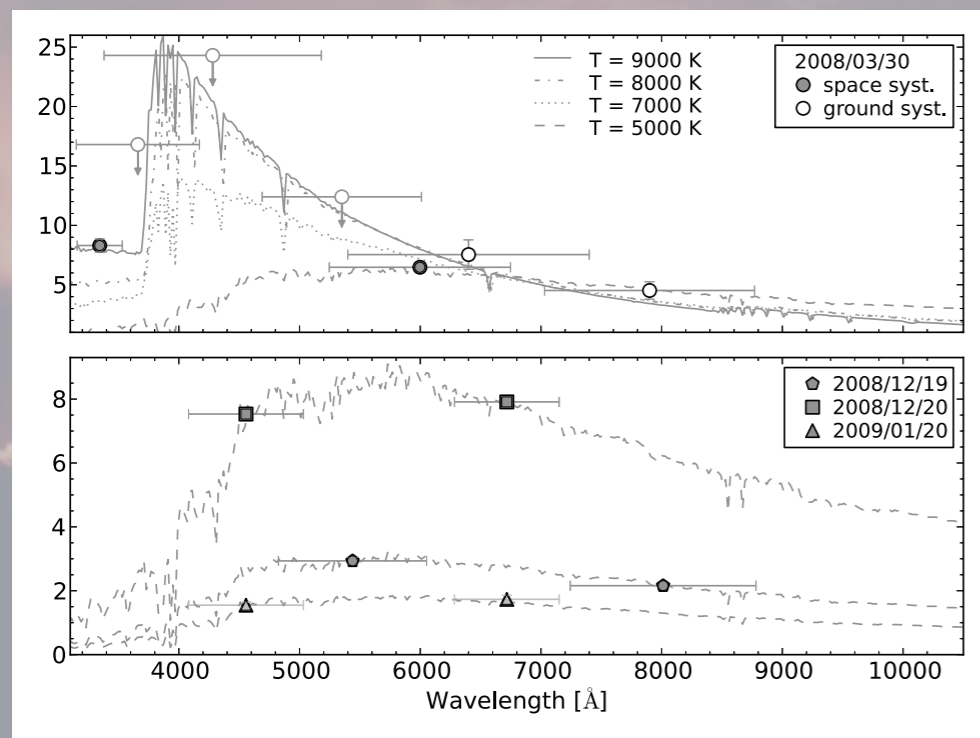
Progenitor evolution

- Since 1994 redwards of LBVs in outburst more luminous than YHG
- Fast variations
- Post SN blue-turn
- SN 2009ip now below „progenitor“
SN 2015bh as well?! already?!!

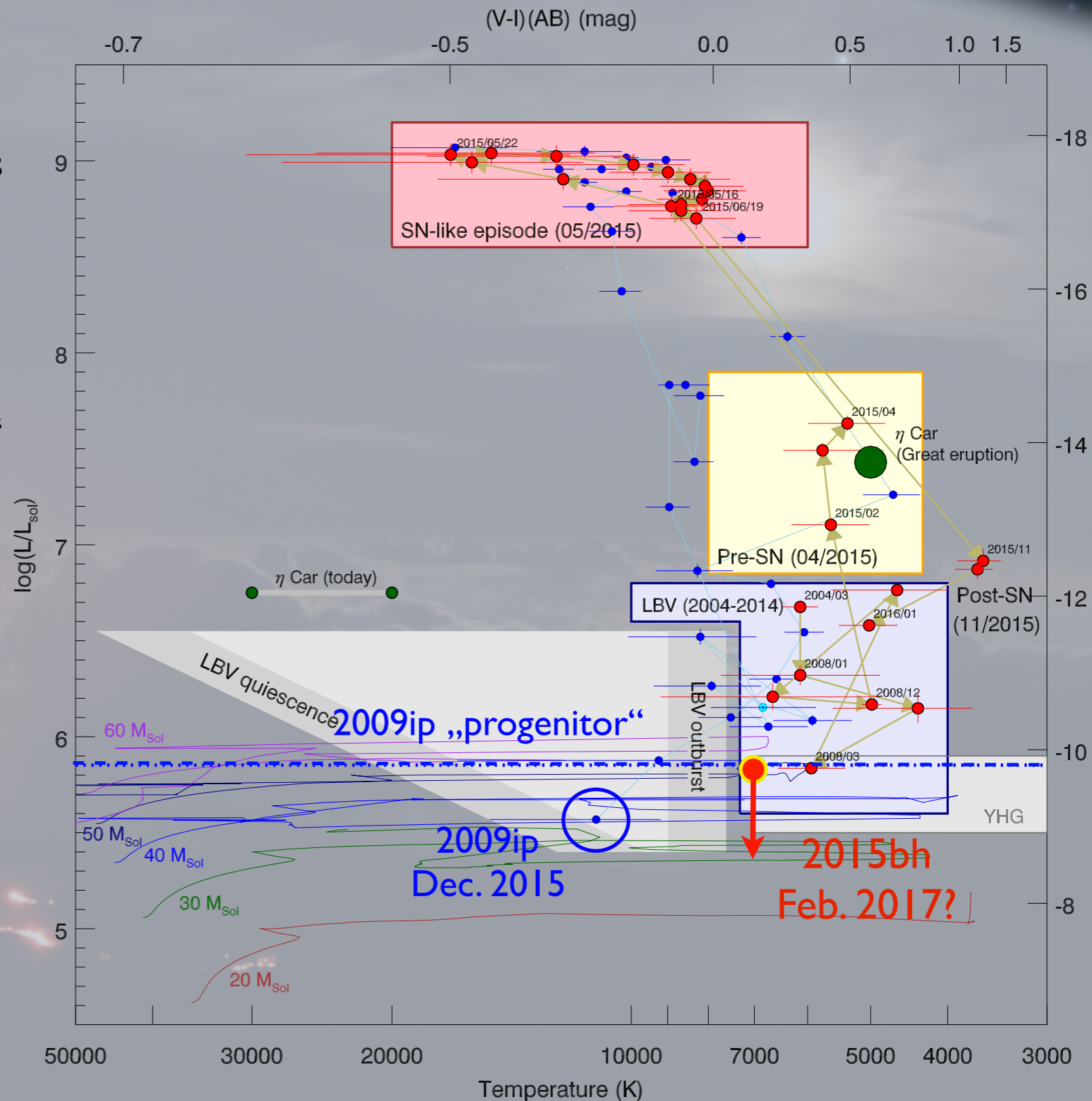


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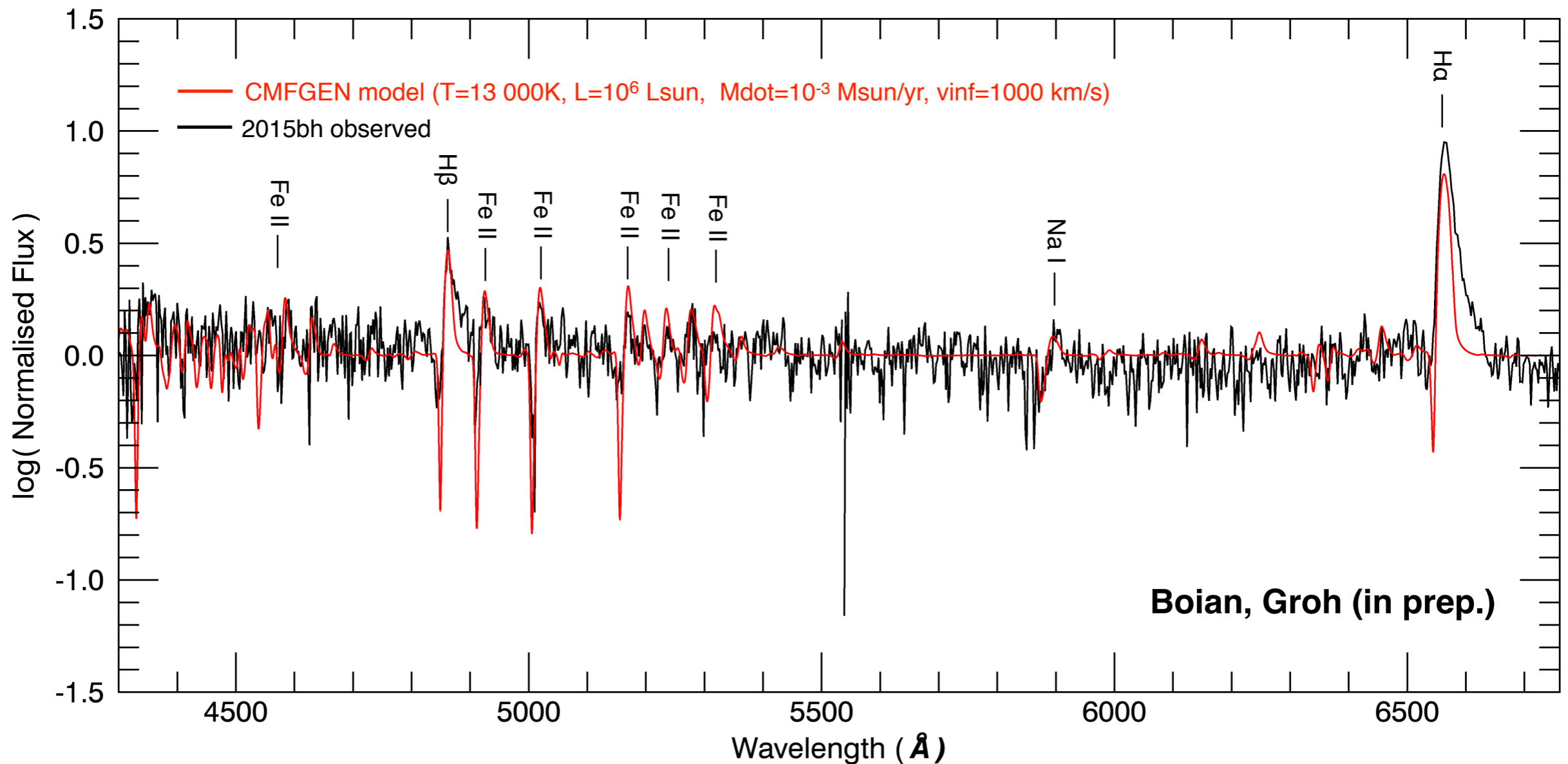


Elias-Rosa et al. 2016



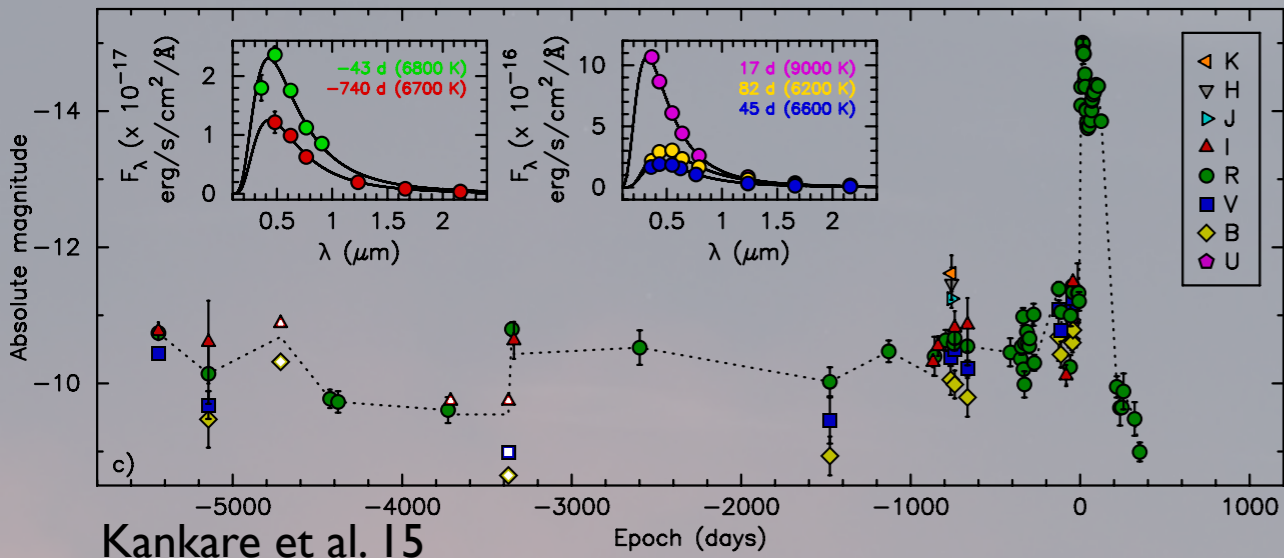
The best pre-SN spec since 1987A?

- Model of the spectrum at -550d
- LBV with dense, fast outflows, YSG, WR etc. excluded
- metallicity about half solar

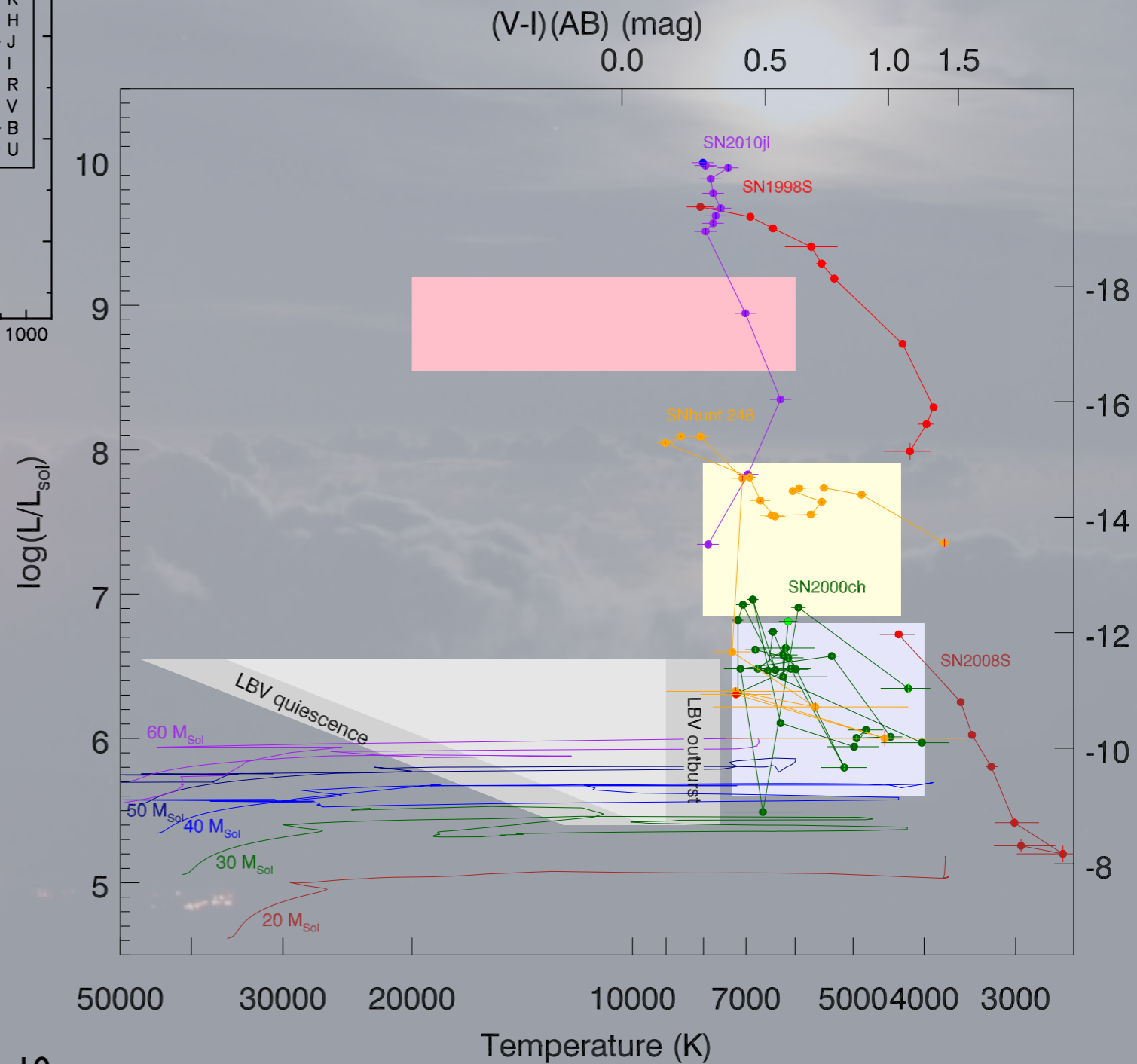
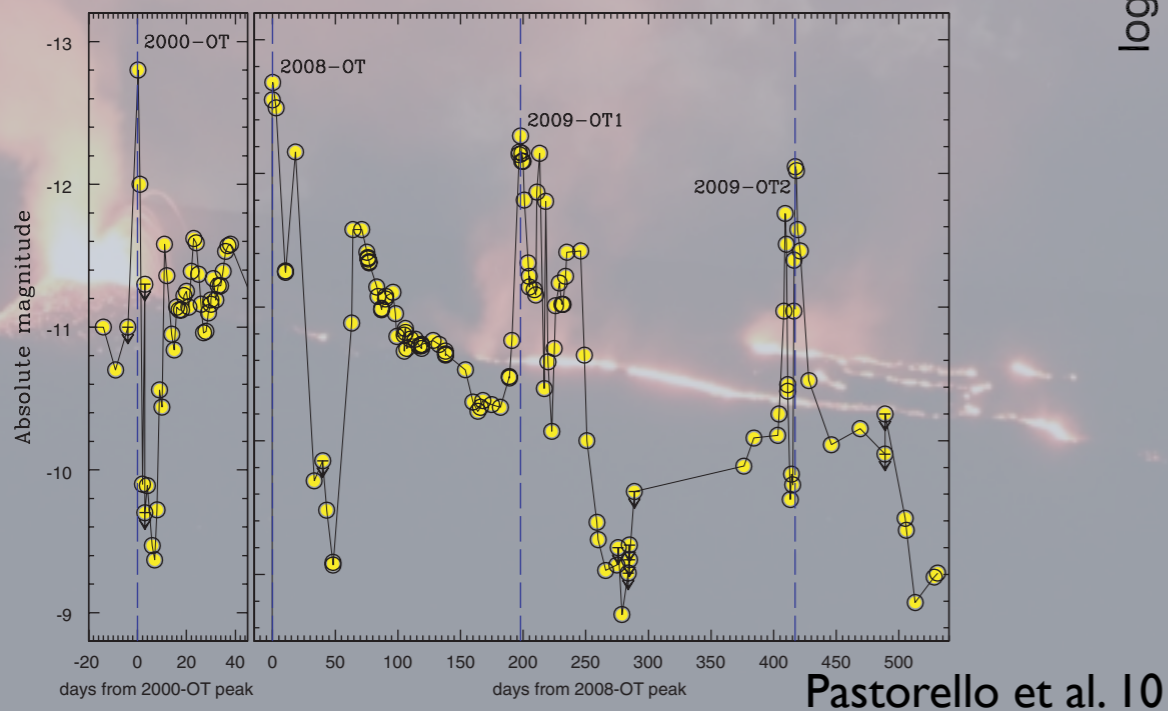


A new class?

- SNhunt 248 low-luminosity case?

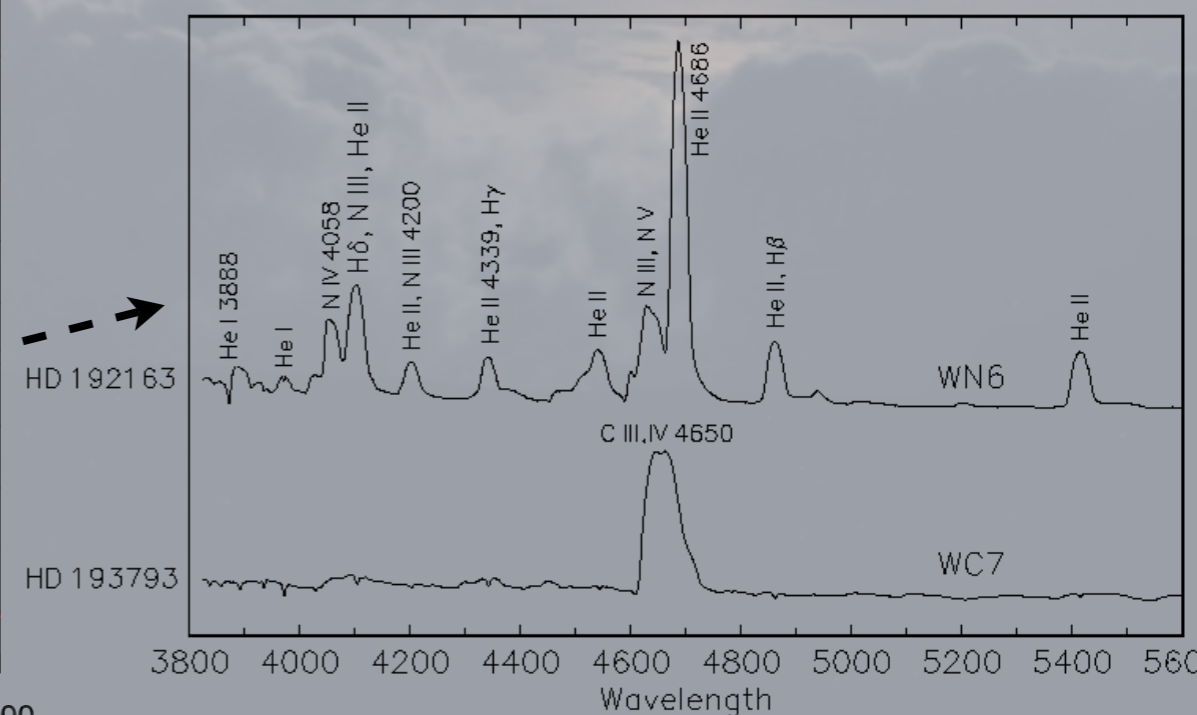
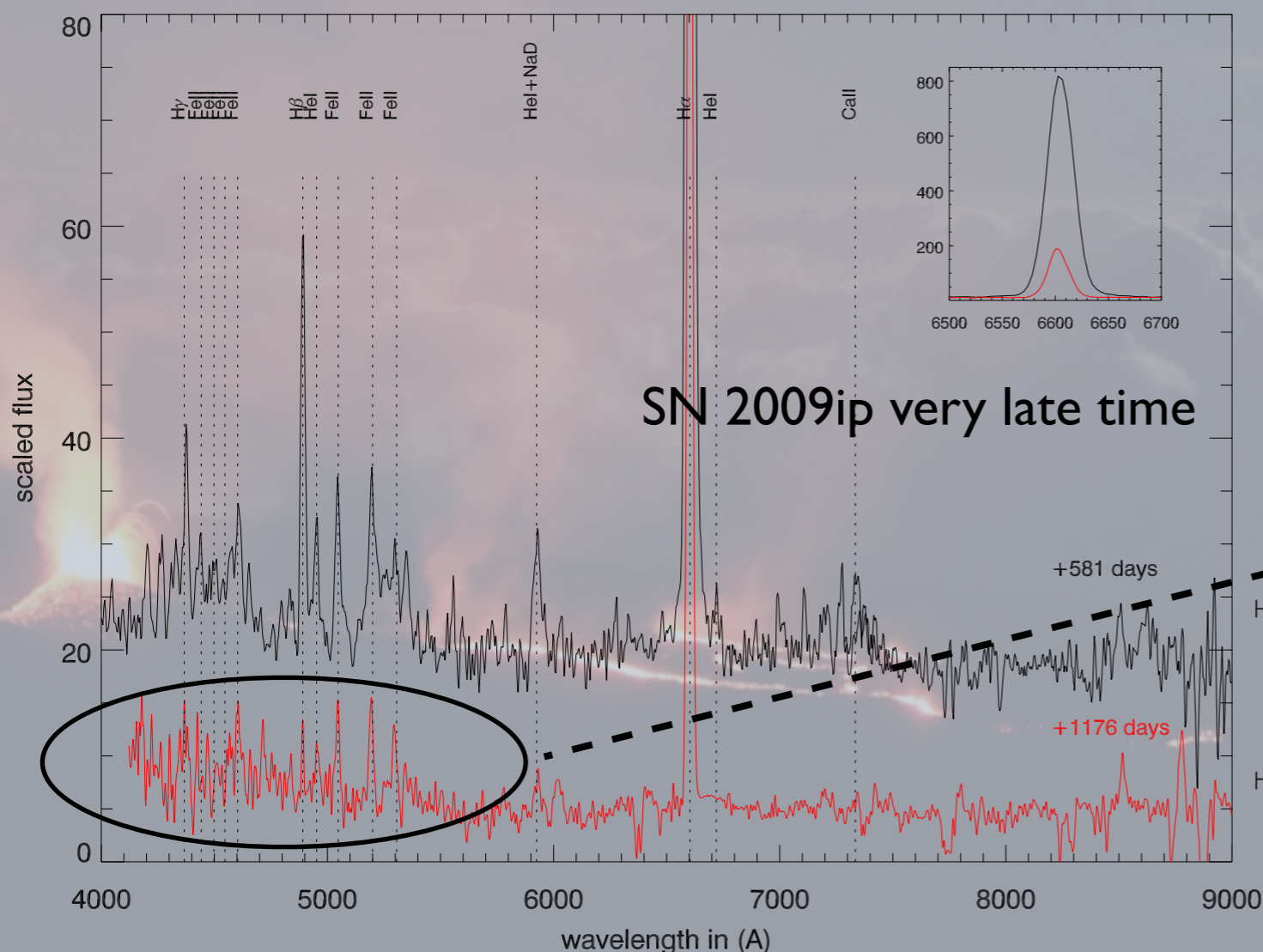


- SN 2000ch = 2009ip+2015bh in outburst?



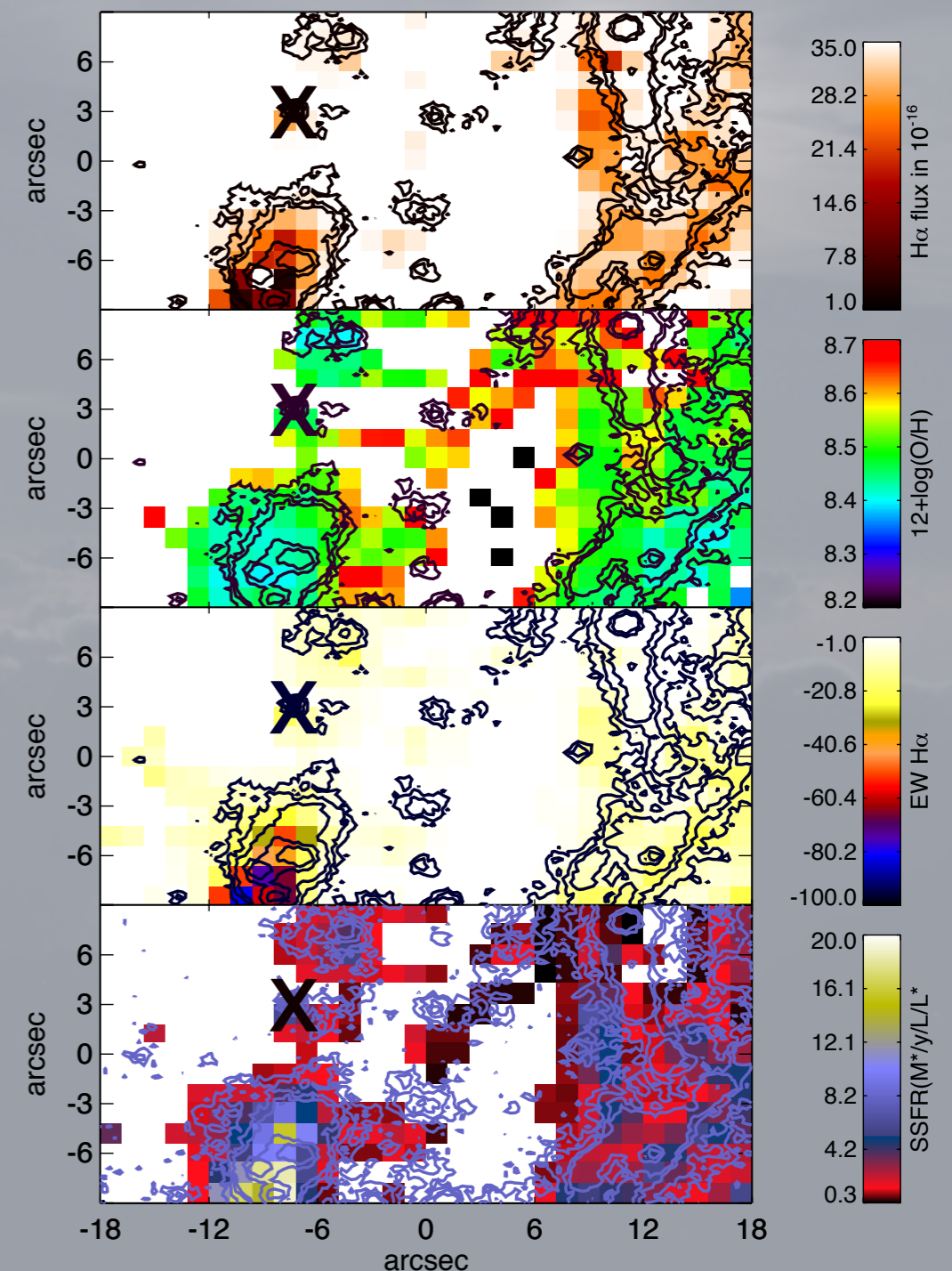
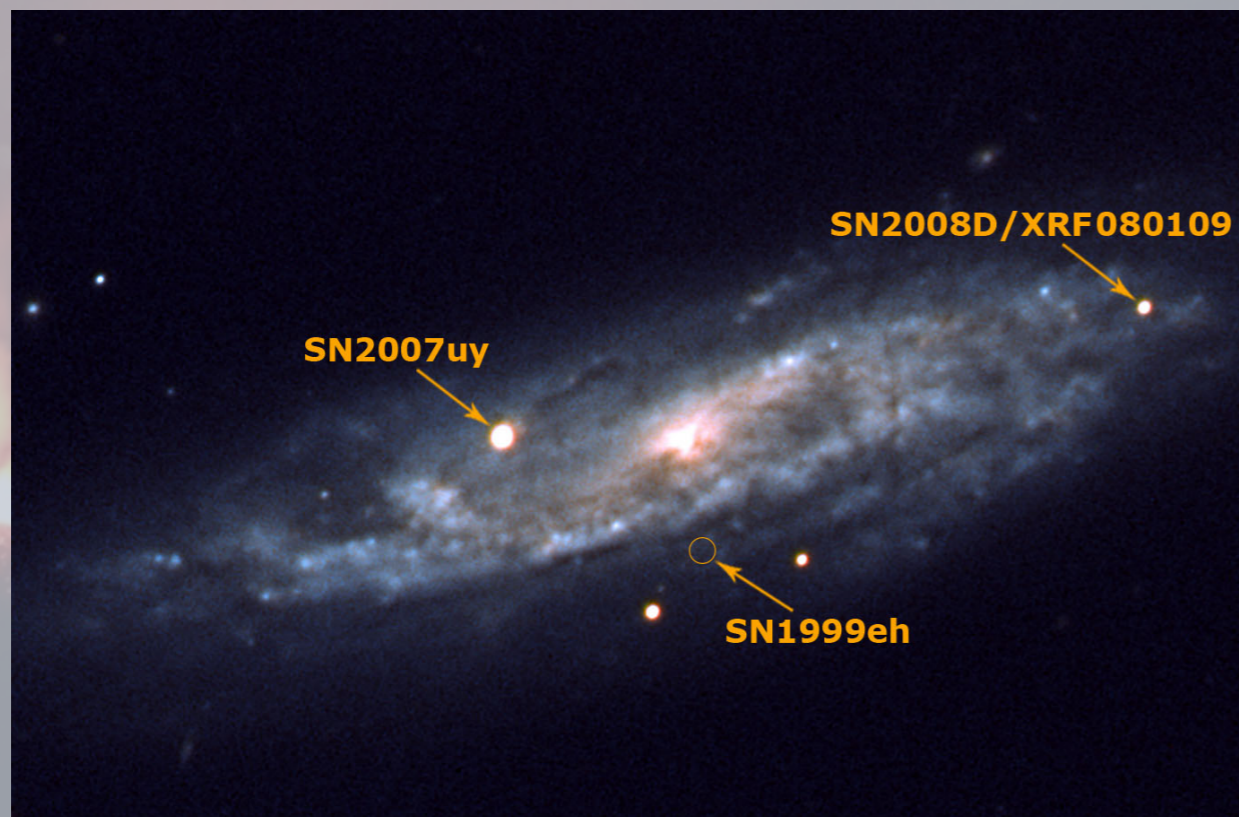
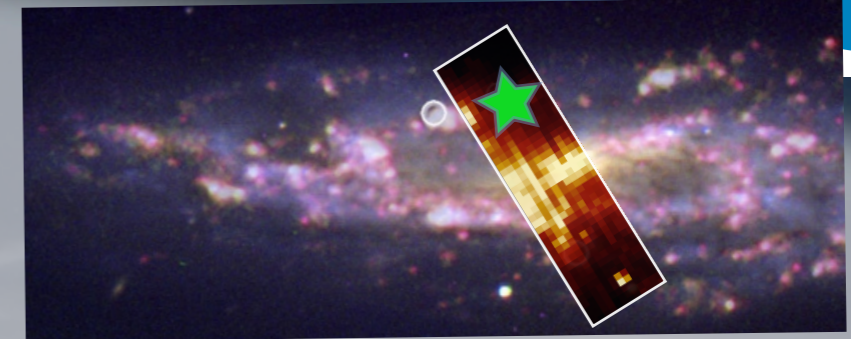
An LBV en route to a WR-star?

- Shed envelope via eruptive mass-loss instead of winds?
- Late observations of possible survivor (WN star?)
2009ip in 2015 has huge H α and Balmer decrement (>50) but no signs (yet) of WR features
- Possible „survivor“ could also be binary companion...



Host and environment

- SN 2015bh in spiral arm
 small underlying SF region?
 (SN 2009ip was far from the host)
- Neighbouring regions:
 metallicity \sim half solar
 SP age \sim 7-10 Myr



Conclusions

- No conclusion about death or survival of SN 2015bh (neither SN 2009ip)
- Pre-explosion outbursts common for SN IIns?
- Glimpse into the last stages (or one of the last) of very massive stars, challenge for modelers!
- Need to detect more of those stars in the pre-main event state
- Need to look for possible survivors and their properties