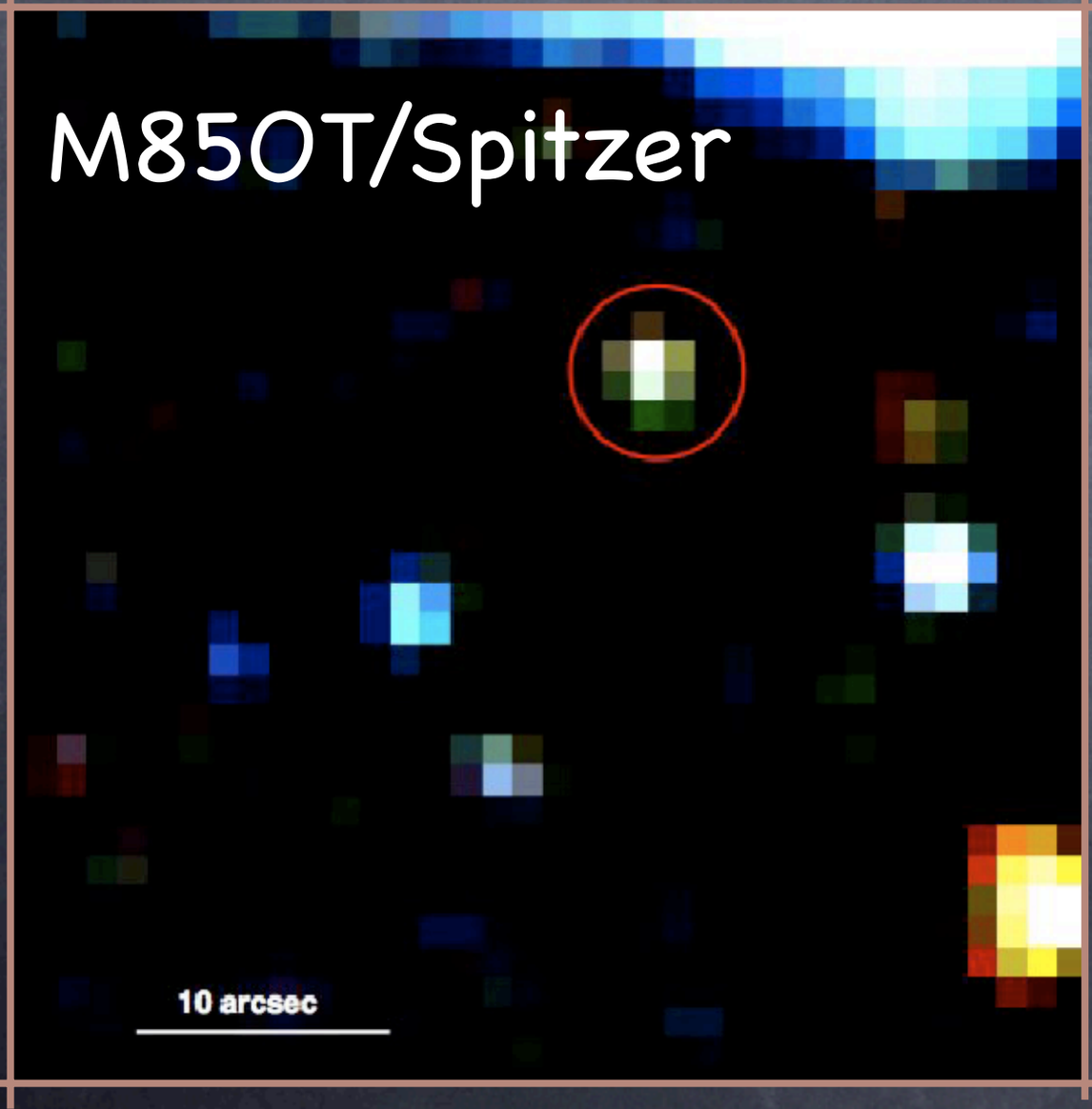
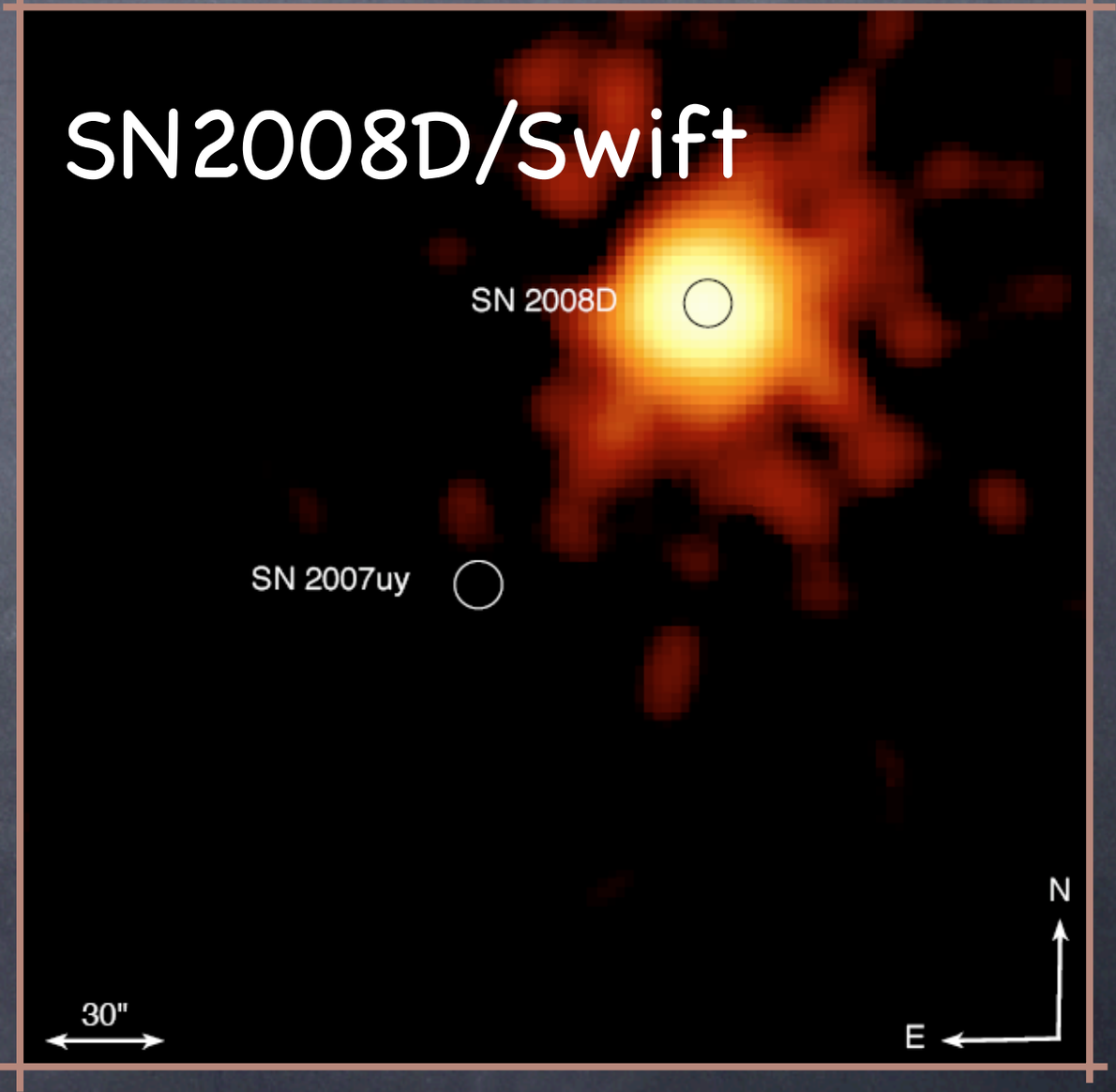
News from the X-Ray to Infrared Transient Sky

Arne Rau (Caltech)

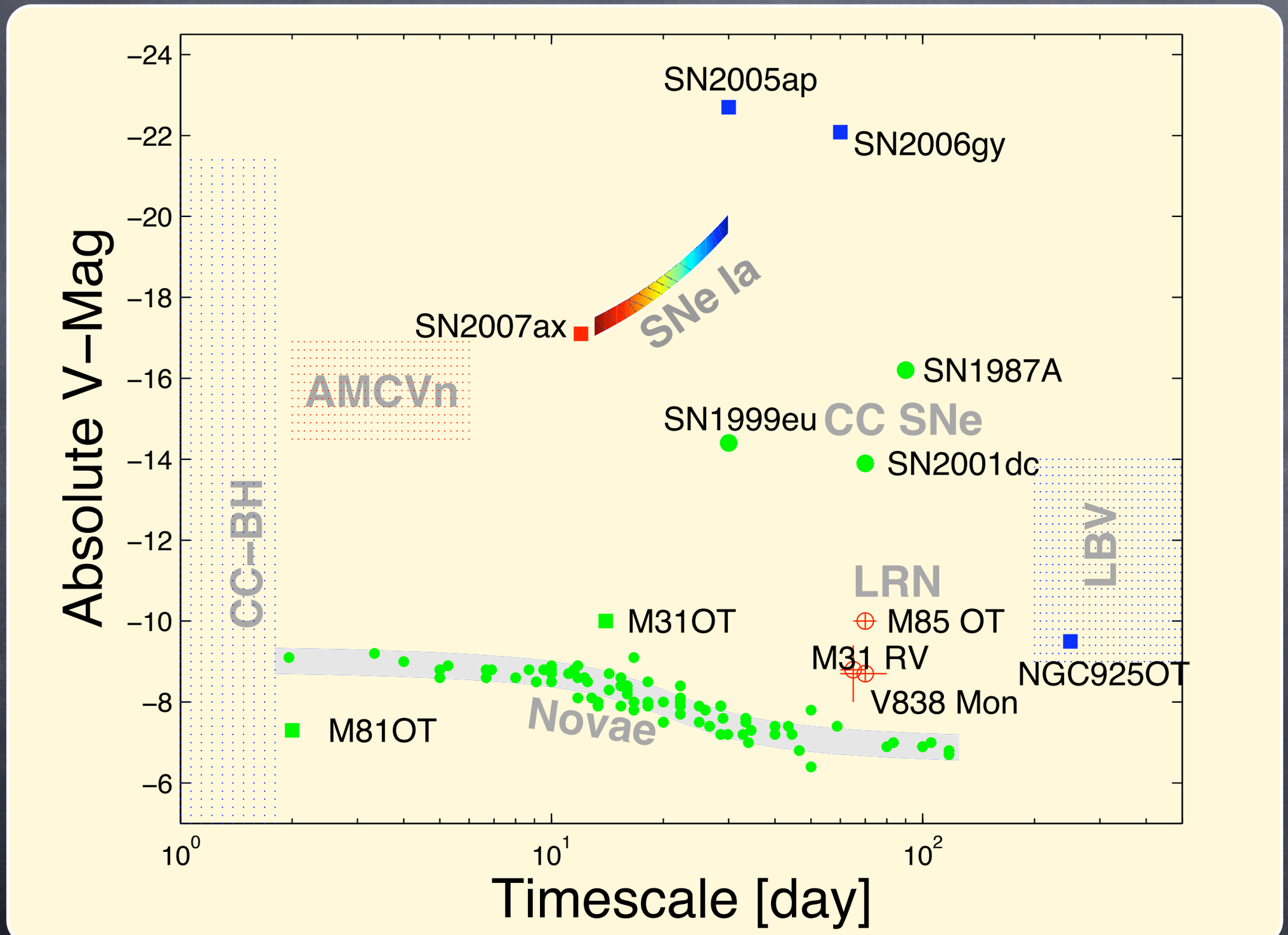
M85OT/Spitzer



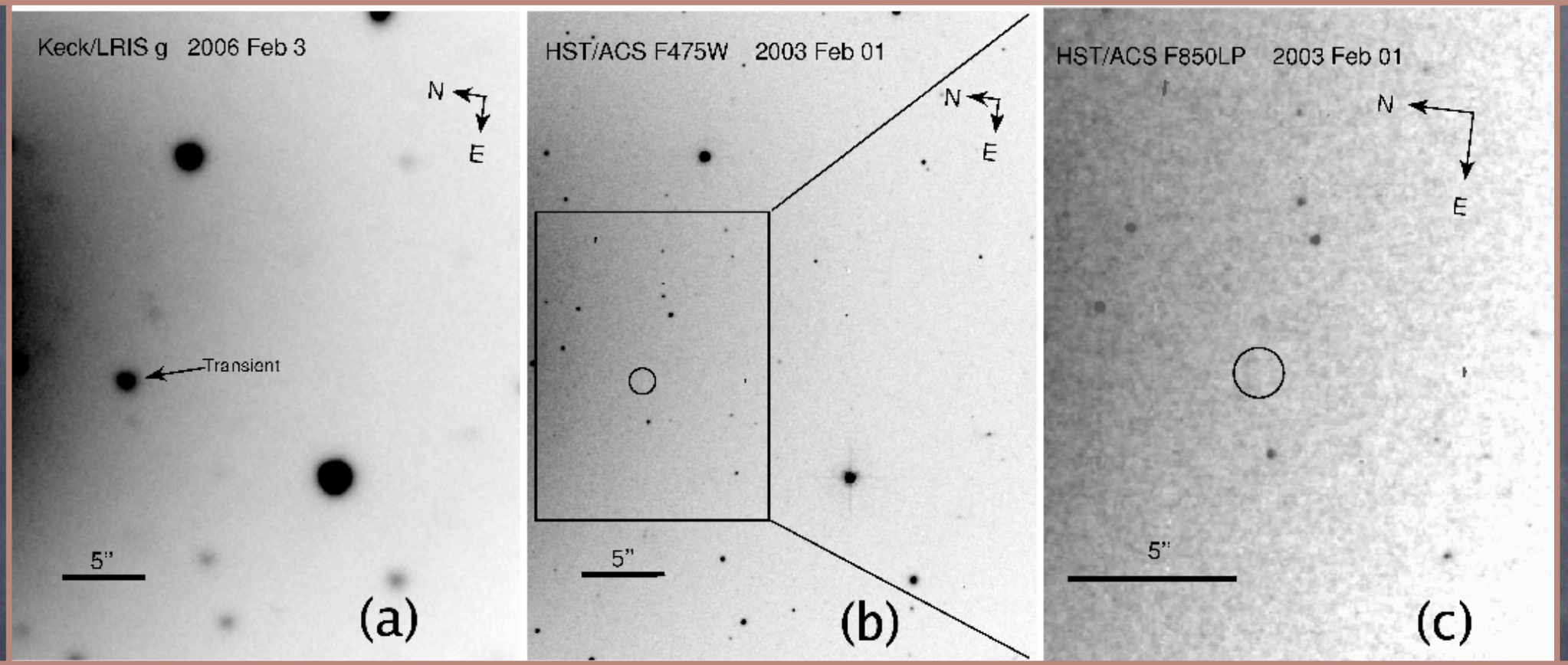
SN2008D/Swift



The phase space of optical transients



M85OT2006-1 - a Luminous Red Novae



- Lick Observatory Supernovae Search, Jan 07 2006 at 19.3mag
- 2.3kpc from center of M85
- peak V=-13
- precursor F475W > -4.3 and F850LP > -6.4
- old stellar population ($M < 7\ M_s$)

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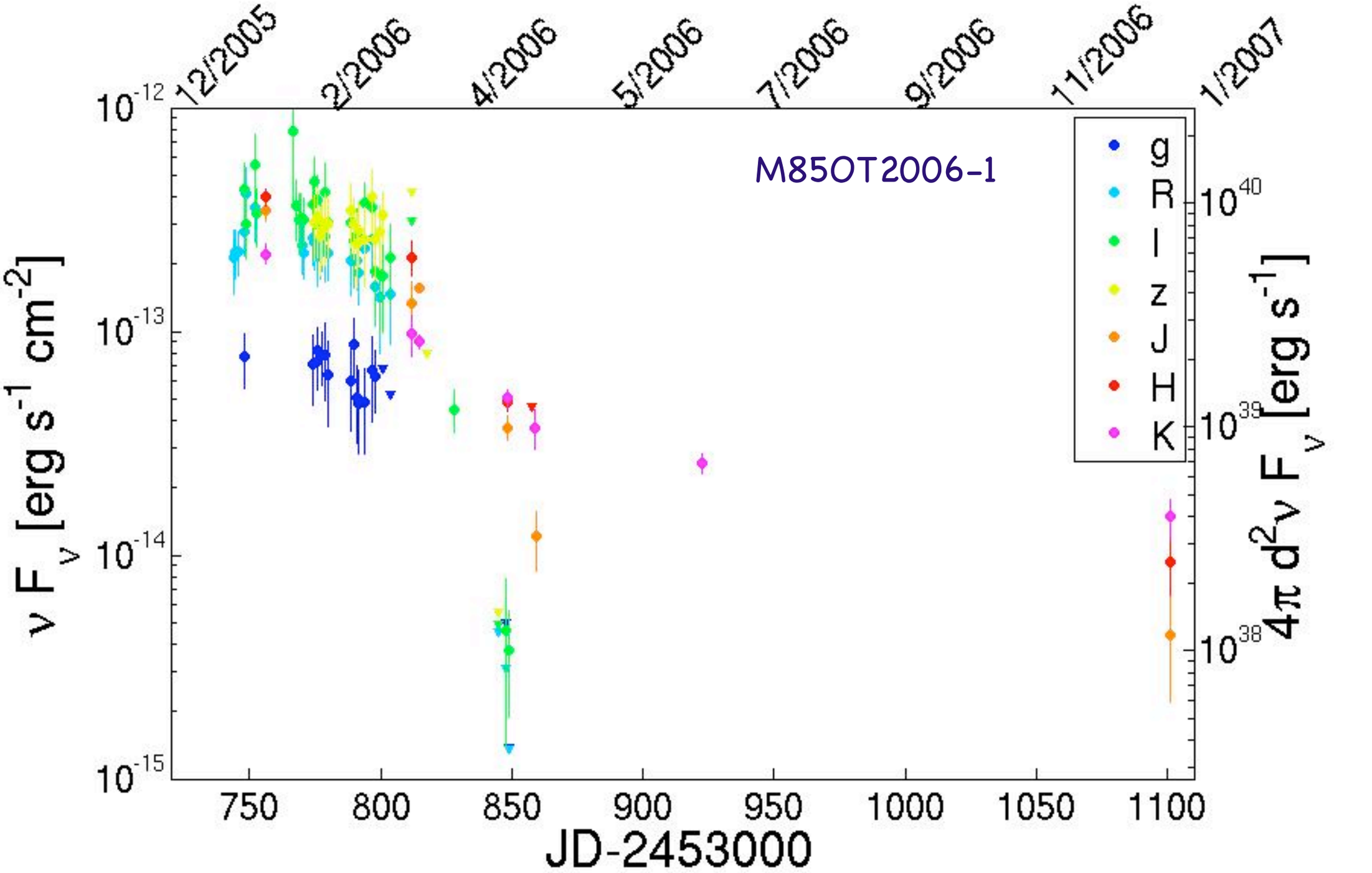
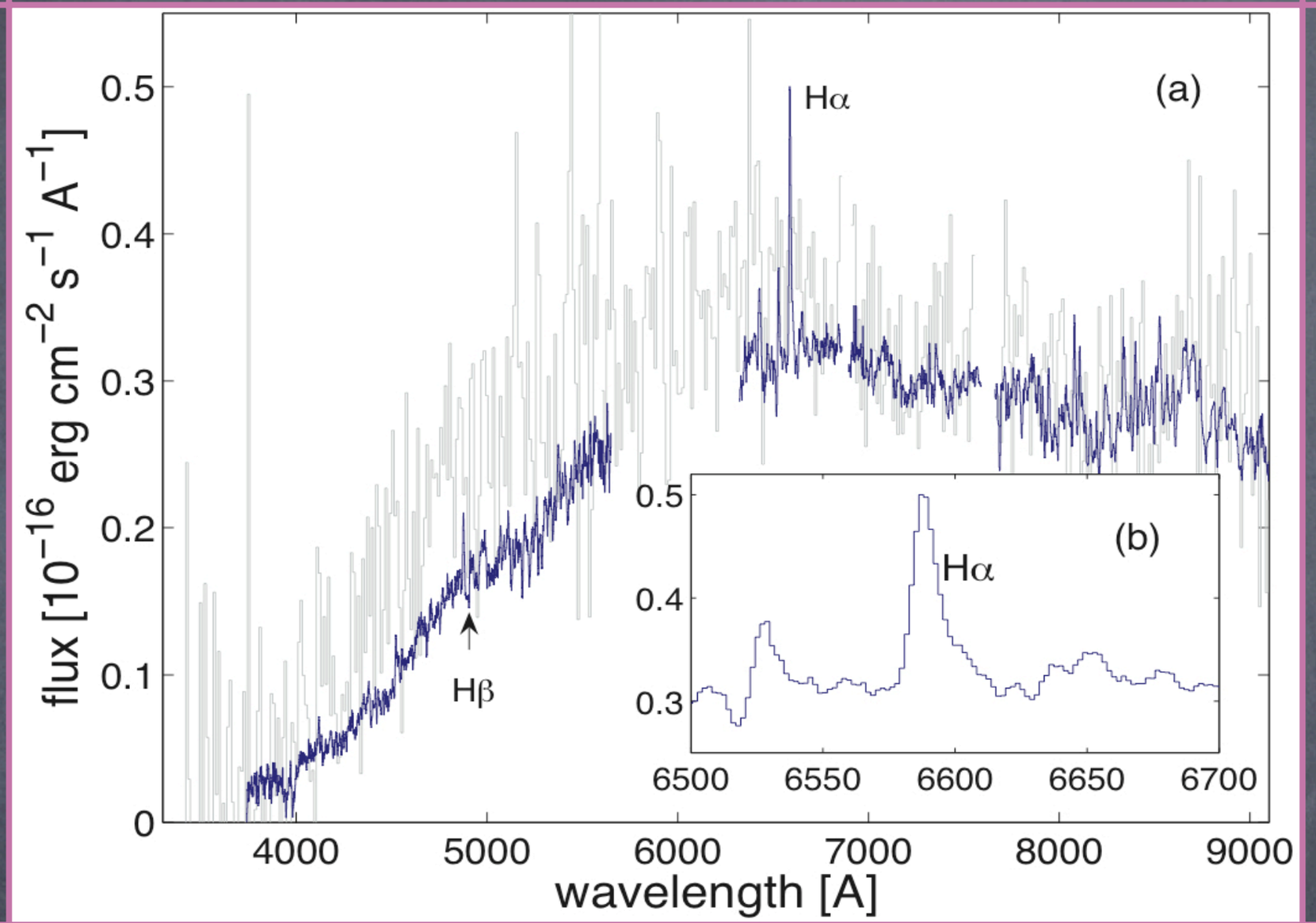


(Kulkarni et al., Nature, 2007)

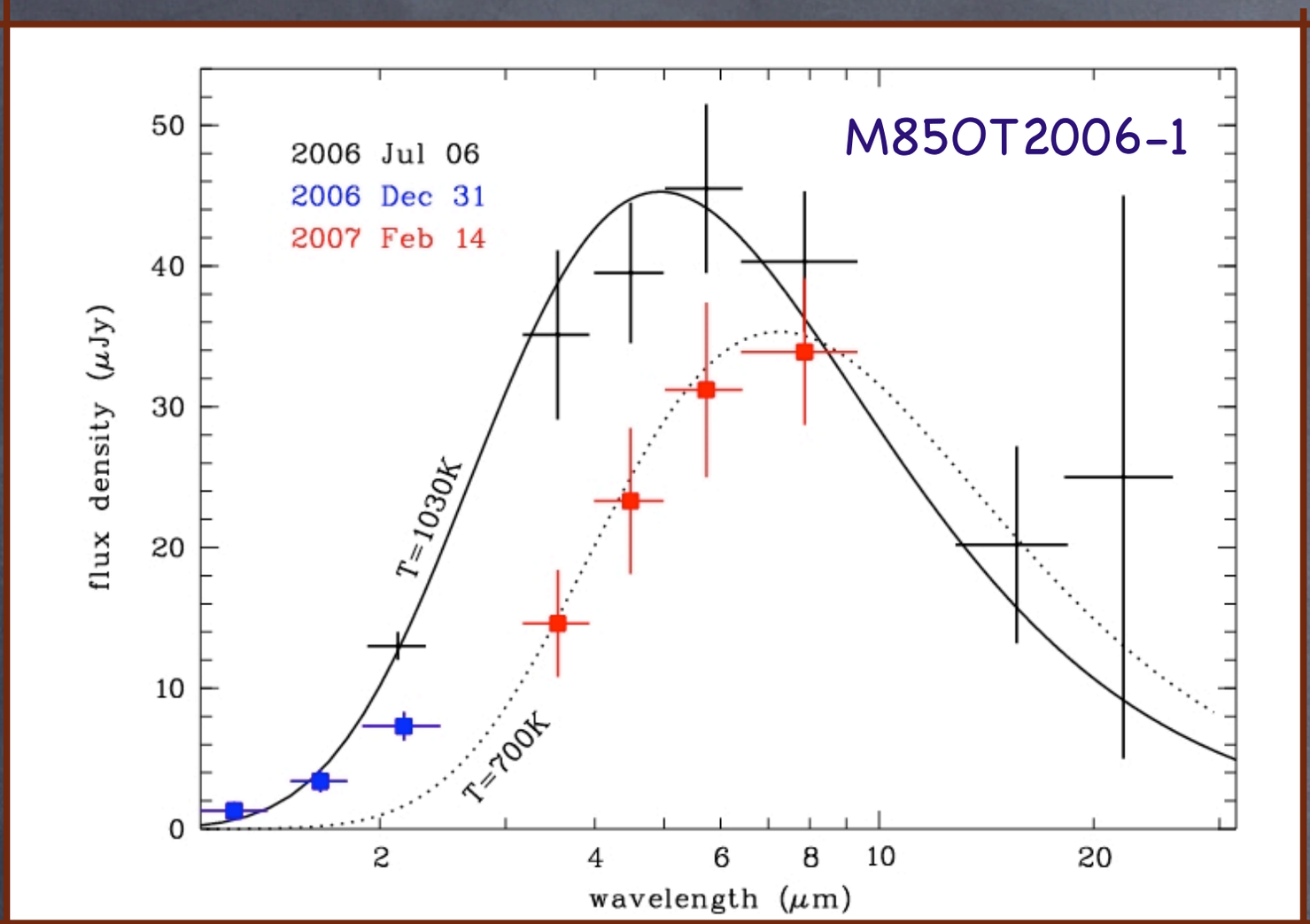
M85OT - Spectrum



(Kulkarni et al., Nature, 2007)

- P200/DBSP (Jan 08) and Keck/LRIS (Feb 24)
- Hα and Hβ at M85 distance (15Mpc), FWHM= 800+350 km/s
- T_{BB} ~ 4600 K
- A_R < 1mag

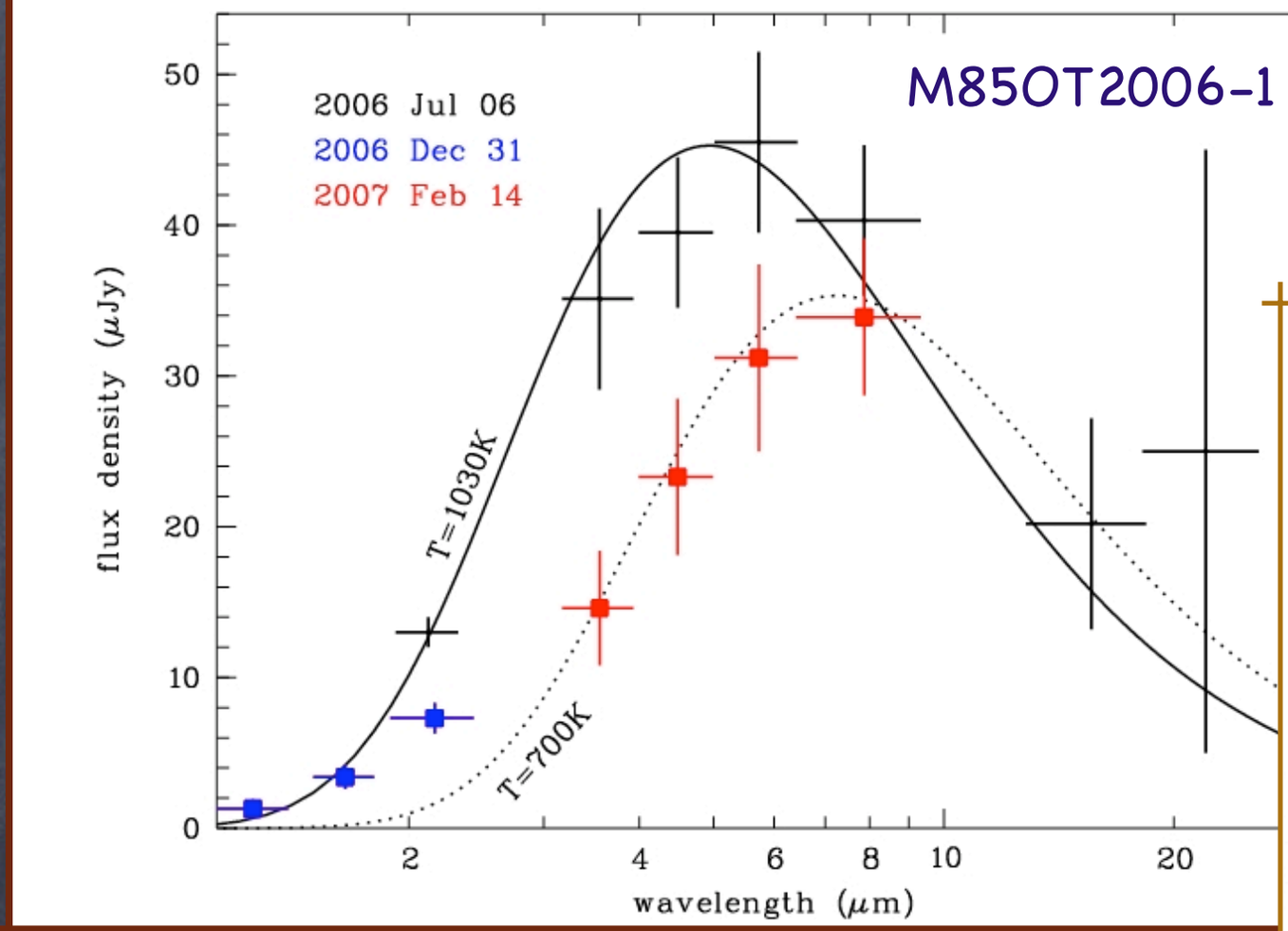
M85OT - Late Time Evolution



(Rau et al. 2007)

- $L_{t=6month} = 10^{39}$ erg/s
- $R_{t=6month} = 20000\ R_{\odot}$

M85OT - Late Time Evolution



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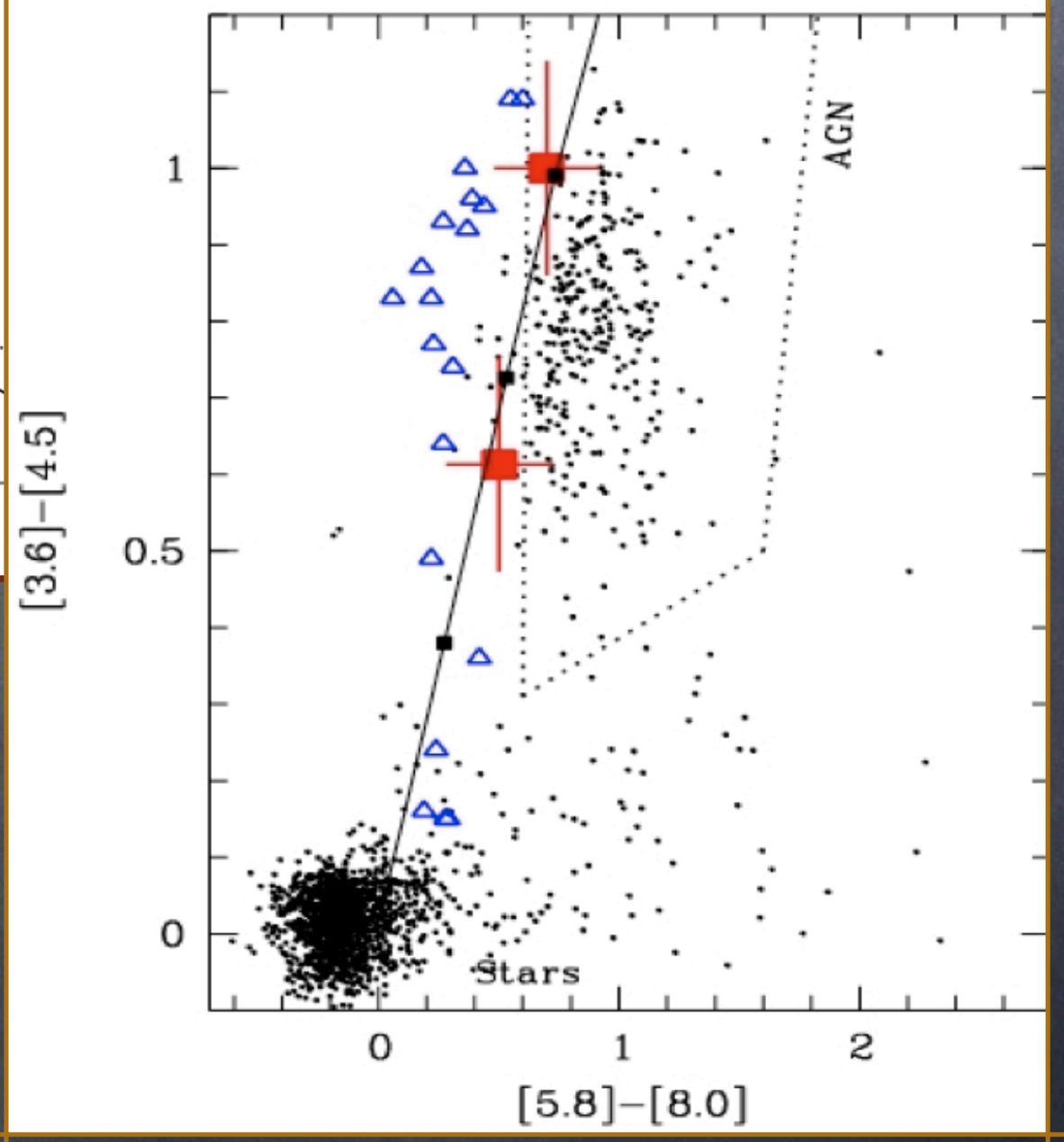
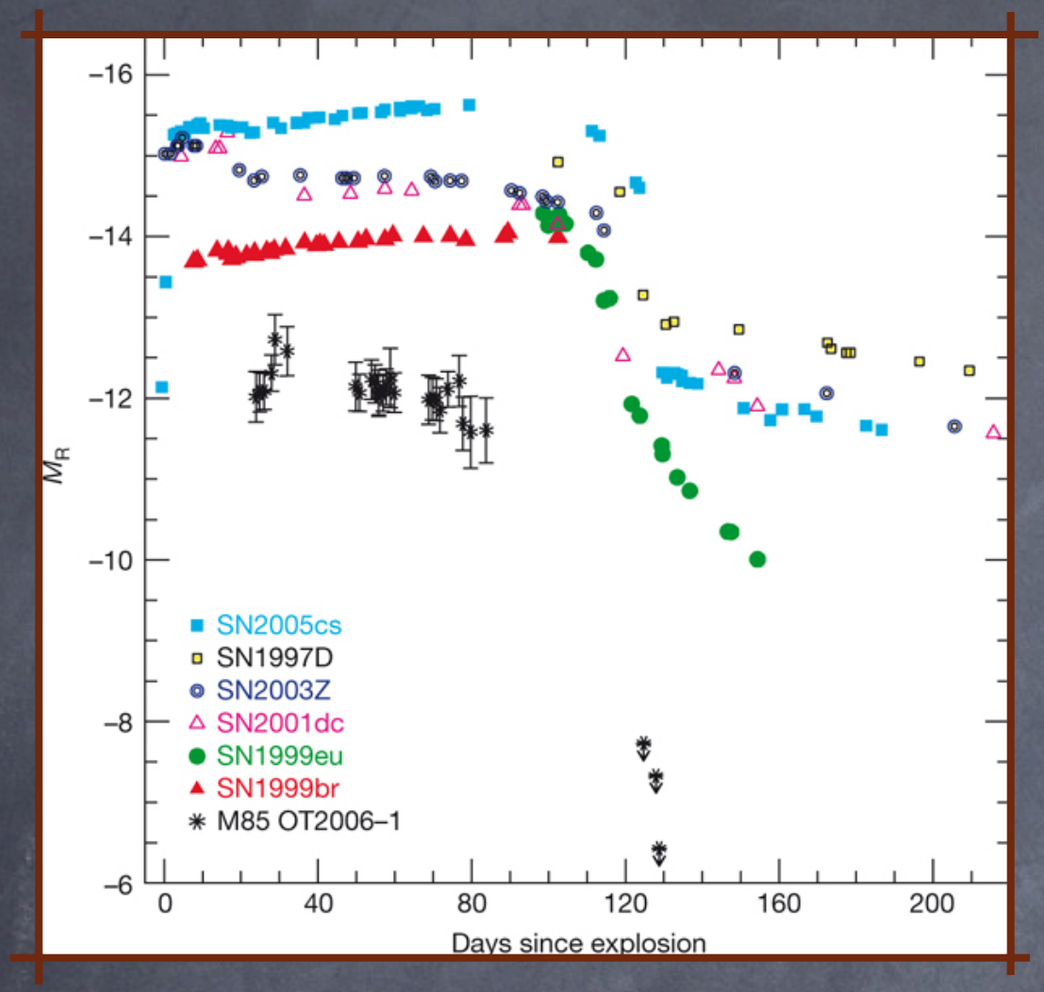


Models - IIP, Stellar Merger, Nova

(Pastorello et al. 2007)



- low-luminosity (<10^{50} erg/s) SN IIP
  - narrow Hα lines,
  - N_i<$10^{-3}M_\odot$, 6-9$M_\odot$ ejected
  - progenitor <12-15$M_\odot$ (K-M SG)
- Stellar Merger **(Tylenda & Soker 2006)**
  - common envelope phase
  - low mass progenitor
  - similar to V838 Mon

- Extreme Classical Nova **(Shara et al. 2008)**
- low mass (0.5$M_\odot$), cold (2-4x10^6K), low M_{acc} ($10^{-10}M_\odot$/yr)
- massive ($10^{-3..5}M_\odot$) H-rich envelopes
- massive ($10^{-3}M_\odot$) low-v (100-400km/s) ejecta - dust/molecule formation
- predicts high-O abundances (as in V838 Mon) and T>10^6K WD remnant (claimed for M31RV)

Rates, Stellar Population etc

The LRNe Sample:

- M31RV (Rich et al. 1989)
- V4332 Sgr (Martini et al. 1999)
- V838 Mon (Brown et al. 2002)
- M85OT-2006-1 (Kulkarni et al. 2007)

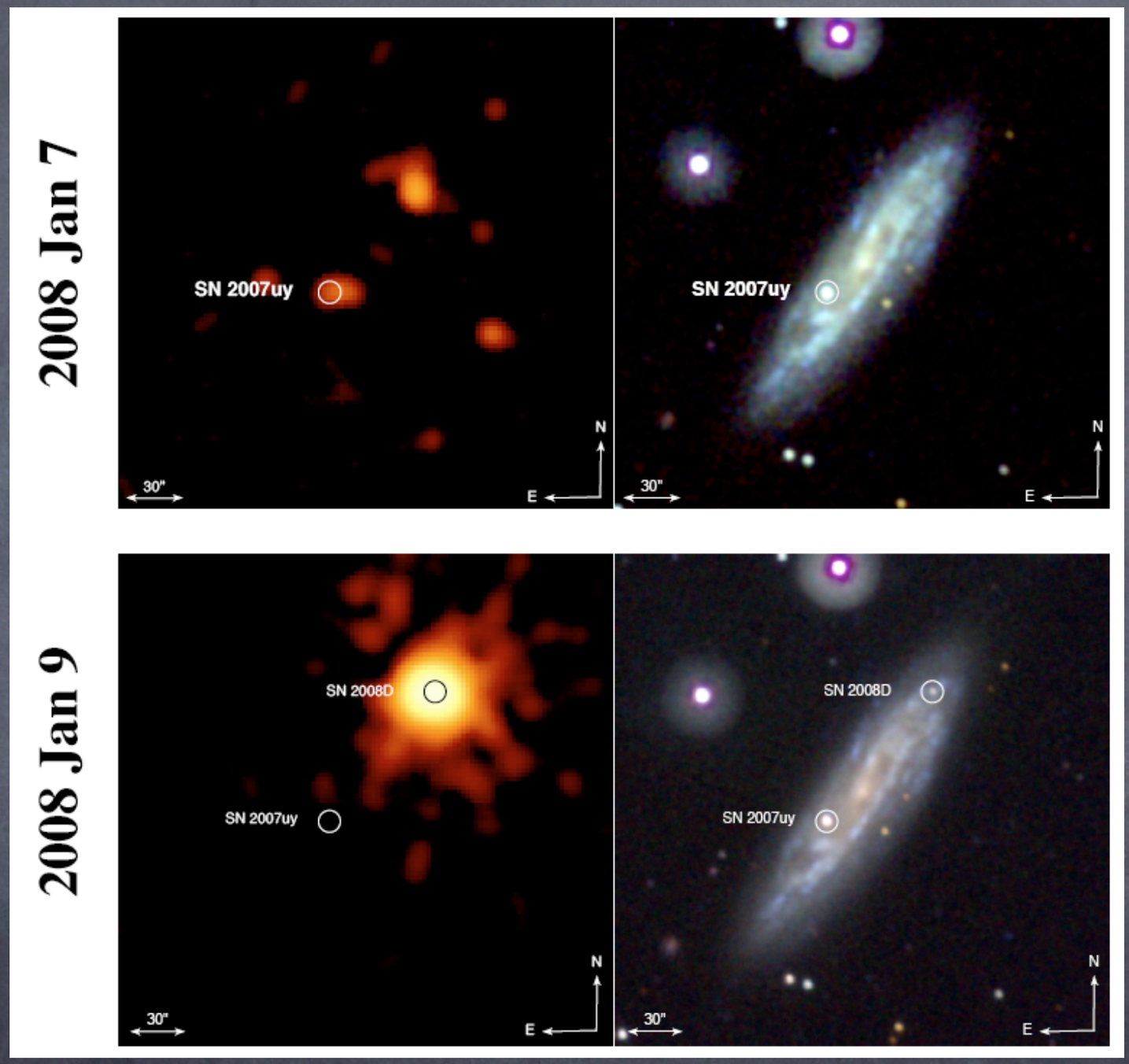
Stellar Population:

- eruption mechanism likely independent of stellar age
- M31RV in bulge, V838 Mon in B-star cluster, M85OT (?)

Event rates:

- 0.016 yr^{-1} L_{MW}^{-1} from known number of events (Ofek et al. 2007) and theory of stellar mergers
- visible out to D (r=24) ~ 150 Mpc (M85OT like) up to 3500 events per year
- identifiable out to D (r=23) ~ 40 Mpc (V838 Mon like) up to 70 events per year

XRO 080910 / SN Ibc 2008D

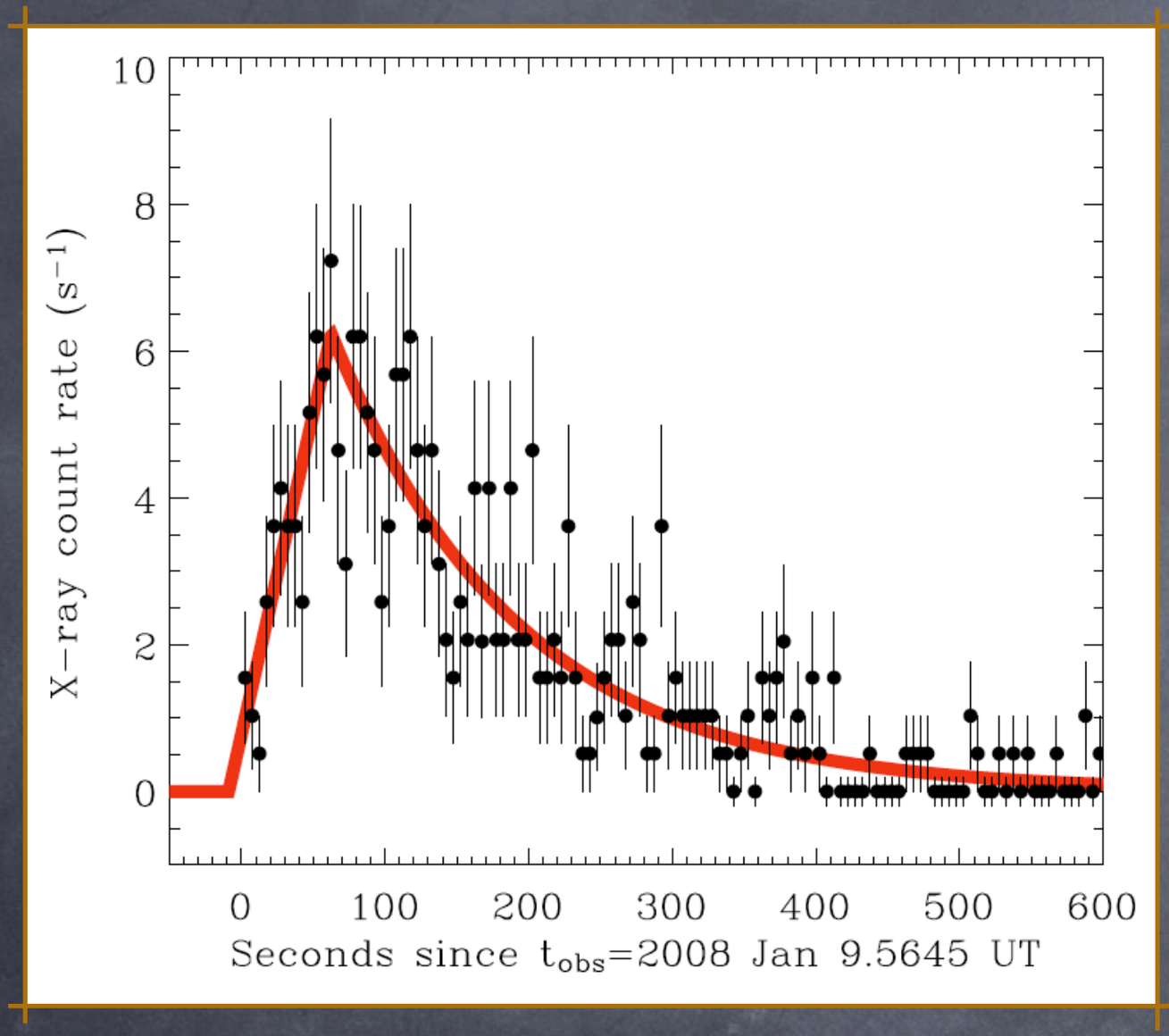


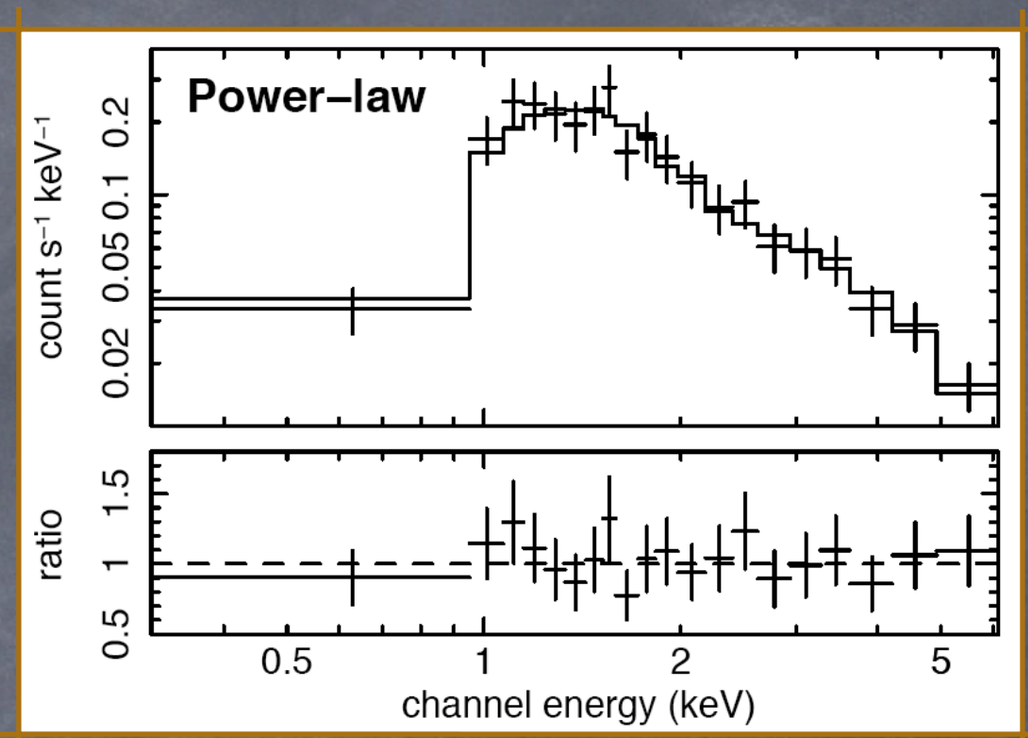
(Soderberg et al., Nature, 2008)

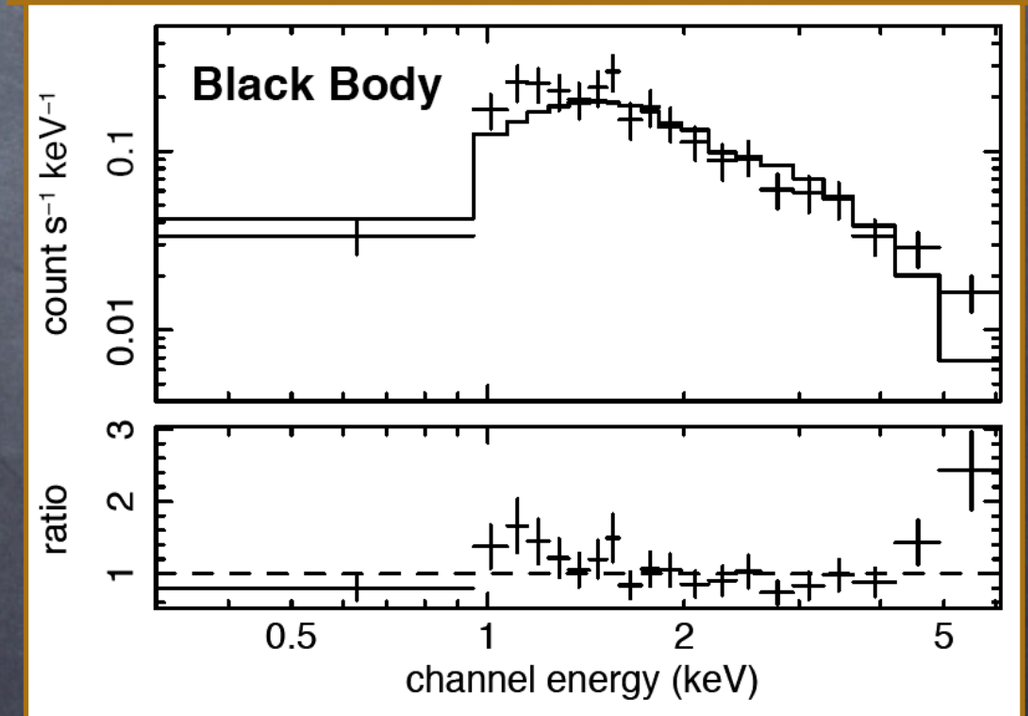
An Extremely Luminous X-ray Outburst

- during serendipitous Swift/XRT observation of NGC2770 (27 Mpc)
- UVOT counterpart appeared 85min later at U=19.8

Properties of the X-ray Outburst





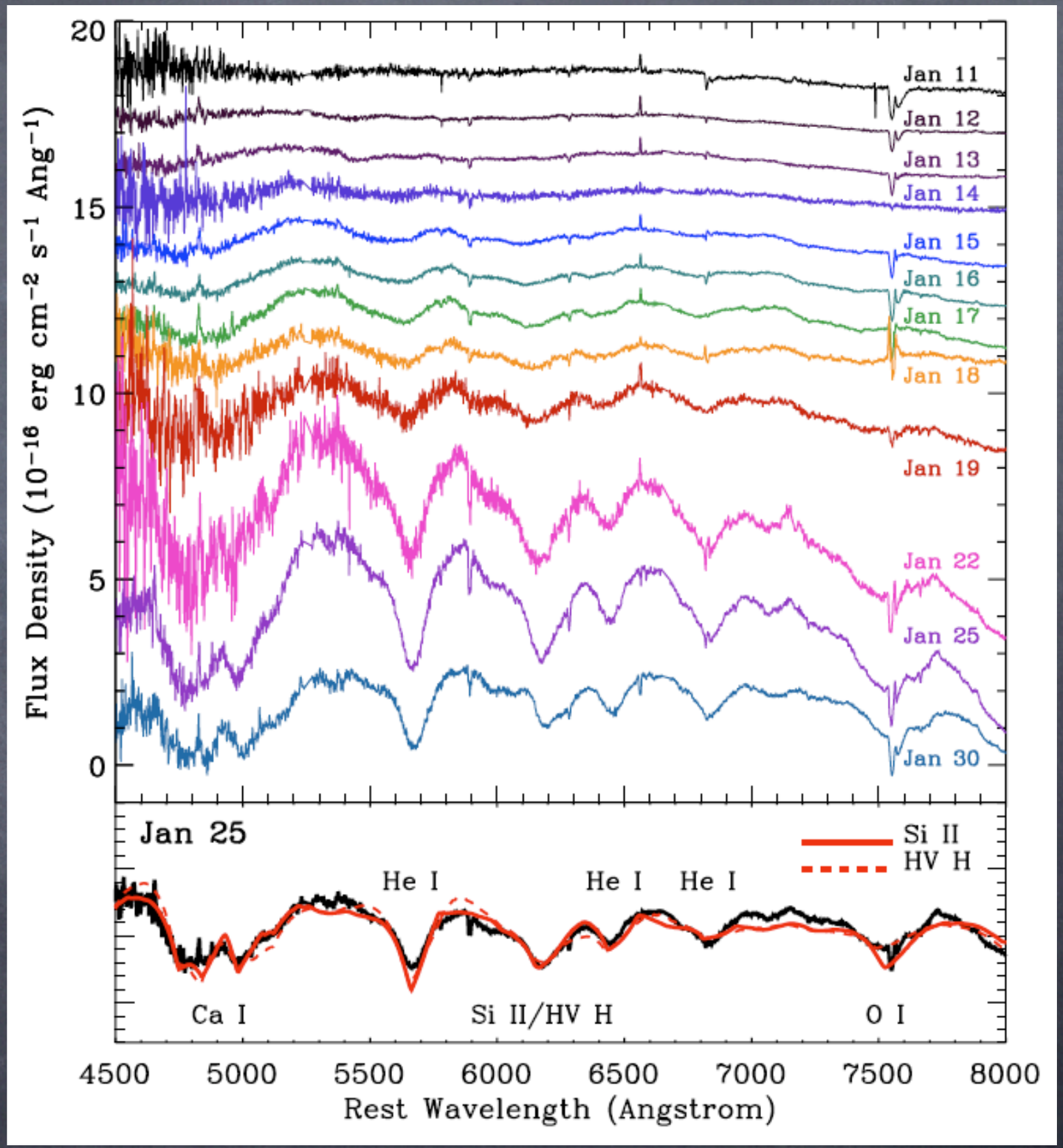


An Extremely Luminous X-ray Outburst

- powerlaw best fit (Γ_{peak}=1.7, Γ_{400s}=3.2, N_H=7x10^{21} cm^{-2})
- BAT limits consistent with XRT extrapolation
- $L_{x,peak}$ 6x10^{43} erg s^{-1}, E_x=2x10^{46} erg
- non-relativistic, shock break-out (thermal below XRT) + bulk Comptonization (powerlaw, soft)
- outbreak radius >7x10^{11} cm --> likely from dense stellar wind lost few hours prior explosion

Optical spectroscopy - it is a Ibc!

- evolution from featureless to broad absorption
- NaI, Hα and SNe abs. = NGC2770
- extinction from Keck/HIRES
- coverage exceeds that of most SNe, including GRB-SNe
- not swamped by an GRB afterglow



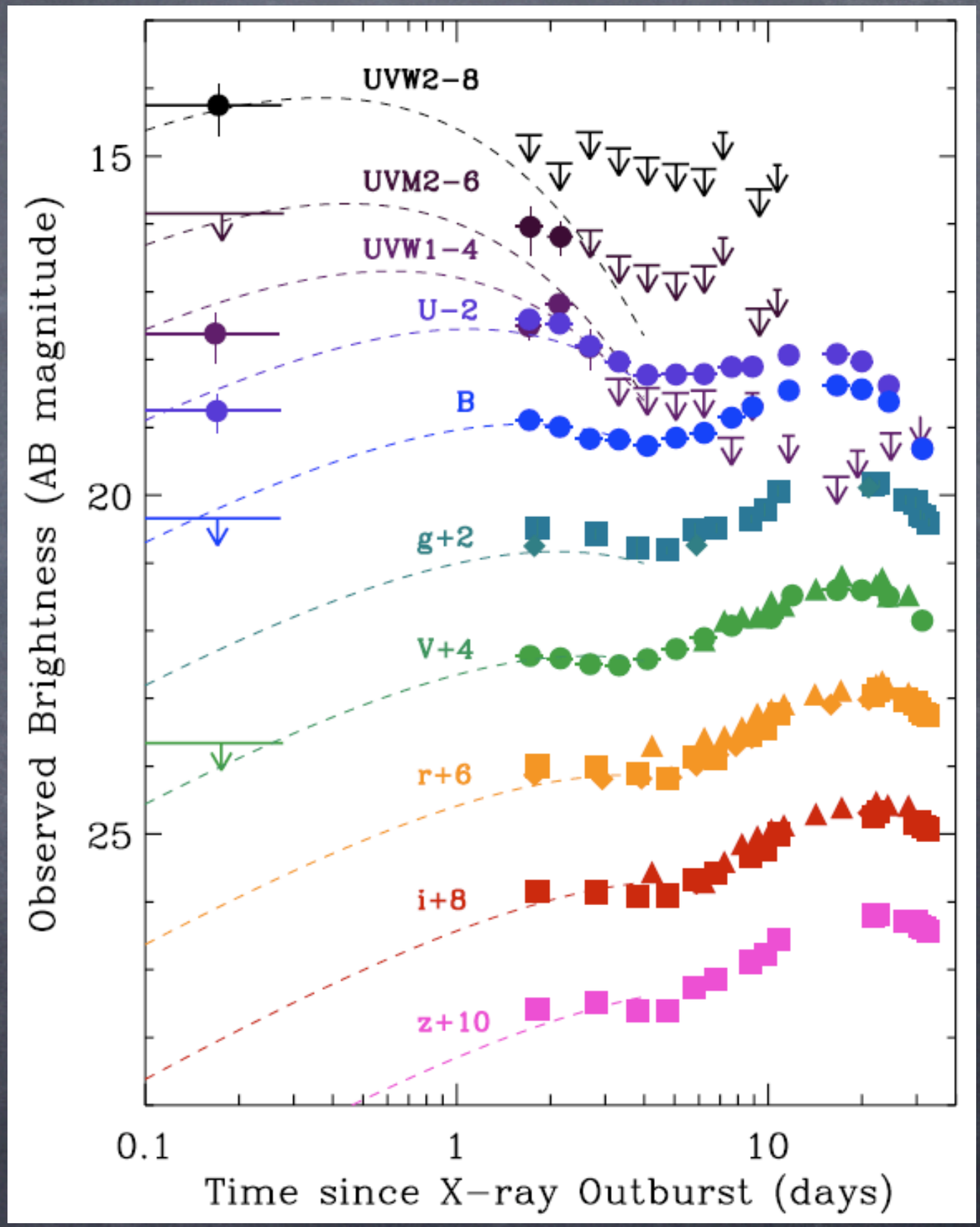
Photometric Evolution - Two Components

Early:

- thermal component from cooling of outer stellar envelope after shock
- $R=10^{11}$ cm (WR consistent)
- T_{ph}=14000K, $R_{ph}(t=1)=10^{14}$ cm

Late:

- normal SN Ibc



Implications

Rates

- discovery consistent with CC SNe rate (from XRT coverage of nearby galaxies)
- BAT (mission) non-detection still consistent for events within 20Mpc
- detection possible (sub-threshold experiment)
- but, NGC2770 may be special (3 Ibc in last decade)

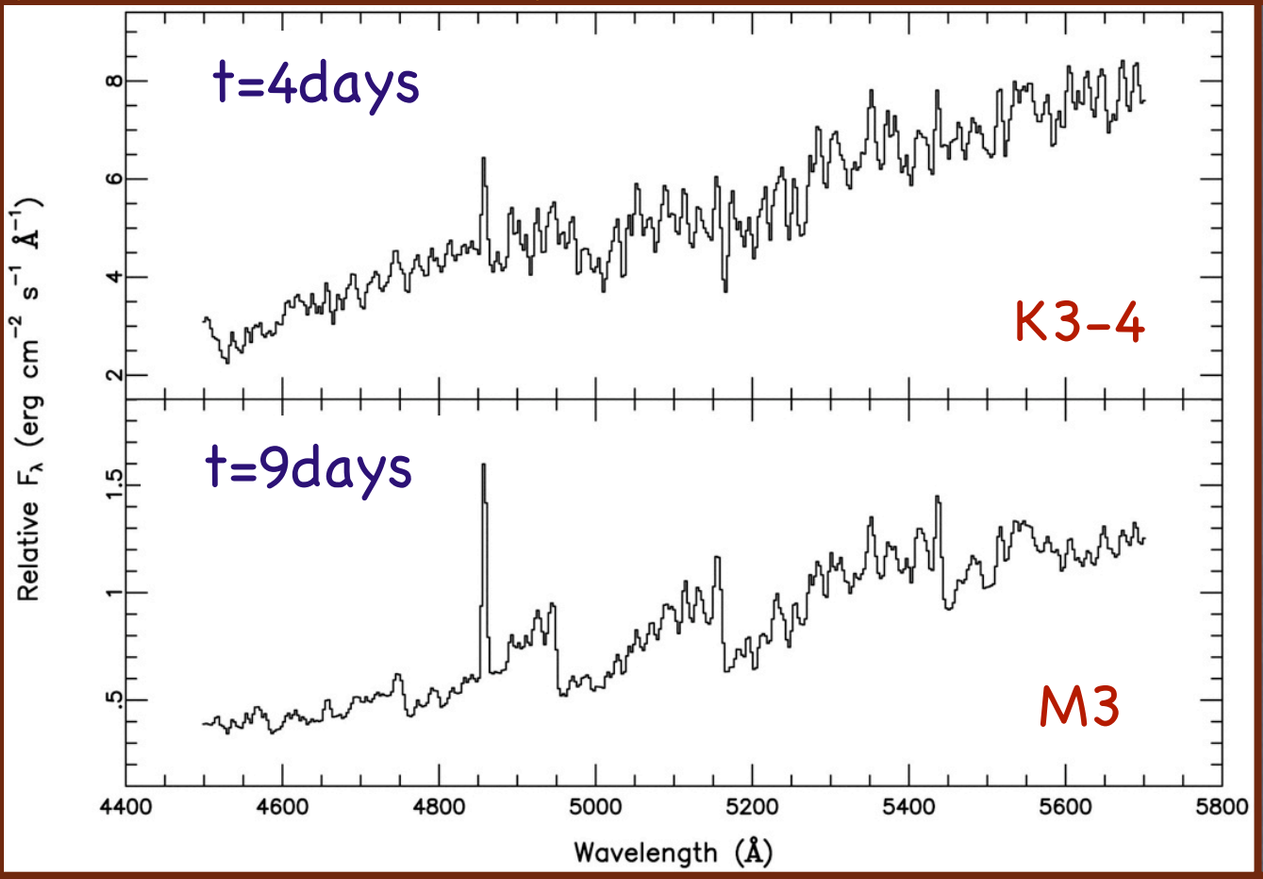
Future

- several hundred CC SNe in wide-field survey with XRT-like sensitivity
- unbiased against dust, even at the time of the explosion

Importance

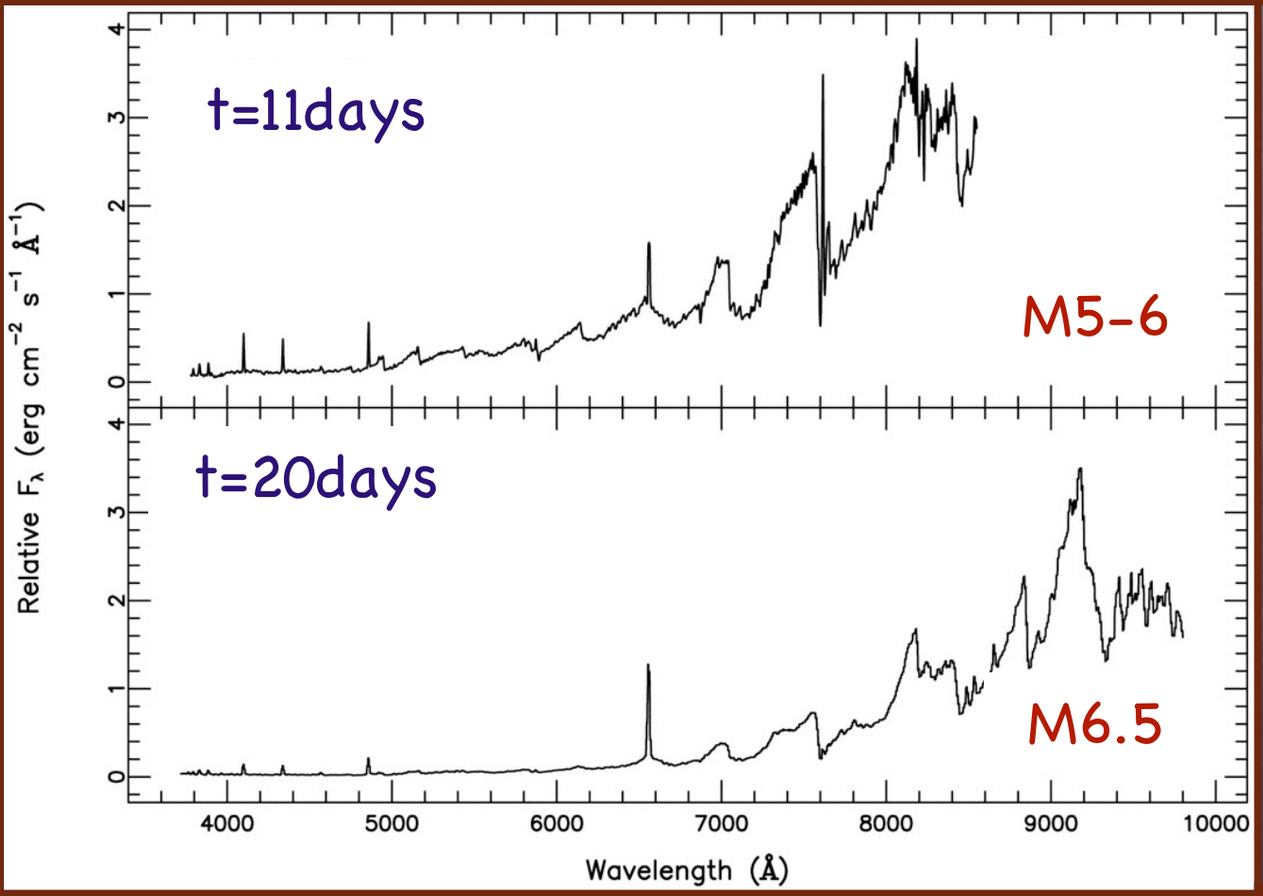
- likely every CC SNe will have shock-breakout
- probe early phases of explosion
- study radius and mass loss (hours before eruption)
- provide crucial temporal triggers for neutrino and gravitational wave detectors

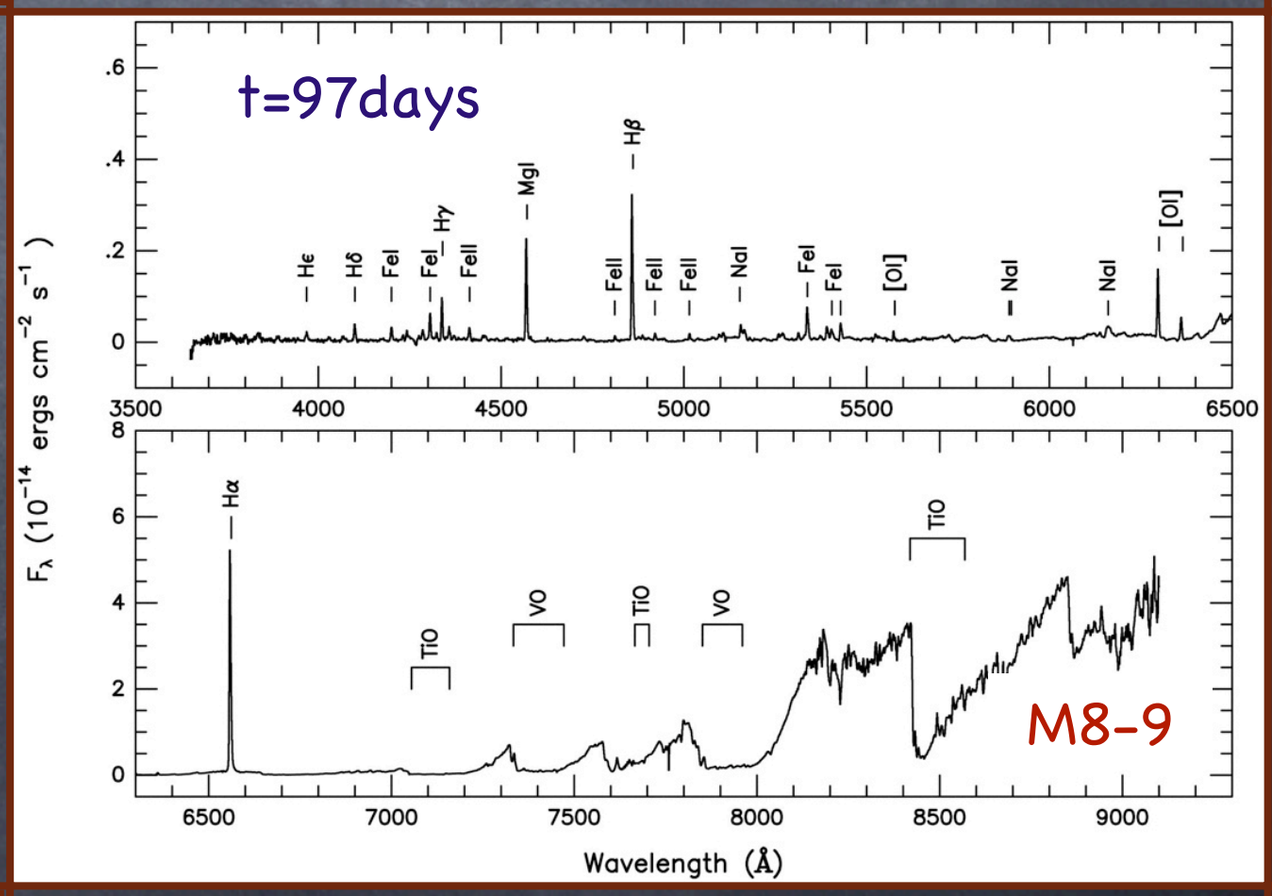
(Martini et al. 1999)



Spectral Evolution
(V4332 Sgr)

- Hα/Hβ (11days) = 2.4
- Hα/Hβ (97days) = 17
- $N_e = 10^{8-9}$ cm^{-3}
- KI, RbI, TiO, ScO emission after 9 years





Open Questions

Observations

- large peak brightness range (-3 to -12)
- single vs multiple outburst
- late time differences (photometric and spectroscopic)
- PCyg lines in all but V4332 Sgr (inverse)
- old (M85OT, M31RV, V4332 Sgr) vs young (V838 Mon) stellar population

Theory

- stellar merger vs massive novae vs faint CCSNe vs ...

Summary

- very small sample of long-lasting transients in brightness gap between novae and supernovae
- low velocity ejecta with strong redward evolution indicating dust condensation
- explosion mechanism independent of stellar population?
- merging stars, unusual bright novae or faint supernovae
- 1 event every 10-50 years per MW-like galaxy
- $10\text{-}10^3$ events with PTF to LSST