Swift Observations of Extragalactic Recurrent Novae

Michael Bode

Astrophysics Research Institute, LJMU

M.J. Darnley (LJMU), J.P. Osborne, K.L. Page, A.P. Beardmore (Leicester), J-U. Ness (ESA), A.W. Shafter (SDSU), F. Walter (Stonybrook), A. Evans (Keele), S.P.S. Eyres (UCLan), J. Krautter (Heidelberg), T.J. O'Brien (Manchester), M. Orio (INAF Padova, Wisconsin), G. Schwarz (AAS), O. Smirnova (Latvia), S. Starrfield (ASU), J. Truran (Chicago)

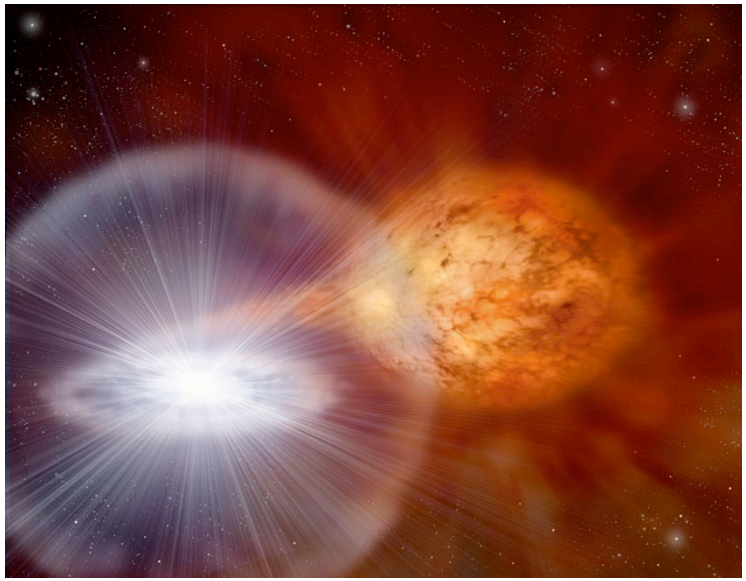
Overview

- RN class of objects and sub-types
- RS Oph (2006) as seen by Swift
- Nova LMC 2009 #1
- M31N 2007-12b
- Concluding Remarks

Recurrent Novae

- Inter-outburst period: ~10–100 yrs
- TNR on high mass WD, plus high accretion rate
- 3 possible sub-types (Anupama 2008; Galactic e.g.s):

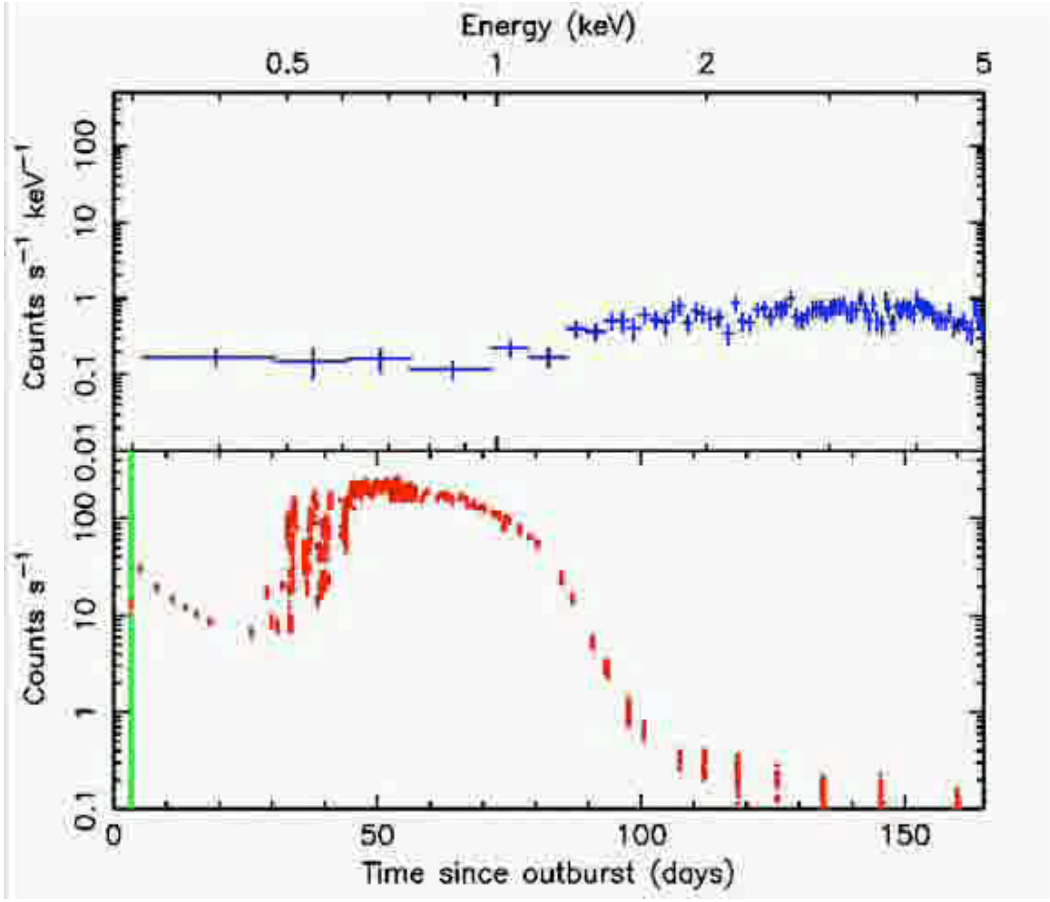
T CrB, RS Oph, V3890 Sgr, V745 Sco
Red giant secondary, P ~ few 100d
M_{WD} ~ M_{Ch}
Very fast optical decline, v_{ej} >~4000 km/s
M_{ej} ~ 10^{-7} – 10^{-6} $M_{\odot}$



U Sco, V394 CrA
Evolved/sub-giant secondary, P ~ day
M_{WD} ~ M_{Ch}
Very fast optical decline, v_{ej} ~10,000 km/s
M_{ej} ~ 10^{-7} $M_{\odot}$
Favoured SN Ia progenitor among RNe?

T Pyx, IM Nor, Cl Aql
MS/sub-giant secondary, P ~ hrs - day
M_{WD} < M_{Ch}
Slower optical decline, v_{ej} ~800-2500 km/s
M_{ej} ~ 10^{-5} $M_{\odot}$, spectral development as CN

RS Oph 2006 - Swift Observations



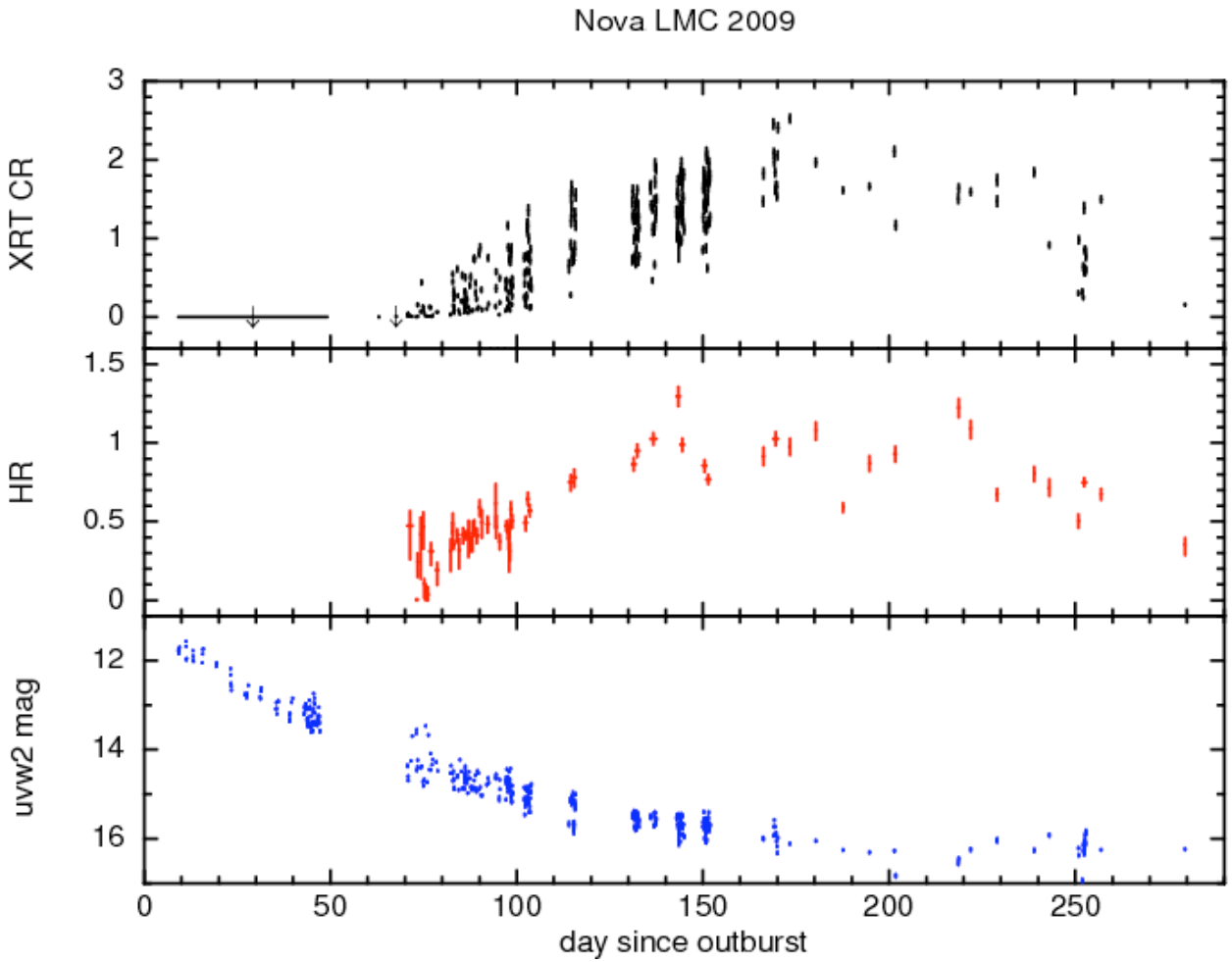
- Shocked wind emission
- Then SSS from t ~ 26d
- Initially highly variable
- "Plateau" phase(?), to t ~ 58d (M_{burn}= (1.7–3.8) x 10^{-7} $M_\odot$)
- P ~ 35s oscillations to t ~ 59d (Beardmore et al. 2008, Orio et al. 2008; nuclear burning instablty?)
- Secular decline to t ~ 90d when SSS phase ends (M_{env} ~ 3 x 10^{-7} $M_\odot$)

• Very much compressed version of V1974 Cyg (and other CN) SSS evolution? ($t_{off} \propto M_{WD}^{-6.3}$; $M_{WD} \sim M_{Ch}$ - several pointers to this) (e.g. Bode et al. 2006; Hachisu et al. 2007; Page et al. 2008)

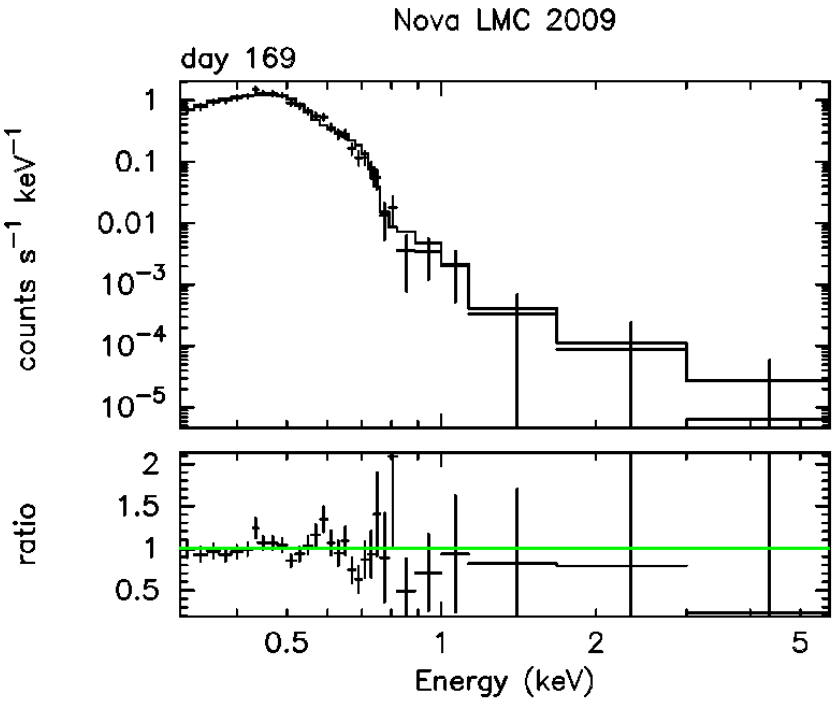
LMC 2009 #1

- Discovered 2009 February 05.07 UT
- Mag at max = 10.6 (unfiltered, IAUC 9019); very fast initial decline
- Previous nova outburst in 1971
- FWHM emission lines ~4200 km/s (ATel 1930)
- Optical spectrum reported initially similar to YY Dor, but no evidence of narrow RG wind or (later) coronal lines as seen in RS Oph

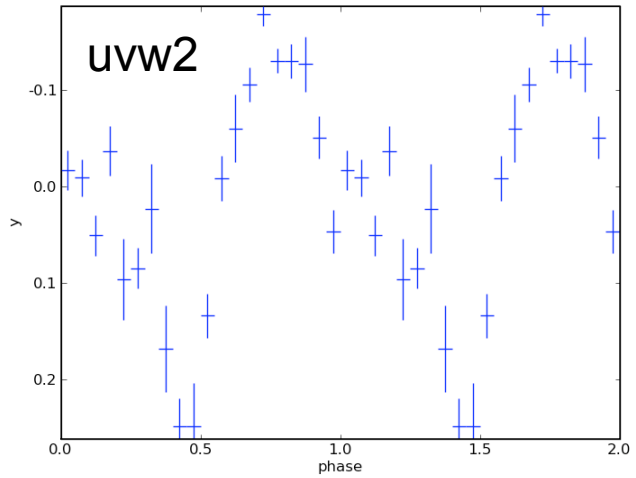
Swift observations began at t = 9 days (continuing)



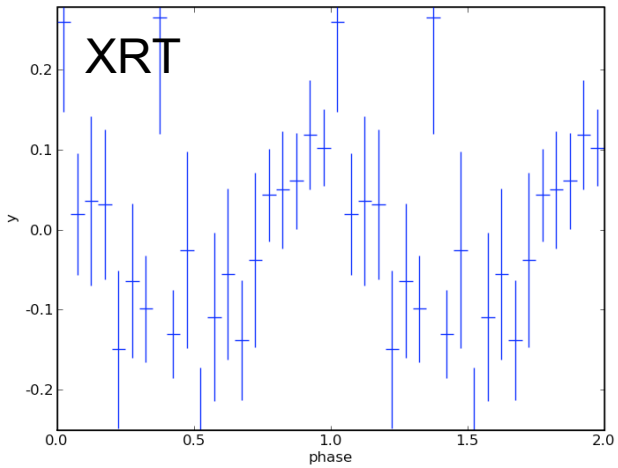
- Detected in X-rays at t = 70.7 days (ATel 2025)
- Again, highly variable SSS
- Long duration soft X-ray emission
- UV has plateaued



- E.g. day 169 data
- Fit with kT_{BB} = 65 +/- 2 eV, + kT = 2.7 keV mekal + 0.7 keV edge (N_H = 1.13 x 10^{21} cm^{-2})
- d = 48.5 kpc, L = 2.7 x 10^{38} erg/s (> L_{Edd} for M_{WD} = $M_\odot$, *but* simple SSS BB fit, so caution here)



- 1.19d period in uvw2 (ATel 2001) also seen in XRT (here days 100-155)
- But apparent lead of UV over X-rays of 0.24d - origin?



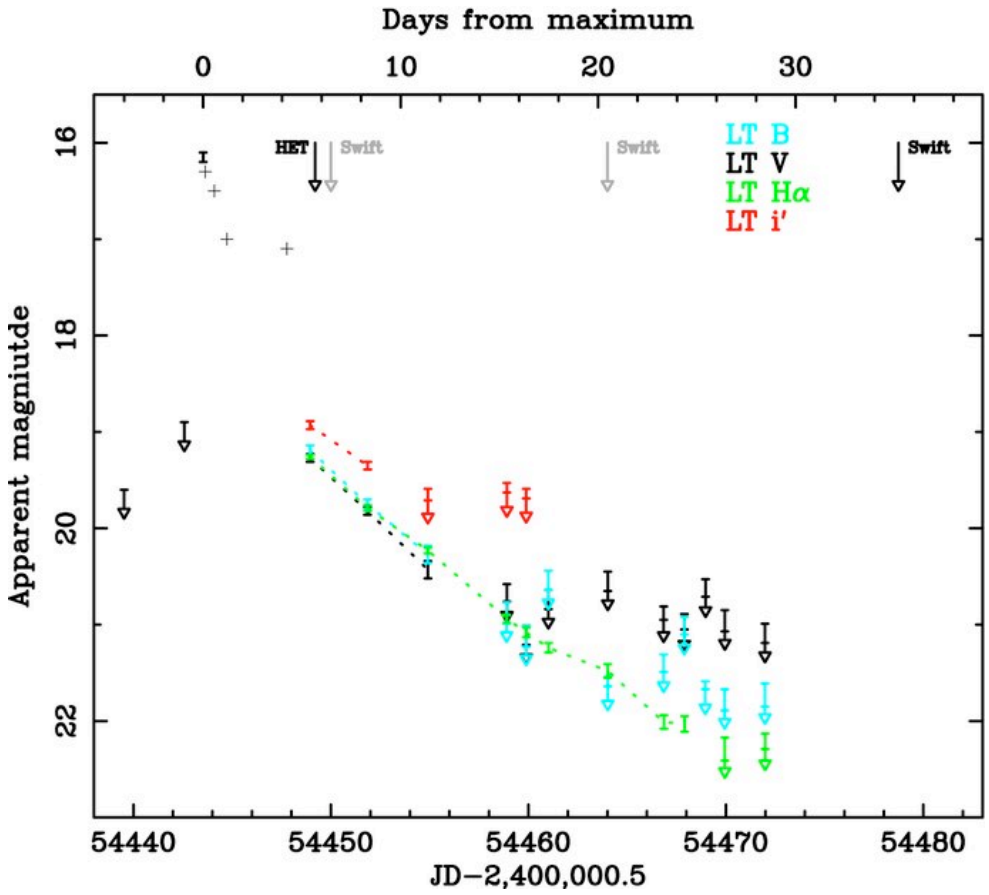
Sub-type?

- 1.19d periodicity: orbital period? (cf. e.g. orbital periodicities in IM Nor - 2.462 hrs, Woudt & Warner 2003; CI Aql - 0.618 days, Mennickent & Honeycutt 1995)
- Progenitor? Work on pre-outburst object ongoing
- But not RS Oph-like (if above is orbital period + no evidence of pre-outburst RG wind)
- Rather different outburst behaviour from either U Sco or T Pyx though!

M31N 2007-12b

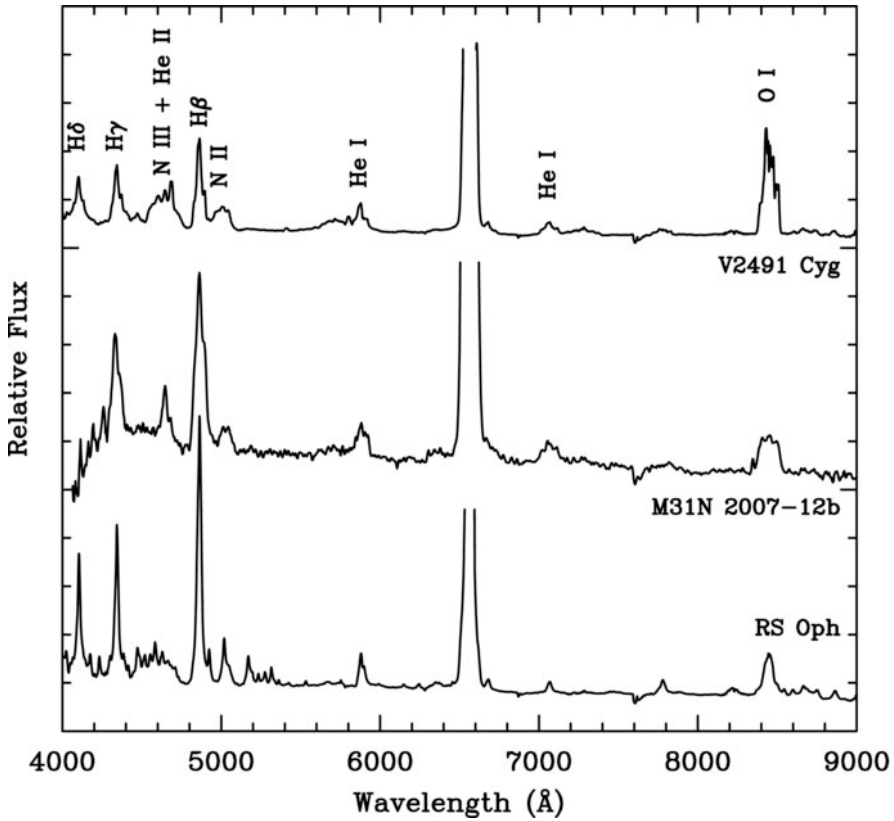
(Bode et al. 2009, ApJ)

- ~ 800 CN candidates discovered to-date in M31 (e.g. Pietsch 2009, AN)
- Among these are several potential RNe (based mainly on positional coincidence of outbursts)
- Most recently, transient source PTF09gfq associated with 1997-11k, 2001-12b *may* be *very* short inter-outburst period RN (but very odd light curve and spectra if so - ATels 2286, 2290)



- HET spectrum at t = 5d
- v ~ 4500 km/s (FWHM Hα)
- Lines typical of He/N CN
- Resembles RS Oph at t = 6d, but not U Sco types
- Even closer match to suspected RN V2491 Cyg at 17-18d

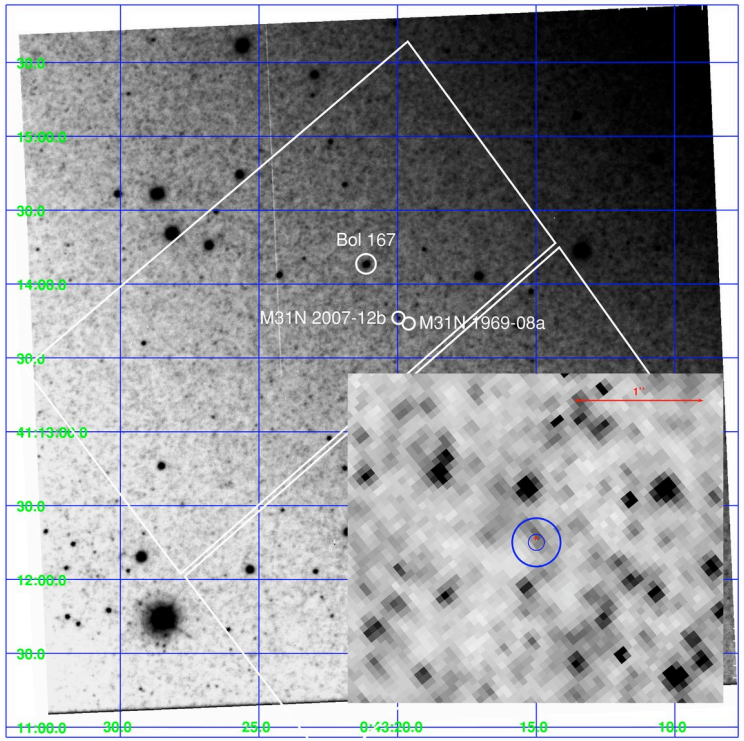
- Fast nova, apparently coincident with M31N 1969-08a
- Serendipitous Swift observations from 17d before to 169d after outburst
- Detected as SSS at t = 35d
- 21 < t_{on} < 35d, t_{off} < 169d
- XMM obs show 1105s oscillations (magnetic WD? Pietsch 2009)



Results from Swift Observations

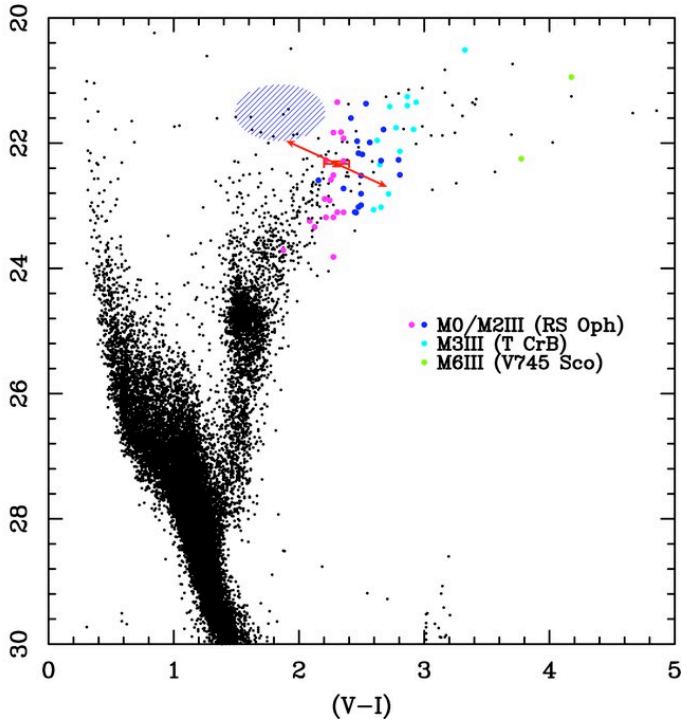
- Fit using N_H = 2.1 x 10^{21} cm^{-2} (fixed, assumed mid-point M31 disk) and d = 780 kpc
- $kT_{BB} = 63^{+10}_{-8}$ eV; $L = 4.5^{+1.9}_{-1.4}$ x 10^{38} erg/s (> L_{Edd} for 1.4 $M_\odot$WD, but same caveats as before)
- t_{on}, t_{off} suggest M_{WD} > 1.3 $M_\odot$
- SSS in U Sco (1999 outburst, t_{on} < 20d) and RS Oph (t_{on} < 30d; t_{off} ~ 90d) would not have been detected for d and N_H of M31N 2007-12b
- However, V2491 Cyg would have been around peak of SSS emission at t ~ 40d

Identification of Progenitor



- Liverpool Telescope image (4.6'x4.6')
- HST ACS (5"x5") insert
- Point source within 0.06" (1σ) of LT position of M31N 2007-12b (note that 1969-08a is **not** coincident with this)
- *V* = 24.61+/-0.09, *I* = 22.33+/-0.04

- C-M Diagram with Red Giants in various Galactic RNe noted
- Hatched region is RS Oph at quiescence
- Candidate marked, together with reddening vectors



Concluding Remarks

- Study of recurrent novae important for several branches of astrophysics, including (of course!) their proposed link to SNe Ia (etc.)
- Detailed studies of individual Galactic RNe (rare objects) are complemented by population studies of RNe in extragalactic systems (particularly M31)
- Beware of misidentifications in M31, but with a suitable set of observations can e.g. identify sub-types - are there sufficient of appropriate sub-type to explain SN Ia rate for e.g.?
- Swift has a continuing important role to play!