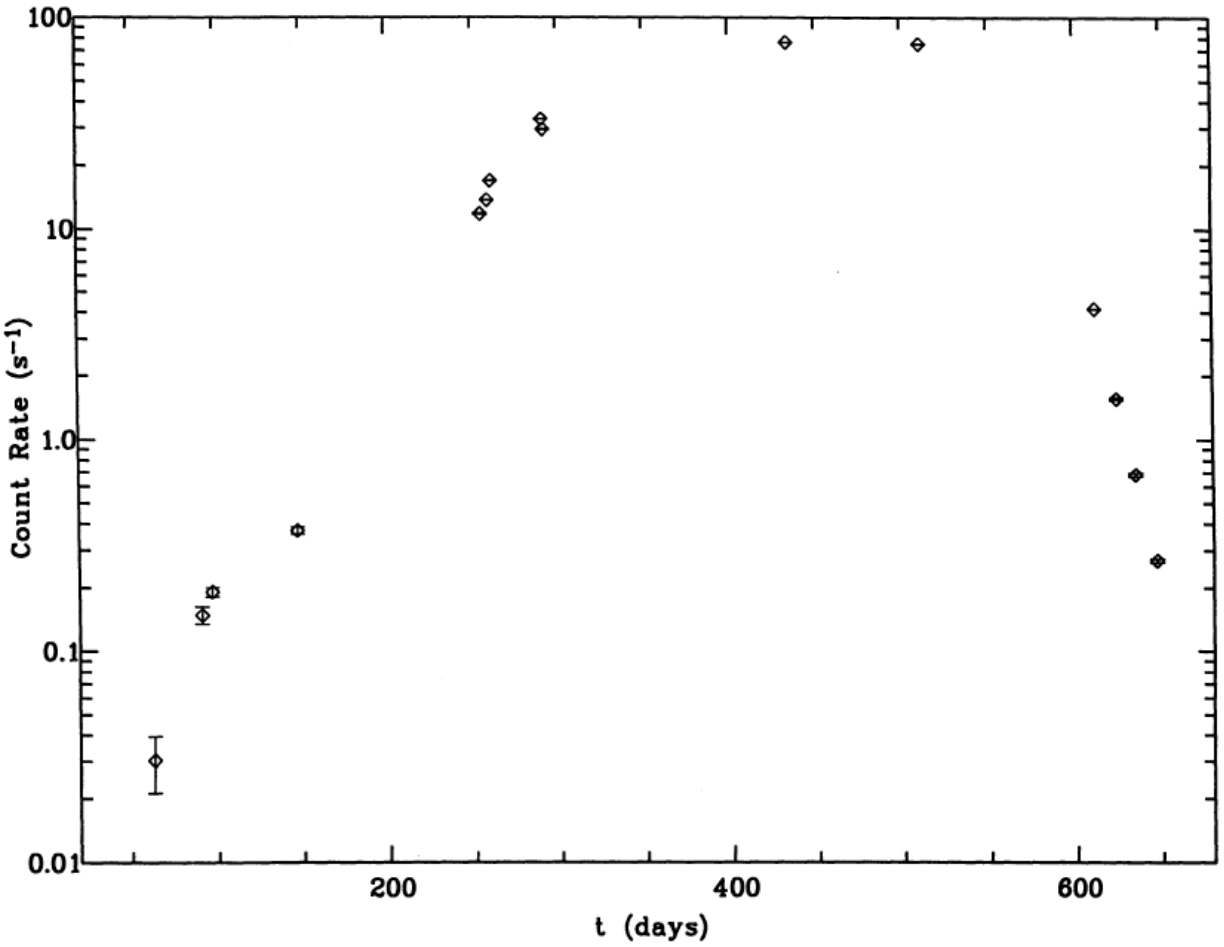
Swift Observations of Novae

Kim Page

(On behalf of the *Swift* Nova-CV Group)

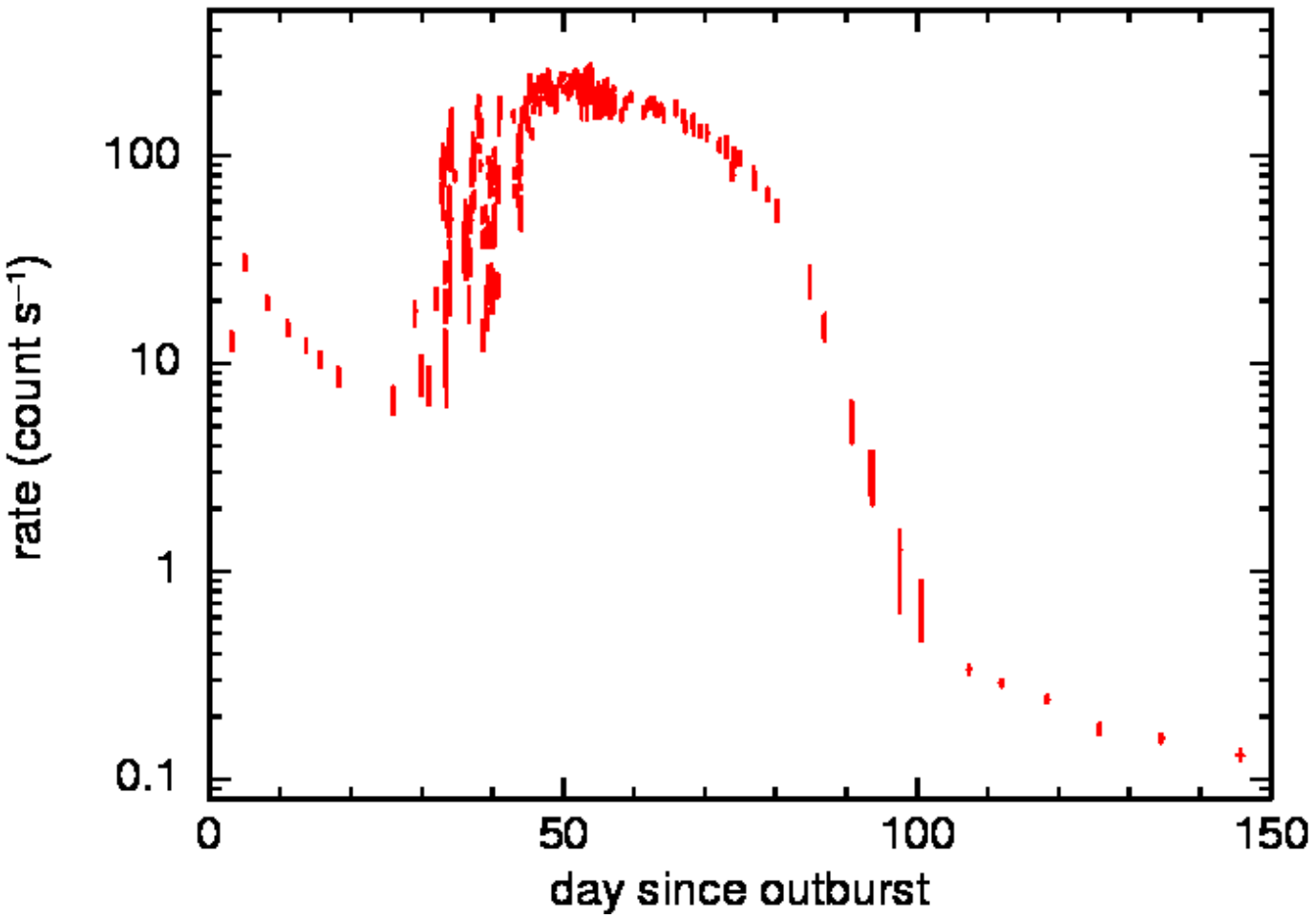
That was then...



Nova V1974 Cyg 1992

Krautter et al. (1996)

This is now!



RS Oph

Osborne et al. (2011)

Galactic and Extra-Galactic Novae

In the past three years, Swift has observed around 30 novae – some just a single snapshot, but most observed multiple times, including a number which were monitored in glorious detail.

While most novae Swift follows-up are within our own Galaxy, we have also observed and detected extra-galactic novae:

LMC: ASASSN-17pf (ATels by Chomiuk et al. 2018; Bahramian et al. 2018)
Recurrent nova LMC 1968-12a (2016 outburst; Kuin et al., in prep)
LMC 2012 (Schwarz et al. 2015)
Recurrent nova LMC 2009a (Bode et al. 2016)

SMC: SMC 2016 (Aydi et al. 2018; Orio et al. 2018)
SMC 2012 (ATels by Schwarz et al. 2012; Page et al. 2013a.b)

M31: RRN M31N 2008-12a (Henze et al. 2014,2015,2018; Darnley et al. 2014,2015,2016)
AT 2018cmi, AT 2017fyp, M31N 2017-05b, M31N 2007-06b .....

M33: M31N 2016-12a, ASASSN-15th, M31N 2009-01a

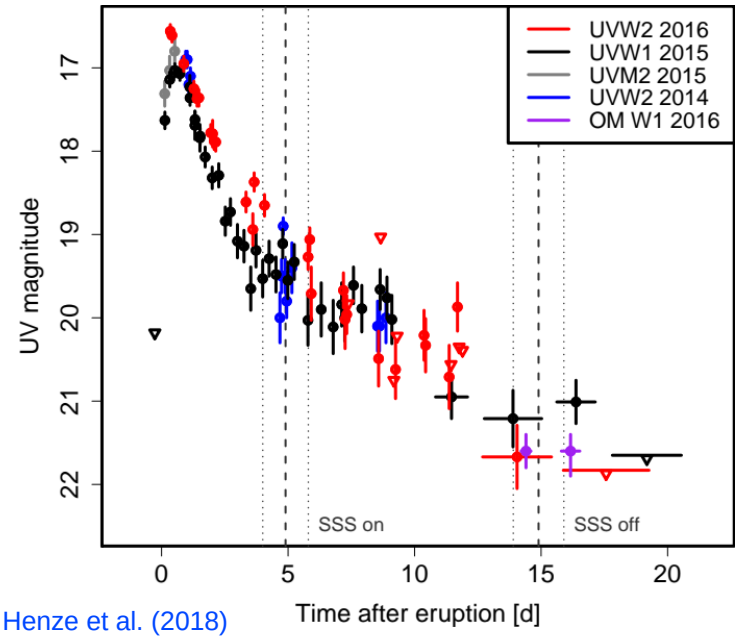
Nova in IC 1613 - Local Group irregular dwarf galaxy (Williams, Darnley & Henze 2017)

AT 2017fvz in NGC 6822 – Local Group barred irregular galaxy (Healy et al., in prep)

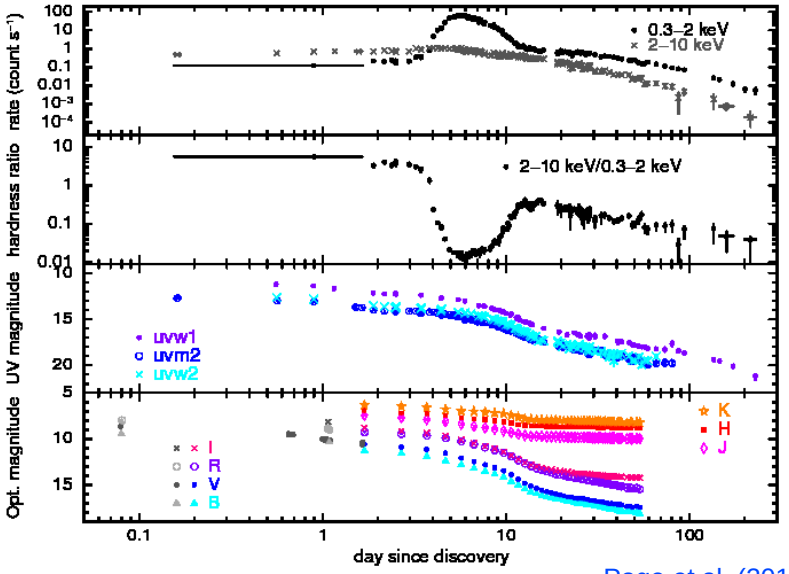
Rapid follow-up

Some novae have been followed up extremely quickly by Swift: observations of V745 Sco started < 4 hours after the optical outburst was announced!

There have also been accepted GI proposals (specifically for M31N 2008-12a – the RRN which goes into outburst about once a year), where the follow-up by Swift has been very rapid (eg < 8 hr).



Henze et al. (2018)

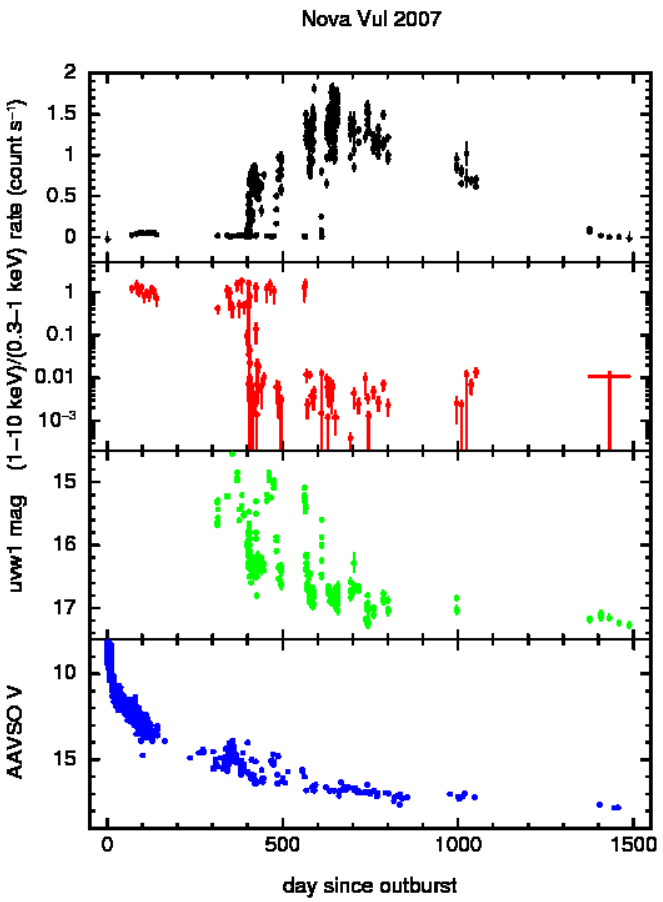


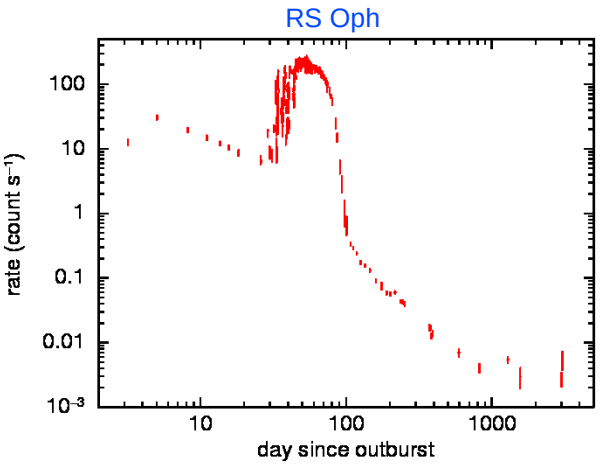
Page et al. (2015)

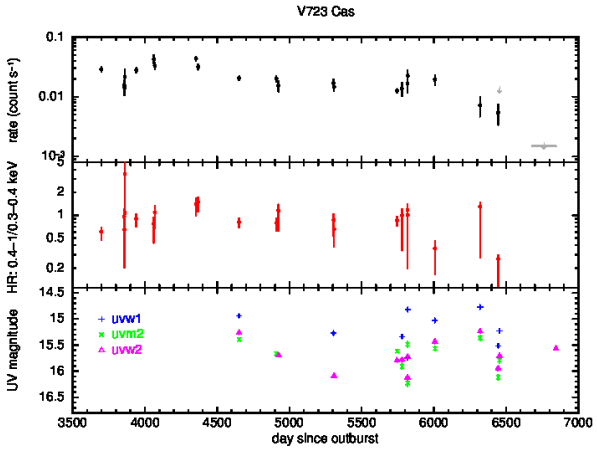
Such a speedy turn-around is unique to Swift, and has been incredibly important for investigating nova SSS emission.

Monitoring

As well as the initial rapid follow-up, Swift frequently monitors novae throughout their evolution, till 100s days – sometimes > 1000 days – after outburst. This means we can measure (or put limits on) the start and end of the SSS phase, which provides information about the WD mass.



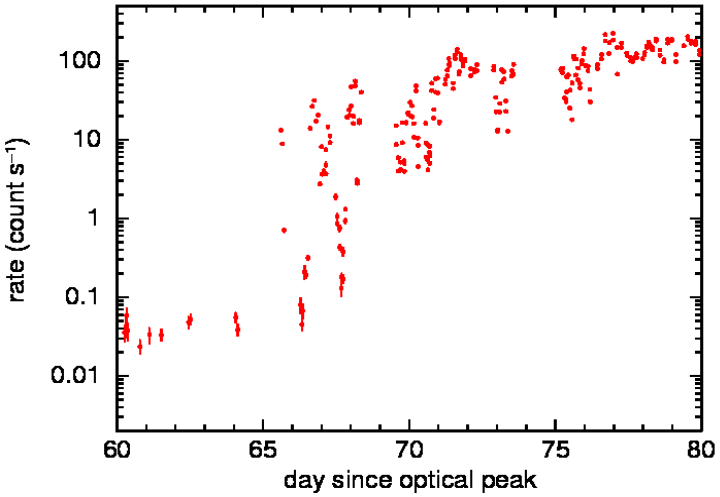




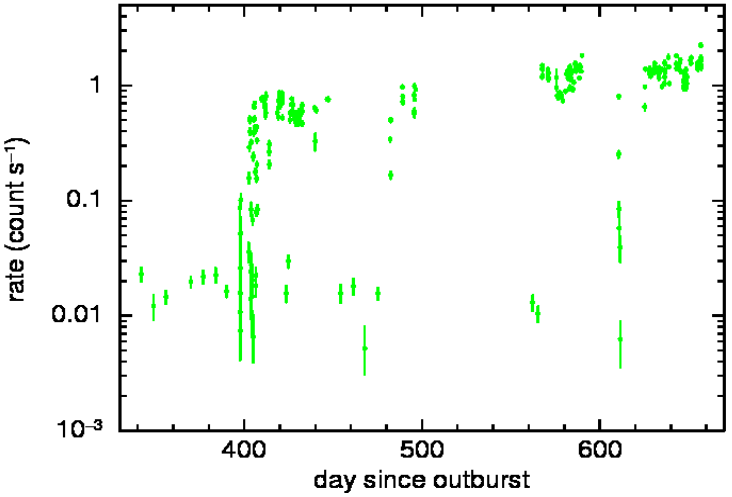
Hamilton-Drager et al. (2018)

High-amplitude variability

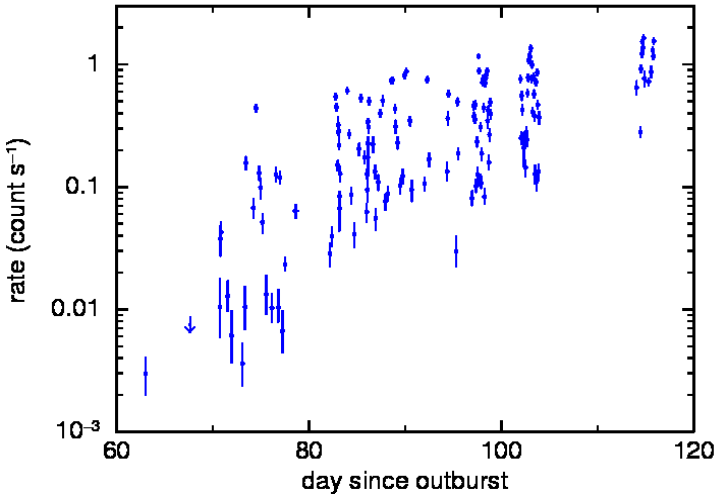
KT Eri

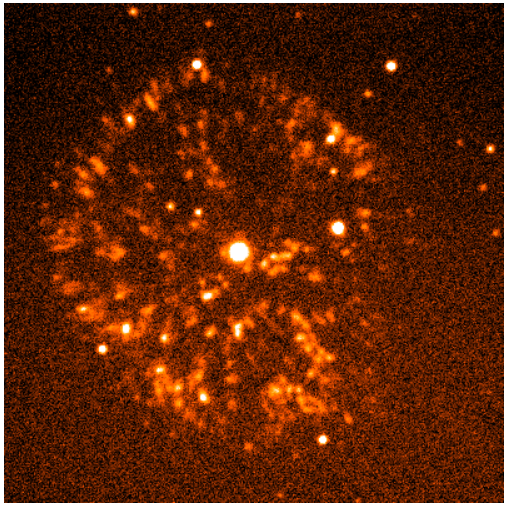


V458 Vul



Nova LMC 2009a





NOAO

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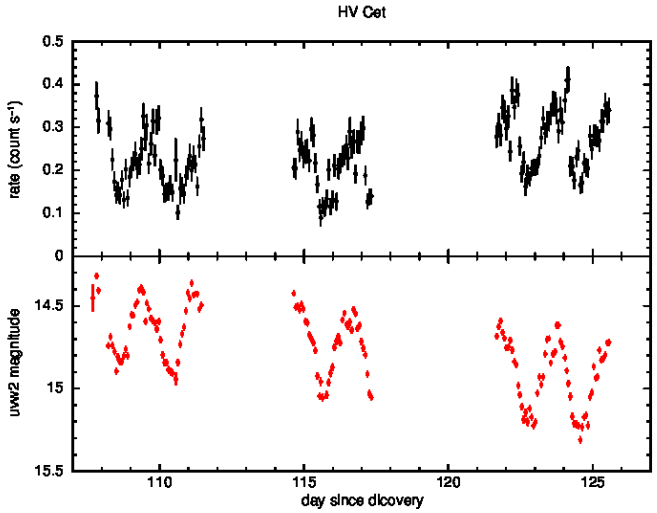
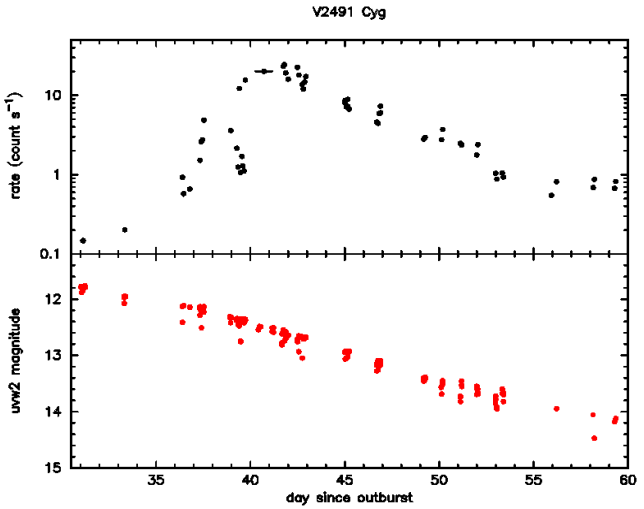
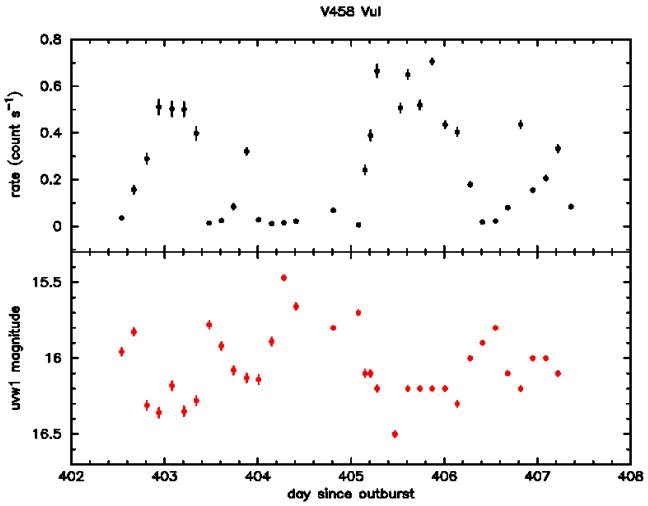
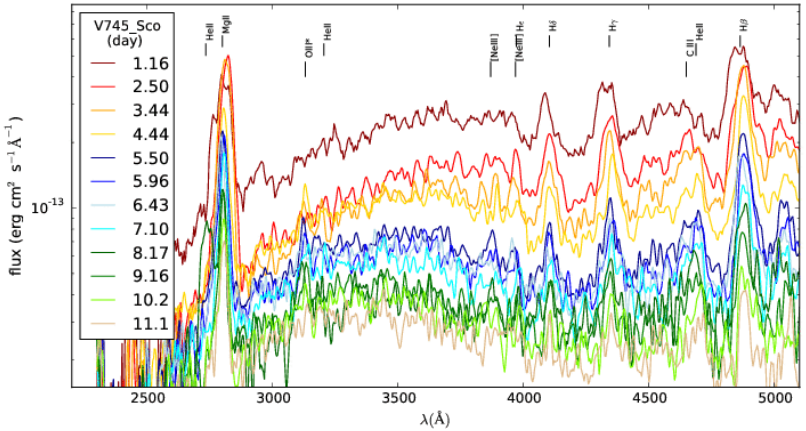
X-ray and UV Variability



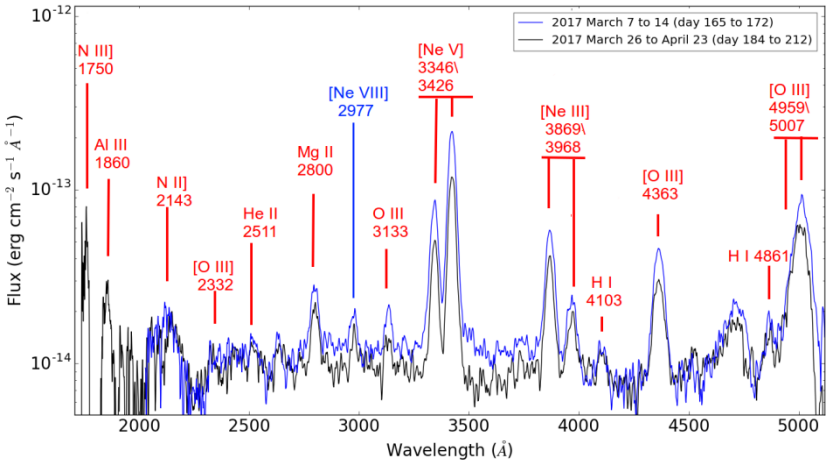




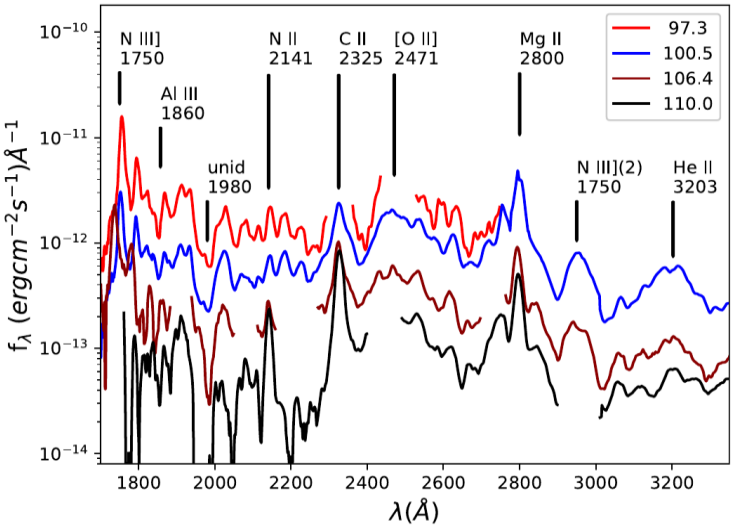
Grism spectra



V745 Sco: Page et al. (2015). Very fast RN.



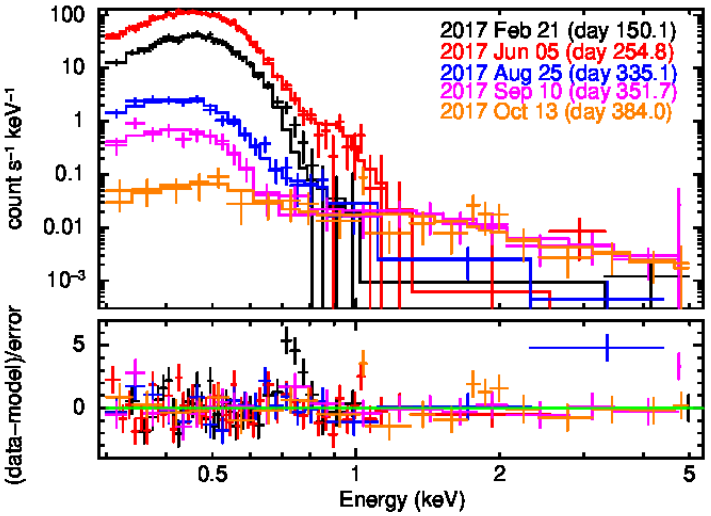
V407 Lup: Aydi et al. (2018). ONe nova; probably an IP.

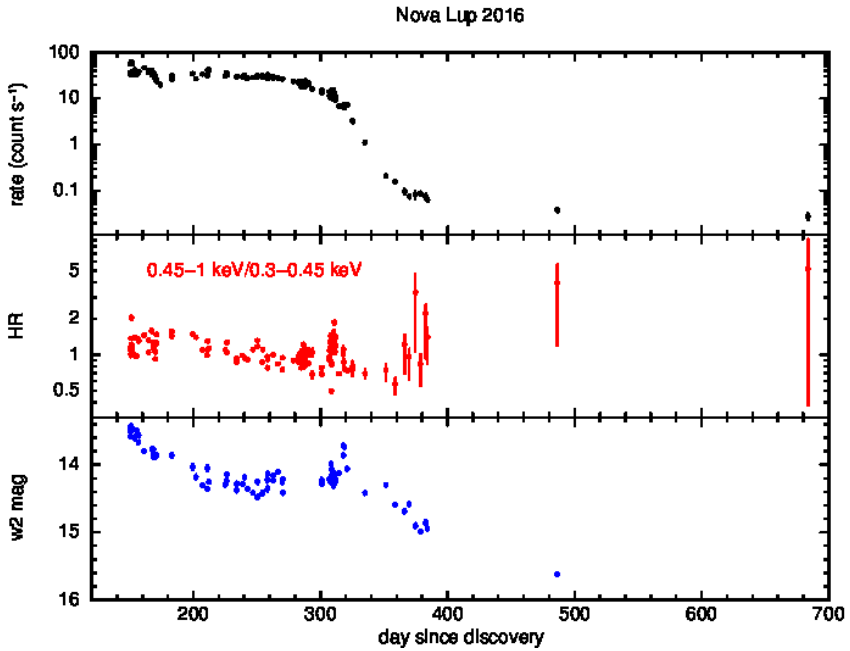


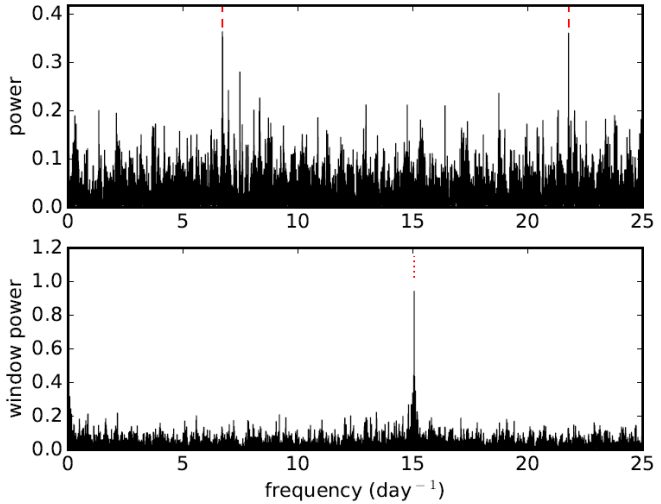
V5668 Sgr: Gehrz et al. (2018)
Dust-forming, CO nova.

Recent highlights: V407 Lup

V407 Lup (ASASSN-16kt) appears to be a nova which erupted in an intermediate polar system: there are 2 X-ray/UV periods (~565 s and 3.57 hr), which can be interpreted as the WD spin and orbital period of the binary, respectively. There is evidence for accretion restarting while the SSS is still ongoing, possibly leading to its duration being extended. See Aydi et al. (2018) for more details.

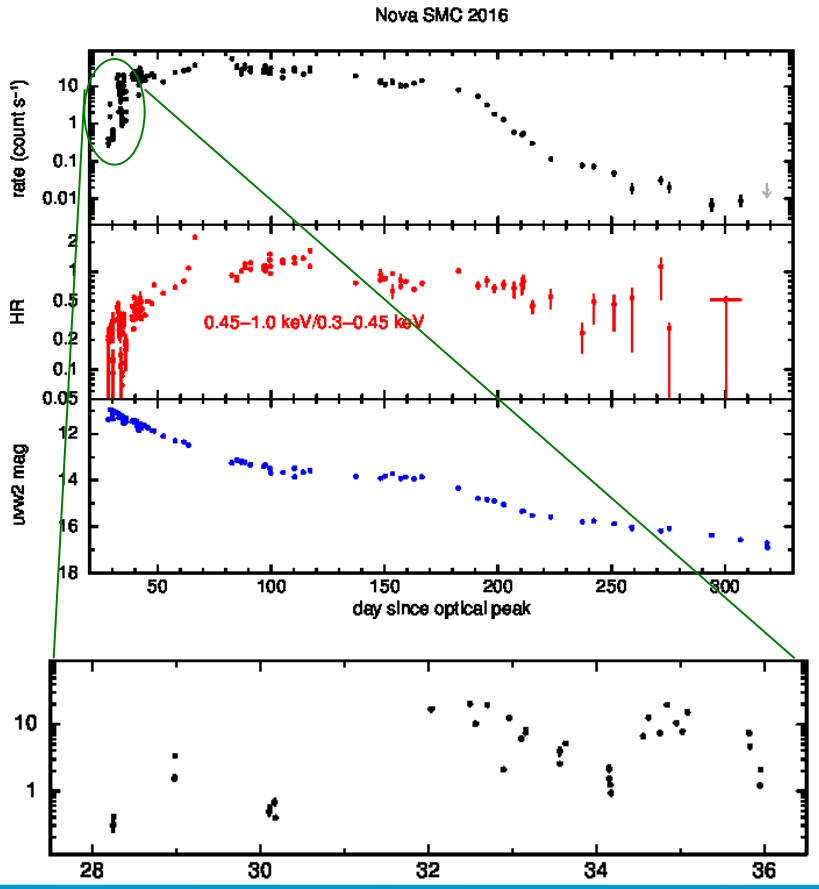


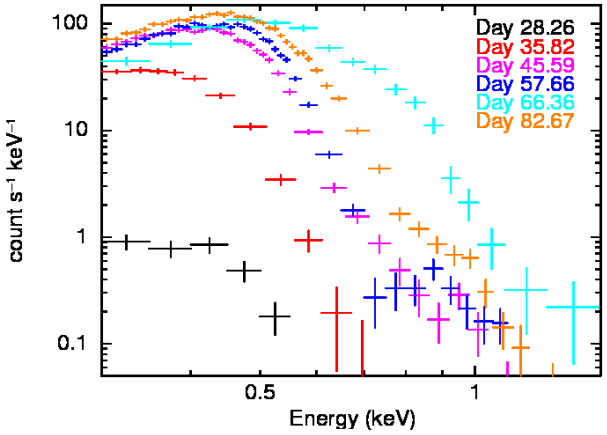


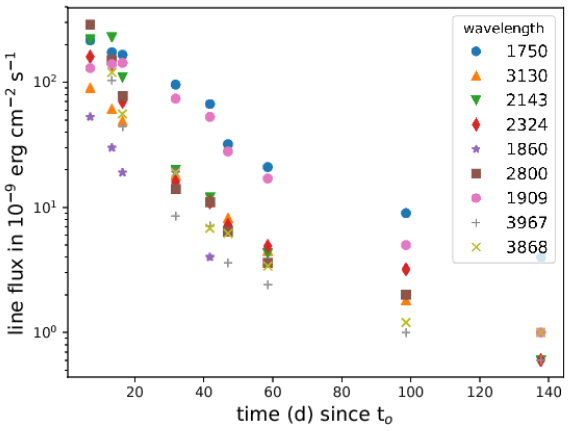


Recent highlights: Nova SMC 2016

Novae in the SMC are relatively rare (~0.9 yr^{-1}, cf 2.4 yr^{-1} for LMC; Mroz et al. 2016), with the two most recent being SMC 2016 and SMC 2012. Nova SMC 2016 was first discovered by OGLE, with Swift observations beginning about a day after discovery. While it was initially bright in the UV, the first X-ray detection wasn't until day 28. One of the brightest novae ever observed – but otherwise appears normal. See Aydi et al. (2018) for more details.







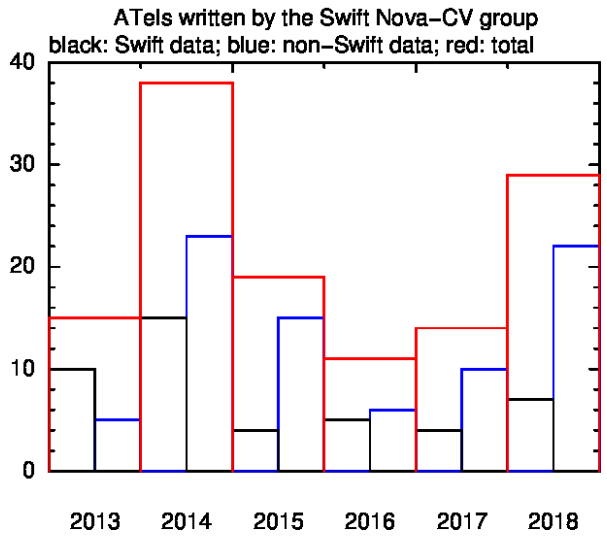
UV line ratios: different temporal development likely related to opacity. The ratios change around the time the ejecta become transparent and the SSS emission emerges.

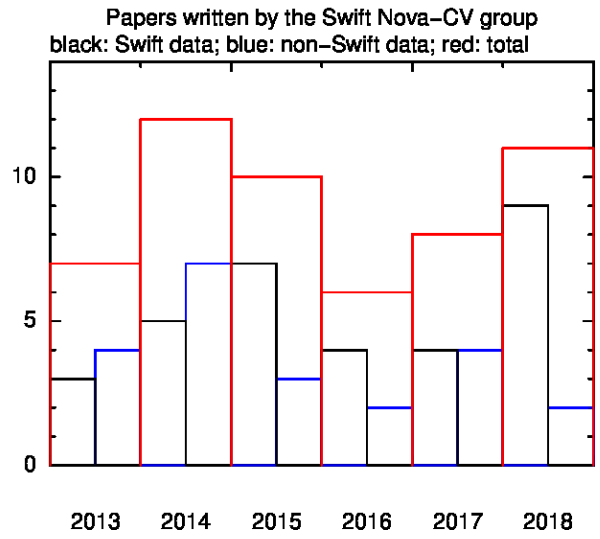
Statistics

About 90 members of the Nova-CV group.

Year	Exposure (ks)
2018	386 and counting...
2017	241
2016	330
2015	391

	Publications since 2013	
	Incl. Swift data	Not incl. Swift data
ATels	45 (8 yr^{-1})	81 (14 yr^{-1})
Papers	32 (5 yr^{-1})	22 (4 yr^{-1})





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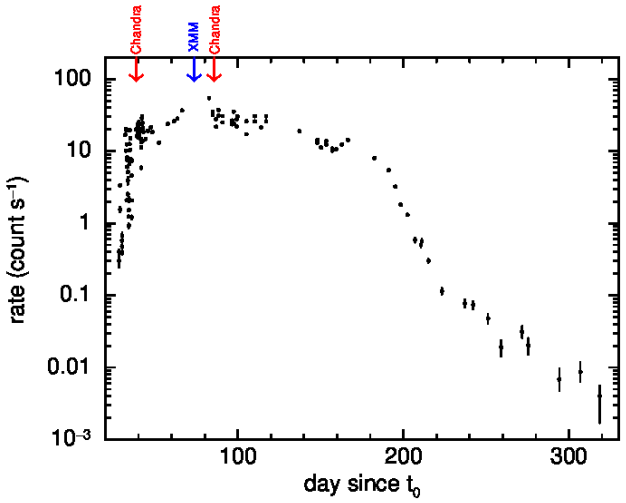
Coordination

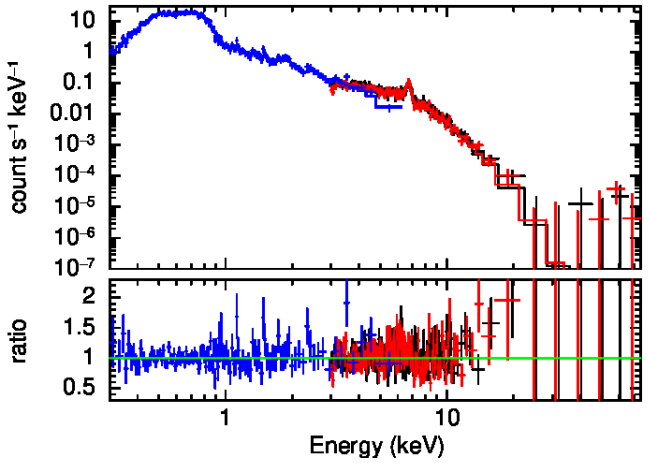


Nova SMC 2016 (Orio et al. 2018)

Swift has been used as a trigger for XMM and Chandra – ensuring the SSS is bright enough for grating observations to be useful

Orio et al. (2015) triggered NuSTAR observations of V745 Sco, finding that there was no X-ray emission > 20 keV, and the NuSTAR spectrum could not be fitted with a power-law, ruling out Comptonised gamma-rays. [At early times, this nova was weakly detected by LAT (Cheung & Jean 2014).]

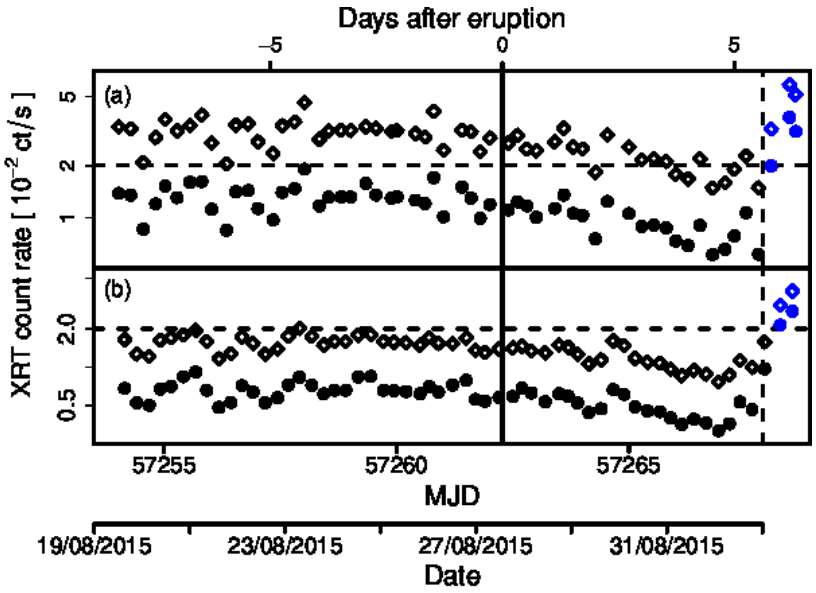
Modelling by Metzger et al. (2014) suggests that the reprocessing of early X-ray shocks by a dense external shell could contribute significantly towards the optical/UV emission in novae. Early (around optical peak) observations with Swift and NuSTAR could provide additional information about this parameter space.



V745 Sco (Orio et al. 2015)

Catching the Flash

Models of nova outbursts predict that there will be a short (0.5+ day) X-ray flash just after hydrogen ignition, but before the optical discovery; the duration of the flash would be an indicator of the WD mass and accretion rate. Problem: need to know when/where to look!
Morii et al. (2016) placed limits on 40 novae with MAXI, but the GSC energy band (2-4 keV) is too high to detect the expected SSS emission (kT < 120 eV).



Kato et al. (2016). Open diamonds: 5σ UL; filled circles: 3σ UL. Panels (a) and (b) are the individual and merged (rolling ~12 hr period) observations, respectively.
There was never more than a 10 hr gap between successive pointings.

Knowing that M31N 2008-12a has a recurrence timescale of about a year allowed us to carry out a high-cadence campaign with Swift in the 8-day run-up to the eventual 2015 outburst – but no X-ray emission was detected.

Best conclusion: the flash occurred more than 8 days before the optical discovery, probably ~15.5 days pre-discovery, due to a lower maximum nuclear burning luminosity of RRNe (despite their high mass).

Future wide-field missions such as Einstein Probe (3600 square degrees; launch date 2022) will hopefully detect such X-ray flashes, which can then be followed-up by Swift.

The next outburst of RS Oph could be any time now: it's been 12.5 years since the last, and intervals range from 9-26 years.
U Sco has a recurrence time of ~10 yr; last outburst 2010.