Spectral and temporal evolution of three recurrent novae in the X-rays during their outburst stages

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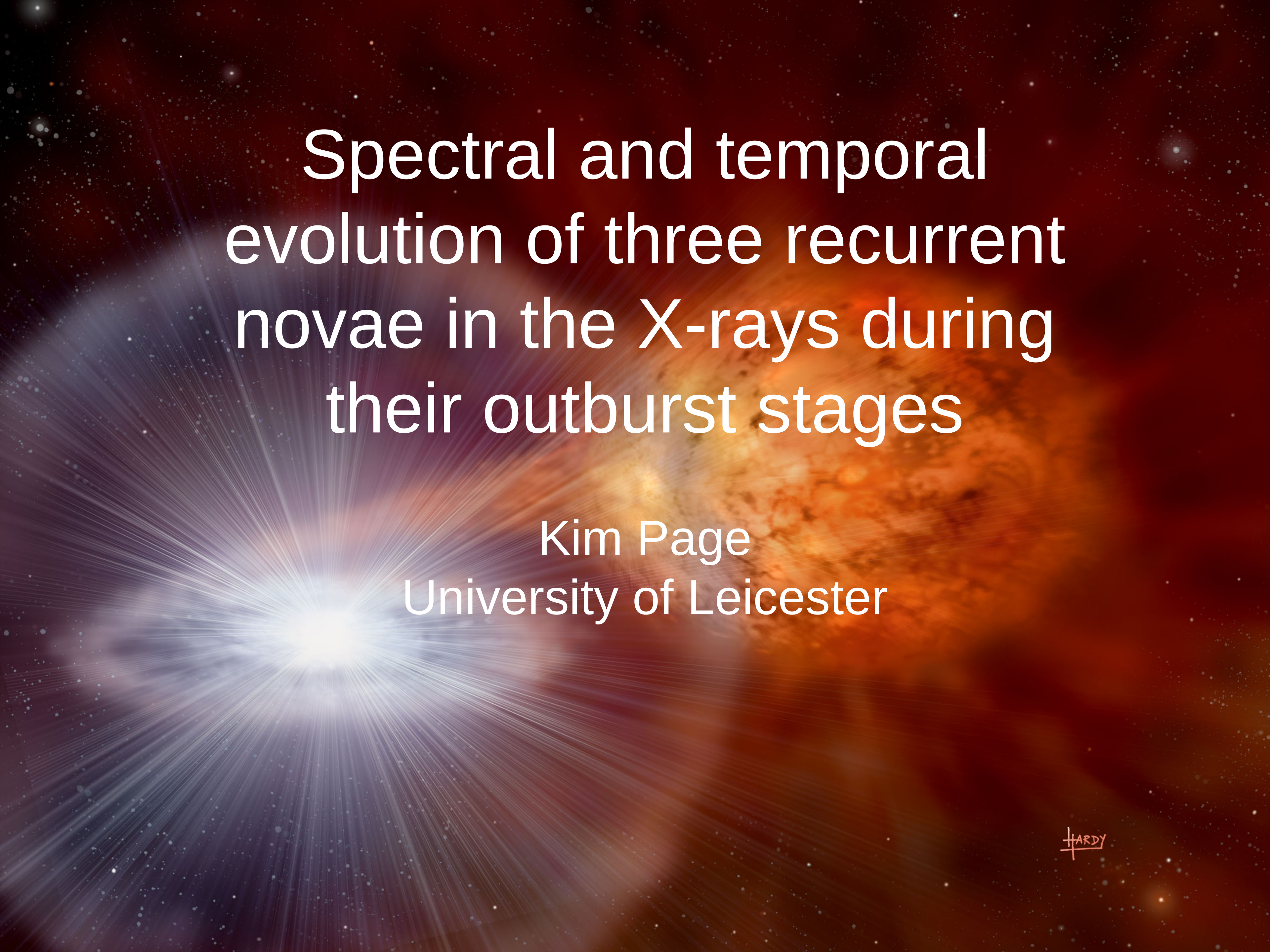
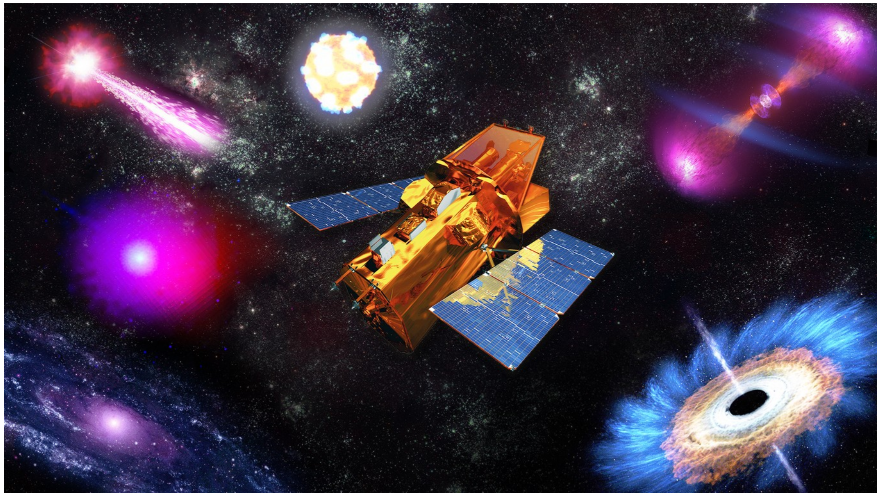


Novae

Novae are binary star systems, comprising a white dwarf which accretes H-rich material from a companion star, until the temperature and pressure are sufficient for a thermonuclear runaway to occur. At this point, material is flung outwards, obscuring the white dwarf surface. A new optical source is typically seen at this point, with the peak brightness occurring at the maximum expansion of the photosphere. As the ejecta become optically-thin, the nuclear burning on the WD surface (usually) becomes visible, and we see the super-soft source emission.



Credit: NASA/GSFC

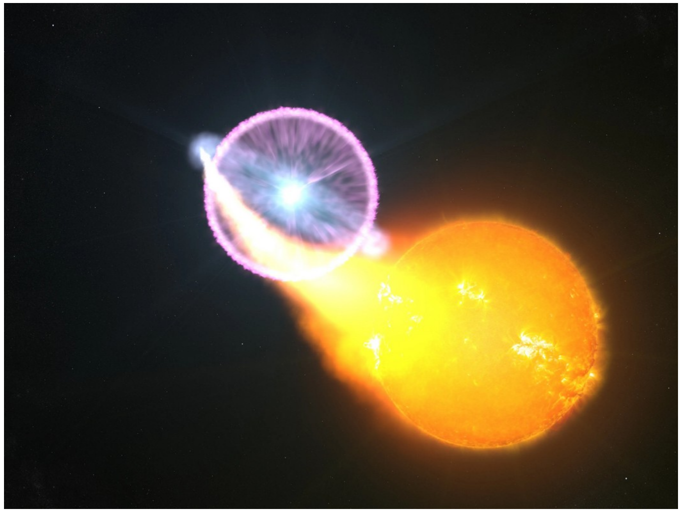
The Neil Gehrels Swift Observatory has been observing novae for almost 20 years, and has followed many through complete eruption cycles – and, as this talk will describe, sometimes through more than one!

Nova Populations

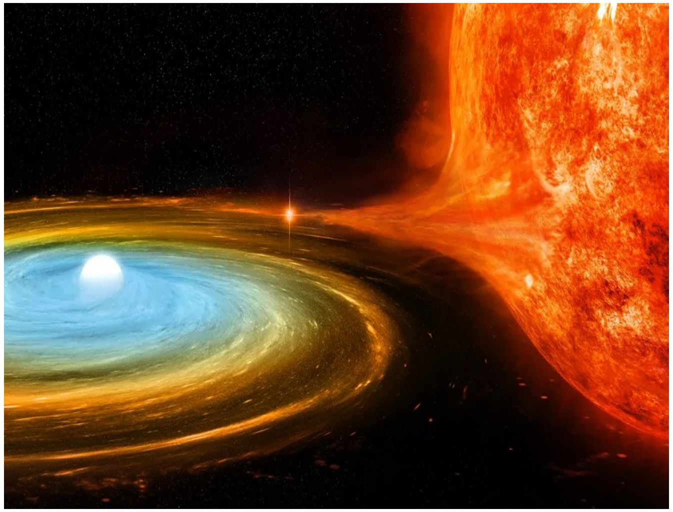
There are two main groups of novae: classical and recurrent.

Classical novae have only been seen in eruption once - though are expected to re-erupt on timescales of 1000s of years.

Recurrent novae have had at least 2 detected eruptions, so have recurrence times of up to ~100 yr (something of a selection effect, dependent on historical records).



Credit: NASA GSFC/S. Wiessinger

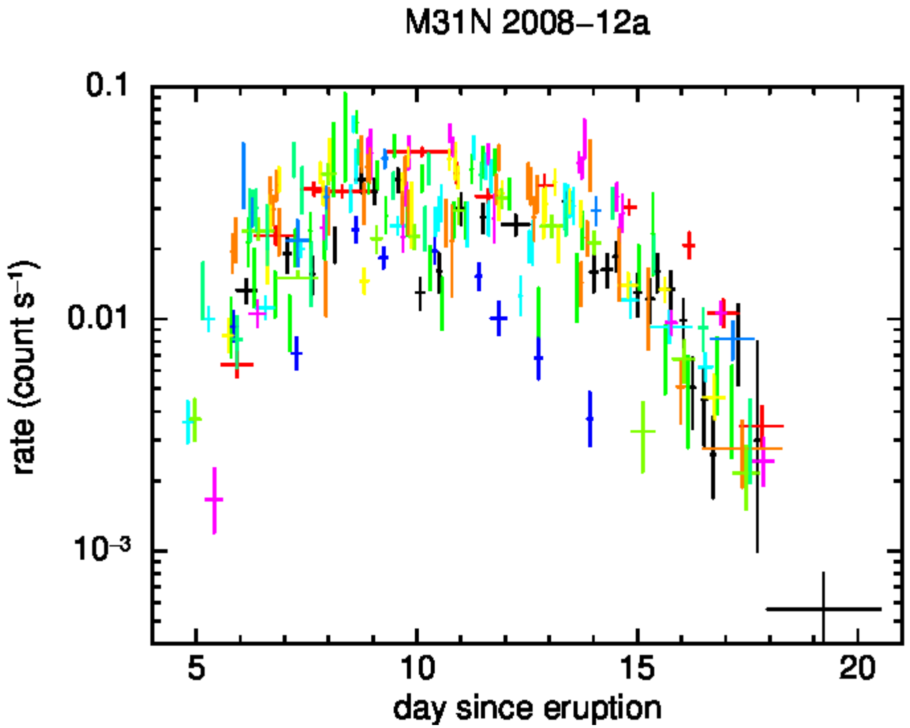


Credit: M. Weiss, CXC/NASA

Recurrent Novae

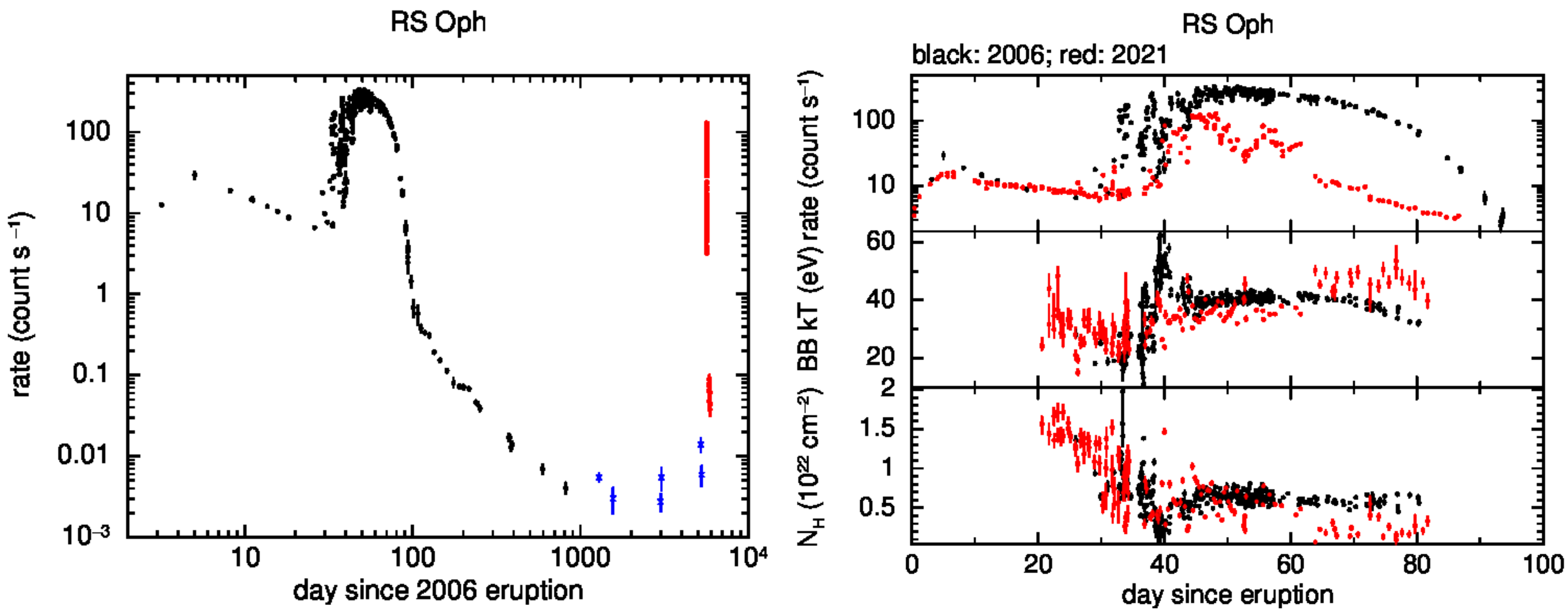
Swift has observed many novae, both classical and recurrent. Of the recurrent novae in the Milky Way or Magellanic Clouds, we have observed three during two separate eruptions, and those are the topic of this talk.

We've also observed M31N 2008-12a during every yearly eruption since 2013 – but that would be a complete talk on its own!



See, e.g., Henze et al., 2018, ApJ, 857, 68 (and references therein).

RS Ophiuchi: 2006 & 2021

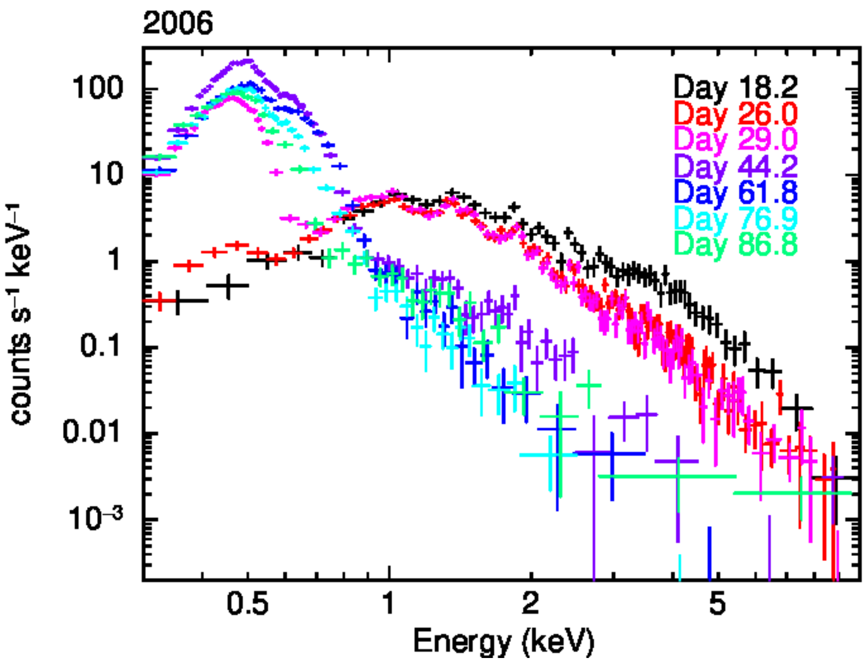


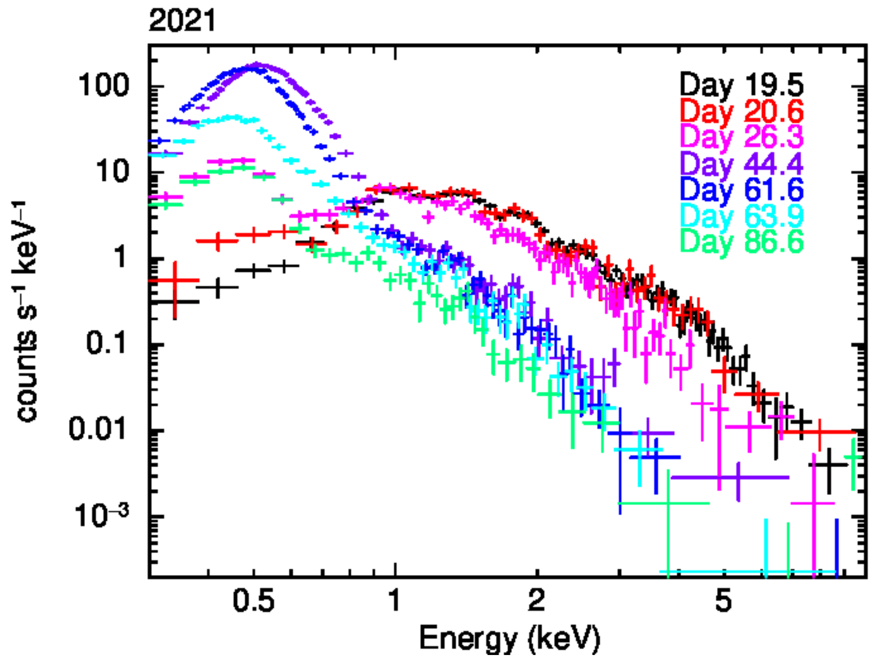
Fit details:

- Galactic N_H (2.4×10^{21} cm^{-2}) plus excess (plotted)
- Fitting 0.3-10 keV, with BB for SSS, and two optically-thin APEC components for shock emission.

Throughout, spectra from https://www.swift.ac.uk/user_objects/ have been used.

RS Oph Spectra





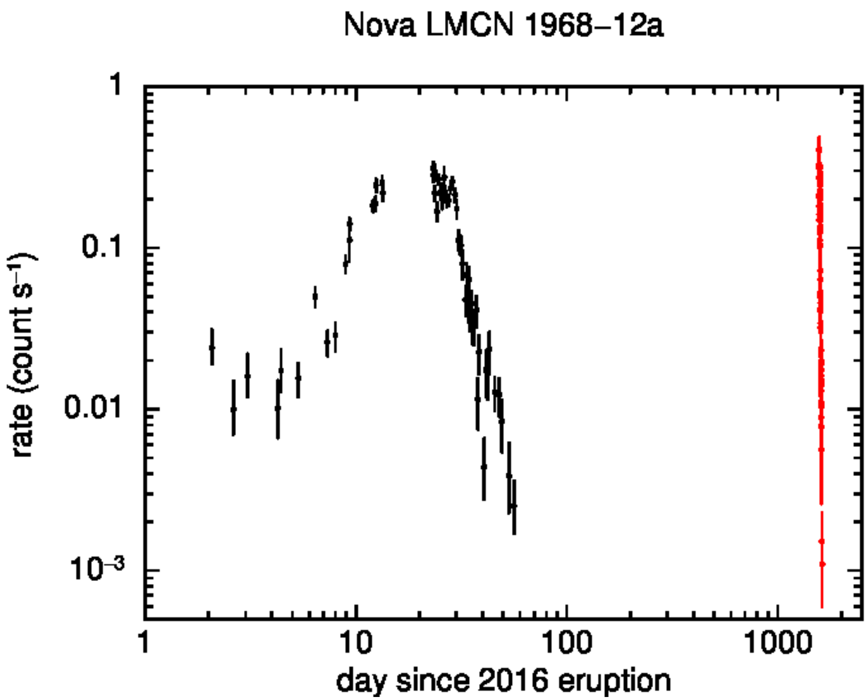
RS Oph Results

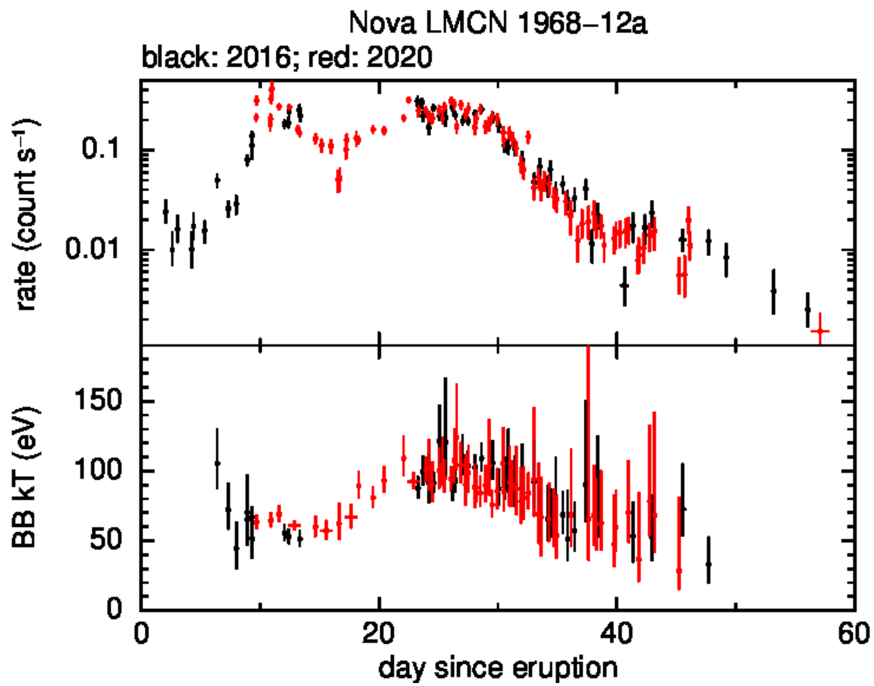
- 7 recorded nova eruptions, another 2 inferred.
- The last 2 eruption periods were 21 and 15.5 yr.
- The soft X-rays were much brighter in 2006.
- The 2006 spectra show stronger evidence for superimposed ionized absorption edges, while the 2021 data appear featureless.
- After around day 60 post eruption, the 2021 X-ray emission appears hottter.

While assuming a basic, neutral absorption model applied to our Swift-XRT CCD data does not appear to explain why the X-rays appeared fainter in 2021, using high-resolution spectra from XMM and Chandra suggests a combination of cold (neutral) and hot (ionized) absorption may be able to explain the differences seen.

See also:
Osborne et al., 2011, ApJ, 727, 124
Page et al., 2022, MNRAS, 514, 1557
Ness et al., 2023, A&A, 670, A131

Nova LMC 1968: 2016 & 2020

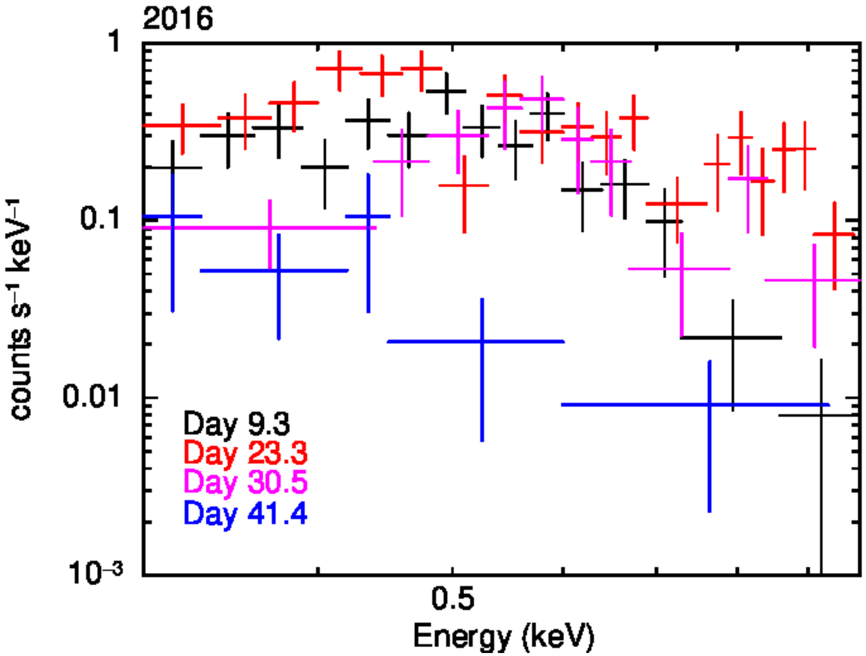


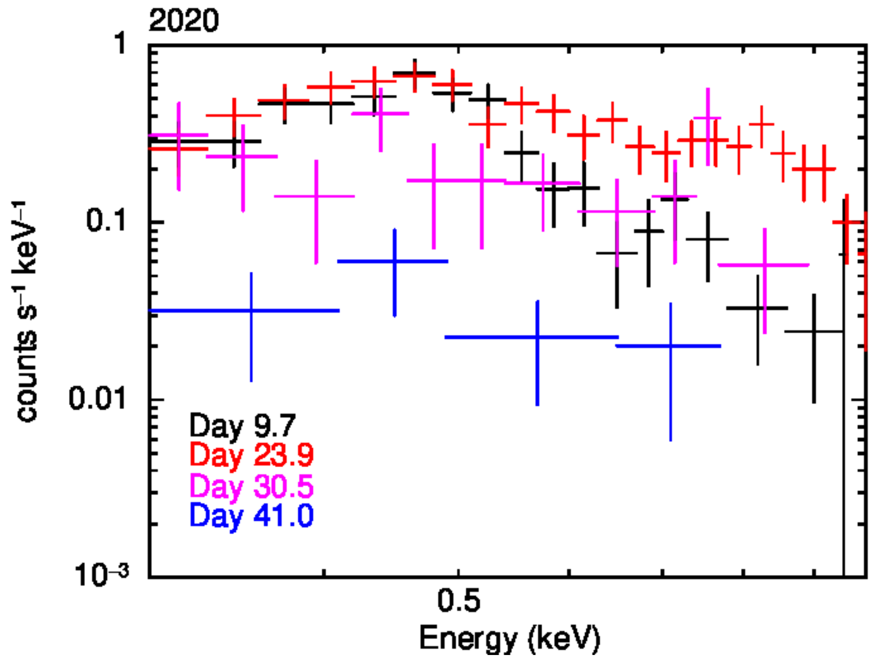


Fit details:

- Galactic N_H (1.78×10^{21} cm^{-2}); no excess required.
- Fitting BB over 0.3-1 keV, since very few counts at higher energies.

Nova LMC 1968 Spectra



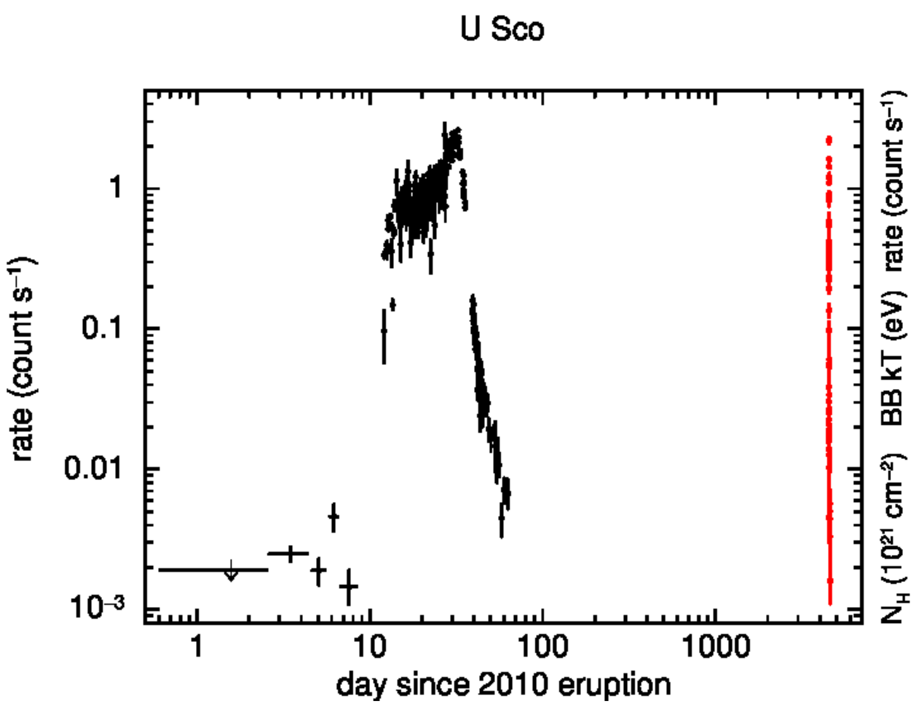


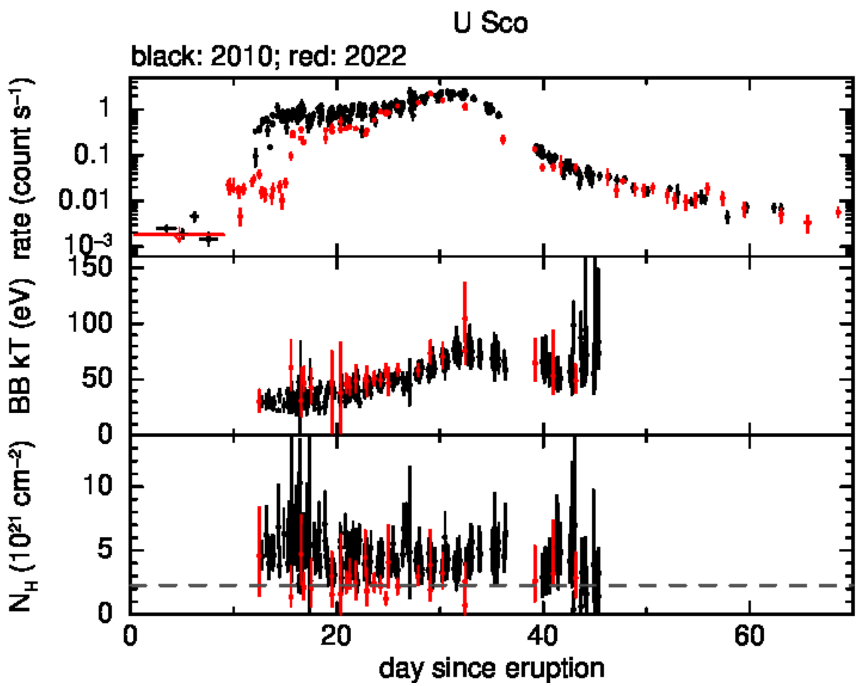
Nova LMC 1968 Results

- 6 known nova eruptions.
- Last 2 eruption intervals were 5.2 yr and 4.3 yr. Next one soon??
- Light-curves basically identical where they overlap in time.
- The spectral fits also appear remarkably similar, with BB temperatures following the same trends.
- This suggests that the conditions (eg amount of material on WD post-eruption) were the same.

See also:
Kuin et al., 2020, MNRAS, 491, 655
Schwarz, Page, Kuin & Darnley, 2020, RNAAS, 4, 142

U Scorpii: 2010 & 2022



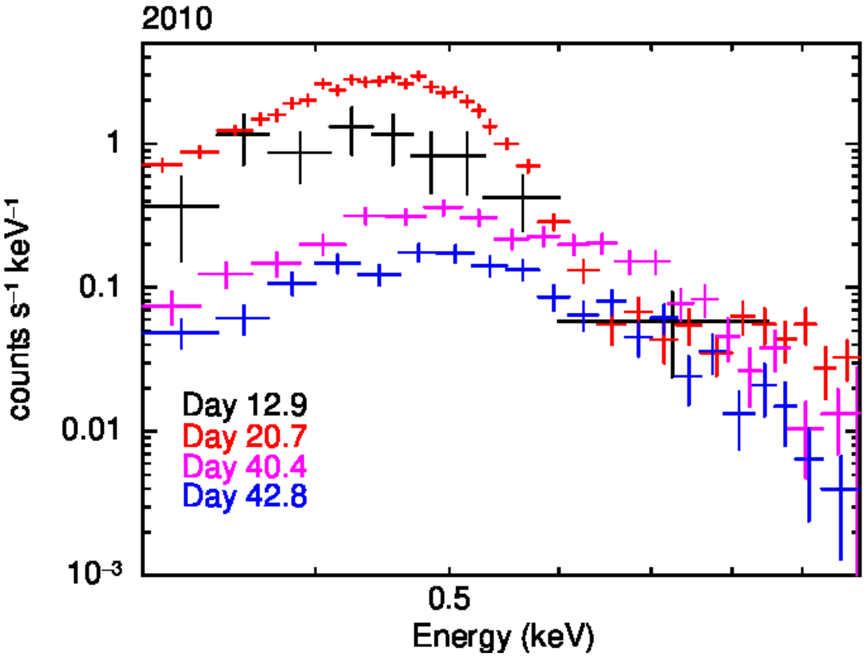


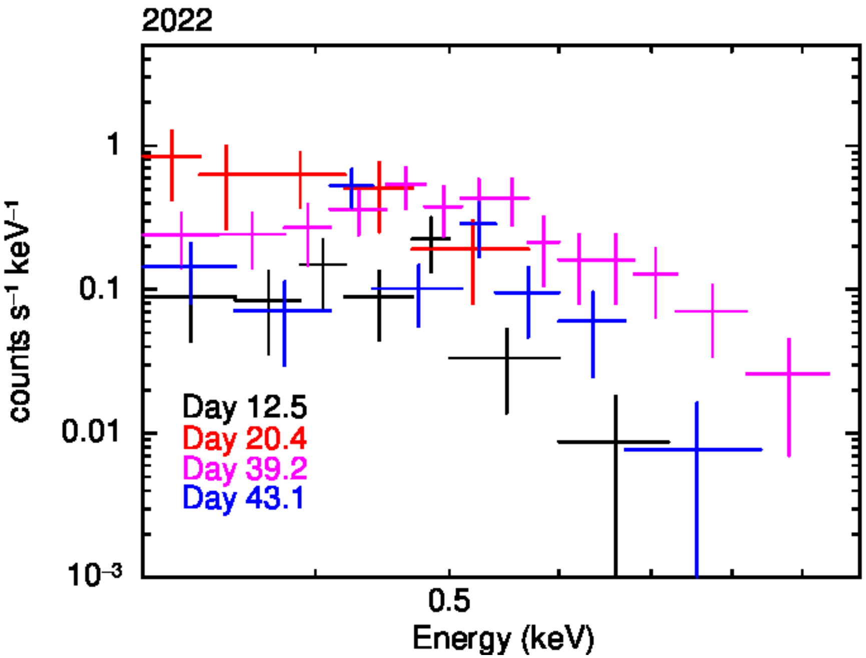
Fit details:

Free N_H; Galactic value (2.28×10^{21} cm^{-2}) shown as dashed line.

Fitting BB over 0.3-1 keV, since very few counts at higher energies.

U Sco Spectra





U Sco Results

- 11 known nova eruptions
- Last 2 eruption intervals were 10.9 yr and 12.3 yr.
- 2022 eruption was slower to rise to peak SSS, though peaked earlier, with the SSS fading away sooner – so a shorter, less luminous SSS duration.
- The peak count rate is approximately the same both times, though, as are the BB temperatures.

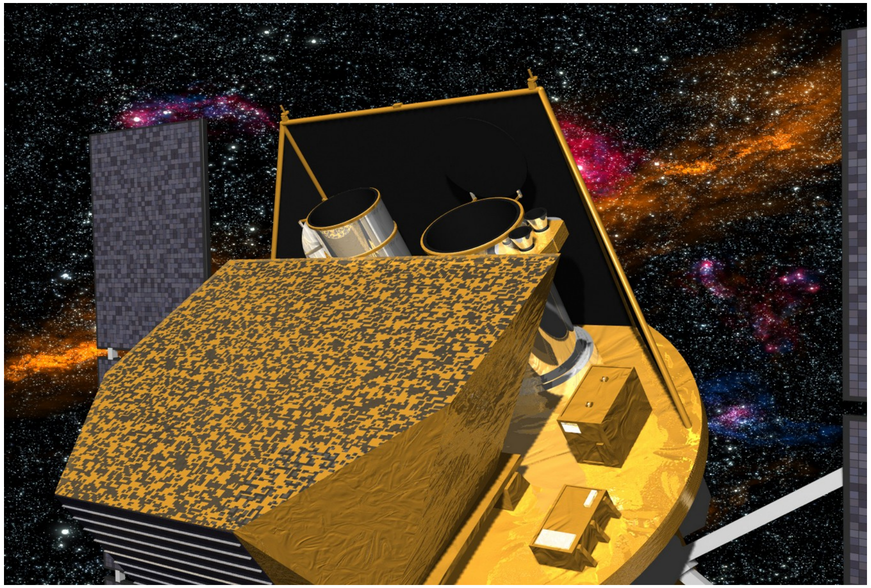
See also:
Ness et al., 2012, ApJ, 745, 43
Pagnotta et al., 2015, ApJ, 811, 32
Evans et al., 2023, MNRAS, 522, 4841

A comparison between the XRT light-curves has also been presented in Muraoka et al., 2024, PASJ, 76, 293

Summary

Being able to monitor any given nova through multiple eruptions using the same instruments is extremely helpful, since it avoids cross-calibration uncertainties.

Fingers crossed that Swift will keep going for many years to come, allowing us to expand this sample!



Credit: NASA/GSFC Conceptual Image Lab.