

Nova Observing Plan and Strategy Report

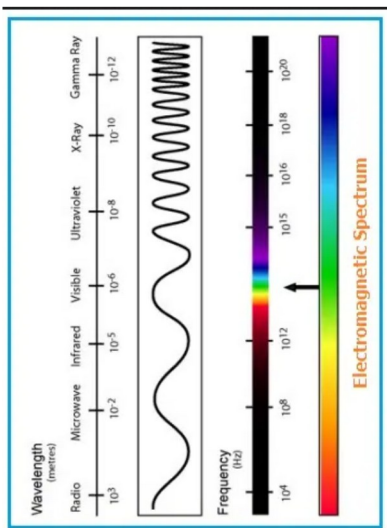
Kim Page (UL) & Elias Aydi (TTU)

HARDY

Nova Timescales

The different phases of nova evolution cover a wide range of timescales:

1. Fireball phase: up to ~0.5 d
2. Optical rise: hours to hundreds of days
3. VHE (TeV) emission: early, lasted for a few days in RS Oph.
4. GeV gamma-rays: may start immediately, or with a delay of days-weeks; can last for up to 10s of days. Tends to coincide with peak visible brightness.
(Neutrinos? Likely at these early times if so. None yet detected.)
- 5a. >10 keV X-rays: can be detected simultaneously with GeV emission
- b. 1-10 keV X-rays: starting within hours for external shocks in recurrent/symbiotic novae with giant companions; days to weeks if shocks are internal to ejecta. Can last for years.
- c. <0.5-1 keV (super-soft) X-rays: starting days to months after eruption; can last for years. Start may be highly variable.
6. UV/optical: can last for years
7. IR: typically starts days to months; may indicate dust formation
8. Radio: non-thermal (shock) peak after a few weeks; later thermal emission may last for months



Triggering Criteria

Estimated nova rate in MW is $\sim 50 +31/-23$ (Shafter 2017) – but only ~ 10 actually observed (obscuration/absorption).

Ten known recurrent novae in MW, with recurrence timescales of 10-100 yr.

Outside our Galaxy, there are many other known novae (including some speedy recurrences: M31N 2008-12a repeats yearly).

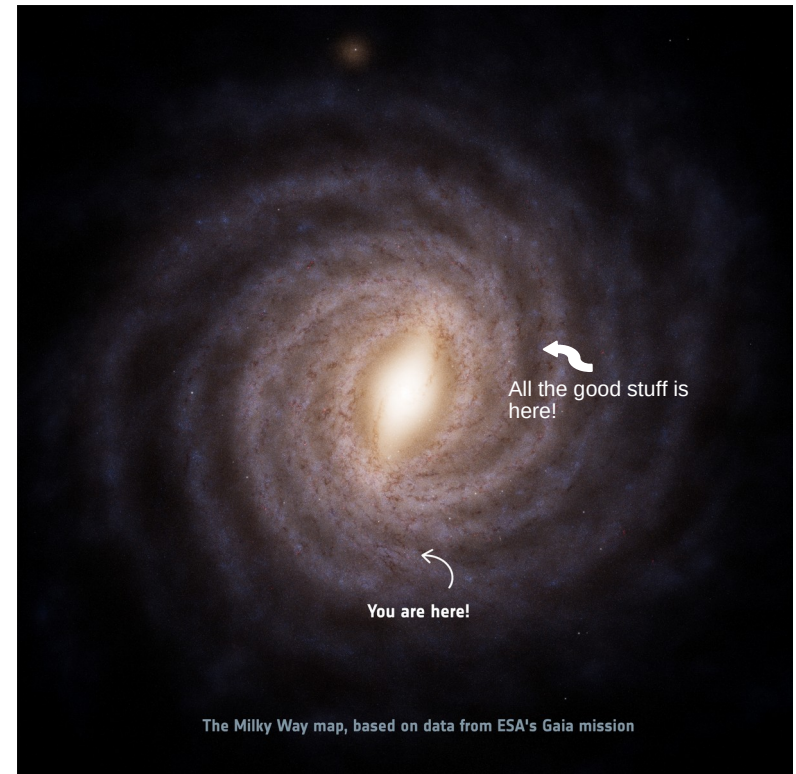
Should be a **fast nova**, otherwise we don't need these proactive plans!

Bright: $V < 5-6$?

Fermi LAT (GeV) detection

Galactic (though not in the plane of our Galaxy, to avoid excess N_H)

Good Sun angle – so easily observable, and for an extended period. (Not doing well with this right now! V462 Lup was detected as a SSS the day before entering Sun constraint; V1935 Cen brightened dramatically just 1 week before Sun constraint.)

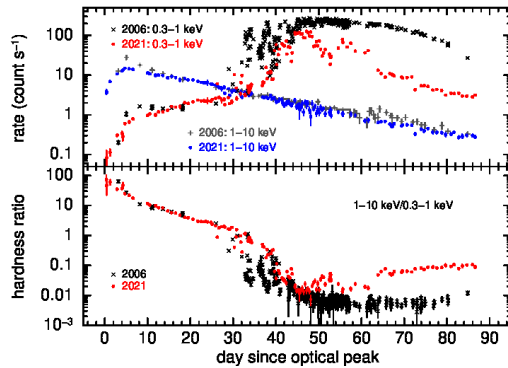


The Milky Way map, based on data from ESA's Gaia mission

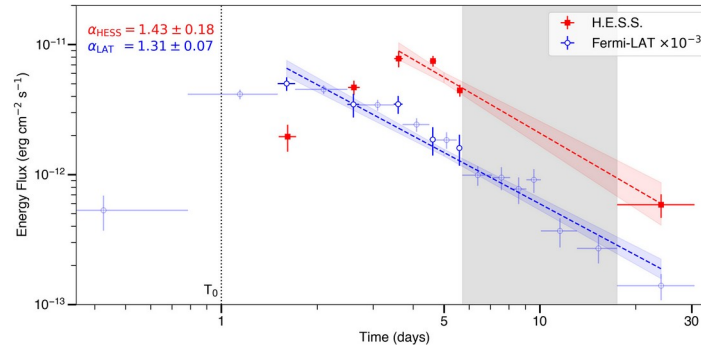
Credit (before edit!): ESA/Gaia/DPAC, Stefan Payne-Wardenaar

RS Oph (2021) as a Case Study

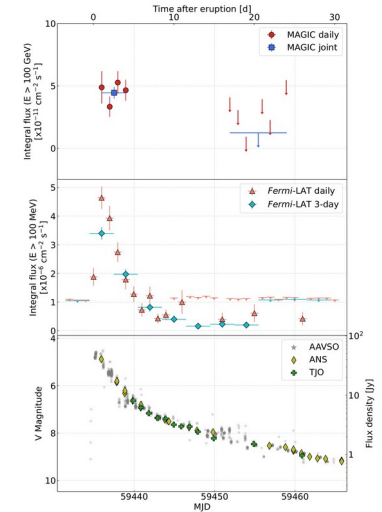
RS Ophiuchi is a recurrent nova, which erupts every 15-20 yr, most recently in 2021.



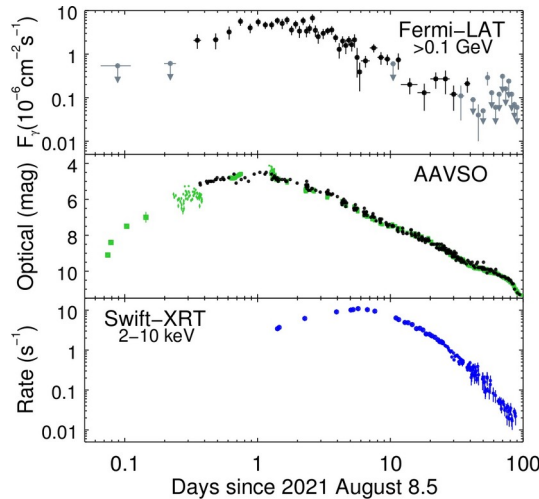
Page et al., 2021, MNRAS, 514, 1557



H.E.S.S. Collaboration et al., 2022, Science, 376, 77

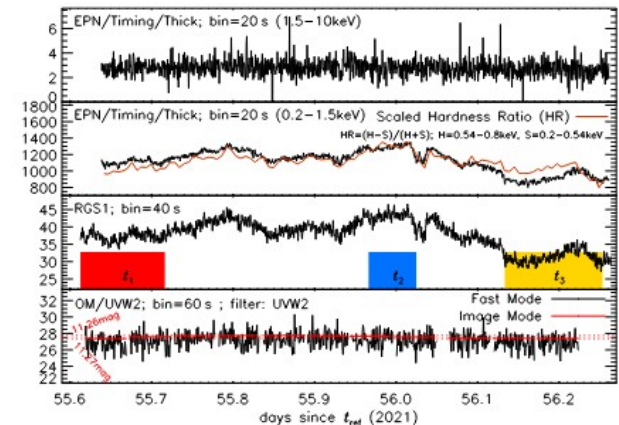


MAGIC Collaboration et al., 2022, Nat Astron, 6, 689



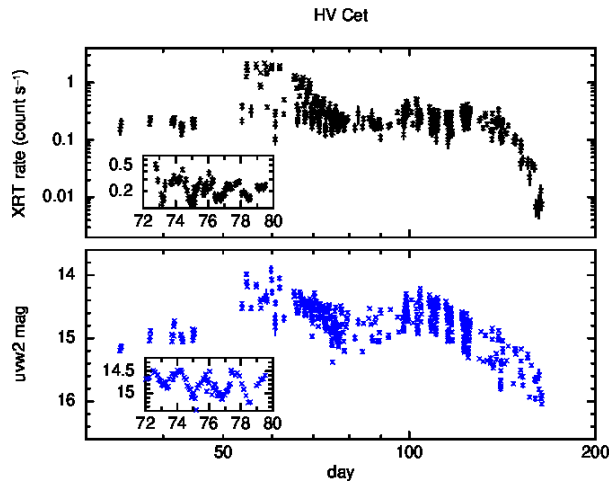
Cheung et al., 2022, ApJ, 935, 44

Even without official “pre-approved” observing plans, RS Oph was well followed-up. With Swift we were on target 1.3 d after the initial discovery – not our speediest ever response, though! (ToO was submitted on a Sunday night.)

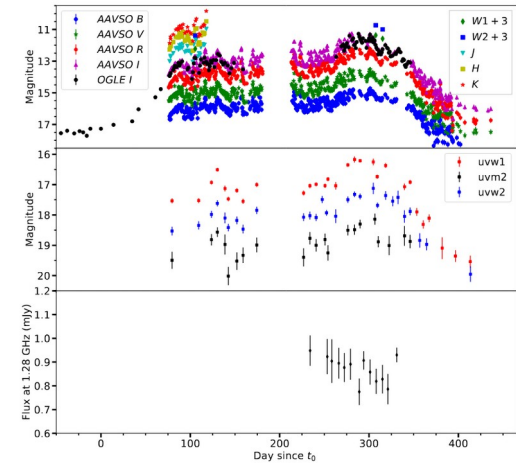
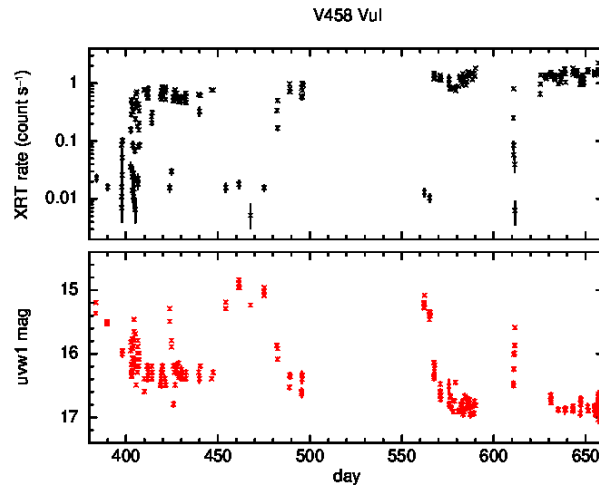


Ness et al., 2023, A&A, 670, A131

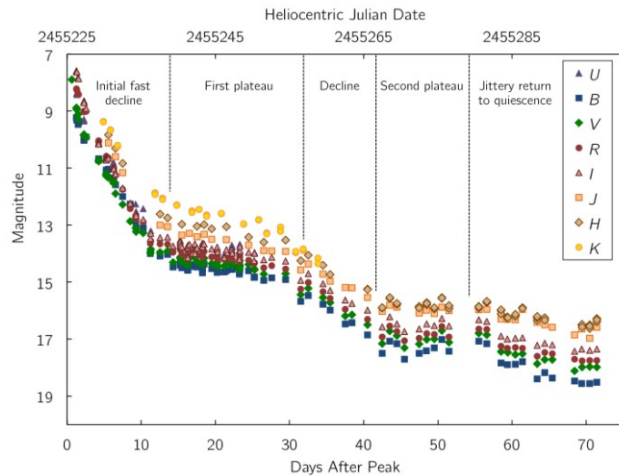
All the light-curves...



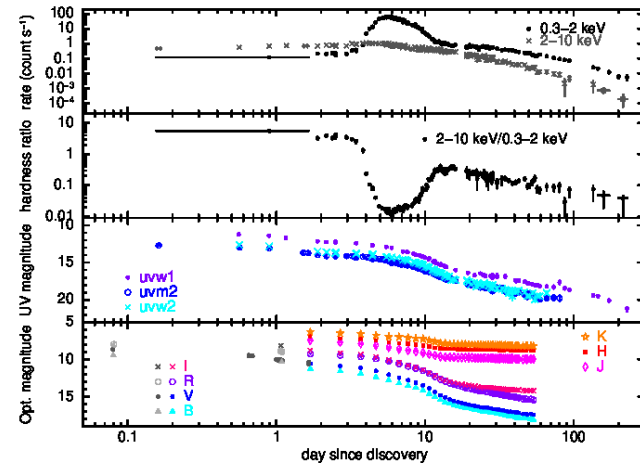
Page, Kuin & Osborne, 2022, Universe, 8, 643



V1047 Cen: Aydi et al., 2022, ApJ, 939, 6



U Sco: Pagnotta et al., 2015, ApJ, 811, 32



V745 Sco: Page et al., 2015, MNRAS, 454, 3108

Which Observatories?

Since (bright) novae are detectable across the EM spectrum (and potentially beyond...), there is a long list of observatories which could provide useful data, from imaging to spectroscopy.

VHE	H.E.S.S., MAGIC, VERITAS
GeV	Fermi-LAT
Hard X-rays	NuSTAR, potentially Swift (BAT survey mode)
X-rays	Swift, NICER (?), EP, XMM-Newton, Chandra
UV	Swift, HST
Optical	Swift, HST, CHARA, VLT/VLTI, Gemini
IR (near/mid)	JWST, VLT/VLTI, Gemini
Radio	VLA, VLBA, e-MERLIN, LOFAR, MeerKAT, SKA
Neutrinos	IceCube and KM3NeT
Any others?	

Recommended Observing Timelines

T0 +0-1 hr	Optical imaging from ground; serendipitous X-rays from all-sky monitoring (maybe even the fireball flash before T0!)
T0 +1-24 hr	X-ray/UV/optical observations (as many as possible!), including with interferometers (e.g., CHARA). Check for neutrinos!
T0 +1-7 days	Multi-epoch coverage (at least daily) from VHE to radio
T0 + weeks-months	Monitor ejecta and SSS emission (multiple times per day when SSS starts); continue until quiescence. High-res imaging with HST and JWST years after eruption.



Observations and Policy Recommendations

Space-based

Swift should monitor the UV and X-rays throughout the evolution (if possible starting within a few hours of eruption), with high-cadence observations during the (hopefully) variable switch-on of the SSS phase.

UV grism exposures at least 2x a week during this time.

NICER, XMM-Newton, Chandra: frequent spectroscopy (RGS, LETG during the SSS specifically) to follow changing line emission and abundances.

Longer, continuous observations will help constrain QPOs (short snapshots can lead to apparent period drift) during SSS.

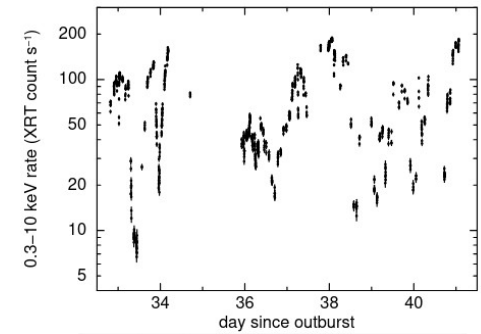
JWST if at all possible! (very few high priority triggers)

Ground-based

High resolution ($R > 2000$) IR (0.7-5 micron) daily for first 2-3 weeks; then decrease cadence to weekly.

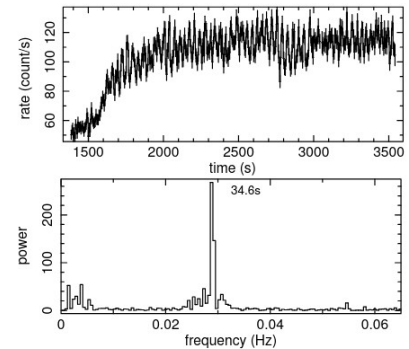
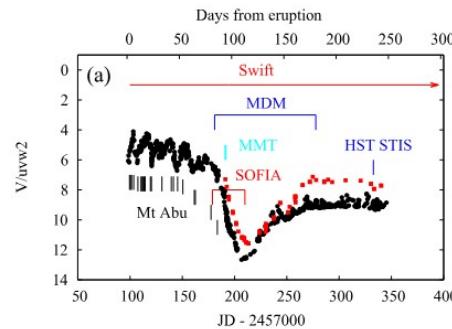
JHK (and LMN?) photometry at least daily early on.

Policy: bump up merit of Swift observations to at least 88 (90+ if coordinated)



What would we like to learn?

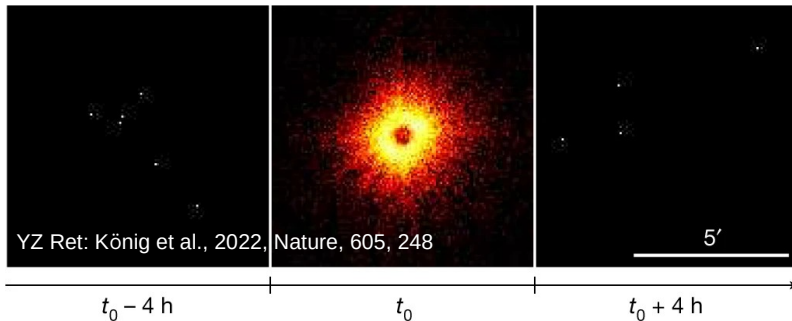
- How do novae eject their envelopes?
- How and where does dust form in novae?
- What determines the shock energetics?
- Are novae multi-messenger sources?



V5668 Sgr: Gehrz et al., 2018, ApJ, 858, 78 RS Oph: Beardmore et al., 2008, ASPC, 401, 296

- SSS phase: can we place good constraints on WD mass, burning efficiency, post-eruption accretion? Do we expect RNe to become SN Ia progenitors?
- Are QPOs due to WD rotation?

If we're really lucky, before this we might catch the early X-ray/UV fireball emission, and hence obtain a unique insight into the immediate aftermath of the TNR.



Each nova eruption – especially the nearby events, such as the hotly anticipated T CrB – is a rich laboratory, with implications extending across stellar and extragalactic astrophysics.

Will T CrB play ball?! 