Fermi-LAT and Swift-XRT Observations of Nova Her 2021

The Transient and Variable Universe 2023 Conference,
University of Illinois Urbana-Champaign
June 21st, 2023

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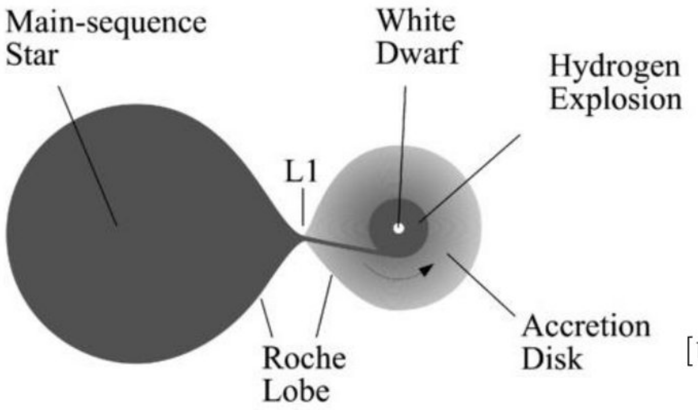
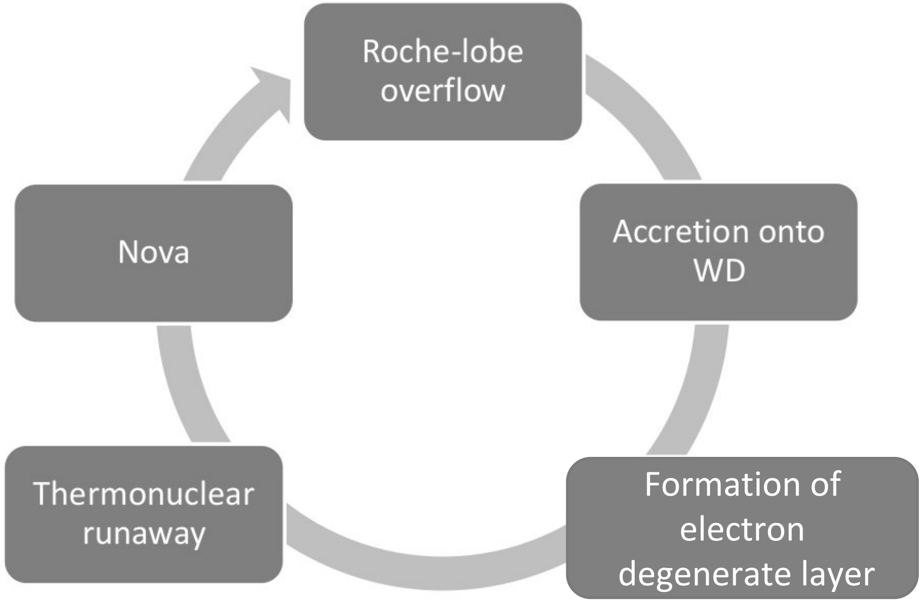
Classical novae

- Thermonuclear explosions on the surface of WD in a close binary system
- Not self-destructive
- Can be recurrent



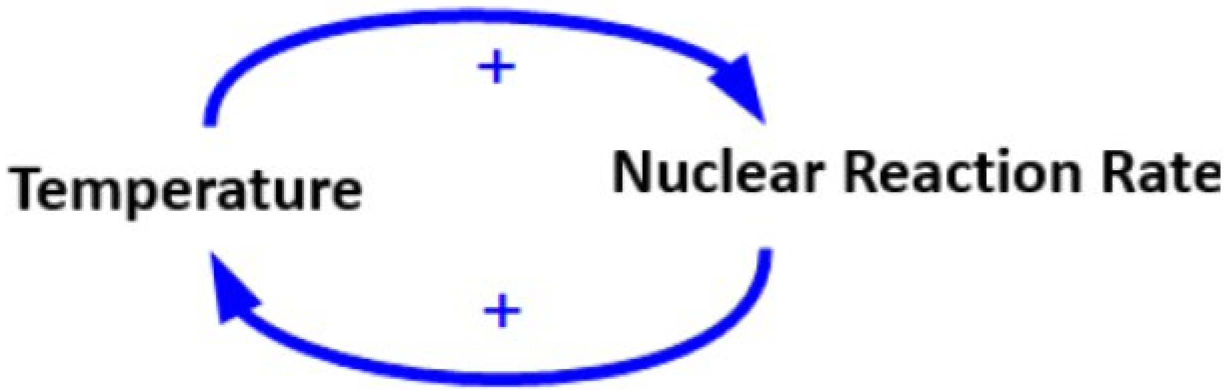
[1]



Classical novae

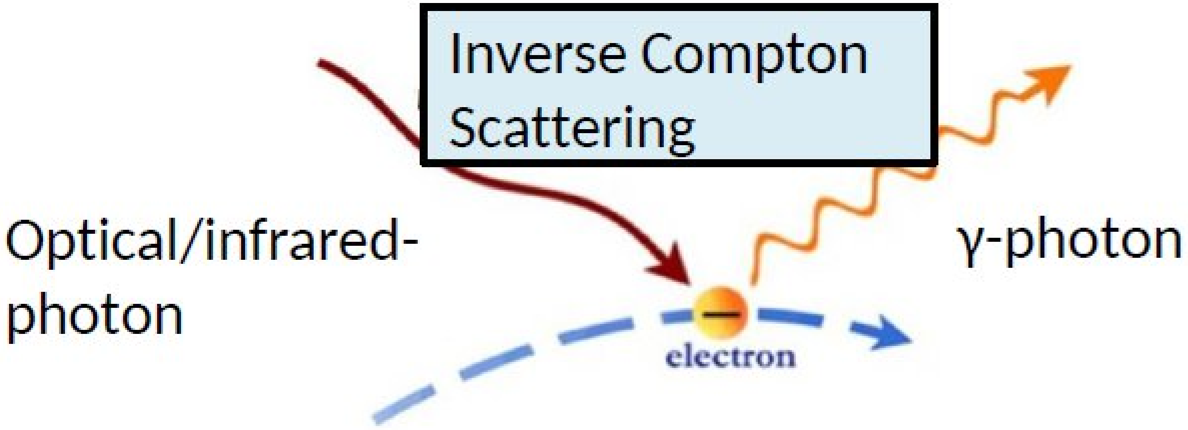
- Temperature independent degenerate gas pressure : $P = K\rho^{5/3}$
- Energy from the nuclear reaction increases temperature
- Nuclear reaction rate is also highly sensitive to temperature changes

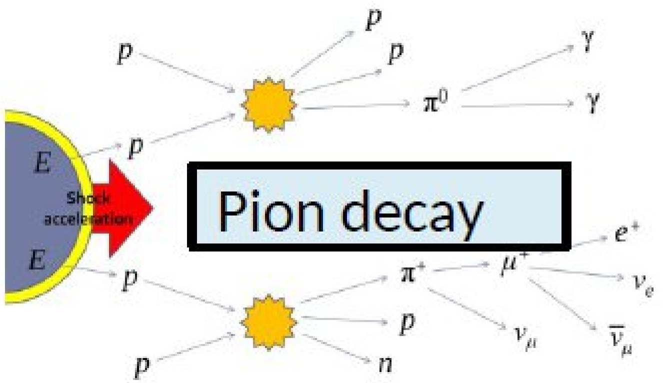
$$q \propto \rho T^{16}$$



Classical novae

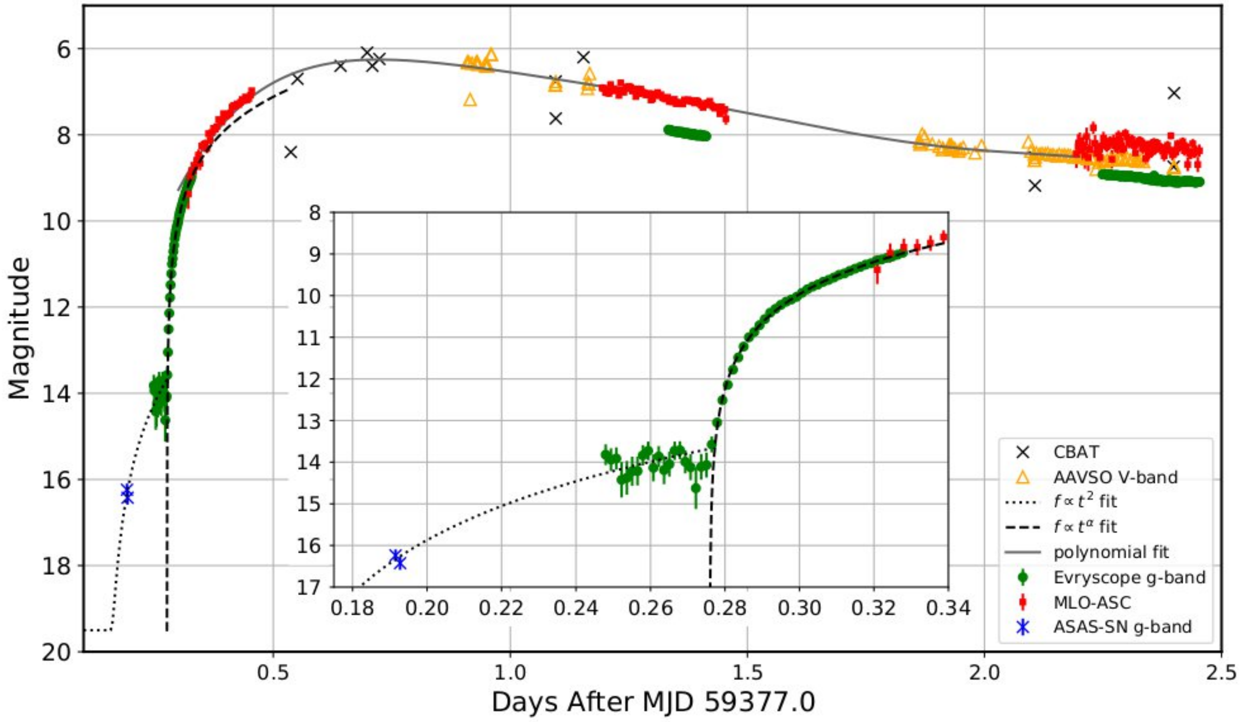
- Matter ejected at supersonic speeds
  - Internal/external shocks
- Particles accelerated via diffusive shock acceleration (DSA) at shock fronts
- DSA - First order (v/c) Fermi acceleration
  - Power law energy spectrum
- Gamma-ray emission:





Nova Her 2021 (V1674 Her)

- Discovered at magnitude of 8.4 on 12 June 2021 by Seiji Ueda, Japan [2]
- Pre-maximum plateau

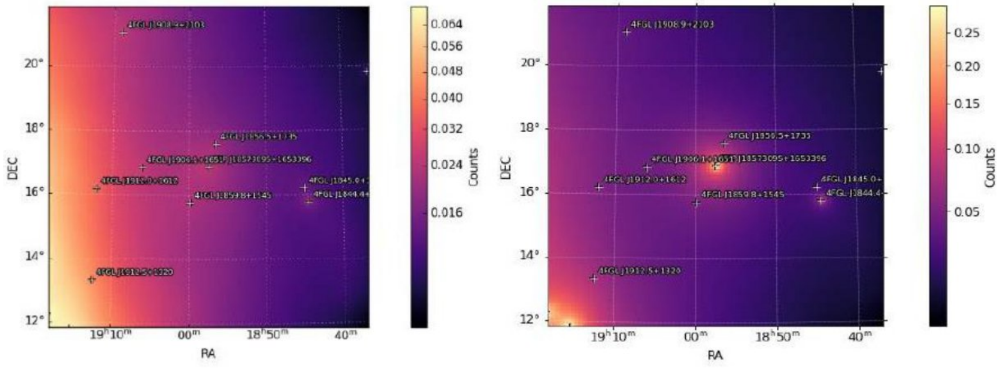


Quimby et al. (2021)

Nova Her 2021 (V1674 Her)

- Fermi-LAT detection on 12 June
- TS value: 30.6

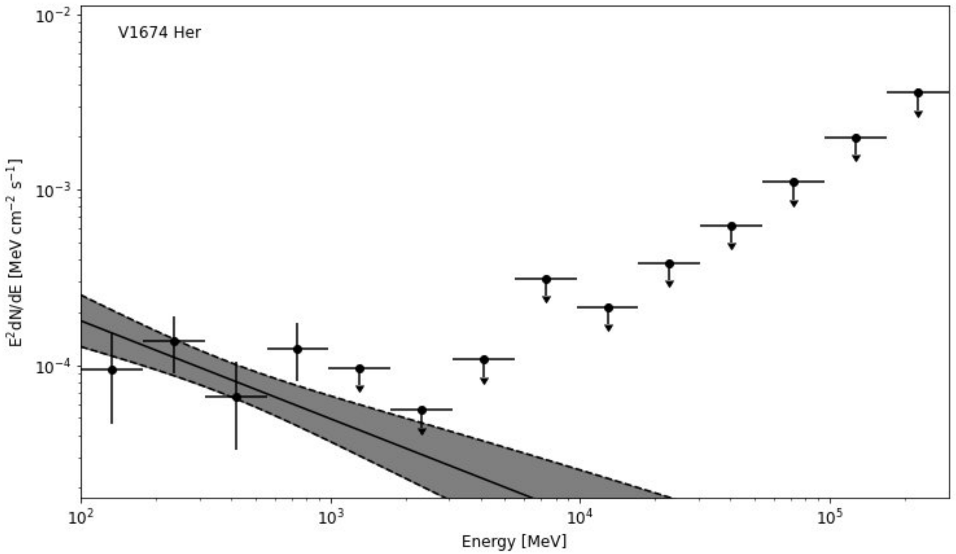
- Described by power-law spectrum



2021 June 11 2021 June 12

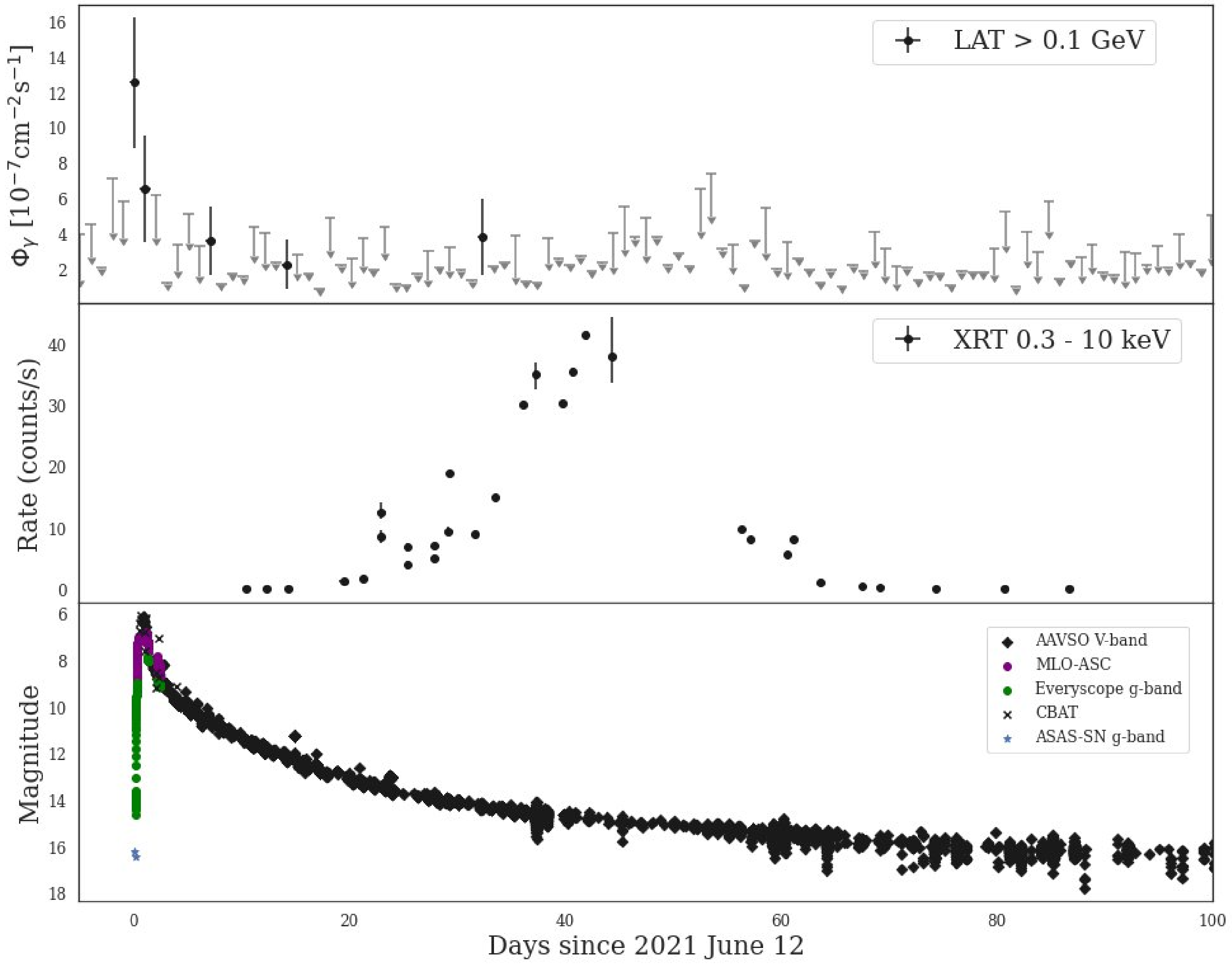
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0} \right)^{\gamma}$$

Prefactor (N_0): 1.2e-06 $\pm$ 3.5e-07
Scale (E_0): 1000 MeV
Index (γ): -2.6 $\pm$ 0.2

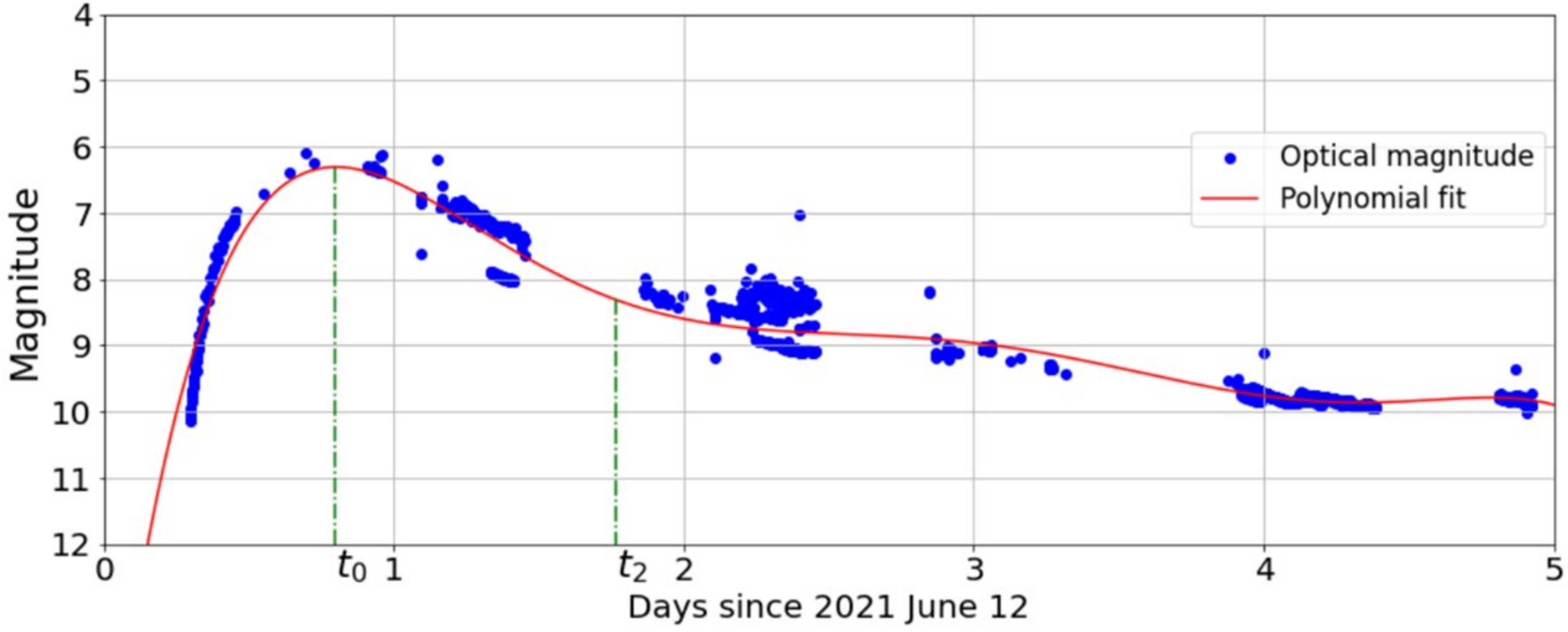


Light Curve

- Peak on 2021 June 12
- γ-ray emission (> 4σ) fades within a day



Light Curve



- Peak magnitude of ~ 6.3 on June 12.8
- $|t_2 - t_0| \sim 1\mathrm{d}$
- V1674 Her is the fastest nova ever recorded

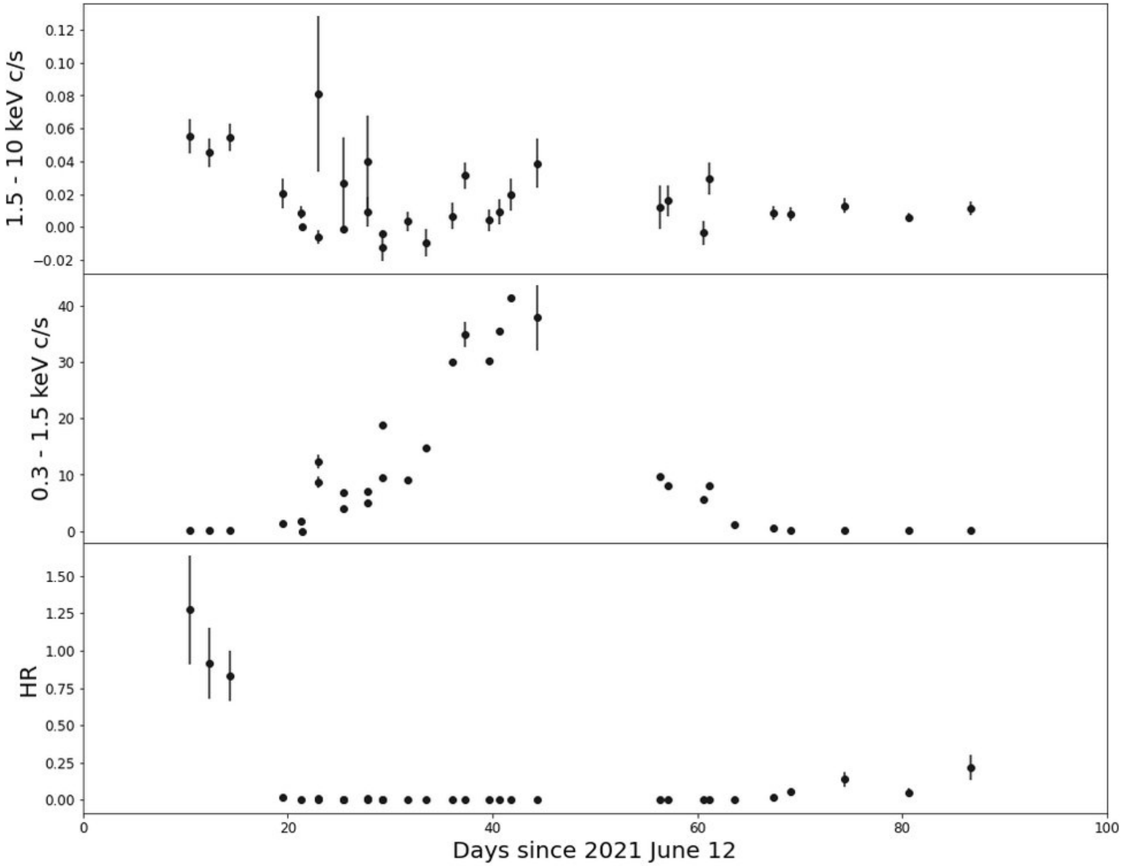
Speed class of nova

Speed Class	t_2 decline (days)
Very fast	< 10
Fast	11-25
Moderately fast	26-80
Slow	81-150
Very slow	151-250

Schwarz (1998)

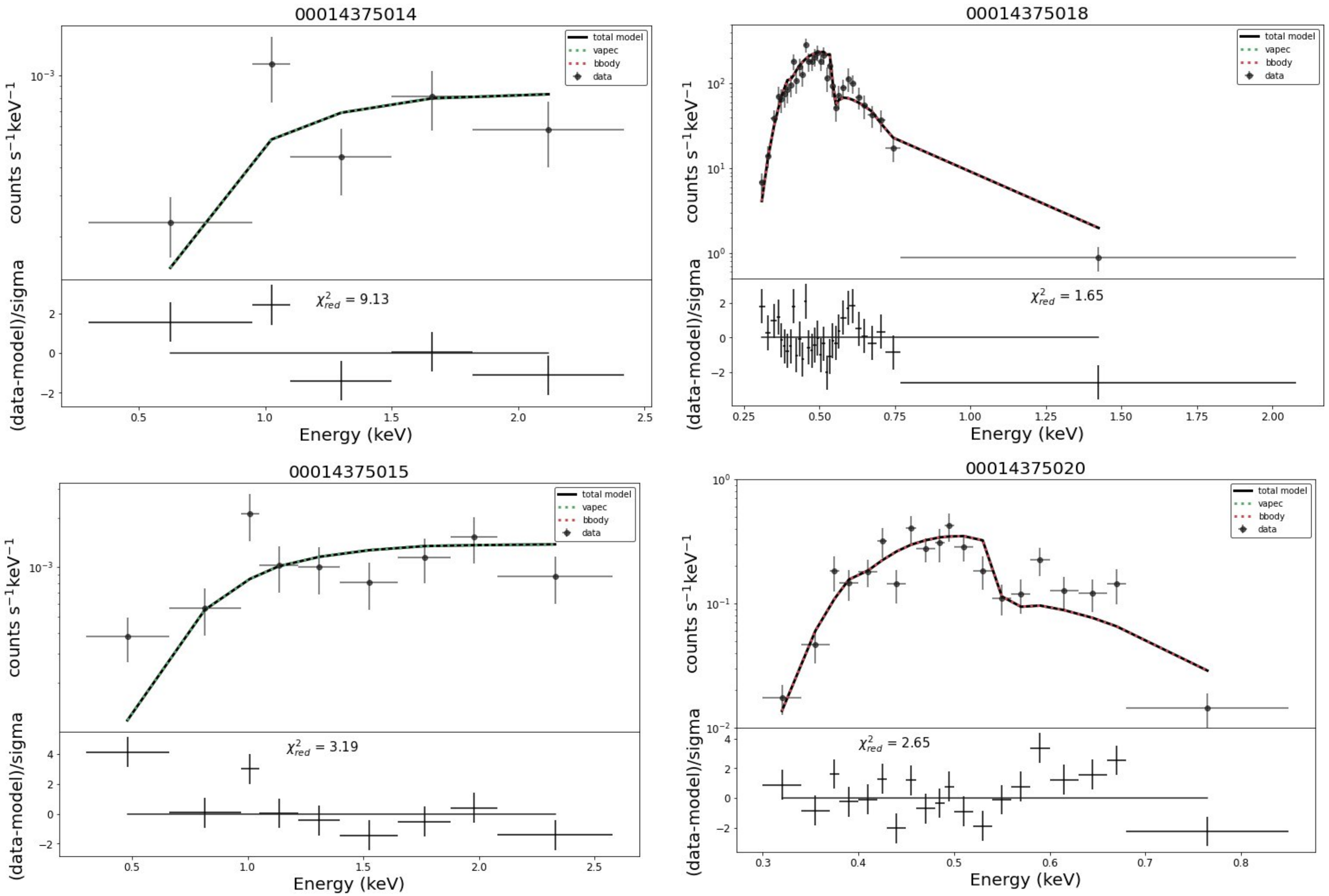
- $M_{ign} \propto M_{WD}^{-7/3}$
- Massive WDs require smaller ignition mass
- Smaller t_2 to burn the fuel
- Likely candidates for type Ia supernovae

XRT Light Curve



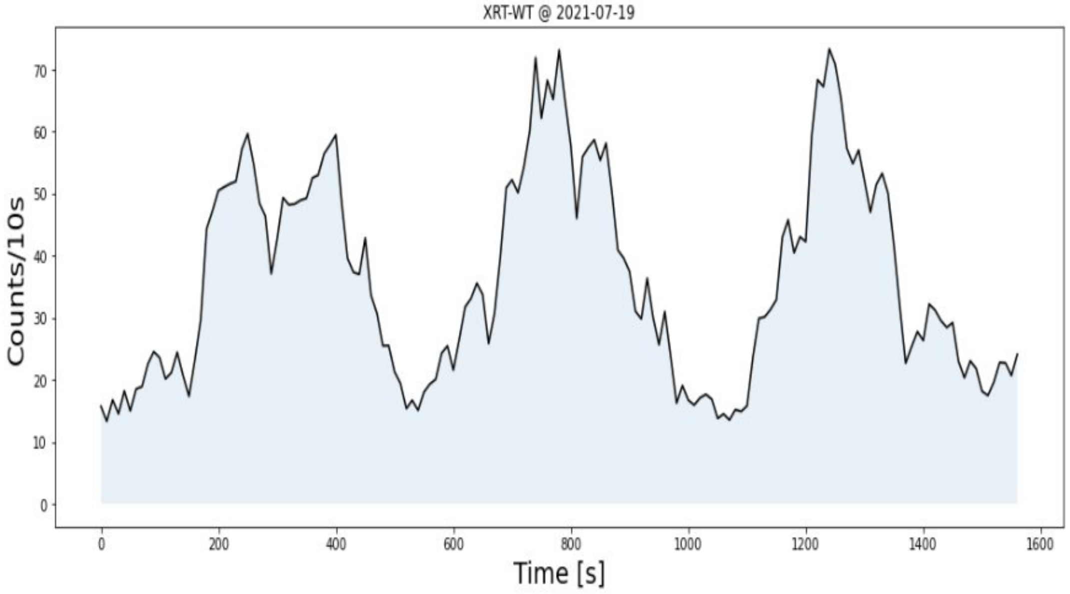
- Early hard x-ray emission due to shock heated gas
- SSS phase

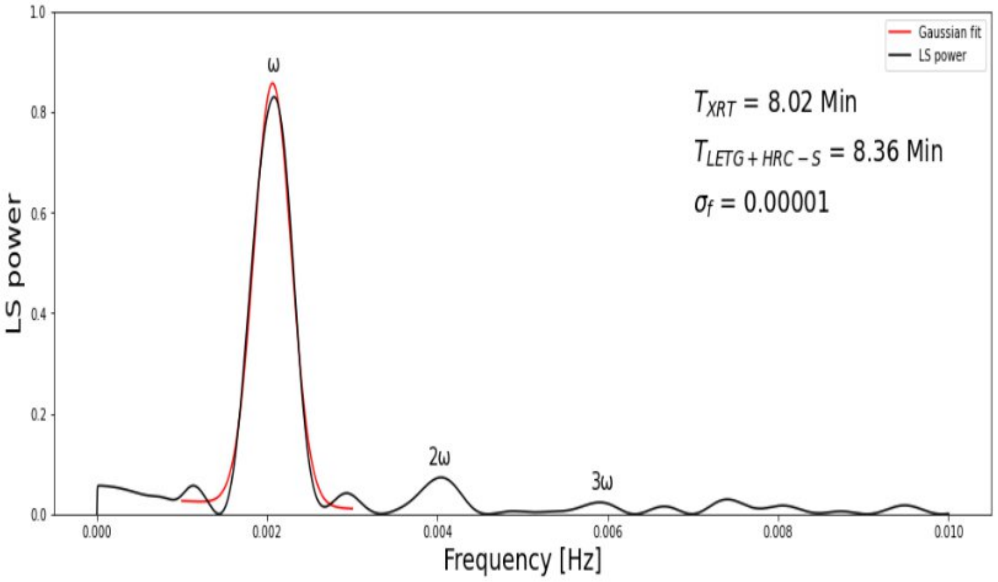
XRT spectrum



Model: tbabs*(vapec+bbody)

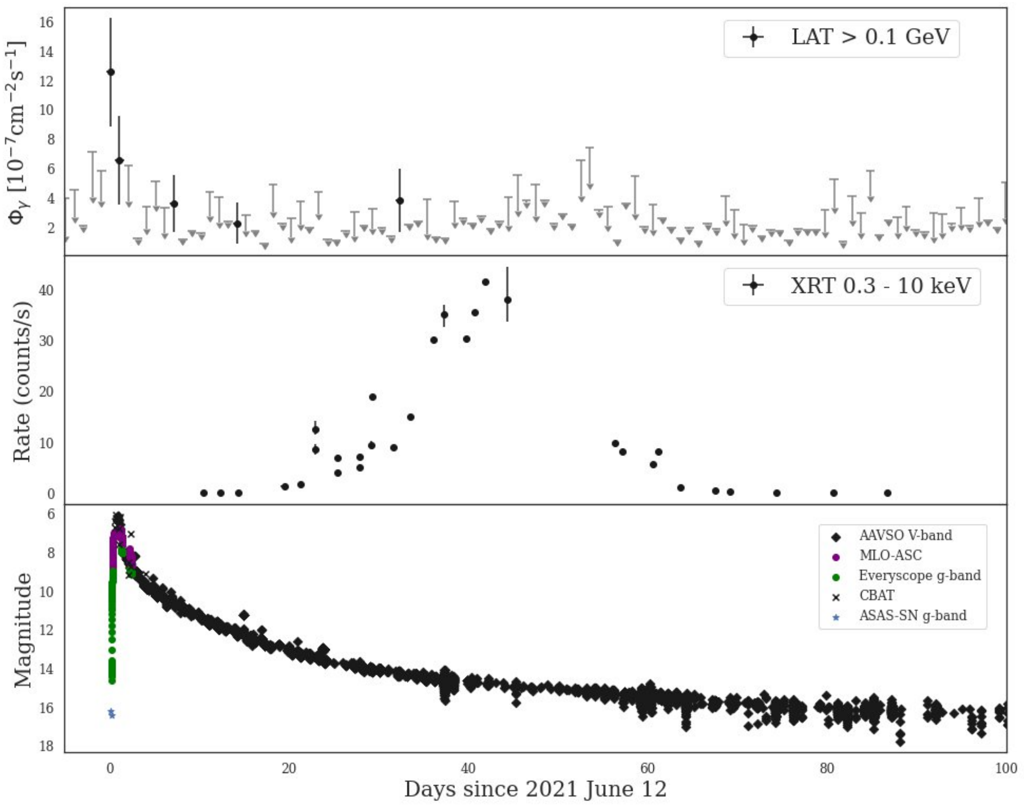
Periodicity in XRT counts

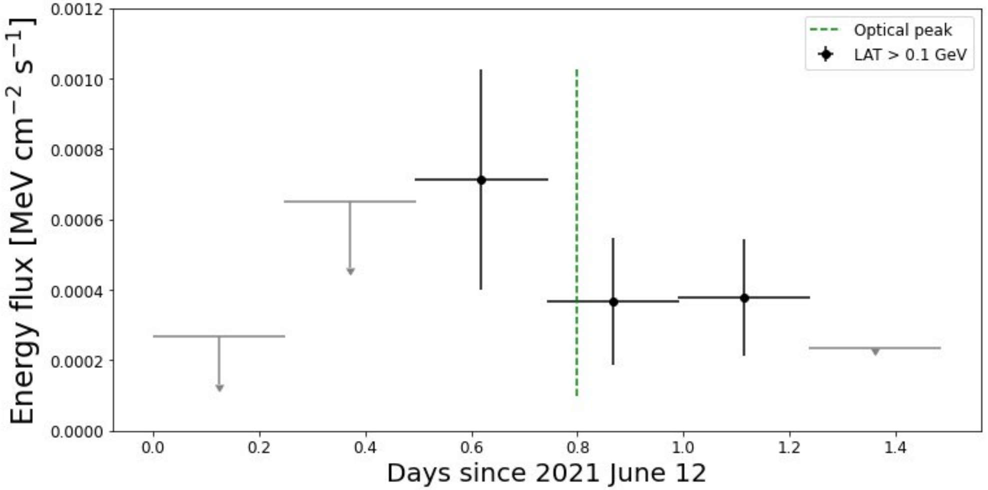




- Modulation with period $\sim$ 8.02 min
- Spin period of magnetic WD in the binary system (IP)
- Inhomogeneous emission
- The XRT period comparable to the values reported from Chandra and CBAT optical data. Drake et al. (2021)
- The minor difference between optical and X-ray spin periods can be due to differential rotation of the effective photosphere

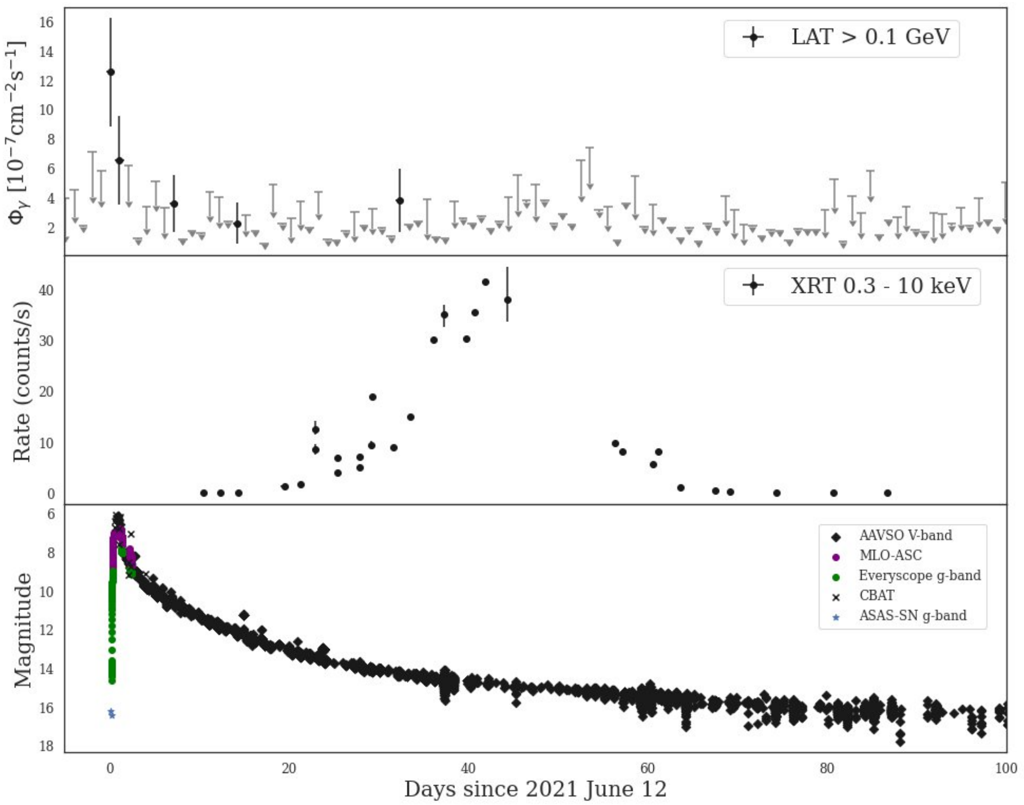
Light Curve



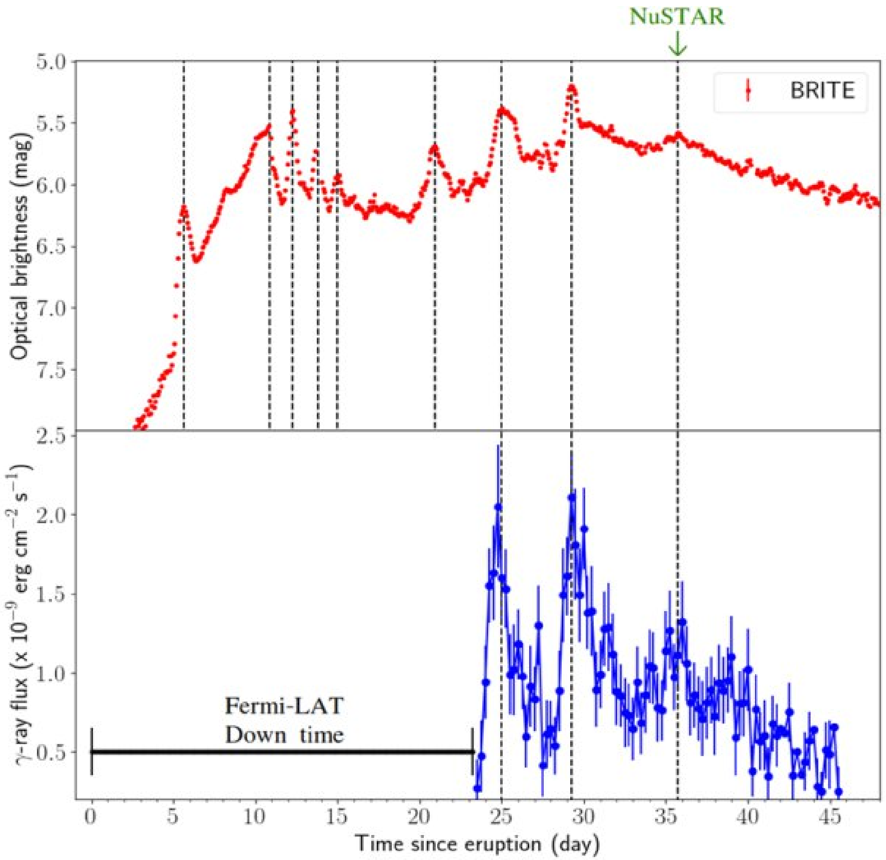


- γ-ray peak and optical peak $\sim$ concurrent
- Emission from shocks contributing to the optical luminosity

Light Curve



V1674 Her



V906 Car Aydi et al. (2020)

- γ-ray peak and optical peak $\sim$ concurrent
- Emission from shocks contributing to the optical luminosity

Summary

- V1674 Her is the fastest novae ever recorded
- The binary system hosts massive WD
- Spin period modulated emission indicates magnetic nature of the WD (IP)
- Fraction of the optical luminosity is likely a contribution from shock emission
- Massive WD in V1674 Her makes it a candidate progenitor for type Ia supernovae

References

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3. Quimby, R. M., Shafter, A. W., & Corbett, H. 2021, Research Notes of the American Astronomical Society, 5, 160, doi: 10.3847/2515-5172/ac14c0
4. Schwarz. (1999, August 23). General Properties of Novae. http://gschwarz.aas.org/main/node3.html
5. Drake J. J., et al., 2021, ApJ submitted
6. Aydi, E., Sokolovsky , K. V., Chomiuk , L., Steinberg, E., Li, K. L., Vurm , I., Metzger, B. D.,Strader, J., Mukai, K., Pejcha , O., Shen, K. J., Wade, G. A., Kuschnig , R., Moffat, A. F. J., Pablo, H., Pigulski , A., Popowicz, A., Weiss, W., Zwintz , K., . . . Sokoloski , J. L. (2020, April 13). Direct evidence for shock powered optical emission in a nova. Nature Astronomy, 4(8), 776 780. https://doi.org/10.1038/s41550 020 1070 y
7. Evans, P. A., Beardmore, A. P., Page, K. L., et al. 2007, A&A, 469

Extra

Simple model for ignition

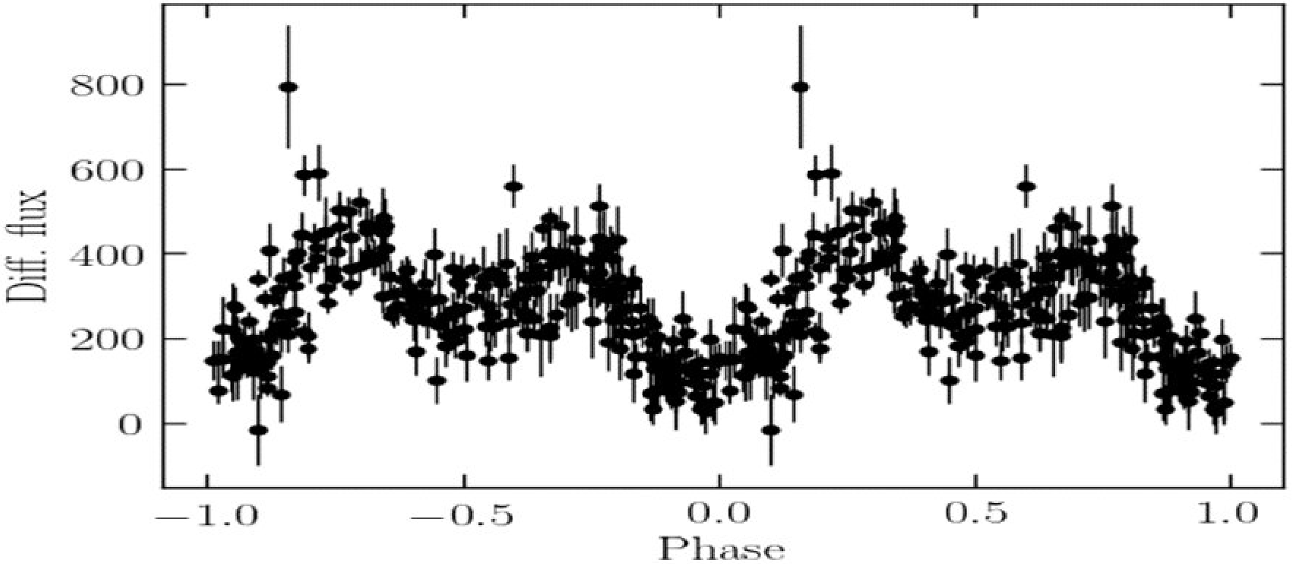
- $T_{\rm b} \gtrsim T_{\rm ign}$ $$RT_{\rm b}\left(\frac{\rho}{\mu_{\rm e}}\right)_{r_{\rm b}} \approx K\left(\frac{\rho}{\mu_{\rm e}}\right)_{r_{\rm b}}^{5/3} \qquad P_{\rm crit} \approx \frac{(RT_{\rm ign})^{5/2}}{K^{3/2}}$$

- Envelope mass to balance the pressure $$P_{\rm crit} \approx \frac{GM_{\rm WD}M_{\rm ign}}{4\pi R^4}$$

- $M_{\rm WD} \propto R^{-3}$ $\rightarrow$ $M_{\rm ign} \propto M_{\rm WD}^{-7/3}$

- More massive WDs require less ignition mass

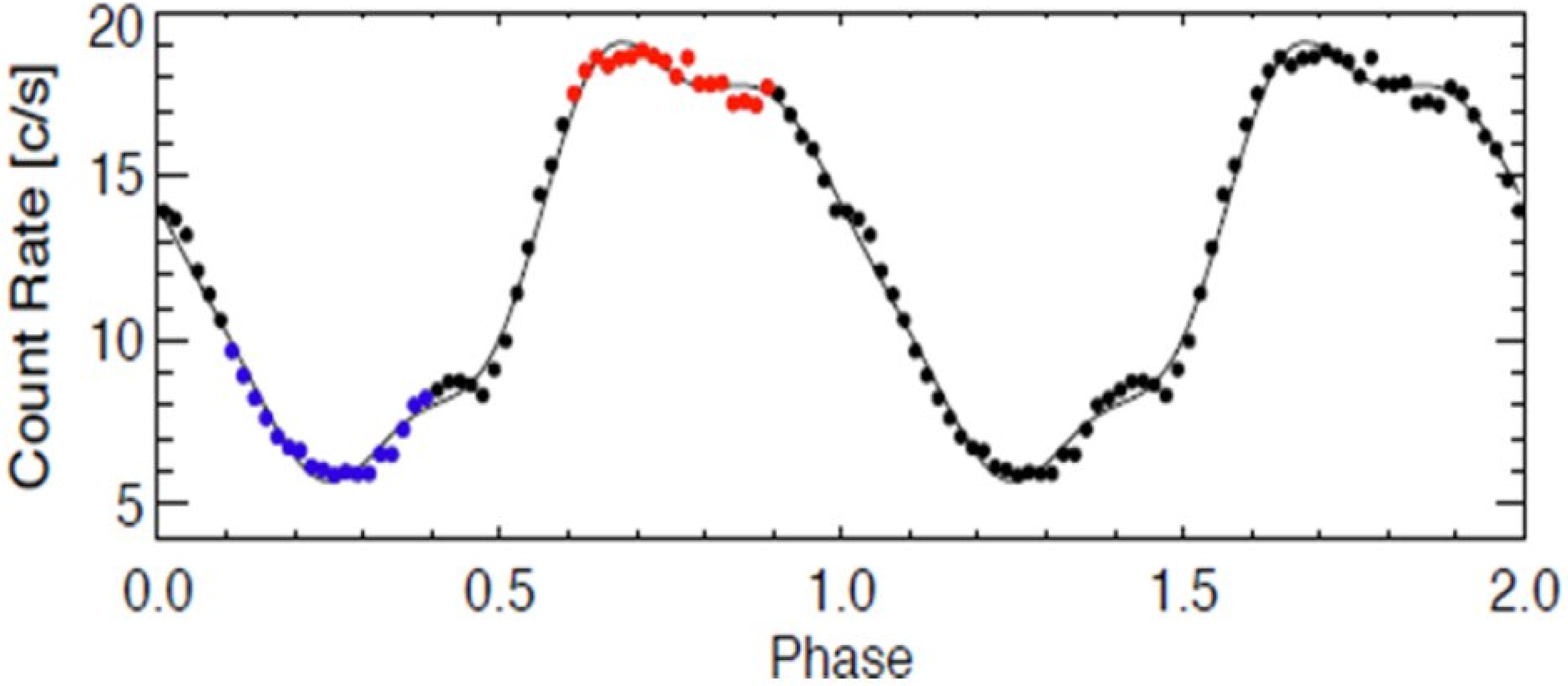
Light curve from ZTF data (2018 March 26 - 2021 June 14)



[1]

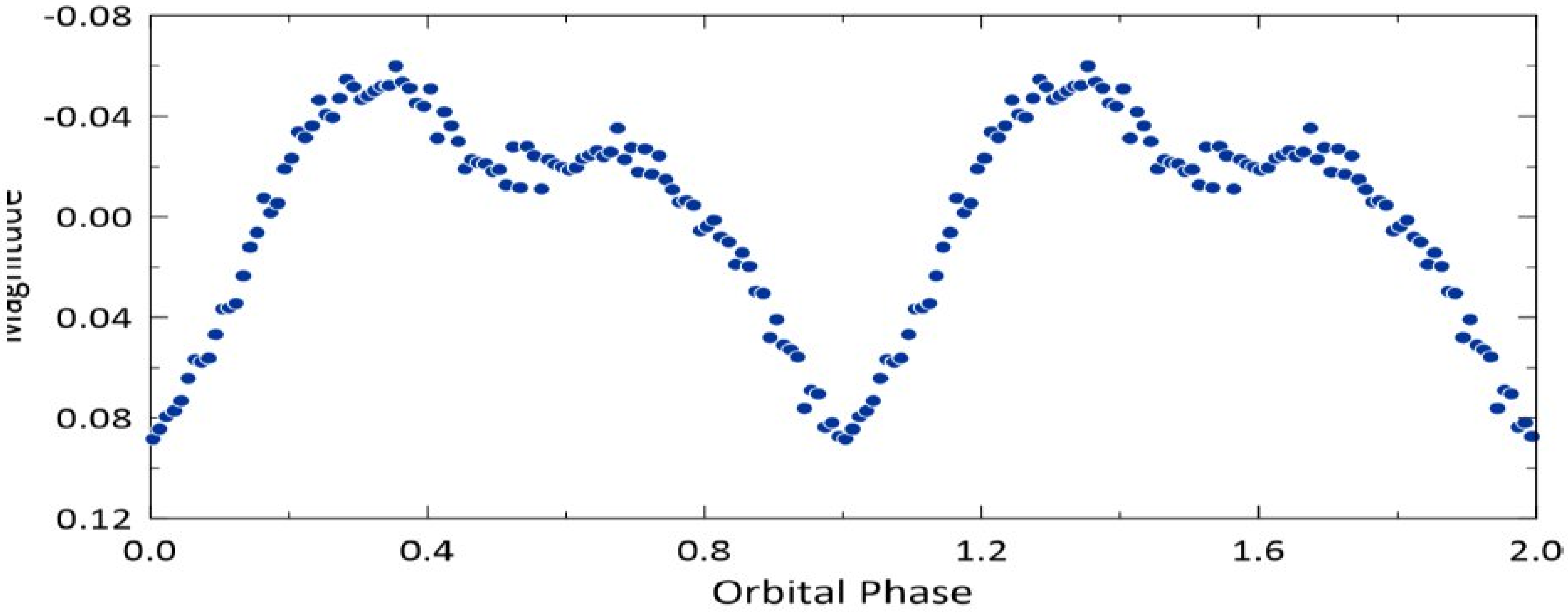
$$P = 501.4277 \pm 0.0002 \text{ s}$$

LETG+HRC-S data (Post outburst)



P = 501.72±0.11s

CBA light curve (2021 July 1 – August 10)

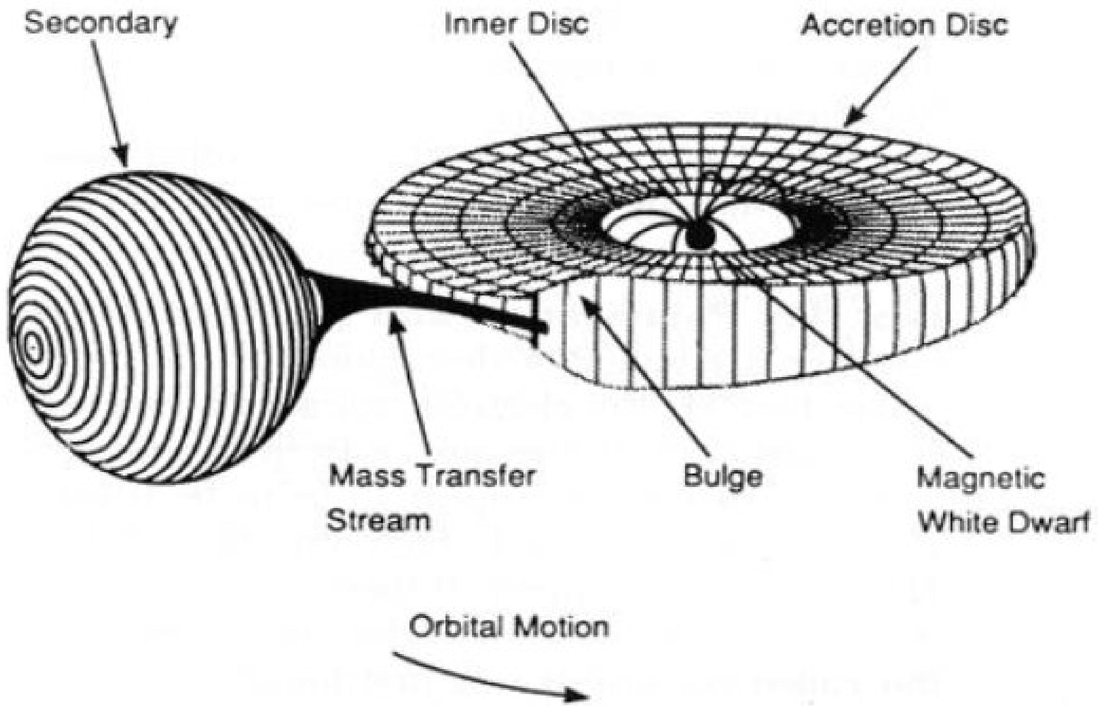


[3]

$$P = 501.52 \pm 0.02 s$$

Intermediate polar system (IP)

- P is interpreted as spin period of white dwarf (WD) in intermediate polar system (IP)

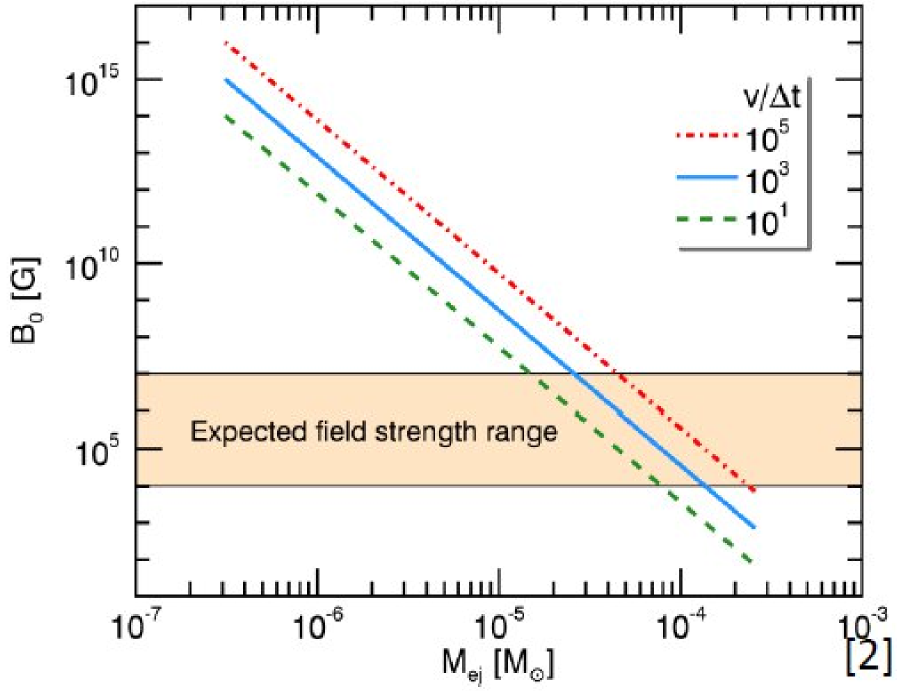


- Magnetic field of the WD disrupts accretion disk

Surface magnetic field strength

$$\frac{r_A}{R_{WD}} = (B_0 R_{WD})^{0.5} \left(\frac{1}{\dot{M} v}\right)^{0.25} \qquad \dot{M} = \frac{M_{ej}}{\Delta t}$$

$$B_0 = \frac{1}{R}(10^{-4} \alpha M_{WD})^{14/3} \left(\frac{v}{\Delta t}\right)^{1/2} \frac{1}{M_{ej}^{25/6}}$$



[2]

B_0: surface magnetic field strength $\dot{M}$: mass loss rate v: outflow velocity

- For typical IP magnetic field strengths an ejected mass is in the range of $2\mathrm{x}10^{-5} - 2\mathrm{x}10^{-4} M_{\odot}$

Differential rotation of the effective photosphere

- Effective photosphere post-outburst is located beyond r_A
- Magnetic field insufficient to enforce strong co-rotation
- Optical photo-sphere lying closer to the WD can have a shorter rotation period than the X-ray photosphere