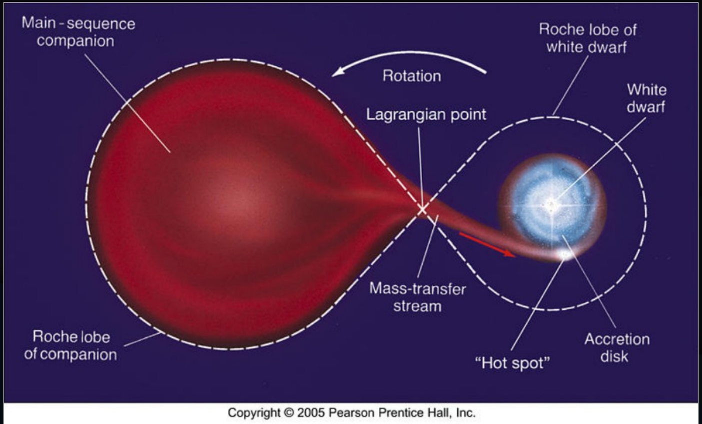
V392 Persei: A γ-ray Bright Nova

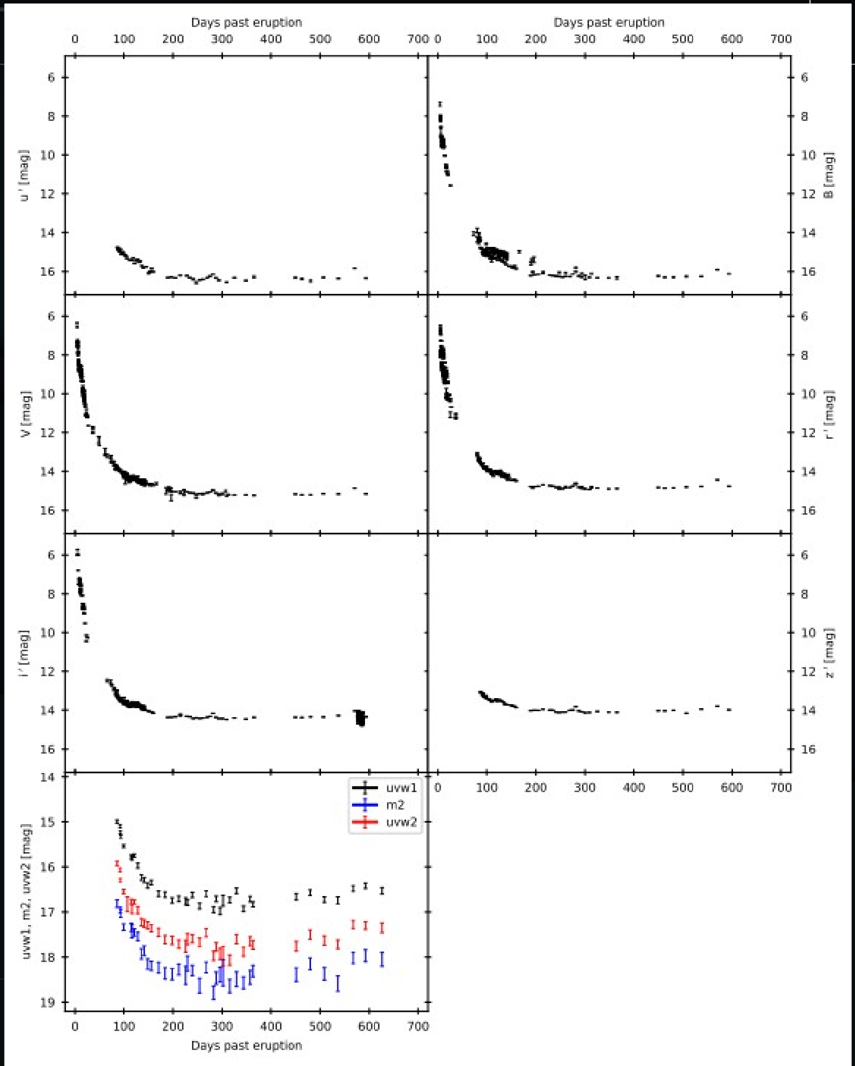
A classical nova eruption (CN) is the result of a thermonuclear runaway on the surface of a white dwarf (WD). This occurs in the H-rich material accreted (via an accretion disk) from the WD's binary companion.



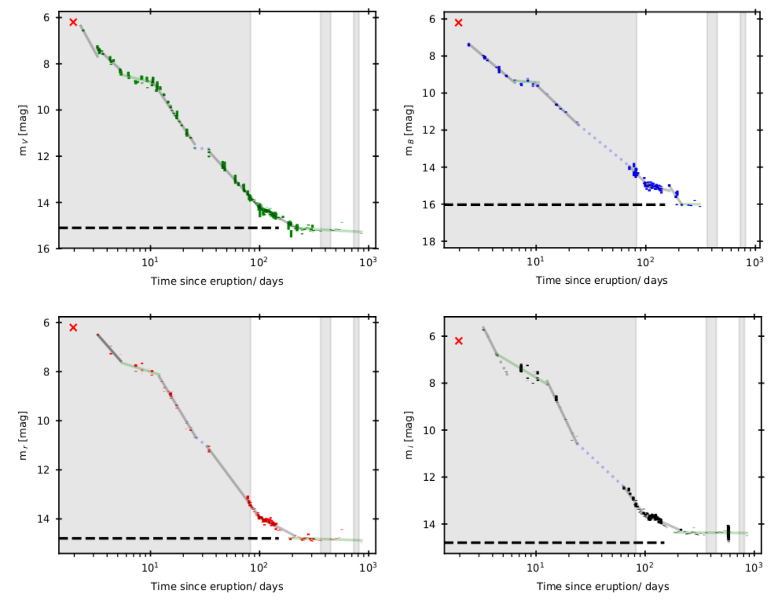
- V392 Persei CN eruption discovered on **29th April 2018** – unfiltered magnitude **6.2 mag**. (Nakamura, 2018; Wagner, 2018)
- Already **known dwarf nova (DN)** system. So we know quiescent magnitude is V~17 mag → Eruption amplitude ~ 10.8 mag

Fermi-LAT **detected γ-rays** from V392 Per the day after discovery of the eruption.

Figure shows light curves for V392 Per in optical and UV filters. Data taken by Liverpool Telescope (LT), AAVSO and *Swift.*



Fits to light curves and spectra



The light curves were fitted with straight lines to find the gradient of the decline. Shaded grey regions indicate V392 Per not observable by *Swift* or LT.

- The fits were used to provide the photometry to **calibrate the spectra**, and to calculate the time to decline from peak by 2 or 3 magnitudes, $\mathbf{t_2}$ and $\mathbf{t_3}$.

- Note the plateaux in the light curves beginning at 4-6 days after eruption, as the accretion disk is unveiled by the receding photosphere of the expanding ejecta. This indicates the nova has entered the supersoft source phase. If V392 Per were observable by Swift at this time, we would detect supersoft X-rays.

- The spectra initially show strong **Balmer lines** Hα, Hβ, Hɣ and **Fe II** (42) and (49) lines during its **principal spectrum** and **diffuse ionised** spectra.
  - The nova is an **Fe II type nova.**

- **P Cygni** features in early spectra, including double absorption troughs in Balmer lines.

- The nova entered the **nebular phase** before it exited the Sun constraint.

- The Balmer lines remained strong, but were **rivalled or exceeded in flux by the appearance of forbidden [O III] lines, and He II lines**.
  - Indicates plasma was hot and dense, but now cooler and less dense.

- In the late time spectra, the **O III is no longer significant** in the spectrum, but the **Balmer lines, HeII and HeI still remain**. This is the post-nova spectrum.

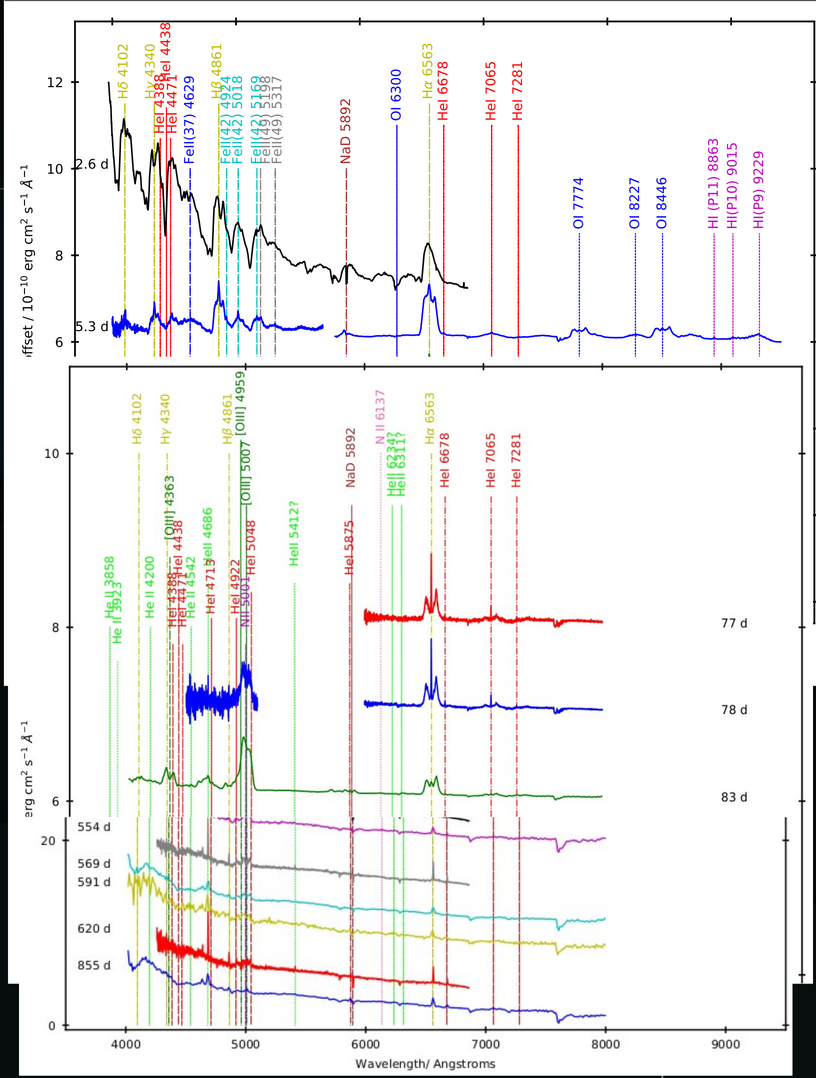
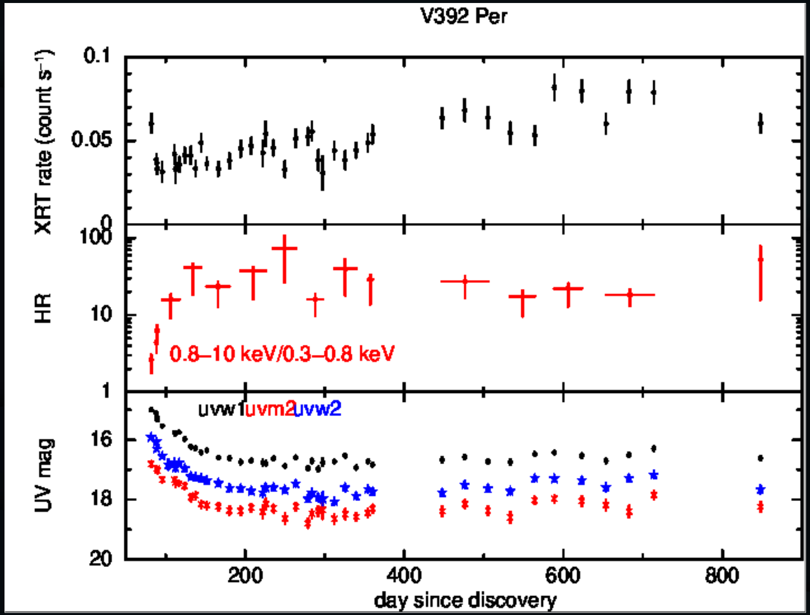


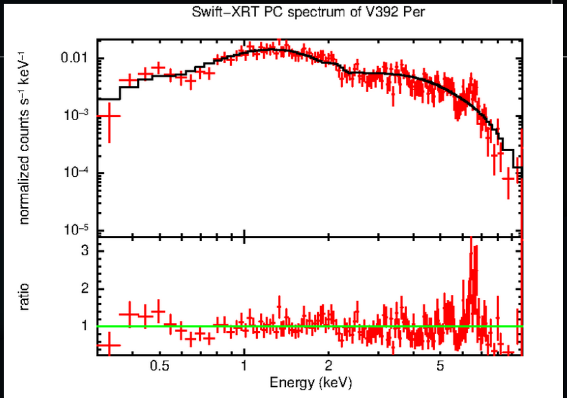
Figure - V392 Per spectra: early (top), nebular (middle) and late (bottom)

X-rays

- *Swift* X-ray and UV observations began in July 2018, after V392 Per exited its Sun constraint.
- By this time, the ratio of supersoft (0.3-0.8 keV) to hard X-rays (0.8-10 keV) – the hardness ratio – was 2-3, and increasing with time (see middle panel).
- This suggests we missed most of the **supersoft source phase**, but possibly caught the end.
- The supersoft source phase begins when the photosphere recedes to the surface of the WD, allowing the detection of X-rays produced by steady-state hydrogen burning continuing on the surface of the WD. The supersoft source phase ends when the supply of hydrogen is exhausted.
- V392 Per continued to emit X-rays at a **fairly constant hardness ratio and count rate** (see top panel). The count rate even increased slightly from ~360 days after eruption.
- The **hard X-ray emission** from V392 Per continued for **over two years** after the eruption, with the final *Swift* observation taken on 24th August 2020.



- The bottom panel in the figure above shows the UV light curves. They reached a steady level from around ~350 days after eruption.



- The X-ray spectrum above combines all the photons collected
- This can be modelled by two APEC components (indicating collisonal excitation) and an absorption column.

What did we learn about V392 Per?

- V392 Per is a **very fast nova**, with decline times:
  - In B, t_2=2.3 d, t_3=4.5 d
  - In V, t_2=1.8 d, t_3=4.3 d
  - In R, t_2=2.1 d, t_3=4.1 d
  - In I, t_2=1.3 d, t_3=2.3 d

- **Ongoing hard X-ray detection**, lasting more than two years following the CN eruption.
- Indicates presence of ongoing shocks.
  - Suggests **collimation process** affecting accretion onto WD
  - Hints at **strong magnetic field**, channelling accreted material towards poles, setting up standing wave shocks in accretion stream.
    - Either Intermediate Polar (10^6 G < B < 10^7 G)
    - Or Polar (B > 10^7 G)

- There were **prominent P Cygni** profiles on the Balmer lines in the early spectra.
- Indicates multiple ejection events, with the earlier ejecta components travelling slower than the later components.
- The ejecta components collided, and the timing of the corresponding **shocks** is consistent with the **detection of γ-rays**, which began the day after discovery.

- Balmer and He I emission lines in early spectra had a triple-peaked structure, with outer peak velocities of up to ~4500 km s^{-1}. The narrow central peak was present throughout and continued into the post-nova spectrum.
- O III and He II emission lines appeared in the nebular spectra. O III had a double-peaked structure and faded away before the post-nova spectrum was reached. He II had a triple-peaked structure and the central peak persisted into the post-nova spectrum.
- Different species reached a plateau in their flux evolution at different times. In conjunction with the line profile shapes, this provides information about the ionization conditions in the ejecta.

For more details, look out for our paper – coming soon!

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