The multi-wavelength view of shocks in the fastest nova V1674 Her

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Paper overview

- Presentations to Galactic group: Now (Dec 21), previously at Collab. meeting Gal. session in Sep
- To be submitted to: MNRAS – proposed as LAT cat 2 paper

LAT internal review – Xian (report in a couple of weeks)

- Future timeline estimates / necessary next steps
  - **? –** WAM walkthrough
  - **early Jan? –** signup deadline for LAT authors
  - **mid. Jan –** Pub-bd and submission to MNRAS

- Pub-board paper page: https://www-glast.stanford.edu/cgi-prot/pub_download?id=2028
- LAT Paper page: https://confluence.slac.stanford.edu/display/SCIGRPS/Nova+V1674+Her+2021+Paper+Page
- Analysis results: https://confluence.slac.stanford.edu/pages/viewpage.action?pageId=311557588

The authors

LAT + former e-Nova team + optical (Evryscope & AAVSO)

The multi-wavelength view of shocks in the fastest Galactic nova V1674 Her

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Intro: novae are exciting!

Nova is a non-destructive thermonuclear runaway on an accreting white dwarf.

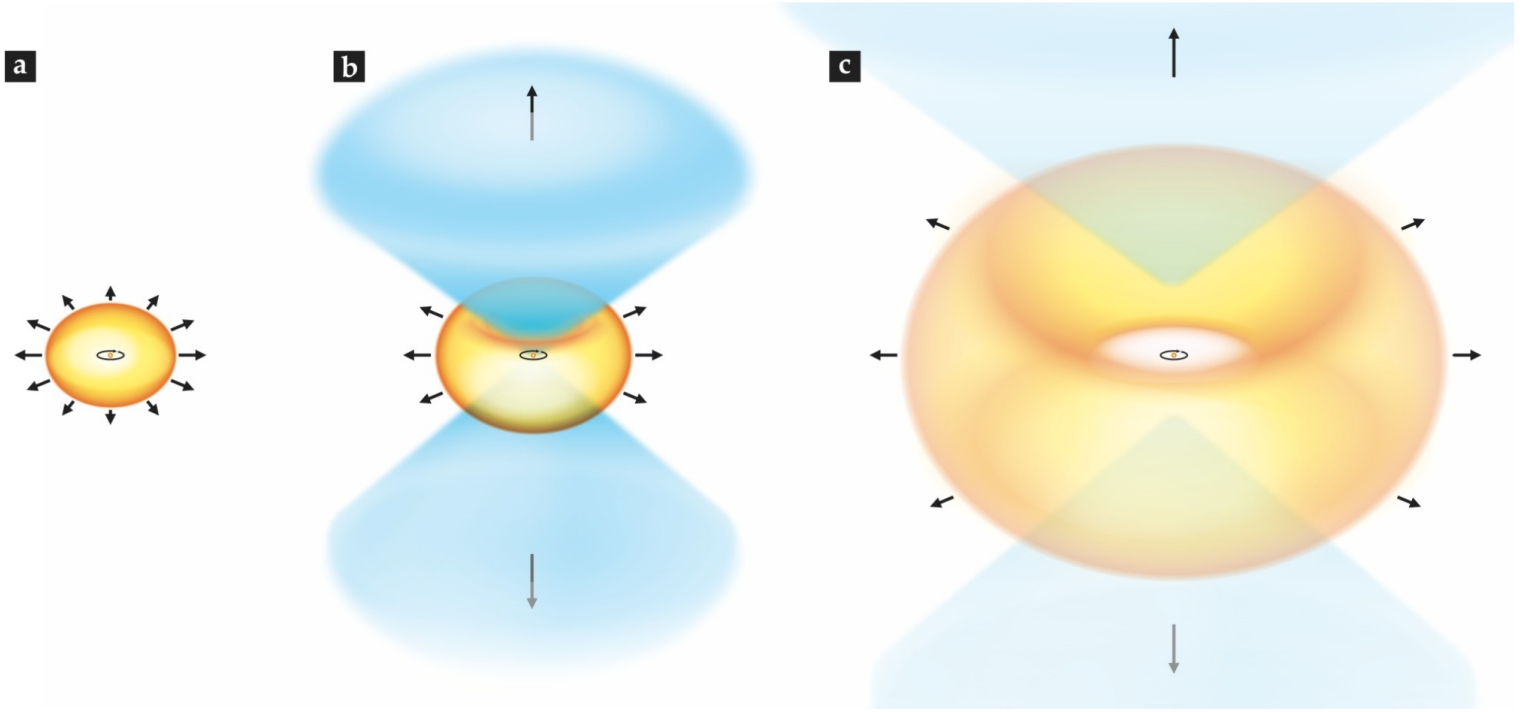
- More like a *born-again star* than an H-bomb
- *Common envelope* interaction right before our eyes!
- *Shocks* in expanding nova envelope (TeV to radio)
- Model for other shock-powered transients

Reviews of this view on novae:

- Chomiuk, Metzger & Shen 2021, ARA&A, 59, 391
- Shen & Quataert 2022, ApJ, 938, 31
- Mukai & Sokoloski 2019, Physics Today, 72, 11, 38

Slow torus - fast wind scenario

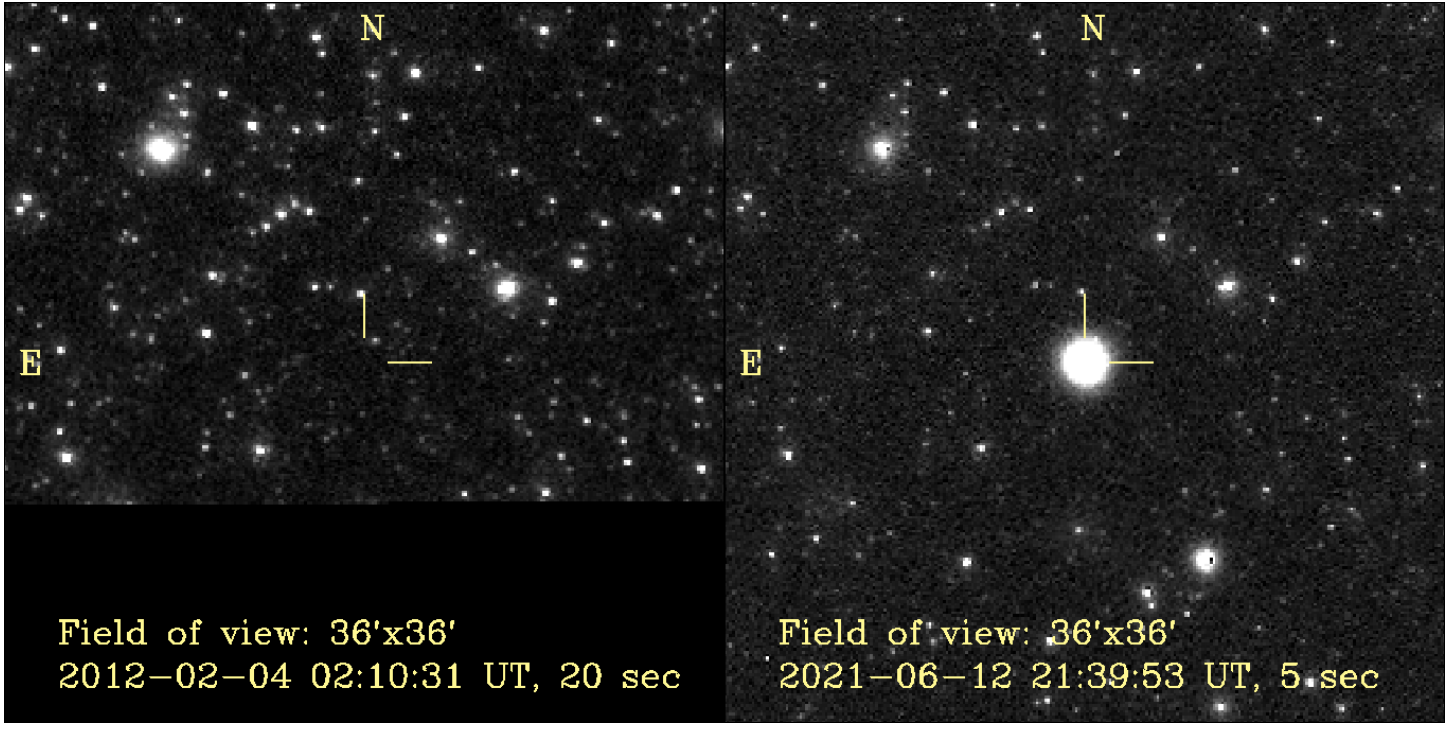
- *Optical spectra* revel 2+ velocity systems, with faster one overtaking the slower one around optical peak.
- *Line profile modeling* and high-res IR/radio *imaging*



V1674 Her

discovered on 2021-06-12.548 UTC by Seiji Ueda at 8^m

- ASAS-SN detection 8^h before discovery at g = 16.6
- Peaked at 6^m, 7^h post-discovery (rise in 15^h)

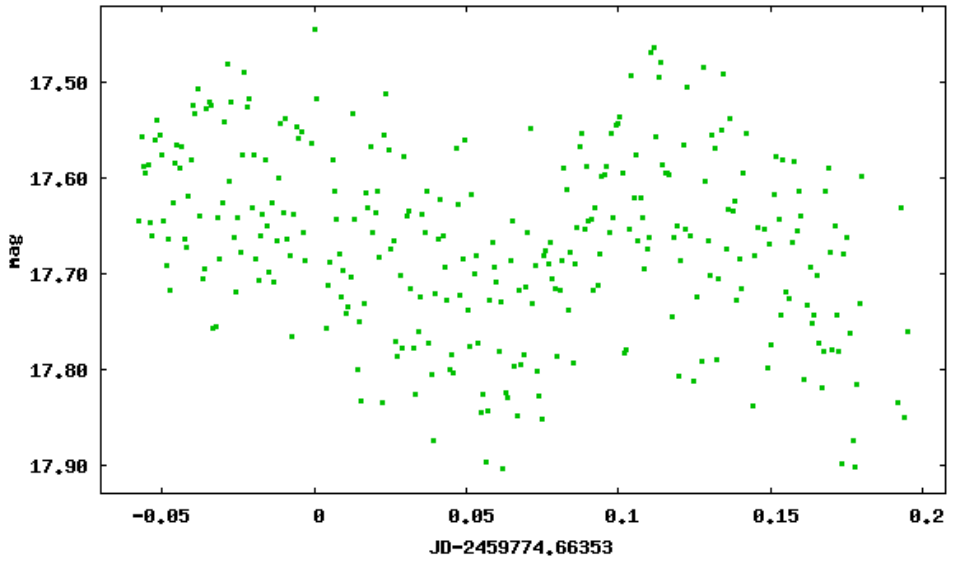


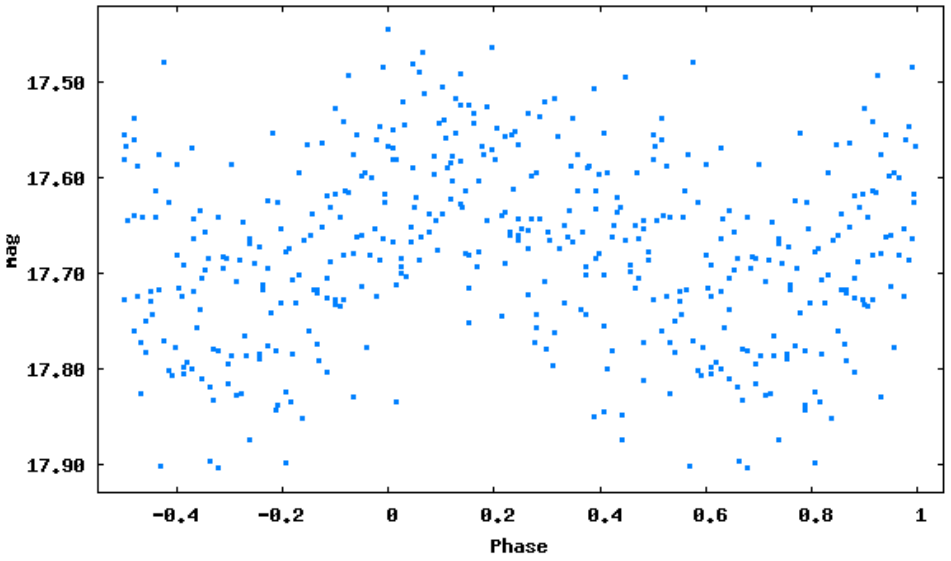
V1674 Her

is a unique nova because:

- The *fastest* nova ever ($t_2 = 1.1^{day}$, caveats apply)
- *Orbital modulation* in optical starting $t_0 + 4^{days}$
- White dwarf *rotation* (optical/X-ray) from $t_0 + 12^{days}$
- Good multi-wavelength coverage starting *early*

Orbital and spin periods





$P_{orb} = 3.67^{h}$

MSU 24' telescope

$P_{rot} = 8.35^{min}$

V1674 Her is an *IP*!

Patterson et al. 2022, ApJ, 940, L56

V1674 Her

detected by Fermi/LAT on the day of optical discovery

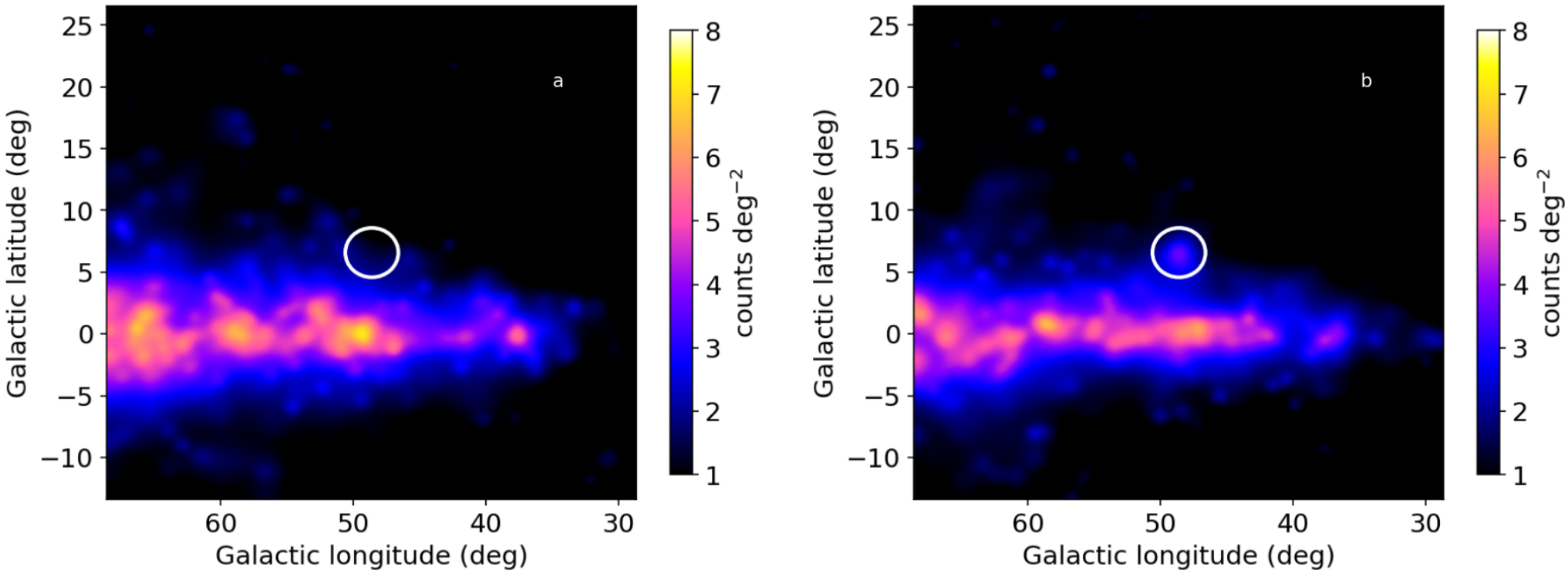
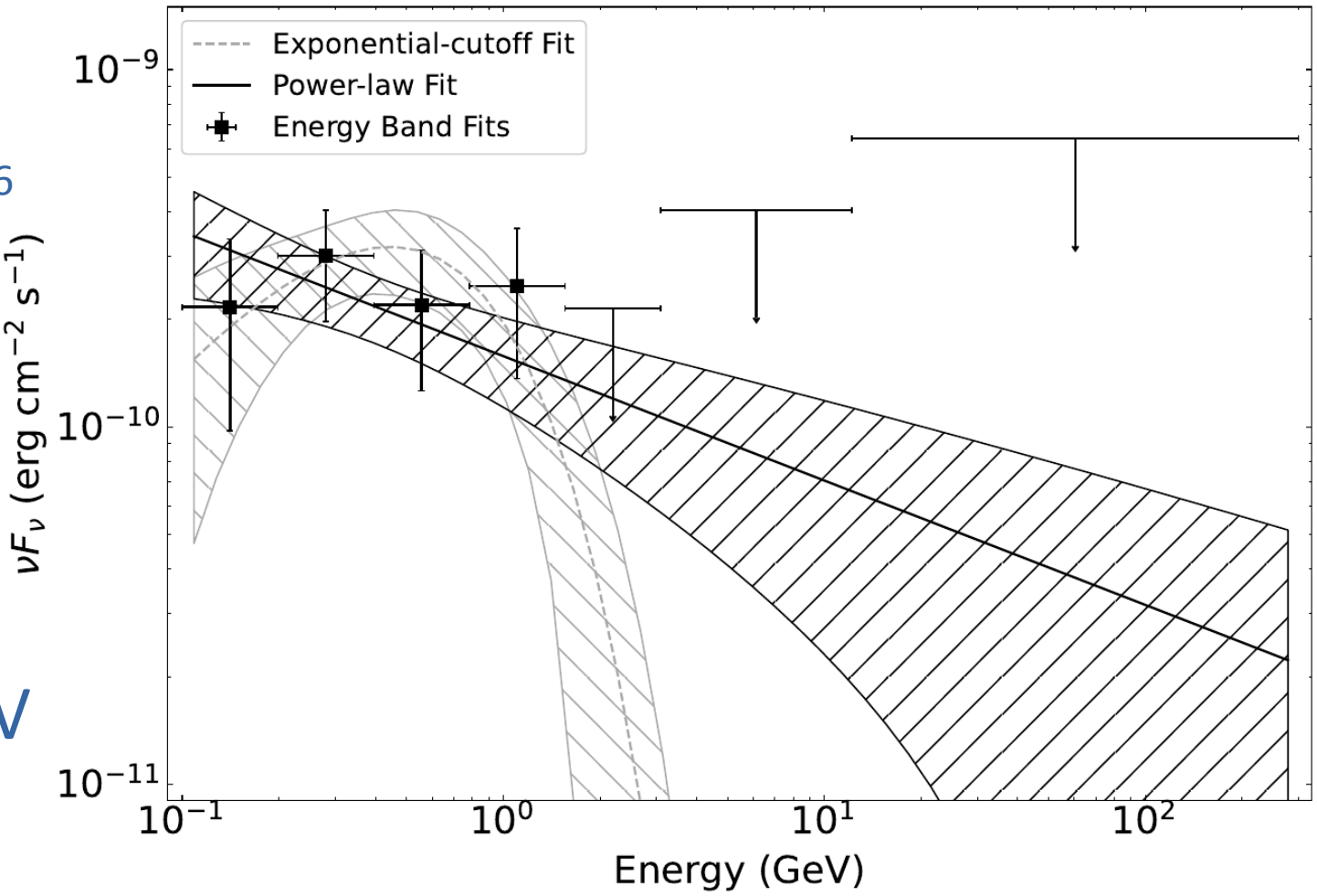


Figure 5. The *Fermi*/LAT smoothed 0.1–2 GeV count images centered on V1674 Her. The left image (a) covers the time interval 2021-06-10 10:34 to 2021-06-11 08:34 UT before the eruption. The right image (b) covers the 18 h interval when the γ-ray emission was detected. The white circle marks the optical position of the nova.

LAT SED

- 18^h integration
  TS=49

  $(1.6 +/- 0.4) \times 10^{-6}$ ph/cm^2/s
- Good PL fit
  Γ=2.3+/-0.2
- PL+EC fit
  Γ=0.9+/-0.9
  EC=0.4+/-0.3 GeV



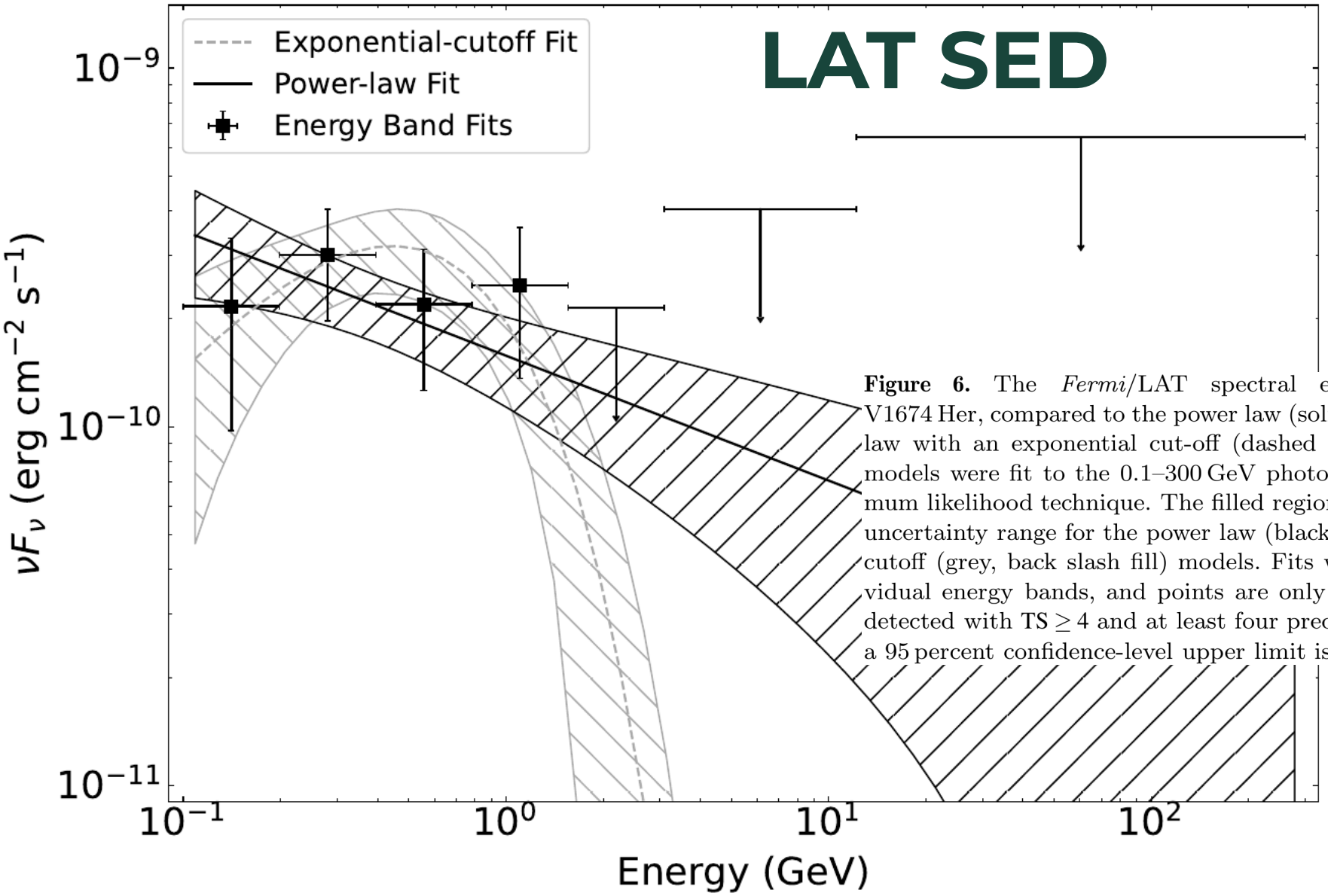


Figure 6. The *Fermi*/LAT spectral energy distribution of V1674 Her, compared to the power law (solid black line) and power law with an exponential cut-off (dashed grey line) models. The models were fit to the 0.1–300 GeV photon data using the maximum likelihood technique. The filled regions correspond to the 1σ uncertainty range for the power law (black, forward slash fill) and cutoff (grey, back slash fill) models. Fits were performed in individual energy bands, and points are only shown if the nova was detected with TS ≥ 4 and at least four predicted counts, otherwise a 95 percent confidence-level upper limit is reported.

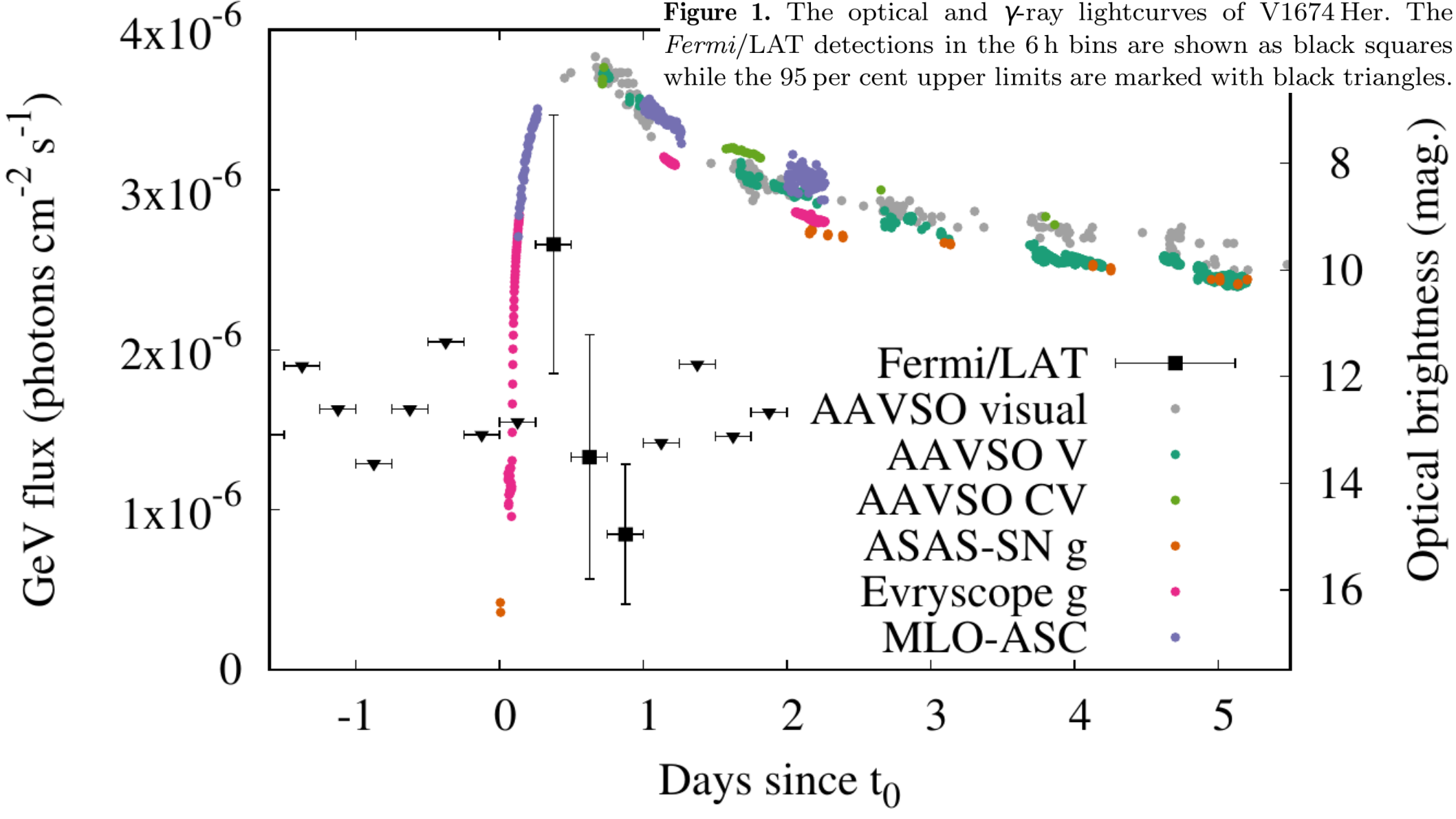
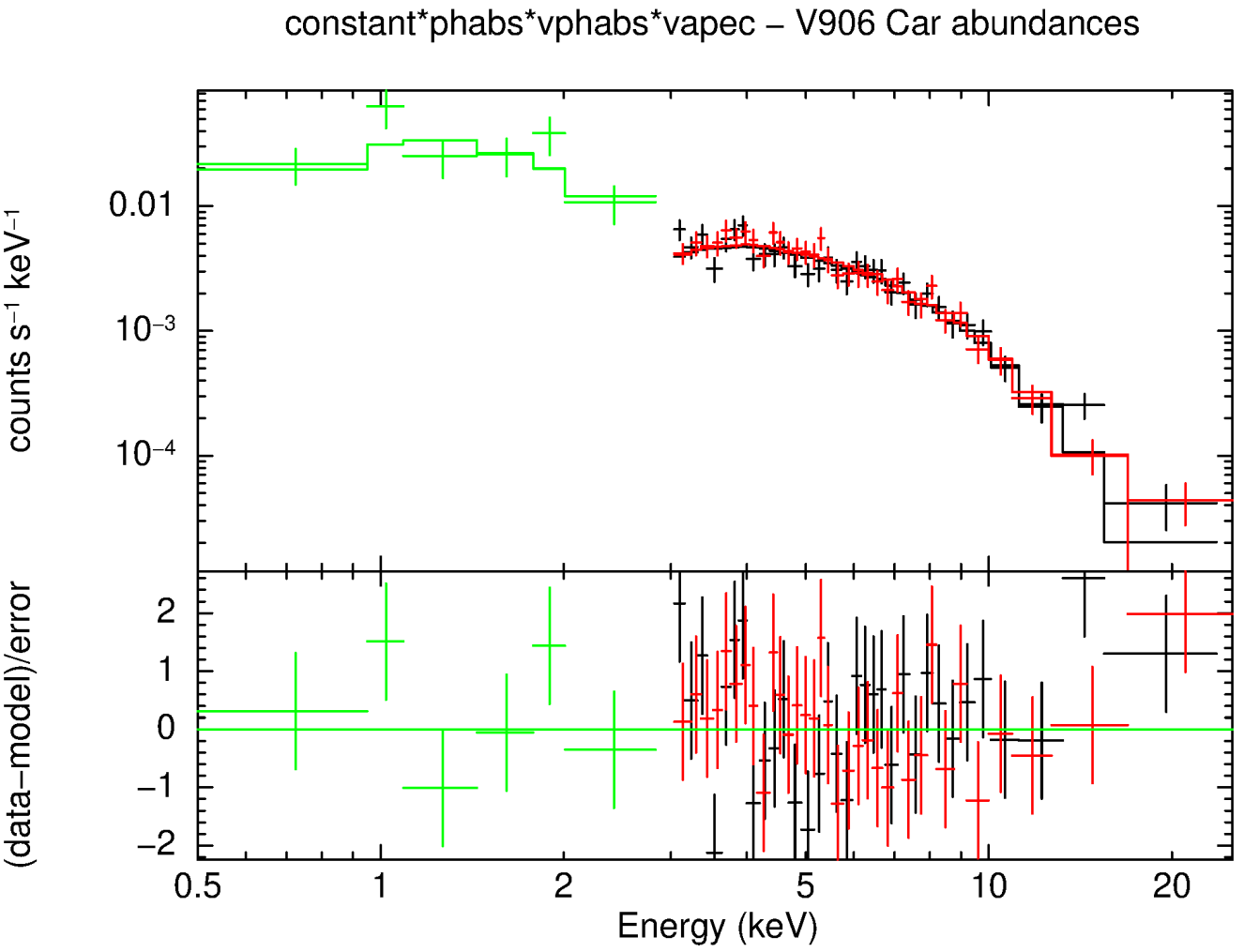


Figure 1. The optical and γ-ray lightcurves of V1674 Her. The *Fermi*/LAT detections in the 6 h bins are shown as black squares while the 95 per cent upper limits are marked with black triangles.

X-ray spectrum (NuSTAR+Swift)

- t_0 + 12^{days}
- Thermal kT = 4 keV
- No intrinsic absorption
- Overabundance of CNO elements



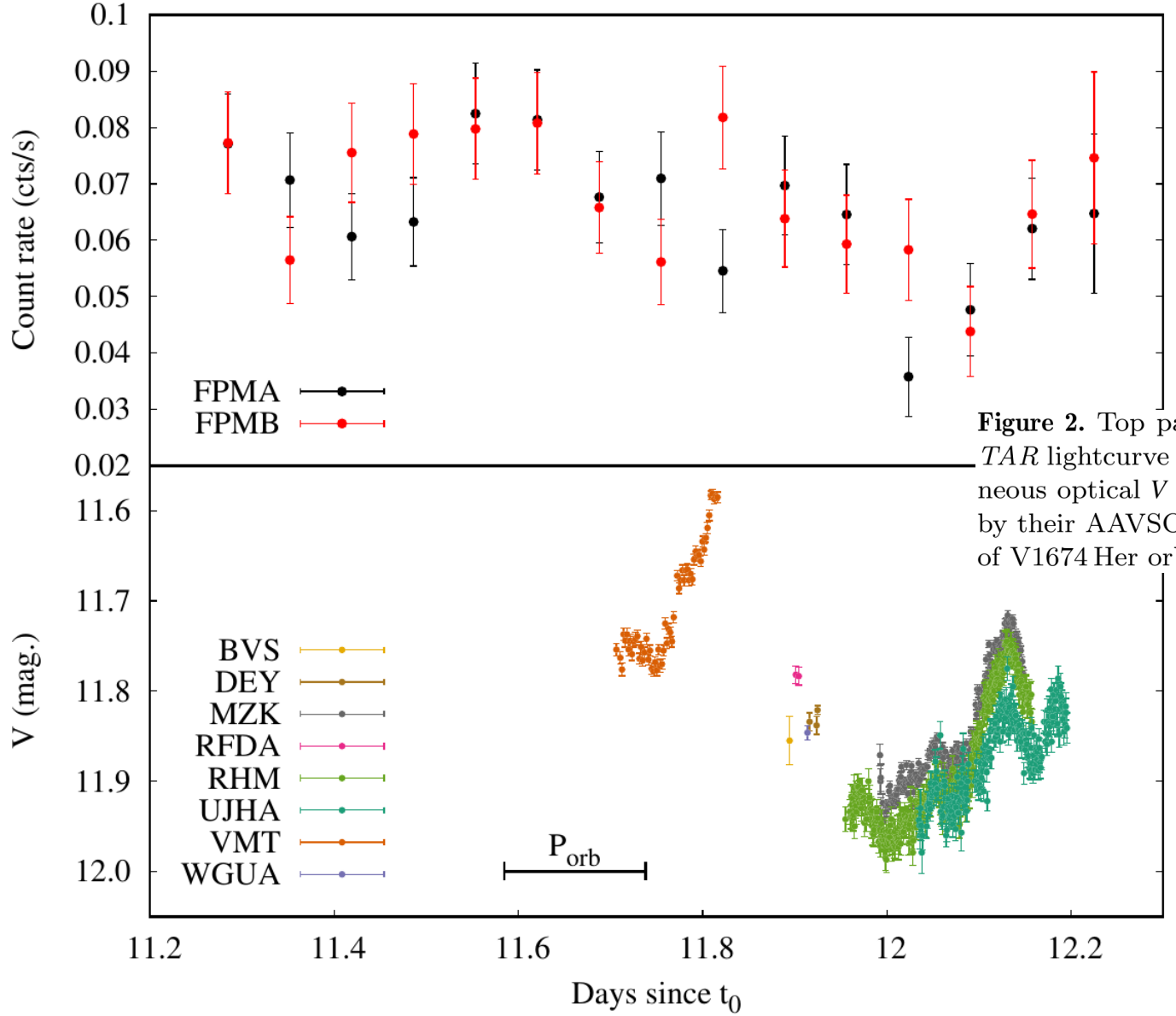
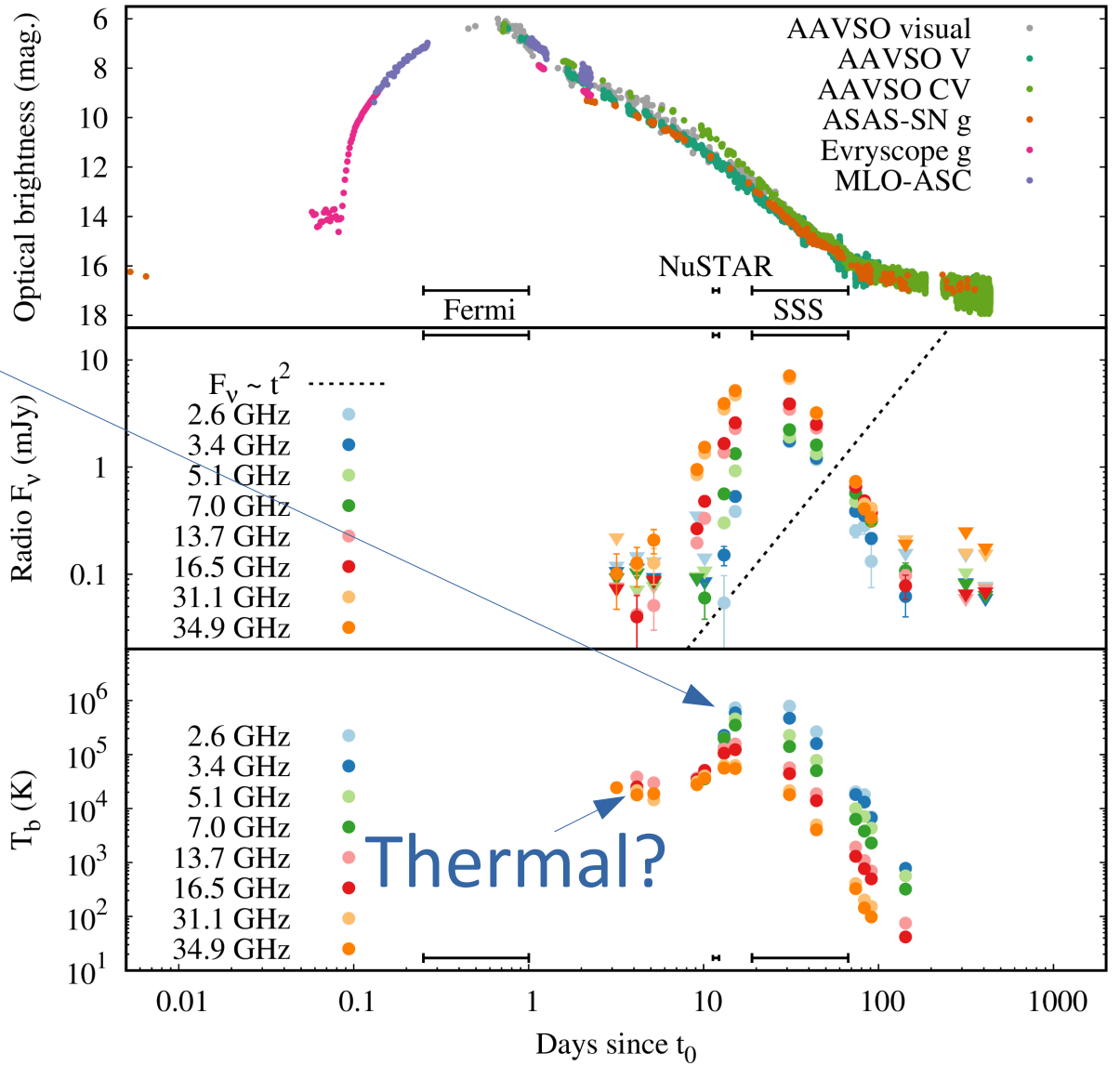


Figure 2. Top panel: the background-subtracted 3.0–30 keV *NuSTAR* lightcurve of V1674 Her (see § 2.1.1). Bottom panel: simultaneous optical V band photometry by multiple observers identified by their AAVSO codes. The horizontal bar indicates the duration of V1674 Her orbital period.

High T_b suggests synchrotron emission in radio



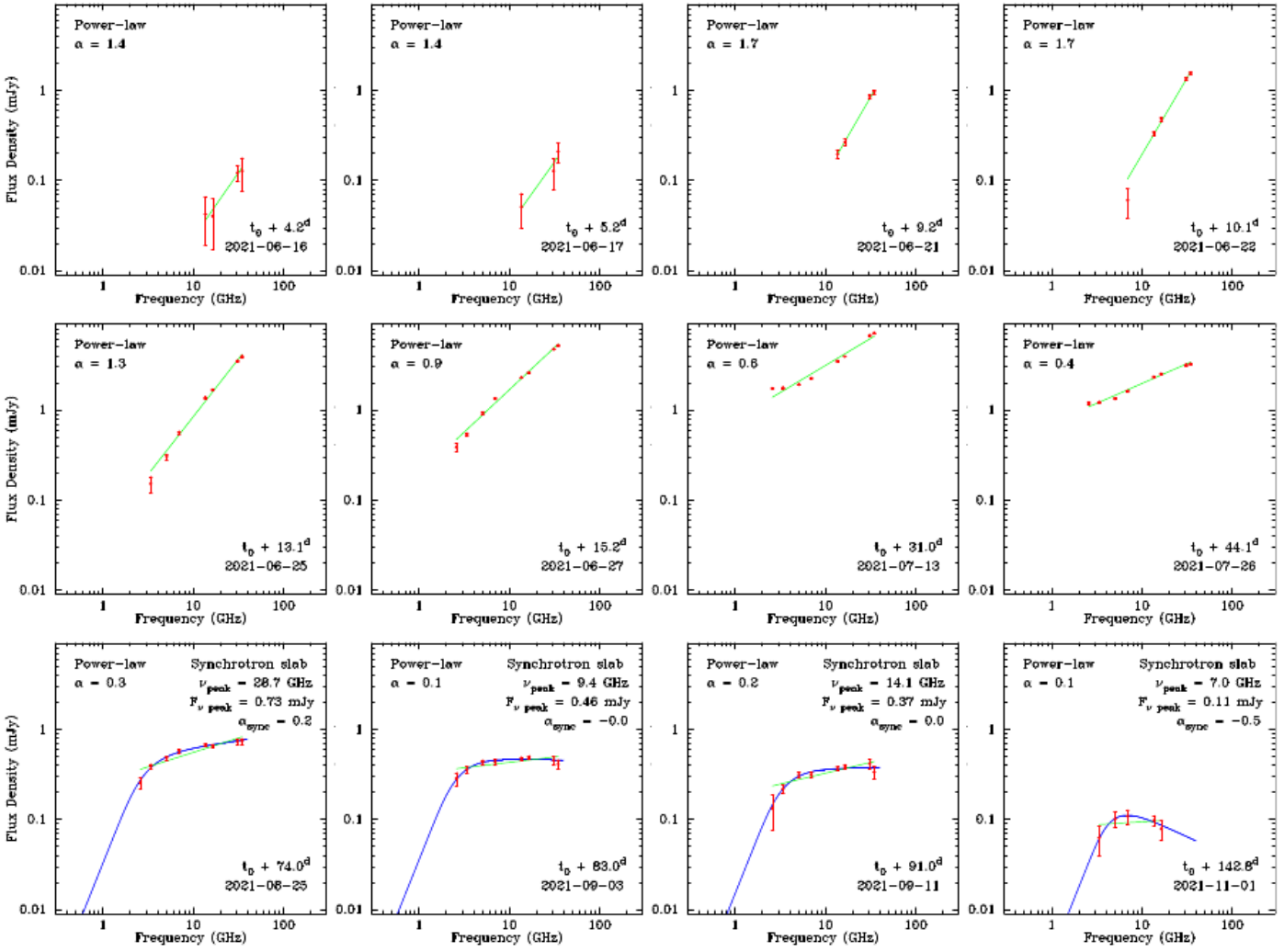


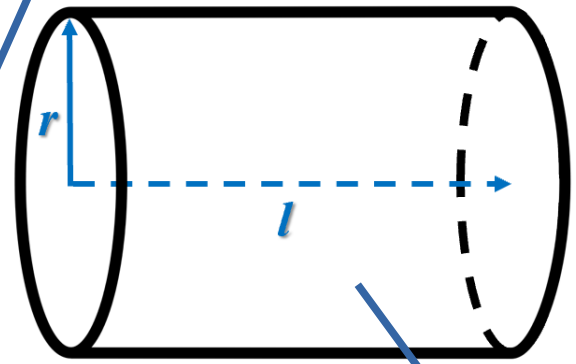
Figure 8. The evolution of the radio spectrum of V1674 Her. The VLA flux density measurements (red) are compared to the simple power-law fit (green line) and a spectrum of a uniform synchrotron-emitting slab. The uncertainty on the reported spectral index values is ~ 0.3 for the power law fits on 2021-06-16, 2021-06-17, 2021-11-01 and $\lesssim 0.1$ in all other cases. The synchrotron slab spectrum can approximate the observations only at late epochs. The spectrum shape is most likely determined by the non-uniform optical depth effects across the source.

Interpreting radio spectra

- High T_b -> non-thermal i.e. *synchrotron*
- Inverted (“hard”) spectrum -> optically thick
- *Can't be synchrotron self-absorption* - would require ridiculously high magnetic field strength
- *Free-free absorption* on an external screen or *Razin-Tsytovich effect* (when synchrotron-emitting plasma is mixed with thermal)?

NuSTAR plasma does not contribute to radio

It's *too faint* and *optically thin*



Line of sight

$$\tau \approx 3.28 \times 10^{-7} \left(\frac{T}{10^4\,\mathrm{K}}\right)^{-1.35} \left(\frac{\nu}{1\,\mathrm{GHz}}\right)^{-2.1} \left(\frac{(\mathrm{EM})_{\mathrm{radio}}}{1\,\mathrm{pc\,cm^{-6}}}\right)$$

$$\tau = 10^{-3} - 10^{-6} \text{ for } \nu = 1 \text{ to } 30\,\mathrm{GHz}$$

$$T_b = (1 - e^{-\tau})T$$

$$(\mathrm{EM})_{\mathrm{X-ray}} = \int n_e n_i dV, \qquad (\mathrm{EM})_{\mathrm{X-ray}} = \pi r^2 (\mathrm{EM})_{\mathrm{radio}}.$$

$$F_\nu = \frac{T_b}{1763\,\mathrm{K}} \left(\frac{\nu}{1\,\mathrm{GHz}}\right)^2 \left(\frac{\theta}{1\,\mathrm{arcsec}}\right)^2 \mathrm{mJy},$$

$$\mathscr{E} = \frac{10^{-14}}{4\pi D_{\mathrm{cm}}^2} (\mathrm{EM})_{\mathrm{X-ray}}, \qquad (\mathrm{EM})_{\mathrm{radio}} = \int n_e n_i dl,$$

$$F_\nu \approx 2\,\mu\mathrm{Jy}$$

Conclusions

Despite being exceptionally fast and magnetic...

- The shock-related properties (GeV/X-ray/radio) of V1674 Her look *remarkably normal* compared to other GeV-emitting novae
- GeV emission appears 6^h (*2 orbital periods*) after the start of the eruption - a *challenge for the common-envelope ejection + fast white dwarf wind scenario* of shock formation

Overleaf draft

https://www.overleaf.com/2459834193khbrhgcbrmsf

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