The orbital period of the nova V1674 Her as observed with TESS

G.J.M. Luna[1,2,3], I.J. Lima[2,4] & M. Orio[5]

[1] *Universidad Nacional de Hurlingham, Argentina*
[2] *Instituto de Astronomía y Física del Espacio, CONICET–UBA, Argentina*
[3] *Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina*
[4] *Facultad de Ciencias Exactas, Físicas y Naturales, UNSJ, Argentina*
[5] *Department of Astronomy, University of Wisconsin, EE.UU.*
[6] *Osservatorio Astronomico di Padova, INAF, Italia*

Received: 09 February 2024 / Accepted: 16 May 2024

Resumen / El satélite TESS observó Nova Her 2021 12.62 días después de su erupción el 12 de Junio de 2021 a las 12 h 53.28 m. Esta variable cataclísmica pertenece al tipo polar intermediario, con un período de spin de ∼501 segundos y un período orbital de 0.1529 días. Durante las observaciones del Sector 40 de TESS, 17 días después de la erupción, se detectó el período orbital de 0.1529(1) días. Además, se detecta una modulación de origen desconocido con una periodicidad de ∼0.537 días desde el día 13 al día 17 luego de la erupción.

Abstract / Nova Her 2021 was observed with TESS 12.62 days after its most recent outburst in June 12.537 2021. This cataclysmic variable belongs to the intermediate polar class, with an spin period of ∼501 seconds and orbital period of 0.1529 days. During TESS observations of Sector 40, the orbital period of 0.1529(1) days is detected significantly 17 days after the onset of the outburst. A modulation of unknown origin with a period of ∼0.537 days is present in the data from day 13 to day 17.

Keywords / binaries: close — novae, cataclysmic variables — stars: individual (V1674 Her)

1. Introduction

V1674 Her (Nova Her 2021) was reported in an outburst on 2021 June 12.537 UT at 8.4 magnitudes by Seiji Ueda (Kushiro, Hokkaido, Japan) reaching naked-eye magnitudes at its peak (Munari et al. 2021; Munari & Valisa 2022 and other references in Drake et al. 2021). Early X-ray observations obtained with *Chandra* (Weisskopf et al., 2000) show an strong modulation with a period of 503.9 s (Maccarone et al., 2021). A period of 501.42 s was later reported by Mroz et al. (2021) found in Zwicky Transient Facility (ZTF) g and r-band data obtained during quiescence. These were the first hints of the presence of a magnetic-accreting white dwarf in the system. The period measurement was refined and confirmed in subsequent X-ray monitoring (Pei et al., 2021; Drake et al., 2021; Orio et al., 2022) and was clearly detected during all the supersoft X-ray phase (Orio et al., 2022).

Photometric data obtained by Shugarov & Afonina (2021) and Patterson et al. (2021) allowed the detection of a 0.15302(2) days period in optical wavelengths. This has since been identified as the orbital period. Then, V1674 Her has the physical characteristics to be identified as a magnetic cataclysmic variable of the intermediate polar type; a binary system where the white dwarf's magnetic field (≈0.1–10 MG) channels material from the inner edge of the truncated accretion disk through the accretion columns. The orbital period was later refined to a value of 0.152921(3) days by Patterson et al. (2022b) by analyzing fast photometry optical data. A 0.153 days period likely present in X-ray data has been reported by Lin et al. (2022).

In this article, we analyze the photometric series obtained with the TESS (Ricker et al., 2015) mission during the scanning of sector 40. The exquisite quality and cadence allow us to search for the orbital period during the decaying phase of a nova. This modulation, observed in fast novae once they fade for about 2-4 magnitudes after outbursts, arise from irradiation of the secondary and/or ellipsoidal variations. We discuss our data and their analysis in Section 2 while results and conclusions are discussed in Sections 3 and 4 respectively.

2. Observations

V1674 Her was observed with TESS during Sector 40, which started on June 25 2021, 12.62 days after the outburst. The total observing time was 676 h. Figure 1a shows the TESS light curve in the context of the post-outburst light curve from AAVSO (Fig. 1b). We extracted the TESS Full Frame Images (FFI) with a cadence of 10 min using `TESSCut` tool (Brasseur et al., 2019) from the Python package `lightkurve` (Lightkurve Collaboration et al., 2018). The target was identified by its `SIMBAD` coordinates and *GAIA* EDR3 catalog (Gaia Collaboration et al., 2021). We tested different aper-

✉ *Contact* / juan.luna@unahur.edu.ar

ture masks thresholds and background masks in order to produce the light curve. The images were selected using hard QUALITY flag discarding unwanted events. We removed the long-term trend, due to the fading of the nova, subtracting a Savitzky-Golay filter (Savitzky & Golay, 1964) (see Figure 1c).

We searched for periods using the Lomb-Scargle (Lomb, 1976; Scargle, 1982) algorithm in the light curve with the SG filter applied (Fig. 1e). We also searched for changes in the orbital period by extracting the power spectrum in 3-days-long sliding windows that overlap 50% (Figure 1d,f).

3. Results

The TESS light curve of V1674 Her from day 17 after the outburst is modulated at the orbital period of P_{orb}=0.1529(1) days, consistent with previous findings. The light curve folded at the orbital period and taking the ephemeris, T_0, from Patterson et al. (2022b), shows a double-peak profile (see Fig. 1g), with secondary minima distant at $\Delta\phi$=0.5 from the main minimum.

Although the observations started 13 days after the outburst, remarkably, the orbital period was not detected until ∼17 days after the outburst, also in agreement with Patterson et al. (2022b). We found that within the error of 0.001 days, we could not detect any changes in the orbital period during the 28.2 days covered by TESS. Patterson et al. (2022b) report a systematic drift toward longer periods in the photometric data taken in 2022 with respect to those taken in 2021. Our observations do not cover the times when the source has returned to quiescence, when the changes in the orbital period seem to manifests.

The variability on time scales longer than the orbital period reported by Sokolovsky et al. (2023) is also observed in the TESS light curve from day 13th until day 17th. A search for periods in this segment of the light curve yields a period of ∼0.537 days, of unknown origin (see Fig. 1h). This period is unlikely to be due to superhumps, which are modulations with periods slightly below or above the orbital period and likely due to a warped/precessing accretion disk. The 0.537 days period is much longer than the orbital period.

4. Conclusion

We analyzed the TESS, observations of Nova Her 2021, that entered into Sector 40 12.62 days after being reported to be in outburst. This nova belongs to the intermediate polar class of cataclysmic variables and, as such, it displays clear modulations with the orbital and white dwarf spin periods. In agreement with other authors, we found that the light curve shows two minima, separated by half a cycle. The secondary minimum is most noticeable once the light curve is decaying more slowly and the systems is reaching quiescence conditions. This secondary minimum could be due to the eclipsed, enhanced emission due to irradiation of the secondary by the still-burning white dwarf (Patterson et al., 2022a).

Acknowledgements: GJML and IJL acknowledge support from grant ANPCYT-PICT 0901/2017. GJML is a member of the CIC-CONICET (Argentina). This research made use of Lightkurve, a Python package for Kepler and TESS data analysis (Lightkurve Collaboration, 2018). We also acknowledge the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

References

Brasseur C.E., et al., 2019, Astrocut: Tools for creating cutouts of TESS images, Astrophysics Source Code Library, record ascl:1905.007

Drake J.J., et al., 2021, ApJL, 922, L42

Gaia Collaboration, et al., 2021, A&A, 649, A1

Lightkurve Collaboration, et al., 2018, Lightkurve: Kepler and TESS time series analysis in Python, Astrophysics Source Code Library, record ascl:1812.013

Lin L.C.C., et al., 2022, MNRAS, 517, L97

Lomb N.R., 1976, Ap&SS, 39, 447

Maccarone T.J., et al., 2021, The Astronomer's Telegram, 14776, 1

Mroz P., et al., 2021, The Astronomer's Telegram, 14720, 1

Munari U., Valisa P., 2022, The Astronomer's Telegram, 15796, 1

Munari U., Valisa P., Dallaporta S., 2021, The Astronomer's Telegram, 14704, 1

Orio M., et al., 2022, ApJ, 932, 45

Patterson J., et al., 2021, The Astronomer's Telegram, 14856, 1

Patterson J., et al., 2022a, ApJ, 924, 27

Patterson J., et al., 2022b, ApJL, 940, L56

Pei S., et al., 2021, The Astronomer's Telegram, 14798, 1

Ricker G.R., et al., 2015, Journal of Astronomical Telescopes, Instruments, and Systems, 1, 014003

Savitzky A., Golay M.J.E., 1964, Analytical Chemistry, 36, 1627

Scargle J.D., 1982, ApJ, 263, 835

Shugarov S., Afonina M., 2021, The Astronomer's Telegram, 14835, 1

Sokolovsky K.V., et al., 2023, MNRAS, 521, 5453

Weisskopf M.C., et al., 2000, J.E. Truemper, B. Aschenbach (Eds.), *X-Ray Optics, Instruments, and Missions III, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, vol. 4012, 2–16

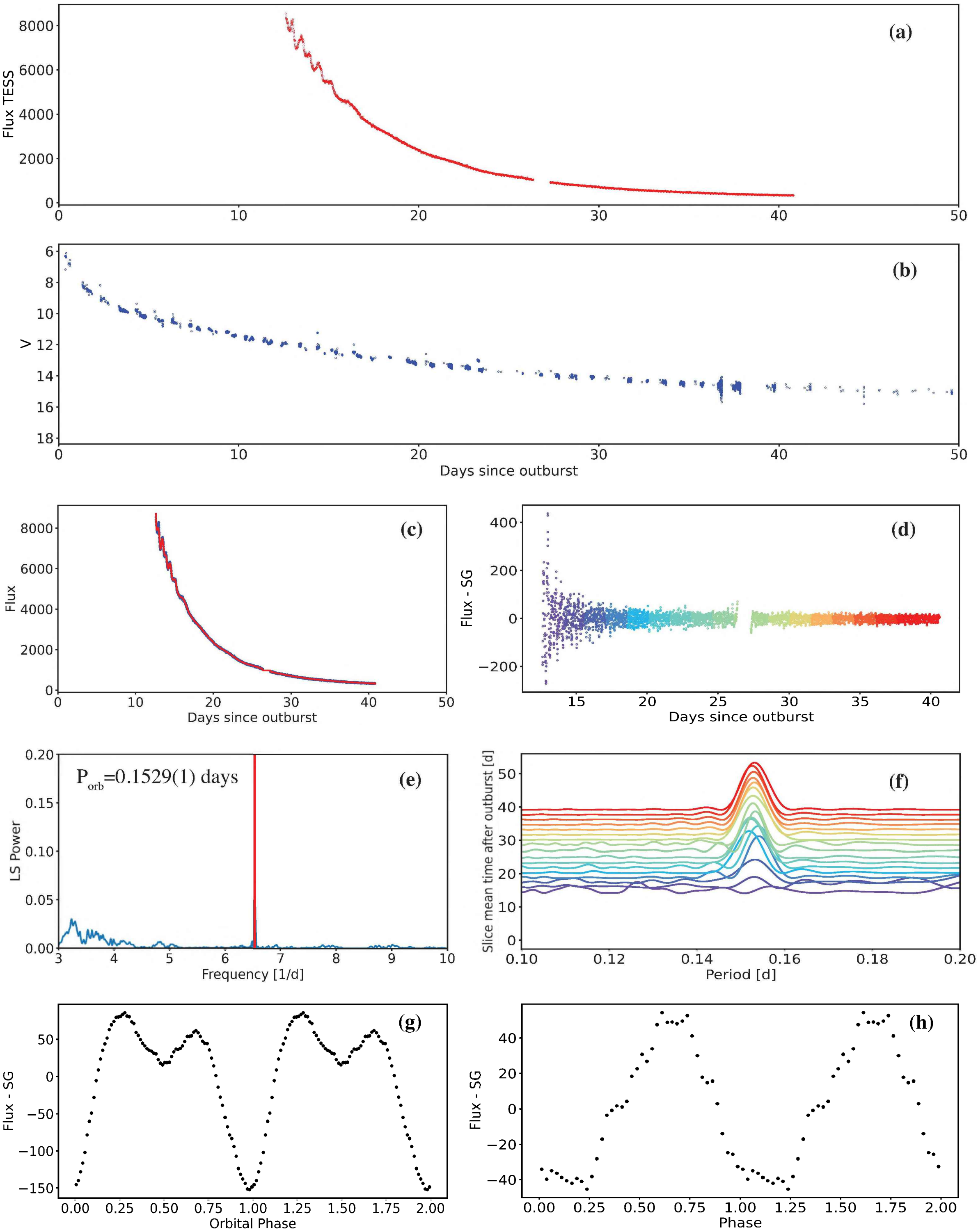

Fig. 1. *Panel (a):* TESS light curve of V1674 Her observed during Sector 40, 13 days after outburst. *Panel (b):* AAVSO, V-magnitud light curve of V1674 Her after outburst on June 12 2021. In both cases the error bars are smaller than the symbol size and thus are not included. *Panel (c):* TESS light curve with a Savitzky-Golay (SG) filter (red line) to remove the long-term trend. *Panel (d):* TESS light curve after applying the SG filter. *Panel (e):* Lomb-Scargle power spectrum of the TESS -SG light curve. The red vertical line marks the frequency of the orbital period at P_{orb}=0.1529(1) days. *Panel (f):* Lomb-Scargle power spectra of each 3-day portion of light curve. Colors correspond to the colors in Panel (d). The 3-day portions of the light curve were extracted from a moving window with 50% overlap. The orbital period is significantly detected after day $\sim$ 17. *Panel (g):* TESS light curve folded at the orbital period P_{orb}=0.1529 days. The light curve was binned at 80 bins/period. *Panel (h):* TESS light curve folded at period P=0.537 days with arbitrary ephemeris. The light curve was binned at 40 bins/period.