Optical studies of γ-ray binaries and candidate systems

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Abstract. Highly accurate photometry of the optical companion in gamma-ray binary systems has the potential to enable the exploration of previously unknown phenomena. Here we report the discovery of repeated optical flares evolving on time scales of about one day in the optical light curve of the well known system LSI +61303. Their amplitude does not exceed 0.01-0.02 magnitudes and, therefore, they are only within reach of space observatories such as the Transiting Exoplanet Survey Satellite (TESS) in the 600-1000 nm bandpass. We tentatively propose that these flaring events are shock-powered in nature as the compact object in LSI+61303 interacts with the circumstellar envelope of its Be star companion. Comparison with other systems (MWC 148 and MWC 656) is also addressed. Moreover, the TESS data appears as a useful complementary tool to search for signatures of binarity in other stellar objects tentatively associated with unidentified gamma-ray sources.

e-Poster presented by

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LS I +61 303 is one of the most famous gamma-ray binaries hosting a B0 Ve optical counterpart with a compact companion recently identified as a neutron star[1]. The system most remarkable property is its orbitally modulated light curve across the whole electromagnetic spectrum with a period close to **26.5 days**.

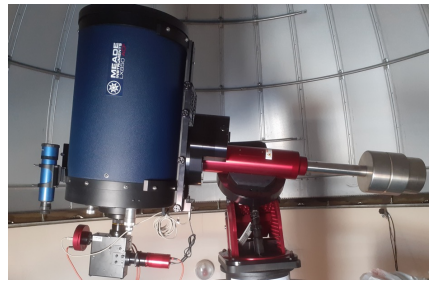
In this poster we report evidence of previously unseen **optical microflares** with small-amplitude (ΔV=0.01-0.02 magnitudes) evolving on daily time-scales[2]. This finding has been possible thanks to the availability of highly accurate photometry from the **Transiting Exoplanet Survey Satellite** (*TESS*).

LS I +61 303 was monitored by *TESS* during its **Sector 18 in November 2019** covering a full orbit. Tens of microflare events were recorded with rise and decay times as short as ~0.1 day. Wavelet analysis points to a recurrence interval of about 1 day, that becomes slightly shorter in the vicinity of periastron passage.

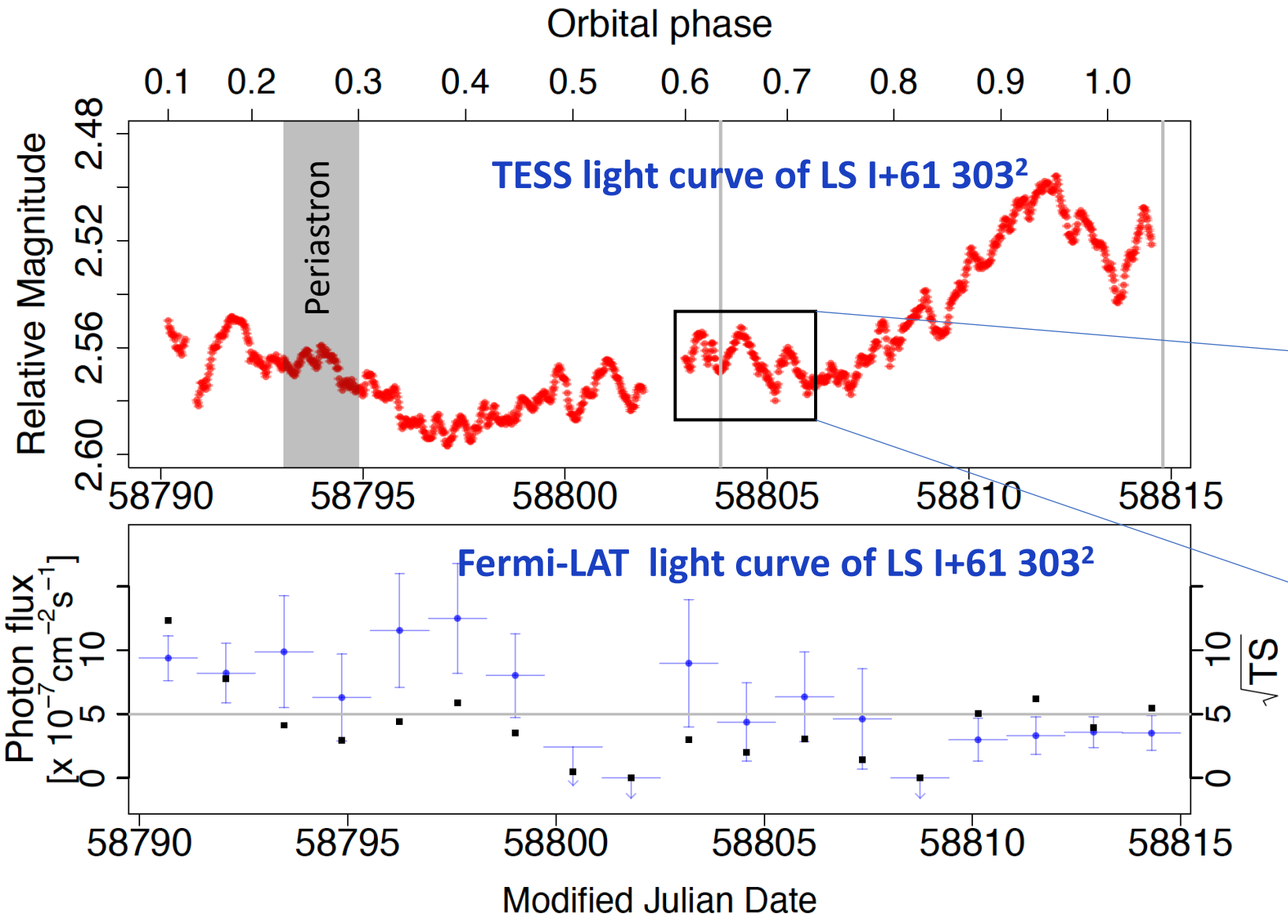
We also analyze and report about other *TESS*-simultaneous observational data: the **gamma-ray light curve** and **optical spectroscopy** provided by the *Fermi* Large Area Telescope (LAT) and the University of Jaén telescope (UJT), respectively.

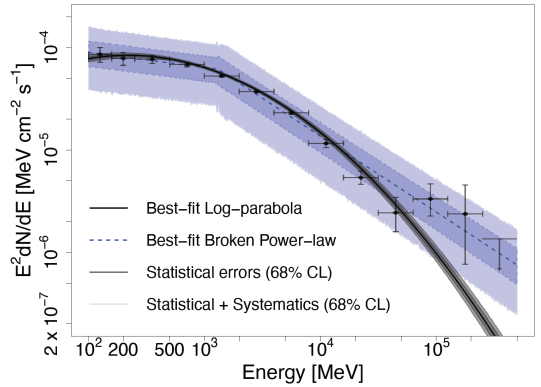
TESS
Credit: NASA's Goddard Space Flight Center

Fermi
Public Domain

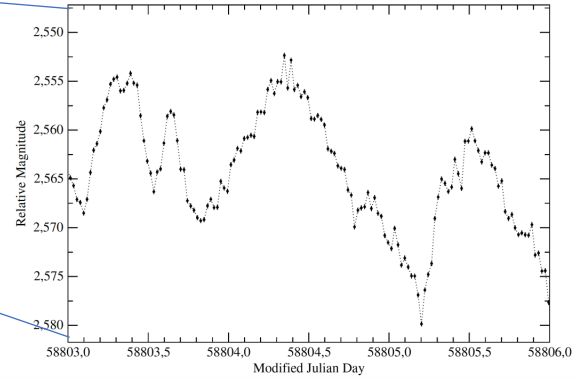


Univ. of Jaén 0.41 m telescope with a LISA spectrograph

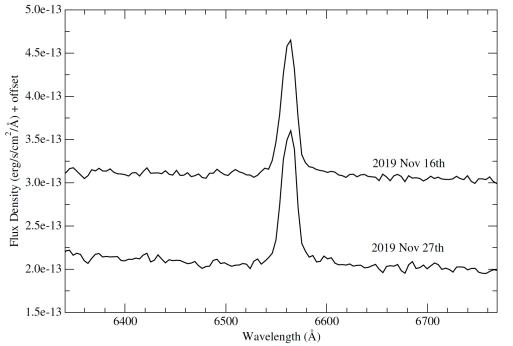




Fermi gamma-ray spectrum



Representative optical microflares



UJT Hα spectra at vertical line times

The time interval shown corresponds to 2019 November 03rd-28th.

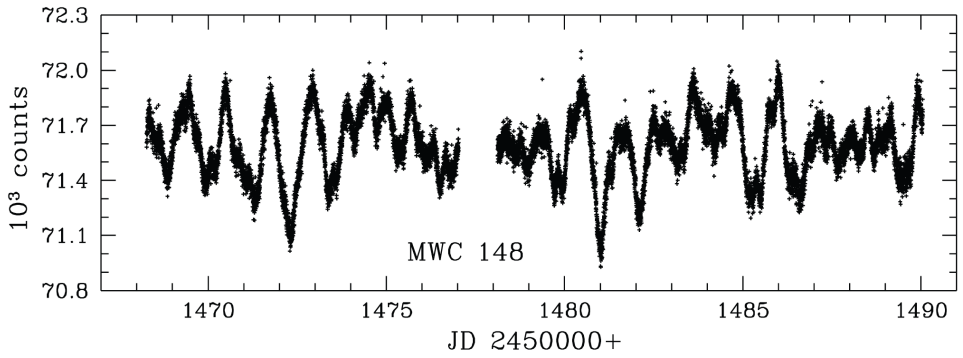
The availability of highly accurate light curves of gamma-ray binaries using *TESS* data opens a new window in the time domain astrophysics of these systems. The reported low-amplitude, multiple flaring events in LS I +61303 are a newly observed fact whose physical interpretation still remains challenging.

We tentatively propose that microflares are due to **optical emission from shocks**[2] created while the neutron star companion interacts with the Be star circumstellar envelope across the system orbit.

The Be star circumstellar disk was actually well developed during Sector 18 pointing. In fact, the Hα equivalent width measured with the UJT (-13.6 Å) appeared close to previously reported maxima.

By analogy with novae-shocks, one would expect some gamma-ray emission enhancement concurrent with the *TESS* microflares. Unfortunately, our simulations render unlikely that this could be detected with current *Fermi*-LAT data due to sensitivity limitations as the required intra-day time binning is too short.

Combined with optical spectroscopy, the *TESS* data of Be gamma-ray binaries and candidate systems also have a strong potential to constrain stellar parameters such as rotational periods and circumstellar disk inclinations[3].



TESS light curve of MWC 148 adapted from (3)

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3. Zamanov, R. K., et al. Astronomische Nachrichten, **342**, 531 (2021)

For further LS I +61 303/*TESS*-related details please look at:

https://arxiv.org/abs/2205.05380

A&A 662, A27 (2022)
https://doi.org/10.1051/0004-6361/202243318

Astronomy & Astrophysics

Optical microflares in LS I +61 303 and the search for their multiwavelength counterpart

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Received 12 February 2022 / Accepted 29 April 2022

ABSTRACT

Context. Stellar sources of gamma rays are one of the front lines in modern astrophysics whose understanding can benefit from observational tools not originally designed for their study.
Aims. We take advantage of the high precision photometric capabilities of present-day space facilities to obtain a new perspective on the optical behavior of the X-ray and gamma-ray binary LS I +61 303. Previously unknown phenomena whose effects manifest with amplitudes below 0.01 magnitude can now be clearly observed and studied.
Methods. Our work is mainly based on the analysis of optical and gamma-ray archival data and uses the tools recommended by the different collaborations that provide these valuable observational resources (in particular, the TESS and *Fermi* orbiting observatories). In addition, complementary ground-based optical spectroscopy has also been conducted.
Results. We report the discovery of small-amplitude optical flares on timescales of a day in the LS I +61 303 light curve. Different alternative scenarios to explain their origin are tentatively proposed.

Key words. stars: flare – gamma rays: stars – X-rays: binaries – stars: emission-line, Be – stars: individual: LS I +61 303

Acknowledgements. JM, PLLE and ESA acknowledge support by grant PID2019-105510GB-C32 / AEI / 10.13039/501100011033 from State Agency for Research of the Spanish Ministry of Science and Innovation. We also acknowledge support by Consejería de Economía, Innovación, Ciencia y Empleo of Junta de Andalucía as research group FQM- 322, as well as FEDER funds. EM acknowledges support by grant P18-FR-1580 from the Consejería de Economía y Conocimiento de la Junta de Andalucía under the Programa Operativo FEDER 2014-2020. JMP, DdS and JN acknowledge financial support from the State Agency for Research of the Spanish Ministry of Science and Innovation under grant PID2019-105510GB-C31 and through the Unit of Excellence María de Maeztu 2020-2023 award to the Institute of Cosmos Sciences (CEX2019-000918-M). This poster includes data collected with the *TESS* mission, obtained from the MAST data archive at the Space Telescope Science Institute (STScI). Funding for the TESS mission is provided by the NASA Explorer Program. STScI is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.