New Online Database of Symbiotic Variables

Variability of symbiotic stars from the New Online Database of Symbiotic Variables with NASA TESS

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4th June 2024 | Symbiotic stars, weird novae, and related embarrassing binaries | Prague, Czech Republic

References:
Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429
Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662
Merc et al., 2020, Contributions of the Astronomical Observatory Skalnaté Pleso
doi: 10.31577/caosp.2020.50.2.426

- **latest** catalog before 2019 published in **2000** (Belczyński et al.)
  - **218** objects (incl. 17 extragalactic)
- new, modern, complex, online database
- **New Online Database of Symbiotic Variables**
  - https://sirrah.troja.mff.cuni.cz/~merc/nodsv/
  - **1190** (284 + 751 + 155) objects in our Galaxy
  - 184 (71 + 107 + 6) in 16 external galaxies
- **confirmed**, **candidates** (likely, possible, suspected) + **misclassified** objects
- census by Akras et al. (2019)
  - 257 confirmed in MW
  - 66 confirmed extragalactic

Symbiotic stars with TESS

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

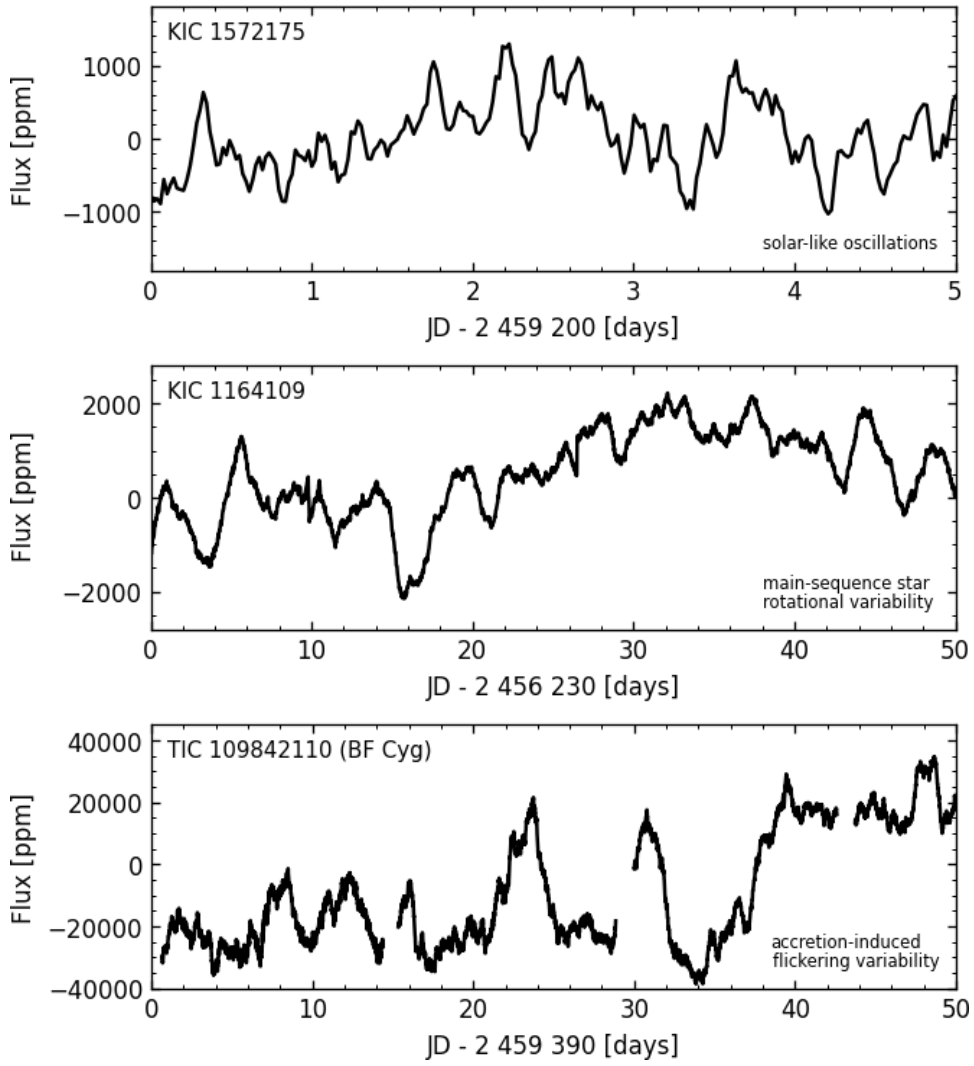

Figure: Comparison of Kepler light curve of KIC 1572175, KIC 1164109, and TESS light curve of BF Cyg.

Flickering variability

- rapid variability studied only **sparcely**
  - few-hour-long light curves from ground
  - variability connected with **accretion**
- flickering
  - **stochastic** variability on timescales of **minutes** and **hours**
  - **amplitude** rising towards **blue** (highest in near-UV; from ground U or B filter)
  - amplitude is **variable in time**
- the source of the flickering variations is though to be **the accretion disk**
  - propagation of disturbances in the inner accretion disk?

References:
Sokoloski et al., 2001, MNRAS
doi: 10.1046/j.1365-8711.2001.04582.x
Scaringi et al., 2015, Science Advances
doi: 10.1126/sciadv.1500686
Munari, 2019, Review in The Impact of Binary Stars on Stellar Evolution
arXiv:1909.01389

Flickering variability

- detected or likely **detected in 22 confirmed** galactic symbiotic stars
  (out of 284 known SySts in the Milky Way)

- flickering is **universal phenomenon** in **accreting** systems
  - AGNs, T Tau stars, X-ray binaries, cataclysmic variables...
  - MS, WD, NS, BH accretors
  - behaviour depends on the **physical size of the accreting object**

- accreting component in symbiotic stars is a **WD or NS**

References:
Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429
Sokoloski et al., 2001, MNRAS
doi: 10.1046/j.1365-8711.2001.04582.x
Scaringi et al., 2015, Science Advances
doi: 10.1126/sciadv.1500686

Flickering variability with TESS

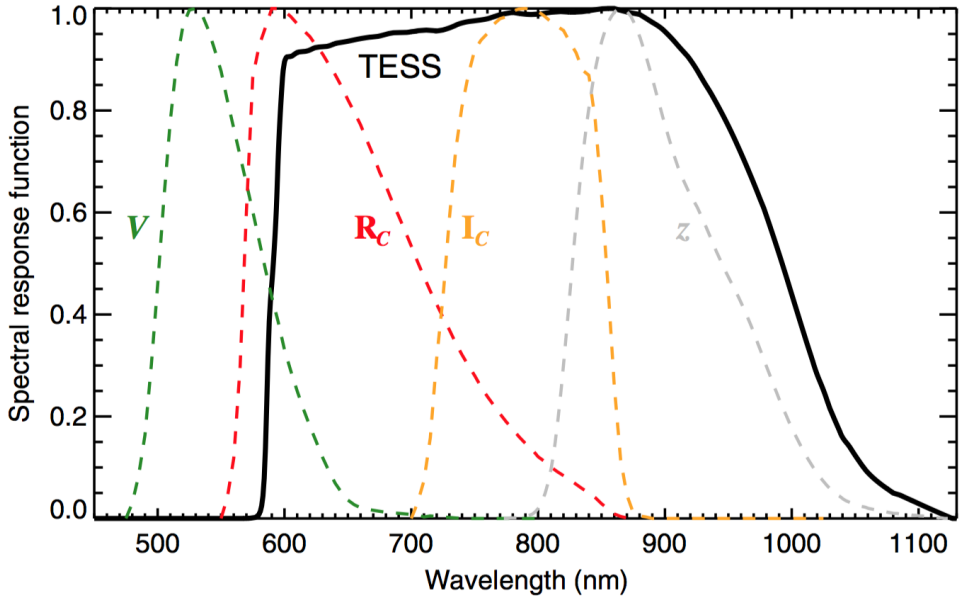

Figure: TESS passband (Ricker et al., 2015).

- **TESS passband**
  - red part of the optical and near-IR
  - in symbiotic stars, flux is **dominated by the giant** at these wavelengths
  - one would expect to see variability connected with the giant

References:

Ricker et al., 2015, *Journal of Astronomical Telescopes, Instruments, and Systems*
doi: 10.1117/1.JATIS.1.1.014003

Flickering variability with TESS

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

- **Should we see** flickering in the TESS band?
  - the amplitude in B -> 0.01 – 0.1 mag
  - sometimes >0.5 mag
  - amplitude in TESS depends on T_{eff} of the giant, disk temperature, flux ratio between disk and giant, amplitude in B

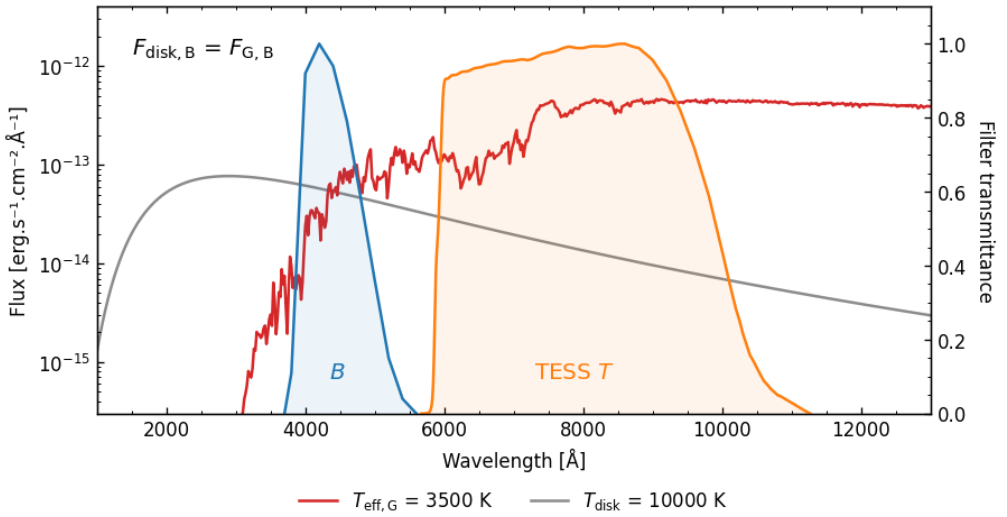

Figure: Case when flux of the red giant and the accretion disk are equal in B band.

Flickering variability with TESS

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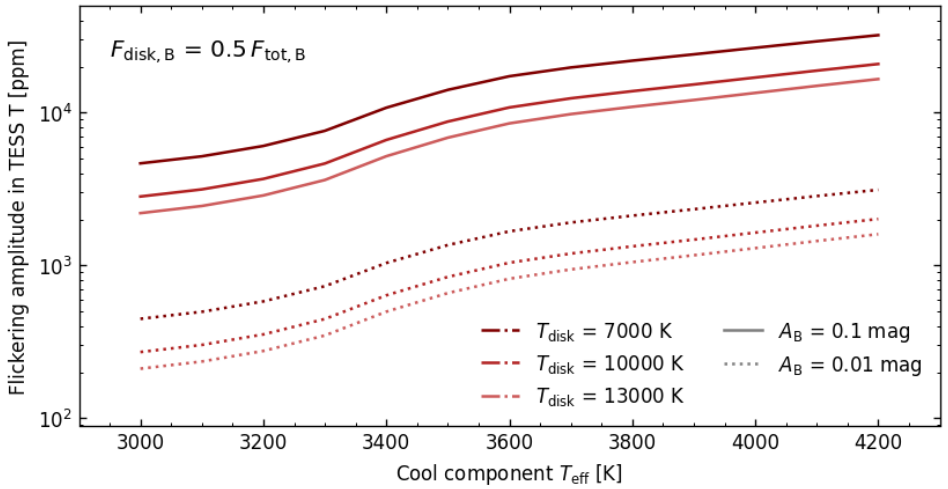
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116



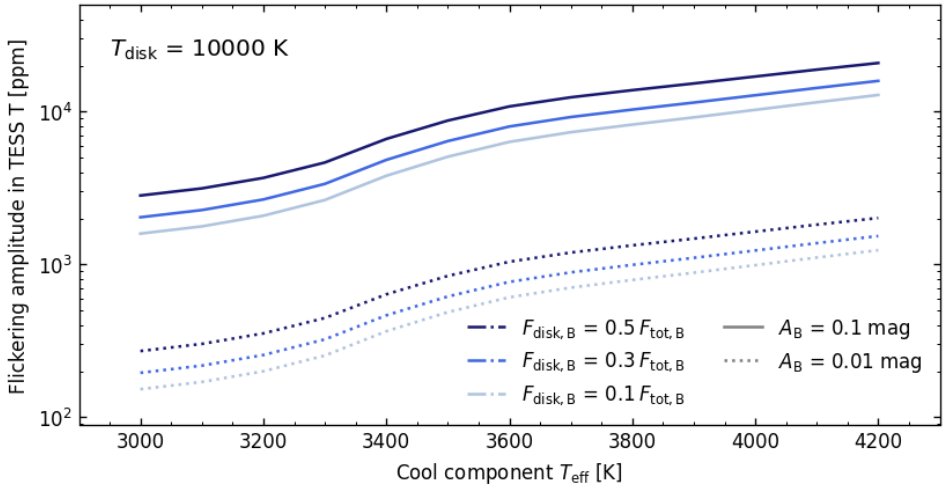


Figure: Expected flickering amplitude.

TESS data on symbiotic stars

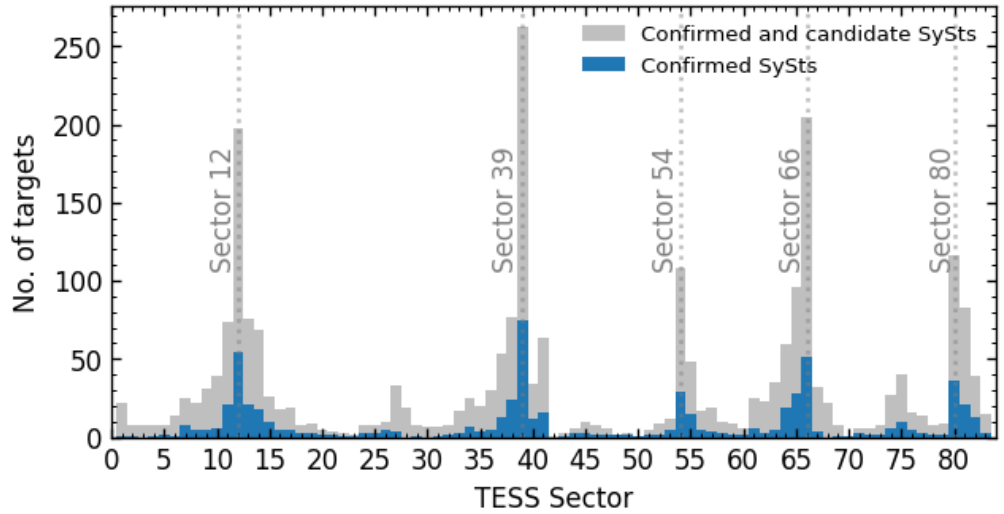


Figure: Number of symbiotic stars in particular sectors.

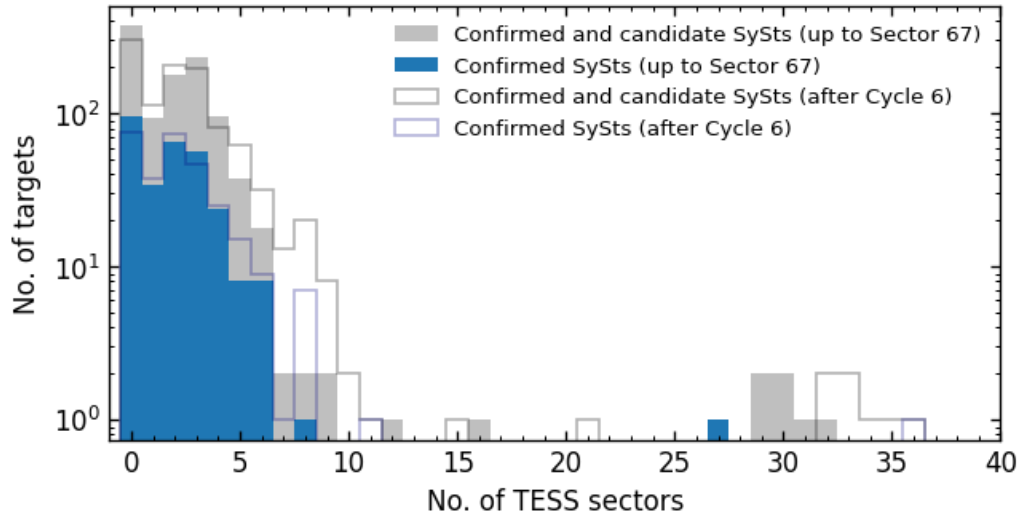


Figure: Number of sectors available for symbiotic stars.

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

TESS data on symbiotic stars

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Merc et al., 2024, Astronomy & Astrophysics
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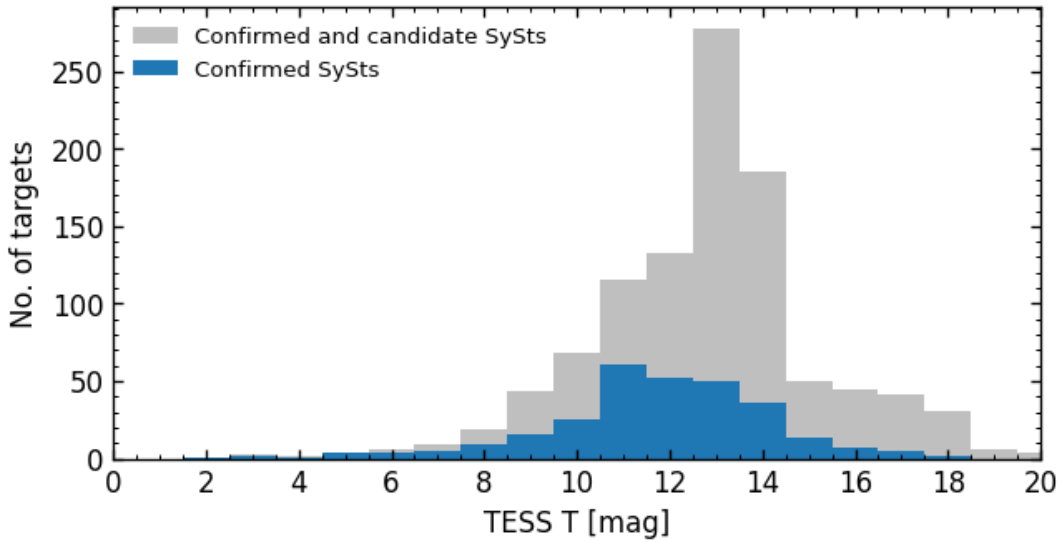

Figure: TESS T magnitude distribution of symbiotic stars.

TESS data on symbiotic stars

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doi: 10.1051/0004-6361/202348116

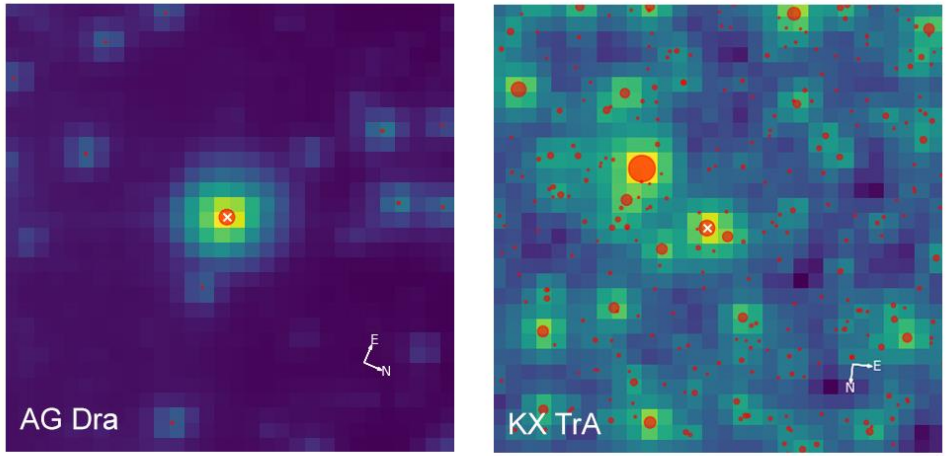

Figure: TESS fields of selected symbiotic stars from tpfplotter by J. Lillo-Box (Aller et al., 2020).

TESS data on symbiotic stars

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Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

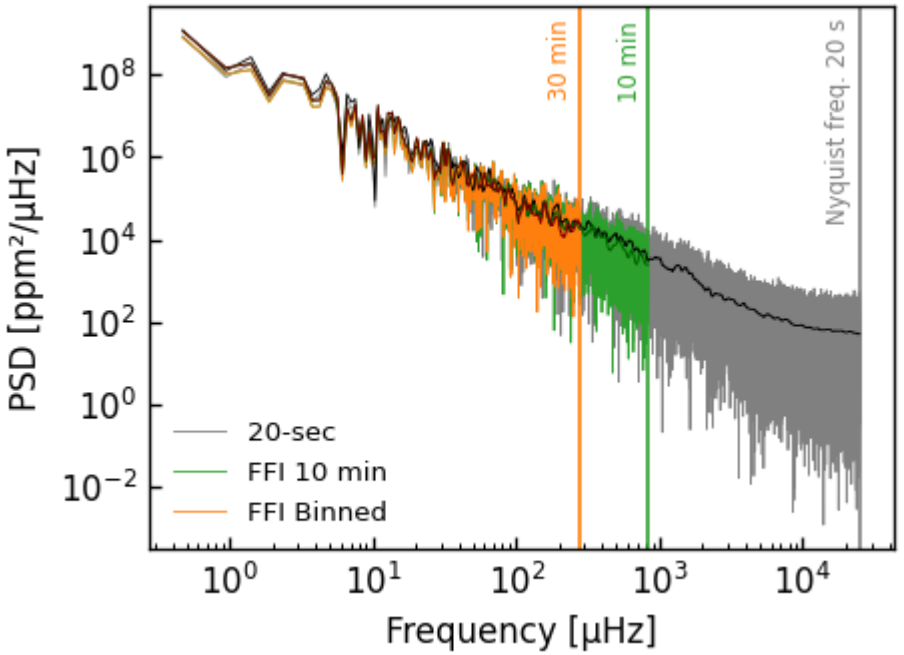

Figure: PSD of T CrB.

Sectors 1 – 26: 30 min cadence
Sectors 27 – 55: **10 min cadence**
Sectors 56+: 200 sec cadence

TESS data on symbiotic stars

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doi: 10.1051/0004-6361/202348116

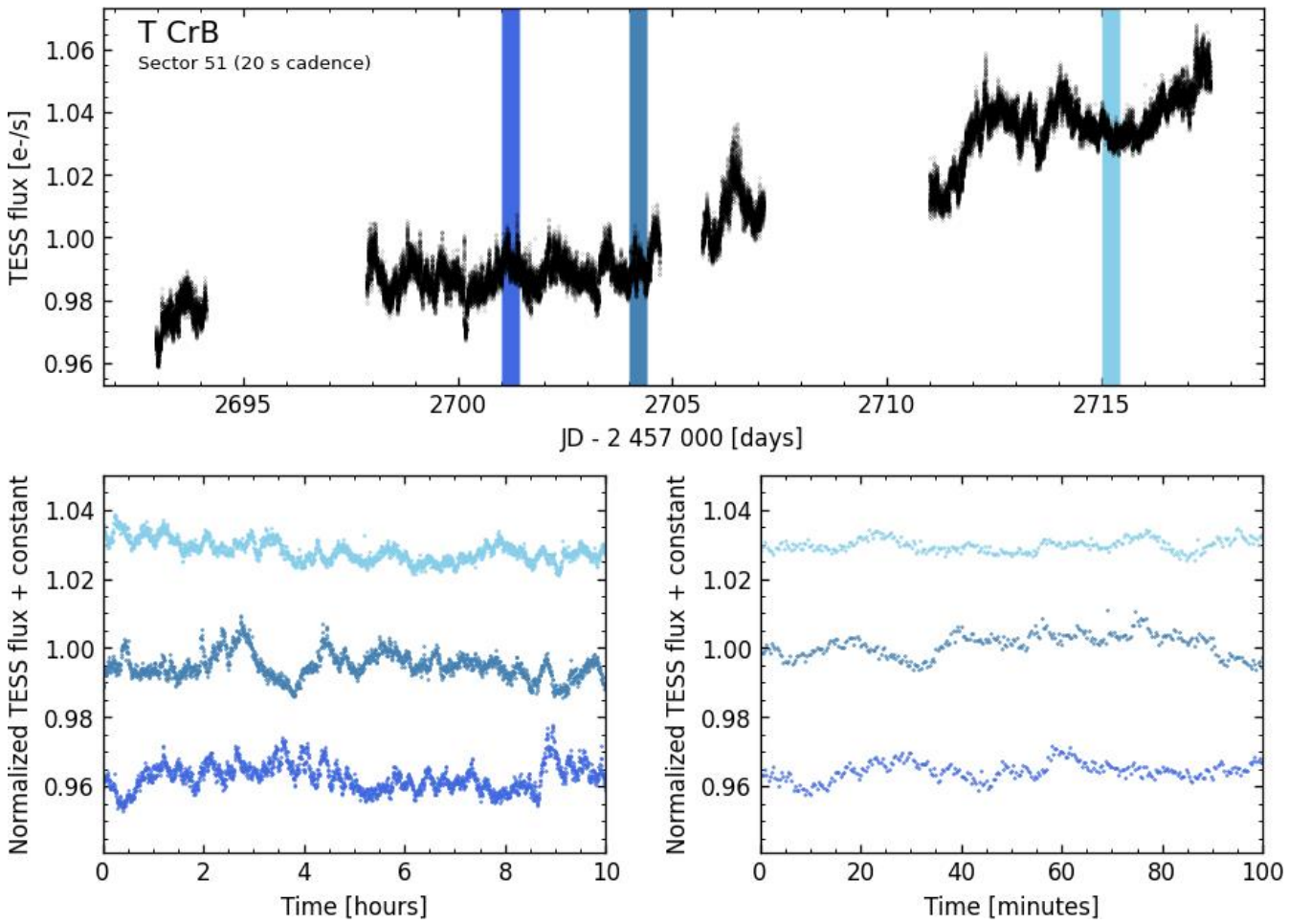
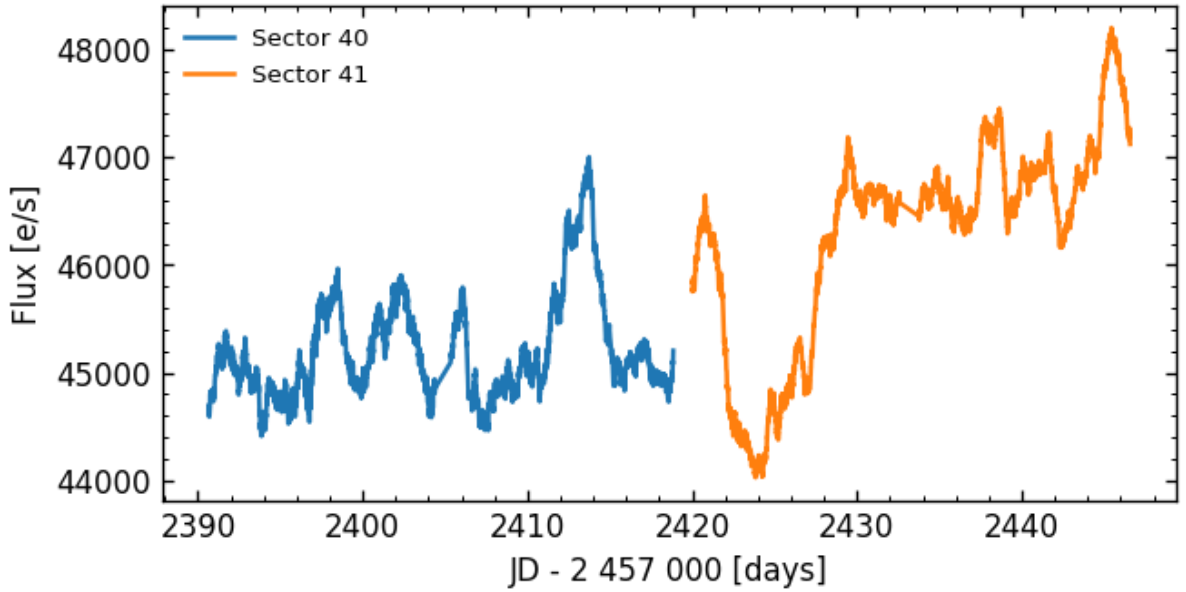
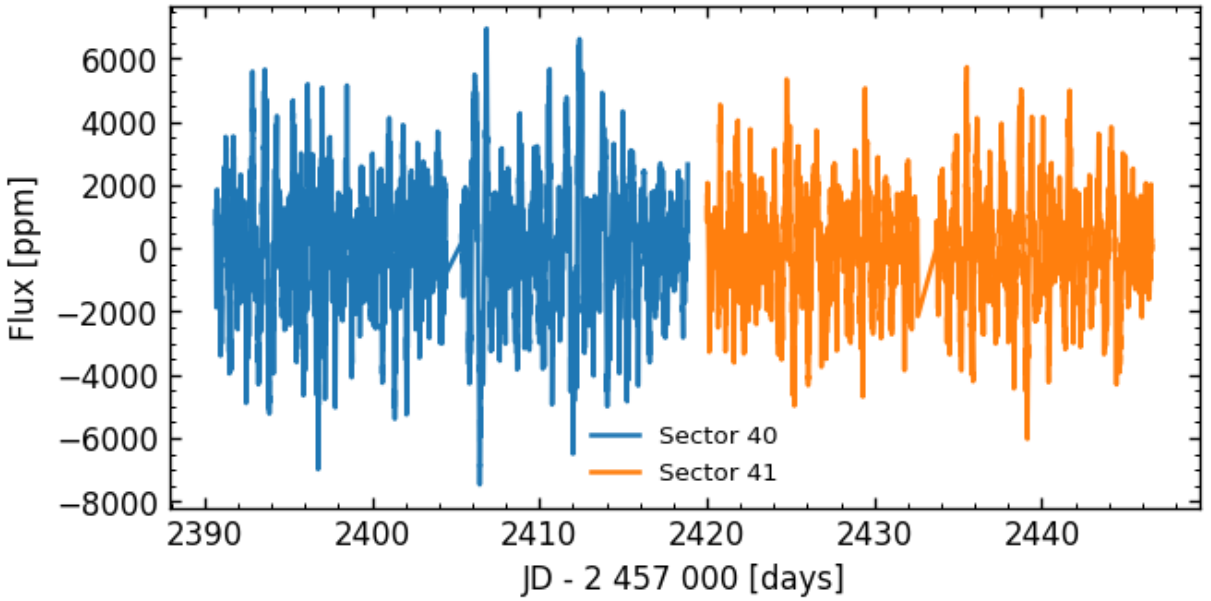


Figure: TESS sector 51 data for T CrB, symbiotic recurrent nova.

Filtering





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Filtering

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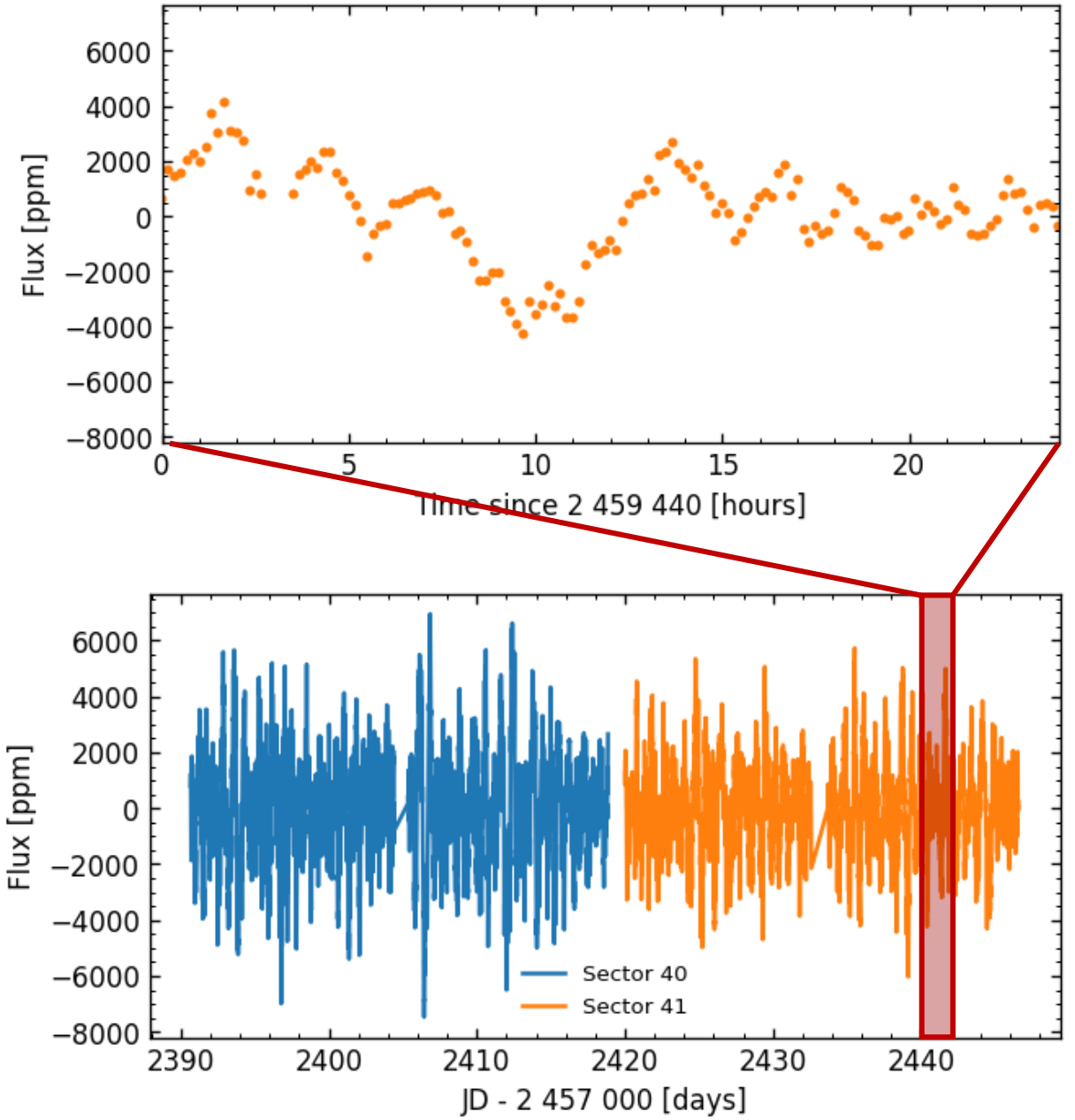
doi: 10.1051/0004-6361/202348116



Flickering amplitude

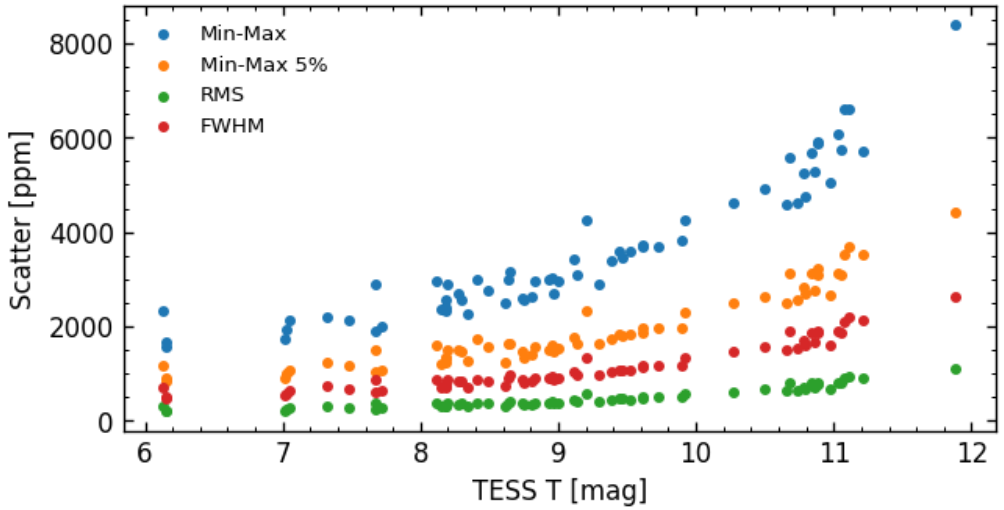


Figure: Noise in the light curves of single giants.

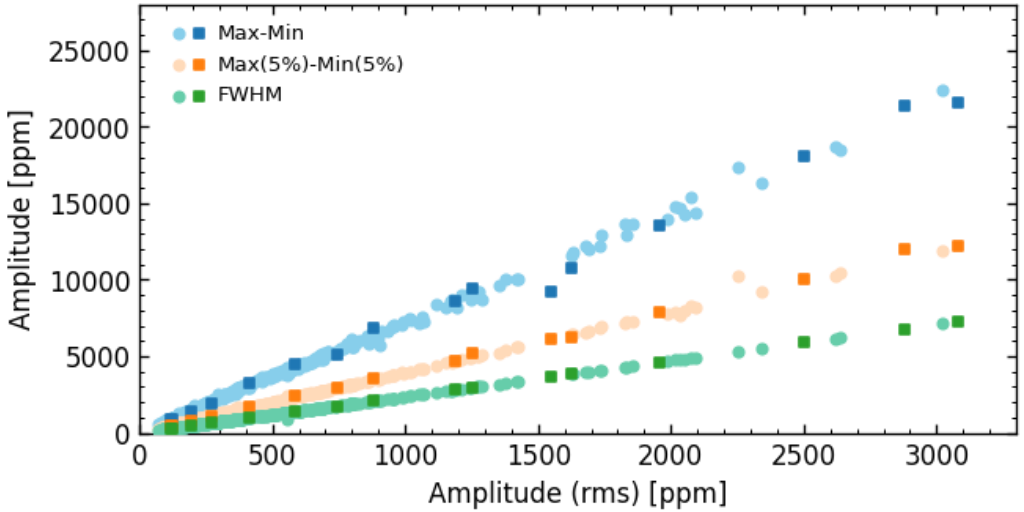
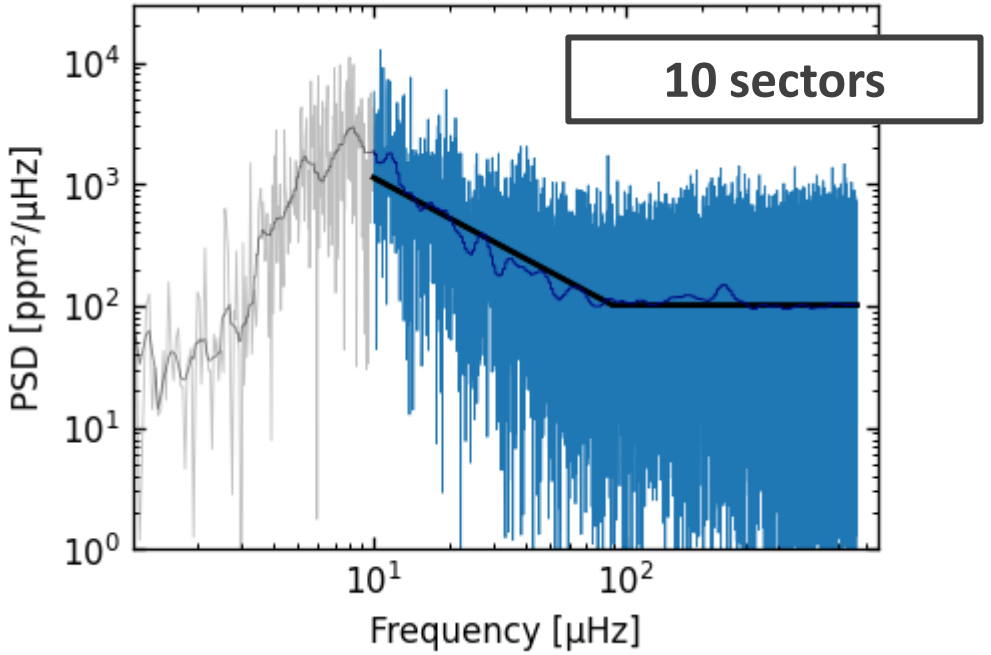


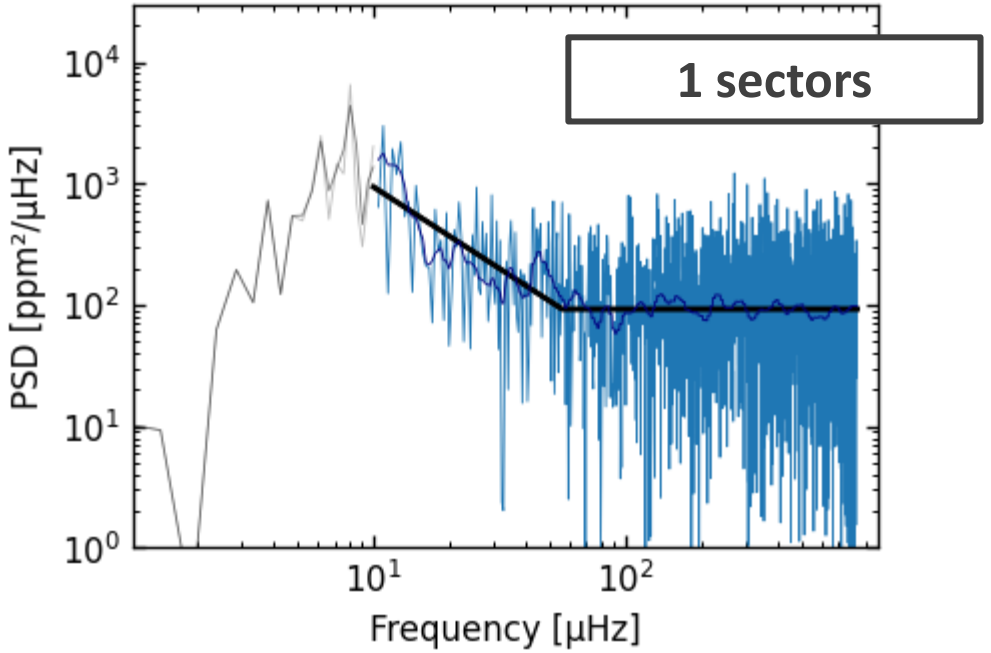
Figure: Various methods to obtain variability amplitude.

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

PSD

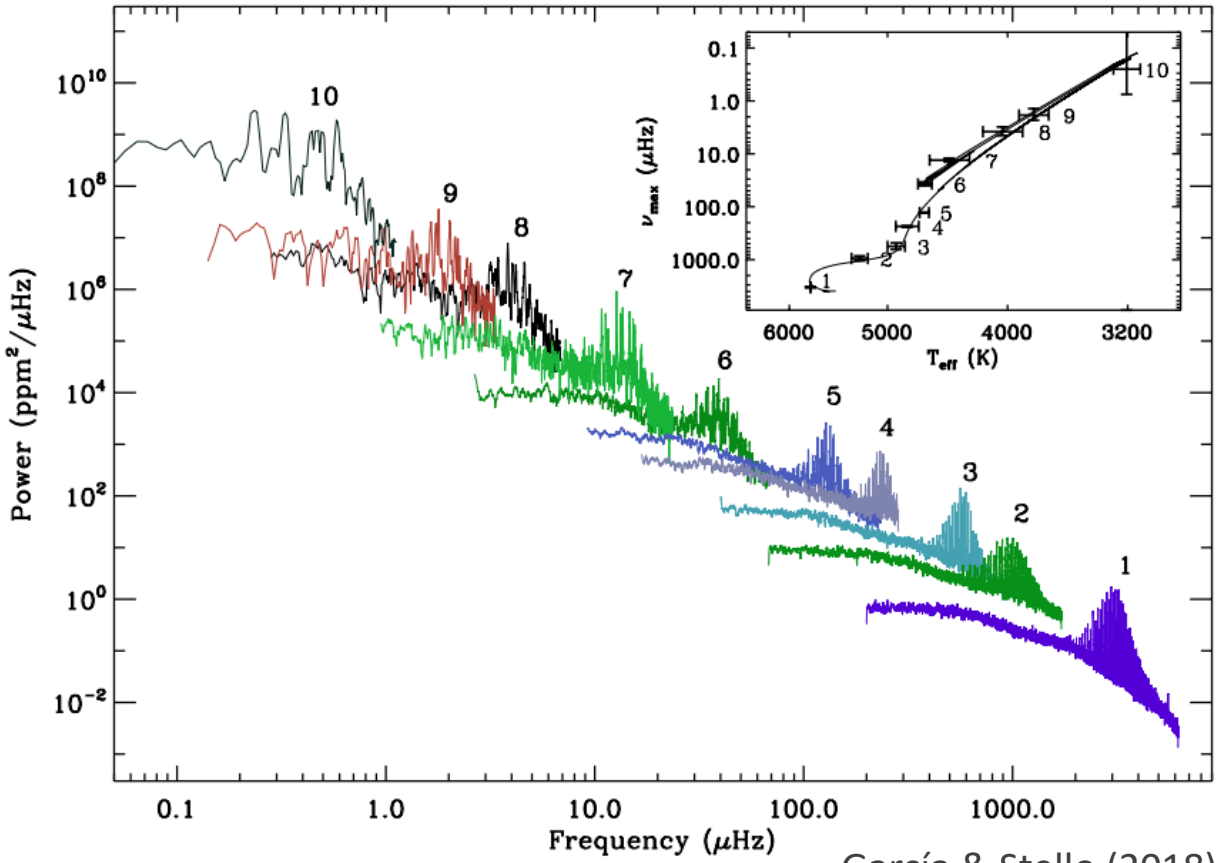
References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116





PSD

References:
García & Stello, 2018, Chapter 11 of the book Extraterrestrial Seismology
doi: 10.1017/CBO9781107300668.014



García & Stello (2018)

- **contribution of the red giant** (granulation)?
  - maximum at shorter frequencies

Flickering in symbiotic stars

- **known flickering sources** among SySts
  - 22 (but three not observed by TESS)
  - 2 very bright (saturated)
  - 1 contaminated by a nearby eclipsing binary
  - in total **16 more-or-less usable**

- **sample of 335 (single) red giants for comparison**
  (3000 K < T_{eff} < 4000 K)
  - Yu et al. (2020) -> Kepler field
  - Mackereth et al. (2021) -> TESS southern continuous viewing zone
  - processed in a same way as SySts

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

Yu et al., 2020, MNRAS
doi: 10.1093/mnras/staa300
Mackereth et al., 2021, MNRAS
doi: 10.1093/mnras/stab098

Flickering in symbiotic stars

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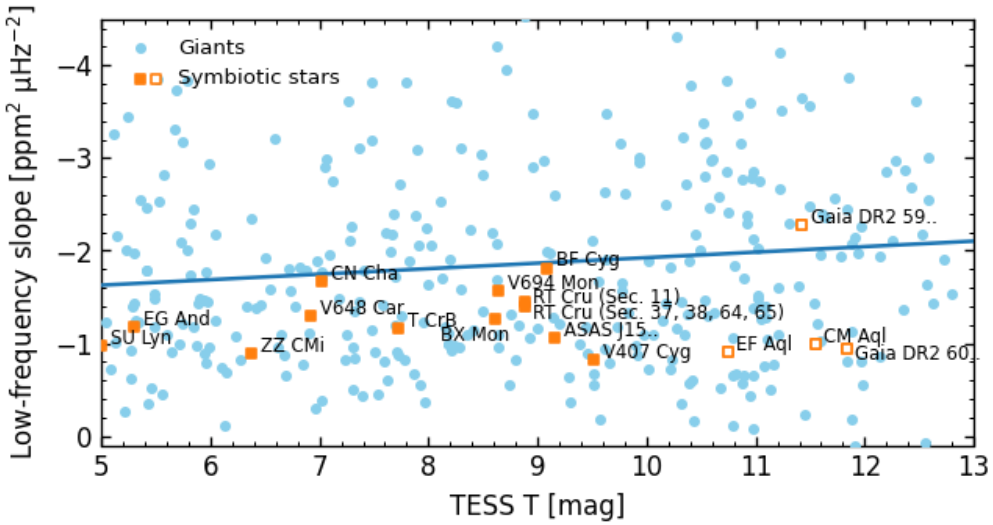

Figure: Low-frequency slope.

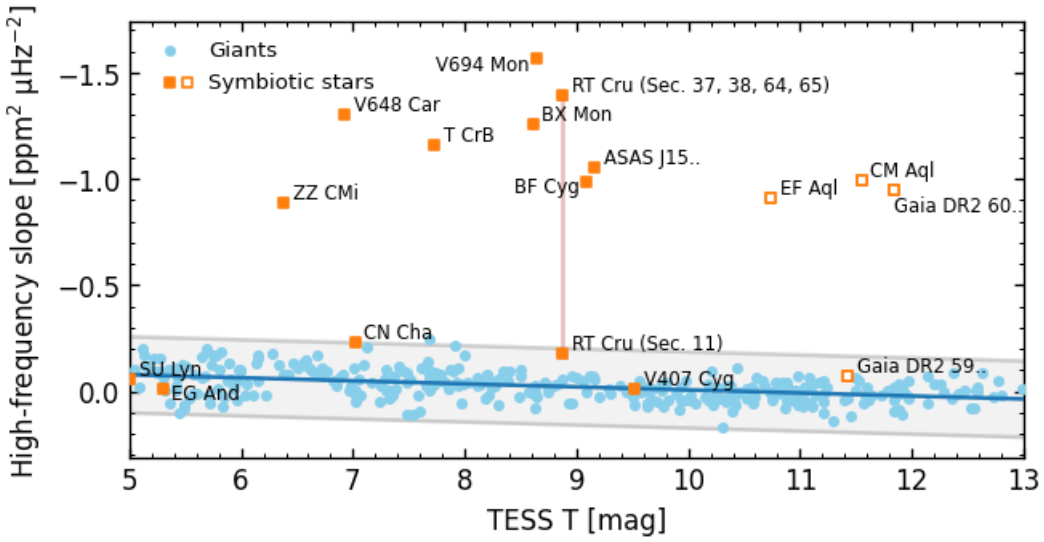

Figure: High-frequency slope.

Flickering in symbiotic stars

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doi: 10.1051/0004-6361/202348116

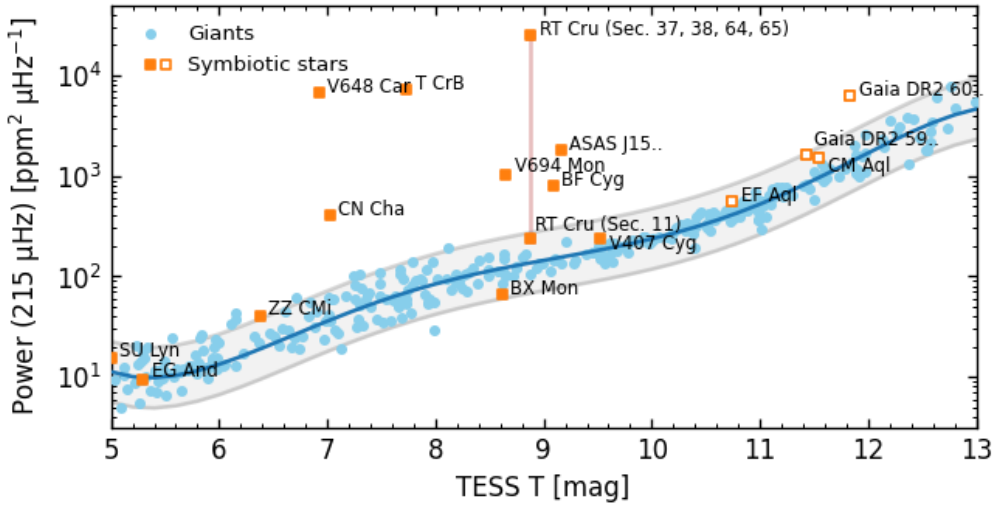

Figure: Power at 215 μHz.

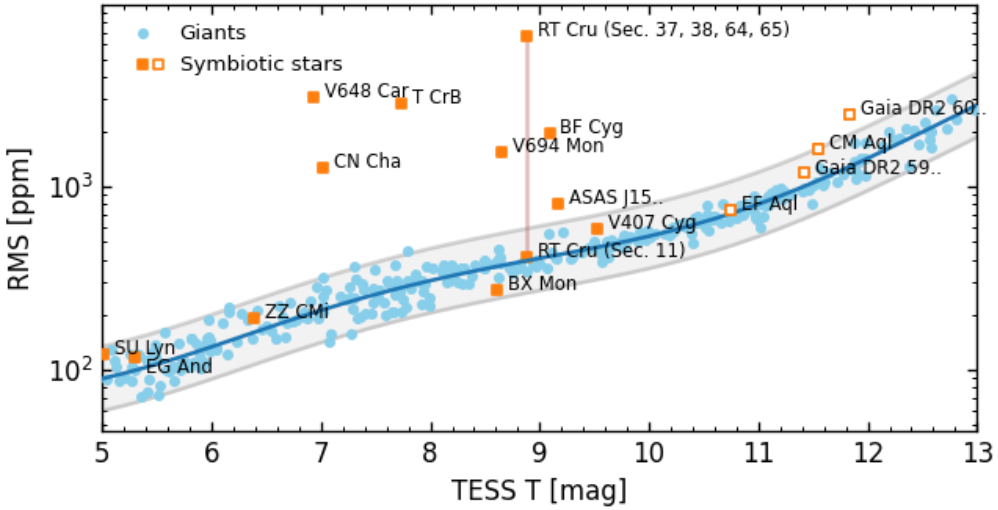

Figure: RMS variability amplitude.

Flickering in symbiotic stars

- TESS is **able to detect** flickering in SySts
- in some of the known flickering sources we have **not detected** flickering
  - with the available **precision**
  - at the **time of observations**
  - within the **TESS passband**

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Flickering in symbiotic stars

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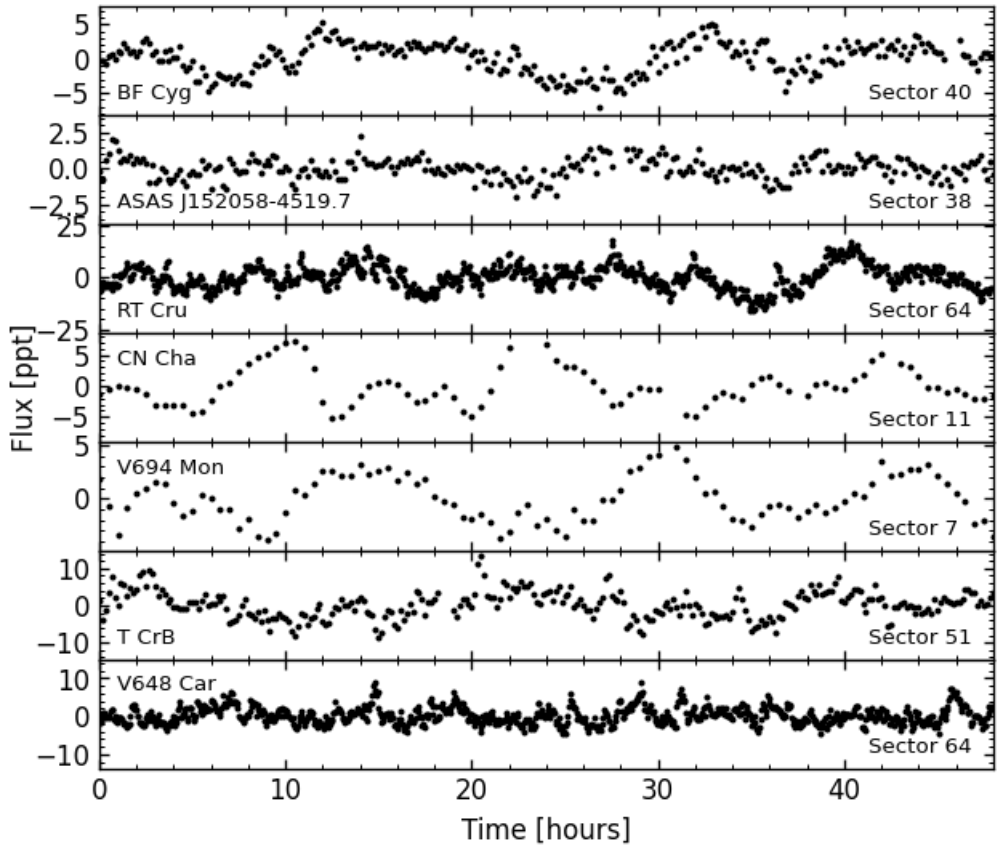

Figure: Filtered TESS light curves of symbiotic stars with detected flickering.

Flickering in symbiotic stars

- we repeated the same analysis for known symbiotic stars not detected in flickering
  - 261 sources -> 174 in TESS fields -> 123 within magnitude range -> **72 studied**
- 13 sources with flickering-like variability reported **for the first time**

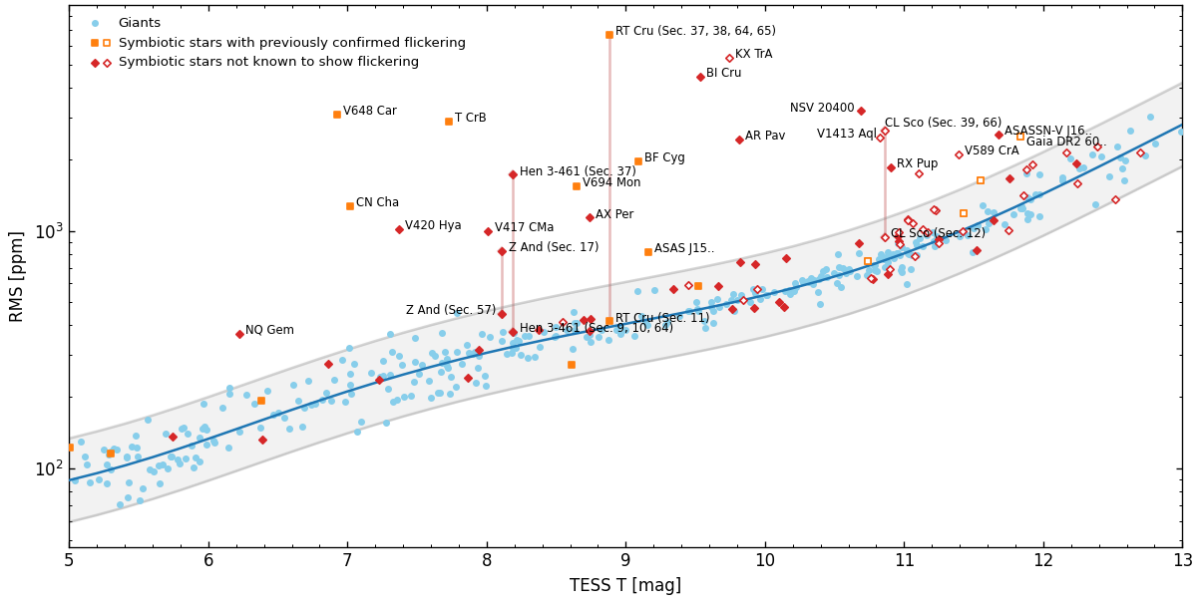

Figure: RMS variability amplitude.

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Flickering in symbiotic stars

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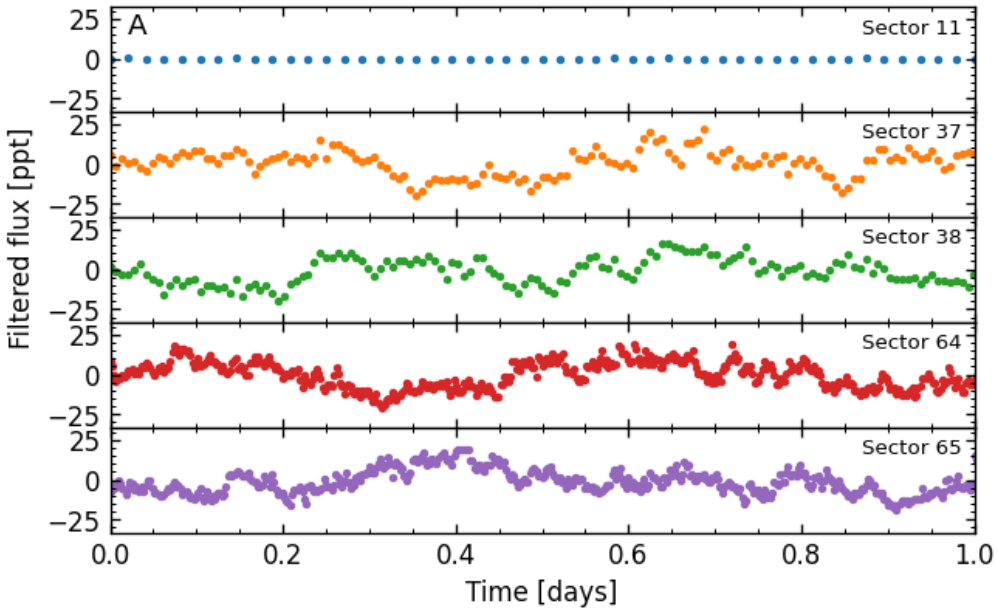
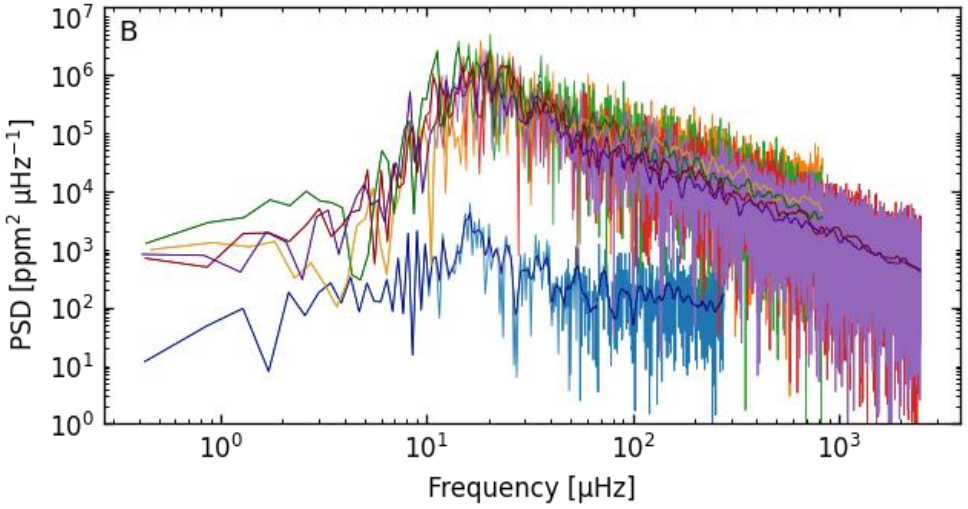
- 13 new sources
- **35 galactic symbiotic stars** with flickering
  - 12% of known SySts in NODSV
  - lower limit -> contamination...
  - only **7 out of 16 (22)** previously known
- majority of them are accreting-only
  - it is **easier to detect** flickering in them
  - over 80% of all accreting-only SySts have flickering detections now
- **accretion disks are <u>common</u> in symbiotic stars!**

Changes in flickering

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

Pujol et al., 2023, A&A
doi: 10.1051/0004-6361/202244967





RT Cru -> changes in accretion rate
(Pujol et al., 2023)

Changes in flickering

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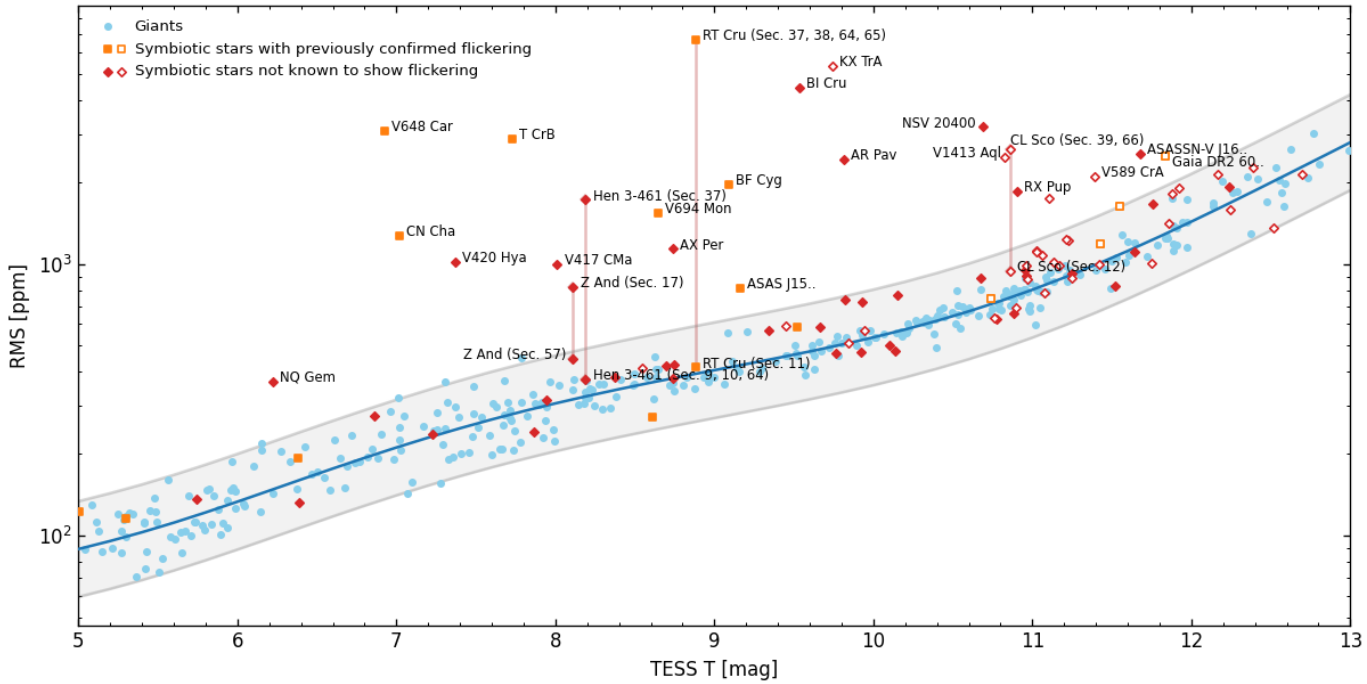

Figure: RMS variability amplitude.

- similar changes observed in **three others**
- flickering is not present at all epochs
  - TESS non-detections

Rotation of the WD in Z And

- **magnetic WD** in Z Andromedae?
- persistent **oscillations** at **P = 1682.6 s (28 min; Sokoloski & Bildsten, 1999)**
  - detected in optical **B band**
  - **no change** over the timespan of 1 yr
  - explained as the **rotation** of an accreting magnetic WD
- TESS observations in **Sectors 12 and 57**
  - S12 -> cadence **30 minutes**
  - S57 -> cadence **200 seconds**

References:
Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

Sokoloski & Bildsten, 1999, ApJ
doi: 10.1086/307234

Rotation of the WD in Z And

References:
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doi: 10.1051/0004-6361/202348116

Sokoloski & Bildsten, 1999, ApJ
doi: 10.1086/307234

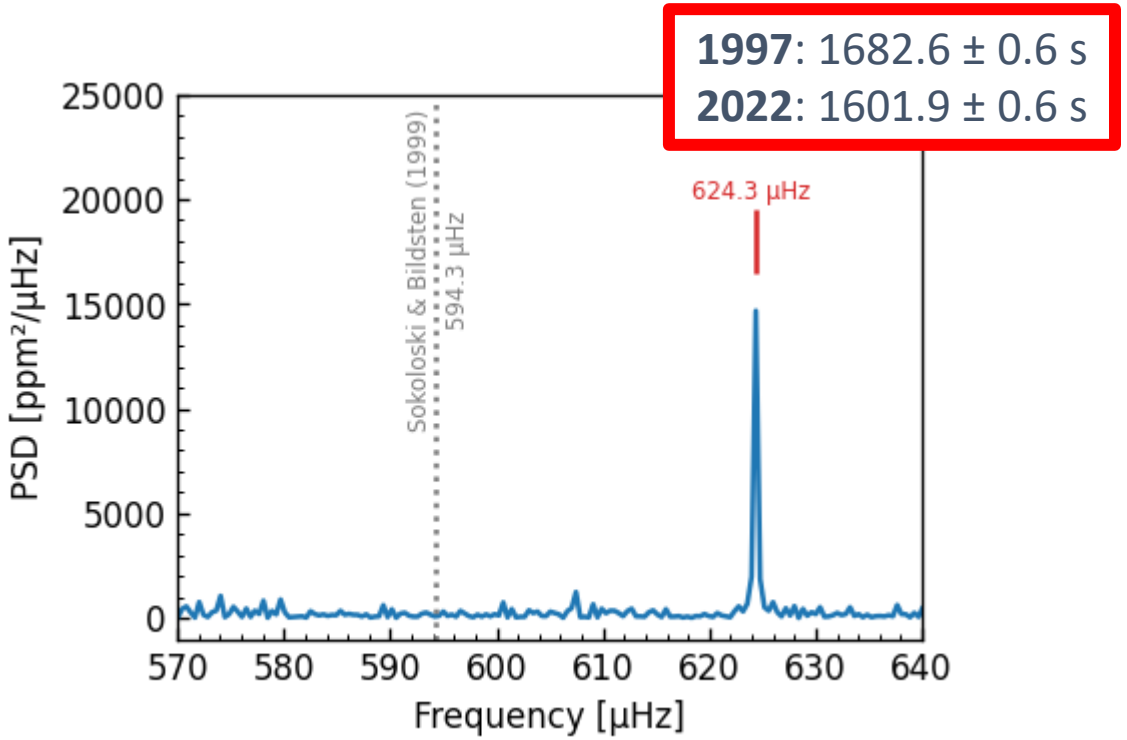

Figure: PSD of Z And Sector 57 data.

Rotation of the WD in Z And

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Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

Sokoloski & Bildsten, 1999, ApJ
doi: 10.1086/307234

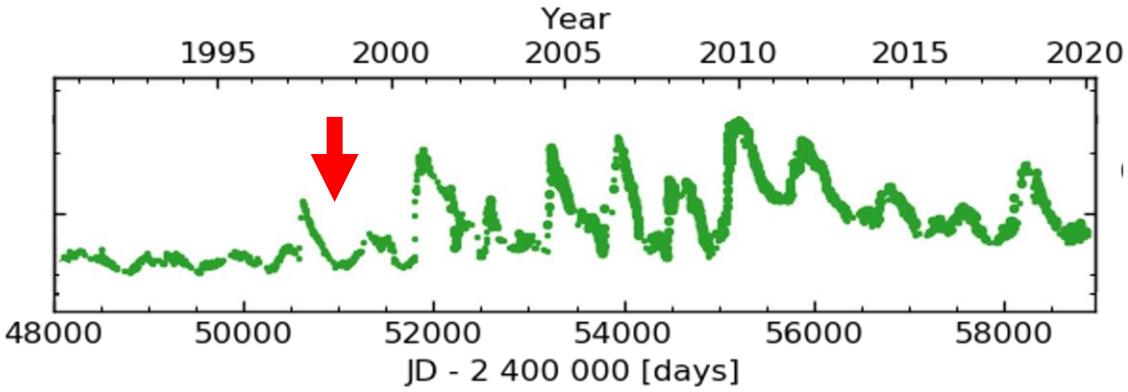

Figure: Light curve of Z And.

Periodic signal in TESS data

- **similar periodic signal** observed in the Kepler light curve of **FN Sgr** (Magdolen et al., 2023) -> 11.3 min
- TESS data -> AE Cir, CI Cyg

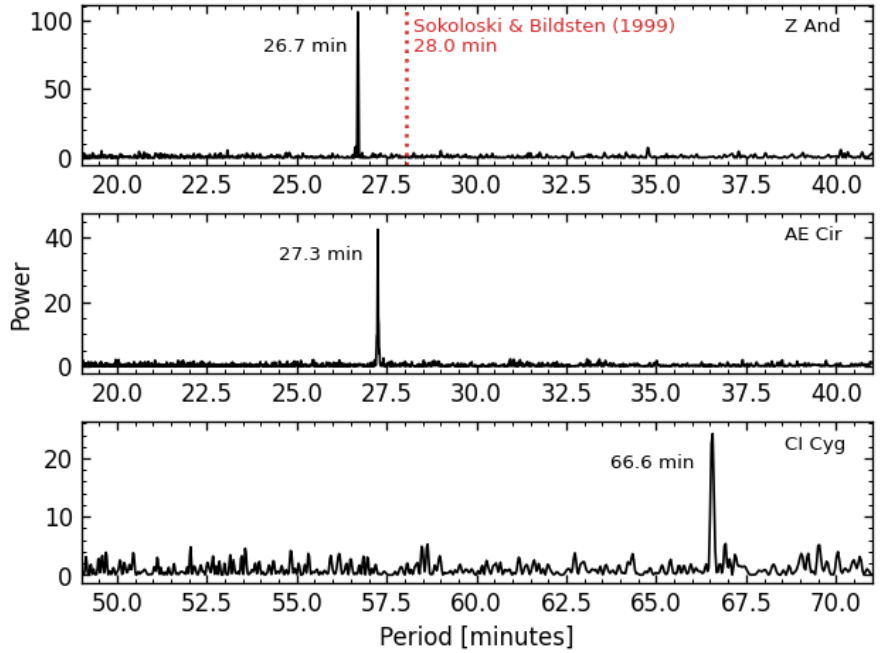

Figure: Periodograms of TESS light curves of Z And, AE Cir, and CI Cyg.

References:

Merc et al., 2024, Astronomy & Astrophysics
doi: 10.1051/0004-6361/202348116

Magdolen et al., 2023, A&A
doi: 10.1051/0004-6361/202345935

A&A, 683, A84 (2024)
https://doi.org/10.1051/0004-6361/202348116

Astronomy & Astrophysics

Accretion-induced flickering variability among symbiotic stars from space photometry with NASA TESS

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ABSTRACT

Context. Symbiotic binaries exhibit a wide range of photometric variability across different timescales. These changes can be attributed to factors such as orbital motion, intrinsic variability of the individual components, or interactions between the two stars. In the range from minutes to hours, a variability induced by accretion processes that is likely to originate from the accretion disks has been detected and subsequently denoted as flickering. This variability could mimic solar-like oscillations exhibited by luminous red giants.

Aims. We aim to investigate whether it is possible to utilize the precise observations of the NASA TESS mission to detect flickering in symbiotic stars, despite the fact that such studies are usually performed at shorter wavelengths than those of TESS observations. Additionally, our goal is to develop a quantitative method for the detection of accretion-induced flickering that does not rely solely on a subjective assessment of the light curves.

Methods. We obtained the light curves of known symbiotic stars and a comprehensive control sample of assumed single red giants from the TESS full-frame images. To ensure consistency, all the data were processed using the same methodology, which involves filtering out the background, systematic, and long-term trends. From the processed light curves and their power spectral densities, we measured the amplitudes of the variability and other relevant parameters.

Results. We introduce a method that enables a differentiation between flickering sources and stars that do not exhibit this type of variability. We detected flickering-like variability in 20 symbiotic stars utilizing TESS data, of which 13 had not previously been identified as flickering sources. Moreover, the TESS observations facilitate the detection of related variations occurring over timescales of a few days, as well as changes in the flickering behavior across multiple sectors.

Thank you
for your attention.