Uniwersytet Wrocławski

UCZELNIA BADAWCZA
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Starspot and flare activity – differences and similarities between stars with different inner structure

XLI Meeting of Polish Astronomical Society

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Toruń

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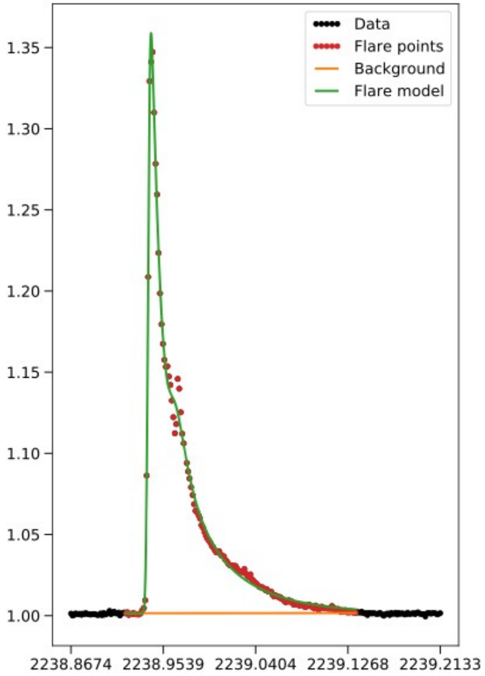
• Flares are highly energetic, rapid events, that occur during magnetic reconnection in the stellar corona

• They are characterized by a fast rise and a slower, exponential decay

• Research of stellar flares has been rapidly developing in recent years thanks to optical photometric surveys (Kepler, TESS)

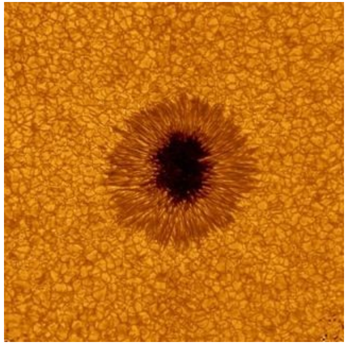
• Flares on solar-type stars have much greater energies than solar flares

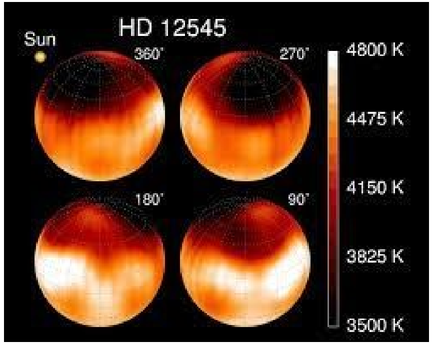
• The appearance of super-flare in the Sun can lead to a geomagnetic storm and widespread blackout



Super-flare detected on YZ CMi (Bicz et al. 2022)

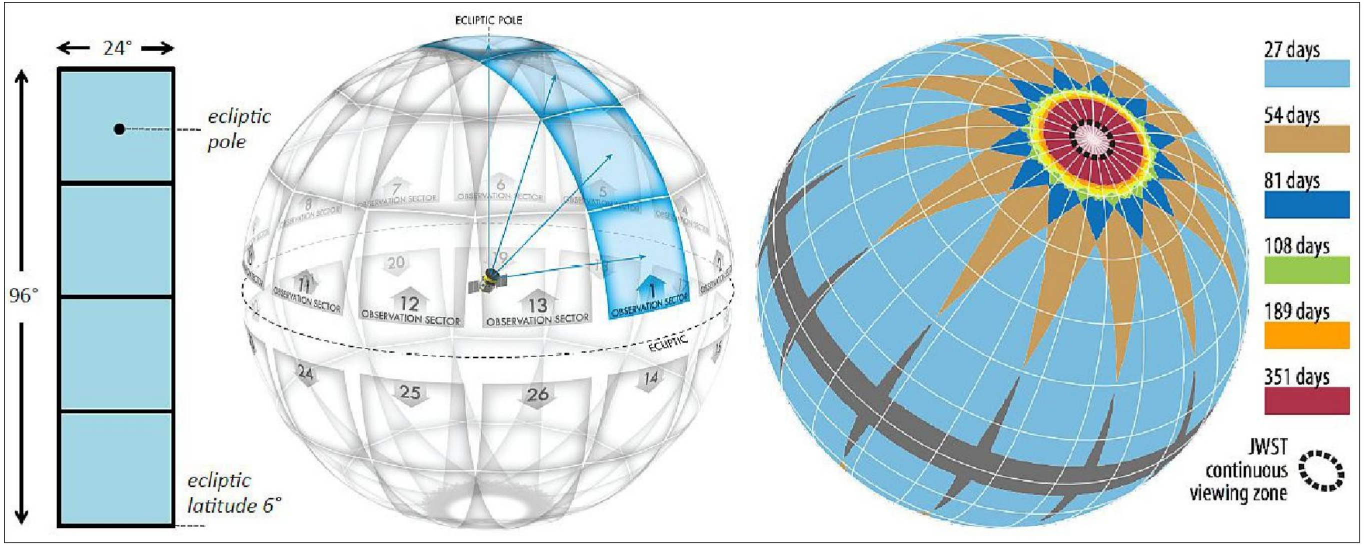
- Starspots are dark, cooler regions on the surface of stars, similar to sunspots on the Sun.
- They are caused by magnetic activity and can appear as small, dark patches on a star's surface.
- They can vary in size from a fraction of a percent of the star's surface area to covering a significant portion.
- Starspots can influence a star's brightness when they rotate into view, causing variations in its light output.
- They are commonly observed on stars other than the Sun, including cool stars like M dwarfs and hot stars like young T Tauri stars.
- Starspots can affect the interpretation of exoplanet observations by causing false signals in transit and radial velocity data.





K.Strassmeier, Vienna, NOIRLab/NSF/AURA

- TESS (The Transiting Exoplanet Survey Satellite) is a space-based telescope launched in 2018
- TESS uses a red-optical bandpass (600 to 1000 nm)



BASSMAN

https://github.com/KBicz/BASSMAN

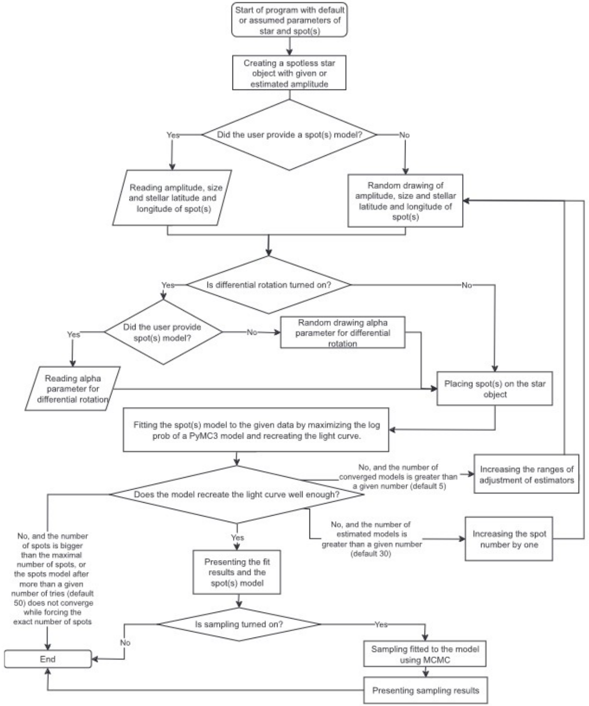


Figure 1. Flow diagram showing the operations of the BASSMAN software/program.

Bicz et al., 2022

Selected active fully convective M-type main-sequence star

YZ CMi

M4Ve

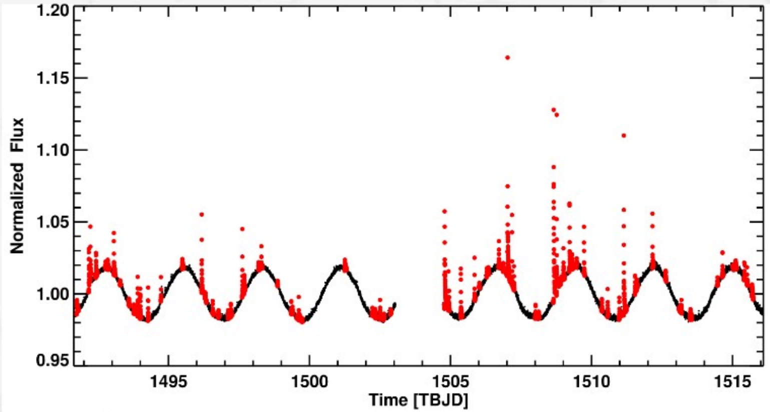
i = 60 deg

Teff = 3181 K

log(g) = 4.89

R = 0.33 R☉

M = 0.31 M☉



The light curve of the TIC266744225 (YZ CMi, sector 7). The flares found by the WARPFINDER pipeline are marked with red dots.

Piertras et al. 2022

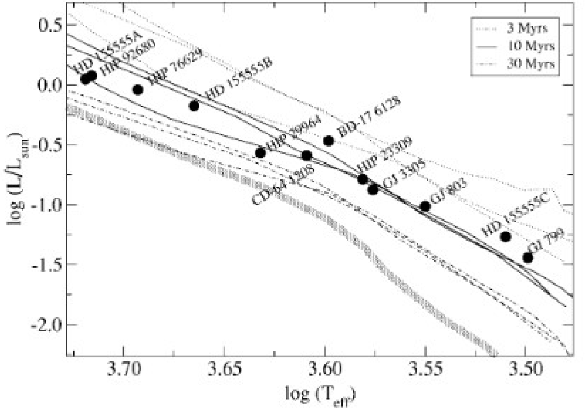


FIG. 1.—H-R diagram showing 3, 10, and 30 million yr solar metallicity isochrones from Siess, Dufour, & Forestini (2000), Palla & Stahler (1993), and D'Antona & Mazzitelli (1997). Measured quantities listed in Table 1 (V, $V-I_C$, and distance from Earth) were translated to luminosity (L) and effective temperature (T_{eff}) with relationships corresponding to the 12 Myr isochrone in Siess et al. (2000) with color-to-temperature conversions of Siess, Forestini, & Dougados (1997). For BD $-17°6128$, $L = 0.34 \pm 0.06\ L_\odot$ and $T_{eff} =$ 3960 K were used (van den Ancker et al. 2001). The thick shaded line represents the zero-age main sequence from Siess et al. (2000).

Zuckerman et al. 2001

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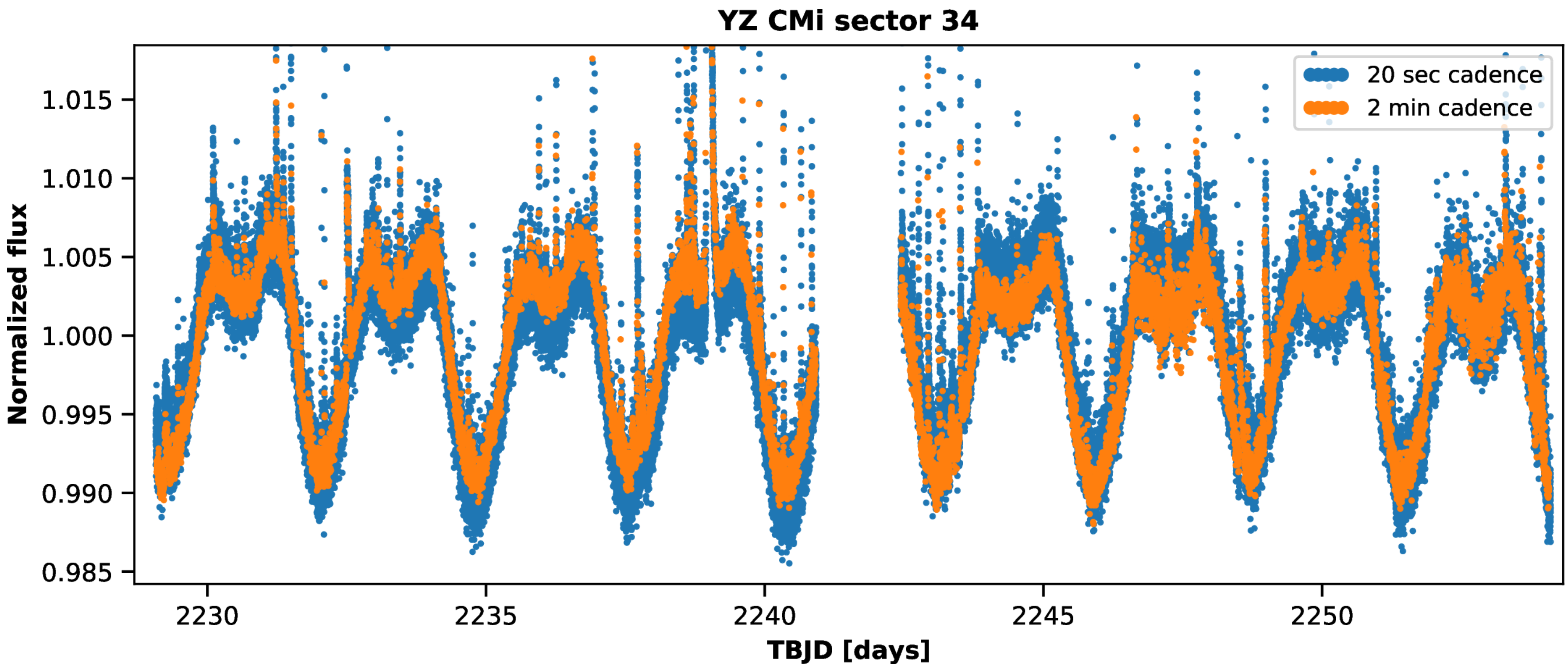
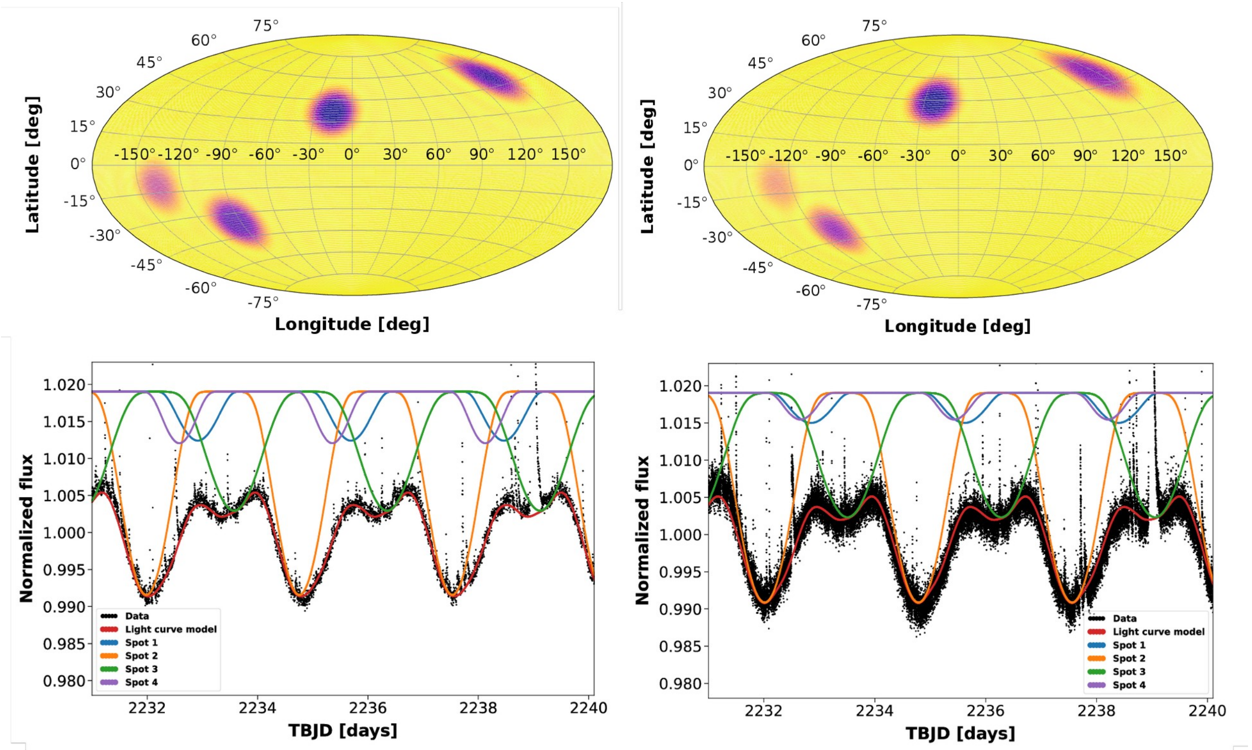


Selected active fully convective M-type main-sequence star

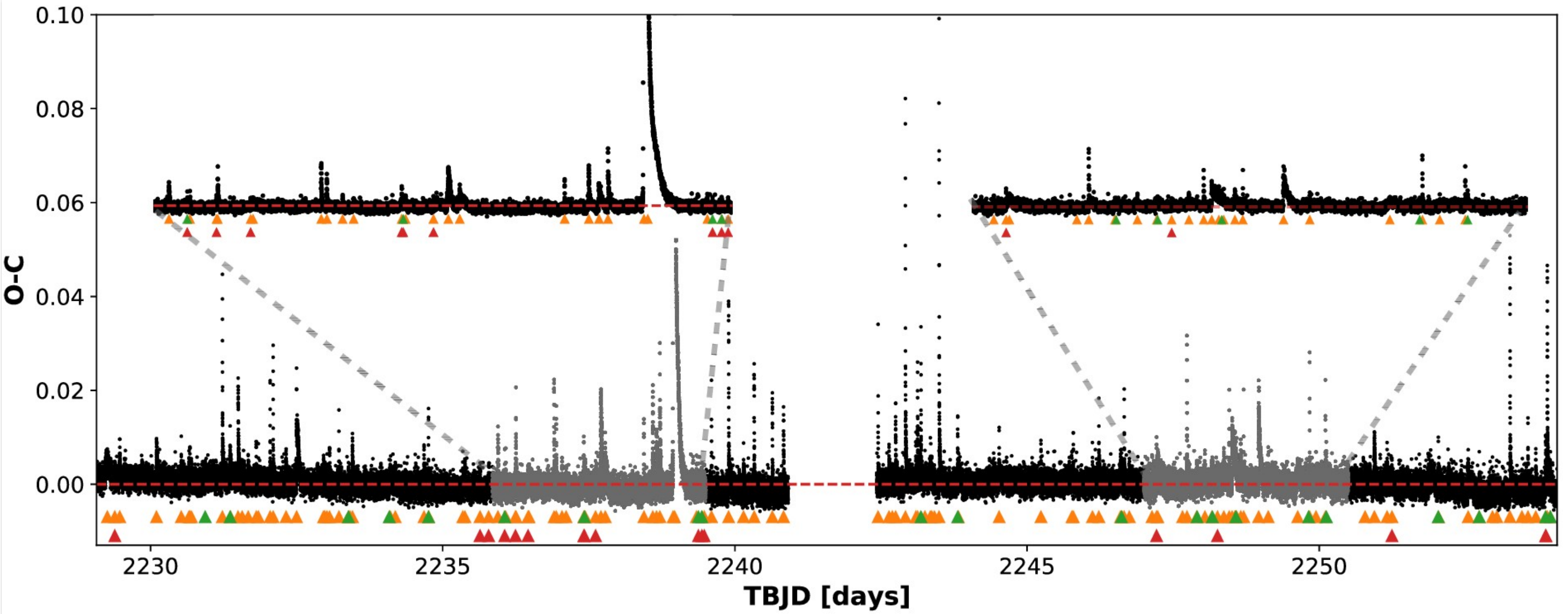
Table 1: Parameters of spots on YZ CMi in sector 34 for both light curves.

Observational cadence	Spot number	Spot relative amplitude [%]	Spot size [%]	Mean spot temperature [K]	Spot latitude [deg]
two-min	1	0.20 ± 0.02	1.53 ± 0.03	2912 ± 235	−12 ± 1
two-min	2	0.36 ± 0.01	1.55 ± 0.06	2713 ± 405	50 ± 1
two-min	3	0.56 ± 0.03	2.14 ± 0.05	2696 ± 478	36 ± 0.4
two-min	4	0.49 ± 0.06	2.13 ± 0.06	2756 ± 420	−36 ± 0.4
20-sec	1	0.12 ± 0.032	1.54 ± 0.061	3023 ± 137	−10 ± 4
20-sec	2	0.29 ± 0.024	1.84 ± 0.13	2755 ± 379	51 ± 5
20-sec	3	0.62 ± 0.071	2.18 ± 0.094	2652 ± 518	44 ± 3
20-sec	4	0.39 ± 0.089	1.52 ± 0.11	2800 ± 335	−39 ± 3

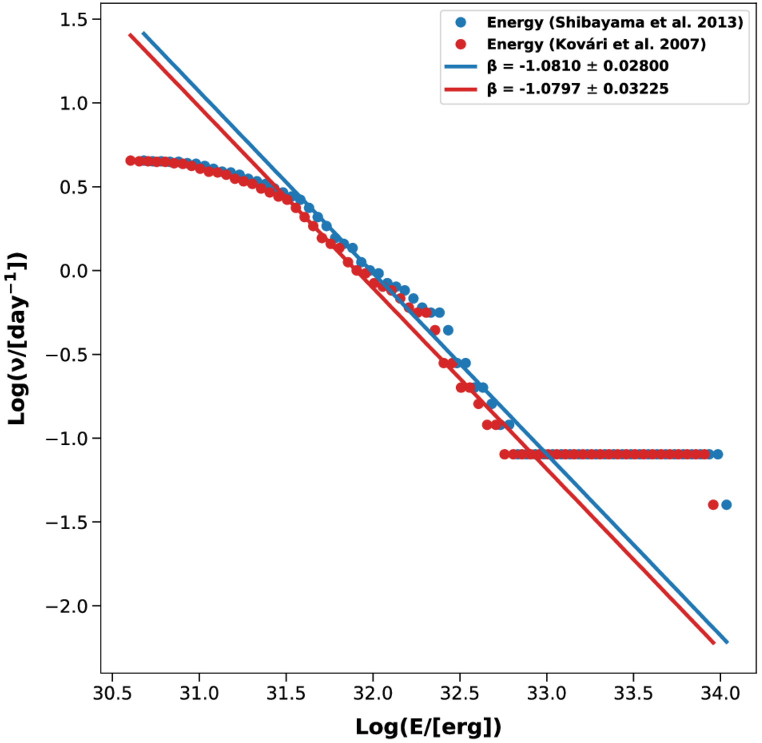
Selected active fully convective M-type main-sequence star

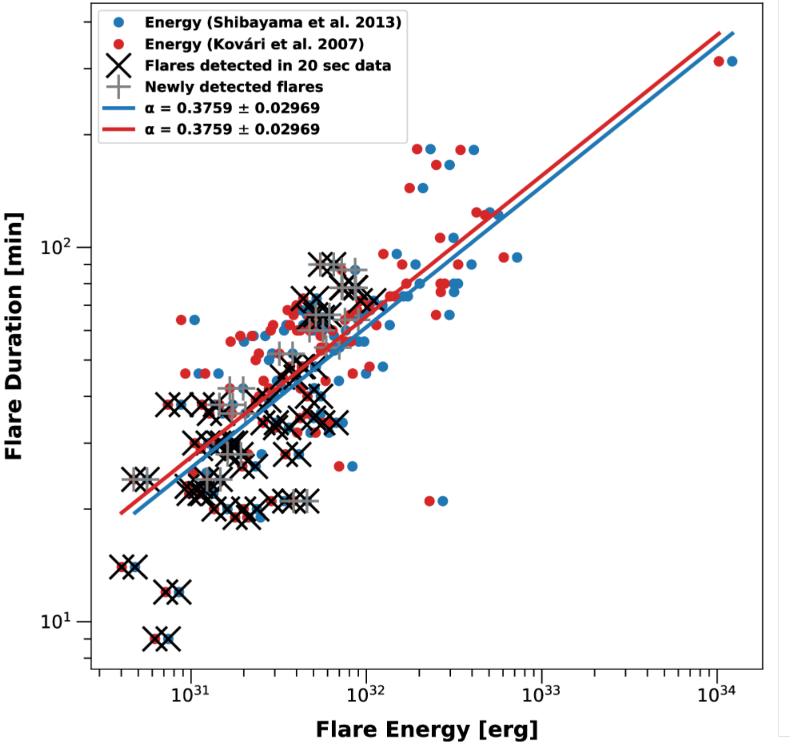


Selected active fully convective M-type main-sequence star

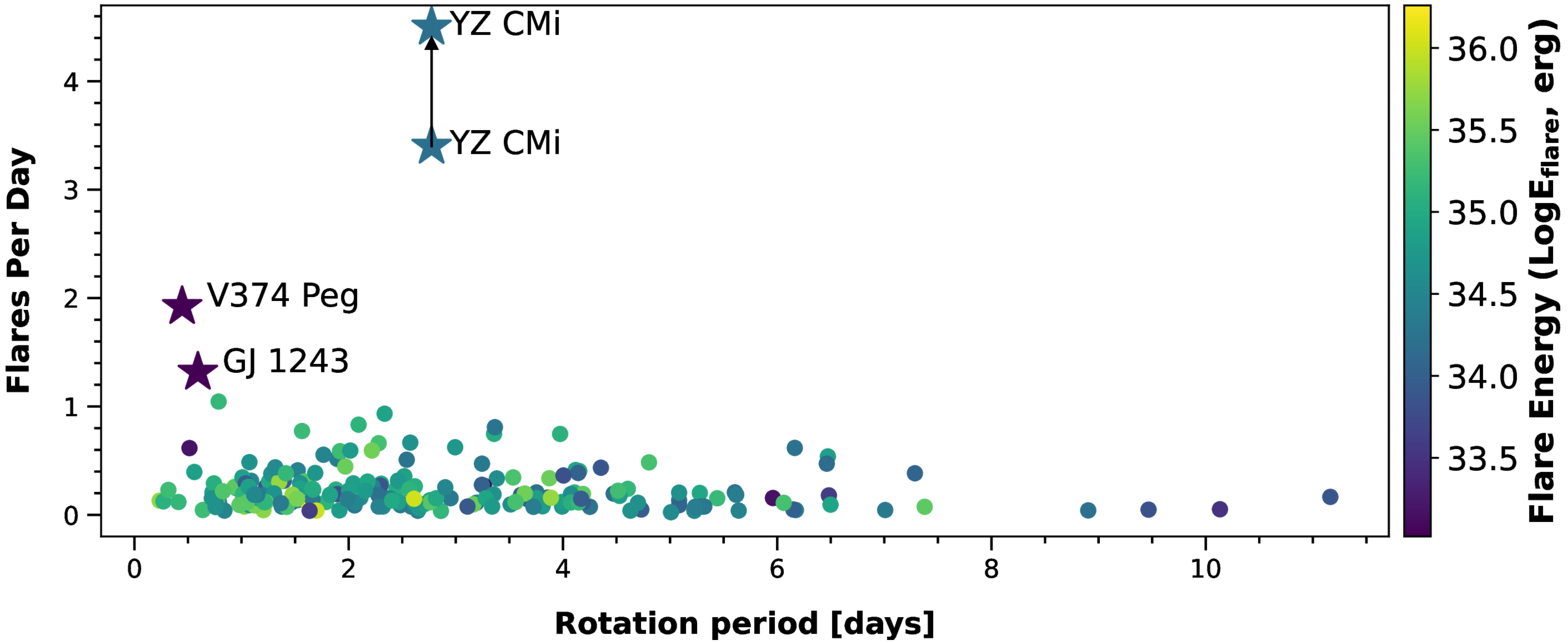


Selected active fully convective M-type main-sequence star

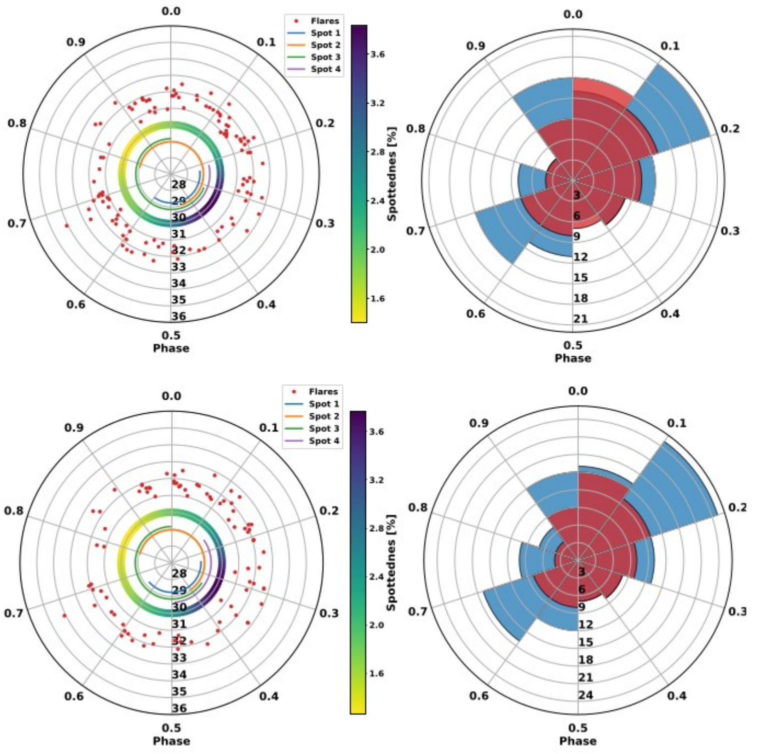


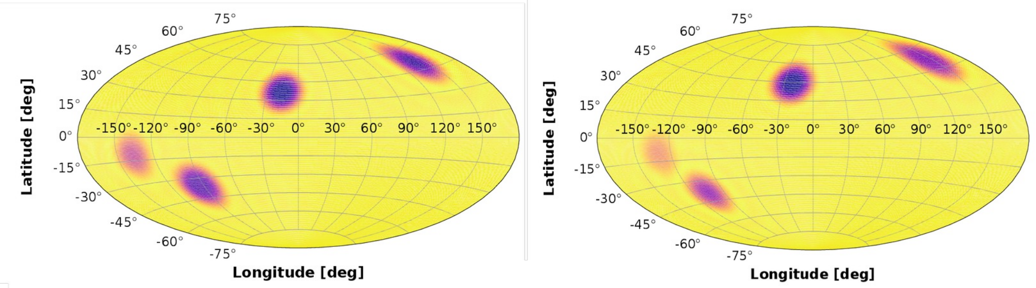


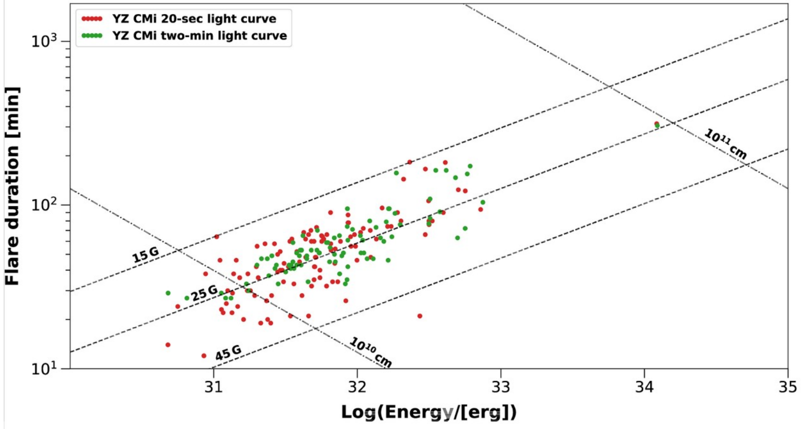
Selected active fully convective M-type main-sequence star

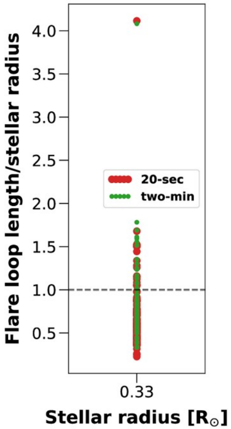


Selected active fully convective M-type main-sequence star









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Partially convective star CD-36 3202

CD-36 3202

K2V(e) C

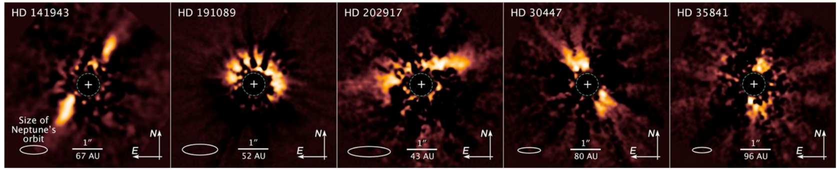
vsin(i) = 170 +/- 17

Teff = 4885 K

log(g) = 4.53

R = 0.8 Rsun

M = 0.8 Msun



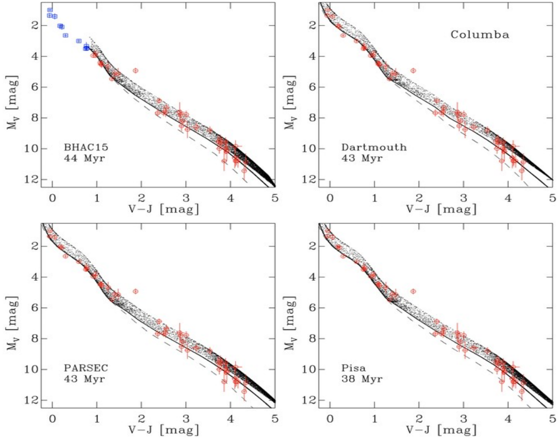
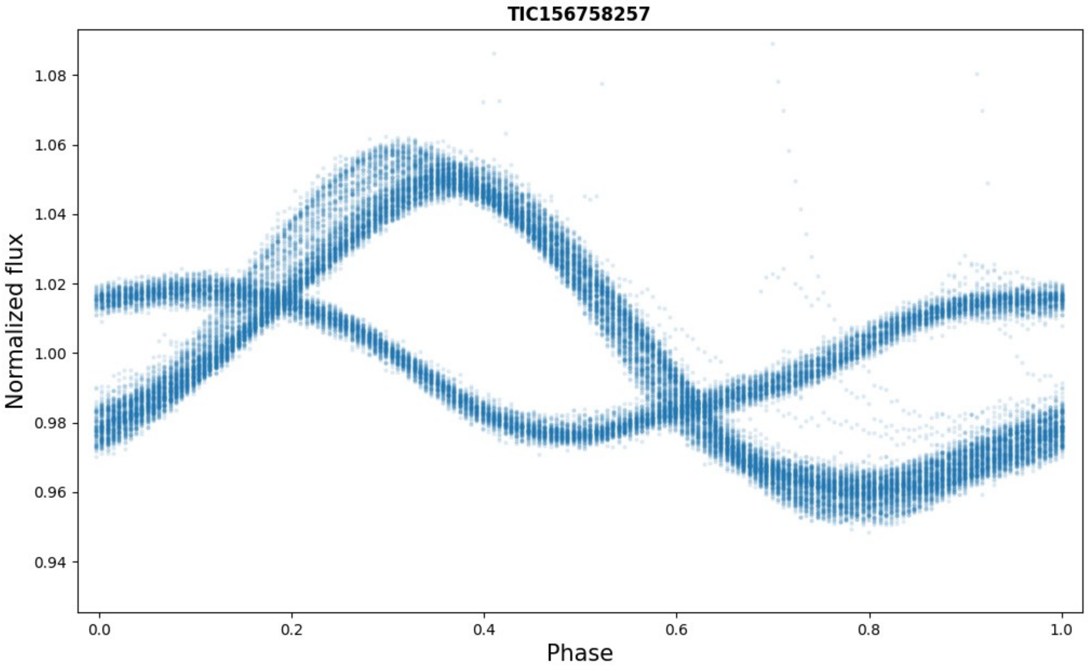


Figure 7. Best-fitting $M_V, V-J$ CMDs of Columba. The coloured symbols and dashed lines are the same as those in Fig. 2. **Top left:** BHAC15. **Top right:** Dartmouth. **Bottom left:** PARSEC. **Bottom right:** Pisa.

Bell et al., 2014

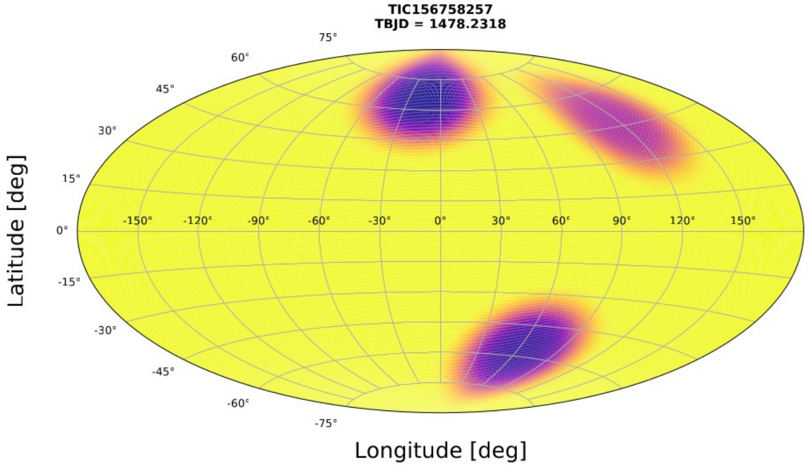
Partially convective star CD-36 3202

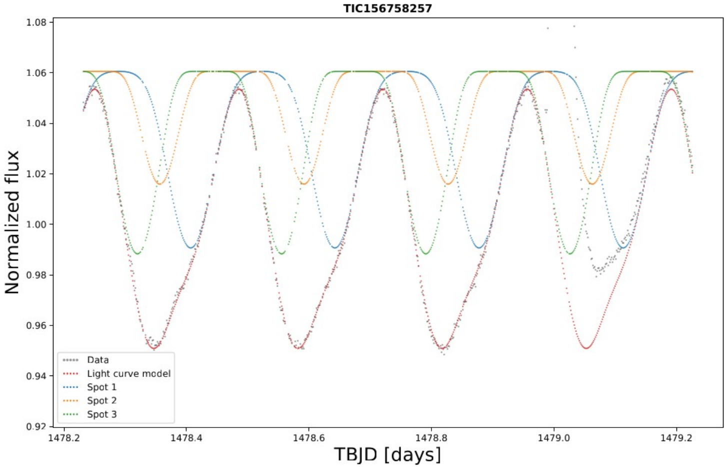


Partially convective star CD-36 3202

Table 1. Mean model of starspots on CD-36 3202 for the sector 6.

Spot number	Spot relative amplitude [%]	Spot size [% of area of star]	Mean spot temperature [K]	Spot latitude [deg]
1	1.50 ± 0.15	3.83 ± 0.2	4038 ± 669	52 ± 2
2	1.83 ± 0.37	3.85 ± 0.2	4057 ± 735	−55 ± 3
3	2.53 ± 0.15	3.93 ± 0.3	3906 ± 852	62 ± 2





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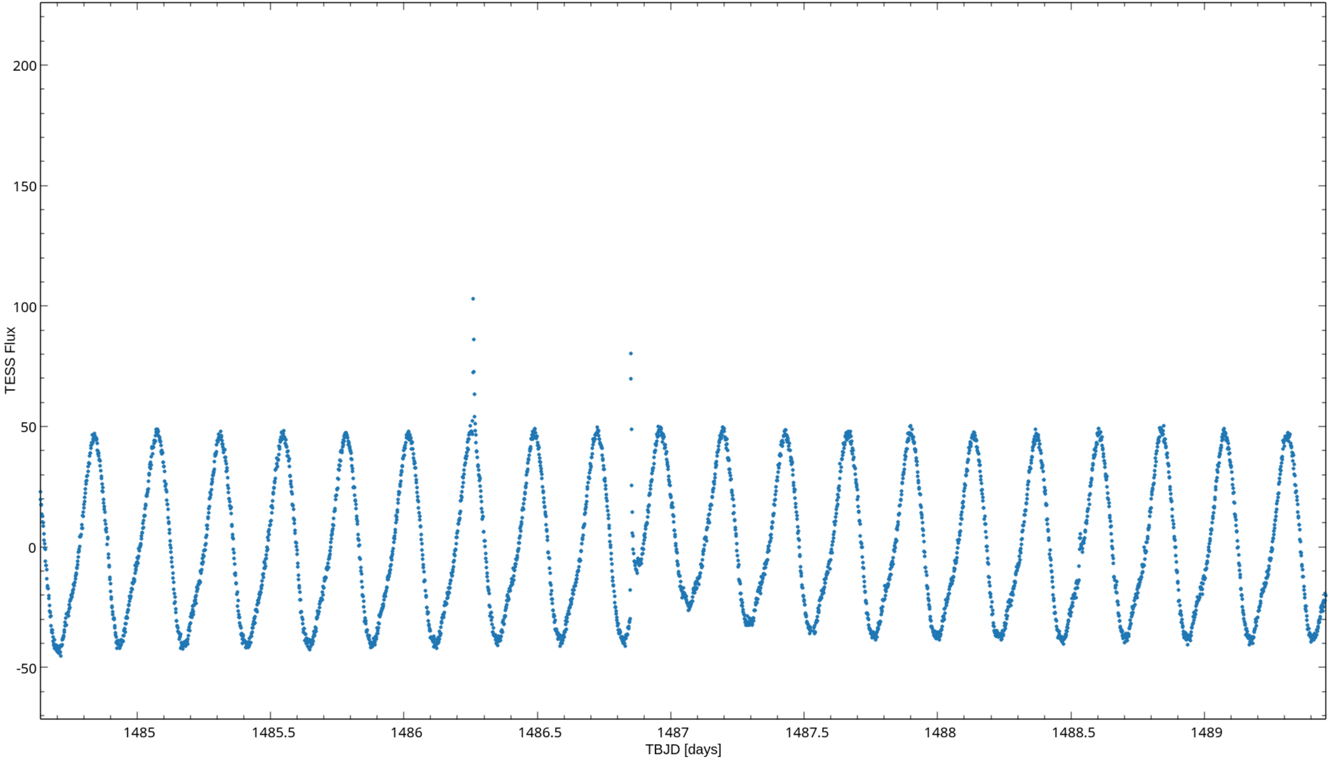
Partially convective star CD-36 3202



Partially convective star CD-36 3202

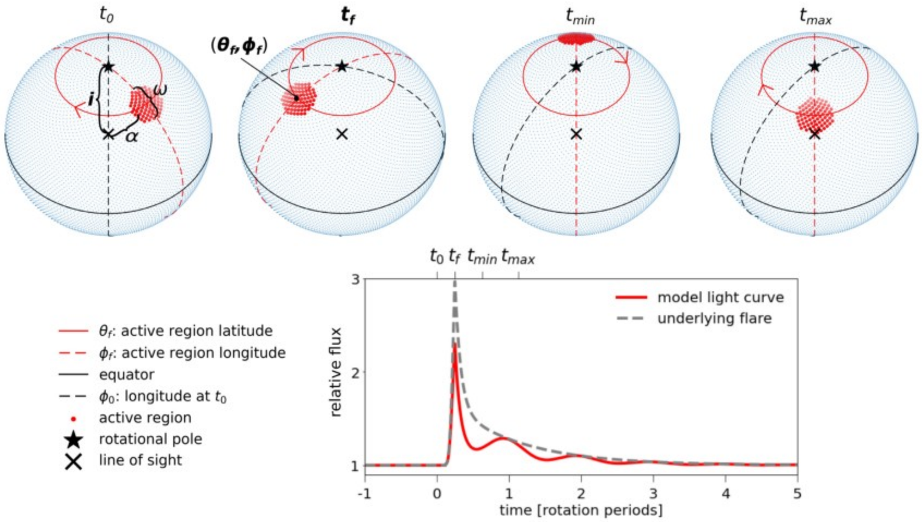


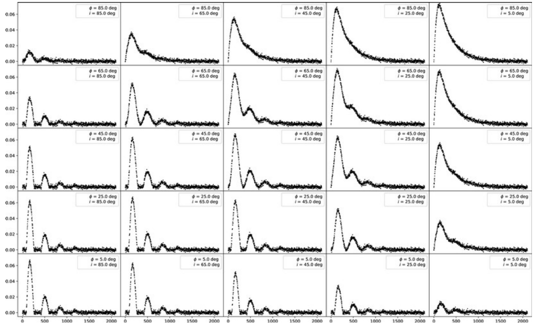
Figure 5. Flare modulation model. From left to right, the top row shows a clockwise rotating star (blue dots) with a flaring region (red dots), from the start of observation at t_0 to the peak flare time t_f, and further to the flaring region being rotated to the stellar far (t_{min}) and near (t_{max}) sides. The angular distance between the rotational pole (black star) and the intersection of the line of sight with the centre of the star (black cross) is the inclination i. α is the angular distance of the flaring region to the line of sight, and ω is the full opening angle of the circular flaring region. The depicted configuration results in the observed light curve (red line) in the bottom panel. The underlying flare model is shown as a grey dashed line in the same panel.

Ilin et al., 2021

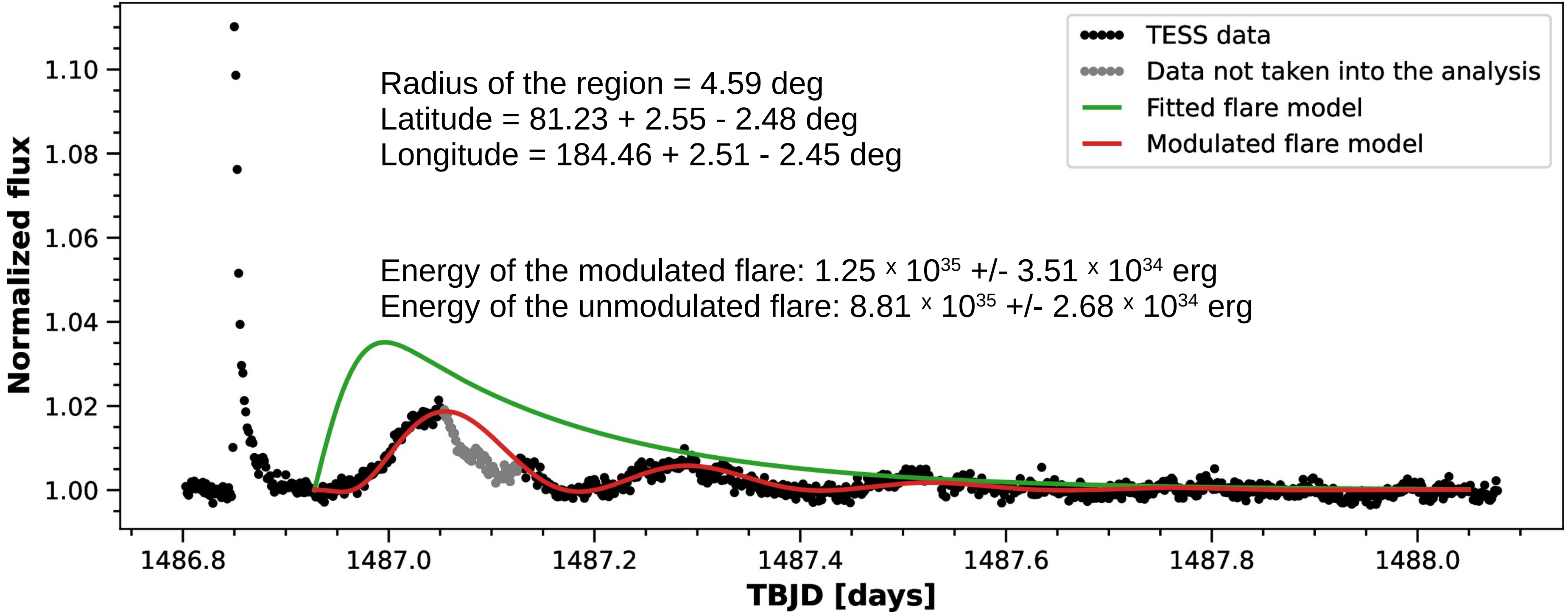
$$\omega/2 = \arcsin\left(\sqrt{\frac{A \cdot L_*}{\pi R_*^2 F_{f,s}(T_f)}}\right).$$

$$\alpha = \arccos\left(\sin\theta\cos i + \cos\theta\sin i\cos(\phi - \phi_0 - \hat{t})\right)$$

$$F_f(\theta, \phi, \hat{t}) = F_f(\hat{t})\cos\alpha(\theta, \phi, \hat{t}).$$



Partially convective star CD-36 3202



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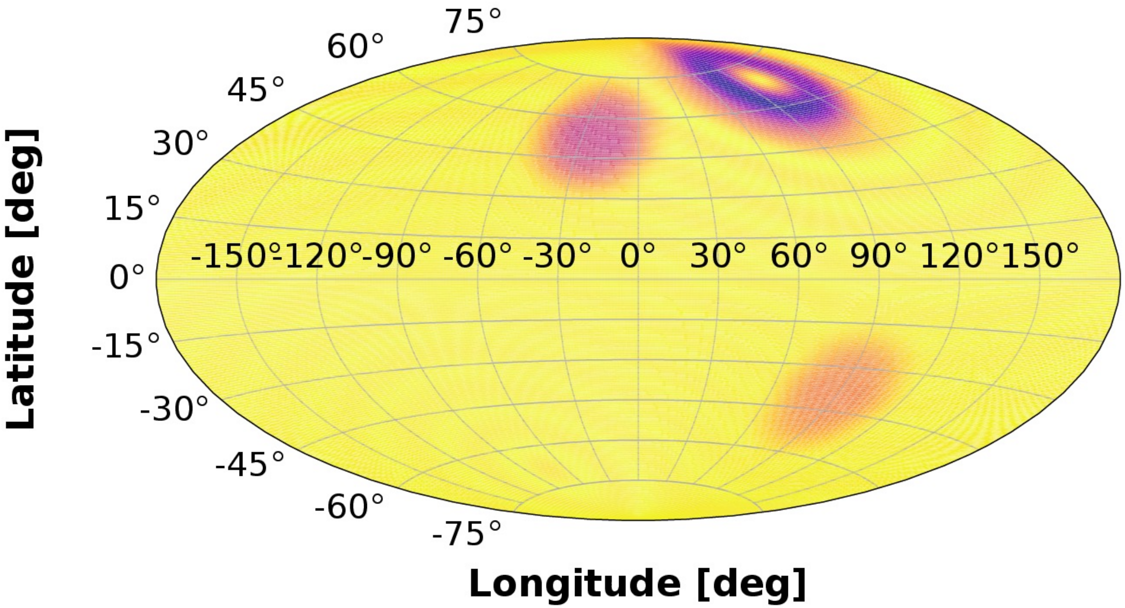
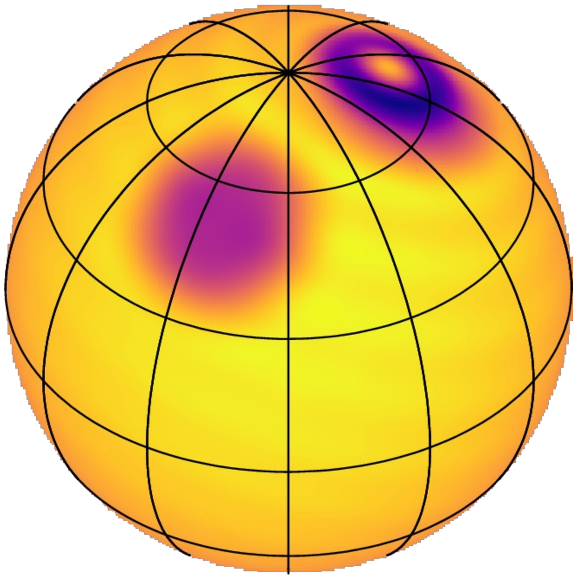
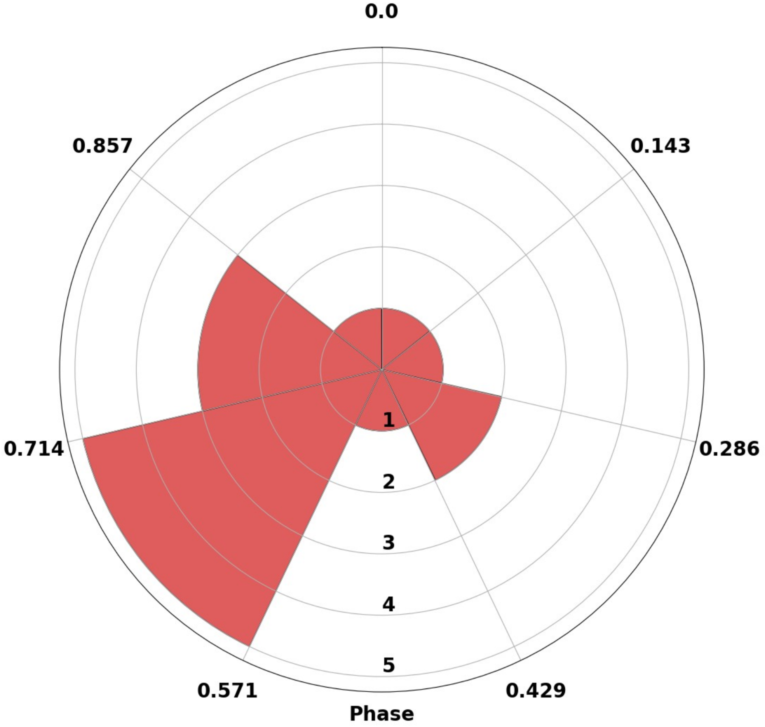
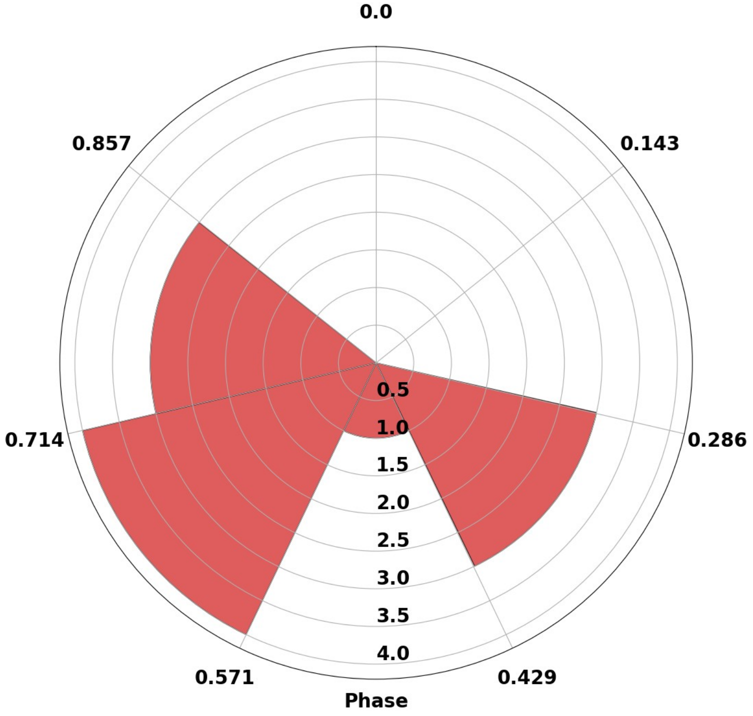
Partially convective star CD-36 3202





Partially convective star CD-36 3202





Thank you for your attention!

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