Unique variability of an A-type magnetic pulsator HD27463 found from the analysis of TESS data

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Abstract

The new photometric data on HD27463 obtained recently with the Transiting Exoplanet Survey Satellite (TESS) are analyzed to search variability. Our analysis shows that HD27463 exhibits **two types of photometric variability**. The low frequency variability with the period P=2.834274 d can be explained in terms of **axial stellar rotation** assuming the **model of oblique magnetic rotator**, while the detected high-frequency pulsations characterize this object as a **δ Scuti variable**. From the analysis of Balmer line profiles visible in two FEROS spectra of HD27463 we have derived its effective temperature and surface gravity that are close to the values published for this star in the TESS Input Catalogue (TIC). Our best fitting model of the observed pulsation modes results in the values of global stellar parameters that are well consistent with the data reported in the TIC and with the data derived from the simulation of Balmer line profiles. We have found that amplitudes and phases of **pulsation modes with highest amplitudes are modulated with time**.

HD27463

- It is known as an **α^2 CVn type variable** with spectral type **Ap EuCr(Sr)** (Houk & Cowley).
- Photometric variability with **P = 2.835 days** has been reported in the Hipparcos and Tycho catalogues (ESA) and confirmed by Renson & Catalano (2001).
- HD27463 is **a long period (≈370 yr) visual binary** with a **separation of 0.3 arcsec** and a **magnitude difference** between the Ap primary and the secondary of about **0.43 in the V band** (e.g. Baize & Petit 1989).
- Using the TESS data, Cunha et al. (2019) and Sikora et al. (2019) have classified HD27463 as a suspected **new δ Scuti variable**.

Global stellar parameters

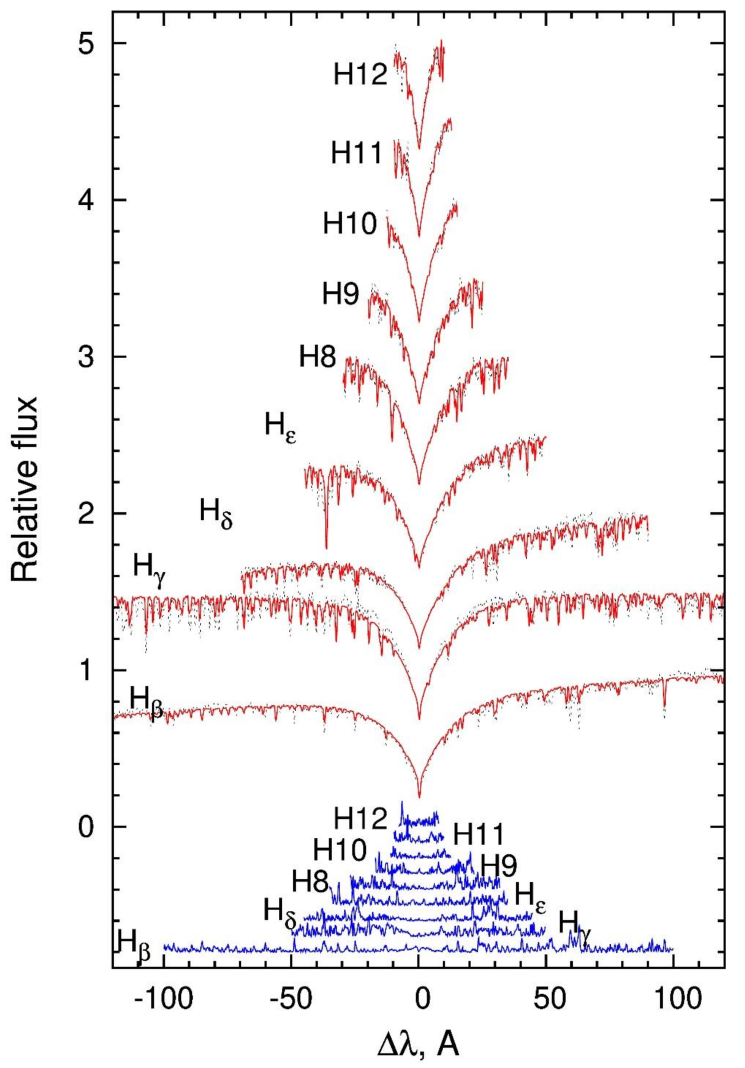

Figure 1. Example of fitting the observed Balmer line profiles (red line) of HD27463 with a synthetic spectrum (thin dotted line) that corresponds to **T_{eff} = 8700 ± 100 K, log(g) = 3.9 ± 0.1, [M/H]= 0.3 ± 0.1** (χ^2_ν = 1.081). The best fit is obtained for the radial velocity **v_r = 22 ± 2 km/s** and **vsin(i) = 27 ± 2 km/s** (see Table 1). Residuals are shown at the bottom of this image in blue.

Table 1. Global stellar parameters

Parameter	TIC, SIMBAD	This article: Balmer lines	This article: Pulsations
T_{eff}, K	8700 ± 200	8700 ± 100	8800 ± 100
$\log g$	3.9 ± 0.3	3.9 ± 0.1	3.89 ± 0.05
[M/H]		0.3 ± 0.1	
$v\sin i$, km s^{-1}		27 ± 2	
v_r, km s^{-1}	26.5 ± 4.8^a	22 ± 2^b	
$L_\star$, $L_\odot$	38.7 ± 10.8		42.5 ± 0.6
$R_\star$, $R_\odot$	2.8 ± 0.4		
$M_\star$, $M_\odot$	2.2 ± 0.4		2.4 ± 0.1
v_{eq}, km s^{-1}		50 ± 7	47 ± 5
i, deg		33 ± 8	
age, 10^8 yrs			5.0 ± 0.4

Analysis of stellar pulsations

- The significant peaks in the TESS light curve of HD27463 have been extracted using the code **Period04** (version 1.2.9) developed by Lenz & Breger (2005).
- To calculated a grid of stellar structure and evolution models we have used **MESA** (version 11554) developed by Paxton et al. (2011).
- We used **GYRA** (Townsend & Teitler 2013) to calculate linear adiabatic pulsation frequencies for each main sequence model with 3.92< log(T_{eff}) <3.95.

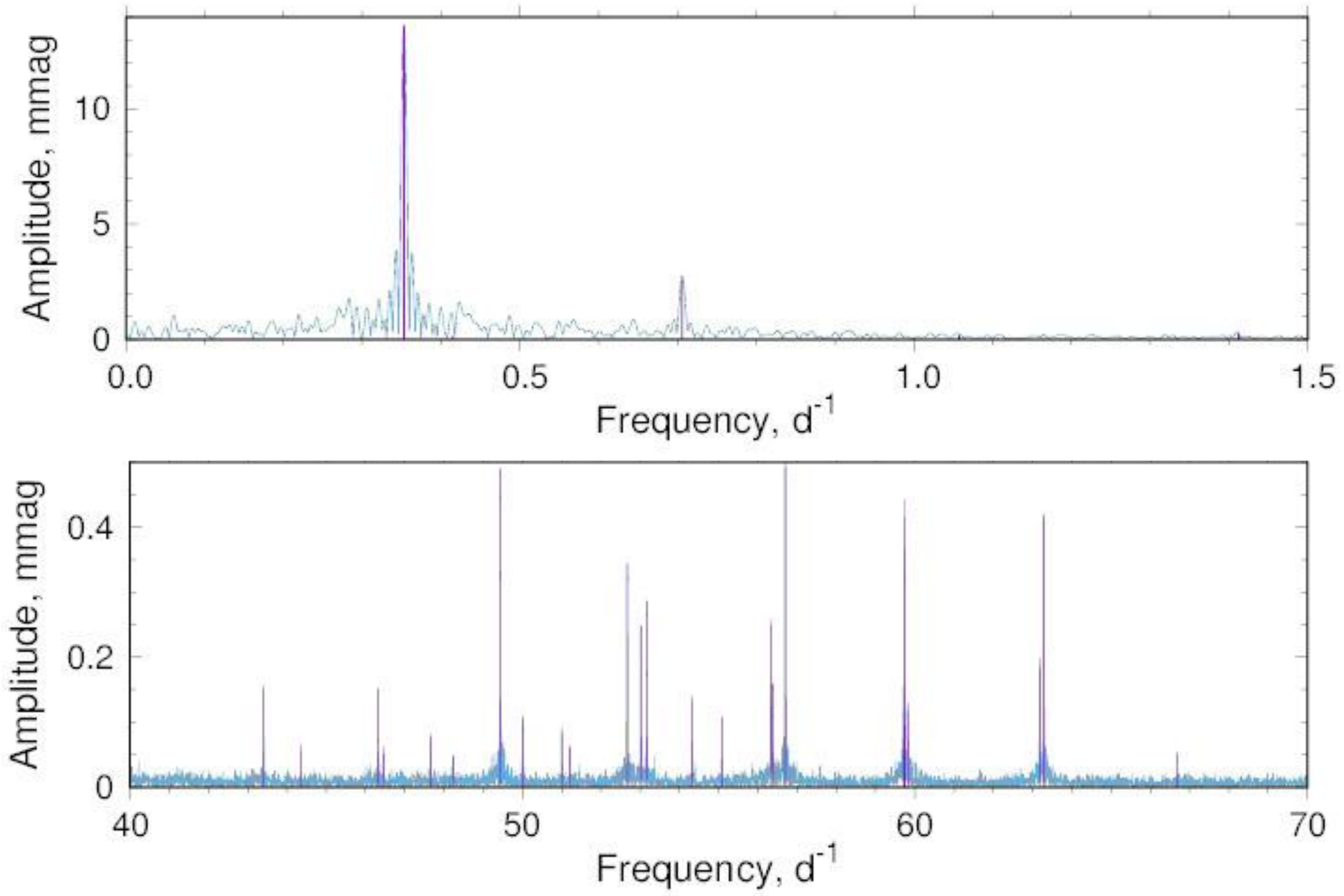

Figure 2. Examples of periodograms derived from the analysis of HD 27463's light curves at the low (upper panel) and high (bottom panel) frequencies. Vertical lines mark the derived frequencies and their amplitudes for the detected periodic signals.

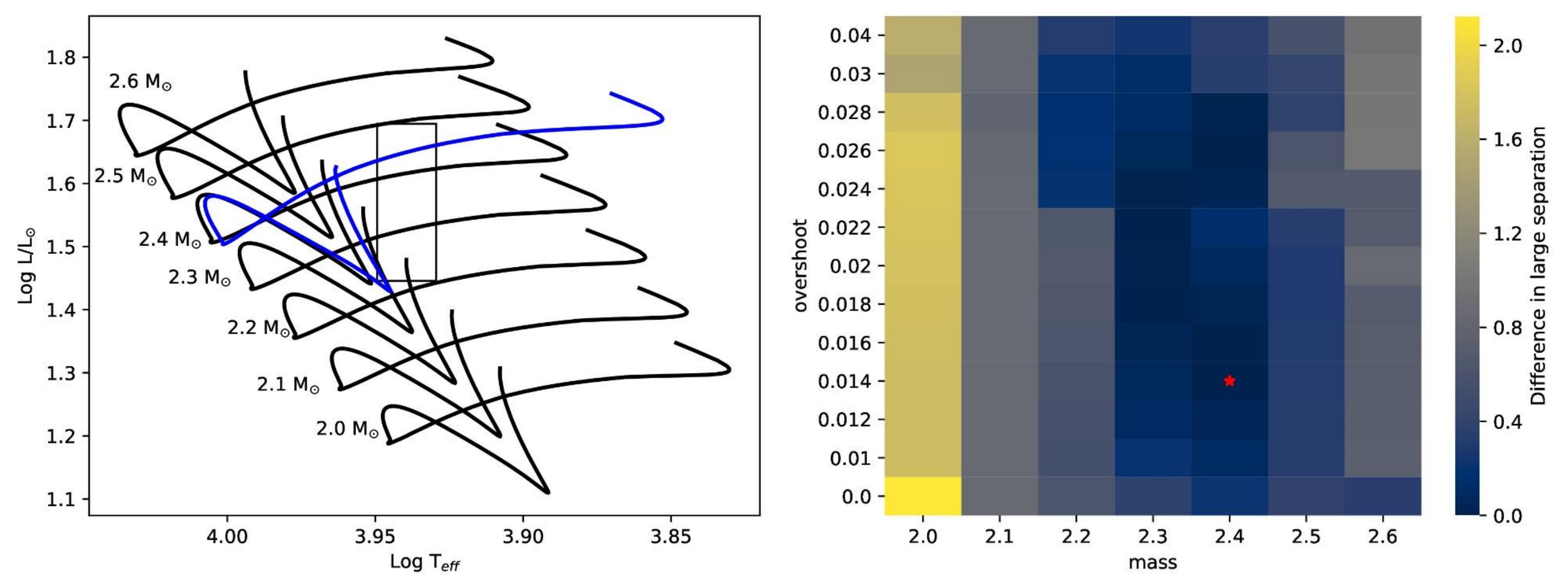

Figure 3. The main sequence evolution tracks for MESA models from 1.9 to 2.6 $M_\odot$, all with zero convective overshoot, are shown in black (left panel). The evolution track for the best fitting model with **$M_\star$ = 2.4 $M_\odot$, f_{ov} = 0.014**, and a **ZAMS rotational velocity of 47 km/s** is shown in blue. The absolute value of the difference in the large separation for the models in our grid compared to the observed value (right panel), shown as a function of mass and overshoot.

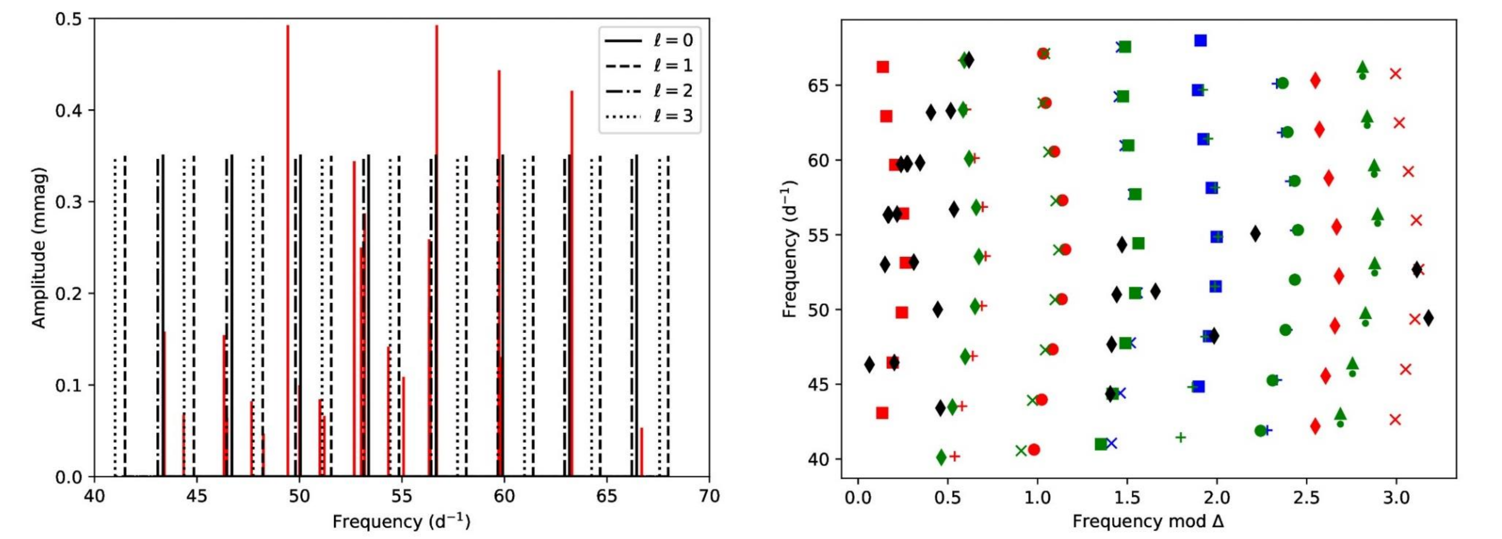

Figure 4. Left panel: Individual frequency matches for the best fitting model. The red lines are the observed frequencies plotted versus amplitude, while the black lines are the ℓ = 0 (solid), ℓ =1 (dashed), ℓ =2 (dot-dashed), and ℓ =3 (dotted) model frequencies. Right panel: The mode splitting in the ℓ = 1 (blue), 2 (red), 3 (green) modes for the best fitting model. The m = -3, -2, -1, 0, 1, 2 and 3 frequencies are denoted by triangles, diamonds, ×, squares, +, circles, and dots respectively. The black diamonds indicate the observed frequencies.

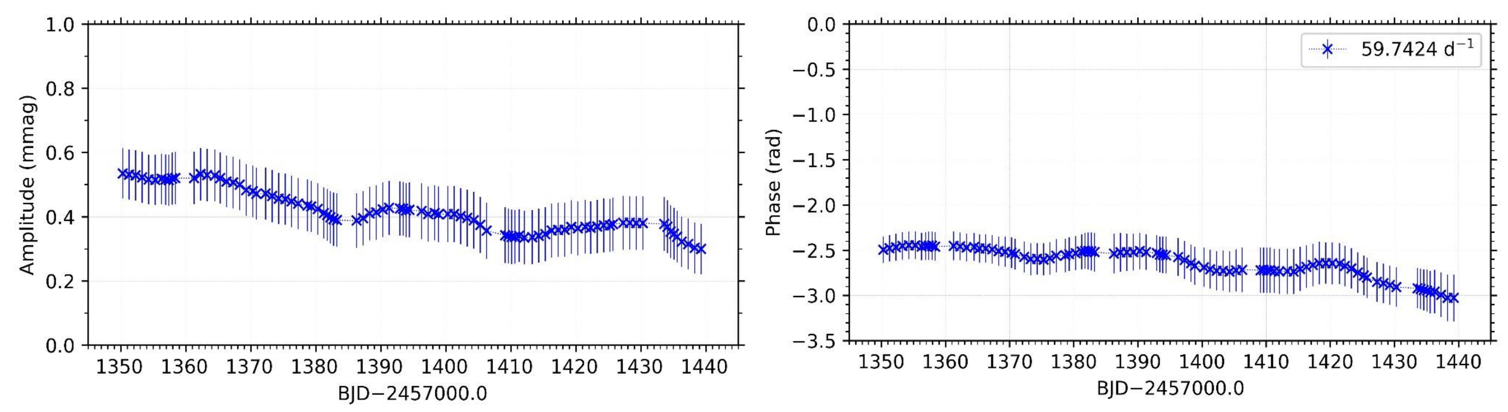

Figure 5. Variability of the amplitude (upper panel) and phase (lower panel) with time for stellar pulsation detected in HD27463 at the frequency **ν = 59.7424 d^{-1}**. 1-σ uncertainties are determined from the least-squares fit.

Conclusion

- The detected photometric period of P=2.834274 days can be explained in terms of **stellar rotation with co-rotating surface abundance patches**, likely due to the presence of a surface **magnetic field**.
- Detected in HD27463 high-frequency pulsation modes are typically found in **hotter δ Scuti stars** (Bowman & Kurtz 2018).
- Our best fitting model corresponds to an **overshoot parameter f_{ov} = 0.014** and an **age of 5.0 ± 0.4 ×10^8 yrs**, which corresponds to a **core hydrogen fraction of 0.33.**
- The **radial orders (11 ≤ n ≤ 19)** inferred from this research are high for the δ Scuti stars and are expected to be exited in **roAp stars**.
- **Amplitude and phase** of pulsation modes with highest amplitudes **are modulated in time.**

References

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