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Pulsation blip in the roAp star HD 60435 detected by SALT and TESS*

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ABSTRACT

HD 60435, a member of the rapidly oscillating Ap (roAp) class of pulsating stars, was recently reported to be the first star to be observed to entirely cease pulsating. This conclusion was drawn from photometric TESS observations that have less sensitivity to pulsational variability than spectroscopic time series data. To that end, we acquired three epochs of time resolved spectra, to coincide with TESS observations, with the Southern African Large Telescope to test for the continued cessation of pulsation. We found the star to show a pulsation blip at a single epoch, then continue to be non-variable at two further epochs. The same signal, and lack thereof, was also seen when analysing the nearly contemporaneous TESS photometry.

Keywords: Rapidly oscillating Ap star (27) — Asteroseismology (73) — Chemically peculiar stars (226) — Oblique rotators (1144) — Photometry (1234) — Spectroscopy (1558)

1. INTRODUCTION

HD 60435 was discovered to be a rapidly oscillating chemically peculiar (roAp) star by Kurtz (1984) based on ground-based B photometric data. It showed a series of alternating odd and even degree modes, making it an ideal star to perform asteroseismic analysis (Matthews et al. 1987). However, the most recent study of the star, utilising TESS space photometry, showed the pulsation modes to be variable in amplitude with an eventual decay below detection of all modes, suggesting the star was no longer pulsating (Kurtz et al. 2025). HD 60435 is the only example of any pulsating variable star to stop pulsating entirely.

It is unclear why the star stopped pulsating. It was postulated that energy transfer between modes may have excited undetectable high-degree modes. Regardless of the mechanism, this cessation impacts statistical studies of roAp stars and the low pulsation rate among Ap stars (Holdsworth et al. 2024). If pulsations are transient, the distinction between roAp and non-oscillating Ap stars blurs, complicating efforts to identify the physical mechanisms behind pulsation.

The changes in pulsation amplitude in HD 60435 suggest that continuous monitoring of the star is required to detect the potential re-excitation of modes. While TESS provides μmag precision photometric data, continuous monitoring is not possible and the lowest amplitude modes in roAp stars (discovered spectroscopically) are not recovered. To that end, we acquired time resolved spectra with the Southern African Large Telescope (SALT; Buckley et al. 2006) at three epochs to test for pulsation. These epochs coincided with TESS observations of HD 60435, enabling investigation of whether pulsations were detectable spectroscopically, photometrically, or with both techniques.

2. OBSERVATIONS, REDUCTIONS AND ANALYSIS

We used the High Resolution Spectrograph (HRS; Crause et al. 2014) on the 10-m class SALT in the medium resolution mode (R∼40 000) to collect three epochs of data: 2024-12-17, 2025-02-05 and 2025-02-24. The first coincided with the start of TESS Sector 87, with the others observed at the two rotation light maxima of the star. At each visit, we collected 25 spectra with exposure times of 120 sec, resulting in a cadence of 195 sec. The data were reduced with the in-house pipeline (Kniazev et al. 2016), then normalised with the SUPPNet code (Różański et al. 2022).

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* based on observations made with the Southern African Large Telescope (SALT)

The analysis was conducted in the same way as presented in Kurtz et al. (2025). Briefly, for unblended lines of Nd III, Pr III and the Hα core, we created a δ-function template for each set of lines independently. Cross-correlation of these templates with the spectra was used to determine the radial velocity (RV) variations of the lines. The amplitude spectra of the RVs were then calculated using the Discrete Fourier Transform code of Kurtz (1985). Given that the spectral line formation in Ap stars is significantly vertically stratified in the atmosphere, we treat the different sets of lines separately.

Our spectroscopic data were obtained (almost) concurrently with TESS observations. We therefore also analysed the TESS photometric data to test if pulsation (or lack of) was apparent in both data sets. We used the SAP SPOC (Jenkins et al. 2016) 120 sec cadence data to calculate the amplitude spectrum as above. The specific observations analysed can be accessed via doi: 10.17909/ymmx-c968.

3. RESULTS

Figure 1 shows the observational data with the corresponding amplitude spectra of the different data sets. The top panel, with the broken abscissa, shows the RV measurements of Pr III in red and portions of the TESS light curve in blue. The significant variations seen in the TESS data are a result of chemical spots in the star's atmosphere modulating the light output over the rotation cycle of the star since the Ap stars are oblique rotators (see Holdsworth et al. (2021) for an introduction to roAp stars).

During the first epoch HD 60435 showed a clear pulsation signal around a known pulsation frequency of $\sim 120\,\mathrm{d}^{-1}$. The Pr III lines showed the most significant signal, but the variation was also detected in the Nd III lines and the Hα core. The TESS photometry, obtained ~ 1 d later, also showed low amplitude variation at the same frequency.

For the later epochs, we timed our spectroscopic observations to coincide with the two rotational maxima of the star since pulsation maximum in roAp stars occurs at the same time as the light maximum (in the red TESS bandpass). However, no pulsation signal was detected in the spectroscopic or photometric data sets.

4. CONCLUSIONS

We conclude that HD 60435 is still undergoing sporadic periods of pulsation. The star has not ceased pulsation entirely, but is subject to pulsation 'blips'. This star warrants regular time-resolved monitoring both spectroscopically and photometrically to enable the discovery of further blips and investigate the redistribution of the pulsation energy. Given the sparsity of the current data, it is unclear if these blips represent the death throes of pulsation in HD 60435 and it will become a non-oscillating Ap star, or if the pulsations are undergoing a form of excitation cycle and we are currently entering a minimum phase. Either way, additional data sets are key for understanding the unique behaviour of HD 60435.

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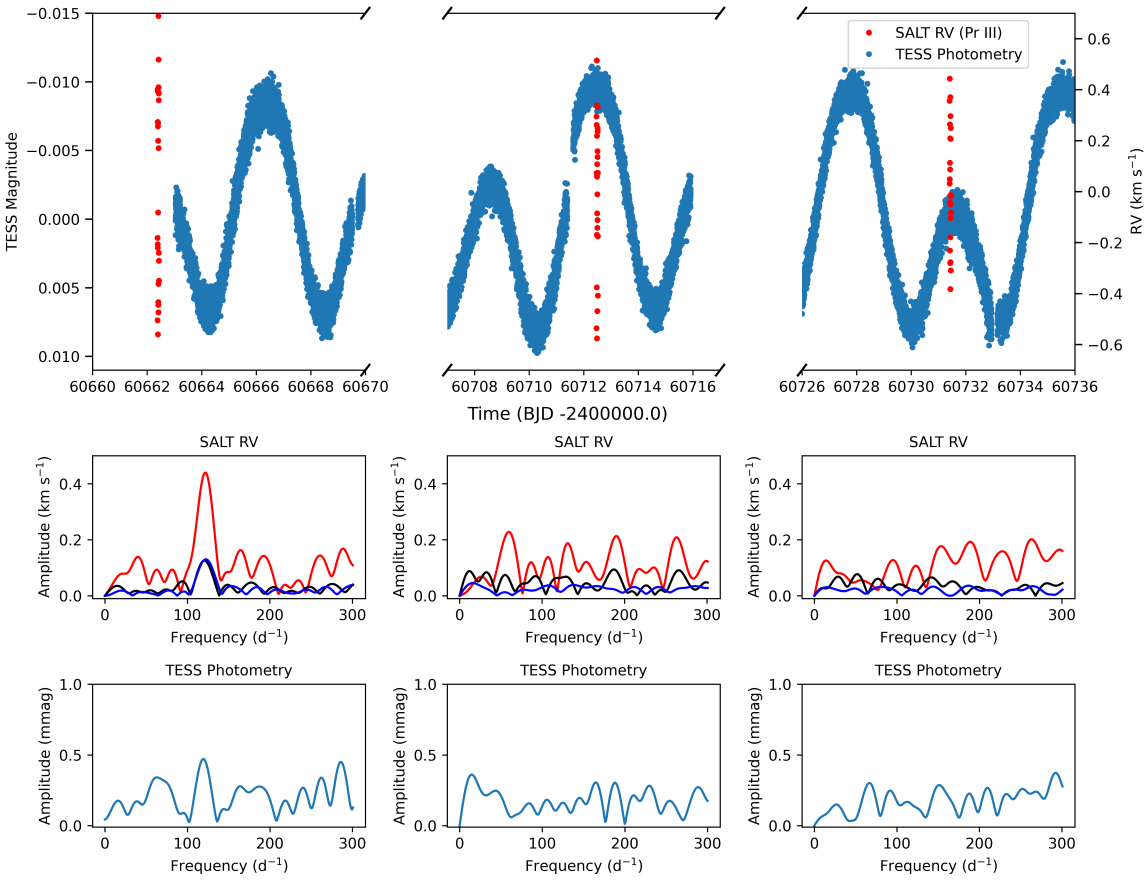

Figure 1. Top: SALT RV measurements (shown for Pr III lines; red points) and TESS photometric observations (blue points). The variation seen in the TESS data is due to stellar rotation. Middle: Amplitude spectra of the SALT RV data (red – Pr III; black – Nd III; blue – Hα core). Bottom: Amplitude spectra of TESS photometry using the same length of data. The first epoch shows significant pulsation amplitude in the spectroscopic observations, with indication of pulsation in photometry. The star is then quiet at subsequent epochs.

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