Mercury-manganese stars in the observations of the TESS satellite

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We present preliminary results of the variability search among known HgMn stars with the use of TESS satellite observations. Out of 188 stars with high-quality photometry, only 16 turned out to be constant. Variability among other stars may mostly be attributed to eclipsing binaries and/or rotational modulation. In addition, we found 24 candidates for pulsating variables. TESS observatory turns out to be a great laboratory for variability surveys among chemically peculiar stars.

1 Introduction

Chemically peculiar (CP) stars are a heterogeneous group of objects characterised by surface abundances that can depart by many orders of magnitude from the solar values (Michaud et al., 2015; Gray & Corbally, 2009). Peculiarities result from the segregation of chemical elements in stellar atmospheres under the influence of atomic transport processes, in some cases in combination with magnetic field and/or stellar wind (see Landstreet, 2004, 2014, and references therein).

Mercury-manganese (HgMn) stars have spectral types from B7 to B9 and luminosity classes III-V. About 190 HgMn stars were classified by the strong line of Hg II at 3983.94 Å and several lines of Mn II visible in the blue part of the spectrum (catalogues: Schneider, 1981; Renson & Manfroid, 2009; Ghazaryan et al., 2018, and publications concerning individual stars). Another 260 new HgMn stars were identified based on H-band spectra obtained via the SDSS@APOGEE survey (Chojnowski et al., 2020).

Abundance anomalies found in HgMn stars are caused by atomic diffusion processes, which are very sensitive to mixing motions (Michaud et al., 2015). That explains why HgMn stars are slow rotators ($v \sin i$ less than about $75\,\mathrm{km\,s^{-1}}$, Landstreet, 2014) and often occur in binary systems (Smith, 1996; Ghazaryan & Alecian, 2016). For some HgMn stars, weak magnetic fields have been detected (e.g. Mathys & Hubrig, 1995). In addition, periodic variability was discovered in the spectra of some HgMn stars (e.g. Prvák et al., 2020) which may indicate the inhomogeneous distribution of chemical elements on the surface under the presence of a magnetic field.

Turcotte & Richard (2003) showed that diffusion in A and B stars can cause a substantial increase in opacity in the region where pulsations in slowly pulsating B stars (SPB) are driven. According to them, roughly 50% of HgMn stars located in the SPB instability domain should show variability with amplitudes of approximately 10 mmag. The TESS observatory is an ideal laboratory for this type of variability search. Indeed, the first candidates for SPB variables were found by Kochukhov et al. (2021). They analysed the TESS 2-min light curves of 64 well-known HgMn stars and identify several HgMn stars showing multiperiodic g-mode pulsations. In our research, we analysed the TESS 2-min and FFI data for 275 stars classified as HgMn.

2 Methods

Time-series photometry has been obtained for 275 HgMn stars selected from Schneider (1981), Renson & Manfroid (2009) and Ghazaryan & Alecian (2016). Of this, 54 stars have been observed with 2-min/20-sec cadence. For them, the TESS data were downloaded via the Mikulski Archive for Space Telescopes[1] (MAST) and subsequently divided into two separate datasets: (i) SAP flux and (ii) PDC flux. Usually, PDC flux was better in quality as has been previously corrected for instrumental trends. For the remaining stars, the Full Frame Images (FFI) photometry has been obtained utilising TESScut[2] package, also available from MAST. In the process of performing FFI photometry, the best aperture has been selected by trial and error. Data points with a non-zero TESS quality flag have been rejected from further analysis. We found that 188 stars had good quality time-series photometry and for the remaining targets only instrumental trends have been visible in light curves.

3 Results

Analysis of the TESS light curves showed that most of the investigated HgMn stars are variable. Only 16 of them were classified as constant based on the TESS data. Their variability is mainly caused by occurrence in multiple systems (e.g. HD 221507, HD 1909 and HD 34364 in Fig. 1) or rotation modulation (e.g. HD 358, Fig. 1). We have confirmed the multiple nature of stars classified as such in the past, but some new binaries, including eclipsing systems, were discovered as well. In many cases, it is impossible to decide if observed variability is caused by rotational modulation or due to binarity. The follow-up photometric multi-band observations, as well as spectroscopic data may be required. The full results of the variability search among HgMn stars are now being prepared (Mikołajczyk et al. 2022, in. prep.). Also, the Gaia (Gaia Collaboration et al., 2016) results will be used to better characterise the analysed stars. The location of the investigated HgMn stars on the colour-magnitude diagram (CMD) based on the Gaia EDR3 photometry is shown in Fig. 2.

Moreover, we also report the existence of a dozen candidates for SPB-type pulsating HgMn stars. The light curve and frequency spectrum of one of them, HD 29589, is shown in Fig. 1. For this star, over 20 independent frequencies, and combinations and harmonics were obtained from the Fourier analysis (2-min data from TESS sectors: 5, 32, 43, and 44). We have checked and excluded contamination from the background sources for this object. In addition, we have performed the spectroscopic analysis of HD 29589 to prove the peculiar nature of this star. For this purpose, we have used an average spectrum prepared using 5 high-resolution and high signal-to-noise FEROS spectra available in the ESO Archive. Atmospheric parameters, determined from Balmer and iron lines are typical for hot HgMn stars. The LTE analysis of all elements but Helium shows an abundance pattern typical for HgMn

[1] `https://archive.stsci.edu/`
[2] `http://mast.stsci.edu/tesscut/`

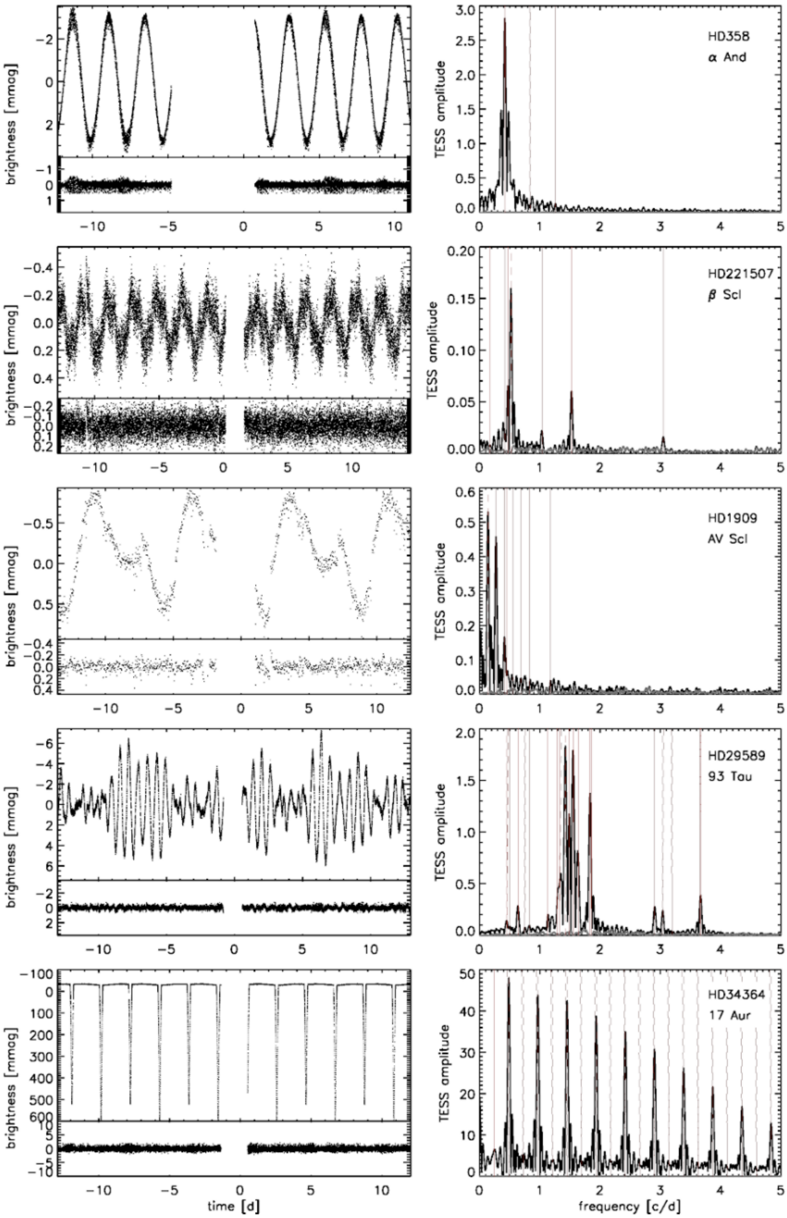

Fig. 1: Light curves and residuals (*left* panels) and Fourier frequency spectra (*right* panels) for five well-known HgMn stars. Obtained frequencies are indicated with red dashed lines. The stars were chosen as representative of all variability types found for these objects in TESS data. HD 358 were classified as rotation variables by Abt et al. (2002); the analysis of TESS data confirms this result. HD 221507, HD 1909, and HD 34364 are known binary systems of different types (see Paxton et al. 2019, Wahlgren et al. 2002 and Pojmanski & Maciejewski 2004, respectively). HD 29589 is a new pulsating HgMn star.

stars (with overabundant P, Ga, Xe, and Hg). Moreover, the non-LTE analysis of Helium indicates the reduced He abundance and its stratification in the atmosphere of HD 29589. Due to its peculiar chemical composition, the star may show rotational variability. We have performed the seismic modelling of HD 29589 (Niemczura et al. (2022)).

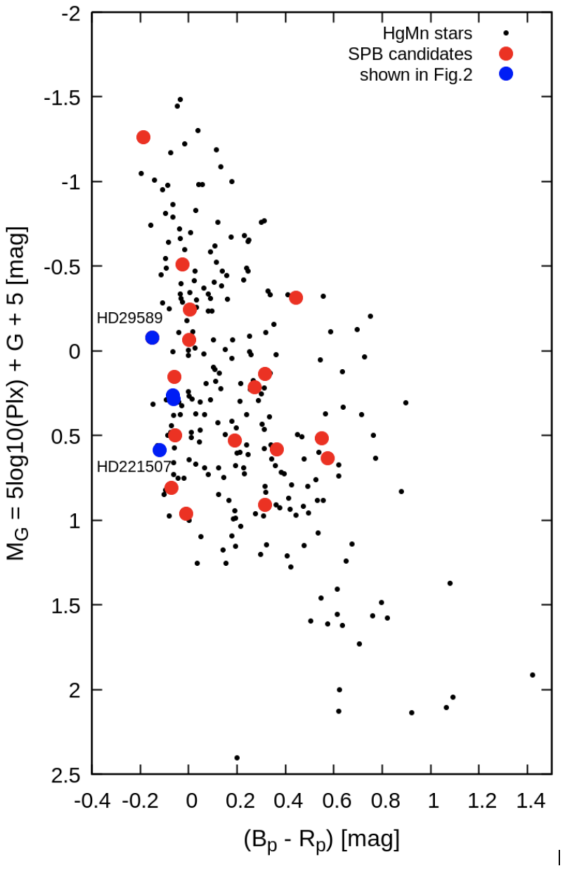

Fig. 2: Colour-magnitude diagram (CMD) for the analysed HgMn stars based on Gaia EDR3 (Gaia Collaboration et al., 2021) photometry. Red filled circles indicate SPB candidates, stars from Fig. 1 are plotted with blue circles. The Gaia EDR3 data are not available for HD 358=α And (the star is too bright). Two stars (HD 1909 and HD 34364) are located close to each other with (Bp-Rp)≈ -0.08 and $M_{\mathrm{G}} \approx 0.25$.

4 Conclusions

The TESS space observatory is the perfect tool for detecting the variability of chemically peculiar HgMn stars. Thanks to high-cadence and almost uninterrupted time-series photometry, we are now able to determine their variability types. Out of 275 investigated stars, only 16 appeared to be constant in the TESS data. Variability of the others is in most cases due to binarity or rotation. This result is not unexpected.

From the previous investigations it was clear that HgMn stars often occur in binary systems (Ghazaryan & Alecian, 2016), which makes them slow rotators, allowing diffusion to work and as a consequence abundance anomalies can be observed in their spectra. Numerous HgMn stars showing rotational modulation suggest the existence of a magnetic field, which is in line with previous discoveries (e.g. Hubrig et al., 2020). The TESS observations in Cycles 3 and 4 deliver a great amount of photometric data with an even better time cadence (20 sec for short and 10 min for long cadence for some targets). Along with previously released data, we should be able to confirm the variability nature of SPB candidates as well as to look for new variables. Summarising, we managed to detect variables of many types in TESS light curves, but the number of SPB pulsators is minuscule, which suggests the existence of a physical mechanism responsible for this fact.

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