Variability of HgMn stars in TESS data

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80	25
Hg	Mn
Mercury	Manganese

Introduction

Chemically peculiar **mercury-manganese (HgMn) stars** have spectral types from **B7 to B9** and luminosity classes III-V. Until recently, about **200 stars** with HgMn peculiarity were known (catalogues: Schneider 1981, Renson & Manfroid 2009, Ghazaryan & Alecian 2016, and publications concerning individual stars). They are classified by the strong line of Hg II at 398.394 nm and/or several lines of Mn II. Other overabundances are detected for the chemical elements like P, Cu, Ga, Y, Xe and Pt, whereas He, Al, Co and Ni are typically underabundant (Ghazaryan & Alecian 2016). The **260 new HgMn stars** were identified on the basis of H-band spectra obtained via the SDSS@APOGEE survey (Chojnowski et al. 2020). HgMn stars are slow rotators ($v\sin i$ less than about 75 km s^{-1}, Landstreet 2014) and often occur in binary systems (e.g. Ghazaryan & Alecian 2016). Hence, abundance anomalies found in HgMn stars are due to atomic diffusion processes, which are working best in quiet atmospheres. For some HgMn stars weak magnetic fields have been detected (e.g. Mathys & Hubrig 1995, Hubrig et al. 2020). In addition, periodic variability was discovered in the spectra of HgMn stars (e.g. Hubrig et al. 2011; Prvák et al. 2020) what indicate inhomogeneous distribution of chemical elements on the surface and indirectly the presence of magnetic field. Moreover, on the Hertzsprung-Russell diagram, **HgMn stars are located in the instability domain of Slowly Pulsating B (SPB) stars** (Pamyatnykh 1999). SPB stars are massive non-supergiant variables whose light, radial velocity and line profile variations are caused by gravity mode pulsations (g-modes). These pulsations are driven by the classical κ-mechanism, operating in the layer where the main source of opacity is a huge number of bound-bound transitions of the iron-group elements (Dziembowski et al. 1993). Turcotte & Richard (2003) showed that diffusion in A and B stars can cause a substantial increase in opacity in the region where pulsations in SPB stars are driven. According to them, **roughly 50% of HgMn stars located in the SPB instability domain** <u>should show</u> **variability with amplitudes of approximately 10 mmag**. This result is highly inconsistent with the observations. The absence of observed pulsating HgMn stars suggests that some important physical process is not included in the models. Nevertheless, investigation of the photometric variability of HgMn stars are still unexpectedly rare, considering available data, both ground-based and satellite.
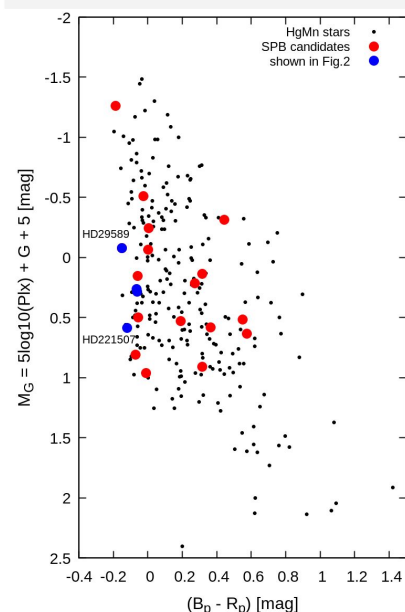

Fig. 1: Colour-magnitude diagram (CMD) for the analysed HgMn stars using Gaia-EDR3 photometry. Red filled circles indicate SBP candidates, stars from Fig. 2 are plotted with blue circles. Gaia DR3 data are not available for HD358=α And (star is too bright). Two stars (HD1909 and HD34364) are located close to each other with (Bp-Rp) ≈ −0.15 and M_G ≈ 0.6.

TESS observations

TESS photometric time series are currently available for **275** HgMn stars, **54 of which have 2-min data** (MAST Archive). For the remaining stars, the FFI (Full Frame Images) data have been extracted using the TESScut package, also available on the MAST Archive. In the process of performing FFI photometry, the best aperture has been selected by trial and error method. Data points with non-zero TESS quality flag have been rejected from further analysis. **For 188 stars the quality of the data was good enough to perform meaningful Fourier analysis and discuss variability type.**

Results

Analysis of TESS light curves showed that most of the investigated HgMn stars are variable. Only **16** of them were classified as **constant** on the basis of TESS data. Their variability is mainly caused by occurrence in multiple systems (e.g. HD221507, HD1909 and HD34364 in Fig. 2) or rotation modulation (e.g. HD358, Fig. 2). We have confirmed 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. Moreover, **we also report the existence of a dozen candidates for SPB-type pulsating HgMn stars.** Light curve and frequency spectrum of one of them, **HD 29589**, is shown in Fig. 2. For this star, over 20 independent frequencies, and combinations and harmonics were obtained from the Fourier analysis. We have checked and excluded contamination from the background sources for this object. In addition, we have performed spectroscopic analysis of HD29589 to proof 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 (see Fig. 3), determined from Balmer and iron lines are typical for hot HgMn stars. The LTE analysis of all elements but Helium shows abundance pattern typical for HgMn 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 HD29589. Due to peculiar chemical composition, the star may show rotational variability. We have performed the seismic modelling of HD 29589 (Niemczura et al. 2021, submitted to MNRAS).

In the case of most identified variables, it is impossible to determine the true variability nature at this stage of research - some follow-up photometric multi-band observations as well as spectra may be required. The full results of variability search among HgMn stars are now being prepared (Mikołajczyk et al. 2021, in. prep.).
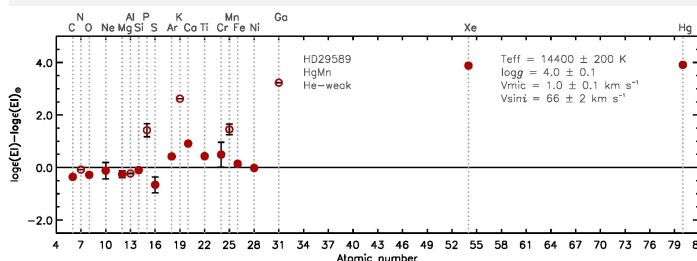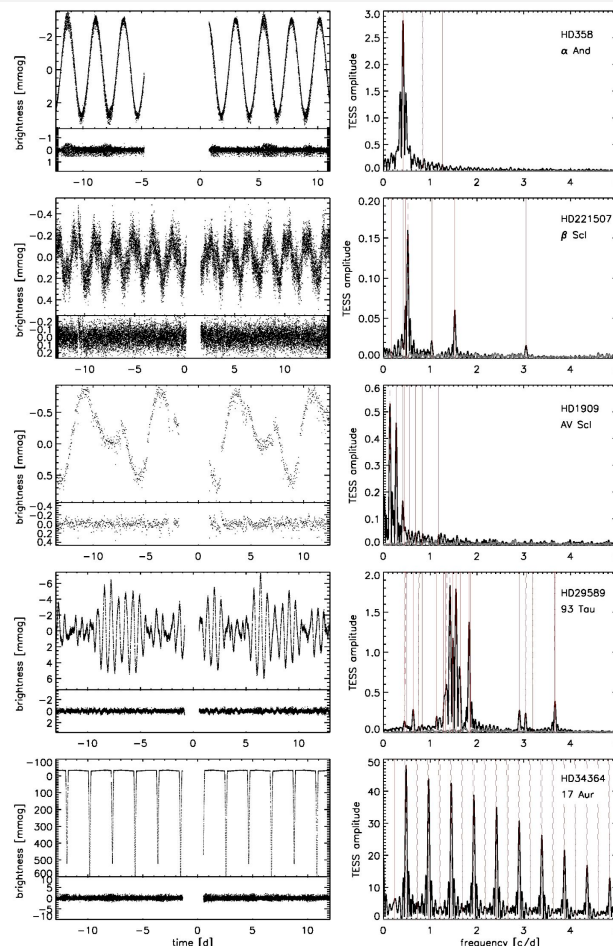

Fig. 2: Light curves and residuals (left panels) and Fourier frequency spectra (right panels) for five well-known HgMn stars. Obtained frequencies are indicated with red dashed lines. The stars were chosen as representative for all variability types found for these objects in TESS data. HD358 was classified as rotation variable by Adelman et al. (2002); the analysis of TESS data confirms this result. HD221507, HD1909 and HD34364 are known binary systems of different types (see Pedersen et al. 2019, Wahlgren et al. 2002 and Pourbaix et al. 2004, respectively). HD29589 is a new pulsating HgMn.

Fig. 3: Abundance pattern of HgMn star HD29589. Atmospheric parameters (effective temperature, surface gravity, microturbulence velocity and projected rotation velocity) are also given in the Figure. Odd-Z elements and even-Z elements are denoted by open and filled symbols, respectively. Solar abundances are from Asplund et al. (2009).

Conclusions

TESS space observatory is the perfect tool for detecting 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 TESS data.** Variability of the others is in most cases due to binarity. This result is not unexpected. From the previous investigations it was clear that HgMn stars often occur in binary systems (e.g. Ghazaryan & Alecian 2016), what makes them slow rotators, allows 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 magnetic field, what is in line with previous discoveries (e.g. Hubrig et al. 2020). The TESS observations in Cycle 3 & 4 will deliver immense amount of photometric data with even better time cadence (20 sec for short and 10 min for long cadence). Along with previously released data, we should be able to confirm variability nature of SPB candidates as well as to look for new variables. Summarizing, we managed to detect variables of many types in TESS light curves, but the number of SPB pulsators is miniscule, which suggests the existence of physical mechanism responsible for this fact.

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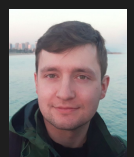51-622 Wrocław, Poland
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