Open Clusters in TESS Data

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We present preliminary results of the variability search in the field of the young open cluster NGC 6200 using TESS data. We confirm the variability of five previously known β Cep stars and found several candidates for B-type pulsators in the cluster. For two stars, ALS 3721 and ALS 3728, we report bump-like features in the raising branches of their light curves. We conclude that NGC 6200 is a good candidate for ensemble asteroseismology. While spatial resolution of TESS images limits the possibility of studying variability in dense open clusters, this is still possible for loose open clusters and OB associations.

1 Introduction

NGC 6200 is a sparse young open cluster located in the constellation Ara close to the Galactic plane ($b = -1.2°$). Stephenson & Sanduleak (1971) found nine O- and early B-type stars in the field of the cluster. Fitzgerald et al. (1977) performed UBV photometry and confirmed at least 14 early B-type stars (13 identified as probable cluster members). These authors found that the reddening across the cluster varies in the range of about 0.3 mag with the mean value equal to 0.63 ± 0.07 mag in terms of $E(B-V)$. They estimated the distance to the cluster at about 2.4 kpc. The age of NGC 6200 is in the range between 8 and 10 Myr (McSwain & Gies, 2005; Kharchenko et al., 2005, 2013). Whiteoak & Gardner (1985) relate the cluster to Ara OB1 association.

The first β Cep star in the cluster, NGC 6200-4[1] (ALS 3721, HD 328862), with a period of 0.202069 d, was found by Pojmanski & Maciejewski (2004). The period and variability type was later confirmed by Pigulski (2005), who analysed its ASAS-3 light curve and found four periodic terms (three independent modes). Using ASAS-3 data, Pigulski et al. (2019, in preparation) found four additional β Cep stars in the cluster. These are NGC 6200-2, 3, 9, and 10 (ALS 3732, 3728, 3717, and 3713, respectively). In consequence, the stars have been proposed for 2-min cadence observations with TESS. TESS mission pointed its cameras towards this part of the sky when observing Sector 12 between May 21 and June 19, 2019. The cluster was placed at CCD#2 in Camera 1. The purpose of this is study is to verify the variability of the known five β Cep stars and search for variability in the remaining B-type members.

2 Methods

Time-series photometry has been obtained for 35 bright stars located in the field of NGC 6200. Four have 2-min cadence photometry from TESS, which was downloaded from Mikulski Archive for Space Telescopes (MAST[2]). For the remaining 31 stars,

[1]The numbering system follows Fitzgerald et al. (1977).

[2]http://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html

the Full Frame Images (FFI) photometry has been obtained by means of TESScut[3] 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 non-zero TESS quality flag have been rejected from further analysis.

3 Results

Analysis of TESS time-series data confirmed all frequencies in five known β Cep stars (Pojmanski & Maciejewski, 2004; Pigulski, 2005) with the sole exception of $f_1 = 8.04966\,\mathrm{d}^{-1}$ in ALS 3713, which is a daily alias of the true frequency of $6.050\,\mathrm{d}^{-1}$ derived from the TESS data (strong daily aliasing in inherent to the ASAS-3 data). Amplitudes of the known pulsation modes and consistent with those reported in the literature. Moreover, the in-depth analysis of TESS data revealed many new pulsation frequencies in these five stars with the extreme case of ALS 3728 for which the final model included 107 sinusoidal terms. Two stars, ALS 3728 and 3721, show bumps at the raising branches of their light curves (Fig. 1), a feature characteristic for the largest-amplitude β Cep stars, BW Vul in particular (e.g. Sterken et al., 1987) and originating from shocks propagating in the pulsating atmosphere (Crowe & Gillet, 1989). This feature was found in three other stars by Pigulski & Pojmański (2008). It was also confirmed in ALS 3721 by Ulusoy et al. (2013b). Ulusoy et al. (2013a) have also reported existence of two frequencies around $4.96\,\mathrm{d}^{-1}$ and $13.4\,\mathrm{d}^{-1}$ in ALS 3728, which are confirmed in the TESS data.

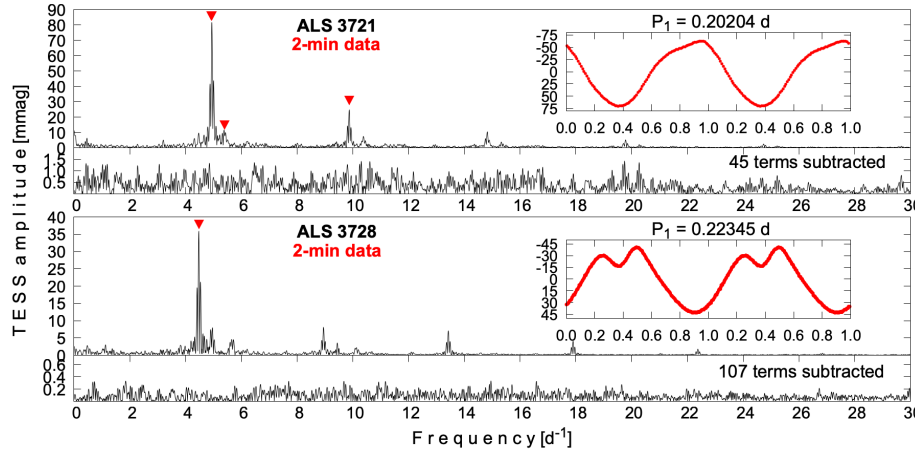

Fig. 1: Fourier frequency spectra of TESS data for two β Cep stars in NGC 6200, ALS 3721 (top) and ALS 3728 (bottom), having the largest amplitudes. Reversed red triangles indicate frequencies found in the ASAS-3 data (Pigulski & Pojmański 2008, Pigulski et al., in prep.). The insets show phased light curves for the dominating modes with a bump-like feature visible in their light curves. Note different ordinate scales for frequency spectra of data and residuals.

We also report the existence of at least four new candidates for B-type pulsating stars among likely members of NGC 6200. These are ALS 3729 (NGC 6200-1) and

[3]http://mast.stsci.edu/tesscut/

ALS 16905, which both show low-amplitude terms in the p-mode frequency range of $5-10\,\mathrm{d}^{-1}$, while two other stars, ALS 3722 and 3738, show variability typical for slowly pulsating B-type (SPB) stars. The full results of the analysis of TESS photometry for stars in NGC 6200 will be published elsewhere.

4 Conclusions

Our study shows that TESS data can be successfully used to detect low-amplitude variability in members of loose open clusters. Owing to the high-cadence and almost uninterrupted time coverage, we were able to detect many additional frequencies in the known B-type pulsators and find new variable stars. NGC 6200 seems to be another Galactic open cluster rich in β Cep stars. This makes the cluster a good candidate for ensemble asteroseismology (Saesen et al., 2010; Moździerski & Pigulski, 2016; Moździerski et al., 2019). Poor spatial resolution of TESS images ($\sim$21 arcsec per pixel) severely limits the number of open clusters that can be searched for B-type pulsators. We selected at least a dozen of good candidates, however. A supreme detection level (down to $\sim$ 0.02 mmag in the best cases) in frequency spectra will surely allow to find new low-amplitude β Cep and SPB stars. We can therefore significantly increase the sample of known B-type pulsators with TESS data. This will allow for statistical studies of their characteristics as well as detailed seismic modelling.

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References

Crowe, R., Gillet, D., *A&A* **211**, 365 (1989)

Fitzgerald, M. P., Jackson, P. D., Moffat, A. F. J., *The Observatory* **97**, 129 (1977)

Kharchenko, N. V., et al., *A&A* **438**, 3, 1163 (2005)

Kharchenko, N. V., et al., *A&A* **558**, A53 (2013)

McSwain, M. V., Gies, D. R., *ApJS* **161**, 1, 118 (2005)

Moździerski, D., Pigulski, A., in A. Różańska, M. Bejger (eds.) 37th Meeting of the Polish Astronomical Society, volume 3, 98–101 (2016)

Moździerski, D., et al., *arXiv e-prints* arXiv:1910.11873 (2019)

Pigulski, A., *Acta Astron.* **55**, 219 (2005)

Pigulski, A., Pojmański, G., *A&A* **477**, 3, 917 (2008)

Pojmanski, G., Maciejewski, G., *Acta Astron.* **54**, 153 (2004)

Saesen, S., et al., *Astronomische Nachrichten* **331**, 1080 (2010)

Stephenson, C. B., Sanduleak, N., *Publications of the Warner & Swasey Observatory* **1**, 1 (1971)

Sterken, C., Young, A., Furenlid, I., *A&A* **177**, 150 (1987)

Ulusoy, C., Niemczura, E., Ulaș, B., Gülmez, T., *New A* **22**, 51 (2013a)

Ulusoy, C., Niemczura, E., Ulaș, B., Gülmez, T., *New A* **23**, 55 (2013b)

Whiteoak, J. B., Gardner, F. F., *Proceedings of the Astronomical Society of Australia* **6**, 164 (1985)