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Stellar activity in open clusters

A. Görgei[1,2,3], K. Vida[1,2], B. Seli[1,2,3], L. Kriskovics[1,2]

[1]Konkoly Observatory, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary
email: gorgei.anna@csfk.org

[2]CSFK, MTA Centre of Excellence, Budapest, Hungary

[3]Eötvös Loránd University, Budapest, Hungary

Abstract. Stellar activity depends on multiple parameters one of which is the age of the star. The members of open clusters are good targets to observe the activity at a given age of the stars since their ages are more precisely determined than that of field stars. Choosing multiple clusters, each with different age, gives us insight to the change in activity during the lifetime of stars. With the analysis of these stars we can also refine the parameters of gyrochronology (Barnes 2003), which is a method for estimating the age of low-mass, main sequence stars from their rotation periods.

Keywords. Stars: activity, rotation, methods: data analysis, techniques: photometry

1. Introduction

Studying stellar activity within open clusters provides a unique laboratory for understanding these astrophysical processes. The proximity and similar ages of cluster members allow us to investigate the impact of stellar environment on the magnetic activity of individual stars while studying clusters of different ages offers a perspective on how this behaviour evolves over time.

2. Cluster membership

In this work, the target of the analysis was the Hyades cluster – this is one of the closest (47pc) young cluster, allowing us to obtain high signal-to-noise observations even of the intrinsically fainter targets. The cluster was observed by the TESS (Ricker et al. 2015) in four sectors. These are S05, S32, S43 and S44. The short cadence TESSLightCurveFile data were also used.

The determination of the cluster membership was done with the HDBSCAN algorithm (McInnes et al. 2017) using Gaia DR3 (Gaia Collaboration et al. 2016, Gaia Collaboration et al. 2023) parallax, proper motion and coordinates. HDBSCAN is a density-based, hierarchical clustering method, the tree of groups in the data can be built as a result of hierarchical clustering. The following steps describe how the method works. First, the data is transformed according to its density and then the distance-weighted graph is built. Then the cluster hierarchy of connected components is determined and compressed according to the minimum cluster size. Finally, the method identifies stable clusters. For this a stability parameters is defined:

$$\sum_{\mathrm{p}\in\mathrm{cluster}} \lambda_{\mathrm{p}} - \lambda_{\mathrm{cluster\ birth}} \quad \text{where} \quad \lambda = \frac{1}{\mathrm{distance}} \tag{1}$$

and p refers to nodes in the built tree.

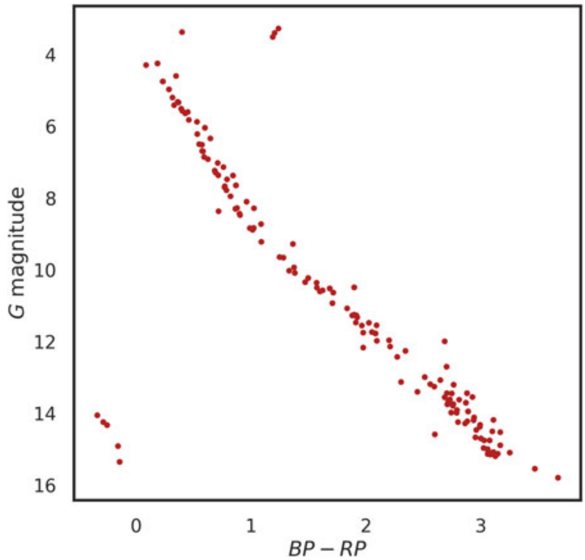

Figure 1. The color–magnitude diagram of cluster members with short candence data.

A cluster is considered stable if its stability is greater than the sum of its subclusters stability. This stability test criteria ensure that the artificial groups resulting from its operation are not included in the selected real groups. After clustering and comparing the coordinates with the TESS field of view 426 stars make up our sample (see Fig. 1).

3. Rotation

Gyrochronology is based on the fact that the rotation of a star changes with its age. This change occurs because the star loses angular momentum through magnetized winds during its lifetime. Rotational period determination was done with the Lomb–Scargle algorithm (VanderPlas 2018). The comparison with archival rotational values is plotted in Fig. 2. Between now and the time of the presentation of the poster, Núñez et al. (2023) published their result of rotational periods based on the same TESS data. The values obtained by my analysis show a good match with theirs.

4. Flare detection

Flare detection on the short cadence light curves was done using the FLATW'RM2 (Vida et al. 2021) program which is based on deep learning and is specialized to analyse TESS and Kepler light curves. In total over 600 flares were found on 135 stars (Fig. 3).

5. Flare statistics

Flare energies are determined based on the bolometric luminosity of the star and the area under the flare. The bolometric luminosities are calculated from Gaia DR3 effective temperatures and surface gravity with the Gaiadr3 Bcg package (Creevey et al. 2023). This analysis gives the cumulative flare frequency diagram as the result (see Fig. 4).

6. Future work

In the continuation of the project we will look at the cluster stars in new TESS sectors to get better flare statistics. LOFAR measurements of some of the member stars were

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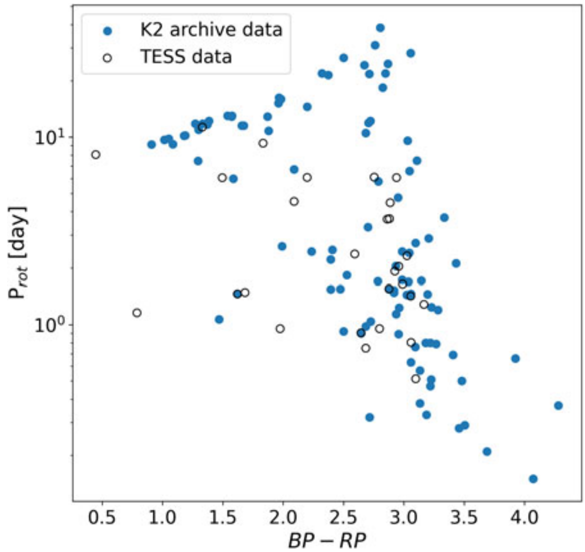

Figure 2. The color–rotation period of the cluster based on TESS short-cadence data overplotted with archived K2 (Douglas et al. 2019) data.

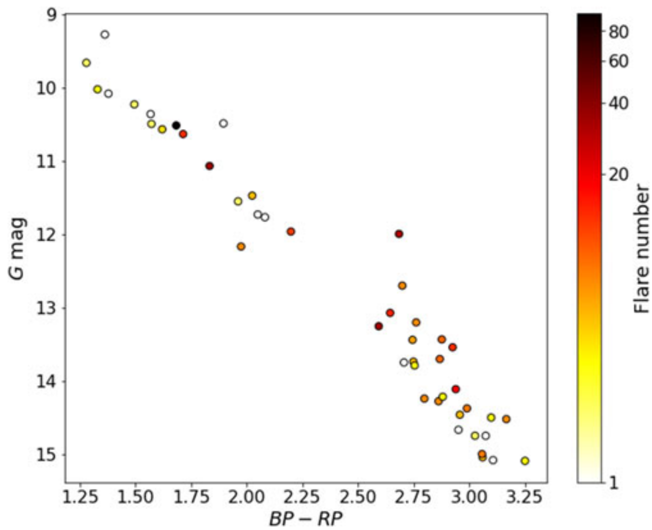

Figure 3. Color–magnitude diagram. Colors indicate the number of flares detected on each star.

gathered simultaneously with TESS sectors S70 and S71, so comparing those to the optical data and looking for flare and (possibly) CME signals is our aim too.

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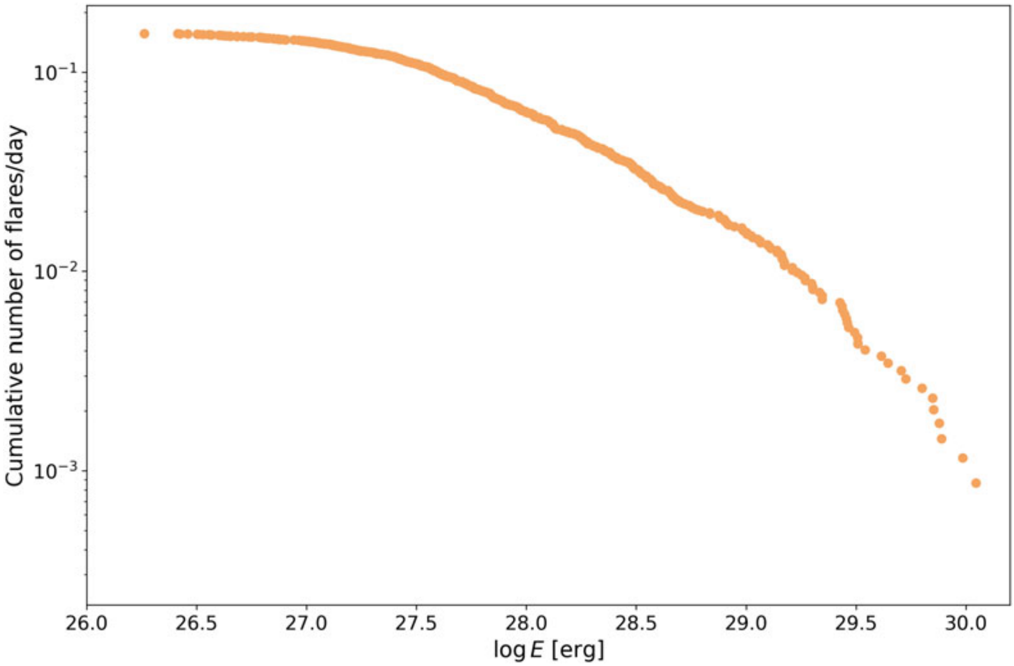

Figure 4. Cumulative flare frequency diagram for the cluster.

data from the European Space Agency (ESA) mission *Gaia* (`https://www.cosmos.esa.int/gaia`), processed by the *Gaia* Data Processing and Analysis Consortium (DPAC, `https://www.cosmos.esa.int/web/gaia/dpac/consortium`). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the *Gaia* Multilateral Agreement. This paper includes data collected by the TESS mission. Funding for the TESS mission is provided by the NASA's Science Mission Directorate.

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