Open Access Online Journal on Astronomy and Astrophysics

Acta Astrophysica Taurica

www.astrophysicatauricum.org

Acta Astrophys. Tau. 3(2), 46–49 (2022)

A search for activity cycles in the selected F, G, and K dwarfs based on long-term wide-field photometric observations

A.A. Shlyapnikov, N.I. Bondar', M.A. Gorbunov

Crimean Astrophysical Observatory, Nauchny 298409
aas@craocrimea.ru

Submitted on November 5, 2021

ABSTRACT

The possibilities of using data from the KWS project of ground-based panoramic observations to search for activity cycles in bright F – K dwarfs are considered. The methods and results of processing observational material are given, and the formation of an interactive database is described.

Key words: solar-type stars, red dwarfs, activity stellar cycles, databases

1 Introduction

Various manifestations of activity in mid- and low-mass stars of spectral types from F to L, including dark spots and light faculae on the photosphere, bright chromospheric active regions, flares in different spectral ranges, coronal mass ejections, are caused by changes in the structure of magnetic fields. The sources of energy for this activity are magnetic fields, and, depending on their configuration, generation and dissipation, there can develop inhomogeneities on different scales in the atmosphere of a star, the characteristics of which vary over time intervals from fractions of a second to decades.

To research the activity cycles produced by photospheric spots, the long-term photometric series are required. Such series can currently be obtained through a compilation of the results of electrophotometry and data from wide-field photometric surveys, which have been held since 2000. An analysis of long-term light curves obtained from the ground-based and space photometric observations of OU Gem, V1005 Ori, and AU Mic has shown that these stars exhibit cycles of about 40 years (Bondar', Katsova, 2020). All these stars have activity cycles of 10–16 years; EQ Vir, V1005 Ori, and AU Mic also show short cycles of 5-6 years. In all cases, the amplitude of the detected long-term cyclic variations does not on average exceed 0.2 mag and $0^m.04 - 0^m.08$ for short cycles. More significant brightness variations ($\sim 0^m.8$) were discovered by analyzing the secular variations in the average annual V values for the star V833 Tau over 120 years (from 1899 to 2019) – the longest series of photometric observations (Stepanov et al., 2020).

In this paper, continuing our earlier studies of the cycles of stars on the lower main sequence (Bondar' et al., 2019), we consider the possibility of using the Kyoto Wide-field Survey (KWS) photometric database for F – K dwarfs of 4-9 mag. The description of the developed interactive application with information about the objects under study is given. Data processing includes a cleaning of the input data, which leads to an increase in their accuracy, a filtering of the random impulsive events of an increase or decrease in brightness, which is important for detecting low-amplitude variations in the brightness of a star. For a number of stars, the results of searching for cycles on the 10-yr scale are given.

2 Interactive application containing the data for analysis

To work with data on the studied objects, a special interactive application was created (Fig. 1). It includes a network access to the basic star information in the SIMBAD (Wenger et al., 2000) and KWS (Maehara, 2014) databases. The page also contains information about the detected or suspected activity cycles, links to illustrations of the filtered and averaged over years light curves as well as to the source data from which they are built. The page is updated as far as new information is accumulated.

More detailed information about the ongoing research is contained in the section Cycles KWS[1], posted on the website Cycles and Flares[2].

3 Data processing

Wide-field photometric observations within the KWS project are performed using a small CCD array in combination with a

[1] http://www.crao.ru/~aas/PROJECTs/CycFla/Cycles_KWS/Cycles_KWS.HTM
[2] http://www.crao.ru/~aas/PROJECTs/CycFla/Cycles_and_Flares.html

The search for a possible cyclic variability from KWS data in selected F - K dwarfs

Website is under construction. Test version. Contact (mag@crao.ru, aas@crao.ru).

Information is presented on the search for possible cyclic variability of selected stars from the list of objects [1, 2].

Table description:

1. N - record number.
2. RAJ (2000.0) - barycentric right ascension (ICRS) at Ep=2000.0.
3. DEJ (2000.0) - barycentric declination (ICRS) at Ep=2000.0.
4. SIMBAD - link to the SIMBAD database [3] for this object.
5. V_mag - V-magnitude from SIMBAD.
6. Sp_Type - spectral type from SIMBAD.
7. P_rot - rotation period (day) [4, 5, 6].
8. KWS - link to the KWS database [7] for this object.
9. Cycle-1 - cycle 1 from [1, 2].
10. Cycle-2 - cycle 2 from [1, 2].
11. LC (KWS) - link to the light courve (LC) and V magnitude with calculated JD (V-data) from this site.
12. LC (FBD) - link to the light curves (LC) with filtered and bins data (FBD) and V magnitude (FB-data) from this site.
13. LC (YED) - link to the light curves (LC) with year mean magnitude and error of data (YED) from this site (YE-data).
14. Note.

N	RAJ (2000.0)	DEJ (2000.0)	SIMBAD	V_mag	Sp_Type	P_rot	KWS	Cycle-1	Cycle-2	LC (KWS)	LC (FBD)	LC (YED)	Note
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	00 18 41.8674	-08 03 10.806	HD 1461	6.47	G3VFe0.5	-	HD 1461	-	-	LC V-data	LC FB-data	LC YE-data	C4
2	00 22 51.7883	-12 12 33.972	HD 1835	6.39	G2.5V	8	HD 1835	9.1±0.3	Long	LC V-data	LC FB-data	LC YE-data	C~6-14, **, X
3	00 35 32.8335	-00 30 20.198	HD 3229	5.94	F5V	2	HD 3229	4.9±0.1	-	LC V-data	LC FB-data	LC YE-data	P1, P3, F, C1.64, X
4	00 45 28.6875	-12 52 50.912	HD 4307	6.15	G0V	-	HD 4307	-	-	LC V-data	LC FB-data	LC YE-data	F, P3, P4, C11.23, **
5	01 10 18.7400	+42 04 53.309	HD 6920	5.67	F9IV, F8V	14	HD 6920	Var	-	LC V-data	LC FB-data	LC YE-data	C9.48

Fig. 1. Fragment of the HTML page of the Flares and Cycles project with a description of the table.

photographic lens. This allows one to monitor simultaneously an area of 5° × 7°.5 with an ability to cover an area up to 120° per night. The photometric accuracy for objects in the range of $V = 5 - 11$ mag is of 5 % or higher. The number of objects in the KWS database is about 200 million.

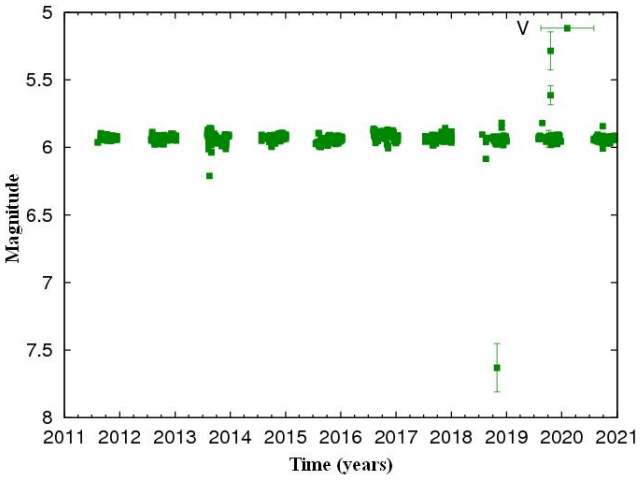

Fig. 2. The original light curve of the star HD 3229 from the KWS database.

To find out the possibility of using the KWS data in the tasks of searching for cyclic activity, 72 bright stars were selected from $4^m.02$ to $8^m.67$ in the V-band with F4V – K4V spectral types. For 22 of them, the estimated cycles of magnetic activity were determined with an accuracy of no more than 0.5 years. (Baliunas et al., 1995; Radick et al., 2018). Note that the cycle duration was determined from spectral observations.

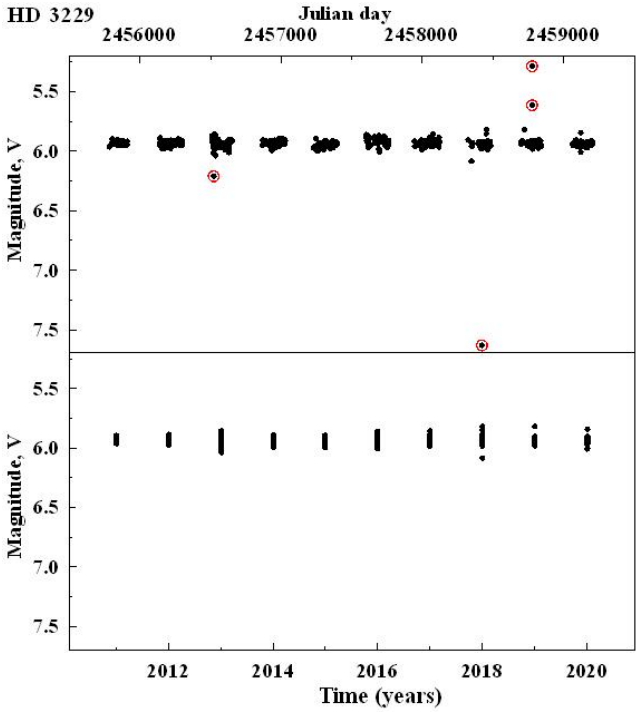

Fig. 3. Original (upper panel) and filtered (lower panel) light curves for the star HD 3229.

In order to automate data processing, a special software was written, which makes it possible to exclude impulse events of increasing or decreasing brightness of a star from the observed series, which improved the accuracy of time series analysis. An example of the processed light curve for the star HD 3229 (F5V, $V = 4.9$) according to the KWS data is shown in Fig. 2. As can be seen from the figure, observations of the star covers a time span of about 10 years.

Figure 3 shows the original and filtered light curves of the studied star, including those with data convolution over years (lower panel). In the top panel, red circles indicate the excluded data.

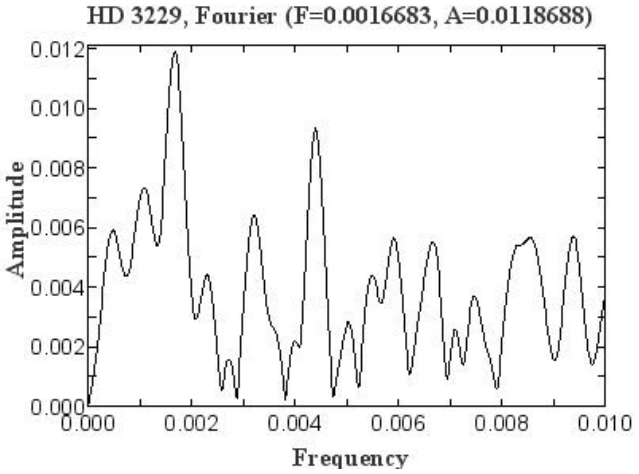

Fig. 4. Results of periodogram analysis.

4 Analysis of data for periodicity and the presence of possible cycles

The results of periodogram analysis and convolution of data with the found periods are shown in Figs. 4 and 5. We have found two possible periods of cyclic brightness changes for the star under consideration: 1.64 yr (Fig. 5a) and 4.9 yr (Fig. 5b). The ratio of the periods is 1/3. Taking into account the measurement errors, the longer period corresponds to three times the short period. Previously, a period of 4.9 ± 0.1 yr was found from changes in the chromospheric activity index (Baliunas et al., 1995).

5 Conclusions

The analysis of observations of the star HD 3229 demonstrates an example of using the KWS project data to search for long-term low-amplitude brightness changes, possibly associated with cyclic activity. One of the determined periods coincides within the error limits with the previously obtained value of the period from long-term spectral observations.

For some of the stars in the sample, the suspected activity cycles were found for the first time. Some of the earlier detected cycles have not been confirmed by our results.

The website indicated in Sect. 2 contains the original and filtered light curves of the studied stars, the results of periodogram analysis, and convolutions of data with the found periods. While implementing the work we have actively used the applications SIMBAD, VizieR, and ALADIN supported by the Center for Astronomical Data in Strasbourg as well as the SAO/NASA ADS bibliographic service. The authors are grateful to everyone who provides access to these services. This work was partially supported by the Russian Foundation for Basic Research, project No. 19-02-00191.

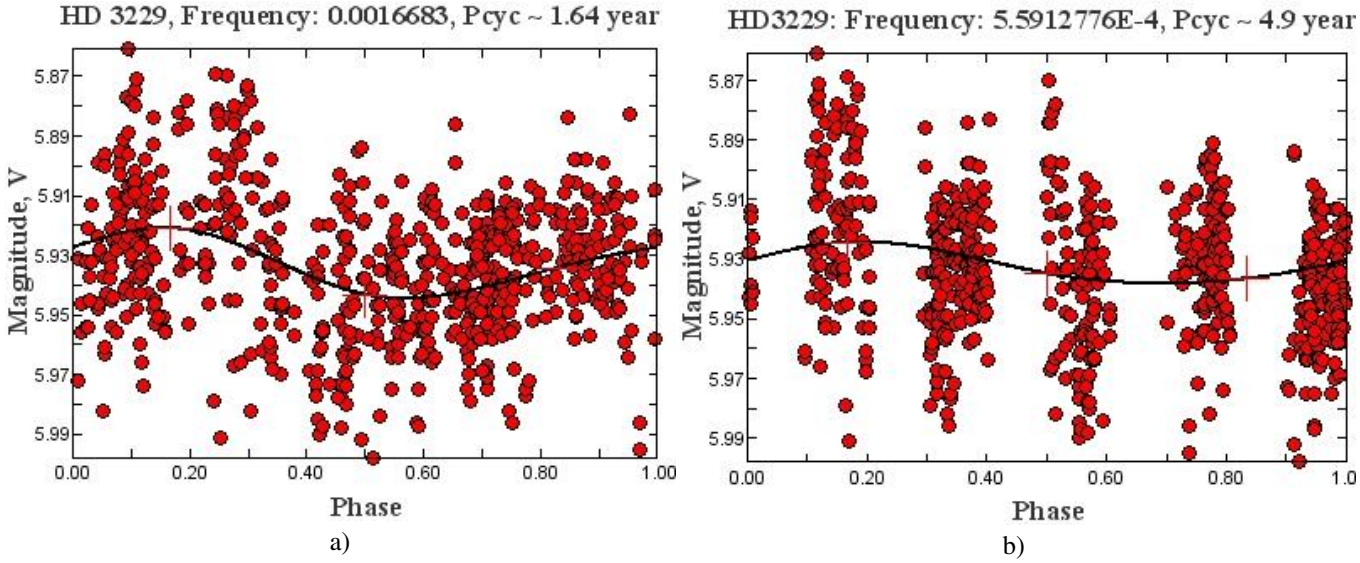

Fig. 5. Possible cycles of changes in the brightness of the star HD3229 according to the KWS data.

References

Baliunas S.L., Donahue R.A., Soon W.H., et al., 1995. Astrophys. J., vol. 438, p. 269.

Bondar' N.I., Gorbunov M.A., Shlyapnikov A.A., 2019. Physics of Magnetic Stars. ASP Conf. Ser., vol. 518, p. 180.

Bondar' N.I., Katsova M.M., 2020. Geomagnetism and Aeronomy, vol. 60, p. 942.

Maehara H., 2014. Journ. Space Sci. Inf. Japan, vol. 3, p. 119.

Radick R.R., Lockwood G.W., Henry G.W., et al., 2018. Astrophys. J., vol. 855, iss. 2, id. 75.

Stepanov R., Bondar' N.I., Katsova M.M., et al., 2020. Mon. Not. Roy. Astron. Soc., vol. 495, iss. 4, p. 3788.

Wenger M., Ochsenbein F., Egret D., et al., 2000. Astron. Astrophys. Suppl. Ser., vol. 143, p. 9.