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Multi-Period Magnetic Activity in Solar-Type Stars

Amina Boulkaboul
Centre of Research in Astronomy, Astrophysics, and Geophysics| Algiers, Algeria
amina.boulkaboul@craag.edu.dz

INTRODUCTION & AIM

Magnetic activity is a fundamental property of solar-type stars, driven by the interaction between rotation, convection, and dynamo processes operating in their outer envelopes [1]. In the Sun, magnetic activity manifests on multiple characteristic timescales, most prominently the ∼11-yr activity cycle [2]. Similar phenomena have been observed in other late-type stars through long-term monitoring of chromospheric and photospheric activity indicators. Subsequent studies revealed that stellar magnetic variability is often more complex than a single periodic cycle, with evidence for multiple simultaneous or time-dependent periodicities, including secondary cycles and short-term modulations [3].
The coexistence of multiple magnetic periods may reflect the presence of different dynamo modes.
Understanding multi-period magnetic activity is especially important in the context of high-precision radial-velocity surveys, where stellar magnetic variability can introduce signals that mimic or obscure planetary companions.
In this work, we investigate multi-period magnetic activity in a sample of solar-type Gaia radial velocity standard stars, using chromospheric activity indicators to identify and characterize coexisting magnetic timescales.

METHOD

Sample Selection
We analyze a sample of solar-type Gaia radial velocity standard stars, selected for their long-term radial-velocity stability and extensive spectroscopic monitoring [4,5]. These stars provide high-quality time series suitable for detecting low-amplitude magnetic variability over both short and long timescales.

Activity Indicators
Magnetic activity is quantified using the Ca II H&K S-index, defined as the ratio of chromospheric line-core flux to nearby continuum flux. The S-index is computed by summing the flux in two 1.09 Å triangular bandpasses centered on the Ca II K (3933.66 Å) and H (3968.47 Å) lines and dividing by the flux in two 20 Å-wide continuum windows centered on the V (3900.0 Å) and R (4000.0 Å) passbands [6].

$$S = \alpha \frac{H+K}{R+V}$$

The Bisector Inverse Slope (BIS) is the velocity difference between the upper part of the CCF bisector (60–90% of the CCF depth) and the lower part (10–40%) [7].

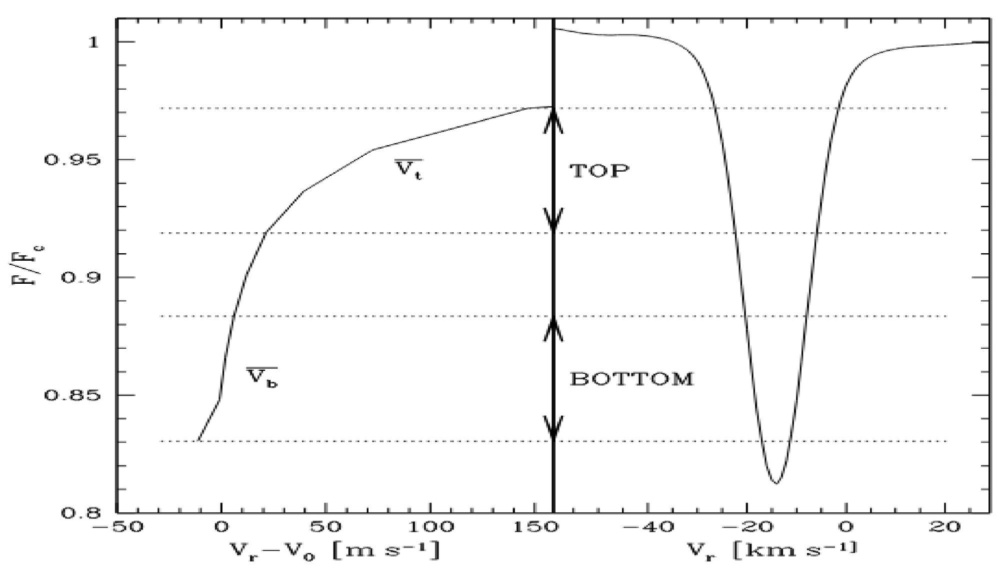

Fig. 1: Right: CCF function of HD 166435's spectra. Left: Bisector of the CCF. (Queloz et al. 2001)

Time-Series Analysis
Apply the generalized Least-Squares periodograms [8]. Significant peaks are identified using false-alarm probability (FAP) thresholds.
To isolate multiple coexisting periodicities, the dominant signal is modeled and removed from the data, and the period search is repeated on the residuals.

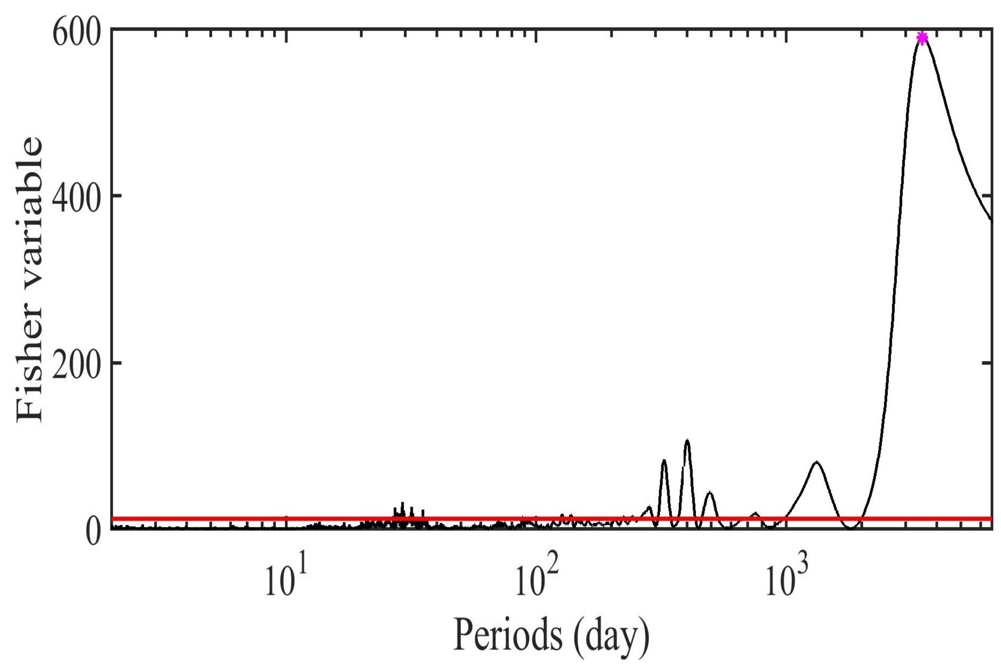

Fig. 2: Periodogram of HIP10301 with the threshold (red).

RESULTS & DISCUSSION

HIP ID	P_1	P_2	P_2/P_1	K_2/K_1	e_1	e_2	Plt	
436	3385 ± 14	1695.0 ± 7.2	0.501 ± 0.010	0.621 ± 0.049	0	0.270 ± 0.016	No	B 1&2
1599	5534.992 ± 0.039	1724.41 ± 0.63	0.31155 ± 0.00014	0.5476 ± 0.0059	0.30365 ± 0.00058	0.65918 ± 0.0002	No	S 1&2
10301	2912.5 ± 4.5	1276.8 ± 3.3	0.4384 0.0047	0.389 ± 0.043	0.5152 ± 0.0086	0.426 ± 0.013	Yes	S 1&2
30503	1950 ± 65	4194 ± 611	2.15 ± 0.33	0.23 ± 0.69	0.147 ± 0.016	0	Yes	S 1&2
40693	4460 ± 13	1323.3 ± 5.3	0.297 ± 0.011	0.147 ± 0.040	0.0143 ± 0.0055	0	Yes	S 1&2
48331	3719.9 ± 1.2	1249.69 ± 0.86	0.3359 ± 0.0012	0.1506 ± 0.0066	0.22337 ± 0.00069	0.4637 ± 0.0029	Yes	S 1&2
64408	617.27 ± 0.29	1005.74 ± 0.20	1.62934 ± 0.00061	1.429 ± 0.023	0.54114 ± 0.00018	0.76141 ± 0.00029	No	S 1&2
79190	5159 ± 35	2661.2 ± 2.0	0.516 ± 0.014	1.109 ± 0.023	0.2077 ± 0.0088	0.6402 ± 0.0036	No	S1 B2

Table. 1: Magnetic cycle periods, ratio of secondary to primary periods, ratio of amplitudes, and asymmetry factors for the stars with two magnetic cycles. The last column represents the source of the periodic signal (BIS or S-index).

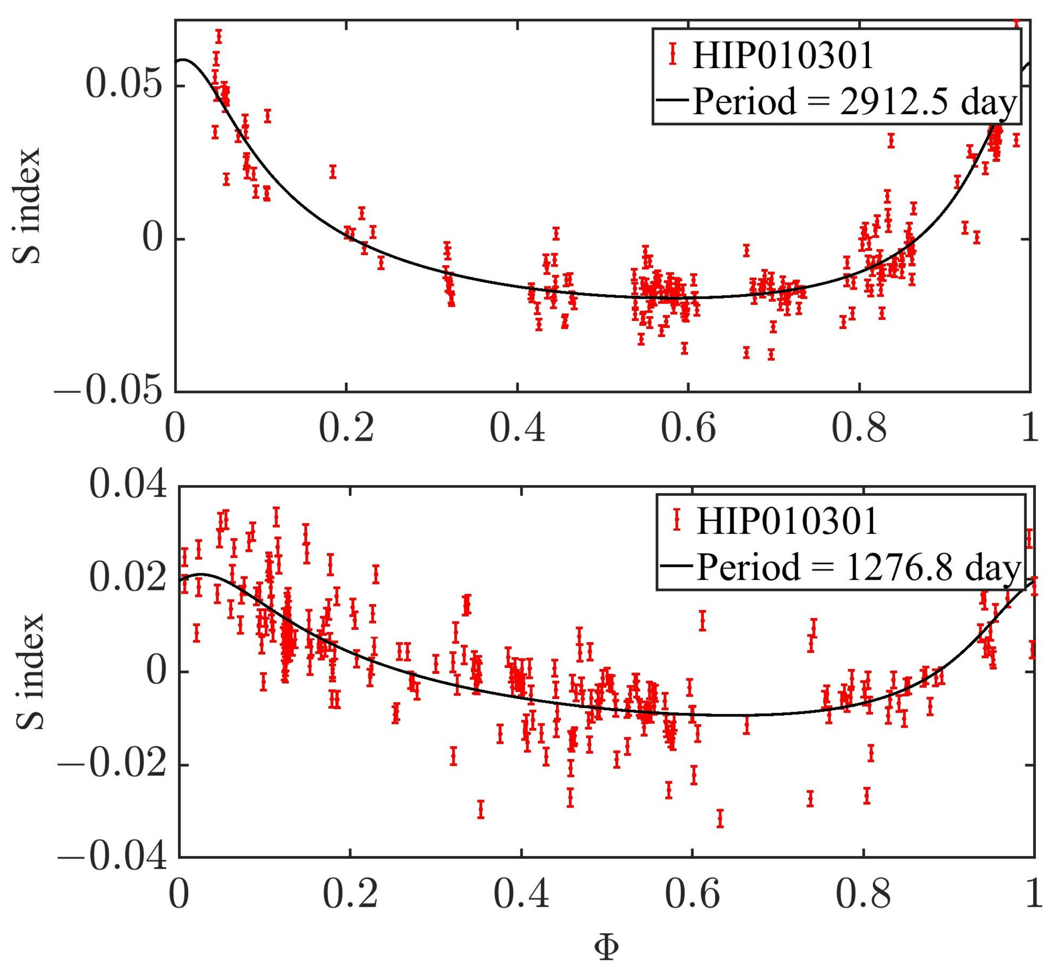

Fig. 3: HIP10301 phase-folded S-index time-series over the two magnetic cycle periods

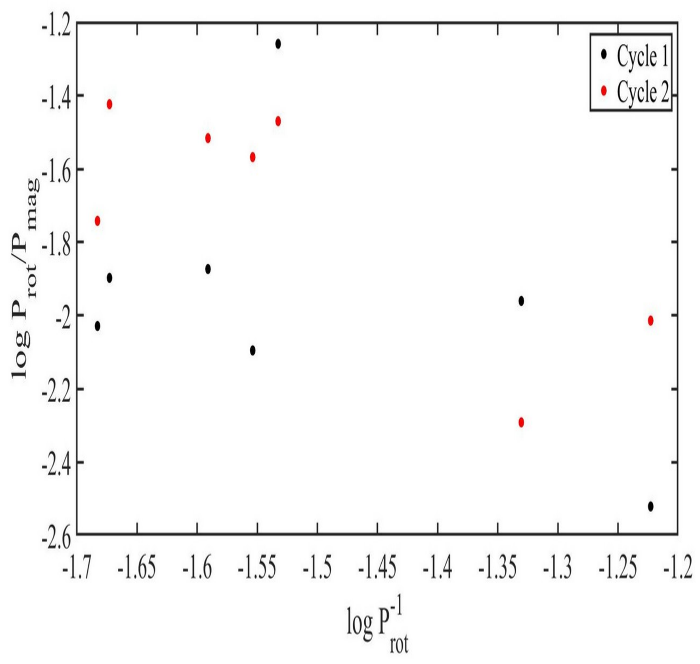

Fig. 4: Logarithmic scale of Prot/Pmag as a function of reverse of the rotation period for the primary (black) and secondary (red) magnetic cycle.

CONCLUSION

Eight stars in the sample show possible evidence of secondary magnetic cycles. The period ratios span a broad range from 0.3 to 2.2, suggesting both shorter and longer secondary cycles relative to the primary one, which may indicate possible cycle dominance switching or beating dynamo behavior. The amplitude ratios range from 0.1 to 1.4, implying that, in some stars, the secondary signal is weak and possibly noise-dominated, while in others it is comparable in strength to the primary cycle.
These results support the idea that multi-periodic magnetic activity is not uncommon among solar-type stars and may offer valuable constraints for dynamo theory.

FUTURE WORK / REFERENCES

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