ВАК 2024 MODERN ASTRONOMY: FROM THE EARLY UNIVERSE TO EXOPLANETS AND BLACK HOLES
300 years Russian Academy of Sciences

Magnetic and photometric variability of the super-slowly rotating Ap star GY And (HD 9996)

V. Bychkov[1], L. Bychkova[1], J. Madey[2], G. Komissarova[3], and N. Metlova[3]

[1] Special Astrophysical Observatory of the Russian Academy of Sciences, Nizhny Arkhyz, 369167 Russia
[2] Warsaw University Observatory, 4 Al. Ujazdowskie, Warszawa, 00–478 Poland
[3] Sternberg Astronomical Institute of the Moscow State University, 13 Universitetsky pr., Moscow, 119234 Russia

Abstract. The star GY And (HD 9996) belongs to a very rare and poorly studied class of super-slowly rotating Ap (ssrAp) stars. The main difficulty in conducting studies of such stars is their unusually long periods, often amounting to tens or even hundreds of years. Based on long-term magnetic monitoring conducted at the 1-m telescope of the SAO RAS and photometric monitoring carried out at the 60-cm telescope of the Southern Station of the SAI, the period (which is just over 23 years) and the parameters of magnetic and photometric variability of GY And (HD 9996) have been clarified.

Keywords: stars: magnetic field, rotation

DOI: 10.26119/VAK2024.051

1 Introduction

Super-slowly rotating Ap star (ssrAp) are of great interest to us from the point of view of stellar evolution. At present, there is no complete understanding of how the star lost its angular momentum. On average, Ap stars rotate 4–5 times more slowly than the same normal ones (Abt & Morrell 1995; Glagolevskij 2021). As suggested by Mathys (2017), Ap stars can have rotation periods lasting up to a thousand years, and this is already confirmed by the observations by Bychkov et al. (2016); Hubrig et al. (2018). A mechanism of "magnetic" braking, considered by various authors, is quite possible. But such a mechanism is only possible in the case of a purely dipole structure of the global magnetic field. In the case of a more complex structure (which is exactly what is observed in GY And), the magnetosphere of the star is significantly spherified, which sharply reduces the efficiency of the "propeller" braking mechanism. Another intriguing observed phenomenon is the huge change in the color index B–V during the period, which corresponds to a change in the effective temperature from 8350 K to 14 440 K (Metlova et al. 2014). Such a large change in temperature can only be explained by the presence of very large cold and hot spots (or groups of spots).

2 Observational data

The duration of photometric monitoring conducted at the Southern Station of the SAI (Crimea) has increased by 7.7 years. In addition, during this time, photometric observations obtained by Pyper & Adelman (2017) in the Stremgren system on the Four College Automated Photometric Telescope (FCAPT) at the Fairborn Observatory were published. We used their measurements in the Y filter (close in parameters to the Johnson V filter) after some reduction accordingly. This made it possible to refine the period. According to our estimates, it is $P = 7718 \pm 55$ days. The average photometric curve in the Johnson V filter is shown in Fig. 1a. Magnetic monitoring was continued at the 1-m SAO RAS telescope with the CEGS coude spectrometer and the circular polarization analyzer (CPA) (Bychkov 2008). As a result, the total duration of magnetic monitoring was almost 30 years. The coverage was 1.36 periods. Fig. 1b shows the average magnetic phase curve (MPC), obtained from estimates only at the 1-m SAO RAS telescope. As can be seen from Fig. 1b, the MPC is not strictly harmonic, which indicates a complex structure of the global magnetic field. Fig. 2 shows the MPC obtained from the surface magnetic field estimates, from the work by Giarrusso et al. (2022). This MPC, based on B_s estimates, also indicates a complex structure of the magnetic field of this star.

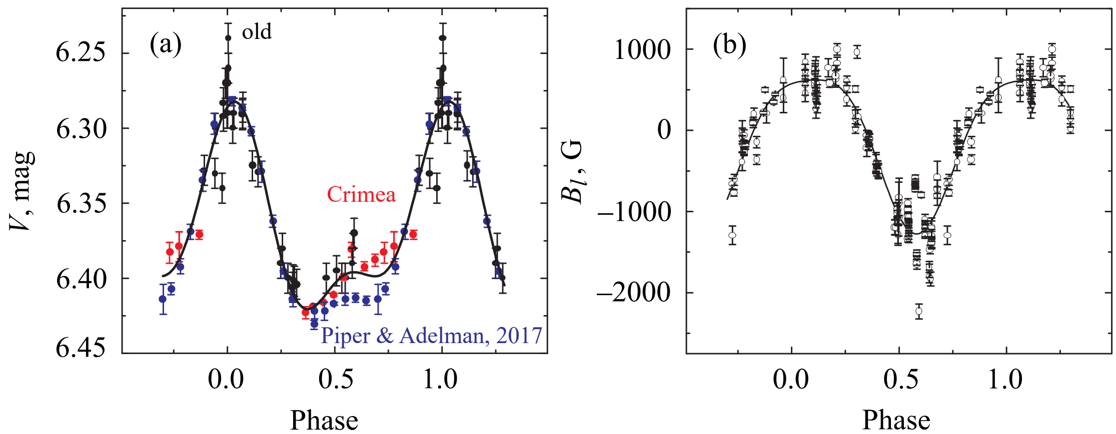

Fig. 1. Average photometric phase curve in Johnson V filter. Average magnetic phase curve obtained from B_l estimates, based on observations with the 1-m telescope of the SAO RAS.

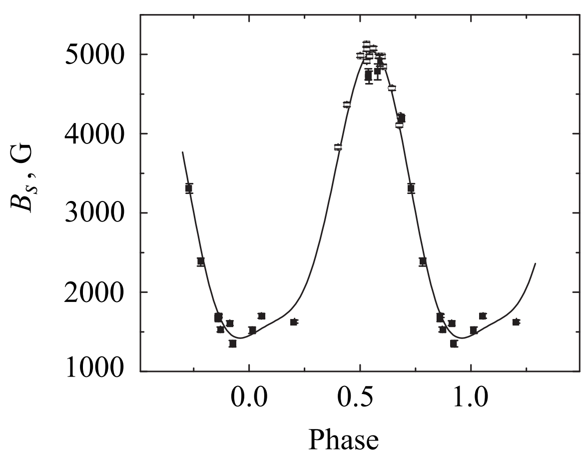

Fig. 2. Average magnetic phase curve obtained from the B_s estimates from paper by Giarrusso et al. (2022).

3 Discussion

A very interesting and still unsolved problem is very long periods observed in some mCP stars. At present, 23 magnetic stars are known, whose rotation period is more than 100 days. The mechanism of “magnetic” braking, considered by various authors for such stars, is quite probable. But the action of such a mechanism is possible only in the case of a purely dipole structure of the global magnetic field. As can be seen from observations, GY And has a complex magnetic field structure. But in this case, the magnetosphere of the star is significantly spherified. This sharply reduces the efficiency of the “propeller” mechanism. The efficiency of braking is sharply reduced due to the interaction with the interstellar medium. The large scatter of measured B_l values relative to the MCP can be explained by the presence of a shorter period of $P = 6.346258 \pm 0.000003$ days, detected by the photometry of the TESS space mission (Giarrusso et al. 2022). But this period should be confirmed undoubtedly by additional measurements. In addition, GY And is part of a wide binary system with a period of $P_{\rm orb} = 272.833 \pm 0.006$ days with a large eccentricity $e = 0.504 \pm 0.004$ (Griffin 2012). This can also affect the properties of the main component.

4 Summary

GY And is a unique ssrAp star that deserves more thorough photometric, magnetic and spectral monitoring. It stands out even against the background of other Ap stars due to its unique properties. The B–V color index change alone reaches a value of 0.3 over the period. This is approximately two orders of magnitude greater than that of other Ap stars. Such features make it necessary to study this object in more detail.

References

Abt H.A. and Morrell N.I., 1995, Astrophysical Journal Supplement, 99, p. 135

Bychkov V.D., Bychkova L.V., Madej J., 2016, Monthly Notices of the Royal Astronomical Society, 455, 3, p. 2567

Bychkov V.D., 2008, Astrophysical Bulletin, 63, 1, p. 83

Giarrusso M., Cecconi M., Cosentino R., et al., 2022, Monthly Notices of the Royal Astronomical Society, 514, 3, p. 3485

Glagolevskij Yu.V., 2021, Astrophysical Bulletin, 76, 1, p. 91

Griffin R.F., 2012, The Observatory, 132, 5, p. 309

Hubrig S., Järvinen S.P., Madej J., et al., 2018, Monthly Notices of the Royal Astronomical Society, 477, 3, p. 3791

Mathys G., 2017, Astronomy & Astrophysics, 601, id. A14

Metlova N.V., Bychkov V.D., Bychkova L.V., et al., 2014, Astrophysical Bulletin, 69, 3, p. 315

Pyper D.M. and Adelman S.J., 2017, Publications of the Astronomical Society of the Pacific, 129, p. 104203