https://doi.org/10.18524/1810-4215.2025.38.341538

OPTICAL SPECTROSCOPY OF SYMBIOTIC STAR EG And. Hα ORBITAL VARIABILITIES

A. B. Rustamova[1], Kh. M. Mikailov[2], B. N. Rustamov[2,1]

[1] Shamakhi Astrophysical Observatory named after Nasraddin Tusi, Azerbaijan
[2] Baku State University, Baku, Azerbaijan
aysel.rustemova@yahoo.com

ABSTRACT. This paper includes the results of the studies of the orbital variability of the emission and absorption components of the Hα line of the eclipsing symbiotic system EG And. We used medium-resolution amateurs about 30 spectra (R = 9,000-11,000) taken from the Astronomical Ring for Access to Spectroscopy (ARAS) database obtained during 2020-2025. Radial velocity curves of the cool component were derived from the mean of the measured radial velocities of selected absorption lines forming in the atmosphere of a M-type red giant. The system's orbital period is approximately 483.3 days (Kenyon & Garcia, 2016). It is assumed that the emission lines, and in particular the Hα line, are formed in the vicinity of a hot white dwarf. We have established that the intensity of the emission component of the Hα line has the greatest value at an orbital phase of about 0.5 (corresponding to the eclipsing of the cold primary component by the white dwarf) and the lowest at about 0.1 (the red giant eclipses the hot secondary component and the region of formation of strong emission lines), and an average at about a phase of 0.8.

Keywords: symbiotic star, binary star, spectroscopy, line profile, radial velocity curve.

АНОТАЦІЯ. У даній роботі представлено результати досліджень орбітальної змінності емісійних та абсорбційних компонентів лінії Hα у затемненій симбіотичній системі EG And. Для дослідження було використано близько 30 спектрів із бази даних ARAS Spectral Database. Ці спектри, отримані в період з 2010 по 2025 роки, мають спектральну роздільну здатність 9 000–11 000. Криві променевих швидкостей холодного компонента побудовано на основі середніх значень виміряних променевих швидкостей окремих абсорбційних ліній, що формуються в атмосфері червоного гіганта спектрального типу M. Орбітальний період системи становить приблизно 483,3 доби. Передбачається, що емісійні лінії, зокрема лінія Hα, формуються поблизу гарячого білого карлика. Встановлено, що інтенсивність емісійного компонента лінії Hα досягає найбільшого значення при орбітальній фазі близько 0,5 (що відповідає затемненню холодного первинного компонента білим карликом), мінімального – при фазі близько 0,1 (коли червоний гігант затемнює гарячий вторинний компонент і область формування сильних емісійних ліній), та середнього – при фазі близько 0,8.

Ключові слова: симбіотична зоря, подвійна зоря, спектроскопія, профіль лінії, крива променевих швидкостей.

1. Introduction

A symbiotic star is a special type of binary star system in which two vastly different kinds of stars coexist and interact in a way that resembles biological symbiosis. The term was introduced in 1941 by Paul Merrill, who borrowed the word from biology, where “symbiosis” describes the living together of different organisms as a single unit. In astronomy, the analogy applies because the two stars, though extremely different in physical properties, are bound together gravitationally and share material and energy in a complex, interdependent relationship.

A typical symbiotic system consists of:

A cool red giant (RG) – a large, luminous star in the late stage of its evolution. In some cases, instead of a red giant, a yellow giant is present. These stars have exhausted hydrogen in their cores, expanded enormously, and have cool outer atmospheres. They lose mass through a slow but dense stellar wind driven by the RG radiation and/or pulsations, ejecting vast amounts of gas and dust into surrounding space.

A hot compact companion — a white dwarf – the dense, Earth-sized remnant of a Sun-like star. The white dwarf has an extremely high surface temperature, often exceeding 100,000 K, and strong ultraviolet radiation. It can pull in matter from the red giant through an accretion disk, a rotating structure of captured gas spiraling toward the white dwarf.

The entire system is embedded in a cloud of ionized gas and dust, formed from the red giant's stellar wind. This nebula glows because the intense radiation from the hot white dwarf ionizes the gas.

The interaction is dynamic: the red giant continuously loses material, and part of this gas flows toward the white dwarf, either directly or via an accretion disk. The gravitational capture of this material can trigger bursts of activity, such as nova-like outbursts, when the accumulated matter on the white dwarf's surface undergoes thermonuclear burning.

Studying symbiotic stars is scientifically valuable because each system is essentially a natural laboratory containing:

A red giant, representing the late stage of stellar evolution for Sun-like stars.

A white dwarf and accretion processes, illustrating mass transfer and disk physics.

A circumstellar nebula, providing insights into gas dynamics, ionization, and dust formation in binary environments. Because of their complexity, symbiotic stars are important for understanding binary star evolution, stellar winds, nova eruptions, and the chemical enrichment of the interstellar medium. They also help astronomers study how matter behave under extreme temperatures, densities, and radiation fields – all within a single, gravitationally bound cosmic partnership (e.g., Kenyon,1986; Mikolajewska, 1997).

EG And (HD 4174) is a low excitation eclipsing symbiotic star with no recorded outbursts. The binary system consists of a white dwarf that ionizes part of the neutral wind from the red giant. The presence of both ionized and neutral regions in this binary, along with its high orbital inclination, is favorable for observing variations in the parameters of spectral line profiles depending on the orbital motion of the system. This facilitates determining, and – over time, as high-precision observational data accumulate – refining the orbital elements of the EG And binary system (Munari, 1993).

The optical spectrum of EG And exhibits optical emission lines of HI, [OIII], and [NeIII] superimposed on the absorption spectrum of an M-type star. Photometric and spectroscopic observations of EG And have revealed orbital periods of 481–483 days (Skopal et al., 1991; Munari, 1993; Fekel et al., 2000; Kenyon & Garcia, 2016). At optical minimum, the red giant eclipses the hot secondary component and the strong emission lines. Using optical and infrared absorption lines, the orbital parameters of the EG And binary have been reliably determined. Nevertheless, to this day, the question of whether the optical variability is caused by ellipsoidal changes, by illumination of the red giant's photosphere, by the stellar wind, or by colliding with winds from the primary and secondary components remains a subject of discussion (Shagatova, Skopal, Sekeras et.al., 2019).

Table 1: . Radial velocities [km/s] of absorption lines formed in the atmosphere of the red giant in the symbiotic EG And system, based on our 29 spectra. Phase calculated using the ephemeris data in Section 2.

Date	JD2450000+	Phase	Rv abs
01.09.2010	5440.5808	0.81538	-100.88233
12.02.2011	5605.2755	0.15615	-89.67833
09.08.2012	6148.5650	0.28028	-89.09367
22.08.2013	6529.5689	0.06241	-88.80767
21.08.2015	7256.434	0.57258	-99.29667
08.10.2015	7304.381	0.67178	-101.23733
27.09.2015	7293.392	0.64905	-100.47033
01.10.2015	7297.428	0.6574	-103.35867
23.07.2016	7592.501	0.26794	-88.15867
06.08.2016	7607.492	0.29895	-89.214
09.09.2016	7641.412	0.36914	-91.663
03.10.2016	7665.359	0.41869	-95.97233
02.09.2017	7999.441	0.10994	-88.96067
19.09.2017	8016.352	0.14493	-89.77867
25.10.2017	8052.413	0.21954	-88.11467
15.11.2018	8437.545	0.01642	-90.06667
22.01.2020	8871.263	0.91383	-94.82133
18.09.2020	9111.336	0.41057	-96.139
22.10.2020	9145.321	0.48089	-99.01733
03.11.2020	9157.343	0.50576	-96.92733
28.12.2022	9942.404	0.13014	-87.427
04.10.2023	10222.313	0.7093	-102.83333
13.11.2023	10262.3252	0.79209	-100.626
17.11.2023	10282.7	0.80046	-98.83167
14.12.2023	10293.3	0.85618	-96.81633
17.01.2024	10327.3328	0.9266	-93.772
28.02.2024	10369.392	0.01362	-92.774
04.12.2024	10649.262	0.5927	-100.44567
03.02.2025	10710.338	0.71908	-102.10133

2. Observations and data reduction

About 30 spectra from the ARAS Spectral Database were used in this research. These spectra were obtained between the year 2010 to 2025 have spectral resolutions of 9000 - 11000 (https://aras-database.github.io/database/).

The reduction of echelle spectra was carried out according to the standard technique using the new version of the DECH 30 program developed by Galazutdinov (http://www.gazinur.com/DECH-software.html).

3. Results of observations

The spectral observation data are presented in ta-

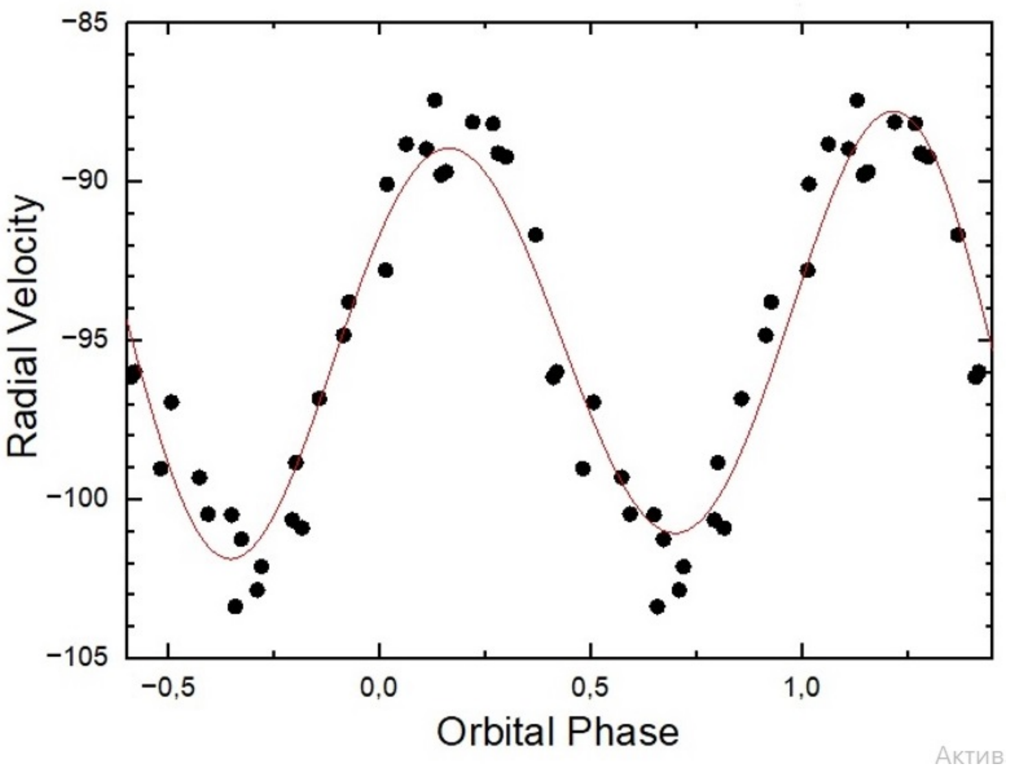

Figure 1: Radial velocity curve for the M star in EG And.

ble1. Radial velocity curves of the cool component were derived from the mean of the measured radial velocities of selected absorption lines forming in the atmosphere of a M-type red giant (table1, Fig.1). For calculation of the orbital phases of EG And we adopt an ephemeris of (Kenyon & Garcia, 2016):

JD spectros. conj.=2450213.508 +483.3×E

Moment of zero phase = moment of inferior conjunction of the giant (spectroscopic conjunction, i.e. when the giant is in front of the white dwarf)

Velocity of the center of mass of the system (γ-velocity): V$\gamma \approx$ -95 km/s.

Based on the available spectra, the profiles of the Hα line in the spectrum of the star EG And were constructed. In order to study the possible dependence of the Hα line emission intensity on the orbital phase of the EG And system, the profiles were grouped according to phase.

It is assumed that the emission lines, and in particular the Hα line, are formed in the vicinity of the hot white dwarf. It has been established that the intensity of the emission component of the Hα line reaches its maximum value at an orbital phase of about 0.5.

This phase corresponds to the moment when the white dwarf eclipses the cool primary component of the system, creating the most favorable conditions for observing the enhanced radiation.

The lowest intensity of the line is observed at a phase of about 0.1, when the red giant obscures the hot secondary component together with the region where strong emission lines are formed. At this moment, a significant part of the radiation is blocked by the giant's envelope, and the lines weaken noticeably. The average intensity of the line is recorded at approximately phase 0.8, reflecting an intermediate state of the system, when neither of the components com-

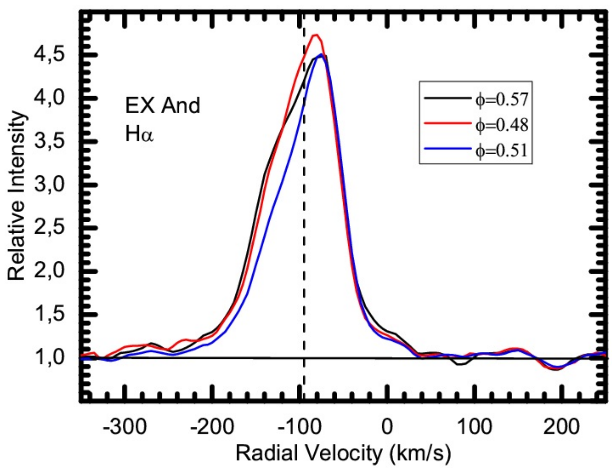

Figure 2: Profiles of the Hα line around the superior conjunction of the red giant in EG And (orbital phase 0.5).

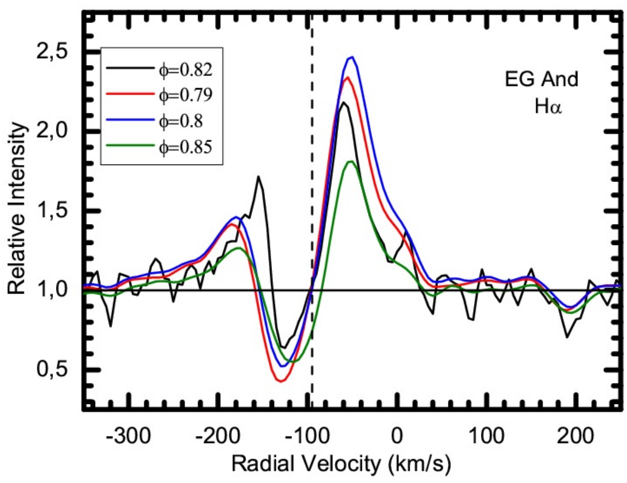

Figure 3: Profiles of the Hα line around the orbital phase 0.8 of the symbiotic system EG And.

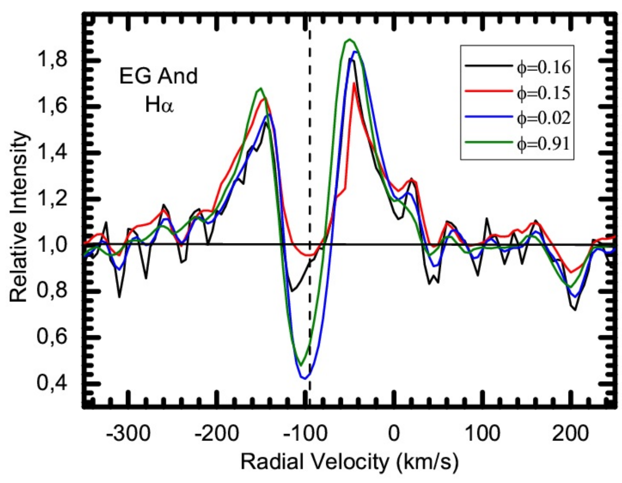

Figure 4: Profiles of the Hα line around the inferior conjunction of the red giant in symbiotic system EG And (orbital phase 0).

pletely covers the key emission-forming regions. Thus, variations in the intensity of the Hα line are closely related to the orbital geometry and the interaction processes of the components in the symbiotic system, confirming that its source is the hot white dwarf and the surrounding gaseous material. (Figs.2–4). In fig. 2-4, the vertical dotted line at the gamma velocity demonstrates the variation radial velocity of the absorption component in the Hα line profile. The solid horizontal line corresponds to the continuous spectrum level. The behavior of the Hα line in the spectrum of the symbiotic star EG And in different eclipse phases is in good qualitative agreement with similar profiles in the work (Shagatova et al., 2019).

4. Conclusions

This paper includes the results of the studies of the orbital variability of the emission and absorption components of the Hα line of the eclipsing symbiotic system EG And:

1. Radial velocity curves of the cool component were derived from the mean of the measured radial velocities of selected absorption lines forming in the atmosphere of an M-type red giant. The system's orbital period is approximately 483.3 days.

2. We have established that the intensity of the emission component of the Hα line has the greatest value at an orbital phase of about 0.5 (corresponding to the eclipsing of the cold primary component by the white dwarf) and the lowest at about 0.1 (the red giant eclipses the hot secondary component and the region of formation of strong emission lines), and an average at about a phase of 0.8.

References

Galazutdinov, G.A.: 1992, *Preprint SAO*, **92**.

Fekel H. et al.: 2000, *Astron. J.*, **119**, 1375 .

https://aras-database.github.io/database/

Kenyon, S. J.: 1986, *The Symbiotic Stars (Cambridge: Cambridge University Press)*.

Kenyon S.J. & Garcia M.R.: 2016, *Astron. J.*, **152**, 1.

Mikolajewska, J.: 1997, *in Physical Processes in Symbiotic Binaries and Related Systems, ed. J. Mikolajewska (Warsaw: Copernicus Foundation for Polish Astronomy*, **3**.

Munari U.: 1993, *Astron.Astrophys*, **273**, 425.

Shagatova N., Skopal A., Sekeras M. et.al.: 2019, *Contrib. Astron. Obs. Skalnat'e Pleso*, **49**, 406.

Skopal A. et al.: 1991, *Astron. Astrophys.*, **245**, 531.