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Spectral observations of the symbiotic star ag pegasi

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Abstract

The results of spectral observations of the symbiotic star AG Pegasi (AG Peg) are presented. The spectra of the star AG Peg were obtained with a spectral resolution of R = 28000 during the period of 2016-2019, in the wavelength range λ = 3900–8000 Å. Based on the AAVSO (American Association of Variable Star Observers), data for the period 1954-2022, a periodicity in the star's brightness changes was identified, with a period of about 815 days. The behavior of selected spectral lines in different phases of the orbit of the AG Peg binary system is described as follows. Profiles of the considered emission lines show strong variability, with a complex structure - single-peaked, double-peaked, and intermediate between them. In general, their variability does not show dependence on the orbital period of the AG Peg binary system. The change in the radial velocities of the absorption lines and the temperature of the hot component corresponds to the light curve of the star AG Pegasus, constructed for a period of P = 815 days, which we found from photometric data.

Key words: *nova-like objects; symbiotic stars; accretion and accretion disks Mass loss and stellar winds*
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1. Introduction

Symbiotic stars are the most interesting because some systems host the most massive white dwarfs (WD), like SN Ia progenitors [1,2]. The symbiotic system consists of two completely different types of stars that coexist – interacting, cold red - RG (in some cases yellow) and hot compact - WD stars. By studying symbiotic stars,

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we simultaneously study 3 different types of space objects:

1. Red giant,
2. White dwarf and accretion disk,
3. Gas and dust surrounding the star system.

In systems of this type, a powerful flow of matter occurs (Roche Lobe Overflow (RLOF) from a cold star, and an accretion disk is formed around a hot compact star. Symbiotic stars can reflect a transitional stage in the evolution of several types of double systems with a powerful flow of matter from a large-mass star to a small-mass star.

The system AG Peg (HD 207757) is the oldest known symbiotic binary [3]. The symbiotic star AG Peg is a binary system that consists of a massive M3 III red giant star (GS) and a less massive hot WD surrounded by nebulous gas. The orbital period of AG Peg is known as 816.5 days. The recent major outburst occurred in 2015, which is the second major one since the first major nova outburst in 1850 [see 3]. The analysis of the observations carried out in different spectral regions during the past years, model of this system – a stage of colliding winds. For the first time this model was proposed by [2] on the basis of three IUE high resolution spectra. Since the cool giant also loses mass through a stellar wind, it was concluded that the two winds probably interact. A model of colliding stellar winds was proposed also by [3] on the basis of profiles, fluxes and radial velocities, derived from homogeneous high dispersion spectral observations in the visual during two consecutive orbital cycles [3].

2. Observations and data reduction

Spectral observations of the symbiotic star AG Pegasi (AG Peg) were carried out at the Cassegrain focus of the 2-meter telescope of the Shamakhy Astrophysical Observatory named after N.Tusi by using the Shamakhy Fiber Echelle Spectrograph (ShAFES [4]. The spectra of the star AG Peg were obtained with a spectral resolution of R = 28000, during the period of 2016-2019, in the wavelength range λ = 3900–8000 Å. Reduction of echelle spectra was carried out according to the standard method using the new version of the DECH30 program developed by Galazutdinov [5]. A list of all used spectra is given in Table 1, 2.

3. Results of observations

Based on the AAVSO data for the period 1954-2022, a periodicity in the AG Peg star's brightness changes was we established, with a period of 814.99 days (fig. 1.)

For the analysis, we chose: emission lines Hα, Hβ, HeI λ 5876 Å, and HeII λ 4686Å, as well as about 30 selected absorption lines of metals, in the spectrum region: 5000-8000 Å. The behavior of selected spectral lines in different phases of the orbit

Table 1. Log of spectral observations star AG Pegasi

№	Date	JD 2400000+	Phase P=815d (Mikailov et al. this article)	Phase P=816.5d Fernie, 1985
1	16.07.2016	57586.391	0.74404	0.21959
2	24.08.2016	57625.316	0.7918	0.26726
3	09.06.2017	57914.472	0.14659	0.6214
4	04.07.2017	57939.449	0.17724	0.65199
5	17.07.2017	57952.327	0.19304	0.66776
6	27.08.2017	57993.343	0.24337	0.71799
7	08.10.2017	58035.384	0.29495	0.76948
8	04.11.2017	58062.362	0.32805	0.80253
9	24.05.2018	58263.489	0.57483	0.04885
10	22.06.2018	58292.446	0.61036	0.08432
11	02.08.2018	58333.331	0.66053	0.13439
12	30.08.2018	58361.493	0.69508	0.16888
13	19.07.2019	58684.452	0.09135	0.56442
14	16.08.2019	58712.37	0.12561	0.59862
15	19.08.2019	58715.293	0.12919	0.6022

Min (Vis)=JD2439050 + 814.99E (Mikailov et al., this article)
Max(V) = JD2442710.1 + 816.5E [3]

Table 2. Radial velocity data of AG Peg in 2016-2019.(units of km/s)

№	Rv (H alpha)				Rv (Hbeta)				Rv (HeII 4686A^0)		Rv
	R	V(1/2)	Vc	V	R	V(1/2)	Vc	V	pics	V(1/2)	(abs.)
1	21	17.82	-0.278	-	-	13.63	-14.12	-	2.16	2.16	-23.38
2	32.24	24.2	-0.57	-	21.05	15.95	-13.65	-	0.82	-4.56	-22.18
3	-3.86	-37.6	-21.76	-91.66	-	-30.84	-45.18	-62.84	-32.01	-22.89	-10.66
4	12.09	-35.55	-20.57	-70.98	1.56	-30.81	-45.56	-52.69	-28.04	-23.13	-12.1
5	13.51	-31.53	-17.24	-		-27.38	-45.64	-	-26.11	-18.21	-11.11
6	16.52	-12.47	-18.93	-	4.69	-20.43	-42.47	-	-23.01	-20.11	-11.23
7	21.28	-3.81	-22.2	-	4.96	-17.81	-44.15	-	-22.35	-22.35	-13.26
8	18.72	-15.28	-19.82	-70.26	5.78	-18.73	-44.43	-	-21.43	-21.43	-13.08
9	21.85	-5.07	-13.15	-40.1	7.65	-9.44	-25.94	-34.78	-4.64	-6.51	-20.89
10	21.07	-2.56	-13.3	-59.55	7.79	-9.03	-23.17	-40	-8.36	-10.44	-21.66
11	19.86	-7.22	-16.26	-	7.5	-10.89	-21.66	-47.66	-10.22	-10.89	-23.89
12	13.47	8.69	-15.22	-	4.23	-11.69	-20.53	-49.73	-10.8	-13.53	-23.45
13	14.73	-33.01	-21.07	-77.83	26.37	-29.05	-37.57	-66.04	-25.25	-22.54	-13.01
14	10.27	-33.3	-	-78.17	-	-32.11	-	-61.16	-23.87	-20.38	-13.76
15	10.94	-32.24	-	-75.6	-	-31.14	-	-59.35	-23.14	-20.15	-13.2

of the AG Peg binary system is described as follows. Profiles of the considered emission lines show strong variability, with a complex structure - single-peaked, double-peaked, and intermediate between them. In general, their variability does not show dependence on the orbital period of the AG Peg binary system.

In 2016, the profiles of all three lines appear as a single emission profile, slightly shifted to the red side of the spectrum, the central intensities of all three lines have the highest values compared to the spectra at our disposal.

In 2017, the profiles represent both two peaks and single ones with depressions

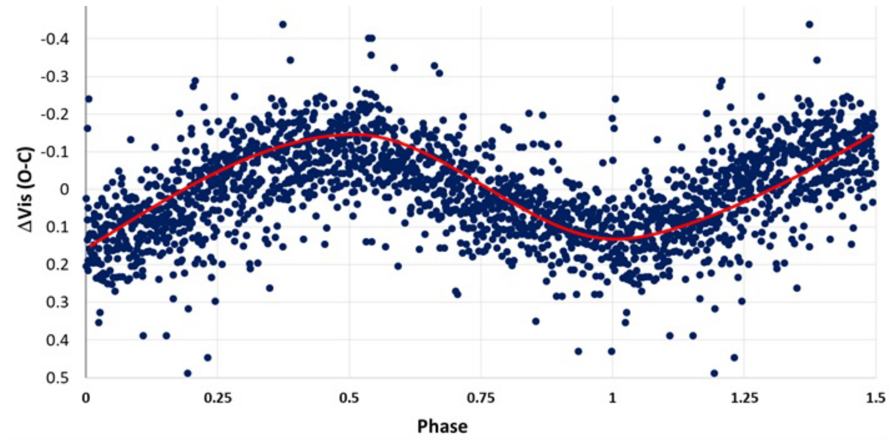

Fig. 1. Common O-C phase diagrams Vis-magnitudes for AG Peg star

indicating the second peak. The two-peak profile is more clearly observed in HeII lines. The intensities of all three lines decreased by approximately half compared to the profiles in 2016. The blue component in the two-peak profile (V) is shifted to the blue side of the spectrum.

In 2018, the profiles of all three lines are almost identical in appearance: a single profile with depression indicating a blue component. The intensity of the lines is almost the same as in 2017. The blue component (depression) is shifted to the blue side of the spectrum.

Finally, in 2019, the profiles of the lines under consideration were complex, double-peaked, with strong variability in the ratios of blue and red emission components (V/R), Hb was subject to stronger changes. The HeII line shows a clear two-peak profile with a V/R ratio of <1. Fig. 2 presents examples of profiles lines Hα, Hb and HeII 4686 in 2018 and 2019 AG Peg binary star spectrum.

In the spectrum of the symbiotic star AG Peg, the radial velocities were measured using select absorption lines (about 30 lines in the wavelength region 5000-8000 A). Figure 3 shows the dependencies of the average values of the measured absorption lines of metals on the phase of the orbit of the AG Peg system. The phases were calculated using the formula:

$$\mathrm{Max(V)} = \mathrm{JD}\ 2442710.1 + 816.5E.$$

The same figure also corresponds to the values of the radial velocities obtained in the scientific paper [3]. The figure 4 shows the dependencies of the radial velocities calculated using metal absorption lines (full red circles) and the HeII (λ4686Å) emission line at the half-intensity level [Rv(1/2)] (full red circles) in the spectrum of the star AG Peg on the orbital phase of the system. As can be seen from the figure, the change in radial velocities of these lines occur in antiphase.

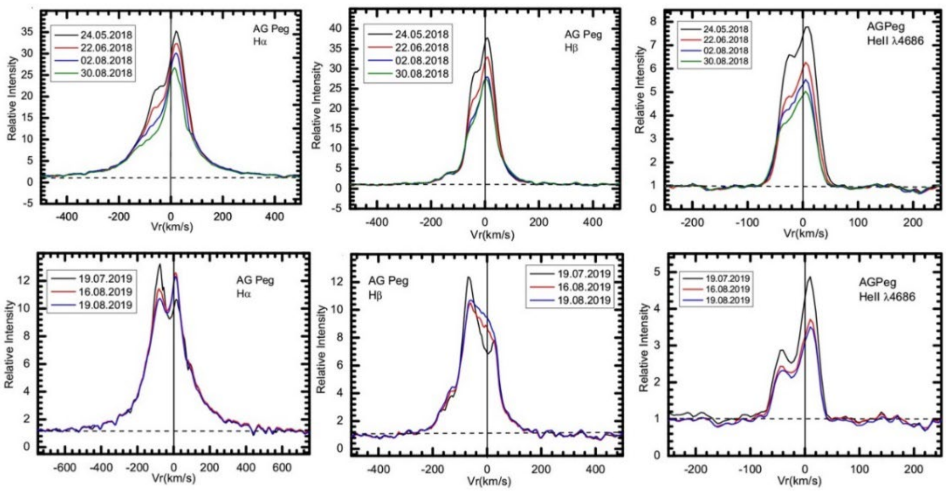

Fig. 2. Profiles lines Hα, Hb and HeII 4686 in 2018 and 2019

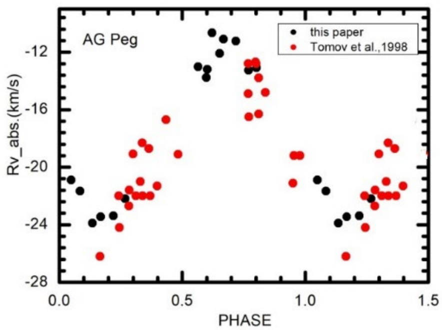

Fig. 3. Dependencies of the radial velocities of metal absorption lines in the spectrum of the star AG Peg on the phase of the orbital period of the system.

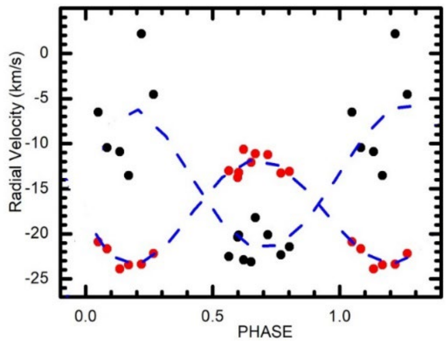

Fig. 4. Dependencies of the radial velocities: absorption lines of metals (full red circles) and V(1/2) HeII lines (full dark circles) in spectrum star AG Peg on the orbital period of the system.

The figure 5, presents the dependencies on the orbital period parameters of the AG Peg system: on the top panel is the light curve in the R-magnitude; on the panels below are the radial velocities based on absorption lines; on the two lower panels are the ratios of the equivalent widths of the HeII (λ=4686Å) lines to Hβ, and the temperature of the hot component of the system, calculated by the ratio of the equivalent widths of the HeII (λ=4686Å) lines to Hβ. The temperature of the hot component is calculated using formula [6]:

$$T_{hot}(in\ 10^4K) \approx 14.16\sqrt{\frac{EW_{4686}}{EW_{H_\beta}}} + 5.13$$

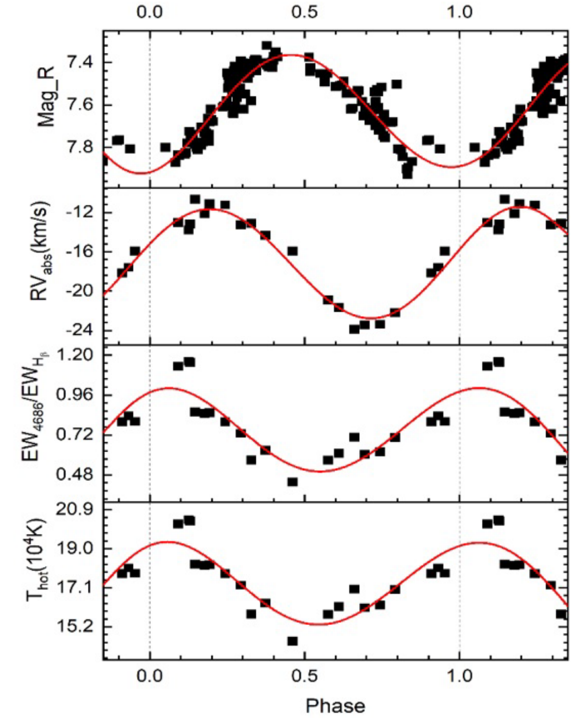

Fig. 5. Dependencies of the parameters star AG Peg on the orbital period of the system.

As seen from the figure, the change in the aforementioned parameters of the symbiotic star AG Peg agrees sufficiently with the period we found for the star's brightness change. Orbital phases were calculated based on the ephemeris

Min(V)=JD2439050 + 814.99E.

4. Conclusions

Based on homogeneous spectral material with high spectral resolutions, the behavior of the main spectral characteristics of the symbiotic star AG Pegasi was studied in different phases of the orbit. The phases were calculated for the period P = 815 days, which we found from photometric data from the database of variable stars AAVSO (American Association of Variable Star Observers). During the period of our spectral observations (15 spectra in 2009-2016), the profiles of selected emission lines (Hα, Hβ, and HeII λ 4686Å) were single, double-peak, and intermediate profiles with strong variability, both in type and in line intensity. The changes in the studied emission lines generally occur synchronously with each other, but do not show a clear correlation with the orbital phase of the AG Pegasi system. The absorption spectrum of the star was studied based on selected 30 absorption lines of metals in the wavelength region 5000-8000 Å. The temperature of the hot component of the AG Pegasi system was calculated according to the ratio of the measured equivalent widths of the HeII and Hβ lines (EW(HeII (λ=4686Å))/EW(Hβ), The change in the radial velocities calculated using absorption lines, the ratio of the equivalent widths of the HeII and Hβ lines and those found from this ratio the temperature of the hot component agrees adequately with the light curve of the star AG Pegasi, constructed for the period $P = 815^d$, which we found from photometric data.

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