ECLIPSING EVENT IN BINARY CTTS TYPE STAR AS 205N

N. Z. Ismailov [a*], ***U. S. Valiyev*** [b]

[a] *Shamakhy Astrophysical Observatory named after N.Tusi, Azerbaijan National Academy of Sciences, Shamakhy region, Azerbaijan*

[b] *Batabat Astrophysical Observatory of Nakhichevan Branch of Azerbaijan National Academy of Sciences*

The results of new photometric observations of the classic T Tauri type star AS 205N, carried out in the 60 cm ShAO telescope, are presented. It was shown that the existence of a period of 24 days is confirmed for individual observation seasons, but this period has stochastic components. We have constructed the spectral energy distribution of the star in the range 0.36-100 μm. Significant infrared radiation is detected in the near and far infrared spectral regions. The excess is also observed in the UV range of the spectrum. The results of the analysis show that, apparently, AS 205N has a cooler component - a star with spectral type M or a low mass brown dwarf, with a temperature of about 2000±500 K.

Keywords: dwarf stars – infared regions – instrumentation system

1. INTRODUCTION

AS 205A = AS205N (V866 Sco) is a young late K5 type dwarf star with an average brightness V = 12.4 mag belongs to a hierarchical triple system. At an angular distance of 1.3" (≈180 AU at 140 ps) from AS 205N, there is a low-mass K7/M0 spectroscopic binary star [1–3]. According to [4], there are two stable periods (P_1 = 6.78 and P_2 = 24.78 days) on the master light curve of AS205N. The P_1 period is a typical CTTS rotation period that can occur due to the presence of cold spots on the star's surface. In this case, U-B color variability in anticorrelation may be a sign of chromospheric emission and a cold spot. The phase diagram of the P_2 period shows the modulation of brightness and red colors, which is an indication of the presence of a cold source. Since AS 205N is about

* E-mail: ismailovnshao@gmail.com

2 magnitudes brighter than AS 205S [5] in the V band, the observed brightness modulation (V = 0.25 mag) belongs to the primary star, or its envelope. The mass of the star AS205N, obtained from the relation between temperature and bolometric luminosity [6], and from the evolutionary tracks of Baraffe et al. [7] expected to be 0.9 M. According to Artemenko et al. [4] Period P_2 must belong to the unknown close component AS205N, which is disturbing the accretion disk with dense waves. According to IR interferometry data [3], [6], the semi-axis of the orbit was predicted to be about 0.18 AU, which is close to the inner radius Rin = 0.14 AU. Artemenko et al. [4] explained the brightness variability with the period P_2 due to the effect of scattering or extinction of the disturbing disk at the radius of dust sublimation.

In this paper, we present the results of an analysis of photometric observations of the star obtained in the data archive and partly at the ShAO.

2. OBSERVATIONS

Photometric BVRcIc observations of the star were carried out with the Zeiss-600 telescope of the Shamakhy Astrophysical Observatory named after N. Tusi of the Azerbaijan National Academy of Sciences. A detailed description of the telescope together with the photometer was presented in [8,9]. After that, the equipment of radiation was changed. The photometer is now equipped with a CCD FLI 4000×4000 camera. The aperture of the telescope is 1: 12.5, the Cassegrain focus is F = 7500 mm. In this case, the scale on the focal plane of the camera was 27.5"/mm. Taking into account the size of one pixel 9 μm = 0.009 mm, for the per pixel resolution we have get 0.247". During observation, depending on the image quality, we used the binarity of the pixels 2×2 and 4×4, which for the resolution, respectively, allow to get 0.49" and 0.99". The total field covered by the camera was about 30’, and the effective linear area in the focal plane was 17’×17’. The whole process of observation and processing of the material was carried out using the MaxDel program. Typical average measurement errors for individual bands were ± 0.008 mag for V and Rc, ± 0.03 mag for B, ± 0.04 mag for Ic bands.

For reference to the Johnson international system, star fields of a group of standards from the Landolt list were observed in 2019 [10]. Figure1 shows transforming plots from instrumental system to the standard the system. The formulas for transformation of our instrumental system to the international BVRcIc system are as follows:

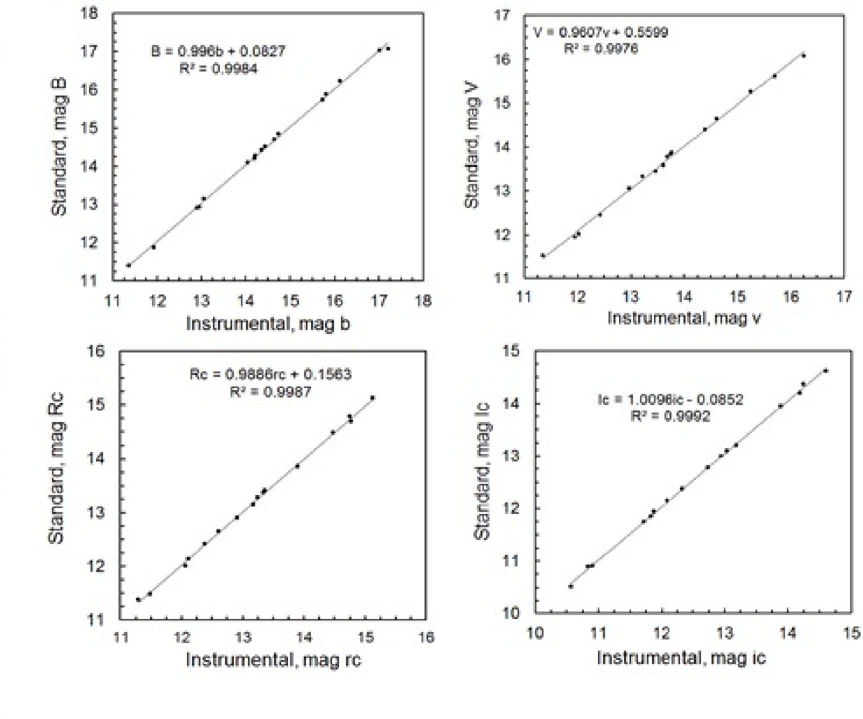

Fig. 1. Transformation of the ShAO instrumental system to the international BVRcIc system. Straight lines were drawn by linear regression with the coefficient of reliability $R^2 = 0.998 \pm 0.001$..

$$B = 0.996b + 0.0827,$$
$$V = 0.9607v + 0.5599,$$
$$Rc = 0.9886r\_c + 0.1563,$$
$$Ic = 1.0096i\_c - 0.0852$$

Here, lowercase letters indicate the data of the instrumentation system. When approximated by linear regression, the coefficient of reliability of the straight line was obtained about $R^2 = 0.998\pm$ 0.001 (Fig.1).The star AS 205N was observed at this complex in 2018-2021. Figure2 shows the search map of the star.

Table 1 has presented the observational data we obtained in different photometric bands. The dash in Table1 shows the absence of data in this band.

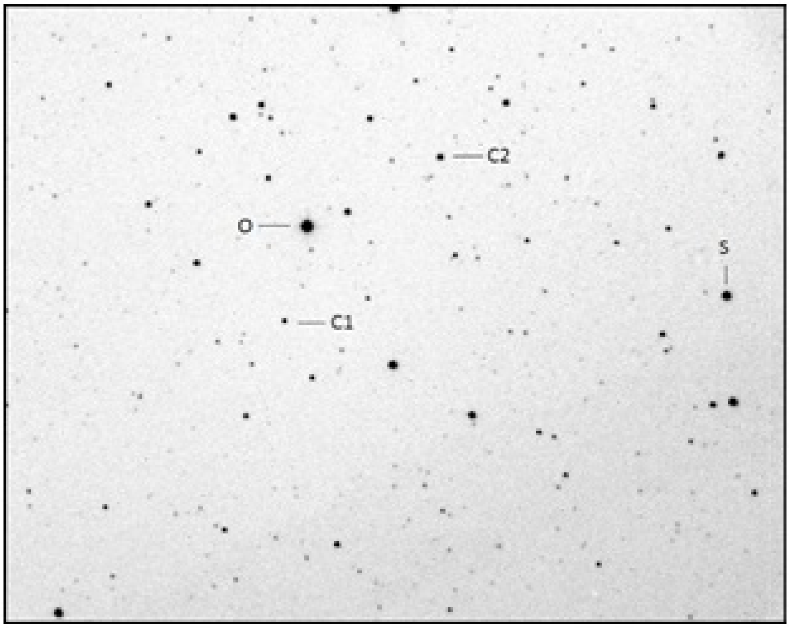

Fig. 2. Searching card of the star AS 205N. O-object, S-standard, C1 and C2 check stars.

3. ANALYSIS OF OBSERVATIONS

Valiyev and Ismailov [11] analyzed in detail the long-term light curve of the star AS 205N. For the analysis, the archived UBV data, which were taken from the archive using CDS photometric data base (anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5)) were also used. In this work, it is shown that, in different observation seasons, three probable periods of variations in the brightness of the star are found: $P_1 = 6.51 \pm 0.6$, $P_2 = 14.6 \pm 1.03$, and $P_3 = 24.71 \pm 0.9$ days. The periods P_1 and P_3 with a slight difference in the values of the period were first discovered in [14], and the period P_2 was discovered by us for the first time. As shown in [12], the P_1 period can be a consequence of the axial rotation of the star. Period P_3, these authors explained by the binarity of the star AS 205N, where one of the components is a cooler star, or protoplanet. Our analysis showed that despite numerous photometric observations, none of the observed periods is sta-

Table 1. The results of our photometric observations of the star AS 205.

JD2450000+	Rc	B	V	I
8667.271	10.675	12.205	11.125	9.217
8668.230	10.889	12.747	11.546	9.411
8669.223	11.303	-	11.951	9.663
8670.381	10.979	-	-	-
8672.334	10.803	-	-	-
8687.228	10.415	13.276	10.983	8.931
8688.219	10.497	12.136	11.007	8.839
8695.267	10.309	12.144	10.846	8.795
8700.269	9.768	-	10.186	8.389
8712.190	10.274	-	10.747	8.906
8998.376	10.537	12.070	11.032	9.102
9000.316	10.438	12.035	10.935	9.001
9012.347	10.537	11.935	-	-
9013.314	10.833	-	11.320	-
9014.225	10.833	12.533	11.224	-
9017.231	10.833	-	11.416	-
9019.283	10.635	12.533	11.032	-
9024.231	10.932	12.632	11.512	9.405
9047.346	10.537	12.035	10.935	9.001
9049.228	11.426	13.429	12.088	9.809
9349.340	12.020	13.828	12.665	10.415
9351.351	12.217	14.326	12.953	10.617
9352.351	11.723	13.728	12.377	10.314
9367.220	11.130	12.832	11.608	9.405
9368.228	10.932	12.931	11.800	9.405
9382.334	10.932	12.632	11.512	9.405
9385.367	10.833	12.533	11.416	9.304
9386.380	10.734	12.433	11.320	9.304
9399.266	10.734	12.433	11.320	9.203
9400.260	10.339	11.836	10.839	8.799
9401.224	10.339	12.035	10.839	8.799
9407.224	10.240	11.836	10.743	8.698
9411.306	10. 339	11.935	10. 935	8.900
9412.341	10. 833	-	11. 416	9.304
9413.266	10. 635	12. 433	11.224	9.102

ble. This indicates that both components of the system are young objects with not yet stable characteristics.

In [12], based on spectral observations in the near-IR region, the authors showed that the star is a spectroscopic binary with a period close to the period P_3 (24.84 days), slightly exceeding the photometric period $P_3 = 24.78$ days and the period $P = 24.71$ days. To refine these results, additional high-precision spectral observations in the IR part of the spectrum are needed.

Figure3 shows the phase light curve of the V-light values for the P_3 period obtained in our observations (left panel). For comparison, the right panel of Fig.3 shows the same phase light curve for the archived data from the CDS catalog. The phases were calculated using the elements Min $I = JD2447379.36 + 24.71E$. As you can see, the curve is characterized by a deep minimum, the amplitude of which exceeds 2 magnitude. At the same time, it can be seen that a stochastic component is observed in both curves, which significantly distorts the picture of periodicity In Fig.4, the left panel shows the phase light curve for the period P_3 of

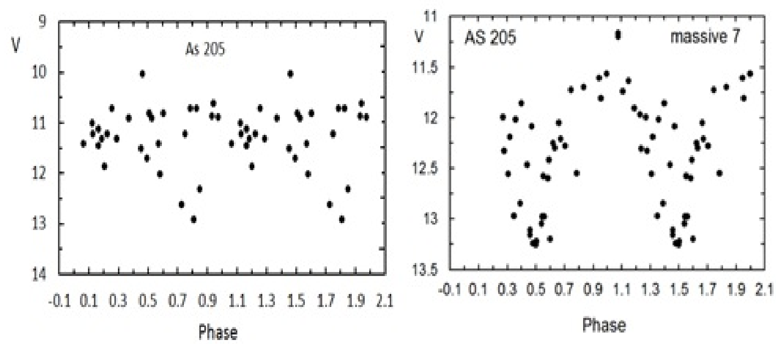

Fig. 3. The phase light curve of AS 205N according to our observations (left panel), as well as archived data (JD 2449138-2449401). The phases were calculated on the elements Min I = JD 2447379.36 + 24.71E.

the star according to the data of two season from the CDS archive, obtained in the time interval JD 2448821-2449401 (black points), as well as all our observations (crosses). The right panel of the figure shows the phase curve averaged with a step of 0.1P over the same points. Vertical bars show the scatter of points around the mean with statistical weights. As can be seen, despite the scatter of points, overall, the average light curve of the star describes well the eclipsing light curve. Moreover, the main deep minimum in this light curve stands out quite clearly, although the secondary minimum is not observed.

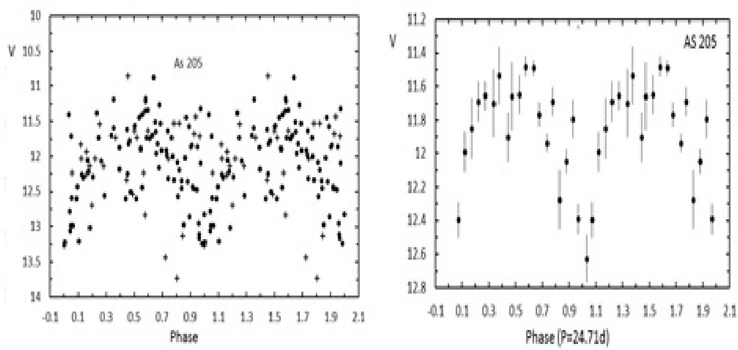

Fig. 4. The left panel shows the phase light curve of AS 2015N based on the archived data of two observation seasons (JD 2448821-2449401) (points) and all our observations (crosses). The right panel shows the averaged over phases with a step of 0.1_3, for the same points. The vertical bars show the deviation of the mean with statistical weights.

4. SPECTRUM ENERGY DISTRIBUTION (SED)

To plot the SED curve in the wavelength range 0.36–100 μm, we collected all UBVR [13], IJHK [14] data, as well as data on the near IR region of WISE [15], and on the far IR region of IRAS [16]. The method for constructing the SED curve was described in detail in [17]. Figure5 shows the resulting SED curve. As can be seen from Fig.5, the star's SED curve can be represented as a combined one, in which it is possible that there is a contribution of at least two stars, with temperatures of 3000 K and 2000 K.

ed curve, radiation of a black body at a temperature of 2000 K. In right panel is shown the subtraction star-model with temperature 3000 K (right panel). The dotted straight line is a level of the spectrum without excess radiation.

The spectral class of the star AS 205N corresponds to K5, (T_{eff} = 4250 K) [2]. As can be seen from Fig.5, the spectral radiation of the star in the optical range corresponds to a temperature of about 3000 K. This indicates the existence of additional absorption in this range by circumstellar matter. It can also be seen from Fig. 5 that the data of different authors show a certain spread in the flux values both in the optical and in the near-IR part of the spectrum. This indicates a significant inhomogeneity of the circumstellar disk.

It can be seen from the right panel in Fig.5 that the difference between the radiation fluxes of the star and the model reveals excess radiation in both the UV and IR parts of the spectrum. In classical T Tauri stars, the origin of UV excess radiation can be explained by the process of disk accretion. Excess radiation in the IR part of the spectrum is detected at $\lambda > 2\mu m$. The excess of radiation in

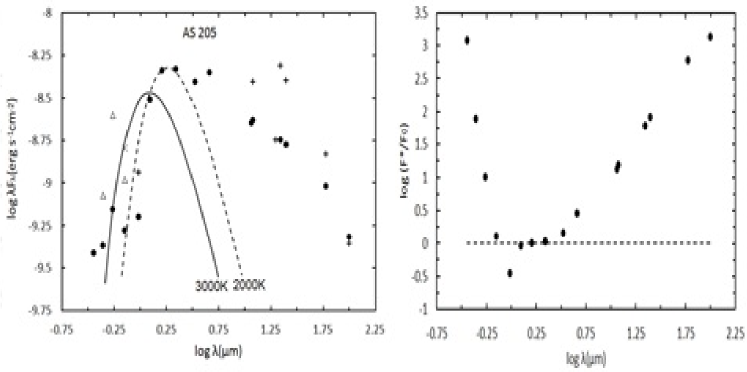

Fig. 5. Energy distribution curve of the star AS 205N (left panel), solid curve - radiation of an absolute black body at a temperature of 3000K, a dashed curve, radiation of a black body at a temperature of 2000 K. In right panel is shown the subtraction star-model with temperature 3000 K (right panel). The dotted straight line is a level of the spectrum without excess radiation.

the near-IR part of the spectrum is usually explained by the emission of gas in the disk, which arises due to the re-emission of energy emitted by the central star. Excessive radiation in the far IR range occurs due to the radiation of cold dust with a temperature of no more than 100 K [18].

5. DISCUSSION AND CONCLUSIONS

So, in this paper, we present new photometric observations of a CTTS type star AS 205N. Our data confirmed the existence of two photometric periods P_1 and P_3, which were determined in [4]. We also pointed out that both observed periods have a stochastic component, which in some seasons significantly distorts the picture of periodicity. As shown in [12], the P_1 period arises due to the axial rotation of the star.

According to our data, the period $P_3 = 24.71$ days is well detected only in certain seasons. The change in the star's brightness over this period can be interpreted as an eclipse of the main component of the K5 star by a secondary, more extended object. The temperature of the secondary body can be in the range of 2000 ± 500 K. We have shown that, most likely, the secondary star also has a circumstellar disk, because a very deep and stable minimum is observed on the phase light curve. The eclipsing nature of this period also confirms the conclusion of the authors of [12] that the inclination of the disk plane to the line of sight is small ($i = 15° - 25°$). The observation of the stochastic component of the periodicity can be associated with the nonstationarity of the components included in the system.

We have plotted the SED curve for the star in the range 0.36-100 μm. It is shown that the star exhibits excess radiation in both the UV and IR regions of the spectrum. The UV excess is explained by the presence of disk accretion, while the IR excess arises from the emission of gas and dust on the disk. The significant emission of the disk in the IR range was also shown in [6].

Summarizing the data, the following conclusions can be drawn.

1. The detected periodic variability with the P_3 period is more likely associated with the eclipsing nature, observed in the pair AS 205N-AS205S. For different observation seasons, a significant deviation from the periodicity is revealed, which is of a random nature.

2. Radiation of a star in the optical range is significantly absorbed by circumstellar matter.

3. The spectral distribution of the star's energy shows that it is possible that the spectrum in the system is emitted by at least two stars, as well as gas and dust. The secondary component of the system can be an M star or a brown dwarf with a temperature of about 2000 K.

To clarify the detailed structure of a young binary system, additional high-precision spectral observations in the IR part of the spectrum are needed.

6. ACKNOWLEDGMENTS

The authors are grateful for the support of the Science Development Fund under the President of the Republic of Azerbaijan (Grant No. EIF-BGM-4-RFTF-1 / 2017-21 / 07/1).

REFERENCES

1. Ghez, A. M., Neugebauer, G., & Matthews, K. 1993, AJ, 106, 2005

2. Prato, L., Greene, T. P., & Simon, M. 2003, ApJ, 584, 853

3. Eisner, J. A., Hillenbrand, L. A., White, R. J., Akeson, R. L., & Sargent, A. I. 2005, ApJ, 623, 952

4. Artemenko, S. A., Grankin, K. N., & Petrov, P. P. 2010, Astron. Rep., 54, 163

5. Herbig, G. H., Bell, K. R. 1988, Lick Obs. Bull. 1111, 1

6. Andrews S. M., Wilner D. J., Hughes A. M., Chunhua Qi, Dullemond C. P. Protoplanetary disk structures in Ophiuchus. ApJ 2009, 700,1502–1523

7. Baraffe, I., Homeier, D., Allard, F., & Chabrier, G. 2015, A&A, 577, A42

8. CCD photometer installed on the telescope ZEISS- 600 of the Shamakhy Astrophysical Observatory: I. Adjustment of CCD photometer with optics ZEISS-600, V.M.Lyuty, B.I.Abdullayev, I.A.Alekberov, N.I.Gulmaliyev, Kh.M.Mikayilov, B.N.Rustamov, AAJ Volume 4, № 3-4 – 2009, pp.36-42

9. B.I.Abdullayev, N.I.Gulmaliyev, S.O.Majidova, Kh.M.Mikayilov, B.N.Rustamov, CCD photometer installed on the telescope ZEISS- 600 of the Shamakhy Astrophysical Observatory ii. the technique of observation and data processing of CCD photometry, AAJ Volume 4, № 3-4 – 2009, pp.42-46

10. Landolt, A. U. 1992, AJ, 104, 340

11. U.S.Veliyev, N.Z.Ismailov. Summary light curve analysis of the T tauri type star AS205.AAJ 2020, No2, 75.

12. P. Viana Almeida, J. F. Gameiro, P. P. Petrov, C. Melo, N. C. Santos, P. Figueira, S. H. P. Alencar, Evidence of a substellar companion around a very young T Tauri star. 2017, A&A 600, A84

13. 2012yCat.1322....0Z

14. 2003yCat.2246....0C

15. SIMBAD-Vizer, 2012yCat.2311, 0C

16. https://irsa.ipac.caltech.edu/IRASdocs/exp.sup/

17. Ismailov N., Alishov S., Veliyev U., Huseynova F. Method for plotting Energy Distribution Curves in spectra of stars according to boardband photometric data. Scientific works ser. Natural and technical sciences. Azerbaijan National Academy of Sciences, Nakhichevan branch office, 2021, № 2, 266-272.

18. Ismailov N.Z., Kholtygin A.F., Romanyuk I.I., Pogodin M.A., Moiseeva A.V.. Relict Gas-and-Dust Disks Around AB Stars in the Orion Nebula. I. IR Excesses. Astrophysical Bulletin, 2021, 76, 4, 350–360.