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L.N. Kondratyeva, E.K. Denissyuk, I.V. Reva, M.A. Krugov

Fesenkov Astrophysical Institute, Almaty, Kazakhstan

lu_kondr@mail.ru, eddenis@mail.ru, alfekka@list.ru, mkrugov@astroclub.kz

**SPECTRAL AND PHOTOMETRIC STUDY
OF THE OBJECT IRAS20462 + 3416**

Abstract. RAS20462 + 3416 belongs to low-mass post-AGB stars with a dense compact envelope, which was formed in the process of the mass loss by the star at the end of the pulsating AGB phase. The spectrum of the object consists of the H I, [NII], [SII] emission lines and of He I, which is mainly observed in absorption.

The temperature of the central star corresponds to the value $T_{\text{eff}} = 19500 \pm 500\text{K}$, the electron density is 10^4 cm^{-3} . Several episodes of gas ejection from the atmosphere of the central star were recorded. So, in 1993 - 1994, PCygni profiles appeared in the UV and optical spectral lines. The stellar wind velocity was $\sim 800 - 990 \text{ km/s}$. The photometric variability of the object was noted by many authors. In particular, quasi-periodic oscillations of brightness in the optical range with an amplitude of $0.^m1 - 0.^m2$ and a period of ~ 4 days were detected. Rapid fluctuations in brightness can be caused by stellar pulsations and continuing mass loss.

In this paper, we present new spectral and photometric data obtained mainly in 2015–2018. Irregular brightness variations were detected in B, V, and R filters with an amplitude of $\sim 0.^m4$. The results of spectral observations indicate a gradual increase in emission line fluxes. Thus, absolute fluxes in H β , H α , [NII] lines increased by about 30 – 40%.

In terms of its physical parameters and the nature of the spectrum, the object is similar to a young planetary nebula of low excitation. However, the irregular variability of brightness and fluxes in emission lines, as well as the observed episodes of the matter ejection, indicate that the shell formation has not finished. Most likely this object can be considered as a protoplanetary nebula.

Key words: protoplanetary nebulae, emission lines; B V R values; individual: IRAS20462 + 3416.

Introduction The object IRAS20462 + 3416 = LSII + 34 26 = V1853 Cyg belongs to the low massive post-AGB stars with a dense compact envelope of gas and dust [1, 2]. The envelope was formed in the process of mass loss by the star at the end of the pulsating AGB phase. According to the radio observations [3], the image of the nebula in the Br γ line has dimensions $2.0'' \times 1.5''$, with the 49° position angle. The object is located at a distance of 2.9 - 4.6 kpc [4]. The emission lines of H I, [NII], and [SII] are observed on the background of the continuum. He I lines are mainly observed in absorption. In addition, numerous metal absorption lines have been recorded. The temperature of the central star according to the observations of 1991 corresponds to the value $T_{\text{eff}} = 19500 \pm 500\text{K}$ [2]. The variability of the intensities and profiles of emission lines is noted. So, in the early spectrograms of 1977 and 1981, only a weak H β emission line was observed, while H γ and H δ were in absorption. Optical observations of the object in 1991-1995 showed the presence of strong Balmer emission and the weaker forbidden lines. The electron density calculated from the ratio of the intensities of the lines [SII], 6717, 6731 Å is 10^4 cm^{-3} . The presence of Si III, C II, Fe II emission lines in the spectrum of the object indicates that there is an internal zone which is located near the central star and has the even higher density. During the observation of the object, several episodes of gas ejection from the atmosphere of the central star were recorded. So, in 1993 - 1994, PCygni profiles appeared in the UV and optical spectral lines. The stellar wind velocity about 800 - 990 km/s was determined from the Si IV, 1400 Å and C IV, 1550 Å line profiles. Observations on September

1997 showed the presence of the PCygni profile in the optical and UV lines, and the broad wings of the H α line [5]. On the IRAS 20462 + 3416 spectrograms (June 4, 2003) the blue wing in the H α profile is weaker than the red — a sign of P Cygni with absorption filled with emission, since the wings are very wide [6].

The photometric variability of an object is noted by many authors. Thus, quasi-periodic brightness variations in the optical range with amplitude of 0.^m1 - 0.^m2 and a period of \sim 4 days were detected [7]. Information on rapid brightness fluctuations with an amplitude of 0.^m3 in filters B and V is given in [8]. They may be due to stellar pulsations and ongoing mass loss.

Observations and processing

The first spectral observations of the object IRAS20462 + 3416 in the Fesenkov Astrophysical Institute were carried out in 2006-2007. Those spectra contained only the Balmer hydrogen lines. That time an absolute calibration of the spectra was not carried out, only equivalent widths of emission lines and the shape of profiles were obtained. Later, in 2015–2018 spectral and photometric observations of the object were performed. The star HD 198183 with a known energy distribution [9] was used as a standard for the absolute calibration of the spectra.

Photometric observations of the object were carried out with the telescope AZT-8, the 1-meter telescope at the Assy-Turgen Observatory, and the 1-meter telescope at the Tian Shan Observatory (TSHAO). The following CCDs: SBIG ST-8 (1530x1020, 9 μ) (AZT-8), SBIG ST-7 (756x510, 9 μ) (Assy-Turgen), Alta F16M (4096x4096, 9 μ) of Apogee (TShAO) and a set of Johnson B V R filters were used.

The initial processing of an image consists of standard operations using the Bias, Dark and Flat service files. Image measurements are performed using the standard software packages MaximDL 6 and IRAF. Correction for atmospheric extinction and transformation of the obtained brightness to the standard system B V R is carried out using a system of corresponding equations.

Spectral observations were carried out using diffraction spectrographs mounted on the already mentioned telescopes. The following CCD: ST-8 (1530x1020, 9 μ) and SBIG STT-3200 (2184x1472, 6.8 μ) were used. The spectral range available for observations is \sim 3500 \AA (4000 \AA -7500 \AA).

Recent years, additional spectral observations were carried out on a 1-meter telescope installed at the Tian Shan Observatory. The telescope is equipped with a new diffraction spectrograph. At the output of the spectrograph, SBIG STT-3200 (2184x1472, 6.8 μ) is installed.

During observations, the spectrograms of an object with a narrow (2" - 3") and a wide (7" - 10") entrance slit are obtained. Observations of a standard star with a known energy distribution are performed with a wide slit, which guarantees the pass and registration of the full radiation flux. File processing consists of subtracting the dark background, taking into account field errors and taking into account atmospheric absorption.

The spectral sensitivity of the equipment is determined by comparing the observed energy distribution in the standard spectrum with the Catalog data. After taking into account all corrections, the values of fluxes are determined in absolute energy units. Spectrograms obtained with a narrow slit and with a resolution of 0.25 - 0.5 \AA /pc are used to study the structure of emission profiles. Log of observations of IRAS20462+3416 is presented in Table 1.

Obtained results

The data obtained from photometric observations are given in Table 2 and in Figure 1. Rapid brightness fluctuations with amplitudes of 0.^m4, 0.^m1 and 0.^m1 were recorded in 2016, in B V R filters, respectively.

The overall picture of the behavior of the object brightness is as follows: at first, its decrease was observed in all three filters, the minimum was in the middle of 2017. Then the reverse process began, and by mid-2018 the brightness increased by about 0.^m15 (Figure 1).

Table 1 – Log of observations of IRAS20462+3416

Date of observations	Type of observations	Wavelength range (Å)	Spectral resolution	Telescope, Observatory
10.10.2007	Spectral	4400 - 5100 6100 - 6800	9800 13000	1-m. Assy-Turgen
18.07.2015	Spectral Spectral Photometric	4400 - 5100 6100 – 6800 B V R	9800 13000	1-m. Assy-Turgen
12.08.2015	Spectral Spectral Photometric	4400 - 5100 6100 – 6800 B V R	9800 13000	1-m. Assy-Turgen
01.08.2016	Spectral Photometric	6100 – 6800 B V R	13000	1-m. Assy-Turgen
03.08.2016	Photometric	B V R		1-m. Assy-Turgen
06.08.2016	Spectral Photometric	4400-5100 B V R	9800	1-m. Assy-Turgen
26.06.2017	Spectral	4400 -5100 6100 - 6800	9800 13000	1-m. Assy-Turgen
21.07.2017	Spectral	4400 - 5100 6100 - 6800	9800 13000	1-m. Assy-Turgen
15.09.2017	Spectral	6100 - 6800	13000	1-m. TShAO
19.09.2017	Spectral	6100 - 7100	9000	0.7m. AZT-8
22.06.2018	Spectral	4400 - 5100	7500	0.7m. AZT-8
09.07.2018	Photometric	B V R		1-m. TShAO
18.07.2018	Spectral	4400 - 5100	7500	0.7m. AZT-8

Table 2 - B V R magnitudes of the object IRAS20462+3416

Date of observations	JD-2400000	B mag	V mag	R mag
18.07.2015	57222.330	11.28±0.01	11.07±0.01	11.02±0.01
12.08.2015	57247.268	11.26±0.05	11.10±0.04	10.97±0.04
01.08.2016	57602.306	11.39±0.01	11.20±0.01	11.14±0.02
03.08.2016	57604.267	11.80±0.06	11.15±0.05	11.13±0.04
06.08.2016	57607.278	11.53±0.01	11.25±0.01	11.04±0.03
21.07.2017	58048.348	11.46±0.01	11.29±0.01	11.23±0.01
09.07.2018	58309.330	11.38±0.01	11.09±0.01	11.14±0.01

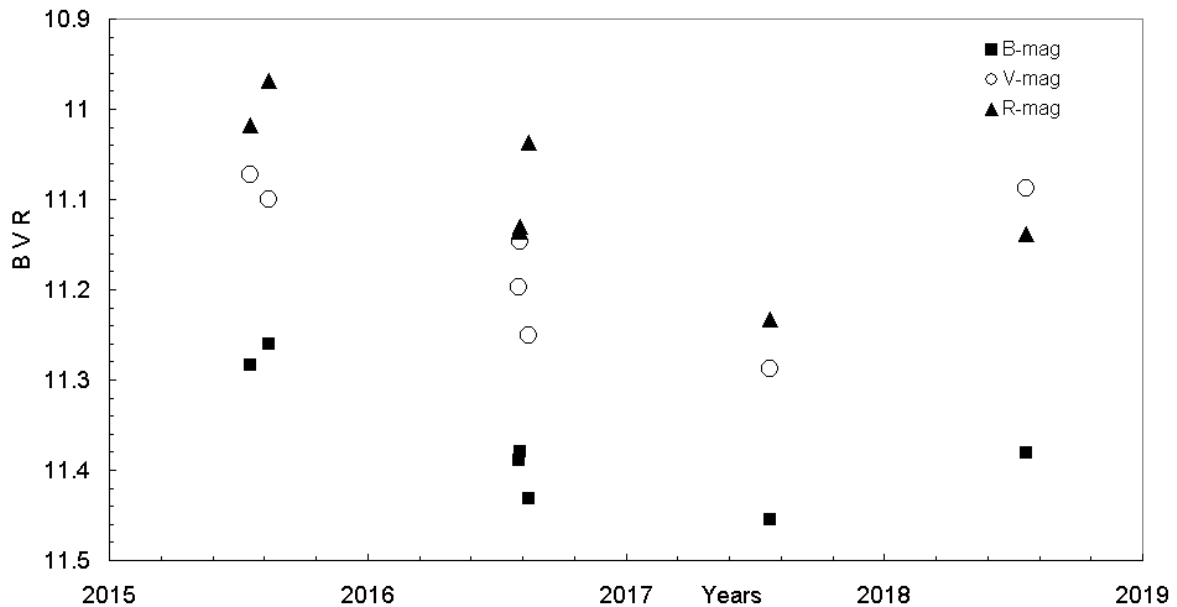
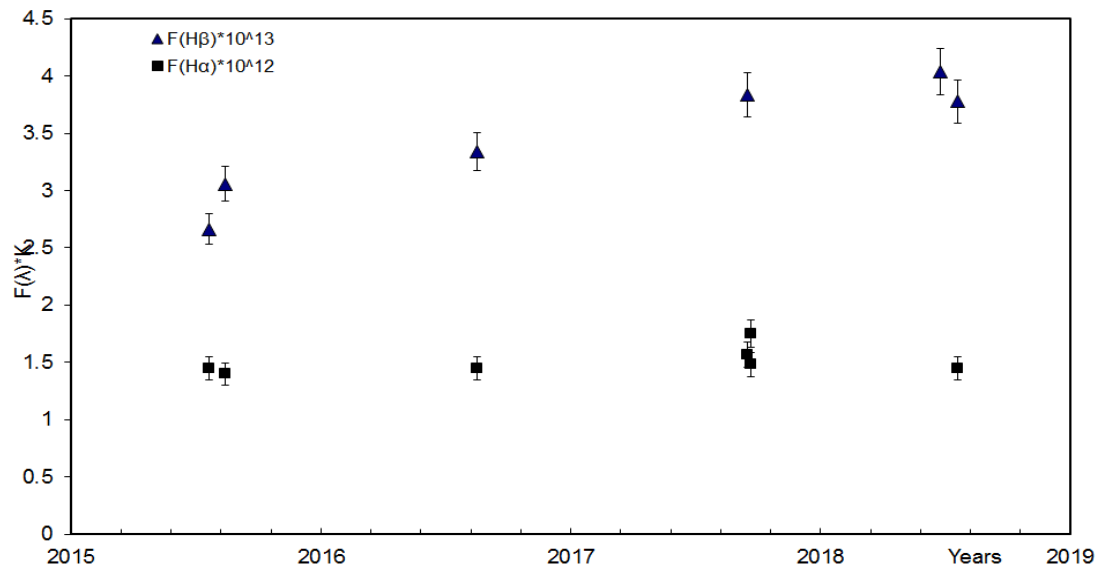


Figure 1 –Change of brightness of the object IRAS20462+3416 in 2015 – 2018

Only emission lines H β , H α , [NII],6548,6583 \AA and HeI, 4921,6678 \AA in absorption are registered on our spectrograms. Absolute fluxes and equivalent widths of lines are given in Table 3. The figure 2 illustrates the behavior of radiation fluxes in hydrogen lines. The results of spectral observations indicate a gradual increase of emission line fluxes during 2015-2018 (Fig 2). A similar trend is observed in the behavior of the forbidden lines [NII], 6548, 6583 \AA .

Table 3 – Characteristics of emission lines in spectrum of IRAS20462+3416

Date of observations	H β		H α		[NII],6583	
	F $\cdot 10^{13}$	EW	F $\cdot 10^{12}$	EW	F $\cdot 10^{13}$	EW
11.09.2006		1.2 \pm 0.2				
12.10.2007		1.3 \pm 0.3		13 \pm 0.6		0.51 \pm 0.09
18.07.2015	2.66 \pm 0.07	0.9 \pm 0.3	1.45 \pm 0.15	6.9 \pm 0.3	0.98 \pm 0.15	0.43 \pm 0.06
12.08.2015	3.06 \pm 0.23	1.0 \pm 0.1	1.40 \pm 0.04	7.3 \pm 0.2	1.10 \pm 0.02	0.58 \pm 0.01
06.08.2016	3.34 \pm 0.28	1.2 \pm 0.1				
21.07.2017	3.84 \pm 0.27	1.4 \pm 0.1	1.57 \pm 0.01	9.7 \pm 0.7	1.00 \pm 0.19	0.63 \pm 0.18
15.09.2017			1.38 \pm 0.12	6.9 \pm 0.2	1.09 \pm 0.12	0.58 \pm 0.11
19.09.2017			1.75 \pm 0.11	8.0 \pm 0.2		
22.06.2018	4.04 \pm 0.16	1.5 \pm 0.1				
18.07.2018	3.78 \pm 0.31	1.2 \pm 0.1	1.45 \pm 0.07	7.2 \pm 0.3	0.98 \pm 0.21	0.49 \pm 0.06

Figure 2 – Change of H β and H α emission line fluxes

Due to its physical parameters: ($T_{\text{eff}}=19500\text{K}$, $N_e=10^4\text{cm}^{-3}$) and the spectrum, the object is similar to a young low excitation planetary nebula. However, the irregular variability of brightness and emission fluxes, as well as the observed episodes of matter outflow, indicate that the shell formation was not finished, and the object is now in a transitional stage from post-AGB stars to planetary nebulae. Most likely, it can be considered as a protoplanetary nebula.

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Л.Н. Кондратьева, Э.К. Денисюк, И.В. Рева, М.А. Кругов

«В.Г.Фесенков атындағы Астрофизика институты» ЕЖШС, Алматы, Қазақстан

IRAS20462+3416 ОБЪЕКТИСІНЕ СПЕКТРЛІК ЖӘНЕ ФОТОМЕТРЛІК ЗЕРТТЕУЛЕР

Аннотация. IRAS20462 + 3416 объектісі, лүпілдеу кезеңінің соңында масса жоғалту нәтижесінде қалыптасқан, тығыз, шағын қабықшалы post-AGB аз массивті жұлдыздарға жатады. Объектінің спектрінде H α , [NII], [SII] және HeI эмиссиялық сызықтары көбіне жұтылу кезінде байқалады. Орталық жұлдыздың температурасы $T_{\text{eff}} = 19500 \pm 500\text{K}$ шамаға сәйкес, электрондық тығыздық 10^4cm^{-3} құрайды.

Орталық жұлдыз атмосферасынан газ бөлшектер жарқылының бірнеше эпизодтары тіркелді. 1993-1994 жылдарда УК профилінде және оптикалық сызықтарда P Cygni құраушылары пайда болды. Жұлдыздық желдің сәйкес мәні $\sim 800 - 990 \text{ км/сек}$ құрайды.

Көптеген авторлар объектінің фотометрлік айнымалылығы туралы атап өтті. Соның ішінде, периоды ~ 4 күн болатын және $0.^m1 - 0.^m2$ амплитудалы жарқырауының квазипериодты тербелісі тіркелді. Объектінің жылдам өзгеруі зат ағынының жалғасуы және жұлдыздық лүпілмен байланысты болуы мүмкін.

Бұл жұмыста 2015-2018 жылдар аралығында алынған спектрлік және фотометрлік жаңа бақылаулар келтірілген. Амплитудасы $\sim 0.^m4$ болатын, B, V және R фильтрларында дұрыс емес жарқырау тербелістері табылды. Спектрлік бақылаулар кезінде эмиссиялық сызықтардың сәулеленуінің біртіндеп өсуі байқалады. Біздің бақылаулар кезінде H β , H α , [NII] эмиссиялық сызықтардағы сәулеленудің абсолюттік ағыны шамамен 20-40 % артты.

Спектрлік және физикалық сипаттамалары бойынша IRAS20462+3416 объектісі белсенді емес жас планеталық тұмандыққа тән. Эмиссиялық сызықтардағы жарқырау ағыны және жарқырау айнымалылығының дұрыс еместігі қабықшаның қалыптасуының жалғасуын көрсетеді. Мүмкін, бұл объектіні протопланеталық тұмандыққа жатқызуға болады.

Түйін сөздер: планеталық тұмандықтар, эмиссиялық сызықтар, ионды сызықтар, жеке объектілер: IRAS20462+3416.

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Л.Н. Кондратьева, Э.К. Денисюк, И.В. Рева, М.А. Кругов

Астрофизический Институт им Фесенкова, Алматы, Казахстан

СПЕКТРАЛЬНЫЕ И ФОТОМЕТРИЧЕСКИЕ ИССЛЕДОВАНИЯ ОБЪЕКТА IRAS20462+3416

Аннотация. Объект IRAS20462 + 3416 относится к маломассивным post-AGB звездам с плотной компактной оболочкой, которая сформировалась, благодаря процессам потери массы в конце пульсационной стадии. В спектре объекта представлены эмиссионные линии H α , [NII], [SII] и линии HeI, которые в основном наблюдаются в поглощении.

Температура центральной звезды соответствует значению $T_{\text{eff}} = 19500 \pm 500\text{K}$, электронная плотность составляет 10^4cm^{-3} .

Зарегистрировано несколько эпизодов выброса фрагментов газа из атмосферы центральной звезды. Так, в 1993 – 1994гг в профилях УФ и оптических линий появились P Cygni компоненты. Соответствующее значение звездного ветра составляет $\sim 800 - 990 \text{ км/сек}$.

Фотометрическая переменность объекта отмечена многими авторами. В частности, были зафиксированы квазипериодические колебания блеска с амплитудой $0.^m1 - 0.^m2$ и периодом ~ 4 дней. Быстрые флуктуации блеска объекта могут быть вызваны звездными пульсациями и продолжающимся истечением вещества.

В данной работе приводятся новые спектральные и фотометрические данные, полученные, в основном, в 2015 – 2018 гг. Обнаружены нерегулярные колебания блеска в B, V и R фильтрах с амплитудой $\sim 0.^m4$. В процессе спектральных наблюдений выявлено постепенное усиление излучения в эмиссионных линиях. Так, абсолютные потоки излучения в эмиссионных линиях H β , H α , [NII] увеличились примерно на 20 – 40%.

По своим физическим и спектральным характеристикам объект IRAS20462 + 3416 похож на молодую планетарную туманность низкого возбуждения. Однако нерегулярная переменность блеска и потоков излучения в эмиссионных линиях, так же как и выбросы материи, указывают на то, что формирование оболочки продолжается. Вероятнее всего, данный объект можно классифицировать, как протопланетарную туманность.

Ключевые слова: протопланетарные туманности, эмиссионные линии; B V R величины; индивидуальные объекты: IRAS20462+3416

Information about authors:

Kondratyeva L.N. - Doctor of Physical and Mathematical Sciences, Fesenkov Astrophysical Institute. lu_kondr@mail.ru;

Denissyuk E.K. - Doctor of Physical and Mathematical Sciences, Fesenkov Astrophysical Institute. eddenis@mail.ru;

Reva I.V. – Junior resecher, Fesenkov Astrophysical Institute. alfekka@list.ru;

Krugov M.A. - Engineer , Fesenkov Astrophysical Institute. mkrugov@astroclub.kz

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