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A NEW CHALLENGE IN THE STUDY OF YOUNG STARS: MASSIVE HBE STARS

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In a short review paper, it is discussed the main spectral and photometric features of young intermediate-and high mass stars. Based on the results of research in this area over the past two decades, have presented the features of massive Herbig Be stars, and the main problems and tasks of researches for understanding the physics and evolution of these stars are noted.

Keywords: Stars: pre-main sequence – star formation – massive Ae/Be Herbig stars – protoplanetary disks – stellar evolution

1. CURRENT STATE OF RESEARCHES

It is known that the vast majority of stars of various masses visible in the optical range at the Pre-Main Sequence (PMS) stage of their evolution are surrounded by circumstellar disks [18]. In such disks, flow - accretion of matter to the star surface continues [9, 64, 66]. At the same time, a strong stellar wind is observed in young stars along with accretion. T Tauri stars (T Tauri stars - TTS) with masses of $0.5\text{--}2.0 M_{\odot}$ are classified according to their spectra, especially according to the intensity of the $H\alpha$ emission line. In addition, in the spectral energy distribution of those stars, a strong excess of radiation in the UV, near and far IR range is detected [24, 41]. TTSs with $H\alpha$ line equivalent width (EW) larger than or equal to $10 \text{ \AA}$ are called as classical TTS (CTTS), and stars with EW $H\alpha$ less than $10 \text{ \AA}$ are called weak TTS (WTTS) [5, 61]. The more massive ($2\text{--}10 M_{\odot}$) analogs of CTTS stars are called as Herbig Ae/Be (HAe/Be) [30] type stars. It was later shown that the line width measured at 10% of the $H\alpha$ line intensity ($H\alpha 10\%$) and the $H\alpha$ profile measured in the high-resolution spec-

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trum are more sensitive for diagnosing the accretion process [35]. Non-accreting objects with ($\Delta V \leq 230 - 270$ km/sec) have a symmetric chromospheric origin profile. However, very wide asymmetric profiles are observed in accreting objects ($\Delta V \geq 230 - 270$ km/s) [42, 80].

H Ae/Be stars show strong emission lines in their spectra and a strong emission excess in the IR range of the spectrum, which is associated with dust emission [18, 70]. In such stars, the spectrum radiated by the circumstellar disk mixes with the atmospheric spectrum of the central star, resulting in a combined spectrum. The selection and study of spectral lines with a circumstellar disk from this spectrum can provide information about the physical processes occurring in the disk and the interaction between the central star and the disk. Such an interaction mechanism in lowmass CTTS stars is relatively well studied, because these stars have dipole-shaped magnetic fields with an intensity of 1kGs. Based on this, magnetospheric accretion models were developed [9]. According to this model, the magnetic field intersects the circumstellar disk, and the pressure of the material flowing from above balances the pressure of the magnetic field created by the stellar surface. The matter spilled in the scattering radius is poured into the stellar surface at ballistic speed along the tubes of the magnetic field lines. Such a model allows to explain the changing activity of radiation lines observed in the spectrum of CTTS stars, the formation of UV radiation excess, and the nature of the additional continuum created in the spectrum, which veils the absorption lines in the UV and optical ranges. The issue of explaining the activity of H Ae/Be-type stars with the magnetospheric accretion model has not yet been confirmed. Measurements of magnetic fields in H Ae/Be stars have shown that the global magnetic fields of these stars are on the order of 100 Gs [1, 2, 33, 34]. Unlike cold stars, in H Ae/Be-type stars, energy is transported away from the center of the star not by convection, but by radiation [23, 35, 57]. confirmed that the formation of the magnetosphere accretion process in the H Ae/Be type stars may occur even at a 100 Gs magnetic field.

As we mentioned above, recently H Ae/Be stars are divided into two subgroups: these are H Ae and H Be types [64]. In recent years, the study of H Ae type subgroup stars has shown that such stars have signs of magnetospheric accretion. For example, [12] studied the profile of the He I $\lambda 1083$ & line in 50 H Ae/Be stars and showed that, while no signs of accretion were observed in hot H Be-type stars, signs of accretion were clearly detected in relatively cold H Be and all H Ae stars. However, the expected radius of the magnetosphere in such stars is smaller than that of CTTS stars and is located closer to the stellar surface.

As mentioned, the mechanism of activity of H Ae stars can be explained in the magnetospheric accretion model by choosing different parameters. However, the number of such studies on H Be-type stars is very few. Both types of stars

have been studied for different small groups by different authors. A serious turn in these studies began only after the operation of the Gaia mission [21, 46, 77]. In these works, according to the more accurate parallax values provided in the Gaia DR2 archive, 252 H Ae/Be-type stars were located on the HR diagram, and thus their ages and masses were determined based on theoretical tracks.

Meeus et al [52] studied the energy distribution of 14 intermediate-mass Ae/Be Herbig-type stars in the IR and sub-mm regions and showed that a great diversity is found in the energy distribution of these stars. Dust particles rich in carbon and others rich in oxygen have been observed in some stellar disks. The authors showed that two main groups of spectral distributions were detected. The IR and sub-mm spectrum of group 1 stars can be described as a function of thermal radiation and the power of a cold body. This radiation can be provided by an optically thick geometrically thin disk and cold body radiation. In group 2 stars, a large amount of cold dust is observed in the near-IR region, regardless of the amount of excess energy radiated. In addition, amorphous and crystalline silicate bands were found in the observed disks.

In recent years, new information about the upper limit of the masses of H Ae/Be-type stars has been discovered. In particular, as a result of the spectral and photometric observations of the extra-atmosphere space mission Gaia, conducted by the European Space Agency in 2013, it has been revealed that the upper limit of the masses of H Ae/Be stars can be up to $40M_{\odot}$. Based on these observations, [27, 77] added the list of such stars to the list of the other 200 known classical H Ae/Be stars.

2. NEW DATA AND UPCOMING CHALLENGES

Knowledge of the upper mass limit of the higher-mass stars that harbor the H Ae/Be phenomenon is not well defined. Such massive stars include various groups of young objects (Young Stellar Objects-YSO). Until recently, 255 well-studied and confirmed H Ae/Be stars were known [70]. The recent work on the study of these stars can be found in these works [27, 77]. The lower mass limit consists of a mixture of cooler H Ae/Be and TTS stars, which has not been rigorously defined in the scientific literature [10, 59, 73, 74].

Objects above the mass limit of $M_{*} > 8 - 10 M_{\odot}$ are called (massive) MYSO. It should be noted here that the difference between the previous H Ae and H Be types and MYSO is not an unequivocal determination, but in many cases, it is determined by the visibility conditions of the object. An extensive list of MYSO objects can be found in [49] work. At present, extensive information about MYSO has been extensively described in the works of [19, 44]. Although several hundred

objects are listed in these works, their extensive research has not been carried out, and their characteristics have not yet been fully studied.

Currently, by Guzmán-Díaz et al [27], a virtual catalog containing data of 318 stars was created (http://svo2.cab.inta-csic.es/projects/harchibe/docs/?page=The_Archive). In that catalog, the mass of more than 40 stars was estimated in the range of $10 - 40M_{\odot}$. This result in itself opens up a new area for research in the study of HAe/Be stars. Thus, until recently, it was considered that the upper limit of the mass of HAe/Be stars that retain the characteristics of this type is $12 M_{\odot}$ [11, 13, 70]. Since the number of HAe/Be stars is still much smaller than the number of low-mass TTS stars, of which there are more than a thousand known, many of their properties are relatively poorly understood. Moreover, since most of such stars are fainter than $V \sim 13$ mag, their spectral observation requires telescopes with apertures of at least 2 m and larger. Such difficulties have not allowed the extensive study of massive young stars so far.

Later [6] determined the physical parameters for 131 HAe/Be stars based on homogeneous results. The most prominent of such works is [79]. This paper not only presented the spectroscopically determined masses, luminosities, surface gravities, and ages from the distances given in the Gaia DR2 archive, but also added these refinements for a large number of stars in the northern sky. These studies showed that the existing characteristics of HAe/Be stars are heterogeneous and can be divided into two parts. The first part is HAe stars, whose ages and masses are $t > 3$ million years, and whose masses are in the range of $M_* \sim 2 - 3M_{\odot}$. HBe type stars are younger, but their masses are larger: $t < 3$ million years, $M^* > 3M_{\odot}$. The deficit of older HBe stars indicates that such protostars reach the main sequence earlier, i.e. the dissipation of their circumstellar disks ends much earlier.

Estimation of disk-to-stellar accretion in HAe/Be stars is by modeling the UV radiation excess of a large number of stars [17, 54, 79], or by correlation of spectral emission lines [6, 79]. Information about the more distant parts of the disc can be diagnosed mainly by means of spectral energy distribution (SED) [31, 52]. The SED curves of different objects depend on the geometry of the disc, the change type as in UX Ori, the presence of accretionary matter and accreting dust particles in the disc, and the amount of gas and dust in the disc.

As we mentioned above, magnetic fields are not generated in high-mass HBe stars. Therefore, there is no reason to apply the magnetospheric accretion model [53]. Recent studies have shown that the most massive star showing signs of accretion had a mass of $4 M_{\odot}$ [26, 79]. In addition, as we move from intermediate to high mass, they behave very differently than low-mass stars. In massive stars that produce strong UV radiation, photoevaporation is stronger, resulting in large gaps (cuts) in the disk [45]. As a result of chemical and shock evolution, the for-

mation of planets in the disc may occur more rapidly [55]. In addition, certain structures are found in more massive stellar disks. For example, spiral structures in the disk are mainly observed in hotter stars [22]. Therefore, it is assumed that giant planets should form mainly in high-mass stars [71]. However, the details of these processes have not yet been clarified. Therefore, the study of massive young stars is an important tool for understanding the evolution of their disk and the formation of planets.

Shamakhy Astrophysical Observatory has been a long time conducting spectral and photometric studies of low, intermediate and high-mass stars with the participation of the Ismailov N.Z. and coauthors. Especially HD179218, AB Aur, IL Cep, and other stars of the medium and large mass H Ae/Be type were extensively studied, and the activity observed in the emission spectrum and the physical properties of these stars were extensively studied [36,37,39,40]. In this direction, the SED curves of 56 stars located in the Orion OB2 starformation region in the range of $0.26 - 100\mu\text{m}$ were constructed, the IR radiation excess around them was estimated, and the fundamental parameters of these stars were determined. Among such stars, characteristic signs of HBe stars have been detected, especially in the spectrum of high-mass stars of the B spectral classes [39].

Recently, the evaluation of the mass of dust in disks in various regions of star formation with ages of 1-5 million years has shown that the mass of dust in disks as a whole decreases with increasing age [14, 14, 25, 72]. The typical dissipation time of protoplanetary disks is 3 million years [50, 65]. According to modern ideas, the dissipation (breakup) of discs occurs due to the following mechanisms: 1) accretion of matter from the disc to the stellar surface [28], 2) scattering of disc material by the wind [28], 3) the process of particle accretion and planet formation within the disk [56, 68]. In addition, factors such as external photoevaporation and dynamical interactions can have a significant impact on the evolution of disks [81]. Studying the characteristics of stars selected from star formation regions of different ages would allow us to clarify which of these factors play an important role in disc dissipation at different ages.

To conduct a proper study of massive young stars, first of all, a variety of objects covering a large range of masses and ages must be selected. Spectral and photometric observations of such stars should be conducted and spectral energy distribution curves should be studied. Spectral observations will allow studying the change of profiles in $\text{H}\alpha$ and $\text{H}\beta$ lines, the structure of the radiation component, and thus check the spatial structure of the circumstellar disk and the detection of accretion signs. Carrying out photometric observations in different broadband filters will allow us to study the photometric characteristics of the interstellar medium and the nature of the disk radiation and to determine the fundamental parameters. Studying the SED curves of the program stars will al-

low us to give an idea about the amount of gas and dust in the disk by studying the energy excess.

Guzmán-Díaz et al. [27] constructed the SED curves of 209 Herbig Ae/Be-type stars using the results of broadband photometric observations and studied the characteristics of the circumstellar disks. The temperature, luminosity, radius, mass, and age of each star were determined. It is shown that the masses of the stars take values in the range of $2\text{--}12 M_{\odot}$. The authors show that there is no correlation between the shape of transition disks and the SED curves, and 28% of stars have transition disks. Gaps detected in transition disks are more frequent in HBe stars than in HAe stars. It has been shown that photoevaporation in these sources does not play a decisive role in disc dissipation.

Testi et al [69] studied the parameters of stars in different young star complexes and showed that the mass, luminosity, accretion rate, and disk mass of the stars in the L1688 cluster of the youngest ρ Oph region, ~ 1 million years old, taken in the neighborhood of the Sun, are similar to those taken from other regions, are not distinguished of the parameters. The age interval with other star clusters was 0.55 million years. In such clusters, the accretion rate is inversely proportional to the age of the stars. The age dependence of the mass of dust in the disk shows a more complex character.

Young stellar disks show radiation excess due to absorption of photospheric radiation by the central star and reradiation mainly in the near and far-IR region [82]. Furthermore, another source of radiative excess is the energy generated during disc accretion [28, 43]. If the gas-dust disc has fragmented, we should not observe accretion signatures, such as ultraviolet (UV) emission excesses and broad wing profiles in the $H\alpha$ line.

It is known that within a few million years of their initial formation, small and medium-mass young stars acquire a circumstellar disk and a magnetic field. The magnetic field formed in the deep convective zone and outer mantle creates expanding cold spots on the stellar surface, hot zones, additional radiation excess in the chromosphere and corona, activity similar to solar activity [24, 60, 61]. Since the rapid study of exoplanets and the confirmation of the existence of planets in most stars in the Galaxy, the study of disks around young stars has generated great interest.

Studies of the Solar System and many young stellar disks have shown that planet formation in the circumstellar disks of nascent stars occurs within several million years of formation [63]. It is now widely accepted that planets form in the disks of young stars that are the product of star formation [67]. In many modern instrument complexes, for example, in the near-infrared (IR) and optical ranges [8], the millimeter Atacama Large Millimeter/submillimeter Array (ALMA) complex has obtained images of the disk around young stars. In the ALMA complex,

several hundred a.u. away from the disk, various disk structures - rings, voids, asymmetric structures caused by the interaction of giant planets were discovered [3, 47, 48]. SPHERE images have shown disc shadows, rings, spiral arms, dips, and fissures in the outer disk at distances of 20-200 a.u. [7]. The nature of such phenomena in massive young stars remains unexplored.

Recent studies have shown that remnant dust disks are currently detected around some very old stars (β Pic, α Lyr) [51]. This indicates that the process of creating planets in those stars has come to an end. Spectral energy distribution curves of such stars constructed in a wide wavelength range show that, compared to normal stars, the radiation excess in these stars manifests itself only in the far infrared (IR) range $\lambda \geq 10\mu\text{m}$ [16]. After the observations of the Infrared Astronomical Satellite (IRAS) mission, it was found that on average only 21% of the stars have Vegatype features, and these features show some dependence with the spectral class. The frequency of encountering protoplanetary disks around young stars is higher, but the direction of change of the amount of dust in such disks at different ages remains unstudied.

A study of the SED curves of a group of stars in the OB1 star cluster located in the Orion Nebula showed that, although this star cluster is considered a young star-forming complex, Vega-type features are also observed around some of the stars located here [39, 40]. These results show that the evolution period of circumstellar disks depends on the age of the stars, their mass, spectral class, possibly chemical composition, etc., and depend on other factors. It is of great importance to investigate which mechanisms are more important during evolution in changing the amount of gas and dust that make up the disk matter.

3. DISCUSSION

Finally, let us mention the following important issues about the evolution of medium- and large-mass protoplanetary disks that are still waiting for their investigation. For example, how does the amount and composition of gas in protoplanetary disks change during evolution? High-resolution $\text{H}\alpha$ spectral observations can unambiguously reveal whether gas accretion is present in the disc. If there is accretion, the disk is rich in gas. However, the lack of accretion does not mean that the disk is low on gas. The accretion rate may vary and may be faint at the time of observation. In addition, accretion may be reduced in the observed disk due to photoevaporation and dynamical interactions.

In general, the evolution of the amount of gas (in other words, the ratio of gas to dust by amount) is currently the most important problem for protoplanetary disks. The amount of gas is an important factor for both the formation of giant

planets and the formation of Earth-group planets, because the gas affects the dynamics of the formed dust particles and ensures the formation of rocky blocks.

Although some models assume the gas-to-dust ratio to be 100, as in the interstellar medium, this is clearly not the case. On the one hand, photoevaporation should reduce the amount of gas. On the other hand, as the particles become planetesimals and planets, the gas to dust ratio must increase. At the end of the initial disc dissipation process, the disc should consist of dusty compounds combined with gas. But the evolution of gas and dust can be more complex than monotonically decreasing. Therefore, it is necessary to take into account that the gas-dust ratio is much more than 100 at the initial stage [32,62,78]. It seems that the mass of the central star should also play an important role in the dissipation process.

The proposed scientific research task is devoted to one of the most important fields of modern astrophysics - the study of the physical properties of disks formed around massive young stars during the formation and initial evolution of stars (1-100 million years). One of the interesting directions of research in this issue is the study of the physical properties of protoplanetary disks formed around young stars using photometric observation material conducted in a wide wavelength range.

Thus, based on the summary given above, it is clear that the study of the characteristics of the circumstellar disks of a statistically significant number of massive stars with different ages and masses is of great importance to determine the process of planet formation and the role of various mechanisms in the protoplanetary disks of such stars and to understand the dissipation process of young stellar disks as a whole. The proposed scientific research task envisages conducting research in this direction.

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ON SPECTRAL CLASSES OF SEYFERT GALAXIES AND THEIR EVOLUTION

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The paper analyzes changes in some physical parameters obtained from theoretical, model calculations in several catalogs for Seyfert galaxies of spectral classes S1 and S2. It is concluded that there is a high probability that the existing evolution of Seyfert galaxies occurs from the spectral class S2 to S1. Based on the analysis of a large array of observational material, it is shown. that the distribution of Seyfert galaxies as a spectral class Sy1. so Sy2 has a bimodal character.

Keywords: Seyfert galaxies –spectral types of Seyfert galaxies – Evolution Seyfert galaxies

1. INTRODUCTION

Since the discovery of the first quasars in the 60s of the XX century, astronomers have tried to bring at least some order to a variety of objects known as galaxies with active nuclei (AGN) which include Seyfert galaxies (hereinafter referred to as SG). These galaxies have supermassive black holes in the center, intensively accreting the extragalactic matter of these galaxies. Further on the basis of ordinary classical mechanics we will try to explain the existing difference between the SGs of different spectral classes.

2. EVOLUTION OF SG AND THEIR DISTRIBUTION IN THE UNIVERSE

At first let us consider a graph of the dependence of the logarithm of the accretion rates of extragalactic matter ($\log(dM/dt)$) on the nucleus on the rotation

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rate of the SG (in our case, this is the FWHM index). These values are obtained directly from observations and the method of their calculation is generally recognized by astronomers. Data for the graphs are taken from the work [4]. (Star

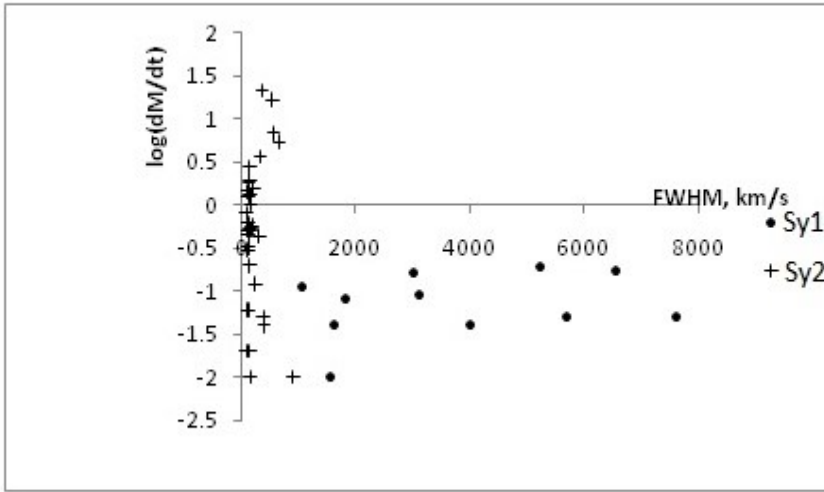


Fig. 1. The dependence of the logarithm of the accretion rates of extragalactic matter on the nucleus on the rotational velocity of the disk of the SG spectral classes Sy 1 and Sy2. Here the points are SG spectral class Sy 1, and the crosses are Sy 2.

formation rate in Seyfert galaxies (Wang+, 2007)).

This figure can be interpreted within the framework of classical mechanics. The fact is that the rotation speed of the SG spectral class Sy1 (as can be seen from the figure) is higher than that of the Sy2 and the resulting centrifugal force prevents accretion. It is also worth mentioning here that if we accept the hypothesis of the presence of evolution in SG in which one spectral class passes into another then at the grossest approximation (if we assume that in SH spectral class Sy1 the morphological type is mainly SA, and in spectral class Sy2 it is SB), then in the first case it is possible to represent SG as a homogeneous disk, rotating around an axis perpendicular to the disk and passing through its center, and in the second case, as a homogeneous rod rotating around a perpendicular axis, then in the first case the moment of inertia of the disk is less than that of a rotating rod and, based on the law of conservation of angular momentum, the disk must rotate faster than the rod (since the mass of the SG of these spectral

classes is on average approximately the same). Such a hypothesis requires the presence of some catastrophic mechanism, not yet very clear, for the transformation of one morphological type into another. From Figure 2 it can be seen that

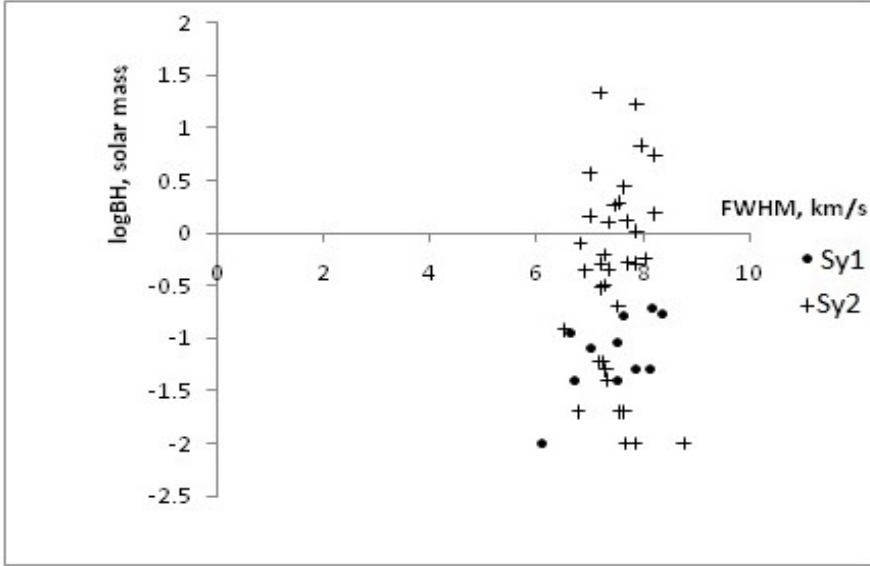


Fig. 2. The dependence of the mass of the SG nucleus of different spectral classes for the different rotational speeds (here the same designations as in Fig.1).

if in the lower part of the figure the mass of the central black hole of the SG of different spectral classes are mixed, then only the SG of the second spectral class remain in the upper part of the figure, i.e. in this case, accretion constantly goes to the core of the SG, which leads to an increase in the mass of the nuclei of these galaxies, as can be seen from the figure. Let us now turn to the analysis of such important parameters for the evolution of galaxies as the rate of star formation (SFR). Previously, it was believed that because during the transition from SG spectral class Sy1 to Sy2, on average, the color indices become redder, then this indicates the evolutionary path of SG, the rate of star formation falls, more and more low-mass, cold stars are born, i.e. such SG is aging. But then there were works in which (see, for example, [1]) this statement is questioned. On the contrary the authors of these works believe that in SG spectral class Sy2, the rate of star formation increases, and the infrared excess in colors arises mainly due to the fact that a large amount of dust in these galaxies is heated by the radiation of massive, hot stars. The fact that there is more dust in the SG spectral class Sy2

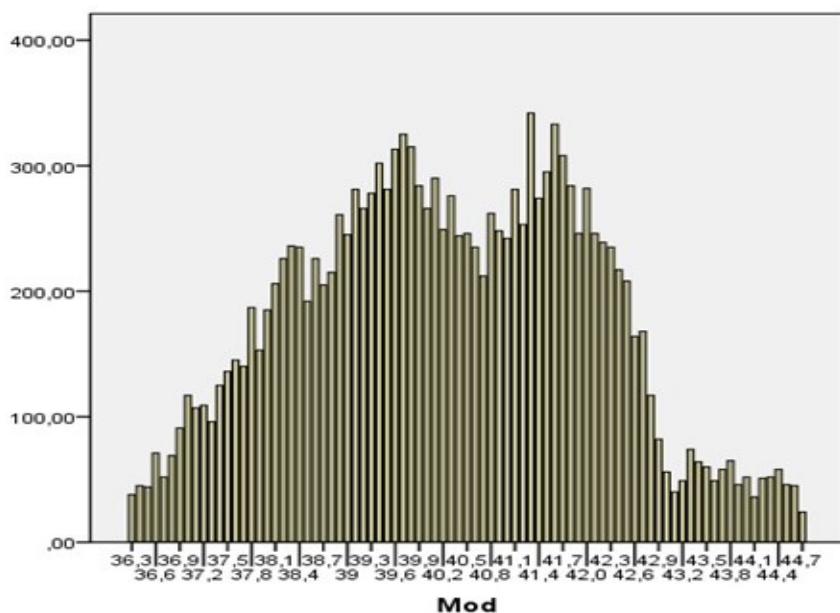


Fig. 3. Distribution of the number of SG spectral class Sy1 depending on the magnitude of the modulus of their distances.

than in Sy1 is also evidenced by our own research. Let's try to solve the resulting contradiction by analyzing the frequency of supernova flares in SG, because if the rate of star formation is large, then more massive, hot stars are born and their explosions also often occur. For this reason we selected from the catalog [5] SG, in which supernova explosions have ever occurred. SG spectral class, Sy1 had seven supernova flares (of which three are repeated flares in the same galaxy) and SG spectral class Sy2 already had thirty-seven (of which eight are repeated), and if considering that for example, [6] (ned.ipac.caltech.edu). gives data for Sy1 spectral class Sy1 about twice as much as for Sy2, as well as then, that the SG in the Universe is only 1-3% of the total number of galaxies, it becomes clear that supernova explosions in the Sy2 spectral class Sy2 are possibly even greater than in ordinary galaxies and there is no need to talk about a decrease in the rate of star formation. But if the rate of star formation in the Sy2 spectral class Sy2 is large, based on the frequency of supernova explosions, then it becomes clear where so much dust comes from in these galaxies. And finally, we can refer here to the fundamental principle of our Universe that entropy grows over time, which no one has yet cancelled.

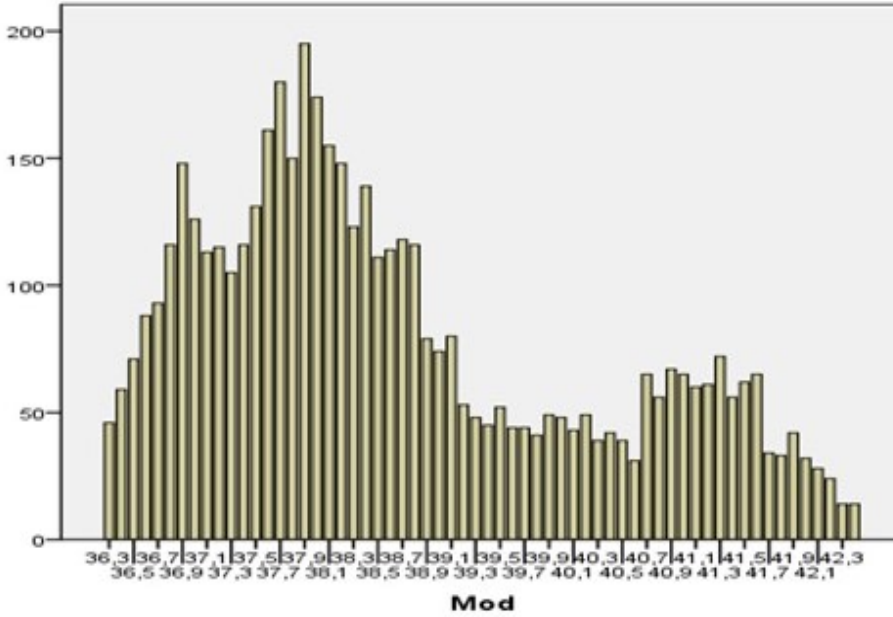


Fig. 4. Distribution of the number of SG spectral class Sy2 depending on the magnitude of the modulus of their distances.

Whether Seyfert galaxies evolve, what are the mechanisms of this evolution, the ways of evolution are today perhaps the most important questions in the light of understanding the nature of these objects, their formation. SGs are known to be divided into spectral classes. In this work paper, we attempt to determine the path of evolution of SG of various spectral classes. Similar work has already been performed (see, for example, [2]), but in our work on the bases of much more observational material and by another method it is shown that the evolution of SG of different spectral classes goes in the direction of Sy2→Sy1.

Since determining the distance to extragalactic objects is associated with certain difficulties, we use a well-known, so-called distance module Mod, in this work, where

$$\text{Mod} = m_v - M_v = 5 \log_{10} r - 5 + A(r)$$

Here, m_v and M_v are the visual and absolute magnitude of the extragalactic object in filter V, respectively, r is the distance, $A(r)$ is the interstellar absorption.

Given that the interstellar absorption in our case is relatively small ($A(r) \approx 0^m.1$ compared to the $\text{Mod} \approx 39^m$ value), we neglect this value in our further calculations. Further, we constructed the distribution curves of the number of SG spectral classes Sy1 and Sy2 separately, which are presented in Fig.

3 and Fig. 4. Here I had to round the values of mv to $0^m.1$, because with such accuracy in the work [3] the values of Mv are given. As can be seen from the figures, the resulting distribution curves are bimodal in nature. Most likely this is due to the fact that the distribution of MV values in [3] also has a bimodal

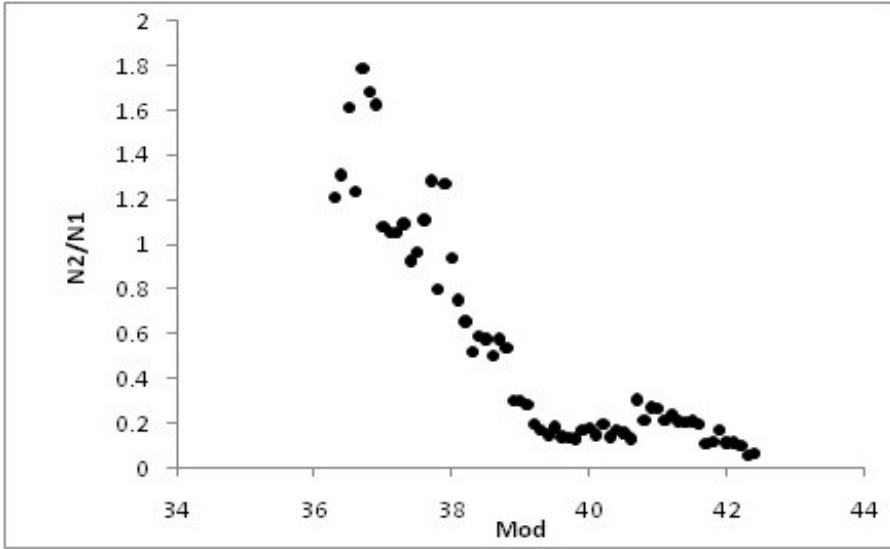


Fig. 5. Distribution of the number of SG spectral class Sy2 depending on the magnitude of the modulus of their distances.

character and proceed from it we will preliminarily introduce names for the left modes in Fig. 3 and 4 SG, low luminosity and for right modes high luminosity.

As can be seen from the above figures 3 and 4 if for the spectral class Sy1 both modes have approximately the same amplitude on the bimodal distribution curve then for the Sy2 spectral class, the right mode in the figure is about two times smaller in the amplitude of the left while the location of both modes in the figures is approximately the same (relative to the values of the modulus of distances) and the border between the modes passes approximately in the same place in both figures. Let us consider now how the number of SGs in the universe surrounding the Earth changes, depending on the modulus of distance. For this reason we will break the space surrounding the Earth into globular layers, with a thickness of $\Delta Mod = 0^m.1$ centered at the location of the Earth, and calculate the number of spectral classes SG Sy1 and Sy2 in each ball layer separately. Then we build

the dependence of the values $N(\text{Sy}2)/N(\text{Sy}1)$ (since the volume of the ball layers under consideration is different) depending on the distance modulus (Fig. 5).

3. CONCLUSION

Thus the present work confirms the conclusion made in the work [1] that the evolution of SH goes in the direction from the spectral class Sy2 to the spectral class Sy1, made on the basis of the analysis of a more extensive observational material and by another method.

The distribution of the number of SG of the spectral class Sy1 and Sy2, depending on the magnitude of the modulus of their distances, has a bimodal character.

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THE GALACTIC DISTRIBUTION OF WOLF-RAYET STARS

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The results of the investigation of the Galaxy distribution of Wolf-Rayet stars have been presented. This investigation is important for the understanding of the evolutionary properties WR stars. It is known that in the formation of these stars, the main factor is the mass loss rate. Massive O star by losing a significant amount of mass transforms into WR star. On the other hand, the mass loss rate depends on metallicity. It is known that metallicity in our Galaxy decreases from the center to the outer parts. Therefore, by investigating the galaxy distribution of WR stars we could clarify the role of metallicity in the formation of these stars. WR stars separate into WN, WC, and WO subtypes. We could also clarify the evolutionary relations between different subtypes. By using the correct values of distances we plotted the galactic distribution of WR stars. Although the Galactic distribution of these stars has also been carried out before, it is important to perform new research. Because every year new stars are discovered and the distances to these stars are already determined correctly than used in earlier researches.

Keywords: Wolf-Rayet stars – Milky Way Galaxy – metallicity – O type stars

1. INTRODUCTION

In this paper, we investigate the galactic distribution of Population I Wolf-Rayet (WR) type stars. Though Population I WR type stars were discovered more than two hundred years ago, many features of these stars are still difficult to explain [1]. These stars are massive young stars at the final stages of their evolution and located in OB associations and galaxy clusters. There are also Population II WR stars, which have spectra with the spectrum like Population I WR stars [2].

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These are less massive and luminous central stars of planetary nebulae [2]. The observational properties of Population I WR stars are comprehensively discussed in [1, 3–6].

Population I WR stars is located in the spiral arms of our Galaxy. It is known that the massive star should lose a significant amount of mass to become WR star. On the other hand, the mass loss rate depends on metallicity [7] and the metallicity in our Galaxy decreases from the center to the outer parts [8]. For the understanding role of metallicity in the formation of WR phenomena it is reasonable investigation of the galactic distribution of WR stars.

In [9–11] empirically determined the relation between the mass loss rate of early-type massive stars as a result of radiation pressure on spectral lines. The empirical dependence of the mass loss in stellar winds on the metal content of their atmospheres is studied. Assuming a power-law dependence of mass loss on metal content, authors of [9, 10] found the following mass loss vs. metallicity relation: $\dot{M} \propto Z^{0.83 \pm 0.16}$

The distribution of the WR stars in our Galaxy for the first time was performed in [12]. At that time were known only 123 galactic WR stars and distances were not known. Because in [12] the galactic distribution was studied by using only galactic coordinates. The main result of this investigation was revealing the absence of WR stars between $137^\circ - 222^\circ$ [12] galactic longitudes. In [13] by using the calculated distances for individual stars the first time plotted the spatial distribution of WR stars in our Galaxy. In subsequent years, this problem was studied in [14–16]. Discovering the new WR stars [17, 18] and more correctly determining of heliocentric distances of these stars makes it reasonable to perform the new investigation of galactic distribution of these stars.

2. DETERMINATION OF GALACTOCENTRIC DISTANCES

For the determination of galactocentric distance i.e. distances from the center of the Galaxy of WR stars, we used the heliocentric distances i.e. distances of stars from the Sun. Heliocentric distances can be easily converted to galactocentric distances by subtracting the heliocentric space vector of the Galactic center, R_0 , from the heliocentric space vector of the object under study R . The distance of the star from the Galactic center (R) is determined by using the following formula [23]:

$$R = \sqrt{[d \cos(b) \cos(l) - R_0]^2 + d^2 \cos^2(b) \sin^2(l) + d^2 \sin^2(b)} \quad (1)$$

where R_0 is the distance of the Sun from the Galactic center, l , b , and d the Galactic longitude, Galactic latitude, and heliocentric distance respectively of

the star. The value of the distance of the Sun from the Galactic center (R_0) is adopted as 8.23 kpc [19]. Note that for the stars located inside or outside of the Solar circle in Galaxy, we could calculate galactocentric coordinates by using this formula.

3. THE RADIAL DISTRIBUTION OF WR STARS

By using heliocentric distances, we plotted the radial (l , d) distribution of WR stars (Fig.1). It is known that WR type stars separate into three subtypes, WN, WC, and WO. We plotted the histogram of radial distribution of Galactic WR stars in three regions: 0-5 kpc, 5-10 kpc, and 10-15 kpc from the Galactic center (Fig.2).

Fig.1 shows the distribution of stars along the spiral arms of our galaxy. For the revealing distribution of WR stars along the spiral arms the picture of our galaxy taken from [24] superimposed with the Fig.1. It is known that since the 1950s, astronomers have known that our galaxy has a spiral structure [20]. The main parts of our galaxy are a nucleus (massive black hole), a central bulge, a disk, spiral arms, a spherical component, and a halo. Gaia mission of the European Space Agency has been mapping our galaxy since 2014, by using the results of measurements of the precise positions and distances from Earth of approximately two billion stars [21]. Due to Gaia satellite star mapping the spiral structure of our galaxy is revealed more distinctively. It is known that the spiral arms emanate from the galactic center and wind through the galactic disc. The spiral arms are actively star formation regions, where located young stars, interstellar dust, and gas. Stars are born from clouds of molecular gas and shine for billions of years in spiral arms. The exact number of arms, and their shapes, are difficult to determine because we are located within our Galaxy. Interstellar dust and gas are primary matters for the formation of new stars.

According to the modern view, there are four main spiral arms (the Norma and Cygnus, Sagittarius, Scutum-Crux, and Perseus) and the number of fragments of arms. Our Sun lies near a small, partial arm called the Orion Arm, or Orion Spur, located between the Sagittarius and Perseus arms. The Sun is located at a distance of 8.23 kpc from the center of the Galaxy [19].

The stars of our galaxy divided into two populations: Population I and Population II. Population I stars are found only in the disk and move in nearly circular orbits around the galactic center. Examples are bright supergiant stars, main-sequence stars of high luminosity (spectral classes O and B), which are concentrated in the spiral arms, and members of young open star clusters. Interstellar matter and molecular clouds are found in the same places as Population I stars.

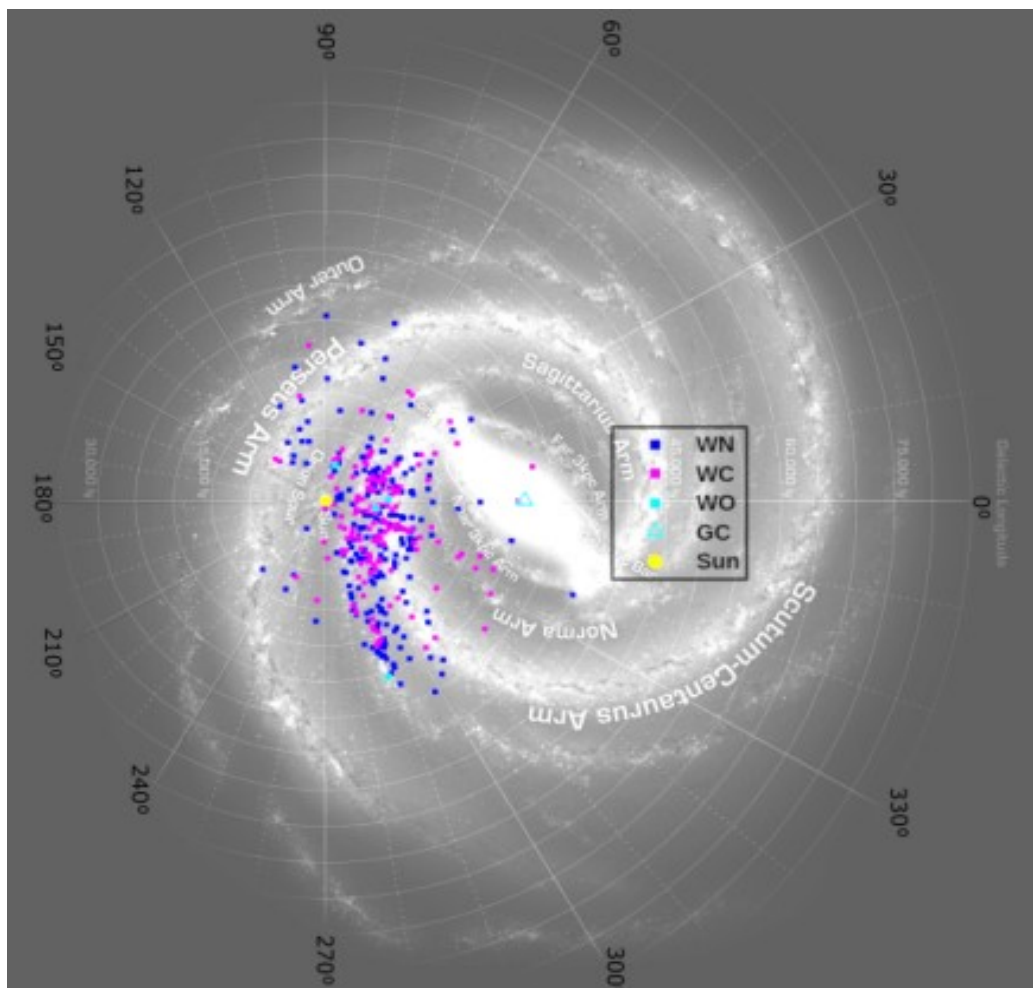


Fig. 1. The radial (l , d) Galactic distribution of WR stars. The distance of Sun from the Galaxy center adopted as 8.23 kpc. There are 76 WR stars at the Galactic Center.

Population II stars show no correlation with the location of the spiral arms. These objects are found throughout the Galaxy. Some are in the disk, but many others move in elliptical orbits because they are at high distances from the galactic disk. Examples are central stars of planetary nebulae and RR Lyr type variable stars. The stars in globular clusters, found almost entirely in the Galaxy's halo, are also classified as population II. These stars are the old metal-poor stars that form mainly the halo of the galaxy.

Population I stars are younger and metal-rich stars. They form the disk of the galaxy. The WR type stars are Population I stars. As seen from Fig.1 these

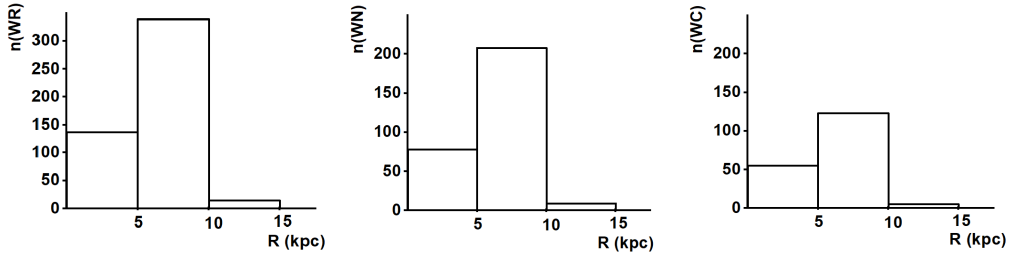


Fig. 2. The histogram of radial distribution of Galactic WR (left), WN(middle) and WC (right) stars.

stars are located mainly in Sagittarius, Scutum-Crux Arm. In this region, there are both WN and WC subtypes. But as seen from Fig.1 WN stars are more in the outer part and WC stars in the inner part of the galaxy. In Perseus Arm also there are a few WR type stars and these stars are mainly WN stars. At the galactic center, there are 76 WR stars (39 WN, 34 WC).

We studied the galactic distribution of WR stars also by plotting the histogram of radial distribution of Galactic WR, WN, and WC stars (Fig.2). As seen from Fig.2 WR, WN, and WC stars are located mainly at distances 5-10 kpc from the galactic center.

4. DISTRIBUTION OF WR STARS PERPENDICULAR TO THE GALACTIC PLANE

Fig. 3 shows the height above the Galactic plane (z) versus the galactic longitude (l), i.e. the (l, z) distribution of WR, WN, and WC stars. According to the results of the theoretical investigation, the WR stars located above ± 250 pc from the galactic plane are considered a candidate for the "runaway" stars [5,6]. Location of these stars at high distances from the galactic plane explained with the kick velocity obtained by the binary system during the supernova explosion. These stars are considered as WR stars with compact components (WR + C). The letter C marks the compact component (neutron star or black hole). However, further studies did not confirm that these stars could be WR + C systems [5,6]. The high distance above the galactic plane and the high spatial velocity of these stars can be explained by the ejection of these stars from massive star clusters due to the action of collective interactions [22].

As seen from Fig.3 the WR stars are confined mainly to the strip ± 250 pc around the galactic plane and some WR stars are located at the distances $z > \pm 250$ pc from the galactic plane. By comparison of the l, z distribution for WC and WN stars we could conclude that more WN stars at the distances

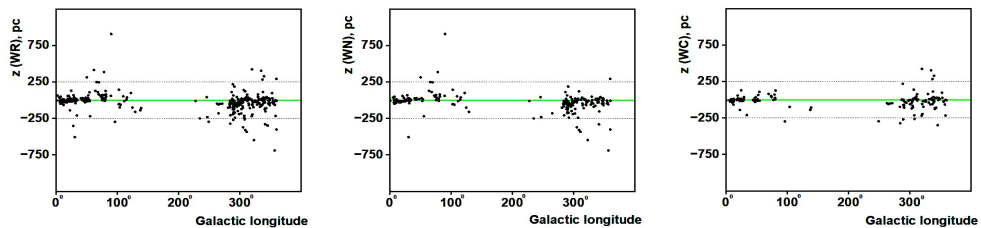


Fig. 3. The height above the Galactic plane (z) as function of the galactic longitude, for WR (left), WN (middle) and WC (right) stars. The stars confined to the strip ± 250 pc separated.

$z > \pm 250$ pc from the galactic plane than WC stars (Fig.3). We also could conclude the absence of WR stars at the galactic longitudes approximately $140^\circ - 230^\circ$ (Fig.3).

5. CONCLUSIONS

The main results of this investigation are:

1. WR stars located mainly in Sagittarius and Scutum-Crux Arms of the Galaxy;
2. In contrast to WN stars, the WC stars dominate the inner part of the Galaxy;
3. In the Perseus arm also there are few WR stars, but they are mainly WN subtype stars;
4. WR stars are mainly located at distances 5-10 kpc from the galactic center;
5. Some WR stars are located at the distances $z > \pm 250$ pc from the galactic plane, and among these stars WN type WR stars are dominant;
6. In the $\sim 140^\circ - 230^\circ$ galactic longitudes, the WR stars have not been found.

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DETERMINATION OF THE CONTENT OF MOLECULAR HYDROGEN IN ATMOSPHERES URANUS AND NEPTUNE

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In the spectra of Uranus and Neptune, the intensities of the absorption bands of molecular gases are significantly enhanced in comparison with the observed intensities on Jupiter and Saturn. In addition, due to the small angular dimensions, it is still practically impossible to study the nature of variations in the intensity of molecular absorption bands along the disk of the planets Uranus and Neptune. For these planets, absorption line profiles in their spectra are formed over all reflected radiation.

Keywords: Uranus – Neptune – two-layer – molecular hydrogen

1. INTRODUCTION

Determining the amount of various gases in the atmospheres of giant planets allows us to understand the past and future paths of their evolution. For example, the fact that the relative amount of primary gas in the planets of Uranus and Neptune compared to the proto-sun is less than that of Jupiter and Saturn indicates that their masses reached a crisis value and were formed later than the first. It is possible to observe the intensity distribution of absorption bands (lines) in the atmospheres of Jupiter and Saturn, which have a large disk size, far from the center.

In 1976-1978, the 2.2-m telescope of the Mauna Kea Observatory with a Fabry-Pero interferometer recorded the profiles of the S(0) and S(1) lines of the H₂(4–0) quadrupole band in the spectra of Uranus and Neptune. The obtained values of the equivalent linewidths turned out to be significantly smaller than those ob-

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tained earlier by other observers. The authors believe that this is due to some systematic instrumental errors in early studies, and the observed line profiles are interpreted within the framework of the simple reflection model and the model of scattering layers in the atmosphere. For these models, growth curves are calculated and an estimate of the H_2 content in the atmospheres of Uranus and Neptune is made: 240 ± 60 km.amagat for Uranus and > 200 km. amagat for Neptune - the most probable values. Since the determination of the amount of gases in the atmospheres of Uranus and Neptune was carried out within the framework of a simple reflection model, the results obtained are incorrect. Most importantly, the multiple scattering of light in the planet's atmosphere is not taken into account in such a model. On the other hand, in the atmospheric conditions of icy planets such as Uranus and Neptune, the dependence of physical quantities on height is more complex. It is also necessary to note that spacecraft detect methane in the upper layers of these planets, indicating the presence of a cloud. That is, the temperature value is higher than the freezing point of methane.

Taking into account the observational facts for the planets Uranus and Neptune, it is correct to carry out theoretical considerations of their atmospheres within the framework of the double atmosphere model, considering that the profile of absorption lines in the spectra of such planets belongs to the entire disk of the planet within the framework of a two-layer atmosphere model. The amount of molecular hydrogen should be determined, and calculations should be carried out. Based on the theory of the spectra of planetary atmospheres, it was necessary to construct a growth curve for the $S(0)$ and $S(1)$ lines of molecular hydrogen located in the visible region of the spectra of the planets Uranus and Neptune within the framework of the two-layer atmosphere model. Assuming that in all measurements, it is more correct to take the line $S(1)H_2(4-0)$, since this line of molecular hydrogen is subject to weak shock compression [1]. Although the quadrupole lines of molecular hydrogen, $S(0)$ and $S(1)$, located in the visible region of the spectrum, have high intensities in the spectra of the planets Uranus and Neptune, they are considered intact. On the other hand, the profile of the absorption line in the spectrum of the planet, the entire disk of which is observed, is due to radiation reflected from different points.

2. GENERAL FORMULAS

In the atmospheres of planets, radiation occurs due to scattering and absorption by both gas particles and aerosols. Denoting by the volume scattering coefficient and the true absorption coefficient in the continuous spectrum by σ and x , the scattering indicatrix by $\mathcal{K}(\gamma)$ and ω_c in the continuous spectrum

$$\omega_c = \frac{\sigma}{\sigma + \varkappa}$$

for the single scattering albedo ω_v in the line $\omega_v = \frac{\sigma}{\sigma + \varkappa + \varkappa_v}$

$$1 - r_v(\eta, \xi, \varphi) = C(\eta, \xi, \varphi) (\sqrt{1 - \omega_v} - \sqrt{1 - \omega_c}) \quad (1)$$

The value of the left side in equation (1) consists of two factors, one of which, $C(\eta, \xi, \varphi)$ [2] depends only on the location on the disk and the other only on the frequency. Therefore, this value of the left side of (1), as a function of τ_v in relative units, is the same on the entire disk $\sqrt{1 - \omega_v} - \sqrt{1 - \omega_c}$. Substituting (1) into the equivalent width expression and taking into account the

$$C(\eta, \xi, \varphi) = \frac{4}{\sqrt{3} - x_1} \frac{u_0(\eta)u_0(\xi)}{\rho_0(\eta, \xi, \varphi)} \quad (2)$$

we get

$$W(\eta, \xi, \varphi) = QC(\eta, \xi, \varphi) \quad (3)$$

where x_1 - parameter is the first coefficient of the expansion of the scattering indicatrix in Legendary polynomials, i.e.

$$x_1 = \frac{3}{2} \int_0^\pi x(\gamma) \cos \gamma \sin \gamma d\gamma \quad (4)$$

where ρ_0 - is the reflection coefficient in the spectral line. In [3] for the expression Q after some mathematical transformations, it turns out

$$Q = 2\Delta v \sqrt{(1+b)(1-\omega)} f(p) \quad (5)$$

where $b = \frac{\varkappa_0}{\sigma + \varkappa}$, $p = \frac{\omega b}{(1+b)(1-\omega)}$, $\varkappa_0, \varkappa_v$ are coefficients of adsorptions. The function of $f(p)$ can be expressed in the following form

$$f(p) = \sqrt{1+p} \left[K \left(\sqrt{\frac{p}{1+p}} \right) - E \left(\sqrt{\frac{p}{1+p}} \right) \right] \quad (6)$$

where, K and E are complete elliptic integrals. As a result, for the equivalent width of the line (or stripe), we get:

$$W/\alpha_D = 2C_s f(p) \sqrt{(1 - \omega_c) \omega_c / \omega_{v0}} \quad (7)$$

Let us apply the two-layer model to the atmospheres of Uranus and Neptune, hence taking into account that it was impossible to obtain data on the distribution of brightness over the disk for these planets from our observations. The two-layer model is characterized by the following parameters: scattering indicatrix, single scattering albedo (ω), optical thickness of the outer atmosphere (τ_v),

and aerosol scattering coefficient (δ_a). Assuming that $\beta_v = \kappa_v/\alpha_a = \text{const}$ and κ_v changing according to one law within the two-layer model, we obtained expressions for calculating the geometric albedo. After some transformations in the expression geometric albedo, the parameter gas layer size is included in the parameter β_v :

$$1 - \frac{A_{gv}}{A_{gc}} = \frac{\rho_{ov}}{\rho_{oc}} (2k_c + 1) \int_0^1 \mu^{2kv} e^{-\frac{b \cdot \beta_v}{\mu}} d\mu \quad (8)$$

After integrating equality of (8), finally we get :

$$\frac{W}{\alpha_D} = \frac{\rho_{ov}}{\rho_{oc}} (2k_c + 1) \int_0^1 \mu^{2kv} e^{-\frac{b \cdot \beta_v}{\mu}} d\mu \quad (9)$$

Taking the logarithm from the equality of (9), we obtain the following integral equality

$$\lg \frac{W}{\alpha_D} = \lg \frac{\rho_{ov}}{\rho_{oc}} + \lg (2k_c + 1) + \lg \left[\int_0^1 \mu^{2kv} e^{-\frac{b \cdot \beta_v}{\mu}} d\mu \right] \quad (10)$$

After that, we construct the dependence of the geometric albedo value on $\lg \beta_v$ and the observed value of the geometric albedo, we calculate β_v and after that, we calculate the content of molecular hydrogen.

3. CONCLUSION

Thus, calculations have shown that the amount of molecular hydrogen in the atmosphere of the planet Uranus is 5 ± 0.2 km.amaga and in that of Neptune it is 5.2 ± 0.2 km.amaga.

In general, the amount of molecular hydrogen in the atmospheres of the planets Uranus and Neptune is less than that of Jupiter and Saturn. For physical reasons and based on mathematical reasoning, the result we obtained can be considered quite realistic [4].

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BVRcIc PHOTOMETRIC MONITORING OF THE SEYFERT GALAXY NGC 3516 IN 2017-2021

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The results of BVRcIc photometric observations of the Seyfert galaxy NGC 3516, conducted in 2017-2021, are presented. The obtained results show that the change in brightness within the observation carried out within the period of 2017-2021 in the BV Rc and Ic filters was 0.36 ± 0.005 ; 0.28 ± 0.005 ; 0.07 ± 0.003 and 0.04 ± 0.004 magnitudes, respectively. This fact proves that there was a change in the spectral type in this galaxy, which was obtained as a result of spectral observations.

Keywords: Seyfert galaxy – NGC 3516 – AGN – CL AGN – UV – optical – photometry – spectroscopy –

1. INTRODUCTION

The variability of the radiation of Seyfert galaxies was first discovered by Fitch et al. [1]. A later observation, the variability of these galaxies was confirmed by Zaitseva and Lyuty [2]. Recent space and ground-based by Dan Maoz et al. showed a change in the brightness of NGC 3516 in the X-ray region and in both the B and R ranges with a characteristic time from a few seconds to several days [3, 4]. Dan Maoz et al also notes the unique effect of delaying the onset of maxima in the optical range relatively to the X-ray maximum.

Yang et al. [5] present the results of observations of 21 new active galaxies in their work that have changed their spectral type (CL AGN). These galaxies are located at a red shift of $0.08 < z < 0.58$, which doubles the number of such objects known at present. The estimated upper transition time limits for galaxies that have changed their spectral type in this survey range from 0.9 to 13 years. The

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flux of the continuum in the optical and mid-infrared ranges becomes brighter and the spectral type changes, when moving from Sy2 to Sy1, or vice versa during the reverse transition. Changes in brightness of more than 0.2 magnitudes were detected in 15 active galaxies (CL AGN) during the transition from one type to another. The authors note the importance of understanding the physical mechanism of spectral type change (CL AGN) for understanding the evolution of the nuclei of active galaxies.

Ilic [8] presents the results of the observation of the Seyfert type I galaxy NGC 3516 in his work, which has changed its spectral type. The authors note that this active galactic nucleus has strong optical variability and changed its spectral type in the past. It has been in a low active state in the optical range since 2013 with some revival from late 2015 to early 2016 it has remained stable.

2. OBSERVATION

We carried out conducted a photometric observation of the BVRcIc Seyfert galaxy of the first spectral type NGC 3516 at the 60-centimeter telescope of the Shamakhy Astrophysical Observatory named after N. Tusi. Photometric observation of the BVRcIc galaxy NGC 3516 was carried out within 2017-2021. The CCD photometer was concentrated at Zeiss 600 telescope for the photometric observations. The observations were carried out with a differential way using close comparison stars. Processing of the obtained photometric materials was carried out using the MAXIM DL 4 software package. Bias, dark and flat frames were obtained for calibration for this reason.

We carried out the photometric observations of Seyfert's galaxy NGC 3516 in February 2017. We chose mainly without lunar nights to observe this galaxy. Observations of the galaxy were carried out in four filters. Our observations were carried out at different times and at different intervals. As you know astronomical observations depend on weather conditions, on the visibility of the object and on the distribution of the observation time.

The standard and control stars are removed every night along with the object. The identification maps compiled as a standard and a control star compiled by Lyuty and Penston [6, 7], the stars A, C1, 2, and 3 were used for this purpose.

As can be seen from Fig.1, there is a change in brightness in the filter of B of different amplitudes. Seyfert galaxy NGC 3516 on July 3, 2017 (JD 2457938) in the filter of B was 14.29 and consequently the object gradually increased its brightness and became 13.84 magnitudes on May 16, 2018 (JD 2458255) in the same filter. The change in brightness was approximately 0.45 magnitudes in the filter of B. And then on June 15, 2018 (JD 2458285), the brightness decreased again to 14.253 magnitudes. It should be noted that until January 28, 2020 (JD

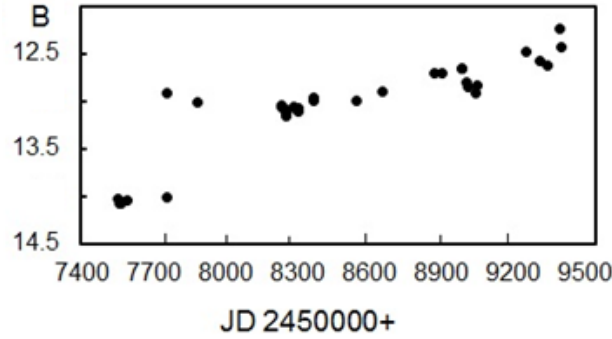


Fig. 1. The light curve in the B filter of the Seyfert galaxy NGC 3516 during the observant

2458877) it remained about the same value magnitude (14.230) in the B filter. And after that the Seyfert galaxy NGC 3516 gradually increased its brightness and on May 28, 2020 (JD 2458998), the magnitude in the filter of B became 13.91. At that time the change in brightness in the filter of B was about 0.221 magnitudes. Our further observations showed that the object weakened again and on October 19, 2020 (JD 2459142) became in the filter B=14.183 magnitudes. These photometric data obtained in filter B also confirm that the change in spectral type occurred in this Seyfert galaxy of type I NGC 3516 [9] within 2017 and 2021.

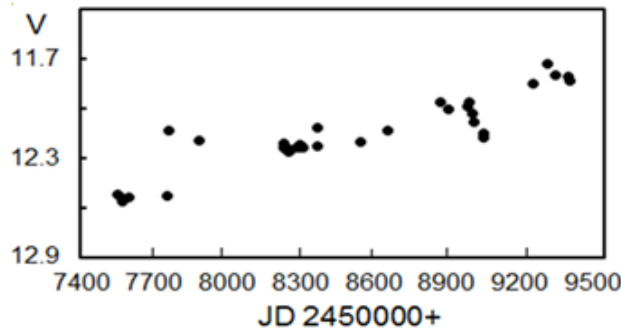


Fig. 2. The light curve of the Seyfert galaxy in the V filter constructed from observations in 2017-2021.

As can be seen from Fig. 2, the brightness also changed in the filter V during the observation period. The nature of the change in brightness in this filter is the same but naturally with smaller amplitude. The brightness of the galaxy on February 19, 2017 (JD2457804) was in the filter V = 13.271 magnitudes. And on July 3 of the same year (JD2457938) the brightness in the filter V was V = 13.372 magnitudes. The object weakened the filter in V by about 0.1 magni-

tudes. After that the object began to increase its brightness again and on May 16, 2018 (JD2458255) the brightness of the galaxy NGC 3516 became $V = 13.001$ magnitudes. The change in brightness was approximately in the filter $V=0.37$ magnitude. About a month later on July 15, 2018 (JD2459285) the object again began to weaken and was in the filter of $V = 13.291$ magnitudes. At the beginning of 2020, and more precisely on January 28, 2020 (JD2458877) the object was revived again and became $V = 13.192$. And on May 21, 2020 (JD2458991) a powerful flash occurred again and the object became brighter in the filter $V = 13.070$ magnitude. The change in brightness was approximately $V = 0.221$ magnitude. It is worth noting that the change in brightness compared to 2018 occurred with smaller amplitude. The change in the filter of V was the same as in filter B . Then the object began to weaken again and on October 19, 2020 (JD2459142) became $V = 13.283$ magnitude.

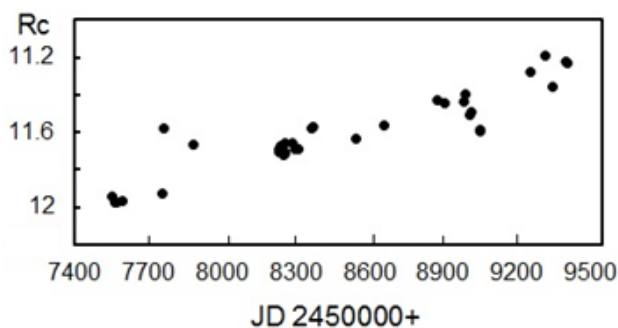


Fig. 3. The light curve of the Seyfert galaxy NGC 3516 in the Rc filter plotted from observations within 2017-2021.

As can be seen from Fig. 3, the brightness change in the Rc filter was 0.071 magnitudes from July 3, 2017 (JD 2457938) to May 16, 2018 (JD 2458255). And then the change in brightness during the observation period occurred on January 28, 2020 (JD 2458877) and on May 28, 2020 (JD 2458998). The change in brightness in the Rc filter was 0.125 magnitudes at that time. And then on October 19, 2020 (JD 2459142) the object returned to its previous state and the magnitude of the Seyfert galaxy NGC 3516 in the Rc filter became 12.534.

As can be seen from Fig. 4 in the filter Ic, the brightness of this galaxy changed during the observation period. The change in brightness occurred from July 1, 2017 (JD2457936) to May 16, 2018 (JD2458255) 0.111 magnitudes. The brightness of the object from May 28, 2020 (JD2458992) to July 20, 2020 (JD2459050) in the filter Ic is increased by 0.164 magnitudes. And then gradually the object began to weaken from July 25, 2020 (JD2459055) and on July 26, 2021 (JD2459309) it became weaker than 0.06 magnitude in the filter Ic.

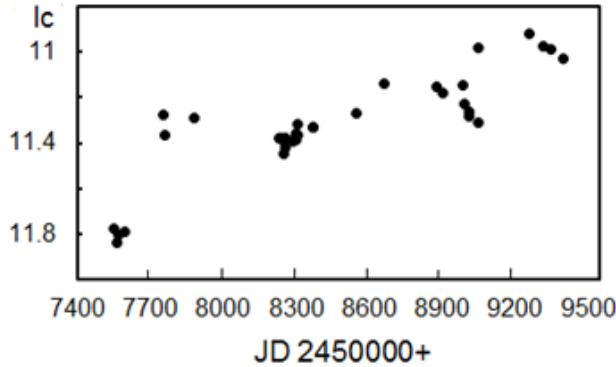


Fig. 4. The brightness curve of the Seyfert galaxy NGC 3516 in the Ic filter based on observations within 2017-2021.

Based on the results of our observations within the period 2017-2021 the change in the brightness of different amplitudes was revealed in the BVRcIc filters. The Seyfert galaxy NGC 3516 was in too active state during this period.

Constructed brightness curves based on photometric observations of the Seyfert galaxy NGC 3516 the 2017-2021 observation periods are shown in Figures 1,2,3 and 4. As can be seen from the figure within the observation period 2017-2021 the brightness of the galaxy either decreases or increases. As can be seen from Fig. 1 in filter B the largest change in brightness was detected within the observation period from July 18, 2017 to May 16, 2018. The amplitude of the change in brightness in filter B was approximately $\sim 0.45 \pm (0.005)$ magnitudes. After that the brightness of the galaxy decreased. And during the observation period from January 28, 2020, the object began to revive again and on May 28, 2020 it became brighter again and the change in brightness in filter B was $\sim 0.343 \pm (0.005)$ magnitudes. According to the spectral observations, the Seyfert galaxy NGC 3516 experienced a change in spectral type during the same period [9]. The same process of changing type occurred in 2018. It should be noted that the results of the photometric observations confirm the change in the spectral type of the Seyfert galaxy NGC 3516 obtained from spectral observations.

Thus our photometric observations of BVRc and Ic show that variability occurred in the Seyfert galaxy NGC 3516 and this fact confirms the change of spectral type detected as a result of spectral observations.

3. RESULTS

Our results from the photometric observations within 2017-2021 confirm the change of spectral type obtained from spectral observations within 2016-2020.

Photometric BVRlc observations also show that the active physical processes occurred in the galaxy NGC 3516 within the period 2017-2021.

The largest brightness change within the 2017-2021 observation period in the BV Rc and Ic filters was $0.36 \pm (0.005)$; $0.28 \pm (0.005)$; $0.07 \pm (0.003)$ and $0.04 \pm (0.004)$ respectively.

The reason for the photometric variability of the Seyfert galaxy NGC 3516 may be the change in the rate of accretion to the galactic nucleus.

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SPECTROSCOPIC AND PHOTOMETRIC OBSERVATIONS OF THE SUPERNOVAE SN2020JEE

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Information on the SN2020jee supernova is first listed in the web page Gaia Alert Index list (<http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia20cgo/>). These data are as follows: date of observation 2020-05-13 UT 08:17:40 (JD 2458982.85), with coordinates RA (2000) = 11: 42: 14.70 DEC (2000) = 20: 05: 51.07. The object is located approximately in the center one of the very weakly radiating galaxy MCG + 03-30-048 in a large cluster of galaxies in this region. We performed spectral and photometric observations of this object from May 21 to June 23, 2020. Table 1 summarizes our observations:

Keywords: Optical – Supernovae – Transient

1. INTRODUCTION

All our spectral and photometric observations were performed simultaneously on the 2 m ShAO telescope. Spectral observations were made at the Cassegrain focus of the 2 m telescope. As a light receiver complex spectrograph UAGS + objective Canon EF (f = 200 mm, f/2) + CCD Andor (ikonL-936-BEX2-DD 2048x2048, $px = 13.5 \mu$) was used. The spectral range is 3750 – 7650 Å. The width of the slit was 3.3". The spectral resolution is about 6 Å/px. The height of the slit was set to the maximum, which made it possible to obtain a background spectrum simultaneously with the spectrum of the object. Spectrophotometric standard stars were observed every night immediately after the object. The spectra were processed using the new version of the DECH software package. All spectra were isolated using an IRAF mask. The process included dark current

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Table 1: Journal of observations SN2020jee.

BV photometry

Date	UT	JD	Bands	mag	$\pm\sigma$	B-V
21.05 .2020	18 : 14 : 24	2458991.26	V	15.45	0.01	0.719
21.05 .2020	18 : 43 : 12	2458991.28	B	16.169	0.02	
27.05 .2020	18 : 57 : 36	2458997.29	V	15.15	0.005	0.71
27.05 .2020	19 : 26 : 24	2458997.31	B	15.86	0.006	
16.06 .2020	19 : 12 : 00	2459017.30	V	16.259	0.010	1.039
23.06 .2020	18 : 43 : 12	2459024.28	V	16.342	0.02	
23.06 .2020	19 : 12 : 00	2459024.30	B	17.381	0.03	

Spectral observations

Date UT	JD	Spectral range, Å	Exposition, sec	S/N
21.05 .2020	18 : 24	2458991.26 3700 – 8000	3600	345
27.05 .2020	19 : 06	2458997.29 3700 – 8000	2000	220
16.06 .2020	19 : 32	2459017.31 3700 – 8000	3000	95
23.06 .2020	18 : 17	2459024.26 3700 – 8000	2000	115

subtraction, correction for flat fields; remove of cosmic rays, 2D linearization of wavelengths and subtraction of the spectrum of the sky. The spectra were calibrated by wavelength and absolute flux. When calibrating by wavelength, the redshift of the host galaxy and the heliocentric correction are taken into account. Information on the spectral material is given in the second part of Table 1.

Photometry of the object was carried out on a 30 cm guide-refractor of the 2 m telescope. A photometer with broadband filters BVRc is installed in the focus of the refractor tube ($F = 5050$ mm). The light receiver was a CCD FLI 2048x3072. The limiting magnitude in V band is 18 mag for 600 sec of accumulation.

An object identification map is shown in Fig. 1. Table 1 shows the the results of measurements obtained in the BV bands and in the last column, the errors of the measurements. Since the brightness of the standard was not known, its brightness value was obtained from special observations using binding to the star's brightness standard TYC1440-44-1, BV values of which are given in the SIMBAD archive ($B = 11.71$, $V = 11.02$).

Figure 2 shows the brightness variation with time for all photometric observations of the object, including those given in the literature. Despite the fact that

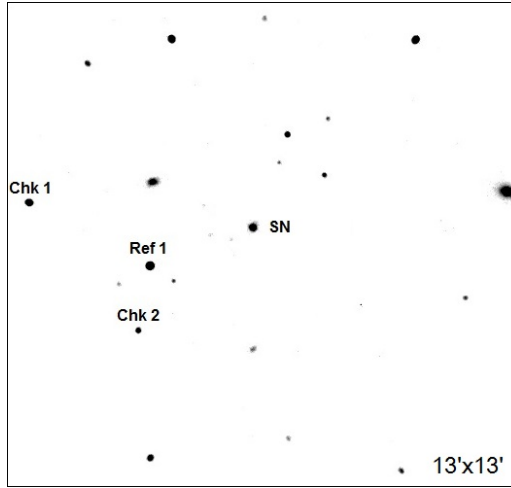


Fig. 1: The searching field of the SN2020jee. Reference star's magnitudes are $V=13.042\pm0.02$, $B=14.031\pm0.01$

the brightness value of the object is given in different system filters, from Fig. 2 we can get information of the brightness variation in time. The vertical bars mark the dates at which the spectra of the object were obtained.

In Fig. 2 it can be seen that the brightness of the object was in the brightest state (maximum) on 05.27.2020 (JD2458997). The total interval of brightness changes from the beginning of all observations of the object is about 2 mag. However, if we take into account that, in inactive state, the galaxy's brightness was 18.65 mag in the G band [1], then the total amplitude of the brightness changes in the G band should be at least 3 mag. Figure 3 shows the spectra of the object

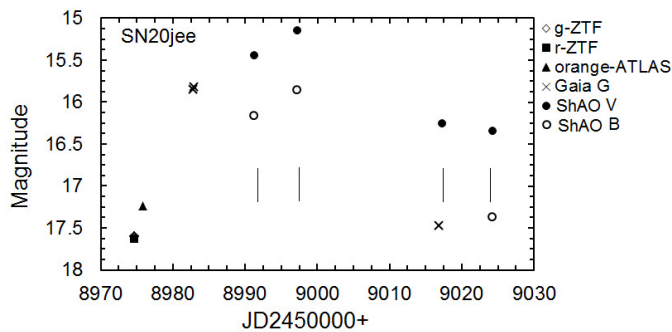


Fig. 2: SN2020jee supernova light variations in time. Different characters in the figure indicate data from different authors. Vertical bars indicate the dates of spectral observations in the ShAO [2].

obtained at different dates. A group of authors [3] obtained the first spectrum. This spectrum was obtained to a maximum of brightness on 05.06.2020. Here, individual details and spectral bands are clearly visible.

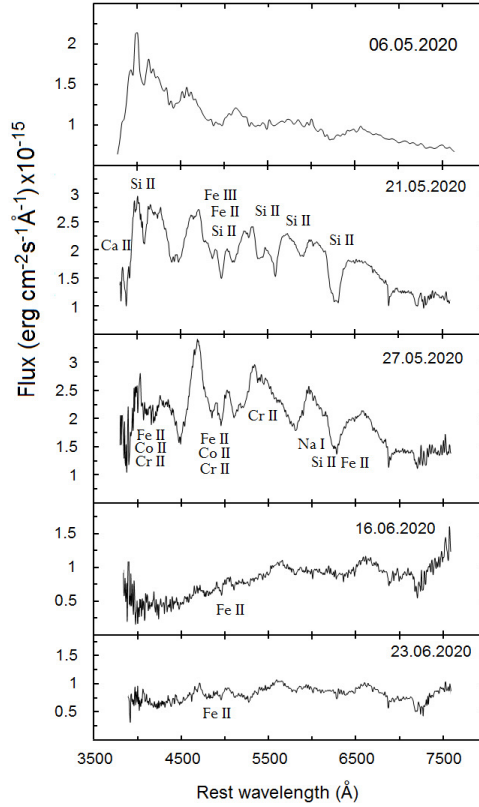


Fig. 3: Results of spectral observations of SN2020jee. First top panel –data from [3].

Other spectrums which are shown in Fig. 3 were obtained in the ShAQ. Judging by the photometric data, a spectrum was obtained at 05.21.2020 to the maximum brightness in bands B and V (Fig. 3). We can see here the bands of the Si II, Fe II, FeIII, Ca II line groups which are clearly distinguished. We measured the shift of the Si II line, where two lines $\lambda 6347 + 6371 \text{ Å}$ are dominated. On May 21, 2020, the enhancement velocity of the photosphere shell was obtained at about $-10116 \pm 15 \text{ km/s}$. Based on the material, an article is being prepared for publication.

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BVRcIc MONITORING OF THE SEYFERT GALAXY OF THE FIRST TYPE NGC 7469

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Here are the results of the observations of the nuclei of the Seyfert galaxy of the first type NGC 7469 carried out in the period 2016-2019 BVRcIc. Observations were carried out on the telescope "SEISS 600" of the Shamakhy Astrophysical Observatory named after N.Tusi. It is reported that discovered from observations of 2016-2019 in the core of the active galaxy NGC 7469 there were 3 flares. The first flare was the most powerful, and the amplitudes of change in brightness was in the BVRcIc filters approximately: $\Delta B = 0.272$; $\Delta V = 0.181$; $\Delta Rc = 0.173$; $\Delta Ic = 0.125$ magnitudes. The second flare of average power and brightness changes was in the BVRcIc filters respectively: $\Delta B = 0.098$; $\Delta V = 0.047$; $\Delta Rc = 0.093$; $\Delta Ic = 0.036$ magnitudes. And the third flash is comparable to the first flash and the change in brightness was in the BVRcIc filters, respectively: $\Delta B = 0.207$; $\Delta V = 0.168$; $\Delta Rc = 0.119$; $\Delta Ic = 0.065$ magnitudes.

We believe that this may be the result of active star formation in the Seyfert galaxy of the first type NGC 7469, as well as the reason for this may be the interaction with the IC 5283 galaxy. The amount of free gas in this galaxy should be greater for this reason. As a result, this leads to a change in the rate of accretions to the core of the galaxy.

Keywords: Seyfert galaxies – nuclei of active galaxies – BVRcIc photometry – NGC 7469 – black holes

1. INTRODUCTION

Seyfert galaxies (SG) being as a separate class of galaxies, were first identified by the American astronomer Seyfert C. in 1943 [1]. He discovered wide lines of hydrogen, helium and ionized iron in the spectra of 12 galaxies. The half-width of

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these lines, in accordance with the Doppler effect, corresponded to speeds of up to several thousand km/s. Thousands of such objects are now known and in some of them the emission spectral lines have widths corresponding to the speed of about 30,000 km /s (0.1 the speed of light!). SGs are giant spiral galaxies. Among them, the proportion of crossed spirals is especially high (about 70%). Seyfert showed the unusual structure and emission spectra of these galaxies. Seyfert galaxies emit in a wide range of wavelengths from the X-ray to the radio region. Basically, the radiation of these galaxies is variable [2]. Knowing the nature of the variability of radiation in different ranges can in principle clarify the mechanisms of variability in different spectral regions. According to the most common modern point of view, radiation in the optical and UV range of the nuclei of active galaxies (NAG) is of non thermal origin (synchrotron radiation) and occurs in the accretion disk surrounding the supermassive black hole. X-rays come from the central regions that eat the closest regions of the black hole (BH). Much of the X-ray radiation falling on the disk is absorbed by the disc and heats it. The other part of the radiation is reflected from the accretion disk of the black hole, located in the core of each active galaxy. The heated disk creates additional radiation in the main optical region of the spectral range. The spectrum of a galaxy consists of electromagnetic radiation from all its constituent objects. The spectrum of an active galaxy has two local maxima. The source of radiation from galaxies is mainly stars, the maximum intensity of the radiation of most of them is in the optical range (the first maximum). As usual, there is a lot of dust in galaxies, which absorbs radiation in the optical range and re-emits it in the infrared range. The second maximum because of this falls into the IR region of the spectrum. The study of photometric and spectral variability is an effective method for diagnosing physical processes occurring in accreting compact supermassive objects, such as most YAGs. The characteristic time of this variability indicates the extremely small size of the regions emitting the optical continuum and wide emission lines. The study of photometric and spectral variability is necessary to elucidate the structure of active nuclei, without understanding which it is impossible to approach the solution of the problem of the central energy source [3]. It is very important to have information about the nature of their variability. In the supermassive black hole model, with an accretion disk, one can expect both periodic and chaotic variability in the brightness of galaxy nuclei. Knowledge of the properties of optical variability can significantly limit the possible types of models. There are two most popular models of a central energy source: an accreting black hole and a non-collapsing magnetoplasmic body. Observations of the strict periodic variability of the brightness of galaxies persisting for several cycles or the absence of a strict periodicity can be a strong argument in favor of one of the two above concepts [4].

2. OBSERVATIONS

NGC 7469 is a well-studied Seyfert galaxy of the first type, included in the original list of six Seyfert spiral galaxies (1943) with a high brightness of the central surface, that is, it has a star-shaped core. NGC 7469 and the nearby company galaxy IC 5283, which probably interacts with it, are at a distance of about 68 Mpc. The bright, knotty, circular nuclear ring of radiation resulting from intense star formation lies at an angular distance of $1^{\circ} 5$ from the core (which corresponds to about 1 kpc) [5]. This galaxy is bright and variable in the optical region of UBVR $\bar{I}$, which makes it attractive for studying both galaxies with active nuclei (AGN) and for studying the properties of star formation. NGC 7469 is a barred spiral galaxy (SBa). This galaxy has been studied by different authors. The work of Oknyansky et al. [6] presents the results of UBVR $\bar{I}$ monitoring of the Seyfert galaxy NGC 7469 in 1997–2005. The study showed that the nucleus is variable and there was a lag effect for different wavelengths. It should be noted that currently delays in variability in longer wavelengths relative to shorter wavelengths have been detected in a number of Seyfert nuclei. It is noted that, the nature of the effect is not yet entirely clear. Lyuty et al. [7] report the results of three-color (UBV) observations of rapid changes in the core of the Seyfert galaxy NGC 7469 conducted between 1990 and 1994. In some cases, there is a noticeable delay in variations in the U-band relative to changes in the V-band and vice versa. This delay is about 7 minutes. In the work of R. Middei et.al, a study of the Seyfert galaxy NGC 7469 is reported using space observatories. The results of spectral analysis of 7 simultaneous are reported. Sources show significant flux variability in each observation but the average flux is less variable [8]. We conducted BVRI observation of the Seyfert galaxy of the first type NGC 7469 in 2016-2019. Observations were made on the ZEISS-600 telescope of the Shamakhy Astrophysical Observatory named after N. Tusi.

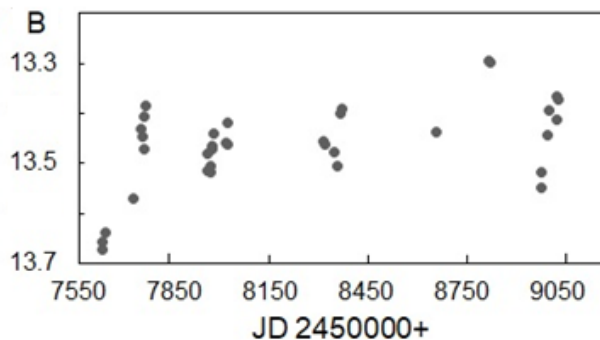


Fig. 1. The light curve in the filter B of the Seyfert galaxy NGC 7469 in 2016-2019

Details about the process of observations with the matrix, about the equipment, the method of processing and analyzing errors can be found in the work [9]. The device is installed in the Cassegrain focus of the Zeiss 600 telescope (aperture 1:12,5) and is equipped with a thermoelectrically cooled CCD matrix FLI 4096×4096 . The photometer is designed to work with the telescope "ZEISS600" for fundamental and applied astronomical research by relative photometry. The resulting material was processed according to the package program MAXIM DL 4 and MAXIM DL 5. The measurement was taken with an aperture (7 pixels) of

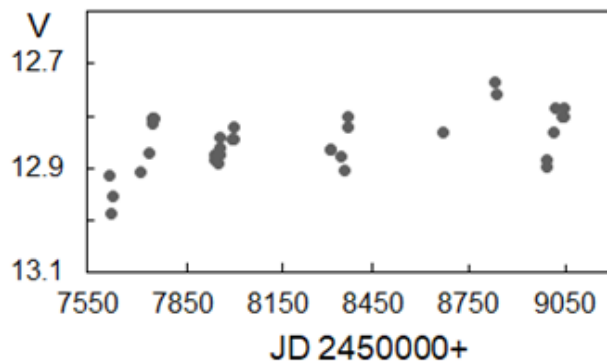


Fig. 2. The light curve in the filter V of the Seyfert galaxy NGC 7469 in 2016-2019

13.5 seconds. For reference to the International Photometric System, close comparison and reference stars were used. Stars of spectral class A0 were chosen for binding. The resulting material is unique in the sense that it was obtained in one telescope, with one photometer and the processing is performed with the same package program. The material is obtained as follows, 5 cycles are removed in each filter. Then the resulting frames are calibrated and the cleaned frames are summed up and the average value of the stellar magnitudes in each filter is taken. For each filter calculated, RMS measurement. In the optical region, the amplitude of variability decreases with increasing wavelength. In Fig. 1 shows the results of our own observations in filter B covering the period from 21 08 2016 - 19 12 2019. As can be seen from Fig. 1. during the observation period, NGC 7469 gradually became brighter. In filter B, the change in brightness was 0.359 magnitudes. Fig. 2 shows the results of observations in filter V, covering the period from 21 08 2016 - 19 12 2019. As can be seen from Fig. 2, NGC 7469 gradually became brighter during the observation period. The change in brightness was in filter V = 0.217 magnitudes.

In Fig. 3 shows the results of our observations in the Ic filter covering the period from 21 08 2016 - 19 12 2019 as can be seen from Fig. 1. During the

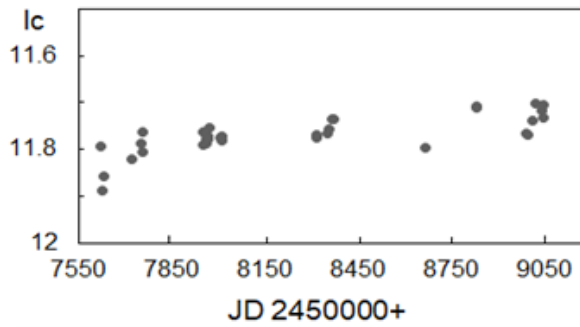


Fig. 3. The light curve in the filter Ic of the Seyfert galaxy NGC 7469 in 2016-2019

observation period, NGC 7469 gradually became brighter. In the Ic filter, the change in brightness was 0.113 magnitudes.

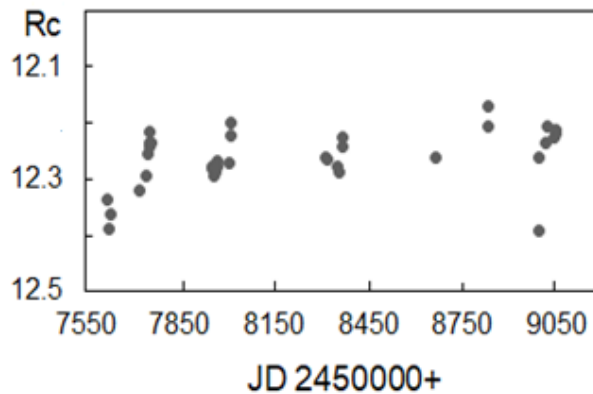


Fig. 4. The light curve in the filter Rc of the Seyfert galaxy NGC 7469 in 2016-2019

In Fig. 4 shows the results of our own observations in the Rc filter covering the period from 21 08 2016 - 19 12 2019 as can be seen from Fig. 1. During the observation period, NGC 7469 gradually became brighter. In the Rc filter, the change in brightness was 0.176 magnitudes. The amplitude of variability increases from filter I to filter B indicating a characteristic burst of brightness in the blue part of the spectrum in the active nuclei of galaxies.

3. DISCUSSION

When analyzing the light curve built on observations of 2016-2019, 3 flashes occurred in the core of the active galaxy NGC 7469. As can be seen from Fig.1,

2, 3 and from Fig. 4, the first flash was the most powerful, and the change in brightness was in the BVRcIc filters approximately: $\Delta B = 0.272$; $\Delta V = 0.181$; $\Delta Rc = 0.173$; $\Delta Ic = 0.125$ magnitudes. The second flash of average power and brightness changes was in the BVRcIc filters, respectively: $\Delta B = 0.098$; $\Delta V = 0.047$; $\Delta Rc = 0.093$; $\Delta Ic = 0.036$ magnitudes. And the third flash is comparable to the first flash and the change in brightness was in the BVRcIc filters, respectively: $\Delta B = 0.207$; $\Delta V = 0.168$; $\Delta Rc = 0.119$; $\Delta Ic = 0.065$ magnitudes. It should be noted that a third outbreak is possible and continues to this day. Unfortunately, we were not able to observe the galaxy NGC 7469 by 2020. Since astronomical observations depend on weather, seasonal conditions and as well as the distribution of observational time. The above observation conditions and interferes will accurately determine the duration of the outbreak. The coordinated observations at different latitudes are very relevant for this reason. The brightness gradient increases from filter Ic to filter B, the amplitude of variability increases from filter Ic to filter B which indicates a characteristic burst of brightness in the blue part of the spectrum in the nuclei of active galaxies.

4. RESULTS

As can be seen from Fig. 1, 2, 3 and 4 of the constructed light curve Seyfert galaxy of the first type NGC 7469 gradually increases its brightness during the observation period. This may be the result of a gradual increase in the amount of matter in the acre ionic disk of the black hole. The increase in brightness in BVRcIc filters is approximately 0.359, 0.217, 0.113 and 0.176 magnitudes, respectively. The amplitude of variability increases from filter I to filter B, indicating a characteristic burst of brightness in the blue part of the spectrum in the active nuclei of galaxies. The brightness curve in filter B and V has a steeper gradient compared to other filters when leaving the cycle minimum and the maximum is reached much earlier than in filters Rc, Ic.

We believe that this may be the result of active star formation in the Seyfert galaxy of the first type NGC 7469, as well as the reason for this may be the interaction with the IC 5283 galaxy. The amount of free gas in this galaxy should be greater for this reason. As a result, this leads to a change in the rate of accretions to the core of the galaxy.

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STUDY OF SOLAR FLARES IN CENTIMETER RANGE BY DYNAMICAL METHODS

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The article investigates oscillatory processes in solar flares based on observational data obtained by a 12-meter radio telescope at a frequency $f=3$ GHz belonging to the Ionosphere Institute of the Kazakhstan Republic. The results of a brief review of methods for processing non-stationary time series suggest that the requirement of adaptability is also important. It is shown that this possibility is provided by the method proposed by Norden Huang. For clarity, the method of implementing EMD (Empirical Mode Decomposition) - the method of decomposing signals into functions (modes) will be considered using the example of a digital signal array $x(t)$. In order to obtain more realistic results, the type of series was determined using fractal analysis. It is shown that at this stage, for the reliability of obtaining quasi-periodic pulsations (QPPs), it is necessary to carry out visual control and compare the results obtained by different methods

Keywords: Solar radio emissions – solar flares –quasi-periodic pulsations – fractal analysis – empirical method of signal decomposition into modes.

1. INTRODUCTION

It should be noted that although facts about the quasi-periodicity of pulsations arising in flare processes on the Sun were discovered 50 years ago, this issue has retained its relevance to this day.

Observations of the Sun provide answers to numerous questions related to solar-terrestrial relationships. The physical processes occurring on the Sun are of great interest for understanding and predicting the interaction of solar plasma with the atmosphere and the Earth's magnetic field. This turn is essential for

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understanding the earth's climate and space weather. The observable Universe is a plasma, so its study is of great interest for modern physics [1].

On the Sun, in addition to such relatively constant processes as thermal radiation, there is also a sporadic impulsive energy release in flares and coronal mass ejections. The duration of these processes is from several seconds to several hours, and the released energy reaches 10^{33} erg. Solar flares occur in the solar atmosphere, mainly in active regions, but sometimes also between them [2].

For a long time, the classical Fourier method and its various modifications have been used for mathematical processing of time series composed of data from objects of various origins, and the results obtained in most cases contradict each other. The main reason for this is that the time series we use for solar flares at centimeter wavelengths are non-linear and non-stationary [6–8].

Increasing the sensitivity and resolution of instruments, improving methods for analyzing observational data, and advancing the development of theoretical modeling of physical processes occurring in flares have led both to an understanding of the causes leading to QPPs.

In order to overcome these shortcomings, which consists of the practical mathematical processing of time series consisting of complex signals, in 1995, "Empirical Decomposition Method (EMD)" was proposed by Norden Huang in the United States [3, 4], to study hurricane waves. The main reason for the wide application of this method in various fields of science and technology is that it is adaptive (i.e., determining the basic function based on the time series under study). We also developed a software package that modified this method based on Huang's algorithm and split the input signal into modes using solar flare time series. The purpose of the proposed work is the application of dynamic methods for the analysis of non-stationary signals. The found periods of solar flare pulses and the estimation of their modes amplitudes are additional indicators for predicting events and diagnosing space weather.

Despite the importance and intensive research, there is still no complete understanding of the physical processes leading to pulsed energy release.

2. EXPERIMENTAL DATA

As observational material, we used 7-isolated solar bursts observed in 2011-2015 on the RT-12 radio telescope in Ionosphere Institute of Kazakhstan Republic. Figure 1(a,b,c,d,e,f,j) shows the time profiles of flare events at $f=3$ GHz for the indicated years. Discretization step $\Delta t = 5$ sec.

It can be seen from these figures that repeated pulsations of radiation fluxes are observed in solar flares, which change according to a harmonic law. However, it is obvious that when observing solar flares, it is impossible to meet exactly

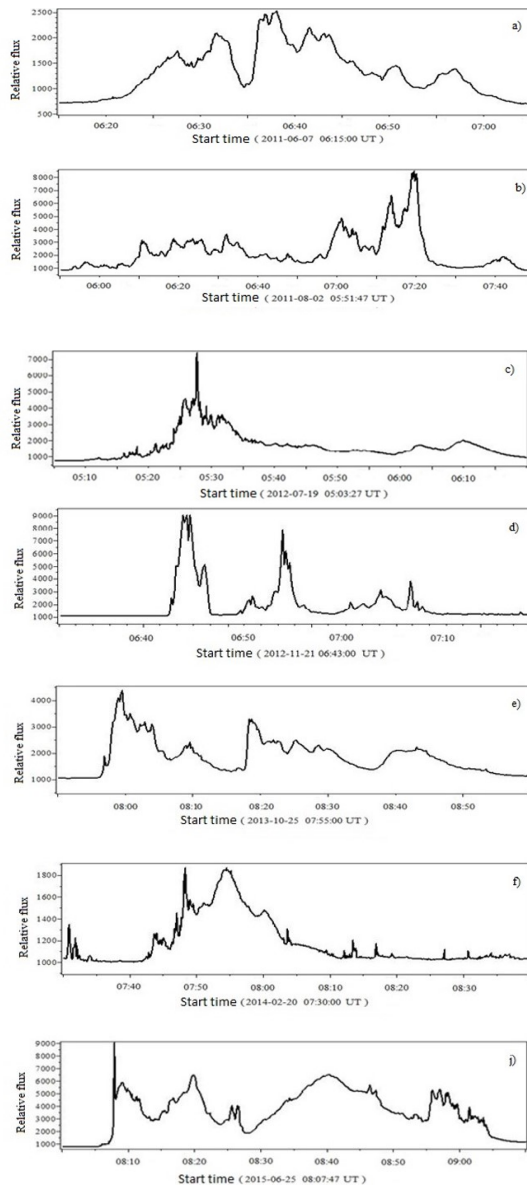


Fig. 1. Time profiles: 7-solar flares observed in 2011-2015 on RT-12 with a QPPs in the microwave range $\lambda = 10.7$ cm in Ionosphere Institute of Kazakhstan Republic.

harmonic signals. Instrumental errors, instrumental noise, the influence of the Earth's ionosphere and troposphere, the different nature of phenomena on the Sun, and others lead to the fact that we are dealing with such deviations from the harmonic signal. All of the above deviations make the observed signal not periodic, but quasi-periodic [2].

The 7 flare events studied by us showed that the existing quasi-periodic pulsations can be conditionally divided into 4 types:

1. Those with stable mean periods in the range 20–40 sec. (7 events),
2. Those with spectral drift to shorter periods, during the rise phase of a burst (4 events),
3. Those with drift to longer periods, during the decay phase (5 events),
4. In the rise phase, quasi-periodic pulsations with a period of 20-60 sec. (4 events).

This result indicates that oscillations are an intrinsic feature of flaring energy release. Thus, our understanding of solar flares cannot be complete without revealing the physical mechanisms responsible for the generation of the periodicity.

3. RESULTS OF PROCESSING AND ITS DISCUSSION

Firstly, for greater accuracy of the results obtained on the basis of studying the time series that we compose during flares, we calculate the exponent H_t - Herest and the degree D_t - of the fractal dimension of each order. It also allows us to determine the type of these series when we examine them. The H_t -Herest exponent determines the type of events being analyzed, D_t -fractal dimension shows the degree of randomness. The table 1 show the duration of the 7 flare events we considered, the types of time series, and the quantitative estimate of randomness.

Based on this table, it can be seen that is the H_t - Herest exponent and D_t - degree of the fractal dimension, respectively equal to $0.5 < H_t \leq 1$ and $1 < D_t < 1.5$. These estimates obtained show that, chaoticity is replaced by smoother chaoticity during solar flares. More precisely, chaoticity turns into non-stationary quasi-periodic beats. The rules for calculating estimates of the Herest exponent and the degree of fractal dimension were fully described in [9].

After defining the type of time series, we use the Empirical Mode Decomposition (EMD) method. It should be noted that the decomposition in the EDM starts from the highest frequency mode contained in the signal $x(t)$, so each subsequent EM contains oscillations of a lower frequency than the previous one. This decomposition is based on the following assumptions: the signal $x(t)$ has at least two extremes (one minimum and one maximum). The characteristic time scale is determined by the time interval between two consecutive extrema. We applied this efficient algorithm to a solar flare that occurred on 07.06.2011 (fig.1a).

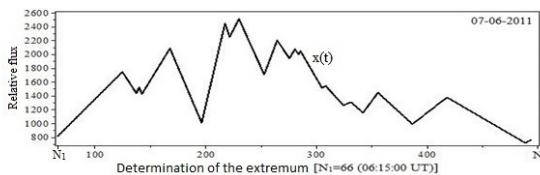
In the general case, for a given signal $x(t)$, an efficient empirical mode decomposition algorithm consists of the following steps [4, 5]:

To obtain the second mode, we take the function $c_1(t)$ as an input signal and repeat steps 1-4. As a result, the function $c_2(t)$ will be obtained, which will be the second component of the EM signal $x(t)$.

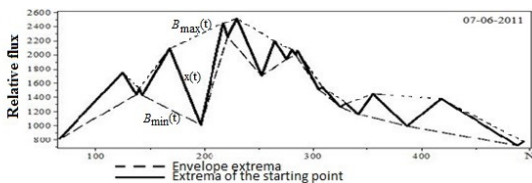
Table 1. The estimates of the Herest exponent and the degree of the fractal dimension.

Date (at the time of events)	Herest exponent H_t	Fractal dimension D_t
07.06.2011 (06 : 15 : 00 – 07 : 08 : 43UT)	0.805	1.194
02.08.2011 (05 : 51 : 47 – 06 : 49 : 00UT)	0.776	1.223
19.07.2012 (05 : 03 : 27 – 06 : 23 : 19UT)	0.775	1.224
21.11.2012 (06 : 43 : 00 – 07 : 16 : 00UT)	0.718	1.281
25.10.2013 (07 : 55 : 00 – 09 : 09 : 15UT)	0.799	1.200
20.02.2014 (07 : 30 : 00 – 08 : 28 : 55UT)	0.799	1.200
25.06.2015 (08 : 07 : 47 – 10 : 58 : 19UT)	0.774	1.225

Step 1. Determination of all extrema of the original signal $x(t)$. Point $N_1 = 66$ corresponds to the beginning of the flare in the observational material, which coincides with 06:15:00 UT. Here the sampling step is $\Delta N = 1$, which corresponds in time to $\Delta t = 5$ seconds.

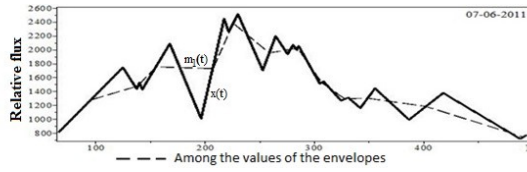


Step 2. Finding the upper $B_{max}(t)$ and lower $B_{min}(t)$ envelopes for all local extrema, respectively.

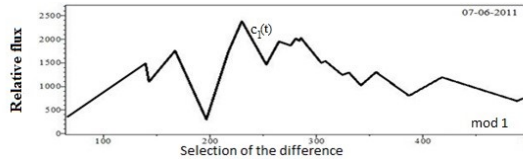


Step 3. Calculation of the average value of the obtained envelopes

$$m_1(t) = [B_{max}(t) + B_{min}(t)]/2.$$

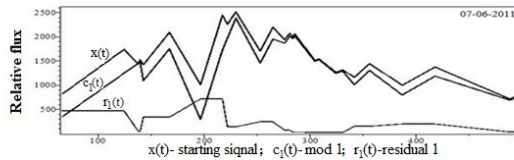


Step 4. Separation of the difference $h_1(t) = [x(t) - m_1(t)]$. If $h_1(t)$ does not satisfy two conditions: the number of extreme points and the number of zero crossings must either be equal or differ by a maximum of one; at any point, the average values of the envelopes must be equal to zero, then $h_1(t)$ is used as the initial signal to repeat steps 1-3 until the function $h_{1k}(t) = h_{(1(k-1))}(t) - m_{1k}(t)$ satisfies the specified condition. Here k is the number of steps required to fulfill the two mandatory conditions. In this case, the function $c_1(t) = h_{1k}(t)$ will be the first components of the EM signal $x(t)$.



Step 5. Subtracting the function $c_1(t)$ from $x(t)$, we get first residual:

$$x(t) - c_1(t) = r_1(t) \quad (1)$$



By repeating this operation, it is possible to obtain n-number of EM components in the signal $x(t)$:

$$\begin{aligned} r_1 - c_2(t) &= r_2 \\ &\dots \dots \dots \\ r_{n-1} - c_n(t) &= r_n \end{aligned} \quad (2)$$

Summing up equations (1) and (2), we can obtain the expansion of $x(t)$ in the form:

$$x(t) = \sum_{i=1}^n c_i(t) + r_n \quad (3)$$

where is the residual r_n , which can be a trend or a constant value.

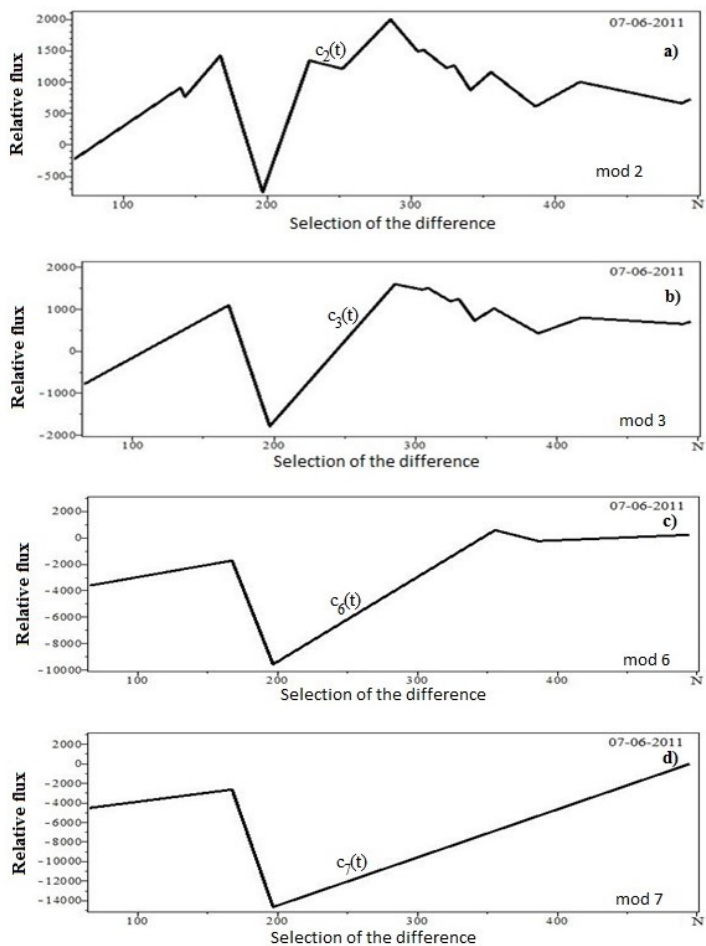


Fig. 2. TDecomposition of the signal $x(t)$.

Implementation of EMD (Empirical Mode Decomposition) - the method of signal decomposition into functions showed that 5-7 iterations are enough to perform high-quality screening of mode functions (fig.2d). It should be noted that, in the case when the residual r_n becomes a monotonic function, from which it is no longer possible to extract the EM, then the sifting process ends.

4. CONCLUSION

The combined application of methods in solar flares to fractal studies and the separation of empirical modes in radio emission in the centimeter range $\lambda = 10.7$ cm made it possible to draw the following conclusions:

1. Non-stationary quasi-periodic pulsations are observed in all phases of solar flares.
2. The observed non-stationarity of quasi-periodic oscillations parameters in the ignition region depends on the dynamics of physical processes independent of each other and the geometric dimensions of the ignition region.
3. In the time-intensity profiles of solar flares, non-stationary quasi-periodic beats with a duration of $20 \div 350$ seconds were found as a result of their division into modes.
4. Determining the period of ignition pulses and estimating the amplitudes of their modes are additional indicators for predicting events and diagnosing space weather.

Thus, one of the important conditions is to add to the simulation the presence of quasi-periodic pulsations in the process in order to explain the physics of the phenomenon of flare events occurring on the Sun. Understanding the specific mechanisms responsible for the appearance of checkpoints, in combination with their observed parameters, makes it possible to diagnose flare regions and can significantly improve flare prediction.

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FUNDAMENTAL PARAMETERS OF SUPERGIANT STAR HD 187982 (A2 Ia)

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The atmosphere of the HD 187982 (A2 Ia) supergiant star was studied using the model and parallax methods. The effective temperature T_{eff} and the surface gravity g of the star were determined based on a comparison of the observed and theoretically calculated values of the photometric quantities $[c_1]$, Q and the equivalent widths of the spectral lines of the hydrogen Balmer series and the using of parallax. Based on the $FeII$ lines the microturbulence ξ_t and the metallicity $[Fe/H]$ were determined. In the atmosphere of the star, the metallicity is close to the metallicity of the Sun.

Keywords: A spectral class supergiant star – fundamental parameters of star

1. INTRODUCTION

In this work, the fundamental parameters of star HD 187982 (A2 Ia) effective temperature T_{eff} , the surface gravity g , microturbulent velocity ξ_t , and metallicity $[Fe/H]$ were determined.

Knowing the effective temperature T_{eff} and surface gravity g the models of stellar atmospheres are calculated and on the basis of these models the chemical composition of stars is determined, also the evolutionary parameters of stars: masses, radii, luminosities, and ages are calculated.

In astrophysics, microturbulence is considered a mechanism for broadening spectral lines. The equivalent width of the spectral line depends on microturbu-

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lence, therefore, to determine the chemical composition, it is necessary to know the microturbulent velocity.

Metallicity is one of the main fundamental parameters of stars. According to the definition of this parameter, it is determined that the star and the Sun are formed from the same or different metallicity matter, the problem of the correctness of the provisions of the modern theory of the chemical evolution of stars is solved.

2. OBSERVATION MATERIAL

The spectra of the star were obtained with the spectrograph of the CCD matrix of the 2-meter telescope of the Shamakhi Astrophysical Observatory of ANAS ($R = 56000$, $S/N = 150 \div 400$). Two spectra of the target star were obtained during the 19.08.2021 night of observation. These spectra were summed up before. The spectra were developed by the DECH program. The equivalent widths of spectral lines were measured. The equivalent widths of the lines of FeII used are given in Table 1.

3. EFFECTIVE TEMPERATURE AND SURFACE GRAVITY

The effective temperature T_{eff} and the surface gravity g of the stars were determined by the model and the parallax method. This method is described in detail in [1, 2]. The effective temperature and surface gravity were determined by comparing the observed and theoretically calculated values of the photometric quantities $[c_1]$, Q , and the equivalent widths of the spectral lines of the hydrogen Balmer series and the use of the parallax method. The parallax method is completely new and does not depend on models.

The index $[c_1]$ is defined as $[c_1] = c_1 - 0.2(b - y)$, in the uvby photometric system, and the Q index is defined as $Q = (U - B) - 0.72(B - V)$ in the UBV system.

These indices are released from the absorption effect in interstellar space. The observation values of the quantities $[c_1]$ and Q are determined from the catalog [3]. The theoretically calculated values of the equivalent widths of the Balmer series are given in [4], theoretically calculated values of quantities $[c_1]$, and Q in [5]. The parallax of stars was measured in [6]. The diagram defining T_{eff} and $\log g$ is shown in Figure 1. Based on this diagram, HD 187982 (A2 Ia) is assigned to the star: $T_{\text{eff}} = 9500 \pm 200K$, $\log g = 1.5 \pm 0.1$

Other authors have obtained the values: $T_{\text{eff}} = 9300K$, $\log g = 1,6$ [7].

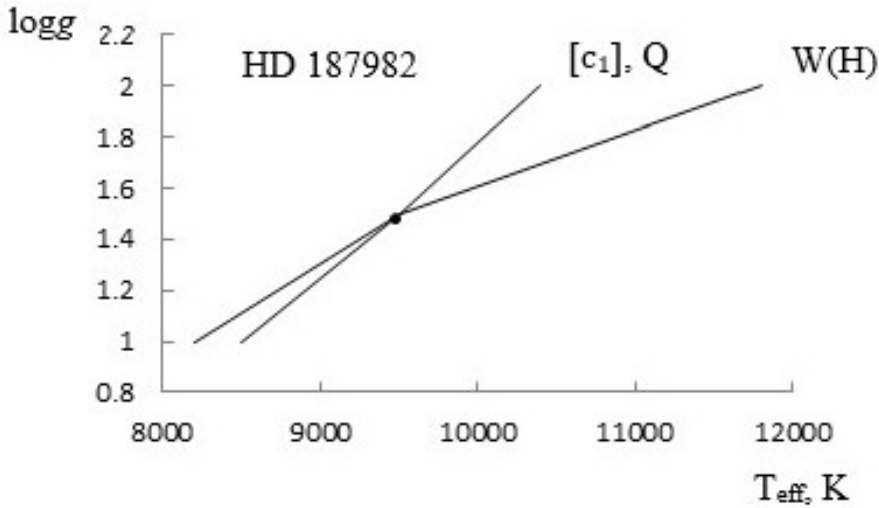


Fig. 1. $\log g - T_{\text{eff}}$ diagram

4. THE MICROTURBULENT VELOCITY

The main parameters are effective temperature $T_{\text{eff}} = 9500 \pm 200 K$ and the surface of gravity $\log g = 1.5 \pm 0.1$. Knowing the star's effective temperature and surface gravity, we calculate their models using Kurucz ATLAS 9 program.

Based on these models, the iron abundance is $\log \varepsilon$ (FeII) calculated by giving different values to the microturbulent velocity ξ_t in the atmosphere of the star. The iron abundance is determined by comparison of the measured from observation and theoretically calculated values of the equivalent width of lines. The atomic data of spectral lines are taken from the VALD 3 [vald.astro.uu.se].

FeII lines used are given in Table 1. The first column of the table shows the wavelength of the spectral lines, the second column the oscillator strengths, the third column the equivalent widths of the lines, and the fourth column the quantity assigned to each spectral line. $\xi_t = 5.8 \pm 1.0$ km/sec was chosen for the speed of microturbulent velocity ξ_t .

Fig.2 are shown the dependence graph of the abundance $\log \varepsilon(Fe)$ determined based on the different equivalent widths of FeII on the equivalent widths W_λ - in the atmospheres of the studied star.

As can be seen from Figure 2 there is no correlation between and, for the star HD 187982 (A2 Ia) at 5.8 km/sec. Other authors have determined the values

Table 1. List of lines of FeII studied in the spectrum of the star HD 187982

$\lambda, \text{\AA}$	$\log gf$	W, m $\text{\AA}$	$\log \varepsilon$
4124.78	-4.38	15	7.35
4314.30	-3.55	73	7.43
4361.25	-6.80	17	7.22
4369.40	-4.05	27	7.40
4385.38	-2.58	162	7.28
4489.18	-3.67	72	7.59
4534.16	-3.25	127	7.59
4549.47	-1.98	241	7.38
4583.84	-1.81	255	7.35
4635.31	-1.48	73	7.21
4670.17	-4.07	24	7.30
4731.47	-3.50	59	7.34
5019.47	-2.77	18	7.49
5100.66	-4.22	32	7.58
5127.86	-2.40	18	7.27
5197.57	-2.23	187	7.35
5264.81	-3.41	60	7.47
5284.81	-2.98	43	7.43
5325.56	-3.19	75	7.39
5337.74	-3.99	21	7.48
6247.56	-2.34	82	7.32
6385.44	-2.66	10	7.22
6446.41	-2.02	16	7.25
7711.73	-2.54	77	7.28
			7.37 ± 0.09

of 7 km/sec in the stellar atmosphere HD 187982 [7]. The method used by us explained in [1, 2] detail, and the accuracy of this method is justified. Therefore, we accept that the obtained results by us are superior.

When analyzing the microturbulence on the basis of FeII lines, the abundance of the iron element $\log \varepsilon(Fe)$ is simultaneously determined: $\log \varepsilon(Fe) = 7.37 \pm 0.09$. The abundance of iron in the sun is $\log \varepsilon(Fe) = 7.47$ [8].

As is shown the metallicity of the studied stars and the Sun is practically the same. The coincidence between the iron abundance of young nearby stars and

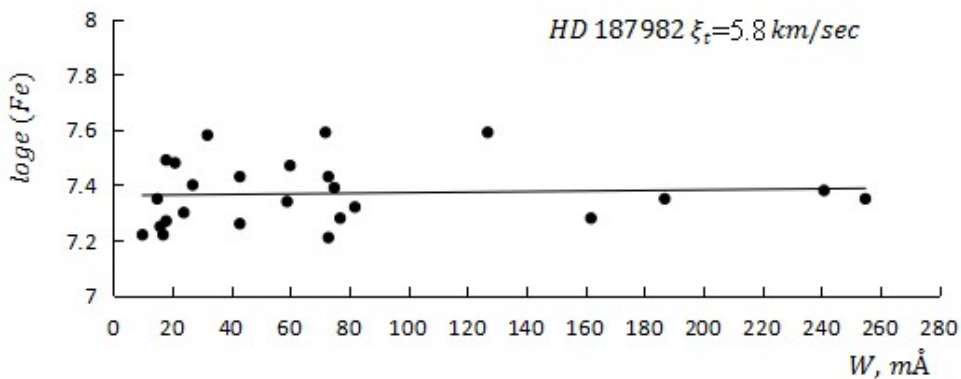


Fig. 2. Determination of microturbulent velocity

that of the 4.5 Gyr old Sun is interesting from the viewpoint of models of galactic chemical evolution (GCE). The question arises: may these results be reconciled with models of GCE? One may cite the recent work of Spitoni et al. [9], where an enrichment of the solar neighbourhood by various metals is studied, in particular, by Fe. One sees from these results that during the Sun's life the Fe abundances in its neighbourhood are predicted to increase by about 0.15dex. The ordinary accuracy of observed abundances in stars seems to be insufficient to detect such a small enrichment.

The microturbulence is investigated by Samedov [10] in the atmospheres of F-spectral class stars using a model method. The dependence graph of the microturbulent velocity (ξ_t) on the surface of gravity (g) for the F-spectral class, stars is plotted. It was found that the microturbulent velocity (ξ_t) on the surface of gravity (g) in stellar atmospheres: decreases with increasing g .

5. MAIN RESULTS

1. The effective temperature and the surface gravity of star HD 187982 have been determined by model and parallax methods: $T_{eff} = 9500 \pm 200K$; $\log g = 1, 5 \pm 01$.

2. The microturbulent velocity has been determined in the atmospheres of the star: $\xi_t = 5.8 \pm 1.0 \text{ km/sec}$.

3. The metallicity was calculated in the atmospheres of the star. It has been found that iron abundance is close to the abundance in the Sun.

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