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N.G. Bochkarev: his life and work in science

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We present a brief personal and scientific biography of Professor N.G. Bochkarev (May 19, 1947 – December 24, 2022), illustrated with photographs from his family archive. He was an outstanding researcher in the fields of extragalactic astronomy, physics of interstellar medium, astrophysics of relativistic stars, archeoastronomy. N.G. Bochkarev was one of the main founders of the Eurasian Astronomical Society (EAAS) and one of the first co-chairmen of this Society. In 1991, he initiated publication of the EAAS scientific journal Astronomical and Astrophysical Transactions and remained its Editor-in-Chief till 2022.

In 2023, a one-day scientific seminar dedicated to the memory of N.G. Bochkarev and an All-Russian conference "Physics of Interstellar Medium: From Local Cloud to Local Galaxies", also commemorating N.G. Bochkarev, were held at the Sternberg Astronomical Institute. Papers presented at these meetings are published in the previous issue (Volume 34, issue 2) and current issue of Astronomical and Astrophysical Transactions.

Keywords: History of astronomy, personalities; interstellar medium; X-ray binaries; active galactic nuclei; archeoastronomy; astrobiology

1 Introduction

Professor N.G. Bochkarev, an astrophysicist with a very wide field of scientific interests and many excellent results in every direction of his research, one of the founders of the Eurasian Astronomical Society, founder and also the first Editor-in-Chief of Astronomical and Astrophysical Transactions, deceased on December 24, 2022. In the first half of 2023, two conferences were held in Moscow to commemorate N.G. Bochkarev. The Proceedings of these conferences are published in Volume 34, issues 2 and 3 of our journal, Astronomical and Astrophysical Transactions.

This paper is a brief personal and scientific biography of N.G. Bochkarev, illustrated with photographs from his family archive.

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2 Ancestors, birth, childhood

Nikolai Gennadyevich Bochkarev was born in Moscow on May 19, 1947. His father, Gennady Afanasyevich Bochkarev (Fig. 1), graduated from Moscow Aviation Institute (this institute now has the status of a national research university) and then worked as an economist engineer.



Figure 1 Gennady Afanasyevich Bochkarev.

N.G. Bochkarev's mother, Elena Konstantinovna Bochkareva (née Shcherbakova; Fig. 2), was educated in a college and then studied at advance training courses (evening university). She also worked as an engineer.

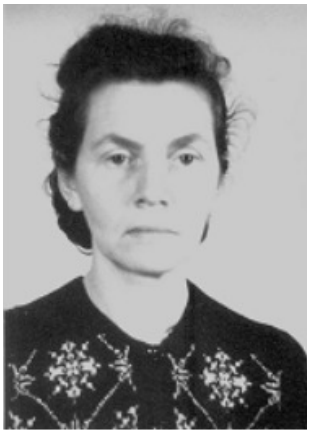


Figure 2 Elena Konstantinovna Bochkareva.

Bochkarev's ancestors were Cossacs from territories to the east of the Baikal lake. Today's maps still show a village named Bochkarevo in Zabaikalsky krai (a large territorial unit in eastern Russia, its main city being Chita). This is the native village of N.G. Bochkarev's grandfather, Afanasy Mitrofanovich Bochkarev (1878.01.26–1956.09.23). He was a colonel in the Far Eastern Cossac Army. Afanasy Mitrofanovich



Figure 3 Kirilov sisters. Left – Maria (N.G. Bochkarev's grandmother), then Lyudmila and Ekaterina; right – Anna Yakovlevna Grebenshchikova, N.G. Bochkarev's great-grandmother.

graduated from Eastern Sciences Institute in Vladivostok, he worked as a teacher, died in Moscow. His wife, N.G. Bochkarev's grandmother, Maria Evgenyevna Bochkareva (née Kirilova; Fig. 3), graduated from one of the first women's higher courses in the Russian Empire (corresponding to the university level), worked as a translator from English, taught English in the Moscow Aviation Institute.

Thanks to the study by a Russian historian Sergey Vladimirovich Volkov (Bochkarev's second cousin), we are able to go far back in the family history and follow the generations and genealogy on the side of the grandmother, M.E. Bochkareva, as far back as the 17th century. Her mother, Anna Yakovlevna Kirilova (née Grebenshchikova; 1863.03.13–1925.02.09; to the right in the photograph in Fig. 3), studied at the natural sciences department of the women's higher courses and graduated with a silver medal, and then became a teacher. Thus, we see deep historical roots of N.G. Bochkarev's profound interest in natural science.

N.G. Bochkarev's great-grandfather, husband of A.Ya. Kirilova, Evgeny Mikhailovich Kirilov (1860–1920) was from an officer's family and reached the rank of a colonel.

The great-great-grandfather of N.G. Bochkarev, Yakov Aleksandrovich Grebenshchikov (Fig. 4), had a fantastic military career and became an infantry general, member of War Council. During the Crimean War, he participated in the defence of Sevastopol, fighting from August 18 till September 25, 1855 at batteries of Inkerman positions and then, till December 18, at positions near Bakhchisaray. He was the commandant of Kovno fortress (now in Kaunas, Lithuania) and participated in its construction. His ancestor Aleksey Grebenshchikov became a nobleman after his company of the Preobrazhensky Life Guards Regiment had helped Elizabeth of Russia to get the throne, having overthrown the regent Anna Leopoldovna.



Figure 4 Ya.A. Grebenshchikov, infantry general, member of War Council.



Figure 5 E.I. Saleri, wife of Ya.A. Grebenshchikov.

Ya.A. Grebenshchikov's wife, N.G. Bochkarev's great-great-grandmother Elena Ivanovna Saleri (1843/45 – 1911.04.04, St. Petersburg; Fig. 5), was a daughter of a Major General. It was possible to follow the history of the Saleri family to Nicholas Saleri (first half of the 17th century). This bloodline is of Polish origin, of noble clan with family's coat of arms Saszor, who lived in Volhynia. Excerpts from town books of Lutsk Castle show that its representatives inherited estates in the Lutsk county in the first half of the 18th century.

We have much less information about N.G. Bochkarev's ancestors on the side of his mother. Her father Konstantin Vasilyevich Shcherbakov, N.G. Bochkarev's

grandfather, was from the family of owners of the textile and paper factory in Ozyory, not far from Moscow (F. Shcherbakov's Manufacturing Partnership). He received a higher education and was an intern in Germany. Small tapestries of his work are still kept in the family.

His wife, N.G. Bochkarev's grandmother, Klavdia Georgievna Shcherbakova, née Konovalova (1901–1978), was from a family of workers. Such a marriage was considered a misalliance at that time. She won her husband by her beauty and brilliant singing. Her father, Georgy Dmitrievich Konovalov (1868–1939), was an excellent, reliable worker and became a clerk at the textile factory.

N.G. Bochkarev attended Moscow school No. 150 and graduated in 1965 with a silver medal. This school was supervised by N.E. Zhukovsky Air Force Engineering Academy, and thus pupils got enhanced training in physics and mathematics and obtained good practical experience. Having finished the school, he not only obtained a secondary-education certificate but also got a profession: an electrical mechanic of electronic computers. N.G. Bochkarev always showed an inclination and interest in natural sciences, mathematics.



Figure 6 The schoolboy Nikolai Bochkarev, a member of a group of astronomy trainees of the Moscow Planetarium.

As a schoolboy, Nikolai Bochkarev joined a group of astronomy trainees of the Moscow Planetarium (Fig. 6). There he made acquaintance with K.V. Kuimov, visited A.V. Zasov's lectures on general astronomy, with certain elements of theoretical astrophysics, for example, electron collisions of the first and second kind. He attended the classes held by K.A. Portsevsky (who was educated at the astronomical department of Moscow University), the Planetarium's deputy director of that time. Also, V.A. Ambartsumian, a member of the USSR Academy of Sciences, spoke about D-bodies; E.A. Grebenikov, also with Moscow University's astronomical education, told the kids about electronic computers.

3 Student time. Solar eclipse expeditions

In 1965, N.G. Bochkarev became a student of the astronomical department at the faculty of physics, M.V. Lomonosov Moscow University; three other trainee group members from the Moscow Planetarium also entered the University. They did not need the general astronomy lectures delivered by Associate Professor N.B. Grigoryeva, so they passed her exam in October, two months after the beginning of their University studies. During his second University year, N.G. Bochkarev started scientific work under the supervision of Dr. Moisey A. Lifshits. He was computing the motion of spicules in solar atmospheres; this was the content of his third year work presented at the University.

Selecting the topic of his fourth-year work took much time. He made a detailed acquaintance with the PhD dissertation of A.M. Cherepashchuk (later, the director of the University's Sternberg Astronomical Institute and member of Russian Academy of Sciences). However, he chose to work on chemical evolution of the Galaxy under the supervision of A.V. Zasov (who was at that time assistant professor), the topic that Zasov's disciple O.K. Silchenko began to successfully develop a decade later. Both the third-year and fourth-year works were practically ready for publication; nevertheless, he never published them. It seemed to him at that time that only outstanding results should be published in Astronomicheskii Zhurnal (today its English version is known as Astronomy Reports).

In 1967, being a third-year student, N.G. Bochkarev attended most talks at the international conference on quasars held at the P.N. Lebedev Physical Institute of the USSR Academy of Sciences, where synchronous translation was provided. Among prominent guests at this conference, there was Professor Geoffrey Burbidge. After 1968, Bochkarev often visited the Joint Astrophysical Seminar held at the Sternberg Institute, with vibrant discussions of the most important news of rapidly developing astrophysics, and hottest debates among scientific gurus like Ya.B. Zeldovich, I.S. Shklovsky, V.L. Ginzburg and their disciples. Somewhat later, he began to attend Ginzburg's weekly seminars.



Figure 7 Sary-Shagan eclipse of 1968. Dr. E.V. Kononovich with students N.G. Bochkarev and E.A. Karitskaya at the German OPTON telescope.



Figure 8 Suburb of Novosibirsk, 2008, after successful observations of the eclipse. Prof. N.G. Bochkarev is in the center, with Dr. E.A. Karitskaya and then Dr. G.V. Yakunina to the right of him. Dr. A.B. Delone is the fifth from the left.

In September, 1968, two students, Bochkarev and one of the authors of the present paper, E.A. Karitskaya, were invited to the Sternberg Institute's expedition sent to Sary-Shagan (at Balkhash lake) to observe a total solar eclipse. The leaders of the expedition, E.A. Makarova and A.B. Delone, gave the students their special task: photographing the solar corona using an MTO-1000 objective. Also, the students had to determine the latitude and longitude of the observing site and to establish necessary orientation of all instruments of the expedition. The expedition was a success, with ideal weather on the eclipse day. This eclipse was the first one among the five total solar eclipses observed together by N.G. Bochkarev and E.A. Karitskaya, who became married in March, 1969. All these expeditions (Sary-Shagan, Balkhash, 1968, Fig. 7; Chukotka, Russian Koshka foreland, 1972; Chukotka, Markovo settlement, 1991; Mt. Terskol near Elbrus, 2006; Novosibirsk, 2008, Fig. 8) were lucky to have good weather.

4 Graduation paper and PhD dissertation

The supervisor of N.G. Bochkarev's graduation paper and PhD dissertation was Prof. Solomon Borisovich Pikelner, an outstanding scientist and a man of excellent personality. The topic was heating and ionization of interstellar gas with cosmic rays and low-energy X-rays. The action of cosmic rays and X-rays on rarefied gas is mainly related to ionization of atoms and ions. The resulting free electrons happen to be energetic enough to ionize, in their turn, the interstellar gas. A cascade of secondary particles is formed. Detailed numerical computations of the emerging cascades were the topic of the graduation paper defended in December, 1970. Unfortunately, the results of the computations were published in detail only several years later, in a

small journal issued by Sternberg Institute (Bochkarev 1973). Also in 1973, similar computations of French colleagues were published in "Astronomy & Astrophysics". Bochkarev's results got no recognition.

To compute the ionization state for each of chemical elements in the interstellar medium, it is necessary to solve a set of ionization equations for each ion of each element. The set of equations turn out to be large (dozens or hundreds of equations) and stiff, i.e. requiring minor integration steps. Similar problems are met in computations of nuclear explosions, but, at that time, solution techniques remained classified, and N.G. Bochkarev had to invent them anew. One should keep in mind the low computer memory volume and productivity at that time. Bochkarev became one of the main, most active users of Sternberg Institute's computer resources; to optimize computations, he had to use his own codes even for standard functions, like an exponent. Computations took his time during the 3-year postgraduate course almost completely.

N.G. Bochkarev successfully defended his PhD dissertation "Physical conditions in interstellar medium heated with X-rays and cosmic rays" in 1974.

5 First working years in Sternberg Institute

After the postgraduate course, N.G. Bochkarev received a job at the Sternberg Astronomical Institute (SAI) of the M.V. Lomonosov Moscow University. For the first seven years (1974–1981), he worked in the laboratory responsible for construction of the SAI Mt. Maidanak observatory (Uzbekistan). The result was authorship in 20 publications on deformation of telescope mirrors and mounts as well as on astronomical climate. Also, Bochkarev repeatedly got urgent errands to perform computations



Figure 9 N.G. Bochkarev and his son Yuri in Crimea (Bakla cave town).

on topics of agreements between the SAI and defense organizations, the main source of extra income for the SAI of that period. At that time, N.G. Bochkarev remained one of the most skillful experts on programming and computer usage in the Sternberg Institute. The first computer was Nairi, with a character of a moody woman,



Figure 10 N.G. Bochkarev and Yuri Bochkarev near the Catherine Palace, Leningrad.

then appeared BESM4M and BESM6. Once, to meet a deadline of an agreement, N.G. Bochkarev had to work three days long without sleeping or resting. The work was ready in time. Later, this work without sleeping had negative consequences for his health.

In 1979, his son Yuri was born. Because of his strong diathesis, N.G. Bochkaev, following physicians' advice, had to take Yuri to Crimea (Fig. 9), to Mt. Maidanak, to Kitab (Uzbekistan), to Abastumani (Georgia). N.G. Bochkarev was a caring father, able to create excellent living conditions away from home, and he taught his son, from his early years, life in tourist camps, nomadic existence. Later, they travelled together a lot: in the Caucasus, Altai mountains, to the site of the Tunguska event, to Chukotka during the 1991 solar eclipse, then along the Northern Sea Route, the Lena river, visited other interesting places (Fig. 10). The result was that his son, Yuri Nikolaevich Bochkarev, graduated from the Geographic Faculty of Moscow University and became an expert on landscapes.

In November, 1975, quite unexpectedly, Prof. S.B. Pikelner died of appendicitis (peritonitis). N.G. Bochkarev continued to deliver lectures of Pikelner's obligatory one-year course of Theoretical Astrophysics, consisting of two parts: stellar atmospheres and interstellar medium. He then lectured on Theoretical Astrophysics for many years.

From memories of N.G. Bochkarev: "*At the time of Pikelner's funeral, his co-author, Prof. S.A. Kaplan, promised to write a new text of the monograph "Interstellar Medium", performing a complete revision of their 1963 Russian-language book with this title as well of the revised English-language edition of 1970. S.A. Kaplan fulfilled his promise: in 1977, he submitted the manuscript of the new book to "Nauka" publishers. Being an experienced author, Kaplan knew that the manuscript would be kept in the publishing house at least for a year without any progress. Because of this, the manuscript he sent to publishers was a version he wanted to continue working on for one year more. Kaplan gave several copies of the manuscript to colleagues, asking them to look it through and make critical remarks. I also received a copy. The state of the manuscript surprised me; being a pedantic young specialist, I suggested more than 500 critical remarks. During the next Kaplan's visit from Gorky to Moscow, he attentively discussed every remark with me, agreed with most of them, and introduced*

changes to the text. From Moscow, he went to Leningrad, but died in an accident under a train on his way back. The head of the "Astronomy" department of "Nauka" publishers I.E. Rakhlin suggested me to complete the preparation of the manuscript for publication. This work took a year, but considerably appended my knowledge of all aspects of physics of interstellar medium, made this knowledge systematic".

The book, with N.G. Bochkarev as the editor, was ultimately published (Kaplan & Pikelner 1979).

N.G. Bochkarev always paid high respects to the memory of his teacher S.B. Pikelner. He made a scientometrics study of his heritage and presented its results at the SAI scientific council and at a memorial conference in 2006. In 2014, the book by N.G. Bochkarev, R.E. Gershberg, M.A. Livshits "S.B. Pikelner's Ideas in the Context of Modern Astrophysics" was published as a result of this conference (Bochkarev et al. 2014).

6 Physics of interstellar medium: working group of the Astronomical Council of the USSR Academy of Sciences

N.G. Bochkarev remembers: "*Several months before the book "Physics of the Interstellar Medium" by S.A. Kaplan and S.B. Pikelner appeared, I was at a trip to Mt. Maidanak. There I was located by Prof. L. Luud from Estonia; he suggested me, on behalf of the Astronomical Council of the USSR Academy of Sciences, to create a new working (problem) group "Physics of Interstellar Medium" in the structure of the Council. Thus, I, still a junior researcher, created a working group of the Astronomical Council, with many Doctors of Science in it, and became its chairman. Georgy Mikhailovich Rudnitsky agreed to become a Science Secretary of the working group. Today this group is a section of the Astronomy Scientific Council of Russian Academy of Sciences, and I am still in the chair*".

Currently, this section of the Scientific Council is headed by Prof. Yu.A. Shchekinov, it is still working effectively and arranges seminars and conferences.

From N.G. Bochkarev: "*Another direction of my interstellar-medium studies is related to large-scale shell structures. Such structures appear to be very frequent in the interstellar medium, so that, in many spiral galaxies, the interstellar medium is literally full of "bubbles". A typical size of such bubbles, more often called super-shells, is 300 pc. In our Galaxy, they were detected and studied with a telescope (Schmidt camera) only 1 cm in diameter (the world-smallest telescope?)*".

"*Smaller shells (with sizes about a parsec) around individual stars possessing strong stellar winds were, and still are, a subject of very successful studies by Dr. T.A. Lozinskaya*".

"*The shells appear due to interaction of stellar wind with interstellar medium. Colliding gas flow should be heated and emit in the soft X-ray range, as it was first noted by Prof. S.B. Pikelner. Attempts to find X-rays from a number of nebulae lasted for several years but had no success*".

When working in the USA, N.G. Bochkarev was successful in discovering X-rays from nebular formed with stellar wind. He remembers:

"*I developed detailed numerical models of X-ray radiation to be expected from such nebulae. Together with Lozinskaya, we found that the highest, observable fluxes should*

be expected from the nebulae NGC 6888 and S119, and not from nebulae already searched for such radiation".

"*During my stay in the USA, I happened to visit the center where archives of X-ray observations were kept, I asked to show me a single field: the unprocessed image of NGC 6888. Already at the first sight, X-rays from the nebula were apparent. In Moscow, by correspondence with the archive, we managed to process the image, and I published it in "Nature", with a remark from the editors suggesting to pay attention to this paper*" (Bochkarev 1988).

"*This is how I became the discoverer of a new class of X-ray sources: nebulae formed with stellar wind*".

Meanwhile, X-ray images of super-shells appeared. The largest of them is the super-shell in Cygnus, its size on the sky exceeding 15 degrees. This discovery was, however, disproved in a detailed 65-page paper published by N.G. Bochkarev together with T.G. Sitnik (Bochkarev & Sitnik 1985). They demonstrated that this horse-shoe image resulted from a projection on the celestial sphere of a large number of unresolved objects located along the local spiral arm of our Galaxy, at distances from 0.7 to 2 kpc from us.

Another large cycle of N.G. Bochkarev's studies on super-shells deals with the so-called local super-shell, a gas bubble formed due to common action of stellar winds and supernova outbursts of the Scorpio–Centaurus association. Writes N.G. Bochkarev:

"*The Sun is inside the bubble, near its edge. This makes it very difficult to see the pattern, one cannot see the forest among trees*".

"*A thorough analysis of heterogeneous observing data, 73 pages in my journal publication of 1987 in "Astrophysics and Space Science", appeared in the same year with the paper by D.P. Cox and R.J. Reynolds (1987ARA&A..25..303)*" (Bochkarev 1987; Cox & Reynolds 1987).

"*The general pattern revealed in both papers is the same, i.e. the studies confirm each other. However, there are differences in details*".

"*This cycle of my publications was concluded with the book "Local Interstellar Medium" "* (Bochkarev 1990).

N.G. Bochkarev defended his D.Sci. (second-level) dissertation "Thermal Regime of Gas Emission in Galaxies and Star Shells" in 1988.

7 Active galactic nuclei

The continuing series of N.G. Bochkarev's papers on active galactic nuclei (AGNe) has the largest number of references. Many pioneering observations of AGNe, with their analysis, were performed in the USSR in 1960s – early 1970s. For instance, remember the studies by Dr. V.I. Pronik (Crimean Observatory) and Prof. E.A. Dibaj (SAI Crimean station).

"*My first study on this topic was performed with the student S. Pudenko and published in 1975. This was the time when people have only begun to develop photo-ionization models and apply them to AGN investigations. In our study, we analyzed variations of flux in spectral lines due to varying photo-ionizing radiation. The time scale of possible changes in observed spectral lines is within an hour*" (Bochkarev & Pudenko 1975).

"*The further stage of this investigation was the study on diagnostics of AGN gas geometry and kinematics from variations of spectral lines (reverberation mapping). The study was performed together with I.I. Antokhin, my student at that time, in 1982–1983, simultaneously with the studies by R.D. Blandford and C.F. McKee that had become widely known*" (Antokhin & Bochkarev 1983; Blandford & McKee 1982).

In the case of instantaneous change of the X-ray flux, relaxation of temperature and volume radiation coefficient in the broad-line formation region (BLR) occurs within 1 hour. This result is based on a numerical solution of the set of differential equations.

Any change of the flux of ionizing radiation causes a wave of ionization (recombination), of changing gas excitation in an AGN. The sequence and amount of observed variations depend on geometry and kinematics of BLR matter. Thus, the observed variations of spectral-line profiles contain information on the size, geometry, and kinematics of the BLR. Hence, we are able to restore geometry and kinematics of gas from changes of the spectral-line profile solving an inverse mathematical problem. This is the basis of reverberation mapping. It requires many spectroscopic observations in a sequence.

During his 1984 stay in the USA, N.G. Bochkarev delivered several talks on the diagnostic possibilities of the methods and its requirements of the necessary amount and quality of observational material. Also in 1984, during his visit to Ohio State University (USA), he had many hours of discussions related to various aspects of importance of the AGN spectroscopic and photometric monitoring with a young astronomer B.M. Peterson, suggesting him to become a coordinator of the observations. For the same purpose, in 1986, N.G. Bochkarev used the meeting's tribune (and especially lobby discussions) of the IAU Symposium No. 121 on AGNe in Byurakan (Armenia) and of other conferences and demonstrated that optimal objects for observations were Sy1.5 Seyfert galaxies. Active work in the frame of this program was provided by scientific teams of A.I. Shapovalova at the 6-m BTA telescope (Special Astrophysical Observatory), V.T. Doroshenko in Crimea, and Martin Gaskell in the USA. Between 1992 and 2002, N.G. Bochkarev was the head of the Russian segment of the "AGN Watch" program.

Since 1982, N.G. Bochkarev started the systematic practical application to AGNe of the echo mapping (reverberation) method. Starting in 1986, together with A.I. Shapovalova and others, he monitored AGNe in order to determine mass, size, structure of the "central engine", predominantly via echo mapping and studies of long-term variations. This scientific team obtained important results: sizes of BLRs and their variations were determined for several objects; stratification of BLRs was confirmed; behavior of broad FeII lines was studied; blue and red wings of broad emission lines were shown to vary quasi-simultaneously, i.e. circular and/or chaotic motions dominated radial motions (cf. Shapovalova et al. 2019 and references therein).

8 X-ray binaries

In 1974, N.G. Bochkarev accepted Dr. N.I. Shakura's suggestion of cooperation on computations of light curves of tidally distorted stars in binary star systems containing neutron stars, black holes, accretion disks. At that time, E.A. Karitskaya, under Prof.

I.S. Shklovsky's supervision, was working on the very promising but extremely vast topic "Nature of X-ray Sources". Thus, they started working together on optical manifestations of X-ray binaries, with many resulting papers in co-authorship.

A code was developed that made it possible to compute light variations of a tidally distorted star taking into account the exact shape of its surface (Bochkarev et al. 1979). The orbital component of photometric variations, due to the ellipsoidal shape of the optical star, was studied in the frame of the Roche model. Limitations on parameters of X-ray systems thus derived remain actual even today. Then the code was appended and it became possible to compute linear polarization of light from the distorted star and accretion disk (see, e.g., Bochkarev, Shakura & Karitskaya 1985; Bochkarev et al. 1985; Bochkarev & Karitskaya 1985).

In the cycle of some 20 papers, N.G. Bochkarev and E.A. Karitskaya studied in detail, for the first time, diagnostic possibilities for geometric parameters of the X-ray binary's optical components. References to these publications still appear. Cherepashchuk (2013) presented a detailed description of their most important conclusions in his two-volume book on binary stars. The strongest polarimetric effects are expected in the ultraviolet range. It was hoped that these studies would find their application in the planned space mission "SPECTRUM-UV". However, the hopes were not fulfilled because of the absence of the planned polarimeter.

An analysis of linear polarization due to electron scattering and re-radiation in atmospheres of the star and disk, applied to the X-ray binary and black hole candidate Cyg X-1 (V1357 Cyg), has shown that variations of linear polarization are mainly due to scattering in the optically thin gas located asymmetrically with reference to the lines connecting the components and precession occurs in the direction of the orbital motion.

In 2000s, when N.G. Bochkarev had left the position of the co-chairman of the Eurasian Astronomical Society, he started a new stage of his studies of X-ray binaries, added spectroscopic studies, observational as well as theoretical. His special interest was with spectroscopic observations, he repeatedly took part in them together with E.A. Karitskaya. With backpacks, they ascended to the Mt. Terskol observatory (altitude 3000 m) and spent about two weeks there each time. They often had to ascend by foot: no car could get to the place because the mountains were still covered with snow. Figure 11 shows N.G. Bochkarev when he rested ascending to the observatory



Figure 11 N.G. Bochkarev at a halt during his ascent on foot to Peak Terskol mountain.



Figure 12 N.G. Bochkarev at the Peak Terskol observatory, July 2008. The dome of the 2-m telescope is behind him.

in 2008. Note that, at that time, he had already been suffering from Parkinsonism for 12 years, but his strong will and inspirational and passionate interest in life and his work were winning and shone through. The photograph in Fig. 12 shows the amount of snow waiting for Bochkarev and Karitskaya at the observatory in July.

There was very fruitful cooperation with the Kazan team of Prof. N.A. Sakhibullin that developed the SPECTR software complex for computations of stellar atmospheres. In co-authorship with V.V. Shimanskii, N.G. Bochkarev and E.A. Karitskaya published a series of papers related to model computations (see, for example, Shimanskii, Karitskaya, Bochkarev et al. 2012, Bochkarev et al. 2013).

Comparing observed high-resolution spectra of Cyg X-1 with model non-LTE spectra, it was possible to restrict parameters of the O supergiant (optical component of the X-ray binary Cygnus X-1): $T_{\rm eff} = 30400 \pm 500$ K, $\log g = 3.31 \pm 0.07$, and abundance excesses of elements: from 0.4 dex to 1.0 dex for He, N, Ne, Mg, Si, i.e. elements produced in the CNO- and α-processes.

Spectral-line profile variations of Cyg X-1 were studied on different time scales. Photometric and spectroscopic variability reveals parameter variations of the supergiant at times of decades. Comparing non-LTE model computations to observations, it was concluded that the radius of the optical star increased by $\sim 3\%$ between 1997 and 2003–2004, and its temperature decreased by ~ 2000 K. The surface became closer to the critical Roche lobe, thus, instability of matter flow, and hence observed instability of the X-ray flux increased. Further spectroscopic and photometric observations demonstrated continuing variations of the supergiant's fundamental parameters, reflected in the relations between X-ray and optical variations, in particular, in variations of absorption-line depths.

N.G. Bochkarev and E.A. Karitskaya, together with Dr. M.I. Agafonov's team from Nizhny Novgorod, performed 2D and 3D tomography of Cyg X-1. They used orbital line-profile variations of the HeII 4686Å line on the base of high-precision spectroscopic observations acquired in Mexico and at Peak Terskol. These studies made it possible to improve the model and obtain information on the gas flow in the X-ray binary Cyg X-1 (Agafonov et al. 2018ab).

Spectropolarimetric observations with the 8-m ESO VLT telescope (Mount Paranal, Chile), obtained according to the proposal submitted by N.G. Bochkarev and E.A. Karitskaya, revealed a magnetic field ∼100 Gs on the surface of the supergiant in the Cyg X-1 system, a probable cause for the stellar wind from this surface being inhomogeneous. To find such a small magnetic field of a relatively faint object featuring a high linear interstellar polarization, N.G. Bochkarev performed a specially thorough reduction of the obtained observation, showing his characteristic persistence in order to reach his goals. Purifying the data and subtracting trends, he achieved Gaussian statistics and removed the false instrumental circular polarization (Bochkarev & Karitskaya 2012). The magnetic field turned out to vary with the orbital phase; at maximum, it is significant at the 6σ level. This was the first confirmation of magnetic accretion on a black hole.

In the late 1970s – early 1980s, together with E.A. Karitskaya, N.G. Bochkarev developed details of the discrete mechanism of matter flow in the X-ray binary Her X-1/HZ Her (the so-called "clock" mechanism suggested by Crosa & Boynton 1980). The model explained a lot of observed facts surprisingly well. A model of matter splattering at the outer edge of the accretion disk, because of a Rayleigh-Taylor instability during interaction with a hot corona around the disk, was suggested. Parameters were determined for the predicted corona and matter blobs rotating around the neutron star at the edge of the accretion disk; their formation is accompanied with the appearance of individual small peaks on optical light curves. A new study based on a vast amount of photometric observations demonstrated that the relation of the times when the small peaks appeared to certain phases of the orbital and 35-day periods could be followed till now.

Thus, over the years there has been no failure in the "clock mechanism" of discrete flow of matter in the X-ray binary Her X-1. This confirms the evidence in favor of the considered model (Karitskaya & Bochkarev 2023).

The SRG/eROSITA all-sky survey has confirmed the existence of the corona above the accretion disk predicted by N.G. Bochkarev (Shakura et al. 2021).

9 Creation of the Astronomical Society, co-chairmanship, and other social activities

The conditions needed to implement the idea to create the Astronomical Society appeared during democratic reforms in the end of 1980s. N.G. Bochkarev was almost completely immersed in this activity. First, at the end of 1988, he was elected the chairman of the Initiative group. At the first Constituent Congress of the Astronomical Society of the USSR (April 6–8, 1990), he became the Society's co-chairman. A year later, the Society changed its status to international and became the Eurasian Astronomical Society (EAAS).

The history of the EAAS is described in Samus et al. (2021).

In 1993–1994, N.G. Bochkarev took an active part in creation of the Association of Planetaria of Russia, which elected him its member of honor in 2002. He was awarded a Certificate of Honor from the Governor of Nizhny Novgorod region for his help in the solution of problems related to the construction of a new building for the Nizhny Novgorod Planetarium.

Beginning with 1990s, N.G. Bochkarev strongly defended the Moscow Planetarium. In 1994, as a non-paid assistant to the Moscow City Duma (parliament) member D. Kataev, he actively participated in preparing and conducting the hearings in the Moscow City Duma concerning the Moscow Planetarium; during later years, he participated in public actions in support of it. As an EAAS co-chairman, together with Prof. A.M. Cherepashchuk (SAI Director of that time), he met with the architect A.A. Anisimov who had developed the planetarium reconstruction project, they discussed the project, and N.G. Bochkarev suggested his recommendations. In 2008, he participated in discussing and editing the new Statutes of Moscow planetarium, his suggestions were introduced in the final version of the document. Then, he was a member of the Moscow Planetarium's scientific council.

N.G. Bochkarev remembers: "*The twelve years (1990–2002) when I was an EAAS co-chairman are known as very difficult years for our country and science, and my position in the EAAS required a complete dedication. Often, I had to work during 16 hours each day for a long time interval. ...*"

"*This hard work not only influenced my health. All scientific ideas disappeared from my head; postgraduate students left me – to business or elsewhere. After that, I had to resume my scientific work literally from scratch. And I started it from archeoastronomy*".

10 Interdisciplinary studies. Archeoastronomy and astrobiology

Professor N.G.Bochkarev possessed a broad outlook and was interested in different aspects of science. He was especially attracted to interdisciplinary studies related to astronomy and among them, there are archeoastronomy and astrobiology. The EAAS considered it important to support interdisciplinary studies and N.G. Bochkarev founded an archeoastronomy seminar.

There were no active and distinguished astronomers in Russia who considered archeoastronomy the main direction of their research, and thus, N.G. Bochkarev had to assume this role from time to time.

In 2000, simultaneously with the conference associated with the congress of the European Astronomical Society (JENAM-2000), the SAI held a conference of SEAC, the European Society "Astronomy in Culture", on scientific research focused on archaeoastronomy, ethnoastronomy, and history of astronomy in culture. After that, N.G. Bochkarev began to receive invitations to SEAC events and to participate in them.

In 2001, P.M. Herouni, a member of Armenian Academy of Sciences, organized a trip to the ancient astronomical observatory Carahunge. N.G. Bochkarev had been so impressed that he presented a talk about this unique object of archeoastronomy at the regular SEAC conference in Tartu in order to inform western colleagues about it



Figure 13 N.G. Bochkarev speaks at the first all-Russia field archeoastronomy seminar on June 21, 2006.

and published a detailed paper (Bochkarev & Bochkarev 2005). He determined the age of the object as 7000–8000 years.

The ensemble consists of more than 200 large-size, vertically positioned basalt stones, from 1 to 2.8 m in height, its total length is about 270 m. The main distinguishing feature of Carahunge are penetrating cylindrical holes in the upper parts of many flattened, elongated stones. The central part of the ensemble resembles Stonehenge. Quite probably, it is one of the most ancient observatories of the world.

A small book about Carahunge by A. Airapetian was published with N.G. Bochkarev as its editor. This work took much of his time (Airapetian 2016, 2018).

N.G. Bochkarev supervised students working in archeoastronomy. Thus, student F.A. Medvedev presented and defended an archeoastronomy graduation paper where he corrected a mistake in Herouni's calculations.

Repeatedly, N.G. Bochkarev organized field archeoastronomy seminars, and headed their organizing committees.

The first all-Russia field archeoastronomy seminar "Astronomical and World-view Importance of the South Urals Archeology Monuments" was held on June 19–25, 2006 (Fig. 13). It was based at the Arkaim archeology center (Chelyabinsk Region). During the seminar, astronomical and geodesic measurements were performed for two intensively studied archeological objects: Arkaim proper (bronze age, 18th–16th centuries BC) and the New Kondurovsky "mustached" mound that belongs to the Kondurovsky group of these mounds (5th–8th centuries AD) (Fig. 14).

The second field seminar, "Astronomical Methods in Studies of Archeoastronomic Objects of the Sunduki Mountain Range and Other Historic Objects", was held on September 21–25, 2016 in Khakassia. The seminar was dedicated to analyzing and



Figure 14 E.A. Karitskaya, N.G. Bochkarev, and T.M. Potemkina during field measurements at the New Kondurovsky "mustached" mound, June 2006.

collecting evidence for astronomical alignment of archeological objects at this mountain range (Fig. 15).

In 2010 during a trip to England, N.G. Bochkarev and E.A. Karitskaya managed to visit some archaeoastronomical objects. Figure 16 shows a photo of Bochkarev against the background of the famous Stonehenge.

Once, Prof. N.S. Kardashev, Russian Academy member, invited N.G. Bochkarev to take part in the discussion on the origin of life organized by another Academy member, Prof. A.Yu. Rozanov, and after that, N.G. Bochkarev participated in conferences



Figure 15 N.G. Bochkarev at menhirs in Khakassian national park. Sunduki mountain range is at the horizon.



Figure 16 N.G. Bochkarev at the Stonehenge, England, 2010.

on this topic. In his talks and papers, he concentrated on astronomical aspects of the problem: influence of interstellar medium on terrestrial processes, role of migration of the dust component in our Galaxy and between galaxies in the process of propagation of life, limits on distances during panspermia (cf. Bochkarev 2016; Bochkarev & Gindilis, 2016; Bochkarev, 2017a; Bochkarev, 2017b). In 2010, N.G. Bochkarev became a member of the Astrobiology Council of the Presidium of Russian Academy of Sciences.

11 His hobbies

N.G. Bochkarev's main and greatest hobby was science. He had a passionate interest in the most recent modern discoveries, theories, trends in different branches of science. He subscribed to Russian popular science journals, including "In the World of Science", "Priroda" ("Nature") and others and read them through, from the first page to the last page.

His second passion was travelling. He used every possibility to visit interesting places, to walk along a picturesque path, to become acquainted with the local fauna and flora, with culture and art of local people. Everything he saw was photographed or recorded with a video camera. First with his wife, E.A. Karitskaya, and then also with his sun, Yuri, N.G. Bochkarev covered the whole Soviet Union. After a visit to Chukotka peninsula, they had the good fortune to traverse the Bering Strait on board a nuclear-powered cargo ship, along the Northern Sea Route, then along the Lena river to Yakutsk, where they took a plane to Moscow. On the Kamchatka peninsula, they took a tourist route to Valley of Geysers and ascended volcanos. There was also a boat trip on Baikal Lake.

N.G. Bochkarev was an organizer of a trip to the site of the Tunguska event. He travelled with his wife and son across all Altai to select a site for a possible

future astronomical observatory. These are only some examples of his many trips and expeditions. In addition, there was a program of international travel including business trips to France, to the USA and after 1990, there were also leisure trips to England, Spain, Morocco, Italy, Israel, Jordan and onwards.

There were especially many trips across Middle Asia in 1970s–1980s, to choose the site for the Mt. Maidanak observatory, to build it, and to put it into full operation. During these trips, N.G. Bochkarev and E.A. Karitskaya made acquaintance with local people's art and became fascinated with it, especially with ceramics. Usually, free vacation days were attached to business trips, and the family visited places famous for local ceramics, where folk artists were still working. N.G. Bochkarev became an art collector. The stories about the folk masters and photographs of their works obtained during travels interested the members of the Folk Art Commission of the USSR Union of Artists. Among them, there were Irina A. Zhdanko (1905–1999),a Soviet painter, graphic artist, monumental artist; Grigory G. Derviz (1930–2019), monumental artist, Honor Member of Russian Union of Artists, Emeritus Artist of Russian Federation; Daniel Yu. Mitlyansky (1924–2006), Soviet and Russian sculptor, Emeritus Artist of Russian Soviet republic, corresponding member of Russian Academy of Art. They were the authors of an excellent book "Modern Ceramics of Folk Artists of Middle Asia" (Derviz et al. 1974). In order to exchange impressions from visits to folk artists, to tell about new findings and show slides, N.G. Bochkarev and E.A. Karitskaya rather often visited Irina A. Zhdanko in her room in Starokonyushenny Lane in Moscow. Bochkarev's collection even participated and was displayed in an exhibition of folk art.

12 Conclusions

In this section, we summarize N.G. Bochkarev's main achievements.

N.G. Bochkarev was a well-known expert in the fields of extragalactic astronomy, physics of interstellar medium, X-ray binaries. He was known for his wide scientific purview and deep approach to his studies. He authored more than 300 scientific papers, scientific reviews, and 8 books and was awarded the honorary title "Distinguished Person in Russian Higher Education". In 1970–1973, he developed a quantitative theory of interaction between hard radiation and rarefied space plasma. In 1982–1986, he proposed and tested the method of echo mapping of active galactic nuclei and quasars that became widely used worldwide. In 1988, he discovered a new class of X-ray sources: X-ray-emitting nebulae formed by stellar wind. In 1986–1992, he studied the structure of the local interstellar medium.

In 1992–2002, N.G. Bochkarev was a co-coordinator (from the Russian side) of the major international program AGN Watch, aimed at identifying mechanisms of intense radiation from active galactic nuclei and quasars in all ranges of electromagnetic waves. Since 1994, he was the head of the Russian program aimed at studies of the structure and radiation mechanisms of the "central engine" of active galactic nuclei. In 2007–2009, together with E.A. Karitskaya, he discovered magnetic fields in systems containing black holes; this was virtually the first observational confirmation of earlier theoretical predictions.

N.G. Bochkarev actively participated in teaching students at the astronomical department, Faculty of Physics, M.V. Lomonosov Moscow University. He published

the tutorial book "Basics of the Physics of Interstellar Medium" (Bochkarev 1992; 2nd edition, Bochkarev 2010).

N.G. Bochkarev was the head of the section "Interstellar Medium and Star Formation" of the Astronomy Scientific Council of the Russian Academy of Sciences. Since 2010, he was a member of the Astrobiology Council of the Presidium of Russian Academy of Sciences. He was also an active member of the International Astronomical Union (IAU) and the European Astronomical Society (EAS). N.G. Bochkarev was a founding member of the Eurasian Astronomical Society; in 1990–2002, he was the Society's co-chairman. He was awarded two memorial medals of the EAAS, in 2008 and in 2020. Since 1991, he was the Editor-in-Chief of the international scientific journal "Astronomical and Astrophysical Transactions". In 1997, he became a member of Russian Academy of Natural Sciences. One of the main belt asteroids is named "19915 Bochkarev" in honor and recognition of his work and contribution.

Professor N.G. Bochkarev always had an active social position and defended the interests of science and education. He made a significant contribution to astronomy and astrophysics and his memory will endure.

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