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# Sergey Nikolaevich Blazhko and the Blazhko effect named after him

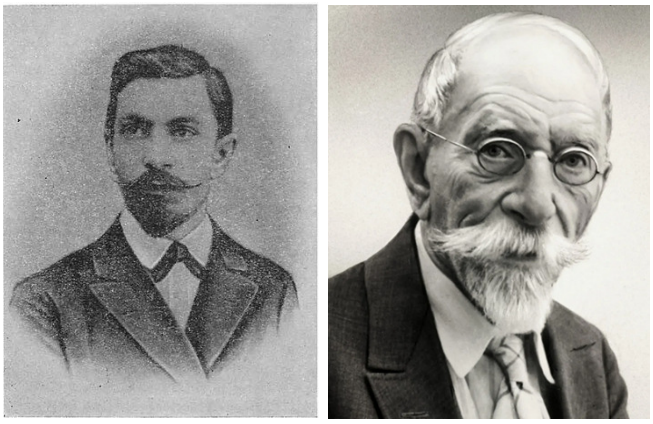
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A brief biography of one of the patriarchs of the Moscow school of astronomy, Sergey Nikolaevich Blazhko, is presented. The question of his astronomical heritage and the effect he discovered that was named after him, which still does not have an exhaustive theoretical explanation, is considered.

*Keywords*: History of astronomy, biography, S.N. Blazhko



S.N. Blazhko in his youth and around 1950.

## 1 Introduction

Sergey Nikolaevich Blazhko was an outstanding astronomer and Corresponding Member of the USSR Academy of Sciences, Stalin Prize laureate, professor and significant figure at Moscow University, and he worked continuously at Moscow University for 60

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years. His contributions to astronomy are based on the study of variable stars, particularly pulsating ones. November 2025 marked the 155th anniversary of S.N.Blazhko's birth, and 2026 will mark the 70th anniversary of his death. The following year, 2027, will mark the 120th anniversary of the astronomical Blazhko effect.

## 2 About Sergey Nikolaevich Blazhko

Sergey was born on November 17 (or November 5, old style), 1870, in Khotimsk, Mogilev Province, Russian Empire to a second-guild merchant being former serf. The family remained without an heir for so long that the parents made a pilgrimage to Sergiev Posad, praying for the continuation of the family line. When the boy was finally born, he was named Sergius, in honor of the monastery's founder, St. Sergius of Radonezh. The boy's mother died young, and his father remarried. Sergey had three half-brothers. Fortunately, his father's wife made no distinction between him and her sons, and Sergey grew up a versatile and inquisitive child.

His notes from 1883 were written in a small notebook and have survived. This diary reveals that the future scientist was not without romanticism, creating rebuses and writing poetry including rhyming lines about the sky, night and the Moon.

There is also a list of books that he read in the summer. This list includes works by I. Turgenev, F. Dostoevsky, A. Tolstoy, and A. Daudet. Blazhko, at the age of thirteen, was also interested in historical novels by Vsevolod Solovyov, including those published in the Russian magazine Niva.

He was also interested in periodicals, and it is likely that he read more than one newspaper. It is interesting that he noted the subscription price: in the late 19th century, the Smolensk Vestnik, published three times a week, cost readers 6 rubles per year. The delivery of the capital's Severnaya Zvezda newspaper was slightly more expensive, at 8 rubles.

In 1880, Sergey Nikolaevich Blazhko graduated from the Khotimsky People's School, then he studied at the Rosslavl Progymnasium, and in 1888, he graduated from the Smolensk Gymnasium. After that, he attended the Imperial Moscow University, from which he graduated in September 1892 with a degree in astronomy.

The museum in Khotimsk also houses S.N. Blazhko's university diploma, where all subjects were graded as "very satisfactory". But did Sergey Nikolaevich really perform poorly at the university? Of course not! There were only three grades in Russian Universities, and "very satisfactory" was the highest of them!

From that moment on, his life was connected with the observatory of Moscow University and the Sternberg Astronomical Institute. Blazhko was awarded a first-degree diploma for his thesis. At the university, he studied under the guidance of professors F.A. Bredikhin and W.K. Ceraski, who suggested that the final-year student S.N. Blazhko conduct photometric observations of stars using an equatorial camera based on Ceraski's ideas.

In 1894, Blazhko began working as supernumerary assistant at the University's Astronomical Observatory. The young scientist conducted photometric observations of comparison stars for variables and took photographs of the Sun using a photoheliograph. He used these photographs to determine the Sun's rotation period based on the movement of the faculae.

Blazhko was the first person in Moscow to start photographing the starry sky. The first plate in the collection, S1, was made in 1895. He also conducted visual observations of newly discovered variable stars using a 7-inch refractor and studied changes in their brightness, which led to the creation of an "astronomical plate collection" of star images, which was constantly expanded by the work of S.N. Blazhko's students. Over time, this library became increasingly valuable.

In 1904, using his own equipment, the young scientist was the first in the world to photograph the spectra of two meteors. Attempts to photograph the spectra of the hot vapors of falling meteors were usually unsuccessful, as the glow of a meteor occurs only for a moment and is always unexpected. After three years of intense work, Blazhko obtained the spectrum of another meteor. For many years, these were among the five known in the world literature. He developed a new theory for processing meteor spectra. It turned out that the hot meteor vapor produced when meteors pass through the atmosphere contains silicon, iron, calcium, and other elements.

The results of deciphering these spectra were published by S.N. Blazhko in 1907 in the article "On the Spectra of Two Meteors" (Blajko, 1907). This was one of the first detailed studies of a meteor spectra.

In 1914, S.N. Blazhko participated in the observation of a total solar eclipse using his method of photographing in polarized light in two mutually perpendicular planes. Blazhko obtained a highly successful photograph of the solar corona, which served as the basis for far-reaching conclusions about the structure of the outer regions of the corona. These photographs revealed the polarization of the solar coronal radiation.

Sergey Nikolaevich began his teaching career in 1896, when he was assigned to conduct practical astronomy exercises. In 1900, he taught at the Women's Pedagogical College, the Shanyavsky People's University, and the Pedagogical Courses of the Educators and Teachers Society. At this time he met his future wife, Maria Ivanovna Ushina who was a teacher.

In 1910, he became a private lecturer at the Department of Astronomy and Geodesy at Moscow University, and in 1918, he became a professor at the same department. Sergey Nikolaevich Blazhko's colleagues were P.K. Sternberg, S.A. Kazakov, and B.P. Modestov (see Fig. 1). Among his students were the founders of the Department of Stellar Astronomy at Moscow University.

It was on his recommendation that M.S. Zverev, a pianist who graduated from the Conservatory, chose astronomy over music and continued his astronomical education at Moscow University.

In 1919, Blazhko proposed a new method for detecting asteroids using photographs on glass plates. The method involves taking three images on a single plate, with breaks between exposures and a shift in the telescope's declination during these breaks. Blazhko also developed several innovative instruments and devices, including a special star spectrograph, a blink microscope, a special magnifying glass for counting divided circles. Blazhko designed a device on the meridian circle to reduce the brightness when observing the moments of star transits, as well as other devices.

During long, cold, clear, winter nights, some observers used a "chemical heater" that warmed them from the inside, in addition to wearing warm clothes. This method helped them stay productive, but it could also lead to errors in their work. At the Sternberg Astronomical Institute, a legend is passed down from mouth to mouth that Sergey Nikolaevich always noted the amount of "heater" used in his observation



**Figure 1** A group of Moscow astronomers in 1901. From left to right: seated – P.K. Sternberg, Mrs Ceraski, F.A. Bredikhin, W.K. Ceraski; standing – S.N. Blazhko, S.A. Kazakov, and B.P. Modestov.

journal. One "shot glass" indicated a small amount and high-quality observations, two indicated a moderate amount, and three indicated a large amount, and the results of observations with this notation should be treated with extra care. This system of notation is known as Professor Blazhko's graphical method (Fig. 2). Currently, there is no need to use Professor Blazhko's method, as observations can be conducted online, and observers are provided with warm and comfortable conditions.

Sergey Nikolaevich paid special attention to the study of Algol-like eclipsing binary stars. He was the first to analyze the effect of edge darkening on the shape of the light curve and the orbital elements determination, and proposed a method for taking this effect into account.

While engaged in spectroscopic research, he was one of the first to study in detail the eclipsing star of the Algol type with a large variability amplitude, U Cephei, in the phase of its normal and minimum brightness.

Cepheids are a class of radially pulsating variables. Their pulsations occur at one of the fundamental oscillation frequencies and are caused by ionization and recombination processes in layers of the star close to their surface. The idea of a pulsation excitation mechanism (the $\varkappa$-mechanism) was proposed by A. Eddington in his book (Eddington, 1926). Later, in Eddington (1941), a variant of this mechanism was pro-



**Figure 2** S.N. Blazhko around friends in Presnya.

posed in which star pulsations were excited in layers where hydrogen ionization took place. It was then shown that this mechanism was not working. The mechanism of excitation of pulsations in the layers of the star, where double ionization of helium occurs, which works in Cepheids, as well as in RR Lyrae and $\delta$ Scuti variables, was first proposed and developed in detail by S.A. Zhevakin in a series of papers published in 1954–1960, starting with (Zhevakin, 1954a,b) (for more information, see (Pulsating Stars, 1975, sect. 1. Zhevakin S.A. Theory of Stellar Pulsation)).

An important distinction between Cepheids and other pulsating stars is the clear, well-studied dependence of their absolute magnitude on their pulsation period, discovered by Henrietta Leavitt at the beginning of the 20th century (Leavitt, Pickering, 1912). The period–luminosity relationship for Cepheids was confirmed by Blazhko from his own observations. This dependence, along with the high luminosity of Cepheids (they are supergiants), allowed these stars to be used as "standard candles" and used to measure distances to nearby galaxies.

S.N. Blazhko also dealt with a number of other issues of important practical application. He obtained more precise formulas for bringing the coordinates of circumpolar stars from the mean position to the apparent position. He also developed a simpler than the standard, but effective theory of astronomical refraction.

Blazhko was not only a scientist, but also a popularizer of science. He gave lectures in workers' clubs and published popular science articles. He also wrote an excellent biography of Copernicus. Sergey Nikolaevich paid a lot of attention to teaching and wrote three textbooks on general, practical, and spherical astronomy.

From 1910, the first course that Blazhko taught was a course in practical astro-



**Figure 3** Photo of Khotimsk.

nomy, later he taught a course in general astronomy for astronomy students, as well as for physicists and mathematicians. For the first time at Moscow University, he taught a course in general astrophysics for astronomy students.

His deep knowledge of the subject and understanding of the importance of teaching methodology, as well as his excellent lecturing skills, provided a solid foundation for his university teaching, which resulted in the creation of the "Course of Practical Astronomy" (Blazhko, 1938), the "Course of General Astronomy" (Blazhko, 1947), and the "Course of Spherical Astronomy" (Blazhko, 1948). These three fundamental textbooks elevated the level of teaching and improved student comprehension, understanding and application of astronomical disciplines not only in Moscow but also in other universities across the country.

The course on practical astrophysics covered the achievements of astronomy in recent decades. Blazhko was a man of the old school, with kind blue eyes and courteous academic manners. It was said that his quiet and even voice could only be heard "in the front rows", but students appreciated his ability to connect with them, explain complex concepts in a clear and understandable manner, and tactfully address misconceptions. S.N. Blazhko's public activities began in 1898, when he delivered a series of 12 public lectures at the Historical Museum in favor of the Society for the Improvement of the Living Conditions of Students in Moscow Primary Schools.

Over 80 scientific papers by Sergey Nikolaevich have been published in print including in international journals and publications.

The result of his many years of photographic reviews was not only the "glass library" of the Moscow Observatory. Sergey Nikolaevich was passionate about photography since his youth. Sixty-two negatives were preserved, which he had taken himself on glass plates where he captured his native Khotimsk (see Fig. 3). These unique images are now collected and preserved as valuable social history.

Sergey Nikolaevich was elected a member of the German Astronomical Society, but in protest against the fascist pogroms of the peaceful Jewish population in 1938, he announced his withdrawal from the Society. For many years, S.N. Blazhko was a member of the editorial boards of the Russian Astronomical Journal and the Variable Stars Bulletin, a member of the Astronomical Council of the USSR Academy of Sciences, and the chairman of its Variable Stars Commission.

During the Great Patriotic War, S.N. Blazhko became one of the organizers and leading specialists of the SAI computing bureau, which was established during the evacuation and was located in Sverdlovsk (now Yekaterinburg) until 1944. He organized the calculation of tables of the rising and setting of the Sun and the Moon for each day. These tables were sent to the Main Directorate of Aviation and the Navy. The scientists provided the calculation of astronomical tables for the navigation services of the Air Force and the Navy. The tables were calculated for each day for 45 settlements west of 90 degrees east longitude, covering the theaters of war on all fronts and many cities in the rear.

Sergey Nikolaevich Blazhko's adopted daughter, his wife's niece, also worked in Sverdlovsk at that time, under his leadership. Her small oil paintings are kept in the museum on Krasnaya Presnya. She was a capable artist.

## 3 The most interesting discovery: the "Blazko effect"

The most interesting discovery made by S.N. Blazhko is the so-called "Blazhko effect". The scientist discovered simultaneous periodic changes in the amplitude, phase, and shape of the light curve of short-period Cepheid RW Draconis (today similar stars are called RR Lyrae type variables). Changes in RW Draconis occurred with a period that is about two orders of magnitude longer than the pulsation period of the star itself. And these phenomena of generally irregular modulation are called the "Blazhko effect" (see Fig. 4). The Blazhko effect is also called long-period modulation. RR Lyrae variables with the Blazhko effect are quite numerous and are regularly discovered. For example, a new such variable was discovered at the Sternberg Astronomical Institute by Antipin, Sokolovsky, and Lebedev (2005).

These results were published in Blažko (1907), and this discovery will be 120 years old in 2027, but there is still no comprehensive explanation for the physical origin of the effect. In terms of the duration of its existence in an unsolved state, this scientific problem is perhaps second only to Fermat's Great Theorem.

Most stars, including all stars on the main sequence, are in a state of hydrostatic equilibrium, when at each point of the star the gravitational force and the pressure gradient balance each other. If such a star is thrown out of balance (for example, spherically symmetrically "squeeze", and then "let go"), then the star will tend to an

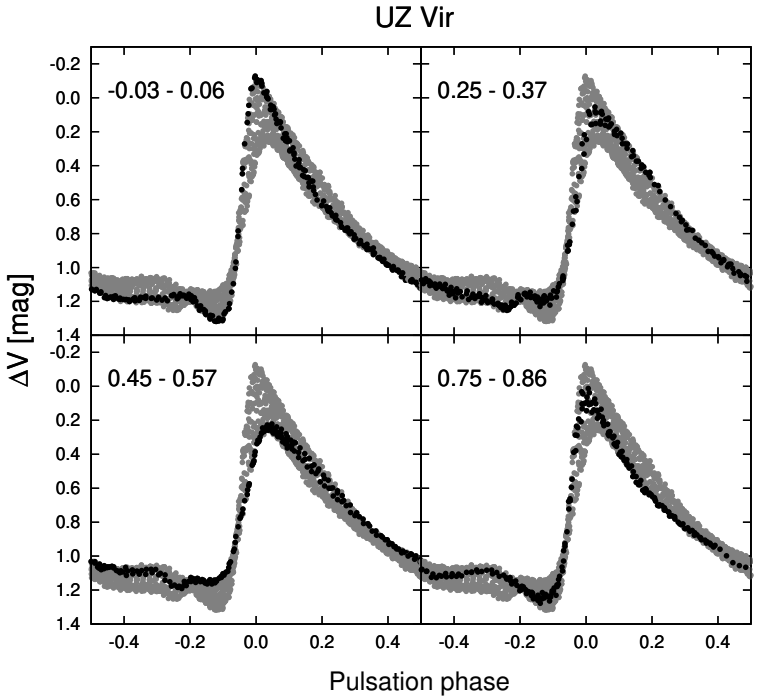



**Figure 4** An example of the Blazhko effect in UZ Virginis, a RR Lyrae variable ($P = 0.4593^{\rm d}$, $P_{\rm mod} = 68.2^{\rm d}$). Gray lines are the light curves for the entire long-term modulation cycle; black lines are for the indicated phase values. The image is taken from Sódor et al. (2012).

equilibrium state, as a result of which fluctuations will occur in it. With a spherically symmetric perturbation, the oscillations will have a radial character: all points move to, or from, the center of the star, and the velocities of all points of the star at the same distance from its center are the same. In the fundamental mode of oscillation, all points of a star move away from or approach its center at one moment in time. Of all the possible radial oscillations of a star, the period of the main mode is the largest and depends only on the average density of the star.

In addition to the fundamental mode of radial oscillations, there are overtones, when excited, the star can be divided into several concentric spherical layers. The directions of movement of matter in neighboring layers are opposite – approaching the center and moving away from it alternately. These layers are separated by spherical surfaces on which the velocity of motion of matter is zero – the so-called "oscillation nodes". The overtone number is equal to the number of nodes in its oscillation profile. The periods of oscillation in overtones are shorter than in the main mode and decrease with increasing overtone number. The specific frequency ratios depend on the structure of the star (on the distribution of pressure and density in it).

Calculations show that stars have low quality factor, and the fluctuations that occur in them quickly fade out – over several periods of fluctuations. The exception

is when conditions for the ionization or recombination of helium (less commonly hydrogen) are met in regions with a large amplitude of radial oscillations in the outer layers of a star during compression or expansion. The ionization/recombination of gas is accompanied by a sharp change in its opacity, as a result of which the radial radiation flux from the center of the star supports its oscillations (this is the so-called "kappa mechanism"). Pulsations of stars are accompanied by a change in the radius and effective temperature of their photosphere, which causes a periodic change in the brightness of the star.

Radially pulsating variables are divided into three types according to their pulsation periods. The Cepheids are the longest-period stars, with periods ranging from 1 to 20 days or more. Variables of the RR Lyrae type occupy an intermediate place. Their periods range from 0.2 to 1.2 days. The shortest-period pulsating stars have periods from 0.02 to 0.3 days. The most numerous of these are variables of the $\delta$ Scuti type. The first two types of stars are subdivided into subtypes. In addition to $\delta$ Scuti type stars, a number of other types of variable stars belong to short-period pulsating variables.

The Blazhko effect was revealed for the RR Lyrae type stars, and later it was found in some of the $\delta$ Scuti type stars. The Blazhko effect is quite common, it occurs in about half of the stars of the RR Lyrae type. The average oscillation period of stars of the RR Lyrae type is 0.5 days, and their modulation periods range from 5 to 1000 days. The typical ratio of periods is about two orders of magnitude, for example, in the prototype of this class of variables, the stars of RR Lyrae, the period of natural oscillations is 0.5668 days, and the modulation period is 41 days.

The changes observed in the Blazhko effect resemble the beats of two radial oscillations with close periods. The difference between these periods should vary from 10% for stars with the fastest Blazhko effects to 0.1% for the longest modulation. However, the theory of stellar oscillations denies the possibility of oscillations with such close periods in stars: for the structure of stars of the RR Lyra type, the ratio of the periods of the 1st overtone and the main mode of oscillation is close to 0.754, the 2nd overtone and the main mode are close to 0.68. Variable stars of this type, oscillating in the 3rd and higher overtones, are not yet known.

Over the years, several theories have been proposed to explain the Blazhko effect (the author of one of the first of them was Sergey Nikolaevich himself). It is fashionable to divide them into two groups. The first category includes theories with a good scientific basis, while the second category includes theories that either have problems with justification or lack developed calculation and modeling methods. Let us discuss them briefly.

1. Tilted magnetic pulsator model (Shibahashi, 2000) – in this model a variable star must have a sufficiently strong magnetic field, the axis of which is inclined to the axis of rotation of the star. To split the oscillations mode requires a strong enough magnetic field, which is not found in direct measurements (Kolenberg, Bagnulo, 2009). In addition, the model predicts strictly periodic modulation and symmetric five-dimensional structures in the frequency spectrum of a star's oscillations, whereas, on the contrary, in stars with Blazhko effect, there is often highly irregular modulation and asymmetric multiplexes in the frequency spectrum.

2. Rotational splitting (Nowakowski, Dziembowski, 2001). In this model there is a radial and an unradial mode of oscillations with short periods. The rotation of the star causes a fine splitting of the radial mode, but does not affect the radial mode. Modulation is due to the 1:1 resonance of these modes. The model predicts strictly periodic modulation and peaks in the frequency spectrum, which is not consistent with observations.
3. Resonance model 9:2 (Smolec, 2016). According to this model there is a 9:2 resonance between the main mode and the ninth overtone, which can cause modulation. The resulting modulation in this model can be quasi-periodic or chaotic. There are no realistic hydrodynamic calculations to support this hypothesis, but it can explain only the Blazhko effects with the shortest modulation periods.

Then there is the idea theory.

4. In the star there is a variable magnetic field, which affects the efficiency of convection in the shell of the star and causes modulation of its pulsations (Stothers, 2006). This model cannot be calculated yet.
5. In the star there are excited radial and nonradial modes close in frequency, which interact with each other non-linearly (Cox, 2013; Bryant, 2015). There are no theoretical tools for a realistic study of the interaction between these modes.

Unfortunately, theories with physical justification have been rejected, and other ideas discussed cannot be well modeled yet. Thus, even 120 years after its discovery, the Blazhko effect remains a mystery.

## 4 Conclusion

Sergey Nikolaevich Blazhko was a brilliant astronomer who worked at the Moscow Observatory and the Sternberg Astronomical Institute (SAI) for over 60 years. He founded the SAI astronomical plate collection and he was one of the first to obtain meteor spectra and record polarized radiation from the solar corona. He made a number of discoveries and inventions but the main topic of his astronomical research throughout this time was variable stars.

In the early 1930s, many young and ambitious scientists entered the field of science, including B.V. Kukarkin, P.P. Parenago, N.F. Florya, M.S. Zverev, P.G. Kulikovsky, and D.Ya. Martynov. Through their efforts, and those of astronomers at other observatories, the methodology for observing variable stars changed. Whereas previously, each astronomer primarily observed stars of personal interest, now mass observations were planned and conducted in "whole batches" from shared lists. Sergey Nikolaevich found it difficult to compete with the new generation and adopt all their new methods.

But S.N. Blazhko was an excellent teacher. His classic lecture courses and textbooks shaped the development and establishment of stellar astronomy and astrophysics not only at Moscow State University but throughout the USSR as a whole. A huge number of students studied under him. There wasn't a single astronomical

institution in the Soviet Union that didn't have at least one of his students. His students included the founders of several scientific schools at the Sternberg Astronomical Institute: stellar astronomy, variable stars, close binary systems, and others.

Blazhko never founded his own scientific school, but he was certainly the founder and patriarch of Moscow astronomy. Sergey Nikolaevich was an excellent observer; and until the end of his life, he observed the stars almost daily, and generously shared his experience with his students.

In his personal life, S.N. Blazhko was a simple, warm-hearted and charming man. He was always ready to help young scientists in word and deed, and to share his rich experience and knowledge. Many Soviet astronomers remembered his criticism and valuable advice. Sergey Nikolaevich Blazhko's responsiveness, his ability to convey to his listeners his love of science, reverent attitude to tools, observations, the content and form of presentation of scientific disciplines, as well as to the purity of the Russian language, including scientific language, made S.N. Blazhko one of the most beloved professors of Moscow University.

In 1929, Sergey Nikolaevich Blazhko was elected a corresponding member of the USSR Academy of Sciences. In 1934, he was awarded the title of "Honored Worker of Science and Technology of the RSFSR". He was twice awarded both the Order of the Red Banner of Labor and also the Order of Lenin, and three medals. He won the Stalin Prize in 1952 for writing a textbook on spherical astronomy and his textbooks have been reprinted many times (Blazhko, 1954, 1979). Minor planet 2445 and a crater on the far side of the Moon are named after him. Meanwhile, the Blazhko effect continues to fascinate theoretical astronomers.

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