LETTERS TO PROGRESS IN PHYSICS

Nikolai A. Kozyrev (1908 – 1983) — Discoverer of Lunar Volcanism

(On the 100th Anniversary of His Birth)

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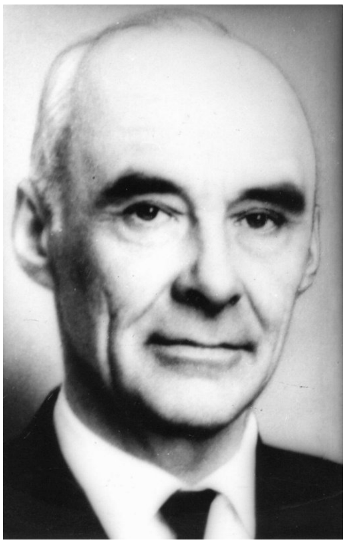
This paper draws biography of Nikolai A. Kozyrev (1908 – 1983), the Russian astronomer who was one of the founders of theoretical astrophysics in the 1930's, and also discovered Lunar volcanism in 1958.



Nikolai A. Kozyrev, the 1970's

Of theories of the internal structure of stars and stellar energy sources scientists nowadays do not show as much interest as in the twenties and thirties of the past century. Interest at that time is explained by the situation then, when thinking about the nature of stellar energy was grounded in the study of the tremendous energy of the atomic nucleus, then new. Already, at the beginning of that century, hypotheses about the structure of the atom had been put forward. That encouraged physicists to study the deep secrets of the atom and its energy. By the end of the 1920's it became a widespread notion amongst astrophysicists that the generation of energy in stars is connected with sub-atomic processes in the chemical elements of which a star is composed. By the end of the 1930's, theoretical physicists had advanced some schemes for nuclear reactions which might explain energy generation in stars, to account for the energy expenditure of a star through radiation into space. Kozyrev's university study and the beginning of his scientific activity was undertaken in the 1920's. Very soon he became known as a serious physicist, and also as an outstanding planetologist. The young scientist had taken a keen interest in the fashionable problem of the origin of stellar energy, but he solved this problem more generally, encompassing not only stars, but also planets and their satellites. He proposed the hypothesis that the genesis of the internal energy of celestial bodies is the result of an interaction of *time with substance*. The discovery of volcanic activity in the Moon, made by Kozyrev when aged fifty, served to confirm his hypothesis. This discovery holds an important place in astronomical history, since a period of some 300 years of telescopic observations until then had not revealed volcanic activity on the Moon; the Moon being regarded as a "dead" heavenly body. Nikolai Kozyrev is rightly considered to be the discoverer of lunar volcanism.

Nikolai Aleksandrovich Kozyrev was born on August, 20 (2nd of September by the New Calendar) 1908, in St. Petersburg, into the family of an engineer, Alexander Adrianovich Kozyrev (1874–1931), a well-known expert in his field, at the Ministry of Agriculture, and who served in the Department of Land Management engaged in the hydrology of Kazakhstan. Originating from peasants of the Samara province, Kozyrev senior, who was born in Samara, was appointed to the rank of Valid State Councillor, in accordance with the 'tables of ranks' in Imperial Russia, which gave to him, and to his family, the rights of a hereditary nobleman. N. A. Kozyrev's mother, Julia Nikolaevna (1882–1961), came from the family of Samara merchants, Shikhobalov. A. A. Kozyrev had three more children: two daughters — Julia (1902–1982); Helena (1907–1985); and a son, Alexei (1916–1989).

Upon finishing high school in 1924, Nikolai Kozyrev went on up to the Pedagogical Institute, and thence, under the insistence of professors at the Institute, was admitted to the Physical and Mathematical Science faculty of Leningrad University, to become an astronomer. He finished university in 1928 and went on to postgraduate study at Pulkovo Observatory.

At the same time two other Leningrad University graduates went on to postgraduate study at Pulkovo — Victor A. Ambartsumian and Dmitri I. Eropkin. Academician Aristarch A. Belopolsky became the supervisor of studies of all three.

The "inseparable trinity" has left its imprint on the Pulkovo Observatory. Each of them was endowed with much talent,

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but they differed in character. Life at Pulkovo proceeded separately from "this world", monotonously and conservatively, as in a monastery: astronomical observations, necessary relaxation, processing of observations, rest before observations, and the constant requirement of silence. The apartments of the astronomers were located in the main building of an observatory, in the east and west wings, between which there were working offices and premises for observations — meridian halls and towers with rotating domes.

The low salary was a principal cause of latent discontent. The protests of the three astrophysicists supported many employees of the Observatory, including the oldest — Aristarch A. Belopolsky.

After postgraduate study, in 1931, Ambartsumian and Kozyrev were appointed to the staff of the observatory as scientific experts category 1. The direction taken by the work of their supervisor is reflected in the character of the publications of the young scientists. But an independent approach was also outlined in these works in the solving of solar physics problems. Their work in the field of theoretical astrophysics was already recognized thanks to the writings of Milne, Eddington, and Zanstr, which they quickly developed on the basis of the successes of quantum mechanics, of the theory of relativity and of atomic and nucleus physics, was quite original. Ambartsumian and Kozyrev closely connected to a group of young theoretical physicists working at universities and physico-technical institutes: George A. Gamov (1904–1968), Lev D. Landau (1908–1968), Dmitri D. Ivanenko (1904–1994), Matwey P. Bronstein (1906–1938). Gamov, Landau and Ivanenko, along with their works on physics, were publishing articles on astrophysics. Ivanenko and Bronstein frequently visited Pulkovo for 'free discussions' of the essential problems of theoretical physics and astrophysics [1]. It was an original "school of talent".

Ambartsumian taught university courses in theoretical physics (for astrophysicists) and theoretical astrophysics. Kozyrev read lectures on the theory of relativity at the Pedagogical Institute. Both participated in working out the problems of a developing new science — theoretical astrophysics.

Courses of study in physics and astrophysics are essentially various. The study of the physics of elementary processes of interaction of matter and radiation is in astrophysics a study of the total result of processes in huge systems that stellar atmospheres as a whole represent. In such difficult systems the process of elementary interaction is transformed into the process of transfer of radiation (energy) from a star's internal layers to external ones, whence radiation leaves for space. The study methods are also various. In physics, a directed action of radiation on matter is possible, and the researcher operates by this action, and the studied process can be modified by the intervention of the researcher. In astrophysics intervention is impossible: the researcher can only observe the radiations emitted into space, and by the properties of observable radiation conjecture as to the internal processes of a star, applying the physical laws established in terrestrial conditions. Meaningful conclusions can be made by means of correctly applied theory. Study within these constraints is of what theoretical astrophysics consists.

The problem cannot be solved uniformly for all objects because astrophysical objects are very diverse. The process of transfer of radiation (energy) in stars of different spectral classes does not occur by a uniform scheme. Still more diversity is represented by stars of different types: stationary, variable, and non-stationary. Besides the stars, astrophysical objects include the planetary nebula, diffuse nebula (light and dark), white dwarfs, pulsars, etc. Theoretical astrophysics is a science with many branches.

From Kozyrev's early publications it is necessary to single out articles about the results of spectro-photometrical studies of the solar faculae and spots on the basis of his own observations. One work dealt with the temperature of sun spots, another the interpretation of the depth of dark spots, and Kozyrev proved that sun spots extend to much deeper layers of the solar atmosphere than was generally believed at that time. Kozyrev's arguments have since found verification.

In 1934 Kozyrev published in *Monthly Notices of the Royal Astronomical Society* a solid theoretical research paper concerning the radiant balance of the extended photospheres of stars [2]. Concerning the problem of transfer of radiant energy, atmospheric layers are usually considered as plane-parallel, for stars with extended atmospheres (photospheres), but such a simplification is inadmissible. Considering the sphericity of the photospheric layers, Kozyrev made the assumption that the density in these layers changes in inverse proportion to the square of the distance from the star's centre and corresponds to the continuous emanation of matter from the star's surface. He used available data on observations of stars of the Wolf-Rayet type and of P Cygni and theoretically explained observable anomalies, namely appearance in their spectral lines of high ionization potentials, which demands the presence of considerably more heat than actually observed on the surface of these stars. In the issue of the above-mentioned Journal, S. Chandrasekar's paper, containing the more common view of the same problem, was published, although received by the Journal half a year after Kozyrev's paper. The theory is called the "theory of Kozyrev-Chandrasekar".

A considerable part of the work during the Pulkovo period was carried out by Kozyrev and Ambartsumian. Together with Eropkin, Kozyrev published two articles containing the results of their expedition research work on polar lights by a spectral method; luminescence of the night sky and zodiac light. Research on the terrestrial atmosphere in those years was rather physical. However, works of a geophysical character stood outside the profile of the astronomical observatory; besides, these works demanded considerable expenditure that led to conflict with observatory management.

In May 1934, Belopolsky died — to the end a defender

Nikolai Kozyrev, 1934

of his pupils. Ambartsumian, in the autumn of 1935, had moved to Leningrad university. The "trinity" has broken up. The Director of Pulkovo Observatory, Boris P. Gerasimovich (1889–1937) decided to remove the two remaining "infractors of calmness". An infringement of financial management during the Tadjik expedition was fashioned into a reason for the dismissal of Dmitri Eropkin and Nikolai Kozyrev. In those years appointment and dismissal of scientific personnel of the observatory were made not by the director, but only with the permission of the scientific secretary of the Academy of Sciences, who upheld the action of the Director. A subsequent investigation for the reinstatement of Eropkin and Kozyrev conducted by the National Court and the commission of the Presidium of the Academy of Sciences occupied more than half a year.

In the meantime, in October, 1936, in Leningrad, arrests of scientists, teachers of high schools, and scientific officers had begun. One of the first to be arrested was the corresponding member of the USSR Academy of Sciences, Boris V. Numerov (1891–1941), the director of the Astronomical Institute, an outstanding scientist in the field of astronomy and geodesy. He was accused of being the organizer of a terrorist anti-Soviet group amongst intellectuals [3].

The wave of arrests reached Pulkovo. Kozyrev was arrested on the solemn evening of the 19th anniversary of October revolution, in the House of Architects (the former Jusupovsky palace). The choice of the date and the place of the repressive operation was obviously made for the purpose of intimidation of the inhabitants. On the night of December 5th (Day of the Stalin Constitution, the "most democratic in the world") Eropkin was arrested in Leningrad. These "red dates" are not forgotten in Pulkovo: all victims of the repression are not forgotten.

The Director of the observatory, Boris P. Gerasimovich was arrested at night, between the 29th and 30th of June 1937, in a train between Moscow and Leningrad. On November 30, 1937, Gerasimovich was sentenced to death and was shot that same day.

The Pulkovo astronomers, arrested between November and the following February, were tried in Leningrad on May 25, 1937. Seven of them, Innokentiy A. Balanovsky, Nikolai I. Dneprovsky, Nikolai V. Komendantov, Peter I. Jashnov, Maximillian M. Musselius, Nikolai A. Kozyrev, Dmitri I. Eropkin; were each sentenced to 10 years imprisonment. The hearings lasted only minutes, without a presentation of charges, without legal representation, with confessions of "guilt" extracted by torture — no hearings, only sentence.

According to the legal codes at the time, the 10 year imprisonment term was the maximum, beyond which was only execution. However, almost all the condemned, on political grounds, were died before the expiry of the sentences. Of the condemned Pulkoveans, only Kozyrev survived.

Boris V. Numerov was sentenced 10 years imprisonment and whilst serving time in the Oryol prison, was shot, on September, 15th, 1941, along with other prisoners, under the threat of occupation of Oryol by the advancing fascist army.

In Pulkovo arrests of the wives of the "enemies of the people", and other members of their families, had begun. It is difficult to list all arrested persons. They were condemned and sentenced to 5 year terms of imprisonment.

Until May 1939, Kozyrev was in the Dmitrovsk prison and in the Oryol prison in the Kursk area, then afterwards he was conveyed through Krasnoyarsk into the Norilsk camps. Until January 1940, he laboured on public works, and then, for health reasons, he was sent to the Dudinsky Permafrost Station, as a geodesist. In the spring of 1940 he made topographical readings of Dudinka and its vicinities, for what Kozyrev was permitted free activity, for to escape there was no possibility: the surrounds were only tundra.

In the autumn of 1940 he worked as an engineer-geodesist, and from December 1940 was appointed to Chief of Permafrost Station. On October 25, 1941, "for engaging in hostile counter-revolutionary propaganda amongst the prisoners" he was again arrested, and on January 10, 1942, he was sentenced to an additional 10 years imprisonment. On the same charges, Dmitri I. Eropkin had been condemned repeatedly, and was shot in Gryazovetsky prison of the Vologda area, on January 20, 1938 [3].

The Supreme Court of the Soviet Russia reconsidered the sentence on Kozyrev as liberal one and replaced it with death execution. But the Chief of the Noril-Lag (a part of the well-known GULAG) tore up the order of execution before the eyes of Kozyrev, referring to the absence in the regional centre, Dudinka, of any "executive teams". Probably, in all reality, this was a theatrical performance. Simply, Kozyrev was needed, as an expert, for the building of a copper-nickel integrated facility, as another nickel mine near the Finnish border was then located within a zone of military action.

After the court hearing Kozyrev was transported to Norilsk and directed to work on a metallurgical combine as a thermo-control engineer. By spring of 1943, owing to his state of poor health, Kozyrev was transferred to work at the Norilsk Combine Geological Headquarters as an engineer-geophysicist. Until March 1945, he worked as the construction superintendent for the Hantaysky lake expedition and as the Chief of the Northern Magneto-Research Group for the Nizhne-Tungus geology and prospecting expedition.

Some episodes of the prison and camp life of Nikolai A. Kozyrev testify to his intense contemplations during this period. Certainly, some stories, originating from Kozyrev himself, in being re-told, have sometimes acquired a fantastic character.

The episode concerning Pulkovo's *Course of Astrophysics and Stellar Astronomy* [4] whilst being held in Dmitrovsky Central (the primary prison in Dmitrov city), is an example. Being in a cell for two people, Kozyrev thought much of scientific problems. His mind went back to the problem of the source of stellar energy. His cell-mate had been sent to solitary confinement for five days and when he returned he was very ill, and died. Kozyrev was then alone in his cell. He was troubled by the death of this cell-mate and his thoughts ceased to follow a desirable direction. A deadlock was created: there were no scientific data which could drive his thoughts. He knew that the necessary data were contained in the second volume of the *Course of Astrophysics*. Suddenly, in a day of deep meditation, through the observation port of his cell was pushed the book most necessary — from the *Course of Astrophysics*.

By different variants in the re-telling of the tale, the prisoner used the book for between one and three days, thumbing through it and memorising the necessary data. Then the book was noticed by a prison guard, and as it was deemed that the use of such specialist material literature was not allowed, the book was taken from him. Kozyrev thought that this book ,which so casually appeared, was from the prison library. That is almost impossible: someone delivered to the prison the special reference book, published in such a small circulation? Was there really a book in the hands of the prisoner or it was a figment of his tormented and inflamed imagination? Most likely mental exertion drew from his memory the necessary data. Something similar happens, sometimes, to theoreticians, when some most complicated problems steadfastly occupying the brain, are solved in unusual conditions, for example, as in a dream.

Another episode: consumed by his thoughts, Kozyrev began to pace his cell, from corner to corner. This was forbidden: in the afternoon the prisoner should sit on a stool, and at night lie on his bunk. For infringement of the rules Kozyrev was sent to solitary confinement for five days, in February 1938. The temperature in the confinement cell where daylight did not penetrate, was about zero degrees. There the prisoners wore only underwear, barefooted. For a meal they got only a piece of black bread and a mug of hot water per a day. With the mug it was possible to warm one's freezing hands but not the body. Kozyrev began to intensely pray to God from which he derived some internal heat, owing to which he survived.

Upon his release from solitary, Kozyrev reflected, from where could the internal heat have come? Certainly he understood that in a live organism the heat is generated by various vital processes and consumption of food. And it happens that a person remains vigorous and efficient, rather long term, without consumption of food, and "lives by the Holy Spirit"? What is Holy Spirit? If He pours in energy then energy can appear through Him, in a lifeless body. What factor of universal character can generate the energy? So Kozyrev's "time theory", advanced by him twenty years later, thus arose.

Both episodes contain mystical elements, but the mysticism accompanied Kozyrev both in imprisonment and in freedom, both in his life and in his scientific activity.

In June 1945 Kozyrev was moved from Norilsk to Moscow for "choice jugée revision". According to the official enquiry [3], choice judgée revision was made under the petition of academician Grigory A. Shayn, requesting liberation of the exiled Kozyrev, for his participation in restoration of astronomical observatories that were destroyed during the war; in Pulkovo, Simeis, Nikolaev, and Kharkov. However the petition of the academician was too weak an argument. Previously, in 1939, the academicians Sergey I. Vavilov and Grigoriy A. Shayn petitioned for revision of the choice jugées of the Pulkovo astronomers, not knowing that some of them were then already dead. The petition by the outstanding academicians was of no consequence.

The petition which was sent to the Minister of Internal Affairs, in August 1944, and registered with the judicial-investigatory bodies as the "letter of academician Shayn", but had actually been signed by three persons [5], namely, the full members of the Academy of Sciences of the USSR, Sergei I. Vavilov and Gregory A. Shayn, and by the correspondent-member of the Academy, Alexander A. Mihailov, the Chairman of the Astronomical Council of the Academy. This petition concerned only Kozyrev. The fate other condemned astronomers was known only to elements of the People's Commissariat of Internal Affairs. The petition for liberation of Kozyrev was obviously initiated those elements of the People's Commissariat of Internal Affairs. How to explain this?

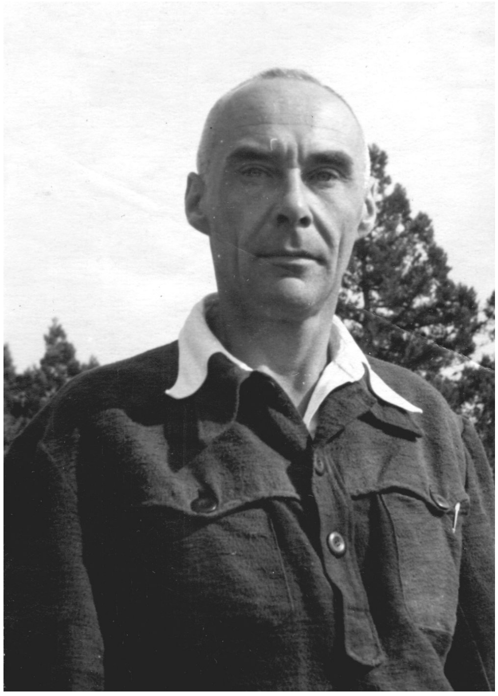
When the Soviet intelligence agencies had received information about research by the USA on the creation of nuclear weapons, the State Committee of defence of the USSR made, in 1943, a secret decision on the beginning of such works in the USSR. As the head of the programme had been appointed Laurentiy P. Beriya, the National Commissar of Internal Affairs [6, p. 57]. Many physicists were in custody. Many were already dead. Those who still lived in prison camps it was necessary to rehabilitate. Kozyrev numbered amongst them.

The "choice jugée revision" is an unusual process, almost inconceivable then. It was a question of overturning the decision of Military Board of the Supreme Court of the USSR, the sentences of which then were not reconsidered, but categorically carried out. The decision was made in the special prison of the People's Commissariat of Internal Affairs on Lubyanka (called then the "Felix Dzerzhinsky Square", in the centre of Moscow) where Kozyrev was held for one and a half years. At last, by decision of a Special Meeting of the KGB of the USSR on December 14, 1946, Kozyrev was liberated "conditionally ahead of schedule". This meant that over Kozyrev's head still hung the sentence of the Taymyrsky court, and with the slightest pretext he could appear again behind bars. Only on February 21, 1958, was the sentence of the Taymyrsky court overruled and Kozyrev completely rehabilitated.

After liberation Kozyrev has spent some days in Moscow that were connected mainly with an employment problem. Gregory A. Shayn, appointed in December 1944 as the Director of the Crimean Astrophysical Observatory (CrAO) then under construction, invited him to work in the Crimea. Kozyrev agreed. He devoted himself once again to scientific work.

But first he went to Leningrad for a meeting with kinsfolk and old friends, for restoration of scientific communications and, primarily, to complete work on his doctoral thesis, the defence of which took at Leningrad University on March 10th, 1947, i.e. only two and a half of months after his liberation. Many colleagues were surprised; when did he have time to write the dissertation? But he had more or less composed the dissertation during his ten years in prison. The strange episodes which occurred in Dmitrovsky Central had been connected with its theme. Kozyrev had some free time in Taymyr, when he was free to wander there for the one and a half years he worked as the Chief of the Topographical Group, and as the senior manager of the Permafrost Station. Besides, during his stay in Lubyanka, the possibility of being engaged within a year on the dissertation with use of the specialist literature been presented itself to him. Then he could write down all that at he had collected in his head. After liberation, possibly, it was only necessary to "brush" the draft papers.

Defence of the dissertation by Kozyrev occurred at the Department of Mathematics and Mechanics of Leningrad University: the dissertation theme, *Sources of Stellar Energy and the Theory of the Internal Constitution of Stars*. Attending as official examiners were the corresponding member of the Academy of Sciences of the USSR, Victor A. Ambartsumyan, professor Cyrill F. Ogorodnikov, and Alexander I. Lebedinsky. As a person working, after demobilization, at the Astronomical Observatory of Leningrad University, I was permitted to be present at this defence. Discussion was rather animated, because, beyond the modest name of his dissertation, Kozyrev put forward a new idea as to the source of the stellar energy, subverting the already widespread conviction that thermonuclear reactions are the source of energy in the entrails of stars. The discussion ended with a voting in favour of the Author's dissertation. On this basis the Academic Council of the University conferred upon Kozyrev the award of Doctor of Physical and Mathematical Sciences (the Soviet ScD), subsequently ratified by the Supreme Certifying Commission.



Kozyrev in Crimean Observatory, after the liberation

Kozyrev's dissertation was published in two parts, in the *Proceedings of the CrAO* [8], in 1948 (a part I), and in 1951 (a part II).

With scheme for nuclear reactions in the Sun and stars proposed by the German theoretical physicist Hans Bethe, in 1939, the question of stellar energy sources seemed to have been solved, and so nobody, except Kozyrev, reconsidered the problem.

Arguing by that the age of the Earth means that the Sun has already existed for some billions of years, and intensity of its radiation has not changed for some millions of years, which geological and geophysical research testifies, Kozyrev concluded the Sun is in a rather steady state, both in its mechanical and its thermodynamic aspects. This necessitates a study of the sources of its energy by which it is able to operate continuously for millions, even billions, of years.

Certainly the character of the source depends on the internal structure of the Sun (a star). Theories of the internal structure of stars are constructed on the basis of many assumptions about a star's chemical composition (percentage of hydrogen and other chemical elements), about the ionization conditions, about the quantity of developed energy per unit mass per second, about the nature of absorption of radiation, etc. The reliability of all these assumptions is determined by comparison of the theoretical conclusions with the data of observations.

The key parameters of a star are its luminosity L, its mass M and its radius R. Kozyrev deduced theoretical dependencies of type M-L and L-R, and compared them with observable statistical dependencies "mass-luminosity" and "luminosity — spectral class" (Herzsprung-Russell diagram). The spectral class is characterized by the star's temperature, and the temperature is connected through luminosity with the star's radius (Stefan-Boltzman's law), i.e. the observable dependence of type L-R obtains. Comparison of the theoretically derived dependencies with observations statistically leads to the conclusion that the temperature at the centres of stars of the same type as the Sun does not exceed 6 million degrees, whereas the temperature necessary for reactions of nuclear synthesis is over 20 million degrees.

Moreover, by comparison of theoretical indicators of energy generation in a star and the emitted energy, these indicators are cancelled out by a star. Hence, in the thermal balance of a star, the defining factor is the energy emitted. But the estimated energy generation of thermonuclear reactions (if they operate in a star) far exceeds the observed emitted energy. Thus, reactions of nuclear synthesis are impossible because of insufficient heat in the stellar core (a conclusion drawn in the first part of Kozyrev's dissertation), and are not necessary (a conclusion of the second part).

Kozyrev drew the following conclusions: 1) a star is not a reactor, not a nuclear furnace; 2) stars are machines that develop energy, the emitted radiation being only a regulator for these machines; 3) the source of stellar energy is not Einstein's mass-energy interconversion, but of some other combination of the physical quantities. He also wrote that the "third part of this research will be devoted to other relations". Kozyrev held that stellar energy must be of a non-nuclear source, and must be able to operate for billions years without spending the mass of a star. The energy generation should not depend on temperature, i.e. the source should work both in stars, and in planets and their satellites, generating the internal energy of these cooler bodies as well. Accordingly, Kozyrev carried out observations, in order to obtain physical substantiation of his fundamental assumptions.

Kozyrev paid special attention to observations of the Moon and planets. About that time the 50-inch reflector, which Kozyrev grew so fond of, had been installed at the Crimean Observatory.

In 1954 Kozyrev published the paper *On Luminescence of the Night Sky of Venus* on the basis of spectral observations made at the Crimean Observatory in 1953. The observations for the purpose of recording the spectrogram of the night sky of a planet possessing a substantial atmosphere, required great skill: it was necessary to establish and keep on a slit of the spectrograph the poorly lighted strip to be completely fenced off from the reflected light of the day side of the planet, the brightness of which is 10,000 times the luminescence of the night sky. Dispersion of light from the horns of the bright crescent extend far into the night part, and can serve as the source of various errors, as the exposure must be long, to embody on a photographic plate the spectrum of the weak luminescence of the atmosphere of the planet. His observations went well; their processing and interpretation led to the detection of nitrogen in the atmosphere of Venus in the form of molecules N_2 and N_2^+.

The English astrophysicist Bryan Warner, in 1960, on the basis of a statistical analysis of Kozyrev's observations, proved identification of nitrogen and, additionally, that part of the spectral lines belong to neutral and ionized oxygen [9]. The presence of nitrogen and oxygen on Venus was definitely verified by direct measurements of its atmosphere by the interplanetary space missions "Venus-5", "Venus-6" (1969) and in the subsequent missions.

The observations of Mars in opposition, 1954 and 1956, inclined Kozyrev to the new conclusions concerning the Martian atmosphere and polar caps. Studying the spectral details of the planet's surface, he has come to the conclusion that observable distinction of the colour of continents and the seas on Mars can be explained by optical properties of the Martian atmosphere. This contention drew sharp objections from Gabriel A. Tihov, the well-known researcher of Mars. The scientific dispute remained unresolved. Kozyrev reasoned, that the polar cap observed in 1956 was an atmospheric formation, similar to "hoarfrost in air". Independently, Nikolai P. Barabashev and Ivan K. Koval (1956), and later also Alexander I. Lebedinsky and Galina I. Salova (1960), came to similar conclusions.

Kozyrev systematically surveyed with spectrograph various sites on the Moon's surface. The purpose of such inspections was to look for evidence of endogenetic (internal) activity which, as Kozyrev believed, should necessarily exist in the Moon. With the help of spectrographs it is possible to locate on the surface the sites of gas ejection, and he was sure that, sooner or later, he would see such phenomena.

In the beginning of the 19th century, William Hershel had reported observation of volcanoes on the Moon. François Arago later showed that visual observations do not permit detection of eruption of a lunar volcano as in the absence of atmosphere the eruption is not accompanied by ignition and luminescence. Kozyrev however approached the question with a belief in the existence of a "cold source" of energy in stars and planets.

His dissertation is devoted to the energy sources of stars. Concerning accumulation and action of the internal energy of planets, Kozyrev had expounded in the years 1950–1951 in the articles *Possible Asymmetry in Llanetary Figures* [10] and *On the Internal Structure of the Major Planets* [11].

The Moon does not differ from the planets in that the non-nuclear energy source should exist in the Moon as well. Its continuous operation should lead to accumulation of energy which will inevitably erupt onto the surface, together with volcanic products, including gas. The gas can be observed with the help of the spectrograph. Before Kozyrev nobody used such methods of observation of the Moon. Difficulties in the observations are due to the necessity of catching the moment of emission because the ejected gas will quickly dissipate. The gases ejected by terrestrial volcanoes consist of molecules and molecular composites. The temperature of eruptions on the Moon cannot be higher. At successful registration the spectrogram should embody the linear spectrum of the Sun, reflected by the Moon, and molecular bands superimposed upon this spectrum, in accordance with the structure of the emitted gas.

Kozyrev found that luminescent properties are inherent to the white substance of the beam systems on the Moon. Supporters of the theory of a volcanic origin of craters on the Moon consider that the beam systems are recent formations of volcanic origins. One night in 1955 the crater Aristarkh differed in luminescence, exceeding the usual by approximately four times. It was possible to explain the strengthening of the luminescence by the action of a corpuscular stream as the light stream from the Sun depends only on inclination of the solar beams to the Moon's surface. As a stream of the charged corpuscles is deviated by a magnetic field, the luminescence should be observed on a dark part of the lunar disc that was not marked. Hence, "the Moon does not have a magnetic field" [12].

Kozyrev had drawn this conclusion three to four years prior to spacecraft missions to the Moon (1959). The discovery of an absence of a magnetic field for the Moon is considered an important achievement of astronautics. But in those years the prediction made by Kozyrev, went unnoticed, as did the results of his research on the atmosphere of Venus.

Also went unacknowledged was his doctoral dissertation which concluded an absence of thermonuclear synthesis in stars. It would seem that his work should have drawn the attention of physicists and astrophysicists in connection with Raymond Davis' experiments on the detection of the solar neutrino.

In 1946 Bruno Pontekorvo described a technique of neutrino detection through physical and chemical reaction of transformation of chlorine in argon. Any thermonuclear reactions are accompanied by emission of neutrino or antineutrino. R. Davis organized, in the 1950's, a series of experiments on the basis of Pontekorvo's method. The observations revealed little evidence for the expected reaction, in accordance with an absence of thermonuclear reactions in the Sun's entrails as had been predicted by Kozyrev.

Throughout the years 1967–1985, Davis continued experiments to measure neutrino streams from the Sun, with an advanced technique. Results were no better: the quantity of detected neutrinos did not surpass one third of the theoretically calculated stream. In the 1990's the experiments were performed in other research centres by other means, reaffirming Davis' results. The Nobel Prize [13] was awarded to Raymond Davis in 2002.

From August 15th, 1957, Kozyrev began to work at Pulkovo Observatory in the same post of senior scientific researcher. He had received a small apartment in Leningrad, on the Moscow Prospect, on a straight line connecting the city with Pulkovo. Twice a year he went to the Crimea to carry out observations, in the spring and autumn, with the 50-inch reflector.

In August, 1958 Kozyrev published his book *Causal or Asymmetrical Mechanics in the Linear Approximation* [14], where he generalized the results of laboratory experiments and astrophysical observations to a conclusion on the non-nuclear energy source of stars. It was a continuation of his thesis for his doctor's degree. Thus, this third part is in style and character very unlike the first two. Discussion of this book began before the death of Kozyrev, and continues.

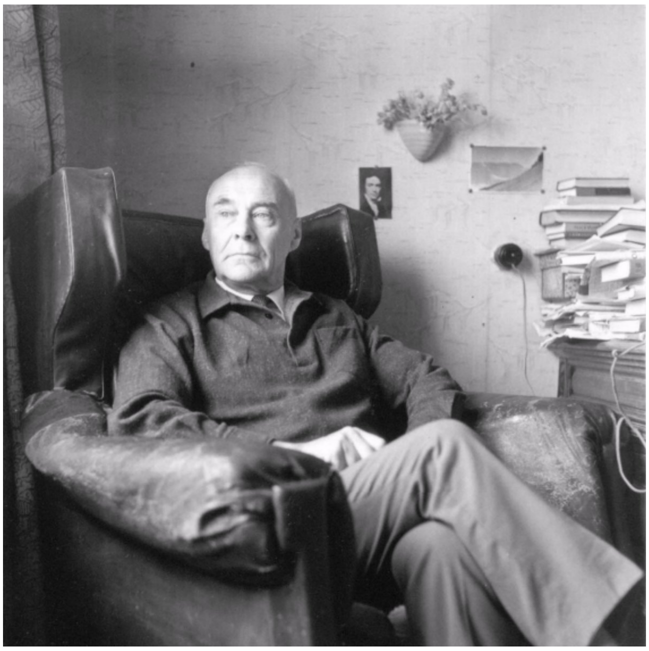
The non-nuclear energy source of stars and planets is attributed in Part III to time. Kozyrev however did not explain what time is, but asserted that time proceeds by physical properties, and he tried to reveal them. He believed that in rotating celestial bodies, time makes energy, which he tried to prove experimentally by weighing of gyroscopes at infringement of the usual relationships between cause and effect.

To consolidate his ideas about transformation of time into energy Kozyrev tried to create a corresponding theory. Postulating an infinitesimal spatial interval between cause and effect, and the same time interval between them, he defines the relation of these intervals as the velocity of transition of a reason into a consequence. After a series of postulates, Kozyrev defined the course of time as the speed of transition of a reason in a consequence, and designates it c_2, unlike the velocity of light c_1. He considered that c_2 is a universal constant, as well as c_1; the value of c_2 he finds experimentally and theoretically, as $c_2 = 1/137c_1$, where 1/137 is dimensionless value equal to Sommerfeld's fine structure constant. Besides that

$$c_2 = a\,\frac{e^2}{h} = a \cdot 350 \text{ km/sec},$$

where e is the elementary charge, h is Planck's constant, a a dimensionless multiplier which is subject to definition.

To describe the character of interaction of the causes and effects by means of mathematical formulae, Kozyrev gave to these phenomena the sense of mechanical forces: reason is active force, and effect is passive force. Thereby Kozyrev *materialized* these concepts just as the definition of force includes mass. Though cause and effect phenomena had already been *materialized* by postulation of the spatial and time intervals between them, Kozyrev used representations about the compactness of bodies and the impossibility of the simultaneous location of two bodies at one point of space. In the same manner Kozyrev also materialized time, or the *course of time*, owing to which there is an intermediate force $\frac{mdv}{dt}$ between the active and passive forces. Values of m and v are not



Kozyrev at home, in Leningrad

explained. Nor does Kozyrev explain how the course of time causes the occurrence of the additional force. It was simply a postulate, which he had not formulated. The *materialization* of causes and effects is also just postulated.

The long chain of postulates included in the long theoretical reasoning is reduced to a statement about the subliminal *flow of time* which exists from extreme antiquity. Directly about the flow Kozyrev does not write; but if the *course of time* proceeds by mechanical force, then the force, over some distance, does work. So the river flow actuates a water-mill.

That is why, according to Kozyrev's theory, energy is created at the expense of time only in rotating bodies. To prove this thesis experimentally, Kozyrev engaged in experiments with gyroscopes, to which a separate chapter in his book is devoted. Later, Kozyrev reconstructed the theory on the basis of Einstein's theory.

The physical essence of the *course of time* nobody has been able to elucidate. However there are no bases to deny that time action promotes energy generation in stars and planets, as Kozyrev's theory specifies. Kozyrev's discovery of lunar volcanism, as a result of his persevering research on the basis of his own theory, also specifies that.

On November 3, 1958, at the Crimean observatory, Kozyrev was observing a region on the surface of the Moon for the purpose of its detecting endogenetic activity. This time Kozyrev concentrated his attention on the crater Alphons, in the central part of the lunar disc. According to American astronomer Dinsmor Alter, a haze observed in the crater Alphons prevented clarification of the details of crater [15].

Kozyrev made a pair of spectrograms. On one of them, in the background of the solar spectrum, with its specific dark lines, the light bands of molecular carbon C_2 and carbon dioxide gas CO_2 were visible. On the other spectrogram taken half an hour after the first, the bands were absent. The slit of the spectrograph crossed the crater through the central hill of the crater. Hence, the gas eruption occurred from the central hill of the crater Alphons. So the discovery was made.

Soon Kozyrev published a short letter in *The Astronomical Circular* (No. 197, 1958) and an article containing the detailed description of a technique and circumstances of the observations, with a reproduction of the unique spectrogram, in *Sky and Telescope* (vol. 18, No. 4, 1959). In response to this article the well-known astronomer and planetologist, Gerard Kuiper, sent a letter to the Director of Pulkovo Observatory in which he declared that Kozyrev's spectrogram was a fake.

From December 6 to December 10, 1960, in Leningrad and Pulkovo, there was held an international symposium on lunar research by ground-based and rocket means (the Symposium No. 14 "Moon"), assembled in accordance with the calendar schedule of the International Astronomical Union (IAU). Well-known planetologists took part in the Symposium sessions and scientists from many countries were present: Gerard Kuiper, Garald Jurys, John Grey (USA), Zdenek Copal (Great Britain), Auduin Dolfus (France), Nicola Bonev (Bulgaria), Nikolai A. Kozyrev, Alexander V. Markov, Nadezhda N. Sytinskaja (USSR), etc.

Kozyrev's report *Spectroscopic Proofs for the Existence of Volcanic Processes on the Moon* [16], with presentation of the original spectrogram, was favourably received. Concerning the decoding of the emittance spectrum which had appeared when photographing the lunar crater Alphons, the skilled spectroscopists Alexander A. Kalinjak and Lydia A. Kamionko reported. Their identification of the spectrum proved the authenticity of the spectrogram. G. Kuiper was also convinced of the validity of the spectrogram, and withdrew his claims of forgery.

Kozyrev's detection of endogenetic activity in the "dead" Moon has not received either due consideration or support in relation to his search for a "cold source" of the energy of the Earth and in stars. Kozyrev's book *Causal Mechanics*, putting forward the flow of time as an energy source, has received inconsistent responses in the press. The first was by the Leningrad publicist and physicist Vladimir Lvov, who published in the newspaper *Evening Leningrad*, from December 20, 1958, the article *New Horizons of Science*. The article's title indicates a positive reception of Kozyrev's book. Subsequently, Lvov repeatedly published in newspapers and periodicals, strengthening the arguments in favour of statements that Kozyrev's theory, in essence, amounts to discovery of a third origin of thermodynamics, which counteracts thermal death of the Universe.

In the same spirit, in *The Literary Newspaper*, from November 3rd of 1959, an article by the well-known writer Marietta Shaginyan, entitled 'Time from the big letter', was published. Meanwhile, in Pulkovo Observatory, Kozyrev's laboratory experiments, which he conducted to substantiate the conclusions of *Causal Mechanics* and his "time theory", had been organized. It was found that the experimental data did not exceed the "level of noise" and so did not reveal the effects predicted by the theory. On the basis of these results, the full members of Academy, Lev A. Artsimovich, Peter L. Kapitsa and Igor E. Tamm reported in the newspaper *Pravda*, on November 22, 1959, in the article *On the Turn in Pursuit of Scientific Sensations*, in which they condemned the article by M. Shaginjan as an "impetuously laudatory" account of the "revolution in science" made by professor Kozyrev.

The Branch of General Physics and Astronomy of the Academy of Sciences organized another more careful check of the experiments and Kozyrev's theory. The examination and analysis was made by scientists in Leningrad and Moscow, appointed by the Branch, with involvement of some Leningrad institutes. The results were discussed by the Academic Council of Pulkovo Observatory on July 1, 1961. Kozyrev's theory, detailed in the book *Causal Mechanics*, was deemed insolvent, and recommendations to improve equipment and to raise the accuracy of experimental data were given.

The book *Causal Mechanics* met with a negative reception, although it deserved some measure of positive evaluation. Kozyrev's theory as it is presented in the book is an investigation, which, before Kozyrev, nobody had undertaken. The investigation occurred in darkness, blindly, groping, producing an abundance of postulates and inconsistent reasoning. Before Kozyrev, time was mostly perceived subjectively as sensation of its flow, from birth to death. The great philosopher Immanuel Kant considered time to be the form of our perception of the external world. It is defined still now as the form of existence of matter. The modern theory of relativity has fixed this concept also, having defined time as one of the dimensions of four-dimensional space-time, by which it amplifies the idea that space and time are the *essence of the form* of the physical world. Kozyrev searched not for formal time, but for time that is actively operating.

Despite criticism of his efforts, Kozyrev continued his investigations in the same direction, following his intuition. He did not change his belief that time generates energy, only his methods of inquiry. After July 1961, Kozyrev almost entirely disengaged from experiments of mechanical character.

Kozyrev was carried along by a great interest in the laboratory study of irreversible processes which might visually reveal time action. For this purpose he designed a torsion balance, with an indicating arm rotating in a horizontal plane and reacting to external processes. Having isolated the device from thermal influences, Kozyrev interpreted any deviations of an arm from its "zero" position as the effect of time. Generally speaking, all processes in Nature are irreversible, by which the orientation of time manifests. This orientation should cause a deviation of the balance arm in one and the same direction, though deviations are possible to different angles, depending on the intensity of the process. In Kozyrev's experiments the deviation of the arm occurred in both directions (to the right and to the left), for which he devised explanations.

Intensive irreversible processes are especially evident. Cases Kozyrev used included the cooling of a heated wire or a piece of metal; the evaporation of spirit or aether; the dissolution of sugar in water; the withering of vegetation. Processes carried out near the device caused deviations the arm which could occur from electromagnetic influence, or waves in the range of ultrasonic or other. Such influences Kozyrev did not study, but any deviations of the arm he considered to be produced by time. He introduced the concept of "time density" in the space surrounding the device. He explained the balance arm deviations in both directions as the passing of a radiant time process ("time density" arises) or the absorption of time ("density" in the surrounding space goes down). What is "time density" Kozyrev did not explain. In some experiments the same irreversible process yielded different results on different days (deviations in opposite directions). Kozyrev explained this by the action of a remote powerful process deforming the laboratory experiment.

In studying irreversible processes by the methods described above, Kozyrev investigated the possibility of time shielding. Kozyrev conjectured that if time signals come from space, these signals can be captured by means of aluminium coated telescopic mirrors. This offered a method for "astronomical observations by means of the physical properties of time". In February, 1963, Victor Vasilevich Nassonov (1931–1986), a skilled engineer and expert in electronics with work experience at a radio engineering factory, visited Kozyrev's laboratory. Nassonov expressed his desire to work as a voluntary assistant to Kozyrev. As such he worked in laboratory until Kozyrev died. Nassonov immediately began improvement of equipment and introduced automatic data recordings which raised their accuracy. Nassonov usually went to laboratory in the evenings, after his work at the radio factory. Kozyrev too worked mainly in the evenings. When Kozyrev was away on observations in the Crimea, Nassonov took holiday leave from the radio factory and, at his own expense, accompanied Kozyrev. Nassonov became Kozyrev's irreplaceable assistant and close colleague.

Kozyrev worked not only in the laboratory or at home behind a desk. He did not alter his periodic trips to the Crimean Observatory where he used the 50-inch reflector. Planets and the Moon were primary objects of his observations. At any opportunity he undertook spectrographic surveys of the lunar surface for the purpose of detection of any changes characterizing endogenic activity. He noted some minor indications but did not again obtain such an expressive spectrogram as on November 3, 1958 — that was a unique find by good luck.

For observations of planets he used the configurations (opposition, elongation), most convenient for the tasks he had in mind. He took every opportunity; adverse weather the only

Nassonov and Kozyrev in front of Pulkovo Observatory

hindrance. In April 1963, Kozyrev conducted observations of Mercury when the planet was at elongation — the most remote position from the Sun, visible from the Earth. He aimed to determine whether or not hydrogen is present in the Mercurian atmosphere. Such an atmosphere could be formed by Mercury's capture of particles which constitute the solar wind; basically protons and electrons. The captured particles, by recombination, form atomic and molecular hydrogen. The task was a very difficult one. First, observations of Mercury are possible only after sunset or before sunrise, when the luminescence of the terrestrial atmosphere is weak. However Mercury is then close to horizon, and noise from the terrestrial atmosphere considerably amplified. Second, Mercury shines by reflected sunlight, in the spectrum of which the hydrogen lines are embedded. It is possible to observe the hydrogen lines formed in the atmosphere of a planet by taking into account the shift of lines resulting from the planet's motion (toward the red when receding from the observer, toward the violet on approach). This shift can be seen as distortion of a contour of the solar line from the corresponding side. In April 1963, Mercury was to the west of the Sun and was visible after sunset. Kozyrev detected the presence of an atmosphere on Mercury. In autumn of the same year, Mercury was east of the Sun, and it was observed before sunrise; its atmosphere was not detected (details are given in [17]).

By means of observations of the passage of Mercury across the Sun's disc on November 10th of 1973, Kozyrev again detected signs of an atmosphere on Mercury [18]. However his conclusion contradicted the results of direct measurements by the spacecraft "Mariner-10", in 1974–1975. This spacecraft, first sent to Venus, and then to Mercury, during a flight around the Sun, took three sets of measurements as it approached Mercury. Concerning the atmosphere of the planet, the gathered data had demonstrated that it contains helium and oxygen in minute quantities, and almost no hydrogen.

Kozyrev's disagreement with the Mariner-10 data can be explained by the instability of hydrogen in the atmosphere because of the great temperature of Mercury's Sun-facing surface (above 500°C) and by Mercury's small force of gravitational attraction (escape velocity 4.2 km/s). Observations of Kozyrev fell to the periods of capture of a corpuscular solar stream; soon the grasped volume of a stream dissipated. Anyway, Kozyrev's observations and conclusions to write-off there are no bases.

Observing Saturn in 1966, Kozyrev detected the presence of water vapour in its rings [19]. Emergence of the water bands in the spectrum of the planet, which is so removed from the Sun, Kozyrev explained as the "photosublimation" process (the term coined by Kozyrev), i.e. by the direct transformation of crystals of ice into water vapour under the influence of solar radiation. G. Kuiper an opponent, argued that the Saturnean rings consist not of the usual ice, but of ammoniac, upon which Kuiper's objections were been based, but subsequently retracted by him.

Only in 1969 did Kozyrev's discovery of lunar volcanism receive official recognition, owing to findings made by the American Apollo-11 mission on the Moon in July, 1969. Astronauts Neil Armstrong, Buzz Aldrin and Michael Collins brought back to Earth a considerable quantity of lunar soils, which consisted mainly of volcanic rocks; proving intensive lunar volcanic activity in the past, possibly occurring even now. Kozyrev's discovery has thus obtained an official recognition.

The International Academy of Astronautics (IAA, Paris, France) at its annual meeting in late September, 1969, in Cloudcroft (New Mexico, USA), made the resolution to award Kozyrev a nominal gold medal with interspersed seven diamonds in the form of constellation of the Ursa Major: "For remarkable telescopic and spectral observations of luminescent phenomena on the Moon, showing that the Moon remains a still active body, and stimulating development of the methods of luminescent researches world wide". Kozyrev was invited to Moscow for the award ceremony, where, in solemnity, the academician Leonid I. Sedov, vice-president of the International Astronautic Federation (a part of which is the IAA) gave Kozyrev the medal.

In December 1969, the State Committee for Affairs of Discovery and Inventions at the Ministerial Council of the USSR, awarded Kozyrev the diploma for discovery for "tectonic activity of the Moon".

Despite the conferring of medal and diploma, the question of a non-nuclear stellar energy source was not acknowledged. To Kozyrev the recognition of his discovery was also recognition of his work on the source of stellar energy. His theoretical research was amplified by his publication of a series of articles detailing his results, along with the formulation of his new considerations about the physical properties of time.

He no longer spoke about time generating energy in celestial bodies. In experiments with irreversible processes the properties of bodies to "emit" or to "absorb" time, forming around bodies a raised or lowered "time density" seemed to have been established, though Kozyrev did not explain how this is to be understand; but he nonetheless used the idea. It is especially strange that in works after 1958 he avoided the interpretation of time as material essence. In the seventies he gradually passed to the representation of immaterial time.

Upon the idea of time "emitting" and "absorption" is based Kozyrev's work *Features of the Physical Structure of the Double Stars Components* [20]. Therein Kozyrev did not investigate the interaction of double star components by light and other kinds of electromagnetic and corpuscular radiation; he postulated the presence of "time radiations" — the main star (primary star) radiates time in the direction of the companion-star (secondary star) owing to which the time density in the vicinity of both stars becomes identical, which finally leads to the alignment of the temperatures of both stars and their spectral classes in accordance with statistical studies of double stars.

By a similar method, Kozyrev investigated the mutual influence of tectonic processes on the Earth and on the Moon [21]. In consideration of tectonic processes Kozyrev could not neglect their gravitational interaction and put forward two kinds of interaction: 1) a trigger mechanism of tidal influences; 2) a direct causal relationship which is effected "through the material properties of time".

For comparison of lunar processes with terrestrial ones Kozyrev used the catalogue of recorded phenomena on the Moon, published by Barbara Middlherst et al. [22]. It is conditionally possible to suppose that all considerable phenomena on the Moon, observed from the Earth, are caused by tectonic processes. Records of the same phenomena on the Earth for the corresponding period (1964–1977) are easy to find. From comparison of the records Kozyrev drew the conclusion that there are both types of communication of the phenomena on the Earth and on the Moon, "independently of each other", though they are inseparable. To reinforcement his conclusions about the existence of relationships "through the material properties of time", Kozyrev referred to such relationships established for double stars, although alternative and quite obvious relations for double stars systems were not considered.

Some words are due about appearance and habits of Kozyrev. Since the age of fifty, when Kozyrev worked in Pulkovo, his appearance did not change much. He was of tall stature, well-built, gentlemanly, with a high forehead, short haircut and clean shaven, and proudly held his head high. He resembled a military man although he never served in the army, and went about his business in an army style, quickly, and at meetings with acquaintances kindly bowed whilst on the move or, if not so hastened, stopped for a handshake. He was always polite, with everybody. When operating a telescope and other laboratory devices Kozyrev displayed soft and dexterous movements. He smoked much, especially when not observing. In the laboratory he constantly held the hot tea pot and cookies: a stomach ulcer, acquired in prison (which ultimately caused his death), compelled him to take often of any food.

When at the Crimean Observatory, he almost daily took pedestrian walks in the mountains and woods surrounding the settlement of Nauchny (Scientific). He walked mostly alone, during which he reflected. Every summer, whilst on holiday, he took long journeys. He was fond of kayaking the central rivers of Russia for days on end. On weekends he travelled by motorbike or bicycle along the roads of the Leningrad region. On one occasion he travelled by steam-ship, along a tourist route, from Moscow, throughout the Moscow Sea, then downwards across the Volga to Astrakhan. He loved trips to Kiev and in to places of Russian antiquity. In the summer of 1965 Kozyrev took a cruise by steam-ship, around Europe, visiting several capitals and large cities. Separately he visited Bulgaria, Czechoslovakia, and Belgium.

In scientific work, which consumed his life, Kozyrev, even in the days of his imprisonment and exile, he, first of all, *trusted in himself*, in his own intuition, and considered, in general, that intuition is theomancy emanating from God. According to Kozyrev, postulates should represent the facts which are not the subject to discussion. Truth certainly sometime, will appear in such a form that it becomes clear to all who aspire to it.

Nikolai Aleksandrovich Kozyrev died on February 27, 1983. He is buried in the Pulkovo astronomer's memorial cemetery. Victor Vasilevich Nassonov continued some laboratory experiments with irreversible processes relating to biology. Nassonov, through overwork that could not be sustained, died on March 15th 1986, at the age of fifty-five.

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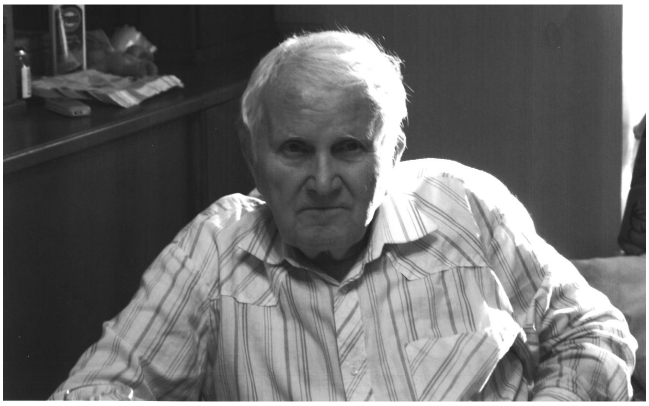

About the Author: Alexander Nikolaevich Dadaev was born on October 5, 1918 in Petrograd (now — St. Petersburg), Russia. In 1941 he completed his education, as astronomer-astrophysicists, at Leningrad University. He participated in the World War II, in 1941–1945, and was wounded in action. During 1948–1951 he continued PhD studies at Pulkovo Observatory, where he defended his PhD thesis *Nature of Hot Super-Giants* in 1951. He was the Scientific Council of Pulkovo Observatory in 1953–1965, and Chief of the Laboratory of Astrophysics in 1965–1975. Alexander N. Dadaev is a member of the International Astronomical Union (IAU) commencing in 1952. The Author would like to express his gratitude to Dr. Markian S. Chubey, the astronomer of Pulkovo Observatory who friendly assisted in the preparation of this paper.

References

1. Martynov D. Ja. The Pulkovo observatory 1926–1928. *Historical Astronomical Research*, issue 17, Nauka, Moscow, 1984 (*in Russian*).
2. Kozyrev N. A. Radiative equilibrium of the extended photosphere. *Monthly Notices of the Royal Astron. Society*, 1934, v. 94, 430–443.
3. Official data about the destiny of the Pulkovo astronomers. *Historical Astronomical Research*, issue 22, Nauka, Moscow, 1990, 482–490 (*in Russian*).
4. Course of astrophysics and stellar astronomy. Ed. by B. P. Gerasimovich. Part I. Methods of astrophysical and astrophotographic researches. ONTI, Leningrad, 1934; Part II. Physics of the Solar system and stellar astronomy. ONTI, Leningrad, 1936 (*in Russian*).
5. In protection of the condemned astronomers. *Historical Astronomical Research*, issue 22, Nauka, Moscow, 1990, 467–472 (*in Russian*).
6. Zalessky K. A. Stalin's empire. Biographic encyclopedia. "Veche" Publ., Moscow, 2000, 120 (*in Russian*).
7. Kozyrev N. A. Sources of stellar energy and he theory of the internal constitution of stars. *Proceedings of the Crimean Astron. Observatory*, 1948, v. 2, 3–13 (*in Russian*).
8. Kozyrev N. A. The theory of the internal structure of stars and sources of stellar energy. *Proceedings of the Crimean Astron. Observatory*, 1951, v. 6, 54–83 (*in Russian*).
9. Warner B. The emission spectrum of the night side of Venus. *Monthly Notices of the Royal Astron. Society*, 1960, v. 121, 279–289.
10. Kozyrev N. A. Possible asymmetry in figures of planets. *Priroda*, 1950, no. 8, 51–52 (*in Russian*).
11. Kozyrev N. A. On the internal structure of major planets. *Doklady Akademii Nauk USSR*, 1951, v. 79, no. 2, 217–220 (*in Russian*).
12. Kozyrev N. A. Luminescence of the lunar surface and intensity of corpuscular radiation of the Sun. *Proceedings of the Crimean Astron. Observatory*, 1956, v. 16, 148–158 (*in Russian*).
13. Davis R., Jr. Solar neutrinos, and the Solar neutrino problem. http://www.osti.gov/accomplishments/davis.html
14. Kozyrev N. A. Causal or asymmetrical mechanics in the linear approximation. Pulkovo Observatory, Pulkovo, 1958 (*in Russian*).
15. Alter D. A suspected partial obscuration of the floor of Alphonsus. *Publications of the Astronomical Society of the Pacific*, v. 69, no. 407, 158–161.
16. Kozyrev N. A. Spectroscopic proofs for the existence of volcanic processes in the Moon. *The Moon*, Proceedings from IAU Symposium No. 14 held in Leningrad, Pulkovo, December 1960, 263–271.
17. Kozyrev N. A. The atmosphere of Mercury. *Sky and Telescope*, 1964, v. 27, no. 6, 339–341.
18. Kozyrev N. A. The atmosphere of Mercury in observations of its passage cross the Sun's disc on November 10, 1973. *Astron. Circular*, 1974, no. 808, 5–6 (*in Russian*).
19. Kozyrev N. A. Water vapour in a ring of Saturn and its hothouse effect on a planet's surface. *Izvestiya Glavnoy Astronomicheskoy Observatorii*, 1968, no. 184, 99–107 (*in Russian*).
20. Kozyrev N. A. Relation masse-luminosité et diagramme H-R dans le cas des binaires: Physical peculiarities of the components of double stars. *On the Evolution of Double Stars*, Proceedings of a Colloquium organiced under the Auspices of the International Astronomical Union, in honor of Professor G. Van Biesbroeck. Edited by J. Dommanget. *Communications Obs. Royal de Belgique*, ser. B, no. 17, 197–202.
21. Kozyrev N. A. On the interaction between tectonic processes of the Earth and the Moon. *The Moon*, Proceedings from IAU Symposium No. 47 held at the University of Newcastle-Upon-Tyne England, 22–26 March, 1971. Edited by S. K. Runcorn and Harold Clayton Urey, Dordrecht, Reidel, 1971, 220–225.
22. Middlehurst B. M., Burley J. M., Moore P., Welther B. L. Chronological catalogue of reported lunar events. *NASA Techn. Rep.*, 1968, R-277, 55+IV pages.