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The Shklovsky phenomenon

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Joseph Samuelovich Shklovsky was born in the town of Glukhov in Ukraine. In 1933 he entered the physicsmath department of Vladivostok University and two years later transferred to the physics department of Moscow University (MGU). In 1938 this young physicist-optician was accepted as a graduate student by the astrophysics department of the P.K. Shternberg State Astronomical Institute (GAISh) at MGU, an institute with which he was to be associated his entire life. Then there followed the start of the war, evacuation to Ashkhabad (because of his poor eyesight he was not sent to the front), then his return to Moscow and GAISh, where he worked for many years at the leading edge of the post-war revolution in astronomy.

The last forty years have been characterized by unprecedented development of observational methods and technology such as radio telescopes and interferometers and infrared, ultraviolet, X-ray, and gamma-ray astronomy. New classes of objects have been discovered: radio stars, radio galaxies, quasars, infrared sources, pulsars, cosmic ray bursters, sources of gamma bursts, background radiation at all wavelengths, and, in particular, background radio radiation. "The question 'What is this?' must be central."

This is the main testament that Shklovsky left to younger researchers. He was one of the first astronomers to recognize the necessity of studying any astronomical object at all wavelengths in the electromagnetic spectrum. Only under such conditions can one hope to construct a proper model and understand the object's nature.

His study of galactic radio emissions appeared in 1947. In that same year he participated in an expedition to observe the total star eclipse in Brazil, the first such expedition to be equipped with a radio telescope. Beginning in 1950 Shklovsky took part in the first infrared observations using an image convertor. His pioneering work, *Galactic Infrared Radiation*, was published in 1953.

At MGU during the winter of 1952-53, J.S.S gave the world's first series of lectures entitled "Radio Astronomy." His audience included not only students, but also many scientists from various institutes. In his lectures Shklovsky revealed a new world; it turned out that radio waves are emitted not only by radio stations, but by practically

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all astronomical objects in the universe. The sun, moon, planets, stars, galaxies, and other as yet unknown sources are sending signals, the nature of which is strongly coupled with the unusual physical processes taking place within these objects. This radiation allows one to determine the most important parameters of those regions where the radio waves are being generated.

Shklovsky understood that new observational methods were needed if astrophysics was to master the new spectral bands. For this reason, in 1953 Shklovsky created a department of radio astronomy at GAISh which soon became an "all wavelength department."

From the very beginning, that is starting in 1957, J.S.S. took an active part in establishing and developing space research in the USSR. He understood that only through such research could astronomy truly extend all wavelengths. In the autumn of 1959, the Soviet Union's second lunar probe released a sodium cloud, thus creating an experimental "artificial comet." Solar rays acted on the sodium atoms and caused them to produce a resonance fluorescence that could easily be observed and studied from the earth. At first these experiments served as a satellite location indicator, but later they were used to study the characteristics of interplanetary medium and the upper layers of the earth's atmosphere. These experiments simulated a process already familiar to J.S.S. from the physics of the interstellar medium. In 1960 J. S. Shklovsky was awarded a Lenin prize for his "artificial comet" experiment.

In 1966 Shklovsky was elected a corresponding member of the USSR Academy of Sciences, and in 1967 he formed the department of astrophysics at the academy's newly created Space Research Institute. The department of astrophysics included laboratories studying the cosmos throughout the entire electromagnetic spectrum.

Almost all of Shklovsky's works rely first and foremost on observational data and contain new, well-defined physical ideas. Typically these works would develop a theory to that level needed to calculate the theory's probable effects and evaluate the possibility of verifying these effects observationally. J.S.S. was one of the first astronomers to analyze the fundamental connection between physical processes that determine the properties of radiation which are characteristic at different regions of the spectrum. From this foundation he created the modern theory of the solar corona. Later he carried out a detailed investigation of the spectra of galactic and extra-galactic sources and thereby identified regions of ionized gas and regions with relativistic electrons. Shklovsky's work explaining the radiation in the radio and optical spectrum of the Crab Nebula (a supernova remnant in our galaxy) via a single mechanism and an analogous work concerning the radio galaxy Virgo A were particularly significant. J.S.S. carried out another work of fundamental significance when he studied the background radio radiation left over from the epoch when the universe was in a super-dense state. This work, which was performed less than a year after the discovery of the background radiation field, explained the anomalous high intensity of the optical interstellar CN spectral lines as a result of the background radio radiation acting on the CN molecules. Thus it was proved that the background radiation truly does extend beyond the boundaries of the solar system.

Shklovsky's development of a new method to determine the distance to planetary nebulae and his determination of the fundamental physical parameters of these nebulae were especially important. This was the work that evidently caused J.S.S. to think about the variability of radio source's formed during powerful explosions. In his last

years Shklovsky returned to the problem of planetary nebulae, he proposed a hypothesis according to which the nuclei of these nebulae might be stars in a presupernova state. Cooling, they lose stability, which might lead to a supernova explosion of the first type. J.S.S. devoted an extensive series of works to the physics of explosions of supernovae, galactic nuclei, and quasars, and he studied the characteristics of the gas clouds and relativistic particles formed during such explosions. According to his hypothesis, the asymmetry of these explosions explains the high velocities of pulsars and the fact that old neutron stars must form an extended halo around galaxies. It is possible that as yet unidentified sources of gamma-ray impulses are associated with these objects. Such explosions in galactic nuclei could lead to the ejection of super-massive black holes.

Another important theme connected with Shklovsky is the development of spectral line studies in radio astronomy. In 1948, basing himself on the pioneering work by the Dutch astrophysicist H. van de Hulst, J.S.S. computed the intensity of the principal radio line (the 21-cm line) of atomic hydrogen – the main component of the interstellar medium – and showed that it could be detected. He foresaw the possibility of observing many molecules present in the interstellar medium. The four hydroxyl lines (OH) near 18-cm were detected ten years, and the CH line seventeen years, after his prediction. Shklovsky proposed a hypothesis by which molecular line radiation might be anomalously high in those regions of the Galaxy where young stars and planetary systems are being formed. These ideas also defined one of the themes of modern astrophysics.

Shklovsky played a great role in providing philosophical interpretations of the latest achievements in modem science (including astrophysics) and the related problems of extraterrestrial civilizations, man's role in the cosmos, and his role in transforming the universe. He was able to expound only a small part of his views on these problems in a series of articles and in the book *Intelligent Life in the Universe*. (M. V. Keldysh aided greatly in the publication of the latter.)

Shklovsky's great talent as an orator and philosopher, the originality of his thoughts and the simplicity of their presentation, his temperament as an orator and his goodwill toward those thirsting for knowledge, his numerous appearances before both specialists and the general public – all of this gained him both great fame and recognition.

J.S.S.'s most characteristic traits as a scientist were his limitless interest in the facts, his quest for the essentials, his striving for simplicity in understanding the phenomena of nature, and his talent for always being on the leading edge of research.

He created a school of contemporary evolutionary astrophysics that encompasses the entire spectrum. Many astronomers both in the USSR and abroad have come under his strong influence.

J.S.S. citated up to now in many scientific conferences and papers. In 2016 in Moscow was undertaken a big international conference "All-wave astronomy" commemorated to 100 years since the birth of outstanding astrophysicist J.S. Shklovsky.



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V.I. Slysh, V.G. Kurt and J.S. Shklovsky. Vnukovo, 1977