PERSONALIA

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Rashid Alievich Sunyaev (on his 70th birthday)

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Academician Rashid Alievich Sunyaev, one of the world's leading astrophysicists, celebrated his 70th birthday on 1 March 2003. His name is associated with a number of fundamental results in modern theoretical astrophysics and cosmology, which are included in all textbooks and university courses,

R A Sunyaev was born in Tashkent into a family of natives of the Penza province — a construction engineer, Ali Sunyaev, and a pharmacist, Saida Kildeeva. R A Sunyaev remembers the tremendous role his father played in the formation of his picture of the world and in the development of his interests. As a result of his origin and the exile of his family, R A Sunyaev's father did not have the possibility of working in his favorite profession, but devoted all his life to self-education; he had very broad interests and a profound respect for science and, especially, the humanities: he loved history, literature, and poetry, and knew them well. After finishing the secondary school in Tashkent, Rashid Sunyaev graduated with honors from the Moscow Institute of Physics and Technology (MIPT) in 1966.

In March 1965, Rashid Alievich met Academician Yakov Borisovich Zel'dovich, a meeting that determined Sunyaev's subsequent life. He first became Ya B Zel'dovich's graduate student and later his PhD student at MIPT and at the Institute of Applied Mathematics of the USSR Academy of Sciences. Meeting Ya B Zel'dovich and then having almost daily contact with him for the next 22 years played a crucial role in shaping R A Sunyaev as a scientist working at the interface of theory and experiment. Working with 'YaB' meant not only a never-ending process of education demanding maximum devotion from the pupil, but also the daily joy of learning the new and the unknown. Yakov Borisovich knew how to inspire his young colleagues and how to imbue in them the most profound interest in science and the belief in the capabilities of experiment. There is no doubt that R A Sunyaev could not have drawn a luckier ticket — he had a wonderful and a unique Teacher.

R A Sunyaev's interests in science cover a wide range of astrophysical issues, from the physics of elementary processes to physical cosmology. Among his results, which have become an essential part of today's astrophysics, are the 'standard' theory of disk accretion onto black holes and neutron stars (Shakura and Sunyaev 1973, 1976); the Sunyaev–Titarchuk formula (1980) for the radiation spectra generated by comptonization of low-frequency photons in hot low-density plasma; the prediction of the influence of acoustic waves in the early Universe on the angular fluctuations of the cosmic microwave background (CMB) and the spatial distribution of galaxies (1970); and the Sunyaev–Zel'dovich effect (1972), which makes it possible to use

Rashid Alievich Sunyaev

clusters of galaxies as a powerful tool of observational cosmology. Astrophysics students around the world learn Sunyaev's name in connection with these results.

The standard Shakura–Sunyaev theory of accretion disks has long been the universally accepted tool for describing matter transfer and energy release in close binary systems. The same theory is applied to describing the accretion of matter onto supermassive black holes and in protoplanetary disks. The paper by Shakura and Sunyaev (1973) on accretion theory has the highest citation index in theoretical astrophysics (5830 citations, according to NASA ADS) and one of the highest citations ever in modern astrophysics (among nearly three million publications). The accreting neutron stars and black holes are observed as powerful X-ray and gamma-ray sources. Comptonization is the main mechanism for the formation of spectra of their hard X-ray emission. The Sunyaev–Titarchuk formula became the key tool for describing the results of observations of such objects. The accuracy of the formula was confirmed by detailed computations carried out using Monte Carlo techniques (Pozdnyakov, Sobol', and Sunyaev, 1983).

The work by R A Sunyaev and Ya B Zel'dovich on physical cosmology and elementary processes in the early

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Universe laid the foundation for modern observational cosmology and helped to transform it into a 'precision' science. Forty years have passed since the publication of R A Sunyaev's and Ya B Zel'dovich's papers on the effect of the decrease in brightness of the CMB in the direction of rich clusters of galaxies. Since then, the Sunyaev–Zel'dovich effect has evolved from a beautiful theoretical idea into one of the most productive methods of observational cosmology; it opened the way to determining fundamental cosmological parameters, such as directly measuring the Hubble constant and determining the role of dark energy in the Universe. This effect was discovered and is actively being studied now in the direction of several thousand clusters of galaxies. The Planck satellite, the South Pole Telescope, the Atacama Cosmology Telescope, and the SZ-array have discovered more than a thousand previously unknown rich clusters of galaxies at redshifts $z > 0.5$ by using the fact that the brightness and frequency spectrum of the effect are independent of the redshift. In 1980, R A Sunyaev and Ya B Zel'dovich demonstrated that observations of the CMB in the directions of clusters of galaxies make it possible to measure their peculiar velocities relative to the CMB (the kinematic effect). The kinematic effect became an instrument of observational cosmology only in 2011–2012. Studies of different manifestations of the 'effect' are included in the observational programs of the largest radio telescopes.

In 1968, R A Sunyaev, Ya B Zel'dovich, and V G Kurt calculated the kinetics of hydrogen recombination in the early Universe, having shown that the rate of this process is dominated by the two-photon decay of the 2s level in atomic hydrogen. In 1970, Sunyaev and Zel'dovich noted the highly important influence of recombination delay on the formation of primary angular fluctuations of the CMB radiation and the position of the 'surface of the last scattering'. In 2006, Jens Chluba and Sunyaev calculated the spectrum of radiation reaching us from the recombination epoch — thousand-fold shifted (into the radio frequency band) UV and optical lines of hydrogen and helium atoms and ions. R A Sunyaev and Ya B Zel'dovich (1969–1970) carried out detailed studies of CMB thermalization and the formation of the Planck spectrum in the early Universe. They showed that any energy release taking place after the electron–positron annihilation and end of nuclear reactions should lead to two types of specific distortion of the CMB radiation spectrum. They were the first to establish at what redshift the surface of last scattering ($z \sim 1100$) and the 'black-hole photosphere' ($z \sim 2 \times 10^6$) of our Universe are located.

Sunyaev and Zel'dovich (1970) predicted the existence of acoustic peaks in the angular power spectrum of the CMB radiation and called them 'Sakharov oscillations'. The angular dimension and amplitudes of the first acoustic peaks are determined by the key parameters of the Universe: the Hubble constant, the baryon density, and the densities of dark matter and dark energy. In 2000, the first acoustic peaks were detected in high-altitude balloon experiments. The WMAP and Planck Surveyor satellites investigated these peaks in great depth. In the same paper, Sunyaev and Zel'dovich also predicted the existence of baryonic acoustic oscillations (BAOs) in the 3D power spectra of galaxies. Presently, BAO observations are one of the most important tools of observational cosmology.

In 1973, T M Eneev, N N Kozlov, and R A Sunyaev carried out pioneering numerical computations of the tidal interaction of galaxies. R A Sunyaev and Yu N Gnedin (1974) predicted the existence of cyclotron lines in X-ray spectra of accreting X-ray pulsars. R A Sunyaev, together with V M Lyutyi and A M Cherepashchuk (1973, 1976), explained the optical photometric effects observed in the close binary X-ray systems Her X-l = HZ Her (X-ray heating of the star and the disk) and Cyg X-l (tidal distortion of the donor star surface). M M Basko and R A Sunyaev (1973) were the first to consider the interaction of X-ray radiation with the surface of a normal star in a close binary system: the heating of the stellar surface, reflection of X-rays, and formation of induced stellar wind. In 1974, Sunyaev and Titarchuk calculated for the first time the X-ray spectrum of radiation reflected by a cold stellar atmosphere. In 1975, R A Sunyaev and A F Illarionov demonstrated the importance of the 'propeller' effect in binary systems which include a neutron star with a strong magnetic field. R A Sunyaev, together with M L Markevich and M N Pavlinskii (1993), predicted the powerful emission in the K-alpha line of iron from molecular clouds in the vicinity of a supermassive black hole within the nucleus of our Galaxy, whose front propagates at a superluminal velocity.

R A Sunyaev played the decisive role in the foundation of and progress in high-energy astrophysics and X-ray astronomy in the USSR and Russia. Having created in 1982 the Department of High Energy Astrophysics at the Space Research Institute (now IKI RAN) and having become its head, he led the selection and development of the science payload, selection of observation programs, and the data analysis and interpretation for three of the most successful astrophysical observatories ever launched in the USSR and Russia: the Roentgen Observatory aboard the KVANT module of the MIR Space Station and the Granat and Integral orbital observatories. The most exciting result of the operations of the Roentgen Observatory was the discovery of hard X-ray emission from the Supernova 1987A in the Large Magellanic Cloud, which is caused by the radioactive decay of ^{56}Co synthesized in the explosion of the star, the emission of gamma quanta, and their subsequent comptonization due to the recoil effect in the cold expanding shell. Among the results of the Granat Observatory are detailed X-ray maps of the central zone of our Galaxy, broad-band spectra of accreting black holes and neutron stars, and the discovery of dozens of new X-ray sources, including the brightest known galactic microquasars. The gamma-ray observatory Integral, launched to high-apogee orbit by a Proton rocket in 2002, continues to work successfully in orbit. Among its results is the measurement of the spectrum of annihilation emission of cold positrons near the Galactic Center (more than 10^{43} positrons annihilate every second in the interstellar gas).

R A Sunyaev is the Principal Investigator of the orbital X-ray Spectrum–Roentgen–Gamma observatory. This is the largest joint Russian–German project in astrophysics, aimed at solving the fundamental problems in cosmology: the nature of dark energy and dark matter, the formation and growth of supermassive black holes, and the search for objects of an unknown nature. If successfully implemented, this satellite will discover more than four million sources in the X-ray sky. R A Sunyaev is a Co-Investigator of the most important experiment on ESA's Planck satellite.

R A Sunyaev has been awarded a large number of prestigious prizes and awards in astrophysics and cosmology, including the Bruno Rossi Prize of the American Astronomical Society (AAS, 1989), the Gold Medal of the

Royal Astronomical Society (1995), the Sir Massey Award and Gold Medal of the Royal Society of London and COSPAR (1998), the Catherine Wolfe Bruce Gold Medal of the Astronomical Society of the Pacific (2000), the Dannie Heineman Prize for Astrophysics of the American Institute of Physics and the AAS (2003), the Gruber Cosmology Prize and the Gold Medal of the Peter and Patricia Gruber Foundation and the International Astronomical Union (2003), the Crafoord Prize in Astronomy and the Gold Medal of the Royal Swedish Academy of Sciences (2008), the Henry Norris Russel Lectureship of the American Astronomical Society (2008), the Karl Schwarzschild Medal of the German Astronomische Gesellschaft (2008), the King Faisal Gold Medal and International Prize for Science (Physics) (2009), the Kyoto Prize in Basic Sciences and Gold Medal of the Inamori Foundation (2011), and the Benjamin Franklin Medal in Physics from the Franklin Institute (2012). In 2000, R A Sunyaev received the State Prize of the Russian Federation for research on black holes and neutron stars with the Granat X-ray and gamma-ray astrophysical observatory in 1990–1998, in 2002 he received the Aleksander Friedmann Prize for Gravitation and Cosmology of the Russian Academy of Sciences, and in 2011 he was awarded the honorary title Man of the Year in Russia.

In 1984, R A Sunyaev was elected a Corresponding Member of the USSR Academy of Sciences, and in 1992 became a Full Member of the Russian Academy of Sciences. He is a Foreign Associate of the USA National Academy of Sciences, a Foreign Member of the Royal Society, London, a Member of the German Academy of Natural Sciences Leopoldina, a Foreign Member of the Royal Netherlands Academy of Arts and Sciences, an honorary member of the Tatarstan and Bashkortostan Academies of Sciences, and several other academies and scientific societies, including the American Philosophical Society.

R A Sunyaev is the scientific head of the Laboratory of Theoretical Astrophysics at the Space Research Institute of the Russian Academy of Sciences, a director of the Max Planck Institute for Astrophysics, the editor-in-chief of the journal *Pis'ma v Astronomicheskii Zhurnal* (*Astronomy Letters*), an honorary professor at Kazan State University and Ludwig-Maximillian University in Münich, an honorary member of Ioffe Physical-Technical Institute, and a Maureen and John Hendricks Visiting Professor at the Institute for Advanced Study in Princeton.

Academician Sunyaev is always in the midst of young scientists. He provides scientific leadership to an active group of bright astrophysicists at the Space Research Institute of the Russian Academy of Sciences working in the fields of X-ray astronomy and cosmology. A number of his students have become well-known experts in the fields of high energy astrophysics, theoretical astrophysics, and analysis and interpretation of the data of orbital observatories. Among them — a corresponding member of the RAS, a laureate of the Russian State Prize for young scientists, and eight doctors of science. Now, students of his students are successfully completing and defending their PhD theses.

With his characteristic energy and enthusiasm, R A Sunyaev continues his intense work covering a wide range of scientific problems. Among them are the physics of hydrogen and helium recombination in the Universe, the spectral distortions in CMB radiation, turbulent motions and physical processes in the hot gas of clusters of galaxies, the theory of the boundary layer at the surface of an accreting neutron star, the theory of disc accretion onto supermassive black holes, star formation in distant galaxies, and physical processes in the vicinity of the supermassive black hole in the Milky Way — this is just an incomplete list of his current interests.

Friends and colleagues cordially wish Rashid Alievich Sunyaev all the best and wish him new theoretical ideas, has success in his ongoing and future astrophysical projects, and makes new discoveries.

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