tion is substantial and the incident wave is effectively attenuated (over a certain length Δx):

$$C\frac{T_0}{\Delta x} \approx \frac{\omega_p^4}{\omega_0^3}\frac{I_0}{nT}J_1 k v_{Ti}, \qquad I_0 \equiv \frac{E_0^2}{8\pi}, \tag{1}$$

where J_1 is the spectral density (on the frequency interval) of the scattered radiation. We assume that the pumping wave interacts directly with the scattered radiation in an interval of width $\sim k v_{Ti}$. The subsequent evolution of J_1 is determined on the one hand by relay pumping in a range of steadily lower frequencies (due to secondary induced scattering) and, on the other, by escape of radiation from the instability band:

$$C\frac{\omega_p}{\omega_0}\sqrt{\frac{\Delta x}{L}}\frac{J_1}{\Delta x} \sim \frac{\omega_p^4}{\omega_1^3}\frac{k v_{Ti}^2}{nT}J_1\frac{dJ_1}{d\omega_1}. \tag{2}$$

We approximate relay pumping of photons across the spectrum by a differential form, in analogy with the problem of plasmon pumping, while the angular spread of the scattered radiation around 90° is taken with consideration of refraction (rotation of the wave vector) in the inhomogeneous plasma:

$$\Delta\Theta \sim \frac{\omega_p}{\omega_0}\sqrt{\frac{\Delta x}{L}}.$$

Then the scattered-radiation spectrum drops off linearly to zero from $\omega = \omega_0$ to $\omega = \omega_r$:

$$J_1 \sim \frac{I_0}{k v_{Ti}}\left(1-(\omega_0-\omega_1)\frac{\omega_0}{\omega_p k v_{Ti}}\sqrt{\frac{I_0}{nT}\frac{1}{k_0 L}}\right). \tag{3}$$

We found the constant of integration by examining the "input-output" balance due to induced scattering near the upper end point of the scattered-radiation spectrum ($\omega_0 > \omega \gtrsim \omega_0 - k v_{Ti}$). As a result, the thickness of the nonlinear-scattering region is found to be on the order of

$$\Delta x \approx \frac{C}{\omega_0}\left(\frac{\omega_0}{\omega_p}\right)^4\frac{nT}{I_0}. \tag{4}$$

The fraction of laser-wave energy absorbed by ions can be estimated as

$$\frac{\omega_0-\omega_r}{\omega_0} \approx k v_{Ti}\frac{\omega_p}{\omega_0}\sqrt{k_0 L\frac{nT}{I_0}}. \tag{5}$$

The range of validity of this model may have an upper limit at high incident-radiation intensities, when induced scattering is transformed into what is known as "modified decay." Still higher intensities $I_0/nT \gtrsim 1$ require a totally different analysis of the interaction of the radiation with the corona, since the radiation forces become basic in the gasdynamics of the corona.

Let us apply the formulas obtained above to the most frequently discussed case of the neodymium-glass laser. At $\omega_0 \sim 2 \approx 10^{15}\ \text{sec}^{-1}$, $\omega_0/\omega_p \sim 2$, $I_0/nT \sim 0.1$, the penetration depth at which the laser radiation is effectively reflected is of the order of 10^{-2} cm $> \Delta x > 10^{-3}$ cm. This value is much smaller than the initial size of the D-T drop and, as we might expect, much smaller than the thickness of the plasma corona at the time of critical compression. Hence the processes considered here may play an important part in the physics of the interaction of a powerful electromagnetic wave with a plasma, and their investigation acquires great applied importance. In view of the complexities in the way of an analytical approach to the problem, it would be most desirable to perform numerical experiments. However, one-dimensional numerical models are hardly conceivable, since they lack the (basic) scattering through the 90° angle and the phase volume of the unstable waves is too small.

[1] Proc. of the 7th Intern. Conference on Quantum Electronics, Montreal, May 1972.
[2] V. L. Ginzburg, Rasprostranenie elektromagnetnykh voln v plazme (Propagation of Electromagnetic Waves in Plasma), Nauka, 1967.
[3] A. A. Galeev and V. I. Karpman, Zh. Eksp. Teor. Fiz. 44, 592 (1963) [Sov. Phys.-JETP 17, 403 (1963)].
[4] V. N. Oraevskiĭ and R. Z. Sagdeev, Zh. Tekh. Fiz. 32, 1291 (1962) (Sov. Phys.-Tech. Phys. 7, 955 (1963)).
[5] B. B. Kadomtsev, In: Voprosy teorii plazmy (Problems of Plasma Theory) Vol. 4, Atomizdat, 1964.
[6] V. N. Tsytovich, Nelineĭnye effekty v plazme (Nonlinear Effects in Plasma), Nauka, 1967.
[7] N. B. Andreev, A. Yu. Kiriĭ, and V. P. Silin, Zh. Eksp. Teor. Fiz. 57, 1024 (1969) (Sov. Phys.-JETP 30, 559 (1970)).
[8] A. A. Galeev, V. N. Oraevskiĭ, and R. Z. Sagdeev, ZhETF Pis. Red. 16, 194 (1972) (JETP Lett. 16, 136 (1972)).
[9] M. N. Rosenbluth, Phys. Rev. Lett. (1972).
[10] A. G. Litvak and Yu. V. Trakhtengarts, Zh. Eksp. Teor. Fiz. 60, 1702 (1971) (Sov. Phys.-JETP 33, 921 (1971).
[11] V. E. Zakharov and Ts. Ts. Rubenchik, Prikl. Mat. Teor. Fiz. 5, 84 (1972).
[12] K. Nishikava, J. Phys. Soc. Japan (1968).
[13] A. D. Pilia, Proc. of the 11th Intern. Conference on Phenomena in Ionized Gases, Oxford, 1971, p. 320.
[14] A. Galeev, G. Laval', T. O'Neil, M. Rosenbluth, and R. Sagdeev, ZhETF Pis. Red. 17, 48 (1973) (JETP Lett. 17, 35 (1973)).

Ya. B. Zel'dovich, Neutron Stars and "Black Holes."

The orbiting of satellites outside of the atmosphere has created a foundation for the development of x-ray astronomy. Discrete x-ray sources (including x-ray pulsars) with luminosities 1000 times that of the sun and even higher have recently been discovered within the limits of our Galaxy. In a number of cases, these sources form (together with ordinary stars that emit light in the optical band) binary systems or, more precisely, close pairs. It has become possible as a result to determine the mass of the x-ray star. The aggregate of data indicates that the x-ray source is in some cases a neutron star and in others a star in a state of relativistic collapse, i.e., a cooled star or, to use the current term, a "black hole."

Let us examine the observational material with the source Hercules X-1 as our example. This source has a period of 1.7 days (about 40 hours), of which about 8 hours are spent in eclipse, with the ordinary star between the source and the observer on the earth. The period of the velocity variation of the ordinary star coincides with the period of the eclipses, and this confirms duplicity.

The x-radiation has a short period of 1.24 sec, i.e., a period in the pulsar range. The 1.24-second period indicates that the source is a rotating neutron star (its mass according to orbital observations is suitable, $\sim 0.8\ M_\odot$, where $M_\odot$ is the sun's mass, 2×10^{33} g), with a magnetic field that controls the directivity of the x-radiation.

This radiation is linked to the incidence and impingement of gas flowing across from the ordinary star onto the surface of the neutron star.

Simple energy considerations demonstrate that it is the accretion (and not the rotation) that is the energy source feeding the x-ray emission. The 1.24-sec period corresponds to a comparatively slow rotation of the neutron star; there would be enough rotational energy for only a few years.

This is the fundamental difference between Hercules X and the pulsar in the Crab Nebula (PC), which also emits x-rays. The period of PC is 0.03 sec, with the result that its kinetic energy of rotation is 1000—2000 time greater, and, in addition, PC is in fact young (only 1000 years). In this case, the energy balance between radiation and rotational-energy loss converges.

The x-ray source in the Hercules X-1 system illuminates the ordinary star; at the surface of the latter, the energy of the x-radiation (which exceeds the intrinsic luminosity of the star) is transformed to optical radiation. As a result, the illuminated part is several times brighter than the dark part. Over the revolution cycle of the binary system, we see the illuminated and dark parts by turns, and this explains the brightness curve of the system and the changes in its light. Heating of the illuminated part causes a gas outflow that intensifies the impingement of gas onto the neutron star. There is another 36-day period associated with the periodic rotation of the pulsar's magnetic axis; this period is not of great fundamental importance and is not discussed here.

There are no eclipses in the binary system Cygnus X-1. Analysis of the Doppler shift of the lines, the brightness curves, and the spectral characteristics of the optical star with consideration of the laws of mechanics leads to the conclusion that the mass of the x-ray source is on the order of $10M_{\odot}$. According to theory, a compact body of this mass must be in a state of relativistic collapse. Impingement of gas "onto the black hole" is accompanied by x-radiation when the incident gas carries rotational momentum. This situation occurs in a binary system. In first approximation, the gas particles revolve around the "black hole" (on circular Keplerian orbits under the influence of the attraction to the "black hole"). The progressive decrease in the radius of the orbit takes place comparatively slowly as the gas yields its rotational momentum in interaction with the gas on neighboring orbits (due to friction). On the whole, the gas forms a disk around the "black hole." The friction in this disk is accompanied by release of energy and x-radiation. Only in the immediate vicinity [of the "black hole"], where the rotational momentum drops below the critical value, are the circular orbits replaced by a short spiral, followed by impingement of gas particles onto the surface of the "black hole"—at the so-called gravitational radius. But this most dramatic part of the process is virtually unaccompanied by radiation of energy.

The total radiated energy is 6 to 20% of the rest mass of the incident gas, which exceeds the energy release that could be obtained from nuclear reactions.

The x-radiation has quasiperiodic fluctuations with a period of less than a second. These fluctuations can be explained by the presence of bright points on the surface of the disk and by the Doppler effect from the rapid rotation of the disk. Their investigation, which is in its initial stage, can, in principle, yield valuable information on the gravitational field of the "black hole." This is because the familiar Schwarzschild solution is valid only for a nonrotating star. A stationary, but not static field appears on the collapse of a rotating star (the Kerr solution). The existence of a gravitational analog of the magnetic field is predicted in the relativistic theory of gravitation.[1)]

The gravimagnetic field influences the orbits of the gas particles, their period of revolution, and the energy released. In principle, these new properties of the gravitational field could be detected in study of the fluctuations.

An x-ray source with a power 100,000 times that of the sun has been discovered in the Magellanic Cloud. It may be assumed that here again the source is a "black hole" in a binary system with an ordinary star.

Thus, x-ray astronomy has presented us with data of enormous interest and importance. The significance of x-ray astronomy arises out of the fact that compact relativistic objects with energy release in a small region of space inevitably accelerate particles to high energies, develop high temperatures, and emit waves of high frequency. X-ray astronomy has opened a passable path to the investigation of such objects as the "black holes," where fundamentally new situations arise and the structure of the four-dimensional complex of space-time is radically altered.

This situation must be regarded as fundamentally new, although the equations from which it arises are the long-established equations of general relativity theory. Let us briefly examine the history of the problem. Before the war, Zwicky, Landau, Oppenheimer, and their colleagues had established the possible existence of neutron stars and "black holes." The theory of these objects was improved by a number of authors, including Ambartsumyan and Saakyan, Cameron, Bethe, and others. It was established that neutron stars cool down within a few years, and that "black holes" vanish from sight within less than a thousandth of a second.

Our group, the Theoretical Astrophysics Division of the Institute of Applied Mathematics, USSR Academy of Sciences, advanced the idea that it might be possible to detect an ultrastrong gravitational field around relativistic objects. The problem of investigating the external matter and its accretion as separate from the emission of the object itself was stated; note was taken of the advantageous position of double stars in this respect. The properties of the objects were evaluated in a number of papers, of which we note a few, most of them by Soviet scientists. Migdal: The Superfluidity of the Nuclear Matter of which Neutron Stars (Pulsars) consist; Ginzburg and Ozernoĭ: Drawing-in of the Magnetic Field by the Black Hole; Kerr (USA): Solution of the GTR Equations for Rotating Bodies, Including "Black Holes," with Angular Momentum. Doroshkevich, Zel'dovich, and Novikov: The Stability of this Solution. Guseĭnov was concerned with the search for binary systems with relativistic stars. The concept of accretion was refined. Shklovskiĭ treated an x-ray source in Scorpio as a neutron star in a binary system. Shakura investigated spherical accretion. Burbidge, Prendergast, and Linden-Bell began the treatment of disk accretion (although for other objects—white dwarfs, galactic nuclei, and quasars).

The discovery of the pulsars came as a surprise to the theoreticians. Working from it as a premise, they were able to recognize neutron stars in the pulsars and use the stability of their periods for precise conclusions as to the structure of these stars. General confidence in the theory of the late stages in evolution was enhanced.

The theoreticians played the next round: two years prior to the corresponding observations, Schwartzmann predicted that a pulsar in a binary system would periodically radiate x-ray pulses due to accretion.

Much work was done within a short time after the observations of binary (including eclipsing-binary) x-ray sources—in Hercules, in Cygnus, and elsewhere. Syunyaev and Basko examined the vaporization of a gas under the action of a flux of x-rays. Syunyaev and Shakura considered the spectrum of the disk. Syunyaev suggested quasiperiodic fluctuations as offering a way to investigate the "black hole."

Novikov and the American physicist Thorne developed a consistent relativistic theory of disk accretion. Lyutyĭ, Cherepashchuk, and Kurochkin, specialists on variable and binary stars at the Shternberg Institute (the State Astronomical Institute of Moscow State University), became involved and, together with members of our group, interpreted the optical observations of the "ordinary companions" of relativistic stars. A new and extremely rapidly developing branch of astronomical science, to which Soviet astrophysicists have rendered meritorious service, has emerged.

General information may be found in "The Theory of Gravitation and the Evolution of the Stars," by Ya. B. Zel'dovich and I. D. Novikov (Nauka, 1972). This book is significantly stronger in the area that is the subject of this paper than the book by the same authors "Relativistic Astrophysics" (Nauka, 1967). On the other hand, recent results are being set forth in a steadily rising stream of communications in "Astrophysical Journal Letters," "Astrophysical Journal," "Astronomy and Astrophysics," "Astrophysics and Space Science," "Astronomicheskiĭ Tsirkulyar," "Astronomicheskiĭ Zhurnal," "Astrofizika," and other journals and to an even greater degree in preprints of the work of Soviet and foreign scientists.

F. I. Fedorov. The Development of Physics in Belorussia.

Before the October Revolution, there were no higher educational institutions or scientific-research agencies on the territory of Belorussia. The Belorussian State University was opened in 1921 by decree of V. I. Lenin. The Belorussian Academy of Sciences was founded in 1929, but it was a long time before it acquired scientific-research facilities in the physicomathematical profile. Only in 1955 was the Institute of Physics and Mathematics organized in the Belorussian Academy of Sciences, and before that date research in these sciences was pursued only in the department of the Belorussian State University.

Note should be taken of the great assistance rendered our republic in the matter of staff training by the scientific agencies and colleges of Moscow and Leningrad, where young Belorussian physicists completed their graduate studies under the guidance of prominent scientists.

At the present time, the principal scientific centers in the BSSR at which physical research is done are the Institute of Physics (IP) and the Institute of Solid-State and Semiconductor Physics (ISSSP) of the Belorussian Academy of Sciences, together with the Physics Department of the V. I. Lenin Belorussian State University.

The Institute of Physics of the Belorussian Academy of Sciences is one of the foremost scientific agencies of our country in the fields of optics and spectroscopy. Many of the results obtained here have been widely recognized both in the USSR and abroad. We shall enumerate a few of them. The Institute has developed engineering methods for computing the optical properties of lasers that are now generally accepted and widely used. A new class of active substance for lasers—complex organic compounds of the dyestuff type—has been discovered. Lasers with smooth output-frequency tuning have been developed on the basis of these substances. For this discovery, the Director of the Institute of Physics of the Belorussian Academy of Sciences, Academician of the Belorussian Academy B. I. Stepanov, was awarded a 1972 USSR State Prize jointly with A. N. Rubinov and V. M. Mostovnikov.

A general consistent phenomenological theory of the optical properties of transparent, absorbing, magnetic, and optically active anisotropic media was developed on the basis of direct tensor-calculus methods. A theory of the propagation of elastic waves in crystals was developed, and an effective method of calculating Debye temperatures for crystals of arbitrary symmetry was elaborated.

The foundations of a theory of the luminescence of complex molecules have been laid. A spectroscopy of negative luminous fluxes has been created. A universal relation has been established between the absorption and luminescence spectra of complex molecules and semiconductors.

The phenomenon of vapor-fluorescence extinction by foreign gases was discovered. A new type of luminescence—sensitized anti-Stokes annihilation fluorescence—has been observed.

Dispersion filters of a qualitatively new type have been created for the infrared region of the spectrum, where they offer substantial advantages.

New methods have been developed for the production of shock waves and supersonic erosive plasma jets. Machines that model complex plasma formations have been built. Spectroscopic and laser methods for low-temperature-plasma diagnostics have been developed.

Theoretical research in quantum-field theory and the general theory of relativity is conducted at the Theoretical Physics Laboratory of the Institute of Physics and in the Belorussian State University Theoretical Physics Department. A general method of projective operators has been developed in the theory of particles with arbitrary spin. A new parametrization, with the aid of three-dimensional complex vector parameters, has been proposed for real and complex Lorentz groups. The tetradic formalism in GTR has been developed in combination with the method of stratified spaces.

Extensive research is being done in solid-state physics at the ISSSP of the Belorussian Academy of Sciences. The nature of the chemical bond in solids and their physical and chemical constants are objects of study; phase transitions, crystal-growth processes, and the optical properties of semiconductors are being investigated. The ISSP is the foremost scientific agency