ing frequency ν ($\tau \propto N_{\mathrm{tot}}^{-n\nu k}$, $n \sim 1-2$, $k \sim 2-3$). Such a variation of ν, in particular, can be explained by taking into account the influence exerted on the MV (which are due to inhomogeneities with dimensions $l \sim 10^{10}-10^{11}$ cm) of larger inhomogeneities with $l \sim (1-5)\times 10^{13}$ cm, which move (relative to the smaller inhomogeneities and to the source) with a velocity $v \gtrsim 5\times 10^{7}$ cm/sec and are responsible in turn for the oscillations of the intensity of the pulsar radio emission with $\tau_0 \sim 10^{5}-10^{6}$ sec[4]. Better agreement with the set of data on MV is obtained in this case under the assumption that the main contribution to the variations is made by inhomogeneities lying in the HII regions surrounding the pulsars.

The possible influence of the inhomogeneities of the pulsar "corona" on the intensity fluctuations, the fine structure, and the waveform of the emission pulses of the pulsars[5] is considered. It is shown that in a number of cases the characteristics of the signal scattered in the pulsar corona can depend very little on the frequency (for example, if the radiation is produced or is reflected from levels where the frequency is close to the plasma frequency, and the change of the plasma concentration with altitude is nearly exponential). It is noted that under certain assumptions concerning the character of the emission in a statistically-inhomogeneous medium, the oscillations of the radiation intensities of the pulsars with characteristic times $\tau \lesssim 1$ sec can have a logarithmic-normal distribution.

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[1] L. M. Erukhimov and V. V. Pisareva, Paper at the Conference on the Near-solar Plasma (Moscow, April, 1968); the same: Izv. Vuzov (Radio-fizika) 12, (6), 900 (1969).

[2] L. M. Erukhimov and V. V. Pisareva, Astron. tsirkul. No. 489 (1968).

[3] B. J. Rickett, Nature 221, 158 (1969).

[4] L. M. Erukhimov, Astron. tsirkul. No. 513, 3 (1969).

[5] L. M. Erukhimov, Izv. Vuzov (Radiofizika) (1969).

V. V. Zheleznyakov. Mechanisms of Pulsar Radiation.

In explaining the radio emission of pulses, and in the case of the NP0532 pulsar in the Crab Nebula also the optical and x-ray emission, the starting point is the quite plausible assumption that the pulsar is a rotating dense (neutron) star with a strong magnetic field. The mechanism of the radio emission with $T_{\mathrm{eff}} \sim 10^{21}$°K should be coherent, for otherwise the required particles have an energy $\mathcal{E} \gtrsim 10^{17}$ eV and conditions are necessary under which the maximum of their radiation lies in the radio band. For the optical ($T_{\mathrm{eff}} \sim 10^{12}$°K) and x-ray band, there is no such need, and $\mathcal{E} \sim 10^{8}$ eV is sufficient. The optical and x-ray emissions are certainly not produced in the hot isotropic photosphere; in that case the emission would be nondirectional and the rotation of the star would not lead to the appearance of pulses.

In the model proposed by V. L. Ginzburg, V. V. Zaĭtsev, and the author[1], the emission of the NP0532 pulsar is attributed to the synchrotron mechanism; the emission comes from relativistic particles contained in the radiation belts of the star. The observed level of the optical radiation ($f \sim 5\times 10^{14}$ Hz) can then be attributed to incoherent synchrotron radiation of electrons with energy $\mathcal{E}_0 \sim 10^{2}\,mc^{2}$ and concentration $N_0 \sim 5\times 10^{15}$ electrons/cm^3, concentrated in a volume $V \sim 10^{19}$ cm^3 (magnetic field $H \sim 2\times 10^{6}$ Oe). We then have the parameter $\delta = H^2/8\,\mathcal{E}_0 N_0 \sim 1$, the optical thickness of the system is $\mu L \sim 1$, and the maximum of the radiation occurs at a frequency $f_{\max} \sim 5\times 10^{16}$ Hz. The lifetime of the electron relative to the synchrotron loss is $t_m \sim 10^{-6}$ sec*. It is important that the radiation power of the same electrons at frequencies $\sim 10^{18}$ Hz suffices to explain the radiation in the x-ray band. The character of the frequency spectrum (for the simplest monoenergetic spectrum of the electrons) correspond qualitatively to that observed: it is gently sloping for the optical band (the spectral index is $\alpha = -\tfrac{1}{3}$) and drops off for the x-rays, although too steeply ($\alpha \approx 4.5$).

For the coherent synchrotron mechanism in the radio band ($f \sim 3\times 10^{8}$ Hz), the following are the optimal parameters of a system with $\delta \sim 1$ and a linear dimension $L \sim 10^{8}$ cm: $N_0 \sim 10^{7}$ electrons/cm^3, $\mathcal{E}_0 \sim 7.5\,mc^{2}$, $H \sim 30$ Oe, concentration of "cold" (nonrelativistic) plasma $N \sim 3\times 10^{8}$ electrons/cm^3, and its temperature $T \sim 10^{4}$°K. The amplification over a system dimension $\mu L \sim 40$ suffices to account (without taking the saturation into account) for the radio emission of the observed intensity.

For a dipole magnetic field ($H \backsim 1/R^3$, R—distance from the center of the star), the ratio of the magnetic fields in the shortness of the optical and radio radiation is characterized by the ratio of the radii of these sources $R_{\mathrm{rad}}/R_{\mathrm{opt}} \sim 50$. The value of R_{rad} for the pulsar NP0532 is limited to 10^{8} cm, which is determined by the width of the pulse 3 msec. If $R_{\mathrm{rad}} \approx 10^{8}$ cm, then $R_{\mathrm{opt}} \approx 2\times 10^{6}$ cm. Thus, the optical and x-radiation come from the nearest vicinity of the neutron star, and the value $H \sim 2\times 10^{6}$ Oe in the stars yields an estimate of the magnetic field H_0 on the surface of the star (it is probable that H_Z is somewhat larger; if the neutron-star radius is $R_0 \sim 10^{6}$ cm, then $H_0 \sim 10^{7}$ Oe).

If the relativistic electrons are localized near the surface of the magnetic equator and have a momentum distribution in the angle interval $\Delta\theta \sim 20-40°$, in which the magnetic equator is included, then the directivity pattern of the radiation becomes "knife-like" (with an aperture $\Delta\theta$), and the duration $\Delta\tau$ of the pulses produced upon rotation of the pulsar will

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*Owing to the high radiation energy density, an important role in the magnetosphere of the pulsars may be played by the inverse Compton effect. In certain cases (as noted by I. S. Shklovskiĭ during the discussion of the paper) the magnitude of the Compton loss may exceed the synchrotron radiation loss. The latter pertains also to the model in question with the indicated parameters, at which the Compton loss decreases the lifetime of the electrons to 10^{-7} sec. The average energy of the Compton quanta then amounts to 2×10^{6} eV. The power of the γ rays produced in this case reaches 10^{37} erg/sec. At the same time, it is possible to choose the model parameters such that the power of the γ rays is greatly reduced. It is clear therefore that measurement of the γ-ray flux from the pulsar NPO532 will make it possible to evaluate more definitely the physical characteristics of the radiating region.

agree with the observed values (1.5–3 msec). Identical values of $\Delta\tau$ for the optical and x-radiation are due to the generation of both radiations by the same electrons. A similar profile of the pulses at the radio frequency is possibly connected with the fact that the distribution of relativistic electrons responsible for the radio emission with respect to the pitch angles is influenced by the action of the powerful optical and x-radiation.

The received radiation becomes pulse-like if the angle β between the rotation axis ω and the magnetic dipole **M** is not equal to zero. When

$$\beta = \pi/2,$$

the radiation pulses, which are registered twice every revolution, follow at equal time intervals (this case is typical of most pulsars). On the other hand, if $0 < \beta < \pi/2$, then in the case of observation at an angle γ to the ω axis ($\pi/2 - \alpha < \gamma < \pi/2$) the intervals between three successive pulses become unequal (a situation typical of the NP0532 pulsar, and also of NP0527 and CP0950).

In the case of rotation of a star having a magnetic moment **M** not parallel to ω, a strong interaction occurs between the magnetic field and the plasma in the magnetosphere of the star and the surrounding medium (effects of plasma dragging, spin-off of matter, and radiation of low-frequency waves, which, in principle, may be responsible for the change of the period of the rotation of the object). The revolution frequency $\omega = 2\pi/\tau \sim 2-2 \times 10^2$ satisfies the inequalities $\omega < \omega_{\mathrm{Hi}}$ or $\omega_{\mathrm{Hi}} < \omega < \sqrt{\omega_{\mathrm{Hi}}\omega_{\mathrm{He}}}$, where ω_{Hi} and ω_{He} are the ion and electron gyrofrequencies in the plasma surrounding the pulsar, i.e., in the interstellar medium or in the supernova envelope. Therefore the radiated low-frequency waves correspond to Alfven waves or to waves in the region intermediate between magnetohydrodynamic waves and waves of the type of whistlers in the earth's magnetosphere. According to estimates by V. P. Dokuchaev and Yu. V. Chugunov, the power $W \sim W_0 n^3$ of the magnetic dipole radiation of a rotating star in a medium will be much higher (by a factor 10^6 and more) than the corresponding power in the vacuum W_0 (owing to the large values of n—the refractive index of these waves).

It is not excluded that the radiation of the low-frequency waves is the main cause of the observed growth of the period of rotation of the pulsar.

N. S. Kardashev. Possibility of Observing Extragalactic Pulsars.

The paper considers the following:

1. The possibility of observing pulsars produced in supernova outbursts of the nearest galaxies. At the instant of the outburst, the pulsar radiation power may be comparable with the radiation power of the supernova envelope. Subsequently, the pulsar radiation exceeds the envelope radiation power. It is noted that it is necessary to organize observations of supernova outbursts in the nearest galaxies. The observations are desirable in the γ, x-ray, optical, and radio bands for different instants following supernova outbursts.

2. The probable role of pulsars in radio galaxies and in quasars. There are three possibilities: 1) a decisive role in the radio sources is played by a supermassive star—s "superpulsar"; 2) in addition to the supermassive star there exists in the source a large number of ordinary pulsars, ensuring generation of cosmic rays; 3) the radio source consists of a large cluster of pulsars. A method is proposed for determining the number of pulsars in the source, the radiation of which is due to a considerable degree to the radiation of these pulsars.

3. The prospects of investigating extragalactic pulsars so as to determine the cosmological parameters, namely, measurement of the density of the intergalactic medium on the basis of the delay, measurement of the parallaxes at cosmological distances, and measurement of the expansion of the universe by determining the change of the periods of remote pulsars.

V. I. Slysh. Scattering of Pulsar X-rays in the Interstellar Medium.

The influence of the interstellar dust on the x-rays from the pulsar in the Crab Nebula NP0532 has been calculated. This influence reduces to pure small-angle scattering. Spherical particles of radius 0.5 μ scatter x-rays with wavelength 5 Å "forward" into a cone of approximate width 1.5′. In the case of NP0532 there is produced around the pulsar a halo with angle dimension 1–2′, containing about 90% of the total pulsar radiation. Since the structure of the x-ray source Tau XR-1 has the same character (the source of the pulse radiation contains 5–10% of the flux of the exnebula), it can be assumed that the radiation of the Crab Nebula itself in the x-ray band is small, and the observed nebula constitutes only the halo of the scattered radiation of the NP0532 pulsar. In this case the following should be observed: first, an increase in the fraction of the pulse radiation on going over to the harder region; second, an increase of the angular dimension of the nebula at longer wavelengths (~15′ at Å wavelength); third, a correspondence between the polarization characteristics of the pulsar and of the nebula. Analogous nebulas with a flux proportional to the interstellar absorption in the visible region should be observed also in other x-ray sources. If the scattered x-radiation is not observed, this will mean that the optical interstellar radiation is due to particles of much smaller dimension.

I. S. Shklovskiĭ. Concerning Pulsars

1. The age of the pulsar PSR0833-45, determined from the period T and its derivative dT/dt, turns out to be ~10,000 years, whereas the age of the radio nebula Vela X, with which this pulsar is identified, should be not less than 30,000–40,000 years. The probability of random coincidence of the coordinates of the pulsar PSR0833-45 and of the radio nebula is very low.

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[1] V. L. Ginzburg, V. V. Zhelezhyakov, and V. V. Zaĭtsev, Usp. Fiz. Nauk 98, 201 (1969) [Sov. Phys.-Usp. 12, 378 (1969)]; the same, Astrophysics and Space Science (1969).