Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics, Academy of Sciences of the USSR (27–28 May 1981)

Usp. Fiz. Nauk 136, 345–346 (February 1982)

PACS numbers: 01.10.Fv

A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on May 27 and 28, 1981 at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following papers were delivered:

May 27

1. *V. V. Zheleznyakov*, X- and gamma-radiation of accreting neutron stars.
2. *G. M. Beskin, S. I. Neizvestnyĭ, and V. F. Shvartsman*, Gravitational lenses in space (a general review and results of BTA observations).

May 28

3. *V. M. Agranovich, V. E. Kravtsov, and A. G. Mal'shukov*, Molecules on metal: Giant Raman scattering, vibrational-spectrum anomalies, and the problem of high-temperature superconductivity.
4. *V. E. Zakharov*, Langmuir-wave collapse and Langmuir plasma turbulence.

We present below brief contents of one of the papers.

V. V. Zheleznyakov. *X- and gamma-radiation of accreting neutron stars.* The shaping of the hard x-ray and gamma spectra of neutron stars that are components of binary systems is discussed. The polar regions of these stars, which are heated by accretion of plasma from the second stellar components, serve as the radiation source. In the case of comparatively steady accretion on a rotating neutron star, the object is observed as an x-ray pulsar; in the case of strong and sharply nonsteady accretion, it appears as a gamma burster. A probable mechanism for the action of a gamma burster[1] consists of heating of a polar spot on the neutron star by the accreting plasma flux and "sweeping" of this plasma out of the circumpolar region by the radiation pressure of the spot (when the temperature reaches $\varkappa T \gtrsim 100$ keV). During an initial phase of intensive accretion, this plasma effectively screens the hard radiation from the spot; when accretion stops, the radiation escapes the object under discussion and is observed in the form of a gamma burst.

Cyclotron lines[2] are characteristic features of the spectra of x-ray pulsars ($\hbar\omega \approx 40$ keV for the object Her $X-1$ and $\hbar\omega \approx 20$ keV for $4U0115+63$). Pulsar hard x-ray spectra containing such lines can be interpreted on the basis of an isothermal model ($T \sim 10^8$ K) of the plasma atmosphere of the hot polar spot.[1,3,4] Here the radiation in the continuous spectrum (continuum) is composed of electron bremsstrahlung attenuated by nonresonant (Thompson) scattering. A cyclotron line in absorption appears against the background of the continuum as bremsstrahlung that is still more strongly attenuated by the more efficient resonant (cyclotron) scattering at the gyro frequency $\omega_{B_0} = eB_0/mc$ (B_0 is the magnetic field in the polar spot). It is highly essential that the formation of the line and continuum emissions occur in those regions of the plasma atmosphere where the polarization of normal waves (ordinary and extraordinary) is determined not by the plasma, but by the magnetized vacuum. Under these conditions, the vacuum also determines the nature of all the absorption and scattering coefficients in the plasma to a considerable degree.

The influence of the accreting plasma on the form of the observed spectrum is insignificant if the electron concentration in the plasma $N_a \ll 10^{15}$ el · cm^{-3}. If $N_a \gtrsim 10^{15}$ el · cm^{-3}, the radiation passing through this plasma is attenuated by efficient cyclotron scattering in gyroresonant layers situated in the inhomogeneous magnetic field $B(h)$ at heights where $B = \omega mc/se$ (ω is the frequency of the radiation and s is the number of the cyclotron harmonic). On x-ray pulsars, this attenuation should be very strong, since densities $N_a \sim 10^{19} - 10^{20}$ el · cm^{-3} are required to maintain the hard x-radiation at an observable level.

The radiation-opaque parts of the gyroresonant layers in the accretion trunk strongly affect the directional pattern of the radiation beyond the limits of the pulsar. In addition, gaps in the emission spectrum at frequencies $\omega \approx s\omega_{B_0}$ may be associated with the screening effect of these layers and be registered as cyclotron lines in absorption. Hence it follows that cyclotron features may also be formed when the emission spectrum of the polar plasma atmosphere does not contain such features.[1]

Registration of gamma bursts by the Venera 11 and Venera 12 spacecraft[5,6] showed that cyclotron lines (for the most part in absorption) and annihilation lines in emission ($\hbar\omega \approx 0.5$ MeV) exist against the background of the hard continuum in the gamma-burster spectrum.

 0038-5670/82/020116-02$01.80

The annihilation lines appear on annihilation of electrons and positions with the appearance of two gamma quanta. The paper discusses a mechanism of annihilation-line formation involving the production of electron-positron pairs in the strong magnetic fields of neutron stars.[7] It is suggested that the radiation of the hot polar plasma in the hard continuum is the source of the high-energy gamma quanta producing the pairs. Estimates indicate that except in directions near that of the magnetic field ($\alpha < 20°$), a significant part of the radiation with energies $\hbar\omega > 2mc^2$ per quantum is consumed in pair production. This indicates the possibility of a sharp collapse of the emission spectrum in the continuum at energies above 1 MeV and makes possible a simple estimate of the maximum annihilation-line intensity that agrees with available data from gamma-burster observations.[5,6]

The formation of a hard continuum containing cyclotron absorption lines can be interpreted[1] on the basis of a two-layer model of the plasma atmosphere in the polar region of a neutron star. The cold upper layer ($\varkappa T \sim 10$ keV) is responsible for formation of the cyclotron line, and the hot lower layer ($\varkappa T \sim 0.1-1$ MeV) is responsible for the hard continuum. Analysis of the observed spectra[5,6] yielded estimates of the integrals $\int N dl \sim 10^{20}$ el$\cdot$cm^{-2} in the cold layer (from the extinction of the transmitted radiation by cyclotron scattering) and $\int N^2 dl \sim 10^{47}$ el$\cdot$cm^{-5} in the hot layer (from the bremsstrahlung, which produces a continuum of exponential form). Here N is the electron density and l is the coordinate along the line of sight in the polar spot. In gamma bursters, the accreting plasma creates a deficit of transmitted polar-spot radiation at frequencies $\omega < s\omega_{B_0} = seB_0/mc$. The depression should be deepest at frequencies below ω_{B_0}. Such a depression is indeed observed during many gamma bursts.[5,6] The magnitude of the depression can be used for direct estimation of the density of the accreting plasma around the neutron star at the time of a burst ($N_a \approx 4 \cdot 10^{14}$ el$\cdot$cm^{-3} for the event of 1 November 1979).[1,4]

[1] V. V. Zheleznyakov, Astrophys. and Space Sci. (1982) (in press).

[2] J. Trümper, in: IAU/Cospar Symposium on X-ray Astronomy, Innsbruck, 1978.

[3] V. V. Zheleznyakov, Astrophys. and Space Sci. **77**, 279 (1981).

[4] V. V. Zheleznyakov, Tsiklotronnoe izluchenie v Astrofizike (Cyclotron Radiation in Astrophysics), IPF Akad. Nauk SSSR Preprint No. 15, Gor'kii, 1981.

[5] E. P. Mazets, S. V. Golenetskii, R. L. Aptekar', Yu. A. Gur'yan, and V. N. Il'inskii, Pis'ma Astron. Zh. **6**, 706 (1980) [Sov. Astron. Lett. **6**, 372 (1980)].

[6] E. P. Mazets, S. V. Golenetskii, R. L. Aptekar, Yu. A. Gur'yan, and V. N. Il'inskii, Nature **290**, 378 (1981).

[7] V. V. Zheleznyakov, Astrophys. and Space Sci. (1982) (in press).