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POSSIBILITY OF DETERMINATION OF RELATIVISTIC PROTONS'
CONTENT IN SOME SOURCES OF SYNCHROTRON RADIATION

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CONTENT IN SOME SOURCES OF SYNCHROTRON RADIATION*

SUMMARY

The author proposes a new method allowing to determine, at least for certain sources, the content of relativistic protons and electrons.

The method is based upon the recently revealed "relict" radioemission filling the entire Metagalaxy. The generation of hard X-ray quanta (inverse Compton effect) is the result of interaction of relativistic electrons in the sources of synchrotron radioemission with the "relict photons".

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The radioastronomical theory of the origin of cosmic rays was beset until very recently with a fundamental difficulty. It consisted in that, when using radioastronomical observations, only the value of

$$H_{\perp}^{(\gamma + 1)/2} \cdot K_e,$$

can be obtained; here K_e determined the density of relativistic electrons, and H is the component of the magnetic field in the source, perpendicular to the trajectory of a relativistic electron. Subsequently, two more assumptions are made:

    a) it is assumed that the energy density of relativistic particles is equal to the energy density of the magnetic field;
    b) and that the energy density of relativistic protons is k times greater than that of electrons.

These assumptions allow us to find separately K_e, $H_{\perp}$ and, consequently, the total energy of relativistic particles in the source (mostly protons). Note that if the assumption a) looks fairly natural, the same cannot be said of the assumption b). It is usually assumed by analogy with the Earth's environment k = 100, which appears to be quite an arbitrary assumption. Several years ago

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* VOZMOZHNOST' OPREDELENIYA SODERZHANIYA RELYATIVISTSKIKH PROTONOV I ELEK-TRONOV V NEKOTORYKH ISTOCHNIKAKH SINKHROTRONNOGO IZLUCHENIYA

when the possibility of secondary origin of relativistic electrons during
nuclear collisions was seriously discussed, certain foundations existed for
such an admission [1]. However, at present one may consider the fact as almost
established that relativistic electrons in a source are primary. This follows
from theoretical considerations [2], and also from analysis of observation data
(see, for example, [3]). By the same token, the arbitrariness of quantity k
introduction into the theory became quite obvious.

It was recently shown that such "classical" source as the Crab Nebula
does not practically contain relativistic protons and heavy nuclei [4]. On the
other hand, mostly relativistic protons are generated during powerful solar
flares. Consequently, the quantity k may vary within the broadest limits in
various sources.

Up until now no independent method has existed for the determination of
content of relativistic electrons and protons in the sources of cosmic radio-
emission. We now propose a method, which will allow, in principle, to resolve
this problem at least for certain sources. As is well known, a high-frequency
"relict" radioemission was recently revealed, which fills the entire Metagalaxy
with energy density of about 1 ev/cm^3 [5, 6]. The energy maximum corresponds
to the spectral region ~ 1 mm, and, consequently, the average energy of photons
$\varepsilon \sim 10^{-3}$ ev. The relativistic electrons, located in the sources of synchrotron
radioemission will interact with these "relict" photons, which will lead to the
generation of hard X-ray quanta (inverse Compton-effect). The energy ε of hard
quanta is determined by the expression:

$$\varepsilon = \frac{4}{3} \ \bar{\varepsilon} \left(\frac{E}{mc^2} \right)^2 \tag{1}$$

where E is the energy of relativistic electrons. In particular, quanta with
$\varepsilon \sim 1 - 5$ kev ($\lambda = 8.7 - 1.7$ A) will be generated by relativistic electrons
with $\varepsilon \sim 10^8 - 10^9$ ev.

The flux of X-ray emission from any source of synchrotron radiation will
be equal to (see [7]) :

$$F(\varepsilon) = \frac{r^3}{6R^2} \ K_e \sigma_0 c \ (mc^2)^{1-\gamma} \ \{ \int \varepsilon^{-(3-\gamma)/2} w(\varepsilon') d\varepsilon' \} \varepsilon^{(1-\gamma)/2}$$

where γ is the index of the differential energy spectrum of relativistic elec-
trons, $w(\varepsilon')$ is the spectral density of relict photons (Planck function at T $\sim 3°$),
σ_0 is the Thomson cross section, r is the radius of the source, R is the dis-
tance to the source.

Since $w(\varepsilon')$ is known, while γ is determined from the synchrotron spectrum
of the source, we determined the quantity K_e from the measured F (ε)

Knowing K_e , we may determine $H_\perp$ from the analysis of source's synchrotron radiation. If the energy density of relativistic electrons is found to be sufficiently close to the magnetic energy, comparatively few relativistic protons will be found in the source. But if the magnetic energy density is k times greater than the energy density of relativistic electrons, this may serve as an indication (but not demonstration!) that a significant number of protons are contained in the source.

With such a method of estimation one should be assured that the unique cause of observed X-ray emission from the source of synchrotron radiation is the inverse Compton-effect on relict photons.

It is evident that this is by far not valid for all the sources. For example, this is knowingly invalid for the Crab Nebula. One may, however, point already to such an object, for which the above-developed theoretical considerations may be applied. It is the double extended source Centaur-A, linked with the radiogalaxy NGC 5128, closest to us. In it the number of relativistic electrons is very large, at least by one order greater than in NGC 4486, and only a few times smaller than in Cygnus-A, which is remote from us by a distance ~ 50 times greater than NGC 5128. The fact that the radioemission flux from Centaur-A is several times lesser than from Cygnus-A is explained by the comparative smallness of the magnetic field in that source.

The metagalactic localization of extended components of Centaur-A excludes the possibility of presence in it of hot and comparatively dense plasma. This is why one may not expect thermal X-ray emission from that source. Nor can one expect, for exactly the same reason, synchrotron X-ray radiation (because of greater steepness of the synchrotron spectrum). Thus, if X-ray radiation should be detected from an extended dual source Centaur-2, one may rest assured that it is conditioned by inverse Compton effect on relict photons.

It should then be expected that the angular dimensions of each of the components will be $\sim 2°$ (by 1/2 brightness), and the distance between the centers $\sim 3°$. The spectral index of X-ray radiation must be the same as in the synchrotron radioemission from the same source, that is, ~ 1 (see [2]).

A reservation should be made, however, namely that an X-ray source is possible in the central region of NGC 5128, where a very bright dual source of radioemission of small dimensions exists, and of which the nature is entirely different from the above discussed. This circumstance should be borne in mind during the planning and analysis of future observations.

The calculations, of which the details will be omitted here, show that the anticipated flux of X-ray radiation from a dual extended source, where relativistic electrons are absent must be 10^{-10} erg/cm$^2 \cdot$ sec. Should there be a large number of relativistic protons, the flux of X-ray radiation would be several times less.

It seems to us that the contemporary technique of X-ray Astronomy allows, in principle, to materialize such observations.

*** T H E E N D ***

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