[7] A.N. Bloch, R.B. Weisman, and C.M. Warma, Phys. Rev. Lett. 28, 753 (1972).
[8] F. Dyson, Phys. Rev. 92, 1331 (1953).
[9] Yu.A. Bychkov and A.M. Dykhne, Zh. Eksp. Teor. Fiz. 51, 1923 (1966) [Sov. Phys.-JETP 24, 1290 (1967)].
[10] I.M. Lifshitz, ibid. 44, 1723 (1963) [17, 1159 (1963)].

POSSIBLE EXPLANATION OF NON-POWER-LAW RADIO SPECTRA OF COSMIC RADIO SOURCES

Yu.N. Gnedin, A.Z. Dolginov, and V.N. Fedorenko
A.F. Ioffe Physico-technical Institute, USSR Academy of Sciences
Submitted 11 May 1972
ZhETF Pis. Red. 16, No. 1, 45 - 47 (5 July 1972)

Braude et al. [1] have observed that the radio spectra of discrete cosmic radio emission sources do not follow the power law in the 30 - 300 MHz range and can be explained by assuming that the radio emission is synchrotron radiation of relativistic electrons whose energy spectrum is given by

$$N(E) = K(E/E_0)^{-\gamma}\exp[p(E/E_0)^{-2}]. \tag{1}$$

This empirical formula was obtained from an analysis of almost 100 radio sources and the parameter ranges turned out to be $0.5 \leq p \leq 5.6$, $E_0 \approx 10$ MeV, and $1.6 \leq \gamma \leq 3.2$ (on the average, $\gamma \approx 2.5$). There was no theoretical interpretation of (1).

We shall show that a spectrum of the type (1) follows naturally from the assumption that the electrons are scattered and accelerated by moving magnetic inhomogeneities if their range $\Lambda(E)$ in a wide energy interval $E > E_0$ decreases with energy like $\Lambda(E) = \Lambda_0(E_0/E)$. Such a $\Lambda(E)$ dependence can be realized, for example [2], in acceleration by Alfven waves, if the exponent of the turbulence spectrum is close to $\nu = 3$. The scattering and acceleration of electrons by moving magnetic inhomogeneities having an energy-dependent range were considered by the authors earlier [3]. The equation for the energy distribution of the electrons, with allowance for the acceleration and energy loss, is

$$\frac{\partial}{\partial E}\left[D(E)E^2\frac{\partial}{\partial E}\left(\frac{N}{E^2}\right)\right] + \frac{\partial}{\partial E}\left[b(E)N\right] = 0 \tag{2}$$

$D(E)$ is the diffusion coefficient in energy space. In the model of moving magnetic inhomogeneities, it takes the form [3] $D(E) = \langle u^2\rangle E^2[3c\Lambda(E)]^{-1}$, where $\langle\Delta u^2\rangle$ is the mean-squared velocity fluctuation of the magnetic field carried by the turbulent plasma. The coefficient $b(E)$, which describes the energy lost to synchrotron and Cerenkov radiation in a fully ionized plasma, is given by [4] $b(E) = A(H_\perp)E^2 + B(n)$, where

$$A(H_\perp)E^2 = 9.8\cdot 10^{-4}\left(\frac{EH_\perp}{mc^2}\right)\left(\frac{\text{eV}}{\text{sec}}\right);\quad B(n) = 7.62\cdot 10^{-9}n\ \times$$
$$\times\left[\ln\frac{E}{mc^2} - \ln n + 73.4\right]\left(\frac{\text{eV}}{\text{sec}}\right), \tag{3}$$

$H_\perp$ is the magnetic-field component perpendicular to the electron velocity, and n is the concentration of the thermal electrons in the acceleration region. The logarithmic dependence on the energy in (3) can be neglected at $E \lesssim 100\ mc^2$. The solution of (2) then takes the form (1), with

$$\gamma = \frac{3c\,\Lambda_0 E_0}{<\Delta u^2>} A(H_\perp) - 2\,; \qquad p = \frac{3c\,\Lambda_0}{2<\Delta u^2>} B(n) \tag{4}$$

E_0 has the meaning of the lowest energy at which the spectrum is steeply cut off as a result of the losses, owing to injection, etc. The relations in (4) impose conditions on the values of $H_\perp$ and n in the acceleration region, regardless of the values of Λ_0 and $<\Delta u^2>$, since

$$(\gamma + 2)/2p = A(H_\perp)E_0^2/B(n)\,.$$

If we choose as $<\Delta u^2>$ the value of the observed scatter of the characteristic velocities of the structure details in the radio sources, then we can estimate $\Lambda(E_0)$ with the aid of (4). Using the data of the table in [1], we obtain the following values of the physical parameters of the synchrotron-radiation region. For example, for the galaxy 3C18, for which $\gamma = 2.4$, $p = 2.8$, $E_0 = 82\ mc^2$, and $H \approx 1.1 \times 10^{-4}$ G, assuming $|\Delta u| \sim 10^7$ cm/sec, we obtain $n \approx 0.1\ cm^{-3}$ and $\Lambda(E_0)$ corresponds to a spatial-diffusion coefficient $\kappa = (c\Lambda/3) \approx 2.7 \times 10^{29}\ cm^2/sec$.

Similar estimates are obtained for n and $\Lambda(E_0)$ also for other extragalactic sources investigated by Braude et al.

[1] S.Ya. Braude, I.N. Zhuk, and B.P. Ryabov, Preprint No. 6, Radiophysics and Electronic Institute of the Ukrainian Academy of Sciences, Khar'kov, 1971; Astrophys. and Space Sci. 12, 349 (1971).
[2] I.M.Toptygin, Proc. Internatl. Seminar on Particle Acceleration in Outer Space, Leningrad, 1972, in press.
[3] Yu.N. Gnedin and A.Z. Dolginov, ZhETF Pis. Red. 11, 534 (1970) [JETP Lett. 11, 366 (1970)]; Astrophys. Lett. 9, 91 (1971).
[4] V.L. Ginzburg and S.I. Syrovatskii, Proiskhozhdenie kosmicheskikh luchei (Origin of Cosmic Rays), AN SSSR, 1963 [Pergamon].

COHERENT PHOTOPRODUCTION OF HEAVY NEUTRAL MESONS ON SPIN-0 NUCLEI

M.I. Adamovich and A.I. Lebedev
P.N. Lebedev Physics Institute, USSR Academy of Sciences

Submitted 24 May 1972
ZhETF Pis. Red. 16, No. 1, 47 - 49 (5 July 1972)

The spins J and parities P are the quantum numbers of heavy neutral meson resonances (X^0, D, E, etc.) whose values have not been uniquely established. Thus, the possible values are 0^- and 2^- for the $X^0(958)$ meson, 0^-, 1^+, and 2^- for D(1285), and 0^-, 1^+ for E(1422) [1, 2]. We discuss below the possibility of determining the spins of the neutral mesons M^0 by investigating the reactions of their coherent (elastic) photoproduction on spin-0 nuclei, for example on He^4

$$\gamma + He^4 \rightarrow He^4 + M^0\,. \tag{1}$$

The table lists the lower multipole transitions of this reaction and the corresponding angular distributions $W(\theta)$ of the mesons in the c.m.s. As seen from the table, the cross section of the process (1) for meson emission angles 0 and 180° vanishes in the case $J^P = 0$ and differs from zero if $J \geq 1$. These properties of the cross sections do not depend on the limitation to a finite number of multipoles, and is a common consequence of the angular-momentum conservation law.

The table does not take into account the modification that must be introduced in the angular distributions to allow for the dependence of the nuclear form factor $F(\Delta)$ on the momentum transfer, $\vec{\Delta} = \vec{k} - \vec{q}$, where $\vec{k}$ and $\vec{q}$ are the