Does the Mesotron Obey Bose-Einstein or Fermi-Dirac Statistics?

WHETHER the mesotron obeys Bose-Einstein or Fermi-Dirac statistics is closely associated with what one assumes regarding the nature of the field, emission and absorption of which by the heavy particle is responsible for the interaction between elementary nuclear particles. If the field be a one-particle field, as postulated by Yukawa[1], the mesotron obeys Bose-Einstein statistics, and has a spin equal to unity (All momenta are expressed in units of $\hbar$.) However, in view of the fact that all known elementary particles obey Fermi-Dirac statistics and possess a spin $\frac{1}{2}$, one is rather reluctant to accept, unless experimental evidence points that way, that the mesotron obeys Bose-Einstein statistics and has a spin equal to unity. If we could suppose that the field involved is a two-particle field instead of a one-particle one, Fermi-Dirac statistics and a spin of $\frac{1}{2}$ could be attributed to the particle concerned. So we suppose that the mesotron is emitted or absorbed by a heavy particle always in conjunction with a neutrino or an antineutrino. In symbols

$$
\begin{aligned}
P &\rightleftarrows N + \eta^{+} + n^{-} \qquad (1)\\
N &\rightleftarrows P + \eta^{-} + n^{+}
\end{aligned}
$$

where N and P stand for a neutron and a proton respectively, n^{-}, n^{+} for a neutrino and an antineutrino, and η^{-}, η^{+} for the negative and the positive mesotron, which now obey Fermi-Dirac statistics and possess a spin of $\frac{1}{2}$.

If we start with a neutron and a proton at $\vec{r}_1$ and $\vec{r}_2$ respectively, processes (1) obviously lead in the second approximation of the perturbation theory to an exchange interaction between the nuclear particles. If we suppose that the spin of the heavy particle is not affected during (1), the exchange force is purely a Heisenberg force; if, on the other hand, the spin of the heavy particle is reversed during (1), we get a purely Majorana force, so that the correct spin dependence of nuclear forces is obtained by choosing for the interaction between the heavy particles and the mesotron-neutrino field a form which combines the above two.

The forces between like particles, which are known[2] to be of the same order of magnitude, for anti-parallel spins at least, as the force between unlike particles, can likewise be explained by introducing the neutral counterpart of the mesotron.

The phenomenon of β-decay can be fitted into this theory if it is assumed that the mesotron disintegrates into a β-particle and a γ quantum; so that the emission of a β-decay particle during a β-decay is accompanied not by a neutrino alone, as on Fermi's theory, but also by a γ quantum. This departure from Fermi's theory should enable us to explain in a more satisfactory way the energy distribution curve for the β-particle transformation.

Detailed calculations will be published elsewhere.

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[1] Yukawa, *Proc. Phys. Math. Soc. Japan*, 1748 (1935).

[2] Tuve, Hafstadt and Heydenburg, *Phys. Rev.*, **50**, 806 (1936); **53** 239 (1938)

Interpretation of Nebular Red-Shifts

IN a recent communication[1], M. E. J. Gheury de Bray discusses the possibility of explaining the red-shifts by assuming that the velocity of light (c_T) is constant throughout the universe at any given time but decreases with time (T).

This hypothesis implies the assumption (*a*) that the atomic frequencies remain constant throughout space and time and may therefore be used as clocks (atomic clock 'AC') for time measurements; (*b*) that measuring rods, other than light years (which contract with a decrease of c_T), can be found. For such measuring rods we may now choose the distances of *the material points* (for example, the nebulæ) in the universe, as according to the hypothesis the universe neither expands nor contracts. Such measuring rods we call 'material rods' ('MR').

It shall be shown here that the proffered hypothesis, based on the measuring system $AC + MR$, is one of three alternative ways of formulating the hypothesis of the expanding universe.

The following clocks and measuring rods can be taken as basis of a measuring system for cosmological purposes:

(*a*) Clocks	(*b*) Measuring rods
AC (atomic clocks); *or*	MR (material rods); *or*
LC (light-clocks: the time taken by light over a given distance—c is here assumed as constant).	LR (light-rods, for example, light years: the distance covered by light in a given time—c is here assumed as constant)

Only the following three combinations of these clocks and measuring rods can be taken as basis of a measuring system: $AC + MR$, which is the basis of Mr. Gheury de Bray's hypothesis; $AC + LR$, a basis which leads to the expansion theory of the red-shifts, and $LC + MR$, which leads to what Milne[2] calls 'dynamical time scale', and to the 'speeding up' theory of the red-shifts.

($AC + LR$). The theory of the expanding universe states that the distances between material points, measured in LR, increase; in other words, it maintains an increase of MR against LR. This leads to the recession of distant nebulæ and to the Doppler effect. The identity of the frequencies of characteristic spectral lines throughout the universe (atomic clocks) is thereby assumed; the measuring system of the theory is thus the $AC + LR$-system. In tracing back the recessive movements it is found that $1{\cdot}86 \times 10^9$ years ago the size of the universe was zero. Thus an absolute scale of time T (based on the atomic clock) is assumed in which the unit is the (atomic) year and the *present value* of T is $T_P = 1{\cdot}86 \times 10^9$. (This 'age of the world' is confirmed by other measurements based on atomic radioactivity clocks.)

($AC + MR$). The above statement that MR increases if measured in LR is equivalent to saying that LR decreases if measured in MR. If MR is chosen and the clocks are not changed, the system $AC + MR$ is adopted. The decrease of LR means a decrease of the velocity of light (measured in MR). This permits an explanation of the red-shift of old light, since c_T was greater at the time $T - \triangle T$ when it was emitted and therefore $\lambda_{T-\triangle T}$ is longer than λ_T.

($LC + MR$). There is a third way to express the same facts. If we allow the light a longer time for its voyage, by defining our clocks in such a manner that they are slowing down as compared with the atomic clocks, then the decrease of c can be made to disappear. In other words, we adopt a new time scale τ in which the atomic frequencies throughout