UNIVERSAL FERMI INTERACTION AND ASTROPHYSICS[x)]

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The hypothesis of a deep analogy between various slow decay processes (both leptons[1)] and non-leptons[2)]) found recently a briliant formulation in the universal interaction (vector and axial-vector) theory of Sudarshan-Marshak[3)] and Feynman-Gell-Mann[4)]. According to this theory scattering of neutrino by electrons is described as a process of first order in the weak interaction constant[4,5)]. Experimental evidence on this process would be extremely desirable. However, direct detection of the scattering by electrons of reactor antineutrino (that is, detection of the ionization produced by antineutrino, not connected with inverse β processes) seems at present quite hard, although in principle the possibility of such experiment should not be excluded.

In the present note we wish to point out that the existence of a first order νe interaction could have macroscopic consequences. Such interaction implies that positron-electron annihilation can result in the emission of a neutrino-antineutrino pair*. Consequently in electromagnetic processes it is possible that a $\nu\tilde{\nu}$ pair, through the virtual production of a e^+e^- pair, is emitted instead of a photon. This general fundamental connection between electromagnetic and lepton processes is a direct consequence of the universal Fermi interaction.

Of course the emission of $\nu\tilde{\nu}$ pairs is extremely unlikely in comparison with the emission of photons. However, the tremendous penetrating power of neutrino suggests that effects connected with the electron-neutrino interaction might exist in big bodies at high temperature T. Let us consider the process of electron bremstrahlung with emission either of a photon or $\nu\tilde{\nu}$ pair in a collision of an electron with a neucleus A with charge Z:

$$e + A \longrightarrow e + A + \gamma \qquad \text{(photon bremstrahlung)}$$

$$e + A \longrightarrow e + A + \nu + \tilde{\nu} \qquad \text{(lepton bremstrahlung)}$$

Let α indicate the ratio of the probabilities W_γ and $W_{\nu\tilde{\nu}}$ that in a deflection of an electron with energy E by a nucleus a photon or a $\nu\tilde{\nu}$ pair is emitted. Dimension arguments suggest that:

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* In particular ortopositronium annihilation with emission of a $\nu\tilde{\nu}$ pair is about 10^{15} times less probable than annihilation into three photons. Parapositronium cannot undergo annihilation with emission of a $\nu\tilde{\nu}$ pair, if neutrinos are longitudinal.

x) JETP, 36, 1615 (1959).

$$\alpha = \frac{W_\gamma}{W_{\nu\tilde{\nu}}} \approx \frac{(e^2Z/\hbar c)^2 \, e^2/\hbar c}{(e^2Z/\hbar c)^2 \, G^2 (E/mc^2)^4}$$

where $G = \frac{m^2 c}{\hbar^3} g$ is the dimentionless weak interaction constant, $g = 1.4 \times 10^{-49}$ $cm^3 erg$ is the Fermi constant and m is the electron mass.

Clearly α is enormously big at any temperature which may be encountered in astrophysics. However, because of the difference in penetrating power of photons and neutrinos, the radiation in space of a given energy (let us say $\sim \kappa T$) in form of photons by stars occurs eventually as a result of a colossal number of photon bremstrahlung processes. Such number is incomparably larger than the number (~1) of lepton bremstrahlung processes in which in form of neutrinos the same energy $\sim \kappa T$ is emitted. Consequently at some stage in the star evolution it may well be that the energies radiated in space in form of neutrinos and photons become comparable in spite of the extraordinary small value of $W_{\nu\tilde{\nu}}/W_\gamma$, characterizing an elementary act.

It should be noted that the dimensions of the Fermi constant imply a very rapid increase with temperature of the relative probability of lepton bremstrahlung. In addition the photon mean free path decreases with increasing Z, a fact which increases the weight of neutrino processes in the energy balance at high Z.

All these considerations suggest that the process might become important at a star evolution stage when the star temperature and average Z are considerably larger than the corresponding solar values. It is not difficult to see that the lepton bremstrahlung mechanism practically does not play any role in the energy balance of the Sun.

$(\kappa T \sim 1\ keV,\ Z \sim 1)$.

The mechanism of neutrino emission by stars suggested above is connected with the first order neutrino-electron interaction and fundamentally differs from the "Urka-process" suggested by Gamow and Shoenberg[6] which is connected with nuclear (direct and inverse) β -processes. Lepton bremstrahlung of electrons is a thresholdless process while the "Urka-process" has a definite threshold.

Recently Gandelman and Pinaev[7] investigated quantitatively the astrophysics effects connected with the mechanism of lepton bremstrahlung suggested above. They showed that in the region of temperature $\kappa T \gtrsim 10\ keV$ and ~~pressures~~ densities $\gtrsim 10^5$ gr/cm^3 the energy radiated by stars in form of neutrino is larger than that radiated in form of photons (Z ≈ 20).

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