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ASTROPHYSICAL LIMIT ON THE COUPLING CONSTANT OF HYPOTHETICAL LEPTONIC PHOTONS TO LEPTONS

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The hypothetical leptonic photons, namely, those that have the coupling to electrons can be produced in the Sun and other star objects by the process of photoproduction. Being weakly interacting particles they could substantially influence the star evolution by changing the process of heat release. In order this not to happen the leptonic coupling constant should be smaller than $\sim 10^{-26}$ i.e. much smaller than $\sim 10^{-12}$ required by the stability of the bodies with respect to leptonic Coulomb forces.

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Leptonic charges are conserved up to present experimental knowledge. Separately electronic, muonic and tauonic lepton numbers are conserved. This one allows to couple massless particles to each of these conserved charges [1]. If this is a case the new long range forces appear and the long range force among electrons due to electronic Coulomb interaction is the most important for terrestrial phenomena. The nonscreened leptonic charge of electrons in the bodies is limited at very high degree by Eotvos like experiments and electronic coupling constant should be smaller than $\sim 10^{-49}$ [2] in this case. Thus the situation with non screened electronic charge is not interesting because of it require extremely small coupling constant ($\sim 10^{-49}$) that cannot be measured in any other experiments. The electronic charge cannot be screened by antileptonic charge of antineutrinos [3], the outwards pressure of antineutrinos will disrupt any body to small pieces with the size $\sim a(\alpha/\sqrt{\alpha_l}) \sim 10^{-4}\,\text{cm}$ (for $\alpha_l \sim 10^{-12}$ [3]). Here $a \sim 10^{-8}\,\text{cm}$ is the dimension of an atom, α is the fine structure constant and α_l is the electronic charge coupling constant. The number $\alpha_l \sim 10^{-12}$ is the experimental upper limit for α_l. The electronic charge could be screened by scalar particles with antielectronic charge, supersymmetric partners of antineutrinos, for example, if they are sufficiently light, say with mass about 1 eV [3]. In this case the electronic coupling constant is limited at the level $\alpha_l < \alpha^6 \sim 10^{-12}$ [4, 5] by the requirement of mechanical stability of skin layer of the bodies. It seems plausible that other terrestrial physical phenomena (like surface tension, for example) could improve this limit. But there is well known extraterrestrial phenomenon (the Sun) that improves the limit up to $\alpha_l <\sim 10^{-26}$ i.e. jourteen orders of magnitude. In the present note we will discuss this new limit obtained from the considerations of possible energy losses by the Sun due to emission of leptonic photons.

The Sun is emitting photons coupled to the electric charge. Photons are produced in the hot ($T_i \sim 15 \cdot 10^6\,^\circ$C) central part of the Sun and diffuse to the outer layers of the Sun about $R^2/\lambda c \sim 10^{11}$ s. Here $R \sim 6 \cdot 10^{10}$ cm is the radius of the Sun, $\lambda \sim 1$ cm is the mean free path of the photons in the inner layers of the Sun, $c = 3 \cdot 10^{10}$ cm/s is the speed of light. The photons that are emitted from the Sun comes from the photosphere of the Sun and have the black body spectrum with the temperature $T_e \sim 6 \cdot 10^3$ °C. Thus, the photon luminosity of the Sun is proportional to $T_e^4 R^2$. Leptonic photons can be produced in the Sun by the process $\gamma e \to \gamma_l e$. The mean free path of leptonic photons is determined by the reverse process $\gamma_l e \to \gamma e$ and can be easily compared to the mean free path of the photons determined by the Compton scattering on electrons $\gamma e \to \gamma e$. Because of the obvious similarity of the above processes we have the mean free path of leptonic photons $\lambda_l = (\alpha/\alpha_l)\lambda$. If $\alpha_l \sim 10^{-12}$, $\lambda_l \sim 10^{10}$ cm$\sim 1/6R$. Then, leptonic photons scatter of the order of $(R/\lambda_l)^2 \sim 36$ times in the Sun and are emitted from the depth $\sim 1/6R$ where they have the temperature close to $T_i >> T_e$. The luminosity of leptonic photons $\sim T_i^4 R^2$ is many orders of magnitude larger than the photon luminosity $\sim T_e^4 R^2$. Therefore the case $\alpha_l \sim 10^{-12}$ is highly forbidden.

If $\lambda_l > R$ (it requires $\alpha_l < 10^{-13}$) leptonic photons are emitted from the Sun without scattering. Let us calculate the luminosity of the Sun in leptonic photons in this case. The number of leptonic photons emitted from the unit volume per unit time is equal to

$$\sigma_{\gamma e \to \gamma_l e} \cdot n_e \cdot n_\gamma = \frac{n_\gamma}{\lambda_l} \sim \frac{T_i^3}{\lambda_l} .$$

They have the energy $\sim T_i$. The luminosity considered is then proportional to $\sim (T_i^4/\lambda_l)R^3$. It should be small compared to photon luminosity $\sim T_e^4 R^2$. Therefore, we should have $\lambda_l >> (T_i^4/T_e^4)R \sim 10^{24}$cm and consequently $\alpha_l << 10^{-24}\alpha \sim 10^{-26}$. This is the desired limit on leptonic coupling constant imposed by what we know about the energy losses of the Sun. Other stars like red supergiants certainly improve this limit like they do it for other weakly interacting particles [6, 7] but even at the present limit $\alpha_l << 10^{-26}$ all terrestrial problems with leptonic photons and leptostatic repulsion seem to be forgotten. In particular, the critical size of the body with unscreened leptonic charge is $\sim a(\alpha/\sqrt{\alpha_l}) \sim 10^3$ cm while the size of the skin layer is [4] $\sim a/^3\sqrt{\alpha_l} \sim 5$ cm. This means that the bodies are far stable with respect to leptonic forces.

So, we conclude, the leptonic coupling constant is limited by the known energy losses of the Sun on the level $\sim 10^{-26}$. This limit can be improved by red supergiants. Terrestrial experiments with leptonic photons are highly questionable.

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