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Higgs Meson Emission from a Star and a Constraint on Its Mass

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In the unified theory of weak and electromagnetic interaction,[1] a presence of Higgs meson is inevitable but its mass, m_ϕ, is arbitrary. In our previous paper,[2] we discussed the effect of the primordial Higgs mesons to the cosmic background radiation and obtained the constraint that the mass cannot be in the range $0.1\ \mathrm{eV} < m_\phi < 100\ \mathrm{eV}$. Here we discuss the Higgs meson emission from stars and it is argued that such a low mass range as $m_\phi < 0.7\times$ (electron mass) should be ruled out, otherwise this emission process would affect the evolution of stars drastically.

The most effective emission process from the stellar core is $\gamma + e \rightarrow \phi + e$. The cross section of this process is given as[3]

$$\sigma = \sigma_0 \{\xi + (4-b^2)\eta\},$$

where $b = m_\phi / m_e$ and $\sigma_0 = (\pi/2)(\alpha g_{\phi ee} \lambda_e)^2 \approx 5\times 10^{-37}\ \mathrm{cm}$, α, m_e and λ_e being fine structure constant, the electron mass and its Compton wave length, respectively. ξ and η are the functions of the incident photon energy and m_ϕ (see Ref. 3)). The coupling constant $g_{\phi ee}$ is related to the Fermi coupling constant G_F as $g_{\phi ee}^2 = \sqrt{2} G_F m_e^2 c/\hbar^3$.

Now, the Higgs meson emission rate from the thermal radiation is given as

$$Q = \frac{1}{\mu_e H} \frac{1}{\pi^2} \left(\frac{1}{c\hbar}\right)^3 \int_{m_\phi c^2}^{\infty} \frac{E^3}{\exp(E/kT) - 1} \sigma c dE$$

$$= \begin{cases} 7.36\times 10^{16} \{b^4/(1+b/2)\} T_7^2 \\ \quad \times \exp\{-593b/T_7\}/\mu_e\ \mathrm{erg/g\cdot sec} \\ \quad\quad \text{for } kT < m_\phi c^2 < m_e c^2, \\ 3.45\times 10^{19} T_7^4/\mu_e\ \mathrm{erg/g\cdot sec} \\ \quad\quad \text{for } m_\phi c^2 < kT < m_e c^2, \end{cases}$$

where μ_e is the mean molecular weight of electrons, H the hydrogen mass and $T_7 = T/10^7 K$. The emission rate for the case $m_\phi > m_e$ is more complicated because the Higgs mesons decay into two photons before they escape from the star; the mean flight length of the Higgs mesons l is given as[4]

$$l \simeq 1.4\times 10^{10} (m_e/m_\phi)^3 \times \sqrt{(1+kT/m_\phi c^2)^2 - 1}\ \mathrm{cm}.$$

First we discuss the cooling of a main sequence star by this process. If the Higgs meson emission rate is greater than the nuclear energy generation rate, the lifetime becomes very short in conflict with the observation. In Fig. 1, Higgs meson emission rates for main sequence stars are shown as a function of m_ϕ.[5),6)] From this figure, we can conclude the m_ϕ should be much

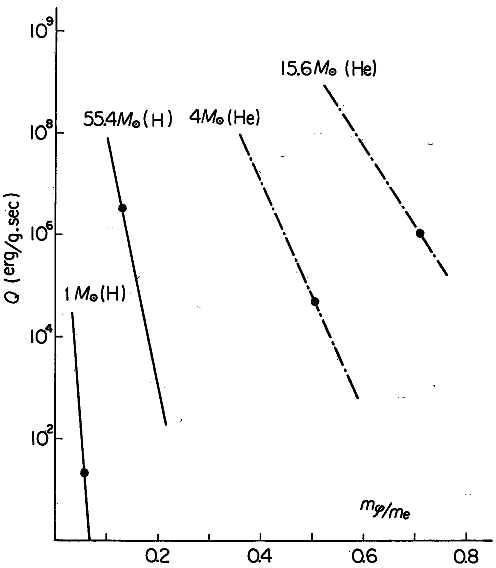

Fig. 1. Energy loss rates by the Higgs mesons for the Main sequence stars (solid line) and the central Helium burning stars (dott-dashed line). The filled circles show the nuclear generation rates at the center of the stars.

greater than $0.055m_e$ at least in order that the evolution of the sun is not affected by this process. If we extend this requirement to more massive main sequence stars like $M>55M_\odot$, though the maximum mass of main sequence stars is rather uncertain,[7] m_ϕ is restricted to $m_\phi>0.13m_e$.

After the exhaustion of hydrogen in the central region, the helium core grows by hydrogen shell burning. When the mass fraction of helium core reaches the Schön-berg-Chandrasekhar limit, the core contracts rapidly.[5] In this stage, stellar core becomes opaque to the Higgs mesons. The cross section of the reaction $\phi+e\rightarrow\gamma+e$ is $5\times10^{-37}\,\mathrm{cm}^2$ $(\equiv\sigma_0)$ and is roughly independent of m_ϕ if $kT\ll m_\phi c^2$. Then, the "optical depth" of the core is estimated as

$$\tau=2.3\times10^{-2}\rho_c^{2/3}(M_{\rm core}/M_\odot)^{1/3}/\mu_e\,,$$

where $\rho_c\,(\mathrm{g/cm^3})$ and $M_{\rm core}$ are the mass density of the core and the core mass, respectively. For $\tau>1$, the energy loss rates can be estimated roughly by ("black body" Higgs meson energy density)/(diffusion time) and, then

$$Q=4.2\times10^{19}\mu_e T_7^{\,2}\rho_c^{-4/3}\times(M_{\rm core}/M_\odot)^{-2/3}b^2e^{-5935/T_7}\ \mathrm{erg/g\cdot sec}\,,$$

which is shown also in Fig. 1. In order that supergiant stars of $h+\chi$ persei cluster (mean mass of the stars $\approx15.6M_\odot$) have the sufficiently long life,[5] m_ϕ should be greater than $0.71m_e$.

If the mean flight length of the Higgs mesons is shorter than the solar distance, that is, if $m_\phi>0.1m_e$, we can detect the decayed γ-rays of the Higgs mesons emitted from the sun. On the other hand, according to the recent observations[8] of γ-ray flux from the sun near the energies of 50 keV ($\sim0.1m_ec^2$), the upper limit of the flux is 10^{-3} counts $\mathrm{cm^{-2}sec^{-1}keV^{-1}}$ and there is no evidence of line γ-rays. Therefore the energy flux of decayed γ-rays of Higgs meson should be smaller than 10^{-15} $\times$(energy flux of visible light), where the band width of detection is assumed 10 keV. From this constraint m_ϕ should be greater than $0.14m_e$.

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