ЭВОЛЮЦИЯ ЗВЕЗД В МОДЕЛИ С НЕСКОЛЬКИМИ АКСИОНОПОДОБНЫМИ ЧАСТИЦАМИ

Выполнил:

Доманевский Данил

Научный руководитель:
д.ф.-м.н. Либанов Максим Валентинович

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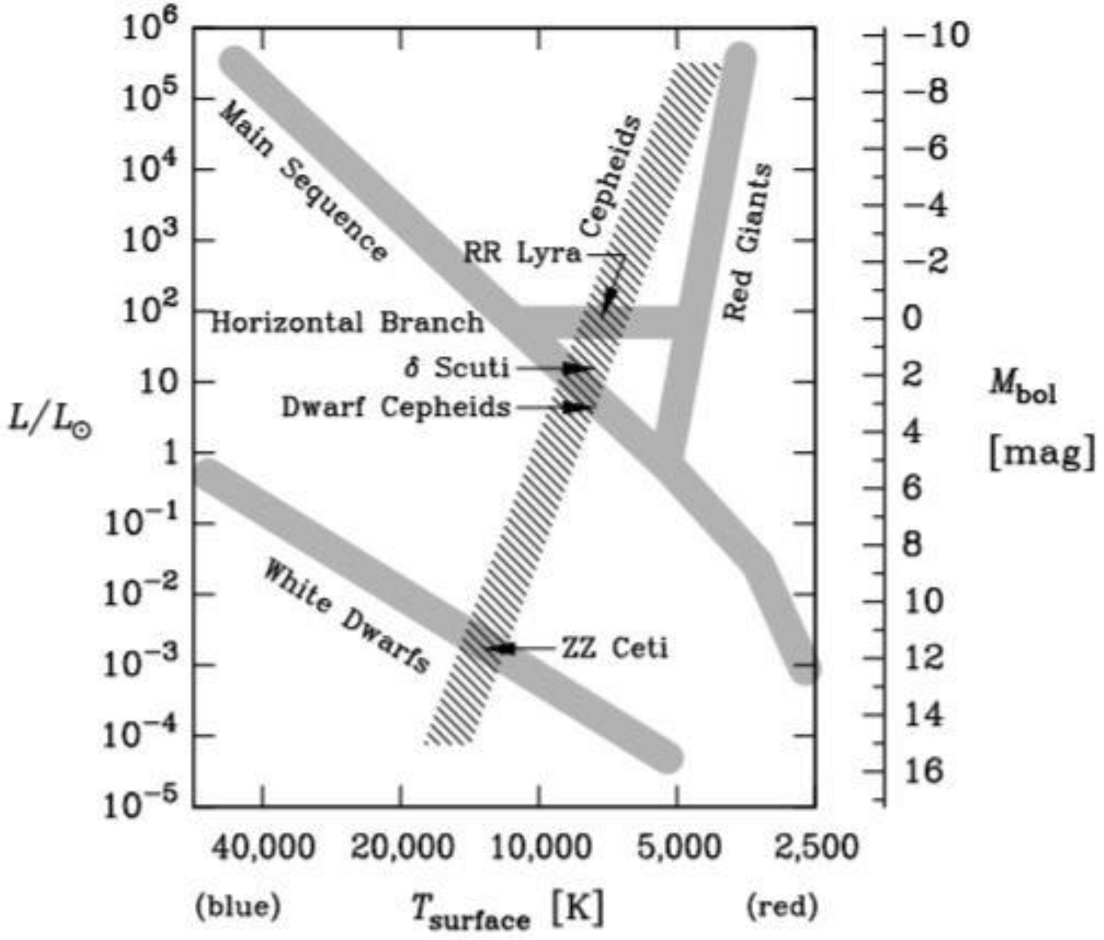
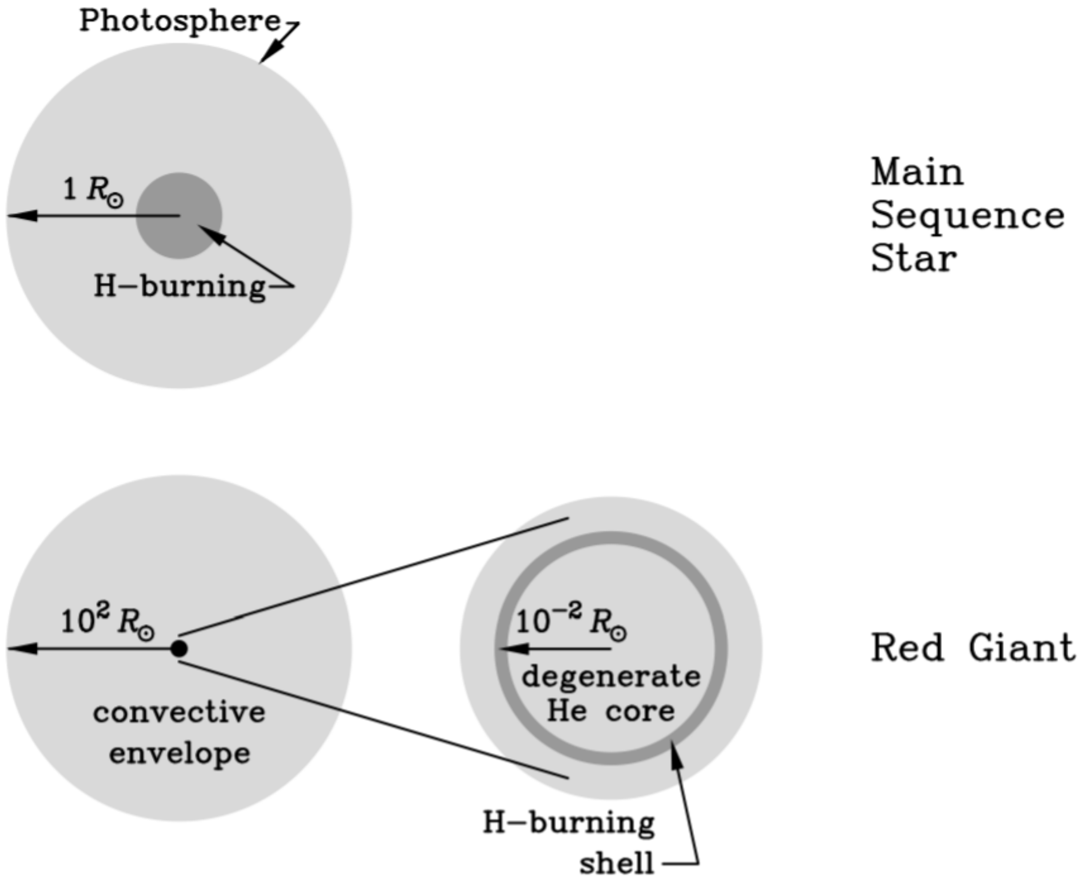
Эволюция звёзд

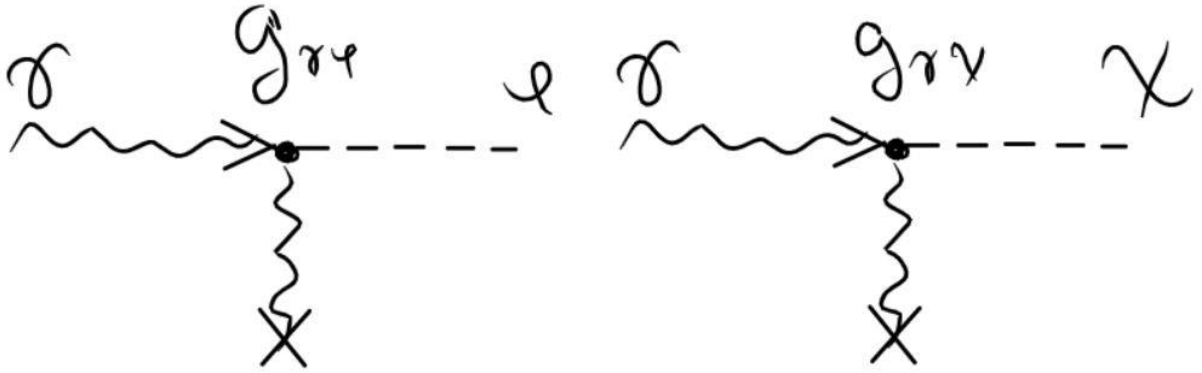




Шаровые звёздные скопления

Константы взаимодействия

$$\langle \epsilon_x \rangle \lesssim 10 \text{ эрг гр}^{-1} \text{ сек}^{-1}$$



$$Q = Q_\phi + Q_\chi = \frac{T^7 F(\kappa^2)}{4\pi} \cdot (g^2_{\phi\gamma} + g^2_{\chi\gamma})$$

$$\langle \epsilon \rangle = (g^2_{10\phi\gamma} + g^2_{10\chi\gamma}) \cdot 30 \text{ эрг гр}^{-1} \text{ сек}^{-1}$$

$$g_{10\phi\gamma} \equiv g_{\phi\gamma} \cdot 10^{10} \text{ ГэВ}^{-1}; \; g_{10\chi\gamma} \equiv g_{\chi\gamma} \cdot 10^{10} \text{ ГэВ}^{-1}$$

$$\Longrightarrow \sqrt{g^2_{\phi\gamma} + g^2_{\chi\gamma}} \lesssim 0.6 \cdot 10^{-10} \text{ ГэВ}^{-1}$$

$$\langle \epsilon_0 \rangle = \sum_n g^2_{10\phi_n\gamma} \cdot 30 \text{ эрг гр}^{-1} \text{ сек}^{-1}$$

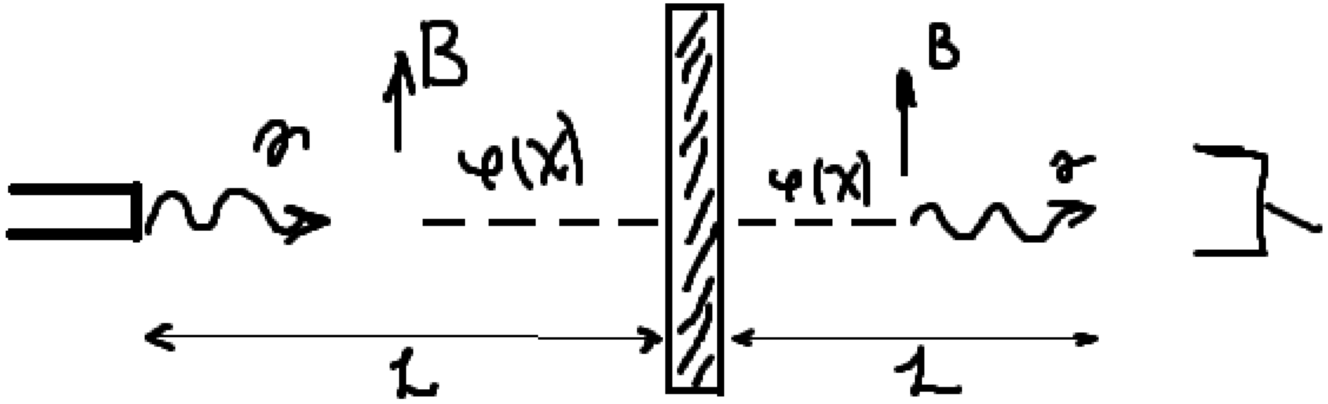
$$g_{10\phi_n\gamma} \equiv g_{\phi_n\gamma} \cdot 10^{10} \text{ ГэВ}^{-1};$$

$$\Longrightarrow \sqrt{\sum_n g^2_{\phi_n\gamma}} \lesssim 0.6 \cdot 10^{-10} \text{ ГэВ}^{-1}$$

Вероятности

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 + \frac{(\partial_\mu \phi)^2}{2} - \frac{m_\phi^2 \phi^2}{2} + M^2 \phi\chi + \frac{(\partial_\mu \chi)^2}{2} - \frac{m_\chi^2 \chi^2}{2} + \frac{1}{8} g_\phi \epsilon_{\mu\nu\rho\lambda} F^{\mu\nu} F^{\lambda\rho} \phi + \frac{1}{8} g_\chi \epsilon_{\mu\nu\rho\lambda} F^{\mu\nu} F^{\lambda\rho} \chi$$

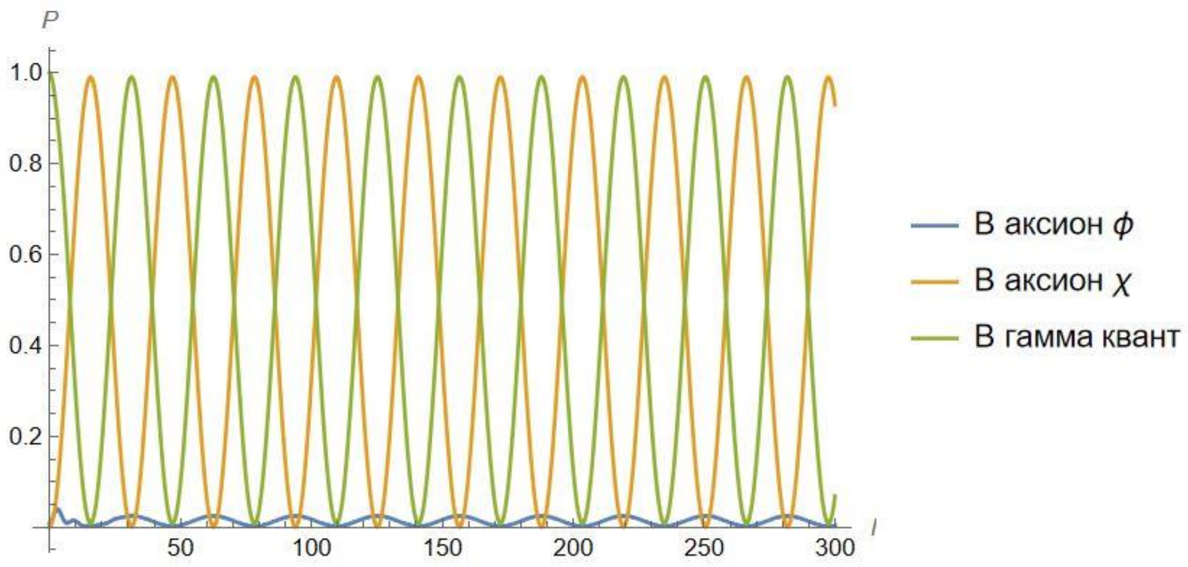
$$P_{\gamma\phi} = \frac{|\langle\Phi|A(t)\rangle|^2}{\langle\Phi|\Phi\rangle\langle A|A\rangle} \Longrightarrow P_{\gamma\phi} = \frac{|\sum_s g_s^* f_s e^{ik_s L}|^2}{\sum_s |f_s|^2 \sum_s |g_s|^2} = \frac{|g_1^* f_1 e^{ik_1 L} + g_2^* f_2 e^{ik_2 L} + g_3^* f_3 e^{ik_3 L}|^2}{(|f_1|^2 + |f_2|^2 + |f_3|^2)(|g_1|^2 + |g_2|^2 + |g_3|^2)}$$



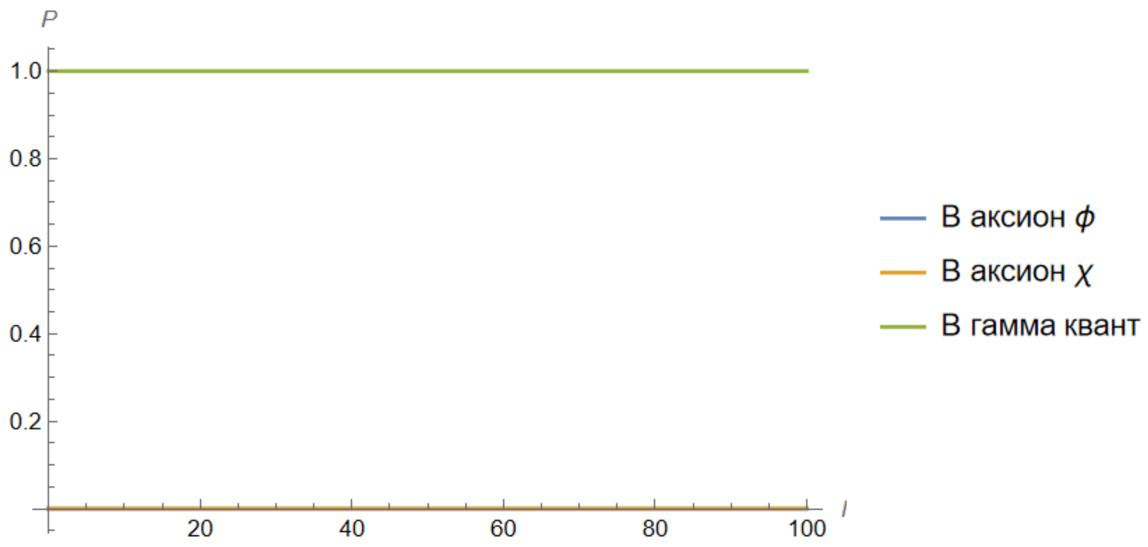
$$P_{\gamma\gamma} + P_{\gamma\phi} + P_{\gamma\chi} + \cdots = 1$$

Программная реализация

$$B \sim \omega$$



$$B \longrightarrow 0$$



$$P_{\chi\phi} \approx 2 \cdot 10^{-7} \neq 0$$

Пустой слайд

Формулы

$$\Gamma_{\gamma\longrightarrow\phi(\chi)} = \frac{g^2_{\phi(\chi)\gamma} T k_s^2}{32\pi}\left[\left(1+\frac{k_s^2}{4\omega^2}\right)\ln\left(1+\frac{4\omega^2}{k_s^2}\right)-1\right]$$

$$Q_{\phi(\chi)} = \int \frac{2\, d^3 k_\gamma}{(2\pi)^3}\cdot\frac{\Gamma_{\gamma\longrightarrow\phi(\chi)}\omega}{e^{\frac{\omega}{T}}-1} = \frac{g^2_{\phi(\chi)\gamma}\, T^7}{4\pi}\cdot F(\kappa^2);$$

$$k_s = \frac{4\pi\alpha}{T} n_B \left(Y_e + \sum_j Z_j^2 Y_j\right) \qquad n_B = \frac{\rho}{m_u}.$$

$$F(\kappa^2) = \frac{\kappa^2}{2\pi^2}\int_0^\infty dx \left[(x^2+\kappa^2)\ln\left(1+\frac{x^2}{\kappa^2}\right)-x^2\right]\frac{x}{e^x-1}$$

$$\langle A|A\rangle = \delta^3(0)\sum_s f_s^*\cdot f_s = \delta^3(0)\sum_s |f_s|^2$$

$$\langle \Phi|\Phi\rangle = \delta^3(0)\sum_s g_s^*\cdot g_s = \delta^3(0)\sum_s |g_s|^2$$

$$\langle X|X\rangle = \delta^3(0)\sum_s v_s^*\cdot v_s = \delta^3(0)\sum_s |v_s|^2$$

$$\langle \Phi|A(t)\rangle = \delta^3(0)\, e^{-i\omega t}\cdot\sum_s g_s^*\, f_s\, e^{ik_s L}$$

$$\langle X|A(t)\rangle = \delta^3(0)\, e^{-i\omega t}\cdot\sum_s v_s^*\, f_s\, e^{ik_s L}$$

$$\langle A|A(t)\rangle = \delta^3(0)\, e^{-i\omega t}\cdot\sum_s f_s^*\, f_s\, e^{ik_s L}$$

$$\begin{pmatrix} p^2 & ig_\phi\omega \mathbf{B}_\perp & ig_\chi\omega\mathbf{B}_\perp \\ -ig_\phi\omega\mathbf{B}_\perp & p^2-m_\phi^2 & -M^2 \\ -ig_\chi\omega\mathbf{B}_\perp & -M^2 & p^2-m_\chi^2 \end{pmatrix}\begin{pmatrix} a \\ \phi \\ \chi \end{pmatrix} = 0$$

$$\int f(x)\delta(x-a)d\,x = f(a);$$

$$\delta(\omega) = \frac{1}{2\pi}\int e^{i\omega t}dt.$$

$$\langle A|A\rangle = \int \psi_a^*\,\psi_a\, d\mathbf{q} = |A|^2(2\pi)^3\delta^3(0)$$

$$\langle A|B\rangle = \int \psi_a^*\,\psi_b\, d\mathbf{q} = |A\cdot B|(2\pi)^3\delta^3(0)$$