MIRROR WORLD

$$m_p - m_e < m_n < m_p$$

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INITIAL SETTINGS

- Decays of proton and neutron are forbidden due to the energy conservation law -> protons and neutrons are stable
- Properties of other SM particles are the same as in the ordinary world

FREEZE-OUT TEMPERATURE & N/P-RATIO

- Freeze-out temperature - the thermodynamic equilibrium between neutrons and protons is violated.
- The thermodynamic equilibrium is broken at the moment when the characteristic weak interaction time becomes larger than the cosmological time t. This corresponds to the moment when the rate of expansion of the Universe begins to exceed the rate of weak interaction processes.
- Calculating that, we will get T~1MeV
- Saha equation:

$$\frac{n_n}{n_p} = \left(\frac{m_n}{m_p}\right)^{\frac{3}{2}} \exp\left(-\frac{m_n - m_p}{T}\right) \longrightarrow 1 < \frac{n_n}{n_p} < 1.65$$

NUCLEOSYNTHESIS

- Let's determine the primary chemical composition of the mirror matter

$$X_{He} = \frac{m_{He} \cdot n_{He}}{m_p(n_p + n_n)} \longrightarrow 0.75 < X_{He} < 1$$

$$X_n = \frac{n_n - n_p}{n_n + n_p} \longrightarrow 0 < X_n < 0.25$$

CONCENTRATION OF FREE PROTONS

- Since the universe is expanding, not all protons could be captured by deuterium nuclei with the subsequent formation of helium. Let's estimate the concentration of free protons.

- The temperature at which nucleosynthesis occurs:

$$X_D(T_{NS}) \approx \eta_B \left(\frac{2.5T_{NS}}{m_p}\right)^{\frac{3}{2}} e^{\frac{\Delta_D}{T_{NS}}} \sim 1 \longrightarrow T_{NS} \approx 60\text{keV}$$

- Mass fraction of free protons that can form hydrogen atoms:

$$X_p = \frac{n_p(t_{NS})}{n_p(0) + n_n} = \frac{e^{-n_n(\sigma v)t_{NS}}}{1 + \frac{n_n}{n_p(0)}} \longrightarrow 10^{-22} < X_p < 10^{-15}$$

MIRROR STRUCTURES FORMATION

- Stars composed of neutrons and helium will form within the framework of this model
- Let's estimate the possibility of beta-decays of some nuclei

$$E_{\mathrm{b}} = \alpha A - \beta A^{\frac{2}{3}} - \gamma Z^2 A^{-\frac{1}{3}} - \delta(A-2Z)^2 A^{-1} + \xi A^{-\frac{1}{2}}$$

- Beta+:

$$\gamma(2Z-1)A^{-\frac{1}{3}} + 4\delta(2Z-A-1)A^{-1} - 2\xi A^{-\frac{1}{2}} > m_e$$

Beta-:

$$-\gamma(2Z+1)A^{-\frac{1}{3}} + 4\delta(A-2Z-1)A^{-1} - 2\xi A^{-\frac{1}{2}} > 3m_e$$

- Nuclei with a significant excess of nucleons can experience beta-decay. Within the framework of this model, the calculation predicts beta-radioactivity of all isotopes of carbon except 12C and 13C, for nitrogen except 14N and 15N.
- Isotopes of the heavier element, uranium, were also considered. It turned out that under this model both 235U and 238U, as in the ordinary world, experience (beta-)-decays, but do not experience beta+

DARK MATTER

- Candidates for the dark matter (DM) in the framework of the considered model will be mirror baryons. To explain all DM, we can make the assumption that the density of mirror baryons will be 5 times the density of ordinary baryons.
- Mirror neutrons and mirror helium make the main contribution to the DM.
- At the recombination temperature of mirror helium, neutral He atoms will form, which will not be affected by radiation pressure forces. Once mirror helium becomes neutral, only mirror neutrons and mirror helium atoms remain. This detaches the nonrelativistic component from the mirror radiation and begins to play the role of DM with the scale of structure determined by the momentum of helium recombination.
- Warm DM + cold DM

CONCLUSION

Here we considered a mirror world model with a ratio of nucleon masses $m_p - m_e < m_n < m_p$

The following properties of the mirror world were established:

- Mirror neutrons and protons are stable particles
- There is an excess of mirror neutrons over mirror protons
- The primary chemical composition of mirror matter is neutrons and helium
- At the temperature of nucleosynthesis, the reaction rate $n + p \to D + \gamma$ significantly exceeds the expansion rate of the Universe, so the concentration of free protons is very low
- Mirror nuclei with a significant excess of nucleons can experience beta-decays
- Mirror neutrons and mirror helium will make the main contribution to the DM (WDM+CDM)