Sexaquark as Dark Matter

In [1, 2, 3] Farrar argues that the sexaquark, (a neutral flavor singlet scalar hadron made of uuddss quarks) is a very interesting candidate for the origin of the Dark Matter. In particular, Farrar argues that the relic abundance of sexaquark particles can reproduce the observed cosmological densirty of Dark Matter. In this scenario the curious 5-to-1 ratio of the mass density of dark matter to that of baryons emerges naturally.

More precisely Farrar argues that if the sexaquark mass in the 1860-1880 MeV mass range (assuring sexaquark and nuclear stability) and assuming the transition temperature from quark–gluon plasma to hadronic pmatter estimated from lattice QCD, the observed $\Omega_{DM}/\Omega_b = 5.3$ is obtained with a $\sim$ 15% uncertainty.

Note that the sexaquark dark matter freezes out before primordial nucleosynthesis and does not significantly impact primordial abundances, so the conventional argument that DM is non-baryonic does not apply.

Farrar argument.

$f_s(T)$ = fraction of strange quarks at temperature T

If all strange quarks enter into sexaquark states:

$$\frac{\Omega_{\rm DM}}{\Omega_b} = \frac{m_S}{2\,m_N}\,\frac{3\,f_s(T)}{1-3\,f_s(T)}$$

If a fraction $k(m_S, T)$ of strange quark goes into the formation of sexaquarks:

$$\frac{\Omega_{\rm DM}}{\Omega_b} = \frac{m_S}{2\,m_N}\,\frac{3\,k(m_S,T)\,f_s(T)}{1-3\,k(m_s,T)\,f_s(T)}$$

$$k(m_S,T) = \frac{1}{1+r_{\Lambda,\Lambda}+r_{\Lambda,\Sigma}+2\,r_{\Sigma,\Sigma}+2\,r_{N,\Xi}}$$

$$r_{j,k} = e^{-(m_j+m_k-m_S)/T}$$

The ratio $\Omega_{\rm DM}/\Omega_b$ can be calculated as a function of T the temperature of the phase transition from quark–gluon plasma to hadronic matter, and m_S (mass of the sexaquark.)

Criticism to the Farrar argument

The estimate of Farrar have been criticised by Gross et al. [4] and Kolb and Turner [5]. (see also Azizi et al. [6])

These authors compute the early-universe production of sexaquarks and find that irrespective of the hadron abundances produced by the QCD quark/hadron transition, rapid particle reactions thermalized the sexaqualrk abundance, and when tracked to the present for the plausible range of dibaryon masses (1860 - 1890 MeV) the sexaquark relic density is very small.

The arguments of [4, 5], can only be circumvented if the coupling of the sexaquark to strange baryons is strongly suppressed.

Astrophysical bounds

The existence if a stable sexaquark can have important astrophysical consequences. A stable sexaquark particle can act as a baryon sink in regions of high baryon density and temperature, with important consequences on the stability of neutron stars, and the emission of neutrinos from supernovae Mc Dermott et al. [7] argues that the observations of neutron stars and of the neutrino emission from the proto-neutron star of Supernova 1987A are incompatible with the existence of a light stable sexaquark unless the cross section for S production is severely suppressed.

References

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