"Astrophobic Axions"

Decoupled from Nucleons and from Electrons

KSVZ axions are decoupled from the leptons ($g_{ae} \approx 0$)

Coupling to nucleons are model independent ($g_{aN} \neq 0$)

DFSZ axions couple to the leptons ($g_{ae} \neq 0$)

Coupling to nucleons nonzero but model dependent ($g_{aN} \neq 0$)

Generalized DFSZ axions can (approximately) decouple from nucleons ($g_{aN} \approx 0$) and from electrons ($g_{ae} \approx 0$)

The two conditions for "Nucleophobia"

From the UV theory we have: $\mathcal{L}_q = \frac{\partial_\mu a}{2 f_a} c_q \, \bar{q} \gamma^\mu \gamma_5 \, q$. We want: $\mathcal{L}_N = \frac{\partial_\mu a}{2 f_a} C_N \, \bar{N} \gamma^\mu \gamma_5 \, N$

C_N in terms of c_q and of matrix elements $s^\mu \Delta_q = \langle N | \bar{q} \gamma^\mu \gamma_5 q | N \rangle$ by matching the matrix elements of $\mathcal{L}_q$ and $\mathcal{L}_N$. One obtains:

$$
\begin{aligned}
(1):\quad C_p + C_n &= (c_u + c_d)(\Delta_u + \Delta_d) - 2\delta_s \qquad [\delta_s \approx O(10\%)] \\
(2):\quad C_p - C_n &= (c_u - c_d)(\Delta_u - \Delta_d)
\end{aligned}
$$

So that, independently of the matrix elements:

$$
\begin{aligned}
(1):\quad C_p + C_n &\approx 0 \quad \text{if} \quad c_u + c_d = 0 \\
(2):\quad C_p - C_n &= 0 \quad \text{if} \quad c_u - c_d = 0
\end{aligned}
$$

Redefine the Condition: $c_u + c_d = 0$

Anomalous axion couplings:

$$\frac{a}{v_a}\frac{g_s^2}{16\pi^2} N\, G\tilde{G}$$

$$\frac{a}{v_a}\frac{e^2}{16\pi^2} E\, F\tilde{F}$$

$X_u = (X_{uR} - X_{uL})/2$

$$\mathcal{L}_a \supset \frac{a}{f_a}\frac{\alpha_s}{8\pi} G\tilde{G} + \frac{a}{f_a}\frac{\alpha}{8\pi}\frac{E}{N} F\tilde{F} + \frac{\partial_\mu a}{v_a}\left[X_u\, \bar{u}\gamma^\mu\gamma_5 u + X_d\, \bar{d}\gamma^\mu\gamma_5 d\right]$$

$$\left(f_a = \frac{v_a}{2N}\right)$$

$$\frac{\partial_\mu a}{2 f_a}\left[\frac{X_u}{N}\, \bar{u}\gamma^\mu\gamma_5 u + \frac{X_d}{N}\, \bar{d}\gamma^\mu\gamma_5 d\right]$$

model independent contributions

$$\frac{E}{N} \to \frac{E}{N} - 1.92(4)\,; \quad \frac{X_u}{N} \to c_u = \frac{X_u}{N} - \frac{m_d}{m_d + m_u}\,; \quad \frac{X_d}{N} \to c_d = \frac{X_d}{N} - \frac{m_u}{m_d + m_u}$$

Therefore:

$$c_u + c_d = \frac{X_u + X_d}{N} - 1$$

$$\xrightarrow[N = n_g (X_u + X_d)]{universality} \frac{1}{n_g} - 1 \neq 0$$

First Condition: $C_u + C_d = 0$

Nucleophobia unavoidably requires DFSZ-type of models with generation dependent PQ charges

such that the contribution to the anomaly from the two heavier generations vanishes: $N_{tot} = N_{(1^{st} gen)}$

Nucleophobia is not possible for KSVZ-type of models

Second Condition: $c_u - c_d = 0$

Scalar content of DFSZ models: H_1, H_2, Φ_a with VEVs v_1, v_2, v_a $(v_1^2+v_2^2=v^2)$ and PQ charges X_1, X_2, $X_a=(X_1 - X_2)(1/2)$

$$
\begin{aligned}
c_u - c_d &= \frac{(\mathcal{X}_{u_R} - \mathcal{X}_{u_L}) - (\mathcal{X}_{d_R} - \mathcal{X}_{d_L})}{2N_\ell} - \frac{m_d - m_u}{m_d + m_u} \\
&= -\frac{\mathcal{X}_1 + \mathcal{X}_2}{\mathcal{X}_2 - \mathcal{X}_1} - \left(\approx \frac{1}{3}\right)
\end{aligned}
$$

$$
\begin{aligned}
&\sum\nolimits_i \mathcal{X}_i Y_i v_i^2 = 0 \\
\Rightarrow\ &\mathcal{X}_1 v_1^2 + \mathcal{X}_2 v_2^2 = 0
\end{aligned}
$$

Goldstone of Hyperchage: $\varphi_Y = (v_2\, \varphi_2 - v_1\, \varphi_1)/v$

To avoid a-φ_Y redefine the charges $X_1=v_2^2/v^2=s_\beta^2$; $X_2=v_1^2/v^2=c_\beta^2$

The (tuned) choice: $X_u - X_d = X_2 - X_1 = 1/3 \longrightarrow c_\beta^2 = 2/3$ allows (in principle) for a complete a-N decoupling

SUMMARY PLOT

KSVZ
SN g_{aN}

DFSZ
SN g_{aN}
WD g_{ae}

Astrophobic Axions