Chapter 10

Strong P, T Problem

One result of the analysis is that a term $\approx \int trG\tilde{G}$ in the action of QCD is not negligible, even though, it is a total derivative (so it does not appear in the classical equations of motion).

Since it is a dimension 4 interaction, it should appear in our canonical form for QCD. Unfortunately it violates P and T, so its processes with a substantial coefficient would not agree with experience. Detailed estimates suggest

$$|\frac{\theta}{2\pi}| \quad (the\ natural\ parameter) \leq 10^{-9} \tag{10.1}$$

Since there is P and T violation in the electroweak interaction, this term will be needed for renormalization so unless there is an extra symmetry to explain why $\theta \approx 0$ (or can be rotated away) we have an ugly situation.

The required symmetry Peccei-Quinn) is essentially axial baryon number, since this counts ($\Delta winding$) and thus powers of $e^{i\theta}$.

If there is a symmetry of this type and spontaneously broken at a high scale F, the kinetic term of its Nambu-Goldstone phase field reads

$$\partial_\mu\varphi\partial_\mu\varphi^+ \stackrel{\varphi=Fe^{i\theta}}{\longrightarrow} F^2(\partial_\mu\theta)^2 \tag{10.2}$$

This puts us back at our earlier analysis. We get, for large F a very light, very weakly interacting particle, the axion.

It is a serious candidate to supply the dark matter of the universe.

For more on axioms, see my $'83$ Erice lectures.