Accidental PQ symmetry from discrete R symmetry

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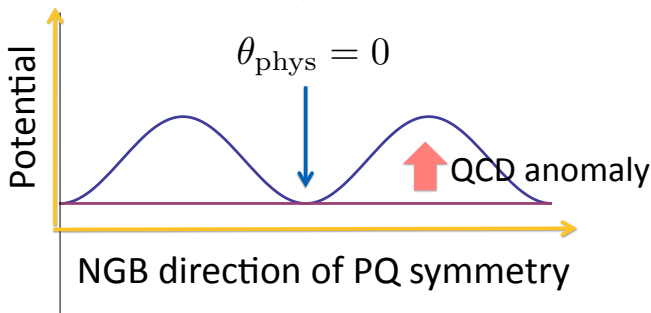
Strong CP problem

Why is the CP violation small in QCD ?

$$\mathcal{L}_{\text{CPV}} = \frac{\theta_{\text{phys}}}{32\pi^2} G^A_{ab} \tilde{G}^{ab}_A \quad \text{Exp} : \theta_{\text{phys}} < 10^{-10}$$

Idea : Peccei-Quinn mechanism

PQ symmetry : almost exact,
            except for anomaly

SSB

$\theta_{\text{phys}} = 0$

QCD anomaly

NGB direction of PQ symmetry

What is an origin of such symmetry?

Hint : Baryon symmetry in the SM

$$SU(3)_c \times SU(2)_W \times U(1)_Y$$

Accidental Baryon symmetry

Our proposal : R symmetry leads to accidental PQ symmetry

Roles of R symmetry in SUSY;

· suppressing cosmological constant

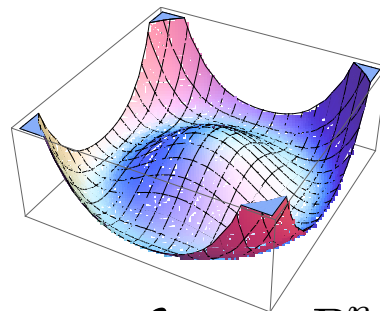· linked to ~~SUSY~~

Assume exact, discrete R symmetry

R-symmetric extension of MSSM

Anomaly free R symmetry requires
additional matters $Q_i(5), \bar{Q}_i(\bar{5})$

R symmetry   ➡   Accidental, anomalous $U(1)_Q$

Mass generating Higgs sector

$$V = (|P|^2 - v^2)^2 + \cancel{P^k} + \cdots$$

R symmetry

Accidental $U(1)_P$

$$\mathcal{L}_{\text{int}} = P^n Q\bar{Q}$$

$$U(1)_P \times U(1)_Q \implies U(1)_{PQ}$$

Superpotential

$$W = X(P\bar{P} - \Lambda^2) + P^n Q\bar{Q} + \cdots$$

Effect of the accidentalness

~~PQ~~ $V = \dfrac{1}{M_{\text{PL}}^k} P^{4+k}$ may appear

Is k >>1 ?

YES ! For $Z_3^R, Z_4^R, Z_5^R, \cdots$
(depend on the charge assignment for
P, Q, …)