CP Violating Dipoles from Warped/Composite Models

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Synopsis

Preamble

- RS models & 4D composite Higgs friends

Act I

- CP asym. in charm decays ≈ 1% in anarchic RS scenarios
- 4D estimate is a bit larger [$m_\rho \sim 10\,\text{TeV} \times g_\rho/4\pi$]

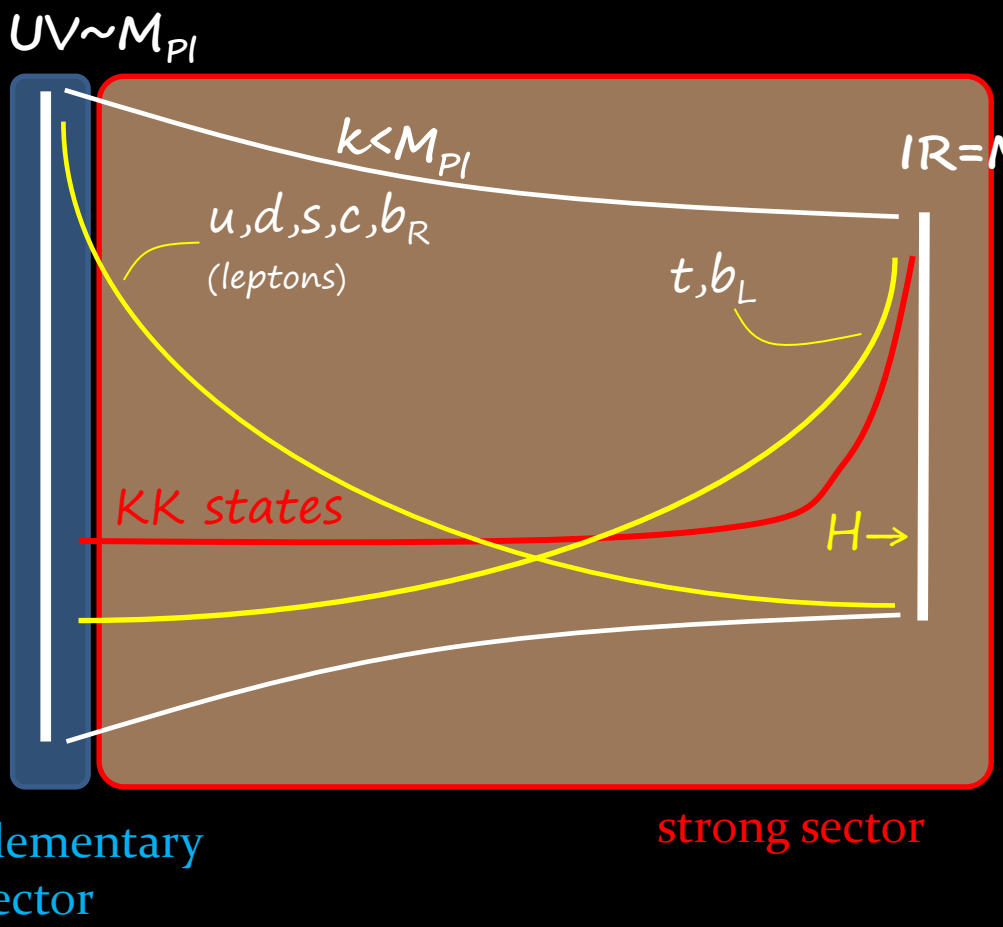
(swiss)italian interpretation → RS's too fancy, don't trust it!
ours → 4D estimate's too naive, don't take it too seriously.

Act II

- RS extra suppression is *NOT* accidental, there is a symmetry in the KK theory, which *applies for all dipole operators!*
- this symmetry is also realized in 4D duals!

Warped/composite essentials

RS'99: « Hierarchy problem is solved in AdS5 bckg: $ds^2 = e^{-2ky} dx^2 - dy^2$ »



- EWPTs → m_{KK}>3-4TeV
  custodial symmetry @work
- SM flavor puzzle addressed
- NP flavor problem almost solved
  RSGIM @work, yet:

  $Im[\epsilon_K]+Im[\epsilon'/\epsilon]$ → m_{KK}>5TeV
- still a little CP problem

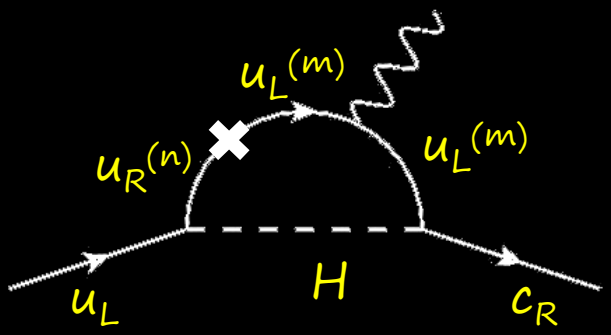
  nEDM → m_{KK}>8TeV

ψ_{SM} (no H) ← *linear mixing* → *H(=PGB) resonances*

CP asymmetries in charm decays from RS

LHCb '11: $\Delta a_{CP} \approx (-1 \pm 0.2)\%$
SM = ?! (<0.1%?)

- If not SM, 2 ways to get it:
  - → $(\bar{u}c)_{V+A}(\bar{q}q)_{V+A}$ with $\Lambda_{4f} \approx 10\,\text{TeV}$ *(potential problem w/ DDbar mixing* Isidori et al '11*)*
  - → $g_s m_c \bar{u}_L \sigma_{\mu\nu} G^{\mu\nu} c_R$ with $\Lambda_8 \approx 20\,\text{TeV}$ *(no tension w/ $\Delta C=2$ thanks to chirality flip* Grossman, Kagan, Nir '06*)*
- anarchic RS/4D partial compositeness expectations
  - → light q are mostly elementary → $\Lambda_{4f} >> 10\,\text{TeV}$ *...hopeless*
  - → for dipoles light q compositeness is swallowed in m_c → *hope!*



$$= g_s m_c \lambda_c \frac{Y_5^2}{16\pi^2 m_{KK}^2} O_\beta$$

bulk H overlap corr.
≈ 0.1 for $\beta = 0$

naively doesn't arise in 4D estimates

What's behind the overlap correction in 5D

- KK theory = *chiral* zero modes (q,u,d)
  + towers of massive *vector-like* states (Q^n, U^n, D^n)

- known facts:
  - *bulk Higgs*: $\mathcal{O}_\beta$ is controlled by the *«wrong» chirality* KK states, whose overlap with H is suppressed → $\mathcal{O}_\beta$ is typically small.

    Agashe, Azatov & '08
  - *IR brane Higgs*: wrong KKs vanish on the IR brane → $\mathcal{O}_\beta = \mathcal{O}$
    but 1-loop dipoles become UV-sensitive → unclear if diagram = $\mathcal{O}$
  - Yet explicit calculation yields a UV-finite 1-loop result for IR Higgs
    → *what's going on?* Csaki et al. '10

- *our answer:* there is an approximate symmetry in the KK theory acting on the wrong chirality states

A protection mechanism for CPV dipoles in RS

- @1-loop only Yukawa int.'s can provide a new CPV phase
  gauge interaction yields dipoles aligned w/ $M_{U,D}$ → real
- in 1 generation limit: $\psi_L=(q,Q^+,U^-)$, $\psi_R=(u,Q^-,U^+)$

$$\text{Yukawa} = \begin{pmatrix} y_{00} & 0 & y_{01} \\ y_{10} & 0 & y_{11} \\ 0 & y_- & 0 \end{pmatrix} \qquad \text{mass} = \begin{pmatrix} y_{00}v & 0 & y_{01}v \\ y_{10}v & m_{KK}{}^{Q} & y_{11}v \\ 0 & y_-v & m_{KK}{}^{U} \end{pmatrix}$$

when $y_- \to 0$ (IR Higgs case) the low-E theory has a $U(1)^{Q^-} \times U(1)^{U^-}$ symmetry only broken by the KK masses.

- $qH\sigma_{\mu\nu}F^{\mu\nu}u$ is $U(1)^2$ invariant, $m_{KK}{}^{Q,U}$ as spurions we get:
  - smallest singlet = $|m_{KK}{}^{Q,U}|^{-2}$ but $\propto y_{00}|y_{01}|^2$ → *highly suppressed!*
  - next = $|m_{KK}{}^{Q}|^{-2} \times |m_{KK}{}^{U}|^{-2}$ → dim8 ops. → *explains finiteness of IR H!*
  - bulk H: $(y_-)^* m_{KK}{}^{Q} m_{KK}{}^{U}$ → dim6 but y_- is suppressed
- universal mechanism @work for EDMs, $b\to s\gamma$, ϵ'/ϵ, $\mu\to e\gamma$

4D realization of the suppression mechanism

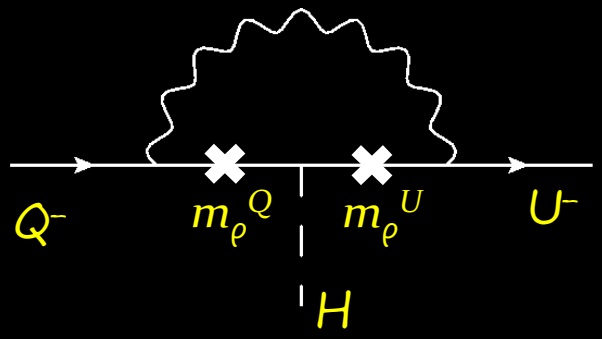
$$L_{2site} \supset -m_\rho^{\,Q}\,\bar{Q}^{+}Q^{-} - m_\rho^{\,U}\,\bar{U}^{+}U^{-} - y\,\bar{Q}^{+}HU^{+} + \Delta_q\,\bar{q}Q^{-} + \Delta_u\,\bar{u}U^{-} + h.c.$$

- in terms of mass eigenstates we get the same Lagrangian than in RS with 1 KK level *without* y_-

  → same $U(1)^2$ also @work in 4D, dipoles suppressed by $(g_\rho v/m_\rho)^2$

- wrong Yukawa y_- isn't required to get SM quark mass

  yet, it is generated radiatively by gauge interactions:



$$\sim (g_\rho^2 y/16\pi^2) \times m_\rho^{\,Q} m_\rho^{\,U}/\left[\left|m_\rho^{\,Q}\right|^2+\left|m_\rho^{\,U}\right|^2\right]$$

suppressed if g_ρ not too large

Epilogue

- Anarchic warped models @3TeV explain the observed CP asymmetry in charm decays through a sizable chromomagnetic dipole operators

- Not overlarge Δa_{CP} is obtained thanks to a suppressed Higgs overlap with the wrong chirality KK states.

- The suppression results from an (approximate) enhanced symmetry in the limit of an IR Higgs (where dipoles are 1-loop finite)

- The symmetry can also be realized in the simplest (2-site) of the 4D composite duals. It is universal and applies to other CPV radiatives processes: EDMs, $b\to s\gamma$, ϵ'/ϵ, $\mu\to e\gamma$

Thank you!