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Exercises for the SMEFT lectures (Adam Falkowski)

1. Calculate the SMEFT dimension-6 operators generated due to integrating out at tree-level the following exotic particles with mass $M \gg m_W$. In all cases, reduce the effective operators to the Warsaw basis, and write down the expression for the SMEFT Wilson coefficients in that basis. Bonus: for the spin-1 bosons, extend the calculation to dimension-8 operators.

- A real singlet spin-1 boson V_μ coupled to the Standard Model (SM) Higgs boson via the interaction

$$\mathcal{L} \supset -i\kappa_1 V_\mu H^\dagger D^\mu H + \text{h.c.} \tag{1}$$

- A complex triplet spin-1 boson V_μ^a coupled to the SM Higgs boson via the interaction

$$\mathcal{L} \supset -i\kappa_3 V_\mu^a H^\dagger \sigma^a D^\mu H + \text{h.c.} \tag{2}$$

A complex scalar leptoquark S_1 with Yukawa couplings to the first generation of the SM leptons

$$\mathcal{L} \supset S_1 \Big[y_L q \tilde{l} + y_R \bar{u}^c \bar{e}^c \Big] + \text{h.c.} \tag{3}$$

2. Consider the so-called νSMEFT, that is SMEFT extended by a singlet (right-handed) neutrino ν^c. What are the additional operators one can construct up to dimension 6? How do they affect the physical observables and power counting? For simplicity, assume one generation of SM fermions and one singlet neutrino.

3. Consider the dimension-6 SMEFT operator $|H^\dagger D_\mu H|^2$. What is the effect of this operator on the W boson mass? What are the constraints on the corresponding Wilson coefficient given the existing experimental measurements of the W boson mass? Bonus: identify all the dimension-6 SMEFT operators that contribute to the W boson mass at tree level.

4. Consider the following 4-fermion dimension-6 SMEFT operators:

$$(e^c l)(u^c q), \qquad (e^c \sigma^{\mu\nu} l)(u^c \sigma^{\mu\nu} q), \qquad (\bar{l}\bar{e}^c)(d^c q). \tag{4}$$

Calculate RG running of the corresponding Wilson coefficients due to 1-loop diagrams with gluons.