One-Loop UV/IR SMEFT dictionary

Based on 2303.16965

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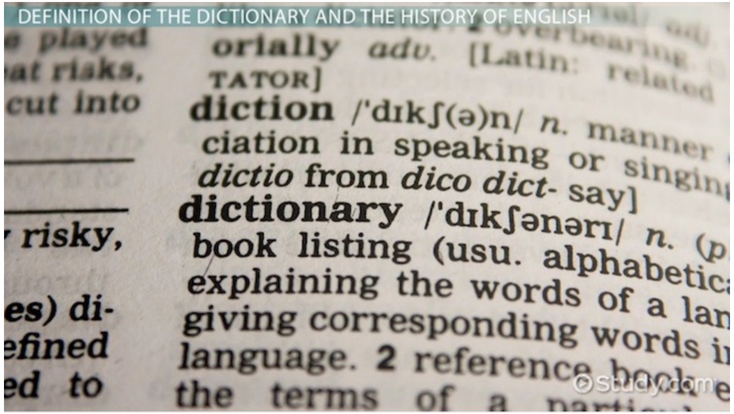
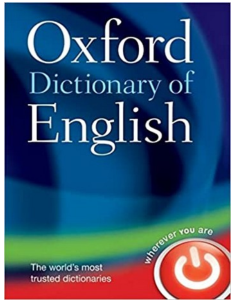
What are UV/IR dictionaries



$\mathcal{L}_{UV}$

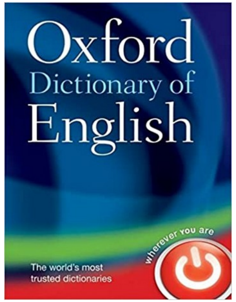
$\Updownarrow$

IR data



Bottom-up approach: UV/IR dictionaries

$$\mathcal{L}_{UV}$$



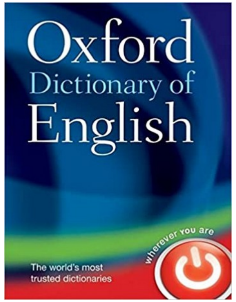
$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \frac{\mathcal{L}_6}{\Lambda^2}$$

- What is the data telling us?
- UV/IR dictionaries tell us ***all*** SM extensions which can contribute to a particular experimental observable (at an order in the EFT expansion)

Top-down approach: UV/IR dictionaries

$$\mathcal{L}_{UV}$$

$$\Big\downarrow$$

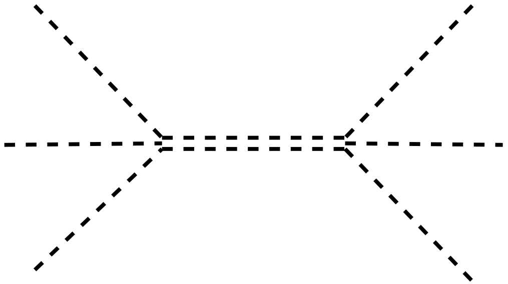


$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \frac{\mathcal{L}_6}{\Lambda^2}$$

- What are the low-energy consequences of a particular UV scenario?
- UV/IR dictionaries allows to map all these contributions finding correlations among WCs.
  - Done at a specific perturbative order through matching.

Dictionary at tree-level

- Tree-level dictionary to the SMEFT @ dim-6 already exists, with ***all*** possible extensions which can generate WCs and their explicity contribution.



$\mathcal{S}$	$\mathcal{S}_1$	$\mathcal{S}_2$	φ	Ξ	Ξ_1	Θ_1	Θ_3
$(1,1)_0$	$(1,1)_1$	$(1,1)_2$	$(1,2)_{\frac{1}{2}}$	$(1,3)_0$	$(1,3)_1$	$(1,4)_{\frac{1}{2}}$	$(1,4)_{\frac{3}{2}}$
ω_1	ω_2	ω_4	Π_1	Π_7	ζ		
$(3,1)_{-\frac{1}{3}}$	$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{4}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$		
Ω_1	Ω_2	Ω_4	Υ	Φ			
$(6,1)_{\frac{1}{3}}$	$(6,1)_{-\frac{2}{3}}$	$(6,1)_{\frac{4}{3}}$	$(6,3)_{\frac{1}{3}}$	$(8,2)_{\frac{1}{2}}$			

N	E	Δ_1	Δ_3	Σ	Σ_1	
$(1,1)_0$	$(1,1)_{-1}$	$(1,2)_{-\frac{1}{2}}$	$(1,2)_{-\frac{3}{2}}$	$(1,3)_0$	$(1,3)_{-1}$	
U	D	Q_1	Q_5	Q_7	T_1	T_2
$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{1}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{-\frac{5}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$	$(3,3)_{\frac{2}{3}}$

$\mathcal{B}$	$\mathcal{B}_1$	$\mathcal{W}$	$\mathcal{W}_1$	$\mathcal{G}$	$\mathcal{G}_1$	$\mathcal{H}$	$\mathcal{L}_1$
$(1,1)_0$	$(1,1)_1$	$(1,3)_0$	$(1,3)_1$	$(8,1)_0$	$(8,1)_1$	$(8,3)_0$	$(1,2)_{\frac{1}{2}}$
$\mathcal{L}_3$	$\mathcal{U}_2$	$\mathcal{U}_5$	$\mathcal{Q}_1$	$\mathcal{Q}_5$	$\mathcal{X}$	$\mathcal{Y}_1$	$\mathcal{Y}_5$
$(1,2)_{-\frac{3}{2}}$	$(3,1)_{\frac{2}{3}}$	$(3,1)_{\frac{5}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{-\frac{5}{6}}$	$(3,3)_{\frac{2}{3}}$	$(\bar{6},2)_{\frac{1}{6}}$	$(\bar{6},2)_{-\frac{5}{6}}$

De Blas, Criado, Perez-Victoria, Santiago, 1711.10391

Dictionary at tree-level

- Tree-level dictionary to the SMEFT @ dim-6 already exists, with ***all*** possible extensions which can generate WCs and their explicity contribution.
- Some operators can be generated at one-loop
  - Considering weakly coupled renormalizable UV

Craig, Jiang, Li, Sutherland 2001.00017

$\mathcal{S}$	$\mathcal{S}_1$	$\mathcal{S}_2$	φ	Ξ	Ξ_1	Θ_1	Θ_3
$(1,1)_0$	$(1,1)_1$	$(1,1)_2$	$(1,2)_{\frac{1}{2}}$	$(1,3)_0$	$(1,3)_1$	$(1,4)_{\frac{1}{2}}$	$(1,4)_{\frac{3}{2}}$
ω_1	ω_2	ω_4	Π_1	Π_7	ζ		
$(3,1)_{-\frac{1}{3}}$	$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{4}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$		
Ω_1	Ω_2	Ω_4	Υ	Φ			
$(6,1)_{\frac{1}{3}}$	$(6,1)_{-\frac{2}{3}}$	$(6,1)_{\frac{4}{3}}$	$(6,3)_{\frac{1}{3}}$	$(8,2)_{\frac{1}{2}}$			

N	E	Δ_1	Δ_3	Σ	Σ_1	
$(1,1)_0$	$(1,1)_{-1}$	$(1,2)_{-\frac{1}{2}}$	$(1,2)_{-\frac{3}{2}}$	$(1,3)_0$	$(1,3)_{-1}$	
U	D	Q_1	Q_5	Q_7	T_1	T_2
$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{1}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{-\frac{5}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$	$(3,3)_{\frac{2}{3}}$

$\mathcal{B}$	$\mathcal{B}_1$	$\mathcal{W}$	$\mathcal{W}_1$	$\mathcal{G}$	$\mathcal{G}_1$	$\mathcal{H}$	$\mathcal{L}_1$
$(1,1)_0$	$(1,1)_1$	$(1,3)_0$	$(1,3)_1$	$(8,1)_0$	$(8,1)_1$	$(8,3)_0$	$(1,2)_{\frac{1}{2}}$
$\mathcal{L}_3$	$\mathcal{U}_2$	$\mathcal{U}_5$	$\mathcal{Q}_1$	$\mathcal{Q}_5$	$\mathcal{X}$	$\mathcal{Y}_1$	$\mathcal{Y}_5$
$(1,2)_{-\frac{3}{2}}$	$(3,1)_{\frac{2}{3}}$	$(3,1)_{\frac{5}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{-\frac{5}{6}}$	$(3,3)_{\frac{2}{3}}$	$(\bar{6},2)_{\frac{1}{6}}$	$(\bar{6},2)_{-\frac{5}{6}}$

De Blas, Criado, Perez-Victoria, Santiago, 1711.10391

Dictionary at one-loop

- Current experimental precision needs one-loop matching.
- Significant progress in the past few years in the development of automatic tools to perform matching at one-loop.
  - **CoDEx/Matchete** – Functional. Das Bakshi, Chakrabortty,Kumar Patra, 1808.04403 Fuentes-Martín, König, Pagès, Thomsen, Wilsch, 2212.04510
  - **Matchmakereft** – Diagrammatic. Carmona, Lazopoulos, Olgoso, Santiago, 2112.10787

See Julie's talk

- However, creating a dictionary at this order is not immediate – infinite completions.

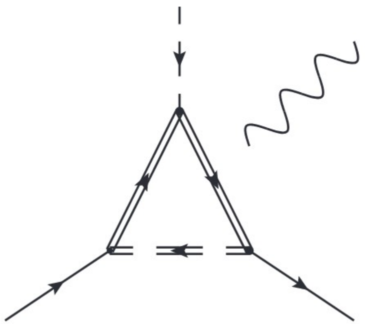
The need for dictionaries: the anomalous g-2

Big effort to explain this discrepancy in **SM extensions**

P. Athron, C. Balázs, D. Jacob, W. Kotlarski, D. Stöckinger, H. Stöckinger-Kim 2104.03691

$$\mathcal{O}_{eB} = (\bar{\ell}\sigma^{\mu\nu}e)HB_{\mu\nu} + \text{h.c.},$$
$$\mathcal{O}_{eW} = (\bar{\ell}\sigma^{\mu\nu}e)\sigma^I HW^I_{\mu\nu} + \text{h.c.}.$$

$\mathcal{O}$(TeV) solutions need chirally enhanced contributions



A. Crivellin and M. Hoferichter, 2104.03202

L. Allwicher, L. Luzio, M. Fedele, F. Mescia, M. Nardecchia, 2105.13981

The need for dictionaries: the anomalous g-2

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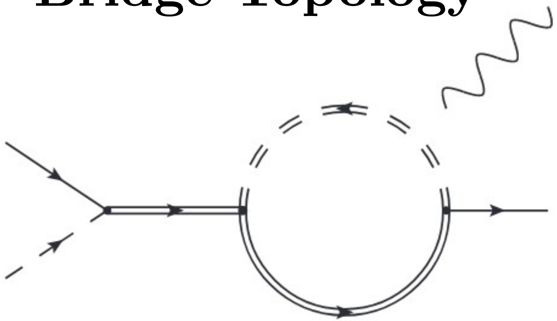
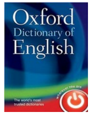
Bridge Topology



N. Arkani-Hamed and K. Harigaya, 2106.01373

L. Rose, B. Harling and A. Pomarol, 2201.10572

- **Systematic classification of UV models which generate the bridge?**



  - New 2- and 3-field extensions
  - Room for connection with tree-level explanations of other anomalies

G. G., P. Olgoso, 2205.04480

The dictionary – first iteration

- Consider operators with **leading** contribution at one-loop (weakly coupled renormalizable UV)
- Limit UV theory to heavy scalars and fermions with renormalizable interactions

X^3	X^2H^2	$\psi^2XH + \text{h.c.}$
$\mathcal{O}_{3G} = f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_{HG} = G^A_{\mu\nu}G^{A\,\mu\nu}H^\dagger H$	$\mathcal{O}_{uG} = (\bar{q}T^A\sigma^{\mu\nu}u)\widetilde{H}G^A_{\mu\nu}$
$\mathcal{O}_{\widetilde{3G}} = f^{ABC}\widetilde{G}_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_{H\widetilde{G}} = \widetilde{G}^A_{\mu\nu}G^{A\,\mu\nu}H^\dagger H$	$\mathcal{O}_{uW} = (\bar{q}\sigma^{\mu\nu}u)\sigma^I\widetilde{H}W^I_{\mu\nu}$
$\mathcal{O}_{3W} = \epsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$\mathcal{O}_{HW} = W^I_{\mu\nu}W^{I\,\mu\nu}H^\dagger H$	$\mathcal{O}_{uB} = (\bar{q}\sigma^{\mu\nu}u)\widetilde{H}B_{\mu\nu}$
$\mathcal{O}_{\widetilde{3W}} = \epsilon^{IJK}\widetilde{W}_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$\mathcal{O}_{H\widetilde{W}} = \widetilde{W}^I_{\mu\nu}W^{I\,\mu\nu}H^\dagger H$	$\mathcal{O}_{dG} = (\bar{q}T^A\sigma^{\mu\nu}d)HG^A_{\mu\nu}$
	$\mathcal{O}_{HB} = B_{\mu\nu}B^{\mu\nu}H^\dagger H$	$\mathcal{O}_{dW} = (\bar{q}\sigma^{\mu\nu}d)\sigma^I HW^I_{\mu\nu}$
	$\mathcal{O}_{H\widetilde{B}} = \widetilde{B}_{\mu\nu}B^{\mu\nu}H^\dagger H$	$\mathcal{O}_{dB} = (\bar{q}\sigma^{\mu\nu}d)HB_{\mu\nu}$
	$\mathcal{O}_{HWB} = W^I_{\mu\nu}B^{\mu\nu}H^\dagger\sigma^I H$	$\mathcal{O}_{eW} = (\bar{\ell}\sigma^{\mu\nu}e)\sigma^I HW^I_{\mu\nu}$
	$\mathcal{O}_{H\widetilde{W}B} = \widetilde{W}^I_{\mu\nu}B^{\mu\nu}H^\dagger\sigma^I H$	$\mathcal{O}_{eB} = (\bar{\ell}\sigma^{\mu\nu}e)HB_{\mu\nu}$

See John's talk for linear SM extensions

See Fabian's talk for the case of 4-fermion ops

The dictionary

$$
\begin{aligned}
\mathcal{L}_{\rm UV} =& \delta_{\Psi_a}\bar{\Psi}_a\left[\mathrm{i}\not{D} - M_{\Psi_a}\right]\Psi_a + \delta_{\Phi_a}\left[|D_\mu\Phi_a|^2 - M^2_{\Phi_a}|\Phi_a|^2\right] \\
&+ \sum_{\chi=L,R}\Big[Y^\chi_{abc}\overline{\Psi}_a P_\chi \Psi_b \Phi_c + \widetilde{Y}^\chi_{abc}\overline{\Psi}_a P_\chi \Psi_b \Phi^\dagger_c \\
&\qquad + X^\chi_{abc}\overline{\Psi^c}_a P_\chi \Psi_b \Phi_c + \widetilde{X}^\chi_{abc}\overline{\Psi^c}_a P_\chi \Psi_b \Phi^\dagger_c + \text{h.c.}\Big] \\
&+ \Big[\kappa_{abc}\Phi_a\Phi_b\Phi_c + \kappa'_{abc}\Phi_a\Phi_b\Phi^\dagger_c + \lambda_{abcd}\Phi_a\Phi_b\Phi_c\Phi_d \\
&\quad + \lambda'_{abcd}\Phi_a\Phi_b\Phi_c\Phi^\dagger_d + \lambda''_{abcd}\Phi_a\Phi_b\Phi^\dagger_c\Phi^\dagger_d + \text{h.c.}\Big],
\end{aligned}
$$

Gauge structure of UV couplings kept arbitrary.
Match using matchmakereft

The dictionary

WCs are therefore given in terms of UV couplings and Clebsch-Gordon tensors.

Example: G.G., Olgoso 2205.04480

$$\alpha_{e\gamma}^{2,2} = \frac{iN_c e}{4} y_M y_F y_b^R \sum_{IJ} T_{I2J} \left[\gamma_\Psi T_{I'I}^{\gamma,\Psi} T'_{2JI'} + \gamma_\Phi T_{JJ'}^{\gamma,\Phi} T'_{2IJ'} \right]$$

The next step is to specify **Quantum numbers of UV scenario** – **GroupMath** computes possible CGs

Fonseca 2011.01764

The dictionary

Dictionary can be used through the Mathematica package:
SOLD (Smeft One-Loop Dictionary)

```
In[1]:= << SOLD`
SMEFT One Loop Dictionary loaded
Version: 1.0.1
Authors: Guilherme Guedes, Pablo Olgoso, José Santiago
Reference: arXiv:2303.16965
Webpage: https://gitlab.com/jsantiago_ugr/sold
XXXXXXXXXXXXXXXXXXXXXXXXXXX GroupMath XXXXXXXXXXXXXXXXXXXXXXXXXXX
Version: 1.1.2 (6/May/2020)
Author: Renato Fonseca
Reference: 2011.01764 [hep-th]
Website: renatofonseca.net/groupmath
Built-in documentation: here
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX-
  XXXX
```

The dictionary

Dictionary can be used in two directions:

Bottom-up: Which UV models generate a specific Wilson Coefficient?

Top-Down: Which Wilson coefficients are generated by a specific UV model?

The dictionary

$$\mathcal{O}_{dG} = (\bar{q}_L \sigma^{\mu\nu} T_A d_R)\, \phi G^A_{\mu\nu}$$

Bottom-up: Which UV models generate a specific Wilson Coefficient? Which restrictions?

```
In[2]:= listofmodels = ListModelsWarsaw[alphaOdG[i, j]];
        MatrixForm[Join[Take[listofmodels[[1]], {1, 3}], {{"....", "....", "...."}}, Take[listofmodels[[1]], {20, 22}],
          {{"....", "....", "...."}}, Take[listofmodels[[1]], {145, 146}], {{"....", "....", "...."}}]]
```

Out[3]//MatrixForm=

Field Content	$SU(3) \otimes SU(2)$	$U(1)$
$\{\phi 1\}$	$\{\phi 1 \to \bar{\mathbf{3}} \otimes \mathbf{1}\}$	$\{Y_{\phi 1} \to \frac{1}{3}\}$
$\{\phi 1\}$	$\{\phi 1 \to \bar{\mathbf{3}} \otimes \mathbf{1}\}$	$\{Y_{\phi 1} \to \frac{4}{3}\}$
....	....	....
$\{\phi 1, \phi 2\}$	$\{\phi 1 \to \mathbf{8} \otimes \mathbf{2},\ \phi 2 \otimes \overline{\phi 2} \supset \mathbf{8} \otimes \mathbf{3}\}$	$\{Y_{\phi 1} \to -\frac{1}{2},\ Y_{\phi 2}\}$
$\{\phi 1, \psi 1\}$	$\{\psi 1 \otimes \overline{\phi 1} \supset \bar{\mathbf{3}} \otimes \mathbf{1}\}$	$\{Y_{\psi 1} \to \frac{1}{3} + Y_{\phi 1}\}$
$\{\phi 1, \psi 1\}$	$\{\psi 1 \otimes \overline{\phi 1} \supset \bar{\mathbf{3}} \otimes \mathbf{2}\}$	$\{Y_{\psi 1} \to -\frac{1}{6} + Y_{\phi 1}\}$
....	....	....
$\{\phi 1, \psi 1, \psi 2\}$	$\{\psi 1 \otimes \overline{\phi 1} \supset \bar{\mathbf{3}} \otimes \mathbf{2},\ \psi 1 \otimes \psi 2 \supset \mathbf{1} \otimes \mathbf{2},\ \psi 2 \otimes \phi 1 \supset \mathbf{3} \otimes \mathbf{1}\}$	$\{Y_{\psi 1} \to -\frac{1}{6} + Y_{\phi 1},\ Y_{\psi 2} \to -\frac{1}{3} - Y_{\phi 1}\}$
$\{\phi 1, \psi 1, \psi 2\}$	$\{\psi 1 \otimes \overline{\phi 1} \supset \bar{\mathbf{3}} \otimes \mathbf{2},\ \psi 2 \otimes \overline{\psi 1} \supset \mathbf{1} \otimes \mathbf{2},\ \psi 2 \otimes \overline{\phi 1} \supset \bar{\mathbf{3}} \otimes \mathbf{1}\}$	$\{Y_{\psi 1} \to -\frac{1}{6} + Y_{\phi 1},\ Y_{\psi 2} \to \frac{1}{3} + Y_{\phi 1}\}$
....	....	....

The dictionary

$$\mathcal{O}_{dG} = (\bar{q}_L \sigma^{\mu\nu} T_A d_R)\, \phi G^A_{\mu\nu}$$

Bottom-up: Which UV models generate a specific Wilson Coefficient? Which Quantum Numbers?

```
In[13]:= modelQNs = ListValidQNs[listofmodels[[1, 145]]];
Print["Model restriction :", listofmodels[[1, 145]], "\nList of Models:\n",
 MatrixForm[Join[Take[modelQNs, {1, 3}], {{"....", "....", "...."}}, Take[modelQNs, {-3, -1}]]]]
```

Model restriction :$\{\{\phi 1, \psi 1, \psi 2\}, \{\psi 1 \otimes \overline{\phi 1} \supset \mathbf{3} \otimes \mathbf{2}, \psi 1 \otimes \psi 2 \supset \mathbf{1} \otimes \mathbf{2}, \psi 2 \otimes \phi 1 \supset \mathbf{3} \otimes \mathbf{1}\}, \{Y_{\psi 1} \to -\frac{1}{6} + Y_{\phi 1}, Y_{\psi 2} \to -\frac{1}{3} - Y_{\phi 1}\}\}$

List of Models:

$$\begin{pmatrix}
\phi 1 \to \mathbf{1} \otimes \mathbf{1} \otimes Y_{\phi 1} & \psi 1 \to \bar{\mathbf{3}} \otimes \mathbf{2} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \mathbf{3} \otimes \mathbf{1} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right) \\
\phi 1 \to \mathbf{1} \otimes \mathbf{2} \otimes Y_{\phi 1} & \psi 1 \to \bar{\mathbf{3}} \otimes \mathbf{1} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \mathbf{3} \otimes \mathbf{2} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right) \\
\phi 1 \to \mathbf{1} \otimes \mathbf{2} \otimes Y_{\phi 1} & \psi 1 \to \bar{\mathbf{3}} \otimes \mathbf{3} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \mathbf{3} \otimes \mathbf{2} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right) \\
\text{....} & \text{....} & \text{....} \\
\phi 1 \to \mathbf{15'} \otimes \mathbf{4} \otimes Y_{\phi 1} & \psi 1 \to \mathbf{10} \otimes \mathbf{3} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \overline{\mathbf{10}} \otimes \mathbf{4} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right) \\
\phi 1 \to \mathbf{15'} \otimes \mathbf{4} \otimes Y_{\phi 1} & \psi 1 \to \mathbf{10} \otimes \mathbf{5} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \overline{\mathbf{10}} \otimes \mathbf{4} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right) \\
\phi 1 \to \mathbf{15'} \otimes \mathbf{5} \otimes Y_{\phi 1} & \psi 1 \to \mathbf{10} \otimes \mathbf{4} \otimes \left(-\frac{1}{6} + Y_{\phi 1}\right) & \psi 2 \to \overline{\mathbf{10}} \otimes \mathbf{5} \otimes \left(-\frac{1}{3} - Y_{\phi 1}\right)
\end{pmatrix}$$

The dictionary

Top-Down: Which Wilson coefficients are generated by a specific UV model?

```
In[5]:= NiceOutput[
  Limit[
   Match2Warsaw[alphaOdG[i, j], {Sa → {1, 1, Y1}, Fa → {3, 2, (1 / 6) - Y1},
       Fb → {3, 1, - (1 / 3) - Y1}}] /. L1[qLbar, dR, phi][__] → 0 // FullSimplify,
   {MFa → MSa, MFb → MSa}], True]
```

{g3 → g_3, MSa → M_{Sa}, L1[Fabar, Fb, phi, L] → $\lambda^{[L]}{}_{\overline{Fa},Fb,\phi}$, L1[Fabar, Fb, phi, R] → $\lambda^{[R]}{}_{\overline{Fa},Fb,\phi}$, L1[qLbar, Fa, Sa][i] → $\lambda_{\overline{qL},Fa,Sa}{}^{[i]}$, L1bar[dRbar, Fb, Sa][j] → $\overline{\lambda}_{\overline{dR},Fb,Sa}{}^{[j]}$}

Out[5]= $-\dfrac{g_3\left(\lambda^{[L]}{}_{\overline{Fa},Fb,\phi}-3\,\lambda^{[R]}{}_{\overline{Fa},Fb,\phi}\right)\lambda_{\overline{qL},Fa,Sa}{}^{[i]}\,\overline{\lambda}_{\overline{dR},Fb,Sa}{}^{[j]}}{384\,\pi^2\,M_{Sa}^2}$

The dictionary – compute all WCs

Automatic creation of **FeynRules** model

Create Lagrangean of UV model

```
In[2]:= CreateLag[{Sa → {{0, 0}, 1, Y1}, Fa → {{0, 1}, 2, -(1/6) + Y1}, Fb → {{1, 0}, 1, -(1/3) - Y1}}]
```

Out[2]= $\{Sa^2\, Sabar^2\, \lambda_{\overline{Sa},\overline{Sa},Sa,Sa} + Sa\, DRbar[sp1, ff0, cc0].Fb[sp1, cc1]\, \lambda_{\overline{dR},Fb,Sa}{}^{[ff0]}\, TC51[cc0, cc1] +$
$Sa\, Sabar\, Phi[ss2] \times Phibar[ss0]\, \lambda_{\overline{\phi},\overline{Sa},\phi,Sa}\, TS11[ss0, ss2] +$
$CC[Fabar[sp1, ss0, cc0]].left[Fb[sp1, cc1]] \times Phi[ss2]\, \lambda^{[L]}{}_{Fa,Fb,\phi}\, TC31[cc0, cc1] \times TS31[ss0, ss2] +$
$CC[Fabar[sp1, ss0, cc0]].right[Fb[sp1, cc1]] \times Phi[ss2]\, \lambda^{[R]}{}_{Fa,Fb,\phi}\, TC31[cc0, cc1] \times TS31[ss0, ss2] +$
$Sabar\, CC[Fabar[sp1, ss1, cc1]].QL[sp1, ss2, ff0, cc2]\, \lambda_{\overline{Sa},Fa,qL}{}^{[ff0]}\, TC41[cc1, cc2] \times TS41[ss1, ss2],$
$\{TS11 \to \{\{1, 0\}, \{0, 1\}\}, TC31 \to \{\{1, 0, 0\}, \{0, 1, 0\}, \{0, 0, 1\}\}, TS31 \to \{\{0, -1\}, \{1, 0\}\},$
$TC41 \to \{\{1, 0, 0\}, \{0, 1, 0\}, \{0, 0, 1\}\}, TS41 \to \{\{0, -1\}, \{1, 0\}\}, TC51 \to \{\{1, 0, 0\}, \{0, 1, 0\}, \{0, 0, 1\}\}\}\}$

Run **Matchmakereft** directly

```
In[9]:= CompleteOneLoopMatching[{Sa->{{0,0},1,Y1},Fa->{{0,1},2,-(1/6)+Y1},
Fb->{{1,0},1,-(1/3)-Y1}},"model"]
```

The dictionary – general results

$\boldsymbol{X^3}$
$\mathcal{O}_{3G} = f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$
$\mathcal{O}_{\widetilde{3G}} = f^{ABC} \widetilde{G}_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$
$\mathcal{O}_{3W} = \epsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$
$\mathcal{O}_{\widetilde{3W}} = \epsilon^{IJK} \widetilde{W}_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$

$$\alpha_{3V} = -\frac{1}{(4\pi)^2} \sum_R \frac{c_R\, g^3}{90 M_R^2} \mu(R), \quad c_R = \begin{cases} 1, & \text{Dirac fermions} \\ \frac{1}{2}, & \text{Majorana fermions} \\ -\frac{1}{2}, & \text{complex scalars} \\ -\frac{1}{4}, & \text{real scalars} \end{cases}$$

$$\mathrm{Tr}(T_R^A T_R^B) = \mu(R)\delta^{AB}$$

Henning, Lu, Murayama 1412.1837

Phenomenology

- Next step would be to use **matchmakereft** to compute the matching results and **smelli** to verify the viability of some parameter points

`Matchmakereft`	&	**`smelli`**
Full one loop matching onto the Warsaw basis		**Fit to observables**

A. Carmona, A. Lazopoulos, P. Olgoso, J. Santiago 2112.10787

J. Aebischer, J. Kumar, P. Stangl, and D. M. Straub 1810.07698

Conclusions

- The effective approach allows us to parametrize low-energy observables through WCs with no mention of UV
- UV/IR dictionaries allow us to efficiently connect these WCs (and therefore observables) with **ALL** possible UV origins
- Since one-loop effects are relevant, dictionary at this order should be computed: **`SOLD`**
- Next steps: include all operators, vectors and non-renormalizable UV.

Thanks

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