# SUPER TRACER

UNIVERSITÄT BERN

AEC
ALBERT EINSTEIN CENTER FOR FUNDAMENTAL PHYSICS

## A Calculator of Functional Supertraces for One-Loop EFT Matching

**Anders Eller Thomsen**

*with J. Fuentes-Martín, M. König, J. Pagès, and F. Wilsch [2012.08506]*

EFT WG Area 5
February 8th 2020

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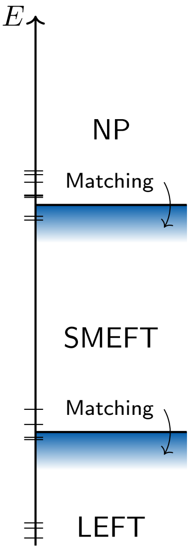
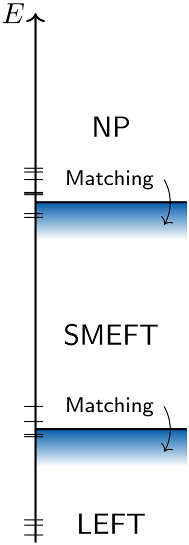
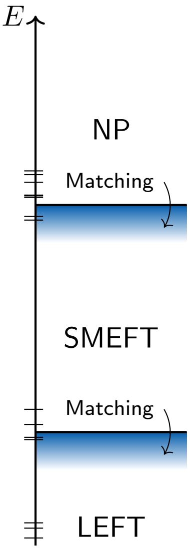
# Matching weakly coupled theories






- Needed to study NP impact on flavor physics.
- Computations are tedious and time-consuming.
- Functional matching is suited for computer implementations.

See also the next talk by X. Lu (Cohen, Lu, Zhang [2012.07851])

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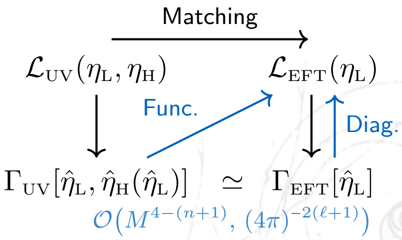

# Functional Matching

Tree-level matching using EoM of the heavy fields:

$$\mathcal{L}^{(0)}_{\mathrm{EFT}}(\eta_{\mathrm{L}}) = \mathcal{L}^{(0)}_{\mathrm{UV}}(\eta_{\mathrm{L}}, \hat{\eta}_{\mathrm{H}}(\eta_{\mathrm{L}}))$$

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Tree-level matching using EoM of the heavy fields:

$$\mathcal{L}^{(0)}_{\mathrm{EFT}}(\eta_{\mathrm{L}}) = \mathcal{L}^{(0)}_{\mathrm{UV}}(\eta_{\mathrm{L}}, \hat{\eta}_{\mathrm{H}}(\eta_{\mathrm{L}}))$$

Henning, Lu, Murayama [1412.1837]
Ellis, Quevillon, You, Zhang [1604.02445]
Angelescu, Huang [2006.16532]
...

Functional matching relies on

$$e^{i\,\Gamma_{\mathrm{UV}}[\hat{\eta}]} = \int \mathcal{D}\eta\; \exp\!\left( i \int \mathrm{d}^d x\; \mathcal{L}_{\mathrm{UV}}[\eta + \hat{\eta}] \right)$$

By saddle point approximation

$$\Gamma^{(1)}_{\mathrm{UV}} = \frac{i}{2}\,\mathrm{STr}\;\ln\left(\Delta^{-1} - X\right)$$

where

$$\delta_{ij}\,\Delta^{-1}_i(P,\,M_i) - X_{ij}(P,\,\hat{\eta}) \equiv \left.\frac{\delta^2 \mathcal{L}_{\mathrm{UV}}}{\delta\eta_j \delta\bar{\eta}_i}\right|_{\eta=\hat{\eta}}$$

$\Delta_i$ is the kinetic piece and $X_{ij}$ the interaction term.

Expansion by regions allows for directly identifying the EFT from the UV quantum action: J. Fuentes-Martin, J. Portoles, P. Ruiz-Femenia [1607.02142], Z. Zhang [1610.00710]

$$\Gamma^{(1)}_{\mathrm{UV}} = \Gamma^{(1)}_{\mathrm{UV}}\Big|_{\mathrm{hard}} + \Gamma^{(1)}_{\mathrm{UV}}\Big|_{\mathrm{soft}}\,, \qquad \Gamma^{(1)}_{\mathrm{UV}}\Big|_{\mathrm{hard}} = \int \mathrm{d}^d x\, \mathcal{L}^{(1)}_{\mathrm{EFT}}$$

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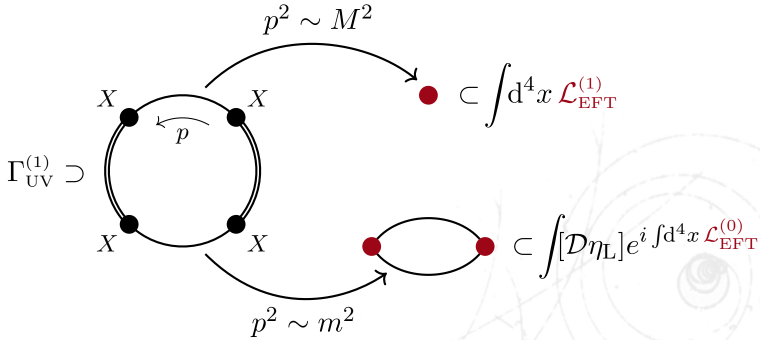
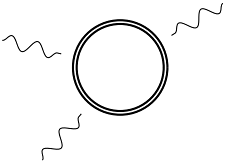
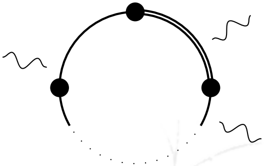


The master formula for 1-loop matching: Cohen, Lu, Zhang [2011.02484]

$$\int \mathrm{d}^d x \, \mathcal{L}_{\mathrm{EFT}}^{(1)} = \underbrace{\frac{i}{2} \mathrm{STr} \ln \Delta^{-1}\Big|_{\mathrm{hard}}}_{\text{Log term}} - \underbrace{\frac{i}{2} \sum_{n=1}^{\infty} \frac{1}{n} \mathrm{STr}\big[(\Delta X)^n\big]\Big|_{\mathrm{hard}}}_{\text{Power-type terms}}$$

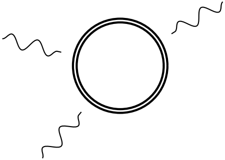


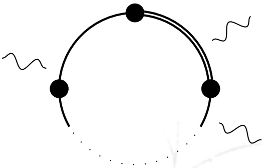


# Covariant Derivative Expansion

The master formula for 1-loop matching: Cohen, Lu, Zhang [2011.02484]

$$\int \mathrm{d}^d x\, \mathcal{L}^{(1)}_{\mathrm{EFT}} = \underbrace{\frac{i}{2}\,\mathrm{STr}\,\ln\,\Delta^{-1}\Big|_{\mathrm{hard}}}_{\text{Log term}} - \underbrace{\frac{i}{2}\sum_{n=1}^{\infty}\frac{1}{n}\,\mathrm{STr}\big[(\Delta X)^n\big]\Big|_{\mathrm{hard}}}_{\text{Power-type terms}}$$



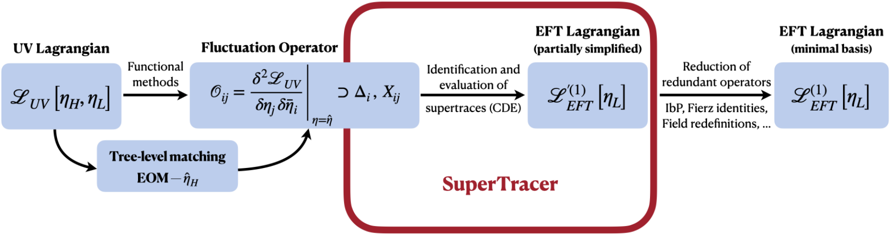


Open derivatives are closed with the CDE, e.g.

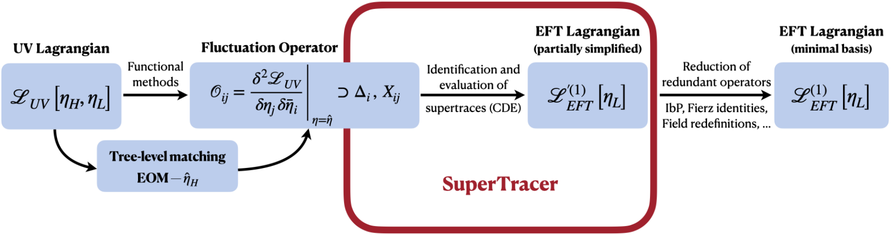
$$e^{-P\cdot\partial_p}\,(p_\mu + P_\mu)\,e^{P\cdot\partial_p} = p_\mu + i\,\tilde{G}_{\mu\nu}\,\partial_p^{\nu}$$

Gaillard '86, Chan '86, Cheyette '88

# SuperTracer work flow



# SuperTracer work flow




i) Construction of supertrace with $\Delta$'s given $\{X\}$
ii) CDE of $\Delta$ and $X$ and momentum derivatives
iii) Dirac algebra simplifications
iv) Loop integrals in $\overline{\text{MS}}$ scheme
v) IbP simplifications

# Log terms in SuperTracer

## Universal log terms:

```
LogTerm[Ψ, 6]
```

$$-\frac{1}{6}\,\mathrm{Log}\!\left[\frac{\overline{\mu}^2}{M_H^2}\right] G^{\mu\nu} \ast\ast G^{\mu\nu} + \frac{1}{15}\,\frac{1}{M_H^2}\,D_\mu G^{\mu\nu} \ast\ast D_\rho G^{\nu\rho} + \frac{1}{90}\,\mathrm{i}\,\frac{1}{M_H^2}\,G^{\mu\nu} \ast\ast G^{\mu\rho} \ast\ast G^{\nu\rho}$$

```
LogTerm[Ψ, {8}]
```

$$-\frac{19\,\frac{1}{M_H^4}\,D^2G^{\nu\rho} \ast\ast D^2G^{\nu\rho}}{33\,600} - \frac{101\,\frac{1}{M_H^4}\,D^2D_\nu G^{\nu\rho} \ast\ast D_\sigma G^{\rho\sigma}}{16\,800} + \frac{89\,\mathrm{i}\,\frac{1}{M_H^4}\,D_\mu G^{\mu\nu} \ast\ast D_\rho G^{\rho\sigma} \ast\ast G^{\nu\sigma}}{3600} -$$

$$\frac{97\,\mathrm{i}\,\frac{1}{M_H^4}\,D_\mu D_\nu G^{\nu\rho} \ast\ast G^{\mu\sigma} \ast\ast G^{\rho\sigma}}{12\,600} + \frac{97\,\mathrm{i}\,\frac{1}{M_H^4}\,D_\mu D_\nu G^{\nu\rho} \ast\ast G^{\rho\sigma} \ast\ast G^{\mu\sigma}}{12\,600} + \frac{157\,\frac{1}{M_H^4}\,G^{\mu\nu} \ast\ast G^{\mu\rho} \ast\ast G^{\rho\sigma} \ast\ast G^{\nu\sigma}}{12\,600} -$$

$$\frac{2}{315}\,\frac{1}{M_H^4}\,G^{\mu\nu} \ast\ast G^{\rho\sigma} \ast\ast G^{\mu\nu} \ast\ast G^{\rho\sigma} + \frac{37\,\frac{1}{M_H^4}\,G^{\mu\nu} \ast\ast G^{\rho\sigma} \ast\ast G^{\mu\rho} \ast\ast G^{\nu\sigma}}{1400} - \frac{19\,\frac{1}{M_H^4}\,G^{\mu\nu} \ast\ast G^{\rho\sigma} \ast\ast G^{\rho\sigma} \ast\ast G^{\mu\nu}}{2520}$$

$$\mathcal{L}^{(1)}_{\mathrm{EFT}} \supset \frac{1}{16\pi^2}\,\mathrm{Tr}\Big[\mathrm{LogTerm}[\Psi,\,6]\Big]$$

# Generic power-type terms

Simple input, e.g. $-\frac{i}{2}\mathrm{STr}\left\{\Delta_\Psi\, X^{[5/2]}_{\Psi A}\, \Delta_A\, X^{[5/2]}_{A\Psi}\right\}$:

(Kinematics determined by field types)

```
STrTerm[{X[{Ψ, A}, 5/2], X[{A, Ψ}, 5/2]}, 6]
```

$$\frac{1}{8}\, i \left(3 + 2\,\mathrm{Log}\left[\frac{\overline{\mu}^2}{M_H^2}\right]\right) \gamma_\mu ** D_\mu X_{\Psi_i A_j} ** X_{A_j \Psi_i} + \frac{1}{2}\left(1 + \mathrm{Log}\left[\frac{\overline{\mu}^2}{M_H^2}\right]\right) M_H X_{\Psi_i A_j} ** X_{A_j \Psi_i}$$

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*But* simplifications limited/impossible in generic expressions:

```
STrTerm[{X[{Ψ, ψ}, 1], X[{ψ, Ψ}, 1]}, 6]
```

$$\frac{1}{144}\left(-5 - 6\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M_H^2}\right]\right) \gamma_\mu ** D_\mu D_\nu X_{\Psi_i \psi_j} ** \gamma_\nu ** X_{\psi_j \Psi_i} + \frac{1}{144}\left(-5 - 6\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M_H^2}\right]\right) \gamma_\mu ** D_\nu D_\mu X_{\Psi_i \psi_j} ** \gamma_\nu ** X_{\psi_j \Psi_i} +$$

$$\frac{1}{144}\left(-5 - 6\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M_H^2}\right]\right) \gamma_\mu ** D^2 X_{\Psi_i \psi_j} ** \gamma_\mu ** X_{\psi_j \Psi_i} + \frac{1}{32}\, i \left(1 + 2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M_H^2}\right]\right) \Gamma_{\mu\nu\rho} ** G^{\mu\nu} ** X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} +$$

$$\frac{1}{32}\, i \left(3 + 2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M_H^2}\right]\right) \gamma_\mu ** X_{\Psi_i \psi_j} ** \Gamma_{\mu\nu\rho} ** G^{\nu\rho} ** X_{\psi_j \Psi_i} + \frac{1}{48}\frac{1}{M_H^2} \gamma_\mu ** D_\mu D_\nu D^2 X_{\Psi_i \psi_j} ** \gamma_\nu ** X_{\psi_j \Psi_i} +$$

$$\frac{1}{48}\frac{1}{M_H^2} \gamma_\mu ** D_\nu D_\mu D^2 X_{\Psi_i \psi_j} ** \gamma_\nu ** X_{\psi_j \Psi_i} + \frac{1}{96}\frac{1}{M_H^2} \gamma_\mu ** D^2 D^2 X_{\Psi_i \psi_j} ** \gamma_\mu ** X_{\psi_j \Psi_i} +$$

$$\frac{1}{96}\, i\, \frac{1}{M_H^2} \gamma_\mu ** G^{\mu\nu} ** D_\nu D_\rho X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} + \frac{1}{32}\, i\, \frac{1}{M_H^2} \gamma_\mu ** G^{\mu\nu} ** D_\rho D_\nu X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} -$$

$$\frac{1}{32}\, i\, \frac{1}{M_H^2} \gamma_\mu ** G^{\nu\rho} ** D_\mu D_\nu X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} - \frac{1}{96}\, i\, \frac{1}{M_H^2} \gamma_\mu ** G^{\nu\rho} ** D_\nu D_\mu X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} +$$

$$\frac{1}{96}\, i\, \frac{1}{M_H^2} \gamma_\mu ** X_{\Psi_i \psi_j} ** D_\mu D_\nu G^{\nu\rho} ** \gamma_\rho ** X_{\psi_j \Psi_i} - \frac{1}{96}\, i\, \frac{1}{M_H^2} \gamma_\mu ** X_{\Psi_i \psi_j} ** D_\nu D_\rho G^{\mu\rho} ** \gamma_\nu ** X_{\psi_j \Psi_i} -$$

$\frac{1}{[illegible]}\, i\, \frac{1}{M_H^2} \gamma_\mu ** D_\mu G^{\nu\rho} ** D_\nu X_{\Psi_i \psi_j} ** \gamma_\rho ** X_{\psi_j \Psi_i} + \frac{1}{[illegible]}\, i\, \frac{1}{M_H^2} \gamma_\mu ** D_\mu X_{\Psi_i \psi_j} ** D_\nu G^{\nu\rho} ** \gamma_\rho ** X_{\psi_j \Psi_i} +$

+[71 terms]

# Toy model with vector-like fermions

Toy model:

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}(\partial^\mu\phi)(\partial_\mu\phi) + \bar{\psi}\, i\not{D}\, \psi + \bar{\Psi}(i\not{D} - M)\Psi - \big(y\, \bar{\psi}_L\, \phi\, \Psi_R + \text{h.c.}\big) + \mathcal{L}_\xi$$

- Determine fields:

$$\eta_\psi = \begin{pmatrix}\psi & \psi^c\end{pmatrix}, \quad \eta_\Psi = \begin{pmatrix}\Psi & \Psi^c\end{pmatrix}$$

- Derive interaction terms:

$$X^{[1]}_{\psi\Psi} = \begin{pmatrix} y\, P_R & 0 \\ 0 & y^*\, P_L \end{pmatrix}\phi, \quad \ldots$$

- Determine EoM of heavy fields

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$$X^{[1]}_{\psi\Psi} = \begin{pmatrix} y\, P_R & 0 \\ 0 & y^*\, P_L \end{pmatrix} \phi, \quad \ldots$$

- Determine EoM of heavy fields

```
AddField[ϕl, ϕ]        (* Light scalar  *)
AddField[ψl, ψ, e[1]] (* Light fermion *)
AddField[ψh, Ψ, e[1]] (*Heavy fermion*)
Xsubs = {
    {Ψ, A} → {{-e γ[α[j]] ** ψh[]}, {e γ[α[j]] ** CConj[ψh[]]}},
    {A, Ψ} → {{-e Bar[ψh[]] ** γ[α[i]], e CConj[Bar[ψh[]]] ** γ[α[i]]}},
    {ψ, A} → {{-e γ[α[j]] ** ψl[]}, {e γ[α[j]] ** CConj[ψl[]]}},
    {A, ψ} → {{-e Bar[ψl[]] ** γ[α[i]], e CConj[Bar[ψl[]]] ** γ[α[i]]}},
    {ψ, Ψ} → {{y PR, 0}, {0, Bar[y] PL}} ** ϕl[],
    {Ψ, ψ} → {{Bar[y] PL, 0}, {0, y PR}} ** ϕl[],
    {ψ, ϕ} → {{y PR ** ψh[]}, {Bar[y] PL ** CConj[ψh[]]}},
    {ϕ, ψ} → {{Bar[y] Bar[ψh[]] ** PL, y CConj[Bar[ψh[]]] ** PR}},
    {Ψ, ϕ} → {{Bar[y] PL ** ψl[]}, {y PR ** CConj[ψl[]]}},
    {ϕ, Ψ} → {{y Bar[ψl[]] ** PR, Bar[y] CConj[Bar[ψl[]]] ** PL}}
   };
Msubs = {M[Ψ] → {Mψh, Mψh}};
Gsubs = {
    G@A → {{}},
    G@ϕ → {{}},
    G@ψ → {{e[1]}, {e[-1]}},
    G@Ψ → {{e[1]}, {e[-1]}}
   };
subs = Join[Xsubs, Msubs, Gsubs];
```

# Toy model with vector-like fermions

With a specific model, great simplification of terms can be achieved:

```
STrTerm[{X[{Ψ̄, ψ}, 1], X[{ψ, Ψ̄}, 1]}, 6, subs]
```

$$\frac{1}{3}\,\frac{y\,\bar{y}}{M\psi h^2}\phi 1^2\,\left(F_e{}^{\mu\nu}\right)^2+\frac{1}{3}\,\frac{y\,\bar{y}}{M\psi h^2}\phi 1\,D^2D^2\phi 1-2\,M\psi h^2\,y\,\bar{y}\,\left(1+\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1^2-\frac{1}{2}\,y\,\bar{y}\,\left(1+2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1\,D^2\phi 1$$

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To easily determine the full $\mathcal{L}^{(1)}_{\mathrm{EFT}}$, SuperTracer can derive all relevant power-type terms:

```
Xterms = {X[{Ψ, A}, 5/2], X[{ψ, A}, 3/2], X[{ψ, Ψ}, 1], X[{ψ, ϕ}, 7/2], X[{Ψ, ϕ}, 3/2]};
LagPower = PowerTerms[Xterms, 6]
```

$$\mathrm{STr}\left[\left\{X^{[5/2]}_{\Psi A}, X^{[5/2]}_{A\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[3/2]}_{\Psi\phi}, X^{[3/2]}_{\phi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}\right\}\right]+$$
$$\mathrm{STr}\left[\left\{X^{[5/2]}_{\Psi A}, X^{[3/2]}_{A\psi}, X^{[1]}_{\psi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[3/2]}_{\Psi\phi}, X^{[7/2]}_{\phi\psi}, X^{[1]}_{\psi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[3/2]}_{\psi A}, X^{[5/2]}_{A\Psi}\right\}\right]+$$
$$\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[7/2]}_{\psi\phi}, X^{[3/2]}_{\phi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[3/2]}_{\Psi\phi}, X^{[3/2]}_{\phi\Psi}, X^{[3/2]}_{\Psi\phi}, X^{[3/2]}_{\phi\Psi}\right\}\right]+$$
$$\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[3/2]}_{\psi A}, X^{[3/2]}_{A\psi}, X^{[1]}_{\psi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}, X^{[3/2]}_{\Psi\phi}, X^{[3/2]}_{\phi\Psi}\right\}\right]+$$
$$\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}, X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}\right\}\right]+\mathrm{STr}\left[\left\{X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}, X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}, X^{[1]}_{\Psi\psi}, X^{[1]}_{\psi\Psi}\right\}\right]$$

# Toy model with vector-like fermions

Full determination of $\mathcal{L}^{(1)}_{\mathrm{EFT}}$, with $\hat{\eta}_{\mathrm{H}}(\eta_{\mathrm{L}})$:

```
LagPower /. STr@x_ :> STrTerm[x, 6, subsEOM] // SuperSimplify
```

$$\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}\phi 1^2\left(Fe^{\mu\nu}\right)^2+\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}D^2\phi 1\,D^2\phi 1+\frac{11}{18}\frac{y\,\bar{y}}{M\psi h^2}D_\nu Fe^{\mu\nu}\,\overline{\psi 1}**\gamma_\mu P_L**\psi 1+$$
$$\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}Fe^{\mu\nu}\,\overline{\psi 1}**\gamma_\mu P_L**D_\nu\psi 1-\frac{1}{3}\,\mathrm{i}\,\frac{y\,\bar{y}}{M\psi h^2}\overline{\psi 1}**\gamma_\mu P_L**D_\mu D^2\psi 1-\frac{1}{4}\frac{y\,\bar{y}}{M\psi h^2}Fe^{\nu\rho}\,\overline{\psi 1}**\Gamma_{\mu\nu\rho}P_L**D_\mu\psi 1+$$
$$\frac{13}{18}\frac{y^2\,\bar{y}^2}{M\psi h^2}\phi 1^3\,D^2\phi 1+\frac{1}{3}\frac{y^3\,\bar{y}^3}{M\psi h^2}\phi 1^6-y^2\,\bar{y}^2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\phi 1^4-2\,M\psi h^2\,y\,\bar{y}\left(1+\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1^2-$$
$$\frac{1}{2}\,y\,\bar{y}\left(1+2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1\,D^2\phi 1+\frac{1}{4}\,\mathrm{i}\,y\,\bar{y}\left(3+2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\overline{\psi 1}**\gamma_\mu P_L**D_\mu\psi 1-$$
$$\frac{1}{2}\,\mathrm{i}\,\frac{y^2\,\bar{y}^2\left(5+4\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)}{M\psi h^2}\phi 1\,D_\mu\phi 1\,\overline{\psi 1}**\gamma_\mu P_L**\psi 1-\frac{1}{2}\,\mathrm{i}\,\frac{y^2\,\bar{y}^2\left(5+4\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)}{M\psi h^2}\phi 1^2\,\overline{\psi 1}**\gamma_\mu P_L**D_\mu\psi 1$$

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```

$$\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}\phi 1^2\left(Fe^{\mu\nu}\right)^2+\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}D^2\phi 1\,D^2\phi 1+\frac{11}{18}\frac{y\,\bar{y}}{M\psi h^2}D_\nu Fe^{\mu\nu}\,\overline{\psi 1}**\gamma_\mu P_L**\psi 1+$$
$$\frac{1}{3}\frac{y\,\bar{y}}{M\psi h^2}Fe^{\mu\nu}\,\overline{\psi 1}**\gamma_\mu P_L**D_\nu\psi 1-\frac{1}{3}\,i\,\frac{y\,\bar{y}}{M\psi h^2}\overline{\psi 1}**\gamma_\mu P_L**D_\mu D^2\psi 1-\frac{1}{4}\frac{y\,\bar{y}}{M\psi h^2}Fe^{\nu\rho}\,\overline{\psi 1}**\Gamma_{\mu\nu\rho}P_L**D_\mu\psi 1+$$
$$\frac{13}{18}\frac{y^2\,\bar{y}^2}{M\psi h^2}\phi 1^3 D^2\phi 1+\frac{1}{3}\frac{y^3\,\bar{y}^3}{M\psi h^2}\phi 1^6-y^2\,\bar{y}^2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\phi 1^4-2\,M\psi h^2\,y\,\bar{y}\left(1+\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1^2-$$
$$\frac{1}{2}\,y\,\bar{y}\left(1+2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\phi 1\,D^2\phi 1+\frac{1}{4}\,i\,y\,\bar{y}\left(3+2\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)\overline{\psi 1}**\gamma_\mu P_L**D_\mu\psi 1-$$
$$\frac{1}{2}\,i\,\frac{y^2\,\bar{y}^2\left(5+4\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)}{M\psi h^2}\phi 1\,D_\mu\phi 1\,\overline{\psi 1}**\gamma_\mu P_L**\psi 1-\frac{1}{2}\,i\,\frac{y^2\,\bar{y}^2\left(5+4\,\mathrm{Log}\left[\frac{\bar{\mu}^2}{M\psi h^2}\right]\right)}{M\psi h^2}\phi 1^2\,\overline{\psi 1}**\gamma_\mu P_L**D_\mu\psi 1$$

Example of scalar leptoquark extension of SM included with the installation.

SuperTracer can also deal with realistic models

# Outlook

- Functional matching tools can greatly simplify the matching procedure: `SuperTracer` and `STrEAM` (see next talk by X. Lu).

- Fully automated matching packages are the next step.

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Matching Efective Theories Efficiently: