## An EFT approach to lepton anomalies

#### Rupert Coy

Laboratoire Charles Coulomb (L2C), CNRS-Université de Montpellier

Cargèse, 13th July 2018

Coy and Frigerio in preparation
Coy, Frigerio and Sumensari in preparation







# What's going on in the lepton sector?

- Massive neutrinos! Implies LFV!  $\Delta m_{ij}^2$  measured at  $\mathcal{O}(1\%)$ ,  $\sin^2(\theta_{ij})$  measured at  $\mathcal{O}(5-10\%)$ ,  $\delta_{CP}$  less well known
- $(g-2)_{\mu}$  anomaly now  $\gtrsim 3.5\sigma$ , could reach  $5\sigma$  in a few years at Fermilab; new  $(g-2)_e$  anomaly at  $2\sigma$  (in other direction)
- Various hints of LFUV in  $b \to s \ell^+ \ell^-$  and  $b \to c \ell \nu$  channels
- LFUV already apparent in hierarchical Yukawas
- Stringent limits on CLFV:  $BR(\mu \to e\gamma) \lesssim 10^{-13}$ ,  $BR(\mu \to eee) \lesssim 10^{-12}$ , while  $BR(\tau \to \mu\gamma, e\gamma) \lesssim 10^{-8}$
- ullet Hint of CLFV at LHC Run 1 in  $h o au\mu$  disfavoured by Run 2



## Effective Field Theory

- Many anomalies and constraints, also many models
- EFT enables a model-independent analysis of the data: relate observables to Wilson Coefficients (WCs) and study the WC parameter space
- Can demonstrate relative compatibility or tension between different data
- Also useful framework to study a specific model by re-expressing it in terms of generated WCs

## Type-I seesaw (in collaboration with Michele Frigerio)

• Simple neutrino mass model, add  $n_s$  RH fermions singlets  $(n_s \ge 2 \text{ for non-zero neutrino masses})$ , with Lagrangian:

$$\mathcal{L} = \mathcal{L}_{SM} + \overline{\nu_{Ri}} i \partial \!\!\!/ \nu_{Ri} - Y_{\nu,ai} \overline{I_{La}} \tilde{H} \nu_{Ri} - \frac{1}{2} \overline{\nu_{Ri}} M_{ij} \nu_{Rj}^c + h.c., \quad (1)$$

- Aim: find d = 5,6 WCs generated by Type-I seesaw at leading order, then calculate observables
- $m{\circ}$   $\mathcal{O}^{(5)}=(I_LH)^2$  generated at tree-level, while  $\mathcal{O}_i^{(6)}$  generated
  - at tree  $C \sim Y_{\nu}^2/M^2$
  - via 1-loop mixing,  $C \sim \frac{g^2}{16\pi^2} \frac{Y_{\perp}^{2,4}}{M^2} \log\left(\frac{M}{\mu}\right)$
  - ullet via finite 1-loop diagrams,  $C\sim rac{g^2}{16\pi^2}rac{Y_
    u^{2,4}}{M^2}$
  - at 2-loop order (neglected)



## Comparison with models

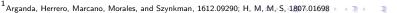
- Compare EFT with calcs made in Type-I seesaw models
- Decay widths calculated in model with exact  $U(1)_L$  symmetry, Dirac masses for sterile neutrinos, for  $k \neq m$  and  $m_k \gg m_m$ :

$$\Gamma(h \to e_k \bar{e}_m) \approx \frac{\lambda^2 m_k^2 v^2 m_h}{(4\pi)^5} \left[ Y_{\nu} M^{-2} \log \left( \frac{M}{m_W} \right) Y_{\nu}^{\dagger} \right]_{km}^2$$

$$\Gamma(Z \to e_k \bar{e}_m) \approx \frac{m_Z^3 v^2}{3.2^{11} \pi^5} \left( \frac{17 g_2^2}{12} + \frac{g_1^2}{12} \right)^2 \left[ Y_{\nu} M^{-2} \log \left( \frac{M}{m_W} \right) Y_{\nu}^{\dagger} \right]_{km}^2$$

which agrees at leading order with previous calcs<sup>1</sup>

- Compute also  $\Gamma(e_k o e_m \gamma)$ , show Type-I seesaw worsens  $(g-2)_\mu$  anomaly
- Computationally simple to find this leading order result
- Also, spurion analysis!



## EFT analysis of B anomalies (with Michele Frigerio and Olcyr Sumensari)

- Performed basis-independent search for unique d=6 operator which explains  $(g-2)_{\mu}$  and  $b\to s\ell\ell$  anomalies: none can, considering tree, 1-loop, and Barr-Zee type two-loop
- Difficulties in a combined explanation include vector vs. tensor operators,  $\Delta F=0$  vs.  $\Delta F=1$
- Next: full EFT analysis of  $b \to s$  anomalies, considering full set of operators (including flavour structure) which can contribute at 1-loop
- Tree-level and one-loop analyses exist<sup>2</sup>, however room to extend the existing studies: consider role of electrons, relax top dominance assumption, consider additional constraints on WCs, e.g. from  $(g-2)_{\mu}$

Alonso, Grinstein, and Camalich, 1407.7044; Celis, Fuentes-Martin, Vicente, Virto 1704.05672