Title: Panel Discussion - Strengths and limitations of EFT (Donoghue, Knorr, Montero, Quevedo, Tolley)

Speakers: John Donoghue, Miguel Montero, Fernando Quevedo, Carlo Rovelli, Andrew Tolley

Collection: Puzzles in the Quantum Gravity Landscape: viewpoints from different approaches

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EFT discussion slides – John Donoghue

All our usual QFTs have underlying assumptions

- smooth 4D continuum spacetime
- axioms of QFT (Lorentz, causality ….)
- observed symmetries and DOF
- rules of QFT

$$Z^{core} \;=\; \int [d\phi d\psi dA dg]_{\rm Limits}\; \exp\left[i \int d^4x \sqrt{-g}\left(-\frac{1}{4} g^{\mu\alpha} g^{\nu\beta} F^a_{\mu\nu} F^a_{\alpha\beta} + \text{...SM...} \right.\right.$$
$$\left.\left. - \Lambda_{cc} + \frac{2}{\kappa^2} R + c_1 R^2 + c_2 R_{\mu\nu} R^{\mu\nu} \ldots \right)\right]$$

Any of these could be (approximately) incorrect

- non-trivial spacetimes
- causality etc
- symmetries can be emergent
- quantum physics as we know it may have limits

But, WE can fail our QFT/EFTs

- our techniques/understanding still evolving
- QFT in classical curved spacetime
- decoherence
- interactions with classical structures (stars, BHs)
- nonperturbative features
- asymptotic series
- inappropriate assumptions

…

It is possible that gravity is where experimental/ theoretical limits of QM will surface

- macroscopiscity
- lack of screening may reveal new phenomena
- gravity effects build up

Andrew Tolley

Panel Discussion
“strengths and limitations of EFT”

STRENGHTS & LIMITATIONS OF EFT
PANEL DISCUSSION

Puzzles in the Quantum Gravity
Landscape workshop,
Perimeter Institute, Oct 23 2023

Miguel Montero
IFT Madrid

“What are the strenghts & limitations of EFT in gravity?”

Same as without gravity!

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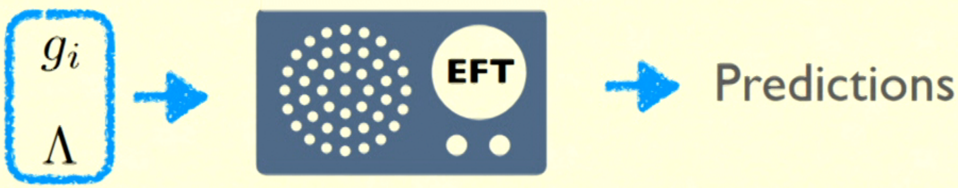
What EFT does:

- Parametrize our ignorance in terms of a finite # of couplings g_i
- Give a framework to compute any observable up to cutoff Λ



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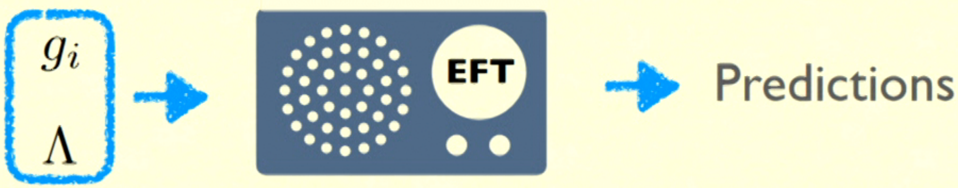

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This is where Swampland helps!

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Gives information (constraints) on the g_i and Λ

$$m \leq g\, M_P$$

(Weak Gravity)

$$\Lambda = M_P\, e^{-\phi}$$

(Distance Conjecture)

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$\delta m \propto \delta g \sim \log(\Lambda)$ (because of WGC)

“Does EFT break @ or below Planck scale?”

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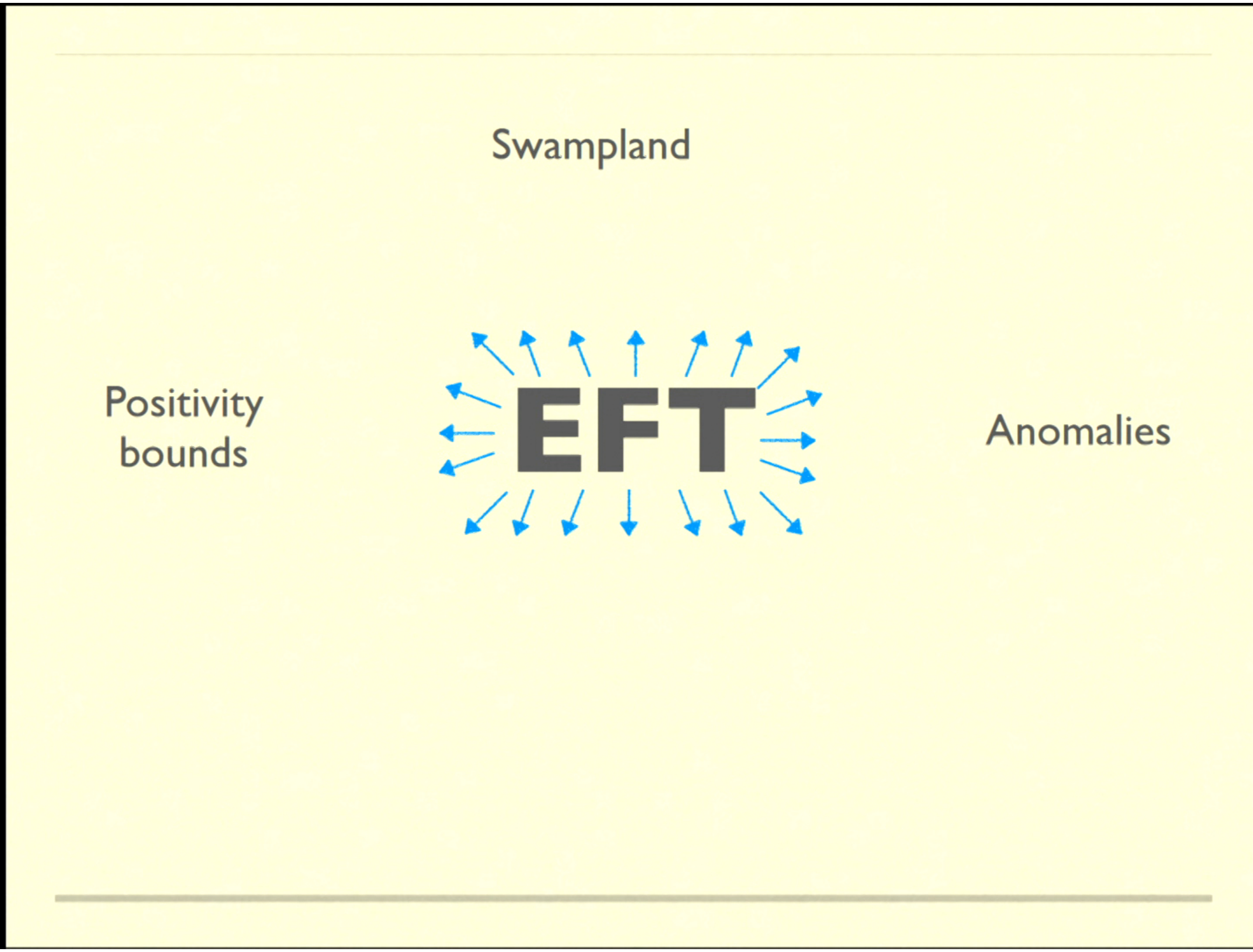
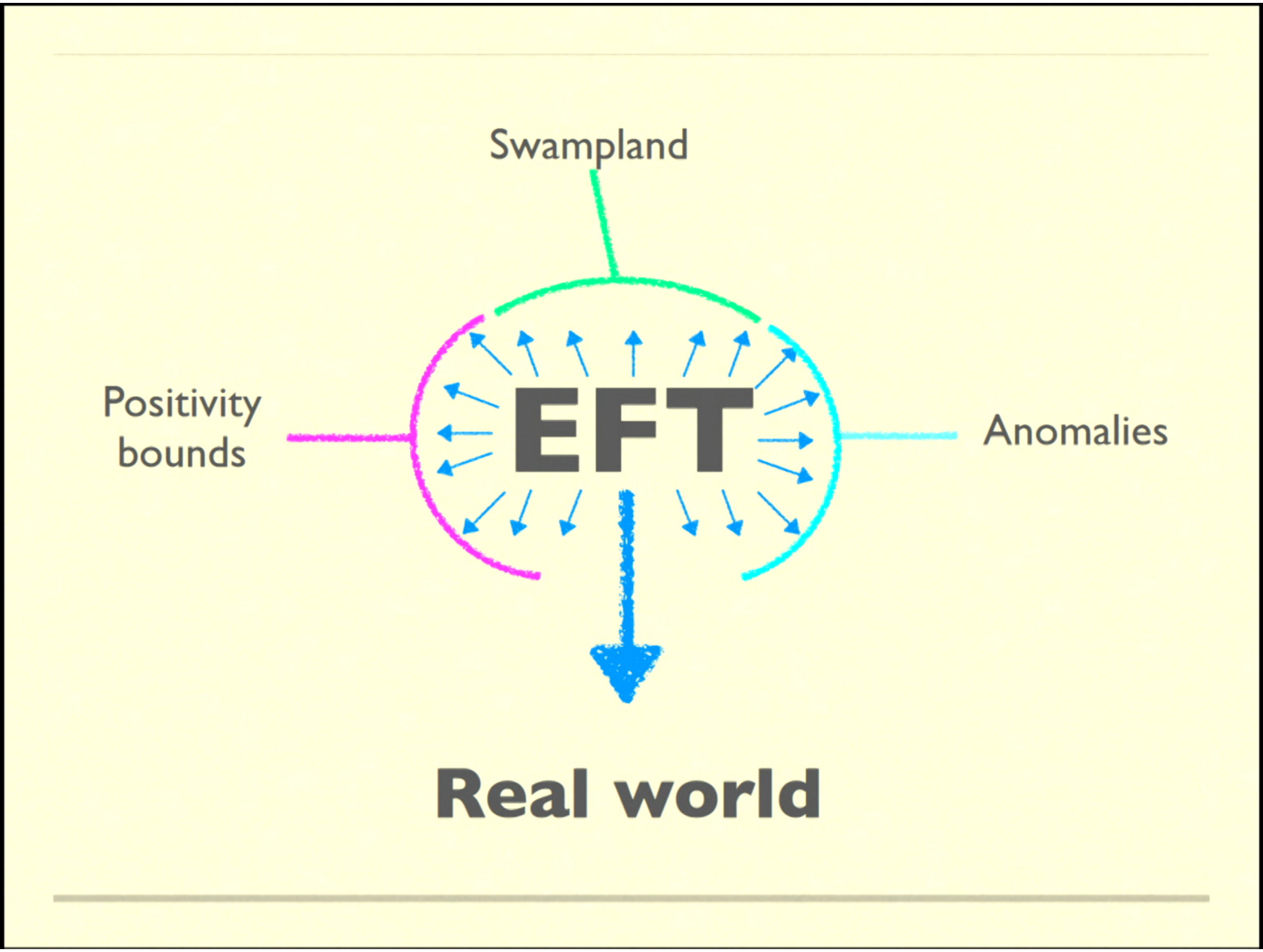
EFT valid up to Planck: 11d M theory

10d strings: EFT valid up to $M_S \sim g_s^{1/4} M_P$

EFT


Swampland
Positivity bounds
EFT
Anomalies


Swampland
Positivity bounds
EFT
Anomalies
Real world

Carlo Rovelli

Panel Discussion
“strengths and limitations of EFT”

Strenghts and Limitations of EFTs

(discussion session)

Fernando Quevedo
University of Cambridge
Puzzles in Quantum Gravity
Perimeter Institute
October 2023

EFTs are best way to understand physics

- **General Relativity as an EFT:** $\mathcal{L}_{EH} = M_P^2 R^{(4)} \sqrt{-g}$

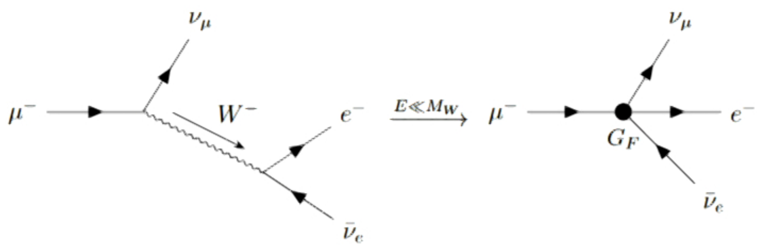
$$g_{\mu\nu} = \eta_{\mu\nu} + \frac{1}{M_P} h_{\mu\nu} \;\Rightarrow\; M_P^2 R^{(4)} = (\partial h)^2 + \frac{h}{M_P} (\partial h)^2 + \frac{h^2}{M_P^2} (\partial h)^2 + \dots .$$

- **Standard Model as an EFT (SMEFT):** $\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{M} \mathcal{L}_5 + \frac{1}{M^2} \mathcal{L}_6 + \mathcal{O}\left(\frac{1}{M^3}\right) .$

$$\mathcal{L}_5 = \left(\frac{\lambda_\nu}{M}\right) H H \nu_L \nu_L \qquad \mathcal{L}_6 = \left(\frac{\beta}{M^2}\right) qqql \; + \dots .$$

- **EFTs within EFTs**

e.g. 4-Fermi interactions



e.g. Chiral perturbation theory

$$\mathcal{L}_\chi = \frac{F_\pi^2}{4} \mathrm{Tr}\left[(D^\mu U)(D_\mu U)^\dagger\right] + \lambda_1 \mathrm{Tr}\left[(D^\mu U)(D_\mu U)^\dagger\right]^2 + \ldots .$$

$$U(x) = \exp\left(\frac{2\mathrm{i}T^a\pi^a(x)}{F_\pi}\right) = \exp\left(\frac{\mathrm{i}}{F_\pi}\begin{pmatrix} \pi^0 & \sqrt{2}\pi^- \\ \sqrt{2}\pi^+ & -\pi^0 \end{pmatrix}\right)$$

$$\mathcal{L}_\chi \to \frac{1}{2}(\partial_\mu \pi^0)(\partial^\mu \pi^0) + (D^\mu \pi^+)(D_\mu \pi^-)^\dagger + \frac{1}{F_\pi^2}\left[-\frac{1}{3}\pi^0\pi^0 D_\mu \pi^+ D^\mu \pi^- + \ldots\right] + \ldots$$

EFTs carry within themselves their own limitations

- EFTs say nothing beyond their regime of validity
- For gravity this is $M \leq M_{planck}$ how much below (M_s, M_{KK}, …) ???
- Positivity bounds + swampland conjectures welcome ideas towards UV completeness. But with limitations…(e.g. swampland different quality of conjectures, is there really a swampland?, impact beyond string theory,…?)