Recursion relations for effective field theories of Goldstone modes

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Based on arXiv:1712.09937 and upcoming work with H. Elvang, C.R.T. Jones and S. Paranjape

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Our goal

Use on-shell amplitude methods like

- Recursion relations
- Ward identities
- Low-energy theorems

to understand effective field theories (EFTs) that can arise from spontaneous symmetry breaking

Background

- [C. Cheung et al., 1509.03309] introduced so-called "Subtracted soft recursion relations" for tree-level scattering amplitudes for effective field theories of massless scalars
- Use
  - Locality $\rightarrow$ Simple poles when internal lines go on-shell
  - Unitarity $\rightarrow$ Residue at poles is a product of lower-point amplitudes
  - Low-energy theorems (Vanishing of amplitude when the momentum of an external state goes to 0)

  to reconstruct all amplitudes of theory from a finite set of input amplitudes

Recursion relations for arbitrary spin

- We generalized the recursive approach to amplitudes of particles of arbitrary spin
- We derived a precise criterion for when a subtracted soft recursion relation has to to be valid

$$4 - n - \frac{n-2}{v-2}[g] - \sum_i s_i - \sum_i \sigma_i < 0$$

n: number of external states of amplitude
v: valence of fundamental interaction
$[g]$: mass dimension of fundamental coupling
s_i: spin of external state
σ_i: soft degree of amplitude for given external state

$$\mathcal{A}_n \xrightarrow[\epsilon \to 0]{p_i \to \epsilon p_i} \epsilon^{\sigma_i}$$

Recursion relations for arbitrary spin

- We use our method to explore the landscape of effective field theories
- For the values of $[g]$ and σ that we know our recursion relations must be valid
  - Write the most general form for the input amplitude
  - Apply recursion relations to calculate higher-point amplitudes
  - If the result of recursion has unphysical poles
    $\Rightarrow$ There cannot be a theory with the given $[g]$ and σ
  - If there are no unphysical poles
    $\Rightarrow$ A theory may exist and we study its properties from the calculated amplitudes.

An example - The quartic Galileon

- Quartic Galileon interactions have 6 derivatives ($[g] = -6$)
- Action has to be invariant under the shift

$$\phi \to \phi + c + b_\mu x^\mu$$

  $\Rightarrow$ Amplitudes must vanish as p^2_{soft}
- Constructibility criterion

$$4 - n + \frac{6}{2}(n-2) - 0 - 2n < 0 \Rightarrow -2 < 0$$

  holds for any positive integer n

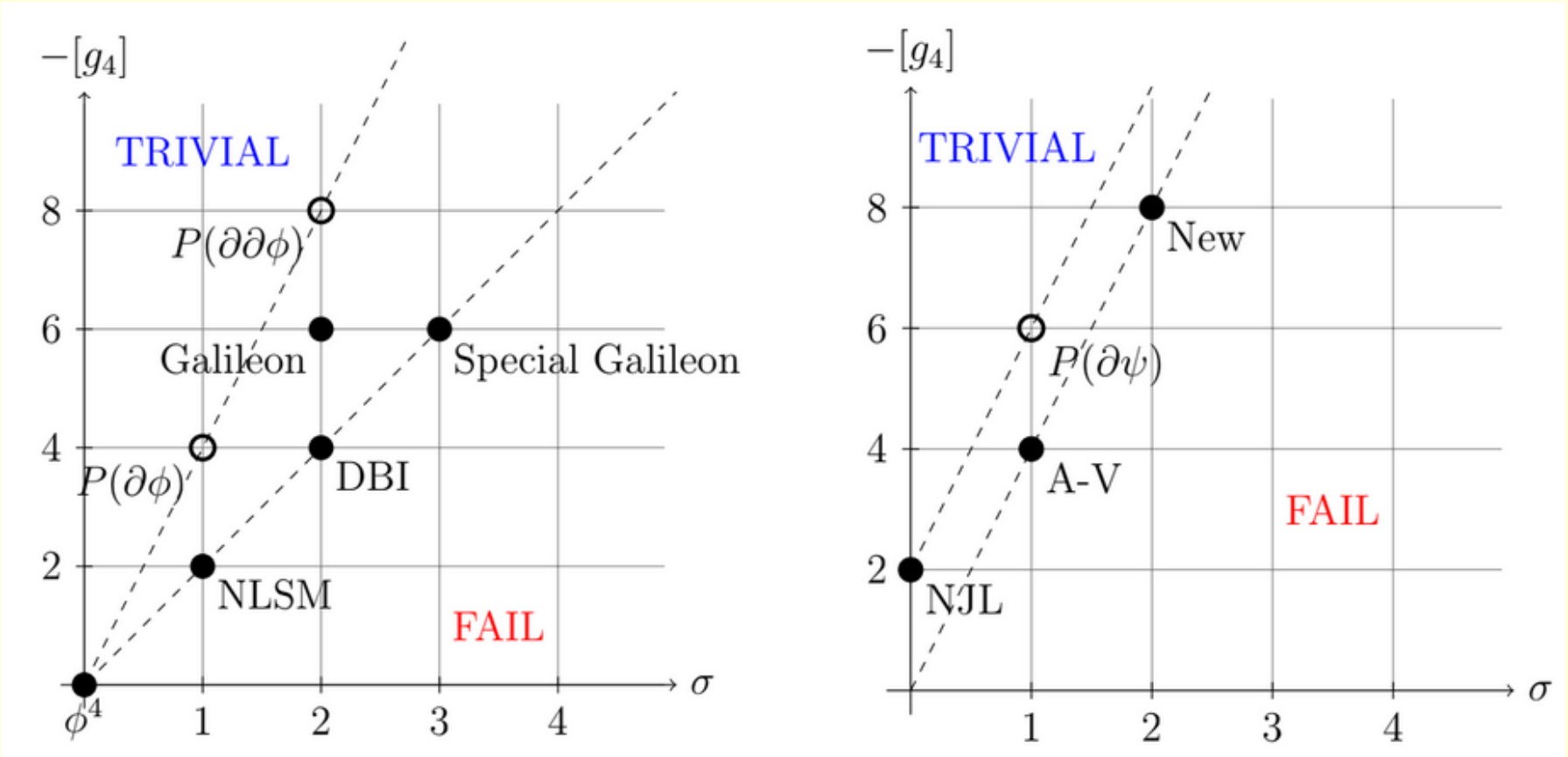
An example - The quartic Galileon

- Expecting supersymmetry, the only allowed 4-scalar amplitude has 2 ϕ's and 2 $\bar{\phi}$'s, i.e. $\mathcal{A}_4(\phi\bar{\phi}\phi\bar{\phi})$
- Most general Ansatz

$$\mathcal{A}_4(\phi\bar{\phi}\phi\bar{\phi}) = g\left(c_1 stu + c_2 t^3\right)$$

- Apply recursion to calculate $\mathcal{A}_6(\phi\bar{\phi}\phi\bar{\phi}\phi\bar{\phi})$
- Reconstructed amplitude has spurious poles unless $\boxed{c_2 = 0}$
- With $c_2 = 0$, 4 and 6-scalar amplitudes match the ones calculated from the Lagrangian of [K. Hinterbichler et al. 1008.1305] using traditional methods - Feynman diagrams

Landscape of reconstructible EFTs



More aspects of our work

- Supersymmetrization of Galileon theories
- Study EFTs arising from spontaneous supersymmetry breaking
- Explore "emergent" symmetries in these EFTs

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THANK YOU!