

QUANTUM GRAVITY AMPLITUDES: FROM FIRST PRINCIPLES TO OBSERVABLES

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QG AMPLITUDES

- scattering amplitudes that include (internal or external) graviton lines
- derived from quantum effective action - only tree-level
- why bother?
 - probes quantum gravity effects
 - direct link to observables (cross sections, cosmological observables etc.)
 - do not depend on arbitrary choices

FROM FIRST PRINCIPLES TO OBSERVATION

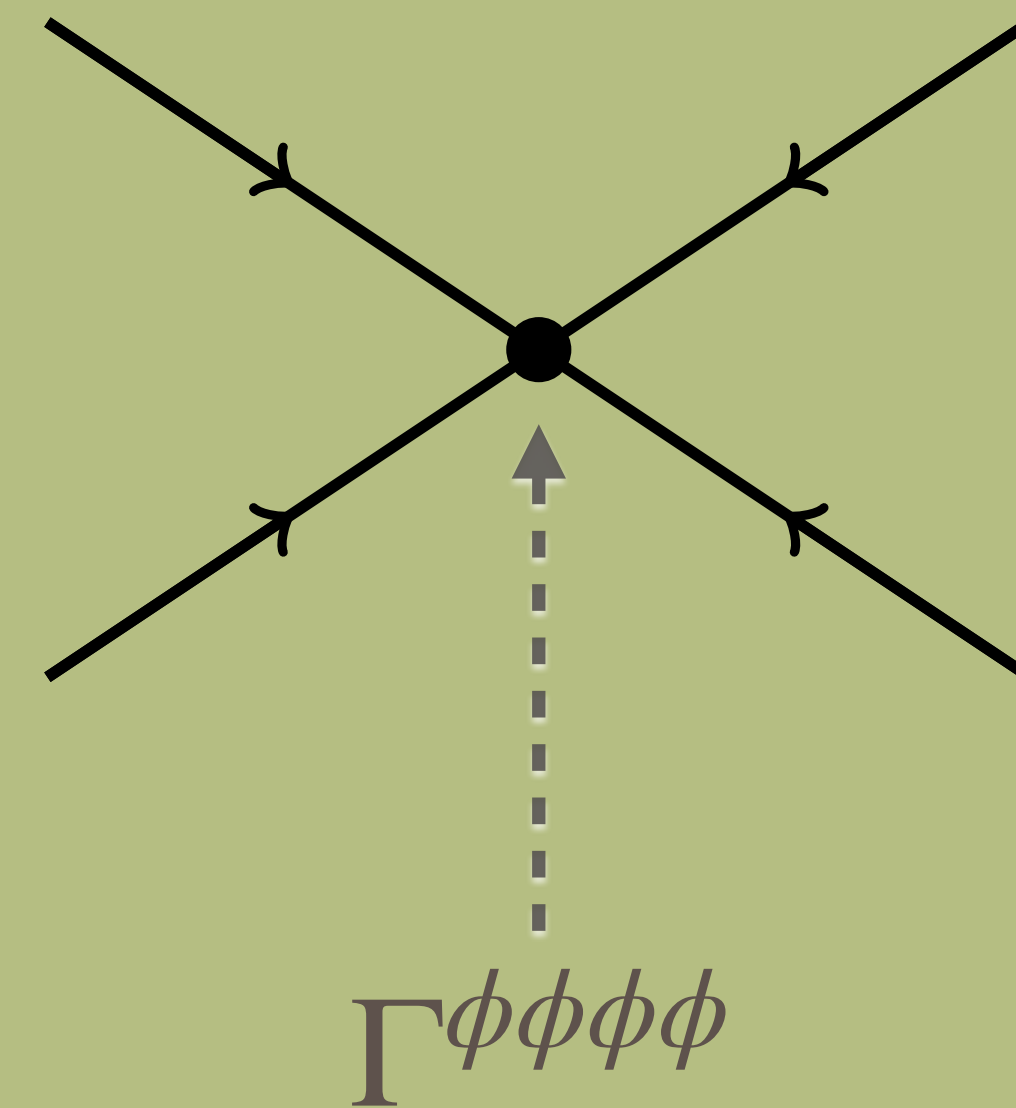
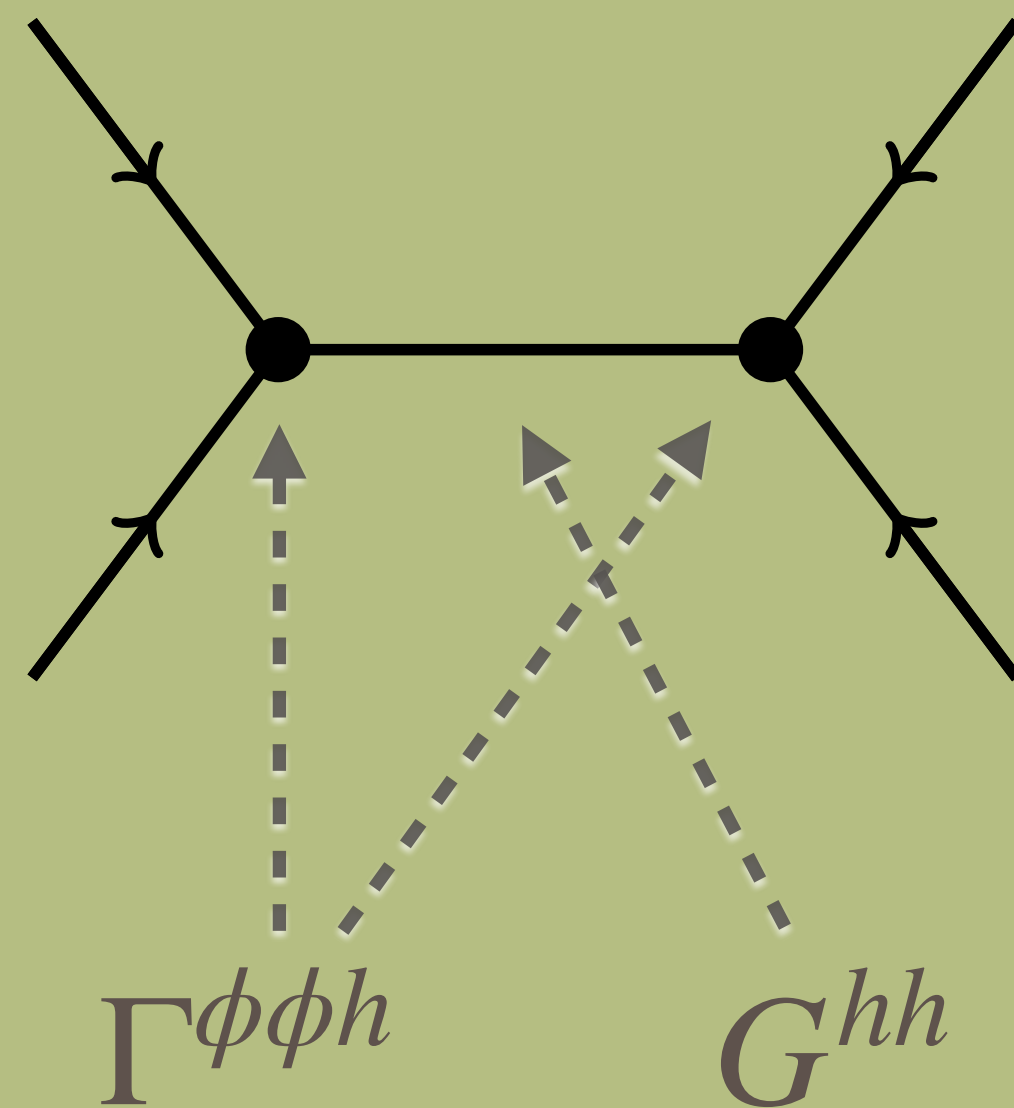
- three step process for any amplitude:
 - parameterise parts of effective action that contribute to the amplitude
 - compute these parts from first principles (within e.g. asymptotic safety)
 - derive observables and compare with measurements and consistency conditions

PART I: PARAMETERISING AMPLITUDES

more details: talk by Chris today 16:15

PARAMETERISING THE AMPLITUDE

- 2-to-2 scattering event of a scalar in flat spacetime:



PARAMETERISING THE AMPLITUDE

- in flat background spacetime, we need:

G^{hh}

$$\Gamma^{\phi\phi\rightarrow\phi\phi} = \frac{1}{16\pi G_N} \int d^4x \sqrt{-g} [-R + R f_{RR}(\Delta) R + C^{\mu\nu\rho\sigma} f_{CC}(\Delta) C_{\mu\nu\rho\sigma}]$$

$$+ \int d^4x \sqrt{-g} \left[\frac{1}{2} \phi f_\phi(\Delta) \phi + f_{R\phi\phi}(\Delta_1, \Delta_2, \Delta_3) R \phi \phi + f_{\text{Ric}\phi\phi}(\Delta_1, \Delta_2, \Delta_3) R^{\mu\nu} D_\mu \phi D_\nu \phi \right]$$

$$+ \int d^4x \sqrt{-g} f_{\phi\phi\phi\phi} (-\{D_i \cdot D_j\}) \phi \phi \phi \phi$$

$\Gamma^{\phi\phi h}$

$\Gamma^{\phi\phi\phi\phi}$

full momentum dependence is key

form factor toolbox:
Knorr, Ripken, Saueressig '19

AN ATLAS OF AMPLITUDES

- progress in mapping out these most general QFT amplitudes:

- gravity-mediated scalar-scalar scattering

Draper, Knorr, Ripken, Saueressig '20

- gravity-mediated scalar-photon and photon-photon scattering

Knorr, Pirlo, Ripken, Saueressig '22

- long-term aim: characterise all 2-to-2 SM+gravity amplitudes

- efforts to go beyond flat spacetime scattering

Knorr, Ripken '20

Ferrero, Ripken '21

PART II: COMPUTING PROPAGATORS AND VERTICES

COMPUTING INGREDIENTS

- most effort so far: graviton (and partly matter) propagators (by the “HD” and “Nijmegen” schools)
- some local/bilocal/trilocal/... computations of graviton vertices
- concerted effort needed to compute necessary correlation functions

SELECTED HIGHLIGHTS

- computation of the full graviton propagator (all modes disentangled)

Knorr, Schiffer '21

- Wick rotation of Euclidean propagator

Bonanno, Denz, Pawłowski, Reichert '21

- computation of **Lorentzian** propagator and graviton spectral function

Fehre, Litim, Pawłowski, Reichert '21

more details: talk by Manuel tomorrow 11:30

PART III: OBSERVATIONS AND CONSISTENCY CONDITIONS

OBSERVATIONS AND CONSISTENCY CONDITIONS

- observables beyond scattering cross sections more difficult, less explored from this general viewpoint

- consistency conditions:

- unitarity&causality

Platania, Wetterich '20, Platania '22

- positivity bounds

recall talk by Scott this morning

- swampland conjectures

Basile, Platania '21

Basile, Borissova, Knorr, Platania, Schiffer wip

- ...

more details: talk by Alessia on Thursday 14:30

RELATED RECENT DEVELOPMENTS

RECENT DEVELOPMENTS

- (minimal) essential RG (Baldazzi, Ben Ali Zinati, Falls '21)
- only essential couplings enter observables like scattering amplitudes
- set up RG flow for essential couplings only - tremendous reduction of complexity

more details: talk by Kevin on Wednesday 11:00

talk by Oleg on Wednesday 17:55

work in progress:

Knorr, Platania

Knorr, Ripken

Baldazzi, Falls, Kluth, Knorr

SUMMARY

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- amplitudes: one of the hot topics in asymptotic safety
- some computations done, many still ahead
- critical questions about asymptotic safety: causality, unitarity, swampland bounds, ...
- promising path to connect to other fields and ideas
- **QG observables**