IGFAE – Retreat

Session: Introduction by IGFAE newcomers

Luca Buoninfante

IGFAE/USC – Research Programme:
String Theory and Related Fields

June 22, 2026

IGFAE
INSTITUTO GALEGO DE FÍSICA DE ALTAS ENERXÍAS

USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

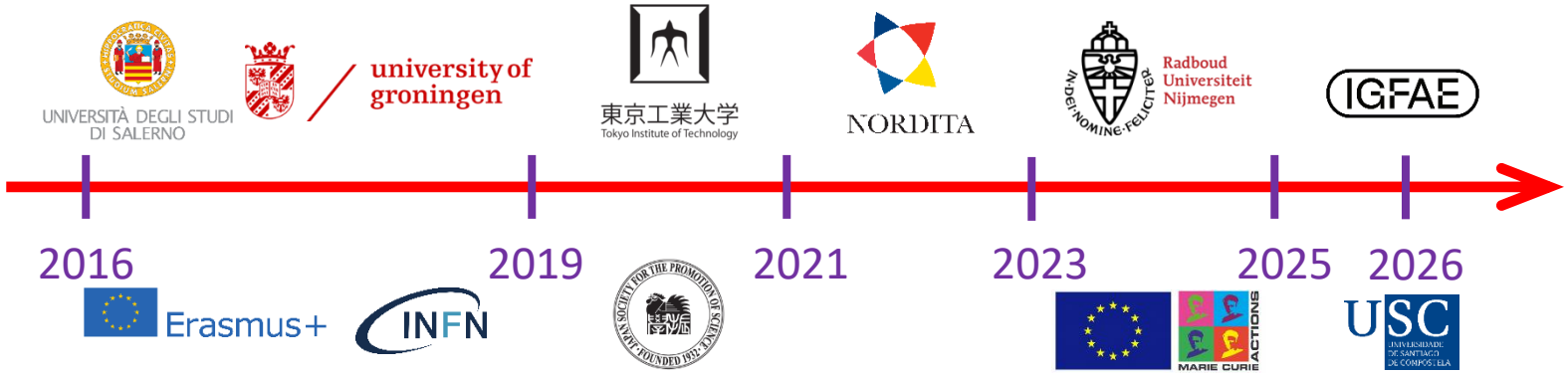
Outline of the Presentation

1. Scientific career so far

2. Research I intend to carry out at IGFAE

Academic Path So Far

- 2016–2019: *Double PhD,* Salerno U. (Italy) & Groningen U. (Netherlands)
- 2019–2021: *JSPS Postdoctoral Fellow,* Tokyo Institute of Technology (Japan)
- 2021–2023: *Postdoctoral Fellow,* NORDITA (Sweden)
- 2023–2025: *Marie Curie Fellow*, Radboud U. Nijmegen (Netherlands)
- 2025–present: *Junior Fellow*, IGFAE/USC (Spain)



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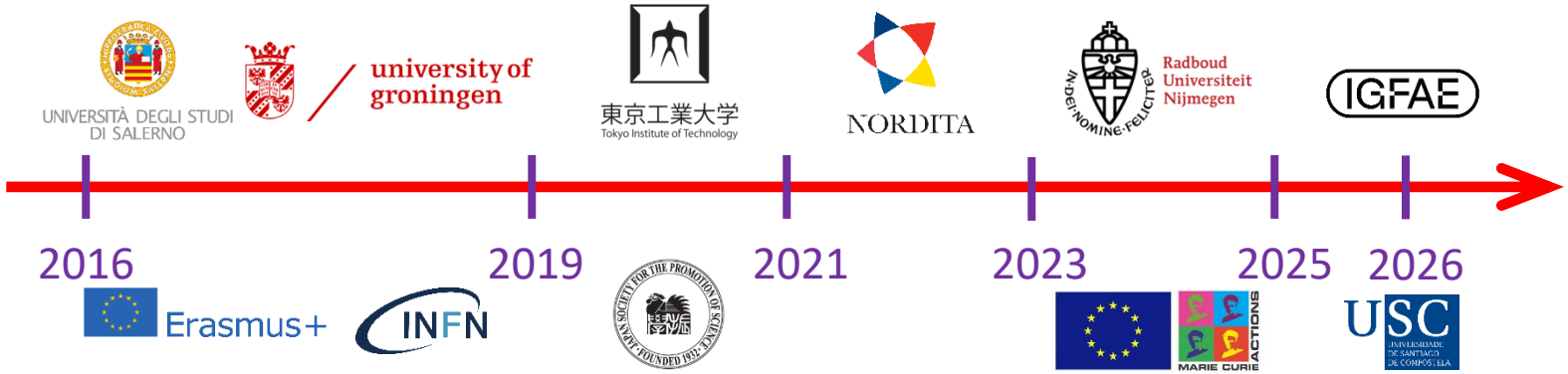


Primary Research Interests:

QFT of gravity, quantum gravity, quadratic gravity, higher-derivative field theories (theory and phenomenology)

Research Activity

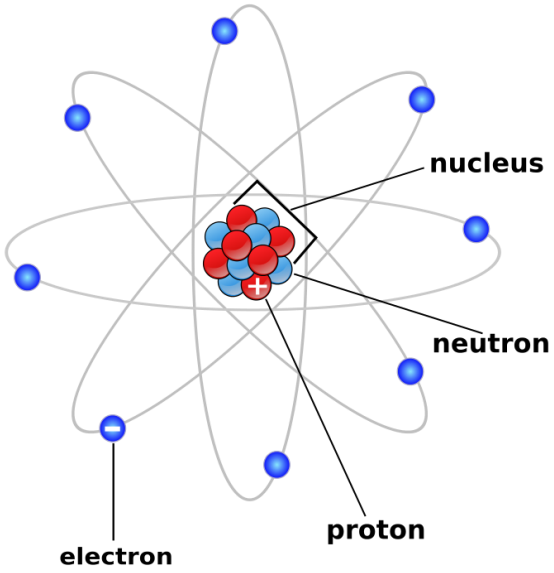
Quantum Field Theory of the Gravitational Interaction

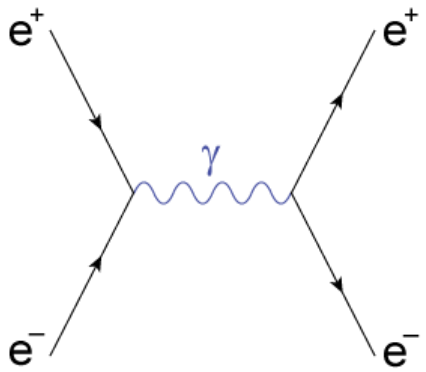
Research Activity

Quantum Gravity as a Quantum Field Theory

Research Activity

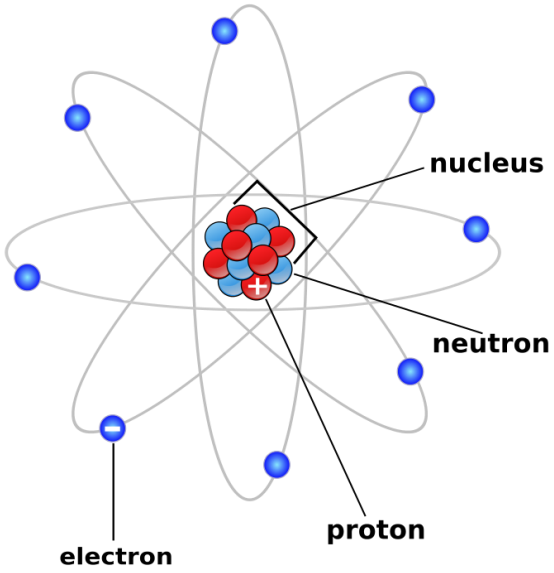
Quantum Physics:

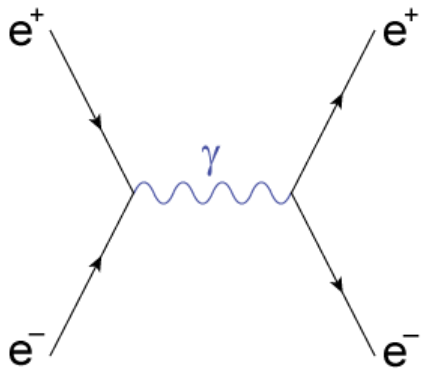




Research Activity

Quantum Physics: Quantum Field Theory (QFT)





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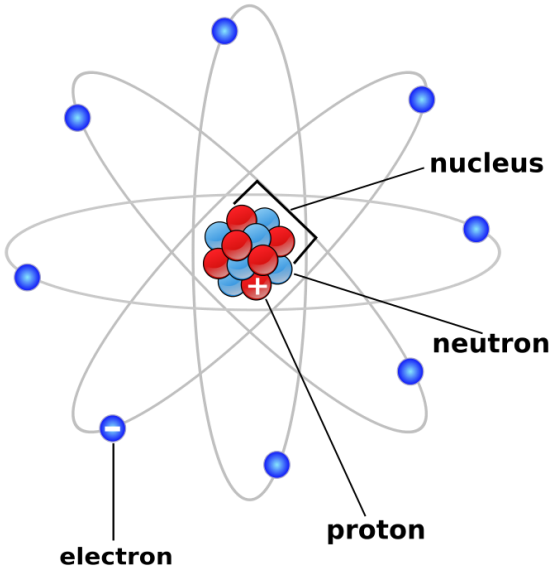
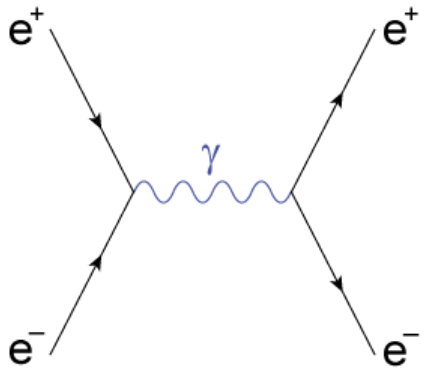




Nature is probabilistic at the fundamental (microscopic) level

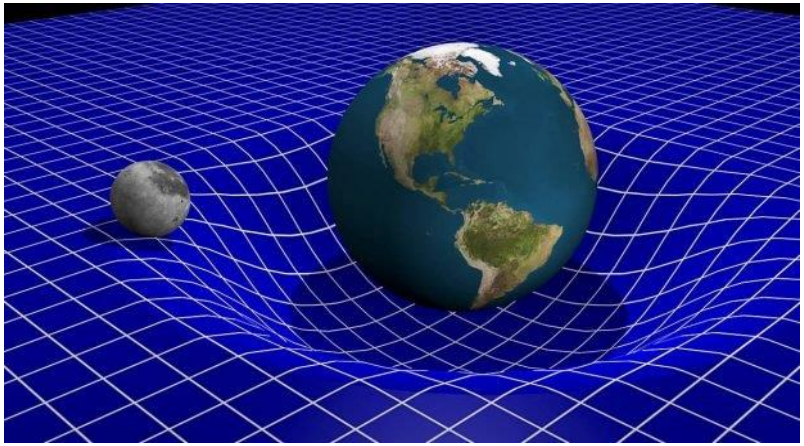
Research Activity

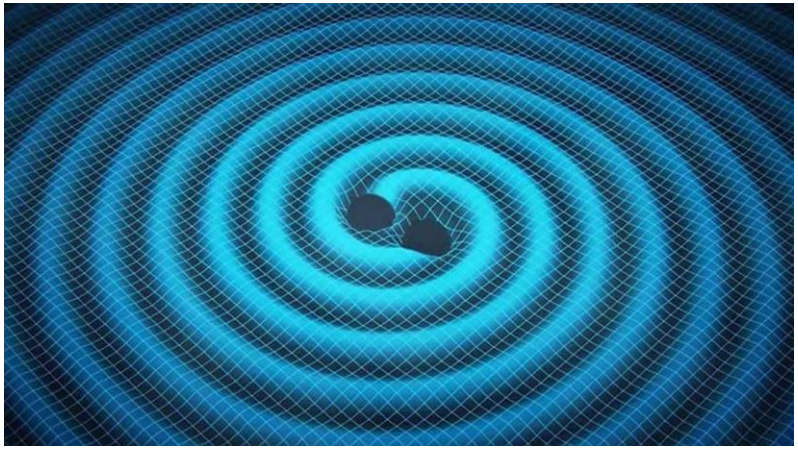
Gravitational Physics:

Research Activity

Gravitational Physics: General Relativity (GR)

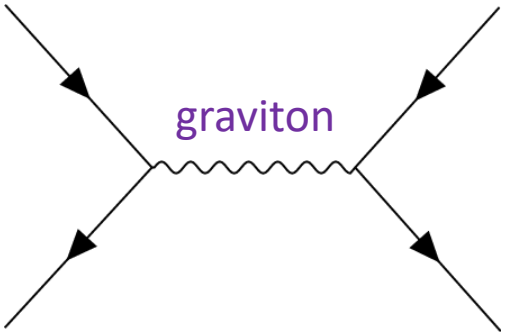
$$\underbrace{R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R}_{\text{Spacetime curvature}} = \frac{8\pi G}{c^4} \underbrace{T_{\mu\nu}}_{\text{matter}}$$

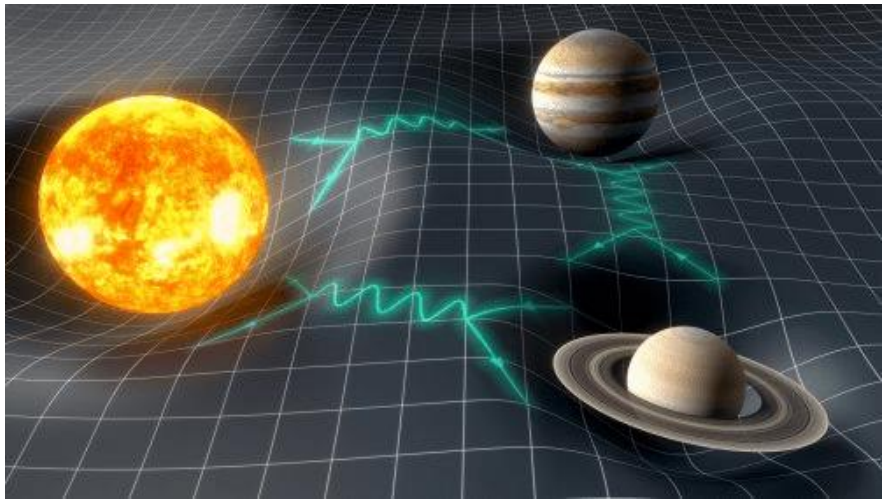




Research Activity

QFT + GR

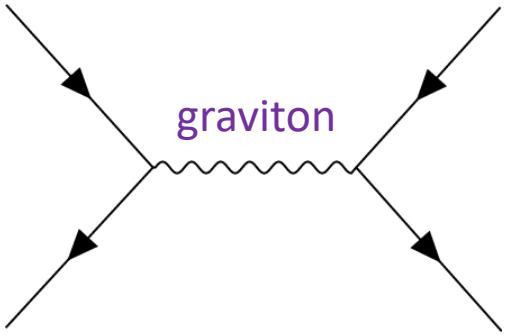


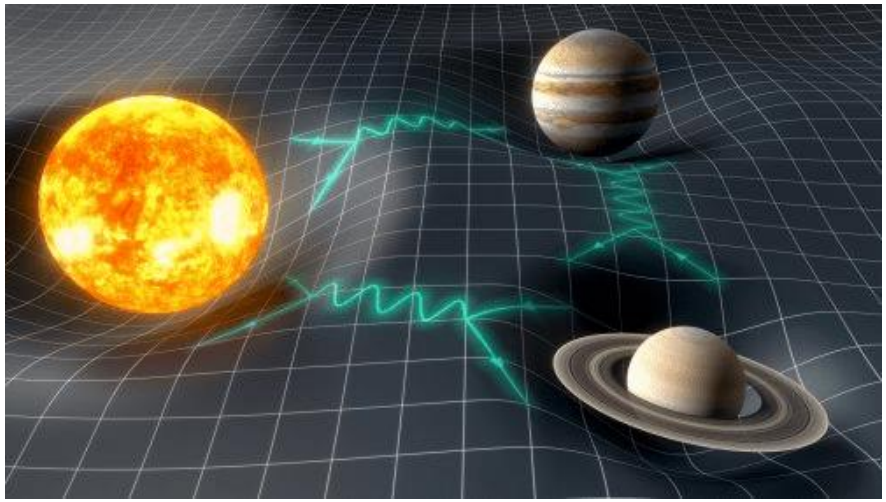


Research Activity

QFT + GR are not fully compatible at high energies:

non-renormalizability! unbounded probabilities!





Research Activity

Analogy with the Standard Model of Particle Physics:

Research Activity

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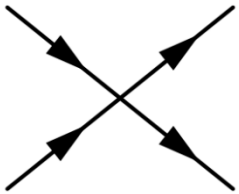
- Fermi theory of weak interaction is not renormalizable



fermions

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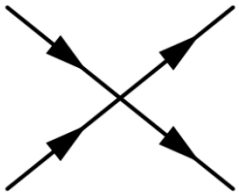
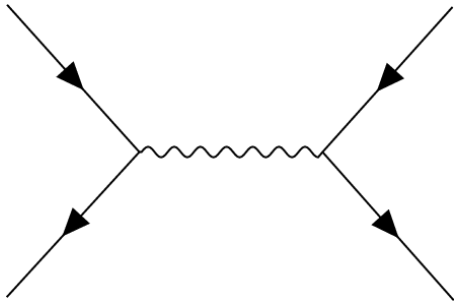


fermions

- Renormalizable completion: Electroweak theory



fermions + vector bosons + Higgs

Research Activity

All QFTs in the Standard Model are renormalizable

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Is there a renormalizable QFT of gravity?

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Quadratic gravity:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + (\text{quadratic curvature modification}) = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$$R^2, \qquad R_{\mu\nu} R^{\mu\nu}, \qquad R_{\mu\nu\rho\sigma} R^{\mu\nu\rho\sigma}, \qquad \partial^2 R^{\cdots}_{\cdots}, \ldots$$

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$\Longrightarrow$ fourth-order field equations!

Research Activity

Analogy in classical mechanics:

$$m\,\ddot{x}(t) = \mathcal{F}\,(x, \dot{x}, t) \quad \longrightarrow \quad \mu \frac{d^{(4)}x(t)}{dt^4} = \mathcal{F}\,(x, \dot{x}, \ddot{x}, \dddot{x}, t)$$

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Implications of higher-order derivatives:

- Additional gravitational degrees of freedom
  (massless graviton + massive spin-zero + massive ‘‘ghost-like’’ spin-two)
- New quantum dynamics
- New testable physics (e.g. early-universe cosmology)
- Quantum-gravitational effects in the sub-Planckian regime

Research Activity

Main research objectives:

- Analyze formal aspects of four-derivative QFTs
  (unitarity, causality, high-energy behavior)
- Elucidate the nature of ghosts as new types of quantum objects
- Challenge quadratic gravity (theoretically and observationally!)
- Make new testable quantum-gravitational predictions

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Grazas pola sua atención