Quantum Black Holes

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Outline

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Semi-classical Black Holes and Quantum Black Holes

Model of low scale quantum gravity:
Formation of small black holes (BH) at elementary particle colliders

Semi-Classical BH

- thermal object
- decay via Hawking radiation into many particle final state
- formation unlikely since $\mathrm{M}_{\mathrm{BH}} \gg \mathrm{M}_{\mathrm{P}}$
- geometrical cross section:

$$\sigma = \pi r_s^2$$

QBH

- non-thermal object
- decay into only a few particles
- interpretation as short-lived state
- cross section from semi-classical case

Effective Operators for QBHs

How to model these states in particle physics processes?
$\rightarrow$ suitable Effective Field Theory

QBH

- e.g. spinless QBH is represented by scalar field
- charges in accordance with gauge quantum numbers of Standard Model

Interaction

- defined by EFT
- matching of cross section with geometrical one

- conservation of gauge symmetries
- no equal assumption for global symmetries

Effective Operators for QBHs

Lagrangian

$$\mathcal{L} = \frac{c}{\bar{M}_P^2} \Box \phi \bar{\psi} \psi + h.c.$$

- ϕ: neutral scalar field $\rightarrow$ QBH
- ψ: fermion field
- c: adjustable parameter to match cross section, depending on CoM energy and relevant masses

Matching of Cross Sections

Cross section for production of scalar field

$$\sigma\left(2\psi \to \phi\right) = \frac{\pi}{s}|\mathcal{A}|^2\,\delta(s - M_{BH}^2)$$

amplitude: $$|\mathcal{A}\left(2\psi \to \phi\right)|^2 = s^2\frac{c^2}{\bar{M}_P^4}\left[s - (m_1 + m_2)^2\right]$$

Geometrical Cross Section

$$\sigma \sim \pi r_s^2 \quad , \quad 4\text{d} : r_s = \frac{\sqrt{s}}{4\pi\bar{M}_P^2}$$

thus: $$c^2 = \frac{1}{4\pi\left[s - (m_1 + m_2)^2\right]}\frac{\sqrt{s}\left[\left(\sqrt{s} - M_{BH}\right)^2 + \frac{\Gamma^2}{4}\right]}{\Gamma}$$

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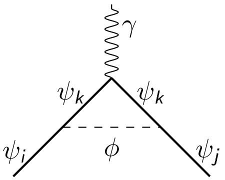
Low energy contributions

Effective Lagrangian

$$L_{eff} = \sum_{ij} \frac{1}{\bar{M}_P} \bar{\psi}_i (A_{ij} + B_{ij}\gamma_5) \sigma_{\mu\nu} \psi_j F^{\mu\nu}$$



1. anomalous magnetic moment
   $\rightarrow \bar{M}_P > 2 \times 10^8\,\mathrm{GeV}$
2. "forbidden" lepton family number violating processes, e.g. $\mu \rightarrow e\gamma$
   $\rightarrow \bar{M}_P > 7.2 \times 10^{12}\,\mathrm{GeV}$
3. CP violation $\rightarrow$ EDM of leptons and quarks of SM, e.g. for neutron
   $\rightarrow \bar{M}_P > 4.5 \times 10^{16}\,\mathrm{GeV}$

Thanks

Thanks for your attention!