The Parton Structure of Black Holes and Graviton Condensates

Tehseen Rug

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Hawking and Black Holes

Hawking: semiclassical treatment of black hole $(M_{BH} \to \infty) \Rightarrow$ exact thermal spectrum

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Question: Is the semiclassical treatment appropriate for real black holes?

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$$M_{BH} = \sqrt{N}\frac{\hbar}{L_P}, \quad r_g = \sqrt{N}L_P, \quad \alpha = \frac{1}{N} \quad (3)$$

Resolution of Black Hole Mysteries

Our picture: quantum effects not exponentially, but rather $\frac{1}{N}$ suppressed.
Decay Rate: $\Gamma \sim \frac{\hbar}{\sqrt{N} L_P} + \mathcal{O}(\frac{1}{N})$.

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Question: How can we perform actual computations in the quantum portrait?
Idea: Borough methods from QCD to describe the internal structure of black holes!

The Parton Model

In the Bjorken limit, $q^2 \to \infty$, $2Pq \to \infty$, $x = -\frac{q^2}{2Pq}$ =const. hadrons look like bound states of partons.

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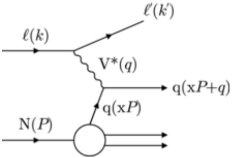

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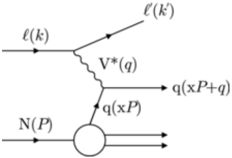

Figure: DIS of leptons and hadrons

In reality, there are also seaquarks and gluons!

Sum Rules

Analytical way to study these constributions: **SVZ Sum Rules** (Shifman, Vainshtein, Zakharov, 1978)

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Main Object: Hadronic Tensor

$$\Pi_{\mu\nu}(q) = \int d^4y \ \exp(iqy)\langle P \mid T[J_\mu(y)J_\nu(0)] \mid P\rangle$$
$$= (q_\mu q_\nu - q^2\eta_{\mu\nu})\Pi(q^2). \tag{4}$$

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Quark-Hadron-Duality: Description of Π in terms of hadrons (spectral density) and in terms of quarks (OPE).

Non-perturbative Vacuum

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Example:

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In the perturbative vacuum $\langle : \Phi(x)\Phi(y) : \rangle = 0$.

In general, this is not true $\Rightarrow$ **Vacuum Condensates**!

Operator Product Expansion

To evaluate the hadronic tensor, perform an Operator Product Expansion (OPE):

$$T[j(x)j(0)] = \sum_{n=0}^{\infty} C_n(x^2)\mathcal{O}_n(0). \tag{6}$$

C_n calculable, $\mathcal{O}$ condensates, e.g. $\langle \bar{q}q \rangle$, $\langle A_\mu^a A^{\mu a} \rangle$.

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In practice, only a few terms can be kept.
To ensure gauge invariance, use **Fock-Schwinger gauge:** $x_\mu A^\mu = 0$.

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Comparison of both description leads to physical quantities, like condensate values, couplings, masses etc.
It turns out, that most of the mass of hadrons is due to gluon condensates!

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Compute

$$\Xi_{\alpha\beta\mu\nu}(q) = \int d^4y \; \exp\left(iqy\right) \langle B \mid T\left[T_{\alpha\beta}(y) T_{\mu\nu}(0)\right] \mid B \rangle \qquad (8)$$

using the OPE!

Results and Challenges

Results:

- Ξ can be computed to lowest order (i.e. parton-like distributions)
- Exact expressions for propagators in external field formalism
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Challenges:

- Computation very technical and demanding
- Modeling of the spectral density for Black Holes
- Truncation of the OPE

Thank You for Your Attention