The Kerr/CFT correspondence:

from Astrophysics to Quantum Gravity

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The Kerr/CFT correspondence: from Astrophysics to Quantum Gravity

- **Near - extreme Kerr black hole**: $GM^2 \approx J$

- **Astrophysics**: model for a realistic black hole, e.g. Cygnus X1, $J/GM^2 > 0.95$

- **Astrophysics applications**: infinite-dimensional conformal symmetry
  → analytic study of emissions from the near horizon, magnetosphere

Gou et al., ’11

Strominger, Lupasca, Porfyriadis, Shi, Gralla, Hadar, Rodriguez (2014 - )
Plan

- brief review of quantum gravity (holography) and its challenges

- the Kerr/CFT correspondence: successes & puzzles

- understanding Kerr/CFT using string theory

- conclusions
Background/state of the art

- **What is Quantum Gravity?**

**HOLOGRAPHY**

- Gravitational theory
  - $d+1$ dimensions

- Field theory (no gravity)
  - $d$ dimensions

- Usual Quantum Mechanics
  - $= \text{"Quantum Gravity"}$

\[ S_{BH} = \frac{A_H}{4G} \]
Background/ state of the art

- Example: the AdS/CFT correspondence

- concrete examples, many successful checks

- universal: match of symmetries, entropy (d=2)

  - quantum entanglement (\(\downarrow \uparrow - \uparrow \downarrow\)) → emergent gravity

  - crossing symmetry \(\Sigma \leftrightarrow \Sigma\) → bulk locality
Quantum gravity in the real world?

Gravitational theory on flat space (e.g.)

HARD! boundary quantum field theory $\rightarrow$ exotic features: non-local

- try to infer its properties (e.g. symmetries, correlation functions)

from gravity side $\rightarrow$ hard if no known examples!
The Kerr/CFT correspondence
The Kerr/CFT correspondence

• Extreme Kerr black hole: \( GM^2 \sim J \)

• Quantum gravity in NHEK = CFT
  - infinite number of symmetries \( f(\phi) \)
    - Virasoro algebra
  - entropy match ✔️

M.G., Hartman, Song, Strominger ’08

- universality (all extremal black holes have Virasoro + entropy match) many people

- scattering amplitudes match ✔️

Bredberg, Hartman, Song, Strominger ’09

- entanglement entropy matches ✔️

Song, Wen, Xu ’16

• so far, looks identical to \( \text{AdS}_3 / \text{CFT}_2 \), but NHEK \( \neq \text{AdS}_3 \) !!!!

- spectrum indicates “CFT” is non-local ❔

→ “dipole CFT”
What are dipole CFTs?

• String theory to the rescue: 1) rich, yet constrained structure & 2) example

• embed Kerr/CFT in string theory → many tunable parameters

Kerr/CFT is a deformation of AdS$_3$/CFT$_2$

\[ S_{\text{dipole CFT}} = S_{\text{CFT}} + \lambda \int d^2x \mathcal{O}_{(1,2)} \]

irrelevant → non-locality

• does not immediately explain Virasoro & entropy

• higher-dimensional generalizations of Kerr/CFT (no Virasoro)

• Example: null dipole-deformed $\mathcal{N} = 4$ SU(N) super Yang-Mills (SYM) → 4d!

  - non-local deformation of $\mathcal{N} = 4$ SYM by very special irrelevant operators
  
    such that entropy is preserved

  - integrable → compute spectrum & match
Conclusions

- Quantum gravity (holography) for realistic backgrounds is hard

- the Kerr/CFT correspondence
  
  → can be applied to astrophysical black holes
  
  → may be tractable: because it is a deformation of $\text{AdS}_3/\text{CFT}_2$

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\[ \text{AdS}_3 \text{ black hole} \quad \quad \text{extremal Kerr} \quad \quad \text{Kerr black hole} \]

\[ \begin{align*}
\text{AdS}_3/CFT_2 & \quad \quad \text{deformation} \\
M^2 &= J & \quad \quad \text{Kerr/CFT} \\
M^2 \geq J & \quad \quad \text{flat space holography ??}
\end{align*} \]
Thank you!