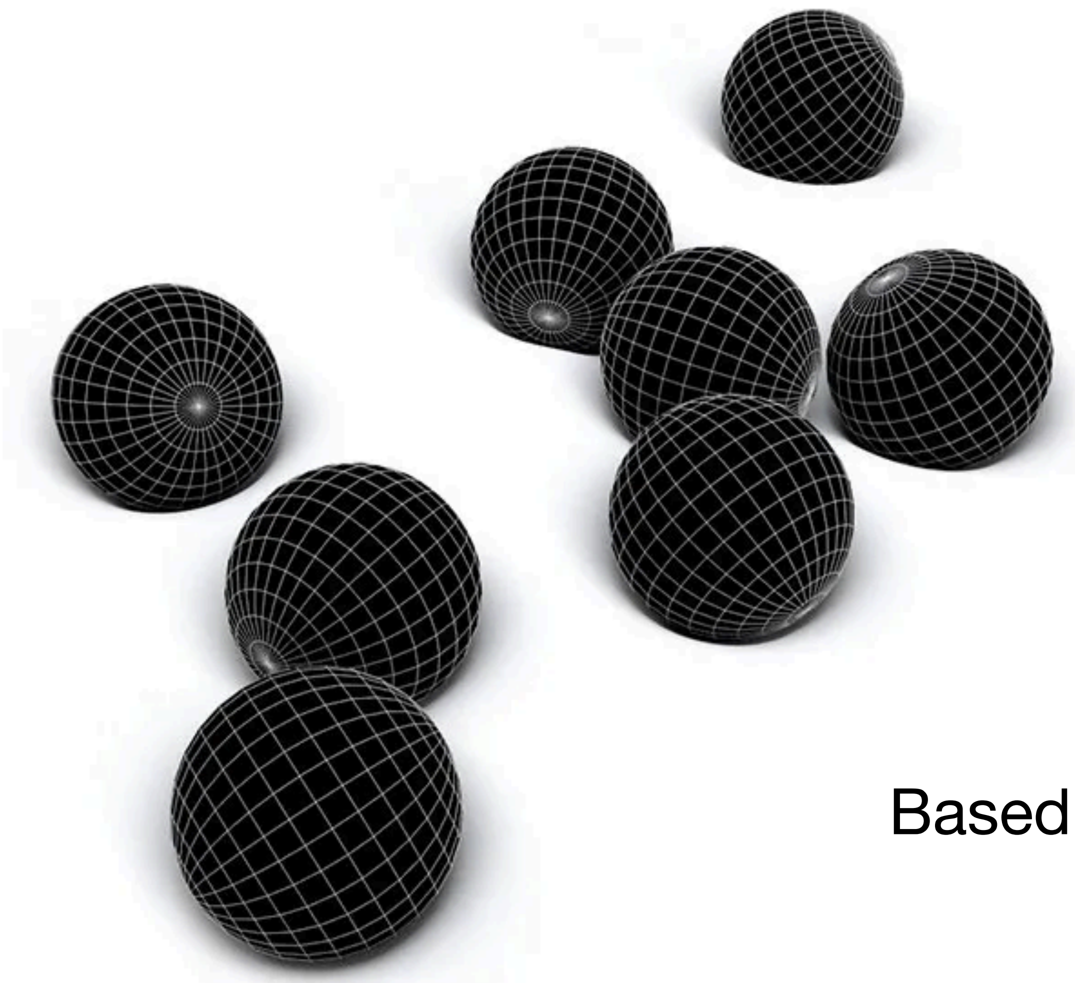
New Spins on the WGC



Based on arXiv:2205.06273
with Gary Shiu

Lars Aalsma
University of Wisconsin-Madison

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

String Phenomenology
July 4-8, 2022

Landscape vs. Swampland

In order to distinguish the landscape from the swampland, various swampland conjectures have been proposed. [cf. many talks]

Typically, these conjectures can be formulated and tested by going to extreme regions of parameter space.

In the swampland/landscape, black holes play a central role. Charged/rotating BHs have an extremal limit: $T \to 0$.

What lessons about the swampland can we learn from extremal BHs?

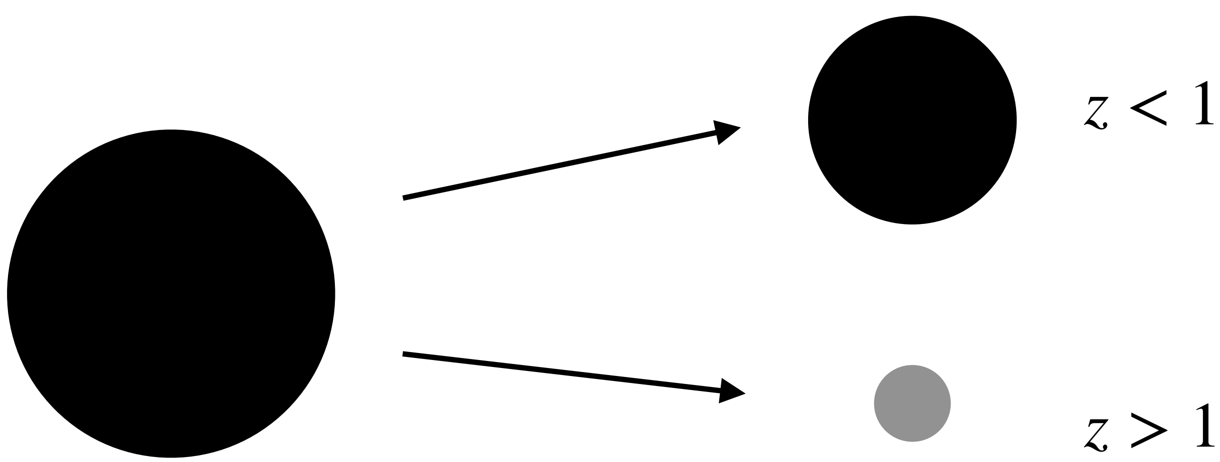
Weak Gravity Conjecture

The WGC suggests that extremal black holes, unless protected by symmetry, should be unstable.

Instability seems to be a key property of the landscape (e.g. AdS instability conjecture, no dS conjecture..)

For charged black holes, this puts a bound on the spectrum.

$$z = \frac{\sqrt{2}Q}{M} = 1$$



Schwinger pair production

WGC = $\exists$ state with $z > 1$

Mild Form of the WGC

The WGC constrains higher-derivative corrections to Einstein-Maxwell, as they modify the extremality bound. [Arkani-Hamed, Motl, Nicolis, Vafa '06] [Kats, Motl, Padi '06]

Leading Corrections:

$$L = \frac{1}{2}R - \frac{1}{4}F_{ab}F^{ab} + \frac{a_1}{4}(F_{ab}F^{ab})^2 + \frac{a_2}{2}F_{ab}F_{cd}W^{abcd}$$

Extremality Bound:

$$\frac{\sqrt{2}Q}{M} \leq 1 + \frac{32\pi^2(2a_1 - a_2)}{Q^2}$$

The WGC requires:

$$2a_1 - a_2 \geq 0$$

Black hole instability constrains EFTs!

Rotating Black Holes

Can we get new constraints by studying different extremal black holes?

What about extremal rotating black holes?

This amounts to a "rotating WGC", but its current status is unclear.

Evidence	**Counter Evidence**
c-theorem for BTZ [LA, Cole, Loges, Shiu '20]	Superradiance
Causality for higher spins [Kaplan, Kundu '21]	Ultraspinning regime in D>5 [Myers, Perry '86]

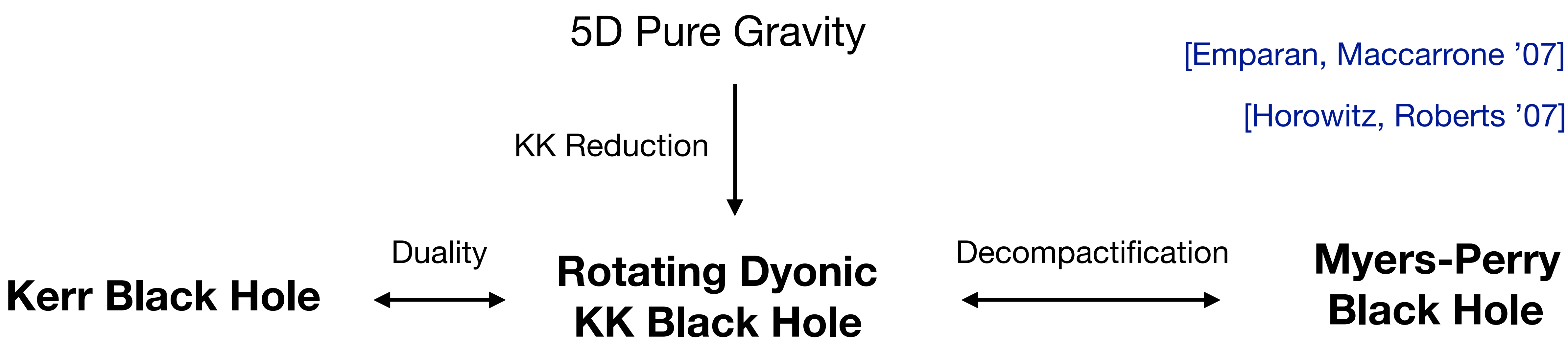
In string theory, we can make use of duality chains to map charge to rotation and vice versa.

Mapping Rotation to Charge

To assess the status of the rotating WGC, we can map rotating to charged black holes.

[Emparan, Maccarrone ’07]

[Horowitz, Roberts ’07]



We can impose the WGC on non-rotating, charged KK black holes.

This will tell us how the charged WGC bounds higher-derivative corrections to rotating black holes.

Correction to MP Black Hole

[LA, Shiu '22]

The black holes of interest are 5D vacuum solutions. The leading corrections are given by:

$$L = R + \lambda(\text{Riem})^2 + \eta(\text{Riem})^3$$

Keeping angular momentum fixed, the mass correction is:

$$\delta M_{\text{MP}} = -4\pi^2\lambda\left(\frac{a^2+b^2-6|ab|}{|ab|}\right) - 16\pi^2\eta\left(\frac{(a^2-14|ab|+b^2)(a^2-|ab|+b^2)}{7|ab|^3}\right)$$

$(a, b) \sim (J_1, J_2)$

For arbitrary ratio of rotations a/b, the sign of the correction is not fixed! No rotating WGC?

Leading Corrections

[LA, Shiu '22]

However, for arbitrary 5D rotation the 4D KK BH is not purely charged.

In the limit of equal 5D rotations, $J_1 - J_2 = 0$, the 4D KK BH contains just charge. The corrections are then:

5D Myers-Perry: $$\delta M_{\rm MP}\Big|_{a\pm b=0} = 16\pi^2\lambda + \frac{192\pi^2}{7a^2}\eta$$

4D Kaluza-Klein: $$\delta M_{\rm KK} = -\lambda M_\lambda(q/p) + \eta M_\eta(q/p)$$ $M_i \geq 0$

4D Kerr: $$\delta M_{\rm Kerr} = \frac{8\pi\eta}{7\alpha^3}$$

Imposing the WGC

[LA, Shiu '22]

We now have computed all corrections and can impose the WGC on the 4D charged black hole.

	$\frac{\lambda}{L}\mathcal{R}^2$	$\eta L \mathcal{R}^3$
δM_4^{KK}	$-\frac{\lambda}{L}\mathcal{M}_\lambda$	$\eta L \mathcal{M}_\eta$
WGC:	$\lambda \geq 0$	$\eta \leq 0$
δM_5^{MP}	$\frac{\lambda}{L}16\pi^2$	$\eta L \frac{192\pi^2}{7a^2}$
Sign:	$+$	-
δM_4^{Kerr}	0	$\eta L \frac{8\pi}{7\hat{\alpha}^3}$
Sign:	n.a.	-

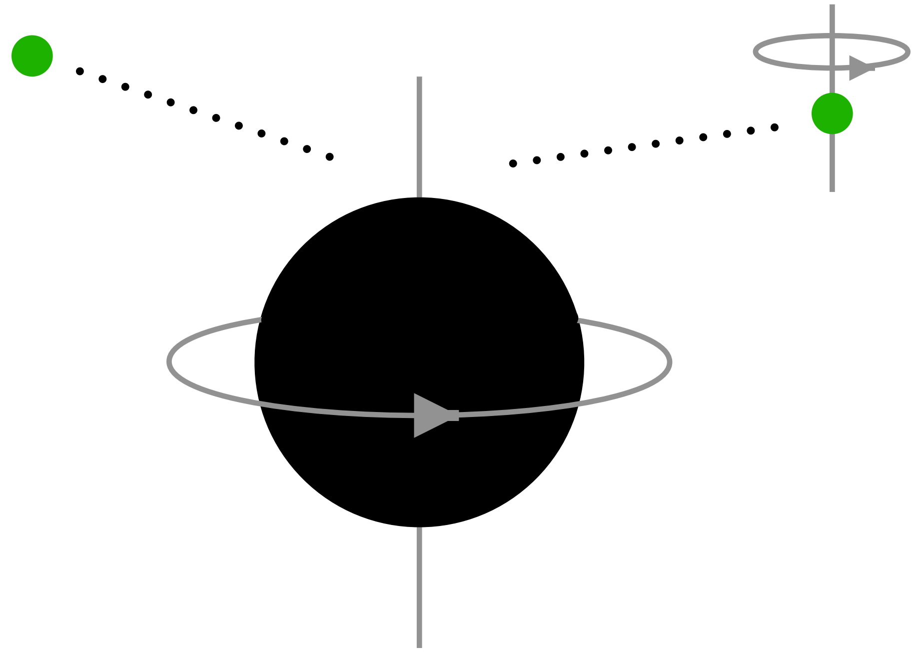
Riem^2 term *increases* the mass of MP.

Riem^3 *decreases* the mass of MP and Kerr.

Superradiance

The charged WGC constrains rotating black holes, but a rotating WGC only holds on a case-by-case basis.

An interpretation of this is that, typically, extremal rotating black holes have a superradiant instability.



No WGC-like constraint on spectrum!

Only non-superradiant extremal black holes should obey additional constraints. BTZ is an example? [Ortíz '11]

Conclusions

Extremal black holes can help us distinguish the landscape from the swampland.

Instability places constraints on EFTs, in particular Wilson coefficients of higher-dimensional operators.

Assuming the WGC, we derived new constraints on rotating BHs by mapping rotation to charge.

Superradiance prevents a universal rotating WGC-like constraint.

Interesting to study rotating solutions that don't superradiate.

Thank you!

laalsma@wisc.edu

@AalsmaLars

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON