

Wormhole fragmentation and the axion Weak Gravity Conjecture

<https://arxiv.org/abs/2609.32063>, w/ G. Shiu

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Main result

The aWGC: Existence of an axion (defect) satisfying the following condition

$$\frac{f S_0}{q} < c M_P^{\frac{D-2}{2}}$$
$$c = \begin{cases} c_{\text{WH}} = \frac{2}{\beta} \sin\left(\frac{\beta}{2} \frac{\Delta\tau}{2}\right), & \text{WH exists } (\beta < \beta_c) \\ c_{\text{ext}} = \frac{2}{\beta}, & \text{No WH } (\beta > \beta_c) \end{cases}$$

$\frac{\Delta\tau}{2} \sim IDB$: (imaginary) moduli distance across half-wormholes

[Maldacena, Maloney, McPeak] and [Di Ubaldo, Iliesiu, Lin, Yan]

$$S_{\text{grav}} = \int d^D x \sqrt{g} \left\{ \frac{M_P^{(D-2)}}{2} [-(R - 2\Lambda) + \partial\phi^2] - \frac{f^2 e^{\beta\phi}}{2} \partial\theta^2 \right\}, \quad S_{\text{defect}}(x) = S_0[\phi(x)] - q\theta(x)$$

The WGC

[Arkani-Hamed, Motl, Nicolis, Vafa]

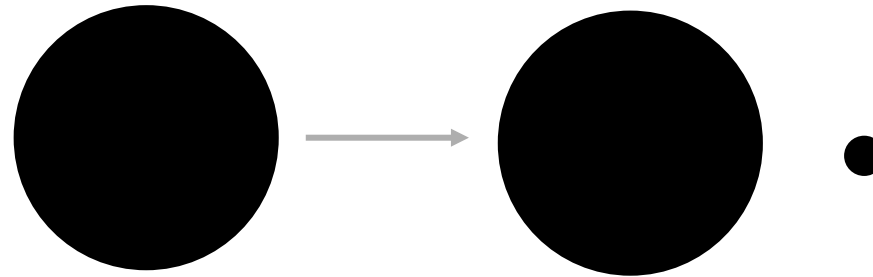
Gravity is the weakest force

Existence of a “super-extremal” particle

Repulsive force

Extremal (all) BHs can decay (Schwinger effect)

} EFT statement



$$\Gamma = 1 - |\langle 0; g, A | 0; g, A \rangle|^2 \sim 2 \text{Im}(S_{\text{eff}})$$

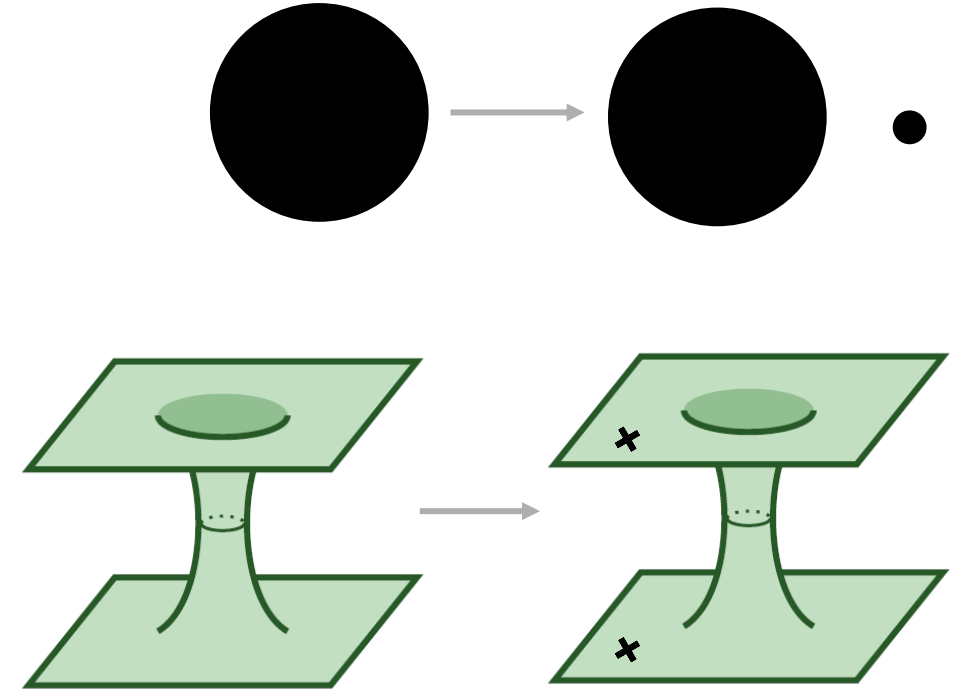
$$\Gamma \sim \sqrt{q^2/m^2 - c_{\text{ext BH}}}$$

The axion WGC

What objects replace the BH and particle?

Gravitational instantons and 0-dim defects

- Core instanton
- Wormholes
- Extremal instantons



Which class of gravitational instantons fixes the aWGC and how?

BH decay $\rightarrow$ extremal instanton/WH fragmentation

Wormhole fragmentation

Massless moduli $\rightarrow$ geodesics in the moduli space

Gravity (WH solution) $\rightarrow$ total distance across WH: $\Delta\tau$

(-1)-brane Defect action:

$$S(x) = \mathcal{T}[\phi(x)] - q\theta(x) = S_0 e^{-\frac{\beta\phi}{2}} - q\theta$$

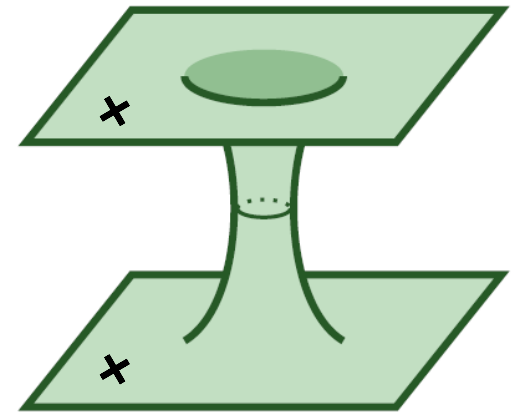
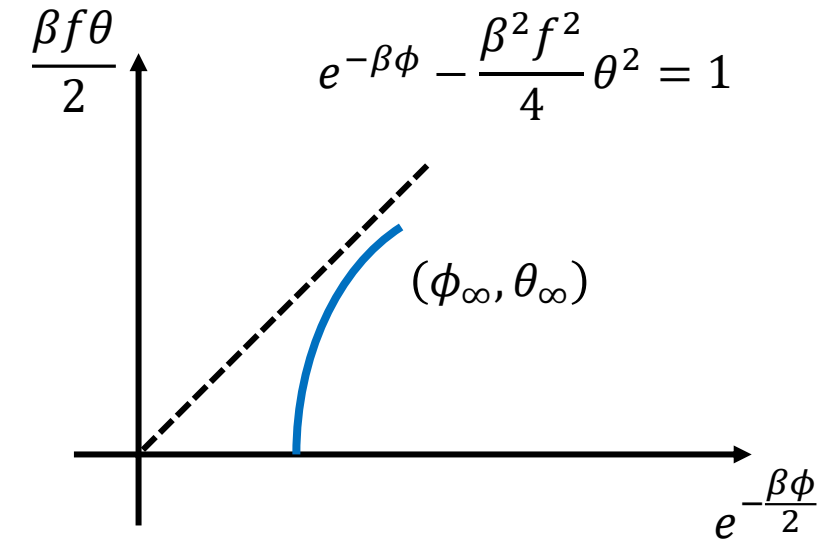
Fragmentation $\Leftrightarrow S_* = \min\{S(x)\} = S(\infty) < 0$

$$\Rightarrow \text{aWGC: } fS_0 < q\mathbf{c}M_P^{(D-2)/2} \quad \dots (\star)$$

$$c = \begin{cases} c_{\text{WH}} = \frac{2}{\beta} \sin\left(\frac{\beta}{2} \frac{\Delta\tau}{2}\right), & \text{WH exists } (\beta < \beta_c) \\ c_{\text{ext}} = \frac{2}{\beta}, & \text{No WH } (\beta > \beta_c) \end{cases}$$

Time-like moduli space distance across the WH: $\frac{\Delta\tau}{2}$ (IDB)

($\star$) holds for general WHs including AdS WHs



Features and implications

$$f S_0 < q \mathbf{c} M_P^{(D-2)/2} \quad \dots (\star)$$

- WHs set the aWGC bound:

$$c_{\text{WH}} = \frac{2}{\beta} \sin \left(\frac{\beta}{2} \frac{\Delta\tau}{2} \right) \leq c_{\text{ext}} = \frac{2}{\beta}$$

- aWGC bound value is less than IDB

$$c_{WH} = \frac{2}{\beta} \sin \left(\frac{\beta}{2} \frac{\Delta\tau}{2} \right) \leq \frac{\Delta\tau}{2} = IDB$$

$\frac{2}{\beta}$: moduli space curvature
 $c_{WH} \sim$ effective distance

- WHs are non-perturbatively unstable: WH $\rightarrow$ defects
WH proliferation, factorization problem?

More: Multi-saxion-axion (see paper), string theory example (WIP)

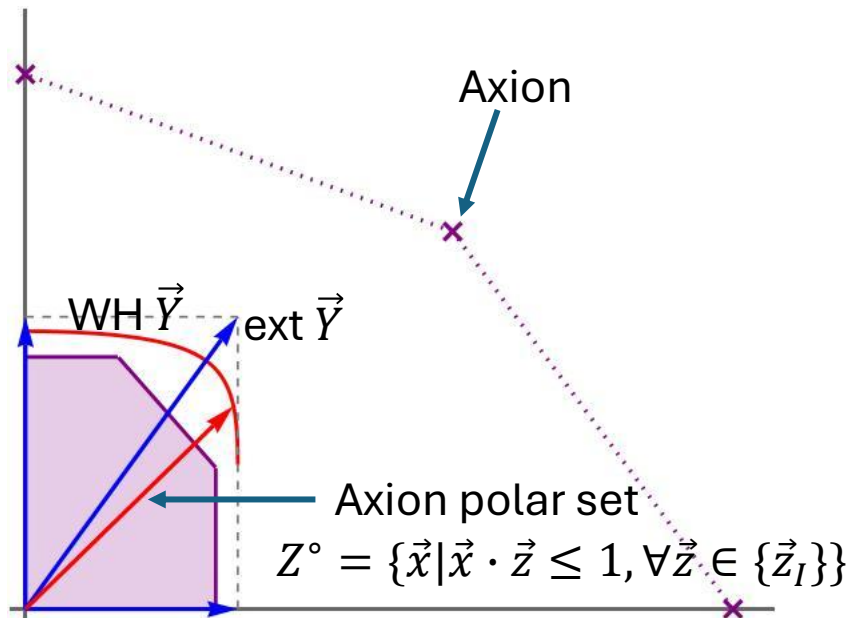
Thank you!

Multi charge aWGC: $S_0^{\text{phy}} < \sum \frac{q_i}{f_i^{\text{phy}}} \frac{2}{\beta_i} \sin(\frac{\beta_i}{2} \frac{\Delta\tau}{2} \Delta_i) \Leftrightarrow \vec{z} \cdot \vec{Y} > 1 \quad \dots (*)$

For all WHs ($\vec{Y} \in \{\vec{Y}\}$), there exists some axion defect ($\vec{z} \in \{\vec{z}_I\}$) s.t. (*) is satisfied

axion: $z_i = \frac{q_i}{S_0^{\text{phy}} f_i^{\text{phy}}}$, WH: $Y_i = \frac{2}{\beta_i} \sin(\frac{\beta_i}{2} \frac{\Delta\tau}{2} \Delta_i)$, Δ_i : partition of total moduli distance, $\sum \Delta_i^2 = 1$

Polar set condition



Convex hull condition

