# Extremal Surface Barriers

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Based on:

N.E., A. Wall arXiv:1312.3699

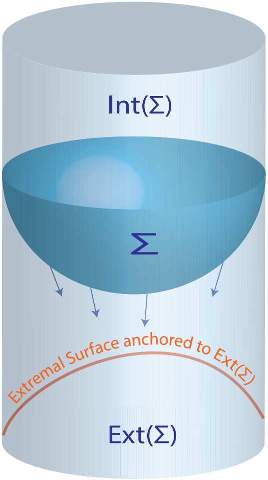
# Sufficient Conditions for an Extremal Surface Barrier

**Theorem:**

- Codimension 1 “splitting surface” $\Sigma$
- $\Sigma$ has $K_{\mu\nu} v^\mu v^\nu \leq 0$ for all $v^\mu \in M$ (Normals to $\Sigma$ converge outside $\Sigma$)

$\Rightarrow$ No boundary-anchored spacelike extremal surface anchored outside of $\Sigma$ can be deformed to cross $\Sigma$ *

- Example: stationary black hole horizons.



# Outermost Barriers

- Do all barriers have nonpositive extrinsic curvature? No!
- Consider extremal surfaces all anchored within a boundary region $\mathcal{R}$. There may be several nested barriers for this region. The barrier that comes closest to the extremal surfaces anchored on $\mathcal{R}$ is the *outermost barrier*.

**Theorem:** The outermost barrier has $K_{\mu\nu} v^\mu v^\nu \geq 0$.

# Barrier Construction

**Theorem:**

- $M$ obeys the NEC and EFE
- $X$ is a codimension 2 spacelike extremal surface
- $\Sigma$ is the union of future- and past-directed null congruences shot outwards from $X$

$\Rightarrow$ $\Sigma$ is a barrier to codim 2 extremal surfaces.

# Trapped Surface Barriers

**Theorem:**

- $\Sigma$ is null and splitting
- $\Sigma$ foliated by *(marginally) trapped surfaces* ($\theta^{\pm} \leq 0$)

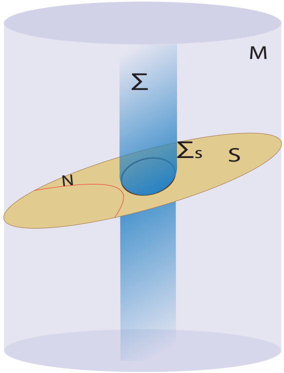
$\Rightarrow$ $\Sigma$ is a barrier to codimension 2 extremal surfaces.

# Compact Barriers Imply Singularities

**Theorem:**

- For nice spacetimes (NEC, EFE, globally hyperbolic, GC) with a totally geodesic slice $S$
- with a barrier with a compact intersection with $S$

$\Rightarrow$ The spacetime is geodesically incomplete



# To conclude...

- Extremal surfaces encounter barriers!
- Trapped surfaces and barriers go hand in hand
- Do codim 2 surfaces encounter more barriers than others? What does this mean for bulk reconstruction from entanglement entropy?
- What is the physical interpretation of barriers?
- Do barriers exist in semiclassical and quantum geometries, or are they a classical artifact? (see Wall's talk)