Basic Notions Presentation: AdS/CFT

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What is a duality?

Some countries have (more than) two official languages

“Genève” **“Genf”**

A **duality** in theoretical physics involves two (or more) different mathematical descriptions of the same phenomena

“metric” **“state”**

Like in the linguistic analogy there exists a **dictionary** to help translate from one side to the other

AdS/CFT

Dualities are found in many areas of physics and mathematics (e.g. particle - vortex duality in condensed matter)

What is special about AdS/CFT duality is that it involves **gravity**

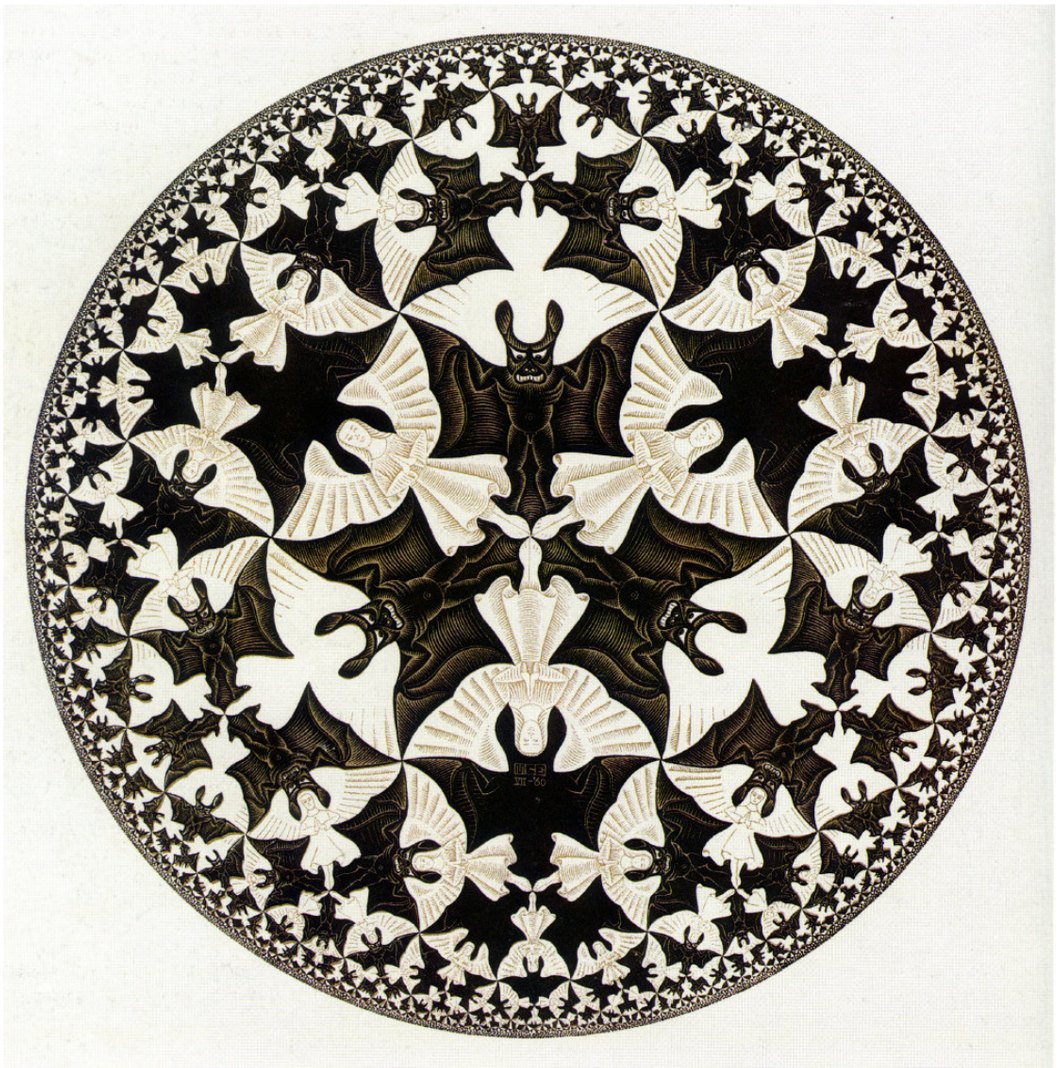
Duality:

quantum gravity in aAdS $\quad = \quad$ quantum field theory on fixed background

[Maldacena , GKP, Witten]

What is “AdS”?

Maximally symmetric pseudo-Riemannian manifold in d+1 dimensions with constant negative curvature — “Anti de-Sitter space”



[Escher, Circle Limit IV]

- Lorentzian version of hyperbolic space
- Gravity: geometry is dynamical
- Quantum gravity: string theory of aAdS spacetime
- Symmetry: group of isometries is

$$\mathrm{SO}(2,d)$$

What is “CFT”?

A quantum field theory in d dimensions equipped with ‘conformal’ symmetry

Conformal transformation (of flat space): $x \to x'$ such that

$$g \to g' = \Omega^2 g$$

Group of all such transformations: $\mathrm{SO}(2,d)$

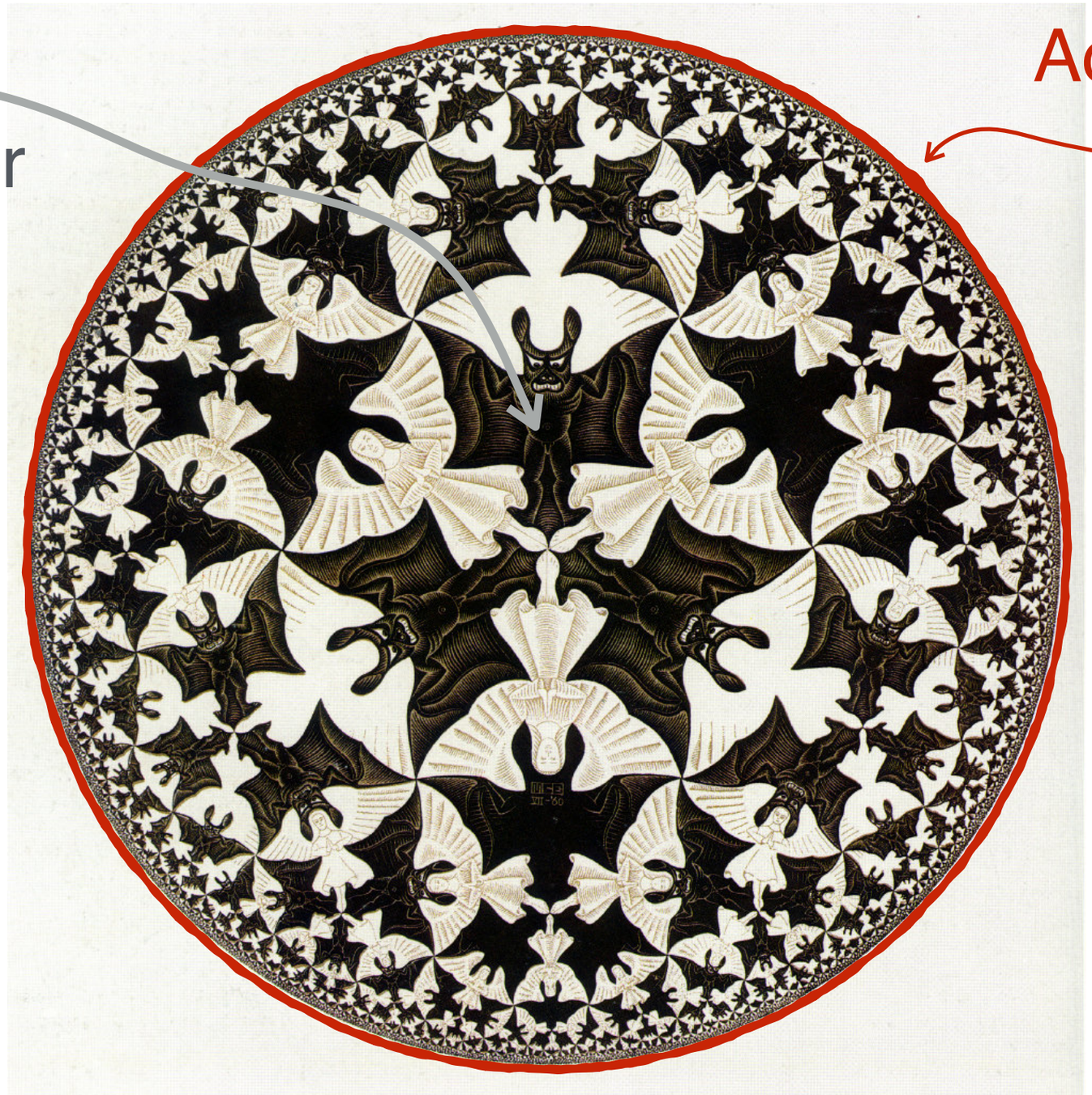
First entry in the dictionary:

“AdS isometries” $\mathrm{SO}(2,d)$ **“conformal symmetry”**

The holographic principle

AdS_{d+1}

AdS interior



AdS boundary

$(\partial \mathrm{AdS})_d$

The CFT ‘lives’ here

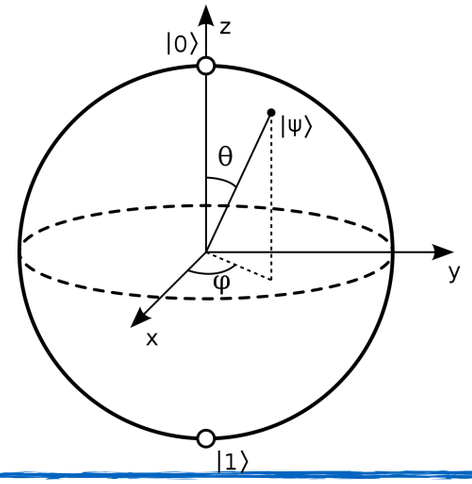
$$S_{\mathrm{BH}} = \frac{A}{4G_N}$$

[Bekenstein; Hawking]

Gravitational physics emerges from a lower-dimensional ‘hologram’

[’t Hooft; Susskind]

More entries in the dictionary

"AdS isometries"	$\mathrm{SO}(2,d)$	"conformal symmetry"
"metric"		"energy-momentum"
"ripples" (perturbations)	$W\left[J\right]$	"correlation functions"
"extremal surfaces"		"entanglement"

Why this is exciting

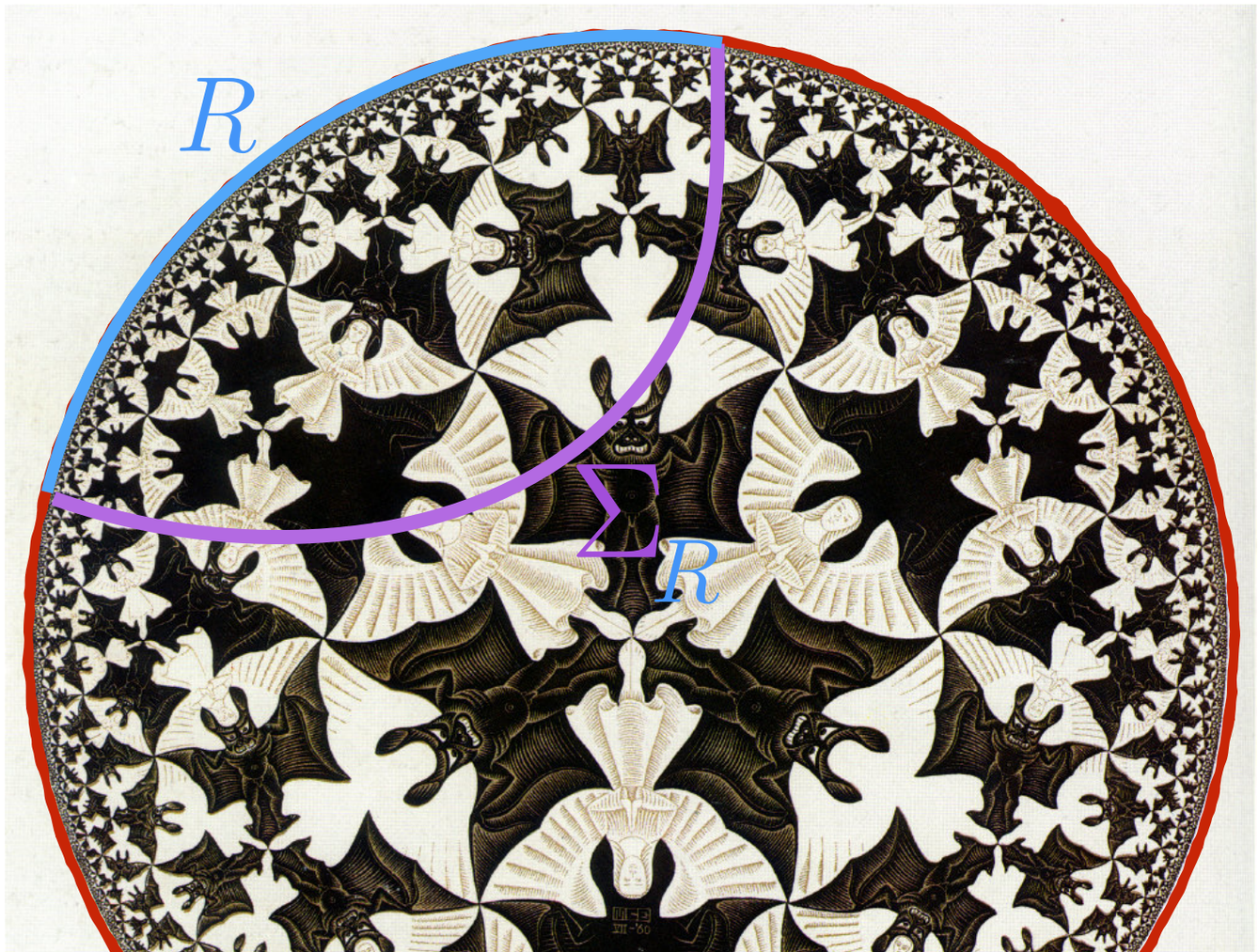
What is hard to express in one language may be easy in another
(extract from index of Landau & Lifshitz, Vol.3)

“Drehimpulswahrscheinlichkeitesdichteverteilungsfunktion”

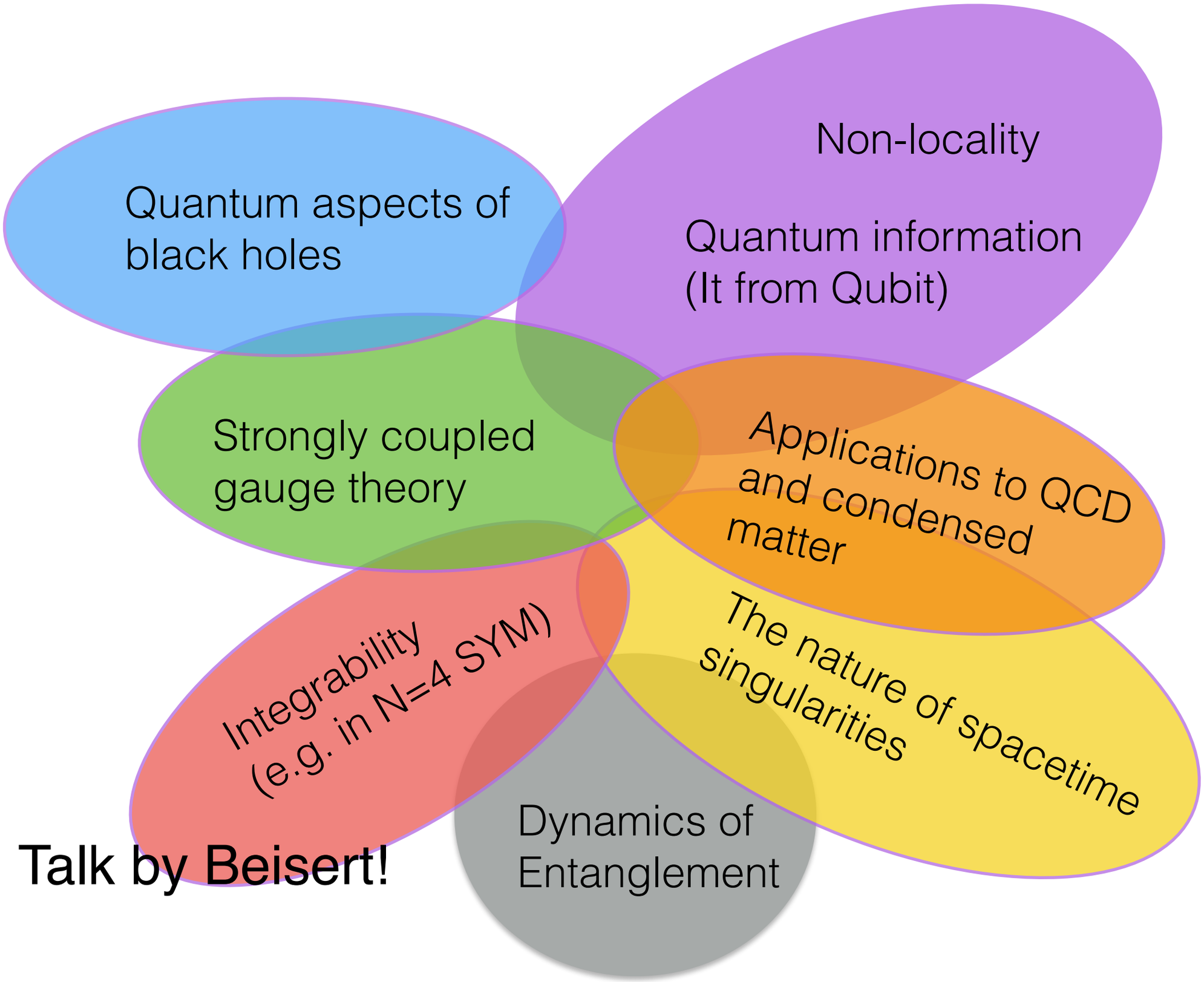
AdS/CFT allows computations that seem impossible otherwise:

$$S(R) = \frac{\text{area}(\Sigma)}{4G_N}$$

[Ryu & Takayanagi]



Some highlights



Talk by Beisert!

Conclusions & Outlook

AdS/CFT or ‘holographic duality’ defines quantum gravity as an emergent phenomenon

Conversely it allows to geometrize quantum field theories (“it from qubit”)

Prove the duality, for example in the canonical case
N=4 SU(N) $\cong$ IIB string theory in $AdS_5 x S^5$

Can holography work for asymptotically flat or de Sitter gravity?

thank you very much
for your attention