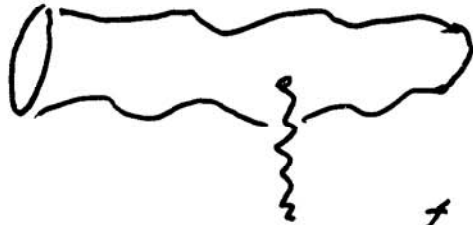


EMERGENT QUANTUM GRAVITY?

WEINBERG WITTEN THEOREM - HOW DOES STRINGS THEORY GET AROUND IT?



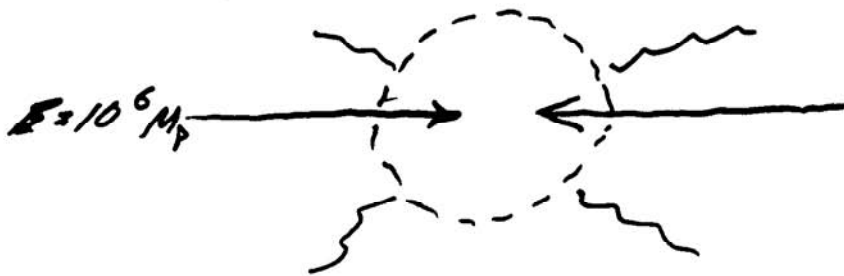
$$X = \sum_n \frac{a_n^\dagger e^{in\sigma}}{\sqrt{n}} + \frac{a_n e^{-in\sigma}}{\sqrt{n}}$$

$$\langle e^{iPX} \rangle = e^{-P^2 \langle X^2 \rangle}$$

$$\langle X^2 \rangle = \sum_{n=1}^{\infty} \frac{1}{n} = \log \infty$$

UV/IR AND FIRST HINT OF HOLOGRAPHIC PRINCIPLE

ENDLESS REDUCTIONISM (SOFT EMERGENCE)



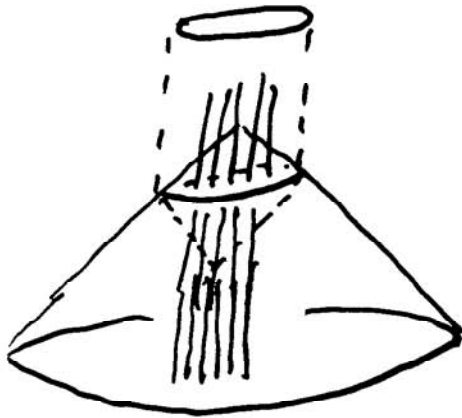
$$T = \frac{\hbar}{8\pi M G}$$



THE HOLOGRAPHIC PRINCIPLE

4

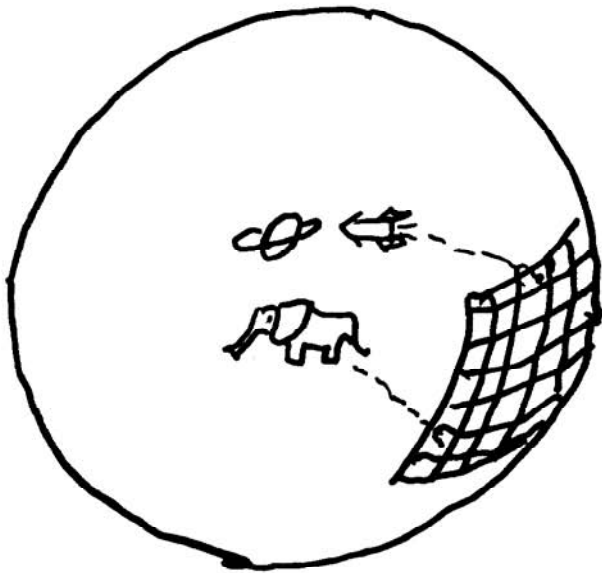
L.S.



2nd Law

$$S < A/4MG\hbar$$

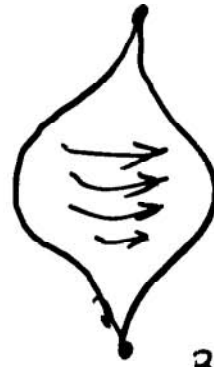
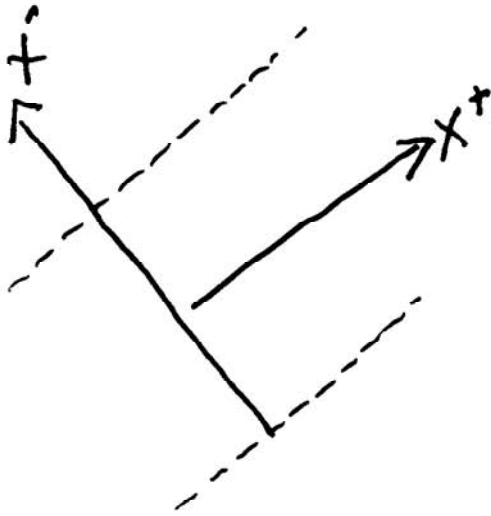
$$S_{\text{MAX}} = \frac{\text{Area}}{4G\hbar}$$



ALL INFORMATION IN A REGION \mathcal{V}
CAN BE COMPLETELY DESCRIBED BY
A THEORY LIVING ON THE BOUNDARY
OF \mathcal{V}

WITH AT MOST, 1 BIT/PLANCK AREA

2 HOLOGRAPHIC THEORIES 11-DIMENSIONAL SUPERGRAVITY



BOUNDARY = POINT

2 FSS MATRIX THEORY



$X_i = N \times N$ MATRIX, $i = 1, \dots, 9$

$$\mathcal{L} = \text{Tr} X_i \dot{X}_i - [X_i X_j]^2 + \text{FERMIONS}$$

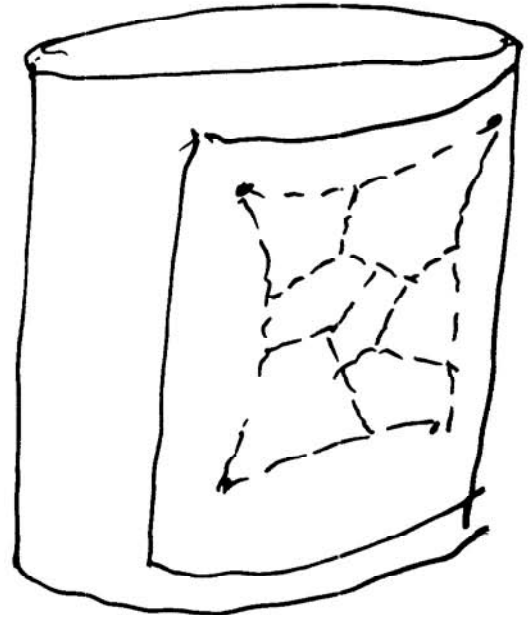
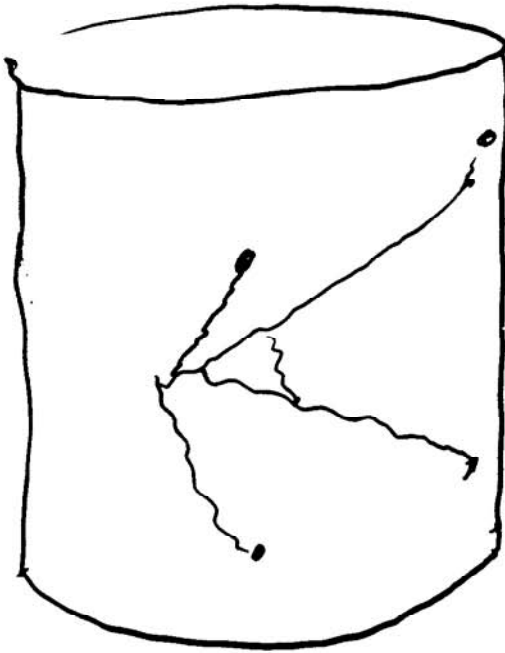
DECOMPACTIFICATION: $N \rightarrow \infty$

GRAVITONS, MEMBRANES, BLACK HOLES
ALL IDENTIFIED.

D. OF F. VERY SPARSE

AdS/CFT

MALDACENA



GRAVITY + METTER
IN BULK (STRING THEORY)

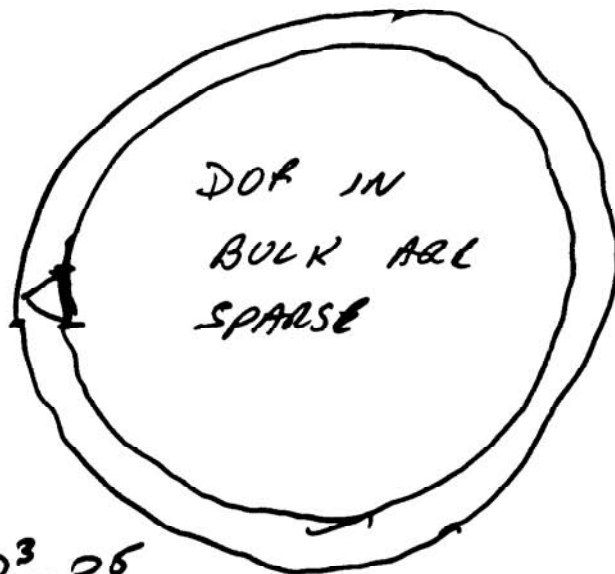
SU(N) GAUGE
THEORY WITH
4 SUPERSYMMETRY

AdS₅ × S⁵

$$\text{AREA} = \infty$$

$$N_{\text{DOF}} = \infty$$

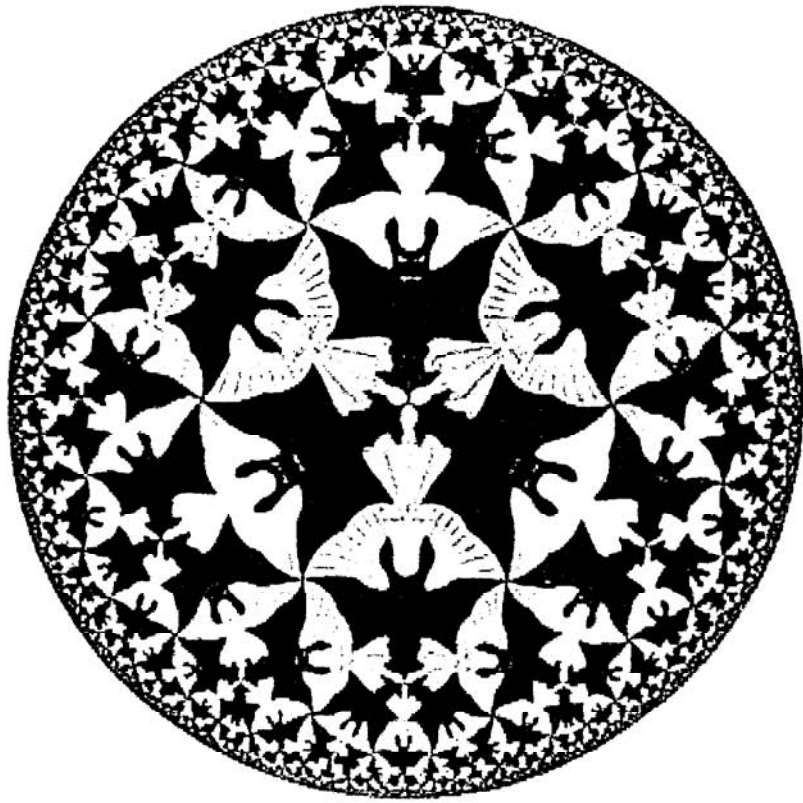
$$\frac{R}{\ell_p} = N^{1/4}$$



$$\text{AREA} = R^3 \times R^5$$

$$N_{\text{DOF}} \approx N^2$$

$$\left[N_{\text{DOF}} / \text{AREA} = \frac{1}{\ell_p^8} \right]$$



EMERGENT 4-D GRAVITY FROM
CONVENTIONAL 4-D CONDENSED MATTER ?

NO TOO MANY DOF

EMERGENT HOLOGRAPHIC THEORY.

ABSOLUTELY.

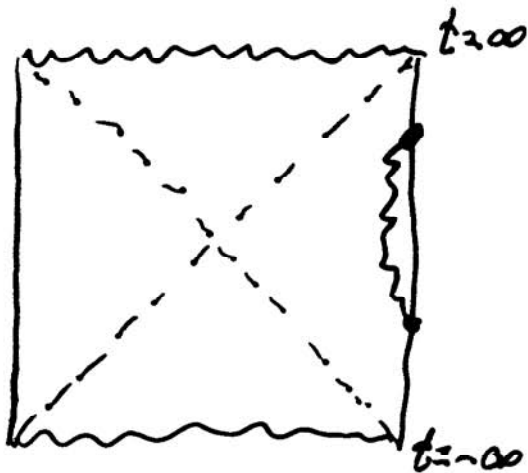
EVERY CFT ON BOUNDARY
IS A GRAVITY THEORY IN BULK.

THE ONLY QUESTION IS HOW
TO MAKE A LARGE MACROSCOPIC
SPACE ($R \rightarrow \infty$) EMERGE.

IN BEST KNOWN VERSIONS

$N \rightarrow \infty$

INFORMATION CONSERVATION



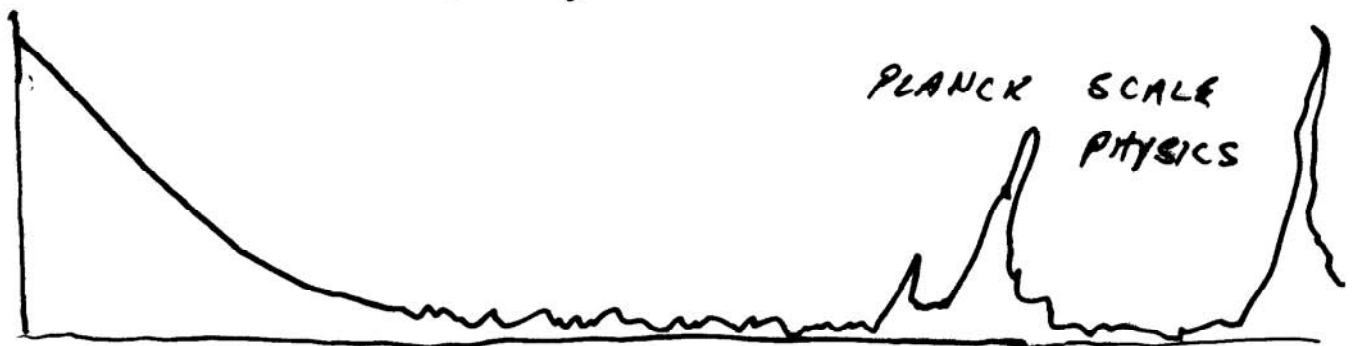
QFT IN BACKGROUND
AS WELL AS UNRUH
DUMB HOLE:

$$\langle \phi(0) \phi(t) \rangle \rightarrow e^{-ct}$$

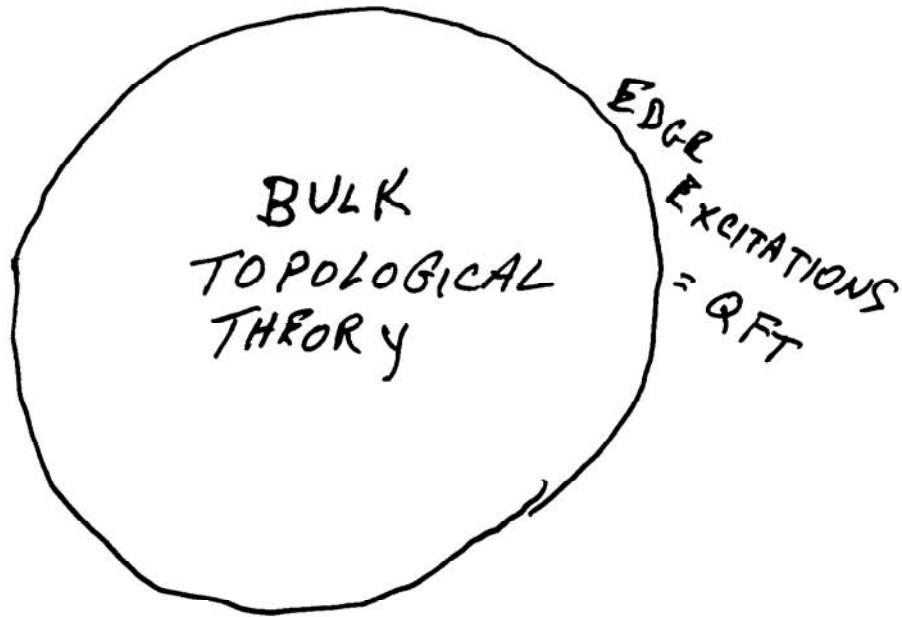
FINITE ENTROPY IMPLIES DISCRETE
SPECTRUM. ALL LEVELS HAVE FINITE
SPACING.

$$\langle \phi(0) \phi(t) \rangle = \sum C_n e^{i \nu t}$$

ALL SUCH FUNCTIONS ARE
QUASI PERIODIC.



WHAT ABOUT LOCALITY ?



IS THERE A BULK TOP THEORY,
(MAYBE SOME SORT OF VERY
FANCY QM SYSTEM) WHOSE
EDGE STATES DEFINE
 $\mathcal{N}=4$ $SU(N)$ GAUGE
THEORY ?

↳ HOOPER'S VIEW IS VERY DIFFERENT
CLASSICAL BULK THEORY.

LOCAL BULK ALTERNATIVES

THEORY WITH ∞ GAUGE SYMMETRY.

SO MUCH GAUGE SYMMETRY THAT WHEN
COMPLETELY FIXED THE ONLY DOF
ARE AT BOUNDARY.

BULK THEORY AT BEST AN
APPROXIMATE CONCEPT

BULK THEORY COMPLETELY
CLASSICAL — DETERMINISTIC. SEE
L'HOFT