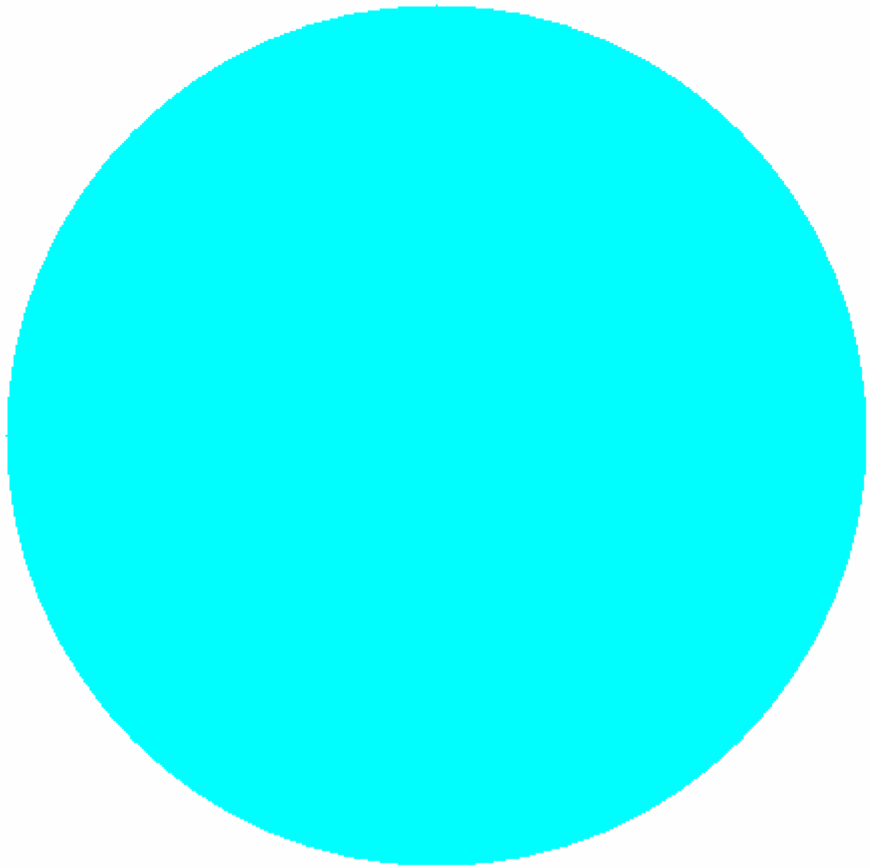
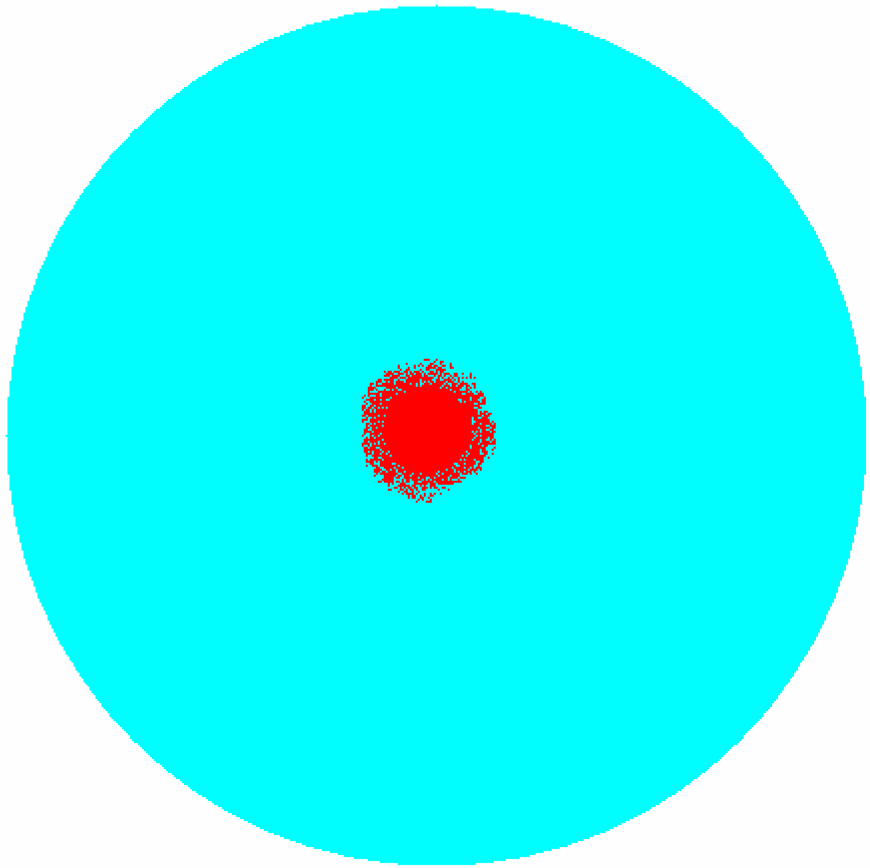
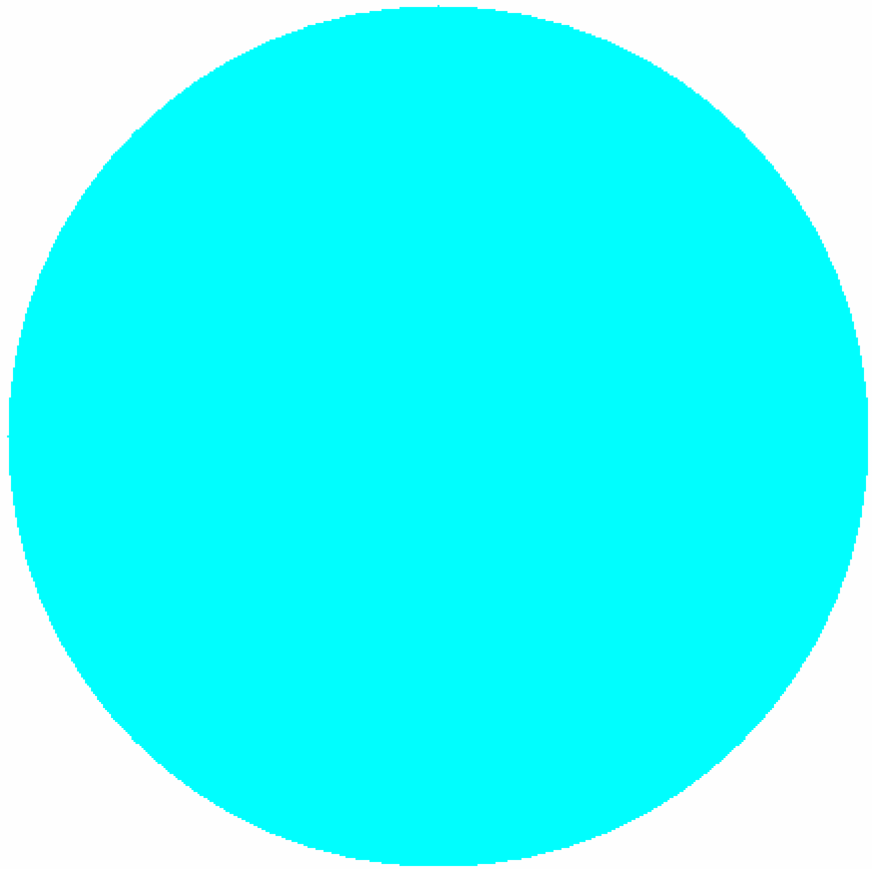
Asymptotic Coldness







Current Logic of String Theory

- Pick an *asymptotically cold* background.
- Calculate the low energy S-matrix (or boundary correlators).
- Find a semiclassical action that gives the same amplitudes.
- Use the semiclassical action (perhaps non-perturbatively) to construct low energy bulk physics.

Background Independence?

Bundling different asymptotically cold backgrounds into a single quantum system (Hilbert Space) does not appear to make sense.

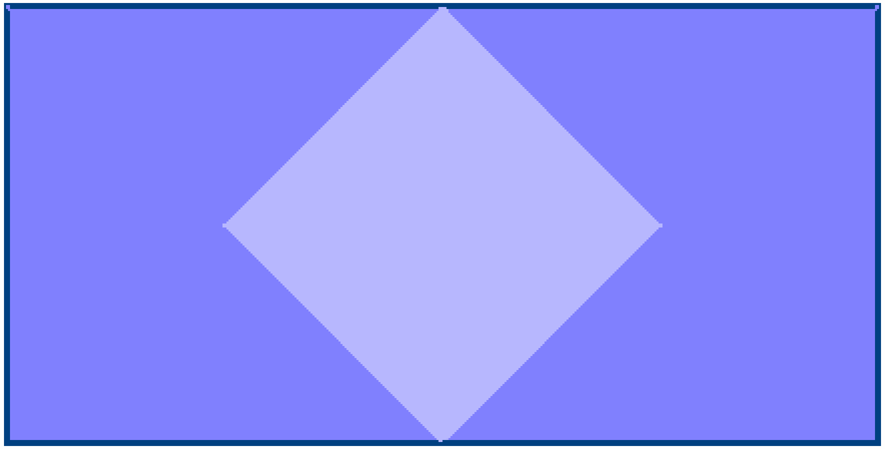
This is a **BIG** problem:

Real cosmology is

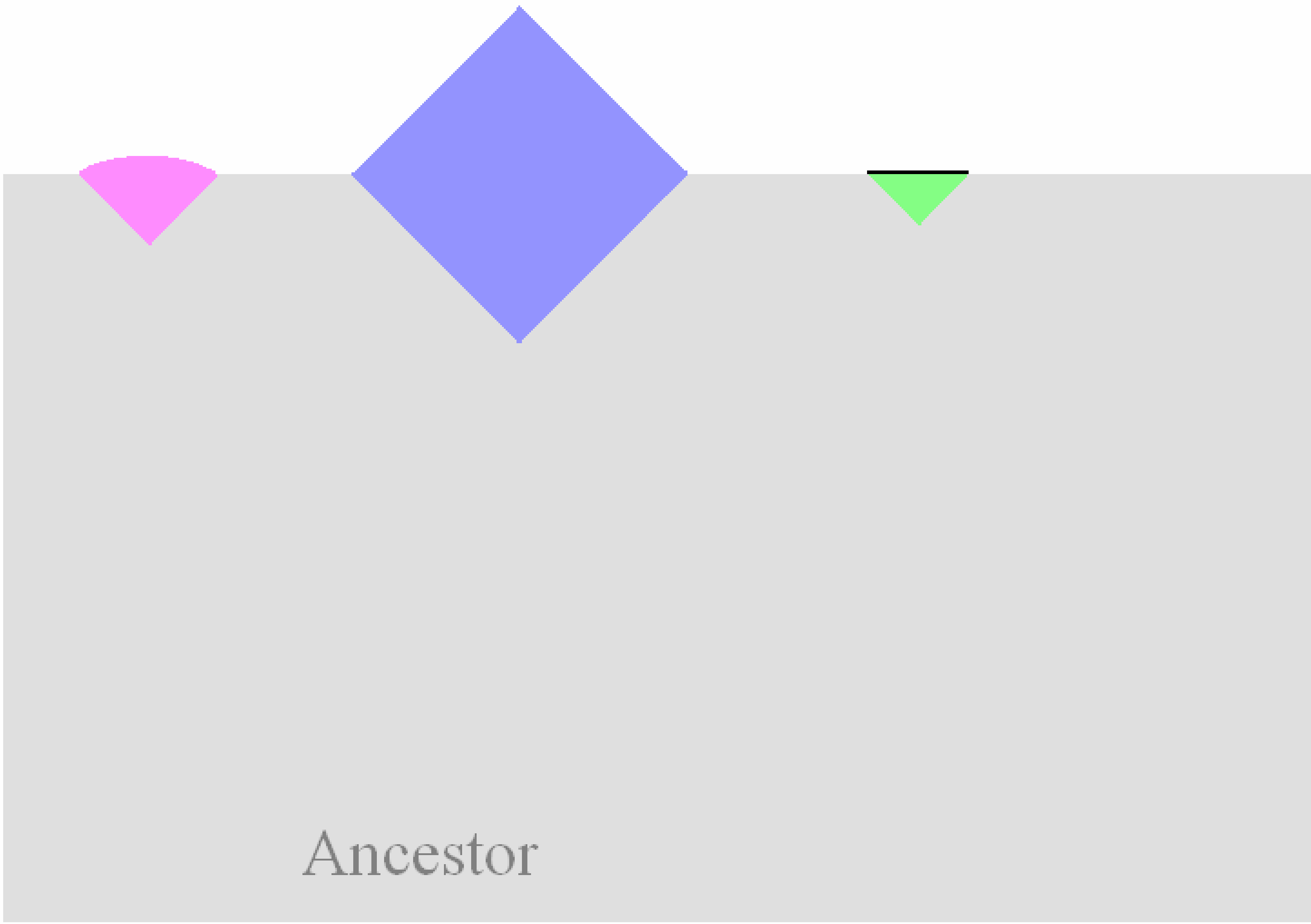
NOT

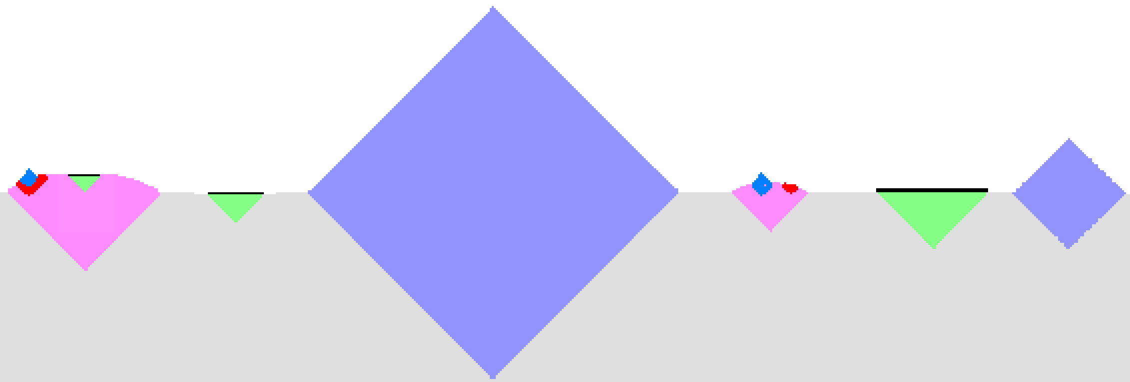
asymptotically cold.

De Sitter space is asymptotically warm.



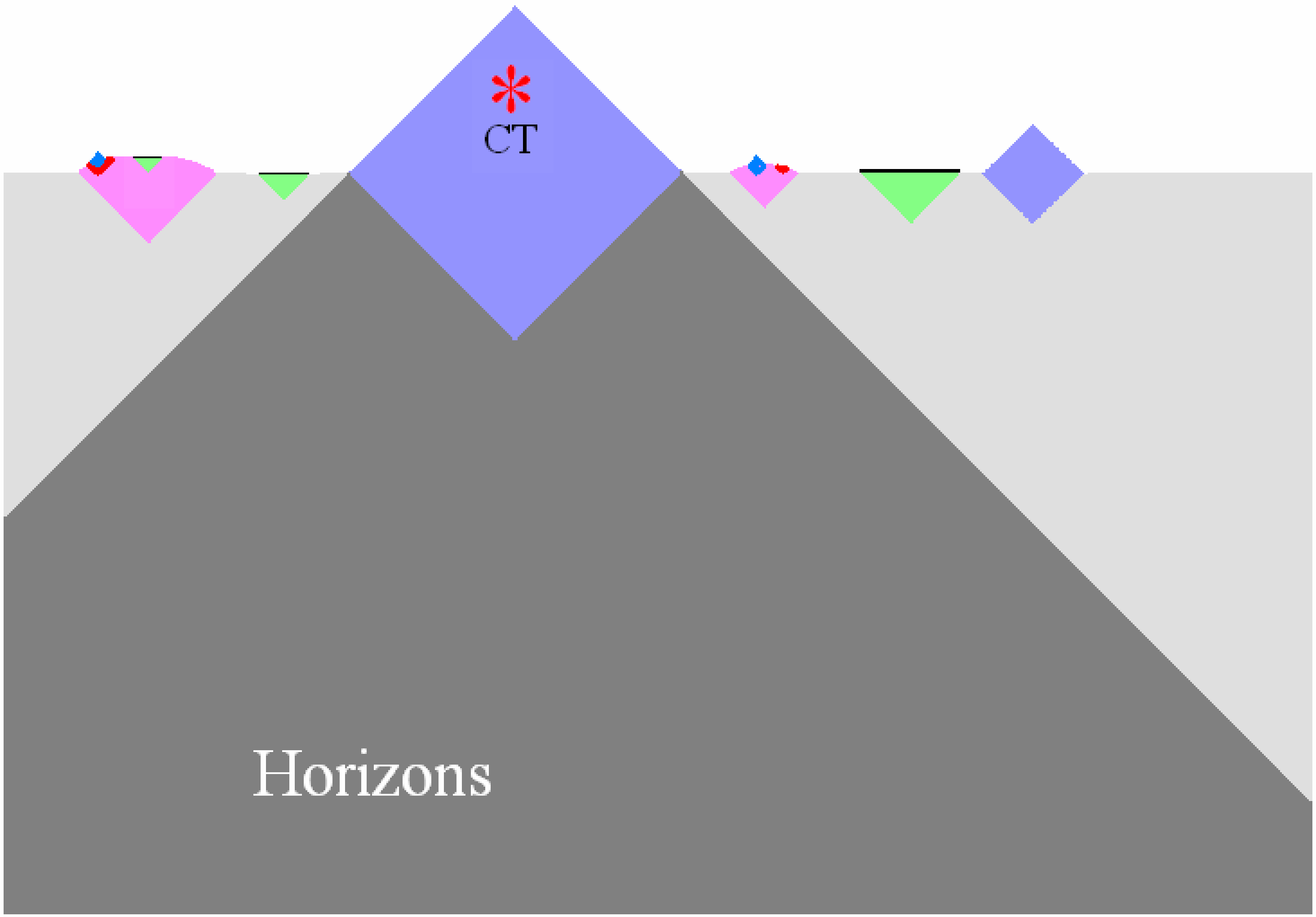
Finite Hilbert space for every diamond. Banks, Fischler


Ancestor



Ancestor

Quantum description
??????????????????



CT
Horizons

Do we have a set of principles that we can rely on?

No.

Do we need them?

Yes.

Do we have a set of principles that we can rely on?

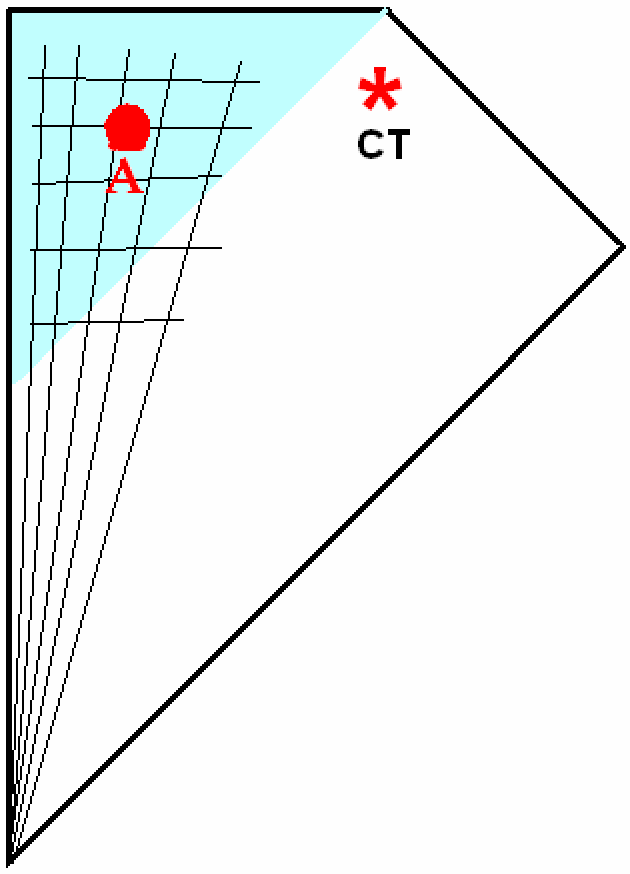
No.

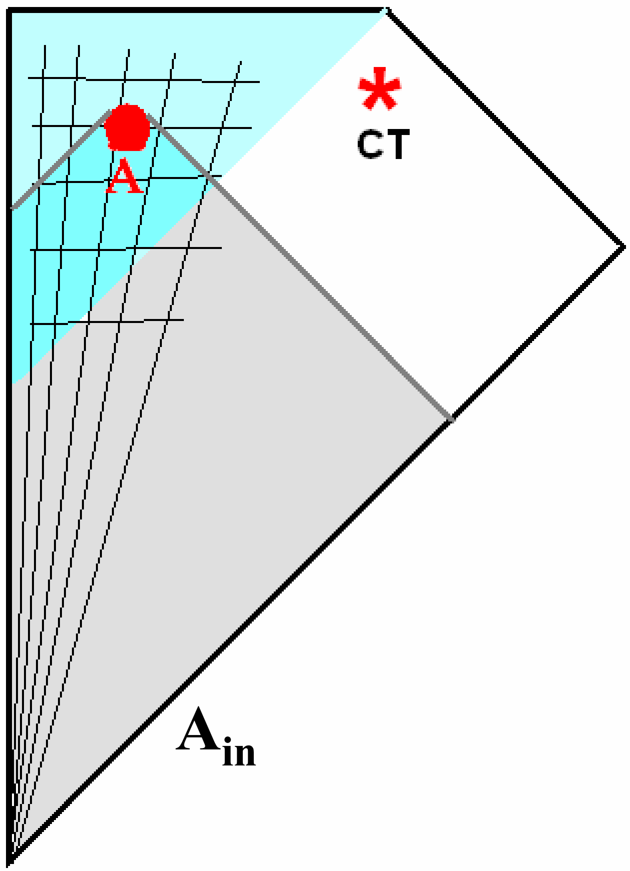
Do we need them?

Yes. The measure problem

Can the CT see beyond the horizon?

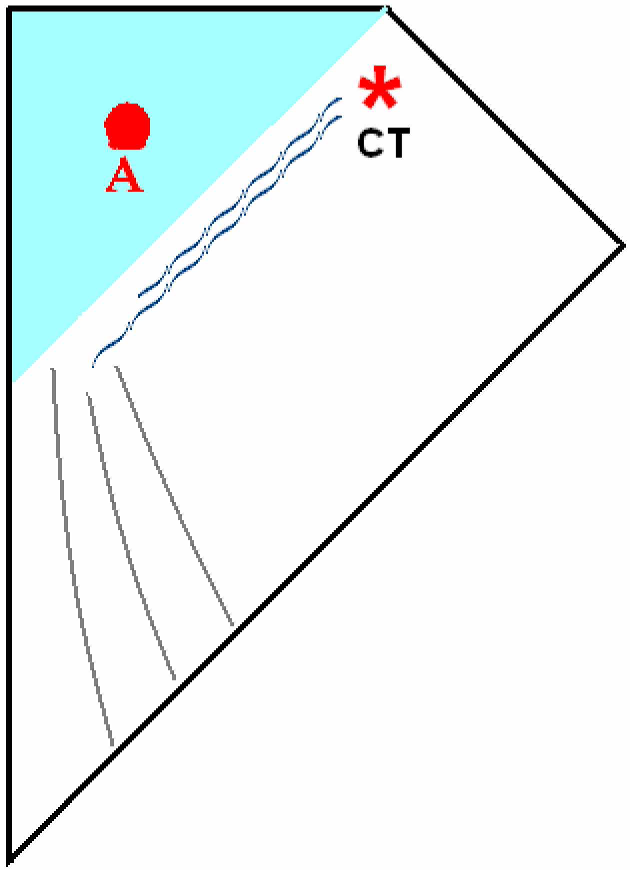
Lesson from black holes





Solve equations of motion in freely falling frame and express A in terms of operators in the remote past.

$$A_{in} = U^{\dagger} A\, U$$



Using the S-matrix we can run the operator to the remote future

$A_{out} = S\ Ain\ S^{\dagger}$

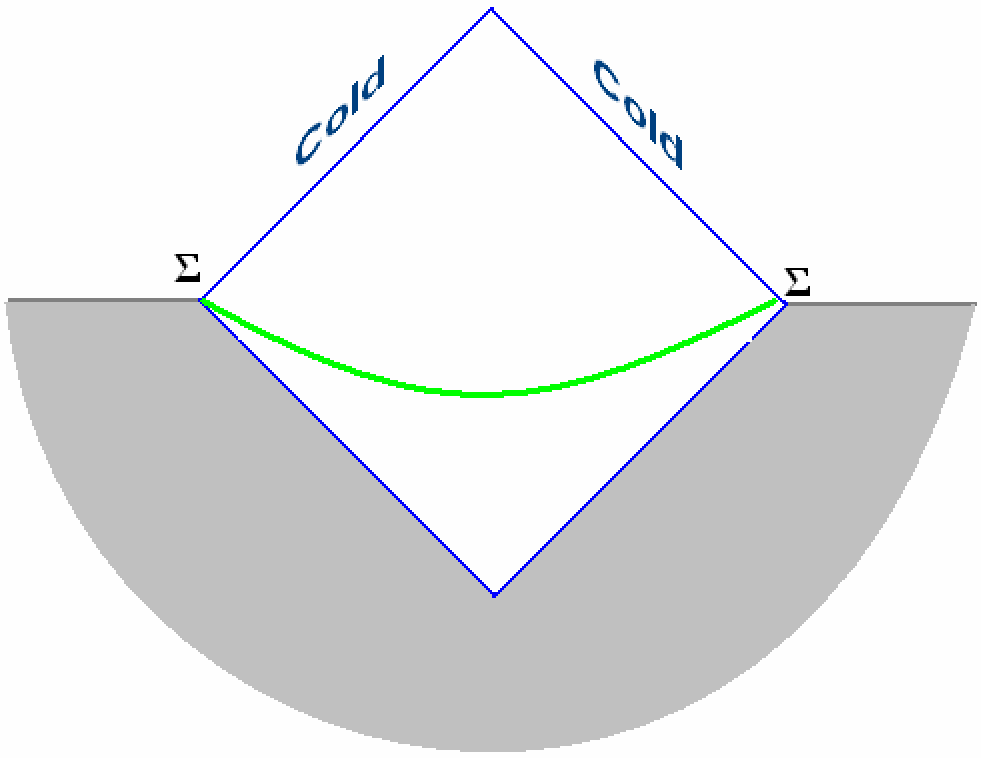
$= (S\ U^{\dagger})\ Ain\ (U\ S^{\dagger})$

A_{out} is an operator in the outgoing space of states that has the same statistics as the behind-the-horizon operator A.

That is the meaning of Black Hole Complementarity: Conjugation by $(S\ U^{\dagger})$.

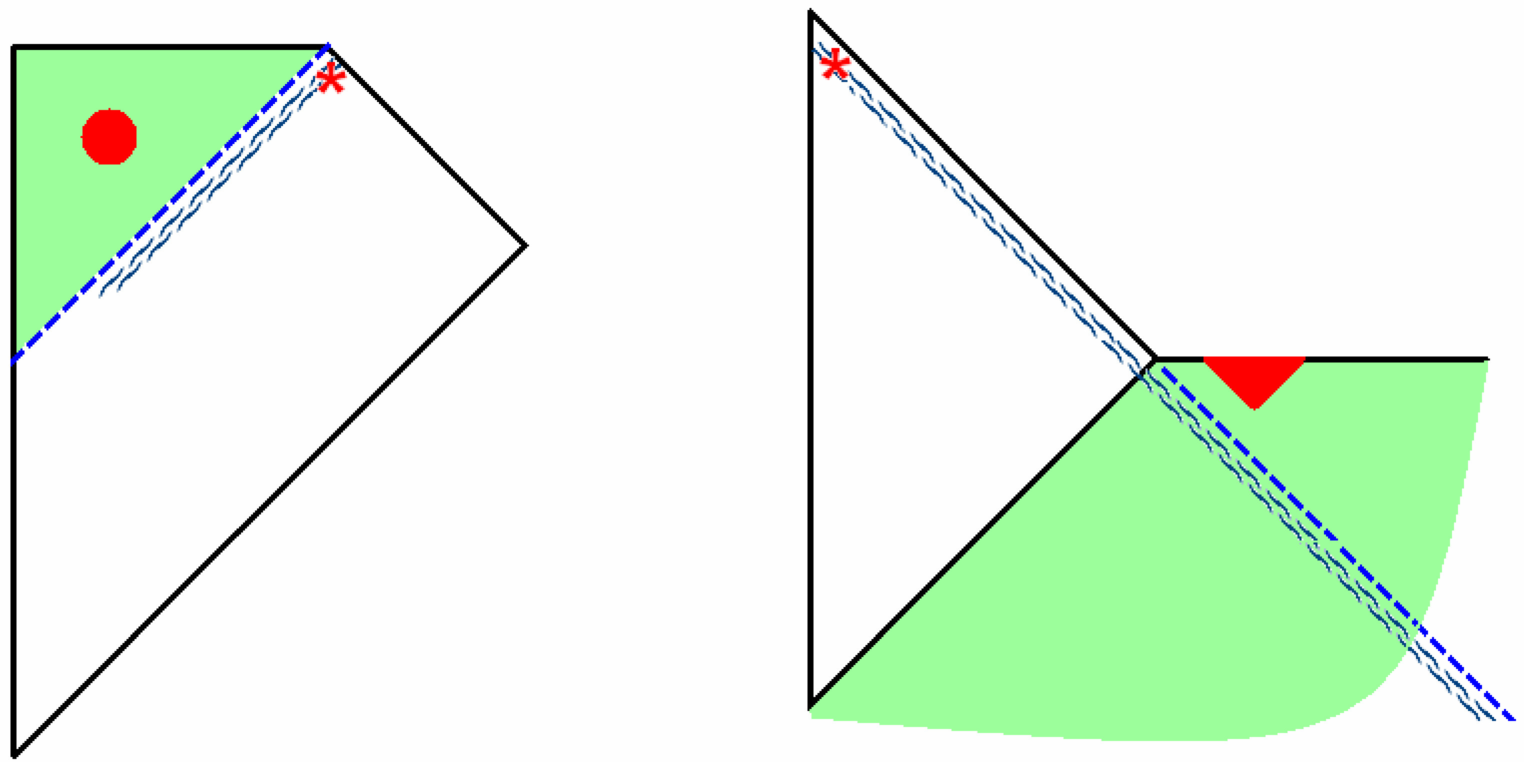
Transition to a “Hat”

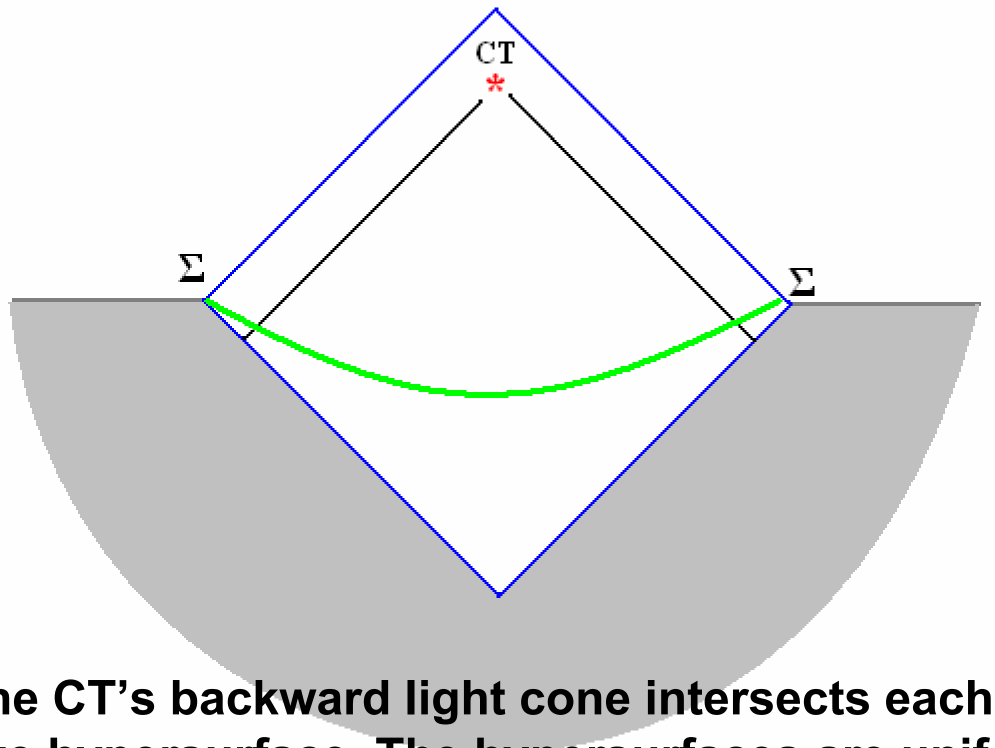
(supersymmetric bubble with $\Lambda=0$)



Asymptotically cold at T →∞ but not as R →∞

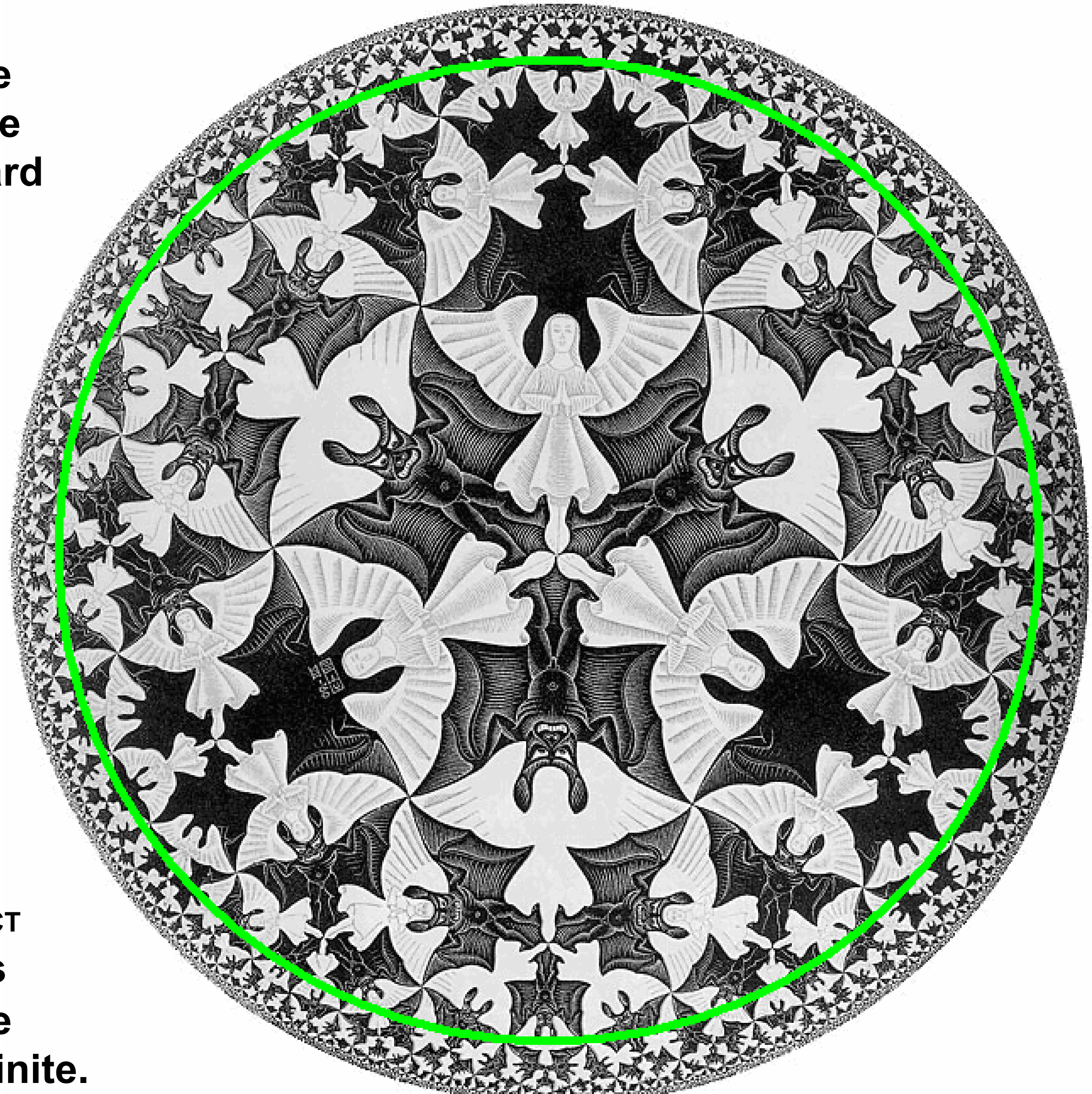
Hat Complementarity?





The CT's backward light cone intersects each space-like hypersurface. The hypersurfaces are uniformly negatively curved spaces.

Space-like hypersurface intersects the CT's backward light-cone.



In the limit $t_{CT} \rightarrow \infty$ the CT's Hilbert space becomes infinite.

Note, the geometry of a spatial slice is Euclidean ADS_3

Symmetry is O(3,1). On the boundary it is conformal symmetry .

Is there a CFT description of the Hat?

(and by complementarity, the global space?)

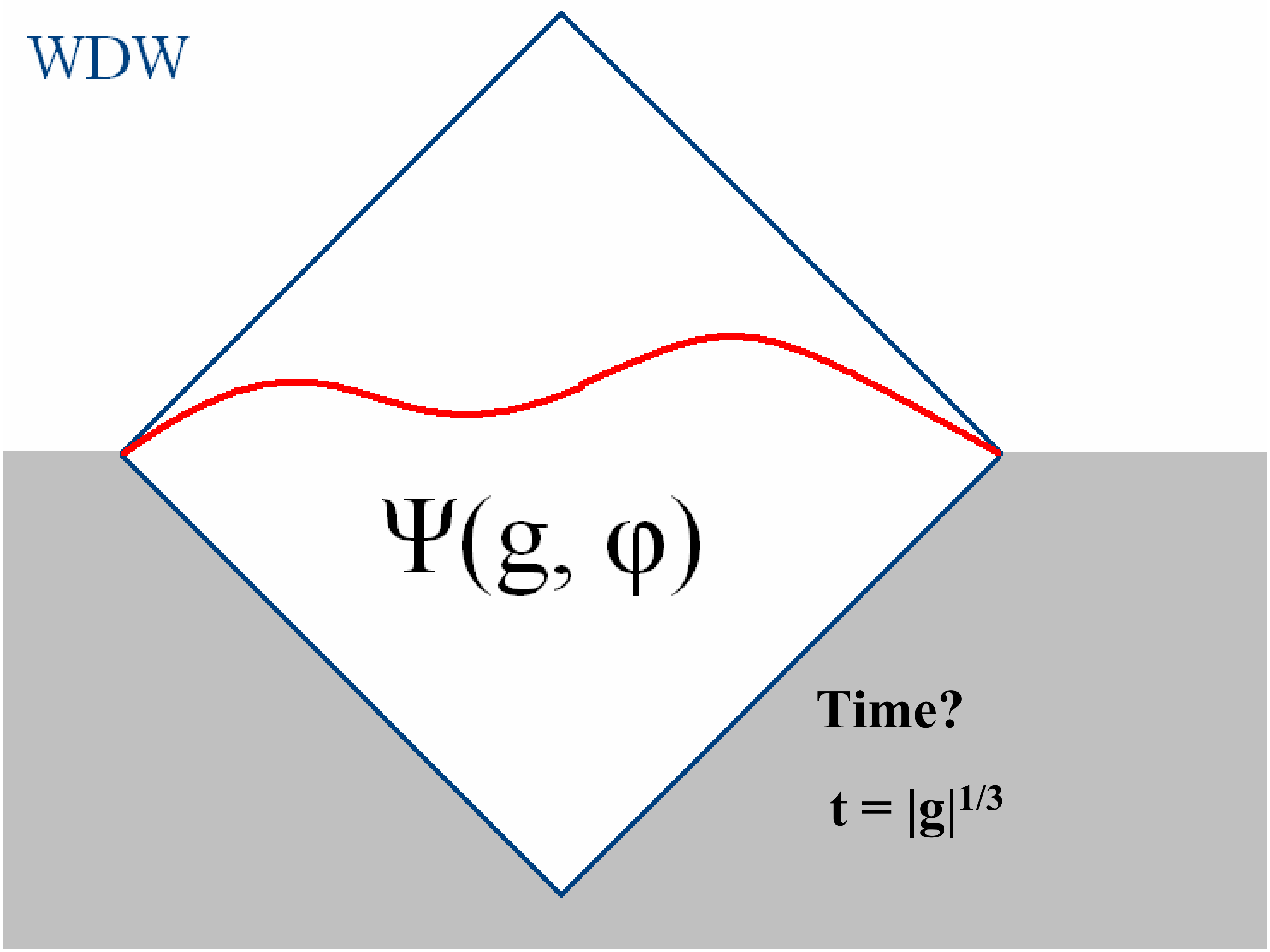
One way to get there is through Wheeler De Witt $\Psi(g, \varphi)$

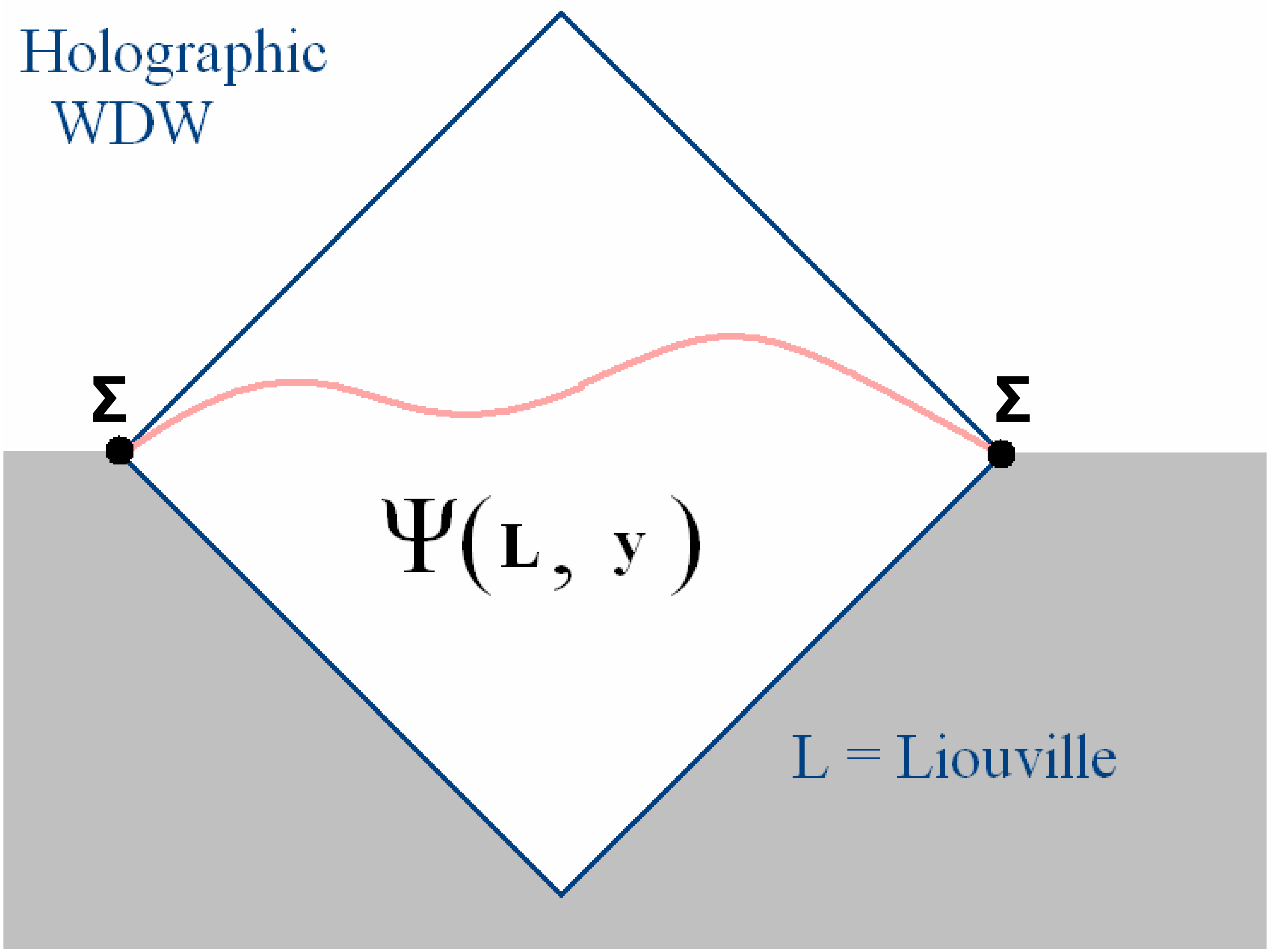
- Quantum Cosmology In (2+1)-Dimensions And (3+1)-Dimensions. T. Banks, W. Fischler, Leonard Susskind Nucl.Phys.B262:159,1985.

Time = Scale Factor

- T C P, Quantum Gravity, the Cosmological Constant and All That...

  Tom Banks, Nucl.Phys.B249:332,1985.


WDW
Ψ(g, φ)
Time?
t = |g|1/3


Holographic
WDW
Σ
Σ
Ψ(L , y)
L = Liouville

We can define a boundary field theory in terms of Ψ.

$$\Psi^*(L, y)\,\Psi(L, y) = e^{-S(L,\, y)}$$

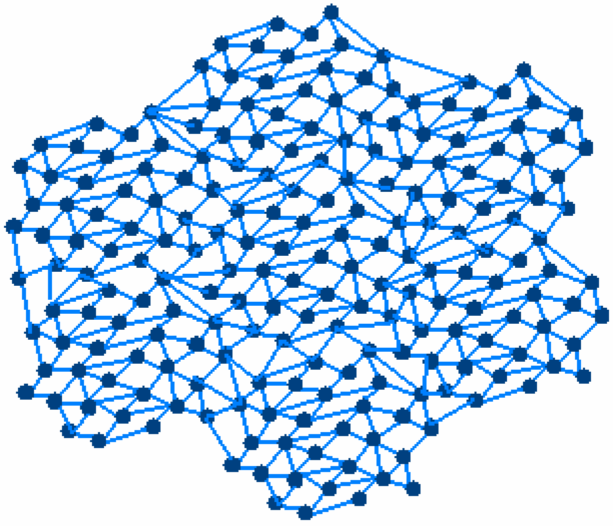
S is the action for a 2D Euclidean

quantum gravity system.

(Is it local? See FSSY hep-th/0606204)

Visualizing Liouville using "fishnet diagrams."

Lay the fishnet down on a background x-space so that it looks locally isotropic.

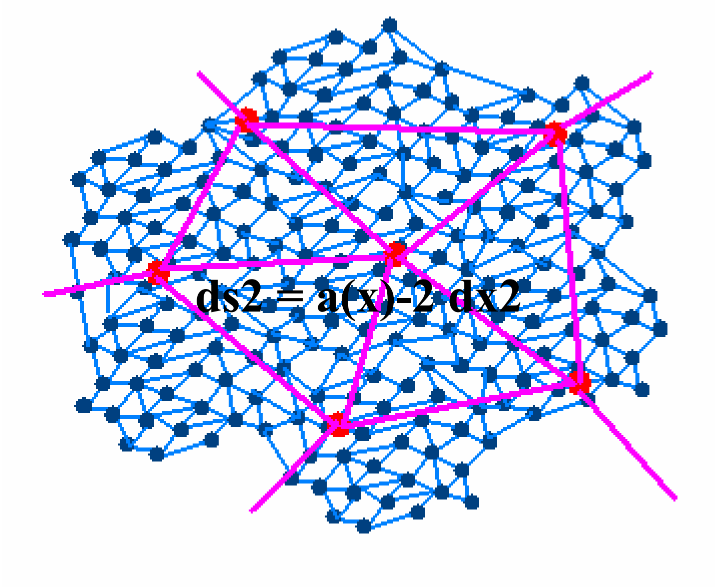


$ds^2 = a(x)^{-2}\, dx^2$

a(x) is the local lattice spacing

Superimpose a fixed reference grid with spacing δ >>a.
δ defines a reference metric on x-space.

$$ds^2_{ref} = \delta(x)^{-2}\, dx^2$$

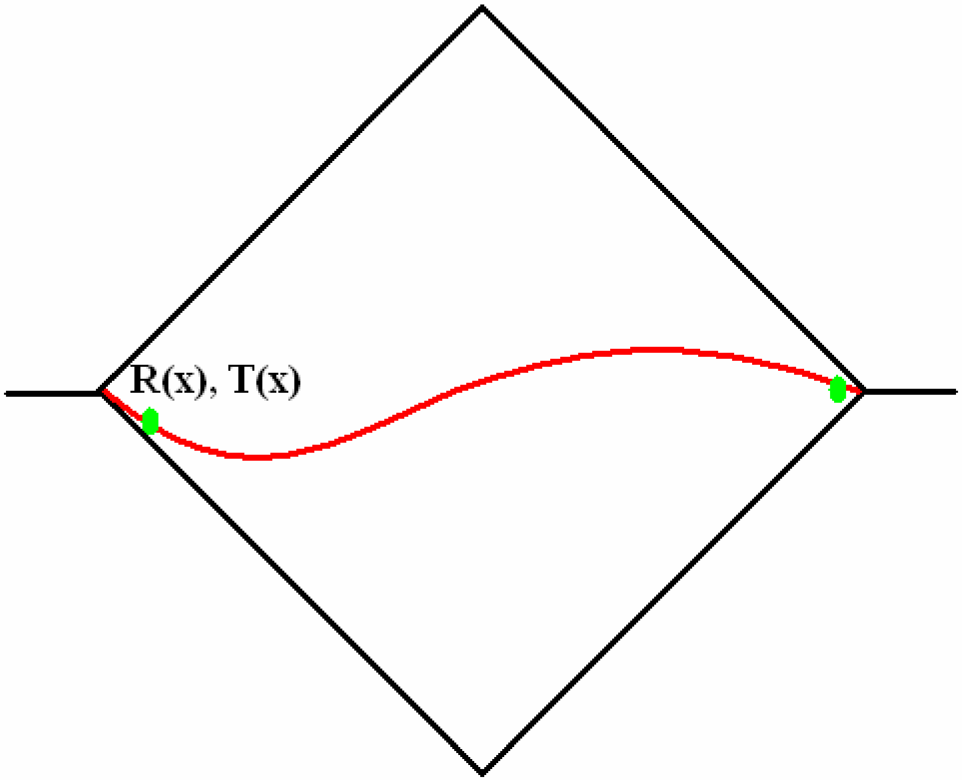


The Liouville field L is defined by $e^L = \delta(x)/a(x)$

$ds^2 = e^{2T} \sinh^2 R \; d\Omega_2^{\,2}$

$\rightarrow e^{2T(x)} e^{2R(x)} \; d\Omega_2^{\,2}$

FRW/CFT



$e^{2R(x)} \; d\Omega_2^{\,2}$ is the reference metric as in ADS/CFT

T(x) is the Liouville field, L. The reason the Liouville field is dynamical is asymptotic warmness.

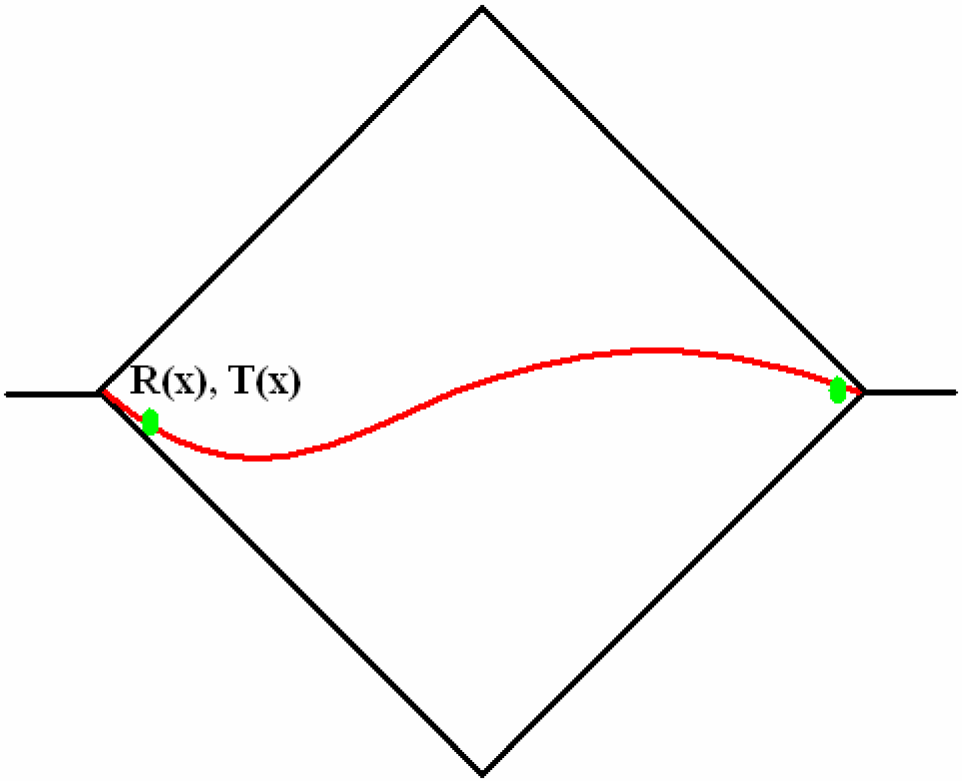
In the limit $T^+ \rightarrow \infty$ asymptotic coldness of the hat means that L decouples leaving a CFT.

FRW/CFT

$R(x) = -\log \delta(x)$

$T(x) = \log(a(x)/\ \delta(x)) = L(x)$

Bare cutoff = $a(x) = e^{-(R(x)+T(x))}$



What do we know about the CFT coupled to Liouville?

C_{matter} = entropy of ancestor (>>26) FSSY

$C_{Liouville} = - C_{matter}$ (time-like Liouville)

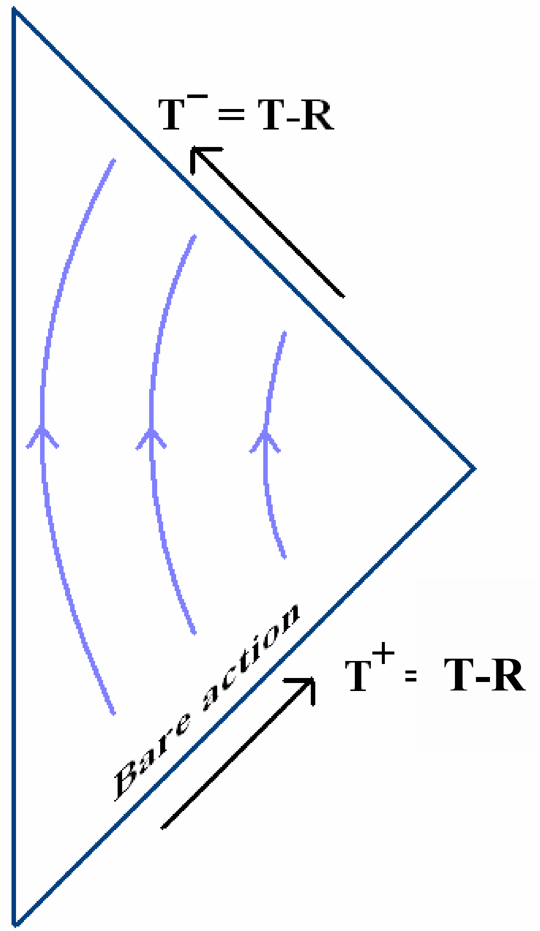
2-dim λ? (Lambda controls the density of the fishnet.)

Liouville with negative C and positive λ has a stationary point in the action describing a 2-sphere.

Carefully comparing with the 2-sphere at R in FRW geometry we find

$$\lambda = e^{-2L}$$
$$= e^{-2T}$$

The 2-D cosmological constant is not a constant. It is a Lagrange multiplier that scans time in the FRW patch.

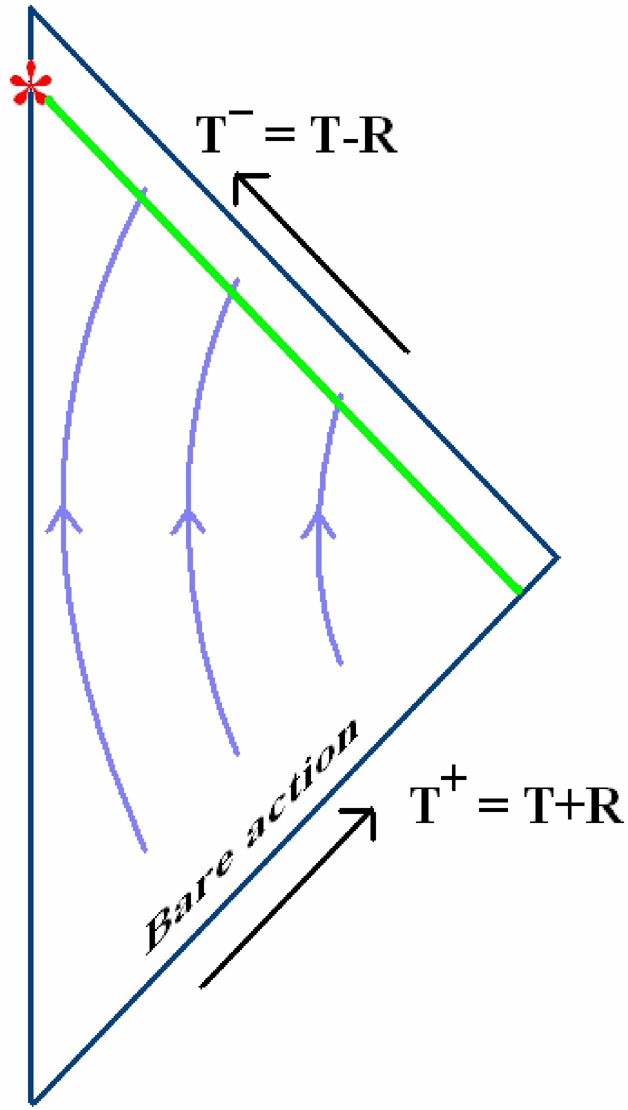


T = Liouville

R = RG scale

Flow from a bare action to a fixed point

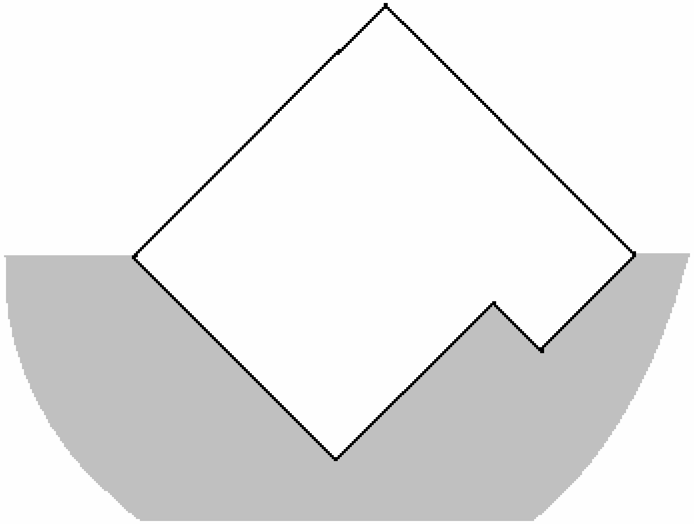
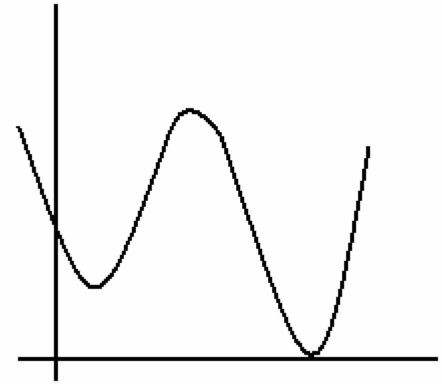
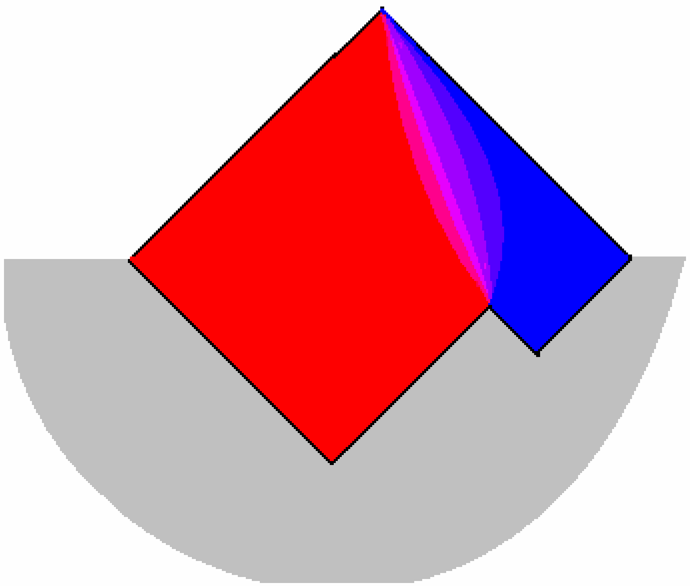
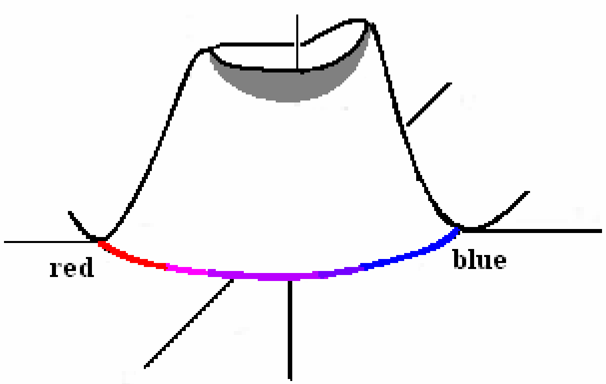
At the FP Liouville decouples from the CFT (asymptotic coldness)

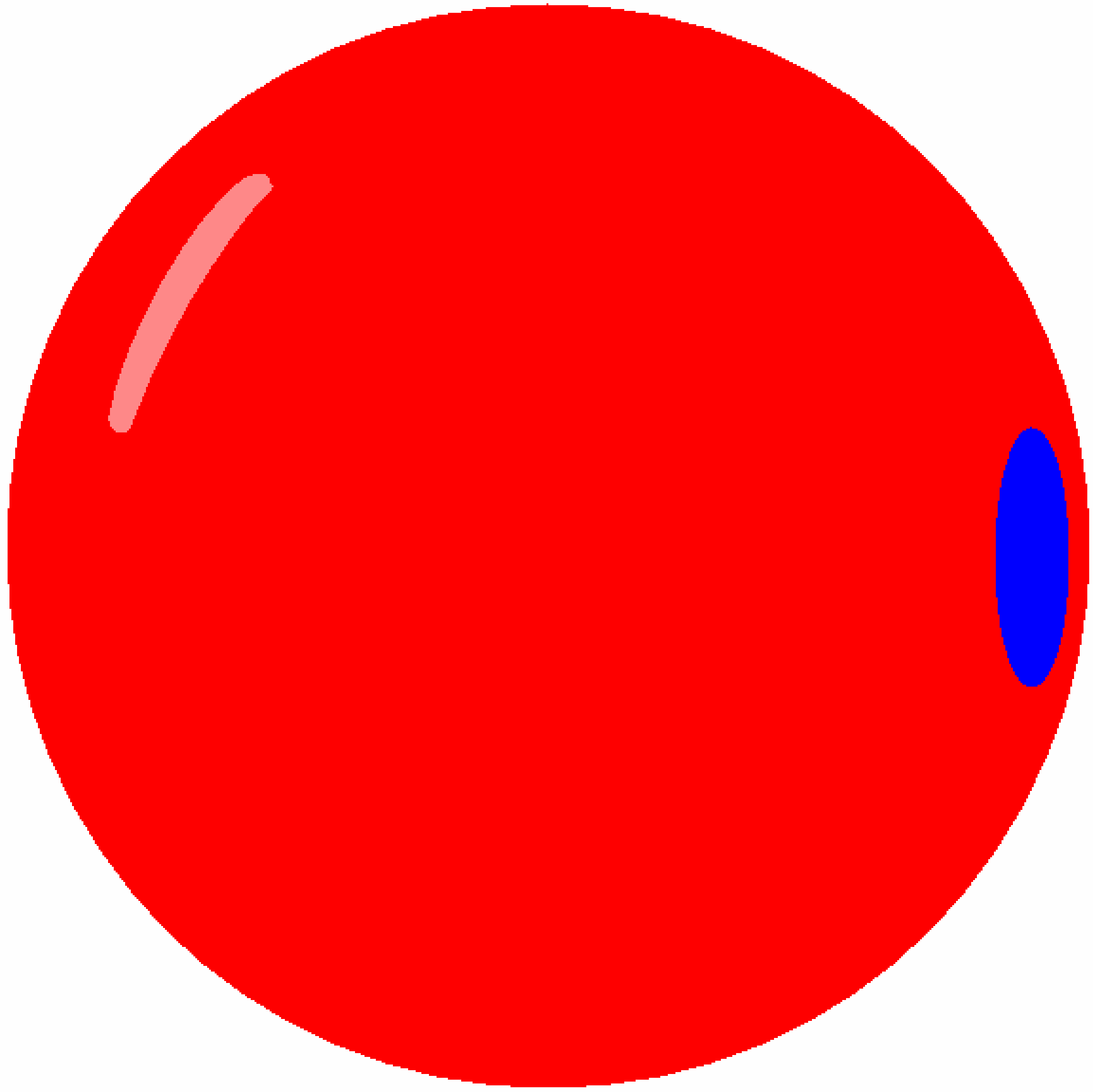


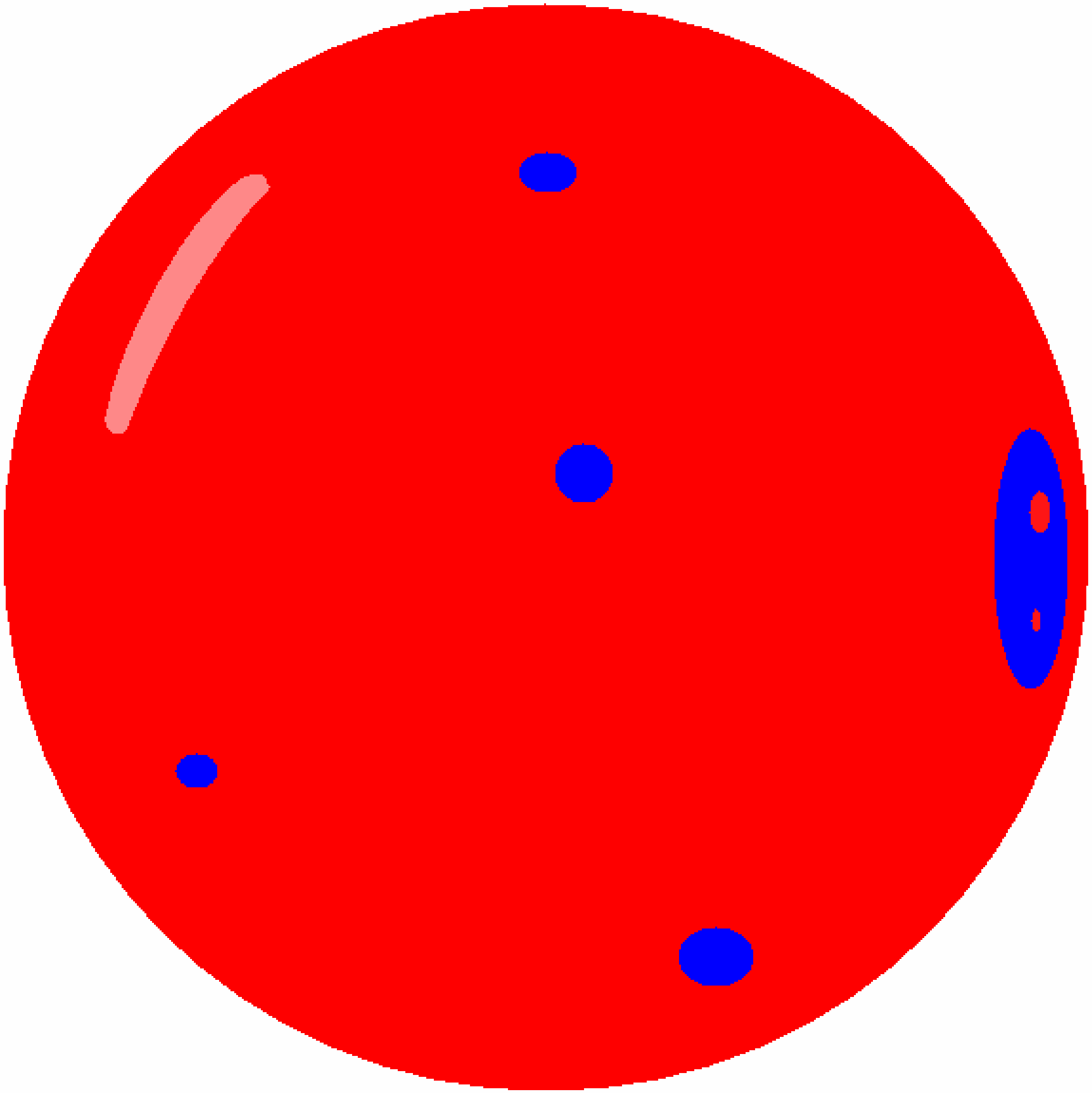
T = Liouville

R = RG scale

Flow from a bare action to a fixed point





red
blue





Thank you Tom and Willy for the many years of friendship and collaboration, so much of which went into what I spoke about today.

Lenny