Spenta Fest

ICTS 13th January 2017

TOY MODEL D=1?

March, 1980 EFI 80/15

80-6-4

N=∞ PHASE TRANSITION IN A CLASS OF EXACTLY SOLUBLE MODEL LATTICE GAUGE THEORIES*

Spenta R. Wadia

The Enrico Fermi Institute

University of Chicago

Chicago, Illinois 60637

D=4 HAWKING PAGE TRANSITION?

On Singularities and Holography For Spenta: A Toy Model in the big picture

Eliezer Rabinovici
Racah Institute of Physics Hebrew University
Jerusalem, Israel/ IHES-France

Works with Jose F Barbon - Madrid


J'ai souhaite être parmi
et avec ceux d'aujourd'hui
à offrir à Garnier un hommage
qui resterait chez lui
Marc Chagall

- **What do singularities reflect?**
- **Usually that something was missed out(QM, massless degrees of freedom).**
- **GR has horizons. What are they hiding? Are singularities different.**
- **Time like singularities- String theory.**
- **Space like singularities**

Singularities:
Can one live with them?
Can they heal?
What can one learn about them?

Are they simple or complicated?
Some are “simple”

What are you trying to say:

Two very different looking boundary theories

Same BULK SINGULARITY

Complementary- Dual

d=1 Toy Model

Introducing the bare "TOY" model

$$H = P^2 / 2m + \lambda/2\, x^n$$

$$H = P^2/2m + \lambda/2x^n$$

$$H = 1/2\ \varepsilon(\lambda,m)(p^2 + x^n)$$

$$H = -\frac{1}{2m}\frac{d^2}{dr^2} + \frac{N^2}{8mr^2} - \frac{e^2}{r} \qquad (6)$$

If now we rescale the radial coordinate, defining $r = N^2R$, then in terms of R, H becomes

$$H = \frac{1}{N^2}\left(-\frac{1}{2mN^2}\frac{d^2}{dR^2} + \frac{1}{8R^2m} - \frac{e^2}{R}\right) \qquad (7)$$

Apart from the overall factor of $1/N^2$, which only determines the overall scale of energy or time, the only N in this Hamiltonian is the N^2 that appears with the mass in the kinetic energy term. The Hamiltonian (7) describes a particle with an effective mass $M_{eff} = mN^2$, moving in an effective potential

$$V_{eff} = \frac{1}{8R^2m} - \frac{e^2}{R} \qquad (8)$$

≠

$$H = P^2/2m + \lambda/2 x^n$$

$$H = 1/2\ \varepsilon(\lambda, m)(p^2 + x^n)$$

n is NOT -2

$\neq$

$$H = P^2/2m + \lambda/2x^n$$

$$H = 1/2\,(p^2 + \lambda x^{-2})$$

Conformal Quantum Mechanics

CONTEXT OF SPACE LIKE SINGULARITIES

Magic of String Theory

No concept* in Math remains unambiguous

Magic of String Theory

Metric

With extended objects

Large=Small

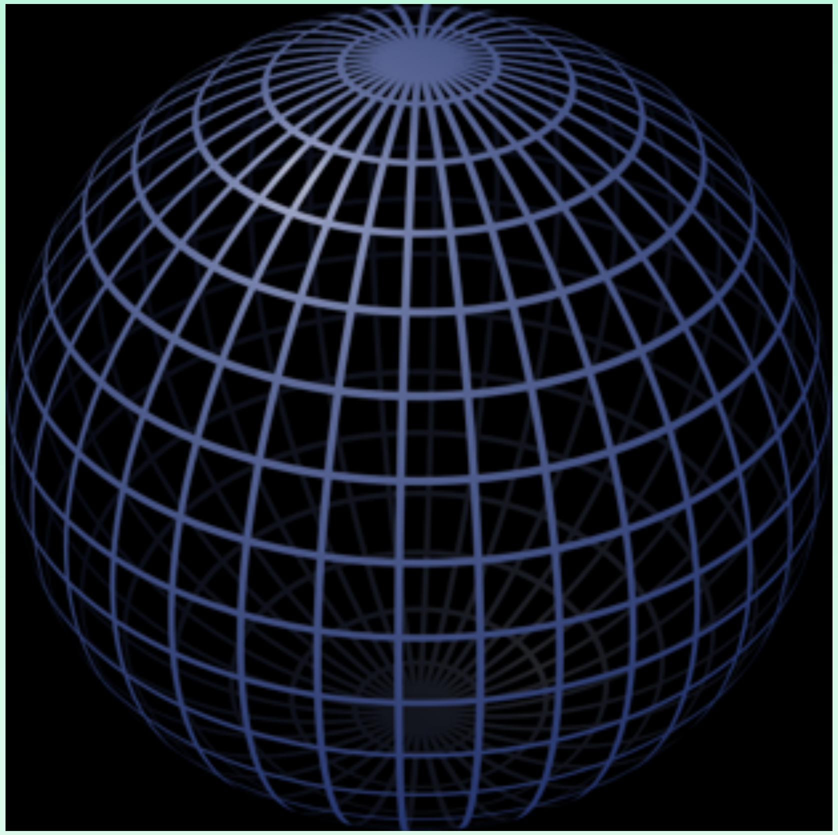
R"="1/R   T Duality

Magic of String Theory

Topology

With extended objects

Surface of a Sphere=Torus



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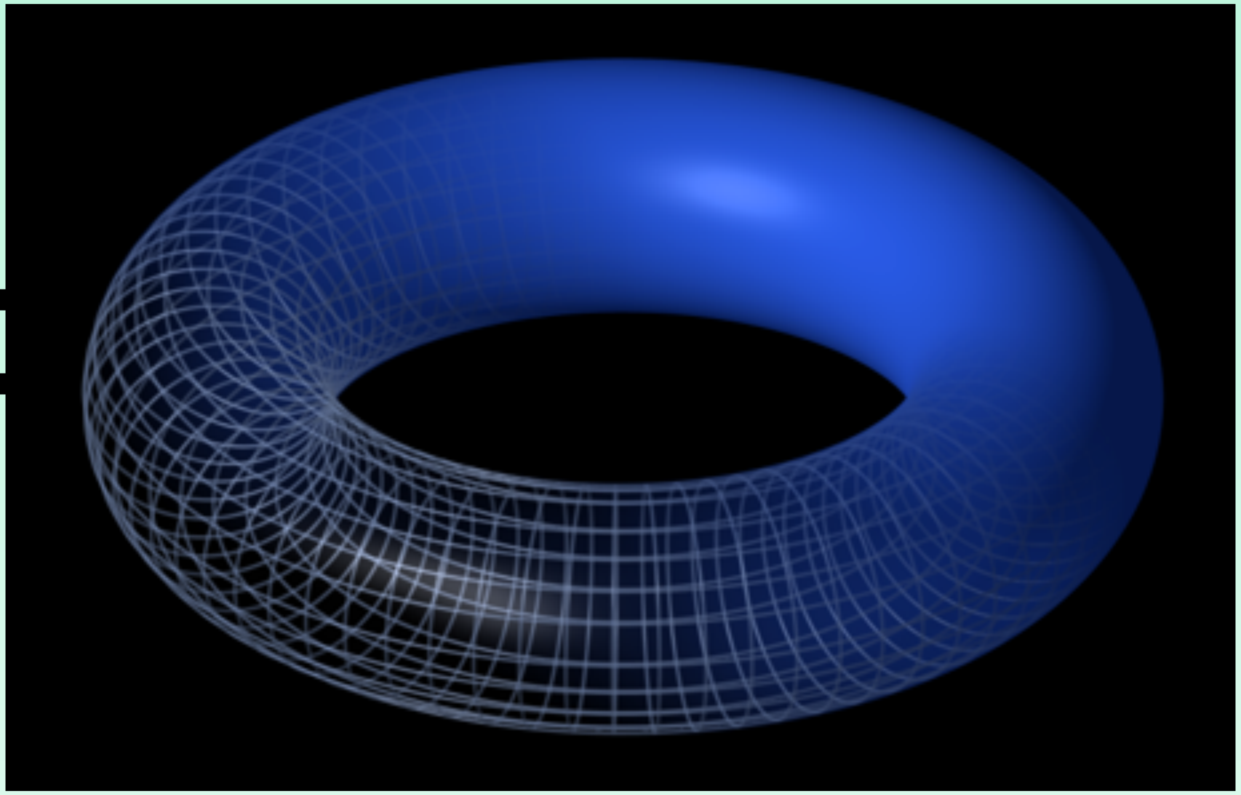
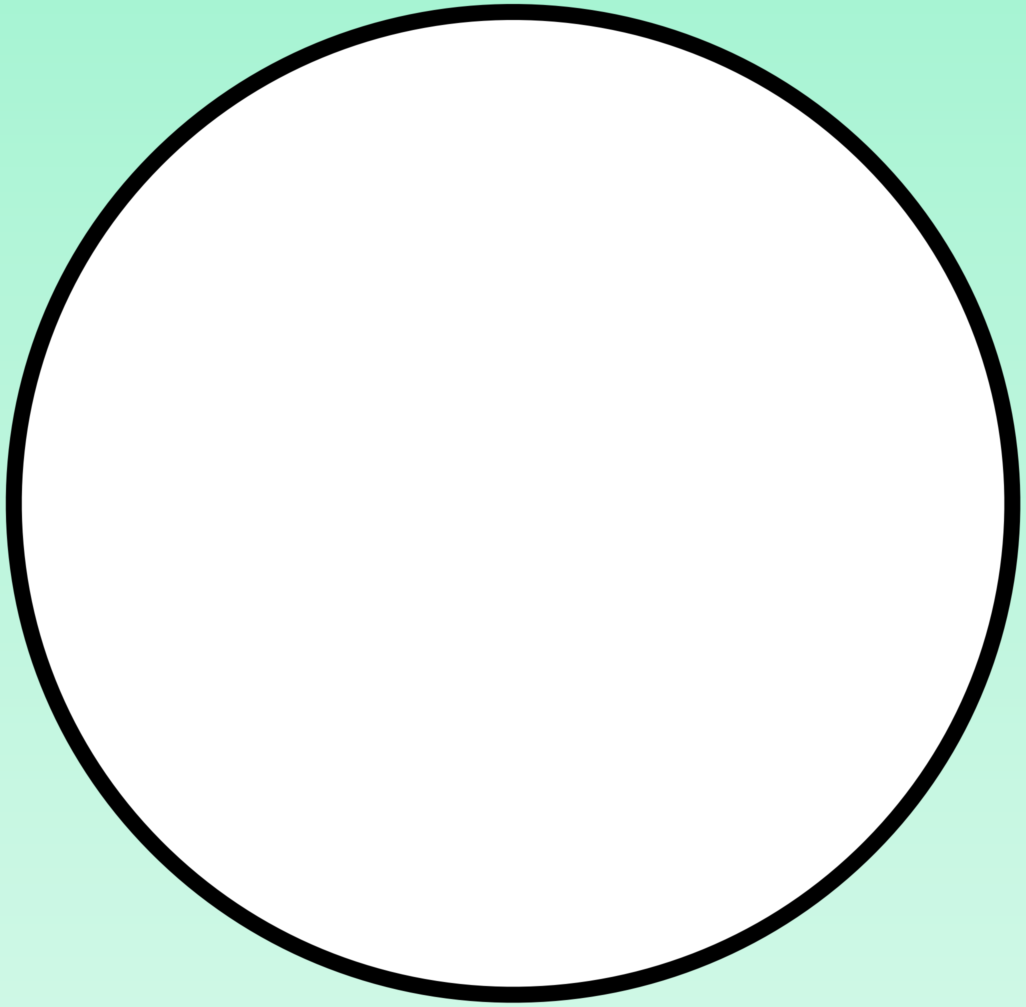


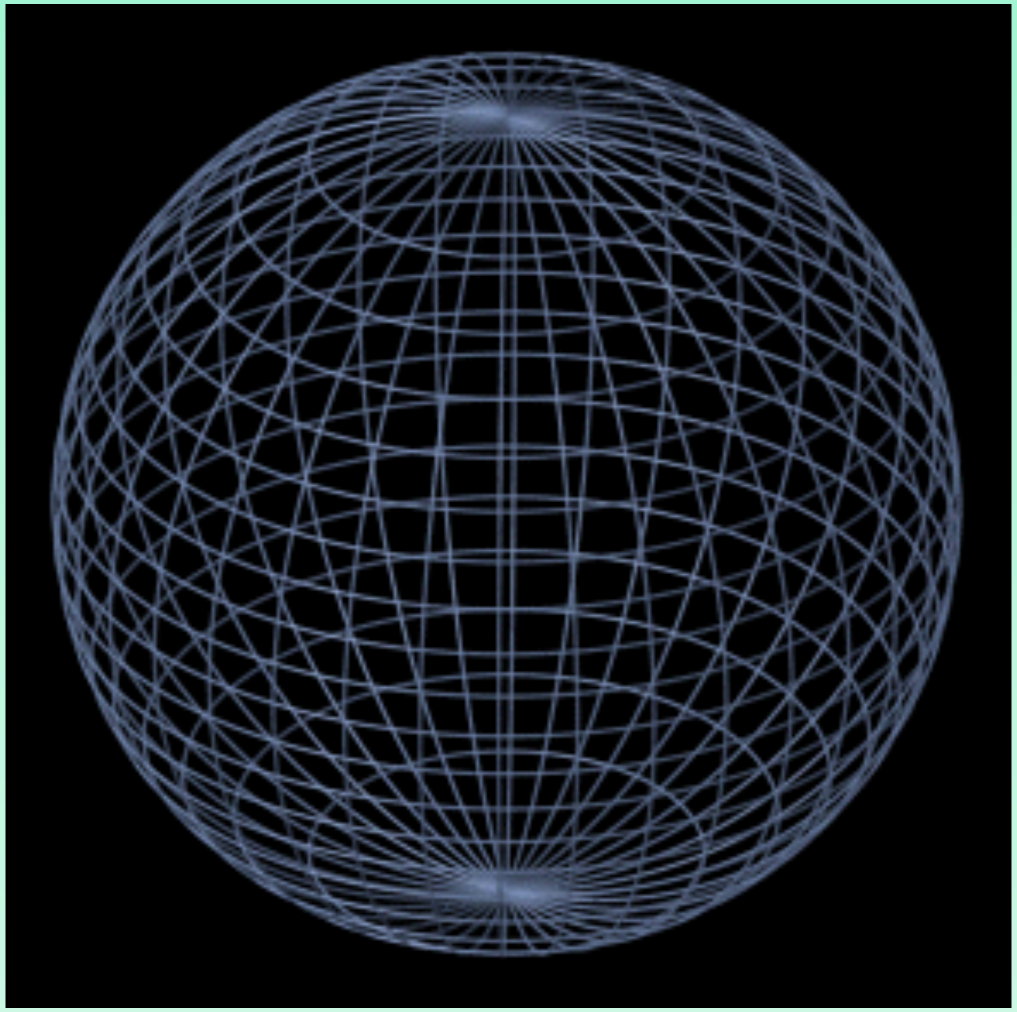
Magic of String Theory

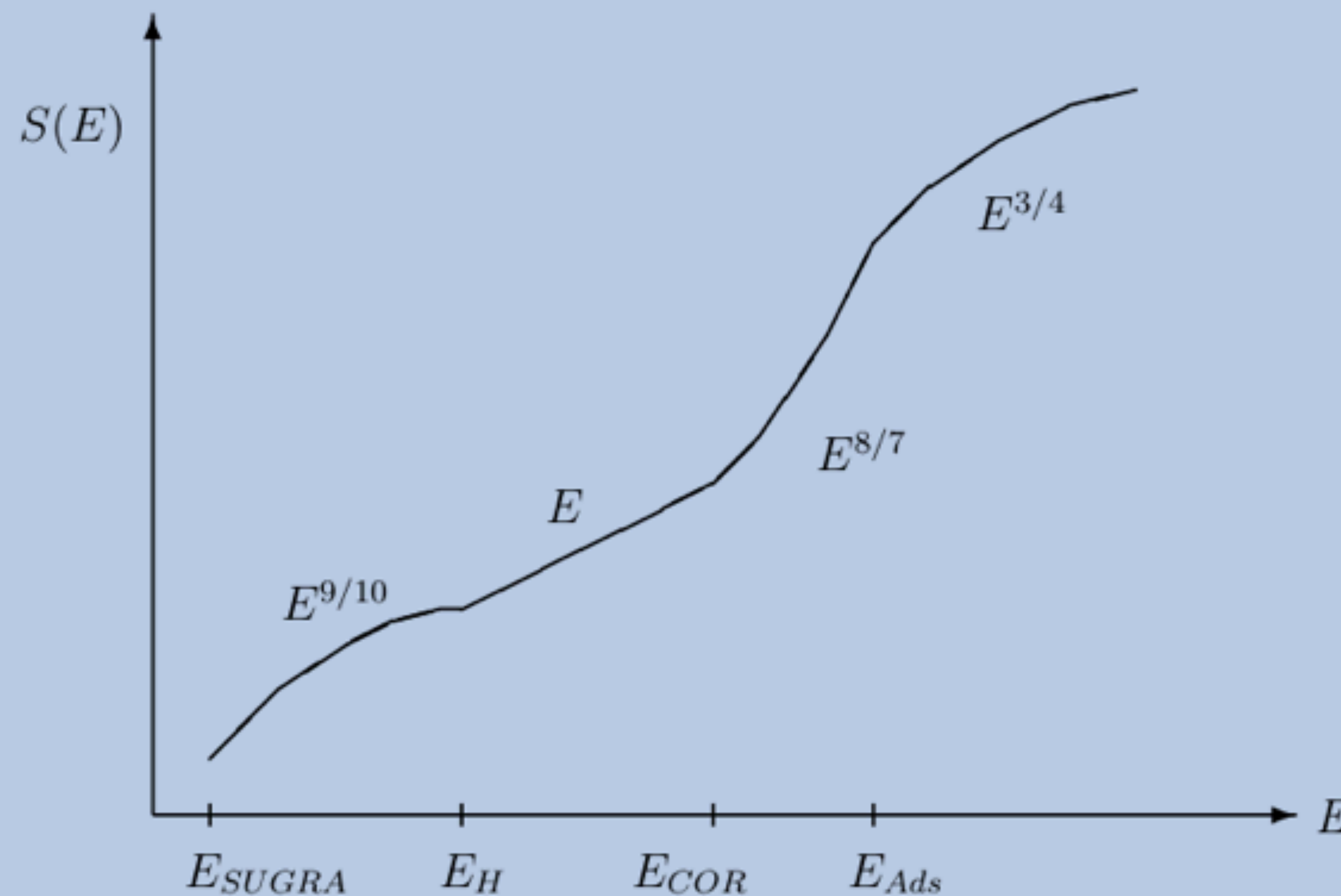
Dimension

With extended objects
1=3 , 4=10

SU(2) dim=3, rank=1







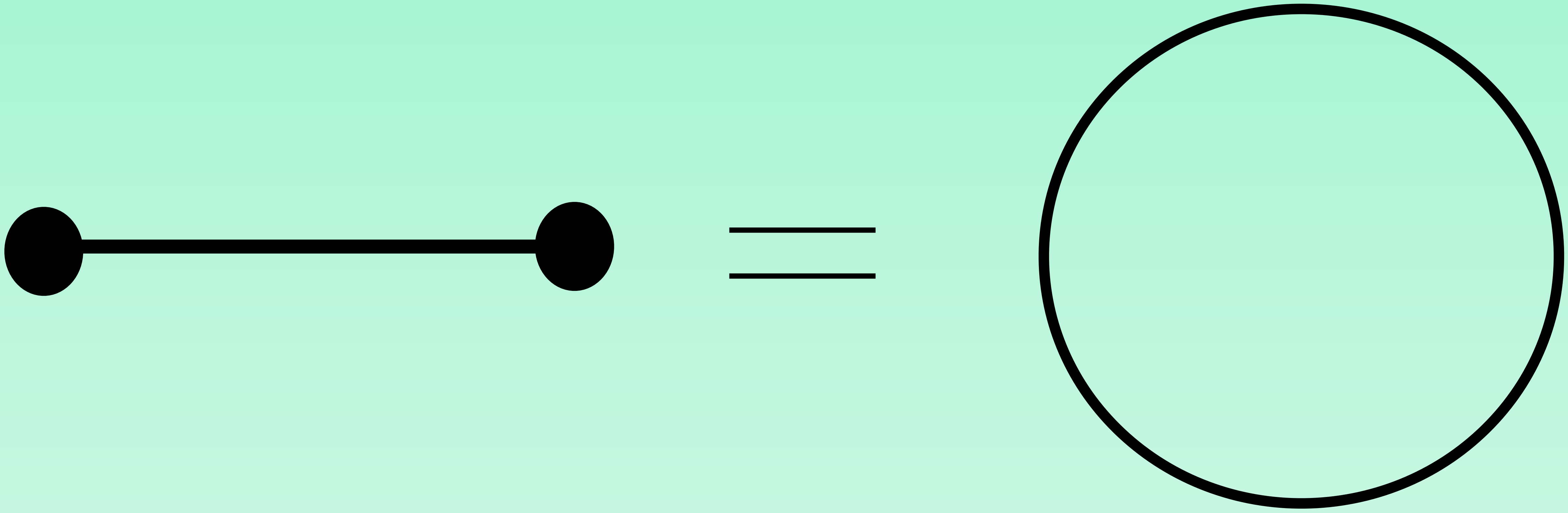
$S(E)$
$E^{3/4}$
$E^{8/7}$
E
$E^{9/10}$
E
E_{SUGRA}
E_H
E_{COR}
E_{Ads}

Magic of String Theory

Singularities

With extended objects

Time Like Singularity



Magic of String Theory

COMMUTATIVITY ?

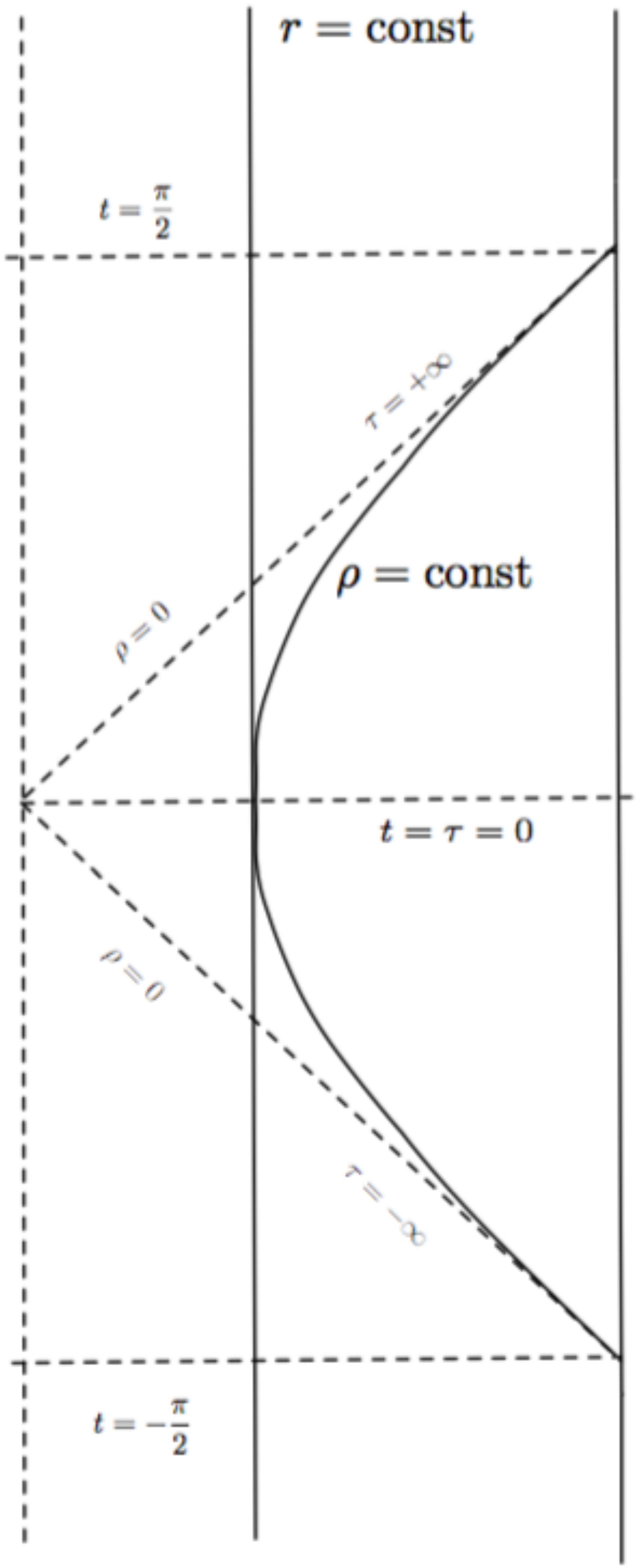
With extended objects

$$[x,y]=0 \quad =$$

Dualities

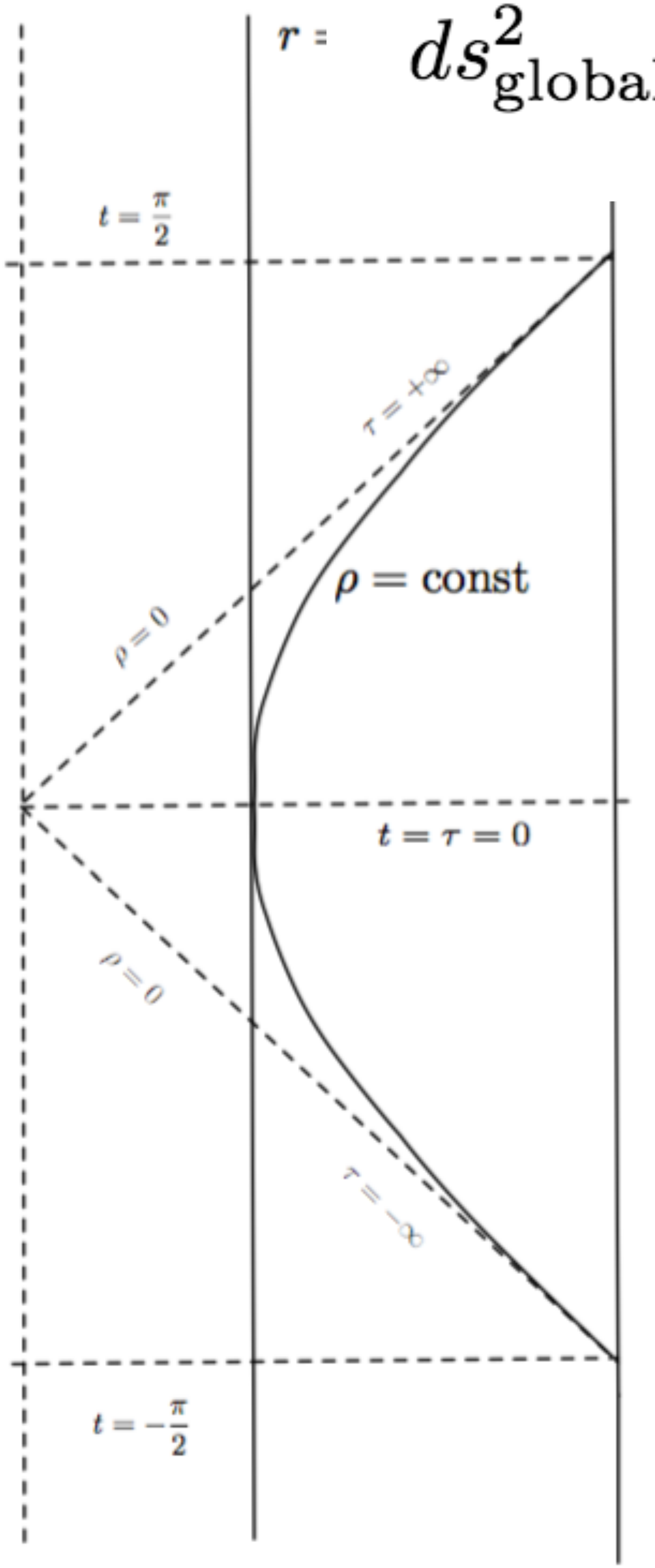
- Geometry
- Topology
- Number of dimensions, small and large
- (non-)Commutativity
- Singularity structure
- Associativity
- NO UNIFIED FRAMEWORK

=



$r = \text{const}$
$t = \frac{\pi}{2}$
$\tau = +\infty$
$\rho = \text{const}$
$\rho = 0$
$t = \tau = 0$
$\rho = 0$
$\tau = -\infty$
$t = -\frac{\pi}{2}$

$$ds^2_{\text{global}} = -(1+r^2)\,dt^2 + \frac{dr^2}{1+r^2} + r^2\,d\Omega^2_{d-1}$$



$$ds^2_{\text{E}} = -dt^2 + d\Omega^2_{d-1}$$

$$ds^2_{\text{global}} = -(1 + r^2)\, dt^2 + \frac{dr^2}{1 + r^2} + r^2\, d\Omega^2_{d-1}$$

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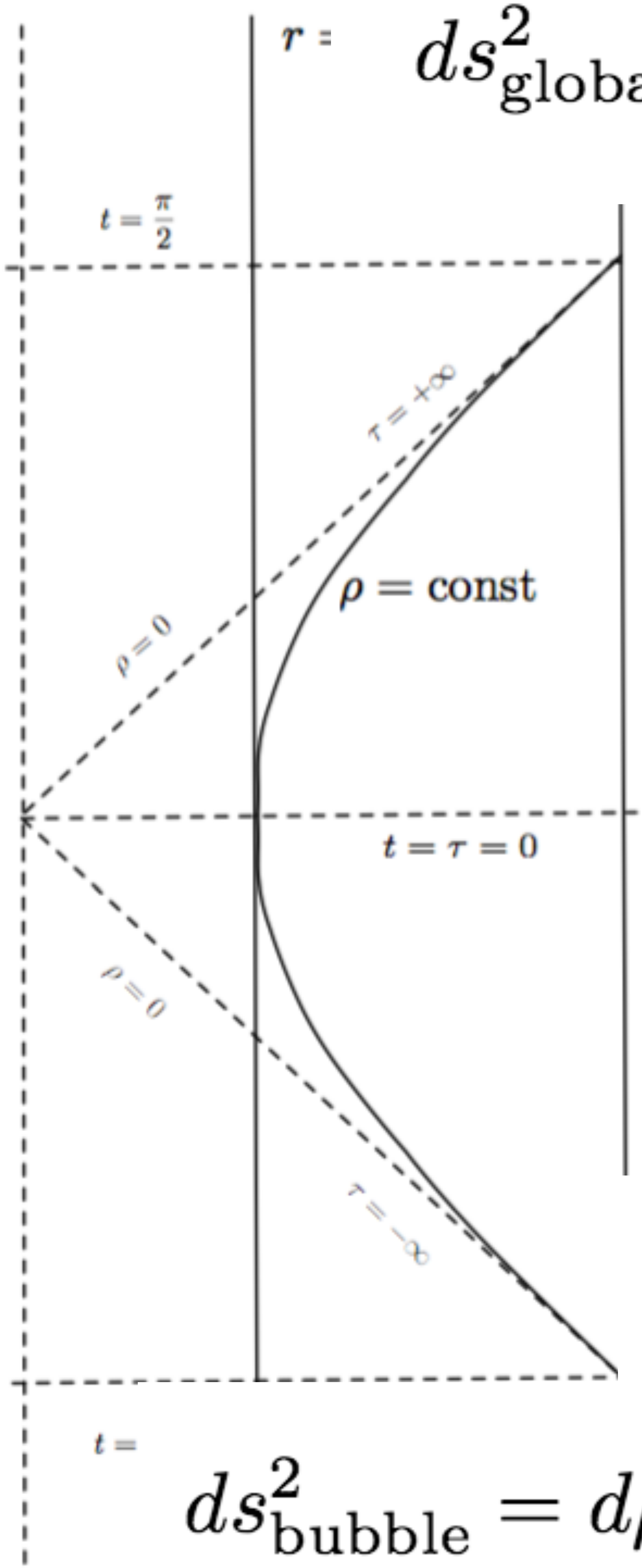
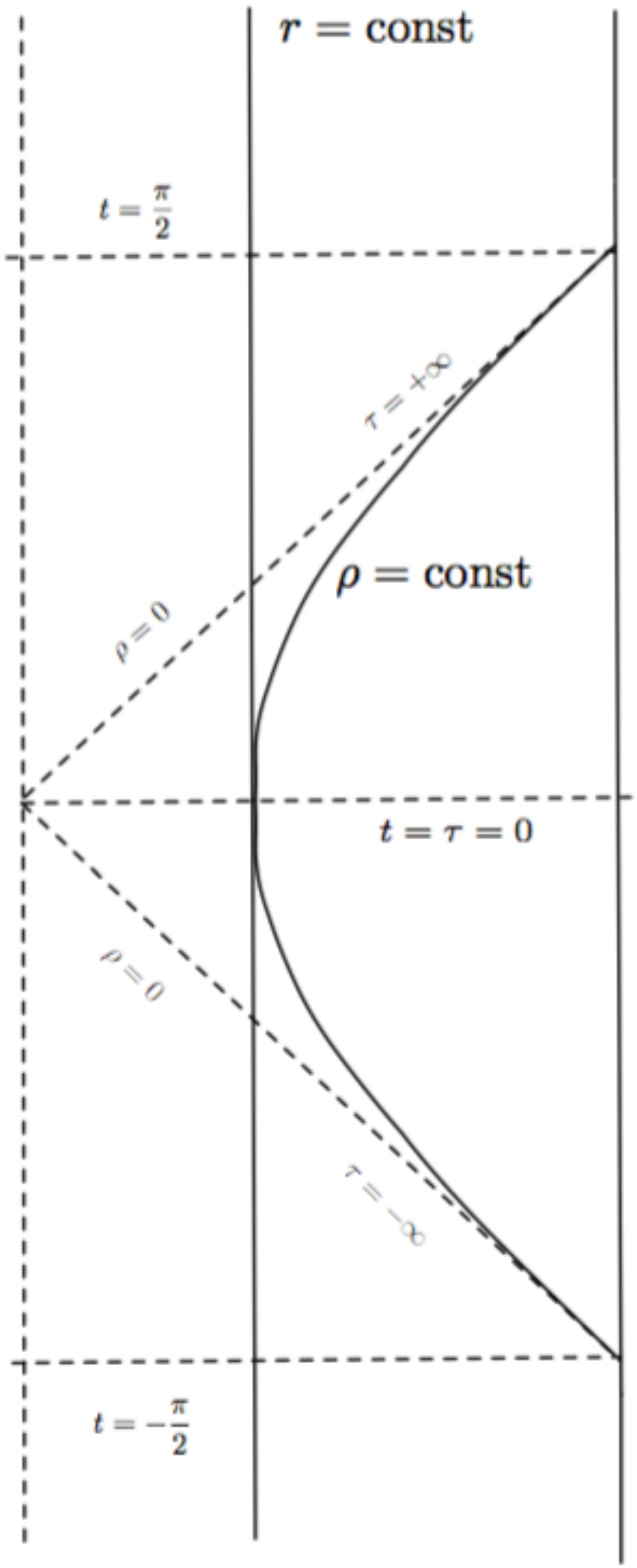


$$ds^2_{\text{dS}} = -d\tau^2 + \cosh^2(\tau)\, d\Omega^2_{d-1}$$

$$ds^2_{\text{bubble}} = d\rho^2 + \sinh^2(\rho)\left(-d\tau^2 + \cosh^2(\tau)\, d\Omega^2_{d-1}\right)$$


$r = \text{const}$
$t = \frac{\pi}{2}$
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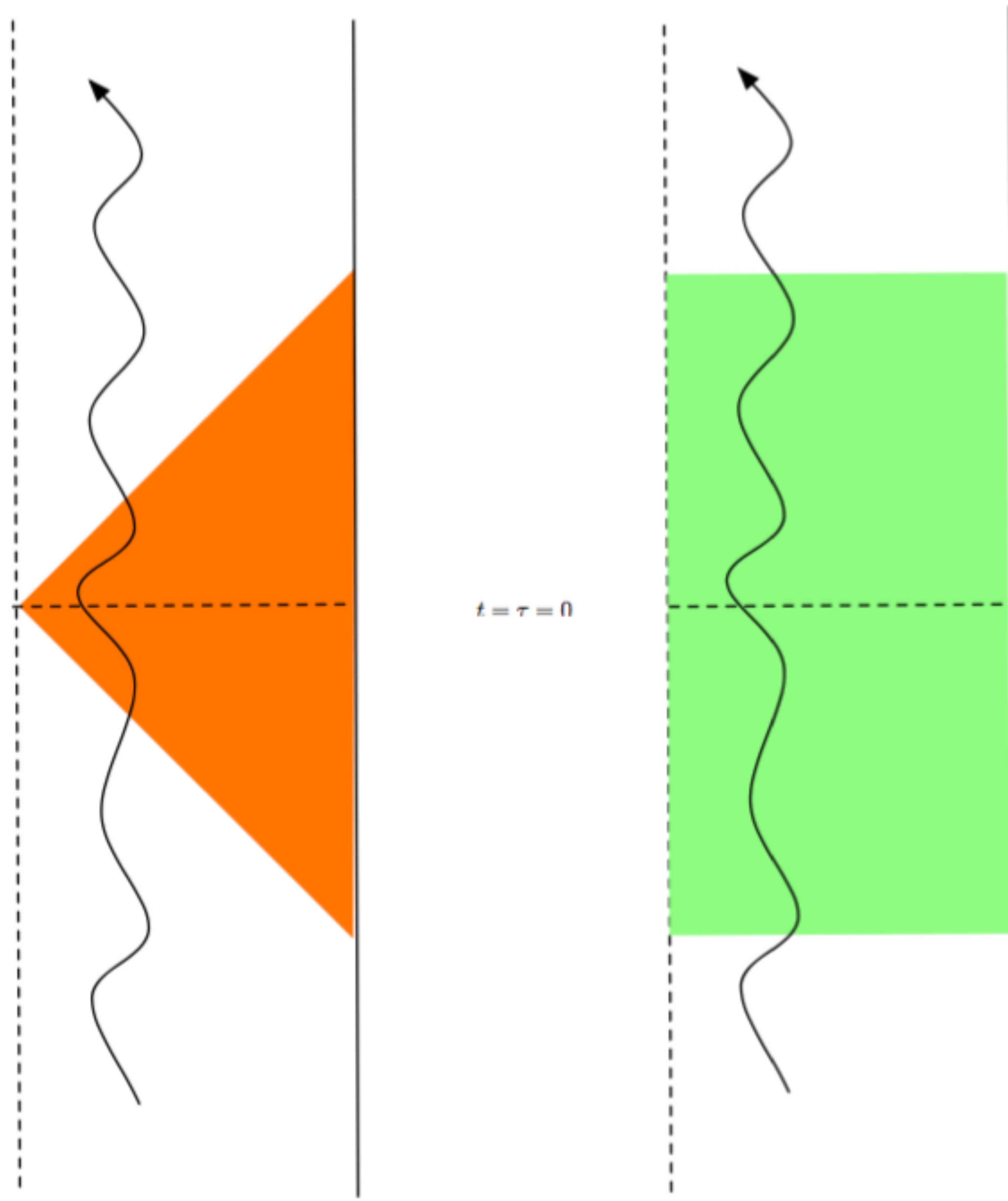
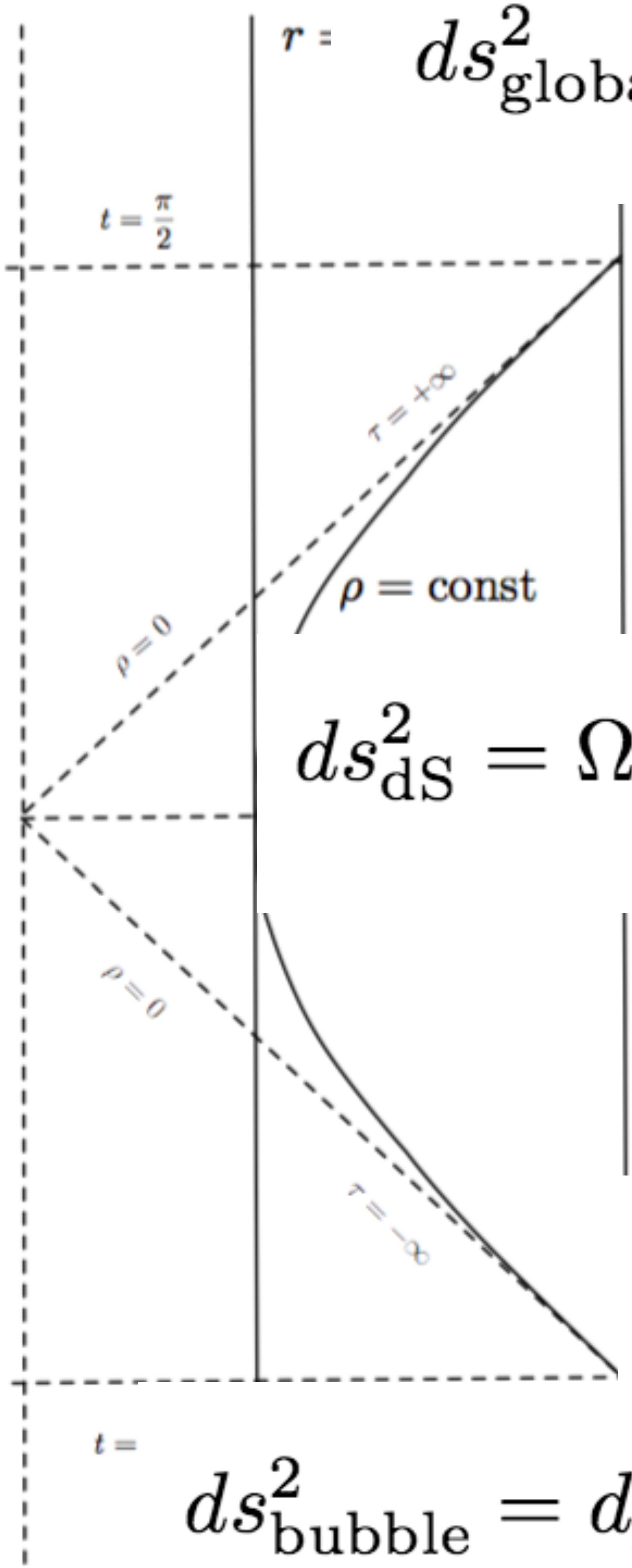

$t = \tau = 0$

$$ds^2_{\text{global}} = -(1+r^2)\,dt^2 + \frac{dr^2}{1+r^2} + r^2\,d\Omega^2_{d-1}$$

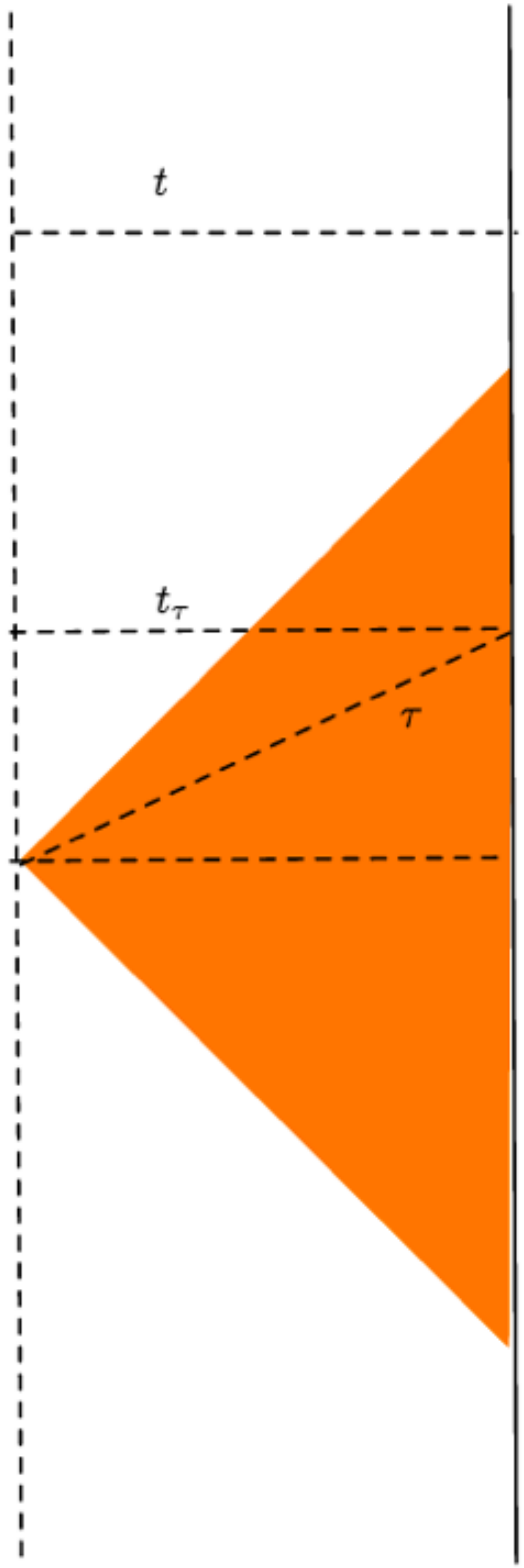


$$ds^2_{\text{E}} = -dt^2 + d\Omega^2_{d-1}$$

$$ds^2_{\text{dS}} = \Omega^2(\tau)\,ds^2_{\text{E}}\,, \qquad \Omega(\tau) = \cosh(\tau) = \frac{1}{\cos(t)}$$

$$ds^2_{\text{dS}} = -d\tau^2 + \cosh^2(\tau)\,d\Omega^2_{d-1}$$

$$ds^2_{\text{bubble}} = d\rho^2 + \sinh^2(\rho)\left(-d\tau^2 + \cosh^2(\tau)\,d\Omega^2_{d-1}\right)$$



$t =$

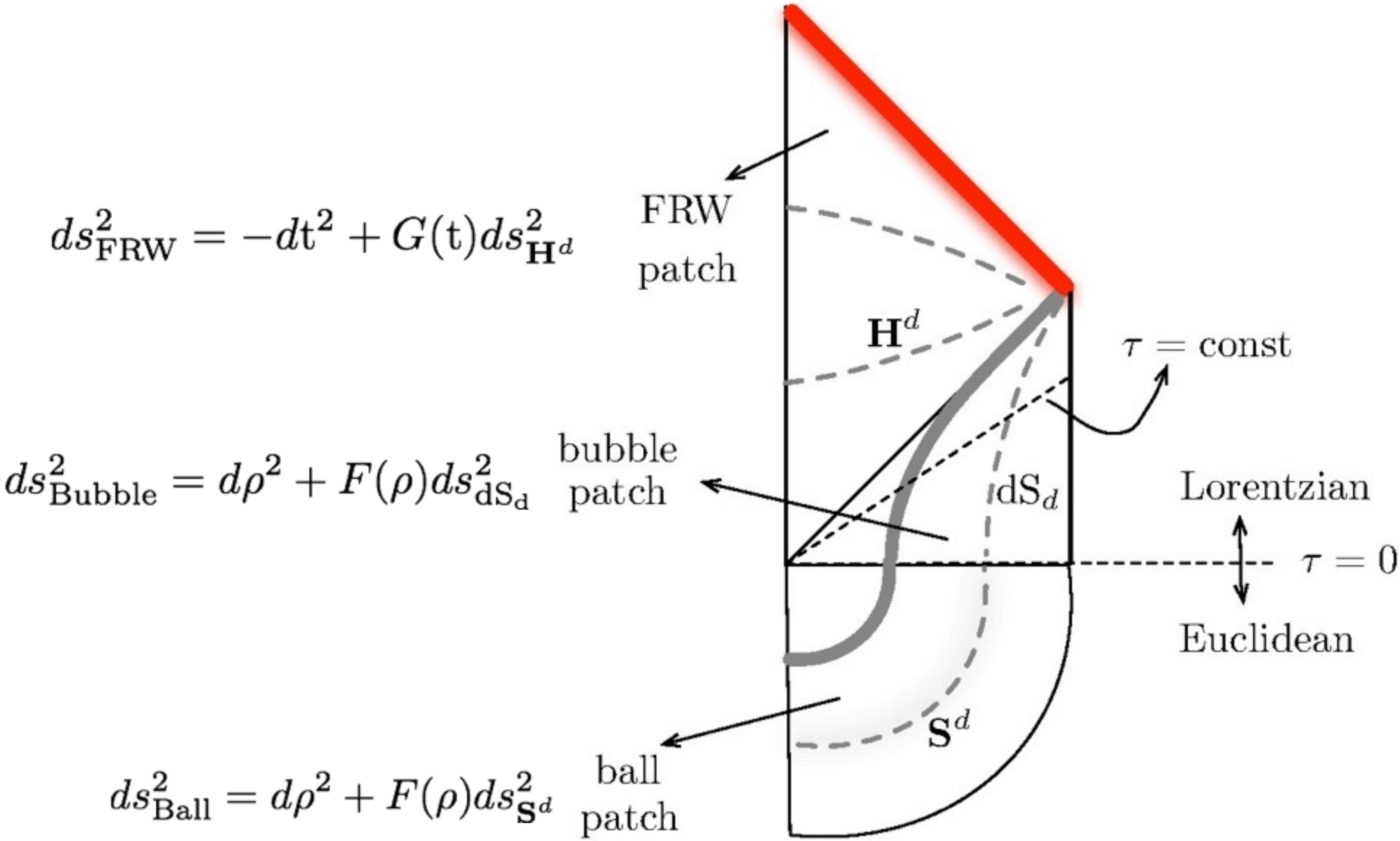
One Can in some cases continue

beyond the coordinate singularity

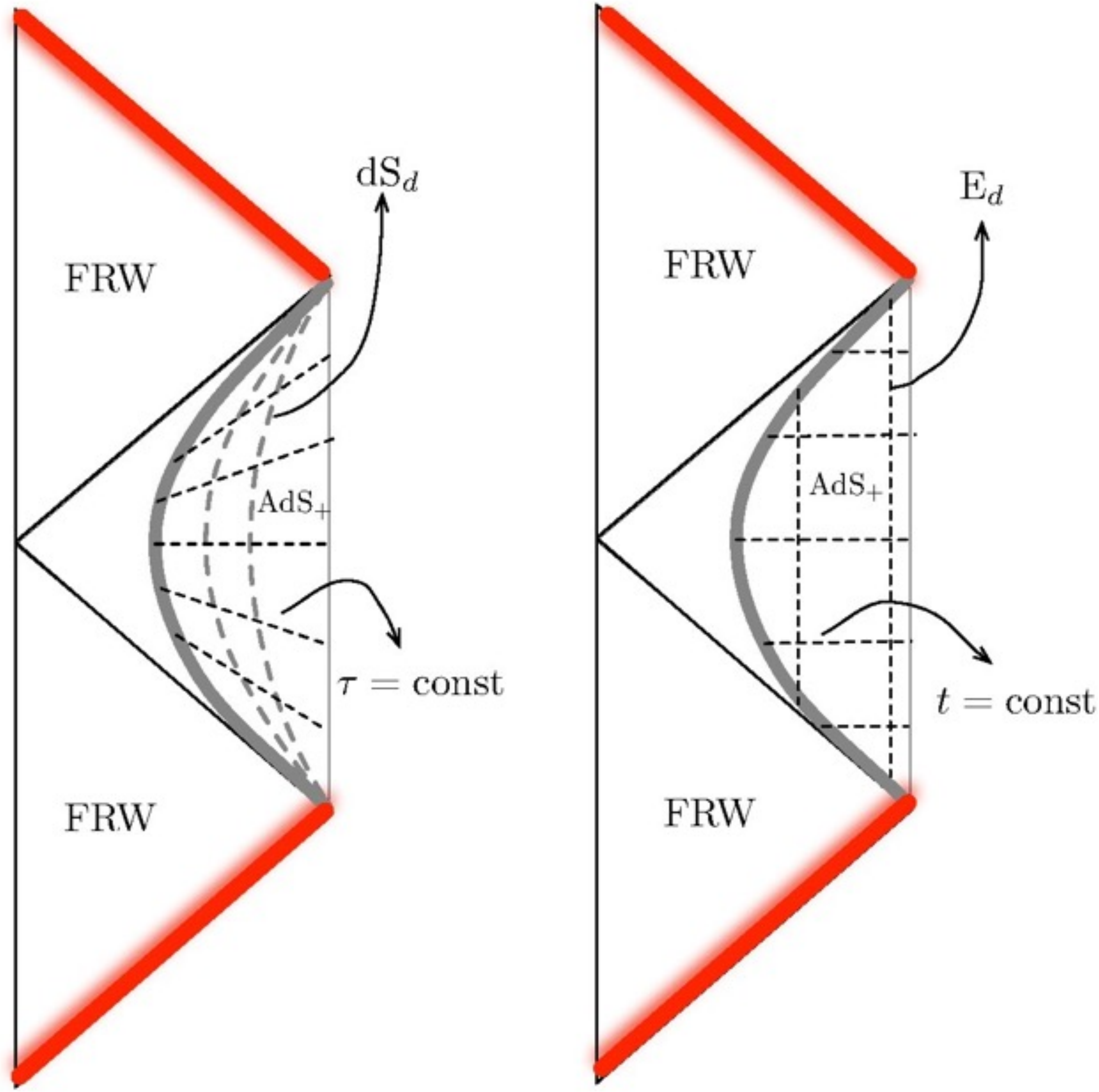
One Can in some cases continue

beyond the coordinate singularity

How about the following case?



$ds^2_{\mathrm{FRW}} = -d\mathrm{t}^2 + G(\mathrm{t})ds^2_{\mathbf{H}^d}$
FRW
patch
$\mathbf{H}^d$
$\tau = \mathrm{const}$
$ds^2_{\mathrm{Bubble}} = d\rho^2 + F(\rho)ds^2_{\mathrm{dS_d}}$
bubble
patch
dS_d
Lorentzian
$\tau = 0$
Euclidean
$\mathbf{S}^d$
ball
patch
$ds^2_{\mathrm{Ball}} = d\rho^2 + F(\rho)ds^2_{\mathbf{S}^d}$



FRW
dS$_d$
AdS$_+$
$\tau = \text{const}$
FRW
FRW
E$_d$
AdS$_+$
$t = \text{const}$
FRW

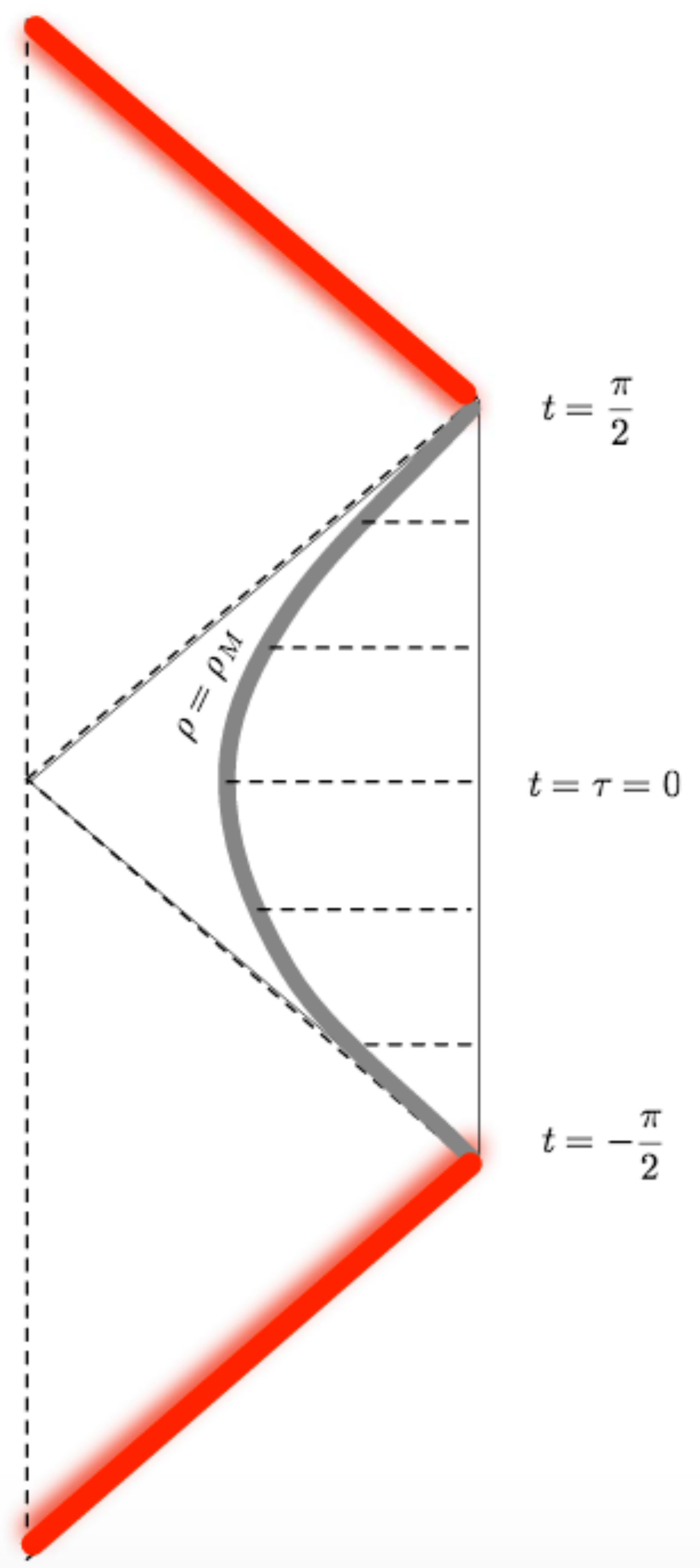
- The Singulariy Reaches the Boundary/UV in
- a Finite Time and thus can be
- Described by Local Boundary Operators.

Engineering Big Crunch Singularities

Add

Marginal or Relevant

operators on the boundary



AN EFFECTIVE ACTION OF A BRANE INDUCES A LG BOUNDARY ACTION

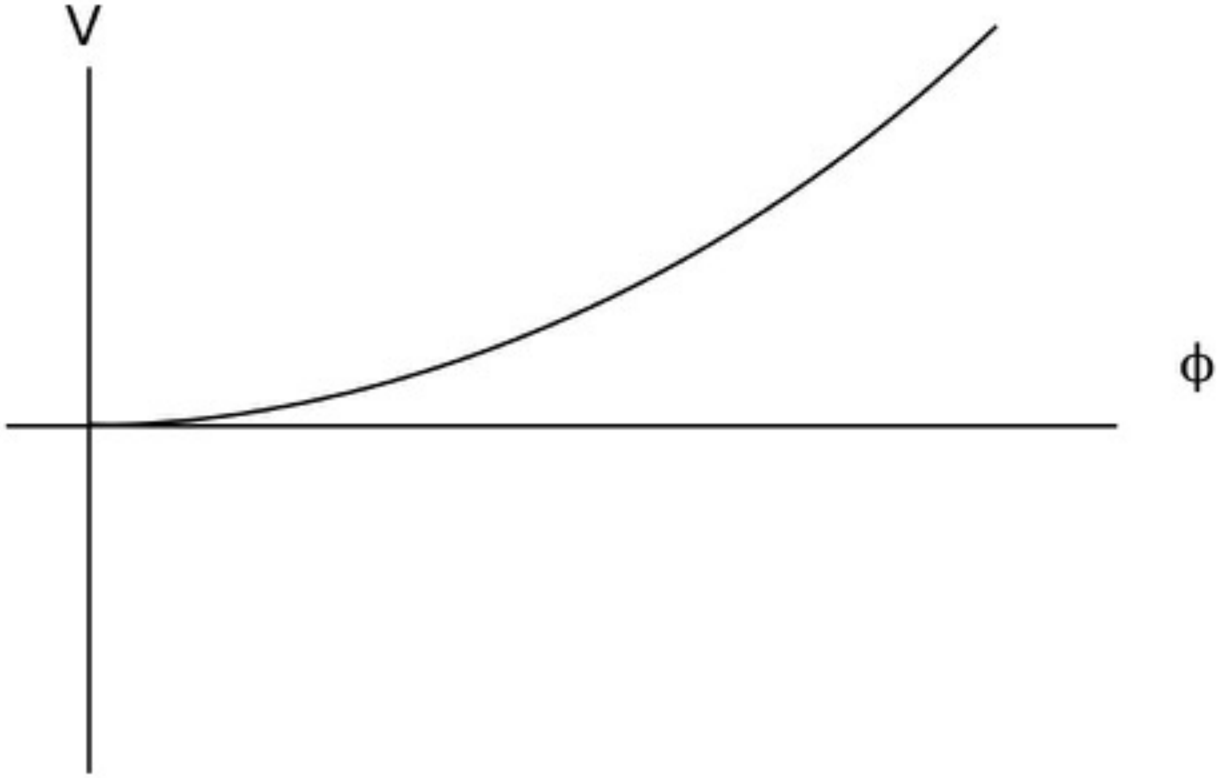
$$\rho_M \sim \log \langle \phi \rangle_M \sim \log(M)$$

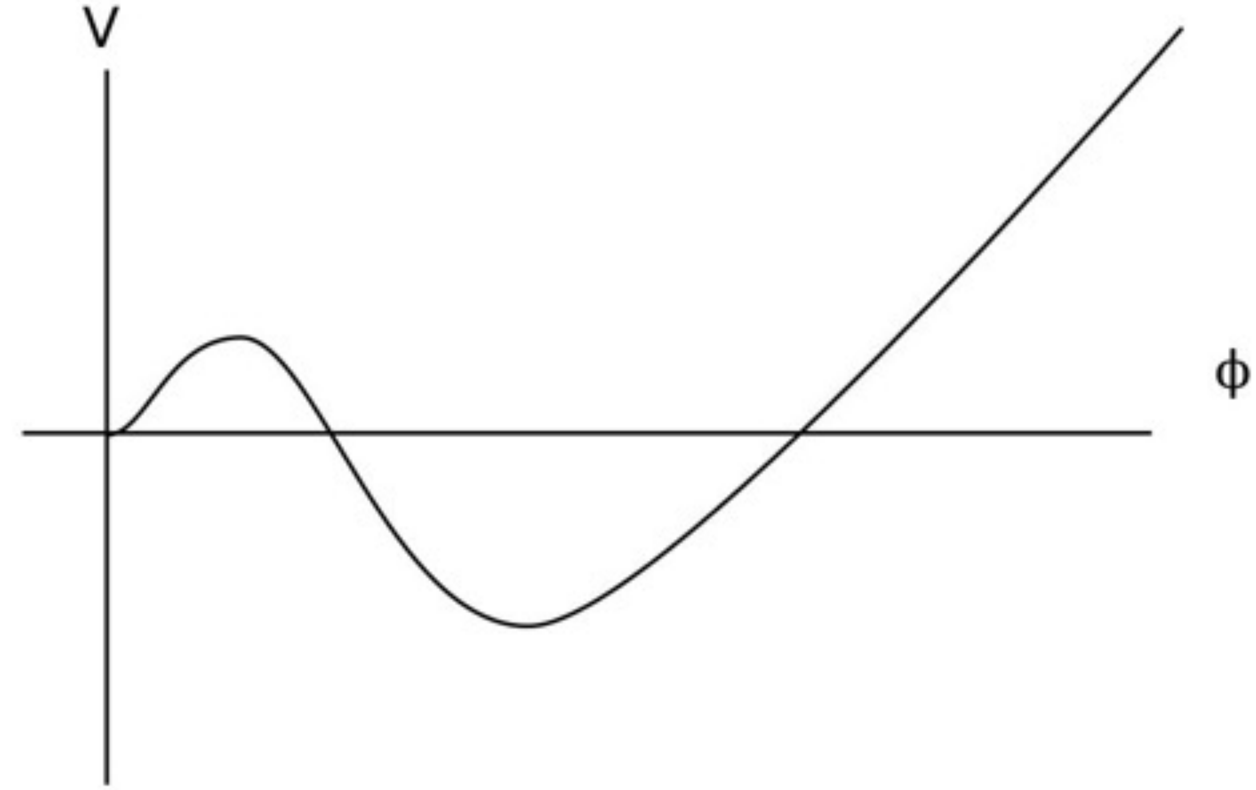
$$\langle \phi \rangle_M \sim M^{\frac{d-2}{2}}$$

Non perturbative definition of the theory.

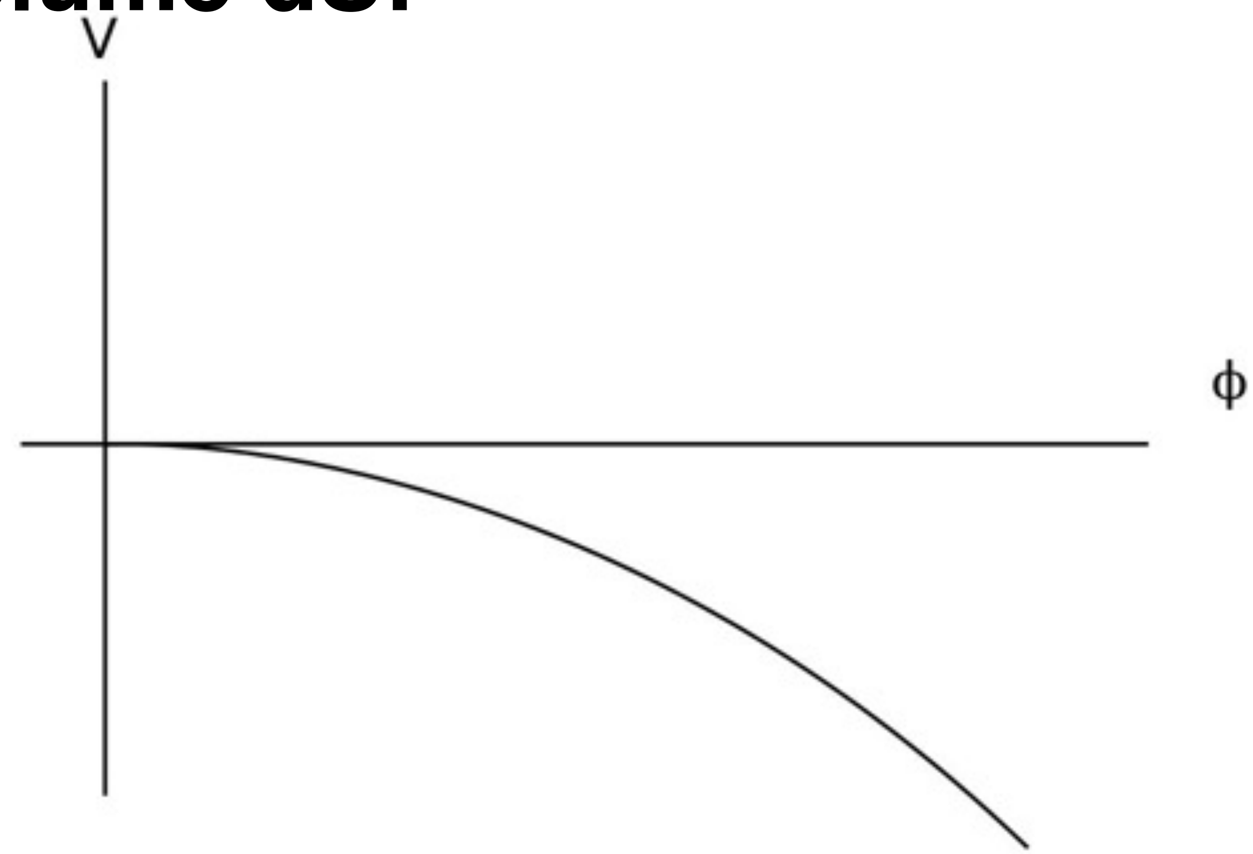
There are several possible QFT duals on the bondary

BOUNDARY





World Volume dS!



- If the boundary theory is well defined so is the crunch in the bulk.
- For the bulk crunch example above the boundary theory is well defined. Possible to describe a crunch.
- It is well defined on a world volume which is dS but there is no gravitational coupling.
- To see the crunch change coordinates on the boundary.

A simple classical model: O(N) on de Sitter

$$S_{\mathrm{dS}}[\vec{\phi}\,] = -\int_{\mathrm{dS}_4} \left(\frac{1}{2}\partial_\mu \vec{\phi} \cdot \partial^\mu \vec{\phi} + \frac{\vec{\phi}^{\,2}}{R^2} + \lambda \left(\vec{\phi}^{\,2}\right)^2 + \varepsilon\, M^2 \vec{\phi}^{\,2} \right)$$

$MR \gg 1$ ⟶ Phases are clear-cut

$$\varepsilon > 0 \qquad \mathrm{UV}_{O(N)} \xrightarrow{\text{RG flow}} \mathrm{IR}_{\mathrm{gap}}$$

$$\varepsilon < 0 \qquad \mathrm{UV}_{O(N)} \xrightarrow{\text{RG flow}} \mathrm{IR}_{O(N-1)}$$

$$ds^2_{\rm E} = -dt^2 + d\Omega^2_{d-1},$$

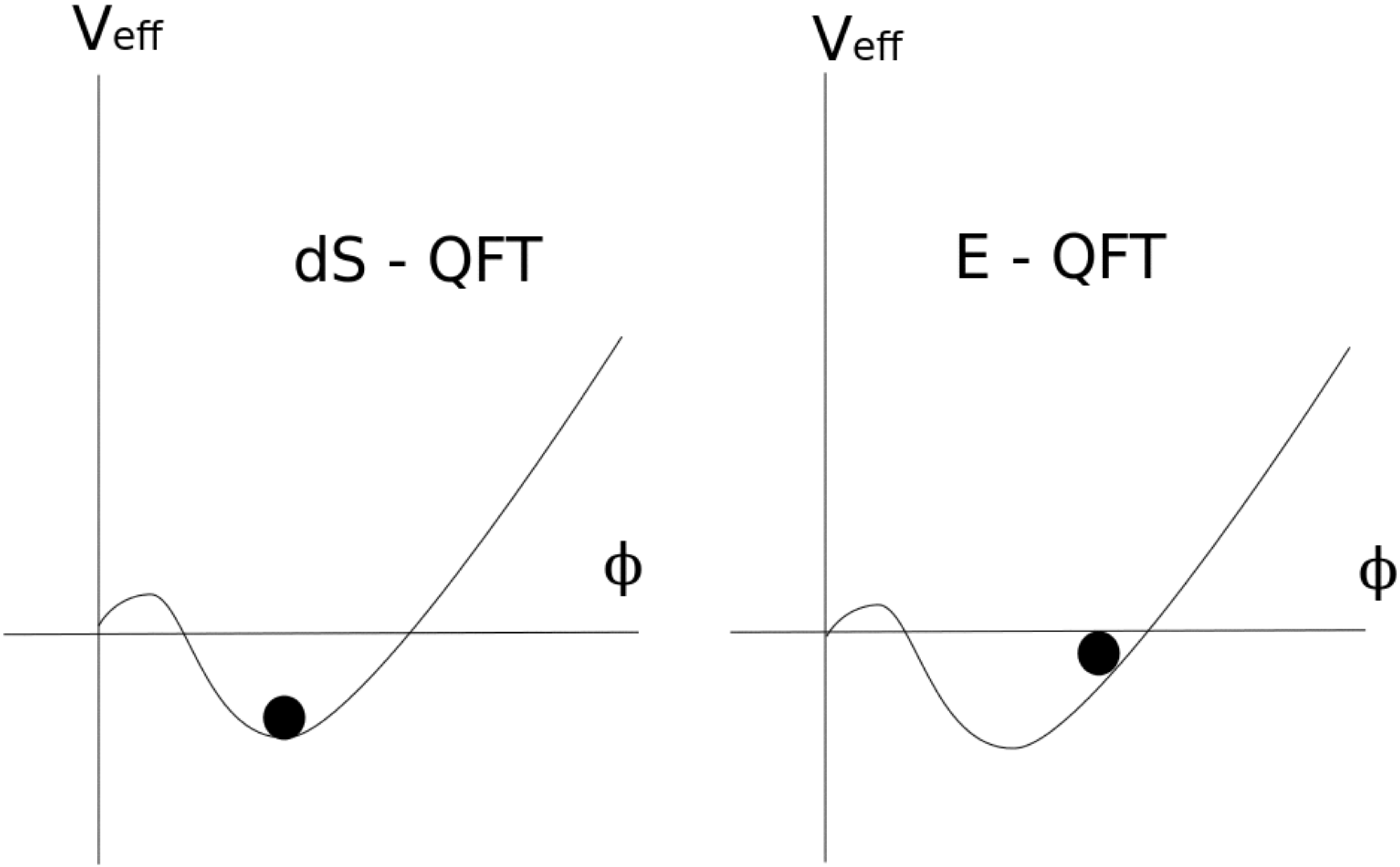
$$ds^2_{\rm dS} = \Omega^2(t)\, ds^2_{\rm E}\ , \qquad \Omega(t) = \cosh(\tau) = \frac{1}{\cos(t)}\ ,$$

$$t = \int \Omega^{-1}(\tau) d\tau = 2\tan^{-1}[\tanh(\tau/2)].$$

Over at the E-frame...

$$S_{\mathrm{E}}[\vec{\phi}\,] = -\int_{\mathrm{E}_4} \left(\frac{1}{2}\partial_\mu\vec{\phi}\cdot\partial^\mu\vec{\phi} + \frac{\vec{\phi}^{\,2}}{2R^2} + \lambda\left(\vec{\phi}^{\,2}\right)^2 + \varepsilon\,\Omega(t)^2\,M^2\vec{\phi}^{\,2} \right)$$

Mass term blows to $\varepsilon\,\infty$
in finite time


Veff
dS - QFT
ϕ
Veff
E - QFT
ϕ


Traverse City
Film Festival


Traverse City


Traverse City

$\mathcal{O}_1 \leftrightarrow \widetilde{\mathcal{O}}_1$ $\mathcal{O}_2 \leftrightarrow \widetilde{\mathcal{O}}_2$

$$V_{\mathrm{dS}}[\phi] = \tfrac{1}{2}\xi_d \mathcal{R}_{\mathrm{dS}_d}\, \phi^{\,2} + \lambda\, \phi^{\,\frac{2d}{d-2}} - \left(\frac{\widetilde{M}}{\cosh(\tau)}\right)^{d-\Delta} \phi^{\,\frac{2\Delta}{d-2}}$$

d=1 is not trivial. 2d/(d-2)=-2 and!

$$\omega_k^2 = \lim_{d\to 1}\, \xi_d\, \mathcal{R}_{\mathbf{X}_k} = \lim_{d\to 1}\, \frac{d-2}{4(d-1)}\, k\,(d-1)(d-2) = \frac{k}{4}$$

and for the LG model on dS_d:

$$\lim_{d\to 1}\, \xi_d\, \mathcal{R}_{\mathrm{dS}_d} = \lim_{d\to 1}\, \frac{d-2}{4(d-1)}\, d(d-1) = -\frac{1}{4}\,.$$

A near boundary slow moving particle probe in AdS2

gives:

$$ds^2_{(k)} = -(r_k^2 + k)\, dt_k^2 + \frac{dr_k^2}{r_k^2 + k}$$

$$S_{(k)} = -m \int dt_k \sqrt{r_k^2 + k - \frac{1}{r_k^2 + k} \left(\frac{dr_k}{dt_k} \right)^2}$$

$r_k \gg 1$ and $|dr_k/dt_k| \ll 1$

$$\phi(t_k) = \left(\frac{4m}{r_k(t_k)} \right)^{1/2}$$

$$S[\phi_k] = \frac{1}{2} \int dt_k \left[\left(\frac{d\phi_k}{dt_k} \right)^2 - \omega_k^2\, \phi_k^2 - \frac{\lambda}{\phi_k^2} \right]$$

$$V_{\mathrm{dS}}[\phi] = \frac{1}{2}\xi_d\,\mathcal{R}_{\mathrm{dS}_d}\,\phi^2 + \lambda\,\phi^{\frac{2d}{d-2}} - \left(\frac{\widetilde{M}}{\cosh(\tau)}\right)^{d-\Delta} \phi^{\frac{2\Delta}{d-2}}$$

d=1 is not trivial. 2d/(d-2)=-2 and!

$$\omega_k^2 = \lim_{d\to 1}\,\xi_d\,\mathcal{R}_{\mathbf{x}_k} = \lim_{d\to 1}\,\frac{d-2}{4(d-1)}\,k\,(d-1)(d-2) = \frac{k}{4}$$

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Classical Maps:

$t \in [-t_\star, t_\star]$ **E= Einstien ; M= Minkowski; dS** $\tau \in \mathbf{R}$

$$dt = \frac{d\tau}{\Omega(\tau)}$$

$$\mathrm{EM}: \quad \omega^2 = 0\,, \qquad \widetilde{\omega}^{\,2} = \frac{1}{4}\,, \qquad \Omega_{\mathrm{EM}} = \frac{1}{2}\,(1+\tau^2) = \frac{1}{2\cos^2(t/2)}$$

$$\mathrm{EdS}: \quad \omega^2 = -\frac{1}{4}\,, \qquad \widetilde{\omega}^{\,2} = \frac{1}{4}\,, \qquad \Omega_{\mathrm{EdS}} = \cosh(\tau) = \frac{1}{\cos(t)}$$

$$\widetilde{\omega}^{\,2} = \Omega^2\,\omega^2 + \frac{1}{2}\,\Omega\,\partial_\tau^2\Omega - \frac{1}{4}(\partial_\tau\Omega)^2$$

“Anomalous”

$$H(\pi, \phi)_{\mathrm{AFF}} = \frac{1}{2} \left(\pi^2 + \frac{\lambda}{\phi^2} \right)$$

$$[D, H] = 2iH \ , \qquad [D, C] = -2iC \ , \qquad [H, C] = -iD$$

$$D \ = \ \tfrac{1}{2}\{\phi, \pi\} \qquad\qquad C = \tfrac{1}{2}\phi^2$$

SL(2,R) Invariant !

$$H(\pi, \phi)_{\mathrm{AFF}} = \frac{1}{2} \left(\pi^2 + \frac{\lambda}{\phi^2} \right)$$

$$[D, H] = 2iH \ , \qquad [D, C] = -2iC \ , \qquad [H, C] = -iD$$

SL(2,R) Yes , GCR no, dismissed for SKY at al.

$$H(\pi,\phi)_{\mathrm{AFF}} = \frac{1}{2}\left(\pi^2 + \frac{\lambda}{\phi^2}\right)$$

$$[D,H] = 2iH \ , \qquad [D,C] = -2iC \ , \qquad [H,C] = -iD$$

For a positive coupling (and > -1/4)

The Spectrum is continuous

The System has no Ground State!

Note analogy to B.F Bound!

Energy is (0,infinity]

$$H(\pi, \phi)_{\mathrm{AFF}} = \frac{1}{2}\left(\pi^2 + \frac{\lambda}{\phi^2}\right)$$

$$[D, H] = 2iH \ , \qquad [D, C] = -2iC \ , \qquad [H, C] = -iD$$

$$H_\omega = H_{\mathrm{AFF}} + \omega^2\, C$$

$$C = \tfrac{1}{2}\phi^2$$

Discrete Spectrum ALSO SL(2,R) Invariant.

Deform CQM by a potential

$$V_\Delta(\phi) = \varepsilon \, \frac{M^{1-\Delta}}{\phi^{2\Delta}}$$

$$V_\Delta(\phi) = \varepsilon \, \frac{M^{1-\Delta}}{\phi^{2\Delta}}$$

Δ

< 1 RELEVANT

=1 Marginal

Between 1 and 0 “softly “ Relevant

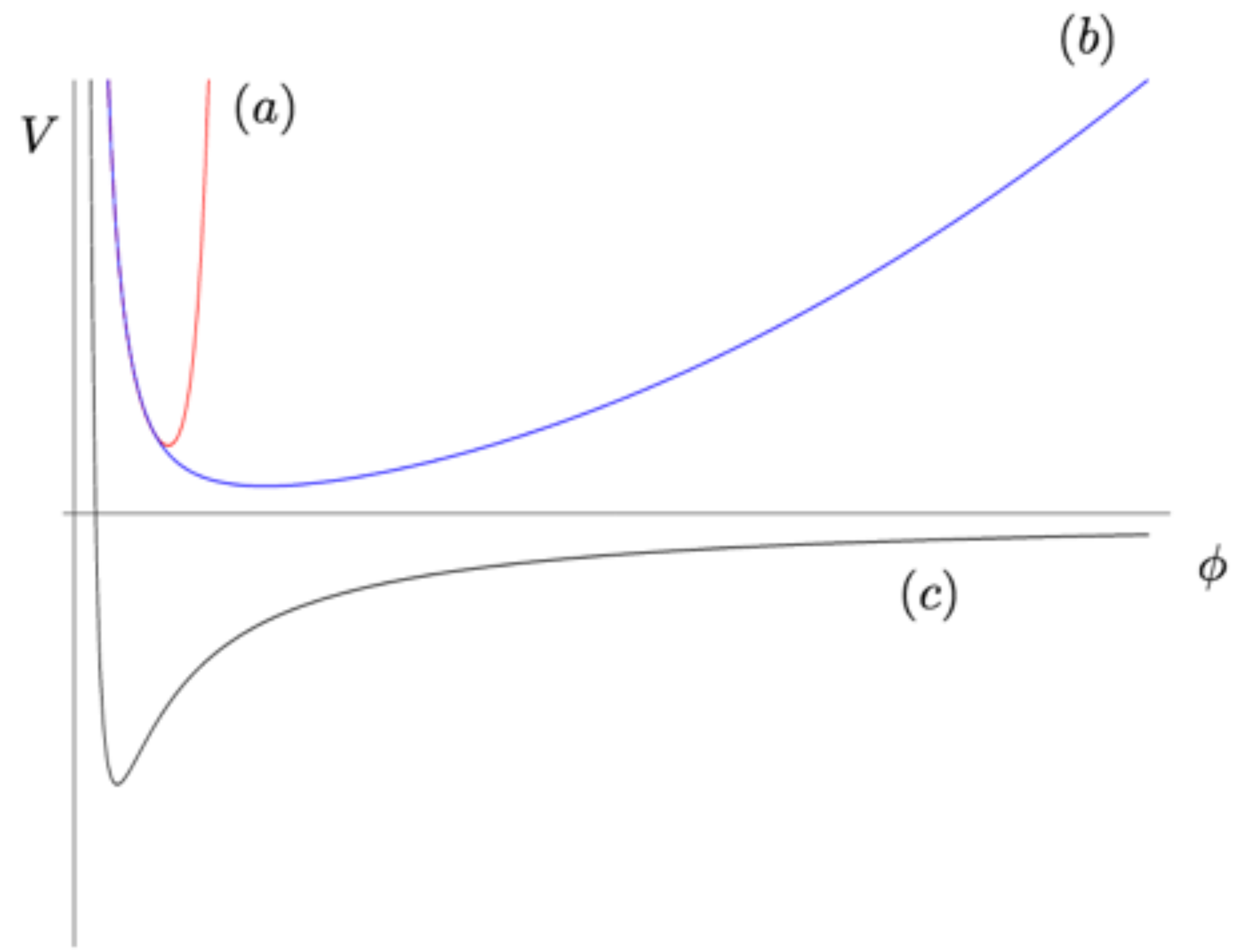


Figure 7: The AFF potential deformed by (a) a positive strongly relevant operator with $\Delta < -1$ (confinement), (b) a harmonic potential, $\Delta = -1$ (trapping), and (c) a negative, mildly relevant deformation, $0 < \Delta < 1$ (condensate).

For Large N even more stable near the origin.

Special "soft" Relevant operator =1/2

$$\left(-\frac{1}{2}\frac{d^2}{d\phi^2} + \frac{\lambda}{2\phi^2} - \frac{\sqrt{M}}{\phi}\right) U_n(\phi) = E_n\, U_n(\phi)$$

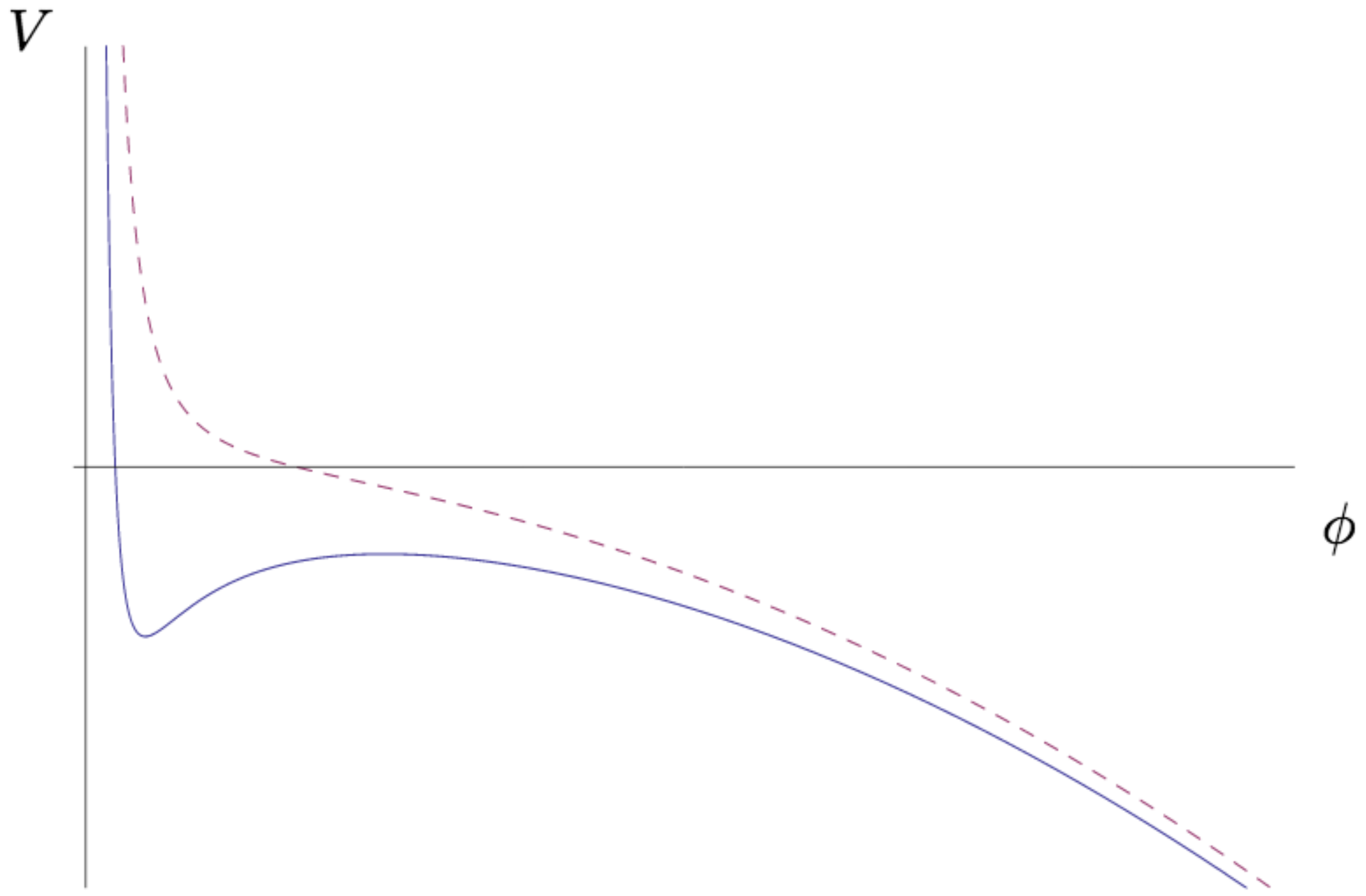
with discrete spectrum of energies

$$E_n = -\frac{2M}{(2n+1+\sqrt{1+4\lambda})^2}\,, \qquad n \in \mathbf{Z}_+\ .$$

Many scattering States!

Like SSB with IR theory non trivial

"Big Crunch"

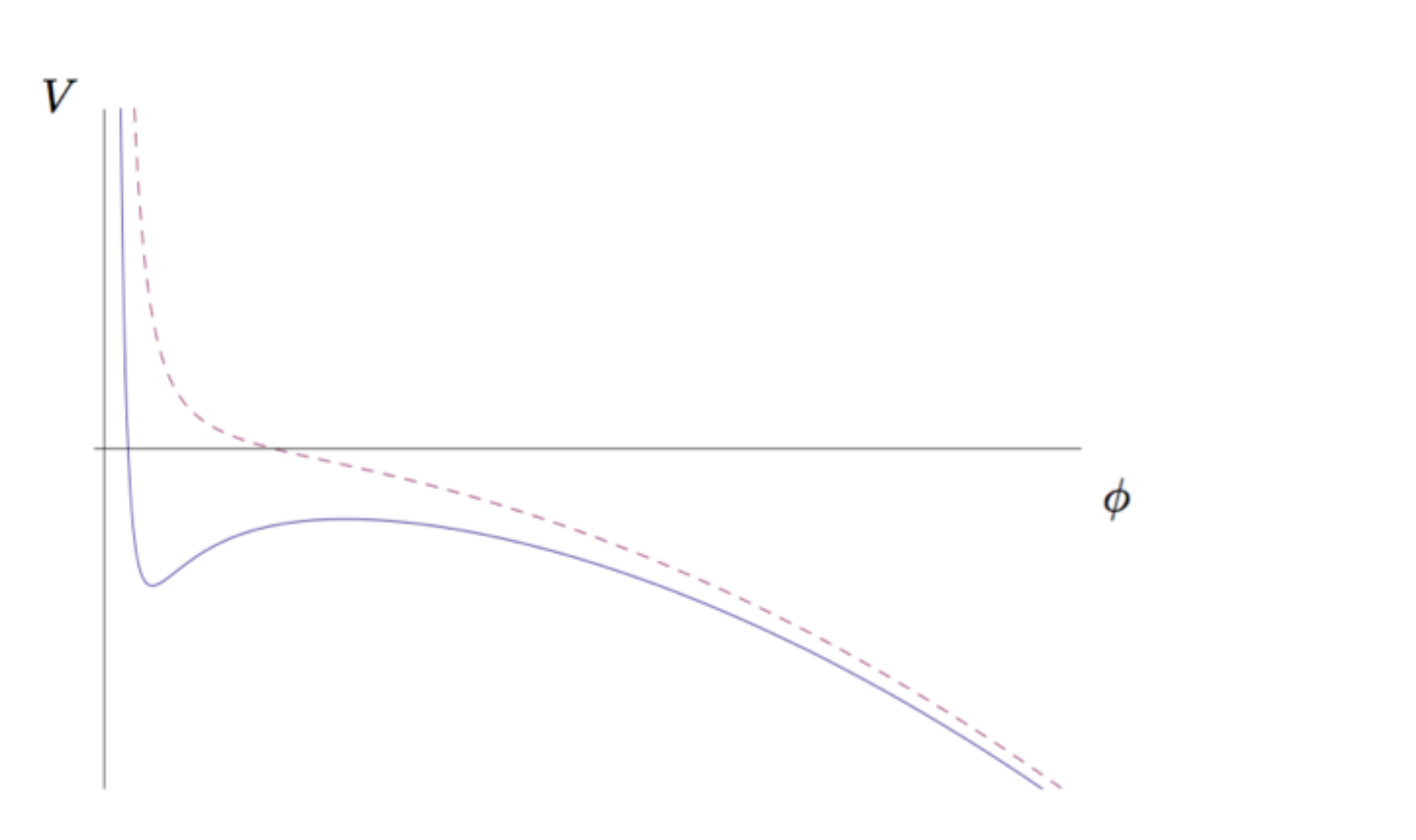


Dashed Line- Ds

Full line- Adding a negative relevant operator!

Tunneling reflects return to the bulk NOT boundary!!

Possible healing happens at d=1 CQM where all can be made Quantum?



$$\Psi_{\rm meta} \approx e^{-\Gamma\tau/2}\Psi_{\rm cond} + \sqrt{1-e^{-\Gamma\tau}}\,\Psi_{\rm run}$$

Classical Maps:

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$$dt = \frac{d\tau}{\Omega(\tau)}$$

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$$\widetilde{\omega}^{\,2} = \Omega^2\,\omega^2 + \frac{1}{2}\,\Omega\,\partial_\tau^2\Omega - \frac{1}{4}(\partial_\tau\Omega)^2$$ **"Anomalous"**

Quantum Maps

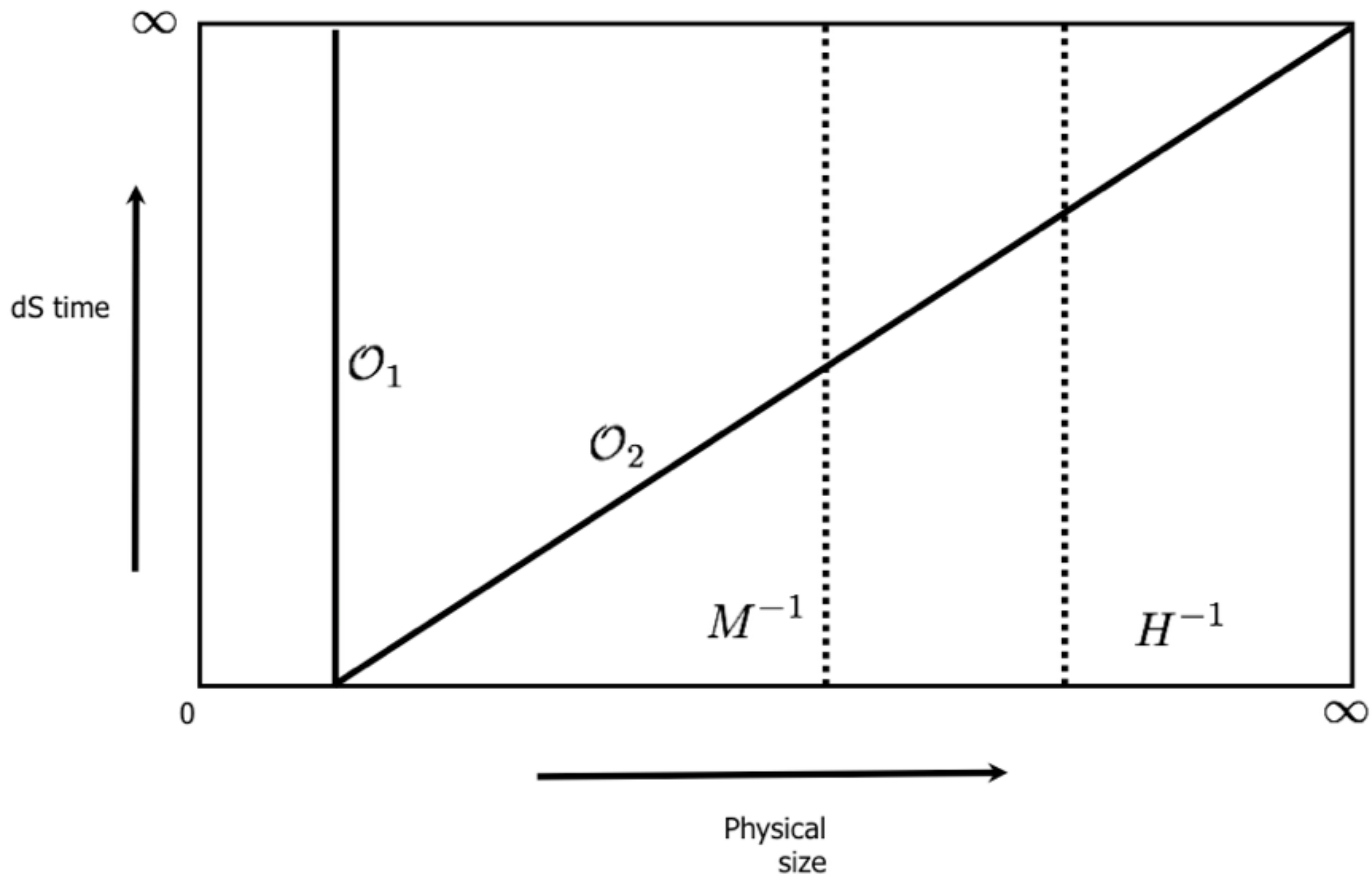
$$\Psi[\phi,\tau] \longrightarrow \widetilde{\Psi}[\widetilde{\phi},t]$$

$$\widetilde{\Psi}[\,\widetilde{\phi},t\,] = \Omega(t)^{\frac{1}{4}}\, e^{i\widetilde{K}(t)}\, \Psi\left[\widetilde{\phi}\sqrt{\Omega(t)},\tau(t)\right]$$

$$\Psi[\,\phi,\tau\,] = \Omega(\tau)^{-\frac{1}{4}}\, e^{-iK(\tau)}\, \widetilde{\Psi}\left[\phi/\sqrt{\Omega(\tau)},t(\tau)\right]$$

$$K(\tau) = -\frac{1}{4}\,\phi^2\,\partial_\tau \log\Omega(\tau)\ , \qquad \widetilde{K}(t) = -\frac{1}{4}\,\widetilde{\phi}^{\,2}\,\partial_t \log\Omega(t)$$

Length scales of complete quantum state in dS variables, as a function of dS time



$$\Omega(t) \sim (t - t_\star)^{-\alpha} \qquad t = \pm t_\star = \pm \alpha\pi/2.$$

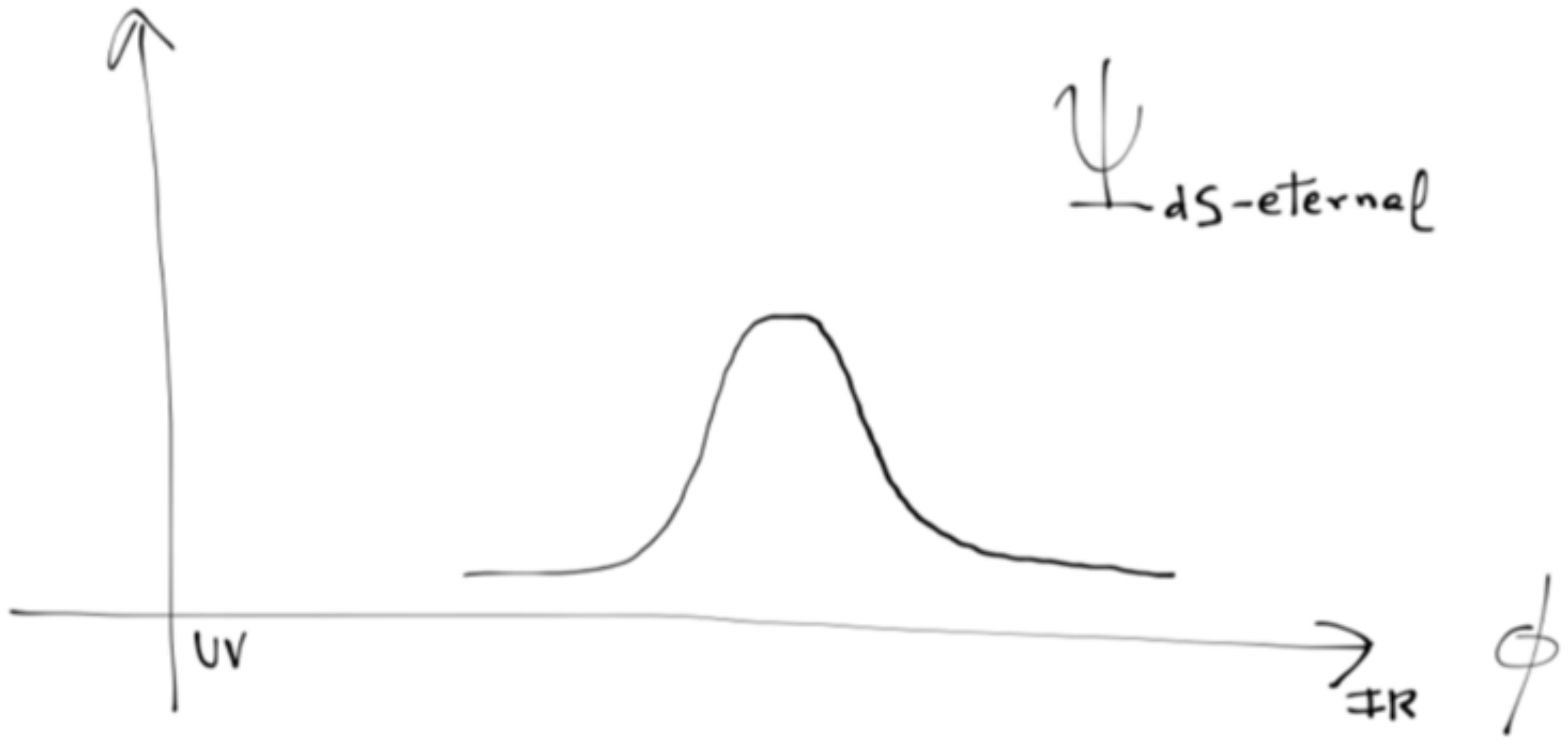
For Candidate Crunches such as

Condensate states stationary in dS

Crunching in E frame

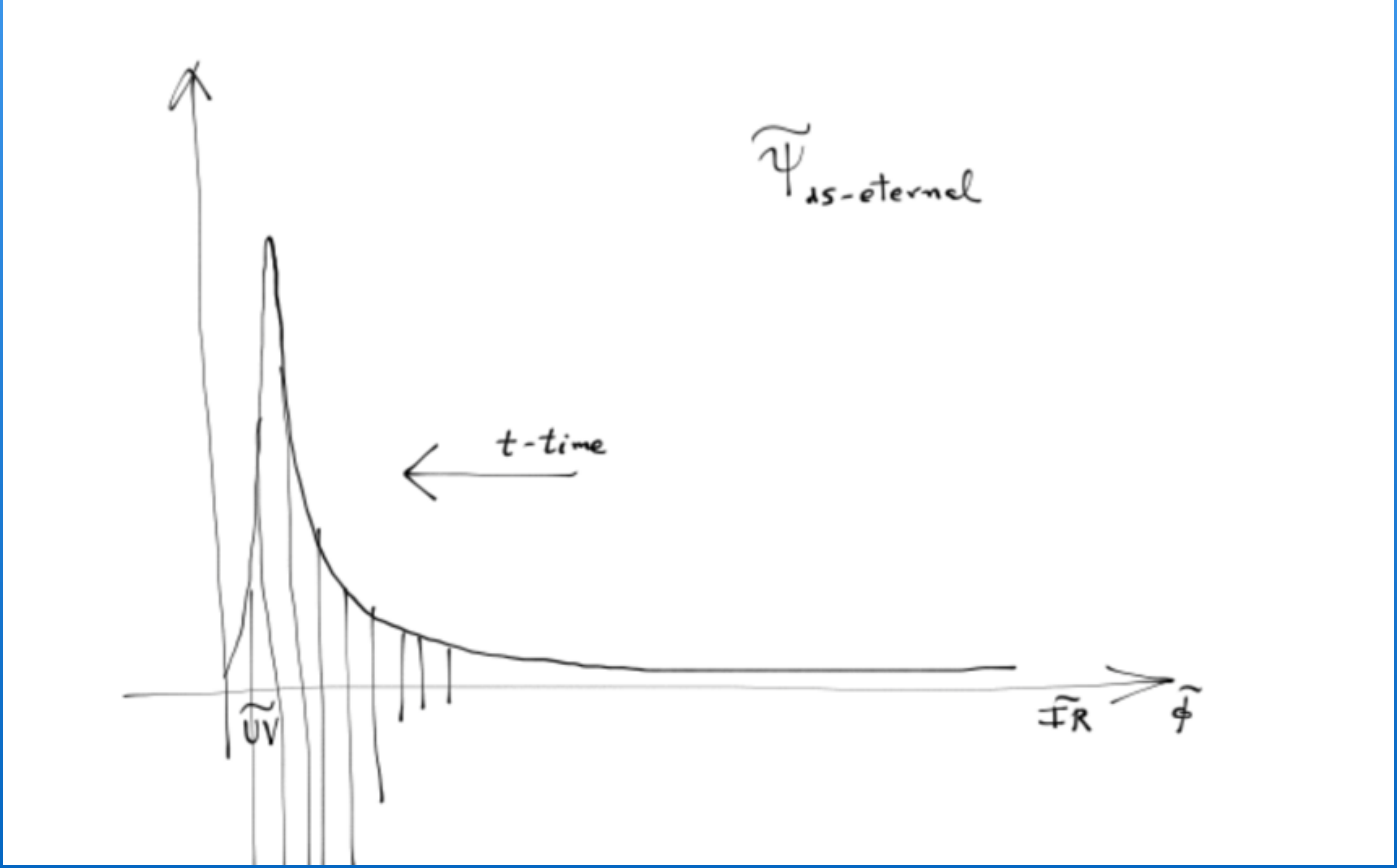
One obtains:

Stationary State in dS



Nothing much happens
Expectation values finite.

In the apocalyptic frame-crunchy contracting in the UV! Expectation values diverge!



In order to further fix the intuition about the meanings of the quantum map, we can consider a smooth τ-static wave function in the eternal quantum mechanics, with width Γ and centered around ϕ_0. Its dual to the apocalyptic frame has a narrowing width $\widetilde{\Gamma}(t) = \Gamma/\sqrt{\Omega(t)}$ as $t \to \pm\alpha\pi/2$, with its center migrating to the origin as $\widetilde{\phi}_0(t) = \phi_0/\sqrt{\Omega(t)}$, while at the same time the phase oscillates wildly. Therefore, the $\widetilde{\Psi}$ wave function is infinitely squeezed into the UV region (small $\widetilde{\phi}$) as we approach the 'apocalypse'.

This Conforms to the Intuition

Potential Energy Expectation Value

For Crunches in the Apocalyptic:

$$\lim_{|t|\to t_\star} \left\langle \widetilde{V}(\widetilde{\phi}\,) \right\rangle_{\widetilde{C}} (t) = -\infty$$

For Bubbles of Nothing

$$\lim_{|t|\to t_\star} \left\langle \widetilde{V}(\widetilde{\phi}\,) \right\rangle_{\widetilde{B}} (t) = +\infty \ .$$

For the Kinetic Energy

$$\left\langle \tfrac{1}{2}\widetilde{\pi}^{\,2}\right\rangle_{\widetilde{\Psi}} = \Omega(t)\left\langle \tfrac{1}{2}\pi^2\right\rangle_{\Psi} - \frac{1}{4}\partial_t \log\Omega\ \left\langle\{\phi,\pi\}\right\rangle_{\Psi} + \frac{1}{8}\Omega^{-1}\left(\partial_t \log\Omega\right)^2\left\langle\phi^2\right\rangle_{\Psi}$$

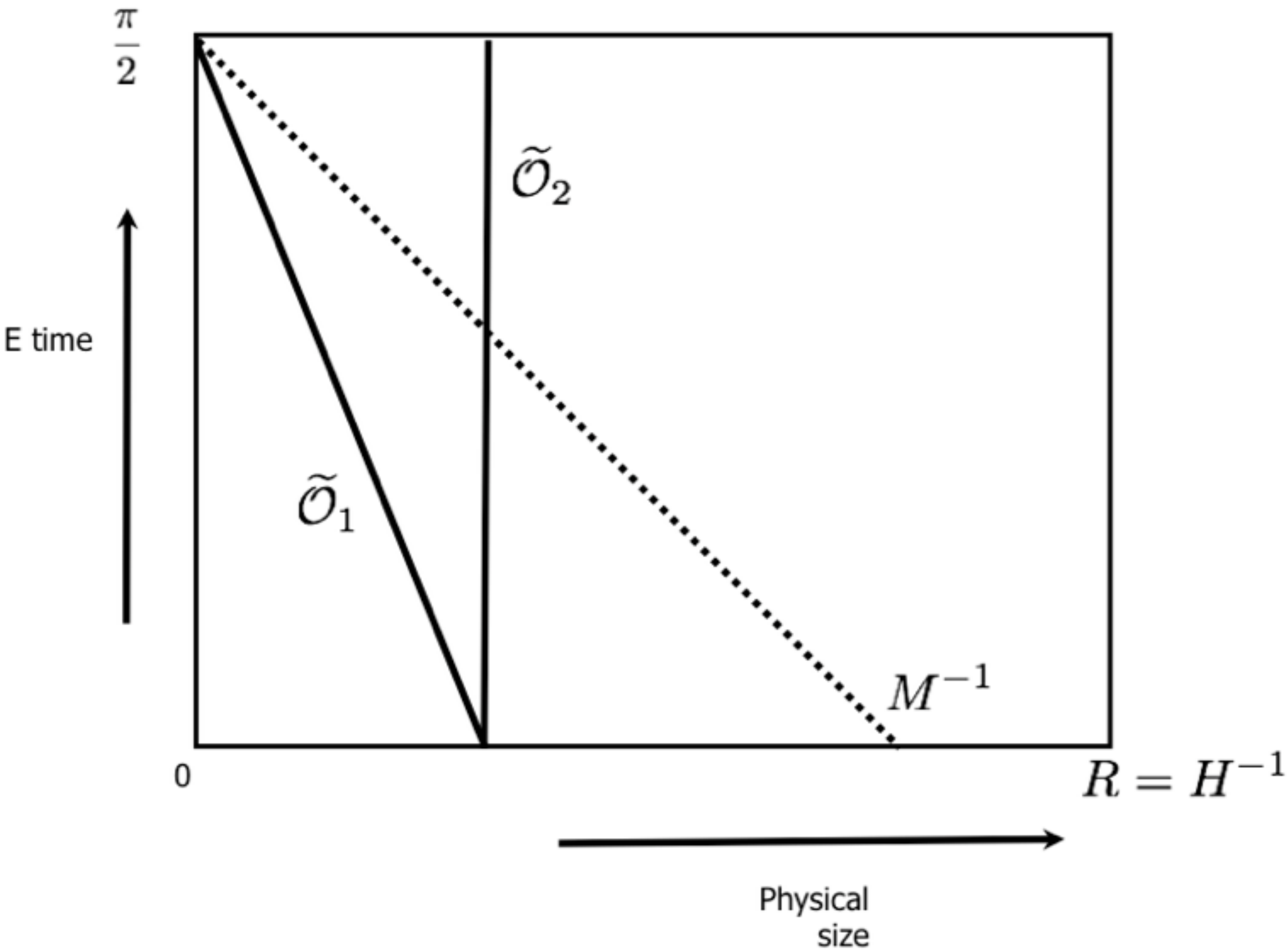
For a condensate-type state in the eternal frame, the three terms in this equation scale as $(t-t_\star)^{-\alpha}$, $(t-t_\star)^{-1}$ and $(t-t_\star)^{\alpha-2}$ respectively. For either the EM or the EdS map, there is always a singular term for generic values of the eternal frame averages, confirming that the eternally stationary state is a singular state in the apocalyptic frame. The anomalous terms (second and third on the right hand side of (5.26)) are subdominant for the EM model ($\alpha = 2$), but have the same scaling as the first term in the EdS case ($\alpha = 1$). [11]

In order to further fix the intuition about the meanings of the quantum map, we can consider a smooth τ-static wave function in the eternal quantum mechanics, with width Γ and centered around ϕ_0. Its dual to the apocalyptic frame has a narrowing width $\widetilde{\Gamma}(t) = \Gamma/\sqrt{\Omega(t)}$ as $t \to \pm\alpha\pi/2$, with its center migrating to the origin as $\widetilde{\phi}_0(t) = \phi_0/\sqrt{\Omega(t)}$, while at the same time the phase oscillates wildly. Therefore, the $\widetilde{\Psi}$ wave function is infinitely squeezed into the UV region (small $\widetilde{\phi}$) as we approach the 'apocalypse'.

This Conforms to the Intuition

Conversely, starting with t-static wave function with fixed width $\widetilde{\Gamma}$ and centered at $\widetilde{\phi}_0$ in the E-frame system, it corresponds to an eternal wave function slipping into the deep IR (large ϕ), trailing the peak at $\phi_0(\tau) = \widetilde{\phi}_0\sqrt{\Omega(\tau)}$, and widening at a rate of order $\Gamma(\tau) = \widetilde{\Gamma}\sqrt{\Omega(\tau)}$.

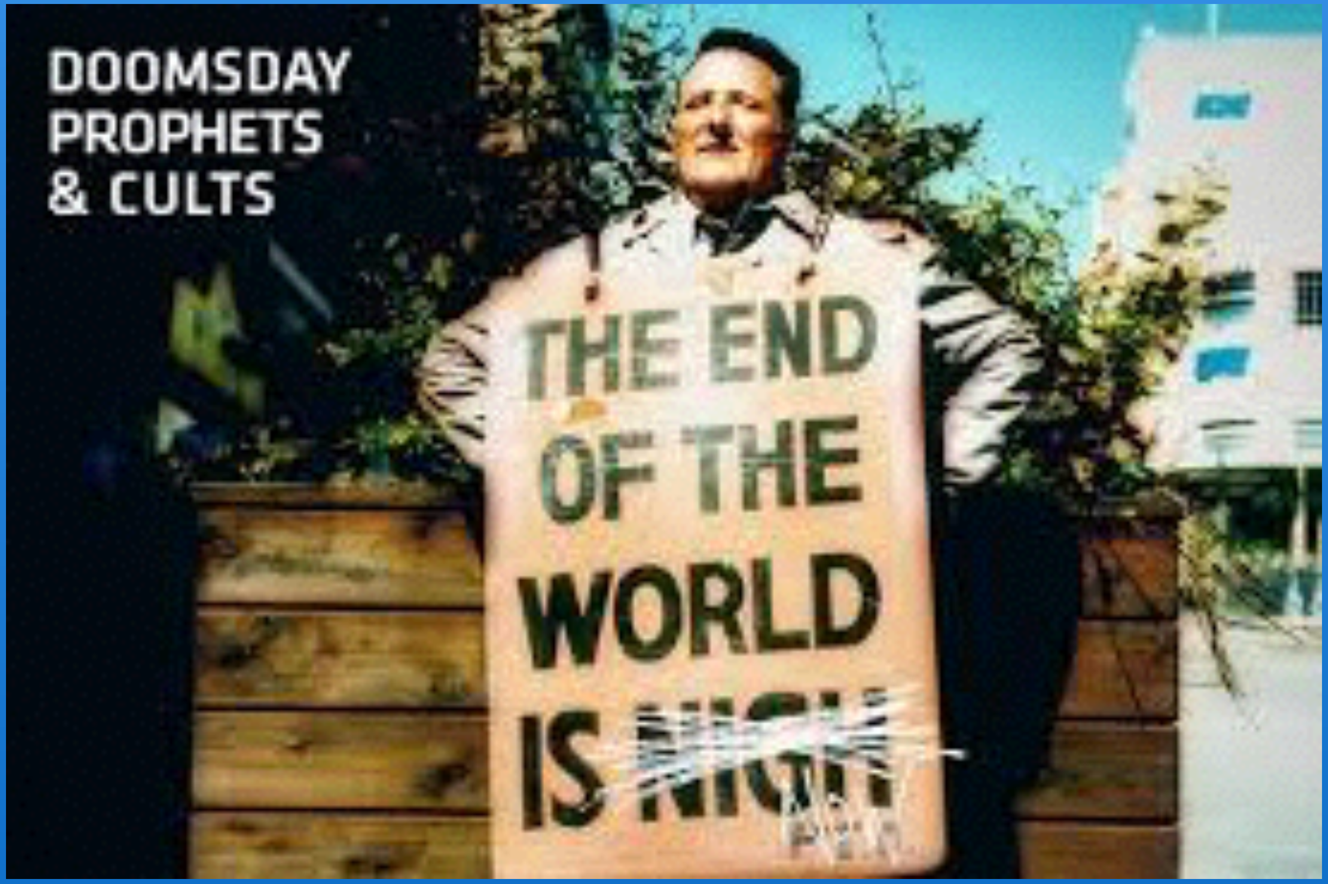
Length scales of complete quantum state in E variables, as a function of E time



T Duality : Is R large or small ?

Locality -Winding modes

Non Local Observers



RESULT:

$$\widetilde{H} = \frac{1}{2}\,\widetilde{\pi}^{\,2} + \frac{1}{2}\,\widetilde{\omega}^{\,2}\,\widetilde{\phi}^{\,2} + \widetilde{V}(\,\widetilde{\phi}\,) = \frac{1}{2}\,\Omega^{-1}\,\widetilde{\omega}^{2}\,\phi^{2} + \Omega\,\left(\frac{1}{2}\,\pi^{2} + V(\phi)\right)$$

$$\left[H, \widetilde{H}\right] = 2i\,\mathcal{A}\,D = 2i\,\mathcal{A}\,\widetilde{D}$$

$$D = \tfrac{1}{2}\{\phi, \pi\} = \tfrac{1}{2}\{\widetilde{\phi}, \widetilde{\pi}\} = \widetilde{D}\ .$$

$$\mathcal{A} \equiv \frac{1}{2}\,\left(\Omega\,\omega^{2} - \Omega^{-1}\,\widetilde{\omega}^{\,2}\right)$$

AND IN GENERAL IT DOES NOT VANISH

BUT ON AdS IT DOES VANISH!

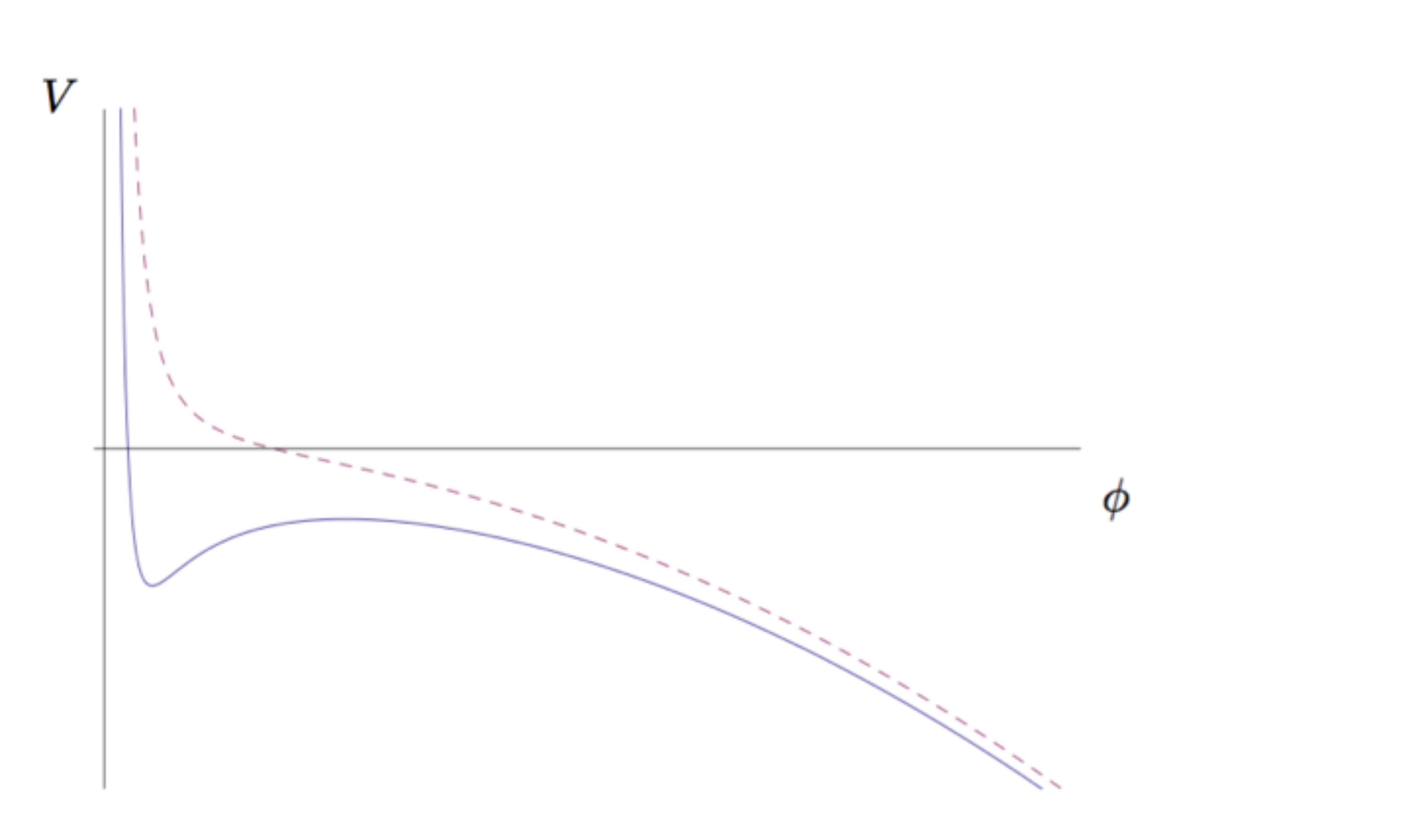
$$\widetilde{H} = \frac{1}{2}\left(\widetilde{\pi}^2 + \frac{\lambda}{\widetilde{\phi}^2}\right) + \frac{1}{8}\widetilde{\phi}^2$$

$$H = \frac{1}{2}\left(\pi^2 + \frac{\lambda}{\phi^2}\right) - \frac{1}{8}\phi^2$$

$$V_\Delta(\phi) = -\frac{M^{1-\Delta}}{\phi^{2\Delta}} \qquad\qquad 0 < \Delta < 1$$

Only Metastable and Give:

Possible healing happens at d=1 CQM where all can be made Quantum?



$$\Psi_{\mathrm{meta}} \approx e^{-\Gamma\tau/2}\Psi_{\mathrm{cond}} + \sqrt{1 - e^{-\Gamma\tau}}\,\Psi_{\mathrm{run}}$$

$$\Psi_{\rm meta} \approx e^{-\Gamma\tau/2}\Psi_{\rm cond} + \sqrt{1-e^{-\Gamma\tau}}\,\Psi_{\rm run}$$

$\widetilde{\Psi}_{\rm cond}$ $\quad e^{-\Gamma\tau/2} \sim |\,t_\star - t\,|^{\Gamma/2}$

$\widetilde{\Psi}_{\rm cond}$ **Contributes to Expectation Values blowing up**

$\Gamma \sim M \exp(-a\, M^{2/3}) \ll 1$ **Semi classically** $\Gamma \ll b$

Depletion not fast enough to avoid crunch

If b of Order 1 there is QUANTUM healing !!!

CONCLUSIONS

New aspects.

There is an Apocalyptic -Eternal Duality.

The Crunch can be seen in the UV.

Must have non-local aspects.

Healing?

Congratulations
Spenta
Many more years of intellectual Stimulation and friendship!