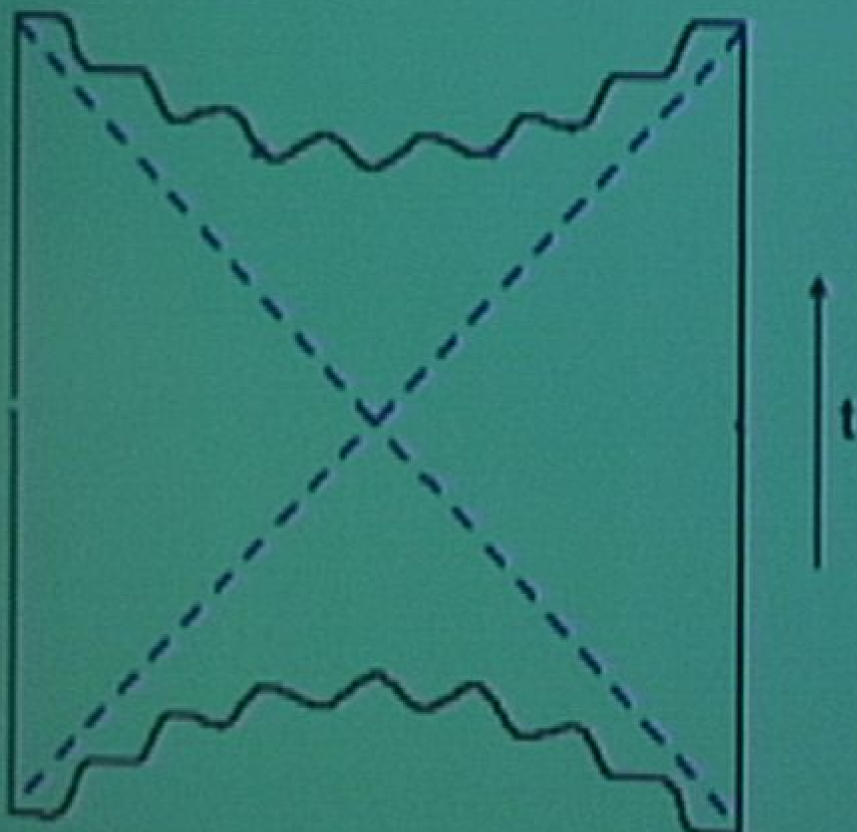
Title: Inside the horizon with holographic Wilsonian RG

Date: Jun 21, 2011 11:00 AM

URL: http://pirsa.org/11060071

Abstract:

AdS Schwarzschild black hole



Certain Super Yang-Mills at finite temperature on S^3.

Example: $\mathcal{N}$=4 SYM with gauge group SU(N)

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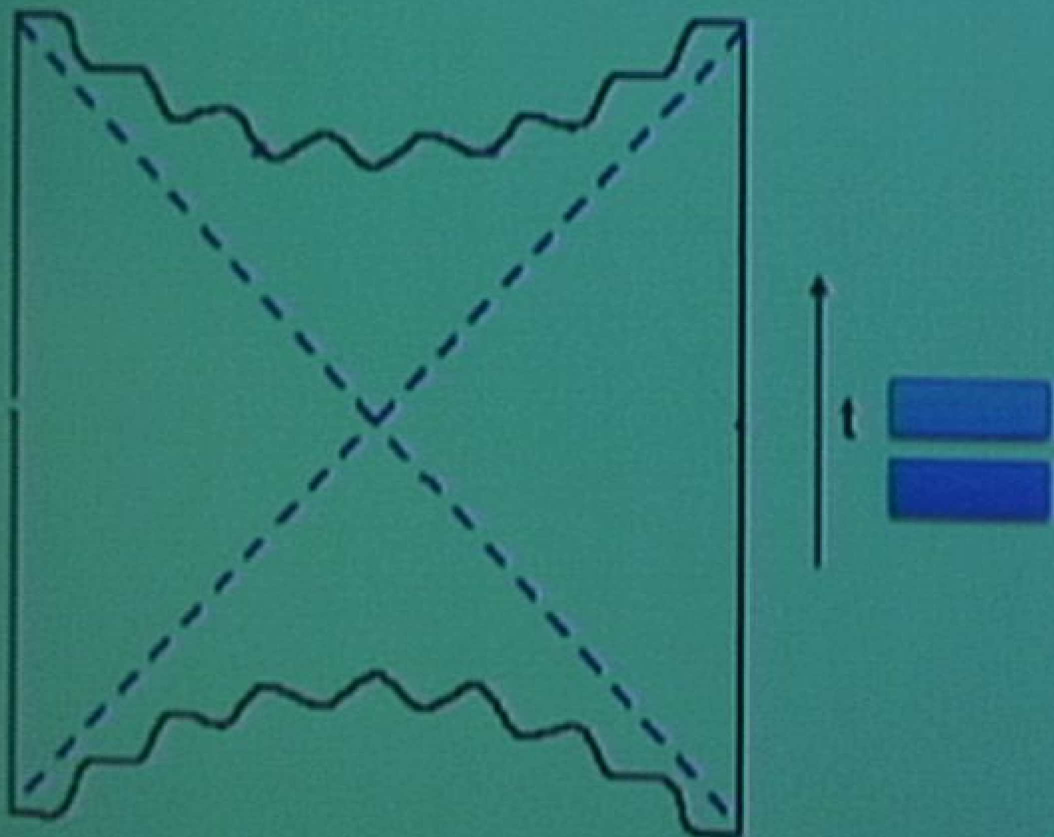

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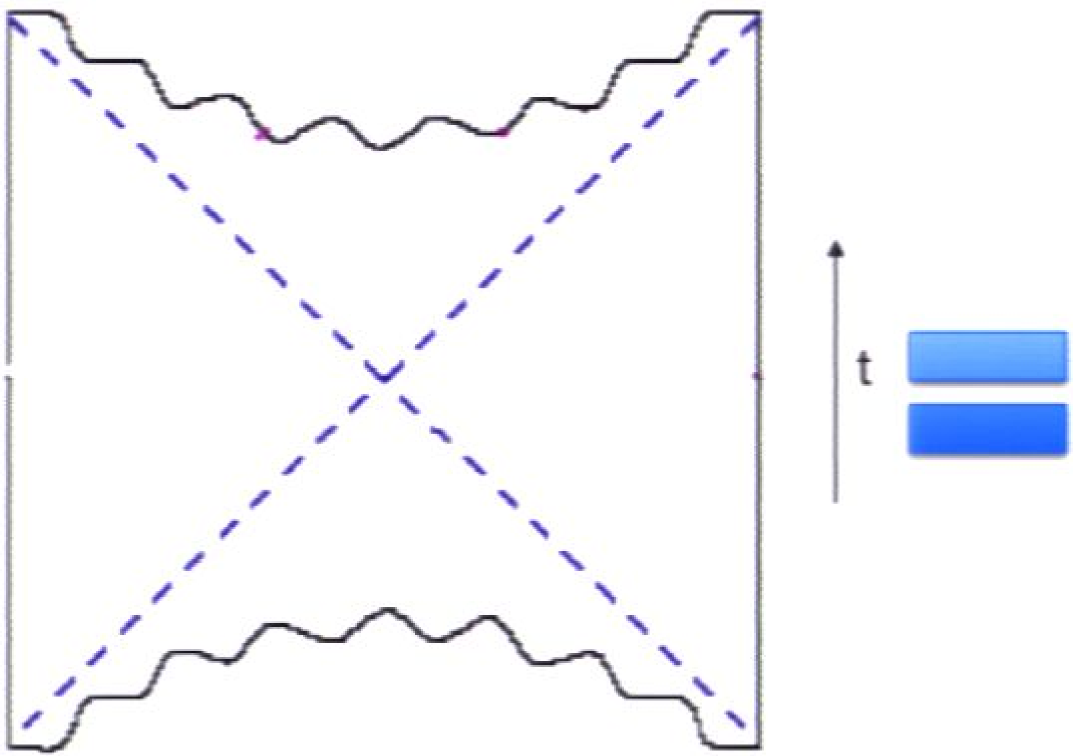

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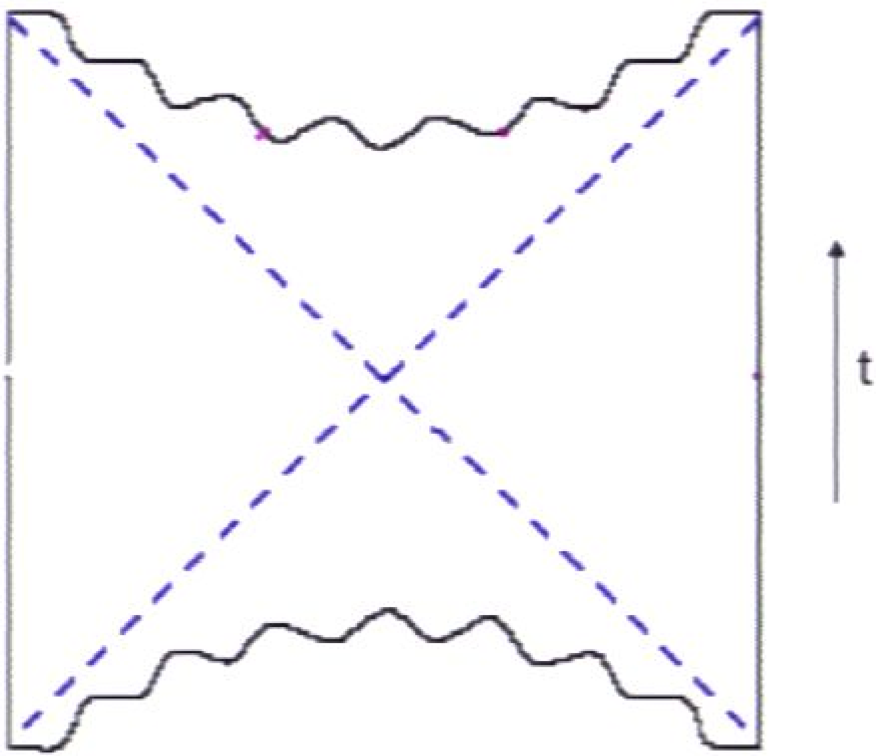

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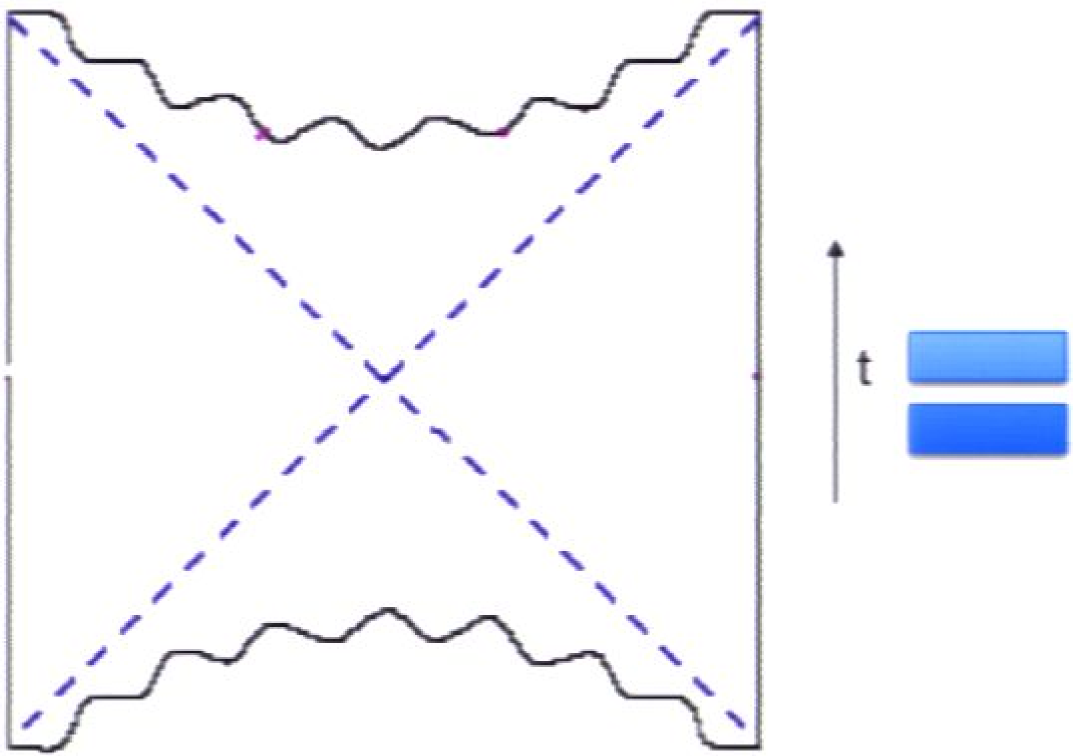

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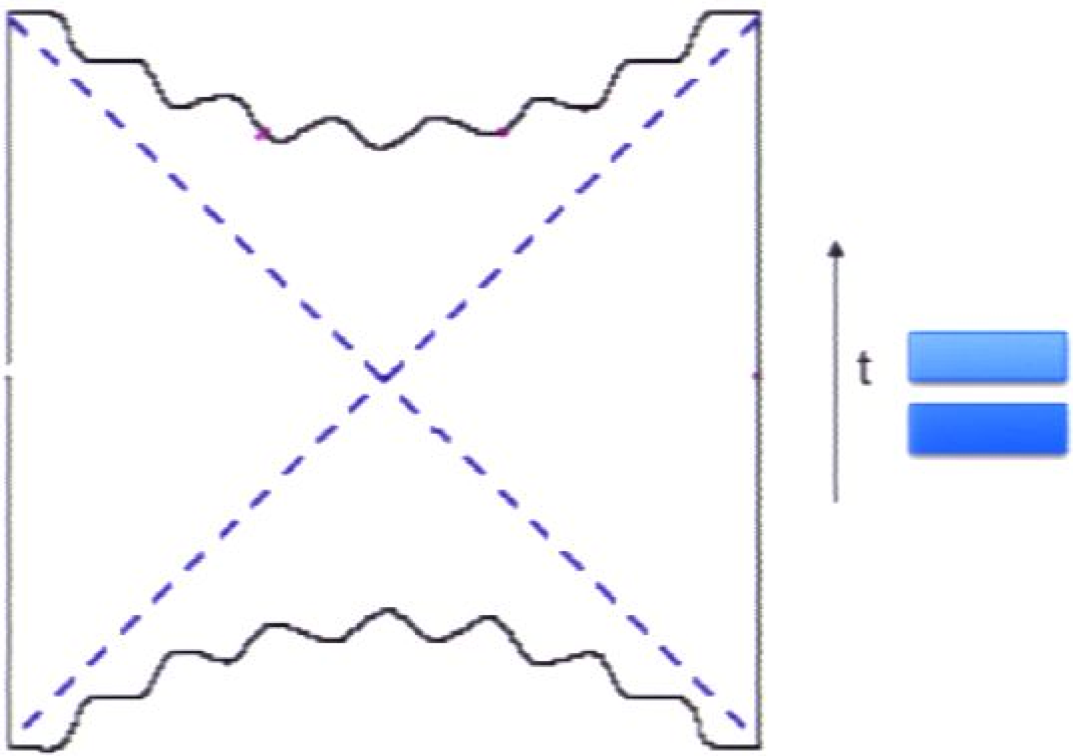

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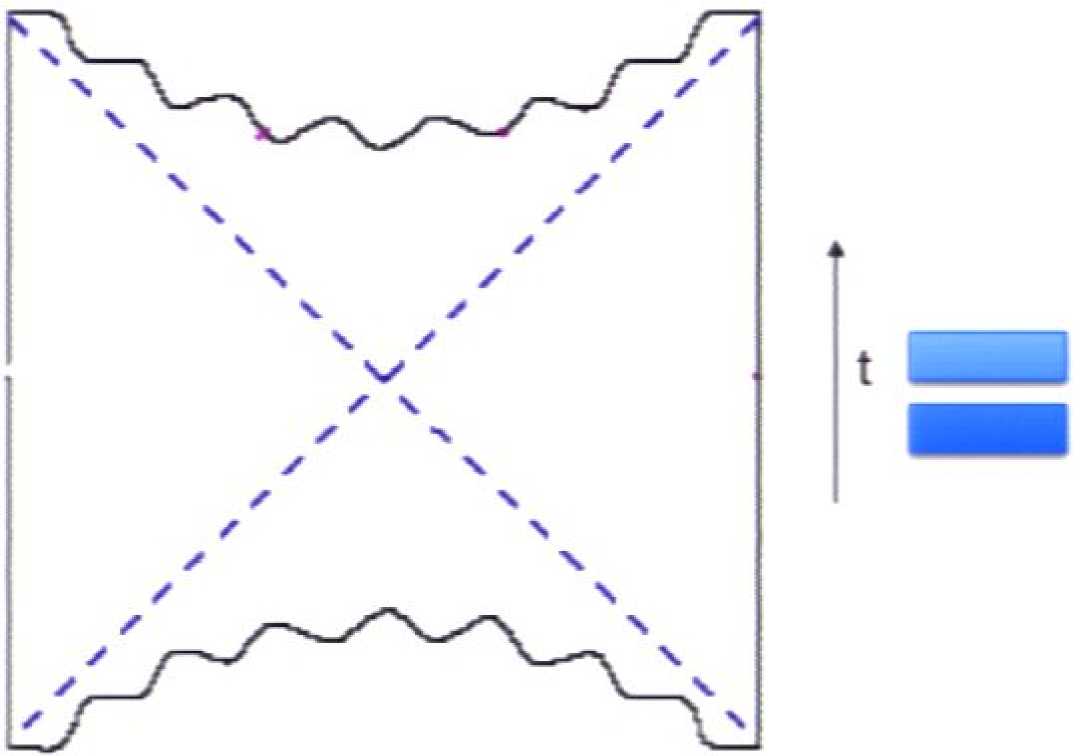

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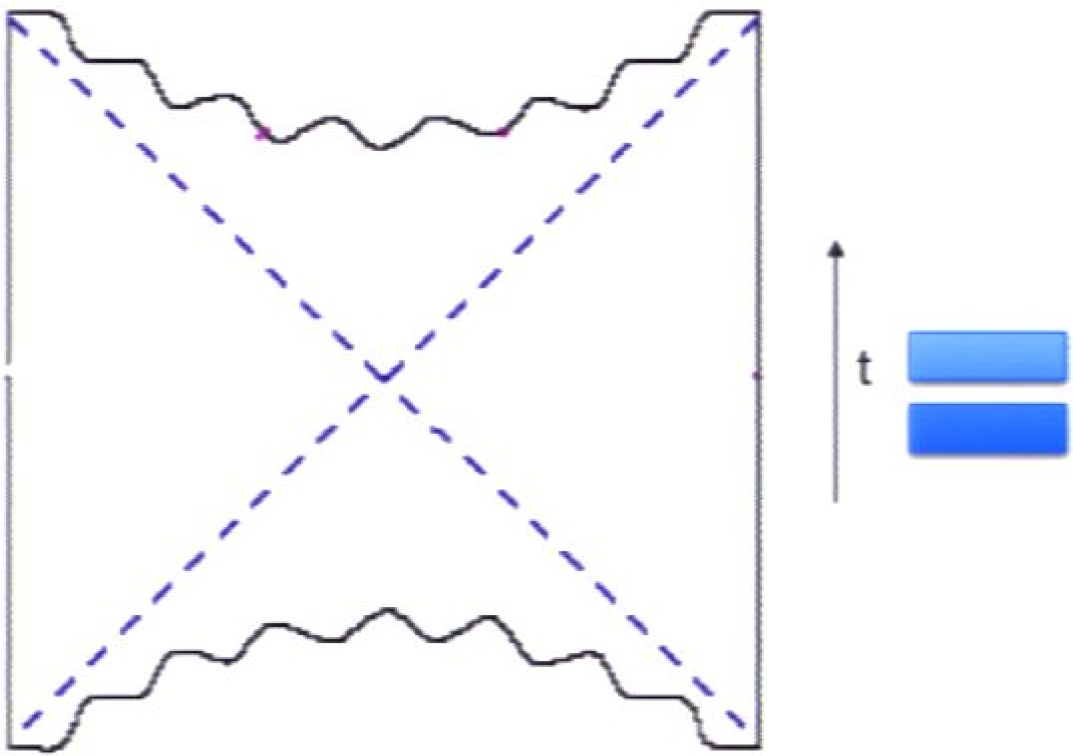

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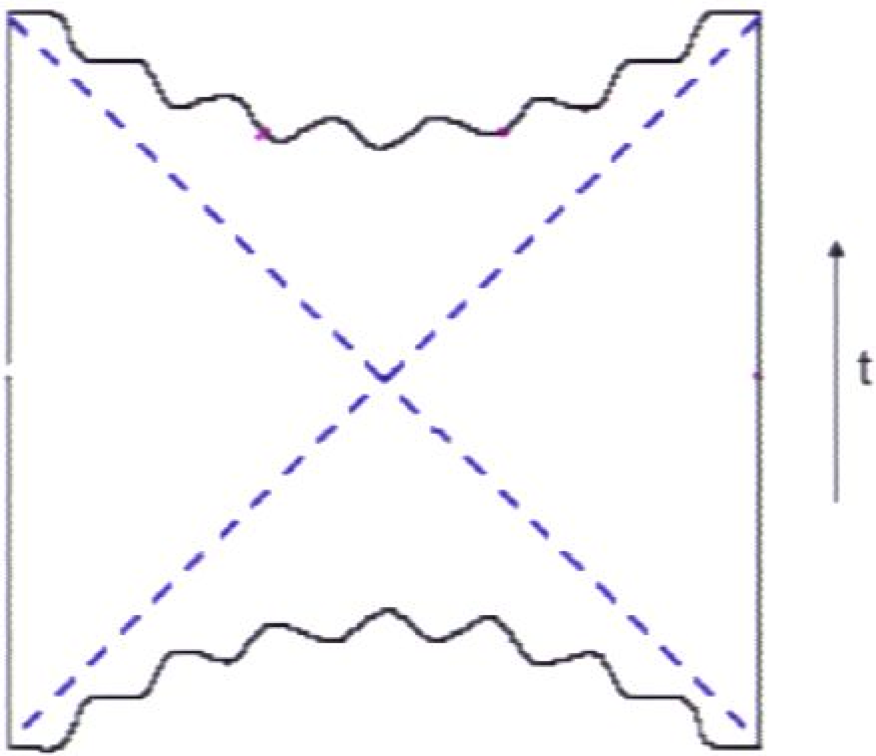

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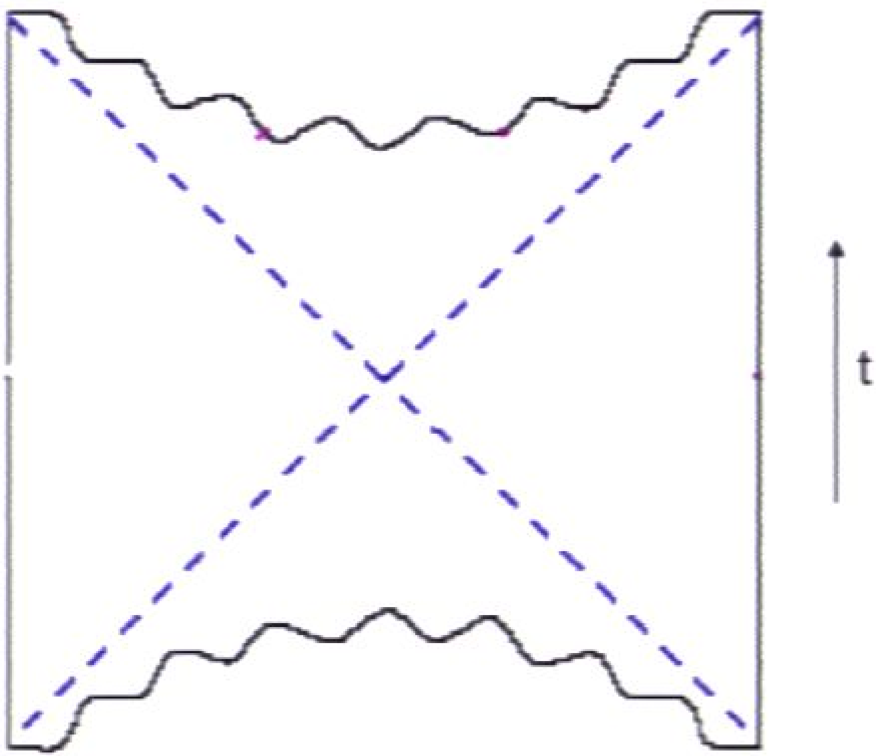

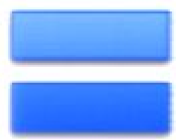

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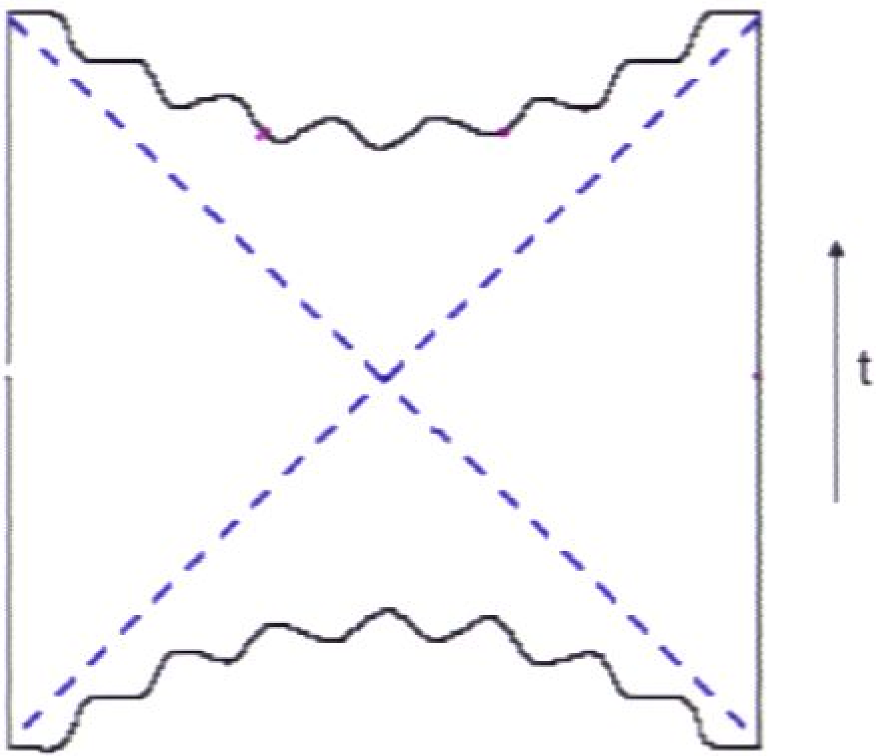

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Plan

- Holographic Wilsonian RG

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- Some speculations on how to describe physics beyond the black hole horizon using AdS/CFT

  Festuccia, HL, hep-th/0506202, hep-th/0611098

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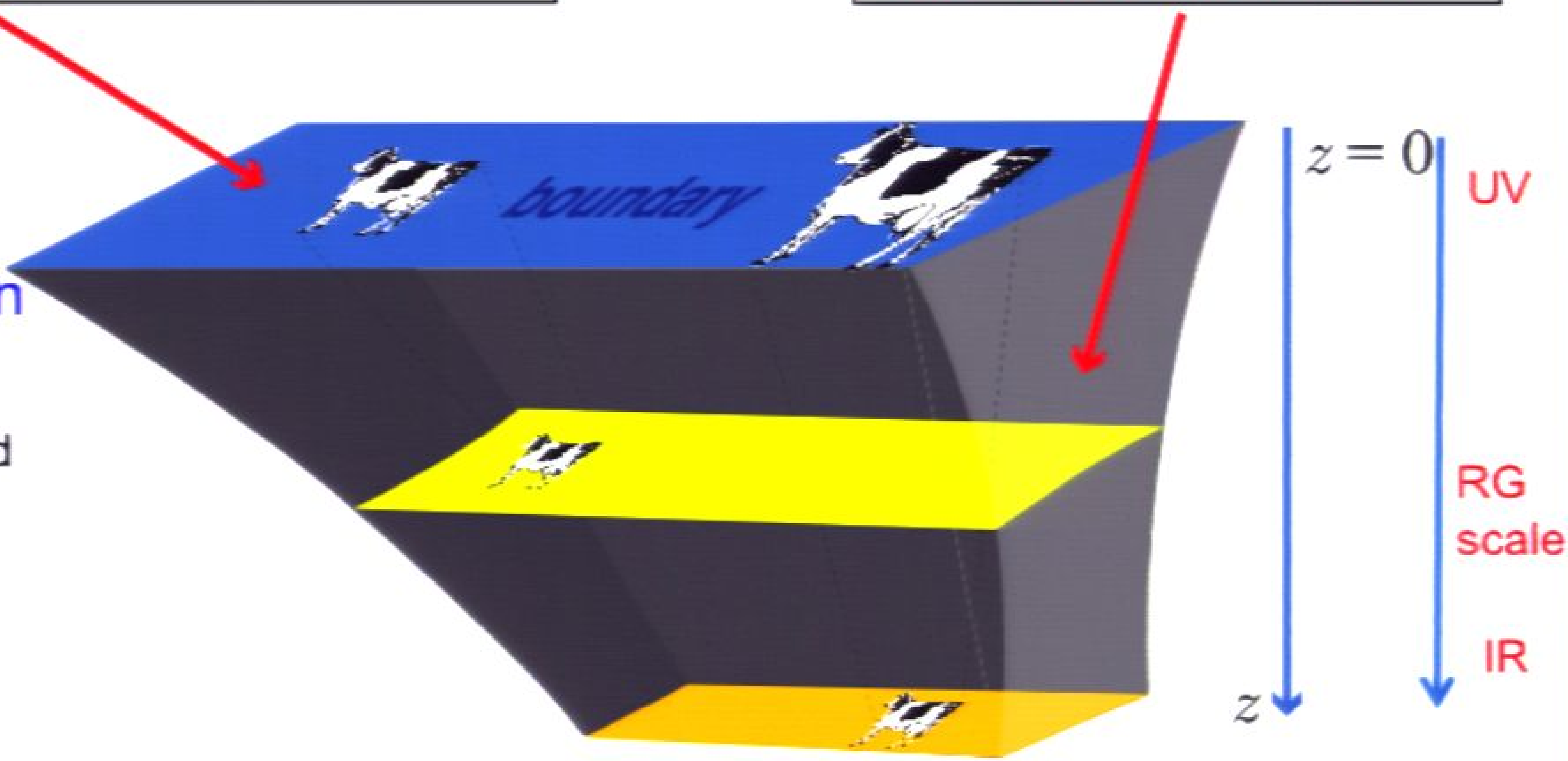

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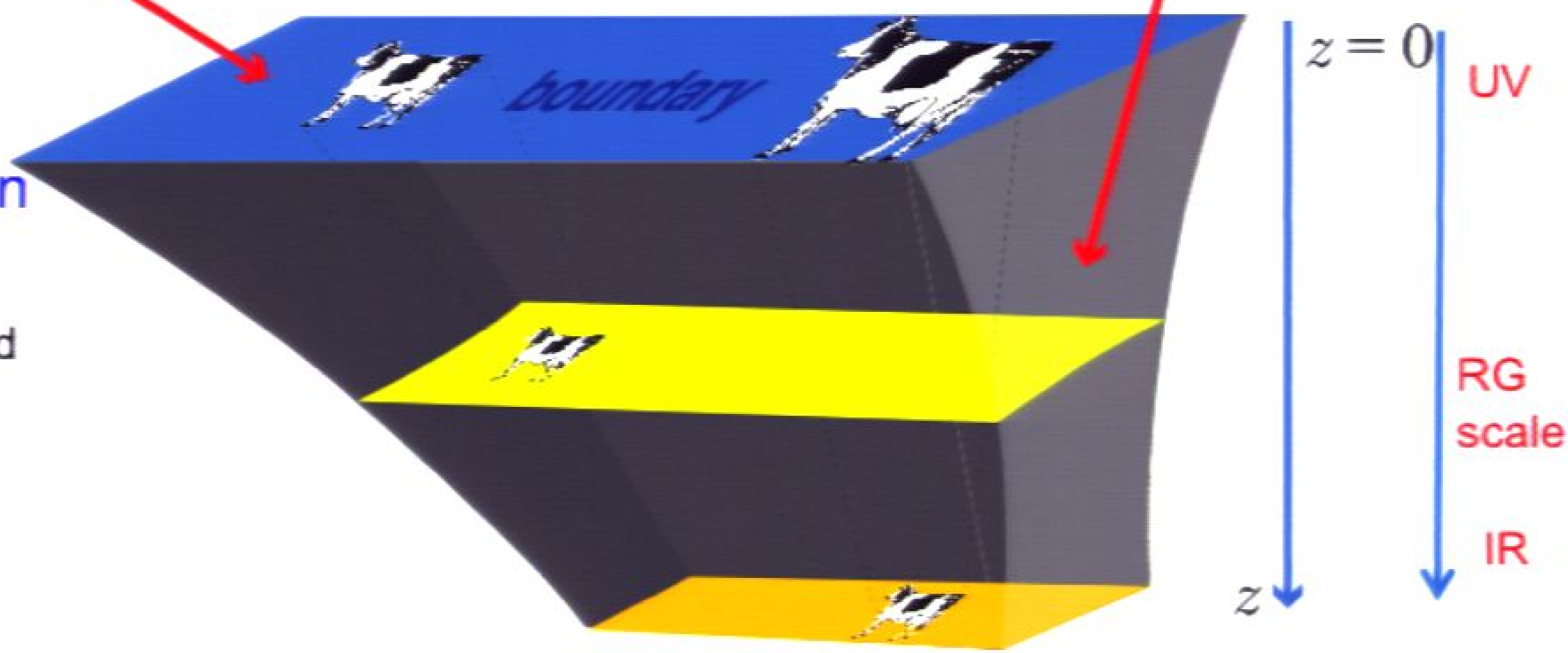

The extra bulk radial direction: geometrization of the renormalization group flow of the boundary system !

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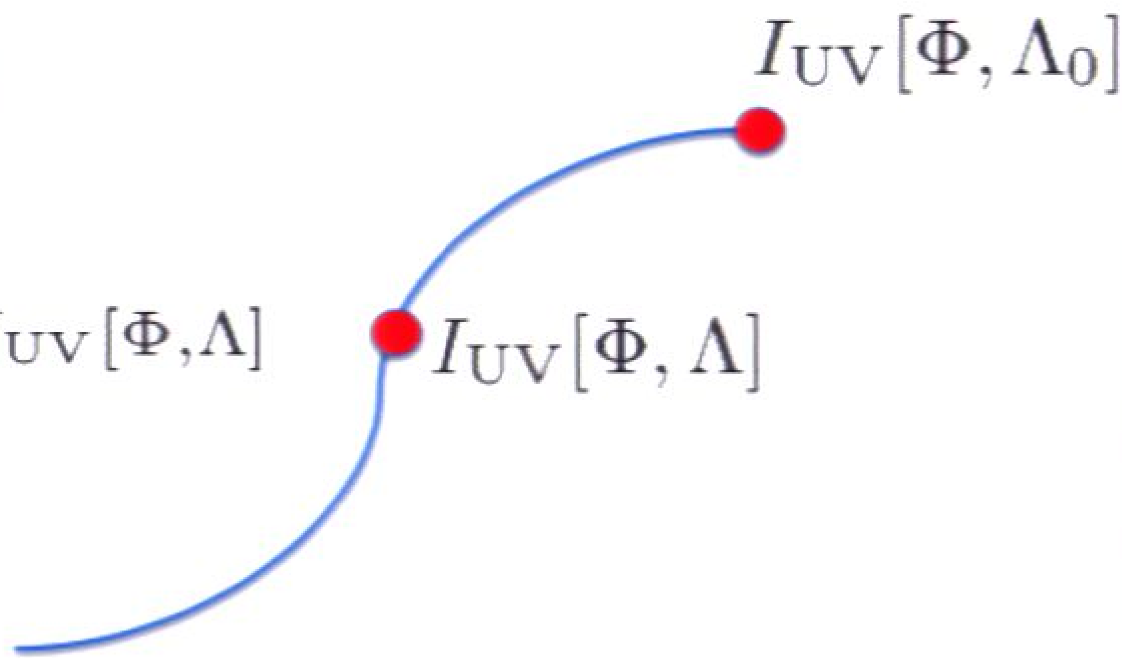

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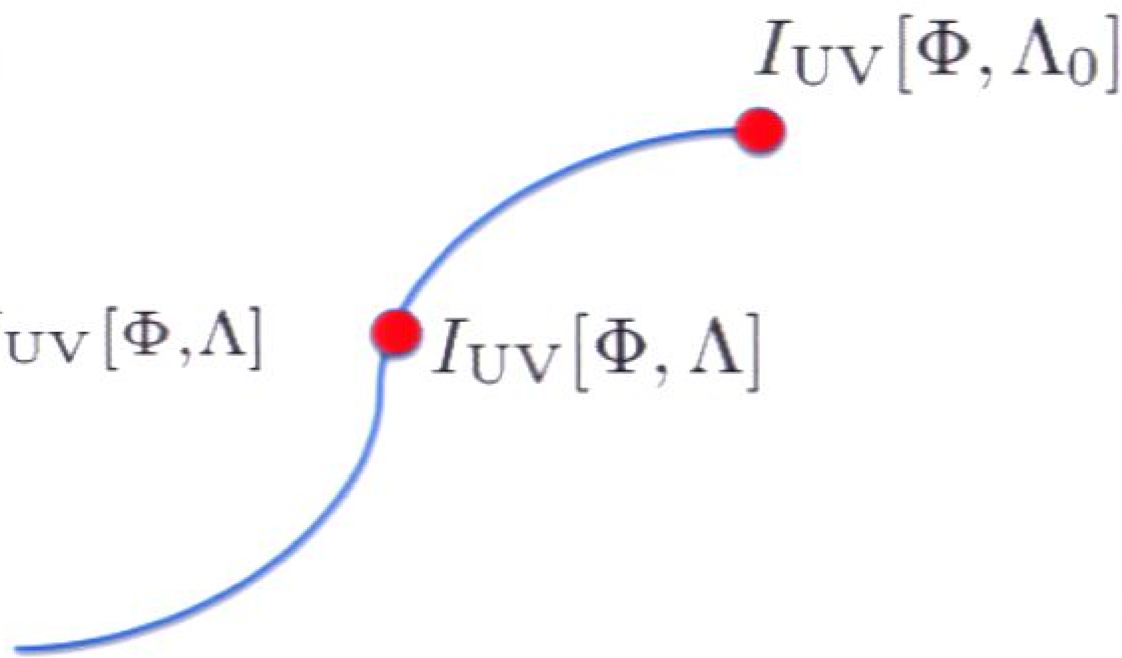

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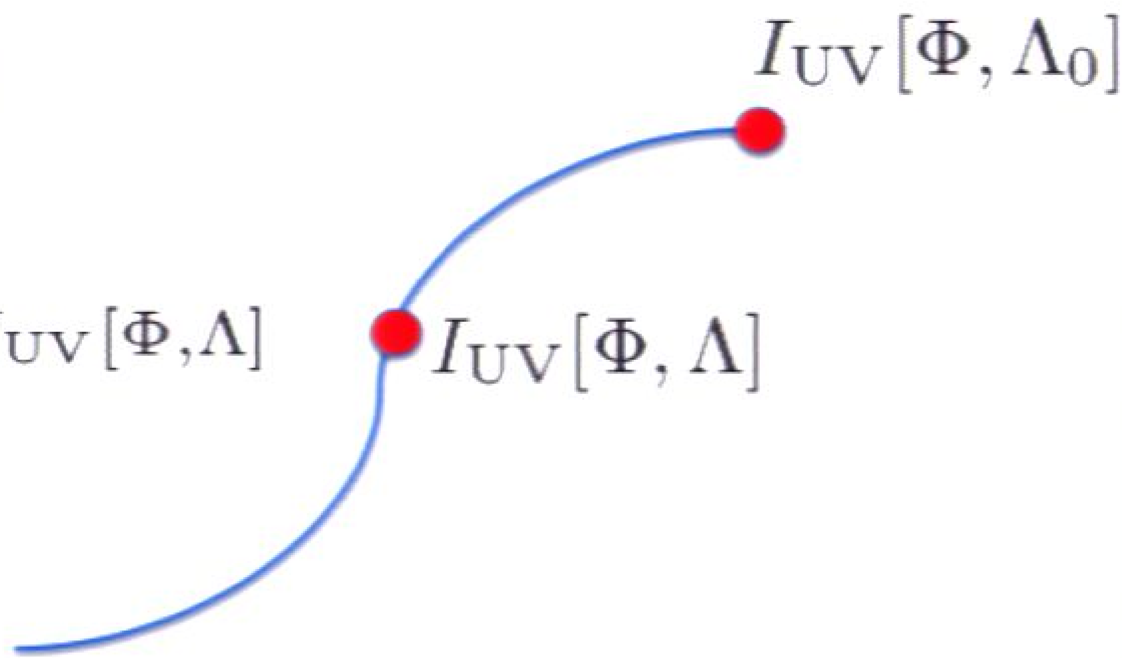

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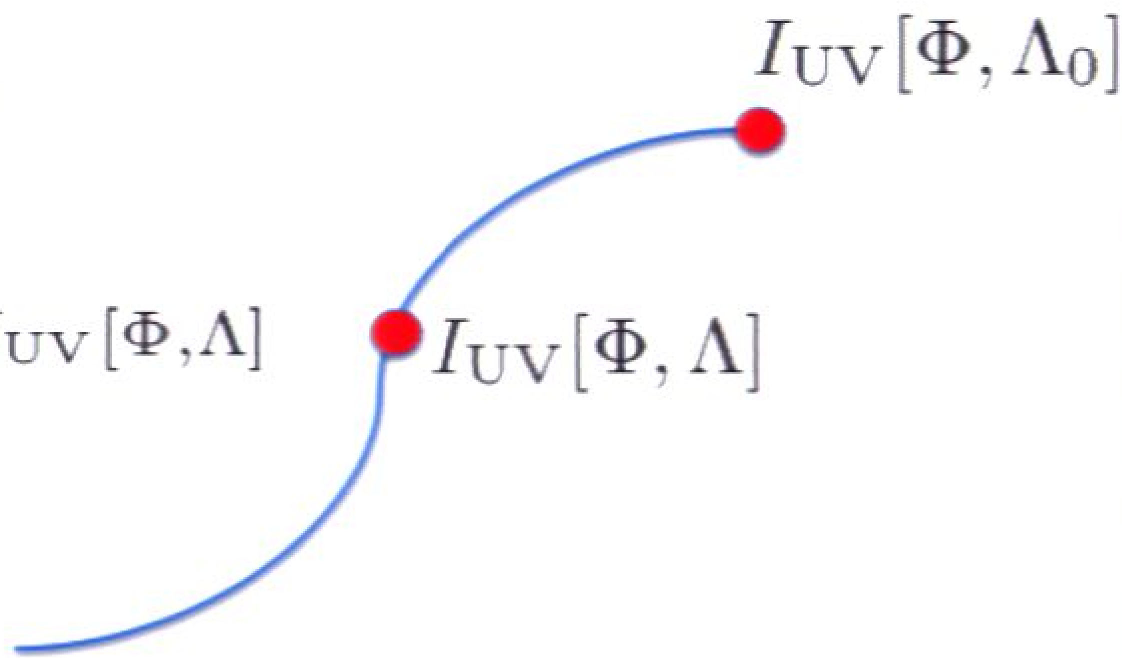

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Will work in the large N limit, i.e. classical bulk gravity.

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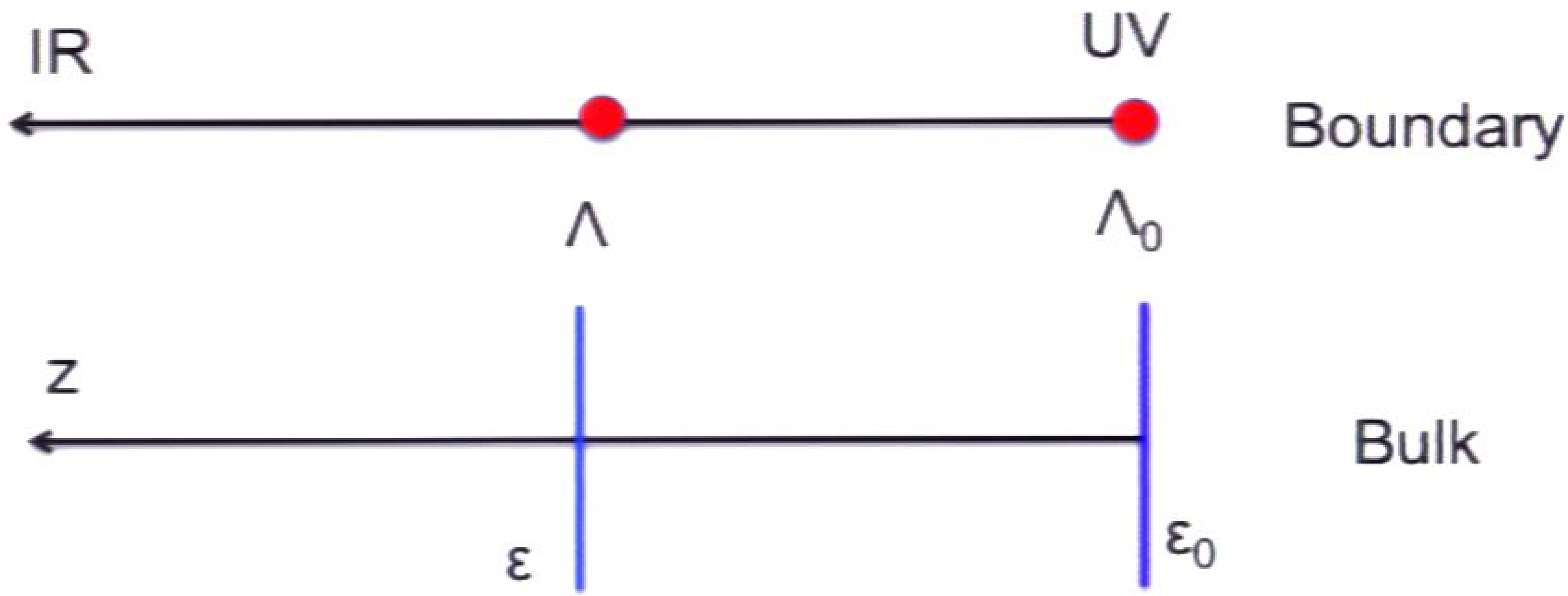

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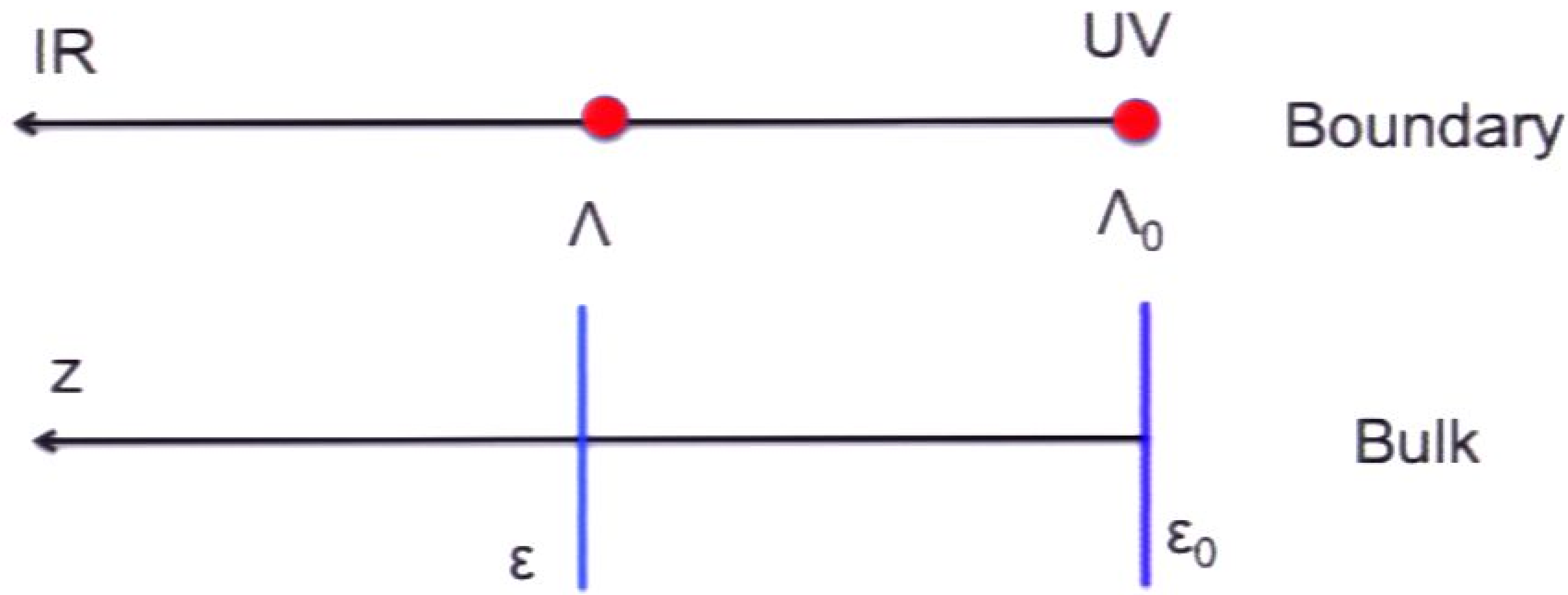

Integrate out bulk d.o.f. in the region $\varepsilon > z > \varepsilon_0$

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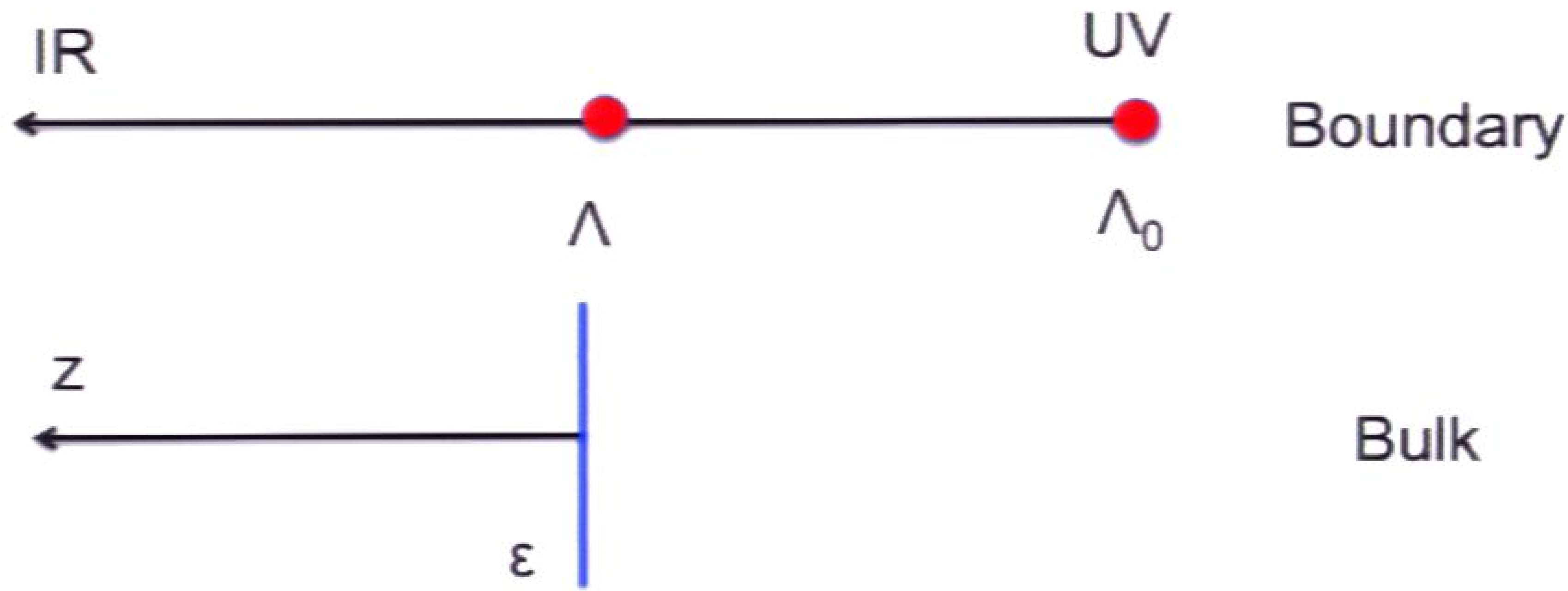

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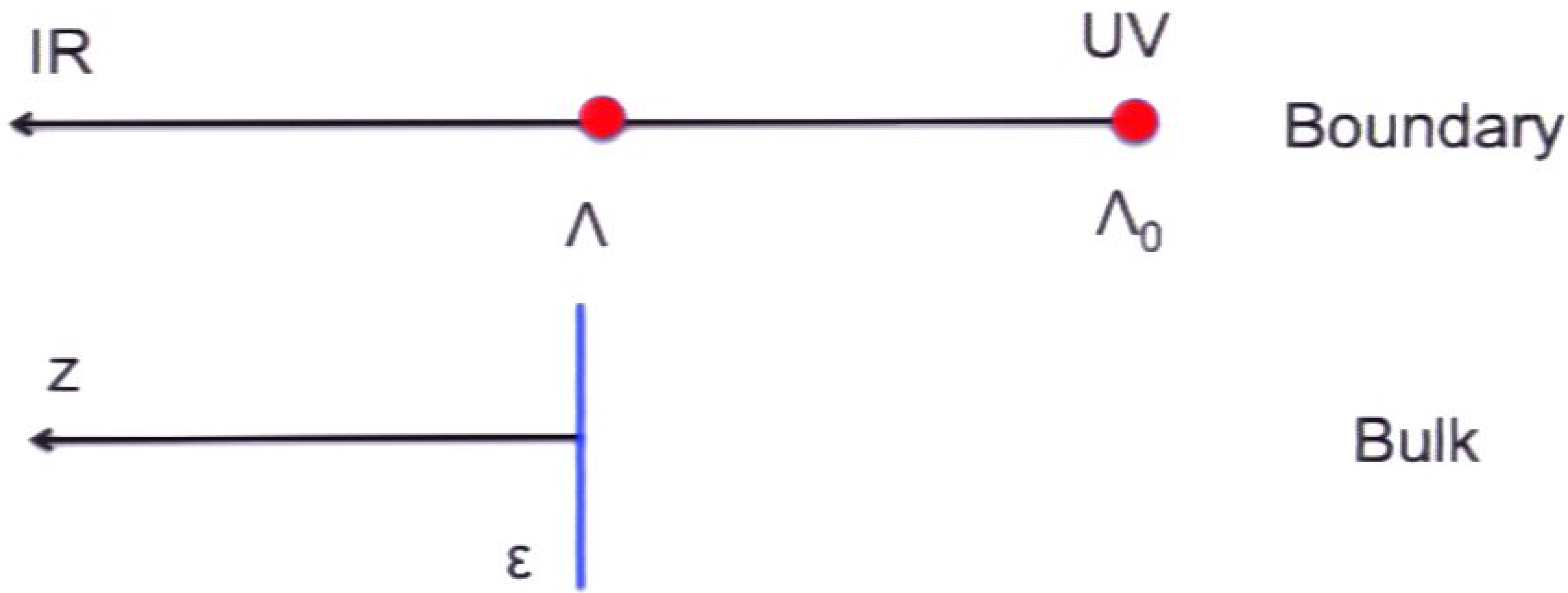

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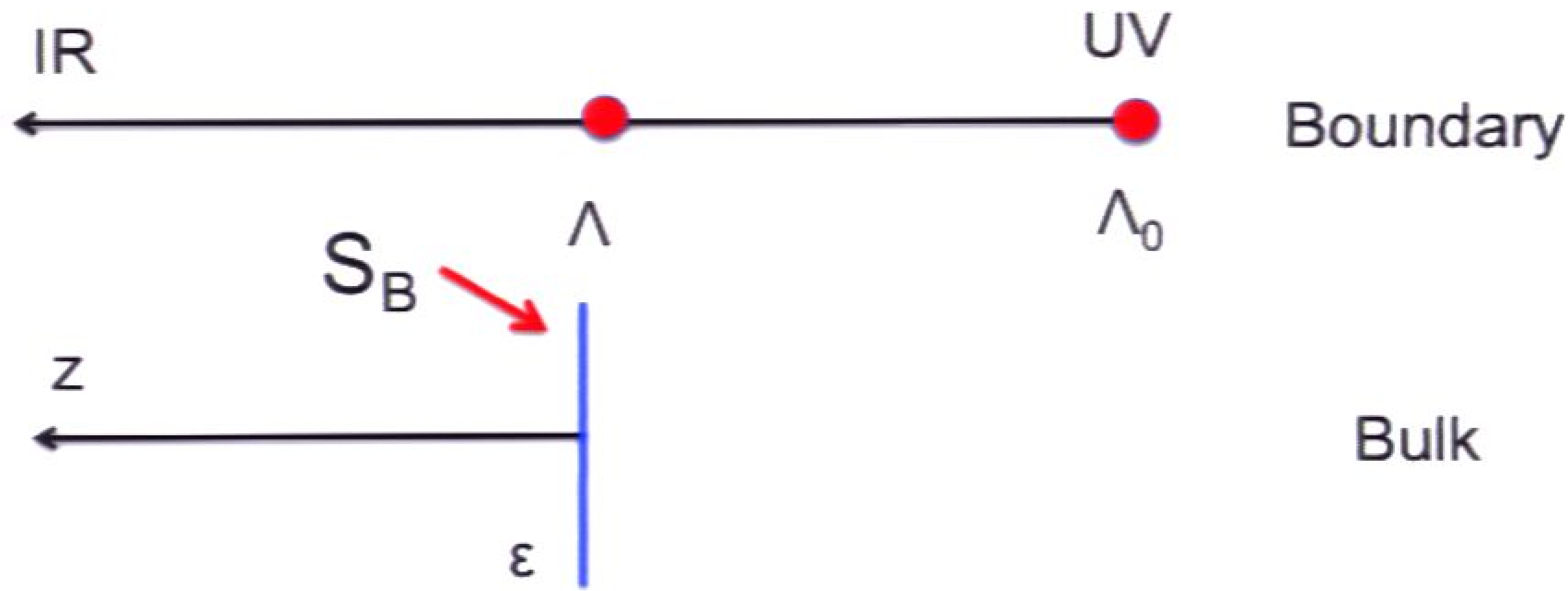

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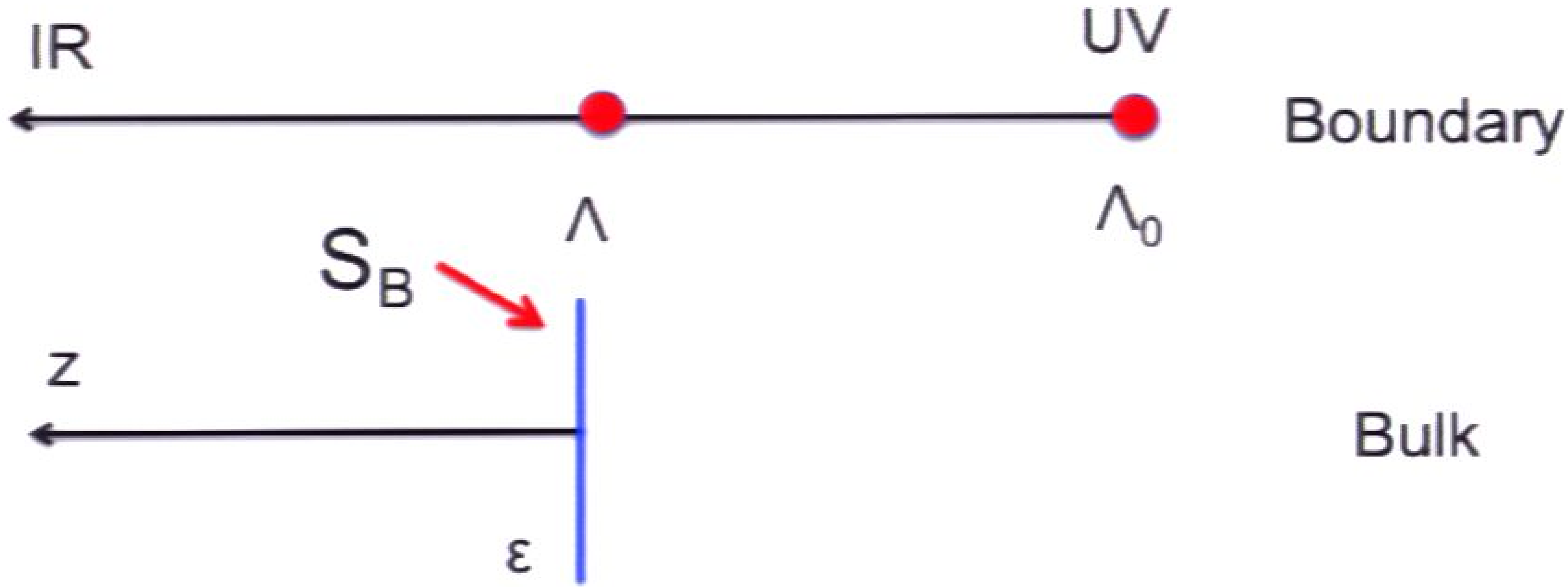

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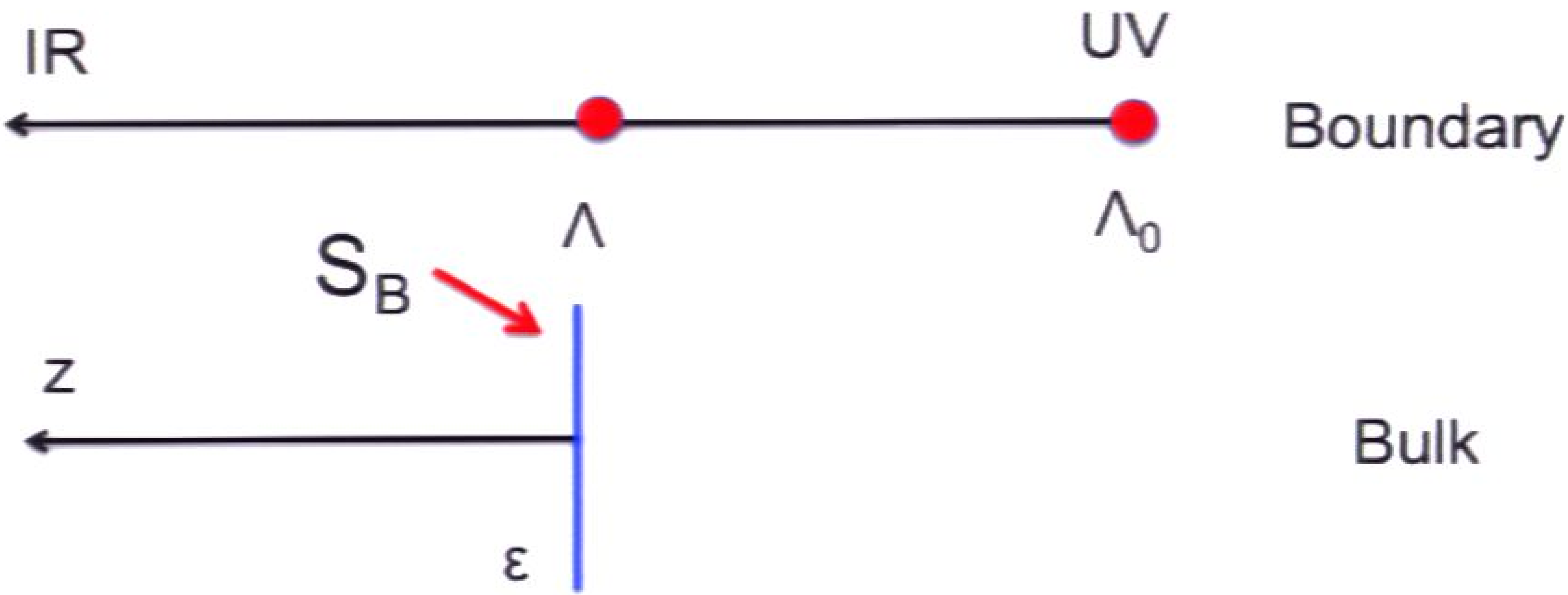

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Consistent with field theory expectations. Miao Li (2000)

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Semi-classical limit: Hamilton-Jacobi equation

$$\partial_\epsilon S_B[\phi,\epsilon] = -\int_{z=\epsilon} d^d x\, H\left(\phi, \Pi = \frac{\delta S_B}{\delta \phi}\right)$$

H: bulk Hamiltonian corresponding to z-foliation.

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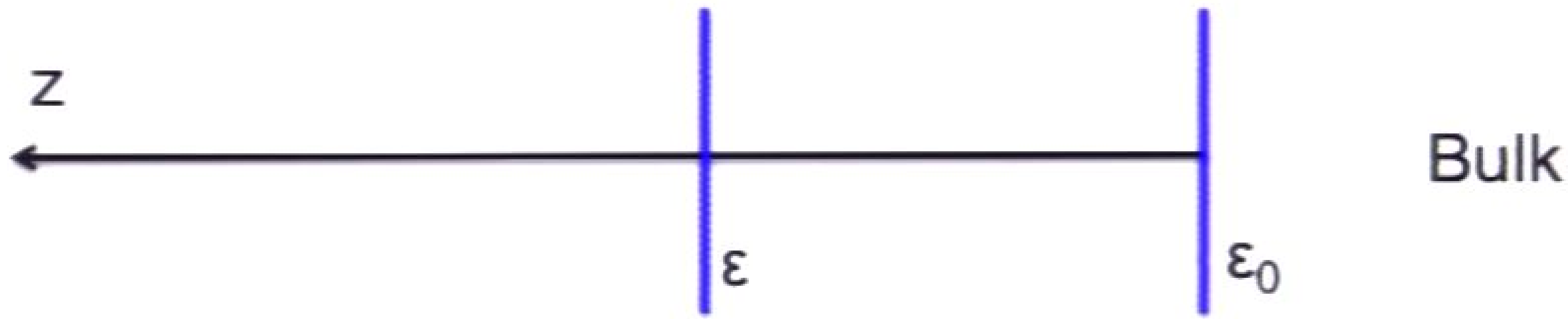

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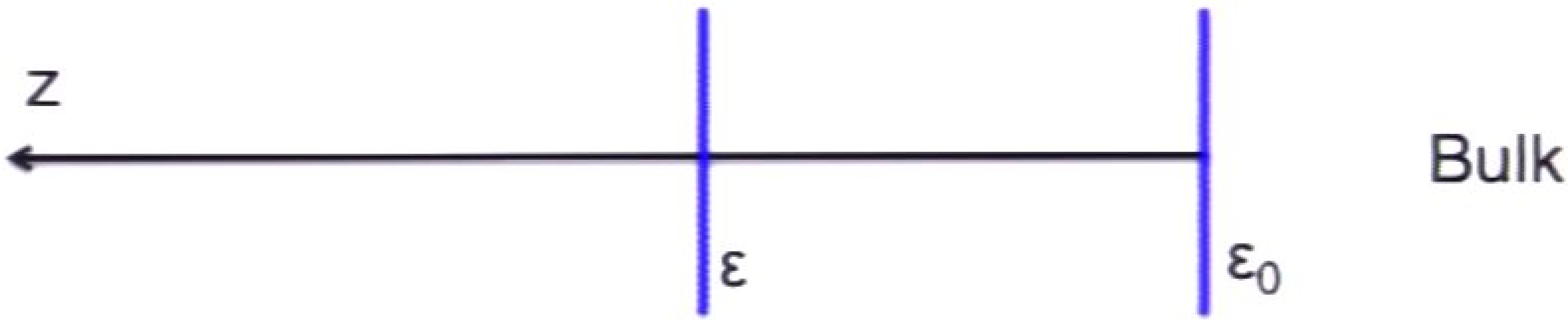

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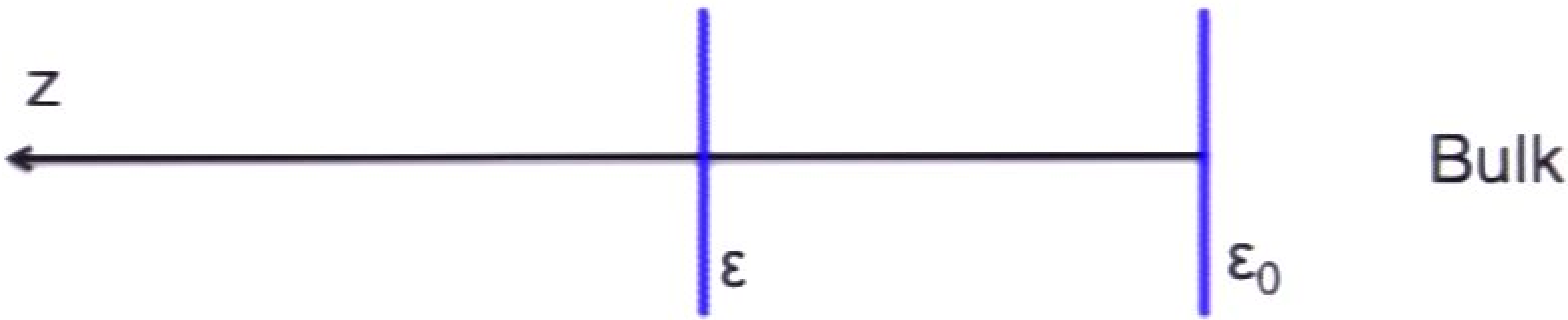

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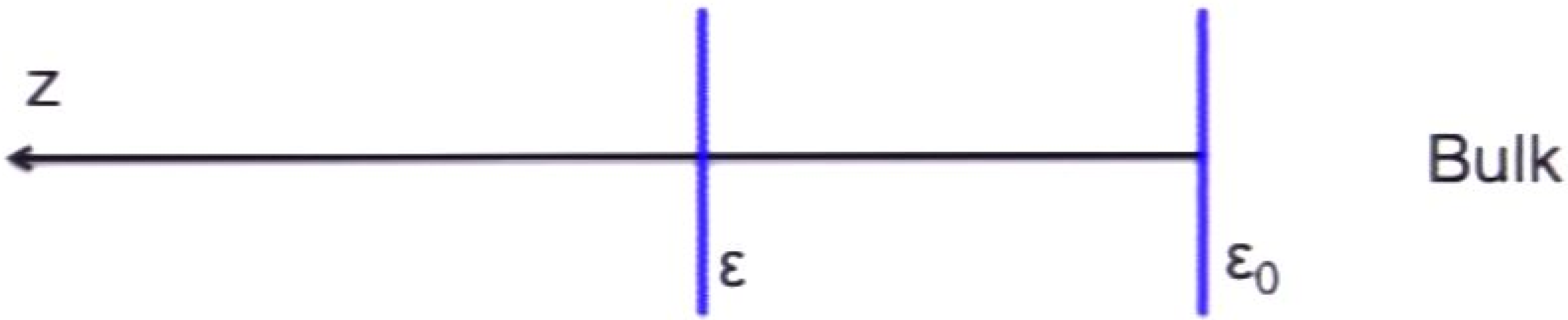

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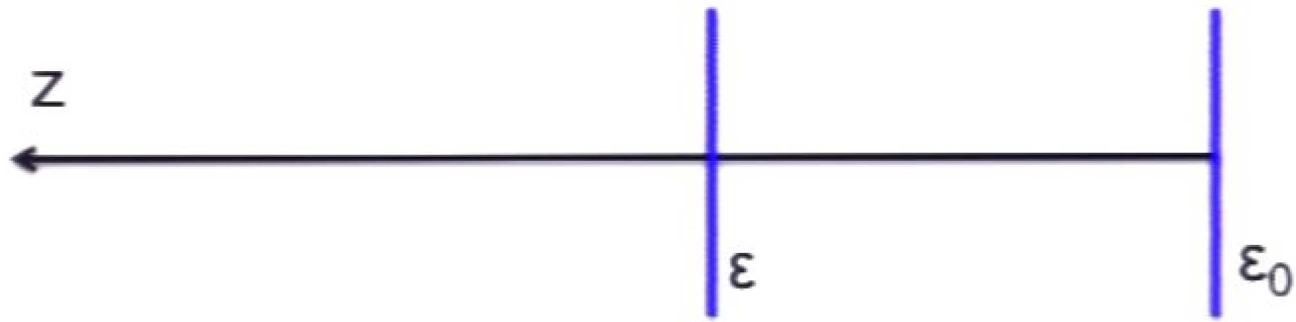

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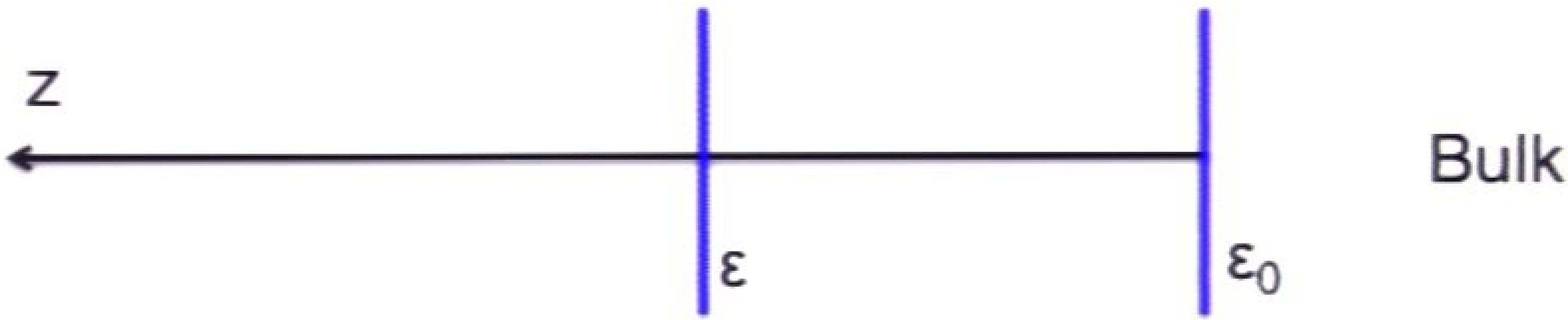

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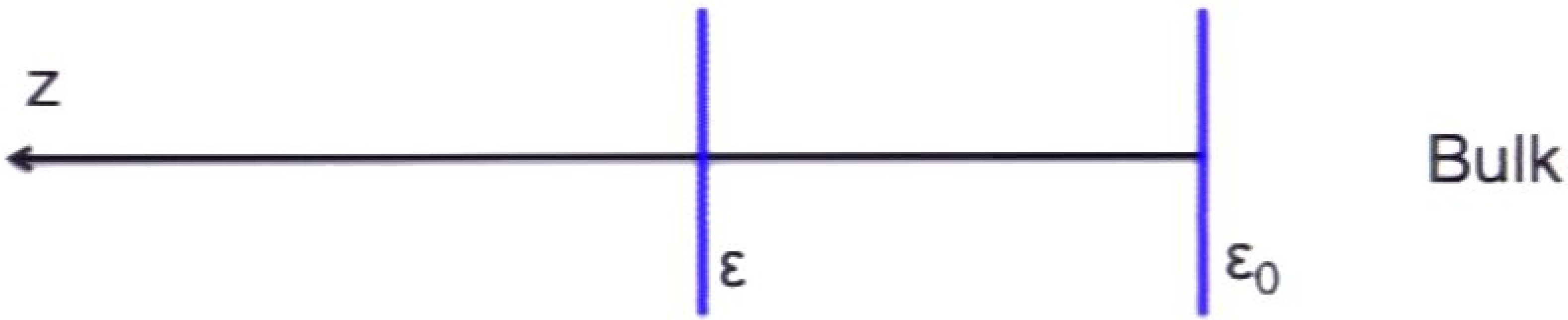

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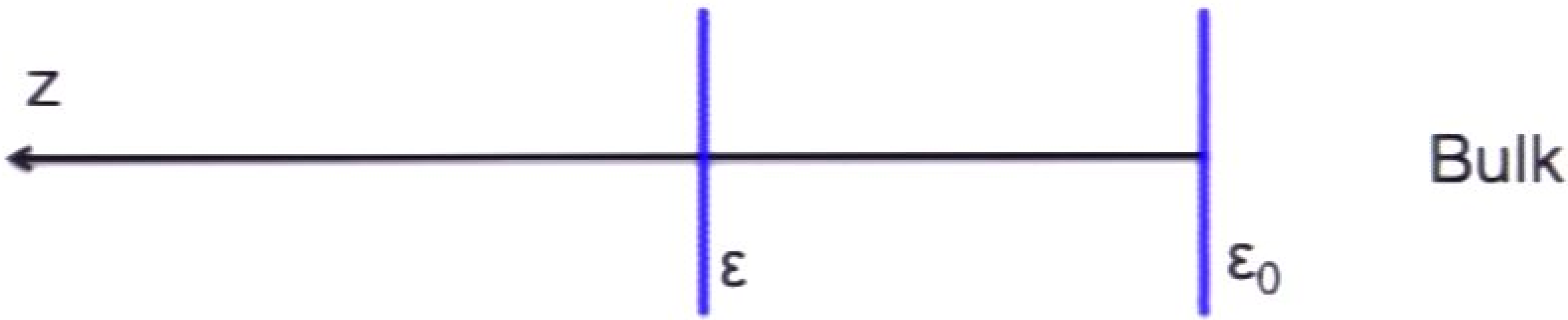

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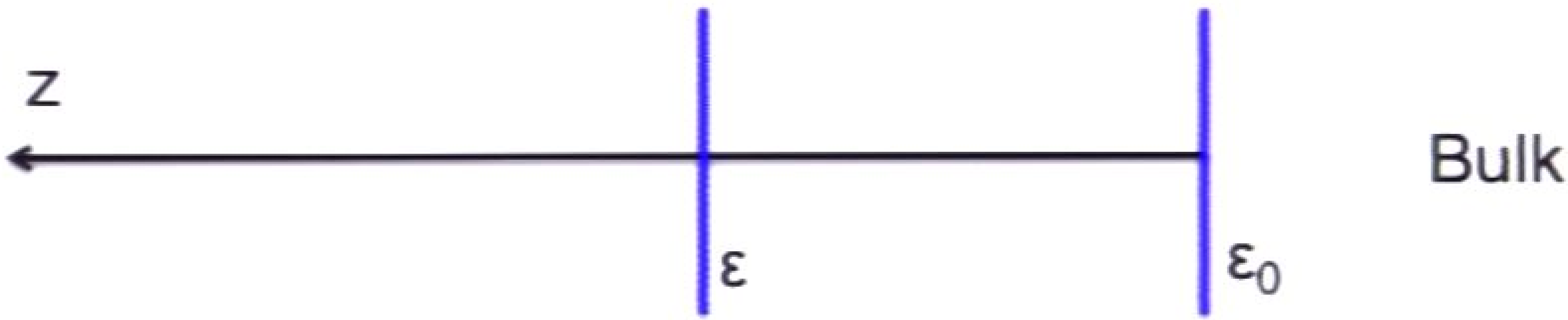

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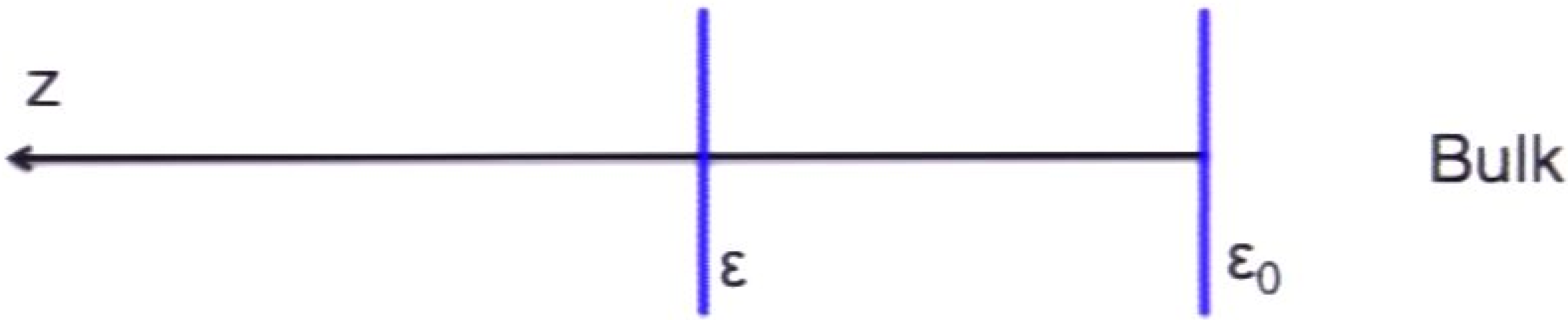

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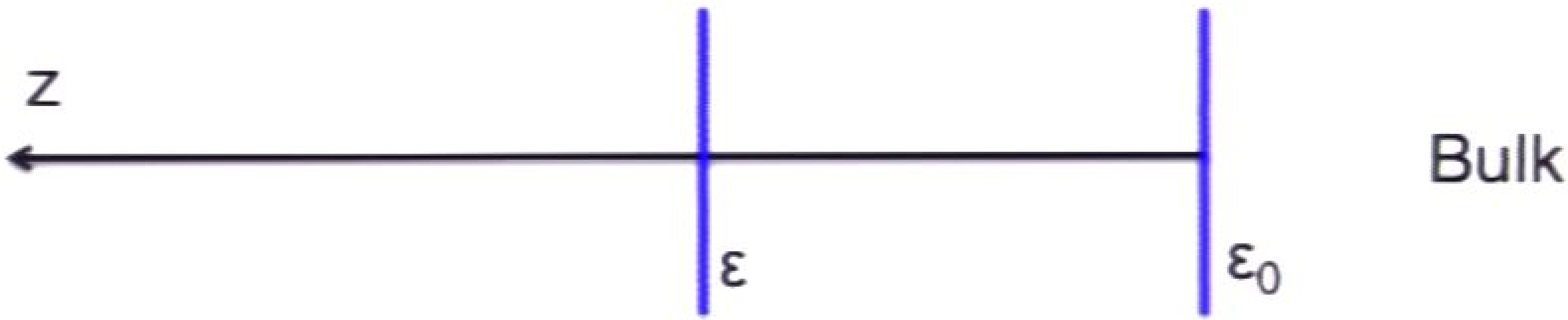

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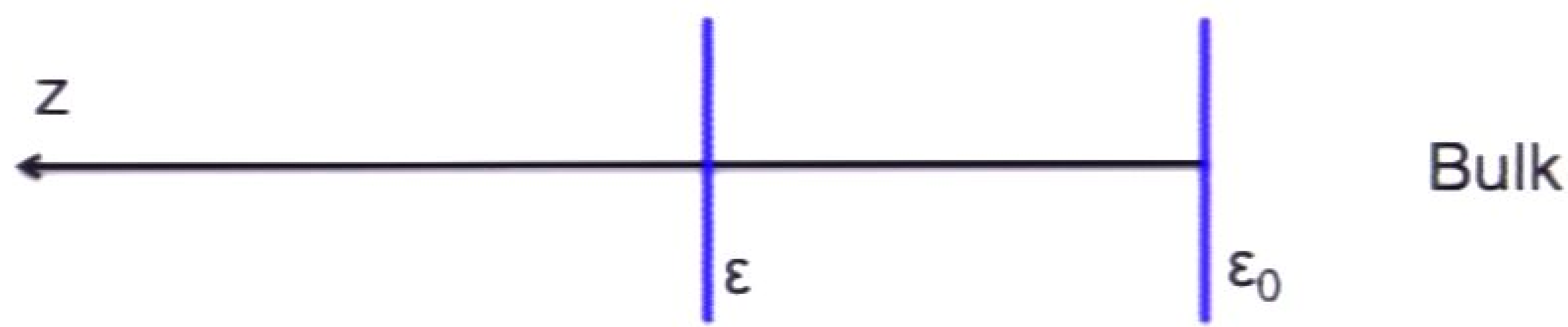

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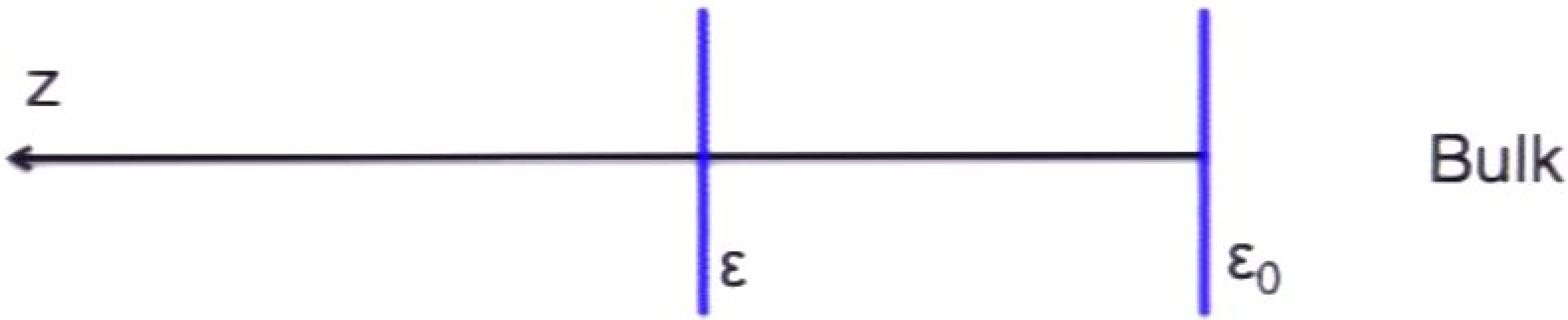

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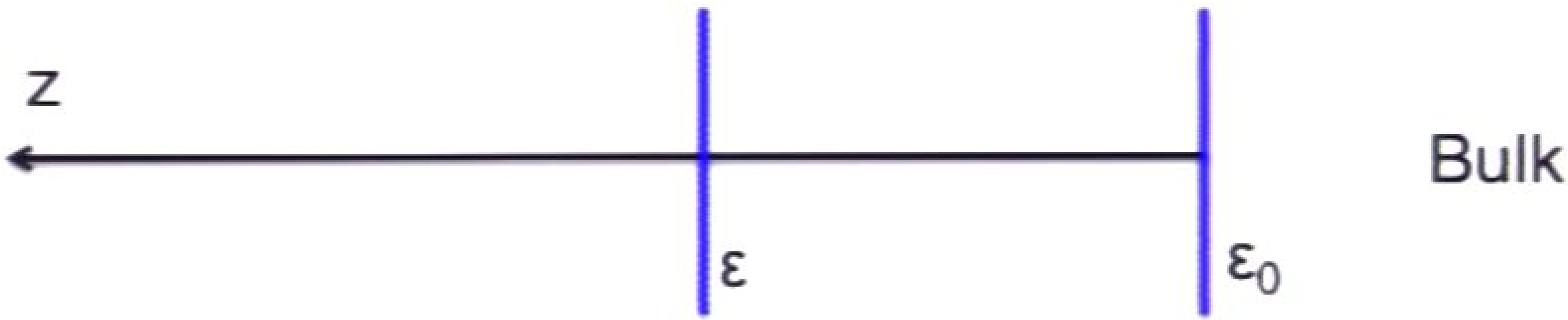

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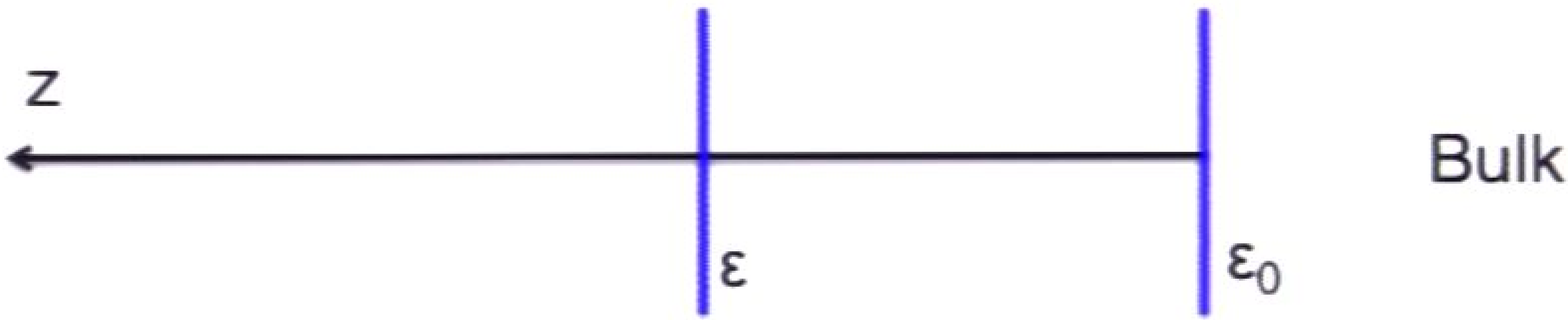

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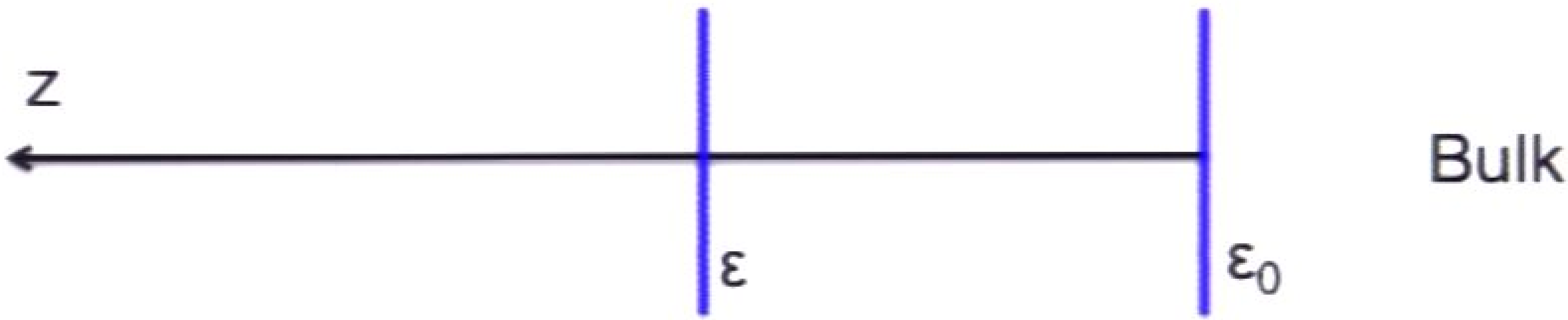

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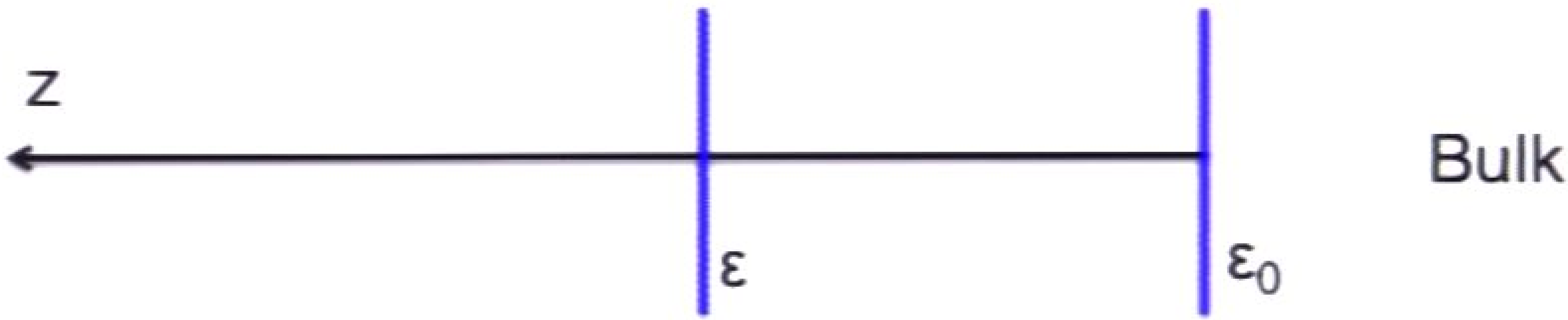

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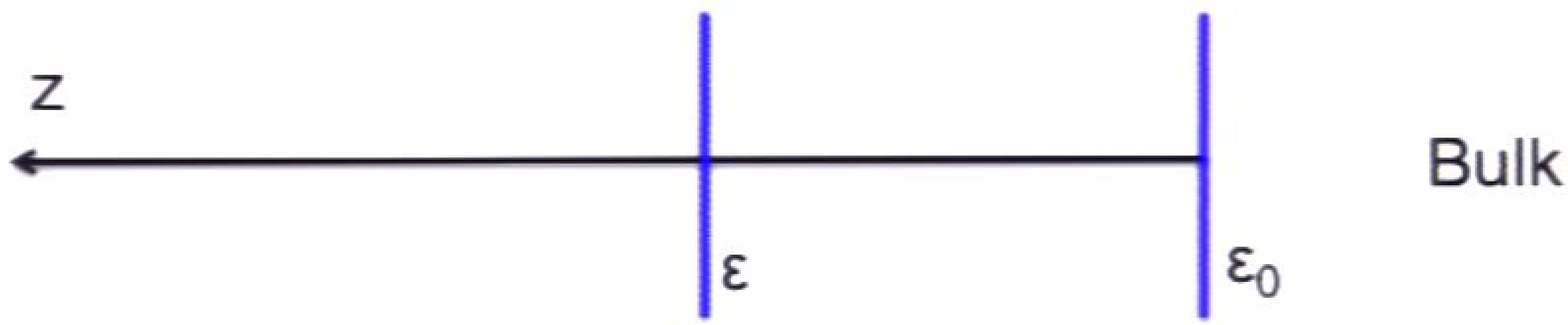

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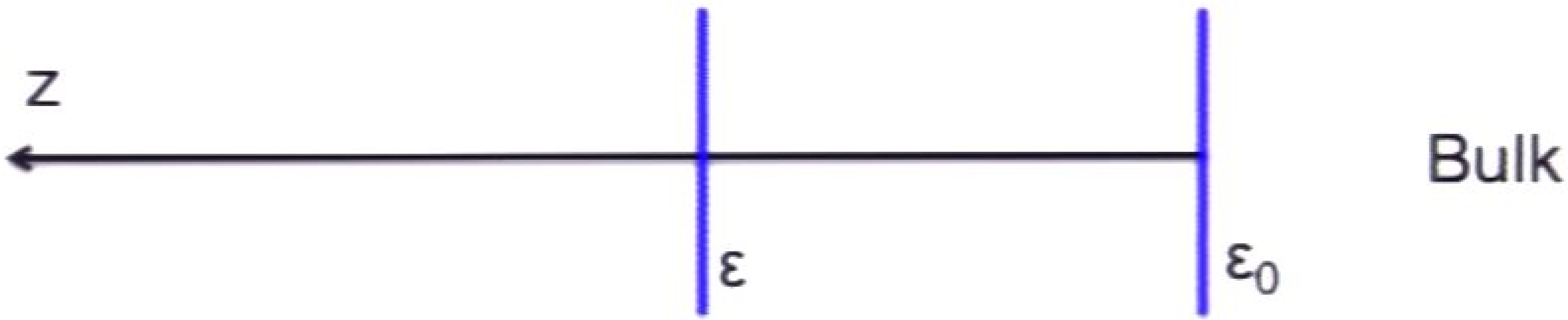

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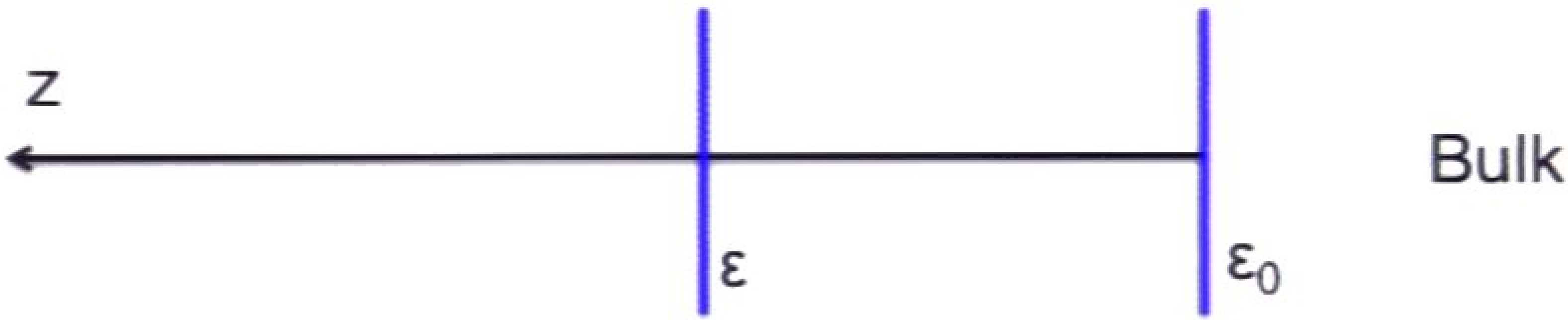

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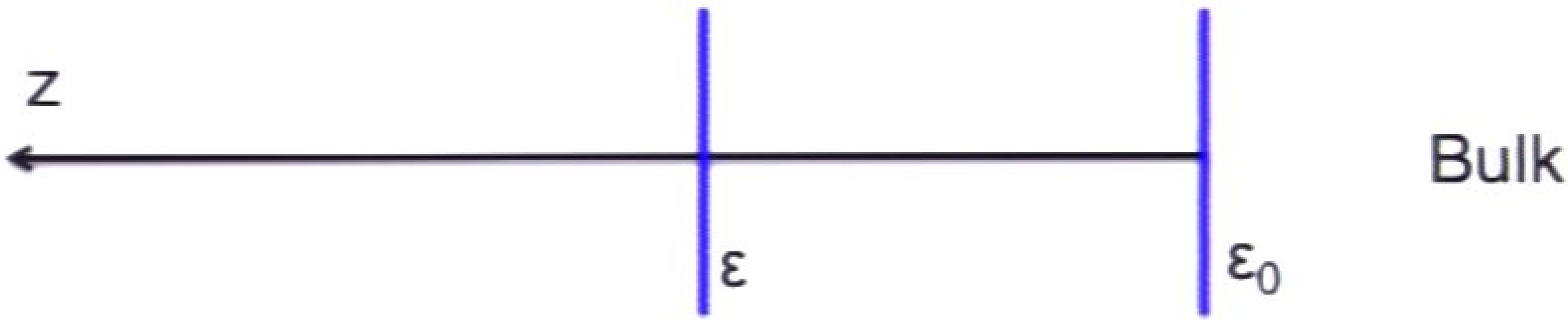

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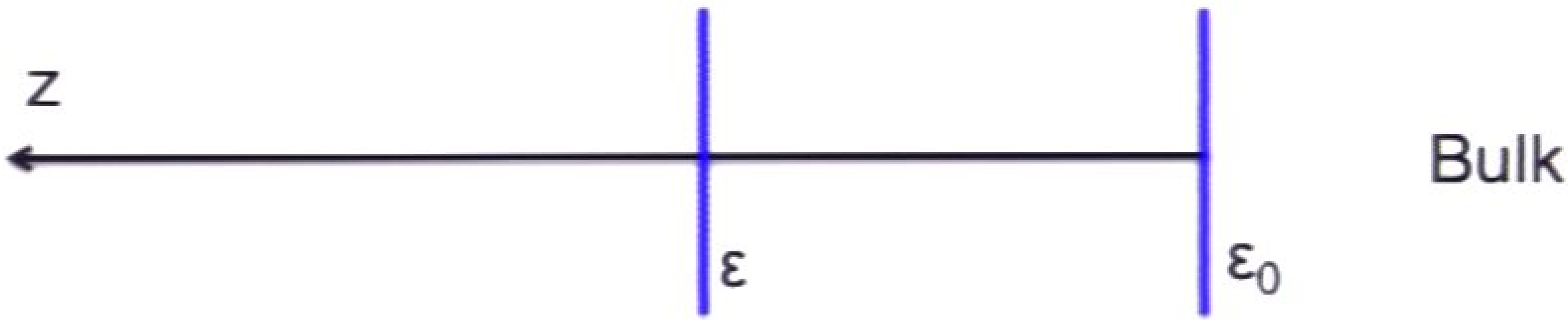

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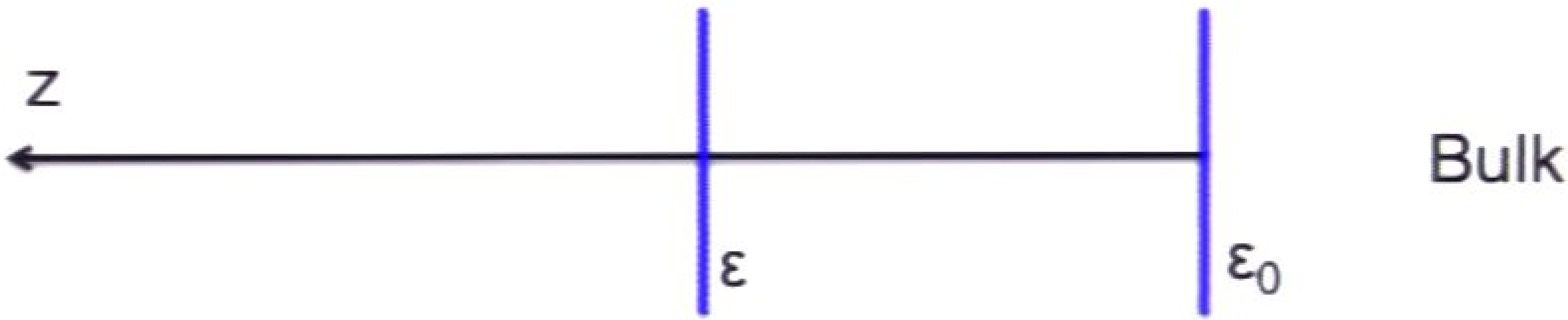

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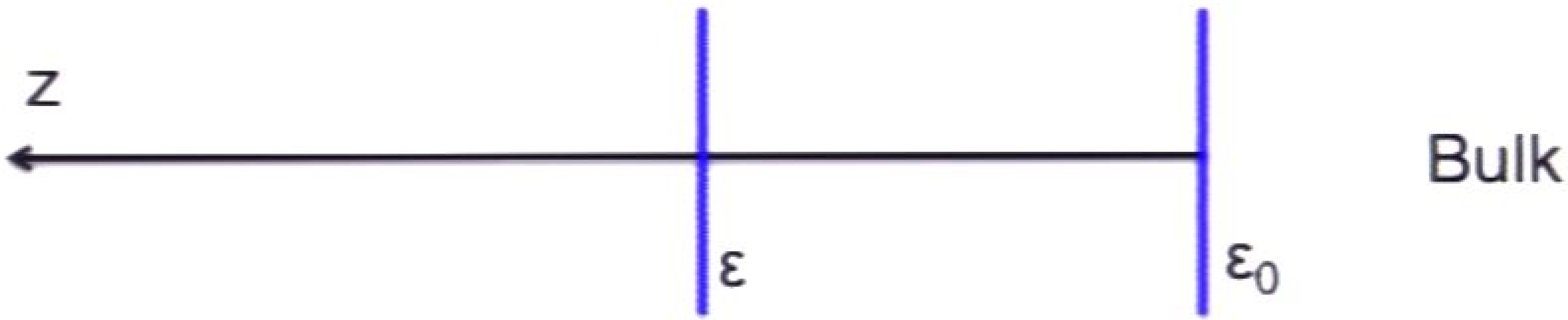

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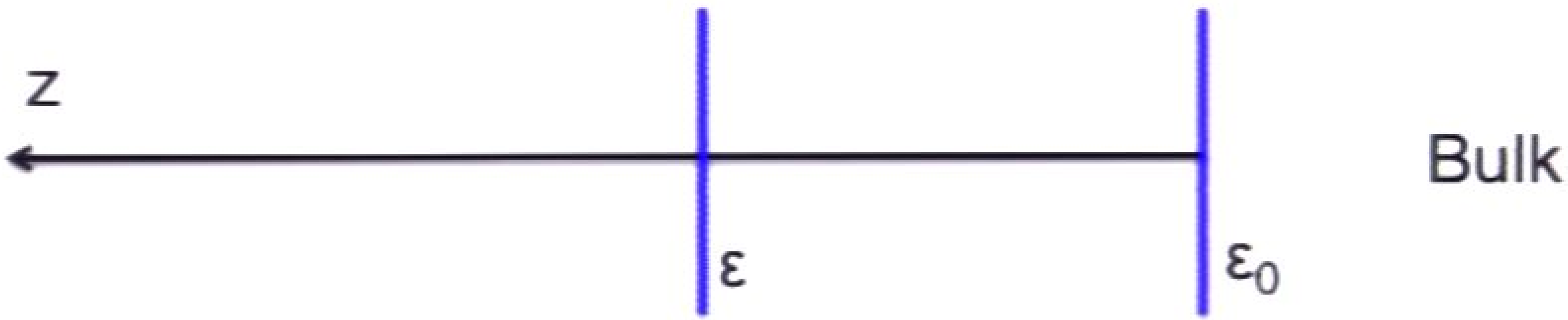

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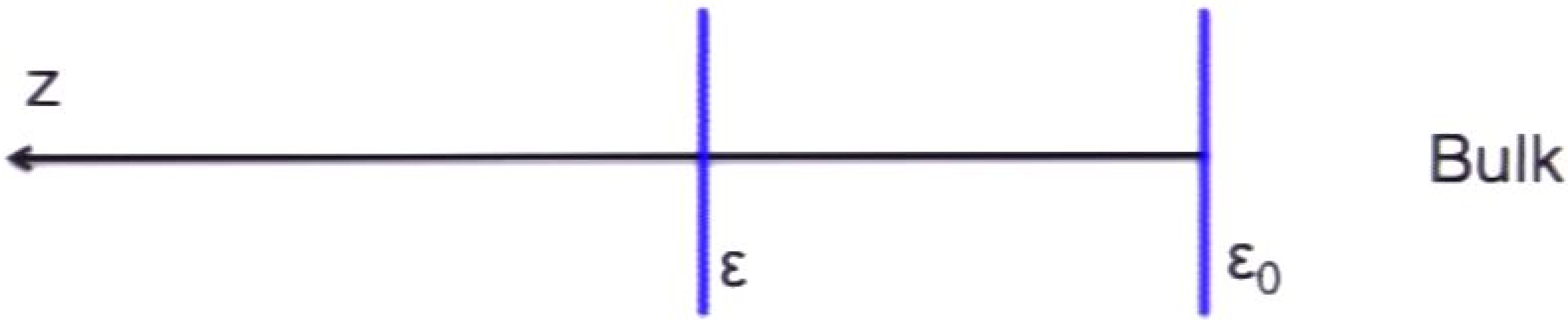

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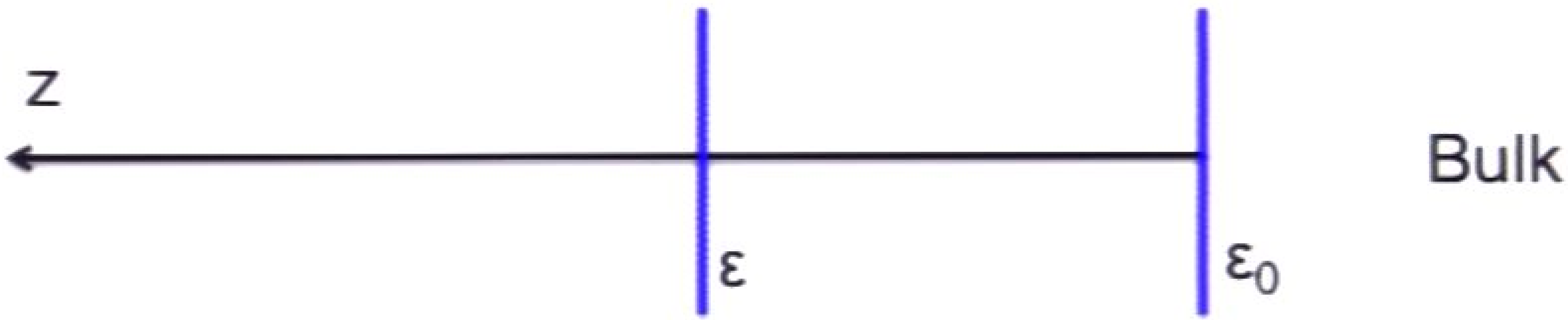

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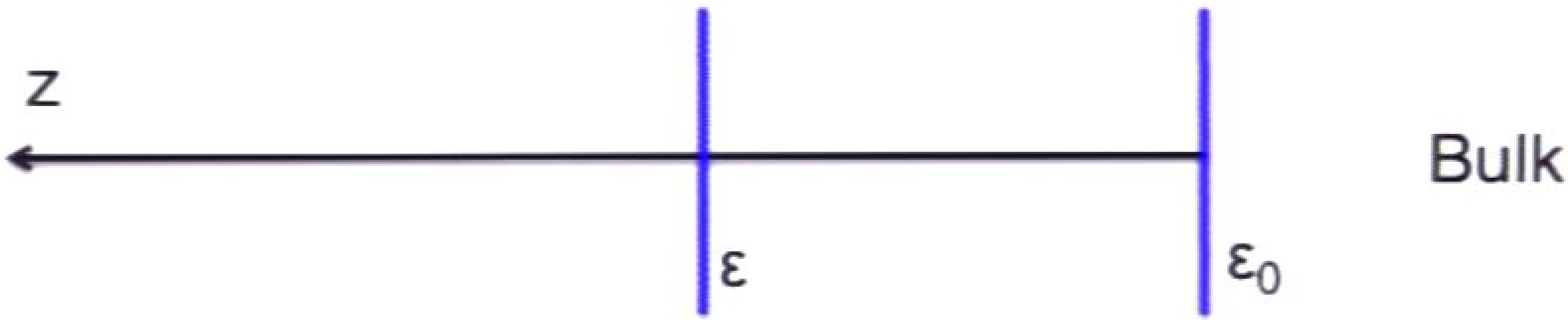

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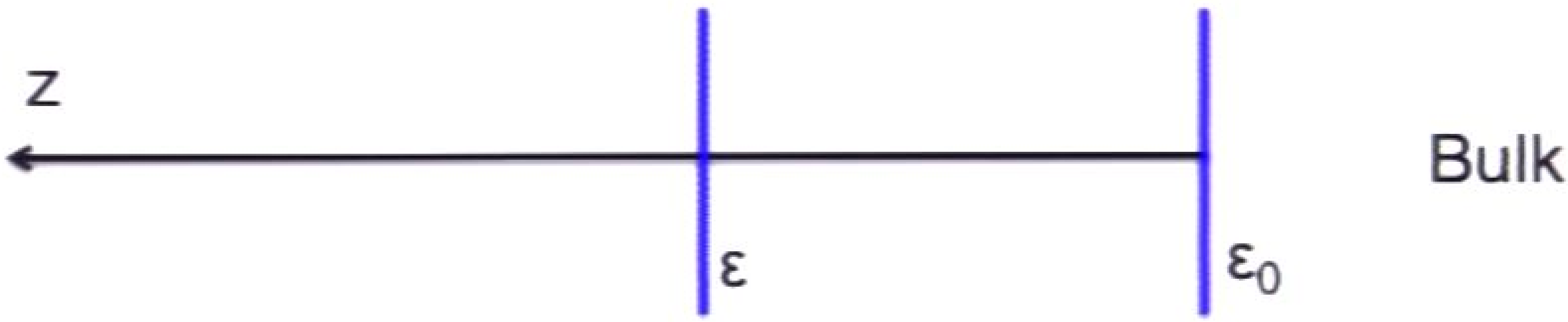

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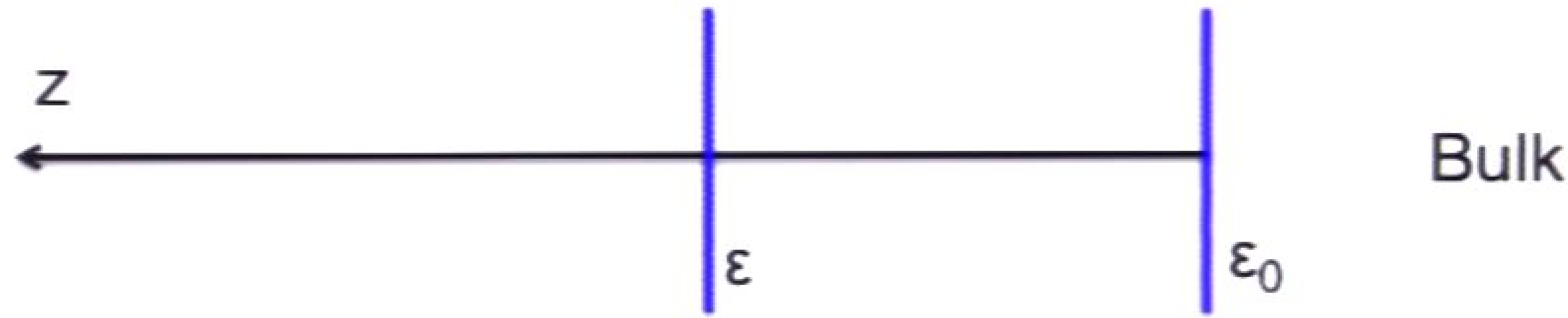

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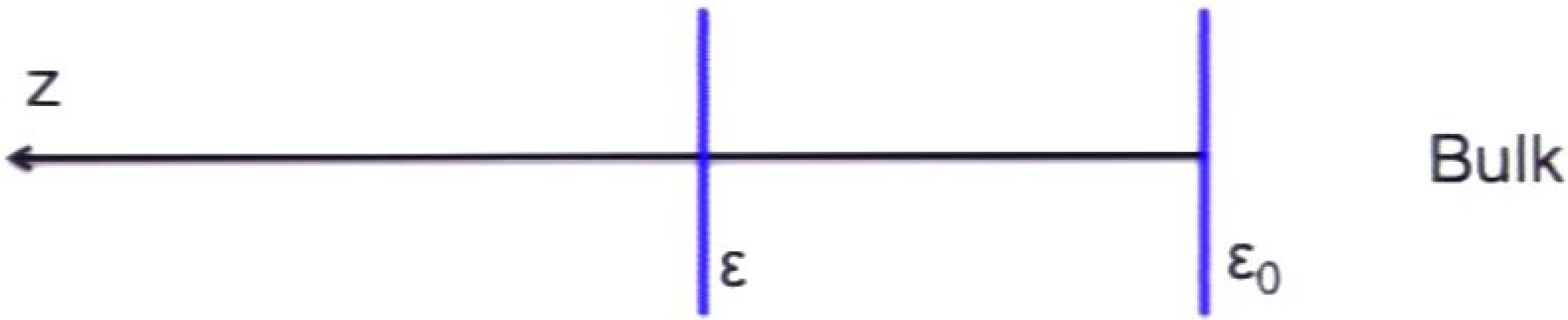

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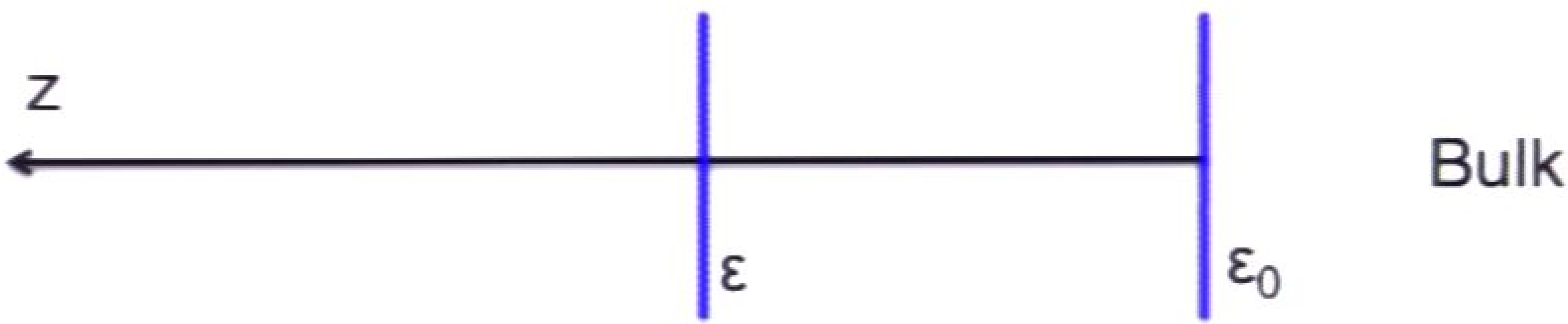

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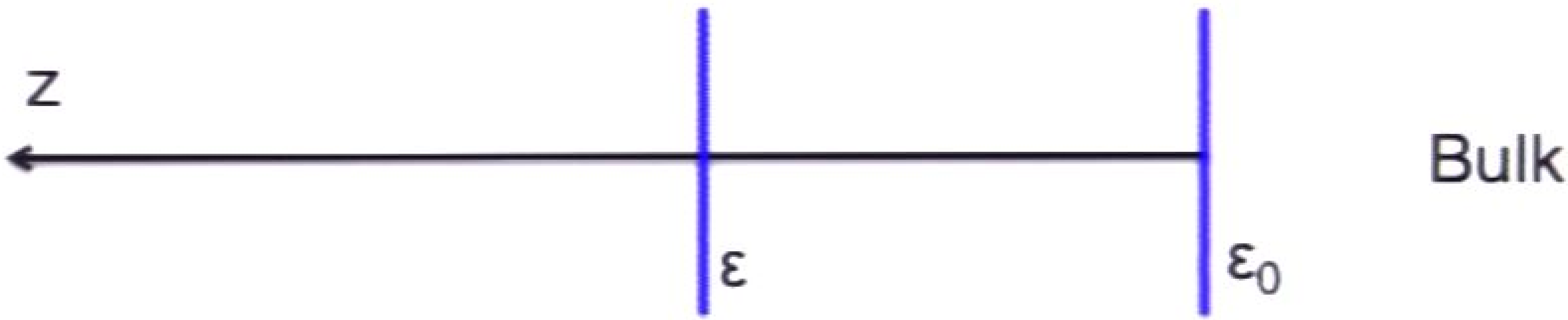

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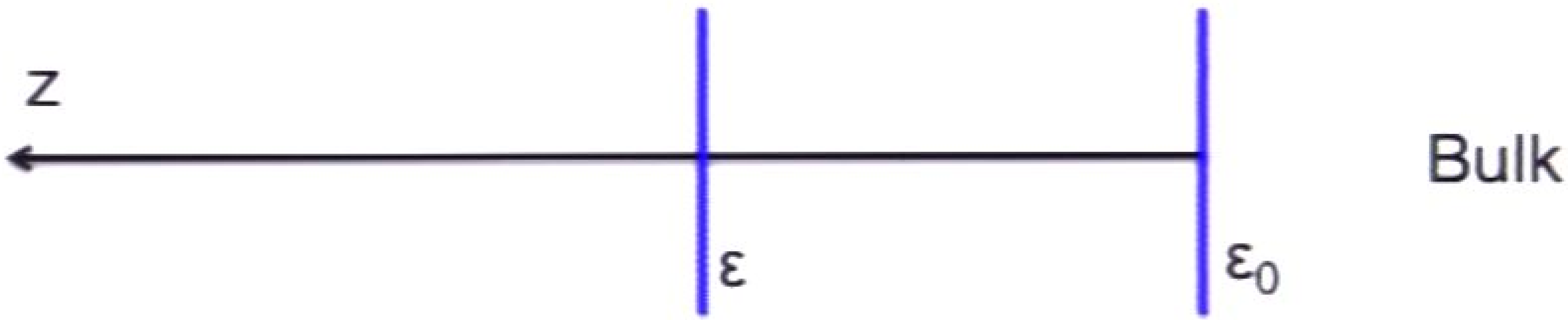

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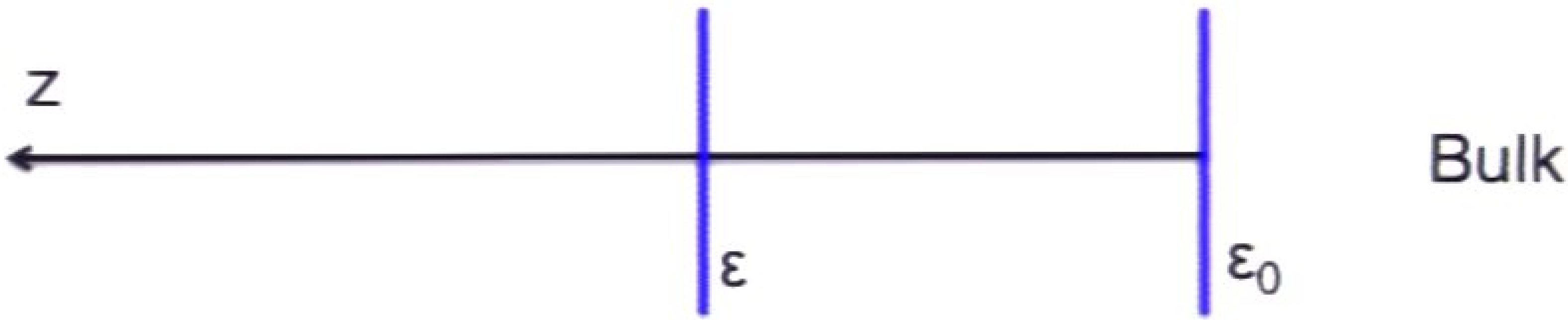

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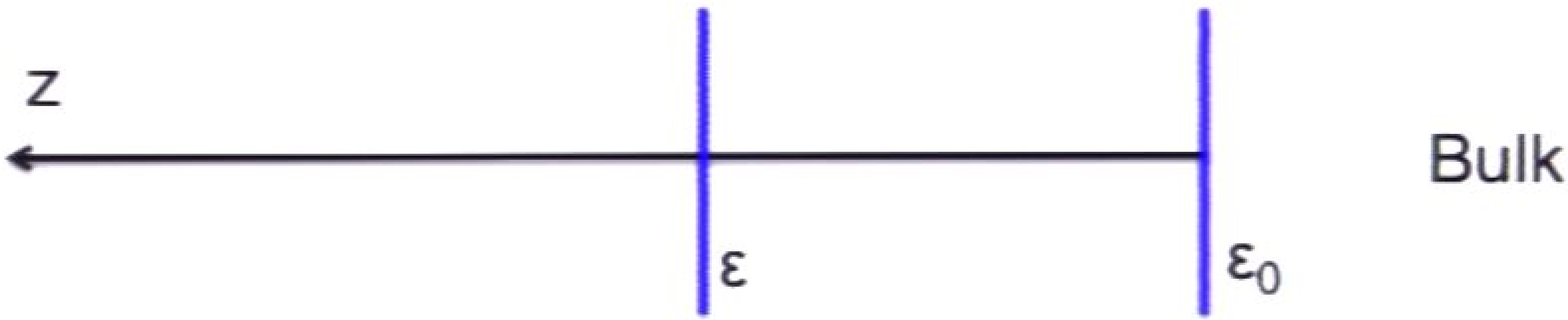

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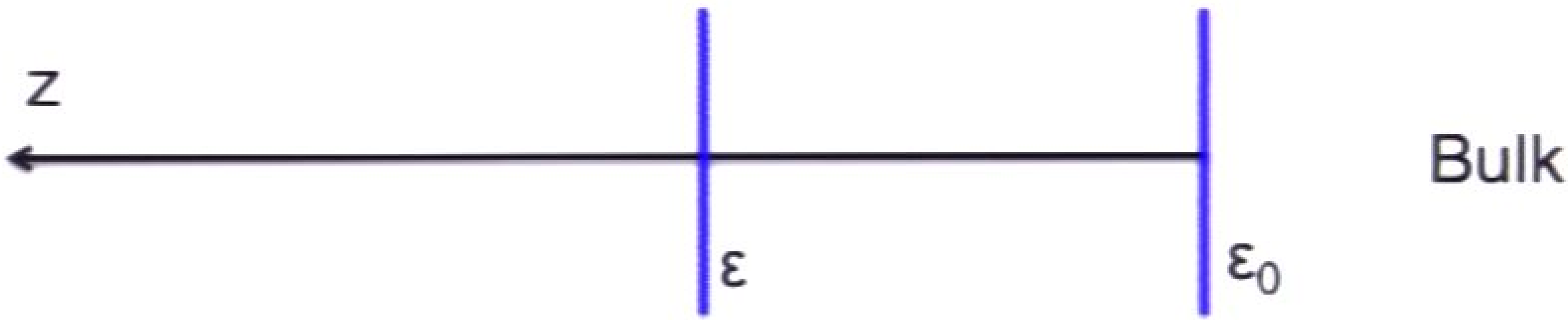

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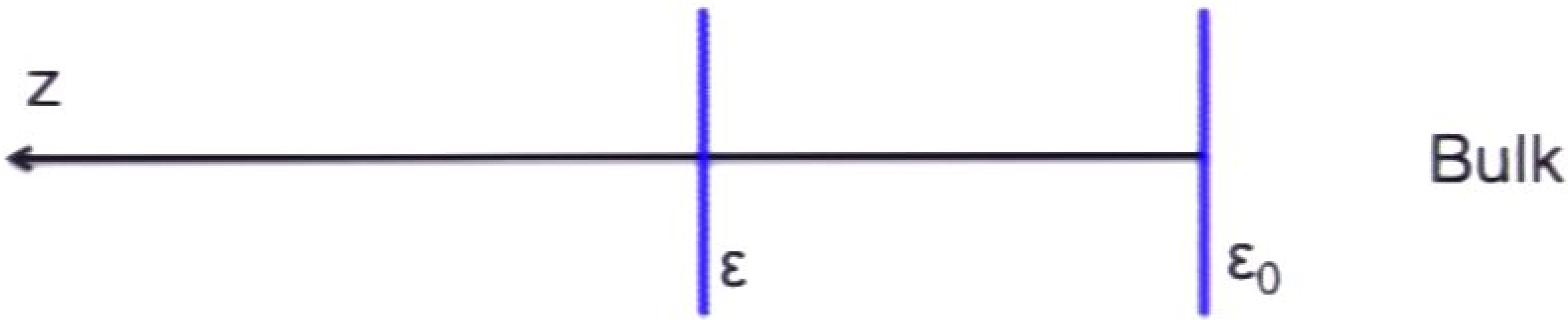

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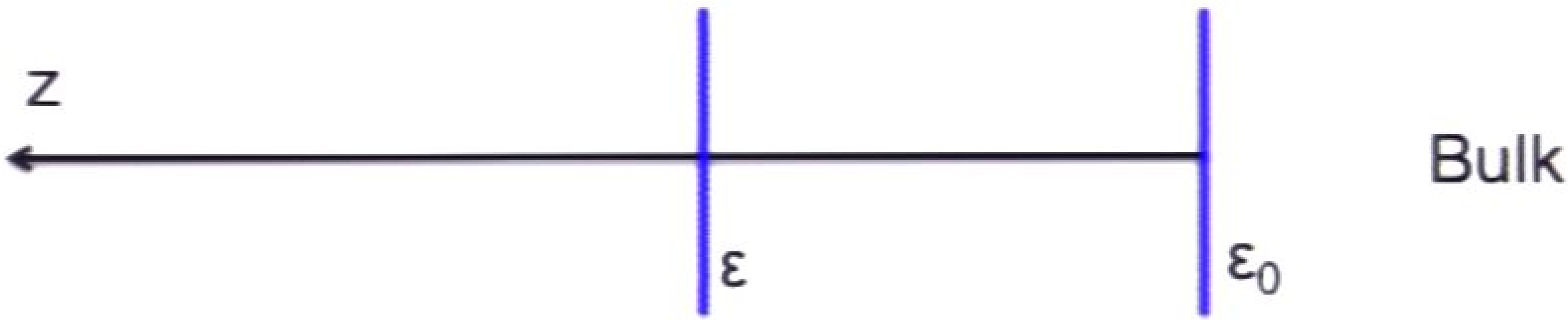

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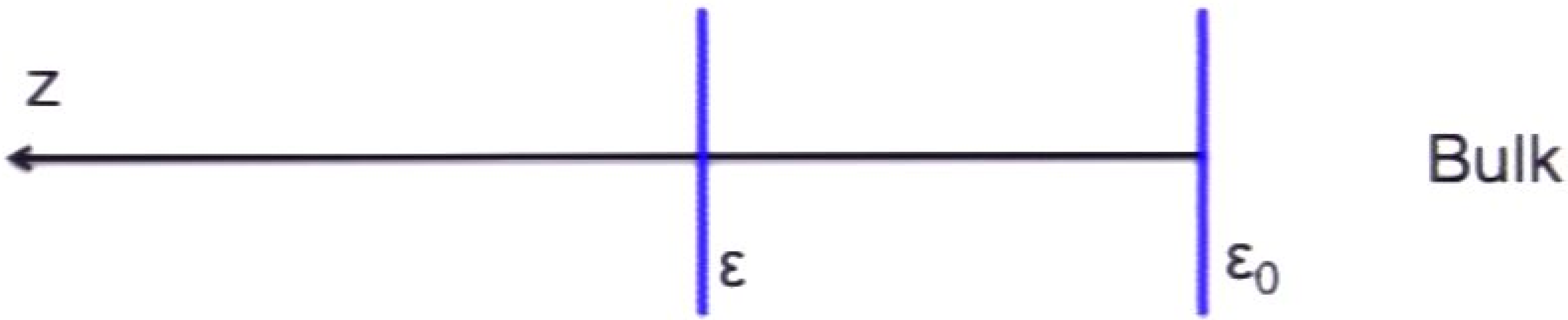

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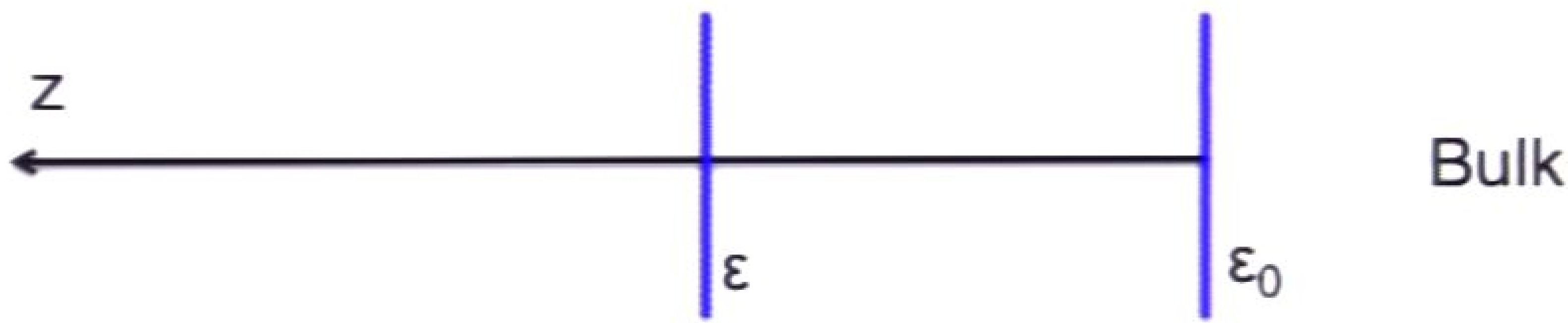

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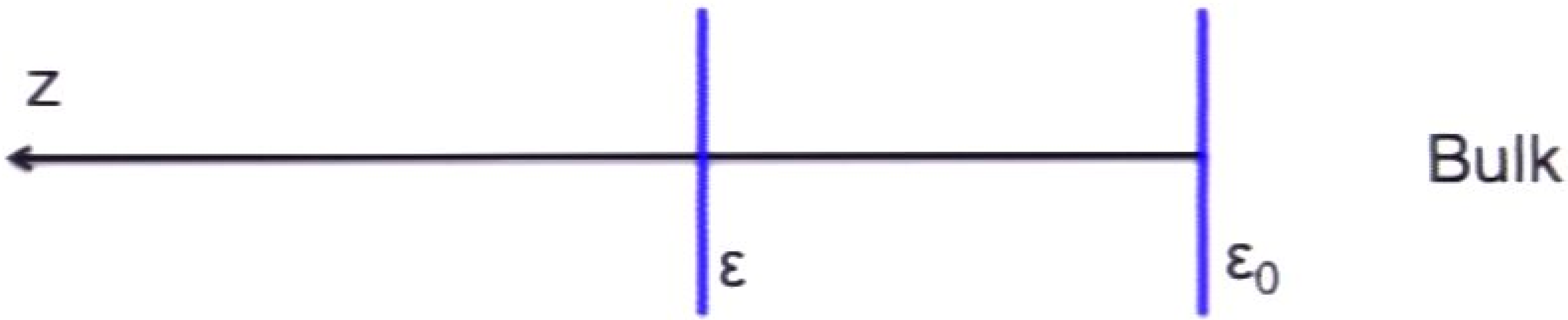

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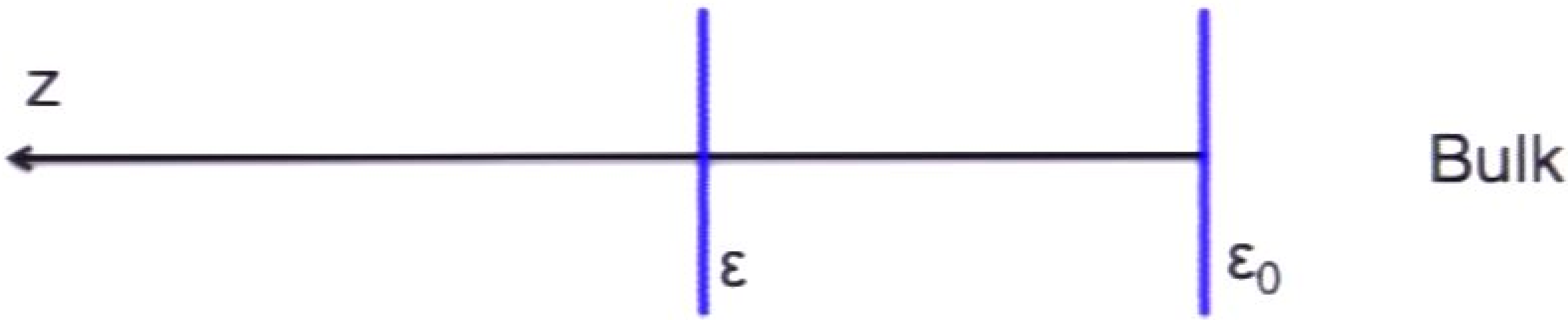

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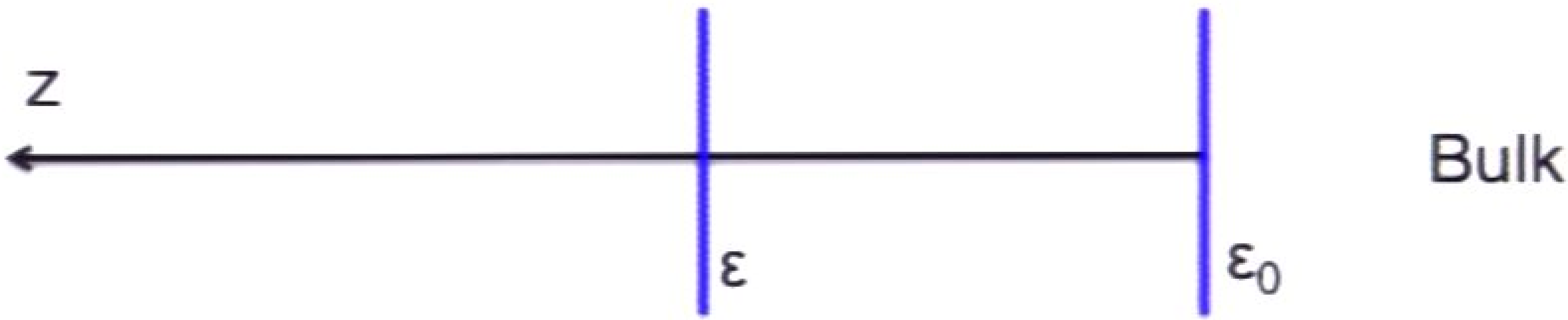

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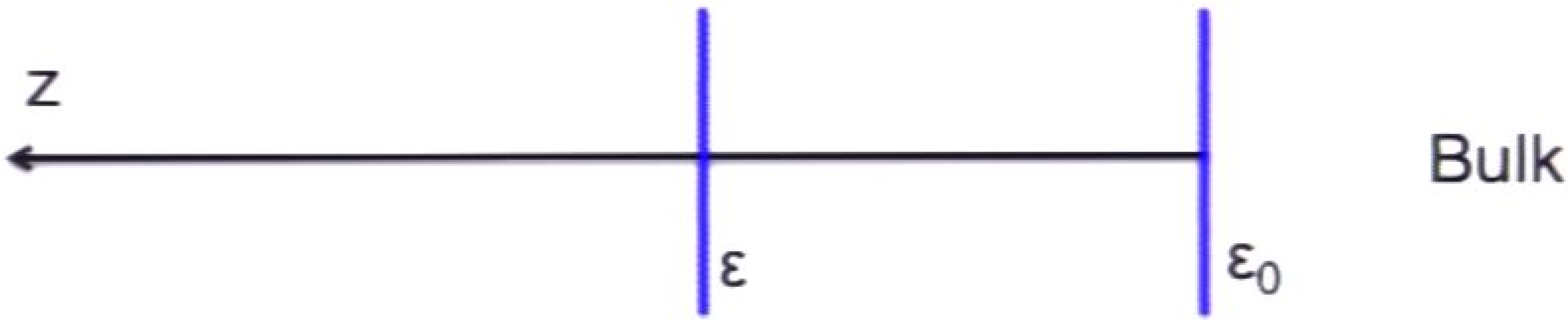

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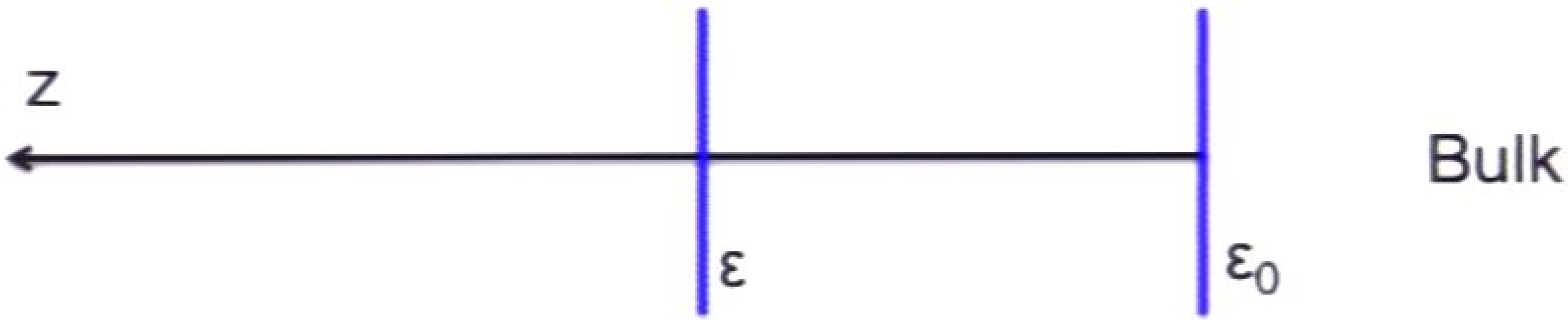

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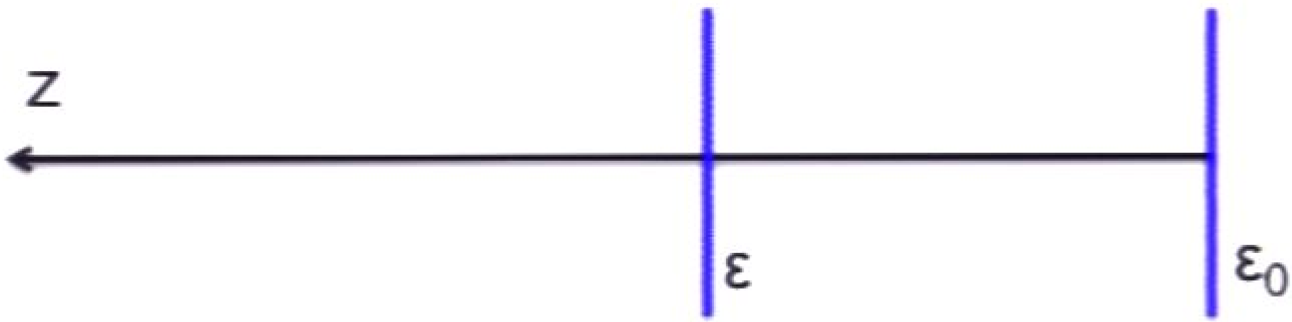

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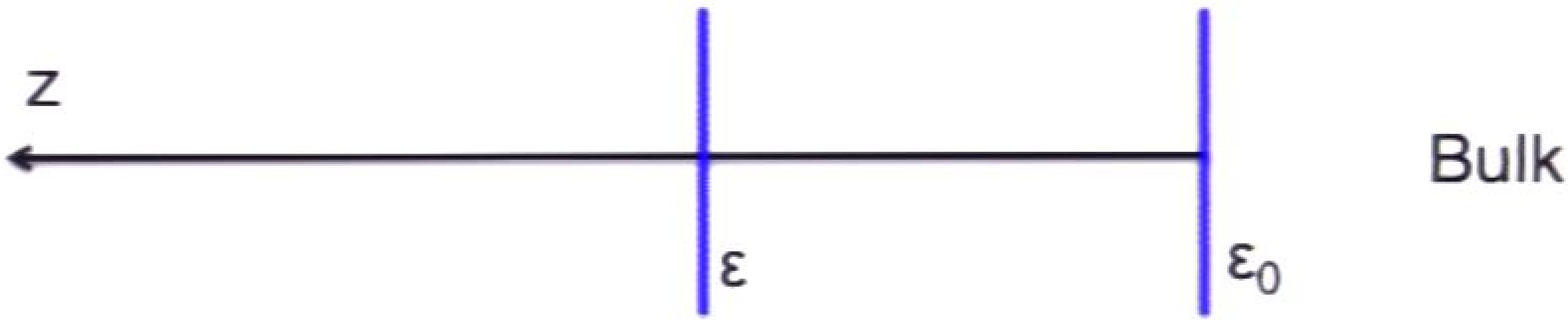

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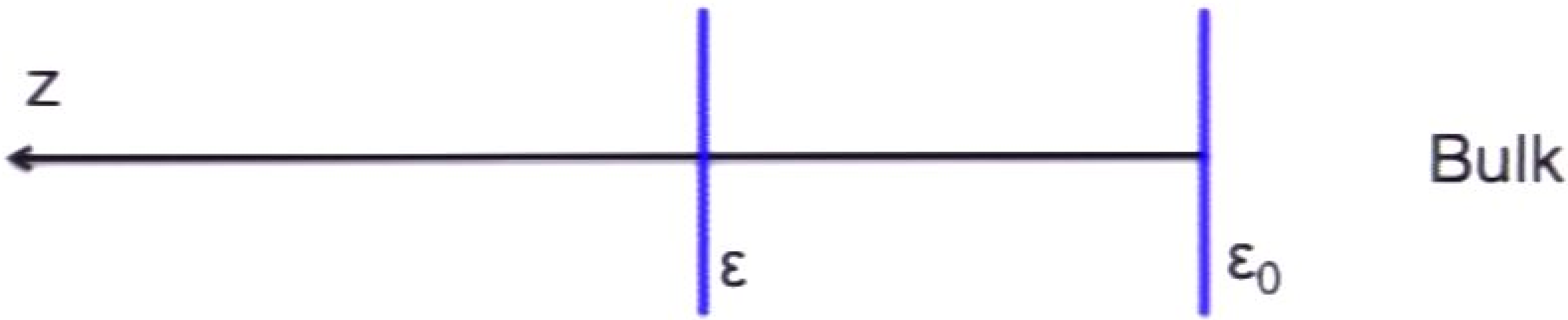

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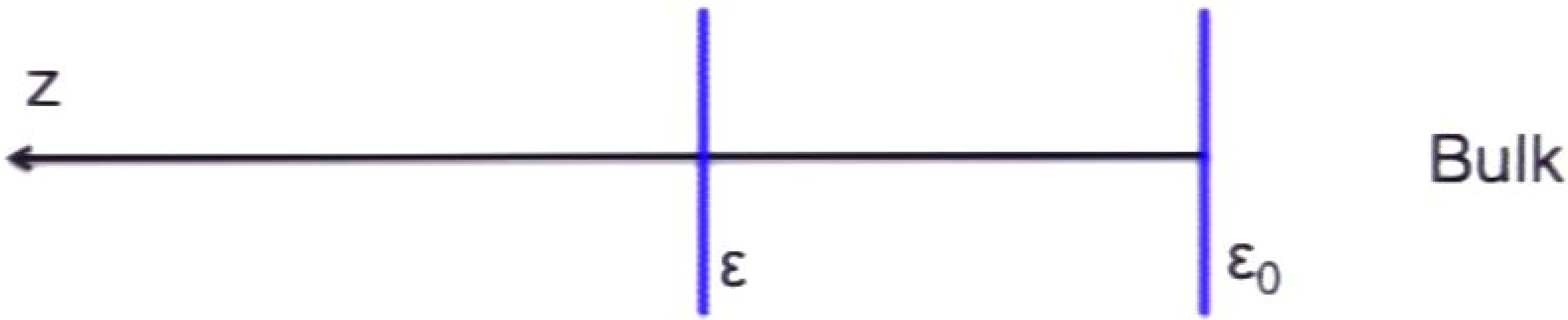

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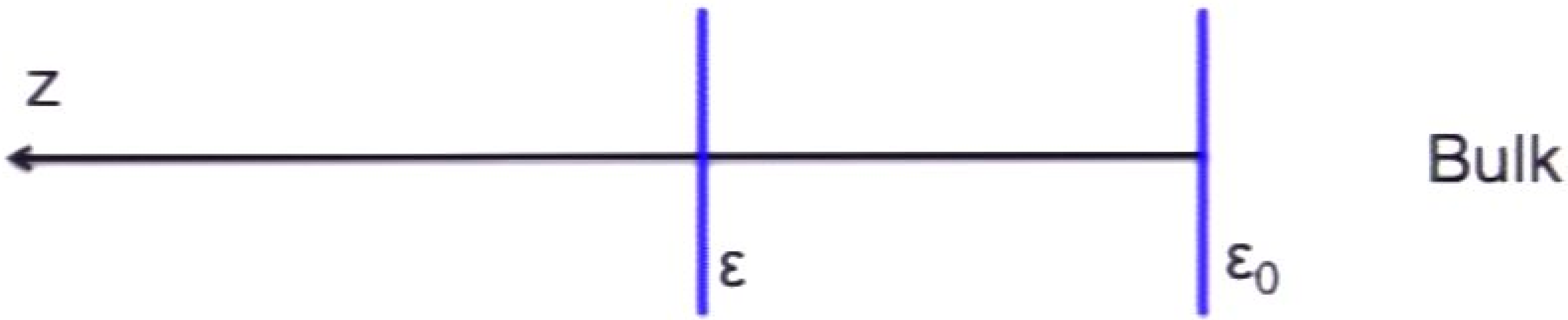

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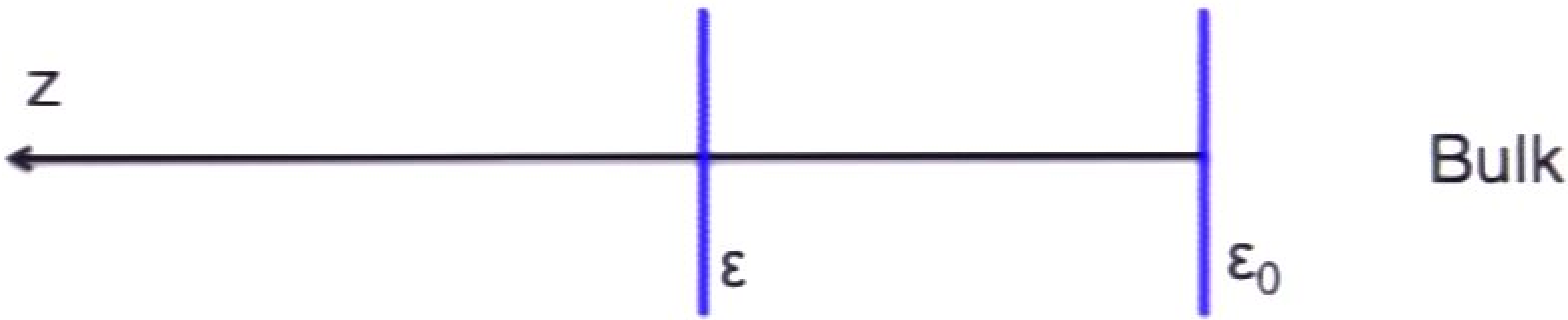

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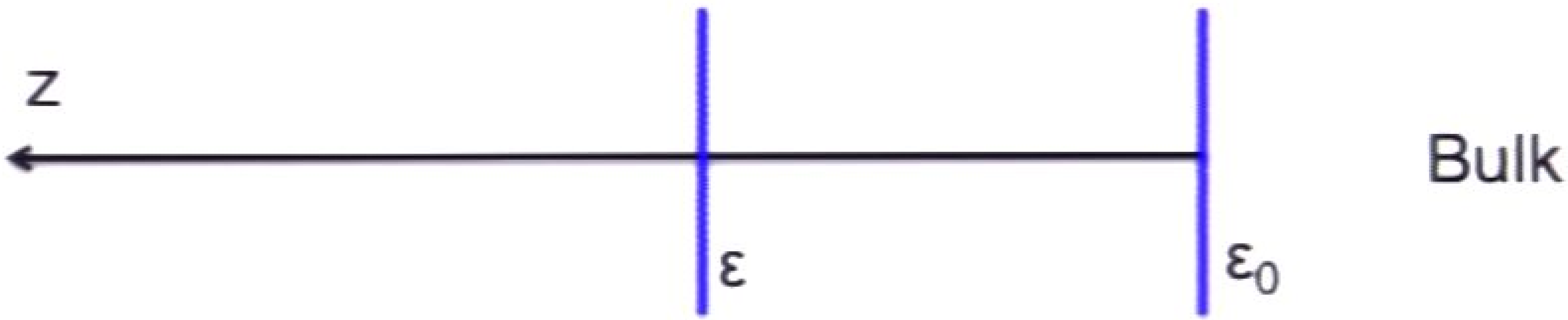

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Flow equation for S_B

Physics should not depend on where we choose z=ε suface

➡ Flow equation for S_B [ε]

Semi-classical limit: Hamilton-Jacobi equation

$$\partial_\epsilon S_B[\phi, \epsilon] = -\int_{z=\epsilon} d^d x \, H\left(\phi, \Pi = \frac{\delta S_B}{\delta \phi}\right)$$

H: bulk Hamiltonian corresponding to z-foliation.

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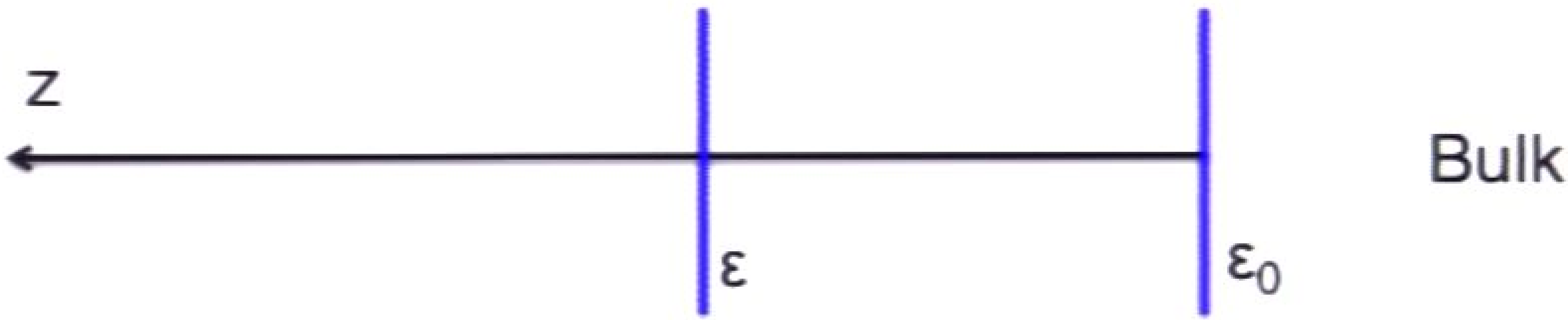

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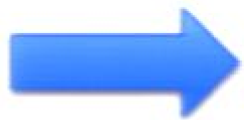
Shift the cutoff surface  flow of boundary conditions

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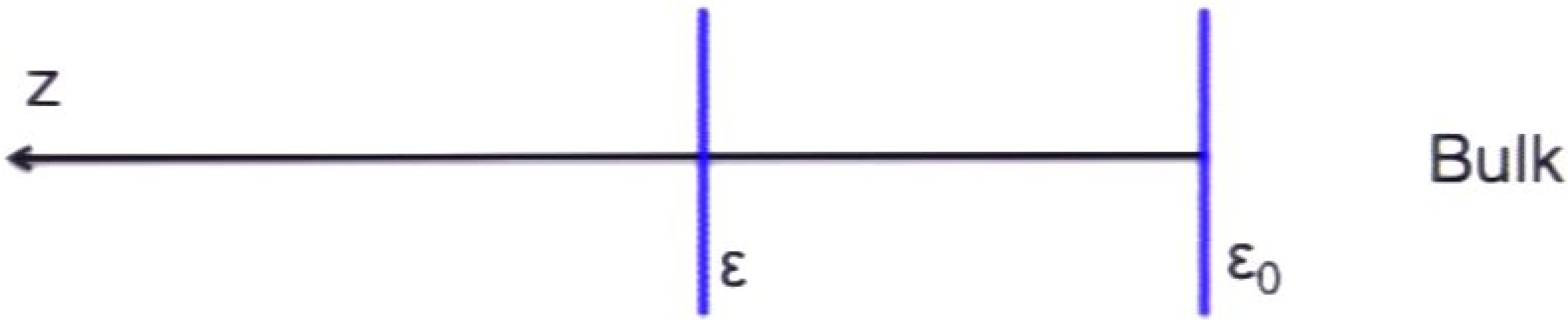

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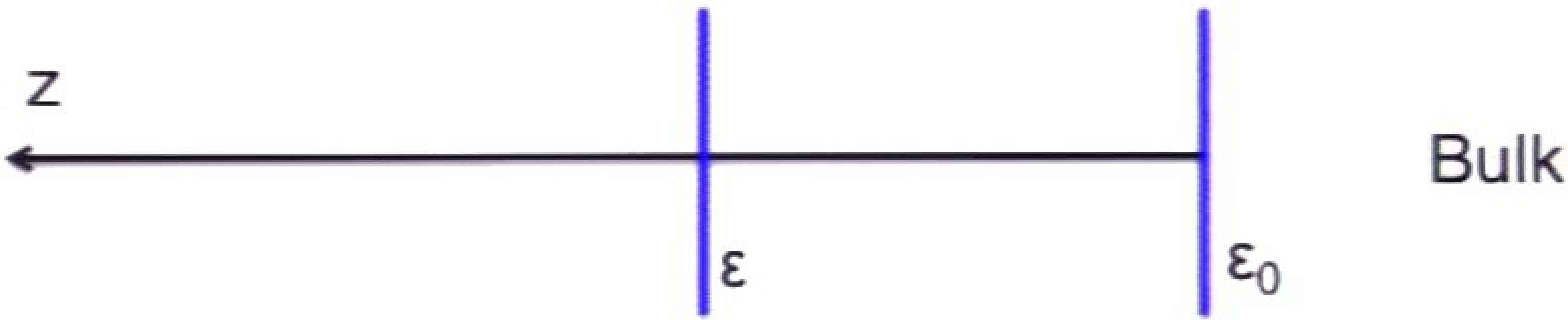

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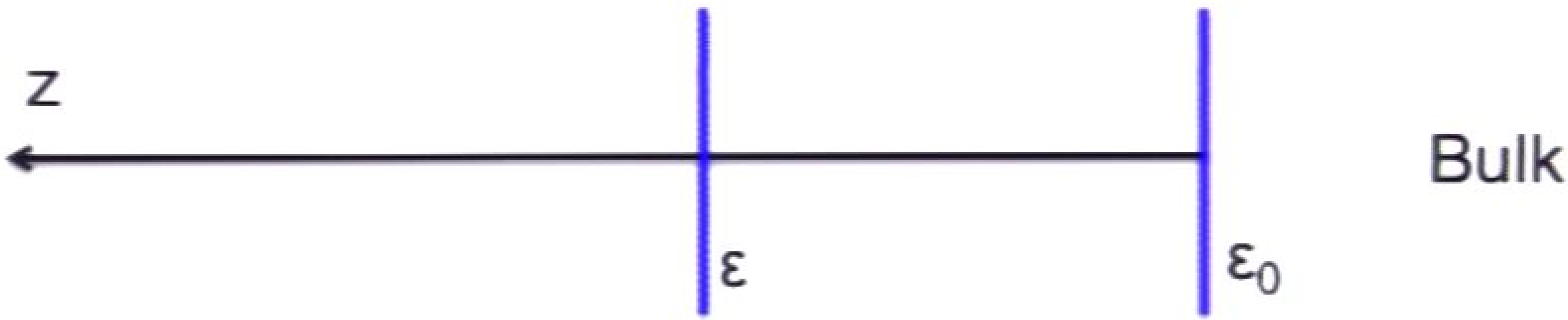

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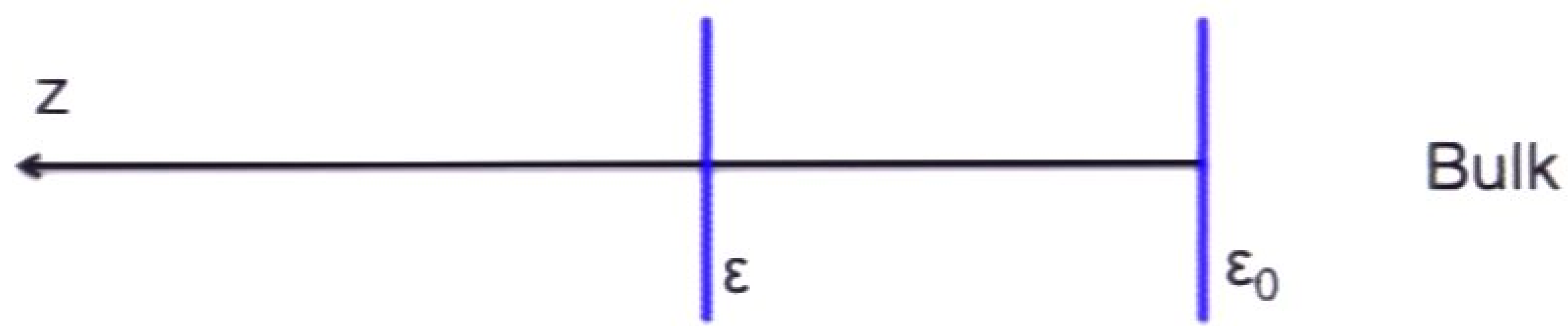

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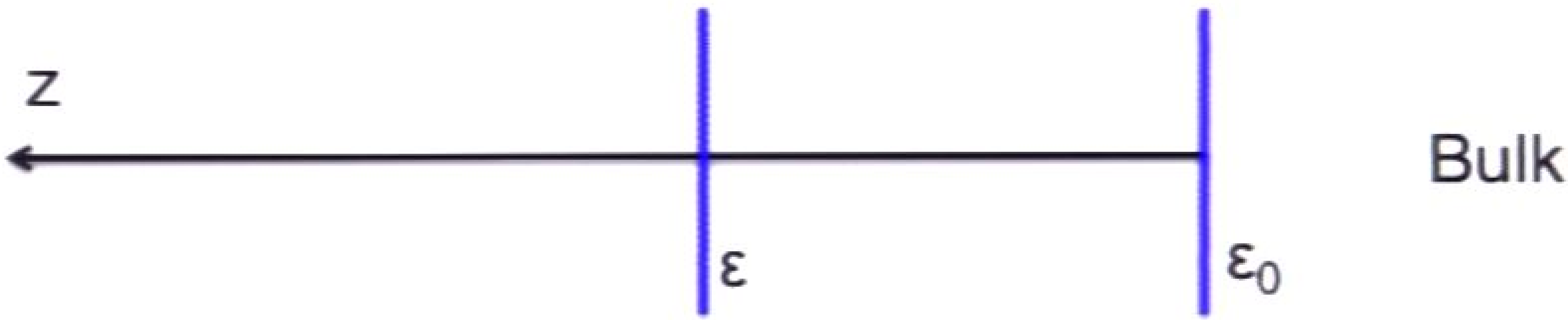

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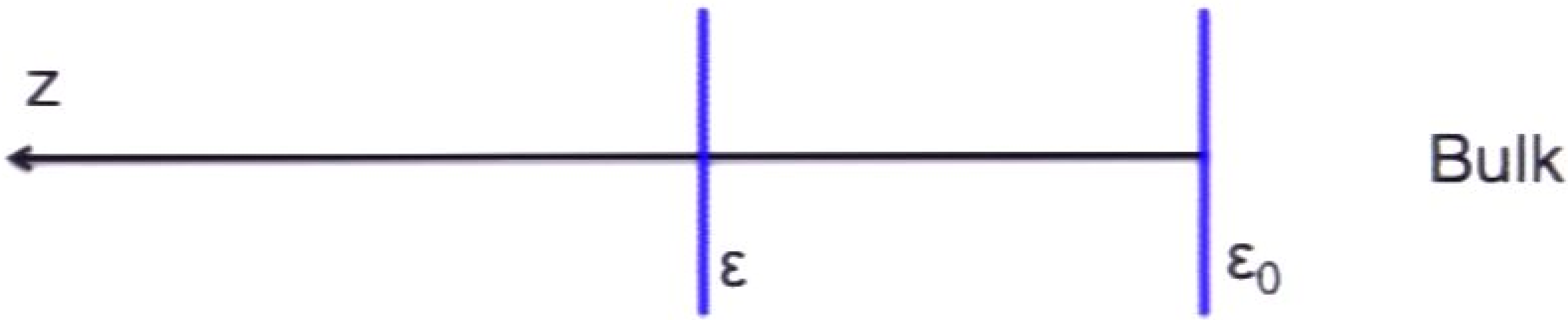

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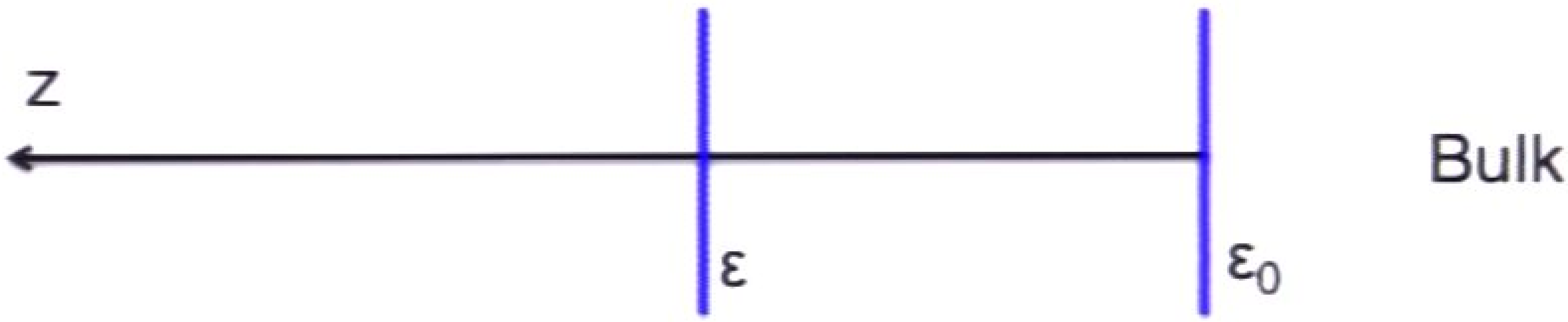

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Relation with earlier work

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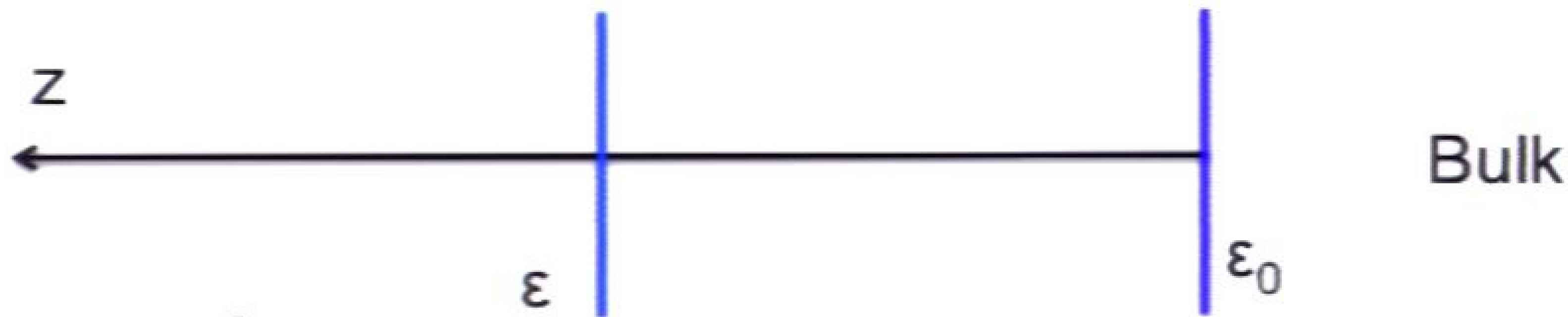

$$Z_{\text{bulk}} = \int_{z \geq \epsilon_0} D\phi \, e^{-S_0[\phi]}$$

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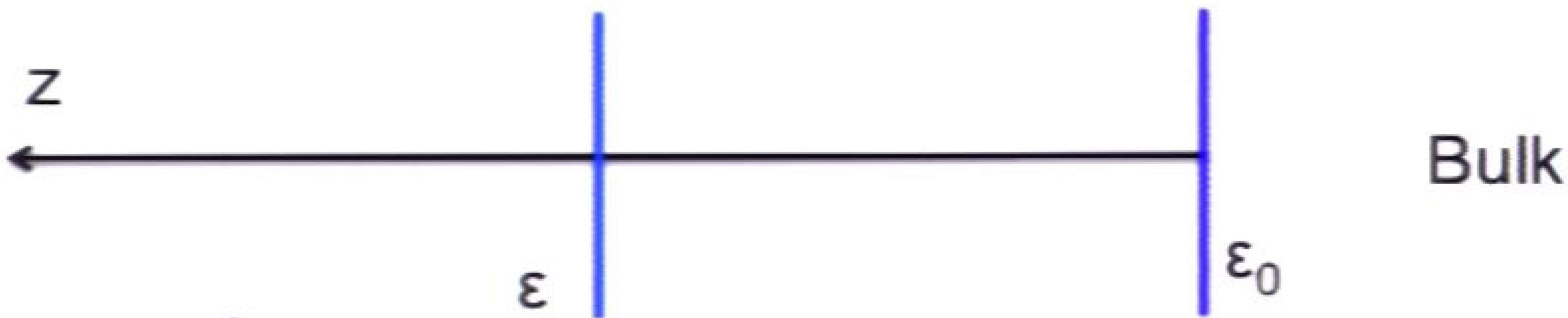

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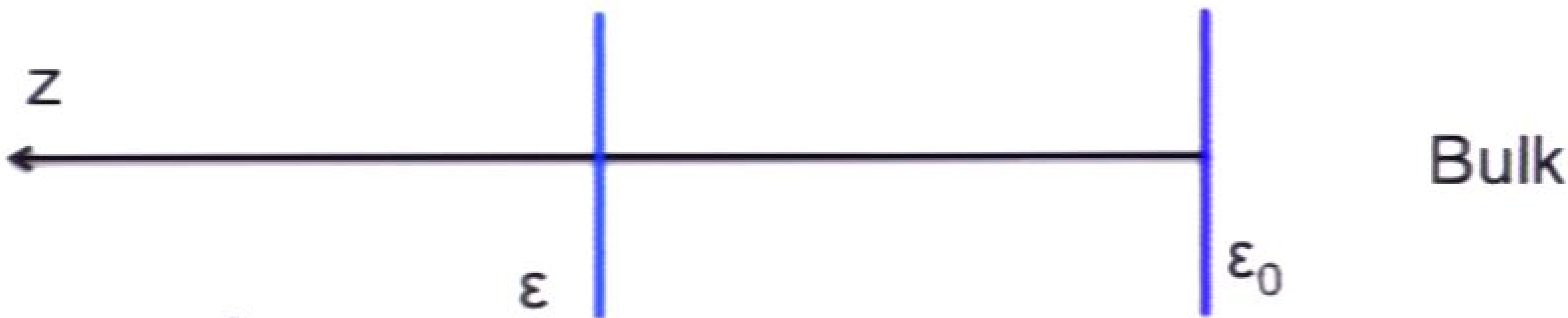

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Both $\log Z_{\rm bulk}[\epsilon_0]$ and S_B satisfy Hamilton-Jacobi equation, but contains different physics

Schwarzschild black hole in AdS

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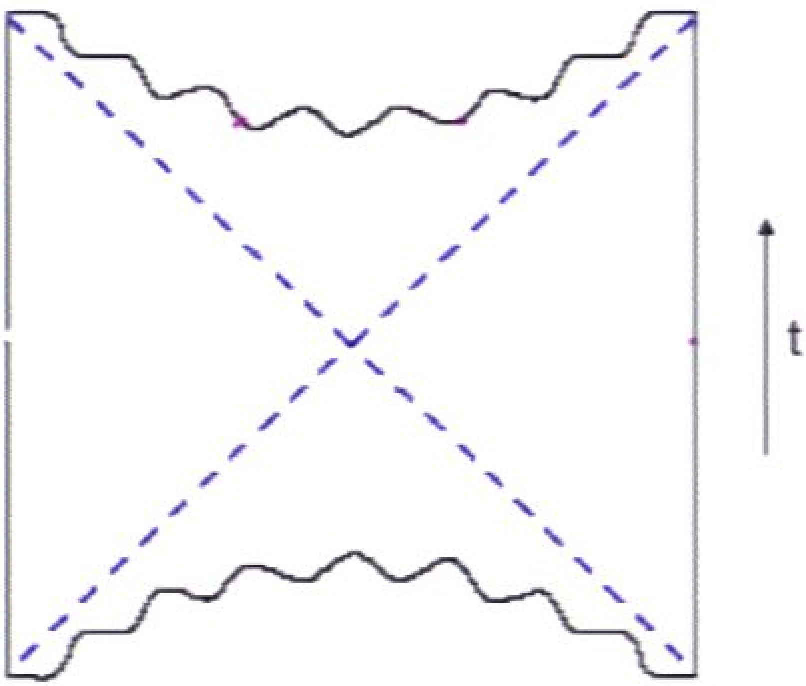

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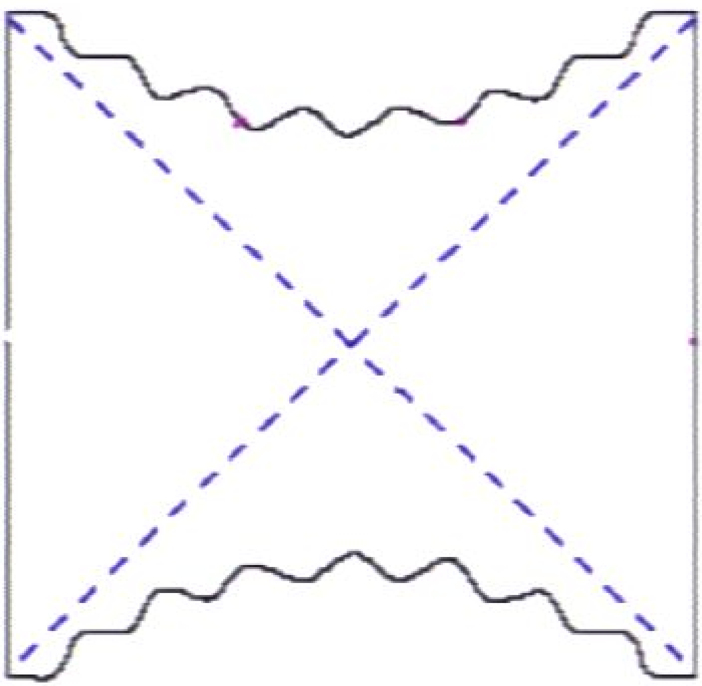

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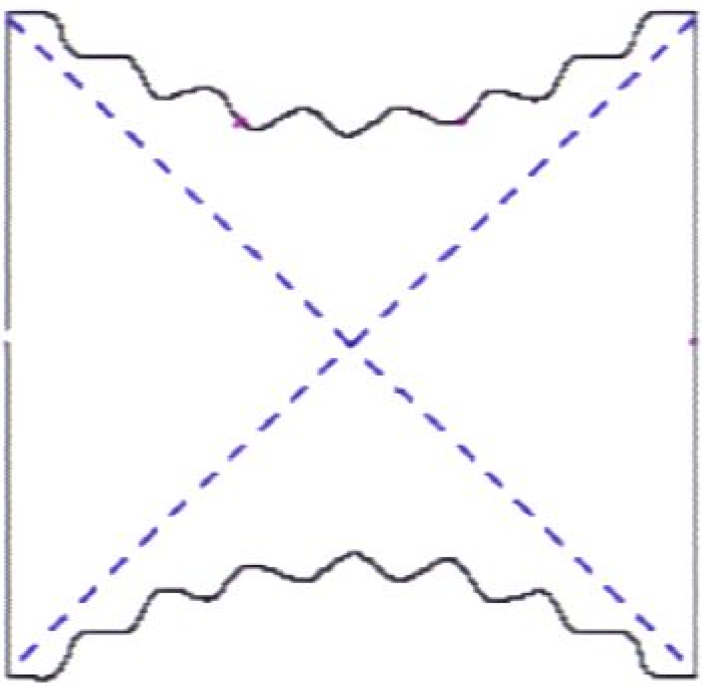

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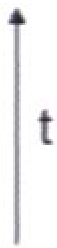

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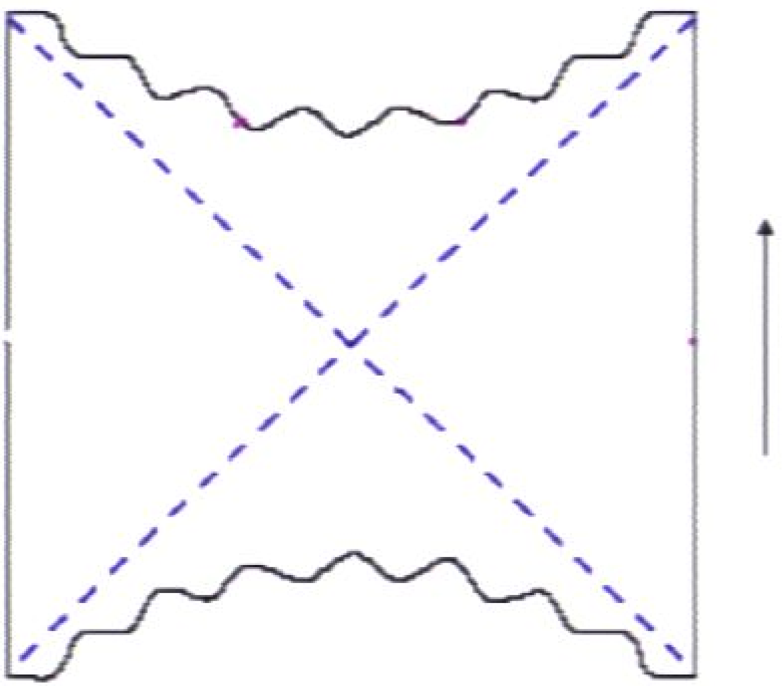

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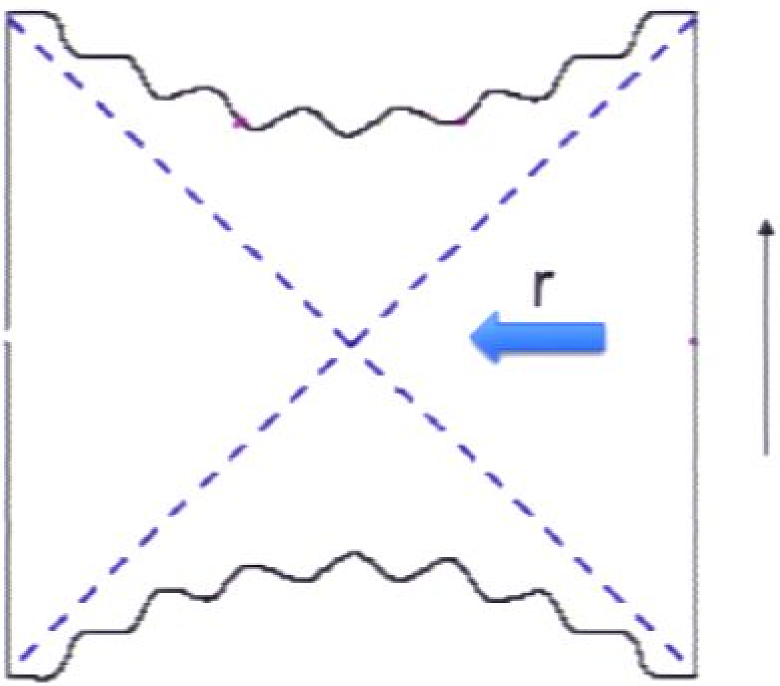

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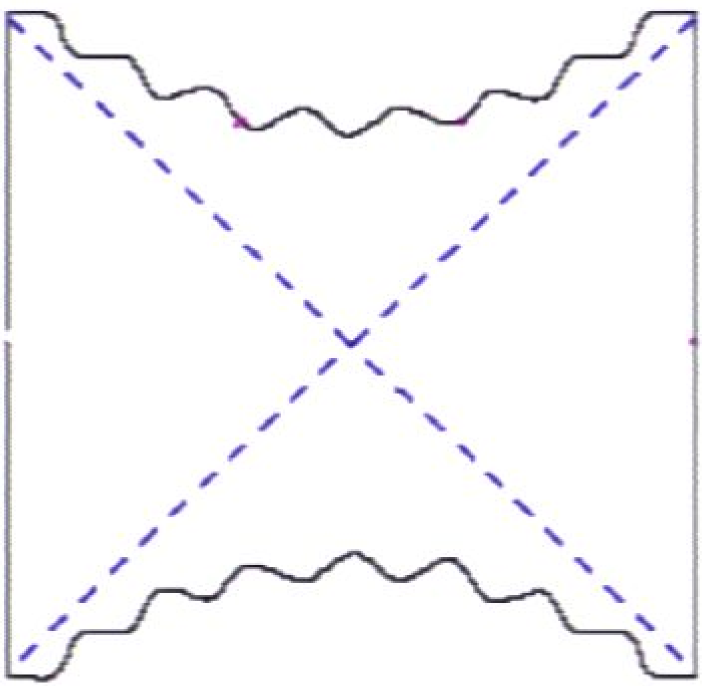

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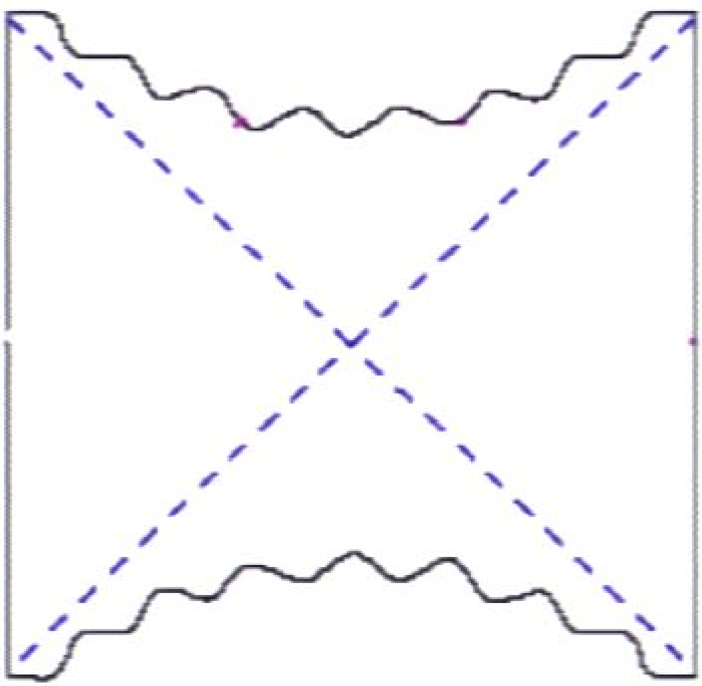

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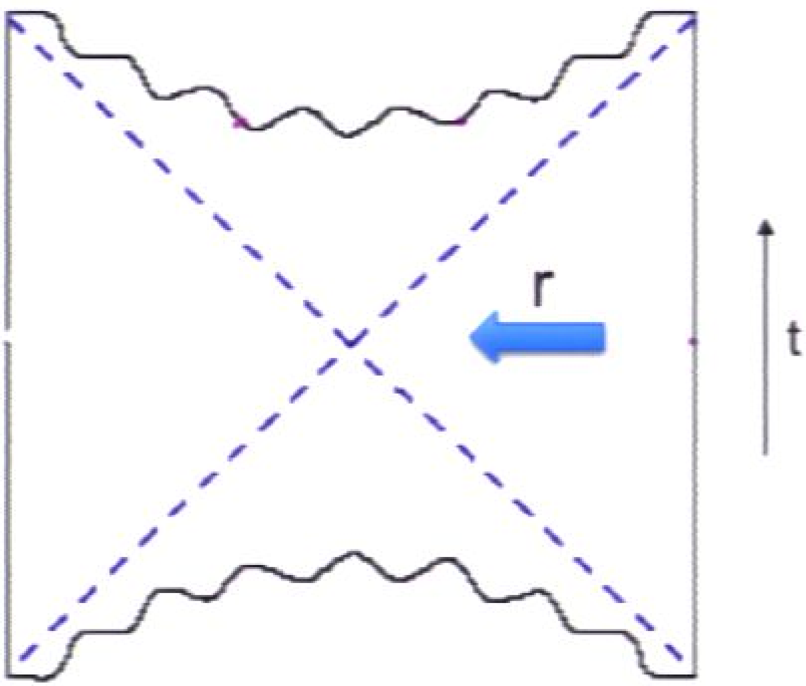

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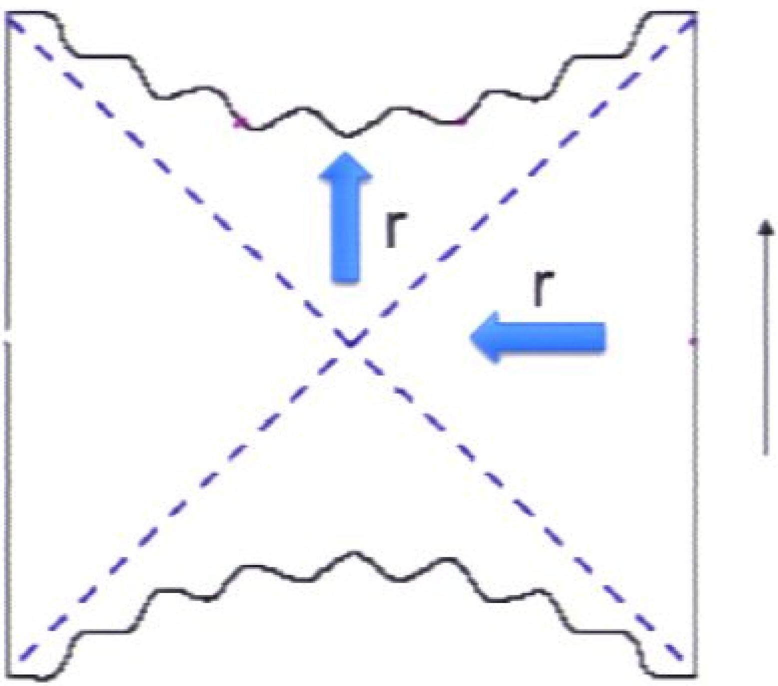

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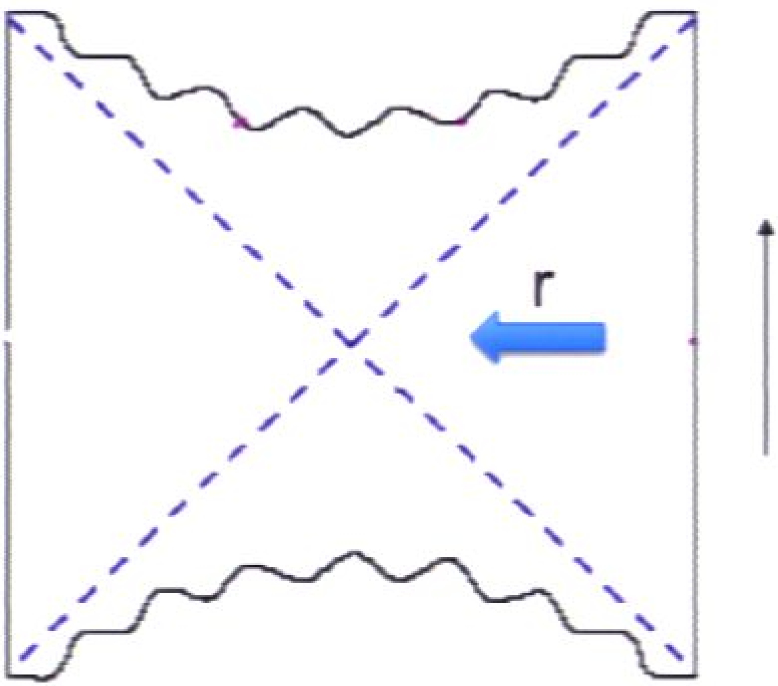

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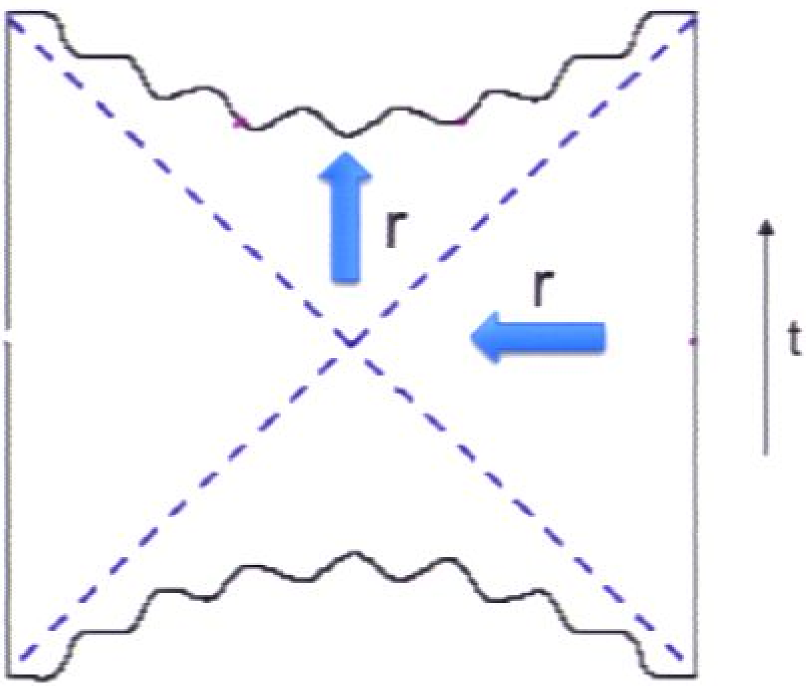

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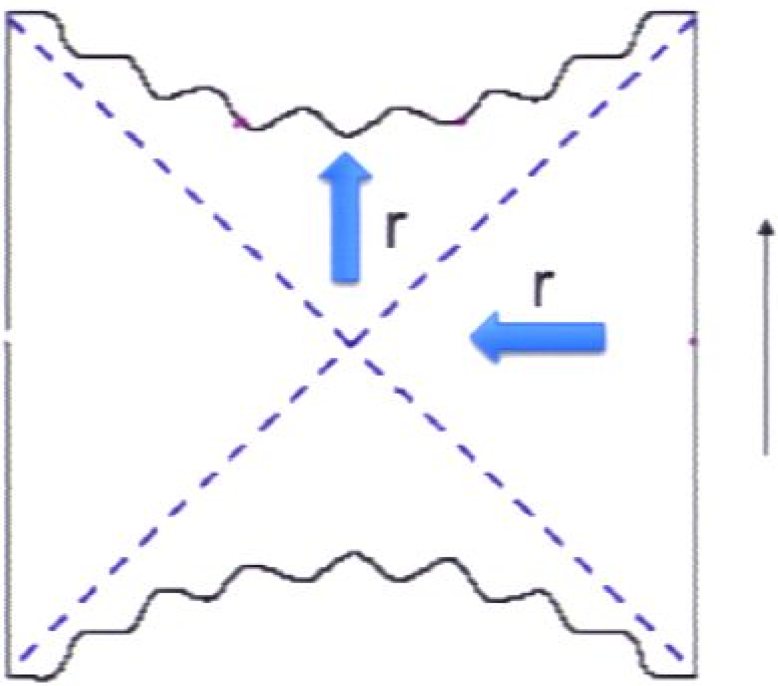

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How to describe the region inside the horizon using AdS/CFT?

UV/UV connection inside the horizon

$$ds^2 = -f\,dt^2 + \frac{1}{f}dr^2 + r^2 d\Omega^2$$

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boundary: UV

horizon: IR

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Bulk evolution in r ⇔ flow in energy scale

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→ boundary: UV

horizon: IR

Bulk evolution in r ↔ flow in energy scale

Inside the horizon: $f < 0$

$$E_{\text{boundary}} = i\sqrt{-f} E_{\text{prop}}$$

E_{prop} : now a spatial momentum

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Bulk evolution in r (time evolution) ⟺ flow in imaginary energy ???

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$$E_{\text{boundary}} = i\sqrt{-f} E_{\text{prop}}$$ ⇒ Singularity: $E_{\text{boundary}} \to \pm i\infty$

E_{prop} : now a spatial momentum

Horizon: $E_{\text{boundary}} \to 0$

Bulk evolution in r (time evolution) ⇔ flow in imaginary energy ???

UV/UV connection inside the horizon

$$ds^2 = -f dt^2 + \frac{1}{f} dr^2 + r^2 d\Omega^2$$

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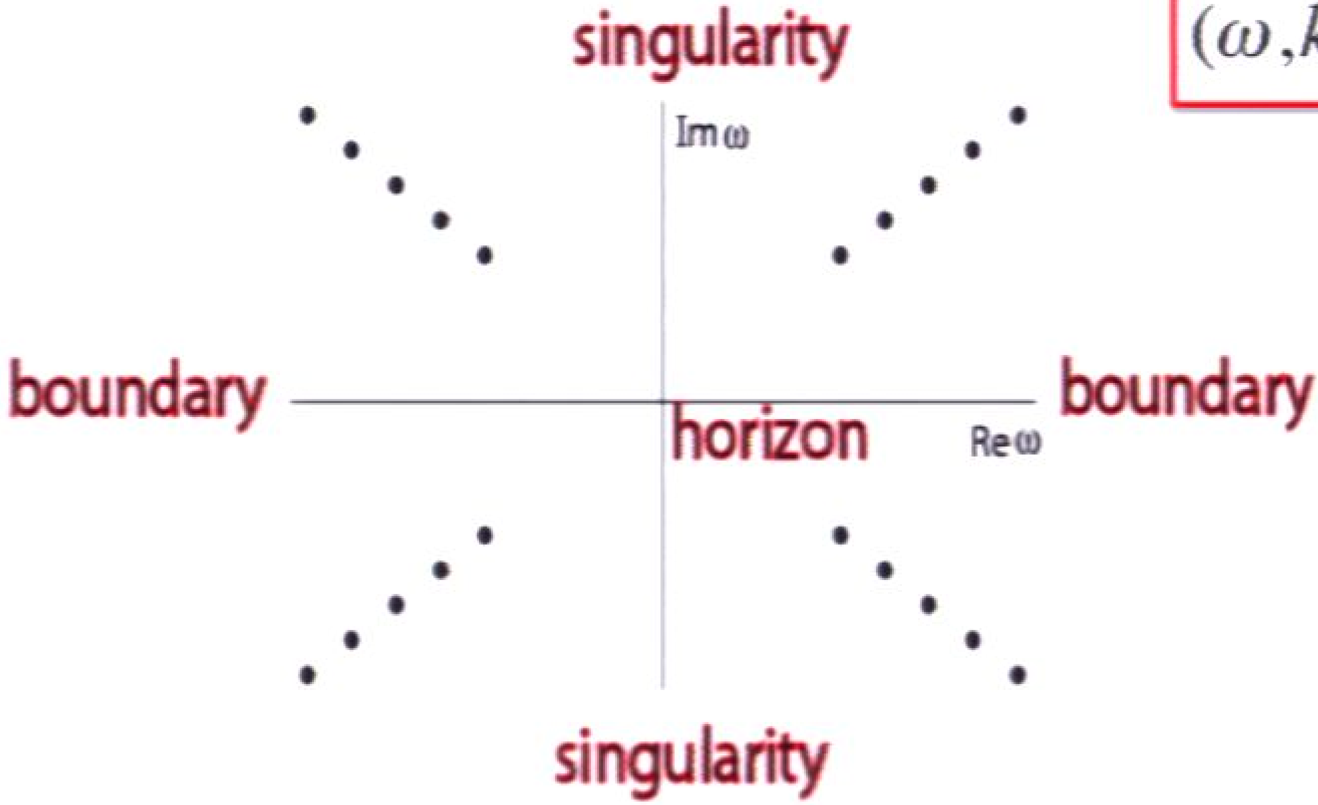

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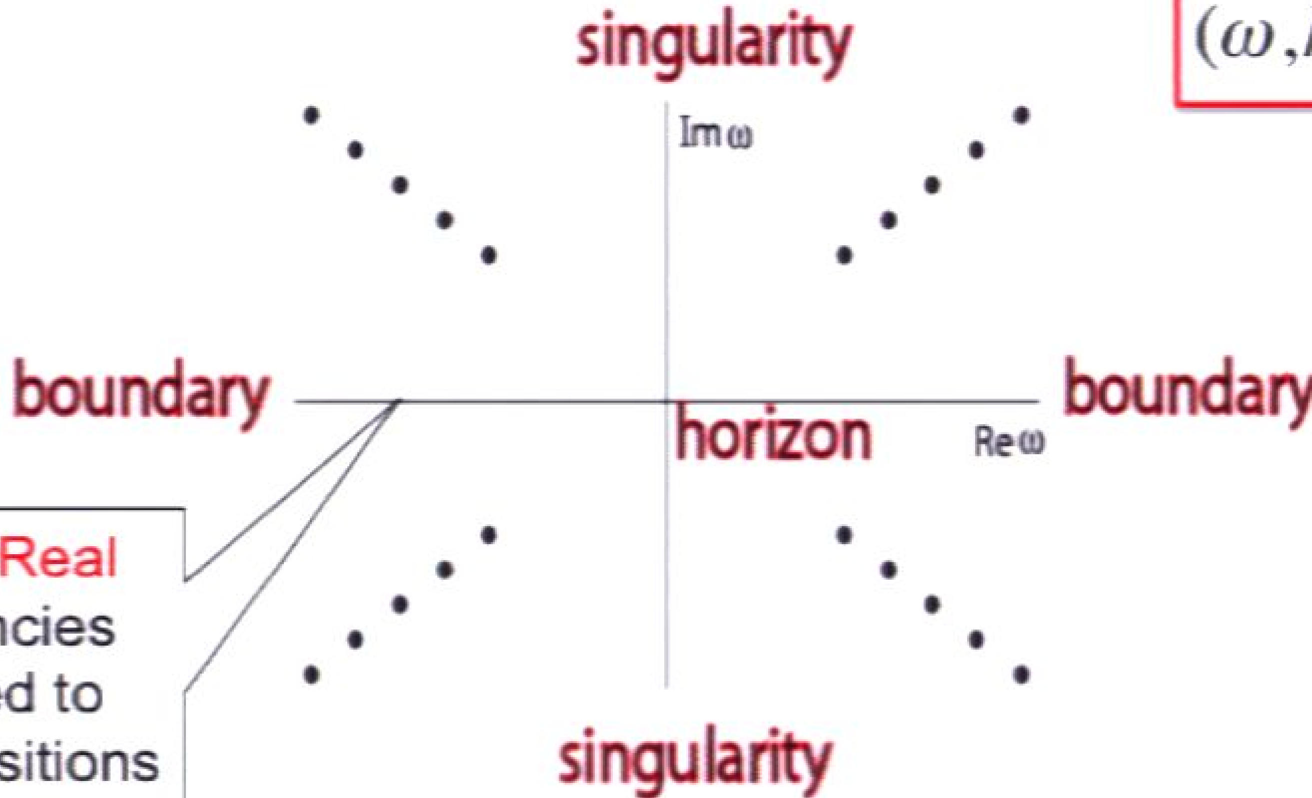

IR/UV: Real frequencies mapped to radial positions outside the horizon

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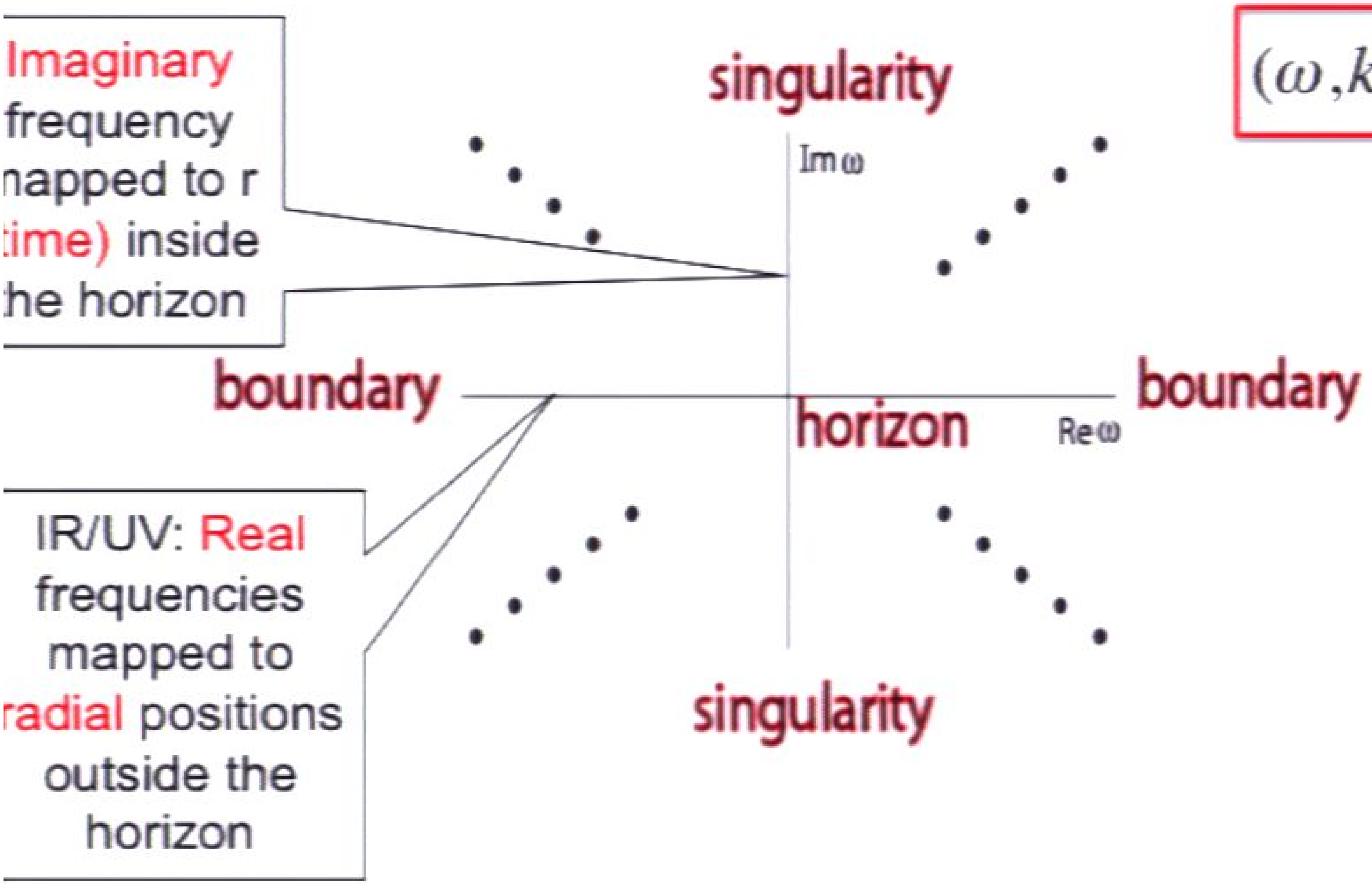

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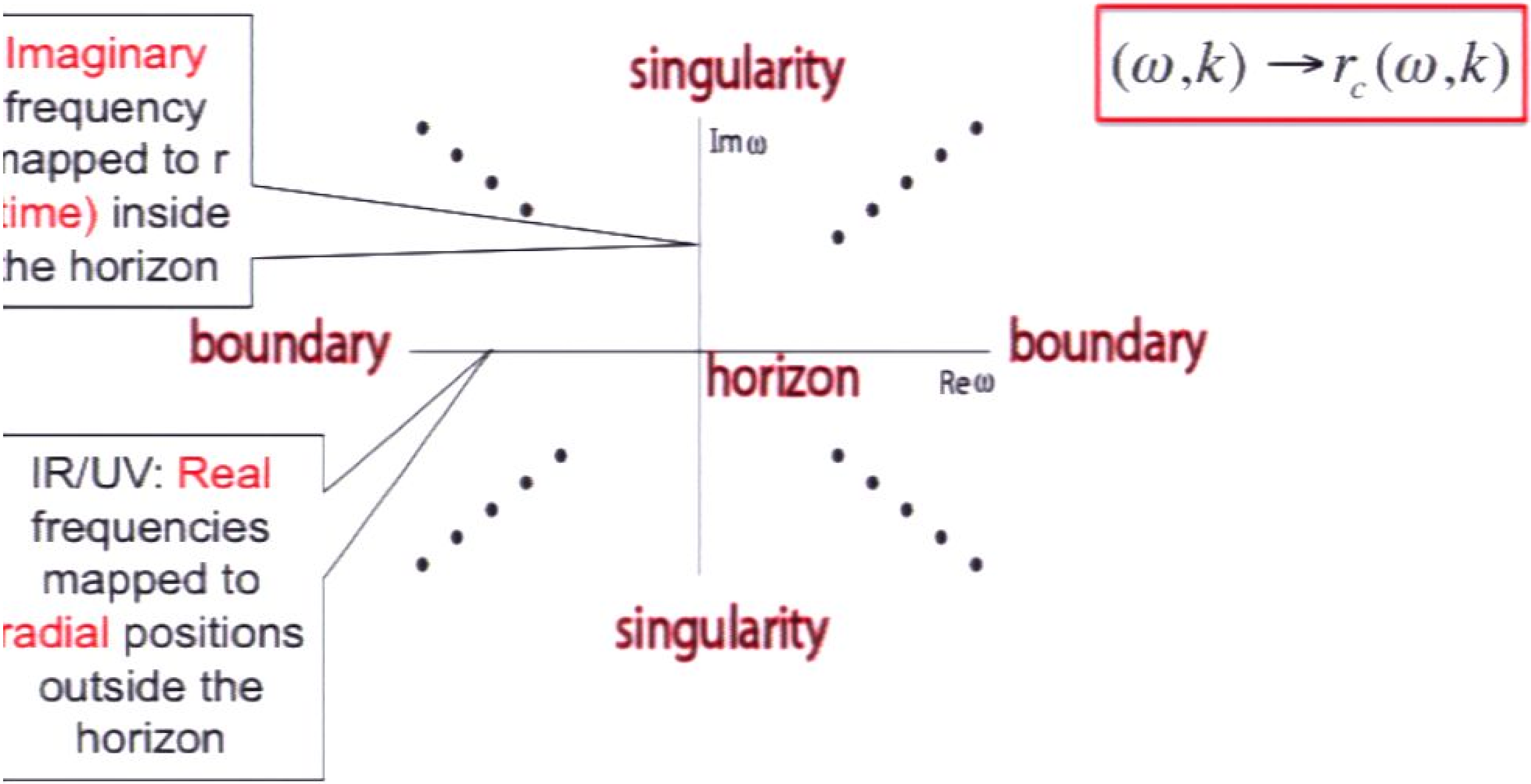

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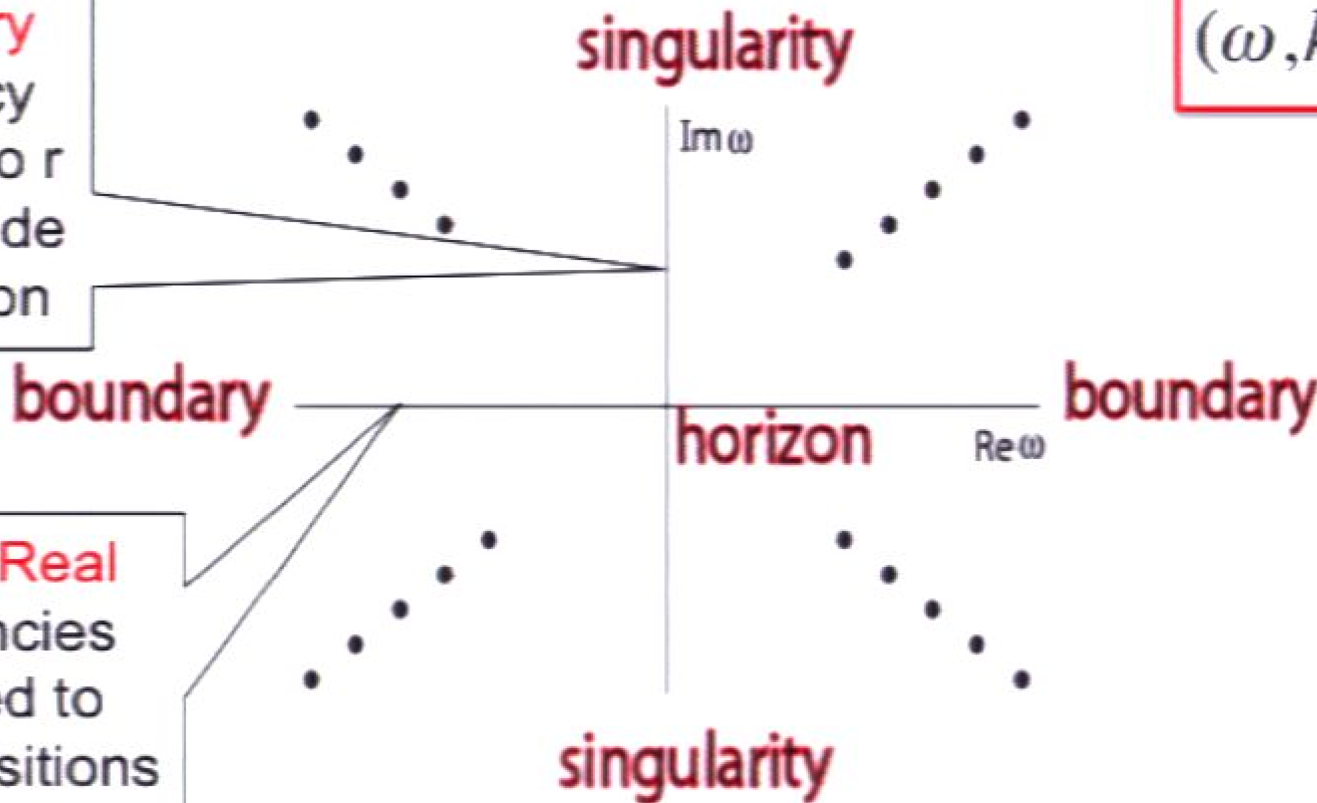

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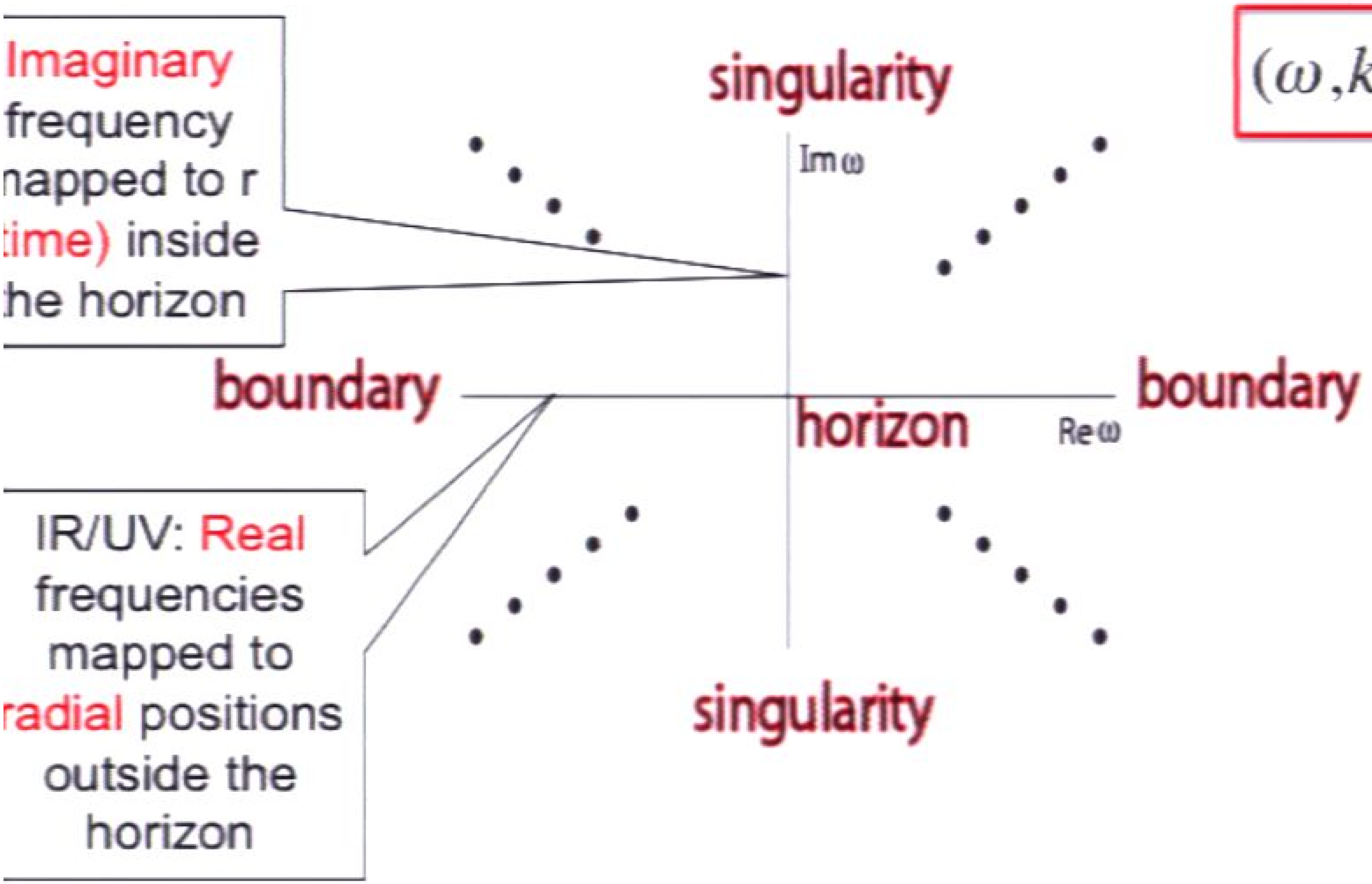

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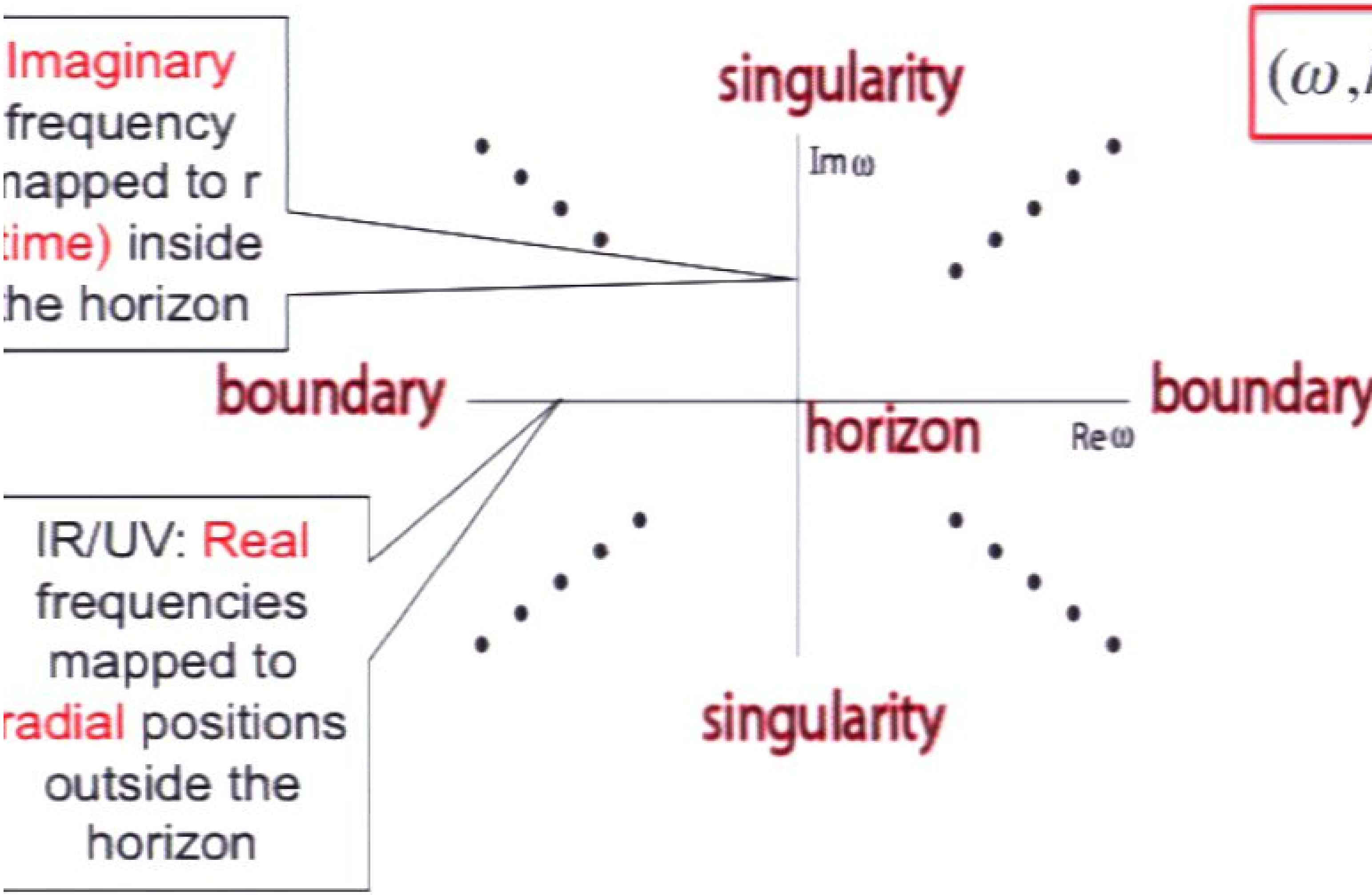

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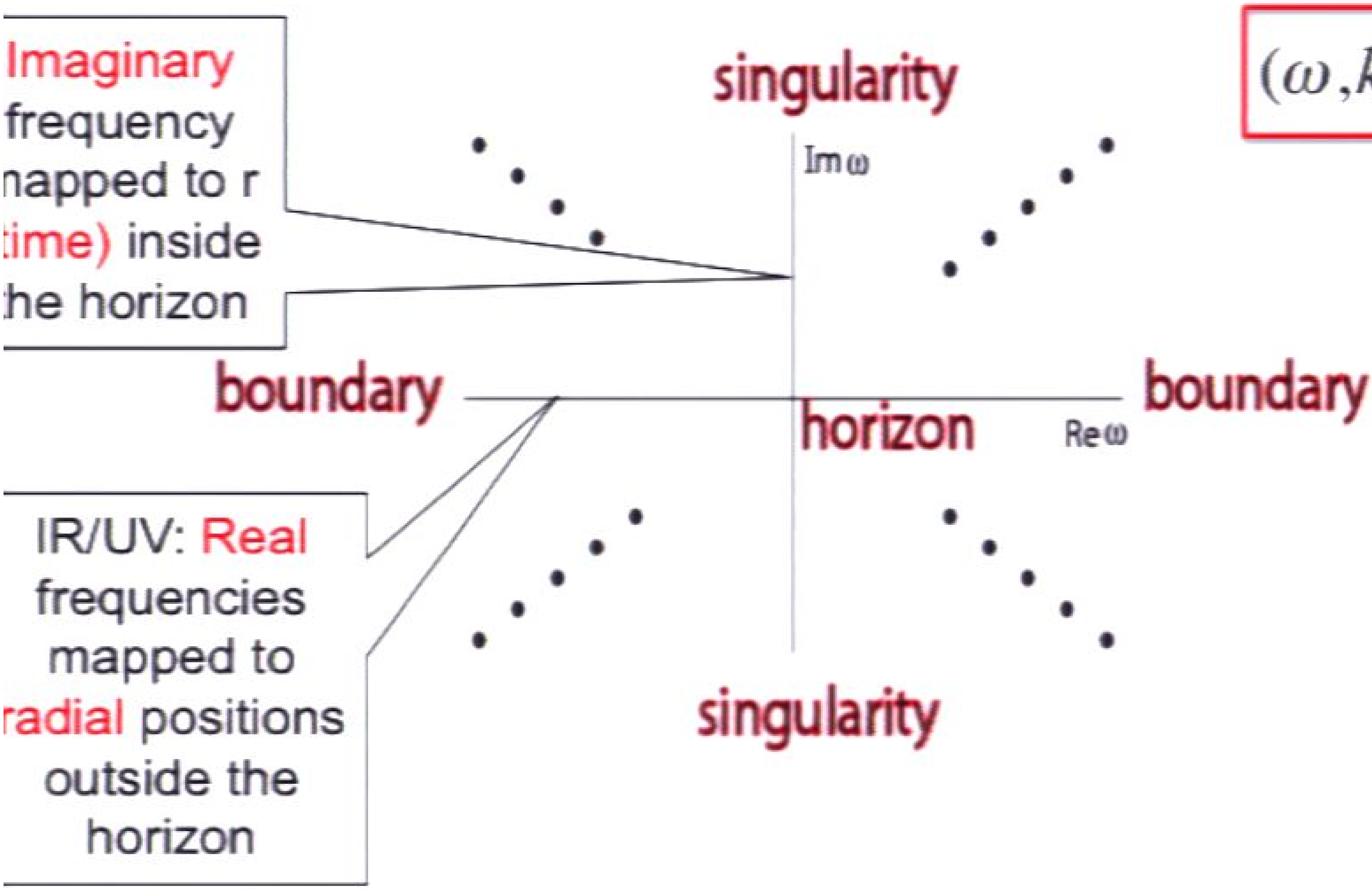

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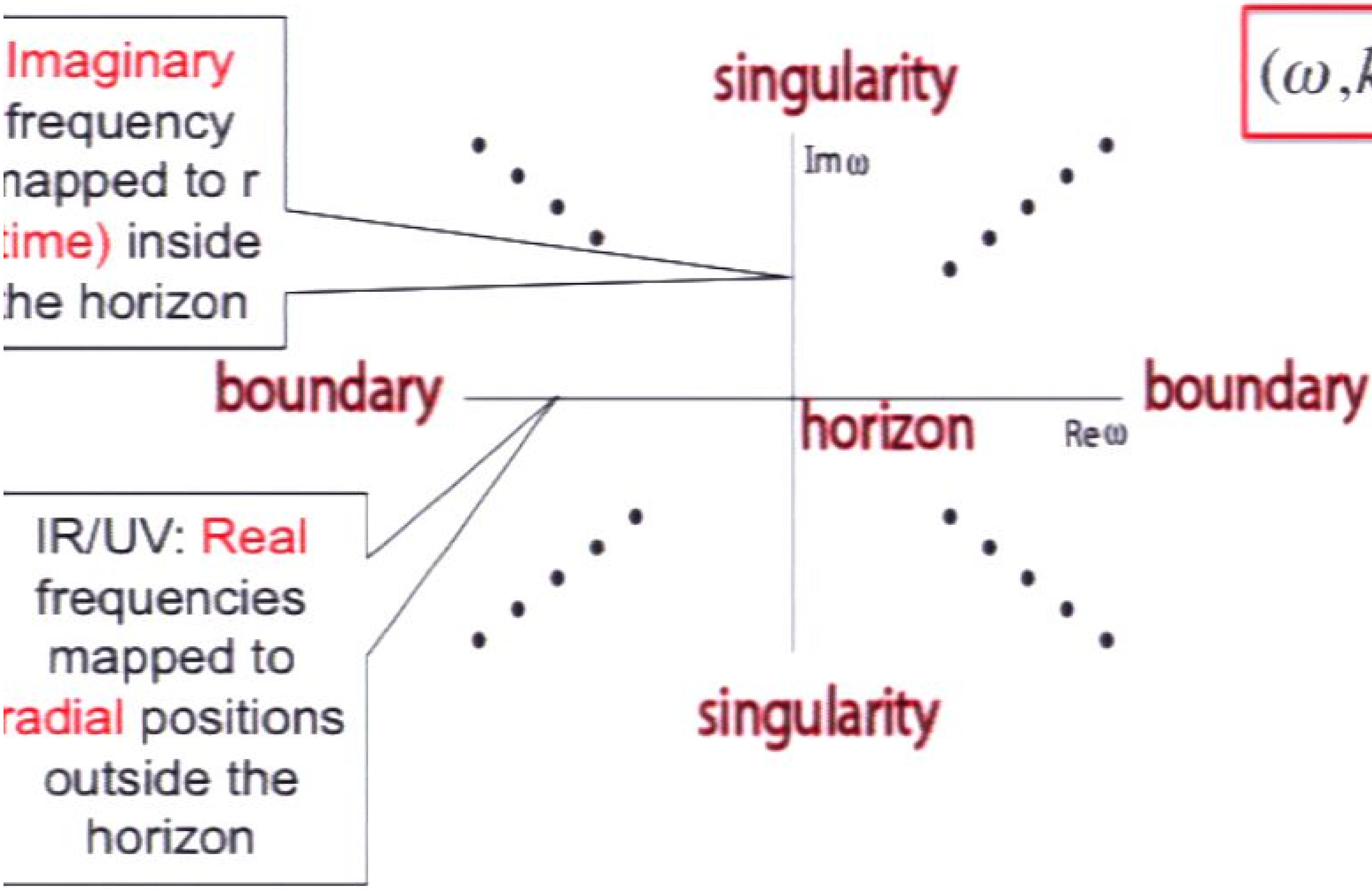

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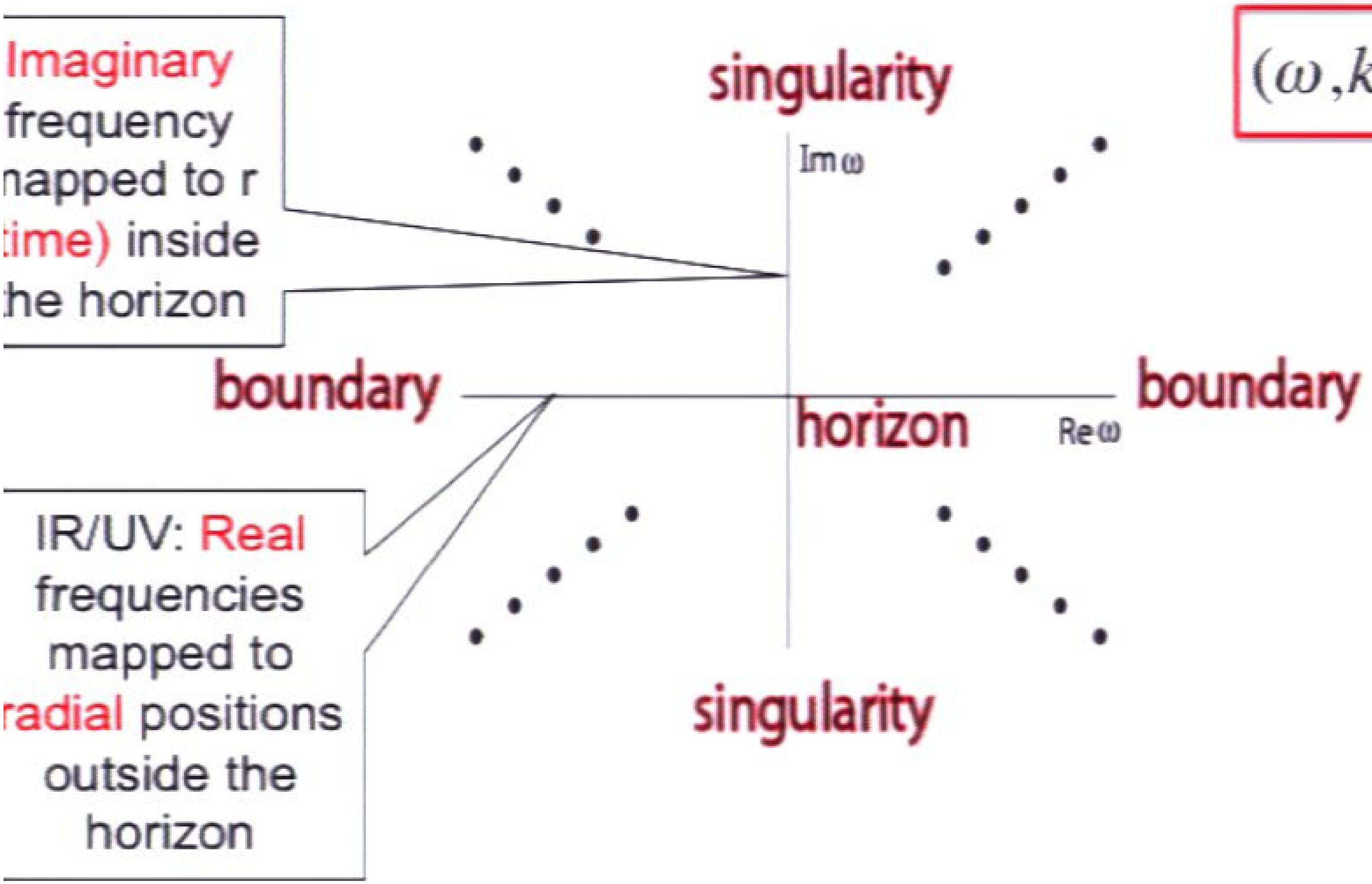

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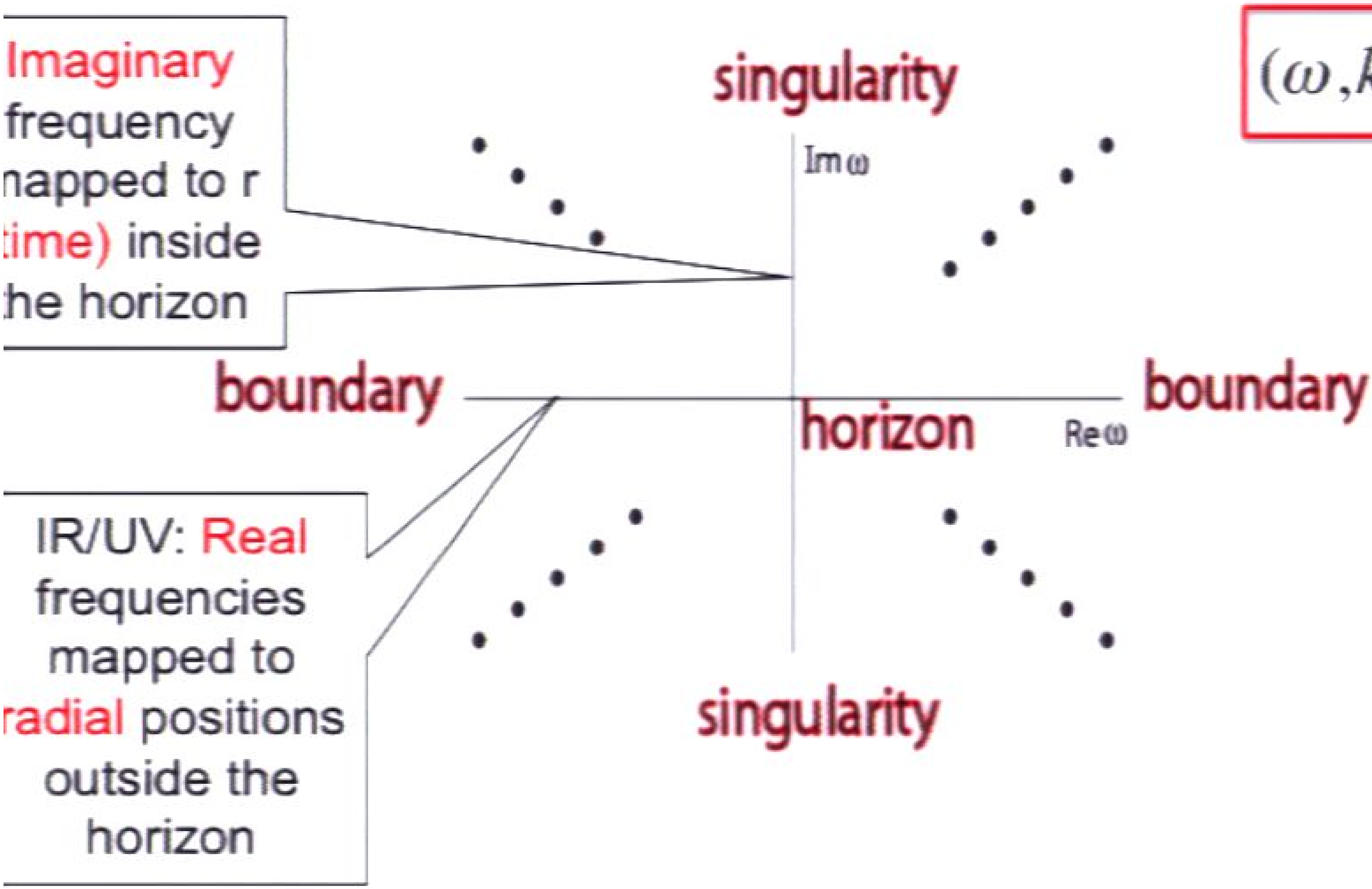

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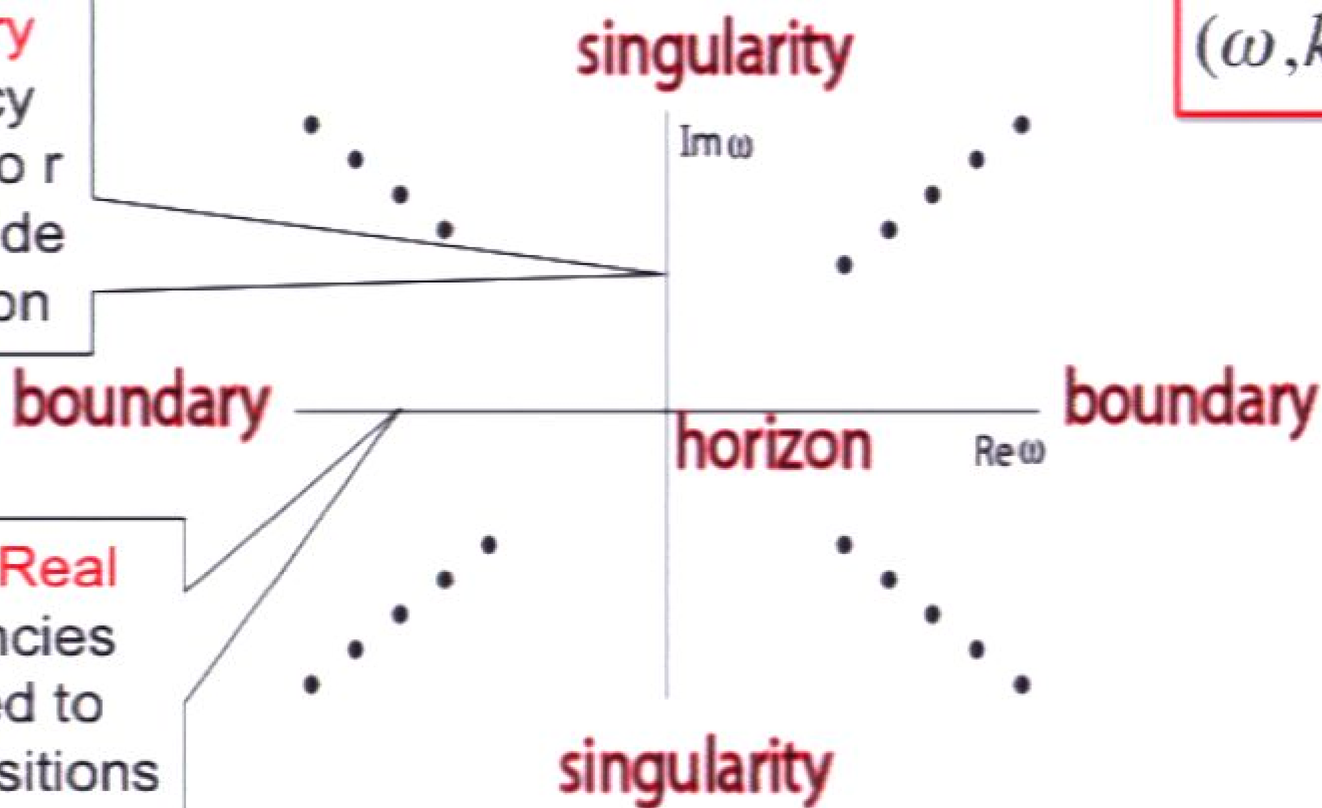

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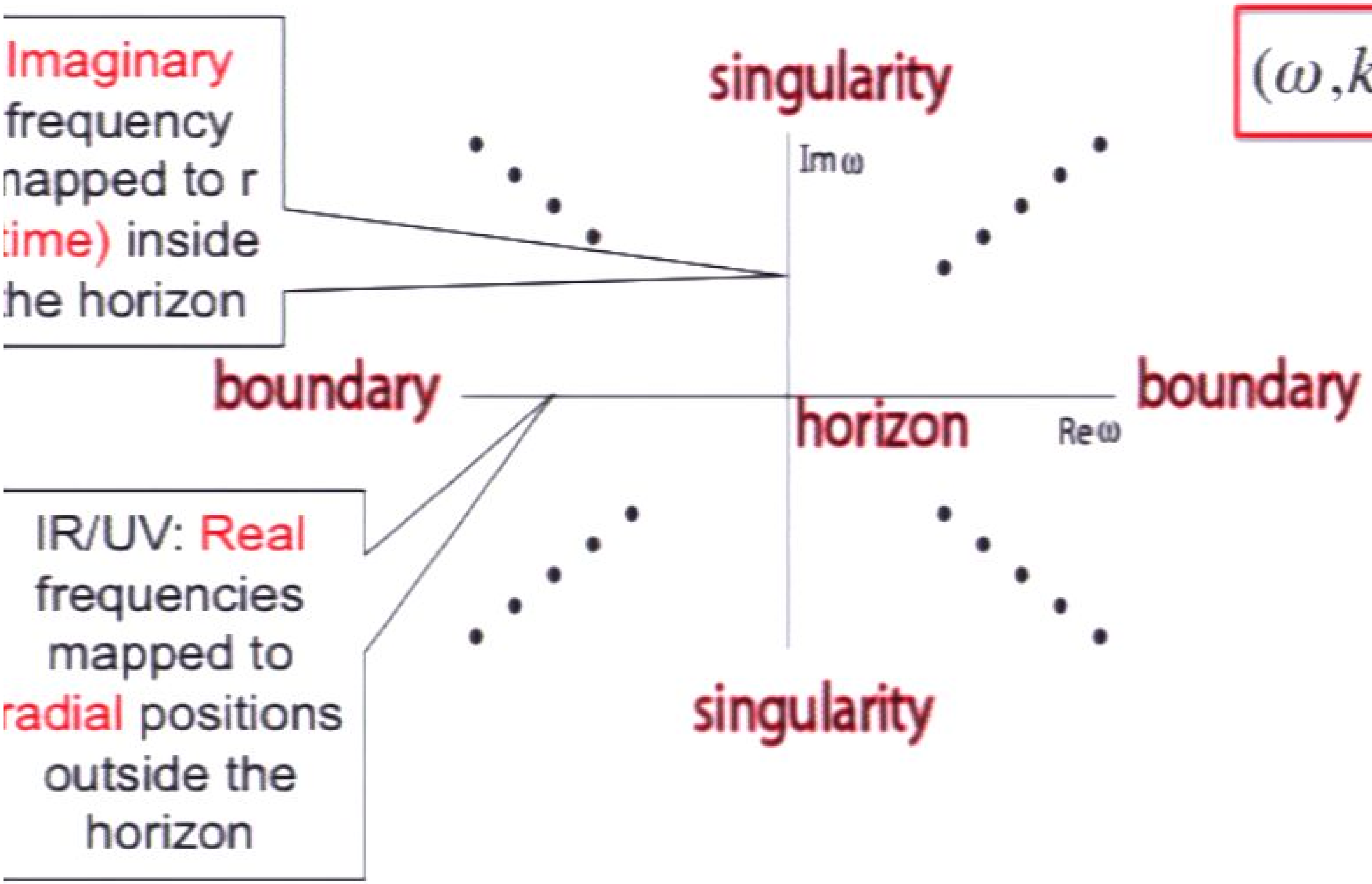

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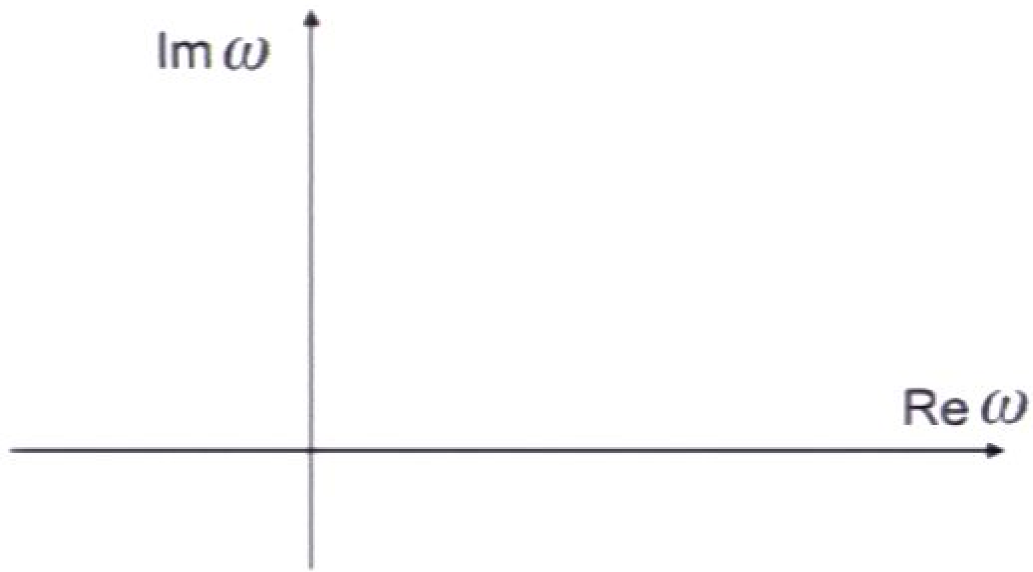

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(outside the horizon)

$\omega \rightarrow -i\omega$

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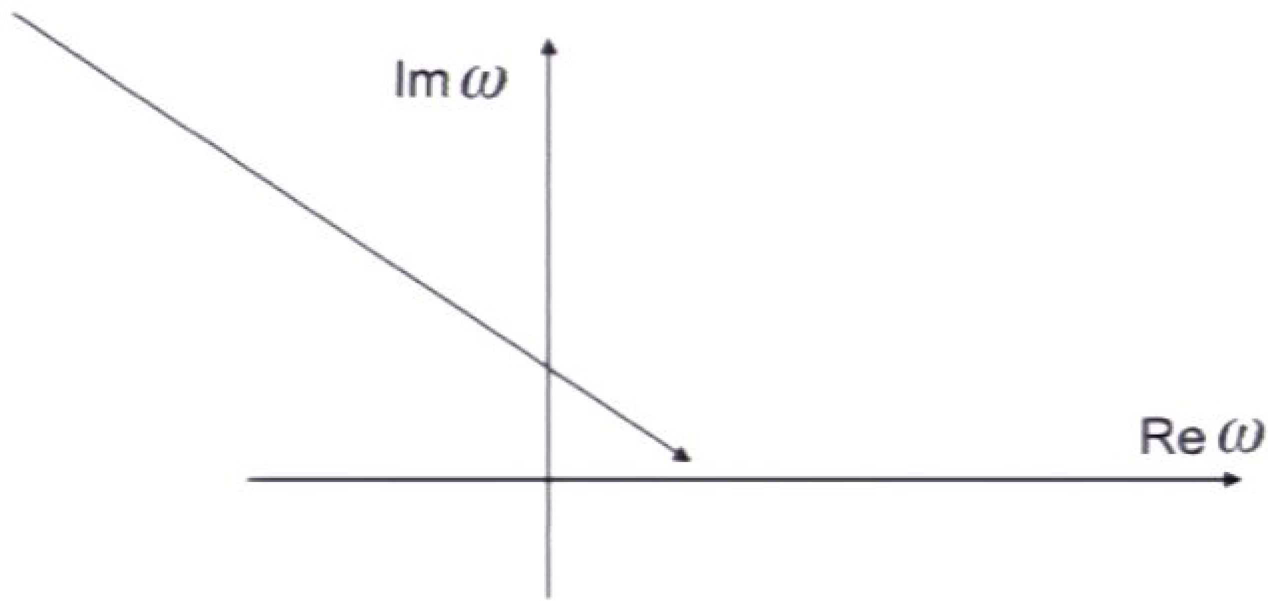

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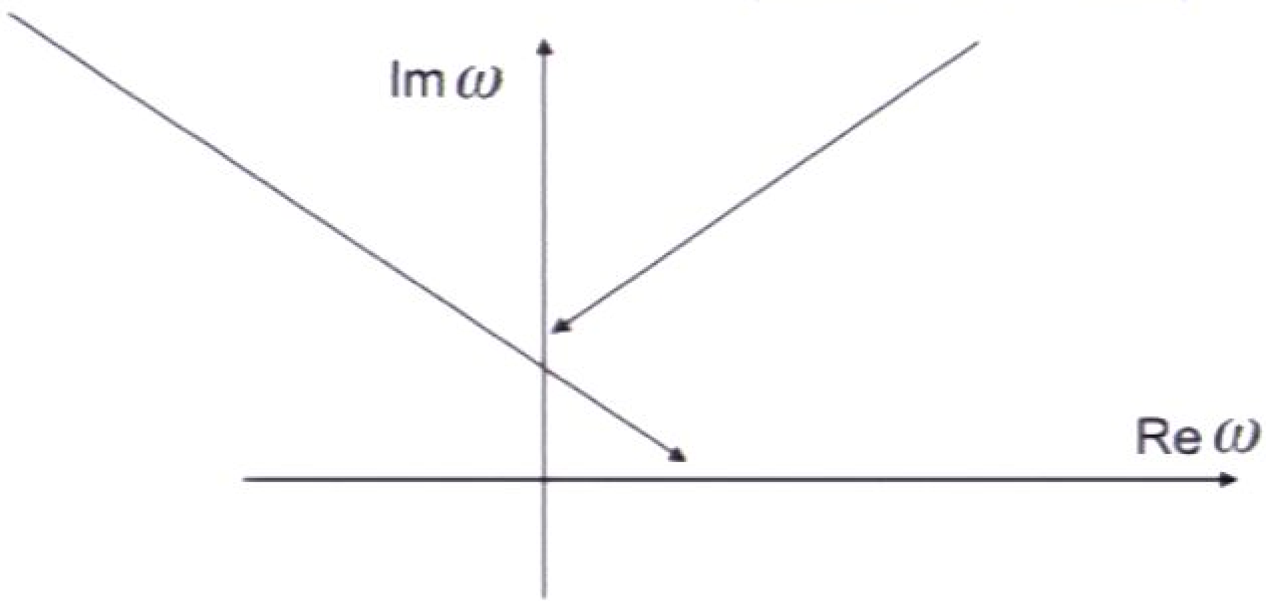
(inside the horizon)



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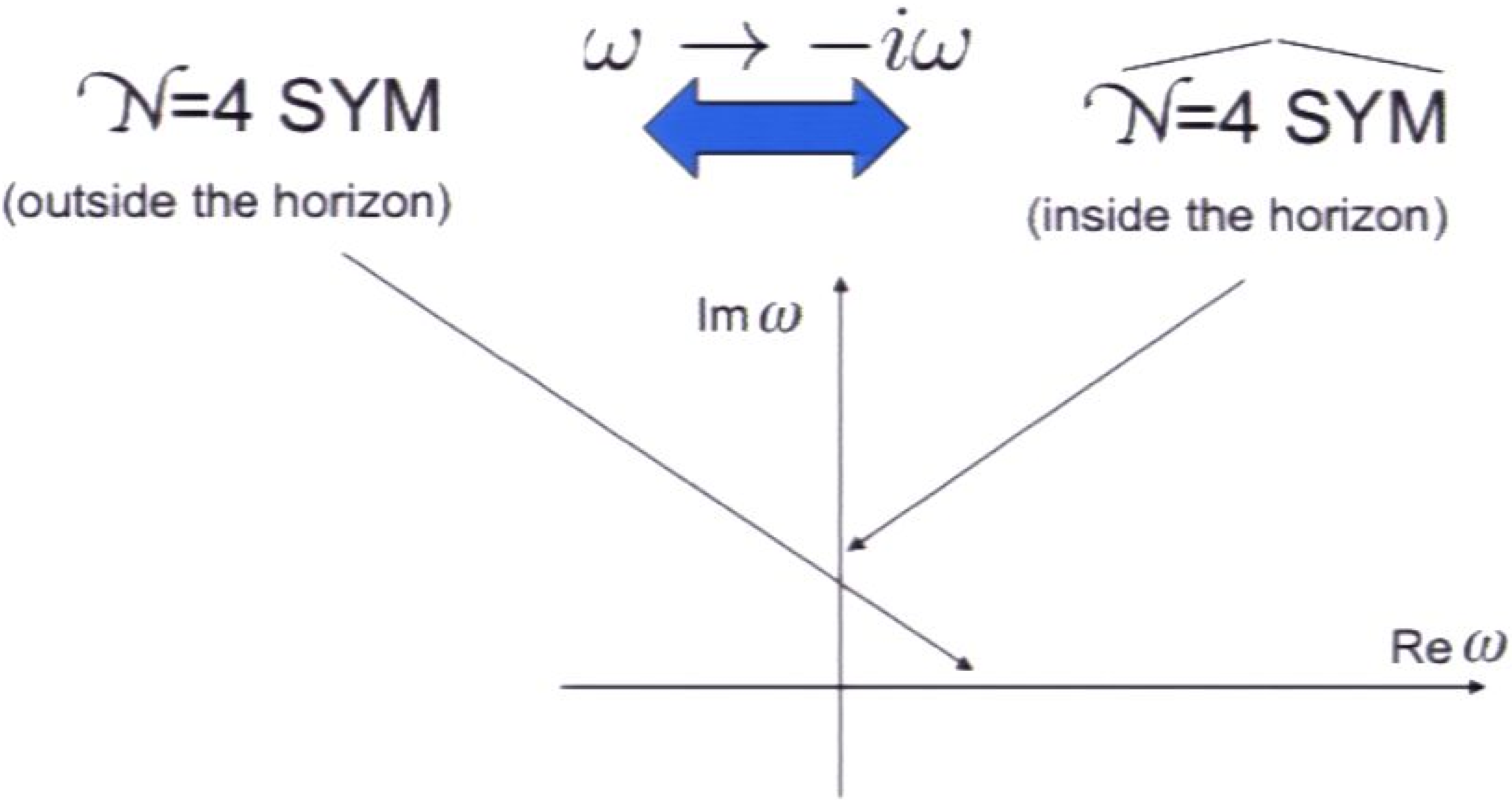

Different from the standard Euclidean analytic continuation!

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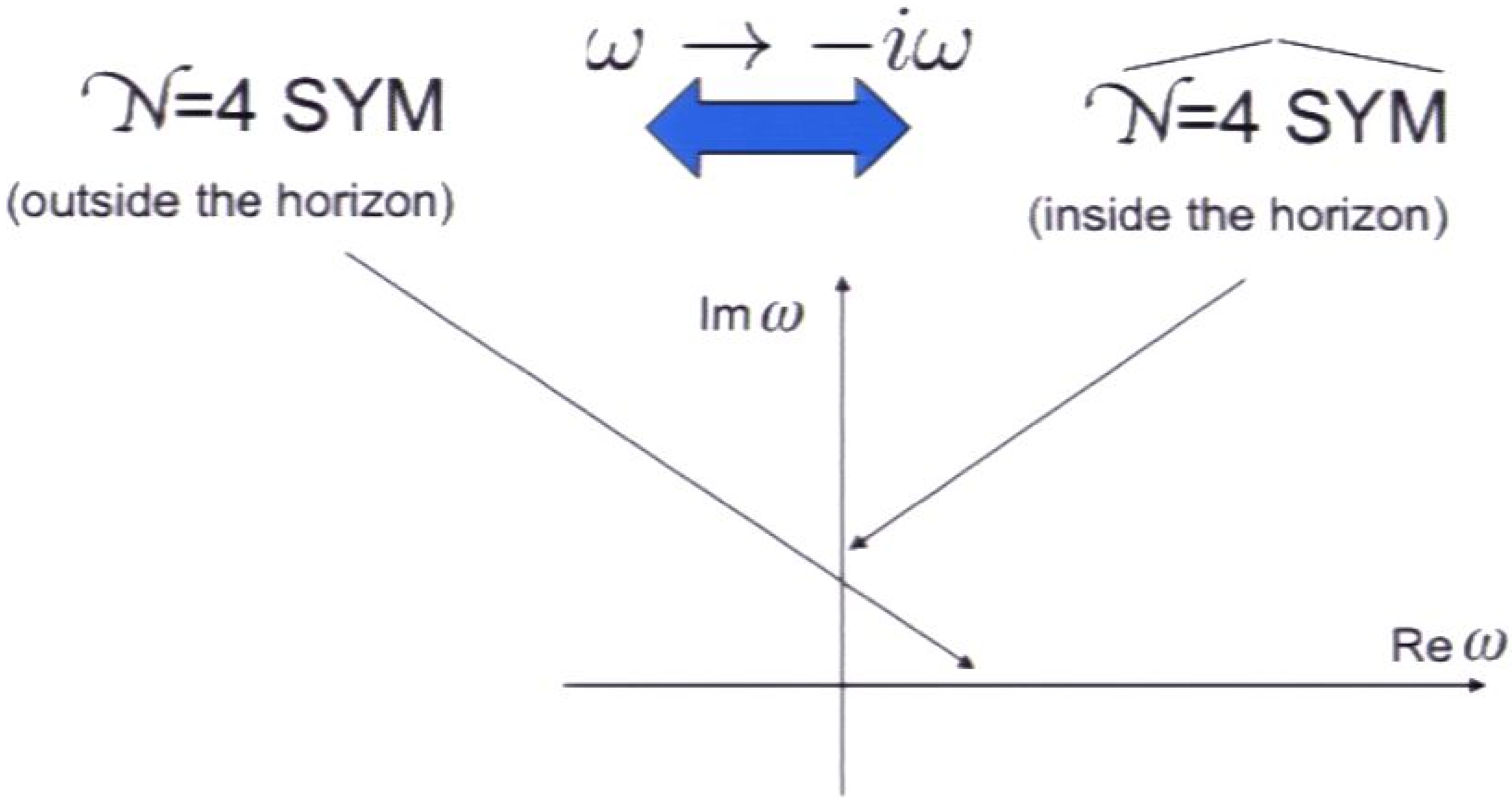

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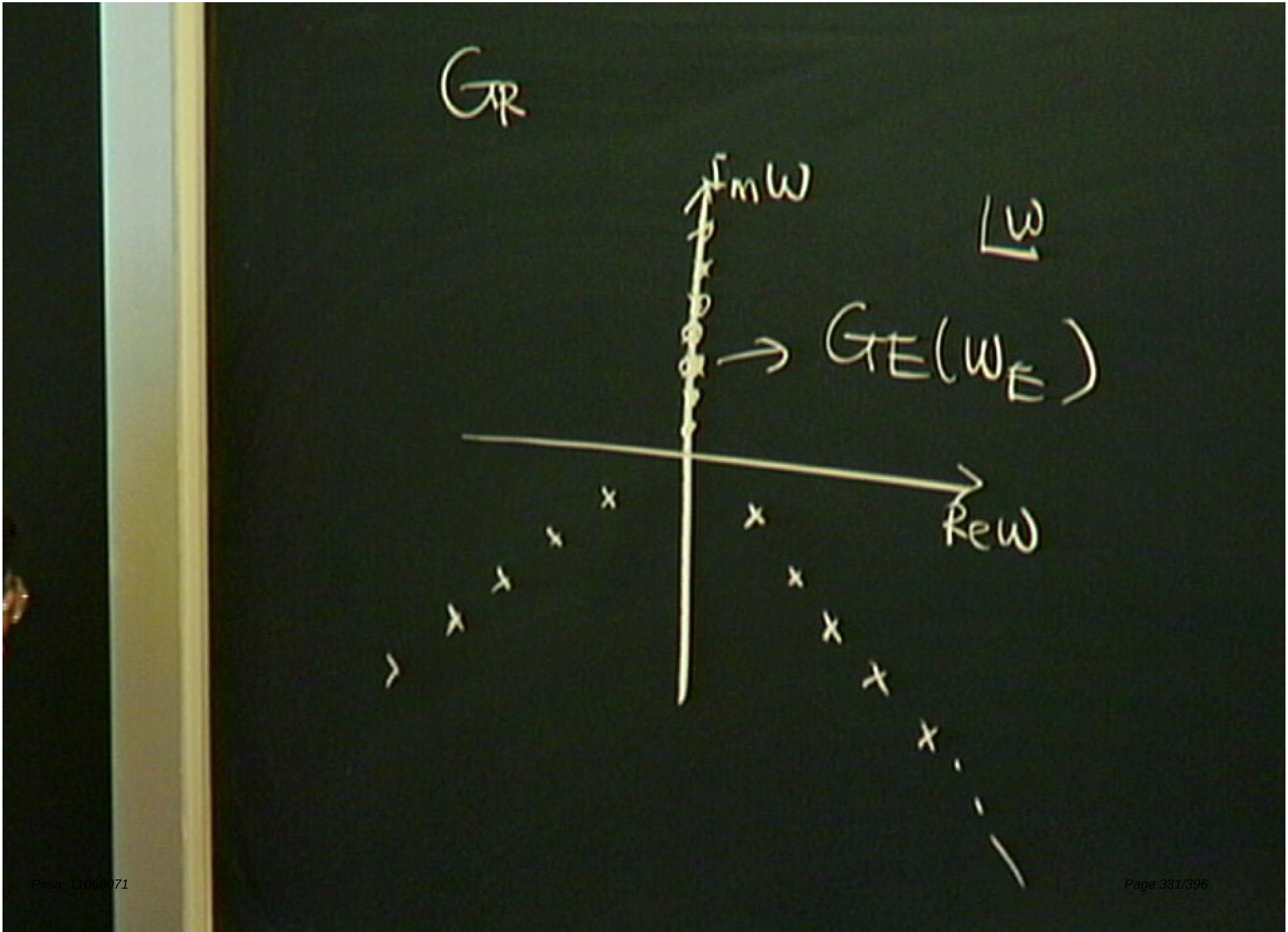
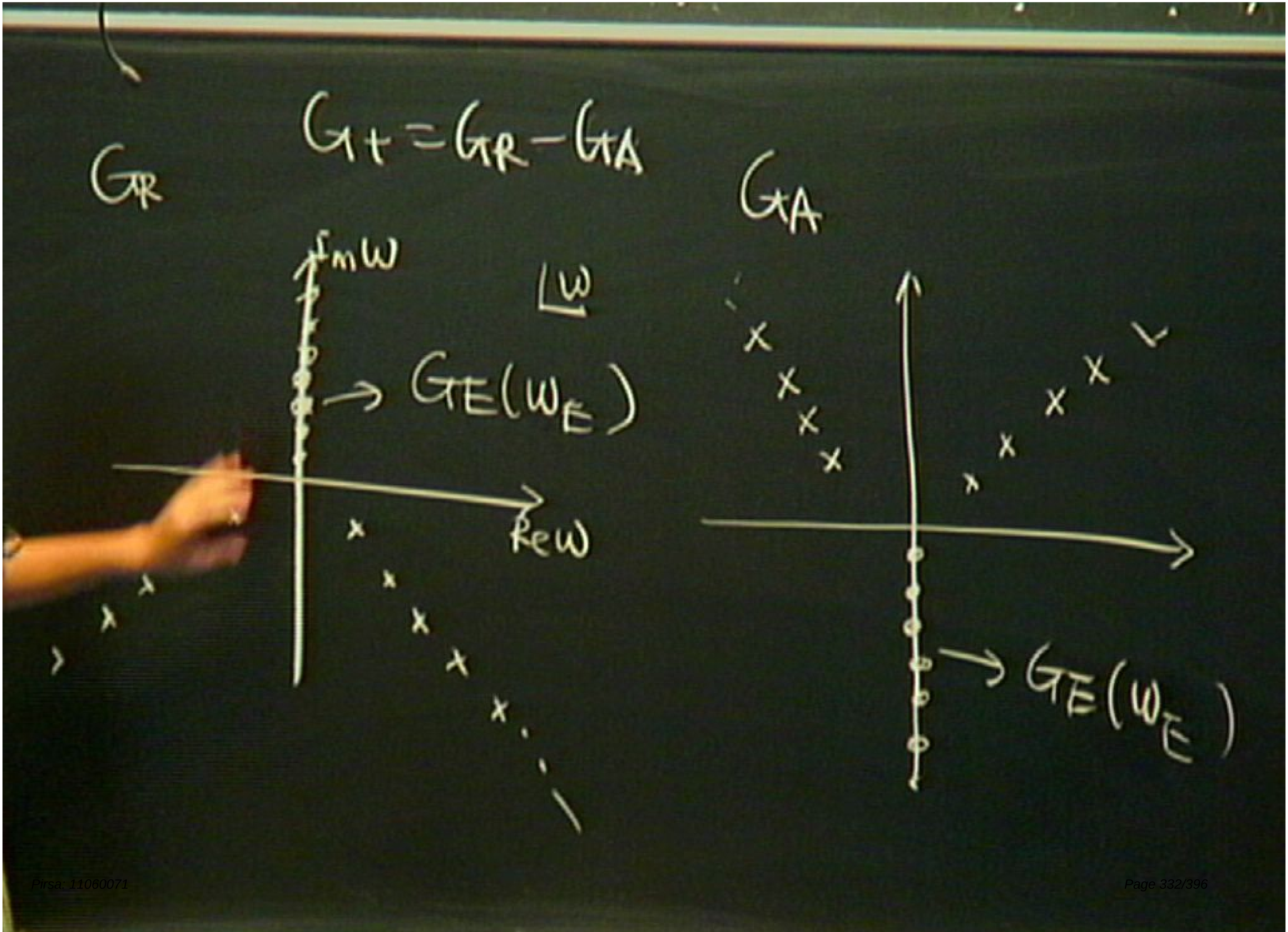


G_R
Im ω
ω
$G_E(\omega_E)$
Re ω


$G_t = G_R - G_A$
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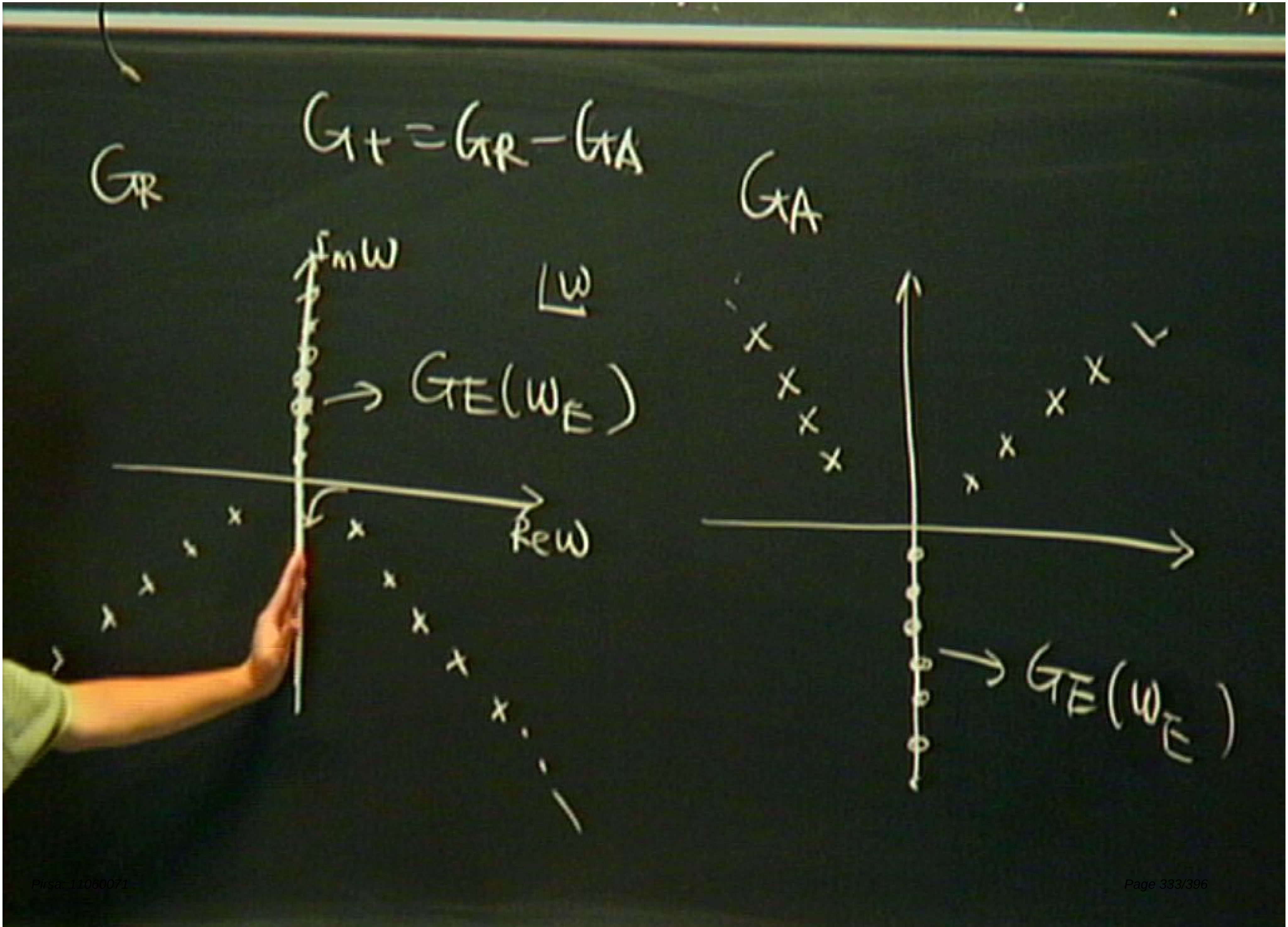

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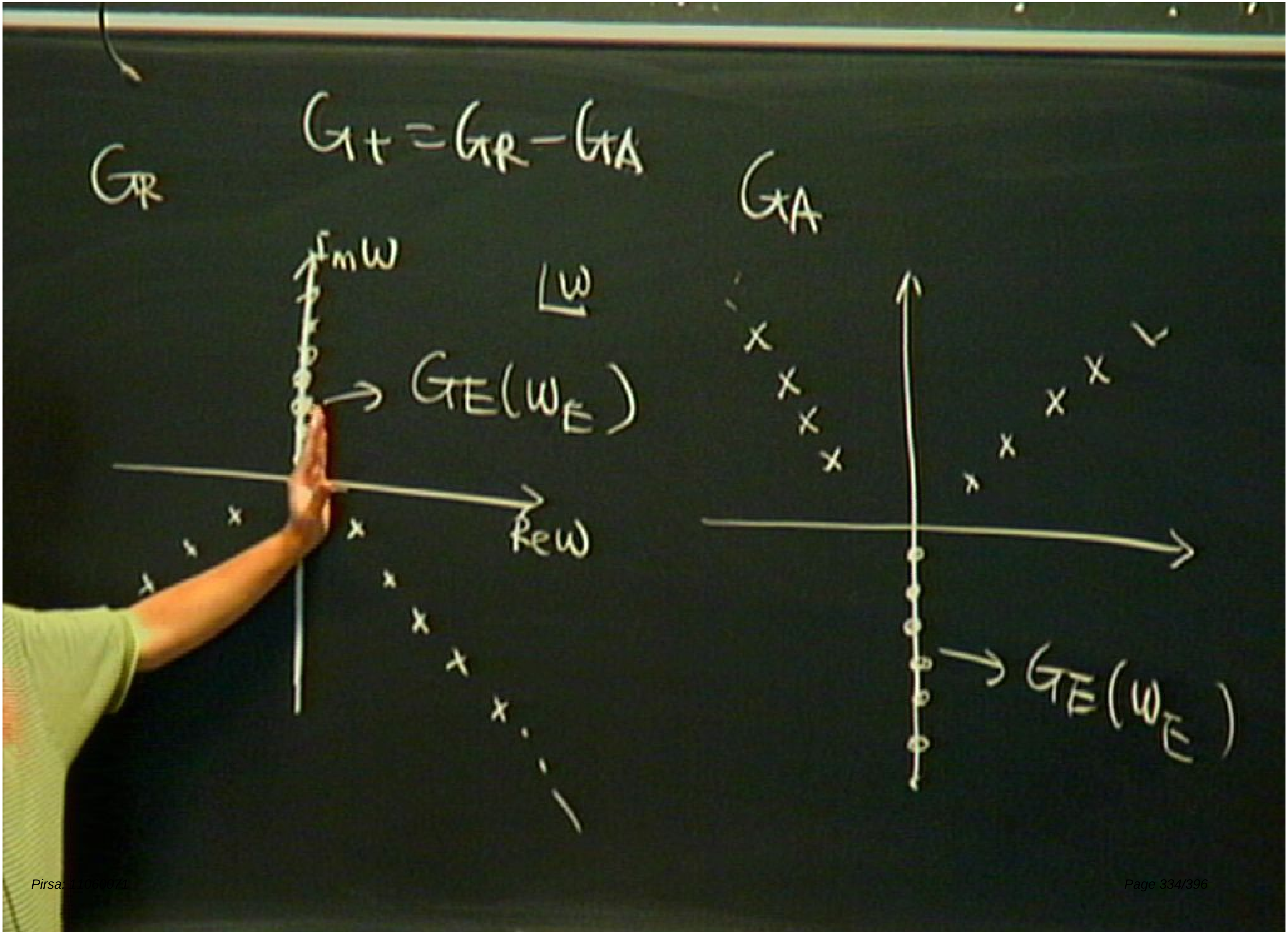

G+ = GR − GA
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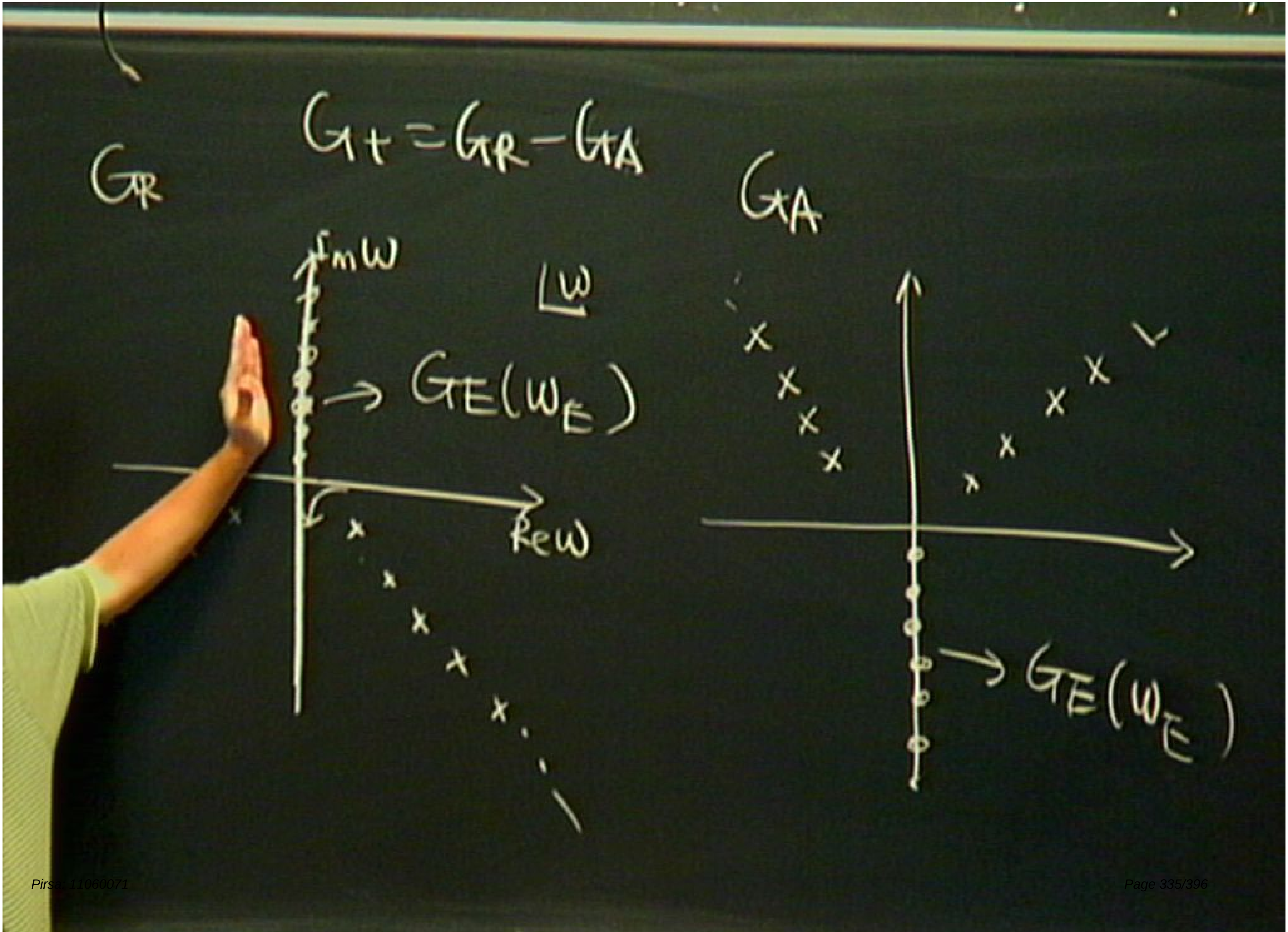
GE(ωE)
Re ω
GA
GE(ωE)



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W
GE(WE)
ReW
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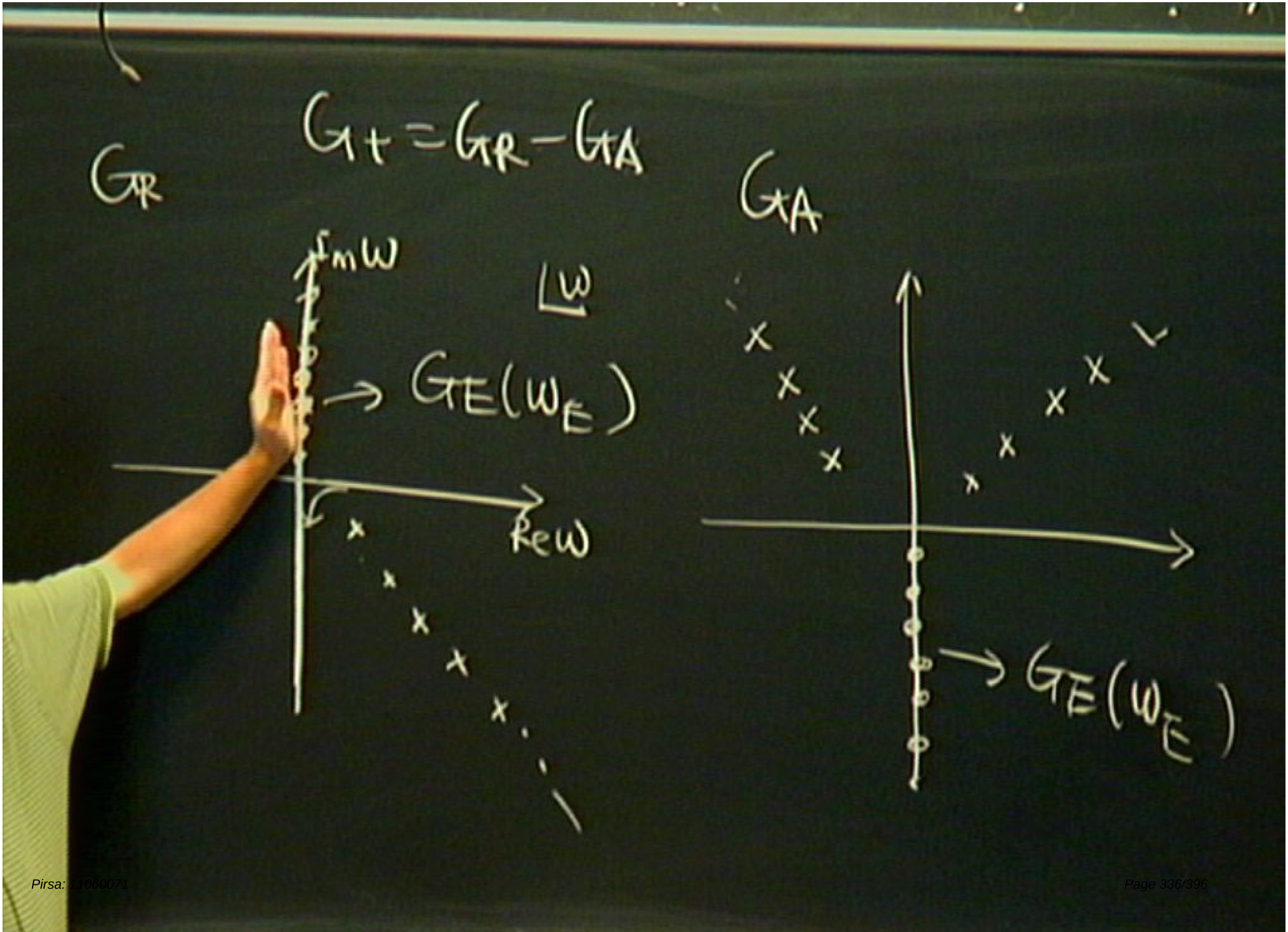

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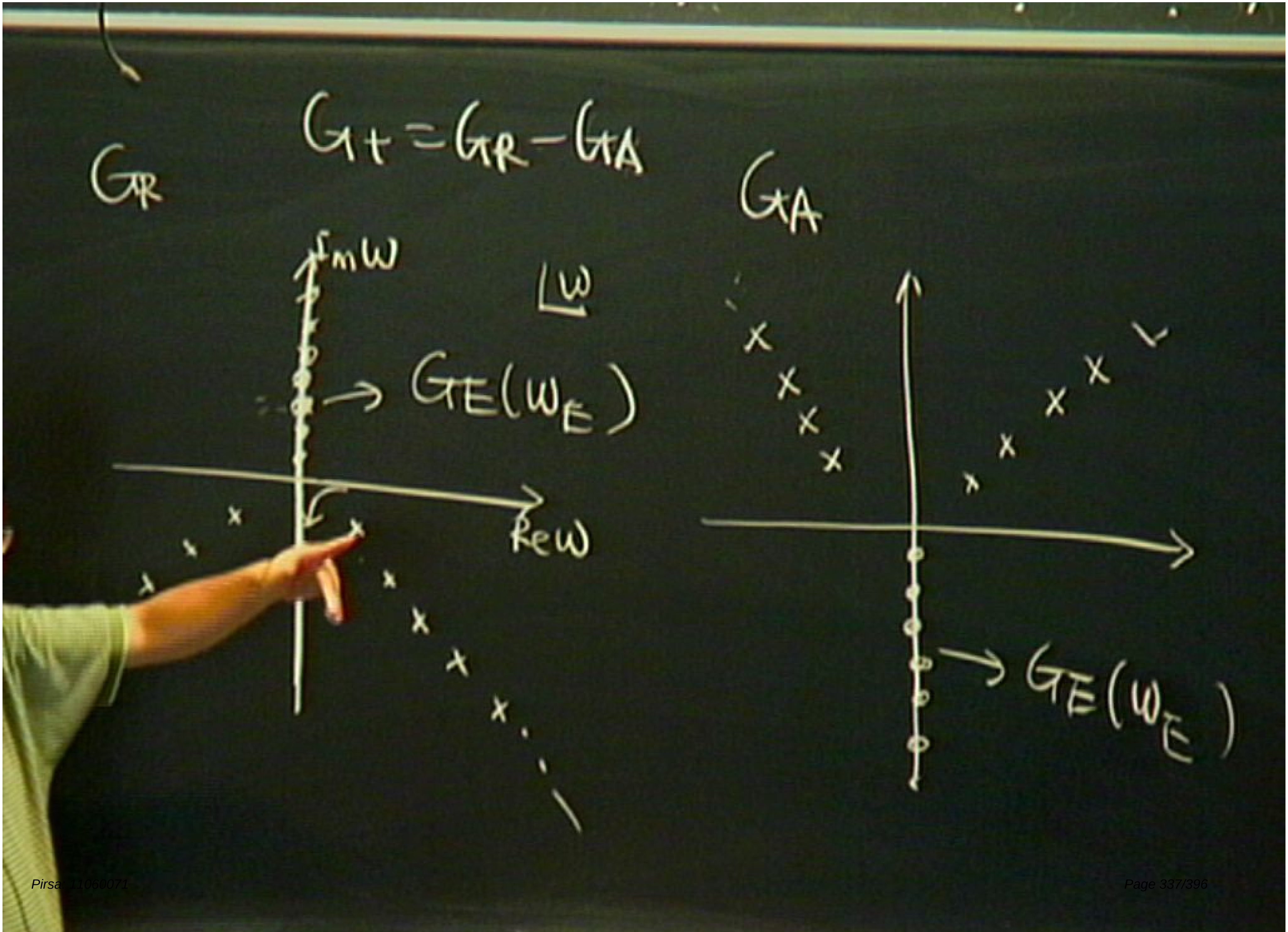

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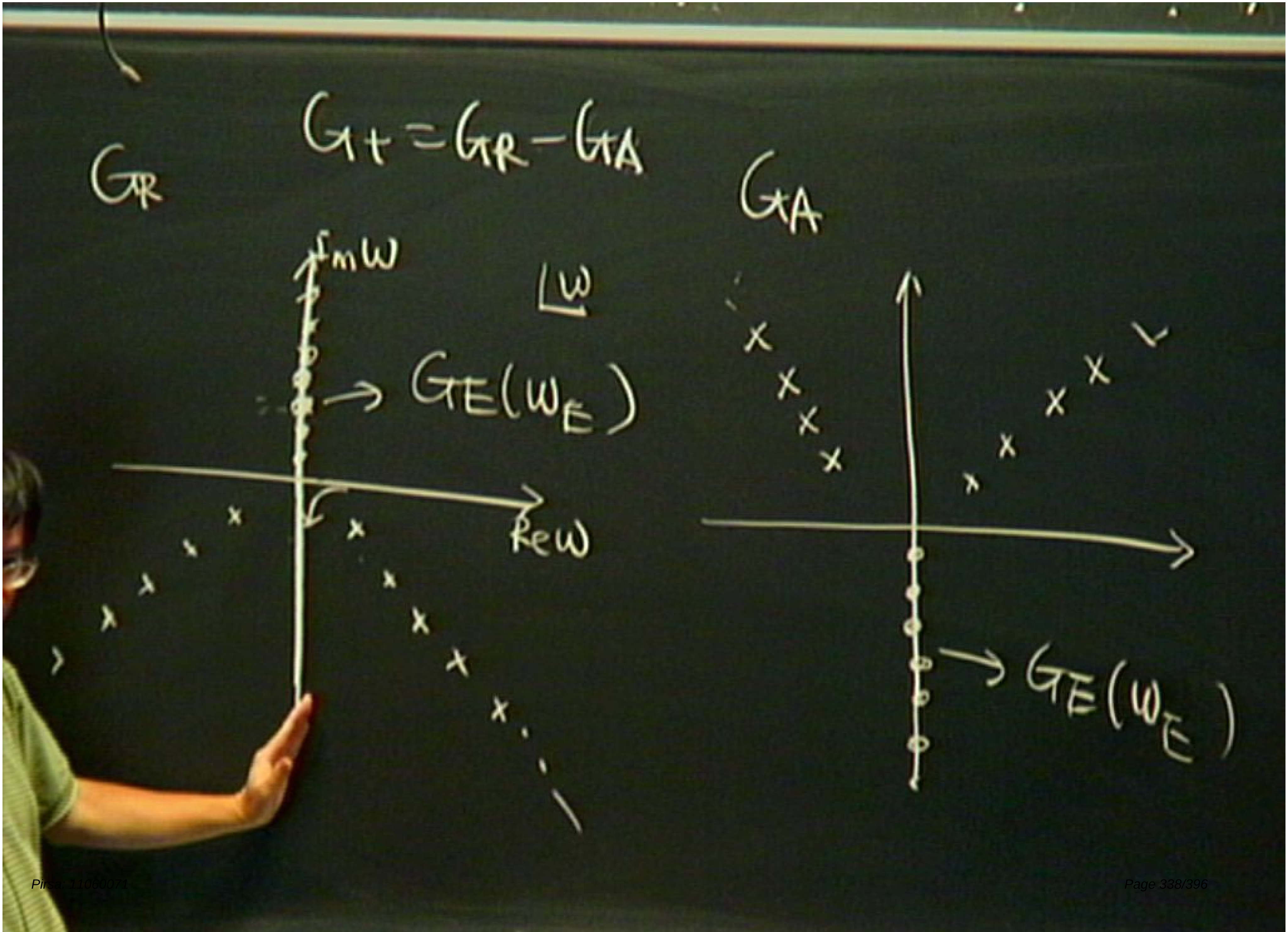

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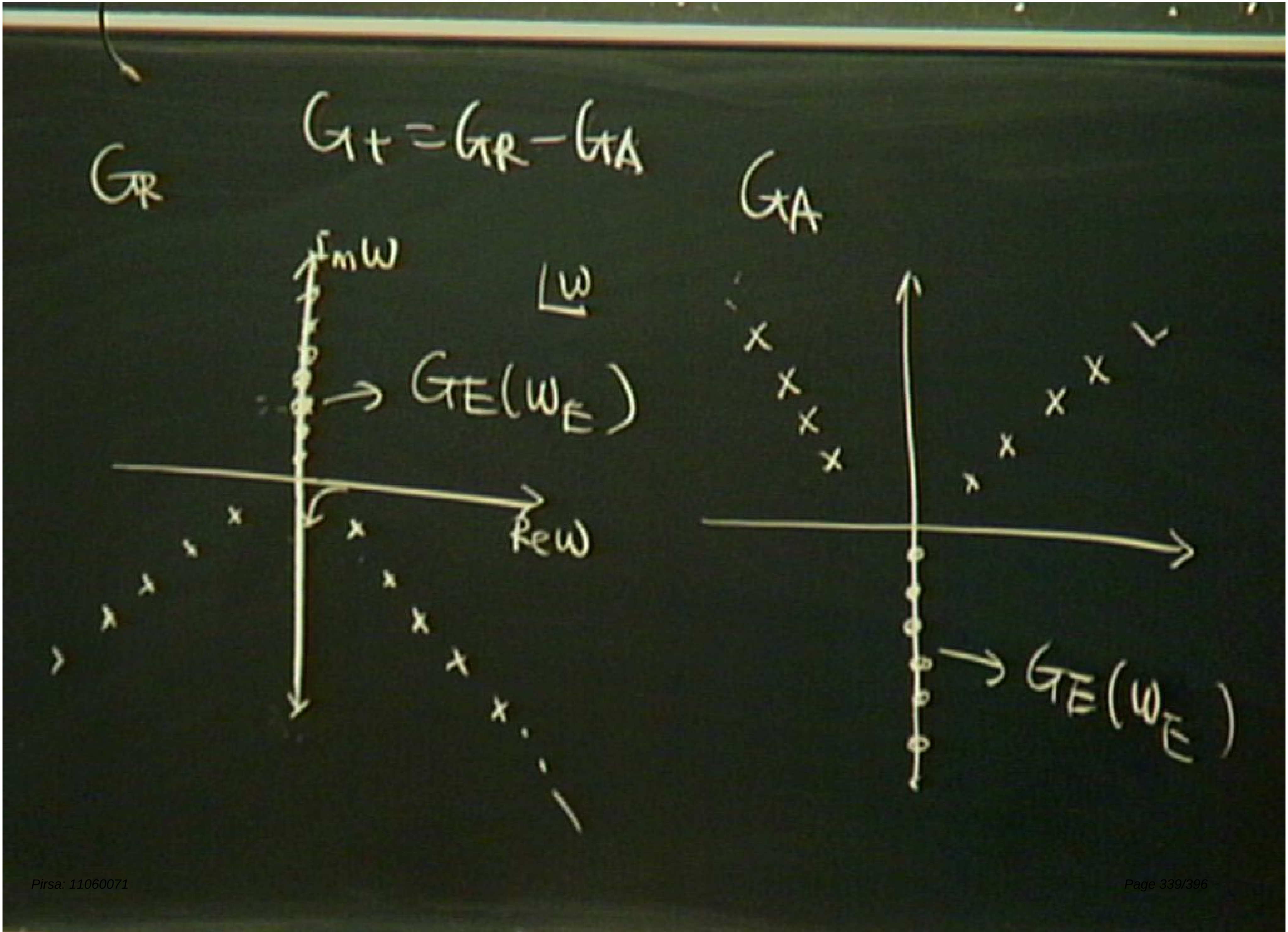

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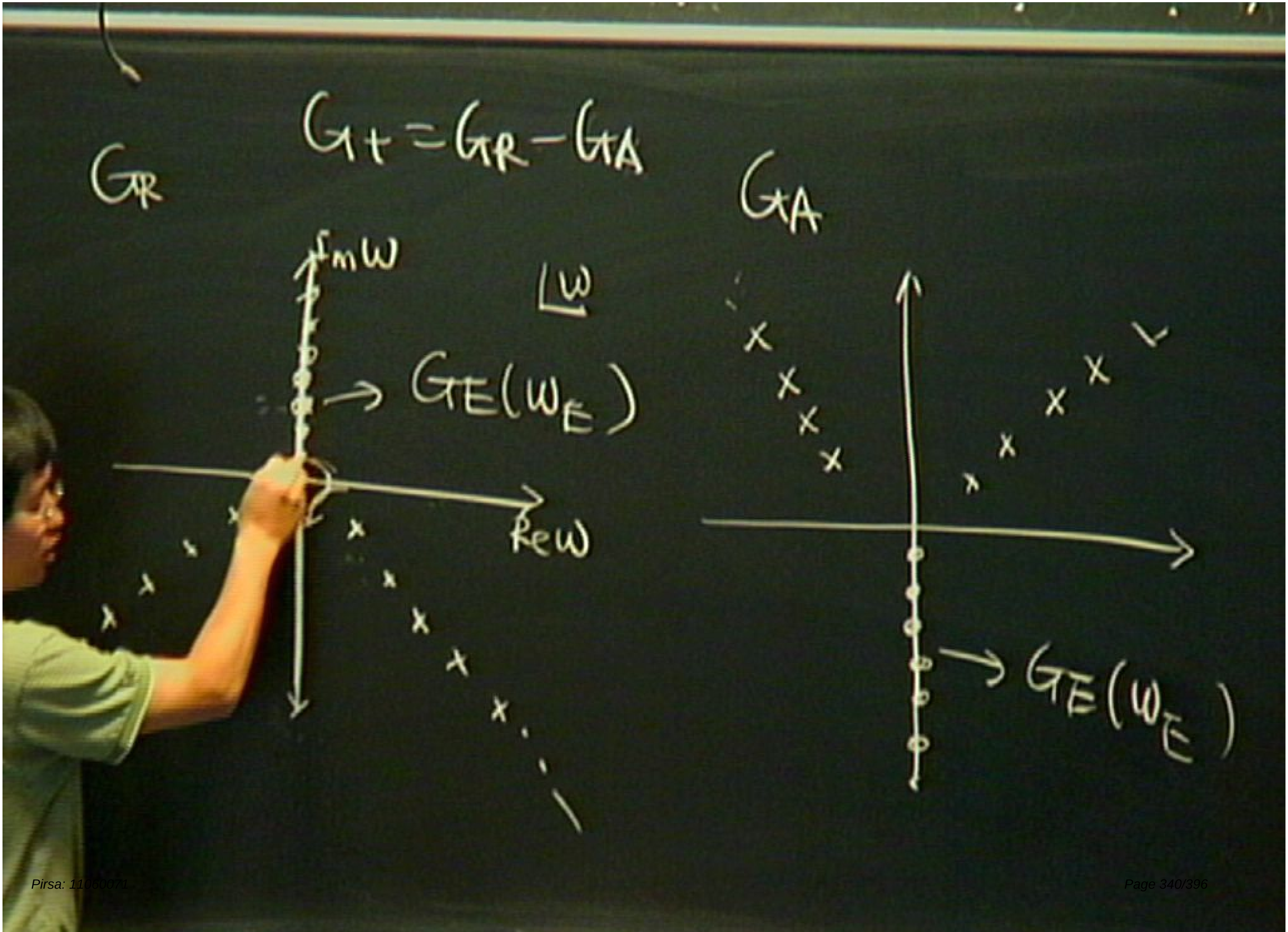
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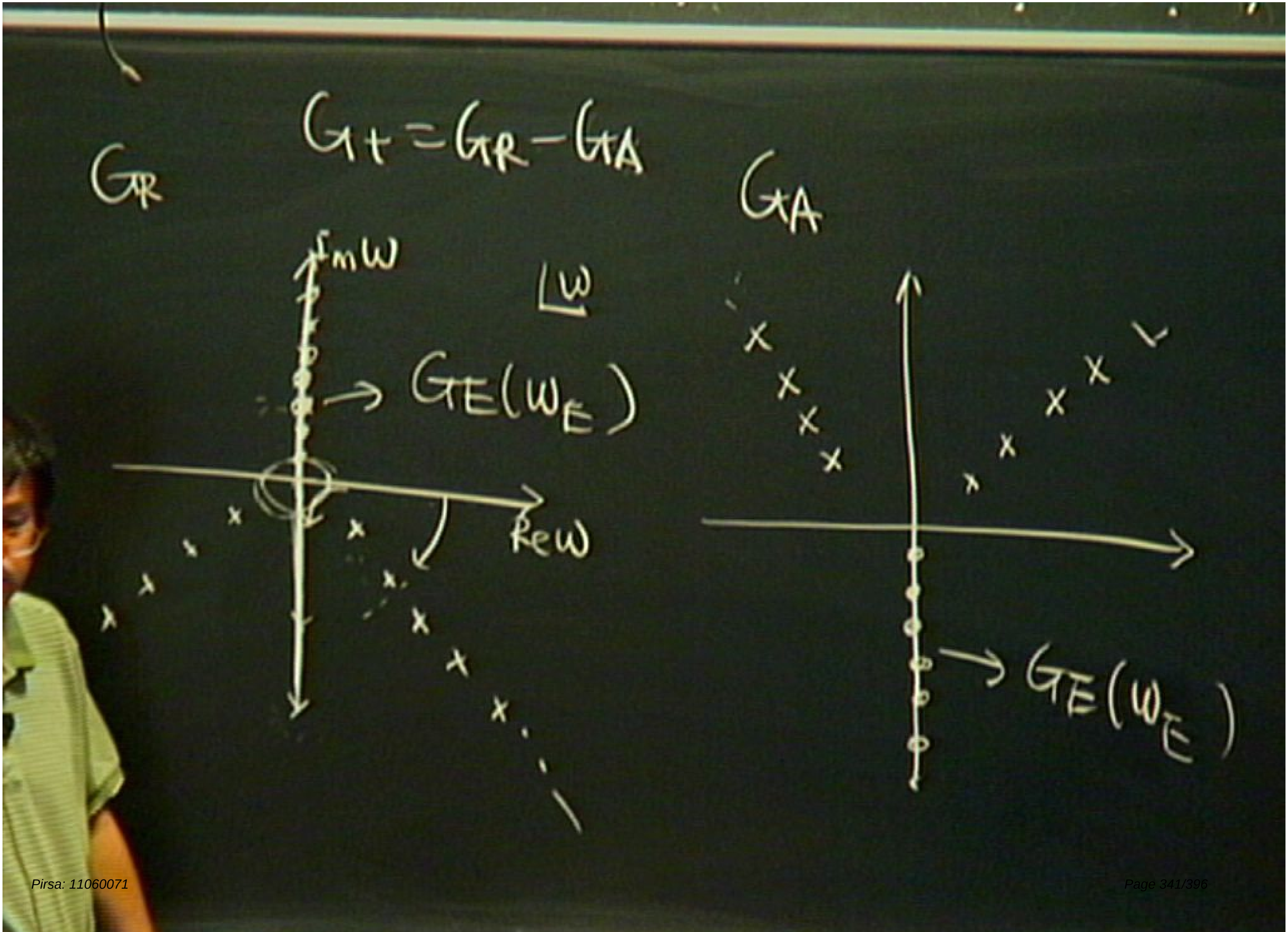

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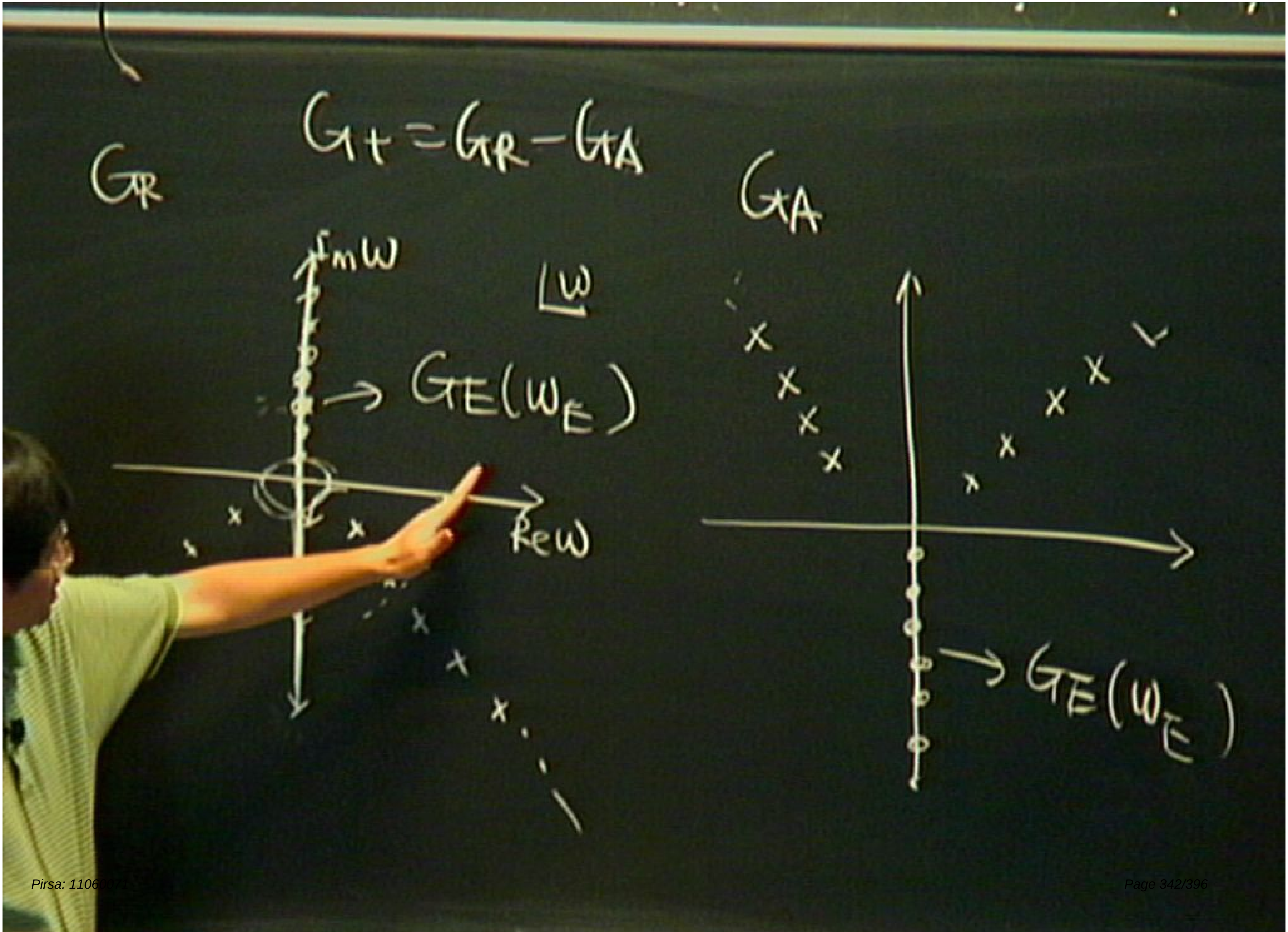
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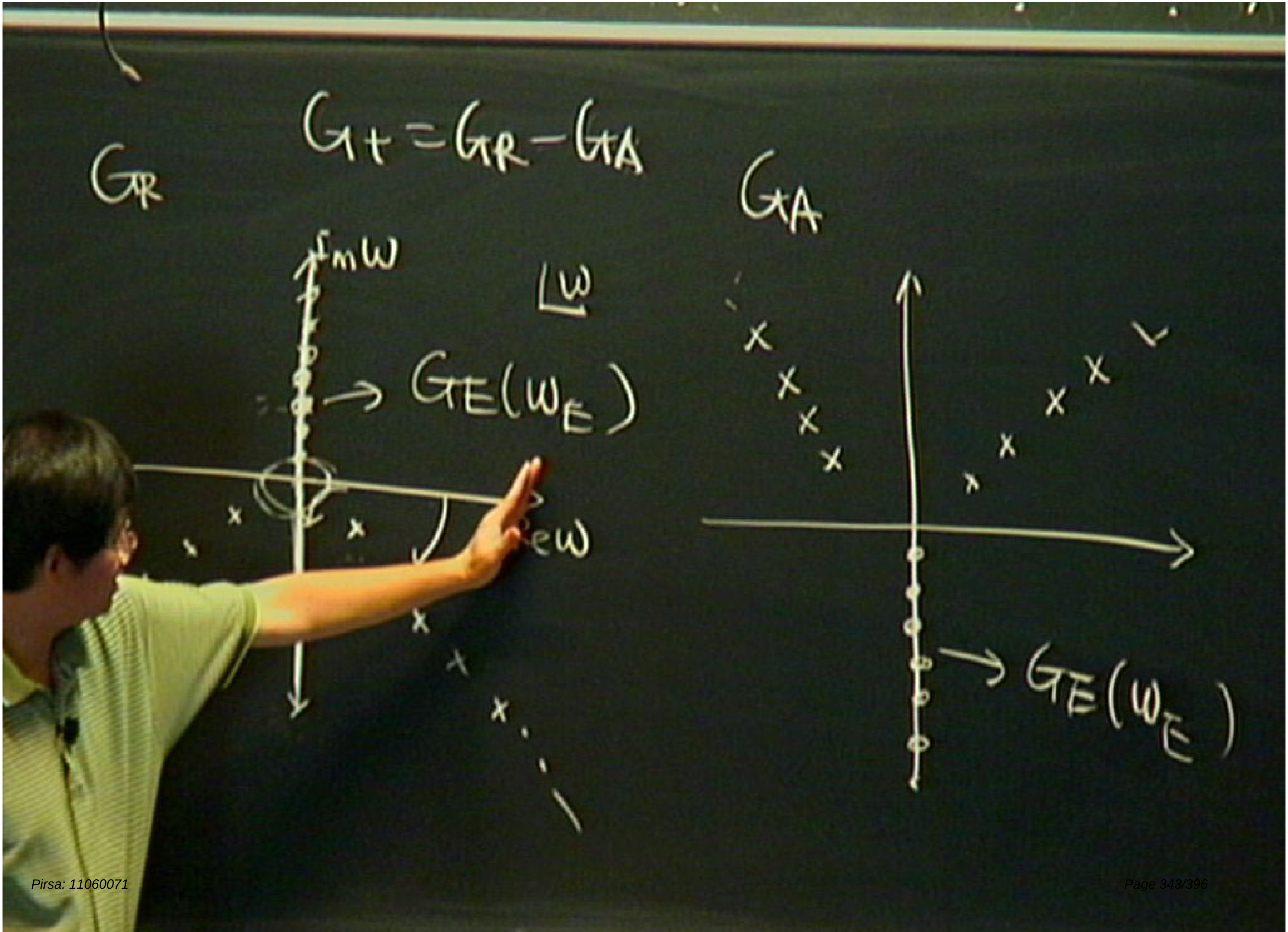

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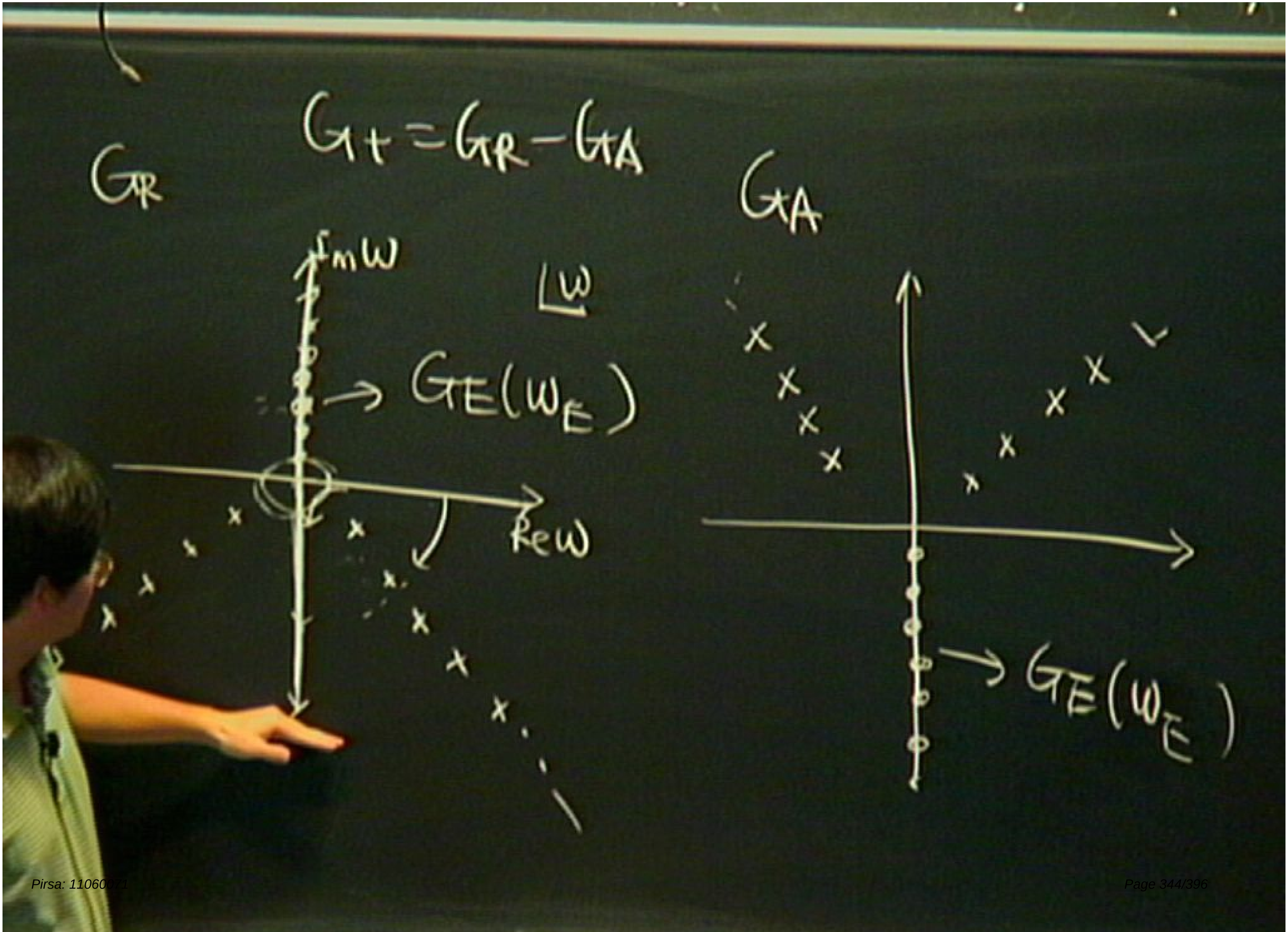
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Singularity as a UV fixed point?

UV of $\mathcal{N}$=4 SYM at finite T

↓

Low energies

↓

Analytic continuation to $\widehat{\mathcal{N}}$=4 SYM

↓

UV of $\widehat{\mathcal{N}}$=4 SYM

Boundary of AdS black hole

↓

Horizon (from outside)

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Horizon (from inside)

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singularity

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The story we just described is at the large N limit.

What happens at finite N?

Correlation functions at finite N

$\mathcal{N}$=4 SYM theory on S^3 at finite N:

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- Discrete energy spectrum.

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- Discrete energy spectrum.

- Wightman functions have simple analytic structure:

$$G_+(\omega, l) = 2\pi \sum_{m,n} e^{-\beta E_m} \rho_{mn} \delta(\omega - E_n + E_m)$$

A discrete sum of delta functions

But the Wightman functions we obtained from gravity have a continuous spectrum, due to presence of horizon.

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Energy spectrum of
SYM on a compact space

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$$E \sim O(1) \qquad \text{level spacing} \sim O(1)$$

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$$E \sim O(N^2) \quad \text{level spacing} \sim e^{-O(N^2)}$$

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Energy spectrum of
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$E \sim O(N^2)$ level spacing $\sim e^{-O(N^2)}$

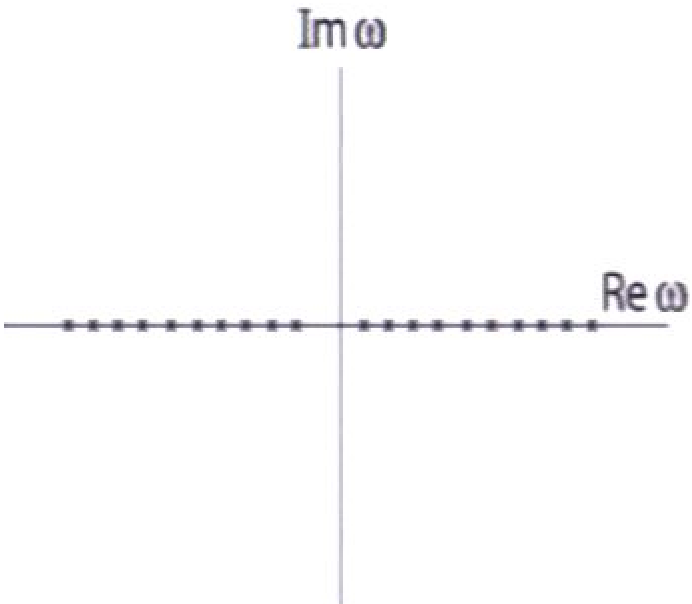
Continuous spectrum in the large N limit

$E \sim O(1)$ level spacing $\sim O(1)$

Energy spectrum of SYM on a compact space

Finite versus infinite N

Finite versus infinite N



finite N

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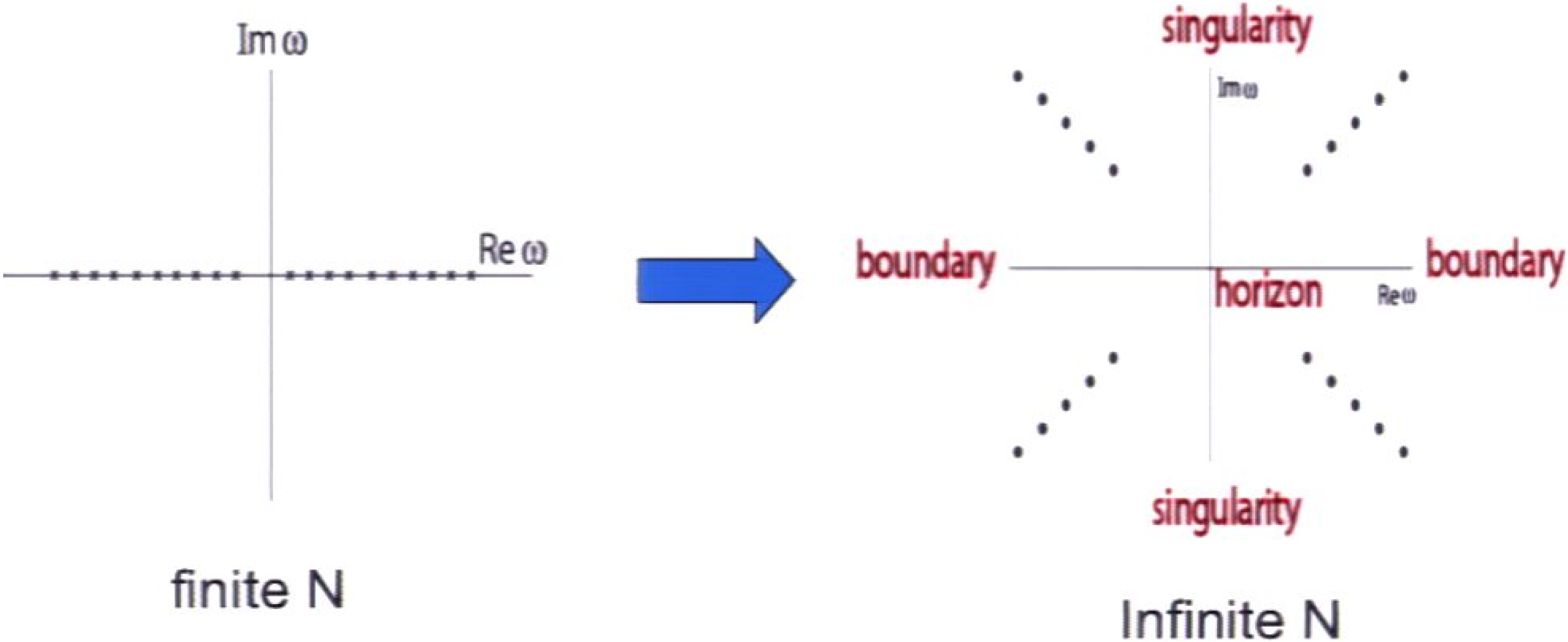

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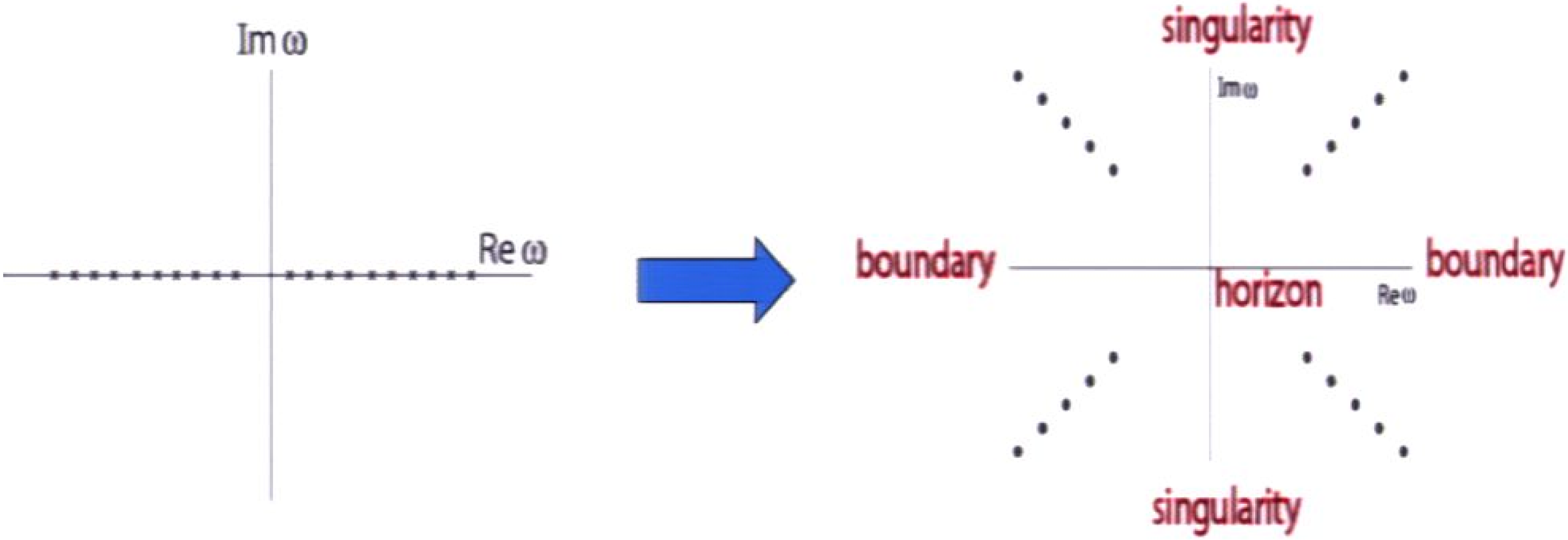


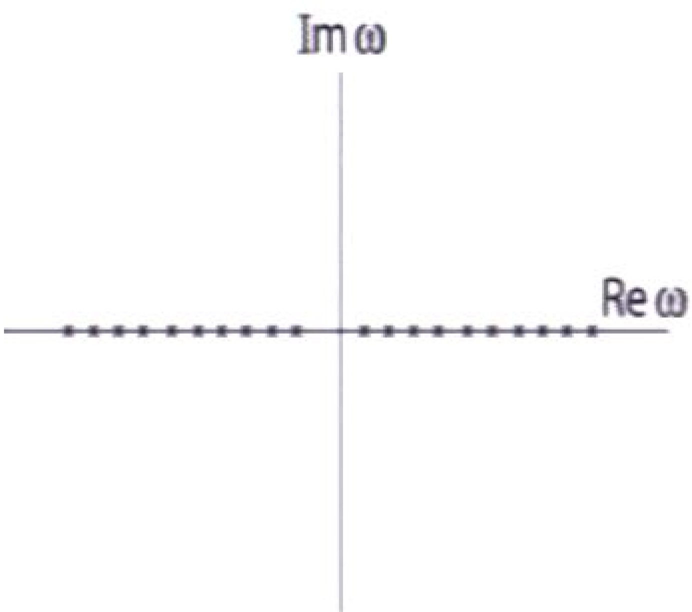
finite N

Infinite N

$\widehat{\mathcal{N}=4 \text{ SYM}}$

spacetime inside the horizon
including singularities:

Finite versus infinite N



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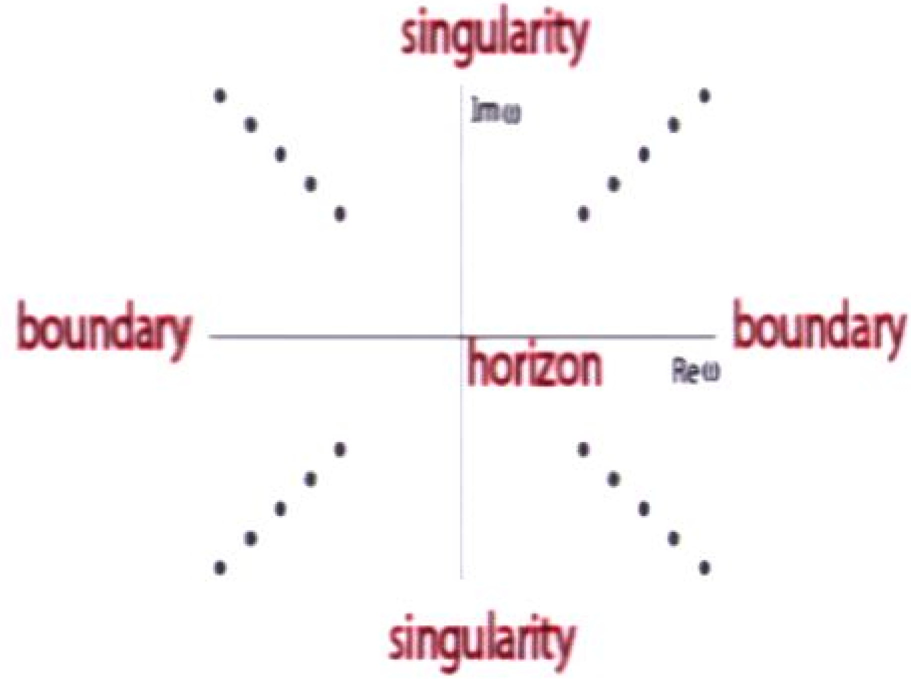

Infinite N

$\widehat{\mathcal{N}=4 \text{ SYM}}$

spacetime inside the horizon including singularities:

approximate concept appearing only in the large N limit

Likely all these structures do not depend on the specific details of SYM theories, and only on the matrix structure.

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Thank You

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No Signal

VGA-1

No Signal

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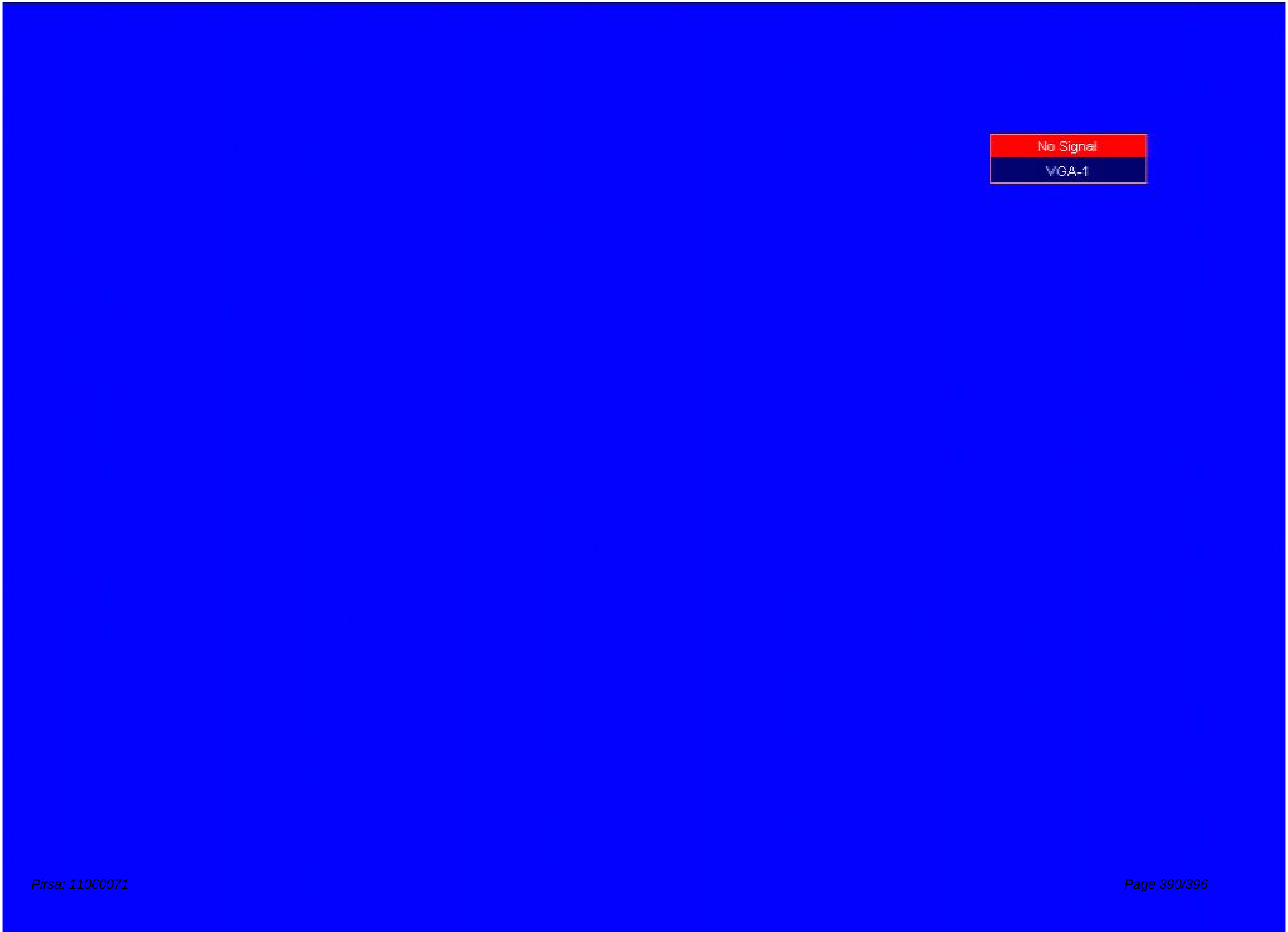
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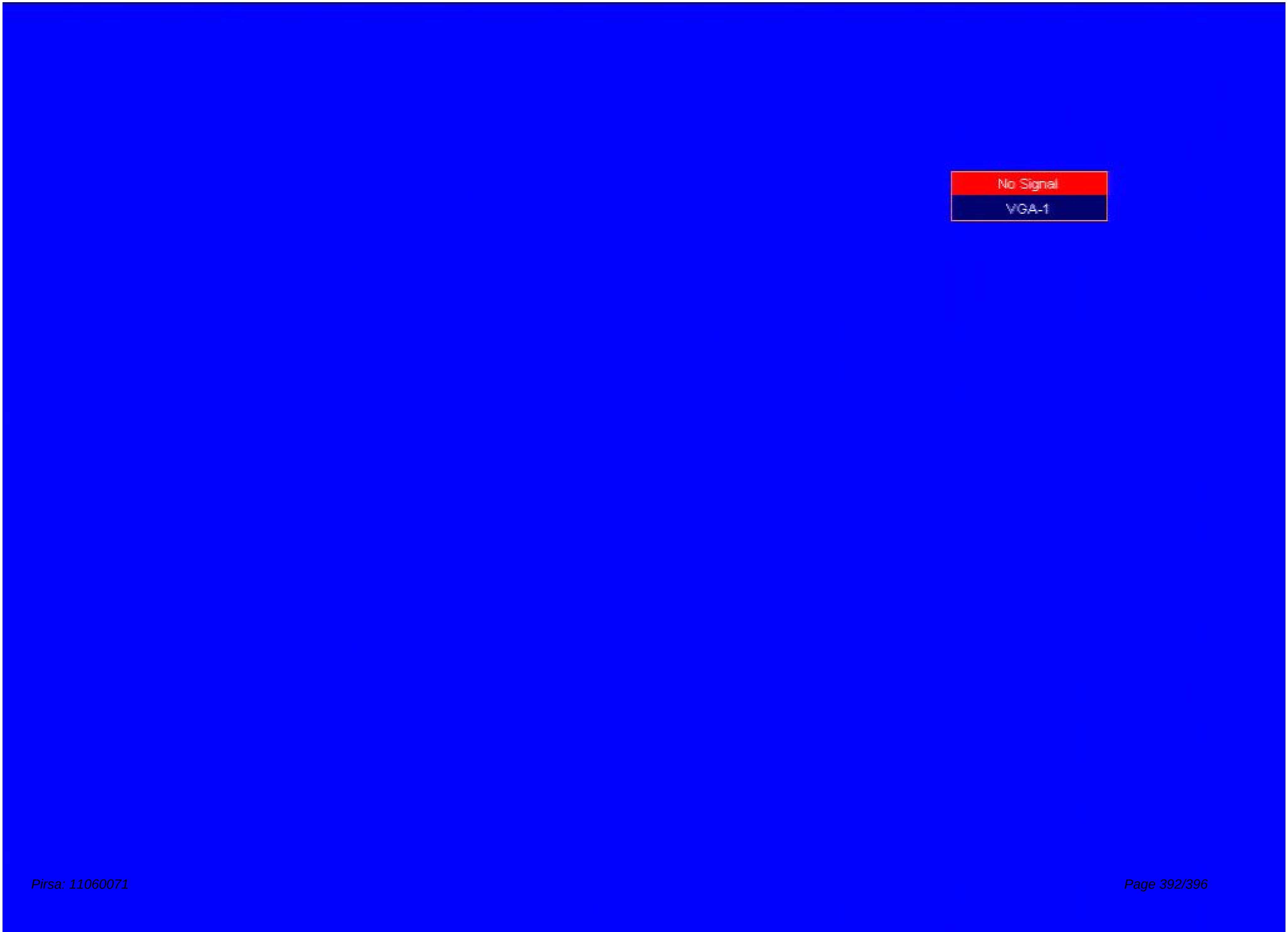
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(77%) Tue 12:01 PM
Macintosh HD
PI talk


Finder File Edit View Go Window Help
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