GRAVITY: THE INSIDE STORY

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(IUCAA, Pune, India)

VR Lecture, IAGRG Meeting

Kolkatta, 28 Jan 09

CONVENTIONAL VIEW

GRAVITY AS A FUNDAMENTAL INTERACTION

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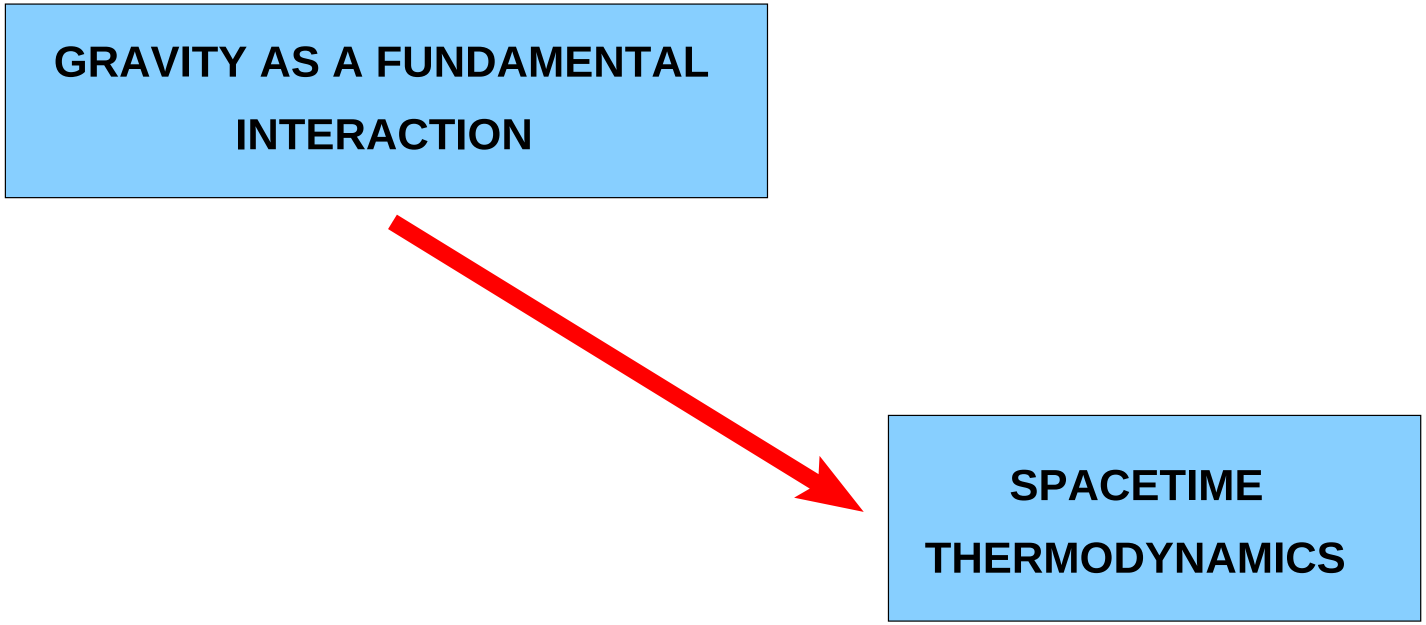
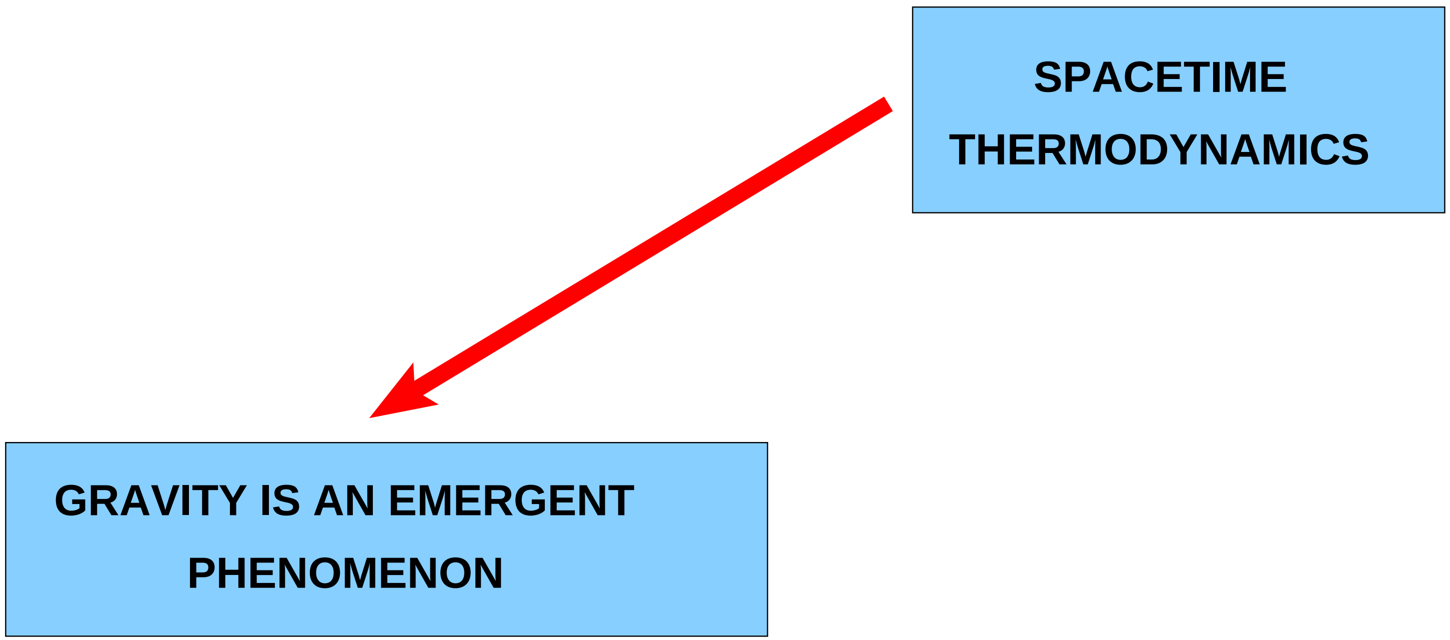


NEW PERSPECTIVE



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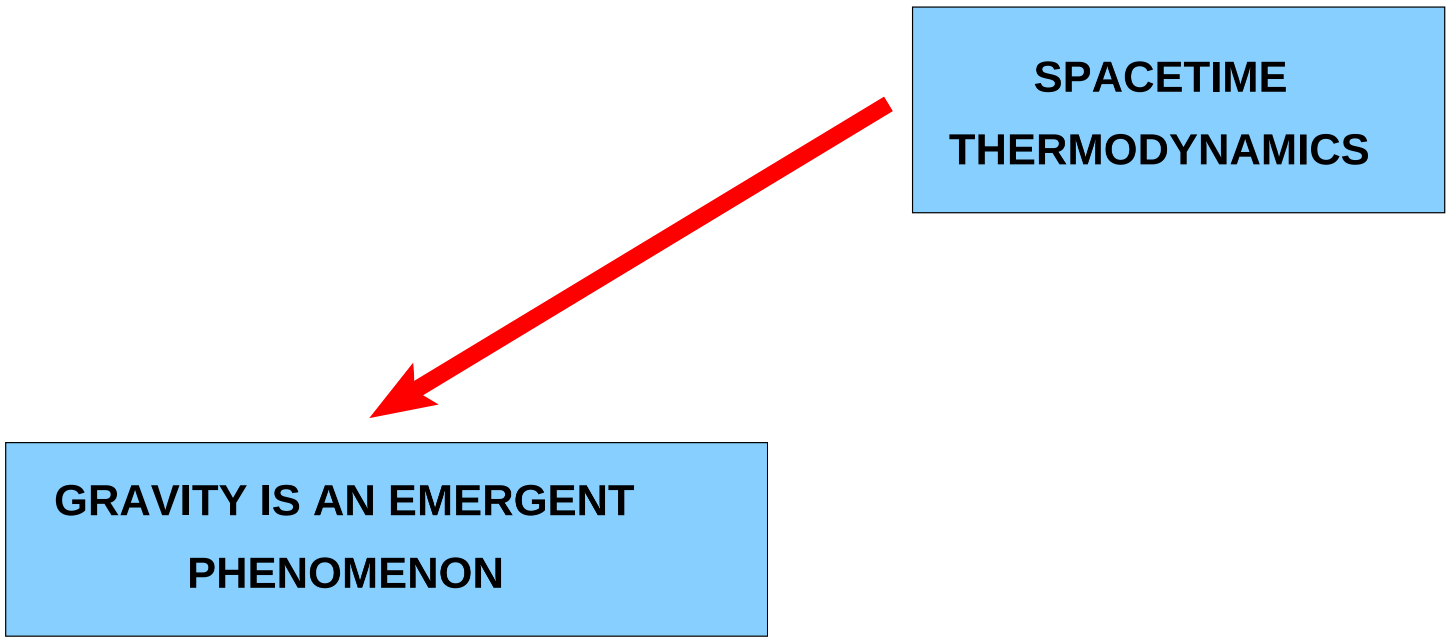

GRAVITY IS THE THERMODYNAMIC LIMIT OF THE STATISTICAL MECHANICS OF ‘ATOMS OF SPACETIME’

GRAVITY AS AN EMERGENT PHENOMENON

SAKHAROV PARADIGM

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- Thermodynamics offers a connection between the two though the form of entropy functional, $S[\xi]$. No microstructure, no thermodynamics!
- *You never took a course in ‘quantum thermodynamics’.*

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- Rindler horizons have a temperature (1975-76)

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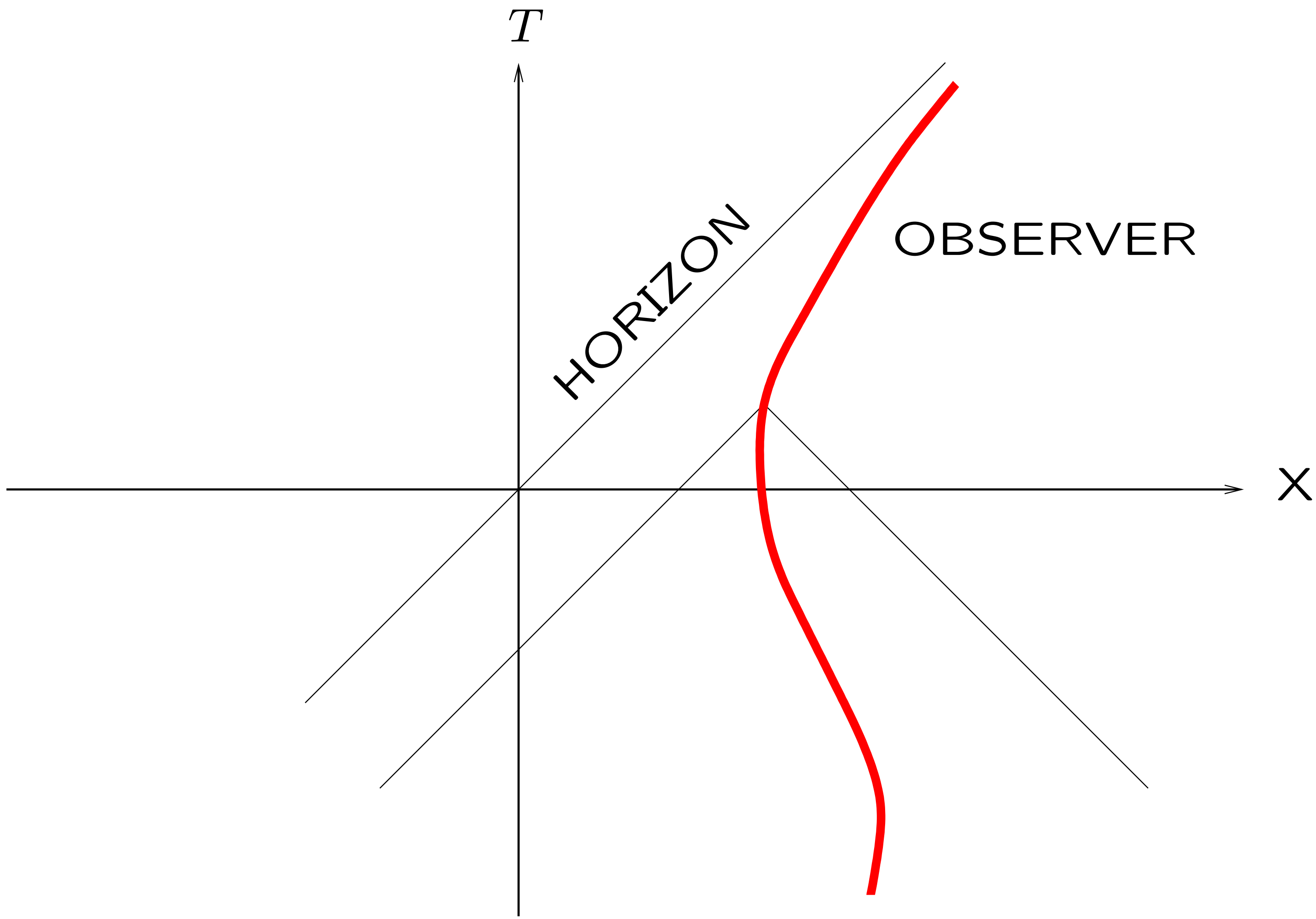

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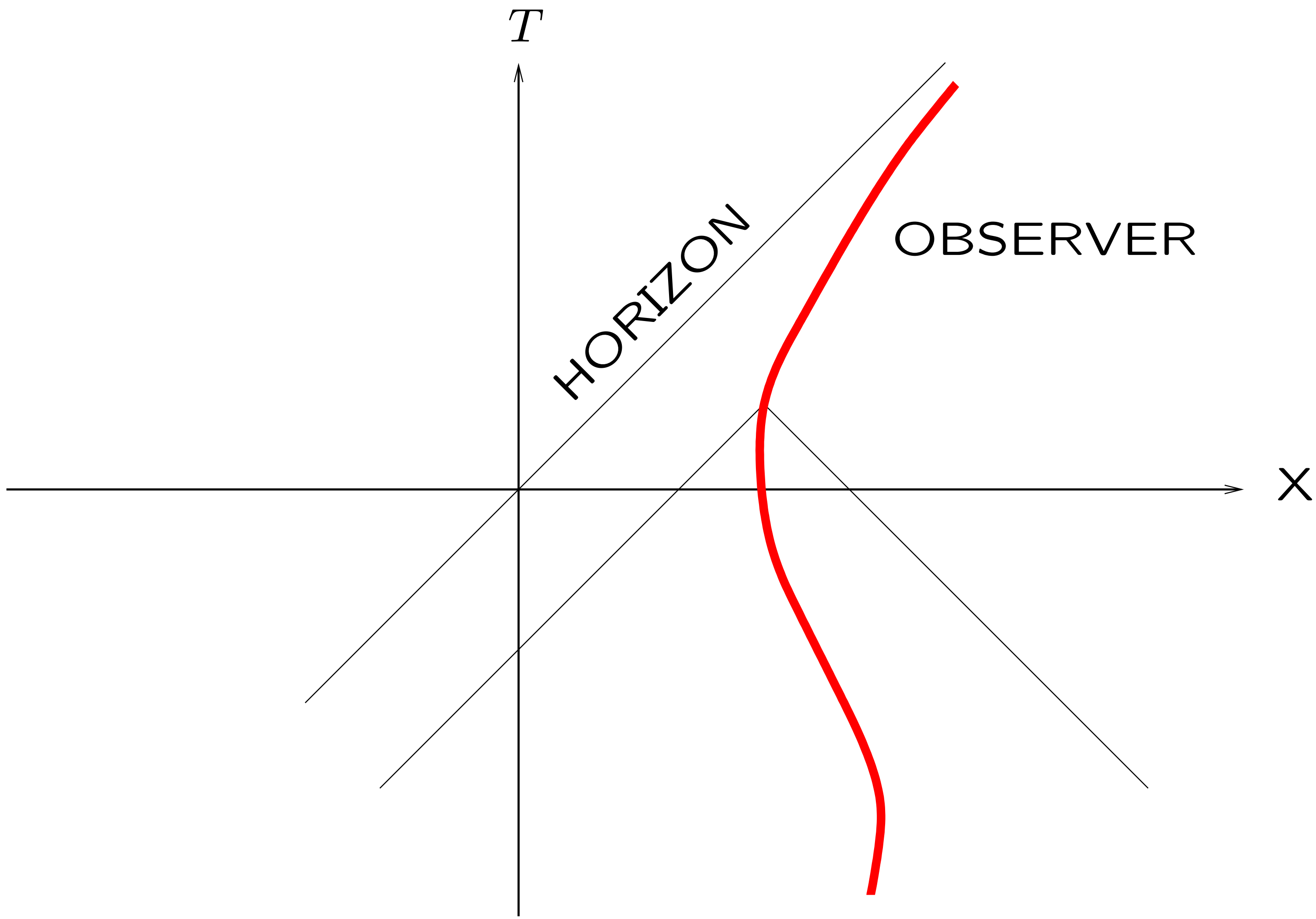

Works for Blackholes, deSitter, Rindler

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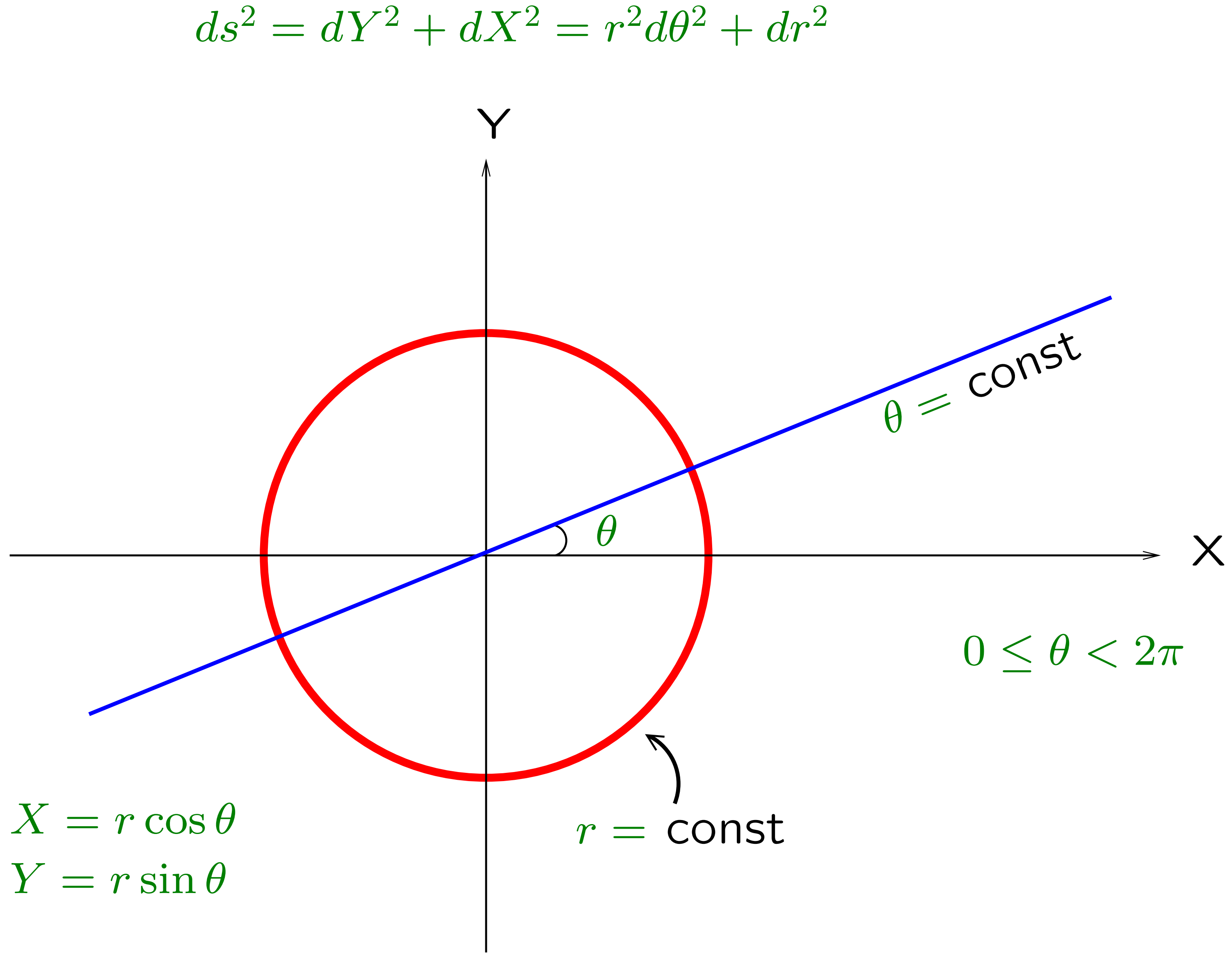
$ds^2 = dY^2 + dX^2 = r^2 d\theta^2 + dr^2$
Y
X
θ = const
θ
$0 \leq \theta < 2\pi$
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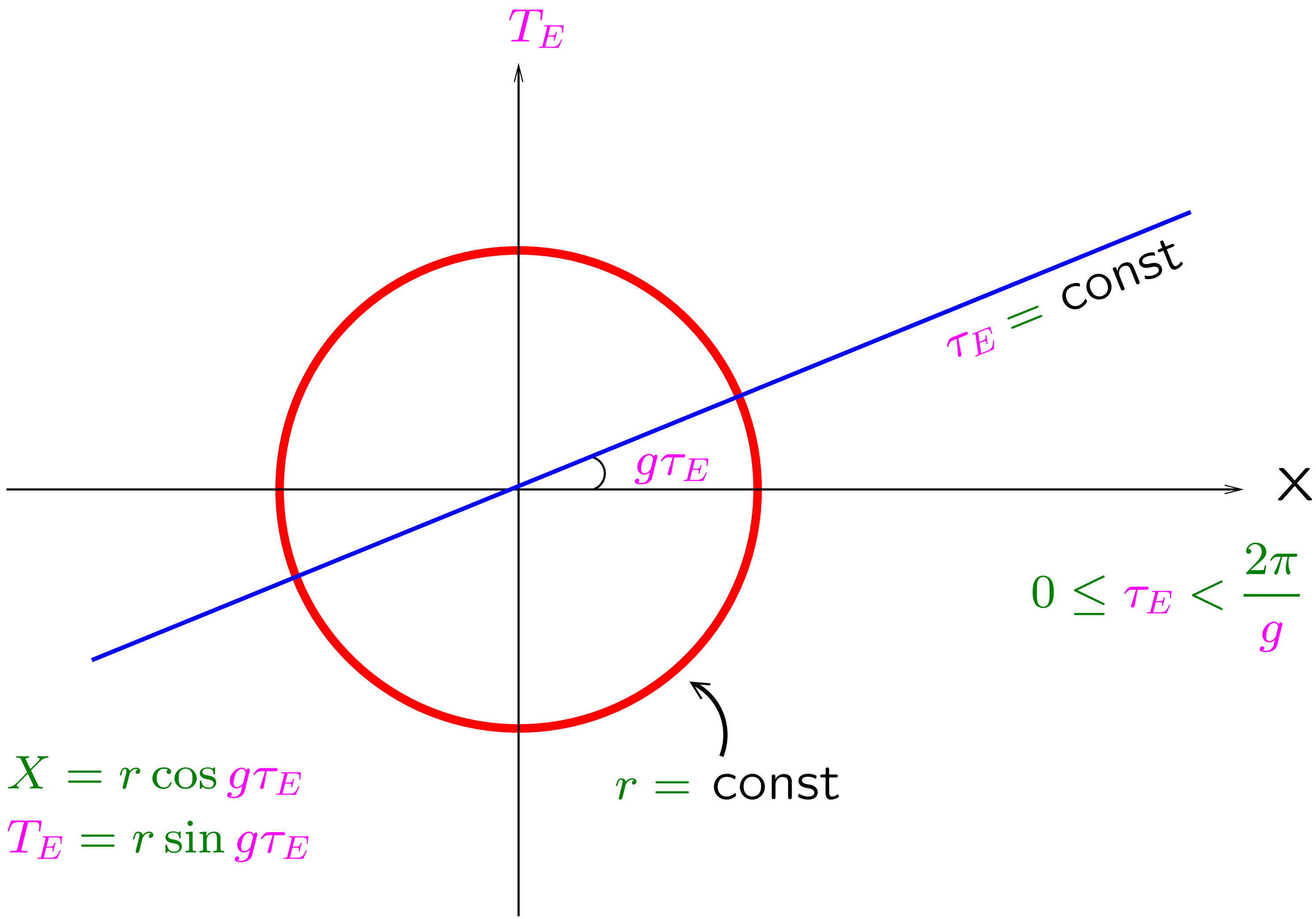

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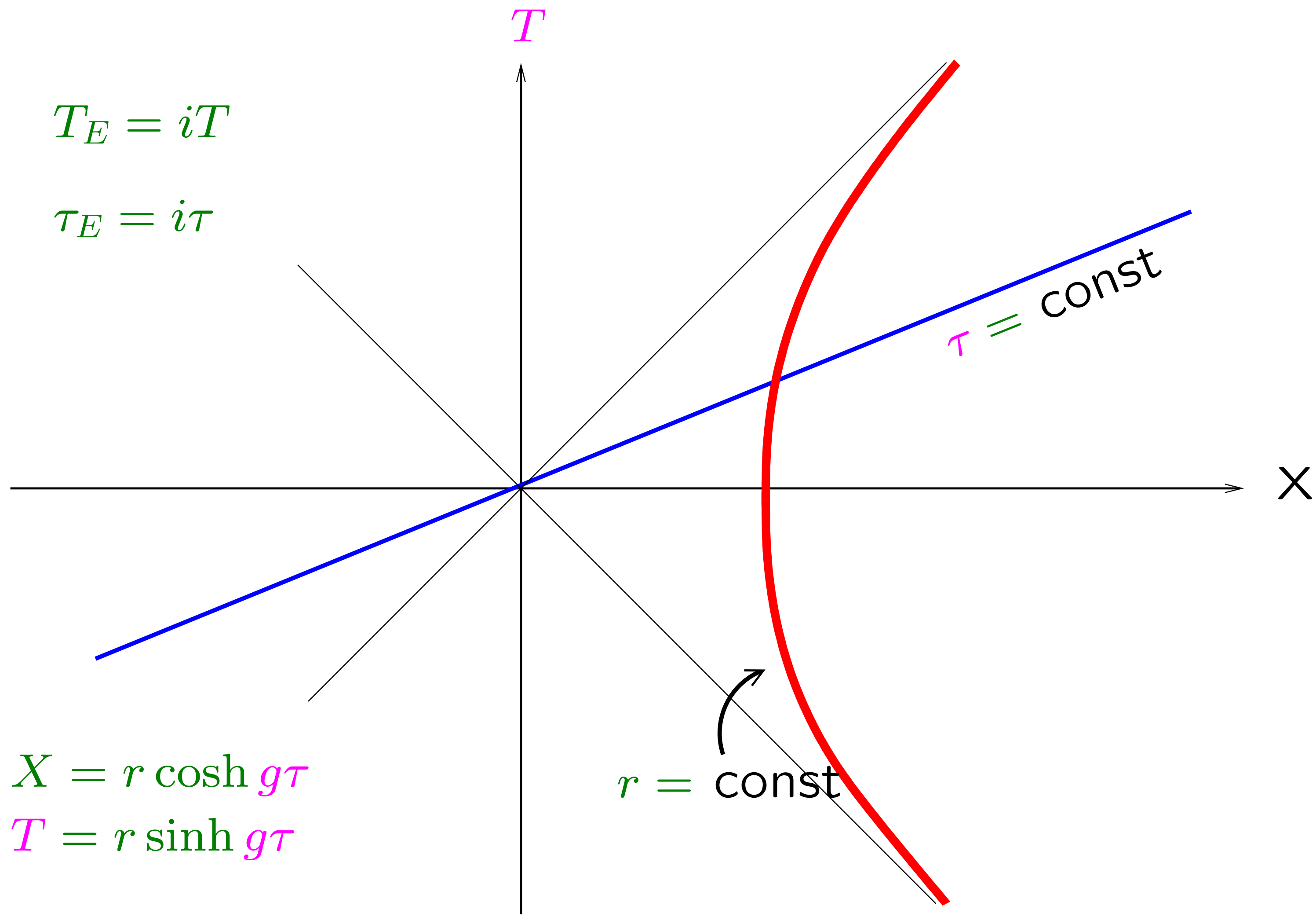

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PHYSICS PROGRESSES BY EXPLAINING FEATURES WHICH WE NEVER THOUGHT NEEDED ANY EXPLANATION !!

EXAMPLE: $m_{inertial} = m_{grav}$

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- Works for Kerr, FRW, ... [D. Kothawala et al., 06; Rong-Gen Cai, 06, 07]

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- In fact, one can develop a theory with $A_{total} = A_{sur} + A_{matter}$ using the virtual displacements of the horizon as key. [TP, 2005]

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- You find that the part you threw away, the $A_{\rm sur}$, evaluated on any horizon gives its entropy !

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- The surface term is closely related to horizon entropy in Lanczos-Lovelock theory.

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- Dynamics should now emerge from maximising $S_{matter} + S_{grav}$ for all Rindler observers!.
- Leads to gravity being an emergent phenomenon described by Einstein's equations at lowest order with calculable corrections.

A NEW VARIATIONAL PRINCIPLE

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- Associate with virtual displacements of null surfaces an entropy/ action which is quadratic in deformation field: [T.P, 08; T.P., A.Paranjape, 07]

$$S[\xi] = S[\xi]_{grav} + S_{matt}[\xi]$$

with

$$S_{grav}[\xi] = \int_{\mathcal{V}} d^D x \sqrt{-g} 4 P^{abcd} \nabla_c \xi_a \nabla_d \xi_b; \qquad S_{matt} = \int_{\mathcal{V}} d^D x \sqrt{-g} T^{ab} \xi_a \xi_b$$

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- This leads to P^{abcd} having a (RG-like) derivative expansion in powers of number of derivatives of the metric:

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- Example: The lowest order term is:

$$S_1[\xi] = \int_{\mathcal{V}} \frac{d^D x}{8\pi} \left(\nabla_a \xi^b \nabla_b \xi^a - (\nabla_c \xi^c)^2 \right)$$

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- In a derivative coupling expansion, Lanczos-Lovelock terms are calculable corrections.

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- Further for *any* solution, in a local Rindler frame, the causal horizons have the correct entropy. At the lowest order, it is quarter of transverse area.

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- The only way out is to have a formalism for gravity which is invariant under $T_{ab} \to T_{ab} + \rho g_{ab}$.
- *All these have nothing to do with observations of accelerated universe! Cosmological constant problem existed earlier and will continue to exist even if all these observations go away!*

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- Then cosmological constant problem cannot be solved; that is, gravitational equations cannot be invariant under $T_{ab} \longrightarrow T_{ab} - \rho_0 g_{ab}$.
- Drop the assumption that g_{ab} is the dynamical variable, identify new degrees of freedom (virtual displacements of null surfaces in spacetime) associate an entropy with them and obtain the dynamics from extremising the entropy.

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- The hierarchy:

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- Connects with $A_{\rm sur}$ giving the horizon entropy

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