Gravity, quantum and blackholes

Hawking's journey through spacetime

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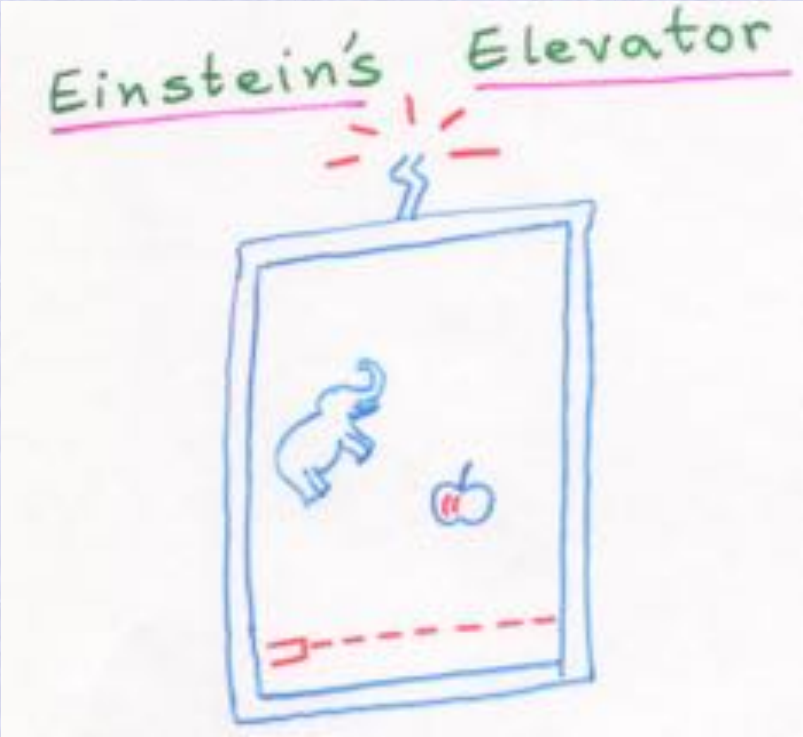
1 Overview

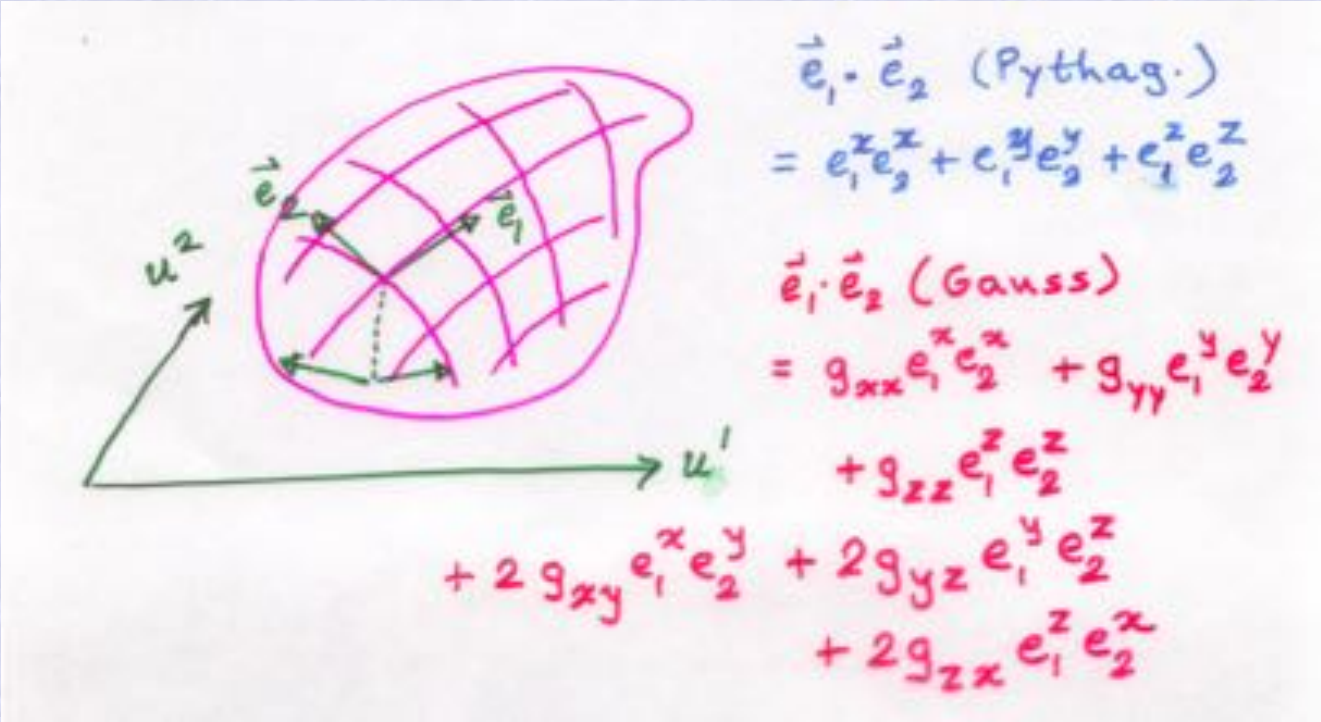
- From "space-time" to spacetime
- Inevitability of the fall … or the bang
- Quantum Mechanics – seamless spacetime
- Some glimpses

2 From space-time to spacetime (J A Wheeler)

Principle of Equivalence



The metric tensor, the local lightcone, and the geodesic



Curvature and energy-momentum

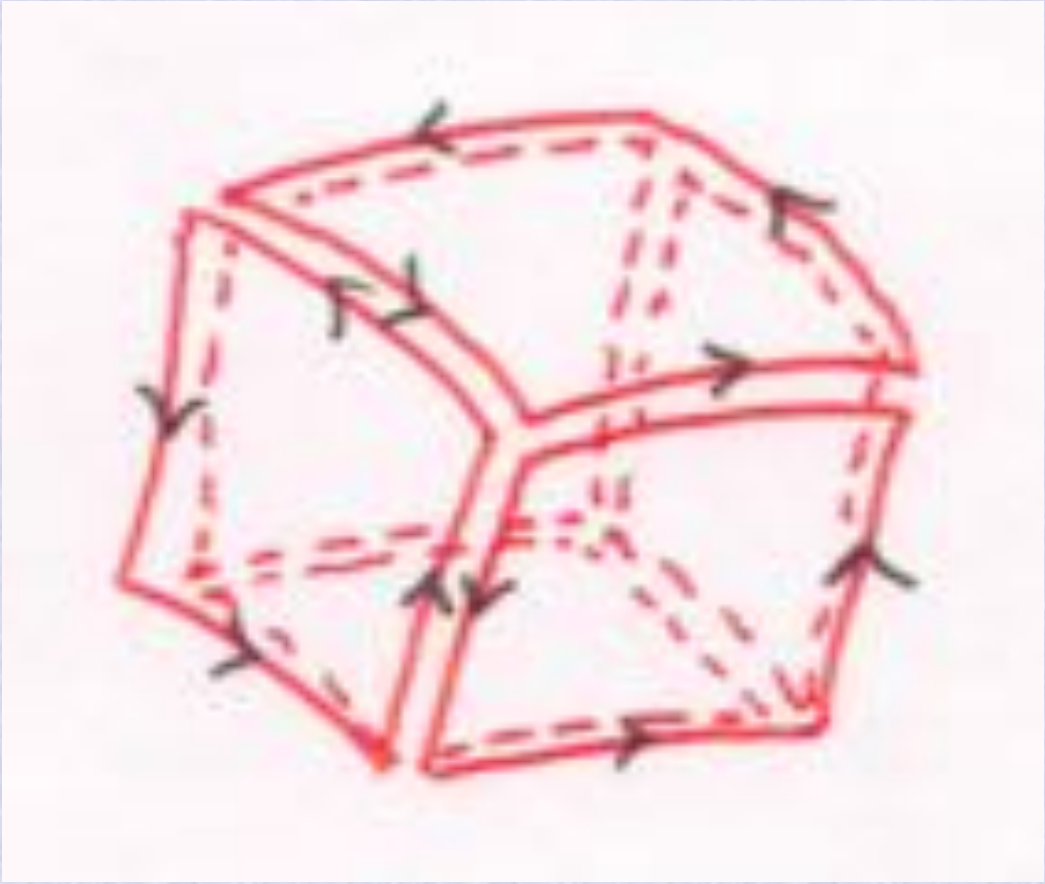
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$$R_{\mu\nu\rho\sigma;\lambda} + R_{\mu\nu\lambda\rho;\sigma} + R_{\mu\nu\sigma\lambda;\rho} = 0$$

Compare Maxwell's Equations

$$\partial_\mu F^{\mu\nu} = 4\pi j^\nu$$

$$F_{\mu\nu,\rho} + F_{\rho\mu,\nu} + F_{\nu\rho,\sigma} = 0$$



- "The boundary of a boundary is zero" is all that is ensured.
- Energy-momentum and geometry are determined through mutual dynamics.

- Neither is energy guaranteed to be positive, nor is spacetime geometry guaranteed to remain free of singularities.
- Hawking Penrose theorems declared inevitability of singularities and helped us accept the Big Bang singularity at classical level.
- Solution to be sought in quantum version of General Relativity.

3 The inevitability of the fall

Theorems of Hawking and Penrose

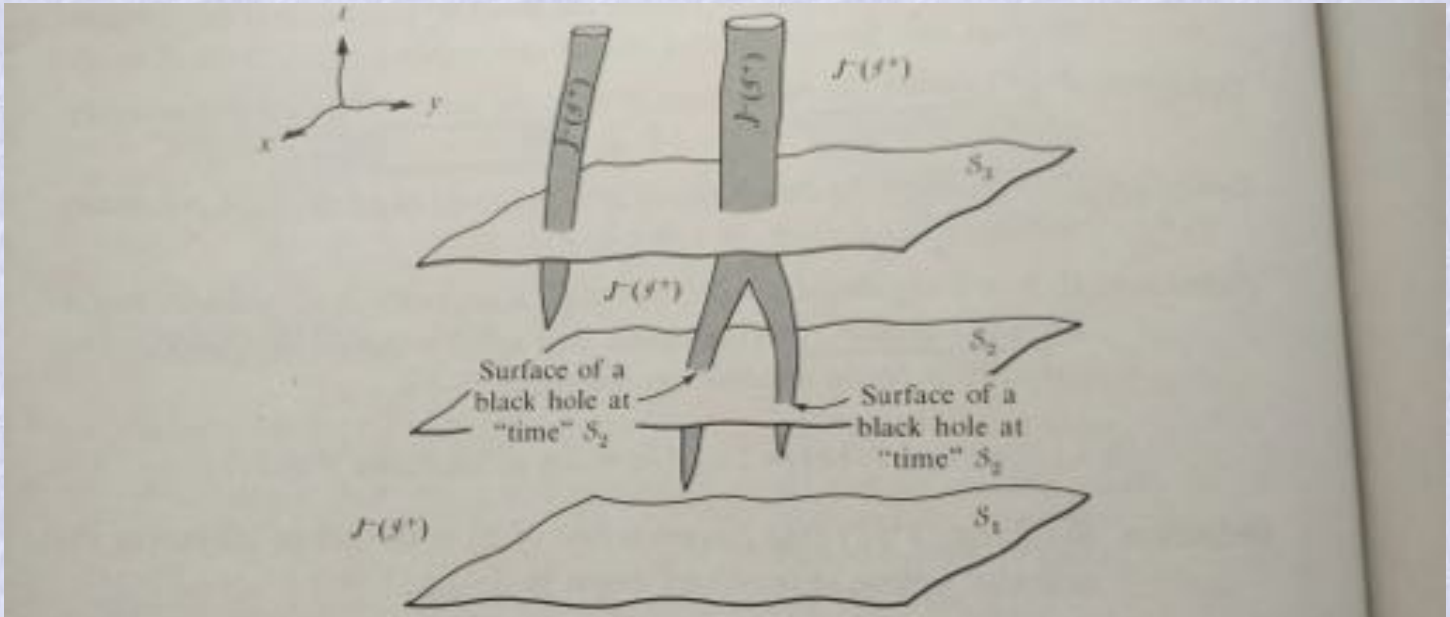


Figure 34.6.
Black holes in an asymptotically flat spacetime (schematic spacetime diagram). $J^-(\mathcal{I}^+)$ is the "external universe"—i.e., the region which can send causal curves to future null infinity. $\dot{J}^-(\mathcal{I}^+)$, the greyish region, is the boundary of the "external universe"—i.e., it is the union of all future horizons. At the "time" of spacelike

The energy condition

A spacetime M necessarily contains incomplete, inextendable timelike or null geodesics (and is thus singular in the Schmidt sense) if, in addition to Einstein's equations, the following four conditions hold: (1) M contains no closed timelike curves (reasonable causality condition); (2) at each event in M and for each unit timelike vector $\boldsymbol{u}$, the stress-energy tensor satisfies

$$\left(T_{\alpha\beta} - \frac{1}{2} g_{\alpha\beta} T\right) u^\alpha u^\beta \geq 0$$

(reasonable energy condition); (3) the manifold is "general" (i.e., not too highly symmetric) in the sense that every timelike or null geodesic with unit tangent $\boldsymbol{u}$ passes through at least one event where the curvature is not lined up with it in a specific way:

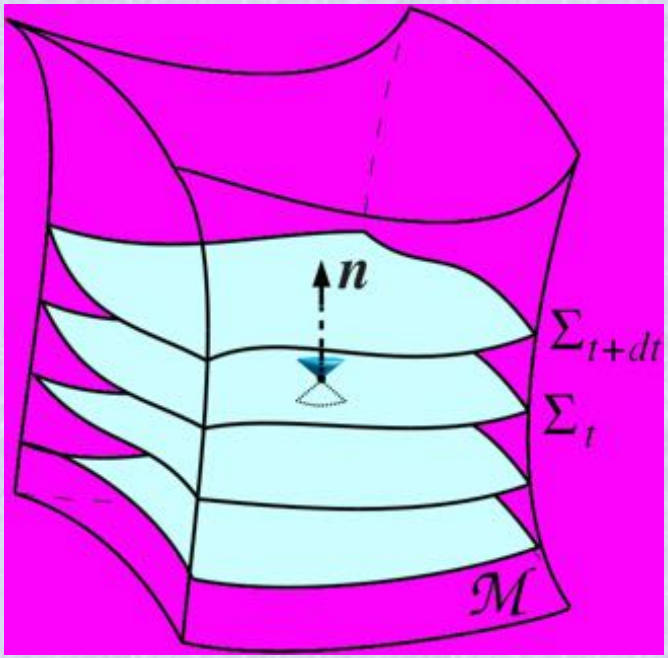
$$u_{[\alpha} R_{\beta]\gamma\delta[\epsilon} u_{\rho]} u^\gamma u^\delta \neq 0 \text{ at some point on the geodesic.}$$

(4) the manifold contains a trapped surface.

... the trapped surface, seem eminently reasonable fo

4 Quantum generating function

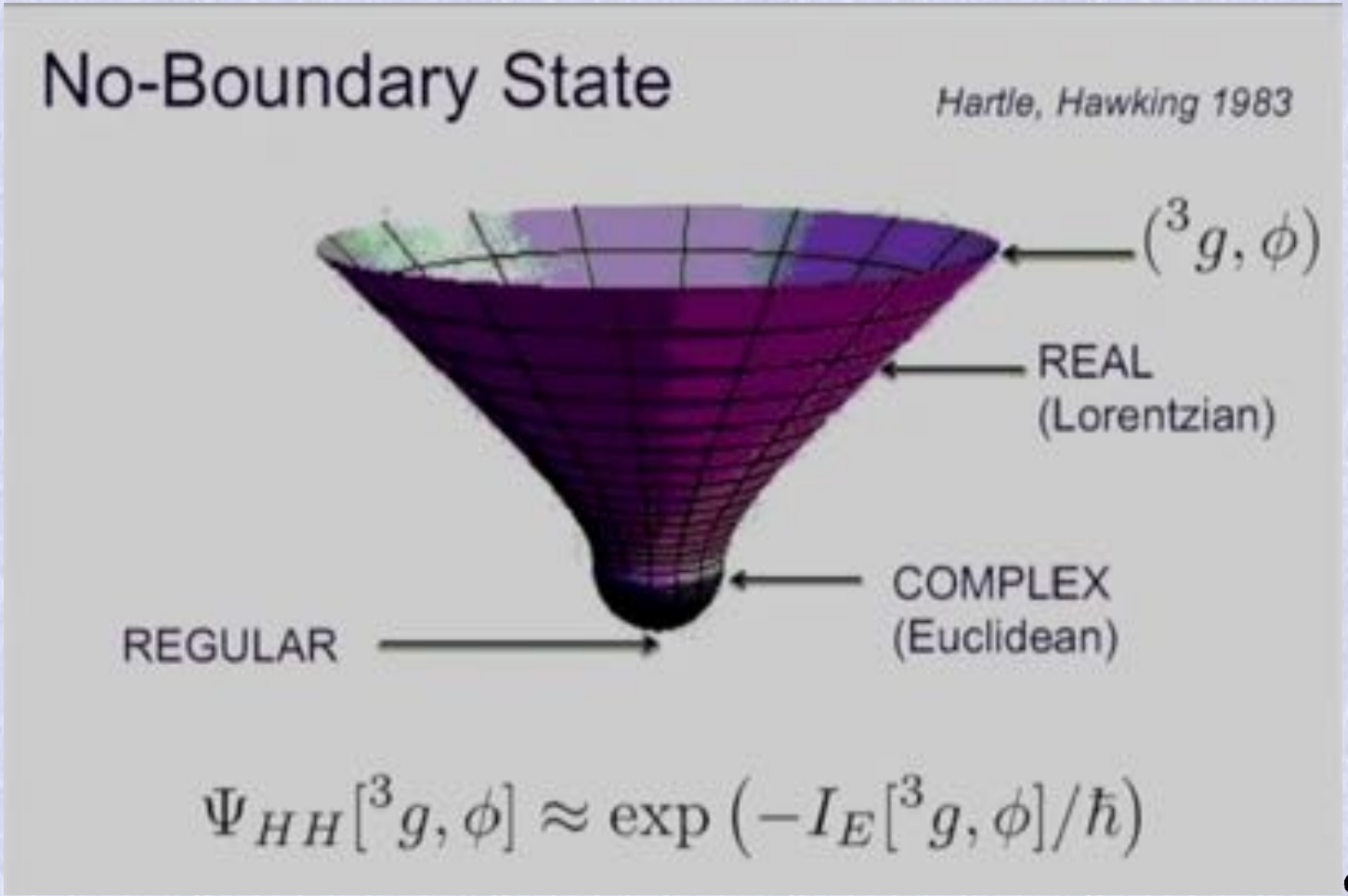
- Dynamical variables of gravity



- From wave equation to Path integral

$$\langle q_{out}, t_{out} \left| q_{in}, t_{in} \right\rangle = \int \mathcal{D}q \;\; \exp\left\{ \frac{i}{\hbar} \int_{q_{in} t_{in}}^{q_{ot} t_{out}} dt \, (p\dot{q} - H) \right\}$$

- Correlation functions and partition function
- The question of time
- Doing away with the boundary



Courtesy Hertog

5 Glimpses

- University of Texas at Austin colloquium 1983 (?)
- Strings conference TIFR 2000

- M Theory Cosmology – "Intergalactic Conference" at Cambridge

August 21-25, 2001
Centre for Mathematical Sciences, University of Cambridge
Wilberforce Road, Cambridge CB3 0WA, United Kingdom

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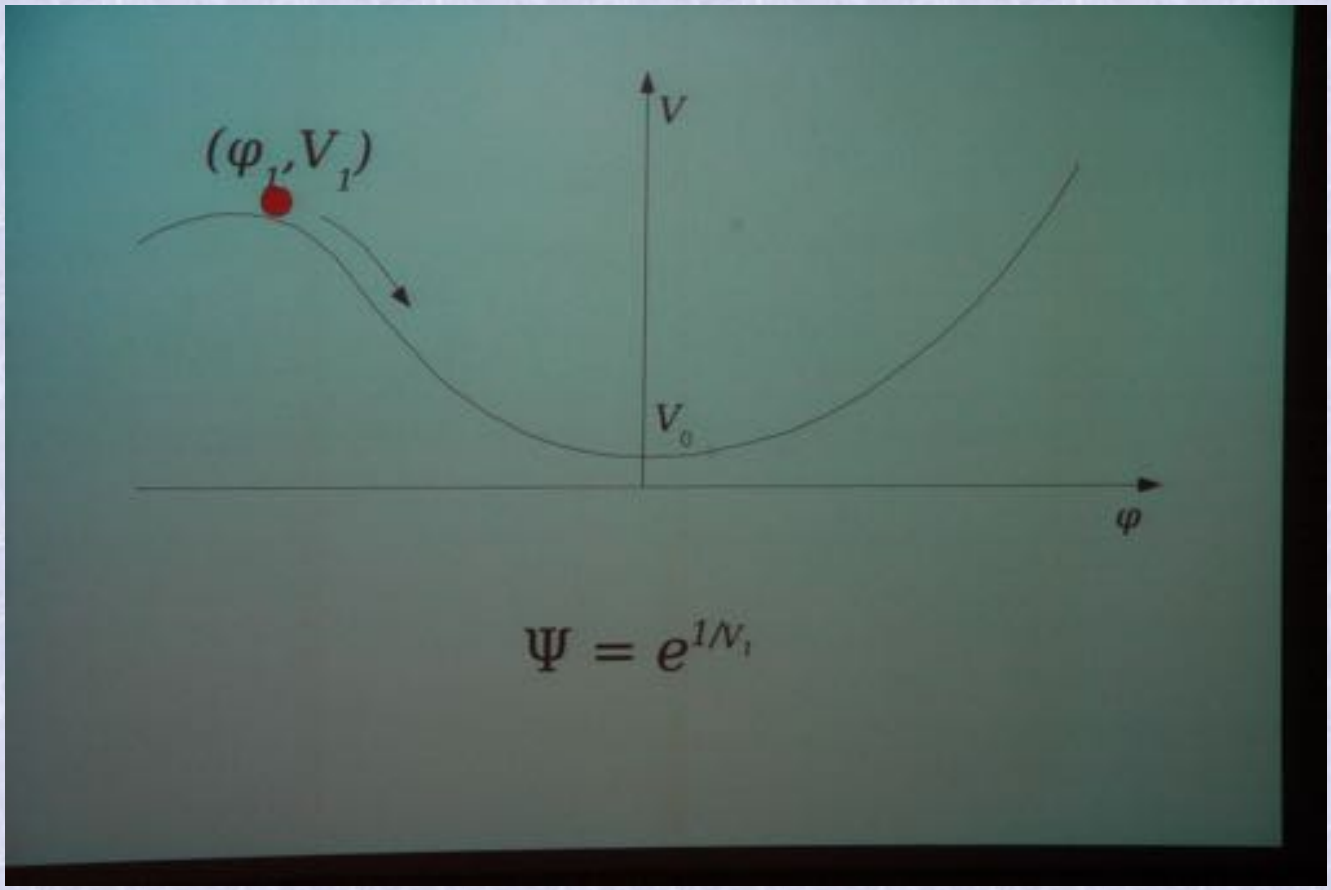
D. Waldram (*)	Queen Mary and Westfield

(*) To be confirmed

Intergalactic Organizing Committee: M.A. Bucher, S.W. Hawking, F. Quevedo, N.G. Turok

- Cosmo conference CERN 2009

(courtsy UAY or Y Y Keum)



- Perimeter Institute October 2015

Thank you !

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