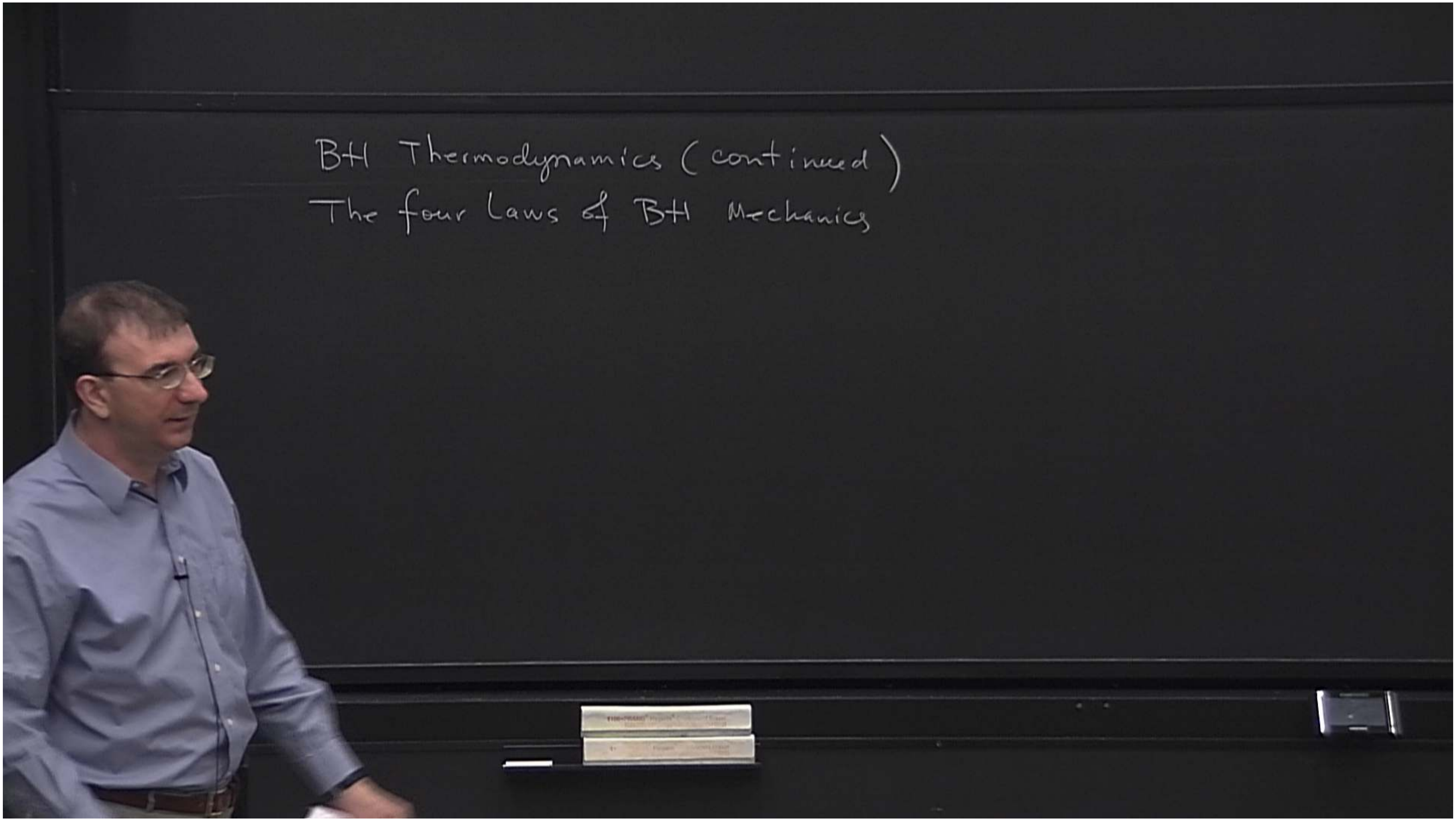
Title: 13/14 PSI - Explorations in String Theory - Lecture 4

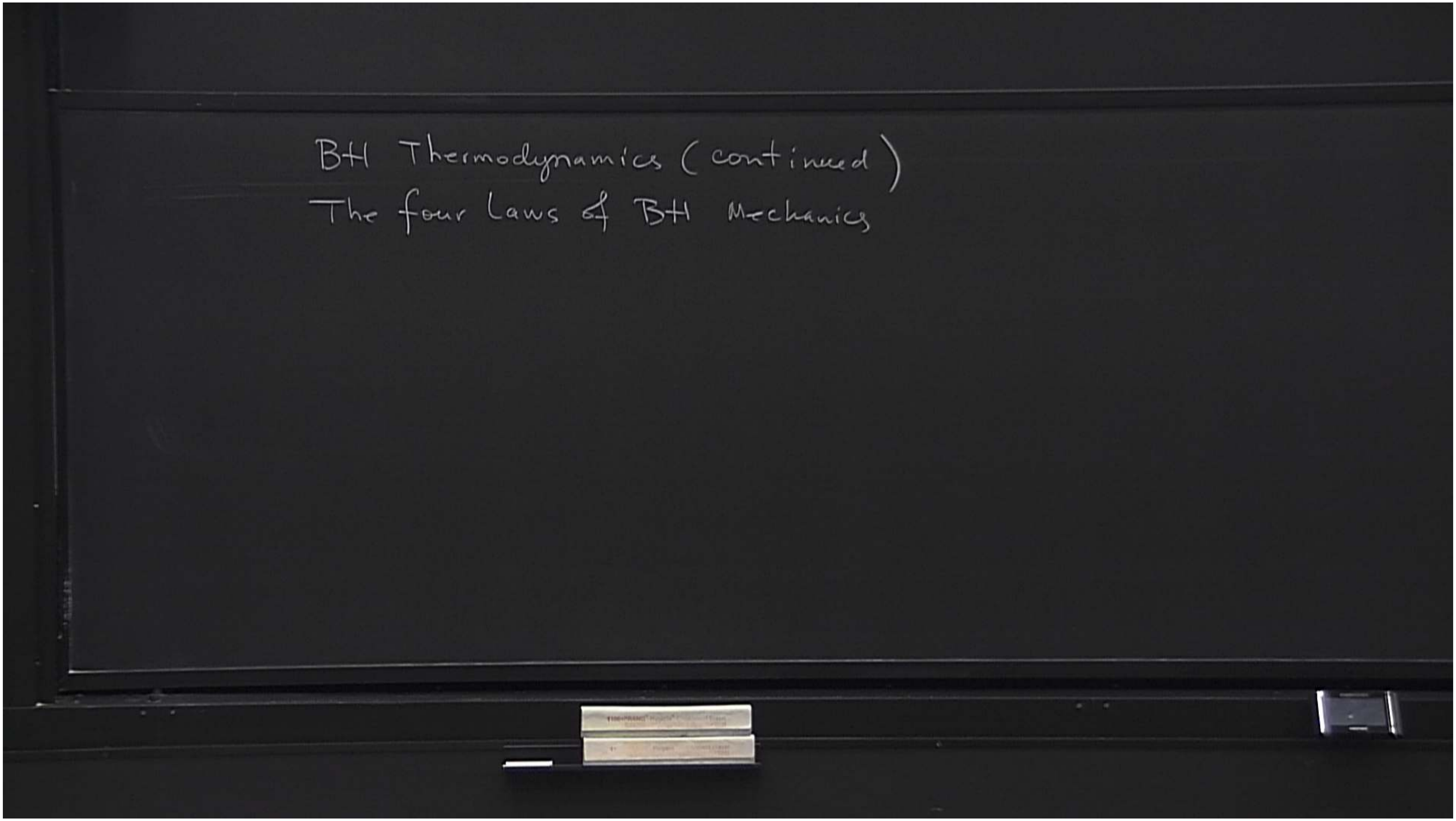
Date: Mar 20, 2014 11:30 AM

URL: http://pirsa.org/14030062

Abstract:


Grav. BG ⟷ QFT
at T, μ_α
. BH in equil.
. Thermal equil.
. Beyond Thermal eq.
. Near-equil. regime


BH Thermodynamics (continued)
The four laws of BH Mechanics


BH Thermodynamics (continued)
The four laws of BH Mechanics

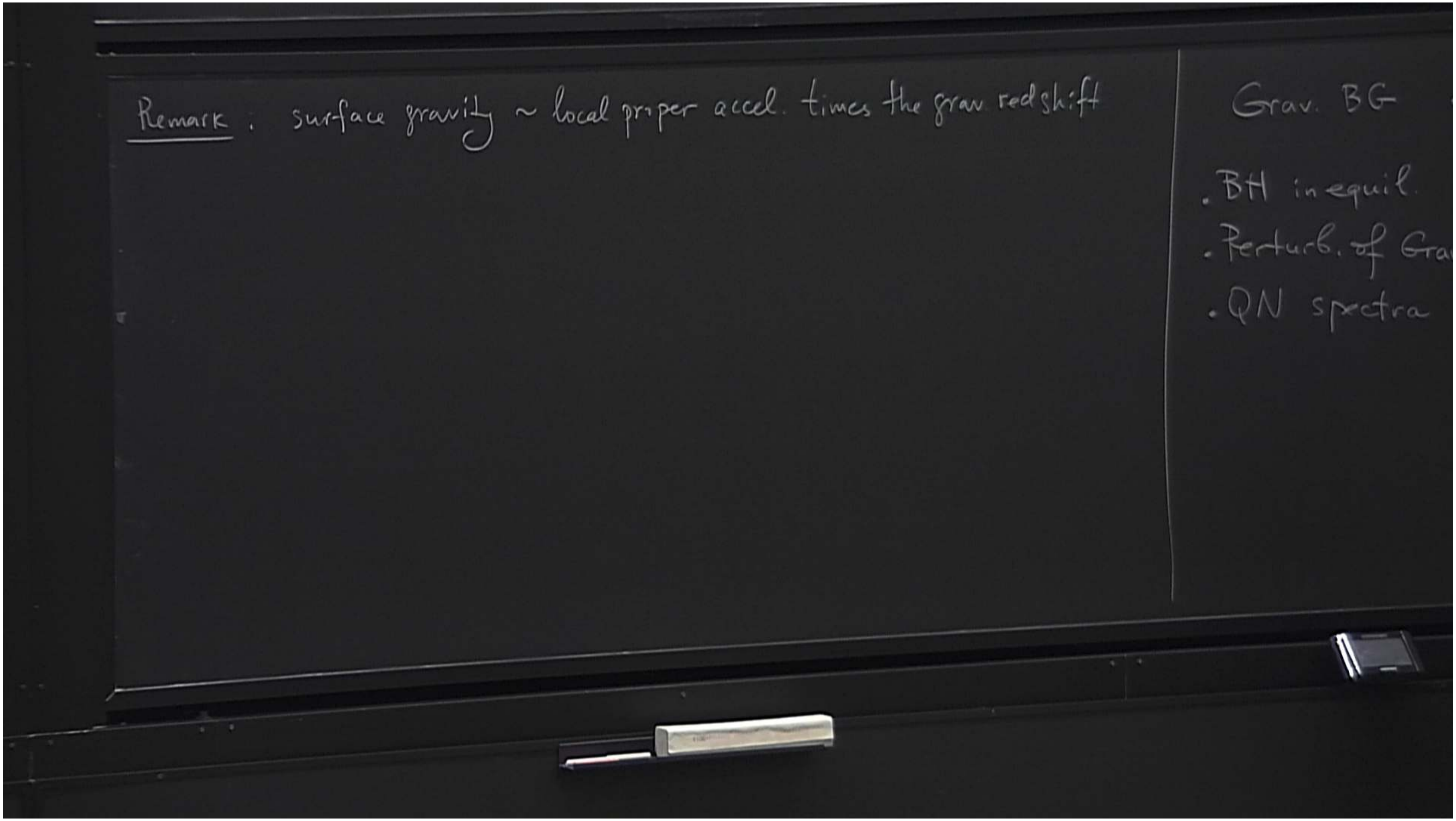
BH Thermodynamics (continued)

The four Laws of BH Mechanics

BH 0: The surface gravity κ is constant over the event horizon

T⊖ 0: Temperature is constant throughout a system in thermal eq.

BH 1:


Remark : surface gravity ~ local proper accel. times the grav. redshift
Grav. BG
. BH in equil.
. Perturb. of Gra
. QN spectra

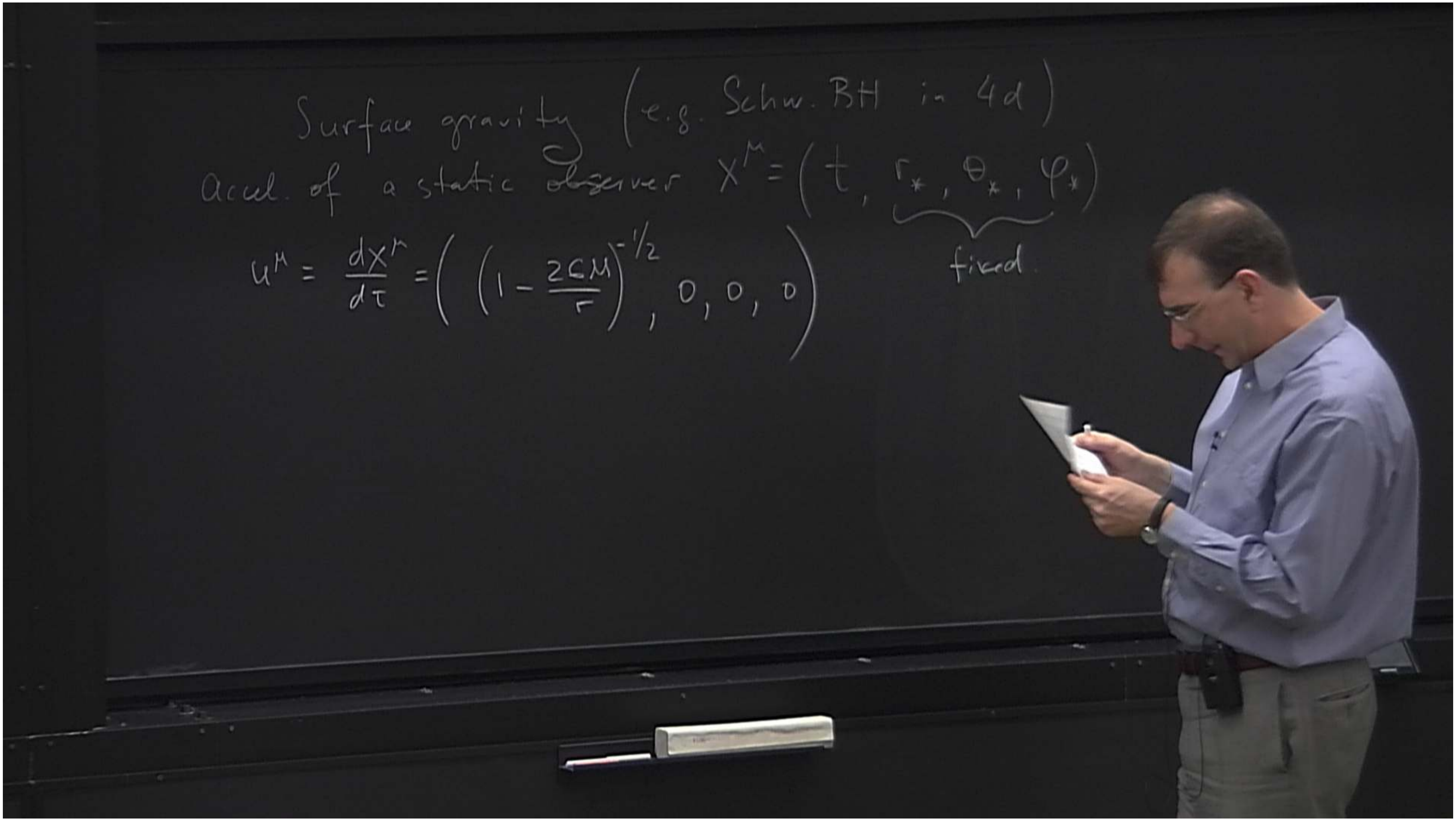
Remark: surface gravity ~ local proper accel. times the grav redshift

The surface grav. $\varkappa$ of a static Killing horizon* is the acceleration (as measured at spat. inf.) necessary to keep an object at the horizon. For a Killing vector K^μ:

$$K^\mu \nabla_\mu K^\nu = \varkappa K^\nu \qquad K^\mu K_\mu \to -1 \text{ at } r \to \infty$$

Grav. BG

- BH in equil.
- Perturb. of Gra[v]
- QN spectra


Surface gravity (e.g. Schw. BH in 4d)
accel. of a static observer $x^\mu = (t, r_*, \theta_*, \varphi_*)$
fixed
$u^\mu = \frac{dx^\mu}{d\tau} = \left(\left(1 - \frac{2GM}{r}\right)^{-1/2}, 0, 0, 0 \right)$

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$$u^\mu = \frac{dx^\mu}{d\tau} = \left(\left(1 - \frac{2GM}{r}\right)^{-1/2}, 0, 0, 0 \right)$$

$$a^\mu = u^\lambda \nabla_\lambda u^\mu = u^0 \left(\partial_0 u^\mu + \Gamma^\mu_{0\rho} \right) u^\rho = (u^0)^2 \Gamma^\mu_{00}$$

Only $\Gamma^r_{00} \neq 0 \Rightarrow a^r = \frac{GM}{r^2}$ $\quad |a| = \sqrt{a_\mu a^\mu} = \sqrt{g_{rr} a^r a^r} = \frac{GM}{r^2} \frac{1}{\sqrt{1 - 2GM}}$

Remark: surface gravity ~ local proper accel. times the grav redshift

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$$mg = G\frac{mM}{R^2}$$

Grav. BG <-

- BH in equil.
- Perturb. of Grav.
- QN spectra

BH Thermodynamics (continued)

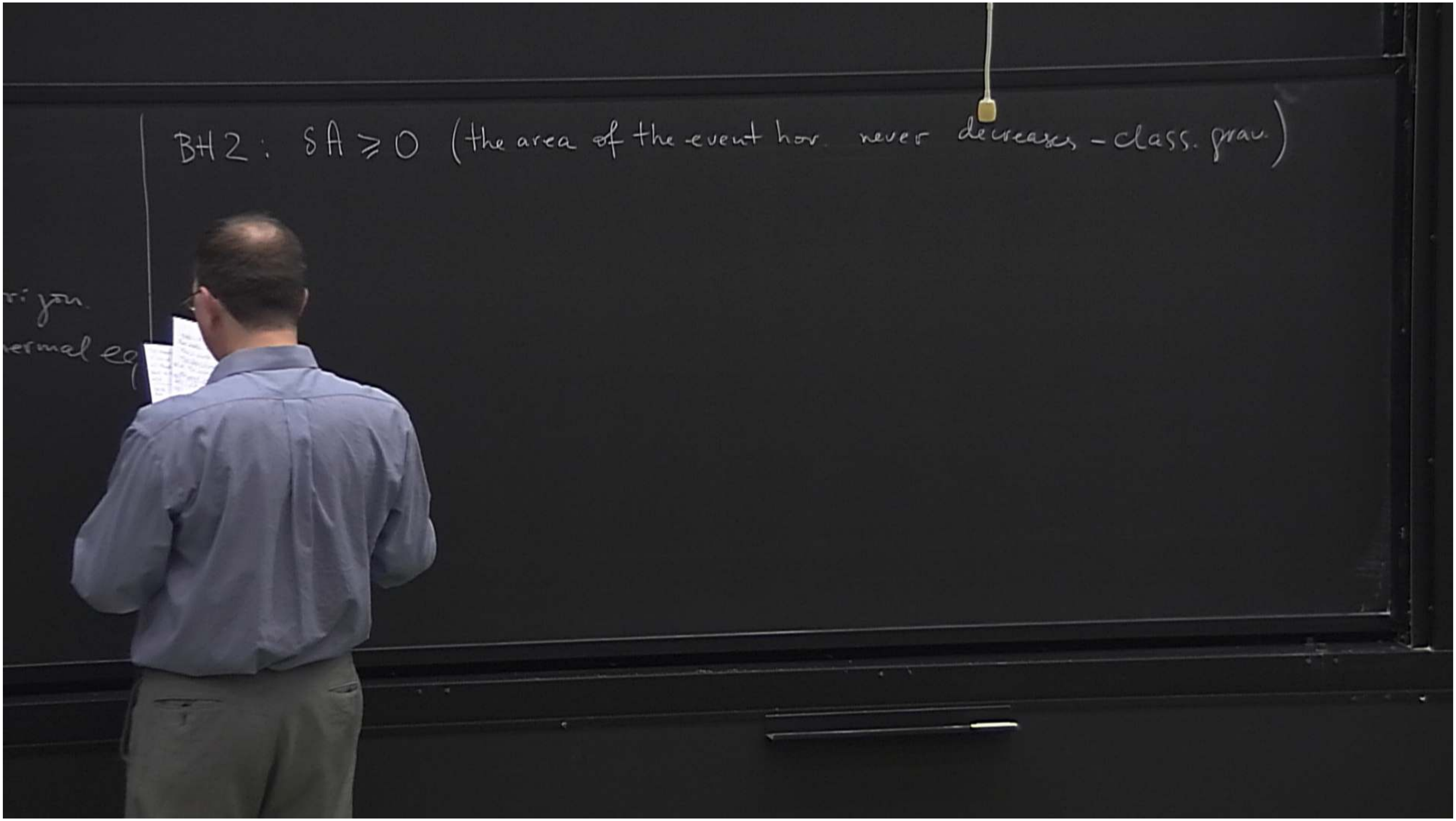
The four Laws of BH Mechanics

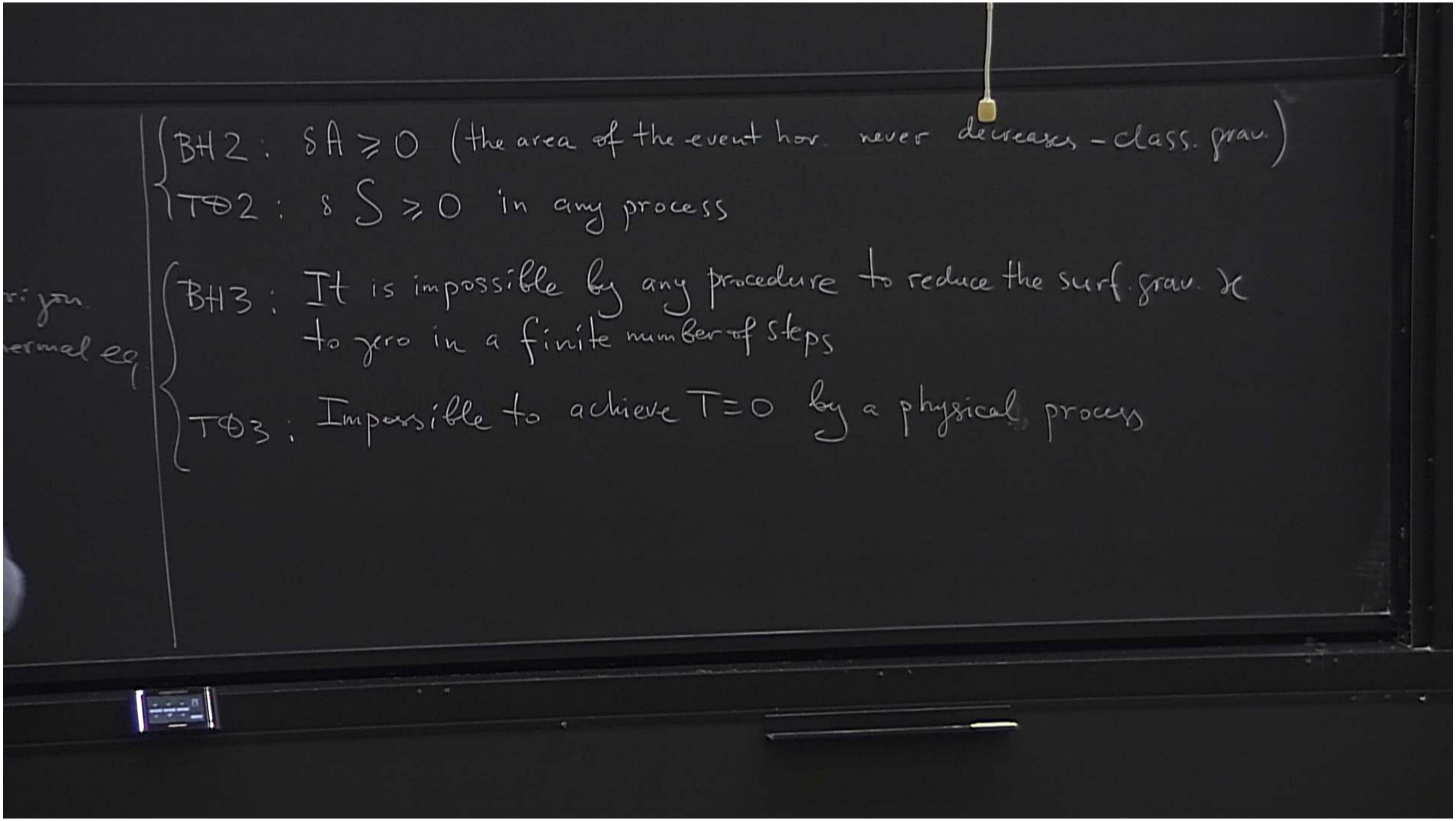
BH 0: The surface gravity $\varkappa$ is constant over the event horizon.

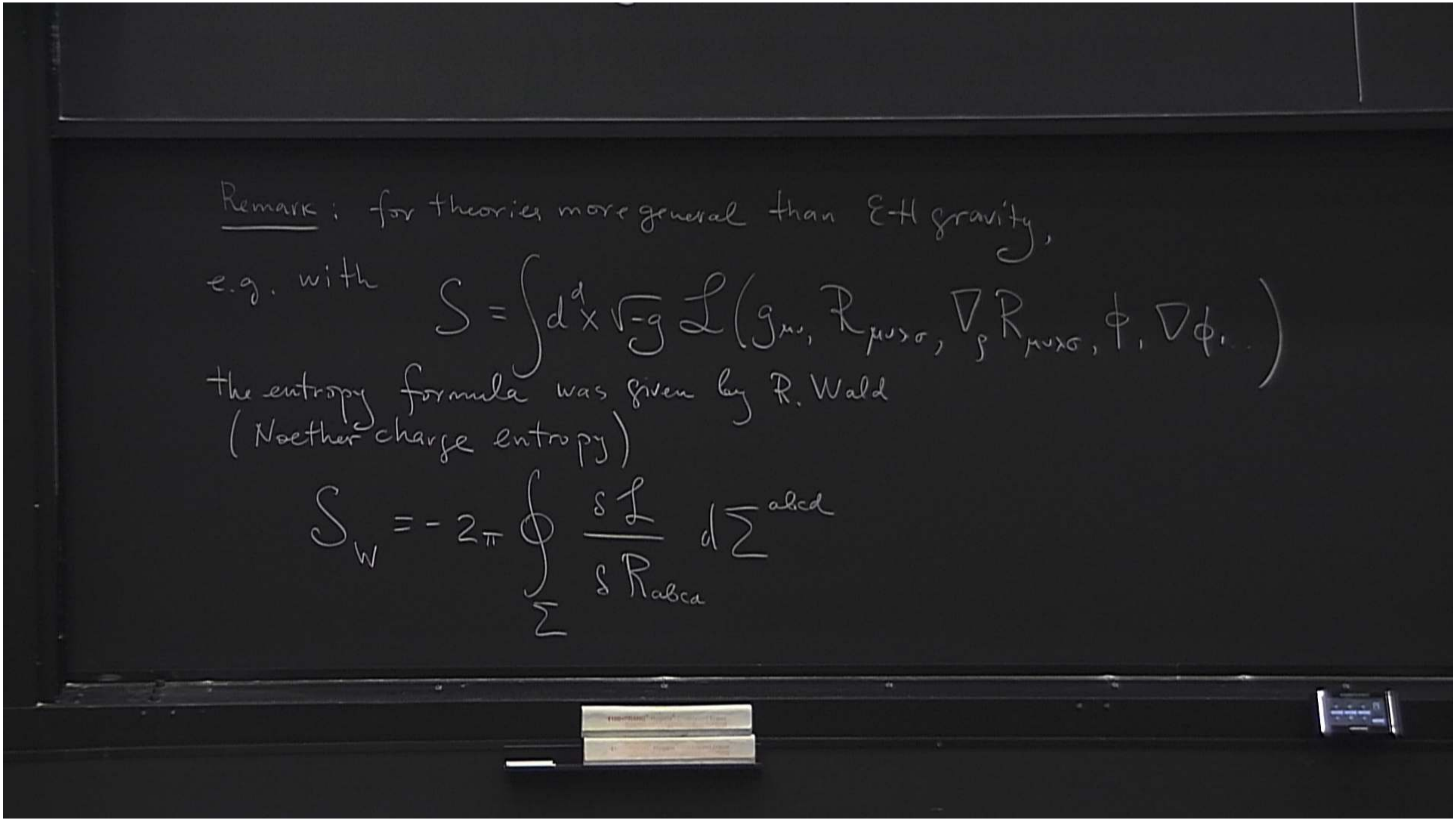
TΘ 0: Temperature is constant throughout a system in thermal eq.

BH 1: $\delta M = \frac{\varkappa}{8\pi G}\,\delta A + \Omega_H\,\delta J + \Phi_H\,\delta Q$

TΘ 1: $dE = T\,dS$ + work terms


BH2: δA ≥ 0 (the area of the event hor. never decreases - class. grav.)


BH2: δA ≥ 0 (the area of the event hor. never decreases – class. grav.)
TΘ2: δS ≥ 0 in any process
BH3: It is impossible by any procedure to reduce the surf. grav. κ to zero in a finite number of steps
TΘ3: Impossible to achieve T=0 by a physical process


Remark: for theories more general than E-H gravity,
e.g. with $S = \int d^dx \sqrt{-g}\, \mathcal{L}(g_{\mu\nu}, R_{\mu\nu\lambda\sigma}, \nabla_\rho R_{\mu\nu\lambda\sigma}, \phi, \nabla\phi, \ldots)$
the entropy formula was given by R. Wald
(Noether charge entropy)
$S_W = -2\pi \oint_\Sigma \frac{\delta \mathcal{L}}{\delta R_{abcd}} d\Sigma^{abcd}$

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Hawking rad : (T) ∃ several ways of „deriving" Hawking rad.

See Carlip 0807.4520 [gr-qc]

Lesson : BH behave as TD objects with

$$k_B T_H = \frac{\hbar \kappa}{2\pi}$$

$$S_{BH}/k_B = \frac{c^3 A}{4 G \hbar}$$

$\ldots, \nabla\phi, \ldots)$

for

$_H$

$\mathcal{L} = R$

A microscopic theory (quantum gravity ++) is supposed to account for BH TD.

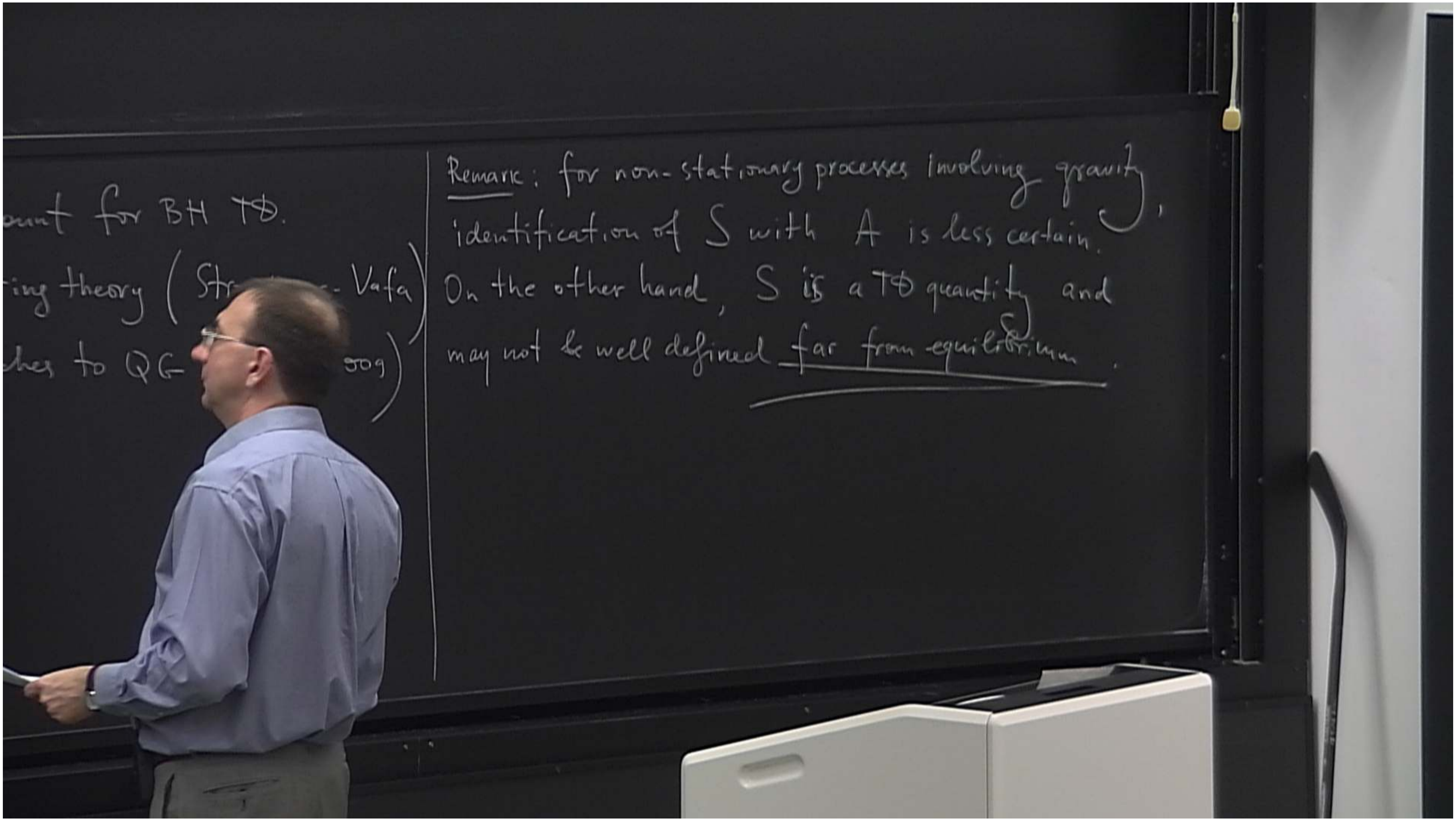
tial success in counting the BH states has been achieved in string theory (Strominger-Vafa 1996)

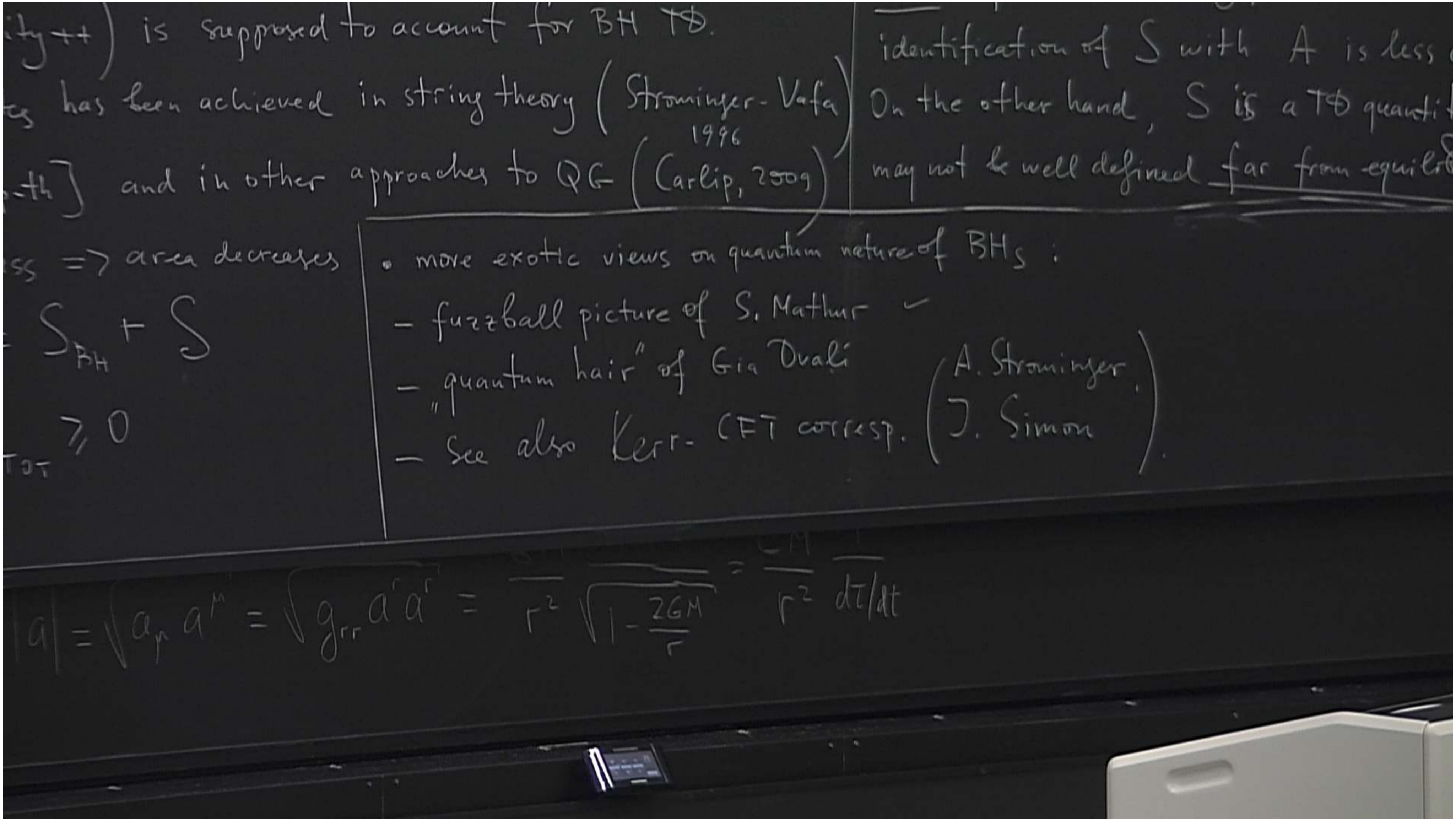
see Sen 0708.1270 [hep-th] and in other approaches to QG (Carlip, 2009)

emark: Hawking rad. reduces BH mass => area decreases

Generalized 2nd Law: $S_{TOT} = S_{BH} + S$

$$dS_{TOT} \geq 0$$


ount for BH TD.
Remark: for non-stationary processes involving gravity,
identification of S with A is less certain.
On the other hand, S is a TD quantity and
may not be well defined far from equilibrium.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ss => area decreases
$S_{BH} + S$
≥ 0
• more exotic views on quantum nature of BHs :
- fuzzball picture of S. Mathur
- "quantum hair" of Gia Dvali
- See also Kerr-CFT corresp. (A. Strominger, J. Simon).
$|a| = \sqrt{a_\mu a^\mu} = \sqrt{g_{rr} a^r a^r} = \frac{}{r^2 \sqrt{1-\frac{2GM}{r}}} = \frac{GM}{r^2} \frac{1}{d\tau/dt}$