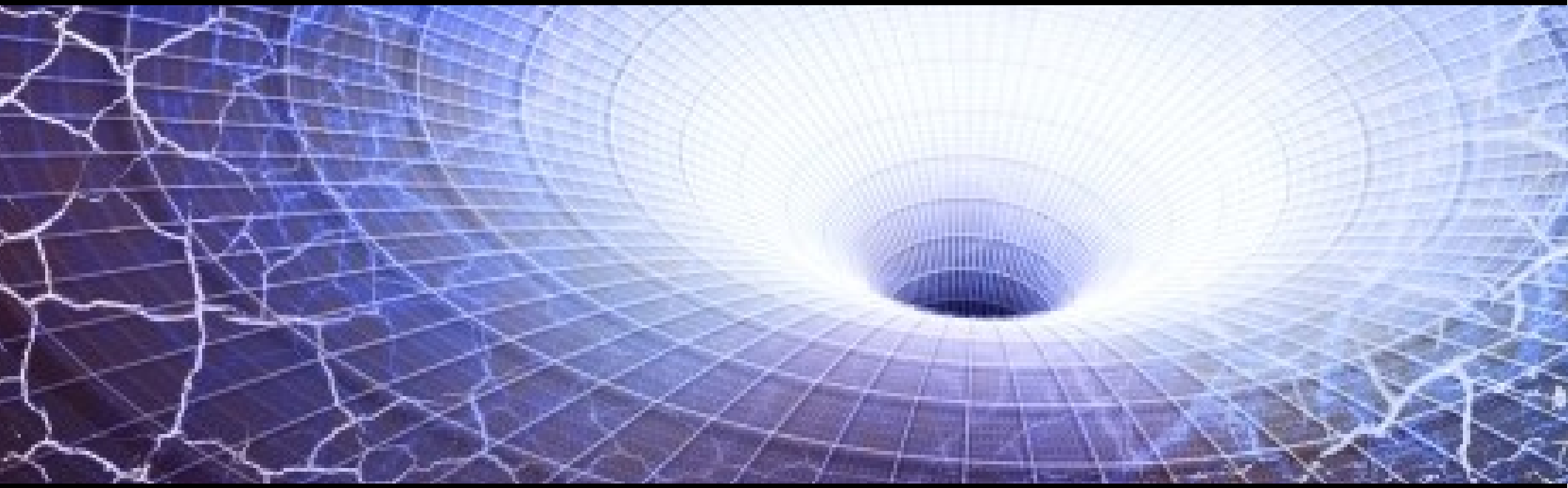
Ultraviolet improved black holes

My Master thesis project



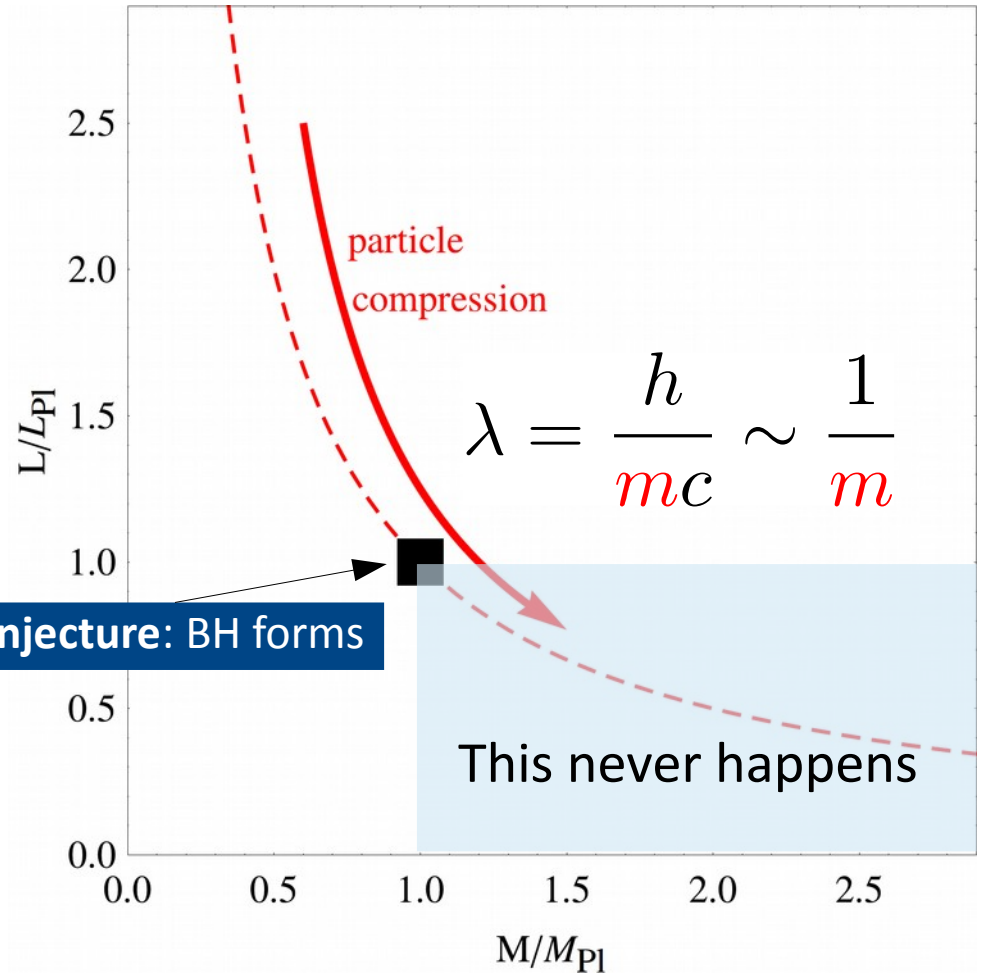
Sven Köppel
koeppel@fias.uni-frankfurt.de
26. Nov 2014 @ FIAS

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

FIAS Frankfurt Institute for Advanced Studies

Facing three problems

1. Black Hole – particle duality

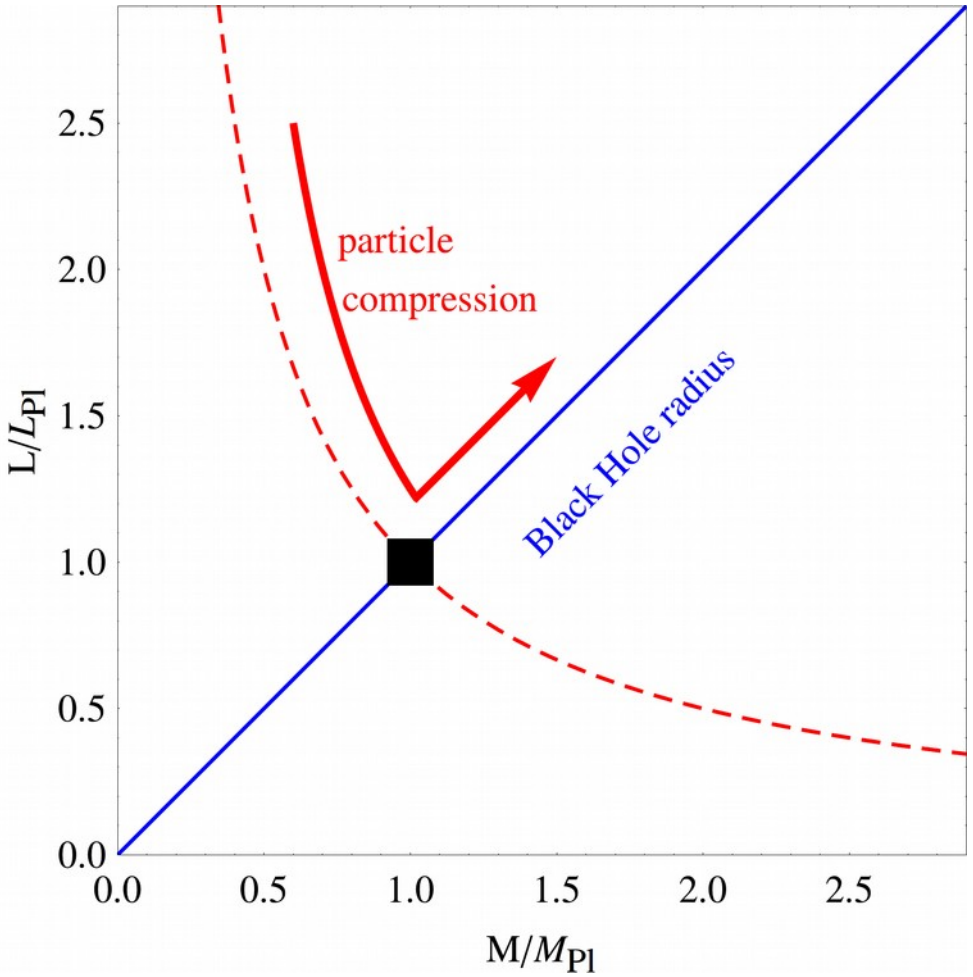


Hoop conjecture: BH forms

1. Particle accelerated

Facing three problems

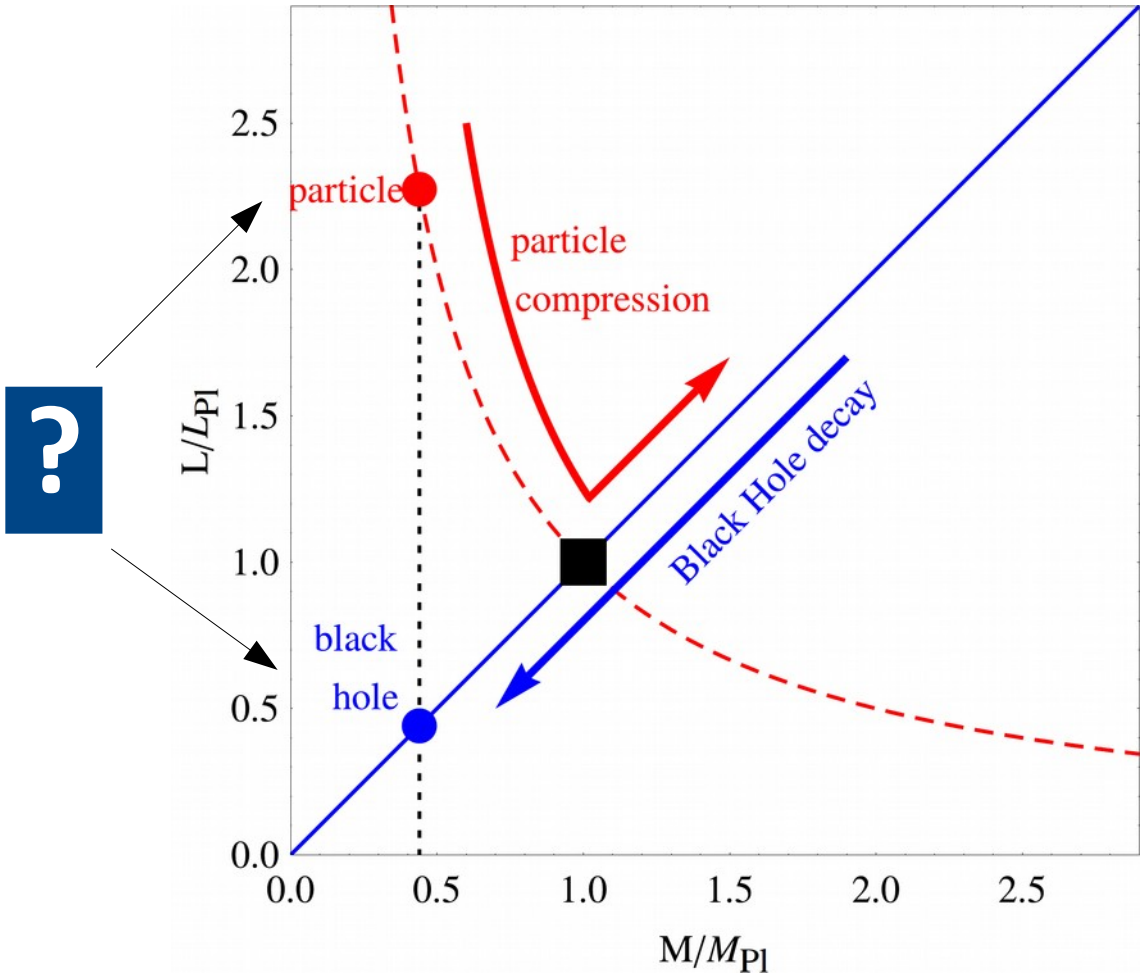
1. Black Hole – particle duality



1. Particle accelerated
2. BH produced

Facing three problems

1. Black Hole – particle duality



1. Particle accelerated
2. BH produced
3. BH decays

Facing three problems

2. Ultraviolet regime of General Relativity

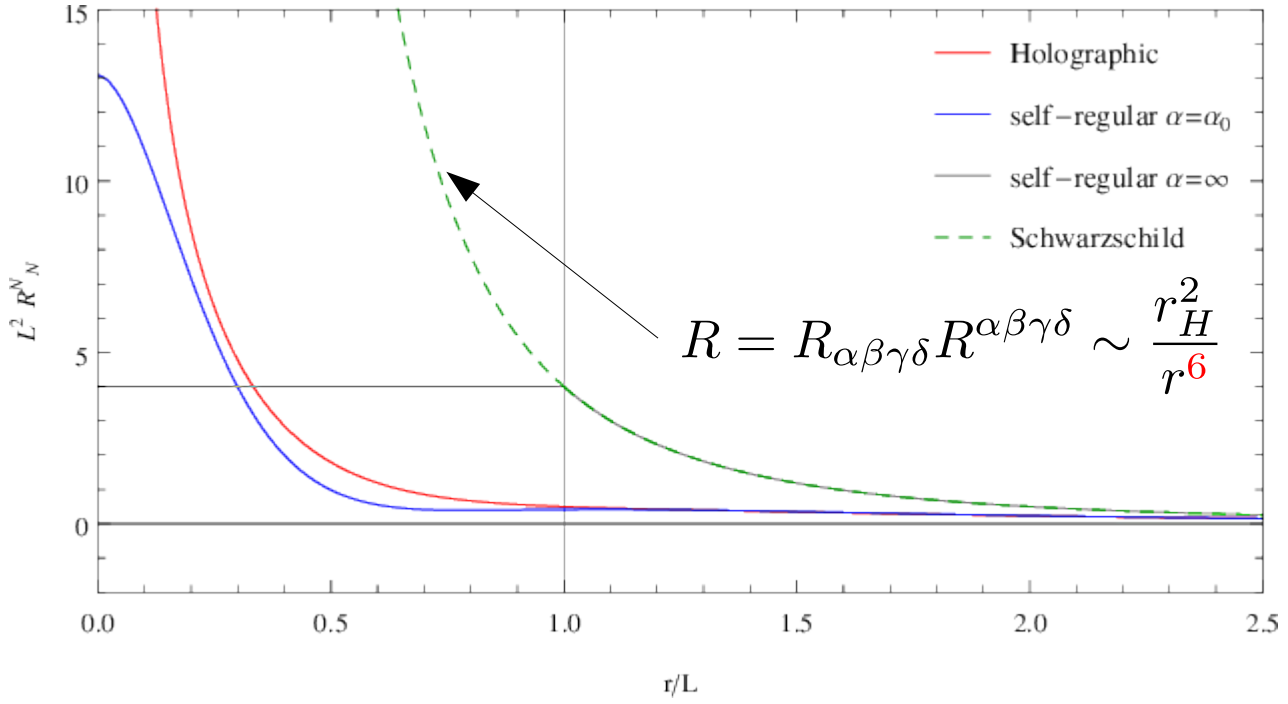
The Schwarzschild line element:

$$\mathrm{d}s^2 = -(1+2\Phi(r))\mathrm{d}t^2 + \frac{1}{1+2\Phi(r)}\mathrm{d}r^2 + r^2\mathrm{d}\theta^2 + r^2\sin^2\theta\mathrm{d}\phi^2$$

With Newton's gravitational potential

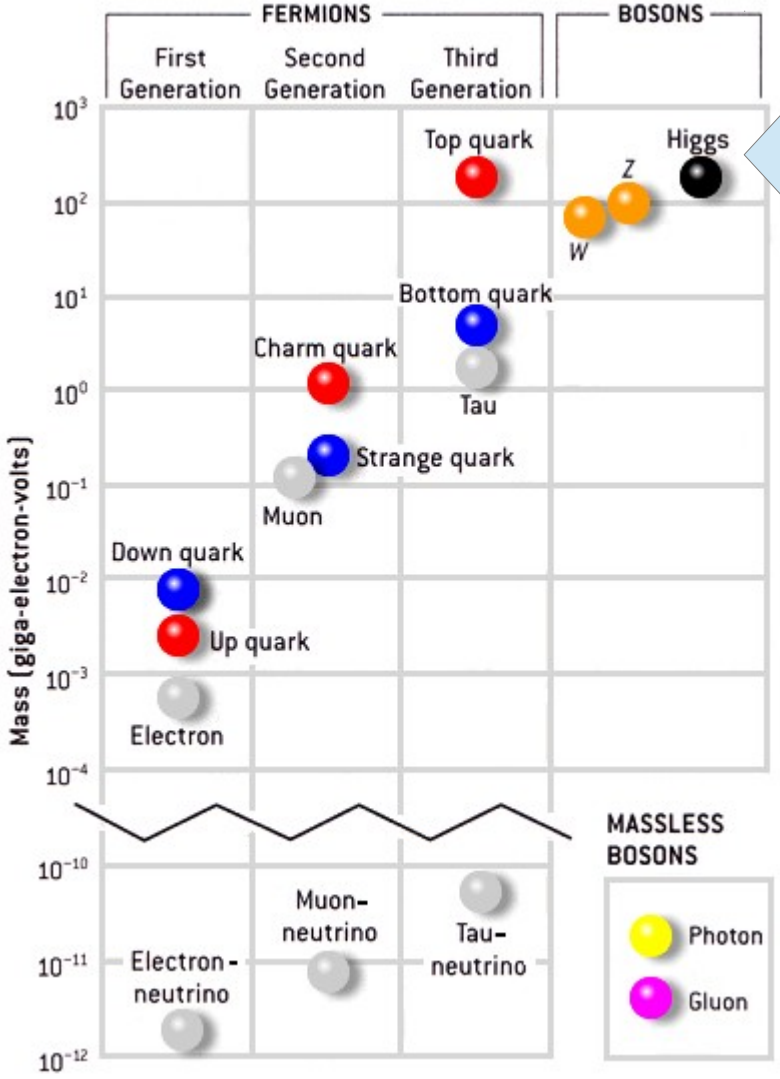
$$\Phi(r) = -\frac{MG}{r}$$

Schwarzschild: Ricci scalar diverges at origin



Facing three problems

2. Hierarchy problem of the Standard Model



Elektroweak scale
$\Lambda_{\mathrm{EW}} \sim 123\ \mathrm{GeV}$

vs.

Planck scale
$M_{\mathrm{Pl}} \sim 10^{19}\ \mathrm{GeV}$

The Approach

Nonlocal gravity

e.g. GUP: Start with Nonlocal Operator

Here: End with Nonlocal Operator

Quantum matter

$$G_{\mu\nu} = 8\pi G\, \mathcal{A}^{-2}(\Box/\Lambda^2) T_{\mu\nu}$$

dual

$$\mathcal{A}^{2}(\Box/\Lambda^2) G_{\mu\nu} = 8\pi G\, T_{\mu\nu}$$

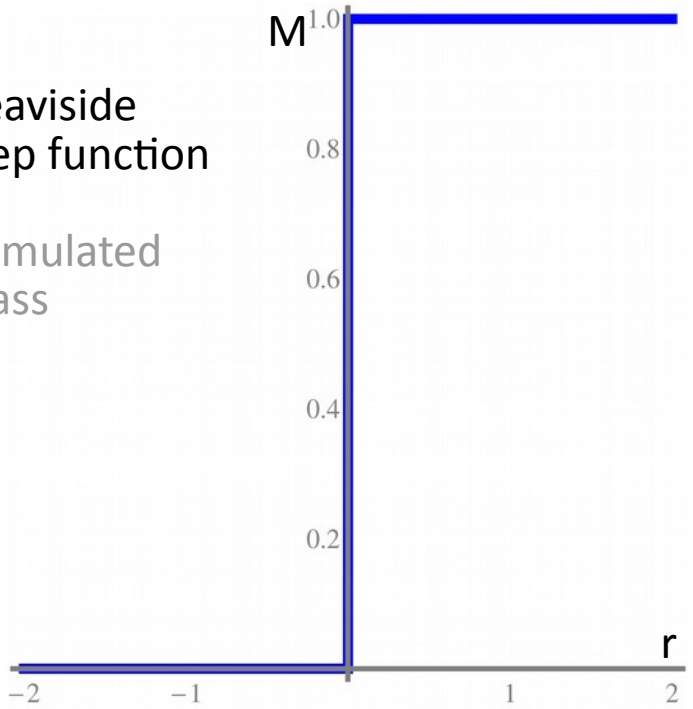
Nonlocal gravity

Engages:

BH-particle duality

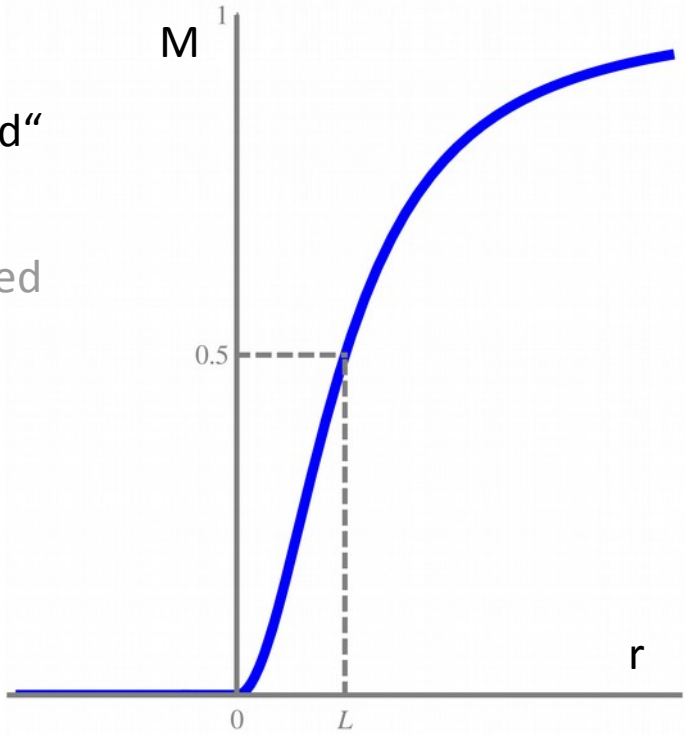
Heaviside
Step function

Cumulated
mass



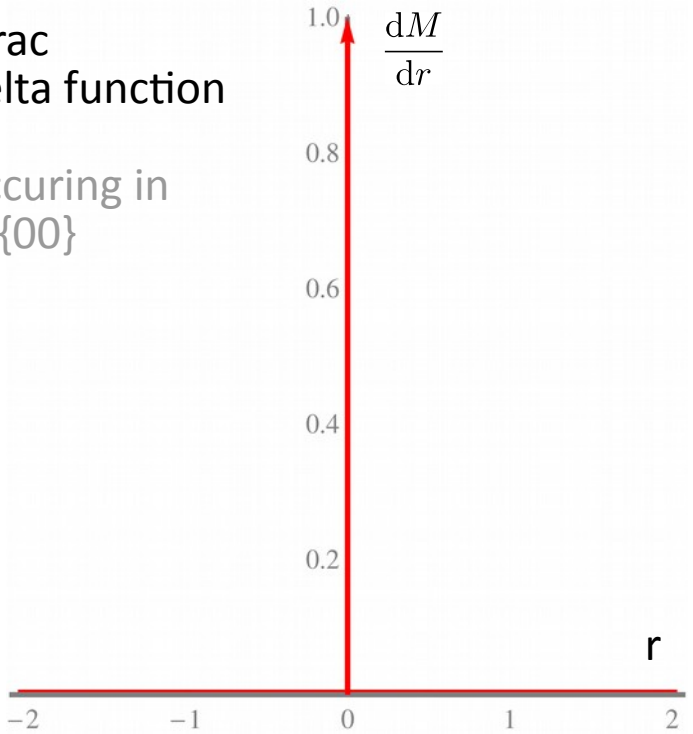
„Smeared“
Mass

Cumulated
mass

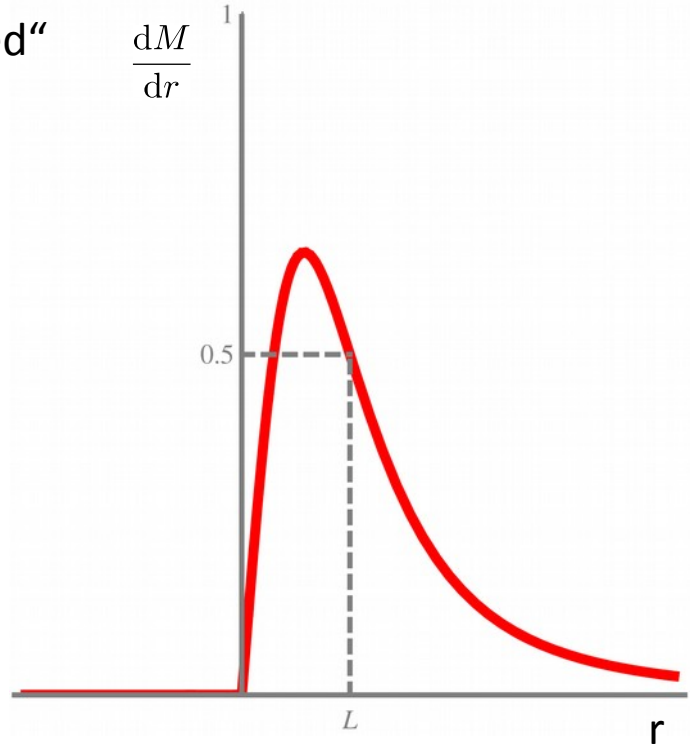


Dirac
Delta function

Occuring in
T_{00}



„Smeared“
Mass



The Approach

ADD
Large Extra Dimensions

$$M_{\rm Pl}^2 = V_n M_*^{n+2}$$

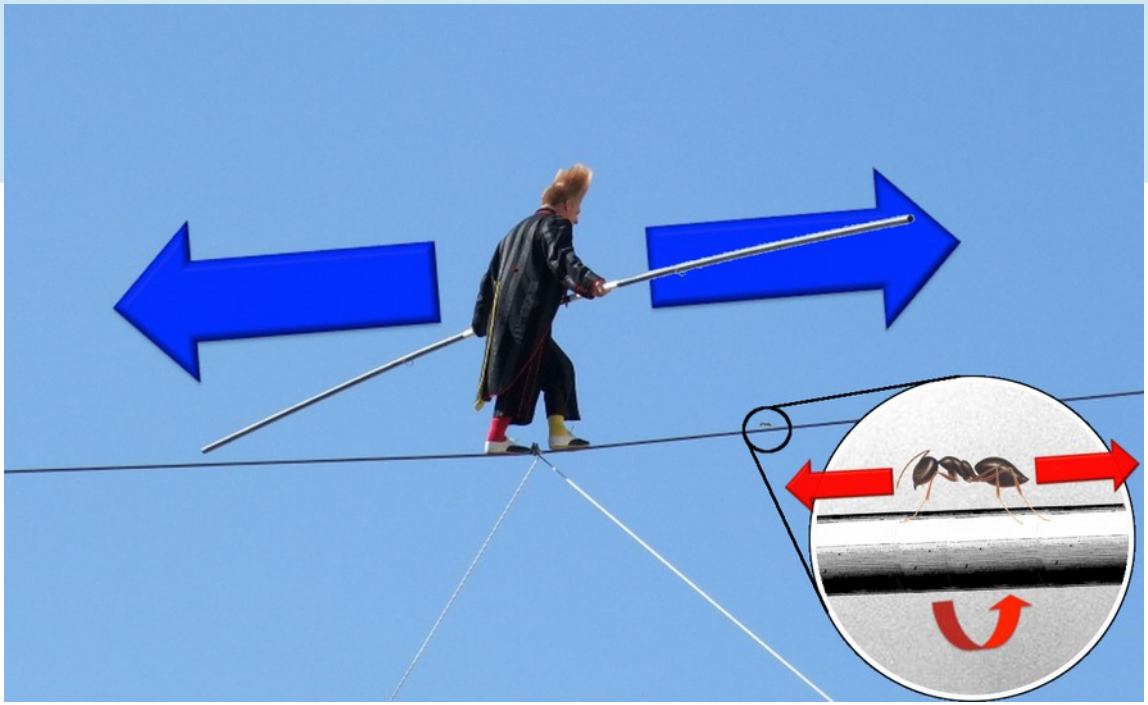
Integrated huge Volume of extra dimensions

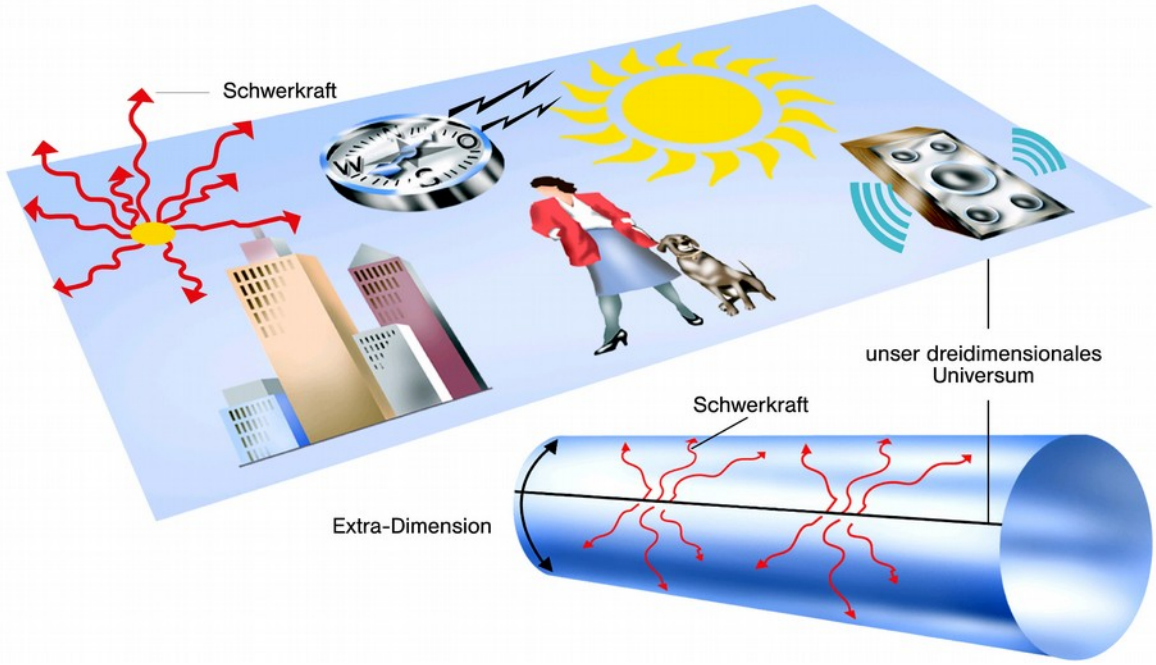
$$V_n = (2\pi R_c)^n$$

Large $\cong$ **μm** up to **mm**

Engages:

Hierarchy problem

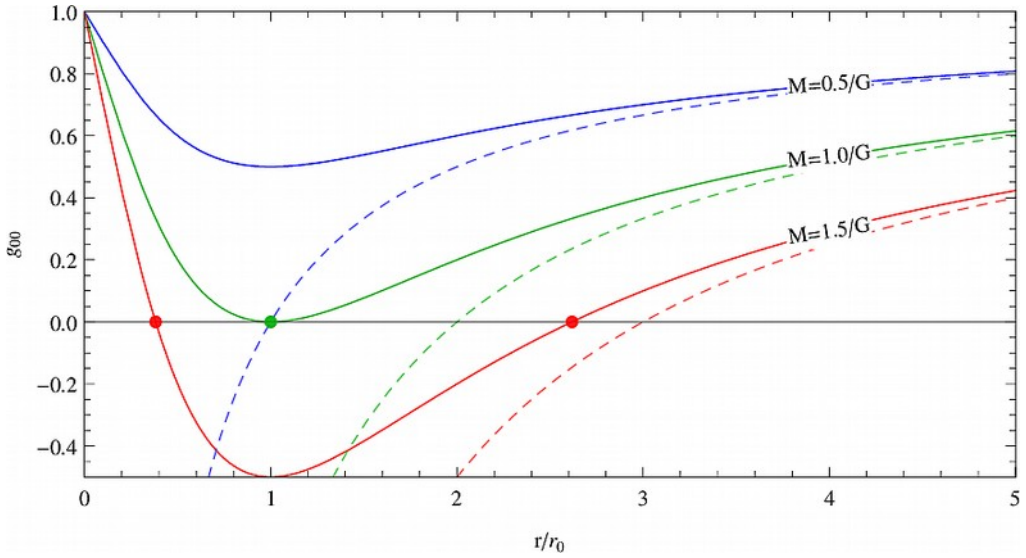




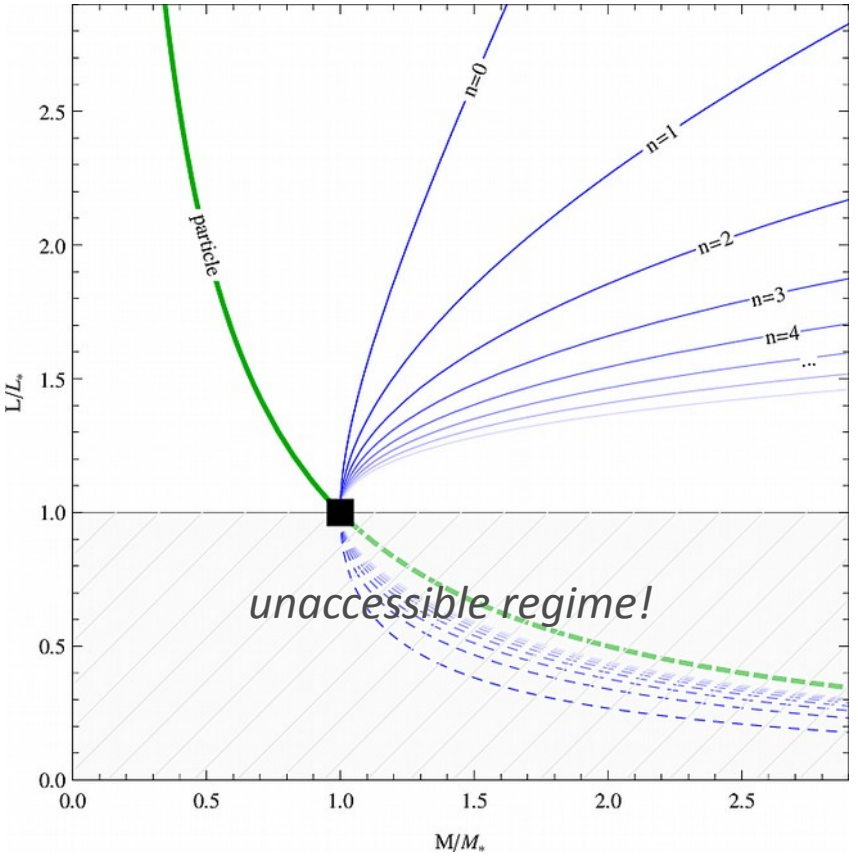
Holographic metric

The holographic metric:

- Regular center? **No**
- Classical low-energy limit? **Yes**
- Self-encoding? **Yes**



Self completeness of GR is given:

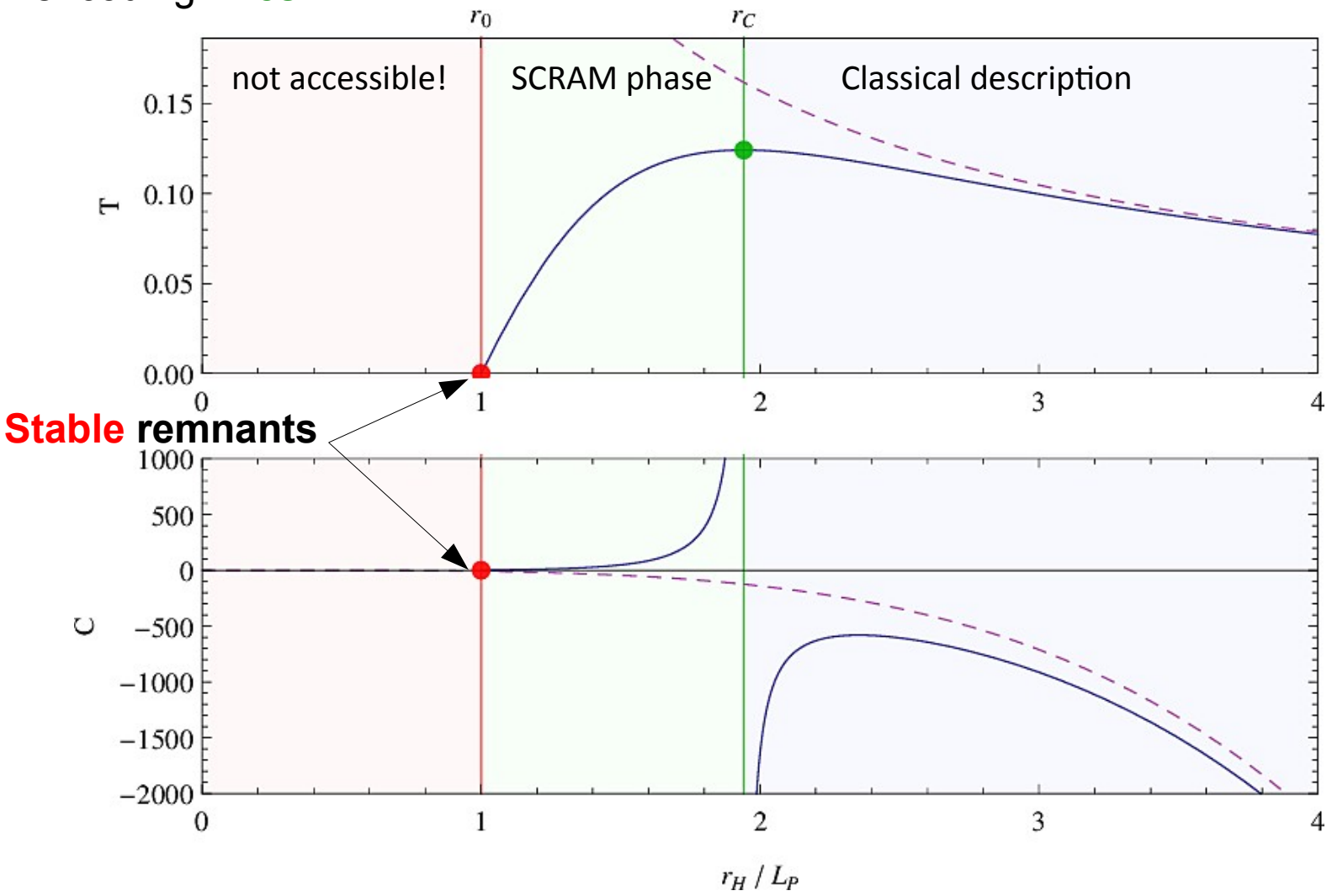


in 4d: $$\mathrm{d}s^2 = -\left(1 - \frac{2ML_{\mathrm{Pl}}^2}{r^2 + L_{\mathrm{Pl}}^2}\right)\mathrm{d}t^2 + \left(1 - \frac{2ML_{\mathrm{Pl}}^2}{r^2 + L_{\mathrm{Pl}}^2}\right)^{-1}\mathrm{d}r^2 + r^2\mathrm{d}\Omega^2$$

Holographic metric: Thermodynamics

The holographic metric:

- Regular center? **No**
- Classical low-energy limit? **Yes**
- Self-encoding? **Yes**



Results: Holographic metric

The holographic metric:

- Regular center? **No**
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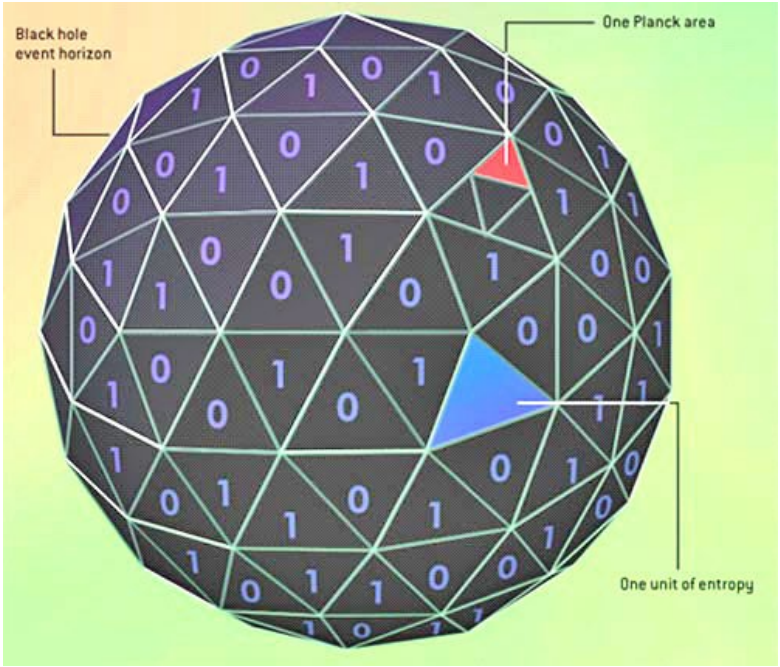


Logarithmic Entropy corrections

$$S(r) = \frac{4\pi}{L_*^{n+2}} \left(r^{n+2} - L_*^{n+2}\right) + 4\pi(n+2) \log\left(\frac{r}{L_*}\right)$$

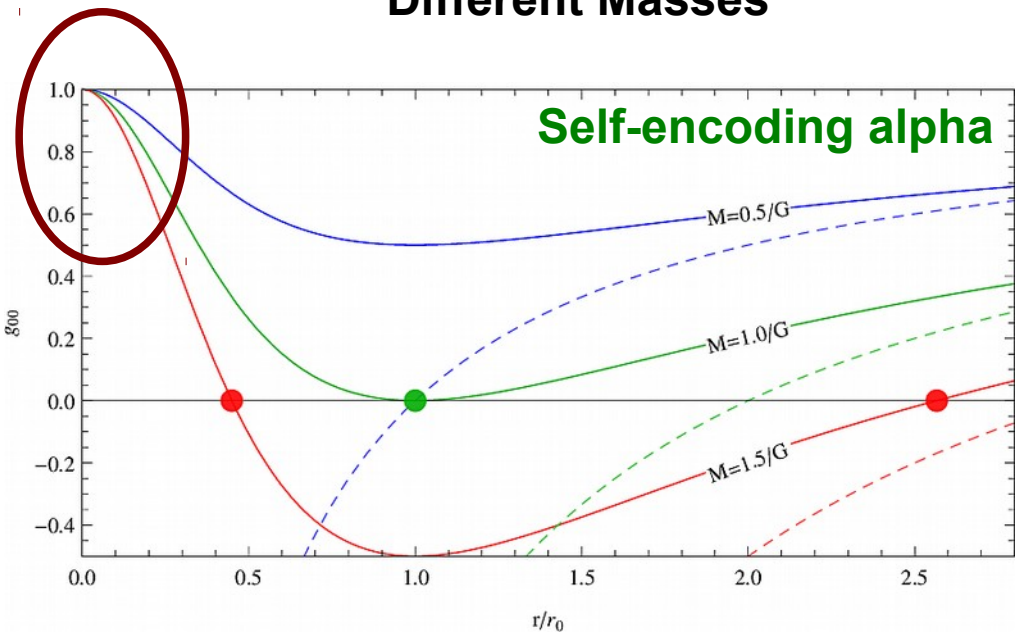
→ Quantization picture of BH surface still holds

Other approaches: Self-regular metric

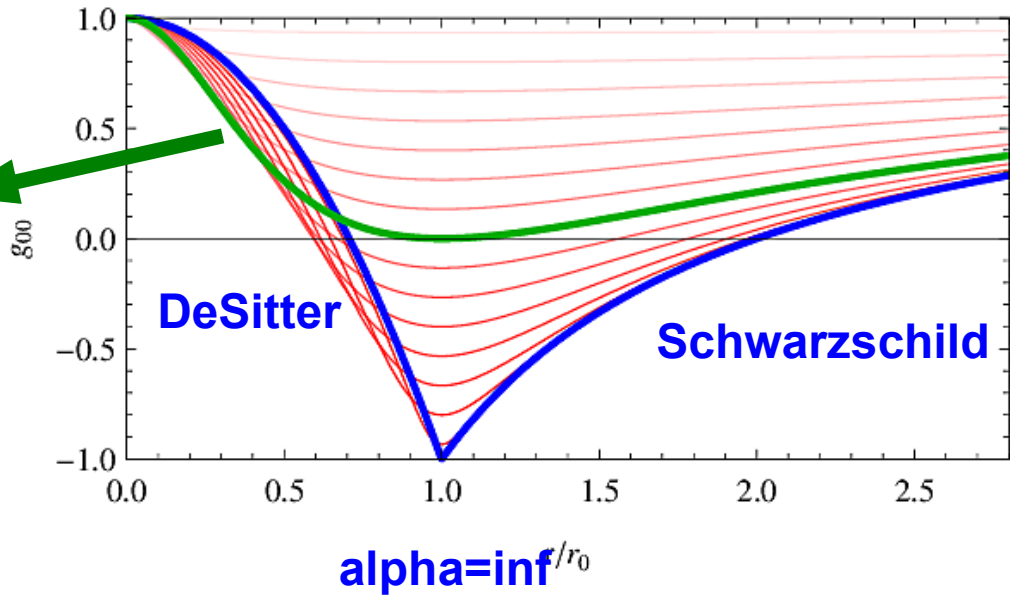
The self-regular metric:

- Regular center? **Yes**
- Classical low-energy limit? **Yes**
- Self-encoding? **Yes**

Different Masses



Different alphas



alpha=inf

Conclusions & Future Work

Possible ways to extend this work:

- How can more complicated Black holes fit into the self-complete paradigm?
- Investigating the Hawking-Page phase transition
- ...

Thank you for your attention

Literature:
Nicolini, Spallucci: „Holographic screens in UV self-complete QR“, ArXiv:1210.0015
Ongoing: Isi, Knipfer, Köppel, Mureika, Nicolini: „Self-Completeness and the GUP in extradimensions“
Ongoing: Bleicher, Dirkes, Frassino, Knipfer, Köppel, Nicolini: „GUP and BHs – a paedagogical review“