Title: Virtual extra dimensions from unparticle fields

Date: Jun 03, 2008 03:15 PM

URL: http://pirsa.org/08060138

Abstract: The phenomenology of TeV-scale physics can be modified by the existence of scale-invariant \'unparticle\' fields that can couple to the standard model sector. In particular, it has been shown that unparticles can alter gravitational interactions in a similar fashion to extra dimensions. Observable results from this mechanism -- most notably mini-black hole formation -- will be discussed, and methods of differentiating unparticles from extra dimensional models will be addressed.

"Virtual" Extra Dimensions from Unparticles
(and LHC black holes!)

LMU | LA
Loyola Marymount University Los Angeles

J. R. Mureika
Department of Physics
Loyola Marymount University

Phys. Lett. B **660,** 561-566 (2008)
arXiv: 0712.1786

ResearchCorporation

Black Holes in 4+n dimensions

Banks and Fischler, hep-th/9906038 ; Landsberg, PRL **88**, 181801 (2002)

Black Holes in 4+n dimensions

- (4+n)-D Schwarzschild metric (below $R_{compact}$):

$$ds^2 = \left(1 - h(r)^{n+1}\right) dt^2 - \frac{dr^2}{1 - h(r)^{n+1}} - r^2 d\Omega^2_{n-2} \qquad h(r) = \frac{r_H}{r} \ .$$

Banks and Fischler, hep-th/9906038 ; Landsberg, PRL **88**, 181801 (2002)

Black Holes in 4+n dimensions

- (4+n)-D Schwarzschild metric (below $R_{compact}$):

$$ds^2 = \left(1 - h(r)^{n+1}\right)\, dt^2 - \frac{dr^2}{1 - h(r)^{n+1}} - r^2 d\Omega^2_{n-2} \qquad h(r) = \frac{r_H}{r} \; .$$

- Modified horizon:

$$r_H = \frac{1}{\sqrt{\pi} M_*} \left(\frac{M_{BH}}{M_*}\right)^{\frac{1}{n+1}} \left(\frac{8\Gamma\left(\frac{n+3}{2}\right)}{n+2}\right)^{\frac{1}{n+1}}$$

Banks and Fischler, hep-th/9906038 ; Landsberg, PRL **88**, 181801 (2002)

Black Holes in 4+n dimensions

- (4+n)-D Schwarzschild metric (below $R_{compact}$):

$$ds^2 = \left(1 - h(r)^{n+1}\right)\, dt^2 - \frac{dr^2}{1 - h(r)^{n+1}} - r^2 d\Omega^2_{n-2} \qquad h(r) = \frac{r_H}{r} \ .$$

- Modified horizon:

$$r_H = \frac{1}{\sqrt{\pi} M_*} \left(\frac{M_{BH}}{M_*}\right)^{\frac{1}{n+1}} \left(\frac{8\Gamma\left(\frac{n+3}{2}\right)}{n+2}\right)^{\frac{1}{n+1}}$$

- $M_{BH} > M_* \sim 1$ TeV, $r_H \sim$ sub-fm scale
- Geometric cross-section: $\sigma = \pi r_H^2 \sim 100$ pb
- Max. luminosity @ LHC: 1 event / second

Banks and Fischler, hep-th/9906038 ; Landsberg, PRL **88**, 181801 (2002)

Unparticle Physics Primer

Unparticle Physics Primer

Scale-invariant Banks-Zaks field (dim. d_{BZ}), weakly interacting with SM via massive exchange particle $M_{\mathcal{U}}$:

$$\mathcal{L} = \frac{1}{M_{\mathcal{U}}^k}\mathcal{O}_{SM}\mathcal{O}_{BZ}$$

Unparticle Physics Primer

Scale-invariant Banks-Zaks field (dim. d_{BZ}), weakly interacting with SM via massive exchange particle $M_{\mathcal{U}}$:

$$\mathcal{L} = \frac{1}{M_{\mathcal{U}}^k} \mathcal{O}_{SM} \mathcal{O}_{BZ}$$

Below some scale, undergoes dimensional transmutation $\mathcal{O}_{BZ} \rightarrow C_{\mathcal{U}} \lambda^{dBZ-dU} \mathcal{O}_{\mathcal{U}}$ to become an "unparticle" field $\mathcal{O}_{\mathcal{U}}$ (scalar, vector, tensor, spinor) at energy scale $\Lambda_{\mathcal{U}}$:

$$\mathcal{L} = \frac{\kappa}{\Lambda^{k_{\mathcal{U}}}} \mathcal{O}_{SM} \mathcal{O}_{\mathcal{U}} \quad , \quad \kappa = C_{\mathcal{U}} \left(\frac{\Lambda_{\mathcal{U}}}{M_{BZ}} \right)^k$$

Unparticle Physics Primer

*Georgi, PRL **98**, 221601 (2007); PLB **650**, 275 (2007)*

Unparticle Physics Primer

- Propagator:

Georgi, PRL **98**, 221601 (2007);
PLB 650, 275 (2007)

$$\langle 0|\mathcal{O}_{\mathcal{U}}(x)\mathcal{O}_{\mathcal{U}}^{\dagger}(0)|0\rangle = \int \frac{d^4p}{(4\pi)^4} e^{iPx} |\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2 \rho(P^2)$$

Unparticle Physics Primer

- Propagator:

Georgi, PRL **98**, 221601 (2007); **PLB 650**, 275 (2007)

$$\langle 0|\mathcal{O}_{\mathcal{U}}(x)\mathcal{O}^{\dagger}_{\mathcal{U}}(0)|0\rangle = \int \frac{d^4p}{(4\pi)^4} e^{iPx} |\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2 \rho(P^2)$$

- Unparticle Phase Space:

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2 \rho(P^2) = A_{d\mathcal{U}} \theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

Unparticle Physics Primer

- Propagator:

Georgi, PRL **98**, 221601 (2007); **PLB 650**, 275 (2007)

$$\langle 0|\mathcal{O}_{\mathcal{U}}(x)\mathcal{O}_{\mathcal{U}}^{\dagger}(0)|0\rangle = \int \frac{d^4p}{(4\pi)^4} e^{iPx} |\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2 \rho(P^2)$$

- Unparticle Phase Space:

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2 \rho(P^2) = A_{d\mathcal{U}} \theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

- SM Particle Phase Space:

$$A_n \theta(P^0)\theta(P^2)(P^2)^{n-2} \quad ,$$

The Unparticle Interpretation

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2\rho(P^2) = A_{d\mathcal{U}}\theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

The Unparticle Interpretation

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2\rho(P^2) = A_{d\mathcal{U}}\theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

Unparticle stuff "looks like" $d_{\mathcal{U}}$ (non-integer) indivisble, massless particles

[Georgi, PRL 98, 221601 (2007)]

The Unparticle Interpretation

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2\rho(P^2) = A_{d\mathcal{U}}\theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

Unparticle stuff "looks like" $d_{\mathcal{U}}$ (non-integer) indivisble, massless particles

[Georgi, PRL 98, 221601 (2007)]

- How does one quantify and/or measure this??

The Unparticle Interpretation

$$|\langle 0|\mathcal{O}_{\mathcal{U}}(0)|P\rangle|^2\rho(P^2) = A_{d\mathcal{U}}\theta(P^0)\theta(P^2)(P^2)^{d_{\mathcal{U}}-2}$$

Unparticle stuff "looks like" $d_{\mathcal{U}}$ (non-integer) indivisble, massless particles

[Georgi, PRL 98, 221601 (2007)]

- How does one quantify and/or measure this??
- More recently: "Sommerfield" model: massless fermions coupled to massive vector field in infrared limit

[Georgi and Kats, 0805.3593]

The Unparticle Interpretation

The Unparticle Interpretation

Unparticle stuff is a composite BZ-particle with a continuum mass spectrum

[Krasnikov, 0707.1419; Nikolic, 0801.4471; McDonald, 0805.1888]

The Unparticle Interpretation

Unparticle stuff is a composite BZ-particle with a continuum mass spectrum

[Krasnikov, 0707.1419; Nikolic, 0801.4471; McDonald, 0805.1888]

- Unparticle operator is "deconstructed" to sum of massive BZ fields with mass $M_n^2 = \Delta^2 n$

$$O_{\mathcal{U}} \to \sum_{n=0}^{\infty} F_n \phi_n \quad , \quad F_n^2 = \left|\langle 0 | O_{\mathcal{U}}(0) | \phi_n \rangle\right|^2 = \frac{A_{d_{\mathcal{U}}}}{2\pi} \Delta^2 (M_n^2)^{d_{\mathcal{U}}-2}$$

- In limit $\Delta \to 0$, mass spectrum, SM $\to \mathcal{U}$ decay rates, etc… become continuous and finite (infinite # of kinematically allowed states)
- $\mathcal{U}$ to SM decay rates vanish (unparticles are stable)

“Ungravity”

$$T^{\mu\nu} + T_{\mathcal{U}}^{\mu\nu}, \qquad T_{\mathcal{U}}^{\mu\nu} \sim \sqrt{|g|}\, T^{\alpha\beta} \mathcal{O}^{\mathcal{U}}_{\alpha\beta} g_{\mu\nu},$$

Goldberg and Nath, PRL **100**, 031803 (2008)

"Ungravity"

- Introduce a tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$T^{\mu\nu} + T^{\mu\nu}_{\mathcal{U}}, \qquad T^{\mu\nu}_{\mathcal{U}} \sim \sqrt{|g|} T^{\alpha\beta} \mathcal{O}^{\mathcal{U}}_{\alpha\beta} g_{\mu\nu},$$

Goldberg and Nath, PRL **100**, 031803 (2008)

"Ungravity"

- Introduce a tensor unparticle operator $O_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$T^{\mu\nu} + T^{\mu\nu}_{\mathcal{U}}, \qquad T^{\mu\nu}_{\mathcal{U}} \sim \sqrt{|g|}\, T^{\alpha\beta} \mathcal{O}^{\mathcal{U}}_{\alpha\beta} g_{\mu\nu},$$

*Goldberg and Nath, PRL **100**, 031803 (2008)*

- "Cosmological constant" term (but there could be other couplings as well)

"Ungravity"

- Introduce a tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$T^{\mu\nu} + T^{\mu\nu}_{\mathcal{U}}, \qquad T^{\mu\nu}_{\mathcal{U}} \sim \sqrt{|g|}\, T^{\alpha\beta} \mathcal{O}^{\mathcal{U}}_{\alpha\beta} g_{\mu\nu},$$

Goldberg and Nath, PRL **100**, 031803 (2008)

- "Cosmological constant" term (but there could be other couplings as well)

- Operator $\mathcal{O}_{\mu\nu}$ represents a spin-2 particle (ungraviton)

"Ungravity"

- Introduce a tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$T^{\mu\nu} + T^{\mu\nu}_{\mathcal{U}}, \qquad T^{\mu\nu}_{\mathcal{U}} \sim \sqrt{|g|}\, T^{\alpha\beta} \mathcal{O}^{\mathcal{U}}_{\alpha\beta} g_{\mu\nu}.$$

*Goldberg and Nath, PRL **100**, 031803 (2008)*

- "Cosmological constant" term (but there could be other couplings as well)

- Operator $\mathcal{O}_{\mu\nu}$ represents a spin-2 particle (ungraviton)

- Note that vector unparticle operator $\mathcal{O}_{\mu}$ can couple to baryon currents as $B^{\mu}\mathcal{O}_{\mu}$ (repulsive)

Newtonian limit of "ungravity"

Goldberg and Nath, PRL **100**, 031803 (2008)

Newtonian limit of "ungravity"

- Do some quantum field theory on propagator; obtain non-relativistic limit of tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$V(r) = V_N(r)\left[1 + \frac{2}{\pi^{2d_{\mathcal{U}}-1}}\frac{\Gamma(d_{\mathcal{U}}+\frac{1}{2})\Gamma(d_{\mathcal{U}}-\frac{1}{2})}{\Gamma(2d_{\mathcal{U}})}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right] = V_N(r)\left[1+\Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right],$$

Goldberg and Nath, PRL **100**, 031803 (2008)

Newtonian limit of "ungravity"

- Do some quantum field theory on propagator; obtain non-relativistic limit of tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$V(r) = V_N(r)\left[1 + \frac{2}{\pi^{2d_{\mathcal{U}}-1}}\frac{\Gamma(d_{\mathcal{U}}+\frac{1}{2})\Gamma(d_{\mathcal{U}}-\frac{1}{2})}{\Gamma(2d_{\mathcal{U}})}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right] = V_N(r)\left[1+\Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right],$$

Ungravity interaction scale

$$R_* = \Lambda_{\mathcal{U}}^{-1}\left(\frac{M_{Pl}}{\Lambda_{\mathcal{U}}}\right)^{\frac{1}{d_{\mathcal{U}}-1}}\left(\frac{\Lambda_{\mathcal{U}}}{M_{\mathcal{U}}}\right)^{\frac{d_{BZ}}{d_{\mathcal{U}}-1}}$$

Goldberg and Nath, PRL **100**, 031803 (2008)

Newtonian limit of "ungravity"

- Do some quantum field theory on propagator; obtain non-relativistic limit of tensor unparticle operator $\mathcal{O}_{\mu\nu}$ coupling to stress-energy $T_{\mu\nu}$

$$V(r) = V_N(r)\left[1 + \frac{2}{\pi^{2d_{\mathcal{U}}-1}}\frac{\Gamma(d_{\mathcal{U}}+\frac{1}{2})\Gamma(d_{\mathcal{U}}-\frac{1}{2})}{\Gamma(2d_{\mathcal{U}})}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right] = V_N(r)\left[1+\Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right],$$

Ungravity interaction scale

$$R_* = \Lambda_{\mathcal{U}}^{-1}\left(\frac{M_{Pl}}{\Lambda_{\mathcal{U}}}\right)^{\frac{1}{d_{\mathcal{U}}-1}}\left(\frac{\Lambda_{\mathcal{U}}}{M_{\mathcal{U}}}\right)^{\frac{d_{BZ}}{d_{\mathcal{U}}-1}}.$$

- Interactions will depend on mass scales $M_{\mathcal{U}} > \Lambda_{\mathcal{U}}$ and mass dimensions d_{BZ}, $d_{\mathcal{U}}$.
- Observable effects include orbital modifications and Cavendish anomalies

Goldberg and Nath, PRL **100**, 031803 (2008)

Unparticle-Enhanced Black Holes

Mureika, PLB **660** (2008) 561-566

Unparticle-Enhanced Black Holes

If $\Lambda_{\mathcal{U}} \sim 1$ TeV, new EW physics without extra dimensions!

*Mureika, PLB **660** (2008) 561-566*

Unparticle-Enhanced Black Holes

f $\Lambda_{\mathcal{U}} \sim 1$ TeV, new EW physics without extra dimensions!

- Metric (weak field and strong field matching):

$$ds^2 = \left[1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)\right] dt^2 + \frac{dr^2}{1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)} + r^2 d\Omega^2 \ .$$

Mureika, PLB **660** (2008) 561-566

Unparticle-Enhanced Black Holes

If $\Lambda_{\mathcal{U}} \sim 1$ TeV, new EW physics without extra dimensions!

- Metric (weak field and strong field matching):

$$ds^2 = \left[1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)\right] dt^2 + \frac{dr^2}{1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)} + r^2 d\Omega^2 \ .$$

- *If* $R_{int} << R_*$, acts like $(2d_{\mathcal{U}}-2)$ extra dimensions!

$$\Phi(r) \sim \frac{GM_{BH}\Gamma_{d_{\mathcal{U}}}}{r}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2} \ .$$

Mureika, PLB **660** (2008) 561-566

Unparticle-Enhanced Black Holes

If $\Lambda_{\mathcal{U}} \sim 1$ TeV, new EW physics without extra dimensions!

- Metric (weak field and strong field matching):

$$ds^2 = \left[1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)\right] dt^2 + \frac{dr^2}{1 - \frac{2GM}{r}\left(1 + \Gamma_{d_{\mathcal{U}}}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2}\right)} + r^2 d\Omega^2 \ .$$

- *If* $R_{int} << R_*$, acts like $(2d_{\mathcal{U}}-2)$ extra dimensions!

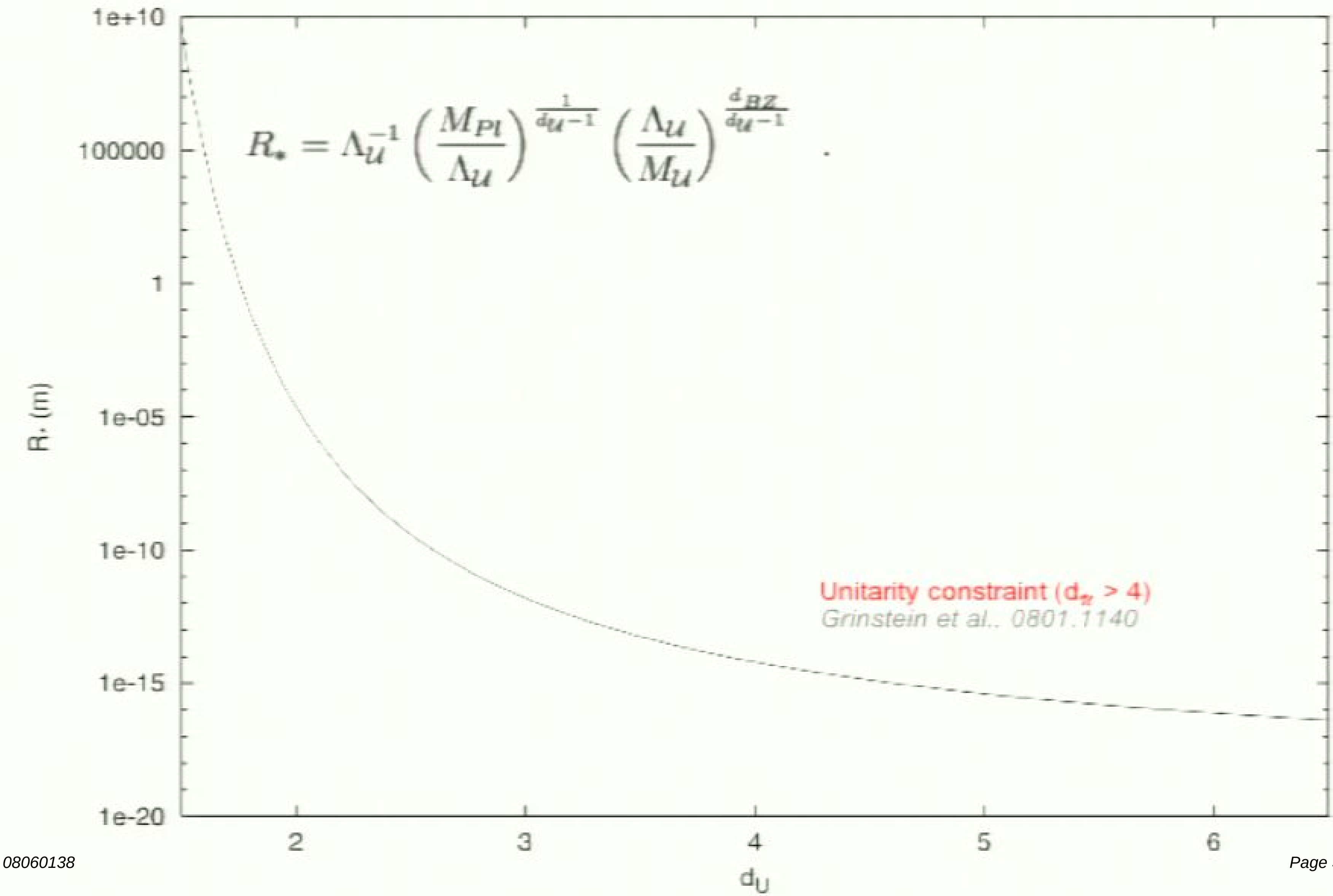
$$\Phi(r) \sim \frac{GM_{BH}\Gamma_{d_{\mathcal{U}}}}{r}\left(\frac{R_*}{r}\right)^{2d_{\mathcal{U}}-2} \ .$$

- Modified horizon (M_{Pl} independent):

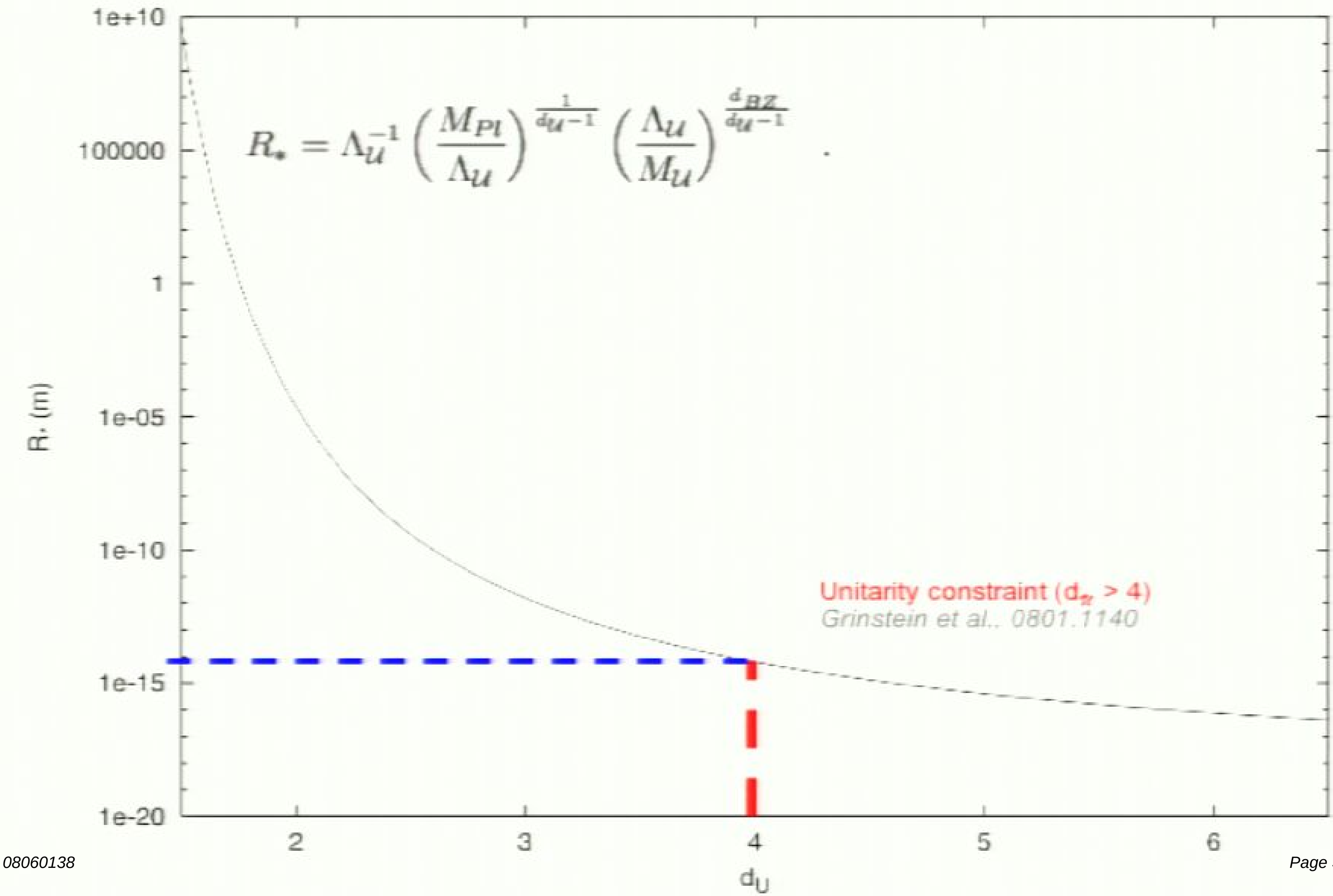
Mureika, PLB **660** (2008) 561-566

$$r_H \approx \left(\frac{2M_{BH}\Gamma_{d_{\mathcal{U}}}}{M_{\mathcal{U}}^2\Lambda_{\mathcal{U}}^{-1}}\right)^{\frac{1}{2d_{\mathcal{U}}-1}} \Lambda_{\mathcal{U}}^{-1}$$

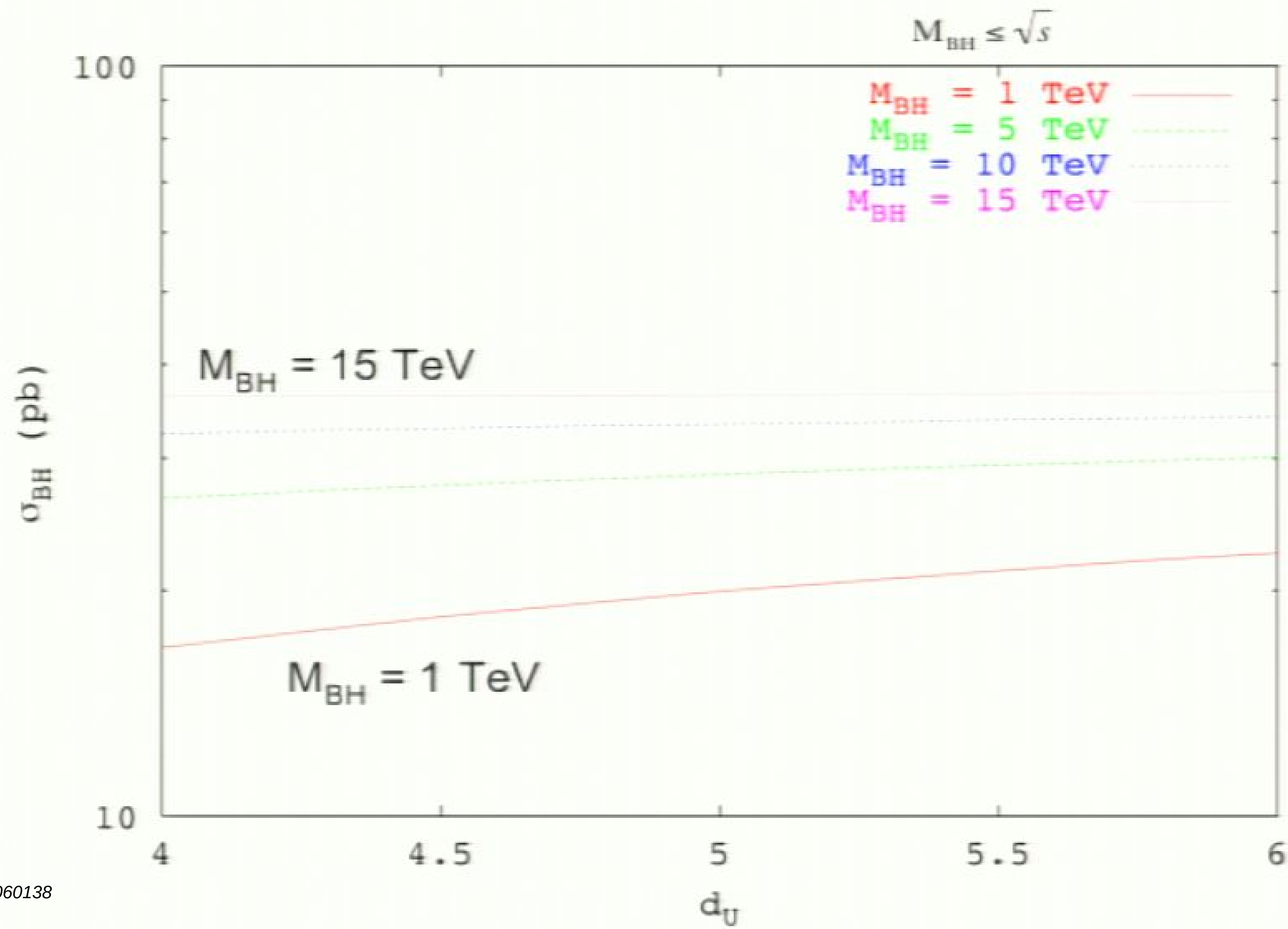
Unparticle interaction scale R* as a function of operator mass dimension $d_{\mathcal{U}}$



Unparticle interaction scale R_* as a function of operator mass dimension $d_{\mathcal{U}}$



Geometric cross-section (pb) for unparticle-enhanced black hole formation, $\Lambda_{\mathcal{U}}$ = 1 TeV



)ifferentiating "virtual" from real extra dims

)ifferentiating "virtual" from real extra dims

- Hawking temperature:

$$T_H = \frac{1}{4\pi r_H} = \frac{\Lambda_{\mathcal{U}}}{4\pi}\left(\frac{2M_{BH}\Gamma_{d_{\mathcal{U}}}}{M_{\mathcal{U}}^2\Lambda_{\mathcal{U}}^{-1}}\right)^{-1/2d_{\mathcal{U}}-1}$$

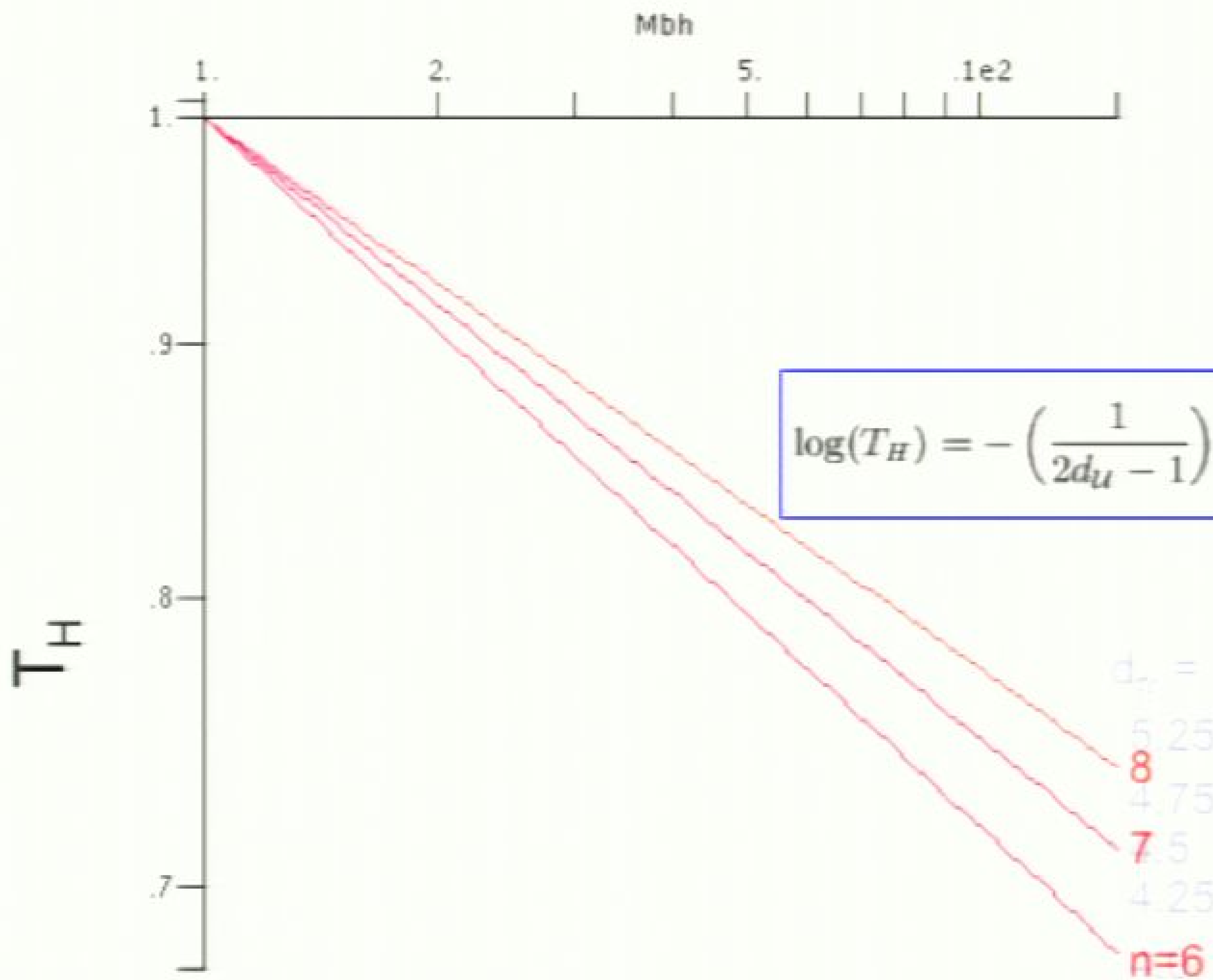
)ifferentiating "virtual" from real extra dims

- Hawking temperature:

$$T_H = \frac{1}{4\pi r_H} = \frac{\Lambda_{\mathcal{U}}}{4\pi}\left(\frac{2M_{BH}\Gamma_{d_{\mathcal{U}}}}{M_{\mathcal{U}}^2\Lambda_{\mathcal{U}}^{-1}}\right)^{-1/2d_{\mathcal{U}}-1}$$

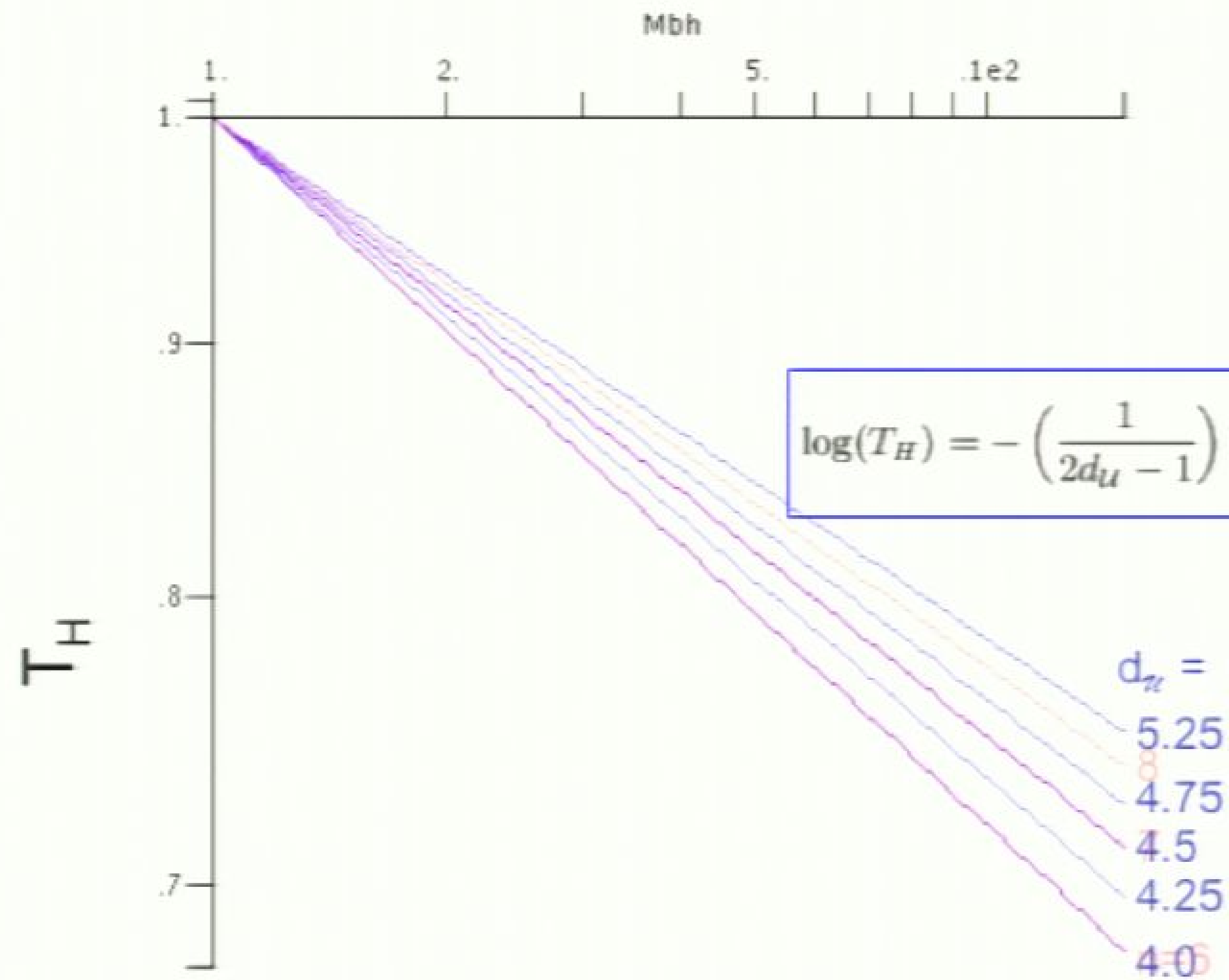
- Unparticle black holes:

$$\log(T_H) = -\left(\frac{1}{2d_{\mathcal{U}}-1}\right)\log M_{BH} + (\text{constant})$$



$$\log(T_H) = -\left(\frac{1}{2d_{\mathcal{U}}-1}\right)\log M_{BH} + (\text{constant})$$

$$\log(T_H) = -\left(\frac{1}{n+1}\right)\log M_{BH} + (\text{constant})$$



$$\log(T_H) = -\left(\frac{1}{2d_{\mathcal{U}} - 1}\right) \log M_{BH} + (\text{constant})$$

$$\log(T_H) = -\left(\frac{1}{n+1}\right) \log M_{BH} + (\text{constant})$$

Differentiating "virtual" from real extra dims

- Hawking temperature:

$$T_H = \frac{1}{4\pi r_H} = \frac{\Lambda_{\mathcal{U}}}{4\pi}\left(\frac{2M_{BH}\Gamma_{d_{\mathcal{U}}}}{M_{\mathcal{U}}^2 \Lambda_{\mathcal{U}}^{-1}}\right)^{-\frac{1}{2d_{\mathcal{U}}-1}}$$

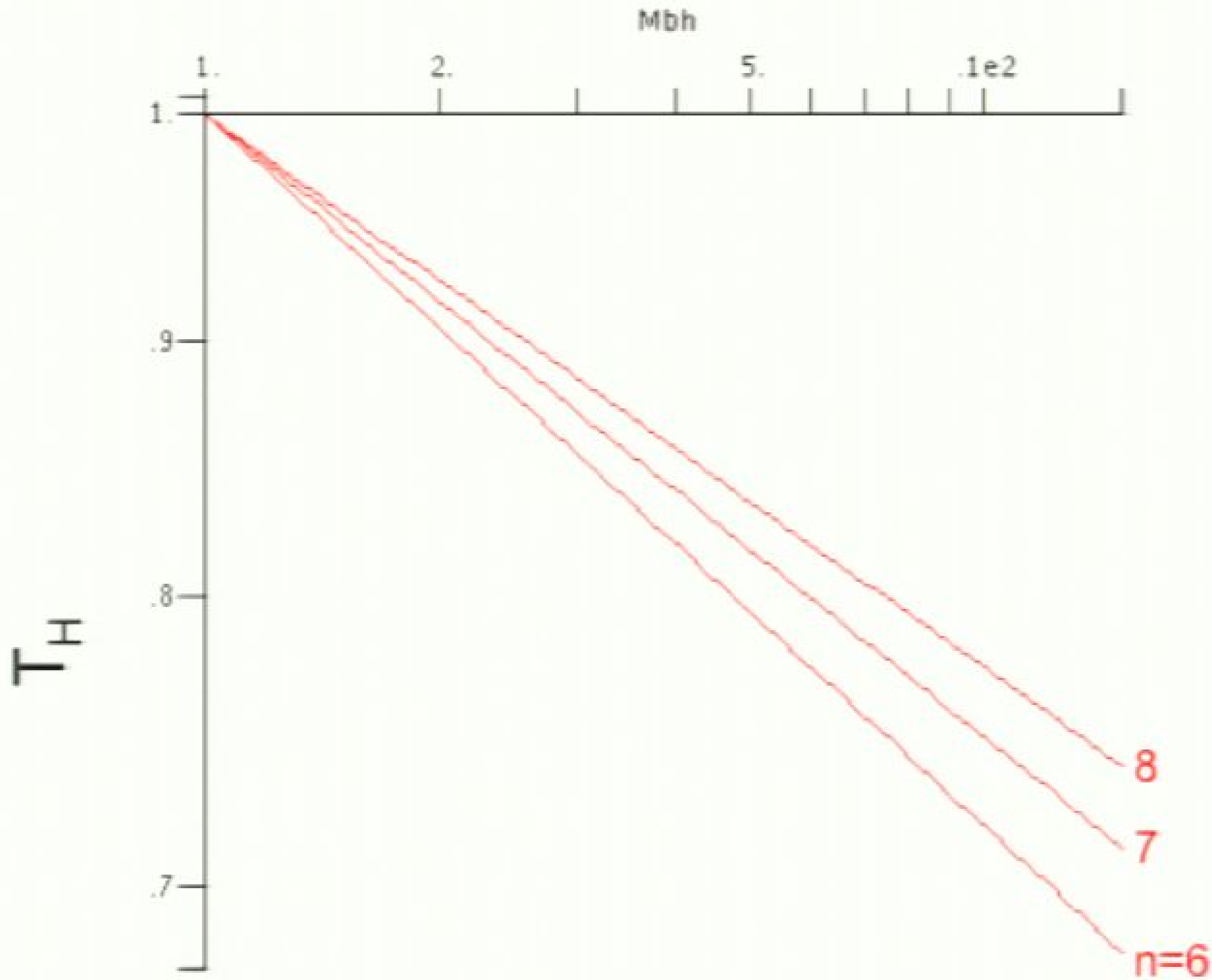
- Unparticle black holes:

$$\log(T_H) = -\boxed{\left(\frac{1}{2d_{\mathcal{U}}-1}\right)}\log M_{BH} + (\text{constant})$$

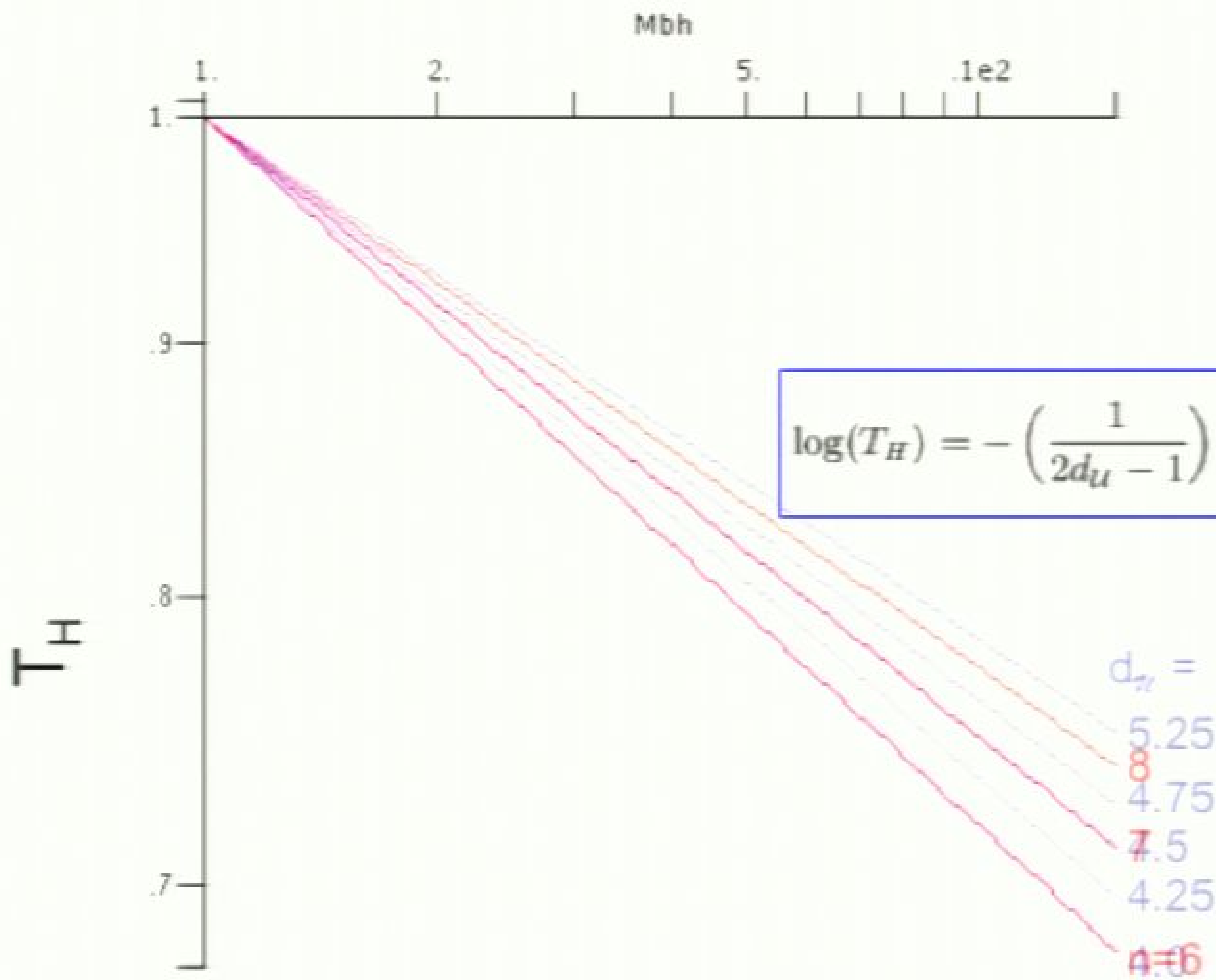
- ED black holes:

$$\log(T_H) = -\boxed{\left(\frac{1}{n+1}\right)}\log M_{BH} + (\text{constant})$$

- $d_{\mathcal{U}} \geq 4 \quad \rightarrow \quad n \geq 6$

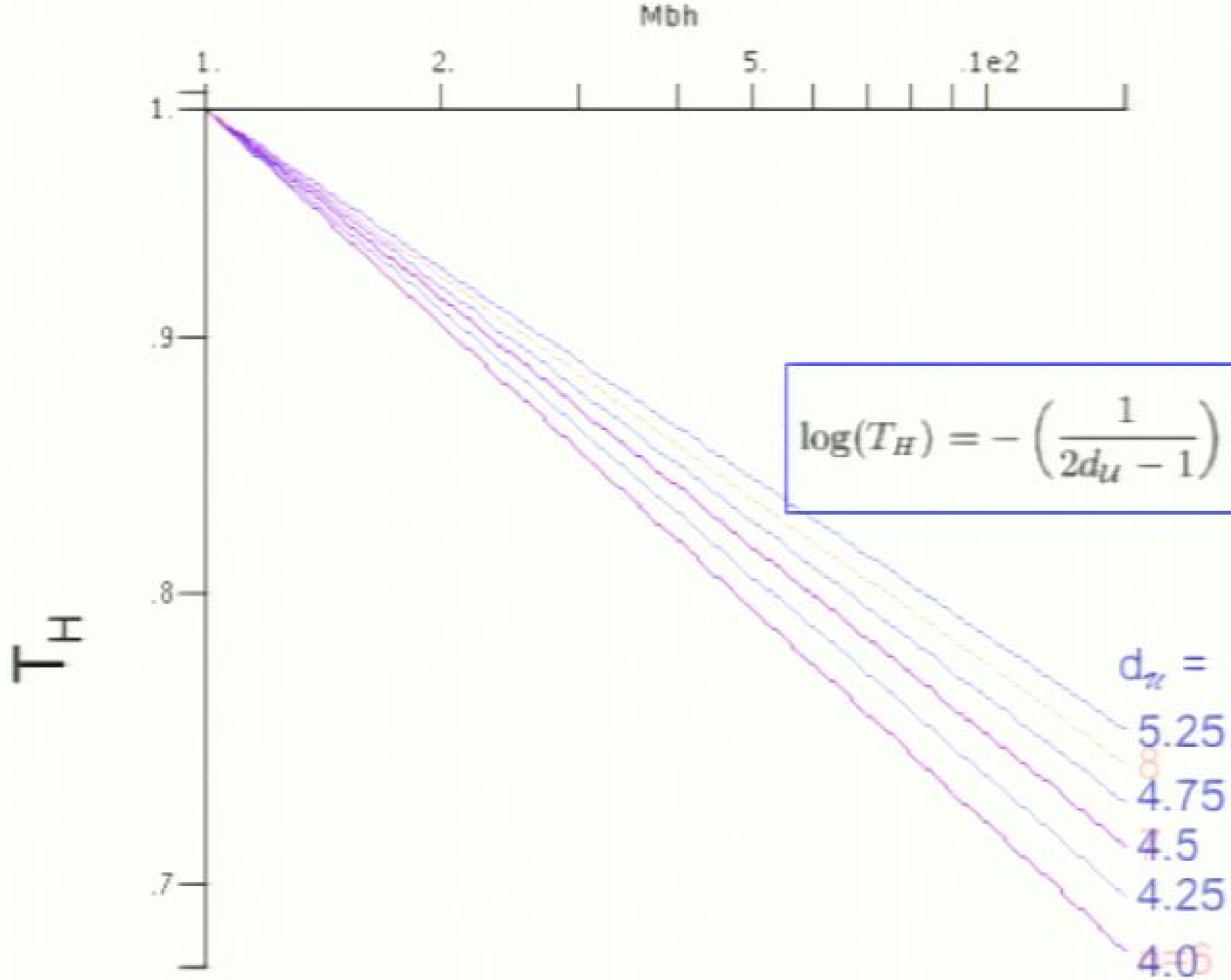


$$\log(T_H) = -\left(\frac{1}{n+1}\right)\log M_{BH} + (\text{constant})$$



$$\log(T_H) = -\left(\frac{1}{2d_{\mathcal{U}} - 1}\right)\log M_{BH} + (\text{constant})$$

$$\log(T_H) = -\left(\frac{1}{n+1}\right)\log M_{BH} + (\text{constant})$$



$$\log(T_H) = -\left(\frac{1}{2d_{\mathcal{U}}-1}\right)\log M_{BH} + (\text{constant})$$

$$\log(T_H) = -\left(\frac{1}{n+1}\right)\log M_{BH} + (\text{constant})$$

Conclusions and future work

Conclusions and future work

- Ungravity provides a source of TeV-scale black holes without need for extra dimensions

Conclusions and future work

- Ungravity provides a source of TeV-scale black holes without need for extra dimensions
- Parton distributions - unique spectrum too?

Conclusions and future work

- Ungravity provides a source of TeV-scale black holes without need for extra dimensions
- Parton distributions - unique spectrum too?
- Properties of "ungravity metric" (cosmological implications?)
  - Vector ungravity: *repulsive* correction (Reissner-Nordström / Kerr type solutions without charge or a.m.)

Conclusions and future work

- Ungravity provides a source of TeV-scale black holes without need for extra dimensions
- Parton distributions - unique spectrum too?
- Properties of "ungravity metric" (cosmological implications?)
  - Vector ungravity: *repulsive* correction (Reissner-Nordström / Kerr type solutions without charge or a.m.)
- CFT/unitarity considerations?

Conclusions and future work

- Ungravity provides a source of TeV-scale black holes without need for extra dimensions
- Parton distributions - unique spectrum too?
- Properties of “ungravity metric” (cosmological implications?)
  - Vector ungravity: *repulsive* correction (Reissner-Nordström / Kerr type solutions without charge or a.m.)
- CFT/unitarity considerations?
- Beyond LHC (>> TeV): interesting stuff?

Thank you!

Email: jmureika@lmu.edu

Mureika, Phys. Lett. B. **660,** 561-566 (2008)
arXiv: 0712.1786