Critical Phenomena in Higher Dimensional Gravity Using Adaptive Mesh Refinement

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Background Critical Phenomena

Initial Data:

$$\psi(R, t=0) = AR^{\delta} \exp\left[-\left(\frac{R-R_0}{B}\right)^2\right]$$

- For $A > A^*$ black holes form
  For $A < A^*$ matter disperses
- Near criticality geometrical quantities scale as[1]:
  $\ln(M) = \gamma \ln(A - A^*) + f(A - A^*)$
  f is periodic
- Both γ and period depend on n
- Echoing:
  $$\psi(Re^{\Delta}, te^{\Delta}) = \psi(R, t)$$

[1] Choptuik, Phys. Rev. Lett. 70, 9 (1993)

Introduction

Gravitational collapse in GR and other theories

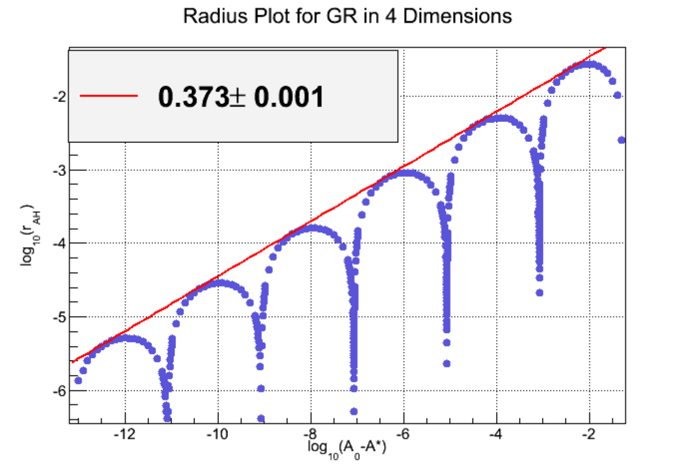
Higher dimensions interesting for several reasons:

- Asymptotic limit of critical exponent
- AdS/CFT correspondence
- Other higher dimensional theories

Problems in higher dimensions

- Stability near $R = 0$
- Horizon radii decrease
- Time to formation increases

Results - 4D



$\gamma = 0.373 \pm 0.001$, $\Delta = 3.45 \pm 0.03$ - Cusps for Δ
Agree with accepted values[2]

[2] Gundlach (1997) PhysRevD.55.695, Hamad & Stewart (1996) Class. Quantum Grav. 13 497

A Much Closer Look at Cusps

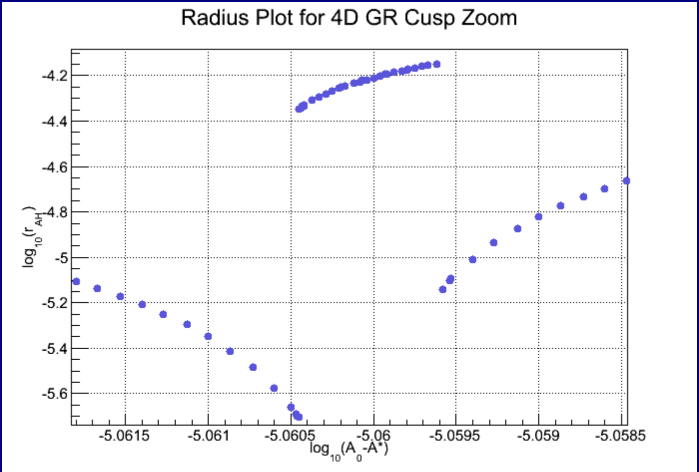
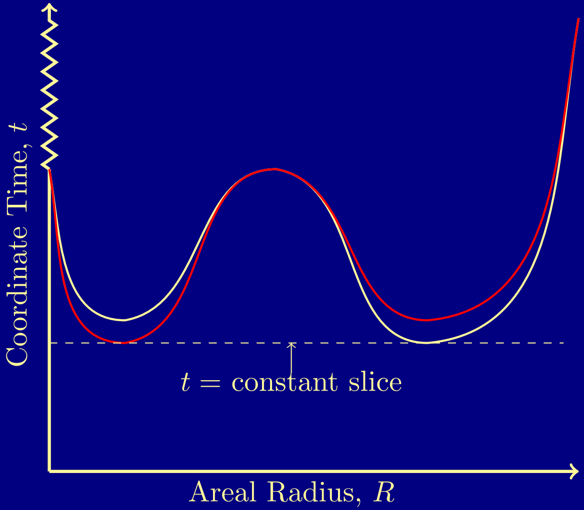
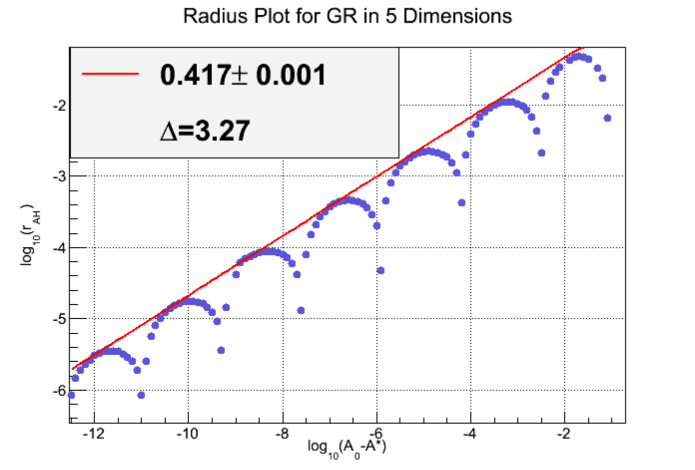


Figure: Zoom in of cusp on a scaling plot in 4 dimensions. Similar behaviour in higher dimensions.

Nature of Cusps

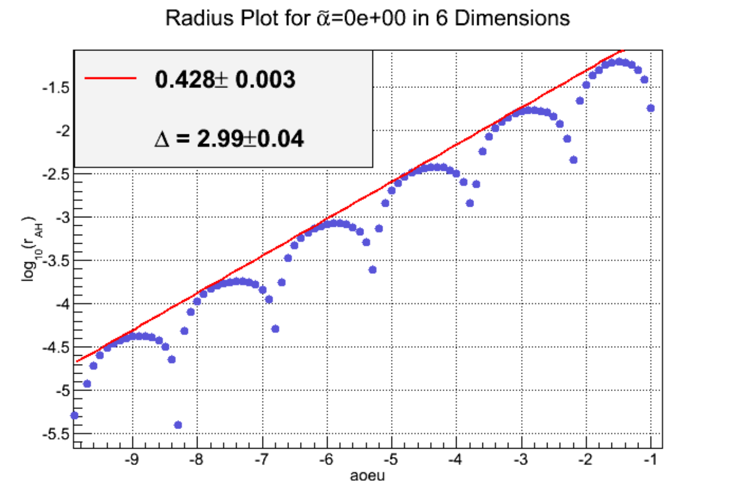


Use generalized flat-slice (PG) coordinates



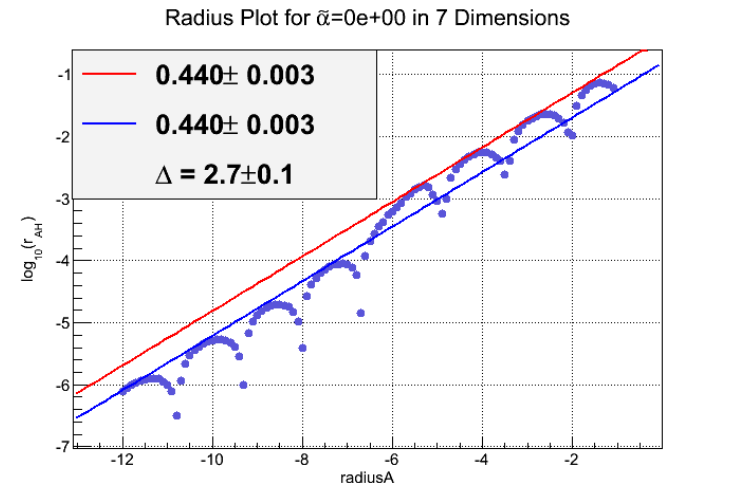
0.408 ± 0.008	Sorkin & Oren, Phys. Rev. D 71, 124005 (2005)
0.412 ± 0.004	Bland et al., Classical Quantum Gravity 22, 5355 (2005)
0.413 ± 0.002	Taves & Kunstatter(2011). PhysRevD.84.044034
0.416 ± 0.002	Taves & Kunstatter(2011). PhysRevD.84.044034

Results - 6D



0.422 ± 0.008	Sorkin & Oren, Phys. Rev. D 71, 124005 (2005)
0.430 ± 0.003	Bland et al., Classical Quantum Gravity 22, 5355 (2005)
0.424	Garfinkle, Cutler, & Duncan, Phys. Rev. D 60, 104007 (1999)
0.429 ± 0.003	Taves & Kunstatter(2011). PhysRevD.84.044034
0.428 ± 0.002	Taves & Kunstatter(2011). PhysRevD.84.044034

Preliminary Results - 7D



0.429 ± 0.008	Sorkin & Oren, Phys. Rev. D 71, 124005 (2005)
0.441 ± 0.007	Bland et al., Classical Quantum Gravity 22, 5355 (2005)
0.440 ± 0.005	Taves & Kunstatter(2011). PhysRevD.84.044034
0.440 ± 0.006	Taves & Kunstatter(2011). PhysRevD.84.044034

Numerical Techniques

- Adaptive mesh refinement
- 6th order in space and time - E_{ADM}
- Dissipation applied as filter (near $R = 0$)
- l'Hôpital's trick for stability:

$$f/R = f_{,R} - R(f/R)_{,R}$$

- Variable time step size
- Echoing period decreases in higher n...
  Smaller time steps: $\rho_t > \rho_s$ sufficient?
  Decrease time step early? Horizon function?

Summary

Investigating critical phenomena in higher D poses challenges:

- Stable equations - l'Hôpital's Trick & variable time stepping
- Sufficient resolution - Adaptive Mesh Refinement
- High order for energy conservation

Acknowledgments

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