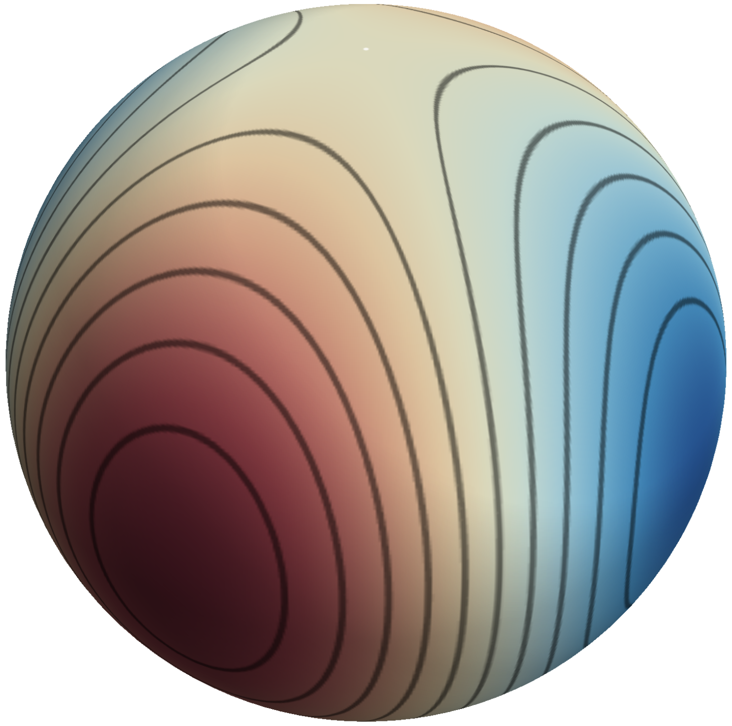
A Global Tour of AdS_4

Benson Way (DAMTP)



Oscar Dias, Jorge Santos, B.W. arXiv:1505.04793

Evading Uniqueness

'No hair' theorem: Kerr is the unique 4-dimensional, asymptotically flat black hole.

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How can we make gravity more interesting?

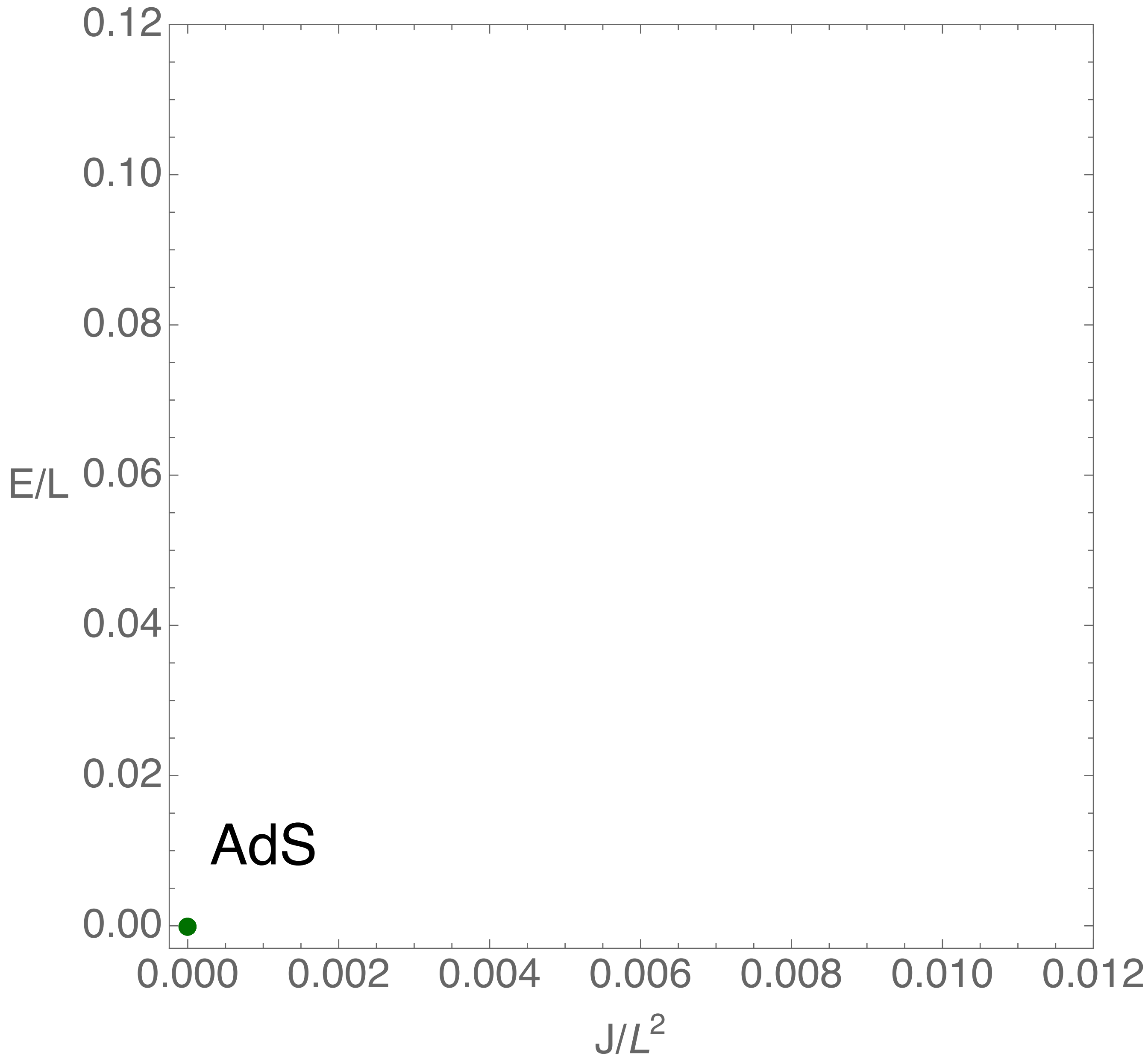
- Go to higher dimensions.
- Consider different asymptotics like global AdS.

The Plan

$$R_{ab} = -\frac{3}{L^2} g_{ab}$$

- Global AdS_4 asymptotics and reflecting boundary conditions.
- Find 'stationary' solutions.
- Compute their phase diagram S(E,J).

AdS_4



0.12
0.10
0.08
E/L
0.06
0.04
0.02
0.00
AdS
0.000
0.002
0.004
0.006
0.008
0.010
0.012
J/L²

Geons

AdS is not the unique horizonless solution!

O.Dias, G. Horowitz, J. Santos arXiv:1109.1825

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- Perturb of AdS and find normal modes labeled by mode numbers (s, ℓ, m, p):

$$\omega_{s,\ell,p} L = s + \ell + 2p$$

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- Perturb of AdS and find normal modes labeled by mode numbers (s, ℓ, m, p):

$$\omega_{s,\ell,p} L = s + \ell + 2p$$

- Continue to higher orders. Generic perturbations lead to resonances (breakdown of perturbation theory).

- For some single-mode data, perturbation theory survives! (Perturbative construction of new solution.)

O.Dias, G. Horowitz, J. Santos arXiv:1109.1825

Geons

Focus on $s = 1,\ \ell = m,\ p = 0$ modes that give geons.

- Geons can be thought of as nonlinear normal modes of AdS, which for small E and J satisfy

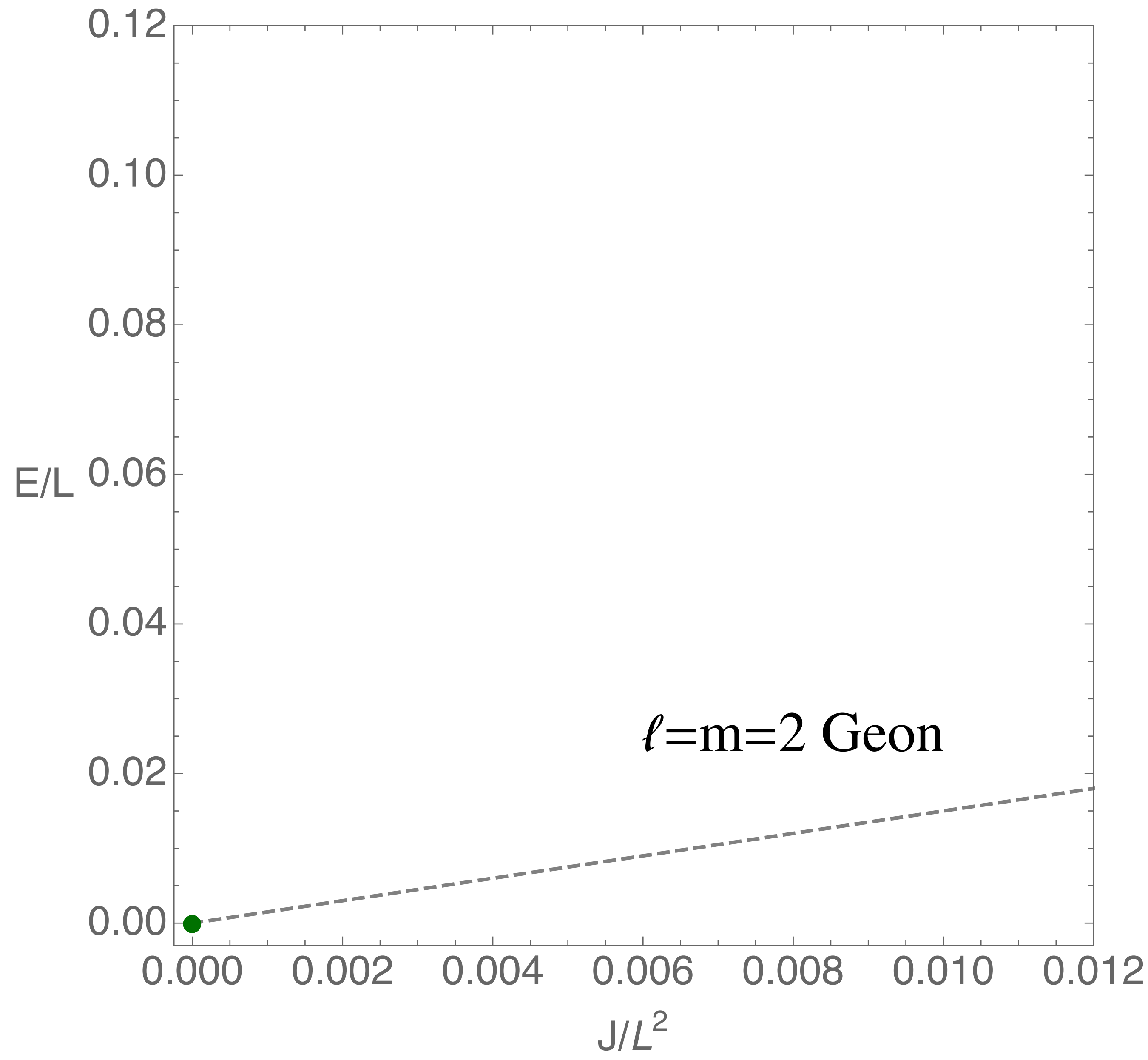
$$EL \approx \frac{\omega}{m} J.$$

- They have a single Killing field given by

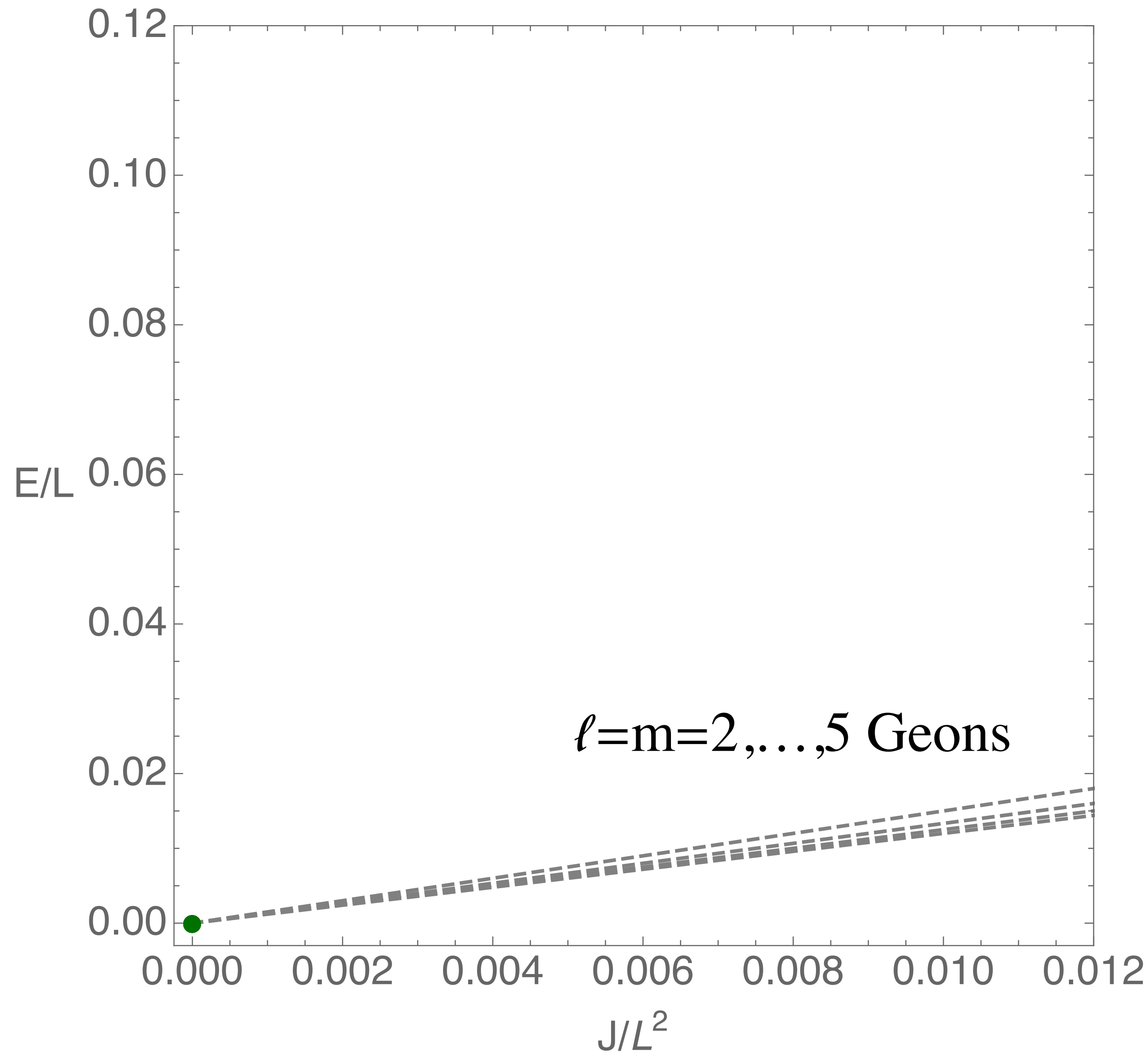
$$K = \partial_t + \Omega \partial_\phi$$

O.Dias, G. Horowitz, J. Santos arXiv:1109.1825

Geon Phase Diagram



Geon Phase Diagram



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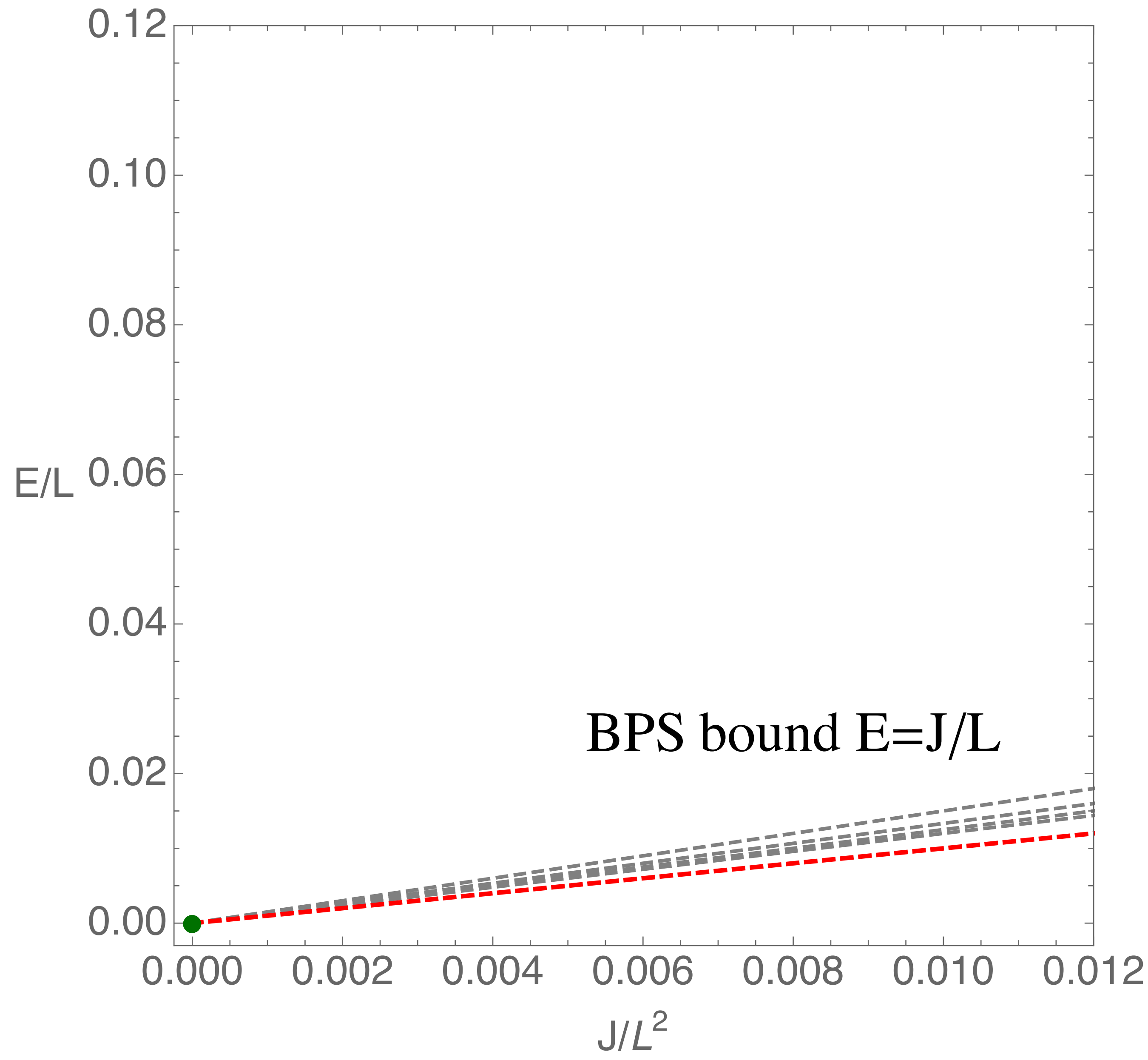

Kerr-AdS$_4$

- 2-parameter family of rotating black holes, bounded by extremality.

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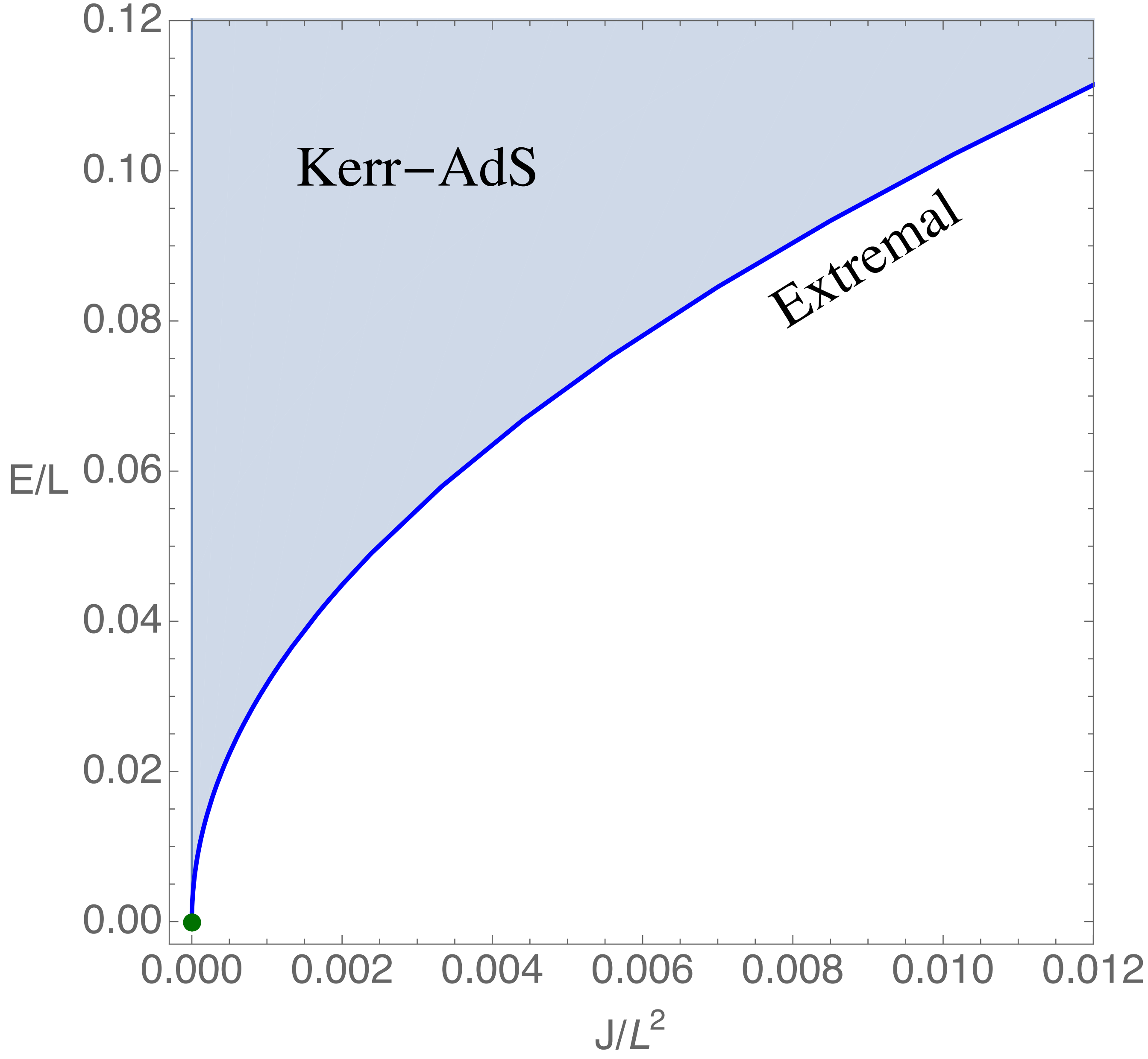
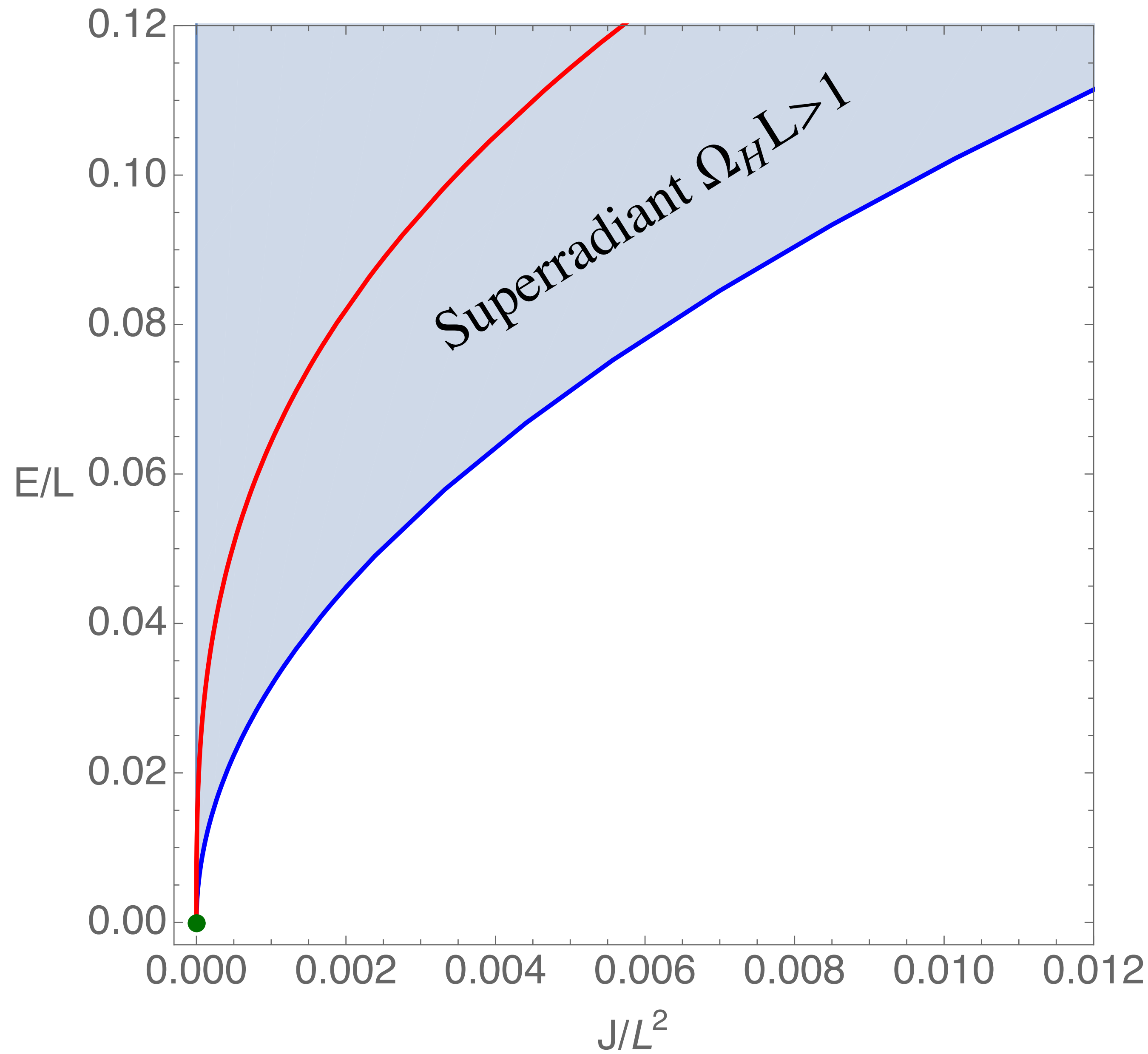
- 2-parameter family of rotating black holes, bounded by extremality.
- Some unstable to superradiance: waves extract energy from ergoregions, but reflect back from the boundary.
- Eventually, energy in wave is large enough to backreact on the geometry, causing an instability.

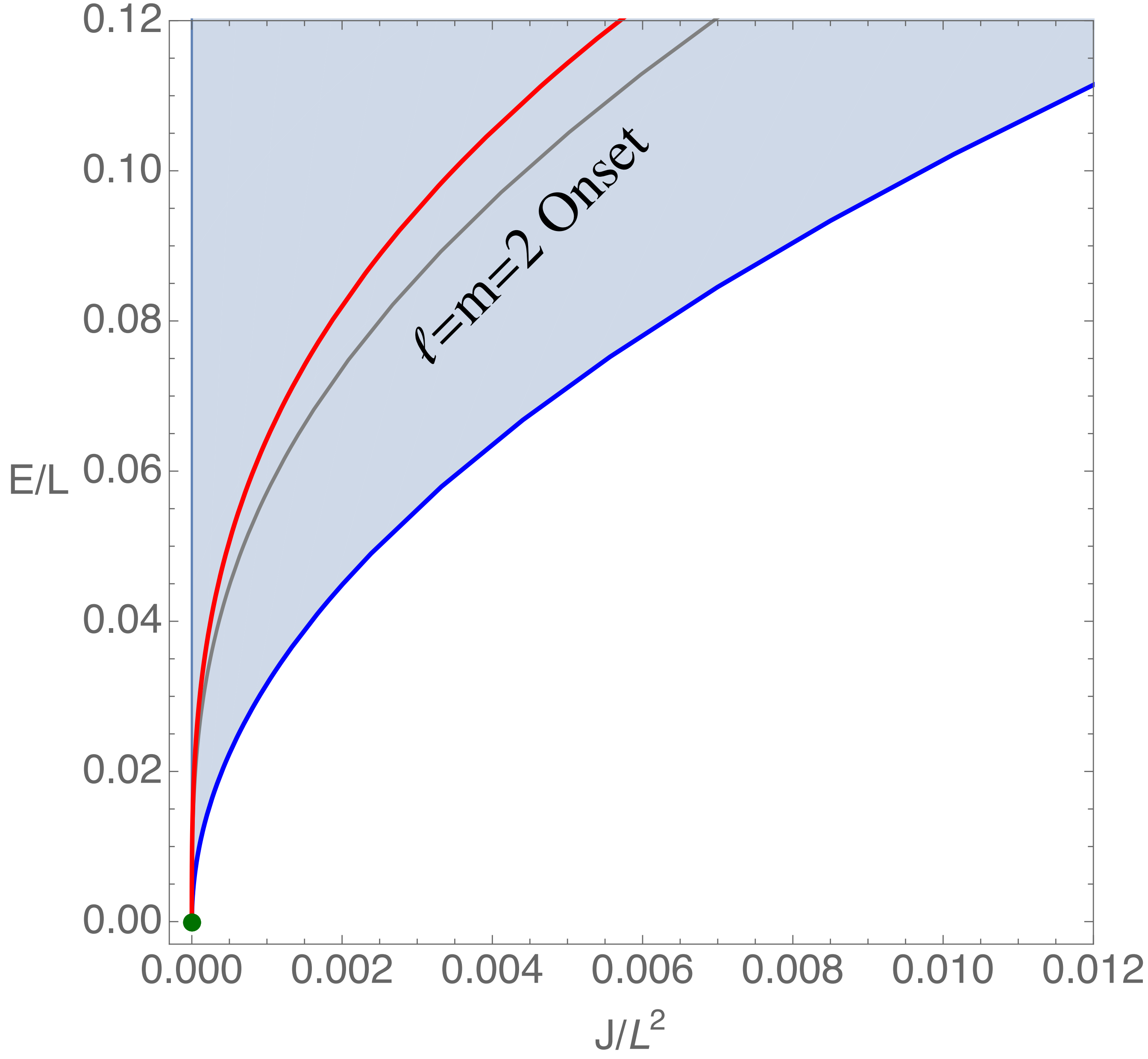
Kerr-AdS Phase Diagram



Kerr-AdS Phase Diagram



Kerr-AdS Phase Diagram



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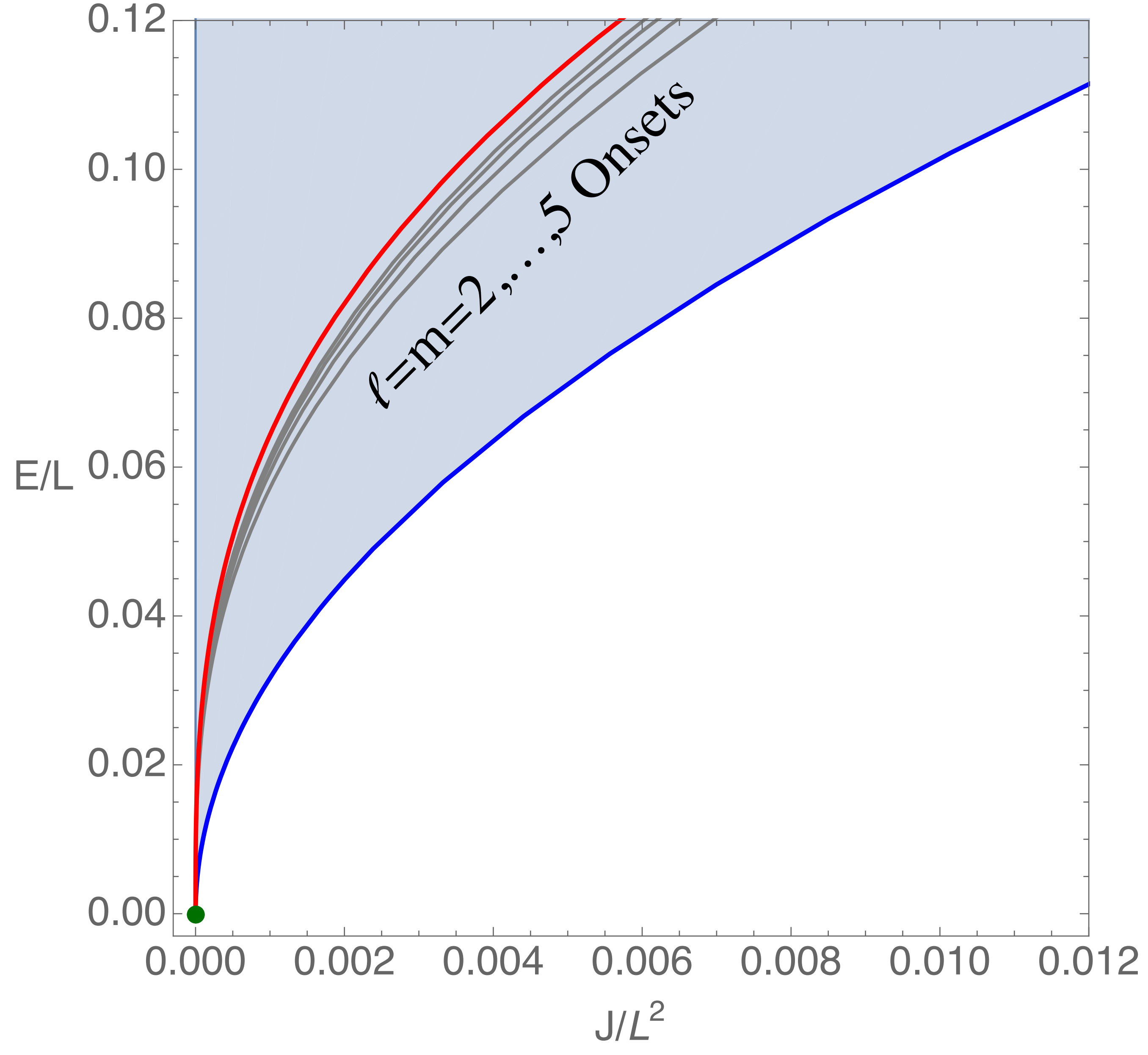
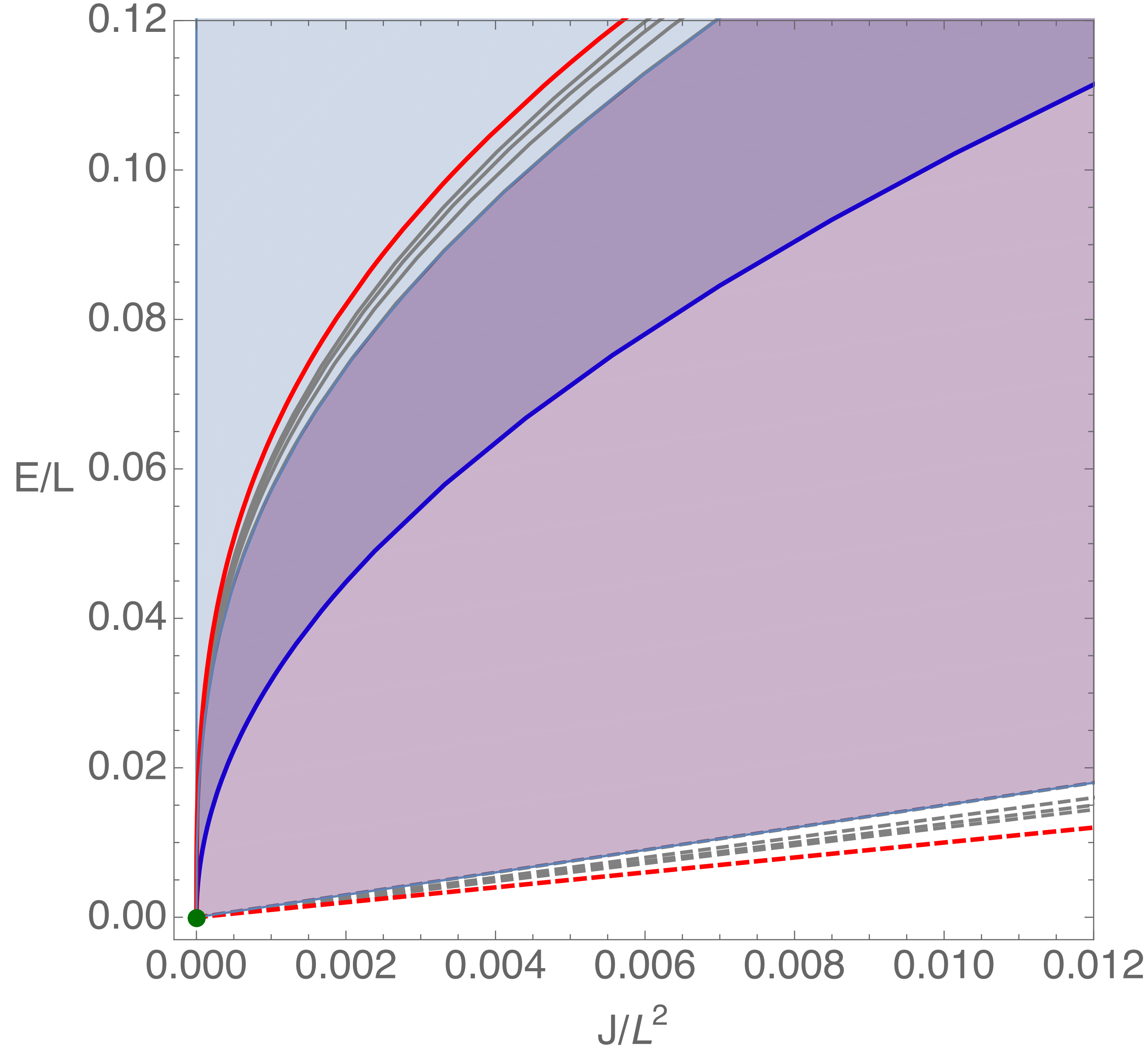


Evidence for New Black Holes

- Onsets for superradiance leads to new solutions.
- Can place a small black hole in a geon if it rotates with the same frequency as the geon.
- These black holes will only have a single Killing field.
- This Killing field must also be the horizon generator to be consistent with the Hawking rigidity theorem.

Black Resonators



$$\ell = m = 2$$

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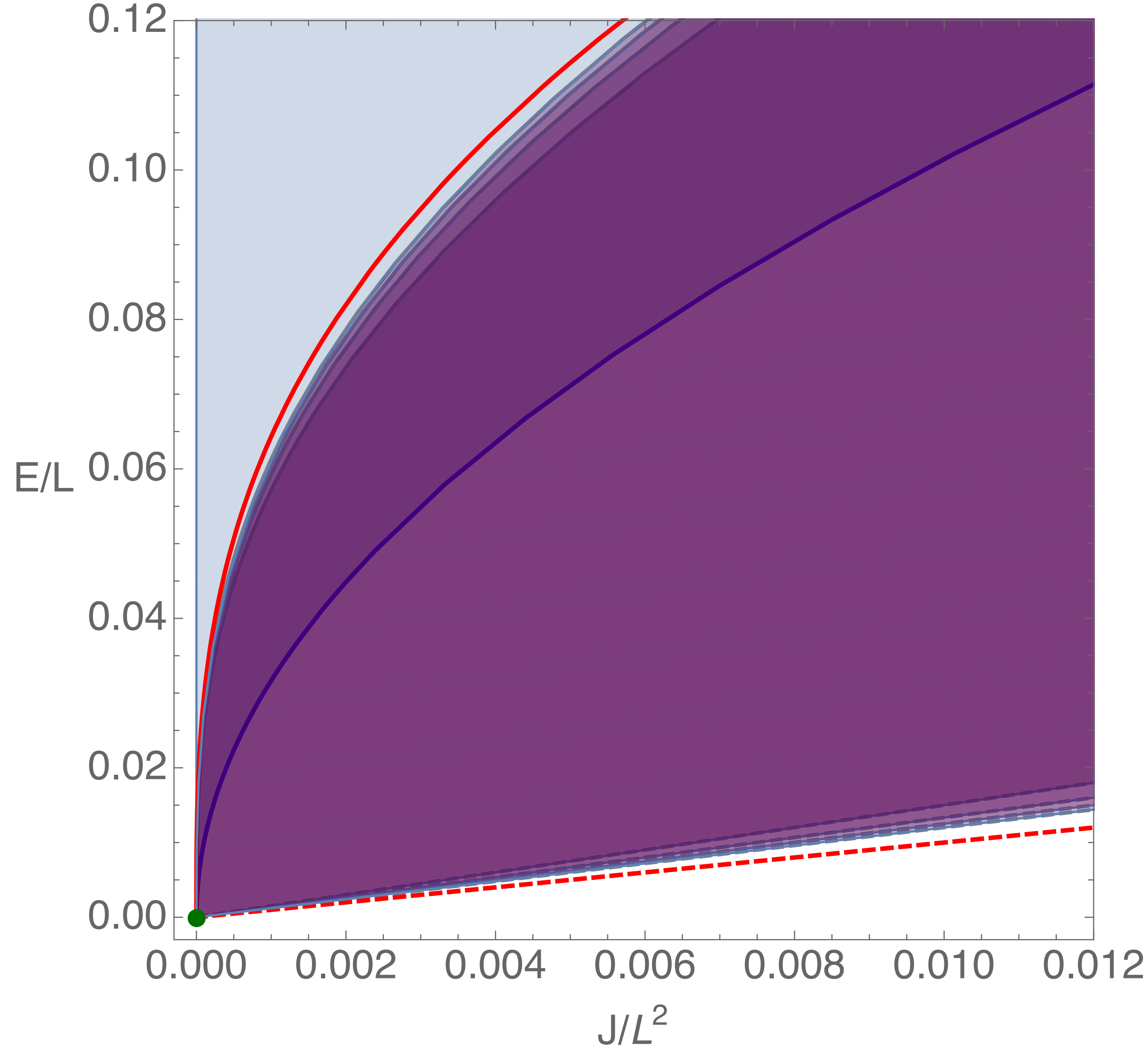
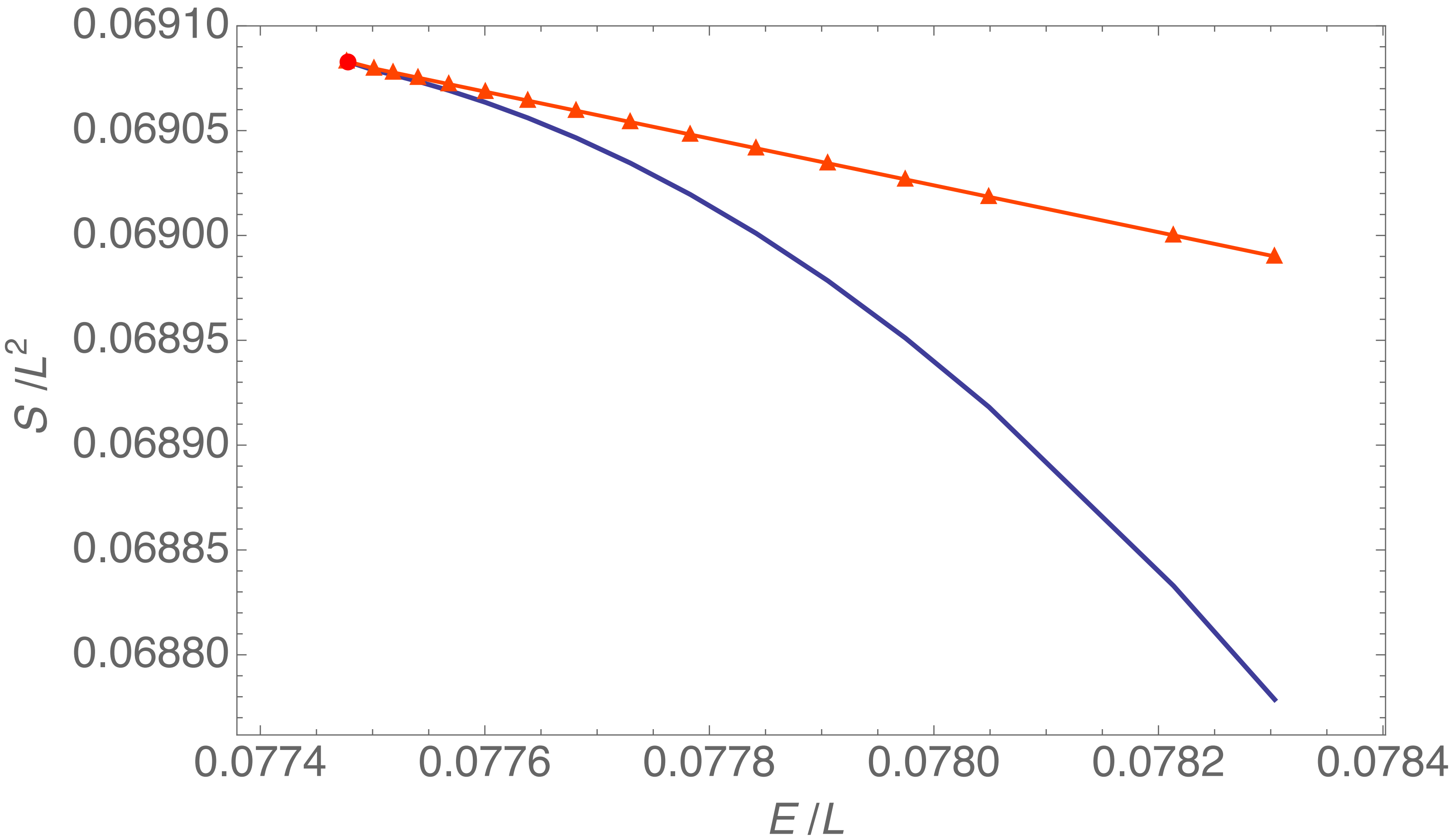


$$\ell = m = 2, \ldots, 5$$

Entropy



$$y_+ = 0.16$$

Entropy

- Resonators have more entropy than Kerr-AdS.
- Perturbative results fit closely with numerical results. For small black resonators with $\ell = m$,

$$S \approx 4\pi E^2 \left[1 - \left(1 + \frac{1}{m}\right) \frac{J}{EL}\right]^2$$

- Entropy increases with increasing m, but remains bounded.

V. Cardoso, O. Dias, G. Hartnett, L. Lehner, J. Santos arXiv:1312.5323

Instability

- Superradiant Kerr black holes can evolve towards black resonators. Black resonators with low m can evolve towards black resonators with high m.

- Yet, all black resonators are likely unstable. There is no Killing field that is everywhere timelike on the boundary. (S. Green, S. Hollands, A. Ishibashi, R. Wald arXiv:1512.02644)

- What is the endpoint of this instability?

Summary

- We've numerically constructed new black holes with a single Killing field.
- They connected the onset of superradiance to geons.
- They dominate over Kerr-AdS in the microcanonical ensemble.
- They are still unstable to superradiance.

Thank you