From Stars to Regular Black Holes

Aitor Vicente-Cano

Based on 2505.09680 & 2512.19796

with Pablo Bueno, Pablo A. Cano, Robie A. Hennigar and Ángel J. Murcia

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Regular Black Holes from Pure Gravity

[Bueno, Cano, Hennigar ’24]

$$S = \int \left(\mathcal{L}_{\rm GR} + \sum_{n=2}^{\infty} \alpha_n \mathcal{L}_{(n)} \right)$$

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$$\mathrm{d}s^2 = -N(r)^2 f(r) \mathrm{d}t^2 + \frac{\mathrm{d}r^2}{f(r)} + r^2 \mathrm{d}\Omega^2$$

A Regular Black Hole: Hayward

[Hayward ’05]

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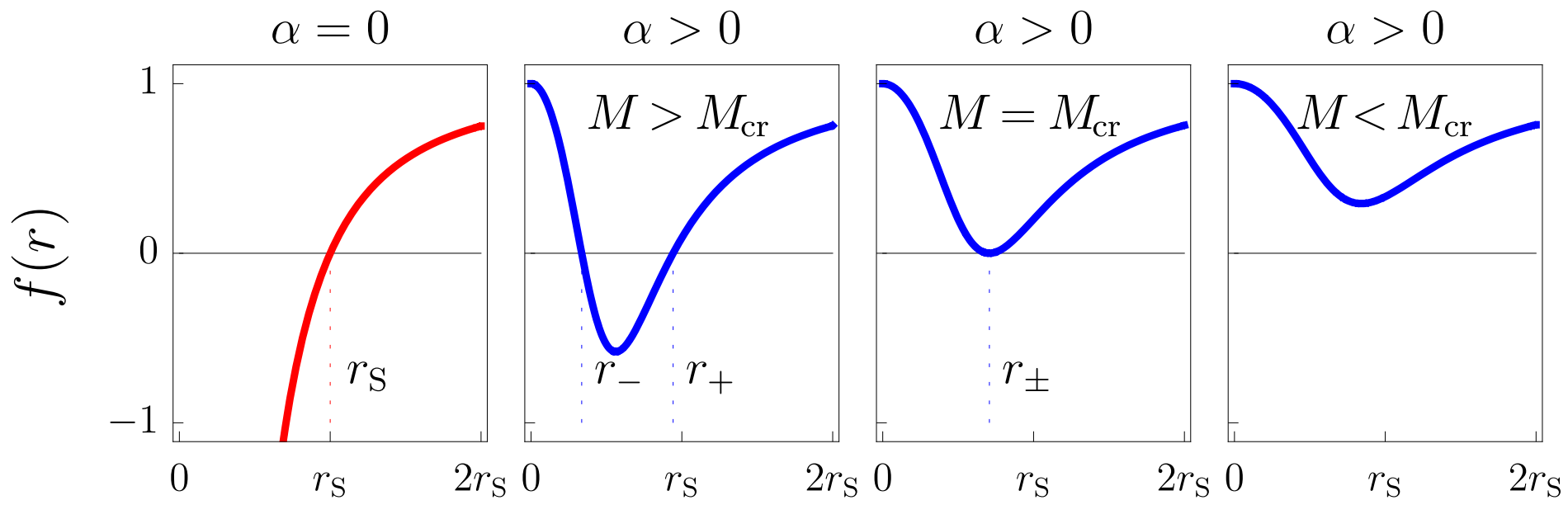


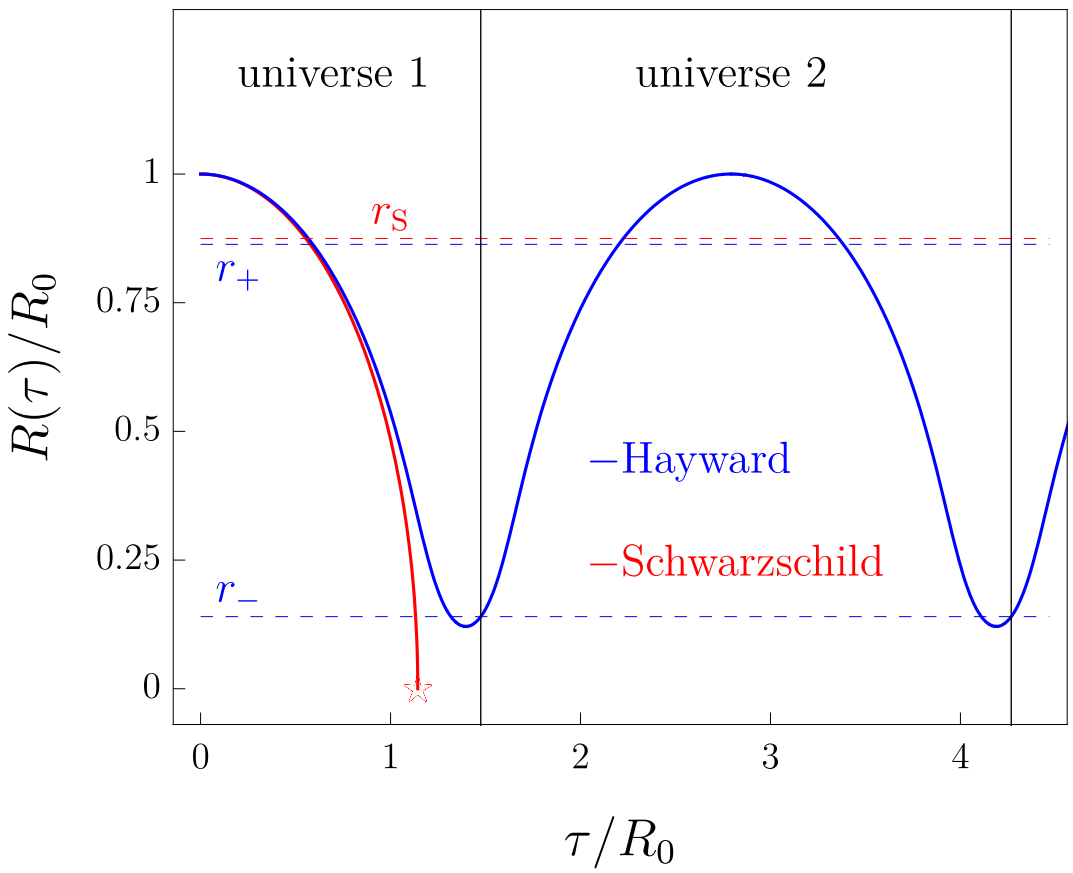
Spherical Symmetric Configurations of Matter

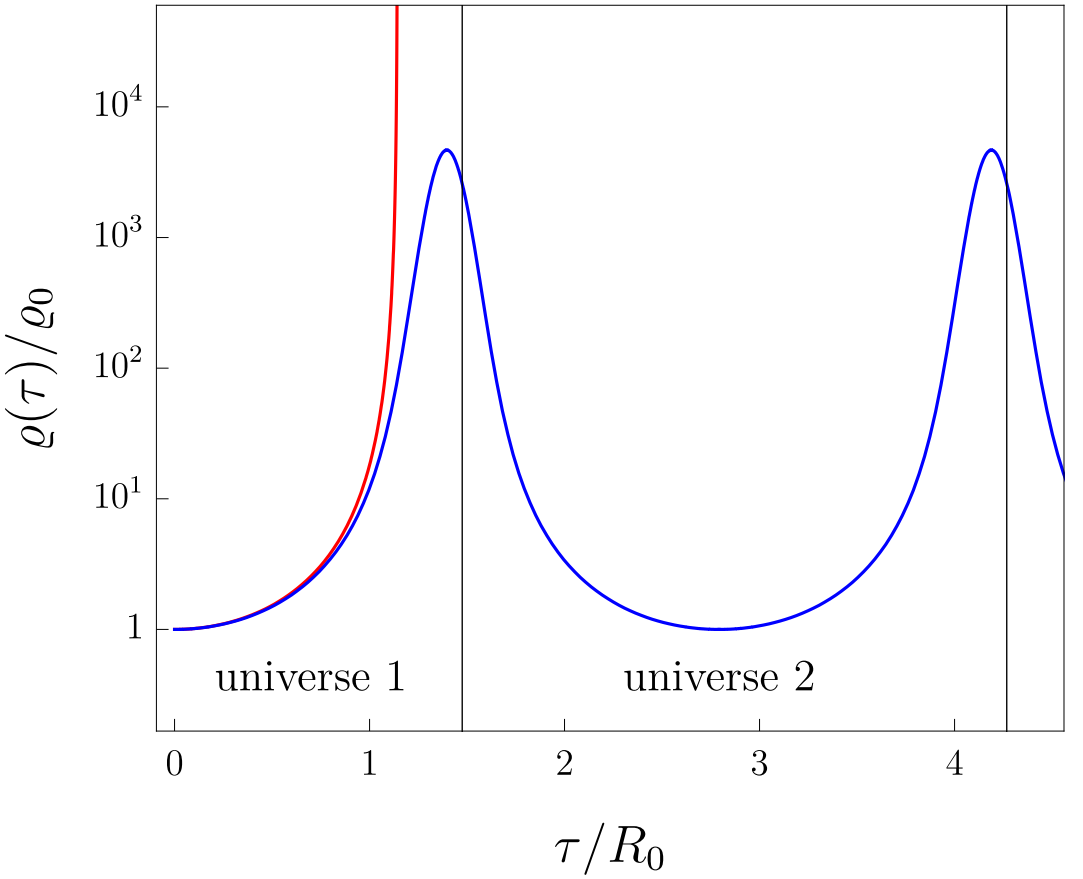
Oppenheimer-Snyder Dust Collapse

[Bueno, Cano, Hennigar, Murcia, AVC '25]

- Equation for the star's radius R

$$\dot{R}^2(\tau) + f(R(\tau)) = f(R_0)$$

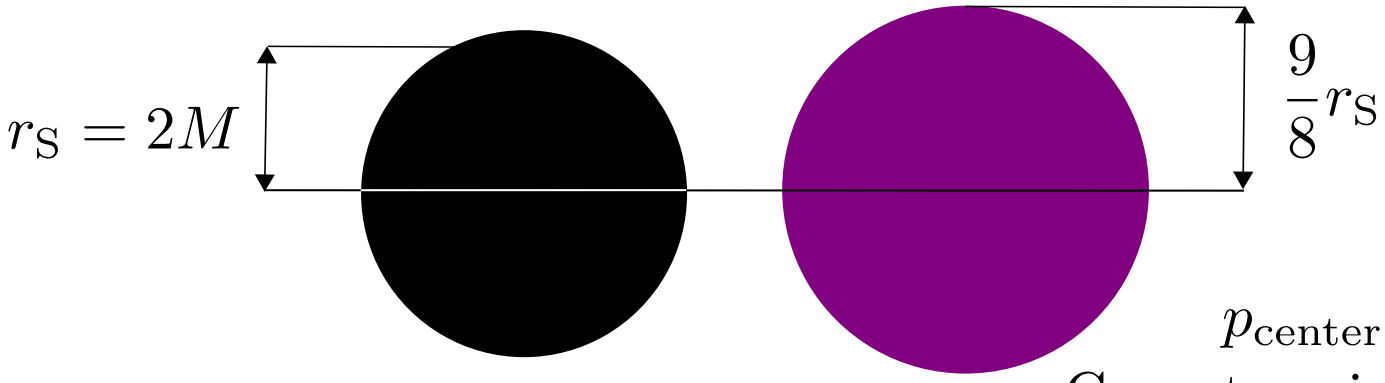

universe 1
universe 2
r_S
r_+
r_-
Hayward
Schwarzschild
$R(\tau)/R_0$
τ/R_0
1
0.75
0.5
0.25
0
0
1
2
3
4


universe 1
universe 2
$\varrho(\tau)/\varrho_0$
τ/R_0
10^4
10^3
10^2
10^1
1
0
1
2
3
4

Static Stars: Buchdahl Limit

[Buchdahl '59]

- Upper bound on a star's compactness



$p_{\text{center}} \to \infty$

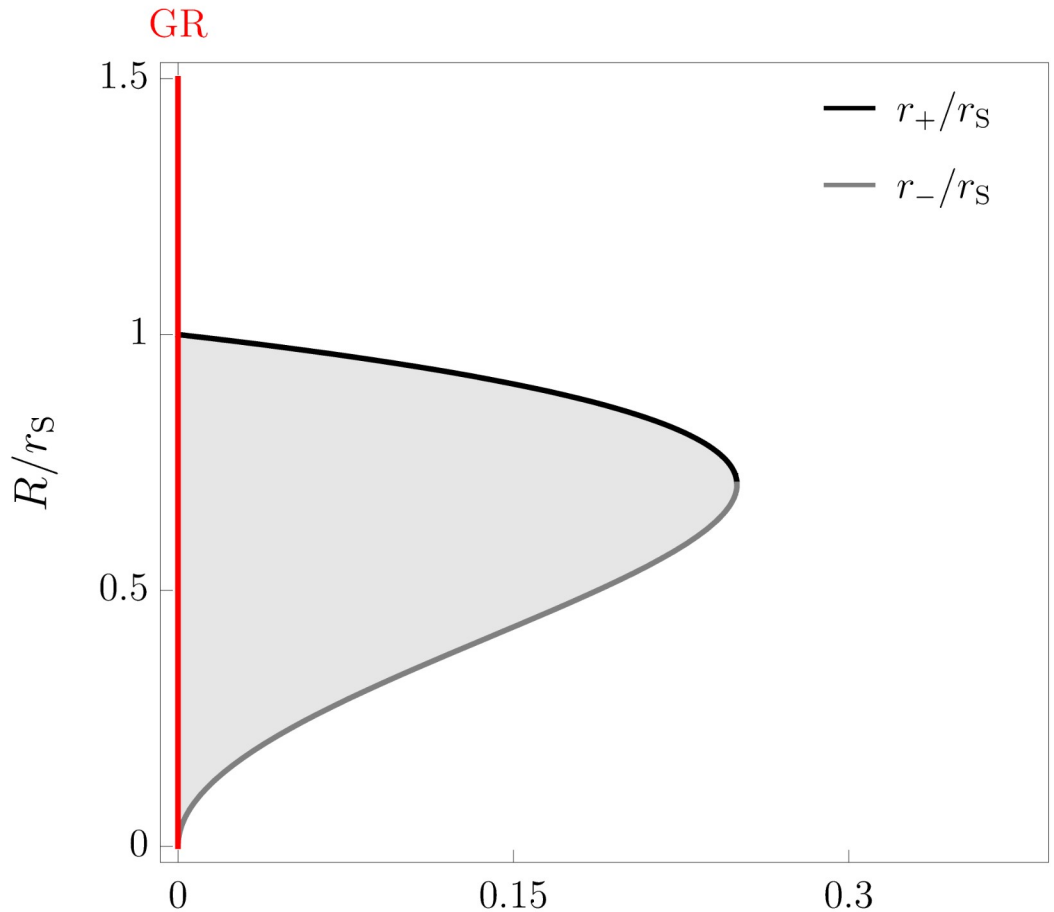
Curvature invariant $\to \infty$

$$\frac{R}{r_S} \geq \frac{9}{8}$$

[Bueno, Hennigar, Murcia, AVC ’25]

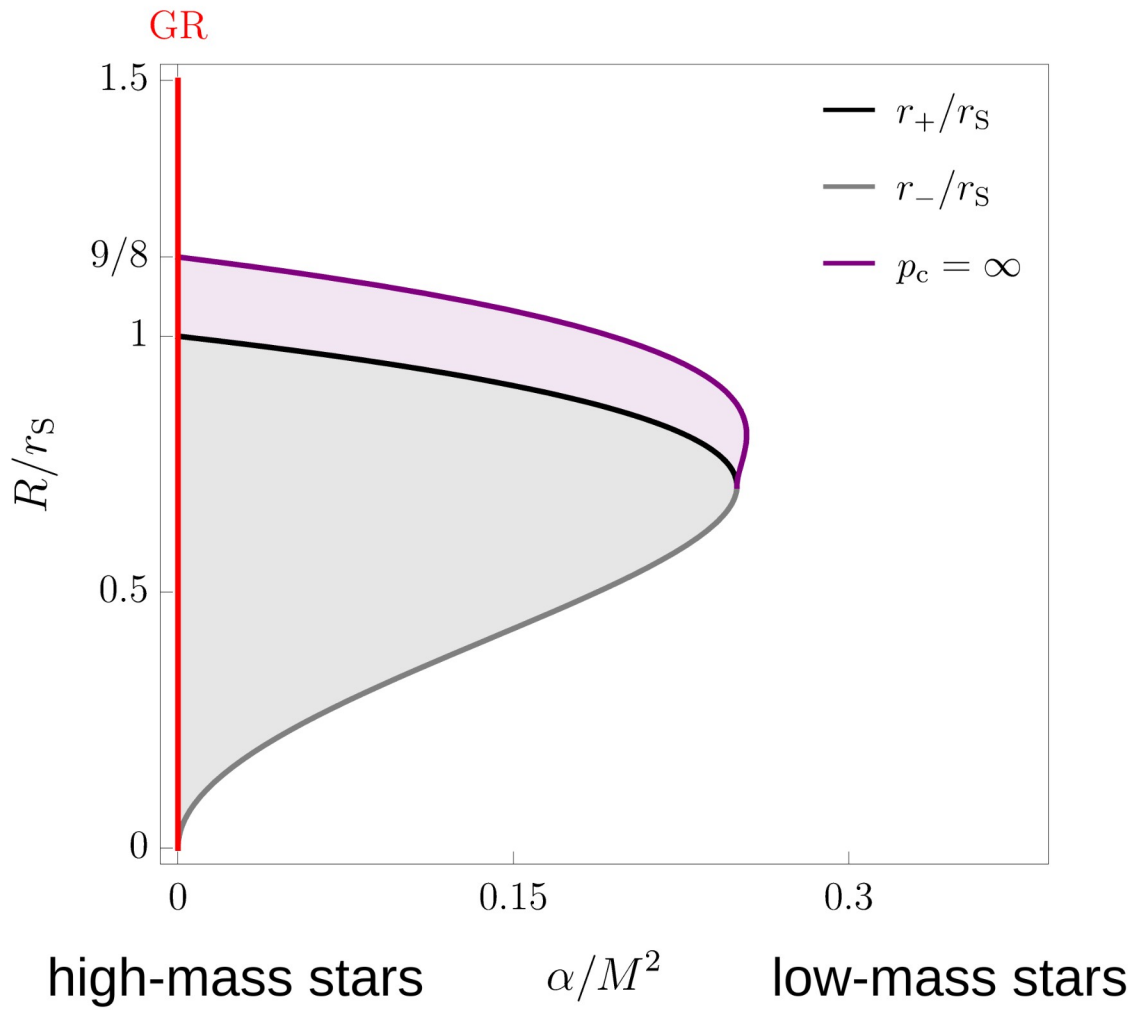
Buchdahl Limit for “Hayward” Stars with Constant-Density

✢ Gray: Black Hole interior

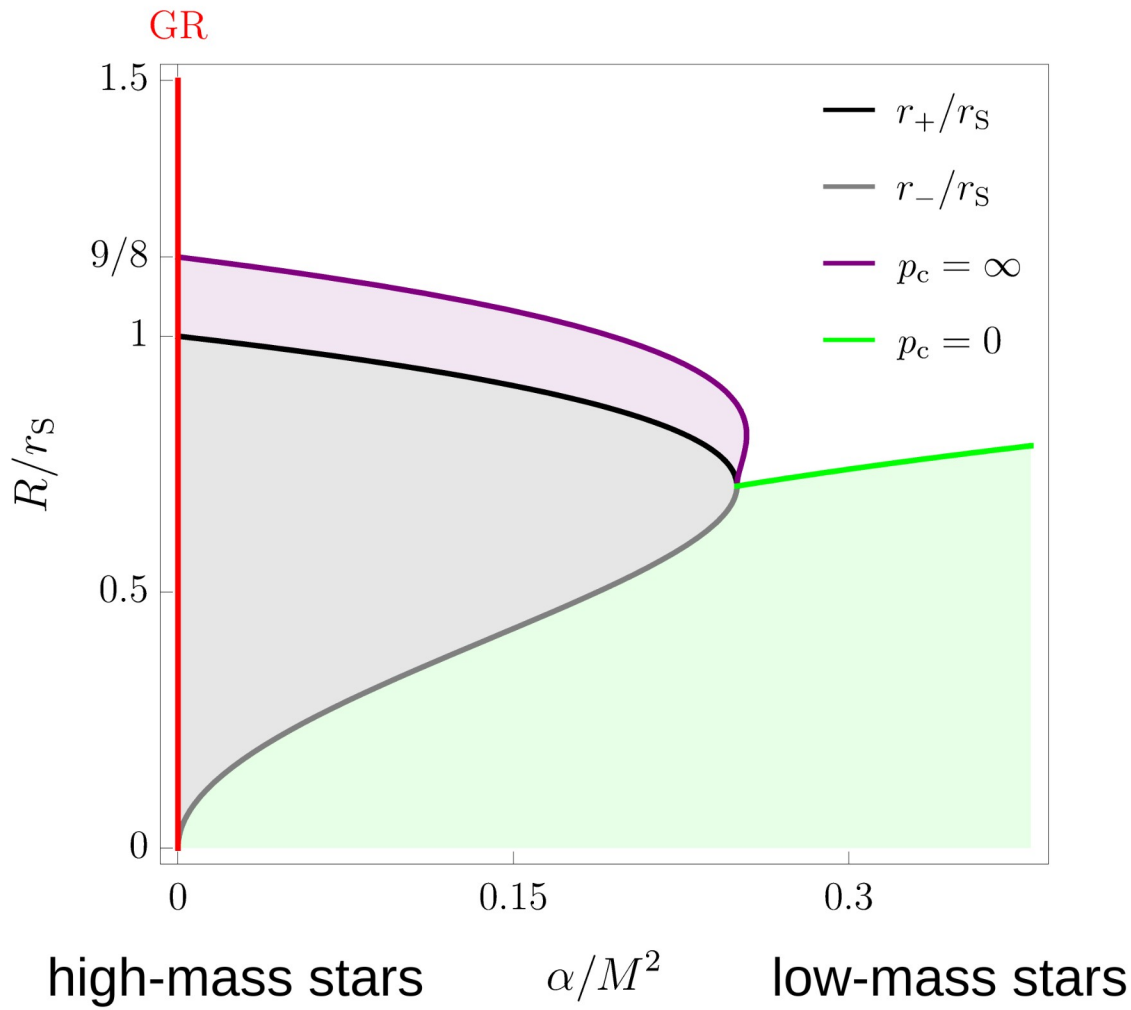


high-mass stars low-mass stars

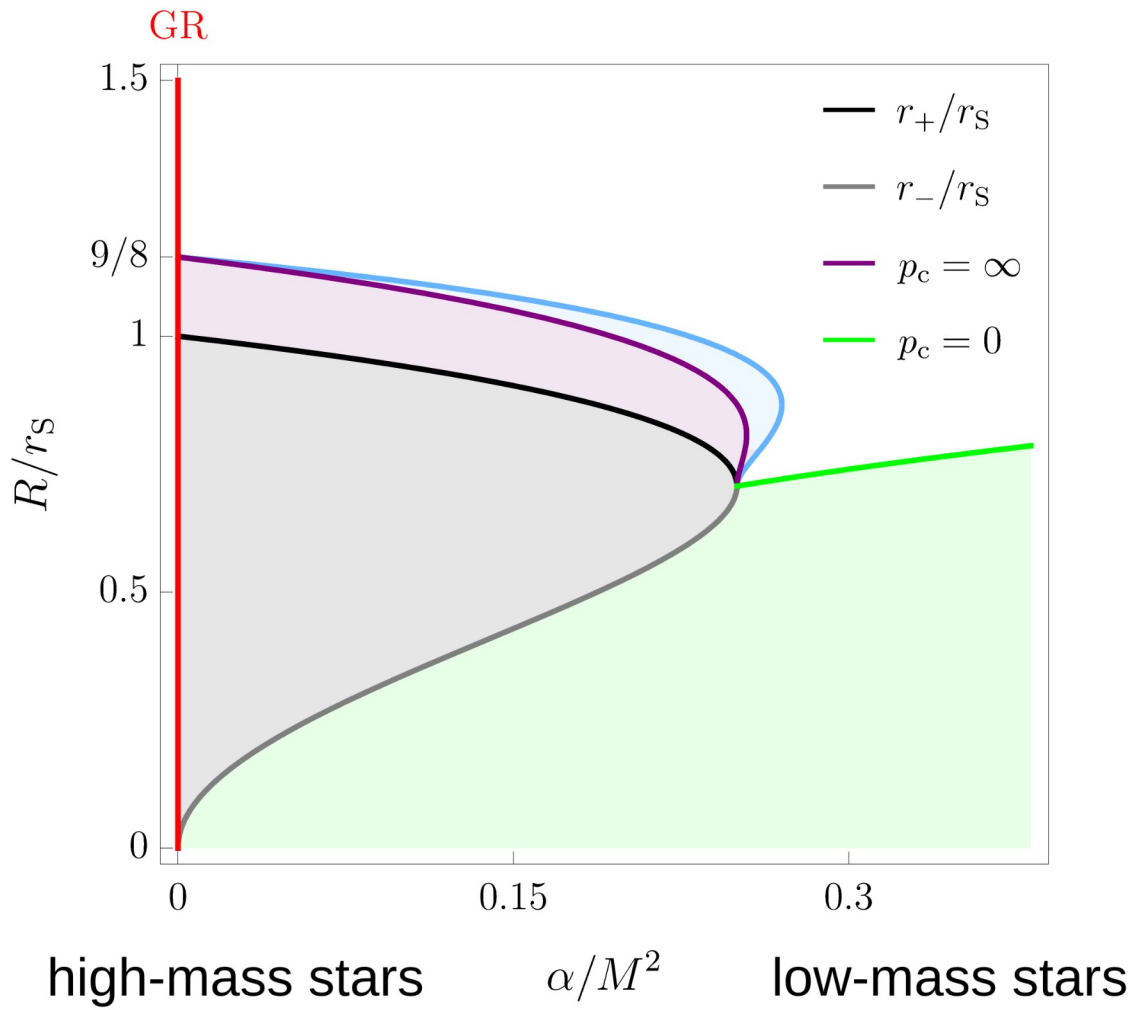
- Gray: Black Hole interior
- Purple: unphysical stars



- Gray: Black Hole interior
- Purple: unphysical stars
- Green: exotic stars $p < 0$



- Gray: Black Hole interior
- Purple: unphysical stars
- Green: exotic stars $p < 0$
- Blue: high-curvature stars



Conclusions

- Regular black holes as vacuum solutions of modified gravity.
- Oppenheimer-Snyder collapse becomes an endless cycle of contraction and expansion.
- Stars can reach higher compactness than in General Relativity.

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THANK YOU!