About a Dynamical Gravastar Model

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Outline

- What is a Gravastar?
- Its structure.
- EKG equation and its solution: A Dynamical Gravastar?
- EKG equation with a source and a cosmological constant.
- Concluding remarks.

Gravitational Vacuum Stars

- Proposed by Emil Mottola and Pawel Mazur to replace black holes.
- The model suggests that a gravitationally collapsing star would force space-time itself to undergo a phase transition, preventing further collapse to the singularity.
- Thus, the star would be transformed into a spherical “quantum vacuum” surrounded by a form of super-dense matter.
- Externally the Gravastars are very similar to a standard BH. It is very hard to distinguish one from the other only by observing gravitational effects.

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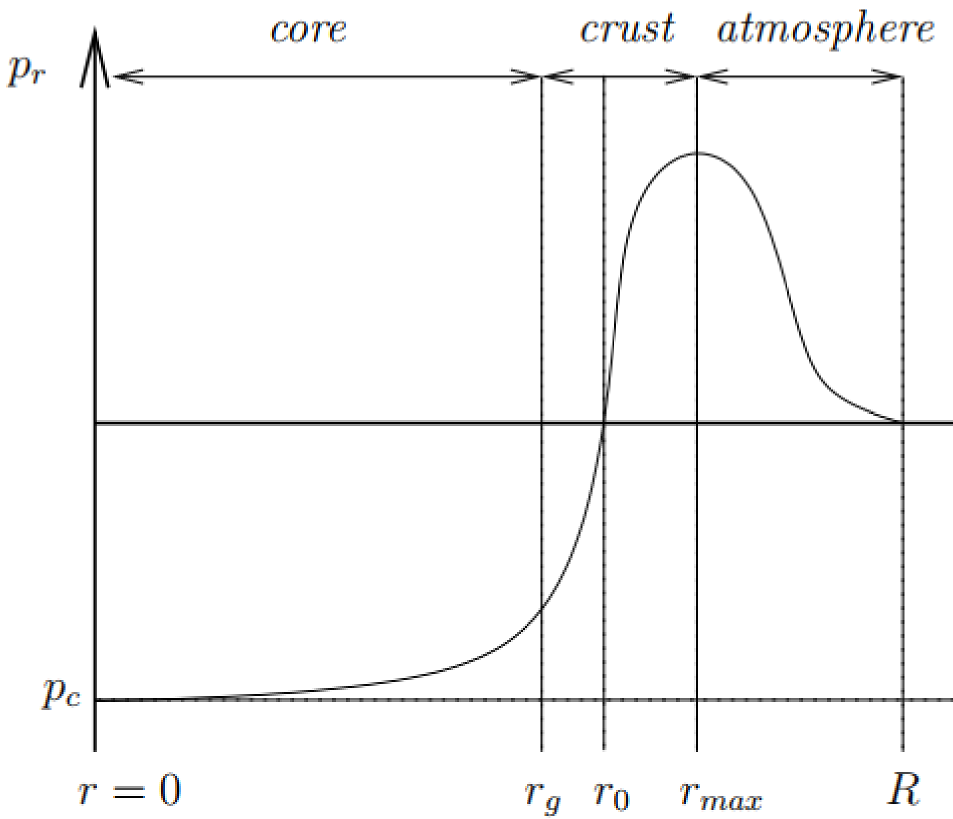
GRAVASTARS

The region $0 < r < r_g$, where the physics is qualitatively similar to that of de Sitter space, will be referred as the “core”. In the core, the local acceleration due to gravity is outward.



The region $r_g < r < r_{max}$, where the physics is still definitely “unusual”, will be referred as the “crust”. In the crust, the local acceleration due to gravity is inward, but the pressure still rises as one moves outward.

The region $r_{max} < r < R$, where the physics is still definitely “normal”, will be referred as the “atmosphere”. In the atmosphere, the local acceleration due to gravity is inward, and the pressure decreases as one moves outward.

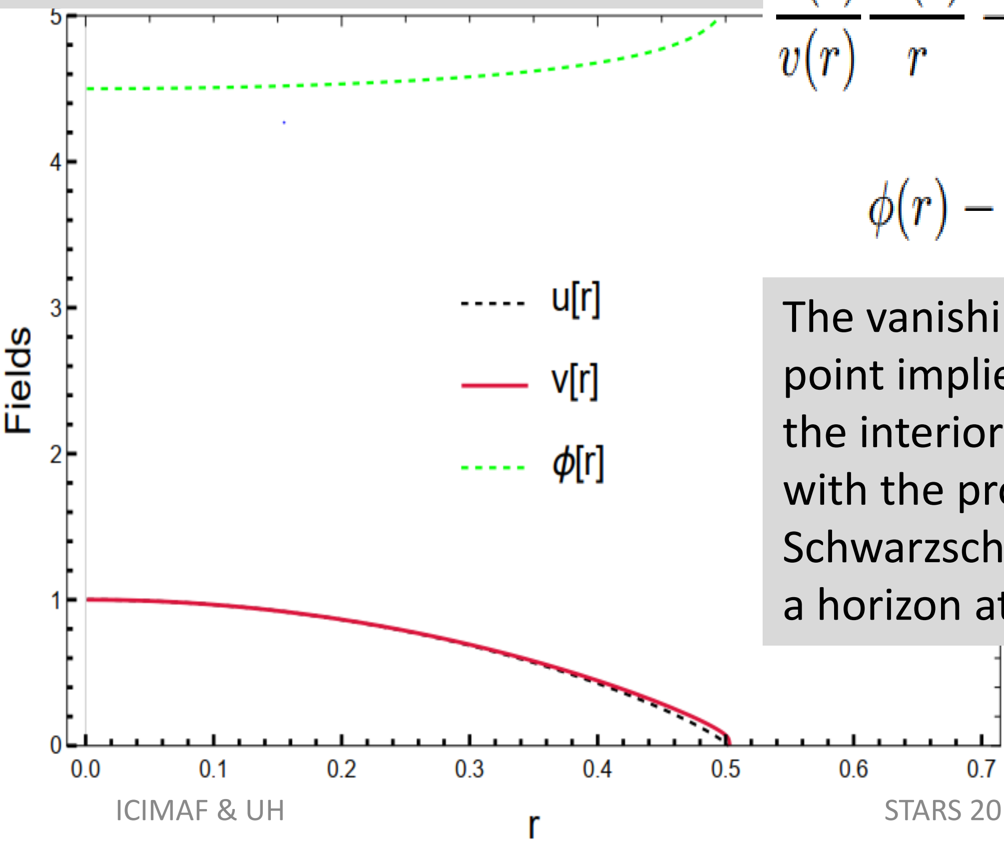
Einstein-Klein-Gordon Equation

From the Hilbert action plus a minimally coupled scalar field Lagrangian, the EKG equations follow:

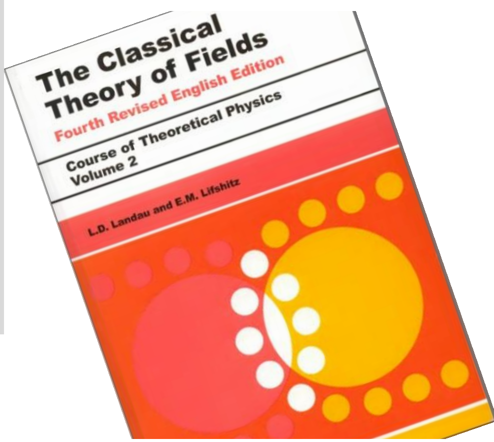
$$\frac{u'(r)}{r}-\frac{1-u(r)}{r^2}=-\frac{u(r)\phi'(r)^2}{2}-\frac{\phi(r)^2}{2},$$

$$\frac{u(r)}{v(r)}\frac{v'(r)}{r}-\frac{1-u(r)}{r^2}=+\frac{u(r)\phi'(r)^2}{2}-\frac{\phi(r)^2}{2},$$

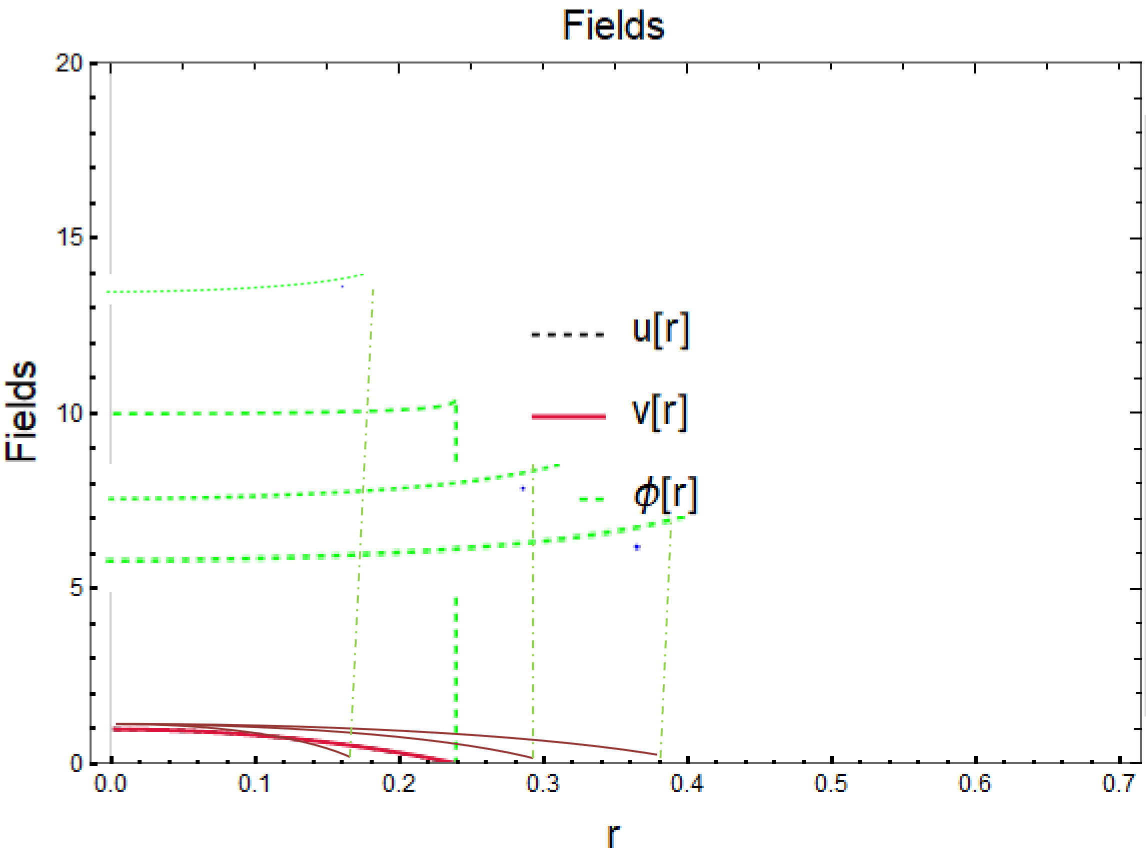
$$\phi(r)-u(r)\phi''(r)=+\phi'(r)\left(\frac{(u(r)+1)}{r}-\frac{r\phi(r)^2}{2}\right).$$



The vanishing of u(r) at a radial point implies that the energy in the interior region coincides with the proper mass of the Schwarzschild solution, showing a horizon at the same radius



Einstein-Klein-Gordon Equation



If we plot a family of the solutions of the EKG equations changing the critical radius. Then the scalar field grows with the reduction of the critical radius. This suggests that in a initial time all the fields could be compressed in a very small critical radius and when the scalar field started to fall inside, this radius increasing

Adding a source and a cosmological constant

Adding a source J(r) and a cosmological constant ε(r) for trying to eliminate the singularity at a given radius .

The source has a form of the unit step function, non vanishing from zero until a certain value.

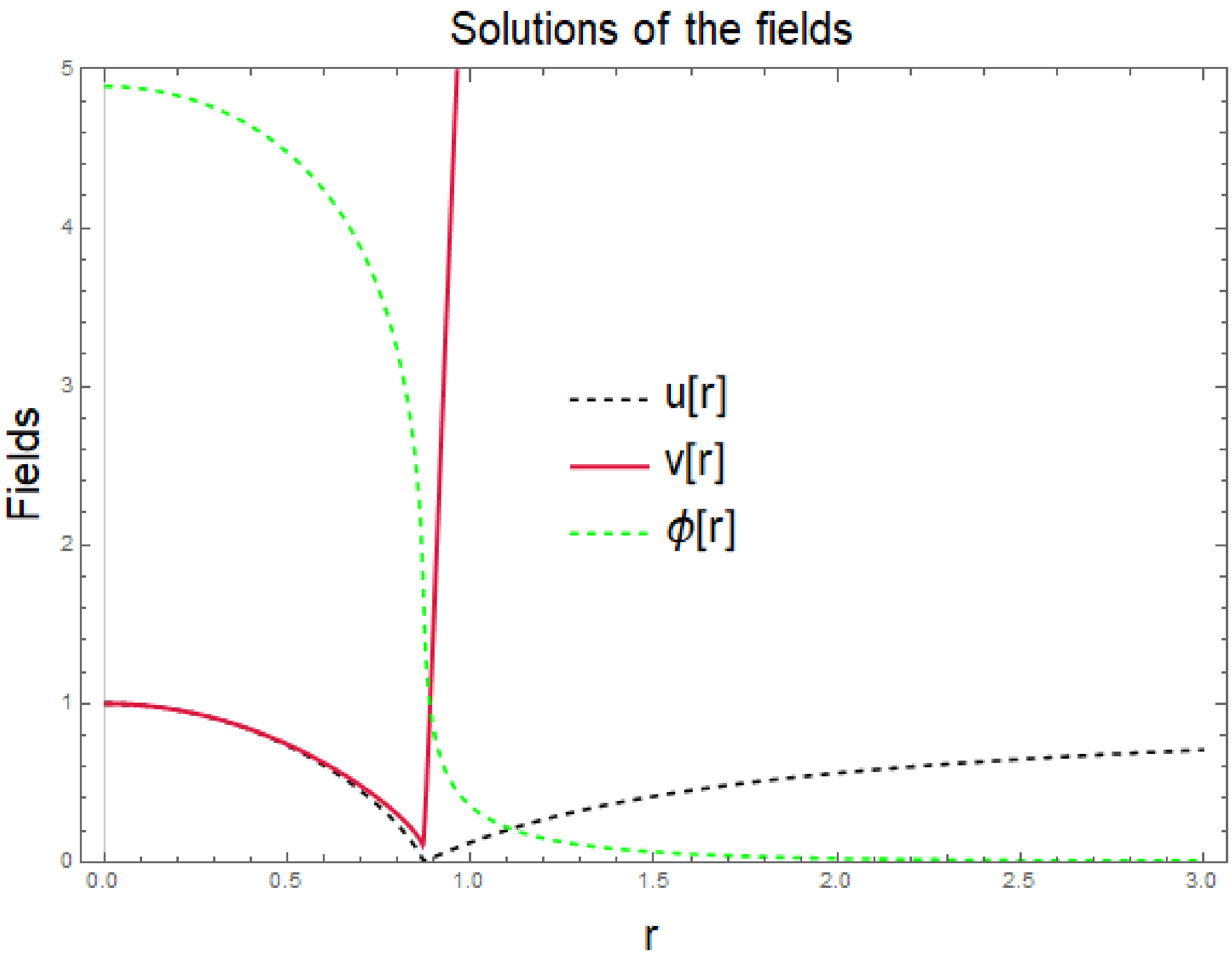
G is a constant that is proportional to the gravitational interaction

$$\frac{u'(r)}{r} - \frac{1-u(r)}{r^2} = -G\left(\frac{u(r)\phi'(r)^2}{2} + \frac{1}{2}\phi(r)^2 + J(r)\phi(r) + \frac{1}{2}J(r)^2 + \varepsilon(r)\right)$$

$$\frac{u(r)v'(r)}{rv(r)} - \frac{1-u(r)}{r^2} = G\left(\frac{u(r)\phi'(r)^2}{2} - \frac{1}{2}\phi(r)^2 - J(r)\phi(r) - \frac{1}{2}J(r)^2 - \varepsilon(r)\right)$$

$$J(r) + \phi(r) - u(r)\phi''(r) = \phi'(r)\left(\left(\frac{1+u(r)}{r}\right) - rG\left(\phi(r)^2 + J(r)\phi(r) + \frac{1}{2}J(r)^2 + \varepsilon(r)\right)\right)$$

Adding a source and a cosmological constant

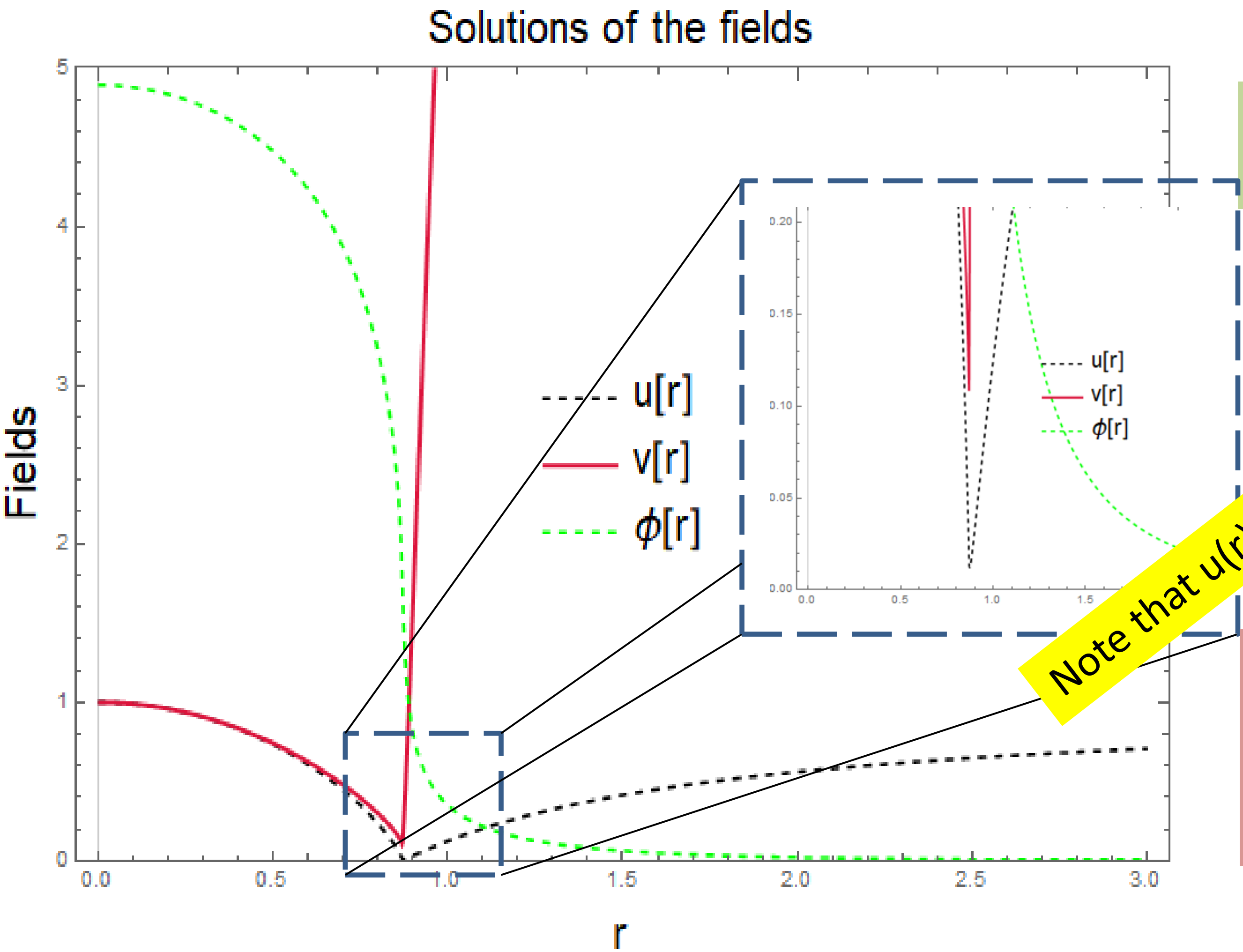


The scalar field tends to zero as a Yukawa potential.

The spatial component of the metric is similar to the Schwarzschild's one to the right side, and to the de Sitter space at the left .

The temporal metric component has a very high value outside, but is continuous...

Adding a source and a cosmological constant



The scalar field tends to zero as a Yukawa potential

The spatial component of the metric is similar to the Schw[illegible]hild’s one to the ri[illegible]e, and to the de [illegible]er space at the left

Note that u(r) is non zero

The temporal metric component has a very high value outside, but is continuous…

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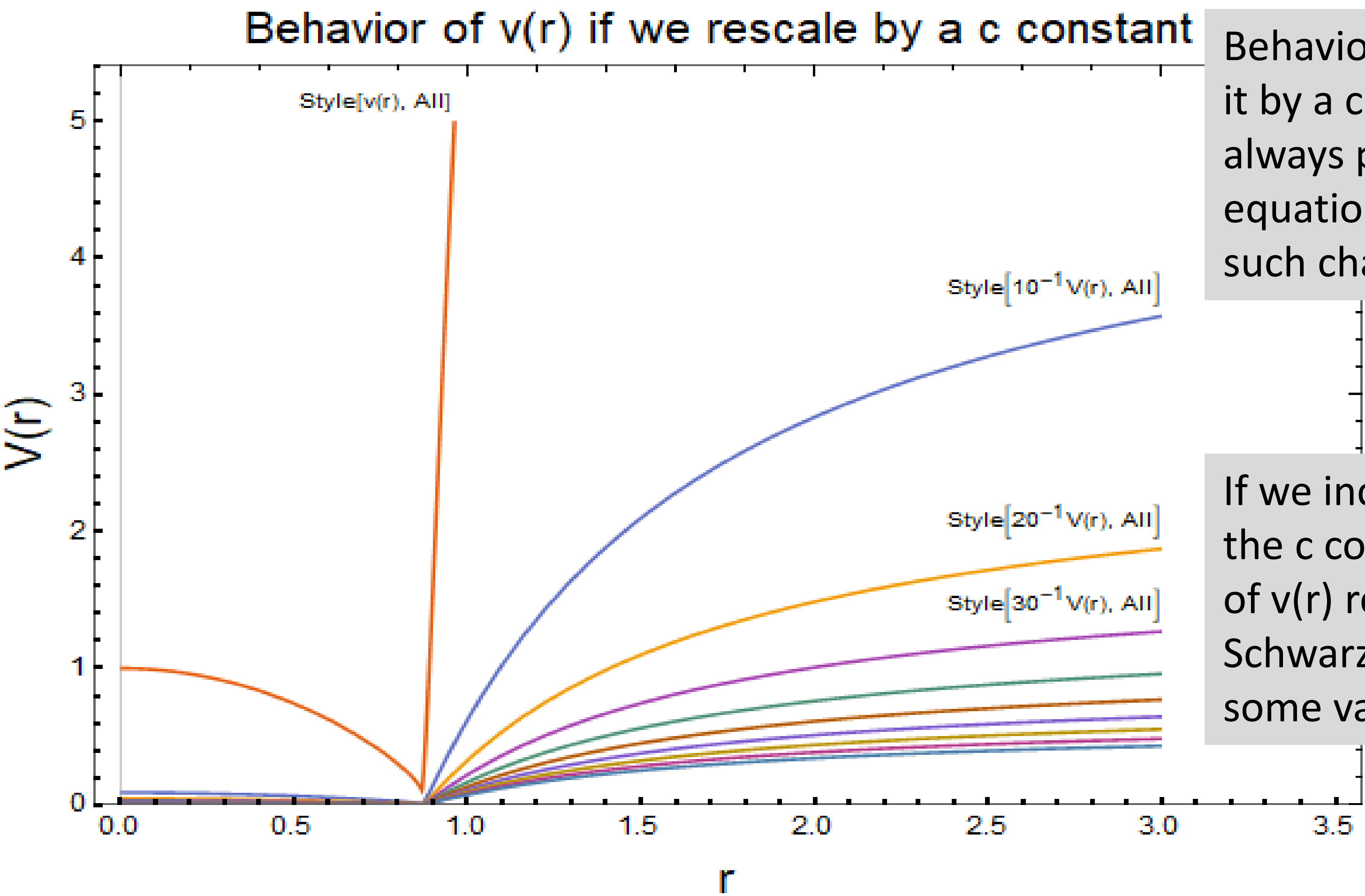
Adding a source and a cosmological constant



Behavior of v(r) if we rescale it by a constant, which is always possible because the equations are invariant under such changes

If we increase the values of the c constant, the behavior of v(r) reproduces the Schwarzschild one outside for some value of this constant.

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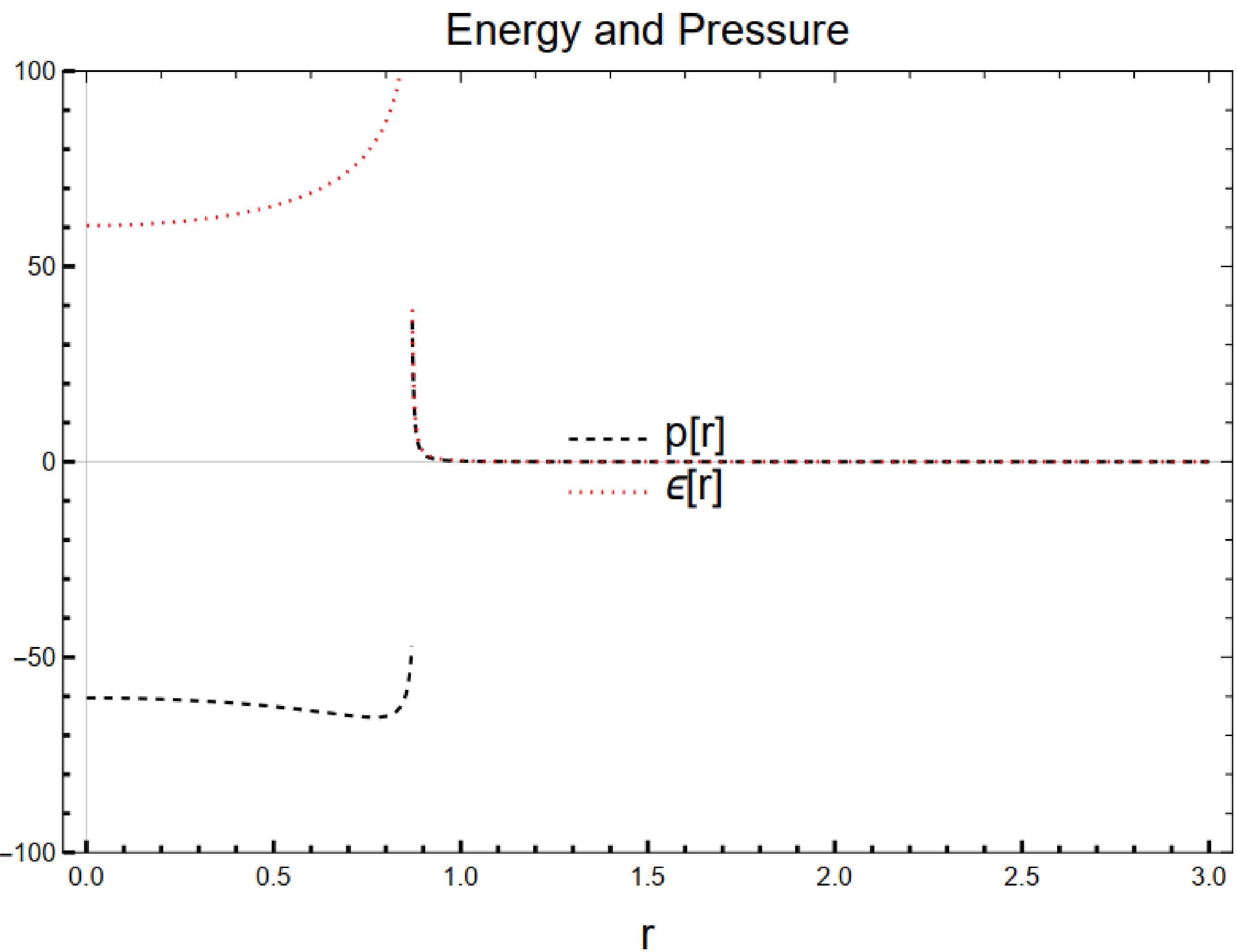
Energy & Pressure



The energy is positive in the core and pressure has a behavior very similar to the one described by Manzur and Mottola

There is a discontinuity in the pressure that could be solved after regularizing the discontinuous unit step function employed

Concluding Remarks

The gravastars are a solution to some of the problem that present the classical BH.

We propose a solution for the end of the gravitational collapse of scalar field where naturally appear the structure of a gravastar, only that here the role of the cosmological constant is played by the scalar fields

In this Dynamical Gravastar the fields are continuous in all the regions and we are working in order to eliminate the discontinuity that appears in the singularity point for the pressure.

So, BH or Gravastar?