Gravastar

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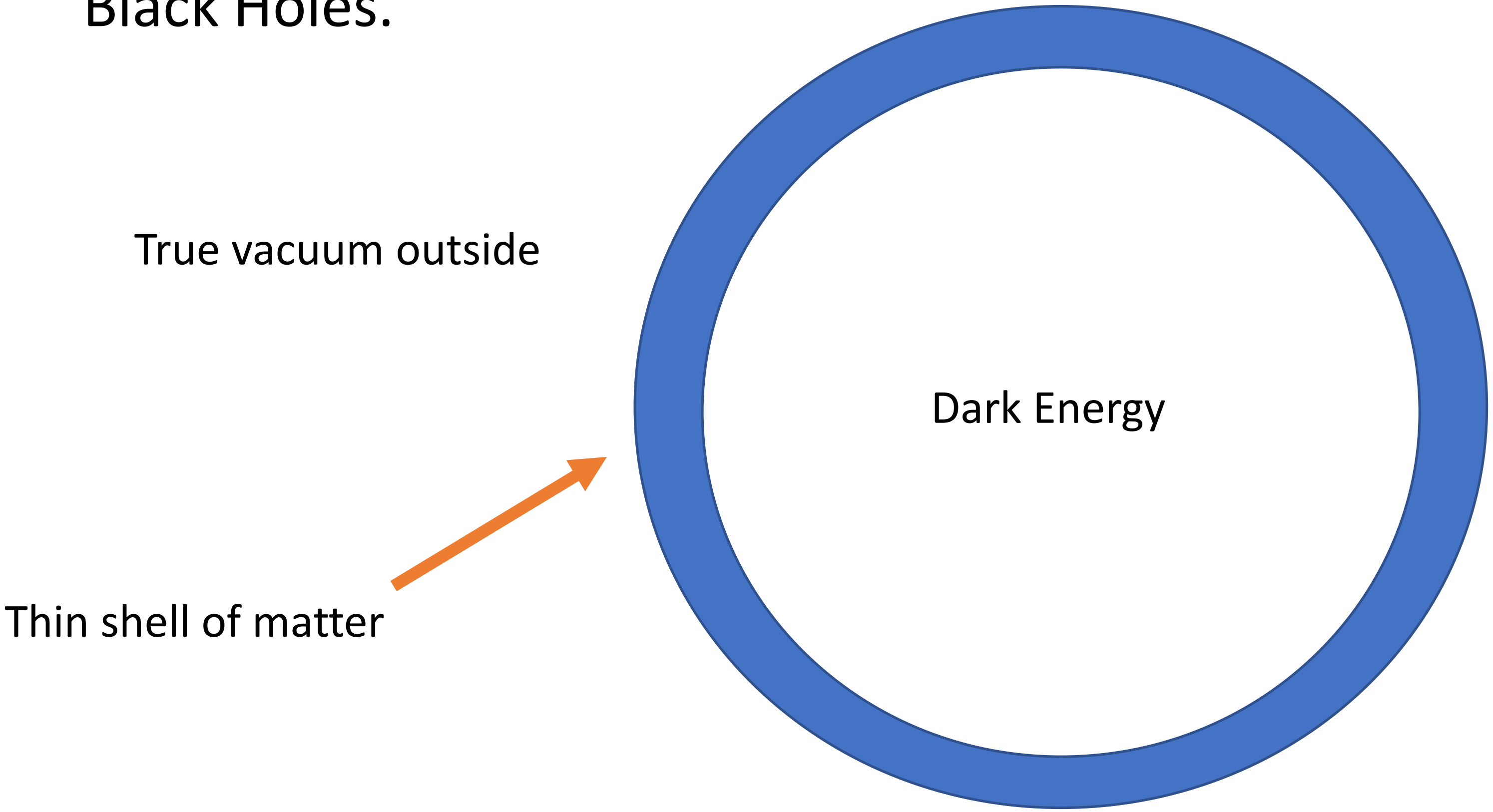
Gravitational Vacuum (Condensate) Star [Mazur; Mottola]

- A new solution for the endpoint of gravitational collapse – An alternative to Black Holes.



[1] – Mazur, Pawel O.; Mottola, Emil (2001). “Gravitational Condensate Stars: An Alternative to Black Holes”. *Universe.* 9(2): 88. arXiv:gr-qc/0109035

Static, spherically symmetric line element

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{h(r)} + r^2(d\theta^2 + \sin^2(\theta)d\phi^2) \qquad (1)$$

Space is divided into 3 regions

$$\begin{array}{llll} \text{I.} & \text{Interior}: & 0 \le r < r_1\,, & \rho = -p\,, \\ \text{II.} & \text{Shell}: & r_1 < r < r_2\,, & \rho = +p\,, \\ \text{III.} & \text{Exterior}: & r_2 < r\,, & \rho = p = 0\,. \end{array} \qquad (2)$$

For the internal region – de Sitter metric

$$\text{I.} \qquad f(r) = C\,h(r) = C\,(1 - H_0^2\,r^2)\,, \quad 0 \le r \le r_1\,. \qquad (5)$$

The Einstein eq. for the perfect fluid at rest:

$$-G^t{}_t = \frac{1}{r^2}\frac{d}{dr}\left[r\,(1-h)\right] = -8\pi G\,T^t{}_t = 8\pi G\rho\,, \qquad (3a)$$

$$G^r{}_r = \frac{h}{r\,f}\frac{df}{dr} + \frac{1}{r^2}\,(h-1) = 8\pi G\,T^r{}_r = 8\pi G p\,, \qquad (3b)$$

together with the conservation eq.,

$$\nabla_a T^a{}_r = \frac{dp}{dr} + \frac{\rho + p}{2f}\,\frac{df}{dr} = 0\,, \qquad (4)$$

For the external region – Schwarzschild metric

$$\text{III.} \qquad f(r) = h(r) = 1 - \frac{2GM}{r}\,, \qquad r_2 \le r\,. \qquad (6)$$

Principal Features

- No singularity
- No event horizon – finite blue shift
- Entropy $E \sim 10^{-38} E_{BH}$ - 38 orders of magnitude lower than Bekenstein-Hawking entropy.
- Matter transforms into an entirely new phase, which has properties of Bose-Einstein condensate.

But

- Rotating gravastars are not stable.
- LIGO's observations of gravitational waves from colliding objects have been found either to not be consistent with the gravastar concept, or to be indistinguishable from ordinary black holes.

Nestar [Jampolski; Rezzolla]

- Gravastars can have nested solutions – one gravastar is layered on another gravastar – this process can go on and on.

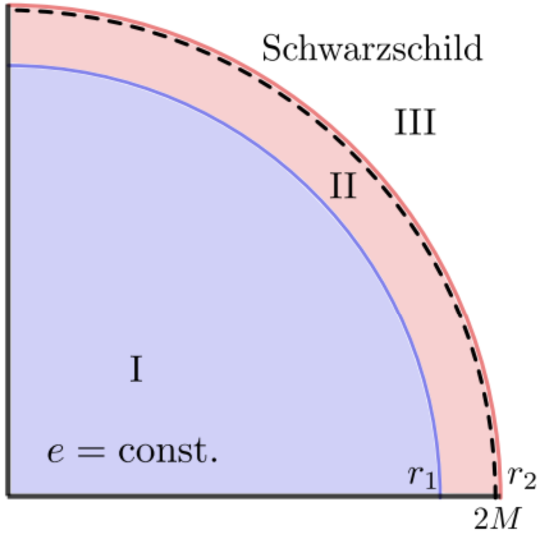


Figure 1: Illustrative representation of a gravastar. Shown with different colours are the three different regions of the spacetime: a de-Sitter region (I., blue-shaded area), the ultra-stiff shell (II., red-shaded area), and the Schwarzschild vacuum exterior (III., white area). Shown with a black dashed line is the position of the surface $r = 2M$, with M the mass of the gravastar.

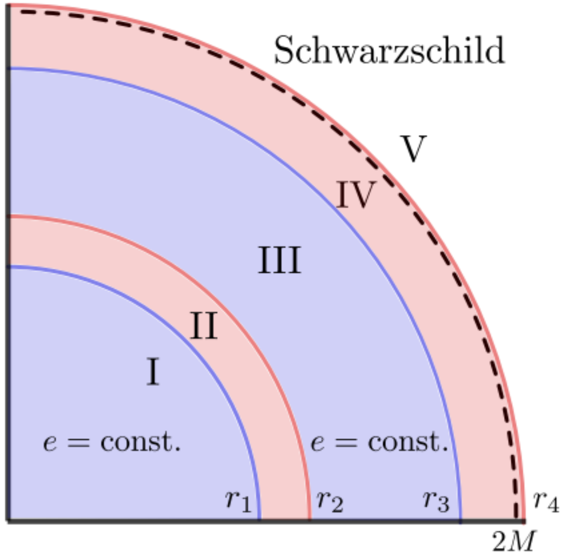


Figure 5: Illustrative representation of a nestar. Note the addition of regions III and IV, which represent a replica of regions I and II, before the spacetime is smoothly joined with the Schwarzschild portion V.

[2] – Jampolski, Daniel; Rezzolla, Luciano (2024-02-15). "Nested solutions of gravitational condensate stars". *Classical and Quantum Gravity.* 41(6):065014. arXiv:2310.13946

Thanks for listening!

[1] – Mazur, Pawel O.; Mottola, Emil (2001). “Gravitational Condensate Stars: An Alternative to Black Holes”. *Universe*. 9(2): 88. arXiv:gr-qc/0109035

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[3] – “Los Alamos researcher says ‘black holes’ aren’t holes at all”. Los Alamos National Laboratory (2006). https://web.archive.org/web/20061213095149/http://www.lanl.gov/news/releases/archive/02-035.shtml

[4] – Black holes might be dark stars with layers: New solution found – Sabine Hossenfelder. https://www.youtube.com/watch?v=Ej9F0hh8rgk