8.962 Lectures 18 & 19
April 18 & 20, 2018

KRUSKAL SPACETIME

Kruskal Coordinates

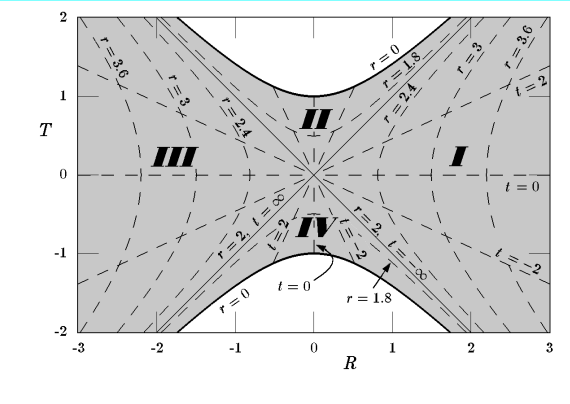
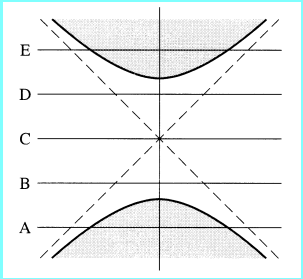
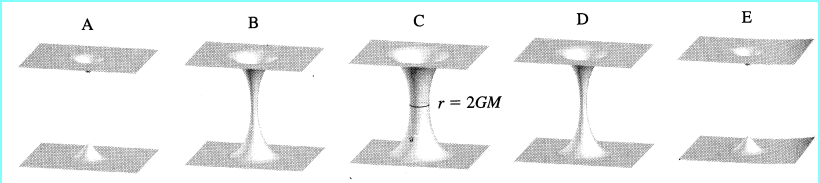


Figure 1: The Kruskal coordinate system and its relation to Schwarzschild coordinates t and r, in units of GM. (The quadrant numbering is different from Carroll.)

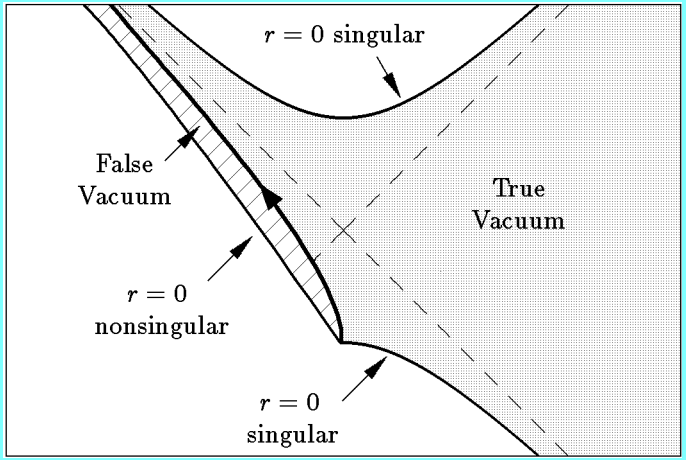
Embedding Diagrams



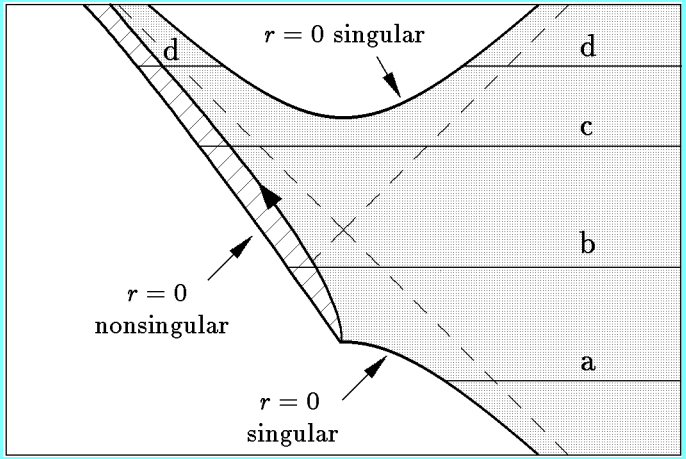


(From Sean Carroll, *Spacetime and Geometry*, Figs. 5.14 & 5.15.)

Evolution of False Vacuum Bubble



Evolution of False Vacuum Bubble



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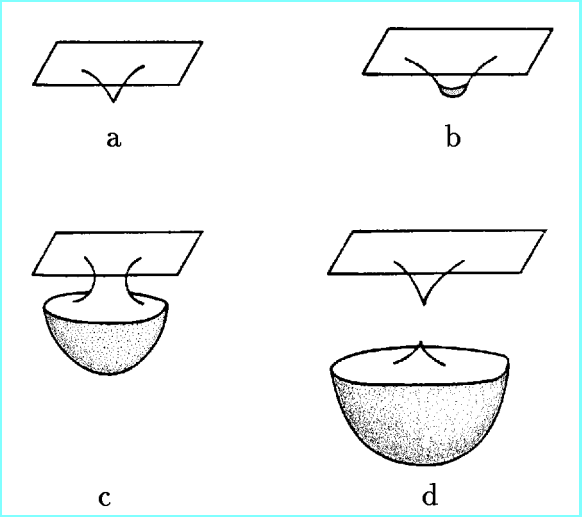
Evolution of False Vacuum Bubble



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References

- S. K. Blau, E. I. Guendelman, & A. H. Guth, *The dynamics of false vacuum bubbles,* Phys. Rev. D **35**, 1747 (1987).
- E. Farhi and A. H. Guth, *An obstacle to creating a universe in the laboratory,* Phys. Lett. B **183**, 149 (1987). This paper shows, using classical equations and the null energy condition, that the false vacuum bubbles that grow without bound must trace back to an initial singularity.
- E. Farhi, A. H. Guth and J. Guven, *Is it possible to create a universe in the laboratory by quantum tunneling?,* Nucl. Phys. B **339**, 417 (1990). In this paper we explored the possibility of avoiding an initial singularity by first producing a false vacuum bubble that is too small to classically grow without bound, but then to have it tunnel to a larger bubble (of the same mass) which would then grow without bound. Is it possible? Maybe. This is still unresolved.