TRAVERSABLE EINSTEIN-ROSEN BRIDGE INSIDE BLACK HOLES

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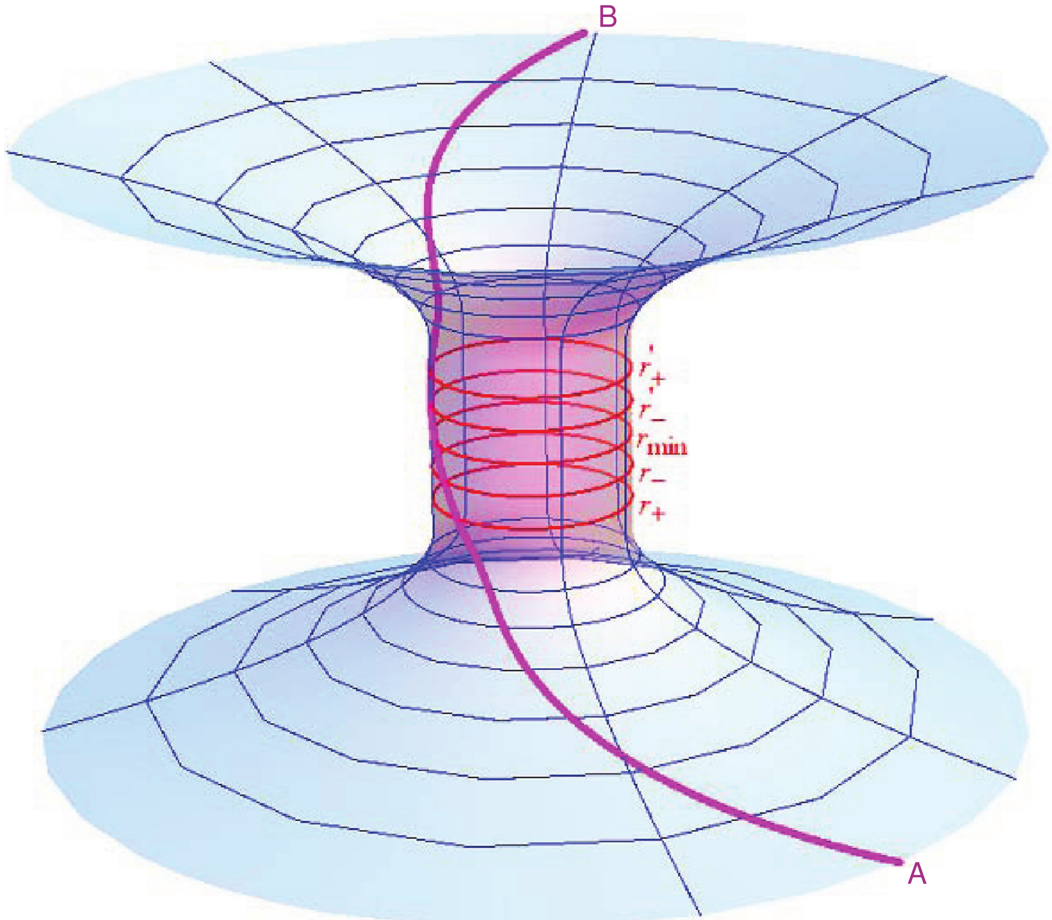
Quarks-2024
Pereslavl 22 May 2024

EINSTEIN-ROSEN BRIDGE



3D visualization of Einstein-Rosen bridge inside black hole connecting two asymptotically flat universes

The spacecraft starts from our asymptotically flat universe (point A) and falls under the event horizon of the black hole.

After the ship crosses the Cauchy horizon inside the black hole, it reaches the turning point and flies out, but into another asymptotically flat universe (point B).

KERR-NEWMAN METRIC

$$ds^2 = \frac{\Sigma}{\Delta}[dt - a\sin^2\theta d\varphi]^2 + \frac{\sin^2\theta}{\Sigma}[(r^2+a^2)d\varphi - adt]^2 + \frac{\Sigma}{\Delta}dr^2 + \Sigma d\theta^2 \quad (1)$$

$$\Delta = r^2 - 2Mr + a^2 + q^2 \quad (2)$$

$$\Sigma = r^2 + a^2\cos^2\theta \quad (3)$$

$$r_+ = M + \sqrt{M^2 - a^2 - q^2} \quad (4)$$

$$r_- = M - \sqrt{M^2 - a^2 - q^2} \quad (5)$$

$$\Sigma\frac{dr}{d\tau} = \sqrt{R} \quad (6)$$

$$\Sigma\frac{d\theta}{d\tau} = \sqrt{\Theta} \quad (7)$$

$$\Sigma\frac{d\varphi}{d\tau} = -(aE - \frac{L}{\sin^2\theta}) + \frac{a}{\Delta}P \quad (8)$$

$$\Sigma\frac{dt}{d\tau} = -a(aE\sin^2\theta - L) + (r^2+a^2)\frac{P}{\Delta} \quad (9)$$

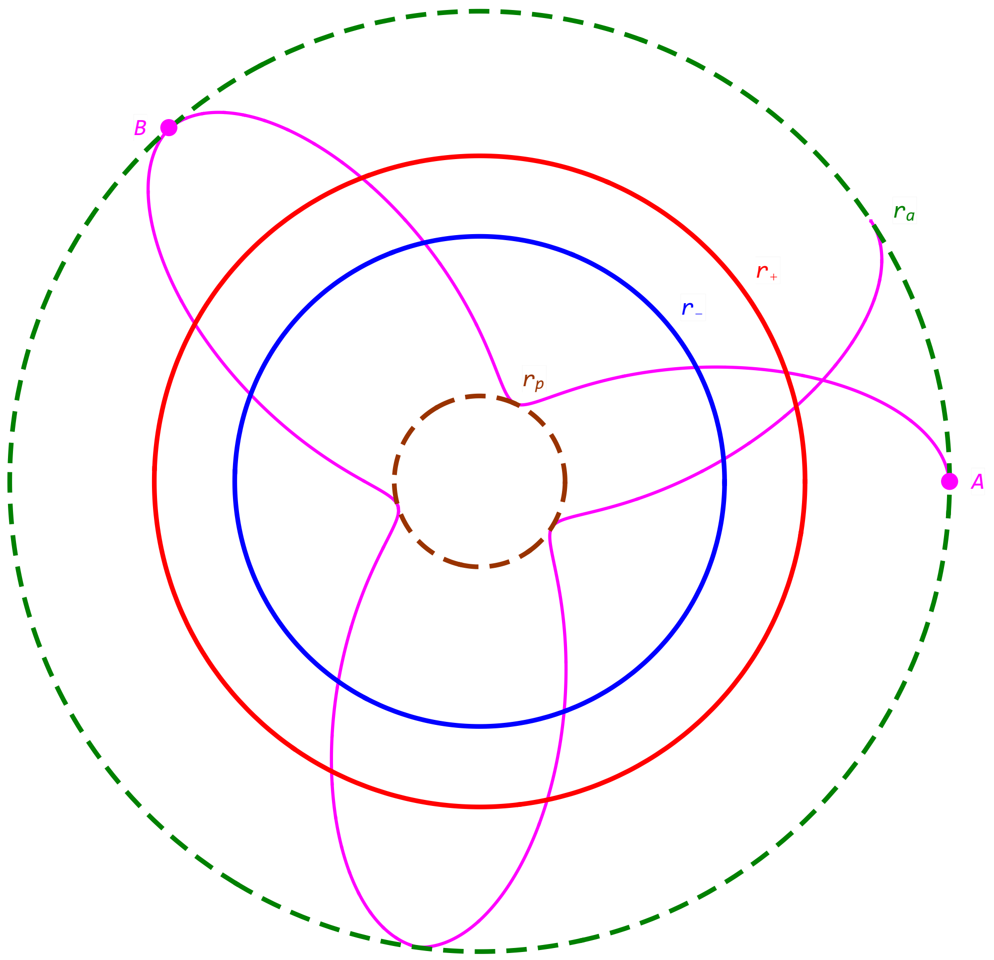
$$P = E(r^2+a^2) - aL + \epsilon qr \quad (10)$$

$$R(r) = P^2 - \Delta[\mu^2 r^2 + (L-aE)^2 + Q] \quad (11)$$

$$\Theta(\theta) = Q - \cos^2\theta[a^2(\mu^2 - E^2) + \frac{L^2}{\sin^2\theta}] \quad (12)$$

$$r_{es}(\theta) = 1 + \sqrt{1 - q^2 - a^2\cos^2\theta} \quad (13)$$

2D VISUALIZATION OF TRAJECTORIES RELATIVE TO THE CENTER OF THE BLACK HOLE



Pink curves are the trajectories of a spacecraft falling into a Reissner-Nordstrom black hole, calculated numerically.

The red circle is the event horizon of the black hole. The blue circle is the Cauchy horizon inside the black hole.

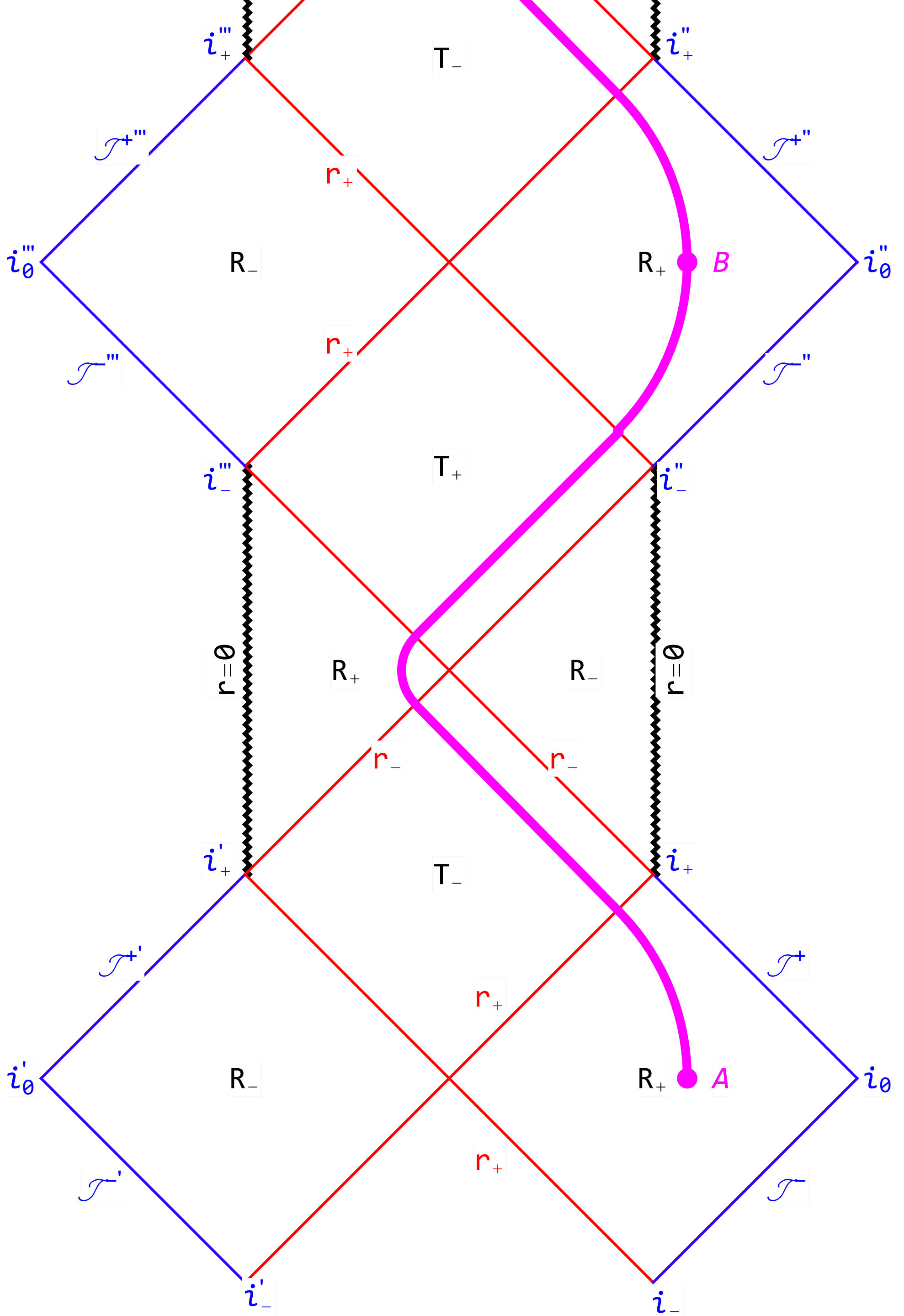
Dotted circles are turning points.

It can be seen that after exiting the black hole, the ship returns to the same radius and can continue moving along a similar trajectory.

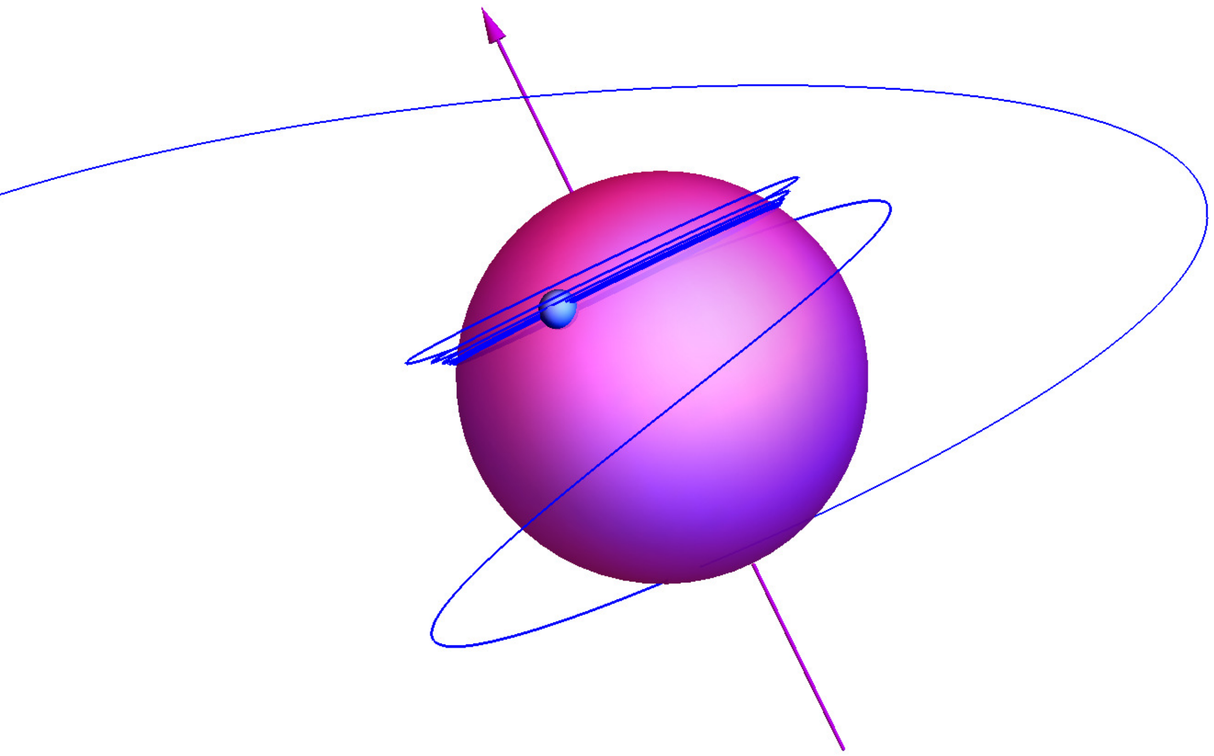
CARTER-PENROSE DIAGRAM

The Carter-Penrose diagram shows that the ship's motion is directed into a region of space-time that is not connected to the original universe.

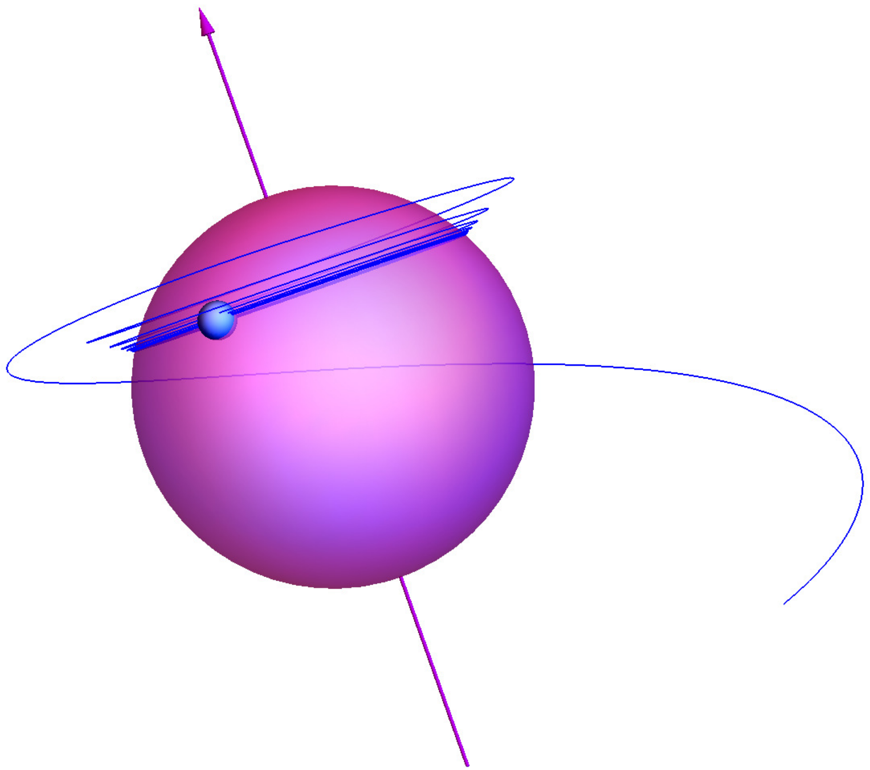
This region inside the black hole is another universe, which is also asymptotically flat away from the horizon of the black hole.



SYMMETRIES AND ASYMMETRIES OF THE TRAJECTORIES OF THE TEST "PLANETS"

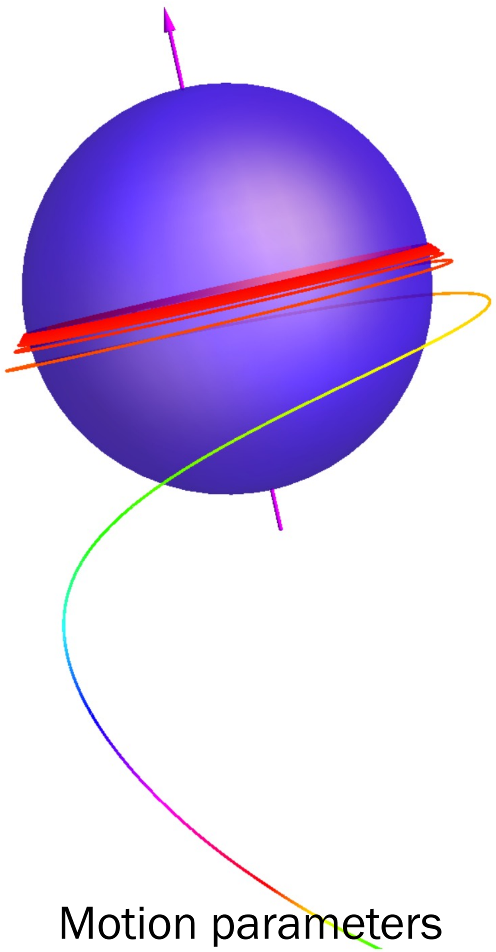


Motion parameters
γ = 0.85, λ = 1.7 and Q = 1



Motion parameters
γ = 0.85, λ = 1.7 and Q = 1

SYMMETRIES AND ASYMMETRIES OF TEST PHOTON TRAJECTORIES



Motion parameters
λ = -1.493 and Q = 12.99

Motion parameters
λ = 2 and Q = 1

RESULTS AND CONCLUSIONS

- A generalization of the concept of the Einstein-Rosen bridge is made, defined as a spatially similar connection between two universes with asymptotically flat regions of space-time in the limit of large distances from horizons.
- The corresponding symmetry and asymmetry properties of the generalized Einstein-Rosen bridge are considered using the examples of Reissner-Nordstrom and Kerr metrics.
- Using the example of Carter-Penrose diagrams, the properties of symmetry and asymmetry are demonstrated when a test body, for example, a spacecraft, moves through many different universes inside a black hole.
- It is important to note that the Einstein-Rosen bridge, which is passable (although only in one direction), exists only in the case of either rotating Kerr black holes ($a \neq 0$) or electrically charged Reissner-Nordstrom black holes ($q \neq 0$). It is completely absent inside the Schwarzschild black hole.

THANK YOU FOR YOUR ATTENTION