Welcome back to 8.033!

Karl Schwarzschild
German, 1873-1916

Image courtesy of Wikipedia.

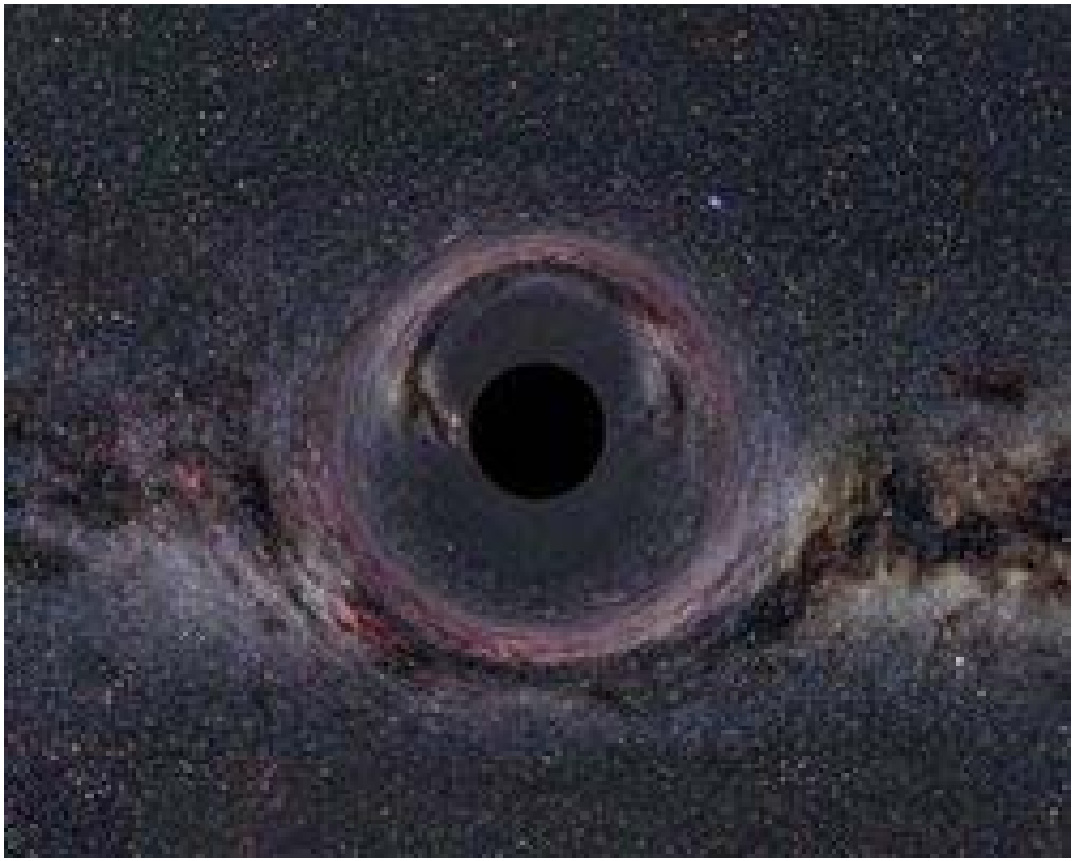


Image courtesy of Wikipedia.

MIT Course 8.033, Fall 2006, Lecture 21

Max Tegmark

TODAY'S TOPICS:

- Schwarzschild metric & black holes
- Interpretation of r and t
- Propagation of radial light rays

SCHWARZSCHILD METRIC & BLACK HOLES

Depth

Be able to solve problems using the Schwarzschild metric.

- The Schwarzschild metric
- Interpretation of the Schwarzschild metric (t-coordinate, r-coordinate, shell coordinates, gravitational redshift, event horizon, Schwarzschild radius, event horizon)
- Geodesics of the Schwarzschild metric: radial and angular, stable and unstable circular orbits, computing general geodesics using the effective potential, computing weak light deflection and Mercury perihelion shift, tidal forces
- Definition of a black hole
- Shapiro time delay

Breadth

- Evidence that General Relativity is correct
- Evidence that black holes exist (both stellar mass and supermassive)
- How black holes probably form
- No-hair theorem: the three properties of a black hole
- Singularity

- Hawking radiation
- Falling into a black hole: what it feels like and what it looks like from afar
- River model of black holes, sense in which nothing special happens at the event horizon
- Time travel: possibilities for going forward and backward, wormholes
- Taylor-Hulse binary neutron star system

Java orbit
simulator

- Escape velocity
- Newtonian metric
- Schwartzschild metric
- β_r, γ_r

Distance to origin < Circumference/2π:

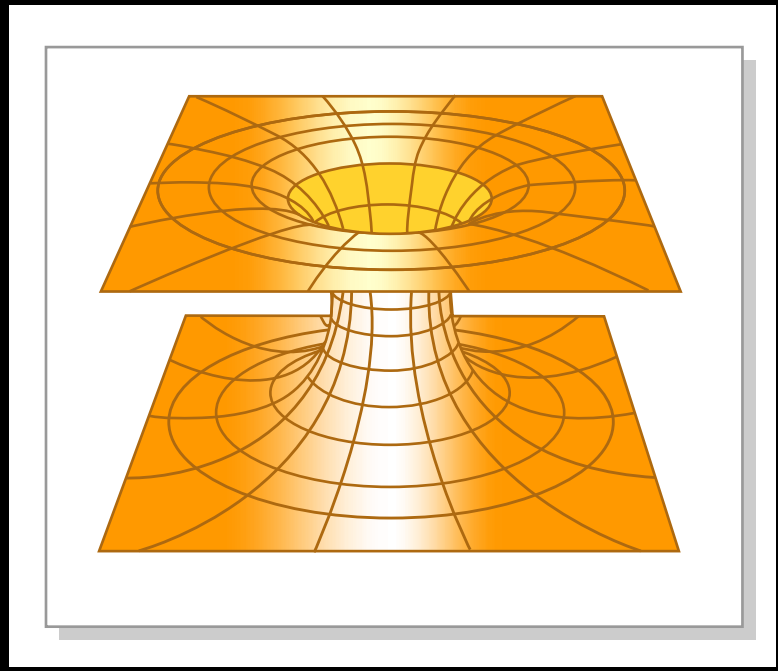


Figure by MIT OCW.

Q: What is a black hole?

A: An object contained within its own event horizon.

Q: What 3 measureble properties do black holes have?

A:

1. Mass
2. Angular momentum
3. Charge

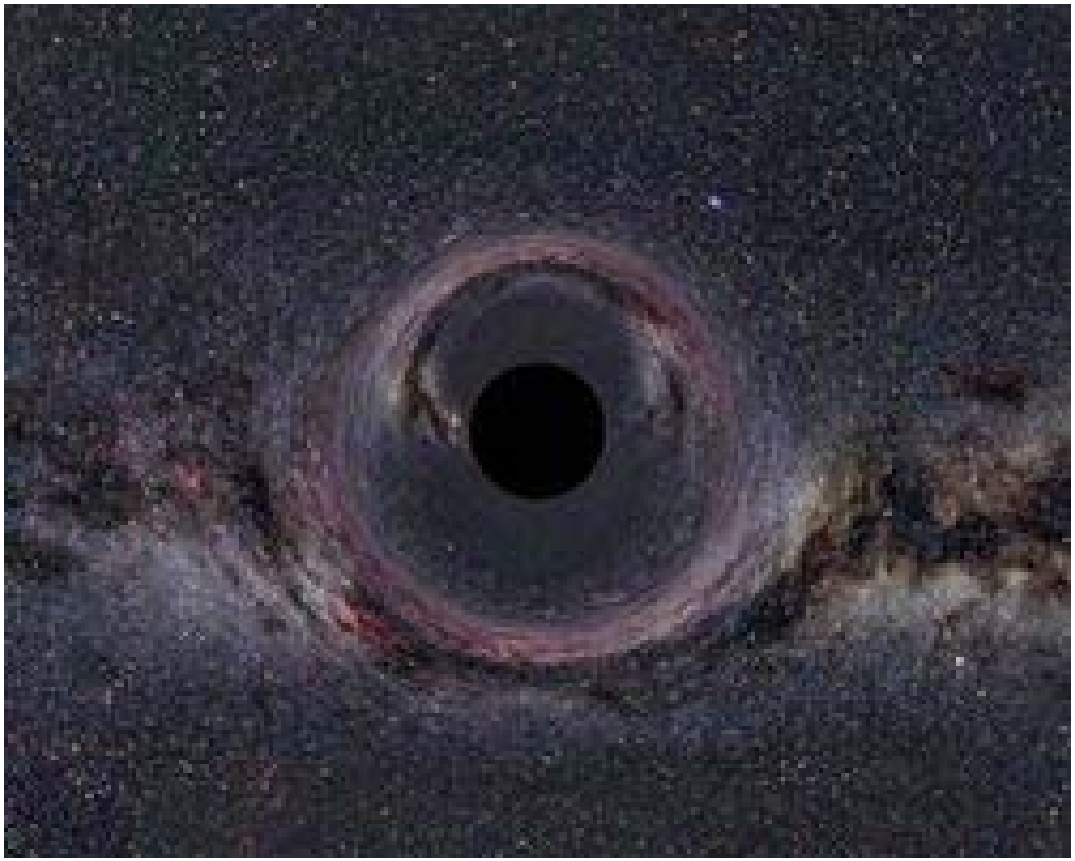


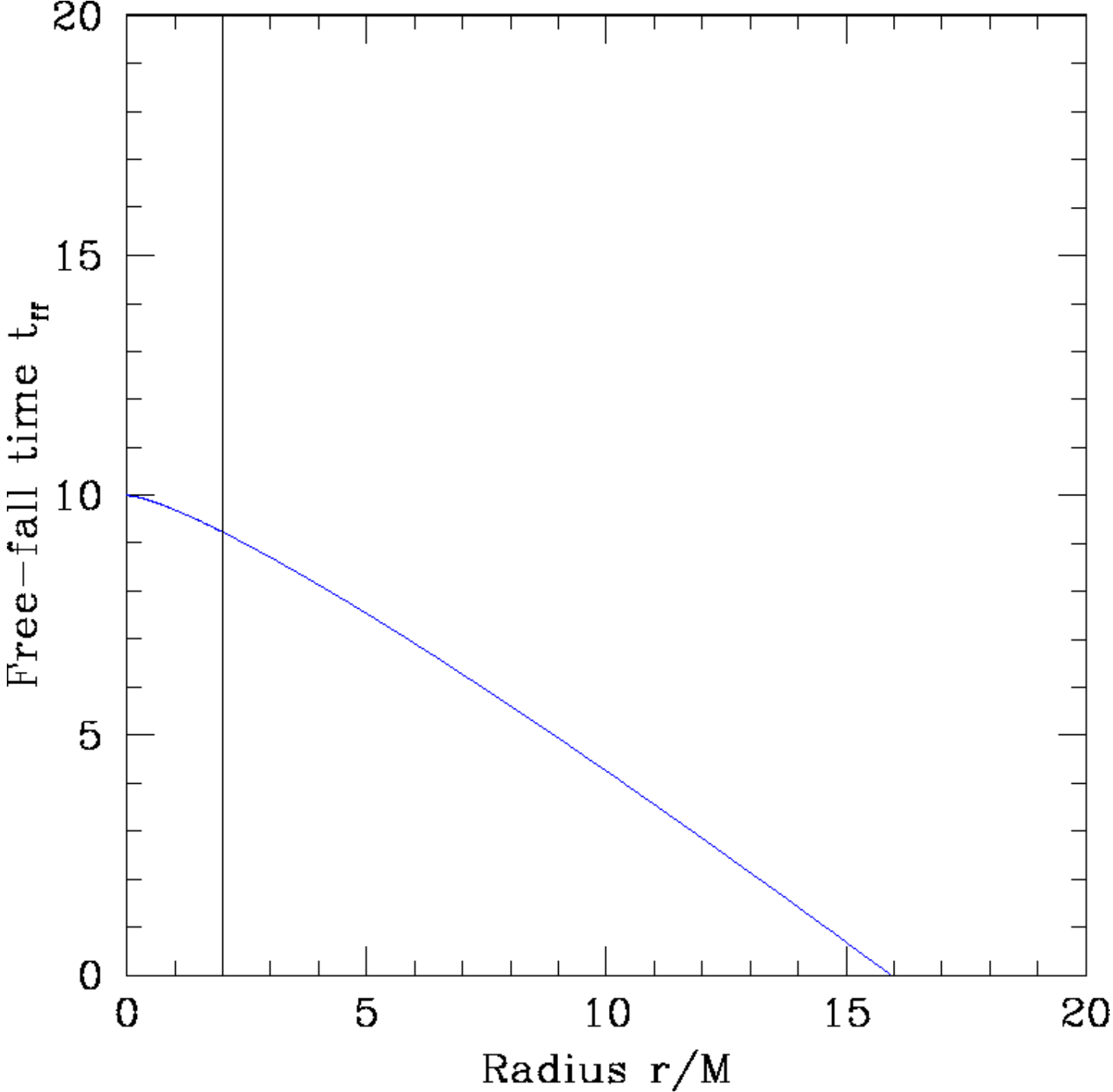
Image courtesy of Wikipedia.

But what is a black hole *really*?

River model gives great intuition!

The river model of black holes

(Hamilton 2004)


Free−fall time t_{ff}
Radius r/M
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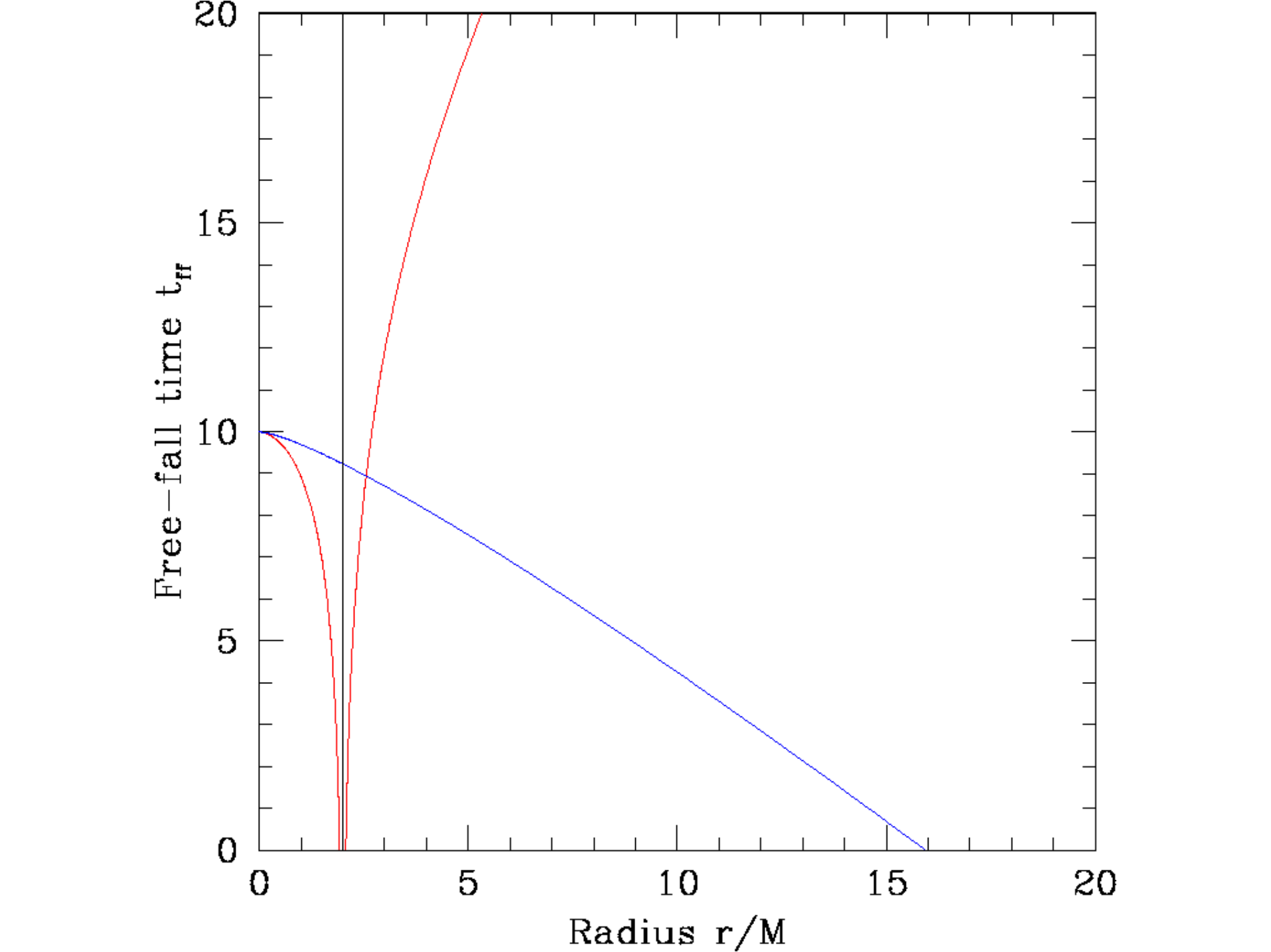
5
10
15
20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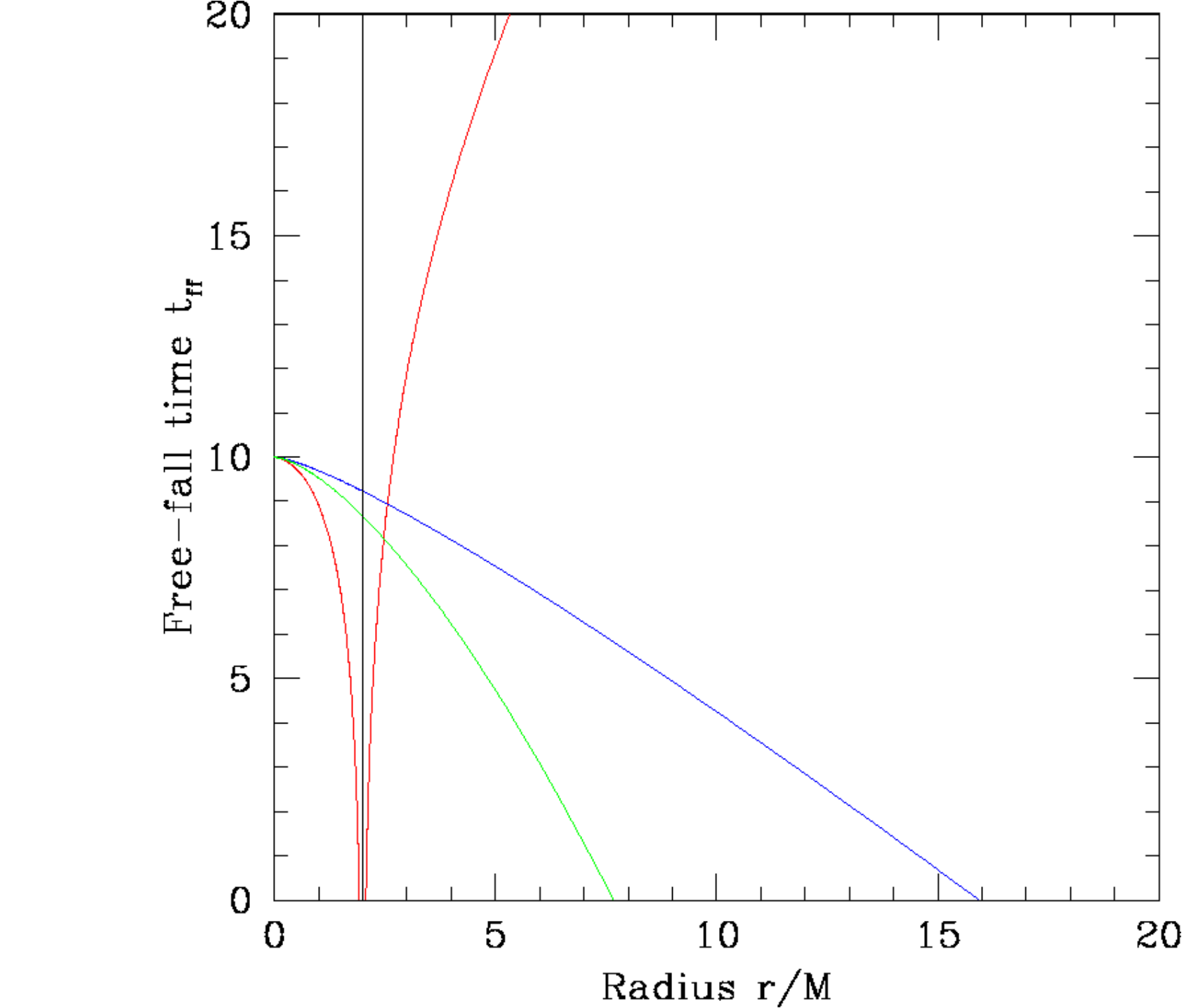
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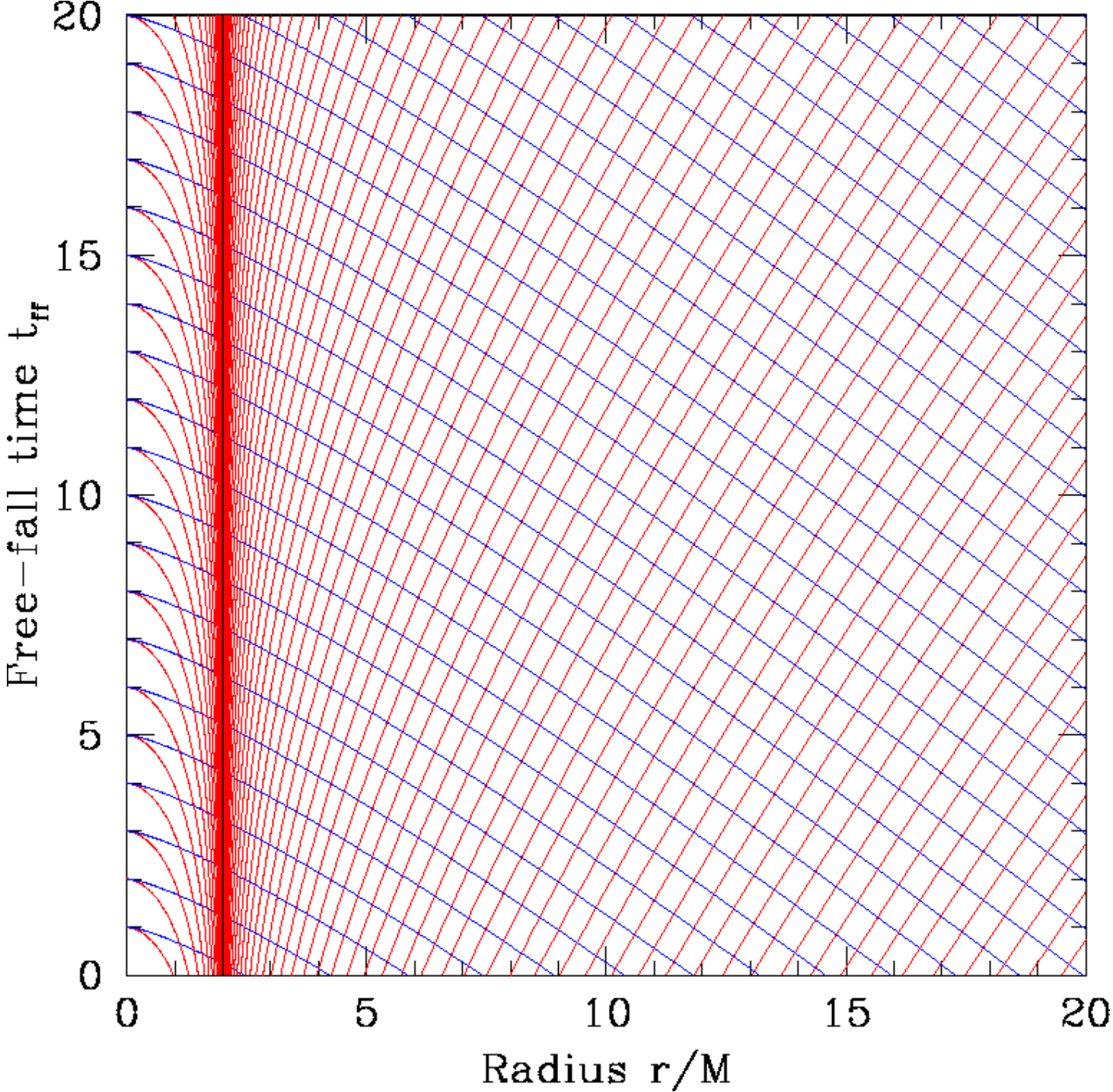
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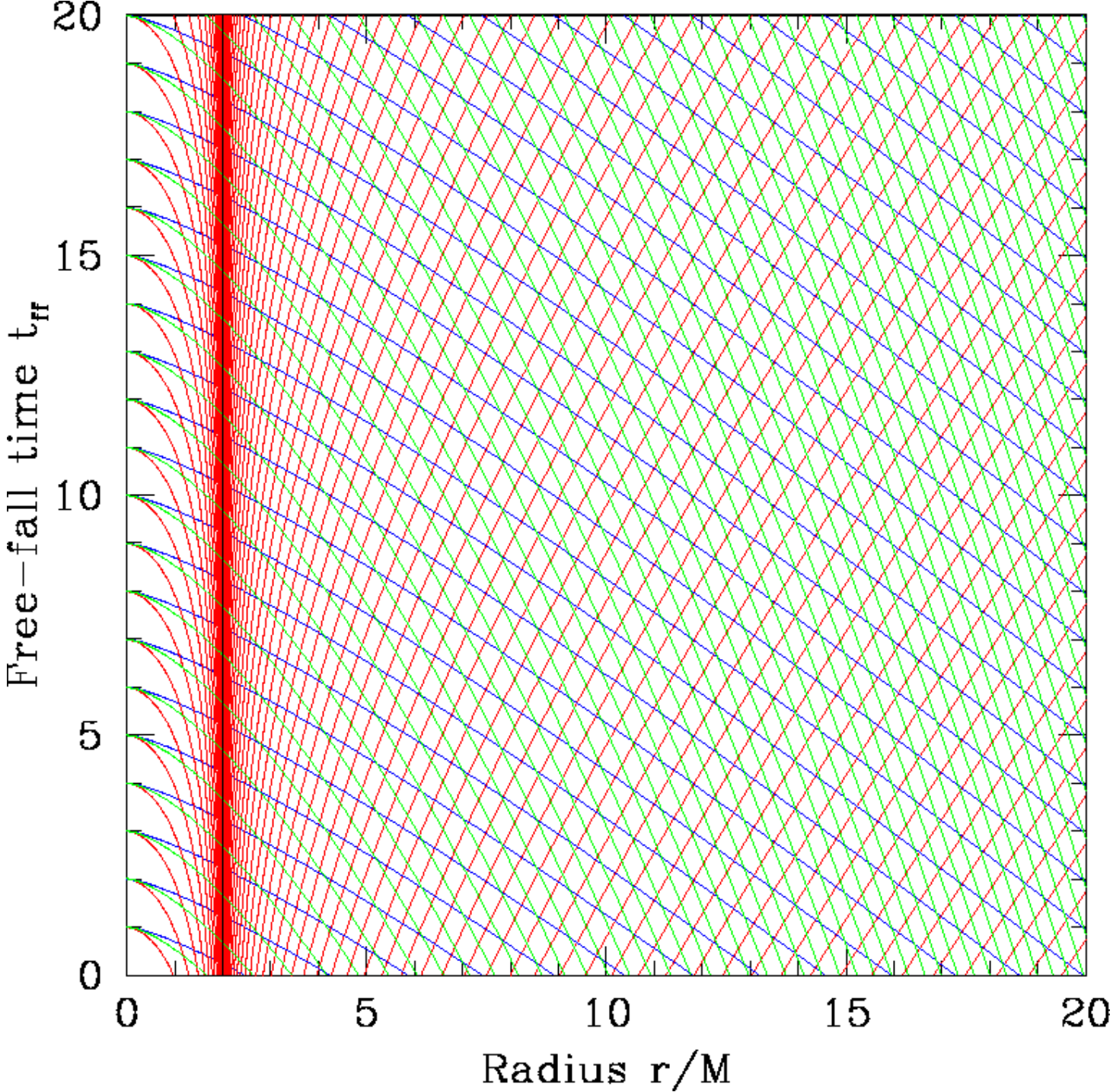
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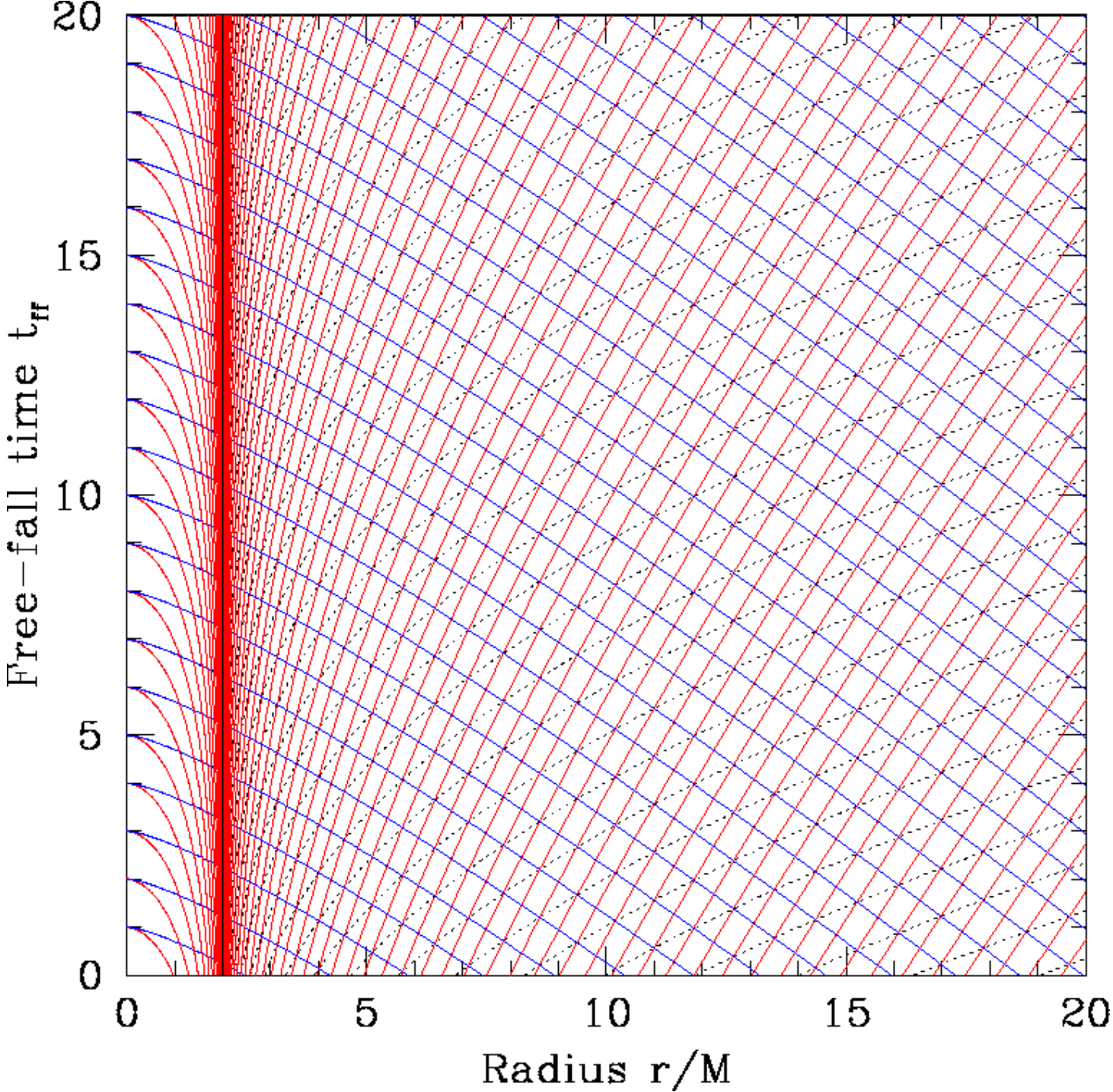
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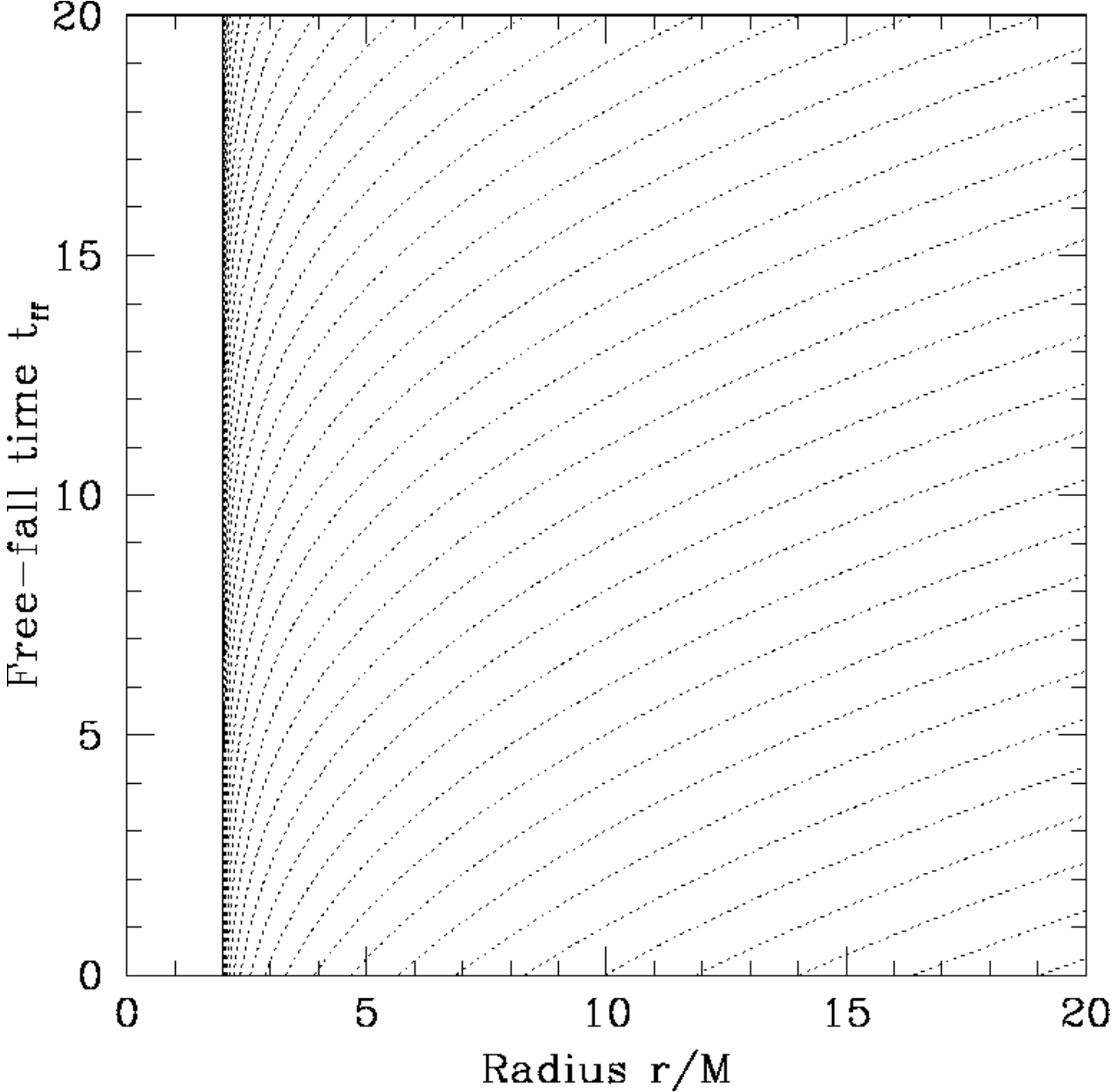
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Radius r/M

The river model explains

- Event horizon & interior (not singular, compare to Niagara swim)
- Tidal forces
- Why t breaks down at horizon
- Why “excess radius” near horizon

How would you die?