

General Relativity as Flowing Space

Given a non-rotating, neutrally charged, point mass M (Schwarzschild geometry), the general relativistic effects at Schwarzschild radial distance r from M are the same as the special relativistic effects due to relative velocity

$$|v| = (2GM/r)^{1/2} \text{ [see derivation below].}$$

Thus, warped 4D spacetime is equivalent to 3D space moving at velocity v toward M (relative to a stationary observer at distance r from M). Also, motion of an object through static space at velocity v is equivalent to flowing space moving at velocity $-v$ past that stationary object.

Select **Rain** to see Schwarzschild geometry from a **Rain** frame observer's point of view (free falling from far away past location at distance r from M).

x, y Grid: local free-fall (rain) spatial coordinates

t Clocks: local free-fall (rain) time coordinates

Select **Shell** to see Schwarzschild geometry from a **Shell** frame observer's point of view (at constant distance r from M).

x', y' Grid: local stationary (shell) spatial coordinates

t' Clocks: local stationary (shell) time coordinates

Select **Far** to see Schwarzschild geometry from a **Far**-away bookkeeper's or mapmaker's point of view (who is at a large distance from M , with the map extended down to the light clock position at distance r from M).

x", y" Grid: global spatial coordinates of far-away bookkeeper/mapmaker

t" Clocks: global time coordinates of far-away bookkeeper/mapmaker

[the far-away frame is the Schwarzschild frame which usually has coordinates (t, x, y) , but in the Lightclock app coordinates (t'', x'', y'') are used instead; **t''** is also known as "ephemeris time"]

Derivation of the "velocity of space"

Modeling gravity as a flow of space means an initially motionless test particle free-falling from far away rides along with space. The test particle's motion, comoving with space, reveals the motion of space. We use Newton's laws to derive the velocity of free-fall (velocity of space), equal in magnitude to the Newtonian escape velocity. This is valid because, in the special case of radial free-fall from far away in Schwarzschild geometry, General Relativity and Newtonian physics agree exactly. The time used in velocity and acceleration is the proper time of the free-falling particle, because a free-falling clock maintains Newtonian time throughout its fall (always an inertial frame, acceleration-free).

let m_g be the gravitational mass of the test particle

let m_i be the inertial mass of the test particle

Newtonian force of gravity on the test particle is $F = -Gm_g M/r^2$

Newtonian acceleration is directly proportional to the force of gravity: $F = m_i a$

therefore: $F = m_i a = -Gm_g M/r^2$

using the Equivalence Principle ($m_g = m_i$) gives $a = -GM/r^2$

show this is consistent with $v^2 = 2GM/r$

by differentiating wrt proper time: $2v\dot{v} = (-2GM/r^2)\dot{r} = -2vGM/r^2$

and dividing by $2v$: $\dot{v} = a = -GM/r^2$ ✓

At the Schwarzschild radius (event horizon in Schwarzschild geometry) $r = 2GM/c^2$ and $v = -c$