General Relativity 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

$|v| = (2GM/r)^{1/2}$ [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).

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).

$$\begin{gathered}
let\ m_g\ be\ the\ gravitational\ mass\ of\ the\ test\ particle \\
let\ m_i\ be\ the\ inertial\ mass\ of\ the\ test\ particle \\
Newtonian\ force\ of\ gravity\ on\ the\ test\ particle\ is\ F = -Gm_gM/r^2 \\
Newtonian\ acceleration\ is\ directly\ proportional\ to\ the\ force\ of\ gravity: F = m_ia \\
therefore: F = m_ia = -Gm_gM/r^2 \\
using\ the\ Equivalence\ Principle\ \left(m_g = m_i\right)\ gives\ a = -GM/r^2
\end{gathered}$$

$$\begin{gathered}
show\ this\ is\ consistent\ with\ v^2 = 2GM/r \\
by\ differentiating\ wrt\ proper\ time: 2v\dot{v} = (-2GM/r^2)\dot{r} = -2vGM/r^2 \\
and\ dividing\ by\ 2v: \dot{v} = a = -GM/r^2\ \checkmark
\end{gathered}$$

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