Slicing the Schwarzschild spacetime block

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In the spacetime of a non-rotating black hole, simultaneity is typically defined using the Schwarzschild-Droste t-coordinate, interpreted as the time at spatial infinity. Under such a choice, 4-dimensional spacetime is sliced into 3-dimensional hypersurfaces, each representing a present moment of constant "time". This coordinate slicing is the same as that determined by static observers, who are situated at a fixed location outside the event horizon. I present a different choice of simultaneity, based on families of observers freely-falling in the radial direction. (Because the observers have zero vorticity such a global time is well-defined by Frobenius' theorem, see Ellis.) This choice yields a different convention of the "present" time in the Schwarzschild block universe.

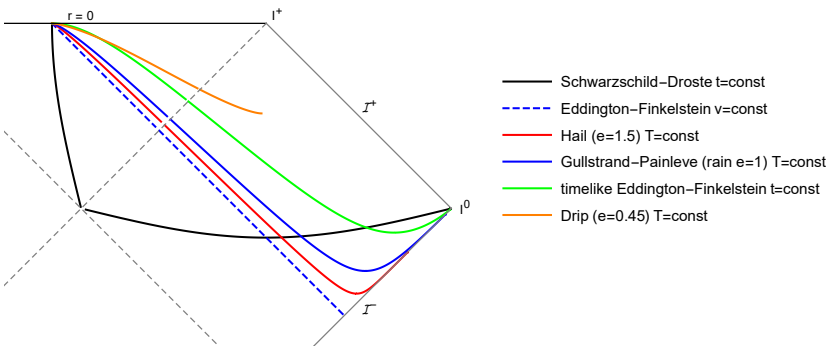

Figure 1: Simultaneity choices under various coordinates and observers, shown in a Penrose diagram. Hail, rain and drips are metaphors for radial motion at various different velocities. The plotted lines are not worldlines (mostly), but rather spatial surfaces (mostly) of constant time. Only one spatial slice is shown for each simultaneity convention, and while they particular slices coincide at the singularity they diverge dramatically near infinity.

Many familiar textbook properties of black holes are implicitly based on the static slicing. For instance 3-dimensional space has a funnel-shaped embedding

geometry (Flamm's paraboloid) under the static slicing, but the geometry of a cone under our slicing because the 3-spaces are different. The usual radial proper distance is measured along a static slice, but the alternate slicing gives a simple formula based on the observer's energy. The way "time at infinity" extends to finite locations is different under the alternate convention, which is conceptually important because of the rough analogy with human observers in the Solar System far from any black hole. Hence an object freely-falling through the horizon takes infinite time at infinity under the static slicing, but only finite time at infinity under the alternative.

I will present new coordinates to describe the falling observers, extending a generalisation of Gullstrand-Painlevé coordinates made by Gautreau & Hoffmann and others. However both the static and falling observers are mathematically well motivated from the intrinsic geometry, being determined from Killing vector fields and asymptotic flatness. If possible I will relate the implications for this simultaneity convention to the various positions on the block universe as presented at the conference.