

## Re: Mass of particles in GR field

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On Feb 6, 7:23 pm, "Rich L." <ralivings...@xxxxxxxxxxxx> wrote:

In QM energy is related to frequency by  $\hbar$ . In Relativity mass is related to energy. A particle at rest can be represented by a wave function  $\exp(-i\omega_0 t)$  where  $\omega_0$  is the frequency corresponding to the rest mass of the particle. GR predicts a gravitational red shift. I assume that this red shift applies to this rest mass frequency as well. Therefore, if I'm thinking about this correctly, the rest mass of a particle deep in a gravitational well (wrt the observer) is reduced. Is this correct, or am I missing a key concept?

Even in flat space, the wave function  $\exp(-i\omega_0 t)$  only applies to the particle at rest, and for a general inertial frame one has instead  $\exp(i k \cdot x - i \omega t)$ ,

Thus  $\omega_0$  corresponds to the energy,  $E$ , of the particle, rather than the rest mass (and  $k$  corresponds to the momentum,  $p$ ). The rest mass is given by  $m^2 = E^2 - p^2$  in all inertial frames (units  $c=1$ ), and so if the particle is not at rest then both  $E$  and  $|p|$  must increase.

To bring in gravity and GR, the generalisation of rest mass for a freely falling particle is

$$m^2 = g_{uv} p^u p^v,$$

where  $g_{uv}$  is the metric tensor (signature  $+---$ ), and  $p^u$  is the 4-momentum. Here, if the spacetime coordinate of the particle is  $x^u$ , and the time measured by a clock falling with the particle (i.e., in the rest frame of the particle) is  $T$ , then the 4-velocity is given by  $dx^u / dT = p^u / m = p^u / \sqrt{g_{uv} p^u p^v}$ .

The geodesic equation implies that  $m$  is a constant of the motion.

Thus, the rest mass doesn't change at all while falling to the horizon.

If this is correct, then by the time such a particle reaches the event horizon it's apparent mass (as seen by the observer higher in the well) will be reduced to zero (since  $g_{00}$  goes to zero at that point). If the particle was allowed to fall freely to this point, I assume all the rest mass energy has been converted to kinetic energy. Of course in the frame comoving with the particle it would always have

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the original rest mass.

No, all observers will see the same rest mass, since it is an invariant as noted above. However, any observer at a fixed location above the horizon will never actually see the particle reach the event horizon, or fall through it (since nothing can escape from the horizon or from within it).