

Questions and answers, and references for the presentation,
“Relativity, Time and Black Holes”,
by Prof. Ted Jacobson

Here are some of the questions people asked after my presentation, with very brief answers.

Q: Is the time difference in the twin effect just a result of the type of measurement or is it a real physical thing?

A: It is real. It corresponds to comparing the number of vibrations of two identical physical systems.

Q: Is there also an effect on lengths?

A: Yes, length contraction. I just focused on time for simplicity.

Q: If you could travel at the speed of light would you not age at all?

A: Yes, but nothing with mass can go at the speed of light.

Q: Since gravity is the attraction between matter, how can light be attracted by the sun?

A: Newton said that gravity is the attraction of masses, but because of Einstein's $E = mc^2$ (Energy = mass x (speed of light squared)), Einstein realized that in fact gravity is caused by any form of energy including light energy, not just mass. So when the sun pulls on light, the light also pulls on the sun. (Since the sun is so massive, it hardly moves at all however.) In the early universe however, the light radiation was so intense that the gravitational effects were dominated by light, not matter.

Q: Since time runs slower lower down in a gravitational well, if I want to live longer, should I live at sea level instead of on a mountain?

A: It depends on what you mean by “longer,” that is, longer than what? You will experience your biological lifetime the same way whatever level you live at. The same amount of time will pass for you. However, if your twin, born at the same time as you, spends his life living on a mountain, then if he comes down to sea level for your 30th birthday party he will be older than you. In that sense, you will have longer to live from that point on than he will. On the other hand, he will have experienced more time up to that point than you.

Q: If I fall into a black hole, will I see the entire past, present and future of the universe in one flash as I cross the event horizon?

A: No, you will see only signals on your backward light-cone, which come from your past.

Q: If the universe has enough matter to re-collapse, does that mean we are inside a black hole?

A: No. It is similar in that in both cases we fall into a final singularity. It is different in that there is nothing corresponding to the event horizon and therefore no region outside the event horizon in the collapsing universe case.

Q: Are all singularities the same?

A: No, they differ vastly in how spacetime is "shaped" there, i.e. in how the curvature becomes infinite. The big bang singularity is very different as far as we know from the singularity inside a black hole. Hence if our universe really did come from the singularity of a black hole in another part of the universe, some process must have interpolated between the two types of singularity.

Q: If you could go faster than light would you age backwards?

A: Hypothetical faster than light particles called "tachyons" have been imagined consistently with relativity, in which case it turns out that messages could be sent backwards in time. However, nothing would "age backwards". If relativity is not exactly right then it might be that some things can go faster than light without the possibility of backwards in time travel.

Q: I read a newspaper article about modifying $E = mc^2$. What's that about?

A: There are some recent ideas that relativity might be only approximately correct. Modern experimental laboratory techniques and observations of high energy particles from space are allowing for much more stringent tests of relativity than previously possible. So far no deviation from relativity has been observed.

References

A few places to start:

Black Holes and Time Warps, K.S. Thorne

General Relativity from A to B, R. Geroch

Flat and Curved Spacetimes, G.F.R. Ellis and R. Williams