Recent Work by Mashhoon et al.

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Mashhoon and others are attempting to go beyond present theory. I do not hold out much hope for their success. It is difficult to understand their motivation and I am not clear that it addresses the problem I raise above. Some references for Mashhoon's work are:

- Acceleration-Induced Nonlocality, arXiv:gr-qc/0301065v1 (17 Jan 2003)
- The Hypothesis of Locality and Its Limitations, arXiv:gr-qc/0303029v1 (7 March 2003)
- Nonlocal Special Relativity, arXiv:0805.2926v1 [gr-qc] (19 May 2008)

Acceleration in Relativity discusses Mashhoon's locality hypothesis, which is a generalisation of the clock and ruler hypotheses in relativity theory. There is already a lot of discussion about the latter in the literature, but I think Bell's paper *How to Teach Special Relativity* says everything we need to know about them: they are statements about specific clocks and rulers which tell us under what conditions they are likely to adequately fullfil their function; and furthermore, our present theories make clear predictions about each specific case, so these hypotheses are always superfluous. I suspect that the same goes for the locality hypothesis. As I understand it (private communication), the locality hypothesis is only superfluous in this sense for Mashhoon because he has developed a non-local relativity theory which allows one to obtain locality as an approximation. My contention is still that it is superfluous without needing his non-local theory, and I fear he does not sufficiently consider the problem of the irrelevance of accelerating observers that I am putting forward.

There is detailed discussion of the more elementary parts of several of the above papers in my aborted third book *Acceleration in Relativity*. My observation there is that he does not try to introduce acceleration symmetries into our theories of non-gravitational physics, nor even consider that, and he confirmed that in an email exchange (if I understand correctly). This suggests that there is no direct connection with my contention that we waste time trying to put ourselves in the shoes of accelerating observers. However, the starting point for his theories is precisely that all real observers will necessarily be accelerating to some extent, and his aim (private correspondence) is to approach the problem of quantising gravity from a quite new angle, on the basis of this observation. This is therefore worth investigating and I believe he is more than willing to discuss these ideas. I still have a long way to go to understand the main part of his theory published with Hehl [F.W. Hehl, B. Mashhoon: A formal framework for a nonlocal generalization of Einstein's theory of gravitation, arXiv:0902.0560v2 [gr-qc] (6 Apr 2009)], so the comments below need to be considered critically.

Just for the sake of completeness in this thoroughly incomplete confrontation of ideas, I asked Mashhoon about my contention that there is a logical problem even in defining a physical quantity for an accelerating observer. I put the problem like this. If we design two different detectors to measure the same physical quantity, then whenever they are moving inertially with the same velocity under the same physical conditions (of whatever is being measured), they will deliver the same value, regardless of that velocity (provided they each have the same velocity, of course). This works because of the Lorentz symmetry of the physical theories that govern both the physical quantity being measured and the measuring device. But when they accelerate with the same acceleration under the same physical conditions, then there is no theoretical reason (according to present theories) why they should deliver the same value.

Note in this context that we know from investigation of the acceleration of the Unruh–DeWitt detector through a quantum vacuum that what a device registers under the same physical conditions can depend radically on whether it has zero or nonzero acceleration, and without some kind of acceleration symmetry in the theory, this constitutes a fundamental reason why one could not naturally define a physical quantity to be what such-and-such a device will measure. One could choose a specific device and use that for the definition, but that would not be a canonical choice.

Even the theoretical ploy of transforming the expression of the physical quantity from an inertial frame to some accelerating frame, in order to define it in that frame, fails here because there is no canonical accelerating frame, and that for the same reason that there is no canonical definition of length and time due to the measurement problem outlined above.

On the face of it, the kernel in his theory, introduced in the first and third of the three references listed at the beginning of this discussion, is modelling the effect of acceleration on a particular measurement device under particular physical conditions and conditions of acceleration. In that case, I presume that it would not in any way represent some universal effect of acceleration in the symmetry sense mentioned above.

In his reply, Mashhoon confirmed the last point but considers that his explicitly acceleration-dependent kernel is indeed a universal effect of acceleration. He also considers that the logical problem I just raised does not threaten his theory, because without even knowing the design of the two detectors I mention, he finds that the kernels his theory associates with them will be the same. It is obvious to me that I do not yet understand this kernel.

I still feel that Mashhoon underestimates the difficulty I raise about accelerating observers. For example, he says at one point: Suppose some device does not behave in the standard manner; then, one can see how it behaves under different accelerations and put this observational data on a microchip and include it with the device, so as to correct things and render the device standard. But my worry here is that there may be no standard manner for accelerating devices to behave. What is the standard that we are trying to aim for with the microchip?

Again, he says: I agree that if you do not know what an accelerated observer measures, then a priori you have the logical problem you mention, as the true theory might be probabilistic in nature. In fact, my worry is this: is there something that an accelerating observer should measure? It still seems to me that, if there is no acceleration symmetry in our theories of physics, then there is no canonical way to define physical quantities for that observer, and this is why I think his theory must assume, or perhaps imply, acceleration symmetry.

So I am still puzzled by: All the devices employed in nonlocal special relativity are such that their internal mechanisms are robust and thus so slightly affected by acceleration that for the whole duration of measurement these internal inertial effects integrate to a negligible influence on the outcome, so they are all standard by assumption in order to let the kernel show us all the explicit effects of acceleration. This once again assumes that there is such a thing as a standard device.

He answers as follows: The fundamental physical flaw with your logical argument is that such inertial devices do not exist in nature. The symmetry deals with ideal things that do not in fact exist at all. You have to have acceleration in nature, but these accelerations, with all their inelegance and troubles, have allowed people to discover wonderful laws of nature. Therefore, your logical question can be answered in the positive both in standard special relativity and in my nonlocal special relativity. These two theories both rely on the imagined existence of hypothetical standard devices and one postulates locality and the other generalizes it to a nonlocal theory.

In fact, I think we thus ended up talking at cross purposes. The main problem I raise is that there is no canonical definition for a physical quantity to be associated with a given accelerating observer. The usual transformation of the standard definition to some given frame adapted to that observer may seem like the natural choice, but that will depend on the frame, and there is no canonical choice of frame adapted to the motion of an accelerating observer. And one cannot use some standard device as the definition, by taking its readings to give the value of the physical quantity, because there is no reason why the values it gives when accelerating should agree with those of another standard device of different design. This follows because our theories contain no acceleration symmetry. The existence of the velocity symmetry we call Lorentz invariance explains why these difficulties do not arise if we wish to define physical quantities in a canonical way for inertially moving observers.

So the problem is not whether there are ideal detectors. We get around that, theoretically at least, by imagining sequences of better and better detectors. The problem is that, according to our non-acceleration symmetric theories as they stand, we just do not know what it is that we should measure.

I also contend that physically this is a non-problem in the sense that it does not matter at all for our present theories. They still make predictions about what will happen to any particular detector when it is accelerating. Why do we need a new theory for that, therefore? Indeed, why should we need to define a physical quantity to be associated with a given accelerating observer? What would that do for us? The only important thing is to be able to predict what will happen to a given detector when it accelerates, and our theories can always do that, in principle, even though the predictions may turn out to be wrong.

In discussions of the Unruh effect, and other cases where observers follow the flow curve of a Killing vector field, there is a theoretically canonical definition for certain physical quantities that could be associated with such observers. But why bother? We can define an energy, but it is not the same energy as we know and love in the standard formulation of physics. What is gained by talking about this energy, or building a whole new particle picture for such observers? Surely the only important thing, once again, is to be able to predict what will happen to detectors, e.g., the Unruh–DeWitt detector, when they follow such worldlines, and the theories we have can do that.