ACCELERATION IN MINKOWSKI SPACETIME

For an object moving in space the following is valid: it is possible to define a coordinate grid, with space dimensions and a time dimension, and all physics taking place can be mapped unambiguously in that coordinate grid. This coordinate grid also defines a 'plane of simultaneity'. What happens to that plane of simultaneity when the object proceeds through a phase of acceleration? Animation 5 suggests that during acceleration the object's plane of simultaneity sweeps through spacetime, settling on another orientation. That "sweeping" is just a metaphor; the 'plane of simultaneity' is only a mathematical abstract, there is no tangible physical counterpart. The point is that during a phase of acceleration it is not possible to map the surrounding space (and the objects in it) in a Minkowski diagram that is co-moving with the object that is accelerating. If you would try you get a mapping with intersecting planes of simultaneity, which is absurd.

Wikipedia has a very impressive animation: motion along a curvilinear worldline.

This is not a matter of whether special relativity can deal with acceleration. Special relativity can deal with acceleration perfectly well, provided you map the motion in an inertial coordinate system. Then the motion of that accelerating object is represented with a curvilinear worldline. The limitation of special relativity is that Minkowki spacetime diagrams are linear, and they extend infinitely. So you can't have Minkowski spacetime diagrams that are co-moving with an object that is accelerating, with the worldline straightened out, such diagrams are not self-consistent.

The animation suggests that something profound happens during physical acceleration. During physical acceleration, an object's relation to its surroundings changes.

Spacetime as a physical entity

In trying to understand special relativity common sense offers no guidance. Special relativity runs very much against expectation. Among the most counterintuitive aspects is the fact that special relativity attributes *physical properties* to spacetime. Minkowski spacetime is a physical entity, participating in the physics taking place. The nature of this participation is that the amount of proper time that elapses in travelling from a certain point A to a certain point B is path dependent. In travelling from point A to point B along a trajectory that is not the spatially shortest trajectory, a smaller amount of proper time elapses than when travelling along the spatially shortest path. This path dependence is key, and to emphasize its importance I'll put it in a box section.

In travelling from point A to point B along a trajectory that is not the spatially shortest trajectory, a smaller amount of proper time elapses than when travelling along the spatially shortest path. The Minkowski metric quantifies the relation between difference in lapse of proper time and difference in pathlength travelled.

Minkowski spacetime is a very interfering spacetime. Classical spacetime is, by comparison, a rather passive spacetime; if you travel in classical spacetime then the path you take is inconsequential. Not so in Minkowski spacetime: not taking the spatially shortest path has physical consequences.

Difference with ether theories

The major difference between ether theories and relativistic physics (arguably the only difference), is that in the case of relativistic physics velocity with respect to the assumed background structure (spacetime), does not enter the theory. It's important to observe the contrast: difference in spatial pathlength not only enters special relativity, it's crucial, and so is acceleration with respect to the background structure. But as a matter of principle*velocity* with respect to the background structure does not enter.

What does and does not enter special relativity:

· Difference in spatial distance travelled: fundamental
· Velocity relative to Minkowski spacetime: does not enter.
· Acceleration with respect to Minkowski spacetime: fundamental.

Time derivatives: Position, Velocity, Acceleration

In classical dynamics the concepts Position, Velocity, and Acceleration are thought of as forming a sort of cascade. Velocity is the time derivative of Position, and Acceleration is the time derivative of Velocity. The "downstream" concepts are thought of as *deriving* from the upstream concept. The downstream entity being a derived entity implies that it must be dependent on its primitive.

- Position
    -
    - Velocity
        -
        - Acceleration

I will refer to the above scheme as **the cascade model**

Quite a few people rely on a tacit assumption that the cascade model carries over from classical dynamics to relativistic dynamics. Given that velocity with respect to inertial space does not enter special relativity it appears that the downstream concept, *acceleration* with respect to inertial space, cannot exist in special relativity either. But the tacit assumption is wrong: the cascade model doesn't carry over.

The twin paradox

There is that most famous paradox of all special relativity paradoxes: the twin paradox. It's interesting to examine why the twin paradox is surrounded with so much tension.

What if you expect that acceleration with respect the background structure does not enter special relativity? If that is the case then the twin scenario constitutes a true paradox. For those who perceive the twin scenario as a true paradox it appears as if there's something fundamentally wrong with relativistic physics. Such people argue that the twin paradox is a straightforward *refutation* of relativistic physics.

There are numerous discussions of the twin scenario, written for the purpose of showing that the twin scenario doesn't refute special relativity. Usually all that is shown is that the mathematics of special relativity is free from self-contradiction. But that doesn't address the actual issue. Those who argue that special relativity is illogical are tacitly assuming that the *cascade model* carries over from classical physics to relativistic physics.

As an example of extensive discussion that doesn't touch the actual issue, read the Usenet Physics FAQ discussion of the Twin scenario. At the very end the author quotes a joke to express in what way his own discussion leaves him dissatisfied:
"Your Honor, I will show first, that my client never borrowed the Ming vase from the plaintiff; second, that he returned the vase in perfect condition; and third, that the crack was already present when he borrowed it."
In all, the discussion in the Physics FAQ presents something like three or four different "rebuttals". This weakens the case rather than strengthening it.

This is what makes special relativity counterintuitive: as a matter of principle velocity with respect to the background structure does not enter the theory, but acceleration with respect to the background structure is fundamental.

Source:

http://www.cleonis.nl/physics/phys256/special.php#section_1