Is Special Relativity compatible with General Relativity?

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Abstract

Is special relativity theory applicable to the universe, as this theory was developed for places with no gravity? Is Special Relativity compatible with General Relativity?

Yes, both theories are compatible although there is a difference between Special Relativity (SR) and General Relativity (GR).

SR relates to speed and time, it was developed by Einstein in 1905 and was based on works done by Newton, Lorentz, Maxwell, Michelson-Morley, and others. GR was suggested by Einstein in 1916 to generalize SR, by including acceleration. According to the equivalence principle, acceleration and gravity are equivalent. As the universe is full of celestial bodies gravity exists everywhere.

SR is based on two main postulates:

1. The laws of physics are invariant (that is, identical) in all inertial frames of reference (that is, frames of reference with no acceleration).
2. The speed of light in the vacuum is the same for all observers, regardless of the motion of the light source or observer.

From postulate 1) of SR it can be concluded that SR is applicable only in deep space, far away from any celestial body, where there is no gravity. Therefore, using SR to solve problems in the universe where gravity exists is not applicable. Nevertheless, SR is used in places that are influenced by gravity, e.g., in the vicinity of Earth. An example is the global positioning system (GPS), which is used many million times a day.

GPS is comprised of three different segments: the space segment, control segment, and user segment. The space segment includes 30+ navigation satellites circling Earth at an altitude of 20,000 km and a speed of 14,000km/h. The control segment is a ground station and the user segment e.g., cellular phone.

According to Einstein, the rate of advance of two identical clocks placed one in the satellite and the other on the ground station, will differ due to the difference in the gravitational potential (GR) and the relative speed between them (SR). From GR, it can be calculated that the orbiting clocks in the satellites tick slightly faster than the clock at the ground station, by about 45 microseconds per day. On the other hand, from SR calculations the orbiting clock ticks slower, about 7 microseconds per day. The net result is that time on a GPS satellite clock advances faster than a clock on the ground by about 38 microseconds per day. If relativity compensation is not taken into account, it would cause navigational errors that accumulate to 10 km per day!

The question is how is SR applicable in gravity fields, in contrast, to postulate 1?

My claim is that SR is applicable in cases where the time of a measurement is small enough so that the change of references frame is negligible. The reference frame direction of the satellite orbiting Earth is constantly changing relative to the reference frame of the ground station. But as the time of measurement is very small, it can be assumed that the frames of reference are not changed.

The following figure shows that at the beginning references frames $G_0$ and $S_0$ are parallel, but if the measurement time is big then the frames $G_f$ and $S_f$, are no longer parallel and are rotated by angle Φ. The smaller the measurement time, the smaller is Φ and the reference frames stay nearly parallel.