November 2001 Meeting: An Insight Into Relativity

by John Geohegan

Einstein's Special Theory of Relativity (SRT) is generally misunderstood for several reasons. Most of us have no need to apply its principles, nor do we have any experience with objects moving at close to the speed of light. Even so, we would like to understand SRT. Popular explanations refer to moving objects gaining mass and shrinking in the direction of motion, and moving clocks running slow, but these explanations are referring only to appearances in much the same manner as statements about the sun rising in the morning, moving eastward across the sky, and setting in the evening. We accept that the sun appears to rise in the morning and we can calculate exactly when the "rise" will occur, but a more accurate and lengthier statement would deny that the sun truly rises and explain the appearance by referring to the rotation of the earth.

Just as the formulas for calculating the sun's apparent motion are likely to contribute nothing to understanding the reason for the appearances, applying the formulas of SRT really doesn't reveal why objects appear to contract and clocks appear to run slow. It's perfectly possible to apply the set of relativistic equations called the Lorentz transformation and obtain a correct numerical answer without having a clue as to why the equations work so well. This is number-crunching without insight.

The following example offers a simple way of gaining insight in relativity.

Imagine two space ships have just passed each other and at the moment of closest approach they have synchronized their clocks at 12:00. As they draw farther apart each sends out a flash of light precisely as his own clock indicates each hour. Brian will receive Alfred's 12:00 signal when his clock reads 12:00 because the signal has no distance to travel, but Alfred's 1:00 signal will be received at some time later than 1:00 depending on their relative velocity. To make things easy, suppose the velocity is great enough that Brian receives Alfred's hourly signals every two hours by his (Brian's) clock. SRT tells us that the same conditions will apply to Alfred; he will receive Brian's clock signals every two hours, at 12:00, 2:00, and 4:00 by his (Alfred's) clock.

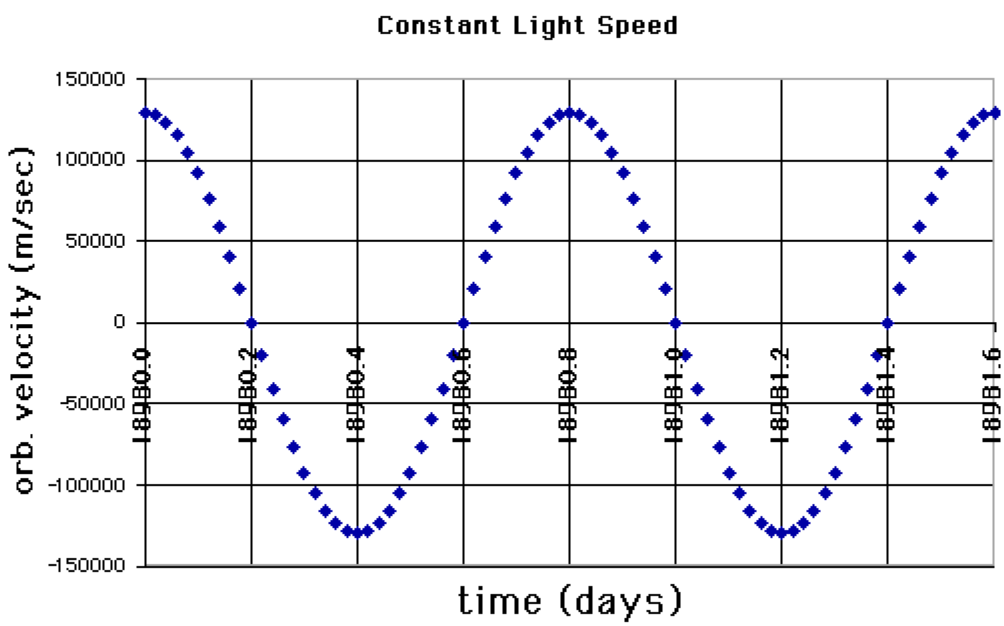
Consider the signal sent out by Alfred at 1:00. It is received by Brian when his clock reads 2:00 and reflected back at the same time to be received by Alfred when his (Alfred's) clock reads 4:00. Not being able to see Brian's clock, Alfred calculates that the signal must have reached Brian at 2:30 (halfway between 1:00 and 4:00). If informed that Brian's clock actually read 2:00, Alfred might conclude that it was a half-hour slow, and thus we see what it was that Einstein discovered: measurements of time intervals depend upon relative velocity. Of course, if Brian sends out a signal when his clock reads 1:00, exactly the same values will be repeated and he will see that Alfred's clock is apparently running slow. Without the insight made possible by this simple example it's possible to misinterpret SRT as claiming that A's clock is running slower than B's at the same time as B's is running slower than A's.

The same example, slightly extended, can be used to explain the so called "twin paradox", which is not a paradox at all. If after traveling for two hours by his clock, Brian were to suddenly change to a return trip at the same relative velocity, he would start receiving signals at the rate of two per hour instead of one every two hours. On his two hour return home he would thus receive four more signals sent out by

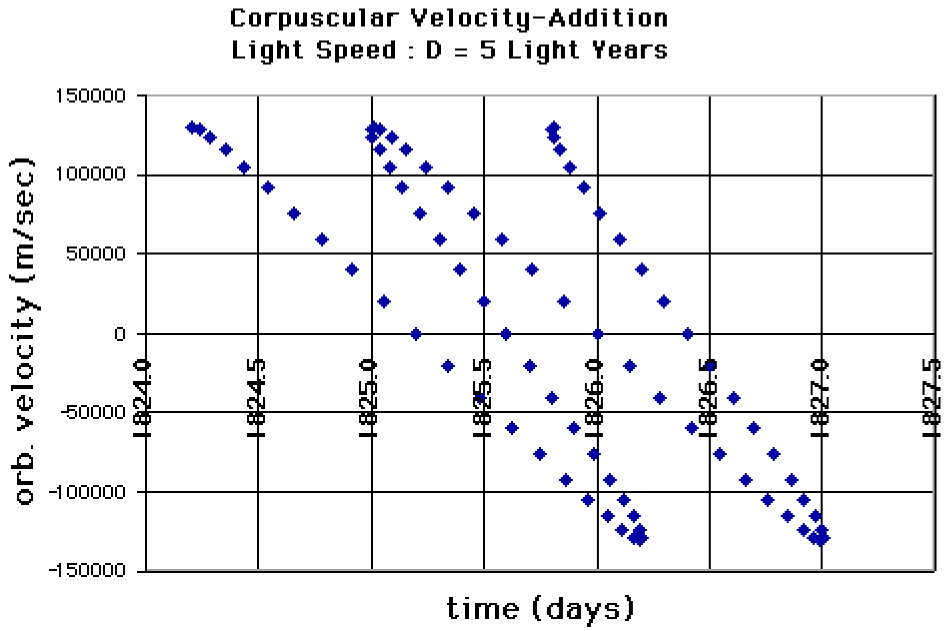
Alfred, arriving home just as Alfred was sending his 5:00 signal. Alfred would have aged five hours while Brian aged only four. This problem illustrates the relativistic nature of time intervals.

It must not be thought that SRT deals only with some sort of illusion. Einstein's theory unified electricity and magnetism and is tested every day for meaningful predictions. The Global Positioning System tests Einstein's predictions millions of times each day, worldwide, and reveals the magnificence and practicality of relativistic calculations.

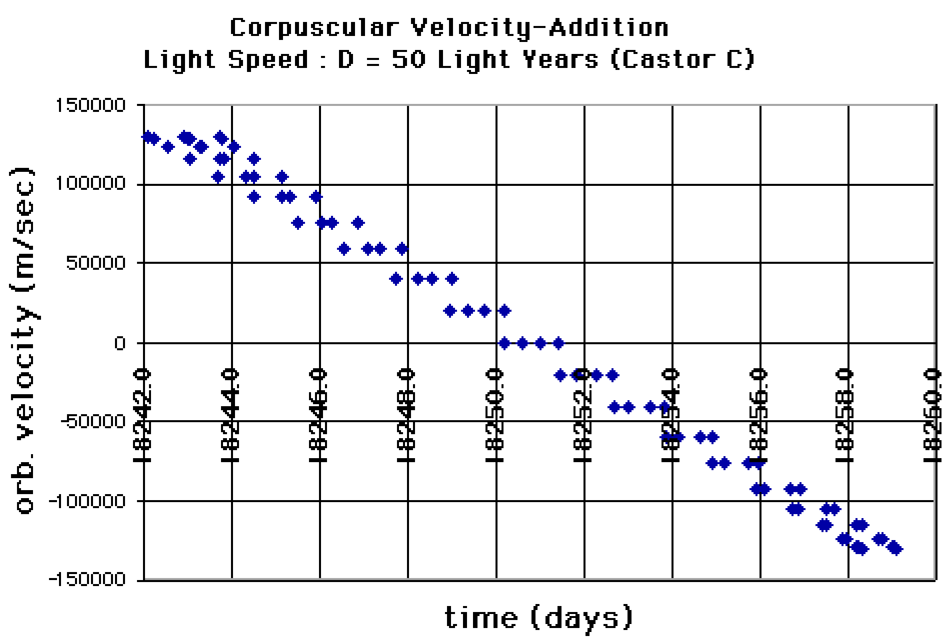
The following images, by Dave Thomas, show how Doppler measurements of the binary stars in system Castor C (in the constellation Gemini) agree with Einstein's theory (speed of light is constant invacuum), but do NOT agree with the predictions of theories in which the speed of light depends on the speed of the light-emitting source.



Expected Time/Velocity Curve of One Star of Castor C (Binary System), if Einstein was RIGHT (Light travels at 299,792,458 meters/sec)

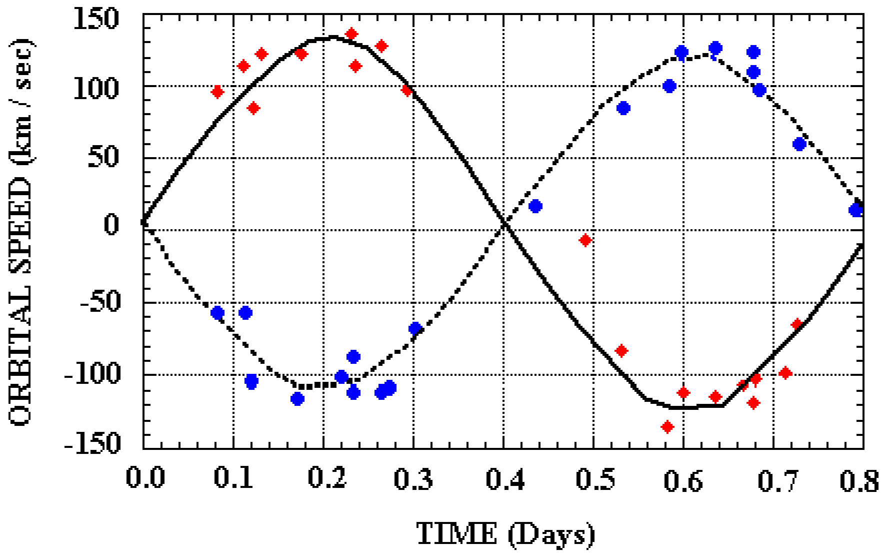


*Expected Time/Velocity Curve of One Star of Castor C (Binary System), if Einstein was WRONG (Light travels at c=299,792,458 m/sec ± **motion of source**); here, Castor C is 5 light-years away. At orbital speeds of 0.0004c, transit times will vary from 5 lightyears/(1-.0004)lightyears/year = 5.002 years = 1827.0 days,to 5 lightyears/(1+.0004)lightyears/year = 4.998 years = 1825.5 days, or about 1+1/2 days.*



*Expected Time/Velocity Curve of One Star of Castor C (Binary System), if Einstein was WRONG (Light travels at c=299,792,458 m/sec ± **motion of source**); here, Castor C is 50 light-years away (about actual). At orbital speeds of 0.0004c, transit times will vary from 50 lightyears/(1-.0004*

)lightyears/year = 50.02 years = 18270 days,to 50 lightyears/(1+.0004)lightyears/year = 49.98 years = 18255 days, or about 15 days.



The actual measurements of both of Castor C's binary stars look decidedly like the first graph, and demonstrate very strongly that Einstein was right. At the binaries' relatively small speeds, the differences in calculated velocities between classical and Einsteinian Doppler shifts is insignificant - only a few miles per hour out of hundreds of times the speed of sound.