2022 9th International Conference on Advanced Materials and Computer Science (ICAMCS 2022)

Special Theory of Relativity in Interstellar - Twins Paradox

Mingzhan Yang

Wesleyan University, Middletown, Ct, 06459, United States

Keywords: Twins paradox, Special relativity

Abstract: In October 1905, the German journal "Annals of Physics" published a paper "On the Electrodynamics of Moving Objects", which announced the advent of the special relativity hypothesis, from Einstein's special relativity can be derived from the existence of a time expansion effect on moving objects. At the Pollon Philosophical Congress in April 1911, the French physicist Paul Langevin used the twin paradox to question the time expansion effect of special relativity, this paper discusses the twin experiment, and through the analysis of theory and practical cases, proves the correctness of special relativity and solves the problem of twin paradox.

1. Introduction

1.1 Background

In the general perception, time is seemingly fair and divine to all, thus humanity tries to compress and save, using the utmost effort to pursue efficiency in the completion of mundane tasks as well as significant goals. In fact, although we cannot change time now, in the future we can achieve true time travel, and it may only take a brief moment to travel from home to a distant planet light-years away. So, today I want to talk about the Twins Paradox, which is a way to show that traveling by high velocity causes different ages. The definition of the Twins Paradox is: the apparent paradox arising from relativity theory that if one of a pair of twins makes a long journey at near the speed of light and then returns, he or she will have aged less than the twin who remains behind. Here is the graph of the three planets on the XY plane[1].

1.2 Description of Twins Paradox

If we want to go to 51 Pegasi b, which is a plant about 50 light years away from Earth. There are two ways we can choose. First is across to GLIESE 581 which is a planet similar to earth and only 20 light years away from us. Another is direct to 51 Pegasi b. As shown in Figure 1.

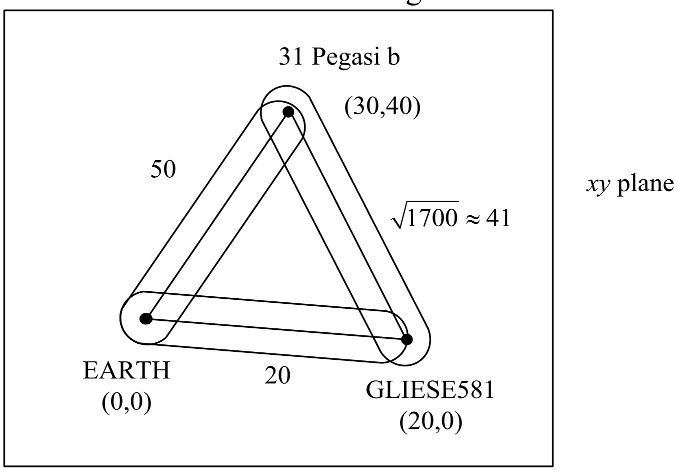

Fig.1 51 Pegasi B

Assuming we can reach eighty percent of the speed of light, now invite our protagonist Leo to play. He just turned 18 this year and he is a Greenland Shark from the Arctic Ocean. He wants to travel to this new planet on behalf of shark kind. Leo is flying from Earth to GLIESE 581 in a spaceship! And then he will go 51 Pegasi b. Of course Leo also has two twin brothers, Eric and

Stevin. In order to make a race with Leo, Eric decided to take different spaceships to set off at the same time as Leo. Instead of traveling, Stevin will stay on the Earth to wait for his brothers' return[2.3].

Twenty-five years later, Leo arrived at GLIESE 581, which the whole world is curious about. Then, he doesn't have any rest and continues to go 51 Pegasi b. Though about fifty-two years, finally, Leo launched on the planet - 51 Pegasi b. After that he used another fifty-two years to go back to GLIESE 581 and then, he directly went back to Earth for 25 years. When he arrived on Earth, he found that his brothers were both older than him. So, what happened? [4]

2. Problem Analysis

2.1 Theoretical Analysis

The X-axis and Y-axis represent light years and t-axis represents years. For Eric, he was along with the purple way, so he needed to go through $\sqrt{30^2 + 40^2}$ (using the rule of pythagoras, on the XY plane, and $x = 30$ light years, $y = 40$ light years. Then, the distance between Earth and 51 Pegasi b is 50 light years.) which is 50 years. (Since the velocity is $.8$ light year per year, the time will be equal to $50/0.8 = 62.5\, years$). And then, Eric used another $62.5\, years$ to go back to Earth. When he arrived on Earth, he only experienced 125 years$(62.5 + 62.5)$. But for Stevin, who is the brother waiting on Earth, already experienced two hundred and eight years. But for Why? By the Time dilation, $\Delta t' = \Delta t/\sqrt{1-(v/c)^2}$, we get $\Delta t' = 125/\sqrt{1-(0.8c/c)^2} \fallingdotseq 208\, years$. But for Leo, along the orange world line, since he went through GLIESE581, the first path he experienced was twenty-five years. (Since the distance between Earth and GLIESE581 is 20 light years, and the velocity is $.8$ light year per year, the time will be equal to $20/0.8 = 25\, years$). It seems simple and ordinary. The second path is similar to the path of Eric. The length of x is equal to thirty minus twenty, which is equal to ten light years.for the length of y is still forty light years.Using the rule of pythagoras, the length of the second part is $\sqrt{10^2 + 40^2} = \sqrt{1700}$ light years which is approximately equal to 41 light years. Then the time is equal to $41/0.8$, which is approximately equal to fifty-two years. Thus, the total way Leo experienced is twenty-five plus fifty-two years which equals seventy-seven years. After that, Leo came back to Earth at the same time. He totally experienced seventy-seven plus seventy-seven equals a hundred and fifty-four years. Similarly with Eric and Steven, actually, by Time dilation, Steven experienced $\Delta t' = 154/\sqrt{1-(0.8c/c)^2} \fallingdotseq 256\, years$. It is amazing. Since Eric arrived at Earth when Steven experienced $208 years$, Eric experienced another $256\, years - 208\, years = 48\, years$ on Earth before Leo came back. Hence, Eric totally experienced $125\, years + 48\, years = 173\, years$. Although Leo, Eric and Steven are twins, now Steven is much older than Eric and Leo. Also, Eric is older than Leo, nineteen years. As shown in Figure 2. And it is called the Twin Paradox[5.6].

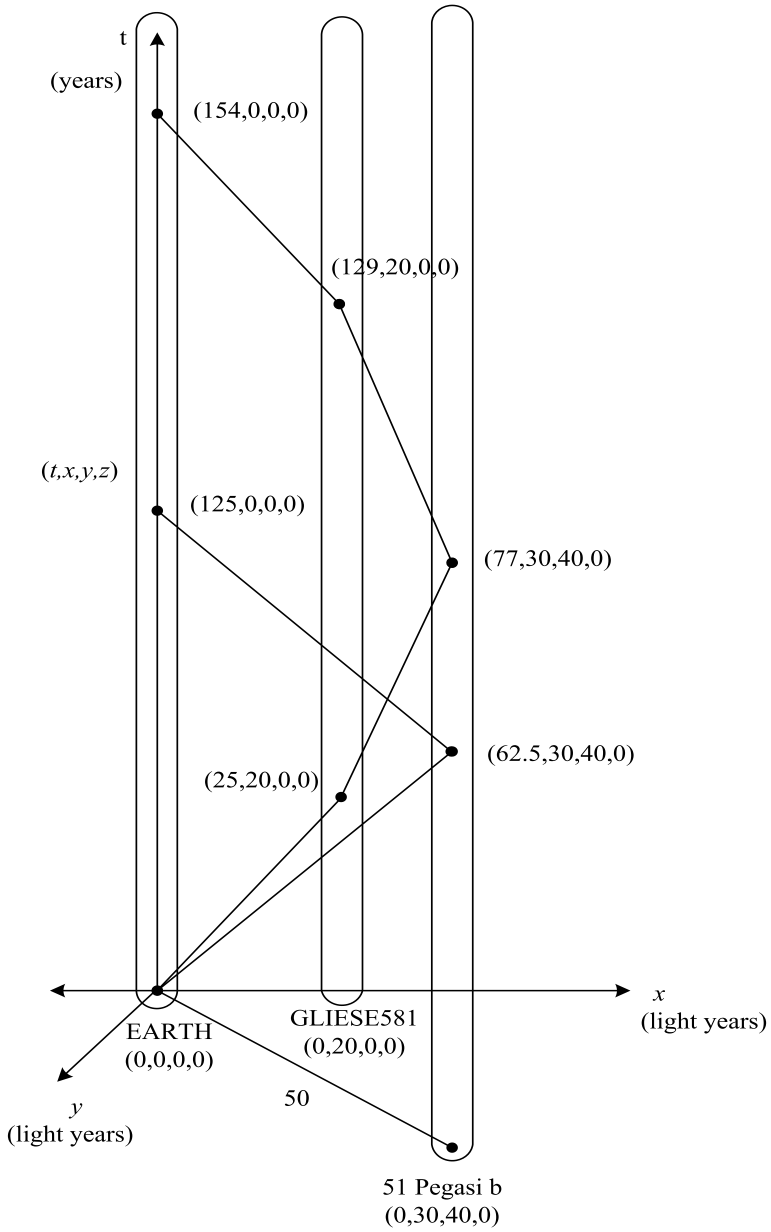

Fig.2 Twin Paradox

2.2 Experimental Proof

In 1971, in order to verify the conclusion of the twin paradox, scientists designed the atomic clock global navigation experiment. First, prepare three groups of high-precision cesium atomic clocks. One group of atomic clocks is placed on the ground as the time benchmark, and the other two groups of cesium atomic clocks are placed in two planes respectively. The plane takes them around the world in the East and west directions respectively. When the flight ends three days later, compare the two groups of atomic clocks on the plane with the group of atomic clocks on the ground to see which group of atomic clocks slows down.

Obviously, during the flight point of the aircraft, due to the rotation of the earth itself from west to East, the three atomic clocks will operate at different speeds. Among them, the atomic clocks left on the ground will be consistent with the rotation speed of the earth; The speed of the atomic clock flying eastward is equal to the rotation speed of the earth plus the speed of the aircraft; The speed of the atomic clock flying westward is equal to the rotation speed of the earth minus the flight speed of the aircraft.

Therefore, the atomic clock flying west is the slowest, the atomic clock flying east is the fastest, and the atomic clock on the ground is between the two. According to the special theory of relativity, the faster the flight speed is, the slower the time becomes. Therefore, according to the speed of clock flight, it is not difficult to know: the atomic clock flying east moves the slowest, the atomic clock flying west moves the fastest, and the atomic clock on the ground also moves between the two.

Of course, due to the gravitational field on the earth's surface, the effect of slowing down the precise time of the atomic clock also needs to deduct the general relativity effect caused by gravity. Finally, within the allowable range of error, the results of the atomic clock flight experiment perfectly confirmed this conclusion: the faster the atomic clock moves, the more obvious the effect of its time slowing down.

3. Analysis of Outcomes Using Special Relativity

It seems that the twin paradox cannot be proved according to this experimental conclusion. The core expression of this paradox is that there is also B > A when A > B.

Without doubting the correctness of the experimental process, there was only A > B, but not B> A, and there was no explanation of how to correct the logical fallacy derived from the theory and the actual conclusion to achieve consistency.

Relativity believes that the length of the world line A is the time spent by A staying on earth, and the length of B is the time spent by B doing Star Trek. The two lines are not the same length, that is, the twin brothers have experienced different lengths of time. Who has experienced it for a long time? Some people will say that A straight line is shorter than a curve, and that A takes less time than B. The twin paradox doesn't mean that B is younger than A? How can it be reversed? In fact, there is no reverse. The reason why you think that line B is longer than line A is that you are fooled by Euclidean geometry. The geometry we usually use is Euclidean geometry, and the distance between two points is the shortest. But in relativity, the geometry of four-dimensional space-time is not Euclidean, but pseudo Euclidean. In pseudo Euclidean geometry, the square of the hypotenuse is equal to the square difference between two right angled edges, and the linear distance between two points is the longest. Therefore, curve B is shorter than straight line A, and the time of B is shorter than A. The time experienced by the star traveler in twins is shorter than that experienced by his fellow brothers on earth. Therefore, when returning to meet, B will be younger than A. The twin paradox is a real effect that allows astronauts to reach very distant galaxies in their lifetime.

What about moving objects? Suppose a rocket moves from point A to point B. The rocket is equipped with a calibrated clock. We still use the midpoint clock method to place a series of calibrated clocks between the two points of AB, A1, A2 and A3, and an observer is set at each position of A1, A2 and A3 to record the time of the rocket. Everything is ready and the rocket is off. The observer at point a immediately found that the clock on the rocket became slower and slower, and the speed of time slowing down was related to the speed of the rocket. According to the observers of A1, A2 and A3, when the rocket passes their position, the indication of the clock on the rocket is the same as that of the local clock. The observer at point B found that before the rocket started, the indication of the clock on the rocket was a little slower than that at point B, but as the rocket gradually approached, the clock on the rocket became faster and faster. When it reached point B, it turned out to be the same as that at point B. If there is also an observer in the rocket, he will come to the conclusion that when the rocket moves, the clock at A o'clock slows down, the clock at B o'clock speeds up, and the time indicated by the clock passing along the way is consistent with the time on the rocket. In the above example, the motion direction of the rocket relative to A and B is different, so the results observed from point A and point B should also be different. The time relative to point A is slower, and the time relative to point B is faster. Whether time gets faster or slower depends on whether the distance between the observer and the observed object increases or decreases. The speed of getting faster and slower is related to the relative motion speed between the two objects.

4. Conclusion

The Twin paradox is just a small part of special relativity. Special relativity is a part of relativity theory. And relativity is a little bit of the stars in physics and mathematics. So mankind has a long way to go in exploring the development of mathematics and physics. I hope that one day we can really realize the dream of interstellar travel at the speed of light.

References

[1] Shuler, and L. Robert . “The Twins Clock Paradox History and Perspectives.” Journal of Modern Physics 5.12(2014):1062-1078.

[2] Mccall, S. . “Chapter 10: Philosophical Consequences of the Twins Paradox.” Philosophy & Foundations of Physics 1(2006):191-204.

[3] Frye, and M. Royal . “Paradox of the Twins.” American Journal of Physics 25.8(1957):553-555.

[4] AMELINO-CAMELIA, and GIOVANNI. “DOUBLY-SPECIAL RELATIVITY: FIRST RESULTS AND KEY OPEN PROBLEMS.” International Journal of Modern Physics D 11.10(2002):1643-1669.

[5] Glashow, S. L. . “Cosmic Ray and Neutrino Tests of Special Relativity.” Nuclear Physics B - Proceedings Supplements 77.1-3(1999):313-318.

[6] Gibbons, G. W. , J. Gomis , and C. N. Pope . “General Very Special Relativity is Finsler Geometry.” Physical review D: Particles and fields 76.8(2007):327-330.