Shaking up Einsteins theory
The anomalous acceleration of the Pioneers

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Abstract

If we assume the Lorentz contraction in Einstein's theory is based on a misconception, we can understand the unexpected acceleration found when measuring the orbital motion of Pioneers 10 and 11. Rejecting the Lorentz contraction leads to a better understanding of the concept of velocity. The actual velocity of an object, when accounting for the time delay, turns out to be slightly greater than the traditionally determined velocity. The time delay in a gravitational field decreases with distance so the actual velocity decreases compared to the traditionally determined velocity. This can be considered the anomalous acceleration measured for the Pioneers. Our calculations show that the actual velocity explains the anomalous acceleration very accurately.

Keywords: Pioneer anomaly · Special Relativity; Lorentzcontraction; Actual Velocity; Gravitational theory.

1 Introduction

A basic analysis of the theory of relativity reveals that one of the conclusions of special relativity, namely that a moving object has shrunk[1] in the direction of motion by the Lorentz factor γ, is based on a fallacy of Einstein's. To understand this, we need to apply what I call the **Fundamental Law of Physics**. We can formulate this as: 'There is only one physical reality'. This means that all observers of a physical event will describe it in such a way that their descriptions agree. Of course, they must correct their observations for the circumstances under which the observation was made.

- *If we construct a structure in which a light flash occurs when two light pulses of a certain intensity converge, we can create a well-defined event. This is achieved if, in the stationary system, the two pulses simultaneously originate from a single point, emitting a light flash, travel an equal distance horizontally and vertically, respectively, and then converge again at a single point. The light flashes at the start and finish will also be observed from a moving system, but calculations show that this is only possible if the horizontal length does not undergo Lorentz contraction.*

Based on the aforementioned fundamental principle, it can be shown that the contraction of a moving object is an error. This is discussed extensively in my book **Time and Cosmos**[2)] . We should point out that with the rejection of the Lorentz contraction, the concept of curved space—which plays a prominent role in the mathematical models surrounding relativity theory—also loses its physical significance.

On the other hand, Einstein's derivation, which showed that time in a frame moving with velocity v is γ times slower than the time in the frame from which the moving frame is observed, remains valid. This result is beyond doubt.

The Lorentz factor γ mentioned means: $\boxed{\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}}$. (1)

For the case that the speed is much smaller than the speed of light, so $v \ll c$, we may write $\gamma \approx 1 + ½v^2/c^2$ as an approximation for the Lorentz factor.

However, besides rejecting the Lorentz contraction, there's something else going on, namely the velocity of a moving object. Traditionally, the velocity v of an object is determined by measuring the time difference Δt between the instants the object passes the starting point and the end point of a distance ℓ. The velocity is then found to be $v = \ell/\Delta t$ m/sec. Naturally, we use synchronized clocks to measure time.

This method of speed measurement, however, appears to contain a (small) error because the clock on the moving object shows a different time than the clocks used for the measurement. If we take this into account, the speed turns out to be slightly higher. We call this the **Actual Velocity**. We will explain this now.

2 Actual Velocity

We can derive the following definition for what is meant by actual velocity. We assume (see Fig. 1) that an object of length ℓ meters between the front point A and the rear point A* – that is, frame AA in which all clocks are synchronized – is moving relative to another object extending from the front point B to the rear point B* – frame BB – also of length ℓ meters and also with synchronized clocks. These two objects (frames) are moving relative to each other along their length. At time **t=0**, points A and B pass each other at point Q.

- *Figure 1 shows a **timeline diagram** in which the objects are drawn at an angle to each other to show the passage of time over the object. Also noted is that the diagram shows the time lead (top point) or time lag (bottom point) at a specific location **x** along the X-axis in one frame relative to the other. In this symmetrical situation, it means that where the lines cross, the times at that point are the same in both frames.*

Of course, because the Lorentz contraction is rejected, the lengths of the systems are equal, regardless of their velocity.

The front point A of system AA moves from point B to point B*. The time at which A passes point B* is t sec according to the clock at point B*, so the velocity at which the object is traveling according to the observer at B* is $v=\ell/t$ m/s.

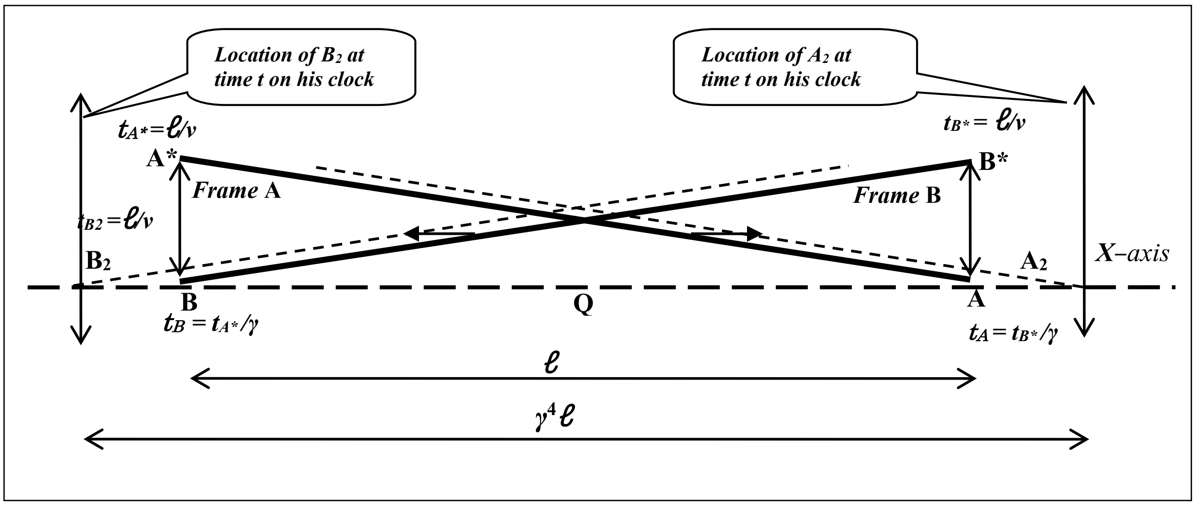

Figure 1. The dotted lines indicate the positions of the systems at time t = ℓ/v sec – according to the clocks in their respective systems – as seen from the front points. At that time, the front points A_2 and B_2 are γ^4 ℓ meters apart. The solid lines indicate the positions of the systems at that time t = ℓ/v sec, as seen from the back points. Their mutual distance is consistent with traditional views, but we must remember that these points themselves were γ^4 ℓ meters apart at the initial time t=0.

The clock at the front point A of the object moving relative to frame BB shows time t/γ sec at that instant, since the clocks in the moving frame AA are slower if viewed from frame BB (and vice versa). The end point A* of the object moving relative to the frame BB passes at that same instant precisely point B. After all, they are of equal length. The clock of A* must then show time t because point B has at that instant travelled exactly the distance ℓ in the frame AA.

People tend to think that the clock in A* should also show time t/γ sec, because clocks A and A* in that frame are synchronized according to the observers in that frame. This is incorrect, but it is one of the most remarkable results of relativity theory. It is called the relativity of simultaneity.
This same situation also applies to clock B*. We must conclude that the events at the front and back points of the objects do not occur at the same time according to the observers in that frame. The clocks in a frame are synchronized, but the event at the back point occurs slightly earlier than the event at the front point.
If we observe a moving frame whose observers keep their clocks synchronized, then, according to our observations, the clock at a point in the moving frame further forward in the direction of motion will lag behind a clock placed further back. However, all clocks in the moving frame run at the same speed for the observers in that frame. According to the observers observing the moving frame, there is a decreasing time lapse toward the forward point.
We now investigate where the point A, which displayed time t/γ when it was at B*, will be at time t. We therefore consider where A is located when its clock shows the same time as point A* with its synchronized clock. A's time will then have increased by the factor γ. It will then have travelled a greater distance.
One is inclined to think that the distance must then also be γ times greater, but one forgets that the distance $\boldsymbol{\ell}$ was covered by A in less than t sec, namely in t/γ sec. Its velocity – seen from the other frame – was apparently γ times greater. If we take both aspects into account, the distance covered becomes γ^2 times greater. That is at point A_2.
The additional distance covered is then $(\gamma^2-1)\boldsymbol{\ell} \approx (2\gamma-1)\ell$, provided that $(\gamma-1) << 1$.
The origin A of frame AA will then have moved a distance of $(2\gamma-1)\boldsymbol{\ell}$ meters in frame BB relative to the origin B of that frame. With $\gamma \approx 1+½v^2/c^2$, this results in a distance of $\boldsymbol{\ell}+(v^2/c^2)\boldsymbol{\ell}$ meters.
At time t sec, points A and B will therefore be at a distance of $[\boldsymbol{\ell}+2(v^2/c^2)\boldsymbol{\ell}]$ meters from each other. We may write this as: $\boldsymbol{\ell}+2(v^2/c^2)\boldsymbol{\ell} \approx (1+½v^2/c^2)^4\, \boldsymbol{\ell} \approx \gamma^4\, \boldsymbol{\ell}$ m.
The velocity that points A and B must attribute to each other is then $\gamma^4 \boldsymbol{\ell}/\mathbf{t} = \gamma^4 \mathbf{v}$ m/s.
Since $\boldsymbol{\ell}$ is an arbitrarily chosen length, this velocity holds at every point of the systems.
We have called this speed the **actual velocity**: $\gamma^4\, \mathbf{v}$ m/s.

The result is general: an object traveling with the traditionally measured velocity v in a frame always has a velocity $\gamma^4\, v$ m/s relative to that frame. When the object, say a race car, travels exactly **360** km/h, its actual velocity is **222x10^{-9}** m/s faster. That's very little, but in the cosmos it counts.

The Lorentz factor here $\gamma = \dfrac{1}{\sqrt{1-v^2/c^2}} \approx 1+\tfrac{1}{2}v^2/c^2$ represents the time delay due to velocity.

In a gravitational field however, we also experience a time delay. In that case, the Lorentz factor

$$\boxed{\gamma_r = 1+\frac{GM}{c^2}\frac{1}{r}} \qquad (2)$$

applies. The time delay in the gravitational field has the same effect on velocity as the time delay due to velocity.
The **actual velocity in a gravitational field** v^* of an object moving with the traditionally measured velocity v is therefore

$$\boxed{v^* = \gamma^4 \gamma_r^4 v} \text{ m/s.} \qquad (3)$$

If both $\gamma-1<<1$ and $\gamma_r-1<<1$ the approximation applies

$$v^* = \gamma^4\gamma_r^4 v \approx \left(1+2\frac{v^2}{c^2}+4\frac{GM}{c^2}\frac{1}{r}\right)v \text{ m/sec.} \qquad (4)$$

We will see in §3 that the actual velocity, because of its dependence on the distance r in the term $4\frac{GM}{c^2}\frac{1}{r}$ from the Sun, also involves an additional acceleration which plays an important role in solving the mysterious acceleration of the Pioneers.

3 Effect of actual velocity on acceleration.

If the velocity of an object at a very great distance from a large mass is v_0 m/s, then, due to conservation of energy, when the object moves past the mass, the velocity due to gravitational acceleration at the distance r is equal to:

$$v = v_0\sqrt{1+2\frac{GM}{r}\frac{1}{v_0^2}} \text{ m/s.} \quad (5)$$

With the expression for v this means for the **actual speed** that

$$v^* = \left(1+2\frac{v_0^2}{c^2}+8\frac{GM}{c^2}\frac{1}{r}\right)v \text{ m/s.} \quad (6)$$

The velocity v^* for spacecraft also hardly deviates from the velocity v traditionally calculated, because v_0^2/c^2 is of order 10^{-9} and the last term within the parentheses at **1** AU, representing the distance from the Sun where the Earth is located at $\approx 150\text{x}10^6$ metre, is of the order of $8\text{x}10^{-8}$. However, the last term does yield values that can be used as a deviation from the acceleration.
We find this acceleration by calculating how much the velocity decreases in **1** sec as the object moves radially away from the sun with velocity v^* m/s. Then the object has travelled a distance of $v^* \approx v$ meters. We find the decrease in velocity in **1** sec by:

$$\Delta g = v_r^* - v_{r+v}^* = \left(1+2\frac{v_0^2}{c^2}+8\frac{GM}{c^2}\frac{1}{r}\right)v - \left(1+2\frac{v_0^2}{c^2}+8\frac{GM}{c^2}\frac{1}{r+v}\right)v = 8\frac{GM}{c^2}\frac{v^2}{r^2} \text{ m/s}^2. \quad (7)$$

Using the expression for v we get:

$$\Delta g = 8\frac{GM}{c^2}\frac{1}{r^2}v^2 = 8\frac{GM}{c^2}\frac{1}{r^2}\left(v_0^2+2\frac{GM}{r}\right) = 8\frac{GM}{c^2}\frac{v_0^2}{r^2}+16\frac{GM}{c^2}\frac{GM}{r^3} \text{ m/s}^2 . \quad (8)$$

The first term of the result decreases quadratic with distance and will therefore, in the traditional approach, be attributed to mass and curved space because it satisfies Newton's law of gravitation. The last term is **14** times larger than the first term near Earth and **2.7** times larger near Jupiter.
The final term

$$\boxed{\Delta g = 16\frac{GM}{c^2}\frac{GM}{r^3}} \text{ m/sec}^2, \quad (9)$$

however, is a cubic term unknown in established theory. We call this the **anomalous acceleration**. This acceleration has the same direction as the acceleration due to gravity.

If we want to measure this acceleration based on the changing velocity, we must measure an object with a velocity such that the distance r changes. This works best if the velocity is directed radially.
When the velocity makes an angle φ with the gravitational acceleration, we measure the component in the radial direction as acceleration relative to the observers:

$$\Delta g = v_r^* - v_{r+v}^* = \left(1+2\frac{v_0^2}{c^2}+8\frac{GM}{c^2}\frac{1}{r}\right)v\cos\varphi - \left(1+2\frac{v_0^2}{c^2}+8\frac{GM}{c^2}\frac{1}{r+v\cos\varphi}\right)v\cos\varphi =$$

$$8\frac{GM}{c^2}\left(\frac{1}{r}-\frac{1}{r+v\cos\varphi}\right)v\cos\varphi = 8\frac{GM}{c^2}\frac{(v\cos\varphi)^2}{r^2} \text{ m/s.} \quad (10)$$

If we elaborate this further we get:

$$\Delta g = 8\frac{GM}{c^2}\frac{1}{r^2}(v\cos\varphi)^2 = 8\frac{GM}{c^2}\frac{1}{r^2}\left(v_0^2+2\frac{GM}{r}\right)\cos^2\varphi =$$

$$8\frac{GM}{c^2}\frac{v_0^2}{r^2}cos^2\varphi+16\frac{GM}{c^2}\frac{GM}{r^3}cos^2\varphi \quad \text{m/s}^2. \qquad (11)$$

The anomalous acceleration as a 3rd power term now takes the form

$$\boxed{\Delta g=16\frac{GM}{c^2}\frac{GM}{r^3}cos^2\varphi} \ \text{m/s}^2. \qquad (12)$$

From this we conclude – because of the term $\mathbf{cos^2\varphi}$ – that an object moving tangentially with respect to its distance from the sun does not exhibit anomalous acceleration because $\mathbf{cos\ \varphi = 0}$. In circular planetary orbits, the anomalous acceleration therefore plays no role.

4 Application to the Pioneers

In March 1972, the **Pioneer 10** spacecraft was launched. Just over a year later – in April 1973 – Pioneer 11 followed. Both described orbits in the plane of the ecliptic, which took them past Jupiter and other planets, ultimately leaving our solar system in opposite directions.

They generated a vast amount of research data about the solar system. One of the goals of the projects was to better understand the gravitational field in the solar system. The measurements of the spacecraft's accelerations were exceptionally precise, measuring them with an accuracy of $\mathbf{10^{-10}}$ m/s^2. However, this precision presented a new problem that remains unresolved.

After passing Jupiter and completing final corrective manoeuvres, the Pioneers showed a faint but unmistakable, constant deceleration as they continued to increase their distance from the Sun, with a final calculated value[3)] of $\mathbf{(8.74\pm1.33)x10^{-10}}$ m/s^2.
The reliability of the measurements is beyond dispute, but the result would imply that both spacecraft would eventually re-enter the solar system. This is completely contrary to common sense.
This is where science fails.

In our improved theory, we believe we can provide this explanation. We use the actual velocity. As we explained in (§2), this refers to the higher velocity of an object than the velocity $\boldsymbol{v}$ that the object has according to traditional measurements. The higher velocity is caused by the time delay.
When an object moves within a gravitational field to regions where time dilation decreases, the difference between its actual velocity and its traditional velocity will also decrease. Consequently, the object will experience an **anomalous deceleration** relative to its traditional velocity.
Both objects – Pioneer and Earth – are in the sun's gravitational field. As Pioneer moves radially away from the sun (and Earth) at a certain velocity, it must experience the anomalous acceleration, which slows it down further as it moves away from the sun. Near Jupiter, however, the measured anomalous acceleration is very small.
Measured from the Pioneer, Earth has the same velocity as the Pioneer, but in the opposite direction. The contribution of Earth to the extra velocity (much closer to the Sun) is also much greater than that of the Pioneer near Jupiter. Objectively speaking, Earth's velocity is unchanged from its normal velocity. Therefore, the extra velocity that Earth and the Pioneer have relative to each other in the system must be entirely accounted for by the Pioneer.

- *This concerns an actual increased speed so that the Pioneer actually moves faster away from the Earth and therefore also away from the Sun.*

The anomalous velocity deceleration is the anomalous acceleration that the Pioneer experiences in the Sun's gravitational field. This is also part of the Sun's gravitational field but has not yet been detected due to its small size. Because this term decreases with the third power of the distance, it behaves differently than Newton's gravitational acceleration. We will investigate the effect this has on the Pioneer's orbital motion.

It has been calculated that Pioneer 10 has a velocity of $\mathbf{v_0}$**= 11.2** km/sec in deep space.
Furthermore, **G=6.6726x10^-11^** → $\mathbf{G=6.6726x10^{-11}}$ $m^3/kg.s^2$ and $\mathbf{M_{zon}=1.9891x10^{30}}$ kg.
Therefore, for the third power term with $\mathbf{r=0.1496x10^{12}}$ meters, we find an anomalous acceleration (9) of $\Delta g = 16\frac{GM}{c^2}\frac{GM}{r^3}$ = $\mathbf{9.37x10^{-10}}$ m/sec² at **Earth**.

At **Jupiter**, at a distance of $\mathbf{r=0.778x10^{12}}$ meters, the anomalous acceleration is $\Delta g = 16\frac{GM}{c^2}\frac{GM}{r^3_{Jupiter}}$ =

$\mathbf{0.0666x10^{-10}}$ m/sec². This last value is barely measurable.

When measuring the acceleration of Pioneer in the Sun's gravitational field near Jupiter by regularly measuring the velocity, the sum of the anomalous accelerations of the Earth and Pioneer $\mathbf{(9.37+0.07)x10^{-10}}$ = $\mathbf{9.44x10^{-10}}$ m/s2 will be included in the measurement.
If we don't correct the measurement results for the anomalous accelerations, we might expect an error of $\mathbf{9.44x10^{-10}}$ m/s² for Pioneer at Jupiter. This result falls well within the error margin used in the literature for the measured anomalous acceleration of $\mathbf{(8.74 \pm 1.33) \times 10^{-10}}$ m/s².
However, a much lower anomalous acceleration is measured at Jupiter. Only beyond Jupiter does the acceleration gradually increase to a value of $\mathbf{9.37 \times 10^{-10}}$ m/s² beyond Saturn.

Figure 2 illustrates that the difference between the actual speed and the traditional speed is mainly formed at Earth, where the time delay in the Sun's gravitational field is much greater than at Jupiter.

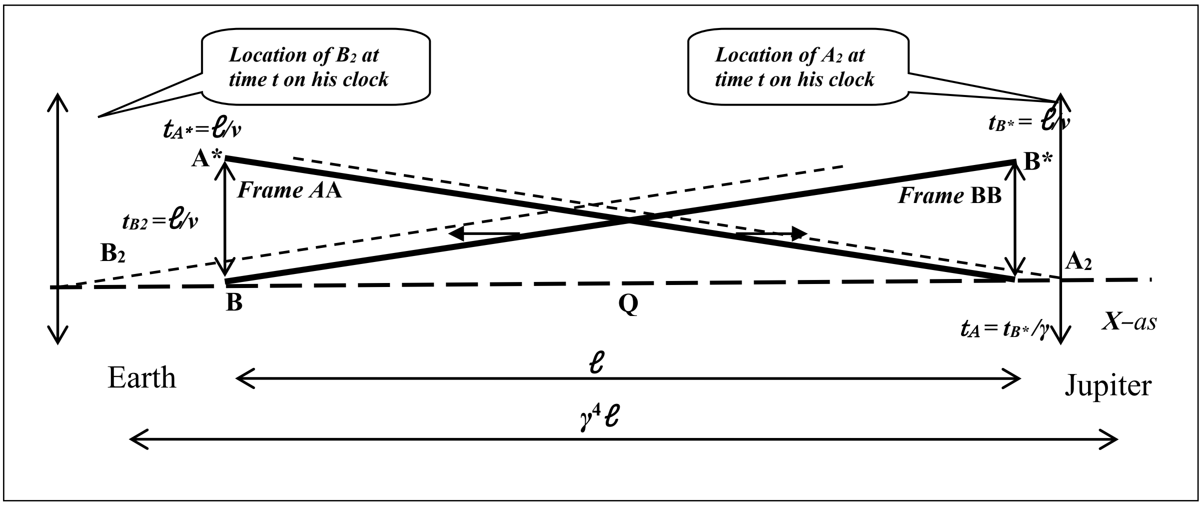

Fig. 2 If an object B* moves past Jupiter at a certain speed, it acquires an actual velocity greater than its traditional velocity. Near Earth, the effect of the anomalous velocity is much greater than near Jupiter. Earth's anomalous acceleration is therefore much greater than that of the Pioneer near Jupiter. The anomalous acceleration that B2 experiences relative to A2 is the sum of both accelerations.

The reason the anomalous acceleration is only noticed past Jupiter is likely related to the corrective manoeuvres the Pioneer occasionally underwent before reaching Jupiter to steer it in the right direction. The Pioneer was steered past Jupiter in such a way that it could optimally utilize the gain in speed from Jupiter's gravitational assistance. Immediately past Jupiter, the Pioneer's trajectory was practically tangential, with the rate at which its distance from Earth and Sun changes practically zero. The Pioneer then no longer has a radial velocity relative to Earth, meaning the extra speed and the anomalous acceleration of the Pioneer relative to Earth do not occur. The measurement of the Pioneer's acceleration then yields the traditional value of the Sun's gravitational field at that location.

As the velocity becomes more radial with respect to the Earth and the Sun at greater and greater distances beyond Jupiter, the excess velocity and anomalous acceleration develop back to full magnitude.

We must use the formula (12) $\Delta g = 16\frac{GM}{c^2}\frac{GM}{r^3}cos^2\varphi$ m/s² for Earth and Pioneer to correct for the angle φ. The anomalous acceleration is then found with the sum:

$$\Delta g = 16\frac{GM}{c^2}\left(\frac{GM}{r_{aarde}^3}+\frac{GM}{r^3}\right)cos^2\varphi \text{ m/sec}^2. \quad (13)$$

We had to estimate the angle φ, the direction Pioneer is moving relative to the line with the Earth, using the drawing (see Fig 3) that NASA released of the orbits of Pioneer 10 and 11.
The sharp angles that the orbits exhibit upon encountering Jupiter are the result of the orbit being deflected by Jupiter's gravitational pull, which also results in a gain in speed.

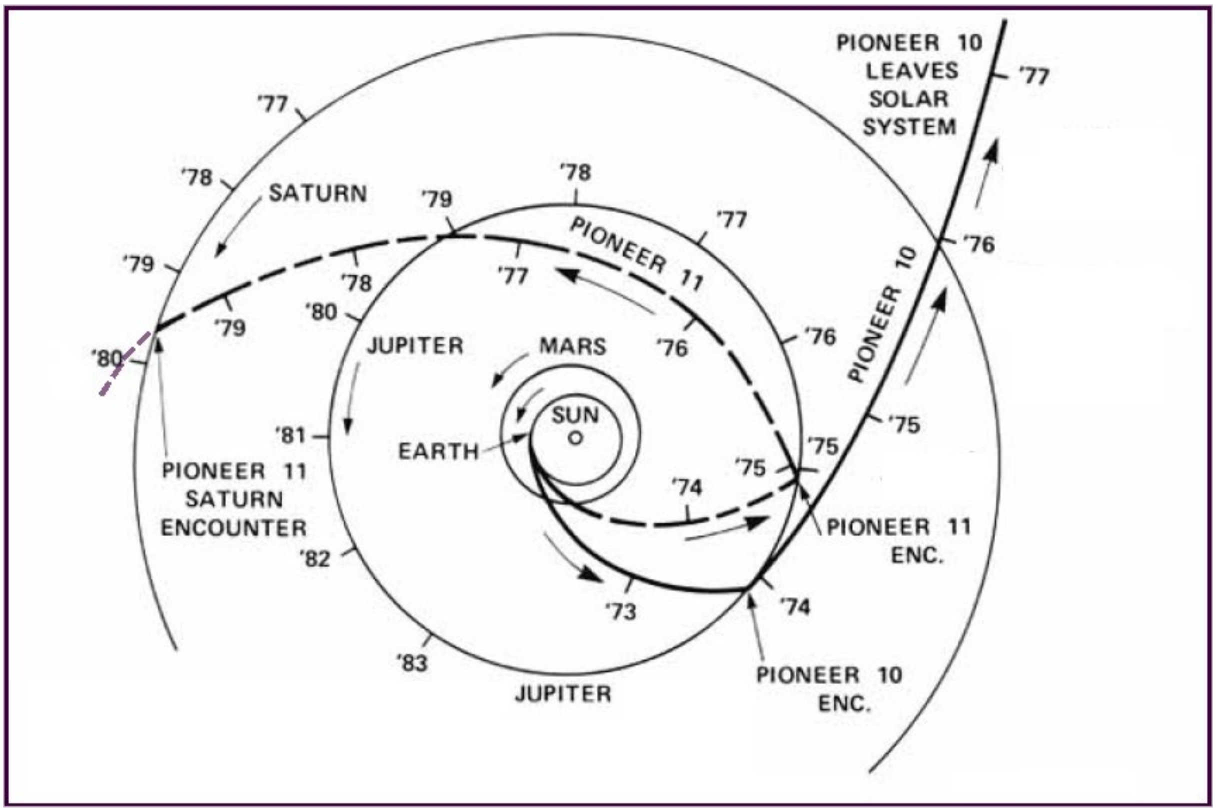

Fig. 3 The orbits that the Pioneers described in the solar system

Using the data from the planets and an estimate of the angle φ and the last formula, we numerically calculated the anomalous acceleration Δg at different distances in the solar system (Table 1).
As an approximation, we've positioned Earth in the direction of the sun. While the Earth's direction beyond Jupiter, as seen from Pioneer, may differ by a few degrees from the direction toward the sun, in the calculations, this will only result in small numerical changes between Jupiter and Uranus. This will not affect the gist of this story. Therefore, we've chosen not to address these deviations in direction.

Distance	Deviation	Correction	Anomalous Acceleration
AU	φ in degrees	$\cos^2 \varphi$	Δg m/sec^2 .
1	*	*	*
2	*	*	*
3	*	*	*
4	*	*	*
5	88	0,00	1.15E-12
6	82	0,02	1,82E-11
7	72	0,10	8,97E-11
8	60	0.25	2.35E-10
9	50	0.41	3,88E-10
10	40	0.59	5.50E-10
11	30	0.75	7,03E-10
12	20	0,88	8,28E-10
13	12	0,96	8,97E-10
14	8	0,98	9,19E-10
15	6	0.99	9,27E-10
16	5	0.99	9,30E-10
17	4	1.00	9,32E-10
18	3	1,00	9,34E-10
19	2	1,00	9.36E-10
20	1	1,00	9.36E-10
21	0	1.00	9.37E-10
22	0	1.00	9,37E-10
23	0	1,00	9,37E-10
24	0	1,00	9,37E-10
25	0	1.00	9.37E-10

Table 1 The anomalous acceleration at the distances beyond Jupiter .

The result of the calculations is also shown in a graph (Fig 4).

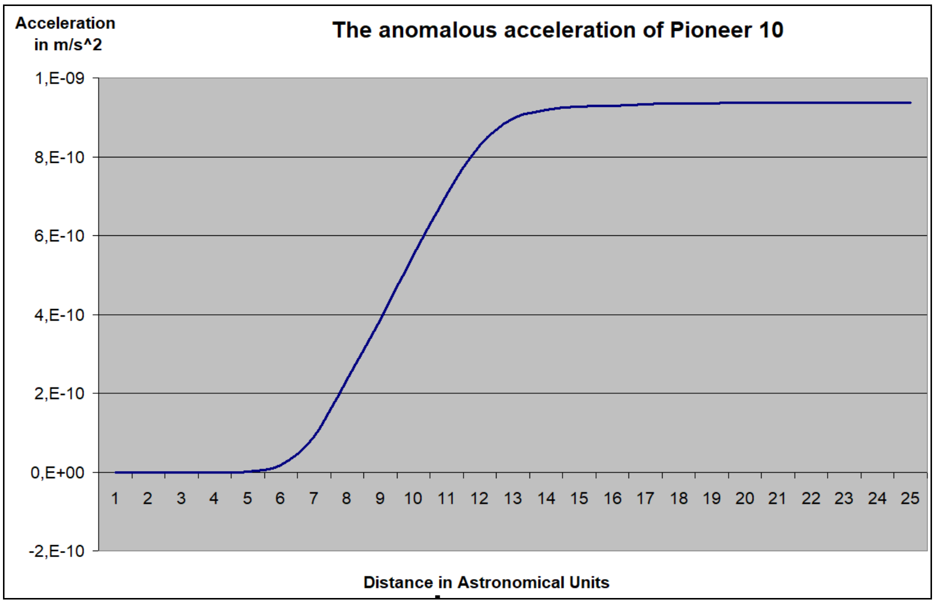

Figure 4 The anomalous acceleration of Pioneer 10 in the solar system according to our improved theory of relativity.

A comparison of the NASA data (Fig 5) with our results (Fig 4) reveals a remarkable agreement. However, there are also differences. For example, in our calculations, the level of constant acceleration is reached at **15** AU, while according to NASA's calculations, this only occurs at distances above **20** AU. Furthermore, according to NASA measurements, the acceleration decreases in magnitude from that point onward, while the anomalous acceleration, according to our theory, becomes absolutely constant.
This discrepancy may be caused by NASA's computer scientists making incorrect corrections to the spacecraft's acceleration calculations in an attempt to explain the anomalous acceleration. These corrections could have extended effects even farther away.

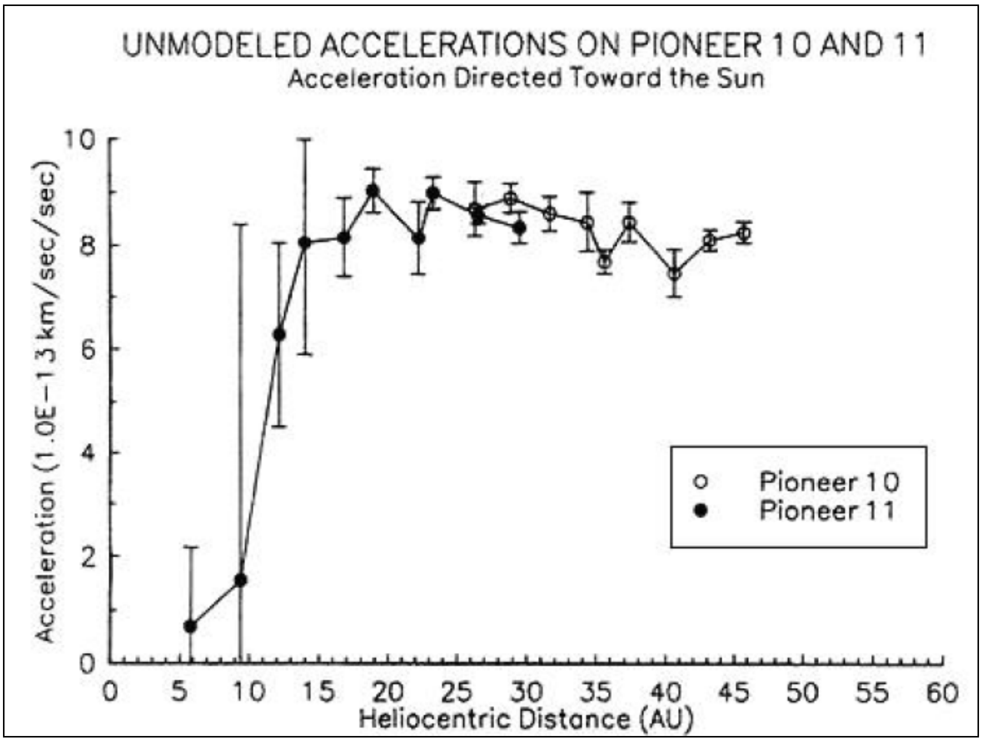

Figure 5 The anomalous acceleration as measured on Pioneers 10 and 11

5 Conclusion

We see here a brilliant example of how improving Einstein's theory can provide a solution to a question that has been troubling established science for decades: how the Pioneer 10 (and 11) spacecraft acquired their anomalous accelerations. While traditional calculations yield an anomalous acceleration of $\mathbf{(8.74 \pm 1.33) x10^{-10}}$ m/sec² for Pioneer 10, our improved theory finds a value of $\mathbf{9.37 x10^{-10}}$ m/sec². This result allows the anomalous acceleration to be fully explained within the margin of error.

[1] Albert Einstein; Annalen der Physik, nr.17: "Zur Elektrodynamik bewegter Körper" p. 891, 1905.
[2] Henk Dorrestijn; Time and Cosmos, A new Cosmological Worldview; 2024 Den Haag.
[3] John D. Anderson et all; Study of the anomalous acceleration of Pioneer 10 and 11; arXiv:gr–qc/0104064v5 10 Mar 2005