

The Deep Mystery of the Universe Behind Zeno's Paradox

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Abstract

Zeno's paradoxes of motion are four related paradoxes created by an ancient Greek philosopher in 500 B.C. In one of the well-known paradoxes, Achilles, who is a fast runner, chases a tortoise who is initially at a point P ahead of him and moving slowly forward. Zeno argued that, by the time Achilles arrives at point P, the tortoise will have moved forward to another point P₁. Although Achilles is now closer to the tortoise, he will not catch up on the second try again because by the time Achilles arrives at point P₁, the tortoise will have moved to another point P₂ and so on. Therefore, Achilles will never catch up with and overtake the tortoise. But we know that a fast runner can overtake a slow runner in reality. This paradox has puzzled philosophers, mathematicians and scientists for millennia. This paper reveals the mystery of the universe behind Zeno's paradoxes. There is no entity called an electron or an atom or a ball moving from one point to another point in space as we know it. It is profound that philosophers were able to probe the deep mystery of the universe by logic alone 2500 years ago!

Introduction

Zeno's paradoxes of motion are four related paradoxes created by an ancient Greek philosopher and logician in 500 B.C. The four paradoxes are known as the Achilles and the Tortoise paradox, the Dichotomy paradox, the Arrow paradox and the Stadium paradox. Zeno's paradoxes survived in Aristotle's writings, in which he attempted to refute Zeno's arguments.

Below I give brief descriptions of each paradox before proposing the solution.

The Achilles and the Tortoise paradox

In this exotic thought experiment, Achilles, who is a fast runner, chases a tortoise who is initially at a point P ahead of him and moving slowly forward. Zeno argued that, by the time Achilles arrives at point P, the tortoise will have moved forward to another point P₁. Although Achilles is now closer to the tortoise, he will not catch up on the second try again because by the time Achilles arrives at point P₁, the tortoise will have moved to another point P₂ and so on. Therefore, Achilles will never catch up with and overtake the tortoise. But we know that a fast runner can overtake a slow runner in reality.



P P₁ P₂

The Achilles and tortoise paradox is perhaps the most irrefutable argument of the four paradoxes.

The Dichotomy paradox

In this paradox, for any object to move a distance D from one point A to another point B, first it has to move a distance $D/2$ to the mid-point between A and B, say point P_1 . Likewise, to move from point A to point P_1 , first it has to move a distance $D/4$ from point A to the mid-point of A and P_1 , say point P_2 , and so on. This implies that the object has to make infinite steps to traverse the distance between A and B and this argument led Zeno to the conclusion that the object cannot move from point A at all. But we know that objects can move between two points in reality. From this, Zeno concluded that all motion is illusion.

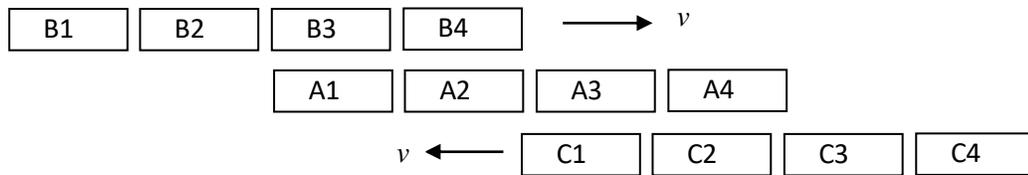


The Arrow paradox

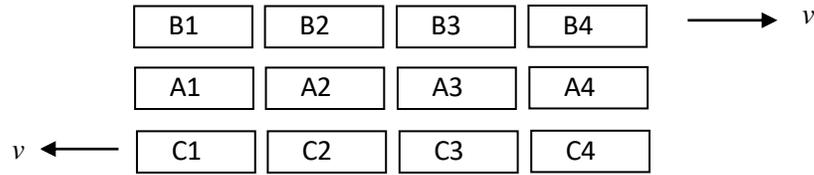
This paradox is about an arrow in flight. At any instant of time, the arrow is at rest because the arrow cannot make any movement in an instant of time, within zero time interval. And if the arrow is at rest at a given instant of time, then there is no way to tell the difference between a moving arrow and an arrow at rest, so a moving arrow cannot move, which is a contradiction[1]. This has been put with an amazing clarity and precision, something like this: “The arrow cannot move to where it is because it is already there, and it cannot move to where it is not because it can’t move in an instant of time”

The Stadium paradox

The stadium paradox is described as follows. We start with three rows of four blocks each at an instant of time as shown below. The ‘B’ blocks move with velocity v to the right and the ‘C’ blocks move with an equal velocity v to the left. The ‘A’ blocks are stationary.



Finally the blocks will look like as follows.



Consider the block B4. It passes two A blocks, but four C blocks during the same time interval. The Stadium paradox concerns these two times. According to Zeno, if the former takes time interval t , the latter takes time interval $2t$. This would be a paradox because B4 passes two A blocks, during the same time interval that it passes four C blocks. Therefore, this would lead to the paradox $t = 2t$.

It is known today that the Stadium paradox of Zeno as presented above is fallacious. It is incorrect because the time it takes B4 to pass two A blocks is equal to $2/v$ and the time it takes B4 to pass four C blocks is $4/2v$. Therefore,

$$t = \frac{2 \text{ blocks}}{v \frac{\text{blocks}}{\text{unit time}}} \quad \text{and} \quad t = \frac{4 \text{ blocks}}{2v \frac{\text{blocks}}{\text{unit time}}} \quad \Rightarrow \quad t = t$$

, so there is no paradox.

Then why is the Stadium paradox called a paradox? It has been speculated that perhaps the above description was a misrepresentation of Zeno's Stadium argument by Aristotle. Therefore, alternative interpretations have been proposed about Zeno's possible argument.

One such interpretation is as follows. Assuming discrete space and time, consider the blocks B4 and C1. At one moment of time, C1 is to the right of B4 and at the next moment C1 is to the left of B4. We notice that there is no moment when these two blocks are aligned. It has been argued that the stadium paradox was devised to refute the idea of discrete space and time. However, I have yet to appreciate this argument.

These four Zeno paradoxes of motion have baffled philosophers, mathematicians and scientists for millennia. They have not been really solved to this date because proposed solutions solved only some of the paradoxes, leaving the others unsolved and because there is no consensus on a solution so far.

In this paper, I propose a new solution which can resolve all the four paradoxes.

The deep mystery of the universe behind Zeno's paradoxes

Consider a row of lamps as shown below.



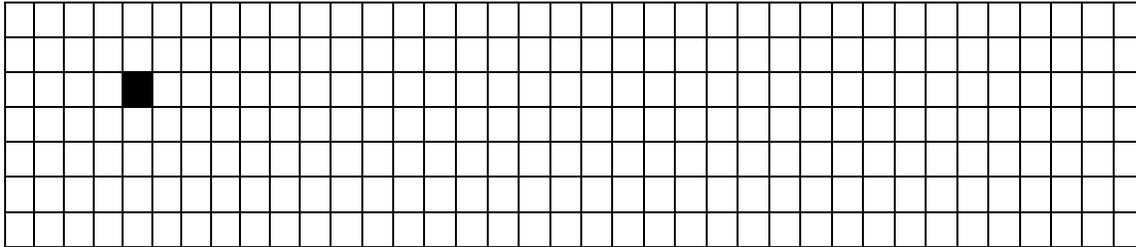
At first all the lamps are turned off, at time $t = t_0$, as shown above. Then at time $t = t_1$ lamp 1 is turned on, as shown below. Then at time $t = t_2$ lamp 1 is turned off and lamp 2 is turned on. Then at time $t = t_3$ lamp 2 is turned off and lamp 3 is turned on, and so on.



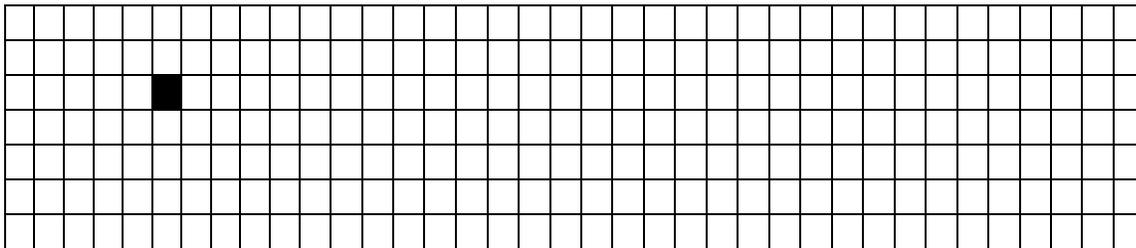
To an observer watching the row of lamps from a distance, it appears as if a single lamp is moving smoothly from left to right. However, we know that this is only an illusion because there is no lamp moving from left to right.

As another example, consider a black dot moving across a computer screen from left to right, as shown below. Each cell represents a pixel or a group of pixels of a computer screen. The positions of the black dot at t_0 , t_1 and t_2 are as shown below.

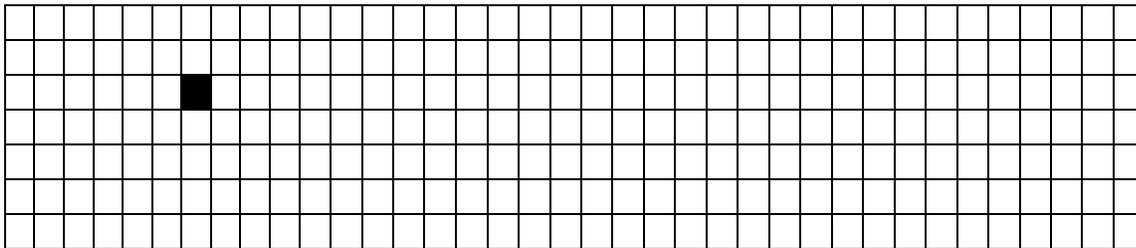
$t = t_0$



$t = t_1$



$t = t_2$



Again, for an observer looking at the computer screen from a distance, it looks as if *a black dot* is moving from left to right. This is only an illusion because there is no ‘a black dot’ moving from left to right. What actually happens behind the illusion is that each pixel is turned on and off at the right time to give the illusion of ‘a moving dot’.

I propose one of the deepest mysteries of the universe as follows.

The motion of a physical object and the physical object itself is basically the same or similar to the moving lamp and the moving dot discussed above. Just like there is no lamp moving from left to right and just like there is no black dot moving from left to right on the computer screen, *there is no physical object moving from one point to another point in space as we know it*. The motion of physical objects is only an illusion, as Zeno concluded. This paper makes the conclusion that not only motion, but also physical objects themselves are an illusion. Motion of a physical object (rather the illusion of motion) occurs as

'pixels' in space 'turn on' and 'turn off' at the right times to give the illusion of motion. Therefore, there is no physical object moving from here to there as we know it.

When a particle moves in space, what happens in reality is that the particle appears at a point in space at one instant of time, and then, at the next instant of time, that particle disappears from that point and an identical particle appears at the adjacent point in space, creating the illusion that the same particle is moving in space. There is no 'the same particle' moving in space, just like there is no 'the same black dot' moving across the computer screen.

Therefore, it will not be surprising if we say, just as the black dot on a computer screen can be deleted at will by the human programmer/ user, a physical object can also be 'deleted' from the universe by the 'programmer' of the universe. Just as one can pause the moving dot on the computer screen, physical objects, for example humans, can be 'paused' or 'frozen' by the programmer or operator of the universe.

Therefore, the universe and the laws and phenomena of the universe, and all the objects in the universe are just illusions on a grand scale or grand 'simulations'. Note that the programmer can create a simulation of physical phenomena, for example gravity, inertia, etc. on the computer. The universe can be thought of as an astronomical size three dimensional computer screen. Just as the screen of a computer is an output device of the computer, the universe is the 'output device'. In the case of a computer, the computations take place inside the CPU. But where do the 'computations' take place in the case of the universe?

The correctness of this theory is evident by the fact that it resolves all of Zeno's motion paradoxes .

The Arrow paradox is automatically solved because at any instant of time, and at every instant of time, the arrow is at rest. There is no motion of the arrow as we know it, and it is only an illusion. Just as the moving dot on the computer screen is at rest at any instant of time, so is a moving object. The answer to the puzzle "then how can there be motion?" is that there is no motion as we know it. There is only an illusion of motion. But what creates the illusion of the arrow moving from one point to the next adjacent point in space? This is like asking : what makes the illusion of the dot moving across the computer screen? The answer is : the program. In the case of the universe also, a grand program creates the illusion of a moving arrow. This is just another way of saying motion is possible because of God. One way to describe this is as follows: to think that objects move by themselves due to inertia would be like thinking that the dot on the computer screen moves by itself due to 'inertia', that is without the program.

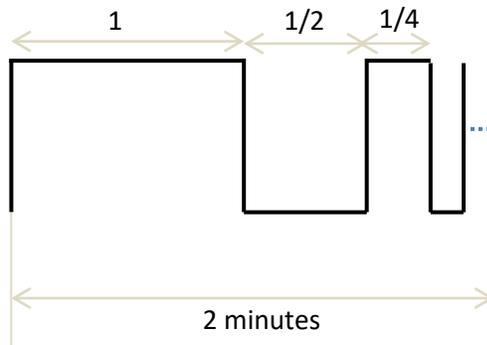
The Achilles and tortoise paradox is also solved because Achilles cannot get closer to the tortoise than the distance between two adjacent 'pixels' in space, and therefore he will catch up with and overtake the tortoise eventually. That is, eventually Achilles cannot get closer to the tortoise without catching up.

The Dichotomy paradox is also solved because a particle moving from one point to another point in space takes only finite number of changes in position, just like the moving dot makes only finite number of steps to move from the left side of the computer screen to the right side.

The Stadium paradox is that there is no moment in time when B4 and C1 are adjacent. This will not be a paradox because no two blocks will be adjacent in reality because there are no moving blocks as we know it, there is only an illusion of motion.

Thomson's lamp paradox

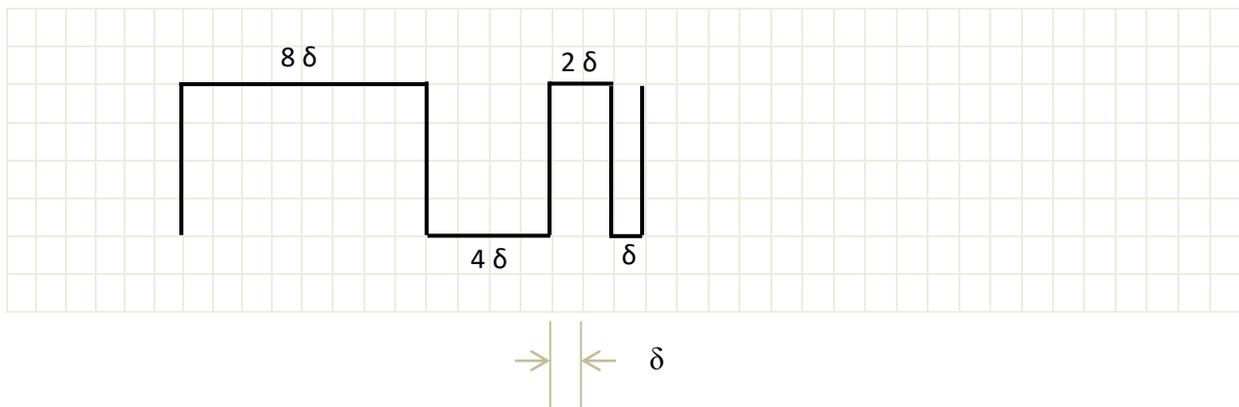
The Thomson's lamp paradox is described as follows. A lamp is first turned on. Then after 1 minute it is turned off. Then after $1/2$ minute it is turned on. Then after $1/4$ minute it is turned on. Then after $1/8$ minute it is turned off, and so on. The sum of the infinite series of time intervals is exactly two minutes. The paradox is : will the lamp be on or off at the end of two minutes?



It can't be on or off at the end of two minutes because this is an infinite series of actions. This is yet another paradox that probes into the deep mystery of the universe.

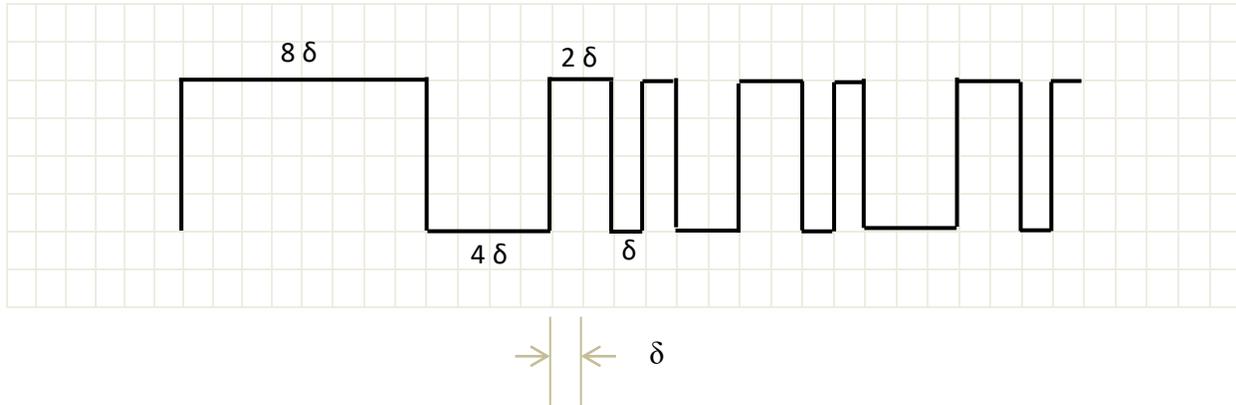
Discrete nature of space, time and all physical quantities in the universe

If we think of time as discrete, then Thomson's lamp paradox can be solved.



As shown in the above figure, time is not a continuous quantity, but a discrete quantity. All time durations are integral multiples of the smallest possible time interval, δ . As shown in the figure,

the lamp was turned on for a time interval of, say, 8δ , then it is turned off for a time interval of 4δ , then it is turned on for an interval of 2δ , then turned off for an interval δ . So we have reached the smallest possible time interval which is indivisible. So what will happen after that? I propose that since δ is not divisible by two, the next time interval will be either δ itself or zero, each with a probability of 0.5. Therefore, the sequence will not end after 2 minutes, but will continue indefinitely as shown below.



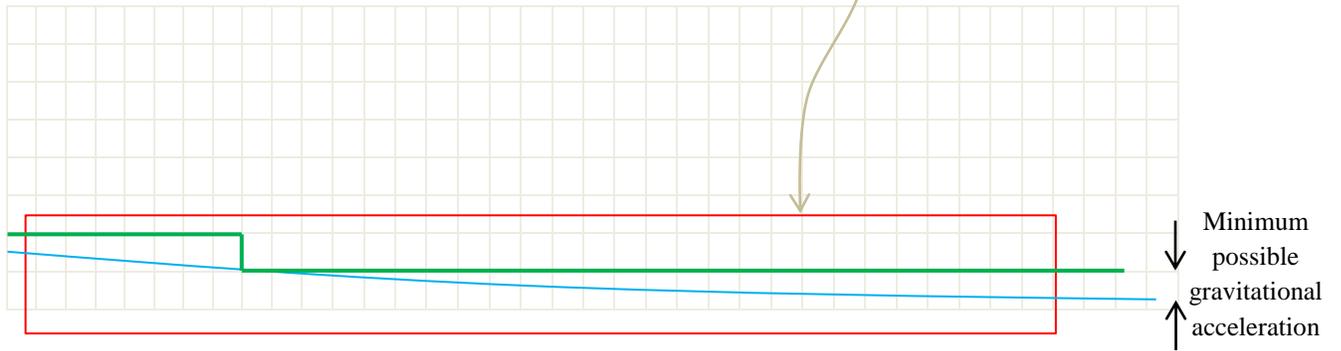
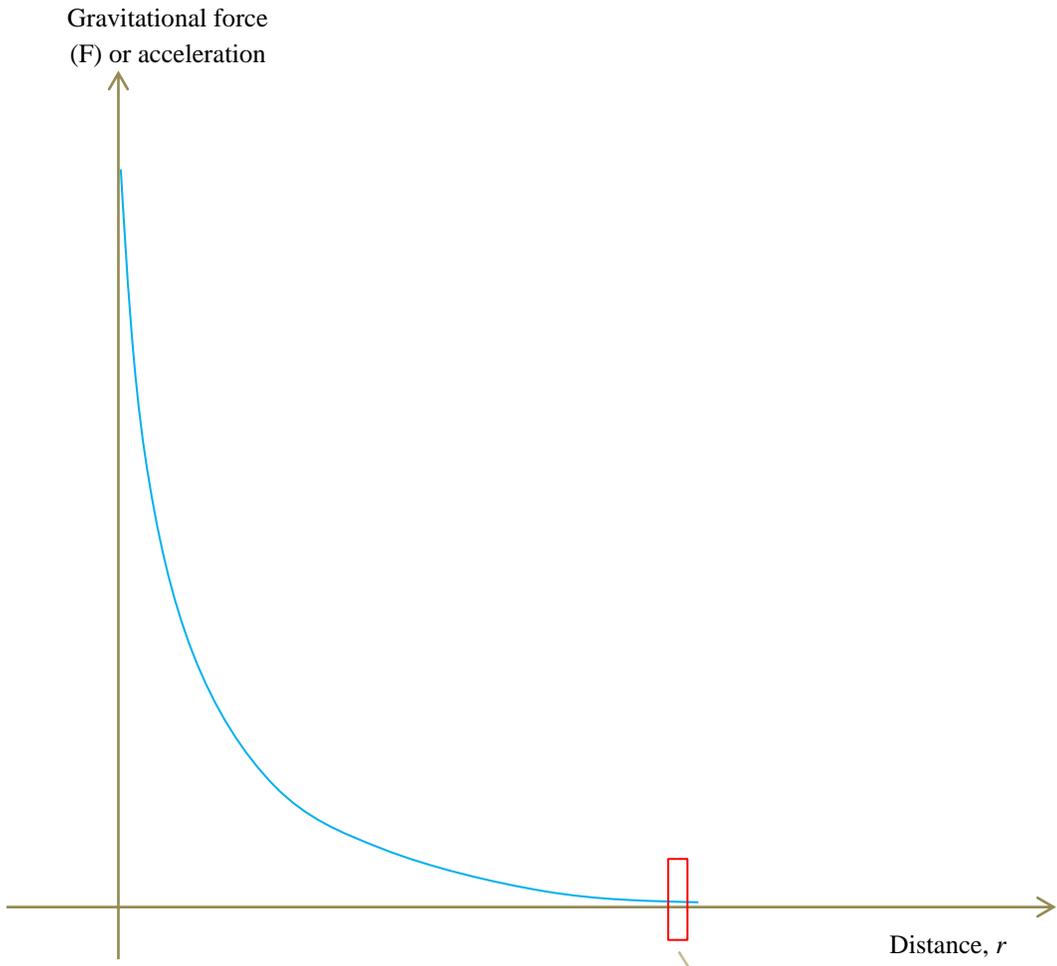
One might ask : what if the first duration is 7δ , instead of 8δ ? Dividing 7δ by two will give 3.5δ , which does not exist. So the next time interval will be 3δ or 4δ , each with a probability of 0.5.

Therefore, the Thomson lamp paradox would be fallacious because it assumes that time is continuous and can be divided indefinitely. One way to describe this is: If this experiment was done actually, it would end up as explained above. But the value of δ is so small that this experiment is impossible to realize with current technology.

Dark matter, dark energy, Pioneer anomaly and fly-by anomaly

These are some of the longstanding anomalies in physics.

As proposed above, space, time and all physical quantities in the universe are discrete. Therefore, the view that space and time are continuous may not be correct.



Ever since Newton formulated the gravitational law, the gravitational force and acceleration has been understood as varying / decreasing *continuously* with distance. Here I propose that, ***the gravitational acceleration is an integral multiple of the minimum possible gravitational acceleration q*** . Therefore, the gravitational force of the Sun decreases discretely, *in steps* with distance from the Sun (the green line), and at sufficiently great distances, the gravitational acceleration reaches the minimum possible value and remains constant with distance. The blue curve represents the current doctrine of *continuous* (as opposed to *discrete*) gravitational acceleration. (Note that the diagrams are only meant to be qualitative and just to describe the new theory and therefore are not accurate and are to-scale.

All physical quantities in the universe are fundamentally discrete. Therefore, there is the smallest possible physical quantity (for example, gravitational acceleration, Doppler shift, etc.). However, this smallest possible quantity is so extremely small, the large physical quantities we encounter on our everyday lives appear to be continuous. The discrete nature of physical quantities can be observed only at the level of extremely small values of the quantities or with highly precise measurements, for example as in the Earth flyby anomaly.

This theory may explain the phenomena of dark matter, Pioneer anomaly and cosmological acceleration. Thus the anomalous constant deceleration ($8.74 \times 10^{-10} \text{ m/s}^2$) in the Pioneer anomaly could be the minimum possible gravitational acceleration, and this is almost equal to the value of cosmological ‘acceleration’ (quoted because it could be deceleration rather than acceleration, as I argued in one of my papers).

This theory may also explain why the velocity of stars in spiral galaxies does not decrease with distance as predicted by Newton’s law, in the phenomenon of dark matter. The galaxy rotation curve almost remains flat as distance from the center increases.

According to Newton’s law,

$$\frac{mv^2}{r} = G \frac{mM}{r^2} \Rightarrow \frac{v^2}{r} = G \frac{M}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

Newton’s law predicts that the velocity v decreases with distance.

According to the new theory,

$$\frac{mv^2}{r} = G \frac{mM}{r^2} \Rightarrow \frac{v^2}{r} = G \frac{M}{r^2} = nq$$

$$\Rightarrow v = \sqrt{nq r}$$

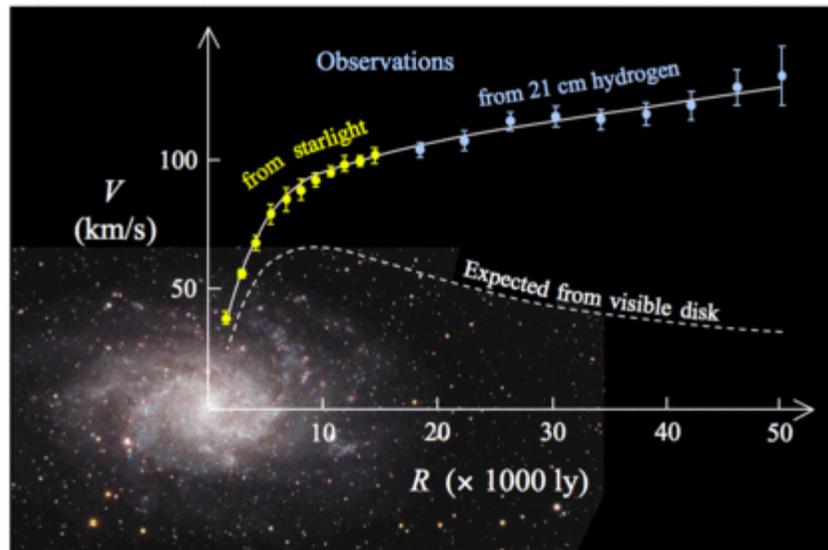
where n is a natural number.

In the last equation, n decreases with distance, and eventually $n = 1$ at large enough distances.

Therefore, the fact that n decreases with distance can partly compensate for the increase in distance r , making the quantity under the square root almost constant. For example, if we assume that n is roughly inversely proportional to r , the velocity v will be roughly constant.

For sufficiently large distances, when $n = 1$, the velocity v will become directly proportional to the square root of the distance r , increasing with distance r ! Not only for $n = 1$, but as n starts dropping below some value, say 1000 (or 100? 10?), the velocity v starts to roughly level off or slightly increase with distance.

Therefore, according to the new theory, the velocity at sufficiently large distances does not decrease with distance. In fact, according to the new formula above, the velocity increases with distance r , for $n = 1$. This agrees with observations as shown in the next figure.



Note that MOND (Modified Newtonian Dynamics) also assumes that gravity is modified beyond a gravitational acceleration of $a_0 \sim 10^{-8} \text{ cm/s}^2$. But this is just about 10 times less than the minimum possible value (q) of gravity we assumed already.

$$a_0 \cong 10^{-8} \frac{\text{cm}}{\text{s}^2}$$

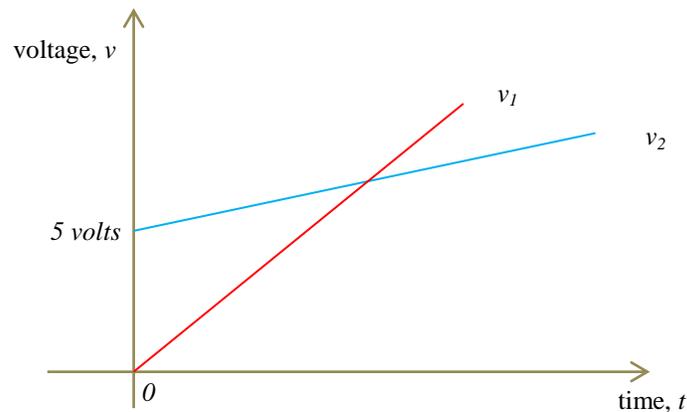
$$q \cong 8.74 * 10^{-10} \frac{\text{m}}{\text{s}^2}$$

Therefore, MOND is at least a model that has probed into the discrete nature of gravity.

The frequency ‘step’ in the flyby anomaly is also in accordance with the new theory: *all physical quantities in the universe are fundamentally discrete*. They appear to be continuous at large values because the smallest possible ‘step’ is extremely small. A *discontinuous* increase in spacecraft velocity of about 3.92 mm/s , corresponding to a Doppler frequency shift of 66 mHz, was observed on Galileo spacecraft. Similar phenomena have been observed on other spacecraft.

Zeno’s paradoxes apply to every physical quantity in the Universe!

Consider two voltage sources, S_1 and S_2 . The output voltage of S_1 , v_1 , increases at a high rate , whereas the output voltage of S_2 , v_2 ,increases at a low rate. We can think of S_1 as Achilles and S_2 as the tortoise. Initially, at $t = 0$ the output voltage of S_1 is zero volts, and the output voltage of S_2 is, say, 5 volts. Graphically, the change in voltage with time of the two sources is as follows.



In reality, even though v_2 is greater than v_1 at $t = 0$, v_1 will catch up with and exceed v_2 after some time because the rate of increase of v_1 is greater than that of v_2 .

But Zeno would make the same argument about the voltages of S_1 and S_2 , as he made about Achilles and tortoise. Initially, at $t = 0$, $v_1 = 0$ volts and $v_2 = 5$ volts. By the time v_1 attains a value of 5 volts, v_2 will have increased to a value greater than 5 volts, say x volts. By the time v_1 equals x volts, v_2 will have increased to x_1 volts , which is greater than x volts, and so on. Therefore, v_1 will never catch up with v_2 . The only way out of this paradox is , therefore, to abandon the view that voltage as a physical quantity increases continuously. All physical quantities, voltage, current, electric field strength, magnetic field strength, frequency, velocity, acceleration, force, mass, temperature, light intensity, etc. are discrete at the most fundamental level. Therefore, the voltage at a given time is an integral multiple of the minimum possible, indivisible voltage (the ‘*voltage quanta*’). The same applies to all other physical quantities.

Conclusion

In this paper, all four of Zeno's paradoxes have been solved. There are no physical objects moving from one point to another point in space, just like there is actually no black dot moving across a computer screen, that is, the motion of the black dot across the computer screen is only an illusion. The view of an electron moving in space is deeply flawed as we know it because *there is no entity called electron moving in space as we know it*. The deep reality is that an electron appears at a point in space at one instant of time. Then at the next (discrete) instant of time, that electron disappears from that point and an identical electron appears at the next adjacent point in space, creating the illusion of an entity called an electron moving in space as we know it. Space, time and all physical quantities in the universe are fundamentally discrete. This view can resolve all four of Zeno's paradoxes and resolve longstanding cosmological mysteries: dark matter, dark energy, Pioneer anomaly and fly-by anomaly.

Glory be to God and His Mother, Our Lady Saint Virgin Mary

Notes and references

1. I was acquainted with Zeno's paradox only relatively recently, not more than two or three years ago. However, long before I knew about Zeno and his paradox, I remember motion paradoxes similar to the Dichotomy paradox and the Arrow paradox coming to my mind at different times in the past, perhaps since thirty years ago?, and being baffled before abandoning them for the time being.

Bibliography

1. *Why Zeno's Paradoxes of Motion are Actually About Immobility*, by Maël Bathfield
2. *Zeno's Paradoxes*, by W. C. Salmon
3. *This Is How Physics, Not Math, Finally Resolves Zeno's Famous Paradox*, by Ethan Siegel, Forbes
4. *Aristotle, Zeno and the Stadium Paradox*, by Kevin Davey
5. *Zeno's paradoxes*, Wikipedia
6. *Zeno's paradoxes*, by Nick Huggett, Stanford Encyclopedia of Philosophy