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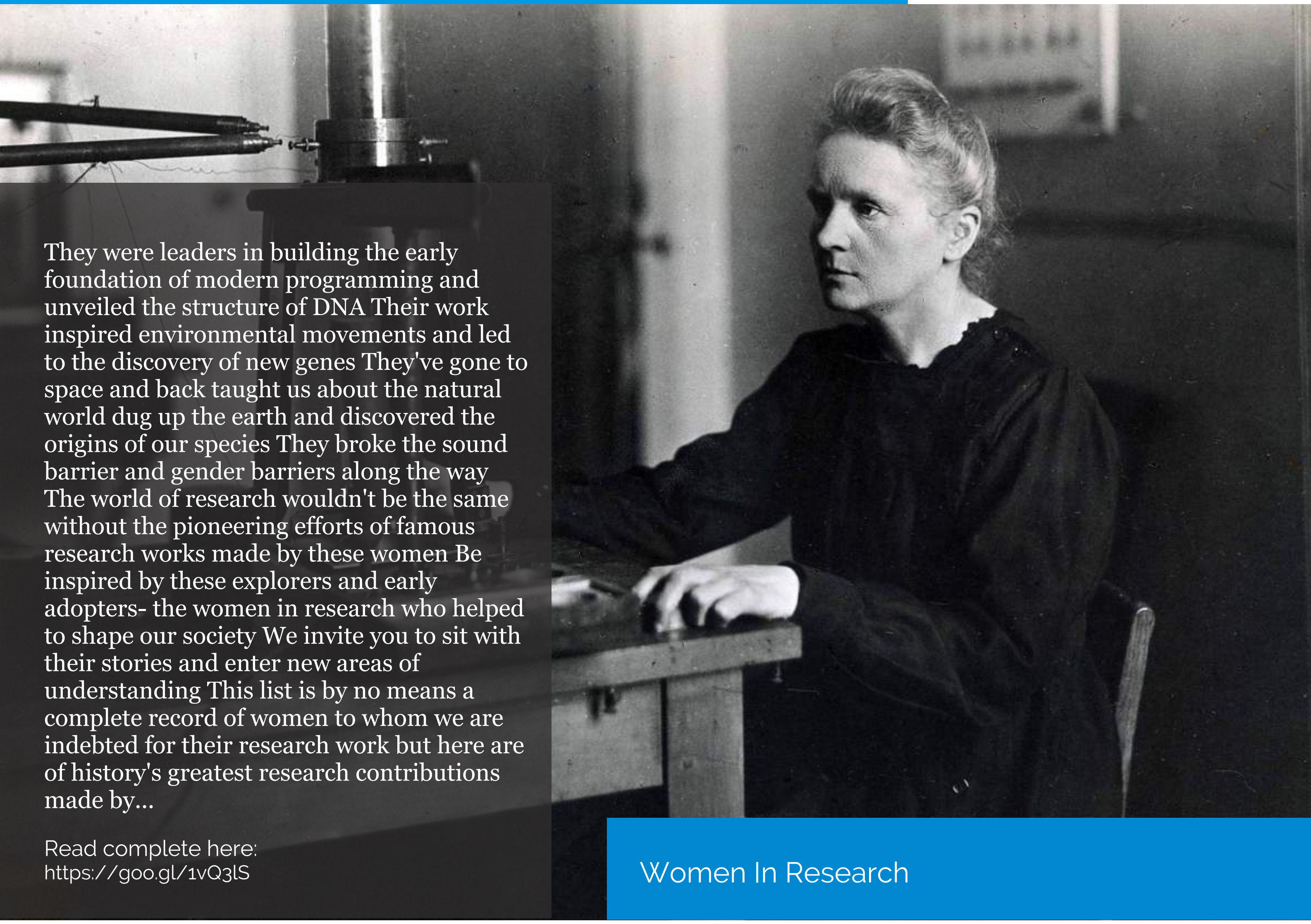

They were leaders in building the early foundation of modern programming and unveiled the structure of DNA Their work inspired environmental movements and led to the discovery of new genes They've gone to space and back taught us about the natural world dug up the earth and discovered the origins of our species They broke the sound barrier and gender barriers along the way The world of research wouldn't be the same without the pioneering efforts of famous research works made by these women Be inspired by these explorers and early adopters- the women in research who helped to shape our society We invite you to sit with their stories and enter new areas of understanding This list is by no means a complete record of women to whom we are indebted for their research work but here are of history's greatest research contributions made by...

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Research papers and articles

Limited Effect Principle of a Relativistic System - The Calculation Results within a Relativity System cannot be Applied to the Real World Outside the System

Sean Yuxiang Wu & Lü Wu

ABSTRACT

We pointed out 3 general concerns and 12 problems in Einstein's theory of special relativity in [1-4], which got positive feedback. Here we present a newly derived "Limited Effect Principle of a Relativistic System." This research followed our method of analyzing mathematical models from the perspective of reviewing the rationality of physical models first, and used this method to derive the Limited Effect Principle of a Relativistic System. This Limited Effect Principle gives obvious evidence that the theory of relativity is misunderstanding the mathematical world from the physical world, which gives us further confidence that the theory of relativity should no longer lead the scientific and technological thinking of mankind.

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ABSTRACT

We pointed out 3 general concerns and 12 problems in Einstein's theory of special relativity in [1-4], which got positive feedback. Here we present a newly derived "Limited Effect Principle of a Relativistic System." This research followed our method of analyzing mathematical models from the perspective of reviewing the rationality of physical models first, and used this method to derive the Limited Effect Principle of a Relativistic System. This Limited Effect Principle gives obvious evidence that the theory of relativity is misunderstanding the mathematical world from the physical world, which gives us further confidence that the theory of relativity should no longer lead the scientific and technological thinking of mankind.

Keywords: relativity, Einstein, special theory of relativity, reference body.

I. INTRODUCTION

In the Third Concern of [2], we pointed out that "The model of the light ray and the rigid rod does not explain how the two reference bodies are bound to each other? How do they form a relative system?" This caused many problems.

Assuming there are 100 rigid rods, how could Einstein make his ray form a relative system with the No.4 rigid rod he wanted to be relative to? Is there any way to bind his ray and No.4 rod to each other so that they can be relative without disturbed by other rods?

For another example, in the experiment of a clock on the airplane and a ground navy clock, how does the airplane clock know it should be relative to the navy clock? Does the airplane clock also be relative to the clocks on space shuttles, on trains, or on cars......?

Since there are no strict definitions of relative systems, when the two reference bodies that make up the relative system are independent of each other, any object or system that moves inertially will often become the reference body in the relative system unconsciously or passively. We define this situation as Passively Relative.

For example, when using an atomic clock on a spaceship and an atomic clock placed on the ground to do a relativity time dilation test, experts only focus on whether or not the data gained from the ground clock and the clock on the spaceship are different. In reality, however, these two clocks are simultaneously passively relative to many different reference bodies, such as white clouds, airplanes, and even birds flying at a constant speed in the air, the rotation of the Earth, countless cars and trains moving at a constant speed, the African lion running at a constant speed, the whales in the sea ... They all can be passively relative to these two clocks, and there is no way to stop them from being so.

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Of course, anyone can imagine one object as only being relative to another specific object, but in reality, there is no way to specify such an exclusively relative object, let alone prevent an object from being passively relative to any other moving objects.

There are many moving objects with different speeds that are passively relative to the atomic clocks on the spaceship and on the ground. According to Einstein’s calculations in theory of relativity, they each will have different effects on the time changes of the two clocks. In fact, for Einstein's system, which maintains relative simultaneity, since the participating reference bodies are completely independent of each other, there will be no connection or link between them. Therefore, in actual application calculations, when a reference body is set to be relative to many other moving reference bodies with different speeds at the same time, the relative calculation will produce contradictory results. But we have not had any way to solve the contradiction yet.

Therefore, we first derive a principle to resolve this contradiction, which is the Limited Effect Principle of a Relativistic System, and then use it to resolve this contradiction.

II. DERIVATION OF THE LIMITED EFFECT PRINCIPLE OF A RELATIVISTIC SYSTEM

Einstein's physical models often fail to take into account the application conditions, leading to various errors. Here is an example.

In Section V of [6], Einstein’s shown below gives us a new protagonist, the raven in Figure 1 below:

V. THE PRINCIPLE OF RELATIVITY (IN THE RESTRICTED SENSE)

In order to attain the greatest possible clearness, let us return to our example of the railway carriage supposed to be travelling uniformly. We call its motion a uniform translation ("uniform" because it is of constant velocity and direction, "translation" because although the carriage changes its position relative to the embankment yet it does not rotate in so doing). Let us imagine a raven flying through the air in such a manner that its motion, as observed from the embankment, is uniform and in a straight line. If we were to observe the flying raven from the moving railway carriage. we should find that the motion of the raven would be one of different velocity and direction, but that it would still be uniform and in a straight line. 1 Expressed in an abstract manner we may say: If a mass *m* is moving uniformly in a straight line with respect to a co-ordinate system *K*, then it will also be moving uniformly and in a straight line relative to a second co-ordinate system *K'*, provided that the latter is executing a uniform translatory motion with respect to *K*. In accordance with the discussion contained in the preceding section, it follows that:

If *K* is a Galileian co-ordinate system. then every other co-ordinate system *K'* is a Galileian one, when, in relation to *K*, it is in a condition of uniform motion of translation. Relative to *K'* the mechanical laws of Galilei-Newton hold good exactly as they do with respect to *K*.

We advance a step farther in our generalization when we express the tenet thus: If, relative to K, K1 is a uniformly moving co-ordinate system devoid of rotation, then natural phenomena run their course with respect to K1 according to exactly the same general laws as with respect to K. This statement is called the *principle of relativity* (in the restricted sense). 2

Figure 1: Einstein's Quotation is an excerpt from Section V of [2].

This example of raven caused several errors in the physical model which we discussed in [1, 2]. The more important role of the raven is that it provides a powerful and intuitive example for the doubts in the following questions and the derivation of the principle of Limited Influence of Relative Systems.

Example in Figure 1 provided two relative systems, one is the static system of the raven and the embankment, and the other is the dynamic system of the raven and the moving carriage. When the raven is viewed from the embankment, it keeps flying at a uniform speed; when the raven is viewed from the carriage, the speed of the raven in different directions is different.

Now the question is: when watching the raven's movement from the moving carriage, does the raven's speed really change, or is it just the "feeling" of the man watching the raven in the carriage (i.e., the raven's speed has not really changed)?

Einstein believed that the raven's speed really changed. (Figure 1)

Figure 2: A train moving at a uniform speed and a raven flying at a uniform speed

Einstein's vision focuses on the relative system composed of two uniformly moving objects, the raven and the carriage, as shown in Figure 1. As can be seen from Figure 1 above, when the raven moves in the opposite direction with a uniform speed w, and the train moving at a uniform speed v, the speed of the raven observed by the man in the carriage is w + v; the speed of the carriage observed by the raven is also v + w. This is the result of the mutual observation of the two reference bodies within the relative system, and it is also the result of Einstein's separation of the relative system and its surrounding environment.

A relative system consisting of a pair of independent reference bodies relatively moving at uniform speeds, such as a raven and a train carriage, is limited to the relative system, that is, between the raven and the train carriage (Figure 1). More precisely, it is limited to the senses of the man observing the raven in the train carriage. When the man in the carriage observes the flight of the raven, the speed observed for the movement of the raven in the same direction as the carriage or in the opposite direction is different. This is the data obtained by subjective observation and measurement, which is real to the man in the train as a reference body.

But if we consider the relative system in the real-world environment, as shown in Figure 3:

Figure 3: A train moving at a uniform speed, a raven flying at a uniform speed, and the surrounding real-world environment. Please imagine that when a raven is flying in the sky, a train comes, a train leaves, or a train is near the flying raven as shown in the picture. Will the train have any effect on the raven 's flight speed? Will the observation, relative calculation, imagination, etc. of the man in the train have any effect on the raven 's flight? There is another lady in the train who wants to keep the raven in a cage.

From Figure 3 as a whole, apart from the train, whether observed from the embankment or from the surrounding trees and land, the raven's flight state and speed have not changed, and are not affected by the thoughts or measurements of the man in the carriage. From this, the following principle can be deduced.

Limited Effect Principle of a Relativistic System: The calculation results within a relative system are only applicable to the two reference bodies within this relative system; the calculation results cannot be taken outside the relative system to apply to the same two objects that are no longer reference bodies.

That is to say, any relative calculation performed in a relative system only applies to the two reference bodies that constitute this relative system, and changes their states as the reference bodies of the system. However, such calculations performed inside this relative system cannot be taken outside the relative system to change the states of the same two objects when they are outside the relative system and are no longer the reference bodies of the system.

This sentence may be difficult to understand. Let's use the relative system of the raven and the train in Figure 3 to further explain.

Assume that the raven moves at a uniform speed w, in the opposite direction to the train moving at a uniform speed v. In the relative system of the raven and the train, the speeds of the two reference bodies, the raven and the train, can be obtained through their own calculations. The man in the train calculates the speed of the reference body raven as $v - (-w) = v + w$, and the speed of the reference body train calculated from the perspective of the raven is $w - (- v) = w + v$. In this relative system, the speeds of the two reference bodies, the raven and the train, moving at a uniform speed, are determined in this way.

However, such calculation results cannot be extended to these 2 objects outside the relative system. Refer to Figure 3. When observing these two objects from any place or object outside the relative system (note that they are not reference bodies at this time), the speed of the raven is still w, and the speed of the train is still v, without any change. When observing from the embankment, from the tree, from the land, from anywhere outside the relative system consisting of the raven and the carriage as reference bodies, their speeds have not changed at all.

From this, we can see that when the raven and the train are used as reference bodies in the relative system, their motion state changes with different observation angles within the system, but this change is only a change within the system. When the motion of these two objects is observed from outside the system instead of being the reference bodies, their motion states are not affected by the changes caused by the relative states.

The conclusion is: when the raven and the train carriage form a relative system as reference bodies, the change of their motion states within the relative system do not affect their motion states when they are outside the relative system and not as reference bodies but as ordinary objects.

This is the essence of the Limited Effect Principle of a Relativistic System: the calculation results obtained when an object in a relative system is used as a reference body cannot be applied outside the relative system when the object is not a reference body.

As can be seen from Figure 2, when the train and the raven are not used as reference bodies to form a relative system, no matter how the man in the train thinks or calculates, it has no effect on the actual movement of the raven. Of course, the raven has no effect on the movement of the train.

Now let's use the following Figure 4 for further analysis.

In Figure 4, two trains are being relative to a raven at the same time. Let's use the Limited Effect Principle of a Relativistic System discussed above to analyze it in detail.

Figure 4: Two trains are running in opposite directions at uniform speeds u and v respectively. How should the relative speed of the raven flying at a uniform speed w be calculated when it forms two relative systems with each of the two trains?

When the raven is relative to the above train running at speed u, the speed of the raven observed by the person in the above train is u – w; the speed of the raven observed by the man in the below train is v + w. However, according to the Limited Effect Principle of a Relativistic System discussed above, the speed of the raven outside the relative system does not change at all and remains w.

This proves that the raven can have multiple relative values as being different reference bodies at the same time when it is used as different reference bodies in each different relative system for each of the relative calculations. It also proves that these multiple calculation values can only be used within the

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relative system. Outside the relative system, the raven, a non-reference body, always maintains its original velocity value w.

Consider this situation: the raven's flying speed w = u. Then, from Figure 4, we can see that the two different relative systems produce completely different results, that is, the same raven forms two relative systems with the upper and lower trains at the same time.

- When the raven and the upper train in the figure form a relative system called "raven-train-upper", the relative speeds of the reference bodies "raven" and "train-upper" are zero (suppose w = u), that is, the raven and the upper train appear to be stationary. At this time, within this relative system, the speeds of these two reference bodies raven and train-upper are both zero.
- At the same time the same raven and the lower train in the figure form a relative system called "raven-train-lower", the relative speeds of the reference body "raven" and the reference body "train-lower " are u + v, that is, the raven and the lower train appear to be speeding. At this time, within this relative system, the speeds of these two reference bodies raven and train-lower are both u + v.
- However, when we put the raven and the train that constitute these two relative systems back to their application environment, as shown in Figure 3 below, the trees, rails, roadbed... do not feel any change in the speeds of the raven and the trains. The speed of the raven is still w, the speed of the upper train is still u, and the speed of the lower train is still v.

Figure 5: Put the raven and trains from Figure 4 into a real application environment for observation

- What we have concluded is that when an object is included in a relative system as a reference body, the state data of the reference body in the relative system will change accordingly with the different conditions of the system. However, this change is limited to the fact that the object is taken as a reference body in this relative system; when the object is separated from the relative system and no longer serves as a reference body, this change of state loses its effectiveness. This means that for the objective world outside the subjectively constructed relative system, any calculation results within the subjectively constructed relative system cannot affect the objective world outside the relative system at all!
- So, in Figure 5, when the raven consists of the upper train to be a relativity system, it had one speed while as a reference body of the relativity system of the "raven" and "train-upper". At the same time, outside this relativity system, the raven becomes itself again, and can be used simultaneously as the reference body of the relativity system of the "raven" and "train-lower", thus got a different speed at the same time as the reference body of another relativity system.

This conclusion can be extended to the entire Einstein's relative systems, but it does not apply to relative systems where two reference bodies are interdependent. Coincidentally, Einstein resolutely and consistently denied the existence of a system that maintains absolute simultaneity for decades, so it has no effect on our criticism of the Limited Effect Principle of a Relativistic System in Einstein's imaginary theory of relativity.

The movement of light relative to any object is independent, and therefore will not be affected by any behavior of another reference body that together with it constitutes a relative system. The invariance of the speed of a light ray is due to the independence of the light ray, not anything else.

Combined with the four key points that need to be paid attention to in the relative system mentioned above, the essential problem revealed by the Limited Effect Principle of a Relativistic System is: in a relative system composed of two objects that are purely mentally bound and named as reference bodies, the results obtained through relative calculations are purely imaginary data and do not have any effect on the motion states or other states of the two objects after they leave the relative system and no longer serve as reference bodies.

The movement of celestial bodies does not change because of relative observation by humans on Earth. All observation results made on a moving reference body can only be used for the reference body, and cannot be used for the object outside the relative system.

This fully illustrates the fantasy nature of Einstein's theory of relativity.

However, Einstein believed that the movement speed of the raven in Figure 1 really changed. He applied the results of the relative motion of relative systems derived from this to the Lorentz transformation, and derived the erroneous results that "the moving ruler becomes shorter" and "the moving clock becomes slower". [5]

III. TIME DILATION IS A PURE RELATIVE ILLUSION

By tracking the conflicting results of simultaneous relative calculations of a single ground-based clock paired with multiple clocks of different speeds, we show you why we say that time dilation is purely an illusion.

We first construct some relative systems to perform time dilation calculations in mind.

Relative experiments were conducted on one ground clock relative to four clocks in the space shuttles and constructed four relative systems at the same time. (Figure 6)

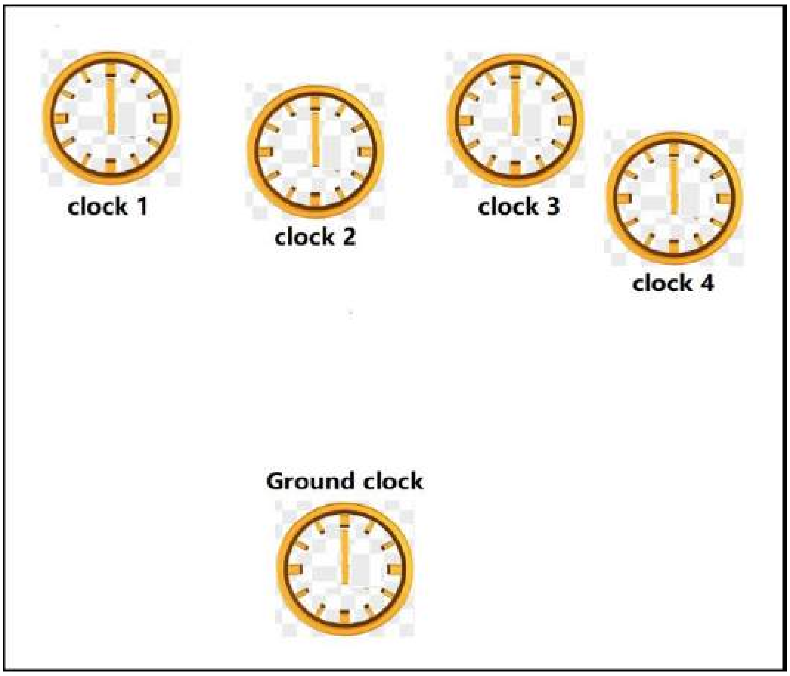

Figure 6: Ground clock is simultaneously relative to four clocks on spacecraft with different speeds.

The time dilation calculator in Figure 7 was used for calculation. The experiment started at 12 noon. One second later, the first set of experimental data was obtained using the time dilation calculator, as shown in the experimental results in the first four rows of Table 1. The spaceship continued to fly until 1800 seconds later, and the second set of experimental data was obtained, as shown in the last four rows of Table 1.

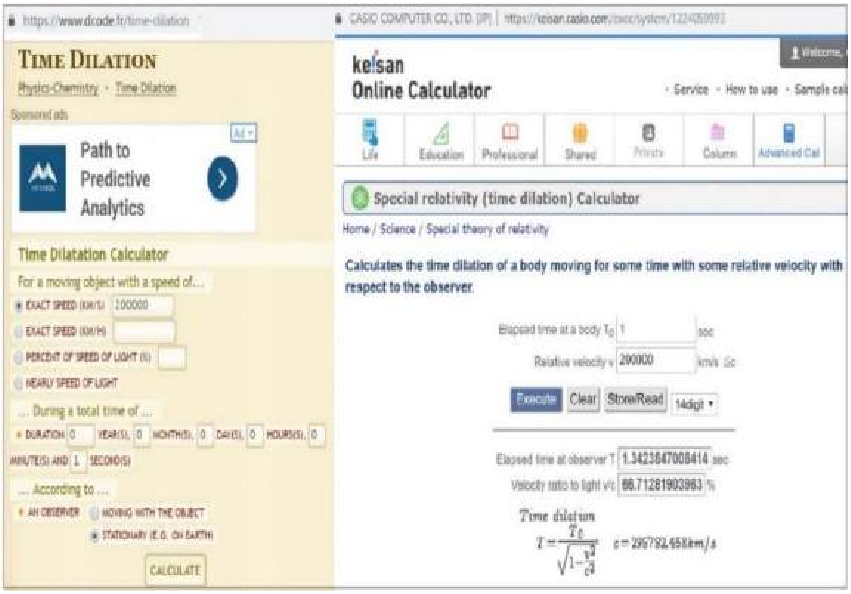

Figure 7: Strictly relativistic time dilation calculator provided by CASC COMPUTER CO, LTD

As can be seen from Table 1, as the duration increases, the time dilation value also increases greatly. Therefore, it is easy to verify whether time dilation is true in the experiment.

Table 1 Calculation results of the ground clock at the same time is relative to multiple spacecraft clocks with different speeds

Experiment time second	Spacecraft speed (m/s)	Ground clock time second	Spacecraft time second
1	200000	0.74494293578673	1.3423847008414
1	150000	0.86582546589248	1.1549671837952
1	100000	0.94272742316888	1.0607520004442
1	10000	0.99944352013705	1.0005567897052
1800	200000	59.3589994339	0.64122891504257
1800	150000	58.48583860647	38.940930831342
1800	100000	16.909361703985	49.353600799567
1800	10000	58.998336246698	1.0022214693684

For these calculation results, we have to ask:

The ground clock in Table 1 obtained 4 calculation results at 12:01 and 4 results at 12:30. So, at 12:01, which of the four experimental results in the first four rows of Table 1 should the ground clock point to? At 12:30, which of the four of the time data in the last four rows of Table 1 should the ground clock point to?

According to existing knowledge, Einstein's theory of relativity cannot answer such questions.

Such questions have been raised in our related works published over the years, and we were unable to answer them before. We can only think that they are problems with the theory of relativity itself.

However, using the Limited Effect Principle of a Relativistic System derived above, this problem can be answered now.

Put the clocks in Figure 6 into a real-world context (Figure 8).

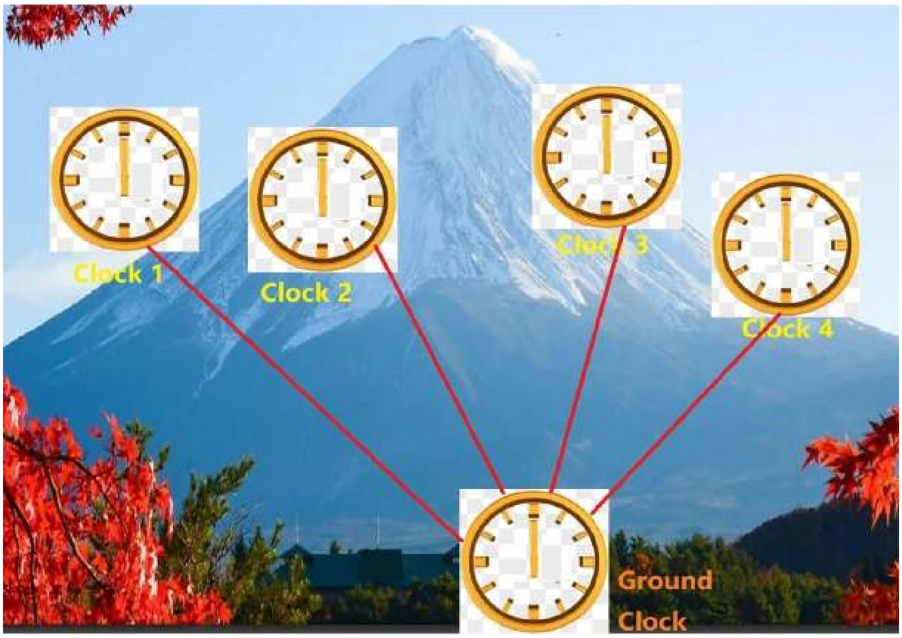

Figure 8: The ground clock is relative to the clocks in four spacecraft simultaneously. It should be noted that this relative is the product of imagination. People have no other way to bind the relativity among the clocks, and Einstein did not stipulate how two reference bodies should be relative. People can also

imagine that these clocks can be relative to each other at the same time, and many clocks on planes, trains and cars can be relative to each other at the same time... What a chaotic scene that would be.

According to the Limited Effect Principle of a Relativistic System derived in the previous section, when a spacecraft with a speed of 200,000 and a ground clock form a relative system, the clock in the spacecraft and the ground clock become the reference bodies of the relative system. The clock time of these two reference bodies is calculated using a standard time dilation calculator (Figure 7) to obtain the results in the first row of Table 1. However, this calculation result only exists in this relative system composed of imagination (is there any other way to make these two objects become the reference bodies of this relative system?), and cannot be applied outside this relative system.

Similarly, three other relative systems can be formed at the same time, and the time values of the clocks on each spacecraft obtained simultaneously and the different time values calculated by the ground clock as different reference bodies in these three different relative systems were calculated and displayed in Table 1.

In fact, it is impossible for a ground clock to have four different time indications at the same time. The Limited Effect Principle of a Relativistic System tells us that the four different time values calculated by the ground clock as different reference bodies are not values in the real world and cannot be applied outside each of the four relative systems.

This actually tells us: the time dilation of a relative system is only a kind of data that applies within each relative system and cannot be applied to the real world. Time dilation is essentially an illusion of relativity.

IV. ANOTHER APPLICATION EXAMPLE OF THE LIMITED EFFECT PRINCIPLE OF A RELATIVISTIC SYSTEM

Next, we apply the Limited Effect Principle of a Relativistic System to solve the problem of "conflicting results when a ground clock and multiple clocks with different speeds perform relative calculations at the same time" (Table 1).

The conflict calculation results in the previous section are the result of previous research, while the use of the Limited Effect Principle of a Relativistic System to resolve the conflict is a new research result. This solution itself further proves the correctness of the Limited Effect Principle of a Relativistic System.

When the ground clock forms a relative system with the spacecraft at 12 o'clock and the speed of the clock is 200,000 km/s, after 1 second of flight, the time measured by the ground clock as the reference body is 0.74494293578673 seconds. However, from the outside of this relative system, the time indicated by the ground clock is 12 hours and 1 second. Similarly, at 12:00 when the ground clock forms a relative system with the spacecraft at 150,000 km/s, after 1 second of flight, the time measured by the ground clock as a reference body is 0.74494293578673 seconds. However, from the outside of this relative system, the time indicated by the ground clock is still 12 hours and 1 second. This inference is also valid for the relative systems consisting of other two spacecrafts.

This shows that according to the Limited Effect Principle of a Relativistic System, it can explain the phenomenon that when multiple objects form multiple relative systems with a certain object at the same time, multiple different relative results will be calculated when the object is used as a different reference body in different relative systems.

This also shows that the Limited Effect Principle of a Relativistic System is correct, reasonable and effective to limit the calculation results within the relative system to the relative system. It can explain the situation when an object is used as different reference bodies in multiple relativistic systems at the same time, and each of these reference bodies is relative to another reference body in different relativistic systems.

V. CONCLUSION

The Limited Effect Principle of a Relativistic System reveals the essence of theory of relativity that the application results of the theory are limited inside the relativistic system, more specifically, limited within the two reference bodies of the system. Those calculated results have no effect outside the reference bodies. And more importantly, when the reference bodies are looked as normal objects and no longer reference bodies, the calculated results applied no more on the reference bodies.

This tells us the theory of special relativity cannot be applied in the real world, cannot extend outside the reference bodies and the relativistic system. It is basically not useful in the real world.

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Fluctuation-Dissipation Relations for the Shock Compression of Hydrodynamic Solids

Yasuyuki Horie & Davi L. Damm

ABSTRACT

This paper is concerned with an extension of the fluctuation-dissipation (F-D) relations proposed by J. von Neumann and D. Grady for the shock compression of hydrodynamic solids by use of an underlying probability density distribution. As a specific illustration of the extension, a beta function is used to develop probabilistic F-D relations. Usefulness of the extension is evaluated in prediction of Pop-plot power coefficients in the pressure-time domain. Predicted values are found to be in a reasonable agreement with measured values. Additional results include a pressure threshold for the appearance of a uniform probability distribution of energy fluctuations and the upper limit of dissipated kinetic energy.

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Fluctuation-Dissipation Relations for the Shock Compression of Hydrodynamic Solids

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ABSTRACT

This paper is concerned with an extension of the fluctuation-dissipation (F-D) relations proposed by J. von Neumann and D. Grady for the shock compression of hydrodynamic solids by use of an underlying probability density distribution. As a specific illustration of the extension, a beta function is used to develop probabilistic F-D relations. Usefulness of the extension is evaluated in prediction of Pop-plot power coefficients in the pressure-time domain. Predicted values are found to be in a reasonable agreement with measured values. Additional results include a pressure threshold for the appearance of a uniform probability distribution of energy fluctuations and the upper limit of dissipated kinetic energy.

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I. INTRODUCTION

It has not been well recognized that von Neumann considered a fluctuation-dissipation relation for hydrodynamic shocks[1] in a technical report prior to the publication of the famous paper (with R. D. Richtmyer) that introduced the artificial viscosity to regularize shocks in hydrodynamic flows.[2] In the report he defined the dissipation ("degradation of energy" in his term) by the variant fluctuations of both kinetic and internal energies and calculated their magnitudes based on harmonic fluctuation oscillations.

Recently D. Grady has published a series of papers that are concerned with the fluctuation-dissipation relation for steady shock transitions in solid materials[3,4]. In contrast to von Neumann, Grady considered a variant velocity correlation function to define energy dissipation with focus on kinetic energy. He then hypothesized an exponential correlation function and derived a dissipated energy-time relationship to characterize the shock transition. The Grady derivation of the energy-time relationship provides a foundational support for his shock invariant concept in the manner of classical action principle. The often referenced fourth power relationship between shock pressure and strain rate[5] is a direct derivative of this invariant relationship. For reference a summary of their approach is described in Section 2.

Study of fluctuations in the shock compression of solid materials is obviously not limited to the works of von Neumann and Grady. As briefly reviewed in a paper[6], noteworthy examples of modeling fluctuations are those of M. Baer[7], his associates[8] and Y. Meshcherikov[9] to name a few. Baer's work was concerned with the multidimensional simulation of shock wave propagation in heterogeneous media by use of CTH code. In contrast Meshcheryakov's work was concerned with the multiscale mechanics of shock compression processes with focus on the meso-macro exchange of momentum and energy. Interestingly, however, there is no discussion of fluctuation-energy relations in their works.

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Other types of fluctuation modeling includes the discrete element modeling of shock propagation in two dimensional anisotropic crystals[10] and a turbulence modeling of entropy change[11]. Among the works on fluctuations in shock waves, unique is the work of L. Margolin. He investigated the meaning of artificial viscosity and interpreted it as a physical phenomenon based on the evolution of integral averages of the fluid solution (Navier-Stokes equations) over finite length scales[12]. His approach is reminiscent of von Neumann's work that made a distinction between average flow and the associated fluctuations to explain the entropy increase across a shock in adiabatic flow.

What separates the work of von Neumann and Grady from others is the idea that fluctuation is the dissipation, which is inherent to shock processes. Von Neumann emphasizes a viewpoint[1] that "oscillations must develop as a shock crosses a mass point, and they have a good physical significance and represent the thermal agitation caused by the degradation of energy through the shock." The idea of inherent oscillation across a shock is basically similar to that of Grady approach. But in the Grady approach fluctuation is defined as a random motion about the average and is only concerned with kinetic energy whereas von Neumann considered the variance of both kinetic and internal energies assuming harmonic motions for the fluctuations of field variables.

Experimental observations of fluctuations in shock waves are macroscopic and based primarily on interferometric measurements of particle velocity of emerging shock wave at rear sample surfaces[6]. Additionally, existing data are mostly visual. So far as the authors are aware, the data on fluctuation have not been quantitatively analyzed and related to dissipated energies. Measurements of stress and density fluctuations do exist[13], but they are rare and are again visual as the interferometric velocity data.

There are three-fold goals of this paper. First is to extend the von Neumann approach by removing the limitation of harmonic oscillations and calculating the variance (dissipation) based on an assumed probability distribution function. The key mathematical tool is the Luss formula for Taylor series expansion of a function of a random variable to calculate the variance[14]. One advantage of the approach based on a probability distribution function is that it enables the investigation of fluctuations in terms of either underlying stochastic heterogenous meso-structures or shock-induced fluctuations in a probabilistic framework. Second is to examine the missing component of the Grady model that considered kinetic energy only. Third is application of the extended model to open a new perspective into looking at subjects such as shock-induced energy localization caused by underlying heterogeneous deformation mechanisms or heterogeneous microstructure or both. In this paper shock initiation of explosives that results in detonation is chosen as a test case. It is thought that probabilistic fluctuation-dissipation relations are well suited for modeling shock initiation of chemical reaction resulting from localized energy distribution. In the next section a brief description of the von Neumann and Grady models is provided for subsequent reference prior to the extension of the von Neumann model.

II. VON NEUMANN AND GRADY MODELS OF FLUCTUATION AND DISSIPATION

2.1 Von Neumann model

There are three key elements of the von Neumann model. First is the decomposition of internal energy into volumetric and entropic parts as shown in Eq. (1).

$$U = U_*(\upsilon) + U_{**}(S) \tag{1}$$

Then the total specific degraded energy Δ_s (per unit mass) across a shock is given by Eq. (2).

$$\Delta_s = \Delta U_{**} = U_{**1} - U_{**0} = \frac{p_1}{2}\left(\upsilon_1 - \upsilon_0\right) - \int_{\upsilon_0}^{\upsilon_1} p\, d\upsilon \tag{2}$$

where $p = -\frac{dU_*}{d\upsilon}$ and it is assumed for simplicity that $p_o = 0$. It is noted that p is isentropic compression pressure. Second key-element is the discretized total energy of the point mass system that approximates the original hyperbolic conservation equations and is given in Eq. (3).

$$\frac{1}{2}\sum_i \left(\frac{dx_i}{dt}\right)^2 + \sum_i U_*(x_i - x_{i-1}) \tag{3}$$

where x_i denotes the coordinate of i-th point mass and $\nu = \nu_i = x_i - x_{i-1}$. Third key-component is the interpretation of "oscillations" of two energies as "degraded energy", representing thermic agitation induced by crossing of a shock wave. He then assumes that the oscillations are harmonic and shows for the kinetic energy that

$$\overline{\frac{1}{2}\left(V_{osc}\right)^2} = \Delta_s(kinetic) = \frac{1}{4}\left(\dot{x}^{am}_{osc}\right)^2 \tag{4}$$

where $\dot{x}^{am}_{osc}$ denotes the velocity amplitude of harmonic oscillations and V_{osc} its velocity. Likewise, the degraded energy due to the oscillation of internal energy U_* is given by Eq. (5). It is noted that flow is assumed to be adiabatic and S in Eq. (1) is constant.

$$\Delta_s\left(U_*\right) = \overline{U_*(x_i - x_{i-1})} - U_*\overline{(x_i - x_{i-1})} = \frac{1}{2}\frac{c^2\overline{\left(\upsilon_{osc}\right)^2}}{\upsilon^2} = \frac{1}{4}\frac{c^2\overline{\left(\upsilon^{am}_{osc}\right)^2}}{\upsilon^2} \tag{5}$$

where $c^2 = \frac{dp}{d\rho,}$ $and\ \rho = \frac{1}{\upsilon}$. c is local sound speed. So, the total degraded energy in Eq. (2) is now given by Eq. (6).

$$\Delta_s(total) = \frac{1}{4}\left[\frac{c^2\overline{\left(\upsilon^{am}_{osc}\right)^2}}{\upsilon^2} + \left(\dot{x}^{am}_{osc}\right)^2\right] = \frac{p_1}{2}\left(\upsilon_1 - \upsilon_0\right) - \int_{\upsilon_0}^{\upsilon_1} p\, d\upsilon \tag{6}$$

It is noted for later reference that Eq.(4) can be put in a form similar to that of Eq.(5). That is,

$$\Delta_s(kinetic) = \overline{\frac{1}{2}\dot{x}^2} - \frac{1}{2}\left(\overline{\dot{x}}\right)^2 \tag{7}$$

where $\overline{\dot{x}} = 0$ for the harmonic oscillations.

2.2 Grady model

Grady model is only concerned with the fluctuation of kinetic energy and starts with the decomposition of particle velocity into average field and its variant fluctuation as shown in Eq. (8)[4].

$$V(x,t) = \mu(t) + \vec{u}(x,t) \tag{8}$$

Dissipated energy is related, as shown in Eq. (9), to the expected value of the square of the variant velocity on a plane (x) whose normal is collinear to the planar shock wave direction. The arrow denotes a vector quantity, but vectorial integrals were not discussed. Instead, integrated quantities such as standard deviation are deployed as shown in Eq. (9). That is, actual vectorial average calculation was not made explicit.

$$Kinetic\ dissipation = E_k(t) = \langle \vec{u}^2(x,t)\rangle/2 = \sigma^2(t)/2 \tag{9}$$

where $\sigma(t)$ *is the standard deviation identified with kinetic dissipation.*

Secondly a fluctuation-dissipation relation shown in Eq.(10) is introduced as "a measure of the temporal correlation of kinetic dissipation and identified physically as "the acoustic phonon viscosity within the shock transition, which is said to be integral to the structuring of the time history of the wave through the shock transition."[4]

$$D(t) = \int_0^\infty \langle \vec{u}(0,t)\ \vec{u}(s,t)\rangle\, ds = \int_0^\infty K(s,t)ds \tag{10}$$

where $s = \frac{\rho x}{Z}$ *and* $Z = \rho c$. Thus, variable s is a normalized space coordinate x scaled by the local sound speed c. That is, $s = \frac{x}{c}$. It is a measure of the domain of influence of sound propagation. He then introduces a quantity called frictional dissipation constant Γ within a time span of τ (shock rise time) such that

$$\Gamma = \frac{1}{2}\int_0^\infty \langle \vec{u}(0,\tau)\ \vec{u}(s,\tau)\rangle\, dm = \frac{1}{2}\int_0^\infty K(s,\tau)Zds \tag{11}$$

where $dm\,(= Zds)$ is said to be an element of areal mass. But there exists an ambiguity in the description of Γ. For example, *it is found that* $dm = Zds = Zd\left(\frac{\rho x}{Z}\right)$. So, $Z(= \rho c)$ will not cancel unless it were constant during a span of shock transition time τ. So, the picture of dm is not clear at least to the uninitiated to the analysis.

Finally, an exponential variant velocity correlation function, Eq. (12), is introduced to perform the integration in Eq. (11).

$$K(s,t) = \langle \vec{u}(o,\tau)^2\rangle e^{-s/\tau} = \sigma^2(\tau)e^{-s/\tau} \tag{12}$$

Last step in the Grady analysis is the integration of Eq.(11) with the assumption of constant Z. The result is shown in Eq. (13).

$$\Gamma = \frac{1}{2}\sigma^2(\tau)Z\tau = E_k(\tau)Z\tau \tag{13}$$

Since Z is assumed constant over the time span of τ (i.e. shock transition), Eq. (13) expresses an energy-time criterion called shock invariant at the terminal Hugoniot state. That is,

$$\frac{\Gamma}{Z} = E_k(\tau)\tau = constant \tag{14}$$

However, the question of whether $Z(= \rho c)$ in Eq. (11) is constant within the time span (τ) of shock transition (or shock rise time) is an unanswered question. But, if Z *were assumed constant*, then we can surmise upon comparison of Eq. (11) with Eq. (10) that

$$D(\tau) = \int_0^\infty K(s,\tau)ds = \frac{\Gamma}{Z} = E_k(\tau)\tau \tag{15}$$

So, $D(\tau)$ is the quantity Grady calls "shock invariant." It may be of interest to close this section by noting that Eq. (14) can be generalized based on energy law observations of the comminution of solids as shown in Eq. (16)[15].

$$\frac{\Gamma}{Z} = \frac{1}{\beta} E_k(\tau)\tau^{\eta} \tag{16}$$

where η *and* β are parameters representing a possible fractal dimension of time and a scaling factor respectively. Appearance of parameter β suggests the existence of a critical time such that $\beta s = \tau_c^{\eta}$. Detail is referred to the paper[15].

III. AN EXTENSION OF VON NEUMANN AND GRADY MODELS

Although specific details of the two models are different, the fundamental idea of relating fluctuation to dissipation is same in that shock dissipation is defined as the variance of field variables such as kinetic and internal energies. An illustration of their equivalence is given in Appendix. However, neither of the two models discusses probabilistic underpinning of the variance of field quantities. Therefore, the purpose of this work is to fill this gap using a distribution function that is amenable to analytic manipulation. In so doing we shall follow and generalize the von Neumann model and consider (1) both the kinetic and internal energies, considering their independence, and (2) show a consequence of treating only the kinetic energy fluctuation.

The chosen probability density function is a β-function as shown in Eq. (17).

$$f(x) = C(x - a)^{\alpha}(b - x)^{\beta} \tag{17}$$

where a *and* b are fixed parameters, $\alpha >- 1,\ \beta >- 1$ *and C is a normalizing constant.*
Expectation (average) and variance of variable x are given in Eqs. (18) and (19) respectively.

$$E[x] = a + \frac{\alpha+1}{\alpha+\beta+2}(b - a) \tag{18}$$

$$var[x] = E\left[x^2\right] - (E[x])^2 = \frac{(b-a)^2(\alpha+1)(\beta+1)}{(\alpha+\beta+2)^2(\alpha+\beta+3)} \tag{19}$$

In a physical space as discussed in the next section, parameters a *and* b represent lower and upper limits of variable x respectively. This means, for example, in the case of particle velocity u, dissipated energy due to fluctuation is proportional to $\bar{u}^2$. Thus, it is of interest to compare it with the original artificial viscosity q given in Eq. (20)[2].

$$q = c_2\rho\left|\frac{du}{dx}\right|^2 \Delta x^2 \tag{20}$$

where c_2 is a dimensionless constant, ρ is mass density, and Δx is the size of a computational cell. Since $\frac{du}{dx}$ can be considered constant over a small computational cell Δx, viscosity q is proportional to the kinetic energy change (Δu^2) over the cell distance Δx. Thus, as done in the analysis of frictional force on the Brownian motion using Langevin equation, the artificial viscosity may be attributed to frictional force on the fluctuating mass motion u. But the demonstration is beyond the scope of this paper.

We shall now consider the kinetic and internal energy dissipations separately though use of Eqs. (17) –(19).

3.1 Kinetic energy fluctuation and dissipation

For the velocity fluctuation we shall assume a domain of particle-velocity magnitude to be finite and defined as $\left(0,\ u_{max}\right)$. Then the probability density distribution of particle-velocity magnitude is given in Eq. (21). The corresponding expectation and variant values are given in Eqns. (22) and (23) respectively.

$$f(u) = C(u)^{\alpha}\left(u_{max} - u\right)^{\beta} \tag{21}$$

$$E[u] = \bar{u} = \frac{\alpha+1}{\alpha+\beta+2}u_{max} \tag{22}$$

$$var\,[u] = \frac{(\alpha+1)(\beta+1)}{(\alpha+\beta+3)(\alpha+\beta+2)^2}u_{max}^2 \tag{23}$$

One of the power coefficients (either α or β) and u_{max} can be determined from the requirement that the maximum density distribution occurs at the average particle velocity $\bar{u}$. That is, average state is considered to be the most probable state. Then,

$$u(at\ df/du = 0) = \frac{\alpha}{(\alpha+\beta)}u_{max} \tag{24}$$

Now, equating Eq. (24) to Eq. (22), it is found that $\alpha = \beta$ and that

$$\bar{u} = \frac{1}{2}u_{max} \tag{25}$$

$$var[u] = \frac{1}{(2\alpha+3)}\left(\bar{u}\right)^2 \tag{26}$$

The maximum particle velocity of $2\bar{u}$ is reasonable considering the fact that the reflection of a shock wave at solid free surface doubles the magnitude of particle velocity in a good approximation.

The determination of power coefficients α and β requires experimental data that are not available at the moment. But a theoretical estimate can be made of their values by considering the overall dissipated energy that can be calculated based, for example, on a linear shock velocity-particle velocity relationship (i.e. $U = c_o + g\bar{u}$) or a thermodynamic argument. That is, it is known[16] that for the linear shock-particle velocity model, the overall dissipated energy is given by Eq. (27).

$$\Delta_s(total\ per\ unit\ mass) = \frac{1}{3}gc_0^2\bar{\varepsilon}^3 + \ldots \tag{27}$$

$$\text{where } \bar{\varepsilon} = 1 - \frac{\bar{\upsilon}}{\upsilon_o} = 1 - \frac{\rho_o}{\rho} = \frac{\bar{\upsilon}}{\upsilon_o}.$$

Then using the linear $U - \bar{u}$ equation as a test case, Eq. (27) can be transformed into the dissipated energy in terms of the particle velocity to the same degree of approximation as shown in Eq. (28).

$$\Delta_s(total,\ unit\ mass) = \frac{2g}{3}\frac{\bar{u}}{c_o}\left(\frac{\bar{u}^2}{2}\right) + \ldots \tag{28}$$

Now equating Eq. (27) and (28), and noticing that the dissipated kinetic energy based on the variance is only one half of the total dissipated energy in Eq. (28) (more later on this subject), one obtains

$$\frac{1}{(2\alpha+3)}\frac{\left(\bar{u}\right)^2}{2} = \frac{1}{2}\left[\frac{2g}{3}\frac{\bar{u}}{c_o}\left(\frac{\bar{u}^2}{2}\right)\right] \tag{29}$$

Rearranging the terms, one finds an estimate for α as given in Eq. (30).

$$\alpha = \frac{3}{2}\left(\frac{c_o}{g\bar{u}} - 1\right) \tag{30}$$

Eq. (30) is valid only for $\bar{u} \leq \frac{c_o}{g}$ within the confine of model assumptions and approximations. Physically, the limiting equality signifies the emergence of a uniform distribution at $\bar{u} = \frac{c_o}{g}$, i.e., $\alpha = \beta = 0$ and Eq. (19) = constant. If the dissipated kinetic energy is the only source to the total energy dissipation as assumed in the Grady analysis, then Eq. (30) needs to be modified to Eq. (31), indicating the emergence of the uniform distribution at a much lower loading.

$$\alpha = \frac{3}{2}\left(\frac{c_o}{2g\bar{u}} - 1\right) \tag{31}$$

At present there is no data to test Eq. (30) or Eq. (31). But it may be of interest to see the level of pressure needed to reach the uniform distribution of kinetic energy fluctuation. As a test case two materials are selected from the LASL Handbook[17]. They are Aluminum Alloy 6061 and PBX 9501 (unreacted) and have the following properties respectively.

$$Al\,6061: \rho_o = 2,710\frac{kg}{m^3}; U = 5.35 + 1.34\,u\left(\frac{km}{sec}\right)$$

$$PBX\,9501: \rho_o = 1,830\frac{kg}{m^3}; U = 2.953 + 1.507\,u\left(\frac{km}{sec}\right)$$

where U *and* u are shock and particle velocity respectively and $u = \bar{u}$. Then, the respective values of the threshold pressure are

$$P(Al\,6061) = 116\,GPa \text{ and } P(PBX\,9501) = 21.2\,GPa$$

These values are reasonable levels of shock pressure to expect the onset of uniform distribution of particle velocity fluctuation. It would be of interest to evaluate the prediction experimentally and numerically. They are well within the existing technical capability.

3.2 Internal energy fluctuation and dissipation

Same procedure as that used for the kinetic energy fluctuation will be followed for calculating the fluctuation and dissipation of internal energy. The difference is the calculation of the isentropic internal energy as defined by von Neumann. In this paper the isentropic energy will be approximated, following Grady[5], by integration of the Hugoniot curve (p_h) based again on the linear U-u relation ($U = c_o + gu$) as a test case. That is,

$$U_*(\varepsilon)\ (per\ unit\ volume) \simeq \int_0^{\varepsilon} p_h d\varepsilon = \int_0^{\varepsilon} \frac{\rho_o c_o^2 \varepsilon}{(1-g\varepsilon)^2} d\varepsilon = \frac{1}{2}\rho_o c_o^2 \varepsilon^2 + \frac{2}{3}\rho_o c_o^2 g \varepsilon^3 + \ldots \tag{32}$$

Then, using the Luss approximation, it is found that

$$\Delta_s(internal\ energy) = \overline{U_*(\varepsilon)} - U_*(\bar{\varepsilon}) = \frac{1}{2}\sigma_\varepsilon^2 c_o^2 (1 + 4g\bar{\varepsilon} + \ldots) \tag{33}$$

where σ_ε^2 is the variance of ε as defined by the density distribution function given in Eq. (34).

$$f(\varepsilon) = K(\varepsilon)^a \left(\varepsilon_{max} - \varepsilon\right)^b \tag{34}$$

The average and variance are given in Eqs. (35) and (36) respectively.

$$E[\varepsilon] = \bar{\varepsilon} = \frac{a+1}{a+b+2}\varepsilon_{max} \quad (35)$$

$$var\,[\varepsilon] = \frac{(a+1)(b+1)}{(a+b+3)(a\,b+2)^2}\varepsilon^2_{max} \quad (36)$$

Then the requirement that the internal energy dissipation is half of the total dissipated energy, yields

$$\sigma^2_{\varepsilon} = \frac{1}{3}g\bar{\varepsilon}^3 \quad (37)$$

Now upon substitution of Eqs. (35) and (36) into Eq.(37), we find that

$$\varepsilon_{max} = \frac{(b+1)(a+b+2)}{(a+b+3)(a+1)^2}\left(\frac{3}{g}\right) \quad (38)$$

Similarly, the requirement that the maximum density distribution is located at the average strain yields the results that are similar to those for the particle velocity and are given in Eqs. (39) and (40).

$$\varepsilon_{max} = \frac{a+b}{a}\bar{\varepsilon} \quad (39)$$

$$\bar{\varepsilon} = \bar{u}/U = \bar{u}\,/(c_o + g\bar{u}), \quad (40)$$

Finally, combining Eqs. (38)-(40), one finds

$$a(= b) = \frac{3}{2}\left(\frac{1}{g\bar{\varepsilon}} - 1\right) \quad (41)$$

Again, uniform distribution of strain fluctuation emerges when the average strain $\bar{\varepsilon}$ reaches the value of $1/g$. A representative value of g in the LASL Handbook is about 1.5. Then Eq. (41) yields a very high relative strain of $\frac{2}{3}$ for the uniform distribution of strain fluctuation. Again, no data are available to evaluate the threshold value, but it is a reasonably high value for the appearance of a uniform distribution.

Since $\bar{\varepsilon}$ *is related to* $\bar{u}$ by the definition: $\frac{\bar{\varepsilon}=\bar{u}}{U=\bar{u}}/(c_o + g\bar{u})$, coefficients a and α are interrelated by Eq. (42).

$$a = \alpha + \frac{3}{2} \quad (42)$$

At present no data are available to evaluate the prediction. But Eq. (42) will be useful to estimate the coefficient a from α that can be determined by interferometric particle velocity measurements.

IV. AN APPLICATION OF PROBABILISTIC FLUCTUATION-DISSIPATION RELATIONS

It is shown in the previous section that with a minimum number of input data fluctuation-dissipation relations for hydrodynamic shock compression can be developed based on an underlying density distribution function of either particle velocity or relative compressive strain or both. An interesting result is the appearance of an upper limit of the dissipated energy for materials exhibiting the linear U-u relation as given in Eq. (43), which also corresponds to the emergence of a uniformly distributed fluctuation and is obtained by combining Eqs. (28) and (29).

$$max.\,\Delta_s(unit\ mass) = \frac{1}{3}\left(\frac{\bar{u}^2}{2}\right) \quad (43)$$

Understanding the meaning of this maximum dissipation fraction for the materials obeying the linear U-u relation is left as a future problem.

The goal of this section is to explore a possible application of the fluctuation-dissipation relations based on the beta density distribution function. A chosen test case is the initiation of detonation for which Eqs. (28) and (33) are interpreted to represent the sum of distributed "hot spots" (high dissipated-energy spots). For example, since $\varepsilon_{max} = 2\bar{\varepsilon}$, $max. \Delta_s = 8\Delta_s(\bar{\varepsilon})$. Then, if we use an approximation for the temperature change through use of the equation: $C_v \Delta T = \Delta_s$ where C_v is the heat capacity, corresponding maximum hot-spot temperature will be eight times the average Hugoniot temperature. This magnification is definitely sufficient to initiate localized chemical reactions even at relatively low shock pressures.

For a specific illustration of application of the distributed internal energy, a simple, but commonly used reaction model is chosen to calculate reaction-completion time as preparation for the next section where reaction time is reinterpreted probabilistically by use of the fluctuation-dissipation relation. It is noted that reaction-completion time is thought to be able to represent several situations. It could be the time necessary to form critical initiation nuclei, time to detonation, or rise time of detonation wave front, depending on the interpretation and form of the kinetic equation[18,19]. In this paper reaction-completion time is considered to be the time-to-detonation in Pop-plots[17].

4.1 Reaction-completion time and modeling threshold conditions

Goal of this section is to calculate the rection-completion time based on the kinetic equation given in Eq. (44) as preparation for application of the fluctuation-dissipation relations. This equation is an analog of standard temperature-based reaction time calculation[19] and resembles the use of variable Z in the CREST model for which Z denotes the entropy-dependent part of internal energy function (e) similar to the von Neumann decomposition in Eq.(1). That is, $e = e_0(\upsilon) + f(\upsilon)Z(S)$ where S is entropy[20].

$$\dot{x} = \nu \exp exp\left(-\frac{E_a}{E_o + \Delta_s + x\Delta q}\right) \tag{44}$$

where x is fraction of mass reacted, $\dot{x}$ its time rate of change, ν frequency factor, Δq energy release due to reaction, E_a activation energy, E_o isentropic compression energy at inert Hugoniot state. In integrating Eq. (44), we assume that the release of Δq has no influence on E_o and Δ_s. Then, the time to completion (τ) is given in Eq. (45).

$$\tau = \frac{1}{\nu}\frac{\left(E_a + \Delta_s\right)^2}{E_a \Delta q} exp\left(\frac{E_a}{E_o + \Delta_s}\right) \tag{45}$$

There are many phenomenological models of threshold conditions such as shock initiation and Pop-plots that make use of the time to reaction-completion[19,21]. In this paper a commonly used power function given in Eq.(46) is chosen to illustrate an application of Eq.(45).

$$P^n \tau = constant \tag{46}$$

where P is sustained inert shock pressure. Then, the power coefficient n can be evaluated and compared with experimental values through use of Eq. (47).

$$n = -\frac{P}{\tau}\frac{d\tau}{dP} \tag{47}$$

In order to calculate Eq. (47) by use of using Eq. (45), some approximations that are commensurate to the level of approximation for calculating dissipated energy in Eq. (27), are introduced. These approximations are

$$u = \frac{c_o \varepsilon}{1-g\varepsilon} \simeq c_o \varepsilon(1 + g\varepsilon) \tag{48}$$

$$P = \rho_o U u \simeq \rho_o c_o^2 \varepsilon\left(1 + 2g\varepsilon + g^2\varepsilon^2 + \ldots\right) \simeq \rho_o c_o^2 \varepsilon \tag{49}$$

Then upon combining Eq. (49) with Eq. (27), it is found that

$$P = \left(\frac{3\rho_o^3 c_o^4}{g}\right)^{1/3} \Delta_s^{1/3} \tag{50}$$

Finally, it may be shown after some algebra that

$$n = -\frac{d\,ln\tau}{d\,lnP} = -\frac{P}{\tau}\frac{d\tau/d\Delta_s}{dP/d\Delta_s} = \frac{3\Delta_s}{(E_o+\Delta_s)}\left[\frac{E_a}{(E_o+\Delta_s)} - 2\right] = \frac{3\Delta_s}{E_h}\left[\frac{E_a}{E_h} - 2\right] \tag{51}$$

where it is noted that the sum of the isentropic energy and the dissipated energy is approximately the Hugoniot energy even when the former is approximated by use of the Hugoniot curve. Also, Eq. (51) can be replaced by Eq. (52) where the equipartition of energy is used at the Hugoniot state, i.e., $E_h = \frac{u^2}{2}$

$$n = \frac{6\Delta_s}{u^2}\left(\frac{2E_a}{u^2} - 2\right) \simeq 4g\left(\frac{u}{c_o}\right)\left(\frac{E_a}{u^2} - 1\right) \tag{52}$$

where it is used that $\varepsilon = \frac{u}{U} \simeq \frac{u}{c_o}$ to the first order, commensurate to the approximation used to get Eq. (27). As expected, n is a function of particle velocity and depends on factors that include the approximations involved. Thus, after a spot check on Eq. (52) in the next section, the effect of particle velocity distribution on n is examined in the succeeding section in stipulation that experimentally measured values of n correspond better to average n than specific functional values based on Eq. (52). Again, data from *LASL Explosive Handbook*[17] are used for the spot check on the function in Eq. (52).

4.2 A spot-check on Eq.(52)

Since LASL data specify the power coefficients for select ranges of impact particle velocity, Eq.(52) may be best checked by inverting it to get the velocity for any given n as shown in Eq. (53), which has a single positive root given in Eq. (54)

$$u^2 + \left(\frac{c_o}{4g} n\right) u - E_a = 0 \tag{53}$$

$$u = \frac{1}{2}\left(\frac{c_o}{4g} n\right)\left[-1 + \sqrt{1 + 4E_a\left(\frac{4g}{nc_o}\right)^2}\right] \tag{54}$$

In testing Eq. (54) with LASL data, the following conversion formula is used: $1\,joule = kg(m/sec)^2$. Four materials are chosen arbitrarily. They are PETN, TATB, TNT, and PBX 9501. Experimental data are grouped by the initial density.

PETN

LASL data:

$E_a = 47.0\ kcal = 0.789 \left(\frac{km}{sec}\right)^2; molar\ weight = 316.15$

$(a)\ \rho_o = 1.72 \frac{g}{cc};\ n = 2.0;\ U = 1.83 + 3.45\, u \left(\frac{km}{sec}\right);$

$0.1 < u < 0.7 \left(\frac{km}{sec}\right); 1.7 < P < 3.9\ (GPa)$

$(b)\ \rho_o = 1.77 \frac{g}{cc};\ n = 4.545;\ U = 2.87 + 1.69\, u \left(\frac{km}{sec}\right);$

$0.5 < u < 1.5 \left(\frac{km}{sec}\right); 1.7 < P < 2.54\ (GPa)$

where the range of P is for Pop-plot measurements.

A scatter is obvious, but the substitution of the data into Eq. (54) yields

$(a)\ u(n = 2.0) = 0.765 \frac{km}{sec};\ P = 5.88\ GPa$

$(b)\ u(n = 4.55) = 0.347 \frac{km}{sec};\ P = 2.12\ (GPA)$

Predicted value of Pop-plot pressure for case (ais outside of the experimental range. But the second prediction is close to the median value of the experimental range. At present it is difficult to interpret the discrepancy in case (a) due to the scatter in the experimental data and their sensitivity to minor differences in microstructure and processing parameters.

TATB (one matching density for shock and Pop-plot)

LASL data:

$E_a = 59.9\ kcal = 0.9701 \left(\frac{km}{sec}\right)^2; molar\ number = 258.18$

$(a)\ \rho_o = 1.876 \frac{g}{cc};\ n = 2.778;\ U = 2.037 + 2.497\, u \left(\frac{km}{sec}\right);$

$0.48 < u < 1.54 \left(\frac{km}{sec}\right),\ 3.27 < P < 5.64\ (GPa)$

$(b)\ \rho_o = 1.876\ g/cc;\ n = 2.778;\ U = 1.663 + 2.827\, u \left(\frac{km}{sec}\right);$

$0.48 < u < 1.54,\ 5.93 < P < 16.5\ (GPa)$

$(c)\ \rho_o = 1.876\ g/cc;\ n = 2.778;\ U = 1.46 + 3.68\, u \left(\frac{km}{sec}\right);$

$0.0 < u < 0.48 \left(\frac{km}{sec}\right),\ 11.4 < P < 16.22\ (GPa)$

Data yield predicted values as follows.

(a) $u(n = 2.778) = 0.7419 \left(\frac{km}{sec}\right);\ P = 5.413\ (GPa)$

(b) $u(n = 2.778) = 0.7996 \left(\frac{km}{sec}\right);\ P = 5.89\ (GPa)$

(c) $u(n = 2.778) = 1.188 \left(\frac{km}{sec}\right);\ P = 13.0\ (GPa)$

Predicted values fall within the ranges of Pop-plot velocity and pressure measurements except case (b). But its deviation is only about 0.6%.

TNT

LASL Data:

$E_a = 34.4\ kcal = 0.6337 \left(\frac{km}{sec}\right)^2; molar\ weight = 227.13.$

$\rho_o = 1.62 - 1.634\ g/cc;\ n = 3.22;\ U = 2.57 + 1.88\,u\left(\frac{km}{sec}\right);\ 0.0 < u < 2.0$

$0.0 < u < 2.0\ \frac{(km}{sec)},\ 9.17 < P < 17.1\ (GPa)$

Corresponding predicted values are

$u(n = 3.22) = 0.418\ \frac{(km}{sec)},\ P = 2.29\ (GPa)$

The value of pressure is well below the experimental pressure range and is an exception among the four cases examined.

PBX 9501

LASL data:

$E_a = 40.1\ kcal = 0.5859\left(\frac{km}{sec}\right)^2;\ molar\ weight = 286.36$

$(a)\ \rho_o = 1.833\ g/cc;\ n = 1.887;\ U = 2.501 + 2.261\,u\left(\frac{km}{sec}\right);$

$0.07 < u < 0.8\left(\frac{km}{sec}\right),\ 2.38 < P(GPa) < 7.32$

$(b)\ \rho_o = 1.844\ g/cc;\ n = 2.222;\ U = 2.953 + 1.507\,u\left(\frac{km}{sec}\right);$

$0.1 < u < 0.9\left(\frac{km}{sec}\right),\ 2.47 < P < 7.21\ (GPa)$

Although initial densities are slightly different (~0.6%), two cases are treated as the same material. That is, the difference in cases (a) and (b) is viewed as a scatter for the same material. Then upon substitution of relevant numbers, predicted velocities and pressures are given as follows.

(a) $u(n = 1.887) = 0.544\left(\frac{km}{sec}\right);\ P = 3.73(GPa)$

(b) $u(n = 2.222) = 0.395\left(\frac{km}{sec}\right);\ P = 2.58\ (GPa)$

These values are well within the experimental ranges of Pop-plot measurements.

Overall, it is concluded that the results of the above-described spot check indicate that the experimentally measured power coefficients are best modeled by considering distributed fluctuations of field variables. That is, measured values of n are averaged n over the particle velocity distribution.

4.3. Influence of distributed velocity field on n

Test calculations in section 4.2 where it is seen that for the select materials the values of n were found to be within or close to the experimental ranges (with the exception of TNT), gave a hint that averaged n over a distributed velocity field would offer a more realistic estimate of experimentally measured values. Therefore, by combining Eqs. (21) and (52), this average is defined as shown in Eq. (55).

$$\bar{n} = k \int_{lower\ bound}^{upper\ bound} 4g\left(\frac{u}{c_o}\right)\left(\frac{E_a}{u^2} - 1\right)(u)^{\alpha}\left(u_{max} - u\right)^{\beta} du \tag{55}$$

where k is the normalizing constant for the distribution function. Since Eq. (55) is not easily amenable to get general analytical solutions, a special case is considered using the previously considered distribution function for which α = β = 1. But here they are not tied to loading strength and considered to be an assumed function. Then, it is found that

$$\bar{n} = \frac{4kg}{c_o}\int_{u_{min}}^{u_{max}}\left(E_a - u^2\right)\left(u_{max} - u\right) du \tag{56}$$

where $k = \frac{6}{u_{max}^3}$ for the distribution range of $(0, u_{max})$. Also, it may be seen now that since $0 < n$, $u_{max} = \sqrt{E_a}$. Then due to the symmetry of the distribution function, u_{min} is $\sqrt{E_a}/2$, which is the average particle velocity, indicating that averaging must be performed over the velocity range where dissipated energy exceeds the average value. Then, the integral of Eq. (56) yields the desired average n ($= \bar{n}$) as shown in eq.(57).

$$\bar{n} = \frac{g}{c_o}\sqrt{E_a}\left(10 - \frac{1608}{192}\right) \simeq \frac{1.63\, g}{c_o}\sqrt{E_a} \tag{57}$$

Again, testing of this equation is done using the samples used earlier for the spot check. The results are listed below. The values of $\bar{n}$ in the parenthesesare experimental values in the Handbook for comparison.

$\underline{\text{PETN}}$. $E_a = 0.789\left(\frac{km}{sec}\right)^2$, $c_o = 1.83\left(\frac{km}{sec}\right)$, $g = 3.45$. $\bar{n} = 2.73\ (2.0)$

$\underline{\text{TATB}}$. $E_a = 0.9701\left(\frac{km}{sec}\right)^2$, $c_o = 2.037\left(\frac{km}{sec}\right)$, $g = 2.497$. $\bar{n} = 1.97\ (2.77)$

$\underline{\text{TNT}}$. $E_a = 0.663\left(\frac{km}{sec}\right)^2$, $c_o = 2.257\left(\frac{km}{sec}\right)$, $g = 1.88$. $\bar{n} = 0.964\ (3.22)$

$\underline{\text{PBX 9501}}$. $E_a = 0.5859\left(\frac{km}{sec}\right)^2$, $c_o = 2.953\left(\frac{km}{sec}\right)$, $g = 2.261$. $\bar{n} = 1.13\ (1.887)$

With the exception of TNT again, predictions are in a reasonable agreement with the experimental values, considering the approximations made in the analysis and the use of an untested, hypothetical distribution function. They can be improved upon once the statistical data become available. At least closeness of the predictions to experimental values indicates a possible new approach to look at Pop-plot data based on the probabilistic fluctuation-dissipation relations.

V. CONCLUSIONS

Fluctuation-Dissipation (F-D) relations proposed by J. von Neumann and D. Grady for shock wave propagation in hydrodynamic solids were extended by introducing underlying distribution functions for both kinetic and internal energies. Due to the lack of experimental data, a beta function is hypothesized for analytical convenience to develop and evaluate the probabilistic F-D relations. One application of the probabilistic F-D relations is investigated in prediction of Pop-plot power coefficients. Predicted coefficient values were found to be in a reasonable agreement with experimentally measured values. The results are thought to open a new perspective to analyze stochastic heterogeneous shock-induced energy localization and its significance through use of probabilistic F-D relations.

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APPENDIX. EQUIVALENCE OF VON NEUMANN AND GRADY MODELS

Von Neumann defined degraded energy as the variance of both K.E. and I.E. For example, if we let v to be the particle velocity, then the degraded kinetic energy is given by Eq. (58).

$$\text{Degraded K.E.} = \langle v^2 \rangle - \langle v \rangle^2 \tag{58}$$

If we decompose v as Grady did in such a way that $v = u + \delta$, then von Neumann's degraded energy is given by Eq. (59).

$$Degraded\, K.E. = \langle (u + \delta)^2 \rangle - \langle u + \delta \rangle^2 \tag{59}$$

Expanding the bracket and assuming that $\langle \delta \rangle = 0$, $\langle u^2 \rangle = \langle u \rangle^2$, and u and δ are independent, we obtain Eq. (60) that shows the equivalence of the two models.

$$\text{Degraded K.E.} = \langle v^2 \rangle - \langle v \rangle^2 = \langle u^2 \rangle - 2\langle u \rangle \langle \delta \rangle + \langle \delta^2 \rangle - \langle u \rangle^2 = \langle \delta^2 \rangle \tag{60}$$

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ABSTRACT

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Next, a probabilistic model with a binomial probability distribution is defined, which will be applied to K_E to calculate a function f(x) for the expected value, E(X), where X is the number of pairs formed by two prime numbers.

Finally, the analysis of this function, f(x), will allow us to prove that the conjecture is tru.

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I. INTRODUCTION

In 1742 the Prussian mathematician Christian Goldbach wrote a letter to Leonhard Euler, see [1], and proposed the following conjecture.

Definition 1. Goldbach's conjecture states that:

"Every even number greater than two can be expressed as the sum of two prime numbers".

Note that, Goldbach's conjecture only requires *the existence of two prime numbers whose sum is an even number greater than two.* Naturally, if there is an even number that cannot be obtained by adding two prime numbers, this even number will be a counterexample to the conjecture.

In the 283 years since its inception, many mathematicians have attempted to prove the conjecture from various angles.

Empirical verification has shown that all even numbers, up to $n \leq 4 \cdot 10^{18}$, hold the the Goldbach conjecture. See [2].

Recently, an empirical approximation of the conjecture was published. This approximation sets an upper bound on the probability that a very large number, N, is a counterexample to the conjecture. Thus, it rules out the existence of counterexamples in practice. See [3]. It would require the use of heuristic reasoning to accept this last statement because it is impossible to prove empirically.

Currently, the conjecture remains unproven.

In this paper, we will use congruences modulo 6 from Gaussian arithmetic, see [4], to accurately calculate the number of pairs of odd numbers that could potentially contain prime numbers and add up to a given even number, n.

Then, we will use a binomial probability distribution to calculate a function $f(x)$ for the expected value, E(X), where X is the number of pairs formed by two prime numbers. With this, we will prove that the conjecture is true.

The paper is organized as follows:

In Section 2, *The Conjecture from the Perspective of Gauss's Modular Arithmetic*; we will use Gauss's modular arithmetic to analyze the conjecture.

In Section 3, *Probabilistic Model and Expected Value*; we will define the probabilistic model and applies its probability distribution to calculate E(X) based on the number of effective pairs, K_E.

Finally, in Section 4, *The Final Theorem*; we will use the function calculated in the previous section, to prove that the conjecture is true.

Notation

(1) $\mathbb{N}_0 = \{k \mid k \in \mathbb{Z},\ k \geq 0\}$: Set $\mathbb{N}$ including cero.
(2) p: Prime number.
(3) P: Set of prime numbers
(4) $\overline{p}$: Non-prime number.
(5) $\overline{P}$: Set of non-prime numbers.
(6) π_n: The quantity of $p \leq n$.
(7) $A \times B = \{(a,b) | a \in A \text{ and } b \in B\}$: Cartesian Product of sets.
(8) $(p,p) \in P \times P$.
(9) $[i]_6 = \{n \mid n \equiv i \ mod.6,\ n \in \mathbb{N}\}, \quad 0 \leq i < 6$, and also,
(10) $[i]_6 = \{n \mid n = 6k + i,\ k \in \mathbb{N}_0\}, \quad 0 \leq i < 6$.
(11) π_1: The quantity of $p \leq n$, belonging to $[1]_6$.
(12) π_3: The quantity of $p \leq n$, belonging to $[3]_6$.
(13) π_5: The quantity of $p \leq n$, belonging to $[5]_6$.
(14) K_T: the total number of pairs of odd numbers, whose sum is a given even number, n.
(15) $K_E \subset K_T$: Effective pairs that can potentially contain prime numbers.

Remark 1. Simplification of subsequent calculations.

(a) For the sake of brevity in the rest of this paper, we will refer to even numbers as n, instead of writing $2n$ or $2k$, since we know that the sum of two odd numbers is always an even number.
(b) In general, all even numbers considered in this paper will be $n > 4 \cdot 10^{18}$, which will allow us to simplify expressions containing negligible numbers compared to n. Only in examples, tables and figures, used for support or reference, will use numbers with small values.
(c) In general, π_5 is slightly higher than π_1, but the difference becomes negligible when n increases. Furthermore, only the prime numbers $2 \ and \ 3 \notin \ either [1]_6 \ or \ [5]_6$, so we will consider that $\pi_i = \pi_j = \dfrac{\pi_n}{2}$, where i, j, will be 1 and 5.

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II. THE GOLDBACH'S CONJECTURE FROM THE PERSPECTIVE OF GAUSS'S MODULAR ARITHMETIC

In this section, we will use congruences, modulo 6, from Gaussian arithmetic to analyze the conjecture.

First, let's review some of the key concepts and properties of modular arithmetic modulo 6, see [4] and [5].

Definition 2. General definition of congruences, modulo k:
"*m is congruent to r, modulo $k, (m \equiv r)$, if $m - r = kn$, with $k, n \in \mathbb{N}$*".

The congruence modulo k is an equivalence relation, because it has the properties *reflexive*, *symmetric*, and *transitive* and, therefore, the k residue classes form a partition of $\mathbb{N}$.

In this paper, we will make $k = 6$ and denote the residue classes as $[i]_6$, with $0 \leq i < 6$.

The choice of $k = 6$ meets the following two criteria:

(a) Keep odd and even numbers in separate sets.
(b) There are 6 classes of residues, modulo 6. $[0]_6$, $[1]_6$, $[2]_6$, $[3]_6$, $[4]_6$ and $[5]_6$. See notations (9) and (10). All primes are odd, except for 2. And $3 \in [3]_6$, the rest of the numbers in this class are multiples of 3, so all the others odd numbers are distributed between $[1]_6$ and $[5]_6$.

Regarding the proof, the relevant property is that the congruence preserves the addition, i.e. we can add the residue classes according to the following table:

Table 1: Symmetric addition table of residue classes modulo 6.

Add	$[0]_6$	$[1]_6$	$[2]_6$	$[3]_6$	$[4]_6$	$[5]_6$
$[0]_6$	$[0]_6$	$[1]_6$	$[2]_6$	$[3]_6$	$[4]_6$	$[5]_6$
$[1]_6$	$[1]_6$	$[2]_6$	$[3]_6$	$[4]_6$	$[5]_6$	$[0]_6$
$[2]_6$	$[2]_6$	$[3]_6$	$[4]_6$	$[5]_6$	$[0]_6$	$[1]_6$
$[3]_6$	$[3]_6$	$[4]_6$	$[5]_6$	$[0]_6$	$[1]_6$	$[2]_6$
$[4]_6$	$[4]_6$	$[5]_6$	$[0]_6$	$[1]_6$	$[2]_6$	$[3]_6$
$[5]_6$	$[5]_6$	$[0]_6$	$[1]_6$	$[2]_6$	$[3]_6$	$[4]_6$

This table shows the following sums whose result is an even number:

(i) $[0]_6 = [1]_6 + [5]_6$ or $[0]_6 = [3]_6 + [3]_6$.
(ii) $[2]_6 = [1]_6 + [1]_6$ or $[2]_6 = [3]_6 + [5]_6$.
(iii) $[4]_6 = [5]_6 + [5]_6$ or $[4]_6 = [3]_6 + [1]_6$.

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Now, to analyze the conjecture and calculate the total numbers of pairs, K_T, and effective pairs, K_E, we will use Figure 1, which is a fundamental and recurring reference here.

In the figure 1, we must look at:
On the horizontal axis, we have:

(1) K_d = number of diagonal elements (pairs).
(2) k = positioning (k_i) of the diagonal elements.
(3) $[i]_6 = i \rightarrow \quad \rightarrow 6 \times (K_d - 1) + i$. Summands belonging to $[i]_6$

On the vertical axis, we have:

(1) K_d = number of diagonal elements (pairs).
(2) k = positioning (k_j) of the diagonal elements.
(3) $[j]_6 = i \rightarrow \quad \rightarrow 6 \times (K_d - 1) + j$. Summands belonging to $[i]_6$

Note that, Kd = the total number of pairs of the sum $[i]_6 + [j]_6$ for a given even number n.

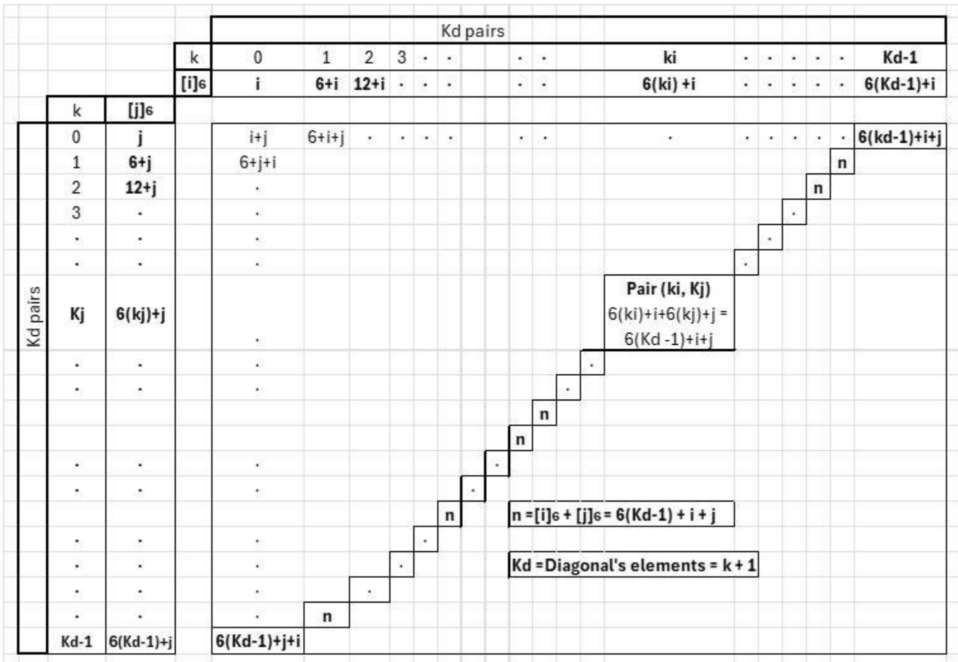

Figure 1: Template for calculating K_T, K_E and K_d, when we know n, i and j.

This figure is a template which allows us to easily calculate the number of pairs for each sum $n = [i]_6 + [j]_6$, with and i *and* $j = 1, 3$ *or* 5 depending on the elements of the sum.

Proposition 1. *The number of pairs, K_T, whose sum is a given even number n, is as follows:*

(i) *For* $n \in [0]_6$; $\quad K_T = \frac{n}{6} + \frac{n}{6} = \frac{n}{3}$.

(ii) *For* $n \in [2]_6$; $\quad K_T = \frac{n-2}{6} + \frac{n+4}{6} = \frac{n+1}{3}$.

(iii) *For* $n \in [4]_6$; $\quad K_T = \frac{n+2}{6} + \frac{n-4}{6} = \frac{n-1}{3}$.

Proof. Table 1 and Figure 1 show that.

If we set i and $j = 1, 3$ or 5 as appropriate and, take into account, that $n = 6(K_d - 1) + i + j$, we get:

(i) $[0]_6 = [1]_6 + [5]_6$ or $[0]_6 = [3]_6 + [3]_6$.
$$K_T = K_d + K_d = \frac{n}{6} + \frac{n}{6} = \frac{n}{3}$$
(ii) $[2]_6 = [1]_6 + [1]_6$ or $[2]_6 = [3]_6 + [5]_6$.
$$K_T = K_d + K_d = \frac{n+4}{6} + \frac{n-2}{6} = \frac{n+1}{3}$$
(iii) $[4]_6 = [5]_6 + [5]_6$ or $[4]_6 = [3]_6 + [1]_6$.
$$K_T = K_d + K_d = \frac{n-4}{6} + \frac{n+2}{6} = \frac{n-1}{3}$$

□

Now, let's calculate the set of effective pairs, K_E that can potentially contain two prime numbers.

Proposition 2. *The number of effective pairs, K_E is either K_d or $K_d + 1$.*

Proof. Bearing in mind that $[3]_6$ only contains one prime, 3.

In all sums that have one of the addends belonging to $[3]_6$, then there will be at most one effective pair. As follow:

(a) Sum $[3]_6 + [3]_6$: It has a single pair $(3, 3)$.
(b) Sum $[3]_6 + [5]_6$: It has a single pair $(3, n-3)$ for all $(n-3) \in [5]_6$ that is prime number.
(c) Sum $[3]_6 + [1]_6$: It has a single pair $(3, n-3)$ for all $(n-3) \in [1]_6$ that is prime number.

So, in this type of sum we will have either 1 or 0 effective pairs.

Now, for the other 3 sums, either $[1]_6 + [1]_6$, $[1]_6 + [5]_6$ or $[5]_6 + [5]_6$, all elements of the diagonal K_d are effective pairs, since, as mentioned in remark 1, all primes, except 2 and 3 belong to $[1]_6$ and $[5]_6$.

In summary, K_E *is either* K_d *or* $K_d + 1$.

Remark 2. In the next section and according to the criterion of simplifying, see remark 1, we will consider $K_E = K_d$ and $n = 6 \times K_d$.

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III. PROBABILISTIC MODEL AND EXPECTED VALUE

First, we should noted that the model does not need to calculate the exact number of prime pairs, not even get close to it.

According to the Conjecture's definition, 1, we only need to prove that $X > 0$, where $X =$ *"the number of pairs of prime numbers, whose sum is equal to n"*, so we are going to find a discrete function that minimizes the lower bound of X, for any n.

This function will be the expected value, $E(X)$, of the probability distribution of the mathematical model that we are going to build.

Definition 3. The proposed model is a probabilistic model with a binomial distribution and expected value:

$$E(X) = K_d \times \frac{9}{(\ln K_d - \ln 2)^2}$$

This value is obtained from the probability distribution outlined in the following proposition.

Proposition 3. *The random variable X follows a binomial distribution, with parameters K_d and $p(x) = \dfrac{9}{(\ln(3 \times K_d))^2}$, whose expected value is $E(X) = K_d \times p(x) = K_d \times \dfrac{9}{(\ln(3 \times K_d))^2}$.*

Proof. According to [6] and [7]

An experiment, $\in$ and an event A associated with it, with probability, $P(A) = p_a$, is called a Bernoulli trial. If we repeat the experiment n times independently and define the random variable $X = number\ of\ times$ A $occurs$, with p_a fixed for all repetitions, then, X follows a binomial distribution.

Therefore, if we define a mathematical model as follows:

(a) We take, as a Bernoulli trial, an experiment consisting of adding the elements of a pair of numbers (x_i, x_j), the result of which is a number $n = 6 \times K_d$, where $x_i = 6 \times k_i + i \in [i]_6$ and $x_j = 6 \times k_j + j \in [j]_6$, see Figure 1. And, also, we define the event A as *"Pair whose elements are prime numbers"* with some probability to be defined.

(b) We repeat that trial according to the following process:

(i) From their Cartesian product, notation (8), the first k_d elements of sets $[i]_6$ and $[j]_6$, we take the K_d elements whose sum is a given even number, n, which correspond to the diagonal (k_i, k_j) of the figure 1.

(ii) And now, we define a random variable X = "the number of pairs containing two prime numbers" where $x = (x_i, x_j)$, is one of them with probability $p(x)$.

We can apply the binomial distribution to this model if it meets the following assumptions:

(1) Each element of the diagonal, (k_i, k_j), whose sum is n, is independent of the others, and we consider them to be so because:

(i) The actual distribution of prime numbers is unknown. While it is clearly chaotic, it is not random: $\pi(n)$ decreases with n as the primes become increasingly separated, although they sometimes appear to cluster together.

(ii) The sum of the elements of x, (x_i, x_j) must add up to n, i.e. $x_1 + x_5 = n$; therefore, as x_1 increases, x_5 decreases and vice versa. This compensates for the non-randomness of the distribution of prime numbers. See figure 2 and, in particular, the line of averages.

(iii) Furthermore, given the magnitude of $K_d = \dfrac{n}{6}$ and $n > 4 \times 10^{18}$, if we wanted to further ensure the independence of the Kd pairs, we could work with a random sample of them. For example, selecting $\dfrac{K_d}{2}$ pairs at random would result in the same probability, $p(x)$, as we will see later. Therefore, it is unnecessary to use a sample to calculate the probability.

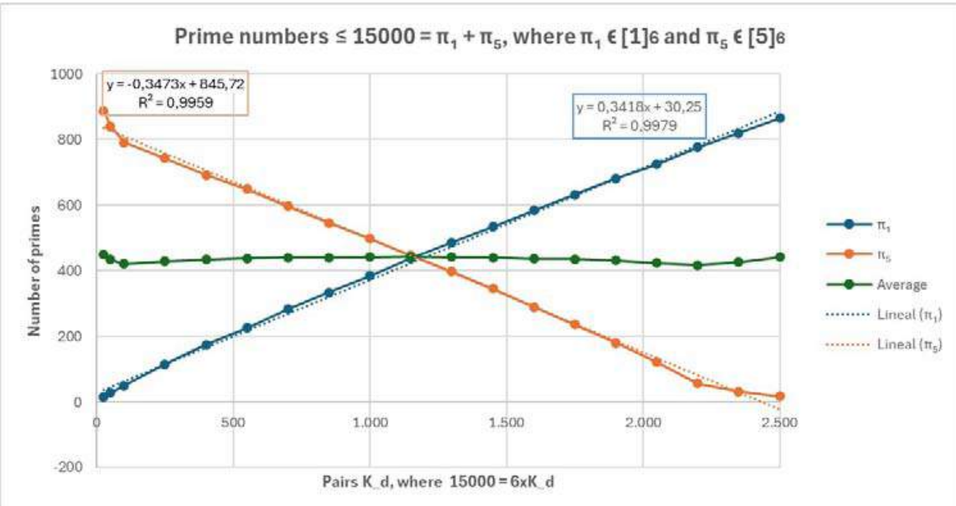

Figure 2: $n = 15,000 = 6 \times K_d$, i.e. $K_d = 2,500$ effective pairs.

(2) We only have two possible outcomes: x with probability $p(x)$ and $\overline{x}$ with probability $(1 - p(x))$.

(3) The probability that the pair contains 2 prime numbers, $p(x)$, must be equal for all pairs.

As we will see below, the probability of each pair depends on its position on the diagonal, so it is different for each pair.

Fortunately, *our objective of minimizing $E(X)$ and the degree of freedom given by the definition of the conjecture 1, allows us to overcome this problem, assigning the smallest of the calculated probabilities to all pairs.*

In the following calculations, we will consider the simplifications in remark 1.

Let $x = (6 \times k_i, 6 \times k_j)$ be any pair on the diagonal (k_i, k_j), figure 1, and we want to calculate the probability that its elements are prime numbers.

As $6 \times k_i \in [i]_6$ and $6 \times k_j \in [j]_6$, we can consider that the probabilities, $p(6 \times k_i)$ and $p(6 \times k_j)$ are independent and we will use the multiplication principle of probabilities, [7], and we get:

$$p(x) = p((6 \times k_i) \cap (6 \times k_j)) = p(6 \times k_i)p(6 \times k_j).$$

Now, we will use the relative frequency to calculate $p(6 \times k_i)$ and $p(6 \times k_j)$, since, when n is extremely large, the relative frequency converges to probability, [7].

$$\text{The relative frequency} = \frac{The\ number\ of\ prime\ numbers}{Total\ number\ considered}.$$

Note that, the number of prime numbers is divided equally between $[i]_6$ and $[j]_6$. See Remark 1.

So, Due to the symmetry with respect to the main diagonal, (k_i, k_i), in Figure 1, we get:

$$p(6 \times k_i) = \frac{\pi(6 \times K_d) - \pi(6 \times k_i)}{2 \times (K_d - k_i)} = \frac{\pi(6 \times k_j)}{2 \times (k_j)} \quad \text{and,}$$

$$p(6 \times k_j) = \frac{\pi(6 \times K_d) - \pi(6 \times k_j)}{2 \times (K_d - k_j)} = \frac{\pi(6 \times k_i)}{2 \times (k_i)}$$

Therefore,
$$p(x) = \frac{\pi(6 \times k_j)}{2 \times k_j} \times \frac{(\pi 6 \times k_i)}{2 \times k_i}.$$

The Prime Numbers Theorem, [8], states that $\frac{n}{\ln n} \leq \pi(n)$, and $\pi(n)$ becomes greater than $\frac{n}{\ln n}$ as n increases. So, applying it to $p(x)$ we get:

$$p(x) = \frac{6 \times k_i}{2 \times k_i \times \ln(6 \times k_i)} \times \frac{6 \times k_j}{2 \times k_j \times \ln(6 \times k_j)},$$

and simplifying; we get: $p(x) = \frac{3}{\ln(6 \times k_i)} \times \frac{3}{\ln(6 \times k_j)}.$

As we can see, p(x) depends on the pair's position on the diagonal and it is variable.

Due to the degree of freedom mentioned above, and since we want to minimize $E(X)$, *let's assign the minimum value of* $p(x)$ *to all pairs*, thereby ensuring that they all have the same value, as required by the binomial distribution, which will also be minimal.

To calculate this minimum value we will use the Fermat's Theorem for differential calculus, [9].

Setting $6 \times k_i = z$ and taking into account that $k_j = K_d - k_i$, and $n = 6 \times K_d$ we can write:

$$f(z) = \frac{3}{\ln(z)} \times \frac{3}{\ln(n-z)}.$$

So, calculating the first derivative $\frac{df(z)}{dz}$ and setting it equal to zero we get the minimum of this function at $z = \frac{n}{2}$, which corresponds to $k_i = k_j = \frac{K_d}{2}$. Value that could be expected due to symmetry and the function is positive within the specified range, $(1, n-1)$. See figure 3

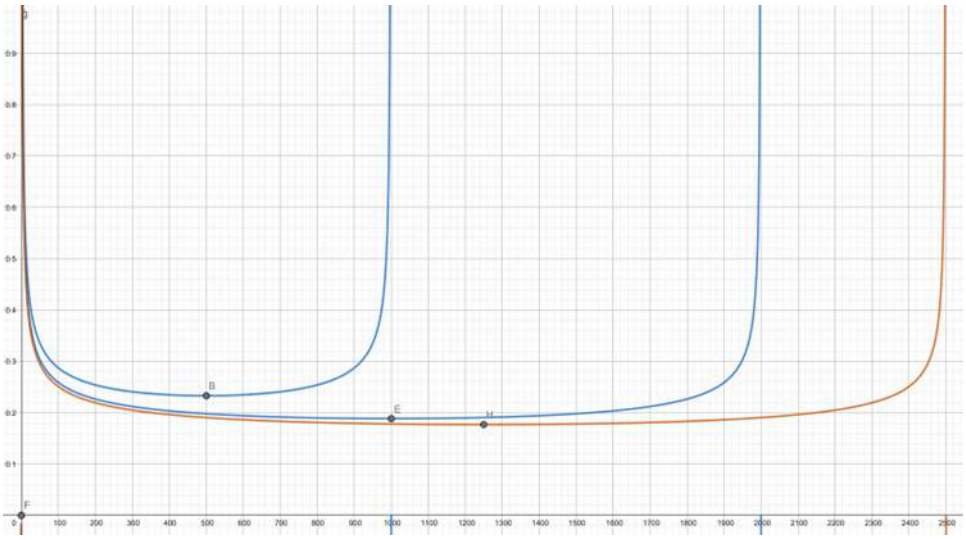

Figure 3: $f(z) = \frac{3}{\ln(z)} \times \frac{3}{\ln(n-z)}$, $n = 1,000;\ 2,000$ *and* $2,500$.

Where $B = (500; 0.233)$; $E = (1,000; 0.189)$ and $H = (1,250; 0.177)$.

Then, the value for all pairs is: $$p(x) = \frac{9}{(ln(3 \times K_d))^2}.$$

And the espected value will be: $$E(x) = K_d \times \frac{9}{(ln(3 \times K_d))^2}.$$

□

Remark 3. As mentioned in point (iii) of the previous proposition, to increase the independence of pairs K_d, we could randomly eliminate $\alpha \times K_d$, then, the sample of $(1-\alpha) \times K_d$ would contain $(1-\alpha) \times \pi(6 \times K_d)$ prime numbers. However, the odds remain unchanged, since:

(i) Random deletion preserves the symmetries of Figure 1, because it only reduces its dimensions.

(ii) So, to calculate probabilities, we can use the formulas from Proposition 3 for relative frequency, but weighted by the factor $(1 - \alpha)$ and we get:

$$p(6 \times k_i) = \frac{(1-\alpha) \times (\pi(6 \times K_d) - \pi(6 \times k_i))}{2 \times (1-\alpha) \times (K_d - k_i)} \quad \text{and,}$$

$$p(6 \times k_j) = \frac{(1-\alpha) \times (\pi(6 \times K_p) - \pi(6 \times k_j))}{2 \times (1-\alpha) \times (K_d - k_j)}.$$

And the factor $(1 - \alpha)$ can be eliminated, so the result is the same as that of the aforementioned proposition. For this reason, it is not necessary to use the random sampling process.

IV. THE FINAL THEOREM

Theorem 1. *Goldbach's conjecture is true.*

Proof. In proposition 3, we obtained that: $E(X) = K_d \times \frac{9}{(ln(3 \times K_d))^2}$.

This discrete function minimizes the lower bound of X, since, in that proposition, we have simplified some values and, in addition, we take the minimum probability value, $p(x)$, for all pairs. Therefore, we can state that: $X > E(X)$.

in figure 4, we can see that, not only is $X(E)$ below X, but the difference becomes greater as K_d increases.

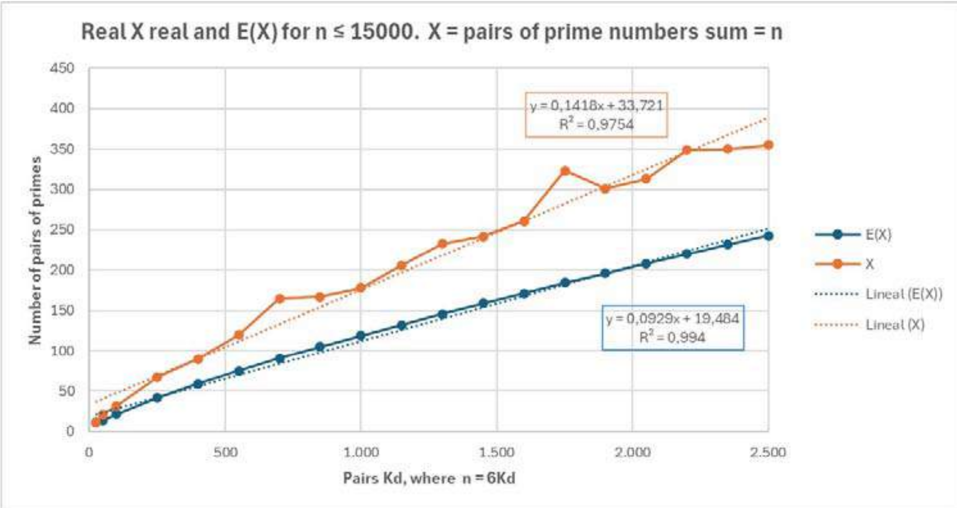

Figure 4: Real X vs $E(X)$, with $n = 15,000$ and $K_d = 2,500$

Finally, we just need to prove that, within the range of interest, $E(X) > 0$ and always increases as K_d increases.. To do this, we could proceed either graphically or analytically.

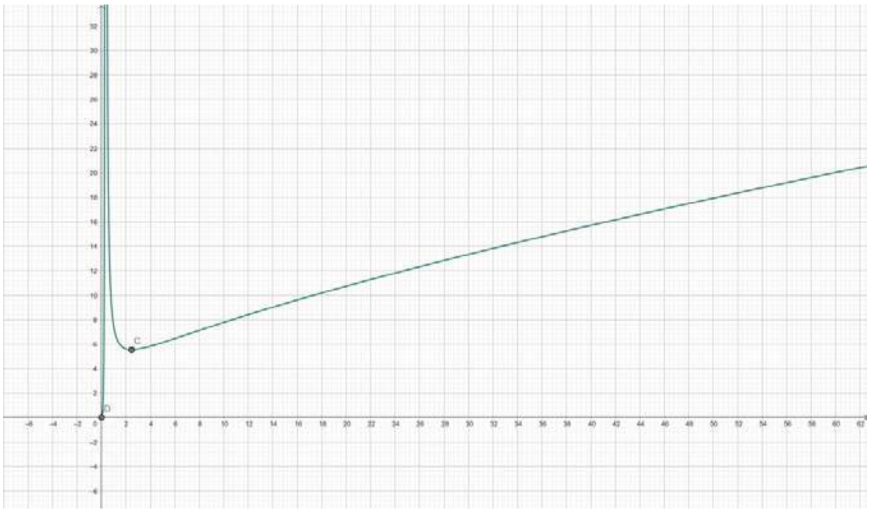

Figure 5: $E(X) = K_d \times \frac{9}{(ln(3 \times K_d))^2}$

Graphically, Figure 5 shows the function and prove that it only has a minimum at C, $2 < K_d < 3$. And, then, the function increases "ad infinitum".

Analytically, we define:

$$f(z) = z \times \frac{9}{(ln(3 \times z))^2}.$$

So, calculating the first derivative $\frac{df(z)}{dz}$ and setting it equal to zero, we get a minimum at $z = \frac{e^2}{3} \approxeq 2.463$, from which the function increases.

In both cases, the conclusion is the same: *Goldbach's conjecture is true.* $\square$

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A Study on the Nature and Form of Zero - The Fundamental Principles of Cosmic Origin Philosophy

Samo Liu

ABSTRACT

Zero is the last number invented by humankind and a truly marvellous one. At first glance, its existence appears meaningless—it represents nothing. Yet, when placed before any digit, it changes nothing; when added after, it increases the number tenfold. Multiplying any number by zero results in zero; dividing zero by any number still yields zero; but dividing any number by zero leads to infinity. Zero symbolises the origin of the cosmos—the beginning of all things. While other numbers express the existence and transformation of matter, only zero represents the primordial origin of the universe and the beginning of phenomena.

The cosmic origin is a state of non-material or immaterial existence—not absolute nothingness, but rather the foundational basis of all being. All things arise from such a base point, and that point is zero. Yet, this is a living, yin-yang阴阳 zero. Let us begin at the beginning and reflect upon the profound significance of this number. The invention of information and knowledge by humanity may indeed serve to explain just this—perhaps it exists for precisely that reason.

Expressed in the language of human-created information: zero is the beginning of the universe and of all things. Returning to zero symbolises balance and the perfect of human knowledge and informatio.

Keywords: zero; cosmic origin; energy, information and matter; force, thermodynamics and existence.

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I. LITERATURE REVIEW: CREATIO EX NIHILO? YES, LET US BEGIN ANEW

Humans emerged within the creation of the universe. That humanity exists is, at the very least, a good thing—from our own perspective. Yet how were we created? That remains unknown. However, humans have invented language, script, and numerical systems, from which knowledge and information have arisen. With these tools, and through philosophical reasoning, let us begin our reflection from the very start.

From current scientific understanding, we know that humans arise from the union of sperm and egg—an integration of yin and yang substances through physical and chemical reactions. These cells originate from the bodies of the parents, sustained and formed through the energy and information derived from food, sunlight, air, and water—a thermodynamic transformation of energy and information in another yin-yang combination (Liu Hongjun & Samo Liu, 2020; 2021a). This process may be described as a physical-chemical reaction, but more fittingly as a thermodynamic causal reaction of "being" and "non-being" (Samo Liu, 2025d), aligning with the philosophy of cosmic origins (Samo Liu, 2025f).

By extrapolation, our parents came from their parents—our ancestors—and so on, back to the very beginning. That origin marks the formation of human cells from a primordial "spatial formal cause" through processes of accumulation and natural selection. Whose design was this? The god of the cosmos, perhaps.

The formation of cells traversed stages: from plant cells, to animal cells, to human cells (Samo Liu, 2025d). The formation of cells arises from atoms and molecules, whose origins are explained by quantum mechanics and relativity—showing their creation from the equivalence of energy and matter, via particles and quarks that resemble non-material energy and material energy, structured by strong force, weak force, and electromagnetism. Notably, gravity is absent at this stage—it is a secondary force emerging from mass (Samo Liu, 2024i).

Physics tells us: without mass, there is no positionality or distance between material entities (Leibniz, 1996), and thus no gravity. The philosophy of cosmic origins and quantum mechanics reveal that particles may possess mass—or not. This reflects the chaotic initial state from which matter is created (Samo Liu, 2024i).

Every form of existence, whether material or immaterial, possesses a structure. This structure is composed of structural information and information about forces, forming a yin-yang nature of being. Every existence must be accompanied by a process of temporal measurement beginning from zero (a human-made concept), as well as a structural form of existence, movement, transformation, evolution, and change—all measured from zero (also human-made). (Samo Liu, 2025f)

Note: Without human-created knowledge and information, the universe cannot be expressed—but regardless of human expression, the universe exists as it is.

Each form of existence carries with it a system of measurement and expression that begins from zero. Without the number zero, the expression of human knowledge and information would lack a point of origin—a coordinate zero-point—from which to begin.

As stated in the first chapter of the Dao De Jing:

"无名天地之始;有名万物之母.(untranslation" (Laozi, 2019; Liu Hongjun & Samo Liu, 2021d)

And in the Heart Sutra:

"观自在菩萨行深般若波罗蜜多时，照见五蕴皆空，度一切苦厄(untranslation" (Sakyamuni, 2020; Liu Hongjun & Samo Liu, 2024).

These teachings mean that the fundamental origin of humanity and all things is "nothingness无" and "emptiness空" (*wu* and *kong*), and that the initial state of their creation is "being有" (*you*). "Being有" includes quarks, particles, atoms, molecules, cells, and more. The emergence of humanity is a comprehensive result of both material and immaterial forms of existence. Of course, this also includes forces, time, and informational elements. All forms of being possess soul灵魂 and mind心灵.

Those who are alive possess soul灵魂 and mind心灵 all the more. (Samo Liu, 2025d)

Zero is the foundation of the universe—the point of origin, the basis and balance point of philosophical inquiry. Humanity and all beings arise from it. Even in the material world, a coordinate system must have a zero-point origin. All existence begins from this point of zero. In daily life, when we begin something, we often say: "Let's start." In the end, we return to zero or a final figure. Zero is a monumental invention of human knowledge and information systems.

Admittedly, with the limits of current human knowledge, we do not know exactly how humanity began—nor do we know how the universe began. Nevertheless, humans have invented language, script, numbers, mathematics, coordinate systems, and scientific methods—tools of knowledge and information that allow us to explore these questions. We can use philosophy to contemplate them—or even exaggerate and imagine freely through art—because humans possess soul and mind, senses感觉 and perception感知, and a unique capacity for dialectical reasoning. Other animals and forms of matter do not possess such faculties.

Before Aristotle, several great thinkers had already told humanity that both humans and material things originate from the primordial conditions of "nothingness无" and "emptiness空" Many people found this difficult to believe, leading to contradictions. Aristotle launched the tradition of material philosophy, telling us that we should consider humanity and matter to have emerged from material substance, and should study them by category and classification. As for the older philosophical ideas that humans and matter arose from "nothingness" and "emptiness," he left those to theology. (Aristotle, 2019; 2016)

More than two thousand years later, humanity has reached the scientific pinnacle of quantum mechanics and relativity. Scientific discoveries have verified that matter and life indeed originate from fundamental conditions of "nothingness" and "emptiness." As a result, we are compelled to revisit the ancient cosmological views of our pre-Aristotelian ancestors—this time through the lens of dialectical materialism. (Samo Liu, 2025f)

British author Jeremy Webb edited a volume titled" *Nothing: From Absolute Zero to cosmic oblivion amazing insights into nothingness* "—a collection of essays on scientific philosophy. This work offers substantial inspiration for thinking about the cosmic origin and the philosophy of zero. (Jeremy Webb, 2018).

It is an excellent work of scientific philosophy. The book employs dialectical materialist logic to investigate the meaning of "emptiness," "nothingness," and zero. Rather than reviewing the book in detail here, we may integrate it with Daoist, Buddhist, and Ancient Greek philosophies of cosmological origins, alongside conclusions from modern physics. From this, we can assign to zero a new philosophical significance:

Zero is the informational foundation of the philosophy of cosmic origin**.**
The book includes a number of essays on zero and "emptiness"/"nothingness," such as:

Richard Webb's *The Birth of Zero* (pp. 25–32)
Paul Davies' *The Beginning of Time* (pp. 47–57)
Ian Stewart's *The Mathematical Magic of Zero* (pp. 129–136)
Paul Davies' *A Space of Nothing* (pp. 139–145)
Ian Stewart's *The Ubiquity of Emptiness* (pp. 175–180)
Michael de Podesta's *Absolute Zero* (pp. 183–193)
Michael Brooks' *The World of Supermatter* (pp. 233–242)

Richard Webb's research suggests that in 628 AD, the Indian astronomer Brahmagupta published the *Brāhmasphuṭasiddhānta* (*The Correct System of Brahma*), in which the concept of zero made its first clear mathematical appearance. Later, the notion of zero experienced various fluctuations in acceptance and use. In the 17th century, French philosopher and mathematician René Descartes established the Cartesian coordinate system, placing zero firmly and irrevocably at the central and irreplaceable position of all spatial and mathematical representation. (Jeremy Webb, 2018, pp. 25–32)
Who exactly discovered or invented the number zero is not the crucial matter here. What truly matters is that this was one of humanity's greatest contributions across mathematics, philosophy, science, and theology—a pivotal creation in the development of knowledge and information.

Paul Davies posed the question of "*the beginning of time*", though he offered no definitive answer within his article. At the very outset, Davies points out that merely suggesting that science might explain the origin of the universe is enough to provoke passionate responses from both theists and atheists.(Jeremy Webb, 2018, pp. 47–57) Why such strong reactions?

I have written extensively on this issue: because the human mind and its cognitive "software" have long been imprisoned by the material philosophy of Aristotle. For over 2000 years, material philosophy has become a trap for human thought, causing humanity to forget that "*time and space"* are themselves philosophical constructs—creations of human cognition in response to natural phenomena. (Samo Liu, 2025c) This issue will be further explored below, along with a suggested answer.

Ian Stewart, in his article *The Mathematical Magic of Zero*, argues that dealing with zero requires strong conceptual flexibility. Zero represents *emptiness* and *nothingness*. It has brought both anguish and joy to mathematicians. Stewart also notes that *nothingness* is one of mathematicians' favourite themes—a kind of Pandora's box, filled with curiosity and contradiction, sitting at the very heart of mathematics.

Pandora's box has been opened, and what flew out was "emptiness and nothingness." This concept is dazzling, unruly, and provocative—yet essential. The "infinity" introduced by zero can undermine the integrity of mathematical calculations. (Jeremy Webb, 2018, pp. 129–136)

The article shows that the allure of zero is not limited to mathematics—it permeates all of humanity's philosophical thinking. Although it analyses zero from a materialist philosophical perspective, it does not fully explore the deeper meaning of this fascination. This paper aims to offer such an interpretation.

In *A Space of Nothing*, Paul Davies raises the question: *How can "emptiness" separate objects in space or possess attributes such as volume and boundaries?* A possible answer will be offered later, with reference to earlier works I have published.

Davies points out that the ancient Greeks held two primary conceptions:

There is a view represented by the perspective of Parmenides, believed that the vacuum was actually filled with an invisible medium—a view inherited and developed by Aristotle. However, from my own study of Aristotle's works, I have found no such development; rather, Aristotle left the concept of "void" to theology and Simplify 'philosophy' into the logical framework of material philosophy and material science.

Another concept is atomism, which believed that the universe was an infinite void filled with innumerable, indivisible particles—*atoms*—which aggregated in various combinations to form matter and physical entities.

The article also discusses the opposing views of Newton and Leibniz on *absolute space*. From my reading, however, I believe that their views were fundamentally aligned. (Samo Liu, 2021c) Leibniz did not deny the existence of absolute space—he simply approached it from a different analytical perspective and ultimately proved its existence. (Leibniz, 1996).

Davies' article touches on the concepts of *fields* and *aether*, as well as the quantum mechanical phenomenon that particles and electrons do not obey Newtonian concepts of space-time. Notably, the article describes quantum theory's astonishing calculation: that an empty box of given volume contains *infinite energy*. Thus, it concludes that a vacuum is not truly empty but is instead filled with boundless energy.

The article ends with the conclusion that *the fate of the universe lies in the nature of the vacuum.* (Jeremy Webb, 2018, pp. 139–145)

This is an excellent piece of science writing that popularises physics and cosmology, though it ultimately leaves the core questions unanswered. These are addressed in my work.

In *The Ubiquity of Emptiness*, Ian Stewart argues that the concept of "emptiness" is, in mathematical terms, an *empty set*. He asserts that zero is a number—the foundation of the entire numerical system. The secret of mathematics lies in the fact that everything reduces to "emptiness."

The article explains the concepts of "nothingness" and zero from a purely mathematical standpoint. (Jeremy Webb, 2018, pp. 175–180) Here, I offer a complementary analysis from the perspective of philosophy.

In *Absolute Zero*, Michael de Podesta proposes that absolute zero is an ideal—unattainable, perfect, and ultimate cold. He asserts that heat is a naturally inherent form of energy. Since the mid-19th century, scientists have tried everything imaginable to get ever closer to this limit. In the process, they discovered a realm of extraordinary beauty and order, enriching the core of science—especially deepening our understanding of temperature and of matter itself.

In my previous writings, I raised a regrettable point: the scientific and technical communities have not yet explored the transformation between non-material and material states from the perspective of the *mass* and *structure* of matter itself.

The article explains how Lord Kelvin established the absolute temperature scale. While scientists typically use the Celsius and Fahrenheit scales, absolute zero corresponds to -273.15°C on the Celsius scale, and the melting point of ice is represented as 273.15K on the Kelvin scale.

From this foundation, humanity began the liquefaction of gases and advanced steadily toward absolute zero. Scientists began to recognise the strange transformations that matter undergoes near this limit—phenomena such as superconductivity and superfluidity emerged. It was also discovered that cooling matter near absolute zero reveals its fundamentally quantum-mechanical nature.
(Jeremy Webb, 2018, pp. 183–193)

However, the article does not apply the philosophy of *cosmic origin* to its analysis. It remains grounded in materialist philosophy, using quantum mechanics and relativity to describe the transformations observed near absolute zero—but fails to examine these as possible traces of the transformation between material and non-material realms. This issue will be explored further below.

In *The World of Supermatter*, Michael Brooks writes that cooling matter to absolute zero is equivalent to removing all of its thermal energy—bringing it closer to an ultimate state. At this threshold, a door opens to an entirely new world in which all the familiar laws of physics begin to break down.

This statement closely mirrors the language used to describe quantum mechanics—and, intriguingly, also echoes the metaphysics that Aristotle once handed over to theology.

The article describes how, at extremely low temperatures near absolute zero, many metals lose their electrical resistance and become superconductors. This transformation is not gradual but occurs suddenly—at a critical temperature—where extraordinary phenomena take place.

Brooks extends the discussion by introducing a profound idea: when temperature nears absolute zero and all thermal energy is removed, particles are left with very few allowable energy states. The only change that can then occur is the swapping of positions among particles, resulting in a change in phase. He introduces bosons and fermions.

(Jeremy Webb, 2018, pp. 233–242)

He also discusses a seemingly single-matter state known as Bose-Einstein Condensate, or BEC for short. In such states, physics appears to transform matter into *energy-matter states* or *information-matter states*—a concept that is undeniably strange.

It is worth noting: once physics begins to describe "*information-matter states"*, it steps perilously close to a philosophical dead end. Both science and information science have already clearly defined that information is neither energy nor matter. (Samo Liu, 2024i)

This introduces a monumental philosophical paradox into physics. There is, however, one known exception: the discovery that *hormonal substances* may exhibit target-specific informational properties. (Liu Hongjun & Samo Liu, 2020).

The article, while exploring *the world of supermatter* from the standpoint of materialist philosophy, does not offer concrete answers. It discusses phenomena, not principles. In this paper, I attempt to provide a response through the lens of *cosmic origin philosophy*.
Philosophical foundations of this work:
Daoist philosophy, Buddhist philosophy, Ancient Greek philosophy, and dialectical materialism.

Scientific foundations discussed:

Modern physics, systems science, and mineral processing science.

Core theme

The mathematical and philosophical functional principles of "*zero"*, as a creation of humanity—serving as the philosophical foundation of *cosmic origin*.

II. DISCUSSION

Humanity has created language, numbers, characters, mathematics, coordinate systems, science, and a wide array of information tools. In the quest for survival and existence, knowledge and information were created, which are now used to study the universe and the existence within it—including the existence of humanity itself. (Samo Liu, 2025g)

The defining characteristic of such knowledge and information is that it is built upon *philosophical reasoning* and represents a standardised, formatted, and unified system of information. The object of study is the universe and all forms of existence within it, including human society. What is sought is *cosmic truth*, and what is used are tools of human information. The information and knowledge generated through these tools are inherently incomplete, evolving, exploratory, and non-absolute.

Humans pursue truth, but the knowledge and information we create can only represent *relative truth*, never absolute truth. Humanity's current mode of thought follows the tradition of *post-Aristotelian material philosophy*—treating the universe, all within it, and human society itself as fundamentally *material* existences to be studied scientifically. Similarly, the "universal truths" uncovered by science are not absolute but relative and always subject to change through exploration.

The cosmological ideas of our ancestors concerning the *origin of the universe*—due to the limited information available in ancient times—were deferred by Aristotle into the realm of *theology*. He set aside the ideas of *emptiness and nothingness* as the cosmic origin, and instead boldly developed the disciplines of *material philosophy* (First Philosophy) and *material science* (Second Philosophy), leading to tremendous advancement in human knowledge and information.

However, upon reaching the peak of scientific development, humanity has now found that what was once deemed metaphysical and relegated to theology is being *validated* by modern physics. The phenomena emerging from modern physics can no longer be adequately explained using only the frameworks of materialist philosophy. Thus, we must revisit and re-integrate the ancient philosophies of *cosmic origin* to *supplement and complete* the current systems of knowledge and information.
We are now required to take the fruits of materialist philosophy and material science, and—together with ancestral philosophies of cosmic origin—reconstruct or re-invent human knowledge and information... starting from zero.

2.1. The Philosophical Foundations of the Study of Zero

Ancient Greek philosophy's study of cosmic origin is most clearly reflected in Parmenides' ontology of origin. In *Physics*, Aristotle once provided a detailed logical critique of this ontological framework. He believed that denying such a "void-based ontology" was relatively easy, yet he did *not* deny it outright. Instead, he acknowledged its form of "existence" but felt insufficiently informed. (Aristotle, 2019)

As a result, in *Metaphysics*, he solemnly assigned this "void-based ontology" to the domain of theology. (Aristotle, 2016) He then earnestly designed a logical classification: material philosophy as *first philosophy*, and material science as *second philosophy*—thus beginning a new intellectual journey for humanity. (Garrett Thomson & Marshall Missner, 2019)

Whether one praises or criticises Aristotle's philosophical concepts, it remains a fact that Western philosophy and science evolved within the framework he designed.

Modern humans have created the digital, mathematical concept of zero. Meanwhile, modern physics and modern science have introduced the yin-yang notion that matter–atoms–originate from nothingness, energy, and information. We must now begin to sort through this concept starting from zero.

The conceptual roadmap includes several yin-yang domains, as follows:

2.1.1 First Yin-Yang Domain

Absolute Zero and Absolute Space –

Zero-dimensional absolute space, with zero time. Time cannot be defined. Spatial form is infinite—no length or distance units can be specified. Energy and information exist as infinite *void and nothingness*. This is the cosmic origin, the starting point of the material universe, and the *existence* referred to by Parmenides.

2.1.2 Second Yin-Yang Domain

Dark Matter and Dark Energy –
The concept of non-material energy and information. These forms lack materiality but possess *structural spatial form*. Though their exact structures are unknown, they are non-material and non-three-dimensional. They do not correspond to absolute zero temperature. They could be termed "zero-dimensional," or given alternative nomenclature. Structure implies process; while the time unit is currently unknown, a new physical time unit could be invented.

2.1.3 Third Yin-Yang Domain:

Quantum Mechanical Energy and Information –

Here begins the emergence of *materialised energy*. The categories of *fermions* and *bosons* have been named. These structures exist in a liminal state—between material and immaterial. For bosons, they should be treated based on information about time and force. (Samo Liu, 2024b; 2024i; 2025c).

Fermions can be interpreted with reference to Prof. Edward Witten's M-theory, though the boundary between material and non-material, as well as gravitational mass, must be clearly defined. *Mass* gives rise to *position* and *gravity*; *structure* gives rise to *charge position* and *electromagnetic force*. Time can be measured in Planck time, and distance in Planck length. (Samo Liu, 2025c)

2.1.4 Fourth Yin-Yang Domain:

Matter –
Here, matter formally emerges in a *trinary yin-yang duality*—the Tai Chi of yin and yang. (Samo Liu, 2025g) In this realm, the study of time and mechanics is well-established. Both mechanics and time reflect the dynamics of thermodynamic motion and transformation. (Samo Liu, 2024i; 2025c; 2025e).

Space is described using a three-dimensional coordinate system, while time uses standard human-defined units of time and length. These time and space units are *inflexible, irreversible, and fixed* within the framework of physics.

2.1.5 Fifth Yin-Yang Domain:

Motion and Energy Conversion of Matter –

Thermodynamics explains all mechanical and temporal processes of existence. The transformation between matter and energy takes place in three-dimensional space. Through the interplay of time and force, these transformations occur as *yin-yang exchanges*. In this domain, spatial units may be measured in light-years or parsecs; time may be measured in kalpas ("劫", a cosmological time unit). (Samo Liu, 2025c)

From the second to fifth domains, we define the realm of thermal energy-based material existence. The total energy of the universe is expressed as negative entropy:

E = Total energy of the created universe
E1 = Energy of material mass
E2 = Energy of material motion and transformation
E3 = Quantum mechanical energy involved in creating material mass
Ex, Ey = Dark matter and dark energy

If the total energy of the universe is represented as 100%, then:

Ex + Ey = 95.1%
E1 = E2 = E3 = 4.9% (Samo Liu, 2024g; 2024h)

E1, E2, E3, Ex, and Ey undergo mutual transformation under thermodynamic conditions of force and time—forming a Tai Chi of yin and yang. (Samo Liu, 2025g)

The first domain is named:
The Infinite—Wu Ji of Yin and Yang.(Samo Liu, 2025g)

The previous article, *"Wu Ji无极 and Tai Ji太极, Yin–Yang阴阳 and Heaven–Earth乾坤"*, outlined a model of the physical universe based on the philosophical thinking of *cosmic origin*. (Samo Liu, 2025g; 2024h; 2024i) This article, in contrast, begins from zero to explore the framework of *existence* itself.

In Buddhist philosophy, ideas of cosmic origin are concentrated in the *Diamond Sutra* and the *Heart Sutra*. (Sakyamuni, 2020) It holds that the world is material, and that the origin of matter lies in "emptiness空" (*śūnyatā*). Emptiness does not mean nothing at all; rather, to comprehend emptiness is to attain enlightenment, known as *Anuttara-Samyak-Sambodhi*阿耨多罗三藐三菩提. (Liu Hongjun & Samo Liu, 2024)

Regarding *space*, true space cannot be defined by humanity. The space humans understand is the three-dimensional coordinate system of physical matter.

Regarding *existence within space*, everything is expressed in terms of *'Cause'* 因*and 'factor's*因素 *"conditions*因缘*"*—a binary nature. When conditions change under a cause, this process is termed *pratītya-samutpāda*缘起 (dependent origination), or *causal relationship*因果关系. The direction and pathway of transformation is called *du*度 (degree/measure/process), and the means and purpose of this transformation is called the *Middle Way*中道. (Liu Hongjun & Samo Liu, 2024)

Different forms of existence correspond to different time scales. In Buddhist philosophy, the time unit for understanding the universe is *kalpa* (劫). In contrast, human-created time units are exceedingly brief when viewed from this perspective.

The last words of Sakyamuni Buddha in the Diamond Sutra are:

"一切有为法，如梦幻泡影，如露亦如电，应作如是观（*untranslation).*"
(Sakyamuni, 2020; Liu Hongjun & Samo Liu, 2024)

All forms of existence have structure and form, and can be represented through process. From emptiness they arise, and to emptiness they return. In other words, whether in form or in process, all things begin at zero, undergo a structured journey (expressible through numbers or mathematics), and eventually return to zero—only to begin again.

This cyclical existence and transformation corresponds with the five *yin–yang* domains previously defined.

Emptiness is the origin本原—and the beginning—which is zero.

Daoist philosophy systematically explores cosmic origin. The roots of this philosophical system begin with the *I Ching*, or *Book of Changes* (Samo Liu, 2025e), and are systematised in Laozi's Dao De Jing, as well as in the *Wenzi*, *Liezi*, and *Zhuangzi*.
(*Laozi, 2019; Liu Hongjun & Samo Liu, 2021d*)

In the *Dao De Jing*, space and existence are described comprehensively:

"道可道，非常道；名可名，非常名。无名天地之始，有名万物之母（*untranslation."*

Here, "无名天地之始" describes the primordial existence of space and the universe. "有名万物之母" describes material existence within space. The opening lines tell us that humanity will *always* need to explore space and its contents—the limitations of language, mathematics, coordinate systems, and even science mean we will never fully explain them. The universe is a fusion of *"being*有*"* and *"non-being*无.*"*

In the *Wenzi*, Space and the existence within is described as:
"四方上下谓之宇，往古来今谓之宙。（untranslation." (*Wenzi, 2019*)

This implies that space may be understood as a three-dimensional realm ("above and below, left and right"), and the material within it exists with beginnings, changes, and movements. Every existence will eventually end. One must consider both the *structure* and the *process* of existence—*form* and *time*—to perceive life itself. This is the cosmic-origin method of observing all phenomena.

This view of spatio-temporal existence is remarkably similar to Einstein's four-dimensional spacetime. All things have a beginning and an end, moving and transforming from zero to some value, and then returning to zero—manifesting the states of *yin* and *yang*.

Perhaps the most poetic expression comes from *Zhuangzi*, in *Gengsang Chu*:
"有实而无乎处者宇也;有长而无乎本剽者宙也。(untranslation"
(*Zhuangzi, 2017*)

"有实而无乎处者宇也."Interpreted through cosmic origin philosophy: tangible matter—like Earth, the solar system, or the Milky Way—occupies *somewhere* in space. But without a coordinate system constructed by humans, we cannot describe where. Furthermore, it suggests that tangible matter originates from *emptiness*. To represent such material existence, a coordinate system must be established—and the *origin* of this system is zero. This is the existence of *yang*阳.

"有长而无乎本剽者宙也."*Zhou*宙 is a form of *yin*阴 existence. It governs the motion and transformation of *yang*阳 entities. It is an informational existence that cannot act upon itself—like *force*, which cannot affect force itself; or *time*, which cannot affect time itself. This force acts only on *yang* entities and is beyond self-perception. In *Dao De Jing* Chapter 21, it is referred to as *jing*精 (spirit 精神) and *xin*信 (information信息)—the *soul*灵魂 *of the cosmos*. It is what animates and transforms the universe and all things within space and time.

The *spirit, mind, and soul of the universe* governs all creation, motion, change, and cycles—beginning from zero.

In *Dao De Jing* Chapter 38, it is said:

The highest benevolence of the cosmic mind is balance. Balance remains the origin of the coordinate system, zero.This *balance* is again the origin of the coordinate system—zero. (Liu Hongjun & Samo Liu, 2021d)
The origin of all things is zero. The end may not always be balance, but it is always the conclusion of a structured process—followed again by a return to zero.

The *Liezi* describes the creation of the universe in four stages:
太易、太初、太始和太素(untranslation. (*Liezi, 2016*)

Each stage represents a structured process beginning from zero—corresponding to the first to the fourth domain outlined earlier.

Later scholars such as Zhang Zai (*Qi Theory*), Zhou Dunyi (*Tai Ji Diagram Theory*), Zhu Xi (*Neo-Confucian Principle Theory*), and Wang Yangming (*Mind Theory*) further systematised and enriched the Daoist philosophy of cosmic origin—retelling the Philosophical Stories of all existence beginning from zero and striving toward balance.

Zero represents *nothingness* and *emptiness*. It does not signify non-existence, but rather the *origin* of the universe—the beginning of all things and their continual cycles of change. Ultimately, the purpose of the cosmos is still balance, and its *essence* remains the origin point of the coordinate system: zero.

In the language of physics:
The universe is a thermodynamic process.

Therefore, relativity in physics is not only Einstein's *Relativity of Mass and Motion*, but also Lord Kelvin's *Thermodynamic Relativity of Absolute Zero. (Samo* Liu, 2024e)

Einstein's special relativity represents the limit and infinity of material motion—that is, zero.
There is no speed beyond light, no curvature of space-time—only *perception, life, and transformation of existence*.

Lord Kelvin's theory of *absolute zero* similarly points to one truth:
The beginning and end of the universe is Absolute Zero.

Note: "*Absolute Space"* was proposed by Newton, but it was Leibniz, who *opposed* the idea, that ultimately *proved* it.(Samo Liu, 2020b; 2021c)
Thus, it may be referred to as the Newton–Leibniz Absolute Space.

The author calls it the Zero-Dimensional Universe—the origin of all things. It can exist without matter, distance, or velocity, but within it lie the yin-yang forces of Wu Ji (Infinite Nothingness Existence) and Tai Ji (Limited Yin and Yang Existence)—a living existence, which we call Zero.

The above presents a philosophical response to the questions posed by the essays in *Nothing: From Absolute Zero to the Forgotten Corners of the Universe* (Jeremy Webb, 2018), including:

Richard Webb's *The Birth of Zero* (pp. 25–32)
Paul Davies' *The Beginning of Time* (pp. 47–57)
Ian Stewart's *The Mathematical Magic of Zero* (pp. 129–136)
Paul Davies' *A Space of Nothing* (pp. 139–145)
Ian Stewart's *The Ubiquity of Emptiness* (pp. 175–180)
Michael de Podesta's *Absolute Zero* (pp. 183–193)
Michael Brooks' *The World of Supermatter* (pp. 233–242)
It is offered as a contribution for academic discourse.

2.2. The Physical Foundations of the Philosophical Study of Zero

American author and physicist Professor Lawrence M. Krauss wrote a book titled" *A Universe from Nothing"*, applying the logic of materialist philosophy and conclusions from material science to depict, in the language of physics, a material universe originating from *emptiness* and *nothingness*. (Lawrence M. Krauss, 2022) From the perspective of materialist thought, it is a popular science work that seeks to explain the philosophy of cosmic origin through scientific reasoning.

Undoubtedly, Professor Krauss is a staunch defender of materialism. The book is replete with a tone of debate against religion—a tone I do not admire, nor participate in.

My own philosophical standpoint draws from religious philosophy, modern physics, and mineral processing science and technology. I have written several books and articles on this subject. I understand that all current human knowledge and information is built upon the foundations of post-Aristotelian materialist philosophy and science. (Samo Liu, 2025g) Whether in religious or scientific circles, human-created systems of knowledge—constructed from language, text, and numbers—remain confined within the paradoxes of Material Philosophy.

The problem of truth demands more than debate—it requires *verification, supplementation,* and *refinement* through scientific knowledge and information.

Modern physics itself is rife with contradictions. For example, the theoretical tension between quantum mechanics and relativity is a result of confinement within Material philosophy. But this is ultimately a philosophical problem—not one to be debated with religion. Ironically, while Professor Krauss declares that we no longer need philosophers, *he himself is a remarkable philosopher of physics*.

The book is professionally written. As an outsider, I would not presume to critique its technical content. Yet from the standpoint of *cosmic origin*, I believe Professor Krauss has provided a scientific explanation of a "*universe from nothing*." The book comprises 11 chapters, each insightful and expertly articulated. (Lawrence M. Krauss, 2022)

> *Chapter 1* discusses the origin of the universe and presents *the Big Bang* as the starting point. This aligns well with the thermodynamic interpretation within the philosophy of cosmic origin.
>
> *Chapter 2* examines how the universe might end. Rather than indulging in various speculative end-of-universe theories common in cosmology, Krauss introduces the concept of *dark matter*. On page 25, he posits: *If we can determine the nature and abundance of dark matter, then we will be able to ascertain the fate of the universe.*

Clearly, Professor Krauss does not seem to engage with religious cosmology or the cosmic origin philosophies found in Aristotle, nor those proposed by Descartes, Newton, Kant, Schelling, or Hegel. In his rejection of a *personal God*, he also implicitly dismisses Schelling's idea of *God as the spirit of nature*. Nor does he appear to consider the perception of existence, the dialectical *yin–yang* nature of life in the universe, or the interplay between *information and energy*. He seems to overlook the philosophical foundations of space and time. (Samo Liu, 2024i)

On page 25, he discusses Einstein's general theory of relativity and the idea of *spacetime curvature*. Krauss praises this theory and accepts the confirmation of spacetime curvature through the bending of light around the Sun.

I have written nine papers analysing the philosophical contradictions between quantum mechanics and relativity from the perspective of cosmic origin. In them, I critique the fallacy of *spacetime reversal*, which I see as a materialist misjudgement of the nature of space and time. (Samo Liu, 2024g–2025f)
In my own study of Einstein's writings, I have found no evidence that he deeply investigated the *philosophical origins* of space and time. From the standpoint of cosmic origin thinking, I conclude that *spacetime reversal* and *higher-dimensional space physics* are philosophical absurdities. I urge the academic community to evaluate these conclusions with the tools of scientific philosophy.

> *Chapter 3,* titled *Light from the Beginning of Time*, resonates—at least in name—with the present article. Here, I propose that *light* is the zero point of time, and likewise the zero point of natural form. This *light* is not the conceptual light known in human language, but a synthesis: the *light of physics,* the *light of theology,* and the *light of philosophy*, all emanating from *absolute zero* within the *absolute space of cosmic origin*.

Evidently, Professor Krauss does not approach it from this angle. Instead, he discusses how to *measure the total mass of the universe* and *calculate its curvature*. Yet this chapter still offers insights into space, time, and existence within space. It inspires reflection on why Einstein proposed *spacetime curvature* in the first place, Einstein's books does not provide a basis for *spacetime reversal*, and opposes theories of *faster-than-light* travel.

My reflection on relativity is this: when the velocity of matter approaches the speed of light, we must *re-examine the original nature of time and space*—and liberate ourselves from the constraints imposed by Aristotelian Material Philosophy.

Chapter 4, titled *Nothing Comes from Nothing*, is where Professor Krauss, after summarising the achievements of relativity and quantum mechanics, confronts the questions of *the origin of matter* and *existence within space*. His answer is clear:
The origin is “Nothingness and Emptiness”—that is, Zero.

This chapter introduces the concept of antimatter. From the perspective of cosmic origin philosophy, I argue that the existence of antimatter represents a misjudgement within the philosophy of physics. (Samo Liu, 2025e) It may in fact be a physical manifestation of *yin-type informational existence*—that is, the “living” informational dimension of the universe. I invite the academic community to explore and debate this interpretation.

This chapter also raises the issue of the *“non-emptiness of vacuum”*. From the standpoint of cosmic origin philosophy, *emptiness* or *nothingness* does not equate to non-existence. Instead, it refers to the presence of *yin and yang* in the form of *energy and information*. This is a form of existence in a *non-material* state—a manifestation of the *infinite yin–yang Wu Ji,* the very essence of zero.

On page 56, Professor Krauss makes a profound statement:

“Particles can emerge from nothing.”

This is a *foundational principle* of cosmic origin philosophy. It extends beyond particles: dark energy and dark matter, quarks and particles, atoms and molecules, cells and humans—all originate *ex nihilo* (from nothing), and are then followed by *being generated from being*.

The “non-doing that does无为而为” of the *cosmic Dao*道 governs the creation, motion, transformation, and cyclical processes of all things in space and within space.

Chapter 5, titled *The Runaway Universe*, discusses the expansion of the cosmos and the role of *dark energy,* touching upon the *unknowable* aspects of physical cosmology. From a cosmic origin philosophical viewpoint, I argue that if physics and cosmology persist in following a purely Material Philosophy framework, they will inevitably encounter more *unknowable phenomena*. These may, however, be solvable if re-approached through the lens of *cosmic origin philosophy*.

In *Chapter 6*, Professor Krauss applies materialist philosophical reasoning to debate whether the universe is *flat or curved*, *open or closed*. This is a classic Material Philosophy framework, and in my view, *cannot yield definitive answers*. According to cosmic origin philosophy, the universe is a union of emptiness and existence. Therefore, a synthesis of cosmic origin philosophy and materialist reasoning is required to approximate a more accurate answer.

The final sentence of this chapter reflects a recognition of this perspective. On page 77, he concludes:

"The universe emerged from nothing. Indeed—so it did."
Chapter 7 presents a melancholic reflection on the *future of the universe*—collapse, expansion, the Big Bang, black holes. These are not hopeful metaphors for cosmic destiny. So what should we do?

The emotional tone of this chapter mirrors my own when writing the sixth article for Great Britain Journals Press. (Samo Liu, 2024f) I was moved to tears as I wrote it.

In truth, *there is nothing to be done*. This is simply the nature of the universe—its natural existence, natural transformation, and natural cycles. Humanity is a form of intelligent matter, having created language, writing, numbers, and other informational tools. With these tools, we explore truth, express existence, and express emotion. Yet human information-processing capabilities can easily amplify or distort natural phenomena.

Consider the dinosaurs—once the rulers of Earth. They disappeared without such emotions, because they lacked the cognitive framework to possess them.

In my writings, *The Origins of the Universe*, *The Origins of Humanity*, and *The Survival of All Things*, I discuss this question. There is no need for humanity to resent the universe.

From the perspective of *cosmic time* measured in kalpas, the current state of the material universe we inhabit is one of *temporary equilibrium*. We have assigned this balance to human time units—years, months, days. These units may be cosmologically imprecise, but for our present moment, they remain relatively stable.

This relative temporal equilibrium has been *solidified* into our everyday time: years, months, days, hours, minutes, seconds.

However, the philosophical stance of modern physics has made the mistake of imagining these time units as capable of *bending* and *reversing*. *This* is impermissible. (Samo Liu, 2025e)

What matters now is how humanity survives and exists. We must use our own achievements to protect ourselves, rather than facilitate our own demise.

This calls for *collective human reflection*, and such reflection must be guided by cosmic origin thinking. In *Chapter 8,* Professor Krauss uses rigorous physics to explore the concept of vacuum energy. However, it may be inaccurate to describe the presence of yin and yang in space merely as *energy*. While physics translates matter into energy through equations (and can precisely express it as E1 = E2 = E3), (Samo Liu, 2024h)—the reverse process of expressing *energy as matter* requires *new terminology* in physics to describe the "*zero-existence"* of *emptiness with perception*.

This chapter also touches upon the *multiverse* and the *centre of the Milky Way*. Professor Krauss discusses *Professor Witten's M-theory* with a degree of satire. Personally, I both *admire* and *oppose* this theory. I admire its *mathematical brilliance*, but I oppose its philosophy of higher-dimensional space, which violates the foundational principles of cosmic origin, breaking through the fundamental truths of space and time.

This will be further discussed later.

This chapter also delves into *extra dimensions* and a possible *grand unified theory*, exposing many of the contradictions and dilemmas within modern physics. While Professor Krauss claims to have no need for philosophers, his search suggests a deep longing for philosophical insight.

Chapter 9 presents a key conclusion: *the laws of nature are everything*. Professor Krauss avoids the concept of a *cosmic deity*, but he nevertheless emphasises the importance of the idea that the universe emerged from nothing, posing the fundamental philosophical question:

"Why is there something rather than nothing?"

This is a question that cosmic origin philosophy is well equipped to address. I have written several books and numerous articles in an attempt to answer precisely this question.
Chapter 10 attempts to resolve this question using the methodology of physics and materialist philosophy.

On page 110, Krauss states:

Given the right conditions, not only can something arise from nothing—it inevitably must.

On page 111, he asserts:

Vacuum instability leads to the production of matter.

Cosmic origin philosophy offers a parallel but deeper view: imbalance is a vital phenomenon of the *yin–yang* cosmos and a core principle of its origin. Imbalance initiates *thermal motion* between yin and yang—thermodynamics is the foundational logic of creation in the universe. Thermodynamics governs the full cycle of creation—from *information to energy,* to form, and back again. This cycle entails a *mutual process of perception—time*—which is inherently tied to *balance*.

One may find this same logic in *Daoist, Buddhist, and Ancient Greek* philosophies of cosmic origin, as I have explored in my published works.

On page 117, Professor Krauss proposes a bold idea: (in Chinese)

The total energy of the universe is precisely zero, and the net charge in a closed universe must also be zero.

On page 120, he concludes:

> "Quantum mechanics not only permits a universe to arise from nothing—it *requires* it."
> He argues that *"nothing"* means the absence of space, time, and everything else, because *nothing* is unstable.

Cosmic origin philosophy holds a different stance: *space and time* are *human-created philosophical constructs,* invented to describe the *form* and *process* of existence. If quantum mechanics and relativity have indeed demonstrated that the universe can emerge from nothing, then we must *break free* from the constraints of Material Philosophy, and *reconceptualise space and time* from their origins—establishing a new coordinate origin, *beginning at zero*.

Chapter 11 deals with the notion of creation. On the surface, Professor Krauss appears to oppose religion, but in reality, he is paying it a kind of respect. He proposes that God is best invoked to explain the origin of *morality*.

I do not claim to be a scholar of religion, but I do admire the cosmic origin philosophies of *Daoism and Buddhism*.

Human beings invented the concept and vocabulary of *morality* to regulate their behaviour and thoughts.

I believe that *Laozi* used the term *Dao De* (道德, the Way and its law) to express the laws and principles that govern the universe.

The *personified God* is a beautiful human creation—and has become the object of faith for many.
In my view, the reason humanity created a personified deity was to express *awe and reverence toward the natural universe*.

I believe in a *"God of Cosmic Nature"*—a form of existence long ago conceived by our ancestors—and that modern physics has already *proven the existence* of this god, albeit unknowingly.
(Samo Liu, 2024g)

Physicists have discovered and confirmed the existence of such a "god," yet remain unaware of it—just as Leibniz proved the existence of absolute space, while many still misunderstood him as its opponent. The *credit or fault* for this confusion lies with Aristotle, who 2,000 years ago constructed the *Material Philosophy framework* that continues to shape human thought.

This issue, too, deserves academic reflection.

This chapter also references *Aristotle's definition of God* as the *"Prime Mover"*. Reading Aristotle, one can interpret him from multiple perspectives. In my view, Aristotle's "Prime Mover" corresponds with the totality of forces studied by modern physics. These forces are the *angels* of the *God of Cosmic Nature.*

(Liu Hongjun & Samo Liu, 2020; 2021a; 2021b)

Two thousand years ago, Aristotle lacked the scientific knowledge to explore such forces in full. He therefore left the question of the first cause to theology and urged humanity to focus instead on the development of material philosophy (first philosophy) and material science (second philosophy).

Today's scientific achievements owe much to him. *Aristotle is one of the greatest physicists in history—the intellectual founder of physics itself.*

The final sentence of this chapter asks:

> Why is there something rather than nothing?
> And answers:" Because things do not last.

From the viewpoint of *cosmic origin thought,* anything that can be expressed in *language*, *text*, or *numbers* must necessarily possess *a structured beginning and end*. Every existence has a start and finish to its process. In form, it follows a cycle from *zero to zero*; in process, it travels from *zero to a value*, then back to *zero*. None of these concepts imply permanence or eternity.

Even as we discuss the origin and existence of the universe today, the truth remains: *let us begin at zero*.

What may be eternal?
Perhaps *space and the existence within space*—we do not yet know what these are.
For now, let us express them through the language of physics.
them be: God and Zero.

Let us explore them, Let physics begin—from *emptiness and nothingness*—to explore the yin–yang life process of existence.

2.3. The Mathematical Foundations of the Philosophical Study of Zero

Mathematics was always my weakest subject. Fortunately, cosmic origin philosophy holds that *mathematics and numbers* are merely informational tools used to study *matter* and *material existence*.

To explore cosmic origin, one needs only study zero.

Richard Webb's *The Birth of Zero* (Jeremy Webb, 2018, pp. 25–32) and Ian Stewart's *The Mathematical Magic of Zero* (Jeremy Webb, 2018, pp. 129–136) are both outstanding essays—valuable mathematical works for studying *zero* as the key to the universe's origin.

Mathematics and numbers are tools created by humanity for survival and existence. They are also the instruments of science, vital for understanding the material world and the nature of physical existence. Yet if humanity's philosophical thinking is flawed, *mathematics can mislead thought itself.*

The invention of four-dimensional spacetime coordinates is a magnificent achievement. However, it led to an unfortunate side effect: it nudged human thought into higher-dimensional space, and this very shift has prompted the re-evaluation of the concepts and origins of *space and time*.

The mathematician and philosopher I most admire is Professor Edward Witten. I deeply respect his mathematical genius, but I fundamentally disagree with the philosophical thought of M-theory. This theory of *multidimensional space* undermines the very foundation of *cosmic origin philosophy*.

I have not studied Professor Witten's original works in detail. However, M-theory is widely discussed in physics classrooms, and its ideas of higher and multidimensional space have gained immense popularity in China and around the world.

Some have even attempted to *incorporate higher-dimensional space theory into Buddhist and Daoist philosophy*, which is *entirely inappropriate*.

In response, I have written several books and numerous essays reflecting on this issue. The focus of my critique is not M-theory per se, but rather the *philosophical implications of four-dimensional spacetime and its origin in Aristotelian material philosophy*.

Through this reflection, I have proposed a *re-examination of the origin of space and time*.(Samo Liu, 2025c)I have also written *The Physical Principles of Natural Philosophy*(Samo Liu, 2024i), and introduced the idea of the God of Cosmic Nature through *cosmic natural philosophy*.(Samo Liu, 2024g)

The core problem of M-theory is that it *fails to clarify the logical relationship between Material philosophical concepts and first principles*.

The concepts of *point*, *string*, and *membrane* are ambiguous. In the material world, any point *string*, and *membrane*—depending on the philosophical framework and coordinate system—can represent both *infinity*无穷大 and *infinitesimality*无穷小.

If we can distinguish between *material* and *non-material*, and treat such entities as *non-material points, strings, and membranes,* they may become powerful *informational tools* for exploring *cosmic origin and creation*.

These *non-material* conceptual entities—points, strings, and membranes—may indeed hold the key to understanding cosmic origin.(Liu Hongjun & Samo Liu, 2021b)

Within the realm of materialist philosophy, humanity formulated Goldbach's Conjecture. But we must ask:

Why is 1 + 1 = 2?

From the perspective of *cosmic origin,* we can ask many similar questions:

> Why does placing zero *before* any digit not change its value, but placing it *after* multiplies it by ten?
> Why is zero plus any number still that number?
> Why is zero minus any number negative?
> Why is zero multiplied by any number still zero?
> Why is zero divided by any number still zero, but any number divided by zero yields infinity?
> And most importantly:
> Why can the binary system—zero and one— serve as the mathematical foundation for computer numerical calculations?

Language, writing, numbers, mathematics, coordinate systems, and science are all informational tools created by humanity for survival and existence.

Mathematics, numbers, and *numerical systems* are tools to express knowledge and information with precision.

This tool is extraordinary.

Without it, not only could we not express the material universe accurately—we could not express cosmic origin at all.

The *creativity of humanity* is truly marvellous. Humanity invented mathematics and numbers to describe the universe—and this expression is extraordinarily *precise* and *seamless*. Why?

Yet, this same creativity, if not guided by sound philosophy, can also be dangerous.
When used improperly, it may mislead thought itself.

No matter what, *humanity was born from the cosmos,* and went on to create language, writing, numbers, mathematics, coordinate systems, and science as tools of information.

We should be grateful to the universe for giving humanity this supreme gift: the ability to *think, research, and explore.*

But even *without humanity,* without language, writing, mathematics, coordinate systems, or science-
the *universe would still exist,*
matter would still exist,
all things would still exist.

Yet, in the absence of anyone to express that existence-
its representation would be: zero.
And could only ever be: zero.

Dinosaurs once roamed the Earth for a very long time. They disappeared, and humanity has been studying them ever since.

Yet aside from fossilised skeletons, we have not discovered any retrievable knowledge or information from them.

Modern physics and the cosmic origin philosophies passed down by our ancestors both suggest that the universe originated from "emptiness and nothingness"—from zero.
Then came the birth of matter. *Something from nothing; something from something.* And eventually, humanity was born.

Human beings created knowledge and information, and have come to realise:
this world is not empty, it is material.

What is astonishing is this:
through quantum mechanics, relativity, and *thermodynamics,* we have discovered that *matter truly arises from emptiness and nothingness—zero.*

Therefore, building on the knowledge and information we now possess, we might reconsider the universe and humanity anew—*starting from zero.*

Thus, zero is the mathematical foundation of cosmic origin philosophy.
Let us bring this to the attention of the academic community for open discussion.

III. CONCLUSION

This article could have been far longer.
But the core idea—that zero forms the philosophical foundation of cosmic origin—has now been expressed with clarity.

It is presented here for the academic community to critique, supplement, and refine.

Let us begin anew—using the scientific knowledge available to us—to reframe human thought, and arrive at a more comprehensive understanding of the universe and of humanity.

May more people join the discussion on the question of cosmic origin.

This question, which has evolved over 2,500 years, now stands at the crossroads of science and philosophy.

Right or wrong, *human thought has reached this critical point*.

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In accordance with publication policies and ethical standards, the data and concepts presented in this article are publicly available in support of open knowledge sharing.

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