An Interpretation of Anomalous Ultra-high-energy Particle Events in Antarctica

Zhi Cheng

Abstract

Antarctic Impulsive Transient Antenna (ANITA) is a device that uses the Askaryan effect to detect the interaction between high-energy particles and density matter. The Askaryan effect has been supported by sufficient experimental evidence, so the measurement results of the ANITA are very reliable. Currently, ANITA has acquired three important ultra-high-energy particle radiation events. The energy detected in all three events is extremely high, reaching an energy level of nearly $0.6EeV$ in the first two times, and exceeding $10EeV$ in the third time. These three events seem to exceed the explanatory power of the standard model. According to the standard model, the collision cross section of such ultra-high-energy particles will be relatively large, so it is easy to collide with rocks and other substances in the earth and cannot run across the earth. Here I try to use the theory of virtual space-time physics to explain. According to the theory of relativity, no particle can move faster than the speed of light. Because when accelerating, as the energy obtained by the particles becomes larger and larger, their motion mass will become larger and larger. However, from the knowledge of physics that we have learned now, the energy of any particle should not have a non-physical state such as infinity. Therefore, we can consider that when a particle gets more and more energy, it will encounter a critical point in a certain mass. This can be regarded as an upper limit of energy that the real physical world should possess. At this upper energy limit, if the particles continue to gain energy, their motion mass will not continue to increase, which will directly cause the particles to move faster than the speed of light. Another possible phenomenon is that the movement of ultra-high-energy particles causes the vacuum polarization to increase, which leads to an increase in vacuum dielectric constant, which in turn causes a decrease in the speed of light. However, if the velocity of the ultra-high-energy particles does not decrease at this time, the phenomenon that the particle running speed exceeds the speed of light may occur. According to the theory of virtual space-time physics, the speed of particles exceeds the speed of light, which means that the movement of particles enters the virtual space-time. This also means that in a certain space and time, particles with high enough energy may suddenly appear somewhere, such as appearing on the surface of the earth and then interacting with rocks or Antarctic ice on the earth to form the Askaryan effect. This should explain the three anomalous particle events detected by ANITA. This article also analyzes some other problems that may occur after the ultra-high-energy particles run faster than the speed of light.

Keywords

Ultra-high-energy particles; Neutrino; ANITA; Virtual space-time

1 Introduction

In recent years, the use of Antarctic resources to detect neutrinos has made a series of important achievements, including the discovery of some ultra-high-energy neutrinos. These devices are mainly two, namely Ice Cube and Antarctic Impulsive Transient Antenna (ANITA).

The Ice Cube uses the Cherenkov scattering effect and uses light sensors to sense the traces of neutrinos passing by. And ANITA mainly uses a variety of detection methods including the Askaryan effect, using radio waves to detect the traces of ultra-high-energy particles passing by.

The Ice Cube uses the Cherenkov effect, which is currently commonly used to detect neutrinos, and has been proved to be a more effective method for detecting neutrinos in the Super Kamoka and Daya Bay neutrino detectors. At present, the Ice Cube has discovered multiple ultra-high-energy neutrino events with energies of the order of EeV. Compared to Ice Cube, ANITA's investment is relatively less. Moreover, although ANITA detects radio wave signals, the Askaryan effect is also a high-energy particle detection method that has been proved to be effective after experimental testing. The particles detected by ANITA may be neutrinos or other high-energy particles.

At present, ANITA has detected three anomalous ultra-high-energy particle events. The first two can determine the propagation direction of ultra-high-energy particles. The third anomaly is currently unable to determine its direction of propagation, and it is impossible to determine its specific source.

According to the calculation of the Askaryan effect, it can be found that the energy of the first two ultra-high-energy particles reaches $0.6EeV$ and $0.56EeV$, respectively, while the energy of the third event is as high as $10EeV$ or more [1].

Whether it is Ice Cube or ANITA, these two devices prove one thing: the existence of extremely ultra-high-energy particle rays in the universe. If we consider the limitations of measuring particle energy on Earth, we can believe that there must be more ultra-higher energy particles in cosmic rays. The energy of these ultra-high-energy particles will likely far exceed $10EeV$ or more.

At present, the interpretation of the source of these ultra-high-energy particles has encountered great problems. Especially the three anomalous particle ray events discovered by ANITA. Mainly because the results of observation data show that all three ultra-high-energy particles are from the ground. The first two ultra-high-energy particles, which can determine the direction of the source, need to cross thousands of kilometers of earth rock to reach the ANITA detector. The third event can now be determined to be launched from the ground upwards. Although the τ lepton produced by the reaction of τ neutrinos with the earth's rocks can then be emitted into the air and detected by ANITA, but the doubt is that even neutrinos, calculated according to the standard model, have such high energy, it is also impossible to cross the earth easily. And ANITA only easily detected such incidents in the few flight processes, proving that such incidents are still very frequent. As for the third anomalous ultra-high-energy particle event, due to the higher energy of the particles, the observations show that this particle should have been produced on the surface of the earth. At present, it is very difficult to explain through standard models. After all, there is no condition for generating such ultra-high-energy particles on the surface of the earth or even inside the earth. Some physicists have focused on dark matter and ultra-high-energy supersymmetric particles. Although it is possible to explain some of these phenomena to a certain extent, it is still far from reaching the level of consummation.

This paper discusses the problem of ultra-high-energy particles' space-time traversal from the theory of virtual space-time physics [2]. This is based on two assumptions. The first is that there is no infinite physical quantity in the real physical world. Therefore, in any space-time, there is an upper limit for the energy carried by particles of a certain rest mass. If the upper limit energy is exceeded, the speed of the particle will exceed the speed of light and enter another space-time. Such particles that enter a space-time will appear to appear suddenly in a certain space-time. Another assumption is that ultra-high-energy moving particles may change the dielectric constant of the vacuum, thereby reducing the speed of light. At this time, if the particle movement speed is constant, the phenomenon that the particle movement speed exceeds the speed of light will also occur.

2 Energy upper limit of particles

For a particle with a rest mass of m_0, the relationship between the speed of motion and energy is:

$$E = mc^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

It can be seen that when the speed of particle motion $v = c$, the energy possessed by the particle is infinite. This is of course physically impossible. Therefore, in order to avoid such a situation in the theory of relativity, an assumption was introduced that all particles cannot run faster than the speed of light.

But this assumption of relativity also poses a problem. Since the speed of a particle can never exceed the speed of light, it means that we can let this particle carry infinite energy. To do this, the Large Hadron Collider at the European Particle Physics Laboratory has been able to carry a proton with 8 trillion electron volts of energy. However, this is not the upper limit of the energy that a particle can carry. At present, detectors including Ice Cube and ANITA have detected the presence of particles of EeV energy level (10^{18} eV). But if a particle can carry more energy, for example, the energy of a particle's movement reaches the energy of the entire solar system explosion, which is not in accordance with the laws of physics. So, what should the upper limit of energy a particle has? This is an issue worth exploring.

At present, we have some important theoretical and experimental evidence for the lower limit of the scale of the micro world.

The uncertainty principle in quantum mechanics can be regarded as the lower limit of a micro-world scale. In the principle of uncertainty, the position and momentum of a particle cannot be accurately measured at the same time; energy and time cannot be accurately measured at the same time. This reflects a lower limit of the space-time scale, that is, the size of particles cannot be infinitely smaller than a certain scale. This illustrates the discontinuity of the space-time we are in now.

Of course, having a lower limit actually means corresponding to the upper limit. From the perspective of symmetry, the reciprocal of infinity is 0. This shows that infinity is actually symmetrical to infinity. Therefore, if the minimum energy of a particle is symmetrical with the maximum energy of a particle, it means that the upper energy limit of the particle is symmetrical with the lower energy limit of the particle. Both are related to an important physical quantity. This physical quantity is Planck's constant. The currently determined upper limit of energy is Planck energy. Planck energy is $1.22 \times 10^{19} GeV$

However, this energy is already much greater than $10 EeV$, which means that the particle energy detected by ANITA is much lower than the Planck energy. It cannot be explained by the Planck energy upper limit.

Of course, a particle reaches Planck energy, which also means that a micro black hole may have been generated. We are now unclear about the various properties of micro black holes.

Another factor worth considering is vacuum polarization. If ultra-high-energy particles pass through the vacuum, the dielectric constant of the vacuum will change, which will cause the speed of light in the vacuum to change. At this time, if the speed of the particles does not change, it means that the speed of the particles may exceed the speed of light. At present, the phenomenon of vacuum polarization has been supported by experimental data. This means that the relativistic mass-energy formula may have very complex nonlinear characteristics in the ultra-high-energy region. It may even happen that the speed of particles without zero rest mass can exceed the speed of light in the area where the particles move at higher speed.

As early as 1934, Furry and Oppenheimer already raised the issue of vacuum polarization [3]. Many authors have also suggested that vacuum polarization may be the basic cause of the vacuum dielectric constant. For example, in Mainland and Mulligan’s work [4], the theoretical vacuum dielectric constant value calculated by the assumption of vacuum polarization is only 2.7% higher than the experimental value. The uncertainty principle must also be considered when calculating the effect of vacuum polarization on vacuum dielectric constant. This shows that vacuum polarization is essentially caused by the smallest structure composed of space and time.

If the dielectric constant of vacuum is indeed caused by vacuum polarization, then it can be inferred that when the energy of a particle is high enough, it will cause more obvious vacuum polarization phenomenon, which will cause the dielectric constant of vacuum to increase and cause the speed of light to drop. However, if the speed of the particles falls less than the speed of light, the ultra-high-energy particles will move faster than the speed of light.

3 Particles travel beyond the speed of light into virtual time and space

If in real spacetime, the particle speed exceeds the speed of light, then according to the requirements of virtual space-time physics, the particle will enter virtual space-time. This can be seen from the relativistic energy formula (1). If *v*> *c*, then

$$E = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = i \frac{m_0 c^2}{\sqrt{\frac{v^2}{c^2} - 1}}$$

At this time, the energy is imaginary. In real spacetime, virtual energy will not produce observable physical effects, so the particle will not interact with real spacetime matter.

The reverse is also true, that is, if the velocity of a virtual space-time particle exceeds the speed of light in the virtual space-time, the particle will enter real spacetime.

Considering that particles enter from one space-time to another in an instant, so in one space-time, it seems as if particles appear suddenly. This can be used to explain why extremely ultra-high-energy particles can suddenly appear on the surface of the earth, and then interact with the matter on the earth to produce the Askaryan effect. As shown in Figure 1.

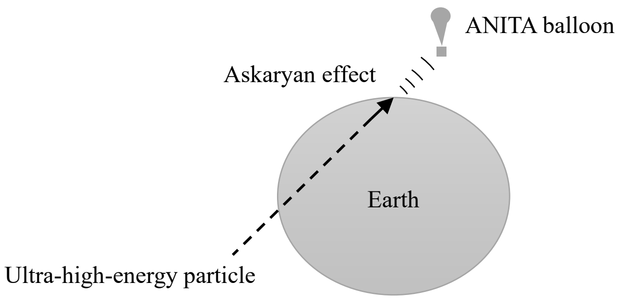

Fig. 1 ANITA's detection of ultra-high energy particles

In Figure 1, ultra-high-energy particles radiate in the direction of the arrow, but the dotted line part reflects the particle's movement in virtual space-time, so the path of the dotted line part does not react with the earth's rocks and can pass through the earth smoothly. And because the energy of the particle in the virtual space-time is high enough to exceed the speed of light after a large vacuum polarization, the particle enters the real spacetime. Due to the existence of high-density earth rocks and Antarctic ice cubes in the real spacetime, the particles will interact with these high-density materials, which in turn will produce the Askaryan effect. The electromagnetic waves radiated by the Askaryan effect will be received by the antenna on the ANITA balloon.

4 Results analysis

The three anomalous ultra-high-energy particle events detected by ANITA, although the first two anomalous events can be explained to some extent by the standard model, they are still far-fetched. The third anomaly is difficult to explain even if it is far-fetched. So, many theories beyond the standard model come into play, including the interpretation of supersymmetric particles.

This article attempts to explain this with virtual space-time physics. Assuming the existence of a virtual space-time, a space-time commensurate with real spacetime, ultra-high-energy particles can have a way to bypass the interaction with matter during movement, which can better explain why ultra-high-energy particles can easily pass through dense rocks of the earth without interaction.

The reason why ultra-high-energy particles can pass from one space-time to another is because in the relativistic energy calculation formula, when the energy of the particles is large enough, it may enter a nonlinear region of energy. In this nonlinear region, the velocity of ultra-high-energy particles may break through the limit of the speed of light and enter another space-time directly. This leads to a particle that may suddenly appear in another space-time. It can explain the three abnormal ultra-high-energy particle events detected by ANITA.

To illustrate the existence of this energy nonlinear region, I assumed two cases of upper energy limits. One is the upper limit of Planck energy. At present, because the Planck energy is too large, far exceeding the energy of anomalous ultra-high energy particles detected by ANITA, it is believed that the nonlinear region of this energy may not be caused by the Planck energy upper limit.

Another possibility is the phenomenon of vacuum polarization. There have been many fruitful discussions on the problem of vacuum polarization in quantum field theory. Including the existence of vacuum dielectric constant may be caused by vacuum polarization. Therefore, this paper makes an assumption that if ultra-high-energy particles move in a vacuum, the effect of vacuum polarization may be strengthened, which in turn leads to an increase in the dielectric constant of the vacuum. Considering that the vacuum dielectric constant is closely related to the speed of light, an increase in the vacuum dielectric constant means a decrease in the speed of light. At this time, if the speed of ultra-high-energy particles does not change, there may be a case where the speed of particles exceeds the speed of light. At this time, we use the knowledge of virtual space-time physics to know that ultra-high-energy particles will enter another space-time and interact with matter in another space-time, thereby slowing down the speed of the particles.

Although I think this explanation is very reasonable. However, there are still some problems, mainly because I cannot calculate the specific value of the effect of ultra-high energy particles on the vacuum polarization phenomenon. This is mainly due to the fact that the information and data available to me are not sufficient, and the vacuum polarization problem is still in the process of being discussed. There are too many assumptions. Perhaps the data of ultra-high-energy particles detected by ANITA helps in turn help us determine the upper limit of particle energy caused by vacuum polarization.

References

[1] Aartsen, M. G., Choi, S., Leonard, K., Koirala, R., Stettner, J., Schneider, J., ... & Alispach, C. (2020). A search for IceCube events in the direction of ANITA neutrino candidates. arXiv: High Energy Astrophysical Phenomena,.

[2] Cheng, Z. Foundations of Virtual Spacetime Physics. LAP LAMBERT Academic Publishing. Brivibas gatve 197, LV-1039, Riga. Latvia, European Union

[3] Furry, W. H. , & Oppenheimer, J. R. . (1934). On the theory of the electron and positive. Physical Review, 45(5), 245-262.

[4] Mainland, G. B. , & Mulligan, B. . (2020). Polarization of vacuum fluctuations: source of the vacuum permittivity and speed of light. Foundations of Physics, 50(5), 457-480.

对南极异常粒子事件的虚时空解释

Zhi Cheng

摘要：南极瞬态脉冲天线(ANITA)是一个利用阿斯卡莱恩效应探测高能粒子与致密物质相互作用的装置。阿斯卡莱恩效应已经获得了足够的实验证据支持，因此南极瞬态脉冲天线的测量结果可信度非常高。目前 ANITA 已经获得了三个重要的高能粒子辐射事件。三个事件探测到的能量都极高，前两次达到近 0.6EeV 的能量水平，而第三次则达到超过 10EeV 的能量水平。这三次事件似乎都超出了标准模型的解释能力。按照标准模型，这么高能的粒子碰撞截面会比较大，因此很容易跟地球中的岩石等物质产生碰撞而无法辐射出来。这里尝试着利用虚时空物理学的理论来进行解释。按照相对论，任何的粒子运动速度都不可能超过光速。因为在加速的时候，随着粒子获得的能量越来越大，其运动质量也会越来越大。然而从我们现在已经了解的物理学知识来看，任何粒子的能量是不应该具备无穷大这样的非物理状态的。因此我们可以考虑当一个粒子获得的能量越来越大的时候，在某个质量上会遇到一个临界点。这可以看作是真实的物理世界应该具备的一个能量的上限。在这个能量上限，如果粒子继续获得能量，其运动质量将不会再继续增加，这将直接导致粒子的运动速度超过光速。另一种可能现象是超高能粒子的运动导致真空极化现象增强，从而导致真空介电常数增加，进而引起光速减少。而如果此时超高能粒子速度不降低，则可能出现粒子运行速度超过光速的现象。从虚时空物理学的理论来进行分析，粒子运行的速度超过了光速，则意味着粒子的运动进入了虚时空。这也意味着在某一个时空，能量足够高的粒子可能会在某个地方突然出现，比如在地球表面突然出现然后与地球上的岩石或者南极冰层产生相互作用形成阿斯卡莱恩效应。这应该可以解释 ANITA 所探测到的三次异常粒子事件。本文也对于超高能粒子运行速度超过光速后可能出现的一些其他问题进行了分析。

关键词：超高能粒子；中微子；ANITA；虚时空

1 导言

近年来利用南极的资源来探测中微子的研究取得了一系列重要的成果，包括发现了一些高能量中微子。这些装置主要为两个，分别是冰立方和南极瞬态脉冲天线(ANITA)。

冰立方利用的是切仑科夫散射效应，利用光线传感器感测中微子经过的痕迹。而 ANITA 则主要利用了包括阿斯卡莱恩效应等多种探测方法，利用无线电波探测高能粒子经过的痕迹。

冰立方利用的是目前探测中微子比较常用的切伦科夫效应，在超级神冈、大亚湾中微子探测器中已经被证明是探测中微子比较有效的方法。目前冰立方已经发现了多个高能中微子事件，能量达到 EeV 的数量级。相比冰立方，ANITA 的投资相对来说更少一些。而且 ANITA 虽然探测的是无线电波信号，但阿斯卡莱恩效应也是经过了实验检验被证明有效的一种高能粒子探测方法。ANITA 探测的粒子有可能是中微子也有可能是其他的高能粒子。

目前 ANITA 已经探测到了三个比较异常的高能粒子事件。其中前两个可以确定高能粒子的传播方向。而第三个异常事件则目前还无法确定其传播方向，也就不可能确定其具体的来源。

按照阿斯卡莱恩效应进行计算,可以发现前两个高能粒子的能量分别达到 0.6EeV 和 0.56EeV,而第三个事件的粒子能量则高达 10EeV 以上【1】。

不管是冰立方还是 ANITA，这两个装置都证明了一件事情，就是宇宙中存在能量极高的粒子射线。如果考虑到地球上测量粒子能量的局限性，我们可以相信在宇宙射线中一定还有更高能量的粒子的存在。这些高能粒子的能量将可能远远超过 10EeV 以上。

目前对这些高能粒子来源的解释遇到了很大的问题。尤其是 ANITA 发现的三个异常粒子射线事件。主要是因为观察数据的结果显示这三个高能粒子都来自地面。而前两个能够确定来源方向的高能粒子需要穿越几千公里的地球岩石才能够到达 ANITA 探测器。第三个事件目前能够确定的是从地面向上发射的。虽然可以用 τ 中微子与地球岩石的反应而产生的 τ 轻子然后发射到空气中而被 ANITA 探测到，但是其中的疑问就是，即便是中微子，按照标准模型计算，这么高的能量要很容易地穿越地球也是不太可能的。而 ANITA 仅有的几次飞行过程就轻易探测到了这样的事件，证明这样的事件发生还是非常频繁的。至于第三次异常高能粒子事件，由于粒子能量更高，观测结果显示出这个粒子应该就是在地球表面产生的。目前来看要通过标准模型来进行解释很困难，毕竟地球表面，甚至地球内部都没有产生这么高能量的粒子的条件。一些物理学家将目光放在了暗物质以及高能量超对称粒子方面。虽然能够在一定程度上解释其中的一些现象，但要达到圆满的程度还很遥远。

本文从虚时空物理学理论【2】来探讨高能粒子的时空穿越问题。这是基于两个假设，第一个是**真实的物理世界不存在无穷大的物理量**。因此任意一个时空，对于一定质量的粒子其所携带的能量有一个上限。如果超过了这个上限该粒子的运动速度将超过光速，从而进入另一个时空。这种进入了一个时空的粒子就会呈现出在某个时空突然出现的现象。另一个假设是**高能运动粒子有可能改变真空介电常数**，从而降低光速。此时如果粒子运行速度不变，则也会出现粒子运动速度超过光速的现象。

2 粒子的能量上限

对于一个静止质量为 m_0 的粒子，其运动速度与能量之间的关系为:

$$E = mc^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

可以看出当粒子运动的速度 $v=c$ 的时候，粒子所具备的能量为无穷大。这当然在物理上是不可能的。因此在相对论中为了避免这样的情况，就引入了一个假设，即所有的粒子运行速度不能够超过光速。

但是相对论的这个假设也带来了一个问题，既然粒子的速度永远都不能够超过光速，则意味着我们可以让这个粒子携带无穷大的能量。要做到这一点，欧洲粒子物理实验室的大型强子对撞机已经能够让一个质子携带 8 万亿电子伏特的能量。然而这并不是一个粒子能够携带能量的上限，目前包括冰立方以及 ANITA 等探测器已经探测到了 EeV 能量级的粒子存在。但如果一个粒子可以携带更大的能量，比如说一个粒子运动的能量达到整个太阳系爆发的能量，这是不符合物理规律的。那么一个粒子具备的能量上限应该是多少？这是值得探讨的一

个问题。

目前我们对微观世界的尺度的下限已经有了一些重要的理论和实验证据。

其中量子力学中的不确定性原理可以看作是一个微观世界尺度的下限。在不确定原理中，一个粒子的位置和动量之间是不能够同时精确测量到的，而能量和时间也是不能够同时精确测量的。这反映出了时空尺度的一种下限，即粒子的运动不能够无限小于某个尺度。这说明了我们现在所处的时空的不连续性。

当然有了下限，实际上也就意味着对应了上限。从对称性的观点来看，无穷大的倒数为 0. 说明了无穷小实际上与无穷大是对称的。因此如果粒子的最小能量与粒子所具备的最大能量是对称的，则意味着粒子所具备的能量上限跟粒子所具备的能量下限是对称的。二者都跟一个重要的物理量相联系。这个物理量就是普朗克常数。目前比较确定的能量上限是普朗克能量。普朗克能量为$1.22 \times 10^{19} GeV$

不过这个能量已经远大于 10EeV，即这意味着 ANITA 所探测到的粒子能量远低于普朗克能量。无法用普朗克能量上限来进行解释。

当然一个粒子达到了普朗克能量，也意味着可能已经产生了一个微型黑洞。我们现在对于微型黑洞的各种性质都是不清楚的。

另一个值得考虑的因素是真空极化。如果高能粒子穿过真空，引起真空介电常数的变化，这将导致真空中的光速产生变化。而此时粒子的运行速度不变，则有可能出现粒子的速度超过光速。目前真空极化的现象已经获得了实验数据的支持。这意味着相对论质能公式在高能区域可能具备非常复杂的非线性特征。甚至有可能在粒子高速运动区域出现超光速的现象。

早在 1934 年 Furry and Oppenheimer 就已经提出了真空极化的问题【3】。很多作者也提出了真空极化可能是导致真空介电常数出现的基本原因。比如 Mainland and Mulligan【4】.通过真空极化的假设计算出的理论数值只比实验值高 2.7%. 在计算真空极化对真空介电常数的影响的时候也必须考虑到不确定性原理。这说明真空极化本质上也是由时空构成的最小结构引起的。

如果真空的介电常数确实是由于真空极化引起的，那么可以推论在一个粒子能量足够高的时候，将可能引起出现更明显的真空极化现象，从而引起真空的介电常数增大，进而导致光速下降。而如果此时粒子的速度下降幅度没有光速下降幅度那么大，则将出现超高能粒子的运动速度超过光速。

3 粒子超光速运行进入虚时空

如果在实时空，粒子运行速度超过了光速，则按照虚时空物理学的要求，该粒子将进入另一个时空。这可以从相对论能量公式（1）看出。如果 v>c，则

$$E=\frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}}=i\frac{m_0c^2}{\sqrt{\frac{v^2}{c^2}-1}}$$

此时能量为虚数。在实时空虚能量不会产生可以观察的物理效应，因此该粒子也将不会跟实时空的物质产生相互作用。

反过来也是这样，即如果一个虚时空的粒子运动速度超过了虚时空的光速，则该粒子将进入实时空。

考虑到粒子从一个时空进入另一个时空是瞬间完成的，因此在一个时空看起来，就好像是粒子突然出现一样。这可以用来解释为何在地球表面可以突然出现极高能量的粒子，进而与地球上的物质相互作用，而产生阿斯卡莱恩效应。如图 1 所示。

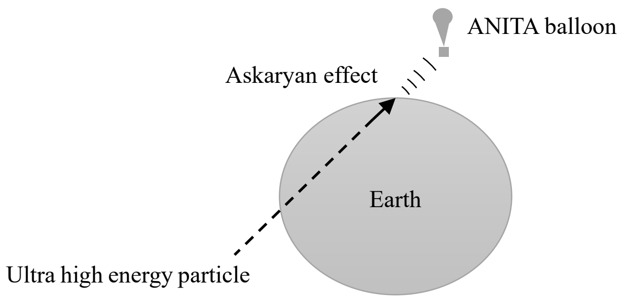

Fig. 1 ANITA's detection of ultra-high energy particles

在图 1 中，超高能粒子沿着箭头的方向辐射，但是其虚线部分反映了该粒子在虚时空运动，因此虚线部分的路径并不会跟地球岩石产生反应，可以顺利通过地球。而由于该粒子在虚时空的能量足够高，超过了经过大幅度真空极化后的光速，导致该粒子进入实时空。由于实时空存在高密度的地球岩石以及南极冰块，该粒子将与这些高密度物质相互作用，进而产生阿斯卡莱恩效应。阿斯卡莱恩效应辐射出来的电磁波将被 ANITA 气球上的天线所接收到。

4 结果分析

ANITA 探测到的三个异常的超高能粒子事件，尽管前两个异常事件可以在一定程度上用标准模型进行解释，但是解释起来还是比较牵强附会的。而第三次异常事件则即便是很牵强的解释也很困难。这样很多超出标准模型的理论开始发挥作用，包括超对称粒子的解释等。

本文尝试这用虚时空物理学来进行解释。由于假设存在了虚时空这样一个与实时空相对称的时空的存在，超高能粒子在运行的时候可以有一条绕过与物质相互作用的途径，从而可以比较好地解释为何超高能粒子可以正常穿过地球致密的岩石而不会产生相互作用。

之所以会出现超高能粒子能够从一个时空穿越到另一个时空，是因为在相对论能量计算公式中，当粒子的能量足够大的时候，可能就会进入一个能量的非线性区域。在该非线性区域中，

超高能粒子的速度可能会突破光速的限制，直接进入另一个时空。这就导致一个粒子可能突然出现在另一个时空。从而可以解释 ANITA 探测到的三个异常超高能粒子事件。

为了说明这种能量非线性区域的存在，我假设了两种能量上限的情况。一种是普朗克能量上限。目前来看，由于普朗克能量太大，远超 ANITA 探测到的异常超高能粒子的能量，因此相信这种能量的非线性区域可能不是普朗克能量上限所引起的。

另一种可能则是真空极化现象。在量子场论中已经对真空极化的问题进行了很多富有成效的探讨。其中包括真空介电常数的存在可能是由于真空极化现象所引起的。因此本文进行了一个推论，即如果超高能粒子在真空中运动的时候，可能会加强真空极化的效应，进而导致真空介电常数的上升。考虑到真空介电常数跟光速密切联系在一起，介电常数的上升意味着光速的下降。而这个时候如果超高能粒子的运动速度不变，就可能存在超光速运行的情况。这时候我们应用虚时空物理学的知识可知，超高能粒子将进入另一个时空运动，并同另一个时空的物质产生相互作用，而减慢粒子的运动速度。

尽管我觉得这种解释非常合理。不过其中还是存在一些问题，主要就是我无法计算超高能粒子对真空极化现象影响的具体数值。这主要还是限于我所能获得的资料和数据不太足够，以及真空极化问题还处于探讨的过程中，存在太多假设情况。或许通过 ANITA 探测到的超高能粒子的数据，有助于反过来帮助我们确定真空极化导致出现的粒子能量上限。

参考文献

[1] Aartsen, M. G., Choi, S., Leonard, K., Koirala, R., Stettner, J., Schneider, J., ... & Alispach, C. (2020). A search for IceCube events in the direction of ANITA neutrino candidates. arXiv: High Energy Astrophysical Phenomena,.

[2] Cheng, Z. Foundations of Virtual Spacetime Physics. LAP LAMBERT Academic Publishing. Brivibas gatve 197, LV-1039, Riga. Latvia, European Union

[3] Furry, W. H. , & Oppenheimer, J. R. . (1934). On the theory of the electron and positive. Physical Review, 45(5), 245-262.

[4] Mainland, G. B. , & Mulligan, B. . (2020). Polarization of vacuum fluctuations: source of the vacuum permittivity and speed of light. Foundations of Physics, 50(5), 457-480.