Cherenkov radiation effect in vacuum

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Abstract: The Cherenkov effect usually occurs in a certain medium. In this medium, such as water, the speed of particles exceeds the speed of light in the medium, which will produce observable Cherenkov radiation. If the dielectric constant in the vacuum may change for some reason, such as the increase in the dielectric constant due to vacuum polarization, it may cause the actual speed of photons in the vacuum to be lower than the theoretical speed of light. In this case, even in a vacuum, the Cherenkov scattering effect may occur. In this paper, the data of supernova 1987A is used to estimate the light speed reduction caused by vacuum polarization, and then the energy of the particles needed to produce the Cherenkov effect in vacuum is given. The estimated results are compared with the excess positron data observed by Alpha Magnetic Spectrometer (AMS), and it is found that the two are basically the same. Therefore, the excess positron phenomenon observed by AMS2 can also be explained by vacuum Cherenkov radiation.
Keywords: Cherenkov effect; speed of light; super speed of light

1 Introduction

The Cherenkov effect mainly refers to that in a certain medium, if the speed of particles exceeds the speed of photons in the medium, a strong radiation phenomenon will occur. According to various existing physical models, the speed of particles cannot exceed the speed of light in a vacuum. However, in a certain medium (such as water), the speed of photons is slower than the speed of light in a vacuum. The particles' speed can exceed the speed of photons in the medium, which will form an effect similar to the shock wave formed by the object exceeding the speed of sound, producing a strong photon or positron-electron pair radiation phenomenon.

However, with people's understanding of the vacuum state, it was found that there is also a polarization phenomenon in the vacuum, which caused the fluctuation of the vacuum energy state. There are some theories [1,2] that assume that vacuum polarization is the basic cause of vacuum dielectric constant. The vacuum dielectric constant is directly related to the speed of light. Therefore, according to this theory, the speed of photons in vacuum will be closely related to the phenomenon of vacuum polarization.

If vacuum polarization is the basic cause of the vacuum dielectric constant, due to different conditions, it will be possible to cause the vacuum polarization intensity to increase, which will cause the vacuum dielectric constant to increase, which in turn will cause the speed of photons in the vacuum to decrease. At this time, the speed of photons running in a vacuum will be lower than the theoretical speed of light.

In this case, we can consider a more extreme situation. Although according to the theory of relativity, the speed of particles cannot exceed the theoretical speed of light, but if energy of the particles is high enough, the speed of such high-energy particles may exceed the speed of photons in vacuum, although the speed of high-energy particles at this time still below the theoretical speed of light.

To specifically calculate the effect of vacuum polarization on the speed of light, an analysis can be made through a vacuum polarization model constructed by other authors. However, at present, the work of these authors is basically qualitative, and the model is relatively rough, so it is difficult to obtain the specific value of the effect of vacuum polarization on the speed of light. For example, Macleod, A. J. used the theoretical model to calculate the effect of vacuum polarization on the speed of light in 2019. [3] In order to generate the vacuum Cherenkov effect, a very strong magnetic field needs to be formed in the vacuum to be able to cause a sufficiently powerful vacuum polarization phenomenon, and then causes the vacuum dielectric constant to become larger. The calculation results show that the energy of the electron needs to reach 1.3TeV. Such a high energy has exceeded the energy of the largest positron-electron collider, and also exceeded the upper limit of 350GeV that can be achieved by AMS measurement [4].

Another approach adopted here is to estimate how vacuum polarization affects the speed of light by analyzing relevant experiments or observing data. We noticed that the supernova 1987A explosion [5,6] has an important feature, that is, when the supernova erupted, the neutrinos reach Earth 7 hours faster than photons. There are many explanations. Considering that neutrinos will not interact with other substances, their speed can be determined as the theoretical speed of light. One of these explanations is that the speed of photons is slower than that of neutrinos due to the effects of vacuum polarization [7]. If such an explanation is in line with the actual situation, we can use this data to estimate the actual speed of light in the vacuum. Then we calculate the energy required for an ultra-high-energy particle to reach that speed according to the theoretical speed of light. Of course, using the observation data of supernova 1987A has another advantage. Even if there is no reason why the vacuum polarization causes the speed of light to drop, the observation data at least reflects that the actual speed of light in the vacuum is indeed likely to be slower than the theoretical speed of light. For the emergence of possible new theories, the conclusions of this article can also apply.

2 Estimation of the effect of vacuum polarization on the speed of light

First, the distance of the supernova 1987A from the earth is calculated by 160,000 light-years. Photons are 7 hours slower than neutrinos. In this way, the actual speed of light can be calculated as

$$v = \frac{ct}{t + 7 \times 3600}$$

Where t is the time when the supernova 1987A neutrino radiated to the earth. And v is the actual speed of light after considering the influence of vacuum polarization.

The time the neutrino is running is:

$$t = \frac{16 \times 10^4 \times 9.4607 \times 10^{15}}{c}$$

In this way, the actual speed of the photon in vacuum can be obtained as

$$v = \frac{1.514 \times 10^{21}}{1.514 \times 10^{21} + 7 \times 3600c} c \approx (1 - 4.99 \times 10^{-9})c$$

It can be seen that the actual speed of light in vacuum is slower than the theoretical speed of light.

3 The energy required to reach the speed of light for a particle

The energy required for a particle of mass *m* to reach the actual speed of light in a vacuum can be calculated by the relativistic energy formula.

According to the relativistic formula:

$$E = Mc^2 = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} \approx \frac{mc^2}{\sqrt{1 - (1 - 4.99 \times 10^{-9})^2}} \approx 10^4 mc^2$$

For electrons, the rest mass is 0.5*MeV*, so the lower energy limit required to exceed the actual speed of light in a vacuum can be calculated to be about 5*GeV*.

If the speed of electrons exceeds the actual speed of light in a vacuum, Cherenkov radiation will be generated. The result of radiation is usually high-energy photons, positive and negative electron pairs. This phenomenon can be verified by measuring the number of positrons in the accelerator or cosmic rays that exceed 5*GeV*.

Considering that, like a sound barrier, the shock wave generated by breaking through the sound barrier usually occurs only near the speed of sound. Therefore, once the particle speed exceeds the actual speed of the photon in vacuum, no additional positron radiation will be generated. This will help to distinguish the positron anomaly from the positron radiation produced by other causes.

4 Support of experimental observation data

The most effective device for detecting high-energy positron radiation in cosmic rays is NASA's Alpha Magnetic Spectrometer (AMS). The device's second version, AMS2, has already detected this phenomenon. The detection results of AMS2 show that there is excessive positron radiation of $10GeV$~$250GeV$ in cosmic rays. It can be seen that the extra positron radiant energy in cosmic rays increases rapidly from $10GeV$. This is basically consistent with the theoretical calculation that the electron exceeds the lower limit of the actual speed of light in vacuum.

The positron velocity range corresponding to this energy is approximately between

$$(1 - 4.99 \times 10^{-9})c \sim (1 - 4.99 \times 10^{-15})c$$

Since the speed of the particles basically does not change significantly when approaching the theoretical speed of light, such a speed change range is quite reasonable. It's just not clear why the speed up-limit is about$(1 - 4.99 \times 10^{-15})c$ instead of higher speed, like $(1 - 4.99 \times 10^{-25})c$ and etc..

5 Results analysis

In the past, the speed of light in a vacuum was generally regarded as the theoretical speed of light. However, with the development of quantum field theory and other theories, people have discovered that there is also a phenomenon of polarization in vacuum, which leads to the problem of quantum fluctuations in vacuum. This vacuum polarization phenomenon directly leads to a change in the dielectric constant of the vacuum, which further causes a decrease in the speed of photons in the vacuum.

When the speed of photons is lower than the theoretical speed of light, the actual speed of particles may exceed the speed of photons in vacuum. An important sign in this case is the Cherenkov effect. Therefore, by observing whether those high-energy particles produces Cherenkov radiation, it can be used to confirm whether the vacuum polarization phenomenon exists.

The calculations in this paper show that when particles with a mass equivalent to electrons run faster than $5GeV$, it is possible to produce the Cherenkov effect in a vacuum. At present, NASA's AMS2 has observed cosmic rays, which in the energy spectrum of more than $10GeV$, there are excessive amounts of positrons, and these excess positrons only exist in a certain energy range. And the current observations also show that this excess positron has a certain isotropic characteristic, which also excludes the situation that these positrons come from a ray source in the universe. Therefore, in addition to the explanation of dark matter, the Cherenkov scattering effect in vacuum can be used as a good explanation.

This article also gives an assumption that the speed of light in the vacuum that was emphasized in the past does not seem to be accurately expressed. Or it should be more appropriate to change "the speed of any particle cannot exceed the speed of light in vacuum" to "the speed of any particle cannot exceed the theoretical speed of light."

Of course, considering that the speed of neutrinos is less susceptible to vacuum dielectric constant, the expression can also be changed to: "The speed of any particle cannot exceed the speed of neutrinos." But the problem with this formulation is that there is currently no experimental device to measure the velocity of neutrinos more accurately.

Therefore, this paper uses the data of supernova 1987A to calculate the effect of vacuum polarization or other reasons on the speed of light. The calculated results are basically consistent with the excess positron phenomenon observed by AMS2.

In addition, it is also considered that the vacuum fluctuations have a certain randomness, so the phenomenon that the speed of particles exceeds the speed of light does not necessarily occur, and may be randomly generated. This may limit the intensity of Cherenkov radiated secondary particles in vacuum to a certain extent.

Of course, there are still obvious differences between this article and some quantum field theory. This article believes that vacuum fluctuations occur naturally and do not necessarily require a strong magnetic field to change. Therefore, the speed of light in vacuum is always slower than the theoretical speed. And breaking through this speed does not require higher energy. This can be verified by accelerator experiments.

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