The coherent scattering of solar neutrinos with crystalline matter in the earth and their thermal effects

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Abstract

Neutrinos are microscopic particles. When they propagate in crystals, coherent scattering will occur, which will greatly improve the probability of scattering.Some calculations show that the cross section of the interaction between neutrino and crystal is directly proportional to the 4 / 3 power of the number of particles in the scatterer (crystal). That is to say, the larger the crystal is, the more particles it contains, the larger the interaction cross section between neutrino and crystal.As we all know, there are a lot of crystal materials in the interior of the earth, in which the inner core is said to be the largest crystal with a diameter of 1200km. Can the solar neutrino interact with the giant crystal in the interior of the earth to form a significant thermal effect?Here, we calculate the thermal effect of the coherent scattering of the solar neutrino and the crystal matter in the earth according to the crystal distribution in the earth. The results show that when the crystal share of the earth reaches a certain proportion and the crystal size reaches kilogram level, the energy released by the interaction between the solar neutrino and the crystal material of the earth can reach 12.39-42.02tw, which may be the source of unknown energy in the earth.

Key words

Solar neutrino; Neutrino coherent scattering; Crystal inside the earth; Energy source of the earth

1 Introduction

Neutrinos are microscopic particles with wave particle duality. When some long wave low energy neutrinos with wavelength close to the nucleon diameter interact with matter, the neutrino nucleus coherent scattering will occur, which will greatly increase the reaction cross section of neutrinos.Freedman[1] first studied this kind of coherent scattering. He believed that when the wavelength of neutrino is greater than the linearity of the nucleus, the nucleus as a whole will scatter neutrino. The amplitude of scattering is equal to the sum of all nucleons, which is proportional to the number of nucleons, while the probability of scattering is the square of the amplitude, which is proportional to the square of the number of nucleons.Therefore, for the heavy nuclei with about 100 nucleons, coherent scattering can increase the scattering cross section of neutrinos by 10000 times.Using 14.6kg cesium iodide crystal scintillator, Akimov et al.[2] have observed the neutrino nucleus coherent scattering phenomenon, and the experimental results are basically consistent with the theoretical calculation.This brings hope for miniaturization of neutrino detection experiments.However, the application of neutrino nucleus coherent scattering is limited. Because coherent scattering has strict requirements on neutrino energy (wavelength) and nuclear (and crystal) size.Generally speaking, the larger the nucleus and its crystal, the higher the cross section of coherent scattering, but the longer the neutrino wavelength (the lower the energy) is required. The lower the neutrino energy, the weaker the physical effect and the more difficult to detect. Therefore, to ensure that it can be measured, the nucleus and crystal used in the experiment cannot be infinitely enlarged.

However, although weak coherent scattering cannot be measured, this physical effect exists after all. If the experimental crystal is large enough, there are enough neutrinos, and the experimental time is long enough, then the effect will be obvious over time. So, how to make crystals large enough, find enough neutrinos and keep them for a long time?It's not difficult. Nature has carried out such experiments for us. This is the earth. As we all know, there is a lot of heat energy in the earth. It is this energy that drives the mantle convection and plate movement, maintains the geomagnetic field, and forms the geothermal flow and so on. However, there has always been controversy about the energy source of the earth's interior [3-5].Currently, the popular view about the energy source of the earth's interior is that one part comes from the decay energy of radioactive elements inside the earth, and the other part comes from the gravitational potential energy at the beginning of the formation of the earth [6]. But there are some obvious drawbacks to this view. Studies have shown that radioactive materials in the earth's interior decrease with the increase of depth [7,8], which is inconsistent with the increase of temperature in the earth's interior with the increase of depth. The latest geoneutrino detection also shows that the decay of radioactive elements in the earth's interior can provide about 23TW energy [9,10], and the current heat flux radiating from the earth's interior to the surface is about 47 ± 2TW[11]. In addition, energy is needed to maintain the geomagnetic field. Some studies estimate that the energy to maintain the geomagnetic field is 1.7TW - 170TW[12]. Therefore, there is still a considerable part of the earth's energy source is not clear. As for the gravitational energy, it is only a conjecture based on the nebula hypothesis of the formation of the solar system, not a definitive conclusion.Finally, in geological history, there have been brief earthquakes and sudden volcanic eruptions [13,14] and drastic changes in the geomagnetic field [15], a source of energy that neither radioactive decay energy nor early gravitational potential energy can explain. Therefore, people have been looking for other possible sources of energy, and put forward a variety of theoretical hypotheses, such as solar neutrino theory[16-23], thermonuclear reaction theory [12], fission theory [24,25], dark energy theory [26], etc., but these theories are not accepted because of their obvious defects.

Research shows that there are a large number of crystal materials of different sizes in the earth's interior, and the sun neutrinos are constantly shooting at the earth. If the neutrino nucleus coherent scattering can transfer some trivial energy to the earth's material, the thermal effect produced in the earth's interior may be very considerable.Based on the crystal distribution in the earth, the thermal effect of solar neutrinos interacting with the crystal material in the earth is discussed by using the method of neutrino - nucleus coherent scattering.and the power of the solar neutrino to provide energy for the earth is estimated, which opens a new way for the study of the energy source of the earth.

2 Thermal effect of coherent scattering of solar neutrinos with crystals in the earth

2.1 Coherent scattering of neutrinos with nuclei and crystal matter

According to the modern physical theory, during the course of solar neutrinos passing through the earth, very few of them will be absorbed by the earth's material, or will scatter with the atoms of the earth's material, transferring part of the energy to the earth's material.There is a threshold energy in the absorption (nuclear reaction) of solar neutrinos by the earth's materials, so the reaction cross section is very small. Compared with it, there is no threshold energy problem in the scattering between solar neutrinos and earth's atoms, so the scattering cross section is much larger than its absorption cross section. The scattering of solar neutrinos in the earth includes the scattering of solar neutrinos and electrons, and the scattering of solar neutrinos and nucleons. Because the coherent scattering with large reaction cross section only occurs between neutrinos and nuclei, we will only discuss the scattering of solar neutrinos and nuclei to deliver energy to the earth instead of other forms.

Freedman [1] gives the formula for the cross section of the neutrino nucleus coherent scattering reaction:

$$\sigma_A = \frac{1}{16}\sigma_0\left[\frac{E_v}{m_e C^2}\right]^2 A^2\left[1-\frac{Z}{A}+(4\sin^2\theta_w-1)\frac{Z}{A}\right]^2 \tag{1}$$

In the above formula, $\sigma_0 = 1.76\times10^{-44} cm^2$, A is the number of nucleons in the nucleus, and Z is the number of protons in the nucleus.

After Freedman,Weber [27] considers that not only the coherent scattering of neutrino and single atomic nucleus is directly proportional to the square of the number of nucleons, but also the scattering cross section of neutrino and crystal is directly proportional to the square of the number of particles N of the scatterer (the whole crystal), i.e. $\sigma \propto N^2$ .According to this conclusion, for a scatterer (crystal) with tens of grams, if there are 10^{20} particles, the reaction cross section of neutrino and its interaction will be increased by 10^{20} orders of magnitude. The interaction cross section of neutrino and single nucleus is about the order of $10^{-43}cm^2$ .if the interaction can be increased by 10^{20} times, the interaction cross section will reach the order of $10^{-23}cm^2$, which is equivalent to the interaction cross section of the same energy gamma ray and matter. If so, the sun's neutrinos will provide considerable energy for the earth. However, although Weber claims that he has verified his theory with experiments, no other scholars can repeat his experiment [28], which has been widely opposed. After studying the theory of Weber, Luo Jun and Chen Xiao et al. [29] thought that the coherent scattering of neutrino and crystal must meet the Bragg requirements of crystal scattering. Therefore, Luo and Chen et al.along the thinking of Weber, introduced the Bragg limit of crystal scattering, calculated the coherent scattering cross section under the condition that the wave length of incident neutrino and the size of scattering crystal are comparable, and deduced the following results:

$$\sigma \approx \pi |U_{IF} \Xi U_{IO}|^2 N^{4/3} / (c^2 \hbar^2 b^2) \tag{2}$$

It can be seen that the scattering cross section is directly proportional to the 4/3 power of the number of scatterer particles N, that is $\sigma \propto N^{4/3}$ .This conclusion is a factor $N^{2/3}$ less than Weber's theory. Compared with Weber's estimation that the interaction force between solar neutrinos and 26 grams of sapphire (containing about particles 10^{22}) can reach 10^{-11} Newton, it is reduced by 15 orders of magnitude, only 10^{-26} Newton, which is far beyond the range of human measurement. In other words, the measurement result must be zero.

However, although the coherent scattering between the sun neutrino and the crystal can not be measured, this kind of interaction exists objectively and its thermal effect also exists. Therefore, if the calculation of Luo and Chen is correct, the cross section of the sun neutrino and its coherent scattering will be $N^{1/3}$ times higher than that of a single atom for a crystal weighing 1kg (containing about 10^{24} atoms), reaching the order of 10^8 . The results show that there are a large number of crystal materials of different sizes in the earth, assuming that the total number of nucleons in crystal materials is N,According to the approximate formula given by kippenhahn and Weigert [30]：

$$\sigma_{\nu} \approx 10^{-44}(\frac{E_{\nu}}{m_e c^2})^2 cm^2 \quad (3)$$

E_{ν} is the energy of neutrino, $m_e c^2$ is the mass energy of electron about 511ev, C is the speed of light, and the average energy of neutrino in the main order of solar proton proton is about 260kev,so $\frac{E_{\nu}}{m_e c^2} \approx 0.509$,and the average cross section of the sun neutrino and the earth's nucleus is $\sigma_{\nu} \approx 2.59 \times 10^{-45} cm^2$ .It is assumed that the sun neutrino can transfer 1 /n energy to the atomic nucleus on average when scattering. In this way, considering the research results of Luo Jun and Chen Xiao [29], [formula(2) (3)], we can get that the energy delivered to the earth by the sun neutrino through coherent scattering with crystal atoms is as follows:

$$Q_{A,\nu} = N^{\frac{4}{3}} \bullet \sigma_{\nu} \bullet \phi \bullet \frac{E_{\nu}}{n} = N^{\frac{4}{3}} n^{-1} \times 10^{-48} J/s \quad (4)$$

Where, $\phi = 6.5 \times 10^{10} cm^2$ is the flux of the sun neutrino to the ground, and $E_{\nu} = 260keV$ is the average energy of the sun neutrino[31].

2.2 Crystal material distribution in the earth

One of the remarkable characteristics of crystal material is its anisotropy. The observation of seismic wave propagation in the earth's interior proves that there is anisotropy in the matter of different depths [32-34]. Although the anisotropy may have different causes, there is no doubt that a considerable part of it is caused by the lattice dominant orientation, which indicates that there are a certain number of crystals in the earth's interior. At present, through high-pressure physical experiments and combined with seismic wave observation, the distribution of mineral crystals and structural phase transition in the earth's interior are given. There are abundant quartz crystals and other minerals in the crust, while there are a lot of expensive diamond crystals in the root of craton [35, 36]. The main component of the upper mantle is olivine. With the increase of depth and pressure, olivine will undergo phase transformation and form spinel and other minerals. The lower mantle is dominated by perovskite minerals, which will transform into post perovskite with completely different structures at 2700km [37-39].

The study of seismic wave shows that the core of the Earth presents elastic anisotropy. The formation mechanism of elastic anisotropy in the core is a research hotspot. It is generally believed that the core anisotropy may originate from the dominant orientation of hexagonal compact packed (HCP) iron crystals

[40] or liquid non spherical inclusions [41], and the mechanism of this dominant orientation may also be the lattice orientation of iron crystals caused by Maxwell stress [42, 43]. At the same time, according to the variation of seismic wave disturbance, it is speculated that there are kilometer size scatterers in the core [44-46].There is also an inner core in the core, which is believed to be a giant iron crystal,directly about 1200km [47]. Even the liquid outer core may be partially in the liquid crystal state [48]. These crystals with different sizes in different layers of the earth's interior structure have strong or weak coherent scattering to solar neutrinos, especially in the deep part of the earth, with the increase of pressure, many dense crystals with special properties will be formed, which will enhance the coherent scattering. Therefore, we can be sure that these coherent scattering can intercept a considerable part of the sun neutrinos, so that they will transfer part of the energy to the earth.

2.3 Heat generated by coherent scattering of solar neutrinos and crystals inside the earth

The number of atoms contained in the earth can be calculated by the following formula:

$$N_{earth} = \sum W_{earth} \bullet e_i N_A / g_i \approx 1.36 \times 10^{50} \tag{5}$$

In the above formula, $W_{Earth} = 5.976 \times 10^{24} kg$ is the earth mass, $N_A = 6.02 \times 10^{23}$ is the Avogadro constant, e_i and g_i are the earth abundance and mole of element I respectively (the earth mass and element abundance are based on the data of Litang [49], the same below). In addition, we only calculated the number of atoms of the elements with the first 8 abundances of Fe, O, Mg, Si, s, Ni, CA, Al, etc., and ignored the content of other elements.

If the inner core of the earth is really a huge crystal with a diameter of about 1200km, if it is all composed of iron atoms, and the number of atoms in the crystal is 1.04×10^{47}, then the cross section of the coherent scattering of solar neutrinos in the inner core can be increased by 10^{15} times.Therefore, when n=100, Substituting $N = 1.04 \times 10^{47}$ into equation (4) leads to $Q_{A,v} = 34.26TW$,that is to say,the sun neutrinos scattered by the inner core can deliver only 1% of the energy to the earth on average, which is enough to provide the energy needed for the earth's evolution.

If the inner core is not a large crystal, but consists of several smaller crystals, considering that the whole earth's core (including the inner core) has a total of $N_{core} \approx 1.06 \times 10^{48}$ iron atoms, even if the core is all composed of sub crystals 10 billion (10^{10}) times smaller than the inner core, if the coherent scattering of solar neutrinos can transfer 1 / 3 of energy to the earth, it can still transfer 11.71 TW of energy to the earth's core.

In addition, there are also a lot of crystal materials in the mantle, and the coherent scattering of solar neutrinos in the mantle is bound to exist in large quantities. Assuming that 20% of the mantle material (68.1% of the total mass of the earth) is composed of crystals, and that 70% of the crystals have a mass of 1g-1kg, 20% of the crystals have a mass of $1kg-10^3kg$, 8% of the crystals have a mass of 10^3-10^6kg, and 2% of the extra large crystals have a mass of 10^6-10^9kg, then the energy transported to the mantle by the solar neutrinos can be calculated to be 0.68-7.76TW (Table 1).Therefore, considering the crystal in the earth's core and mantle, we can know that the coherent scattering of the solar neutrino and the crystal matter of the earth, the energy transported to the earth is 12.39-42.02TW. Therefore, we believe that the energy source of the earth's interior, in addition to the radioactive material, is likely to be the coherent scattering of the solar neutrinos and the crystal atoms in the earth's interior.

Table 1: energy estimates of solar neutrino transport to the mantle

Crystal mass	Proportion (%)	Number of atoms contained	Scattering cross section ($\times 10^{-44} cm^2$)	Energy to the mantle
1g-1kg	70	$10^{22}-10^{27}$	10^7-10^9	0.001-0.16TW
$1kg-10^3kg$	20	$10^{27}-10^{30}$	10^9-10^{10}	0.04-0.46TW
10^3-10^6kg	8	$10^{30}-10^{33}$	$10^{10}-10^{11}$	0.18-1.85TW
10^6-10^9kg	2	$10^{33}-10^{36}$	$10^{11}-10^{12}$	0.46-4.61TW
Total	100			0.68-7.76TW

3 Discuss

Strictly speaking, our work is a kind of qualitative research. Due to the unclear distribution and size of the crystal inside the earth, our estimation of the energy transfer from the sun neutrino to the earth is very rough, which cannot be said to be a quantitative calculation in a strict sense.However, this does not affect our conclusion. At present, although the research on the size and distribution of crystal matter in the earth's interior is not completely clear, from these fuzzy studies, we can also find a large number of crystals with different sizes in the earth's interior.

Huguet et al. [50] showed that the molten primitive earth based on the gravitational potential energy could not keep the outer core liquid by cooling and crystallizing to form the solid earth core. Under the condition of high temperature and pressure inside the earth, in order to crystallize the core, it is necessary to make the temperature of liquid metal lower than the freezing point (or melting temperature) by up to 1000 degrees. At the same time, if the center of the earth reaches this temperature, the whole core will crystallize rapidly, but this is not the case. In fact, the temperature of the earth's interior is very slow. It only decreases by 100 degrees every one billion years. It is impossible to have a large temperature drop of 1000 degrees all of a sudden. Therefore, the solid core cannot be produced from the homogeneous liquid outer core.That is to say, either the solid core has another cause, or the liquid outer core is formed later. If the outer nucleus is later formed, a heating factor is required. We think that this heating factor is the sun neutrino.

So how is earth matter heated by the sun's neutrinos? As you know, the atoms in the crystal are not fixed, but vibrate near the equilibrium position. The more energy the crystal absorbs, the higher the temperature, and the greater the vibration amplitude.According to quantum mechanics, the energy of crystal lattice vibration is quantized. If the lattice is composed of N atoms, its energy is [51]:

$$E_n = U + \sum_{i=1}^{3N}(n_i + \frac{1}{2})h\nu \qquad (6)$$

$(n = 0,1,2,\ldots$。 $i = 1,2,\ldots,3N$。 $)$

Where u is the energy of the crystal when the atom is still in the equilibrium position. This shows that the energy of crystal is composed of two parts: static energy and vibration energy. The vibrational energy can be continuously distributed from zero to the energy needed for the atom to be knocked out of equilibrium. Therefore, the crystal can intercept all kinds of solar neutrinos with various energy spectra.When the sun neutrino collides with the nucleus of the crystal, it exchanges a Z boson with a quark of the nucleus, and transfers some of its momentum to the nucleus, so that the nucleus is in a certain excited state. Then the nucleus will emit a photon to release this part of energy or convert it into heat energy by lattice vibration. Of course, neutrinos with high enough energy can even directly knock atoms out of their equilibrium positions and make them diffuse.This kind of energy transfer is not affected by neutrino oscillation and can keep the neutrino flux unchanged. At the same time, due to the absorption of natural current, neutrinos lose energy and are not necessarily annihilated. Assuming that the energy of the sun neutrino is 260kev, the energy lost due to the impact of the crystal atom is 60keV, which will still carry 200keV energy across the earth and go away.

According to the above research, if the energy released by the coherent scattering of the solar neutrino and the earth crystal material is the main source of energy inside the earth, then the core of the earth center is the center of the earth heat source, and the places where there are crystals in the mantle can also generate energy, but with the production and accumulation of energy, the crystals will be melted into liquid. As the crystal disappears, the coherent scattering cannot be carried out, the energy production stops, the liquid cools and recrystallizes to form the crystal. Therefore, the coherent scattering of neutrinos begins again, energy accumulates again, crystal melts again, and so on, which leads to a series of material and energy flows inside the earth.

4 Conclusion

Although the cross section of the interaction between the sun neutrino and matter is very weak, because the neutrino is a micro particle with typical wave particle duality, when the sun neutrino propagates in the crystal material inside the earth, if its wavelength is close to the size of the crystal atom, then the sun neutrino will have coherent scattering, which will greatly improve its scattering cross section, There are a large number of crystal materials with different sizes and densities inside the earth, and the coherent scattering of solar neutrinos with these crystal materials can produce a significant thermal effect. This paper gives an estimated result of the thermal effect of 12.39-42.02TW, which is enough to provide energy for various evolutions of the earth.

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