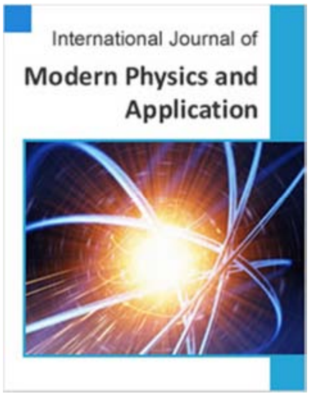
**International Journal of Modern Physics and Application**
2017; 4(1): 1-7
http://www.aascit.org/journal/ijmpa
ISSN: 2375-3870

American Association for Science and Technology




# Formation and Variation of Geomagnetic Field and Other Planetary Magnetic Fields as Well as Geomagnetic Declination and Geomagnetic Reversal

**Cui-xiang Zhong**

Department of Science and Technology, Jiangxi Normal University, Nanchang, China

## Email address
cuixiang_zhong@sohu.com

## Keywords
Glacial Period,
Interglacial Period,
Geomagnetic Field,
Geomagnetic Declination,
Geomagnetic Reversal

Received: January 29, 2017
Accepted: February 23, 2017
Published: June 3, 2017

## Citation
Cui-xiang Zhong. Formation and Variation of Geomagnetic Field and Other Planetary Magnetic Fields as Well as Geomagnetic Declination and Geomagnetic Reversal. *International Journal of Modern Physics and Application.* Vol. 4, No. 1, 2017, pp. 1-7.

## Abstract
Although geomagnetic field has been found and utilized for a long time, and many hypotheses have been proposed about the cause of geomagnetic field, so far none of them is able to completely answer every question about the geomagnetic field. Thus the author has researched the formation and evolution of the geomagnetic field again, and discovered that during an interglacial period, under the action of solar ultraviolet rays and cosmic rays, Earth's atmosphere can produce a large amount of positive ions and negative ions, then form the positive charge layer at the top of cloud and the negative charge layer at the bottom of the cloud; with the rotation of Earth, the two charge layers generate a superposition of geomagnetic fields. This kind of magnetic field conforms to all the known characteristics of geomagnetic field. It can well explain the inhomogeneity of the spatial distribution of geomagnetic field and its characteristic of constant change over time, including geomagnetic declination and reversal. If the Earth enters a glacial period, the land and the sea would be covered by ice, then the bottom of the clouds would touch the ground, making the charge at the bottom of clouds become 0 and the surface charge be approximately equal to 0. At this time only the positive charge layer at the top of cloud has an effect on forming geomagnetic field, therefore realizing geomagnetic reversal. The formation and reversal of other planets' magnetic fields are similar with that of geomagnetic field.

## 1. Introduction

As early as two thousand years ago, Chinese ancient working people have accumulated a large amount of knowledge about magnetic phenomena and invented the compass, which has been applied to navigation and travel. It can also be known from Shen Kuo's *Dream Pool Essays* of the Song dynasty (960–1279) that China has found and used geomagnetic field and geomagnetic inclination very early indeed. Although the invention of the compass in China was 800 years earlier than that of the European compass, China wasn't able to reveal the electrical nature of magnetic phenomena in theory until Oster found "magnetic effect of electric current" in 1820 and Faraday discovered the phenomenon of "electromagnetic induction" in 1821, which were used to invent motors and generators respectively later. Only since then people have had a fundamental understanding of the electrical nature of magnetic phenomena [1]. Even so, people haven't got enough knowledge of the geomagnetic field around them, nor can they thoroughly understand the cause and variation law of the geomagnetic field. Although people have studied the origin of Earth's magnetic field for nearly 400 years and put forward a variety of hypotheses, none of them is able to completely answer every question about the geomagnetic field [2]. Thus according to the formation and evolution of the Earth and general galaxies, the author has researched the formation and evolution of the geomagnetic field and discovered the formation cause and the variationlaw of the geomagnetic field, which can be introduced as follows.

## 2. Temporal and Spatial Characteristics of Geomagnetic Field

From the viewpoint of spatial distribution, the Earth can be regarded as a magnetic dipole. The geomagnetic south pole is located near the geographical north pole while the geomagnetic north pole is located near the geographical south pole, and the geomagnetic poles are not exactly coincident with the geographical poles, there is an angle between the two kinds of poles, which is called magnetic declination. With the slow movement of the Earth's magnetic poles, the magnetic declination also slowly changes [3]. In addition, the intensity of the entire magnetic field reaches its maximum in North America, Siberia and near part of the Antarctic continent. The Earth's magnetosphere is compressed by the force of charged particles in the day area (dayside), and extends outward in the dark area of the Earth (the back surface).

Earth's Magnetic field not only distributes unevenly but also changes over time. According to the time scale, the change of geomagnetic field can be divided into slow change and rapid change. Slow change (also known as long term change), including the change in the intensity of the geomagnetic field during the stable period, the movement of the geomagnetic poles on the Earth's surface and the westward drift of the geomagnetic field and so on. Fast change is mainly manifested as geomagnetic reversal and drift. During geomagnetic reversal, the geomagnetic intensity will decrease greatly, and the structure of geomagnetic field will become more complicated. The latest geomagnetic reversal, the Brunhes–Matuyama reversal, occurred 780,000 years ago. The research of Sagnotti et al. found that the time to complete the reversal is less than 100 years [4, 5, 6, 7]. This result presented a great challenge to geodynamo theory for geomagnetic field formation, and there are still a lot of controversy.

In addition, geomagnetic field is a weak magnetic field. The average magnetic induction intensity on the ground is $0.5\times10^{-4}$ T, while the magnetic induction intensity at the north and south poles is $(0.6\sim0.7)\times10^{-4}$ T. Surveys also found theintensityweakeningofthegeomagneticfieldin recent 2000 years. The intensity of the geomagnetic field has decreased by 10% compared with 1840, on average, 5% per hundred years. By the end of 2013, the European Space Agency launched a new generation geomagnetic satellite *swarm*. The latest observation results show that the geomagnetic intensity has been inacceleratingdecline, and the acceleration is 10 times as much as the previous estimation. As to why the geomagnetic field is a weak magnetic field and the intensity of the geomagnetic field has been inaccelerating decline, it's still unknown and has become a hot issue in science.

## 3. The Existing Hypothesis About the Origin of Geomagnetic Field

Due to the importance of the geomagnetic field, people have been exploring the cause of the formation of the geomagnetic field for a long time. After several hundred years of research, people have got a deeper understanding of the characteristics of geomagnetic field and put forward a variety of hypotheses.

Initially, people thought that the Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth, as is shown in Fig. 1. The problem with that picture is that the Curie temperature of iron is about 770°C. The Earth's core is hotter than that and therefore no magnetic. So the Earth couldn't get its magnetic field from such a bar magnet.

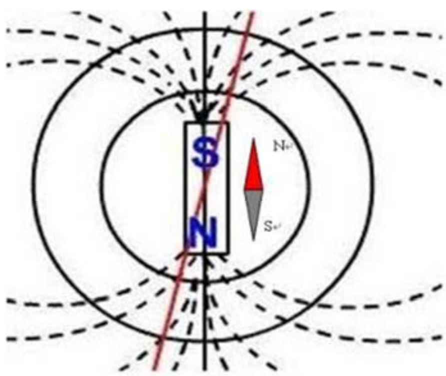



***Fig. 1.*** *Earth's magnetic field.*

Magnetic fields surround electric currents, so one may surmise that circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field. A current loop gives a field similar to that of the Earth. From these points of view, the German-born American physicist Walter M. Elsasser and the British geophysicist Edward Bullard during the mid-1900s proposed dynamo theory to explain the origin of the Earth's main magnetic field in terms of a self-exciting (or self-sustaining) dynamo. In this dynamo mechanism, fluid motion in the Earth's outer core moves conducting material (liquid iron) across an already existing, weak magnetic field and generates an electric current. (Heat from radioactive decay in the core is thought to induce the convective motion.) The electric current, in turn, produces a magnetic field that also interacts with the fluid motion to create a secondary magnetic field. Together, the two fields are stronger than the original and lie essentially along the axis of the Earth's rotation [4, 5, 6].

Although various other mechanisms for generating the geomagnetic field have been proposed, only the dynamo concept is seriously considered today. But it still couldn't explain the inhomogeneity of the spatial distribution of geomagnetic field and the characteristic of constant change over time, including geomagnetic declination and geomagnetic reversal. Hence, it isn't plausible to use this mechanism to explain the formation of the geomagnetic field.

# 4. Real the Cause of the Formation of Geomagnetic Field

## 4.1. Revealing the Cause of the Formationof Geomagnetic Field from the Formation and Evolution of Atmosphere

It's already known that the age of the Earth is $4.54 \pm 0.05$ billion years. The evolution from the formation of the original Earth to the formation of the Earth's layered structure needs only hundreds of millions of years. The most primitive crust appeared about 4 billion years ago, but the earliest geomagnetic records discovered so far were 3.5~4 billion years ago. So the origin of the Earth's magnetic field is later than the formation of Earth's layered structure, but close to the formation of atmosphere in time. In addition, the temporal and spatial variability of Earth's magnetic field also shows that the formation of geomagnetic field is closely related to the formation and evolution of the atmosphere. So in the study of the origin of the geomagnetic field, we should start with the formation and evolution of the atmosphere.

The Earth's atmosphere is the product of the Earth's formation and evolution. The Earth's evolution has undergone three distinct stages: Earth's primordial atmosphere, Earth's second atmosphere and Earth's third atmosphere. With the increase of Earth's mass, the atmosphere is gradually thickened. The whole atmosphere shows different characteristics with different height, so it is generally divided into five layers [8, 9]:

1) *Troposphere*——It is the first layer above the surface and contains about 80% of the total mass of the atmosphere. Its average thickness is 12km. Clouds exist only in this layer.
2) *Stratosphere*——Above the tropopause is the stratosphere. This layer extends from an average altitude of 11 to 50 kilometers above the Earth's surface. This stratosphere contains about 19.9% of the total mass found in the atmosphere, but very little weather occurs in the stratosphere.
3) *Mesosphere* ——It stretches from 50 km to 85 km.
4) *Thermosphere* ——It extends from about 85 km to more than 690 km. Under the action of solar ultraviolet rays and cosmic rays, the air of this layer is ionized, leaving the ions and free electrons floating. Some of these ions will diffuse down into the troposphere, gathered at the top of the cloud.
5) *Exosphere*——Exosphere is the upper limit of the atmosphere. Itranges from about 690 km up to 10,00 km. This layer is where atoms and molecules escape into space. The atmosphere becomes very thin in this layer. Gas particles in the exosphere either come down into the lower atmosphere due to Earth's gravitational pull or escape into outer space.

Thus we see that common clouds can only be formed in the troposphere, because only in a place where air's vertical motion is strong, can water vapor rise to meet cold air to form clouds, but above the troposphere this condition is not satisfied. In fact, there are various clouds with different altitudes, which can be divided into high, middle and low clouds. The altitude of high clouds is between 8 km and 13 km, looks like thin veils or feathers; the altitude of middle clouds is between 2 km and 8 km, usually covering all the sky, sometimes also producing continuous precipitation; the altitude of low clouds is below 2 km, looks like cotton candies or expanding foams, sometimes also producing thunder showers. Hence, the study of cloud charging mechanism should mainly consider the middle and low clouds.

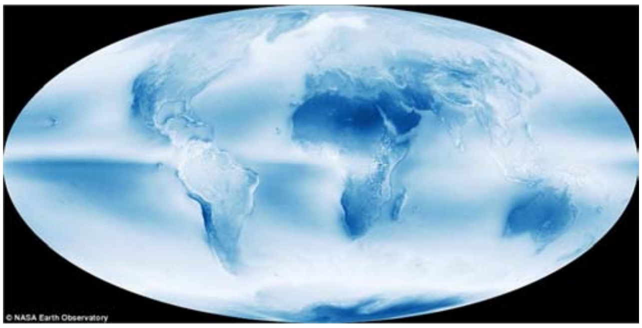



***Fig. 2.*** *The beauty of the Earth beneath the clouds.*

In addition, nearly 70 percent of the surface of the Earth is covered by oceans while the land occupies only about 30 percent of the Earth's surface, moreover, the oceans are connected to each other and Earth's land is divided into some smaller land masses by oceans. Hence, some foreign media reported that at any moment, about 70% of the Earth's surface is covered by clouds, as is shown in Fig. 2. This is a map produced by NASA using Aqua satellite to obtain the related data, it shows the beauty of the Earth beneath the clouds.

Due to the action of solar ultraviolet rays and cosmic rays, the Earth's atmosphere can produce a large amount of positive ions and negative ions. The charge distribution is uneven on the droplets in the cloud: The molecules of the outermost layer is negatively charged while the molecules of the intralayer is positively charged, the potential difference between the inner layer and the outer layer is 0.25 Volts. In order to balance this potential difference, water droplets in the cloud must first absorb negative ions in the atmosphere, causing the droplets to be negatively charged. When the convective activity begins, the lighter positive ions are gradually brought up by the updraft to the upper part of the cloud, while the larger cloud droplet is either suspended in the middle of the cloud or falls toward the lower part of the cloud, causing the lower portion to be negatively charged and the upper portion to be positively charged.

According to the previous statistical data and the aerial map of clouds, we can see that about 70% of the Earth's surface is covered by clouds, especially over a number of interconnected oceans, there are some clouds (including middle and low clouds) surrounding the Earth. In addition, when the air humidity is very large and there is a voltage difference between two clouds, the moist air will become a conductor letting electrical current pass through the space between the two clouds. Hence, when the Earth rotates from west to east, the negative charge in the lower portion of the cloud follows the Earth's rotation to form a circular current from the east to the west, therefore producing a magnetic field whose magnetic south pole is located near the geographical north pole while the magnetic north pole is located near the geographical south pole; meanwhile, the positive charge in the upper portion of the cloud also follows the Earth's rotation to form a circular current from the west to the east, therefore producing a magnetic field of the opposite orientation. But the lower portion of the cloud is much closer to the ground than the upper portion of the cloud, so the previous magnetic field is stronger than the latter one, and the superposition of the two magnetic fields produces the current geomagnetic field, whose magnetic south pole is located near the geographical north pole while the magnetic north pole is located near the geographical south pole.

Although the atmospheric electric field also causes negative charges on Earth's surface, the negative charge on Earth's surfacehas little effect on the geomagnetic field, because if the negative charge on Earth's surface follows Earth's rotation from west to east to produce a circular current from the east to the west, whose magnetic induction at the two poles should be $(0.36\times10^{-4})\times10^{-8}$T, only $1/10^{8}$of the actual geomagnetic field intensity, which is $(0.6\sim0.7)\times10^{-4}$ T.

## 4.2. The Scientificness of the New Explanation of the Cause of Geomagnetic Field

From above, we see that whether the most representative"dynamo theory" or other special hypotheses have troubleexplaining the inhomogeneity of the spatial distribution ofgeomagnetic field and the characteristic of constant changeover time, while the new explanation of the cause ofgeomagnetic field, proposed above, can well explain thetemporal and spatial variability, hence it's a more scientifictheory.

(1). The reason for the tilt of Earth's axis and the formation of geomagnetic declination

Geomagnetic declination has been found and used for a long time, but the formation and changes of geomagnetic declination is still a mystery. The reason for the tilt of the Earth's axis is also unknown. But if we start with the formation and movement of the atmosphere, we can easily analyze and solve these problems.

The original Earth has only a thin atmosphere, evenly wrapping around the Earth, so solar radiation to Earth's atmosphere could not produce a big pressure difference between Earth's dayside and night-side, this causes the Earth's original axis to be perpendicular to the plane of the Earth's orbit, almost consistent with the axis of the atmosphere's rotation. But as the Earth constantly absorb cosmic dust and gases near the orbits to become larger and larger, the atmosphere also become thicker and thicker, now it is up to tens of thousands of kilometers thick. Due to the inhomogeneity of atmospheric motion, there are significant differences in atmospheric pressure on different parts of the Earth, leading to the tilt of Earth's axis. This can be proved as follows:

(i). since the lower latitude region receives more heat, air expands and rises easily, while polar region and high latitude region receive less heat, air contracts and sinks. Because the pressure over the equatorial region is higher than that in the polar regions, the air above the equatorial region would flow toward the poles, piling up and sinking in there, forming a polar high pressure area.

(ii). According to Kepler's first law, the orbit of Earth is slightly elliptical and the Sun is at a slight offset from the middle, at the focus of ellipse. What this means is that the Earth will closer to the Sun at some point (which is called the perihelion) and farther away from the Sun at some other point (which is called the aphelion). Also, according to Kepler's second law, the Earth sweeps equal areas in orbit in equal time. So the winters in Northern hemisphere are shorter and summers longer, while the winters in Southern hemisphere are longer and summers shorter. Hence, the time of the Sun shining directly over the Northern hemisphere is longer than that of the Southern hemisphere. In fact, subsolar point moves across Northern hemisphere from March 21st to September 23rd every year, during this period, the Earth pass through the aphelion with lower average speed of revolution, taking about 186 days; subsolar point moves across Southern hemisphere from September 23rd to March 21st next year, during this period, the Earth pass through the perihelion with higher average speed of revolution, taking about 179 days. Consequently, the summer half year of Northern hemisphere is longer than the winter half year by 7 days, and the polar day near the north pole is longer than the polar day near the south pole by about 7 days. Hence, the time of the Arctic high pressure is longer than that of the Antarctic, the atmospheric pressure over the dayside of Arctic region is usually greater than that of the dayside of Antarctic region, eventually leading to that the Earth's axis is tilted from perpendicular to the plane of the ecliptic by 23.45° or 23°26′, as is shown in Fig. 3. But the air above the equatorial region and lower latitude region would continue flow toward the poles, piling up and sinking in there, adding the evaporated water vapor from the new added day region which has a latitude span of 23.45°, forming a new polar high pressure area. Half the air of the new added polar day region would move to the polar night region, eventually the rotationaxis of the atmosphere is tilted only about 11.53°(≈½×23°26′), making the included angle between the rotation axis of the atmosphere and the rotation axis of Earth is about 11.5°, as is shown in Fig. 4.

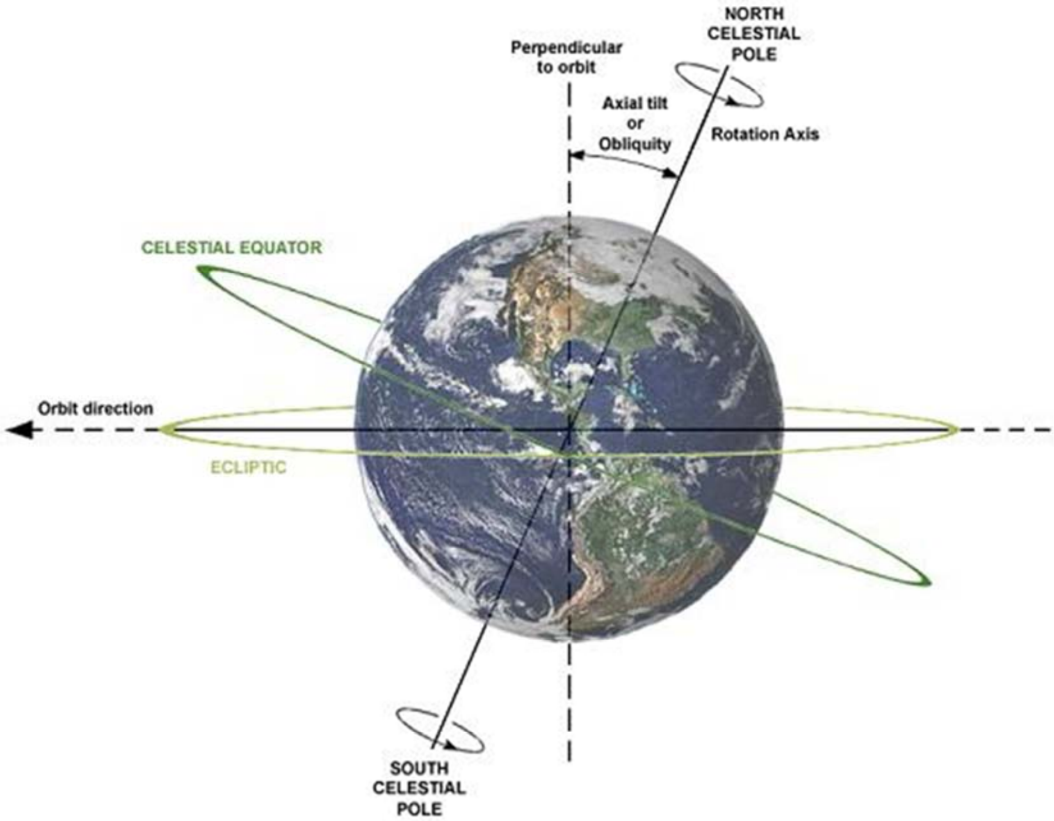



*Fig. 3. Earth's axial tilt.*

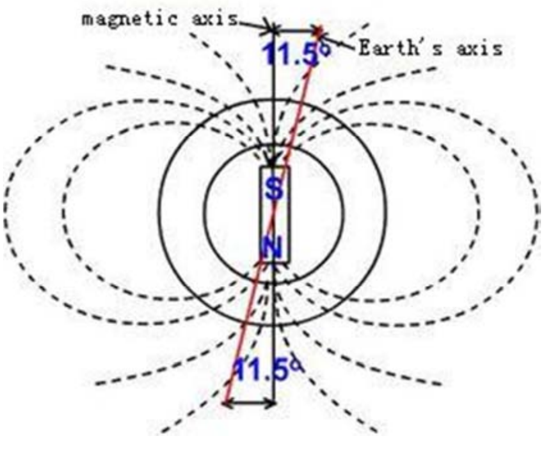



*Fig. 4. Magnetic declination.*

(2). Inhomogeneity of the spatial distribution of geomagnetic field

In the northern hemisphere, when cold air of the polar high-pressure areas is flowing southward, it is deflected to the right, becoming easterly winds; when warm air of the subtropical high-pressure areas is flowing northward, it is also deflected to the right, becoming westerly winds in the mid-latitude. These two streams converge near 60° N, warm air is lifted up by cold air and cooled into clouds, then moving through high space to the poles and subtropical zones. So near 60° N, there are thick and wide clouds. The upper layer of the clouds can collect a large amount of positive ions, the lower layer of the clouds can collect a large amount of negative ions, therefore being able to form strong magnetic fields there. Hence, the intensity of the entire magnetic field reaches its maximum in North America, Siberia and near part of the Antarctic continent.

Since the equatorial region of dayside receives more heat, air expands and rises easily, making the pressure over the equatorial region is higher than that in the polar regions, the air above the equatorial region would flow toward the poles, forming an equatorial low-pressure zone. In this low-pressure zone, air density is small and the clouds is thin, only a weak magnetic field can be formed. So the intensity of the entire magnetic field reaches its minimum in the central Pacific Ocean near the equator. Central South America is also close to the equator and has less moisture than the central Pacific, air density is small, it’s difficult to form thick clouds, only a weak magnetic field can be formed. So the intensity of the entire magnetic field also reaches its minimum in Central South America.

(3). Earth’s magnetic field changes over time

With the revolution and rotation of the Earth, the Earth's atmosphere is changing slowly, causing the slow movement of the geomagnetic poles on the Earth's surface. When the Earth rotates from west to east, the negative charge in the lower portion of the clouds follows the Earth’s rotation to form a circular current from the east to the west, therefore producing a magnetic field whose magnetic south pole is located near the geographical north pole while the magnetic north pole is located near the geographical south pole; meanwhile, the positive charge in the upper portion of the clouds also follows the Earth's rotation to form a circular current from the west to the east, therefore producing a magnetic field of the opposite orientation. But the lower portion of the clouds is much closer to the ground than the upper portion of the clouds, so the previous magnetic field is stronger than the latter one, and the superposition of the two magnetic fields produces the current geomagnetic field, whose magnetic south pole is located near the geographical north pole while the magnetic north pole is located near the geographical south pole. Hence, during the rotation of the Earth, people seem to feel a westward drift of the geomagnetic field.

In addition, since cloud charge is usually high and revolves around the Earth slowly, additionally the magnetic field produced by the lower layer's negative charge and the magnetic field produced by the upper layer's positive charge have opposite polarities, the previous magnetic field has been partially offset by the later one, leading to the geomagnetic field is a weak one. Moreover, with the growth of Earth's mass, Earth can absorb more and more greenhouse gases from both the cosmic space and human production, including water vapor, carbon dioxide and dust particles, making atmosphere thicker and thus the greenhouse gases captured by the atmosphere difficult to escape, finally enhancing greenhouse effect, causing global warming. Therefore, it is becoming more and more difficult to form clouds in the low sky, and only in high cold sky can clouds be formed. So the clouds are getting higher and thinner, leading to the weakening of the intensity of geomagnetic field.

## 5. Causes of Geomagnetic Reversal

According to the previous discussion, the reason why we have today's geomagnetic field whose geomagnetic south pole is located near the geographical north pole while the geomagnetic north pole is located near the geographical south pole, it is because of that under the action of solar ultraviolet rays and cosmic rays, Earth's atmosphere can produce a large amount of positive ions and negative ions, then form the positive charge layer at the top of cloud and the negative charge layer at the bottom of the cloud, with the rotation of Earth, the two charge layers generate a superposition of geomagnetic fields. The orientation of today's geomagnetic field undoubtedly makes people feel puzzled. In fact, through an investigation, we can find that if there is only the positive charge layer at the top of cloud, then a magnetic field of opposite orientation can be produced, realizing geomagnetic reversal. But when is there only a positive charge layer at the top of cloud? As we know, it's easy to see clouds enveloping the ground in the morning of low temperature, at this time the bottom of the clouds touches the ground; similarly, the ground temperature is low in winter, the condensation height of clouds is also low, generally from winter to summer, the condensation height increases gradually. If the Earth enters a glacial period from interglacial period, the land and the sea are covered by ice, then the bottom of the clouds would touch the ground, spreading the negative charge at the bottom of clouds to the vast land, making the charge at the bottom of clouds become 0 and the surface charge be approximately equal to 0. At this time only the positive charge layer at the top of cloud has an effect on forming geomagnetic field, therefore with the rotation of Earth, this positive charge layer generates a geomagnetic fields whose geomagnetic north pole is located near the geographical north pole while the geomagnetic south pole is located near the geographical south pole, realizing geomagnetic reversal. As the sun moves with its planets in the Milky way, it is easy for the solar system to enter into a space surrounded by multiple layers of planets and lacking in fuel resources. In this case, the heat produced by the sun is greatly reduced, and the Earth enter into a bitterly cold glacial period, causing geomagnetic reversal.

## 6. The Magnetic Fields of Other Planets

According to the formation mechanism and variation law of geomagnetic field, the reason for the Earth has a magnetic field is as follows. The Earth has a thick atmosphere and many clouds attracted by the gravitational force of the Earth, and under the action of solar ultraviolet rays and cosmic rays, a large amount of positive ions and negative ions have been produced, forming the positive charge layer at the top of cloud and the negative charge layer at the bottom of the cloud; with the rotation of Earth and the consequent revolution of clouds, the two charge layers generate a superposition of geomagnetic fields.

So we can infer that only if a planet has a thick atmosphere and receives ultraviolet radiation and cosmic radiation can it have magneticfields. Since the moon and other general satellites lack dense atmosphere or clouds, and they rotate very slowly, they don't have magnetic fields. Since Mercury and Venus have only a thin atmosphere and rotate slowly, their magnetic fields are almost zero or very weak. While Earth, Mars, Jupiter and Saturn have dense atmospheres and clouds, and they can receive strong solar radiation, so they have magnetic fields. But Mars' atmosphere is thin, so its magnetic field is very week. If a planet's climate changes violently, its magnetic field may reverse its orientation.

Since Jupiter's surface temperature is-168°C, it's very cold there, Jupiter's thick clouds condense on the surface of Jupiter, making it impossible for the explorer to distinguish the surface of Jupiter. Just because of the bottom of Jupiter's clouds touch the ground, only the positive charge at the top of the clouds plays a major role in the formation of Jupiter's magnetic field, therefore the orientation of Jupiter's magnetic field is opposite to that of Earth's magnetic field.

## 7. Conclusions

Since some people have wrongly attributed the cause of the Earth's magnetic field to the result of the movement of the Earth's interior material, ignoring the movement of atmosphere and the change of winds and clouds, therefore the existing hypotheses about the origin of geomagnetic field are contradictory and unbelievable, unable to explain the inhomogeneity of the spatial distribution of geomagnetic field and the characteristic of constant change over time, including geomagnetic declination and geomagnetic reversal. Thus the author, starting from the formation and evolution of the Earth, has analyzed the formation and evolution of atmosphere and found that due to the action of solar ultraviolet rays and cosmic rays, cloud charge is formed, then with the rotation of Earth and the consequent revolution of clouds, geomagnetic fields is formed. The author's new theory about the formation and evolution of geomagnetic fields can well explain the inhomogeneity of the spatial distribution of geomagnetic field and the characteristic of constant change over time, including geomagnetic declination and geomagnetic reversal. Hence, it's a more scientific explanation.

## References

[1] Han Feng. On the Origin of Geomagnetic Field [J] (in Chinese). Journal of Hechi University. 2008, 28(2):26-30.

[2] Li An-sheng, JiaShuan-wen. The Extrapolation on the origin of geomagnetic field and the change of Curie temperature along with the intensity of pressure [J] (in Chinese). Progress In Geophysics, 2007, 22(2): 443-445.

[3] Wan Jiexian, Li Haojun. Calculation and formula deduction of geomagnetic declination and geomagnetic inclination [J] (in Chinese). Journal of Geodesy and Gedynamics, 2009, 29(3).

[4] Miyagoshi T. Hamano Y. Magnetic field variation caused by rotational speed change in magnetohydrodynamic dynamo [J]. Phys Rev Lett. 2013,111:124501.

[5] Pacca I G. Frigo E. Harmann G A. Possible relationship between the Earth's rotation variations and geomagnetic field reversals over the past 510 Myi [J]. Front Earth Sci. 2015,3:14.

[6] Sagnotti L, Scardia G, Giaccio B, et al. Extremely rapid directional change during Matuyama-Brunhes geomagnetic polarity reversal. Geophys J Int, 2014, 199:1110-1124.

[7] Li L G. What Causes Geomagnetic reversal? [J] (in Chinese). Chin Sci Bull. 2016, 61:1395-1400.

[8] J. M. Wallace, P. V. Hobbs. Atmospheric Science: An Introductory Survey, Academic Press, New York, 1977.

[9] Cui-Xiang Zhong. Revealing the Cause of Global Climate Change from the Formation and Evolution of Atmosphere [J]. International Journal of Geophysics and geochemistry, 2016, 3(1): 1-5. Published online, Mar. 2, 2016.

[10] Cui-Xiang Zhong. The Formation and Evolution of Galaxies and the Expansion of the Universe as Well as Dark Matter & Dark Energy [J]. AASCIT Journal of Physics, 2016, 2(3): 18-26. Published online, Mar. 2, 2016.