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Identification Cause of Earth's Magnetism

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ABSTRACT

Earth's magnetic field, called the geomagnetic field, is the magnetic field that extends from the earth's interior out into space. When the solar wind, a stream of charged particles emanating from the sun, interacts with the earth's magnetic field, most of them are trapped in the Van Allen radiation belt and protects the earth from the harmful charged particles and cosmic rays. The earth exhibits like a bar magnet in which the North geographic pole actually represents the South pole of the earth's magnetic field, and conversely the South geographic pole corresponds to the North pole of the earth's magnetic field. The scientists described the cause of the earth's magnetism that the magnetic field is generated by electric currents due to the motion of convection currents from a mixture of molten iron and nickel in the earth's outer core; these convection currents are caused by heat escaping from the core, a natural process called a geodynamo. The circulating ions that are highly conducting in the outer core of the earth result in the formation of the current loops. These current loops are the reason behind the formation of the magnetic field. Then paleomagnetism is developed to measure the magnetism in rocks that was induced by the earth's magnetic field. In this paper, cause of the earth's magnetism is enlightened in a new way. The existence of molten iron and nickel in the earth's outer core is incorrect; because of this high temperature evolving in the outer core of the earth, the materials in other layers also melt. Actually the cause of the earth's magnetism is the interaction of electric fields (electric current) induced by the solar wind (coronal discharge) and the movement of the earth including both rotations about its own axis and the sun as per Faraday and Lenz's laws of electromagnetic induction. For this cause, all other planets and the satellites (e.g., moon) in the solar system are having magnetic field which obstructs the maximum high energy particles from the sun (solar wind) to discharge on their surfaces.

KEYWORDS: *Earth's magnetic field; Solar wind; Van Allen radiation belt; Convection currents; Geodynamo; Paleomagnetism; Laws of electromagnetic induction*

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1. INTRODUCTION

Earth's magnetic field, also known as the geomagnetic field, is the magnetic field that extends from the earth's interior out into space, where it interacts with the solar wind, a stream of charged particles emanating from the sun. Thus the magnetosphere is the region above the ionosphere that is defined by the extent of the earth's magnetic field in space. It extends several tens of thousands of kilometres into space, protecting the earth from the charged particles of the solar wind and cosmic rays that would otherwise strip away the upper atmosphere, including the ozone layer that protects the earth from the harmful ultraviolet radiation.

Some of the charged particles from the solar wind are trapped in the Van Allen radiation belt. A smaller number of particles from the solar wind manage to travel, as though on an electromagnetic energy transmission line, to the earth's upper atmosphere and ionosphere in the auroral zones near north and south poles. The only time the solar wind is observable on the earth is when it is strong enough to produce phenomena such as the aurora and geomagnetic storms.

The solar wind exerts a pressure, and if it could reach earth's atmosphere it would erode it. However, it is kept away by the pressure of the earth's magnetic field. The magnetopause, the area where the pressures balance, is the boundary of the magnetosphere. Despite its name, the magnetosphere is asymmetric, with the sunward side being about 10 Earth radii out but the other side stretching out in a magnetotail that extends beyond 200 Earth radii [1]. Sunward of the magnetopause is the bow shock, the area where the solar wind slows abruptly [2].

Inside the magnetosphere is the plasmasphere, a donut-shaped region containing low-energy charged particles, or plasma. This region begins at a height of 60 km, extends up to 3 or 4 earth radii, and includes the ionosphere. This region rotates with the earth [1]. There are also two concentric tire-shaped regions, called the Van Allen radiation belts, with high-energy ions (energies from 0.1 to 10 million electron volts (MeV)). The inner belt is 1-2 earth radii out while the outer belt is at 4-7 earth radii. The plasmasphere and Van Allen belts have partial overlap [3], with the extent of overlap varying greatly with solar activity as shown in Fig. 1.

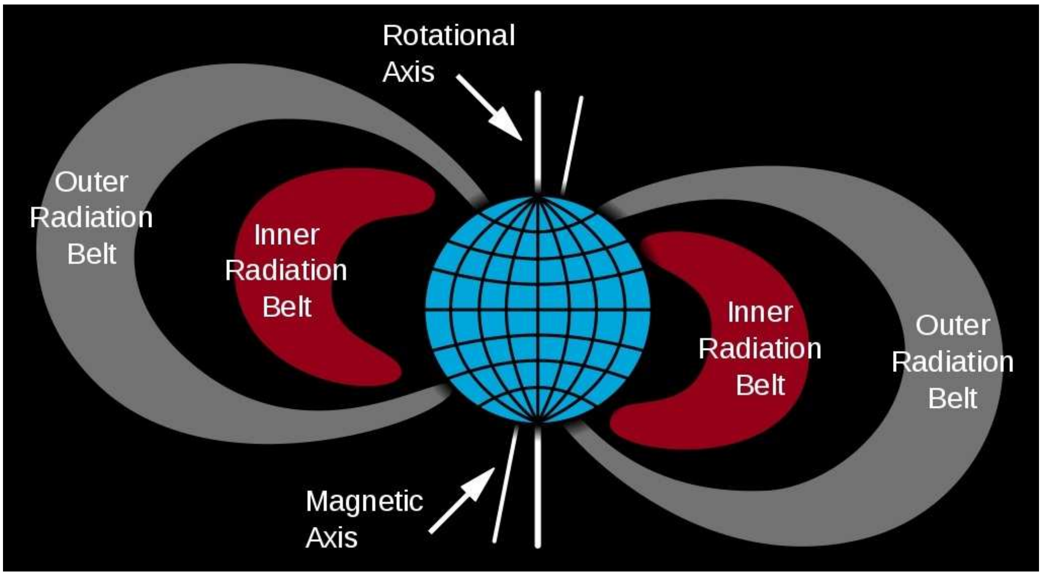

Fig 1 Solar wind (high energy charged particles) trapped in Van Allen Belts.

As well as deflecting the solar wind, the earth's magnetic field deflects cosmic rays, high-energy charged particles that are mostly from outside the solar system. Many cosmic rays are kept out of the solar system by the sun's magnetosphere, or heliosphere [4]. By contrast, astronauts on the moon risk exposure to radiation. Anyone who had been on the moon's surface during a particularly violent solar eruption in 2005 would have received a lethal dose [1].

When solar material streams strike earth's magnetosphere, it can become trapped and held in two donut-shaped belts around the planet called the Van Allen Belts as shown in Fig. 1. The belts restrain the particles to travel along earth's magnetic field lines, continually bouncing back and forth from pole to pole. The innermost belt begins about 400 miles from the surface of earth, which keeps its particle radiation a healthy distance from earth and its orbiting satellites.

In addition, positive ions slowly drift westward and negative ions drift eastward, giving rise to a ring current. This current reduces the magnetic field at the earth's surface [1]. Particles that penetrate the ionosphere and collide with the atoms there give rise to the lights of the aurorae and also emit X-rays [2].

The varying conditions in the magnetosphere, known as space weather, are largely driven by solar activity. If the solar wind is weak, the magnetosphere expands; while if it is strong, it compresses the magnetosphere and more of it gets in. Periods of particularly intense activity, called geomagnetic storms, can occur when a coronal mass ejection erupts above the sun and sends a shock wave through the solar system. Such a wave can take just two days to reach the earth. Geomagnetic storms can cause a lot of disruption; the "Halloween" storm of 2003 damaged more than a third of NASA's satellites. The largest documented storm occurred in 1859. It induced currents strong enough to short out telegraph lines, and aurorae were reported as far south as Hawaii [1][5].

2. Strength of the Earth's Magnetic Field

The scientists said that the magnetic field is generated by electric currents due to the motion of convection currents of a mixture of molten iron and nickel in the earth's outer core; these convection currents are caused by heat escaping from the core, a natural process called a geodynamo, The magnitude of the earth's magnetic field at its surface ranges from 25 to 65 μT (0.25 to 0.65 gauss) [3]. As an approximation, it is represented by a field of a magnetic dipole currently tilted at an angle of about 11 degrees with respect to earth's rotational axis [6], as if there were an enormous bar magnet placed at that angle through the center of the earth. The North geographic pole actually represents the South pole of the earth's magnetic field, and conversely the South geographic pole corresponds to the North pole of Earth's magnetic field (because opposite magnetic poles attract and the north end of a magnet, like a compass needle, points toward the earth's South magnetic field, i.e., the Geographic North Pole) [7],[8]. In 2005, the North geomagnetic pole was located on Ellesmere Island, Nunavut, Canada and the South geomagnetic pole was located near Vostak Station, Antarctica.

While the North and South magnetic poles are usually located near the geographic poles, they slowly and continuously move over geological time scales, but sufficiently slowly for ordinary compasses to remain useful for navigation. However, at irregular intervals averaging several hundred thousand years, the earth's field reverses and the North and South magnetic poles respectively, abruptly switch places. These reversals of the geomagnetic poles leave a record in rocks that are of value to paleomagnetists in calculating geomagnetic fields in the past. Such information in turn is helpful in studying the motions of continents and ocean floors in the process of plate tectonics.

Earth's magnetic field, predominantly dipolar at its surface, is distorted further out by the solar wind. This is a stream of charged particles leaving the sun's corona and accelerating to a speed of 200 to 1000 kilometres per second. They carry with them a magnetic field, the interplanetary magnetic field (IMF) [1].

The strength of the magnetic field at the earth's surface ranges from less than 30 microteslas (0.3 gauss) in an area including most of South America and South Africa to over 60 microteslas (0.6 gauss) around the magnetic poles in northern Canada and south of Australia, and in part of Siberia. The average magnetic field strength in the earth's outer core was measured to be 25 Gauss, 50 times stronger than the magnetic field at the surface.

3. Cause of Earth's Magnetism Explaining by Bar Magnet with NASA Report

The field is similar to that of a bar magnet. The earth's magnetic field is mostly caused by electric currents in the liquid outer core. The earth's outer core is hotter than 1043 K (3000 – 4500 K), the Curie point temperature above which the orientations of spins within iron become randomized. Such randomization causes the substance to lose its magnetization.

Convection of molten iron within the outer liquid core, along with a Coriolis effect caused by the overall planetary rotation, tends to organize these "electric currents" in rolls aligned along the north-south polar axis. When conducting fluid flows across an existing magnetic field, electric currents are induced, which in turn create another magnetic field. When this magnetic field reinforces the original magnetic field, a dynamo is created that sustains itself. This is called the Dynamo Theory and it explains how the earth's magnetic field is sustained.

Earth's magnetic field acts like a protective shield around the planet, repelling and trapping charged particles from the sun. But over South America and the southern Atlantic Ocean, an unusually weak spot in the field – called the South Atlantic Anomaly, or SAA – allows these particles to dip closer to the surface than normal. Particle radiation in this region can knock out onboard computers and interfere with the data collection of satellites that pass through it – a key reason why NASA scientists want to track and study the anomaly [9].

The South Atlantic Anomaly is also of interest to NASA's Earth scientists who monitor the changes in magnetic field strength there, both for how such changes affect earth's atmosphere and as an indicator of what's happening to earth's magnetic fields, deep inside the globe.

Currently, the SAA creates no visible impacts on daily life on the surface. However, recent observations and forecasts show that the region is expanding westward and continuing to weaken in intensity. It is also splitting – recent data shows the anomaly's valley, or region of minimum field strength, has split into two lobes, creating additional challenges for satellite missions.

A host of NASA scientists in geomagnetic, geophysics, and heliophysics research groups observe and model the SAA, to monitor and predict future changes – and help prepare for future challenges to satellites and humans in space.

The South Atlantic Anomaly arises from two features of earth's core: The tilt of its magnetic axis, and the flow of molten metals within its outer core.

4. Speed of the Earth for Earth's Rotation around its Own Axis and the Sun

Earth's rotation or earth's spin is the rotation of planet earth around its own axis, as well as changes in the orientation of the rotation axis in space. Earth rotates east to west ward, in prograde motion. As viewed from the north pole star Polaris, earth turns counter clockwise. From a vantage point above the north pole of either the sun or earth, earth would appear to revolve in a counter clockwise direction around the sun. From the same vantage point, both the earth and the sun would appear to rotate also in a counter clockwise direction about their respective axes.

The movement of the earth's surface is considered with respect to the planet's center. The earth rotates once every 23 hours, 56 minutes and 4.09053 seconds, called the sidereal period, and its circumference is roughly 40,075 kilometers. Thus, the surface of the earth at the equator moves at a speed of 460 meters per second or roughly 1,000 miles per hour or 1609 km/h. Again the earth is moving about the sun in a very nearly circular orbit (actually the orbit is an ellipse). The distance from earth to the sun - called an astronomical unit - is 92,955,807 miles (149,597,870 kilometers), according to the International Astronomers Union. That is the radius (r). The circumference of a circle is equal to $2 \times \pi \times r$. So in one year, Earth travels about 584 million miles (940 million km).

Since speed is equal to the distance traveled over the time taken, Earth's speed is calculated by dividing 584 million miles (940 million km) by 365.25 days and dividing that result by 24 hours to get miles per hour or km per hour. So, Earth travels about 1.6 million miles (2.6 million km) a day, or 66,627 mph (107,226 km/h).

It covers this route at a speed of nearly 30 kilometers per second, or 67,000 miles per hour. In addition, our solar system - earth and all - whirls around the center of our galaxy at some 220 kilometers per second, or 4,90,000 miles per hour.

There would be some other weird effects if the earth stopped spinning completely, NASA said - For one, the magnetic field would presumably disappear because it is thought to be generated in part by a spin. We'd lose our colorful auroras, and the Van Allen radiation belts surrounding earth would probably disappear, too. Then earth would be naked against the fury of the sun. Every time charged particles toward earth will hit the surface and bathe everything in radiation.

5. Identification the Cause of Earth's Magnetism

In the above discussion it is clear that the earth is subjected under two revolutions, one around its axis at a speed of 1,000 miles/hour or 1609 km/h and the other around the sun at a speed of 66,627 mph or 107,226 km/h, and both the motion of the earth is counterclockwise or anticlockwise as seen from the geographical North pole or Polaris. Earlier the dynamo theory describes the process through which a rotating, convecting and electrically conducting fluid can maintain a magnetic field over astronomical time scales.

According to Michael Faraday's laws of electromagnetic induction, a voltage (e.m.f.) is produced when a magnet moves in a coil of wire or a conductor rotates in a magnetic field, and vice versa. Thus it signifies that any one form of energy can be obtained from interaction of other two forms of energy, i.e., electrical energy (voltage or current in closed circuit) is obtained from the interaction of (by cutting magnetic lines of forces, i.e., rate of change of magnetic flux) mechanical energy (rotating or moving) and magnetic energy in case of generator; and mechanical energy (in case of motor) is obtained from the interaction of electrical energy and magnetic energy. However, magnetic energy (magnetic lines of forces) can be created by the interaction of electrical energy (voltage or current) and mechanical energy (movement) [10].

Since the earth spins around its axis at a speed 1609 km/h and moves around the sun at a speed 107,226 km/h both in counterclockwise direction as seen from the geographic North pole, the solar winds emitted from the sun composed of charged particles and cosmic radiation exerts an electric field (current or voltage) on the earth, by the interaction of these mechanical and electrical fields, a magnetic field will be evolved according to Faraday and Lenz's electromagnetic induction laws. The strength of the magnetic field depends on the intensity of the solar winds (i.e., distance of the earth or planet from the sun) and the earth's (planet's and satellite's) mass and radius (i.e., area of exposure the solar wind), direction of rotations (e.g., prograde or retrograde) and other factors etc. The comparison of different parameters like mass, radius with magnetic field existing above the surface of different planets and moon in the solar system with that of the earth is shown in Table I. It is observed that all planets and moon of the solar system are having magnetic field (magnetosphere) which obstructs the solar wind (charged particles) at most and maintain their environment.

TABLE I. PARAMETERS OF DIFFERENT PLANETS AND MOON IN THE SOLAR SYSTEM

Name of the Planet/Satellite according to distance from the Sun	Mass	Equatorial Radius	Planet Mass/Earth Mass	Planet Radius/ Earth Radius	Planet's Magnetism compare with respect to Earth's Magnetism
1. Mercury	3.30×10^{23} kg	2,439 km	0.0553	0.383	Exist & Weak
2. Venus	4.8673×10^{24} kg	6052 km	0.815	0.949	Exist
3. Earth	6.0×10^{24} kg	6400 km	1	1	Exist
3A. Moon (Satellite)	0.07346×10^{24} kg	1738 km	0.0123	0.2725	Exist & Weak
4. Mars	6.416×10^{23} kg	3396 km	0.107	0.532	Exist
5. Jupiter	$1{,}898 \times 10^{24}$ kg	71,492 km	317.83	11.209	Exist & Strong
6. Saturn	5.6865×10^{26} kg	6.0268×10^{4} km	95	9.4	Exist
7. Uranus	86.811×10^{24} kg	25,559 km	14.54	4.007	Exist
8. Neptune	102.409×10^{24} kg	24,764 km	17.15	3.883	Exist

6. Conclusion

The outer core temperature of the earth is not high at all, because when pressure is falling in connected layers or surfaces, the pressure is distributed and remains same throughout all layers of the earth, hence the temperature will not increase in the connected regions or layers. For example, the ground surface layer of the Himalayas or Alps or other mountain regions is having the same temperature, therefore the concept of high temperature (i.e., 3000 – 4500 K) existing in the outer core of the earth composed of molten iron and nickel lying above the earth's solid inner core is totally incorrect. The outer core of the earth remains at normal temperature with natural solid materials. Moreover, if the outer core of the earth contains liquid materials mostly iron and nickel at very high temperature (upto 4500 K), then surrounding materials in other layers and the inner core also melt, that is not happening at all. Also, all planets and satellites in the solar system may not be composed of liquid materials at very high temperature inside their core.

According to Faraday and Lenz's laws of electromagnetic induction, the earth's body acts as a conductor for flowing currents by the solar wind, i.e., the some parts of the charged particles and photon (from the sun rays) are continuously grounded causing current flow, and the interaction of this electric current to the earth's motion (both rotation about its own axis and the sun) develops the earth's magnetic field. This electric current is more (in magnitude) in the earth's interior body and also the speed of rotation of different layers is decreasing as we approach inward of the earth's core; as a result the intensity of the magnetic field is having more magnitude in the earth's interior layers. This earth's magnetic field varies in different places and spaces depending on so many parameters like day or night (timing period), latitude, longitude, mass, radius, direction of rotation about axis and the sun etc. Likewise, all planets and satellites (e.g., moon etc.) in the solar system possess their own magnetic field above their surfaces due to the interaction of solar wind discharging electric currents and their different types of motions. Hence, stability is achieved for controlling the solar wind and cosmic ray discharging to the surface of the planets and the moon by their established magnetic fields.

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