Possible Source of The Earth's Geomagnetic Field

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The earth's geomagnetic field provides a safe environment for the earth's biology against solar wind. However, revealing source of geomagnetic field is very challenging and it has puzzled people for several hundred years. Here, based on the previously proposed Yuheng Zhang effect, I show a simple theory to account for generation of geomagnetic field. This theory only has two requisites, one is metallic core, the other is self-rotation of the earth. Based on this theory, several interesting points are concluded: 1) negative charges accumulate at a metallic thin layer (MTL) at core-mantle boundaries (CMB) and positive charges distribute within the earth's core; 2) rotation of the separated charges would yield geomagnetic field and gives field strength for the Earth, Ganymede and Mercury, which are in agreement with measurement values; 3) misalignment of MTL rotation axis with the earth's rotation axis causes geomagnetic declination and a quadrupole field; 4) for a planet, a solid metallic core will generate a geomagnetic field without magnetic declination and geomagnetic reversal, and geomagnetic declination suggests a liquid metallic core; 5) dynamic evolution processes of MTL dominate long-term geomagnetic variations and reversals, e.g., a slower MTL rotation causing a geomagnetic reversal and recovery of MTL rotation eliminating geomagnetic reversal; 6) at center of the earth's inner core, the geomagnetic field would show a reversal at a critical radius, and geomagnetic fields

point from the earth's south pole to north pole; 7) the earth's geomagnetic pole and some quadrupoles would exhibit the same angular velocity of westward drift; 8) even if geomagnetic dipole vanished, quadrupole fields would continue to sustain and protect biology from harmful ultraviolet radiation and the solar wind; 9) absence of internal magnetic field for the Venus, Moon and Mars implies non-existence of metallic core in these planets and moons. In all, this theory provide people a new sight to understand the source of the earth's geomagnetic field.

The Earth's geomagnetic field is a natural safeguard, and it protects biology from harmful ultraviolet radiation and most of the solar wind. It has been utilized for several thousand years and many pioneers have tried to unravel source of geomagnetic field since maturation of electromagnetics, especially foundation of Maxwell Equations. But most people and most proposed theories failed to reveal the source of geomagnetic field. Up to now, only the famous dynamo theory becomes the most prominent and potential candidate [1]. However, the dynamo is very complex and has many requisites. Is nature really so complex? Is there a much more simple theory for geomagnetic field?

To tackle this so long-standing problem, in this work, a simple theory based on Yuheng Zhang effect [2] was put forward.

Let us first consider magnetic field induced by charge separation across shock wave front in metals. Based on Yuheng Zhang effect, as shown in Figure 1, negative charges accumulate in front of shock waves and positive charges accumulate at back of shock waves [2]. And they move with the same velocity as shock waves. According to Maxwell Equations, moving charges yield magnetic field, therefore a magnetic field is expected to exist around the shock wave front. Assuming shock wave front width is $2d$ and electric field E across the shock wave front is uniform. The problem lies in how one can estimate the transferred charges at the front and back surfaces of shock wave front. According to Maxwell Equations, the transferred charge density $\rho(\vec{r})$ is

$$\nabla \cdot \varepsilon_0 \varepsilon(r) \vec{E}(\vec{r}) = \rho(\vec{r}) \tag{1}$$

where ε_0 denotes vacuum dielectric parameter and $\varepsilon(r)$ is relative dielectric function, and $\vec{E}(\vec{r})$ is the electric field within shock wave front in metals. Here the key is how to obtain the relative dielectric function $\varepsilon(r)$.

For metals, Tomas-Fermi screening potential function gives $\varepsilon(r) = \exp(r/r_s)$, where the screening length is $r_s^2 = \frac{a_0}{4(3/\pi)^{1/3} n^{1/3}(r)}$ [3], $n(r)$ is conduction electron density (CED). In the other respect, the definition of electric polarization vector is $\vec{P} = n(r) q \vec{l}$ [4], where $\vec{l}$ is dipole vector. Electric polarization vector can also be given by $\vec{P} = \varepsilon_0 [\exp(l/r_s) - 1] \vec{E}(\vec{r})$ [4]. It is reasonable, because when the separation distance between negative and positive charge is l, the related relative dielectric function is $\exp(l/r_s)$. This is the key point in the following calculations.

$$\varepsilon_0 [\exp(l/r_s) - 1] E(\vec{r}) = n(r) q l \qquad (2)$$

Through analysis, the following approximation might be acceptable,

$$\varepsilon_0 exp(l/r_s) E(\vec{r}) \approx n(r) q l = C = constant \qquad (3)$$

Assume the shock wave front zone in a cylindrical metal of radius r_0 to be from $-d$ to d, and $r_0 >> d$. The charge distribution is $\rho(\vec{r}) = C\delta(z-d) - C\delta(z+d)$. Therefore, magnetic field produced by moving charges is [4]

$$\vec{B}(\vec{R}) = \frac{\mu_0 v}{4\pi} \int \frac{\rho(\vec{r})}{\left|\vec{R} - \vec{r}\right|^3} \hat{\vec{z}} \times \left(\vec{R} - \vec{r}\right) dV \qquad (4)$$

where v is shock wave velocity, μ_0 is magnetic susceptibility, $\vec{B}(\vec{R})$ is position $\vec{R}$ dependence of magnetic field and $\vec{R} = (R, 0, Z)$, $\vec{r} = (r\cos\theta, r\sin\theta, z)$,

$$B_y(\vec{R}) \approx \frac{\mu_0 v}{4\pi} \int \frac{6CZz_0 (R - r\cos\theta)}{\left[r^2 + R^2 + Z^2 - 2Rr\cos\theta\right]^{5/2}} dV$$

For simplicity, let $\vec{R} = (\Delta + r_0, 0, Z)$ and $\Delta << r_0$, $Z < r_0$,

$$B_y\left(\vec{R}\right) \approx \frac{30\mu_0 vCdZ}{r_0^2} \tag{5}$$

$B_y \approx 1\sim100$ Gauss, which needs to be confirmed by experiments further.

In the following parts, source of the Earth's magnetic field, which has been a long-standing problem over several hundred years, will be touched carefully. For the earth's iron core, spherically symmetrical strains are produced by gravity. And Yuheng Zhang effect exists along radius of the Earth's iron core and forms an interesting charge distribution, i.e., negative charges at a metallic thin layer (MTL) at core-mantle boundaries (CMB) and positive charges in the inside. In this situation, when the Earth's core rotates spontaneously, a geomagnetic field along the rotation axis is naturally generated.

According to Yuheng Zhang effect, the electric field along the radius follows [2],

$$\nabla E_F\left(\vec{r}\right) = q\vec{E}\left(\vec{r}\right) \tag{6}$$

where $E_F\left(r\right)$ is the radius r dependence of Fermi energy, q is electron charge, $\vec{E}\left(\vec{r}\right)$ is electric field as schematically shown in Figure 2(a). So, negative charges accumulate at MTL whereas positive charges accumulate within earth's core. Simultaneously, the earth should be neutral, otherwise it would attract charged particles from outer space to reach neutrality. Using the same analysis and approximation as described by Equation (2) and (3), the charge distribution in spherical coordinates $\left(r,\theta,\varphi\right)$ is

$$\rho_1(r) = -2C/r + C\delta(r - r_0) \tag{7}$$

where r_0 is radius of the earth's outer core. Based on theories and experiments on metal liquid, CED does not obviously alter when a metal is subject to the solid-liquid phase transition [5, 6, 7]. So CED is believed to be continuous across the boundaries between

Earth's inner core and outer core. The current density resulting from net charge rotation is given by

$$\vec{J}_1 = \frac{\rho_1(r) 2\pi r \sin\theta}{T} \tag{8}$$

where T is self-rotation period and equals 24 hours for the earth, r is the distance from center of the earth's core. The produced magnetic field at position $\vec{R}$ follows [4]

$$\vec{B}_1(\vec{R}) = \frac{\mu_0 C}{2T} \int \frac{\rho_1(r)}{\left|\vec{R} - \vec{r}\right|^3} \hat{\vec{\ell}} \times (\vec{R} - \vec{r}) r^3 \sin^2\theta \, dr \, d\theta \, d\varphi \tag{9}$$

where $\hat{\vec{l}} = (-sin\varphi, cos\varphi, 0)$ is the rotation unit vector at the position r, $\vec{R} = (Rsin\psi \, cos\varphi', Rsin\psi \, sin\varphi', Rcos\psi)$ and $\vec{r} = (r\sin\theta\cos\varphi, r\sin\theta\sin\varphi, r\cos\theta)$

For simplicity, take φ'=0, magnetic field outside the earth's core is

$$B_{1x} = \pi \frac{\mu_0 C}{2T} \frac{r_0^4}{R^3} sin2\psi \quad (R > r_0) \tag{10}$$

$$B_{1z} = \frac{\pi}{3} \frac{\mu_0 C}{2T} \frac{r_0^4}{R^3} (1 + 3cos\,2\psi) \quad (R > r_0) \tag{11}$$

Radius of Earth's outer core is $r_0 \approx 3.4 \times 10^6$ *m* [8] and $R \approx 6.4 \times 10^6$ *m* [9]. The CED is taken to be one tenth that of iron at the same density, i.e., $n(r) \approx 2 \times 10^{22} / cm^3$. It may be reasonable, because electric conductivity of the earth's core is only several percent of pure iron at room conditions, and this fact suggest the much lower CED than pure iron. On the other hand, this is also in agreement with the chemical composition of Earth's core, i.e., presence of light elements such as sulfur and oxygen would reduce the CED obviously. Thus the estimated screening length is $r_s \approx 0.7$ *Å* and the constant $C \approx -10$ *Coulomb/m*^{2}. Substitute these parameters into Equation (10) and (11), one may obtain B= 0.77 *Gauss* at the equator and B=1.53 *Gauss* at the poles. These values are in accord with geomagnetic filed 0.5 *Gauss* at equator and 0.65 *Gauss* at poles [10].

Let us investigate and estimate the geomagnetic fields for other terrestrial planets and moons such as Ganymede, Mercury and so on. In the following estimations, the same constant *C* as earth's core is utilized, meaning the same CED. Likewise, using Equations (10) and (11) and substitute parameters into them, magnetic fields at equators are estimated and shown in Table 1. As shown in the last two columns, theoretical results can be totally comparable to measurement results. Wherein, remarkably, the calculated magnetic field for Ganymede is in good agreement with measured value, suggesting power and applicability of this simple model. For Mercury, theoretical value is a little larger than the measured field value, implying a little lower CED than Earth's core or a bit smaller metallic core.

Table 1. Parameters of terrestrial planets, moons and estimated magnetic field at their equator based on Equation (10) and (11).

Planets	Mean radius (10^3 *km*)	Metallic core radius (10^3 *km*)	Sidereal rotation period	Calculated internal field at equator (*Gauss*)	Intrinsic field at equator (*Gauss*)
Earth	6.4 [9]	3.4 [8]	1 *d*	0.77	0.5 [10]
Ganymede	2.6 [1]	0.8 [1]	7 *d* 3 *h* [11]	0.005	0.0072 [12]
Mercury	2.44 [13,14]	1.8 [15]	58.6 *d* [13]	0.019	0.003 [16,17]
Titan	2.58 [1]	None [18]	16 *d* [1]	None	None [1]
Callisto	2.4 [19]	None [1,19]	16.7 *d* [19]	None	None [1]

Table 2. Various parameters of terrestrial planets, moons and estimated magnetic field at their equator based on Equation (10) and (11).

Planets	Mean radius (10^3 *km*)	Radius of core (10^3 *km*)	Sidereal rotation period	Calculated internal field at equator (*Gauss*)	Intrinsic field at equator (*Gauss*)
Moon	1.7 [1]	0.24 [1]	27.3 *d* [1]	4×10^{-5}	None [1]
Mars	3.4 [1]	1.8 [1]	24.7 *h* [1]	0.4	None [1]
Venus	6 [12]	unknown	243 *d* [1]	unknown	$<10^{-4}$ [1]

Furthermore, let us address other terrestrial planets and moons, such as Moon, Mars and Venus. Their various parameters, calculated and measured magnetic fields are shown in Table 2. For Moon, existence of metallic core is inconclusive [1]. If a metallic core of radius 240 *km* indeed exists, an internal magnetic field will appear and its strength may reach 4 *nT*, however, measurements suggest no internal field. This contrary infers much lower CED or absence of metallic core in Moon. By comparison with Mars and Venus, the situations might be similar, i.e, absence of metallic core in these planets.

In the previous parts, magnetic field outside terrestrial metallic core is discussed, here geomagnetic field within Earth's core is touched and given by

$$B_{1x} = -\pi\frac{\mu_0 Cr}{2T} sin2\psi \ \left(r < r_0\right) \tag{12}$$

$$B_{1z} = -\frac{\mu_0 C}{2T}\frac{8\pi}{3}r_0 + \frac{\mu_0 C}{2T}\pi r\left(5 - \cos 2\psi\right) \ \left(r < r_0\right) \tag{13}$$

On contrary to the conventional belief that magnetic field in Earth's core points to Earth's south pole, surprisingly, as described by Equation (13), the field at the center of Earth's core points from south pole to north pole. And the magnitude may be ~20 *Gauss*. The magnetic field near CMB may reach ~25 *Gauss* which is in agreement with previously reported value [20]. Of noted is reversal of magnetic field at a critical radius r_c in Earth's core, i.e., magnetic field points to Earth's north pole for $r<r_c$ whereas points to south pole for $r> r_c$. According to Equation (13) the critical radius r_c is

$$r_C=\frac{8r_0}{3(5-\cos 2\psi)} \tag{14}$$

Alternatively, as given by Equation (12), the transverse field B_{1x} does not present radius dependence of field reversal.

Now let us turn to the case that the rotation angular velocity of MTL at CMB is distinct from the earth's angular velocity. The geomagnetic field outside Earth's core is

$$B_{1x}=\pi\frac{\mu_0 C}{2}(2/T'-1/T)\frac{r_0^4}{R^3}\sin 2\psi \quad (R>r_0) \tag{15}$$

$$B_{1z}=\frac{\pi}{3}\frac{\mu_0 C}{2}(2/T'-1/T)\frac{r_0^4}{R^3}(1+3\cos 2\psi) \quad (R>r_0) \tag{16}$$

where T' denotes self-rotation period of the MTL at CMB, T is regarded as self-rotation period of both earth's inner core and outer core and the difference between them is neglected for simplicity. As described by Equation (15) and (16), to one's surprise, once the rotation period of MTL increases to $2T$, i.e., the angular velocity is smaller than half of Earth's angular velocity, the magnetic field will present a reversal outside Earth's core. It may be possible, because large-scale convection is believed to happen in Earth's outer core and once large volume of metallic liquid from inner core-outer core boundaries arrived at CMB the angular velocity would decrease considerably due to conservation of angular momentum and Coriolis force. Simultaneously, viscous force among MTL, mantle and Earth's core may restore angular velocity of MTL, which tends to eliminate geomagnetic reversal. Thereby, the dynamic evolution processes of MTL determine long-term geomagnetic variations and reversals. It may be the physical mechanism for the famous geomagnetic reversal in history. On the other hand, if rotation axis of MTL at CMB misaligns with the earth's rotation axis, a geomagnetic declination and a quadrupole field would be expected to appear, which may be the source of geomagnetic declination. Distinct from the famous dynamo for source of geomagnetic field, if Earth's outer core was cooled and solidified to a total solid core, the geomagnetic field would still persist but geomagnetic reversal and geomagnetic declination would vanish. Further, it is implied that existence of geomagnetic field for a planet suggests a metallic core, and existence of geomagnetic declination and geomagnetic reversal suggest a liquid metallic core.

Magnetic field within Earth's core follows,

$$B_{1x} = -\pi \frac{\mu_0 C}{2T} r\, sin2\psi \;\left(r < r_0\right) \tag{17}$$

$$B_{1z} = \frac{\mu_0 C}{2}\frac{8\pi}{3}\left[\left(2r - 2r_0\right)/T + r_0/T'\right] - \frac{\mu_0 C}{2T}\frac{\pi r}{3}\left(1 + 3\cos 2\psi\right) \;\left(r < r_0\right) \tag{18}$$

Owing to the angular velocity difference between MTL and Earth's core, Hall effect appears and causes an electric field perpendicular to the earth's rotation axis as shown in Figure 2(b), resulting in charge redistribution further,

$$\nabla\; E_F\left(\vec{r}\right) + q\vec{v}_r\left(\vec{r}\right) \times \vec{B}(\vec{r}) = q\vec{E}(\vec{r}) \tag{19}$$

$$\rho_2(r) = -2C'/r_0 + C' \sin^2\theta\,\delta(r - r_0) \tag{20}$$

$$C' = \varepsilon_0 \varepsilon_r 2\pi r_0 (\frac{1}{T} - \frac{1}{T'}) \frac{\mu_0 C}{2} \frac{8\pi}{3} \frac{r_0}{T'} \tag{21}$$

where r_0 is radius of the earth's outer core, $v_r(r)$ is relative rotation velocity. The current density resulting from net charge rotation is given by $j_2(r) = \left(\frac{-2C'}{Tr_0} + \frac{C' \sin^2\theta}{T'} \right) 2\pi r \sin\theta$, where T is 24 hours, r is distance from the center of Earth's core. The magnetic field at position $\vec{R}$ follows $\vec{B}_2(\vec{R}) = \frac{\mu_0}{4\pi} \int \frac{j_2(r)}{|\vec{R} - \vec{r}|^3} \hat{\vec{\ell}} \times (\vec{R} - \vec{r}) r^3 \sin^2\theta\, dr d\theta d\varphi$, where $\hat{\vec{l}} = (-\sin\varphi, \cos\varphi, 0)$ is the rotation unit vector at the position r.

For simplicity, the generated fields outside and within Earth's core are obtained,

$$B_{2x} = \mu_0 C' \frac{2\pi}{5} (\frac{2}{T'} - \frac{1}{T}) \frac{r_0^4}{R^3} \sin 2\psi - \mu_0 C' \frac{\pi}{14T'} \frac{r_0^6}{R^5} (1 + 7\cos 2\psi) \sin 2\psi \quad (R > r_0) \tag{22}$$

$$B_{2z} = \mu_0 C' \frac{2\pi}{15} (\frac{2}{T'} - \frac{1}{T}) \frac{r_0^4}{R^3} (1 + 3\cos 2\psi) - \mu_0 C' \frac{\pi}{140T'} \frac{r_0^6}{R^5} (9 + 20\cos 2\psi + 35\cos 4\psi) \quad (R > r_0) \tag{23}$$

$$B_{2x} = -\mu_0 C' (\frac{2\pi}{5T} - \frac{8\pi}{35T'}) \frac{r^2}{r_0} \sin 2\psi \quad (r < r_0) \tag{24}$$

$$B_{2z} = -\mu_0 C' \frac{4\pi}{3T} (r_0 - \frac{r^2}{r_0}) - \mu_0 C' \frac{2\pi}{15T} \frac{r^2}{r_0} (1 + 3\cos 2\psi) + \frac{\mu_0 C'}{T'} [\frac{16\pi}{15} r_0 - \frac{4\pi}{35} \frac{r^2}{r_0} (1 + 3\cos 2\psi)] \quad (r < r_0) \tag{25}$$

Now let us calculate the third electric field E_3 which is parallel to Earth's rotation axis shown in Figure 2(c), and the induced charge distribution is

$$\vec{E}_3 = 2\pi \sin\theta (\frac{1}{T} - \frac{1}{T'}) \mu_0 C' \frac{8\pi}{35T'} \frac{r^3}{r_0} \hat{\vec{z}} \sin 2\theta \quad (r < r_0) \tag{26}$$

$$C'' = \varepsilon_0\varepsilon_r\pi(\frac{1}{T}-\frac{1}{T'})\mu_0 C'\frac{8\pi}{35T'}r_0^2 \quad (r<r_0) \tag{27}$$

$$\rho_3(r) = -\frac{C''}{5}sin^2 2\theta\delta(r-r_0) + C''\frac{r^2}{r_0^3}sin^2 2\theta \quad (r<r_0) \tag{28}$$

where $\rho_3(r)$ is the third electric field-induced charge distribution in the earth's core. And the caused fields are

$$B_{3x} \approx \frac{\mu_0 C''}{2}\frac{32\pi}{35}(\frac{1}{7T}-\frac{1}{5T'})\frac{r_0^4}{R^3}sin\,2\psi + \frac{\mu_0 C''}{2}[\frac{4\pi}{21}(\frac{1}{9T}-\frac{1}{5T'})\frac{r_0^6}{R^5}sin\,2\psi + \frac{4\pi}{3}(\frac{1}{9T}-\frac{1}{5T'})sin\,2\psi\,cos\,2\psi]\frac{r_0^6}{R^5} \quad (R>r_0) \tag{29}$$

$$B_{3z} \approx \frac{\mu_0 C''}{2}\frac{32\pi}{105}(\frac{1}{7T}-\frac{1}{5T'})\frac{r_0^4}{R^3}(1+3cos\,2\psi) + \frac{\mu_0 C''}{2}[\frac{2\pi}{3T}(\frac{1}{35}+\frac{4}{63}cos\,2\psi+\frac{1}{9}cos\,4\psi) - \frac{2\pi}{T'}(\frac{3}{175}+\frac{4}{105}cos\,2\psi+\frac{1}{15}cos\,4\psi)]\frac{r_0^6}{R^5} \quad (R>r_0) \tag{30}$$

Of emphasized is that magnetic field generated by the third electric field would reversely affect the second field which alters the third electric field, eventually electromagnetic equilibrium would be reached within Earth's core. In the above analysis, only the first-order approximation is offered and this approximation might be good for qualitatively understanding the source of geomagnetic field. The total field may be the summation of three components, $B_x = B_{1x} + B_{2x} + B_{3x}$ and $B_z = B_{1z} + B_{2z} + B_{3z}$. Seen from Equation (15), (16), (22), (23), (29) and (30), even if the main dipole field vanished, quadrupole fields would still maintain and continue to protect biology on the earth. Also concluded is that if MTL rotates slower than Earth's core, geomagnetic dipole and some quadrupoles will exhibit westward drift concurrently with the same angular velocity, which may be internal reasons for westward drift of non-dipole geomagnetic field.

Let us compare the famous dynamo with theory in this work. For dynamo, four requites must be satisfied, 1) metallic fluid surrounding a solid inner core [1]; 2) planetary rotation-induced kinetic energy and vigor of fluid motion must exceed its magnetic Reynolds number which approximates 20-50 for Earth [1]; 3) a very huge internal power source to drive convections within the metallic fluid core; 4) an initial seeded magnetic field. For theory in this work, only two conditions should be required, i.e., planetary rotation and existence of metallic core regardless of its liquid state, solid state and mixture of them. And it is much more simple and does not need great power source to maintain geomagnetic field.

At last, this theoretical model for source of geomagnetic field is commented. This theory provides a simple picture for source of geomagnetic field and successfully draws geomagnetic field for the earth, some planets and moons. However, due to roughness of approximation, i.e., Equation (2) and (3), and lacking in vital parameters of earth's core, this theory can only give a rough picture, and more precise descriptions and explanations for source of geomagnetic field of Earth, other planets and moons should be refined further according to more accurate parameters. For example, accurate charge distribution within Earth's core and the more precise dynamic evolution processes of MTL under several actions such as Coriolis force, viscous force and so on. This theoretical model only gives the key point that under rotation, the separated and accumulated charges at MTL and in the earth's core respectivley is large enough to generate present geomagnetic field. The remnant important problem is how one can prove this theory. A possible method may be to measure estimated magnetic field strength (see Equation (5)) around a metal plate under shock loading, described at beginning of this paper, which may prove this theory right nor not.

In summary, a simple theory built upon charge separation within the earth's core according to Yuheng Zhang effect is proposed for source of geomagnetic field in this work. This theory requires a metallic core and self-rotation for generation of geomagnetic field. By means of analysis, several interesting conclusions are obtained: 1) negative charges accumulate at a MTL at CMB and positive charges distribute within the earth's core; 2) rotation of the separated charges would yield geomagnetic field and gives its strength 0.77 *Gauss* for Earth, 500 *nT* for Ganymede and 1900 *nT* for Mercury at their equators, which are in agreement with measurement values; 3) misalignment of MTL rotation axis with the earth's rotation axis causes geomagnetic declination; 4) geomagnetic declination suggests a liquid metallic core for a planet and a solid metallic core will generate a geomagnetic field without magnetic declination and geomagnetic reversal; 5) geomagnetic reversal could happen because of smaller rotation angular velocity of MTL at CMB than the earth's core; 6) at center of the earth's inner core, geomagnetic fields point from the earth's south pole to earth's north pole and the geomagnetic field would show a reversal at a critical radius; 7) geomagnetic pole and some quadrupoles would exhibit westward drift with the same angular velocity; 8) even if the main geomagnetic dipole field disappeared, quadrupole fields would still persist and continue to protect biology on the earth; 9) absence of internal magnetic field for the Venus, Moon and Mars implies non-existence of metallic core in these planets and moons. In all, this theory paves a new way for people to understand geomagnetic field and it may be verified by measuring magnetic field around a metal under loading.

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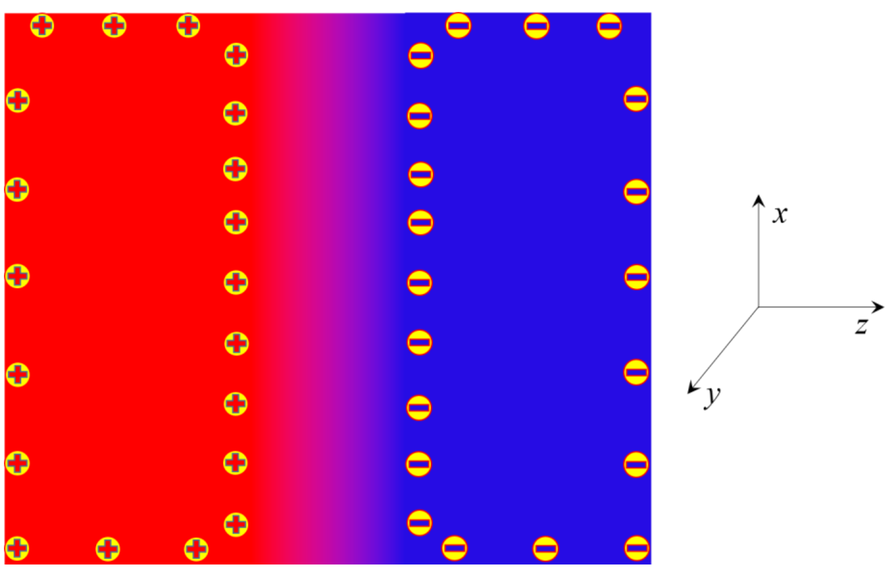

Figure 1. Schematic diagram of Yuheng Zhang effect. The red area denotes compressed metal region while the blue area is the uncompressed metal region. The yellow circled with “+” and “-” signs denote the accumulated positive charge and negative electrons, respectively. For the red region under compression, the free electron density increases and thus Fermi energy rises, so the conduction electrons diffuse into the blue region. As a result, net positive charges are left in the compressed region whereas net negative charges exist in the uncompressed region, causing an electric voltage between the two metal regions.

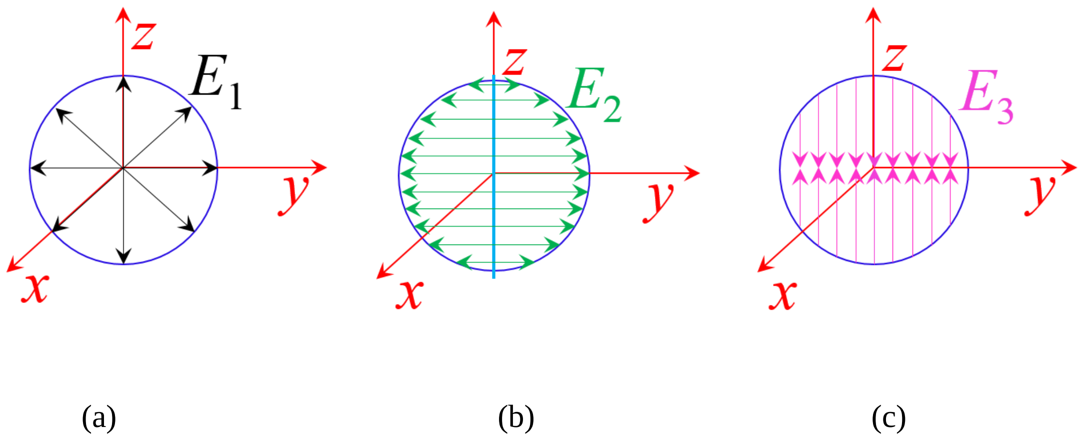

Figure 2. Schematic diagrams of Earth's electric fields E_1, E_2 and E_3: a) electric field E_1 points from Earth's center to core-mantle boundaries (CMB), and it is caused by Yuheng Zhang effect; b) electric field points from Earth's rotation axis to CMB, and it is induced by Hall effect; c) electric field points from Earth's pole to equator, and it is also caused by Hall effect.