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The Creation of Cosmic Magnetic Fields

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Abstract

In 1983, on the basis of Scriptures implying the original created material of the earth was water, I proposed that God created the water with the spins of its hydrogen nuclei initially aligned in one direction (Humphreys, 1983). That would produce a strong magnetic field. After 6,000 years of decay, including energy losses from magnetic reversals during the Genesis Flood, (Humphreys, 1986a, 1990c) the strength of the earth's magnetic field would be what we observe today. In 1984 I extended the theory to the other planets of the solar system, the Sun, and the Moon (Humphreys, 1984). The theory explained the observed magnetic field strengths of those bodies very well. It also correctly predicted the field strengths of Uranus and Neptune measured by the Voyager 2 spacecraft several years later, (Humphreys, 1986b, 1990a, b) as well as magnetizations of surface rocks on Mars (Humphreys, 1999).

In this paper I improve the theory and apply it to updated solar system data, meteorites, and the larger moons of Jupiter and Saturn. Then in a brief survey I apply it beyond our solar system to ordinary stars, magnetic stars, white dwarf stars, pulsars, "magnetars," galaxies, and the cosmos itself. The theory appears to be able to explain the magnetic fields of all heavenly bodies for which we have magnetic data. In contrast, the origin of cosmic magnetic fields is still a great mystery to uniformitarian theorists (Langer, Puget, & Aghanim, 2003).

Keywords

Planetary, Stellar, Galactic, Cosmic magnetic fields, Creation, Water origin

Introduction—Creationists and the Earth's Magnetic Field

In 1971 a creationist physics professor at the University of Texas at El Paso, Dr. Thomas G. Barnes, began publicizing a "trade secret" about the earth's magnetic field: it is decaying remarkably fast. Most of the field today has a *dipole* shape, having two poles, one north, one south. The strength of the source of that part of the field, its *dipole magnetic moment*, is decreasing by about 5% per century (Barnes, 1971).

That means the magnetic field *intensity* (usually called *B*), which gives the torque exerted on a compass needle at any given location, is also decreasing at the same rate. The decay has been going on continuously since Karl Friedrich Gauss first measured the field globally in the 1830s (Gauss, 1838).

In fact, studies of magnetizations in old bricks and pottery show that the decrease in dipole magnetic moment has been going on steadily for over a millennium (Merrill & McElhinney, 1983). Barnes explained the decrease by a simple and physically robust model: the electrical resistance of the core wears away the electrical current producing the field (see Figure 1), causing the dipole moment to decay steadily (Barnes, 1973).

From the observed decay rate of the dipole moment, Barnes calculated the average electrical conductivity of the core, about 40,000 Siemens per meter (1 Siemens = 1 S = 1 mho = 1 ohm^{-1}). His result is consistent with materials-science estimates of what the core's conductivity should be (Stacey, 1967).

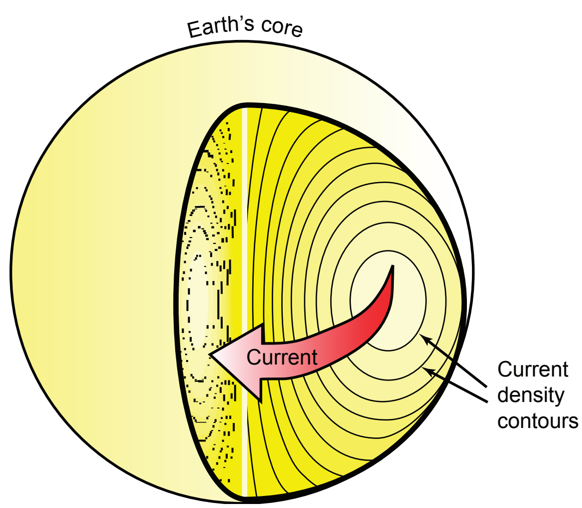

Figure 1. Six-billion ampere westward electric current in earth's core. Current density contours calculated from Barnes (1973).

Dr. Barnes assumed that motions of the core fluid would not perturb the field significantly. That would mean that field intensities on earth have always decreased steadily from creation to now. That is not correct. *Paleomagnetic* data (magnetizations of rocks) (Merrill & McElhinney, 1983,pp. 135–168) show the field changed intensity and reversed direction many times in the past during, as I think, the year of the Genesis Flood. *Archaeomagnetic* data (magnetizations of artifacts) show that after the Flood, intensities at the earth's surface did not decrease steadily. Instead, they fluctuated up and down for several millennia after the Flood.

During the Flood and for several thousand years thereafter, the shape of the field was much more complicated than today's dipole. It had strong *non-dipole* (more than two poles) components. The strengths of the non-dipole parts decayed faster than the dipole until even the most persistent non-dipole component (the quadrupole) eventually became smaller than the dipole part at about the time of Christ (Humphreys, 1986a, pp. 118–120).

In 1986 and 1990 I generalized Barnes's model to include the effects of motions in the core fluid (Humphreys 1986a, 1990c). This generalization explained how direction reversals of the earth's field would occur during the Genesis Flood. It correctly predicted that evidence for extraordinarily rapid reversals would be found (Coe, Prévot, & Camps, 1995). It also explained the strong post-Flood fluctuations in the field's intensity B.

Although Dr. Barnes did not reckon with the past complex behavior of the field, it now seems clear he was correct in saying that the *energy* of the earth's magnetic field has always decreased. The energy E contained in a volume V of magnetic field depends on the volume integral of the square of the field intensity B:

$$E = \frac{1}{2\mu_0} \iiint_V B^2 dV$$

where μ_0 is the magnetic permeability of the vacuum, $4\pi \times 10^{-7}$ Henry per meter. (I use SI units throughout this paper, except that I often cite magnetic field intensity in Gauss rather than in Tesla, 1 Gauss $= 1\,G = 10^{-4}$ Tesla). My generalized theory says that the energy in the field has always decayed at least as fast as now, and faster during the reversals and fluctuations. In 2001 I surveyed the previous 30 years of detailed geomagnetic data and showed that the total energy E of the field (both dipole and non-dipole parts) has been decaying with a half-life of 1465 ± 166 years (Humphreys, 2002).

We can extrapolate the energy decay backwards in time to estimate the maximum age of the field. Figure 2 shows this extrapolation. Using very general reasoning (such as melting of the earth's mantle) to put approximate upper limits on the energy of the field at creation, Barnes showed that the field could

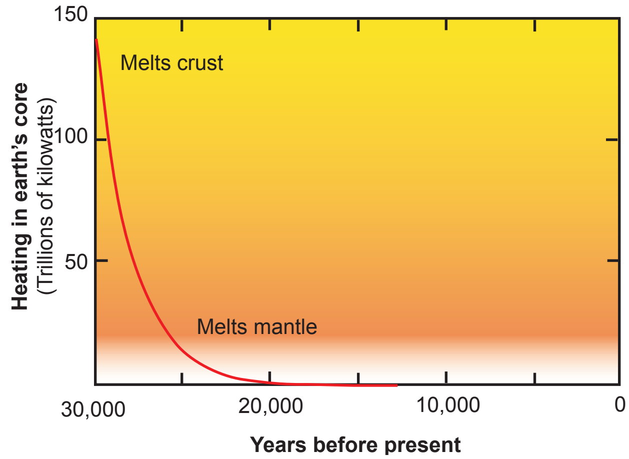

Figure 2. Joule heating in earth's core, extrapolated backwards from today's energy decay rate.

not be much older than tens of thousands of years. However, since he knew no way to calculate exactly what the initial energy of the field was, Barnes could not be more precise in his age estimates.

A Water Origin for the Field

In the late 1970s, when I worked at the General Electric Company's High Voltage Laboratory in Pittsfield, Massachusetts, I would often spend my break times in the GE power transformer manufacturing plant next door. As I watched the construction of gigantic transformers for electric power utilities, from their silicon-steel magnetic cores on up, I pondered the question of how God started up the electric current which generates the earth's magnetic field. On what basis did He chose the current to be a particular value? If we had some way to independently estimate that initial value, we could have tighter limits on the age of the field and a more complete theory. I considered and rejected many theories. As I pondered, one Scripture kept coming back to me, part of 2 Peter 3:5 (NASB): "… the earth was formed out of *water* and by *water* …"

I knew that the Greek word translated "formed" (συνίστημι, *sunistēmi*) has a basic meaning, "to place together, to set in the same place, to bring or band together," (Thayer, 1977, p. 605) that is consistent with nuclear and chemical transformations (putting nuclei or atoms together). Thus this verse, along with others (Genesis 1:2, 6, 7, 9), suggested to me that God created the earth first as *water*. Then He would have transformed the water into the materials of which the earth consists today.

If the original matter was water, how would that relate to the earth's magnetic field? I began to consider magnetic fields in a water molecule. The major source of magnetic fields in most materials is the atomic electrons, whose rapid spins produce strong fields. However, the ten electrons in a water molecule group themselves into pairs with opposite spins in each pair. That cancels out any large-scale effect of their magnetic fields.

But protons and neutrons generate tiny magnetic fields of their own, about a thousand times smaller than the magnetic fields of electrons. Just as in the case of the electrons, the eight protons in an oxygen nucleus group themselves into pairs with opposite spins in each pair. The eight neutrons do likewise. So an oxygen nucleus makes no contribution to large-scale magnetic fields. But the nuclei (single protons) of the hydrogen (H) atoms in a molecule of water are far away from each other (Figure 3), so they interact only weakly. Normally, the spins of the H nuclei throughout the water point in random directions and cancel out their overall magnetic field. But would that have been true at creation? What if God created the hydrogen nuclei with *all their spins pointing in the same direction*?

In that case, the tiny magnetic fields of the H nuclei would add up into a large overall magnetic field, resulting in a large amount of *magnetic flux* (which you can visualize as magnetic lines of force). This flux would come into existence instantaneously along with the water as God created it.

Magnetic Moment at Creation

In an iron bar magnet, the individual magnetic moments of electrons in the iron atoms add up linearly to comprise the magnetic moment of the whole magnet. In the same way, the individual magnetic moments of the hydrogen nuclei in the created water would add up linearly to make an overall magnetic moment at the instant of creation. To be general, I assigned the symbol k to represent the fraction (0 to 1) of hydrogen nuclei God aligned. Then using the mass m_w, 2.992×10^{-26} kg, of a water molecule, and the observed magnetic moment μ_p, 1.41×10^{-26} Ampere-meter^2 (A-m^2), of a proton, (Weast, 1986[1]) I represented the magnetic moment M_0 at creation of a mass m of water as:

$$M_0 = k\alpha_0 m \quad \text{where} \tag{1}$$

$$\alpha_0 \equiv \frac{2\mu_p}{m_w} = 0.9425\,\frac{\text{A - m}^2}{\text{kg}} \tag{2}$$

The constant α_0 is the magnetic moment per unit mass of a water molecule with aligned hydrogen nuclei. Using the mass of the earth, 5.979×10^{24} kg, for m in equation (1) gave me an M_0 of k times 5.6×10^{24} A-m^2.

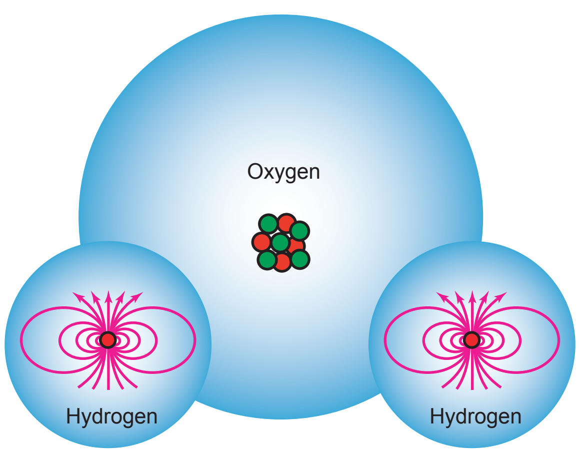

Figure 3. Water molecule. Only the two hydrogen nuclei can have non-cancelling magnetic fields.

Conductors Preserve the Magnetic Flux

If God allowed His physical laws to proceed normally from that point, thermal collisions of the newly-created water molecules would quickly disorient the nuclear spins. What would happen to the magnetic field? First, pure water at room temperature has enough electrical conductivity that for an earth-size sphere of it, the effect I describe below would preserve magnetic flux for more than a dozen seconds (Glasstone, 1946, p. 891[2]). But probably the interior of the water would be hot, either by having been created in thermal equilibrium, or by immediate gravitational contraction. Hot water under pressure conducts electricity well (Mattsson & Desjarlais, 2006). So the created magnetic flux would be embedded in a large electrical conductor. The magnetic flux Φ (number of lines of force) in a conductor of area S containing a magnetic field B is:

$$\Phi \equiv \iint_S \mathbf{B}\cdot d\mathbf{S}$$

where the bold font indicates vectors and $\mathbf{dS}$ is a surface element. Two well-known theorems, *Lenz's law* in electrodynamics (Jackson, 1995) and *Alfvén's theorem* in magnetohydrodynamics (Shercliff, 1965) say that an electrical conductor containing a flux Φ will tend to conserve the flux even if the conductor changes size or shape. The only change in the total flux will be a decay due to resistive losses in the conductor. In the case of planet-sized or larger bodies, this loss turns out to be small, because the half-life of the decay is much longer than the time God took to make the bodies. For stars and larger bodies, the half-lives are comparable even to the billion-year ages evolutionists allege.

[1] One Ampere-meter^2 = 1 Joule/Tesla = 1000 Gauss-cm^3. For example, the magnetic moment of a 6 billion Ampere current traveling in a thin ring 4000 km in diameter would be $(6\times109\,\text{A})\times\pi\times(2\times10^6\,\text{m})^2 = 7.5\times10^{22}$ A-m^2, close to today's value of the earth's magnetic moment.

[2] Glasstone gives the conductivity σ of "ultra-pure" water at 18°C as (converted to SI units) 5×10^{-6} S/m. Using that value and $R = 6.4\times10^6$ meters in equation (18) in this paper gives a time constant of 26 seconds

In the mid-1980s while I worked at Sandia National Laboratories, I became acquainted with a device that dramatically illustrates flux conservation. It uses explosives to compress a copper tube containing magnetic flux aligned with the cylinder axis (Tucker, Hanson, & Cnare, 1983). The ohmic loss time constant (equation 11) of the tube is much longer than the implosion time. As the tube's interior cross-sectional area S decreases, the average magnetic field intensity B (the number of lines of force per unit area) within the tube increases while the amount of magnetic flux Φ stays the same:

$$B(t) = \frac{\Phi}{S(t)}$$

This principle allows such devices to extract the energy of the implosion as a strong electrical pulse. This illustrates how conductors tend to conserve magnetic flux.

So as thermal collisions of the newly-created water molecules knocked the nuclear spins askew, at the same time a large electric current would spring up in the water and sustain the magnetic flux. I showed in my 1983 paper that ohmic losses in the water would be small during an ordinary-length day of creation (Humphreys, 1983, p. 92). The time constant in high temperature, high pressure water would be about one year. Through all the succeeding transformations, the conductors present would continue to preserve the magnetic flux. Then the flux would decay with a half-life proportional to the electrical conductivity and cross-sectional area of the conductor, as in equation (18).

In my 1983 paper, I assumed that it was the magnetic moment that would be conserved throughout various transformations into a planet. Conservation of magnetic flux is more accurate. However, as I will show, the two methods give approximately the same result, except for objects of mass density much higher or lower than that of water.

Earth: First Test of the Hypothesis

My first question was: would the resulting magnetic moment be of the right order of magnitude to account for the magnetic field of the earth? The magnetic moment of the earth in 1978 was about 8×10^{22} A-m^2. Extrapolating exponentially backwards in time for the biblical age of 6,000 years, using Dr. Barnes' estimated value of the observed dipole moment decay rate, gave me an initial value for the earth's magnetic moment of about 1.5×10^{24} A-m^2, give or take about 50% due to the error in our knowledge of the decay rate.

As I mentioned at the end of equation (1) gives a created magnetic moment of k times 5.6×10^{24} A-m^2, where, again, k is the fraction of H nuclei God aligned. If k were about ¼, then the magnetic moment of equation (1) would be 1.4×10^{24} A-m^2, agreeing with the estimate above from the decay rate, 1.5×10^{24} A-m^2. This agreement would not occur for ages substantially greater than 6,000 years, or for other materials than water, such as pure hydrogen, silicon, iron, calcium, potassium, aluminum, etc.

So, using a quantum-mechanical rationale for why God would align only one-fourth of the nuclei, I assumed that the value of k should be 0.25. I now think that assumption was wrong.

I wasn't worried about factors of four. I thought it remarkable that such a simple calculation could be within even one order of magnitude of being right. In physics, wild conjectures usually give results that are off-target by factors of thousands to trillions. So I thought that coming within a factor of four was an indication that I was on the right track. I published the results for earth a few years later, in 1983 (Humphreys, 1983).

Evidence that God Aligned *all* the Hydrogen Nuclei

After the theory's success with earth, I began calculations to see if it would explain the magnetic fields observed by various spacecraft at other bodies in our solar system. It did so remarkably well. I published the results in 1984 (Humphreys, 1984). The article included predictions of the magnetic moments of Uranus and Neptune, whose fields had not been measured by that time. The predictions depended not only on the initial fields, but also on the rate of decay, determined by the size and conductivity of each planet's core. Since we had little information on the cores of the outer planets, I qualified my predictions with "on the order of." Nonetheless, when Voyager II visited Uranus in 1986 and Neptune in 1989, the results were close to the middle of the ranges I had calculated. Since evolutionary "dynamo" theory predictions for many solar system bodies (especially Mercury, the Moon, Mars, and Uranus) had been disastrously wrong, I was greatly heartened by the contrasting success of the water origin theory.

The calculation for Jupiter turned out to require a k of at least 0.87 to fit the observed field. I began to wonder if k had been greater than 0.25, perhaps 1.00, for all planets. If so, that could mean that sometime in the past the earth's field had lost energy faster than today's rate.

When I published my 1986 paper on reversals of the earth's field during the Genesis Flood, I decided that k ought to be 1 for the earth also. The reason was that the reversals and post-Flood fluctuations I was considering would probably dissipate some of the field's energy. With a k of 1 and the additional losses, the time scale of 6,000 years would fit in very nicely. A

k of 0.25 would require lower losses. By the time of my 1990 paper (spelling out a reversal mechanism), I was convinced that k should be 1 for all bodies. Therefore we should add

$$k = 1 \tag{3}$$

to equations (1) and (2). That gives us one less adjustable parameter, thus tightening up the theory. It is more satisfying for me to imagine God aligning *all* the hydrogen nuclei He created, not just some of them.

Water Origin for the Heavenly Bodies, too

In my 1984 paper, I did not make a strong biblical case that God made other bodies besides the earth out of water. The clearest scripture, 2 Peter 3:5, may refer only to the earth, although there is a possibility it includes the heavens also (Dana & Mantey, 1957[3]). The water-mentioning verses in Genesis 1:2, 7, 9, 10 (NASB) range from cosmic to earthly:

> … and darkness was over the surface of the *deep* … the Spirit of God was moving over the surface of the *waters* … Let the be an expanse in the midst of the *waters*, and let it separate the *waters* from the *waters* … And God made the expanse, and separated the *waters* which were below the expanse from the *waters* which were above the expanse. And God called the expanse heavens … Let the *waters* below the heavens be gathered into one place … and the gathering of the *waters* He called *seas* …

But in 1984 I didn't understand those verses well enough to use them. Such details require us to have a creationist cosmogony, a scientific understanding (based on Scripture) of how God created the universe.

In 1985 I began working on a young-earth creationist cosmology. By 1994 I felt it was mature enough to present at the Third International Conference on Creationism (ICC). My book *Starlight and Time* (Humphreys, 1994) outlines this cosmology and includes my ICC papers as appendices. There I suggested that the "deep" and the "waters" in Genesis 1:2 were the original material out of which God formed the heavenly bodies.

However, now I think it likely from Isaiah 40:26 that He created additional matter on the fourth day, out of which He then formed the Sun, Moon, and stars. That additional Day 4 matter may have been initially water also. The Hebrew word for "heavens" may in itself mean "that which is of the waters," or "the place for water," although those meanings are controversial. (Koehler & Baumgartner, 2000[4]). These Scriptural considerations suggest, but do not confirm, the watery origin of other bodies besides the earth.

The Primordial Magnetic Field was 7.9 Gauss

Most of the details of cosmogony are not essential to a water-origin theory of astronomic magnetic fields. The two essential points for calculating magnetic fields are:

(1) origin of all matter in the cosmos from created ordinary water, and
(2) preservation of magnetic flux throughout the various transformations into the earth and the heavenly bodies.

The water-origin hypothesis allows us to calculate the intensity of the magnetic field at the beginning of creation. Imagine a spherical region of water at the instant God creates it. Let's call the initial volume of the sphere V. The magnetization $\mathfrak{M}$, or magnetic moment per unit volume, throughout the sphere would be simply the created magnetic moment M_0 of the whole sphere divided by its volume:

$$\mathfrak{M} \equiv \frac{M_0}{V} \tag{4}$$

According to equations (1) through (3), the created magnetic moment is the constant α_0 times the mass m of the sphere. Using that fact and calling the initial density of the sphere ρ_0 (=density of ordinary water=1 gram/cm^3=1000 kg/m^3) gives us the initial magnetization:

$$\mathfrak{M} = \frac{\alpha_0 m}{V} = \alpha_0 \rho_0 = 942.5 \ \frac{\text{Amperes}}{\text{meter}} \tag{5}$$

Electromagnetics textbooks show that the magnetic field intensity B within a uniformly-magnetized sphere is constant throughout the interior:

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[3] paragraph 5, "Perphrastic Pluperfect." There is a possibility that 2 Peter 3:5 should be translated, "… that by the word of God, the heavens and the earth of old were formed out of water and by means of water." This would mean that God meant the Greek words for "were" and "formed" to be taken together as a periphrastic pluperfect use of the finite verb and participle. A problem may be that the Greek participle translated "formed" is feminine singular, agreeing with "earth" and not "heavens," which are masculine plural. However, the participle cannot agree with both nouns, so it may have been acceptable in Koine Greek grammar for it to agree with the last noun listed. If this translation were correct, it would suggest that God created the matter in the heavens out of water also.

[4] The authors imply the normal understanding would be that the noun "should be composed with the relative-determinative pronoun *ŝa*, to mean that which is of the waters, or the place for water." That is, the word *shamayim* (heavens) would consist of two words, *sha* (that which, where) and *mayim* (waters). But then they cite scholars who disagree, saying that the assumption "is too much focused on an inner Hebrew explanation." However, Scripture says it was God himself who gave that name to the expanse (Genesis 1:8), in a language the biblical evidence strongly indicates was very similar to Hebrew. That being so, we should indeed look for an "inner Hebrew explanation" for why God chose a name that contains the word for "waters." In other words, the cited scholars' reason for rejecting the simple explanation seems to be no more than doubt in the possibility that the name might mean something.

$$B = \tfrac{2}{3}\mu_0 \mathcal{M} \tag{6}$$

Using equation (5) in equation (6) gives us the *primordial magnetic field intensity* in a sphere of any size:

$$B_0 = \tfrac{2}{3}\mu_0 \alpha_0 \rho_0 = 7.896 \times 10^{-4} \text{ Tesla} \tag{7}$$

or 7.896 Gauss. For comparison, the intensity of the earth's magnetic field at the surface in medium latitudes is presently about 0.5 Gauss. Since α_0 is twice the ratio of the proton magnetic moment to the mass of a water molecule [equation (2)], B_0 is an exact number with no arbitrary factors. It depends only on fundamental constants of physics. It seems remarkable that a simple theory can make a precise claim about conditions at the mysterious beginning instant of creation.

Magnetic Flux in a Spherical Mass

In this section we calculate the magnetic flux Φ created in a sphere of water of mass m. The initial radius of the sphere is R_0 and its mass is m. Since the magnetic flux is uniform throughout the sphere (Figure 4), the total flux (in Webers) passing through the circuit marked out by the equator of the sphere is simply its cross-sectional area times the primordial field B_0 of equation (7):

$$\Phi = \pi R_0^2 B_0 \tag{8}$$

The mass m of the sphere is:

$$m = \tfrac{4}{3}\pi \rho_0 R_0^3 \tag{9}$$

Solve this equation for R_0, then substitute the result and equation (7) into equation (8). That gives us the initial flux in terms of the sphere's mass m:

$$\Phi = \beta_0 m^{2/3} \qquad \text{where} \tag{10}$$

$$\beta_0 \equiv \tfrac{1}{2}\mu_0 \alpha_0 \left(\tfrac{4}{3}\pi\rho_0\right)^{1/3} = 9.546 \times 10^{-6} \frac{\text{Webers}}{\text{kg}^{2/3}} \tag{11}$$

As I showed, we would expect the flux in a spherical heavenly body at the end of Creation week to be about the same as the flux in a section of the initial deep having the same mass, regardless of compression, expansion, and transformation. Equations (10) and (11) tell us the amount of that flux.

Magnetic Properties of a Planet or Star

Now we need to calculate the magnetic moment of a newly-transformed spherical heavenly body. If the

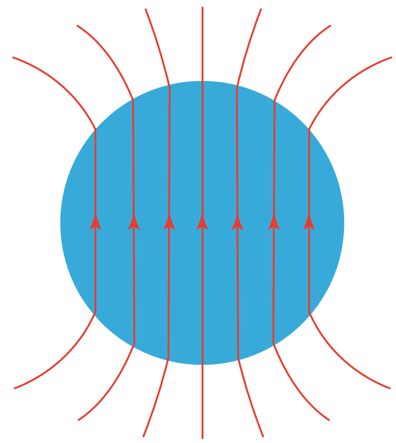

Figure 4. Uniform magnetic field inside initial sphere of magnetized water

body is a terrestrial-type planet with a conducting core, flux conservation will gather the magnetic flux of equation (10) into the core as the rest of the planet (its mantle and crust) becomes non-conducting. That is, the increase of resistance in a outer layer will shift current down into an adjacent layer that is more conductive. That happens in two ways: (1) by ohmic shunting (the inner layer being in parallel with the outer layer and having less resistance, and (2) by transformer action, the outer layer acting as a primary winding and the inner layer as a secondary.

Eventually the flux will distribute itself throughout a core of radius R_C in a way that minimizes the ohmic power losses by maximizing the volume of the core through which the current flows. Then the current will have the toroidal distribution Barnes calculated, shown in Figure 1 (Barnes, 1973, p. 225, equation (30[5]). Barnes derived expressions for the magnetic field intensity **B** throughout the core produced by that current. Integrating his z-component of **B** over a slice through the magnetic equator (Barnes equation (32), gives the total magnetic flux Φ contained in the core:

$$\Phi = \pi R_c^2 B_p \left(\frac{R}{R_c}\right)^3 \tag{12}$$

where B_p is the field intensity at the magnetic pole at the planetary surface, of radius R. In terms of the magnetic dipole moment M_1 of the planet newly transformed from water, the intensity on the surface at the pole is (Merrill & McElhinney, 1983, p. 93, equation [3.39][6]):

$$B_p = \frac{\mu_0 M_1}{2\pi R^3} \tag{13}$$

Use equation (13) to replace B_p in equation (12) and

[5] With $\theta = \pi/2$, so that the unit vector for θ is in the z-direction.

[6] With $F \to B_p$, $p \to M_1$, $\theta = 0$.

solve for M_1. That gives us the magnetic moment of the transformed planet in terms of its core radius and the created magnetic flux Φ_0:

$$M_1 = \frac{2R_c\Phi_0}{\mu_0} \tag{14}$$

The planet's mass m depends on its average density ρ and its surface radius R:

$$m = \tfrac{4}{3}\pi\rho R^3 \tag{15}$$

Using equations (10), (11), and (15) in equation (14) gives us a handy expression for the magnetic moment M_1 of a newly transformed planet in terms of its core radius R_c relative to its surface radius R, its average density ρ relative to that of water ρ_0, the constant α_0 of equation (2), and its total mass m:

$$M_1 = \frac{R_c}{R}\left(\frac{\rho_0}{\rho}\right)^{1/3}\alpha_0\, m \tag{16}$$

The mean density of the earth is 5.518 g/cm^3; the radius of its core is 0.545 of the surface radius; (Allen, 1976, pp. 112, 118). For the earth, the product of the first two factors of equation (16) is 0.3084. In my early papers I used equation (1) with k=0.25. So equation (16), which has a more rigorous basis, does not give results greatly different from my early results. However, because for planets this new factor is less than one, it does reduce my 1990 estimate of the field's loss of energy from creation through the end of the post-Flood fluctuations. Perhaps the reversals were more efficient than I thought, or perhaps the core was less lossy before the Flood than afterward.

As I mentioned above, it is the magnetic flux of a body that tends to be preserved, not its magnetic moment. Equation (14) with the presently-observed magnetic moment M and core radius R_c gives the presently-observed flux Φ:

$$\Phi = \frac{\mu_0 M}{2R_c} \tag{17}$$

Tables 1a and 1b show the physical and magnetic properties of the Sun, the planets, and various moons. Most of the bodies listed previously have essentially the same created and present magnetic moments as in my 1984 table. The Sun is the main exception. I have added transformed magnetic moments, created and present magnetic fluxes, and included several new bodies for which we now have measured magnetic moments: Uranus, Neptune, the Galiean moons of Jupiter, and the largest moon of Saturn, Titan.

Figure 5 compares created and presently-observed magnetic flux for each body. The smaller bodies have less flux than the created flux, probably because of ohmic losses in their smaller conducting cores. If we call R_c the radius of a region in which there is significant electric conductivity (perhaps greater than the official core radius), and the average conductivity σ, then the time constant τ for exponential decay is

$$\tau = \frac{\mu_0\sigma R_c^2}{\pi^2} \tag{18}$$

Figure 6 shows the amount of exponential decline (a straight line on that type of graph) the magnetic field of each body would have to experience to get today's observed magnetic flux. The slope of each line determines the time constant τ. The decline may not be entirely due to electrical resistance, but may also

Table 1a. Physical and magnetic data for the Solar System.

Name	Mass (kg)	Radius (km)	Density (g/cc)	Core Radius (km)	Period (days)	M created (A m²)	M trans (A m²)	M now (A m²)
Sun	1.99E+30	6.96E+05	1.41	6.96E+05	24.66	1.84E+30	1.64E+30	1.33E+30
Mercury	3.18E+23	2433	5.431	1800	58.82	2.94E+23	1.24E+23	4.80E+19
Venus	4.88E+24	6053	5.256	2700	244.59	4.51E+24	1.16E+24	<1.00E+19
Earth	5.98E+24	6371	5.519	3480	1	5.53E+24	1.71E+24	7.84E+22
Moon	7.35E+22	1738	3.342	350	27.4	6.80E+22	9.16E+21	<1.30E+15
Mars	6.42E+23	3380	3.907	1750	1.03	5.93E+23	1.95E+23	200E+17
Jupiter	1.90E+27	69758	1.337	69758	0.41	1.76E+27	1.60E+27	1.55E+27
Io	8.93E+22	1818	3.53	900	1.77	8.26E+22	2.68E+22	9.00E+19
Europa	4.80E+22	1561	3.014	750	3.55	4.44E+22	1.48E+22	4.50E+18
Ganymede	1.48E+23	2634	1.936	1895	7.15	1.37E+23	7.91E+22	1.32E+20
Callisto	1.08E+23	2408	1.839	600	16.69	9.95E+22	2.02E+22	
Saturn	5.68E+26	58219	0.688	35000	0.43	5.25E+26	5.95E+26	4.21E+25
Titan	1.35E+23	2575	1.883	1650	15.94	1.24E+23	6.45E+22	
Uranus	8.68E+25	23470	1.603	12000	0.45	8.03E+25	6.86E+25	3.90E+24
Neptune	1.03E+26	22719	2.272	12000	0.66	9.49E+25	7.22E+25	2.20E+24
Pluto	1.31E+22	1170	2.1	300	6.4	1.21E+22	2.42E+21	
Charon	1.58E+21	604	1.71	100	6.4	1.46E+21	2.02E+20	

Table 1b. Further magnetic data for the Solar System. Fields are on the surface at the poles.

Name	B trans (Gauss)	B now (Gauss)	DecayTime (years)	Ave Cond (S/m)	Core Cond (S/m)	Flux Created (Webers)	Flux Now (Webers)	Flux Ratio
Sun	9.74	2.077	26038	13	13	151.15E+	120.15E+	0.794
Mercury	17.19	0.007	761	31843	58176	445.10E+	16.87E+	0.000
Venus	10.44	0	<514	3473	<17500	275.11E+	<2.4E+06	<0.000009
Earth	13.21	0.611	1935	11808	39575	315.11E+	142.10E+	0.045
Moon	3.49	0	<380	31164	<77000	168.10E+	<2400	<0.0000002
Mars	10.1	0	<435	9423	<35000	710.10E+	<72000	<0.000001
Jupiter	9.4	9.427	>124726	6348	6348	147.13E+	140.13E+	0.953
Io	8.94	0.03	1050	78667	32.15E+	191.10E+	62.87E+	0.003
Europa	7.76	0.002	739	75154	32.65E+	126.10E+	37.76E+	0.000
Ganymede	8.66	0.014	935	33391	64513	267.10E+	43.87E+	0.001
Callisto	2.9	0	357			216.10E+		
Saturn	6.03	0.436	2897	212	586	655.12E+	826.11E+	0.126
Titan	7.56	0	334			251.10E+		
Uranus	10.61	0.464	2708	1218	4658	187.12E+	204.11E+	0.109
Neptune	12.32	0.256	2069	993	3559	209.12E+	115.11E+	0.055
Pluto	3.03					53.19E+		
Charon	1.84					13.09E+		

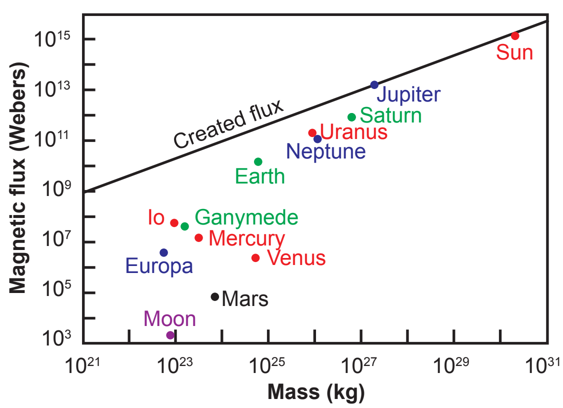

Figure 5. Created and present magnetic flux in solar system bodies.

include the effects of losses occurring during magnetic polarity reversals. However, we can use the slopes from Figure 6 (excluding those for the Sun and Jupiter, which are too close to zero to be well-determined) to get effective time constants in Table 1b, and then solve equation (18) to get an effective conductivity. Table 1b and Figure 7 show the results. The conductivities tend to fall into two reasonable groups: high for terrestrial bodies with small cores, and low for gas giant planets having significant conductivity out to large radii.

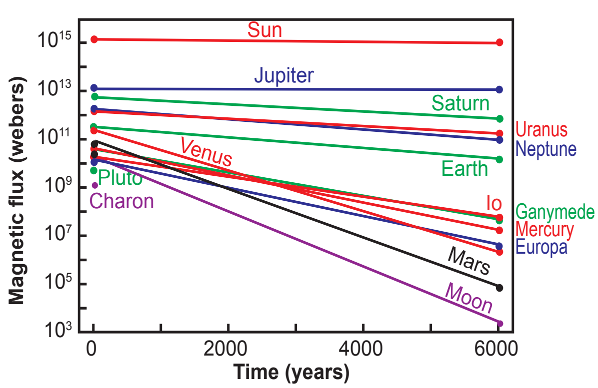

Figure 6. Decay of magnetic flux from Creation to now. On this type of graph, exponential decay is a straight line.

The Inner Planets

Here are updated comments on the magnetic features of each of the planets from Mercury to Mars:

Mercury remains a major mystery to uniformitarians (Stevenson, 1984). Its small size would normally cause a liquid core to solidify during its alleged 4.5 billion year existence, and a liquid core is the *sine qua non* for a "dynamo theory" of a planet's magnetic field to work (Stevenson, 2002, pp. 1–11). Hence dynamo theorists had predicted that Mariner 10 would measure no magnetic field during its 1974 and 1975 flybys. They were rudely shocked when it found an appreciable magnetic field. Recent

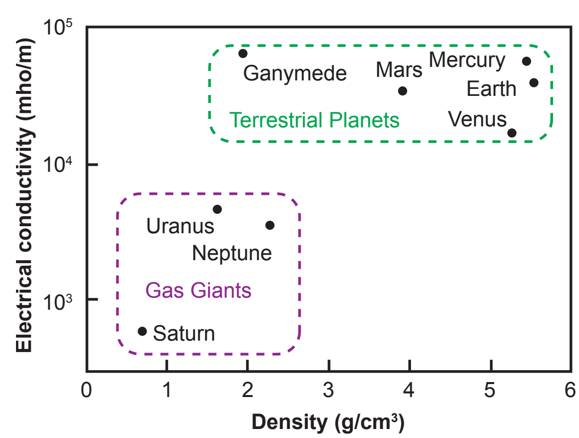

Figure 7. Electrical conductivity in various planets.

radar observations of the planet suggest it may have a molten interior (Margot, Peale, Jurgens, Slade, & Holin, 2007), but theorists now need to explain how it could have one after billions of years. They suggest adding a light element like sulfur to lower the melting point of the core. But a liquid core does not solve three other big problems for dynamo theorists: Mercury's very slow rotation (59-day period), small core size, and expected low conductivity. The latter would occur because adding a light alloying element to the core and reducing its temperature could reduce its conductivity tenfold (Stacey, 1969). If the dynamo theories ever move far enough beyond the hand-waving stage to make precise quantitative predictions, they could easily run aground on those last three features.

Creationists, on the other hand, have no problem explaining Mercury's magnetic field. During 6,000 years, a decay constant of 761 years would reduce the created flux to today's value. The resulting core conductivity is consistent with that of the other terrestrial bodies, as Figure 7 shows. The relatively fast decay implies that in its first flyby in January 2008 (after the final draft of this article), the Messenger spacecraft now on its way to Mercury should record a magnetic moment 4.4 (±0.4) % lower than Mariner did in 1974. This number is not different from predictions I made in 1984 and 1998 (Humphreys, 1999). The error range accounts for possible episodes of not-well-determined magnetic reversal losses in the past. Preliminary results from the January 2008 flyby do not contradict the prediction (Humphreys, 2008). When Messenger begins orbiting Mercury in 2011, the magnetic moment should be an additional 0.3% lower than in 2008.

Venus is still apparently without any measurable internal field. Dynamo theorists would explain that by the slow rotation of Venus (period of 244 days). The water origin theory suggests that the decay time constant is less than 510 years, which would imply a core conductivity somewhat lower than that of the other terrestrial bodies, although still on the same order of magnitude. This could be due to a lower core temperature and more alloying lighter elements (Stacey, 1969). Thus either theory could account for Venus' present low field. Venus' high created field would have magnetized surface rocks, but its high surface temperatures may have destroyed much of such magnetizations by now.

Earth has had its magnetic field measured much more accurately in the past three decades, as I mentioned previously. That allows a better estimate of the present contribution of the field's non-dipole parts to the total energy in the earth's magnetic field. Taking that into account, the total energy is decaying with a half-life of 1465±165 years, or an energy decay time constant of 2114±238 years (Humphreys, 2002, p. 10). Combined with likely energy and dipole moment losses during the magnetic polarity reversals of the Genesis Flood, that is consistent with the average dipole magnetic moment decay constant, 1935 years, deduced from the water origin theory.

Mars has been visited recently (1997–2001) by the Mars Global Surveyor mission. It provided a more accurate upper limit on its present low magnetic moment. It also found striking evidence that Mars had a strong magnetic field in the past, confirming a prediction I made in 1984 (Humphreys, 1984, p. 147). Orbiting low over the Martian surface, the spacecraft measured alternate-polarity magnetic "stripes" of magnetization in the crustal rocks. Figure 8 shows these "magnetic crustal anomalies." These linear features are similar to those found on earth's ocean floors, but the Martian magnetizations are up to 20 times stronger than those on earth (Acuña et al., 2001, pp. 23403–23417). That points to a strong field reversing many times in the past, when the rocks were formed. It is difficult for theorists to explain why a Martian dynamo would be functioning robustly in the past but not at all in the present. The water origin theory, on the other hand has no problem with both past and present fields, and as I said, even predicted crustal magnetizations. The core conductivity required is close to that of earth, so it is within the expectations of the water origin theory.

The Outer Planets

Several spacecraft have toured the outer parts of the solar system since 1984, and they have sent back major confirmations of the water origin theory. Here are updates:

Jupiter, like the Sun and stars, appears to have a conducting volume nearly the same as the total volume. In that case, the "core" radius comprises nearly all of the planet's radius ($R_c \approx R$), and equation (16) becomes simpler:

$$M_1 = \left(\frac{\rho_0}{\rho}\right)^{1/3} \alpha_0 \, m \qquad (19)$$

For Jupiter, the average density is 1.34 g/cm^3, making the first factor 0.9071. As I remarked before, the observed magnetic moment of Jupiter is 0.87 $\alpha_0 m$. This means the observed field is only 3.7% smaller than the maximum value allowed by the water origin theory. If the few percent difference is due solely to ohmic losses in the interior, the average electrical conductivity of Jupiter would be about 6000 S/m. That is consistent with materials-science estimates of the conductivity in Jupiter's interior (Nellis, Weir, & Mitchell, 1996). If Jupiter, due to its high interior heat outflow (Guillot, 2005, p. 506, Table 2), is reversing its magnetic field as the Sun does, the water origin theory suggests it is near the maximum field of its

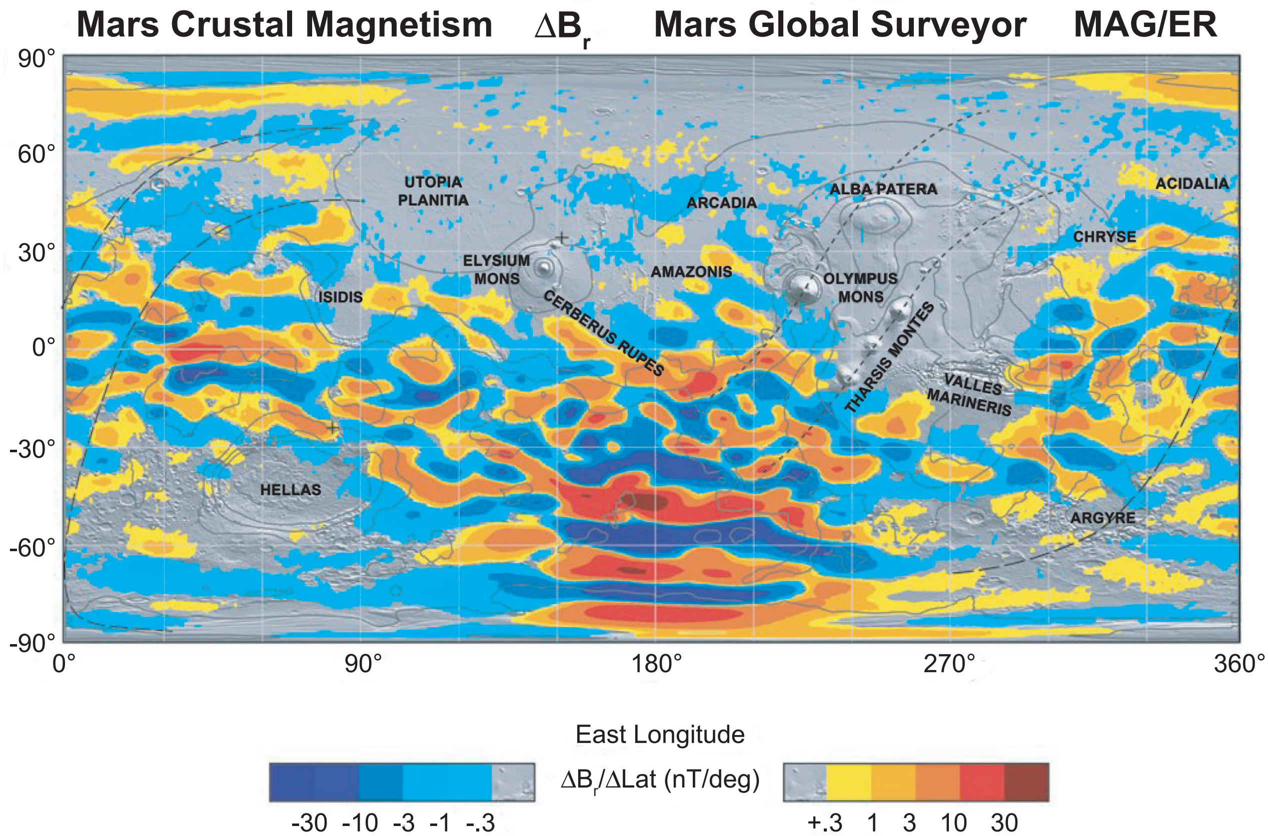

Figure 8. Magnetic anomalies measured in Mars' crust by the Mars Global Surveyor (Acuña et al., 2001). Image: NASA.

cycle. See discussions on Saturn and the Sun below. The fact that Jupiter's magnetic field is close to the limit set by the water origin theory, but under it, is strong support for it.

Saturn had an updated analysis of its magnetic moment in 1986, revising its magnetic moment downward slightly by 1.8% (Davis & Smith, 1986). Its apparent eightfold loss of flux since creation points to a smaller and more resistive conducting volume than Jupiter. That is not too surprising, because it is only about half the average density of Jupiter, suggesting a major difference in composition. Another possibility is that Saturn is partway into a slow magnetic reversal. Saturn has a significant heat flow from its interior (Guillot, 2005) and a rapid spin. Those could cause enough convection and differential rotation stretching of flux to cause magnetic reversals such as we observe on the Sun (see discussions about Jupiter and the Sun). That would mean the flux we observe is only part of the total flux, the rest being wrapped toroidally around the planet beneath its surface.

Uranus was visited by the Voyager 2 spacecraft (Figure 9) in January 1986 (Ness, et al., 1986, pp. 85–89) two years after my planetary fields paper was published. Its magnetic moment measurements confirmed my order-of-magnitude prediction (Humphreys, 1984, p. 146[7]). In fact, the result was within a factor of two of my initial estimate based on published guesses about the core of Uranus. Predictions based on dynamo models were several orders of magnitude lower than the observations (Dessler, 1986). Nobody predicted that the field would be tilted 60° away from Uranus' rotation axis, putting its magnetic pole nearly at its equator. Nor did they anticipate that its field would be offset from center by nearly one-third of the planet's radius.

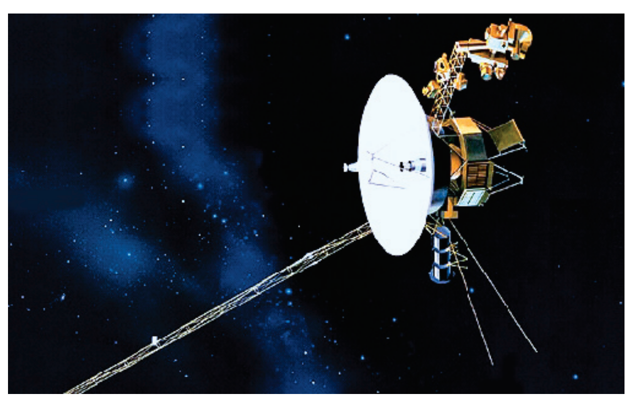

Figure 9. Voyager spacecraft. (Image: NASA.)

[7] On the order of 10^{24} J/T.

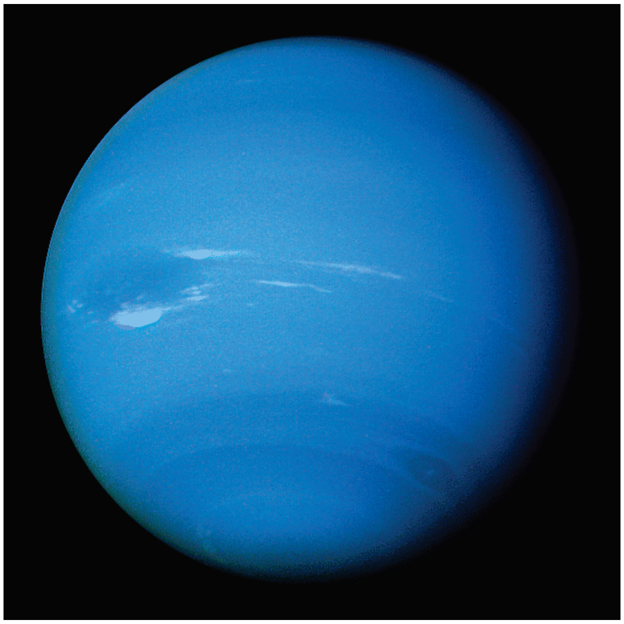

Figure 10. Neptune photographed by Voyager 2. (Image: NASA.)

Neptune, (Figure 10) visited by Voyager 2 in August 1989 (Ness, Acuña, Burlaga, Connerny, Lepping, & Neubauer, 1989) turned out to have a similar field strength as Uranus, which the water origin theory had predicted. Surprisingly, it too has a large tilt and offset, dampening uniformitarian explanations of Uranus' field oddities as those of a magnetic reversal in progress, because it would be too coincidental to have two such transitions going on simultaneously. These features are hard to reconcile with a dynamo theory (Bloxham & Stanley, 2004) but not at all difficult for a young solar system theory using what the theorists call (in the case of much larger bodies) "relict" or "fossil" fields.

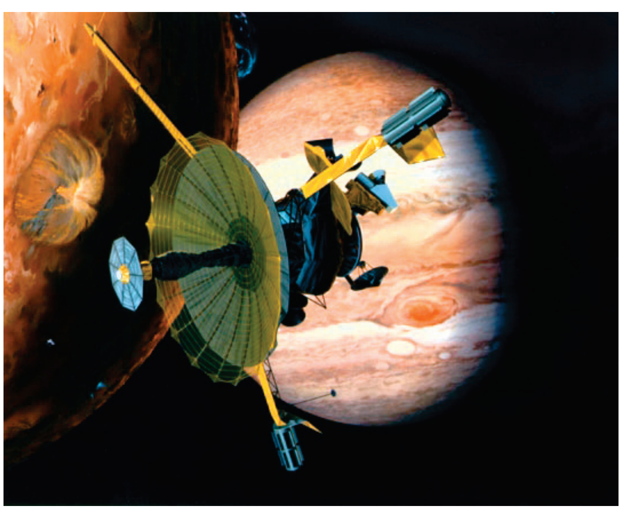

Figure 11. Galileo spacecraft at Io and Jupiter. (Image: NASA.)

Pluto has suffered the indignity of being demoted from full planet status, being now called a "dwarf planet." It has a low density (Null, Owen, & Synnott, 1993, p. 2319) suggesting it is mostly ice. That plus its small size suggest that most of its magnetic field has already faded away. We can say similar things about dwarf planet **Eris** in the Kuiper belt (Brown & Schaller, 2007).

Moons, Asteroids and Meteorites

Even the larger moons are small enough that conditions in their interiors are critical to preserving their magnetic fields for 6,000 years. A factor of only two in the half-life (that is, in $\sigma R_c^{\,2}$) can make the difference, as it apparently did for Ganymede and Titan. Asteroids and meteorites are too small to have retained field sources of their own, but spacecraft coming close to them can tell whether they have been magnetized.

Earth's Moon remains a magnetic mystery to uniformitarians. Its slow rotation (period of 27.4 days) and tiny core make it difficult to imagine how a dynamo could ever work. Yet magnetized rocks from its surface show it once had a strong internally-generated magnetic field. The water origin theory can account for both the past high field and the present low field, with the observed small core giving a decay constant of less than a few centuries. Some lunar surface rocks have the lesser magnetizations that would be characteristic of a decayed field one or two millennia after creation, possibly associated with events happening while the Genesis Flood took place on earth.

Jupiter's moons were visited by the Galileo spacecraft in 1996 (Figure 11), which measured magnetic fields of the four largest moons as it passed them (Showman & Malhotra, 1999, pp. 77–84). **Europa** and **Callisto** (Khurana, Kievelson, Russell, Walker, & Southwood, 1997; Kievelson et al., 1997, 1999) may have no internal sources of magnetic field, suggesting they have no highly-conductive cores (Anderson, 1998, pp. 2019–2022). **Io** has a field, but its closeness to Jupiter makes it difficult to say whether it is internally generated or externally induced by Jupiter's strong magnetic field (Khurana, Kievelson, & Russell, 1997). However, **Ganymede** has a remarkably large magnetic field, clearly generated internally. That was a rude shock to dynamo theorists, because Ganymede offers serious problems for the essential dynamo theory requirements, which are a fluid, highly-conductive, hot, large, rapidly-rotating core (Sarson, 1997). On the other hand, the field of Ganymede fits in just fine with equations (16) and (19). So does the observed (though controversial) field of Io. Tables 1a and 1b show the magnetic field data and theoretical predictions for the four moons.

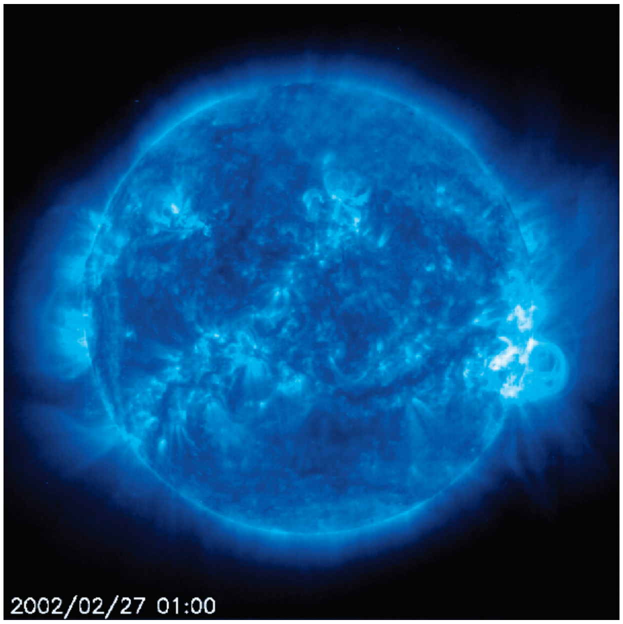

Figure 12. Sun in ultraviolet light, showing magnetic features. (Image: SOHO/NASA.)

Titan, the largest moon of Saturn, was visited by the Cassini spacecraft in October 2004 (Backes et al., 2005). It found no evidence of an internally-generated field. That suggests a low-conductivity interior.

Charon, Pluto's moon, is about half the size and half the density of the "dwarf planet" it orbits. These factors make it unlikely to have any magnetic field left after 6,000 years.

Asteroids and meteorites show evidence of having experienced significant magnetic fields in the past. Spacecraft have detected relatively strong magnetizations in the asteroids Gaspra and Braille (Acuña et al., 2002; Richter et al., 2001[8]) and meteorites have magnetizations that would have been produced in fields of 0.05 to 1 Gauss (Collinson, 1994). For comparison, Table 1b shows creation-week values of polar magnetic fields for the various solar system bodies. The interior fields would have been on the same order of magnitude. Those fields would need to decay by one or two orders of magnitude to give the magnetizations recorded. That could suggest meteorites and asteroids acquired their magnetizations within small parent bodies a short time after creation. If the parent bodies were moon-sized, the magnetizing could have been a few millennia after creation, possibly during events occurring at the same time as the Genesis Flood on earth.

The Sun

Since 1984, earthbound observatories and spacecraft have made more detailed measurements of the magnetic field of the Sun (Figure 12), updating the listed global field strength to about fourfold greater. During "quiet Sun" years, when the sunspot cycle is at its minimum, the Sun's global field is close to being a pure dipole. At the last such time for which I have data, April 1996, the total flux observed in each hemisphere of the Sun was equal, 1.2 ($\pm$0.1)$\times 10^{15}$ Webers (de Toma, White, & Harvey, 2000[9]). (1 Weber=1 Tesla-meter^2=10^8 Maxwells=10^8 Gauss-cm^2.) That is only 15 to 30% lower than the calculated flux at Creation that Table 1 shows. An astrophysical data handbook, presumably representing more than one solar cycle, lists the total flux at solar minimum as 1.5 to 2.0$\times 10^{15}$ Webers (Foukal, Solanki, & Zirker, 2000).

As the Sun continues to turn past the sunspot minimum, differential rotation (observed different rotation speeds at different latitudes and presumably at different depths) begins to wind the magnetic flux (locked into its plasma) toroidally around the Sun parallel to its equator, like rubber bands being wound many times around a ball. As the number of windings build up, the dipole part of the field decreases. According to the observations, the total flux in each hemisphere increases.

Like rubber bands, the lines of force have a tension (proportional to B^2), and as the tension and twisting increases, part of the flux erupts from the surface in great loops, making sunspots where they leave and re-enter the surface. Gradually the number of sunspots builds up and the global dipole field decreases. Five to six years after sunspot minimum, the sunspots are at a maximum and the global dipole field appears to be zero. The total flux (not from a global dipole) in each hemisphere is now at a maximum, 5 to 10 times higher than at sunspot minimum (Foukal, Solanki, & Zirker, 2000).

Just past sunspot maximum, the global dipole re-appears, only now it is of reversed polarity. Differential rotation now adds new lines of toroidal flux in parallel to the previous ones, but pointing in the opposite direction. New and old lines of force begin to cancel each other out in the process called "magnetic reconnection," producing spectacular sprays of particles. Sunspots begin to disappear, and the reversed dipole field increases. At the next sunspot minimum, eleven years after the first, the dipole field is at maximum strength again, but in the opposite direction as it was in the previous quiet Sun year. The

[8] Table I has data not only on Braille, but also Gaspra and four other asteroids.

[9] See p. 1104, Figure 5, Carrigan rotation number 1908. The errors I cite are my rough estimate based on the irregularities in the graph.

total magnetic cycle (from one dipole peak to the next peak of the same polarity) takes about 22 years.

If the cycle frequency has been fairly constant, there have been more than 270 magnetic cycles during the 6,000 years since Creation. If the cycles are not fully self-sustaining, instead losing net magnetic energy due to inefficiencies, then the twenty percent or so loss of flux since creation would mean roughly a 0.07% loss of flux per cycle, or a 0.14% net loss of magnetic energy per cycle. Until we have a rigorous analytic theory of this reversal process, we can't say whether that is a reasonable number, but it is not out of the question, considering the high electrical conductivity (and consequent low ohmic losses) of the solar plasma. To sum up, the closeness of the dipole flux at solar minimum to the calculated dipole flux at creation is strong support for the water origin theory.

Ordinary Stars, Magnetic Stars, Pulsars, and Magnetars

The Sun is the star with which we have the closest acquaintance, and our information about the magnetic fields of other stars is not nearly so detailed. Astronomical observations of a star usually give an average field intensity B over the visible surface. That value would be similar to the surface field at the pole of a dipole. Using equations (7), (9) and (19) in equation (13) gives a polar field strength B_p at the end of Creation week (after transformation to its present materials) in terms of the average density ρ of the star:

$$B_p = B_0 \left(\frac{\rho}{\rho_0} \right)^{2/3} \qquad (20)$$

where B_0 is the primordial field of equation (7), 7.896 Gauss, and ρ_0 is the density of water. In terms of the mass m and radius R of the star, the polar field after creation week works out to be:

$$B_p = (9.9\ \text{Gauss}) \frac{(m/m_{sun})^{2/3}}{(R/R_{sun})^2} \qquad (21)$$

where m_{sun} and R_{sun} are the mass and radius of our Sun. We can use this equation to evaluate magnetic field data for the various kinds of stars listed below.

Most stars appear to have magnetic fields below the limit of astronomical detectability, about a hundred Gauss for nearby bright stars. However, one astronomer says, "Stellar magnetic fields are directly detected or inferred across the whole Herzsprung-Russell diagram," implying that all types of stars have magnetic fields (Mestel & Landstreet, 2005). According to equation (20), stars similar to the Sun in mass and size would have fields below the detectability limit, agreeing with observations.

Magnetic stars are a small minority, but they have strong magnetic fields, between a few tenths kG and a few tens of kG. These few hundred stars are in a subclass of the A and B spectral classes, the "peculiar" A and B stars, called Ap and Bp stars. They are hot, bluish-white stars with surface temperatures from 10,000 to 25,000 Kelvin, roughly two to five times hotter than the Sun. They have masses and radii several times those of the Sun. Ap stars that rotate fast (periods less than 25 days) are "oblique rotators," meaning their magnetic axes are tilted far away from their rotation axes, between 30° and 86° (Landstreet & Mathys, 2000, p. 216). This is a major problem for dynamo theories, which would prefer to have magnetic and rotation axes aligned.

The large obliquities suggest to me that although these stars started out with fields given by equation (20), differential rotation brought about by strong convection has wound their flux around the stars hundreds of times (rather than tenfold as for the Sun, as shown previously), amplifying their flux and fields by the same factor (Parker, 1979). Unlike the case of galaxies (see next section), oppositely-directed lines of force would be in the opposite hemisphere, so that there would be no cancellation of flux by magnetic reconnection. That would explain the large values of magnetic field. This explanation requires that in these stars, polarity reversals would take place much less frequently than in the Sun, so that the lines of force could be wound up many more turns.

Compact objects are a variety of compressed stars that have strong magnetic fields, according to somewhat indirect indicators of B. **White dwarf**s have theoretical densities of 10^6 to 10^9 g/cm^3 (Baym, Pethick, & Sutherland, 1971, p. 314, Figure 4) and some have magnetic fields of 10^6 to 10^8 Gauss (Angel, Borra, & Landstreet, 1981, p. 458, Table 1). **Pulsars** (rapidly rotating neutron stars) have theoretical densities from 10^{14} to 10^{16} g/cm^3, and have magnetic fields (deduced from observations) in the range 10^{11} to 10^{13} Gauss (Zhang & Harding, 2000, p. L53, Figure 1). **Magnetars** have the strongest magnetic fields observed, as high as several times 10^{14} Gauss (Zhang & Harding, 2000). Only a few are known. They may be a variety of pulsar (they appear to be oblique rotators), but little is known about them. If they have about the same mass as the Sun, then according to general relativity they could be no denser than about 2×10^{16} g/cm^3 without becoming black holes. Lower masses could have higher densities.

Figure 13 shows polar magnetic field ranges of all these types of stars. The solid "No flux winding" baseline represents equation (20), with its 2/3 power law. The water-origin theory determines the y-intercept, giving B_p at density 1 g/cm^3. The magenta "300×" line represents a 300-fold amplification of

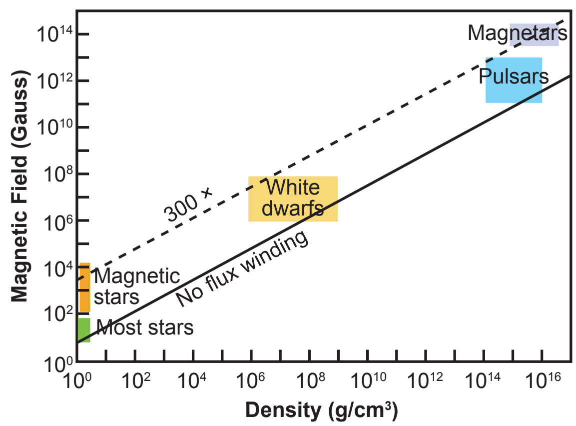

Figure 13. Polar magnetic fields of various types of stars.

the baseline field due to flux winding by differential rotation, as I mentioned previously and in the "Magnetic star" subsection. The next section offers an alternative to flux winding for explaining fields a few orders of magnitude above the baseline.

Most of the stellar magnetic observations fall between the two lines in Figure 13. This general agreement with equation (20) over a very wide range of densities and fields—up to the highest magnetic field strengths observed in the cosmos—is remarkable. Thus stellar magnetic fields strongly support the water origin theory.

Galaxies

Magnetic lines of force run parallel to the arms of spiral galaxies, both within the arms and alongside them. Figure 14 is a sketch of one observed configuration, called "bisymmetric." It has flux lines entering the outer edge of one spiral arm and leaving by outer edge of the other arm. Presumably the lines join in the central hub. The other observed configuration is the "axisymmetric" one, having flux lines in the same direction, say inward, in all the arms, with flux leaving the hub along the galaxy's axis of rotation. Figure 15 shows two computer-simulated snapshots of differential rotation. The physical and magnetic configurations observed in galaxies would result from about a few hundred million years of differential rotation (at the observed rates) of "bars" of stars and ionized hydrogen containing magnetic flux aligned along their length (Ruzmaikin, Shukurov, & Sokoloff, 1988, p. 99, Figure V.1 and p. 103).

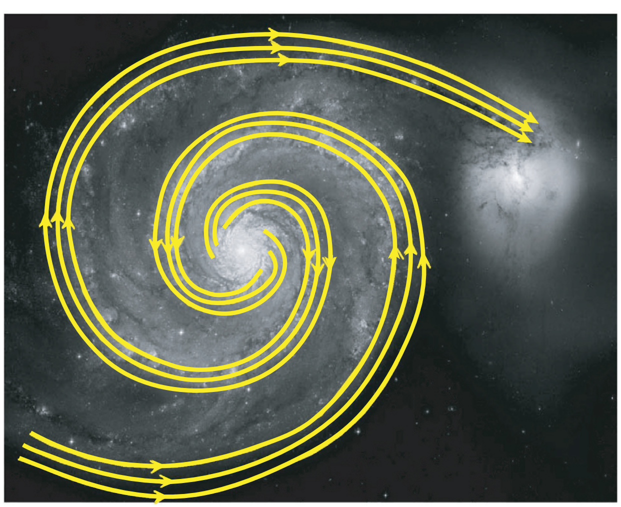

Figure 14. Typical bisymmetric magnetic flux lines superposed on "Whirlpool" galaxy as photographed by the Hubble Space Telescope (Image: NASA).

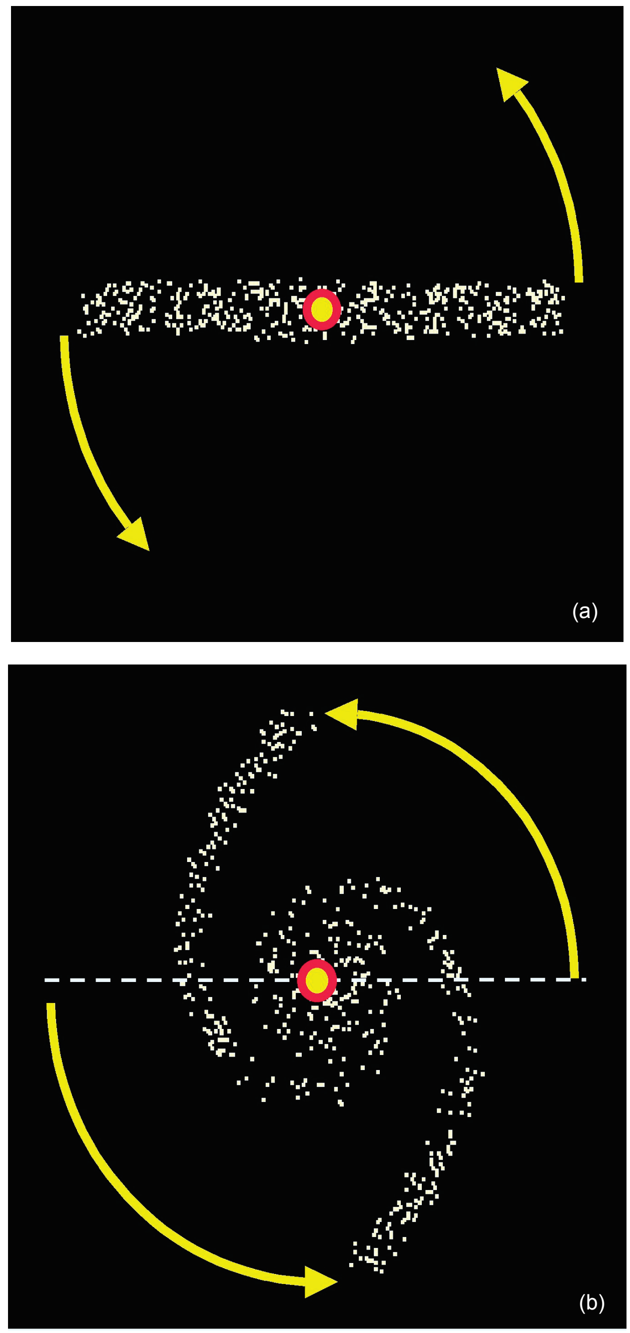

Figure 15. Simulated differential rotation of stars in a typical galaxy using observed rotation speeds. (a) Initial "bar" of stars. (b) After 100 million years as measured by the galaxy's clocks.

Uniformitarians have a problem with this simple theory: they want galaxies to be much older, up to ten billion years. After a few hundred million years, differential rotation would wind up alternating layers of opposite polarity tightly enough that the flux lines would destroy each other in the process called magnetic reconnection.

Uniformitarians also have a problem with the physical structure of the spiral arms: differential rotation at the observed rates would destroy them after a few hundred million years, smearing the spiral arms into a smooth disk of stars. To preserve both the physical and magnetic spirals for billions of years, uniformitarians have devised two complex theories: (1) "density waves" (concentrating or spreading stars) and (2) "galactic dynamos" (complex flows of plasma and stars generating magnetic fields).

Neither theory has gotten much further than the hand-waving stage. Moreover, they do not seem to be compatible with each other. For example, the waves of density would not move stars and plasma with them any more than waves in a pond move floating corks. Any spiral arms formed by density waves would rotate around a galaxy faster than the actual stars and plasma move in their orbits. The magnetic flux lines, being locked into the plasma, would not keep up with the spiral arms, contrary to observations. So the uniformitarians' insistence that galaxies be billions of years old has saddled them with two theories that don't work well either separately or together.

Creationist cosmologies, however, offer ways that all galaxies would have been only a few hundred million years old (by their clocks) when the light we observe started out from them toward us. I hope to explain this more fully in later publications. If the images we see are of relatively young galaxies, then differential rotation would be a perfectly adequate explanation of both their physical and magnetic structure.

Observations show that the average (non-turbulent) field in galaxies is in the range of 1–10 microgauss. In our own galaxy, the field averages about 2.2μG (Zweibel & Heiles, 1997, p. 133) and seems to be mainly confined within the spiral arms, in a cross-sectional area roughly 400×800 parsecs in size (Ruzmaikin, Shukurov, & Sokoloff, 1988, pp. 80, 130). That would give us a flux per arm on the order of 10^{29} Webers. That is about three orders of magnitude higher than the total flux from the individual stars in our galaxy, assuming 4×10^{11} stars (Trimble, 2000, p. 571, Table 1[10]) having flux comparable to the Sun. So how did God generate that flux? The following scenario is one possibility. The millions of years (by their clocks) worth of action would take place during one ordinary day of earth's time, the fourth day of creation.

First, a ball of ordinary-density water having the mass of 400 billion suns would have a radius of 5.8×10^{12} meters. That is much smaller than the Schwarzschild radius of such a mass, 1.2×10^{15} meters, meaning that such a ball would be well within the event horizon of a black hole! If the ball had a density of only 1 gram/cm^3, it would immediately start collapsing rapidly. Also, equations (10) and (11), which assume that density, say that the total flux in the ball would be only 8.2×10^{22} Webers, roughly a million times less than the amount of flux we need.

But suppose God created (with fully-aligned H nuclei) this ball of water already *pre-compressed* to a very high density? Equations (1) and (3) in equation (17), putting $R_c=R$, and solving for the latter gives us the radius necessary to get a given magnetic flux Φ:

$$R = \frac{\mu_0\,\alpha_0\,m}{2\Phi} \qquad (22)$$

where m is the mass of 400 billion suns, about 8×10^{41} kilograms. To get the needed flux of 10^{29} Webers, the radius of this "galactic kernel" would have to be about 1.2×10^{6} meters, about 1.4% of the radius of the sun. This ball would be even deeper in a black hole than the previous one. The density would be 1.1×10^{20} g/cm^3. The polar field given by equations (13) and (14) would be very high, 1.9×10^{14} Gauss. That is as high as the observed field of a magnetar, close to the quantum "critical" field for which the magnetic energy (dipole moment times B) of an electron is equal to its rest mass energy.

Then, to get the hydrogen that comprises most of the mass in stars and galaxies, imagine that God converts the neutrons in most of the oxygen nuclei to protons, perhaps by a process similar to the normal energy-releasing beta decay of a neutron. The resulting nuclei of 16 protons apiece would blow themselves apart immediately, releasing scores of MeV of energy per nucleus (comparable to a nuclear weapon). The extreme magnetic field would confine the particles to jets moving outward along the magnetic axis of the ball. The magnetic energy (pressure) driving the jets would be enormous, over 1 GeV per proton. Imagine now that God imparts whatever additional energy might be needed to move the jets of plasma out beyond the event horizon, producing a "white hole." Any residual mass left inside the horizon would constitute a black hole, which may be the reason most galaxies appear to have billion-sun mass black holes at their centers.

The jets of plasma leaving the event horizon (Figure 16) would carry magnetic flux outward for many kiloparsecs. For the values chosen above, the average magnetization of the plasma would be 1.25×10^{-13}

[10] With only a small contribution from the alleged "dark halo."

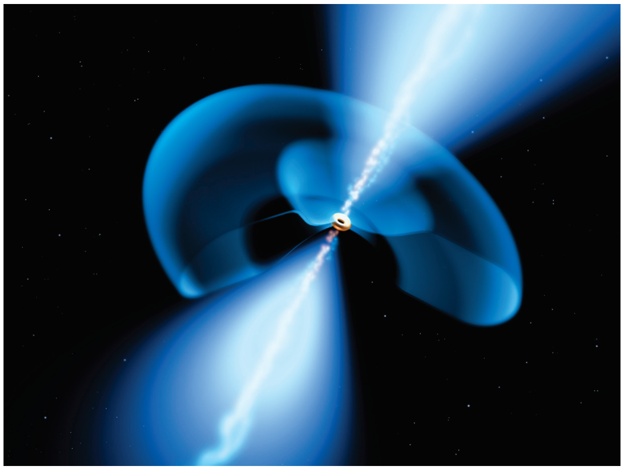

Figure 16. Artist's conception of plasma jets from a black hole. (Image: ESA/NASA).

Webers/kg, and irregularities in the turbulent plasma could produce several orders of magnitude deviations from place to place. As the plasma cooled and slowed down, God formed it into the individual stars of the galaxy, embedding flux in the stars as He did so. If there were little flux loss or cancellation during jet emission or star formation, stars the mass of the Sun would have, on the average, an initial flux of 2.5×10^{17} Webers, several hundred times the initial flux of the Sun. This would give fields falling between the two lines of Figure 13. So even though the details of the star formation scenario outlined here are different from the ones earlier in this paper, the results are the same.

The emitted jets would thus produce the "bars" of stars I mentioned earlier. Then differential rotation would twist the "bars" into spiral arms, taking the magnetic flux with them. This brief outline shows one way the water-origin theory could explain the magnetic fields of galaxies.

The Universe

The universe itself may have a magnetic field, but if so, it appears to be less than 10^{-12} Gauss (Vallée, 1990). Another article of mine estimates the mass of the "waters above the heavens": about 20 times the mass of all the stars in the cosmos (Humphreys, 2007, p.64). These waters would start as a sphere several light-years in diameter, the "deep" of Genesis 1:2. The field within the sphere would be the 7.9 Gauss in this paper. The expansion of the heavens mentioned in many Scriptures would move the "waters above" out to become a thin shell of ice particles at least 13.8 billion light-years (the currently-estimated redshift horizon) away from earth. This roughly 10-billion-fold expansion would reduce the primordial field by a factor of 10^{20}, giving us a present average field throughout the cosmos on the order of 10^{-19} Gauss. This field, on the average, would be oriented in one particular direction. This may be related to various astronomical observations reporting a "cosmic axis." Future observations may detect this weak but universal field. It would be the biggest of God's magnets.

Conclusion

Magnetic fields, or vestiges of them, appear to exist everywhere throughout the cosmos. The water-origin theory offers an explanation which works quantitatively over a very wide range of phenomena. For most of the bodies in the solar system, the theory only works for an age of about 6,000 years. Throughout the cosmos, it only works for a water origin, not for the other materials that now constitute most of the heavenly bodies, such as hydrogen, silicon, iron, and so forth. The agreement of theory and observations thus strongly supports the biblical account of Creation. God may have left us magnetic fields in the heavens as evidence of His handiwork.

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