The Sun-Earth Connection (& Other Considerations)

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Erroneous assumptions about plasmas and the implications of correcting those errors in theories based on observations of plasmas and magnetic fields in local and deep space are considered. Several behaviors of electric currents through plasma are briefly discussed on their own and with relation to a brief survey of select press releases regarding observations from local and deep space over the last decade. The spectre of revisiting foundational assumptions about space that were emplaced before the age of space telescopes, satellites and plasma physics is raised. A case is made that we should adopt a more cosmicentric model of the universe, making ubiquitous use of known aspects of plasma physics, prior to inventing 'new physics,' due to the fact that over 99% of the observable matter in the universe is in the plasma state.

1. Introduction

What is plasma? Where is plasma? Why is plasma important? Since this paper will deal with plasma, in a physical, astronomical and cosmological context and shall be read by laymen in addition to the technically inclined, it is prudent to answer these three questions first and in broad, general terms.

Plasma is a state of matter distinct from our typical daily experience of solids (ice and rocks), liquids (water) and gases (air and steam). In plasma, a non-trivial number of atoms are ionized (meaning, generally, that between one and all electrons have been knocked loose from individual atoms). Those atoms no longer have a 1:1 ratio of positive to negative charges in the nucleus and electron shells, respectively. They can be said to be individually non-neutral and the entire volume of plasma within a given radius may generally be considered only quasi-neutral (approximately equal quantities of oppositely charged ions and electrons). Since the charge carriers in plasma are freer to move about, plasma is highly conductive (but not perfectly so) and also responds more readily to electromagnetic fields.

With respect to states of matter, plasma is sometimes referred to as the 'fourth state' of matter (beyond solids, liquids and gases). With the discovery of Bose-Einstein condensates, which also have properties distinct from the usual solid, liquid and gas phases, it would not be unreasonable to even call it a 'fifth state' of matter. However, there are many who would, on account of its pervasiveness, call plasma the 'first state' of matter [1].

This brings us to the question of *where* plasma is. Point of fact: plasma is nigh **everywhere**. From observations of the cosmos, it becomes quickly apparent that upward of 99% of the *directly observable* matter in the universe is in the plasma state [2] (including, but not limited to, the interplanetary, interstellar and intergalactic media, stars and galaxies). That said, the question may rightly be turned on its ear: where *isn't* plasma?

In fact there are very few places in the universe at large where plasma does not exist. Some of the few places known for limited supplies of plasma are regions near planetary bodies, where solids, liquids and gases may form and persist [3]. We live in one of the few bastions of such phases of matter in the universe.

Why is plasma important? In order to fully understand the majority of the universe, it is necessary to properly understand and describe its constituent materials and full range of behaviors. Since the majority of observable matter in the universe is in the plasma state, it behooves us to understand plasma. However, being natives of a small provincial island of solids, liquids and gases, it may be necessary to give up a few of our cherished, but moderately geocentric, scientific models and to adopt a more cosmicentric model that acknowledges, accepts, properly describes and models the universe in terms of the plasma of which it is, in overwhelming majority, composed.

Mercifully, we can create and study plasmas in Earth-based laboratories and it has been shown that the results are scalable [4] in time and spatial dimensions over many orders of magnitude, up to and surpassing the dimensions and time scales of galaxies and other constituents of the filamentary web of matter composing the whole of the observable universe.

This paper argues, in large part from a qualitative standpoint, that a quantitative analysis based in proper electrodynamic models is called for as a counterpoint to the increasingly fanciful gravito-centric model currently in vogue. A model which coincidentally often misuses and abuses certain electrodynamic concepts (*vis á vis*, 'magnetic reconnection,' the so-called 'frozen in' condition of magnetic fields in plasma, relating to the equally incorrect oversimplification of treating plasma as an 'ideal conductor' [a superconductor] and the largely *assumed* macro-scale 'near-perfect neutrality' of the matter in space); all concepts of which astronomers should be swiftly, soundly and roundly disabused.

Such endeavors to describe our local environment and the universe at large from the perspective of plasma electrodynamics have already yielded not insubstantial fruit through the efforts of such pioneering researchers as Kristian Birkeland, Hannes Alfvén, C.E.R. Bruce, Ralph Juergens, Wallace Thornhill, Donald Scott, Anthony Peratt, Eric Lerner, and many others.

2. Theoretical Errors Corrected

2.1. Discharge Regimes

Electrical discharges can be broken down into three basic modes of discharge: dark mode (a current flows, insufficient to generate visible emissions), glow mode (a current flows, sufficient to generate a diffuse visible glow) and arc mode (a current flows, emits copious amounts of electromagnetic radiation in visible and other portions of the spectrum and may be magnetically 'pinched' into a filament).

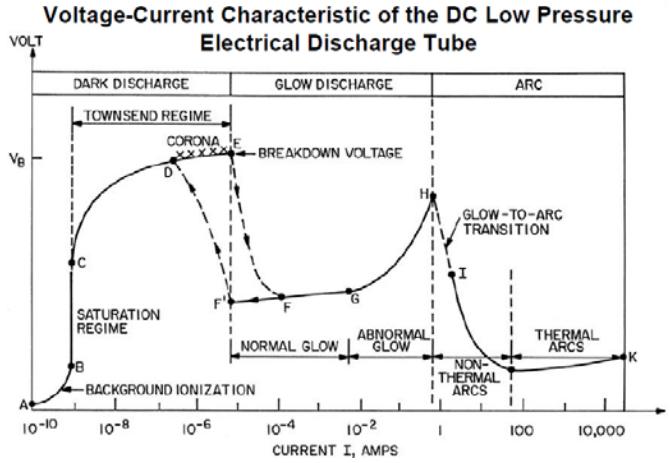

Fig. 1. Discharges are distinguished not only by their luminescence but also by their Current-Voltage characteristics, the current density and breakdown voltage. [5]

2.2. Plasma's Electrical Resistance is Non-Zero at All Times. Plasma is Not a Superconductor.

Electrical resistance can be defined by the equation:

$$R = V / I \tag{1}$$

where resistance R is the ratio of voltage V across to current I through a conductive medium [6].

In considering the known voltage-current graph of all plasma discharge regimes (section 2.1), it is quickly evident that voltage V, while sometimes low, is never strictly zero, except at the origin where no current flows (thus the origin is of no interest with respect to resistance).

Since V is always non-zero, V/I is also always non-zero. Therefore, plasma's resistance R is always non-zero. Ergo, oversimplifications aside, it is easily shown that in the real world plasma can and does support internal electric fields across all discharge regimes and is ***not*** an 'ideal conductor' (a strictly zero-resistance superconductor). The rest of the house of cards quickly falls once this error is eliminated.

2.3. Plasmas Cannot and Do Not 'Freeze in' Magnetic Fields

One erroneous oversimplification leads to another. It has been assumed, since it was assumed that plasmas were 'ideal conductors,' that plasmas are unable to sustain internal charge imbalances (AKA, voltages or electric fields). The theory went that if all regions within a plasma had identically zero-valued electric fields, as they would have to be if plasma were an ideal conductor (superconductor), then any magnetic fields within the same region of plasma would have to be time invariant ('frozen' into the plasma and carried along with it) [7].

As has been demonstrated (above) all plasmas can and do sustain non-zero internal voltages (regions of localized charge imbalance between which exist electric fields). If plasma is not an ideal conductor, and there are slight voltage differences between different points in a region of plasma, then magnetic fields cannot be 'frozen in' to plasma or 'carried along wholesale and unchanging.'

These points being well-supported, how do we proceed?

2.4. What Are Magnetic Fields?

To paraphrase the explanation offered by Drs. David P. Stern and Mauricio Peredo (authors of the NASA educational site "The Exploration of the Earth's Magnetosphere") [8]:

> "Those unfamiliar with magnetic fields often view them as mysterious properties of specially treated iron or lodestones. However, though there are few bar magnets in space, magnetic fields are pervasive."

In 1821, Hans Christian Oersted found that an electric current produced a magnetic 'force.' André-Marie Ampère resolved the mystery: magnetic fields were neither a function of independent magnetic charges (monopoles) nor restricted to bar magnets. They are a force between **electric currents**.

- Parallel currents in the same direction attract one another.
- Parallel currents in opposite directions repel one another.
- A magnetic dipole may be created by curving the current into a loop.
- Parallel loop currents in the same direction attract.
- Parallel loop currents in the opposite direction repel.
- This is true at all scales from the atomic to the cosmic.

Permanent magnets such as bar magnets and lodestones are nothing more than a special case wherein many small dipoles (at the atomic scale) line up their magnetic axes in such a way as to amplify their overall effect additively creating the larger scale magnetic field of the macroscopic object (according to the 'Ampère model' [9]).

In the lab, in and on the Sun, and in space, electric currents are the ***only*** source of magnetic fields. Put another way, Richard Fitzpatrick of the University of Texas, states in a course on classical electrodynamics:

> "...steady *electric* and *magnetic fields cannot generate themselves*. Instead, they have to be generated by stationary charges and steady currents. So, if we come across a steady *electric field* we know that if we trace the field-lines back we shall eventually find a charge. Likewise, a steady *magnetic field* implies that there is a steady current flowing somewhere. All of these results *follow from vector field theory* (*i.e.*, from the general properties of fields in three-dimensional space), *prior to any investigation of electromagnetism*" [10]. (Emphasis added.)

2.5. Do Magnetic Monopoles Exist?

The short answer: If Maxwell's Wonderful Equations are correct, as currently formulated, then no, magnetic monopoles do not exist. Maxwell's second equation:

$$\nabla \bullet \mathbf{B} = 0 \tag{2}$$

says that magnetic **B** fields are solenoidal vector fields, their divergence is zero and they are continuous (they never begin or end) [11]. Effectively, this also means that there is no such thing as a magnetic monopole.

2.6. Can Any Other 'Open Magnetic Field Lines' Exist?

For the same reason that there are no magnetic monopoles, there can be no such thing as 'open' magnetic field lines. Any claims of magnetic field lines left flapping in the [solar] wind are falsified, if Maxwell's equations are correct.

Consider a topographical map. Each elevation outline is continuous. Sometimes a contour runs off the page, maps being drawn on paper with finite space. This does not mean that the mountain is cloven in two, *in reality*. The contour simply continues on the next piece of paper. The mountain itself is whole and none the wiser of the cartographer's finite page.

The same is true of isobars on weather maps and of the 'magnetic field lines' used to visualize the contours, direction and/or strength of a magnetic field. While the 'field lines' may run off the page or outside the bounds of the simulation, it doesn't mean they don't close, *in reality*. To obey Maxwell's second equation (appropriately, equation 2, above), the field lines **must** close *somewhere*. 'Open' field lines cannot and do not exist, if we accept Maxwell's equations.

2.7. Can Magnetic Field Lines be Broken or Reconnected?

The answer is bipartite:

1. For reasons similar to those previously given with respect to 'magnetic monopoles' and 'open' field lines, if we accept Maxwell's equations, magnetic fields cannot be cut, broken and/or 'reconnected' [7][12].
2. 'Magnetic field lines' are a draftsman's artifice. They do not exist in real 3-dimensinal space as physical objects or strings that can be stretched, tangled up, cut, broken, reconnected. There is no material substance to a 'field line.' They exist only on paper as a helpful visualization tool denoting characteristics such as the strength or direction of the field [7]. Furthermore, a field line does not persist. Each moment, for instance in a simulation, all field lines or magnetic field vectors are completely re-drawn from scratch as conditions change. The pre-existing 'line' is gone forever, completely wiped out. A similar line may be redrawn nearby. However, since there is no physical tangible thing at that location, one cannot accurately say that it is the 'same line,' either stretched or relaxed, broken or reconnected. We must disabuse ourselves of this incorrect notion for progress to be made.

Nobel prize winning plasma physicist Hannes Alfvén maintained that 'magnetic merging' (or 'reconnection') was a pseudoscience perpetrated by those who failed to understand how electric currents and magnetic fields work [13].

We will return to the issue of 'magnetic reconnection' for additional discussion later in this paper.

3. Additional Plasma Properties and Behaviors

3.1. Pinch Effect (Z-Pinch, Plasma Pinch, Magnetic Pinch)

A 'pinch' is the compression of a conductor (usually plasma, but sometimes metal as in the case of lightning rods) due to self-magnetic forces [14][15]. As the current through a conductor increases, so too does the magnetic field it generates. This self-magnetic field may exert a compressing force on the conductor until equilibrium is reached between gas pressure and the compressive force of the magnetic field.

A byproduct of this effect is current channel becoming compressed into a cylinder or 'filament' [16]. Examples include lightning strokes and the filaments in plasma lamps.

3.2. Field-Aligned 'Birkeland' Currents

Magnetic fields, generally speaking, play a steering role with respect to charged particles in motion (whereas electric fields play an accelerating role). For instance, magnetic fields are used to steer the particles used in circular particle accelerators, in order to bend their paths around the accelerator.

If a current encounters a strong enough magnetic field, its path may bend to approximately follow the direction of the magnetic field.

If a particle is traveling on the plane perpendicular to the 'field line', it may simply circle the magnetic field line. If, however, the particle has a component of motion that is parallel to the field line in addition to the component that is perpendicular to it, the particle will instead follow a helical path centered on the magnetic field line. Think of it as a combination of rotating in a circle around the field line while at the same time being pushed along the line. The resulting motion would be a helix or spiral.

If many charged particles (as in an electric current) all encounter the same 'field line' they'll all have a similar reaction to it. Thus one can say that electric currents will tend to align themselves with magnetic fields becoming 'field-aligned.'

Norwegian scientist Kristian Birkeland predicted this type of action in several monographs he published in the early 1900's, regarding the auroras. Electric currents so-aligned were named after him circa the 1970's when spacecraft confirmed at least one such prediction. Such currents are alternately referred to as 'field-aligned currents' or as 'Birkeland currents.' The latter term has slowly earned a certain cachet and may refer to field-aligned currents other than those strictly in the auroral region of Earth's magnetopshere.

3.3. Long-Range Attraction, Short-Range Repulsion

Parallel currents in the same direction attract one another (section 2.4). For this reason, such parallel electric currents in lab or space plasmas are considered long-range attractive. However, charged particles often do not move strictly in a straight line, but rather move in a helical manner having two velocity components: one component in the axial direction and one circular component perpendicular to the long axis (the azimuthal component). Whereas the components of the currents aligned with the long axes are long-range attractive, the azimuthal components are short-range repulsive [17].

3.4. Doubleness, Braiding, Twisting and Vorticity

Since parallel currents are, generally speaking, long-range attractive and short-range repulsive, they do not necessarily merge into a single current as one might expect. Rather they often maintain their own identities to some degree. However, the situation is not perfectly stable and the filaments may feel a torque and become distorted [18]. This frequently leads to a braiding, twisting and/or corotation of the filaments.

These are frequent formations in plasma discharges. Moreover, these braided filaments may congregate with other similarly braided filaments to make even larger braided filaments. Some have termed such single or multiple braided filament configurations 'plasma ropes' or occasionally 'magnetic ropes' (on account of the fact the magnetic fields generated by the underlying elec-

tric currents are often easier to observe than the currents themselves).

4. Real World Examples in Local Space

Having confronted a number of stumbling blocks (section 2) and discussed several known features and behaviors of plasma (section 3), we shall now concern ourselves with examples from the real world, culled from selected geophysical, astrophysical and astronomical press releases and papers over the last decade.

Over the last century, it came to be largely accepted that the universe was largely a vacuum, in which stars and rocky bodies floated on clockwork paths according to the strictest rules of gravity alone. With that fiction came the notion that we live on an isolated rocky body, cut off from interaction with any other constituent of the universe. Much to science's detriment, this notion has been somewhat unshakable.

Not only is space not a complete vacuum, but the voids between planets, stars and galaxies is filled with dusty plasma, that plasma has structure, and is itself permeated by magnetic fields. Moreover, physical bodies engulfed in this plasma interact with it and vice versa.

For now let us speak primarily of the physical interactions between the Earth and the Sun, with brief excursions to Mercury and Mars.

4.1. Magnetic Ropes Connect Earth's Atmosphere to the Sun

In 2007, NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission observed "evidence of magnetic ropes connecting Earth's upper atmosphere directly to the sun." The magnetic ropes were described like "a twisted bundle of magnetic fields organized much like the twisted hemp of a mariner's rope." Of the dimensions, it was said to be "very large, about as wide as Earth, and located approximately 40,000 miles (70,000 km) above Earth's surface in the magnetopause." Furthermore, they "believe that solar wind particles flow in along these ropes, providing energy for geomagnetic storms and auroras" [19].

Lastly, and most indicative of the point we wish to make, the panelist multimedia for the AGU 2007 event includes a succinct graphic that summarizes what is going on. Specifically, it notes that "THEMIS discovered a flux rope pumping a 650,000 Amp current into the Arctic" and likened the interaction to there being a "30 kV battery in space" [20].

It is here suggested that what the THEMIS mission has observed are in fact magnetic field-aligned 'Birkeland currents,' the equivalent of such features predicted by the Norwegian scientist Kristian Birkeland c. 1903 and confirmed by Triad satellite measurements in the 1970's [21][22]. It is thus unclear why these are considered to be 'new' physics, when there is a century-long history of predictions and a few observations on precisely this topic. While newer and more detailed observations are always welcomed, 'new physics' (or, at least, new terminology) seem unnecessary when existing physics and terminology will suffice.

4.2. Vortex Current Bundles

To wit, LANL plasma physicist and IEEE senior member Anthony Peratt, in a 1990 paper entitled "The Evidence for Electrical Currents in Cosmic Plasma" (published fully 17 years ahead of the THEMIS findings), addressed precisely this issue from the electrical / plasma vantage point:

> "The tendency for charged particles to follow magnetic lines of force and therefore produce field-aligned currents has resulted in the widespread use of the term 'Birkeland currents' in space plasma physics. Their discovery in Earth's magnetosphere in 1974 has resulted in a drastic change in our understanding of aurora dynamics, now attributed to the filamentation of Birkeland charged-particle sheets following the Earth's dipole magnetic-field lines into *vortex current bundles*" [23]. (Emphasis added.)

Consider that twisted or co-rotating 'vortex current bundles' would likely produce magnetic fields resembling those said to be "organized much like the twisted hemp of a mariner's rope."

4.3. Magnetic Portals Connect Earth to the Sun

In 2008, the THEMIS and Cluster satellites discovered that 'magnetic portals' through the magnetosphere open and close frequently (as often as every 8 minutes) allowing charged particles from the solar wind to flow through. "[Charged particles in our magnetosphere] enter by following magnetic field lines that can be traced from *terra firma* all the way back to the sun's atmosphere."

The opening and closing 'magnetic portals' they call 'flux transfer events.' They describe the interactions as follows:

> "…Earth's magnetic field presses against the sun's magnetic field. Approximately every eight minutes, the two fields briefly merge or 'reconnect,' forming a portal through which particles can flow. The portal takes the form of a magnetic cylinder about as wide as Earth" [24].

It is here suggested that what is being witnessed are electrical discharges between regions of imbalanced space charge. Any filamentary discharge of this type will generate its own encompassing magnetic field. Is it plausible that the 'magnetic cylinders' observed are merely byproducts of electric current?

4.4. The Auroras Shine 24-7 if You Know Where to Look

"Imagine living on a planet where Northern Lights fill the heavens at all hours of the day. Around the clock, even in broad daylight … Astronomers have discovered such a planet. Its name is Earth" [25]. In a 2008 press release from Marshall Space Flight Center, we learn that while visible auroras may only be so at specific times (usually at night or during large solar storms), the auroras shone 24-7 if you look in the right part of the spectrum (for instance, in the ultraviolet portion) with satellites. Since the Polar satellite had a good vantage point and the proper sensor(s), its data has been invaluable in establishing the fact that auroras shine all day every day (albeit in parts of the spectrum invisible to the naked eye).

4.5. Cluster's 'Magnetic Reconnection' Data

In 2007 and 2008, the Cluster satellites made great strides in collecting data about our magnetosphere's structure and behaviors. One such item of great interest was the data relating to substorms and the auroras.

In a 2007 press release, it is learned that scientists have detected **electric fields** in the magnetospheric plasma near so-called 'reconnection' sites [26]. This appears a strong indicator that the supposition of plasma being an 'ideal conductor,' in which electric fields cannot be sustained, is physically incorrect (falsified on its face), with implications for the theory of 'frozen in' magnetic fields in plasma (see sections 2.2 and 2.3 of this paper, above), which relies on plasma's perceived status as an ideal conductor. It also notes that so-called 'reconnection' can trigger bipolar jets of particles, which may be important later in this paper (section 4.6).

A related press release from 2008 provides additional data to be considered with respect to substorms, 'reconnection' and the auroras. In it, graphics and data of the magnetic and electric fields of a reconnection region are provided, with mention of electron trapping at a magnetic 'null point' central to the 'reconnection' region [27].

4.6. Is it Really 'Magnetic Reconnection'?

We have previously noted that Maxwell's equations (as currently formulated) do not allow for 'magnetic monopoles,' nor for 'open' magnetic field lines (see sections 2.5 and 2.6, above). We have also stated that 'magnetic field lines' are not a physically real material substance taking up 3 dimensional space. Rather they are a draftsman's artifice, a useful visualization tool standing in for the topology, strength and direction of magnetic fields, which are themselves generated by electric currents. Thus, we believe 'magnetic reconnection' to be a poorly predicated and erroneous theory. What then should take its place?

In his 2007 paper [7], electrical engineer Don Scott addresses the issue of 'magnetic reconnection' (among other prevailing astrophysical misconceptions he endeavors to set right) and proposes an alternative theoretical construct in accord with Maxwell's equations as well as known plasma behaviors.

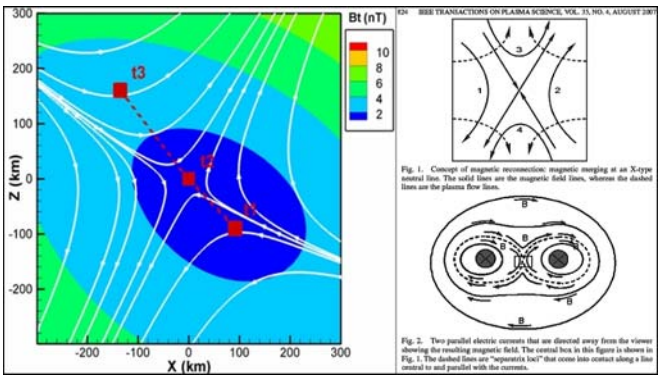

Fig. 2. *Left:* Magnetic field lines around a magnetic null observed by Cluster. Image credit: He, J.-S., *et al*. *Right:* Figs. 1 & 2 from Real Properties of Magnetic Fields in the Cosmos [7]. Image credit: Don Scott.

In short, the graphic detailing magnetic field lines observed by Cluster appears to equate well with the central region of a larger set of magnetic fields that would be created by parallel current filaments. It is suggested that the Cluster data may give only a partial glimpse of the overall situation. Additional observations would be of great merit in determining which model is physically correct, *experimentum crucis*.

4.7. Electrical Tornadoes Power the Auroras

In 2009, we are told, the THEMIS (Time History of Events and Macroscale Interactions during Substorms) satellites flew through structures that the teams could best characterize as "'space tornadoes,' which span a volume as large as Earth and produce electrical currents exceeding 100,000 amperes," defining a 'space tornado' as "rotating plasmas of hot, ionized gas flowing at speeds of more than a million miles per hour," further stating that "space tornadoes ... generate huge amounts of electrical currents inside the funnel. These currents ***flow along twisted magnetic field lines*** *from space* into the ionosphere where they power several processes, most notably bright auroras such as the Northern Lights" [28]. (Emphasis added.)

Here, again, we see structures in space that may easily be characterized as powerful (100k+ Ampere) magnetic field-aligned electric currents (see section 3.2), displaying vorticity or corotation (see section 3.4), all features expected of electric currents flowing through plasmas in the lab or in space.

4.8. 'Magnetic Tornadoes' at Mercury

Let us next take a brief excursion to Mercury, where the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft is preparing to enter orbit as this paper is being written (2011). However, we will revisit an earlier encounter from a flyby in 2009.

In this release, we learn that it is now believed that "through a process called 'sputtering,' solar wind particles that crash into Mercury's surface transfer sufficient energy to launch some atoms into ballistic trajectories high above the surface and replenish Mercury's atmosphere."

The science release for the flyby under question also notes that in order for the solar wind to liberate particles from the surface, it must get past Mercury's magnetosphere.

It turns out Mercury isn't so different from Earth, at least in terms of magnetospheric structures and processes. During the flyby, "the spacecraft encountered magnetic 'tornadoes' – twisted bundles of magnetic fields connecting the planetary magnetic field to interplanetary space – that were up to 500 miles wide or a third of the radius of the planet" [29].

This author strongly suspects that these 'magnetic tornadoes' are equivalent to the 'electrical tornadoes' observed to power our own auroras (section 4.8), and that the 'twisted bundles of magnetic fields' are equivalent to those observed in relation to so-called 'magnetic ropes' or 'flux ropes' (section 4.1).

We also see a reuse of 'flux transfer events' (in this case apparently the preferred technical term over the equivalent, but more colloquial, 'magnetic portals'; section 4.3).

All of these we consider equivalent to the magnetic field-aligned 'Birkeland' currents described by plasma physicist Anthony Peratt as 'vortex current bundles' (section 4.2) and referred to ubiquitously in both the Plasma Cosmology and Electric Universe models.

5. Real World Examples in Deep Space

Now that we've seen several examples of features in our solar system and near-Earth space which can be reasonably shown to be electrical in nature, it is not unreasonable to apply the same

logic to the rest of space. Are there examples of structures in space that can reasonably be said to indicate the presence of electric currents or any of the other the aforementioned plasma processes (see section 3)?

5.1. A Nebula Shaped like DNA (or Corotating Current Filaments)

More confidently here suggested to be electrical in nature is a double helix-shaped nebula, which is gives the visual impression a giant strand of DNA (hence also earning it the affectionate nickname 'DNA Nebula').

Commentators on this discovery, could only gape in slack-jawed awe and remark, "Here's one that scientists really weren't expecting: an entire nebula shaped like a DNA double helix ... Nobody has ever seen anything like that before in the cosmic realm." Perhaps not in the *cosmic realm*. The plasma physics lab, on the other hand, is an entirely different story. In the lab, not only are such features ***not*** *surprising*, they are **expected**. Such twisting, braided formations are commonplace when parallel electric currents flow through plasma (section 3.4).

Also suggestive are the following comments:

> "Astronomers studying the image believe that the irresistible pull of magnetism created the intertwining spiral strands. Strong magnetic-field lines, perhaps a thousand times more powerful than those around the Earth, run through the nebula" [30].

Under an electrical interpretation this sounds approximately correct. Parallel electric currents are long-range attractive and short range repulsive (section 3.3) and may feel a torque that causes the currents to twist and braid around one another (section 3.4). In addition, currents tend to become field-aligned (section 3.2), thus the revelation that strong magnetic fields run through the nebula and may play a non-trivial role in shaping it is not altogether surprising.

Additional speculation from the release, that magnetic field lines are somehow anchored to nebular clouds rotating around a black hole at the galactic center, which then twist and tangle the magnetic field lines as though they are rigid material entities, is merely that: speculative and, in this author's opinion, completely unnecessary in the face of known electrical processes capable of explaining the structure without resorting to borderline 'new physics.'

5.2. Astronomers Find a 'Magnetic Slinky' in Orion

In 2006, researchers from the University of California, Berkeley, presented findings indicating what appeared to be "the first discovery of a helical magnetic field in interstellar space, coiled like a snake around a gas cloud in the constellation of Orion." To illustrate the point, they invoked the image of "a giant, magnetic Slinky wrapped around a long, finger-like interstellar cloud" and "magnetic field lines … like stretched rubber bands; the tension [squeezing] the cloud into its filamentary shape."

Of the observation techniques, they had the following to say:

> "Using the [Green Bank Telescope], Robishaw and Heiles observed radio waves along slices across the Orion Molecular Cloud and found that the magnetic field reversed its direction, pointing towards the Earth on the upper side of the cloud and away from it on the bottom. They used previous observations of starlight to inspect how the magnetic field in front of the cloud is oriented ... When they combined all available measurements, the picture emerged of a corkscrew pattern wrapping around the cloud" [31].

As we've come to see over the course of this paper, scientists and journalists grappling with physics often resort to analogies and colorful language when presenting new data. We must look past obfuscations and the vagaries of language and see what is actually being described with a cool and calculating eye.

To wit, we know that electric currents in lab and space plasma tend to 'pinch' and become filamentary (section 3.1), and that an electric current generates an encompassing magnetic field. Is it then plausible that such observed magnetic fields indicate the presence of electric currents flowing through the dusty plasma of the nebula? It appears a reasonable extrapolation.

However, Heiles offers a note of caution that another explanation may be possible: "The field might be wrapped around [only] the front of the cloud … [the nebula] happens to lie inside the hollowed-out shell of a very large shock wave that was formed when many stars exploded in the neighboring constellation of Eridanus. That shock wave would have carried the magnetic field along with it, he said, 'until it reached the molecular cloud! The magnetic field lines would get stretched across the face of the cloud and wrapped around the sides.'"

It is this author's opinion that the cautionary note above can be safely disregarded. Here we must return to reality, to Maxwell's equations and to the known properties of plasma. Maxwell's equations, if they are correct (and a century of science and industry appears to bear out that contention), then magnetic fields are solenoidal, their divergence is zero and all field lines must close (the fields are continuous). Magnetic monopoles do not exist, neither 'open' magnetic fields lines nor reconnection. Moreover, plasma is not an 'ideal conductor' (zero-resistance superconductor) and is not able to either 'freeze in' or 'carry along' magnetic fields, unchanging. Thus the contention that magnetic fields could be 'carried along' by a shock front or discontinuously 'draped over' the nebula with what one assumes would have to be 'open field lines' is not supported physically (by known properties of plasmas) or mathematically (by Maxwell's equations).

Heiles goes on to dismiss his own cautionary note, for other reasons, saying "What really convinces us that this is a helical field is that there seems to be a constant pitch angle to the field lines across the face of the cloud."

One additional statement of note surfaces out of the report: "In making theoretical models of these clouds, most astrophysicists have treated them as *spheres* rather than *finger-like filaments*. However, a theoretical treatment published in 2000 by Drs. Jason Fiege and Ralph Pudritz of McMaster University suggested that when treated ***properly***, filamentary molecular clouds should exhibit a helical magnetic field around the long axis of the cloud. This is the first observational confirmation of this theory." (Emphasis added.)

Effectively, this passage admits that many, if not most, astrophysicists have misused and abused both physics and math in treating such nebulae. This author would suggest that the error

has been applied to many such filamentary features at larger and smaller scales. This can precipitate an unfortunate case of garbage in, garbage out, whereby an erroneous assumption leads to erroneous results. But why is this particular abuse of interest?

5.3. Magnetic Field of a Spherical Dipole vs. a Long Thin Filament

It is roundly claimed that gravity rules the cosmos and that A) plasmas cannot support internal electric fields, thus are of no consequence (this is clearly a false assumption on its face; section 2.2) and B) magnetic fields fall off exponentially with the cube of the distance, whereas gravity falls off with only the square of the distance (thus it is claimed that the reach of gravity is superior to the reach of magnetic fields).

It is true that a spherical dipole magnetic field falls off with the cube of the distance from the source [32]. However, a different equation is used when considering a 'long thin wire' (generally, a long thin current through any conductive medium: plasma, wire or potato). A long straight electric current generates a magnetic field that falls off not with the third power of the distance (as with a dipole magnetic field), nor with the second power of the distance (as with gravity), but with the first power of the distance (the distance itself) [33]. That is to say, whereas a magnetic dipole and a source of gravitation lose their force exponentially (with gravity's reach exceeding that of a dipole magnetic field), a long thin electric current's force falls off only linearly, making it the ***longest-reaching*** force available!

If this is true, does this not mandate a reconsideration of one of the most fundamental assumptions of the space age: that gravity is the sole arbiter of cosmic behavior?

5.4. Our Filamentary Universe

"One of the earliest predictions about the morphology of the universe is that it be filamentary (Alfvén, 1950) In the laboratory and in the Solar System, filamentary and cellular morphology is a well-known property of plasma… plasma at astrophysical dimensions must also be filamentary. During the 1980s a series of unexpected observations showed filamentary structure on the galactic, intergalactic, and supergalactic scale… The observational evidence for galactic-dimensioned Birkeland currents is given based on the direct comparison of the synchrotron radiation properties of simulated currents to those of extra-galactic sources including quasars and double radio galaxies" [34].

It is now known with reasonable certainty that the universe is structurally composed of filaments, walls, and voids, not unlike those structures seen regularly in laboratory plasmas. One can take as an example the recent discovery that galaxies often show a common axial alignment along large filaments, "like beads on a string" [35].

Is it not then at least conceivable that the filamentary structure of the cosmic web itself comes from the same self-magnetic forces felt by electric currents through a plasma medium? Is it plausible that the 'pinch effect' applies just as readily to supergalactic scales as it does to solar system and microscopic scales?

6. Conclusion

We've seen examples of 'magnetic ropes' connecting the sun to the Earth, 'magnetic portals' being dynamically generated as charged particles flow into the magnetosphere, 'electrical tornadoes' sparking the auroras while 'magnetic tornadoes' allow the solar wind to machine the surface of. Moreover, we've seen cosmic plasma twisted into filaments and double helixes, not to mention molecular clouds encompassed by a corkscrew-shaped 'magnetic slinky.'

While terminology may differ from mouth to mouth, it seems reasonable to conclude that such diverse structures as magnetic ropes, flux ropes, flux tubes, magnetic portals, electrical tornadoes, magnetic tornadoes and flux transfer events may share a certain underlying physical basis. Specifically, many of these structures involve charged particles moving in alignment with local ambient magnetic fields. Moreover, they produce encircling magnetic fields which are more easily observed.

Is it not reasonable to suppose that these features are in substantial accord with the features of field-aligned 'Birkeland' currents and that very little 'new physics' should be necessary in order to understand and properly identify them? Keeping in mind that plasma structures and behaviors scale over many orders of magnitude, from the lab to the cosmos.

Where we see magnetic fields encircling filamentary structures, we should now know to ask, *by default*, "what electric current structure generates the magnetic fields we're seeing?"

If we now further accept that plasmas are not superconductors and do not 'freeze in' magnetic fields, must we not consider that all magnetic fields observed ubiquitously in local and deep space must take root in nearby electric currents, which are likely driven by voltages (large-scale electric fields) inherent to the cosmic plasma itself? Also, if long thing filamentary currents (as in the DNA-shaped nebula or the cosmic web) produce magnetic fields that fall off not with the cube of the distance from these sources but linearly, must we not consider these forces with a closer eye when evaluating which forces may be dominant in shaping the cosmos?

As a starting place, it is suggested that work be done to further the progress of electrodynamic simulations of the cosmos. A starting place may be the dual papers [36, 37] on the **Evolution of the Plasma Universe** (Peratt, 1986). Out of which papers, as an aside, appears to come an explanation of galaxy rotation curves without resort to 'dark matter' or other 'new physics.'

One must agree in spirit with electrical engineer Don Scott, who states:

> "Maxwell showed that magnetic fields are the inseparable handmaidens of electric currents and vice versa. This is as true in the cosmos as it is here on Earth. Those investigators who, for whatever reason, have not been exposed to the now well-known properties of real plasmas and electromagnetic field theory must refrain from inventing 'new' mechanisms in efforts to support current-free cosmic models. 'New science' should not be invoked until all of what is now known about electromagnetic fields and electric currents in space plasma has been considered. Pronouncements that are in contradiction to Maxwell's equations ought to be openly challenged by responsible scientists and engineers" [7].

Perhaps, in time, future generations will find Nobel prize winner Hannes Alfvén's assertion that "gravitational systems are the ashes of prior electrical systems" ringing equally true.

One hopes that the basic case for properly describing the form and function of electric fields, electric currents and magnetic fields in plasma is made. As well, the fact that we should disabuse ourselves of several physical fallacies (plasma-as-superconductor, 'frozen in' field lines, 'reconnection') currently engrained into the fabric of the astrophysical sciences and be vigilant about exploring all the known physical laws before resorting to 'new physics.'

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