Exploration of Electromagnetic Energy Between Stars Planets and Planetary Objects Using Digital Twins

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*Abstract*—A relevant and current bias is derived from three centuries usage of *gravitation* before implementation of *Magneto-Hydro Dynamics (MHD)*. An overestimation of the role of neutral matter resulted, compared to more dominant *electromagnetic* (e.m.) phenomena effecting the state of matter inside deep planetary interiors. *Long wavelength e.m.* energy *induction* effects thus remain unaccounted. In addition to the classical processes, the rigorous generalization of the *Cowling theorem*, which is a debated classical concern of astrophysics since 1934, leads to the definition of the “*Cowling dynamo*”. Closed trajectories always occur in finite systems. The *Cowling dynamo* applies to every closed path of charged particles and is the prime process of *MHD* as it explains the transformation of thermal and kinetic energy into e.m. energy. This is a crucial and universal process at all space and timescales. It applies to micro-processes and upscales to stars, galaxies, and galactic superclusters. This is a universal result, almost like the Pythagoras theorem. The *Cowling dynamo* can explain a long list of phenomena that are presently reported as unexplained. Likewise, *variation principles* are a generally underestimated tool that are likely the backbone for understanding several phenomena in physics and other disciplines. The role of *Hamilton’s variation principle* must be emphasized. *Gravitation* makes matter implode altogether, the *Cowling dynamo* determines strong self-confinement of charged matter and the self-collimation of jets, while thermonuclear (fusion) reactions impose an explosive breaking of any confinement and forbid any excessive concentration in space of both matter and energy. The role of nuclear magnetic moments justifies the existence of a previously unnoticed state-of-matter, i.e. “*magpol*” (after *magnetic polarization)*, that can explain the mysterious leading dipolar component of the geomagnetic field. *Digital Twin composite* representations of these mechanisms, that govern our magnetic fields B, will account for *long wavelength e.m.* improving capabilities to forecast and manage solar disruptions for *space mission awareness* and *solar-terrestrial relations*.

Keywords—gravitation, Magneto-Hydro Dynamics (MHD), electromagnetic, long wavelength e.m., induction, Cowling dynamo, Hamilton’s variation principle, magpol - magnetic polarization, Digital Twin composite, space mission awareness, solar-terrestrial relations

# Introduction to Bias in the Historical Heritage

A relevant historical bias derives from the almost three-century gap between gravitation by Newton (1687), through Maxwell (1865), through the implementation of Magneto-Hydro Dynamics (MHD) (Alfvén, 1950). The 300-year delay caused an overestimation of the role of neutral matter with respect to more dominant electromagnetic (e.m.) phenomena. Thus, long wavelength e.m. energy induction effects remain unaccounted. Consider objects with disjoint components that - owing to tidal forces - can move relative to each other. These objects are characterized by a *tide-driven (TD) dynamo*, such as occurs on Earth. The energy released by the TD-dynamo of the Earth supplies all endogenous phenomena. This correlation between an endogenous **B** and tectonism is similar on other planetary objects and denotes a Joule-heat energy source. TD-dynamos are a common feature in all objects of the Solar System. A representative parameter is the product of the object-diameter times the local spatial gradient of gravitation [1. 2].

# Cowlings Dynamo

In addition to the classical processes, the MHD dynamo (*Cowling dynamo*) applies to stars (according to the former proposal by Larmor in 1919-1920 [3]), to galaxies, and to galactic superclusters, affecting the state of matter deep inside of planetary interiors. The rigorous generalization of the Cowling theorem, which is a debated classical concern of astrophysics since 1934, leads to the definition of the “Cowling dynamo” which explain how MHD transform thermal and kinetic energy into e.m. energy (Fig. 1). Given an ionized fluid with an internal dynamic (such as with convection cells or other), two, and only two, kinds of performance can be envisaged.

This is a crucial and universal process at all space and timescales. This is a general result, almost like the Pythagoras theorem, that applies everywhere. In 1934 Cowling [4] proved that a system with ideal cylindrical symmetry cannot be a self-sustained dynamo. Since then, the classical Cowling theorem has been a nightmare for all solar and stellar MHD modelers. The theorem was later proven, with different approximations, in several different ways. The *generalized and rigorous proof* of the theorem [1] gets rid of such a nightmare. The Cowling dynamo can explain a long list of phenomena that are presently unexplained. A leading result deals with the “*Biermann blocking*”. Biermann in 1941 [5] pointed out that **B** inside sunspots is so large that electrons are trapped along **B** field-lines. That is, the system forbids cooling of its elements by means of its own generated **B** field. In this respect, the Cowling dynamo imposes that the Sun, or a star, is self-confined and blocked by the huge **B** of the Cowling dynamo. That is, the Sun or a star should be strictly forbidden to release even one photon. But this is a paradox in terms of energy balance. Thermonuclear (fusion) reactions get rid of such a paradox. The final scenario is that gravitation makes matter to implode, the Cowling dynamo determines strong self-confinement of charged matter and the self-collimation of jets, and thermonuclear (fusion) reactions impose an explosive breaking of any confinement and forbid any excessive concentration in space of emp (emp denotes the sum of energy and mass, acronym for energy, mass, primordial).

A remarkable implication of the Cowling dynamo deals with the observed self-collimation of the solar wind, which is reported in the literature not to be explained. On much larger scale-size, the identical mechanism applies to astrophysical jets or filaments, and to the alignment of stars inside galaxies, and of galaxies inside galactic superclusters. But an implication of paramount importance is the conversion of cloud convection into e.m. energy that explains the transient luminous events (TLEs), and of the deadly "terrestrial gamma flashes" (TGFs), which are eventually responsible for unexplained air-crashes. But a most important effect is the positive charging of the ionosphere. The positive sign derives from the positive charge of the solar wind (see below). The Cowling dynamo thus supersedes the old and logically feeble generally agreed assumption by Wilson [6]. The phenomenon finally results into the generation of a large electrostatic charge of the ionosphere, which is an exploitable huge source of clean energy that will exist while the Sun shines [7].

# Variation Principles

Likewise, variation principles are a generally underestimated tool, that are likely the backbone for understanding several phenomena in physics and other disciplines. The role of Hamilton’s variation principle [8] must be emphasized. Engineers often use variation principles. Every axiomatic formulation of higher physics relies on variation principles. In contrast, usual applications in Earth science do not take advantage of this powerful tool – e.g., no physical justification was ever given for the existence of the neural sheet inside the magnetosphere: Hamilton’s principle is a straightforward physical explanation.

Opposite to the variation principle approach, present science is fully oriented on the fully equivalent continuity-approach by differential calculus. But no infinitesimal entity exists, neither any infinite quantity. The limit either to zero or to infinity is a scheme suited for the limited capability of human mind. Max Planck got rid of the paradoxical consequence of the continuum hypothesis by means of discrete quanta. In this respect, MHD relies on the continuity assumption. The consequent logical drawback implied to “kill” Maxwell equations, by which a **B** field-line are broken and “reconnected”. That is, “reconnection” is a clever and generally agreed trick aimed to save the formalism of continuous MHD, even when the charge of an electron is smeared out in space. Differently stated, “reconnection” is an unphysical and approximate trick, while physics ought to refer to particle/particle interaction.

The argument for energy transport inside the Earth or a planetary object, is as follows. Every current **j** generated inside the object expands as much as possible, due to Hamilton’s, and reaches a region where a rapid decrease occurs of electric conductivity **, where **j** decay by Joule heat. If a lesser bump occurs on the surface reached by **j**, the smaller the local radius of curvature of the surface, the greater the **j** concentration, the greater the Joule heat, and ** increases. Thus, the **j** can propagate upward. The former bump shrinks, and a spike is formed: the interior of the object thus reminds one about a sea-urchin.

# Magpol – Magnetic Polarization

Refer to a planetary object. The state-of-matter is “cold” at its surface, where chemistry and biology exist, altogether with crystalline bonds, and solid, liquid and gas state. This is a negligible fraction in the universe, compared to the amount of ionized matter - and maybe even more, compared to “dark matter”, i.e., matter where atomic nuclei are totally ionized, i.e., “naked”. That is, nuclei can be said “naked” when they have no electrons in their electron shells and cannot emit visible photons. In fact, deep inside a planetary object, the transformation of gravitational compression into kinetic energy determines an increase of temperature, hence of ionization. When ionization is large, a state is attained that reminds about the “metallic state” that planetologists claim to characterize the interior of Jupiter and of other outer planets. Jupiter is said to be composed of “metallic hydrogen”, i.e., of protons that have lost their electron, i.e. they are “naked”. “Naked” nuclei interact due to their respective magnetic nuclear moments. That is, “naked” nuclei are packed altogether, all pointed in the same direction, and generate a state that reminds about a fibrous structure, with a parallel orientation of nuclear magnetic moments. This state-of-matter, compared to the metallic state that is basically an MHD medium, is a different state that can be called “magpol” (acronym of magnetic polarization state). Repulsive forces of the positive magpol core hypothetically produce a natural tetrahedron conductor surrounding the magpol.

The magpol state is the likely condition of the inner core (IC) of the Earth that, according to textbooks of solid Earth, is generally claimed to be “solid”, just because it is crossed by S waves (i.e., shear waves). It is unbelievable, how seismologists propose an explanation that is inconsistent with the assessment of solid-state physics. The magpol state can be crossed by S waves due to the coupling between nuclear magnetic moments, reminding one about a state that is like a solid crystalline bond. The force between nuclear magnet moments is likely to be stronger than crystalline bonds, being a second quantization effect. This is also the explanation of the overwhelming dipolar component of the geomagnetic field. In addition, the so-called diamond-anvil experiments are carried out by clever experimenters who guess having thus reproduced the state-of-matter in the deep outer core or even deeper. In contrast, they are likely to reproduce the state-of-matter located much above the metallic state layer.

A related concept is the battery behavior of the Earth, which stores and releases energy at different times. Energy can be stored either chemically, or inside a condenser, or by a change of state. Inside the Earth, energy is stored by a change of state, as shown, e.g., by the change vs. time of the radius of the IC of the Earth since AD 1400. The IC radius that is plotted in Fig. 2 is derived by applying an energy balance argument to the observed geomagnetic secular variation. The difference with respect to the seismic value is envisaged by the seismic determination available during the last several decades. [1].

It should be stressed that identical arguments apply to every planetary object of suitable size. But two additional processes have to be taken into account: (i) the implications derived from the TD-dynamo process (see below), and (ii) an eventual nuclear reactor. Herndon [9] formerly envisaged a nuclear (fission) reactor inside the Earth that ought to have been active, perhaps, during the first 2-2.5 Ga of Earth’s history. Observational evidence is given by the Oklo nuclear reactor (Gabon), and by the ratio 3He/4He inside rocks, which is too high compared to the atmospheric ratio, and it ought to have been originated during the early time of Earth’s history. No other explanation seems available for such a He anomaly.

# States of Matter within Celestial Objects Interiors

In the 1930s interplanetary space was believed to be empty and crossed by clouds of matter that had to be supposed electrically neutral to avoid being spread through space. After 1958 the Parker MHD model [11] and in situ records showed the existence of the solar wind, with self-collimation through the Cowling dynamo. However, the paradigm of electrically neutral solar wind still survives. In addition, the size of the Earth or of a planet is much smaller than the size of a solar streamer. The Earth’s magnetosphere intercepts a fraction ~ 0.45 × 10-9 of the expanding solar corona. It is therefore reasonable to expect that the Earth - like every planetary object - is steadily impacted by a self-collimated, and largely variable, flow of solar wind having some non-null total electric charge. That is, electrostatic forces are expected to play an even crucial role in the interaction of every object with the solar wind.

All charged particles on the Sun are trapped around **B** field-lines. The gyration radii of electrons are several ten thousand times smaller than the gyration radii of protons or of positive ions. Thermal evaporation implies mechanical stripping of particle from their trapping orbits. Protons and positive ions have greater chance to be ejected into the expanding solar corona. Hence, the solar wind is positively charged (mean value) and the Sun gets progressively negatively charged. When the Coulomb repulsion on the Sun is above a threshold, ejections occur of electrons. The phenomenon is cyclic. That is, the sunspot cycle is electrostatic. Huge van de Graaff generators periodically project through space violent electron jets that break though the photosphere looking like sunspots. These huge electron flows cause electron-auroras on the Earth and on other objects.

The Pluto/Charon binary system is most interesting. In fact, both orbital planes are the same, either of the couple Pluto/Charon, or of their 4 mini-satellites. This common plane is perpendicular to the ecliptic plane. [12, 13]. In addition, all four mini-moons are fast-spinning rocky bodies with rotation poles perpendicular to - and with “strategic” location - inside the Pluto-Charon orbital plane [14, 15]. These features, which are completely unexplained in any other way, can be very easily explained if Pluto, Charon, and all mini satellites have an electrical charge, because orbiting and spinning objects generate a **B** field that interacts with IMF. Pluto/Charon looks to be therefore a natural lab suited to check the non-vanishing electric charge of the solar wind [16]. In addition, the unimaginable variety of the landscape on both Pluto and Charon is an unexpected test for the validity of the TD-dynamo, due to the varying efficiency of the TD dynamo during the Hadean year, depending on the highly eccentric orbit [15].

# Exploration of Digital Twin Planetary Stellar transformers

Digital Twins are illustrated in a framework of considering long wavelength e.m. fields when celestial objects act as Stellar Transformers. This is a natural process like the electrical transformer process that steps down energy generated at a power plant to your home or business. Digital Twin Predictive Model composite representations can account for the processes and mechanisms that govern magnetic fields **B** long wavelength e.m. energy induction effects. These effects are presently unaccounted, due to a current bias treating this process within a gravitational framework. Gravity application captures only a small component of tidal energy related to friction, while completely ignoring induction effects that can occur within internal magnetic elements. These induction effects are multi-directional X, Y, and Z and associated with natural occurring elements outlined in Fig. 3. The Stellar Transformer model [17] accounts for long wavelength e.m. induction effects improving capabilities to forecast and manage solar disruptions for space mission awareness and environmental consequences on Earth substantially improving weather models.

## Structured Earth Elementals

Structured Earth elementals can be intuitively and approximately explained in terms of three geospatial components of the e.m. induction process [17].

Earth's Axial-Y dipole induction effects the poloidal (E) electric field primarily induce into polar connected North-South circuits of the Mid-Ocean Ridges (MORs), Western Pacific Rim, and inner core. Trends of mantle circuits can be mapped with satellite mantle *g*ravityimaging of the thermal signatures given off through Joule heat of the MOR circuits [18, 19] (Fig. 3).

Earth's Radial-X induction effects of the toroidal (E) electric field, primarily associated with variations of the magnetic moment of solar winds Interplanetary Magnetic Field (IMF) strength and polarity variability, concern the Earth's outer core and the East-West oriented “orthogonal” fracture systems (Fig. 3) as “COILS” of Earth’s *Stellar Transformer*[20].

Earth's Vertical-Z induction effects, primarily associated with magnetic moment of Sun-Moon tidal variations i.e., *TD dynamo*, affects volcanic and magmatic electric Joule spike (anode plasma tufts) energy production [1] (Fig. 3).

## Magnetic Moment Alignment

Changing magnetic fields associated with solar cycles and activity such as sunspots, solar flares, coronal hole sweeps and mass ejections drives Earth-Sun transformer induction energy processes [17] (Fig. 3). Induction characteristics are determined by magnetic moment alignments between layers in the Earth and polarity. The alignment and polarity determine the variations of electric charge that occur due to the non-neutral electric charge of the solar wind. The interplay of attractive and repulsive forces within the magpol core distributes charge on our planet [17] (Fig. 3). To simplify the understanding of the relationships, solar coronal holes that are aligned with the Sun’s North-South polar axis approximates axial induction elements while those aligned with the equator can be considered radial induction elements [17] (Fig. 3). Many coronal hole configurations represent some combination of the axial and radial elements. These dark coronal holes on the Sun represent the induction current elements of the *Solar Stellar Transformer* (Fig. 3), important because *the elements on Earth* *are directly energized by alignments between these Sun-Earth elements controlled by* *magnetic moment* orbital physics [17]. The vector components of solar e.m. induction may be accounted for by geophysical processes within circuits of the dynamic e.m. core (Fig. 4).

## Lightning Indicates Diurnal Ridge Induction Effect

Review of 18 years of NASA lightning climatology, by Albrecht et al. in 2016 [21], reveals, “*Where are the Lightning hotspots on Earth?*” Close inspection reveals a noon/midnight induction effect when magnetic moments of North-South aligned *MOR* structures (circuits) align with the solar axis. Especially along the *East Pacific Rise* (*EPR*) and the northern component of the *Southeast Indian Ridge* (*SEIR*), situated 180° longitude antipodal. The largest peaks of lightning activity in *Catatumbo* at *Lake Maracaibo*, on the coast of Venezuela, activate when the *EPR* aligns at midnight. The largest peaks of lightning activity in *Mitumba Mountain*s of Congo activate when the *SEIR* aligns at midnight. Lesser lightning peaks at noon alignments (Fig. 5).

## Mars as a Stellar Transformer

The Insight lander spacecraft detected the planet emits unexplained “magnetic pulses” at dusk in Ultraviolet (UV) aurora [22, 23] (Fig. 6a and 6b). Investigators are trying to figure out if the pulses originate at or near the planet’s surface, or whether they come from deep underground. Considering the *Mars–Sun system as a Stellar Transformer* [24, 25], may be explained by considering a magnetic induction model based on similar octahedron e.m. harmonics driving lightning on Earth. Pulses consistently occur at Martian dusk with a geographic separation of approximately 90° along the equator. This octahedral harmonic is a well-known Platonic solid aligning with 90° separation along the equator and is suspected responsible for this pulse alignment [26]. Crustal magnetic fields are strong enough to drive features in the Martian upper atmosphere akin to the aurorae seen on Earth – such features have been seen by ESA's Mars Express. Plasma soars to far higher altitudes than expected in regions with vertically oriented crustal fields, and areas with stronger crustal fields, are topped by denser and more extensive layers of ionosphere than weaker or absent fields. The auroral brightening peaks when solar energetic electrons and protons flux both peak. During the declining phase, faint narrow wisps and small patches of auroral emissions briefly appear. The featuresapproximately align with open field lines near strong crustal magnetic fields inMars’ southern hemisphere [26].

# Digital Twin Engine control layer

The Digital Engine Control Layer (Fig. 7) is designed with induction *Stellar Transformer* functions built into the dynamical core (Fig. 4). Fig. 7 outlines general inter-relationships and organized flow dynamics within the ecosystem. Generic control layers and data structure contribute to flexibility for workflow and algorithmic execution and coupling to forecast models. It comprises many of the fundamental interoperability areas encompassed by the industrial infrastructure, electrical, networked communications, and security, among others [27].

## Develop Inputs to Existing Forecast Models

The Digital Engine Control Layer must be geared to a large variety of host and client entities. Agencies hosting coupled modeling abilities vary. In the United States: NOAA’s - Non-hydrostatic Icosahedral Model (NIM); NASA’s - Goddard Earth Observing System **(**GEOS-5); DoE’s - Energy Exascale Earth System Model (ESMD/E3SM); and NCAR’s Community Earth System Model (CESM). International modeling centers include European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) combine forces in – Destination Earth program; UK Met Office’s - Unified Model (UM); Swiss National Supercomputing Centre (CSCS) – (COSMO); and Japan has world’s largest supercomputing facilities [28].

# Conclusions

The current bias and central role of gravitation vs. electromagnetic considerations has created a logical paradox in theoretical development of space science, This is overcome by using e.m. theories accounting for the larger role of magnetic moment induction that scales from galactic to atomic. Application of fundamental physics such as *Cowlings Dynamo* and *Hamilton’s Variation Principle* provide for scaling the phenomena. Thus solar-terrestrial relations occur through the “external way” – according to the well-known “space-weather”. But also, the “internal way” referring to solar influence through e.m. induction inside deep solid Earth. Long wavelength e.m. induction occurs through e.m. harmonics of a deep tetrahedron magpol conductor in the core reflected in polar circuits [2]. While an octahedron conductor in the mantle is evidenced by the geographical pattern of lightning hotspots pon Earth and auroral pulses on Mars [26]. In addition, the possibility to exploit the electrostatic energy of the atmosphere is most relevant, being an inexhaustible, clean energy source for world economy and/or for the management of climate change [2].

Digital Twins models are devoted to the exploitation of such a mechanism. Modeling use cases include space and Earth weather forecasting, ocean currents, climate modeling, forecast global EMP and effects, earthquakes, lightning, tornados, hurricanes, and certain types of wildfire outbreak associated with CME’s. Ground truthing environmental data develops quantitative algorithms for regional geographic locations. Enhancing Digital Twin predictive power using the dynamic e.m. core base model (Fig. 4).

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