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A Behavioural Model of the Solar Magnetic Cycle

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1. Introduction

All recent models of solar magnetic cycle behaviour assume that the Ω-effect stretches an existing poloidal magnetic field into a toroidal field using differential rotation (Featherstone and Miesch 2015). The α-effect recycles the toroidal field back to a poloidal field by convection and rotation and this is repeated throughout the cycle. Computer simulations based on that conceptual model still leave many questions unanswered. It has not resolved where the solar dynamo is located, what it is or what causes the differential rotation which it takes for granted. Does this paradigm need changing? The conceptual model presented here examines the sun in horizontal sections, analyses its internal structure, presents new characterizations for the solar wind and structures found and shows how their interaction creates rotation, differential rotation, the solar dynamo and the magnetic cycle.

2. Model Inputs and Interpretations

2.1. *Ions Heavier Than H^+ Travel Faster*

Researchers report that heavier positive solar wind ions (He^{+2}, O^{+6}, etc.) travel faster than the bulk plasma and Pierrard (2012) has derived a kinetic model for their velocity distribution. The data from Pierrard can be approximated by the expression

$$u^2 = U^2 - \frac{A - GMm}{2\pi m r} \tag{1}$$

where A = force of expansion, u = velocity of ion, m = mass of ion, r = distance from the sun, U = final velocity, G = Gravitational Constant, M = mass of the sun. Estimated values: U ≈ 5x10^5 m/s, the Heliopause is ≈ 2.8x10^9 m from the sun, A ≈ 1.2x10^{-5} Nm^2, GMm ≈ 2.21x10^{-7} Nm^2, A ≈ 55 x GMm. The solar wind would therefore easily expand into space against gravity.

2.2. *Electric Current in the Solar Wind*

Since heavier positive ions travel faster than the bulk plasma, the solar wind is an electric current with positive ions as the charge carriers. The sun is therefore a current source and no "return path" is required or necessary for this ion current to flow. Current flow is ideally radial from all points on the solar surface. The electric current density $\boldsymbol{J}_r$ at distance $\boldsymbol{r}$ from the Sun is

$$J_r = \sum_{i=1}^{n} \rho_i \delta v_i \text{ (summed across all heavy ion species; >50 ion species)} \tag{2}$$

where ρ_i is the volume charge density of heavy ion species "i" (<10% by volume cumulatively) and δv_i is the velocity difference between the heavy ion species "i" and the bulk plasma.

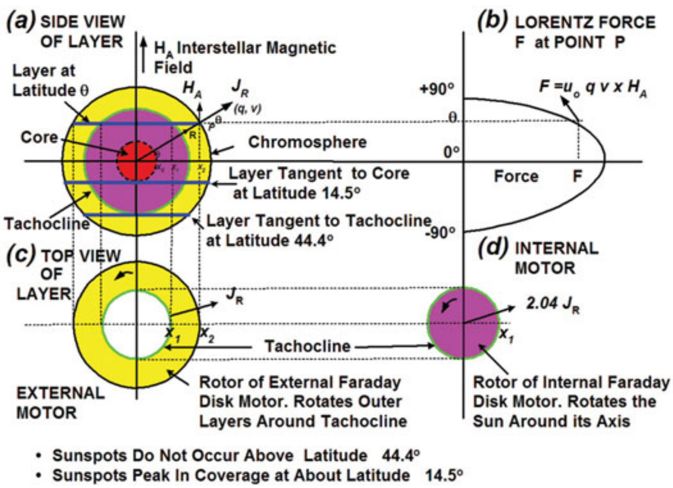

Figure 1. Typical Layer with 2 FD motors.

2.3. *The Solar Wind Rotates the Sun as Stacked Layers of Faraday Disk Motors*

Busby and Mason (2004) report that contours of constant angular velocity lie roughly on lines of constant latitude throughout the convection zone. The sun is sliced into horizontal layers, since all points on each layer rotate at the same speed throughout the zone. Ions which become the solar wind are assumed to maintain the electric current from the core to the surface. Photons are estimated to take about 175000 years to cross the 300000 km wide convection zone. Helium and Hydrogen ions may also take a comparable time. Electrons at this velocity create a current density of about $8.5\text{x}10^5$ Amps/m^2 in 20 gauge copper wire. Since the sun is in the interstellar magnetic field, $\boldsymbol{H}_A$ (N-pole upwards), the ion current interacts with $\boldsymbol{H}_A$ and Lorentz forces rotate the layer anti-clockwise. Analysis shows that layers which intersect the tachocline contain 2 concentric Faraday Disk (FD) electric motors with 360^o wrap-around brushes and the ions exit the solar surface to become the solar wind. Figure 1 shows a layer in the northern hemisphere which intersects the tachocline and identifies the 2 concentric FD motors embedded in that layer. These motors can be “run” to determine system performance.

2.4. *Rotation and Differential Rotation*

The Internal FD motor rotates the entire sun about the vertical axis and has as its rotor the radiative zone. The maximum torque (at equator) per unit area of solar surface is

$$T_{Max} = \pi\mu_0(H_D + H_A)R^3 J_r \text{ n.m/m}^2 \tag{3}$$

$\boldsymbol{H}_A$ is the ambient magnetic field, $\boldsymbol{H}_D$ is the dipole magnetic field created by the External FD motor and $\boldsymbol{J}_r$ is the current density of the solar wind at the solar surface. The External FD motor rotates the outer layers differentially around the tachocline. Its rotor extends from the tachocline to the solar surface. The latitude-dependent torque on an External FD motor is

$$T_\theta = 0.51\pi\mu_0 H_A R^3 J_r \cos^2\theta \text{ n.m/m}^2 \tag{4}$$

2.5. *The Solar Magnetic Field*

The apparent solar magnetic field has three components: (1) The ambient (interstellar) magnetic field $\boldsymbol{H}_A$, (2) A monopole component $\boldsymbol{H}_M$. Being an electric current, the solar wind carries its own magnetic field. Since the current is spherically symmetrical, its

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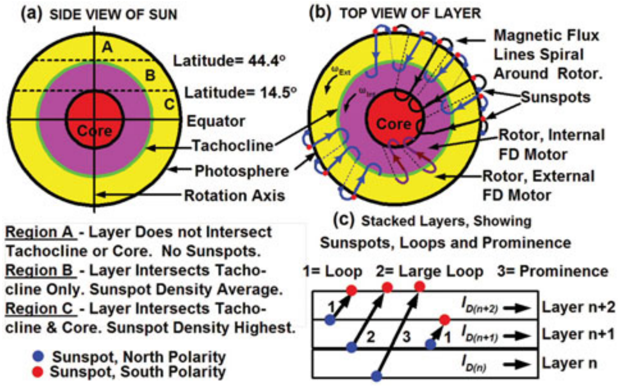

Figure 2. Sunspot formation.

magnetic field should also be spherically symmetrical. This is a monopolar magnetic field. The Ulysses spacecraft observed this (Schatten, 1999) and Dirac magnetic monopoles were observed in the laboratory (Ray et al, 2014). This shows that the monopolar magnetic field exists. This model, supported by the Ulysses data, shows that the sun is a special case and a term must be added to Maxwell's fourth equation to reflect that $\nabla . B \neq 0$. (3) A dipole component $\boldsymbol{H}_D$ created by rotation and induction and in accordance with Lenz's law opposes $\boldsymbol{H}_A$.

The resultant magnetic field has 4 sectors of alternate magnetic polarity separated by current sheets. It is formed in the vertical plane, but centrifugal forces and gravity twist it into a near-horizontal plane. This distortion persists throughout as folds in the heliospheric current sheet.

3. The System

3.1. *The Solar Magnetic Cycle, the Solar Dynamo and Sunspot Formation*

The Internal FD motor has as its magnetic field the dipole field of the External FD motor. Feedback produces oscillations in the speeds of the FD motors. Induced and conduction currents in the rotors also follow the harmonic oscillations. The operating magnetic fields of the FD motors form the solar magnetic cycle. The induced and conduction currents in the system across all the FD motors form the "Solar Dynamo". Figure 2 shows that sunspots are formed where the magnetic flux lines on the rotor of the External FD motor break the surface. Magnetic flux lines are spirals since the medium itself is moving.

3.2. *The Fast and Slow Solar Winds and the Solar Corona*

Solar wind ions exiting at the poles travel along open monopole field lines as the Fast Solar Wind. Ions exiting at lower latitudes become trapped in the dipole to form the corona and accumulate there until their gas pressure exceeds the magnetic pressure of the dipole, when they escape to form the Slow Solar Wind. The loss of kinetic energy heats up the corona to about 2x10^6 K. Majahan *et al.* (2002) have also proposed this. The estimated heat capacity of the solar wind is 2x10^4 to 10^5 J/kg.K. Trapping of solar wind ions by the dipole explains the shape and temperature of the corona and the greater heavy ion content of the Slow Solar Wind.

4. Discussion and Conclusions

4.1. *Implications of the Model*

If there were no heavy ions in the solar wind, the sun would have no magnetic field and no corona. Stars of this type would group by gravity (Globular Clusters). If there were

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no ambient magnetic field, the sun would not rotate and would be an ideal magnetic monopole. If the ambient magnetic field were larger then the magnetic cycle would be longer and deeper, enabling ions trapped in the corona to reach higher gas pressures. When the dipole field is decreasing, the gas pressure in the corona can exceed the magnetic pressure of the dipole, leading to a coronal event (CME or even Supernova). An FD motor would only reach equilibrium speed when $\boldsymbol{H}_D \approx \boldsymbol{H}_A$. If the sun were at the centre of the Galaxy where billions of stars contribute to $\boldsymbol{H}_A$, the sun would accelerate for billions of years without being able to reach equilibrium speed, since it cannot create a sufficiently large magnetic field to balance $\boldsymbol{H}_A$. Centrifugal forces would progressively flatten the convective zone followed by the radiative zone until the inner core is exposed. Immense magnetic forces would anchor the flattened tachocline and corona to the core and nuclear radiation and products would exit directly into space at the exposed poles (Quasars, Pulsars, Black Holes). Astronomers are searching for planets like ours in the Goldilocks zone of other stars. They should also consider whether the star is soon to become a Supernova.

4.2. *Conclusions*

This conceptual model of the solar magnetic cycle provides a sound and useful basis for further investigations. Starting from only first principles and with published data on the internal structure of the sun and composition of the solar wind, it predicts many aspects of behaviour that are characteristic of the sun and solar wind. The model shows: (1) heavier positive ions in the solar wind travel faster because of their greater mass; (2) the solar wind is an electric current of positive ions, with implications for Earth and space; (3) the solar magnetic field is an active field and not derived from a fossil field, with implications for the α- and Ω-effects; (4) the solar magnetic field has a monopole component, with implications for Maxwell's fourth equation.

Specifically, the model provides reasoned explanations for: (1) the rotation, differential rotation and cyclic magnetic activity of the sun and solar-type stars; (2) the Hale Magnetic Cycle and the solar dynamo; (3) the nature of sunspots. This model also accounts for (1) the empirically determined Gnevyshev – Ohl rule and (2) why the surface of the sun rotates slower than the interior and that a special case of this effect accounts for the anti-solar type rotation found in some stars (where the poles rotate faster than the equator; Featherstone & Miesch 2015).

Positive electricity in the solar wind is another form of electricity. Therefore investigating its properties would (1) improve the understanding of solar-terrestrial relations, (2) enable better protection from the potential negative effects on humans and conventional electric and electronic systems, and (3) potentially enable harnessing the solar wind as an energy source.

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