What is Beneath the Sunspots?

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ABSTRACT

Sunspots continued to represent enigma phenomena. The recent detection and measurement of sunspot magnetic field region, while emerging from solar interior, lead to suggestion of an elongated plasma body model composed of oppositely gyrating electrons and protons. It is thought to produce the Plasma Body External Magnetic Field (PB_{Ex}). Magnetic field emanating from PB_{EX} is thought to interacts through Active Region External Magnetic Field (B_{AREx}), with the granules and photosphere constituents, magnetizing these layers, and forming patches or sunspots. Produced magnetic force resulted from that, pulls the granules forming Wilson depression. An inter-atomic mechanism that decreased granules (sunspots) temperature due to B_{AREx} interaction with atomic magnetic field, is proposed. The knowledge of these mechanisms may help to understand the solar activities and how it should be predicted to protect humanity from any hazardous consequences.

Key words: Sun activity; granulation; photosphere; sunspots; Sunspot Model; surface magnetism

1: Introduction

The sunspot phenomenon, with its reduced temperature and intense magnetic field, continued to be without scientific explanation, until now [1], but recent developed technologies had improved specialized satellites studying the sun [2], with ability to convey above and sub-surface solar activities data in several wavelengths [3], that had opened the Heliospheric to in-depth solar data activities, making possible to conceive sunspots as a block unit [4].

Sunspots are the dark spots seen on sun's surface [5], they are regions where strong magnetic fields emerge from solar interior and where major eruptive events occurs [6], it was studied individually as a phenomenon with strong magnetic field [5].

Until now, sunspots are conceived as a magnetic flux entity that emerged from sun's interior [7], but the Helioseismology–methods allowed for in-depth analyses of sun's interior [8], while the Solar Dynamic Observatory (SDO) footages clarify many obscurities [9], but the ignorance of the subsurface structure of sunspots, had led to arbitrary interpretations for the magnetic field conditions underlying the sunspot [10], which had led to such many approaches and theories tackling sunspots concentrating on magnetic flux tubes perspectives [1].

There are two main hypotheses for the structure of the subsurface magnetic configuration of the spot: the monolithic model and the jellyfish/cluster/spaghetti model [11], and although there are several existing classes of sunspot models, but they are more or less suited to local helioseismology [11], and as new sunspots images may bring challenge to solar physics such as treatment of penumbra filaments as "convection cells" [12], or the twisting motions of penumbral filaments [13], and realization of existence of several sunspots penumbras in photosphere layers [14]. With many examples demonstrate that, and that, the numerical simulations are capable of reproducing many features of the helioseismic measurements [11], but it was found that, the simulations models, cannot address fundamental questions regarding the subsurface structure and origin of sunspots [11], and with current universal invocation of magnetic field in the theoretical interpretation of nearly all anomalous or active stars and galaxies, it was suggested that, some attentions are to be given to the development of the basic physics of the magnetic fields themselves [1], and although some simulations were carried out, but still they didn't address the question of the nature of the deep structure of sunspots [11]. Therefore, if any advancement is thought to be achieve within the solar physics studies, the plasma body responsible of producing that magnetic field must be investigated, together with the mechanism producing sunspot magnetic field.

This paper analyzed the detected and emerged sunspot underneath sun surface [6] together with the ultraviolet footage of sunspot drifting beneath photosphere in synchronization with effects on solar surface[15], these had lead to a proposal of a shape for a plasma body beneath the sunspot, a body which is responsible of generating intense Plasma Body External Magnetic Field ($\boldsymbol{PB_{Ex}}$). Although the production of external magnetic field (***ExMF***) outside an atom was previously suggested [16], but the formula used is to obtained the $\boldsymbol{PB_{Ex}}$, when the Sunspot External Magnetic Field ($\boldsymbol{B_{SEx}}$), together with the radial distances ($\boldsymbol{r_{pp}}$), from middle of the plasma body to the measured point are known, (this could be adjusted to be known at any photosphere altitude).

The Active Region External Magnetic Field ($\boldsymbol{B_{AREx}}$) emerging from $\boldsymbol{PB_{Ex}}$, is thought to magnetized the known changes on the granules and upper photosphere [14], while the decrease in granules (sunspots) temperature is thought to take place due to interaction of the $\boldsymbol{B_{AREx}}$ with granules atoms on micro-levels, leading to reduction in excitation energy, and temperatures of these atoms, hence sunspot temperature. Interaction of the resulted magnetization with $\boldsymbol{B_{AREx}}$, produced Wilson Depression Magnetic Force ($\boldsymbol{F_{WD}}$), pulling the granules within the $\boldsymbol{B_{AREx}}$ radius.

The knowledge of such plasma body and the $\boldsymbol{PB_{Ex}}$ would change many perceived ideas about sunspots, solar interior and will help building logical theory about sunspots, solar flares and the solar activities in general, with ability to predict the solar storms in advance, which in final analysis will reflects positively on human ability to regulate environments and safeguard human and technologies in Earth and space.

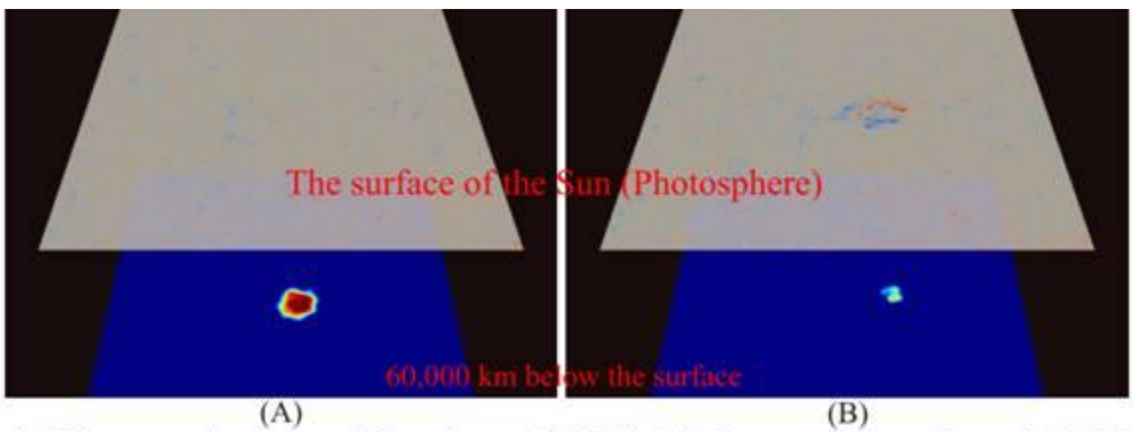


Fig.1. Using acoustic waves, and from the movie [17], in (A) the sunspots were detected 65,000 km bellow the sun's surface. In (B) magnetization effects start appearing on solar surface.

2: Emerged Sunspots and Measured Magnetic Fields

The study of sun’s interior, using acoustic waves, in time-distance helioseismology, detected sunspots, 65,000 km while submerged deep inside the sun [6], as shown in Fig.1 [17].

The study, also showed simultaneous changes on both the photosphere and the detected magnetic fields intensity, where the magnetic flux rate of Active Region (AR) 8164, steeply increased when it started emerging from deep inside the sun, as shown in Fig.2-D by the red line [6], this also brings to attention that, since the detected flux reflects intensity and location of the internal magnetic field on the solar photosphere [18], therefore the magnetic field as shown in Fig.2, was attained gradually while the sunspot is raising towards the photosphere, as shown in Fig.1.

3: An Elongated Submerged Body

An elongated sunspot body was detected by SOHO at lesser depth, as shown in Fig.3, in which the distance between the surface and the end of the submerged body is 24 Mm [4]. Relative measurements of this distance within the figure, gives the distance between the top of the plasma body and the umbra and penumbra on the surface as 6.5 Mm, and the radial distance from the middle of the plasma body to the photosphere (r_{pp}) as 15.2 Mm, from Fig.3. the object clearly shows the elongated nature of the plasma body.

The plasma body structure of Fig.3, is in contrary to the notion that both umbra and penumbra are part and parcel of sunspots entity, that constitute an integral part of sunspot body as depicted by the raising flux tube [19], although studies were carried on the physical characteristics of umbral dots (UD) such as temperature stratification, magnetic field vector, and line-of sight (LOS) velocity to understand the nature of UDs [20], and number of simplified (and partly conflicting) models have been suggested to explain the structure and outflows of penumbrae [4], but a comprehensive theoretical understanding of the basic mechanisms does not exist [10], therefore the true picture and nature of sunspots not yet been elaborated .

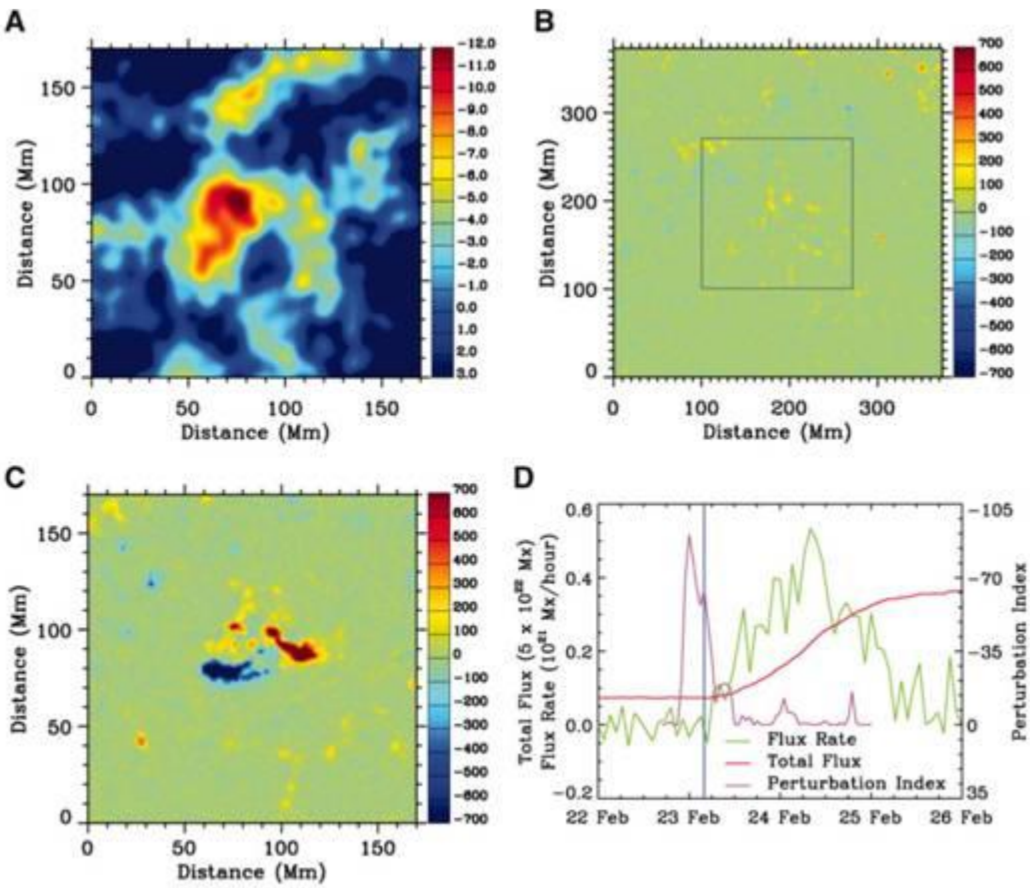


Fig.2 Active Region (AR) 8164, while at depth of 42-75,000 km. In (A) the mean travel-time perturbation map in seconds, (B) shows the photospheric magnetic field (in gauss) at the same time as (A), (C) shows the photospheric magnetic field (in gauss) at the same location as (A) but 24 hours later. (D) Total unsigned magnetic flux (red line) and magnetic flux rate (green line) of AR 8164 [6].

4: Sunspots: The Elongated Body Verses the Magnetic Effects

In the two snap shots shown in Fig.4, from UV and light wavelength movie by Solar Dynamics Observatory (SDO), sunspot group is shown moving westwards of the solar disk [15], from Fig.4-B, some observations were made that, the leading negative (-Ve), Blue color sunspot rotate clockwise, while the positive (+Ve) Magenta color sunspot rotates counterclockwise, this is also seen in a continually play short part of the movie [21], and as shown in Fig.4-A, and regardless of the movements in the movie, that both the leading –Ve Blue color and the lagging +Ve Magenta color sunspots are connected by closed magnetic lines of force, while an open magnetic lines of force emerged from both the encircled leading –Ve Blue color and the lagging +Ve Magenta color sunspots. The magnetic lines of force connecting both the leading –Ve Blue color and the lagging +Ve Magenta color sunspots, rotates along what seem to be an imaginary axis joining the –Ve Blue color sunspot and the +Ve Magenta color sunspot, as shown in Fig.4-A.

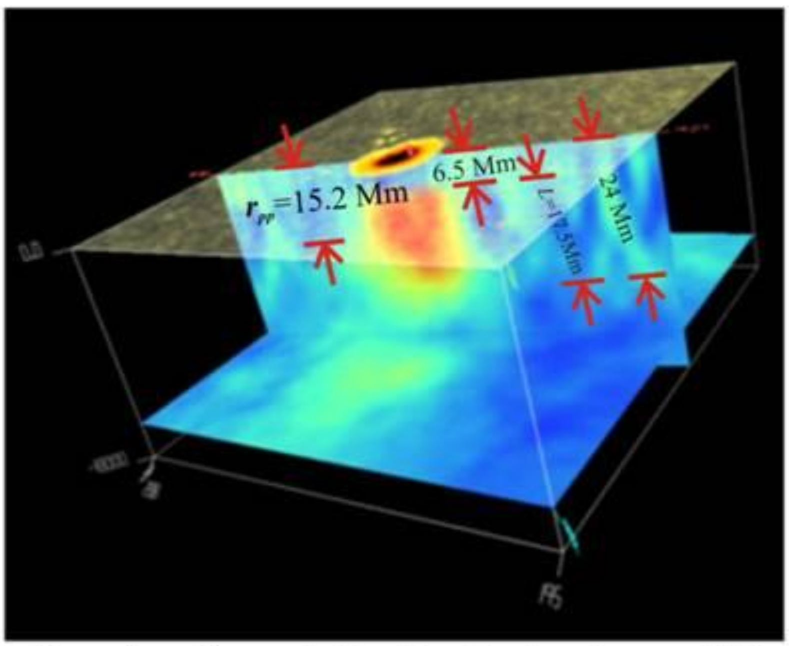
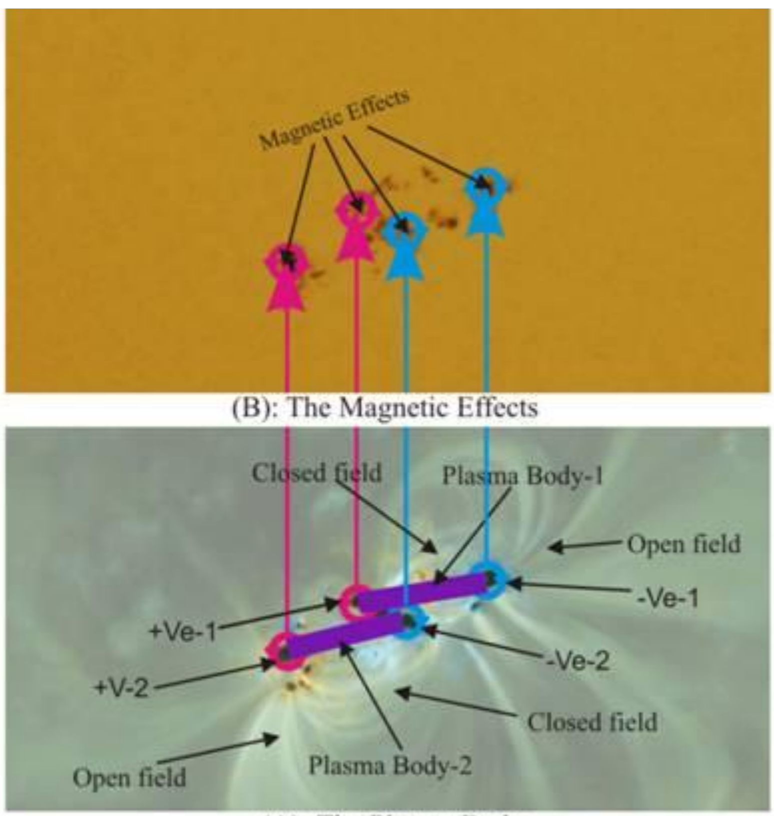


Fig.3. Three dimensions of sunspot subsurface structures to several kilometers. Both the umbra and penumbra were reflected at the surface, while the main elongated body still deep below the surface, at 6.5 Mm [4].

Therefore from these observations and descriptions, and as the main footage shows a rotation along an imaginary axis [21] and as from direct surface measurements, it is well known that active regions rotate faster than quiet ones, which was confirmed with helioseismology [12], therefore, it is clear that, an elongated body of plasma connecting both the negative and the positive poles, this body is depicted in Fig.4-A by the violet color body, it is thought to consist of plasma joining both the –Ve-1 with +Ve-1 poles and –Ve-2 with the +Ve-2 poles therefore, these submerged plasma bodies depicted in Fig.4-A are the one producing the magnetic field that caused effects on the photosphere shown in Fig.4-B.

5: The External Magnetic Field (ExMF) and the Magnetization Effects

As an elongated plasma body detected by SOHO and shown in Fig.3 [4], and as suggested, in Fig.4-A, that an elongated plasma body links poles of opposite magnetic fields, and since the Maps of the travel-time anomalies showed the signatures of emerging flux that are mostly concentrated in circular areas with a typical size of 30 to 50 Mm [6], and the field lines at these points are usually directed away from the surface, or vertical field [22], and that, while the main plasma body raises towards the surface or drifts westwards, it continually produced intense magnetic fields as shown in Fig.4-A by the magnetic lines of force emerging or entering -Ve-1, +Ve-1, -Ve-2 and +Ve-2 poles, and since an intense magnetic field was detected and measured raising in linear proportionality with the raises of the plasma body as shown in Fig.2-D [6], and also measurement analysis showed that the longitudinal component of these magnetic fields change with the height, where the umbrae and penumbrae of sunspot exhibits longitudinal magnetic fields that decrease with height, as shown in Fig.5 [23], which imply an increase of the magnetic field inward to the plasma body in the sun interior.



(A): The Plasma Body

Fig.4. Snapshots of submerged and on surface-sunspots [15, 21]. (A) Shows the spinning -Ve and +Po plasma body poles and the proposed elongated spinning plasma body (violet). While (B) shows the magnetized photosphere materials (granules).

Therefore, as it was suggested, an intense External Magnetic Field (***ExMF***) could be produced by a plasma body [16], thus an ***ExMF*** is also produced by plasma body shown in Fig.4-A, and such fields is the one measured in Fig.2-D and other figures [23], the intensity of which is strongest at the body center, and is designated as the Plasma Body External Magnetic Field (***PB**$_{Ex}$*), hence the radial magnitude of this field as measured from the sunspot is designated as the Sunspot External Magnetic Field ($\boldsymbol{B_{SEx}}$), and it is given by

$$B_{SEx} = \frac{PB_{Ex}}{r_{pp}^2} \sin\theta \quad T \qquad \{1\}$$

Where, $\boldsymbol{PB_{Ex}}$ is the Plasma Body External Magnetic Field in Tesla, $\boldsymbol{r_{pp}}$ is the radial distance from the middle of the plasma body to the granules or the interaction distance as shown in Fig.3, θ is the angle of the detected magnetic field at the photosphere, and the measured Sunspot External Magnetic Field ($\boldsymbol{B_{SEx}}$), is in Tesla.

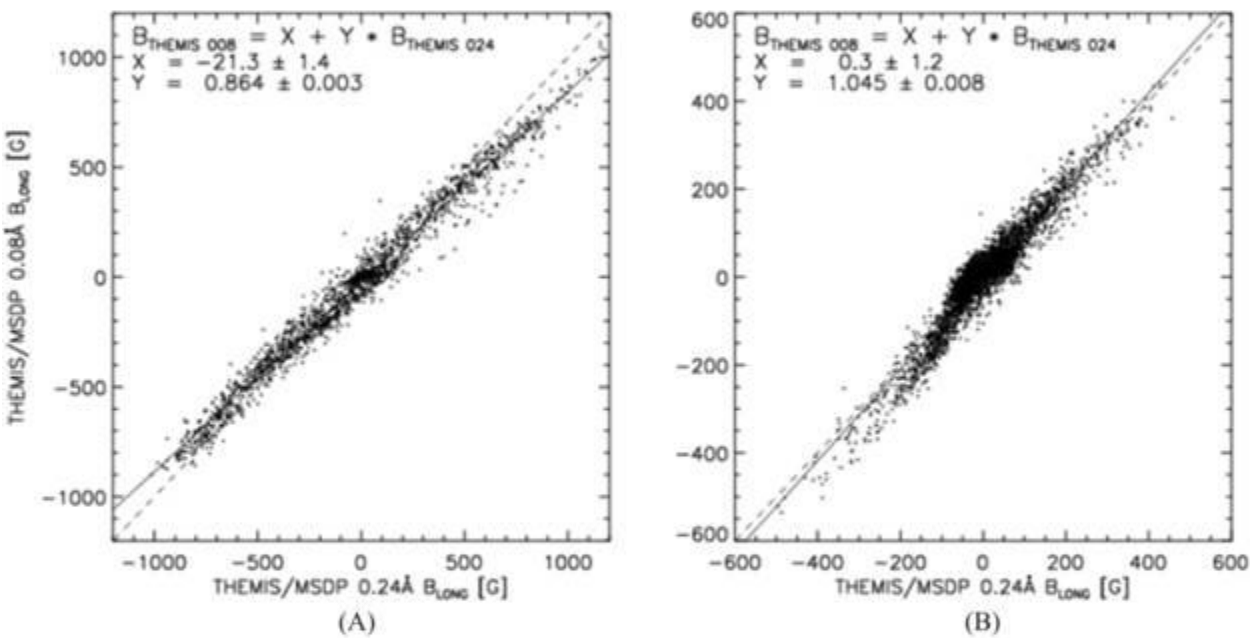


Fig.5. Scatter plots of the longitudinal magnetic field B_{THEMIS} at 0.08 Å vs. B_{THEMIS} at 0.24 Å, (A) shows the area covering the sunspots and (B) shows the area covering only the solar network [23].

The total produced Plasma Body External Magnetic Field ($\boldsymbol{PB_{Ex}}$), at the center of the plasma body, is given by

$$B_{SEx} = B_{SEx}\, r_{pp}^2 \quad T \qquad \{2\}$$

Where, $\boldsymbol{B_{SEx}}$ is the Sunspot External Magnetic Field, is in Tesla, and the total produced Plasma Body external magnetic field $\boldsymbol{PB_{Ex}}$ is in Tesla.

Since a physical similarity of convection existed between the granulation and penumbra [10], and that the measured value of magnetization depends on the value of applied magnetic field

[24], therefore, it is suggested that, the magnetic field produced by the plasma body shown in Fig.4-A, the magnitude of which is given by Eq.{1} above, interacts and magnetized different layers of the photosphere starting with the granules, as shown in Figs.1, 3, 4 and different other layer as shown by Figs.6 & 7, [25, 14], the magnetization is given by

$$M_{ss} = B_{SEx} = \frac{B_{AREx}}{\mu} - H \quad T \qquad (3)$$

Where, $\boldsymbol{B_{AREx}}$ is the Active Region external magnetic field, it is the field produced by the plasma body Plasma Body External Magnetic Field ($\boldsymbol{PB_{Ex}}$) in Tesla, H is the H-field it is ampere-turn per meter or Tesla, the $\boldsymbol{\mu_0}$ is the permeability of free space ($4\pi\times10^{-7}$ V·s/(A.m), and the magnetized Sunspot Field $\boldsymbol{M_{SS}}$, or the sunspot external magnetic field ($\boldsymbol{B_{SEx}}$) in Tesla.

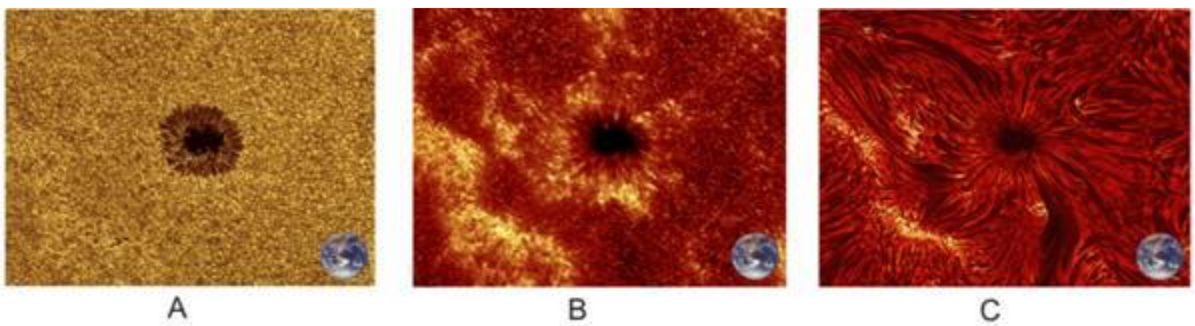


Fig.6. Three sunspots images of active region AR-10675 [25], in (A) the umbra formed due to magnetization of granules by strong open field, in (B) few hundred kilometers above photosphere, the existed elements are magnetized by the close field, in (C) few thousand kilometers into the chromosphere, the whole materials are completely magnetized by the close field.

The magnetization is also given by [24].

$$M_{ss} = B_{SEx} = \chi_m H \quad T \qquad (4)$$

Where, $\boldsymbol{\chi_m}$ is the volume magnetic susceptibility and H is the applied magnetic field.

As the magnetized Sunspot External Magnetic Field ($\boldsymbol{B_{SEx}}$) given in Eqs.{3&4} is not the Active Region external magnetic field ($\boldsymbol{B_{AREx}}$), produced by the plasma Body and shown in Eq.{3}, and as clearly seen, $\boldsymbol{B_{SEx}}$ is only a reduced magnitude of $\boldsymbol{B_{AREx}}$, therefore, $\boldsymbol{B_{SEx}}$ given by Eq.{1}, becomes

$$B_{SEx} = \frac{PB_{Ex}}{r_{pp}^2 \, M\%} \sin\theta \quad T \qquad \{5\}$$

Where, $\boldsymbol{M\%}$ is the percentage of Magnetization loss of the original $\boldsymbol{B_{AREx}}$, in Tesla.

From the above discussion, the total magnitude of the of the Plasma Body External Magnetic Field ($\boldsymbol{PB_{EX}}$), given by Eq.{2}, becomes

$$PB_{Ex} = B_{SEx}\, r_{pp}^2\, M\% \quad T \qquad \{6\}$$

Therefore from Eq.{5}, the Active Region external magnetic field (***B**$_{AREx}$*), is given by

$$B_{AREx} = B_{SEx} M\% = \frac{PB_{Ex}}{r_{pp}^2}\, sin\theta \quad T \qquad \{7\}$$

6: The Wilson Depression

As the polarity of detected and measured magnetized sunspot field ($\boldsymbol{M_{SS}}$), or the Sunspot external magnetic field ($\boldsymbol{B_{SEx}}$) is opposite to the Active Region external magnetic field ($\boldsymbol{B_{AREx}}$), therefore both fields interacts and resulted in the attractive magnetic force [26] or the Wilson Depression force ($\boldsymbol{F_{WD}}$), the $\boldsymbol{F_{WD}}$ polls the magnetized granules, and it is given by

$$F_{WD} = B_{SEx}\, B_{AREx}\, r_{SP}^2\, c\, \theta \quad N \qquad \{8\}$$

Where, $\boldsymbol{B_{SEx}}$ is sunspot external magnetic field, $\boldsymbol{B_{AREx}}$ is the Active Region External Magnetic Field at the lower edge of the granules, $\boldsymbol{r_{PS}}^2$ is the radial distance from the Plasma Body to the granule's sunspot center, c is the speed of light, θ is the angle between both magnetic fields, and the Wilson Depression magnetic force $\boldsymbol{F_{WD}}$ is in Newton.

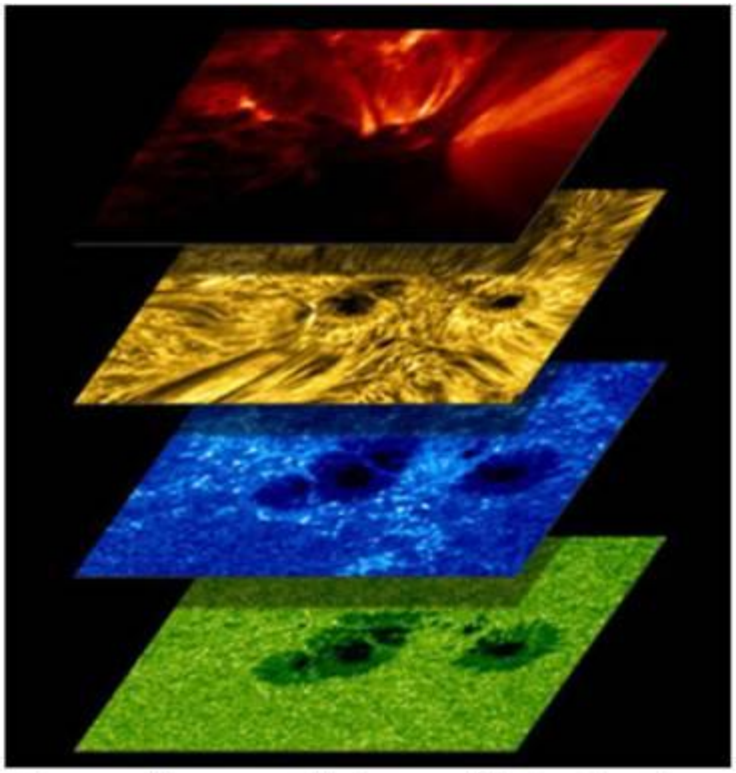


Fig.7. Sunspots are shown on four composite images of photosphere layers, where the field is strong and coherent. The first green panel shows the visible surface at about 5,000 °C (9,000 °F). The blue image (not to scale) shows the emission up to some 6,500 kilometers above the solar surface. The yellow image shows the Sun in the light of hydrogen gas. The top image shows the corona, over 1.5 million km above the solar surface, where the temperature exceeds 1 million °C (1.8 million °F) [14], these layers are interpreted as resulted from magnetization process.

If the Sunspot external magnetic field ($\boldsymbol{B_{SEx}}$) is equal in magnitude to the established field, or the un-magnetized Active Region external magnetic field ($\boldsymbol{B_{AREx}}$), therefore Eq{8} becomes

$$F_{WD} = B_{SEx}^2 \, r_{SP}^2 \, c \, \theta \quad N \qquad \{9\}$$

7: The Plasma Body

As given by Eqs.{3&4}, appearance and sunspots patches movements on solar surface doesn't always reflects the true shape of the internal body creating the sunspots, rather it reflects some of features it posses, such as the ability to magnetized umbra and penumbra as shown in Figs.1,2,3,4,6 and 7.

With lack of recognized sunspot model, that could withstand scientific credibility, and based on the analysis carried on Fig.4, and since sunspot is an ideal situation to guide the theoretical development because the spot is observable down to the small details [1], therefore the plasma body beneath the surface is thought to consist of two inter-related charged particles, capable of producing ***ExMF*** [16] or the $\boldsymbol{PB_{Ex}}$, the electrons structure in front, followed by the protons structure, as shown in Fig.8, the plasma body is characterized by the followings:

The $\boldsymbol{PB_{Ex}}$ produced by the sunspot in Fig.8, is in line with the conventional idea of the magnetic field configuration of a sunspot [1].

The red plasma body structured formed by gyrating electrons, spinning clockwise, while the lower blue plasma body formed by gyrating protons, that spinning counterclockwise.

The intense magnitude of produced $\boldsymbol{PB_{Ex}}$ is at the center of the plasma body.

The intense portion of the field is the polar field (θ factor) which first interacts and magnetized the Granules forming the umbra, hence designated as umbra zone.

In Fig.8, the closed field, which interacts with the Granules and upper photosphere's layers (Eq.(4)) forming the penumbra, it is designated as penumbra zone.

The upward movements of the plasma body, as shown in Fig.8-A, represented by the small radius at the top, occurred during the photosphere raises, as detected and shown in Fig.1, and Fig.2-D.

The poleward or westwards movement, shown in Fig.8-B, is where the plasma body inclined while drifting, the heavy protons at lower end and at rear, while the lighter electrons on top and in front, similar to westwards movement shown in Fig4-A.

Due to imbalance between the heavy protons and lighter electrons constituents, the whole spinning of the plasma body is so strange.

8: The Magnetic Effects

When the plasma body raises towards photosphere, $\boldsymbol{B_{SEx}}$ intensity as given by Eq.5, increased, hence the polar field, shown in Fig.4-A and Fig.8, it interacts with the granules according to Eqs.{3&4},resulting in the magnetization and formation of magnetic patches on the granules [10], afterwards the less nonpolar field, also interacts with photosphere materials and magnetized them accordingly, forming patches, which could also be formed at upper layers within the photosphere [14] depending on existed elements types, as shown in Fig.6 [25] and Fig.7 [14] or only on the granules as shown in Figs.1, 3, and 4.

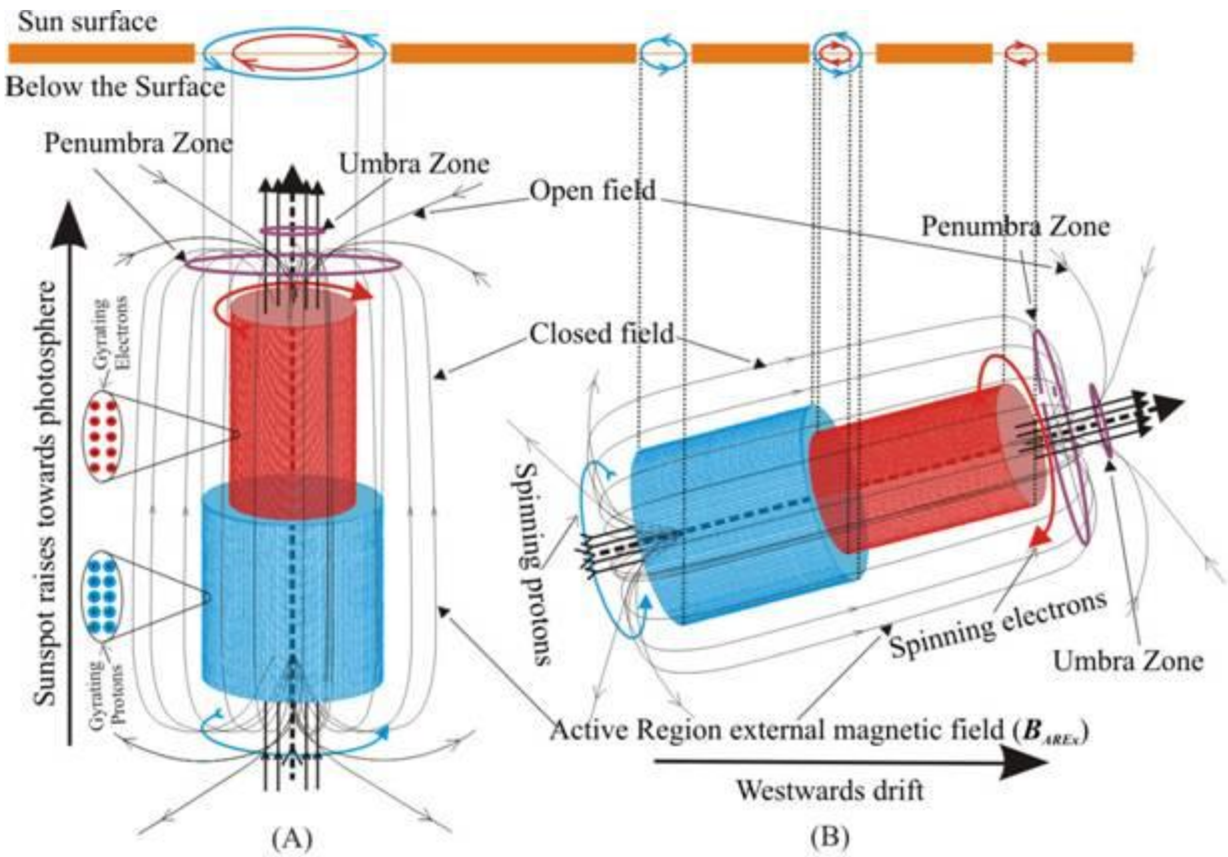


Fig.8. Proposed sunspots plasma body consist of gyrating electrons and protons producing Plasma Body External Magnetic Field (***PB***$_{Ex}$) shown as Active Region external magnetic field (***B***$_{AREx}$) [16]. In (A), The body raises toward the photosphere, while (B) shows how the body drifts westwards, northwards or southwards as in Fig.4-A. Opposite rotation of plasma bodies and magnetization effects are reflected on the granules.

Since the photosphere elements are known [27], and that the interaction increased with the materials susceptibility in each layer as given in Eq.{4}, hence this re-shaped the penumbra to trace the open magnetic lines of force as shown in Fig.6-C and Fig.7, thus the created sunspot effects, is similar in process to iron filings attracted to horseshoe magnetic fields or lodestone field [28], which also explained the seen twisted motion of the filaments as an actual twisting motion or turn of individual filaments about their axis [13], as a process within line of force.

Therefore, it could be stated that, the Umbra and Penumbra reprepresents the level at which the granules or different photosphere constituents can be magnetized by the raising intense plasma body magnetic field.

From observations of pores and their transformation into sunspots [11], pores are low degree of magnetization due to low intensity of $\boldsymbol{B_{AREx}}$, this occurred when the plasma body in Figs.3 & 4 are raising to the surface, and the interaction distance $\boldsymbol{r_{pp}}$ is less than to trigger the magnetization effects. If the closed (horizontal) field angle increased to θ (γ) ≥ 35∘ [11], this lead to increase in magnetization, hence penumbra appeared and pore transformed into sunspot.

Since the intense open magnetic field produced by the plasma body is circular around the poles, therefore, the magnitude of magnetic field towards the closed field, decreased, reducing magnetization given by Eq.{3}, this explained observed bright rings around sunspots [11].

9: Sunspots Temperature Phenomenon

Knowing that, the detailed structure of granulation is not as simple as suggested by its convective origin [29], therefore the raising magnetic field, such as detected and shown in Figs.1&2. [9] and proposed by Fig.8, interacts (in addition to Eqs.{3&4}) with the granules in accordance to Eq.(3), together with the first law of thermodynamic [24], the resulted energy is given by

$$\pm dU = Q - W \qquad J \qquad (10)$$

Where, Q is the heat added to the system, W is the work done by the system, and the change in the internal energy ±dU is in Joule.

Since the photosphere is one of the coolest regions of the Sun (6000 K), and only a small fraction (0.1%) of the gas is ionized (plasma state) [30], this imply that almost all photosphere elements are in a continual excitation state, therefore the atom's energy at such state is given by [26]

$$E_n = \frac{r_n\, q\, v_D\, B_{1U}}{2} \qquad J \qquad \{11\}$$

Where, $\boldsymbol{B_{1U}}$ is the nucleus spinning magnetic field (***SMF)*** [26], $\boldsymbol{v_D}$ is the excitation velocity, $\boldsymbol{r_n}$ is the excited orbital radius, $\boldsymbol{q}$ is electric charge, and the energy $\boldsymbol{E_n}$ is in Joules.

The balance of energy for Eq.{11}, is given by

$$\frac{m_e v_D^2}{2} = \frac{r_n\, q\, v_D\, B_{1U}}{2} \qquad J \qquad \{12\}$$

Where, $\boldsymbol{m_e}$ is electron mass in kg, and the nucleus ***SMF*** is given by

$$B_{1U} = \frac{m_n v_D}{q r_n} \qquad T \qquad \{13\}$$

The deduced $\boldsymbol{B_{AREx}}$ given by Eq.{7}, effected the granules' inter-atomic parameters, and interacted with the nucleus ***SMF*** or $\boldsymbol{B_{1U}}$ of granules, as given by Eq.{13}, therefore subtracting $\boldsymbol{B_{AREx}}$ from $\boldsymbol{B_{1U}}$, thus Eq.{13} becomes

$$(B_{1U} - B_{AREx}) = \frac{(v_D - \delta v_D)}{q\,(r_n + \delta r_n)} \qquad T \qquad \{14\}$$

Reduction in $\boldsymbol{B_{1U}}$ lead to reduction of the excitation velocity $\boldsymbol{v_D}$, increase in the excited orbital radius $\boldsymbol{r_n}$, hence reduction in the atomic excitation energy, therefore based on Eq.{13}, the balance of energy given by Eq.{12} becomes

$$E_n = \frac{m_n(v_D^2 - dv_D)}{2} = \frac{q(r_n - \delta r_n)(v_D - \delta v_D)(B_{1U} - B_{AREx})}{2} \quad J \qquad \{15\}$$

But the formula of heat energy [31] is given by

$$H = Cp \times m \times \Delta T \quad J \qquad (16)$$

Where, Cp is the Specific heat in J/kg x degrees C, m is the mass in kilograms, delta T is the change in temperature in Celsius, the Heat energy (H) is in Joules.

We assumed that, Heat energy produced by Eq.(16) is equivalent to that produced by Eq.{15} multiply by number of electrons involved in that, thus

$$H = Cp \times m \times \Delta T = \frac{n_e q(r_n - \delta r_n)(v_D - \delta v_D)(B_{1U} - B_{AREx})}{2} \quad J \qquad \{17\}$$

Where, $\boldsymbol{n_e}$ is the number of electrons in unit volume.

It was proved that, there is strong relation between Umbral normalized continuum intensity vs. umbral field strength $\boldsymbol{B_{Sex}}$ [32], therefore from Eq.{17}, the field strength is proportional to lose in intensity or the temperature, and the change in temperature ΔT is given by

$$\Delta T = \pm \frac{n_e q(r_n - \delta r_n)(v_D - \delta v_D)(B_{1U} - B_{AREx})}{2\, Cp \times m} \quad J \qquad \{18\}$$

The number of electrons to produce that heat is given by

$$n_e = \frac{Cp \times m \times \Delta T}{q\, r_n\, v_D\, B_{1U}} \qquad \{19\}$$

Equation {18}, explained reduction in granules temperature, after been magnetized by Eq.(3) or Eq.(4) to form what is known as the ***sunspot***.

10: Discussion

- Observations confirmed noticeable differences in the temperature and field strength of umbra of large and small spots [11], this is due to that, the magnetic field obtained in Eq.{6} is related to the plasma size, while Eq.{18} which explain the decreased in temperature, is also depends on Eq.{6} which depends on plasma size.

- The current suggested sunspot plasma body model, is to replace the previous one [33], and the new model will slightly altered some of the pre-conceived ideas about solar flare mechanism [34].

- The distance between the end of plasma body and umbra surface, in Fig.3. is 24 Mm [4], as shown relative distances in Fig.3, in relations to that distance, gives the interaction radius, or $\boldsymbol{r_{pp}}$ at 15,243. If the measured sunspot magnetic field intensity ($\boldsymbol{B_{SEx}}$) at the umbra is 200 gauss. Using Eq.{2}, therefore:

o when the $\boldsymbol{B_{SEx}}$ = 200 gauss = 0.02 Tesla, and $\boldsymbol{r_{pp}}$ = 15.2 Mm, therefore, the total produced Plasma Body External Magnetic Field ($\boldsymbol{PB_{Ex}}$) = 1.4 x 10^{18} Tesla.

o If the $\boldsymbol{B_{SEx}}$ = 500 gauss = 0.05 Tesla, therefore, $\boldsymbol{AR_{EX}}$ = 1.7 x 10^{19} Tesla!

11: Acknowledgments

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12:0 Glossaries

$\boldsymbol{B_{AREx}}$: The Active Region External Magnetic Field detected at lower edge of the granules

$\boldsymbol{B_{Sex}}$: The Sunspot External Magnetic Field

$\boldsymbol{B_{1U}}$ = ***SMF***: The nucleus spinning magnetic field

$\boldsymbol{B_{SEx}}$: The Sunspot External Magnetic Field

C: The speed of light

Cp: The Specific heat in J/kg x degrees C

±**dU** : The change in the internal energy

ExMF External Magnetic Field

$\boldsymbol{E_n}$ is Atom’s energy at excitation state

$\boldsymbol{F_{WD}}$ Wilson Depression magnetic force is in Newton.

LOS: The Line-of sight

M: The mass in kilograms

$M\%$: The percentage of Magnetization loss of the original B_{AREx}, in Tesla.

m_e : The electron mass in kg

M_{SS} : The Magnetized sunspot field

n_e : The number of electrons in unit volume

PB_{Ex} : The Plasma Body External Magnetic Field

Q : The heat added to the system

q : The electric charge

r_n : The excited orbital radius

r_{pp} : The radial distances

r_{PS}^2 : The radial distance from the Plasma Body to the granule's sunspot center

SDO : The Solar Dynamic Observatory

UD : The Umbral Dots

v_D : The excitation velocity

-Ve : Negative

+**Ve** : Positive

W : The work done by the system

ΔT : Delta Heat energy (H)

θ : The angle between two magnetic fields

μ_0 : The permeability of free space ($4\pi\times10^{-7}$ V·s/(A.m)

χ_m : The volume magnetic susceptibility

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