The Production of Plasma Pillars Intense Magnetic Fields (PPIMF) and Their Roles in Solar Activities

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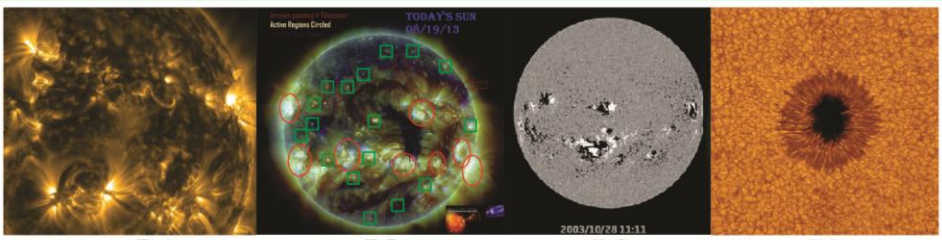
Abstract

It’s very difficult to understand the mechanism producing solar magnetic fields, as it mingled with various activities, it also hindered by gaseous model of the sun; an alternative view is suggested based on characteristics of electrons exhibited in electric current; in 1820 Ørsted discovered both the relation between electricity and magnesium and the Circular Magnetic Field (CMF) produced by electric current, later discovered its produced by electrons in motion; thus the bulky rotation of charged particles (electrons, protons and ions) in tornado mode, produced intense CMF, designated as Plasma Pillar Intense Magnetic Field (PPIMF) with magnitude exceeds millions Tesla; and since EUV images in F-A, illustrates subsurface intense Magnetic Lines of Force (MLF), it also shows activities of Solar Flare (SF), both are suggested as due to PPIMF, which accounted for most solar activities, the Active Region (AR) as in F-B suggested to represent the PPIMF, where AR near surface are in circle, while AR at deep depth in squares; at deep depths the influence of PPIMF on photosphere during quiet sun resulted in pairs of negative and positive magnetic fields represented by magnetogram in F-C; during active sun, PPIMF raise nearer photosphere, it’s negative and positive fields interacted with the photosphere’s state, resulted in pairs of sunspots in F-D, look like iron filings, but formed by plasma, their shapes determined by proximity to PPIMF; as charged particles gyrate around the pillar, any increase in field’s intensity reduced radius of gyration, hence the adjacent distances between ions, thus at critical distance Solar Flare (SF) is triggered producing great energy, radiations and plasma including heavy ions; this knowledge will unlock dynamics of the sun, it’s internal structures and related mechanisms, it will help attained the alternative renewable energy, avert negative consequences of climate change, improve prediction of solar activity and space weather among others.



F-A *F-B* *F-C* *F-D*

Fig. 1 (F-A, F-B, F-C and F-D) The produced Plasma Pillars Intense Magnetic Fields (PPIMF), exhibits numerous unique characteristics shown in F-A as an Active Regions (AR) and Solar Flare (SF) (NASA-SDO/AIA 171), in F-B large PPIMF near surface in circles are the recognized AR (Space Weather Trackers), then deeper PPIMF in square are AR, while the deepest are not shown, F-C shows deeper PPIMF interacted with photosphere resulted in +ve and -ve magnetic fields measured as magnetogram image (SOHO) and F-D shows the great affects of PPIMF nearer photosphere exhibited as sunspot (Akasofu, 2018), its plasma face of iron filings.

(A)- Introduction

The sun as an opaque sphere, endowed planet Earth with energy that modeled our lives and climate; among the most complicated phenomenon leading that role is the solar magnetic field, which display it's characteristics through unexpected phenomena, only the aftereffects of which are detected or felt, while different transformations are taken place vaguely, with unfamiliar mechanism. Despite the past intense studies to realize that; but two factors hindered and complicated that, first the concept of action at distance which mathematized physics, then the gaseous theory which conceived the sun and all stars as a hot ball of gas made up mostly of hydrogen atoms in form of plasma (NASA, 2016), both concepts diverted attentions from logical interpretation into descriptive mathematical setup based on Ampere's electrodynamics (Assis, et al 2015) and related theory of magneto-hydrodynamic waves (Alfvén, 1956) and developed ideas of wrapped fields (McDonald, 2005).

In this IPoster, we reviewed that historical dispute in 1820, between Ampere verse Ørsted, Faraday, Biot, and Savart, and how their failure to counter Ampere's challenge (Assis, et al 2015), resulted in the current fundamental physics; our efforts to understand the core ideas of Ørsted and supporters, in that dispute, and the possible interpretations of his discovery, resulted in a mechanism together with the concept of "*field's interaction and its formula*" (Yousif, 2018a); which explained many phenomena, then developed to interpret the magnetic fields of the sun as composed from three independent entities, the dipole moment (Yousif, unpublished a), the Active Regions (AR) and the spicules (Yousif, Unpublished-b). We investigated the subsurface elongated plasma body forming the AR, named it the *Plasma Pillar Intense Magnetic Field (PPIMF)*, this body is behind the appearance of sunspots and the Solar Flare; both and others are explored with details in Yousif (Unpublished b).

Finally, the current #AGU20 slogan of lowering carbon footprint, require an effective alternative renewable energy; thus developing the External Magnetic Field (ExMF) produced in PPIMF, is in the core of this motto; while detail knowledge of solar cycle can improve prediction of solar activity, magnetic storm and a better interpretation of space weather among many others.

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(B)- The Field's Interactions and the Production of External Magnetic Field (ExMF)

Ampere's electrodynamics in 1820 had generated contentious dispute, not resolved and forgotten, but continued to vibrate weakness in the structure of the fundamental physics, if resolved, the course of physics and related space science will greatly change, and the challenges facing humanity due to climate changes will be countered, the following is the dispute and our interpretation: On July 21, 1820, Hans Christian Ørsted discovered the relation between electricity and magnetism (MAXWELL, 1891), as shown in Fig. B-1, while demonstrating to his students (Wikipedia, Ørsted, 2020).

Fig. B-1

Ørsted also discovered that, electric current produced Circular Magnetic Field (CMF) around and along the conductor (Assis, et al 2015) as shown in Fig. B-2 and Fig. B-4-(A).

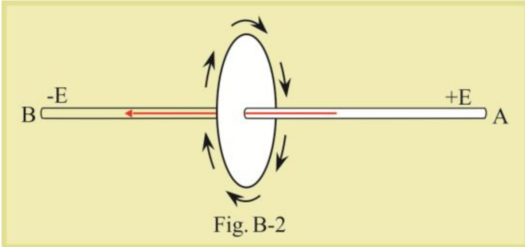


Fig. B-2

Ampere interpreted Ørsted Discovery as "*an interaction between the current flowing in the conductor and the supposed currents existing inside the magnet*," he also claimed "*there's an electric current in the Earth which produced the geomagnetic field*" (Assis, et al 2015), thus one can imagine how that guided scientists in many fields, like the sun as well; the simplest Ampere' formula representing his ideas, coined for two conductors carrying electric current shown in Fig. B-3-1, is given by

$$F = \frac{2k\, l\, I_1\, I_2}{d} \qquad (B-1)$$

Where, I_1 is current in conductor one, I_2 is current in conductor two, *l* is the length of the conductors, *d* is distance between them, *k* is constant and *F* is the force.

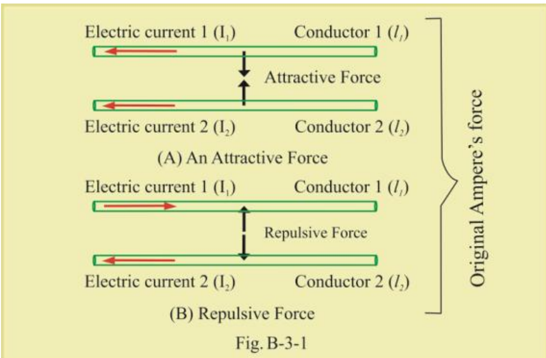


Fig. B-3-1

Later the formula was modified to include the magnetic field (Hyper Physics, 2018) as shown in Fig. B-3-2.

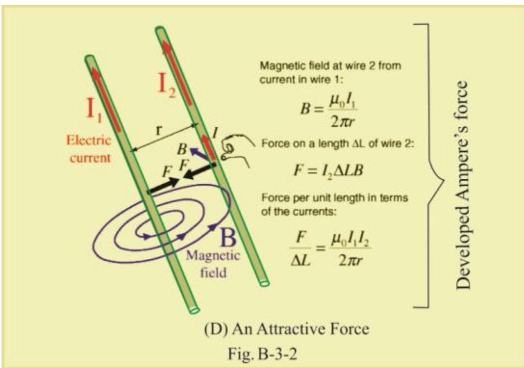


Fig. B-3-2

Ampere's formula consolidated the concept of "*Action at distance*," initiated by the inverse square laws of gravitation, then Columba's law of electrostatic and force between two magnetic poles, they mathematized physics (mathematic solution lacking physical justification) (Assis, et al 2015) (Yousif, 2018a).

Although Ampere' work was criticized by Ørsted, Biot, Faraday, Savart, and others, but he challenged them to derive an alternative formula, something they couldn't attained (Assis, et al 2015).

Electron was discovered in 1997 (Trinklein, 1990), while in motion, it produced Circular Magnetic Field (CMF) (Alonso, 1967) as shown for electric current and electron in Fig. B-4-(A&B).

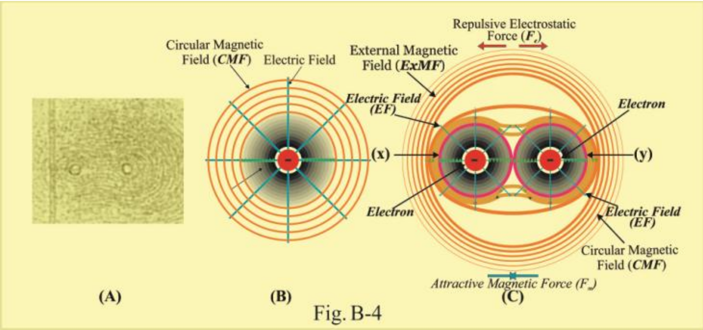


Fig. B-4

Regardless of its importance, the Circular Magnetic Field (CMF) was never been considered by scientists in any theoretical works.

J. J. Thomson realized that shortage saying "*the detection of a train of waves associated with the movement of electrons was not predicted by Maxwell's equations, emphasizing that, such a view of the electron had to be wrong*." (Navarro, 2008), it was strong statement, but lacking the formula demanded by Ampere.

In 1999 we derived that formula, its equivalent to Eq. (B-1), which gives Ampere' force, but based on *field's interaction* with an established mechanism (Yousif, 2003), it's given by

$$F_m = B_1 B_2 r\, l\, k^{-1} \qquad (B-2)$$

Where, B_1 and B_2 are Circular Magnetic Field (CMF) produced by currents on conductors C_1 and C_2 in Tesla, r is radial distance between the two conductors, k is constant = $5.0\text{x}10^6$, N/ T^2. m^2, and the magnetic force F_m in Newton (Yousif, 2003a, 2018a).

Later we generalized the formula, it resolved different magnetic and electrostatic forces, based on Faraday's concept of attractive and repulsive characteristics of magnetic and electric lines of force (Yousif, 2018a), as shown in Fig. B-5 for magnetic fields, the generalized formula for field's interaction, is

$$F = F_1\,(r)\,F_2\,(r)\,r^2\,k \qquad (B-3)$$

Where, F_1 is the first Field, F_2 is the second field, r is the radial distance between the two fields, k is constant which differs from case to other and the force F in Newton.

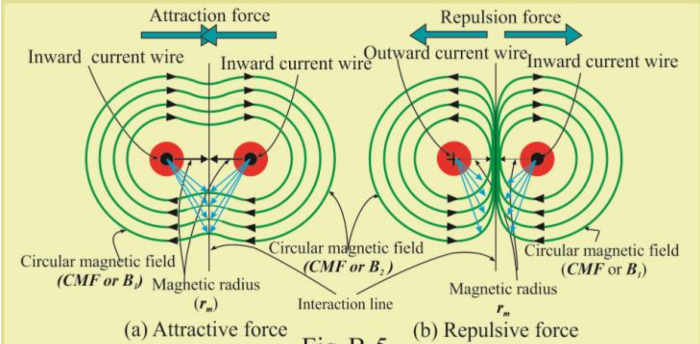


Fig. B-5

As we shared Thomson's above view, but supported with Eq. (B-3), the formula also explained "*Electromagnetic Radiation Mechanism*" (Yousif, 2014a) and a formula for "*Electromagnetic Radiation Force* (F_{mR})" showing electron can be remove from atom without the need for photon in "*The Photoelectric Effects-Radiation Based With Atomic Model*" (Yousif, 2015), we resolved "*The Compton Effect*" (Yousif, 2016), showing how Compton's was mistake in "*Compton was Greatly Mistaken Using the Quantum*" (Yousif, 2018a), we tackled "*The Double Slit Experiment-Explained*" (2016) and "*Electron Diffraction Re-Explained (The Intense Magnetic Field Interaction with Crystals)*" (Yousif, 2016), which are the backbone of quantum mechanics,, thus we can state that "*Since dynamical charged particles produced magnetic fields, scientists should have seek an answer to how these fields could have interacted with each other in the physical world?*"

The motion of two electrons in Fig. B-4 (C), constitute the addition of two CMF, where the interaction of electron's and proton's CMF with magnetic field (B), shown in Fig. B-6, explained why both particles are captured by B, and the reason for their opposite gyration, it also showed the produced CMF (Alonso, 1967, French, 1968, Butler, 1963), which in the context of Fig. B-6, represents a micro production of External Magnetic Field Type-A (ExMF-A), as enlarged in the insight lower left of Fig. B-6, the CMF is given by

$$B_{Ex} = \frac{q\,V}{r_m^2\,c} \qquad (B-4)$$

Where, V is velocity of charged particle (electron, proton and ion) in m.s^{-1}, c is the speed of light in m.s^{-1}, r_m is the magnetic radius in meter, and the micro External Magnetic Field Type-A ($B_{Ex\text{-}A}$) in Tesla (Yousif, 2004)

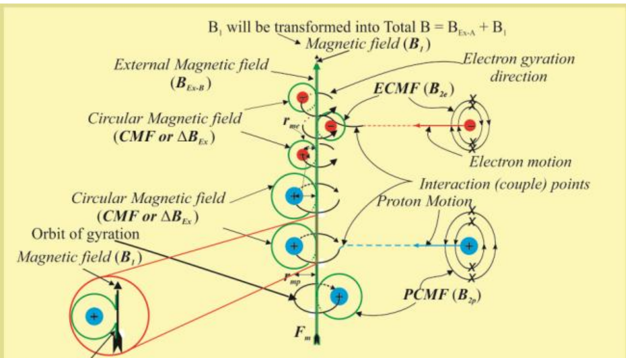


Fig. B-6

The flow of electrons in a cable is shown in Fig. B-7-(A), the adding up of all CMF's produced greater CMF; therefore by forcing electrons shown in Fig. B-7-(B) to move like natural electrons in conductor shown in Fig. 7-B-(A) by different mechanical force like tornado, this will also produce great CMF, named External Magnetic Field Type-B (ExMF-B) (Yousif, unpublished b).

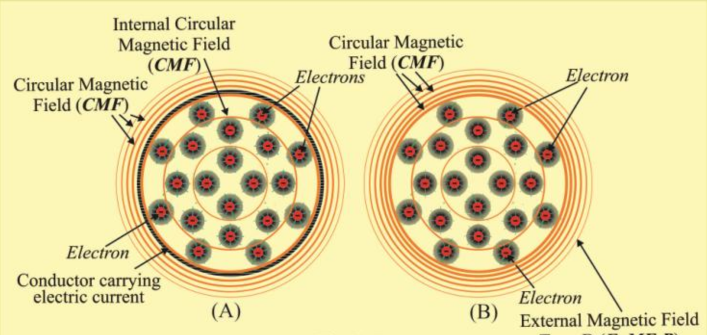


Fig. B-7

Therefore, these are the two methods that produced ExMF outside the atom on micro scale, increasing the number of electrons, protons and ions, increased the produced ExMF-(A&B), thus this decreased the radius of gyration, thus increased the produced ExMF-(A&B).

Among the intrinsic characteristics of electrons, protons and neutrons it's continual spinning around its axis thus producing a continuous Spinning Magnetic Field (SMF), it's suggested that, the interaction of two protons' SMF produced the Spinning Magnetic Force (SMFs) or the nuclear force (Yousif, 2003a, 2003b, 2018b) as shown in Fig. B-8, it also produced the related energy (Yousif, 2003b, 2004, 2018b), this SMFs is an important characteristic in nuclear fusion and the solar flare.

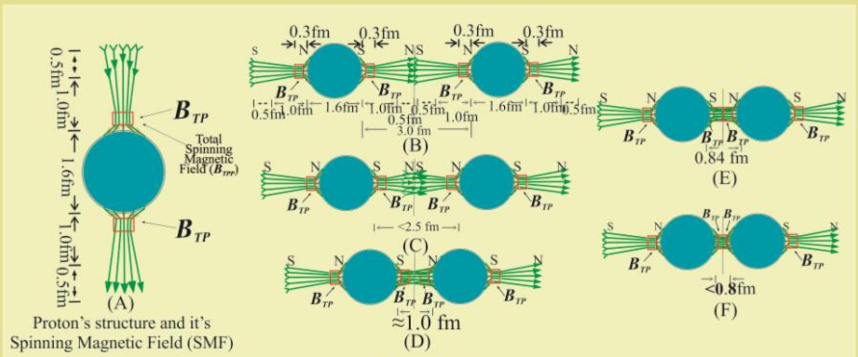


Fig. B-8

(C)- The Active Regions & Plasma Pillar Intense Magnetic Field (PPIMF)

The Active Regions (ARs) are areas of intense and complex magnetic activity that can sometimes give rise to solar eruptions such as solar flares and coronal mass ejections (Zell, 2017), ARs seen as bright objects in EUV and soft x-rays images, this video showing an Active Region (AR) 1429 On March 2, 2012 , rotated into view. It has let loose two M-class flares and one X-class solar flare (NASA Goddard), it also showing the AR rotating clockwise.

https://youtu.be/edRuLAlAysE

Another example of an AR, with an inset Earth for size reference, in extreme ultraviolet (Credit: Credits: NASA’s Goddard Space Flight Center/Solar Dynamics Observatory/Steele Hill), the image shows the flux rotating around fixed axis.

https://youtu.be/OYKRTD7k2R8

While, during the last solar cycle, between 14 and 18 May 2015, The Sun displayed a galore of ARs (Credit: Solar Dynamics Observatory, NASA), carful study of the fields shows cases similar to Fig. C-4-C.

https://youtu.be/EiSicUWJ0Iw

These movies are good examples of ARs, where they are associated with strong magnetic bipolar fields that tracing bipolar regions on the Sun’s surface, the ARs are formed within a few days as massive amounts of magnetic flux break through the solar surface, the magnetic flux densities of up to 100G and more can be reached in the lower corona above a strong bipolar region (Solanki, 2006), the following images shows how the idea about the Plasma Pillar Intense Magnetic Field (PPIMF) was developed as an AR:

The three images of the Magnetic Lines of Force (MLF) or fluxes in Fig. C-(A) (Window to the Universe, 2010), (B) (Ualberta, sites) and (C) (SciTechDaily, 2017) are fluxes from ARs; shown in Fig. C-1, the first one is attached with horseshoe and the other two with bar magnets, these represent imaginary sources of the magnetic fields producing these fluxes, it represents a general conviction about the sources of these fields.

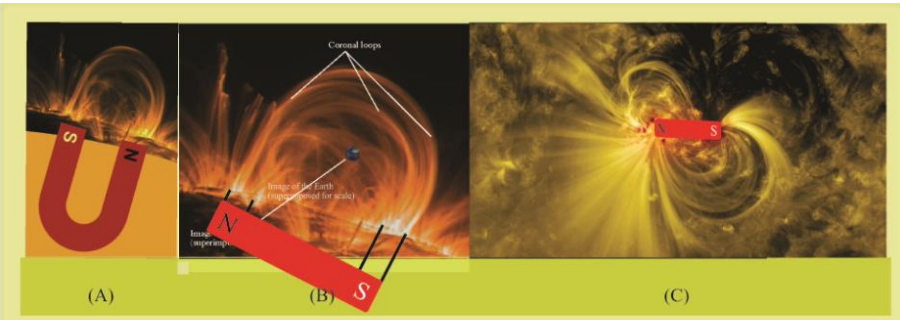


Fig. C-1

The EUV image in Fig. C-2-(A), is believed to be imperfect, as there’s a missing mechanism between the two magnetic poles, but since the magnetic lines of force connected both poles existed, in addition to coincidence of emerged flux with arrival of AR, these factors led to the suggestion of existence of horseshoe or bar magnet in the AR shown in Fig. C-1, although impractical, but the suggestions developed into the idea for the existence of Plasma Pillar Intense Magnetic Field (PPIMF) between the two poles as shown in Fig. C-2-(B).

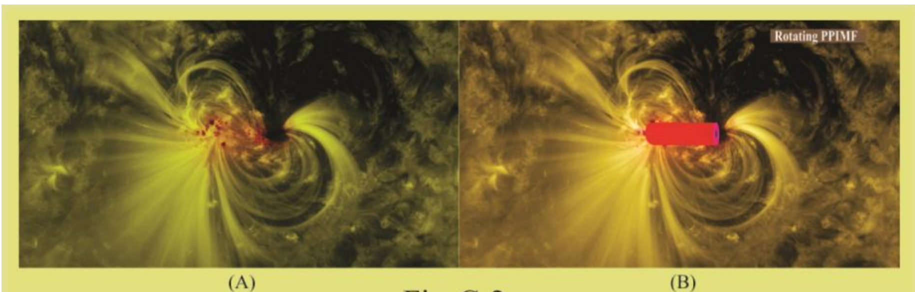
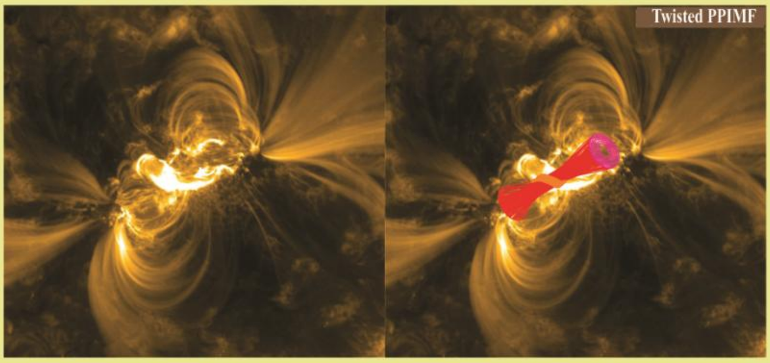


Fig. C-2

While the strange image in Fig. C-3-(A), which is in EUV of AR 11158, with Magnetic Lines of Force (MLF) have complex poles, it's first interpreted in Fig. C-3-(B) as due to twisted single PPIMF.



(A) Fig. C-3 (B)

But detail studies of the above Active Region (AR) 11158 of ARRL 14, 2011, by the authors Sun et al., (2016) shows in Fig. C-4-(c) the strange shape of the AR in EVU is more complex than perceived, its remapped HMI vector magnetogram in (a) vertical current density in (b) and Magnetic Lines of Force in (d), if our PPIMF is correct, then what cause this strange shape of AR, with strange poles and lines of forces?

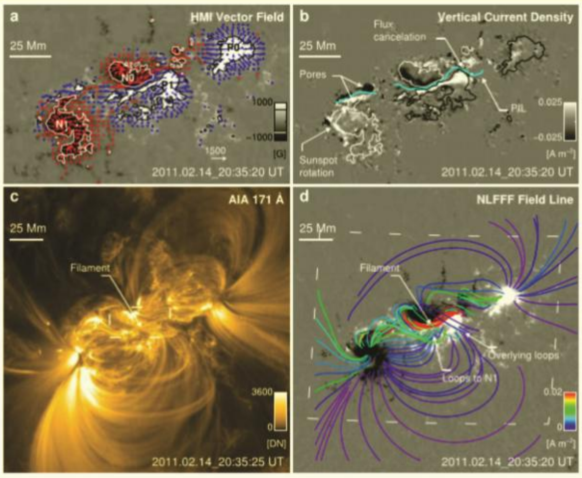
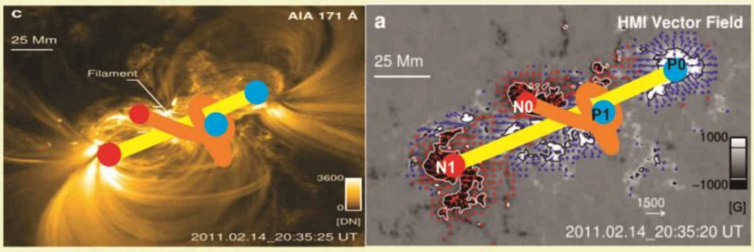


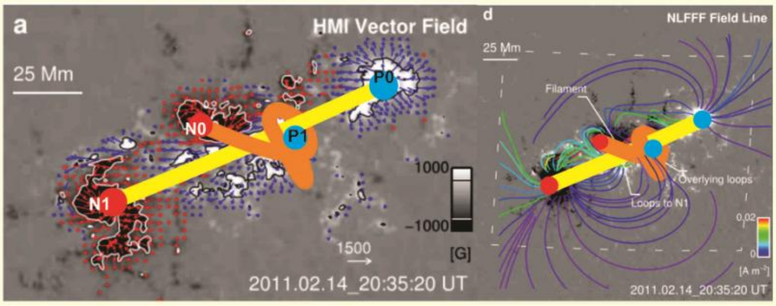
Fig. C-4

It's realized from Fig. C-4 of the Active Region (AR) 11158 , shown in Fig. C-5 (B) (Sun et al., 2016), that there are two poles of positive and negative magnetic fields; hence we suggested the entanglement of the orange PPIMF around the yellow PPIMF as the reason behind this strange shape, as shown in both Fig. C-5-A&B for the two PPIMF.



(A) Fig. C-5 (B)

The HMI Vector Field in Fig. C-6-(A) and the NLFFF field line in Fig. C-6 (B) in AR 11158 (Sun et al., 2016), are replaced with two PPIMF each, where the entanglement of the orange PPIMF around the yellow PPIMF formed this strange shape, the -ve and +ve magnetic poles are where the lines of force are connected, while some fields from the yellow PPIMF shortcut its path and joined the middle orange PPIMF.



(A) Fig. C-6 (B)

Therefore, from the above examples, we can stated that, the complexities of Magnetic lines of force and poles in some EUV images, are interpreted as due to two or more PPIMF which intersected as shown Fig. C-7, then they may intermix or entangled or twisted around one another or each others, thus producing complex magnetic fields with many poles, as shown in above images.

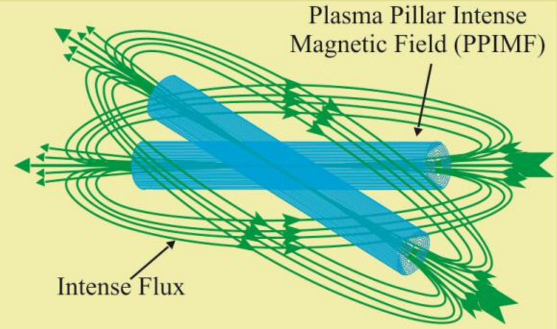


Fig. C-7

The Magnet Line of Force (MLF) or flux of an AR is shown in Fig. C-8 with image of Earth for comparison (Ualberta, sites), the width of MLF is around 0.77% of diameter of the earth.

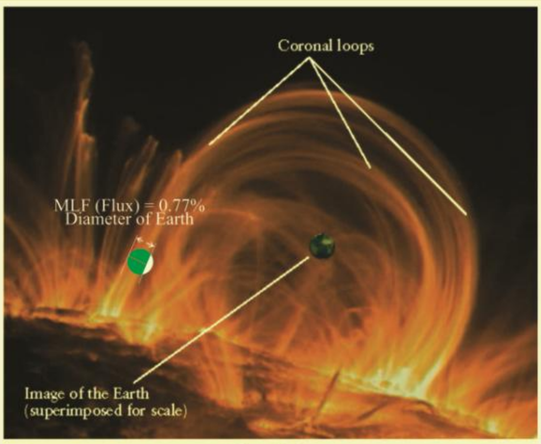


Fig. C-8

Thus the production of dipole moment in the core of the earth and the sun (Yousif, Unpublished-a), or such as the PPIMF, in which the Lines of Force (MLF) are very thick, or any magnetic lines of force, therefore, based on the derived relations between the MLF and magnetic fields (Yousif, 2003c), a formula had been developed to derive the magnitude of the PPIMF, when the width of the MLF (Flux) is known, it's given by

$$PPB_{Ex-D} = 10^8 \, w^2 \qquad (C-5)$$

Where, w is the width of flux, and $PPB_{Ex\text{-}DM}$ is the Dipole Moment (MDM) of the Plasma Pillar External Magnetic Field Type-B ($PPB_{Ex\text{-}DM}$) in Tesla m^2, therefore, PPIMF represents a movable dipole moment (Yousif, Unpublished-b).

If w = 0.77% of the diameter of the earth which's 12,742 km, hence w = 9,811.34 km, using this in Eq. (5), the dipole moment producing this field is $9.62623925956 \times 10^{15}$ T.m^2, this magnitude is either for a single PPIMF (AR) or resultant of two PPIMF (AR) joined together, its greater than what been derived for the dipole moment of the sun, which's $1.016464516758502245 \times 10^{14}$ (Yousif, Unpublished-a).

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Eq. (C-5) is very interested; as a generalized, it can be used even for small magnetic fields.

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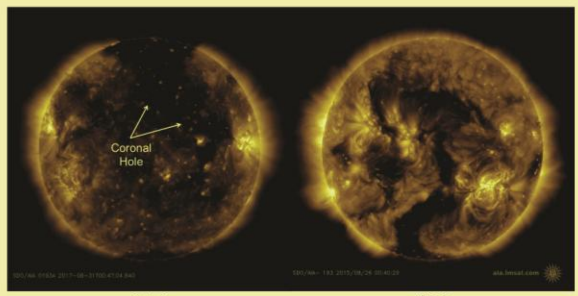
This video shows an active region, taken in EUV by the SDO (NASA video), it shows the rotation of the flux around PPIMF.

https://youtu.be/gBc8tOIT_iw

(D)- The Production of Plasma Pillar Intense Magnetic Fields (PPIMF) and Their Role in Solar Cycle

In the previous section, the characteristics of the Active Region (AR) showed how it can produce intense magnetic field, this is the intensity accompanied the thick and long flux shown in Fig. C-8, and since Plasma Pillar Intense Magnetic Field (PPIMF), is suggested to produce these intense magnetic fields, therefore the characteristics of both phenomena are common, hence the PPIMF is suggested to represent the plasma body forming the AR; and that the PPIMF is suggested to be produced in manner similar to the spicules, which are seen ejected from the high chromospheric part of supergranule boundaries and reach speeds of 20 to 30 km s^{-1} and heights of about 11,000 km before fading, the spicules have diameters of 50 to 1,200 km, maximum lengths of 10,000 to 20,000 km, temperatures of 10,000 to 20,000 K and electron densities of 3×10^{10} to 3×10^{11} cm^{-3}. (Basu, 2001), these density decreases from 1.6×10^{11} cm^{-3} at 2 Mm to 4.3×10^{10} cm^{-3} at 8 Mm (Tei et al., 2019), but the environment in which spicules are produced differ in that it doesn't allowed its continuation, while PPIMF did with compound results, therefore AR is consists from PPIMF, which is similar in nature with spicules, hence it can be compared with spicules, in the followings points we will illustrate how solar cycle started by the production of PPIMF and ended with the extinction of PPIMF, we will not start at the beginning of the cycle millions or billions years ago, rather the start is at the end of each solar cycle:

At the end of each solar maximum, all Active Regions (ARs), after carrying several solar flares explosions, moved nearer the northern and southern solar magnetic poles (Yousif, 2012), where they are accumulated and attracted to each others, the buildup of these very long ARs suggested to make them incapable of rotation, hence they ceased rotating as shown in Fig. D-1, for mostly northern in (A) and southern in (B) (NASA-SDO), thus when AR ceased to rotate, the bulky PPIMF started losing its magnetic field, that state is of extinction, which we think is the longest period in the solar cycle.



(A) Fig. D-1 (B)

When coronal holes start losing magnetic fields, electrons, protons and ions disintegrated from the AR, spreading and diffusing towards the equator, immediately they interacted with Solar Magnetic Lines of Force (SMLF), its basics had been given in Fig. B-6, the interaction started at the boundary between polar and non-polar fields, which is around latitude 70^o as shown in Fig. D-2, then the interactions moved consecutively to lower latitudes of the SMLF concurrently with the spreading of the charged particles, in this process, each SMLF attracted charged particles, which gyrate around the rotating SMLF and produced smaller Plasma Pillars Intense Magnetic Fields (PPIMF) as shown in Fig. D-2, this concurrently with the produced External Magnetic Field Type-A (ExMF-A), its mechanism is shown in Fig. B-6 (Yousif, 2004, 2013, 2014b).

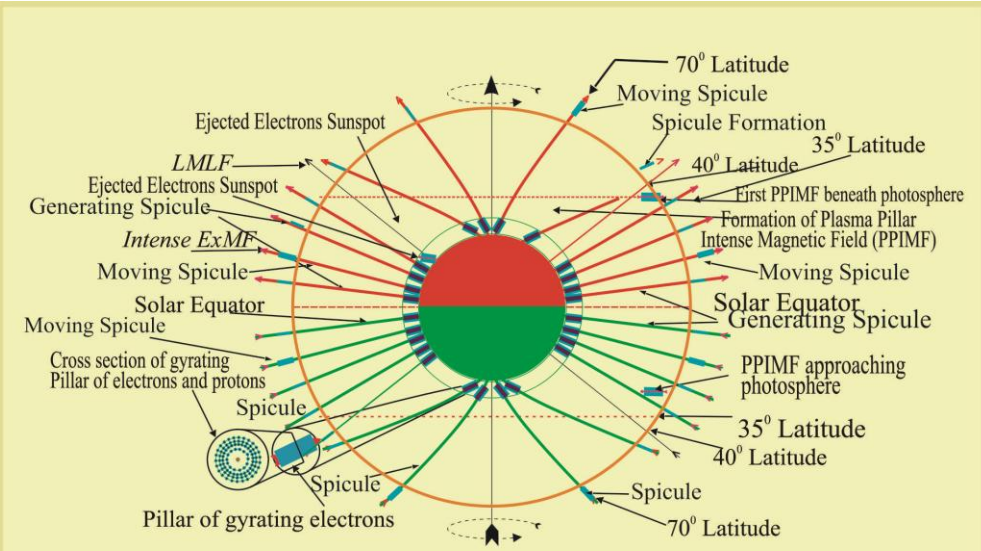


Fig. D-2

Charged particles continue gyrating and energized (Yousif, 2004) for a period equal to the lifetimes of spicules which usually between 10 and 60 s for type II, and 3–7 minutes for Type I (DE PONTIEU et al., 2007), then each PPIMF is ejected from the SMLF consecutively, this process is depicted in this movie of "The Sunspots Mechanism" (Yousif, 2012b, 2013):

https://youtu.be/ropGu6AGJ7s

As depicted in this video, the mechanism producing PPIMF is similar to spicules (Yousif, unpublished-b); while the PPIMF is shown in Fig. D-3, thus when PPIMF is ejected, it spent sometimes moving in the vast internal Solar space towards the photosphere, and since the ejected PPIMF still maintains the previously produced ExMF-A, this continued as long as charged particles still rotating around the PPIMF, where it's rotation is similar to tornado in addition to the gyration of electrons, protons and ions in orbits around the lengthy PPIMF, increased the produced ExMF, which now transformed into External Magnetic Field Type-B (ExMF-B) after being ejected from SMLF as shown in Fig. B-7, this tornado like movement, produced ExMF-B continually as long as PPIMF keeps intact (Yousif, Unpublished b), during the production of both ExMF-(A&B), charged particles continually undergoing energization process which maintain the production of the ExMF-B (Yousif, 2004), they can entangled with each others as in section-C.

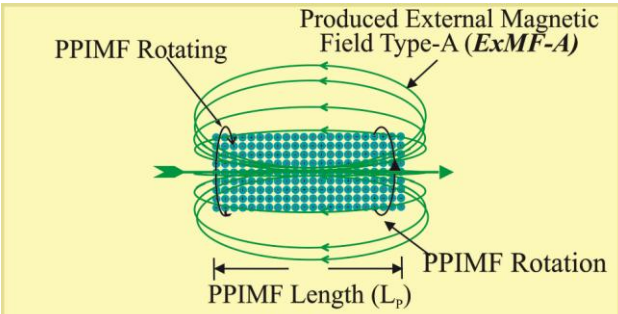


Fig. D-3

The tornados characteristics of rotational plasma in the sun was captured by SDO in February 2012, where the captured images shows strange plasma tornados on the solar surface, observations found these tornadoes, which were created by magnetic fields spinning the plasma, it could rotate at speeds up to 186,000 miles per hour (52 RPS). On Earth tornadoes only reach speeds of 300 miles per hour. The video is assembled from images taken by NASA's SDO spacecraft. (Credits: NASA's Goddard Space Flight Center)

https://youtu.be/BPyTHW8UoKM

Another video of Limb spicule spectra in the Mg II k line observed by IRIS on 2016.02.21 (Tei et al., #AGU20), the rotation is suggested to be similar to the Plasma Pillar Intense Magnetic Field (PPIMF).

https://youtu.be/vbqHy_Y_F00

The tornado like rotation of the PPIMF, produced intense CMF, this builds intense ExMF-B, as shown for a cross section across a single orbit in Fig. D-4.

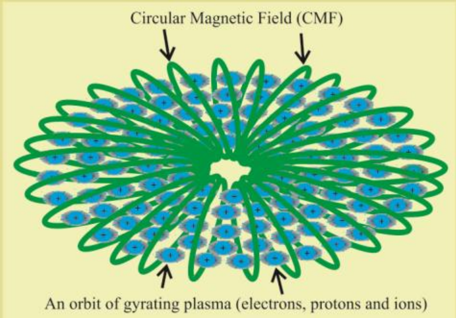


Fig. D-4

In Fig. D-2, because PPIMF move in straight line from source of production around latitude 70^o but this is the extension of latitude 35^o, it's the reason why each new PPIMF appears nearer to the equator; the Plasma Pillar Intense Magnetic Field (PPIMF) is shown in Fig. D-5, each unit is different from others; and each PPIMF continually undergone energization process (Yousif, 2004), while the magnitude of each ExMF-B is given by

$$B_{EB} = \frac{2\pi^2 q\, V\, r_{pp}\, lp}{r_{XP}^2} \qquad (D-6)$$

Where, q is the charge in Coulomb, *v* is the frequency of the rotating PPIMF revolution s^{-1}, r_{pp} is the radius of PPIMF in meter, *l* is the length of the PPIMF in meter, *p* is the density of the PPIMF in P m^{-3}, r_{XP} is the distance at which the B_{EB} is measured from the center of the PPIMF in meters, and B_{EB} is the measured intensity of the produced magnetic field by the PPIMF at radial distance r_{XP} in Tesla (Yousif, Unpublished-b), but the PPIMF shown in Fig. D-5, behave like Movable Dipole Moment (MDM).

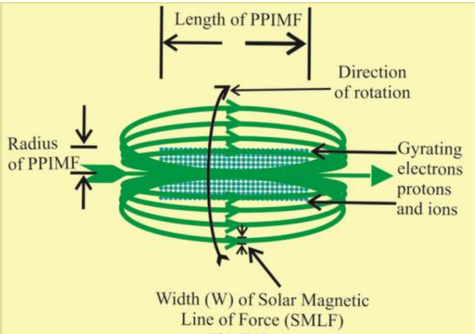


Fig. D-5

Therefore, from the above definition, this Dipole Moment (DM) of the Plasma Pillar External Magnetic Field Type-B (PPB_{Ex-DM}) in T m^2, is given by (Yousif, Unpublished-b)

$$PPB_{Ex-D} = B_{ES}\, r_{XP}^2 = 2\pi^2 q\, V\, r_{pp}\, lp \qquad (D-7)$$

When PPIMF reached the photosphere, it's denied access to emerged from the photosphere, it magnetized photosphere's materials (as will be seen), then moved to northern direction to northern solar magnetic pole for northern PPIMF and to the southern magnetic pole for southern PPIMF, during which it carries several solar flare explosions, then when its nearer the solar magnetic poles, each PPIMF attracted and attached to each other as shown in Fig. D-6, and depicted in the above movie, in "*The Sunspots Mechanism*" (https://youtu.be/ropGu6AGJ7s), and shown in section (F).

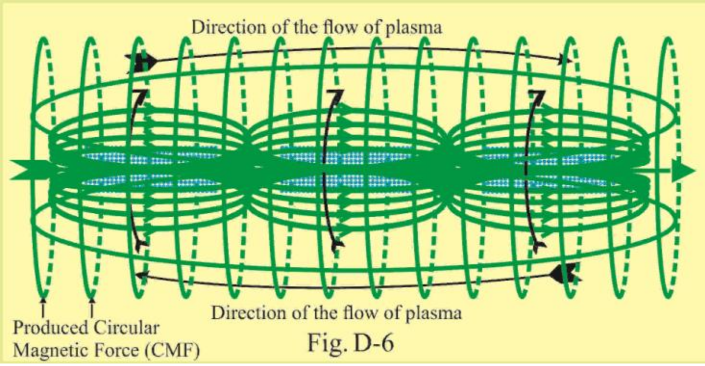
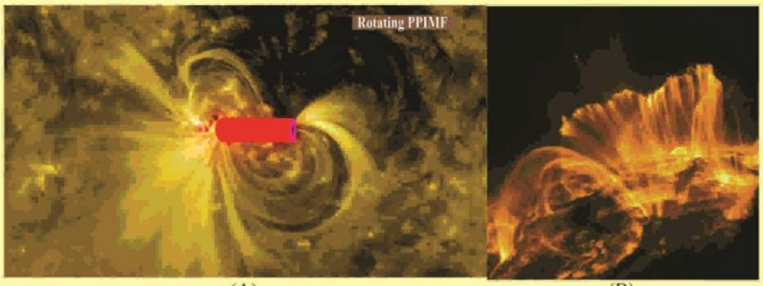


Fig. D-6

These PPIMF interacted and attached to each other forming a very long PPIMF, where plasma flows in longer flux, changed the MLF from the lengthy fluxes shown in Fig. D-7-A into circulars flux as shown in Fig. D-7-B, the accumulation of PPIMF increased with the depletion of charged particles from the interaction zone for PPIMF production in Fig. D-2, signaling the end of the solar maximum, and the start of solar minimum.



(A) (B)
Fig. D-7

The accumulation of the attached PPIMF is shown for a single very long PPIMF in Fig. D-8, similar to Fig. D-7 (B); the bulky AR9077 produced loops or Circular Magnetic Field (CMF), taken in July 14, 2000 by TRACE, it had produced a massive flare, the false-color image covers an expansive 230,000 by 170,000 kilometer area on the Sun's surface (Earth's diameter is about 12,800 kilometers), (TRACE, Stanford-Lockheed, 2000), from its length, the loop is 271,818 km long, which is smaller to the prominence shown in Fig. D-9 (UCAR.EDU) which is nearly 920,119 km.

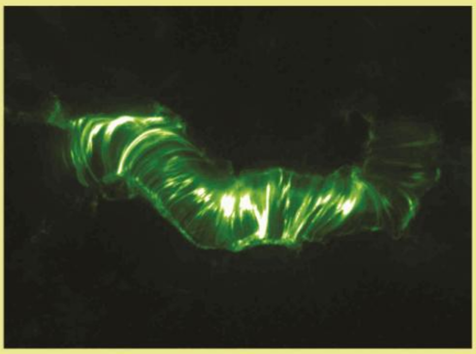


Fig. D-8

The Grand Prominence of 1946 (UCAR.EDU), in Fig. D-9, is suggested to contain too many attached PPIMF, its sector been extended to obtain the full circumference of the sun; the interaction of collective PPIMF-C with the solar dipole moment (Yousif, Unpublished-a), thought to resulted with violent force of levitation uplifted the whole combined PPIMF-C or corona hole to such altitude of 200,000 km (UCAR.EDU) above the solar surface, using Eq. (2) in relation with Fig. D-10, the magnetic force caused this levitation can be derived, the levitation would persist until its magnetic field depleted then charged particles, falls back to the sun, which also explain the filaments levitation. From Fig. D-9, it can be inferred that, the solar cycle is a regulated circulation of the PPIMF from the start till the end, shown by the blue arrows.

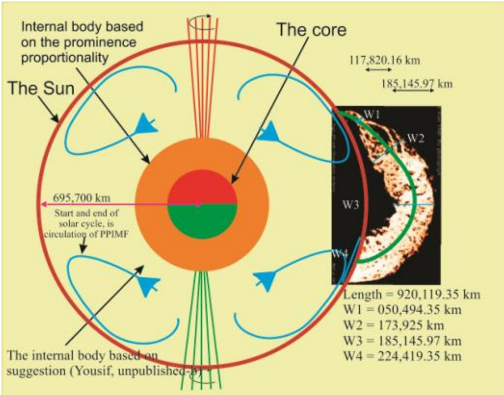


Fig. D-9

The normal position of this prominence (UCAR.EDU), inside the sun, which is one of the coronal holes shown in Fig. D-1, it illustrated how it's been accumulated inside the sun before the levitation; when interacted with the dipole moment of the sun, this cause change in the rotation of the internal body of the sun (Yousif, Unpublished-b), as shown in Fig. D-10, thus instantly changing the direction of the solar magnetic field (Yousif, Unpublished-b).

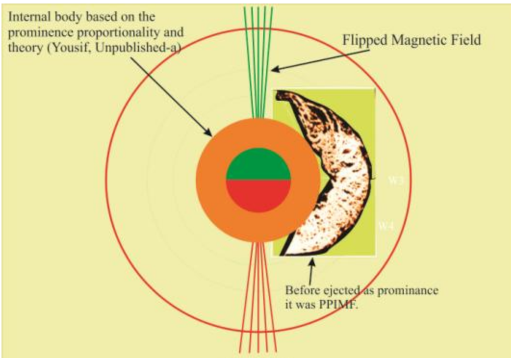
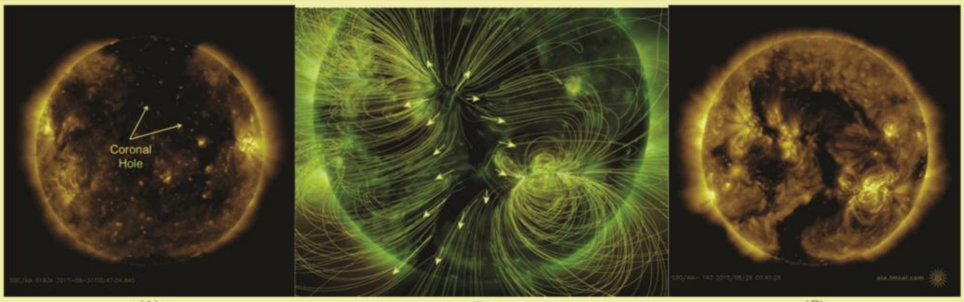


Fig. D-10

As the whole coronal hole composed from PPIMF that have been stopped rotating, the ExMF-B is no longer produced by PPIMF, and solar flare explosions ended, the coronal hole is quite and the sun will be calm, as shown by the coronal holes in Fig. D-11, where (A) and (C) shows two examples of coronal hole, while (B) shows two or three nearby lately produced PPIMF linked by their MLF, the coronal holes contained most of the inner free-charged particles of the sun, it's the reason why sunspots are rare during this period.



(A) (B) (C)

Fig. D-11

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The slow disintegration process of the coronal hole takes a long period of time until the remnant of ExMF-B finished, then PPIMF will start disintegrating, and electrons and ions start spreading towards the equator, interacted with SMLF, ejected new PPIMF, which moved towards the photosphere, thus marking the start of a new solar cycle, as given in the top of this page by Fig. D-2, and in this movie: "The Sunspots Mechanism"

https://youtu.be/ropGu6AGJ7s

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A sample of solar coronal holes around the time of the maximum of sunspot activity (April 2014). Note the Polar Regions are devoid of coronal holes but a large hole appears in the southern hemisphere (Video credit to: NASA's Scientific Visualization Studio).

https://youtu.be/UxJuUbAGcDA

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A long coronal hole can be seen right down the middle of the sun in this video captured by NASA's Solar Dynamics Observatory on March 23-25, 2016. (Credit: NASA/SDO), it's an example of the end of solar maximum.

https://youtu.be/VP4xB5bH1ic

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The Solar Cycle as Seen from Space (Video credit: NASA's Goddard Space Flight Center). The video illustrate the difference between solar maximum and minimum, the disorganized magnetic fields by PPIMF at maximum, the dipole field at minimum, coronal loops and corona holes among others.

https://youtu.be/Z0uIcLZ5rh8

(E)- The Sunspots: The Magnetized Photosphere

Sunspots are the dark spots seen on sun's surface (Brandat and Hodge, 1964), where strong magnetic fields emerge from solar interior and where major eruptive events occurs (Zhao and Kosovichev 2011), the followings are some discoveries suggested to relate sunspots with the Plasma Pillar Intense Magnetic Field (PPIMF), and the relation with sunspots:

A body is detected at the depth of 60,000 km, shown in Fig. E-1-(A), using acoustic wave, concurrently with appearance of a trace of Sunspots starts forming on the surface of the sun as shown in Fig. E-1-(B) (Phillips, 2011c), we suggested the detected body represent the PPIMF (Yousif, 2012).

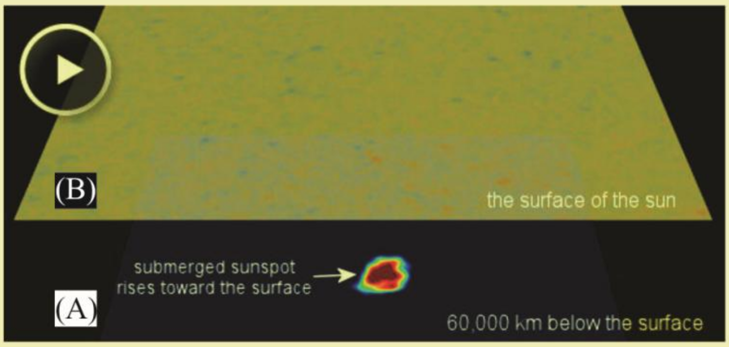


Fig. E-1

Predicting the appearance of the sunspots, Sunspot Breakthrough: August 25th, 2011 (Skyywatcher88-CD Baby) (Science@NASA), the movie shows how the PPIMF is detected before traces of sunspots start appearing on the photosphere surface:
https://youtu.be/v53I0trqaSA

An AR 8164 in Fig. E-2, 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) Shows the Total unsigned magnetic flux (red line) and magnetic flux rate (green line) of AR 8164 (Zhao and Kosovichev 2011), this also shows the movement of the PPIMF towards the photosphere (Yousif, 2012).

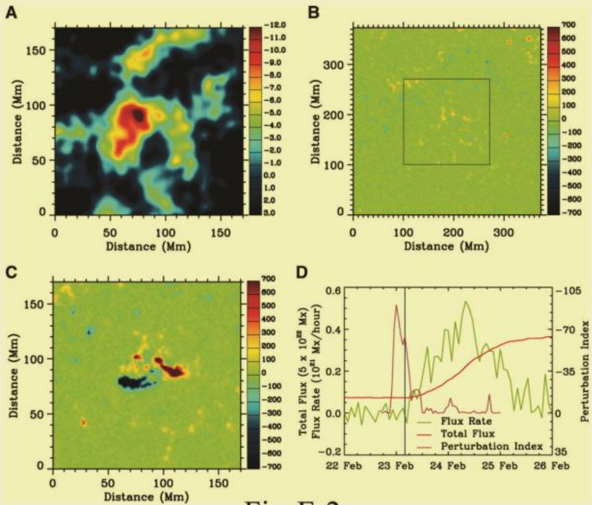


Fig. E-2

The surface and subsurface image of the sun is shown in Fig. E-3, the sunspot is shown on the surface, while an elongated body is in subsurface (SOHO/MDI, 2006); from relative measurements we estimated the body is 17.5 Mm long and at depth of 6.5 Mm from surface, the average distance to the center of the body is 12 Mm , this body is suggested to represent the PPIMF while approaching photosphere.

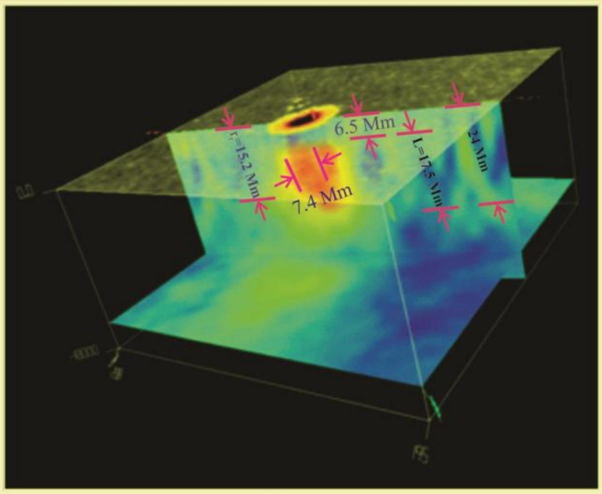


Fig. E-3

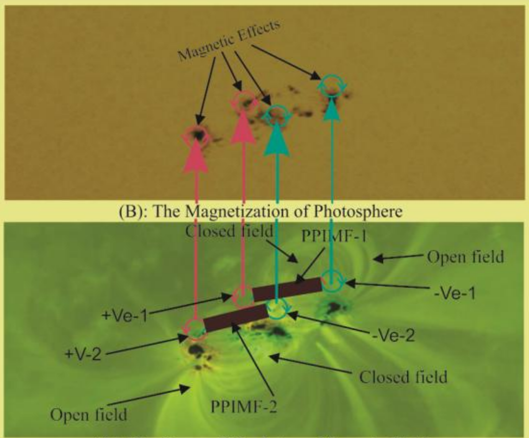
A snapshot in Fig. E-4-(A) from the movie above showing two sets of subsurface rotating Magnetic Lines of Force (MLF) due to an AR, while Sunspots are seen at the surface in Fig. E-4-(B) (Philip, 2010a, Philip, 2010b), we analyzed both images and suggested the existence of two PPIMF in (A) (Yousif, 2012a), thus from these points we can conclude that:

a) There are two elongated body of plasma several thousand kilometers bellow the sunspots, it's what we named PPIMF.

b) The X-rays & EUV images, showing magnetic lines of force, therefore these fields must have northern and southern poles, with MLF connected both poles.

c) From the above, we state that, the elongated plasma body in Fig. E-4-(A) is similar to image in Fig. C-2-A, and both constitutes a movable PPIMF continuously approaching the photosphere, while producing intense magnetic fields.

d) The depth of the elongated PPIMF from the photosphere determines the shapes and area of the sunspots.



(A): The Plasma Pillar Intense Magnetic Field

Fig. E-4

The Active Regions (ARs) always emerged from inside the sun, when the flux of an AR emerged on the surface, during solar cycle as shown in Fig. C-8, this means the start of solar cycle, and other PPIMF will follow, looking to both images in Fig. E-5 (A) for an AR and Solar Flare (SF) (NASA-SDO/AIA 171) and Fig. E-5 (B) for an AR (Space Weather Trackers), in both images there are shallow AR enclosed by large circles, while there are deeper AR enclosed in square, and still others very small less bright are much deeper; therefore these showed PPIMF as described emerged from deep zone inside the sun as detected and given in Figs. E-1, 2, 3&4 and illustrated in Fig. D-2, the figure also shows the existence of large space in the sun.

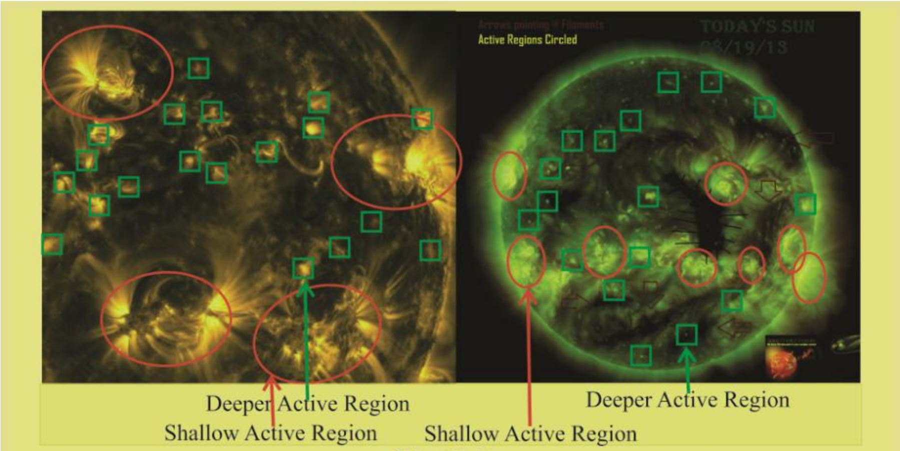


Fig. E-5

In the magnetic image of the visible hemisphere in Fig. E-6, taken during maximum activity cycle, it's dominated by large bipolar magnetic regions and extended unipolar domains (SOHO-ESA/NASA) (Solanki et al., 2006), this is similar to Fig. E-5, it shows the existence of too many PPIMF on different areas and depths of the sun, which suggested the view that great space existed in the sun as illustrated in Fig. D-2 & Fig. D-9.

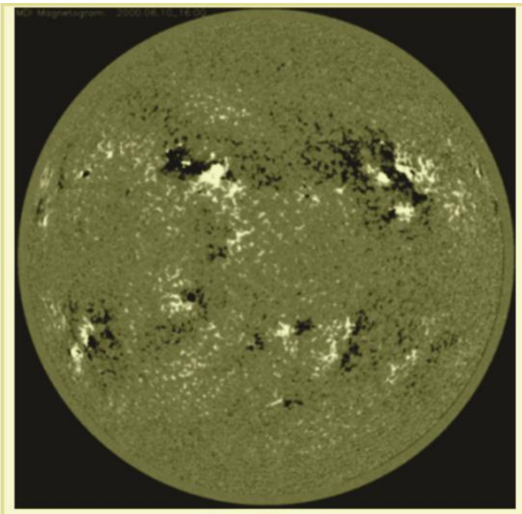


Fig. E-6

Therefore, from these points and as shown in Fig. E-7, sunspots are the magnetized effect on photosphere plasma, it looks like iron filings, formed by the produced intense PPIMF in the subsurface, the shapes and areas of the sunspots depends on the strength and depth of the PPIMF.

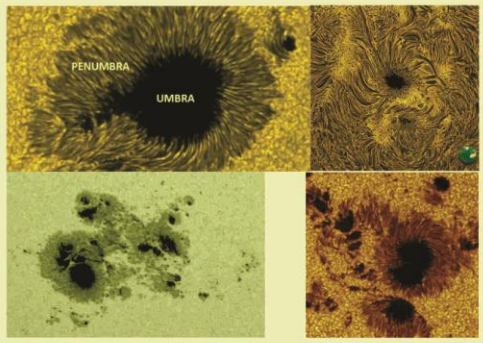


Fig. E-7

As treated and derived in the "Exploring the High-altitude Nuclear Detonation and Magnetic Storms" (Yousif, 2014b), if the magnitude of the measured magnetic field at sunspot is multiplied by the square of the distance to the center of the PPIMF shown in Fig. E-3, then the resultant will be equal to the magnitude of the PPIMF derived using formula given by Eq. (D-6), at the same time this formula shows PPIMF as a movable dipole moment, (Yousif, unpublished-b), the formula is given by

$$PPB_{Ex-D} = B_{ES}\, r_{SD}^2 = 2\pi^2 q\, V\, r_{pp}\, lp \quad (E-8)$$

Where, B_{ES} is the measured intensity of magnetic field on sunspot in Tesla, r_{SD} is the distance from sunspot to the center of the PPIMF in meters, q is the charge in Coulomb, *v* is the frequency of the rotating PPIMF in revolution s^{-1}, r_{pp} is the radius of PPIMF in meter, *l* is the length of the PPIMF in meter, ρ is the density of the PPIMF in P m^{-3}, and PPB_{Ex-D} is the Dipole Moment of the Plasma Pillar External Magnetic Field Type-B in Tesla m^2. (Yousif, Unpublished-b)

Since sunspots fields strength in their darkest portions is B_{ES} = 0.25-0.35 T and 0.07-0.1 T at their outer edges (Sami et. al, 2006), and average distance to PPIMF in Fig. E-3 is 15,250 km, using these in the central part of Eq. (E-8), therefore the

PPB_{Ex-D} are: = 5.8140625×10^{13} T m^2. = 8.1396875×10^{13} T m^2, respectively. If the length of the PPIMF in Fig. E-3 is *l* = 15,250,000 m, q = $1.602176634\times10^{-19}$ C, v = 10 revolution s^{-1}, r_{pp} = 7.4×10^{6} m, p = (1×10^{11} P cm^{-3},), 1×10^{17} pm^{-3} therefore using Eq. (E-8), PPB_{Ex-D} = 3.57×10^{14} T m^2.

If the above PPB_{Ex-D} = 3.57×10^{14} T m2, and r_{pp} = 15,250 km as above, using the middle formula in Eq. (E-5), therefore B_{SS} = 15.35T, if the above PPB_{Ex-D} = 3.57×10^{14} Tesla m^2, and B_{SS} = 0.35 T as above, using the middle formula in Eq. (E-5), therefore r_{pp} = 31,937.43 km.

From these calculations, although the difference between the two measurements are not great, it's clear the magnitude of measured magnetic field intensity on sunspots (B_{ES}) either not accurate, or the distance of PPIMF is smaller, hence if we get the proper data, things will be much better and clearer. The question is, can 0.35 T magnetized photosphere to such extend?

Finally, as the sun goes through its natural solar cycle approximately every 11 years, marked by the increase and decrease of sunspots, visible as dark blemishes on the photosphere; and as illustrated in Fig. E-8 (NASA/SDO, 2012) the greatest number of sunspots in any given solar cycle is designated as “solar maximum” the lowest is “solar minimum.”

Therefore, solar maximum and minimum are the reflection of the level of production of PPIMF and its existence in the vicinity of the photosphere, to magnetized photosphere and carried solar activities.

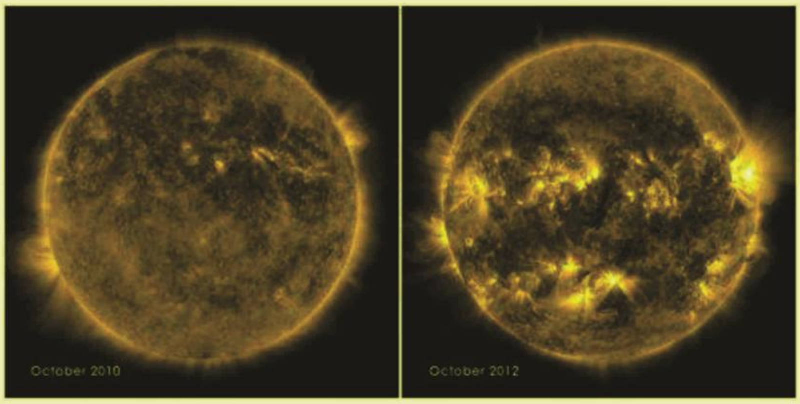


Fig. E-8

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An interested Two Weeks in the Life of a Sunspot (PPIMF): On July 5, 2017, the Solar Dynamics Observatory watched an AR or PPIMF, rotate into view. During its 13-day trip across the face of the Sun, the AR put on a show for several NASA Sun-watching satellites, producing several solar flares, a coronal mass ejection and a solar energetic particle event. (Credits: NASA’s Goddard Space Flight Center/SDO/SOHO/CCMC/SWRC/Genna Duberstein, producer), such video help understanding the role of the PPIMF in solar activities.

https://youtu.be/SungFXUsoqw

(F)- The Solar Flare Mechanism

The link between solar flare and nuclear fusion was rejected due to low densities in upper chromosphere or lower corona (Brandat and Hodge, 1964), in 1950, a Red Army sergeant suggested an idea later been developed into Tokamak, a device used powerful magnetic field to confine hot plasma in a volume with a shape of a torus to press ions together and ignite sustain nuclear fusion (Wikipedia Tokamak).

The density in the upper chromosphere or lower corona is really low, but this is not the density of the subsurface elongated plasma body named the Plasma Pillar Intense Magnetic Field (PPIMF).

The log of temperature, static loop models with uniform heating predict densities of approximately 10^7 cm^{-3} at the largest heights and about 8×10^7 cm^{-3} at the lowest heights (Warren and Amy, 2003), also the ranges of density derived for a particular active region as a function of temperature as loops heat up and then cool, range from about 2.9×10^9 to about 9.4×10^9 cm^{-3} (DOSCHEK et al, 2007); comparing this with the high density in the inner core of the earth, which is 10^{13} cm^{-3} [Stevenson, 1983], while the spicules which is suggested to be produced in similar mechanism like PPIMF (Yousif, Unpublished-b), it have maximum lengths of 10,000 to 20,000 km (Basu, 2001), with average heights between 6,500 and 9,500 km and diameters between 400 and 1,500 km for Type-I (BECKERS, 1972), while Type II spicules is not longer than 1,000–2,000 km, they can reach several megameters (DE PONTIEU et al., 2007) and width of 150–200km (DE PONTIEU et al., 2007), while for sunspots, from the given length of 25,000 km in Fig. C-6-d (Sun et al., 2016), the length of that yellow PPIMF is 112,500 km, which is the same in Fig. C-6-a, while the width of PPIMF shown in Fig. D-8 is 173,000 km (although it's a combination of several PPIMF), with this huge difference, while the density of spicules is ranging between 3×10^{10} to 3×10^{11} cm^{-3} (Basu, 2001), such high density while it doesn't produced explosions (solar flare), on the other hand comparing spicules with PPIMF, Type II spicules lifetimes at any one height are usually between 10 and 60 s, and Type I" spicules lifetimes is around 3–7 minutes (DE PONTIEU et al., 2007), while PPIMF which suggested to start with smaller length and diameter as shown in Fig. D-3 can be similar to spicules, but it takes longer periods to reach photsphere, during which both its thicknesses and length, increased while capturing more particles as shown in Fig. D-5, therefore the Density of the PPIMF is much greater than that of spicules, our estimation between 1×10^{11} and 1×10^{12} cm^{-3}, (1×10^{17} - 1×10^{18} m^{-3}), therefore the Solar Flare is an explosion carried by nuclear fusion (Yousif, 2003b, 2018b), and the following are the two mechanisms of fusion carried by the PPIMF.

(A) Fusion: Natural Triggered Mechanism

The main function of the Tokamak, shown in Fig. F-1, is to confine the plasma under very high temperature and pressure to cause fusion (Wikipedia Tokamak), but is there any other mechanism in nature that brings these ions together to ignite the fusion?

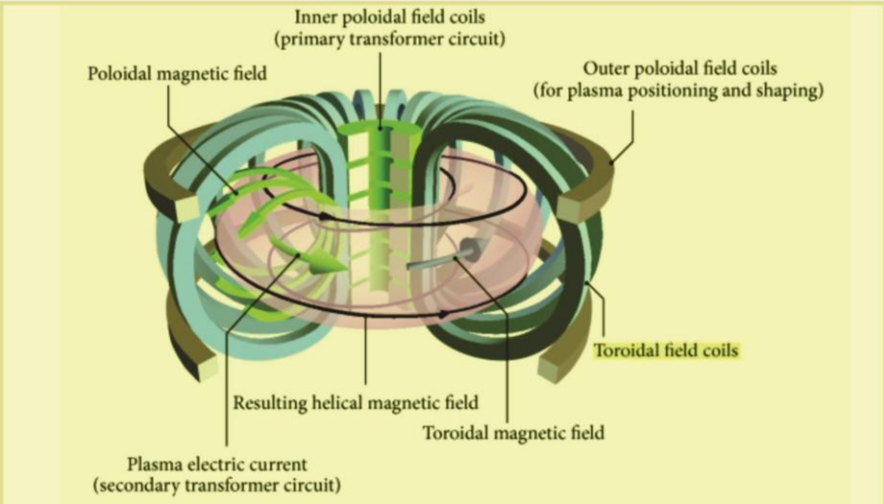

Fig. F-1

Yeas, this occur but with different concepts, that electrons, protons and neutrons produced Spinning Magnetic Field (SMF) as shown in Fig. B-8, the interaction of two SMF produced the Spinning Magnetic Force (SMFs) or the nuclear force and the related energy (Yousif, 2003a, 2003b, 2018b), with this as background, we continue with the followings:

The Plasma Pillar Intense Magnetic Field (PPIMF), consist of protons, electrons and ions, each gyrate in separate orbits or sections within the PPIMF, as shown in Fig. F-2 for protons.

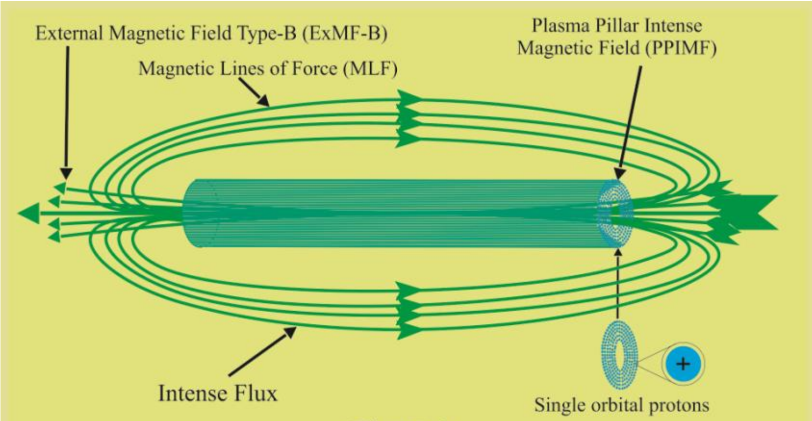

Fig. F-2

The produced External Magnetic Field Type-B (ExMF-B) is in the center of the gyrating ions as B_1 in Fig. F-2, and since the space of the sun is full with charged particles, any increase in the capture of these particles increased the magnitude of the new produced ExMF-B, this mechanism is shown in Fig. F-3, the produced magnetic field is added to the existed B_1, to become B_{m1}, this new field decreased the radius of gyration, forced protons to move from radius r_{m1} to r_{m2}, the effect of these increases in produced ExMF is to forced ions to move closer to each others, and as shown in Fig. F-3, the +ve Spinning Magnetic Field (SMF) of the protons are coming closer to the -ve SMF of adjacent proton, thus while gyrating, a critical distance between adjacent protons is reached, when any increase in B_{EP} will reduce the radius from r_{m2} to r_{mT}, where the SMF will attracted each other producing Spinning Magnetic Force (SMFs) or the fusion (Yousif, 2003b, 2018b), the expulsion of particles in form of CME and the related energy (Yousif, 2004), which represent the natural trigger mechanism.

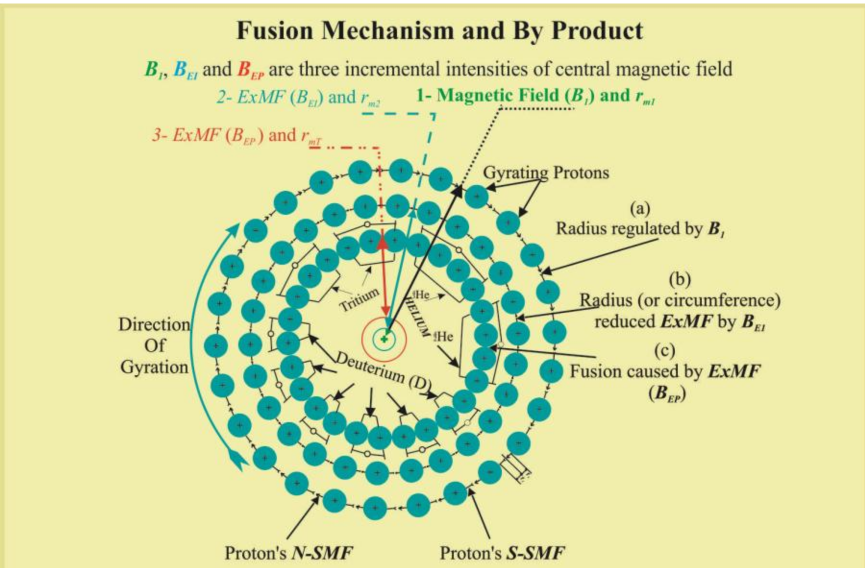

Fig. F-3

B) ***Fusion: Connection Triggered Mechanism***

When there are two or more PPIMF (AR) during high activities of solar cycle, another mechanism usually take place for PPIMF before heading to the magnetic poles; as shown in

Fig. F-4, where the Circular Magnetic Field (CMF) shown for radial group (three protons in this micro example), each produced CMF, different groups formed larger and stronger CMF added to the general ExMF-B, when this first ExMF-B-(1) is connected with another adjacent ExMF-B-(2), a sudden massive increase in both PPIMF's magnetic fields raised the magnitude of their ExMF-B-(1) directly to B_T, where the radius of gyration will move directly from rm1 to r_{mT}, where proton's SMF will be attracted each other thus reduced the distances between adjacent ions and it reached the critical point thus igniting the fusion, hence producing SMFs (Yousif, 2003, 2003b, 2018b) and the related fusion energy (Yousif, 2004), and massive electrons, protons and ions will fly away with electromagnetic radiation (Yousif, 2011).

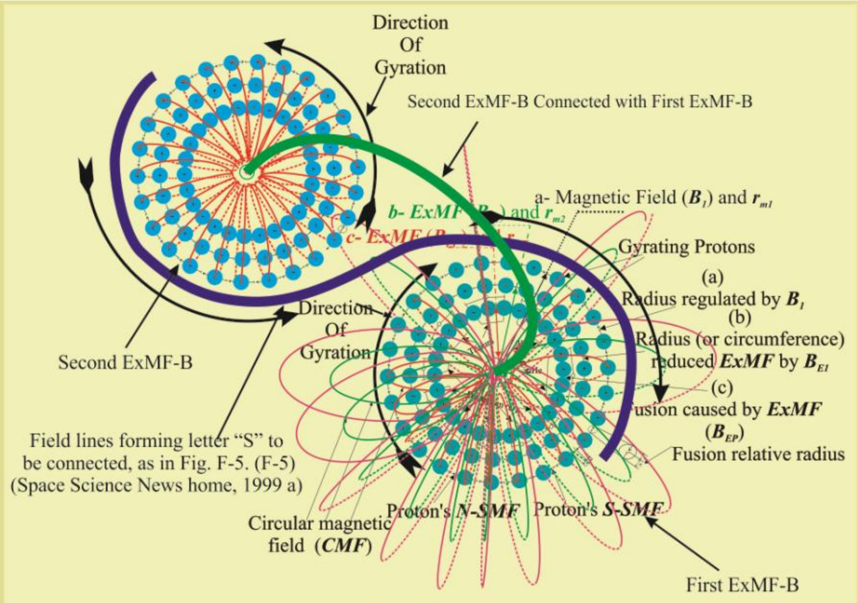

Fig. F-4

The connection (or what perceived as reconnection) had been documented from observations and studies of different flares, it became known that sunspots group with complex magnetic field configurations, often are sites of flares (Windows to the Universe, 2005 a), and, the solar magnetic field lines forming the letter 'S', to be connected, it like a coronal short circuit, causing the coronal mass ejection (CME), thus solar flare occurred due to Connection of magnetic fields (Space Science News home, 1999 a) or PPIMF, the connection depicted by an artist shown in Fig. F-5 (Space Science News home, 1999 b).

But as shown in Fig. F-4, the 'S' doesn't related to the connection, its merely a shape linking the rotation of the two PPIMF, while the connection is through the line of force in green (or any opposite line of force), where the two PPIMF are connected through their two opposite magnetic poles, or any opposite line of force, this resulted in a sudden violent movements of the rotating charged particles towards the center of rotation, which gives the blinking flash and abruption of different electromagnetic radiations of various wavelength with sudden massive flow of charged particles from the inner toward the outlet, all these takes from a minutes to as long as hours (Space Science News home, 1999 c), or timescales of minutes to tens of minutes (Wikipedia, Solar flare), which means, when the first central produced External Magnetic Field Type-B-(1) (ExMF-B-(1)) is connected with the second ExMF-B-(2) as shown in Fig. F-4, this ignited the SMFs and triggering the massive fusion, by both PPIMF (AR) (Yousif, 2011).

From the above two descriptions, we can state that, before the grouping of PPIMF pollards, system B of Fusion: Reconnection Triggered Mechanism takes place, because the flares are triggered by the open magnetic lines of force and connection. But when PPIMF attracted each other and formed coronal holes, it become highly energized from the energization process (Yousif, 2004) and since they become lengthy with CMF or closed loops, therefore the internal ExMF-B caused orbits to come close together finally leading to class (A) Fusion, or Natural Triggered Mechanism, with extremely high energy this cause CME of higher class such as X3 and above.

Fig. F-5

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Example movie of Solar Flares Type-A Fusion: Natural Triggered Mechanism: Several flares captured by NASA's Solar Dynamics Observatory (SDO) (Credits: NASA's Goddard Space Flight Center/Scott Wiessinger), these flares are good example of Type-A Fusion the Natural Triggered Mechanism, for example signal at time 1:07 initiated the flare at 1:08, the decrease in ExMF-B brings orbits together causing smaller flare after which a larger flare.

https://youtu.be/q-ZQBlWdlAY

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Example of Type-B) ***Fusion: Reconnection Triggered Mechanis*** of Solar Flare:

Movie showing 23 of the 26 M- and X-class flares on the sun between Oct. 23 and Oct. 28, 2013, as captured by NASA's Solar Dynamics Observatory. (Credit: NASA/ESA/Goddard Space Flight Center), the flares are thought to be caused by Type-B connection fusion.

https://youtu.be/K8XwfyNm5XQ

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Movie: "***The Sunspots Mechanism***"

This movie in 2011, was an attempt to illustrate how the Plasma Pillar Intense Magnetic Field (PPIMF) are produced, and their activities through the solar cycle until the flip of solar magnetic field, although the structure of the sun in this movie needs revision, but many of the ideas are good.

https://youtu.be/ropGu6AGJ7s

(G)- Conclusion

The solar cycle is the most complicated series of events taken place in the sun within specific period of time, to understand it, there is a need to review our concept in the fundamental physics from "*action at distance*" to the "*field's interaction*" and to review our understanding of the sun based on the logical conclusions derived from the new concept.

The activities in the sun throughout the solar cycle is perceived based from the "*field's interaction*," which allowed for the production of the Plasma Pillar Intense Magnetic Field (PPIMF), when charged particles (electrons, protons and ions) interacted and captured by the rotating Solar Magnetic Line of Force (MLF), the PPIMF instantly produced the External Magnetic Field Type-A (ExMF-A); after a while the thin PPIMF is ejected, while rotating like tornado, and start moving towards the photosphere, thus continuously producing the ExMF, but in different mechanism, named ExMF Type-B (ExMF-B), within this rotational motion the PPIMF kept capturing electrons protons and ions in the inter-sun space and continued been energized, within this a state is reached, where any sudden increase in the ExMF-B (naturally or by a proximity to another PPIMF unit) led to an interactions of Spinning Magnetic Field (SMF), resulted in the fusion of charged particles, and the production of Spinning Magnetic Force (SMFs), or the Nuclear Force (NF) or solar flare, accompanied by immense energy and expulsion of particles (electrons, protons and ions); the PPIMF reached the photosphere to emerged from the sun, but restricted by the photosphere, then moved to northern or southern poles, based on location in solar hemisphere, where PPIMF attracted each other and formed lengthy PPIMF or the coronal holes, which is an accumulation of intense units of ExMF-B having charged particles energized to extremely high energies, which carried several Natural Triggered Mechanism Type-A nuclear fusion (solar flares), before it been depleted from ExMF-B, then it goes into long period of subsidence then disintegration and extinction, after which charged particles are freed to start a new cycle.

This knowledge is vital for the continuation of human and different spices on Earth, from different perspectives; taken the current trend in climate change and the grim future perspectives of our planet, therefore its vital to review different concepts, particularly if there could be a possibility to develop an advance system of alternative renewable energy that may help humanity to overcome the consequences of climate change and related global warming as estimated by scientists, such measures may secure the future of the coming generations, if great efforts are exerted.

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