
Solar or Interplanetary External Magnetic Field?

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PAC No: 96.50.Ci; 96.50.Bh; 96.50.Fm; 07.55.Db; 94.30.cj; 52.35.-g; 96.60.T-, 96.60.Tf; 94.30.Lr

ABSTRACT

Analysis of Pioneer V engulfment with solar plasma on March 30, 1960, showed that solar magnetic field was not detected by the probe, rather a high interplanetary magnetic field (IMF) was later measured after first been recorded by Honolulu earth station; this questioned envisioned embedded solar magnetic field. A proposed mechanism of solar wind captured at and before the bow shock, producing Interplanetary-External Magnetic Field (***I-ExMF***), led to energization of these particles; while boundaries between IMF represent space between intermittent produced ***I-ExMF***. Intense ***I-ExMF*** (***II-ExMF***) is produced around $12.5R_E$ within magnetosheath, igniting transitory magnetic waves (lion roars); initiating the sudden commencement and related main phase. Explanation of these, and the propagation of magnetic disturbances and the interplanetary sector structure, is based on ***I-ExMF*** characteristics. Understanding these mechanisms will reflect positively on attaining the alternative renewable green energy that can protect our planet, environment and establishment of more advanced human society.

1.0 Introduction

Contrary to the name, the interplanetary magnetic field (IMF) refer to the magnetic field embodied in the solar plasma [*Parker*, 1958], that means, the solar magnetic field present in the Corona is carried by the emitted particles, hence the solar wind is said to carry an entrained magnetic field [*McDonald*, 2005], which means the solar wind and its entrained IMF, could be carried all along the nine planet to inflate the heliosphere [*McComas et al*, 2011], or as far as solar plasma can reach.

The usage of rockets in 1947 for scientific studies, had lead to the launch of first satellites Sputnik 3 in 1958 for magnetic measurement, then Vanguard 3 in 1959 that measured strong field near earth, [*Heppner*, 1967], culminated with more investigations during the international Geomagnetic Year 1958/57 [*Ness and Burlaga*, 2001; *National Academy of Science*,1961], then came series of satellites, the unique of which was Pioneer V which presented what thought to be the prove for the solar origin of the IMF [*Coleman et al*., 1961], then came the Interplanetary Monitoring Platform-1 (IMP-1 or IMP-A) satellite, in 1963 to study the IMF, radiation between the earth and the moon, and earth-sun relationships [*Heppner*, 1967], all of which resulted in the discovery of Van Allen radiation belt [*Van Allen*, 1959], and an anomalies magnetic field opposite in direction to the geomagnetic field, several radial distance from the earth [*Wilcox*, 1966].

The IMP-1 satellite magnetic data was interpreted as a proof to Pioneer V data [*Wilcox and Ness*, 1965], and related to observations on the sun [*Wilcox*, 1966; *Wilcox and Ness*, 1965], in accordance to the solar spiral magnetic field theory by Parker [*Parker*, 1958], developed into the reconnection theory to resolve auroral problems [*Dungey*, 1962], but the IMF originated from a page by Hannes Alfvén to *Nature* in 1942 [*Alfvén*, 1942a], and the frozen in magnetic field expression appeared later [*Alfvén*, 1942b], both papers got attention in 1948, when the prominent physicist Enrico Fermi appreciated seminar by Alfvén in public saying "*of course such waves could exist*." [*Fälthammar*, 2012].

The IMF has brought the idea of neutral points, with the formation of current sheet, to explain the discontinues changes in field direction [*Dungey*, 1967], thus IMF, was suggested to explain detected and measured anomalous magnetic fields, which opposite in direction to geomagnetic field and continuously changing in direction [*Heppner* 1967]. Some thinks the IMF had complicated the solar wind as a material to be dealt with, [*Russell*, 2000] and consequences to that, the IMF brought with it three types of disturbances as a mechanism to allow for the plasma/field to be interacted with the magnetosphere [*Russel*, 2000a], thus the IMF had great impact on astrophysics, with nearly all related present theories and interpretations emerged from it, among such interpretations are:

- The magnetosphere was suggested [*Gold*, 1959; *Beard*, 1964] and conceived to be closed cavity [*Beard*, 1964].
- Solar wind was suggested to carry away lines of force of the outer geomagnetic field as suggested by Parker [*Wolfe and Mayers*, 1966].
- The solar wind was envisioned to flow around the cavity [*Dungey*, 1961]
- The introduction of neutral points [*Dungey*, 1967].
- The suggestion of reconnection mechanism for substorms [*Dungey*, 1961].
- Interpretation of neutral sheet [*Ness*, 1965], which brought credibility to *Dungey* [1961], connection of geomagnetic field lines with the interplanetary magnetic field, which was also tackled by *Alfvén* [1963].
- The mechanism of Aurora particles in Auroral Oval was thought to be driven by magnetic reconnection from magnetotail [*Dungey*, 1963].
- Connection mechanism also taken to the sun [*Priest and Forbes*, 2000].
- The Solar Flare explosion is thought to be activated through the magnetic reconnection [*Priest and Forbes*, 2000], and is thought to play major role in the energy release process and possibly in the subsequent evolution, it has been invoked

to explain chromospheres eruptions and many other solar phenomena [*Karpen et al.*, 1989].

On March 11, 1960, Pioneer V was launched, in orbit sufficiently far from Earth and its magnetic field and solar wind interaction region so as to sample the physical properties of the undisturbed interplanetary medium [*Ness and Burlaga*, 2001], it was nearly at 5.2 x 10^6 km or 863R_E on the Sun-Earth line on 30 March 1960, when a large solar flare erupted on the sun, the plasma reached the satellite and earth the following day [*Coleman et al*., 1961]. Combination of measured data by *Fan et al*. [1960a], and *Coleman et al*. [1961], lead to a conclusion that Pioneer V didn't detected the embedded IMF when first engulfed with the incoming plasma, rather a maximum interplanetary magnetic field of 23γ was measured eight hours later, and the peak of that IMF was measured by Pioneer V two hours after a similar peak changed the horizontal component of geomagnetic field at Honolulu station [*Coleman* et al., 1961], that lead to a confusion in determining the source of the IMF, although earlier *Fan et al.* [1960a] stated that "*our results describe large-scale transient magnetic fields over great distances from Pioneer V, the magnetometer in Pioneer V registers field changes at the position of the vehicle perpendicular to its spin axis*." Local production of IMF was also assume from Pioneer V data as expressed by *Fan et al*. [1960a] "*Both kinds of observations show that magnetic fields are being* ***moved or generated*** *in interplanetary space as a consequence of the solar flare on March 30.*" The above lead to confusion, with no alternatives, they added "*The* ***only known way*** *by which these transient fields could be established, or existing fields manipulated, is by moving, conducting plasma of solar flare origin.*"

The first statement should have lead to more experiments of that kind instead, a decision was made to support *Parker* [1958] theory, and *Fan, Meyer, and Simpson* [1960] stated that "*Therefore, we believe these Pioneer V results provide the most direct evidence to date for the existence of conducting gas ejected at high velocity from solar flares, a concept strongly supported already by many solar and terrestrial observations.*" Although this last statement bears no historical responsibility, but the question is what if the IMF was and is "*generated in the interplanetary space as a consequence of the solar flare or solar wind interaction with geomagnetic field?*" as inferred from *Fan et al*. [1960a] first two statements?

Within five years from Pioneer V launch, the IMF was envisioned as of solar origin, and after nearly five decades, from endorsement of Parker theory [*Parker*, 1958], Pioneer V results is fading away, and the IMF became more complicated.

These discrepancies, required a review of the old literatures, related to early satellites measurements, hence generally, although the radial variation of the IMF strength up to 19 AU was thought to be in consistent with Parker's model, [*Burlaga et al*., 1998], and that is supported by some, who thinks the IMF magnitude only varies by fractions of a gamma on long time, [*Ness et al*., 1964], while *Coleman et al*. [1960b] deduced that the measurements would be much more irregular, if the field were imbedded in clouds of turbulent gas emitted from the sun, and it has been determined that the IMF falls off significantly faster than predicted by Parker, as stated by *Slavin et al*. [1984], who also implies the existence of other factors that may be responsible about the production and declination of the IMF, where several studies by Pioneer 11 data suggest that the magnetic field strength decreases more rapidly with distance than predicted by Parker's model [*Smith and Barnes*, 1983].

On the other hand, the sudden increase in magnetic field which determines the bow shock, boosted an already existed IMF, such increases is interpreted at the time at which the average field level deviates from the interplanetary level, it is usually identifiable within two seconds [*Heppner et al*., 1967], abnormally strong IMF, can reach 63γ at 10.5R_E, and magnitude of 125γ had been measured at 8.25R_E [*Cahill and Amazeein*, 1963], while the magnetopause location also depends on the IMF intensity [*Heppner et al*., 1967] and that the simultaneous plasma measurements from OGO-A and Vela 2 satellites shows that the abnormal bow shock position is primarily the result of an exceptionally strong IMF occurring simultaneously with an inflated magnetosphere [*Heppner et al*., 1967], such anomalies were even detected at the magnetic clouds between 2 and 4 AU which were larger than those seen at 1 AU [*Burlaga et al*., 1982], all these raised a question about the limit of embedded solar magnetic field, which should allowed for alternative option, such as the local production of magnetic field within the interplanetary space.

Then came the greatest shock; the magnetosphere which was considered an impenetrable blunt body [*Russel*, 2000a], was breached, in several places and continually [*Angelopoulos et al*., 2008], some tried to seek explanation within the solar IMF-origin, by proposing Hidden Portals in Earth's Magnetic Field [*Phillips*, 2002]. But as the penetration recently proven [*Angelopoulos et al*., 2008], it was already been known that, solar wind continually blow into the magnetosphere [*Neugebauer and Snyder*, 1962], and flow of energetic protons is the prominent feature of the magnetosheath [*Gosling et al*., 1967], and that, satellites measurements, established strong relation between increase in magnetic field, solar wind density, and energization process, *Heppner et al*. [1967]. All these points to the extreme complexity of the magnetosheath which is dominated by phenomena such as local acceleration, injection, and diffusion of high energy electrons, twisted magnetic fields, turbulent plasma flow, and probably a great variety of wave phenomena [*Wolfe and Mayers*, 1966].

The odd status of the boundaries [*Cahill and Amazeein*, 1963] are highlighted as an example to emphasize relationship between these boundaries and intermittent anomalies magnetic fields, while detection of such southward-directed rotation of field ***F***, by Exp. 6 around 8R_E, found to be similar to rotation of dipole field lines detected by Exp. 10 between 6-20R_E, [*Smith*, 1962], as these showed deformation of the geomagnetic field, it also showed existence of different method that produced these anomalous fields, hence a suggestion of spatial production of intermittent *Interplanetary-External Magnetic Field* (***I-ExMF***) along the geomagnetic lines of forces; resulted from captured and gyrating solar wind along these lines of force at or before the bow shock, these characteristics energized captured particles to higher energy levels. Thus the source of the magnetic event recorded at Honolulu station and later by Pioneer V [*Fan et al*., 1960a], is traced to magnetosheath at 12.5R_E, during magnetic storms, when energetic protons flow across the boundary, where intense ***I-ExMF*** (***II-ExMF***) is thought to be produced. As the paper tackle the production of ***I-ExMF***, from perspective related to the IMF, the magnetic storms are been related to the production of the magnetic waves (Lion roars) [*Smith et al*., 1969] which is thought to modulate the produced ***II-ExMF***, and initiated geomagnetic storms, measured world wide as Dst. The interplanetary sector structure, which was thought to originate from the sun [*Wilcox and Ness*, 1965] is explained based on ***I-ExMF*** related characteristics.

If Lord Kelvin in 1892 can refute, any connection between magnetic storms and any kind of dynamical action on the sun [*Curto et al.*, 2007], and that the autocentric principle can dominate human believes at pre-Copernican dogma [Carter, 2006], both examples showed how error can form a guiding principle for an individual or general scientific community.

But what about measurements carried out IMF by many satellites during the past five decades, all of which shows IMF existence?

Since solar wind speed of flows was found to be about 400 km s^{-1} with density of 5 cm^{-3} [Russell, 2000], and the IMF resulted mainly from relatively steady magnetic field of ~4.5nT and a highly variable components [Svalgaard, et al., 2003], therefore the relatively steady ***I-ExMF*** component is the one always produced at specific local spatial areas as long as the solar wind continued flowing from the sun and interacts at appropriate planet field, while the variable components is caused by any increased in solar wind.

The accurate knowledge of mechanism causing different stages of magnestorm in our near vicinity is the first step towards a better understanding of our sun, nearest stars, Galactic system, and a process towards developing the required alternative, sustainable and renewable energy and related propulsion systems needed by current and future generations.

2.0 Assertion of the Interplanetary Magnetic Field

Pioneer V measurements were conducted during an active period of March to June 1960, and gave raises to interplanetary magnetic field of 20-50γ, greater than normal field component of 2.5γ, although this later been corrected [*Ness and Burlaga*, 2001], the field was perpendicular to the probe's spin of axis, thus nearly perpendicular to the earth-sun line [*Coleman et al*., 1961] a year later, Exp. 10 was launched on March 25, 1961, it confirmed these readings and added that, a steady increase in measured filed, till 42.5R_E, and from 42.25 to 42.7R_E, the field increased by more than 25γ, [*Heppner et al*., 1963] or an increase of 250% percentage.

Later, Exp. 12 was launched on August 16, 1961, it confirmed the above, and measured magnetic fields of 63γ, at 10.5R_E, and 50γ at the same spatial area after 14 hours on an outbound flight, and again on 13 September 1961, it measured a field of 125γ at 8.25R_E, while changes in both angles α and ψ indicate that the field immediately outside the boundary is antiparallel to the earth's field [*Cahill and Amazeein*, 1963]. Mariner 2, launched on August 27, 1962, gave measurements that consistent with interplanetary field in the plane of the ecliptic with a strength of approximately 5γ normal to a sun-satellite direction, with magnitude comparable to Pioneer 5 data, but different by 90^o [*Ness et al*., 1964].

Thus results from Exps.6, 10, 12 and 14 lead some authors to conclude that the obtained data seemed to fit *Dungey's* [1961] model of the distorted geomagnetic field, which includes the connection of geomagnetic and interplanetary field lines [*Ness*, 1965].

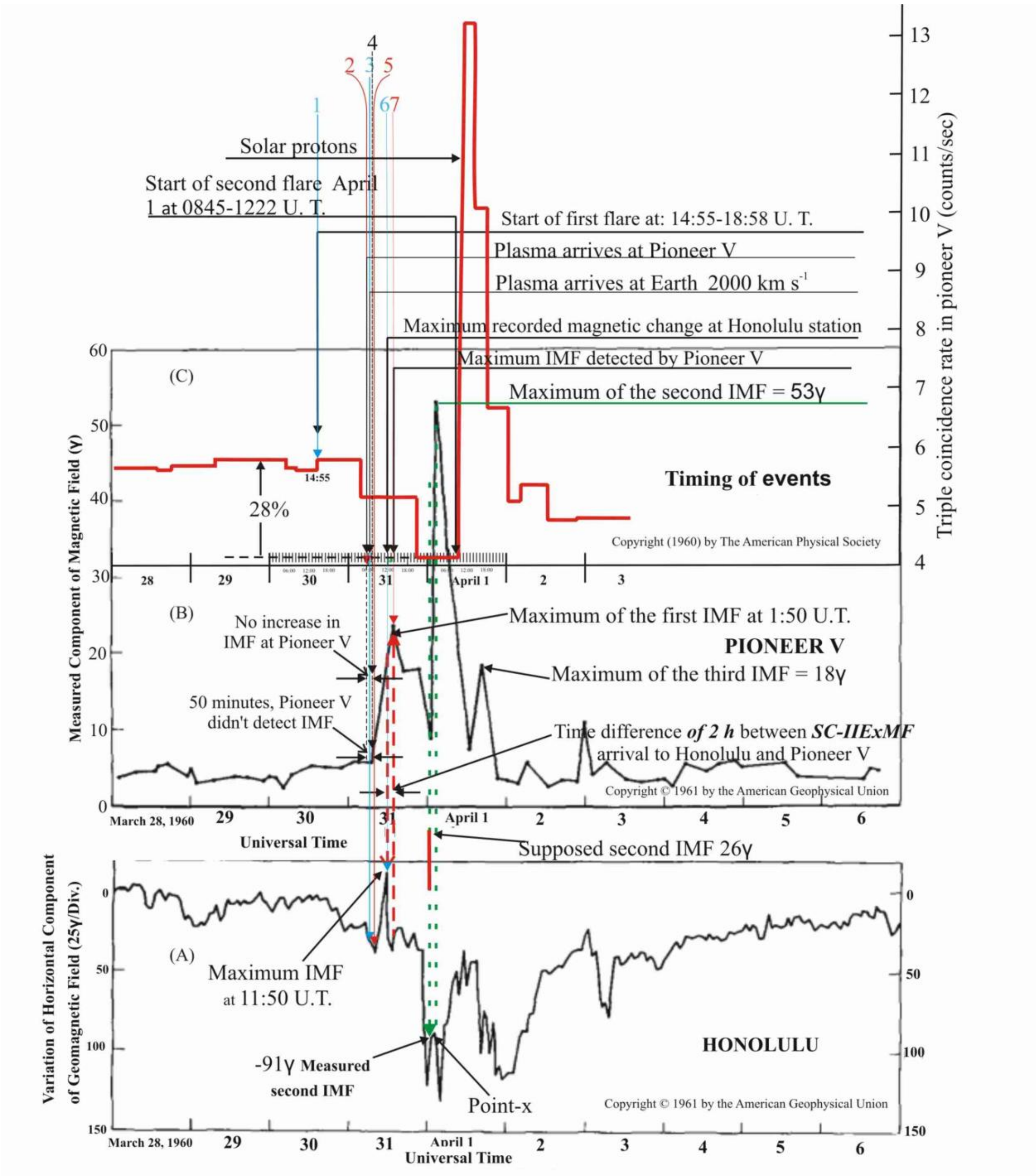

Fig.1. Re-analysis of March 30/31, geomagnetic storms, by combining Fig.2.a&b *Coleman et al.* [1961], with Fig.2-A *Fan et al.* [1960]. The figure shows the following sequence: Starts of the solar flare, plasma arriving at Pioneer V, no detection of an embedded solar field, arrival to the earth, registration of Horizontal field at Honolulu, and high magnetic field measured 6 hours later at Pioneer V satellite.

For all these, the interplanetary monitoring platform IMP-1 (or Exp. 18) was sent to investigate the magnitude, direction, and temporal variations of the IMF, the results strongly suggested existence of filamentary structure in the interplanetary medium associated with sources of solar magnetic fields, interpreted as stretched from the sun by the plasma as discussed by *Parker* [1958], it also explained the abrupt decrease of magnetic field magnitude to zero as a null surface separating regions of opposite fields [*Ness et al*., 1964].

2.1 Re-Visiting the Historical Experiment

Exps.6, 10, 12, 14 and 18, probes were sent to confirm the measured high IMF magnitude by Pioneer V, which occurred nearly concurrently with the registration of large amplitude change in the horizontal component of the geomagnetic field, at Honolulu station shown in Figs.1-A&B [*Coleman et al*., 1961], the measurements confirmed strong link between both events [*Coleman et al*., 1961].

In one of their reports about that experiment, there was doubts about where IMF was produced, as *Fan et al*. [1960a] stated "*great transient magnetic fields was produced far from Pioneer V, but measured by Pioneer V*", such discrepancy is clear from the statement that,

"*solar plasma either carries magnetic fields, or manipulate an interplanetary magnetic field* [*Fan et al*., 1960a]." But there is no mention about an embedded magnetic field, rather they referred it indirectly to the sun due to lack of alternative, where *Fan et al*. [1960b] stated that "*The only known way by which these transient fields could be established, or existing fields manipulated, is by moving, conducting plasma of solar flare origin.*"

Since the measurements represent a corner stone in the current theory for the solar origin of the IMF, and all related explanations emerged from it, we would like to re-visit the experiment, because we observed loophole in it, in addition to the failure of current models to replicates the great source of energy contained within the solar wind.

The large event of March 30, 1960, was detected and analyzed by Pioneer V, while the probe was nearly 5.2 x 10^6 km or 863R_E on the Sun-Earth line [*Fan et al*., 1960a]. The ejection of plasma from the solar flare of importance 2 at 14:55 – 18:58 U. T. on March 30 led to the commencement of the geomagnetic storm and the beginning of the cosmic radiation intensity decrease at about 12:00 U. T. on March 31; with average velocity of 2000 km/sec, the time difference between plasma arrival at Pioneer V and at the earth was estimated around ~43 (50) minutes [*Fan et al*., 1960a].

Fig.1, is a composition of both Figs.2.a&b by *Coleman et al*. [1961] depicting magnetic field measurements at both Pioneer V and Honolulu station, with the same time sequence of events, the other is Fig.2-A, by *Fan et al*. [1960a], it shows timing of the solar flare, and plasma arrival at Pioneer V and the earth. These three figures are combined in Fig.1-A-B-C respectively, in a manner representing the true timing and sequence of March 30/31, 1960 events, from the start of solar flare, plasma arrival at Pioneer V, plasma arrival at earth boundary, the starts of change in horizontal component at Honolulu and detection of IMF by Pioneer V; all these can be described in the following sequences, where the numbers of these sequences are printed at top of Fig.1-C, and traceable to the timeline and designated positions:

1- The first flare Started on 30 March 1960, at 14:55–18:58 U.T. Fig.1-C. [*Fan et al*., 1960a]

2- Arrival of first plasma at Pioneer V orbit on 31 March 1960, at 05:40 U.T. (~50 minutes before arrival at earth), Fig.1-C. [*Fan et al*., 1960a].

3- Arrival of first plasma with speed greater than 2,000 km s^{-1}, to earth on 31 March at 6:30 U.T. (50 minutes after first arrival at Pioneer V), till Fig.1-A. [*Fan et al*., 1960a].

4- First increase in IMF as measured by Pioneer V on March 31, 1960, at 07:20 U.T. (1h 40 min. after plasma first arrival at Pioneer V), from Fig.1-B&C.

5- Severe geomagnetic storm, accompanied by major earth current disturbances, a complete blackout of the North Atlantic communications channel, and auroral displays, started on earth on March 31 at 08:00 U.T. (2h 20min after plasma first arrived to Pioneer V), Fig.1-A. [*Arnoldy et al*., 1960]

6- Maximum magnitude of horizontal field registered at Honolulu, on March 31, 1960, at 11:50 U.T. (6h 10 min. after first plasma arrival at Pioneer V), Fig.1-A. [*Coleman et al*., 1961].

7- Maximum magnetic field of 23.4γ registered at Pioneer V on 31 March, at 1:50 U.T. (8h 10 min. after plasma first arrival to Pioneer V), Fig.1-B. [*Coleman et al*., 1961].

From this sequence and in relation with Fig.1 (A, B, and C), the following observations are made:

- For more than 1:40 hours, after been engulfed with plasma, Pioneer V didn't detect any increase in the interplanetary magnetic field, as shown in Fig.1-B.
- After solar plasma arrival to the earth at 6:30 U.T., magnetic fields at Pioneer V start increasing gradually, while it first decreased at Honolulu station.
- Magnetic field recorded at Honolulu station increased and reached maximum reading, as shown in Fig.1-A, by point 6 at 11:50 U.T., after 6:10 hours from plasma arrival at Pioneer V.
- Maximum magnitude of 23.4γ measured by Pioneer V, as shown in Fig.1-B, by point 7 at 13:50 U.T. after 8:10 hours from Pioneer V first engulfment with the plasma, and after 2:03 hours from maximum field measured at Honolulu, the same measurement was recorded at Fort Belvoir [*COLEMAN et al*., 1960a].

Since Pioneer V failed to detected any increase in IMF for more than 1:40 hours, after first engulfed by solar plasma, and the magnetic fields charts for both Honolulu station and pioneer V start changing simultaneously, afterwards as shown in Fig.1-A&B, and the maximum magnitude of magnetic field recorded at Honolulu occurred before Pioneer V, and since *Fan et al*. [1960a] first conclusion was in line that "*large-scale transient magnetic fields over great distances from Pioneer V, measured by Pioneer V*", therefore we concluded that *the magnetic field which was measured at Honolulu station and the IMF at Pioneer V, were produced from one source, and it is not of solar origin*, and that:

1- If the IMF was embedded in the plasma, Pioneer V should have detected it, instantly when Pioneer V was first engulfed with the solar plasma.

2- If the IMF was embedded in the plasma, Pioneer V should have detected it before Honolulu station.
3- Sequence of events showed that, the magnetic field spreads towards both Honolulu, where it disturbs the horizontal component of geomagnetic field, and to Pioneer V, thus both fields' moves oppositely from one source of production.
4- The IMF was produced at a period of time, between plasma arrival to the earth boundary and first magnetic change at Honolulu station.
5- The IMF was produced at a spatial location, nearer to Honolulu station rather than to Pioneer V.

Based on above conclusion, a model will be presented based on measurements and analysis been carried out during the past five decades.

3.0 Boundaries or Spatial Produced Interplanetary Magnetic Fields?

Reviewing Exp.12 measurements given by *Cahill and Amazeein*, [1963] in Fig.2; it showed many anomalies fields, some were interpreted as boundaries, with magnitudes greater than the computed fields, with difference $\Delta F = F$ (measured) – $\boldsymbol{B}$ (computed). In these measurements, the number of changes between fields are nearly equivalent to number of change in angles detected by both ψ and α, as given in Table.1, which is derived from figures, 4, 5, and 6 [*Cahill and Amazeein*, 1963].

From Figures		Radial Distance ($\boldsymbol{R_E}$)	Number of $\boldsymbol{B_x}$ Change	Number of $\boldsymbol{\psi}$ Change
Fig.4	1st	4.3 to 8.74	40	42
	2nd	10.4 to 13.1	27	32
Fig.5	1st	4.4 to 5.73	9	14
	2nd	5.5 to 13.2	61	66
Fig.6		4.5 to 10.9	44	49

Table.1. Number of measured magnetic fields boundaries ($\boldsymbol{B_x}$), is equal to change in angle ψ, as given in Figures 4, 5 and 6, by Exp.12 [*Cahill and Amazeein, 1963*], the boundaries are thought to represents intermittent production of magnetic fields.

The change in magnetic fields or boundaries phenomena was revealed by satellites measurements [*Heppner*, 1967; *Gosling et al*. 1967], the satellites were found to cross several boundaries during such experiments, with thickness of each boundary range from 100 km to 1000 km, [*Cahill and Amazeein*, 1963; *Heppner*, 1967], and a single and multiple crossings of the shock are observed [*Gosling et al*., 1967], while seven boundaries crosses took place within three hours [*Burlaga and Ogilvie*, 1968], and as the boundary is traversed, often multiple crossings of the boundary occur for which the boundary apparently sweeps back and forth across the spacecraft [*Gosling et al*., 1967], and boundaries were perpendicular to the earth-sun line in many cases [*Heppner*, 1967; *Coleman et al*., 961; *Ness et al*., 1964], which means they were perpendicular to the magnetic lines of force, while such fields were detected by Exp.12 at lower radial distance of 4 to 4.5R_E, as shown in Fig.2, which is a representation of Figure 5 by *Cahill and Amazeein* [1963], and the fields also has been detected between 42.25 to 42.7R_E, with magnitude of 25γ [*Heppner et al*., 1963]. While for magnetopause, the magnetic field directions adjacent to the boundary were, in general tangential to the magnetopause surface but oppositely directed on the two sides, although they were perpendicular in some cases [*Heppner*, 1967], and *Coleman et al*. [961] concluded that geomagnetic field termination took place near 14R_E on the ground that the *field intensities between 7 and 13R_E were greater than expected*, and the field on the far side of the boundary decreased more rapidly than $1/r^3$, and power level of fluctuation decreased in passing the boundary [*Heppner*, 1967], while on some other passes there is indication that the boundary has moved past the satellite [*Cahill and Amazeein*, 1963], this been consolidated by results obtained from Exps.12, 14 and 18 in sunward hemisphere, which showed that the termination near 14R_E as detected by Pioneer 1 and 5 is now identified with the shock front [*Heppner*, 1967], and Exp.12 located the magnetopause near the earth-sun line of the noon meridian, which was consistently identified by the change in field direction, and the change in angle, an indication that the field outside the boundary was anti-parallel to the field inside [*Heppner*, 1967], while *Wolfe and Mayers* [1966], located maximum distance of magnetopause in their Table.1 at 30.7R_E, and they put the transition region at 31.5R_E, which forced one to question position of the geomagnetic fields, or the magnetosphere boundary, does it extended to 30R_E?

The average boundaries positions are probably strongly determined by the interplanetary solar wind velocity, density, and direction of flow, [*Gosling et al*., 1967], but it was found that, the fluctuating part of geomagnetic field, between the shock wave and the magnetosphere is not part of the geomagnetic field, but rather the compressed and distorted interplanetary field [*Spreiter and Jones*, 1963].

These discrepancies lead *Heppner et al*. [1967], to question factors determining magnetosphere boundaries? The nature of bow shocks multiple crossings? The speedy movements of the bow shock, and variations in the field associated with the shock, and to state that, "***it is more complex than the internal plasma pressure***", while *Montgomery et al*. [1970], questioned the existence of several regions, and *Bame et al*. [1980] questioned criteria that constitute judgment for the encounter of the bow shock?

These and many others, forced itself due to oddness of these boundaries, for example, the fast crossing of total shock structure in less than 12 seconds, while 20 crosses took place in a single pass [*Heppner et al*., 1967], these clearly shows that, the link between these boundaries are, spatial anomalies magnetic field divided by empty space, where field directions are opposite on both sides of the boundary, and these phenomena can exist from 4R_E [*Cahill and Amazeein, 1963*], to more than 241.40R_E as detected by ACE [*Russell et al*., 2000].

Hence one can suggested that, what had been crossed is something different from solid spatial fixed structure, therefore these fields boundaries suggests the existence of variable intermittent production of spatial magnetic fields along the geomagnetic lines of force.

4.0 Gyrating Solar Wind

As shown in Fig.1-B&C, and the above events explanations, it took the energetic protons only 50 minutes to cross to magnetosphere peripheries from Pioneer V, so why it took more than one hours for any sign of IMF to be detected at Pioneer V? And 8 hours for IMF to reached maximum magnitude at Pioneer V?

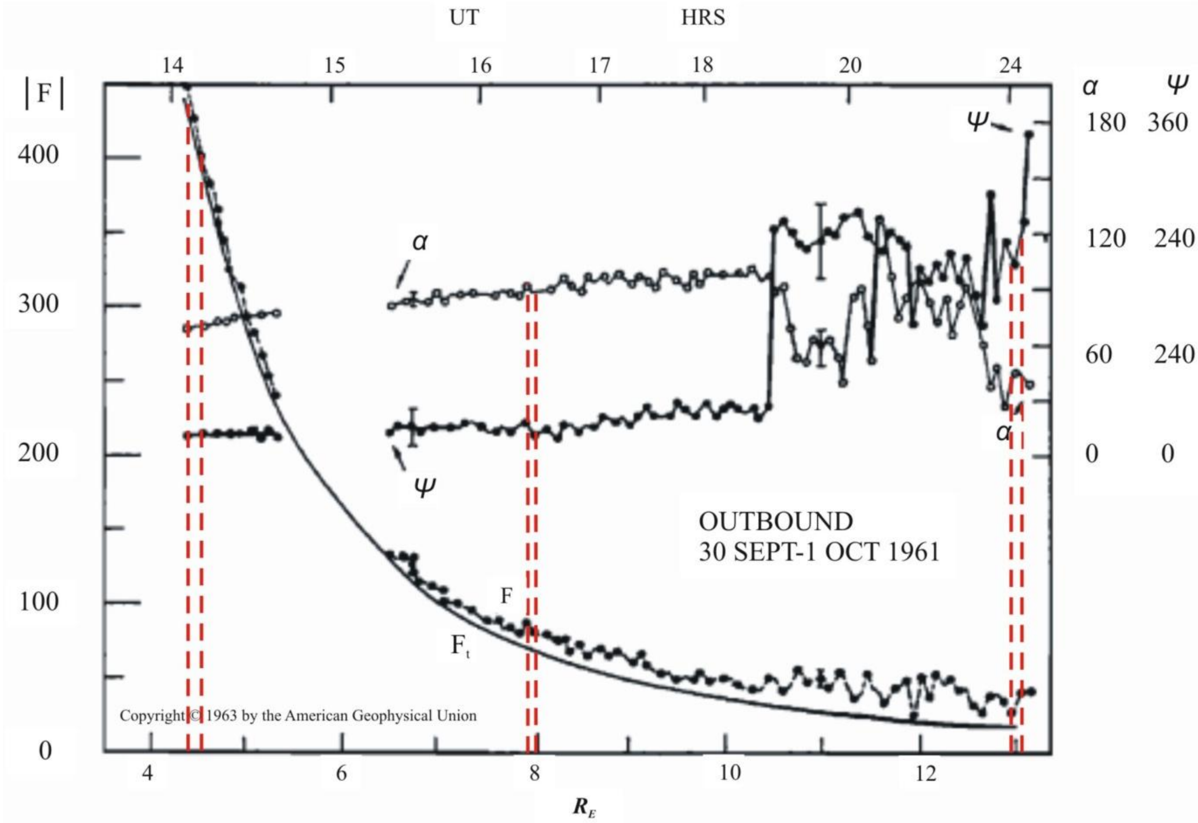

Fig.2. Variation in measured magnetic fields, some are highlighted at 4.5, 8, and 13R_E, with changing angles (α-Ψ) [*Cahill and Amazeein, 1963*]. The intermittent fields packages divided boundaries are characteristics of intermittent spatial produced magnetic fields.

There is a delay between the start of sudden commencement storm due to the existence of bow shock, where great turbulence associated with unstable magnetic fields [*Watermann et al*., 2009], and solar wind existed with varied speed and density [*Montgomery et al*., 1970], it is where solar wind changes flow from supersonic to subsonic [*Axford*, 1962], this is thought due to reduction in particle's velocity to gyrating frequency, while there are increase in particle's density and magnetic field strength [*Axford*, 1962], which are due to particle's concentration while gyrating around the geomagnetic lines of force.

The process of capturing solar wind, constitute part of the magnetic force, lead to drop in particle speed as it experienced a large change in momentum, [*Thomsen et al*., 1986], and since gyration was detected as gyrating ions distributions observed between ~9 and ~83 R_E from the shock, which are characterized by gyromotion around the magnetic field [*Meziane et al*., 2001], and gyrating protons in both quasi-perpendicular and quasi-parallel geometries of backstreaming in the foreshock, and multiple reflections along the shock, [*Thomsen*, 1985] or the gyrating ion distributions, ***which may be gyrotropic,*** which is a torus in velocity space whose symmetry axis is parallel to the magnetic field [*Thomsen*, 1985], it is also commonly observed in association with the magnetic foot and overshoot of quasi-perpendicular, supercritical shocks [*Paschmann et al.*, 1982] and it was observed by Wind spacecraft at distances larger than $20R_E$, and can be found at more than 80 R_E from the shock [*Eastwood et al.*, 2005], such existence allowed *Anderson et al*. [1985] to state that, gyrophase bunching is an inherent and fundamental property of the bow shock for ions, and for Electron under certain conditions.

Therefore solar wind and the streaming ions are thought to interact with the geomagnetic lines of force before and at the bow shock spatial boundary, the resulted interaction cause charged particles to gyrate around the geomagnetic lines of force, producing magnetic force [*Yousif*, 2003] given by

$$F_M \ = \ B_g \ B_{e/p} \ r_m^2 \ c \ \vartheta \ sin \ \theta \ = \ q \ v_c \ B_g \ \vartheta \ \sin \theta \qquad N \qquad \{1\}$$

Where, $\boldsymbol{B_g}$ is the geomagnetic field in Tesla, $\boldsymbol{B_{e/p}}$ is the electron's or proton's circular magnetic field (***CMF***) [*Yousif*, 2003a] in Tesla, $\boldsymbol{r_m}$ is the magnetic radius in meter, c is speed of light, ϑ is factor related to the capturing process, θ is the angle between the two fields during the capturing process, q is the elementary charge in Coulomb, $\boldsymbol{v_s}$ is the solar wind velocity when captured and the magnetic force $\boldsymbol{F_m}$ is in Newton (N).

4.1 Production of Interplanetary External Magnetic Field (I-ExMF)

The exterior of geomagnetic field is typically 30 to 40γ, occasionally it rises above 75γ, and seldom below 20γ, and fluctuations are seen from $10R_E$ outwards to $14R_E$ as measured by Pioneer I [*Cahill and Amazeein*, 1963], and a large fluctuations were observed in the magnetic field components between $9.5R_E$ and $15.7R_E$ [*Coleman et al*., 1960a], and large fluctuations in solar wind flow speed and flow direction occurred simultaneously with the solar wind ion density fluctuation [*Bame et al*., 1980], and the turbulent flow in the plasma cloud might cause regions of enhanced magnetic field to exist [*Bryant et al*., 1962], related these to magnetic fluctuation at comet Halley observed by both VEGA-1 and VEGA-2 spacecrafts, which seems more turbulent than those in the undisturbed solar wind [*Le et al*., 1991], and the total magnetic fields measured by ACE at $241.40R_E$ and Wind at $183.64R_E$, gives anomalous field of ~35γ each, while Geotail at $20.22R_E$, measured ~45γ an increase of 28%, and the Interball which was at $11.46R_E$, in the magnetosheath measured total field of ~56γ [*Russell et al*., 2000], and since all these large anomalous fields lead many to state that magnetic fields should not be neglected in theoretical treatments [*Fairfield*, 1976], therefore the incoming solar plasma which carrying nearly equal parameters, if it is embedded with solar magnetic field, then the fields should have measured higher magnitudes solarward not downstream, thus the increase of 28% and 60% measured by above Geotail and Interball respectively, are of changeable parameter not like solar wind [*Russell et al*., 2000], which gives impression that, the IMF is locally produced magnetic field, rather than originated from the sun.

With boundaries been interpreted merely as distances between intermittent local spatial produced magnetic fields, and suggestion that solar wind gyrate around the geomagnetic lines of force, as given by Eq.{1}, and gliding downstream along the guiding center [Kern, 1967]. And with disregard to *Gold* [1959] abstract ideas on transportation of magnetic field of solar origin with solar gas, regulation of ionized material in the magnetosphere by insulating sheath, and instability of material on tube of force, therefore the IMF is thought to be produced within, before and after the area of the great turbulence interaction [*Bame et al.*, 1980] and fluctuated magnetic field, or the bow shock, [*Mariani*, 1965; *Ness et al*., 1964; *Cahill and Amazeein*, 1963], therefore the captured solar wind (electrons and protons) given by Eq.{1}, gyrates along the geomagnetic lines of force, in clusters waves of electrons or protons, with above high density concentrations, this would produced the above mentioned intermittent magnetic fields, namely the Interplanetary-External Magnetic Field (***I-ExMF***), it is produced in a manner different from known induction theory, as shown in Fig.3-A, the magnetic fields are produced in a range of magnitudes, with angles continually giving impression of either away from the sun or toward the sun, such as observed by IMP-1 satellite [*Wilcox*, 1966] or as shown in Figs.3&5, the produced ***I-ExMF*** is such that, it opposed the initial geomagnetic field producing it, and in line with Lenz's Law, that "*Produced **I-ExMF** is in such a direction that it opposes the field that produced it*." [Trinklein, 1990]

The ***ExMF*** idea was first mentioned by Kapitza, who thought the production of intense magnetic field outside an atom, could cause change in atoms characteristics [*Kapitza*, 1967], the ***I-ExMF*** which is thought to represents the filamentary structure detected in the interplanetary medium by IMP-1 [*Ness et al*., 1964], thus the intermittent boundaries shown in Fig.2, are local spatial produced ***I-ExMF***, and each produced ***I-ExMF*** may give diverse magnitudes, proportional to number (or density) of the solar wind (electrons/protons) and the length of gyrating particles along the geomagnetic lines of force as shown in Fig.3-A.

If number of electrons or protons in solar wind interacted with geomagnetic lines of force along one meter is denoted by (n_m), with field intensity ($\boldsymbol{B_g}$), therefore produced ***I-ExMF*** as a result of interaction given by Eq.{1}, and shown in Fig.3&4, is given by

$$B_{IEx} = (B_g + n_m \, l \, B_{e/p}) = B_g + n_m \, l \, \frac{q^3 \, B_g^2}{m_{e/p}^2 \, v_s \, c} \quad T \qquad \{2\}$$

Where, l is the effective length of the magnetic lines of force, $\boldsymbol{B_{e/p}}$ is circular magnetic field (CMF) produced by electrons or protons, $m_{e/p}$ is electron's or proton's mass, v_s is velocity of the solar wind particles, and the produced Interplanetary External Magnetic Field ($\boldsymbol{B_{IEx}}$) is in Tesla.

4.2 Solar Wind Energization Process

The magnetopause was identified by the rapid jumps and very large magnitudes of fields with abrupt change of direction at $9.7R_E$ [*Ness et al*., 1964], but magnetopause position was later been identified by appearance or disappearance of streaming protons that are determinate feature of the magnetosheath, and are not generally observed inside the magnetosphere [*Gosling et al*., 1967]. These energetic magnetosheath particles are accelerated and transmitted by the bow shock [*Katırcıoglu et al*., 2009], where energetic electrons expanded to 182 keV [*Sibeck et al*., 2002], and these energetic particles are found to be a general feature related to anomalous produced magnetic fields [*Fredricks et al*., 1970].

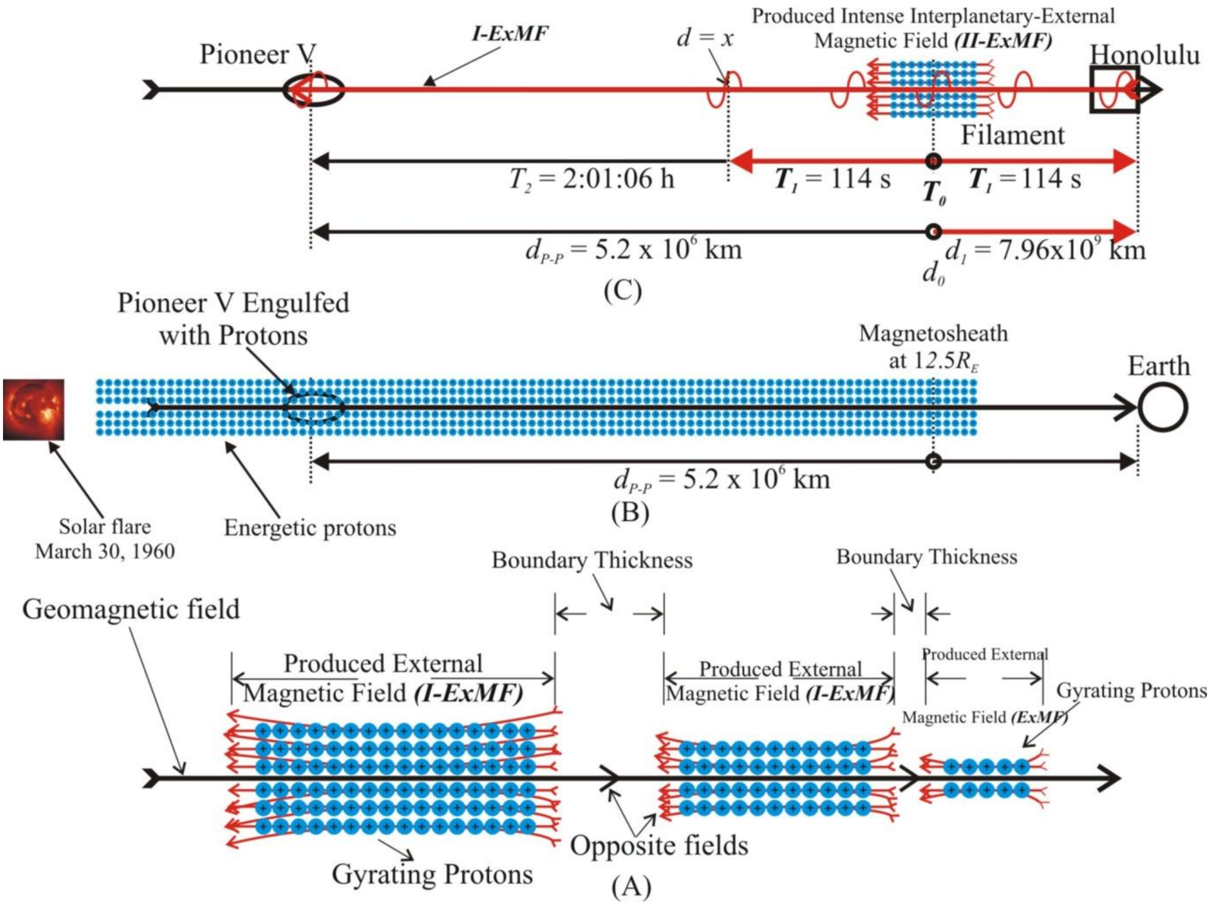

Fig.3. In (A) simple representation of, gyrating protons, producing Interplanetary External Magnetic Fields (***I-ExMF***), magnitude of each is proportional to number of protons (density) and length of gyrating protons [*Yousif*, 2004], it also shows the boundaries. In (B), flow of solar flare protons and (C) the produced intense ***I-ExMF*** (***II-ExMF***) propagates towards Honolulu and Pioneer V at the same time, but reached the satellite at T_1+T_2.

Thus it was also found that, the ***increase in electrons density***, lead to an increased in ***magnetic field magnitude***, thus increasing ***electron's energy***. [*Neugebauer et al*., 1971], and that, ***ions heating, occur behind the magnetic structure*** [*Morse and Greenstadt*, 1976].

Therefore particles acceleration in nature is thought to be carried out in the follows sequence:

Electrons and/or protons high density **=** (or synonymous to) ***gyrating around magnetic lines of force*** → *anomalous magnetic field* = (or synonymous to) ***production of I-ExMF*** → *accelerated particle* = (or synonymous to) ***energization of particles***.

As this process is what is consistently been found, *Paschmann et al*. [1988]; *Neugebauer et al*., [1971]; *Morse and Greenstadt*, [1976], that the energization process, taking place during ***I-ExMF*** production, is related to electrons/protons density, therefore any detected momentary increase in solar wind density in the interplanetary space means a capturing gyrating process as given by Eq.{1}, that could lead to production of the ***I-ExMF*** given by

Eq.{2}, hence both of these leading to the energization of the solar wind, therefore energy given at step *i* by K_i is given by [*Yousif*, 2004]

$$K_i = 10^8 \, \delta_i \left(d \, \gamma_{PS} \, q \, v_c B_g^2 + \frac{d \, \gamma_{PS} \, n_m \, l \, q^4 \, B_g^3}{m_{e/p}^2 \; c} \right) \sin\theta \quad J \qquad \{3\}$$

Where, γ_{PS} is the relative magnitudes of both the ***P & S-ExMF*** in production of ***ExMF*** [*Yousif*, 2004], and K is the energy gained by a particle.

If $\boldsymbol{B_{IEx}}$ given by Eq.{2} continuously increasing, then energy built up gained by charged particles given in Eq.{3} may be approximately computed as measured [*Yousif*, 2004]

$$K_T = K_i + K_2 + K_3 \;\ldots\ldots + K_n + \varepsilon \quad J \quad \{4\}$$

Where, K_1, K_2 … K_n are energization executed, $\varepsilon = \varepsilon_i$ where ε_i is the error of continuity approximation at step *i*, $\boldsymbol{K_T}$ is the total approximate energy acquired or gained by the charged particle in Joules.

5.0 The Sudden Commencement Magnetic Storm-First Approach

Magnetosheath streaming protons, [*Gosling et al*., 1967], were similar to the one which engulfed Pioneer V on March 31, 1960 [*Fan et al*., 1960a], and later ignited the sudden commencement detected at Honolulu and Pioneer V [*Coleman et al*., 1961].

Vela 2A was on the magnetosphere side and close to the boundary, when it recorded movements of such protons on June 9, 1965 then an IMF starts increases at 04:40 U.T. (to be linked with IMF increase at Pioneer V), then streaming protons fluxes appeared at 04:55 U.T., causing changes in earth's field [*Gosling et al*., 1967], another Sudden Commencement (SC) storm occurred on March 12, 1965; at the impulse, Vela 2A was within the magnetosheath and close to the average position of the magnetopause, when great influx of protons were detected, simultaneously with an increase in the horizontal component of the field at Guam station [*Gosling et al*., 1967].

The persist existence of energetic protons at magnetosheath boundary with magnetopause, prior to the start of the SC and the start of magnetic changes on magnetopause and earth surface, as demonstrated by above examples, was also recorded by IMP-1 where, immediately after the geomagnetic sudden commencement storm at 21:14 U.T., on December 2, 1963, a clear unique event was observed to occur in the interplanetary magnetic field data three minutes before the terrestrial magnetic field event [*Ness et al*., 1964], such strong relation between the geomagnetic storms and protons streaming into magnetosheath, also exhibited by the large ion flux during January 31, 1964 geomagnetic storm, which occurred when IMP-1 was in inbound to 15.7R_E, and it detects flux with large fluctuations in both flux and direction of incidence, [*Wolfe and Mayers*, 1966], and since the daily variation of sudden impulses (si) at Honolulu seems to be diurnal, with maximum around noon and minimum around midnight [*Nishida and Cahill*, 1964], this means the si or the initial positive phase ($D_{st} > 0$) is related to solar wind activities blowing from the sun, as proposed [*Akasofu and*

Chapman, 1963], but how variations in the solar wind produce the variations in the magnetic field measured on Earth as *Gannon* [2012] asked?

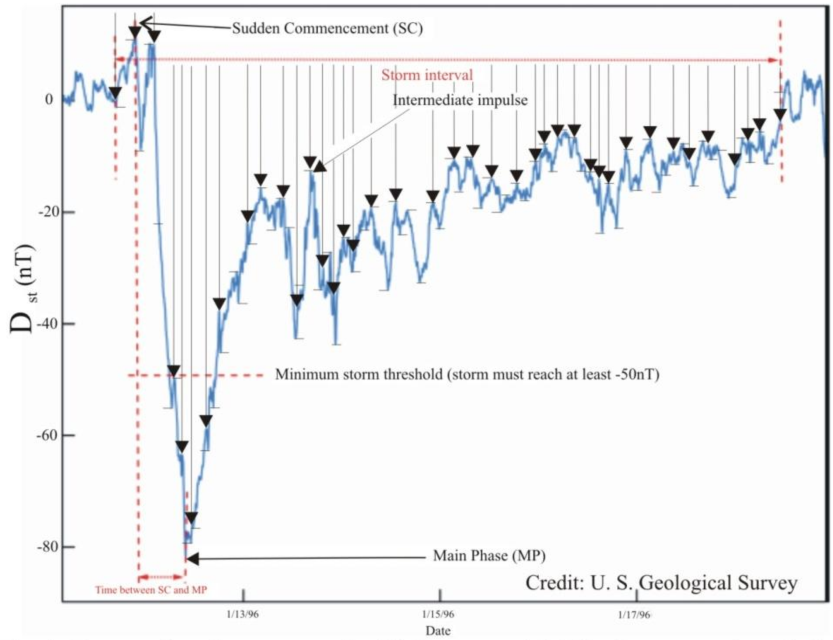

Fig.4. Example of storm period [*Gannon*, 2012], the arrow head shows the repetitive sinusoidal nature of the Dst at each cycle, starting from the sudden commencement, the main phase and the recovery phase.

The relative magnitudes of si's at various observing points, showed that large magnitude three times greater than that of Honolulu, was obtained around a radial distance at 12.46R_E [*Nishida and Cahill*, 1964], which could be inferred as at/or near to the source of the magnetic field production, and that region (12.46R_E) is the region of high turbulence in the magnetic field, which separates the magnetopause from the shock wave [*Ness et al.*, 1964], it is where accelerated solar wind are transmitted by the bow shock [*Katırcıoglu et al*., 2009], and since the position of the bounding surface of the magnetosheath is often inaccurate [*Wolfe and Mayers,* 1966], and the magnetosheath region was detected at various radial distances, among them at 15.2 R_E, 15.7R_E, 16.4 R_E, while the cutoff was detected at 11.3R_E [*Wolfe and Mayers*, 1966], therefore the cutoff could move up to or bellow, hence the central radial distance of the magnetosheath is thought to be nearly at 12.5 R_E, near si above region.

Observations due to Pioneer V failure to detect embedded solar magnetic fields with the incoming plasma, on March 31, 1960, and with Parker theory strong momentum [Parker, 1959], force *Fan et al*. [1960a] to state that "*magnetic fields are either being moved from the sun or generated in the interplanetary space*", therefore reviewing that failure and the nearly concurrent detection of IMF by both Honolulu station and two hours later by Pioneer V [*Fan et al*., 1960a], which cast great doubt about the solar origin of the IMF, and with the detection of such as high density magnetosheath solar wind positive ion density ranging between 35 to 127 cm^3 [*Gosling et al.*, 1967], in contrary to background proton's solar wind density of 5-10 cm^3 [*Watermann et al.,* 2009], such ions concentration is the main sequence towards achieving - gyration+ ***I-ExMF*** + Energization - process, *Paschmann et al*. [1988]; *Neugebauer et al*., [1971]; *Morse and Greenstadt*, [1976], and as *Fan et al*. [1960a] stated in regards to origin of Pioneer V measured IMF that, "*solar plasma either carries magnetic fields, or manipulate an interplanetary magnetic field*", hence as given by Eq.{2}, ***I-ExMF*** is produced along the geomagnetic lines of force by such solar wind concentration; therefore, as energetic particles accelerated from bow shock towards the magnetosheath, with gyrating radius due to balance of force given by Eq.{1} with centripetal force ($Bev=mv^2/r$), thus the magnetic radius become smaller with an increased in ***I-ExMF*** magnitude, given by Eq.{2}, therefore the magnetic radius is given by

$$r_m = \frac{m_{e/p}\, v_s}{B_{IEx}\, q} \quad m \qquad \{5\}$$

Where, r_m is the magnetic radius, and with such reduction in radius, and since each geomagnetic storms depends on specific solar wind that drive them [*Gannon*, 2012], therefore that state starts with the production of an intense Interplanetary External Magnetic Field (***II-ExMF***) [*Yousif*, 2004] in the magnetosheath, centered at $12.5R_E$, as demonstrated in Figs.3, it is given by

$$B_{IIEx} = 10^8 \left(\gamma_{PS}\, B_{gx}^2 + \frac{\gamma_{PS}\, n_m\, l\, q^3\, B_g^3}{m_{e/p}^2\, v_c\, c} \right) \quad T \qquad \{6\}$$

Where, 10^8 is the relative number of geomagnetic lines of force in square meter [*Yousif*, 2003b], γ_{PS} is the relative magnitudes of both produced primary and secondary ***ExMF*** (***P & S-ExMF***), $\boldsymbol{n_m}$ is gyrating number of electrons/protons in volume of geomagnetic lines of force, l is the effective length of the magnetic lines of force around which charged particles gyrates, $\boldsymbol{B_{gx}}$ is the previous field intensity, and the produced intense ***II-ExMF*** ($\boldsymbol{B_{IEx}}$) is in Tesla.

5.1 Magnetic Storms and Lion Roars

There is an intense, sporadic bursts of narrow-band magnetic noise in the earth's magnetosheath with frequencies near 100 Hz [*Smith et al*., 1969], with the Pioneer V measurements during solar activity, *Coleman et al*. [1960a] concluded that a collisionless magnetoacoustic waves may be formed in the interplanetary medium, the burst was detected and found to be a persisted feature of the magnetosheath [*Smith et al*., 1967] the signals which is intense was found to occupy narrow band centered between 100 and 300 *Hz* [*Smith et al*., 1969], when the recorded signal played in a loudspeaker, the low frequency burst sounded like a roaring lion [*Smith and Tsurutani*, 1976]. The wave is circularly polarized in a counterclockwise sense; or the sense where electrons gyrate around the magnetic field, and found to propagate along the magnetic field [*Smith and Tsurutani*, 1976], these waves are thought to represents the gyrating ions which are often associated with low frequency MHD, the center of which rotates around the ambient magnetic field [*Paschmann, et al., 1979*; *Meziane et al*., 2001].

A strong correlation has been found between the probability of lion roars occurrence and geomagnetic activity [*Smith and Tsurutani*, 1976], and the level of that activity as measured by K_P, and the probability of occurrence ranges from 10% in magnetically quiet intervals to 75% during disturbed periods [*Smith and Tsurutani*, 1976].

But the observed frequencies of lion roars were found to exist roughly midway between proton and electron gyrofrequencies [*Smith et al*., 1969], which suggest the phenomenon to represents the production of magnetic waves by both electrons and protons, therefore gyrating charged particles (electrons and protons), which produced ***II-ExMF*** at 12.5R_E in the magnetosheath region, accelerated by the Lorentz force given by Eq.{1}, the force increased with the produced ***II-ExMF*** or $\boldsymbol{B_{IIEx}}$ given by Eq.{6}, with smaller radius given by Eq.{5}, therefore the acceleration would creates radiation, and since the ***II-ExMF*** is relatively intense, the produced wave is at low frequency, this frequency is given by [Turku, 2006]

$$f_c = \frac{q\, B_{IIEx}}{2\,\pi\, m_{e/p}\, c} \quad Hz \qquad (7)$$

Where, the cyclotron frequency f_c is in hertz, and proportional to the magnitude of intense ***II-ExMF***.

5.2 The Sudden Commencement & Main Phase-First Approach

The occurrence of the interplanetary magnetic field (IMF) data three minutes before the terrestrial magnetic field event [*Ness et al*., 1964], with field events occurred after sudden ion flux, such as that of December 2, 1963, at 21:14 U.T., which started approximately three minutes with a sudden impulse-type magnetic storm observed worldwide [*Wolfe and Mayers*, 1966], or the proton flux of March 12, 1965, detected by Vela 2A while within the magnetosheath and close to magnetopause [*Gosling et al*., 1967], and that the sudden flux enhancement of magnetosheath coincided with the onset of the storm [*Nishida and Cahill*, 1964], therefore these events were similar to the solar protons which engulfed pioneer V on March 31, 1960, then caused geomagnetic storm six hours later, detected at Honolulu station and two hours later by Pioneer 5 [*Fan et al*., 1960a] and since magnetosheath boundary at 15.7R_E, revealed extremely chaotic plasma flow characterized by high temperatures (broad energy spectra) and variability in the direction of incidence and flux amplitude [*Wolfe and Mayers*, 1966], and that shortly before the terrestrial observations of the sudden commencement, the field decreased very rapidly and varied somewhat for several hours, eventually returning to a configuration similar to that before the storm [*Ness et al*., 1964], the sequence of which explained in Fig.3-B&C and also to be related to Fig.1, and since the center of the magnetic storm is estimated to occur within the magnetosheath at 12.5R_E, from the earth's center, that point is the center for intense ***II-ExMF*** production as given by Eq.{6}.

In Fig.4, the whole of Dst shape including the SC, the main phase (MP) to the recovery phase (RP); is interwoven with low frequency pulses, each cycle is designated by arrows, but as explained, the source of magnetic disturbances at the magnetosheath, is where great turbulence in magnetic field exists [*Ness et al.,* 1964], where there are two types of waves [*Smith et al*., 1969], having frequencies ranges from 3 to 300 Hz [*Smith et al*., 1967], with amplitude magnitude between 40 and 160mγ [*Smith and Tsurutani*, 1976] in addition to high amplitudes it do have low durations [*Smith et al*., 1969]. As the region is suggested to produced intense ***II-ExMF*** given by Eq.{6}, it is such field thought to be measured at Honolulu and two hours later at Pioneer V [*Fan et al*., 1960a]. As shown in Fig.1, there was second IMF on April 1, 1960 due to the second flare, the IMF measured 53γ at Pioneer V [*Coleman et al*., 1960a], and since the difference in propagation time between Honolulu and Pioneer V to attain IMF peak magnitudes is two hours as measured in Fig.1-A&B for the first flare of 31 March, therefore tracing a two hours on the left side of IMF maximum of 53γ on second IMF of April 1st, will bring the line to the main phase of Honolulu Dst at point x, with field measurement of 91γ.

Given Honolulu first magnetic disturbance = 11.6γ, Pioneer V first IMF = 23γ, and Pioneer second IMF = 53γ, and since both data are perceived to be produced from one source, therefore from these data, the magnitude of the second Honolulu SC caused by the second magnetic disturbance is given by the following ratio

$$\frac{B_{H2}}{B_{H1}} : \frac{B_{P2}}{B_{P1}} = \frac{B_{H2}}{11.6} : \frac{53}{23} \quad \therefore \quad B_{H2} = \frac{(53) \times (11.6)}{23} = 26\gamma \qquad \{8\}$$

Where, B_{P1} is Pioneer V first IMF on 31 March, B_{P2} is Pioneer second IMF on April 1, B_{H1} is Honolulu first magnetic disturbance of 31 March, and B_{H2} is Honolulu supposed magnitude related to the second magnetic disturbance two hours before the peak measured at Pioneer V as shown in Fig.1-A & B by the dashed green lines, the magnitude of the second magnetic disturbance at Honolulu, coincided with the main phase (MP) of the first magnetic disturbance, thus the impact of the second 26γ is that it changed the recovery phase and formed a strange peak shown in Fig.1-A as point-x, therefore the net resultant of SC on the MP is the reduction of the negative magnitude of the MP; that performance, in addition to the strong relations between occurrence of Lion roars and geomagnetic activity as measured by K_P [*Smith and Tsurutani*, 1976], with the initial positive phase ($D_{st} > 0$) attributed to the impact of a solar stream on the earth's magnetic field [*Akasofu and Chapman*, 1963], and the sudden commencements are associated with enhancements of solar wind and the Z component of the IMF with geomagnetic activity [*Burton et al*., 1975]. With SC rise time range from 1 to 10 minutes [*Curto et al*., 2007], and since Pioneer I, waves were found to be generated between 12 to 15 earth radii; with a lifetimes of 2 to 5 cycles and periods of 10 seconds [*SONETT et al*., 1959], and the Lion roars occurs at nearly the same place, every few seconds for intervals of minutes to hours [*Smith and Tsurutani*, 1976], with amplitudes ranging between 40 and 160 mγ. [*Smith and Tsurutani*, 1976], while that of DCF does not exceed 70γ during very intense storm [*Akasofu and Chapman*, 1963], and with prominent correlation between lion roars occurrence and decreases in magnetic field magnitude at magnetosheath, and that all lion roars are accompanied by decreases in magnetic field, and vice versa, for intervals of tens of minutes [*Smith and Tsurutani*, 1976] and the magnetosheath field having frequencies variations below 1 hz have been reported extensively, with variable intensity [*Smith et al*., 1967], and since in most cases, a negative impulse is superposed on the MI of SC, the period of the negative impulse differ in each event, and the occurrence of the negative impulse does not seem to be dependent on geomagnetic activity [*Tsunomura*, 1998], and the contribution from the external source of the sudden impulses (si) is estimated to reach 2/3 of the total magnitude [*Nishida and Cahill*, 1964], which is thought due to ***II-ExMF*** as given by Eq.{6}.

Therefore it is suggested that, the starts of first frequency of Lion roars given by Eq.{7} together with ***II-ExMF*** magnitude given by Eq.{6}, initiate the SC of the Dst as shown in Fig.4, and in reaction to ***II-ExMF*** production, the geomagnetic field will opposed such production, in accordance with Lenz's law, hence the start of the main phase, therefore producing a shaped interwoven with low frequency magnetic wave as shown in Fig.4, therefore such magnetic disturbance can be expressed as follows

$$D_{st} = (B_g + (B_{IIEx} + 2f_d)) + (B_g - (B_{IIEx} + nf_d)) \quad T \qquad \{9\}$$

Where, $\boldsymbol{B_g}$ is the geomagnetic field, $\boldsymbol{B_{IIEx}}$ is the ***I-ExMF***, f_d is Lion roars frequency, n is the number, and $\boldsymbol{D_{st}}$ or the ***SC-II-ExMF*** is the magnitude of the magnetic disturbance in Tesla.

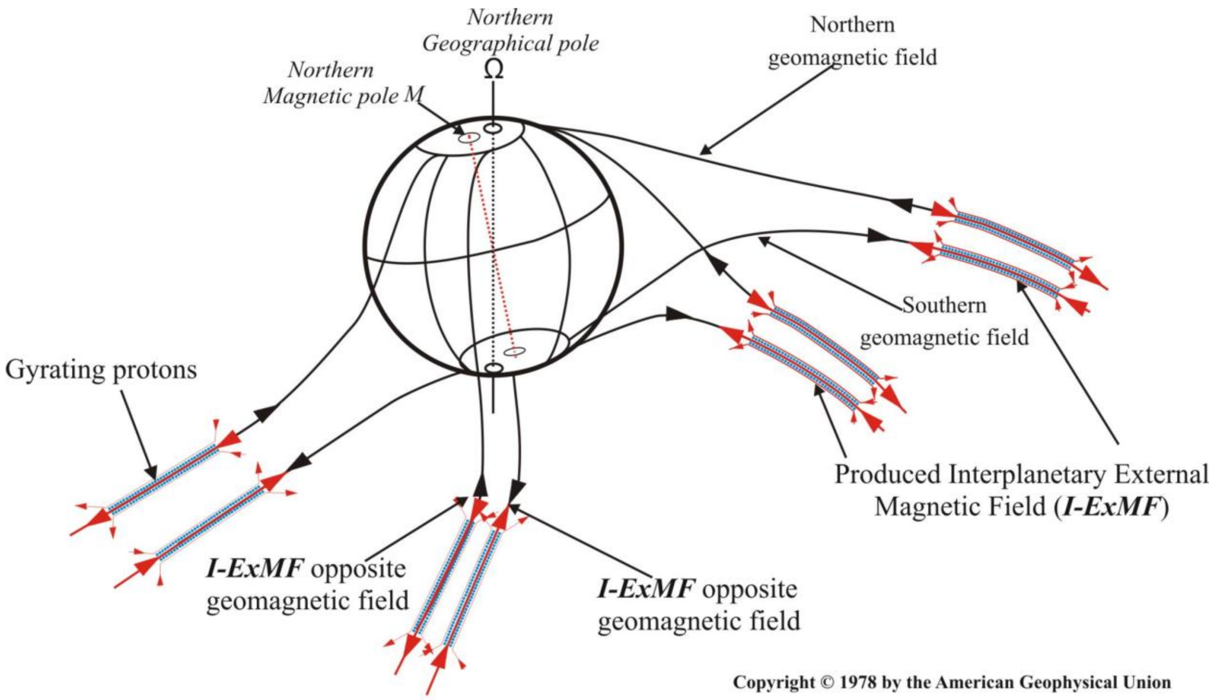

Fig.5. Three-dimensional sketch of the production of the Interplanetary-External Magnetic Fields (***I-ExMF***) by geomagnetic lines of force, at magnetosphere peripheries, the axis of the geomagnetic field M is tilted relative to the Earth rotation axis Ω. The produced ***I-ExMF*** gives impression of sector structure [*Smith and Tsurutani* 1978].

The change given by Eq.{9}, explained the correlation between changes in the magnetic field magnitude, direction and the occurrence of lion roars as observed above, where the lion roars starts when the field magnitude decreases and end as the magnitude recovers [*Smith and Tsurutani*, 1976], and since ***II-ExMF*** production is carried out by periodic intermittent waves of solar winds, this cause intermittent start and decrease of both the lion roars and the geomagnetic field, all of which occurs during small period of time, hence explained why the lion roars can occurs every few seconds for intervals of minutes to hours [*Smith and Tsurutani*, 1976], and since the streaming protons could produce both the waves and the field decreases and all three occurs at the same time [*Smith and Tsurutani*, 1976], this understandable since the streaming protons produced the ***II-ExMF*** given by Ex{6}, the later in turn produced Lion roars as given by Eq.{7}, and both the lion roars and the ***II-ExMF*** caused geomagnetic storms and drop in geomagnetic field given by E.{9}, as a result of that decreases the ***II-ExMF*** ceased and Lion roars stops.

Since the solar protons were arriving before and after the sudden commencement on March 31, 1960 [*Coleman et al*., 1961], therefore the sudden intense production of the ***SC-II-ExMF*** given by Eq.{7} is thought to represents the final resultant of accumulated mechanism lasted four hours (deduced from Fig.1) during the gyration process that finally produced the ***SC-II-ExMF***.

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
name	1/1-1	1/1-2	1/1-3	1/2-1	1/2-2	1/2-3	1/3-1	1/3-2	1/3-3	1/4-1	1/4-2	1/5-1	1/5-2	1/6-1	1/6-2	1/7-1	1/7-2	1/8-1	1/8-2
polarity	+	+	+	o	o	o	o	o	-	-	o	-	-	-	-	-	o	-	o
Measured I-ExMF	2.2γ	2.2γ	2.4γ	4.0γ	4.2γ	4.2γ	4.6γ	4.8γ	5.8γ	5.85γ	5.85γ	6.1γ	6.1γ	6.1γ	6.1γ	6.5γ	6.5γ	6.5γ	6.7γ

Table.2. Data of the first sector, measured by IMP-1 during the first orbit, as given by *Wilcox and Ness*, 1965]. These data are used in Fig.6, to show readings along the yellow and green colors orbit.

5.3 Geomagnetic Storm Propagation "Pioneer V Events"

As shown in Fig.1-A-B&C, the ***SC-II-ExMF*** recorded maximum magnitude at Honolulu station before Pioneer V, this due to short distance between ***SC-II-ExMF*** source of production and Honolulu station, thus as the ***SC-II-ExMF*** spreads at the same time along the geomagnetic lines of force in both directions, hence the time T_1 travelled by ***SC-II-ExMF***, first arrived at Honolulu station, while the same field/time arrived at an equivalent distance $d=x$ in the opposite direction towards Pioneer V, as shown in Fig.3-C. But the time for sudden increase in magnetic field at Honolulu due to ***SC-II-ExMF*** production and the start of SC as given by Eq.{9}, is to be related to detection of the field after three minutes in later related events [*Ness et al*., 1964]; therefore the speed at which change in magnetic field propagates towards Honolulu station is given by

$$V_{SC} = \frac{d_{xH}}{t_{xH}} \quad ms^{-1} \qquad \{10\}$$

Where, d_{xH} is the radial distance from the spatial point at which ***SC-II-ExMF*** is produced ($12.5R_E$) in meters to Honolulu, t_{xH} is time travel by ***SC-II-ExMF*** (to reach earth station) in seconds, and the ***SC-II-ExMF*** velocity $\boldsymbol{V_{SC}}$ is in Tesla.

Since the known propagation velocity of 700 km sec^{-1} was measured due to magnetic disturbances on December 2, 1963, by *Ness et al*. [1964], while the probe seems to be at $19.7R_E$, therefore the magnetic disturbances, or the produced Dst moves towards Honolulu and Pioneer V at the same time as shown in Fig.3-c, and the suggested Dst production point is at $12.5R_E$, from Honolulu, therefore with V_{SC} = 700,000 ms^{-1}, the time to reach Honolulu is = 114 s equivalent to t = 1:54 minutes.

As the same ***SC-II-ExMF*** was also moving towards Pioneer V (d_{PE}) in opposite direction, at a distance of 5.2×10^9 meters from earth [*Fan et al*., 1960a], therefore the distance from Pioneer V to the ***SC-II-ExMF*** spatial production point (x) is given by

$$d_{Px} = (d_{PE}) - (d_{xH}) \quad m \qquad \{11\}$$

Where, d_{PE} is the radial distance from Pioneer V to earth in meters, and d_{xH} is the distance from ***SC-II-ExMF*** production point to earth's (Honolulu), and the distance from Pioneer V to ***SC-II-ExMF*** production point d_{Px} at $12.5R_E$ in meters.

Since d_{PE} = 5.2 x 10^6 km [*Fan et al*., 1960a], therefore the time for the ***SC-II-ExMF*** to propagate to Pioneer V is given by

$$t_{xP} = \frac{d_{Px}}{V_{SC}} \quad s \qquad \{12\}$$

From Ex.{12}, the time required for the produced ***SC-II-ExMF*** to propagate to Pioneer V is 2:03 hours when d_{PE} = 5.2 x 10^6 km [*Fan et al*., 1960a], referring to Fig.1, this is the difference in time between disturbances arrival to Honolulu and to Pioneer V, which is 2:00, therefore all parameters are correct, including ***SC-II-ExMF*** production point, and the field which is coming from $12.46R_E$ in magnetosheath, and larger three times in magnitude than registered si at Honolulu [*Nishida and Cahill*, 1964].

6.0 What Is the Sector Structure?

As Exp. 18 was sent to investigate the magnitude, direction, and temporal variations of the interplanetary magnetic field (IMF), [*Ness et al*., 1964], the results were analyzed based on Pioneer V interpretations [*Fan et al*., 1960a], and the origin of measured anomalies interplanetary magnetic field was settled to emerged from the sun and embedded with the plasma, in accordance to Parker theory [*Parker*, 1959].
But one of the most complicated interpretations emerged during IMP-1 experiment which lasted three solar rotations of the quiet sun, was the observation of a quasi-stationary corotating structure in the interplanetary medium [*Wilcox and Ness*, 1965], the sector structure consists of seven sectors, divided into four, according to fields direction (+) to /or (-) from the sun, they are (+2/7) (-1/7) (+2/7) and (-2/7), these sectors were thought to originate from the sun [*Wilcox and Ness*, 1965], and the observed direction of the interplanetary field is

on the average was thought in consistent with the Archimedean spiral picture predicted by *Parker* [1958], but the negative and positive sense of the field changes from time to time [*Wilcox and Ness*, 1965].

As attention had been drowned to the failure of Pioneer V to detect embedded solar magnetic field with the solar plasma, and the detection of IMF eight hours later, both of them were overlooked, and instead solar magnetic field was chosen as the origin of the IMF due to lack of alternative theory [*Fan et al*., 1960a], and distortion from ***I-ExMF*** by other planet on 1 December 1963, is excluded according to that day Orrery [The Orrery, 2013] therefore these sectors are to be analyzed in accordance with the suggested alternative ***I-ExMF***; but before that, the main ***I-ExMF*** characteristics are to be draw into attention to help in the analysis of IMP-1 measurements, these characteristics are:

a- Charged particles gyrate along the geomagnetic lines of force to produce the Interplanetary External Magnetic Field (***I-ExMF***).
b- Many lines of force will be covered by gyrating charged particles.
c- Line/or lines of force may have lengthy or intermittent charged particles.
d- Line/or lines of force may produced intermittent ***I-ExMF***.
e- The direction of produced ***I-ExMF*** is opposite to the geomagnetic field.
f- Each intermittent produced ***I-ExMF*** polarity is opposite to the adjacent one.
g- Magnitudes of produced ***I-ExMF*** varied from intermittent group to another.

6.1 Spatial Measurements of I-ExMF

The average magnitude of the IMF within each of the seven sectors was given in Fig.7 by *Wilcox and Ness* [1965], the first sector which represents measurements carried out during IMP-1 first orbit [*Wilcox and Ness*, 1965], is given in Table.2.

The time required for the 1/7 sector given in table.2, to rotate past the earth is almost equal to one orbital period of the satellite [*Wilcox and Ness*, 1965], which is 93.05 hours or 3.9 days [*Car*, 1966, *Ness et al*., 1963], and the interplanetary measurements cannot be made during perigee passes; when IMP-1 within geomagnetic field which is one day [*Wilcox and Ness*, 1965], therefore the spatial interplanetary boundary that adjacent to the magnetosphere, where the ***I-ExMF*** is produced, is shown in Fig.5, while the spatial positions where IMP-1 first orbit, is shown in Fig.6, this is the spatial space where the ***I-ExMF*** could be produced based on Eq.{2}, it is covered by intermittent strips of yellow and green colors.

As shown in Fig.6, the radial distance of measurements in the interplanetary space was the satellite apogee which was 30.7 R_E [*Car*, 1966, *Ness et al*., 1963], starting from around 5R_E, most of the space is covered with solar wind, protons in this case because energetic protons of MeV were detected by IMP-1, during the three solar rotations, [*Wilcox and Ness*, 1965], although it can consist of electrons or mixture of both.

Each cluster of protons gyrate around the geomagnetic lines of force producing the ***I-ExMF***; the polarity of which is opposite to adjacent one and to that of the geomagnetic field, as shown in Figs.3,5&6, hence fields' polarities between adjacent produced ***I-ExMF*** could cause confusion. The magnitudes of produced ***I-ExMF*** varies with particle's density and cluster length according to Eq.{2}, hence with sudden shift from one proton's cluster to adjacent with less proton's density, the magnitude is reduced, and the field sense of direction, away or toward the sun [*Wilcox and Ness*, 1965] could means a movement from one cluster to another as could be deduce from Fig.6, therefore these represents reversal of field direction, with an abrupt decreased of field magnitude to zero when moving from cluster to another, which represents the null point [*Ness et al*., 1964], as measured by satellites, and shown in Fig.6 and Fig.3-A.

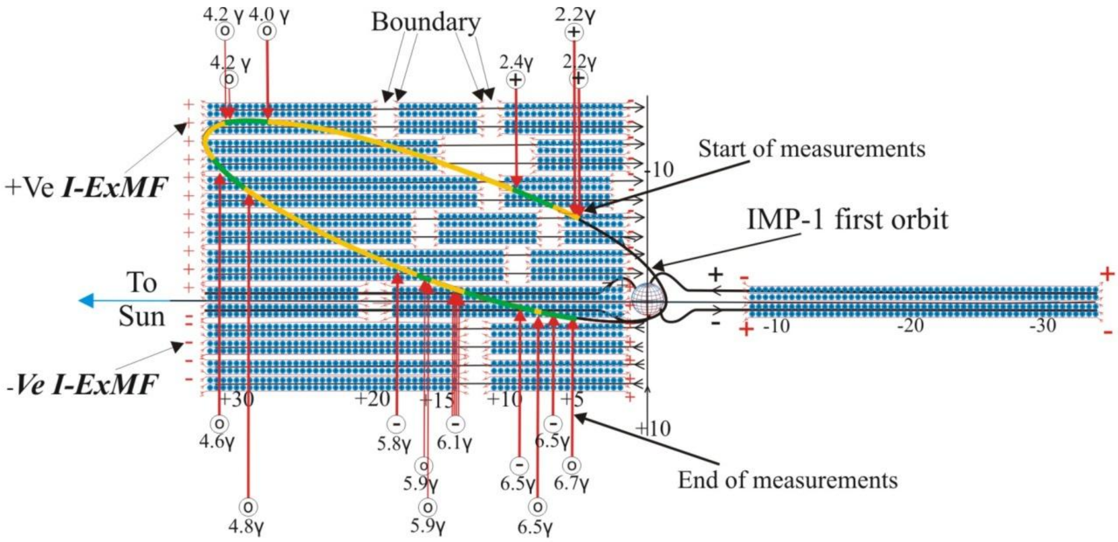

Fig.6. Tow dimensional image shows the IMP-1 1st orbit around the earth up to apogee of 30.7 R_E [*Car*, 1966, *Ness et al*., 1963]. The yellow & green colors around the orbit, are the spatial places of measured Interplanetary-External Magnetic Field (***I-ExMF***) produced around the geomagnetic lines of force, it was perceived as the first sector of quasi-stationary corotating structure in the interplanetary medium [*Wilcox and Ness*, 1965].

Given these, and as shown in Fig.6, IMP-1 measurements during the first orbit started after 5R_E, while the satellite moves across and through clusters of gyrating protons at various angles, while detecting charged particles [*Wolfe and Mayers*, 1966], and since the sector boundary is the position at which the sense of direction of the interplanetary magnetic field changes [*Wilcox and Ness*, 1965], whereas proton's clusters produced intermittent ***I-ExMF*** which has space between them, hence that is what are perceived as boundaries according to above definition, and since solar wind plasma is thought to be organized by sector structure [*Wilcox and Ness*, 1965], and as given by Eq.{2}, the ***I-ExMF*** production is also proportional to solar wind density, therefore measurements of magnitudes, density, polarities and angles of ***I-ExMF*** by IMP-1, at positions designated by green and yellow colors, within the IMP-1 first orbit shown in Fig.6, or what had been perceived as quasi-stationary corotating structure in the interplanetary medium [*Wilcox and Ness*, 1965], is merely measurements of magnitudes, polarities and angles of local spatial produced ***I-ExMF***.

Such ***I-ExMF*** production in magnetosphere peripheries is also shown in Fig.5, which had been perceived as sector structure [*Smith and Tsurutani* 1978].

7.0 Conclusion

The paper generates many questions, which with little efforts can be resolved, such as:

- Re-confirmation of Pioneer V engulfment with solar plasma, which could be replicated with three satellites, one at $5x10^6$ km, the second at 17RE and the third at 12.5RE, to confirm or dispute the first results.
- How the earth's dynamo system compensate the drop given by Eq.{9}?

Acknowledgement

Gratitude to my son Mustafa for waiting these periods, and friends who helped reduce pains of past two years while surviving, Mr. John Ongay Kassiba, Ramadan Nimir, Bona Thiang, Ramadan Omba, Yagoub Adam Sad-Alnur, Ali Abdulrhman, Awutu Aluiuda Ndeke, Rashid James, John Nassar, Elsafi Noraldin Ibrahim, Boshara Suliman Alnor and the American Geophysical Union (AGU) for references used.

8.0 Reference

Akasofu, S. I. and S. Chapman, The Development of the Main Phase of Magnetic Storms, JOURNAL OF GEOPHYSICAL RESEARCH VoL. 68, No. 1 JANIJARY1,1963.

Alfvén, H., Existence of electromagnetic-hydrodynamic wave, *Nature*, *150*, 405–406, doi:10.1038/150405d0, 1942a.

Alfvén, H., On the existence of electromagnetic-hydrodynamic waves, *Ark. Mat. Astron. Fys.*, *29B*(2), 1–7, 1942b.

Alfvén, H. A., Hydromagnetics of the magnetosphere, *Space Sci. Rev.*, 2, 862-870, 1963.

ANDERSON, K. A., R. P. LIN, C. GURGIOL, G. K. PARKS, D. W. POTTER, S. WERDEN, AND HEME, A Component of Nongyrotropic (Phase-Bunched) Electron, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 90, NO. All, PAGES 10,809-10,814, 1985.

Angelopoulos, V., D. Sibeck, C.W. Carlson, J.P. McFadden, D. Larson, R.P. Lin, J.W. Bonnell, F.S. Mozer, R. Ergun, C. Cully, K.H. Glassmeier, U. Auster, A. Roux, O. LeContel, S. Frey, T. Phan, S. Mende, H. Frey, E. Donovan, C.T. Russell, R. Strangeway, J. Liu, I. Mann, J. Rae, J. Raeder, X. Li, W. Liu, H.J. Singer, V.A. Sergeev, S. Apatenkov, G. Parks, M. Fillingim, J. Sigwarth, First Results from the THEMIS Mission, *Space Sci Rev* (2008) 141: 453–476 DOI 10.1007/s11214-008-9378-4, Springer Science+Business Media B.V., 2008.

Arnoldy, R. L., R. A. Hoffman, and J. R. Winckler, Solar cosmic rays and soft radiation observed at 5,000,000 kilometers from earth, *J. Geophys. Research*, 65, 3004-3007, 1960.

Axford, W. I., The Interaction Between the Solar Wind and the Earth's Magnetosphere, *J. Geophys. Res*., 67, No. A10, 3791, 1962.

Bame, S. J., J. R. Asbridge, W. C. Feldman, J. T. Gosling, G. Paschmann, and N. Sckopke, Deceleration of the solar wind upstream from the earth's bow shock and the origin of diffuse upstream ions, *J. Geophys. Res*., 85, 2981, 1980.

Beard, D. B., The Solar Wind Geomagnetic Field Boundary, *Rev. Geophys*., 2, No. 2, 335, 1964.

Bryant, D. A., T. L. Cline, U. D. Desai, and F. B. McDonald, Explorer 12 observations of solar cosmic rays and energetic storm particles after the solar flare of September 28, 1961, *J. Geophys. Res*., 67, 4983, 1962.

Burlaga, L. F., and K. W. Ogilvie, Observations of the magnetosheath-solar wind boundary, *J. Geophys. Res*., 75, 6167, 1968.

Burlaga, L. F., L. Klein, N. R. Sheeley Jr., D. J. Michels, R. A. Howard, M. J. Koomen, R. Schwenn, and H. Rosenbauer , A magnetic cloud and a coronal mass ejection, *Geophys. Res. Lett.*, *9*(12), 1317–1320, doi:10.1029/GL009i012p01317, 1982.

Burlaga, L. F., N. F. Ness, Y. M. Wang, and N. R. Sheeley Jr. , Heliospheric magnetic field strength out to 66 AU: Voyager 1, 1978–1996, *J. Geophys. Res.*, *103*(A10), 23,727–23,732, doi:10.1029/98JA01433,1998.

Burton, R. K., R. L. Mcpherron, and C. T. Russell, An Empirical Relationship Between Interplanetary Conditions and D_{st}, Vol. 80, No. 31, Journal of Geophysical Research, November 1, 1975.

Cahill, L. J., and P. G. Amazeein, The boundary of the geomagnetic field, *J. Geophys. Res*., 63, 1835-1854, 1963.

Car, Frank A., Flight Report Interplanetary Monitoring Platform Imp-I-Explorer Xviii, N a t i o n a l Aeronautics And Space Administration Washington, D. C. April 1966.

Carter, Brandon ANTHROPIC PRINCIPLE IN COSMOLOGY, arXiv:gr-qc/0606117vl 27 June 2006

COLEMAN, P. J., JR., C. P. SONETT. D. L. JUDGE, AND E. J. SMITH, Some preliminary results of the Pioneer-5 magnetometer experiment, *JOURNAL OF GEOPHYSICAL RESEARCH*, VOLUME 65, NO. 6 JUNE 1960a.

Coleman, P. J., Jr., L. Davis, and C. P. Sonett, Steady Component of the Interplanetary Magnetic Field: Pioneer V, *Physical Review Letters*, Vol. 5, pp. 43-46, July 15, 1960b.

INTERNATIONAL GEOPHYSICAL YEAR WORLD DATA CENTER A IGY WORLD DATA CENTER A, CORPUSCULAR RADIATION, MAGNETIC FIELD, AND MICROMETEORITE OBSERVATIONS WITH SATELLITES AND SPACE PROBES, Rockets and Satellites, National Academy of Science, No. 14, July 1961.

Coleman, P. J., Jr., C. P. Sonett, and L. Davis Jr., On the interplanetary magnetic storm: Pioneer V, *J. Geophys. Res.*, *66*(7), 2043–2046, doi:10.1029/JZ066i007p02043, 1961.

Curto, J. J., T. Araki, and L. F. Alberca, Evolution of the concept of Sudden Storm Commencements and their operative identification, RESEARCH NEWS Earth Planets Space, 59, i–xii, 2007.

Dungey, J.W., Interplanetary magnetic field and the auroral zones, *Phys. Rev. Letters*, 6, 47-48, 1961.

Dungey, J. W, THE INTERPLANETARY MAGNETIC FIELD AND THE AURORAL ZONES, University Park, Pennsylvania, March 15, 1962.

Dungey, J. W.: 1963, in C. DeWitt, J. Hieblot, and A. Lebeau (eds.), *The Earth's Environment*, Gordon and Breach, New York.

Dungey, J. W, (A Model With an Interplanetary Magnetic Field), Physics of Geomagnetic Phenomena, Vol.II, Edt. By S. Matsushita and Wallace H. Campbell, *Academic Press*, New York, 1967.

Eastwood, J. P., E. A. Lucek, C. Mazelle, K. Meziane, Y. Narita, J. Pickett, and R. Treumann, The foreshock, *Space Sci. Rev*., 118 , 41– 94, 2005.

Fairfield, D. H., A SUMMARY OF OBSERVATIONS OF THE EARTH'S BOW SHOCK, Physics of Solar Planetary Environments: Proceedings of the International Symposium on Solar-Terrestrial Physics, Boulder, Colorado, Volume II Vol. 8, 1976.

Fälthammar, Carl-Gunne, The scientific legacy of Hannes Alfvén, Article first published online: 18 MAY 2012, Eos, *Transactions American Geophysical Union*, Volume 93, Issue 21, pages 201–202, 22 May 2012.

Fan, C. Y., P. Meyer, and J. A. Simpson, Rapid reduction of cosmic radiation intensity measured in interplanetary space, *Phys. Rev. Letters*, 5, 269, 1960a.

FAN C. Y., P. MEYER, and J. A. SIMPSON, Preliminary Results from the Space Probe Pioneer V, JOURNAL OF GEOPHYSICAL RESEARCH VOLUME 65. No. 6, 1960b.

Fredricks, R. W., G. M Crook, C. F. KenneI, l. M, .Green, F. L. Scarf, P. J. Coleman and C. T. Russell: OGO 5 Observations of electrostatic turbulence in bow shock magnetic structures. *J. Geophys. Res*. 75, 3751-3768, 1970.

Gannon, J.L., Superposed epoch analysis and storm statistics from 25 years of the global geomagnetic disturbance index, USGS-Dst: U.S. Geological Survey Open-File Report 2012–1167, 15 p. 2012.

Gold, T., Plasma and Magnetic Fields in the Solar System, *J. Geophys. Res*., Vo. 64, No. A11, 1665, 1959.

Gosling, J. T., J. R. Asbridge, S. J. Bame, and I. B. Strong, Vela 2 measurements of the magnetopause and bow shock positions, *J. Geophys. Res*., 72, 101, 1967.

Heppner, J. P., (Satellite and Rocket Observations) Physics of Geomagnetic Phenomena, Vol.II, Edt. By S. Matsushita and Wallace H. Campbell, *Academic Press*, New York, 1967.

Heppner, J. P., N. F. Ness, C. S. Scearce, and T. L. Skillman (1963), Explorer 10 magnetic field measurements, *J. Geophys. Res.*, *68*(1), 1–46, 1963.

Heppner, J. P., M. Sugiura, T. L. Skillman, B. G. Ledley, and M. Campbell, Ogo A Magnetic field observations, *J. Geophys. Res*. 72, 5417-5471, 1967.

Kapitza, P., Collected Papers of P. Kapitza (The Production of and Experiments in Strong Magnetic Field), Edited by D. Ter Hear, *Pergamon Press*, Oxford, 1967.

Karpen, Judith T., Spiro K. Antiochos, C. Richard Devore, and Leon Golub, Dynamic Responses To Magnetic Reconnection In Solar Arcades, *The Astrophysical Journal*, 495:491È501, 1998 .

Katırcıoglu, F. T., Z. Kaymaz1, D. G. Sibeck, and I. Dandouras, Magnetosheath cavities: case studies using Cluster observations, *Ann. Geophys*., 27, 3765–3780, 2009

Kern, John W., (Magnetosphere and Radiation Belts), Physics of Geomagnetic Phenomena, Vol.II, Edt. By S. Matsushita and Wallace H. Campbell, *Academic Press*, New York, 1967.

Le, G. and C. T. Russell, THE MAGNETIC FIELD TURBULANCE AT COMET HALLEY OBSERVED BY VEGA 1 AND 2, Cometary Plasma Processes, *Geophysical Monograph 61*, *American Geophysical Union*, 1991.

Mariani, F., Results on magnetic field inside and outside the magnetosphere, Lecture given at ESTEC (*European Space Technology Centre*) in Noordwijk 011 December 17th, 1965.

McComas, D. J., H. O. Funsten, S. A. Fuselier, W. S. Lewis, E. Möbius, and N. A. Schwadron, IBEX observations of heliospheric energetic neutral atoms: Current understanding and future directions, *GEOPHYSICAL RESEARCH LETTERS*, VOL. 38, L18101, 9 PP., 2011.

McDonald, Richard, Planetary Magnetic Fields, themcdonalds.net, 2005. http://www.themcdonalds.net%2Frichard%2Fastro%2Fpapers%2F602-magfields.pdf

Meziane, K., C. Mazelle, R. P. Lin, D. LeQue´au, D. E. Larson, G. K. Parks, and R. P. Lepping, Three-dimensional observations of gyrating ion distributions far upstream from the Earth's bow shock and their associated with low-frequency waves, *J. Geophys. Res*., 106, 5731, 2001.

Montgomery, M. D., J. R. Asbridge, and S. J. Bame: Vela 4 plasma observations near the earth's bow shock. Journal of Geophysical Research, *Space Physics*, Vol. 75, No. 7, 1970.

Morse, D. L. and E. W. Greenstadt: Thickness of magnetic structures associated with the earth's bow shock. *J. Geophys*. 81, 1791-1793, 1976.

National Academy of Science, International Geophysical Year World Data Center A, IGY World Data Center A, Corpuscular Radiation, Magnetic Field, And Micrometeorite Observations With Satellites And Space Probes, Rockets and Satellites, No. 14, July 1961.

Ness, N. F., The Earth's magnetic tail, *J. Geophys. Res.*, *70* (13), 2989–3005, doi:10.1029/JZ070i013p02989, 1965.

Ness, N. F. and L. F. Burlaga , Spacecraft studies of the interplanetary magnetic field, *J. Geophys. Res.*, *106*(A8), 15,803–15,817, doi:10.1029/2000JA000118, 2001, DOI: 10.1029/2000JA000118, Article first published online: 19 DEC 2012

Ness, N . F., C. S. Scearcea, and J. B. Seek , Initial results of the Imp 1 magnetic field experiment, *J. Geophys. Res*., 69, 3531-3569, 1964.

Neugebauer, M., and C. W. Snyder, The mission of Mariner II: Preliminary observations, solar plasma experiment, *Science*, 138, No. 3545, 1095-1096, Dec. 1962.

Neugebauer, M., C. T. Russell, and J. V. Olson, Correlated Observations of Electrons and Magnetic Fields at the Earth's Bow Shock, *Journal of Geophysical Research*, Vol. 76, No. 19, July 1, 1971.

Nishida, A. and L. J. Cahill Jr., Sudden impulses in the magnetosphere observed by Explorer 12, *J. Geophys. Res.*, *69*(11), 2243–2255, doi:10.1029/JZ069i011p02243, 1964.

Parker, E. N., "Dynamics of the interplanetary gas and magnetic fields." Astrophysical Journal 128, 664, *American Astronomical Society, Provided by the NASA Astrophysics Data System*, 1958.

G. Paschmann, N. Sckopke, S.J. Bame, J.R. Asbridge, J.T. Gosling, C.T. Russell, E.W. Greenstadt, Association of low-frequency waves with suprathermal ions in the upstream solar wind. *Geophys. Res. Lett*. 6, 209–212, 1979.

Paschmann, G., N. Sckopke, S. J. Bame, and J. T. Gosling, Observations of gyrating ions in the foot of the nearly perpendicular bow shock, *Geophys. Res. Lett*., 9, 881, 1982.

Paschmann, G., G. Haerendel, N. Sckopke, E. Mobius, H. Luhr, and C.W. Carlson, 3-Dimensional plasma structures with anomalous flow directions near the Earth's bow shock, *J. Geophys. Res*., 93, 11,279 –11,294, 1988.

Phillips, Tony, Hidden Portals in Earth's Magnetic Field, NASA science, *Science News*, 2012.

http://science.nasa.gov/science-news/science-at-nasa/2012/29jun_hiddenportals/

Priest, Eric and Terry Forbes, Magnetic Reconnection MHD Theory and Applications, *Cambridge University*, 2000.

http://assets.cambridge.org/052148/1791/sample/0521481791WSN01.pdf

RUSSELL, CHRISTOPHER T., THE SOLAR WIND AND MAGNETOSPHERIC DYNAMICS, Institute of Geophysics and Planetary Physics University of California, Los Angeles, U.S.A. , Originally Published In: Correlated Interplanetary and Magnetospheric Observations, (ed. by D.E.Page), P. 3, D. Reidel Publ. Co., Dordrecht, Holland, 1974.

Russell, C. T., Solar Wind and Interplanetary Magnetic Field: A Tutorial. 63p., 2000. http://wwwssc.igpp.ucla.edu/ssc/tutorial/solwind_magsphere_tutorial.pdf

Russel, C. T., The Solar Wind Interaction with the Earth's Magnetosphere: A Tutorial, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 28. NO., 2000a.

http://www-ssc.igpp.ucla.edu/personnel/russell/papers/SolWindInteraction.pdf]

Russell, C. T., Y. L. Wang, J. Raeder, R. L. Tokar, C. W. Smith, K. W. Ogilvie, A. J. Lazarus, R. P. Lepping, A. Szabo, H. Kawano, T. Mukai, 7 S. Savin, Y. I. Yermolaev, 8 X.-Y. Zhou, and B. T. Tsurutani, The interplanetary shock of September 24, 1998: Arrival at Earth, *J. Geophys. Res*., 105, 25,143 – 25,154, 2000.

Sibeck, D. G., T. D. Phan, R. Lin, R. P. Lepping and A. Szabo, Wind observations of foreshock cavities: A case study, *JOURNAL OF GEOPHYSICAL RESEARCH*, VOL. 107, NO. A10, 1271, doi:10.1029/2001JA007539, 2002.

Slavin, J. A., E. J. Smith, and B. T. Thomas , Large scale temporal and radial gradients in the IMF: Helios 1, 2, ISEE-3, and Pioneer 10, 11, *Geophys. Res. Lett.*, *11*(3), 279–282, doi:10.1029/GL011i003p00279. , 1984.

Smith, Edward J., A Comparison of Explorer VI and Explorer X Magnetometer Data, Journal of Geophysical Research Volume 67, No. 5, 1962.

Smith, E. J., and A. Barnes, Spatial dependencies in the distant solar wind: Pioneer 10 and 11, in Solar Wind 5, NASA Conf. Publ., *NASA CP CP 2280*, 521, 1983.

Smith, E. and Tsurutani, B., Magnetosheath lion roars. *Journal of Geophysical Research* 81(A13), Article first published online: 19 DEC 2012, DOI: 10.1029/JA081i013p02261, 1976.

SMITH, EDWARD J., AND BRUCE T. TSURUTANI, Observations of the Interplanetary Sector Structure up to Heliographic Latitude, VOL. 83, NO. A2, *JOURNAL OF GEOPHYSICAL RESEARCH*, 1978.

Smith, Edward J., Robert E. Holzer, Malcolm G. McLeod and Christopher T. Russell, Magnetic noise in the magnetosheath in the frequency range 3–300 hz, *Journal Of Geophysical Research* Vol. 72, No. 19, 1967.

SMITH, EDWARD J., ROBERT E. HOLZER AND CHRISTOPHER T. RUSSELL, Magnetic emissions in the magnetosheath at frequencies near 100 Hz, *JOURNAL OF GEOPHYSICAL RESEARCH*, SPACE PHYSICS Vo, 74, No. 11, 1969.

SONETT, C. P., D. L. JUDGE, AND J. M. KELSO, Evidence Concerning Instabilities of the Distant Geomagnetic Field: Pioneer I, JOURNAL of GEOPHYSICAL RESEARCH, VOLUME 64, No. 8, 1959.

Spreiter, J. R., and W. P. Jones, On the effect of a weak interplanetary magnetic field on the interaction between the solar wind and the geomagnetic field, *J. Geophys. Res*., 68, 3555-3564, 1963.

Svalgaard, L., E. W. Cliver, and P. Le Sager, Determination of interplanetary magnetic field strength, solar wind speed and EUV irradiance, 1890–2003, in Solar Variability as an Input to the Earth's Environment, ISCS Symp., Eur. Space Agency, Paris, 2003.

Theplanetstoday.com http://www.theplanetstoday.com/

Thomsen, M. F., Upstream suprathermal ions, in Collisionless Collisionless Shocks in the Heliosphere: *Reviews of Current Research*, edited by B. T. Tsurutani and R. G. Stone, *AGU*, Washington D. C., 253, 1985.

Thomsen, M. F., J. T. Gosling, S. A. Fuselief, S. J. Bame, and C. T. Russell, Hot, diamagnetic cavities upstream from the Earth's bow shock, *J. Geophys. Res*., 91, 2961-2973, 1986.

Trinklein, F. E., Modern Physics, Holt, Rinehart and Winston, N.Y, 1990.

Tsunomura, Satoru, Characteristics of geomagnetic sudden commencement observed in middle and low latitudes, Earth Planets Space, 50, 755–772, 1998.

Turku, University of: Lecture 4 : Synchrotron Radiation, 2006.

http://www.astro.utu.fi/~cflynn/astroII/l4.html

Van Allen, J. A., The Geomagnetically Trapped Corpuscular Radiation, *J. Geophys. Res*., 64, No. A11, 1683, 1959.

Watermann, J., P. Wintoft, B. Sanahuja, E. Saiz, S. Poedts, M. Palmroth, A. Milillo, F. A. Metallinou, C. Jacobs, N.Y. Ganushkina, I.A. Daglis, C. Cid, Y. Cerrato, G. Balasis, A.D. Aylward, A. Aran, Models of Solar Wind Structures and Their Interaction with the Earth's Space Environment, *Space Sci Rev* DOI 10.1007/s11214-009-9494-9, pp.5. 2009.

Wilcox, J. M., Solar and interplanetary magnetic fields, *Science*, 152, 161, 1966.

http://www.sciencemag.org/content/152/3719/161.long]

Wilcox, J. M. and N. F. Ness, Quasi-stationary corotating structure in the interplanetary medium, *J. Geophys. Res.*, *70*(23), 5793–5805, doi:10.1029/JZ070i023p05793. , 1965.

Wolfe, J. H., R. W. Silva, and M. A. Myers, Observations of the solar wind during the flight of Imp 1, *J. Geophys. Res.*, *71*(5), 1319–1340, doi:10.1029/JZ071i005p01319., 1966.

Yousif, Mahmoud E. "The Magnetic Interaction", Modified version: http://www.exmfpropulsions.com/New_Physics/MIH.htm

Fist published, 09-Oct-2003b, in Journal of Theoretics at: http://www.journaloftheoretics.com/Links/Papers/MY.pdf

Yousif, Mahmoud E. The Spinning Magnetic Field, at: http://www.exmfpropulsions.com/New_Physics/SMFc.htm

First published on 09-Oct-2003a. in Journal of Theoretics at: http://www.journaloftheoretics.com/links/papers/my-s.pdf

Yousif, Mahmoud E. THE UNIVERSAL ENERGIES, at: : http://exmfpropulsions.com/New_Physics/New_Energy/UE.htm

First published, on 18-Jan-2004, in Journal of Theoretics at:

http://www.journaloftheoretics.com/Links/Papers/Yousif.pdf

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