National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No.NAS-5-12487

ST-GM-IS-10735

RELATIONSHIP BETWEEN THE DIRECTION OF THE INTERPLANETARY MAGNETIC FIELD AND STEADY OSCILLATION CONDITIONS

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

by

O.V. Bol'shakova
&
V.A. Troitskaya

(USSR)

AUG 1968
RECEIVED
NASA STI FACILITY
INPUT BRANCH

15 AUGUST 1968

N68-31553
(ACCESSION NUMBER)
7
(PAGES)
CR-96139
(NASA CR OR TMX OR AD NUMBER)
(THRU)
1
(CODE)
13
(CATEGORY)
FACILITY FORM 602

ST-GM-IS-10735

RELATIONSHIP BETWEEN THE DIRECTION OF THE INTERPLANETARY MAGNETIC FIELD AND STEADY OSCILLATION CONDITIONS

Doklady Akademii Nauk SSSR,
Geofizika, Tom 180, No.2,
pp 343-346, Moscow, 1968.

by
O.V. Bol'shakova and
V.A. Troitskaya

SUMMARY

This work establishes that the direction of the interplanetary magnetic field in the ecliptic plane is the determining parameter of excitation or attenuation mechanisms of steady oscillations of the various Pc groups. The Pc amplitude modulation is determined by the change in field direction, the former decreasing to zero when the latter is perpendicular to the line Sun-Earth. The data obtained allowed the authors to establish for the first time the nature of the agent responsible for the sudden onset and vanishing of Pc oscillations.

*
* *

For steady oscillations of the Earth's electromagnetic field in the Pc 2-4 range there exists, alongside with oscillation amplitude control in accordance with local time [1], an obvious modulation of conditions as a whole in accordance with UT. Thus, for example, cases of simultaneous commencement or simultaneous ending of steady oscillations were observed on the entirety of the globe and so forth. These cases represented a riddle for all investigators and attempts to interpret them did not result in a satisfactory solution of this problem. A special network of identically equipped stations was created in order to study the influence of universal time on steady oscillations. These stations were spread longitudinally at approximately 120° along the perimeter of the globe. Alongside with the global modulation, days were ascertained (approximately 1-2% of all the observed cases), when steady oscillations were altogether absent which could in no way be in agreement with the theory on Pc excitation by continuous solar wind at magnetosphere boundary.

Consequently, the source of steady oscillations must possess properties whose variations would have a determining action on the excitation or attenuation of these oscillations in a planetary scale. As is shown by the results of the present work, the direction of the interplanetary magnetic field in the ecliptic plane is such a determining parameter. On the average, the interplanetary field intensity is $\sim 5\ \gamma$, whereupon the fluctuations of the field value are considerably lower than those of its direction. However, constant variations notwithstanding, the interplanetary field has a certain preferred direction which coincides with the direction of the Archimedes spiral.

Analysis of basic characteristics of steady oscillations was conducted during the period 1 to 14 December, 1963 for which detailed measurements of the interplanetary field made on IMP-I and averaged for each 5.46 min., were made available [2]. The direction of the field in the ecliptic plane was used as the interplanetary field parameter. This selection was due to the fact that the total vector of the interplanetary magnetic field is disposed at a small angle toward the ecliptic plane, while the field value is subject to relatively slight fluctuations. In all, use was made of more than 1500 values of direct interplanetary field measurements, on the basis of which histograms were plotted of the preferred direction of the field for each 24 hour period and detailed analysis was performed of global Pc excitation conditions. It should be noted that the direction of the interplanetary field was not identical on all days. Most frequently (7 out of 14 days) the direction of the interplanetary field coincided with the direction of the Parker spiral. On some days it is difficult to determine the preferred direction: the magnetic field fluctuates and its direction varies constantly during the 24 hr period. In spite of the existing concepts, the preferred direction of the field during three days of the investigated time period was perpendicular to the Sun-Earth line (Fig.1 c).

Such a variation in the preferred direction of the interplanetary field from one day to another proved to correspond to a specific change in steady oscillation groups, namely: to the basic field direction coinciding with the Parker spiral direction corresponds the most widespread type of steady Pc 3-oscillations ($T = 10 - 45$ sec); of the Pc 4 ($T = 50 - 150$ sec) or Pc 3-4 - types. The case of the field perpendicularly directed toward the Sun-Earth line is an absolutely special case during which steady oscillations are not excited and are absent in the Earth's scales. Since the data used represent values of field direction averaged for a short interval of time, it was possible to compare the sequence of field direction variations with the continuous recordings of steady oscillations (Fig.2). The direction of the interplanetary field in the ecliptic plane was plotted directly on the tape. The field direction values were averaged for unequal time intervals determined by a sufficient constancy of field direction ($\pm 10°$). As may be seen from our example (Fig.2a), steady type Pc 3 oscillations correspond to an interplanetary field

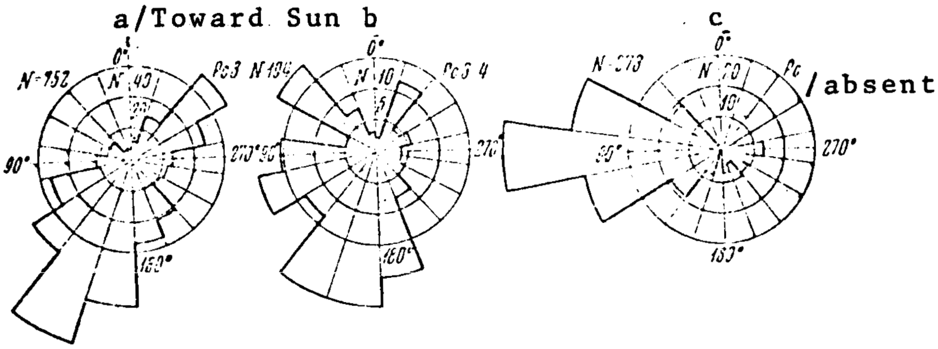

Fig.I

Distribution histograms of interplanetary magnetic field direction corresponding to specific Pc types.

direction close to the Parker spiral. At the moments of time when the field vector approaches a direction perpendicular to the direction toward the Sun, steady oscillations disappear. Fig.2b shows an example of Pc fading during several hours, whereupon the magnetic field direction along the perpendicular toward the line Sun-Earth was virtually constant.

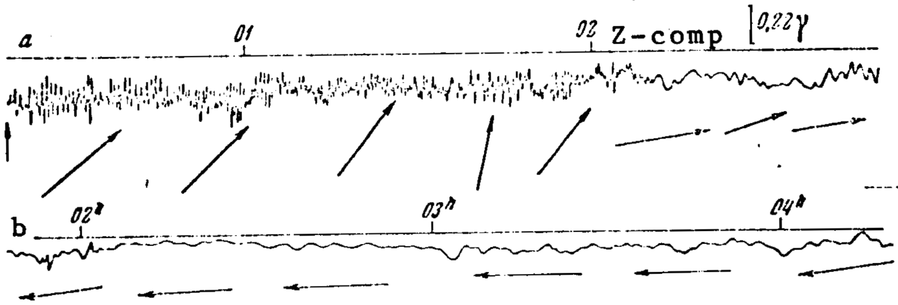

Fig.2

Examples of recording comparison of steady oscillation conditions and of interplanetary magnetic field direction. Petropavlovsk-Kamchatskiy. a) 12 Oct. 1963; b) 14 Dec. 1963

A quantitative evaluation of the number of cases of steady oscillation conditions coinciding with a specific field direction was performed for each 24 hrs period separately. On the average, coincidence is observed in 85% of all the cases compared, and the less sharply expressed the preferred field direction (Fig.I,b) the smaller the percentage of coincidence. But with a clearly expressed preferred direction the indicated correlation may at-

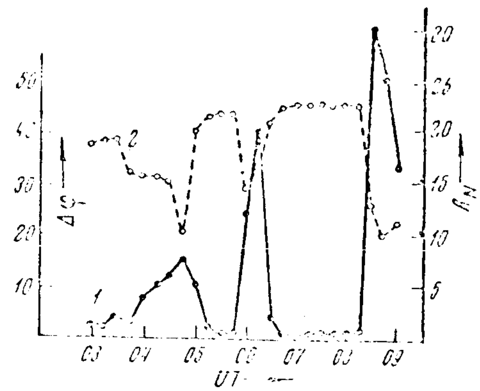

Fig.3

Dependence of normalized Pc 3 [1] amplitude on interplanetary field's deflection angle from the Parker spiral [2]. December 9, 1963.

tain 99% (for instance, on 3 December, 1963).

In the case when the field direction coincides with the Parker spiral or is sufficiently close to it the amplitude of Pc 3-oscillations is maximum. With field deviation from spiral direction, the Pc-amplitude decreases. When the field is perpendicular to the direction toward the Sun, the Pc-amplitude approaches zero. Therefore, the Pc-amplitude is apparently determined by the deflection angle between the interplanetary magnetic field and the preferred direction. As is shown in Fig.3, a clear inverse dependence exists between these two values.

A detailed investigation of the preferred day to day direction inside one sector from December 2 to 12, shows that a preferred field direction perpendicular to the direction toward the Sun accompanies field inversion. Inasmuch as to such a direction corresponds an attenuation of Pc intensity or their total absence, it becomes possible to assume that cases of Pc absence correspond to times of interplanetary field inversion, i.e. to sector boundaries. This assumption can be verified by utilizing the data obtained on "PIONEER-6" and IMP-I regarding the polarity reversal of the interplanetary field. In 75% of all the compared cases field inversion corresponded to an attenuation or decrease to zero of the Pc-amplitude. The Pc 3-amplitude drops along the direction toward the boundaries of the sector and usually has a maximum in the first half of the sector, smoothly decreasing in its second half. This variation in Pc-amplitude within the sector is in good correlation with solar wind velocity behavior during the same time. The values of solar wind velocity inside the sector were obtained from direct measurements, as well as indirectly, making use of the ration between this

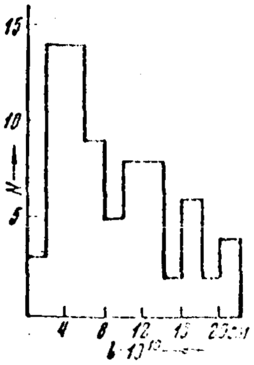

Fig.4

Spectrum of Pc "fadings" for the period 1-14 December 1963 converted into the linear dimensions of interplanetary magnetic field inhomogeneities.

velocity and the Pc-periods obtained in [4]. The decrease in velocity at sector boundary may contribute to the attenuation of steady oscillation intensity.

One may attempt to explain the effect of interplanetary magnetic field orientation on Pc conditions by assuming that steady oscillations of the geomagnetic field set in as a consequence of hydrodynamic instability of the magnetospheric plasma. It is considered [5,6] that Pc-oscillations are excited when solar wind flows past the magnetosphere. In this case surface waves are excited and the steady oscillations observed on Earth result from the transformation of surface waves into Alfen or magnetoacoustic resonance waves.

This transformation takes place when the interplanetary field is directed at an angle toward the magnetosphere surface. On the other hand, if there exists only one component of the interplanetary field, perpendicularly directed toward the Sun, the surface waves at magnetosphere boundary are damped and no steady oscillations are observed on Earth.

At the present time it is considered on the basis of the results of observations from satellites, that the interplanetary magnetic field consists of separate tubes of force of $\sim 10^6$ km in diameter mutually intertwined and forming a complex structure. Bends and expansions of tubes of force, which are not inherent to the Parker spiral were detected. Such disruptions of the orderly interplanetary field structure may serve as the inhomogeneities on which the field is directed perpendicularly to the Sun-Earth axis and the instants of their approach to magnetosphere boundary correspond to the instants of the disappearance of steady oscillations. Apparently, the dimensions of such inhomogeneities correspond to the "fading" time of steady oscillations. The continuous KPK recordings being available, it is possible to plot the spectrum of such "findings" for a specific Pc group, for instance Pc 3. Taking the value of solar wind velocity corresponding to these Pc periods [4], one may attempt to determine the mean dimension of these interplanetary magnetic field inhomogeneities. When using the average fading time value of Pc 3, t_{av} = 10-20 min. and $v_{av} = 6\cdot10^7$ cm/sec the mean inhomogeneity dimensions are $l_{av} = v_{av}t_{av} = 17 \times 60 \times 6\cdot10^7$ cm. In the case of maximum values we have $l_{max} = 1,4\cdot10^{11}$ cm. This is in agreement with the evaluations of the interplanetary field inhomogeneity dimensions based on cosmic ray anisotropy [7] and with the theoretical evaluations of expansion and bend dimensions of the tubes of force given in [8].

Therefore, the excitation of the steady oscillations of various Pc groups is connected with a specific orientation of the interplanetary magnetic field. The modulation of Pc-amplitude is determined by the variations in field directions, whereupon the amplitude decreases to zero when the direction of the field is perpendicular to the line Sun-Earth.

The obtained data have made it possible to establish for the first time one of the fundamental facts essential for the understanding of the Pc excitation mechanism, namely, the nature of the agent responsible for their sudden appearance and disappearance in the planetary scale.

The established connections make it possible to plan the following ways of utilizing the observations of steady oscillations for the determination of a series of solar wind structure parameters of major importance.

1. The fact of the excitation of various types of steady oscillations bears witness to the existence of a definite orientation of the interplanetary magnetic field; the absence of Pc conditions constitutes the indicator of sharp change in the preferred interplanetary field direction from a direction close to the Parker spiral to that perpendicular to the direction Sun-Earth.

2. The detected correspondence of prolonged Pc "fadings" with the instants of interplanetary field inversion can be used to evaluate the regularity of interplanetary field's sectorial structure in various phases of the solar activity cycle.

3. The spectrum of separate Pc "fadings" can be used to evaluate the mean dimensions of interplanetary magnetic field inhomogeneities.

* * * THE END * * *

Institute of Physics of the Earth ,
In the name of O.Yu. Schmidt
of the Academy of Sciences
USSR.

Manuscript received
5 January, 1968.

Translated by
Daniel Wolkonsky
2 August 1968
Revised by
Dr. Andre L. Brichant
12 August 1968

ALB/ldf

REFERENCES

1. O.V. BOL'SHAKOVA:
   Thesis. IFZ im. O. Yu. Shmidta AN SSSR, 1966.
2. J.M. WILCOX, NORMAN F. NESS:
   Solar Physics, 89, No.1, (1968).
3. L.F. BURLAGA, NORMAN F. NESS:
   Macro-Micro Structure of the Interplanetary Magnetic Field. NASA-GSFC Preprint X-612-67-278, June 1967.
4. V.A. TROITSKAYA, O.V. BOL'SHAKOVA, R.V. SHCHEPETNOV:
   Rep. at the 14th Assembly of the MGGS, September 1967.
5. J.V. DANGY: (DZh.V. Danzhi) Geophysics, Near-Terrestrial Space Lecture at the Summer School of the Grenoble University, M., 1964, p.423.
6. Yu.L. MOSKVAIN, D.A. FRANK-KAMENETSKIY:
   Geomagnetizm i aeronomiya, 7, No.1, 144, (1967).
7. V.I. SHISHOV: Geomagnetizm i aeronomiya, 7, No.3, 451, (1967).
8. F.C. MICHEL: J. Geophys. Res., 72, No.7, (1967).
