ΑΣΤΡΟΝΟΜΙΑ.— **On the power Spectrum of Inferred Interplanetary Magnetic Sector Structure,** *by C. S. Zerefos - C. C. Repapis - V. P. Tritakis*.* Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰω. Ξανθάκη.

ABSTRACT

Time series of the polarity of the interplanetary magnetic field, inferred from magnetic observations at high latitudes, are subjected to conventional power spectrum analysis during the period 1962 - 1970. The analysis showed that the dominant oscillations of the interplanetary magnetic field polarity are those near the solar rotation period and its second harmonic. It is tetantively proposed that magnetic sector structure may be different during the different phases of the solar activity cycle.

The sector structure of the interplanetary magnetic field, discovered by Wilcox and Ness (1965), was used by several investigators in the field of solar-terrestrial relations. Wilcox and coworkers (1973, 1974) found the sector structure of the interplanetary magnetic field, to influence the hemispheric vorticity area index (VAI). They found that the hemispheric VAI at 300 mb decreased by 10% about a day after the earth intersects a solar magnetic sector boundary. Solar sector boundaries were also found to be related to geomagnetic activity in such a way, that a day or two after the boundary, the geomagnetic Kp index rose to a peak resuming next its decline (Wilcox and Colburn, 1972). On longer time scales, we can assume that sector boundaries may well trigger rainfall on earth (Xanthakis, 1972, 1975) by changing tropospheric vorticity (Olson et al., 1975).

From the above short discussion it is clear that it is worth examining periodicities in the polarity of the interplanetary sector structured magnetic field, mainly those of the order of the solar rotation period and its higher harmonics. A relation between the polarity of the interplanetary magnetic field and the type of diurnal variation of the geomagnetic field inside the polar cap found by Svalgaard (1968) and Mansurov (1969), was used by Svalgaard (1972) to infer the polarity of the

* Χ. Σ. ΖΕΡΕΦΟΥ - Χ. Κ. ΡΕΠΑΠΗ - Β. Π. ΤΡΙΤΑΚΗ, 'Επὶ τῶν περιοδικοτήτων τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου.

interplanetary magnetic field for each day during the period 1926 - 1971. Fougere (1974) calculated power spectra of the positive and negative perturbations of the interplanetary magnetic field inferred by Svalgaard. Fougere found peaks at 27 days period and possessing clear harmonics up to the sixth. He also found a very prominent peak at a period of one year, but here we are not concerned with oscillations having periods greater than about the solar rotation period.

In the following we shall try to objectively check the significance of the spectral peaks discussed above and to confirm some of the unexpected periodicities with other data samples. The 9-year period from 1962 to 1970 was used instead of the 45-year period (1926 - 1971) used dy Fougere. One reason for choosing the period 1962 - 1970 is that it is more likely representative of the physical reality than the earlier years. A day with negative perturbation in Svalgaard's list has assigned the number ($-$ 1) and a day with positive perturbation is assigned the number ($+$ 1). With this procedure we obtain a time series of daily positive and negative pulses which is next subjected to a power spectrum analysis. For each year one power spectrum was computed using truncation length of 91 days (about $^1/_4$ of the yearly record length). Having computed nine spectra, each for a given year of the period 1962 - 1970, we next calculate the average spectrum of them shown in figure 1. Superimposed on that spectrum are the 95% and 99% conventional confidence limits.

From the spectrum in fig. 1 it appears that significant peaks, at the 95 and 99 percent level, are evident in the bands between 26 and 30 days and between 14 and 13 days as well as at about 2.4 days. A useful way of a p o s t e r i o r i testing unexpected periodicities in a spectrum, is to use a p r i o r i significance levels that are higher than conventionally employed (Mitscell, 1966). Based on these criteria we found that the peak at 2.4 days could not a p o s t e r i o r i be accepted at the 95% level. On the other hand, it is highly probable that the two bands mentioned before (26 - 30 days and 14 - 13 days) are statistically real at a better than the 99 percent level. From fig. 1 it also follows that none of the higher than the second harmonics of the solar rotation period could a p o s t e r i o r i be accepted as significant at the 95 percent level.

Our analysis does objectivelly confirm Fougere's (1974) solar rota-

tion control of Svalgaard's index. However we failed to prove as signif-
icant anyone of the higher harmonics from the third up to the sixth of
the solar rotation period, which were found by Fougere (1974). To further
test the significance of the third harmonic (9-day peak in fig. 1), we
examined each one of the nine yearly spectra shown in figs 2 through 10
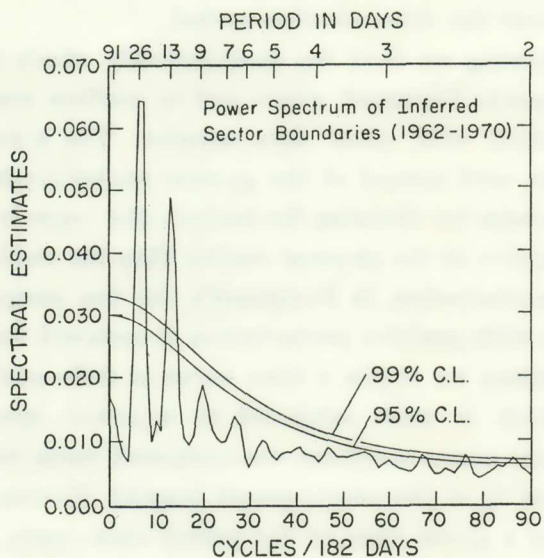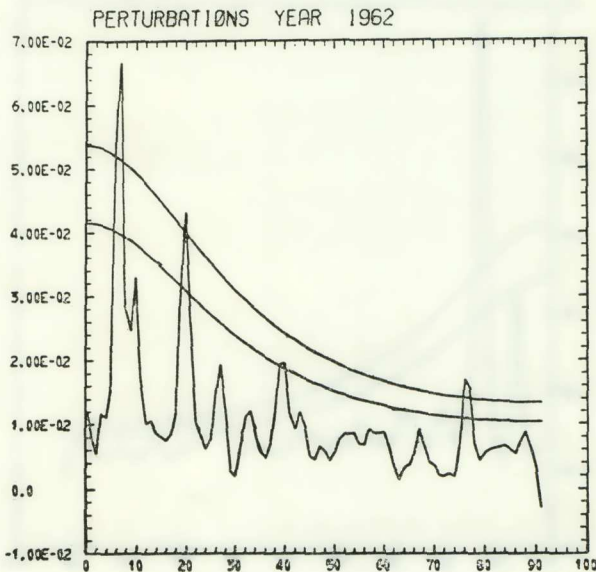

Caption to fig. 1. Power Spectrum of the Interplanetary
Field Polarity from Inferred Magnetic Observations at
High Latitude (see text).

of the Appendix. This examination added more significance to the 9-day
peak in the average spectrum of fig. 1, since that peak was found to be
a more or less consistent feature in all nine spectra under consideration.
It is thus probable that, in spite of its lower a posteriori signif-
icance, the peak at 9 days in fig. 1 should tentatively be taken into
account. Higher harmonics are, as mentioned before, insignificant in
our sample in contrast with their prominency in Fougere's longer data
sample perhaps due to an artifact in the data prior to 1962, as was
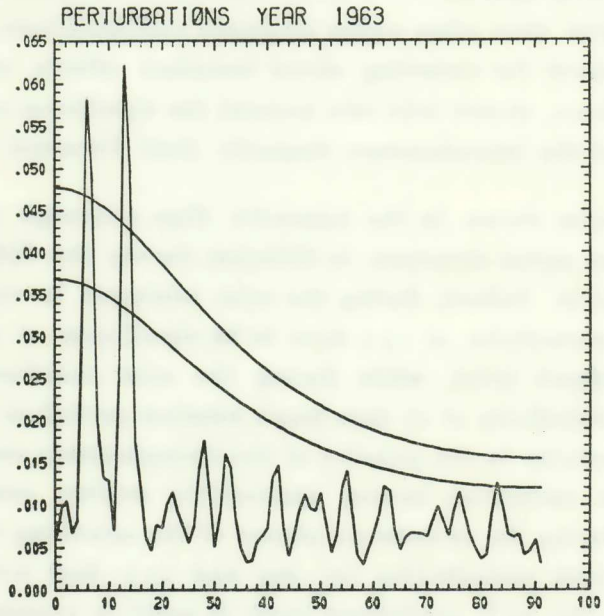already suspected by Fougere (1974).

Following the above discussion we can conclude that, under the
assumption that Svalgaard's list of 1962-1970 perturbations is repre-
sentative of the conditions in the interplanetary magnetic field, then a

two to four sector structure or a quasi-two sector structure of that field is more probable than other sector structure configurations. We propose that future search for recurring sector boundary effects on the earth's lower atmosphere, should take into account the significant oscillations of the polarity of the interplanetary magnetic field discussed in this note.
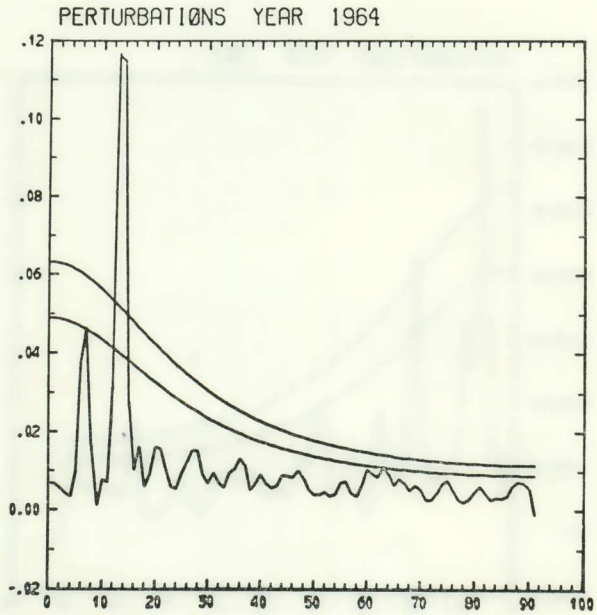
The figures shown in the Appendix (figs 2 through 10) may suggest that solar sector structure is different during the different phases of the solar cycle. Indeed, during the solar minimum in 1964/65 we can only see the periodicity of 13.5 days to be significant at a better than the .05 confidence level, while during the solar maximum phase in 1969/70 the periodicity of 27 days (sun's rotation period) is the only significant periodicity in the polarity of the interplanetary magnetic field, the 13.5-day oscillation having appreciably smaller power in solar maximum. During the in-between phases of the ascending branch of the solar cycle, both periodicities (27-day and 13.5-day) are statistically significant at the 99% confidence level. It could be expected that these features can be generalized for other solar cycles as well, provided that a much longer time series of solar sectors is examined.
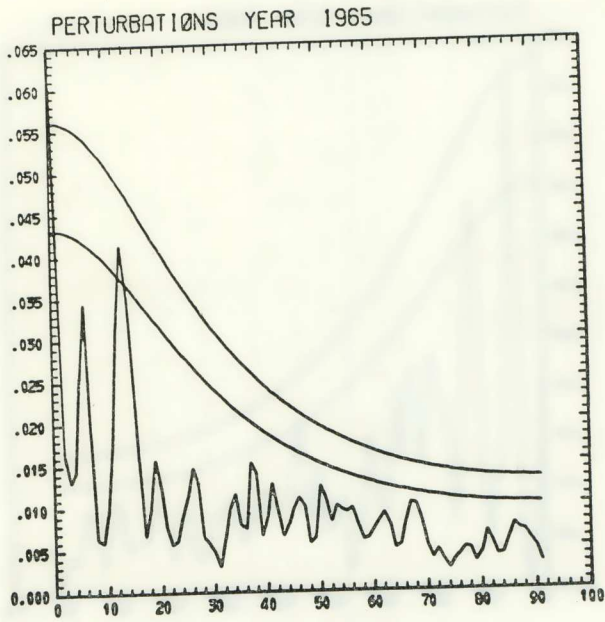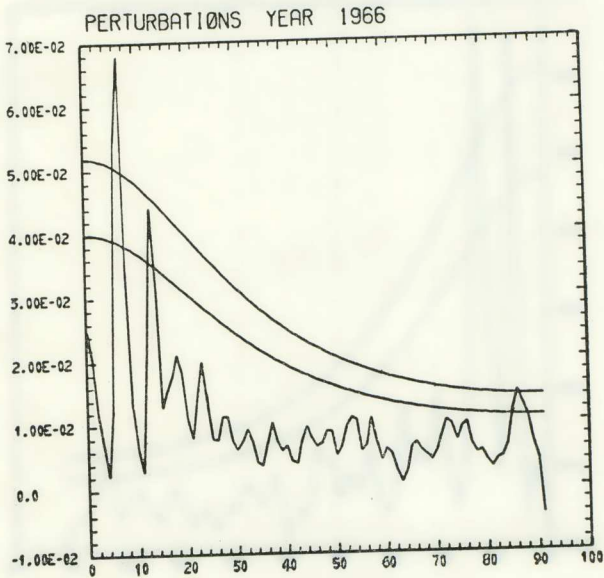
PERTURBATIONS   YEAR   1962

Appendix: Fig. 2.
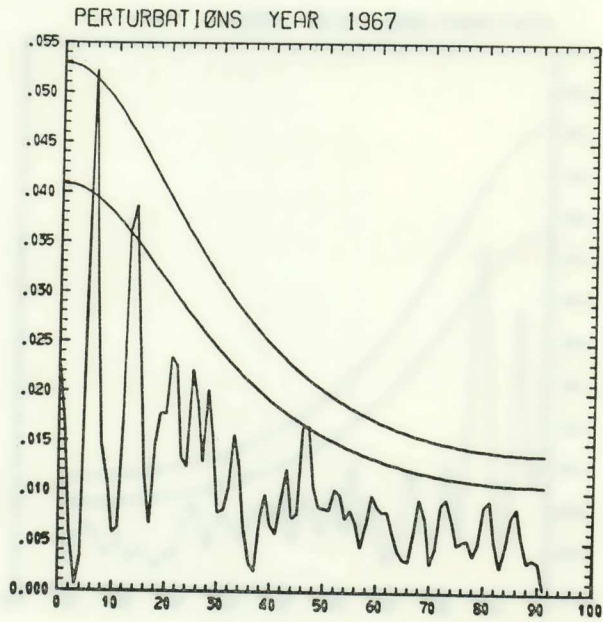
PERTURBATIØNS YEAR 1963

Appendix: Fig. 3.

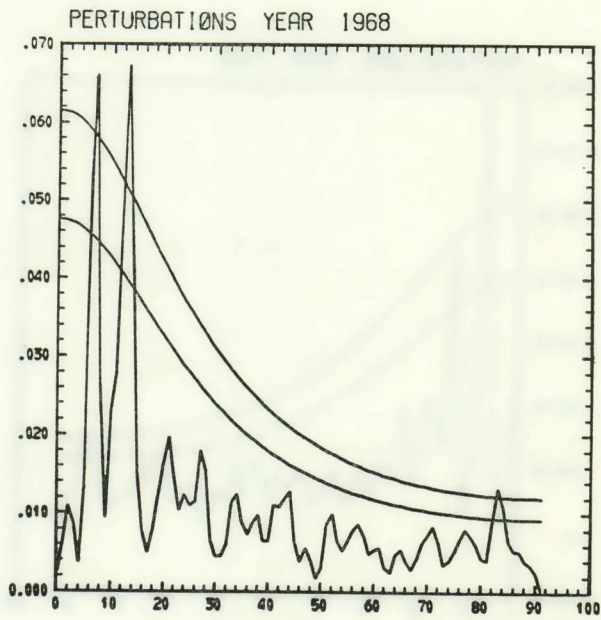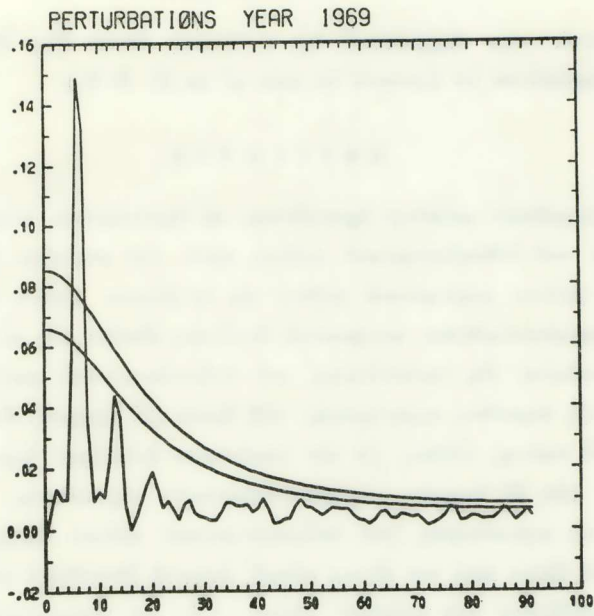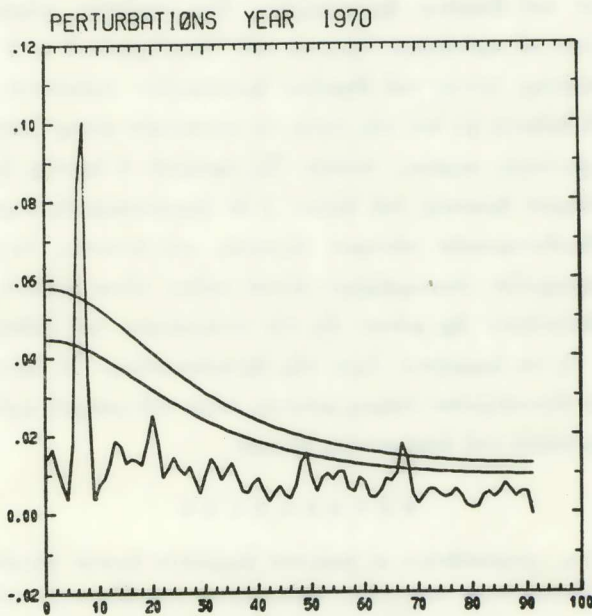PERTURBATIØNS YEAR 1964

Appendix: Fig. 4.

Appendix: Fig. 5.

Appendix: Fig. 6.

PERTURBATIØNS YEAR 1967

Appendix: Fig. 7.

PERTURBATIØNS YEAR 1968

Appendix: Fig. 8.

PERTURBATIØNS YEAR 1969

Appendix: Fig. 9.

PERTURBATIØNS YEAR 1970

Appendix: Fig. 10.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν μελέτην ἐρευνῶνται αἱ ὑφιστάμεναι περιοδικότητες εἰς τὴν πολικότητα τοῦ ἐνδοπλανητικοῦ πεδίου κατὰ τὴν περίοδον 1962 - 1970, ἐκ παρατηρήσεων γηΐνου μαγνητικοῦ πεδίου εἰς τὰ βόρεια πλάτη (μέθοδος Svalgaard). Ἡ χρησιμοποιηθεῖσα φασματικὴ ἀνάλυσις ἔδειξεν ὅτι αἱ προεξάρχουσαι περιοδικαὶ μεταβολαὶ τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου εἶναι ἐκεῖναι τῆς περιόδου περιστροφῆς τοῦ ἡλίου (27 ἡμέραι) ἕως καὶ τοῦ δευτέρου ἁρμονικοῦ ταύτης. Οὐδεὶς ἐκ τῶν ὑπολοίπων ἀνωτέρων ἁρμονικῶν τῆς βασικῆς περιόδου τῶν 27 ἡμερῶν εὑρέθη στατιστικῶς σημαντικός. Ἡ εὕρεσις ὅτι αἱ μεταβολαὶ τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ πεδίου ἐλέγχονται ὑπὸ τῆς περιστροφῆς τοῦ ἡλίου περὶ τὸν ἄξονα αὐτοῦ, ἀποκτᾶ ἰδιαιτέραν σημασίαν καθότι ἀφορᾶ εἰς τὸ πρόβλημα τῶν σχέσεων Ἡλίου - Γῆς καὶ γενικώτερον τῶν σχέσεων Ἡλίου - Καιροῦ. Πράγματι ἐδείχθη ὑπὸ διαφόρων ἐρευνητῶν ὅτι τὴν ἐναλλαγὴν τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ πεδίου ἀκολουθεῖ σημαντικὴ μεταβολὴ εἰς τὸν στροβιλισμὸν τοῦ Βορείου ἡμισφαιρίου, ἥτις λαμβάνει χώραν ἐντὸς ὀλίγων ἡμερῶν. Ἐξ ἄλλου αἱ πρόσφατοι ἔρευναι τοῦ Ἀκαδημαϊκοῦ κ. Ι. Ξανθάκη ἔδειξαν ὅτι εἰς ὡρισμένας ζώνας τοῦ Βορείου ἡμισφαιρίου ὑφίσταται μεγάλη συσχέτισις μεταξὺ τοῦ δείκτου Ια καὶ τῆς ὑπὲρ τὸ κανονικὸν μέσης ζωνικῆς βροχοπτώσεως εἰς τὰ βορειότερα, κυρίως, πλάτη. Ἐξ ὁρισμοῦ ὁ δείκτης Ια ἐξαρτᾶται ἐκ τῶν ἐνεργῶν κέντρων δράσεως τοῦ ἡλίου, ὁ δὲ ἀτμοσφαιρικὸς στροβιλισμὸς ἐξαρτᾶται ἐκ τῶν ὑδροδυναμικῶν κέντρων δράσεως καὶ συνεπῶς ἐκ τῶν καθέκαστα ἰσχυρῶν ἀτμοσφαιρικῶν διαταράξεων. Κατὰ ταῦτα εἶναι πιθανὴ ἡ εὕρεσις τῶν ἀνωτέρω περιοδικοτήτων ὄχι μόνον εἰς τὴν πολικότητα τοῦ ἐνδοπλανητικοῦ πεδίου ἀλλὰ καὶ εἰς τὰ ἡμερήσια ὕψη τῆς βροχοπτώσεως. Ἡ ἔρευνα ὅμως αὕτη θέλει ἀποτελέσει ἀντικείμενον ἑτέρας μελέτης λόγῳ τοῦ μακροῦ χρόνου τὸν ὁποῖον ἀπαιτεῖ ἡ ἐπεξεργασία τοῦ ὑπάρχοντος ὑλικοῦ.

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Ὁ Ἀκαδημαϊκὸς κ. **Ἰωάννης Ξανθάκης,** παρουσιάζων τὴν ἀνωτέρω ἀνακοίνωσιν, εἶπε τὰ ἑξῆς :

Εἰς τὴν παροῦσαν ἀνακοίνωσιν οἱ κ. κ. Χ. Ζερεφός, Κ. Ρεπάπης καὶ Β. Τριτάκης ἐρευνοῦν, μὲ τὴν μέθοδο Svalgaard, τὰς περιοδικότητας εἰς τὴν πολικότητα τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου κατὰ τὴν περίοδον 1962 - 1970 ἐπὶ τῇ βάσει τῶν παρατηρήσεων τοῦ γηίνου μαγνητικοῦ πεδίου εἰς τὰ Βόρεια Πλάτη.

Ἡ ἐφαρμογὴ τῆς φασματικῆς ἀναλύσεως ἐπὶ τῶν δεδομένων ἑνὸς ἑκάστου ἔτους ἔδειξεν ὅτι αἱ προεξάρχουσαι περιοδικαὶ μεταβολαὶ τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου εἶναι 27 ἡμέραι, δηλαδὴ ὅση καὶ ἡ περίοδος περιστροφῆς τοῦ ἡλίου περὶ τὸν ἄξονά του καὶ τὸ ἥμισυ ταύτης δηλαδὴ 13 $1/2$ ἡμέραι. Οὐδεὶς ἐκ τῶν ὑπολοίπων ἀνωτέρω ἁρμονικῶν τῆς βασικῆς περιόδου τῶν 27 ἡμερῶν εὑρέθη στατιστικῶς σημαντικός. Ἡ εὕρεσις ὅτι αἱ μεταβολαὶ τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου ἐλέγχονται ὑπὸ τῆς περιστροφῆς τοῦ ἡλίου περὶ τὸν ἄξονά του ἔχει ἰδιαιτέραν σημασίαν διὰ τὰ προβλήματα τῶν σχέσεων Ἡλίου - Γῆς καὶ γενικώτερον τῶν σχέσεων Ἡλίου - Καιροῦ. Πράγματι ὑπὸ διαφόρων ἐρευνητῶν ἔχει δειχθῆ ὅτι τὴν ἐναλλαγὴ τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου ἀκολουθεῖ σημαντικὴ μεταβολὴ εἰς τὸν στροβιλισμὸν τῆς ἀτμοσφαίρας εἰς τὸ Βόρειον Ἡμισφαίριον ποὺ λαμβάνει χώραν ἐντὸς

ὀλίγων ἡμερῶν μετὰ τὴν ἀλλαγὴν τῆς πολικότητος. Ὁμοίως, κατὰ τοὺς ἐρευνητάς, αἱ ἀνωτέρω περιοδικότητες εἶναι πιθανὸν νὰ εὑρεθοῦν ὄχι μόνον εἰς τὴν πολικότητα τοῦ ἐνδοπλανητικοῦ μαγνητικοῦ πεδίου ἀλλὰ καὶ εἰς τὰ ἡμερήσια ὕψη τῆς βροχοπτώσεως δεδομένου ὅτι ὁ ὑπὸ τοῦ ὁμιλοῦντος εἰσαχθεὶς δείκτης τῶν ἐμβαδῶν τῆς ἡλιακῆς δραστηριότητος ὅστις παρουσιάζει ὑψηλὰς συσχετίσεις μὲ τὴν μεταβολὴν τῆς ζωνικῆς βροχοπτώσεως εἰς τὰ βόρεια πλάτη, ἐξαρτᾶται ἐκ τῶν ὑδροδυναμικῶν κέντρων δράσεως καὶ συνεπῶς ἐκ τῶν καθέκαστα ἰσχυρῶν ἀτμοσφαιρικῶν διαταράξεων.

Ἀναμφιβόλως ἡ διαπίστωσις ὑπὸ τῶν τριῶν ἀναφερθέντων, δι᾽ αὐστηρᾶς καὶ ἀκριβοῦς στατιστικῆς μεθόδου, τῆς ὑπάρξεως περιοδικοτήτων 27 καὶ 13 $^1/_2$ ἡμερῶν εἰς τὴν μεταβολὴν τῆς πολικότητος τοῦ ἐνδοπλανητικοῦ πεδίου εἶναι λίαν ἐνδιαφέρουσα. Πλὴν ὅμως ἐπιθυμῶ εἰς τὴν ἀνακοίνωσιν ταύτην νὰ συμπεριληφθῇ ὑπὸ τύπον σχολίου ἓν βασικὸν χαρακτηριστικὸν τὸ ὁποῖον διέφυγε τῆς προσοχῆς τῶν συγγραφέων. Πράγματι αἱ ὑπὸ τῶν τριῶν ἐρευνητῶν παρεχόμεναι εἰκόνες 2 - 10 τῶν περιοδικοτήτων, δεικνύουν σαφῶς ὅτι ἡ δομὴ τοῦ μαγνητικοῦ πεδίου, ὅσον ἀφορᾷ τὴν πολικότητα αὐτοῦ, παρακολουθεῖ τὰς φάσεις τῆς ἡλιακῆς δραστηριότητος. Οὕτω κατὰ ἔτη 1962 - 1963, δηλαδή, πρὸ τοῦ ἐλαχίστου τῆς ἡλιακῆς δραστηριότητος, αἱ ὑπὸ τῆς φασματικῆς ἀναλύσεως παρεχόμεναι περιοδικότητες εἶναι αἱ περίοδοι τῶν 13 $^1/_2$ καὶ 27 ἡμερῶν. Κατὰ τὰ ἔτη 1964 - 1965, κατὰ τὰ ὁποῖα ἔλαβε χώραν τὸ ἐλάχιστον τῆς ἡλιακῆς δραστηριότητος, ἡ περιοδικότης τῶν 27 ἡμερῶν ἐξαφανίζεται καὶ εἶναι λίαν ἐμφανὴς μόνον ἡ περιοδικότης τῶν 13 $^1/_2$ ἡμερῶν. Ἀντιστρόφως κατὰ τὰ ἔτη τοῦ μεγίστου τῆς ἡλιακῆς δραστηριότητος, δηλαδὴ 1969 - 1970, ἡ περιοδικότης τῶν 13 $^1/_2$ ἡμερῶν ἐξαφανίζεται καὶ ἐμφανίζεται μόνον ἡ περιοδικότης τῶν 27 ἡμερῶν. Τέλος κατὰ τὰ ἐνδιάμεσα ἔτη 1966 - 1967 - 1968, δηλαδὴ μεταξὺ ἐλαχίστου καὶ μεγίστου τῆς ἡλιακῆς δραστηριότητος ἐμφανίζονται καὶ πάλιν ἀμφότεραι αἱ περιοδικότητες τῶν 13 $^1/_2$ καὶ 27 ἡμερῶν. Δηλαδὴ κατὰ τὰς ἀκραίας φάσεις τοῦ μεγίστου καὶ τοῦ ἐλαχίστου τῆς ἡλιακῆς δραστηριότητος ἡ πολικότης τοῦ ἐνδοπλανητικοῦ πεδίου παρουσιάζει μίαν μόνον περίοδον 27 ἡμερῶν κατὰ τὸ μέγιστον καὶ 13 $^1/_2$ κατὰ τὸ ἐλάχιστον αὐτῆς ἐνῷ κατὰ τὰς ἐνδιαμέσους φάσεις ἐμφανίζονται καὶ αἱ δύο προαναφερθεῖσαι περίοδοι συγχρόνως.

Θὰ ἦτο λίαν ἐπιθυμητὸν νὰ ἐπεκταθῇ ἡ ἔρευνα αὕτη ἐπὶ τῇ βάσει τῶν παρατηρήσεων τῶν δορυφόρων καὶ διὰ τὰ μετὰ τὸ 1970 ἔτη, κυρίως διὰ νὰ διαπιστωθῇ κατὰ τρόπον ἀναμφισβήτητον τὸ φαινόμενον ποὺ περιγράψαμεν ἀνωτέρω.