GEOMAGNETIC MICROPULSATIONS*

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Summary

Incorporating world-wide data, a summary of observational knowledge of geomagnetic pulsation is given.

Continuous pulsations (pc) are observed in the day-time, and the amplitude of pc increases with latitude, reaching a maximum in the auroral zone.

Pulsation trains (pt) are observed at night and their amplitude attains a maximum in the auroral zone. The pt pulsation seems to be emitted from a local centre in the auroral zone near midnight, and there is a close correlation between the noise bursts of hiss and the occurrence of the pt pulsations.

The primary source of pc pulsation is attributed to intense hydromagnetic disturbances in the outermost exosphere such as are found by Sonett *et al.* by magnetic surveys from rockets.

I. Introduction

As is well known, geomagnetic micropulsations—the rapid variations of the geomagnetic field—have become of significant importance in geophysics, e.g. in recent theoretical investigations of the exosphere of the Earth.

In the present paper a brief summary of the observational results is given.

Continuous pulsation (pc pulsation) is observed during the day-time and its amplitude increases with latitude reaching a maximum in the auroral zone, whereas the train of pulsation (pt pulsation) is observed during the night-time and is mainly an auroral zone phenomenon.

It is considered that pc pulsation is caused by hydromagnetic disturbances in the outermost exosphere, such as are found by Sonett *et al.* by magnetic survey from rockets.

Since the periods of these observed disturbances in the outermost exosphere have a wide range from about 300 seconds to a few seconds, the above characteristics of intensity and period of pc pulsations may be due to the dispersive characters of the exosphere.

II. Induction Magnetometer for the Measurement of Geomagnetic Micropulsations

The induction magnetometer is used to observe the geomagnetic micropulsations. The induction magnetometer used at the Onagawa Magnetic Observatory is made by winding the induction coil around a highly permeable alloy.

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For the highly permeable metal we used a Sendust bar, an alloy of iron, aluminium, and silicon. The Sendust core is 240 cm long and 2·3 cm in diameter and its apparent permeability is about 1000 e.m.u. The coil of 7200 turns has a resistance of 33 Ω which is the same as the critical damping resistance of the 4 s period galvanometer. The inductance of the coil with the core is about 60 H.

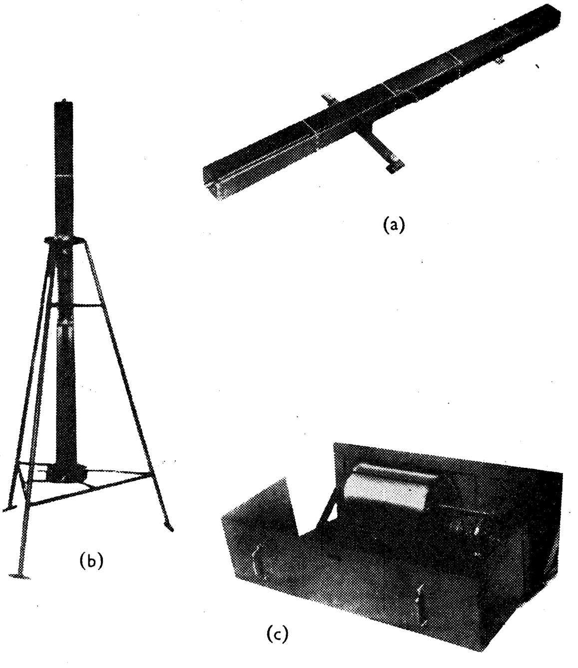

Fig. 1.—Induction magnetometer. (*a*) Horizontal component, (*b*) vertical component, (*c*) recorder.

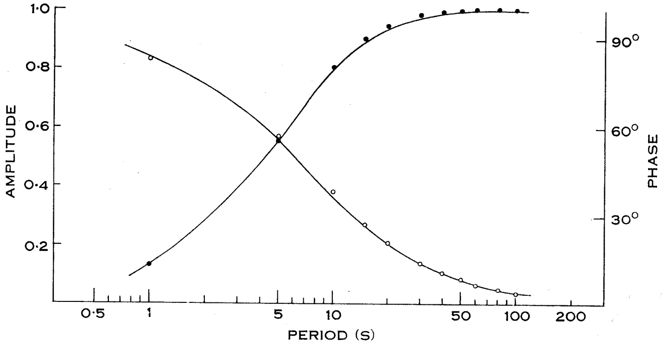

Fig. 2.—Frequency characteristics of induction magnetometer.

Figure 1 shows this induction magnetometer and the error of amplitude and phase lag caused by the inductance of the coil does not exceed 10% for the former and 20° for the latter, for periods of oscillation exceeding 8 s.

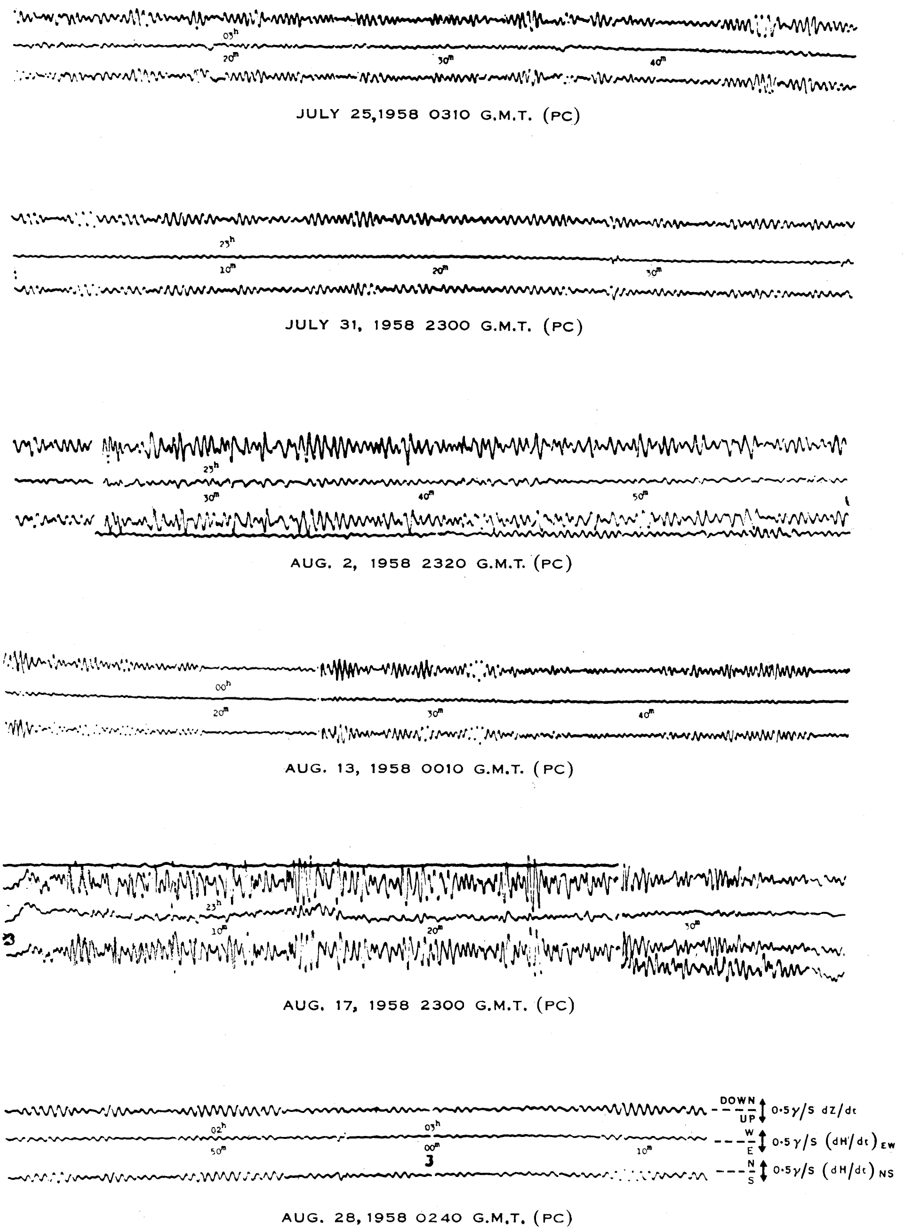

Fig. 3.—Records of pc pulsations obtained at the Onagawa Magnetic Observatory.

Figure 2 shows the frequency characteristics of this equipment. Three components of micropulsations, $(\mathrm{d}H/\mathrm{d}t)$NS, $(\mathrm{d}H/\mathrm{d}t)$EW, and $\mathrm{d}Z/\mathrm{d}t$ are recorded of the same photographic paper rotated at 5 mm per minute.

III. Continuous Train of Pulsation (pc Pulsation)

The pc is the continuous pulsation which has a period between 10 and 40 s, and lasts for several hours.

It is clear that pc pulsations appear only in the day-time and become intense after the activity of magnetic storm. The remarkable but irregular pulsations during magnetic storms are called storm-time pulsations, whereas the continuous and regular ones after the last phase of the magnetic storm are the pc pulsations; these may last for one or two days or more.

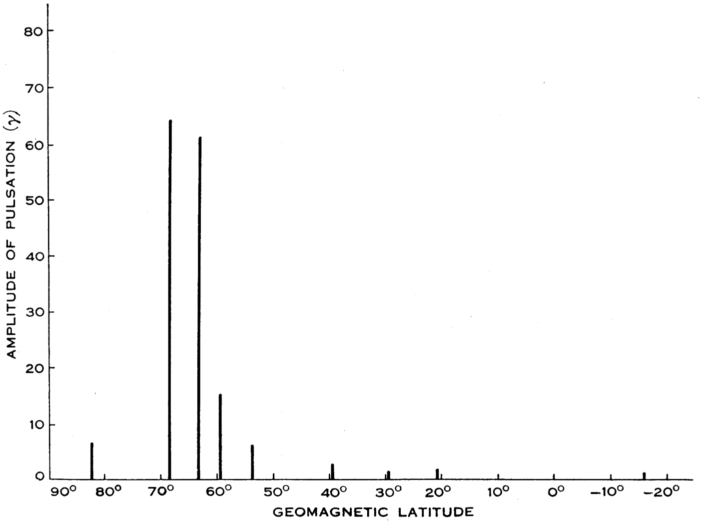

Fig. 4.—Dependence of intensity of pc pulsations on latitude. (Horizontal component, $23^{\mathrm{h}}\ 55^{\mathrm{m}}$ G.M.T. Oct. 1, 1957.)

Figure 3 shows some examples of the pc pulsations recorded at the Onagawa Magnetic Observatory (geographical latitude 38° 26′·3 N., geographical longitude 141° 27′·5 E.; geomagnetic latitude +28°·3, geomagnetic longitude 206°·8).

The amplitude of the pc pulsation increases with rise in latitude, and reaches its maximum at the auroral zone.

Figure 4 shows the characteristics of the latitudinal dependency of the intensity of pc pulsations of period between 10 and 40 s.

Besides the abovementioned relatively short period pc pulsations, regular sinusoidal pulsations of period five minutes or more are simultaneously observed in the auroral region.

IV. pt Pulsation

It is well known that these damped oscillations are usually observed at the commencement of bay disturbances, continuing till their maximum phase; during the decline of the bay disturbance no pt pulsations are normally evident.

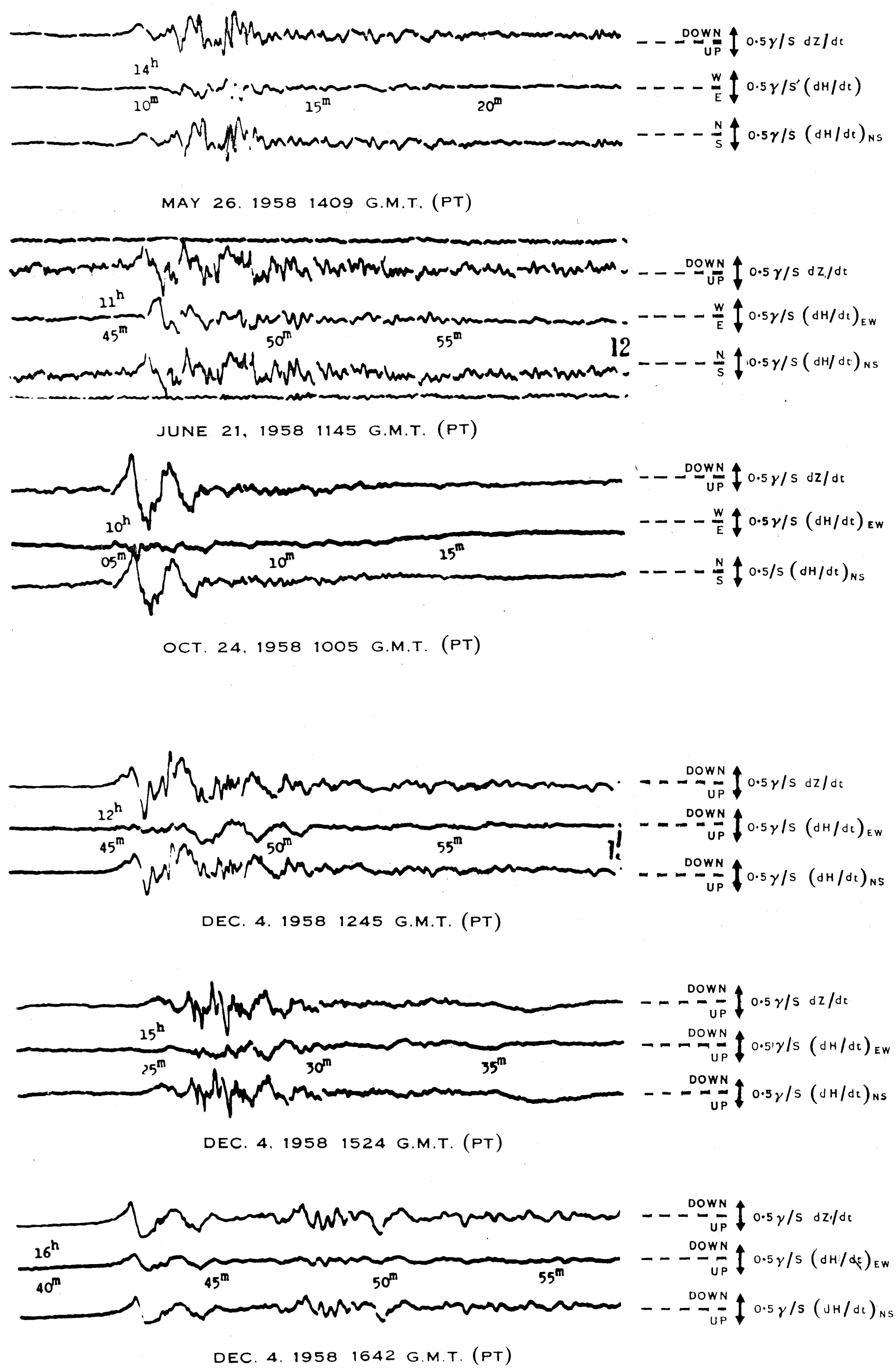

Fig. 5.—Records of pt pulsations obtained at the Onagawa Magnetic Observatory.

Figure 5 is an example of pt pulsations obtained by the induction magnetometer at the Onagawa Magnetic Observatory. The period is between about 60 and 100 s but usually 10–20 s short-period oscillations overlap them.

The amplitude becomes larger in high latitudes, reaching an abrupt maximum in the auroral zone, as shown in Figure 6.

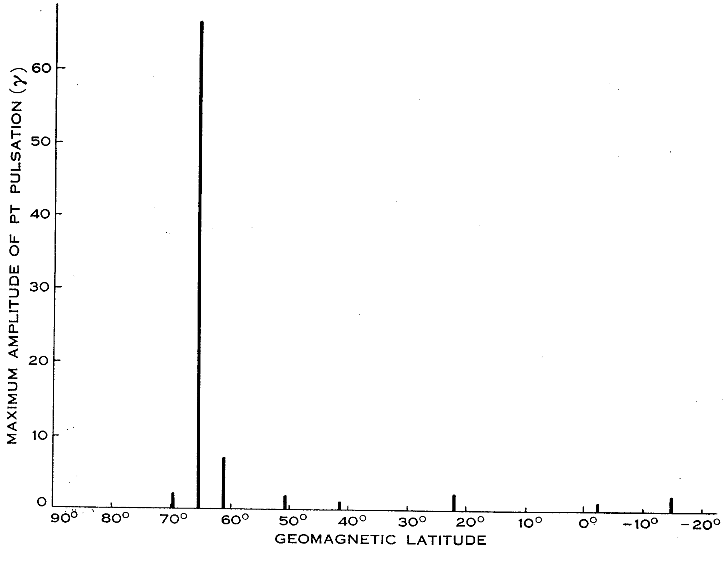

Fig. 6.—Dependence of intensity of pt pulsations on latitude. (Horizontal component, $11^{h}\ 00^{m}$ G.M.T. Oct. 17, 1957.)

V. pc Pulsation Excited by the Coronal Streamer

The outer corona, as observed at the time of eclipses, has a pronounced fine structure. Dr. K. Saito of the Tokyo Astronomical Observatory observed the fine coronal streamers at the sunspot minimum during the solar eclipse of June 20, 1955.

Figure 7 shows the result of his investigation, and indicates that there are several fine coronal streamers denoted by A, B, C, D, and E on the figure. Saito concluded that these streamers are emitted from fixed sources, or from the bright green corona observed on the solar disk as shown in Figure 8.

Figure 9 shows that there is an intimate correlation between the activity of pc pulsations observed at the Onagawa Magnetic Observatory and the meridian passage of these bright green coronal sources.

Figure 10 shows the correlation between the mean value of the activity of pc pulsation and the meridian passage of the above-mentioned individual green coronae.

The activity of pc pulsations becomes intense 2 or 3 days after central meridian passage of the green corona, when the coronal streamers sweep the outermost exosphere of the Earth.

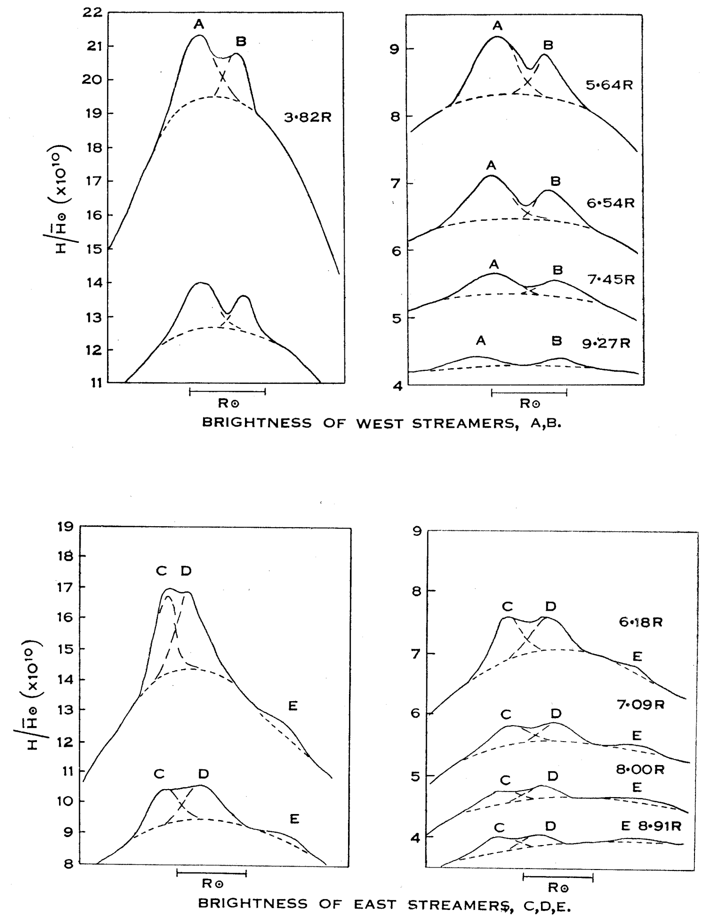

Fig. 7.—Brightness of fine coronal streamers observed by Dr. K. Saito during the solar eclipse of June 20, 1955.

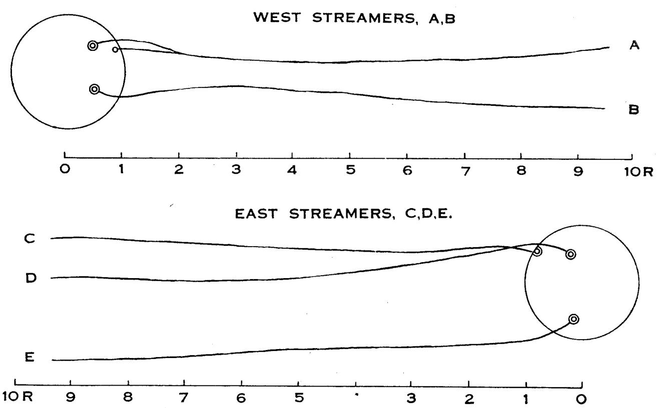

Fig. 8.—Root of streamers and green coronal sources.

VI. PT Pulsations and Noise Burst of Hiss

It is notable that pt pulsations and noise bursts of hiss are observed simultaneously.

Figure 11 shows that pt pulsations and noise burst of hiss were observed at Camden simultaneously by Professor G. R. A. Ellis, while at the same time pt pulsations were recorded at the Onagawa Magnetic Observatory in the northern hemisphere.

Professor Ellis and his colleagues found that the sources of these noise bursts are situated in some part of the auroral zone.

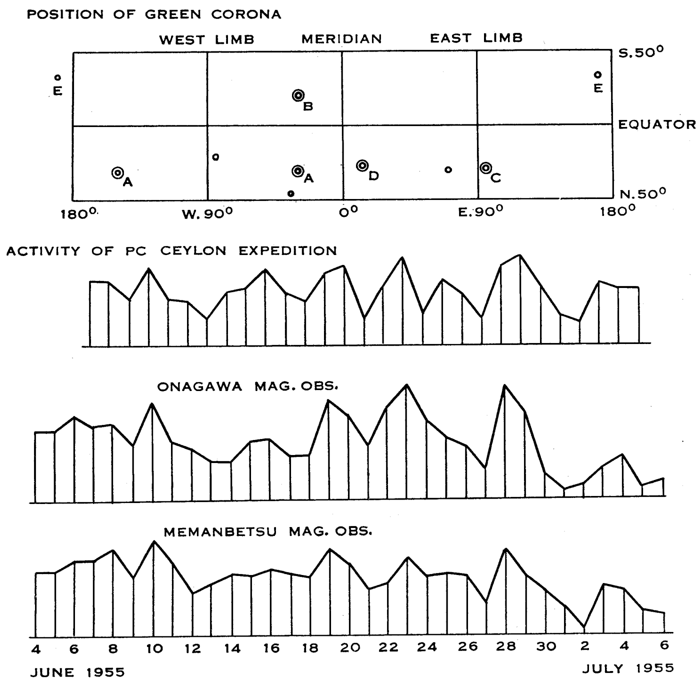

Fig. 9.—Correlation between activity of pc pulsations and meridian passage of green coronal sources.

On our part we could determine the vector direction of pt pulsation, and indicate that its emitting source too is in the auroral zone, as shown in Figure 12. It appears that there is an intimate correlation between the occurrence of pt pulsation and outbursts of hiss noise.

VII. Hydromagnetic Disturbance of the Outermost Exosphere and the Geomagnetic Micropulsation

The primary source of day-time pulsation (pc pulsation) is attributed to the large amplitude disturbances in the outermost exosphere found by Sonett *et al.* in their satellite magnetic surveys.

We can divide the exosphere into three regions as shown in Figure 13.

(1) $r/r_0 < 7$ Magnetic cavity. This region may have the surface of revolution of the magnetic lines of force going through the corresponding distance. In this region the magnetic pressure is far greater than the gas pressure in the exosphere.

(2) $7 \leqslant r/r_0 \leqslant 10$ The weakly disturbed region.

(3) $10 \leqslant r/r_0 \leqslant 14$ Strongly disturbed region (outermost exosphere).

(4) $r/r_0 > 14$ Interplanetary space with intensity of its magnetic field steady at $2{\cdot}5\ \gamma$.

The observed short-period disturbances in the outermost exosphere at geocentric distance (r) between 10 and 14 Earth's radii (r_0) should be interpreted as hydromagnetic disturbances caused by the interaction between the solar stream and the geomagnetic field within the region wherein the magnetic pressure is comparable with the gas kinetic pressure of the corpuscles.

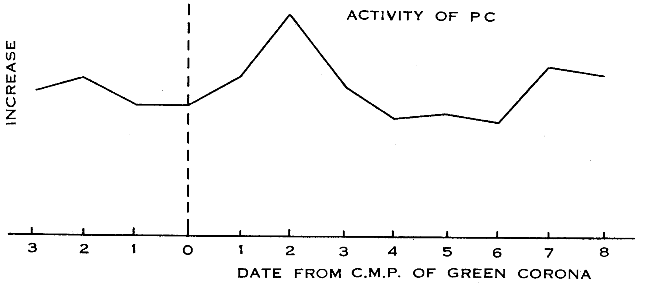

Fig. 10.—Correlation between the mean value of the activity of pc pulsation and the meridian passage of the green coronae.

On the other hand it is well known that there are three modes of hydromagnetic waves in a homogeneous plasma with finite temperature under a steady field; these are the Alfvèn wave, the modified Alfvèn wave, and the retarded sound wave.

Since the temperature of the exosphere is about 10^5 °K, the velocity of sound is exceedingly small compared with the Alfvèn wave velocity.

The Alfvèn wave cannot propagate in the direction perpendicular to the steady field and the energy flux is transported along the lines of force. The modified Alfvèn wave propagates isotropically with a speed of $V_A = H/(4\pi\rho_0)^{\frac{1}{2}}$.

The former is the transverse wave and the latter is the isotropic wave.

As shown in Figure 14, it was suggested by Dessler that there is a level in the exosphere at which the Alfvèn velocity is a maximum. Therefore we can expect that some hydromagnetic disturbances will be subject to total reflection at altitudes beyond this level.

As there is a general tendency for the velocity to decrease with increase of altitude in the exosphere beyond the level of maximum speed, the longer period isotropic waves will be reflected at higher altitudes.

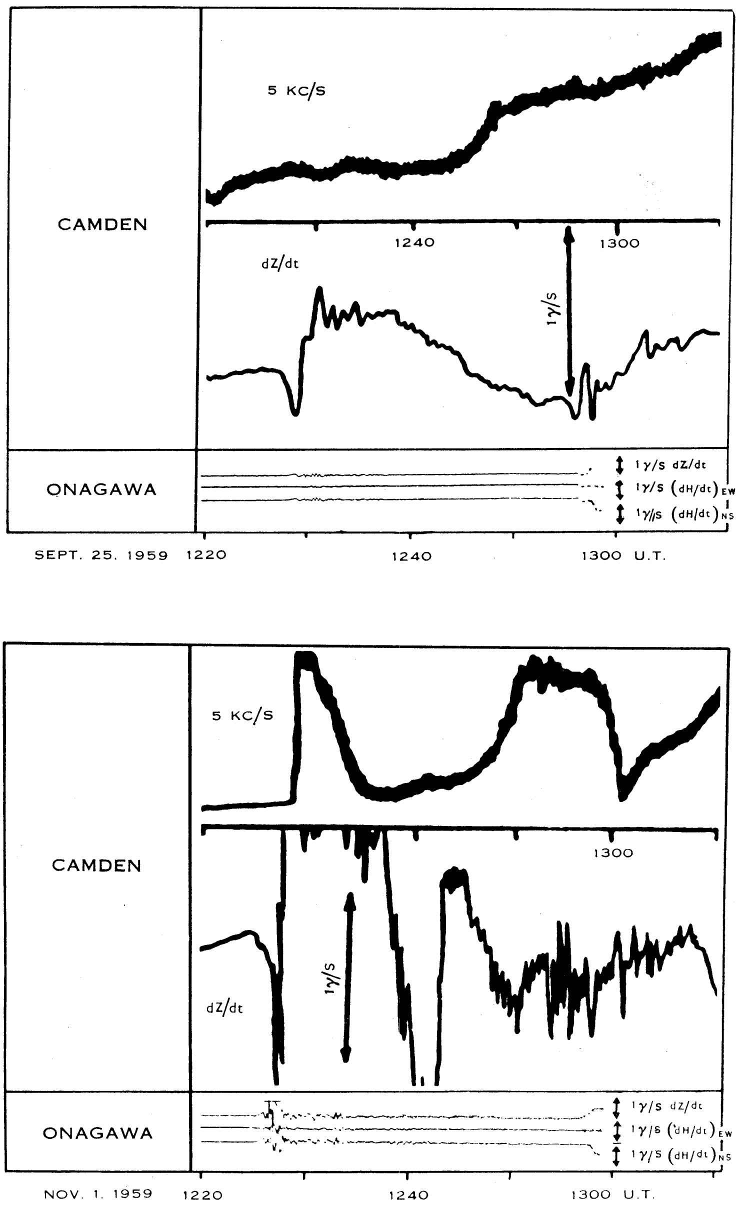

Fig. 11.—Examples of simultaneous observations of pt pulsations at Camden and Onagawa, together with hiss at Camden.

A part of the energy of these reflected waves will be transformed into transverse waves and be propagated to higher latitudes along the lines of geomagnetic force.

On the other hand isotropic waves which can penetrate this level of maximum speed (periods of 20∼40 s) propagate perpendicular to the line of force and there is no transverse wave within this cavity.

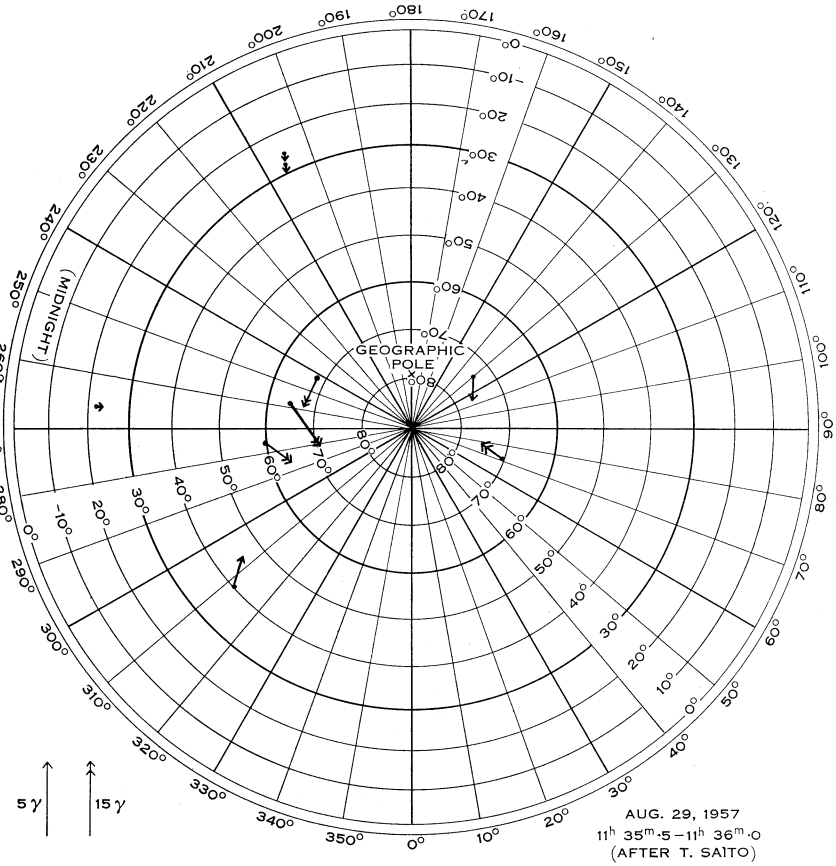

Fig. 12.—Vector directions and sources of pt pulsations, from $11^{h}\,35^{m}\cdot5$ to $11^{h}\,36^{m}\cdot0$ on August 29, 1957 (after Mr. T. Saito).

As already mentioned in an earlier section the 20∼40 s period pc pulsation can be observed universally in the day-time. In middle and lower latitudes its mode is poloidal oscillation, while in the higher latitudes and in the auroral zone the amplitude becomes larger and reaches a maximum in the auroral zone. The mode of oscillation becomes torsional, and those of longer period or of about more than 5 min appear simultaneously only in the auroral zone.

It is concluded that the primary cause of pc pulsation is hydromagnetic disturbance in the outermost exosphere, caused by the interaction between the solar corpuscular stream and the geomagnetic field.

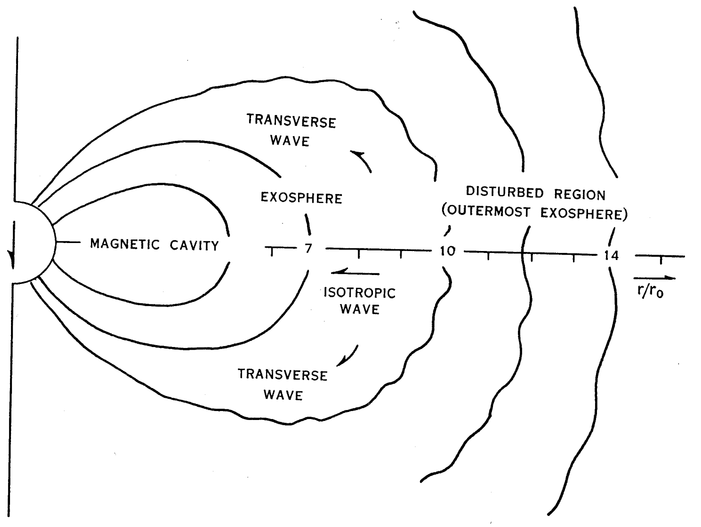

Fig. 13.—Regions of the exosphere.

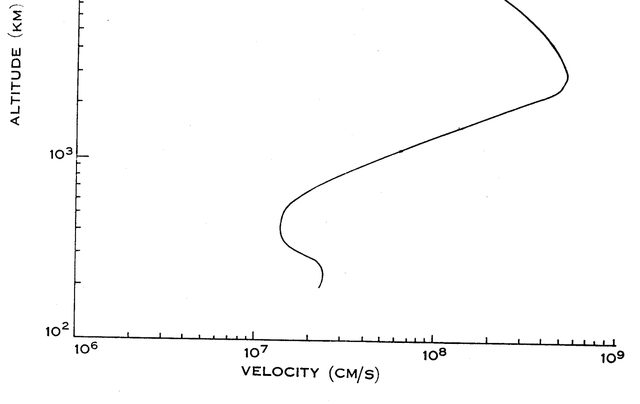

Fig. 14.—Variation of Alfvèn velocity with height.

For the cause of pt pulsation we must consider another mechanism of hydromagnetic disturbance, because the pt pulsation occurs only in the midnight hemisphere.

The pt pulsations may be a phenomenon associated with the precipitation of solar corpuscles in the night-time auroral zone, or with some mechanism responsible for the occurrence of bay disturbance. In the former case we consider that the corpuscle beam penetrating parallel to the lines of force is not sufficient to produce the pt pulsation unless we suppose an unreasonably large flux of precipitation.

It is suggested that the pt pulsation is a hydromagnetic oscillation caused by the interaction between the geomagnetic field and a radial equatorial electric field in the night hemisphere of the exosphere ; the latter field may be set up by the interaction between the impinging positive particles trapped by the geomagnetic line of force going through the auroral zone and electrons already trapped in the exosphere.

It is probable that instability will be caused in the magnetic field of the exosphere by the above-mentioned hydromagnetic wave, and owing to this instability the electrons will be precipitated in the ionosphere of the auroral zone. This could produce the bay disturbance. However this may be, the pt pulsation appears to be associated with the hydromagnetic oscillation caused by the interaction between the geomagnetic field and the radial equatorial electric field in the night hemisphere of the exosphere.

VIII. Conclusions

The primary cause of pc pulsation is the hydromagnetic disturbance in the outermost exosphere found by Sonett *et al.* by their rocket magnetic survey.

The pt pulsation is caused by the hydromagnetic damped type oscillation arising from the interaction between the geomagnetic field and the radial equatorial electric field in the night hemisphere of the exosphere.

IX. Acknowledgments

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