Detection of Rapidly Moving Ionospheric Clouds

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RAPIDLY moving ionospheric clouds were detected in the earth's outer atmosphere (ionosphere) during the magnetic storm March 25–26, 1946, at the Kensington Ionospheric Laboratory, Department of Terrestrial Magnetism, Carnegie Institution of Washington. The clouds move in from long to short range or out again in intervals of few minutes. They are first detected at maximum ranges of 800–900 km. They are tracked inward at velocities of 1 to 2 km per second to *F*-layer levels (300–400 km). Occasionally they are seen to move out again at about the same rate. They are observed both during the night when background ionization is low and during the day when background ionization is high. Angle of arrival of the signals cannot be ascertained by the method employed.

These clouds were observed repeatedly during the interval 15^h00^m, March 25, to 07^h00^m, March 27, 1946—the first opportunity for application of the new recording technique to observation of magnetic-ionospheric storms. The observations were made with the new "panoramic" ionospheric recorder, developed with support of the United States Signal Corps which sweeps over the range, 1.5 to 20.0 Mc/sec. at adjustable intervals of 5 to 30 seconds. Repetition at such short intervals registers ionospheric fluctuations of short duration which have been missed by earlier instrumentation. The technique has been perfected to the extent that successive records can be projected as motion pictures. Compression of the time-scale as a result of projection provides a sense of continuity which simplifies visualization and interpretation of an otherwise long succession of events.

The panoramic sweep is displayed on a cathode-ray tube and records are made automatically by successive exposures of single frames of film for each sweep. Examples of normal records with 15-second sweep at 30-second intervals for three minutes are illustrated in Fig. 1 while rapidly changing disturbed conditions are illustrated in Fig. 2. Although illustration of a cloud tracking is not immediately feasible, Fig. 2 serves to demonstrate the rapid changes which may occur in a 30-second interval between exposures. Both figures are enlarged from 16-mm film. The parallel horizontal lines are height-markers at 50-km intervals upward from the base-line at 0-km and the "pips" at top of record are frequency-markers at 1-Mc/sec. intervals with increasing frequency from left to right. In the figures the visible range is from 1.5 to 14 Mc/sec. The total elapsed interval in each case is three minutes with time progressing downward from top to bottom.

The principal effects of influx of the clouds are: (1) sudden changes in *F*-layer ionization; (2) rapid changes in *F*-layer heights indicating turbulence which is often progressive from high to low heights and from high to low frequencies; (3) rapid fluctuations of echoes at the lower frequencies with occasional temporary disappearance indicating high absorption.

We are inclined to attribute these clouds to an inflow of corpuscles which are bombarding the atmosphere in an irregular manner during magnetic disturbance. These probably are the first direct quantitative observations of such bombardment. They are interpreted as establishing that corpuscular radiation contributes to the net ionization of the *F*-region. The equivalent maximum electronic density is estimated from magneto-ionic theory to be 2 to 4×10^6 electrons per cc. Much of the uninterpreted scatter of the disturbed *F*-region previously seen on slow recorders can doubtless be traced to chance registration of various aspects of rapidly moving clouds. It is considered probable that other higher velocity cloud movements exist which will be detected by even faster recordings.

The new technique of ionospheric recording and presentation provides a very powerful tool for study of special ionospheric features which occur during magnetic storms,

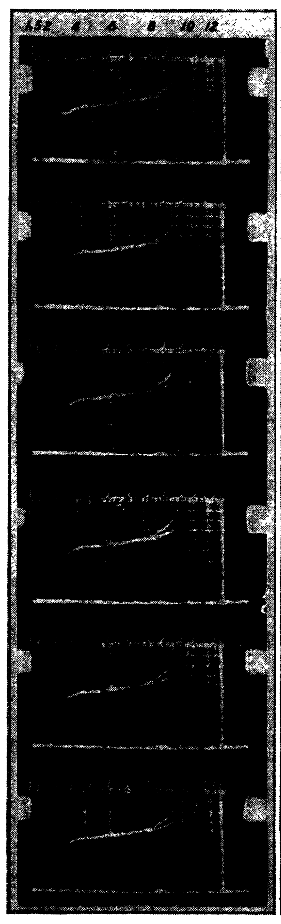

FIG. 1.

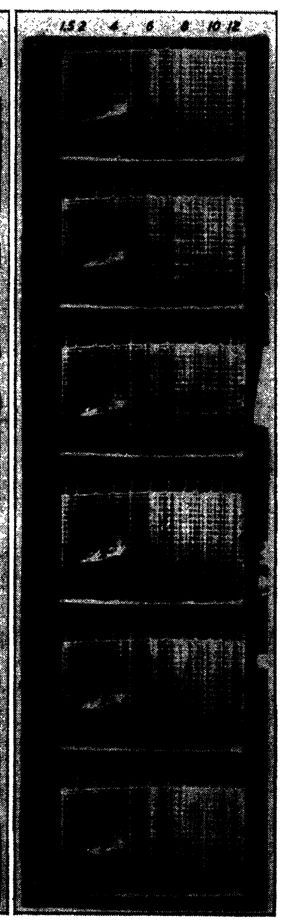

FIG. 2.

FIGS. 1 and 2. (1) Six successive normal ionospheric 15-sec. records during three minutes afternoon March 19, 1946; (2) six successive disturbed ionospheric 15-sec. records during three minutes of magnetic storm, March 25, 1946, showing rapid changes. (Records are reproduced from original 16-mm film; height-markers are at 50-km intervals, frequencies are indicated from 1.5 to 14 Mc/sec.)

eclipses, radio fade-outs, sporadic E, $F2$ scatter, and abnormal stratifications. Projection makes possible quick scanning of an enormous wealth of data, selection of portions for critical study, and visualization of dynamic events of short duration.

Lowering of Electrical Breakdown Field Strength at Microwave Frequencies Due to Externally-Applied Magnetic Field

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THE following effects have been observed in connection with 3-cm microwave breakdown studies[1] conducted on air gaps in wave guide:

(1) An approach of a permanent magnet to a gap which is on the verge of microwave sparking can make the gap spark over. In one favorable experiment 35 spark-overs took place out of 36 approaches with a magnet.

(2) A magnet of pole-face cross section smaller than the patch of wave guide over which it is poised may lower the breakdown field strength by 20 percent or more, depending on certain conditions, such as strength of the magnetic field and height of the breakdown gap.

(3) When the magnet is swept along on the outside of the vertically-narrowed wave guide (which encloses the breakdown gap) the gap may spark at a field strength lower by as much as a factor of 2 or more than when the magnet is absent. The sweeping magnet must remain upright, for the effect mentioned.

(4) No sparking effect can be reliably reported when the magnetic field is applied at right angles to the microwave electric vector, either along the direction of propagation, or crosswise to it.

(5) When broadface permanent magnets are used, the poised (stationary) effect and the sweep effect are much diminished.

The following possible explanations have been considered: (a) Vertical magnetostriction of the wave guide, including the possibility of interaction between the applied magnetic field and the currents in the wave guide surface. (b) Magnetic spiral-focusing in the gap (oscillating helices) leading to more intense concentrated ionization. (c) Larmor precession resonance with accompanying increase of gas conductivity.[2] For various reasons, and the fact that the lowering of breakdown peak power by a factor of 4 (Poynting vector proportional to field squared) in the sweep cases is equivalent in violence to the shrinking of the height of the gap[3] by the same factor 4, none of the mentioned possible explanations seems at the moment to be adequate. However, further investigation of both the effect and the possible causes is being continued.

[1] D. Q. Posin, Bull. Am. Phys. Soc. **21**, No. 2, April, abstract L6.
[2] Appleton and Childs in experiments cited by K. K. Darrow, Bell Sys. Tech. J. **11**, No. 4, 605.
[3] D. Q. Posin, Ina Mansur and H. Clarke, Radiation Laboratory Report 731.

The Two-Body Problem in Einstein's and Birkhoff's Theories

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C. GRAEF[1] has obtained the solution of the two-body problem according to Birkhoff's theory.[2] After the substitution $x_1\rightarrow\eta_1$, $x_2\rightarrow\zeta_1$, $y_1\rightarrow\eta_2$, $y_2\rightarrow\zeta_2$, and after the correction of some obvious typographical errors his equations may be written as follows

$$\begin{aligned}\ddot{\eta}_i/m_2=+(\eta_i-\zeta_i)/r^3[3/2r^2\{(\eta_k-\zeta_k)\dot{\zeta}_k\}^2\\ -2\dot{\zeta}_k\dot{\zeta}_k-\dot{\eta}_k\dot{\eta}_k+4\dot{\eta}_k\dot{\zeta}_k-1]\\ +(\eta_k\zeta_k)(\dot{\zeta}_k-2\dot{\eta}_k)(\dot{\zeta}_i-\dot{\eta}_i)/r^3,\quad(1)\end{aligned}$$

where

$$r^2=(\eta_k-\zeta_k)(\eta_k-\zeta_k).$$

The repetition of an index implies summation from one to two. Another set, for $\ddot{\zeta}_i$ is obtained by replacing η with ζ and m_2 with m_1. Let $\alpha_i=M^{-1}(m_1\eta_i+m_2\zeta_i)$ be the coordinates of the center of gravity where $M=m_1+m_2$. Then

$$\begin{aligned}\ddot{\alpha}_i=m_1m_2(\eta_i-\zeta_i)/Mr^3[3/2r^2(\{(\eta_k-\zeta_k)\dot{\zeta}_k\}^2\\ -\{(\zeta_k-\eta_k)\dot{\eta}_k\}^2)-\dot{\zeta}_k\dot{\zeta}_k+\dot{\eta}_k\dot{\eta}_k]\\ +m_1m_2(\eta_k-\zeta_k)(\dot{\eta}_k-\dot{\zeta}_k)(\dot{\eta}_i-\dot{\zeta}_i)/Mr^3.\quad(2)\end{aligned}$$

Einstein, Infeld, and Hoffman[3] have obtained the equations for the two-body problem on the basis of the general theory of relativity. The equations that correspond to (2) are

$$\begin{aligned}\ddot{\alpha}_i=m_1m_2(\eta_i-\zeta_i)/Mr^3[3/2r^2(\{(\eta_k-\zeta_k)\zeta_k\}^2\\ -\{(\zeta_k-\eta_k)\dot{\eta}_k\}^2)-\dot{\zeta}_k\dot{\zeta}_k+\dot{\eta}_k\dot{\eta}_k+(m_1-m_2)/r]\\ +m_1m_2(\eta_k-\zeta_k)(\dot{\eta}_k-\dot{\zeta}_k)(\dot{\eta}_i-\dot{\zeta}_i)/Mr^3.\quad(3)\end{aligned}$$

Thus, as far as motion of the center of gravity is concerned, the only difference between (2) and (3) is the term

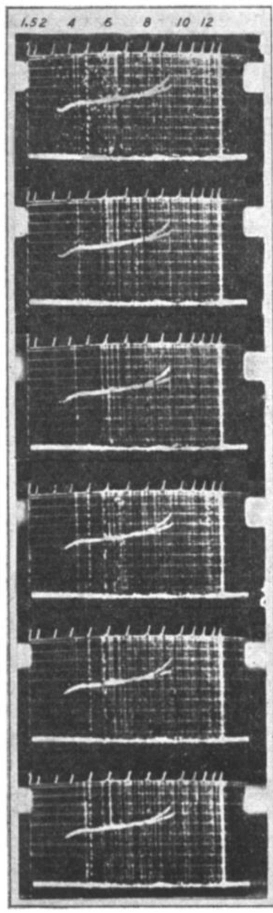
$$(Mr^4)^{-1}m_1m_2(\eta_i-\zeta_i)(m_1-m_2)\text{ in (3).}\quad(4)$$

Robertson[4] has shown that the average value of $\ddot{\alpha}_i$, $\langle\ddot{\alpha}\rangle_{\text{Av}}=\frac{1}{T}\int_0^T\ddot{\alpha}_i dt$ over a period of the classical motion, is zero for Eq. (3); i.e., there is no secular change in the velocity of the center of gravity. The average value of (4) however, is not zero, and for Eq. (2) this leads to the result that $\langle\ddot{\alpha}_1\rangle_{\text{Av}}=m_1m_2(m_2-m_1)\epsilon/2Ma^{3/2}p^{3/2}$ and $\langle\ddot{\alpha}_2\rangle_{\text{Av}}=0$ where $r^{-1}=p^{-1}[1+\epsilon\cos w]$. This acceleration is in the direction of the periastron of the minor component of a double star. Levi-Civita[5] has given an example of a binary star for which such an acceleration might be detected.

Berenda[6] has suggested that the difference in the results of the two theories, may be caused by different methods of approximation. This remark would not apply to the result deduced above, since the extra term in (3) is an interaction term which arises on account of the nonlinear character of the field equations.[7]

I wish to thank Dr. Infeld for suggesting this problem to me.

[1] C. Graef, Boletin Sociedad Mat. Mexicana **1**, Nos. 4 and 5, 25.
[2] G. Birkhoff, Boletin Sociedad Mat. Mexicana **1**, Nos. 4 and 5, 1.
[3] Einstein, Infeld, and Hoffman, Ann. Math. [1] **39**, 65.
[4] H. P. Robertson, Am. Math. [1], **39**, 101.
[5] T. Levi-Civita, Am. J. Math. **59**, 225. Oddly enough the magnitude of the acceleration is the same as that obtained by Levi-Civita from relativity theory through a mistake in the calculation.
[6] C. W. Berenda, Phys. Rev. **67**, 56 (1945).
[7] H. P. Robertson, reference 4, p. 103 footnote.



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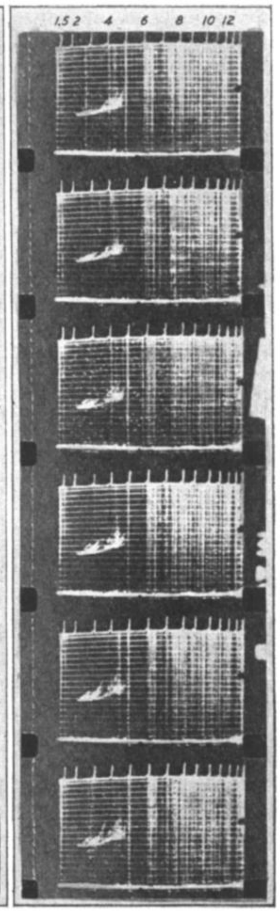

FIG. 2.

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