PHYSICAL REVIEW LETTERS

VOLUME 6 MARCH 15, 1961 NUMBER 6

SOME EVIDENCE OF HYDROMAGNETIC WAVES IN THE EARTH'S MAGNETIC FIELD*

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(Received February 13, 1961)

Hydromagnetic waves, which were originally predicted theoretically by Alfvén,[1] have been demonstrated in mercury or in liquid sodium in the laboratory.[2] A number of authors have discussed the possible astrophysical[3] and geophysical[4] importance of hydromagnetic waves.

This Letter presents an observational result that may be considered as evidence of hydromagnetic waves propagated to the earth from its outer atmosphere.

Dungey[5] and subsequently other authors[6] discussed oscillations of the lines of magnetic force in the earth's outer atmosphere, in order to account for certain types of magnetic pulsations. For the sake of simplicity these authors assumed an isotropic conductivity. Piddington[7] showed that because of the anisotropic conductivity of an ionized gas in the presence of a magnetic field, plane hydromagnetic waves of small amplitude, propagating along the magnetic field, are circularly polarized in opposite senses. For an oblique propagation the polarizations of the corresponding waves become elliptical.

Damped oscillations observed with the rapid-run magnetometers by the U. S. Coast and Geodetic Survey Magnetic Observatory at College, Alaska, are now being analyzed. Figure 1 illustrates a typical example. The curves, for the horizontal force H, declination D, and the vertical force Z, were traced from the rapid-run magnetograms without smoothing.

By combining H and D, changes in the horizontal magnetic vector were obtained at intervals of one minute. Figure 2 shows the locus of the

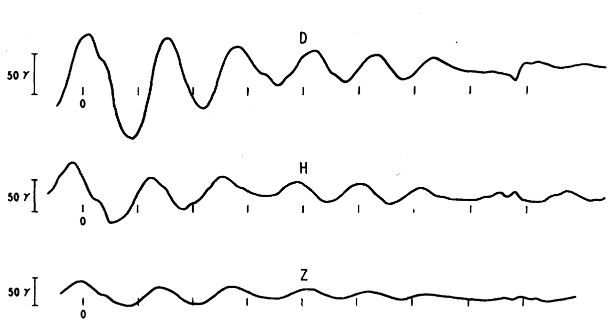

FIG. 1. An example of damped hydromagnetic waves observed at College, Alaska, in the three orthogonal magnetic components, declination D, the horizontal force H, and the vertical force Z; $1\ \gamma \equiv 10^{-5}$ gauss.

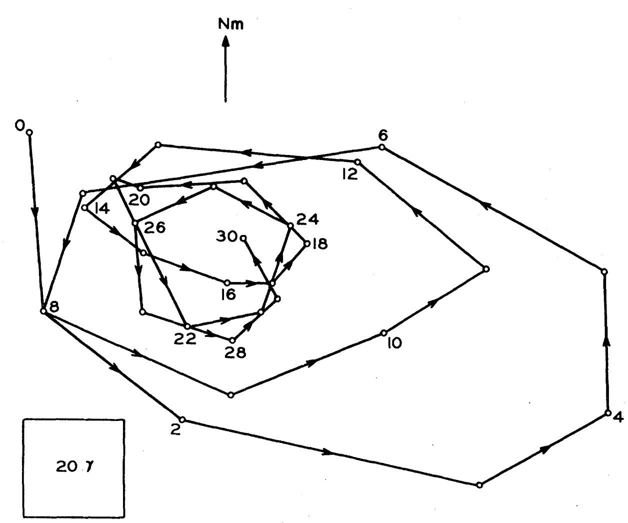

FIG. 2. The locus of the end point of the magnetic vector for the hydromagnetic waves shown in Fig. 1; projection onto the horizontal plane.

end point of the changing vector; circles indicate the epochs at which readings were actually made, and the attached numbers show the time elapsed, reckoned in minutes from the epoch 0459 U.T., April 4, 1960.

The maximum ranges in D, H, and Z were 124, 97, and 44 γ ($1\ \gamma \equiv 10^{-5}$ gauss), respectively. The period varied to some extent from one cycle to the next, probably due to modifications of wave forms by various secondary effects; the average period was about 6 minutes. This is the typical period of damped oscillations, observed at College, of the kind discussed here.

It is evident that the wave is very nearly elliptically polarized. The remarkably regular polarization of the magnetic waves strongly suggests that they are transverse hydromagnetic waves, generated in the outer atmosphere at an altitude of several earth radii, and propagated along the lines of magnetic force. This argument is supported by two important related facts, to be demonstrated later: (a) Magnetic oscillations of this type are found to be mostly confined to the auroral zones. (b) They occur simultaneously in magnetically conjugate regions in the northern and southern hemispheres, namely at College (geomagnetic latitude 64°.7 N) and Macquarie Island (geomagnetic latitude 61°.1 S). The IGY records of the standard magnetometers at Macquarie Island have been compared with both the rapid-run and sensitive magnetograms taken at College; rapid-run magnetometers were not operated at Macquarie Island. The polarization at Macquarie Island is being studied, but the accuracy is limited owing to the slow speed of the standard magnetometers.

The hydromagnetic waves are probably generated by a sudden motion of the gas or by an electric field suddenly imposed on the gas. There appear to be preferential local times at which the hydromagnetic waves are generated; this point will be discussed elsewhere.

There is a possibility that these oscillations originate in the ionosphere, e. g., from transient phenomena such as those discussed by Cowling[8] in connection with the motion of solar material across magnetic fields, and by Piddington[9] in a more general form. Such oscillations might be propagated along the lines of magnetic force to the other hemisphere as in very low frequency radio noises of natural origin,[10] known as whistlers, or in those generated artificially.[11] It should be noted, however, that the wavelength of the hydromagnetic waves here considered is extremely long; hence, the propagation must be quite different from that for very low frequency radio waves. A preliminary examination indicates that the above possibility is unlikely.

Another evidence of propagation of hydromagnetic waves from the outer atmosphere is provided by sudden commencements of magnetic storms. Examples of nearly elliptically polarized variations have been found in some sudden commencements, and will be published later by C. R. Wilson and the present author.

The author is indebted to Professor S. Chapman for valuable discussions, to Mrs. Jean Chorbajian for her assistance in the analysis, and to the Coast and Geodetic Survey for making the data available.

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*This research was supported by a grant from the National Science Foundation.

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X-RAY CONTINUA AND LINE SPECTRA FROM HIGHLY STRIPPED ATOMS IN A MAGNETICALLY COMPRESSED PLASMA*

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A single-crystal x-ray spectrometer has been constructed and applied to the study of the x-ray spectrum emitted from the deuterium plasma in the Scylla fast magnetic compression experiment.[1,2] The Scylla magnetic field rises sinusoidally to 55 kgauss in 1.25 μsec and produces a deuterium plasma with an ion density of $5\times10^{16}/cm^3$ which emits neutrons and soft x rays for about 0.8 μsec near the maximum of the second half-cycle of the magnetic field.

The diffracting element of the spectrometer is a beryl crystal, ground for reflection from the $10\bar{1}0$ planes ($2d = 15.94$ A), which allows examination of the plasma emission spectrum between 5 A and 15 A. The energy resolution of the spectrometer is determined by the angular definition of the slit system, which is 10′ of arc for the measurements here reported. The diffracted x rays are recorded by a plastic scintillator–photomultiplier detector, and the time-resolved signal is displayed on an oscilloscope. The detector does not record individual x rays, but rather a pile-up signal whose amplitude indicates the time variation of the intensity of diffracted x rays produced during the 0.8-μsec emission interval at maximum plasma compression.

The line spectra emitted by the deuterium discharge are shown in Fig. 1. The hydrogen-like spectrum of O^{VIII} and the helium-like spectra of Na^{X}, Mg^{XI}, Al^{XII}, and Si^{XIII} are well de-

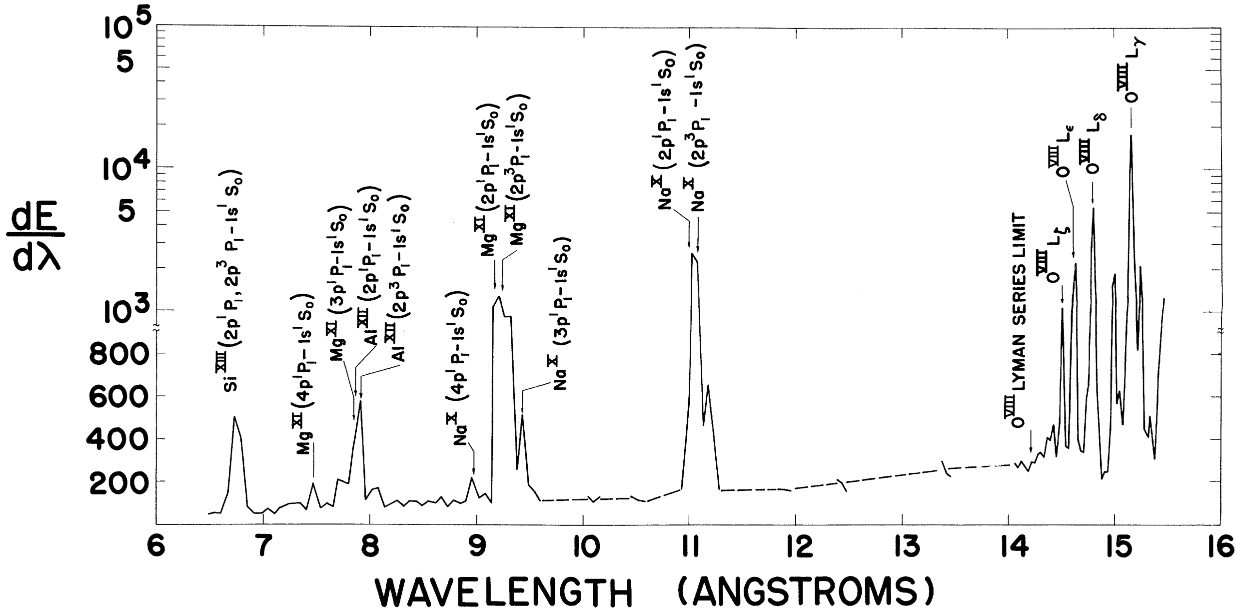

FIG. 1. Spectrum of the deuterium discharge in Scylla. The arrows indicating the identified lines are at the predicted wavelength for each line.