clusions. LePichon (*2*) suggests that major lithosphere movements are episodic with a period of roughly 30 million years. He offers the intriguing speculation that this would be the time required to depress lithosphere slabs down along the "Gutenberg fault" (earthquake) zones to a depth of 800 km below volcanic arcs. Presumably the plates cannot be depressed further, so a modification of plate boundaries must occur to initiate a new episode of movements.

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References and Notes

1. W. J. Morgan, *J. Geophys. Res.* **73**, 1959 (1968); B. Isacks, J. Oliver, L. R. Sykes, *ibid.*, p. 5855.
2. X. LePichon, *ibid.*, p. 3661.
3. R. J. Adie, Ed., *Antarctic Geology* [Interscience (Wiley), New York, 1964]; R. Brinkmann, *Geologic Evolution of Europe* (Engl. transl., Hafner, New York, 1960); R. Furon, *Geology of Africa* (Engl. transl., Oliver and Boyd, London, 1963); A. S. Laughton, *Phil. Trans. Roy. Soc. London Ser. A* **259**, 150 (1966); D. V. Nalivkin, *The Geology of the U.S.S.R.* (Engl. transl., Pergamon, New York, 1960).
4. M. Minato, M. Gorai, M. Hunahashi, Eds., *The Geologic Development of the Japanese Islands* (T. Shokan Co., Tokyo, 1965); T. Matsuda, K. Nakamura, A. Sugimura, *Tectonophysics* **4**, 349 (1967); T. Matsumoto, *ibid.*, p. 595.
5. H. J. Harrington, "Geology of the Pacific Ocean Region," in *UNESCO Symposium on Continental Drift*, Montevideo, Uruguay, 1967 (in press).
6. R. W. Van Bemmelen, *Mountain Building* (Nijhoff, The Hague, 1954).
7. T. W. E. David, *Geology of the Commonwealth of Australia* (Arnold, London 1950).
8. J. C. Grover, "The Solomon Islands—Geological Exploration and Research," *Brit. Solomon Islands Geol. Surv. Mem. 2* (1958); F. T. Banner *et al.*, *J. Geol. Soc. Aust.* **8**(1) (1961); W. R. Dickinson, *Tectonophysics* **4**, 543 (1957).
9. G. W. Grindley and H. J. Harrington, *Proc. Ninth Pacific Sci. Congr., Bangkok* (1961), p. 198; H. W. Wellman, *Roy. Soc. N.Z. 10th Sci. Congr.* (1962), p. 105; R. P. Suggate, *Trans. Roy. Soc. N.Z. Geol.* **2**(7), 105 (1963).
10. F. B. Van Houten, *Amer. J. Sci.* **259**, 612 (1961); D. I. Axelrod, *Bull. Geol. Soc. Amer.* **73**, 183 (1962); *ibid.* **79**, 713 (1968).
11. C. E. Weaver, *Bull. Amer. Ass. Petrol. Geol.* **29**, 1377 (1945); W. D. Lowry and E. Baldwin, *Bull. Geol. Soc. Amer.* **63**, 1 (1952).
12. O. E. Childs and B. W. Beebe, Eds., "Backbone of the Americas," *Amer. Ass. Petrol. Geol. Mem. 2* (1963); A. J. Eardley, *Structural Geology of North America* (Harper, New York, 1962).
13. G. P. Eaton, in *Guide to Geology of Los Angeles and Ventura Regions* [Amer. Ass. of Petroleum Geologists (Pacific Section), Los Angeles, 1958], p. 55.
14. J. C. Crowell, *Geol. Soc. Amer. Spec. Pap. 71* (1962).
15. R. H. Dott, Jr., *J. Geophys. Res.* **70**, 4687 (1965).
16. W. Hamilton, *Bull. Geol. Soc. Amer.* **72**, 1307 (1961); D. G. Moore and E. C. Buffington, *Science* **161**, 1238 (1968); R. L. Larson, H. W. Menard, S. M. Smith, *ibid*, p. 781.
17. H. R. Katz, *J. Geol.* **70**, 595 (1962); H. Bürgl, *Tectonophysics* **4**, 429 (1967); C. Galli-Olivier, *Science* **158**, 653 (1967).
18. W. W. Menard, *Marine Geology of the Pacific* (McGraw-Hill, New York, 1964); J. R. Heirtzler, G. O. Dickson, E. M. Herron, W. C. Pitman III, X. LePichon, *J. Geophys. Res.* **73**, 2119 (1968).
19. F. J. Vine, *Science* **154**, 1405 (1966).
20. J. Ewing and M. Ewing, *ibid* **156**, 1590 (1967).
21. Alsaka: C. A. Burk, *Geol. Soc. Amer. Mem. 99* (1965); Taiwan: C. S. Ho, *Tectonophysics* **4**, 367 (1967); Philippines: F. C. Gervasio, *ibid.*, p. 379; Marianas-Caroline arcs: H. H. Hess, *Bull. Geol. Soc. Amer.* **59**, 417 (1948); M. Minato *et al.*, see (*4*).
22. A. E. Maxwell, (abstract) *Trans. Amer. Geophys. Union* **50**, 113 (1969).
23. X. LePichon and J. R. Heirtzler, *J. Geophys. Res.* **73**, 2101 (1968).
24. M. Talwani, W. Pitman III, J. R. Heirtzler, (abstract) *Trans. Amer. Geophys. Union* **50**, 189 (1969).
25. T. H. Van Andel, J. D. Phillips, R. P. Von Herzen, *Earth Planet. Sci. Lett.* **5**, 269 (1969).
26. E. Irving and W. A. Robertson [*J. Geophys. Res.* **74**, 1 (1969)] go so far as to suggest that apparent polar wandering as well as a change of polarity reversal frequency near the Paleogene-Neogene time boundary (about 25 million years ago) resulted from a major change of lithosphere plate drift patterns.
27. R. H. Dott, Jr., "The antiquity of the Scotia arc," in *UNESCO Symposium on Continental Drift*, Montevideo, Uruguay, 1967 (in press). H. R. Katz [in *Geol. Rundschau* **54**, 1195 (1964)] postulated a similar rupturing of the Andean belt, but he relegated this entirely to the Andean orogeny and assumed a sialic crust beneath the Scotia Sea. I referred the rupturing chiefly to late Cenozoic time and argued, from limited geophysical evidence, that the crust there is more oceanic. Most earlier authors have assumed "uniformitarianly" that the arc formed by continuous eastward bending of Andean structures.
28. My own research, upon which this paper is partially based, has been financed by grants from the Wisconsin Alumni Research Foundation for work in the Pacific Northwest, and from the U.S. Antarctic Research Programs Office of The National Science Foundation for work in Chile and Antarctica. I thank especially C. Craddock, I. W. D. Dalziel, and C. Clay for valuable criticisms.

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DQ Herculis: Synchronous Photometry

Abstract. *Synchronous signal averaging, applied to the photometry of the steller system DQ Herculis in order to study the 71.1-second pulsations discovered by Walker in 1956, yields a light curve which is a pure sinusoid, within the accuracy of measurement. The binary period is increasing, probably as a result of mass lost from the system.*

The periodic variations in brightness discovered by Walker (*1*) in the old nova DQ Herculis (Nova Herculis 1934) have been studied with the technique of synchronous signal averaging first developed by Clark (*2*), in order to reduce the effects of the sporadic variations in light common to old novae and similar variables. Pulses of light from the star were counted in a 400-channel multiscaler which was carefully synchronized to the effective pulsation period (*3*) corrected for the motion of the earth in the direction of the object. The pulsation cycle was divided into 20 time segments, and 10 to 12 cycles were summed for each scan.

The light curve of the eclipsing binary system was simultaneously monitored by conventional pulse-counting techniques in order to relate each synchronous scan to the binary phase. Walker's finding that the pulsations disappear abruptly during eclipse was verified, and an estimate of the rate of disappearance was obtained: the pulsations disappear completely in one cycle, implying that the pulsating body is smaller than previously estimated and is almost certainly an extremely dense white dwarf.

A total of 35 scans, each containing the information from 10 to 12 pulsation cycles, was obtained during four nights in August 1968, on the 82-inch (208-cm) Struve reflector at McDonald Observatory. Each scan showed about the expected improvement in suppressing the sporadic "flickering," but each was still to some extent distorted by this effect. Twenty-two scans were selected, those made during eclipse and the few which were severely distorted were omitted. The ones selected were carefully aligned in phase and averaged. Figure 1 represents the best measure of the pulsation light curve which can be obtained from our data. The solid line is the best-fitting (in the sense of least squares) sine curve, with amplitude and phase selected by a two-variable differential corrector computer program. The fit is sufficiently good that any deviation from a pure sinusoid amounting to 10 percent or more would almost certainly have been detected. The power of this signal-averaging technique can best be appreciated when it is noted that the curve in Fig. 1 represents a variation of about 2 percent in the total light of this 14th-magnitude star.

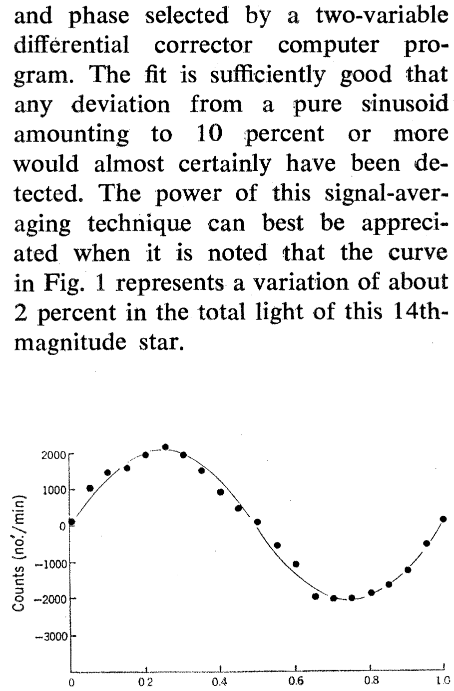

Fig. 1. Light curve obtained by synchronous signal averaging of the 71.1-second pulsations in DQ Herculis.

During the course of our investigation we observed five eclipses of the white dwarf by its companion and found that, in every case, the time of eclipse was later than that predicted by Walker's carefully derived elements for the system. Walker had observed a small discrepancy in this same direction in 1960, amounting to an average of 0.0009 days. By the time of our measurements this discrepancy had grown to 0.00456 days. Walker's measurements in 1960 were made 2224 days after his original epoch for elements, while our measurements were made after 5117 days. If we assume that this discrepancy is due to an error in the original elements, and is accumulating linearly as a result of this error, we can calculate the discrepancy Walker should have observed in 1960. This amounts to 0.0020 days, a value not in agreement with his observation. If the period of the binary system is actually changing linearly with time, however, then the observed phase discrepancy accumulates according to a quadratic formula, slowly at first and then more rapidly. Using our data in this way to compute the value for 1960 gives 0.00086 days, a figure in excellent agreement with Walker's observation.

A lengthening period in a binary system implies a loss of mass from the system, and we can compute the amount of mass lost in a year of this "leakage" as 1.0×10^{-7} solar masses, which must be taken as a lower limit because mass transfer between the components of a binary can shorten the period and mask the loss of mass from the system. It is known that mass transfer occurs in the system, but the amount is not readily determined.

The revised elements for the binary system, which predict the times of eclipse minimums and take into account the changing period, are:

$$T_{\min} = 2434954.94475 + 0.19362070E + 6.529 \times 10^{-12}E^2 \text{ days}$$

where E is the number of eclipse cycles since the original epoch (term 1).

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References and Notes

1. M. F. Walker, *Publ. Astron. Soc. Pac.* **66**, 230 (1954); *Astrophys. J.* **123**, 68 (1956).
2. W. A. Clark, *M.I.T.* (*Mass. Inst. Technol.*) *Res. Lab. Electron. Quart. Prog. Rep.* *114* (1968).
3. M. F. Walker, *Astrophys. J.* **134**, 171 (1961).

24 January 1969

Magnetic Flux-Trapping Experiment with a Moving Conductor

Abstract. *An aluminum conductor moving into and out of a magnetic field of 75 gauss traps within itself for varying lengths of time a detectable fraction of the encountered flux, which subsequently decays. A time constant of about 0.005 second, which is the order of magnitude predicted by classical electrodynamics, is measured. The result is of interest in connection with the "frozen-in field" concept of Babcock's sunspot model.*

All theories of sunspot formation which depend on the nonuniform rotation of the solar photospheric plasma, such as that of Babcock (*1*), use the concept of the "freezing-in" of a magnetic field which occurs detectably in a moving conductor of sufficiently large linear dimensions and conductivity (*2*). Babcock assumes the infinite conductivity of the photospheric plasma; if the conductivity is finite, a diffusion of the field competes with flux-trapping (*3*). The evidence for flux-trapping and diffusion from a controlled laboratory experiment has not been reported as far as I have been able to determine; thus I attempted to detect the flux trapped in a metallic conductor (aluminum) after it had passed between the pole pieces of an electromagnet.

An aluminum disk (38 cm in diameter by 0.63 cm thick) with a conductivity of 3×10^7/ohm-m is rotated between the pole pieces, where the magnetic field is about 75 gauss. Embedded in the disk is a coil of fine wire; the electromotive force induced across the coil by its encounter with, and departure from, the magnetic field is recorded (through slip rings) on a fast-response recorder.

The experiment demonstrates the temporary freezing of a magnetic field in a conductor and also demonstrates the requirement for nonzero conductivity for the effect to occur. In the aluminum sample used, the flux that was trapped decayed in about 5 msec. This value is supported by theoretical considerations.

The data appeared in the form of voltage readings, from the pickup coil, recorded optically on a print-out chart moving at a rate of 64 inch/sec, with a calibration of 0.1615 volt/inch. Representative peaks, which occurred approximately every 0.04 second at a disk rotational speed of about 1500 rev/min, were enlarged ×2 onto graph paper (1/20-inch squared) for analysis.

The physical significance of the areas under the curves may be described as follows. Each curve, generated as the pickup coil passes between the pole pieces, is divisible into a part due to encounter with the flux ϕ and a part due to departure from the flux (Fig. 1). These two sections of the curve display opposite voltage polarity, since the voltage is proportional to $(d\phi/dt)$. Furthermore, the encounter and departure fluxes are equal in the case of a nonconducting Textolite disk used as a control. In the latter case, the symmetrical curve reflects merely the shape and magnitude of the field. In the case of the aluminum disk, the encounter and departure fluxes, proportional to areas between the curves and the time axis, still are equal to within less than 2 percent. However, in this case the curves for the encounter and departure fluxes themselves are not similar. Their asymmetric character—if we neglect the electrical impedance characteristics of the pickup coil circuit—is determined entirely by (i) the flux encountered, as in the control case, (ii) the counterflux generated in the moving aluminum in accordance with Lenz's law, and

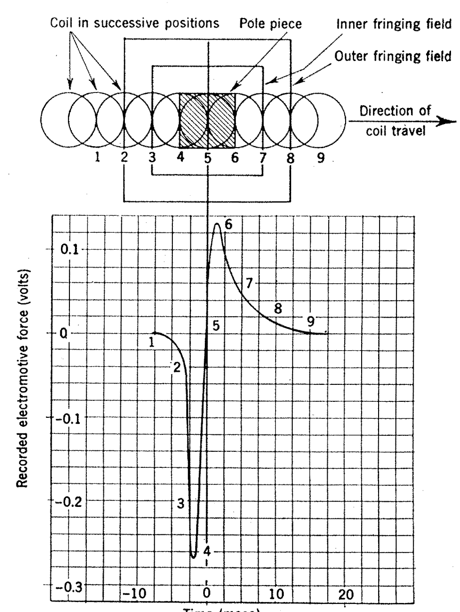

Fig. 1. Coil passing through pole pieces, accompanied by frozen-in field (schematically represented), with corresponding recorded voltage wave form.