Letters to the Editor

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New Researches in Gyromagnetism[1]

S. J. BARNETT

University of California, Los Angeles, California, and California Institute of Technology, Pasadena, California

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AT the Strasbourg *Réunion sur le Magnétisme*,[2] where it devolved upon me to make the report on gyromagnetic phenomena, the President, Professor P. Weiss, said to me: "Your work has now become classical, but it must be extended to more substances and to the same substances in different states; and for this purpose it is necessary to increase the precision. And you are the man that has to do the work." This extensive program was, in fact, already underway, but it is urgent that many others should participate in it. It is difficult because the theoretically important differences between the gyromagnetic ratios are relatively small and the errors which have to be eliminated are seriously large. This investigation constitutes the initial part of the program, and consists of new and completely independent determinations, by means of the effect known as *magnetization by rotation*, or the *Barnett effect*, of the gyromagnetic ratios of a number of ferromagnetic substances. Although it is now certain that the work can be greatly improved after the end of the war, important confirmations of earlier work have already been achieved, and discrepancies have been reduced.

The general method of electromagnetic induction by which the effect involved was discovered in 1914 was used, but with numerous and important modifications. The sensitivity was greatly increased by using two galvanometers, the principal galvanometer acting as a fluxmeter and the other being actuated by it with the help of two photoelectric cells or, in about one-quarter of the work, a Moll relay. In most of the work, including all of that with the photoelectric cells, deflections were closely proportional to flux changes; and only this work is reported in the tables below. The magnetic rotors were identical with, or similar in construction to, those used by S. J. and L. J. H. Barnett in Washington, in magnetometer measurements on the same effect. The sources of error were reinvestigated and were largely eliminated, most of them by processes used in the earlier work. In all the new work the rotors were driven at exactly 60 r.p.sec. by small synchronous motors. In the greater part of the work the rotor axis was horizontal, and the rotor was driven from either end at will. It appears that only by driving from both ends can all of the errors be completely eliminated. In the latest work the axis was vertical, and the rotor was driven from above only. An important improvement consisted in making the sensitivity and gyromagnetic measurements simultaneously.

TABLE I. Gyromagnetic ratios (ρ) from new determinations ($e/m = 1.759$ e.m.u.).

Rotor	No. of sets	$\rho \times e/m$	Rotor	No. of sets	$\rho \times e/m$
Electrolytic iron III	15	1.025 ± 0.012	Cobalt I	16	1.072 ± 0.006
Electrolytic iron IV	12	1.031 ± 0.011			
Norway iron	4	1.028 ± 0.011	Hopkinson's iron-nickel alloy	19	1.019 ± 0.016
Mean for soft iron	31	1.028 ± 0.002	Permalloy	6	1.053 ± 0.006
Steel III	10	1.039 ± 0.008	Cobalt-iron	22	1.029 ± 0.009
			Cobalt-nickel	13	1.080 ± 0.020
Nickel I	17	1.054 ± 0.028	Heusler alloy	21	0.989 ± 0.006

TABLE II. Gyromagnetic ratios (ρ) of ferromagnetic substances. Values of $\rho e/m$ from the three extensive investigations in the author's laboratories ($e/m = 1.759$ e.m.u.).

Material investigated Investigation	Effect	Soft iron	Steel	Nickel	Hiper-nik	Hopk. alloy	Perm-alloy	Cobalt	Cobalt-iron	Cobalt-nickel	Heusler alloy
I	Barnett	1.049	1.047	1.031	—	1.016	1.054	1.070	1.067	1.068	1.011
II	Einstein-de Haas	1.032	1.038	1.051	1.051	1.023	1.046	1.085	1.025	1.076	—
III	Barnett	1.028	1.039	1.054	—	1.019	1.053	1.072	1.029	1.080	0.989
Mean I and III	Barnett	1.038 ±0.010	1.043 ±0.004	1.042 ±0.010	—	1.018 ±0.002	1.054 ±0.000	1.071 ±0.001	1.048 ±0.019	1.074 ±0.006	1.000 ±0.011
Mean of II and mean I and III	Both	1.035 ±0.003	1.040 ±0.002	1.046 ±0.004	—	1.017 ±0.001	1.050 ±0.004	1.078 ±0.007	1.036 ±0.012	1.075 ±0.001	—

The means of the gyromagnetic ratios obtained as indicated above are given in Table I. A *set* consisted of 48 (in some cases 64) observations made in a symmetrical manner and on a strict time schedule.

In Table II these values are compared with those obtained in Washington from an investigation of the same effect but by the magnetometer method, and with those (II) obtained in Pasadena from an elaborate investigation of the converse effect (Einstein-de Haas effect). For the purposes of this table all values for soft iron are combined into one mean, likewise all values for steel, etc.

For I the authors claimed only a mean error for *all the rotors* not greater than 2 percent. It has now long been clear, and the present investigation makes it still clearer, that the mean error for the *individual rotors* in the Washington work is less than this. The values in II are considered by the author the most precise values of the gyromagnetic ratios hitherto obtained, those for Permalloy and soft iron being estimated to be correct to one-half percent or less. In view of the difficulties involved the three investigations agree remarkably well. The large value for soft iron in I is owing to the inclusion of an excessive result for a certain rotor, electrolytic iron II, and is not confirmed by II, as electrolytic iron IV was cut from the same rod, and electrolytic iron III was cut from similar material. The large value for cobalt-iron in I is not confirmed by either II or III.

For important papers on the theory, which, so far as it has yet been developed, is in agreement with such values as are given above. See Gorter and Kahn[3] and C. J. Gorter;[4] also reports by Gorter and Kronig and R. Forrer[5] and the discussions by Kramers and others.[6] See also R. Forrer.[7]

[1] Report of a paper presented by invitation of the American Physical Society at its 1942 Los Angeles meeting. See Proc. Am. Acad. Arts Sci. **75**, No. 5 (August, 1944).
[2] The *Rapports* of this Congress were printed in France by the International Institute of Intellectual Cooperation and the French Central Service for Scientific Research, but their general distribution has hitherto been prevented by the war.
[3] Gorter and Kahn, Physica **7**, 753 (1940).
[4] C. J. Gorter, Phys. Rev. **60**, 836 (1941).
[5] Gorter and Kronig and R. Forrer, Strasbourg Réunion (1939); see also reference 2.
[6] Kramers *et al.*, see reference 2.
[7] R. Forrer, Comptes rendus **207**, 1390 (1938).

A Strong Infra-Red Radiation from Molecular Nitrogen in the Night Sky

JOEL STEBBINS, A. E. WHITFORD, AND P. SWINGS
Carnegie Institution of Washington, Mount Wilson Observatory, Pasadena, California

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SOME four years ago, in the course of photoelectric measures of the colors of stars and nebulae, Stebbins and Whitford found an intense infra-red radiation from the night sky which is scores of, if not a hundred, times as strong as the ordinary persistent auroral line at 5577A. That the new radiation must come from the atmosphere was shown by its variation with zenith distance, by its usual progressive decrease through the night, and by its variability from night to night and from season to season.

Renewed interest was awakened on July 20, 1944 when the radiation was doubly strong and was varying rapidly, as much as 10 or 15 percent in five minutes. No marked magnetic disturbance occurred on that night. It was then suggested by Swings that the radiation was undoubtedly molecular in origin and very likely could be traced to the (0,0) band of nitrogen at about 10,450A.

With this suggestion as a guide the wave-length was determined with the photo-cell and various thicknesses of a glass filter with a steep gradient in the transmission curve across 10,000A. The filters were readily calibrated in the first-order solar spectrum of the 75-foot grating of the 150-foot tower telescope on Mount Wilson.

From accordant measures of the sky on several nights the following values were obtained:

From 1 filter, 10,427A, weight 1;
From 2 filters, 10,452A, weight 2;
Mean 10,444A±10A.

The assigned probable error does not allow for other nearby lines or bands, but the main radiation is so strong compared with everything else in the whole range from 3500A to 12,000A that probably no other radiation is effective.

The only possible identifications that suggest themselves for this night sky emission are:

(a) the forbidden $^2D-^2P$ multiplet of *NI*, λ10,407.3 −λ10,397.8;
(b) the (0,0) band of the first positive group of N_2.

The [*NI*] lines do not provide a satisfactory identification. Their mean wave-length λ10,403 is definitely shorter than that of the observed infra-red radiation. Moreover, their total intensity should only be 49 times that of the $^4S-^2P$ line at λ3466.4 which is absent from or hardly visible in the night sky. Hence the [*NI*] lines could not account for the intense radiation observed.

If emitted in the upper atmosphere, the (0,0) band of N_2 should have its intensity maximum somewhere near λ10,450. Failure to observe other strong N_2 bands indicates in the night sky a mechanism enhancing the (0,0) band relative to the other vibrational transitions. It is suggested that during the night N_2 molecules are brought in the level $v'=0$ of the $B^3\pi_g$ state in three-body recombinations $N+N+N_2 \rightarrow N_2+N_2^{exc}$.

The nitrogen atoms would be formed during the day through photo-dissociation of N_2 by solar radiation. The suggested mechanism can be considered only for the value $D(N_2)=7.38$ v of the heat of dissociation of N_2 which agrees almost exactly with that of the $v'=0$ level of the $B^3\pi_g$ electronic state. In fact, the energy $D=7.38$ v is just a little larger than $B^3\pi$, $v'=0$, but smaller than $B^3\pi$, $v'=1$.

This mechanism, which is similar to that suggested by Chapman for the [*OI*] night sky emission, implies the presence of a fairly large number of nitrogen atoms in the upper atmosphere. Although the photo-dissociation of N_2 by solar radiation is usually considered as very weak compared to that of O_2 it is by no means negligible. This question has been considered recently by Ta-You Wu.[1] To