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LETTER TO THE EDITOR

Observation of magnetic monopoles in the field of a line conductor with a current

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Abstract. It has been established that some ferromagnetic aerosol particles when exposed to a high-intensity light beam move in the magnetic field of the direct current along coaxial trajectories with respect to the current. Such a character of the motion indicates that these particles carry magnetic monopoles.

The submicron size particles produced during the electro-erosion dusting of a ferromagnetic in an argon medium can acquire a non-zero magnetic moment $\boldsymbol{P}$ due to spontaneous magnetisation. The magnetic field $\boldsymbol{H}$ of a line current $\boldsymbol{I}$ acts on such a particle with the force

$$\boldsymbol{F}_{\mathrm{d}}=\frac{2}{cR^2}[\boldsymbol{IP}]. \tag{1}$$

The force direction at a given $\boldsymbol{I}$ is determined by the spatial direction of the vector $\boldsymbol{P}$.

The magnetic field of the current of the infinite conductor is

$$\boldsymbol{H}=\frac{2}{cR^2}[\boldsymbol{IR}]. \tag{2}$$

The magnetic moment of the free particle will obviously be oriented in the direction of the strength vector $\boldsymbol{H}$ and thus the force $\boldsymbol{F}_{\mathrm{d}}$ will be directed to the conductor axis.

If a particle moves in a gas by the Stokes' law, its movement occurs with constant velocity, the direction of which at any moment coincides with that of the outside force. Therefore the particles possessing the magnetic moment should move in the field of the line-constant current from the periphery to the conductor axis.

It is not difficult to show that the interaction of the field $\boldsymbol{H}$ with higher-order multipoles will also cause the radial movement of the particle. In this case the force of interaction is known to decrease as $1/R^{1+n}$ where n is the order of multipolarity. Therefore, the contribution of a term with $n>1$ will be negligible.

It should be noted that the picture described does not depend on whether a particle is in the light flux or not.

However, as has been reported earlier (Mikhailov 1983) some particles of the ferromagnetic being illuminated behave in the uniform magnetic field as the objects carrying the magnetic charge $\pm G$. In the line conductor field such particles will be acted on by a force

$$F_M = \pm \frac{2G}{cR^2}[IR] \tag{3}$$

and their trajectories should coincide with the arc of a circle of radius R. In this case the equation of the particle's motion can be written as

$$M\frac{d^2R}{dt^2} + k\frac{dR}{dt} = \frac{2G}{cR^2}[IR] \tag{4}$$

where $\boldsymbol{R}$ is the particle's radius vector originated from the current axis, k is the friction coefficient and M is the particle mass. For a Stokes' character of motion of the spherical particle of radius r we get $k/m \sim 1/r^2$, i.e. for $r \sim 10^{-6}$ cm $k \gg M$ (Mikhailov and Mikhailova 1985).

Then from (4) for stationary conditions we have

$$\omega = \frac{2GI}{kcR^2} \qquad R = \text{constant} \tag{5}$$

i.e. the particle should move with angular velocity ω along the circle with a constant independent of the time radius R.

The purpose of this work is to check the correspondence of the last statement with the experimental results.

The objects of our investigation are magnetite aerosols produced in iron dusting (Mikhailov and Mikhailova 1985). The scheme of the experiment is shown in figure 1. The curent $\boldsymbol{I}$ running in the conductor 1 perpendicular to the figure plane produces the magnetic field $\boldsymbol{H}$. Aerosol particles weighed in the gaseous atmosphere are injected in the vicinity of the conductor. The beam of the He–Ne laser with wavelength $\lambda = 6328$ Å and approximately 200 mW power is perpendicular to the conductor axis. The transverse cross section of the outline 2 is exposed to the beam in the figure. After passing the focusing installation the light flux density in the region of observation is

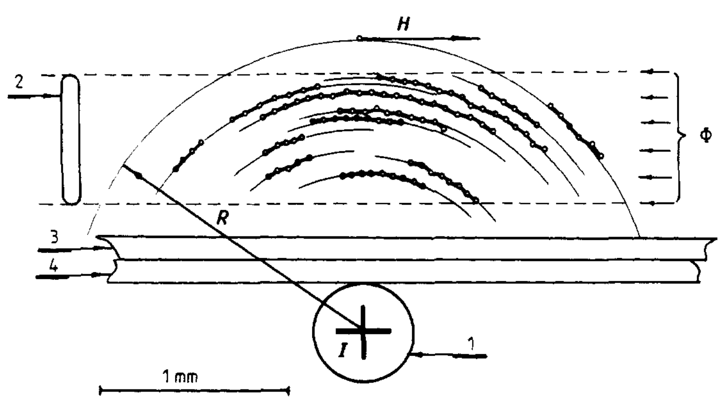

Figure 1. The particles' trajectories in the magnetic field of the line current. 1 is the conductor with a current $\boldsymbol{I}$ perpendicular to the figure plane, 2 is the cross section of the light beam, 3–4 is the thermal screen (3 is copper, 4 is glass). The clockwise and counter-clockwise motion of the particles is equally probable.

about 300 W cm^{-2}. To prevent the convection fluxes in the gas arising due to heating of the conductor by a current, the region of observation is isolated from the conductor by the thermal screen 3–4.

The details of the installation's construction and the procedure for the production and observation of aerosol particles were presented in an earlier article (Mikhailov 1983).

The figure shows the trajectories of twelve particles moving along the magnetic field force lines, the current in the conductor being $I = 10$ A. We present the information taken from three microphotographs of particle tracks obtained with an exposure of about 10 s. In the photographs the trajectories of the particles interestingly represent the arcs which are clearly seen at the background of a large number of particles, executing ordinary Brownian motion and insensitive to the magnetic field. The observed length of the particle trajectory is determined by the time of its stay in the light beam. The Brownian motion makes the particle leave the beam in the direction perpendicular to the figure plane. The track coordinates are measured by an optical microscope with 50× magnification. The point dimension in the figure characterises the measurement accuracy.

It follows from the experiment that the motion of the particles in the magnetic field is well described by an equation of type (4), i.e. the interaction of observed objects with the magnetic field is of pure monopole nature.

The absence of a visible radial particle shift can be understood from the following. The ratio of the forces acting on the particle can be written as (see equations (1) and (2))

$$F_d/F_M = P/GR. \tag{6}$$

The magnetic moment P of a one-domain particle can be expressed in terms of the saturation induction B_s and the volume. Replacing in (6) the values of forces by the proportional lengths of the radial S_r and transversal S_t paths passed during the same time we obtain

$$S_r/S_t = B_s r^3/3GR \tag{7}$$

where r is the radius of the observed particle.

Substituting into (7) the mean values of particle parameters $B_s \sim 10^{-3}$ G, $r \sim 10^{-6}$ cm (Mikhailov and Mikhailova 1985) and the value of the charge $G = 5.8 \times 10^{-13}$ G cm^2 obtained in (Mikhailov 1983) for $R \sim 10^{-1}$ cm

$$S_r \sim 10^{-2} S_t. \tag{8}$$

This value is comparable with the measurement errors and is consistent with the results presented in figure 1. The last remark cannot be considered as the main result of this work. Nevertheless, it once again indirectly acknowledges the correctness of the magnetic charge value determined earlier (Mikhailov 1983) by another technique.

From the above we can conclude that the particle in the magnetic field being exposed to light of high intensity is acted on by a force identical to that which would arise in the case of interaction of the magnetic monopole with a field. This statement necessarily leads us to a conclusion that the phenomenon observed is caused by magnetic monopoles forming in the presence of light flux coupled systems with aerosol particles of ferromagnetics (Mikhailov 1984).

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