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Mikhailov's Experiments on Detection of Magnetic Charge

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In a reanalysis of Mikhailov's experiments, it is argued that observations of magnetic charge $g=(1/2)(1/137)(1/3)e$ on ferromagnetic aerosols are incorrect. Future experiments of the type conducted by Mikhailov must take into an account the component of particle velocity orthogonal to **E** and **H**. It is shown that Mikhailov's data are consistent with the existence of a Dirac unit of magnetic charge $g=(137/2)e$ found in meson spectroscopy.

1. INTRODUCTION

The search for the magnetic monopole has been quite extensive over the years since Dirac (1931) first postulated its existence. In a review article, Cabrera and Trower (1983) tabulated the experiments conducted to find magnetic monopoles. Recently, Mikhailov (1983, 1985) reported evidence for magnetic charge on ferromagnetic aerosols. Moreover, Akers (1986, 1987) found evidence from meson spectroscopy to support the existence of a Dirac magnetic monopole with mass $M=2397$ MeV and with Dirac charge $g=(137/2)e$. Mikhailov (1983) studied 1198 ferromagnetic particles for the observation of magnetic charge. In his analysis, Mikhailov finds evidence for magnetic charge that is a multiple of $g=(1/2)(1/137)(1/3)e$.

In this paper, I discuss the results of Mikhailov's experiments and argue that his analysis is incorrect. In Section 2 a reinterpretation of Mikhailov's results is presented. Concluding remarks are made in Section 3.

2. REANALYSIS OF MIKHAILOV'S EXPERIMENT

In a repeat of an experiment by Ehrenhaft (1930), Mikhailov (1983) claims to have observed evidence of magnetic charge on ferromagnetic

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aerosols. The details of the experimental apparatus can be found in Mikhailov's paper and will not be repeated here. Mikhailov photographed and measured 1198 tracks of ferromagnetic particles placed in an electromagnetic field with **E** and **H** orthogonal to each other. The velocities $\mathbf{v}_E$ and $\mathbf{v}_H$ along their respective fields were measured for each aerosol particle. Particle-velocity distributions were measured for each value of E/H. Mikhailov was able to derive an expression for g/e as a function of E/H and v_E/v_H from the forces acting on the aerosols:

$$\mathbf{F}_E = k\mathbf{v}_E = e\mathbf{E}, \qquad \mathbf{F}_H = k\mathbf{v}_H = g\mathbf{H} \tag{1}$$

The expressions (1) used by Mikhailov are incorrect, because there are additional terms as suggested by Blaha (1949):

$$\mathbf{F}_E = e\mathbf{E} + f(\varepsilon, K)\nabla(E^2), \qquad \mathbf{F}_H = g\mathbf{H} + f(\mu, K)\nabla(H^2) \tag{2}$$

The function $f(\varepsilon, K)$ depends on the dielectric constant ε and the shape K of the aerosol particle, and $f(\mu, K)$ depends upon the magnetic permeability and the particle's shape. In addition, dipole interactions have to be taken into account for $\mathbf{F}_H$ in equation (2). Therefore, Mikhailov's derivation for g/e from the ratio of terms in equation (1) is not valid, and he incorrectly finds a magnetic charge that is a multiple of $g = (1/2)(1/137)(1/3)e$.

From the fact that Mikhailov uses the most probable values of $\mathbf{v}_{E_0}$ and $\mathbf{v}_{H_0}$ as determined from particle-velocity distributions, we know that the aerosols are accelerated in the applied fields **E** and **H**. Furthermore, there must be a velocity component orthogonal to both **E** and **H**. Mikhailov (1983) does not report how he dealt with this problem.

I wish to consider the forces acting on the aerosols by imposing a coordinate system on the fields: let **E** act along the y direction and **H** in the z direction. For an aerosol particle carrying electric charge e, the forces are

$$\begin{aligned} \mathbf{F}_x &= e\mathbf{v}_E \times \mathbf{H} \\ \mathbf{F}_y &= M\dot{\mathbf{v}}_E = e\mathbf{E} \\ \mathbf{F}_z &= 0 \end{aligned} \tag{3}$$

where M is the mass of the aerosol particle and $\mathbf{v}_E$ is its velocity along the y axis. By analogy, if the aerosol carries a magnetic charge g, then the forces are

$$\begin{aligned} \mathbf{F}_x &= g\mathbf{v}_H \times \mathbf{E} \\ \mathbf{F}_y &= 0 \\ \mathbf{F}_z &= M\dot{\mathbf{v}}_H = g\mathbf{H} \end{aligned} \tag{4}$$

If there were no velocity component $\mathbf{v}_x$ along the x axis (orthogonal to **E** and **H**), then the forces $\mathbf{F}_x$ in equations (3) and (4) would be equal and opposite for an aerosol particle carrying *both* electric and magnetic charges:

$$g\mathbf{v}_H \times \mathbf{E} = e\mathbf{v}_E \times \mathbf{H} \tag{5}$$

Since the velocities and fields are orthogonal, we have

$$g/e = (v_E/v_H)H/E \tag{6}$$

We can now determine g/e from Mikhailov's data; our analysis is shown in Table I. Mikhailov measured 1198 candidates for electric and magnetic charges. The first column of Table 1 shows the number of particles for each measured value of H/E and of v_E/v_H. The measured value of v_E/v_H is defined for the most probable velocities $\mathbf{v}_{E_0}$ and $\mathbf{v}_{H_0}$ from the velocity distributions (Mikhailov, 1983). The fourth column, for g/e, is the product of H/E and v_E/v_H. If the aerosols carry a Dirac charge of $g=(137/2)e$, then any additional charge must be a multiple of $g/e=68.5$. By dividing the fourth column for g/e by the Dirac unit of 68.5, we have the number Z of magnetic charges on each aerosol particle. This is shown in column five of Table I.

The first row of 328 candidates shows a $Z=1.13$ or ~ 1. The second row indicates a $Z=1.8$ or ~ 2. The fourth row shows a $Z=3$. The third row has a value $Z=1.5$. A reason for this value is that there is a possible velocity component $\mathbf{v}_x$ orthogonal to **E** and **H**. Hence, equation (5) would not be valid in that case, because the forces $\mathbf{F}_x$ are not balanced for this series of particles.[2]

Criticism of our analysis can follow the same lines as that for Mikhailov's analysis. There can be gradient terms such as $f(\varepsilon, K)\,\nabla(E^2)$ and $f(\mu, K)\,\nabla(H^2)$ for expressions (3) and (4). Magnetic dipole interactions

Table I. Analysis of Mikhailov's Data[a]

N	H/E^b	$v_E/v_H{}^b$	g/e^c	Z^c
328	59.9	1.29	77.3	1.13 ~ 1
270	78.7	1.59	125.5	1.8 ~ 2
285	99.0	1.06	105.2	1.5
315	208.3	0.96	202.4	2.96 ~ 3

[a] N is the number of particles in a series.
[b] Mikhailov's data.
[c] Present analysis.

[2] A more reasonable explanation is that the series of 285 particles carried three Dirac units of magnetic charge and two units of electric charge, such that $G/C = 3g/2e = 1.5(g/e)$ or $Z = 1.5$ in Table 1.

should be considered as well in equation (4). However, the cross products for $\mathbf{F}_x$ in (3) and (4) are still valid, provided the dipole terms are small. Hence, equation (5) is valid when there is no velocity component $\mathbf{v}_x$ orthogonal to **E** and **H**.

3. CONCLUSION

Mikhailov's experiment on the detection of magnetic charge can be reconciled with the evidence for a Dirac magnetic monopole from meson spectroscopy. Our analysis of Mikhailov's data involves studying the cross products of the particle velocities with their respective fields. We show that Mikhailov's data are consistent with the existence of a Dirac unit of magnetic charge $g = (137/2)e$. Future experiments of the type conducted by Mikhailov must take into an account the component of particle velocity orthogonal to the fields. The present experiment by Mikhailov does not consider this component. Also, velocity directions ($\mathbf{v}_E$ and $\mathbf{v}_H$) must be reported to determine the sign on Z in Table I. Moreover, it would be of interest to see how v_E/v_H varies as a function of temperature.

In a related experiment, Mikhailov (1985) studied the trajectories of ferromagnetic aerosols and claimed that their character indicates the presence of magnetic charge. Mikhailov has informed me that his experiments are being reproduced by colleagues in the USSR. I would like to see his work reproduced elsewhere as well.

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