Gravitational Magnetism: an Update

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Abstract

Gravitational magnetism (or the Blackett effect) is the generation of a magnetic field by an electrically neutral rotating mass, whose magnitude is determined by analogy with the magnetic field generated by a rotating electric charge. Since 1947, there is increasing evidence for this effect by the measurements of the magnetic fields of the solar planets, the sun, other stars, and even pulsars, as well as the galactic magnetic field. However, the attempt to measure this effect in the laboratory depends on the ability to measure extremely weak magnetic fields and the shielding of extraneous magnetic fields. Early attempts to measure this effect in the laboratory depended on ad hoc extensions of the simple rotational version of gravitational magnetism. Recently there have been more sophisticated laboratory approaches. Also the extended observational evidence has generated a plethora of theoretical attempts to derive the Blackett equation in a larger context. Of particular interest is the work of R.I. Gray, who performed an advanced version of Blackett's static experiment, and also related the Blackett effect to several other theoretical and empirical relations particularly the Wesson effect--the constancy of the ratio of spin to mass-squared for planetary, stellar, and galactic bodies. Pauli's anomalous magnetic moment (as a Blackett effect) is also considered as a bridge to the gravitomagnetic field generated by superconductors.

The Early Work: 1912 - 1979

In 1912 Arthur Schuster[1], in discussing "the possible causes of terrestrial magnetism," made the very tentative hypothesis: "If magnetisation and rotation go together, the sun and the planets would all be magnetic." Here presumably mass in rotation would play the role analogous to that of charge in rotation. Schuster's speculation was tested experimentally by Wilson[2] and by Swann and Longacre[3]. However, these tests were not tests of the straightforward analogy suggested by Schuster. This situation was reviewed by P.M.S. Blackett[4] in 1947, when he showed that the ratio of magnetic moment P to angular momentum U for the earth, the sun and the newly measured star 78-Virginis was a close fit to the simple formula:

$$\frac{P}{U} = \beta\frac{\sqrt{G}}{2c} \text{ (in emu);} \qquad \frac{P}{U} = \beta\frac{\sqrt{G}}{2\sqrt{k}} \text{ (in SI units).}$$

Where G is Newton's constant, c is the speed of light, and β is a "form factor" which should be close to1. Note that this equation is usually written in Gaussian electromagnetic units, where the Coulomb constant is c^2. But I have rewritten it in SI units where k is the Coulomb constant, to make the parallelism more clear. The consequences of this equation are called the Blackett effect, although for historical reasons it is also called the Schuster law, or the Schuster-Blackett law, or the Wilson-Blackett law.

[**Note well**: in my 1979 paper[5], I called the consequences of the Blackett equation the Blackett effect and also the gravi-magnetic effect. And other papers have followed this "gravi-magnetic" nomenclature. However, in 1984 a paper was published[6], which used the term "gravitomagnetic field" to describe (by analogy with Maxwell's equations) the purely gravitational field, one of whose consequences is the well known Lense-Thirring ("frame dragging") effect. Since then, the term "gravitomagnetism" has become standard. (See especially reference 7: Ciufolini & Wheeler.) Therefore, I will use only the term Blackett effect; and will drop the use of "gravi-magnetism" to avoid confusion with the term "gravitomagnetism."]

It is widely believed[8, 9] that Blackett did a laboratory experiment which ruled out this equation. However, his huge experimental paper[10] described a static test in which a 15-kg gold cylinder at rest was presumed to pick up an induced current (producing a small, but measurable, magnetic field) from the rotation of the earth.

In my 1979 paper[5] "Gravitational Magnetism" I pointed out that the Blackett effect had yet to be definitively tested in the laboratory. Also I compiled the data from several newly measured astronomical bodies, which was a near fit to the Blackett equation. Thus I proposed that a fresh attempt be made using the latest magnetic field detectors (SQUID-magnetometers) to test the simple rotational version of this equation.

The trend line of the data for P/U (magnetic moment versus angular momentum) was fairly systematically offset from the prediction line, where β is set to 1, so that the offset is indicated by the average β. Of course, there would also be electrical-magnetic effects in many of the astronomical bodies, so that these electrical “dynamo” and other effects serve to dampen somewhat the primary Blackett effect. This idea is supported by the fact that Mercury provides the datum point closest to the prediction line. Because of Mercury’s slow rotation rate and small size, it was presumed that Mercury had no magnetic field. When Mariner 10, which was equipped with a magnetometer to measure the magnetic field of Venus, also measured a magnetic dipole field on Mercury, it was a great surprise[11].

The only datum point to fall far short of the Blackett prediction line is Mars. This may indicate that we are seeing Mars when the interaction between its primary (Blackett) field is being pumped down by its interaction with the electrical “dynamo” field. Here I should mention that Surdin[12] has proposed a formula (based on stochastic electrodynamics, SED) similar to the Blackett effect in which polar flipping is to be expected. He has suggested that Mars is presently being viewed in process of changing polarity. Surdin[13] has also done an experiment in which he claims to have measured the rapid changes of polarity of an electrically neutral rotating body. The measurement depends on signal autocorrelation, and various possible “parasitic” effects have to be ruled out. This very intriguing experiment needs to be repeated.

Post 1979 Work

The most straightforward test of the Blackett equation would be to measure directly the magnetic field of a rotating neutral body (which is not also a ferromagnetic substance). Blackett[4,10] suggested that a 1-meter bronze sphere spun at 100 Hz would do nicely, except that this is the maximum safe speed, and there are severe problems in nulling out extraneous magnetic fields. With modern SQUIDs and mu-metal shielded rooms, such an experiment can be attempted. Exactly such an experimental design[14] was described at the SQUID ‘85 conference in Berlin. However, the results of this experiment have not been published.

Another experimental result is not widely known because it is described in the book, *Unified Physics,* by R.I. Gray[15]. He found the simple rotational version of the Blackett effect experiment too difficult, so he carried out an improved version of Blackett’s static experiment with positive results. Gray also found an intriguing relationship between the Blackett effect and the somewhat analogous effect described by Wesson[16], in which the ratio of angular momentum to the square of the mass of astronomical bodies remains fairly constant over the vast range of planetary bodies to galactic clusters. If “fairly constant” can be idealized to “constant”, these two effects can be compared, in this pristine form, as follows (and note that Blackett’s symbols for magnetic moment P and angular momentum U have been replaced by μ and J, to make the relationships clear):

The Blackett constant $$b = \frac{\mu}{J}$$ can be written as: $$b = \frac{\sqrt{G}}{2c}$$

The Wesson constant $$w = \frac{J}{M^2}$$ can be written as: $$w = \frac{137G}{2c}$$

(where Gaussian units have been used; and where G is the gravitational constant, c is the speed of light and 137 is the inverse of the fine structure constant α). This suggests various relationships between b and w, such as:

$$\frac{w}{b^2} = \frac{2c}{\alpha} \quad \text{and} \quad \frac{b}{w} = \frac{\alpha}{\sqrt{G}}$$

The fundamental nature of such relationships hints at deep connections between the microscopic world and the macroscopic world of astronomical objects, on which both the Blackett effect and the Wesson effect are based. Blackett himself[4] was motivated by the possibility of finding a connection between macroscopic physics and microscopic physics. Gray[15] has pushed this relationship much further. Jack Sarfatti (in these proceedings) has extended Gray’s ideas to black-hole physics and the Planck-scale world, in which there is a mass-scale duality (as in M-theory) between the Wesson and Blackett effects.

M-theory is a generalization of superstring theory, which is based on a fundamental Wesson-like parameter. As Abdus Salam[17] puts it:

“A closed string is a loop which replaces a spacetime point. Its quantum oscillations correspond to particles of higher spins and higher masses, which may be arranged on a linear trajectory in a spin-versus-mass^2 (Regge) plot. If the slope parameter of this trajectory – the only parameter in the theory – is adjusted to equal the Newtonian gravitational constant, one can show, quite miraculously, that in the zeroth order of the closed bosonic string there emerges from the string theory Einstein’s gravity in its fullness! (The higher orders give modifications to Einstein’s theory with corrections which have a range of Planck length = 10^{-33} cm.)”

Note that here, Salam is using units in which c is set to 1, so that the J/m^2 Regge plot is being “adjusted” to G/c, which is essentially the Wesson constant 137G/2c for the J/m^2 of astronomical objects.

Peter Brosche[18] has also analyzed the “mass-angular momentum diagram of astronomical objects” and his work (as well as Wesson’s) was compared to the Blackett effect by V. De Sabbata and M. Gasperini[19]. This analysis was continued in the book by De Sabbata and C. Sivaram[20], *Spin and Torsion in Gravitation.* Here torsion is described in the standard way of Cartan as “the antisymmetric part of an asymmetric affine connection.” However, in this context, they push torsion beyond the formalism of the Einstein-Cartan theory, where (usually) torsion is minimally coupled to spin and cannot propagate.

Nonminimal coupling of electromagnetism and gravitation is implicit in the Blackett effect, as is argued by James F. Woodward[21], who devotes most of his paper to an attempt to use 100 pulsars as data points to provide evidence for the Blackett effect. He finds that the Blackett “form factor” β must evolve somewhat over the lifetimes of pulsars. This may indicate that there is some peculiar aspect of pulsars not yet understood.

Perhaps the most sophisticated approach to the Blackett effect is that of A.O. Barut and Thomas Gornitz.[22] Here the concept of magnetic moment is analyzed in the context of 5-dimensional Kaluza-Klein theories of unification of gravity with electromagnetism. In particular, Pauli’s (1933)[23] papers on spin in 4-d projective space (with 5 homogenous coordinates) are reviewed. In addition to the usual K-K type minimal coupling of gravity and electromagnetism, Pauli found an anomalous coupling to the electromagnetic field, in which the ratio of the anomalous magnetic moment to the spin of an elementary particle is

$$\frac{\sqrt{G}}{c}.$$

Thus Pauli says: “from the extra term it can be concluded that electrically neutral masses with a nonzero spin moment must have a small magnetic moment (which is with respect to the problem of the earth’s magnetism not without interest).” Barut and Gornitz suggest that in a macroscopic body each elementary particle will have an anomalous magnetic moment equal to the spin S multiplied by

$$\frac{\sqrt{G}}{c}$$

Thus in a rotating macroscopic object, magnetic moment will accumulate and rise to the Blackett magnetic moment:

$$\mu = \beta \frac{\sqrt{G}}{c} J \quad .$$

In this picture, the accumulation of elementary spin magnetic moments is due to the fact that elementary spins are really orbital angular momenta in the 5th dimension. Thus they say: “In conventional gravitational theories it seems to be difficult to understand a relationship of the type [Blackett’s equation] without going to the fifth dimension.”

If the idea that spins (and therefore the anomalous Pauli magnetic moments) can accumulate via rotation of macroscopic bodies is correct, then there may be a relationship between the Blackett effect and the gravitomagnetic field.

Readers who have heeded the “Note well” caveat near the beginning of this paper, will remember that the gravitomagnetic field is quite different from the Blackett- effect magnetic field, which I called the gravi-magnetic field in 1979. The gravitomagnetic field is not a magnetic field but a gravitational analog by way of writing the equations of general relativity in the form of Maxwell-like vector equations.

The bridge between the Blackett-effect magnetic field and the gravitomagnetic field might be built by way of the work of Ning Li and David Torr[24,25,26]. The key idea seems to be that, although ordinarily, the gravitomagnetic (and electrogravitic) fields are too small to measure, the alignment of spins in the lattice ions of superconductors, make the gravitomagnetic field much larger (by 11 orders of magnitude) than the magnetic field. As we have seen, according to the Barut-Gornitz picture, the rotation of a macroscopic body will accumulate (and thus magnify) the tiny anomalous magnetic moments associated with elementary spins. It would now seem that superconductivity is another way for anomalous magnetic moments to accumulate by the alignment of spins. This accumulation of anomalous magnetic moment would have the same form as the Blackett effect.

According to Torr and Li[26], “It is shown that the coherent alignment of lattice ion spins will generate a detectable gravitomagnetic field, and in the presence of a time-dependent applied magnetic vector potential field, a detectable gravitoelectric field.” It would seem that the Blackett effect may well be entailed in these superconductors via the lattice ion spin analog to the Pauli-Barut-Gornitz rotational mechanism. Some possible technological consequences of work of Li and Torr are described in references 27 & 28.

I have listed additional references, 29-35, to the Blackett effect. See especially reference 35, where the Blackett effect is (like the Wesson effect) extended to galactic and intergalactic structures. As Opher and Wichoski say (in Ref. 35):

> “As far as we know, cosmic magnetic fields pervade the Universe.”

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