Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory

Title

BARTON MAGNETIC MOMENTS FROM TOPOLOGICAL THEORY

Permalink

<https://escholarship.org/uc/item/7ms4w8jd>

Author

Chew, G.F.

Publication Date

1981-04-01

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Physics, Computer Science & Mathematics Division

Submitted for publication

BARYON MAGNETIC MOMENTS FROM TOPOLOGICAL THEORY

G.F. Chew and J. Finkelstein

April 1981

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

BARYON MAGNETIC MOMENTS FROM TOPOLOGICAL THEORY*

G. F. Chew

Lawrence Berkeley Laboratory

and

Department of Physics
University of California,
Berkeley, California 94720

and

J. Finkelstein**

Department of Physics,
San Jose State University,
San Jose, California 95192

An early quark-model success was the qualitative explanation of baryon magnetic-moment ratios,^[1] although later it became appreciated that the predicted ratios do not agree quantitatively with the naive quark model.^[2] Recently there has been proposed a new theory of hadron electromagnetic properties^[3] which extends the dual topological theory of strong interactions.^[4] This theory bears some similarity to the quark model, but there are important differences which radically affect the magnetic moment picture: Topological "quarks" carry integral rather than fractional charge and do not individually carry momentum; part of a baryon charge resides not in quarks but in a "core". The entire spin content of a baryon nevertheless is carried by topological quarks. In this note we report a preliminary calculation of baryon magnetic moments based on the theory of Ref. [3].

* This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U. S. Department of Energy under Contract No. W-7405-ENG-48.

** Participating guest at Lawrence Berkeley Laboratory.

In the latter theory electromagnetic amplitudes consist of an infinite sum of terms of increasing topological complexity. The first term in the expansion (the analogue of the "planar" component of meson strong-interaction dual topological models^[5]) has been called the "minimum entropy" component, and all successive terms are in principle calculable once minimum-entropy terms are prescribed. We present here the minimum-entropy contribution to baryon magnetic moments, together with an estimate of the higher-entropy contributions.

Minimum-entropy amplitudes have the spin-flavor structure expected from a constituent model. The baryon constituents are three integrally-charged spin- $\frac{1}{2}$ topological objects which we call "quarks" and a spin-zero object carrying electric charge -1 which we call a "core". The spin-flavor wave functions of the quarks in a baryon are the same in topological theory as in the standard fractional-charge model; the proton, for example, consists of 2 u quarks each of charge +1, one d quark of charge 0 and a core of charge -1. These "constituents" however, do not carry energy or momentum.

Calculation of the minimum-entropy contribution to hadron magnetic moments is simple. The core, being spinless, does not contribute. A quark of charge q and spin vector $\vec{\sigma}$ in the baryon rest frame contributes $\frac{q}{2m_0} \vec{\sigma}$ to the magnetic moment; here m_0 is the "zero-entropy" hadron mass, reflecting the absence in topological theory of any "quark-mass" notion. Although m_0 is not equal to any physical hadron mass, it is supposed that m_0 approximates the mass of low-mass "elementary" hadrons such as the nucleon and the p

meson.* Given a value for m_0 together with the above expression for a topological quark magnetic moment, it is straightforward to compute the values (not just the ratios) of hadron magnetic moments. For the proton this calculation gives $4/3$ in units of $\frac{e}{2m_0}$ while for the neutron it gives $-\frac{1}{3}$. These values appear in the last column of Table I together with the corresponding values for other members of the baryon octet. (The topological strange quark has zero charge.) Measured baryon magnetic-moment values, in units of $\frac{e}{2m_p}$ where m_p is the proton mass, are given in the first column.

It is seen that, even allowing for some difference between m_0 and m_p , the agreement of minimum entropy with experiment is not close, although the order of magnitude and general trend are correct. This circumstance is not surprising because the magnetic-moment interaction vanishes at $q = 0$ ($p_\perp = 0$) and the topological expansion depends for its convergence on phase coherence associated with low momentum transfer. Low- $p_\perp$ electromagnetic interactions are dominated by the electric charge (correctly given by minimum entropy), with the magnetic-moment contribution being a small correction.

As it becomes better understood how to calculate higher-order contributions from the topological expansion, it may be hoped that the agreement between magnetic-moment measurements and topological-theory prediction will systematically improve. For the present we propose the following estimate of these contributions: At minimum

* The physical π -meson mass is believed to be substantially smaller than m_0 because of unusually-large higher-order contributions from the topological expansion.

entropy "elementary" hadrons have "intrinsic" magnetic moments, such as listed in the last column of the table; there is no electromagnetic structure corresponding to an "anomalous" magnetic moment. Anomalous moments of physical hadrons correspond to higher entropy. Since topological theory is founded on analyticity properties of the S matrix, it is plausible to estimate anomalous moments through the "classical" analytic S-matrix approach of assuming dominance in electromagnetic structure functions by lowest-mass singularities. For the proton and neutron this is well known to mean the 2π channel in the sense of Fig. 1(a). It is important to appreciate that the topological expansion classifies such a contribution as being of higher order. The intrinsic "elementary proton" moment of $\frac{4}{3} \frac{e}{2m_0}$ is separate and distinct from such contributions--whose topological complexity prevents contraction to the topology of minimum entropy.^[3] (The foregoing statements do not preclude a vanishing at large q^2 of the physical proton electromagnetic form factors.)

The $\pi\pi p$ vertex in Fig. 1(a) can be approximated, according to duality, either by a ρ pole in the $p\bar{p}$ channel or by a baryon pole in the πp channel. We are interested in the neighborhood of zero photon momentum, and the latter approximation turns out to be more appropriate, corresponding to Fig. 1(b). In the "classical" spirit of low-energy dominance we here do not include the Δ pole. That is, we think of the most probable proton "structure" as arising from its dissociation into the "nearest" communicating channel--a neutron plus a π^+ --with the π^+ then absorbing the photon. The measured value of the $p \rightarrow n\pi^+$ coupling constant leads to a proton magnetic moment contribution of $1.67 \frac{e}{2m_p}$, as was

computed long ago.^[6] This number we take as our estimate of the correction to minimum entropy.

The corresponding pionic correction to the neutron magnetic moment is $-1.67 \frac{e}{2m_p}$, and one sees from Column 2 in Table I that such corrections have the magnitude and sign needed to improve agreement with experiment. Column 2 gives, in units of $\frac{e}{2m_p}$, the intrinsic proton and neutron moments if the anomalous moments were exactly ± 1.67 . The numbers in Column 2 are seen to be reasonably close to the predicted intrinsic moments if m_0 is not far from the proton mass.

The observed magnetic moments of other baryon-octet members can be similarly "corrected" for structure. The estimates of Column 2 are made, as above, by considering the "nearest" baryon-meson channels. (For the meson-baryon coupling constants we used SU(6) values, which are thought to be reasonably adequate.) Thus for μ_Λ we consider $\Lambda \rightarrow p + k^-$; for μ_{Σ^-} we consider $\Sigma^- \rightarrow \Sigma^0 + \pi^-$, $\Sigma^- \rightarrow \Lambda + \pi^-$ and $\Sigma^- \rightarrow n + k^-$, etc.

Although it remains to be shown that higher-order components of the topological expansion actually agree with the estimates made here, we find encouraging the comparison between Columns 2 and 3 of the table. This comparison shows that topological theory, even though it has integral quark charges, may eventually yield the correct values for hadron magnetic moments.

One of us (J. F.) acknowledges the hospitality of the LBL theoretical group. We are indebted to M. Suzuki for helpful discussions.

REFERENCES

1. See for example J. J. J. Kokkedee, The Quark Model (Benjamin, 1969).
2. See for example D. B. Lichtenberg, Zeit. fur Physik C 7, 143 (1981).
3. G. F. Chew, J. Finkelstein, R. E. McMurray, Jr. and V. Poenaru, Physics Letters 100B, 53 (1981); LBL preprint 11435, submitted to Phys. Rev.
4. G. F. Chew and V. Poenaru, Physical Review Letters 45, 229 (1980); LBL-11433.
5. G. F. Chew and C. Rosenzweig, Physics Reports 41C, No. 5, May (1978).
6. P. Federbush, M. L. Goldberger and S. M. Trieman, Phys. Rev. 112, 642, 1958.

TABLE I

Particle	$\mu_{\text{exp}} / \frac{e}{2m_p}$	μ_{exp} minus "lowest" meson contrib.	$\mu_{\text{min. entropy}} / \frac{e}{2m_0}$
p	2.79	1.12	$\frac{4}{3}$
n	-1.91	-0.24	$-\frac{1}{3}$
Λ	-0.61	-0.08	0
Σ^+	$2.33 \pm .13$	$1.40 \pm .13$	$\frac{4}{3}$
Σ^-	$-1.41 \pm .25$	$-0.43 \pm .25$	0
Ξ^0	$-1.20 \pm .06$	$-0.34 \pm .06$	$-\frac{1}{3}$
Ξ^-	$-1.85 \pm .75$	$-1.26 \pm .75$	0

Table I: Baryon magnetic moments. First column gives experimental values as listed in the Particle Data Tables. Second column (in same units as first) includes our estimate of "structure" correction. Third column is the minimum-entropy prediction for the quantity in the second column--the "intrinsic" baryon magnetic moment.

FIGURE CAPTION

Calculation of the proton magnetic moment by approximating the higher-entropy terms by the contribution of the 2π channel.

XBL 814-742

FIGURE 1