Magnetic field characterization and the search for a permanent electric dipole moment in ^{199}Hg

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Outline

Purcell and Ramsey (1950)

that this electric dipole would be a polar vector, being the product of the angular momentum (an axial vector) and the magnetic pole strength, which is a pseudoscalar in conformity with the usual convention that electric charge is a simple scalar.

The argument against electric dipoles, in another form, raises directly the question of parity. A nucleon with an electric dipole moment would show an asymmetry between left- and right-handed coordinate systems; in one system the dipole moment would be parallel to the angular momentum and in the other, antiparallel. But there is no compelling reason for excluding this possibility. It would not be the only asymmetry of particles of ordinary experimence, which already exhibit conspicuous asymmetry in respect to electric charge. Although magnetic poles were used above as an illustration of a particular mechanism by which a nuclear electric dipole could arise, this is, of course, not the only possibility.

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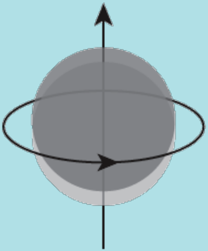
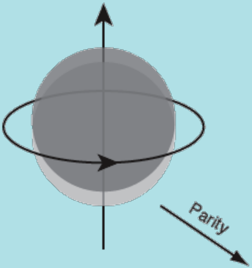
- *Parity*
- *Time reversal*

Permanent EDMs and symmetry violation



Permanent EDMs and symmetry violation



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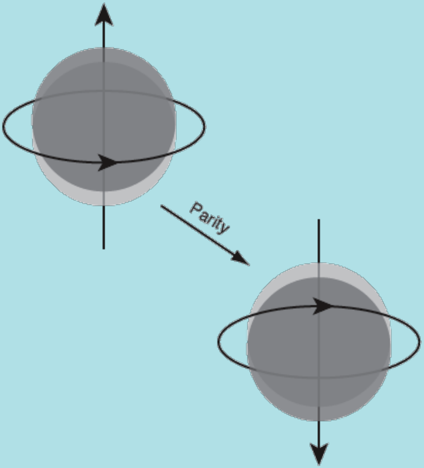

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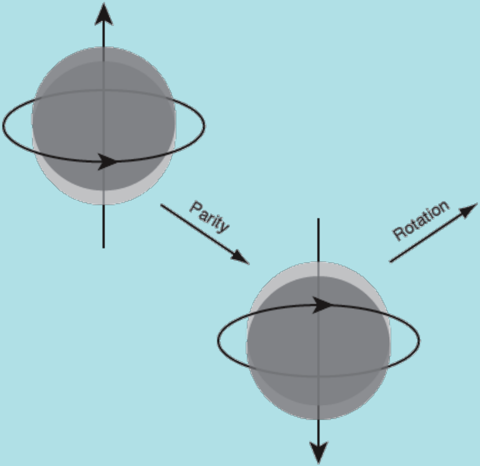

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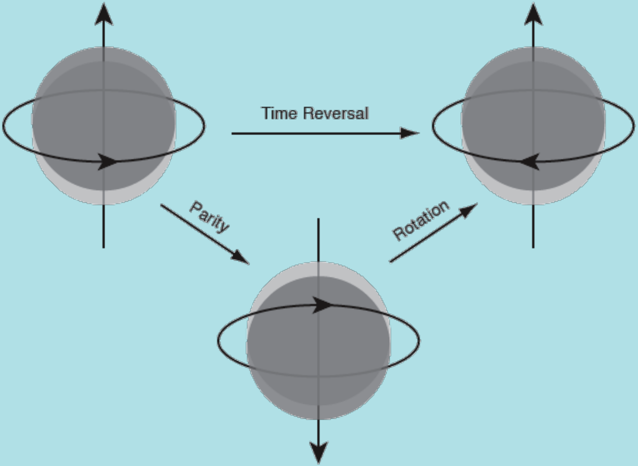

Image: Matthew Swallows

Why look for a permanent EDM?

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- *CPT* Theorem: $CP \leftrightarrow T$
- The existence of matter
- Supersymmetry

Search for a permanent EDM of ^{199}Hg

- ^{199}Hg is diamagnetic (no unpaired electrons) $\rightarrow$ nuclear EDM
- $|d(^{199}\mathrm{Hg})| < 3.1 \times 10^{-29} e\,\mathrm{cm}$ (95% C.L.)

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- $\uparrow$ This is exceedingly small

Larmor precession

$$\tau = \mu \times B + d \times E$$

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$$\tau_{E||B} - \tau_{E\,\text{anti-}||B} = 2dE\sin\theta$$

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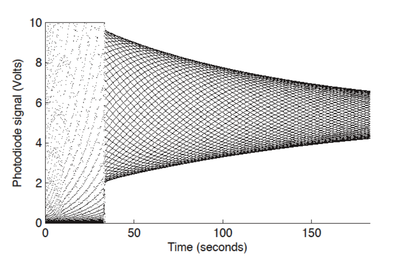

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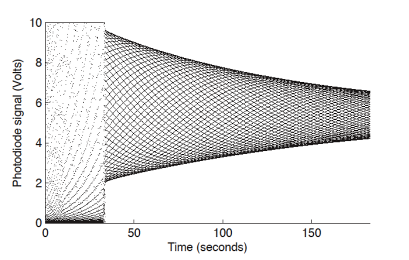
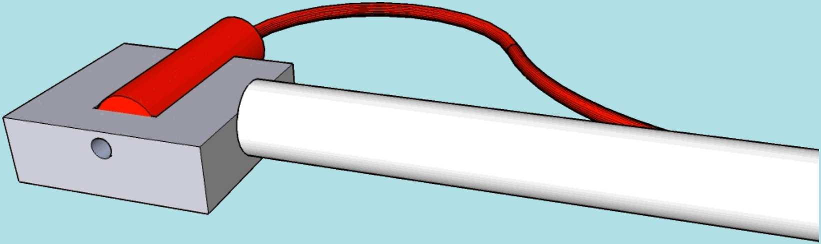


Image: Matthew Swallows

↑ This is where I come in

The flux gate



- .01 milligauss precision
- 10 second measurement intervals, 50 Hz sampling rate

The cosine coil

- Actually three coils: vertical, axial, transverse
- Enclosed in three layers of magnetic shielding

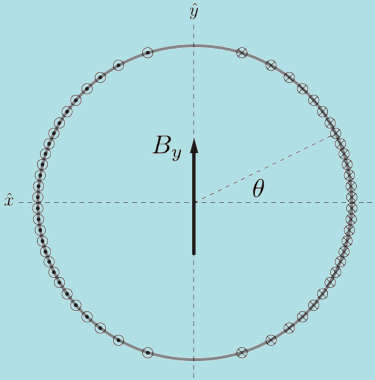


Image: Matthew Swallows

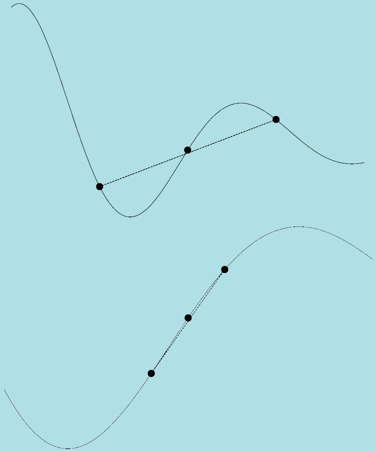
Data collection

Object: To characterize behavior of field at center of coil

- Cubic lattice of 27 points, 5 mm between adjacent points
- 6 runs: {vertical, axial, transverse} $\times$ 2 orthogonal positions*

Taylor series expansion

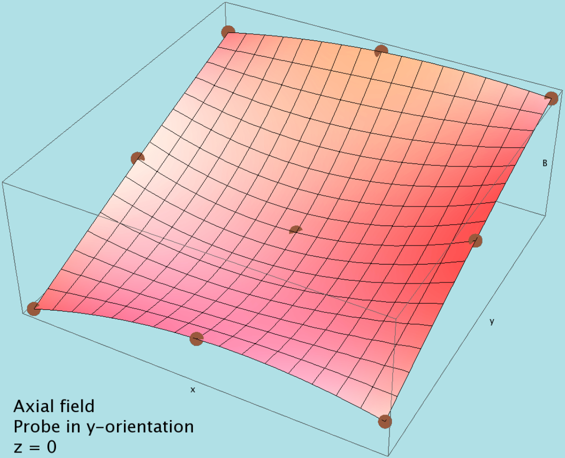
- Second order Taylor series expansion about center
- Requires lots of derivatives



Solving for $\mathbf{B}$

A completely determined* system requires nine linearly independent equations:

$$\nabla \times \mathbf{B} \quad (3)$$
$$\nabla \cdot \mathbf{B} \quad (1)$$
$$\nabla B_a,\ a = x,\ y,\ \text{or } z \quad (3)$$
$$\nabla B_b,\ b = x,\ y,\ \text{or } z \text{ and } b \neq a \quad (2)$$



Axial field
Probe in y–orientation
z = 0

The next step

- Finish data collection on other coil
- Design additional coils to address “worst” gradients

Acknowledgments

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References

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[5] W. C. Griffith et al., Physical Review Letters **102**, 101601 (2009).

Questions?