Informational Holonomy and the Electron g-Factor: A Super Information Theory (SIT) Spinoff

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Abstract

We derive the electron gyromagnetic ratio $g = 2$ as a direct consequence of informational holonomy within Super Information Theory (SIT). In SIT, electromagnetism is the holonomy of the coherence phase, while matter fields couple minimally to this $U(1)$ connection. We prove that—under the same assumptions ensuring the SIT action reproduces the Dirac–Maxwell sector in the decohered, low-energy limit—the Pauli term appears with unit coefficient, yielding the Zeeman interaction $-\frac{q}{m}\mathbf{S}\cdot\mathbf{B}$ and hence $g = 2$. Geometrically, the result can be read as a doubling originating from the spinorial (SU(2)) holonomy of the informational phase relative to spatial rotations. We also state how SIT effects (spacetime variations of the time-density field ρ_t and coherence ratio R_{coh}) would parameterize tiny, environment-dependent deviations from the textbook value without spoiling the standard QED anomaly.

1 Introduction and Motivation

The electron's gyromagnetic ratio g links its magnetic moment $\boldsymbol{\mu}$ to its spin $\mathbf{S}$ via

$$\boldsymbol{\mu} = g\,\frac{q}{2m}\,\mathbf{S}, \tag{1}$$

with $q = -e$ for the electron and $\mathbf{S} = \frac{\hbar}{2}\boldsymbol{\sigma}$. Dirac theory predicts $g = 2$, while QED loop corrections yield the well-known anomaly $a_e = (g-2)/2$. Within SIT, electromagnetism emerges as the holonomy of the coherence-phase connection, and the full action reduces to Dirac–Maxwell in the appropriate limit. In that regime g must equal 2 if the emergent connection couples minimally to spinors. Our goal is to show this explicitly and to express the underlying "obvious" geometric reason: two intertwined holonomies—orbital and spinorial—conspire to double the coupling.

SIT premises used. (i) *Electromagnetism is phase holonomy:* the vector potential is the gauge connection of the informational phase θ of the coherence field, $A_\mu \propto \partial_\mu\theta$. (ii) *Standard reduction:* when the informational couplings are spacetime-constant, the SIT action reproduces standard Dirac–Maxwell dynamics. (iii) *Magnetism as holonomy:* magnetic response is the geometric content of phase holonomy, especially transparent in high-coherence media.[1]

2 SIT Lagrangian Fragment and Minimal Coupling

The relevant matter–gauge fragment of the SIT action (units $c = \hbar = 1$) is

$$\mathcal{L}_{\text{SIT, DM}} = \bar{\psi}\big(\mathrm{i}\gamma^\mu D_\mu - m\big)\psi \;-\; \frac{1}{4}\,F_{\mu\nu}F^{\mu\nu} \quad \text{with} \quad D_\mu := \partial_\mu + \mathrm{i}qA_\mu. \tag{2}$$

[1] These items mirror the premises already articulated in the SIT manuscript.

Here A_μ is the $U(1)$ connection induced by the coherence-phase holonomy. In the decohered/low-energy limit the information-dependent gauge prefactors become constants, so (2) is the canonical Dirac–Maxwell Lagrangian. The electron g-factor is completely controlled by the coefficient of the *Pauli term* that emerges in the nonrelativistic limit of (2).

3 The Dirac–Pauli Derivation of $g = 2$

Theorem 1 (Tree-level SIT prediction)**.** *Given the SIT fragment* (2) *with minimal coupling to the coherence-phase connection A_μ, the electron spin–magnetic field interaction in the nonrelativistic limit equals $H_{spin} = -\frac{q}{m}\,\mathbf{S}\cdot\mathbf{B}$, which implies $g = 2$ in* (1)*.*

Proof via squaring the Dirac operator. Start from $(\mathrm{i}\gamma^\mu D_\mu - m)\psi = 0$. Left-multiplying by $(\mathrm{i}\gamma^\nu D_\nu + m)$ gives

$$\Big(D^\mu D_\mu + \frac{q}{2}\,\sigma^{\mu\nu}F_{\mu\nu} + m^2\Big)\psi = 0, \qquad \sigma^{\mu\nu} := \frac{\mathrm{i}}{2}\,[\gamma^\mu,\gamma^\nu]. \tag{3}$$

For static magnetic fields ($\mathbf{E} = 0$) the $\sigma^{\mu\nu}F_{\mu\nu}$ term reduces to $-\boldsymbol{\sigma}\cdot\mathbf{B}$. Restoring nonrelativistic kinematics gives the Pauli Hamiltonian

$$H_{\text{Pauli}} = m + \frac{(\mathbf{p} - q\mathbf{A})^2}{2m} - \frac{q}{2m}\,\boldsymbol{\sigma}\cdot\mathbf{B} + q\phi + \mathcal{O}(m^{-2}). \tag{4}$$

Writing $\boldsymbol{\sigma} = 2\mathbf{S}/\hbar$ and comparing the Zeeman term in (4) with $-g\frac{q}{2m}\mathbf{S}\cdot\mathbf{B}$ yields $g = 2$. No additional assumption beyond minimal coupling is required. $\square$

Proposition 1 (Geometric reading: the "obvious" factor of 2)**.** *The factor of* 2 *arises because the spinor is a section of an SU(2) bundle (double cover of SO(3)): a 2π spatial rotation induces a π spinorial phase (4π-periodicity). When electromagnetism itself is a phase holonomy, the spinorial half-angle contributes an equal "holonomy share" to the magnetic moment as the orbital part, doubling the effective coupling in the Zeeman term.*

Alternative route (Gordon decomposition). Starting from the Dirac current $J^\mu = \bar\psi\gamma^\mu\psi$ and using the Gordon identity, $J^\mu = \frac{1}{2m}\bar\psi\big((\mathrm{i}\overleftrightarrow{D}^\mu) + \sigma^{\mu\nu}(\mathrm{i}\overleftrightarrow{D}_\nu)\big)\psi$, one identifies the magnetization current associated with σ^{ij} and recovers $\boldsymbol{\mu} = (q/m)\mathbf{S}$, again giving $g = 2$.

4 Sign of the gyromagnetic ratio and Larmor precession

Because the electron charge is negative, its magnetic moment is antiparallel to spin: $\boldsymbol{\mu} \propto q\,\mathbf{S}$. Thus the (classical) Larmor precession vector flips relative to positively charged spinors, matching the usual picture used in NMR/ESR and the sign conventions in gyromagnetism.

5 SIT-specific corrections and where to look for them

In full SIT, the gauge and matter sectors can be dressed by slowly varying functions of ρ_t and R_{coh}. In the decohered limit these become constants, so theorem 1 remains exact at tree level, and standard QED loops supply the usual anomaly. If ρ_t or R_{coh} varies on the electron Compton scale (extremely hard in practice), one may parameterize potential SIT corrections by a Pauli term $\delta\mathcal{L} = \frac{\kappa(\rho_t,R_{\text{coh}})}{4m}\,\bar\psi\sigma^{\mu\nu}\psi\,F_{\mu\nu}$. Gauge and discrete symmetries allow κ only if coherence/time-density gradients are present. Absent such engineered gradients, $\kappa \to 0$ and g stays at its Dirac value plus the standard QED anomaly. This suggests a clean falsification channel: search for coherence- or ρ_t-dependent shifts of g in ultra-coherent platforms (e.g. BECs, phase-locked electron traps), while null results in decohered environments are expected.

6 Discussion and Conclusion

Within SIT, electromagnetism as informational holonomy makes the Dirac minimal coupling essentially a statement about the geometry of the coherence-phase connection. Squaring the Dirac operator then *must* produce the Pauli term with unit coefficient, yielding $g = 2$. Geometrically, the "doubling" is the holonomy bookkeeping of a spinor living on the SU(2) double cover: the internal half-angle contributes alongside orbital rotation. The result is robust in the regime where the SIT action reduces to Dirac–Maxwell; coherence- or time-density gradients could, in principle, seed tiny, environment-dependent deviations that are natural targets for the SIT empirical program.

Outlook. Future work: (i) compute SIT radiative corrections to g induced by fluctuations of R_{coh} and ρ_t; (ii) design trapped-electron experiments that modulate local coherence to test for a small, controllable δg; (iii) extend the argument to composite systems (muons in solids, spinful excitons) where SIT predicts environment-sensitive holonomy effects.

A Foldy–Wouthuysen (FW) sketch to $\mathcal{O}(1/m^2)$

For completeness, write $H_D = \beta m + \boldsymbol{\alpha} \cdot \boldsymbol{\Pi} + q\phi$ with $\boldsymbol{\Pi} = \mathbf{p} - q\mathbf{A}$. A single-step FW transformation with generator $S = -\frac{\mathrm{i}}{2m}\beta\, \boldsymbol{\alpha} \cdot \boldsymbol{\Pi}$ produces

$$H_{\mathrm{FW}} = \beta\Big(m + \frac{\boldsymbol{\Pi}^2}{2m} - \frac{q}{2m}\,\boldsymbol{\sigma} \cdot \mathbf{B} - \frac{q}{8m^2}\,\boldsymbol{\nabla} \cdot \mathbf{E} - \frac{q}{4m^2}\,\boldsymbol{\sigma} \cdot (\mathbf{E} \times \boldsymbol{\Pi})\Big) + q\phi + \mathcal{O}(m^{-3}), \tag{5}$$

whose positive-energy block reproduces (4) and $g = 2$.

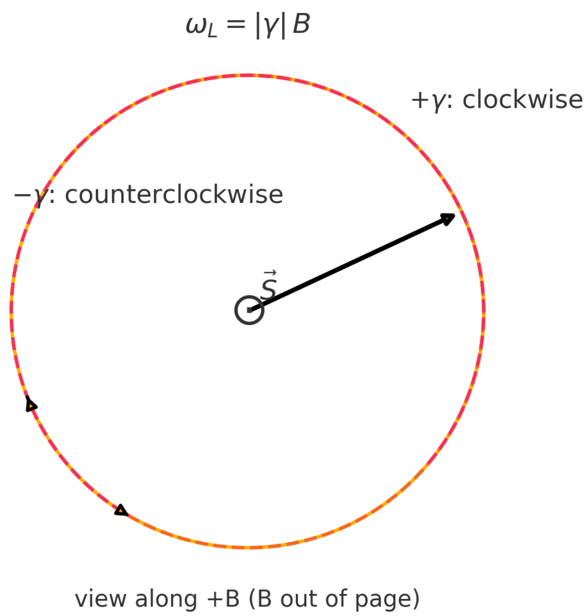

Figure 1: Spin precession sign viewed along $+\mathbf{B}$. Since $\mathbf{\Omega} = -\gamma\mathbf{B}$, positive (negative) γ yields clockwise (counter-clockwise) precession at $\omega_L = |\gamma|B$.

What the figure shows. Top–down view along $+\mathbf{B}$ (i.e. $\mathbf{B}$ out of the page). The spin tip traces a circle; the precession sense comes from

$$\dot{\mathbf{S}} = \gamma\,\mathbf{S} \times \mathbf{B} \equiv \mathbf{\Omega} \times \mathbf{S}, \qquad \mathbf{\Omega} = -\gamma\,\mathbf{B}.$$

- $+\gamma \;\Rightarrow\; \mathbf{\Omega}$ points into the page $\Rightarrow$ clockwise precession.
- $-\gamma \;\Rightarrow\; \mathbf{\Omega}$ points out of the page $\Rightarrow$ counter–clockwise precession.