Torsion Balance Search for Lorentz-invariance, Dark Energy and Dark Matter

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Why search for violations of Lorentz-invariance?

General Relativity

the Standard Model

GR + SM = Lorentz-symmetry breaking???
What about Dark Energy and Dark Matter?

We’re also not sure what the universe is made of:

- Dark Energy
- Ordinary Matter, 4%
- Dark Matter
- 96% new particles and fields that mediate forces we may be able to measure in the laboratory
Spin-dependent forces

*spin* is a property of all fundamental particles.

Theories of quantum gravity, dark energy and dark matter predict forces between a particle’s spin and:

- A background field fixed in space.
- Sources of unpolarized matter.
- Another particle’s spin.
Torsion balances

Coulomb’s torsion balance:

A high precision measurement of forces coupled to electrons in 1871
How they work:

attractor: a background field, a distant mass, something we made . . .

thin fiber

pendulum rotates w.r.t. attractor

mirrors: use retroreflected laser beam to detect angular deflection, long path length ⇒ resolve small angles
The spin pendulum

- large net electron spin
- negligible external magnetic field
- more spins
- greater symmetry
- gold-plated
- magnetically shielded
- 4 mirrors

Alnico  SmCo

2.6 cm
The torsion balance apparatus

- vacuum can
- prehanger
- fiber
- autocollimator
- thermal shield
- pendulum
- turntable
- HH coils
- compensation masses
- magnetic shielding
Recent Results: limits on a background field

$|b_\perp| = (1.8 \pm 2.5) \times 10^{-22} \text{ eV}$

$b_z = (-29 \pm 39) \times 10^{-22} \text{ eV}$

expect to see effects of new physics at:

$(m_e/m_{pl})m_e \sim 10^{-17} \text{ eV}$
More Recent Results:

95% CL limits

- Ni, et. al.
- Youdin, et. al.
- Wineland, et. al.
- this work
Torsion balance + spin sources
New torsion pendulum
Thanks to . . .

Blayne Heckel
Eric Adelberger
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Stephan Schlamminger
Erik Swanson

Ted Cook
William Terrano
Typical Data

Hypothetical

\[ b_x = 5 \times 10^{-20} \text{ eV} \]

\( (b_y, b_z = 0) \)

Best sidereal fit:

\[ b_x = (-0.2 \pm 1.9) \times 10^{-21} \text{ eV} \]

\[ b_y = (-0.1 \pm 1.9) \times 10^{-21} \text{ eV} \]