GEE Lab's Submillimeter Torsion Balance

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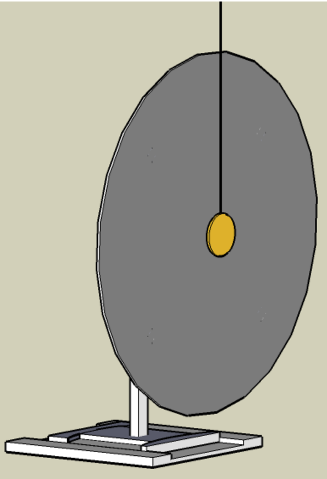
Outline

Basic Design Concept

- Large diameter source mass ($D_s \sim 33$cm)
- Smaller diameter test mass ($D_t \sim 7.5$cm) suspended from torsion fiber
- Face to face seperation, z_0, small compared to radius of source mass
- Angular modulation about vertical axis and linear modulation in $\hat{z}$ direction



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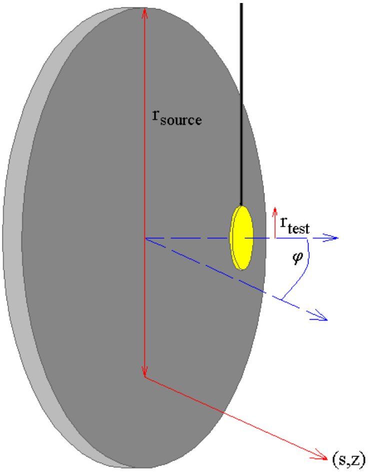
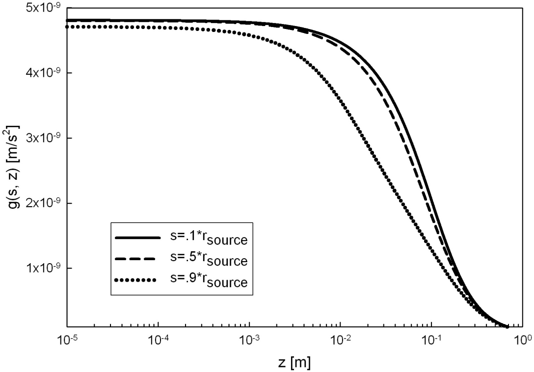
Design Advantage



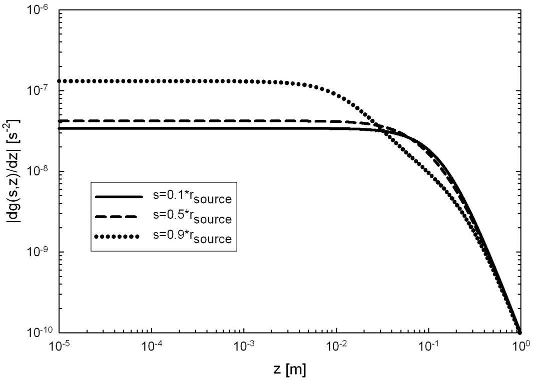
- Gravitational field nearly independent of z near source mass (analogous to infinite plane of charge)
- Property that is unique to $1/r^2$ law forces, making deviations due to Yukawa or like forces stand out
- Source mass oriented at angle φ with respect to test mass, induces small Newtonian gravitational torque on test mass

Newtonian Gravitational Field of source plate



- Close to the plate the Newtonian field is nearly constant.
- As the radial distance from axis of source plate, *s* increases, field gradients become more prominent.

Field Gradients



- Field gradients produce Newtonian torques, i.e. $\tau_N \propto \frac{dg}{dz}$
- Newtonian effects generate <u>constant</u> background

Edge Effects

- Small gradients in the Newtonian field give rise to torque

$$\tau_N \approx \frac{\pi^2 G \rho_s \rho_t t_t t_s r_t^4}{2 r_s} \left[1 + 2 t_s z_0 / r_s^2\right] \varphi$$

  i.e. constant to first order.
- As experiments are performed at different z_0, Newtonian torque remains constant.
- Variation of total torque on balance with respect to z_0 implies the existence of a non-Newtonian signal.

Yukawa-like signals

- Yukawa potential created by a point particle given by

$$U(z) = -\alpha G m \frac{1}{z} e^{-z/\lambda}$$

- Extending this to the interaction between the source plate and the balance disk we find the torque induced on our balance

$$\begin{aligned} \tau_y &\approx \alpha \frac{8\pi G \rho_s \rho_t r_t^4 \lambda}{3} \varphi \left\{1 - e^{-t_s/\lambda}\right\} \left\{1 - e^{t_t/\lambda}\right\} e^{-z_0/\lambda} \\ &\sim \alpha r_t^4 \lambda \varphi e^{-z_0/\lambda} \end{aligned}$$

Modified Gravity

- Randall-Sundrum Model

$$U_{RS}(z) = -Gm\frac{l_s^2}{z^3}$$

- Power-law Potentials

$$U_k(z) = -\beta_k \frac{Gm}{z^k}$$

- For $k = 5$ the torque looks like

$$\tau_k \sim \beta_k r_t^4 \varphi \left\{ (z_0 + t_t)^{-3} - z_0^{-3} - (z_0 + t_t + t_s)^{-3} + (z_0 + t_s)^{-3} \right\}$$

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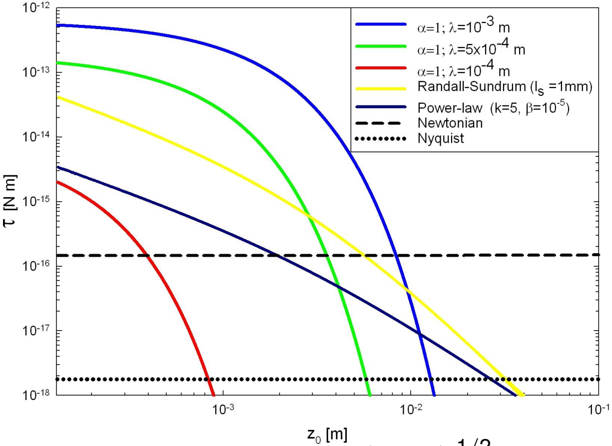
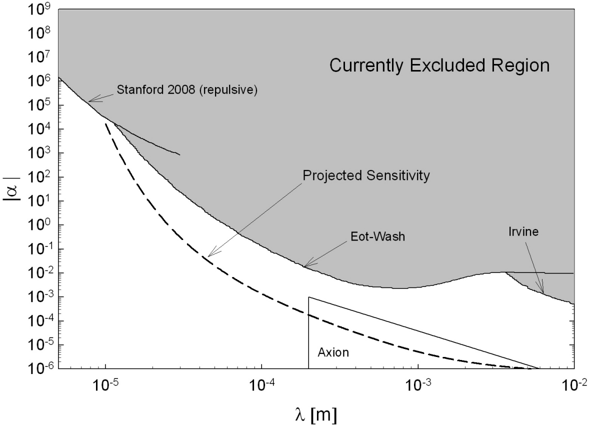
Signal and background torques



- Nyquist torque given by $\tau_{nyq} = \left(\frac{4kTk_f}{3Qt\omega_0}\right)^{1/2}$

Projected Sensitivity



- Current limits taken from [1, 2]

Thank You

References

- E. Adelberger *et al.*, Prog. in Part. and Nuc. Phys. **62**, 102 (2009).
- D. Weld *et al.*, Phys. Rev. D **77**, 062006 (2008).

Ideas presented here to appear on the arXiv shortly