Taking a “Closer” Look at Newtonian Gravity

Forces with Sub-millimeter Dimensions

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Renewed Interest in Gravity

- Unexplainable 1% deviations from the inverse square law
- 33 orders of magnitude of untested gravitational force
- Higher Dimension Possibilities: impacts on string theory and solutions to the hierarchy problem

The Hierarchy Problem:

The Weak Force unites with the Electric Force at 10^3 GeV $\approx 10^{-18}$ centimeters, but with $1/r^2$ Gravity at 10^{18} GeV $\approx 10^{-33}$ centimeters.

A Solution:

Perhaps Gravity is not simply $1/r^2$ at the quantum level. Gravity would be much stronger, thereby uniting sooner, if it followed a $1/r^3$, $1/r^4$, or $1/r^?$ growth at small distances.

Gravity components exist in very small, compact spatial dimensions

Our Gauss's law for gravitational potential is then

$$V(r) = G_4 m_1 m_2 \times \frac{1}{r} \quad + \quad G_{4+n} m_1 m_2 \times \frac{1}{r^{n+1}}$$

$G_4 = M_{Pl(4)}^{-2}$ is the Newtonian gravitational constant and

$G_{4+n} = M_{Pl(n+4)}^{-(2+n)}$ is the coupling constant for the added gravitational component.

$M_{pl(4)}^2 = M_{Pl(n+4)}^{2+n} \times \text{Volume}^n_{\text{Extra Dimensions}}$

Notice that gravity is essentially $G_{4+n} m_1 m_2 \times \frac{1}{r}$ for very large "r"

$G_{4+n} m_1 m_2 \times \frac{1}{r^{n+1}}$ for very small "r"

How Big is "n"?

Since we want to unite the electroweak force with gravity, we set $m_{ew} = M_{pl(4+n)}$ and choose "R" such that we produce M_{pl}

$$\therefore \qquad R \approx 10^{30/n - 17}\ \text{cm} \times \left(\frac{1\text{Tev}}{m_{ew}}\right)^{1 + 2/n}$$

- n = 1: $R \approx 10^{13}$ cm --> solar system sized dimension and deviations
- n = 2: $R \approx 1$ mm --> the distance where present experimental measurement stops
- n = 3: R--> TeV^{-1} distances

Testing n = 2 with a torsion pendulum

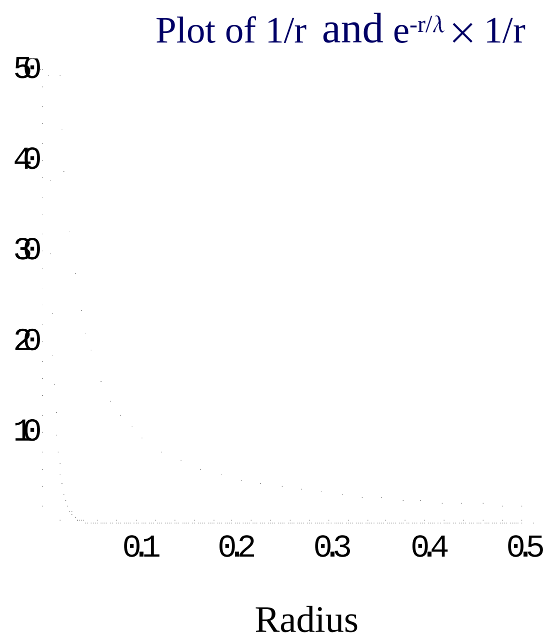
We need to construct a torsion pendulum that has

- **Zero torsion-attraction to a source due to $V_{g(4)} \propto 1/r$**
- **Maximum attraction due to $V_{g(4)} \propto 1/r^{n+1}$ or $e^{-r/\lambda} \times 1/r$**

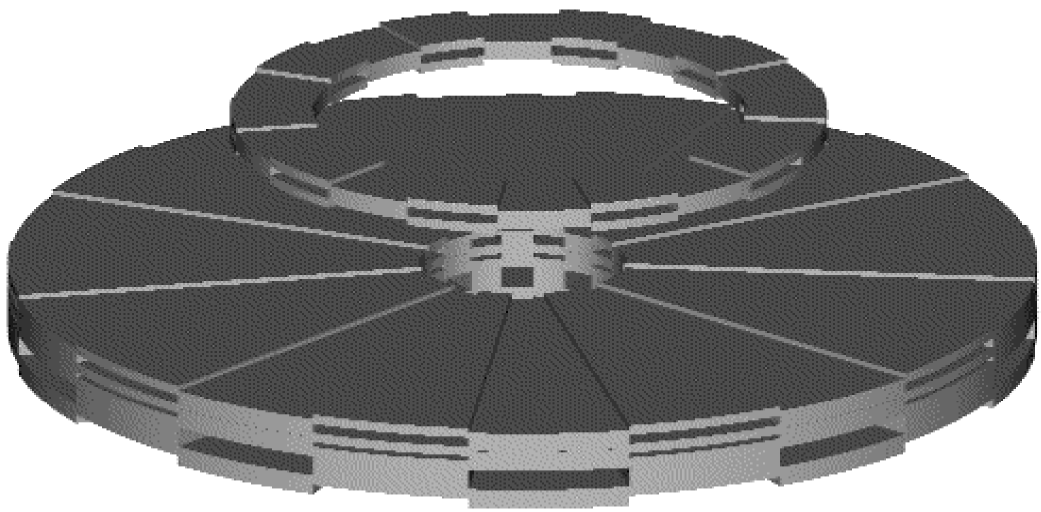
The potential due to gravity and an additional Yukawa interaction can be written

$$V(r) \approx -\int dr1 \int dr2 \frac{G\rho 1(r1)\rho 2(r2)}{r}[1+\alpha \exp(-\frac{r12}{\lambda})]$$

Where G is the Newtonian gravitational constant, r12 is the distance between r1 and r2, ρ(r1) and ρ(r2) are mass densities, α is strength of the Yukawa force relative to gravity, and λ is the range of the Yukawa force.



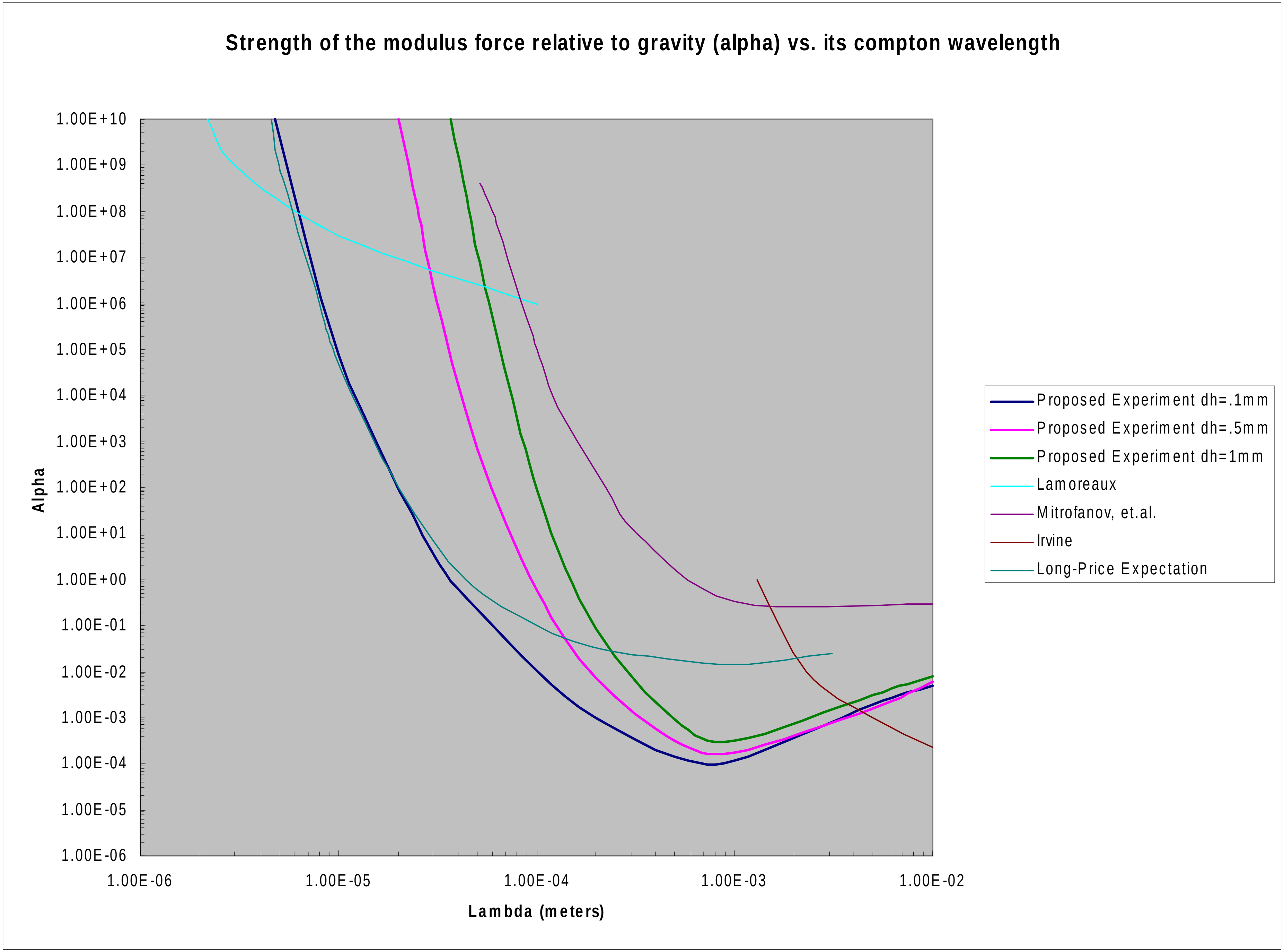
Pendulum and Source Design



The Results Race...

•The optimized pendulum yields a 100 to 1 signal-to-noise ratio for a Yukawa force with 0.1 mm Compton wavelength--roughly 10^5 times more sensitive than previous experiments

•Construction began in August, and data collection will commence in late Fall or early Winter.


Strength of the modulus force relative to gravity (alpha) vs. its compton wavelength
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
Alpha
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
Lambda (meters)
Proposed Experiment dh=.1mm
Proposed Experiment dh=.5mm
Proposed Experiment dh=1mm
Lamoreaux
Mitrofanov, et.al.
Irvine
Long-Price Expectation

Acknowledgements

•Eric Adelberger and Blayne Heckel

For engineering and leading this project

•Nathan Collins

For guiding me through theoretical quantum gravity and the modeling process

•CD Hoyle

For many, many useful comments and answers

This work is supported by the National Science Foundation's grant for an R.E. U program at the University of Washington