Searching for New Short Range Forces Using Optically Levitated Microspheres

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Abstract: Although gravity is the most familiar of the fundamental forces from our everyday experience, we still do not understand its fundamental nature at microscopic distances. Due to the extreme weakness of gravity relative to the other forces, existing experiments have not been able to measure gravitational interactions, or significantly constrain deviations from the inverse square law, at distances below ~50 μm. However, many theories of physics beyond the standard model that attempt to provide a consistent microscopic description of gravity or to account for the nature of dark matter and dark energy can produce such deviations. Searching for deviations from Newtonian gravity at short distance can thus provide a powerful probe of models of new physics that can be difficult to test with other techniques.

We are developing novel techniques to search for new forces at micron length scales using optically levitated dielectric microspheres in vacuum. At high vacuum, dissipation of the microsphere’s motion due to residual gas collisions becomes small, allowing sub-atttonewton force sensitivity. As a first demonstration of this force sensing technique, we have performed a search for stable particles with charge <<1 e- bound in terrestrial matter. These techniques will also enable extremely sensitive searches for new forces that couple to mass or charge at short distance. We will describe the experimental apparatus, the results from the search for milli-charged particles, and the expected sensitivity of searches for non-Newtonian and non-Coulombic forces at micron length scales.