Entanglement based probe new macroscopic forces

Ryan J. Marshman[a], Peter F. Barker[b], Sougato Bose[b] and Anupam Mazumdar[c]

[a]*Centre for Quantum Computation and Communication Technology, School of Mathematics and Physics, University of Queensland, Brisbane, Queensland 4072, Australia*

[b]*Department of Physics and Astronomy, University College London, Gower Street, WC1E 6BT London, United Kingdom.*

[c]*Van Swinderen Institute, University of Groningen, 9747 AG Groningen, The Netherlands.*

Quantum entanglement provides a novel way to test short distance physics in the non-relativistic regime. We provide a protocol to *potentially* test new physics using two charged, massive particle interferometers in close proximity to other. Being charged, the two superpositions will be entangled via electromagnetic interactions mediated by photons, including the Coulomb and the Casimir-Polder potential.

We show that by chosing a specific geomtry for the system we can open up two experimental regimes. One where the entanglement phase due to the known particle-particle interactions is not present, so any entanglement present heralds new or unknown interactions. A second regime is described where the known particle-particle forces cancel, allowing the distances probed to be decreases significantly, although care is then needed to retieve a reliable signal.

We will bring a method of *entanglement based tomography* to seek time evolution of very small entanglement phases to probe new physical effects mediated by *hitherto unknown macroscopic force*. We consider a Yukawa type potential and Yukawa modified known forces as the source of the new entangling interaction.

We will be able to constrain the Yukawa couplings $\alpha \geq 10^{-35}$ for $r \geq 10^{-6}$m for a new physics, and modifications to the gravitational potential with $\alpha_g \geq 10^{-8}$ for $r \geq 10^{-6}$m. Furthermore, our protocol can also constrain the axion like particle mass and coupling, which is complimentary to the existing experimental bounds.