ABSTRACTS

New Experiments in Gravitational Physics

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I will describe 4 new experiments. I will provide the theoretical motivation, design of apparatus, expected sensitivity and noise levels. (i) Spinors and gravity sources have radically different geometries. This experiment is meant to examine the nature and magnitude of spinors coupling with gravitational fields. (ii) Much speculation has been expended on the quantum or classical nature of the gravitational field. I propose an experiment to answer this question. In the process I will identify the source of the high temperatures seen in the solar corona. (iii) Do quantum field excitations follow geodesics? I have designed an experiment to determine whether or not quantum field excitations follow geodesics. The estimated effect is calculated for an experiment. The apparatus consists of a pair of metal plates that are stressed by Casimir force. Details of the calculations, apparatus design, sensitivity etc. are estimated. (iv) Although red shifts can occur because of the Doppler effect as well as gravity there does not seem to be any way to distinguish the two sources. I will describe a method that can be used to do so.

Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Karim.pdf

Testing the Weak Equivalence Principle on a Sounding Rocket

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I will describe SR-POEM, a Galilean test of the weak equivalence principle that is to be conducted during the free fall portion of the flight of a sounding rocket payload. The WEP is a key postulate of general relativity, but is violated in many theories that attempt to join gravity with the standard model of particle physics. This test of a single pair of substances will have a measurement uncertainty of $\sigma(\eta) < 2\times10^{-17}$ after averaging the results of eight separate drops, each of 120s duration. The entire payload is inverted between successive drops to cancel potential sources of systematic error. The WEP measurement is made with a set of six of the SAO laser gauges, which have achieved an Allan deviation of 0.04 pm for an averaging time of 30 s. I will discuss aspects of the current design with an emphasis on those that bear on the accuracy of the determination of η. Among these is the as-yet unpublished redesigned test masses that are less susceptible to local gravitational perturbations. The discovery of a WEP violation ($\eta \neq 0$) would have profound implications for physics, astrophysics and cosmology.

Link to presentation:

http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Reasenberg.pdf

Millimeter tests of the gravitational inverse-square law

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Motivated by a variety of theories that predict new effects, we tested the gravitational inverse-square law at separations down to 0.4 mm using a dual-modulation torsion pendulum. We find no deviations from the Newtonian inverse square law with 95% confidence level, and this work establishes the most stringent constraints on non-Newtonian interaction in the ranges from 0.7 to 5.0 mm, and a factor of 8 improvement is achieved at the length scale of several millimeters. An overview of our experimental methods, current results, and future planes will be presented.

Measurement of Newtonian Gravitational Constant with Angular Acceleration Feedback Method

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Up to now, the values of Newtonian gravitational constant G measured by different methods are still in poor agreement. So in the same laboratory, we measure this value using torsion balance with two methods, time-of-swing method and angular acceleration feedback method. This report is mainly about the latter. The principal experiment has been completed. And the preliminary results show that the repeatability of the angular acceleration of the turntable reaches to 100ppm. An overview of our experimental methods, current results, and future planes will be presented.
Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Chao%20Xue.pdf

Test of non-Newtonian forces at sub-micrometer range using a sensitive cantilever

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Physicists have devoted an intense effort to find a unified theory that may connect gravity to the rest of physics. Many of the proposed theories predict modification of Newtonian gravity at sub-millimeter range. In other words, non-Newtonian forces may exist at this short length scale. A large amount of dedicated experiments have been performed to search for such forces. At the sub-micrometer range, the strongest constrains on non-Newtonian forces are mainly derived from the precision measurements of Casimir force, which would depends on the precision of

theoretical calculation of Casimir Force. Here we propose a new experimental design with a special consideration to reduce the effects of Casimir force as well as electrostatic force. In this experiment, a density modulated source mass is adopted with its surface covered by a thin Au film to separate the signal of non-Newtonian forces and Casimir force. A sensitive cantilever perpendicular to the source mass surface is used to sense the force component horizontal to the source mass surface. This further reduces the contribution from Casimir force and electrostatic force. We will also report our preliminary experimental progress.

G measurement with time-of-swing method by using a high-Q silica fiber

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Based on the HUST-09 G measurement, we develop the new G measurement with time-of-swing method by using a high-Q coating silica fiber. The main improvements: 1.A silica fiber with Q-factor of 50000 is used as the suspension fiber to reduce the anelastic effect and advance the stability of the period of pendulum. The fiber's surface is coated with 8 nm thicknesses of germanium and bismuth layers to reduce the electrostatic effect; 2.The background gravitational field of the environment is measured by using a dipolar pendulum and compensated with 800 kg lead blocks. 3.A 5-mm-thickness copper tube is installed around the fiber to decrease the temperature discrepancy; 4. The aluminum material is used to replace the gold and copper materials for coating the pendulum. This report will present the detailed experimental methods and processes.
Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/QingLi.pdf

Terrestrial tests of general relativity: ring lasers and atomic beams

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I shall review the opportunities lent by ring lasers and atomic beams interferometry in order to reveal gravitomagnetic effects on Earth. Both techniques are based on the asymmetric propagation of waves in the gravitational field of a rotating mass; actually the times of flight for co- or contra-rotating closed paths turn out to be different. After discussing properties and limitations of the two approaches I shall describe the proposed GINGER experiment, which is being developed for the Gran Sasso National Laboratories in Italy. The experimental apparatus will consist of a three dimensional array of square rings, 6 meters times 6 meters, that is planned to reach a sensitivity in the order of 1 pF/Hz$^{1/2}$ or better. This sensitivity would be one order of magnitude better than the best existing ring, which is the G-ring in Wettzell, Bavaria, and would allow for the terrestrial detection of the Lense-Thirring effect and possibly of deviations from General Relativity. The possibility of using either the ring laser approach or atomic interferometry in a space mission will also be considered. The technology problems are under experimental study using both the German G-ring and the smaller G-Pisa ring, located at Gran Sasso.
Link to presentation:

http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Tartaglia.pdf

Performance of an ultra-high sensitivity atom interferometry absolute gravimeter

Zhong-Kun Hu

A cold Rubidium atom fountain interferometry gravimeter with an active vibration isolator was demonstrated. The natural resonance frequency of the active vibration isolator is 0.016 Hz, and the vertical vibration noise is greatly reduced by a factor of 100 from 0.1 to 1 Hz. After substantial suppression of the vibration noise, the gravimeter has reached a sensitivity of $4.2*10^{-8}g/Hz^{1/2}$. We measured the local gravitational acceleration g by this sensitive gravimeter with a resolution of $0.5*10^{-9}g$ after 60 s.

Analysis review of a measurement of G using a cryogenic torsion pendulum

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We review the analysis of a measurement of the gravitational constant G. The measurement used a cryogenic torsion pendulum operating in a "dynamic" ("time of swing") mode. Features of the experiment include: 1) operation at cryogenic temperatures (2 – 4.5K) to minimize anelastic sources of systematic bias, reduce thermal noise, and increase frequency stability, 2) operation at large pendulum oscillation amplitudes which correspond to extrema of the pendulum's torsional period shift, for optimal signal/noise ratio and reduced effect of amplitude determination error, 3) use of a pair of source mass rings to produce an extremely uniform field gradient, and 4) use of a thin quartz plate as torsion pendulum to minimize sensitivity to pendulum inhomogeneity and dimensional uncertainties. The measurement was conducted over a period from year 2000 to 2006, using three types of torsion fiber: CuBe as drawn, CuBe heat treated, and Al5056 as drawn. Comparison of G values obtained with the three fiber types, operating at widely varying torsional amplitudes, provided important consistency checks.
Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Newman.pdf

The speed of gravity

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Newton's law of gravity is a theory of instantaneous action at a distance. However, Einstein's general relativity states that the speed of gravity equals the speed of light which is finite. Based on the post-Newtonian approximation, we show that the observational effect for the speed of gravity is irrelevant to the velocity of a moving source, but is depending on its acceleration. Therefore the effects of the speed of gravity currently are too small to be observed due to technology limitations.

Precise determination of the amplitude of signal with known frequency based on correlated noise model
Jie Luo

Based on Gauss correlated noise model, a method is suggested to determine the uncertainty of the amplitude for a sinusoidal signal with known frequency in each period, where the correlation analysis and the weighting statistical analysis are incorporated to improve the precision of determining the amplitude of the signal. The uncertainty of determining the amplitude with this method has been improved fourfold than before in dealing with the experimental data in determining limits on the photon mass.

Testing Gravitational Physics Using Artificial Satellites (towards a 1% measurement of frame-dragging with LARES, LAGEOS, LAGEOS 2 and GRACE)
Ignazio Ciufolini
University of Salento
Link to presentation:
https://docs.google.com/viewer?a=v&pid=sites&srcid=c2pmYy5lZHV8aXNlZzV8Z3g6MzIzMDFjZTIwMzkyZjZh

Detecting gravitational waves using a quantum fluid
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Recently, we have measured a significant magnetoelectric (ME) effect from a pure niobium crystal containing the ^{93m}Nb nuclear gamma excitation. The obtained ME symmetry by rotating the sample in magnetic field reveals that the gamma is confined in crystal as a spinful quantum fluid. Although the non-trivial structure of the spin and the orbit momentum remains to be identified, it already gives us the green light to measure the gravitational waves. Niobium has only one stable isotope ^{93}Nb and a long-lived Mössbauer state ^{93m}Nb of the M4 multipolar transition. Because of these two natures, *i.e.*, multipolar transition and 100% identical isotope, there is a biphoton branching decay from ^{93m}Nb to the ground state. The Nb crystal thus behaves like a photonic crystal for the gamma biphoton, the wavelength of which automatically matches the crystal lattice. The biphoton is delocalized and confined in crystal to become a massive nuclear spin-density wave (NSDW). NSDW undergoes the Bose-Einstein condensation, when the ^{93m}Nb excitation is beyond a critical density. Gravitational waves passing the sample shall modulate the spinful quantum fluid by a Raman-like effect introduced from the Linet-Tourrenc term $\boldsymbol{P}\overleftrightarrow{h}\boldsymbol{P}$ with the spin-2 gravitational waves $\overleftrightarrow{h}$. Detailed estimation of sensitivity will be given in this report.
Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/YaoCheng.pdf

Search for Non-Newtonian Behavior of Weak-field Gravity: A Progress Report

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Empirical tests of Einstein's weak-field (Newtonian) gravity could play an important role in judging theory-driven extensions of the so-called Standard Model of fundamental interactions. Even small deviations from Newtonian behavior could provide new insights.

We are completing analysis of data from a UW/UCI experiment searching for non-Newtonian interactions with range of order 10 cm and with precision an order of magnitude higher than in previous work. If no significant effect is evident, a stringent upper limit may substantially restrict the viability of some theoretical speculations. Alternatively, detection of an effect could point to new physics.

The experimental design we describe here is based on a method for detecting specifically the presence of a non-Newtonian potential through the unique signature of its non-zero Laplacian, thereby implying a violation of the inverse-square law. Our approach involves a cryogenically cooled torsion pendulum with carefully designed mass distribution undergoing large-amplitude oscillations in proximity to a source mass also of special configuration. Sensitivity to Newtonian gravity as well as to electromagnetic forces is strongly suppressed in order that this effort qualify as a null experiment. Preliminary, empirical performance estimates of this apparatus and methodology will be reviewed.

Link to presentation:
http://dl.dropboxusercontent.com/u/39112874/ISEG5pdf/Boynton.pdf