**Budget Justification**

# Personnel support

Funds in the amount of $45,378 are requested for one month of summer salary for PI Ortiz and CO PI Sabry.

Funds in the amount of $142,058 are also requested to support two graduate research assistant for 12 months each year of the project. One graduate student will come from the Physic Department and work with PI Ortiz and the other graduate student will come from Informatics & Computing Department and will work with CO-PI Sabry.

Salaries have a projected 3% increase in each subsequent year.

# Fringe benefits

The rate for faculty summer salary is calculated at 26.20% of base salary. Mandatory Student Health Insurance is budgeted in year one at $6,560 with annual 6% for Informatics rates and 10% increase for Physics rate increases. All rates are established by the Trustees of Indiana University.

# Equipment N/A

# Travel

Funds in the amount of $24,510 are requested to cover domestic and foreign travel during the three-year duration of the project. Funds will be used to cover costs associated with domestic and trans-Atlantic collaboration, project-related conference travel, and other travel related to dissemination of project findings.

The budget includes a total of $12,600 for domestic travel for the PI, CO PI and /or graduate students. Destinations are yet to be announced so we estimate air fare to be $600, lodging $175 a night, $75 per diem and ground transportation to be $50 a day for each traveler.

The budget also includes a total of $11,910 for International travel for the PI, CO PI and/or graduate students. Destinations are yet to be announced so we estimate two travelers each year for air fare $800, lodging $250 a night, per diem $95 a day and ground transportation at $50 a day.

# Other Direct Costs

# Consultant: Professor Emeritus of Computer Science Andrew Hanson will be hired as a consultant in years two and three of the project. He will be paid $500 a day for 26 days. Professor Hanson has participated heavily in the lead-in projects from their inception, and was co-author of both of our group's published articles on discrete quantum computing. The omission of year one is required by certain legal Indiana University legal requirements placing restrictions on post-retirement compensation until a specified amount of time has passed.  Hanson is trained as a theoretical physicist, with a PhD from MIT in high energy physics related to the early days of string theory, and has a strong background in mathematical physics ranging from quantum field theory and gauge theories to a solution of Einstein's equations, the Eguchi-Hanson metric, that plays a major role in many areas of modern physics, including supersymmetry and the ADE class of metrics that appear in supersymmetry (the Eguchi-Hanson metric was the first known metric of that class, the A1 metric).  His particular strength in differential geometry and the manipulation of complicated mathematical models using the Mathematica symbolic algebra system played essential roles in our team's currently published work on the subject of discrete quantum computing; Hanson will continue to provide support in these areas, most specifically in mathematical modeling and simulation, in which he has broad experience ranging from astronomy simulation and planetarium design to the applications of quaternion mapping to proteomics.  (He is the inventor of the Quaternion Gauss Map and the author of the 498 page monograph "Visualizing Quaternions" (Elsevier, 2006), in which the techniques of the Quaternion Gauss Map are explored in detail.) Among the various project-relevant tasks in which Hanson will play a critical role, we note the simulation of quantum mechanical processes with discrete variables, the extension of the concept of the Bloch sphere space of irreducible states to a diverse range of more complicated cases, and the exploration of event measurement and analysis processes based on Bayesian related methods such as the Hough transform, with which Hanson had wide experience in image understanding projects while working for a decade in the machine Vision group at the SRI (formerly Stanford Research Institute) Artificial Intelligence Center prior to coming to Indiana University.  Since many of the novel insights we shall hope to be pursuing in this project relate to combining the relevant aspects of Bayesian event-measuring analysis with finite-cost-based quantum mechanical theories, Hanson's connection with the Bayesian methods will be of potentially unique value.  Finally, we expect that many of the most interesting aspects of our proposed research will involve constructing visualizations of complex mathematical models, analysis of data, and quantum mechanical phenomena; Hanson has worked in and taught machine vision and computer graphics and visualization for over three decades, and is one of the world's experts in the construction of visualization methods for extremely challenging mathematical objects, and the graphics that he created for our first paper were chosen for the cover of the issue of the  journal in which our paper was published.  His role in the project will continue to be an important one, as it has been in our work to date.

**Fee remission:** Funds in the amount of $62,134 are requested for graduate student fee remission with an estimated 5% increase included for years two and three.

**Indirect costs**: The federally negotiated indirect cost rate for on-campus research is 56% for year 1 of the modified total direct costs (MTDC) which excludes fee remission; equipment costing more than $5,000; participant support; and subcontracts in excess of the first $25,000. In years 2 and 3, the rate will change to 57.5%. Indiana University’s indirect rate agreement is negotiated with the U.S. Department of Health and Human Services (D.H.H.S.).