Evolving Antennas for Detection of Cosmic Neutrinos

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We propose to use Evolutionary Computation (EC) to revolutionize antenna design across the field of ultra-high energy (UHE) astrophysical neutrino detection [1]. UHE neutrinos are unique messengers to the cosmos at macroscopic energies and can probe fundamental physics at energies unparalleled by accelerators on earth. By applying EC to produce antennas tailored for neutrino detection, we expect to invoke a leap in the sensitivity of detectors, expedite a first discovery and advance the field by a decade.

This proposal in *Science and Engineering Research* is timely and can only be carried out by this team. Evolution of antenna designs [2] has been well established over the last decade, while tools have matured in UHE neutrino astronomy to now make meaningful optimization of antenna designs possible. Connolly and Wissel have been at the forefront of radio neutrino experiments over the last fifteen years, including the ANITA balloon experiment and the ARA array in Antarctica. Staats is the developer of Karoo GP, unique in its open source foundation with scalability across CPU and GPU architectures as a Python algorithm; a LIGO and SKA-SA collaborator using Karoo for classification and noise mitigation [3]. S. Hausman (Lodz University of Technology) *et al.*, developers of an automated antenna optimization tool using XF, have begun to collaborate on this project. Through our world-class expertise in GP, finite-difference time domain modeling with XF, simulations of neutrino interactions and detectors, data analyses, and antenna design and testing, and field deployment, and through the RF testing and computing facilities at OSU and Cal Poly, *for the first time we will evolve antenna designs that give the highest fitness scores in detectability of UHE neutrinos.* We have begun to integrate these tools and plan to test an initial evolved antenna for ARA this year.

Support from the Keck Foundation is essential since this would not be funded by federal agencies for two reasons. *First, this forward-thinking and design-dedicated proposal would not fall under any of the NSF solicitations.* The most natural choice would be NSF's Particle Astrophysics - Experiment. However, a proposal to transform antenna design across the field over the next decade would not give the physics outcomes needed within a 3-5 year grant period. Also, while NSF has funded many projects using machine learning for data mining, we found only about ten awards for evolved antenna designs (compared to 1000 publications on the topic in the past decade), and no awards where the antennas were optimized for a physics outcome.

Prof. Wissel submitted an ultimately unsuccessful NSF proposal in 2016 with antenna optimization being a significant component. The review panel asked for "more details on the current limitations of the ARA antenna design," and we have begun to quantify potential improvements from altered antenna beam patterns and antenna gains. For an E^{-2} neutrino spectrum, a factor of ten higher gain would lead to a factor of $\sqrt{10N}$ increased neutrino rate, for N phased antennas. However, the panel response highlights the second reason that Keck funding is needed. *The very aspect of evolved antennas that makes them so exciting is a disadvantage at a federal agency - we cannot fully quantify the expected improvement that they will bring about in advance of performing the work because the algorithms produce designs that experts would not.*

We budget $600k for personnel, $300k for equipment and $100k for operations. Our team is primarily composed of women, underrepresented minority students (UMS), non-traditional students and undergraduates at teaching colleges.

[1] W. Scient, May '17, 217-240. [2] Int J Antennas Propag, '16,1010459. [3] APS '17 X6.8.