Research Statement

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I am a research scholar at the Harish-Chandra Research Institute, India pursuing a doctorate in physics in the theory of high energy interactions of elementary particles. I expect to receive my doctorate in Physics in the year 2013. In particular, my present research work, under the supervision of Prof. Raj Gandhi, concerns the interactions of neutrinos, which are the lightest particles known to man, having almost zero mass, at the ultra high energies (UHE), energies way more than what we can generate at our earthly labs – the particle colliders. Most of the particles, not least the neutrinos, at these energies stream to the earth from dense astrophysical sources where they are produced due to the simultaneous presence of incredibly high electric and magnetic fields, and temperatures. As neutrinos interact extremely feebly with matter, the detection of these ultra-high energy particles necessitates detectors with very large volumes. One of the most sensitive among such detectors is the *IceCube* — a 1 Km^3 volume detector built entirely into the Antarctic ice-bed, whose construction finished only recently (Dec, 2010), and which has been collecting data since its construction started much before. My work specifically relates to the implications for fundamental physical interactions when neutrino events are seen at the IceCube in the future. In particular, if the event numbers seen in the future do not agree with predictions from standard particle physics, it might signal the existence of some exotic non-standard physics affecting the propagation of the neutrinos from the distant astro-physical sources. We have shown that the observation of UHE events strongly differing from that expected from standard calculations can be explained by the presence of such exotic physics as neutrino-decay, the tiny effects of Lorentz-invariance violation possibly originating at the energies at unification scale and trickling down to these, much lower, energies and so on, during the propagation of the neutrinos from the source to the detector, and playing a significant role in modifying the otherwise standard rules of neutrino oscillation.

The study of neutrinos and their interactions at the highest energies expected in the universe has been a challenge, one thoroughly engrossing and enlightening. Apart from the obvious inputs from the theory of elementary particles and their interactions, my studies have required computation skills to, among others, analyse large matrices in several dimensions, and solve differential equations and integration over several dimensions by the so-called Monte-Carlo methods. Such requirements have honed both my theoretical knowledge and programming skills, and the general knack of problem solving. I believe that the rigours of pursuing a doctorate in high energy neutrino physics, thus, stands me in good stead, equipped to apply the skills I have acquired toward solving a variety of problems.

Additionally, I have also worked on baryogenesis and leptogenesis, which attempts to explain the observed abundance of matter over anti-matter in the present universe. I have collaborated on a work that investigates the general implications of fundamental symmetries of nature like *CPT invariance* on models for baryogenesis and leptogenesis. Based on these implications, we built up a "toy" model for leptogenesis, effective at the TeV scale energies.

In the future, I wish to keep working on physics related to the understanding of the properties, production and detection of neutrinos. With the IceCube detector only starting to see the first couple of extra-galactic neutrinos late in the summer of 2012, the study of these high energy neutrinos is only getting started and I believe there is a plethora of interesting analyses that will needed to be done to understand the physics implications of the number of events that will be seen at this and future Km^3 detectors. I also see a lot of potential for exciting work in building up particle physics models beyond the established *standard model* to explain the origin of the present over-abundance of matter over anti-matter via baryogenesis and/or leptogenesis in the early universe. Finally, I am also interested in exploring particle physics models beyond the standard model to explain the origin of dark matter in today's universe, and, thanks to a project I worked in, have an understanding of the relevant calculations commonly used in such work, such as the analysis of Boltzmann equations and so on.