Research Statement

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The Standard Model(SM) has been extremely successful in describing matter and its interactions, even more, it has predicted the existence of many (now discovered) particles. Still, it is well known this is an incomplete theory: Dark Matter (DM) and Dark Energy are not included, neutrinos are massless, there is no explanation for the values of the coupling constants, the gravitational interaction is not part of the model, etc.

The newest results(July 2012) from the Large Hadron collider (LHC) have given convincing evidence of the existence of a new boson, though calling this particle the Higgs (or the EW breaking particle) could be premature. The excess in the gamma gamma channel ,and the deficiency in the tau tau channel are very interesting results, and if they persist in the future, they would provide the first collider evidence of Physics beyond the Standard Model. Whether these effect are confirmed or not, the LHC will provide in the near future a huge amount of new data that will be used to test new models.

These SM extensions aim to address one or more of the above deficiencies.

The neutrino sector is an area I'm very interested in, the lack of right handed neutrinos in the SM, and the conclusive experimental evidence of neutrino oscillations give very strong indications of new physics. Still, the lack of precise measurements for the neutrino masses, of some of the mixing angles and the CP phases, allow the possibility of many models that can be used to describe the current values. Adding discrete symmetries is a possible way to extend the SM, this approach aims to understand the neutrino mass matrix. The tetrahedral symmetry A4 is one of the most frequent discrete symmetries theorist use, given its simplicity in reproducing the Tribimaximal (TBM) mixing form of the neutrino mass matrix (originally proposed over 10 years ago by Ma).

Last year new experimental results showed that the mixing angle θ_{13} is different from zero, this has important theoretical implications: first TBM is no longer a viable description of the neutrino mass matrix, and second this result imply the possibility that there is CP violation in the neutrino sector, which could be measured in future experiments.

In collaboration with my PhD advisor, Prof. E. Ma, I have worked with 2 different discrete symmetries as possible extensions to the neutrino sector, first we proved that A4 can accommodate $\theta_{13} \neq 0$, while still maintaining neutrino masses within the current experimental limits, moreover, though we assumed vanishing CP violating phases, this constraint can be easily relaxed. On the second project we proved that by using the heptagonic symmetry (D7) we were able to describe both the quark and lepton sector mass matrices, for the quark sector to the predicted mixing angles and CP phases lie within 1 sigma of the Particle Data Group (PDG) values. For the neutrino sector we obtained predictions for the neutrino masses and the CP Phases (for inverted hierarchy), while being able to get mixing angles and square mass differences inside the 1 sigma PDG values.

I have done some work in models with Weakly Interacting Massive Particles (WIMP) as Dark Matter. Probably one of the most common (and simple) extensions of the SM assumes the presence of an extra SU(2) gauge symmetry, which is usually associated with right handed fermions. My PhD advisor Dr. Ma (in collaboration with J. Lorenzo Diaz-Cruz, Subhaditya Bhattachar and myself), realized that it is possible for the extra SU(2) to be neutral in charge, in this case one of the new gauge bosons will be a spin 1 DM candidate. Though the possibility of vector DM was proposed earlier in much more exotic models(Universal Extra dimensions, little Higgs, and hidden sectors), this was the first time that a vector DM was proposed as a consequence of a simple extension to the SM. In this "dark" vector-gauge boson model the DM candidate mass is constrained to be around 1 TeV by the relic abundance measured by WMAP, the model will also be consistent with the current direct detection limits set by XENON, and will have some interesting (though not unique) LHC signatures, for example: missing energy, two opposite sign leptons and 1 or 2 jets.

Currently, for my dissertation, I'm working on an extended Left-Right SUSY model. The particle content of the model is chosen to be able to get gauge coupling unification at the GUT scale. Also, one of my goals is to explain the small neutrino masses by generating them at 1 loop, introducing an extra U(1) symmetry (that could be understood as a generalized lepton number) makes possible to prevent tree-level neutrino mass contirbutions, but give rise to 1 loop masses. This model has three conserved symmetries, (the previously mentioned U(1), and two Z2 discrete symmetries) then, given the extensive particle content, there will be three DM candidates: a neutralino, a Higgs-like exotic scalar and a right handed neutral lepton (scotino). Computer simulations will be done to check for discovery viability at LHC.

SUSY is the most frequent SM extension that is complete and self-consistent. With LHC lack of ability to find (so far) any evidence of new physics, and with new data being released regularly, it seems like we are in need to start paying more attention to alternative theories. My current training is with model building, but my interests are more varied. I 'm not only interested in current phenomenology other examples you'd like to explore in the future are: A consistent quantum gravity theory, will be able to explain matter and is interaction at the Plank scale which will help understand the processes that happened during the Big Bang and could also explain Dark Energy. Universal Extra Dimensions is (tough exotic) a fascinating idea with unique phenomenological effects. More study on QCD is still required to understand interactions at colliders and confinement, but even more is necessary to understand non-Abelain gauge theories. Finally I am interested in GR extensions. Ultimately I'm interested in what nature has chosen to model that explains the Universe and how we can extract this information from current and future experimental data.