Crossroads of Neutrino Physics

Final Report

Steen Hannestad, Patrick Huber, Joachim Kopp, Alexei Smirnov

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Neutrinos im Astrophysics

One of the focus topics of the scientific program "Crossroads of Neutrino Physics" was the impact of neutrinos in astrophysics. This included

- An update on solar neutrinos (Alexei Smirnov)
- A talk and a lively discussion session on collective effects in supernova neutrino oscillations (Georg Raffelt, Baha Balantekin, Evgeny Akhmedov, Cristina Volpe). It was recently found that this problem is even more challenging than previously thought. Numerous instabailities in the 3-flavor system imply that simplified 1d or 2d treatments cannot be trusted, and only a full 3-dimensional simulation could hope to capture all relevant effects. The effort for such a simulation would be comparable to the effort that goes into hydrodynamical simulations of supernovae. Moreover, a simulation of neutrino evolution should ideally be coupled with a hydrodynamical simulation since the two systems influence each other.
- Several talks (Eli Waxman, Zurab Berezhiani, Mauricio Bustamante, Toshihiko Ota) and a discussion session (Arman Esmaili, Danny Marfatia) on high energy astrophysical neutrinos. In spite of the discovery of high energy astrophysical neutrinos in IceCube, their origin remains a mystery. We learned that star forming galaxies, which can stop charged cosmic rays up to energies of 100 PeV, are a promising source candidate. The flavor ratios of astrophysical neutrinos remain an intriguing observable, even though measurements are not yet accurate enough to allow for discrimination between models. Finally, some extensions of the Standard Model can leave an imprint on the high energy neutrino flux, making IceCube well-suited to search for such new physics scenarios.

Most of this discussion took place in week 1, and part of it also in week 3. A discussion on results from the ICRC conference, led by Pasquale Serpico, provided a forum for the very latest results on this topic. Week 1 was completed with a colloquium on neutrinos in cosmology by Steen Hannestad.

Neutrino Oscillations

The second major topic of the workshop was neutrino oscillations, including in particular the possibility of new physics in the neutrino sector such as the possible existence of sterile neutrinos. The diverse discussions in this field of research centered around the following issues:

- How large can non-standard neutrino interactions be in realistic models (Pedro Machado and Yasaman Farzan)?
- How likely is it that light sterile neutrinos exist, and how could their existence be reconciled with strong bounds from oscillation experiments and from cosmology? This question was addressed in a long and fruitful discussion session led by Baha Balantekin, André de Gouvea and Joachim Kopp, and in a talk by Yong Tang.
- How would the existence of sterile neutrinos influence the search for CP violation in long baseline experiments (Boris Kayser)?
- How well can we probe neutrino oscillations in a large future iron calorimeter detector (Sanjib Agarwalla)?
- New analytic results on neutrino oscillation probabilities (Hisakazu Minakata)
- Can wave packet decoherence influence future oscillation experiments (Steven Wong)?
- How robust is the reactor neutrino anomaly (Patrick Huber)?

Neutrino Models

On the more theoretical side, we saw several very interesting presentations embedding neutrinos in extensions of the Standard Model. Borut Bajc explained the role that neutrinos play in Grand Unified Theories (GUTs) and how some of their masses and mixing parameters can be predicted in GUTs. Claudia Hagedorn illustrated how sterile neutrinos at the eV scale (for the oscillation anomalies) or at the keV scale (as a dark matter candidate) can be embedded in models of flavor, in particular models with discrete flavor symmetries. André de Gouvea discussed various aspects of seesaw models, focusing in particular on what we know and what we can learn experimentally about the heavy right handed neutrinos in such models. Motivated by the IceCube events, possibly pointing towards new physics at the PeV scale, Urjit Yajnik discussed a model in which an $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ symmetry is broken at a high scale, and leptogenesis takes place during the breaking of that symmetry. A discussion session on neutrino models was led by Zurab Berezhiani.

Connections between Neutrinos, Dark Matter and Collider Physics

In the final week of the workshop, we learned about several interesting ways of probing neutrino physics in experiments traditionally not associated with that field of research. Bhupal Dev discussed searches for electroweak scale seesaw models at the LHC, and Pilar Coloma illustrated how neutrino experiments can be exploited to search for dark matter particles directly produced in the neutrino production targets.