Sandhya Choubey

Research Summary:

Sterile neutrinos have been the subject of much discussion recently, following the much-awaited MiniBooNE results. One way to look for presence of sterile neutrinos is to look at signature of sterile neutrinos in the supernova neutrino signal in next generation detectors. We have studied these signatures in the next generation megaton water Cerenkov detectors and in the upcoming km^3 neutrino telescopes like IceCube. Time dependent modulation of the neutrino signal emerging from the sharp changes in the oscillation probability due to shock effects is shown to be a smoking gun signal for the existence of sterile neutrinos. These modulations and even the entire expected neutrino event spectra is seen to be different for the case with only three active neutrinos and the cases where there are additional sterile species, mixed with the active neutrinos. Effect of turbulence is taken into account and its seen that the shock effects even though diluted, are not completely washed out. Supernova neutrino signal in water detectors could therefore be used to give unambiguous proof for the existence of sterile neutrinos. Finally, these time dependent modulations in the signal due to shock effect can be used to trace the evolution of the shock wave inside the supernova.

Foremost among the next generation terrestrial neutrino experiments are the future betabeam and neutrino factory set-ups. A betabeam facility might come up at CERN and an intensive R&D is underway to look into its feasibility. At the same time we are working hard in India to build the detector INO, which will have 50 ktons of magnetized iron, interleaved with glass resistive plate chambers, which will act as the active detector element. We underscore the physics advantage of an experiment where neutrinos produced in a beta-beam facility at CERN are observed in a large magnetized iron calorimeter (ICAL) at the India-based Neutrino Observatory (INO). The CERN-INO distance is close to the so-called "magic" baseline which helps evade some of the parameter degeneracies and allows for a better measurement of the neutrino mass hierarchy and θ_{13}. We expound the possibility of using radioactive ^8B and ^8Li as the source isotopes for the ν_e and $\bar{\nu}_e$ beta-beam, respectively, and show that very good sensitivity to both the mass hierarchy and θ_{13} is possible with a boost γ in the 250-500 ballpark.

Betabeams can also be very efficiently detected in water Cerenkov detectors, where one would be able to detect the electron type neutrinos. We show that the earth matter effects in the $\nu_{\rm e} \to \nu_{\rm e}$ survival probability can be used to cleanly determine the third leptonic mixing angle θ_{13} and the sign of the atmospheric neutrino mass squared difference, Δm^2_{31}, using a β-beam as a ν_e source and a megaton water Cerenkov detector.

Large matter effects in atmospheric neutrino experiments can also help us to determine the sign of Δm^2_{31}. Observation of Δm^2_{21} driven sub-dominant effects in atmospheric neutrinos can be used to study the deviation of θ_{23} from maximality and its octant. We showed how non-zero values of θ_{13} affects this measurement. At the same time non-zero θ_{13} drives large matter effects in atmospheric neutrinos and these can be used to study the deviation of θ_{23} from maximality and its octant.

One needs a neutrino mass model which consistently explains all observations of neutrino experiments. We modify the Zee mass matrix by adding a real one parameter perturbation which is purely diagonal and trace-less. We show that in this way we can explain both solar and atmospheric neutrino oscillation data. There is a correlation between the deviation from strict maximality of $|U_{\mu 3}| = 1/\sqrt{2}$, with the emergence of a small but non-zero U_{e3}. We calculate how big a value can U_{e3} get when we restrict ourselves within the allowed regions of solar and atmospheric neutrino masses and mixing angles. We also discuss the impact of a S_2 permutation symmetry on our mass matrix and show how a small $U_{e3} \neq 0$ can emerge when this S_2 permutation symmetry between the second and the third generation is broken.

Publications:

1. Sanjib K. Agarwalla, Sandhya Choubey, Srubabati Goswami, Amitava Raychaudhuri, *Neutrino parameters from matter effects in in the nu(e) survival probability long baselines*, Phys. Rev. D **75**, 097302 (2007).

2. Sanjib K. Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Neutrino mass hierarchy and theta(13) with a magic baseline beta-beam experiment*, Nucl. Phys. B **771**, 1 (2007).

3. Abhijit Bandyopadhyay, Sandhya Choubey, Srubabati Goswami, S.T. Petcov, *Solar Model Parameters and Direct Measurements of Solar Neutrino Fluxes*, to appear in Phys. Rev. D (2007).

4. Biswajoy Brahmachari, Sandhya Choubey, *Modified Zee mass matrix with zero-sum condition*, Phys. Lett. B **642**, 495 (2006).

5. Sandhya Choubey, N.P. Harries, G.G. Ross, *Probing neutrino oscillations from supernovae shock waves via the IceCube detector*, Phys. Rev. D **74**, 053010 (2006).

Preprints:

1. Sandhya Choubey, N.P. Harries, G.G. Ross, *Turbulent Supernova Shock Waves and the Sterile Neutrino Signature in Megaton Water Detectors*, hep-ph/0703092 (under review in Phys. Rev. D).

2. Sandhya Choubey, *What we can learn from atmospheric neutrinos*, arXiv:hep-ph/0609182.

3. Sandhya Choubey and other members of ISS physics working group, *International scoping study of a future Neutrino Factory and Super-beam facility*. http://www.hep.ph.ic.ac.uk/iss/wg1-phys-phen/index.html

4. Ram Lal Awasthi and Sandhya Choubey, *Confusing Sterile Neutrinos with Deviation from Tribimaximal Mixing at Neutrino Telescopes*, in preparation.

5. M.Sajjad Athar et al, [INO Collaboration], *India-based Neutrino Observatory: Project Report*

Conference/Workshops Attended:

1. *The XXII International Conference on Neutrino Physics and Astrophysics*, USA, June 2006.

2. *XII IFT-UAM/CSIC Christmas Workshop*, Spain, December 2006.

3. *The 17th DAE-BRNS High Energy Physics Symposium*, India, December 2006.

4. *21st International Workshop on Weak Interactions and Neutrinos*, India, January 2007.

5. *Joint Indo-German School And Workshop 2007 Neutrinos in Physics, Astrophysics and Cosmology*, February 2007.

Visits to other Institutes:

1. University of Oxford, Oxford, United Kingdom, May to August, 2006.

Invited Lectures/Seminars:

1. *What We Can Learn from Atmospheric Neutrinos*, Invited plenary talk at "The XXII International Conference on Neutrino Physics and Astrophysics", Santa Fe, New Mexico, USA, June 13-19, 2006.

2. *Neutrino Phenomenology: Current status and future prospects*, Invited plenary talk at "XII IFT-UAM/CSIC Christmas Workshop, Madrid, Spain, December 18-20, 2006.
3. *Atmospheric neutrinos: What more can we learn?*, Invited plenary talk at "The 17th DAE-BRNS High Energy Physics Symposium", IIT, Kharagpur, December 11-15, 2006.
4. *Neutrino Physics: Future Directions*, Invited talk at "21st International Workshop on Weak Interactions and Neutrinos", SINP, Kolkata, January 15-20, 2007.
5. *Neutrino Oscillation Phenomenology*, Lecture series at "Joint Indo-German School And Workshop 2007 Neutrinos in Physics, Astrophysics and Cosmology", TIFR, Mumbai, February 12-23, 2007.
6. *Supernova Shock Waves and Sterile Neutrinos*, Invited talk at "Joint Indo-German School And Workshop 2007 Neutrinos in Physics, Astrophysics and Cosmology", TIFR, Mumbai, February 12-23, 2007.
7. *Neutrino Physics*, Lecture series at "INO Training School", HRI, Allahabad, India, April 10-25, 2006.

Other Activities:

1. Organizing schools/conferences:
   - (a) Co-organizer of the Ino Training School at HRI, Allahabad, April, 2006.
   - (b) Co-ordinator of the neutrino physics, astroparticle and cosmology working group at WHEPP X, to be held at Chennai, January, 2008.
   - (c) Member of the organizing committee of the Neutrino Meeting to be held at HRI, February, 2008.
2. Teaching at HRI: Gave a special course on 'Statistical Modeling of Data and Error Analysis in HEP', March-May, 2006.
3. Mentoring Project Students: Guided Ram Lal Awasthi on the project, 'Solar Neutrino Problem and its Solution', October-November 2006.
4. Reviewing Papers: Refereed papers for
   - (a) Physical Review Letters
   - (b) Physical Review D
   - (c) Journal of High Energy Physics
   - (d) Physica Scripta.

5. Talks at HRI:

   (a) *Solving the degeneracy of the lepton-flavor mixing angle* $theta_{atm}$ *by the T2KK two detector neutrino oscillation experiment*, pheno-lunch on November 11, 2006.

   (b) *Neutrino Physics: Future Directions*, HRI Internal Symposium, March 2007.

6. Committees Served:

   (a) Office and Furniture Committee (member)

   (b) Rajbhasha Committee (member)

   (c) Guest House and Pantry (member, convenor for a period of 4 months)

   (d) HRIRA (chair-person)