Physics 711 *and* 712
Fall 2009 *and* Spring 2010

Neutrino Physics and Astrophysics

This course is aimed at graduate students in physics and astronomy, not restricted to particle physics. Auditing is permitted, and faculty persons are welcome. There will be no ordinary homework, but students will be expected to give one lecture per semester (towards the latter part), on one of the topics, as they choose.

Professors John Learned *and* Sandip Pakvasa

Meetings: **once per week, 2:00-3:30 PM in the Physics Library, 417a Watanabe Hall.**

Prospectus:

0. Introduction and overview 711-1.ppt (8/28 and 9/2)

1. Summary of Standard Model 711-SM1.pdf (9/2 and 9/9)
Neutrino Interactions in the Standard Model

2. Neutrino Mass 711-SM1.pdf (9/9)
General Theory (Dirac vs Majorana etc); Nu Mass in SM; GUTS, SU(5), SO(10) etc; See-Saw etc

3. Neutrino Mass Experiments
Beta decay end point; e-capture; pi, K decays; tau decays; Double Beta Decay

4. Neutrino Mixing and Oscillations
Flavor Mixing; Sterile Mixing; CP Violation; Non-orthogonality of massless nus; Kinematics, coherence etc; Matter Effects; Neutrino Decays.

5. Atmospheric Neutrinos
Introduction to Cosmic Rays; Expectations for neutrino fluxes; Comparison to data and implications; Future experiments and expectations.

6. Solar Neutrinos
Modeling and fluxes; Summary of experiments and results; Future expectations.

7. Reactor Neutrinos
KamLand experiment and results; Future Experiments; Geo-Neutrinos and Future experiments.

8. Accelerator Neutrinos
K2K results; MINOS results; Future long baseline experiments.

9. Summary of the current status of 3 flavor mixing from global analysis of all data.

10. Summary of results of LSND, MiniBoone and relevant phenomenology of sterile neutrinos

11. Neutrinos and Supernovae

Supernova modeling neutrino expectations; Nus from SN1987A; Future Supernovae detection and prognosis.

12. Very High Energy Neutrino Astronomy

Very High Energy Gamma Ray Astrophysics; High Energy Neutrinos from AGN, GRB etc (incl GZK neutrinos); Neutrino Telescopes and Signals(KM3 etc).

13. Cosmology and Neutrinos

Expected properties of CMB nus; Proposals for Detection of CMB nus; BBN Nucleosynthesis and Nus; Leptogenysis.

14. WIMP Searches with Neutrinos

15. Geoneutrinos

Student learning outcomes: We would like the students to acquire a first level working knowledge of the theory and experiment in elementary particle physics and astrophysics, relative to neutrinos. The course is designed to bring graduate students and others to the level of professional understanding of forefront neutrino work.

We will use the following two texts, more or less:

- **"Fundamental Neutrinos Physics and Astrophysics", C. Giunti and C. W. Kim (Oxford 2007)**
- **"Physics of Neutrinos and Applications to Astrophysics", M. Fukugita and T. Yanagida (Springer 2003).**

Other useful general references are:

- **"Particle Astrophysics" by Don Perkins (Oxford 2003). Has excellent introduction to particle physics for non-specialists. I think it is a little short on some of the topics above, such as the origins of cosmic rays and neutrinos.**
- **"Cosmology and Particle Astrophysics" by Lars Bergstrom and Ariel Goobar (2nd edition, Springer 2004). Has a strong introduction to cosmology. A bit more formal intro to particle physics, and again a bit short, in my view, on the topics above.**
- **"High Energy Cosmic Rays" by Todor Stanev (Springer 2003). The best book around on Cosmic Rays. There are older books but I would start here for an overview of the field, and quite a bit of detail on interactions in the atmosphere.**
- **"Neutrino Physics" by Kai Zuber (IoP 2004). This is the best recent introduction to everything you want to know about neutrinos.**
- **"Neutrino Astrophysics" by John Bahcall (Cambridge, 1989, but his web page says a new version due out in 1998 though I have not seen it). This is the definitive book about solar neutrinos.**
- **"Current Aspects of Neutrino Physics", David Caldwell, Editor (Springer 2001). One of the best overall neutrino resources for experts (but jgl biased as he wrote one of the chapters).**
- **Link to Prof. Pakvasa's public page with more material: Sandip_pub**

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jgl and sp, 10 August 2009