MITOCW | L8.5 Neutrino Physics: Results of Neutrino Oscillation Experiments

MARKUS KLUTE: Welcome back to 8.701. So in this lecture and also the next one, we'll look at some of the experimental findings of neutrinos. Given the sheer number of experiments and the long history in which we are trying to understand neutrinos and neutrinos' behavior, this can be rather confusing. So I'm trying to condense this a little bit and just give you the highlights, or the basic pieces of information.

So this one here shows a summary of what we know from neutrino oscillation. So if we look at atmospheric neutrinos, we find that mirror neutrinos and anti-mirror neutrinos disappear, and they're most likely converting into tau neutrinos and anti-tau neutrinos. We look at accelerating neutrinos-- here we are using mirror neutrinos and anti-mirror ones-- we can show that they disappear over distances of 200 to 800 kilometers.

From accelerators, we also know that they appear or reappear as electron or anti-electron neutrinos over those same distances. From the solar neutrinos, we know that electron neutrinos convert into mirror neutrinos and/or tau neutrinos. There is more detail to this story than I'm giving you here, where we would have to discuss the interaction of the matter effects of neutrinos. That is for a different lecture. That goes beyond the scope of what I want to discuss here. From reactor neutrinos, we also know that anti-electron neutrinos disappear as well.

So the name of the game now is to take all of those pieces of information and extract information about the neutrinos' property. And in order to do that, one has to make assumption about the number of available neutrino generations, and in some part of the interpretation, also about the nature of the neutrinos.

As you can simply figure out of the exercise we had before, it matters to the neutrino oscillation probabilities whether one assumes two or three or four neutrinos in the mix. But if you just focus here on three neutrinos, you still have the problem that we have degeneracies in the discussion.

And they can be boiled down to two major kind of trends. One is where the spectrum of the neutrino mass follows a normal ordering, meaning that the mass of the first is smaller than the mass of the second is smaller than the mass of the third, or that the spectrum is inverted, meaning that the mass of the third might be smaller than the mass of the second and the mass of-- the first and the second. Data suggests that the difference squared in mass splittings between those states is such that delta m12 squared is much smaller than delta m31 squared, which is approximately the same size as delta m32 squared.

So if you look now at the numbers for the normal hierarchy spectrum, we find that the mass of the first is much, much smaller than the mass of the second, which is a little bit smaller than the mass of the third. Numerically, we find the mass of the second is in the order of 8 times 10 to the minus 3 electron-volt, and the mass of the third in the order of 0.05 electron-volts, so really, really small masses.

The inverted spectrum-- here the story is slightly different. Here we find that m1 is about 0.05 election-volts, which is similar to the square root of the mass splitting between 3 and 2, which is also 0.05 electron-volts.

The information of the neutrino oscillation experiment, and then how to map into the individual parameters of our neutrino CKM matrix is summarized here, and also in the mass information. And I don't want to read the entire table. I'll just leave this here for you.

So in order to understand this, one has to go back to the first slide and understand what kind of information we extract from various neutrino experiments-- for example, the solar neutrino experiments-- and then think about, is this sensitive to oscillations between the first and the second generation, or the first and the third generation? So that's kind of the mapping you have to do in order to understand this table fully. There are some experiment where the information just dominates the position of a certain measurement. In others, there is combinations of results coming out.

The other reason why I put this table here in this lecture is to just illustrate how diverse the landscape of experiments is and why that's needed. In order to get a full picture of neutrinos and their properties, one has to identify the individual properties in the experiments and then put the picture back together in a global fit or in a general analysis of the data.