Jonathan Feng – Lecture 1 Questions

Questions marked in green were answered during the Q&A session. I haven't tried to correct grammar/spelling. Where a slide number was given it is shown.

Q1 (slide 10). To me it seems this second "miracle" is even more interesting because it suggests dark matter particles would have some interaction mechanism with SM particles beyond gravity. Is this the right idea, or is this not necessarily true?

The WIMP miracle is the miracle that suggests that DM has non-gravitational interactions with the SM. The miracle described in slides 10 and 11 takes this one step further: if the DM interacts with the SM, one might expect it to be able to decay to 2 SM particles. The argument on page 11 says that, no, this is not necessarily true, and in fact, there are reasons to think this decay is forbidden by a symmetry.

Q2 (slide 10). How do we know that a new particle couldn't be a new force mediator between four SM particle interactions? Do precision EW measurements only exclude this in the case that the new particle is an electro weak mediator?

If the new particle interacts with an order 1 coupling and has mass around the 100 GeV to TeV scale, as required to resolve the gauge hierarchy problem, then, if it mediated 4-point SM interactions, it would typically be excluded by LEP electroweak precision measurements. The new particle doesn't have to be an electroweak particle -- any new particle that does this would be subject to the same LEP constraints.

Q3 (slide 12). For the wimpless miracle, do you need some amount of fine-tuning in the dark sector to get the right relic density?

One always needs some fine-tuning to get the relic density exactly right, since it's known to 1%. This is true for both the WIMPless miracle and the WIMP miracle. But the fact that light particles are correlated with small couplings can come about naturally, for example, in theories of gauge-mediated or anomaly-mediated supersymmetry breaking.

Q4 (slide 16). Could you describe a little more how UHE Cosmic Rays could be used for detection?

UHE cosmic rays have been detected t energies around 10^20 eV, which means the COM energy when they collide with a proton i nthe atmosphere is above the LHC's. So there is plenty of energy. The trick is to find a signature that can be detected above backgrounds. One example is looking for a high energy neutrino colliding with a p in the atmosphere to create a slepton and a squark, and the slepton then can be long-lived and detected in, e.g., IceCube. See papers by Albuquerque, Burdman, and Chacko, hep-ph/0605120 .

Q5 (slide 19). What motivates the breaking of the SU(2) symmetry at dm ~ 160 MeV?

This is a loop-effect and is about the same throughout parameter space. The ttree-level splitting varies much more, but it is typically much smaller, so of little consequence. This is discussed in hep-ph/9904250.

Q6 (slide 26). Is the F^{\mu\nu} the electromagnetic tensor of dark photons? Could you please explain how this interaction terms lead to the Feynman diagram of the coupling of one SM photon to one dark photon?

The coupling of Fmunu from the visible sector to the Fmunu from the dark sector is generated by a Feynman diagram where there is a particle with both visible and dark charge in the loop. You can find the details in Holdom's original dark photon paper.

Q7 (slide 27). Why is it a good guess that the dark sector has its own U(1) symmetry? Is U(1) favored over other gauge groups for some reason? Thanks!

If the dark sector's gauge group is not U(1), there is no renormalizable Fmunu Fmunu-type coupling. So one way to say this is that if there are multiple gauge groups in the dark sector, the one that couplings most strongly is likely the U(1) gauge group, and so in this sense it is favored.

Q8 (slide 28). When do our limits on Higgs couplings reach the precision that the dark Higgs stops being able to explain the DM density we observe?

This is an interesting question, but probably this is not going to happen any time soon. Limits on the invisible decay of the Higgs boson will be about 1% at best for a long time, and this is not a very stringent limit on Higgs-dark Higgs mixing parameters.