Jodi Cooley Lecture Questions

Most questions were answered during the Q&A session. Original questions listed without correction for grammar/spelling, except some similar/related questions are merged. Where a slide number was given it is shown.

General: The mixing matrix of photon and dark photon is not orthogonal, it should result in some jacobian matrix right? Does that matrix have any visible effect or relevance, or I am missing some point here.
The effect of the mixing is reflected in the effective couplings that we define, so there is Jacobian, but it's taken into account already.

The physical effect that we would measure in a detector is the scattering off an electron or absorption by an atom (that then gives off an electron). Direct detection experiments would see this as an ER interaction.

General: What are MACHOs.
MACHOs are MAssive Compact Halo Objects. These are objects that do not emit light in visible, x-ray or infrared. Objects that are considered MACHOs include neutron star, brown dwarfs, and black holes. They are generally detected using a variety of gravitational lensing techniques.

Slide 6: Does "absorption" mean that the electron absorbs the DM?
For many years we have discussed dark matter detection by "scattering" off a target nucleus or electron. Another possible mechanism for detection is absorption. The idea is that the absorption process causes the affected atom to eject an electron. This electron can then produce a signal in the detector. (ie. https://arxiv.org/abs/1905.12635)

Slides 11-12: How were these four formulas derived? (generally)
These are all formula that involve nuclear shell calculations. To see how these formula are derived, I suggest reviewing this classic paper:

- J.D. Lewin, P.F. Smith, "Review of mathematics, numerical factors, and corrections for dark matter experiments based on elastic nuclear recoil ", Astroparticle Physics 6 (1996) 87-112, in particular the section on the nuclear form factor correction

To highlight the calculations note the following

- Assume that the wavelength is not large compared to the nuclear radius. This is represented by the "form factor" which depends on the momentum transfer and the effective radius.
- The form factor is calculated using the plane wave (Born) approximation.
- Numerous fits to the form factor have been proposed. For the spin-independent case, the Woods-Saxon form factor is often used. For the spin-dependent case, you need to include proton, neutron and interference terms.

Other classic resources for details of the calculations of form factors can be found in the following resources:

- V. Dimitrov, J. Engel, and S. Pittel, "Scattering of weakly interacting massive particles from Ge- 73",Phys.Rev.D51(1995) 291–295, hep-ph/9408246.

- J. Engel, “Nuclear form-factors for the scattering of weakly interacting massive particles”,Phys. Lett.B264(1991) 114–119
- J. Engel, S. Pittel, and P. Vogel, “Nuclear physics of dark matter detection”,Int. J. Mod. Phys.E1(1992)1–37.

Slide 14: How is the local dark matter density measured?
There are two techniques that are used: local measures and global measures. Local measures use the vertical motion of tracer stars near the sun. Global measures extrapolate the density from measured rotation curves and make assumptions about the galactic halo shape.

Slide 17: What does it mean to use a chlorine or fluorine eigenvector?
The F/Ge eigenvector refers to the eigenvector for a WIMP mass of 100 GeV scattering in the respective target. Since these materials have different nuclear compositions, they are sensitive to different operators. Operators have dependence on spin, relative velocity of the incoming WIMP and nucleon and momentum transfer.

The F/Ge eigenvector is the non-zero vector that when the operator is applied, does not change direction. It can only be scaled by an eigenvalue. The eigenvector for fluorine is not the same as the eigenvector for germanium as they have different nuclear properties.

In this example since the fluorine eigenvector is not parallel to the germanium eigenvector, the germanium event rate evaluated at the fluorine vector is suppressed and vice versa. In addition, since the xenon and germanium eigenvectors are nearly parallel in this case, the two rates are comparable at the 30 keV NR energy at which the eigenvectors are evaluated.

For a more detailed explanation see:
https://lss.fnal.gov/archive/2015/pub/fermilab-pub-15-393-ae.pdf

Slide 17: This would be also the case even if we don't use effective field theory, right? The cross section depend on the form factors (every nucleus have its own form factors)
I suppose this depends on what you use for your form factor. Experiments are going to report measurements and we will try to explain those measurements with theories. EFT provides a framework for interpreting signals in a straightforward way.

Slide on “WIMP wond”: Can we assume that the DM halo is static with respect to the galactic centre--how do we know that there is no stirring/movement of DM particles within the DM halo?
No, the dark matter halo is not really static. The standard halo model I presented is assumed to be isotropic and have a velocity distribution function that has a Maxwellian form, truncated at the escape speed.

The local velocity distribution of DM cannot currently be directly measured. However, recent hydrodynamical simulations that include baryons find distributions that are close to Maxwellian.

Slide 43: What's assay information?
This information about the radio-contamination (U, Th, K, etc) of material measured in an instrument.

Slide 49-50: why is there a gap in mass around 3 GeV?
This is not real. It is an artifact of the way the plot was made.