Many (all) the questions have been answered during the Q&A period. Nevertheless, we ask that you provide written answers below so students can come back to read them again. Thanks!

1. (Slide on coma cluster) Could you please, explain in detail, how Zwicky estimate visible mass & total mass? (how he obtained data and how he came to conclusion of missing mass?)

He combined a number of observations:
Firstly, he used the virial theorem to determine how much mass should be in the cluster, i.e. gravitational potential, given the galaxy velocities (these velocities were measured earlier by Doppler shifts). In other words, for the system to remain bound despite its kinetic energy, it needed to have a sufficiently strong gravitational potential. In equilibrium we expect KE = -½ PE where KE is kinetic energy and PE is gravitational potential energy.
Secondly, he could compare this to how much mass there seemed to be just from the luminosity of the cluster. There, he counted the galaxies to add up to some total luminosity, converted the mass using a mass-to-light ratio of about 3, which was calibrated from the local Kapteyn stellar system.

He found that the numbers were not consistent; the luminosity alone (baryonic matter) was not enough to explain the apparent mass. This led him to conclude there was indeed a missing mass, or dark matter component in the coma cluster.

2. (Slide 66?) Hasn't the WIMP miracle argument be oversold? After all its only a numerical coincidence and there is no evidence from any astronomical observation that CDM is a WIMP. (There are many other such numerical coincidences in particle astrophysics/ cosmology which no one takes seriously one example is Zeldovich relation discovered in 1967, viz cube of QCD scale = Hubble scale in natural units)

I don't think so at all! It's certainly very hard to know what model is the right model for dark matter, because we only have gravitational evidence at the moment. So what principle should we use? To me, the fact that we have matter already at the weak-scale, and the amount of DM is comparable to the amount of SM, gives us a good motivation to also search for dark matter around the weak scale. Matter we know exists already at this scale, so I think it is highly motivated to search for weak-scale interactions for dark matter. We definitely shouldn't only search for such particles though, a wide and as model-independent as possible search program is very important. Alongside other tests and searches, I think weak-scale interaction searches should be exhaustively tested.

3. (CMS Dark Matter evidence). How do we know DM does not experience radiation pressure, only gravity ? Is it because we have no model for the CMB if it does, or is it because we have extra observation (galaxy inner rotation / interaction between galaxies ...) to get to that conclusion ?

This simply comes from the acoustic peaks / anisotropies we see in the CMB. If DM felt a lot of radiation pressure like the SM, the peaks would be measured to have very different values from what they do, because DM would also be driven to oscillate with the competition between gravity and radiation pressure.

In other places/times in the Universe, we also observe that DM doesn't seem to interact very much at all with the SM, and at least not too strongly with itself (see e.g. bounds from the bullet cluster).

4. Mukhanov and Chamseddine showed (arxiv:1308.5410) that if you reformulate Einstein's theory of gravity, isolating the conformal degree of freedom by rewriting the physical metric in terms of auxiliary metric and a scalar field and they showed that the scalar field acts as a dark matter. Would you call this model as "modified gravity" which dispenses with dark matter or dark matter?

Technically, at least as far as the literature goes, I think this would fit in the category of modified gravity rather than dark matter. But this is to some degree semantics; if we need to add in new particles and fields to explain the dark matter problem, like your question suggests, these aren't necessarily very different things. Given the vast range of evidence for DM, and as the evidence as grown, I think a lot of these modified gravity suggestions have moved somewhat away from the original motivation of modified gravity in order to explain the evidence. We should of course keep an open mind about the dark matter problem, because we have little idea what it is, but it seems the evidence on the whole points towards us needing some new matter component.

5. Can we constraint dark matter self-interaction through the weak gravitational lensing ?

Yes. One way is as was found with the bullet cluster – imaging the hot gas in x-rays showed us where the SM matter was colliding, and weak gravitational lensing showed the bulk of the mass was centered either side of the SM matter. This can be interpreted as DM which does not interact very much with the SM or itself; if DM interacted too strongly it wouldn't have passed through so easily to the other side. This gives us great constraints on the dark matter self-interaction cross section.

6. (Slide 60) You did not mention massive graviton which has been considered in literature as dark matter. Is that ruled out?

Massive gravitons are not generically ruled out, and can still be considered as dark matter. The slide is not complete in that it definitely does not list all dark matter models, those that are listed are only a small number of examples. We'll discuss more models in tomorrow's lecture!

7. What is the relationship between dark matter and dark energy? Are there models of dark matter that also predict the rate of the expansion of the universe?

Generally dark matter and dark energy are two separate things, and are not considered together – they solve two different problems (invisible large extra mass component, accelerated expansion of the Universe respectively). In that sense they really behave very differently, one slows down the expansion of the Universe while the other speeds it up. But of course it's possible to make a model that aims to address aspects of both; but it doesn't come together in any nice picture.

8. (DM detection) How can we distinguish, in colliders, the missing momentum coming from neutrinos from the missing momentum coming from dark matter? Granted that in colliders we are looking for weakly interacting DM.

We understand neutrinos reasonably well (there are of course several open questions for neutrinos, but they are vastly better understood than dark matter!). As such, we have fairly good estimates for the event rates for neutrinos in colliders, along with the expected transverse momentum distribution (missing pT is the main thing we want to use for the weakly interacting particles). As such, we can compare our theoretical predictions for the neutrino rates, with our theoretical predictions for a given DM theory model. The DM model generally will look very different, and should be distinct from the SM background distribution which will already be modeled to include the neutrinos.