

## Tim Tait – Lecture 2 Questions

Questions marked in green were answered during the Q&A session. No attempt was made to correct grammar/spelling issues. Where a slide number was given it is shown.

Q1: For us undergrad, could you give the answer or hints to the answer or some reference material?  
Thank you!

Some good over-views are TASI lectures by Feng or Slatyer. You can find write-ups and recordings of the lecture online.

Q2 (slide 5): Is there any experimental way to predict what happened before BBN?

We could hope to learn something from gravitational waves or neutrinos.

Q3 (slide 11): How important are thermal effects for freeze-out calculation?

This is something currently under investigation. Usually, they are not extremely important, but in some cases they can be.

Q4 (slide 13): If a SM particle were to decay into a DM particle, would that decay necessarily be mediated by some dark sector particle?

Usually, yes.

Q5 (slide 14): There are lot of theories which could give rise to correct density? Is there a way to differentiate between different cosmologies at early universe ?

In principle, if we knew which theory it was, yes. But right now we don't.

Q6: Given the lack of evidence for SUSY at LHC, why SUSY-theories are still good candidates for DM?

There is still a good chance that SUSY could be discovered in the future at the LHC.

Q7 (slide 25): Are SUSY particles described by the same gauge groups as their SM particle counterparts?

Yes!

Q8 (slide 27): Could we use our current estimated proton lifetimes to instead set a constraint for the rate of relevant SUSY interactions, instead of invoking R-parity?

Yes, one usually does this and finds limits that are very strong.

Q9 (slide 28): What are the  $t$  particles?

Top quarks.

Q10 (slide 28): Is the Bino the SUSY partner of the Z boson?

It's a linear combination of the partner of the Z boson, Photon, and Higgs bosons.

Q11 (slide 37): Sorry--what does Beta refer to again?

The ratio of the VEVs of the two Higgs bosons in the MSSM.

Q12 (slide 32): Is the problem of neutralino annihilation leading to too much Bino production solvable by tweaking early universe parameters?

In principle, yes. There was work by Gondolo and Gelmini in this direction.

Q13 (slide 28): Why  $H_u$  has much stronger Q dependence than  $H_d$  ? top quark ? What's the significance of  $H_u$  going negative and extended Higgs sector as source of DM ?

$H_u$  has much stronger effects from the large top Yukawa interaction. It's  $m^2$  going negative is what causes the electroweak symmetry to break.

Q14: There are a lot of plots today labeled  $\Omega h^2$ , is this the same as the strain  $\Omega_{\text{GW}} h^2$  that the gravitational waves lectures were talking about last week?

It's measuring the same way (in terms of normalization with the critical density), but is a different species whose energy density is being measured.