GP Carosi 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.

Slide 3: Is the small neutron edm the same thing as the strong CP problem?
Yes, the fact that the neutron edm should, from standard QCD, be easily measurable (of order 10^{-16} e-cm) but is in fact consistent with 0. Another way to look at it is that it appears that QCD preserves CP symmetry even though elements of the QCD lagrangian are CP-violating.

Slide 5: What does a naive estimate of the neutron EDM mean?
It comes from the fact that the neutron is a constituent particle with 3 quarks and the gluons holding it together. The QCD Lagrangian can be used to describe this system and

Slide 6: Why does SN1987a/white dwarf cooling set a bound on axion mass?
The QCD axion's coupling to two photons provides an alternative cooling mechanism to Super Nova 1987a and, if the couplings were strong enough, it would have limited the number of neutrinos that were seen. Since the coupling is directly related to the mass the number of neutrinos also puts a limit on how high the mass can be.

Slide 6: There's that small range where "pre-inflation" and "post-inflation" overlap---would an axion mass at that point just not give very much information about inflation?
Difficult to say until there is a detection. There is debate on where that line of pre vs post inflationary symmetry breaking might be. Other cosmological measurements such as the search for primordial gravitational waves in the cosmic microwave background could also shed light on this.

Slide 11: What is co-genesis?
Co-genesis is a general term that describes the emergence of two things at the same time. In the context of the axion co-genesis this is a theory being advocated by Raymond T. Co, Lawrence J. Hall, and Keisuke Harigaya. It effectively postulates that the dark matter and baryonic densities can be explained by the addition of an Axion-Like Particle (ALP) that possesses an initial field velocity and couplings to SM particles. I'll refer you to this very recent paper on the arXiv for further details:
https://arxiv.org/abs/2006.04809

Slide 12: Why is the axion, and not the photon, able to go through the "wall"?
In this slide the experimental concept is to have an extremely large photon field provided by a strong laser bouncing light back and forth in a Fabry-Perot resonator threaded by a strong magnetic field. The idea is this would produced axions that would not be stopped by the inner wall of the Fabry-Perot resonator and appear in the 2nd cavity and could then be reconverted to detectable photons.

Slide 16: What is a “bore”?
This just refers to the inner diameter of the cylinder that makes up the solenoid magnet.

Slide 26: What's the probability that statistical anomalies will still be detected on the rescan? Would it be good to do multiple rescans?
This is an interesting optimization process. There is certainly chances that a statistical anomaly that shows excess power at a specific frequency however if it shows up a 2nd time there is usually a flag in which that particular frequency space receives extra scrutiny. Usually when that occurs it’s a synthetic axion signal that is injected on purpose to calibrate the system or it’s an external radio signal that has slipped past our shielding. A real axion would be persistent signal who’s power is directly related to the B-field which can easily be adjusted.

Slide 28: Does this figure mean that significant areas of the parameter space permitted for QCD axions are already excluded?
Yes, however there is still a lot of range to cover. Currently we are scanning frequencies in the 1 GHz range and have plans to search frequencies at least to 10 GHz (and beyond).

Slide 32: Are there plans to go to lower frequency as well?
Yes, there are plans to do lower frequency searches using lumped element LC-circuits as well as completely different detection strategies such as using nuclear spins in NMR type experiments. See the SLIC, ABRACADABRA, DM Radio, and CASPer experiments.

General: Are there any other haloscope/dark matter experiments for axions that are as advanced as ADMX?
No, but I’m clearly biased :)
I add that all these haloscopes have strengths and push the field forward. For instance there is a very nice recent paper out from the HAYSTAC group on the first results of their system employing squeezing to get below the quantum limit and increase scan speed. It’s a really exciting result: https://arxiv.org/pdf/2008.01853.pdf

Slide 33: Why does HAYSTAC experiment need 9.4 T magnetic field. How do they achieve this ?
This was the largest magnet that they could reasonably buy with the proposal they put forward. We would all love stronger magnets as it increases the number axion-to-photon conversions but there are tradeoffs between solenoid bore, field-strength and cost.

Slide 34: Why are copper cavities preferred for Axion search experiments ?
Up to now copper cavities provide the highest quality factor (lowest amount of loss from the currents in the resonant modes running up and down the cavity walls) in a high magnetic field. Superconducting cavities can be made with much higher Q but, generally, they are driven normal in a high-magnetic field. There are a number of groups though working on producing superconducting cavities that can withstand high magnetic fields.

Slides 6/9: Do we currently have experiments targeting the whole range of possible QCD axion masses? Are there regions of the parameter space not addressed by any experiments so far?

There are a large number of experiments looking over a wide range but there are still several gaps (especially in the 100 GHz - THz range, though there are some ideas on ways to get there). It should be noted that most of the experimental concepts I described are in the early R&D phases and could run into practical limitations requiring other ideas. Up to know ADMX is the only experiment that has reached DFSZ axion sensitivity in the lighter mass range (< eV)

Slide 51: If the axion is not a fifth-force carrier, it would have to be a boson that doesn't mediate a force?

I'm sorry but I don't quite understand the question. If the axion existed it would certainly be a boson. It's defined as a spin-0 neutral pseudo-scalar boson which is why the only way it can interact with photons is through a virtual loop in a process known as the inverse Primakoff effect. I think a better way to think of the interaction of axions that would show up as a fifth force is that virtual axions could be exchanged and modify interactions at very short ranges.

General: If the axion is not the QCD axion, but just an ALP, would it still solve the other main problems (astrophysical cooling, string theory implications, strong CP problem)?

Yes, potentially. This is actually some of the motivations for ALPs existing as they would need to have mass & couplings different than the QCD-axion to solve some of the other hints. However only the QCD-axion solves the strong-CP problem. If an ALP was discovered far from the QCD-axion band theorists would need to work hard to figure out why (or we'd still need to search for the classical QCD-axion).