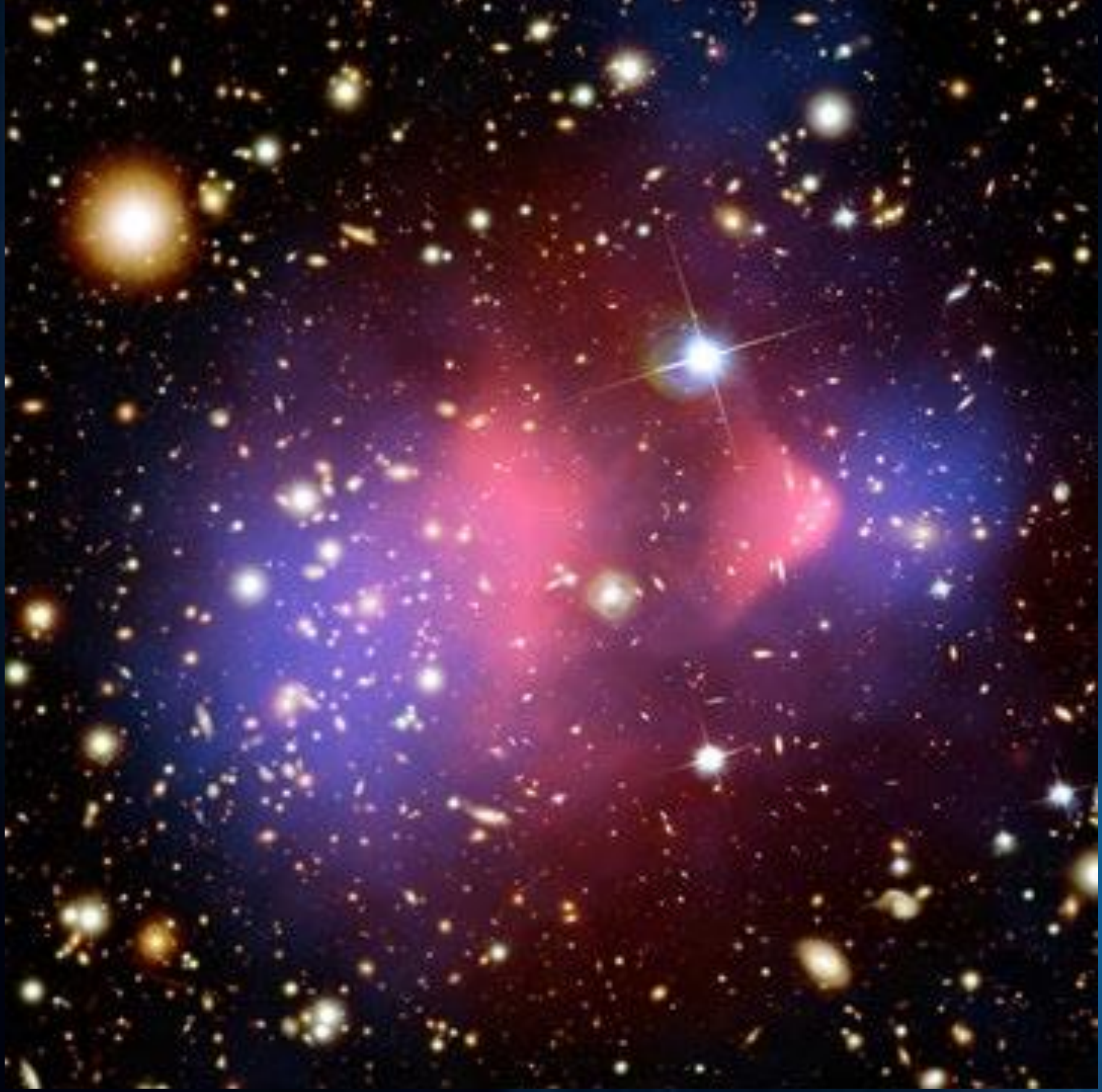
The Hunt For Dark Matter

What is Dark Matter?

- Based on a wealth of observational evidence, 26.8% of our Universe is made up of an invisible form of matter.
- It's the dominant form of matter, composed of as yet unidentified particles.
- This offers the fascinating possibility of a hidden sector, as rich and diverse as the Standard Model, yet almost entirely separate from it.

Evidence For Dark Matter

- We can estimate the mass of a galaxy using the light it emits in certain wavelengths, and inferring how many of each type of star it contains.
- But the rotation of galaxies is so rapid, the visible mass they contain should not be enough to keep them together.
- Gravitational lensing is an effect predicted by general relativity. Light is distorted by large masses, and this allows the distribution of dark matter to be mapped.



Dark matter is shown in blue, X-ray emitting gas clouds are red.

Dark Matter Candidates

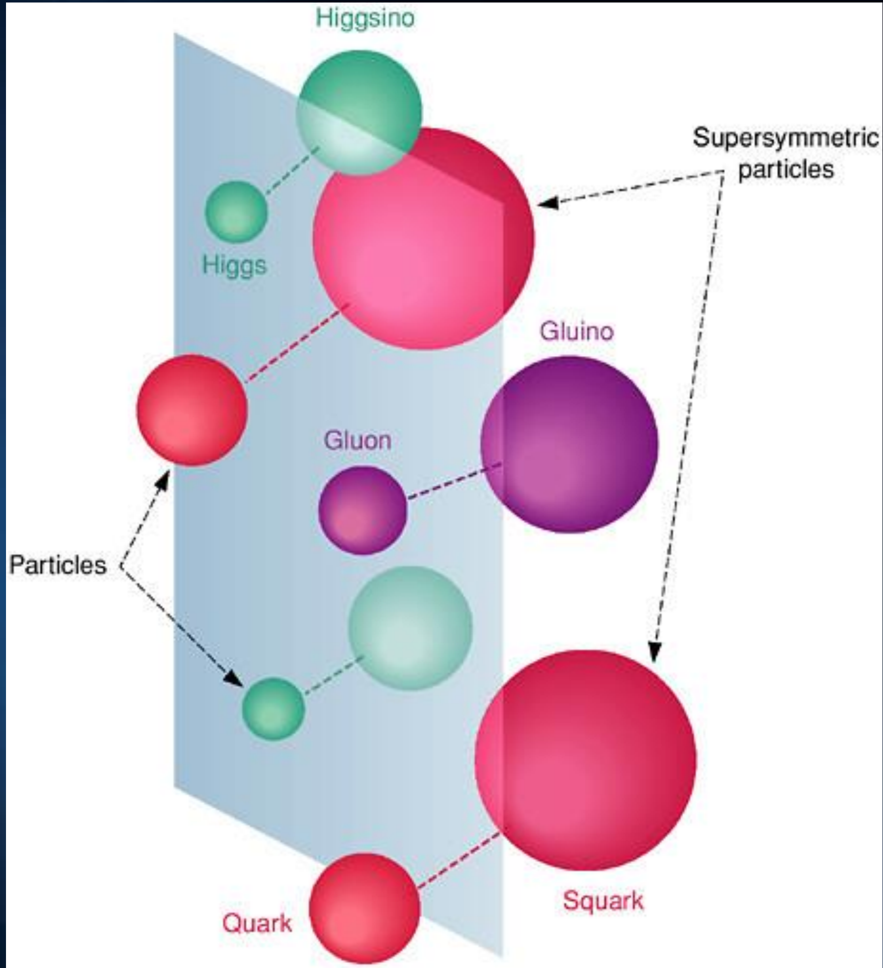
- WIMPs
- WISPs
- MOND

WIMPs

- Large masses compared to Standard Model particles

- Many WIMPs arise from the theory of supersymmetry.

- Supersymmetric particles have proven hard to find. Runs I and II of the LHC should have been capable of finding them, but did not.



WISPs

- Very light particles, with masses in the sub-eV range – the electron has a mass of 0.5 MeV.

- Two of the most prominent WISP candidates are the axion and the Hidden Sector Photon (HSP). But many others are hypothesised.

- They often arise in theories of physics beyond the standard model, and in particular come up frequently in string theory.

Axions

- Axions arise from a solution to the strong CP problem.
- The strong CP problem is the lack of evidence for CP violation in strong interactions. But the standard model predicts it should happen!
- Something is suppressing this effect…

Axions

- One particularly compelling solution was proposed by Peccei and Quinn.

- The PQ mechanism produces the axion as a side effect, and it happens to make a perfect dark matter candidate!

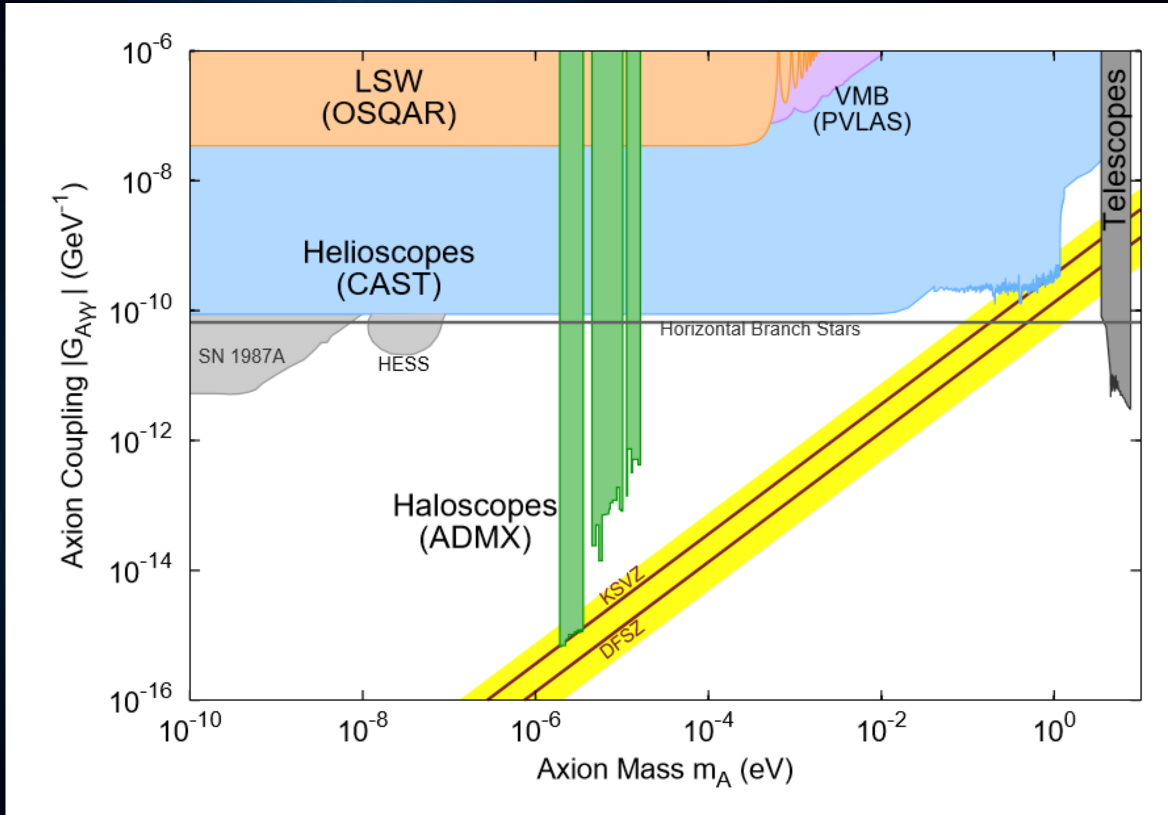
- Axions are light, neutral and very long-lived. There are plenty of mechanisms through which they could have been produced in the early universe, leaving us with abundant amounts of them today.

- Should they exist, they solve two problems in one go.

Axions

- But the mass and coupling strength of the axion aren't predicted by theory, so we don't know exactly where to look.

- Instead we search a vast region of parameter space, and use experiments to set limits that exclude certain regions.



At the LHC:

- Dark matter would show up as ‘missing energy’
- But how do we know the missing energy isn’t neutrinos?
- We can look for an excess of these events with missing energy, i.e. if it’s happening more often than we would expect, based on SM predictions. We can find events in which the missing transverse energy is very high – remember neutrinos are light but WIMPs are not!