Astrophysics - Decoupling

20 April 2021 09:30

From the AQA Teaching notes

"Further supporting evidence came from the discovery of the cosmological microwave background radiation. This is a ‘glow’ from all parts of the Universe, the spectrum of which follows a black-body radiation curve with a peak in the microwave region. This peak corresponds to a temperature of 2.7 K. It can be interpreted as the left over ‘heat’ from the big bang, the photons having been stretched to longer wavelengths and lower energies (**more correctly perhaps, it is the radiation released when the Universe cooled sufficiently for matter and radiation to ‘decouple’, with the combination of protons and electrons to form neutral atoms**)."
https://filestore.aqa.org.uk/resources/physics/AQA-7407-7408-TG-A.PDF

The word 'decoupling' is rather unhelpfully just thrown in.

From Science and Maths revision there is this helpful timeline

- Big bang – space-time begins, the universe is dense and hot – a single point
- 10-35s– rapid expansion of the universe called inflation, only electromagnetic radiation exists, no matter.
- 10-6s– quarks, leptons and antiparticles come into existence.
- 10-4s– Universe cool enough for quarks to form protons and neutrons – still no atoms. Matter and antimatter annihilation to produce high energy photons.
- 100s – protons and neutrons fuse to make light nuclei – up to beryllium.
- 250000 years – temperature cooled to around 104K, now low enough for hydrogen and helium atoms to form. **Matter and radiation decouple – photons can now travel through space.**
- 30 million years – Stars begin to form, heavier elements made by fusion.
- 13.7 billion years – present day. Billions of galaxies have been formed each containing millions of stars.

From <https://www.scienceandmathsrevision.co.uk/topic/evolution-and-fate-of-the-universe/>

Prior to decoupling there were subatomic particles, but no atoms.

Wikipedia

Photon **decoupling** is closely related to recombination, which occurred about 378,000 years after the Big Bang (at a redshift of z = 1100), when the universe was a hot opaque ("foggy") plasma. During recombination, free electrons became bound to protons (hydrogen nuclei) to form neutral hydrogen atoms. Because direct recombinations to the ground state (lowest energy) of hydrogen are very inefficient, these hydrogen atoms generally form with the electrons in a high energy state, and the electrons quickly transition to their low energy state by emitting photons. Because the neutral hydrogen that formed was transparent to light, those photons which were not captured by other hydrogen atoms were able, for the first time in the history of the universe, to travel long distances. They can still be detected today, although they now appear as radio waves, and form the cosmic microwave background ("CMB"). They reveal crucial clues about how the universe formed.

From <https://en.wikipedia.org/wiki/Decoupling_(cosmology)>

This passage from wikipedia clarifies it. Prior the universe was not transparent to photons (ie they could not freely move around over large distances). This is due (in part) to the free electrons, and is connected to discussion of mean free path, scattering of photons by electrons and expansion rate which is beyond scope for us (thankfully). Electrons were captured in high energy states by small nuclei. Subsequently these electrons de-excited emitting photos which we now detect as the CMB since these photons are able to travel much more freely.

I think I would suggest that most of this is useful background radiation (ha ha - see what I did then.... I mean content not radiation), and that the teaching notes first quoted give the scope.