Cosmological Heat Death Encyclopedia Article

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Cosmological Heat Death

Cosmological **heat** death is the name given to the fate of the **universe** if it continues to expand forever. In standard cosmological models, the universe is finite, so it has a finite amount of **energy**. Because the universe is expanding, the energy is being spread throughout a larger and larger volume; less energy in a given volume means that the **temperature** in that volume is decreasing. Eventually, the energy **density** becomes so low that the temperature approaches **absolute zero**. At this point, heat death sets in and, for all practical purposes, all activity ceases from that **time** onward.

Soon after the discovery of general relativity by **Albert Einstein** in 1915, the theory was applied to the entire universe by Friedmann, Robertson, and Walker (FRW). The solution of Einstein's equations in this case predicted that the universe was expanding, prompting Einstein to introduce his flawed **cosmological constant** to counteract the expansion. Edwin Hubble's 1929 discovery that the universe was indeed expanding embarrassed Einstein, but opened up a new era in cosmological predictions.

The most important parameter in the FRW model is the density of the universe today. A critical density determines whether the universe will eventually contract back to a point (the big crunch) or whether it will continue expanding forever. If the density is greater than the critical density, the universe will at some point begin to contract. If the density is less than the critical density, then the universe will expand forever at an accelerating rate. If the density is equal to the critical density, then the expansion will continue forever but will approach zero after a long time.

When the density is less than or equal to the critical density, the expansion never stops, leading to cosmological heat death. Based on current observations, this heat death should occur when the universe is about 10^{98} years old; at this time, galactic **black holes** will evaporate, leaving no observable structure in the universe. The universe is about 10^{10} years old now, so it is highly unlikely that humans will exist to observe the occurrence of the heat death.