Are We Heading Towards Absolute Zero?

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Abstract: The universe was born with the Big Bang as an unimaginably hot, dense point. When the universe was just 10^{-34} of a second or so old, it experienced an incredible burst of expansion. Our universe is expanding since then. It is a known fact that expansion results in cooling. Observations suggest that the expansion of the universe will continue forever. If so, then a popular theory is that the universe will cool as it expands, eventually becoming too cold to sustain life. For this reason, this future scenario once popularly called heat death is now known as the Big Freeze. This clearly indicates that the temperature would drop to absolute zero at which all molecular motion and biological processes cease. The present paper discusses the very idea that universe is heading towards the state of Absolute Zero.

Keywords – Expanding Universe, Cosmological Redshift, Absolute Zero, Bose-Einstein Condensate

I. INTRODUCTION

The universe was born with the Big Bang as an incredibly hot and dense point. Before the Big Bang, there was nothing, everything was dark and cold (not to be confused with coldness as degree of temperature because before the Big Bang, even the temperature didn't exist). In fact, we don't know what was there before the Big Bang exactly. The space and time weren't there. Everything just came into existence just in a single click (I am using the word click because I cannot use the unit of time as time didn't exist then). This whole phenomenon started from nothing but singularity. When the universe was just 10^{-34} of a second or so old — that is, a hundredth of a billionth of a trillionth of a trillionth of a second in age — it experienced an incredible burst of expansion known as inflation, in which space itself expanded faster than the speed of light. During this period, the universe doubled in size at least 90 times, going from subatomic-sized to golf-ball-sized almost instantaneously. As space expanded, the universe cooled and matter formed. One second after the Big Bang, the universe was filled with neutrons, protons, electrons, anti-electrons, photons and neutrinos. Roughly 380,000 years after the Big Bang, matter cooled enough for atoms to form during the era of recombination, resulting in a transparent, electrically neutral gas, according to NASA. Although the expansion of the universe gradually slowed down as the matter in the universe pulled on itself via gravity, about 5 or 6 billion years after the Big Bang, according to NASA, a mysterious force now called dark energy began speeding up the expansion of the universe again, a phenomenon that continues today. Almost 95% of what our universe comprises is dark matter and dark energy which are still a mystery for us. The expansion of the universe was further confirmed by astronomer Edwin Hubble through his observations on the redshift of the galaxies.

II. EXPANDING UNIVERSE

In the 1920s, astronomer Edwin Hubble discovered that the universe was not static. Rather, it was expanding. In 1998, the Hubble Space Telescope's observations of very distant supernovae revealed that a long time ago, the universe was expanding more slowly than it is today. In other words, the expansion of the universe was not slowing but instead inexplicably was accelerating. The name for the unknown force driving this accelerating expansion is dark energy, and it remains one of the greatest mysteries in science. Astronomers observed that light from distant objects in the universe is redshifted (shift in the frequency of light towards red color), which tells us that the objects are all receding away from us. The blue shift explains the approaching of objects towards each other and the redshift explains the receding away of objects from each other. In case of our universe and galaxies, what has been observed till date is the Redshift. All the galaxies are shifting away from each other and the speed of certain galaxies are even greater than the speed of the light. This is all happening at a very precise rate and continuously. This is true in whatever direction you look at: all the distant galaxies are going away from us. This can only be due to the fact that the Universe is expanding.

III. COSMOLOGICAL REDSHIFT

The cosmological redshift is a redshift caused by the expansion of space. As a result of the Big Bang, the Universe is expanding and most of the galaxies within it are moving away from each other. Astronomers have discovered that all distant galaxies are moving away from us and that the farther away they are, the faster they are moving. This recession of galaxies away from us causes the light from these galaxies to be redshifted. As a result of this, at very large redshifts, much of the ultraviolet and visible light from distant sources is shifted into the infrared part of the spectrum.

IV. ABSOLUTE ZERO

Absolute zero is defined as the point where no more heat can be removed from a system, according to the absolute or thermodynamic temperature scale. This corresponds to 0 K or -273.15°C. In everyday solids, liquids and gases, heat or thermal energy arises from the motion of atoms and molecules as they zing around and bounce off each other. But at very low temperatures, the odd rules of quantum mechanics reign. Molecules don't collide in the conventional sense; instead, their quantum mechanical waves stretch and overlap. They suffer identity crisis and all of a sudden they act as one single entity. When they overlap like this, they sometimes form a so-called Bose-Einstein condensate, in which all the atoms act identically like a single "super-atom". Absolute zero is something which scientists have yet not been able to achieve, though they have made attempts to reach closer to it but exact absolute zero state is considered to be impossible to achieve in real world.

V. UNIVERSE IS HEADING TOWARDS ABSOLUTE ZERO

If dark energy—represented by the cosmological constant, a *constant* energy density filling space homogeneously, or scalar fields, such as quintessence or moduli, *dynamic* quantities whose energy density can vary in time and space—accelerates the expansion of the universe, then the space between clusters of galaxies will grow at an increasing rate. Redshift will stretch ancient, incoming photons (even gamma rays) to undetectably long wavelengths and low energies. Stars are expected to form normally for 10^{12} to 10^{14} (1–100 trillion) years, but eventually the supply of gas needed for star formation will be exhausted. As existing stars run out of fuel and cease to shine, the universe will slowly and inexorably grow darker, one star at a time. According to theories that predict proton decay, the stellar remnants left behind will disappear, leaving behind only black holes, which themselves eventually disappear as they emit Hawking radiation. Ultimately, if the universe reaches a state in which the temperature approaches a uniform value, no further work will be possible, resulting in a final heat death of the universe. This heat death signifies nothing but the state of absolute zero.

The universe was warmer before but now it is much cooler. As measured by the scientists, the present average temperature of the universe is approximately 2.7 K. Starting from something extremely hot, it has reached down to much colder temperature. The main reason behind this is the expansion of universe because expansion always leads to cooling. The galaxies are receding away from each other at a much faster rate, the rate of expansion is quite fast. This expansion will drop the temperature further down. After about a million of years, a stage might reach when temperature would reach 0 K which is considered as Absolute Zero. At 0 K, the molecular motion is expected to cease and the so-called bosons (the integral spin particles) tend to form Bose-Einstein Condensate (BEC) i.e. they all agglomerate and form single entity. At very low temperature, the bosons flatten and their wave nature dominates their particles nature. Around absolute zero, the size of the waves becomes larger than the average distance between two atoms, thus these waves superimpose on each other and it is difficult to recognize which is which. Thus at absolute zero, whatsoever particles exist would tend to form BEC and thus everything would shrink to one particular entity. The bosons include photons (force carrier of electromagnetic force), gluons (force carrier of strong nuclear force), intermediate bosons $W^{\pm}$,Z^0 (force carriers of weak nuclear force) and Higgs Boson (responsible for mass). All these force carriers would tend to form Bose-Einstein Condensates and thus the vast expansion of electromagnetic, strong nuclear and weak nuclear forces would no longer exist and everything would coalesce to something extremely cold and dark.

Using the CSIRO Australia Telescope Compact Array, scientists led by Sebastien Muller have made the most precise measurement ever of how the universe has cooled down during its 13.77 billion year history. "When we look at this galaxy with our telescopes, we see it as it was when the universe was younger – and warmer – than it is now", says Sebastien Muller. The astronomers used a clever new method to measure the temperature of the cosmic microwave background – the very weak remnant of the heat of the Big bang that pervades the entire universe. They observed radio waves from molecules in a galaxy so far away that its light has taken 7.2 billion years to reach us.

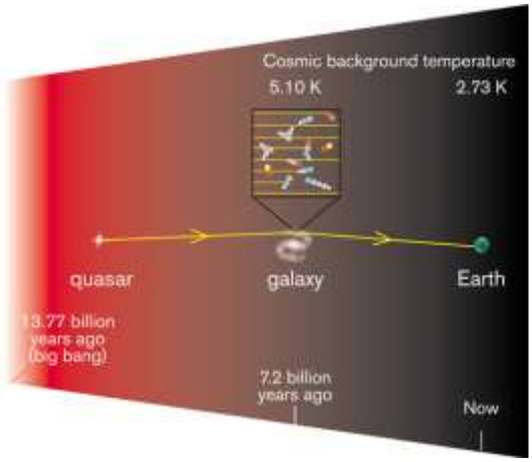

Fig. 1[Image credits: Onsala Space Observatory/R. Cumming/S. Muller]

As shown in the Fig. 1, the temperature of the cosmic background radiation they measured was 5.08 Kelvin (+/- 0.10 Kelvin). This is extremely cold, but significantly warmer than the temperature which scientists measure in today's universe, 2.73 Kelvin. Scientists measure temperatures in Kelvin above absolute zero (0 Kelvin = -273 degrees Celsius). One Kelvin is the same size as one degree Celsius. According to the Big bang theory, the temperature of the cosmic background radiation drops smoothly as the universe expands. "That's just what we see in our measurements. The universe of a few billion years ago was a few degrees warmer than it is now, exactly as the Big bang theory predicts", concludes Sebastien Muller.

VI. CONCLUSION

It is universally accepted fact that our universe is expanding and expansion results in cooling. The present average temperature of entire universe is 2.73 K. It has cooled down to 2.73 K since Big Bang. Further expansion would result in further cooling down, the process would take years for sure but eventually a state of Big Freeze would come when everything would freeze out. So it is possible that we are all heading towards the state exactly what it was before the Big Bang- Everything dark and cool! My idea is the universe is definitely heading towards absolute zero. Significant research needs to be done in this regime. This would definitely help us to understand the fate of our universe in a better way.

VII. ACKNOWLEDGMENT

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