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THE ANTHROPIC PRINCIPLE

The anthropic principle was set down by Dirac who analysed Eddington's magic numbers. Although the Copernican anthropic principle had been around for quite awhile, it was Dirac along with Dicke who reinvented it for the 20th century. Sir Arthur Eddington revealed that the ratios of the electromagnetic force between the proton and the electron and the gravitational force of the proton and the electron is about 1040. Also that the ratio of the radius of the universe and the electron radius is also 1040.

$N_1 = \frac{e^2}{Gm_p m_e} \approx 2.3 \times 10^{39}$ = ratio of the electric force and gravitational force between the electron and the proton.

$N_2 = \frac{t_0}{e^2 / m_e^2 c^3} \approx 6 \times 10^{39}$ = ratio between the age of the universe and the atomic light crossing time.

His theory led onto the calculation of the square root of the number of particles in the universe which turned out to be about 1040 for a universe where k=1.

Two people who studied these results were Robert Dicke and Paul Dirac. Dirac deduced that these numbers remain the same at all epochs of the universe, so that the fundamental constants must change with time. Dirac's analyses states that gravity must grow weaker in inverse proportion to time and the number of particles must increase in direct proportion to the square of time. This became known as Dirac's large number hypothesis (LNH). Dicke however proposed that we as observers are at a special epoch of which life has had a chance to evolve for us to pose such questions. Certain conditions have been set down by the fundamental constants that allow life to exist. This became known as the anthropic principle. From the Greek word anthropos; man. Its' underlying statement is thus:-

Why are we here?

Why does the universe have such special properties to create life?

Is it pure chance or is there a reason?

Two versions of the anthropic principle were developed- the weak and strong.

The Weak Anthropic Principle

Intelligent life can only develop in special places at particular times, so observers see very special properties due to the natural selection effect. The weak AP looks for those coincidences in nature that create life, but offers no insight as to why the universe is this way.

The Strong Anthropic Principle

The preconditions of the early universe was such that it made it a necessity for life to evolve. That is to say the universe must have been constructed this way and could not have come into existence any other way.

Argument For The Weak Anthropic Principle

For observers to exist, the universe must be a certain age. This age is governed by the fact that to create an observer, carbon, oxygen and other heavy elements must be in abundance. These elements are produced in supernova, so a rough time estimate is the lifetime for a star to go from creation to supernova. This time is:-

$$t_* \approx \left(\frac{Gm_p^2}{hc}\right)^{-1} \frac{h}{m_p c^2} \approx 10^{10} years$$

Now $\alpha_G = \frac{Gm_p^2}{hc} \approx 10^{-39}$ and $N(t) = \frac{c^3 t}{Gm_p}$ where N is the number of nucleons in the visible universe at time t.

$$n(t_*) \approx \frac{t_*}{Gm_p c^3} \approx \alpha_G^{-1}$$

So

Now Dirac's conclusion to his LNH was that the gravitational constant G decreases with time. Dicke used the above method to prove that this is unnecessary and G can remain as a constant in nature. This proves a selection effect that we as observers occupy a special place at a special time and strongly backs up the weak anthropic principle.

Argument For The Strong Anthropic Principle

There are three interpretations of the strong anthropic principle.

1. There is one universe with the sole intention of developing life. Being religious in nature, this statement can neither be proved nor disproved and is generally open to the theologians and teleolgians for interpretation.

2. Observers are solely necessary for the universe to come into being.

3. A number of different universes or 'worlds' are needed for the existence of our universe. This is the interpretation that has the most significance to modern science.

The many worlds interpretation of quantum mechanics was developed by Hugh Everett who could not believe the idealistic Copenhagen interpretation. He could not understand why the wave function should collapse, and so developed for his PhD thesis a paper on a many worlds theory.

In the many worlds interpretation, he proposed that the universe branches off like a tree at every interaction between its constituent particles. This then stated that instead of the probability of a particle being at a point in space time, it is either there or it isn't. SchrÖdinger's cat could not be only 30% dead. Brandon Carter went on to describe how the universe has branched off a stupendous amount of times and that we happen to lie on a branch where all the fundamental constants are just right to produce life. This also says that there must be a number of universes that were still born and that when life has developed in a universe it will always be there. This generalisation is part of the final anthropic principle.

Although the many worlds interpretation seems a very improbable theory, the methods of quantum mechanics along with experiment has proved its hypothesis.

Each constant in the universe is at such a value just right for life. A small change in G or e will make life impossible. Most of the constants in nature can be described using dimensionless

fundamental constants, these are:-

α_G = Gravitational fine structure coupling constant.

α =Electromagnetic fine structure coupling constant.

α_S =Strong force fine structure coupling constant.

α_W = Weak force fine structure coupling constant.

$\frac{m_p}{m_e}$ = Proton to electron mass ratio.

For those studying the anthropic principle it is needed that they know whether the universe is a fortunate coincidence or to be expected.

The Universal Gravitational Constant.

If this was slightly stronger, star formation would proceed more effectively and all the stars would be more massive than our sun. These stars would burn up too quickly to produce life on any orbiting planet. If it was weaker, stars would be smaller than our sun. It would be impossible to form life because the heavy elements needed for planets and life can only be produced in larger stars.

Strong Nuclear Force.

If this was weaker, multi-proton nuclei would not be held together. Any element heavier than hydrogen would be impossible to produce. On the other hand, if it was stronger, hydrogen would be a very rare element in the universe and so hydrogen fusion would be impossible.

Weak Nuclear Force.

This effects leptons and in particular beta decay.

$$n \rightarrow p + e^- + \overline{\nu_e}$$

If the weak force was slightly larger, neutrons would decay more and so there would be less available to produce helium in the fusion process.

Charge On The Electron.

This binds the electrons in the atom to the protons in the nucleus. If e was smaller, no electrons

would be held in the atom. If it was stronger, an electron would not be able to share an orbit with another electron. Either way life would be impossible.

The Ratio Of Electron To Proton Mass.

If this was slightly higher or lower, then it would be impossible for molecules to form.

The Age Of The Universe.

It takes about three billion years for the first stars to form. It then takes another ten to twelve billion years to turn into supernova and to throw enough heavy elements out to form rocky planets suitable for life to evolve. The time period for life is very narrow.

The Velocity Of Light.

As this can be represented using functions of other constants such as the fine structure constant, a small change in c would negate the possibility of life.

It is seen that if any of these constants were slightly different, then it would be impossible for life to develop. Although Copernicus stated that we do not occupy a central position in the universe, we are privileged in some way to get the correct conditions for life (i.e. temperature, chemical abundance, age etc…).

Most scientists involved in the anthropic principle have come out against the strong and for the weak. This is because of the natural selection effect that allows us in 'this' universe to develop into the people that we are. This does not mean the debate is closed, the theory that Everett proposed is still a very good contender to sway the argument towards the strong anthropic principle.

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