CCC11B: The Fine-Tuned Photon:Baryon Ratio? Aguirre's Cold Big Bang Counter-Example

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In CCC11 we have argued that if the photon:baryon were less than $\sim 10^6$ then structure formation would be prevented because the universe would be permanently opaque and hence small density fluctuations would be supported against gravitational collapse by radiation pressure. We shall also argue in CCC12, following Tegmark and Rees (1997), that the magnitude of the primordial density fluctuations, Q, is anthropically constrained to be within an order of magnitude of its value in this universe. Despite this, Aguirre (2001) has presented the case for a universe capable of supporting life in which the photon:baryon ratio is of order unity, and Q is smaller than in this universe by a factor of 10^{-6}. We shall summarise a few salient features of Aguirre's analysis below. Its morale, however, is the same as that of the weakless universe of Harnik, Kribs and Perez. By varying more than one universal constant at once, and by being bold enough to vary them by many orders of magnitude, it is possible to discover distant regions of parameter space which appear to be anthropically allowed. The key is varying more than one parameter at once, the change in one effectively offsetting the other. In addition, by making very large changes, the nature of the physics involved changes qualitatively.

Aguirre (2001) considers a cosmology with a photon:baryon ratio within an order of magnitude of unity. In the jargon, this is known as a "cold big bang". The other cosmological parameters, and the universal constants of physics, are not greatly changed apart from Q. Based on Aguirre (1999), it is claimed that this can result in Big Bang nucleosynthesis which produces hydrogen and helium in comparable abundance to our universe, but which also produces substantial metallicity, comparable to that of the Sun. Thus, anthropically, we are off to a head start with the life giving elements, carbon, oxygen and nitrogen, all produced in the required quantities within the first seconds – in fulfillment of Gamow's original programme.

Aguirre's argument then focuses on structure formation. For this he refers to Carr (1977). His main argument concerns assumed fluctuations in the range $10^{-11} < Q < 10^{-8}$, i.e. between 3 and 6 orders of magnitude smaller than in this universe. The claim is that, at early times, masses of $\sim 100M_{\odot}$ will cool faster than they collapse, and hence fragment. The claim is that this will lead to stars of "much smaller mass", which is supposed to imply stars of roughly solar mass. This occurs at only 10^2 to 10^6 years. By 5 Gyr a process of collapse on increasing size scales (bottom-up) is claimed to result in clusters of 10^6 to 10^{10} stars. In short, a rough approximation to the star-galaxy structure of our universe has been reproduced, albeit with rather smaller galaxy sizes. Moreover, this has been done on an anthropically sensible timeframe. The fact that the stars are roughly of solar mass also ensures stellar lifetimes which are anthropically favourable, all nuclear reaction rates and heat transfer rates, etc., being unchanged since none of the universal constants of physics have been changed.

However, the fact that stars and galaxies of the correct mass range form in the right timescale is not sufficient for the emergence of planetary life. It is also necessary, as noted by Tegmark and Rees (1997), that planetary systems are not disrupted by close encounters with other stars during the period over which life is evolving. If they were, huge changes in the physical conditions prevailing on the planet would be a virtual certainty, with catastrophic effects on the nascent life forms. Indeed, the planet might be ejected from its orbit completely. Aguirre analyses the time between such stellar close encounters in his universe. Unfortunately, it *is* on a time scale which would be disruptive. However, Aguirre also calculates the timescale for stellar ejections from the stellar clusters (galaxies). He finds that at least 1%, and up to virtually all, the stellar systems would be ejected before disruption. Moreover, he argues that this ejection would occur without the need for stellar close encounters in the process. This evaporation argument appears to be crucial to Aguirre’s case, and may be its Achilles heel.

Aguirre’s conclusion is that the existence of such a counter-example greatly reduces the explanatory power of anthropic arguments. In other words, many different sets of values of the universal constants may be consistent with the formation of life, even if they are changed by many orders of magnitude. The key is that changes in one parameter can be offset by changes in another.