Carbon, the Anthropic Principle, and Multiple Universes (Part 3)

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In his 1997 book *Life on Mars?: The Case for a Cosmic Heritage* (co-authored with Chandra Wickramasinghe), Fred Hoyle appraises his own achievement in identifying the origin of carbon:

"The weak anthropic principle serves to remove otherwise inexplicable cosmic coincidences by the circumstance of our own existence. One of the present writers [Hoyle] was involved in an early application of the weak anthropic principle…. It was shown in 1952–53 that to understand how carbon and oxygen could be produced in approximately equal abundances, as they are in living systems, it was necessary for the nucleus of ^{12}C to possess an excited state close to 7.65 Mev above ground level. No such state was known at the time of this deduction but a state of almost exactly the predicted excitation was found shortly thereafter. So one could say this was an example of using the weak anthropic principle in order to deduce the way the world must be, although the concept of the anthropic principle had not been explicitly formulated at that time."

Andrei Linde, one of the originators of the inflationary universe theory, offered a similar assessment in his 2007 paper "The Inflationary Universe," writing that "[t]he existence and properties of this resonance was one of the first successful predictions based on the anthropic principle."

If these conclusions are correct, then reasoning based on the weak anthropic principle should be useful methodology in science. Is it, though?

A number of people before Hoyle also attempted to account for the origins of carbon. Examples include Enrico Fermi and Anthony Turkevich. The extreme instability of atoms with mass numbers of 5 and 8 was a major obstacle to carbon's existence. If the triple-alpha process was a way for the 8 obstacle to be overcome, then one alternative approach to the 5 obstacle may be conceived as follows:

$$^{3}H + {}^{4}He \rightarrow {}^{7}Li \qquad (1)$$

In late 1949, Fermi and Turkevich hypothesized that a resonance energy level corresponding to 400KeV from the baseline state exists in ^{7}Li. This would allow for large quantities of ^{7}Li to be produced through the equation above; carbon, in turn, could be easily produced through various subsequent reactions. Unfortunately, their hypothesis failed at the testing stage; experiments showed no excited state equivalent to 400KeV.

In their reasoning, Fermi and Turkevich had approached things no differently from the way Hoyle had when he discovered the 7.65MeV energy level for carbon. Could it be claimed that the reason for Hoyle's success can be traced to his reasoning based on the anthropic principle? The weak anthropic principle offers nothing to account for why nature selected the triple-alpha process over equation (1) for the formation of carbon. If carbon were produced through reaction (1), such a universe would not preclude the possibility of human existence. The self-evident proposition at the heart of the weak anthropic principle—that the properties of the universe must be consistent with the fact that humans do exist—lacks sufficient binding force to be used as a scientific tool. It is unquestionably true that Hoyle benefited from some degree of luck in his carbon resonance level discovery. This is not at all meant to diminish his achievement—luck only translates into great discoveries when it operates in conjunction with intuition and grit.

Quite a number of people remain dissatisfied with the weak anthropic principle's "weakness." Human psychology is a strong thing, and we tend to be drawn more to the conclusive. The popularity of the strong anthropic principle continues unabated. When it comes to the universe we live in, there are innumerable questions that scientists cannot answer. Why should the gravitational constant be equal to 6.67384×10^{-11} m^3 kg^{-1} s^{-2}? Why is the speed of light 299,792,458 m s^{-1}? Why not a gravitation constant of 9000 m^3 kg^{-1} s^{-2} instead? If the gravitational constant were that large, life would have been an unlikely prospect. There was a time when physicists anticipated being able to explain 22 basic constants based on first principles, including the gravitational constant, the speed of light, and Planck's constant. All attempts so far have failed. According to the conclusions that have been tentatively reached, the values for all of those constants were determined at the moment of the Big Bang. Sheer coincidence? How can that be scientific? Does that mean there is no meaning, no purpose to anything, to the lives we're living here? Preposterous. Better to believe in a god as designer. It must be that the universe had already seen human beings coming!

The Israeli-American astronomer Mario Livio and a few of his colleagues tried an interesting numerical experiment in the late 1980s. They considered how much different the amount of carbon formed in the universe would be if its resonance energy level was set 0.06MeV higher than its actual 7.65MeV. Their calculations showed the efficiency of the triple-alpha process to diminish at the temperature and density given by their predictions. So far, not especially interesting—but they also found a corresponding increase in helium shell pressure within stars that had reached the asymptotic giant branch stage. This rise in pressure resulted in more explosive nuclear reactions involving the helium shell, which led to huge volumes of carbon being created. So while raising the resonance energy level arbitrarily by 0.06MeV may have lowered the efficiency of the triple-alpha process, the changing properties within stars were such that no major changes arose with the total amount of carbon produced over their lifespan. Publishing the findings in a 1989 *Nature* paper, Livio offered the following as his conclusion:

"The implications for these results for evaluating the anthropic 'coincidence' on which our existence seems to rely are not entirely free from subjective feelings. Whether or not one must conclude that the 0+ level has to be exactly where it is depends on whether we should regard a change of 60keV as small or large.... For this reason, we believe that a few forms of the strong anthropic principle that claim the 0+ level must be exactly where it is are somewhat undercut by our findings."

The strong anthropic principle is reliant on the argument for "fine-tuning." The universe appears finely tuned for the emergence of life. This tuning seems too precise to be attributed to chance. Livio's experiment shows the hole in that argument. How precise do the physical properties we understand have to be for us to speak of "fine-tuning"? Similar thought experiments could be done for various other physical constants besides carbon's resonance energy level. Could we recreate the history of the universe by making the gravitational constant a value roughly 5% larger than it is now? The landscape might look a bit different, but there would be no qualitative difference in terms of the formation of matter. Stars would still create the atoms necessary for life, and planets like our earth would still exist with some frequency throughout the universe. So is 5% a big difference or a small one? Isn't it a form of subjective human prejudice for us even to talk about "fine-tuning"?

The shock inflicted by modern cosmology is similar to the shock we feel when we approach someone we've had a fleeting encounter with, believing them to be our predetermined destiny—only to be rebuffed. Some extreme version of the strong anthropic principle, such as the argument for intelligent design, seem like an attempt to overcome that shock by latching on and trying to win the person over. The countless instances of chance that determined the course of our life can only hold meaning through retrospection. Attributing that sort of a priori purpose remains a personal freedom—but it is not the place of science.

How does science explain the coincidence that is the universe we inhabit? We can answer that surprisingly easily when we think back to the time where we believed the earth to be special. The exquisitely right distance between the sun and earth, the way the earth's rotational movement is sustained in a stable fashion, the geomagnetic field that shields our atmosphere from the high-energy particles arriving from outside—how to account for an earth environment that does seem fine-tuned for the emergence of life? Yet as implausible as this coincidence may seem, it ends up turning into something ordinary when we consider the vastness of the universe—the sort of thing we might expect to come about every so often. Based on statistical data for the extra-solar planets discovered to date, our Milky Way alone is estimated to be home to tens of billions of earthlike planets where water is capable of existing in liquid form; within the scope of the observable universe, that number rises to tens of billions multiple by several trillion. It would not be at all surprising for one or two of them—or even a few hundred million or more—to be "special" like the earth. Appeals to "fine-tuning" tend to lose much of their persuasive force when confronted with enormous sample sizes.

Similarly, the multiple universe hypothesis is the most natural way of accounting for the specialness of our universe. That hypothesis is not something arbitrarily posited for the sake of convenience—it is a theoretical prediction of the expanding universe theory, string theory, and other frameworks in modern physics. According to its predictions, a nearly infinite number of completely different universes exist outside of our own. Some of them may be filled with black holes instead of stars—the result of a different early form of quantum fluctuation or a stronger gravitational force than electromagnetic force. In some of them, the nuclear force may be weaker than the electromagnetic force, such that none of the different atoms we know could exist. Our universe is not special and utterly unique, but merely the realization of one of an infinite variety of possibilities. In a sense, this is perfect deconstructionism. Obviously, the hypothesis is still waiting to be tested.

Having begun our journey with carbon, we have now arrived at the limits of modern science. Here, we become aware of one interesting implication: not only is human existence a historical accident, but the very laws of nature that govern our universe are also a historical accident, determined by the historical incident that was the Big Bang. Eternal essence, ultimate phenomena, original form, *logos*—these and other concepts that have captivated and often constrained innumerable people appear likely to lose their currency.

Could there be an ultimate principle that transcends or determines the laws of nature? Perhaps the only example we can find of universality separate from historical specificity lies in mathematics. The US astrophysicist Max Tegmark has even proposed a "mathematical universe" hypothesis, arguing that mathematical structure is the external reality of the physical world. Reminiscent of Plato, his argument is unlikely to win support from scientists who value an empirical approach. Emotionally, however, I can understand it.

What the anthropic principle debate teaches us is how interpretations of nature are rarely free from the preconceptions of the human observer. When we latch on to these limitations and insist that the hard-won intellectual achievements of science are really just subjectively based and unconnected to the reality, that is another form of prejudice, one that willfully imposes limits on humanity. If anything, the Big Bang theory is an intellectual legacy that humankind should regard with great pride—for it was achieved "in spite of" our limitations as finite human beings. Like Tegmark, human beings will continue making efforts to explore all possibilities, knowing full well that a satisfying answer as to the ultimate identity of the ultimate may remain outside our grasp even in the distant future. The reason the universe is capable of stimulating us to constantly take up the challenge is because it lies in a place that truth cannot reach.

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