The Recycling Cosmos: Older Than the Big Bang ?

Stalking the Cosmological Constant (and Other Cosmic Mysteries)

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Note to the Reader: the first draft of this essay was written in 2006 (published by New Forks, LLC in 2007), and then slightly edited in 2009 and 2015. Some of the theoretical information in it may likely be updated, or even disproven, in the coming years.

There are many mysteries that continue to challenge our best scientific minds—the greatest of which involve the age and fundamental nature of the Universe we inhabit. This is the science of *cosmology*, and its practitioners—cosmologists—speak of things far removed from everyday perception. A discussion of cosmology typically begins with the positing of vibrating 'superstrings' and/or sub-atomic particles fluctuating in a great 'cosmic soup', then casually leaps to relativistic, macro-scale phenomena like super-clusters, black-holes, and quasars, and then back in time to the 'singularity'—the infinitely dense 'point' of matter that somehow expanded (or exploded) in a 'Big Bang', some 14 billion years ago.

But in the past decade or so, cosmology has been preoccupied with two 'new' (and not wholly verified) forms of matter: *dark matter* and *dark energy*. These two forms are distinct and refer to two fundamental, oppositional activities of the universe; dark matter *pulls* (keeping heavy matter gravitationally clustered), while dark energy *pushes* (maintaining the constant, observable expansion of the cosmos). This primordial activity characterizes and maintains the universal enterprise that we all are somehow a part of. To understand this 'dark side' of the universe, we must acquire a clearer conception, though simplified, of the universe *as a whole*. This is not easy to achieve, as the cosmic 'picture' is still rather fuzzy, and as always, deeply mysterious. Still, we must try.

Most of observable space is apparently devoid of luminous matter. This is traditionally known as the "vacuum" ('that which Nature abhors'). The existence of the vacuum is fundamental to our conceptualizing of an expanding or "inflationary" universe —the type of universe that we think we occupy today. But 'empty' does not equal 'nothing.' Scientists have speculated for some time that this vacuum is not really "empty", but instead contains 'dark' forms of energy and matter, as well as myriad sub-atomic and quantum particles. Most of these particles—the progeny of constant quantum fluxes—do not exist for very long (like one *40 billionth* of a second). Nonetheless, according to Quantum Theory, these ceaseless, countless fluctuations ensure that every square micro-unit of the vacuum has a *non-zero* energy value. And, according to theory and calculation, the total 'vacuum energy density' remains constant. This 'energy density' is equated with the 'cosmological constant' that physicists denote in their calculations with the Greek letter *lambda* (Λ). This *lambda*--a mathematical 'fudge factor,' used first by Einstein in his General Theory of Relativity-- is used to explain away why the universe does not collapse from its own 'cosmic gravitational attraction'.

In Einstein's General Theory, the energy of the vacuum produces a repulsive (hence non-zero), 'anti-gravity' force. But this energy must not be too high, otherwise, it would produce a rate of acceleration that was too great, and the universe would thereby inflate beyond control—disallowing the possibility of galactic, stellar, and planetary formation, and, or course, life-forms like us. This force—later termed 'dark energy'—should be constant throughout the observable Universe.

So, what's the problem?

Well, the problem is that the mathematical calculations of *lambda* don't square with the observable data. The original 'Big Bang' theory, or 'standard cosmological model' of the universe leads to the natural conclusion that, as we go further away from the high energy state of the early universe (and as more proto-galaxy formation occurs), this 'cosmic expansion' would tend to slow down significantly due to the gravitational pull of matter. But this is not what is happening. Originally, calculations 'after the bang' (ATB) were predicated on a *constant* rate of expansion. Physicists now know that, at some earlier point in the 'inflationary epoch', the expansion of the universe began speeding up—*exponentially.* This accepted fact led to the adoption of the *inflationary* model by modern cosmological physicists. Pin-pointing exactly *when* this change occurred has remained a mystery until quite recently (more on this point later). But, answering the *how* of this sudden, accelerative change might take much longer to work out.

Now, Einstein's General Theory of Relativity gives a value for *lambda* that is many magnitudes of order (about 120) greater than what can be measured by our best instruments and observations. This is because Einstein derived the force of the constant as a function of empty space, so, as space expands, its force—the 'pushing' pressure—also becomes greater. The value of this 'constant' is supposedly set very early on in the inflationary epoch of the cosmos. In the very earliest moments after the Big Bang—in the first three minute referred to as the 'Planck Time'—the energy density was enormously higher than now. As the universe expanded, this *lambda* value should have remained constant. However, we appear to live in a (positive) 'low energy' universe, according to Quantum Theory calculations.

Explanations for this discrepancy are many and most involve all sorts of calculations of positive and negative contributions from various species of particle, the function of which are the cancellation of these positive and negative energies, bringing the cosmological constant back close to zero and in line with observable data. But to do this, physicists must invoke 'hidden symmetries' and 'super-partner particles' to force a precise cancellation of energies (equaling the cosmological constant value). Such hidden symmetries (and their 'dualitites') are common occurrences in the mathematics and geometry of String Theory (the currently most popular candidate for a 'Theory of Everything'). Of course, any such symmetry must not act to provide a *complete* cancellation of the constant, other wise we would have a 'do-little', non-inflating universe. This mysterious 'cancellation' must somehow exactly equal the present value of *lambda*. Invoking such hidden symmetries and partner particles is a bit of a mathematical trick to smooth out calculations, and in any case, they have yet to be verified directly, or through particle acceleration experiments. Further, observations of a class of super nova, termed *type 1a supernovas,* revealed that the rate at which the universe expands increases over time (this is referred to as the 'Hubble Constant'). This has been used to indirectly support the theory of a positive, repulsive force at work—and thus a non-zero value for *lambda.*

So, according to observation and calculation, the universe is not just undergoing expansion, this expansion is *accelerating.* Although physicists like to make confident claims concerning our cosmos, there is some degree of uncertainty here, as such supernova explosions are seldom uniform, and thus inject what is known as 'scatter' into the calculations. The only way to mitigate this stellar uncertainty is with still more supernova observations and peering even further back in time—11 billion years or more (remember that the further away a star is, the older it is, and the 'further back in time' we observe).

Over the past five decades, physicists have grown accustomed to repeatedly verifying or validating the theoretical predictions made by Einstein almost a century ago. But if Einstein's prediction of a high value for *lambda* is correct, then by all measures the universe would have been 'blown apart' by its own massive repulsive force; *nucleo-synthesis*—the process by which hydrogen and helium atoms fuse—could not have occurred, nor any subsequent material formations like stars or planets. So then, in light of this, has Einstein finally been proven wrong?

Recently, in the fall of 2006, researchers using the powerful Hubble Space Telescope were able to see back in time—nine billion years ago to be precise—and observe ancient supernova evidence indicating a sudden 'speeding up' of cosmic expansion at around the *five billion year* ATB mark. Somehow, a sudden *instability* emerged within the 'cosmic bubble'. Yet, the value calculated for the cosmological constant in both ancient and more recent time frames is the same (plus or minus a 10-50% error probability). This implies that *lambda* is real—that there is a steady, anti-gravity force at work in the cosmos. Is this the theoretical 'dark energy'? If so, why its sudden appearance, or accumulation, to such a degree that the universe was given a massive 'kick in the pants' 5 billion years ago? Regardless, this is not exactly welcome news to String Theorists who, as noted earlier, preferred their *lambda* not so constant. Of course, all the data that would prove or disprove Einstein is far from 'in'. What is more likely to happen is a validation of the constant through dark energy verification, and with modification to Einstein's mathematics for calculating it.

The Cosmic Coincidence

In addition to the 'vacuum energy discrepancy' problem, there is also the related 'Cosmic Coincidence' problem. Both matter and energy (which are inter-transformable at relativistic speeds) have their own density values. In our present, observable universe the energy density of the vacuum is about twice that of the matter density (as observed in galaxies, for example). The curious thing is that these two types of density values react differently as the universe expands; over time, the matter density will decrease, while the energy density would remain roughly the same. So, at any given time in the universe, the differences in density values should be great. And yet, we live at a point in the 'inflated' universe in which the densities are very close in value. How coincidental….

To explain this coincidence, some physicists have fallen back on what is known as the ‘anthropic principle’ which holds that the universe appears to us as it does because we are here to observe it. Essentially, the closeness of matter and energy density values is occurring at the right time for the emergence of certain physical phenomena—human life, in this case—and so, we can not but observe the universe as it is, at this moment in its evolution. It is our existence at this ‘moment’ in the life-span of the universe that 'selects' how the universe *must* therefore appear.

The anthropic view just expounded does not appeal to hard core scientists, who prefer to derive all constants from ‘first principles’ (those not believed to be functions of subjective consciousness, but of '*a posteriori*' data). But the so-called anthropic principle is favored by some String theorists. String Theory posits the existence of many "constants", many values for Einstein's *lambda.* This anthropic explanation leads to the conclusion that because the energy density varies in different regions of space, then life is only possible in one of those rare regions where the vacuum energy density is extremely low. Life as we know it, therefore, is an extremely rare phenomenon. Such a possibility—that life is a rarity in the Universe—does not jibe well with the views of many astronomers and physicists whose calculations predict an abundance of possible, life-sustaining worlds.

As an aside, the theoretically posited rarity of life in the cosmos may have to stand for now, as the search for other, Earth-like planets—via the Space Interferometry Mission--has been delayed for at least three years. When research that could indirectly verify theory or observation is curtailed for some reason, we have a situation where we assert, disjunctively, that something is false (‘life is common in the cosmos’) because another theory must be true (‘there are many values for lambda’), or worse, because it has not been proven true yet (or false, either). And yet, if the cosmological constant is real and true—that values taken before and after the start of this inflationary epoch are the same (which seems to be the case)—then this should be true for all regions of space, giving Life (in any form) ‘equal opportunity’ to arise and evolve. As the old rational philosophers’ axiom goes, ‘Absence of evidence is not evidence of absence.’ But in light of this recent theorizing, and the anthropic principle, neither is it ‘evidence of existence’.

Apart from these theoretical symmetries, and the *anthropic* viewpoint, some theorists had placed their hopes on finding some quantum gravity effect (perhaps mediated by the still theorized *graviton*) to explain the discrepancy. There is also some growing support for a theory of ‘hidden dimensions’, which offers a *geometric* solution to this problem (and also the ‘hierarchy problem’ of Newtonian and quantum scales). The validation of this cosmological model awaits future experiments from the newly completed Large Hadron Collider in Switzerland.

Another possible approach has been the positing of some as yet unknown ‘relaxation mechanism’ that allows for different values of our vacuum energy density at different stages of the Universe. In order for such a mechanism to be compatible with an inflating universe model, the *time* that this relaxation takes must vary in relation to the ‘Hubble

Time'—the inverse of the Hubble Constant—which assumes that the rate of expansion of the universe has been the *same* throughout its history. When trying to estimate the age of the Universe, scientists project this Hubble Time gauge backwards in time to the first femto-seconds after the Big Bang. What becomes clear is that, if the Universe was expanding *faster* in an earlier phase than at present, then the Hubble Time over-estimates the age of the Universe; if it was expanding *slower* than at present, it leads to an under-estimation of the age of the universe. Any such mechanism must jibe with current measurements of the age of the universe determined by 'black body background' radiation experiments. This 'background' radiation is the 'echo' of the Big Bang and is found in equal amounts everywhere one points one's detection instruments (note: this is termed the CMB, for Cosmic Microwave Background).

Indeed, in the last ten years, scientists have announced several 'adjustments' in the calculated age of the Universe, with most now agreeing to an age of about 13.7 billion years—starting at the 'birth' of the universe: the Big Bang. But as it turns out, it is precisely this age, and its presumed starting point, that may be causing the cosmological constant problem in the first place.

Quite recently, in the way of offering a natural model and means for this relaxation to occur, two noted physicists (Steinhardt and Turok, *Science*, May 26, 2006), have proposed and an alternative explanation: *recycling*. More exactly, they propose that the universe has gone through (and will go through) many cycles of expansion and contraction -- Big Bangs and Big 'Crunches'-- throughout its 'life-span'. Their model posits a long sequence of vacuum states as the original high-energy universe transitions to a low-energy universe. In this model, the energy density is high at the start of a cycle (the Big Bang phase) and lowered as expansion proceeds. But as *lambda* approaches zero, these transitions become longer (slower), and so the recycling universe spends more time in this 'relaxed' state.

If this 'cosmic recycling' model provides a valid relaxation mechanism, and one that is compatible with the inflationary model of the cosmos, then the relaxation time must be initially much longer than the Hubble Time (to allow for cosmic inflation), then much shorter than the Hubble Time (to allow for the fusing of H and He atoms), and then, finally, much longer again. In this phase of the cycle, the universe 'relaxes' and the vacuum density equals the cosmological constant, as we currently observe.

A careful reading of the foregoing reveals that this model describes two completely different time scales: the '*lambda* time' and the Hubble Time. But how can any accurate model of cosmogenesis permit two separate time scales? According to Steinhardt and Turok, this is quite natural, given that the universe is "exponentially older than the Hubble Time." In other words: the cosmological constant is small *because the universe is older than the Big Bang*. This is, at first hearing, a remarkable assertion. But according to these two theorists, there is "no known limit to the number of cycles that have occurred in the past", and therefore, it is quite plausible that our universe is extraordinarily older than present Hubble Time calculations say it is, and yet, can still be capable of forming galaxies, star clusters, and eventually planetary bodies. To these two maverick cosmologists, it is only natural for this relaxation period to grow exponentially long as the cosmological constant (the vacuum energy density) approaches zero. They estimate that a complete cycle lasts somewhere around a trillion years. For most of this time, dark energy—the cause of accelerated expansion--dominates the cosmic landscape (as has recently been hypothesized by other physicists). What follows this long, relaxation phase, is (presumably) the gradual accumulation of gravitational forces, the 'collapse' of the cosmological constant, and the eventual, inevitable 'Big Crunch'. At this point, the energy density returns to the primordial Planck scale (extremely high energy density), where upon the cycle may start over again.

This new theory does a good job of explaining why the present (observable) universe's energy density is so low (and positive), and also why the 'anthropic principle' seems to be valid for the present, observable universe. It might also let Einstein 'off the hook', saving him posthumously from his first theoretical prediction failure. But more than this, the theory is also rather awe-inspiring in its assertion of an inconceivable ancientness to the Cosmos. What's more, the scientists also assert that this 'recycling' theory can accommodate the possibility of multiple "bubbles" of cosmic matter/energy—only one of which is our observable universe—that are *locally* low energy, but which leave the global, inflationary universe (what we can't truly observe) in a much higher energy state…ready to begin again. So then, we have the possibility of an infinite number of universes coexisting, and/or a possible infinity of cosmological cycles in the past.

One curious note about cosmic recycling: if such a mechanism were true, in would mean that the *total* cosmos (seen and unseen) was akin to a humongous 'perpetual motion machine'—able to continuously renew itself through its autonomous, push-pull 'enterprising', in defiance of the more 'local' laws of physics that say this is forbidden. Otherwise, we are back to Descartes and his question of the 'prime mover' (i.e., God as the efficient cause).

But, after all the mathematics and cosmological theorizing is over (for now), what it comes down to is basic economic/ecological cosmic sense: the smartest way to save on "the cost of doing business" is to *recycle*.

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