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The Cosmic Landscape

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Susskind's new book, The Cosmic Landscape: String Theory and the Illusion of Intelligent Design is now out. It's basically a lengthy version for the general public of the argument that he has been, with some success, trying to sell to the physics community for the last few years. In short, the argument is that the compatibility of string theory with an essentially infinite variety of different physics is not a bad thing (because it can't predict anything), but a good thing (because it allows an anthropic argument for the small size of the cosmological constant).

Susskind devotes quite a lot of space to attacking the argument that the string theory picture of unification is "elegant", instead promoting the idea that the properties of the universe come from some more or less random very complicated "Rube Goldberg" construction of a vacuum, one whose nature is just constrained by the anthropic principle. He asks:

But is String Theory beautiful? Does String Theory live up to the standards of elegance and uniqueness that physicists demand? Are its equations few and simple? And, most important, are the Laws of Physics implied by String Theory unique?

He answers these questions by first making fun of the supposed mathematical elegance of the theory:

Elegance requires that the number of defining equations be small. Five is better than ten, and one is better than five. On this score, one might facetiously say that String Theory is the ultimate epitome of elegance. With all the years that String Theory has been studied, no one has ever found even a single defining equation! The number at present count is zero. We know neither what the fundamental equations of the theory are nor even if it has any.

He goes on to argue that the laws of physics implied by string theory have turned out to be highly non-unique:

During the 1990s the number of possibilities grew exponentially. String theorists watched with horror as a stupendous Landscape opened up with so many valleys that almost anything can be found somewhere in it.

The theory also exhibited a nasty tendency to produce Rube Goldberg machines. In searching the Landscape for the Standard Model, the constructions became unpleasantly complicated. More and more "moving parts" had to be introduced to account for all the *requirements, and by now it seems that no realistic model would pass muster with the American Society of Engineers — not for elegance in any case.*

From this he draws the following bizarre conclusion:

Judged by the ordinary criteria of uniqueness and elegance, String Theory has gone from being Beauty to being the Beast. And yet the more I think about this unfortunate history, the more reason I think there is to believe that String Theory is the answer.

He remarks with surprise that no one has drawn the obvious conclusion that these arguments just imply that string theory is wrong:

What I have never heard is criticism based on the unfortunate inelegance or the lack of uniqueness of String Theory. Either of these tendencies might be thrown back at the string theorists as evidence that their own hopes for the theory are misguided. Perhaps part of the reason that the enemies haven't pounced is that string theorists have kept their Achilles heel under wraps until fairly recently. I suspect that now that it is becoming public, partly through my own writings and lectures, the kibitzers on the sidelines will be grinning and loudly announcing, "Ha, ha, we knew it all along. String Theory is dead."

adding a footnote to this paragraph in proof:

This remark was written in the spring of 1994, [presumably he means 2004] *but by the time I completed writing 'The Cosmic Landscape' a year later, the vultures had descended in force.*

He seems to have forgotten about at least one particular vulture, who back in 2003, tried to make this point at the question session after one of his colloquium talks.

Susskind's argument that string theory's compatibility with just about anything is actually an advantage is based on the fact that this makes a place for Weinberg's 1987 anthropic principle argument for the size of the cosmological constant (which from what I've seen gets it wrong by at least one to two orders of magnitude if you only vary the CC, more if you vary other parameters). He addresses criticism of the anthropic principle as unscientific by denouncing the field of philosophy of science, and the criterion of falsifiability in particular:

Frankly, I would have preferred to avoid the kind of philosophical discourse that the Anthropic Principle excites. But the pontification, by the "Popperazi," about what is and what is not science has become so furious in news reports and Internet blogs that I feel I have to address it.

He then goes on to quote from something he wrote for a debate with Smolin at the Edge web-site. For the bizarre story of how this debate came about, including the rejection by the arXiv of a submitted "paper" by Susskind about this, see here. He begins with:

Throughout my long experience as a scientist I have heard unfalsifiability hurled at so many important ideas that I am inclined to think that no idea can have great merit unless it has drawn this criticism. I'll give some examples:

The examples he gives are:

1. Behaviorist psychologists like B. F. Skinner who argued that statements about emotions were unscientific. Here I think Susskind is confusing positivism (the philosophy that science should just deal with directly observable quantities), with falsifiability, which is different. A theory may be based on quantities that are not directly observable, and still make falsifiable predictions about experimentally observable quantities. In any case, physics is supposed to be a much "harder" science than that part of psychology dealing with human emotions, and it is pretty strange for a physicist to be arguing that what he is doing really is science using this as an example.

2. The theory of quarks. Again, Susskind completely confuses positivistic objections (that if quarks are not directly observable you shouldn't talk about them), with falsifiability. While quark theory was problematic until 1973 since there was no workable dynamics, it was taken seriously because it made some very impressive, highly falsifiable predictions. The best known example is the quark theory prediction of the mass, spin and charge of the Omega-Minus particle. If string theory had made some predictions like this, few people would be criticizing it.

3. The theory of inflation. Susskind claims that after Guth first came up with this in 1980, it was attacked as unfalsifiable. I don't recall ever having heard such a criticism, although it was always clear and remains true to this day that experimentally distinguishing between the predictions of different mechanisms for inflation is difficult. From what I remember, there was actually a lot more optimism in the early 80s about this than now, since people were pretty enthusiastic about GUT models, and there seemed to be a good chance that one of the scalar fields in a simple GUT model would do the trick. Susskind writes: "It took 20 years to do the experiments that confirmed inflation." As far as I know people were calculating the effects of inflation on the CMB and starting to design experiments to see them within a few years after Guth's work. I don't see the relevance of the fact that it took a while to get a sufficiently sensitive experiment working.

4. The theory of evolution. Susskind joins other string theorists like Lubos Motl and an anonymous Cambridge referee I dealt with in believing that the status of string theory is much like that of the theory of evolution. He seems to believe that fossil evidence is irrelevant to testing Darwin, writing:

And it took more 100 years or more for to decisively test Darwin (some would even say that it has yet to be tested).

I'll leave it to a professional biologist like P. Z. Myers to argue this point with him, but it seems to me both nutty and irresponsible, given the ongoing battles over the teaching of evolution (which Susskind is getting himself involved with in the very subtitle of this book).

After attacking falsifiability as a criterion for a scientific theory, Susskind does admit that a theory has to make some predictions, even if they're not the sort that could falsify the theory. He acknowledges difficulty in coming up with any predictions:

Is there any way to explain in which of these anthropically acceptable vacuums we live? Obviously, the Anthropic Principle cannot help us predict which one we live in — any of these vacuums is acceptable.

This conclusion is frustrating. It leaves the theory open to the criticism that it has no predictive power, something that scientists are very sensitive about.

He discusses the idea of using statistical arguments, acknowledging that there are severe problems with this due to the "measure problem" of not being able to compare sizes of infinite sets, as well as the problem of not knowing what a priori probability to assign to any given vacuum state. Finally he does try and come up with some suggestions of how the theory might be tested, they are:

1. Evidence in the CMB that our universe was formed by bubble nucleation:

If we are very, very lucky, the largest lumps in the CMB might date to a time just before the usual Inflation got started — in other words, just as the universe was settling onto the inflationary ledge…

If we are that lucky, then the Inflation did not go on long enough to wipe out evidence for the curvature of space… If our pocket universe was born in a bubble nucleation event, the universe must be negatively curved.

At the level of accuracy that the curvature of space has been measured, there is no indication of such curvature. This idea may fail because standard Inflation probably has been going on for a long time when the largest visible lumps were formed.

So, this is both very unlikely to be something we can observe, and even if we did it would only tell us that the universe was born in a nucleation event, still giving us just about zero information about the supposed landscape and none whatsoever about string theory.

2. Cosmic superstrings. Here Susskind is referring to claims by Polchinski and others that amidst the infinity of possible physics due to string theory, one can cook up special cases where certain kinds of superstrings of astronomical dimensions exist and have properties precisely such that we wouldn't have seen them yet, but could see their effects in gravitational wave experiments like Advanced LIGO. As far as I've ever been able to tell, these are contrived constructions, with no reason at all that the vacuum state of the real world should be such as to support them. These are highly non-falsifiable "predictions"

of string theory. No string theorist is going to give up on string theory just because Advanced LIGO doesn't see these effects.

3. High energy physics. Susskind talks about the LHC and the question of whether the fine-tuning problem of the Higgs mass will be resolved by supersymmetry or is anthropic. He acknowledges that, based on Landscape arguments:

My original guess was that supersymmetry was not favored, and I said so in print. But I have changed my mind — twice — and probably not for the last time.

This isn't much of a argument for predictivity on this issue, but I guess his point is that sufficient study of the Landscape might somehow resolve this question, although all the evidence so far is that this is not possible.

The bottom line here is that Susskind is unable to come up with any remotely plausible way of ever getting any scientific predictions out of the string theory landscape framework, and yet he thinks it is a good idea to write a popular book designed to sell it to the public. He makes clear that he is doing this because he sees himself at war with that part of the theoretical physics community which still believes in the idea of continuing to try and do what theoretical physicists have always done: find a more mathematically beautiful, more compelling, more predictive theory than the one we have now. In one chapter he surveys the state of the ongoing political battle for the hearts and minds of his fellow theorists. He crows (with some justification) that Weinberg agrees with him, saying physicists have to give up the paradigm of how to do physics they pursued during the last century, that Witten is facing defeat and getting depressed, that Joe Polchinski says there's no alternative, that the entire Stanford theoretical physics group are his allies, that 't Hooft won't rule out anthropic explanations, that Maldacena believes in the Landscape, that Michael Douglas is on his side, that cosmologists Linde, Vilenkin, Rees and Tegmark are in his camp, and that Alan Guth is at least a fence sitter. One of the few active opponents that he sees left on the scene is David Gross, whose reasons for opposition he describes as "more ideological than scientific." He sees Gross as dead meat: "the field of physics is littered with the corpses of stubborn old men who didn't know when to give up."

In coming weeks, it will be interesting to see how the physics community deals with the challenge presented by Susskind's publicity campaign for changing how theoretical physics is done. So far the initial signs are depressing. Michael Duff's review in Physics World just more or less respectfully repeats Susskind's argument, not challenging it in any way. In a review of the Duff review, Clifford Johnson answers the question of whether this sort of thing is still science with "I have not yet made up my own mind whether it sits well with me or not…" He makes a distinction between postdiction and prediction that I don't quite agree with (if Susskind's framework accurately postdicted even a few of the known Standard Model parameters, I'd be a believer). He takes the usual stance favored by most sensible string theorists who want to keep working on the theory that they don't understand the theory well enough yet to know whether they are stuck with the Landscape or not. Finally he thinks there's a chance that maybe the structure of the Landscape is such that once one anthropically fixed the CC and some other constants, the remaining set of vacua would actually predict something. I don't see the slightest evidence for this, but it's the argument many are now using to justify exploring the Landscape and surrounding swampland instead of giving up on string theory and trying to find a better idea.

Update: I should have mentioned a recent well thought out review of Susskind's book at Tech Central Station by Kenneth Silber. It's quite sensible and worth reading if you're following this story. Another review of the book has just appeared, this one by George Ellis at Nature. Ellis is much more critical of Susskind than Duff was, realizing that the crucial issue is that Susskind has no evidence for his claims, and writing in his final paragraph:

Physicists indulging in this kind of speculation sometimes denigrate philosophers of science, but they themselves do not yet have rigorous criteria to offer for proof of physical existence. This is what is needed to make this area solid science, rather than speculation. Until then, the multiverse situation seems to fit St Paul's description: "Faith is the substance of things hoped for, the evidence of things not seen." In this case, it is faith that enormous extrapolations from tested physics are correct; hope that correct hints as to the way things really are have been identified from all the possibilities, and that the present marginal evidence to the contrary will go away.

One peculiar thing about Ellis's review is that he accuses Susskind of ignoring the fact that there is no experimental evidence for negative curvature of the sort one might get if the universe was formed by bubble nucleation. In Susskind's defense, he does address this point, saying it is very unlikely we can see this negative curvature since inflation is likely to have gone on long enough to make it unmeasurably small.