# The Klog Metric for Assessing Physics Theories [1]

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In 1965, mathematician Andrey Kolmogorov realized that one way to define the information content of a complex system was to find the most compact computer program — the one with the fewest bytes of rules and numbers — capable of recreating all available data on that complex system.[2] Thus under the Kolmogorov definition, a good physics theory is indistinguishable from a good data compression algorithm.[3]

How does one rate a compression algorithm? Just like your computer does: Divide the number of bytes in the raw set of observed data and divide it by the number of bytes in the program that reproduces that data. A compression factor of 8 means the compressed data takes up only one-eighth the bytes of the original. Similarly, a compression factor of 1 means you did nothing but rearrange the data. If the compression factor is below 1, it means you did the opposite of what you intended: You bloated the data, adding irrelevant noise to it.

For physics theories, the compressed form of the raw data always takes the form of an attempt to create a Kolmogorov minimum program. The Kolmogorov size of the attempt is the number of bytes required to state the theory precisely and, ideally, in a form that is sufficiently formal to be executable.

For Kolmogorov compressions, I like to express the compression ratio as a base-2 logarithm. With this Kolmogorov logarithm metric or Klog — think of it as waiting for the missing shoe to drop — successful compressions are positive, and failed compressions are negative. Thus an 8-fold Kolmogorov compression has a Klog of 3. Klog 3 is pretty good computer data since it represents almost an order of magnitude of compression, but it's downright sad for physics theory. That's because good physics theories capture and represent the behaviors that often apply to the *entire* universe, often for all of time.

Thus a huge positive Klog means you have a good theory. A small positive Klog means the theory may not amount to much more than better data formatting, and a zero Klog means your theory failed: You did nothing but juggle and perhaps encrypt the data set, though at least you did not damage it. And, of course, a *negative* Klog is a bad sign indeed. It means that instead of capturing the more profound rules and invariances of the universe and using them to compress its data, all you did was add *theory noise* to the data set.

Theory noise is just that: Human-created data that does not reflect any discernable patterns discernable in experimental reality. Beautifully and precisely formatted theory noise, most often in the forms of large sets of equations or equation-like formalisms disconnected from any experimental data, can cause immense damage by making it nearly impossible to find and comprehend the non-noise "signals" in the data. One example is Sabine's description of a surprisingly predictive fitting graph buried in a vast literature of non-predictive inflation papers. Physically invalid applications of otherwise excellent and well-structured mathematical frameworks are the most devasting type of theory noise. These can waste entire careers — or entire generations of careers — on problems that exist only within the noise generated by those frameworks and have nothing whatsoever to do with the original experimental data they are nominally supposed to explain. While some are blatant due to their close association with specific, well-defined theories, others are more impactful due to the subtlety of how they disconnect with physical reality.

A simple adage from computer science applies: Noise breeds noise. When the spread of noise is left unchecked, it multiplies until your system either stops working or begins spewing out utter nonsense, which you may nonetheless decide to sell as a product. (I name no names.) Good software and good physics theories must both vigilantly seek to find and remove human-introduced noise if only to keep themselves from generating nonsense at an exponentially expanding rate.

Not surprisingly, the best source of noise reduction for physics is always the lab. Modern condensed matter physics applies lab-based noise reduction well, resulting in rock-solid theories with often spectacular commercial results. For example, did you remember to thank your local condensed matter physicist lately for that fantastic new flat-screen TV you just bought?

Areas such as cosmology and particle physics sometimes perform even better, in no small part due to the quite literally "universal" scope of the data they compress. Under a Kolmogorov assessment of theory quality, the theory of General Relativity remains, even after a century, the best physics theory ever devised. It uses a paltry few hundred bytes of equations and numbers to capture and accurately predict the observed behaviors for most of the large-scale universe. Its ability to compress natural data is nothing less than astonishing, giving it a Klog that approaches infinity since *all* of that natural data goes into its numerator.

Interestingly, and despite its now-glaring faults, Newton's theory, when used with limiters that define when *not* to use it, also gets an extraordinarily high Klog rating. Newton's theory of gravity, when combined with range qualifiers that add more bytes to the Klog denominator, to this day gives extraordinarily high-quality, high-fidelity compressions of data for the vast majority of observed astrophysics objects and relationships.

As Sabine noted, the Standard Model [4] also rates well under any predictions-per-equation metric. Its Klog metric approaches positive infinity since, except for gravity, it predicts pretty much all of reality. It also qualifies as decently compact, though not nearly as compact as those short glossy tables of fermions and bosons that are its forward face to the public might make you think.

With that said, it is highly improbable that the Standard Model is close to the best Kolmogorov compression possible for particle data. It contains far too many oddly repeating internal patterns, with the three observed but never-predicted generations of fermions as an especially glaring example.

What a fascinating situation that is! The Standard Model is a compelling and rock-solid theory that *already* captures enormous natural data with exquisite precision. Yet simultaneously, it displays features indicating a substantial distance from the Kolmogorov minimum for its data set. One way to approach this issue more analytically is to view the Standard Model *itself* as a data set needing further Kolmogorov compression. That is, no significant new collider data is needed, just a re-examination of the data *already* nicely captured in the Standard Model. The computer science term this strategy is refactoring. Thus the most significant outstanding challenge for the Standard Model is not to collect more data but to refactor the existing model into a more concise and insightful form.

Next, how has theoretical physics done on noise reduction in more recent times, say over the past half-century? Um… not very well.

Regarding inflation theories, does anyone care to guess how the figures that Sabine quoted as an example of social reinforcement — 14,000 inflation papers written by 9,000 people — rates under a Kolmogorov compression assessment?

Right: Not very well. While there is, of course, a far larger body of papers written about General Relativity, those papers are *about* General Relativity. The vast corpus surrounding GR is an *application* of GR, not an integral part of it. In sharp contrast, since there is *no* consensus on which of the inflation models is the right one to use, the bytes for the *entire* set of inflation papers go into the Klog denominator as the best possible representation of inflation theory.

And how much of the natural world do all of those bytes in 14,000 papers predict? Sabine stated it beautifully: "the data … comes down to a few numbers."

Thus the Klog for inflationary models as they stand now is an enormous negative number. The qualifier is the same one Sabine noted: Buried within all that decompression noise are a few curves that, like MOND [5], predict things that such simple numbers have no obvious right to predict. That's actual data and meaningful compression! Thus, as Sabine suggested, a good strategy for anyone in this domain is to look for such buried nuggets of inexplicable explanatory power.

Finally, I cannot possibly close a session about the Klog metric of theory quality without mentioning my favorite *bad* example of a Klog metric. That would be superstring theory [6], which unfortunately gets called "string" theory these days.[7] For the Klog metric of superstring theory, what is the number of numerator bytes of experimentally meaningful predictions? Zero, as best I can tell — and I've looked, many times, over decades. Next, what is the Klog denominator for superstring theory? It is one of the largest, if not *the* largest, sets of science-funded papers created in human history.

The denominator is just icing on the cake since based solely on the zero numerator, the Klog for superstring theory is negative infinity. Additionally, I'm not even aware of any nice data-fit curves popping out of that body of work. If any such curves exist, they almost certainly would have popped up — along with all of the usual popular press articles — during the funding renewals cycles.

Finally, how do cyclic universes rank in all of this? That is indeed an interesting question that needs further consideration.[8]

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REFERENCES AND NOTES

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https://sarxiv.org/bkr.2022-03-05.0800.pdf
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[7] I try hard to maintain the historically correct distinction between "string theory" and "superstring theory" because the original 1960s string theory was based directly on actual patterns — Regge trajectories — that were abundant in the collider results of that period. The results indicated that string-like vibrations were the source of these Regge trajectories, resulting in the name "string theory." We now know — they did not then — that the "strings" involved were composed of the strong force, which does not dissipate with distance. That means that in sharp contrast to both electric and gravity forces, the strong force behaves a *lot* like a string. This strong-force string binds two or three heavy quarks that twirl around each other like the weights on a bola. Add quantized angular momentum, and voila! you get Regge trajectories. "Super" strings, in contrast, were a downward generalization of such hadron data by *twenty orders of magnitude,* all the way down to the utterly inaccessible Planck scale. Instead of postulating what force replaces the string-like strong force at that level and what particle-like weights

replace the quarks, folks just tossed that kind of realism out the window and decided that all they needed were human-designed vibration equations. Don't believe me? Ask any string theorist about the nature of the energy fields (or materials? really?) that form their strings.

So, given this complete abandonment of all of the physical constraints that led to string vibration results in the first place, is it shocking that the jump down 20 orders of magnitude using only completely unconstrained, human-devised, and experimentally-disconnected wave equations resulted in an almost infinite number of possible universes?

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[8] Last week I posted a single PNG figure that captures the core of an entirely new "dual universe" take on Penrose's Conformal Cyclic Universe (CCC) [9] model:

https://sarxiv.org/bkr.2022-02-26.2321.png

Usually, I would not say "entirely new" about any concept — the deep literature is quite full of surprises, yes? However, the combination of Penrose's idea (not his fault!) with a model that exists only in my notes and differs in essential points from any other dual-universe models makes this assertion entirely plausible.

I am still surprised that such a merger may be possible, even conceptually. I was initially just as skeptical of the Penrose cyclic model as I was of the 2002 Steinhardt-Turok cyclic [10] model for similar reasons: Dilution alone *does not* erase entropy since it only gives an illusion of smoothness. Particles endure, and by doing so, they behave like a highly intransigent form of entropy.

I did not like my dual universe model because it behaves as a one-shot with a finite duration. The dual universes are born and begin slowly (yes, *slowly*) to accelerate up and down the torus surface like smoke rings. They reach their maximum expansion rates just as the two closed, smoke-ring-like universes reach the top and bottom of the torus and then begin to *decelerate*. Just as they reach a complete stop at the outer equator of the torus, they also bang head-on into each other *in time* (not in space!). The result is a return to the mass-free, energy-free, time-free Void. For non-trivial reasons, the overall process is not that different from how virtual electron-positron pairs become real enough to, say, polarize the vacuum, yet leave no trace of their "particle-ness" after mutually annihilating. Virtual particle pairs are one of the few known phenomena that can claim actual information erasure, even if only in a somewhat trivial sense.

Gee… where have I heard of some need to erase all scale metrics before a new universe can get going? Moreover, multi-scale unevenness in the Final Fade process provides at least the potential for entropic information from one cycle to influence the form of the next cycle.

Adding Penrose conformal rescaling to dual universes gives *context* to otherwise self-erasing pairs. They can have history, but it's not some free-for-all multiverse that is too lacking in constraints to mean much of anything. A dual universe cycle with Penrose conformal rescaling at both ends has both an ancestor and a descendent, potentially with unevenness to transfer structure. Here is one cycle of "eon" in Sir Penrose's terminology:

https://sarxiv.org/bkr.2022-03-03.1300.pdf

Once a sufficiently persistent entropy-transfer Void takes hold, each new cycle can, in principle, *grow* in size, duration, and complexity. In the reverse-cycle direction, the earliest cycles could be as small as one hydrogen atom, one positronium atom, one quark or less, or even less than one quark.

(For a possible example of "less than one quark," picture a T rishon [11], but without any V rishon. The V rishon is just a placeholder for the mutual orthogonality of the three emerging color states. The charges of such mutually orthogonal T particles would be singular, but from our perspective, they would look like the mixed electric-color charges of (anti) down quarks. This color-electric symmetry would break in a later cycle.)

In the forward-cycle direction, increasing Void perturbations should enable more states in each new cycle. It's a cascade breakdown, but of the friendly variety, since otherwise we wouldn't be here.

I'll publish a full paper titled "A Dual-Universe Interpretation of Conformal Cyclic Cosmology" soon, hopefully, this week. As of 2022-03-05, this paper is not yet online. Its eventual publication URL is:

https://tarxiv.org/tao.2022-02-27/

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(Good luck on that one. Google Scholar is always worth a try.)

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