Why Are There Laws of Nature?

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Abstract

It is argued that solving the enigma of information theory via a self-consistency requirement implies straightforwardly that the information content of nature is logarithmically small, which means that there are laws of nature.

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Invariances, alias symmetries, alias redundancies, alias laws of nature, are the basic subject of the physical sciences. They allow us to know parts of nature there and then – in whatever space may be relevant – from what they look like here and now. For example, if we measure the energy of a closed classical system at one instant, this means that we know this quantity forever.

There are some very interesting aspects of such invariances, with Noether's theorem as a key. However, the most pressing questions reach down even deeper, to where the only concept left is that of information itself. Why is nature not completely random? To what extent is nature redundant?

We define "nature" here to be everything relevant to the following discussion, be it the universe or more. When I speak about the "state" of nature,

Table 1. Numbers characterizing the screen described in the text.

Number of pixels	N
Number of possible states	$\exp N$
Number of factual states	1
Semantic content of factual state	"N"
Nonredundant information	$\log N$

this is nothing dynamic. Rather, it spans all relevant dimensions, including time – or even a greater number of timelike dimensions. To illustrate the situation, I shall use the metaphor of a "screen" and call the element of information a "pixel". There is evidence that the element of information is a two-valued "bit", but a base of 2 for the exponential function is not crucial for the following conclusions. The symbols "exp" and "log" should be read in an abstract sense.

So, one has a screen showing an image with symmetries, which means an image with less information than the maximum possible: the image can be produced by a computer code consuming fewer pixels than the screen has available. This leads to the basis of information theory; indeed, to the very meaning of the idea of "information". Though omnipresent in modern physics (in the entropy of black holes, information loss [1], entanglement [2] and many more areas), information theory is not yet free from a fundamental enigma. Instinctively, one would say that the information associated with a screen is what one sees there, for example a sketch of the expanding universe. However, such semantic content should correctly be considered as the factual state of the screen, while the information content is defined to be the number of pixels – which is the logarithm of the number of possible states. Now, if these two aspects of the information coincide, this conflict is solved in a self-consistent manner. This means that the factual state of the screen displays its number of pixels. Translated back, *the one and only state of nature encodes its number of degrees of freedom.*

Something of that kind can occur in everyday life when a screen is used to advertise itself. Suppose the screen displays a message such as "5 Megapixel Screen – Promotion". Addressed to humans, this message contains some linguistic encoding and an additional message. The fonts are human-sized as well, and consume a lot of pixels. But, in a strict, "puritanical" sense, the number of pixels needed to encode a number is only the logarithm of that number. The rest of the screen is filled with redundant content. This yields the numbers characterizing the screen shown in Table 1.

So, as a clear result, *the information content of nature is logarithmically small.* Is this plausible? In [3], a drawing appears showing God pointing at a tiny portion of phase space. This illustrates exactly how incredibly small the entropy of nature is (to be precise, the drawing refers to the entropy of our universe at early times – I shall not discuss that topic, apart from repeating that I see information as nondynamic).

For speculations on the value of N_{nature}, estimates on black hole entropy may serve as a lower limit, as it is the case in [3]. However, is N_{nature} finite at all? Quantization creates a yet poorly understood interplay between the continuum and a countable set. A plausible solution would be to have the non-redundant information countable, while the number of degrees of freedom is continous, i.e. $\log N_{nature} = \beth_0$, $N_{nature} = \beth_1$.

References

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