CAUSALITY AND COMPLEXITY

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In linear systems there is a direct link between cause and effect. This is not the case in non-linear systems where causes are inter-related. This is, of course, well known in social systems where the attribution of blame is often a matter of opinion or convenience. Often the approach taken is to appeal to a notion of *perturbative causality* where small changes in causes are traced to their effects, other things being equal, or at least, as equal as possible given the constraints. In this situation, small causes may appear to generate large effects at tipping points, neglecting the interaction of the small perturbation with the other system variables. In complex systems it is the interactions of the agents, rather than the attributes of the individual agents, that leads to emergent, thereby undermining a naïve reductionist view.

In cosmology the emergent properties of the Universe are attributed to special values of the fundamental constants on the grounds that small perturbations of these values cause large deviations from the observed features, particularly the existence of sentient observers. Thus we are not surprised to find ourselves inhabiting an instance of the multiverse that can support life. This is an example of perturbative causality and gives rise to the idea that the parameters of the system have been fine-tuned.

An alternative view seeks to understand emergent behaviour as a probable consequence of complexity. One example is Kauffman's NK model applied to the origin of life: in this model life (in the sense of a metabolic network) evolves wherever complex chemistry is possible as the natural outcome of a complex system without any fine tuning. Taking this further, we can imagine that the multiverse admits complex behaviours in any of its ground states. In this view there is nothing special about the values we find for the fundamental constants: life, as a complex system, is bound to emerge in any universe with a sufficient number of interacting fields, that is, in high enough dimensions.