



ON THE NATURE OF PHYSICAL LAWS

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Human beings—even physicists—are very capable of holding two totally incompatible concepts in the mind at once. Few of us have never attempted verbal communication with a pair of dice, for instance, even as we continued to subscribe firmly to the laws of Newtonian dynamics.

It is the nature of physics that its generalizations are continually tested for correctness and consistency not only by careful experiments aimed directly at them but, usually much more severely, by the total consistency of the entire structure of physics. Deterministic dynamics of macroscopic objects is just one, if possibly the best tested, of the laws of physics. That the trajectory of a roulette ball is deterministic was tested, rather thoroughly and directly, by a group of now eminent physicists calling themselves the Eudaemonics, for fun and profit [this episode in the lives of Ralph Abrahams, Jim Crutchfield, Dooyne Farmer, Norman Packard and others is very readably told in the book *The Eudaemonic Pie*, by Thomas A. Bass (Houghton Mifflin, 1985)], but much more severe tests are made every day via the internal dynamics of our instruments and our technology. We can measure the fundamental constants to precisions of 10^{-7} – 10^{-8} using the modern quantum techniques due to Brian Josephson and Klaus von Klitzing, and we can measure time, using the wonderful technology of millisecond pulsar timing, to six orders of magnitude better than that. Any such precise measurement is a triumph of deterministic dynamics, as is the achievement of the almost unthinkable precision that brings beams of electrons and positrons together at LEP. The values of $\hbar/e^2$ and $e/\hbar$ do not depend on the mood of the experimenter, and evil thoughts do not prevent those beams from colliding. Recently the entire

science of deterministic dynamics—misnamed “chaos” in the popular mind, but as we all know, more aptly called “deterministic chaos”—has very much bolstered our understanding that what goes on in the most apparently random physical systems, such as turbulent jets and convection cells as well as dice games and roulette wheels, is simply “sensitive dependence on initial conditions” acting in a perfectly deterministic system.

It is disturbing, then, that some who call themselves physicists set out seriously to test the effect of “thinking at them” on sensitive electrical measurements, on card-shuffling machines or on bouncing ping-pong balls. It is much more disturbing to see positive results announced on the basis of statistical deviations at the few- σ level. The problem is, of course, the question of the consistency of the structure of physics: If such results are correct, we might as well turn the National Institute of Standards and Technology into a casino and our physics classes into séances, and give back all those Nobel Prizes, since the measuring apparatus with which we think we have been achieving all this precision can actually be bent out of shape at the behest of the first Uri Geller who comes along, and our vaunted precision is all in our heads.

It is for this kind of reason that physicists, quite properly, do not take such experiments seriously until they can be (1) reproduced (2) by independent, skeptical researchers (3) under maximum security conditions and (4) with totally incontrovertible statistics. Oddly enough, the parapsychologists who claim positive results invariably reject these conditions.

Less thoroughly entwined with the very nature of physics, but still very much subject to this important concept of the immense overdetermination of the structure of science in general, are various other laws that have been questioned recently: for example, the equivalence principle, in the weak sense that gravity and inertia do not depend on internal states of motion, which was challenged by a widely publicized paper on gravitational effects of rotation; or the principle of invariance of the branch-

ing ratios for nuclear reactions. With the fantastic level of confirmation of the laws of general relativity that has recently been achieved, especially by Joseph Taylor’s group studying the binary pulsar PS 1916, for example, and the recent very severe tests of the equivalence principle occasioned by the “fifth force” controversy, it is hard to see why statistically weak and physically naive challenges to these laws deserve publication in *Physical Review Letters* and front-page coverage in newspapers. Equally, when cold fusion is claimed to produce heat without neutrons or neutrons without tritium, it takes very little thought to realize that some very basic principles on which whole technologies have been based have been suddenly abrogated, and one is better advised to examine the challenger or his methods than his results. The statisticians have a word for it: When we are trying to be “objective” and taking such results at face value, we are distorting the “priors,” which is to say we are not properly weighting all the other evidence.

My moral, finally, is that physics—in fact, all of science—is a pretty seamless web. If we challenge one of its smaller generalizations, we may be successful if we replace it with something else that holds all of the strands together. It is wonderful to discover that no outside fact forbids fivefold symmetry or high- T_c superconductivity, only our prejudices; but even those prejudices were soundly based, since the prior conditions for them were explicitly and clearly stated in the classic literature: In the first case it was *assumed* that a periodic structure existed; in the second it was *assumed* that the BCS–Eliashberg dynamic screening mechanism held. Results that rip the fabric to shreds must be expected to be almost invariably wrong, and it will save everyone a lot of energy and time if we recognize that such results should be examined with a tougher mind than we physicists are used to applying. Perhaps, as has been advocated elsewhere, in the worst instances we should call in those who are more used to dealing with flimflam, such as magicians and policemen. ■

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