Quasars and Physical Constants

Another cosmological question is now referred to quasars: whether physical constants change as the universe ages

BY DIETRICK E. THOMSEN

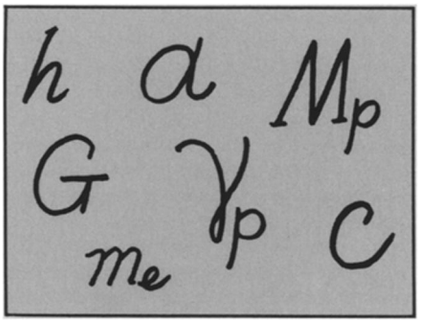
Anyone who has studied physics or even has a nodding acquaintance with the science will be aware of the pivotal role played by the so-called fundamental constants, such numbers as the universal gravitational constant, the fine-structure constant, Planck's constant, the speed of light and so forth. They serve as important links in the chains of theoretical derivation. Their values are of crucial importance in the formulas by which the actual effects of physical systems are calculated and compared with one another.

One of the most thought-provoking (and annoying) characteristics of the fundamental constants is their apparent arbitrariness. It is difficult, and in most cases impossible, to devise *a priori* arguments that justify either their necessity, their constancy, or their values. They are what they are; their values come from empirical observation, and theory must swallow them *ad hoc*.

Naturally this has caused a good deal of philosophizing. John Wheeler once remarked that God made the fine-structure constant, which measures the strengths of electromagnetic forces, to be $^1/_{137}$ so that we would arise to worship Him. The argument is that with any other value of the constant, the types of carbon bonding that allow the long chain molecules essential to biochemistry would not be possible. Among the physics buttons that Hla Shwe has produced is one that paraphrases *Genesis:* "And God said, '[Maxwell's equations]' and there was light." The constancy of the speed of light is the thread on which Maxwell's theory is hung.

But the constancy of c goes deeper than that. Einstein noticed that c remains constant under Lorentz transformation. Unlike other velocities it does not change its value when one moves among frames of reference going at different speeds relative to each other. On this, Einstein built the special theory of relativity, then generalized it, and in so doing wrought a revolution in our way of regarding reality that extends far beyond theoretical physics. For just two examples, it provides the atmosphere for much of Kafka's work, and Hermann Hesse was explicit about its importance for him and his characters in *Steppenwolf*. And from *Steppenwolf* by way of the rock group of the same name we can make our way to the Beatles' classic *Yellow Submarine* with its explicit and charming exploitation of Einsteinian notions.

All this reverential bowing in the direction of the fundamental constants is not without objectors. Countervailing opinion wonders why physics should be sprinkled with arbitrary constants that stand like fixed beacons in a sea of uncertainty. The opposite attitude is sometimes called Machian after Ernst Mach, who articulated it in the late 19th century in the context of gravitation and cosmology.



Basically it holds nothing fixed; everything is variable, and everything depends on everything else. Mach went so far as to propose that even a body's mass, its most basic physical quality, its quantity of matter, can vary. A number of luminaries of contemporary physics including among them, P.A.M Dirac (SN: 2/19/74, p. 92), Fred Hoyle (SN: 6/14/75, p. 386) and Robert H. Dicke with C.H. Brans (SN: 7/11/70, p. 44), have produced cosmologies and gravitational theories in which fundamental constants and/or mass are allowed to vary. Kafka would have gone ape over these formulations; they provide even weirder worlds than Einstein did. Einstein was basically a conservative striving to save as much of the Galilean and Newtonian program as he could.

But in physics finally everything must come down to the dirty-fingernailed world of experiment and observation. Here, at first glance, we find catalogues of data from a large number of times and places that go to prove that the fundamental constants are in fact constant. True, say the opponents, but the proof they give is entirely a secular one: They show that the constants have remained constant, or nearly so, over the last couple of centuries, during which precise experiments have become possible. We are talking about variation over eons. How has it been through the history of the universe?

It has become possible to get observational evidence that bears on that question. Most of it comes from astronomical sources, and although there are pronouncements on both sides, evidence for the negative side seems to be mounting more and more, the latest pronouncement claiming no change in several of the fundamental constants over at least 35 percent of the universe's history.

The most positive person is Thomas C. Van Flandern of the U.S. Naval Observatory who has been going around for the last couple of years saying that his studies of the moon's motion show that the gravitational constant varies. He has been severely attacked, but has stuck by his data.

Meanwhile, another study of lunar motion, the LURE or laser-ranging experiment, has failed to find evidence for the so-called Nortvedt parameter, a factor that should appear in the moon's motion if the gravitational constant varies. But one must say that not all the people involved with that experiment are entirely satisfied with the results. I. I. Shapiro of Massachusetts Institute of Technology and colleagues have been trying to get some information on the same point through radar studies of planetary motions, but so far have not come up with a definite pronouncement.

In the July 26 PHYSICAL REVIEW LETTERS, A. M. Wolfe of the University of Pittsburgh and Robert L. Brown and Morton S. Roberts of the National Radio Astronomy Observatory, report that they used the radio emanations of the source AO 0235+164 to check the variability of the fine-structure constant and certain other values which should also remain constant in a well-ordered Einsteinian universe: the mass of the proton, the mass of the electron and the nuclear g factor of the proton (a measure of its magnetic properties and therefore of its internal structure). *Continued on page 158*

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The observation could be made because something near the radio source produces absorption lines in its spectrum. The ones specifically concerned here are the fine-structure lines of magnesium and the hyperfine structure lines of hydrogen. Fine and hyperfine structures are produced by magnetic interactions in the absorbing atom (or the emitting one if that is the case) that split what would otherwise have been one spectral line into two or more closely spaced ones. Comparing the frequencies of the fine-structure lines is a classic way of determining the fine-structure constant (in fact, that's why it has the name).

Wolfe, Brown and Roberts report that their observations uphold the constancy of the fine-structure constant and two quotients involving the other terms: first, the square of the fine-structure constant times the g factor of the proton times the ratio of electron mass to proton mass; second, the g factor of the proton times the ratio of electron mass to proton mass. Since the last two numbers involve multiplications and divisions, it is possible that any one factor in them may vary provided some other or others vary in a compensatory manner. But, as the three observers point out, that in itself places a heavy constraint on the non-Einsteinian theories, which have a tendency to allow all these numbers to vary in a much freer manner. And the finding implies the constancy of the three values over the last 35 percent of the age of the universe because the distance to the absorbing medium indicates that the emanations of AO 0235+164 that we now receive passed through the absorber that long ago.

So it seems as if the weirdly fascinating worlds of the non-Einsteinian cosmologies are going glimmering down the path taken by other plausibilities, the swamps of Venus and the canals of Mars. □