LETTERS

Walking the Planck Length through History

Frank Wilczek's Reference Frame article in the June 2001 issue of PHYSICS TODAY (page 12) shows how simple dimensional analysis, together with a few elementary facts, can lead to profound conclusions.

I would like to comment from personal experience on one historical point. Speaking of Planck's proposal that the Planck mass (M), length (L), and time (T) should form a fundamental system of units, Wilczek notes that the proposal was at first merely formally correct, but that "over the course of the 20th century, however, his proposal became compelling." But I can testify that it was still considered heretical well into the 1960s.

In 1959, I submitted a paper proposing that the Planck length L and time T should play a fundamental role in physics. In the case of L, the idea was based on an analysis of Werner Heisenberg's microscope experiment, taking account of the gravitational field of the photon used to measure the position of the particle. For T, the analysis involved the problem of keeping clocks synchronized in view of both the uncertainty relation between the reading of a clock and its energy, and the influence of gravitational energy on the rate of the clock. In both cases, I found that one runs into trouble when trying to obtain a position measurement (clock synchronization) with error less than L (T). At the time, I knew nothing of Planck's proposal. Eventually this paper, and a follow-up, were published.[1] While my paper was suffering referee trouble, a similar idea was proposed by Asher Peres and Nathan Rosen.[2]

I don't claim that my papers deserved any better fate than they received: years of referee trouble, eventual publication, a cold shoulder from the physics community. But some of the reasons for this cold shoulder are worth noting. At the time, I read many referee reports on my papers and discussed the matter with every theoretical physicist who was willing to listen; nobody that I contacted recognized the connection with the Planck proposal, and few took seriously the idea of L as a possible fundamental length. The view was nearly unanimous, not just that I had failed to prove my result, but that the Planck length could never play a fundamental role in physics. A minority held that there could be no fundamental length at all, but most were then convinced that a fundamental length L', of the order of the proton Compton wavelength, was the wave of the future. Moreover, the people I contacted seemed to treat this much longer fundamental length as established fact, not speculation, despite the lack of actual evidence for it. Of the people I contacted, the only ones I can recall who had a positive attitude to the idea of L as a fundamental length were Henry Primakoff, David Bohm, and Roger Penrose.

I don't know when or how the transition of the Planck proposal from heresy to conventional wisdom took place, but I can attest that it had not even begun in the mid-1960s. I suspect that it did not really begin to take hold until at least the mid-1970s, but perhaps others can enlighten me on this.

References

1. C. A. Mead, *Phys. Rev.* **135**, B849 (1964); *Phys. Rev.* **143**, 990 (1966).
2. A. Peres, N. Rosen, *Phys. Rev.* **118**, 335 (1960).

C. ALDEN MEAD
(camead@compuserve.com)
Savannah, Georgia

WILCZEK REPLIES: It is true and significant that the Planck length arises naturally when one considers the ultimate limits to measurement. Crudely, it happens because refined length measurement requires large momentum, according to Heisenberg's uncertainty principle, but when the momentum becomes too large, its gravitational effect becomes strong, curving spacetime and distorting the interval one seeks to measure. Thus a fundamen-

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tal difficulty arises in resolving lengths below the Planck scale. This point has been "rediscovered" many times, but C. Alden Mead's discussion is the earliest I'm aware of. It nicely supplements the article, in which the Planck length was introduced in a somewhat different way.

One can understand the source of the bias Mead encountered, and in the process highlight an important principle: What quantities one chooses to regard as fundamental can depend on what domain one seeks to describe. A good approximate description of much of chemistry and molecular biology can be obtained by taking only the electron mass and charge as inputs, using Planck's constant $\hbar$ as the unit of action, and regarding atomic nuclei as infinitely massive point-particles. In this system, the Bohr radius $\hbar^2/e^2m$ appears as the fundamental unit of length; indeed this sets the scale for atomic and molecular sizes. A good approximate description of strong-interaction physics can be obtained by taking only the quantum chromodynamics mass scale Λ as input, using Planck's constant and the speed of light c as units of action and velocity. In this system the fundamental unit of length is $\Lambda/\hbar c$; and indeed this sets the scale for proton and nuclear sizes. In the 1960s and early 1970s, strong-interaction physics was the primary focus of fundamental physics, and this system (implicitly) seemed most natural.

FRANK WILCZEK
wilczek@mit.edu
Massachusetts Institute of Technology
Cambridge

On Keeping Chinese Science Students

I'd like to add to the story by Lynley Hargreaves (PHYSICS TODAY, May 2001, page 24) on the dropout rate among Chinese physics PhD students. I am the chair of the graduate admissions committee in chemistry at Colorado State University. Since 1991, I have noticed similar trends among our chemistry students from the People's Republic of China. Like many state schools, CSU has significantly different tuition for resident versus nonresident graduate students. This is a cost that the department or the research advisor's grants