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Hypothesis of quantized particle lifetimes reexamined, and its connection with the hypothesis of quantized time

Robert Ehrlich
Department of Physics, State University College, New Paltz, New York 12561
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Recent data on resonant-particle widths do not conform to the hypothesis of quantized particle lifetimes to the degree that previous data did. However, other factors not noted in a previous article may lend support to an elemental unit of time of magnitude 2.20×10^{-24} sec.

In a recent article,[1] this author observed a regularity in the widths of resonant-particle states which he interpreted as possible evidence for the quantization of particle lifetimes in units of half the ρ-meson lifetime: $\frac{1}{2}\tau_\rho = (2.20 \pm 0.03) \times 10^{-24}$ sec.[2] In this note we point out that more recent data[3] do not agree with the quantization hypothesis as well as previous data did, but that other factors may actually tend to make it somewhat more plausible.

All resonant states having uncertainties in lifetimes less than one sixth the ρ-meson lifetime have been listed in Table I. Four states have computed lifetimes differing from integral multiples of $\frac{1}{2}\tau_\rho$ by 1.5–3.0 "standard deviations,"[4] and two states are more than three standard deviations away. While these data do represent a very serious challenge to the quantized-lifetime hypothesis, there are possible explanations for the discrepancies that would not require abandoning the hypothesis. It is not unlikely, for example, that among the baryon resonances there may be some systematic errors present owing to the complex model dependence of the analysis.[4] Furthermore, $N(1470)$, the state showing the biggest discrepancy may actually be two nearby resonances rather than one.[5]

Much has been written[6] about the possibility of time being quantized in elemental units, i.e., "chronons."[7] While a direct test of the chronon hypothesis might seem to require a measurement of individual particle-decay times, it is quite possible that data on resonant-particle lifetimes can be used instead. This is because individual particle-decay times cannot be measured with a precision anywhere approaching the state lifetime, owing to limitations imposed by the uncertainty principle.[8] One interesting consequence of the possible connection between the chronon hypothesis and resonant-particle lifetimes is that the narrowest possible nonspreading wave packet would then travel a distance, δx, in one chronon less than its own width, Δx, i.e.,

TABLE I. Full widths and lifetimes of meson and baryon resonant states, using values from the 1976 Table of Particle Properties (Ref. 3). Lifetimes are expressed in units of half the ρ-meson lifetime, where the width of the ρ is taken to be $\Gamma_\rho = 148.8$ MeV. Only states having an uncertainty in lifetime less than one sixth the ρ-meson lifetime are listed. A number of states, indicated by single arrows, have lifetimes differing from integers by 1.5 standard deviations or more. Two states indicated by the double arrows have a lifetime more than three standard deviations from an integer; however, it is uncertain if one of these represents a single resonance.

	Resonance	Full width (Γ) in MeV	Lifetime (τ) in units of half the ρ lifetime $\tau = 2\Gamma_\rho/\Gamma$
Mesons	$g(1680)$	180 ± 30	$1.65^{+0.33}_{-0.21}$
	$f(1270)$	180 ± 20 →	$1.65^{+0.21}_{-0.16}$
	$\rho(770)$	152 ± 3	1.96 ± 0.04
	$\omega(1675)$	150 ± 20	$1.98^{+0.31}_{-0.23}$
	$B(1235)$	125 ± 10 →	$2.38^{+0.21}_{-0.18}$
	$K^*(1420)$	108 ± 10	$2.76^{+0.28}_{-0.24}$
	$A_2(1310)$	102 ± 5	$2.92^{+0.15}_{-0.14}$
	$K^*(892)$	49.8 ± 1.0 [a]	5.98 ± 0.12
Baryons	$\Delta(2420)$	300(300 to 500)	$0.99^{+0.0}_{-0.39}$
	$N(2220)$	300(250 to 350)	$0.99^{+0.20}_{-0.14}$
	$\Delta(1950)$	220(200 to 240) ⇉	$1.35^{+0.14}_{-0.11}$
	$N(1470)$	200(180 to 220) ⇉	$1.49^{+0.16}_{-0.14}$
	$\Delta(1670)$	200(190 to 260)	$1.49^{+0.18}_{-0.35}$
	$\Delta(1910)$	200(160 to 230)	$1.49^{+0.37}_{-0.20}$
	$N(1670)$	155(145 to 165)	$1.92^{+0.13}_{-0.12}$
	$N(1688)$	140(120 to 145) →	$2.13^{+0.35}_{-0.08}$
	$\Delta(1650)$	140(140 to 200)	$2.13^{+0.0}_{-0.64}$
	$\Delta(1232)$	101.0 ± 1.0 [a] →	2.95 ± 0.03

[a]Value obtained from an average of charge states.

$$\delta x = v\tau_{\min} = \frac{vh}{\Gamma_{\max}} = \frac{vh}{c^2 \Delta m} = \frac{v^2}{c^2}\frac{h}{\Delta p} = \frac{v^2}{c^2}\Delta x$$

and therefore $\delta x \lesssim \Delta x$.

This inequality means that even if time is quantized, the situation that the ancient Greek philosopher Zeno found so paradoxical cannot occur: A particle which has not yet reached some point at one instant cannot be totally past this point one chronon later, so that there always exist some time when a particle occupies any given position.

There are several numerical coincidences which may tend to support the idea of a chronon of magnitude $\tau_{\min} = (2.20 \pm 0.03) \times 10^{-24}$ sec. For one such coincidence, this happens, within the experimental uncertainty, to equal the time $\frac{1}{2}h/m_p c^2$, which makes it a reasonably "natural" fundamental unit.[9] Unknown to this author at the time of his prior publication, Pokrowski[10] in 1928 suggested a chronon of magnitude $h/m_p c^2$ based on his calculations of the energy density, or temperature, of nuclear matter which he assumed to be the maximum possible temperature. More recent work by Hagedorn[11] supports the idea of a maximum possible temperature of hadronic matter; however, the connection between a maximum temperature and a shortest time remains a matter for speculation. Moreover, the energy $2m_p c^2$ associated with the time $\frac{1}{2}h/m_p c^2$ is considerably in excess of Hagedorn's estimated value, $kT_{\max} \sim 160$ MeV, obtained from fits to particle-production data.

Several cosmological coincidences concerning the time $h/m_p c^2$, originally noted by Dirac,[12] may also support the idea of this time having some fundamental significance. Recent evidence[13] on the variation of the gravitational "constant" with time tends to support Dirac's conjectures.

The hypothesis of quantized time is completely compatible with relativity,[14,15] and it is also consistent with continuous space, i.e., no minimum length.[16] Thus, negative searches for a minimum length may not be relevant to the existence of a quantum of time.

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[1]R. Ehrlich, Phys. Rev. 13, 50 (1976).

[2]Lifetimes are calculated using the width-lifetime relation $\Gamma\tau = h$. To obtain lifetimes in units of half the ρ-meson lifetime, we use $\tau = 2\Gamma_\rho/\Gamma$.

[3]Particle Data Group, Rev. Mod. Phys. 48, S1 (1976), p. 26. The data in Ref. 1 were taken from Particle Data Group, Phys. Lett. 50B, 1 (1974).

[4]Baryon widths are not listed as $\Gamma \pm \Delta\Gamma$, but are instead given as a best estimate, Γ_0, and an estimated range $(\Gamma_{\text{low}} - \Gamma_{\text{high}})$, owing to the complex model dependence of the methods used in their determination. The estimated range does not include all experiments, *and in some cases it actually excludes most of them.* [See, for example, the $N(1470)$ listings for which only 5 out of 22 experiments fall within the listed range of 180–220 MeV (p. 167 of Ref. 3).] Thus, the lifetime uncertainties listed in Table I computed from the listed range may convey considerably more precision than the data warrant. For the baryon resonances, therefore, it is quite inaccurate to speak of a discrepancy from integer lifetimes as some number of "standard deviations." It is therefore difficult to determine to what degree the baryon data actually conflict with the integer lifetimes hypothesis.

[5]Particle Data Group, Rev. Mod. Phys. 48, S1 (1976), p. 166.

[6]R. Ehrlich (unpublished report), gives a number of references.

[7]The name is originally due to Levy [see R. Levy, C. R. Acad. Sci. (Paris) 183, 1026 (1926)].

[8]The rest energy of individual resonant particles is known much more accurately than the width of the state for a broad resonance. Therefore, the individual decay times cannot be determined with an accuracy anywhere approaching that of the state lifetime.

[9]This numerical coincidence was pointed out to me by A. Harkavy, and it has also been noticed by F. Schwarz and P. Volk, unpublished report.

[10]G. I. Pokrowski, Z. Phys. 51, 730 (1928); 51, 737 (1928).

[11]R. Hagedorn, CERN Report No. 71-12, 1971 (unpublished).

[12]P. A. M. Dirac, Proc. R. Soc. London A165, 199 (1938); Nature (London) 139, 323 (1937).

[13]T. C. Van Flandern, Sci. Am. 234, 44 (1976).

[14]H. S. Snyder, Phys. Rev. 71, 38 (1947).

[15]C. N. Yang, Phys. Rev. 72, 874 (1947).

[16]V. G. Kadyshevskii, Zh. Eksp. Teor. Fiz. 41, 1885 (1961) [Sov. Phys.—JETP 14, 1340 (1962)].