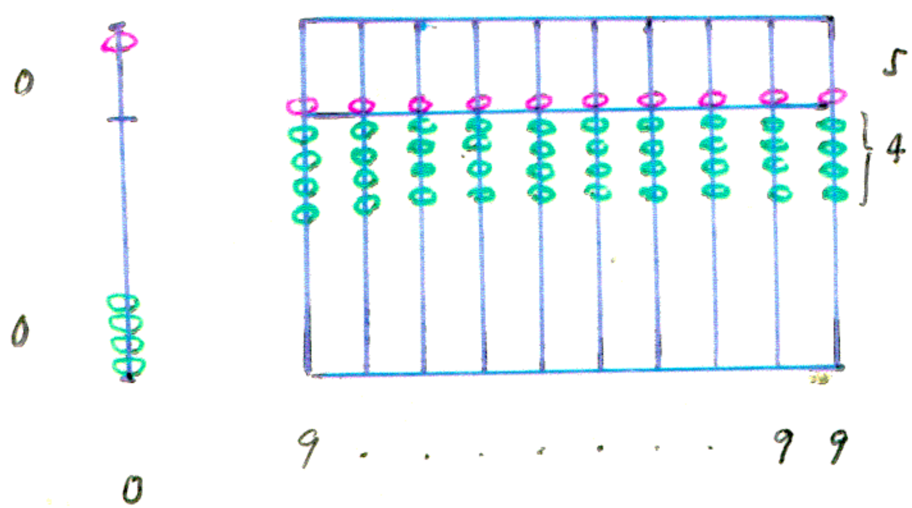
SID Drell Symposium

On the occasion of the 99th anniversary of the American Physical Society

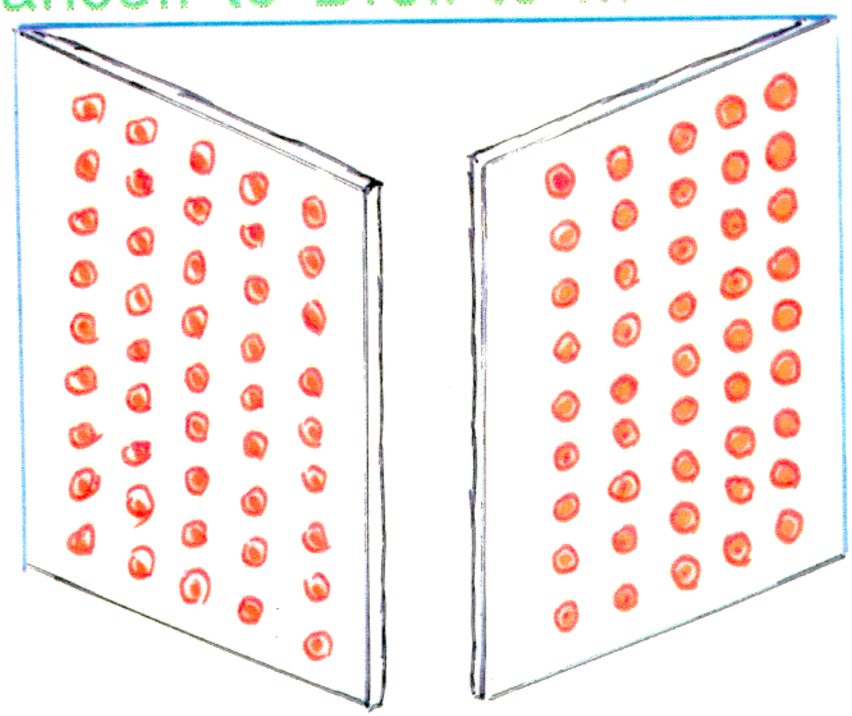
THEORETICAL PHYSICS IN THE NEW WORLD

From Oppenheimer to Dancoff to Drell to ...

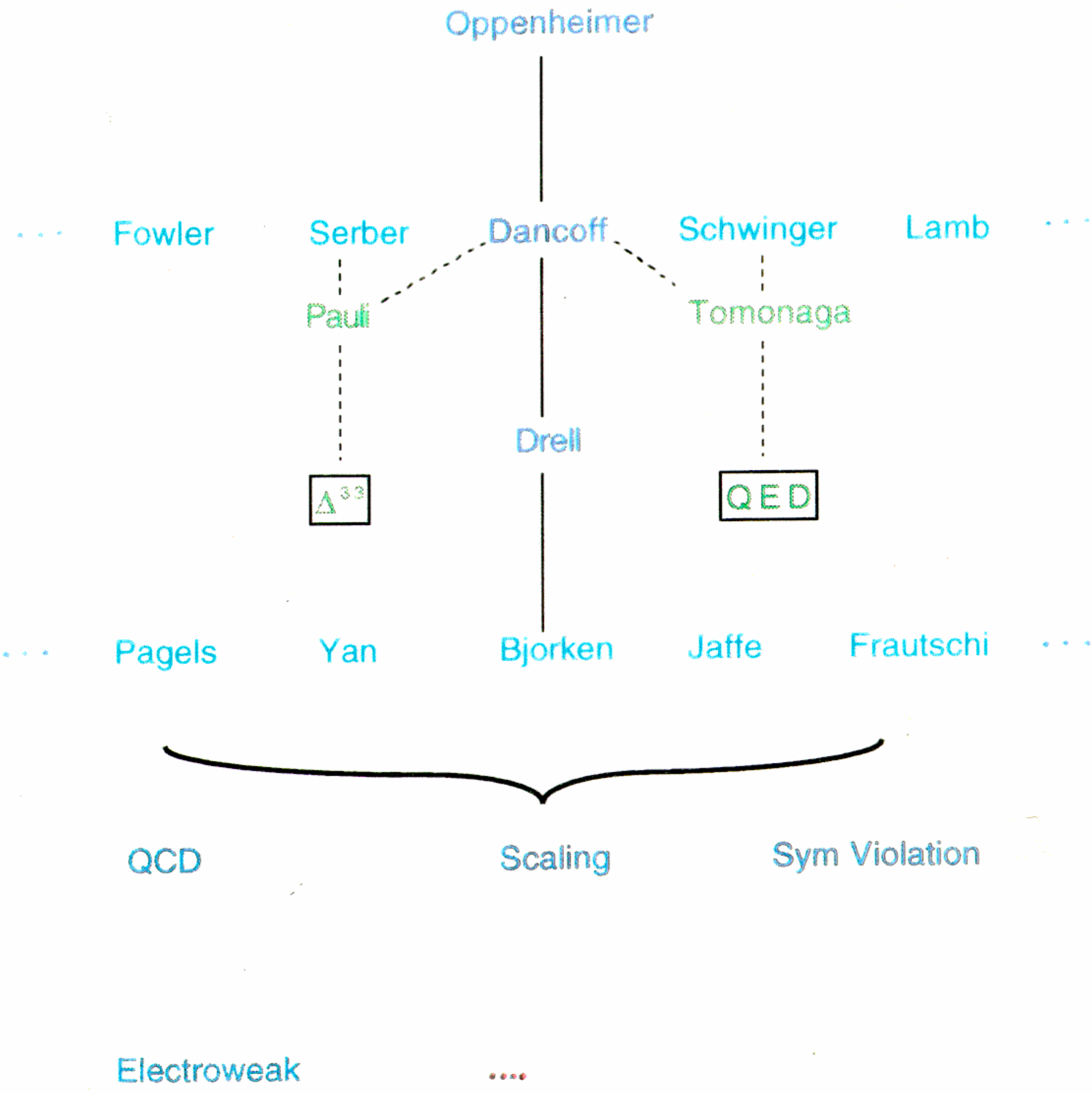
abacus



九九之数



palace gate


Oppenheimer
. . . Fowler
Serber
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Tomonaga
Drell
Δ33
QED
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Yan
Bjorken
Jaffe
Frautschi . . .
QCD
Scaling
Sym Violation
Electroweak
....

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Electrostatic Scattering of Neutrons*

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(Received January 6, 1949)

A weak force of attraction between electrons and thermal neutrons is indicated in recent experiments by Havens, Rabi, and Rainwater, and by Fermi and Marshall. According to meson theory this would be expected, since the neutron is considered as one charge state of a nucleon (the proton is the other state) which is coupled to a meson field. The attraction is then interpreted as an electrostatic scattering of the neutron which exists part of the time as a proton and meson. We perform a third order perturbation calculation in the approximation of weak coupling between mesons and nucleons. Neutrons and protons are here treated as Dirac particles which are coupled to a meson field of spin zero. The results indicate that the observed interaction is suitably described in terms of the meson field.

1. INTRODUCTION

If the nuclear forces are to be accounted for wholly or partly in terms of the exchange of charged mesons between nuclear particles then it will follow that the neutron will be subject to a deflection when passing through an inhomogeneous electric field. This is brought about by the action of the field on the proton and mesons which exist in virtual states in the neighborhood of the neutron. Attempts to detect such interaction were made by Havens, Rabi, and Rainwater[1] and by Fermi and Marshall,[2] who studied the scattering of neutrons in lead and in xenon, respectively. The scattering arises predominantly from three sources:

(a) Scattering by the specific nuclear forces;
(b) Electric scattering of the type in question due to the nuclear charge;
(c) Electric scattering due to the atomic electrons.

The scattering (a) is strongly predominant. Nevertheless, the interference which exists between (a) and the electric scattering makes it not unreasonable to look for experimental effects of the latter—effects which would surely be far below the present limits of experimental sensitivity were not (a) simultaneously present.

Scattering of slow (thermal) neutrons by nuclear forces will be spherically symmetric and will, in general, have no dependence on wave-length. On the other hand, thermal neutrons have a wave-length comparable with atomic dimensions, so that scattering of the type (c) will show a marked wave-length dependence and will not be spherically symmetric. Thus if one can extract from the observed scattering any part which varies with wave-length and scattering angle in a manner consistent with the atomic form factor, then one has a measure of the effect being studied.

A theoretical estimate of the magnitude of the effect has been given by Fermi and Marshall.[2] Their calculation is not based on any specific meson theory, but makes use of qualitative features of meson theories in general. Their numerical result might be expected to be in order-of-magnitude agreement with that obtained from any particular formulation. Since the experiment in question is such a critical test for the validity of the meson field hypothesis it was felt desirable to have at hand theoretical values as precise as can be derived.

The present calculation is based on the assumption that protons and neutrons (nucleons) obey the Dirac equation and that the mesons have spin zero (scalar). The assumption is frequently made that the massiveness of nucleons makes it possible to treat them as undeviated by the acts of virtual emission and reabsorption of mesons. Our results show that the latter assumption would lead to a serious quantitative error in this problem. We also find that a change in the equations of motion of the nucleon would lead to a small but appreciable change in the result.

* The method and results of this calculation were first presented at the November, 1948 meetings of the American Physical Society in Chicago (Phys. Rev. 75, 341A (1949).
[1] W. W. Havens, I. I. Rabi, and L. J. Rainwater, Phys. Rev. 72, 634 (1947).
[2] E. Fermi and L. Marshall, Phys. Rev. 72, 1139 (1947).

Annals of Physics: **4**, 75-86 (1958)

QUANTUM ELECTRODYNAMICS AT SMALL DISTANCES*†

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The validity of quantum electrodynamics (Q.E.D.) at small distances is discussed in the light of present experimental information. Large angle pair production in hydrogen, together with elastic electron-proton scattering, is analyzed as a means of obtaining further information on the small distance behavior of Q.E.D.

In this paper, I would like to discuss the possibility of confronting the not-yet-respectable theory of Q.E.D. with further experimental tests. In particular, let us consider the problem of testing the behavior of the theory at small distances. Our motivation is as follows:

Number of Physicists Who Received Their Nobel Prizes for Work Done in the U.S.

	Experiment	Theory
1901-09	1	0
1910-19	0	0
1920-29	2	0
1930-39	3	0
1940-49	2	0
1950-59	7	4
1960-69	4	4
1970-79	6	9
1980-89	9	3
1990-97	14	0
	48	20

Oppenheimer
Dancoff
Drell
Peak

NOBEL PHYSICS PRIZES FOR WORK DONE IN THE U.S.

Year	
1907	A.A. Michelson
1923	R.A. Milliken
1927	A.H. Compton
1936	C.D. Anderson
1937	C.J. Davisson
1939	E.O. Lawrence
1944	I. I. Rabi
1946	P.W. Bridgman
1952	E.M. Purcell F. Bloch
1955	W.U. Lamb P. Kusch
1956	J. Bardeen W. Shockley W.H. Brattain
1957	T.D. Lee C.N. Yang

Year	
1959	E.G. Segrè O. Chamberlain
1960	D.A. Glaser
1961	R. Hofstadter
1963	M. Goeppert-Mayer
1964	C.H. Townes
1965	J. Schwinger R. Feynman
1968	L.W. Alvarez
1969	M. Gell-Mann
1972	J. Bardeen L. Cooper J.R. Schrieffer
1973	L. Ezaki I. Giaever
1975	J. Rainwater

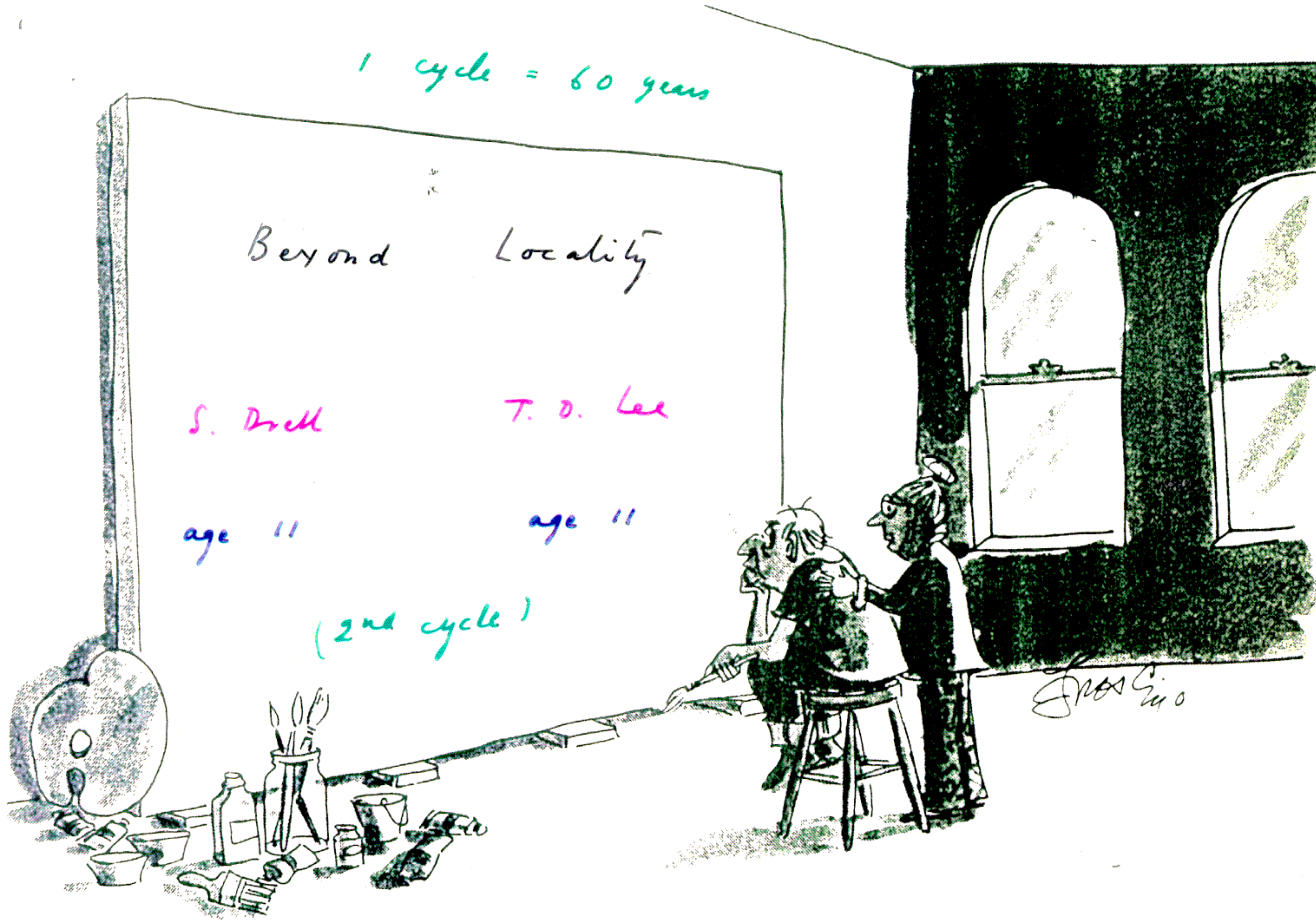
NOBEL PHYSICS PRIZES FOR WORK DONE IN THE U.S.

Year	
1975	A. Bohr
1976	B. Richter S. C. C. Ting
1977	P.W. Anderson J.H. Van Vleck
1978	A.A. Penzias R.W. Wilson
1979	S.L. Glashow S. Weinberg
1980	J.W. Cronin V. L. Fitch
1981	N. Bloembergen A. Schawlow
1982	K.G. Wilson
1983	S. Chandrasekhar W.A. Fowler
1988	L.M. Lederman M. Schwartz J. Steinberger

Year	
1989	N.F. Ramsey H.G. Dehmelt
1990	J. Friedman H.W. Kendall R.E. Taylor
1993	R.A. Hulse J.H. Taylor, Jr.
1994	C.G. Shull
1995	M. Perl F. Reines
1996	D.M. Lee D.D. Osheroff R.C. Richardson
1997	S. Chu C. Cohen-Tannoudji W.D. Phillips

WHAT COMES AFTER

THE ODD PEAK ?

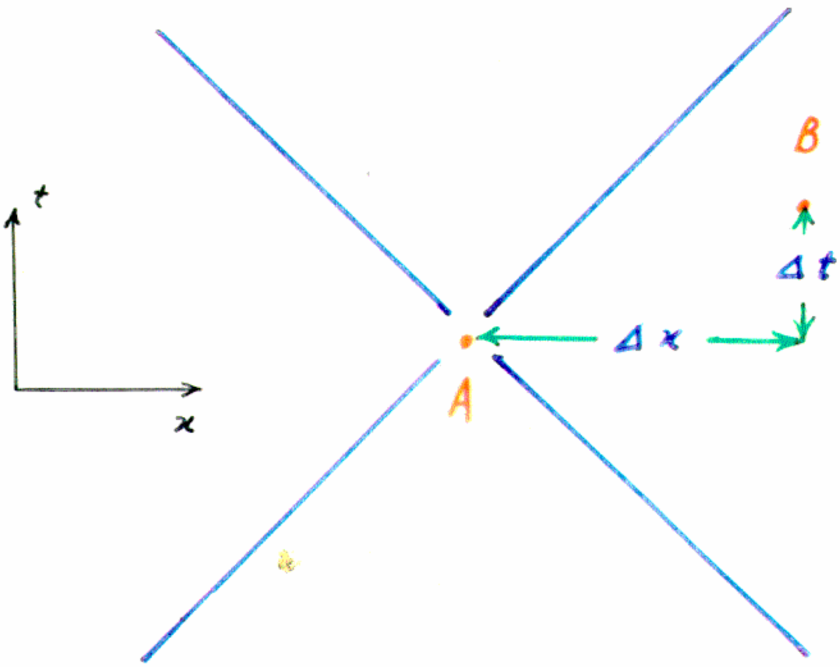


"If only you could have frozen some ideas in your prolific youth."

- Discrete lattices can have exact continuous sym. — translat'ns, rotat'ns, ...

- Difference eq'ns can yield exact conservation laws — energy, mom., ...

two local measurements at A and B



$\hbar = c = 1$

$\Delta t < \Delta x <$ Planck length $l_p \sim 10^{-33}$ cm

local field theory states that A and B are independent

But $\Delta E \sim \frac{1}{\Delta t} > \frac{1}{l_p}$

black hole horizon rad $\sim G \Delta E > G \frac{1}{l_p}$

$\therefore$ " $> l_p > \Delta x$!

How can A & B be independent ?

Beyond Locality

- Both difference and differential equations can have the same continuous groups of sym.

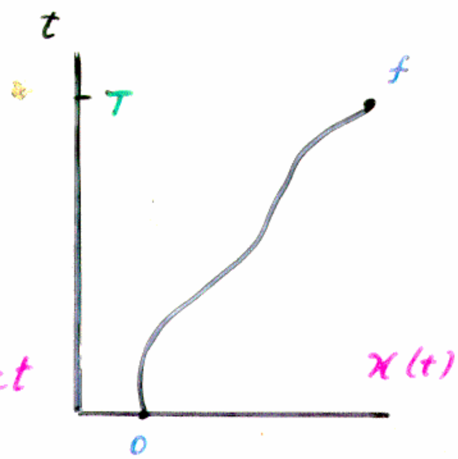
- Difference equations have chaos and fractal type solutions, not possessed by differential equations

- Differential equations are only approximations to difference equations

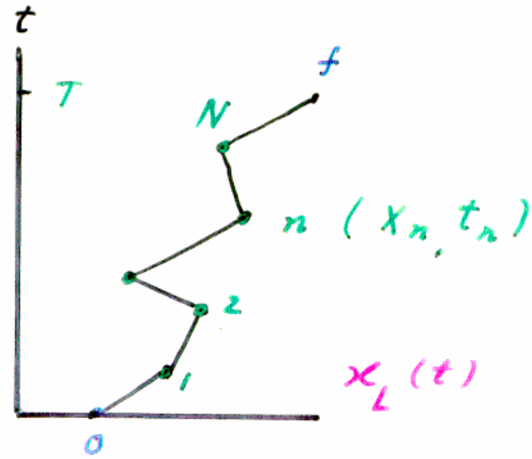
- Physics should be described by difference equations, not differential equations.

example: Classical Mech.

restrict



to



action $A(x(t)) = \int [\frac{1}{2}\dot{x}^2 - V(x)]\,dt$

becomes $A_L = A(x_L(t))$, $\boxed{\frac{N}{T} \text{ fixed}}$

$\therefore$ time translational inv.

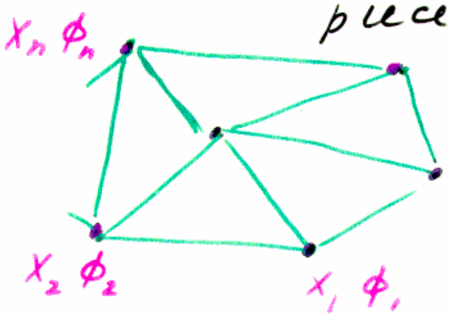
$$A_L = \sum \left\{ \frac{1}{2}\frac{(x_n - x_{n-1})^2}{t_n - t_{n-1}} - \frac{1}{2}\left[V(x_n) + V(x_{n-1})\right] \cdot (t_n - t_{n-1}) \right\}$$

$\delta A_L = 0$ gives exact energy cons.

Relativistic Field Theory

field ϕ , D-dim coord. x

restrict $\phi(x)$ to $\phi_L(x)$ = continuous piecewise flat functions



$\phi_L(x)$ depends only on (x_n, ϕ_n)

continuum	discrete
$A = A(\phi(x))$	$A_L = A(\phi_L(x))$
$e^{-HT} = \int e^{-A}[d\phi(x)]$	$\mathcal{G}(T) = \int e^{-A_L}[dx_n][d\phi_n]$
	$n = 1, \dots, N$
	$\frac{N}{vol} = \left(\frac{1}{\ell}\right)^D =$ constant

Same Continuous Sym Properties

$$\frac{\partial A_L}{\partial x_n} = 0 : \qquad v_n - v_{n+1} = -\frac{1}{2}(t_{n-1} - t_{n+1}) \frac{\partial V(x_n)}{\partial x_n}$$

where $v_n = (x_n - x_{n-1})/(t_n - t_{n-1})$

$$\frac{\partial A_L}{\partial t_n} = 0 : \qquad E_n = \frac{1}{2} v_n^2 + \frac{1}{2}[V(x_n) + V(x_{n-1})]$$

$$= E_{n+1}$$

General Relativity

$$A_S = \int_S \sqrt{|g|}\, R\, d^D x$$

S = arbitrary D-dim smooth manifold

Discrete Gravity

Restrict S to L = D-dim continuous piecewise flat surface of D-simplices

$$A_L = \int_L \sqrt{|g|}\, R\, d^D x$$

Both A_L and A_S are inv. under $x_\mu \to x'_\mu$

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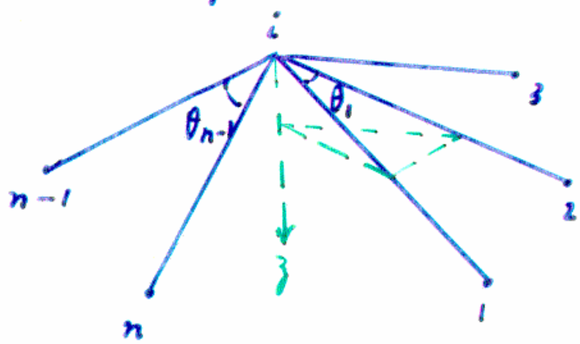
example $\qquad D = 2 \qquad$ Embed L in R_3



Δ = 2 - simplex

$$A_L = \sum_i 2\epsilon_i$$

$$\epsilon_i = 2\pi - (\theta_1 + \theta_2 + \cdots + \theta_n)$$

= deficit angle

$R_3 = (x, y, z)$ space

Embed L in R_N, $\quad \min N = \begin{cases} 3 & D = 2 \\ 7 & 3 \\ 19 & 4 \end{cases}$

Thm For any L of D-dim

$$A_L = \int_L \sqrt{|g|}\, R \, d^D x = 2 \sum s \, \epsilon_s$$

(Regge Calculus)

s = vol of $D-2$ simplex

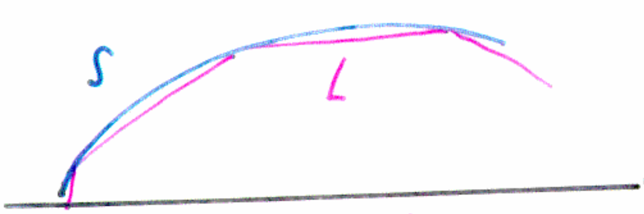
ϵ_s = deficit angle around s

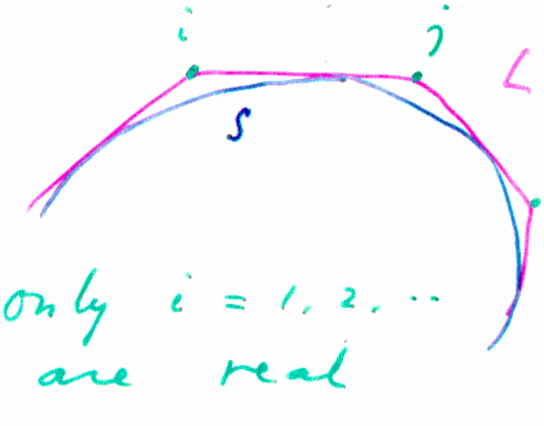
$D = 2$ $\quad A_L = 2 \sum_i \epsilon_i$ (Gauss-Bonnet)

3 $\quad = 2 \sum_l l \, \epsilon_l$

4 $\quad = 2 \sum_\Delta \Delta \, \epsilon_\Delta$

Regge's idea	Discrete Gravity
Fix S	Fix L
vary $L \to S$	vary $S \to L$





Discrete gravity has <u>more</u> sym ! $\quad \therefore$ only $i = 1, 2, \ldots$ are real