A very brief history of quantum field theory

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Birth of modern physics

Triumphs of physics before 1905:

1. Newton's laws of motion
2. Newton's law of gravitation
3. Lorentz force law
4. Maxwell's equations

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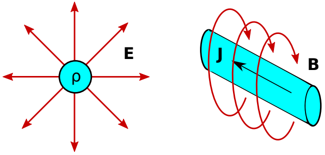

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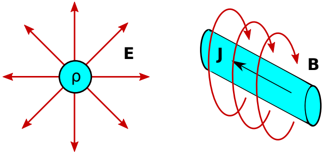

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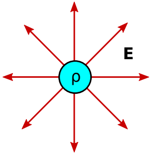

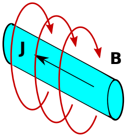

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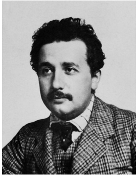

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$$(\Delta s)^2 = (c\Delta t)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2$$

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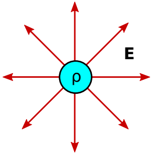

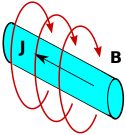

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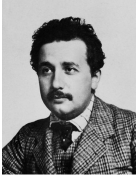

These provide a hint towards relativity:

$$\begin{aligned} (\Delta s)^2 &= (c\Delta t)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2 \\ m^2 c^4 &= E^2 - (cp_x)^2 - (cp_y)^2 - (cp_z)^2 \end{aligned}$$

Enter the quantum

Particle	Field
Photon γ	Electromagnetic A_μ
Electron e^-	Dirac ψ

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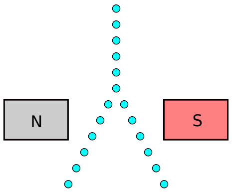

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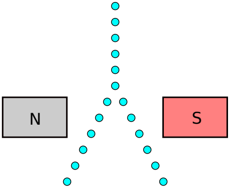

Dirac field satisfies $i\gamma^\mu \partial_\mu \psi - m\psi = 0$ where γ^μ is a 4×4 matrix.

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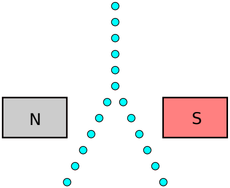

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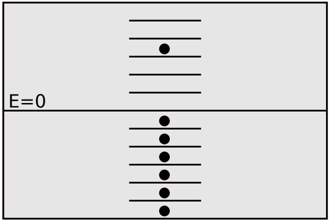

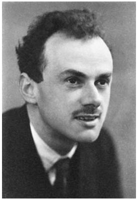

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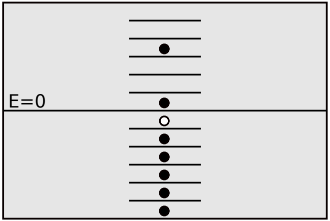

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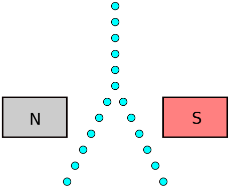

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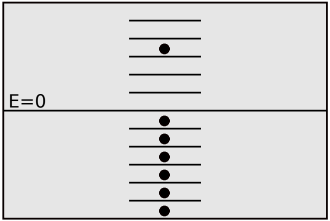

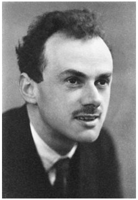

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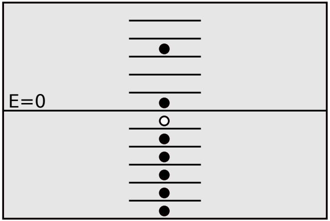
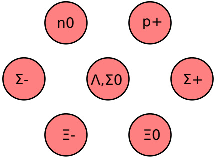
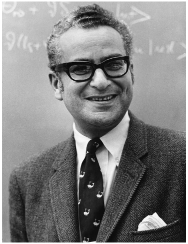


Positron discovered experimentally in 1932.

Quantum electrodynamics successfully formulated in 1950.

Lingering doubts





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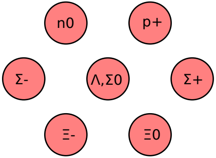

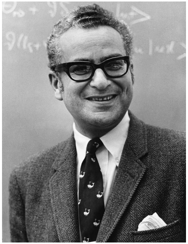

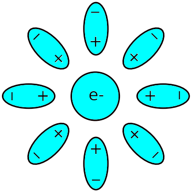

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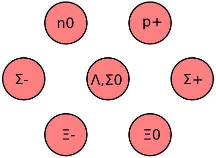

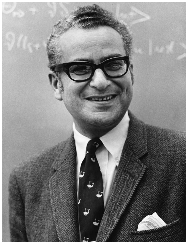

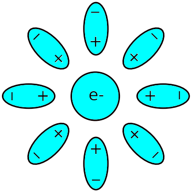

Many proposed QFTs had the same high energy behavior as QED.

$$g_{QED}(E) = \frac{g(E_0)}{1 - \frac{2}{3}\log\left(\frac{E}{E_0}\right) g(E_0)}$$

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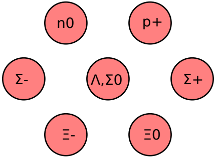

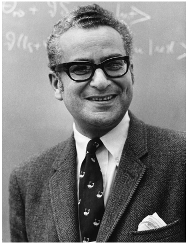

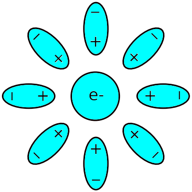

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Coleman suggested this problem to his student Politzer.

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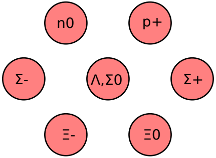

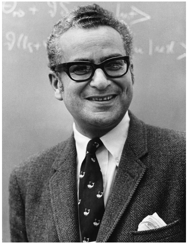

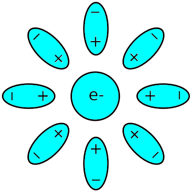

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Ultraviolet Behavior of Non-Abelian Gauge Theories*

David J. Gross† and Frank Wilczek
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08540
(Received 27 April 1973)

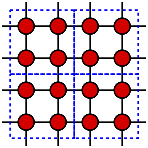
It is shown that a wide class of non-Abelian gauge theories have, up to calculable logarithmic corrections, free-field–theory asymptotic behavior. It is suggested that Bjorken scaling may be obtained from strong-interaction dynamics based on non-Abelian gauge symmetry.

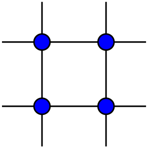
Reliable Perturbative Results for Strong Interactions?*

H. David Politzer
Jefferson Physical Laboratories, Harvard University, Cambridge, Massachusetts 02138
(Received 3 May 1973)

An explicit calculation shows perturbation theory to be arbitrarily good for the deep Euclidean Green's functions of any Yang-Mills theory and of many Yang-Mills theories with fermions. Under the hypothesis that spontaneous symmetry breakdown is of dynamical origin, these symmetric Green's functions are the asymptotic forms of the physically significant spontaneously broken solution, whose coupling could be strong.

A feature, not a bug





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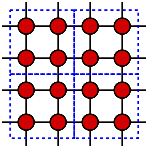

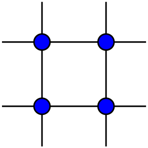

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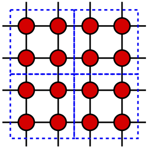

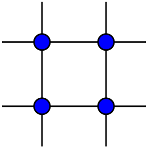

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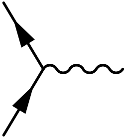
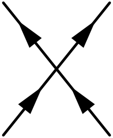
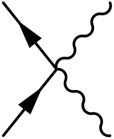
A completion of QED might include these interactions.

$g_1(E_0)$  $+g_2(E_0)$  $+g_3(E_0)$  $+\dots$

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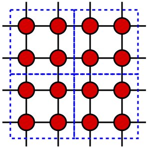

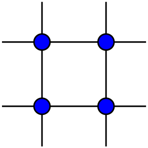

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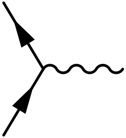
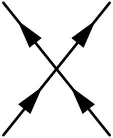
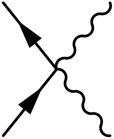
$g_1(E_0)$  $+g_2(E_0)$  $+g_3(E_0)$  $+\dots$

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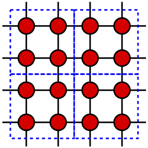
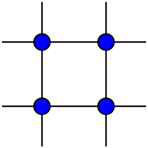

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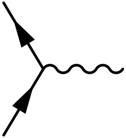
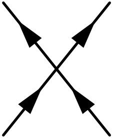
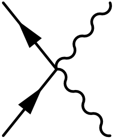
$g_1(E_0)$  $+g_2(E_0)$  $+g_3(E_0)$  $+\dots$

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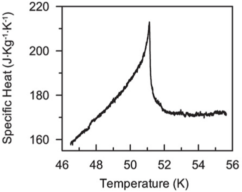
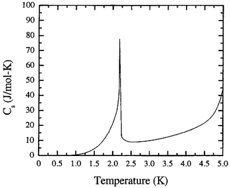
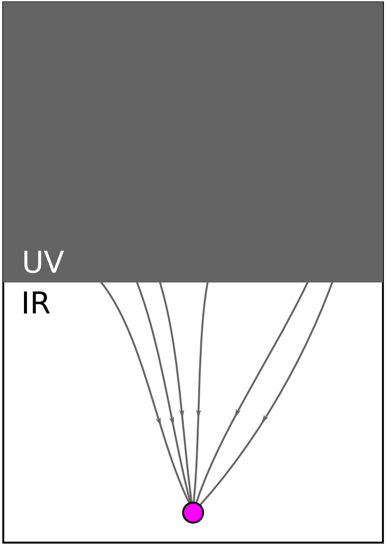




[Oleaga, Salazar, Bunkov; 2014]

[Donnelly, Barenghi; 1998]

Exploring the landscape



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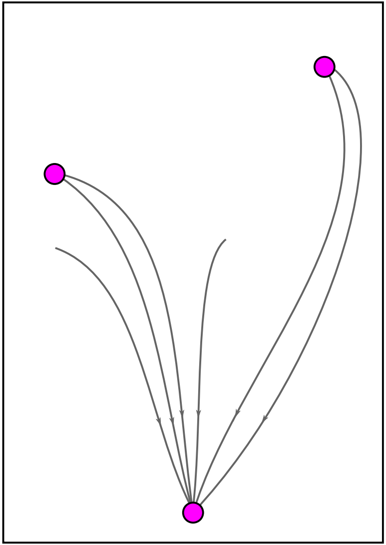

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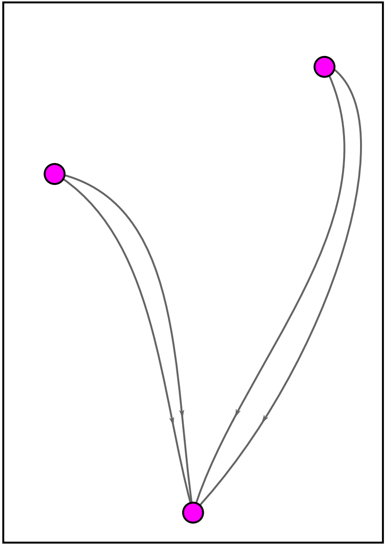

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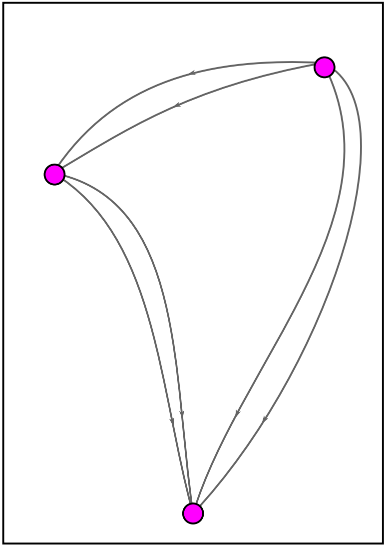

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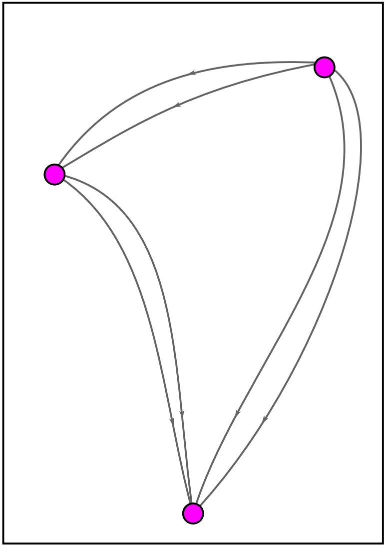

Solving the (special) endpoints will reveal all paths going between them.

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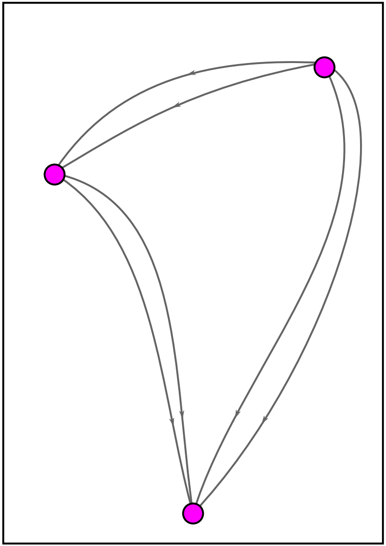

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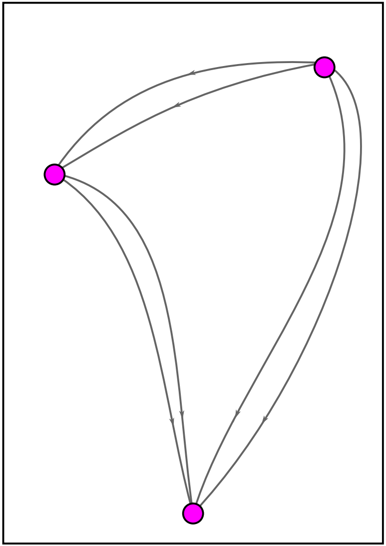
- Exact solution of many fixed points in two dimensions.

  [Belavin, Polyakov, Zamolodchikov; 1984]

Exploring the landscape



Solving the (special) endpoints will reveal all paths going between them.

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  [Belavin, Polyakov, Zamolodchikov; 1984]

- Carving out theory space numerically in all dimensions.

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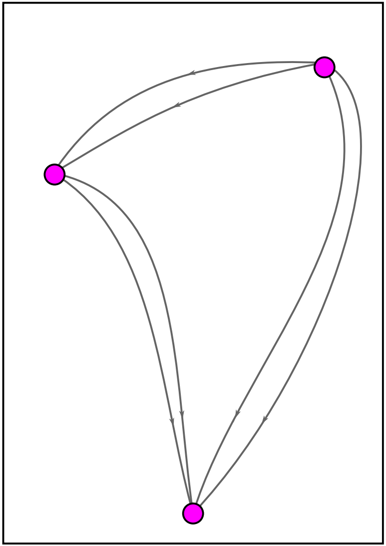

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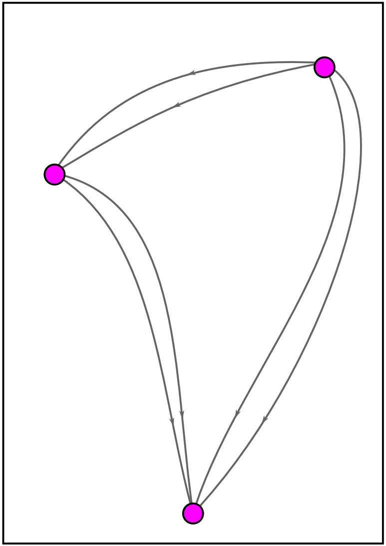

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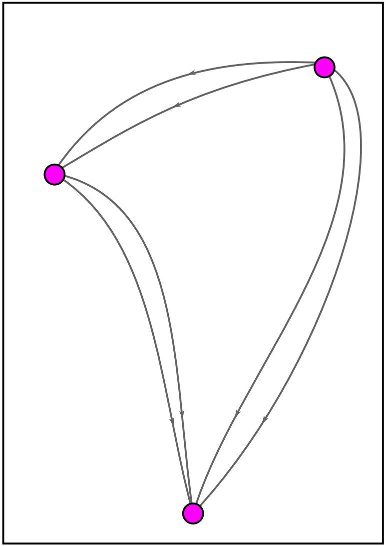

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- Application to a line of fixed points.

  [Beem, Rastelli, Van Rees; 1304.1803]

Enjoy the rest of the talks!