THE EVOLUTION OF IDEAS IN HEP

In honour of J. Zinn-Justin
Saclay, September 29, 2008

An EVOLUTION OF some theoretical IDEAS IN HEP

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Two Lines

I. Dynamics

Building consistent dynamical models for the fundamental interactions.

II. Symmetries

Discovering their symmetry properties.

Dynamics

The two classical forces

-Electromagnetism

-Gravitation

are both described by the same classical potential:

$$V(r) \sim 1/r$$

which is singular for $r \to 0$.

A classical atom is unstable!

Non-Relativistic Quantum Mechanics solves this problem

$$\Delta(x)\ \Delta(p) \geq \hbar$$

The energy levels in an electromagnetic *or* a gravitational potential are quantised.

but the relativistic corrections bring it back!

Modern theoretical Physics has a precise date of birth:

June 2-4 1947, the Shelter Island Conference

Birth of Quantum Electrodynamics

The first consistent Quantum Field Theory,
free of singularities at all distances!

Why electrodynamics and not gravitation?

Symmetries

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Space-Time vs Internal Symmetries.

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$$\Psi(x) \rightarrow e^{i\theta}\Psi(x)$$

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1932: Isospin. Higher Internal Symmetries

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Local, or **Gauge Symmetries**

The motivation is purely Geometrical

The example of space translations

$$\vec{x} \longrightarrow \vec{x}' = \vec{x} + \vec{a}$$

A gauge translation

$$\vec{x} \longrightarrow \vec{x}' = \vec{x} + \vec{a}(\vec{x})$$

The example of space translations

The question is purely geometrical and we would expect a geometrical answer, without any physical interest

Surprise:
The Dynamics which is invariant under local translations is

GENERAL RELATIVITY

The resulting force is Gravitation
One of the four fundamental forces of Nature

The Standard Model

All Interactions have a geometric origin

The gauge group is

$$U(1) \times SU(2) \times SU(3)$$

The internal space may be a five-dimensional complex space

Locality

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but some are more local than others

Locality

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-The four-dimensional physical space
-The internal space

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But all transformations are local with respect to the physical space only.

The geometry of the internal space does not participate in the dynamics

Locality

In General Relativity the space-time transformations are local with respect to space-time.

General Relativity is a real Geometric theory.

The resulting dynamical variable is the metric of space-time

In the Interactions of the Standard Model, however, the internal space transformations are local, not with respect to internal space, but again, with respect to space-time. The geometry of the internal space remains frozen and does not participate in the dynamics.

Locality

How does this affect the problem of the short-distance singularity?

The key to the solution is always the Uncertainty Relation, expressed in terms of the fundamental dynamical variables.

For the Standard Model, they can be taken to be local fields.

For General Relativity they are the components of the space-time metric.

It has not been possible to consistently impose Uncertainty Relations for the metric using only local fields.

Possible answers

Unify physical and internal space.

Gauge transformations are local translations.

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Theory of Strings
And other extended objects

THE TIME FOR SPECULATIONS WILL BE SOON OVER!

L.H.C. IS COMING

Precision measurements at one energy scale

allow us to guess New Physics at the next scale

EXAMPLE:
Yukawa's prediction of the π meson.

The Physics was accurate, the details were not

In the same way New Physics is predicted for LHC

What we have learnt

Perturbation theory is remarkably reliable

Outside the region of strong interactions

Possible (Predictable) LHC Results

THE ABSENCE OF A LIGHT HIGGS

IMPLIES NEW PHYSICS

BUT A LIGHT HIGGS IS UNSTABLE

WITHOUT NEW PHYSICS

CONCLUSIONS

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Jean, welcome back to theory!!