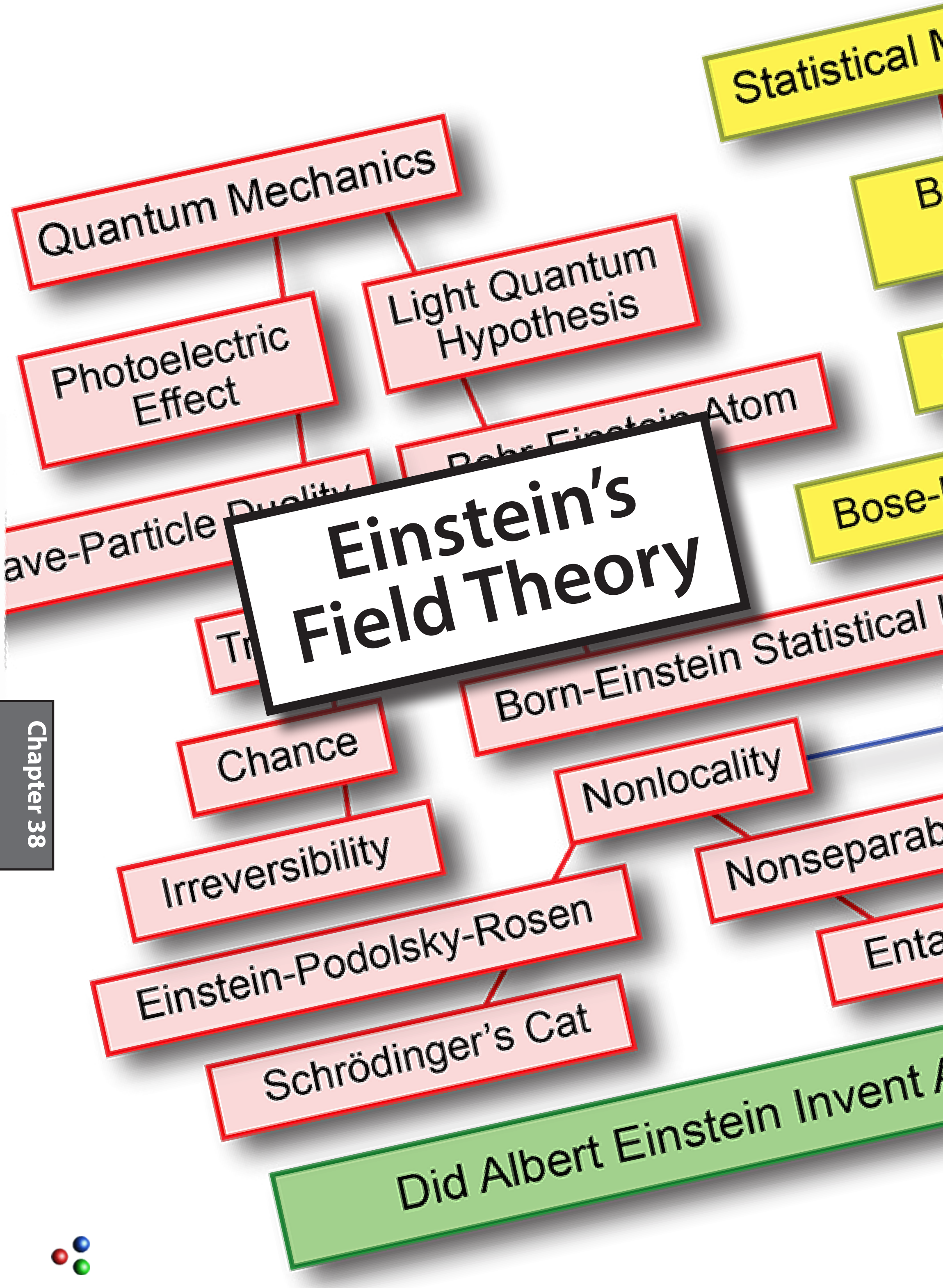
Chapter 38

Einstein's Field Theory



Einstein's Field Theory

In the last thirty years of his life Einstein's main mission was to create a *unified field theory* that would combine the gravitational field of Newton (or Einstein), the electromagnetic field of Maxwell, and perhaps the probability field of quantum mechanics.

But he also worried much of his life that continuous fields are only theories, purely abstract information, whereas discrete particles have a more substantial reality, arranging themselves in material *information structures*.

But the ideal and pure information of continuous field theories clearly has causal powers over the "discrete" material world, as we saw in the two-slit experiment (chapter 33).

Einstein in his later years grew quite pessimistic about the possibilities for deterministic continuous field theories, by comparison with indeterministic and *statistical* discontinuous particle theories like those of quantum mechanics.

Einstein deeply believed that any physical theory must be based on a continuous field. For Einstein, physical objects must be described by continuous functions of field variables in four-dimensional space-time coordinates. In quantum field theory (QFT), particles are functions of (singularities in) these fields. In quantum electrodynamics (QED), fields are merely properties of aggregated particles. Which then are the more fundamental?

It appears to be particles, especially today when the last fundamental particle predicted by the standard theory (the Higgs boson) has been found. Einstein suspected that his dream of a unified field theory may not be possible.

In his 1949 autobiography for his volume in Paul Schilpp's *Library of Living Philosophers*, Einstein asked about the theoretical foundation of physics in the future, "Will it be a field theory [or] will it be a statistical [particles] theory?"

> "Before I enter upon the question of the completion of the general theory of relativity, I must take a stand with reference to the most successful physical theory of our period, viz.,

> the statistical quantum theory which, about twenty-five years ago, took on a consistent logical form (Schrödinger, Heisenberg, Dirac, Born). This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events. This theory, on the one hand, and the theory of relativity on the other, are both considered correct in a certain sense, although their combination has resisted all efforts up to now. This is probably the reason why among contemporary theoretical physicists there exist entirely differing opinions concerning the question as to how the theoretical foundation of the physics of the future will appear. Will it be a field theory; will it be in essence a statistical theory? I shall briefly indicate my own thoughts on this point. [1]

Castle In The Air

In 1954 Einstein wrote his friend Michele Besso to express his lost hopes for a continuous field theory like that of electromagnetism or gravitation,

> "I consider it quite possible that physics cannot be based on the field concept, i.e:, on continuous structures. In that case, nothing remains of my entire castle in the air, gravitation theory included, [and of] the rest of modern physics." [2]

In the same year, he wrote to David Bohm,

> I must confess that I was not able to find a way to explain the atomistic character of nature. My opinion is that if the objective description through the field as an elementary concept is not possible, then one has to find a possibility to avoid the continuum (together with space and time) altogether. But I have not the slightest idea what kind of elementary concepts could be used in such a theory. [3] (Einstein to David Bohm, 28 October 1954).

Einstein sees a conflict between relativity and quantum mechanics

Again in the same year, he wrote to H.S.Joachim,

> it seems that the state of any finite spatially limited system may be fully characterized by a finite number of numbers. This speaks against the continuum with its infinitely many

1 Schilpp, 1949, p.81
2 Pais, 1982, p.467
3 Stachel, 1986, p.380

> degrees of freedom. The objection is not decisive only because one doesn't know, in the contemporary state of mathematics, in what way the demand for freedom from singularity (in the continuum theory) limits the manifold of solutions. [4]

The fifth edition of Einstein's *The Meaning of Relativity* included a new appendix on his field theory of gravitation. In the final paragraphs of this work, his last, published posthumously in 1956, Einstein wrote,

> "Is it conceivable that a field theory permits one to understand the atomistic and quantum structure of reality ? Almost everybody will answer this question with "no"...
>
> "One can give good reasons why reality cannot at all be represented by a continuous field. From the quantum phenomena it appears to follow with certainty that a finite system of finite energy can be completely described by a finite set of numbers [quantum numbers]. This does not seem to be in accordance with a continuum theory, and must lead to an attempt to find a purely algebraic theory for the description of reality. But nobody knows how to obtain the basis of such a theory." [5]

No one has described Einstein's doubts about continuous field theories better that John Stachel, one of the early editors of the Collected Papers of Albert Einstein. Stachel speculated about "another Einstein" with doubts about a continuum and field.

Stachel points to Einstein's 1923 article "Does Field Theory Offer Possibilities for the Solution of the Quantum Problem?," in which Einstein points out that the great successes of quantum theory over the last quarter of a century should not be allowed to conceal the lack of any logical foundation for the theory.

He quotes Einstein...

> The essential element of the previous theoretical development, which is characterized by the headings mechanics, Maxwell-Lorentz electrodynamics, theory of relativity, lies in the circumstance that they work with differential equations that uniquely determine events [das Geschehen] in a four-

4 *ibid.581*

5 Einstein, 1956, pp.165-66

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> dimensional spatio-temporal continuum if they are known for a spatial cross-section...In view of the existing difficulties, one has despaired of the possibility of describing the actual processes by means of differential equations.[6]

The linear Schrödinger differential equation for waves cannot give us the details of individual particles, only the statistics of ensembles of particles. Stachel provides several powerful statements from 1935 to Einstein's posthumous writings pointing toward discrete "algebraic" theories of particles replacing continuum field theories.

In modern terms, the arrangement of particles would be described by integers, the quantum numbers as "bits" of information in a "digital" theory, not the continuum of an "analog" theory.

> In any case one does not have the right today to maintain that the foundation must consist in a field theory in the sense of Maxwell. The other possibility, however, leads in my opinion to a renunciation of the time-space continuum and to a purely algebraic physics. Logically this is quite possible (the system is described by a number of integers; "time" is only a possible viewpoint [Gesichtspunkt], from which the other "observables" can be considered—an observable logically coordinated to all the others. Such a theory doesn't have to be based upon the probability concept. For the present, however, instinct rebels against such a theory (Einstein to Paul Langevin, 3 October 1935).[7]

> It has been suggested that, in view of the molecular structure of all events in the small, the introduction of a space-time continuum may be considered as contrary to nature. Perhaps the success of Heisenberg's method points to a purely algebraical method of description of nature, to the elimination of continuous functions from physics. Then, however, we must also give up, on principle, the utilization of the space-time continuum. It is not inconceivable that human ingenuity will some day find methods that will make it possible to proceed along this path. Meanwhile, however, this project resembles the attempt to breathe in an airless space ("Physics and Reality,"

6 Stachel, 2002, p.149

7 *ibid.*, p.140

> [1936], cited from Einstein Ideas and Opinions 1954, 319).[8]
>
> In present-day physics there is manifested a kind of battle between the particle-concept and the field-concept for leadership, which will probably not be decided for a long time. (Einstein to Herbert Kondo, 11 August 1952).[9]

Einstein might even endorse gravitation theories today, like string theory and loop quantum gravity, which describe tiny structures that might be the gravity particle - the "graviton." Some fit the graviton into standard particle theory as a spin-2 boson. Spin-1 bosons like the photon have an infinity in quantum field theory that can be removed by renormalization. The infinity shows up as a single loop in a Feynman diagram. A spin-2 particle has two loops in its Feynman diagram and no method is known to eliminate them.

Particles might have no infinity problems in an algebraic theory?

Objective reality does not lead to Einstein's "Unified Field Theory," but it does leave us with three very useful fields, the electromagnetic, the gravitational, and the quantum mechanical probability field, all generating *abstract* information that makes very accurate predictions about the behavior of *real* particles.

Einstein's "castle in the air," "breathing in empty space," should not lead us to despair about quantum field theories, but only to see them more clearly as Einstein first described a wave, as "ghost fields" or "guiding fields."

We might say that where particles are concrete and "real," fields are abstract and imaginary - "free creations of the human mind."

Particles are actual. They are involved in actions and interactions.

Fields are possibilities. Wave functions allow us to calculate the probabilities for each possibiity, making predictions to degrees of accuracy unheard of in the other sciences.

In short, fields are *theories*, mere ideas, abstract information about *continuous* functions across infinite space and time.

Particles are *facts*, derived from *discrete* concrete experiments done in the here and now.

8 *ibid.*, p.150
9 *ibid.*, p.150