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# The Bootstrap Principle and the Uniqueness of the World

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## Unity and Self-Consistency: The Bootstrap Principle

The *bootstrap* hypothesis emerged first as a possible explanation of certain experimental data in particle physics. This hypothesis was formulated for the first time in 1959 by Geoffrey Chew (1959; Chew & Jacob, 1964), a professor at the University of California, Berkeley, and was immediately used, for detailed physics calculations, by Chew and Mandelstam (1961). The word *bootstrap* itself is untranslatable. Indeed, bootstrap, in the proper sense laces, also means to levitate while dragging your boots. The most appropriate term in translation would be that of *self-consistency.*

The bootstrap theory has emerged as a natural reaction against classical realism, which received a death blow, and against the idea, to which it was associated, of a need for equations of motion in space-time, during the formulation of quantum mechanics, around 1930.

According to Newton, we learned about the existence of equations of motion, in order to describe physical reality: Newton's equation regarding macroscopic bodies, Maxwell's equations for electric and magnetic fields, and Schrödinger and Dirac's equations for the movements of atomic systems. The movement described by these equations is that of certain entities considered as fundamental building blocks of physical reality, defined at each point of the space-time continuum. By definition, these equations possess an intrinsic deterministic character (the fact that, in some cases, large ensembles of objects can lead to a chaotic behavior does not alter the deterministic character of the basic equations of motion).

Quantum entities are not subject to classical determinism. The bootstrap theory is just drawing the logical conclusions of this situation by proposing the abdication of any equation of motion. This attitude is consistent with the schedule of the matrix S (*S* is the initial for the English word *scattering*) initiated by Heisenberg in 1943: A realist theory must be expressed in terms of quantities directly related to experimental observation (Cushing, 1990).

The abdication of any equation of motion has an immediate consequence: the absence of any fundamental brick of physical reality.

In bootstrap, the part appears simultaneously as the whole. Nature is conceived as a global entity, inseparable at a fundamental level. The particle plays the role of a system in the irreducible interaction with other systems, which is a first rapprochement between the bootstrap theory and the current systemic thinking.

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What is in question in the bootstrap theory is actually the notion of a precise identity of a particle, substituting the notion of a relationship between events, the *event* signifying the context of the creation or annihilation of some particles. Responsible for the emergence of what is called a particle are the relationships between events. There is no object in itself, possessing its own identity, which can be defined as separate or different from other particles. A particle is what it is because all other particles exist simultaneously: The attributes of an entity that is physically determined are the result of the interaction with other particles.

The bootstrap is therefore a vision of the world's unity, a principle of nature's self-consistency: the world built on its own laws through self-consistency. It represents a break with the scientific thinking based on the tradition of Democritus and Newton: the concept of fundamental (and thus arbitrary) entities, characterizing material substance, is replaced by a concept of the organization of matter—that of self-consistency. The only compatible world with the laws of nature (which are themselves deductible, in principle, through self-consistency) is, according to the bootstrap principle, the world of nature: It is impossible to find a system without internal contradiction on the logical plane, and which is at the same time, in agreement with everything that is observed or will be observed. In other words, we can only make a series of approximations.

The conception of a postulation of a very general form of the bootstrap principle is logical, including not only particles, but also macroscopic bodies, life and even consciousness: the self-consistency of the whole requires including all aspects of nature. Under this very general form, the bootstrap principle has, with the current state of knowledge, an unscientific character. The fact was emphasized by Chew (1968). Thus, we have to make a difference between the entire, unscientific bootstrap, and the partial, truncated bootstrap, which can be scientifically productive and effective. Such a partial bootstrap—the *hadron bootstrap*—is the one which enjoyed the interest of physicists in the decade 1960–1970.

**Is There a Nuclear Democracy?**

The partial bootstrap proposed by Chew in 1959 refers to the world of hadrons (like the proton or the neutron) which have a strong interaction, which is exercised at the atomic nucleus scale. Most of the currently known particles are included in this category. Other particles such as leptons or photons are excluded from the hadron bootstrap, which is already an inherent limitation of the approach.

The hadron bootstrap is formulated within the general framework of the S matrix theory (Chew, 1961). The essential idea of this theory is that of focusing efforts on the scientific description of the hadrons, as they appear before and after their interaction. An element of the S matrix describes a specific reaction between particles, depending on the quantity of motion and on the initial and final hadrons' spins (*the spin* is the intrinsic angular momentum of the particle). It is not described what happens at the very moment of the interaction. Thus, it is not necessary to introduce a space-time at a microscopical scale: macroscopical space-time is sufficient for the experimental definition of the quantities of motion and of the hadrons' spins. In particular, it is not necessary to define the position of a hadron.

These elements of the S matrix describe all the reactions that can be designed between hadrons. They represent the amplitudes of probability, regarding the probability that a given set of measures in the final state comes next after a given set of baseline measures. These amplitudes of the probability of transition directly correspond to measurable quantities.

A true theory must therefore be able to predict the ensemble of these elements of a matrix that is the S matrix itself. The hadron partial bootstrap postulates that it is possible that a single S matrix could be predicted based on some very general restrictions. The axiomatic meaning of these constraints determines the partial character of the hadron bootstrap: in turn, those restrictions should, in principle, be deductible by self-consistency.

## The Bootstrap and the Anthropic Principle

Apparently, there is no relationship between the bootstrap theory, formulated in particle physics, and the *anthropic principle,* postulated in cosmology. A subtle and significant connection can nevertheless be established between the two approaches.

Let us simply recall some important aspects of the anthropic principle.

The anthropic principle (*anthropic* comes from the Greek word *anthropos* meaning man) was introduced by Robert H. Dicke in 1961, two years after the formulation of the hadron bootstrap. Its usefulness was largely demonstrated by the works of many scientists.

Today there are different formulations of the anthropic principle. Despite their diversity, there could be recognized a common idea that crosses all these formulations: the existence of a correlation between the occurrence of the human, of intelligent life in outer space (and therefore on Earth, the only place where we could identify this intelligent life) and the physical conditions governing the evolution of our universe. This correlation seems to be subject to strong restrictions: If you change the value of certain physical constants or that of the parameters occurring in some places a little, then the physical, chemical and biological conditions, which allow the appearance of humanity on Earth, are no longer met.

Some strong constraints seem to be exerted on the age of the universe and also on other physical and astrophysical quantities. Brandon Carter underlined the role of the gravitational coupling constant, which has to be close to the experimentally observed value, so as the planets could survive long enough, and could appear. A gravity that is too strong or too weak leads to the impossibility of the formation of planets. The coupling constant characterizing strong interactions is also very constrained.

In fact, a vast self-consistency, that concerns both physical interactions and the phenomena of life, seems to govern the evolution of the universe. Galaxies, stars, planets, humanity, and the atomic and quantum world seem united through one and the same self-consistency. The relationships emphasized by the anthropic principle are, in my opinion, a sign of this self-consistency. Again, they raise the problem of the uniqueness of the observed world.

It is precisely through this self-consistency that a link between the general bootstrap principle and the anthropic principle might be determined. It might be even argued that the anthropic principle is a special case of the bootstrap principle.

Even if the human being is, in a sense, a peripheral phenomenon, he or she seems to be necessary for the self-consistency of the whole. The human being is not the center, but rather a link of reality that includes him/her, a participant in the dynamic, evolving structure of the universe: the center is everywhere. It is the interpretation that we could offer if the anthropic principle is placed inside the perspective of the general bootstrap's principle. The finality (which passes through the human being, but which is not limited to him or her) is not pre-existing: it is built by the universe itself.

## Methodological Considerations

Ever since its formulation, the bootstrap principle has had bitter detractors and passionate advocates.

Thus, in 1965, three Japanese physicists belonging to the materialist-dialectical school in Nagoya (formed around Sakata and Taketani), wrote; "such trials will lead us to Leibniz's philosophy, which conceives the universe as having a predetermined harmony. This view will introduce religious elements in science and will stop scientific thinking at this level" (Maki, Ohnuti, & Sakata, 1965, p. 109).

The first novelty of the bootstrap principle is, as physicist James Cushing (1985) rightly notices, of methodological nature. The hypothetical-deductive method has become increasingly more prevalent in physics over the last three centuries: It presupposes the existence of certain fundamental laws, raised to the rank of axioms, all their consequences being deducted. A scientific explanation should follow this path. Usually, the assumption that these laws shall be exercised within certain fundamental entities, contingent and independent, but in interaction, is also formulated.

By proclaiming the absence of laws and fundamental entities, the bootstrap principle introduces a radically new methodology into science. It is true that, in practice, it is limited to a partial bootstrap, which tolerates some axioms as a starting point, and so there is a certain resemblance to the standard, hypothetical-deductive methodology. But the refusal to introduce fundamental entities and equations of motion that are associated with them, persists in various schemes of the partial bootstrap. Therefore, the bootstrap, as it is applied in physics, represents a deviant methodology, which is only accepted when the standard methodology is in crisis.

This is precisely what happened with the hadron bootstrap—formulated in an era characterized by a tremendous proliferation of various hadrons. In such circumstances, it was impossible to maintain the assumption of fundamental entities among these hadrons.

The aesthetic attraction of the bootstrap approach, associated with its successes regarding experimental data, has made such a deviant methodology become dominant in the physics of strong interactions in the decade 1960-1970. Meanwhile, the standard methodology has seen a dramatic reversal by inventing the quarks model and by developing the quantum field theory.

Beyond physics and its methodology, the bootstrap principle has also attracted the attention of philosophers. An immediate temptation is to relate the bootstrap to Leibniz's monadology. Scholarly studies were published in this direction by George Gale (1974, 1975). It is still difficult to advance anything other than a few analogies. As a simple substance, without parts, the monad, even if it is a mirror of everything, seems very different from a particle, which consists of all other particles. The relationship between monads is static, while the one between particles is dynamic, based on a continuous exchange of information. In addition, the bootstrap's world is not "the best of all possible worlds," it is neither the worst, nor the best, and it is simply the only one that can exist by self-consistency. The bootstrap principle seems in this respect, closer to Anaxagoras (c. 500–c. 428 BC), which proclaims that everything is in everything, and that an object is what it is because all the other objects exist at the same time (an object simply corresponds to its predominant component): "In reality, nothing is neither made, nor destroyed, but is made and separated, based on beings that exist" (Dumont, 1984, p. 78). His doctrine about the *homeomerie*s is not foreign to the notion of unobservable sub-constituents. Other ideas of Anaxagoras, such as the unity of contradictories (e. g., "snow is white, but water is black"), the unity of matter in the universe, the purpose that is created through the progress of rationality, deserve also to be mentioned in this context (Graisser & Graisser, 1977).

Another temptation is to approach the bootstrap and Taoism (Capra, 1975). However, the bootstrap is closer to Anaxagoras, Boehme, and Peirce or to the current systemic thinking, than to Leibniz or Eastern philosophy.

Whatever the fascination exerted by the bootstrap principle on the philosophical plan its interest lies in something else. More than a new theme in physics, it is rather a symbol, causing a view on the world's unity. This symbol is inexhaustible, still always remaining the same. Its richness includes the manifestation in the field of natural systems. Certainly, there is a total bootstrap, which is a view of the world, and a partial bootstrap, which corresponds to a scientific theory. One without the other is poor and, ultimately, sterile. The view of the world is nourished and enriched with information derived from the natural world and, in turn, the scientific theory gets a human dimension through the existence of a vision. The major interest of the bootstrap principle is that of unifying a view on the world with a scientific theory in one and the same approach.

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