The Philosophy of Sir Arthur Eddington

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PART ONE

Some Theses in the Philosophy of Science

Introduction

Sir Arthur Eddington was born in Kendal, England, on 28 December 1882. His father was the principal of the Quaker School at Stramongate, the school in which John Dalton had been sub-master. Eddington himself is a fervent Quaker and, as we shall see, his religion has had a profound influence on his philosophy. He received his higher education in Manchester first, at Owen College, and then at Trinity College, Cambridge. It was there that he was the "senior wrangler" in 1904, a title given the student who excels in mathematics and literature equally. His writings have an exceptional literary value. His knowledge of classical and modern literature is astonishing. In 1907 he was given the Smith prize from his college and in the following year was elected a Fellow of that celebrated institution.

His first scientific writings were published while he was assistant to the head of the Greenwich Observatory (1906–1913). To that point he seemed destined to have a career as a professional astronomer. But in 1913 he was named Professor of Astronomy in the Plumian Chair at the University of Cambridge, a chair that he still occupies today.

In 1914, he was put in charge of the Cambridge Observatory and in that same year was named a Fellow of the Royal Society. He is a member of many scientific societies, in England and abroad. He has been awarded prizes and medals everywhere, too many to enumerate here. In 1930, he was knighted and acquired the title Sir.[1]

In 1920 another Eddington showed himself with the publication of a work which marked an epoch in the philosophy of science: *Space, Time, and Gravitation.* This work demarked for the first time the domains of science and of philosophy in what concerns the theory of relativity. With this work he became the leader of philosophers of science. And he inspired confidence, because he was himself one of the most celebrated representatives of modern science. With him, there could be no question of preconceived ideas.

It has been said that the work is merely one of popularization. It is much more than that. It is first of all a philosophical contribution to the problem of modern science. His contributions have not been merely negative, as has been the case with many other modern scientists, Einstein included, who are content to chase philosophers from their domain—very rightly, moreover. In the work, *The Analysis of Matter,* Lord Bertrand Russell writes: "(Eddington), better than Einstein or Weyl, has the theory (of relativity) in the form best adapted to the needs of philosophers. . . . In philosophy, I have been guided almost exclusively by Eddington."[2]

The Nature of the Physical World, the Gifford Lectures of 1927, were an even more important revelation than the preceding work. The demands of these lectures in Edinburgh obliged him to deal with transcendental problems, something he did with extraordinary skill. This work assured him of a place among the most distinguished contemporary philosophers. He has been sharply criticized but today everyone must take him into account.

For us, Eddington has a double interest. First, he has carefully delimited the philosophical problem of relativity and quantum indetermination. But he has also given us a rather complete metaphysical system. He calls himself an idealist, an interesting point, because he says that he was carried toward idealism by his scientific work.[3]

The problem of the relation between scientific knowledge (in the restricted sense) and metaphysical knowledge interests us profoundly, especially because this problem is presented in a rather embroiled way by our own philosophers. Perhaps Eddington, who knows the sciences in depth, and who is no less a philosopher, offers us a chance to make the relation precise.

SECTION ONE

Epistemology and Metaphysics

Let us review the chief original contributions of Eddington to science in the experimental domain as well as in the domain of theory. This will enable us better to situate his personality. For it must be acknowledged that Eddington is above all a physicist who does philosophy only on the side—"a little," in his estimation! His competence in the scientific domain make his extra-scientific speculations all the more interesting in that he is capable of envisaging these problems from within physics. His assertion that we must go beyond physics is therefore all the more grounded. We cannot overlook this point. He is, very exceptionally, a great physicist and a great philosopher. These two qualities are inseparably united in his very personality, and we would distort it if we neglected either the one or the other.

I. The Double Stellar Current [*Le double courant stellaire*]

It was in 1906 that he attracted the attention of the astronomical world on the occasion of his first presentation to the Royal Society, entitled "The Systematic Motions of the Stars."[4] In this study he takes up a hypothesis advanced by the celebrated Dutch astronomer Kapteyn in 1904, an hypothesis which held that the movements of the ensemble of stars is not fortuitous, as the current opinion would have it, but that there are two favored movements. Until then, this hypothesis had had no success. Here Eddington already displays "the feeling of being on the right path before any proof," of which he often speaks.[5] He allows himself to be first guided by the aesthetic appearance of a theory.

This is how this problem should be situated. Since the time of Herschel the hypothesis has been suggested that the galactic system has the form of an extra-galactic nebula. This hypothesis extends only to the static form of the system. The known movements were considered to be proper to each star taken individually, whereas the movements of the whole were fortuitous. It was then that Kapteyn showed that the stars seemed to follow two opposed directions in the galactic plan: the movement of stars in the neighborhood of the sun would follow two opposed courses: there are two systems, one in a movement opposed to the other.

Eddington wanted to verify this hypothesis by an independent investigation. The rotary movement of the nebula was known. The demonstration of this hypothesis would show that the galactic system is itself a dynamic system, just like the extra-galactic nebula. This demonstration would provide a point of reference for new studies of the origin of this system and of its situation in the whole universe.

His investigation took from eight to nine years. In 1914, we find these results synthesized in a volume titled *Stellar Movements and the Structure of the Universe.* The conclusion was affirmative. It was based first of all on a minute analysis of the Catalogue of Professor Boss which gave the proper movements of about six thousand stars. Applying the statistical method, Eddington showed that it is necessary to divide them into two systems. He found a second confirmation of the hypothesis of Kapteyn in the spectroscopic speed of stars.

By this quantitative demonstration of the Hollendale hypothesis, the name of Eddington would remain associated with this branch of sidereal astronomy. This work taken in its entirety marked, according to the expression of de Sitter, an advance in the history of astronomy.[6]

II. The Internal Constitution of Stars

The first attempt to classify stars according to their spectra was made by the Italian Jesuit Secchi (1818–1878). He divided the life of a star into four stages which marked a greater and greater decrease of temperature. Then Lane (in 1878) showed that when a gaseous body contracts in losing heat, its temperature increases. It was therefore equally possible that stars having a reddish [*rougentre*] spectrum, and thus belonging to a lower stage, increased in temperature while losing heat. Therefore they could be, contrary to the view of Secchi, in their youth. In 1913 H.N. Russell and E. Hertzsprung showed that it was necessary to place stars in two categories: giants and dwarfs. The first are of great size, but of weak density, whereas the second are shrunk, more dense, and losing temperature. Thus each star passes twice through the same degree of temperature.

Eddington's study, "On the Radiative Equilibrium of the Stars,"[7] gave a theoretical explanation of these observations. The investigations were conducted on the basis of the laws of a perfect gas. They were thus restricted to the study of giant stars, the dwarfs being thought to be too dense to obey these laws.

There are therefore in a star two opposed tendencies: the upper strata cooling by contracting, whereas the lower strata increase in pressure. But, observation shows us that the structure of stars is relatively constant: so two tendencies of equilibrium must be recognized.

The mass and superficial temperature of the sun are two known magnitudes. Eddington asked himself if there were not a way to explain this equilibrium by a theory based on the known laws of the internal structure of stars. Direct calculations made on known magnitudes lead to impossible results.

III. The Theory of Relativity Generalized

Even before taking up the problem of stellar equilibrium, Eddington had been much interested in the theory of relativity. Perhaps it was because of this that he advanced his theory of the pressure of radiation with such confidence.

Already in February 1915, therefore before he knew the developments achieved by Einstein, he had written,

> It is scarcely too much to say that the nature of gravitation remains as much a mystery to-day as when the law was first formulated by Sir Isaac Newton. In the meantime, theories of matter, of aether, and of electricity have arisen, have held their vogue, and have been superseded by others; but gravitation stands apart from these changing views. No experiments have as yet shown any relation between it and the other phenomena of nature; the simple law, unconditional and universal, has been all-sufficient hitherto. We have grown accustomed to regarding gravitation as something outside the scope of ordinary physical theories. If a new model of the atom is put forward, we ask if it accounts for

> the Zeeman effect, for chemical affinity, for the dispersion of light, and a host of incidental phenomena; but it would be considered unfair to suggest that it ought to account for the one fundamental and universal property of matter—gravitation.[8]

Then, after rejecting explanations given up to that time, he suggested: "Does gravitation conform to the Principle of Relativity?"

There is an interesting remark in this same article. The possibility of finding an experimental phenomenon in favor of an application of this principle to gravity catches his attention. "It would be extremely difficult to detect this deflection [of light] even during a total eclipse. . . . But a positive result would mean that gravitation has been pulled down from its pedestal, and ceases to stand aloof from the other interrelated forces of nature."[9]

It was Eddington himself who, on 1 February 1918, drew the attention of the members of the Royal Society to the possibility of exploiting the total eclipse of 29 May 1919. In articles and conferences he spread the idea. And all this during the war, for which, being a Quaker, he had a supreme disdain. It was under his direction that the two expeditions were made, one to Sobral, and the other to the Ile de Prince. The result was positive. This was an experimental proof in favor of the theory of Einstein. The first communication of these results was made to the Royal Society in the *Philosophical Transactions of the Royal Society of London* (220, series A [1920]: 291–333).

It was from the enthusiasm of this success that was born the work *Space, Time, and Gravitation.* He no longer hesitated. The whole basis of physics must be profoundly rethought. The philosophical conceptions of physicists are altered by these demands. There remain only philosophical prejudices and Eddington gave himself the task of reversing them.

Up until now, his part in the development of the theory of relativity was purely experimental. It was Eddington, and Eddington alone, who presented Einstein to the English public. But he also played a role in the theoretical development itself. This contribution appeared in 1921 under the title "A Generalization of Weyl's Theory of the Electro-magnetic and Gravitational Fields,"[10] and was incorporated into the synthesis, *Mathematical Theory of Relativity.*[11] For Einstein, mass and the quantity of motion were equal to certain characteristics of the geometry of space-time. But Eddington had shown that mass and quantity of motion are not the names under which we recognize these geometrical characteristics in physical experiments. Einstein invoked a law of nature which is cause of this equality, whereas Eddington reduces this putative law to a tautology. It is here that he showed his skill in scientific methodology and made a rigorous application of this theory of physical theory, which always contains two aspects.[12] The mathematical theory of relativity is above all an analysis which operates on certain symbols. When we apply this theory to the physical world, we should find the connection by the identification of properly physical entities with the entities of the mathematical analysis. These constitute there two parallel systems which ought to be identified at each point. But there must be also some identities which are fundamental and from which one can deduce the others. Without that, we will have no point of reference. It is on the basis of the identity of the mass and of the quantity of motion that one can identify the other parallel entities.

There are then three domains in which he excelled. It was Eddington who was among the first to be captivated by the theory of quanta, and who made the first applications of it in the domain of astrophysics. It was Eddington who discovered Abbé Lemaitre, who moreover had been one of his students. To trace a precise and adequate portrait of Eddington the physicist is quite outside my competence, but these few remarks perhaps suffice to convince us that we have to do with a flexible spirit, youthful, who has an exceptional flair for the truth, and to introduce the physicist whose philosophy we will study.

SECTION TWO

The Philosophy of Exact Science

In the second and third sections we propose to give as objective as possible an exposition of the doctrine contained in the different philosophical works of our author. Is this possible? Let us from the outset introduce necessary reservations. We have, first of all, our own philosophy, and I think it is difficult to abstract from it. When a non-scholastic author speaks of "reality," "actuality," and of "substance," and so on, and does not give us a sufficiently precise definition of these terms, we are inclined to assimilate the meaning of these expressions to our own. And in the case of Eddington who does not pretend to give us a well-defined and achieved system, the danger is considerable. It is indeed possible that here and there I force the matter. Sometimes he comes remarkably close to a metaphysics akin to ours and then goes in a direction in which he would refuse to follow us. The doctrine treated here was dispersed almost everywhere in a sketchy manner. The very wish to systematize ideas not always firmly delineated runs serious risks, and we will not be able to systematize them without tightening them. All the same, we cannot simply juxtapose his ideas and make a dictionary. But we will refrain from tightening them too much. By seeking to establish an explicit continuity among these elements, we are doing something that Eddington has not done for us. One further remark. We cannot study all the points that Eddington calls "philosophical." The meaning of this term is very ambiguous among the English, as we shall soon see. Even problems to which scholastics have given a philosophical value will not occupy us. Such as the problem of the end of the universe based on the second fundamental law of thermodynamics.[13] This physical law, whatever its real value, cannot be made into a philosophical truth. The philosopher can have his own reasons for predicting the end of the universe, but these will never be assimilable by the physicist. A theory can be scientifically true, but that does not give it a value, or rather a meaning, that is philosophical.

The restriction that we impose on ourselves is not arbitrary. We find its basis in distinctions made by Eddington himself. Thus, the distinction he makes between "the point of view" of relativity and the "principle" of relativity. The first is clearly philosophical. But Eddington does not explicitly characterize it as such. And the same is true for the problem of indeterminism.

Chapter I. The Sources

Space, Time, and Gravitation is the first philosophical work of Eddington. He wrote it as a result of the famous expedition to Sobral and to the Isle of Prince that he himself organized. Einstein's theories had been received with a great deal of skepticism by English physicists and philosophers. Eddington perceived that the prejudices were philosophical and not of the scientific order. And it seems to us that he succeeded wonderfully in dissipating them.

The Nature of the Physical World is the series of Gifford Lectures that he delivered in Edinburgh in 1927. Their subject was dictated by the foundation. It is thanks to these requirements that we have a view of the whole on his philosophy. The conferences that he gave before these appeared contain nothing that is not assimilated in them.

Science and the Unseen World is a lecture as well, one he gave to a religious society, the Society of Friends, better known as the Quakers. They contain important precisions on the problem of God and on the religious problem generally.

Since then we have from him two important philosophical articles. The first, "Physics and Philosophy," appeared in *Philosophy.* This was a lecture given before the British Philosophical Association. The second appeared in the *Collection des Actualités Scientifiques et Industrielles.* Both are above all precisions on the problem of indeterminism. Two other works, less philosophical, but which contain many important precisions, have been used: above all, *Mathematical Theory of Relativity* (1923), an elaboration of the appendix to the French translation of *Space, Time, and Gravitation,* which was exclusively mathematical;[14] second, the little book, *The Expanding Universe* (1933), which contains interesting remarks on physical theory.

I do not think that one can find any evolution in Eddington's ideas. The extensions and clarifications of the more recent contributions are all in direct continuity with the first. I will not hesitate, accordingly, to assemble texts from different works without regard to their dates.

As for the historical and ideological sources of Eddington's philosophy itself, it seems to me that it would be difficult to trace them. He certainly knows Hegel and Berkeley.[15] And yet his idealism (we will soon see how it is with his idealism) has nothing specifically in common with these two philosophers. He even has a rather naive conception of the subjectivism of German idealist philosophers. He also knows Bergson. We find in him distinctions to be found in Bergson as well, such as the distinction between realism and idealism.[16] His terminology and the way he poses transcendental problems recalls the English philosopher Bradley and his disciple Bosanquet. But the indications given will not suffice to establish a true dependence. Moreover, the conclusions differ radically.

The one source we can determine with certitude is his religion. Eddington is above all a religious man, and of the species Quaker. We have a special chapter on this subject in which we will try to determine to what degree it exercised an influence on his philosophy. His colleague, Sir James Jeans, defends ideas very analogous to those of Eddington, but much less precisely. In any case, the philosophical works of Jeans are later than those of Eddington.[17]

Chapter II

Article 1. The Notion of Philosophy

Before raising the special problem of his philosophy of science, it will be interesting to know what Eddington himself means by "philosophy." Unhappily, he does not give us any sufficient indication. Occasionally, he mentions some of its properties or functions.

There is first of all the text in *Space, Time, and Gravitation* which attributes a proper point of departure to philosophy, "physical theory starts with the simplest constituents, philosophical theory with the most familiar constituents" (166 [205]). The distinction is clear enough. But one must read it in its context. It is a question notably of a distinction introduced when speaking of the materialist philosophy of Mach. But the thesis envisaged has