

Heraclitus work ‘On Nature’: a first reading from the physicist’s point of view

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ABSTRACT. In this paper we try a first reading of the fragments of Heraclitus work ‘On Nature’. We interpret those fragments that refer to Heraclitus theory of physis (nature), namely to his ontology, gnoseology and cosmology, and try to evoke their deeper essence in the framework of modern physical ideas.

RESUME. Dans ce travail nous essayons de faire une lecture des fragments de l’oeuvre d’Héraclite ‘De la Nature’. Nous interprétons ces fragments, qui se rapportent à la théorie de la Nature d’Héraclite et spécialement à son ontologie, gnoséologie et cosmologie, en nous essayant d’évoquer leur sens profond dans le domaine des idées physiques modernes.

1. Introduction

Many philosophers, thinkers and poets have already written about Heraclitus. Yet it seems that his work remains an inexhaustible source for comments, interpretations and delve. From the antiquity already he was renowned for his obscurity. In spite of the fact that his first fragment seems to be something like an introduction to a book and, as Diogenes Laertus comments [1] “The book said to be his is called ‘On Nature’ from its chief comment ...”, nevertheless there are many who maintained (e.g. Diels) that “Heraclitus wrote no consecutive book, but merely gave repeated utterance to a series of carefully-formulated opinions or $\gamma\nu\tilde{\omega}\alpha\iota$ ” [2]. But there is also the opposite opinion that Heraclitus book is authentic. This view is based both to the critical analysis of the saved

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fragments and to the evidence from the antiquity. Thus, according to the first, we can note that there is a well organised structure in the book with plot, symmetry and consistency such that a thorough and lasting polishing up of the work by Heraclitus himself is proved. Furthermore, these latter characteristics show up the endeavour to present an integrated philosophical system. Aristotle, on the other hand ('Rhetoric'), referring to Heraclitus sayings in the first fragment, points out that the Ephesian expresses himself that way "in the beginning of his book". This evidence is given by Aristotle for he undoubtedly knew by first hand the existence of the book. Thus we shall consider, for the purpose of our study, that Heraclitus wrote indeed a consecutive book 'On Nature', the content of which we discuss right now.

Heraclitus book is a sort of scientific treatise combining the characteristics of the poetry. It is indeed and foremost a treatise on nature, a philosophical work on the essential characteristics of the cosmos, the microworld as well as the universe as a totality. It contains ontological and gnoseological principles and a bewildering scheme of cosmology. This, in our opinion, is the fundamental essence of the book. In parallel it deals also with political and ethical problems of human behaviour. This parallel treatment of the two subjects, the world itself and the man in the world, in society, is achieved through the multiple significance of the main concepts he uses. His style is rather short and comprehensive. He manages to say *multum in parvo*. The poetic language he uses permits him to express both the human (more explicitly) and the universal (in many cases metaphorically). Almost every fragment can be interpreted in both aspects, the physical and the human.

The obscurity of Heraclitus sayings rests with this characteristic double meaning of his concepts as, e.g., Logos, God, Fire, War, etc. But this constitutes also the strength of his sayings. As far as the very content of his book is concerned one can discern roughly three parts: in the first Heraclitus presents his theory of the Logos, i.e. the meaning of the things and the possibility of man to have access to this meaning; the second part deals with his theory of fire, i.e. his theory of the deepest understanding of the function of the world, its essence, its beginning, etc; and the third part deals with ethical and political issues. In this paper we shall deal only with the two first parts.

To our knowledge among the many readings and interpretations of Heraclitus fragments there is none made by a physicist. We think that such a treatise on Nature, where the main issues concern the natural

phenomena, the 'physis' and the world as a physical structure, deserves to be read and commented from the point of view of a physicist. In such an endeavour it is natural that many of the authentic interpretations given until now by several authoritative philosophers and thinkers will be viewed from a new angle and, unavoidably, some fragments will be interpreted with some sort of arbitrariness.

As in many cases the construction of modern theories in physics presupposes the fruitful use of inspiration and intuition, we stress to the point that Heraclitus imagination and intuition based primarily on an extremely high potentiality to observe nature and its phenomena and to penetrate deeply into their essence, led to an enigmatic anticipation of the very concepts used in present-day theories of physics. This phenomenon is common to the thought of the ancient greek philosophers who expressed so intuitively the essence of the world structure and answered to many great questions raised by nature itself. Heraclitus is one of the greatest thinkers of antiquity who approached so intimately and geniously the relevant issues of philosophy. A century after the genesis of philosophy in Lonia, Heraclitus envisaged the philosophical problems under a more critical consideration and using a more 'scientific' foundation. He is the first to have used many examples from the immediate experience of men as arguments in a demonstrative process.

We shall organise our study in the following way. We first give the fragments in a sequence we find to be the more appropriate. Next we analyse the most important concepts used in Heraclitus fragments and at the same time we proceed to our interpretation of them from the physicist's point of view.

2. The fragments

We cite now all the fragments with which we shall deal in this paper. We put an asterisk on the numbers that represent the enumeration adopted by us and in parenthesis we give the standard enumeration. Half of the fragments in english translation are borrowed from reference 1 and the remaining from reference 3 .

1*(Fr. 1) Of the Logos which is as I describe it men always prove to be uncomprehending, both before they have heard it and when once they have heard it. For although all things happen according to this Logos men are like people of no experience, even when they experience such words and deeds as I explain, when I distinguish each thing according to

its constitution and declare how it is; but the rest of men fail to notice what they do after they wake up just as they forget what they do when asleep.

2*(Fr. 17) For many men –those who encounter such things– do not understand them, and do not grasp them after they have learnt; but to themselves they seem (to understand).

3*(Fr. 34) Not understanding, although they have heard, they are like the deaf. The proverb bears witness to them: ‘Present yet absent’.

4*(Fr. 35) Men who love wisdom must be inquirers into very many things indeed.

5*(Fr. 72) [The Law (Logos)]: though men associate with it most closely, yet they are separated from it, and those things which they encounter daily seem to them strange.

6*(Fr. 55) The things of which there is seeing and hearing and perception, these do I prefer.

7*(Fr. 101a) The eyes are more exact witnesses than the ears.

8*(Fr. 18) If one does not expect the unexpected one will not find it out, since it is not to be searched out and difficult to compass.

9*(Fr. 86) (Most of what is divine) escapes recognition through unbelief.

10*(Fr. 101) I searched out myself.

11*(Fr. 107) Evil witnesses are eyes and ears for men, if they have souls that do not understand their language.

12*(Fr. 93) The lord whose oracle is in Delphi neither speaks out nor conceals, but gives a sign.

13*(Fr. 123) The real constitution of things [= physis] is accustomed to hide itself.

14*(Fr. 54) An unapparent connexion is stronger than an apparent one.

15*(Fr. 22) Those who seek gold dig much earth and find little.

16*(Fr. 28a) The most wise-seeming man knows, (that is) preserves, only what seems.

17*(Fr. 56) Men are deceived over the recognition of visible things, in the same way as Homer, who was the wisest of all the Hellenes; for he too was deceived by boys killing lice, who said: ‘What we saw and grasped, that we leave behind; but what we did not see and did not grasp, that we bring’.

18* (Fr. 40) Much learning does not teach one to have intelligence; for it would have taught Hesiod and Pythagoras, and again, Xenophanes and Hecataeus.

19* (Fr. 129) Pythagoras, son of Mnêsarchus, practised research most of all men, and making extracts from these treatises he compiled a wisdom of his own, an accumulation of learning, a harmful craft.

20* (Fr. 81) (On Pythagoras). Original chief of wranglers.

21* (Fr. 28b) Furthermore, retribution will seize the fabricators of lies and the (false) witnesses.

22* (Fr. 42) Homer deserves to be flung out of the contests and given a beating; and also Archilochus.

23* (Fr. 57) Hesiod is the teacher of very many, he who did not understand day and night: for they are one.

24* (Frs 114 and 2) Those who speak with sense must rely on what is common to all, as a city must rely on its law, and with much greater reliance. For all the laws of men are nourished by one law, the divine law; for it has as much power as it wishes and is sufficient for all and is still left over.

Therefore it is necessary to follow the common; but although the Logos is common the many live as though they had a private understanding.

25* (Fr. 89) To those who are awake, there is one ordered universe common (to all), whereas in sleep each man turns away (from this world) to one of his own.

26* (Fr. 50) Listening not to me but to the Logos it is wise to agree that all things are one.

27* (Fr. 10) Things taken together are whole and not whole, something which is being brought together and brought apart, which is in tune and out of tune; out of all things there comes a unity, and out of a unity all things.

28* (Fr. 51) They do not apprehend how being at variance it agrees with itself [literally, how being brought apart it is brought together with itself]: there is a back-stretched connexion, as in the bow and the lyre.

29* (Fr. 125) The 'mixed drink' (Kykeôn: mixture of wine, grated cheese and barley-meal) also separates if it is not stirred.

30* (Fr. 108) Of all those whose discourse I have heard, none arrives at the realisation that that which is wise is set apart from all things.

31*(Fr. 41) The wise is one thing, to be acquainted with true judgement, how all things are steered through all.

32*(Fr. 80) It is necessary to know that war is common and right is strife and that all things happen by strife and necessity.

33*(Fr. 53) War is the father of all and king of all, and some he shows as gods, others as men; some he makes slaves, others free.

34*(Fr. 59) For the fuller's screw, the way, straight and crooked, is one and the same.

35*(Fr. 60) The path up and down is one and the same.

36*(Fr. 103) Beginning and end are general [common] in the circumference of the circle.

37*(Fr. 61) Sea is the most pure and the most polluted water; for fishes it is drinkable and salutary, but for men it is undrinkable and deleterious.

38*(Fr. 13) Do no revel in mud. (Swine enjoy mud rather than pure water).

39*(Fr. 9) Donkeys prefer chaff to gold.

40*(Fr. 48) The bow is called Life, but its work is death.

41*(Fr. 12) Upon those that step into the same rivers different and different waters flow.

[And Plato, in 'Cratylus']: Heraclitus somewhere says that all things are in process and nothing stays still, and likening existing things to the stream of a river he says that you would not step twice in the same river.

42*(Fr. 88) And as the same thing there exists in us living and dead and the waking and the sleeping and young and old: for these things having changed round are those, and those having changed round are these.

43*(Fr. 126) Cold things grow hot, hot things grow cold, the wet dries, the parched is moistened.

44*(Fr. 111) Disease makes health pleasant and good, hunger satiety, weariness rest.

45*(Fr. 23) They would not know the name of Right, if these things (i.e. the opposite) did not exist.

46*(Fr. 62) Immortals are mortal, mortals are immortal: (each) lives the death of the other, and dies their life.

47*(Fr. 30) This world-order [the same of all] did none of gods or men make, but it always was and is and shall be: an everliving fire, kindling in measures and going out in measures.

- 48*(Fr. 124) The fairest universe is but a dust-heap piled up at random.
- 49*(Fr. 94) Sun will not overstep his measures; otherwise the Erinyes, ministers of Justice, will find him out.
- 50*(Fr. 31) Fire's turnings: first sea, and of sea the half is earth, the half 'burner' [i.e. lightning or fire].
- 51 a*(Fr. 31) <earth> is dispersed as sea and is measured so as to form the same proportion as existed before it became earth.
- 51 b*(Fr. 90) All things are an equal exchange for fire and fire for all things, as goods are for gold and gold for goods.
- 52*(Fr. 65) Need and satiety.
- 53*(Fr. 84a) It rests from change (Elemental Fire in the human body).
- 54*(Fr. 84b) It is a weariness to the same (elements forming the human body) to toil and to obey.
- 55*(Fr. 64) Thunderbolt steers all things.
- 56*(Fr. 66) Fire, having come upon them, will judge and seize upon (condemn) all things.
- 57*(Fr. 91) It scatters and gathers, it comes together and flows away, approaches and departs.
- 58*(Fr. 6) The sun is new each day.
- 59*(Fr. 36) For souls it is death to become water, for water it is death to become earth; from earth water comes-to-be, and from water, soul.
- 60*(Fr. 45) You would not find out the boundaries of soul, even by travelling along every path: so deep a measure does it have.
- 61*(Fr. 118) A dry soul is wisest and best.
- 62*(Fr. 67) God is day night, winter summer, war peace, satiety hunger [all the opposites, this is the meaning]; he undergoes alteration in the way that fire, when it is mixed with spices, is named according to the scent of each of them.
- 63*(Fr. 102) To god all things are beautiful and good and just, but men have supposed some things to be unjust, others just.
- 64*(Fr. 79) Man is called childish compared with divinity, just as a boy compared with a man.
- 65*(Fr. 52) Time is a child playing a game of draughts; the kingship is in the hands of a child.

3. The theory of Logos

As we mentioned already in this paper we shall deal with the fragments that refer to the theory of Logos (*A*) and to the theory of fire (*B*) and not with the fragments referring to ethical and political issues, since we just try a reading of Heraclitus work from the physicist's point of view.

The first group of fragments (group *A*) deals with the fundamental position of Heraclitus about the nature of the world (ontology), from which he starts developping his theory of fire, namely his theory of the function of the cosmos (group *B*). We shall divide the first group into two subgroups A_1 and A_2 . The subgroup A_1 (frs. 1*-25*) contains the following two fundamental ideas:

- i) The Logos is the deepest ontological essence of the world.
- ii) Physis (i.e. the real constitution of things) is accustomed to hide itself.

These two ideas are implicated in the general confirmation that although the Logos is the deepest essence of the world (and this results through a thorough examination of physis), because physis is accustomed to hide itself, for this reason not all men can understand the fundamental element of the world, the Logos. Heraclitus tries to prove this claim with examples where some of the wisest men of antiquity (e.g. Homer, Pythagoras, Hesiod and others) were proved ignorant of the very essence of physical reality.

Fragment 1* has been greatly commented. We believe that 'always' is referred to 'Logos being (such) as I describe it' and not to 'men prove to be uncomprehending'. This view is strengthened by what follows: 'for although all things happen according to this Logos ...'. This points out to an everlasting feature of nature, namely that nature is always ruled out by the Logos. Thus the meaning of this fragment is the following: There is (and there was and will be always) a deeper essence of all things in the world, which is the Logos, according to which all phenomena happen. Many people, although they know the data of the experience, they cannot understand this truth (fr. 2* in my enumeration always) and they form their own opinions. Thus, even if they heard about Logos, they are like the deaf (fr. 3*). And although they are questioning and know many things (fr. 4*), nevertheless those things which they encounter seem to them strange (fr. 5*).

In the subsequent fragments Heraclitus sets the problem of the acquisition of experience and distinguishes the senses giving further estimations of methodological character. Thus in fr. 6* he declares that he prefers to start from the experience of the senses of whom he makes an evaluation (fr. 7*); in modern language this amounts to say that the experiment is the ultimate criterion of the theories about physis. But Heraclitus admits also another epistemological principle, namely the fact that the exploration of physis cannot be based only on experience. He thus proceeds to formulate his epistemological principle according to which 'if one does not expect the unexpected one will not find it out, since it is not to be searched out and difficult to compass' (fr. 8*). This is the same principle adopted by many scientists of our century, e.g. Einstein and de Broglie, who believed also that there is a hidden reality which one can approach by means of free inventions and simple symmetry principles (to which Heraclitus refers elsewhere). And since the deepest essence of things (i.e. the Logos) and the deepest structure of cosmos seem to be unbelievable, all these fundamental ideas escape most of men (fr. 9*). The first step in the search of truth about physis is to investigate the things in depth, starting from man himself. Thus Heraclitus declares: 'I searched out myself' (fr. 10*). From this investigation results the limit to which one can trust experience, as one senses it and follows the acknowledgement of the value of the process according to which free invention and intuition could approach what experience hides from us; thus, when we are not prepared to follow this process, then 'evil witnesses are eyes and ears for men, if they have souls that do not understand their language' (fr. 11*). And it follows the idea, which supports Heraclitus arguments, that, like the lord of Delphi oracle neither speaks out nor conceals, but gives a sign (fr. 12*), nature is not like an open book wherefrom one can easily acquire the knowledge of cosmos, neither conceals it completely, but gives signs, implicitly conveys the hints to all those who ask the 'right' questions and investigate to find out the unexpected.

Thus physis neither speaks out nor conceals, but is accustomed (likes) to hide itself (fr. 13*). Hence harmony is to be revealed hidden in the physis: actually symmetry principles and conservation laws, particularly the unifying the forces of nature law are hidden. But this hidden harmony, the unapparent connexion is stronger than the apparent one (fr. 14*). To reveal this deepest harmony is a task (of science and philosophy) hard, laborious and continuous, as to seek gold one has to dig much earth and find little (fr. 15*).

To support this thesis (that the process to knowledge is difficult and non accessible to all men) Heraclitus uses examples, a methodology first introduced by him (to this extent) as an argumentation process, pointing out that even the wisest among men do not succeed in approaching the truth but they insist on their own opinions (fr. 16*). But before we make comments on the examples, we shall criticize Heraclitus' thesis that only a few men are capable to grasp the true knowledge. It has been pointed out that this thesis is in harmony with Heraclitus aristocratic origin and his political ideas. But one can actually ask, is this thesis untrue? And ask further how many people can today understand the steps made by science in order to approach the deepest laws of physis, the description of the phenomena of microworld and of megaworld (particle physics, modern astrophysics and cosmology)? And outside the strict framework of science, how many have struck a mature attitude on the problem of the world's origin, which (world), according to the last scientific views could be come out of a random disturbance of the vacuum? It is obvious that only a part of specialized scientists can follow the steps of modern science and this is a true fact and not an eclecticism.

The examples cited by Heraclitus, a first demonstrative process, comprehend some of the wisest men of the antiquity. And if they are deceived over the recognition of visible things, how much more does this hold for the less wise men? Thus Homer, who became the wisest of all Hellenes, could not answer to a simple question asked by children (fr. 17*). Erudition is not sufficient for the knowledge of the deepest essence of cosmos; 'for it would have taught Hesiod and Pythagoras and again Xenophanes and Hecataeus' (fr. 18*). Especially Pythagoras is criticised by Heraclitus: although he 'practised research most of all men, he compiled ... an accumulation of learning (which is) a harmful craft' (fr. 19*); and for this reason he is characterised by Heraclitus as the 'original chief of wranglers' (fr. 20*). Heraclitus characterizes further these erudites as the fabricators of lies and the (false) witnesses (fr. 21*). He considers also Homer and Archilochus as deserving 'to be flung out of the contests and given a beating' (fr. 22*); and equally Hesiod who was 'the teacher of very many, he who did not understand day and night: for they are one' (fr. 23*). We notice how strong was the dispute and the antagonism at that time too.

After citing these examples Heraclitus concludes that by using the mind, the imagination and the intuition one must 'rely on what is common to all, as a city must rely on its law and with much greater reliance.

For all the laws of men are nourished by one law, the divine law ...' (about the concept of the 'divine' in Heraclitus we shall see below). But, although the general ratio, the Logos, is common (to all things and to all men), 'the many live as though they had a private understanding' (fr. 24*). Thus men could be divided 'to those who are awake, (for which) there is one ordered universe common (to all)', and to those who are in sleep and 'turn away (from this world) to one of their own' (fr. 25*).

With this fragment we have brought to completion our reading of the first subgroup (A_1) of the group A . We shall now continue with the subgroup A_2 .

This subgroup has as a leading fragment the fr. 26*, which is one of the most characteristic of Heraclitus thought: 'Listening not to me but to the Logos it is wise to agree that all things are one'. We shall call this fragment the 'identity 26'. In this fragment are contained two of the most important ideas of Heraclitus. The first one refers to the objectivity of the general law of physis, i.e. of the Logos. Heraclitus points out that you will listen 'not to me (i.e. subjective ideas) but to the Logos' (which is an objective, common to all physical phenomena, law). It is the objective law which determines that 'all things are one' (the second idea). In other words, for this law all things are one, i.e. this is the most general law of nature, which governs all things, and according to which all physical phenomena happen. This is, indeed, a bewildering view, that there exists in nature one unifying law towards whom all things are one, i.e. they all are controlled by this unique law. We see that in such a dense in meaning fragment coexist as much Heraclitus ontology as his general theory of physis, the latter being his fundamental model for his cosmology with which he deals in the group B of the fragments.

In Heraclitus times there was a general view concerning the unity of cosmos, according to which to the great many varieties, particularities and opposite appearances of the phenomena one objected the unity. Heraclitus made a further step: he proceeded to a genius identification of all things to one, not in the sense that all things are the same, but in the sense that the (hidden) deepest essence of all things is common, making all things to obey to one and the same law (the Logos); thus the one contains all things. Even the opposites obey to a unifying principle, the principle of the unity of the opposites.

This last proposition is a cornerstone of Heraclitus thought and a landmark in the history of philosophy, the starting point of dialectical

thinking. The fragment 27* is thus the general law of the unity of the opposites: ‘Connexions (*ξυλλαμεις*) (things taken together are) whole and not whole, something which is being brought together and brought apart, which is in tune and out of the tune; out of all things there comes a unity, and out of a unity all things’. The first part of this fragment indicates the coexistence of the opposites; the second points out the unity of the opposites, in the form of which all things are emerging in the world. Thus the opposite things in nature are but the two faces of the same coin. Furthermore the coexistence of the opposites and the strife between them is a fundamental structural and functional attribute of all things, and this is the next step of Heraclitus thought, namely that the strife of the opposites (action-reaction, waves-particles, matter-antimatter) is the intrinsic harmony of the constitution and the function of the world: this is the meaning of the fr. 28*: ‘there is a back-stretched connexion, as in the bow and the lyre’. Thus the continuous strife between the opposites is a fundamental process and leads to a dynamical equilibrium which, again and again, is disturbed leading to a new situation and so on; it is by this process that the function of the world is ‘conserved’; otherwise “Kykêon (the mixte drink) also separates if it is not stirred” (fr. 29*).

This dynamical state, which follows as a clash and a synthesis of the opposites, is interpreted by Heraclitus as a back and forth movement of the being (of the deepest essence of the world) from the one to the many (things) and from the many to the one (fr. 27*). Thus the identity 26 has not only a cosmological meaning but an ontological one as well, that is it concerns not only the dynamical state of the universe but its essence as well. The actual meaning of the identity 26 is that in it the *one* means the general and the ‘all things’ means the particular. Thus the identity 26 shows also the ontological relation between the general and the particular. For the general is distinguished from the particular (fr. 30*), i.e. Heraclitus clearly distinguishes the general (the basic essence common to all things because of which all phenomena obey the unique law, (the Logos) from the particular (this prodigal multitude of the forms in the realm of the experience). This distinction marks the demarcation point between Heraclitus and Parmenides, who to this distinction proposes the one between the real and the apparent. And this Heraclitus distinction (between the general and the particular) means further that in the particular phenomena hold particular relations (laws), all of which can come under the unity of the general law. This is the deepest meaning of the identity 26 .

To make things clearer we shall consider an example from physics: the electric and magnetic phenomena. In each case particular laws hold. Maxwell achieved the unification of these phenomena through his electromagnetic theory. This means that the deepest nature of these phenomena is such that a more general law (or laws) could describe both categories of phenomena. Thus from the two types of phenomena ("all things") results the more general law ("the one") and from the general law result the two categories of phenomena ('from the one result all things'). We now know that there are four kind of forces in nature. And physicists now believe, as Heraclitus believed twenty five centuries ago, that there exists some fundamental element which is common to all these forces giving the possibility to describe them through one general law (a superforce, the Logos of Heraclitus); physicists working on this field are hoping to achieve, sooner or later, this goal. The achievement of this endeavour would mean that there is a deeper relation of essence between the objects that are subjected to different kind of forces and thus there would be proved the ontological character of the identity 26 .

The difficulty encountered in the endeavour to unify all the forces of nature is related also to the meaning of the fr. 30*: that that is wise, i.e. the Logos, the one, 'is set apart from all things', it does not show up itself in all things (i.e. in the particular phenomena –what an ingenious idea !), because it is the deepest Logos of their existence (and behaviour), and being the deepest essence of all things it is not 'easily' recognizable, it is (in modern terminology) a *higher symmetry* not recognizable in the particular phenomena, a higher symmetry from which all the lower symmetries (the particular laws) can result.

The next fragment (31*) points out how it is important to know the most general law, the Logos: 'The wise is one thing, to be acquainted with true judgement, how all things are steered through all', i.e. that the most general law acts on all things through all. In the particular phenomena the general law is expressed through particular relations, but in its generality it embraces all the objects in the universe.

Another element introduced by Heraclitus is the determinism of physical phenomena. Having founded the existence of one general law, which governs all phenomena, he points out that the conflicting forces acting upon all things are common ('the war is common') and that upon these forces depends the evolution of all phenomena ('and right is strife') and that all phenomena happen according to the laws and the necessity (imposed by these laws): 'all things happen by strife and necessity' (fr.

32*). The next fragment must be read metaphorically: Thus war, the conflicting forces, is the cause of all that happens, the cause of all the differences, both quantitative and qualitative, in the world. The relevance of these fragments is conspicuous. ‘All things happen by strife and necessity’: this is a point of culmination in Heraclitus thought and it is verified by the modern development of physics; here necessity means the existence of laws underlying the process of all phenomena, even the stochastic phenomena.

In the next fragments Heraclitus repeats his argumentation using again examples to support his ideas of the subgroup A_2 . These are the fragments 34* to 46*. We shall make some comments on the following four: fr. 35*, apart from the identity of the two opposites (‘The path up and down is one and the same’) declares also a symmetry principle, as does the next fr. 36*, and from this point of view these two fragments could also be incorporated in the group B . This symmetry principle, as expressed particularly in the fragments 34*, 35* and 36*, is also a fundamental concept in Heraclitus thought and has been proved excessively fruitful in modern times as used by Einstein, de Broglie, Dirac, in the case of Noether’s theorem and in modern theories of elementary particles.

Fr. 41* means first that time, as the water in a river, cannot stop but flows continuously. It has a constant direction of flow (like the river) and thus, we could say, physical phenomena evolve following the positive direction of time. The same fragment has also the meaning that all things change with time. This is also one of the most famous fragments of Heraclitus work. Its deeper meaning goes along with the modern ideas of physics: nothing in nature remains unaltered; everything evolves, changes with time.

Finally, fr. 39* must be read metaphorically: in every class of phenomena there are particular and appropriate relations which govern them, e.g. different particles obey to different relations, i.e. they show a particular ‘preference’ for some kind of interaction. We may do this reading because, as we already pointed out, Heraclitus likes using examples from life to express relations hidden in physical phenomena. This constitutes the poetic element in Heraclitus work.

4. The theory of Fire

The group B of Heraclitus fragments we shall now examine, is referred to a general scheme of the function of the world, i.e. to what we

could call a general physical theory, in which Heraclitus cosmology is comprised too. Indeed, the very first fragment of this group is referred to cosmogony (fr. 47*): "This world (the same of all) did none of gods or men make but it always was and is and shall be: an everliving fire, kindling in measures and going out in measures". What a daring cosmological principle ! One could write a thesis on this fragment. We shall restrict ourselves to some comments:

First, this fragment points out to the idea that the world is the same for all (observers); because it is an objective world ruled out by an objective general law. Second, there is the idea of the general constituent of the world: this is the everliving Fire. The notion of Fire in Heraclitus is a very complex one, having different meaning according to the relative context. In this fragment we believe that it expresses the most general aspect of the world state; in modern terminology this aspect corresponds to the notion of the vacuum, the Dirac aether, a vacuum full of energetic particles (matter) and radiations. We make thus the assumption that the everliving Fire is equivalent to the modern notion of vacuum. Thus the world came out of the everliving Fire and 'lives' in the everliving Fire.

Third, Heraclitus drops out the idea of the creation of the world by a metaphysical force or being. In this line of thought, asking where the world came from, we are evidently in the limit of science (because nothing as the creation of the world could ever be proved by experiment, the sole criterion used by science. Nevertheless some observational data of astronomy and astrophysics could be –and actually are– used to test the proposed theories). Modern cosmology, based on some daring modern physical theories, tries to give an answer to this question. If this answer will deserve to be called scientific it is not our purpose to discuss it here. Thus, according to one of the most recent hypotheses the universe came out of a sudden, random disturbance of the vacuum [4]. Admitting now the equivalence of the everliving Fire to the vacuum and the correspondance of the Logos to the structure of space-time (which gives the deepest law of physical processes), we have Heraclitus proposition for the origin of the universe (cosmos). To these ideas one now should add this surprising, this astonishing fr. 48*, in which the poet says: "The fairest universe is but a dust-heap piled out at random". As this is a hypothesis both in Heraclitus word and in modern cosmology, the correspondance may be admitted without much arbitrariness. Here, we try to give a deeper physical meaning to Heraclitus ideas which constitute the 'mythology' [5], i.e. the first roots of modern ideas. And this

constitutes the grandeur of Heraclitus thought as well as of the whole set of ideas expressed by the philosophers of antiquity.

We should add some remarks on Heraclitus use of the words. In his work we encounter many times this kind of ‘amphisemia’ (double-meaningness) and the notional wealth of the words used by Heraclitus, words that in many cases express adequately the very nature of the things they describe. Thus, e.g., the word Fire in a case could ‘mean’ the energy; in a second case Fire is identified to the common constituent of all things, like the Logos; in a third sense, as in fr. 47* (the everliving Fire) it ‘means’ the vacuum (‘means’ here has the meaning explained previously: a try to enrich the physical content of Heraclitus sayings).

Indeed, in the following fragments it is more appropriate to give to the word Fire the meaning of energy. And the Logos, the general law of nature, includes all the fundamental principles of conservation as well as the laws of motion, to which Heraclitus makes reference in the subsequent fragments.

In fr. 49* he says that all things move according to laws that result from the general law, the Logos, the Measure. The fragments 50*, 51a* and 51b* constitute a try to a quantitative expression of the principle of conservation of matter and energy (admitting that Fire expresses the energy, which also follows from the neighbouring fragments, and that sea and earth express the matter). In fr. 51b* is expressed the principle of transformation of energy in other forms of energy or in matter and vice versa. And all these happen because there is a hidden general law which rules “(the) need and (the) satiety” (fr. 52*). The changes lead sometimes to some stable forms (equilibrium states, fr. 53*), although the general rule is that the changes come out of the interactions of the things themselves, which thus ‘toil’ to conserve their identity, which results in their ‘weariness’, the loss of ‘force’, i.e. of energy (fr. 54*) and thus leading to a more stable state.

Now, the particular role of Fire, even the ‘condensed’ Fire, is pointed out in the fr. 55*: “Thunderbolt steers all things”; thus the correspondence of Fire to energy is made more evident; which is underlined more emphatically in fr. 56*: the Fire (energy) controls the interaction of all things; and “having come upon them, will judge and seize upon all things”. There comes in the appropriate place the fr. 57*, which expresses the action of fire according to the previous fragment. The Fire is subjected to changes of any kind, which here (fr. 57*) is expressed

by the verbs "it scatters and gathers, it comes together and flows away, approaches and departs", verbs with opposite meaning.

We note thus the exceptional role that Fire plays in Heraclitus world system. It is known that for many greek philosophers fire was considered (e.g. by Plato) as one of the four fundamental constitutive elements of the universe. In Heraclitus thought Fire plays an essentially particular role, acting on all things and intervening in all physical processes controlling them quantitatively. Moreover, as it is evident from fr. 47*, Fire is the deepest essence of the world; it changes continuously ("Kindling in measures and going out in measures") and gives rise to all physical phenomena.

The meaning of fr. 58* is also deep and similar to that of fr. 41*: "The sun is new each day"; this means that the sun changes every day, as a result of some unobserved changes that occur on it. This view about the sun is in harmony with the general view, expressed in many cases, that all things change with time. In fr. 59* Heraclitus introduces the idea of soul and those of 'genesis' and 'death'. In the broader context of Heraclitus physical ideas, the soul is referred to one of the states of matter, more probably the gaseous state, and then water and earth stand for the liquid and solid states respectively. Thus fr. 59* describes the changes from one state to another; and 'genesis' and 'death' refer to these changes.

In the following two fragments (60* and 61*) the soul, as Fire, takes a more general meaning, it is a higher quality, whenever it is dry, and thus one cannot find its boundaries "even by travelling along every path: so deep a measure does it have". Even the notion of god in Heraclitus loses its metaphysical meaning and is meant as a physical being, similar to Fire, changing and giving rise to opposites (day-night, winter-summer, war-peace, satiety-hunger, fr. 62); i.e. the god of Heraclitus is identified to the notion of energy, in its absolute brightness and its ontological necessity. It is the really being, the constitutive element of every being. It is, in other words, the fundamental element of Heraclitus ontology. A similar treatment of this notion is encountered in Aristotle and Einstein. But Heraclitus was the first to express these fundamental ontological ideas. God is then the highest law, which is always true; yet there are men who do not know this law and so they suppose "some things to be unjust, others just" (fr. 63*). The next fr. 64* expresses the same idea.

In the last fr. 65* we have a deep analysis of the notion of time in Heraclitus thought. The disadvantage in this case is that we do not pos-

sess a similar fragment to which we could found our reading. Our interpretation will take into account the whole scheme of Heraclitus physical theory and will thus be a modern interpretation. A first reading goes as the following: $\alpha\omega\nu$ (i.e. age, century, time which we first identify with a man's life-time) is like a game of chance and whoever plays with devotion for it (like a child does), he does win, *he wins the life*, which acquires thus its full meaning through the participation to the game.

Now, in a broader context again, we could give a deeper interpretation to this fragment: The $\alpha\omega\nu$ is the Time, which plays an essential role in the evolution of the world and in the physical processes. Time 'plays' with physical phenomena as a child plays a game of draughts. The notion of the game introduces the probabilities that (as in a game of chance) emerge in the process of physical phenomena giving rise to the one or the other result. Thus Time is the physical entity which governs the process of physical phenomena. But this game of Time is not a completely random process. It is a game with concrete rules: the laws of nature. Thus the development of the game, that splendid game of the world and of its phenomena, is tied to the essential, but hidden, law, the Logos, about which Heraclitus has already spoken. For this reason, i.e. because there is a hidden general law in nature, there is not the probabilities that govern the world but Time as a parameter-variable who enters into this law, and thus Time, through this law (as the child in Heraclitus fragment) governs the function of the world and the process of the phenomena in it.

5. Conclusion

"In spite of much obscurity and uncertainty of interpretation, it does appear that Heraclitus thought possessed a comprehensive unity which ... seems completely new. Practically all aspects of the world are explained systematically, in relation to a central discovery –that natural changes of all kinds are regular and balanced, and that the cause of this balance is fire, the common constituent of things that was also termed their Logos [6]" .

In many cases we stressed to the point that in reading Heraclitus fragments we have to make some comment referring to the ideas adopted by modern physics. This does not mean that Heraclitus could make explicit allusion to such ideas. But it seems reasonable to suppose that he had caught an important part from the essence of the physical processes. We mean this in the same way one could support that many ancient

greek philosophers (e.g. the atomists, Aristotle and others) spoke with a remarkable accuracy and insight over many of the problems referring to cosmos as well as to human behaviour. Heraclitus was one of the most original thinkers, who consistently presented an ontology as well as a general theory of physical phenomena.

Heraclitus believes in the existence of an objective reality which, in spite of the difficulties due to the multiformity and the complexity of physical phenomena, we may understand and describe, at least this part of men (today the specialized scientists), who hope and search to find the unexpected, who believe in the deepest connexion of all (things) and in the preponderant role of the unifying law of nature, the Logos of Heraclitus.

We saw, thus, that Heraclitus is based on an ontology and a gnoseology that having been developed through the centuries in the course of the evolution of philosophical ideas, constitute the fundamental principles on which is based the thought of all those scientists of our era who are characterised as realists, like Einstein, de Broglie, Schrödinger and others.

Heraclitus also believed that, in the last analysis, it is experience (observation for the ancient philosophers, observation and experiment for contemporary science) that constitutes the last criterion of our theories. But he admitted also (and had applied it with bewildering farsightedness) the epistemological principle that observation (today, experiment) is guided by theory, which is based on some fundamental principles and hypotheses such as symmetry principles, the principle of the unity of the opposites and so on.

Heraclitus invocation that man ought to search for the Logos in order to understand cosmological and anthropological problems refers indeed to the instigation for a complete *mise en valeur* of our intellectual faculties, which leads to invention and understanding of the fundamental principles. This is the foundation-stone of Heraclitus philosophy and this seems to be the main line of thought in contemporary physics.

References

- [1] Kirk G.S. and Raven J.E., *The Presocratic Philosophers*, Cambr. Un. Press, Cambr. 1977, p. 184. The fragments borrowed from this book are the following: 1, 6, 8, 10, 11, 12, 13, 14, 24, 26, 27, 28, 31, 32, 33, 35, 37, 41, 42, 44, 47, 49, 50, 51a, 51b, 55, 57, 58, 59, 60, 61, 62 and 63. The remaining come from reference 3.

- [2] Ibid., p. 185.
- [3] Freeman K., *Ancilla to the Presocratic Philosophers*, Oxford, Basil Blackwell, 1971.
- [4] Davies P.C.W., *Superforce, the search for a Grand Unified Theory of Nature*, Unwin Paperbacks, London, 1984.
- [5] Christidis T.M., *La mythologie des ondes et des corpuscules*, Ann. Fond. L. de Broglie, **13**, 259 (1988).
- [6] Cf. footnote 1, p. 214.

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