A note on Einstein's Annus Mirabilis

Michael Bushev

Bulgarian Academy of Sciences, Institute of Solid State Physics
72 Tzarigradsko Chaussee blvd., 1784 Sofia, Bulgaria

ABSTRACT. Within one only year, 1905, Einstein framed the three epoch-making theories of relativity, of Brownian movement and of photoelectricity. This year of creative outbreak - Einstein's ANNUS MIRABILIS - raises the crucial question : what was the common source of these seemingly different problems within the context of physics at the time ? In the proposed here symmetrized connection of the physical theories centred around the phenomena of light, Einstein's research program is represented as a response of the genius to the state of physics at the turn of 20 century and a problem addressed to the science of coming 21 century.

RÉSUMÉ. Au cours d'une seule année, 1905, Einstein a élaboré trois théories qui font époque : de la relativité, du mouvement Brownien et de la photoélectricité. Cette année d'explosion créatrice - l'ANNUS MIRABILIS d'Einstein - soulève une question crucialle : qui est la source commune de ces problèmes apparemment différents dans le contexte de la physique de l'époque ? Dans la liaison symétrique des théories physiques ici proposée, centrée autour des phénomènes de la lumière, la programme de recherche d'Einstein est présentée comme la réponse du génie à l'état de la physique à l'aube du 20-ème siècle et comme un problème adressé au 21-ème siècle

> *"I will never stop pondering on the question of the essence of light."*
>
> A. Einstein [1]

1. ANNUS MIRABILIS

In 1905 the 26-year-old expert in a patent office in Bern, Albert Einstein, published in ANNALEN DER PHYSIK 5 papers which later turned to be the prime sources of three fundamental fields in physics : quantum theory (QT), theory of Brownian movement (BM) and theory of relativity (TR). The distance of time as well as the overall development of scientific thought during the coming to its end 20th century, brightly illuminated by Einstein's prophetic ideas found in his 1905 works allow to unhesitatingly call this year Einstein's ANNUS MIRABILIS [2,3]. Let us recall some basic facts about these works :

1. *On an heuristic viewpoint about the emergence and conversion of light* [4] - submitted in March. For the first time the idea of light quanta (photons) was applied to explain the photoelectric effect, the photoionization and related phenomena. In 1921 Einstein won the Nobel prize "For services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect".

2. *A new determination of the molecular dimensions* [5] - submitted in April. This was Einstein's doctoral thesis in which a relation was established between drift mobility and diffusion coefficient.

3. *On the movement, required by the molecular theory of heat, of particles suspended in a motionless fluid* [6] - submitted in May. The theory is built of Brownian movement, the reality of molecules is demonstrated as well as of their heat motion, and the statistical methods for the analysis of this motion are elaborated.

4. *Towards the electrodynamics of moving bodies* [7] - submitted in June. The special theory of relativity (STR) is built in which the dynamics of bodies and fields is unified by the relativistic invariance of movements in the four-dimensional space-time continuum.

5. *Does the inertia of a body depend on the energy it contains ?* [8) - submitted in September. It is shown that the answer to this question is positive, and the inference is made that : "If the theory corresponds to the facts, then radiation transmits inertia between the emitting and the absorbing bodies".

Each one of these works solves specific physical problems. At the same time each of them reveals easily discernible features of a program vision. The latter is confirmed by the further investigations of Einstein on QT (specific heat capacities of bodies, emission and absorption of radiation, quantum theory of a monoatomic ideal gas), on quantum statistics (the series of papers on Bose - Einstein statistics), and on TR (whose development culminated in the General Theory of Relativity and continued in the works on cosmology and the attempts to build a unified field theory).

2. The enigma of ANNUS MIRABILIS

The 1905 papers of Einstein treat three so different areas of physics that one can only be astonished by the ability of the author to cover them essentially at one and the same time in his studies. It is a matter of fact that even today, at the end of the century, TR, QT and BM represent rather distant sections in the courses of theoretical physics. In the abundant biographical studies about Einstein and in the memoirs of his collaborators and contemporaries the separate discussion predominates of the works from ANNUS MIRABILIS.

"But how could such a miracle originate in his mind ? This question is . . . illogical. For if our mind could cope with this "how", then there would be no more miracle". This is what Einstein himself wrote about Newton [9].

It is not my intention to step on the shaky ground of the psychology of creativity by asking the question : how could such a miracle occur in Einstein's mind ? Instead I shall make an attempt to understand by what logic of the situation in physics at the beginning of 20 century Einstein's 1905 studies are parts of one and the same problem.

That such a formulation of the question is not only possible but is also quite sensible one can detect in the writings of closely related to Einstein scientists, such as Louis de Broglie, Max Born and Wolfgang Pauli. In 1949 De Broglie wrote : "It is by no accident that the creator of the theory of relativity is also the precursor of wave mechanics and of modern quantum theory" [10]. Again in 1949 Born stated : "Einstein's view of the physical world cannot be divided into waterproof sections, and we could not even imagine that he would bypass some of the fundamental problems of his own times" [11] . And Pauli, in his habitual point-blank manner, noted in 1958 : "One can clearly see from Einstein's lecture, given in 1908 at the congress of natural scientists in Salzburg, how closely related were at that time (1905) his works on TR and QT" [1] . It is only to be regretted that such a perceptive thinker as Pauli did not set himself the task of thoroughly retracing the relationship between the three mentioned directions of study.

It should be noted that though Einstein himself emphasized in the above mentioned lecture [12] the profound interrelation between TR, QT and statistics, he left behind the screen the logic he was guided by in his 1905 studies.

However, he left no doubt that there was such a logic, as well as a problem connected with his 1905 publications. In 1922, when his collected works were published for the first time, in Japan, Einstein wrote a short preface to this publication. There we find the significant words : "I would like to especially draw the attention of my younger colleagues to the works on special relativity, on the theory of Brownian movement and quantum theory, published in the period between 1905 and 1917, and containing certain ideas which, as it seems to me, have not received enough attention" [13].

It is utterly reasonable to assume that Einstein spoke, in particular, of a problem emerging on the crossing of the mentioned by him three directions of study, a problem related to deeply hidden common roots of relativity, quanta and statistics.

3. Light and contradictions

What was the state of physics on the eve of ANNUS MIRABILIS ? On the threshold of 20 century the scientific community felt inclined to generally appraise the situation in physics as more or less serene and unclouded. Lord Kelvin saw only "two small clouds" on the horizon of physics, and within the physical community the opinion was widely shared that the edifice of physics was practically completed [14]. As a matter of fact, the idea of "the end" of the scientific enterprise in physics was floating in the air.

A talented person solves problems which others cannot, while a genius solves problems which others cannot perceive. The feature which emphatically distinguished Einstein from his contemporaries is the comprehension of the state of ideas in physics toward the beginning of 20 century. His numerous subsequent publications contained a critical analysis of the theories existing at that time and thereby revealed the areas of contradictions not realized even by the most distinguished representatives of the scientific community of the time. Here is how Einstein characterized in his *Autobiographical Notes* (1949) the situation in physics toward the beginning of 20 century : "Although in separate areas physics was flourishing, in the questions of principle a dogmatic stagnation dominated. At the beginning (if there was such) God created Newton's laws of motion along with the necessary masses and forces. In this way everything was finished, and the rest has to be deduced by inference, as a result of the elaboration of the appropriate mathematical methods" [15].

The fundamental physical theories that had taken shape by the end of 19 century were : Galilei - Newton's dynamics (D), Faraday - Maxwell's electrodynamics (ED) and phenomenological thermodynamics (ThD).

Dwelling on thermodynamics, Einstein stated plainly that this is the only physical theory which, within the frames of validity of its basic concepts, will never be refuted [15].

Newton's dynamics was qualified by Einstein as "the foundation of mechanics" and as "the program of all theoretical studies in physics until the end of 19 century", the program of optics (corpuscular and subsequently wave optics) and the foundation of the kinetic theory of heat [16]. Weak points of this theory are the concepts of absolute space and time, the understanding that light consists of particles of substance, the arbitrary character of the interaction forces, and so on [17].

Electrodynamics raised the continuity of fields as an opposition to the discrete character of material particles in dynamics and became the basis of the wave theory of light confirmed by experiments. ED was the second program in theoretical physics ; it was not complementary to D but even competed with it [18].

Einstein was the first to discern the areas of conflict between the fundamental theories.

The conflict between D and ED was particularly expressed in the phenomena of light propagation (e.g. the Michelson - Morley experiment). The electron theory of H. Lorentz (ETL) was an attempt to unify D and ED through a compromise between the continuity of electromagnetic fields and the discreteness of electric charges (Newtonian particles). However, this theory encountered too certain difficulties posed by light ; for example, the Michelson - Morley experiment cannot be explained without additional *ad hoc* hypotheses [19].

The problem of black-body radiation was the arena where ThD and ED clashed. The way out of the contradiction was shown by Max Planck (1900) who raised the hypothesis that the energy of a system of electromagnetic resonators consists of discrete energy quanta. Thus light was rooted again in the contradiction which necessitated (once more *ad hoc*) the quantum hypothesis [20] . Finally, D and ThD clashed not only on the ground of the kinetic theory (where the contradictions reversibility-irreversibility and atomism-energetism were most expressed [21]) but also in connection with the behavior of a material body under the action of light pressure.

Thus we conclude that the fundamental theories clashed on the ground of problems at the root of which light unavoidably lurked [22]. The theories which Einstein found at the beginning of the century, as well as those which embodied the attempts to solve the existing contradictions between the fundamental theories, were as follows : (I) the contradiction D + ED - the electron theory of Lorentz (ETL) ; (ii) the contradiction D + ThD - statistical mechanics (SM) ; (iii) the contradiction ThD + ED - quantum hypothesis (QH). This is illustrated by Figure 1.

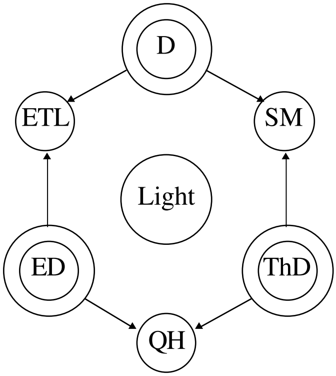

Figure 1. The theoretical background by ANNUS MIRABILIS : fundamental theories (D - dynamics, ED - electrodynamics, ThD - thermodynamics), their contradictions related with light, and the attempts to solve these (ETL - electron theory of Lorentz, QH - quantum hypothesis, SM - statistical mechanics).

4. Einstein's program

Einstein never offered explicitly the above picture. Still it is to a great extent extracted from his writings. If we assume that such a picture underlied Einstein's research program by ANNUS MIRABILIS, then we shall arrive at some fascinating results :

1. The earliest publications of Einstein, those from 1901 to 1904, represent his research on molecular-kinetic theory and statistical mechanics [23] . They are continued in the papers (2) and (3) from ANNUS MIRABILIS. With regard to this cycle of works Einstein says : “My primary goal was to find out such facts which would confirm in the most reliable way the existence of atoms of definite finite sizes” [24] . It is clear that in these works Einstein concentrated his efforts on the part of the program containing D-SM- ThD. The outcome were his findings

in the theory of fluctuations and specifically of the Brownian movement. Thus he came to the irrefutable proof of the atomistic hypothesis [25] and alongside with that attained the conviction that statistical mechanics incorporates features of mechanical as well as of thermodynamical description.

2. Einstein was the first to accept (Planck's hypothesis of) quanta as physical reality and considered radiation as an aggregate of independent quanta [26]. This allowed him to approach the problem of heat radiation as a problem of gas of particles, viz. light quanta, in a closed volume. Considering a semitransparent mirror in the field of such a radiation (i.e. a lamella in photon gas), Einstein came to the obtained earlier by him expression for the average momentum of a Brownian particle. This was a natural road to the problems of ED-QT-ThD (Fig. 1), where Einstein explored specifically the phenomena of photoelectric effect, photoionization, etc. Thus the idea of the structural nature of radiation (corpuscular aspect of light) won recognition, and on the ground of the dilemma wave or particle character of light the contradiction D-ED came to the fore. The photoelectric effect proved the restricted validity of Maxwell's theory.

3. Making his way into the third part of the program, ED-ETL-D, Einstein leaned on the relativistic invariance of ED [27]. However, knowing the restricted validity of the theory of Maxwell (e.g. the photoelectric effect), he postulated the general covariance of natural laws with respect to Lorentz transformations. In his special relativity (SR) he obtained the unification of D+ED which was free of the flaws of ETL and also allowed him to come to the celebrated relation between energy and mass. The idea of mass of the radiation convinced him that radiation must possess specific structure. The (reversible) conversion of light quantum $h\nu$ into energy of the electron ε brought Einstein back to the photoelectric effect [28].

Thus the complete cycle was closed of the program in the center of which stood light. In this cycle the cell ETL (Fig. 1) was superseded by SR, QH turned already into QT, and in the cell of SM atomism also gained the status of a theory. Einstein had an acute sense not only of the contradictions but also of the asymmetry in a theoretical construction [29]. It is quite credible that the three theories created by him, namely, SR, BM and that of the photoelectric effect (PhE), - came as a result of his marked pursuit of unification and symmetry of the theories, for instance of the type shown in Fig. 2.

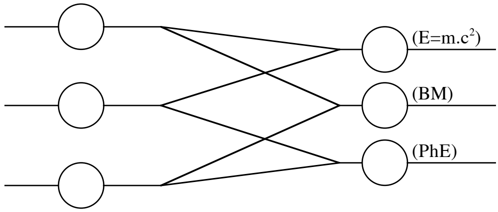

Figure 2. The unified, and symmetrized, picture of the physical theories (SR - special relativity, SM - statistical mechanics and QT - quantum theory) which came into being after ANNUS MIRABILIS.

It is the belief of the present author that this picture of a symmetrized unification holds a clue to Einstein's ANNUS MIRABILIS.

5. Einstein's aporias

Einstein's ANNUS MIRABILIS gathers as if into a focus the whole creative work of the great scientist. In it the analysis is contained of the physical picture of the world found by Einstein, as well as his own scientific program. The centre of this program, at least in the early stage, was the question of the essence of light. Looking for the answer, Einstein faced the dilemmas : fields - particles, continuity - discreteness, determinacy - indeterminacy. They remind of the centuries-old Zeno's aporias (all the time solved and never completely resolved). Einstein not only came to the formulation of these aporias (e.g. the famous Bohr - Einstein debate, the EPR paradox, etc.) but, in his inclusive program embracing the General Relativity, made titanic efforts to solve them.

This is a grandiose program addressed to the future. It demonstrates that "in science the movement forward is always a return back to the foundations" (G. F. Hegel) ; it also shows that every paradigm is only a limited stage in the cognitive process, and for this reason a phrase like "end of science" should be interpreted simply as the end of the existing paradigm [30].

On approaching the end of 20 century one feels an urge to turn back to its main achievements. No matter how controversial the image is of the expiring century, Einstein's ANNUS MIRABILIS marks a bright vision of human nature(31).

Notes and References

[1] W. Pauli.*Albert Einstein in der Entwicklung der Physik*. Universitas, 13, p. 593-598, 1958.

[2] Max von Laue. **zu Albert Einsteins 70-tem Geburtstag**. Rev. Mod. Phys., 21 (1949), No 3, p. 348. In this article Laue speaks of *Denkwürdige Jahre* 1905 (the remarkable year 1905) and of *Schicksalsjahre* 1905 (the decisive year 1905).

[3] S. Weinberg. a) *the discovery of subatomic particles*. W.H.Freeman and Co. New York - San Francisco, 1983 ; b) *dreams of a final theory*. Vintage, London, 1993. In both books Weinberg speaks explicitly of the year 1905 as Einstein's **annus mirabilis**.

[4] A. Einstein. über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. Ann. der Physik, 17 (1905), s. 132.

[5] A. Einstein. eine neue Bestimmung der Moleküldimensionen. (Inaugural dissertation, Zürich Universität) 1905.

[6] A. Einstein. über die von molekülarkinetischen Theorie der Wärme Geforderte Bewegung von in Ruhenden Flüssigkeiten suspendierten Teilchen. Ann. der Physik, 17 (1905) s. 549.

[7] A. Einstein. zur Elektrodynamik der bewegter Körper. Ann. der Physik, 17 (1905), s. 891.

[8] A. Einstein. ist die Trägheit eines Körpers von seinem Energieinhalt abhängig ? Ann. der Physik, 18 (1905), s. 639.

[9] A. Einstein. Isaak Newton. Manchester guardian, 19 March 1927.

[10] Louis de Broglie. L'oeuvre d'Einstein et la dualité des ondes et des corpuscules. Rev. Mod. Phys., 21 (1949), No 3, p. 345.

[11] M. Born. the statistical theories of Einstein. In : Albert Einstein : Philosopher - Scientist, 1949. Here, among other things, Born stressed that Einstein succeeded to raise the kinetic theory of matter from the level of likely, probable, useful hypothesis up to the level where it would have observable results.

[12] A. Einstein. über die Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung. Phys. Zs., 10 (1909), s. 817. This paper of Einstein inspired De Broglie to conjecture the wave aspect of electron's motion and thus to predict wave-particle duality. (Cf. e.g. L.Lederman and D.Teresi. the God particle. New York, 1993. Ch.5.)

[13] A. Einstein. foreword to the Japanese collected scientific papers of Albert Einstein. Kaizosh Publ. House, 1922.

[14] In his famous lecture "The clouds of 19 century over the dynamic theory of heat and light" given on the edge of the two centuries, in 1900, Lord Kelvin spoke of two small clouds on the horizon of physics, namely, the negative result of the Michelson - Morley experiment and the blackbody spectrum. Historians and philosophers of science often point to this excessive optimism of the leading scientist and to the playful smile of Clio as the two Kelvin's "small clouds" did not wait to give birth to the theory of relativity (A. Einstein, 1905) and to quantum theory (M. Planck, 1900).

[15] A. Einstein. Autobiographical notes. In : Albert Einstein - Philoso- pher Scientist , ed. by P. A. Schilpp. Evanson (Illinois), 1945, pp. 1 - 95.
[16] Opus cit. [9].
[17] A. Einstein. Maxwell'S influence on the development of the concept of physical reality. In : James Clerk Maxwell : A Commemoration Volume. Cambridge University Press, 1931.
[18] ibid. It should be noted that even after the quantum and relativistic theory were well established, the scientific community still tended to regard Newton and Maxwell as "the tandem of classical physics" ; Maxwell was esteemed as "a distinguished continuator of the great achievements of Newton" (see e.g. N. Bohr's paper in : James Clerk Maxwell : A Commemoration volume. Cambridge Univ. Press, 1931). The contradictions between Newton's and Maxwell's physical worldviews were still effectively disregarded.
[19] See Ref. [9]. The asymmetrical explanation of electromagnetic induction, which depends solely on the relative motion of the magnet and the conductor, is a fundamental drawback of the theory (of Maxwell - Lorentz), as "asymmetry is not inherent in phenomena" (A. Einstein, opus cit. [7]). Namely, arguments of such a type were critical for the formulation of relativity by Einstein, not the negative result of Michelson - Morley experiment, which in this context was irrelevant and for this reason was not mentioned in [7].
[20] A. Einstein, opus cit. [9].
[21] With the establishment (by the middle of 19 c.) of the universal law of energy conservation a new method of study, called energetic (and also thermodynamic or phenomenological) appeared in science. The main feature of the method was that processes were considered as energy transformations, the internal mechanisms being disregarded. Based on this method, the philosophic concept of energetism (often associated with the name of the Scots engineer William Rankine) originated by the end of 19 c. Energetism insisted that energy in thermodynamics should be considered in no relation whatsoever with the movements of molecules, and even suggested that the concept of matter be replaced with that of energy. The dramatic clash between atomism and energetism reached its climax in the suicide of Ludwig Boltzmann (in 1906) who was driven to despair by his intellectual isolation among such powerful scientific adversaries as H.Poincaré, W.Ostwald, E.Mach (see, for example, the book by P.Coveney and R.Highfield, THE ARROW OF TIME, London, 1990, pp. 21-22).
[22] In the first of the two fundamental books of Roger Penrose devoted to the problem of mind from physicist's point of view (THE EMPEROR'S NEW MIND, Oxford Univ. press, New York, 1989) I found almost the same viewpoint clearly expressed. Penrose wrote : "It is a striking fact that all the established departures from the Newtonian picture have been, in some fundamental way, associated with the behaviour of light.. First, there are the disembodied energy-carrying fields of Maxwell's electromagnetic theory. Second, there is the crucial role that the speed of light plays in

Einstein's special relativity. Third, the tiny deviations from Newtonian gravitational theory that Einstein's general relativity exhibits become significant only when speeds need to be compared with that of light. (Light deflection by the Sun, Mercury's motion, escape velocities in black holes, etc.). Fourth, there is the wave-particle duality of the quantum theory, first observed in the behaviour of light. Finally, there is QED which is the quantum field theory of light and charged particles. . . Newton himself would have been ready to accept that deep problems for his picture of the world lay hidden in the mysterious behaviour of light." (p. 221). Einstein took this "mysterious behaviour of light" as a starting point in his 1905 studies.

[23] Einstein's first scientific paper was written in the form of a letter to his uncle, in 1896. The title of this "paper" speaks for itself : "On the Study of the State of Ether in a Magnetic Field". There ether is considered as an element of physical reality along with electric and magnetic fields ; see : R.Nougaev, a reconstruction of the process of supersedure of scientific theories, Kazan University, 1989 (in Russian).

[24] A.Einstein, opus cit. [9].

[25] Even Ostwald felt forced to publicly admit (in the preface to the next edition of his book "outlines of chemistry", 1913) that energetism had collapsed and that he himself had been wrong. His changed position was stated clearly and frankly in the following words : "The isolation and the counting of gaseous ions on the one hand . . . and on the other the agreement of the Brownian movement with the requirements of the kinetic hypothesis . . . justify the most cautious scientist in now speaking of the experimental proof of the atomic theory of matter. The atomic hypothesis is thus raised to the position of a scientifically well-founded theory". (Quotation from the paper : R. A. Millikan, Albert Einstein on his seventieth birthday, Rev. Mod. Phys., 21 (1949) No 3, p. 343).

[26] Strange as it may seem, Planck who was awarded the 1918 Nobel Prize "in recognition of the services he rendered to the advancement of physics by his discovery of energy quanta" nourished extremely skeptical feelings toward the very idea of jump-like processes and discreteness in Nature. At the beginning of 20 century most of the physicists shared these feelings. That is why, when Einstein applied the idea of quantization to specific phenomena, he came up against a strong opposition. Here are a few of the most impressive examples. Even in his Nobel speech (delivered in 1920) Planck emphasized how unacceptable ("monstrous and almost inadmissible") was for him, as a classically thinking physicist, the idea that the frequency of the light quantum might be differing from the frequency of the emitting electron. It was in 1913 when four of the most prominent German physicists, namely, Planck, Nernst, Rubens and Wartburg, on recommending Einstein for a member of the Berlin Academy of Sciences, incidentally wrote : "Among the great problems abounding in contemporary physics, there is not a single one toward which Einstein hasn't taken his important position. That is why he should not be blamed too severely that in his studies he sometimes steps out of

the boundaries of the target, as is for example his hypothesis of light quanta". (Quoted after : M. Born, Albert Einstein and light quanta, Naturwissenschaften, 42 (1955) p. 425). It was not accidental that Planck called the hypothesis of light quanta "Einstein's hypothesis". He himself, the inventor of the very idea of energy quanta, considered it only a convenient means for describing the black-body radiation. That is why one could state with confidence that the 1905 work of Einstein was the one which laid the foundations of quantum theory.

[27] A. Einstein, über das Relativitätsprinzip und die aus denselben gezogenen Folgerungen, Jahrbuch der Radioaktivität und Elektronik, 4 (1907) s. 411-462.

[28] The effect, discovered by A. Compton (1928) and bearing his name, is described by Einstein's relativistic formulae for the electron : $\varepsilon = mc^2$, p = mc, $m = m_o/(1 - \nu^2/c^2)^{1/2}$, and by Planck - De Broglie's quantum formulae for the photon : $\varepsilon = h\nu$, $p = h\nu/c$.

[29] See e.g. : P. H. Byrne, the origins of Einstein's use of formal asymmetries. Annals of Science, 38 (1981) pp. 191 -206.

[30] The conviction that science can reach one or another form of its "end" is shared by a number of leading contemporary scientists. Thus, R. Feynman firmly stated that in a not too distant future practically all laws (or 99,99 % of them) will be discovered and this will bring the scientific research to an end (R. Feynman, the character of physical law, Cox and Wyman Ltd., London, 1963, Lecture 7). St. Hawking, on becoming a Lucas professor (April 1979), delivered a speech on the topic of a plausible "end of theoretical physics" as a result of reaching the ultimate theory of matter (St. Hawking, black holes and baby universes, Bantam Books, 1993, Ch. 7). St. Weinberg published a book devoted to the idea of a forthcoming unified supertheory of all physical interactions (St. Weinberg, dreams of a final theory, Vintage, London , 1993) but firmly declared that "the discovery of a final theory will not end the enterprise of science" (p. 191). The 1989 Nobel Conference (The Gustave Adolf College, Minnesota, USA) was devoted to the topic "The End of Science" and the unanimous conclusion was summarized as follows : "The conviction grows that science as a universal and objective effort is coming to its end". On discussing this problem (M. Bushev, the thesis of the "end" of science and interdisciplinarity", The World of Physics, No 2, 1995, p. 9 ; in Bulgarian) the present author came to the conclusion already stated that a final theory or an end of science can make sense only within the context of the existing paradigm.

[31] **Acknowledgements**. This work was started some 10 years ago when in the University of Shoumen I read a 30-hour course of lectures on selected topics from the philosophy and history of science to teachers in physics and mathematics. In 1999 I gave a short talk at the Conference of the Bulgarian Academy of Sciences dedicated to the 120 anniversary of Einstein's birth. Discussions with numerous friends countenanced me when I was about to lose the Ariadne thread. Prof. V. Petkov (now in Canada) encouraged me to continue the study. Acad. A. Polikarov, known

for his in-depth studies of A. Einstein's life and work, was a hard to please but benevolent critic of the final versions of this study. Prof. N. Todorov encouraged me to submit this work for publication. It is a pleasure to thank them.

(Manuscrit reçu le 17 avril 2000)