NASA TECHNICAL MEMORANDUM NASA TM-76227

(NASA-TM-76227) THE CREATIVITY OF EINSTEIN AND ASTRONOMY (National Aeronautics and Space Administration) 16 p HC A02/MF A01 CSCL 03A

N81-13816

Unclas
G5/89 29461

THE CREATIVITY OF EINSTEIN AND ASTRONOMY

Ya. B. Zel'dovich

Translation of "Tvorchestvo Einshteyna i Astronomiya". Academy of Sciences USSR, Institute of Space Research, Moscow, Report PR-451. 1979, pp 1-14

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 JUNE 1980

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-76227		

4. Title and Subtitle	5. Report Date
THE CREATIVITY OF EINSTEIN AND ASTRONOMY	JUNE 10, 1980
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Ya. B. Zel'dovich	
	10. Work Unit No.
9. Performing Organization Name and Address	**11. Contract or Grant No.**
SCITRAN Box 5456 Santa Barbara, CA 93108	NASW-3198
	13. Type of Report and Period Covered
	Translation
12. Sponsoring Agency Name and Address	**14. Sponsoring Agency Code**
National Aeronautics and Space Administration Washington, D.C. 20546	

15. Supplementary Notes

Translation of "Tvorchestvo Einshteyna i Astronomiya", Academy of Sciences USSR, Institute of Space Research, Moscow, Report PR-451, 1979, pp 1-14

16. Abstract

A discussion is given of Einstein's scientific achievements for the 100th anniversary of his birth. His works dealing with thermodynamics are described, along with his quantum theory of radiation. Most of the article discusses his general theory of relativity.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	U.S. Government and contractors only.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified	14	

NASA-HQ

THE CREATIVITY OF EINSTEIN AND ASTRONOMY

Ya. B. Zel'dovich

Academy of Sciences USSR
Institute for Space Research

The development of physics and astronomy in the 20th century is a /2*
remarkable collective achievement of scientists from many countries. The development of science is closely interrelated with the development of technology: science becomes a productive force, enriching technology. However, there is also a reverse connection -- modern technology is opening new research possibilities for scientists, ranging from accelerators to extra-atmospheric X-ray telescopes.

However, the large-scale and collective character of modern science does not exclude the roles of individual scientists. Among the creators of modern physics, among those who had a decisive influence on the development of physics and astronomy over the last 100 years, the remarkable figure of Albert Einstein stands out. During the days when the 100-th anniversary of his birth is being celebrated (March 14, 1879 in the city of Ulm , Germany), it is appropriate to remember Einstein's scientific direction and achievements.

Einstein once wrote in an article dedicated to Newton: "To think of him is to think of his work". These words are also fully applicable to Einstein himself. His name is often associated with the special theory of relativity and the general theory of relativity (GTR). This is true, but it is far from the whole truth. Before turning to these theories, we would like to note other outstanding works of Einstein in order to show the tremendous range of his work.

---

*Numbers in the margin indicate pagination in the original foreign text.

Einstein devoted a number of works to the foundation of thermodynamics from the point of view of the molecular theory and to the application of thermodynamics to problems of radiation, absorption, and dispersion of light. These works are notable primarily for their clear ideological direction. The work of G. Gibbs on the strict statistical basis of thermodynamics was not yet known in Europe. Many people considered that thermodynamics fully replaced the molecular theory. In these conditions, the brave generalisations of Einstein were particularly significant. Particles consisting of hundreds of millions of atoms which are visible only through a microscope may also be viewed as large molecules. In the process of studying their movement, it is possible to verify the molecular theory. The experiments of J. Perren and Einstein's theory turned out to be the decisive quantitative substantiation for the molecular theory, and it was they that made it possible to determine the mass of molecules. Included in this group are also works on the theory of surface tension of liquids, viscosity of solutions, and others.

Long before the creation of the modern, logically complete quantum theory of radiation, Einstein formulated the principle: a new theory cannot change the conclusions of molecular theory concerning the translatory motion of molecules, even if the molecules emit and absorb light. As early as 1899, M. Planck proposed the hypothesis according to which light is radiated by quanta. It seemed that this did not alter the theory of light diffusion. However, an analysis conducted by Einstein showed that with every act of emitting or absorbing light, the atom undergoes a jolt. Therefore, a quantum of light is emitted in the opposite direction. There would be no efficiency if a wave were emitted in all directions. Thus, the concept of the light quantum (photon) as a particle first appeared.

Soon works followed which explained, from the quantum point of view, photo-effect, laws attributed to by the world of chemical reactions (the ionization of gas may be considered a special case of such a reaction) and the heat capacity of bodies. In 1917, also by a comparison of thermodynamics and quantum theory, Einstein draws the conclusion that excited atoms in a quantum beam will intensity this beam. Thus, the principle of induced radiation was formulated -- the principle which is at the basis of quantum radio-electronics, at the basis of masers and lasers.

Influenced by the work of Indian physicist, Bose, on radiation, Einstein develops a new quantum theory for gas, consisting of such particles as, for example, atoms of helium. Today we know that this theory is the basis for the phenomena of superfluidity and superconductivity. This in no way decreases the accomplishments of the physicists who created lasers and masers, who discovered and explained superfluidity and superconductivity. Naturally, it is these physicists more than others who value Einstein's contribution.

In 1926, Einstein simply and elegantly explained Ber's law, according to which in the Northern hemisphere rivers erode their right bank (it is assumed that the right side is determined by a person facing downstream). At first glance it is enough to say in explanation that centrifugal and Coriolis forces deflect the current to the right. However, a slight elevation in water level at the right bank may stop this deviation. Einstein notes that it is necessary to examine the bottom layer of water, and illustrates his position by the example of the behavior of tea leaves in a glass when put into a swirling motion by stirring with a spoon...

We will not continue. The illustrated examples are enough to get a feeling for the liberalness and breadth of talent which found problems everywhere and proposed solutions for them which remain significant for centuries. I believe that Mozart was this way in music and Pushkin in poetry. The complex of Einstein's work is taken as light, cheerful creativity. But in this same period, starting in 1905, work of unusual depth is also created.

Foremost is the special theory of relativity. Let us list some of its results: the unification of space and time, characterized by the Lorenz transformation and the Poincare group; the principle of equivalence of mass and energy, the famous formula $E = mc^2$; new relativistic mechanics, in which the mass of a particle increases infinitely as the speed of the particle nears the speed of light.

Of special significance for astronomy was the conclusion that the change of hydrogen into helium can provide stars with the necessary reserve of energy. This conclusion was made on the basis of only one measurement of atomic weights, long before nuclear physics was able to indicate concrete ways of realizing this process. We will note that in certain details there is as yet no full quantitative agreement of theory with practice. The measurement of neutrino obtained during secondary reactions in the Sun's interior, yields results which differ with calculations. However, the general totality of data definitely confirms the theory of thermonuclear energy sources within stars.

The principle of equivalence also predicted the possibility of emitting high energy as a result of the heaviest nuclei (primarily uranium) changing into nuclei of medium atomic weight, which is the basis for modern nuclear energetics.

Of great importance for astronomy was the theory of ultrarelativistic electrons and their radiation. The role of Soviet scientists is great in the development of high energy astrophysics.

The great cognitive significance of the special theory of relativity lies in the fact that this theory goes beyond the bounds of "common sense", and more precisely, beyond the limits of generalizations of everyday experience based on observations of relatively slow processes and phenomena. Therefore, based on everyday experience we intuitively, without noticeable error, utilize the concepts of simultaneity, of absolute time, of Galilean transformation (in a moving system the laws of physics do not change, time reading does not differ from time reading in a system at rest). It was difficult to reject these concepts. For many years, the theory of relativity was challenged, and numerous attempts were made to disprove it. However, the theory of relativity has been confirmed by experiments. It is not the whim of one man or a group of people, but rather it represents an important contribution to the knowledge of objective laws of nature. 17

It is curious (but sad) that anti-Einstein opinions have even today not ceased. Their content has changed. Instead of rejecting the theory, attempts were made to reject Einstein's role. The role of G. Lorenz, A. Poincare, and a number of other scientists was undoubtedly significant, and their names are preserved quite justifiably in the names "Lorenz transformation","Poincare group". However, G. Lorenz and A. Poincare examined the theory of electromagnetic phenomena, the reduction of linear dimensions of moving bodies as a concrete objective result in the changes of forces in the moving body (thus, for example, in the system of charges at rest there are only electrical forces, but if this entire system is moving -- a magnetic field appears). They came to the right conclusion, that as a result of the physical changes in a moving body its movement will be undetectable. However, only Einstein understood that /8 these changes in bodies and transformations reflect the true properties of space and time, that any theory of any phenomena in nature must be relativistic invariant, that all uniformly moving systems are fully equivalent. With this it was necessary to reject such fundamental concepts as absolute space and time, simultaneity. Thus appeared relativistic mechanics, thus requirements were formulated for future physical theories -- the theory of the neutrino, the theory of nuclear forces and mesons, and even for theories which are as yet not known to us today. It is specifically because of his cognition of a new nature in the connection between material and space and time and the universality of the special theory of relativity that Einstein was able to express the idea of energy of nuclear reactions long before the creation of nuclear physics.

Let us turn now to the general theory of relativity -- GTR. Is it necessary to remind the modern reader of its content? As a compromise, let us list very briefly the basic theses: space and time are described by Riemannian geometry. Roughly speaking, the complex of space - time is curved. The interrelation between the picture of the world of the special theory of relativity and GTR is the same as between the flat surface with Euclidian geometry and a curved surface.

Remaining from the special theory of relativity is the inseparable bond between space and time, which remains in force locally, in a small vicinity of any point in the world. Thus, a small area of a smoothly curved surface may be considered flat by a greater right than a smaller examined area. Space -- time has a certain elasticity. A certain set of values characterizing the curvature of space turns to zero wherever matter is absent (atoms, particles, electromagnetic field). Matter bends space - time, and the respective curvature depends on the density of the mass (equal to the density of energy divided by the speed of light squared), on beams, i.e., on movement of matter and on the pressure or stresses in matter.

It is easy to imagine that a bend in one place as a result of the elasticity of space - time causes a certain warping in the neighboring empty area. A subsequent examination of the problem leads to Newton's law of gravity. Newton's law is obtained as the ultimate law at a great distance from a massive body which creates a gravity field.

In the GTR, naturally, equality of inert and gravitational mass is set forth. Finally, the theory requires that the laws of preserving energy and impulse be fulfilled. As applied to the motion of individual bodies, this requirement leads to Newtonian laws of motion (this profound result was obtained as early as the 30's independently by Einstein and the Soviet scientist V. A. Fok and his associates).

New consequences of the GTR are associated with deviations from Newton's law. As compared with Newton's theory, predictions concerning the distribution of light in a field of gravity -- deflection of a ray and change in light frequency -- are changed. The existence of gravitational waves is predicted -- unique changeable fields of gravity.

The first "contacts" of the GTR with astronomy took place specifically along the line of checking new inquiries. Anomalies in the motion of Mercury, which were inexplicable in Newton's stellar mechanics, substantiated the GTR. For the first time in 1919, two years after its prediction, the deflection of stellar light during passage of the ray near the sun was verified. Modern

radio astronomy has made it possible to measure this deflection with precision of up to 1%. The shift of spectral lines was also confirmed /10
by astronomical observations (later it was possible to discover this phenomenon also in the laboratory during experiments in which there was a drop or rise in gamma-photons with a total height difference of 25 m).

It may be said that at that time astronomy gave more than it received. Astronomy convinced physicists of the correctness of the GTR. It must be said to the credit of astronomers that they are impartial. They like situations in which the fate of a physical theory depends on the results of astronomical observations. As strange as it may seem, astronomers find this situation more favorable than the reverse, in which physicists take it upon themselves to determine what is possible and what is impossible in the heavens...

The predominant role of gravity in astronomical phenomena is obvious and is not subject to doubt since the times of Newton. Nevertheless, for several decades (from approximately 1920 to 1960) it seemed that the creation of a principally new theory of gravity -- GTR -- gives little to astronomy. The fact was overlooked that the laws of gravity and motion of classical mechanics took on their true substantiation within the framework of the GTR. They became conclusions of more fundamental premises. Pragmatically minded astronomers said that one way or the other, celestial mechanics were created before Einstein, and there were few corrections left for the GTR to make... Such a "localized" point of view (limited to our solar system or our galaxy) was already not shared by all in the indicated period.

The first application of the GTR to astronomy with fundamental results is associated with cosmology. Einstein stated the question, but in his first work his intuition failed him. Einstein was seeking a solution which would describe the unchanging static Universe. It is known that the correct solution was found in 1922 - 1924 by our countryman A. A. Fridman. After a /11 short discussion, Einstein confirmed the formal correctness of this solution. The discovery of the red shift by Hubble convinced Einstein of the fact that our Universe is indeed evolving. Moreover, in the 30's, when astronomers were attributing greatly overstated significance to Hubble's constant, Einstein noted the difficulties associated with the fact that the age of the earth (4-5 billion years) is greater than the age of the Universe. Today we know that the age of the Universe is 15-20 billion years. This follows from new measurements of expansion of the Universe and corresponds well with all other astronomical and geological data.

The original example of applying the GTR in astronomy takes place before our very eyes, primarily in connection with the discovery of radio pulsars, X-ray pulsars, and compact sources of X-ray radiation.

In all fairness we must note that the existence of ultimate mass for dwarf stars followed from Newtonian theory. The change of a substance from a combination of individual nuclei surrounded by electron gas into a neutron liquid was predicted in the mid 30's by both physicists and astronomers. L. D. Landau, R. Oppenheimer, V. Baade, F. Tsvikki wrote about neutron stars; astronomers associated the formation of neutron stars with the flaring of supernova. Moreover, at the end of the 30's, R. Oppenheimer and H. Snyder investigated relativistic collapse and the formation of the black hole. And still these works did not attract great attention from astronomers until the mid 60's, possibly because there was no observational inquiry.

A new uplift began with the work of V. A. Ambartsumyan and G. S. Saakyan, J. Wheeler and the Moscow group of astrophysicists. It became clear that if not the neutron stars and black holes themselves, then the gas falling on /12 them must be a strong source of X-ray radiation. And this discovery coincided with the birth of X-ray astronomy. The discovery of radio pulsars was to some measure unexpected for theoreticians, and now we know that they emit great energy in the gamma range. Today the GTR is at the center of attention for all of astrophysics. In particular, attempts are being made to link the puzzling phenomena in quasars and centers of galaxies with black holes.

But we are not describing the entire history of astrophysics, but are merely outlining the history of Einstein's scientific work and his brainchild -- the general theory of relativity. Einstein once said that all his other works would have been realized if not by him then by others, maybe 2-3 years later. But for the GTR he made an exception. He said that the birth of the GTR may have been delayed without him for as long as 50 years.

A remarkable coincidence: it was precisely in the 60's that theoretical physicists better understood the structure of field theories. These theories are closely tied with laws of conservation. The conservation of an electrical charge (together with the special theory of relativity) dictates the form of the theory of the electromagnetic field. In this same sense, the conservation of energy and impulse dictates the form of the theory of gravity. A conscientious, although not a brilliant theoretician will today routinely come to the conclusion that Newton's theory needs to be generalized. He will come to the conclusion that gravitational waves must exist. Moreover, he will see that the gravitational field itself has energy, "weight", and therefore it acts upon itself. Consequently, the theory is non-linear. This is how the theory is built, all of whose conclusions coincide exactly with the GTR (today this is observed in detail). Therefore, is Einstein's prediction being fulfilled?

This question cannot be answered singularly, because it is impossible to raise /13
a good theoretician, shielding him until scientific maturity. Will such a "guinea pig" guess that his theory is equivalent to the GTR in its conclusions? But without this guess, without this idea of the curving of space - time which illuminated Einstein, we would have lost in considerable degree the beauty of the theory. There is every reason to believe that the further development of the theory of gravity and its unification with quantum theory will significantly utilize specifically the geometrical aspect of the theory. Einstein's achievements for science and for humanity are unsurpassed.

What can we say about Einstein the man? His wholeheartedness, clearness of purpose, and at the same time his humility, democracy, goodwill, and humor are striking. Let us quote an excerpt from a letter he wrote in 1912: " I have been living with my parents for three weeks now and seeking the position of assistant... I would have found it long ago had it not been for the intrigues against me. Nevertheless, I have decided to try all methods and do not lose my sense of humor. God created the donkey and gave him a tough hide. We are having a beautiful spring here and the entire world is bathed in a warm, happy smile... My friends who are music lovers do not let me be discouraged".

Einstein and music -- what harmony! I cannot imagine Einstein watching television or rooting for a hockey team...

Einstein's childhood years are interesting, and the subsequent statements associated with them concerning methods of teaching which "should not destroy the natural curiosity".

In 1923, Einstein together with other prominent German activists, organized the Society of the Friends of the Soviet Union. In 1926 Einstein was elected as a foreign member of the USSR Academy of Sciences. He sharply criticized fascism and left the Prussian Academy of Sciences. He criticized McCarthyism and the kindling of the cold war in the USA -- the country where he spent the /14
last 22 years of his life.

At the beginning of World War II, Einstein turned to the president of the USA, F. Roosevelt, with a call to urgently step up work on creating atomic weapons so that fascist Germany did not surpass the Allies. In 1945 Einstein criticized and agonized over the atomic attack on Hiroshima and Nagasaki. He keenly felt the atomic-hydrogen bomb threat to the existence of all mankind.

Einstein died of a rupture of a hardened aorta on April 18, 1955 at the age of 76.

One hundred years has passed since the birth of Albert Einstein, 60-70 years since the creation of the special and general theory of relativity. The figure of Albert Einstein -- the scientist and the man -- does not fade, does not become blotted out of our grateful memory. Years pass, and we are able to better comprehend the scientific greatness of his ideas, the full humanity and purity of his life.