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PROFESSOR EINSTEIN AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

ADDRESSES AT THE DINNER IN HIS HONOR[1]

MR. ALLAN C. BALCH, PRESIDENT OF THE ATHENAEUM:

THIS is a dinner of some two hundred California Institute Associates, held at the Athenaeum, a building designed as a club house and meeting center for three groups of people: First, the staffs of the three adjacent cooperating institutions, the California Institute of Technology, the Mount Wilson Observatory of the Carnegie Institution of Washington and the Henry E. Huntington Library and Art Gallery; second, eastern and foreign scholars who are drawn to this research and educational center for participation in, or some sort of association with, its activities; third, the group of residents of this Southern California community known as the California Institute Associates, who are interested in and promotors of the scientific and scholarly work going on in these institutions.

I wish to call first on Russell H. Ballard, president of the Southern California Edison Company and president, also, of the California Institute Associates.

MR. BALLARD:

Mr. Balch, Professor Einstein and the California Institute Associates:

It is rare good fortune that there is at this moment a conjunction here at the Athenaeum of a large number of the men who have worked as colaborers in the development of those phases of modern knowledge and modern thought to which the guest of honor tonight has made far-reaching contributions. I am going to call the roll, in the order of seniority, of this group of Einstein collaborators here present:

Albert A. Michelson, emeritus director of the Ryer-

[1] The Athenaeum, California Institute of Technology, January 15, 1931.

son Physical Laboratory of the University of Chicago, now a permanent resident of Pasadena and an associate of both the California Institute and the Mount Wilson Observatory; Charles E. St. John, astrophysicist of the Mount Wilson Observatory; William Wallace Campbell, president emeritus of the University of California and formerly director of the Lick Observatory; Robert A. Millikan, director of the Norman Bridge Laboratory of Physics of the California Institute; Albert Einstein, professor of theoretical physics of the University of Berlin; Walter S. Adams, director of the Mount Wilson Observatory; Richard C. Tolman, professor of physical chemistry and theoretical physics of the California Institute; Edwin P. Hubble, astrophysicist of the Mount Wilson Observatory.

This is just the sort of meeting the California Institute Associates will participate in, we hope, each year, and a number of times each year, throughout all the coming years, and I welcome you all to this first meeting of this sort in this new and extraordinarily beautiful Athenaeum.

MR. BALCH:

I now wish to call on Robert A. Millikan to act as toastmaster in the introduction of the scientific speakers.

DR. MILLIKAN:

The distinguishing feature of modern scientific thought lies in the fact that it begins by discarding all *a priori* conceptions about the nature of reality—or about the ultimate nature of the universe—such as had characterized practically all Greek philosophy and all medieval thinking as well, and takes instead, as its starting point, well-authenticated, carefully tested experimental facts, no matter whether these facts seem at the moment to fit into any general philosophical scheme or not—that is, no matter whether they seem at the moment to be reasonable or not. In a word, modern science is essentially empirical, and no one has done more to make it so than the theoretical physicist, Albert Einstein. That, in a sentence, is, I take it, his greatest contribution to modern thought. It will stand out repeatedly in all that is said to-night.

Throughout the nineteenth century we had been building up what seemed a wonderfully consistent "natural philosophy" as to the nature of radiant energy—a beautiful wave-theory of light. Professor Michelson's own researches on interference had furnished some of its strongest supports. This theory required that it be possible, by noting the difference in time required for a beam of light to get back to the observer when, on the one hand, it was sent forth in the direction of the earth's motion and back by reflection from a mirror to the observer, and when, on the other hand, it was sent a like distance forth and back at right angles to the earth's motion, to find the speed with which the earth is moving through the ether. But this experiment, when first performed with extraordinary skill and refinement by Michelson and Morley in 1887, yielded with great definiteness the answer that there is no such time-difference and therefore no observable velocity of the earth with respect to the ether. That unreasonable, apparently inexplicable experimental fact has now been checked by a multitude of observers—very recently and very carefully by Michelson himself, and also in extraordinarily exact measurements by Roy J. Kennedy at the California Institute, so that it is now a well-authenticated fact.

For twenty years after this fact came to light physicists wandered in the wilderness in the disheartening effort to make it seem reasonable. Then Einstein called out to us all, "Let us merely accept this as an established experimental fact and proceed to work out its inevitable consequences," and he went at that task himself with an energy and a capacity which very few people on earth possess. Thus was born the special theory of relativity, and I now wish to introduce the man who laid its experimental foundations, Professor Albert A. Michelson, my own chief and my adviser and friend for twenty-five years at the University of Chicago, the man who gave me my own opportunity in physics, and by his own example—the greatest of stimulants—showed me how to use it.

DR. MICHELSON:

I very highly appreciate this opportunity of greeting Dr. and Mrs. Einstein and welcoming them to our institute. We consider it one of the highest honors and trust that the stay of our guest of honor may be so delightful that he will take frequent opportunities of repeating the experience. I consider it particularly fortunate for myself to be able to express to Dr. Einstein my appreciation of the honor and distinction he has conferred upon me for the result which he so generously attributes to the experiments made half a century ago in connection with Professor Morley, and which he is so generous as to acknowledge as being a contribution on the experimental side which led to his famous theory of relativity. I may recall the fact that in making this experiment there was no conception of the tremendous consequences brought about by the great revolution which Dr. Einstein's theory of relativity has caused—a revolution in scientific thought unprecedented in the history of science.

In concluding, may I be permitted to congratulate the trio, the California Institute of Technology, the Mount Wilson Observatory and the Huntington Library, and especially Dr. George E. Hale, whose influence brought about the realization of this dream. May it continue to prove the attraction which it has shown in bringing to these delightful precincts these celebrated men culminating in the presence of our distinguished guest.

DR. MILLIKAN:

You and I are not interested, nor should we be expected to be interested, in just how Professor Einstein worked out the consequences of his assumption that it is impossible to detect the motion of the earth with respect to space, nor indeed in what additional postulates he had to make to round out the theory and make it more general so that it might cover not only predictions on the relations of bodies moving with constant relative velocities, but also predictions in cases in which rates of change of velocities, or accelerations, were involved. These are technical matters which we should no more expect to be able to follow into their details than we should expect to be able to follow the steps by which an astronomer computes the orbit of a planet, or an assayist analyzes a sample of ore. What we do wish to know, however, is simply this: Does the computation or the analysis yield results which can be experimentally verified? Professor Einstein himself has repeatedly assured us that his work must stand or fall by that test alone. I wish, therefore, to introduce to you now William Wallace Campbell, one of the group of experimental astronomers who has himself made one of the accurate tests of Einstein's predictions, and I am herewith assigning to him the task of sketching the development of the experimental credentials of the general theory of relativity.

DR. CAMPBELL:

When Professor Einstein published his immortal theory of relativity, a theory evolved within the four walls of his study room, he in effect advised his colleagues in the world of science to delay their acceptance of it until after it had been subjected to certain observational tests. He described three such tests all astronomical by which his theory must stand or fall.

Test No. 1: The theory of relativity, he said, must explain and remove the discrepancy between the predicted motion and the observed motion of the planet Mercury. This little brother of the earth, revolving around the sun at an average distance about one third as great as the earth's distance from the sun, refused to follow the path assigned to it by Sir Isaac Newton's law of gravitation. The discrepancy was very small, but nevertheless certain. For a half a century before Einstein, astronomers had sought diligently but in vain for the explanation. Promptly following the publication of Einstein's work, he himself as well as astronomer De Sitter of Holland applied the test to Mercury, and the theory of relativity accounted in full for the discrepancy referred to.

Test No. 2: The theory of relativity, he said, requires that a ray of light, say from a distant star, when passing close to the surface of our sun, should be bent slightly from its straight-line course by the gravitational pull of the sun upon the light ray and, in addition, as an effect of the curvature of the space in which the sun is immersed. That a ray of light should be subject to gravitational attraction and that space should be curved were results or hypotheses new to the world. Einstein urged that astronomers endeavor to observe the phenomenon at times of total solar eclipse, the only times when the test can be applied by photographing the eclipsed sun's surroundings in order to record on the photographic plates the images of the stars in the neighborhood of the sun—though of course these stars would be millions of times as far away from us as the sun is. The star images should be slightly displaced from their normal positions, he said, and those nearest the sun be displaced the most. In 1919 there occurred a total solar eclipse extremely favorable as to its astronomical elements, and the British Eclipse Committee, represented by astronomers Eddington and Davidson, sought to observe the Einstein phenomenon from Africa and Brazil. Unfortunately, both programs of observation were sorely afflicted by clouds and the images of only a few stars, none at all on some of the plates up to a maximum of seven stars on other plates, were recorded. Nevertheless, the measurements of the plates showed that the rays were bent from their straight-line courses in passing the sun, through angles approximately of the minute dimensions predicted by Einstein.

The William H. Crocker expedition from the Lick Observatory, University of California, represented by astronomers Campbell and Trumpler, observed the total solar eclipse of 1922 from the northwest coast of Australia, using four photographic telescopes specially designed and constructed to apply with great efficiency upon the Einstein test. The observing conditions were practically perfect. Hundreds of star images were recorded on the plates, all in excellent focus. The images of from 62 to 147 stars, on the ten plates, whose light had passed the sun at various distances were selected for measurement. The ten results from the ten plates were each in good and satisfactory accord with Einstein's prediction, and the combined results were essentially in precise accord with the predictions for the displacements of the star images at their various distances, up to seven or eight degrees, from the sun.

Test No. 3: If the positions of the thousands of dark lines in the spectrum of the sun, representing the gases and vapors of the chemical elements composing the surface strata of the sun, be measured very accurately, it should be found, Einstein said, that the lines are displaced by an exceedingly small but definite amount toward the red end of the spectrum, because the strong gravitational pull of the sun upon the radiating materials at the sun's surface would affect the outgoing waves of light in such manner as to lengthen them slightly; and we know that a lengthening of the waves always shifts a spectrum toward the red end of it.

Several astronomers endeavored to observe this phenomenon, but by far the most comprehensive and successful test was that conducted by Dr. St. John, of the Mount Wilson Observatory, based upon photographs secured with the powerful tower telescopes on Mount Wilson. Although several influences in the sun are known to be capable of displacing the lines of its spectrum very slightly toward the red, yet St. John's results, after eliminating the other influences as well as possible, were in good agreement with the Einstein prediction.

A little later, through the work of Eddington and others, it became evident that the fainter component of the well-known double star Sirius, though known to be about as massive as our sun, is a surprisingly small but astonishingly dense body. A cubic inch of it, on the average, it is confidently believed, would weigh as much as 50,000 cubic inches of water. That is, a cubic inch of the star, if brought to us on the earth, would here weigh about 1,800 pounds. It was pointed out that the Einstein displacement of the lines in this star's spectrum should therefore be about twenty-seven times as great as for the lines in the sun's spectrum. Director Adams, of the Mount Wilson Observatory, using the 100-inch reflecting telescope, succeeded in the extremely difficult problem of observing this displacement, and he found it to be of the dimensions required by the Einstein theory. I may say, also, that Astronomer Moore, of the Lick Observatory, using the James Lick telescope, later succeeded in confirming Director Adams' results.

And thus did the theory of relativity meet and stand the three tests set for it by its distinguished author.

DR. MILLIKAN:

I now have the extraordinary pleasure of introducing Professor Einstein himself, but in doing so I wish to dispel a very common misconception, for the average man, who only knows science from afar, labors, I suspect, under the misunderstanding that we honor Einstein only because he was the author of the theory of relativity. Now, every physicist knows that the Nobel prize committee, which awarded him that honor in 1921, did not have to consider the theory of relativity at all in making that award. They might have given it on any one of at least four grounds, and the scientific world would have been unanimous in applauding the award on any one of them. I myself have the best of reasons for knowing which one of these four they actually chose, for the late Professor Gullstrand, the chairman of the Nobel committee, in making the 1923 award stated that it was the experimental verification of the Einstein photoelectric equation that removed all doubt as to its validity in the minds of the committee, so that they chose the first theoretical statement of that equation in 1905 by Professor Einstein as the basis of the award to him in 1921 and the experimental verification thereof as the half basis of the 1923 award. Now, this equation has nothing whatever to do with relativity, but I think that all students of modern physics will agree that it is of quite as far-reaching significance as is relativity, or, indeed, as is anything that has appeared in modern physics, for it necessitated, as soon as it was firmly established, our return to at least a semi-corpuscular theory of the nature of radiant energy. The extraordinary penetration and boldness which Einstein showed in 1905 in accepting a new group of experimental facts and following them to what seemed to him to be their inevitable consequences, whether they were reasonable or not as gauged by the conceptions prevalent at the time, has never been more strikingly demonstrated.

Any small contributions that I myself may have made to the progress of physics have been largely in the nature of experimental verification of predictions contained in three theoretical equations first set up by Einstein, and but one of these has had anything to do with relativity. The first of these was the Brownian movement equation (1905) whose verification by a number of observers removed the last doubts as to the atomic theory of matter; the second was the afore-mentioned photoelectric equation (also 1905), which changed radically our conception as to the nature of radiation; the third was the equation expressing the interconvertibility of mass and energy. This grew out of special relativity (also 1905) and it has recently predicted for me verifiable relations in the radio-active field, and it also constitutes the most important basis for the cosmic ray conclusions that I am now wishing to draw. All these three are of equal significance, I think, with the predictions from the general theory of relativity, the experimental verification of which Dr. Campbell has just described. You can throw general relativity into the waste basket, if you will, and Professor Einstein's position as the leading mind in the development of our modern physics would still remain unchallenged. It is a very high honor to be able to introduce him to the associates to-night.

DR. EINSTEIN (*Translated by Professor William B. Munro*):

From far away I have come to you; but not to strangers. I have come among men who for many years have been true comrades with me in my labors. You, my honored Dr. Michelson, began with this work when I was only a little youngster, hardly three feet high. It was you who led the physicists into new paths, and through your marvelous experimental work paved the way for the development of the theory of relativity. You uncovered an insidious defect in the ether theory of light, as it then existed, and stimulated the ideas of H. A. Lorentz and Fitz Gerald, out of which the special theory of relativity developed. These in turn pointed the way to the general theory of relativity, and to the theory of gravitation. Without your work this theory would to-day be scarcely more than an interesting speculation; it was your verifications which first set the theory on a real basis.

Campbell's determination of the bending of rays of light coming past the sun; St. John's determination of the red shift of spectral lines due to the gravitational potential existing at the surface of the sun; Adams' determination of the red shift in the light which comes to us from the companion of Sirius—these provide the best support for the general theory of relativity.

Going beyond all this, the work of your wonderful observatory, through the recent discoveries of Hubble concerning the dependence of the red shift in the spectral lines of the spiral nebulae on their distance, has led to a dynamic conception of the spatial structure of the universe, to which Tolman's work has given an original and especially illuminating theoretical expression.

Likewise in the realm of the quantum theory I am grateful to you for important assistance because of your fundamental experimental investigations. Here I acknowledge gratefully Millikan's researches concerning the photo-electric effect, which first proved conclusively that the emission of electrons from solid bodies under the influence of light is associated with a definite period of vibration of the light itself, which result of the quantum theory is especially characteristic for the corpuscular structure of radiation.

While I let my spirit reflect upon all this, I account myself exceedingly fortunate to be able to break bread with you here in joyous mood, full of the happy conviction that your researches will continue through the future to broaden and deepen, without let or hindrance, our knowledge of nature's mysterious forces. From my heart I thank you all.

ADDRESS AT THE LUNCHEON[1]

THE presence here of hundreds of people to greet a distinguished man of science is a part of something without parallel in our American life. When newspapers everywhere continue, day after day, to give front page space to a man whose work does not directly touch the lives of the people, it signifies something unusual. The public itself would first catch the humor of a suggestion that it knows anything about relativity; and yet the warm interest in the man who has given us relativity continues.

Part of this interest is our spontaneous response to a gracious personality, full of modesty and kindness and humanity. For the rest, it means, I think, that our imagination has in some way been touched. We realize that Professor Einstein has done things on the remote frontiers of science where man seems to approach the mystery of his existence; we know that he has changed the space and time we thought a safe framework to which we might tie all our activities; that he has dared to think about the bounds of the universe itself. Those who have seen his work at first hand feel the beauty of its logical structure; others marvel that there could be any new way of thinking about stubborn old realities. And why shouldn't these things stir the imagination?

Nevertheless, Einstein himself would insist on the purely intellectual character of what he has done. He has remarked, "Relativity has nothing to do with the soul; it is a matter only for the head." But what intellectual achievement ever remained wholly detached from human feeling? The work of Copernicus was such an achievement. Yet it precipitated the bitterest of controversies because it tumbled man out from the place of honor in the center of the universe and suggested that he was of less importance than he thought. Again, the painstaking inductions of Darwin put life into the long-dormant doctrine of evolution; and you well know the emotional reactions to that intellectual effort. These are extreme instances; but even the work of Newton, which held no threat for man's cherished beliefs, profoundly influenced his outlook on life as well as his views of the physical world. And so, before such an achievement as relativity, we can not remain passive. Even though we know none of its details, we feel the freshening wind of new thought and find ourselves stirred; and we feel that it is good to be so stirred.

No one at this moment would dare predict how the

[1] Remarks on behalf of the Mount Wilson Observatory at a luncheon in honor of Professor Einstein, given by the Chamber of Commerce at Pasadena, California, February 24, 1931.