did not understand the theory himself, which was very likely to be true.

The third reason for personal gratification lies in the fact that my first real research work in physics, which was my doctor's thesis at Princeton, constituted, I believe, the first reasonably conclusive experimental proof of the famous Einstein photoelectric equation and through it the correlation of the frequency of light, the contact potential characteristic of any metal illuminated by the light, and the kinetic energy of electrons ejected from the metal under the influence of the light. It was this work which was refined in certain particulars by Millikan four years later to give the most accurate experimental determination of that famous constant of modern physics known as "Planck's constant."

Professor Einstein's interpretation of the rôle of Planck's constant in phenomena which involve the interaction of radiation and matter has been the real foundation of all the marvelous development in spectroscopy and atomic structure, which is the outstanding achievement of physical science in the past twenty years—perhaps because big things are more spectacular than little things, or perhaps because people like to talk and to hear about things which they sense vaguely but do not understand, or perhaps for some other reason which I can not analyze, the public fancy has been taken much more with Professor Einstein's contributions to the theory of relativity than with his contributions to atomic physics and radiation. While the former contributions have been far more extensive, I believe that public opinion should not lose sight of the fact that Professor Einstein's basic contributions to the development of the quantum theory have probably been of even greater influence in effecting the development of the physical sciences than his great general theory of relativity.

Perhaps any attempt to estimate the relative importance of these two great contributions which Professor Einstein has made to twentieth century science is futile because the estimate may be different if gaged on the minute scale of the instantaneous condition of an atom or by the enormous scale of the universe as it is extending through all the ages. This contrast, however, will at least serve to emphasize the great range of interest and of application of the work of Professor Einstein.

It is needless for me to say that all American scientists are delighted with the new arrangement under which Professor Einstein will be regularly one of us. We are delighted not only because of the prestige which his presence will give to our institutions, but also because of the interest and stimulation which his presence will arouse in our young American scientists, who will see in him an ideal which unconsciously beckons them to "go thou and do likewise." Finally, we are delighted with the new arrangement because those of us who have had the privilege of coming to know Professor Einstein personally appreciate him as a person and are glad on personal grounds to have him as an associate. In this welcome we include also the most effective of all his colleagues, Frau Einstein.

ADDRESS ON "THE COSMIC PARADE" BY DR. HARLOW SHAPLEY, DIRECTOR OF THE HARVARD COLLEGE OBSERVATORY

I AM requested to describe the universe of which our guest of honor is a part and concerning which he busies himself at times. I am asked to tell the story of a world that contains electrons, galaxies, space, comets, politics, slush and after-dinner speakers. I am to describe a universe that spreads throughout more than a million, trillion, trillion, cubic light years, that has existed for some thousands or millions of millions of years—and I have for this descriptive job ten minutes, minus the time taken by the introducer. You should pardon me if here and there I am rather brief with minor details. Indeed, I shall consider chiefly the grosser cosmos and not bother much with the intricacies of the atom or the private life of electrons.

As interpreters of the world we do not know how good we are, nor how bad. We must leave to future generations to say just where we went wrong. I suspect that if any attention whatever is paid to the science and scientists of the first third of the twentieth century it will be to the fundamental deductions and to the pioneer observations (crude as they are). I suspect that we are too near the front in this battle of nature's secrets against test-tubes, spectroscopes and mathematical analysis to realize how much we pursue current fads, how enthusiastically we over-interpret fragmentary observations of fragments. But even at this close range we can see the oncoming mortality of practically all current theories, both of the microcosmos and of the macrocosmos. There is an over-population of hypotheses; they crowd and cancel one another. New observations add to the slaughter. Within the past year, almost accidentally, we stumble upon fundamentals like the neutron and the positron, entities that had not been explicitly included in the atomic models and pictures of the preceding years. But brave hypotheses are necessary to guide, transiently; the observations stand for a while; the good measures, in fact, are essentially permanent; and the enthusiasm back of it all, the will to know and the willingness to fumble as we learn to know—they are eternal.

Leaving the fascinating though uncertain world of the atom and the molecule, let us accept matter as

proved though not defined and gaze into the ominous astronomical world.

To picture for you most easily this universe of stars which stretches quite beyond reason, space and time and imagination, let me parade the cosmos before you, bit by bit. You are for the occasion transformed into super-cosmic beings, brought in for this show, let us say, from a place that lies beyond the bounds of our space-time and from an epoch preceding the beginning of time—impersonal spectators, you are looking us over. While you cosmics sit before me, smoking or fiddling with the spoons or thinking or perhaps just sitting, I start the sidereal parade with a waving of nebulous banners and a blare of celestial trumpets; for the first body ushered in is nothing less than Number Three. That is, Planet Number Three—dear old earth herself. On the return trip there will be less trumpeting, I surmise, when Number Three appears. Number Three, ladies and gentlemen, is one of the funniest things I can show you; the only place in the universe, so far as I am aware, where demagogues rule, where man destroys man, where imbecility of various sorts is bought and sold in the open market. It is, however, also the abode of ideals, altruism, reasoning thought.

Numbers One and Two are Mercury and Venus in this numbering of the planets outward from the local star. The star itself, one of thousands of millions, is a hot, radiant turmoil of mixed gases. If our star, the sun, were reduced in scale so that its million-mile diameter is but six inches (about that of this microphone) the planets on the same scale would be the dimensions of coarse sand grains and bits of gravel and of much the same importance. Number Three, a small sand grain, is fifty feet away and plodding its yearly trip about the sun in a circular orbit with astonishing monotony. How we all cling to that rocky fragment, holding on desperately, not physically of course, because gravity takes care of that; but holding on temporally, in time, for just as many turns as possible. Sixty, seventy, eighty whirls, and we let go —that is our portion on this merry-go-round that has already whirled dreamily about the sun a few thousand million times with scarcely any evidence of running down.

The furthermost of the planetary sand grains now known is Pluto, about five city blocks from this microphone sun; to the nearest star neighbor it is some three thousand miles.

But enough of this part of the parade; enough of Number Three with its superficial whiff of atmosphere, splash of ocean and smear of biology. We turn attention to phenomena more fundamental than planets.

A long interval now passes before you cosmic spectators—a parade of nothingness. Interstellar space is passing, the phenomenon, or lack of phenomena, that incites sober men to cosmogony, that leads thoughtful men to strange comments concerning space and time, infinity and eternity.

But look closely and you will see that the emptiness is not completely empty. In every cubic yard of interstellar space are a hundred atoms that have been ejected violently and driven from the hot atmospheres of stars. But these hundred atoms per cubic yard do not alleviate the stark emptiness. There are a trillion trillion times as many atoms in a cubic yard of the atmosphere in this room. Interstellar space is effectively a vacuum.

In addition to the few hurrying atoms and molecules, space is everywhere permeated with the weak radiation of all stars. The light of a thousand million stellar sources pours at the rate of fifteen thousand trillion pulses per second through every cubic inch of interstellar space. And, in spite of this, almost complete darkness prevails. Is it any wonder that scientists dream dreams when they seek to interpret the universe as a whole—its meaning in space and in time?

Coursing also through this pseudo-emptiness are occasional lost planets and comets, and frequently high-speed cosmic meteors, which record themselves as shooting stars when they strike and expire in our earth's protecting atmosphere. We have recently proved at the Harvard College Observatory the prevalence outside our solar system of these minute stony fragments from past explosive catastrophies. The speeds of meteors frequently exceed a hundred miles a second. Their significance in cosmogony is deep, their source is obscure and intimately tied up with the origin of the phase of the world that now exists. But numerous as they are, they do not relieve the essential vacuity of space.

The procession moves on and we pass before you stars of all sorts—giant spheres, a million times the volume of our own star; dwarf, shrunken suns that appear to be perishing from exhaustion of their radiant energy; stars of various temperatures and stages of evolution; double stars, triples, stars in groups, clusters and clouds. You will note that the chemistries are much alike from type to type, that the chemical elements of stars are the same as the elements of the flying meteors and of the crust of the earth. You will note also that regardless of the region of space or interval of time from which I select the sample stars for this procession, the same gravitational principles operate, the same laws of radiation prevail as those familiar now in the solar system—a common universal chemistry and common laws.

As the procession of stars goes by we do not see

any little planets or moons. They may be there, though invisible, but after all that's not an important matter.

The parade goes on, and now appear the nebulae, some bright and some dark, the most spectacular part of the pageant. For the bright nebulae are of weird form, of vast dimensions, agglomerations of radiant gases and of meteoric grains of sand and iron. And the dark nebulae are impressive because of the secrets they conceal by hiding great portions of the universe; impressive also because they originate, possibly, from exploded planets and stars or from earlier disrupted universes. Are they the materials from which eventually new stars and galaxies will arise?

In the procession that I have to this point passed before you were, first, the minor bodies, such as the planets and comets of the solar system. Next came a sample of interstellar space and its thin content of radiation and of stellar débris. Then the stars, singly and multiply, and the diffuse nebulosity, bright and dark, which may be star plasma or the wreckage of stars or, in a long-time universe, may be both.

We now rise to a higher order in the pageantry that passes. Here are not stars but great systems of stars which we call galaxies or, if they are remote and therefore hazy and indistinct and unresolved, we misname them nebulae or nebulous stars. Also in great variety the galaxies go by, some gigantic, some so dwarfish that they may contain but a few thousand million ordinary stars; some are spherical, most of them flattened, and more than half show that their population of stars is arranged in spirals.

These common spiral galaxies occur singly, doubly, in close confused triples and multiples, and in clusters and in great clouds and streams, which we term supergalaxies, sometimes millions of light years in extent.

A few of these galaxies have been observed with the spectroscope. There is a startling red shift of their spectral lines. Interpreting that red shift in the normal way as a recession of the galaxies, we are led to the concept of the expanding universe, a scattering of the galaxies, a lowering of the density of matter in space. We are led to the speculation that the origin of the present phase of the universe occurred not much more than three thousand million years ago, disturbingly recent to the orthodox astronomer. We are led to remarkable preliminary speculations connecting the theory of relativity with the recession of galaxies, from which we deduce evidence for a spherical finite world.

Finally, at the end of the procession, we try to exhibit the metagalaxy, the all-inclusive universe of galaxies; but the display is poor because, with a reach of only a hundred million light years, our sample possibly is misleading. We note, however, three conspicuous features:

(1) Exceeding non-uniformity in the distribution of matter.

(2) No evidence that our own galaxy is significantly placed with respect to the millions surrounding.

(3) No suggestion that in our deepest exploration we anywhere approach a boundary to the universe.

The cosmic parade is finished. I now retransmute you from super-cosmic beings to primates on Planet Number Three; and I leave with you the thought that, although in the last twenty years our knowledge of the sidereal world has more than doubled, the list of things we want to know has trebled or quadrupled, leaving us relatively more ignorant than heretofore, but making us also keener than ever to attain that spiritual satisfaction that only the struggle to comprehend can give.

ADDRESS BY PROFESSOR EINSTEIN

LET me first give expression to my delight and gratitude for the wonderful reception which has been given to me in this festive hall by so prominent and distinguished an assemblage. But this honor, at so serious a time, would depress rather than exalt them, if it were not for the redeeming consciousness that, by this visit, I could be of service to two institutions which are very close to my heart—the University in Jerusalem and the Jewish Telegraphic Agency.

Let us fix our eye first upon Palestine. It should fill us with pride and joy that our work of upbuilding is made possible, to a great extent, by liberal gifts, and that those whose hearts and hands have achieved this upbuilding have imposed upon themselves a hard lot in order to serve a high ideal. We may therefore say that this work rests upon the shoulders of the best of our people. It is because of this that it has until now wonderfully withstood all the difficulties of trial and affliction and stands to-day more sound and promising than many settlements in lands more favored by nature. If the speed of growth does not satisfy some of our hot-headed and impatient brethren, let us remember that in social structures as well as in organisms the most worth-while are not those which grow and mature most rapidly.

As old as the plan of the upbuilding work itself is the plan for the establishment of the Jewish University in Jerusalem. This is not to be wondered at in a people who have for nearly two millennia treasured as the highest good the pursuit of the spiritual for its own sake. So it was that soon after the war, on one of the most beautiful spots of the country, the university was founded. Originally, it was not intended primarily as an institution of instruction but as a center of research.