interpreted as the 'radius of the universe', has nothing to do with the rate of evolutionary change of stars and stellar systems.

It seems to me that the current interpretation, and the consequent models of the universe as an expanding hypersphere (or elliptical space), may in course of time be found to be too simplistic, and be replaced by one in which the apparent contradictions are more satisfactorily hidden from view. But this does not affect the theory, which will retain its value, independent of the interpretations put upon it.

By Sir ARTHUR EDDINGTON, F.R.S.

DISCUSSION of detailed theories of stellar evolution is overshadowed by the fact that the time-scale is once again in the melting-pot. I think it will be agreed that if Prof. de Sitter is right in regarding the facts as indicating a rapid expansion of the universe or scattering apart of the galaxies, the very long time-scale of billions of years which has been fashionable of late becomes exceedingly incongruous: we should have to accept an age of the order 10^{10} years for the galaxies and presumably also for the stars. But the theory of the expanding universe is in some respects so preposterous that we naturally hesitate before committing ourselves to it. It contains elements apparently so incredible that I feel almost an indignation that anyone should believe in it—except myself. I have had a special reason for believing it which I have referred to from time to time, but it was not until last month that I was able to put it into definite shape.

I believe that from pure physical theory we can not only predict that this phenomenon of expansion will occur but also predict the actual rate of expansion; and the calculated result agrees with the observed recession of the nebulæ. This result comes out of the wave equation for an electron—the fundamental equation of modern quantum theory. When I adapt the wave equation to take account of the curvature of space, I find that it ought to contain a term $\sqrt{N}/R$, that is to say, the square root of the number of electrons in the universe divided by the radius of the universe in its equilibrium state.

I do not suppose that this is a new term to be inserted as a correction to the ordinary equation; it is already in the equation in disguise. It is the term attributed to the mass of the electron and ordinarily written mc^2/e^2. Sir J. J. Thomson was the first person to measure the mass of an electron. I do not think he realised in 1897 that the thing he was after—the constant which was responsible for the effects in the vacuum tubes attributed to mass—was the square root of the number of electrons in the universe divided by the radius of the universe. Really he was poaching on astronomical preserves. He was finding the rate of recession of the spiral nebulæ, or at least a very little calculation will derive it from his measures.

I take the value of $\sqrt{N}/R$ (or as Sir J. J. Thomson mysteriously called it, mc^2/e^2) according to his measurements and those of his successors, and combine it with well-known formulæ of the relativity theory which Prof. de Sitter has described; then I can find at once the principal data about the size of the universe. For example, its original radius was 1070 million light-years, before it started to expand. I find also $N = 1{\cdot}29 \times 10^{79}$; and, what is of special interest, the rate of recession of distant objects can be calculated; the result in the usual units (km. per sec. per megaparsec) is 528. This is the whole expansion effect, which will be reduced a little by the attraction of the galaxies on one another, but the reduction is not likely to be large.

The value found from astronomical observation ranges from 430 to 550 according to various determinations.

Naturally this close accordance of theory and observation has made me believe that both are right and that the observed motions of the nebulæ are genuine; so that we must accept this alarmingly rapid dispersal of the nebulæ with its important consequences in limiting the time available for evolution.

By Prof. ROBERT A. MILLIKAN, California Institute of Technology, Pasadena, Calif.

ANYONE who knows me is quite aware of the fact that I have no qualifications for participating in a discussion of the evolution of the universe, unless perhaps it be because of my interest and activity in the development of our knowledge of the cosmic radiation. Since, however, results in this field now seem destined to exert a profound, if not a determinative, influence upon all theories of stellar evolution, it may not be out of place for me to outline the present status of our experimental findings in it, and to do what I can to show whither they point.

I note first, however, that the opening up of this amazing new field of knowledge is the work solely