earthquake. They would rather err on the conservative side and it follows that the average geologist, who as a rule has had but little training in recognizing the evidences of activity, usually describes faults simply as faults, without distinction as to their activity.

These conditions led to a difference of interpretation of the term active as it is used in separate sections of the Fault Map. Mr. Wood, who gathered from many generous contributors much of the fault data shown on the southeast, and the southern portion of the southwest, sheets of the map, subsequently examined many of these faults in the southeast region, and some elsewhere, and found it desirable to recognize a considerable number of grades of knowledge corresponding as nearly as might be to the degrees of certainty with which the faults, and their symptoms of activity, were determined. His manuscript map shows the following distinctions: active fault well located; active fault uncertainly located; fault probably active; line probably active fault (?); fault well located; fault uncertainly located; line probably active; line including all from probably fault to very doubtful; line including all from probably fault to very doubtful and uncertainly delineated. Mr. Willis, who is responsible for the mapping in the districts north of San Luis Obispo, with the assistance of Mr. Robin Willis, made a reconnaissance survey of the area between San Luis Obispo and Santa Rosa, and extended the application of the term active to faults which he recognized as such on physiographic evidence as well as on indications more commonly employed, whenever in his judgment the facts justified that classification. He thus classified as active many faults which he would not have identified as such without personal examination.

The task of transferring the manuscript data to the copy for the printer fell to Mr. Willis and involved the adjustment of the differences of interpretation in so far as it might be possible to bring them into accord. It was not possible, however, to reach that desirable unity of statement which might have been attained if all the evidence could have been reviewed by a single observer. It was necessary also to reduce the number of distinctions to that which could be shown by a moderate number of printings on the map. The adjustments were made by Mr. Willis on the eve of his departure for Chile and an explanatory note was inserted by him in the legend of the map just before sailing, without opportunity of consultation with Mr. Wood. The note falls somewhat short of a complete statement of the facts. On the southeast sheet it reads that the faults thereon shown as active "have been active during historic time" and it should further explain that the classification as active also includes such as "exhibit specific surface indications of recent activity, such as fresh scarps and trace phenomena." Furthermore, a considerable number of the faults shown on the southeast sheet, and also on the southwest sheet, that are marked dead, would better be indicated as, "probably active, but without definite indication of recent disturbance." Were these changes made in the map itself the number of active faults shown in the southern half of the map would more nearly approximate that of the active faults delineated by Mr. Willis in the northern half.

In making this compilation we have been placed under obligations to many individuals, corporations and institutions. Some of them have wished not to be named and the list of others who have contributed to the advancement of our knowledge of California is too long to be given here. It is appropriate to state, however, that the work was done in cooperation with the Advisory Committee on Seismology of the Carnegie Institution of Washington, with the U. S. Geological Survey, represented especially by Messrs. Noble and Kew, with the U. S. Hydrographic Office, with the Navy Department, with the University of California and with Stanford University. While the Seismological Society of America is directly responsible for the publication, it could not have accomplished it without the cordial cooperation given by these organizations.

Bailey Willis,
H. O. Wood

DETERMINATION OF THE CURVATURE INVARIANT OF SPACETIME

On January 30, 1924, and on the two following days a remarkable series of lectures was delivered by Dr. Silberstein to the Physical Society of McGill University, Montreal. Not only did Dr. Silberstein present to his audience one of the vastest problems with which the human mind can grapple, but he gave for the first time in public an exposition of his own investigations of the intrinsic properties of spacetime as the frame of the universe.

The preliminary lectures dealt with the geometries of space and spacetime; the early attempts to formulate mathematical equations which would hold true not only for terrestrial measurements but also for planetary measurements; the discrepancies which invariably occurred between theory and observation in the latter class of measurements; the great conception of Einstein whereby the universe was to be treated mathematically as a four-dimensional "spacetime" continuum, and his later inspiration, whereby he conceived spacetime as finite according to the principles of elliptical geometry; the modification of the Einstein spacetime equation by de Sitter, whose beautiful theory has overcome the outstanding difficulty of

Einstein cosmology and has prophesied not only measurable but conspicuous deviations from classical theory for measurements dealing with distances as great as those of the remote stars and nebulae.

The third lecture dealt with Dr. Silberstein's own investigations based upon the spacetime theory of de Sitter. Attention was confined to a discussion of Radial Velocity. This velocity in the line of sight is measured by the Doppler effect, that is to say, by the displacement of a spectral line in the spectral photograph of a star relative to the position of that line in the spectrum of a similar source of light on the earth.

Both de Sitter and Weyl showed theoretically that the greater the distance of the star from the observer, the greater would be the shift of the spectral line; but their theories only allowed for a shift towards the red end of the spectrum. In the case of de Sitter, this was because he limited himself to the perfectly artificial assumption of the star fixed relative to the observer; and in the case of Weyl because he introduced the quite gratuitous assumption that the world lines of all the stars belong to a unique pencil of geodesics diverging into the future. Observation, however, shows that not all the stars are receding, a considerable proportion having motions towards the solar system, while of the 42 spiral nebulae whose velocities have been measured four are approaching and likewise a large proportion of the globular clusters. Thus the spectral shift equations of de Sitter and Weyl are untenable; first, because they are theoretically unsatisfactory, being based on a gratuitous or a narrow assumption and, secondly, because they are flatly contradicted by many of the most remote celestial objects.

Dr. Silberstein has taken up the problem without introducing any limitation whatever into de Sitter's spacetime theory, thus entirely abandoning the prejudice of the universal scattering of matter. He treats the observing station and the star as two free particles and integrates the equations in their full generality. This leads him to a formula for the complete spectral displacement, a general Doppler formula containing two terms due to (1) an individual characteristic of the star considered, namely, the radial velocity which it would have at its closest approach to the observer, whether that position occurred in the past, or would occur in the future, and (2) the ratio of the distance of the star from the observer to the radius of curvature of spacetime. Although these two factors are inseparably amalgamated, yet the first dominates the result for stars near the sun, while the second far outweighs the first for stars near the boundary of our galaxy or for the spiral nebulae which are themselves probably small galaxies lying far out beyond the confines of our galaxy.

Dr. Silberstein has collected all the numerical results which are available—namely, Shapley's observational data—with regard to the Doppler displacements and distances of globular clusters and the Magellanic Clouds, and inserting these values in the equation embodying the relations above described he solves for the only unknown—the radius of curvature of spacetime. The results are so consistent from the clusters, whether approaching or receding, and from the two Magellanic Clouds, that it is impossible not to attach a tremendous importance to this achievement of Dr. Silberstein's. Thus, an intrinsic feature of the universe, the radius of curvature of four-dimensional spacetime, having a clear mathematical significance but utterly impossible of visualization in the ordinary sense of three-dimensional realization, has been evaluated numerically with a precision and weight never before approached. The consistency of the nine values obtained gives rise to a law which can be enunciated in terms of physical observable things, thus: the product of the Doppler displacement and the parallax is a constant, and this constant has the simple physical meaning of the smallest possible parallax in such a spacetime, namely, the ratio of the earth's distance from the sun to the radius of curvature of spacetime.

The figures given by Dr. Silberstein as the measure of this radius of curvature are as follows: The mean of determinations from seven globular clusters is 6.0 multiplied by 10 to the power twelve in astronomical units, and the mean value of these seven clusters, together with the Greater and Lesser Magellanic Clouds, is 6.07 multiplied by 10 to the power of twelve.

Gigantic though this figure may be, it yet implies a finite volume of the elliptical space as a section of spacetime, and the thought of "a closed elliptic cage" would be intolerable to the undaunted imagination of Dr. Silberstein, were it not relieved by this inherent property of the spacetime, strangely stimulating to what Clifford termed "cosmic emotion," that a light signal from a star near the observer's polar (the polar is a sphere around the observer of the greatest possible radius in that space) would take an almost infinite time to reach the observer, while from a star actually on the polar the signal would come—never.

A. Vibert Douglas

McGill University

SCIENTIFIC EVENTS

THE MASSES AND LUMINOSITIES OF THE STARS[1]

An important paper on this subject was read by Professor A. S. Eddington at the meeting of the

[1] From *Nature*.