through which the less luminous surface layer of the interior gases becomes visible. The varying frequency of spots is accounted for by supposing that at minimum the heat of the central nucleus is prevented from escaping by a photosphere of relatively great thickness, and that afterwards, owing to contraction, the temperature of the nucleus increases to such an extent that the photosphere becomes attenuated and subject to perforations in the form of spots and pores. Radiation from the nucleus is then facilitated, so that the photosphere again increases in depth, and eventually produces another minimum. The chromosphere, prominences, and corona are regarded by Dr. Brester as effects of a permanent aurora, which is maintained by electrons projected from the photosphere.

THE NEW PHYSICS.

COPIES have reached us of five of Prof. Levi-Civita's recent mathematical papers,[1] three of which deal directly with Einstein's theory of gravitation, and suggest some remarks on the aspect of theoretical dynamics, as it appears at present to a comparative layman unable to criticise rival theories in detail. Speaking broadly, we may say that the theory of mathematical physics is based upon a comparatively small number of fundamental differential equations. Until recently time was explicitly or implicitly treated as the independent variable, in terms of which the other variables had to be found; and all phenomena were supposed to take place in a three-dimensional Euclidian space, where we can use the formula $ds^2 = dx^2 + dy^2 + dz^2$ for the distance between two very near points. In the theory expounded by Minkowski and others we have a different formula, $ds^2 = c^2dt^2 - (dx^2 + dy^2 + dz^2)$, where we may regard dt as an element of time, and speak of a "world-point" (x, y, z, t) determined not only by its position, but also by its age. Einstein has developed his gravitation-theory from the general expression, $\Sigma g_{ij}dx_idx_j$ $(i, j = 0, 1, 2, 3)$, assumed for ds^2, where ds is an element of distance in a four-dimensional space. (It may be remarked that in the previous theory, as Minkowski pointed out, we might take dt as a variation of a co-ordinate distance; then phenomenal processes in our space might be regarded as "sections," so to speak, of a four-dimensional system.)

With Einstein's form of ds^2 we can at once use all the known geometrical theory of infinitesimal geometry in four dimensions, and, in fact, the well-known symbols of Riemann and Christoffel directly enter into Einstein's gravitation formulæ. This is a matter of mathematics merely; the most striking fact, from the physical point of view, is that Einstein has used his formulæ successfully to account for the secular motion of the perihelion of Mercury. This does not show that Einstein has said the last word on the theory of gravitation, but it does show that these post-Newtonian theories provide a calculus which gives a better image of actual facts than the purely Newtonian theory seems able to do. The more predictions the new theory can give us, which are verified by experiment, the more we shall be inclined to trust it; and this is quite independent of what we call the "real meaning" of the symbols involved. For instance, Prof. Levi-Civita's paper No. 2 seems to show that if we could produce a sufficiently strong magnetic field, we should find it inducing upon the three-dimensional space to which, so far, our intuition appears to be confined, a corresponding "curvature" measured by $1/R^2$, where R is a length. Assuming that the field is one of 25,000 gauss, the author deduces that $R = \frac{2}{3} \cdot 10^{20}$ cm., or about ten million times the mean distance of the earth from the sun. As he points out, there is little hope of testing this by experiment, but he obtains a formula for the velocity of light, $V = c_1 \exp(x/R) + c_2 \exp(-x/R)$, with a damping coefficient in the second term, which he suggests might come within the range of observation.

Philosophically, the trouble still seems to be about *time*, in the philosophical sense. If we could look at the universe *sub specie aeternitatis*, we might perhaps find our greatest delight in its unchangeable perfection; but so long as we are constrained by processes (even processes of thought), time, *in some sense or other*, is apparently indispensable, and if we evict it from one habitation, we may expect it forthwith to be in occupation of another.

G. B. M.

[1] (1) "Statica Einsteiniana"; (2) "Realtà fisica di alcuni spazî . . ."; (3) "Sulla espressione analitica spettante al tensore gravitazionale . . ."; (4) "Nozione di parallelismo in una varietà qualunque . . ."; (5) "Sulle linee d'azione degli ingranaggi." (1), (2), and (3) are reprints from *Rendic. della R. Accademia dei Lincei* (Rome, 1917); (4) from *Rendic. del Circ. Mat. di Palermo* (Palermo, 1917); (5) from *Atti e Memorie della R. Accad. di Padova* (Padua, 1917).

METEOR ORBITS.

A PAMPHLET on "The Determination of Meteor Orbits in the Solar System," by G. von Niessl, has just been published in Smithsonian Miscellaneous Collections (vol. lxvi., No. 16, Washington, 1917). The pamphlet is a translation by the late Cleveland Abbe of a paper published in the "Encyclopädie der mathematischen Wissenschaften," dated Vienna, 1907. The author, who has had considerable experience in computing meteor paths and orbits, gives his views as to the mathematical treatment of the subject. He indicates the best method to be followed in determining the radiant and geocentric velocity of meteors and fireballs of which multiple observations have been obtained. Not the least interesting part of his discussion is that in which he deduces the mean errors in the results:—

Mean error of azimuth = 5·8°, 351 observations.

Mean error of apparent altitude = 4·1°, 235 observations.

Mean error of radiants = 3·3°, 43 cases, 537 observations.

Mean error of inclination = 6·5°, 250 observations.

The radiant positions of the chief periodical showers he gives to within 1° of probable error.

Tables are furnished of the average terminal velocity and altitude of meteors, from which he concludes that they "can penetrate deeper into the atmosphere in proportion as they move with a low velocity"—a fact previously well ascertained. With regard to atmospheric resistance, von Niessl's opinion is that direct observations make it probable that the velocity of meteors in the upper atmospheric regions is slighter, while in the lower strata of the air it is greater, than theoretical views.

The masses of fireballs and shooting-stars are discussed from various data. Prof. A. S. Herschel dealt with this part of the subject many years ago, and held the view that a first magnitude meteor is usually a few grams in weight, while the very small meteors are only the fraction of a gram. V. F. Sands found from the Leonids of 1867 that the average mass, or weight, of a meteor equal to Jupiter in brightness was 0·67 gram, while a fourth magnitude object was only 0·006 gram.

Von Niessl finds it necessary to assume decidedly hyperbolic orbits for the majority of meteors, for their "observed geocentric velocity far exceeds the limits for parabolic orbits. Therefore the large meteors in general are undoubtedly of interstellar origin." Schiaparelli arrived at similar conclusions half a century ago.

The paper is an instructive contribution to the litera-