it gives positiveness to one's opinions and conduct, that one more readily forms his final conclusions from first impressions, and that a well disciplined mind might avert many sad experiences, which an undisciplined mind is obliged to go through, is undisputed. That the college graduate has many edges to round off when he enters upon the struggle for existence is manifest. During his entire college course he has only heard of the highest standards of the intellect and of morality. Although he has been taught to deal with things as they are, yet a large portion of his instruction has been devoted to things as they should be; and therefore when he starts in life he must adjust himself to life as it is. Whether this is a fault in that the training is not held within the limits of the practical may be an open question. But on the other hand, that a college education has the tendency to make one more humane, to broaden one's views of life, to make one more liberal, to quicken one's perception, to lend accuracy to the judgment, and insure more logical thinking, cannot be denied. FRANKLIN A. BECHER.

## THE SYSTEM OF ALGOL.[1]

THE steady advance of exploratory research in the system of Algol promises to furnish one of the most curious and instructive episodes in the history of science. Vague hypothesis, determinate theory, and triumphant verification have already played their logically sequent parts in the discovery of the eclipsing satellite. Goodricke's conjecture, however, had to wait nearly a century for Pickering's formulization, while this was ratified within a decade by Vogel's disclosure of the anticipated tell-tale spectroscopic effects.

Progress has, indeed, of late notably quickened its pace; and we may therefore hope for a prompt and effective application of the Ithuriel-spear of adapted observation to the latest creation of speculative intelligence in the lately organized department of "dark stars." Since Argelander's time it has been tolerably evident that Algol had other attendants besides the agent in producing its periodical eclipses. For their recurrence was shown by him to be subject to minute irregularities in point of time, and these irregularities are of such a nature as to demand for their explanation the presence of at least one disturbing mass. A highly complex piece of mechanism could plainly be seen to be at work; yet the penetration of its intricacies presented a task so formidable that astronomers of, at any rate, the present generation might well have despaired of its accomplishment. It has, nevertheless, been undertaken by Dr. Chandler, and his labors have been rewarded with an encouraging measure of success.[2]

They have been necessarily of a more or less tentative character, and their result must be looked upon as merely provisional; but there is much reason to suppose that it at least approximates to the truth. It is, moreover, perfectly plain and straightforward; there is nothing of the *obscurum per obscurius* about it; the consequences it involves are definite, and admit of definite verification.

The new and enticing hypothesis now presented for the consideration of astronomers is mainly founded upon certain well-ascertained inequalities in Algol's period of variation. These were shown by Dr. Chandler's discussion some little time since[3] to be slowly compensatory. They are oscillatory, not progressive. Consistently in advance of their due time down to about the year 1804, the obscurations of the star then began to fall behind it, and the delay had accumulated in 1843 to 165 minutes. A gradual process of restoration thereupon set in, and the normal epoch was reached near the beginning of 1873. It was quickly, however, transcended, for acceleration is still going forward, and is likely to continue operative during some years to come.

These irregularities are evidently comprised in a cycle considerably exceeding one hundred years, and for that very reason it is difficult to account for them on gravitational principles; since a third body, exterior to the close pair, should, in order to produce any marked purturbational effects, revolve much nearer to them than would be consistent with so long a period. Another mode of explanation is, accordingly, resorted to by Dr. Chandler. The varying intervals needed for the transmission of light from different parts of a large orbit described by Algol and its dark satellite round a remote primary, are, in his view, the fundamental cause of the alternate anticipations and retardations in the occurrence of Algol's eclipses. They are, in fact, apparently shifted backwards and forwards in time, just in the same way as are the eclipses of Jupiter's satellites through the orbital movement of the earth. Algol may, then, be regarded as the solitary luminous number of a multiple combination of opaque masses. The common centre of gravity, round which the pair hitherto known revolves in a period of about 131 years, lies by the present hypothesis at a distance from it just equal to that of Uranus from the sun. The path thus traced out is, we are further informed, sensibly circular, and its plane is inclined 20° to our line of vision. Obviously, however, during the whole time occupied in travelling over its remoter half, the light-minima of the star must be recorded somewhat later than if we saw them in the precise order of their actual occurrence; and this remoter half was swept over between the years 1804 and 1869, when the observed phases were always in arrear of calculation. Now, on the other hand, that the star is on the hither side of its orbit, the epochs of its eclipses are apparently anticipated, and will not coincide with their true times until the passage of the "ascending node," about 1934. The dimensions of Algol's orbit, with its inclination, of course prescribe the amplitude of the oscillations by which its periodicity appears to be disturbed; and this "light-equation," as we may call it, proves to be 149 minutes. This should be the maximum extent, whether of acceleration or of retardation; but in point of fact, as we have seen, delay mounted up in 1843 to 165 minutes. Hence the theory cannot be said to represent the observations as satisfactorily as could be desired. The deviations, indeed, are large enough to suggest to Dr. Chandler further complications, the unravelment of which may challenge the utmost skill and patience of investigators. Meantime, a touchstone of the general truth of his hypothesis will soon be at hand; for it involves a cessation within the next ten or twelve years, and a subsequent reversal of the shortening process at present affecting the star's period of luminous change; and the fulfilment of this prediction will serve as a hall-mark of its genuine quality. An additional test may be derived from the spectrographic evidence. The velocity of Algol in the large orbit attributed to it is 2.7 miles per second; but of this, less than one-half, or about one mile per second, is at present directed towards the earth. It constitutes, however, a goodly proportion of the 2.3 miles of continuous approach determined from the Potsdam plates; but which should in the course of a score of years, if the new theory be true, completely disappear, neutralized by the altered direction of the star's orbital motion. It remains,

[1] From Knowledge for May.
[2] Astronomical Journal, Nos. 255, 256.
[3] Ibid, vol. vii., pp. 165-183.

indeed, to be seen whether the whole of its supposed translatory speed may not really be of a circulatory character.

Dr. Chandler's theory does not rest wholly on the cyclical inequalities of Algol's light-changes. He alleges also in its support periodical disturbances of proper motion, brought to view by a careful discussion of all the observations of the star, from 1753 to the present time, and indicating, in his opinion, a combination of elliptical travelling with a progressive advance. But the average proper motion of Algol is so very small—less than 2″ of arc a century—that variations or irregularities in it can at present be regarded only as an interesting possibility. They would give, if confirmed, 2.7″ for the longest diameter of the ellipse into which the wide orbit traced out by Algol round its unseen primary is projected upon the sky. And since this little span represents an actual expanse of 38 earth-to-sun distances, or "astronomical units," it implies a parallax for the star of 0.07″, corresponding to a distance of nearly 47 light-years—a statement that is in many ways worth thinking about. Although claiming only qualified credence, it nevertheless conveys the upshot of assuredly the most promising attempt yet made to determine, by indirect means, the parallax of a star. In itself, too, it seems probable enough. Assuming its accuracy, we gain the information that Algol emits 63 times as much light as the sun, which, in its place, would show with little more than the brightness of a seventh-magnitude star. The famous variable, moreover, according to Dr. Vogel, is just one million miles in diameter, so that it presents only once and a third the solar radiating surface; yet it is, as a light-giver, 63 times more effective. The remarkable conclusion follows, that Algol is intrinsically 47 times more brilliant than the sun. The emissions from its photosphere are, per unit of area, 47 times more powerful. And should its parallax eventually—as seems not unlikely—prove to be smaller than 0.7″, this disparity will be still further enhanced.

By means, accordingly, of investigations of this nature, more fully and securely carried out, the question as to comparative stellar brilliancy may finally obtain a sufficiently satisfactory answer. It is a very important one. The process by which photospheric light is manufactured is still largely enigmatical, but the ideas commonly entertained about it are not easily compatible with the existence of considerable differences in the shining faculty of photospheric shells presumably identical in point of chemical composition. Reliable evidence of such differences has not hitherto been available. That light-power in stars bore no fixed proportion to mass was patent in numberless examples; but the density, consequently the dimensions of the emitting bodies remaining unknown, it could not be determined whether distension of substance, or innate strength of incandescence, was more concerned in producing a great sum-total of light relative to quantity of matter. The indications, however, now derived from Algol are overwhelmingly in favor of the latter alternative.

The primary member of its system, even if illuminated solely by the borrowed rays of its brilliant neighbor, may not, Dr. Chandler thinks, be out of reach of telescopic discovery. But his hopes, in this case, appear somewhat chimerical. It is not difficult to show that, under the circumstances supposed, a body of planitary constitution could not possibly be disclosed by any optical means at present available. Its position-angle relative to Algol is just now, we are told, 32°, while its distance from the same star is in the inverse ratio of its mass. This is considered by our author to be indeterminate; but it is not so, unless we reject Dr. Vogel's value for the combined mass of the close pair forming the variable. Assuming its approximate correctness, and that Algol and its immediate attendant accordingly contain two-thirds the solar quantity of matter, and admitting, further, that they revolve together, at a distance of nineteen astronomical units, in a period of 131 years, round their common centre of gravity with another body, it follows that the mass of that body is about equal to that of the sun, and that it circulates at twelve units of distance from the gravitational centre of the system. It should be found, this being so, if found at all, at an apparent interval of rather less than 2″ from Algol. The real gap of space separating them—the radius, that is to say, of Algol's relative orbit—would be measured by thirty-one radii of the earth's orbit; and the effectiveness for visual purposes of a still problematical body, shining by reflected light alone, can hence be estimated. If of the same density with Algol, it presents a disc of five-fold area, which, endowed with Jupiter's high reflective power, or an albedo of 0.62, would possess a total lustre $\frac{1}{2,680,000}$ that of the original source of its radiance. This is equivalent to saying that it should be fainter by sixteen stellar magnitudes. Yet the suppositions introduced above are perhaps unduly favorable to conspicuousness. Evidently, however, an eighteenth-magnitude star, in the close vicinity of one of the second, is far below discernment with any telescopic or photographic powers likely to be in use for a considerable time, if ever; so that visual confirmation of Dr. Chandler's theory can only be looked for if the unknown mass it has brought ideally into existence be in some degree self-luminous.

That theory, as he remarks, "has a much wider cosmological meaning than the mere explanation of the phenomena" of a single star. Most "eclipse-variables" exhibit irregularities of the same type with those of Algol, and which will doubtless prove amenable to a similar explanation. Moreover, an incalculable number of stars which, from our point of view, escape eclipse, unquestionably belong to systems organized on the same general plan. One such, indeed, is already known in $\alpha$ Virginis, a first-fruit of discovery in this particular branch; and Procyon, perhaps, is one of many others essentially resembling it, although inaccessible to spectrographic research, because revolving in planes nearly perpendicular to the line of sight. Thus the intimate association of dark and bright bodies of the same order of mass would appear to be no exception in the universal order. And this scarcely allows us any longer to regard a sun-like condition as representing simply and solely a stage in the condensation of a primitively nebulous mass. Some further conditions are plainly needed to produce the brilliant and concentrated evolution of light characteristic of "suns."

Dr. Chandler concludes his valuable paper with an appeal for micrometrical measures of Algol stars, adapted to detect and determine possible systematic disturbances of their proper motions. Measures of the kind might, in his opinion, lead to highly significant results, which would probably, in the case of Y. Cygni, be reached with particular promptitude. "If the research gave favorable results in this instance," our author continues, "it could then be extended to $\lambda$ Tauri, which appears to be also a promising candidate." It is to be hoped that the suggestion will not remain unheeded. Owners of heliometers could hardly turn them to better account than by applying this simple criterion to an hypothesis which opens yet one more road through the daily widening field of sidereal discovery.

MISS A. M. CLERKE.