"The Elements of Quaternions."

IN answer to my reviewer's question (*vide* p. 154), I must frankly admit that

(*a*) Eq. 8, p. 40, should have been a group of six equations, $i = \sqrt{-1}$, $j = \sqrt{-1}$, &c. ; and that

(*b*) The inference should have been that *i*, *j*, &c., are (unequal) square roots of negative unity. H. W. L. HIME.

THE LICK OBSERVATORY.

THE recent issue of volumes ii. and iii. of the "Publications" of the Lick Observatory serves to give some indication of the growing activity of this world-famed institution, and to foreshadow the great part which it is destined to play in the astronomy of the future. As in the case of so many other observatory publications, these volumes contain much with which the various astronomical journals have already made us familiar, and one of their chief objects appears to be to collect the observations into a convenient form for reference.

Volume ii. is entirely devoted to the magnificent micrometric work on stars and nebulæ performed by Mr. Burnham during his four years' connection with the Observatory, which, to the general regret, terminated in June 1892. It will be a matter of satisfaction to all interested in the progress of astronomy to learn that this keen-sighted astronomer has nothing but praise for the great telescope. He says: "It has more than satisfied the severest tests which could be applied, and the highest expectations concerning its performance have been realised. It is a monument of the genius and skill of the unrivalled opticians, Alvan Clark and Sons, to whom the progress of astronomical work all over the world is so largely indebted." The fact that powers up to 2600 have been successfully employed, further emphasises the excellence of the objective.

Mr. Burnham strongly insists upon the advantages to be gained by the use of a micrometer in which the wires are bright on a dark field. With this method of illumination, he tells us, "any object that can be seen under any circumstances, however faint, can be well and accurately measured. There is no such thing as a star too faint for measurement, if it can be seen at all."

Besides the immense number of numerical results, the volume gives a mass of most interesting information relating to the various objects observed. Some of this has already been published, but many new points have been added. Thus, it appears that the observations of θ Orionis show that "the six principal stars are absolutely fixed with reference to each other, so far as any change is concerned which could be detected by observations covering more than half a century." The fulness of the account of this remarkable group, and of the numerous supposed discoveries of stars within the trapezium, furnish an excellent example of the thoroughness which is so characteristic of Mr. Burnham's work. With reference to the very faint star discovered within the trapezium by Mr. Alvan E. Clark soon after the telescope was erected, he writes: "It is a difficult object with the 36-inch, and certainly has never been seen before, notwithstanding the numerous alleged discoveries with telescopes down to three or four inches aperture. Not less than a dozen of these imaginary stars have been distributed about the interior of the trapezium."

To the average astronomer, the star 95 Ceti would probably not be of absorbing interest, but to Mr. Burnham it is "the most mysterious and strange double star in the heavens." The companion was discovered by Clark with a 7½-inch, was subsequently measured by Dawes in 1854, and by Burnham with some difficulty in 1888, since when he has not been able to see it even with the 36-inch.

Mr. Burnham finds that "none of the stars which have been supposed from spectroscopic observations to be close doubles, have shown any evidence of the fact when examined with the large telescope under the most favourable conditions." He then goes on to say that "it is possible some other explanation will be found for the recurrent phenomenon first discovered by Miss Maury in the Harvard spectrum photographs. At all events, it is hardly worth while, until the method has been verified upon some of the numerous known pairs suitable for this purpose, to consume the valuable time of the great telescope in a further examination of objects of this class." One would almost imagine that Mr. Burnham had failed to grasp the fact that the separation of the component stars in such cases, by the spectroscopic method, is solely due to their relative velocity, which in ordinary pairs is relatively small. At any rate, it has been estimated that a telescope of sufficient dividing power to separate the components of β Aurigæ must have an aperture, not of three, but of eighty feet!

Limitations of space forbid further reference to the rich feast which Mr. Burnham has provided; the value of much of his work will probably be only fully realised by astronomers of another age, but at the same time a large proportion of his results are of the greatest immediate interest and value.

Vol. iii. of the "Publications" consists of Prof. Weinek's now well-known selenographical studies; a report on specimens of glass similar to those used in the construction of the great object-glass; an investigation of the glass scale of the measuring engine; and Prof. Keeler's observations of the spectra of nebulæ.

It comes as a surprise to us to learn from Prof. Holden's introduction to this volume, that the work of the Lick Observatory is not without danger of suffering for want of funds. Even so small a matter as a suitable instantaneous shutter "could not be constructed until the summer of 1893, for lack of funds and of skilled workmen." In the early stages of the lunar photographic studies, we are also informed that the work would have been seriously interrupted had not the Smithsonian Institution come to the rescue with "several small appropriations of money." The appearance of the present volume has been made possible by the generosity of Mr. Walter W. Law, of New York City, in providing funds to cover the whole cost of producing the fifteen magnificent plates of the moon which embellish its pages. They are modestly described as "a gift to science," and they afford another example of the practical sympathy with astronomical inquiries displayed by so many of our American cousins.

Few will be inclined to deny the great value of the lunar photographs which have been taken at the Lick Observatory, and it is a matter for congratulation that the astronomical world has so soon been made acquainted with the first-fruits of their investigation.

Prof. Holden tells us that it was quite impossible to undertake the investigation of the negatives at the Lick Observatory, owing to the limited staff, and they were therefore placed freely at the disposal of Prof. Weinek, "whose previous experience in lunar observations and in photography, as well as his very unusual artistic skill, made his advice and assistance of extreme value."

No pains have been spared to make the study of the objects selected as complete as possible. As an instance we may mention that Prof. Weinek's drawing of Copernicus, enlarged twenty times from the negative, represents the great labour of 224¾ hours, and is described by Prof. Holden as "a monument of skill and patience."

It is proposed that a complete map of the moon, on a scale of 3 feet to the diameter, shall eventually be made, though the practicability of making a map on four times the scale is demonstrated by an enlargement of Tycho. The photograph of the Lunar Apennines, on the 3-foot scale, reproduced in Fig. 1, is a magnificent example of a camera enlargement from one of the negatives.