tempt to prove too much. In the general field of visual observations and in astrophotographic work the refractor is for many reasons superior to the reflector, but in spectroscopic, spectrographic and allied branches of astrophysical investigations, the latter instrument is far more efficient than the former. This has been so often pointed out and so abundantly demonstrated by the results of observation that, considering the importance which spectrotcopic research has now assumed in the development of modern astronomy, it seems surprising that on the one hand the claims of the reflector should not be more generally recognized in the equipment of modern observatories, and that on the other some steps should not have already been taken to turn the large reflectors already constructed to account in the investigation of some of the many problems now pressing for solution in this already vast and daily extending field of research; the opening of which, little more than thirty years ago by the pioneering labors of Huggins, Vogel, Young and others, makers, it is safe to say, the beginning of an era which will be even more fruitful of astronomical discoveries and possibilities of development of astronomical knowledge, than that with which the name of the Herschels will remain forever associated.

YERKES OBSERVATORY.
24th Dec., 1897.

III. ON THE BEST METHOD OF OBSERVING THE MILKY WAY.

A. PANNEKOEK.

FOR POPULAR ASTRONOMY.

The aim of all our researches of the Milky Way is to get a picture of all its details representing as correctly as possible its appearance to the naked eye. It is only on account of its extraordinary faintness that we are obliged to use special methods and precautions in this research. Among these precautions the following are the most important.

The observer should not be acquainted with the results of former researches. For its great faintness makes it very easy to see, what we expect to see; and preconceived ideas will soon vitiate the results. Another important precaution to be taken is to avoid the inconvenience caused by artificial illumination. This diminishes the sensitiveness of the eye to the faint glow of the Milky Way and small differences of brightness remain unper-

ceived. It is often observed that sometimes a quarter of an hour after leaving a lighted room the eye is still dazzled. Therefore good observations of the Milky Way can only be made when the eye has been some time in darkness, and it is most earnestly advised to write in darkness without artificial illumination of the paper.

It stands to reason that the sky should be wholly clear and cloudless. Even the slightest veiling of the sky will wholly vitiate the aspect of the Milky Way, and observing should in this case be wholly avoided. Moonlight too may be very injurious; not only making the faintest parts of the Milky Way invisible, but also by the general illumination of the sky and of the surroundings causing the eye to become insensible to slight differences of brightness.

Some difficulty is presented in observing all these precautions, but in every case the observer should take care to note all the circumstances that may perhaps diminish the value of the observations, so that afterwards each of them may be valued according to its comparative certainty.

When an astronomer takes up this line of research he should first make himself acquainted with all the stars in the Milky Way regions. At the same time he may take a survey of the principal spots and streamers of the Milky Way itself, for only when the observer knows the general aspect, will he be able to study the further problems successfully. These may be divided into two different lines of research, viz, the investigation of the minutest visible details and the examination of the general distribution of brightness.

When we wish to follow the first line, it is best to study at once, only a limited part e. g along a longitude of 30 — 60 degrees. This part is surveyed till we know exactly what we see, and as soon as we can describe in words all its peculiarities we note them down. In this manner we describe the position of bright and dark spots and their boundaries by the stars on them; also the streamers, which connect these spots, or which lose themselves in the darkness of the background. Moreover we notice the appearance of a spot, whether it is equally luminous, or whether it diminishes from one side to another, whether its boundaries are marked or whether the light gradually fades into the surrounding darker parts; whether the light is even or whether it is dotted by numerous little stars, or clusters to little flakes of light. In bright spots it is often advantageous to look at dark lanes, that divide them, and I have always fonnd it best

to look not exactly at the point that is being examined but somewhat above or at one side of it. By this indirect vision minute details appear, that are not visible when looked at directly. If desirable the description can be completed by little sketches, e. g. of irregular boundary lines. The brightness of the different spots may be designated by numbers; these will never leave doubt as to what the observer has seen, and therefore are much clearer than the adjectives faint, bright, very bright, etc. A scale with 5 for the brightest spot, 0 for the background of the sky will, I think, suffice.

When the observer has in this manner filled up his sheets of paper with the description of a part of the Milky Way, they should be copied at home as soon as possible; for often the lines will be confusedly and illegibly written and he will then still be able to recollect what is meant. A sketch of the examined region can be added, not as an exact representation, but only to supplement the description and make it clearer.

The same region should be examined several times in this manner, and the observer will soon perceive that during subsequent observations he is able to see more peculiarities than at the first. In midsummer the regions of Aquila and Ophiuchus can be taken up, and during autumn the further course of the Milky Way through Cygnus, Cassiopeia and Perseus is examined, till in winter the research is concluded with the Auriga and Orion regions. The next year the observations are repeated, till a sufficient quantity of materials is collected for a good general description, which nowhere leaves doubt about the appearance of the Milky Way.

Particular emphasis has been laid on the verbal description; indeed it is much more intelligible to every one than a picture; for a picture gives the opportunity of doubting of what is seen by the observer, especially when the inaccuracies of the multiplying process add to the impossibility of drawing everything exactly as we desire it. On the other hand a picture has the advantage of showing in a moment what would require a long verbal description. Whoever therefore gives preference to drawing for this purpose can make himself very useful by drawing an accurate picture of the Milky Way. But I believe this will be much more difficult.

In taking up the second problem, the investigation of the general distribution of brightness, the observer should pay attention only to the principal peculiarities, that are perceived by an experienced observer at first sight; greater parts of the Milky Way may then be treated at once. The method, that has pleased me

most, is by drawing lines of equal brightness (isophotic lines). After having examined the region thoroughly, a boundary line is picked out and its course is followed along the Milky Way, everywhere tracing the places of equal brightness. After having finished such a line and after having marked its course upon the chart, another is chosen, shaping its course along a track of greater or lesser brightness. It will be necessary often to compare the brightness of more distant parts. It will soon appear that only 4 or 5 different degrees of brightness can be used without confusion. The different regions that are examined one after another must be linked together by parts they have in common; and comparison of regions at great distance will control their relative brightness. In this research the parts of the Milky Way examined should not be at too low an altitude for then the extinction of their light by our atmosphere has too great influence.

For these observations it is very useful to have charts, that can be used without artificial illumination. Such charts may be easily constructed by taking dull-black paper (which can be made e. g. by covering the paper with a coat of blacking and starch mixed) and dotting the stars upon it with a white body-color *f. i.* white-lead. When the Milky Way diagrams of Marth are divided by means of the strokes along the edges into squares of 5°, and when a similar net on a larger scale is drawn upon the paper, the squares can be filled up with stars by eye estimate. On such a chart chalk may be used to draw the lines; when they are copied at home on the white charts, the lines may be effaced by means of a wet sponge.

Another means of getting materials for the general distribution of brightness is to compare the brightness of spots along the whole Milky Way, at small and at great distances. The brightness may be expressed by numbers from 1 to 5; and in this manner a catalogue may be constructed where each spot or streamer has its brightness expressed in the same manner as a star by its magnitude. The place can at first be given by alignments of small stars in the neighborhood; and afterwards at home by their galactic longitude and latitude according to the diagrams of Marth. Perhaps it is useful to choose standards of brightness in different parts of the sky; these should be chosen, where greater spots of even light occur.

For the advancement of science it is necessary to publish the immediate results of both methods of working. The study of the general distribution of brightness may give great profit, in connection with star gauges, in researches on the construction of the

universe, like Herschel's, Struve's and Gould's, while the study of minute details may be useful in such researches as Easton's as to the connection of the distribution of the smallest stars with the appearance of the Milky Way, and in the future, to discuss the question, whether changes in the appearance of the Milky Way take place. But as it will be a great satisfaction for an observer to have a picture as exact as possible, I will explain the manner in which to construct it from the observations; moreover it may make the foregoing explanations somewhat clearer. When on a star chart we draw the lines of equal brightness, described on p. 525-6 by shading the region between them with increasing deepness, then blending these shades into one another at their boundary lines, we have a picture with good distribution of brightness, but showing only the more general details, though it gives the general appearance very well. Upon this background we can draw the minutest peculiarities, taken from the results of the studies of p. 526-7 we then have a picture that contains all that the observer has been able to see, and which still shows the brightness of the different parts in a very exact proportion.

ON THE "WORTHLESSNESS"* OF METHODS OF GEOMETRICAL OPTICS IN DEALING WITH THE PROBLEMS RELATING TO THE DEFINITION AND THE DELINIATING AND RESOLVING POWER OF TELESCOPES.

F. L. O. WADSWORTH.

FOR POPULAR ASTRONOMY.

It has often happened in the history of science that the most celebrated men of their time have, through their conservatism or worse yet active opposition to new ideas, greatly retarded the progress of science. So it was in the case of Berthollet who in the

* I feel that an apology ought to be offered for using such a strong expression as this in the title of a paper. It is not mine but is borrowed from the title of a recent article in the *Astronomical Journal* ("On the 'Worthlessness' of a Proposed Form of Telescope,") by Professor Schæberle. If however the expression was justifiable in that case, it will be admitted, I think, that it certainly is in the present one; (see note "On a New Form of Mirror for a Reflecting Telescope," which appears elsewhere in this issue.)

In this article Professor Schæberle has remarked that "certain fundamental principles of optics have remained hidden ever since the invention of the telescope." It will hardly be admitted I think that physicists and opticians at least, are in general so ignorant of one of the most important branches of their subject as Professor Schæberle would have us believe by his statement, although it can not be denied that there are some astronomers who are either ignorant of or choose to ignore, "certain fundamental principles."