A 100-INCH MIRROR FOR THE SOLAR OBSERVATORY

By GEORGE E. HALE

I am permitted to announce that Mr. John D. Hooker, of Los Angeles, has presented to the Carnegie Institution of Washington the sum of forty-five thousand dollars, to be used to purchase for the Solar Observatory a glass disk 100 inches (2.54 m) in diameter and 13 inches (33 cm) thick, and to meet other expenses incident to the construction of a 100-inch mirror for a reflecting telescope of 50 feet (15.24 m) focal length. These expenses will include the erection of a building in which the mirror can be ground, figured, and tested; the construction of a large grinding-machine, with crane for lifting the mirror; the provision of a 54-inch (1.37 m) glass disk, to be made into a plane mirror for testing purposes; the purchase of glass disks for the various plane and convex mirrors required in the telescope, etc. The optical work will be done by Professor G. W. Ritchey and the assistant opticians employed under his direction by the Solar Observatory.

In making this gift, Mr. Hooker's desire is to secure the realization of the great possibilities in astrophysical research which a large reflector seems to offer. He has absolute confidence in the ability of Professor Ritchey to make an essentially perfect mirror 100 inches in diameter; no one could ask better evidence of this than his gift affords. He knows, also, that in several classes of work, such as the measurement of the heat radiation of the stars, and the spectroscopic study of the faintest objects, the mirror is sure to yield results fully commensurate with its great size. But he is nevertheless aware that for certain other classes of work, in which the most perfect definition is essential to the highest success, the construction of a mirror of such great aperture must be regarded as an experiment. The immense block of glass will weigh four and one-half tons—four and a half times as much as the disk of our 60-inch (1.52 m) mirror. The difficulty of providing a mounting capable of carrying it with the necessary precision is not slight. The glass is certain

to be distorted by temperature changes, which would ruin its performance if not obviated. The atmospheric conditions, even on Mount Wilson, may not be sufficiently good to permit so great an aperture to be used to full advantage. Of these and other obstacles Mr. Hooker is fully informed, and he does not underestimate their importance. But he perceives and appreciates, with the understanding of one who has himself invented and developed mechanical appliances, that experiment is necessary to progress. He therefore does not hesitate to provide the means for undertaking an optical experiment on a large scale. Let us consider its probable outcome.

In the first place, the question arises whether a sufficiently homogeneous glass disk of the required dimensions can be obtained. Our long experience with the Plate Glass Company of St. Gobain leads us to believe that no insuperable difficulty will be encountered. This old and reliable company has cast for us scores of disks, from which Professor Ritchey has made a large number of plane and concave mirrors, from the smallest sizes up to 60 inches. At present the 60-inch is receiving the finishing touches in our optical shop, and two 36-inch (0.91 m) mirrors, for testing purposes, are well advanced, in addition to several large plane and convex mirrors for the 60-inch reflector. In all of these cases the glass disks furnished by the St. Gobain Company have left nothing to be desired. The 60-inch disk, 8 inches (20.3 cm) thick, and weighing a ton, is fully equal in quality to the smaller ones. We are therefore inclined to believe, since the St. Gobain Company expresses its deliberate opinion that a satisfactory disk, 100 inches in diameter and 13 inches thick, can be produced, that they will be able to carry out the order we have given them.

As for the work of grinding and figuring, no one who has watched the progress of our 60-inch mirror would be likely to doubt Professor Ritchey's ability to accomplish this difficult task. The method of parabolizing which he has recently perfected will apply as well to a 100-inch mirror as to the 60-inch. It eliminates the necessity of any hand-work, and has already yielded a paraboloidal figure so perfect that almost any other optician would be more than contented with it. Professor Ritchey rightly believes, however, that a still higher degree of perfection will be worth attaining, since its advan-

tages will be felt under the most perfect atmospheric conditions. I am confident that he will find no difficulty in bringing the 100-inch mirror, as well as the 60-inch, to this highest order of perfection.

The mounting should offer no great obstacles, especially as it will not be designed until the mounting of the 60-inch has been thoroughly tested on Mount Wilson. Unless I am greatly mistaken, this latter instrument will meet our best expectations. Professor Ritchey has taken the greatest pains with the design, and the co-operation of the able staff of engineers at the Union Iron Works has been most useful. The mechanical execution of the parts is admirable, and with the heavy machinery available, a mounting much larger than that required for the 100-inch mirror should be easily within the bounds of possibility. To a firm which has built some of the most powerful battleships and cruisers in our navy such a mounting would appear much less formidable than to the average instrument-maker, accustomed to a different class of work. Fortunately, the ideas of the Union Iron Works Company, as to the degree of precision required, are entirely in harmony with our own, and appear to have been met in the mounting of the 60-inch, which has just arrived in Pasadena.

The prevention of change of figure due to changing temperature should not prove a very serious problem. During the fine nights of the best observing season on Mount Wilson the temperature remains almost perfectly constant after 9 P. M. It will therefore only be necessary to maintain the mirror (or possibly the entire telescope) at approximately this temperature throughout the day, by means of suitable refrigerating machinery. In the long periods of absolutely cloudless weather the change of temperature from night to night is extremely small, so that little difficulty should be encountered on this score. If the slowly falling temperature during the early evening should prove to give trouble, the observational work might be deferred until after nine o'clock. The dome and building like those designed for the 60-inch reflector, will be so constructed that no air can enter during the day; they will also be protected by louvers from the heat of the Sun. The problem is, of course, altogether different from that encountered in the case of the Snow telescope, where the mirrors are required to give good images in spite of their exposure to direct sunlight.

Assuming that these various difficulties can be successfully overcome, it still remains a question whether the atmospheric conditions on Mount Wilson will be sufficiently good to permit the telescope to give satisfactory images. This cannot be definitely determined until after the 60-inch reflector has been used for some time. Even if it should prove, however, that only a very few nights in the course of a year can be utilized to the fullest advantage, the construction of such a telescope would nevertheless be desirable. For under the ordinary conditions, which are much finer than those in the eastern part of the United States, results of the highest value can be obtained in many classes of work, such as the photography of stellar spectra, the measurement of the heat radiation of the stars, etc. The immense amount of light which this mirror will collect should render it particularly suitable for spectroscopic work of all kinds.

It need hardly be said that the 100-inch mirror, when suitably mounted, will play a most important part in the scheme of research of the Solar Observatory. The investigation of stellar evolution, upon which we are engaged, frequently calls for adequate spectroscopic study of stars beyond the reach of existing instruments. In my work on the red stars of Secchi's fourth type, with the 40-inch Yerkes telescope, I encountered this difficulty, in spite of the great light-collecting power of that instrument. It was impossible to obtain satisfactory evidence as to the transition from solar stars to those of the fourth type. The large number of stars within the reach of a 100-inch reflector should greatly increase the possibility of finding the intermediate types, which are so important in their bearing upon the relationship of solar and red stars. This is only a single instance, but it forcibly suggests itself when considering our program of research. In other fields the large reflector should be equally valuable, especially for the photography of the numerous small spiral nebulae, the details of which should be brought out to good advantage with a focal length of 50 feet; minute study of the large nebulae, in the hope of detecting changes in their form; the study, with very high dispersion, of the spectra of bright stars, etc. The remarkable calm of the summer nights on Mount Wilson should assist materially in all of this work, since vibration of the tube, caused by the wind, would undoubtedly be a serious drawback under less favorable conditions.

No provision has yet been made for the mounting and dome. It is not known from what source funds for this purpose will come, but I believe a donor will be found by the time they are needed. Mr. Hooker's gift is very opportune, because of the fact that it permits us, now that the 60-inch mirror is nearly completed, to retain and use to the best advantage the services of the opticians trained by Professor Ritchey for our present work. The making of the glass disk, and the grinding and figuring of the various mirrors, will probably occupy about four years. Since the Union Iron Works Company will require only a year for the construction of the mounting and dome, it is evident that no funds for this purpose will be needed at present, and that the experience gained with the 60-inch reflector can be utilized in designing them.

PURCHASE OF THE SNOW TELESCOPE BY THE SOLAR OBSERVATORY

As stated in previous papers, the authorities of the University of Chicago were kind enough to loan the Snow telescope to the Solar Observatory for a period of two years. It subsequently became the opinion of all parties concerned that, in view of the very satisfactory performance of this instrument on Mount Wilson, it would be advisable to keep it there permanently. Accordingly, the Snow telescope has been purchased by the Solar Observatory, and will thus form a part of its permanent equipment. I wish to express my sense of obligation to Miss Snow, to Professor Frost, Director of the Yerkes Observatory, and to Acting President Judson and the Trustees of the University of Chicago, for the courtesies shown us in connection with the loan and sale of this valuable instrument.

SEPTEMBER 1906.