

### Some Tests of the 100-in. Hooker Telescope.

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THE construction of a telescope of very large aperture is necessarily an experiment the final success of which can be determined only by the results of astronomical observations. After the mechanical and optical difficulties have been overcome, there remain those disturbances of the atmosphere which are of little importance with small apertures and low magnifying powers, but become more and more serious as the diameter of the objective and the scale of the image are multiplied. Thus in undertaking the construction of a reflecting telescope of 100-in. aperture, while we had the advantage of experience with the 60-in. Mount Wilson reflector, we frankly recognised that the outcome must remain in question until the completion of tests made under customary atmospheric conditions.

As contrasted with the 60-in. reflector, the full measure of advantage attainable under *perfect* atmospheric conditions would be as follows:

	Light collecting power	Scale of focal image	Resolving power
60-in. reflector	1	1	1
100-in. " "	2.8	1.7	1.7

This means that either in direct photography or in spectrographic work with a given dispersion the larger instrument should bring within range stars about one magnitude beyond the reach of the 60-in. The advantage thus gained would be important, as two illustrations, out of many that might be given, will suffice to show. Only two or three of the brightest stars can be studied with the most powerful spectrograph of the 60-in. telescope, which is not much inferior in dispersion to the instrument used by Rowland in his work on the solar spectrum. The same high dispersion, if employed with the 100-in. reflector, could be applied to several times as many stars, representing most of the principal stages of stellar evolution. At the other end of the magnitude scale, the 100-in. telescope should be able to record photographically many millions of stars too faint to be reached by the 60-in.

In the second place, the increased scale of the focal image, whether in the principal focus of the large mirror or at the Cassegrain focus, where the 100-in. telescope has an equivalent focal length of 134 ft., should separate more widely the crowded stars at the centre of globular star clusters, thus permitting them to be studied without confusion with one another; it should increase the precision of measurement in such difficult work, for example, as that involved in detecting the very small changes in the configuration of spiral nebulae caused by their internal motions; and, to give no other illustrations, it should permit minute details, not previously photographed, to be recorded on negatives of such objects as the moon.

Finally, the increased theoretical resolving power, if realisable in practice, should permit the

visual measurement of the components of very close binary stars, which cannot be separated by the smaller instrument, not merely because of the overlapping of their images during periods of poor seeing, but also because of their inherent irresolvability due to the wave-length of light itself.

In spite of the fact that most of the tests have been applied under the comparatively poor atmospheric conditions of the winter season, the early results are very satisfactory. It has become possible to include in our regular spectrographic programme stars one magnitude below those studied with the 60-in., so that the radial velocities and spectroscopic parallaxes of stars down to the tenth magnitude are being measured in large numbers by Dr. Adams and his associates. This involves a notable extension of the range of our investigations on the structure and motions of the stellar universe. Similarly, an important advance in our researches on stellar evolution has also been rendered possible, bringing to light new and curious types of stellar spectra and interesting phenomena in the spectra of variable stars at minimum brightness. The spectra of the long-period red variables of the Md class, most of which were too faint for satisfactory observation with the 60-in., are now being systematically photographed by Dr. Merrill with the Hooker telescope. One of these stars has been found to show the chief nebular lines in its spectrum, a matter of peculiar interest because of the fact that these lines have previously been observed only in nebulae and in temporary stars. With low dispersion, the spectra of stars of the fourteenth magnitude have been photographed by Dr. Shapley with moderate exposures at the centre of globular clusters.

The preliminary results of the photography of nebulae have also been very satisfactory, both at the principal (Newtonian) focus of the 100-in. mirror and at the 134-ft. Cassegrain focus. The photographs indicate an important advance over the 60-in. telescope, and leave no doubt that the desired increase in the precision of measurement, rendered possible by the larger scale of the images, will aid materially in the study of the internal and proper motions of spiral nebulae. A striking feature of these negatives, as compared with those taken with the 60-in., is the increased contrast of the minute nuclei in spiral nebulae, which are brought into greater prominence by the larger aperture. This will render available for measurement a large number of sharply defined symmetrical points.

The character of the images may be judged from the accompanying reproduction of a photograph of the moon (Fig. 1), taken by Mr. Francis G. Pease at the 134-ft. Cassegrain focus on September 15, 1919. This negative, like others obtained by Mr. Pease with the Hooker telescope, shows smaller details of structure than we have previously been able to photograph.

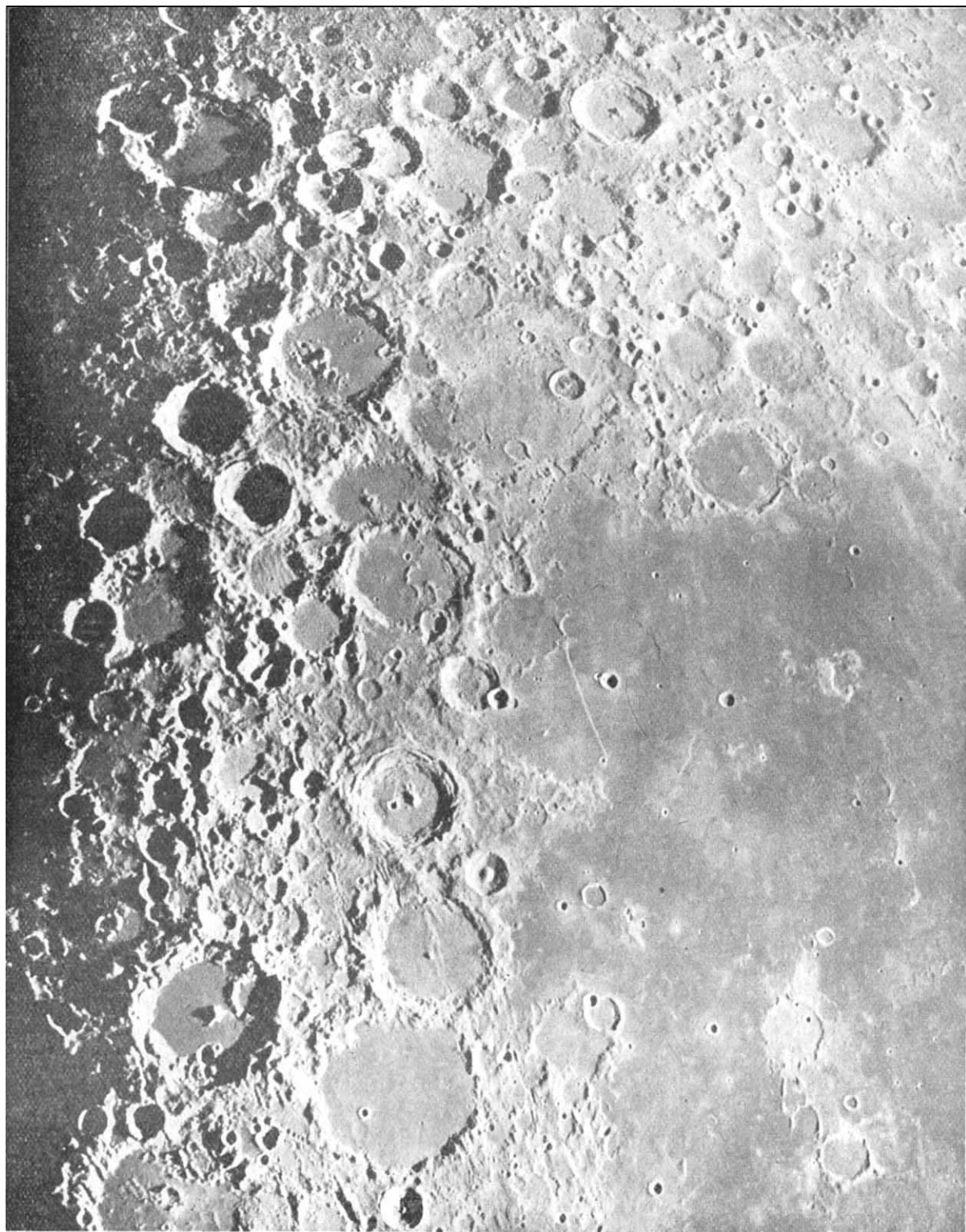


FIG. 1.—North central portion of the moon at last quarter. Photographed with the Hooker telescope of the Mount Wilson Observatory on September 15, 1919, by Mr. F. G. Pease. Scale: 1 in. about 90 miles.



Perhaps the most interesting application of the 100-in. telescope hitherto made is that rendered possible by the utilisation of Michelson's interference method for the measurement of the spectroscopic binary star Capella. The method consists in completely covering the 100-in. mirror by a screen in which are two slits, which can be placed at any desired distance apart. Light coming from a point source, such as a single star at a very great distance from the earth, passes through the two slits and is brought to focus by the large mirror. A system of interference fringes may then be seen under a telescopic power of about 5000 diameters, which are sharply defined even on a night of poor seeing. If the star is single, the fringes remain visible even when the slits are separated by the full diameter of the 100 in. mirror. But if the star is a very close double, the fringes will disappear (assuming the members of the pair to be nearly equal in brightness) when the slits, set by observation at the proper position angle, are moved apart to a distance that depends upon the angular distance between the star's components.<sup>1</sup>

The following measures of Capella, made by Dr. Anderson, indicate the possibilities of the method:

		Position angle	Distance
1919, December 30	...	148°0	0'0418
1920, February 13	...	5°0	0'0458
" " 14	...	1°0	0'0451
" " 15	...	356°4	0'0443
" March 15	...	242°0	0'0505

<sup>1</sup> In practice, a somewhat different technique, giving the same result with higher precision, is employed by Dr. Anderson.

When plotted, these points fall accurately on an ellipse. The method, which has been tested experimentally in the laboratory, not only allows binaries that cannot be resolved by other means to be measured with very high precision, but also permits *twice* the theoretical resolving power of the Hooker telescope to be attained in practice, even when the seeing is poor.

This application of the interferometer was suggested by Prof. Michelson many years ago and used by him in the measurement of the diameter of Jupiter's satellites at the Lick Observatory in 1891. The possibility of seeing the fringes under ordinary atmospheric conditions with the full aperture of the Hooker telescope was demonstrated by Prof. Michelson during a visit to Mount Wilson last September. The method will have many applications, and should be utilised by observers with instruments of moderate aperture who wish to resolve close doubles and to increase greatly the precision of their measures.<sup>2</sup>

From this record of the preliminary tests of the Hooker telescope it will be seen that in light-collecting power, in the increased scale and improved photographic definition, and in the added possibilities of optical resolution attained through the application of Michelson's method, the new instrument has not disappointed our hopes. We must now endeavour to utilise these advantages in the extension and development of our researches on stellar evolution and the structure of the universe.

<sup>2</sup> For an account of this method, see Michelson, "On the Application of Interference Methods to Astronomical Measurements," *Phil. Mag.*, July 1890.

## Artillery Science.

By SIR GEORGE GREENHILL, F.R.S.

"THE religious attachment of the officer of artillery to the practice of his predecessors" was described by Benjamin Robins about 1740, and his attachment persisted with unimpaired devotion right up to the war. There he found himself outclassed at the outset, out-gunned and out-gunnered; the little artillery he took out was small and puny, and not of the right sort required—"pas de celle qu'il faut." Our Artillery Authority cannot be said to have understood what it spelt, the word "artillery."

On the assumption of our politicians that this country was never going to war again, an interdict had been laid on England of seven lean years; and when they were up, the lean years got an extension leading right up into the war.

A well-disciplined Army Council had been formed, obsequious to the Minister, with instructions to resist all suggestions of military progress—housed in a magnificent new palace in Whitehall, the barracks of an army of War Office clerks, provided out of a reduction of the Regular soldiers.

Temple of Victory it cannot be called. The stone slab over the portal is still blank, ready to

receive the appropriate motto, with no derangement in the epitaph:

PACEM PARA BELLUM SI VIS.

The mentality of the Army Council can be glimpsed in its attitude to Flight in warfare. The Wright brothers framed on their wall the egregious answer of the Secretary in the official jargon: "I have nothing to add to my last letter to you. The War Office is not disposed to enter into relations with any manufacturers of air-planes."

This was in March, 1913, and only the next year we were running the risk of our whole Army being completely surrounded, with no airmen to scout for us. The evil name "Maubeuge" would have been written on our history as indelibly as "Jena" and "Sedan" were on others. No wonder the German squadrons could fly all over England and London with impunity, in the face of all our air defence.

The belated arrival in the war of the Tank is another similar story. Military prejudice preferred to muddle along in a stalemate of trench