SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor, J. McKeen Cattell, Garrison-on-Hudson, N. Y.

REPORT OF THE WATSON TRUSTEES ON THE AWARD OF THE WATSON MEDAL TO DAVID GILL.

At the last annual meeting of the National Academy of Sciences the Watson medal was, on recommendation of the Trustees, awarded to Dr. David Gill, Her Majesty's Astronomer at the Cape of Good Hope, for his work in perfecting the application of the heliometer to astronomical measurements resulting in an important advance in astronomy of precision especially in the determination of the parallaxes of the sun and stars, and of the positions of the planets. In accordance with our custom I now have the honor to submit a fuller report on the work in question.

It is as true of the astronomer as of the poet that he must be born, not made. Although there is no branch of research in which a wider knowledge of the whole field of physical science and a broader grasp of first principles are necessary than in astronomy, it is none the less true that this knowledge and grasp must be supplemented by that indefinable quality born in the man which leads him to pursue astronomy with zeal and success. The career of our medalist offers a remarkable example of this fact. So far as can be inferred from his writings, his early training was rather in the direction of mathematical science, especially horology, than in that of astronomy. His first appearance as an active worker in the latter science was in connection with the transit of Venus in 1874. He was at that time the coadjutor of Lord Lindsay, afterward Earl of Crawford and Balcarres, who was so much interested in astronomy that he had erected an observatory at his seat, Dunecht, near Aberdeen. Gill was placed in charge of the institution and the works done there were published in the joint names of the two.

When the transit of Venus of 1874 was approaching, a special private expedition for its observation was fitted out by Lindsay, with Gill as his leading assistant. Here the latter gave the first evidence of that tireless energy which has marked his whole career. Not satisfied with merely executing the work pertaining to the expedition, he organized, under Lindsay's direction, a campaign to determine a chain of telegraphic longitudes from Berlin to Malta, Alexandria, Suez and Aden. From here the chain extended to Bombay, in the east, and to the Seychelles, Reunion, Mauritius and Rodriguez in the south. Thus the expedition, in addition to the observations which were its main objects, made an important contribution to geodesy and geography.

It was in connection with the observations of the transit that he made his first application of the heliometer, an instrument which he has since done so much toward bringing to its present state of perfection. Although this instrument had been in use in Germany for nearly half a century, and was celebrated as that with which Bessel had first determined the parallax of a star, astronomers were not alive to its possibilities. Its application was greatly restricted by the imperfection of its construction and, although one had long been mounted at Oxford, little use was made of it in England. In fact its application was limited by a defect of its construction. The Repsolds of Hamburg introduced the important improvement of making the two divided halves of its object glass slide in a circle having its center at the focus, instead of moving in plain guides, as in the former construction. Its range was thus greatly widened and its accuracy increased.

With the instruments as thus improved Gill, in addition to the observations which were the main object of the expedition, made at Mauritius his first essay in the line which he has since followed with such success; the determination of the solar parallax by observations of the minor planets. The planet chosen for the purpose was Juno. The method was that of observations as far as possible to the east and west of the meridian, the parallatic effect being obtained by the motion of the observer as he was carried around by the earth's rotation, instead of by differences of direction from two distant stations. The result of the observations was 8″.77, which we now believe to be a nearer approach to the truth than was supposed at that time.

The success of this attempt led our medallist to inaugurate another on a larger scale in which he was himself the sole actor and mover. This was his celebrated expedition to the Island of Ascension in 1877, in order to determine the solar parallax by observations of Mars at its perihelion approach to the earth, which occurred in September of that year. The method was the same as at Mauritius, the instrument used being the heliometer, and the parallatic effect being obtained by the difference in the direction of the planet in the morning and in the evening. The result of the work was worked out with that thoroughness which is characteristic of the highest order of astronomical research. One of its most important features was a discussion of the personal error in the right ascension of faint stars depending on their magnitude, an error which had long been suspected, but had evaded all efforts to so determine it that it could be eliminated from the results. It is now well established that, in our traditional method of determining right ascensions by transits of stars over the threads of a meridian instrument, all observers, whatever method they adopt, note the transit of a faint star too late relatively to a bright one. The error varies with the observer and the conditions to such an extent that its amount almost defies exact determination. The problem of getting rid of it is among the most serious with which the astronomer has now to contend.

One circumstance will illustrate the extreme precision reached by Gill in this work. The final discussion of his observations brought out a seeming periodic change in the longitude of Mars, going through its period in about half a month. Theory afforded no explanation of such a change. Years afterwards it was traced to an error in the ephemeris of the planet, which had been prepared for him by an official authority, in which certain extremely minute terms of the nutation were not consistently applied. So minute an error would never have been detected by any other method of observation.

The result found for the solar parallax was 8″.78. The main source of doubt to which it is subject, apart from unavoidable accidental errors, arises from the possible uncertainty in bringing the image of a star into coincidence with the center of a planetary disc. The effect of phase and a possible difference of personal equation in estimating the center of the planet on the two sides of the meridian introduce a certain amount of doubt. At the same time there is some reason to believe that the value is as near the truth as any that we can get at the present time.

One result of this expedition is of more than astronomical interest. It gave rise to a very pleasant book by Mrs. Gill, 'Six Months in Ascension,' describing life on a far distant island within the tropics, as well as the work of the expedition.

In 1881 Gill was appointed Director of the Observatory at the Cape of Good Hope, succeeding Mr. E. J. Stone. Although under the capable direction of the latter this establishment had continued to add to its reputation as one of the few important observatories in the southern hemisphere, no one could have seen in it an inviting field for astronomical research generally. Its instruments were antiquated, its means in other respects extremely limited, and its staff insufficient to the execution of any important enterprise. The general impression might therefore have been that, while an astronomer of ability might be able to do some good work at the Cape Observatory on traditional lines, it would be impossible for him to enter upon a great career. But the new astronomer soon showed that his energies were not limited by his unfavorable surroundings. He had learned what could be done with the heliometer, and what further improvements could be made in it in order to bring it to the highest state of perfection. Then he found an inviting field for its application.

The question of the parallax of the fixed stars has long been, from a scientific point of view, one of the most important with which the astronomer has to deal. To determine this quantity is equivalent to determining the distances of the stars and hence making a step towards estimating the dimensions of the universe and the arrangement of its constituent bodies in space. Twenty years ago the parallaxes of a number of fixed stars had been measured, but, in the greater number of cases the difficulty of the problem was such that the results were open to more or less doubt. The new and perfected heliometer was the best instrument for deciding the question and, by using it in the southern hemisphere, it was applied to a field almost entirely uncultivated. It is gratifying to us to know that, in this work, he found an able colleague in our fellow member, W. L. Elkin, who spent some time at the Cape Observatory, carrying on with Gill the work of the new instrument. It was one of the happy results of this co-operation that the Yale University was equipped with the finest heliometer that had then been made, and the instrument placed in the hands of Gill's coworker. This is the only instrument of the kind that has yet been mounted on this side of the Atlantic.

The result of Gill's enterprise is that, at the present time, the parallaxes of perhaps a dozen stars of the southern celestial hemisphere have been determined with greater general precision than has been attained in the case of any corresponding number in the northern hemisphere. One conclusion from this work is of a nature to excite universal interest. The second brightest star in the heavens, Canopus, almost as bright as Sirius, has no measurable parallax. What must be the actual size and brilliancy of a star, which appearing to us as bright as Canopus is yet so enormously distant as to defy the most refined methods of determining its annual parallax? We can only answer with confidence that it is thousands of times the brightness of the sun. Whether we should say 20,000, 10,000 or 5000, no one can decide. What adds to the singularity of the result is that this case is by no means unique. Rigel and Spica, both of the first magnitude, are also beyond our range of measurement even with the most refined of instruments.

One prominent feature of the astronomy of our time is the initiation of international co-operative enterprises to carry on such of its researches as require to be conducted on a large scale. One of these enterprises was organized by our medallist. His experience in determining the solar parallax from observations of Mars and Juno led him to point out the advantages offered by near approaches of the minor planets generally to the earth for the determination in question.

In the course of a little more than a year, from the summer of 1889 to the autumn of the year following, there were to be three favorable approaches of these planets to the earth. An arrangement was made with the observatories of the world which had good heliometers in use, and were willing to engage in the work, to make the required observations. The labor involved in carrying out the whole plan in the best way was very great. The mere making of the observations was a simple matter compared with the subsequent reductions and investigations. The first step in the process was a determination, made with all possible precision, of the positions of the stars of comparison. Not only observers who used the heliometer, but all others who were willing to engage in the work took part in this branch of it. Then it was necessary to derive the best possible elements of motion of the three planets. The question how to discuss the observations so as to obtain results which should be as free as possible from the necessary errors in the elements was another important consideration.

The entire work appeared in 1897–98 as Vols. VI. and VII. of the Annals of the Cape Observatory. An examination of these magnificent volumes will give a better conception than anything that I can say of the amount of research devoted by Gill to this investigation. It is impossible within the limits of the present report to give even an abstract of their contents. We must therefore limit our notice to the general statement already made. It should, however, be mentioned in this connection that the discussion of the observations of one of the planets, Iris, was especially taken in charge by the collaborator whom I have already mentioned, Dr. Elkin.

The definitive results for the solar parallax from the three planets separately were :

From Victoria :	8''. 801 ± 0''.006
" Sappho :	8''. 798 ± 0''.011
" Iris :	8''. 812 ± 0''.009

the combined result from the three, stated in round numbers, is 8''.00. This value has since been adopted, I believe, in all the astronomical ephemerides. That it will stand the test of time is however too much to expect. The improvements now being made in the means and the methods of research will necessarily include the solar parallax in their scope. But no change that may thus be made in the accepted value will diminish our admiration of the skill, industry and perseverance which our medallist has spent upon his greatest work.

While the investigations which I have mentioned, especially the last, are those which the academy had in view in awarding its highest honor in the field of astronomy, there is a work of another class of the first order of importance which cannot be passed over in silence. I refer to the 'Photographic Durchmusterung' of the southern heavens, from 18° of south declension to the pole. The third and completing volume of this work has just appeared. It offers several features of general interest. One is the curious fact that, with its completion, we now have a better knowledge of the stars of the southern heavens, invisible in out latitudes, than we have of the northern. It is an act of simple justice to one of our own countrymen now pursuing his work in the Argentine Republic, to say that this disparity in our knowledge of the stars in the two hemispheres is being markedly increased by the survey of the southern heavens carried on by Dr. Thome at the Argentine National Observatory. The fact that Dr. Thome employs the visual method instead of photography adds to its value in the present connection.

This enterprise of Gill's is intimately associated with the great international enterprise of making a photographic chart of the heavens. In 1882 a great comet appeared, and Gill engaged a Cape Photographer to take its picture. He was interested and surprised to find that along with the comet were taken the surrounding stars down to the 9th magnitude. Evidently here was a method of making star maps which offered great advantages over the laborious process of dotting down stars from eye observation. He communicated his suggestion to Admiral Mouchez, Director of the Paris Observatory and the question was taken up experimentally by the Henrys. The result was the Paris Photographic Conference of 1887, which inaugurated the enterprise now, we hope, approaching its completion.

An interesting circumstance may well command our attention. The Cape Photographic Durchmusterung is the work of two men, whose co-operation offers a remarkable example of that disinterested devotion to the increase of knowledge which is so conspicuous a mark of all modern science. The mere taking of the photographs was not the whole work, it was not even its main portion. The position of the stars on the glass plates must be carefully measured one by one, and every star-image studied by itself, with the view to determine its magnitude. How was it possible to devote the necessary attention to 350,000 separate objects? The one to do it was found outside of all English connections in the person of Professor J. C. Kapteyn, of the University of Groningen, Holland. I know not how many years of patient toil, which would have made the fortune of a business man, was spent by Kapteyn in this work. What gives interest to it is that it is an almost unique example in the history of science of a man of the highest order of general scientific ability in one country devoting his time to what was formally an official work of the government of a foreign country.

This attempt to set forth in a few words the scope and significance of twenty-five years unremitting labor on the part of one who would have made his mettle felt in any sphere of activity he might have chosen to enter may well appear to others, as it does to us, extremely inadequate. The work of Gill may fairly be called epoch-making in a sense even better than that in which the term is commonly used. If we find in it no brilliant discovery to attract the attention of the public, it offers us what is yet better; improved instruments and methods of research applied with such tireless industry, conscientious care, sound judgment, and accurate knowledge of every related subject as not only to expand our intellectual horizon, but to supply the astronomer of the coming generation a pattern which he can study with profit to himself and advantage to his science.

S. NEWCOMB.

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*EXPERIENCE NOTES UPON PLOT EXPERIMENTS.**

FIELD experiments are not easy to plan and very difficult in execution. Uncertainty attends every step from the soil to the seed —the cultivation to the harvesting of the crop.

During the past six years the writer has had two acres under experimentation, and no lesson has been more impressive than that of the lack of uniformity of the soil. An apparently even plot will vary in the composition and texture of the soil, almost from one foot to another. This may be due to many causes, not the least important being the rock strata, gravel beds, etc., that underlie the soil. The surface is usually far from level and the shaving down and filling in to bring the surface to a grade only emphasized the differences that already existed, as results upon the experiment grounds before mentioned abundantly prove.

The field itself should be laid off with exactness, and this means the aid of the surveyor or his instruments. The corner stakes should be set deeply and never removed, and those of each plot should be established once for all. Unless this is so the plots will move and the subdivisions will vary, and shortly the whole area is unsatisfactory, if not in confusion.

Ideal experiment grounds should have the same exposure. There are objections to perfectly flat land, and there are more to a rolling surface. The grounds under the charge of the writer are upon a slight incline, nearly uniform throughout the two acres; but even there a wash of the soil is always troublesome during heavy rains, and introduces an element of uncertainty when soil treatment obtains upon the plots.

There should be no tree, bush or other tall object upon or close to the trial grounds. The shade of a single tree may do more to disturb the course of an experiment with sun-loving crops than the sapping of the soil of plant food by the roots of the same tree.

This matter of the influence of shade has been tested by means of lath by the writer; it is very great, and incidentally it should play no part in the experiment grounds. It is not safe to grow corn or any like tall crop within many feet of any small crops, as lettuce or spinach. The scheme needs to be so planned that the question of shade is reduced to a minimum. This is one reason why the outside plants are not comparable with these in the interior of the plot.

A single back furrow or a dead furrow

* Presidential address before the Society for the Promotion of Agricultural Science, Columbus, Ohio, August 19th.