THE AIM OF THE YERKES OBSERVATORY. ¹

By George E. Hale, Director.

It gives me very great pleasure to extend to you all, on behalf of the members of the staff of the Yerkes Observatory, a most cordial welcome. The feeling of satisfaction which I share with my colleagues at seeing so many present is deepened by the peculiar circumstances under which we have come together. Removed from the neighborhood of great cities, and from the more populous regions of the United States, the Yerkes Observatory could hardly have hoped to draw hither so many well-known investigators. Realizing as we do the great distances many of you have come to favor us with your presence today, we assure you of our high appreciation of the honor thus done to the Observatory. The season and the place alike render difficult the provision of such entertainment as we would wish to offer. But all that we have is placed freely at your disposal, in the hope that the week may not be without some element of pleasure or profit to every one who has come to take part in these conferences.

I am sure that those who have watched, with an interest not confined to a single field, the recent parallel advances of astronomy and physics, will feel a peculiar sense of satisfaction in our gathering today. The fact that the programme of the conferences has attracted hither not only astronomers whose researches deal with all phases of their subject, but also physicists, fresh from the investigations of the laboratory, will indicate my meaning. If I mistake not the signs of the times, the Yerkes Observatory can render no better service to both astronomy and physics than to contribute, in such degree as its resources may allow, toward strengthening the good will and common interest which are ever tending to draw astronomers and physicists into closer

¹ Address delivered at the conferences held in connection with the dedication of the Yerkes Observatory, Oct. 19, 1897.
touch. During its three years of publication, the Astrophysical Journal has had the same end in view. The annual meetings of its editors, of late devoted mainly to the informal discussion of astrophysical investigations, have invariably been of great interest and value. Both physical and astronomical subjects have been considered equally appropriate for presentation, and the privilege of listening to discussions in which both sides of a question received attention has been greatly valued by those who have taken part in the meetings. In the pages of the Journal one is likely to find a paper on radiation in a magnetic field in close proximity to an account of nebular photography or a discussion of stellar motion in the line of sight. For the scope of astrophysical work is far from narrow. In considering it we must remember that the problems it offers may be viewed in two ways. He who is primarily an astronomer, when examining the photographic spectrum of some remarkable variable star, will be inclined to seek in the shifting dark and bright lines evidence of orbital motion, or indications that may lead to the discovery of the nature of the system. The physicist may find himself equally interested in the photograph, but in a different way. The peculiarities of the spectral lines may have to him the highest significance in connection with some of his own molecular studies. The special conditions of temperature or pressure needed to bring out certain series of lines, known through theoretical investigation perhaps, but not to be developed by any familiar laboratory process, may actually exist in the atmosphere of this distant star. To the physicist, and even to the chemist, this fiery crucible may afford the means of performing experiments far beyond the scope of terrestrial laboratories. In such a case the spectroscope might well be considered the essential instrument of research, the telescope playing a lesser, but nevertheless a very important rôle. It is sometimes interesting to remember that from certain points of view a telescope may not improperly be defined as an instrument for forming an image of a celestial object on the slit of a spectroscope.
Hydrogen gas affords a most interesting illustration of what has just been said. When first studied in the laboratory its spectrum showed four lines in the visible region, and none in the ultra-violet. Then came the pioneer work of Sir William Huggins in photographing the spectra of the stars. He at once found from investigations of Sirius and other white stars that the four bright lines represented only the first few terms of a beautiful rhythmic series stretching far into the ultra-violet. The regularity of the grouping was such as to compel belief in the physical continuity of the series, in spite of the failure of the ultra-violet lines to make their appearance in the vacuum tube. Almost simultaneously with Sir William Huggins' discovery of the stellar series, the gas was made to emit these radiations in the laboratory for the first time. In 1885, after the wave-lengths of the new lines had been carefully measured by Cornu and others, it was found by Balmer that the wave-frequencies are harmonically related, in accordance with a simple formula. In 1868 the visible members of the series had been observed in the spectrum of the solar chromosphere, and in 1891 the ultra-violet members were found by the aid of photography. It was still a mystery, however, why the spectrum of hydrogen should apparently contain only a single series of lines, for the spectra of most of the other elements have been shown by Kayser and Runge to give two or more such series. It is only in the present year that a second series has been found, not yet in the laboratory, but in the spectrum of an inconspicuous southern star, which in all probability would have retained its secret for many years longer, had it not been for Professor Pickering's extensive explorations with the objective prism as a part of the Henry Draper Memorial. Two series thus being known, it might be thought possible to compute the wave-lengths of lines in a third by taking advantage of the important relation discovered by Rydberg, and independently by Schuster and Balmer. This has recently been done by Dr. Rydberg himself, and in the October number of the Astrophysical Journal may be found the computed wave-lengths of the lines of the hitherto unknown princi-
pal series. Thanks once more to Professor Pickering's work, the theoretical results find complete confirmation. The faint star \( H. P. 1311 \) has in its photographed spectrum a bright line at wave-length 4688, while the computed wave-length of the first line in the principal series of hydrogen is 4687.88. There can be little doubt that the line 4687 in the spectra of certain planetary nebulae, observed many years ago by Sir William Huggins, and more recently by Campbell and others, is the same hydrogen line. Rydberg's computed wave-lengths place the other lines far in the ultra-violet, where atmospheric absorption renders them beyond the reach of observation. It now remains for the physicist to reproduce in the laboratory the special conditions which obtain in the atmospheres of these stars, in order that the two new series may be developed by artificial means.

Illustrations similar to this might easily be multiplied, particularly in the very interesting case of helium. But it is surely unnecessary to dwell longer upon the importance of astrophysical work, or to insist further upon the desirability of bringing about its harmonious development on both the astronomical and physical sides. I must not fail to add, however, that the best results, and the most rapid development of both phases of the subject, are likely to follow when the two are worked out together. Let us suppose that the astrophysicist, while investigating the spectrum of a Sun-spot, or a nebula, or a star, finds some remarkable peculiarity not to be accounted for by appealing to the established results of physics. He may be content to call the attention of physicists to the phenomenon, in the hope that some of them may be ready to drop their own investigations in order to assist in answering the question. But he would certainly regard it as more satisfactory to have at hand a well-equipped laboratory, in which just such experiments as he might wish to make could be performed at any time. To take a definite example, he might find in the spectrum of a Sun-spot a line which for various reasons could be identified as due to a certain element, but which was displaced from its normal position. Now it is known that spectral lines may be displaced in two
ways—(1) by motion in the line of sight; (2) by the effect of pressure. If the displacement is toward the red it may be due to either of these causes. In this connection it becomes important to ascertain just how much pressure is needed to shift the line the measured amount. And it might be hardly less interesting to examine the appearance of the line in order to see how its condition is altered by the pressure to which it is subjected. As for the displacement due to the pressure, we might be fortunate enough to find it in Dr. Humphreys' valuable tables, published in the October Astrophysical Journal; but as of necessity no very great number of lines in any one spectrum have been examined by Dr. Humphreys, the chances would be against our finding the desired shift. It may be a long time before more extensive investigations on pressure shifts are made, and one would not like to be compelled to wait for an indefinite period in order to get at a possible interpretation of his results. It is obvious that if the observer had at his command a large spectroscope and a pressure arc mounted ready for immediate use, it would be a comparatively simple matter to experimentally determine the amount of shift for any line at any attainable pressure. The observer would then have under his eyes a phenomenon which he could compare directly with what he had seen or photographed in the Sun-spot. There would be not only the advantage of a saving of time, but in addition to this, and perhaps even more important, would be the advantage which must result from an intimate acquaintance with both the solar and terrestrial phenomena derived from observations made by a single observer.

It seems unnecessary to dwell further upon this point. In it I think we have complete justification for equipping a large observatory in which astrophysical observations are to be made, with complete physical laboratories. This is not a new thing, as you all know. We have a most brilliant example in the case of the Astrophysical Observatory at Potsdam of what may be done in this direction. But in the United States, less for lack of means than for lack of inclination, such observatories have
hitherto been few. In discussing such a matter as this we must not forget the remarkable pioneer work of Rutherford and Draper, whose observatories were at the same time laboratories, and whose investigations were almost as important to physics as to astronomy. Nor must we forget the Allegheny Observatory, where Professors Langley, Keeler, and Very have obtained such valuable results in both celestial and terrestrial spectroscopy, nor the Smithsonian Observatory, where the traditions of the Allegheny Observatory are being continued. It has seemed to me, however, from the time when the Yerkes Observatory first acquired a prospective existence, that there was good reason to give further expression to this idea. Accordingly this Observatory has been planned in such a way as to give opportunity for various physical investigations, interesting and valuable in themselves, and also in their connection with astrophysical work.

While the plans were being made I was fortunate enough to have frequent access to the Potsdam Observatory, and from an acquaintance with its arrangement acquired at that time, as well as from kindly suggestions from Director Vogel and other members of the staff, many ideas which have been embodied in this Observatory were obtained. Valuable suggestions received from other astronomers and physicists have also been adopted. I will not burden you with a detailed description of the building. It is before your eyes and ready for your inspection. The equipment, it is true, is still far from complete, and much remains to be done to put the Observatory in working order in all its departments.

But I must point out that these departments are intended to include not only astrophysical work, but other classes of astronomical investigation as well. In completing the equipment it will be our aim to secure an observatory in which any phase of an astronomical, astrophysical or related physical problem can be investigated. It is very far from our desire, in giving such expression as will be given here to astrophysical work, to in any way crowd out the long established traditions of the astronomy of position. On the contrary, it is
fully recognized that questions of position and of motion are equally important with questions of constitution and physical condition. If we are at work upon a star we must not be content to investigate its spectrum, to determine the chemical composition of its atmosphere, the conditions of temperature and pressure that exist in it, and the motion of the star in the line of sight. Surely there is no fundamental peculiarity that makes the component of the motion which lies in the sight-line more interesting than the component at right angles to it. Thus there may well be associated with the astrophysical investigations just referred to researches on the absolute position of the star and upon its proper motion. Parallax investigations may advantageously be carried on simultaneously, and in fact we can omit from consideration none of the methods or problems of the astronomy of position. It is hoped, then, that when instruments and staff are sufficiently large to permit investigations to be undertaken in these various fields of research, that astronomical, astrophysical and physical problems may receive the attention they deserve.

But so ambitious a programme is not to be developed in the first few years of the Observatory’s history. While our staff is small and our instruments comparatively few, we must confine our attention to those fields where our equipment and the special tastes of our observers give promise of the best results. To determine, then, the best fields of investigation to be pursued at the present time, it seems to me that we should consider the special qualities of the large telescope. In subjecting this instrument to a series of tests we have found that these qualities are just what we might have expected them to be. You may perhaps be interested to know what these tests have been, and how they have resulted. On account of its great size and excellence, and the important work which has been done with it, the Lick telescope has naturally served as our standard in all comparisons.

The resolving power of the object-glass has been tested by Professors Burnham and Barnard by observing very close
double stars. Such an object as Kappa Pegasi, the components of which are now less than a tenth of a second apart, was clearly and beautifully seen as an elongated disk under a power of 2080. As the theoretical resolving power is about one-tenth of a second, this observation could not have been more satisfactory. Close double stars were subsequently seen by Professor Barnard with a power of 3750 so well defined that micrometrical measurements could easily have been made. As it is probable that so high a power as this has not previously been advantageously used with any telescope, it would seem that no better proof could be offered of the excellence of the object-glass. I should also mention that Professor Barnard has picked up four or five very close new double stars. Incidentally it may be added that the atmospheric conditions which would permit the use of a power of 3750 must have been of the very best. Of course such powers cannot be used often; but Professor Barnard has found that the best nights here are fully as good as the best nights at the Lick Observatory, though the average night seeing is not as good as it is at Mt. Hamilton. Of the day seeing I shall speak further on.

As for the light-gathering power of the telescope, this seems to be quite as great as the large aperture would lead one to expect. Perhaps the best proof of this is afforded by Professor Barnard's observation of a new companion to Vega, which had not been seen with the Lick telescope. The distance of this object from Vega is too great to permit us to suppose that there is any physical connection between the two bodies, and the discovery is therefore to be regarded as of no special astronomical significance. But it does afford excellent evidence of the light-gathering power of the object-glass, as well as the perfection of polish, for without this latter quality so faint an object would not be visible in the immediate neighborhood of so bright a star.

Nebulæ, too, are beautifully seen with the Yerkes telescope. Professor Barnard has examined many of these objects with which he had become familiar at Mt. Hamilton, and he assures
me that he now sees them better than he could see them with the Lick telescope. Without making any special search for them he has already discovered some twenty new nebulae. Hind's remarkable variable nebula in Taurus has recently been seen here by Professor Barnard, although it was invisible when last looked for at Mt. Hamilton. It may be that the present visibility is due to an increased brightness, but Professor Barnard is inclined to attribute it to the instrument with which the observations were made.

I have obtained further proof of the great light-gathering power of the object-glass in some preliminary work on stellar spectra. The star images are extremely bright and the exposure times in making photographs are correspondingly short.

Another peculiarity of the Yerkes telescope, which Professor Barnard finds to be of the highest importance in his micrometrical work, is the remarkable steadiness of the mounting. A reference to some of Professor Barnard's measures will illustrate this better than any mere description could do. The difference of declination between Atlas and Pleione was recently measured on five successive nights (the telescope being in motion) with the following results: Aug. 27, 300°.65; Aug. 29, 300°.60; Sept. 2, 300°.66; Sept. 3, 300°.72; Sept. 4, 300°.67. It will be noticed that the distance is a large one to measure with an ordinary filar micrometer, and yet the greatest difference between any two observations made on different nights amounts to only 0°.12. It will be interesting to compare this with some of Professor Barnard's previous measures which he had always considered very satisfactory. In 1893 he measured the distance between Nova Aurigae and a neighboring star with the Lick telescope. Measures made on thirty-two nights gave a distance of about seventy-four seconds, the greatest difference between any two observations made on different nights amounting to 0°.60. Five successive observations are given for comparison with the more recent measures: 74°.73, 74°.53, 74°.38, 74°.33, 74°.69. The difference in the character of the objects, which may affect the results to some extent, should, however be taken into
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consideration. Professor Barnard has made with the Yerkes telescope a number of micrometrical observations of the satellite of Neptune, the planetary nebula N. G. C. 7662, and other objects, and in every case has found his measures to be of great precision.

The great object-glass has received another and a different test in my own observations of the Sun. Fortunately for this work the atmospheric conditions enjoyed here in the day time are exceptionally good. For instance, I have seen the details in the solar chromosphere and prominences beautifully defined under a power as high as 600, which would usually be regarded as excessive for such work. But the special advantages of this satisfactory combination of good atmospheric and instrumental conditions have been most clearly emphasized in observations of the spectrum of the Sun's limb. It has been found that the quiet chromosphere gives many bright lines not hitherto recorded, even in the case of violent eruptions. Among these we may probably include the green fluting of carbon. So many new lines have already been seen that it seems desirable to undertake a complete revision of the chromospheric spectrum.

The success of these various tests convinces me of the desirability of carrying into effect the plan of work mapped out for this Observatory in 1892. This includes various classes of solar investigation; micrometrical observations of double stars, planets, satellites, nebulae, comets, etc; parallax work; photographic studies of stellar spectra, including determinations of motion in the line of sight; and various physical researches in the laboratories. Miss Bruce's recent gift of a ten-inch photographic telescope will render possible additional photographic observations of many celestial phenomena. Later, when increased staff and instrumental equipment permit, it may become possible to enter other fields. But for the present we may profitably confine our attention to the investigations just enumerated.

I venture to invite your special attention to the instrument and optical shops of the Observatory, for I believe them to be a most important adjunct in our work. With the facilities here
provided it is possible to construct the various pieces of special apparatus which are constantly in demand, particularly in astrophysical and physical work. At the present time you will see in process of construction a 24-inch heliostat, an equatorial mounting for a 24-inch reflecting telescope, a ruling machine for optical gratings, a solar spectroscope and spectroheliograph for the 40-inch telescope, and a 60-inch mirror for stellar spectroscopic work. In this connection I cannot omit to express my appreciation of the services rendered by Professor Wadsworth in designing instruments, and supervising their construction. Mr. Ritchey has done valuable work, not only in making optical surfaces, but also in designing the large grinding machine, a considerable part of which he has built with his own hands. Much credit for the excellent work of the instrument shop is due to Messrs. Lorenz, Mors, and Kathan, who have proved themselves most efficient. In fact, not only in the shops, to which I have alluded on account of the special place they occupy in this Observatory, but in all the phases of our work of preparation, each member of the staff has fully done his part.

I wish to acknowledge at this time the obligation of the Yerkes Observatory to the many institutions and individuals whose gifts of books have enriched our library. For these liberal donations we return our warmest thanks. Nor must we forget those who have contributed so much to the success of these conferences by loaning instruments for the demonstrations. From its very inception the Observatory has received the support of men of science in all parts of the world. For all these evidences of interest in our work we are deeply grateful.

The time has now come when we may turn from anticipation to realization, from planning to performance. We have before us the serious task of carrying into execution the investigations which have been projected. It is the ambition of the members of the Observatory staff that the work to be done here shall acquire a reputation for thorough reliability. We mean to do all we can to discourage sensationalism, the evils of which
have been only too apparent in recent astronomical literature. Finally, we share the hope expressed by Mr. Yerkes that this Observatory may take its place among sister institutions, not as a rival, but as one which would gladly do its part in the advancement of a common cause.