It is a satisfaction to report that the exceptional progress in research recorded last year has shown no sign of abatement. Its future continuation, sufficiently assured by the productive vigor of the Observatory staff, will be further promoted by the establishment of close and effective cooperation with the California Institute of Technology, and by the initiation of promising new enterprises, some of which involve important additions to our instrumental equipment. In epitomizing the year's advances special mention should be made of Seares's researches on the masses of the stars, and on the progressive changes of temperature, diameter, and density that mark the course of stellar evolution; the discovery by Strömberg of the identity of the two star streams found by Kapteyn among the A-type stars with the Taurus and the Ursa Major groups, and of the marked difference in stream motion of the giant and dwarfs of the later spectral types; the development by Adams and Joy of a spectroscopic method of measuring the absolute magnitude (and hence the distances) of the white (A) stars, and its immediate application to 544 of these objects; the theoretical investigations of Russell on the nature of dark nebulae; the proof by Hubble that the radiation of the nebulae is stimulated by stars lying within them; the discovery by Nicholson and Pettit that the total radiation of certain red variables of the ninth magnitude is as great as that of white stars of the second magnitude; the measurement by Abbot of the energy distribution in the spectra of certain of the brighter stars and the promise this work yields of great advances in this important field of investigation; the progress made by Michelson in the re-determination of the velocity of light and his contributions to other important physical problems; the detection of invisible sun-spots by their Zeeman effect; the import-

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1From the Annual Report of the Director of the Mount Wilson Observatory for the year ending August 31, 1922.
Ant contributions made by St. John and Babcock toward the establishment of the system of standards of arc wave-lengths now internationally adopted, their measurements of solar lines and the continuation of their investigations of the causes giving rise to the displacements of lines in the Sun; the proof by Anderson that an electrically exploded wire attains a temperature of 20,000° and that its vapor totally absorbs light from a brilliant source; and the confirmation by Russell, St. John, and King of various predictions based on Saha's ionization theory. The last named work has been done in the light of repeated discussions with the physicists and chemists of the California Institute of Technology, and partly in direct cooperation with Dr. Noyes. Future possibilities have been enlarged by the design of a 50-foot interferometer telescope, with independent equatorial mounting, already under construction, and by the preparation of plans for a new physical laboratory which, if funds for its erection can be obtained, will greatly facilitate our laboratory researches.

But as we record these evidences of progress, we are saddened by a heavy loss, keenly felt throughout the scientific world. The death of Professor Kapteyn on June 18 removes from us a great and inspiring pioneer, to whom astronomy owes, as Eddington has said, its first firm footing among the intricacies of the stellar universe. Before him all attempts to make order out of seeming chaos had been in vain. Double and multiple star systems, globular clusters, and irregular star groups moving together in space were known. But the vast mass of stars had yielded no sign of larger relationships, and the constitution of the Galaxy was a sealed mystery. Kapteyn's great discovery of the two star streams, which comprise between them a large proportion of all stars whose motions are known, pointed the way that many astronomers have since pursued with success. His carefully devised plan for the intensive study of the stars in Selected Areas of the sky, toward the realization of which observatories in all parts of the world have contributed, will be continued, it may be hoped, by his friends and collaborators. We at Mount Wilson, who have profited greatly by Kapteyn's wide vision and wise counsel, and have enjoyed the advantage of
his personal friendship, will be glad to do our full share toward its completion.

A different mode of approach to the problem of the structure of the universe, pursued at Mount Wilson with marked success, is that of Dr. Shapley, who has made use for this purpose of his photometric studies of the stars in globular clusters. His conclusions that the galactic system is vastly larger than was formerly supposed, though attacked in some quarters, has received substantial support from several recent studies. Shapley's appointment as Director of the Harvard Observatory deprives us of another able investigator, but we shall hope to continue to cooperate with him in the study of stellar problems.

Turning now to the results of the year, we may first refer to the extensive investigation by Mr. Seares on the masses and densities of the stars. Our knowledge of absolute magnitudes has been greatly extended by the spectroscopic results of Adams and his associates. With these and other data, especially those for visual binaries, a progressive change of absolute magnitude with spectral type is found, ranging from $-1.6$ for B0 through A, F, G, and K to $+9.8$ for Ma. For the same sequence of types the geometric mean masses for single stars, derived from the hypothetical absolute magnitudes of binaries, vary progressively from 10 to 0.6, respectively, in terms of the Sun's mass. The small dispersion in mass among visual binaries of known parallax is noteworthy, and, as Russell has pointed out, may be a consequence of the use of the spectroscopic method in which line-intensity perhaps depends wholly upon the temperature and density in a star's atmosphere. By an indirect method, however, Russell has confirmed the conclusion that the dispersion in mass is small.

The densities, effective temperatures, surface brightness, and volumes of both giant and dwarf stars have been derived by Seares from a discussion of this material. The later-type dwarfs are found to be considerably hotter than giants of the same type, and to be about 500,000 times as dense. The surface brightness, checked by Pease's measurements of stellar diameters for a few giants, ranges from $+4.8$ for stars at the lowest temperature to $-2.7$ magnitudes at the highest (Sun $= 0$). These results, with
some exceptions, support Eddington’s theory of the relative equilibrium of giant stars and the pulsation theory of Cepheids and tend to confirm the empirical proportionality of mass to radius. Changes of temperature and pressure at various points within a star are shown by theoretical computations to be such as to maintain an approximately constant degree of ionization throughout, implying a nearly constant mean atomic mass which changes but little in giants of increasing temperature even with marked changes of density.

Through a combination of the values of the masses of the dwarf stars with the space-velocities obtained at Mount Wilson, Seares has found that the mean energy (mean mass times mean square space-velocity) for all types of dwarfs from A0 to Ma is practically constant, in spite of a variation in mass of 10 to 1. Assuming that equipartition of energy holds for giants such as the Cepheid variables, the probable dispersion in mass among 28 such stars for a given magnitude and type is only about 20 per cent.

The spectroscopic method of determining absolute stellar magnitudes has received further important development in the hands of Mr. Adams and Mr. Joy. Through the rigorous classification of stellar spectra and the separate grouping of stars giving diffuse lines and stars giving sharp lines, the absolute magnitude of the white (A) stars, not measurable by the earlier method, are derived. This permits the spectra of 544 stars, previously photographed with the 60-inch and the 100-inch telescopes, to be utilized for parallax work, thus yielding a large and welcome addition to available data.

The continuation of measurements of radial velocity has led to the accumulation of large amounts of results which have already been used by Strömberg and others in discussions of stellar motions. A list of over 1000 stars with radial velocities obtained at Mount Wilson has been prepared for publication by Adams and Joy and should prove of especial value to astronomers because of the large proportion of stars with known distances. In addition to these results the completion of the determination of the velocities of stars of the Md type of spectrum.
by Merrill provides the material for an investigation of the motions of this important class of variables.

The stellar spectroscopic work of the year has included a great variety of investigations in addition to those already mentioned. Among these, reference may be made to the studies of the spectra of variable stars by Adams, Joy, and Merrill; Sanford's computations of the orbits of spectroscopic binaries; spectral classification of faint stars in the Selected Areas by Humason; and measurements by Sanford tending to confirm the relative displacements of enhanced and arc lines in the spectra of bright stars. The report of the Committee on the Spectral Classification of Stars prepared for the International Astronomical Union by Adams and Russell represents an attempt to add to the existing system of classification symbols which shall describe in a more adequate way numerous important characteristics of stellar spectra.

Of especial significance in its bearing on our knowledge of the nature of the two star-streams discovered by Kapteyn and the character of the motions of the stars within our stellar system is an investigation by Mr. Strömberg of the space-motions of stars of spectral types A to M. With the aid of the parallaxes obtained for the A-type stars by the recently discovered spectroscopic method of Adams and Joy, and the radial velocities observed at Mount Wilson and other observatories, Strömberg has computed the individual space-velocities for 332 stars. An analysis of these motions at once leads to the important conclusion that Kapteyn's first stream may be identified with the Taurus group and his second stream with the Ursa Major group. The remaining stars belong to a central group of small systematic motion which is the O-group of Halm and with which the B-type stars probably are associated.

The results of a similar investigation of stars of types F to M show that the giant stars form a single group with a small systematic motion relative to the commonly adopted origin. Their velocity distribution is ellipsoidal and shows a regular diminution of ellipticity with spectral type, being nearly spherical for stars of the later K and M types. The dwarf stars also form a distinct group as regards their motions. Their distribu-
tion is ellipsoidal but the directions of the axes and the systematic motion of the group are entirely different from those of the giant stars. Rapidly moving stars regardless of spectral type or absolute magnitude show an extraordinary avoidance of motion in the direction of the first quadrant of longitude relative to our galaxy.

Mr. Hubble has completed an investigation on the relationship between stars and diffuse nebulosity. Particular stars, obviously involved in luminous nebulosity, are found to have similar spectra. If the stellar spectra are earlier than B1, the nebulae give emission spectra; if later than B1, the spectra of the nebulae are continuous. At the critical type B1, the nebular spectra are mixed. The relationship thus suggested is strikingly confirmed by the observed dependence of the extent and brightness of the nebulosity upon the apparent magnitude of the stars involved. The photographic magnitudes of the stars, over a range of more than 14 magnitudes, are in linear relationship with the logarithm of the greatest angular extent of associated nebulosity. The results indicate that the amount of light radiated from the nebulosity, whether it have an emission or a continuous spectrum, is equal to the amount of light received from the dominating star or stars. This indicates, as Russell had previously suggested on theoretical grounds, an absorption and re-emission of starlight by the nebulosity rather than simple reflection, and points to important possibilities of further researches.

The great division in the Milky Way between Ophiuchus and Aquila contains within its borders a number of objects catalogued as nebulae. Hubble has photographed many of these and finds them all to be clusters of faint stars, in some cases extremely condensed. The rather high color-index of these stars may be due to their type, or perhaps to scattering by the extensive dark nebulosity which Hubble believes to account for the forked appearance of the Milky Way.

From a theoretical investigation of the dark nebulae, Professor Russell concludes that these objects, catalogued in great numbers by Barnard, probably consist mainly of dust particles a few millionths of an inch in diameter, driven away from stars
by radiation pressure. Particles of the most effective size (with a circumference 1.12 times the wave-length), and of the density of water, are repelled from the Sun with a force 10 times, and from white (B) stars 100 times greater than gravitational attraction. Dwarf stars, on the contrary, hardly repel dust at all. The final effect of the repulsion of fine dust would be to scatter it to an indefinitely great distance were it not for the gravitational forces of vast masses of dust, which may account for the sharp outlines of dark nebulae. In Russell's opinion, such an object as the great Nebula in Orion consists of wisps and clouds of dust, slowly drifting about, and carrying gas with them. When in the radiation field of the Trapezium stars, this gas is rendered luminous: brilliantly so, with excitation of the nebular lines, in the near neighborhood of the stars; faintly, without bright lines, in the outlying regions. In some places this secondary radiation is partly or completely obscured by intervening dust clouds, producing the dark structures seen visually and in photographs.

The measurements of Mr. van Maanen upon three additional spiral nebulae confirm results already obtained from four others and point to motion outward along the spiral arms rather than rotational motion. From these values combined with radial velocities, and from a discussion of the proper motions of a large number of spirals, and the theoretical considerations of Jeans, van Maanen arrives at parallaxes for the spirals of from 0".0001 to 0".0010. This would indicate distances considerably less than would be required by the island universe theory.

Van Maanen assisted by Gingrich has carried on measurements of parallax and proper motion and has now determined the trigonometric parallaxes of 160 stars. A new discussion of the systematic errors of these parallaxes by several methods, some of which depend upon objects whose distances are known with high accuracy from independent sources, yields a result of $-0".0024 \pm 0".0003$. Several objects of special interest have been investigated and the probable distance of the nebula near $\eta$ Persei is found to be about 350 light-years.

The continuation by Mr. Pease of his measurements of stellar diameters with the 20-foot Michelson interferometer has given results for $\alpha$ Orionis and $\alpha$ Scorpii in fair agreement with...
those obtained previously. A slightly larger value for the angular diameter of \( \alpha \) Orionis is probably to be ascribed to the effects of seeing. A study of the visibility curves of \( \alpha \) Tauri, \( \alpha \) Bootis and \( \beta \) Pegasi indicates that the fringes of these stars would disappear at a separation of the interferometer mirrors of about 25 feet which would correspond to an angular diameter of 0'.022. A more extensive extrapolation gives probable values for the separation of 30 to 40 feet in the case of \( \gamma \) Andromeda, and 40 to 50 feet in that of \( \alpha \) Arietis (about 0'.015 and 0'.012, respectively). Numerous stars have been observed in which the visibility of the interference fringes is from 50 to 80 per cent.

The use of an auxiliary interferometer with one variable aperture, as suggested by Michelson, for the purpose of calibrating the principal set of fringes has been investigated extensively by Pease. Under good conditions of seeing this has proved most valuable, both for determination of visibility and of seeing. With poor seeing, however, the two sets of fringes show marked relative variations and simple visual estimates based upon experience appear to be preferable.

Immediately after the first successful measurements of the diameter of \( \alpha \) Orionis, Messrs. Hale and Pease made provisional designs of a 50-foot interferometer, on independent equatorial mountings. These were too expensive, however, for serious consideration, and the problem was dropped for the time. As it is now evident that a large instrument of this kind must be provided, Hale has devised a 50-foot interferometer telescope, the detailed design of which has been worked out by Pease and Nichols. The essential feature of this instrument is its extreme simplicity of form, and the precautions which have been taken to avoid the necessity of large and expensive machine work. Theoretical considerations indicate that the diameters of about 30 stars brighter than the fourth magnitude can be measured with this instrument, the construction of which has been undertaken in our instrument and optical shops.

In the department of stellar photometry reference may be made to the progress in the determination of the photographic magnitudes of the stars in the Selected Areas under the direction of Mr. Seares. The combination of the Mount Wilson and
Groningen magnitudes is now complete for 67 Areas and half finished for 72 others. The study of the colors of the stars in the Areas of the 30° zone is well advanced and similar observations have been made upon a few other fields of exceptional interest. In one of these, Selected Area No. 110, which lies between two branches of the Milky Way south of Cygnus the star density is remarkably low and the stars are red, no color-index of less than 0.5 mag. having been observed among the stars between the fourteenth and nineteenth magnitudes.

A photometric catalogue of the central stars in the planetary nebulae is being made by Hubble. The photographic magnitudes of 20 stars and the photovisual of 10 have been determined so far, with color-indices ranging from —0.2 to —0.7 mag.

Seares and Humason have carried out a further investigation of the magnitude scales for the stars of the Polar Sequence from plates taken with the 100-inch refractor. These results, together with the investigation by Jones at Greenwich, appear to leave little doubt of the reliability of the scales now available. Seares has devoted much time to this subject in connection with the preparation of the report of the Committee on Photometry for the meeting of the International Astronomical Union at Rome. A series of standard magnitudes was adopted at this meeting which is based upon eight separate determinations of the photographic scale made at six different observatories. For stars brighter than the sixteenth magnitude the average deviation of a final magnitude for any one observatory is +0.024 mag.

The measurement of the total radiation of stars is a subject of great interest and promise, as remarked in a previous report. Nicholson and Pettit, who began the development of special thermocouples for solar investigations and for use with the Koch microphotometer, have also obtained valuable results in the measurement of stellar radiation. Coblentz made excellent observations of stellar radiation in 1914 with a thermopile attached to the 36-inch Crossley reflector at Mount Hamilton, and discovered that "red stars emit 2 to 3 times as much total radiation as blue stars of the same photometric magnitude." One star of class N was found by him to give twice the deflection
of a class M star of the same visual magnitude. Nicholson and Pettit find the following values of the ratio of total energy of stars of different spectral types to that of an A0 star of the same visual magnitude: A0, 1; K, 3; Ma, 9; Mc, 16; N, 16; Md, 1300 at minimum). The extraordinarily great proportion of infra-red radiation in the case of the Md star indicates, as Milne has pointed out, the very low temperature of 1700°. A very important feature of Nicholson's and Pettit's work is its extreme precision, rendered possible, among other means, by a photographic recording device. Six observations of Vega at different altitudes gave values which, when plotted against air-path, indicated 0.002 magnitude as the largest residual. The application of this method to the detection of very slight variations in the radiation of bright stars will depend upon the precision with which the atmospheric absorption can be eliminated.

Mr. Abbot has applied an improved type of vacuum bolometer and galvanometer to the measurement of the energy spectra of Aldebaran, Capella, and Betelgeuse at the Coudé focus of the 100-inch reflector.

The first successful bolometric observations of the distribution of energy in the spectra of stars is an event of great importance in the progress of astronomy. Using a prism of U. V. Crown glass with an equivalent angle of 36°, a galvanometer with a period of single swing of 1.56 seconds, and a mirror scale distance of 4.7 meters, Abbot observed visually maximum deflections of 14 mm in the infra-red of Betelgeuse, and about one-half that amount in Aldebaran and Capella. The energy distribution in the spectrum of Capella is found to be similar to that of the Sun, while that of Betelgeuse is very different and shows a sharp maximum at 0.83 mm. The spectrum of Aldebaran shows results intermediate between those for the other two stars.

The extraordinary degree of sensitiveness required for these observations is shown by the fact that with the apparatus used the current passing through the galvanometer corresponding to deflection of 1 mm on the scale is $2.5 \times 10^{-11}$ ampere, and the corresponding rise of temperature of the bolometer strip $8 \times 10^{-8}$ degree C. In Abbot's opinion an increase of at least ten-fold
in sensitiveness can be attained, and with the aid of photo-
graphic registration deflections of 0.5 mm can be observed with-
out difficulty. This will make it possible to secure spectrobolo-
metric observations of stars to the third and possibly the fourth
magnitude.

Professor Michelson's investigations of the possibility of
measuring the velocity of light between two stations separated
by a distance of over 20 miles, show that while the intensity of
the return beam in the direct Foucault arrangement with the
rotating mirror is insufficient, ample light may be secured by a
combination of the Foucault and Fizeau forms of apparatus.

In the form adopted the observer sees the light returned from
the distant station with an intensity which depends upon the
speed of the rotating mirror. The light gradually becomes less
intense as the speed of the mirror increases, falls to zero, and
then suddenly rises to its full amount when the speed is such that
a second face of the rotating octagonal mirror replaces the first.
The observation accordingly consists in adjusting the speed of
the mirror to the rate at which the light suddenly reappears, and
with good seeing Michelson considers that this can be done with
an error not exceeding 1 part in 55000. Apparently the measure-
ment of the speed of the mirror with the requisite accuracy will
present no serious difficulty to judge from previous experience.
The essential question of the intensity of the return light being
answered satisfactorily we expect to be able during the coming
winter to construct the apparatus necessary for a complete test
of the method when Michelson returns next summer.

Reference was made last year to the experiment devised by
Michelson for examining the effect of the Earth's rotation on the
velocity of light. If a beam of light is divided and sent around
a circuit of 1 mile in opposite directions the resulting interfer-
ence fringes should show a displacement of about 0.15 fringe
according to the generalized theory of relativity or the hypothesis
of a stationary ether. If no displacement or one smaller than
this amount were observed, the result would be difficult to
reconcile with the theory of relativity, but would point rather
to an ether completely or partially dragged along by the Earth
in its rotation.
Experiments were made by Michelson on Mount Wilson with two circuits, 6500 and 5200 feet in length, and although fringes were observed their quality was such as to preclude the possibility of accurate measurement. In these tests the path of light was close to the level of the ground, and it is possible that a site might be found for which the conditions of seeing would be greatly improved. If this could not be done it is probable that Michelson's suggestion of a pipe line exhausted of air would offer a definite solution of the problem.

The use of an iris diaphragm not far from the focus of a telescope has been suggested by Michelson as a means of securing objective measurements of condition of seeing. The aperture of the diaphragm is diminished, thus diminishing the effective aperture of the telescope until diffraction rings appear. Tests made by van Maanen with such a diaphragm on the 60-inch telescope show that the simple relationship

$$S = 1 + 0.15d$$

where $S$ is the seeing on a scale of 10 and $d$ the effective aperture of the mirror in inches represents the results of observation in a satisfactory way.

The solar activity has continued to diminish, and many days now occur on which no sun-spots are visible.

Of the 33 spot groups observed during the first four months of 1922, four were of irregular polarity. Although this high percentage (10) of irregular spots might be due to the small number observed, a close watch of all spots has been kept as the minimum approaches. As a result a small spot was observed by Ellerman on June 24 which is probably the forerunner of the new spot cycle. Its latitude was $31^\circ$ North and its polarity was opposite to that of regular preceding spots in the northern hemisphere.

Messrs. Hale, Ellerman, and Nicholson have detected invisible sun-spots by searching for evidences of the Zeeman effect in promising regions, such as areas of flocculi following a large spot. A special polarizing apparatus permits very small magnetic fields to be found by the alternate widening to red and violet of the iron triplet $\lambda 6173$.

The results confirm the view that a spot represents a vortex,
which becomes visible only when the cooling due to expansion is sufficiently great to produce a perceptible decrease in the brightness of the photosphere.

The continued study of the Zeeman effect in sun-spot spectra by Hale, Nicholson, and Ellerman has yielded further results bearing on the variation of the field-strength at different levels. Nicholson has proved that the apparent displacements of the $p$-component of spot triplets on photographs taken with a compound quarter-wave plate are subjective phenomena, due to the photographic influence of closely adjoining lines. The results are also important in their bearing on other classes of spectroscopic work.

The results of the cooperative efforts of a number of observers of standards of wave-length are seen in the adoption at the Rome meeting of the International Astronomical Union of a list of 305 tertiary standard lines in the arc spectrum of iron to be used as reference lines in the international system of wave-lengths. The values adopted depend upon an average of 5 or 6 observations, and have a probable error of less than 0.001 Å. The measurements of St. John and Babcock have contributed in an important degree to this valuable collection of reference material, and the difficult task of combining and weighting the observations has in large measure been carried on by St. John as Chairman of the Committee on Standards of Wave-Length.

In continuation of their previous work St. John and Babcock have measured the wave-lengths of several hundred solar lines with the double purpose of securing standards for the revision of the table of solar spectrum wave-lengths, and studying the relative displacements of the lines in Sun and arc which form so essential a test of the generalized theory of relativity. The complicated variety of phenomena in the Sun which may give rise to the displacements of lines requires extensive investigation and the study of the shift between center and limb is well adapted to throw light on some of these difficult questions. The powerful spectroscopic apparatus of the 150-foot tower telescope and an interferometer used in conjunction with the Snow telescope are being employed in the measurement of these small displacements.
St. John, assisted by Miss Ware, has continued throughout the year his study of the solar rotation. No measurable change has been detected during the 8 years now covered by his observations, but they will be extended to include a complete sun-spot cycle. Special attention is being given to the rate of rotation in high latitudes where it now seems probable that Faye's formula does not fully represent the results of observation.

Russell, King, and Noyes have obtained important results supporting the validity of Saha's theory of ionization in solar and stellar atmospheres. Barium is highly ionized in the reversing layer of the Sun, and even in spots, though neutral atoms are also present. Russell has explained on theoretical grounds why it is more highly ionized than sodium, in spite of the equality of their ionizing potentials. King has confirmed in the electric furnace Saha's prediction that the enhanced lines of calcium, strontium, or barium, obtained when these elements are vaporized alone or in the presence of elements having equally high ionizing potentials, are not visible when substances like potassium or caesium, of lower ionizing potentials, are vaporized with them. He has also found, in harmony with Saha's theory, that a mass of gas too cool to emit light is still able to absorb lines of the principal series. King has photographed the absorption spectrum of iron at 1600° as far as \( \lambda 2298 \), though the emission spectrum for the same temperature ends at \( \lambda 3440 \). He has also found that the A and B bands of oxygen in the solar spectrum can be produced in the laboratory by the absorption of air columns only seven and forty meters long, respectively. The water-vapor band \( a \) was observed with an air-path of only 9.5 meters, under conditions of low humidity. These results have an important bearing on the question of the presence of oxygen and water-vapor in planetary atmospheres.

The above results were obtained with the new and very effective vacuum furnace. The old furnace is being used by King, in collaboration with Noyes, in a study of the conductivity of vapors at high temperatures. It is especially well adapted for such work because of the high temperatures available, the control which may be kept over the temperature and other conditions during the experiments, and the ease with which the
concentration of the vapor may be varied. In the work so far carried on with the chlorides of calcium, sodium, and potassium preliminary measures indicate that the variation of conductivity with the square root of the concentration appears to hold for temperatures as high as 1600° C. The use of temperatures as high as 2000° seems to be well within the range of the apparatus.

The value of Anderson’s method of electrically exploded wires has been further demonstrated. A sensitive thermopile, used in conjunction with a quartz spectrograph, has permitted the spectral energy distribution of the radiation to be measured, showing that the maximum value of $\epsilon \lambda$ is at a wave-length less than $\lambda 2800$ and probably below $\lambda 2400$. The energy distribution corresponds almost exactly with that of a black body at a temperature of 20,000° C. Although the average pressure in the explosions is less than 5 atmospheres, the layer of vapor (about 4 cm thick) is completely opaque to radiation. This fact may prove to be of considerable importance in solar and stellar physics.

Babcock has made an interesting study of the green auroral line with a Fabry-Pérot interferometer. With a camera working at F/4 or faster, the fringes can be photographed in a few hours at Pasadena on any night, whether the sky be clear or cloudy. Preliminary work on Mount Wilson shows that the width of the line does not exceed 0.035 A. Improved instrumental arrangements will soon give precise measures of the wave-length and a reliable determination of the maximum width of the line.

At the desire of Dr. Day, Director of the Geophysical Laboratory of the Carnegie Institute of Washington, a cooperative plan has been undertaken for the study of the volcanic gases emitted by the crater of Kilauea at times when the level of the lava is high. Attempts will be made to photograph the spectra of the burning gases with small spectrographs especially built for the purpose in our instrument shop. These were designed by Babcock, who will join the expedition when conditions at the volcano become favorable for observational work.

Reference was made last year to the repetition on Mount Wilson of the Michelson-Morley experiment by Professor Day-
ton C. Miller of the Case School of Applied Science. Although this work has been carried on as an independent investigation, we are permitted by Professor Miller to give the results of his most recent observations. These indicate that the displacement in the direction of that due to a possible ether drift cannot exceed one-tenth of the predicted amount. It is possible, however, that certain factors to be considered in computing the predicted displacement are not complete.

Dr. H. O. Wood has continued his seismological investigations under the auspices of the Carnegie Institution of Washington. The Observatory has been able to render assistance to a certain extent in the design and construction of apparatus.

The constant search for new instruments and methods, always a prime factor in our policy, has been continued throughout the year. The chief results, some of which have been mentioned in preceding paragraphs, are the method of measuring the absolute magnitudes of A stars; the application of the bolometer to the measurement of the distribution of energy in stellar spectra; the improvements in thermocouples and their application to the Koch microphotometer; the use of the electric furnace for precise conductivity measurements; the method of detecting invisible sun-spots; the use of the Fabry-Pérot interferometer for work on the aurora; the use of pyrex glass to reduce the heat distortion of coelostat mirrors; the design of the 50-foot interferometer telescope, and the design of a 75-foot spectrograph for a new physical laboratory in Pasadena. The latter instrument will differ materially from the 75-foot spectrograph of the 150-foot tower telescope, as the focal length of its collimator can be made 13, 30, 50, or 75 feet, while cameras of any desired dimension, from a portrait lens of 10 inches aperture and 45 inches focal length to a two-lens system of 75 feet focal length, can be used with any suitable collimator.

It goes without saying that in all of this work the Division of Drafting and Design, the machine and optical shops, and the Construction Division on Mount Wilson, remain indispensable. The latter has built a reservoir on Mount Wilson of 530,000 gallons capacity, to protect us against possible droughts, such as
have been threatened in recent years. The shops have been operated to their full capacity, and the long list of instruments and optical surfaces produced testifies to their efficiency.