MOUNT WILSON OBSERVATORY

GEORGE E. HALE, HONORARY DIRECTOR
WALTER S. ADAMS, DIRECTOR
FREDERICK H. SEARES, ASSISTANT DIRECTOR

SURVEY OF THE YEAR’S WORK

The outstanding astronomical phenomenon of the year has been the outburst of Nova Herculis. As to what happens when a nova suddenly appears we have little certain knowledge. The catastrophic nature of the occurrence is evident, and the course of some of the physical changes undergone by the star is gradually becoming clear; but the essential conditions preceding the outburst and the circumstance that sets it under way are still largely matters of speculation.

There is, however, perhaps more than a hint—although only one of several possibilities—in Milne’s recent studies of stellar constitution. These studies involve mathematical discussions of hypothetical models of stars consisting of spheres of gas. Definite distributions of pressure, density and temperature within the sphere follow from the assumed physical properties of the gas and the conditions affecting its radiation. Under certain circumstances a critical state occurs such that the gas sphere is no longer able to maintain its structure. The sphere collapses into one of higher density and much smaller volume with an explosive development of radiation. Temperature and luminosity are enormously increased, and part of the gaseous material may be driven away into space as a nebulous shell. This theoretical approach to the problem is suggestive, but hardly convincing because it is by no means certain that the gas-sphere models really correspond to stars. Moreover, it does not seem to provide for the observational fact that novae usually occur close to the galactic plane.

Observationally, what happens, and at this stage it is the observational data that require emphasis, is that an inconspicuous telescopic star, within a few hours or a few days at most, rises to a maximum of luminosity perhaps ten or twenty thousand times greater than that before the outburst, then, with many fluctuations in brightness, slowly declines until after weeks or months it is again inconspicuous and easily lost among other faint stars. Some months after the outburst, powerful telescopes may show the development of a disk or ring of nebulosity surrounding the star, which expands, apparently at a uniform rate.

The real complexity of the phenomenon, however, is revealed by the star’s spectrum. Continuous during increasing brightness except for faint absorption lines, the spectrum suddenly alters near the time of maximum light; very broad emission bands then appear, especially of hydrogen, bordered on their violet edges by corresponding absorption lines. The wide emission bands indicate the presence of an expanding gaseous envelope. The portion of the envelope in front of the star absorbs radiation coming from the star itself and produces the adjacent absorption lines. The large displacement of the absorption lines from their normal position, as well as the great width of the emission bands, indicates upsurging velocities of hundreds of kilometers per

\(^1\) Address: Mount Wilson Observatory Office, Pasadena, California.
second. Structural details appear within the bands, and the corresponding absorption lines may be double or even more complex, thus suggesting the presence of two or more shells, expanding at different rates, and of other features not yet understood. Later, as the light declines, the spectrum gradually alters. The characteristic lines of a diffuse nebula appear, widened into bands, and in turn slowly fade away, while the spectrum of the central nucleus finally changes into that of an O-type star.

The extraordinary transformations and the scale on which they occur render the phenomena of novæ among the most impressive known to the observer, and probably also among the most fruitful for the study of stellar constitution. For Nova Herculis, however, it is still too soon even to summarize the observational results. Several features undoubtedly will make its appearance noteworthy: first, the relatively slow approach to maximum, at least to the first maximum observed, thus permitting detailed study of early stages of its spectral development; second, the star's unusual brightness and slow decline from maximum, giving special opportunity for favorable observation; and, finally, its observation with the high dispersion of the coudé spectrograph under conditions not hitherto available. The optical power of this instrument, together with the great number and the sharpness of the widely displaced absorption lines, will certainly yield a rich fund of information when the observations are discussed.

Another occurrence of noteworthy interest has been the extensive observation of the eclipsing variable star ζ Aurigæ. Once every thousand days (973 to be exact) a relatively small, hot, B-type star, revolving about a much larger and more massive K-type giant, passes behind the giant star and remains totally eclipsed for about 37 days. The dimensions and the physical characteristics of the stars and their relative orbit are of interest, but, except in the length of the period, present nothing unusual. Immediately preceding and following the interval of total eclipse, however, are two stages of partial eclipse, each lasting 1.7 days, during which light from the small B star shines through the extensive and tenuous atmosphere of the K-type giant and reaches the observer after having suffered absorption by the gases in this atmosphere. As the partial eclipse progresses, the spectral pattern alters. Lines change in intensity and appear or disappear in a manner determined by the rate of motion and the abundance and the distribution of the elements in the atmosphere of the K-type giant. It is possible to eliminate the influence of the light of the K star and thus isolate completely the effect produced by the atmosphere of this star on the radiation that it transmits from the small B-type companion. This effect is a record of the constitution of the atmosphere itself, which can thus be studied under conditions that are unique. The results obtained indicate serious defects in all the present hypotheses concerning the constitution of stellar atmospheres.

The long-period variable R Aquarii, surrounded by faint diffuse nebulosity, presents a complicated sequence of phenomena which may include features of general astrophysical interest. Its complex spectrum includes that of a typical long-period variable; the spectrum of a gaseous nebula, which changes in intensity and shows remarkable irregularities in the displacements of its lines; and, finally, that of an early-type "companion," first seen in
1922, which also varies in a puzzling manner. The spectroscopic observations show that both the M-type star and the companion contribute to the observed variation in light, and with their aid the light-curve may be analyzed into its component parts. Objects of this kind, like novae, give valuable information on stellar constitution, although the application of what is learned is not always immediately evident. The fact that they change and that transitions are observable oftentimes suggests a connecting link between isolated physical states in different stars.

The fundamental part played by the distances of the stars in any study of the structure of our stellar system is obvious. The difficulties incident upon the accumulation of information on stellar distance are well known. The straightforward trigonometric method, which utilizes the shift in the position of the earth from one side of its orbit to the other, on the opposite side of the sun, can be applied only to the nearest stars. The introduction twenty years ago of the spectroscopic method, which relieves to a large extent the restriction in distance, therefore afforded the means of an important advance. The first large accumulation of results, including 1646 stars, was published in 1920. Since then the method has been refined, the early results have been revised, and much additional material has been collected. The appearance of a second list comprising the spectroscopic parallaxes of 4179 stars, which has recently come from the press, marks the completion of another stage in an investigation which underlies or in some way bears upon every phase of the Observatory's work.

Even the spectroscopic method of determining stellar distance has, however, its limit of applicability. Very distant objects are, in general, so faint that their light is insufficient for spectroscopic analysis. In certain cases the observer may then have recourse to the remarkable relation between the cycle of light changes in a Cepheid variable and the intrinsic brightness of the star. The longer the period of light variation, the more luminous the star. By determining the period, the intrinsic brightness can be found; and then, just as in the spectroscopic method, comparison with the star's apparent brightness gives its distance. The use of Cepheid variables in determining the distances of globular clusters and extra-galactic nebulae has done much to center interest upon this important class of stars. In addition, they have an interest of their own, for their changes in brightness, caused apparently by pulsations of the gaseous mass of the star, set them in a position of importance in any study of the internal constitution of stars. Finally, not only can their distances be determined with accuracy; they are themselves objects situated at very great distances, and hence in a key position for a study of such questions as the absorption of light in space and the rotation of the galaxy. A program of spectroscopic observation of Cepheids pursued for many years has been practically finished, and some of these questions are now under discussion.

Occasional sun-spots belonging to the old cycle were still to be seen in low latitudes during the year 1934. The sharp increase in the numbers appearing in high latitudes from 2 in 1933 to 52 in 1934 indicated, however, that the new cycle was well under way; and it now seems clear that the intensity of the sun's ultra-violet radiation has also passed a minimum. The magnetic
polarities of spots maintain their customary regularity in the distribution of the algebraic sign of the field and firmly establish the complete reversal of signs in the new cycle relative to the old announced a year ago. Study of the frequencies of dark hydrogen flocculi suggests that they follow the main fluctuations in the earth's magnetic field more closely than they do those of the sun-spot curve. The intensities of the bright hydrogen associated with spot groups show no correlation with the sun-spot cycle. Continued investigation of the sun's rotation, with special attention to systematic errors produced by scattered light, increases the rotational values obtained since 1914 by about 4 per cent and makes the Mount Wilson measures as a whole much more consistent. Further improvements in sensitizers for photographic plates have made it possible to push the limit of spectroscopic observation on the sun another thousand angstrom units into the infra-red. Investigations in the infra-red region are still largely of such fundamental matters as the scale of wave-lengths and the intensities of lines. As a rich source of astrophysical information, the field is still almost untouched.

Although the constitution of the moon can not be studied with the spectroscope as that of the sun or a star is studied, special methods which partially overcome this disadvantage are being used successfully to determine some of the physical properties of the moon's surface rocks. The investigation is only one phase of the work of the Moon Committee, composed of specialists from different fields of science. Measurements of radiation from the planet Mercury show that the relations between phase angle and both planetary heat and reflected sunlight are similar to those for the moon. The temperature at the point directly beneath the sun varies 130° C. with the position of the planet in its orbit (282° C. to 412° C.) but is always far above that of boiling water.

Equally important with distances as fundamental data are the apparent magnitudes of the stars. In fact, the magnitude of a star must be known before spectroscopic criteria or Cepheid variability can be used to find its distance. The determination of suitable standards of brightness, well distributed in the sky, is one of the essential steps in supplying the photometric data needed to obtain the distances not only of stars but also of globular clusters and extra-galactic nebulae. Much progress in standardization is now being made, partly of the faintest stars observable with the 100-inch telescope and partly of stars brighter than the twelfth magnitude, whose brightness is still imperfectly known in spite of the fact that they are within easy reach of small telescopes.

Directly associated with measurements of brightness are measurements of color, which have a significant bearing on the absorption of light by interstellar clouds of dust and gas. Measurements of this kind made with the photoelectric cell are proving of exceptional value. Observed in this manner, B-type stars, globular clusters and extra-galactic nebulae all reveal the stratum of absorbing material close to the galactic plane and a dependence of color on position which denotes increasing absorption as the direction of the center of the stellar system is approached.

The studies of extra-galactic nebulae continue to bring forth results of outstanding interest. Red-shifts of spectral lines corresponding to recessional
velocities of 24,000 and 39,000 km. per second have been confirmed, and for an object in a faint cluster of nebulae in Ursa Major a value of 42,000 km. per second, from a single spectrogram, however, is now available. The evaluation of the influence of the red-shift on the apparent magnitudes of these remote objects has already become a pressing matter, because any calculation of the distribution of nebulae in space depends on the values of the magnitudes freed from this disturbance. The amount of the correction, however, will be determined by the physical interpretation of the red-shift itself; and although we know only motion in the line of sight as a competent explanation, it would be incautious on present evidence to assert that motion is certainly the correct interpretation.

An intensive study of red-shifts, regarded as the consequence of motion, for 30 nebulae in the Virgo Cluster has led to a number of striking conclusions, among them a value for the average mass of the individual nebulae which is a hundred times that derived from isolated non-cluster nebulae. These results are not necessarily inconsistent; but if the high value for the cluster nebulae is of the right order, it probably indicates the existence of a great amount of inter-nebular material within the cluster. The question is of great importance for cosmological investigations.

In the past the physical characteristics of nebulae have been somewhat neglected because interest then centered on their distribution and motions. A beginning has now been made, however, with some of the elliptical nebulae. One of these objects, M 82, shows no appreciable polarization of its light; its nucleus apparently may be regarded as a separate entity having an angular diameter of the order of 1″; its spectrum along the major axis is constant, the type being dG3, a little later than that of the spirals. Regarded as a gigantic star cluster, its stellar content would seem to be only a thousandth part that of our stellar system, whereas the space density of stars at its center would be of the order of ten million times that near the sun.

The extraordinary advance made in theoretical spectroscopy in recent years has put heavy demands on the physical laboratory. To utilize the full advantage of these gains on the theoretical side, they must be made applicable to definite astrophysical problems. For this purpose term analyses of the spectra of the different elements must be available. At this point laboratory data on the positions, intensities and temperature characteristics of spectral lines become an essential. For some years the complicated spectra of the rare earths have been under observation in the Laboratory of the Observatory. The magnitude of the task is suggested by the numbers of the lines studied and classified—for example, 1200 for europium, 3000 for gadolinium, and nearly 4500 for samarium. The stronger lines of the ionized spectra of all three elements appear in the sun, but not the neutral lines, in accordance with the usual behavior of the rare earths. The experimental work indicates that the phenomenon is one of abundance. Low vapor density affords so few opportunities for recombination of electrons with ionized atoms that neutral lines do not appear. The inference is, therefore, that these elements are scarce in the sun, as on the earth.

The publication of the final results of the measurement of the velocity of light closes an investigation started ten years ago by the late Albert A.
Michelson of the University of Chicago. Four series of measures, each including several hundred observations made with a mile-long vacuum pipe line during intervals of 2 to 5 months, give mean values which show an average deviation of 3.5 km. per second and a final mean of 299,774 km. per second. The internal agreement points toward an uncertainty of 1 or 2 km. per second in the final result. The value found from the measures made in 1926 (a few of low weight in 1925) over the open-air path of 22 miles between Mount Wilson and Mount San Antonio was 22 km. per second higher. The cause of this disagreement is not known. The observing conditions in the two cases were, however, entirely different: in one, a relatively short path of 8 or 10 miles, obtained by multiple reflections within the pipe line under a pressure of only a few millimeters of mercury; in the other, an air path of 45 miles that twice traversed a wide deep canyon. However we rate the influence of this difference in conditions, a striking feature of the recent measures should be noted. Even with all possible care in the manipulation of the apparatus, abnormal values of the observed velocity, sometimes high and sometimes low, persisted at times during days or even weeks, thus indicating the existence of disturbing influences of unknown origin. It is possible that the value of the velocity from the 1926 measures is systematically affected by error of this kind. The two-year interval covered by the four recent series and the general accordance of their respective results suggest, on the other hand, that the influence of any such error on the adopted mean velocity must be relatively small.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his investigations of the general magnetic field of the sun, giving special attention to improvements in the method of measurement. He has also continued his supervision of the plans for the 200-inch telescope. Dr. Walter S. Adams, Director, carried on investigations in stellar spectroscopy and conducted the administrative work of the Observatory until May 18, when he left for Paris to attend the meeting of the International Astronomical Union. Dr. Frederick H. Seares, Assistant Director, served as Acting Director after May 18. He has continued his work on the standardization of stellar magnitudes and given much time to editorial supervision of the Observatory publications.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has been occupied chiefly with temperature classifications of lines in rare-earth spectra and the segregation of the lines important as a basis for term analysis of the various spectra. Dr. John A. Anderson has been concerned with the completion and perfection of the vacuum spectrograph and with administrative duties connected with the 200-inch telescope. Dr. Edwin Hubble has reviewed the numerical data resulting from his extended surveys of extragalactic nebulae and the results now available on the distances and velocities of nebulae. Jointly with Professor Richard C. Tolman of the California Institute, he has studied the bearing of the observational results on theoretical explanations of the red-shift. Mr. Harold D. Babcock has continued his study of the infra-red solar spectrum with special attention to the scale.
of wave-lengths. He has also devoted much time to the perfection of the new ruling machine. Dr. Paul W. Merrill has extended his spectroscopic observations of various classes of stars, among them the long-period variables, of which R Aquarii was studied in detail. Professor Alfred H. Joy, Secretary of the Observatory, has practically concluded his comprehensive spectroscopic study of Cepheid variable stars. Dr. Seth B. Nicholson has supervised the regular observations of solar and sun-spot activity, solar rotation and the polarities of spots, and has assisted in the study of methods of measuring spectrograms taken for the determination of the sun's general magnetic field. Dr. Francis G. Pease has finished the discussion of the measurement of the velocity of light and continued his work connected with the design of the 200-inch telescope. In December he was present at the successful pouring of the 200-inch disk of pyrex glass to be used for the mirror of this instrument. Dr. Adriaan van Maanen has carried on his measurements of trigonometric parallaxes and proper motions. In May he left Pasadena for attendance at the meeting of the International Astronomical Union in Paris. Dr. Roscoe F. Sanford has completed his investigations of N- and R-type stars and of three Cepheid variables and has observed numerous spectroscopic binaries and other stars of variable radial velocity. Dr. Edison Pettit has made observations of ultra-violet solar radiation and the forms of prominences, and, jointly with Dr. Nicholson, has discussed the measurements of radiation from Mercury. During July and August Dr. Pettit visited the Yerkes Observatory to carry on observational work on prominences. Dr. Walter Baade has been occupied chiefly with the magnitudes of faint stars in several Selected Areas and integrated magnitudes of nebulae and with variable stars in a globular cluster. Dr. Gustaf Strömgren has taken part in observations of stellar spectra and continued his cosmological studies and other theoretical investigations. Dr. Theodore Dunham jr. has devoted much time to the design and experimental tests of the new coudé spectrograph and has undertaken a systematic study of the intensities and contours of spectrum lines. Mr. Milton Humason has made numerous spectroscopic observations of faint dwarf stars, novae, globular clusters and extra-galactic nebulae. Dr. Sinclair Smith has accumulated spectroscopic data on extra-galactic nebulæ with special reference to their bearing on various physical characteristics of the nebulæ. Mr. Ferdinand Ellerman has shared in the solar observations and continued in charge of most of the general photographic work. Dr. Robert S. Richardson has given attention to the relation of solar activity to terrestrial magnetic disturbances and devoted much time to a study of the observations of solar rotation. Dr. Robert B. King has made laboratory observations of multiplet intensities and Zeeman patterns. Mr. Joseph Hickox has made regular solar observations on Mount Wilson and continued to test photographic emulsions.

In the Computing Division Miss Louise Ware has been engaged with measurements of the intensities of solar lines, both center and limb, in the region 25400-16000. Miss Elizabeth E. Sternberg has continued her work relating to solar activity and sun-spot phenomena, preparing character figures and much of the solar material supplied to other observatories. Mr. Edward F. Adams has measured spectrograms relating to solar rotation and the sun's
general magnetic field. Miss Myrtle L. Richmond has continued to measure
and reduce the curves recording ultra-violet solar radiation and has assisted
in the radiation measurements of Mercury and with miscellaneous computa-
tions. Until his resignation on September 15, Mr. Howard C. Willis mea-
asured stellar parallaxes and proper motions. Since November 1, Dr. P. Th.
Oosterhoff has continued this work and, in addition, undertaken researches
in photometry. Miss Mary C. Joyner, as in former years, has assisted Dr.
Sears and has collaborated with him in the derivation of standard magni-
tudes. Miss Cora G. Burwell has continued to aid Dr. Merrill in his spec-
troscopic work. Miss Elizabeth MacCormack has devoted much of her time
to the measurements of spectrograms and to special computations, and has
collaborated with the Director in a study of abnormal displacements of
stellar lines. Dr. Olin C. Wilson and Mr. William H. Christie have continued
the regular observation and reduction of radial velocities and have jointly
studied the important data associated with the eclipse of ζ Aurige. Dr.
Wilson has also given much attention to the interpretation of the spectra
of novae. Miss Ada M. Brayton has been engaged with miscellaneous cal-
culations and the final details of the manuscript and proofs of the Catalogue
of Spectroscopic Parallaxes. Mr. Wendell P. Hoge has continued to assist
Mr. Babcock in investigations of the infra-red solar spectrum. Miss Dorothy
J. Carlson, special part-time computer, has assisted Dr. Dunham in the study
of line intensities and contours. Dr. R. M. Langer, also special part-time
computer, has made measures of the sun’s general magnetic field. Miss
Elizabeth Connor, Librarian, has continued to aid in the editorial work of
the Observatory.

Dr. Henry Norris Russell, Research Associate and Director of the Uni-
versity Observatory, Princeton, spent two of the autumn months in Pas-
aadena, engaged in theoretical investigations in spectroscopy. Dr. Joel Stebbins,
Research Associate and Director of the Washburn Observatory of the Uni-
versity of Wisconsin, was in residence at Pasadena from January until April
and, in collaboration with Dr. Albert E. Whitford, National Research Fellow,
continued his studies of stars and nebulae with the aid of the photoelectric
photometer.

Among visiting astronomers who carried on researches at the Observato-
ry at various times during the year were Dr. Frank E. Ross of the Yerkes
Observatory of the University of Chicago, who made photometric observa-
tions and extended his photographic map of the Milky Way; Dr. S. A.
Mitchell, Director of the McCormick Observatory of the University of Vir-
ginia; Dr. John C. Duncan, Director of the Whitin Observatory of Wellesley
College; Dr. Caroline E. Furness, Director of the Observatory of Vassar
College; Dr. O. L. Dustheimer, Professor of Mathematics and Astronomy at
Baldwin-Wallace College; and Dr. Charlotte E. Moore, University Observa-
tory, Princeton. Dr. Fred. E. Wright of the Geophysical Laboratory of the
Carnegie Institution spent the summer months of 1934 on Mount Wilson
engaged in researches on the moon. Since his arrival on September 22, Mr.
A. D. Thackeray, Fellow on the Commonwealth Fund, has carried on solar
investigations. Dr. Rupert Wildt, Fellow of the Rockefeller Foundation, in
residence since February 11, has been occupied with spectroscopic investiga-
tions. Dr. Rudolf Minkowski arrived in Pasadena on June 1 for a year's
residence as a visiting investigator. During the summer months Mr. Horace
Babcock and Mr. William Humason served as temporary observers.

With deep regret the Observatory records the death on April 26, 1935, of
Dr. Charles Edward St. John, a distinguished member of its staff from 1908
until 1930 and Research Associate during the years 1930 to 1935. St. John
made many notable contributions in the field of solar physics and his per-
sonality and enthusiasm were a constant source of inspiration to the members
of the staff, especially throughout the formative years of the Observatory.

**OBSERVING CONDITIONS**

Observations were made during the whole or part of 287 nights, a number
close to the average of 289. Solar observations were obtained on 268 days,
about 40 less than the average, owing to exceptional cloudiness during day-
light hours. The extreme temperatures were 99° F. on July 27, 1934, and 17°
F. on March 9, 1935. The snowfall was moderate, only 34 inches; but the
total precipitation, 46.24 inches, was 50 per cent above normal and the third
highest in 31 years. The accompanying table shows the distribution of
observing time according to the record for the 60-inch telescope.

<table>
<thead>
<tr>
<th>Month</th>
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<td>All night</td>
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<td>February</td>
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<td>4</td>
<td>March</td>
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<tr>
<td>November</td>
<td>13</td>
<td>10</td>
<td>May</td>
<td>21</td>
<td>7</td>
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<tr>
<td>December</td>
<td>12</td>
<td>7</td>
<td>June</td>
<td>26</td>
<td>3</td>
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<tr>
<td>Total</td>
<td>222</td>
<td>65</td>
<td></td>
<td>203</td>
<td>86</td>
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**SOLAR RESEARCH**

The usual observations of the numbers, areas and polarities of sun-spots
have been continued, and daily records have been made with the spectrohelio-
graph. Daily measurements of ultra-violet radiation and of the horizontal
intensity and direction of the earth's magnetic field have also been continued,
and the magnetic character figures for each day have been supplied to the
Department of Terrestrial Magnetism of the Carnegie Institution for pub-
lication in *Terrestrial Magnetism*. Special observations include spectral and
photometric studies of sun-spots, spectrograms of the chromosphere in the
near infra-red, studies of prominences with the spectroheliograph, and of the
radiation-curve of the sun with special reference to the ultra-violet region.

Since April 1, 1935, daily observations of bright hydrogen flocculi have
been made during at least one hour each afternoon. These observations
include hydrogen spectroheliograms taken at four-minute intervals, supplemented by observations with the spectrohelioscope. The results are communicated to Commission 11 of the International Astronomical Union as a contribution to the cooperative program of solar observing with the spectrohelioscope. It is planned to make the photographic record automatic and continuous, at least during the afternoon hours.

Areas and positions of sun-spots on 82 days have been supplied to the Naval Observatory for publication in the *Monthly Weather Review*, and reports of the number of sun-spots observed have been communicated daily to Science Service at Washington. Estimates of character figures of solar activity have been made by Nicholson and Miss Sternberg on 283 days in 1934 for calcium floculi and on 285 days for hydrogen floculi, and have been sent to Commission 10 of the International Astronomical Union for publication in its Bulletin. The measurements of ultra-violet radiation by Pettit and Miss Richmond are also published in this Bulletin.

The mirrors of both tower telescopes were coated with aluminum in November 1933. They have given excellent service and the surfaces appear still to be as bright as when first coated.

**SOLAR PHOTOGRAPHY**

Direct photographs of the sun were made with the 60-foot tower telescope on 268 days. The solar observers, Ellerman, Hickox, Nicholson and Richardson, also obtained plates with the 13-foot spectroheliograph as follows:

<table>
<thead>
<tr>
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<th>1933</th>
<th>1934</th>
<th>1935</th>
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<tbody>
<tr>
<td>Hα of the disk</td>
<td>274</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kα of the disk</td>
<td>262</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K of prominences</td>
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<td>320</td>
<td></td>
</tr>
<tr>
<td>Hα of spot groups</td>
<td></td>
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</table>

Spectroheliograms have been sent regularly to the Kodaikanal and Meudon observatories as in previous years.

**SUN-SPOT ACTIVITY**

During the calendar year 1934, solar observations were made at Mount Wilson on 326 days, on 140 of which no spots were visible. The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the accompanying table.

<table>
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<td>1934</td>
<td>1935</td>
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<td>January</td>
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<td>0.5</td>
<td>0.6</td>
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<td>October</td>
<td></td>
<td>0.4</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td></td>
<td>0.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td></td>
<td>0.0</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Yearly average</td>
<td></td>
<td>0.6</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
The number of groups in the northern hemisphere belonging to the old cycle decreased from 34 in 1933 to 11 in 1934; in the southern hemisphere, from 7 to 3. The number of groups in the northern hemisphere belonging to the new cycle increased from 1 in 1933 to 17 in 1934; in the southern hemisphere, from 1 to 35. In low latitudes, where the spots of the old cycle occurred, the northern hemisphere was the more active, as in 1933. In high latitudes, where the spots of the new cycle occurred, the southern hemisphere was the more active. The mean distance of the low-latitude spots from the equator decreased from 8°1 in 1933 to 3°3 in 1934. In 1934 the mean distance of the high-latitude spots from the equator was 25°4.

### SUN-SPOT POLARITIES

The accompanying table indicates the numbers of groups of spots classified from July 1934 to July 1935. "Regular" groups of the new cycle in the northern hemisphere are those in which the preceding spot had N (north-seeking),

<table>
<thead>
<tr>
<th>Hemisphere</th>
<th>Polarity</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Regular</td>
<td>Irregular</td>
<td>Unclassified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Old cycle</td>
<td>New cycle</td>
<td>Old cycle</td>
<td>New cycle</td>
<td>Old cycle</td>
</tr>
<tr>
<td>North</td>
<td>7</td>
<td>25</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>South</td>
<td>2</td>
<td>58</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Whole sun</td>
<td>9</td>
<td>83</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

or positive, polarity and the following spot S polarity. In the southern hemisphere these polarities are reversed. In the old cycle, "regular" groups are those in which the distribution of magnetic polarities is opposite to that just described for the new cycle.

### SOLAR ROTATION

A long series of spectrographic determinations of the equatorial rotation of the sun was begun by St. John in 1914. Since 1932 the spectrograms for the continuance of this program have been made by Nicholson and Richardson, the measurements by E. F. Adams.

An investigation of the effect of scattered light on the solar-rotation values was started in 1932. Plates taken with the rotation apparatus in the usual way consist of narrow strips of spectra a millimeter apart produced by simultaneous exposures on the center and on points about 14" inside the east and west limbs of the sun. With this arrangement diffracted light from each spectrum is superposed on the adjacent spectra, which should make the measured displacements of the lines too small. To avoid this complication the east and west limbs were photographed separately with greater distance between the spectra on the plate. The mean of twenty exposures made in this way gave 2.014 km/sec., while exposures taken in the regular manner gave
1.987 km/sec. The difference of 0.027 km/sec. indicates that the rotation values from the regular program should be increased by about 1.5 per cent to correct for the effect of superposed diffracted light.

In addition, since 1933 exposures have also been made directly upon the slit, which was set about 2.3 inside the limb to reduce the effect of scattered light in the optical system. Rotation values derived from these direct exposures are consistently higher than those obtained from exposures made with the regular apparatus. The mean values are (number of exposures in parentheses):

<table>
<thead>
<tr>
<th>Year</th>
<th>With Rotation Apparatus</th>
<th>Direct Exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1932</td>
<td>1.99 (20)</td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td>1.98 (19)</td>
<td>2.05 (16)</td>
</tr>
<tr>
<td>1934</td>
<td>1.97 (16)</td>
<td>2.05 (11)</td>
</tr>
</tbody>
</table>

These results indicate that the values of the solar rotation determined at Mount Wilson since 1914 should be increased by about 4 per cent.

SOLAR ACTIVITY AND TERRESTRIAL MAGNETIC DISTURBANCES

The hydrogen flocculi recorded on the Mount Wilson daily spectroheliograms from January 1917 to March 1935 have been catalogued by Richardson. The intensity of the bright hydrogen associated with all spot groups was estimated on a scale of 0 to 5, while the dark markings were classified as small, medium, large and very large. Exceptional disturbances, such as the sudden appearance or disappearance of intensely bright hydrogen, and cases of bright hydrogen appearing where no sun-spot is visible were also noted. Of special interest in connection with the dark hydrogen is the disappearance of large prominences from one day to the next and the peculiar formations that prominences sometimes assume.

Weights were assigned inversely proportional to the frequency of the hydrogen flocculi, thus emphasizing the very bright flocculi and large prominences, which presumably should be the most effective in producing terrestrial magnetic disturbances. Graphs constructed from these data show the variations in the bright and dark hydrogen flocculi during the last eighteen years. Comparison with the curves for terrestrial magnetic activity, available only to December 1930, and for relative sun-spot numbers shows that, in its main features, the curve for dark hydrogen resembles the curve of terrestrial magnetism more closely than that of either the bright hydrogen or the relative sun-spot numbers. This resemblance is increased by using only large and very large dark hydrogen markings in forming the curve. None of the curves agrees with the terrestrial magnetic activity when only short-period fluctuations are compared.

A graph of the intensity of bright hydrogen flocculi per sun-spot group during the last eighteen years shows no evidence of the eleven-year cycle and is fairly constant throughout the entire range. Apparently the hydrogen flocculi associated with sun-spots are, on the average, just as intense at sun-spot minimum as at maximum.

INTEGRATED SPECTRUM OF THE SOLAR DISK

The study of the infra-red solar spectrum has been continued by Babcock with special attention to the improvement of the scale of wave-lengths, the
extension of the observations still farther beyond the red, the estimation of intensities, and the identification of the solar lines. After adding a few observations with the interferometer and refining some of the earlier reductions, a list of 263 selected lines most suitable for use as standards was supplied for the Report of Commission 14 of the International Astronomical Union. Comparison with a preliminary list prepared three years ago shows only small changes. The new list extends from $\lambda 7050$ to $\lambda 12425$ and, when tested by several applications of the combination principle, appears to be self-consistent and correctly related to the scale already adopted in the visual region. Details are given in a Contribution now nearly ready for publication.

New sensitizers have so extended the spectral region within reach of photographic observation that useful measurements of the solar spectrum are now being made beyond $\lambda 13500$. Considerable difficulty is met in this region, owing to the presence of a prominent absorption band of terrestrial water-vapor which obscures the solar detail.

Dr. Charlotte E. Moore of the Princeton Observatory spent two months at Pasadena in the study of our solar data. During that time and since her return to Princeton she has continued the estimation of the intensities of the spectral lines on Mount Wilson spectrograms. A fairly satisfactory method has been developed by which the intensities are expressed on an arbitrary scale definitely related to the Rowland scale. When complete, these results will enable Russell to proceed with a revision of the calibration of Rowland's scale and the resulting distribution of elements in the sun that he has undertaken. Miss Moore has also added numerous identifications to those known a year ago. For this work Rowland's method of coincidences has been amplified by the utilization of recent advances in the analysis of many of the atomic spectra.

The spectroscopic evidence for the presence of sulphur in the sun has been augmented, and the presence of phosphorus has been established. New series lines of magnesium not yet found in the laboratory have been clearly brought out in the infra-red solar spectrum, and homologous lines of sodium and lithium are suspected. Three important absorption lines of the Paschen series in hydrogen, analogous to $\beta$, $\gamma$, $\delta$ of the Balmer series, are now available for study in the sun. Some of the strongest infra-red solar lines are due to silicon, and numerous strong iron lines have also been found.

SPECTRUM OF THE SOLAR CHROMOSPHERE

During the summer months Horace Babcock has continued his observations of the chromosphere with the 150-foot tower telescope and 75-foot spectrograph in the more accessible part of the infra-red region and in selected parts of the visual region. With the Snow telescope and a rapid concave-grating spectrograph, he has photographed some of the stronger emission lines as far as $\lambda 10938$, a line due to hydrogen. The outstanding chromospheric line thus far noted beyond $\lambda 10000$ is $\lambda 10830$, the first member of the principal series of helium triplets, whose well-known fine structure is unresolved in the chromosphere. The identification of the observed emission lines is not yet complete.
Thackeray has identified certain chromospheric lines occurring within the wide wings of the H and K lines of calcium with the ionized rare earths Nd and Ce. These lines extend, as emission lines, much farther into the disk than ordinary chromospheric lines because the weakened radiation within the wings of H and K results in a reduced absorption of the frequencies of the chromospheric lines. Absorption and emission by the rare-earth atoms seem to occur mainly above the layers of calcium that produce the wings of H and K.

ULTRA-VIOLET SOLAR RADIATION

The daily measurements by Pettit of the ratio of ultra-violet to green solar radiation on Mount Wilson are in their twelfth year. It now appears that a minimum value of this ratio amounting to 0.9 occurred during the summer of 1932. Except in three instances, the monthly means have been greater than unity since January 1933, with the highest value, 1.4, occurring in March 1935. There seems to be a tendency for the values still to increase, although it is too soon to be certain. The extensive measurements of the photographic records have been made by Miss Richmond.

The measurements of the energy-curve of the sun from λ0.7µ into the ultra-violet at λ0.292µ made on Mount Wilson in 1934 with the double quartz monochromator and thermopile have been reduced to a point where the trend of the results can be seen. The recent measurements check in considerable detail the work done at Tucson, Arizona, in May 1931 and, like those measurements, show that the ultra-violet energy in the sun itself is nearly constant from λ0.38µ to λ0.325µ. The measurements were repeated during 1935 and will be repeated each year during the present sun-spot cycle.

These observations with the double quartz monochromator and vacuum thermopile give the energy in each 100 angstroms in the solar spectrum, and, of course, include the effect of all the absorption lines. It is desirable, however, to know also the form of the energy-curve in the continuous spectrum. Although it may be questioned whether any of the spaces between the thickly clustered lines in the ultra-violet are wholly free from absorption, it was thought worth while to determine ratios of the intensity between the lines to the average within each 100 A as a means of reducing the thermopile curve to the continuous spectrum. A 21-foot concave grating of 8 inches aperture giving a bright first-order spectrum was set up on Mount Wilson and fed with light from the 12-inch siderostat. The problem has been attacked both photographically and photoelectrically: First, spectra were photographed as usual, but with a moving slit in order to integrate the lines; second, the instrument was used as a monochromator with both sodium and potassium quartz photoelectric cells and amplifiers, the amplifiers being constructed under the supervision of Whitford. With this equipment two methods have been used in both of which the spectral energy-curves within 100 A were recorded photographically on a revolving drum: (a) The detailed spectral energy-curve within 100 A was recorded and followed by a second record made with the first slit vibrating in order to integrate the lines: (b) A quartz monochromator with a salt-water prism was put in front of the first slit of the 21-foot concave to filter the light and thereby secure greater purity of spectrum; in this case the vibrating slit was not used and
the integration was done with a planimeter. Thus far the investigation has been carried only to 10.36μ.

The contour of the K line which results directly from this work was sketched on the record and upon this same sketch were plotted the values obtained photographically by Thackeray with the same dispersion. The plot fits the photoelectric contour almost precisely except within one angstrom of the center of the line. It is expected that useful line contours will be obtained as a by-product of the investigation.

SOLAR SPECTROPHOTOMETRY

An improved high-dispersion monochromator has been devised by Dunham for trial in connection with the 30-foot grating spectrograph in the Snow telescope. A 15-foot focus off-axis concave mirror is used with a flint glass prism and plane mirror in a Littrow mounting. No change in focus is required in passing from one wave-length to another. A section of the spectrum of any extent down to 1Å may be thrown into the main spectrograph, thus nearly eliminating the effects of scattered light. The combination is being used for photoelectric measurements of the shapes and intensities of solar absorption lines.

GENERAL MAGNETIC FIELD OF THE SUN

Several years ago, during a period of low solar activity, Hale undertook a study of the general magnetic field of the sun at the Solar Laboratory in Pasadena. The purpose was a new attack on the problem by methods partially enumerated in the Report for 1931-32.

This investigation, involving the use of a Zeiss microphotometer especially adapted for the measurement of new photographs taken with the 75-foot spectrograph, revealed once more the extreme difficulty of measuring the minute Zeeman displacements produced by the weak general magnetic field. Similar difficulties had been encountered in 1912, when the field was first detected after much strenuous work (Mount Wilson Contributions, Nos. 71, 72, and 148). The grain of the photographic plate, slight local distortions of the film, and the effect of occasional local magnetic fields complicate the problem, which is sufficiently difficult with any form of measuring device, even in the hands of the most skilful and experienced measurer. In the early work it was found that only about half the measurers could obtain consistent results. Most of the results were in agreement so far as the sign, distribution and order of magnitude of the field were concerned, but some showed considerable systematic differences in magnitude.

In a case of this kind it is essential to have many thousands of measures made by a number of different persons, using measuring machines of several types. In fact, after encountering many new obstacles, some of them due to defects in the spectrograph, Hale felt it advisable to remeasure many of the negatives used in the investigation of twenty years ago as a check on the previous conclusions.

The measuring devices used in this recent study have included the Zeiss microphotometer in several forms, adapted for both photographic and visual work; the original micrometer, with tipping plane-parallel glass plate, used for most of the earlier measures; a machine of the same type, with some
improvements due to Nicholson; a measuring machine of the Evershed type; and recently a new form of measuring machine, of a design chiefly due to Langer. Moreover, several series of direct measures have been made on selected lines in the second- and third-order spectra of the 75-foot spectrographs on Mount Wilson and in Pasadena. These visual measures have been made in part with the tipping plate and in part with the aid of photoelectric amplifiers, adapted for this purpose by Dunham, Stebbins and Whifford, who joined Strong and Hale in the observations. Furthermore, Mr. Evershed kindly measured some of the original negatives at his own observatory in England.

Confirmations of the polarity and order of magnitude of the general magnetic field on plates of the old series have been obtained by Strong (visual measures with a special form of Zeiss microphotometer), Evershed (with his own measuring machine), and Langer (with a tipping-plate micrometer). On the other hand, zero results have been obtained by Nicholson and E. F. Adams (with an improved form of tipping-plate micrometer) and W. Humason (with a Zeiss microphotometer). These zero results have not yet been explained.

The most recent measures, of a collection of plates of the old series, have just been completed by Langer, using a new form of combined measuring, recording and computing machine devised chiefly by himself. In addition to its advantage of great rapidity of operation, the use of this instrument frees the observer from any danger of possible bias. The results obtained from a total of about twenty-five thousand settings on the line \( \lambda 5247.7 \), on forty quarter-wave strips on twenty-three plates, unmistakably reveal the general magnetic field. Its polarity and order of magnitude are in good agreement with the early results.

As for the general magnetic field of the sun in 1933, a number of measures by Hale, made by Evershed's method on spectra photographed at the Solar Laboratory give zero results. The data, however, were insufficient in number and precision to yield safe conclusions. A series of differential measures made with the photoelectric amplifier seem, on the other hand, to show the existence of a weak field of the same polarity as previously observed.

**LUNAR AND PLANETARY INVESTIGATIONS**

Most of the spectroscopic observations of planets have been interrupted pending the reconstruction of the coudé spectrograph. Wildt, however, has observed Jupiter and Saturn with a provisional arrangement of the coudé instrument for the purpose of determining the intensity distribution of the continuous spectrum.

**RADIATION FROM MERCURY**

The measurements of radiation from the planet Mercury made by Pettit and Nicholson in 1923-25 have now been reduced in final form. Preliminary reductions showed the desirability of deferring the final solution until a catalogue of radiometric magnitudes of comparison stars had been compiled and a detailed study of the radiation of the moon had been made.
twenty-six observations of Mercury taken between phase angles 32° and 126° were reduced to a common standard of radiometric magnitude and intensity of planetary heat and reflected light. The relations between phase angle and both planetary heat and reflected light outside the atmosphere are very much like those of the moon. The variation of planetary heat approximates that to be expected from a smooth slowly rotating black sphere.

The planetary heat from the whole planet at full phase, reduced with the distribution function found for the moon, yields a temperature of 600° K for the subsolar point of the planet at mean distance from the sun. A solar constant of 1.95 cal cm⁻² min⁻¹, corrected for the reflected sunlight as measured with the thermocouple and water cell, gives 617° K. For an adopted mean of 610° K, the resulting sub-solar temperature of Mercury at perihelion is 685° K and at aphelion 555° K.

**MOON COMMITTEE**

The Committee on Study of the Surface Features of the Moon is making an extended series of measurements of the changes which take place in the sun's rays on reflection by different parts of the moon's surface and by terrestrial materials. These changes are of two kinds: (a) the relative intensities of different wave-lengths of light are altered slightly on reflection, according to the nature of the reflecting materials (selective reflectivity); (b) plane-polarized light is introduced in amounts which differ with the character of the reflecting substance and with the angle between the impinging sun's rays and the reflected rays (phase angle). These changes are being measured by four independent methods: visual, photoelectric cell, thermoelement and polarization spectrograph. At present the visual method is receiving special attention in an effort to complete this part of the task during the construction of the new mounting for the 20-inch telescope which, it is expected, will be finished by the end of 1935. This instrument will then serve for detailed measurements by the three remaining methods. For the visual method a special eyepiece is used, which recently has been improved so that it is now possible to measure the percentage plane polarization in any beam of light with an accuracy of one-fifth of one per cent. Such measurements are being made in the light reflected by selected areas on the moon and by many different kinds of terrestrial materials, including rocks, minerals and other crystalline and amorphous substances.

The series of lunar photographs projected on globes 13¾ inches in diameter, begun two years ago, is being retaken under improved conditions. These miniature moons, which are angle true, aid the geologist in the physiographic study of the lunar surface.

**GREEN AURORAL LINE**

Whitford has studied the intensity of the green auroral line in the spectrum of the night sky as a function of zenith distance, with the object of finding the height of the glowing layer in the earth's atmosphere. Preliminary results indicate a height of 100 kilometers.
MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES

The measurement of trigonometric parallaxes has been continued by van Maanen, the total number of fields completed now being 406. During recent years the program has included a large number of faint stars having large proper motions, with the result that the parallaxes of 76 stars fainter than the tenth apparent magnitude have been added to the list of only 10 stars of this kind known in 1924. The absolute magnitudes of many of these are fainter than 10 on the photographic scale.

PROPER MOTIONS OF FAINT STARS

In duplicating early photographs taken at the 80-foot focus of the 60-inch telescope, several faint stars of large proper motion were found by van Maanen, the most interesting being a companion of ε Cygni, considerably fainter than the known optical companion. On the basis of 0.037 as the parallax of ε Cygni, the absolute magnitude of the new companion is 12.6.

In *Mount Wilson Contribution* No. 412, 1930, van Maanen and Willis gave the proper motions of 122 stars measured in 42 Selected Areas on 60-inch reflector plates taken at an interval of about 18 years. The investigation has been continued by Oosterhoff, who has measured proper motions for 705 stars in 91 additional Selected Areas. For the 6 remaining Areas of the program the late plates are still to be taken. Only those stars which showed unquestionable displacements in the stereocomparator were measured. Of the 705 new proper motions, 181 occur in the recently published Radcliffe Catalogue. The magnitudes of stars not appearing in the *Mount Wilson Catalogue* or in *Harvard Annals*, 101 are still to be determined. Although no special search was made for variables, 15 have been found during the work.

PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

The determination of standard magnitudes of stars north of 80° declination by Seares and Miss Joyner in cooperation with Dr. F. E. Ross of the Yerkes Observatory is well advanced. The photographic magnitudes are complete except for occasional minor corrections for color arising from later revisions of the color index. About 300 provisional photovisual standards have been derived, and the photographs for the main photovisual program have been taken and measured. Color indices, approximate values at least, are now available for all the stars.

The data thus far accumulated have been published in mimeograph form (*Magnitudes and Colors of Stars North of 80°*) for use until the investigation is finished. The Catalogue includes 2269 stars, mostly brighter than photographic magnitude 11.5. The precision of the catalogue magnitudes (photographic values) varies greatly, and in general increases with the declination, at least up to 84° or 85°, because of more favorable observing conditions and increasing abundance of material. The number of plate-pairs per star ranges from one to seven. Between magnitudes 9 and 11 the probable error for a single plate-pair is ±0.021 mag.; for all magnitudes together,
±0.027 mag. The agreement with the international system in zero point, scale and color, so far as indicated by the 28 NPS stars included in the investigation, is satisfactory.

**MAGNITUDES OF FAINT STARS IN SELECTED AREAS**

Photographic magnitudes to 20.5, determined by Baade, are now available for Selected Areas 51, 57, 68 and 89. The results are to be considered provisional, however, until the direct intercomparisons of the different Areas have been reduced. Since S.A. 89 is well situated to serve as a standard region for a number of the nearest extra-galactic systems (Andromeda Nebula, M 33, NGC I 1613 and NGC 6822), the photovisual scale will also be established in this Area. Preliminary tests show that with the new Eastman IC plates this scale can be extended to magnitude 18.5 or even 19.0 without excessive exposure times.

Owing to unfavorable weather conditions during the spring, only a few plates have been obtained which test the photometric properties of the new aluminum coats on the mirrors. The total gain, regardless of spectral type, seems, however, to be of the order of 0.3 mag.

**MAGNITUDE OF COMPANION OF SIRIUS**

Observations of the companion of Sirius by Stebbins and Whitford with the photoelectric amplifier at the Cassegrain focus of the 100-inch telescope give a visual magnitude of 8.5, which is so near the Harvard value of 8.4, used by Eddington in calculating the extraordinary density of this body and by Adams in verifying the predicted relativity shift of the spectrum lines, that the numerical results and general conclusions already derived from the magnitude of the star need no revision.

**OBSERVATIONS OF VARIABLE STARS**

With the straffierkassette at the 10-inch telescope Oosterhoff measured the photographic magnitudes of ζ Aurigae during its 1934 eclipse (Mount Wilson Contribution, No. 518). Measures of XX Virginis indicate that the star is not an ordinary Cepheid, but of the RR Lyrae type, with the rather unusual period of 1.35 days. Measures of the short-period variable VV Puppis on two nights at the 60-inch telescope suggest that its mean brightness is subject to considerable fluctuation. Both at maximum and minimum, it was about a magnitude fainter than when previously measured by other observers.

With the 10-inch and 5-inch cameras, Oosterhoff is studying the variables brighter than magnitude 16 within a field 10° x 12° in the Scutum Cloud. Through the courtesy of the Leiden Observatory, observations of this region were made with the Franklin-Adams telescope at Johannesburg on two nights during which measures were also in progress at Mount Wilson. Combination of these observations will considerably facilitate the determination of the periods of some of the stars. In addition, the fainter variables are being studied with the 60-inch telescope in two fields, each about two-thirds of a square degree. Although the fields are small, the intercomparison of five pairs of plates has revealed 14 variables.
VARIABLE STARS IN GLOBULAR CLUSTERS

M 5, 12, 53 and NGC 6171 were photographed by Oosterhoff at the Newtonian focus of the 60-inch telescope for a study of variable stars in the clusters. Several new variables were found in M 5 and M 53; none in M 12, and 8 in NGC 6171. For the last two clusters, however, only two pairs of plates have been compared.

COLORS OF GLOBULAR CLUSTERS

Stebbins and Whitford have completed measures of color of 69 globular clusters, practically all those visible from Mount Wilson. As already reported, globular clusters show distinctly the effect of selective absorption near the median plane of the galaxy, the color excess being most marked in the direction of the galactic center.

COLORS OF B-TYPE STARS

Stebbins and Whitford have nearly completed color measurements of about 400 B-type stars between magnitudes 7.5 and 10, in extension of similar work on the brighter B stars done at the Washburn Observatory. The photoelectric measurements of nebulae, globular clusters and B stars all contribute to the determination of interstellar absorption within the galaxy.

STELLAR INTERFEROMETER

Measures by Pease with the 50-foot interferometer indicate that the fringes for $\gamma$ Aquilæ and $\epsilon$ Pegasi vanish at a mirror separation of about 55 feet, and for Antares at 11.5 feet. For the three stars we have therefore the accompanying results.

The diameters for Antares refer to the mean date August 10, 1934.

<table>
<thead>
<tr>
<th>Star</th>
<th>Appt. Mag.</th>
<th>Spectrum</th>
<th>Parallax $\lambda$</th>
<th>Effective $\lambda$</th>
<th>Angular diameter (Sun = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$ Aquilæ</td>
<td>2.8</td>
<td>K2</td>
<td>0.018</td>
<td>5615</td>
<td>0.0084</td>
</tr>
<tr>
<td>$\epsilon$ Pegasi</td>
<td>2.5</td>
<td>K0</td>
<td>0.009</td>
<td>5600</td>
<td>0.0084</td>
</tr>
<tr>
<td>Antares</td>
<td>1.22</td>
<td>Map</td>
<td>0.019</td>
<td>5750</td>
<td>0.041</td>
</tr>
</tbody>
</table>

DISTRIBUTION OF ABSOLUTE MAGNITUDES

Strömbärg has developed a new method of determining statistically the distribution of absolute magnitudes in a group of stars of known apparent magnitude, radial velocity and proper motion. The method consists in projecting the velocities on several arbitrary axes fixed in direction. From the distribution of the reduced proper-motion components and the projected radial velocities, the distribution of the absolute magnitudes is derived for each of the arbitrarily chosen axes. Although more laborious, the method is superior to similar methods based on peculiar and parallactic motions. Applications to certain groups of stars are in progress.
FORMATION OF GALAXIES

Strömgren has continued his theoretical studies of the formation of stars from a primordial, viscous and compressible gas of very low density. The system of gas remaining after portions of large mass motion and molecules of high velocity have escaped, in general, contracts owing to dissipation of mechanical energy into heat and to radiation. The motions tend to become more and more regular because of very high kinematic viscosity of the gas, and, on the supposition that a final steady state of motion is approached, certain properties of this motion can be deduced. The scalar velocity is found to remain approximately constant. Gravitational energy is converted into heat and radiation, but the gross kinetic energy remains unchanged after the steady state has been reached. An explanation has for the first time been found for the observed connection between physical properties of stars and their motions. Most of the phenomena of the motions of the planets, asteroids and satellites in the solar system probably can also be explained in a way similar to that found for the stars in the galaxy. When angular momentum was imparted to them, the galaxy and the solar system were both much larger than at present. The high-velocity stars in the galaxy and the satellites in the solar system were formed outside the central plane before the motions had become circular.

PHOTOELECTRIC TESTS OF SEEING

A new application of the photoelectric amplifier by Stebbins and Whittford is the measurement of the rapid fluctuations of a star's light which accompany poor seeing. With additional stages giving a current amplification of $10^9$ or more, it has been possible to follow the variations of first-magnitude stars with a 3-inch telescope. In conjunction with an oscillograph and photographic recorder, the amplifier will show variations in a star's light amounting to 50 per cent or more with frequencies up to 50 per second. It is hoped that the method can be developed to give an impersonal quantitative measure of the seeing at any time.

 STELLAR SPECTROSCOPY

The efficiency of stellar spectrographic observation has been greatly enhanced by aluminizing the 60- and 100-inch mirrors. While no quantitative tests have been made, it is evident that in the usual photographic region the speed of the spectrographs has been materially increased relative to that attained with silvered mirrors used under average conditions of deterioration. In the ultra-violet region the spectra extend 200-300 A farther toward shorter wave-lengths than those previously obtained under similar conditions with silvered mirrors.

The new mounting of the coudé spectrograph was completed in December and has been successfully used for observations of Nova Herculis, the planets, and a number of stars. The design is such that by rotating the slit, either prismatic or grating spectrographs may be used. The slit and the optical parts of the 9- and 15-foot auto-collimating spectrographs and the plane grating are carried on a heavy inclined frame of structural steel, which floats on balls in such a way that no strain in the concrete pier can be transmitted to the spectrograph frame. The grating receives light from either of two
collimating mirrors having focal lengths of 115 and 184 inches, respectively, and mounted, along with the lenses for the Littrow spectrographs, on sliding carriages which may be brought easily into position as required. A Ross lens of 9-foot focus and its plateholder, and cameras of shorter focal length of the Schmidt type, are mounted for interchangeable use on a horizontal frame attached to the main frame. The temperature of the sensitive parts may be maintained within 0°02 C. The Pfund arc is so arranged that light from only the central part of the arc reaches the slit.

The other spectrographic equipment has been used without essential change. The observers have been Adams, Christie, Dunham, Humason, Joy, Merrill, Sanford, Strömberg and Wilson. For two stars of especial interest, ζ Aurigae and Nova Herculis 1934, extended observing campaigns involving several observers have been carried through.

During the year 1369 stellar spectrograms have been obtained; 583 with one-prism, 281 with grating, 430 with three-prism ultra-violet, 66 with coudé, and 59 with low-dispersion spectrographs.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX

The catalogue containing the absolute visual magnitudes and parallaxes of 4179 stars, by Adams, Joy, Humason and Miss Brayton, has been published as Mount Wilson Contribution, No. 511. It includes nearly all the stars of types F, G, K and M, as well as a few A-type stars, that have been spectrographically observed at Mount Wilson during the last 25 years. The absolute magnitudes have been determined on a uniform system, based upon trigonometric parallaxes in the case of the dwarf stars and upon mean absolute magnitudes derived from parallactic and peculiar motions in the case of the giants. The probable error of a single determination of absolute magnitude derived from the internal agreement among 429 members of physical systems, such as binary stars and moving clusters, is ±0.27 mag. The mean systematic differences calculated for the various spectral types show that the internal systematic errors between different reduction-curves are negligible.

A plot of the distribution of the absolute magnitudes of the catalogue against spectral type shows in a striking way the well-known sequences. The giant series and the main sequence are well defined. The scattering supergiants, the group of faint giants and the intermediate white dwarfs are suggestive of other sequences.

RADIAL VELOCITIES

Since the radial-velocity observations of Boss stars of late type are nearly complete, considerable attention has been given to the formulation of a new program of radial-velocity determinations. A list of about 1500 stars has been compiled, and observations have been begun. The new list comprises chiefly stars from Schlesinger's Catalogue of Bright Stars, stars in the Selected Areas, bright and faint components of binary systems, stars for which trigonometric parallaxes are available, members of moving clusters, and faint dwarf stars having large proper motions.

Unpublished radial-velocity determinations for about 600 stars are now in hand. Most of the measurements and reductions of spectrograms of the regular radial-velocity program have been carried on by Miss MacCormack, Christie and Wilson.
STEellar SPECTrophOTOMETRY

Dunham has obtained with the coudé spectrograph calibrated photometric plates of a limited number of bright stars for the determination of the shapes and intensities of absorption lines. Miss Carlson has helped with the measurements and has tabulated the theoretical intensities within a large number of multiplets that are astrophysically important.

ζ Aurigæ

At the time of the eclipse of ζ Aurigæ in 1934, special effort was made to obtain as complete a spectrographic record as possible of the spectral changes occurring when the light of the smaller B-type companion passed through the atmosphere of the giant K-Type star. Christie and Wilson have measured the spectrograms and, with the aid of the spectrographic orbit of Harper and the photometric observations by Oosterhoff and by Huffer, have determined the elements of the system. (Mount Wilson Contribution, No. 519.)

From a number of microphotometric tracings of spectra of ζ Aurigæ taken during ingress and egress of the companion, they were able to devise a method whereby the effect of the light of the K star could be eliminated from the measures of the tracings. This process enabled them to measure the total absorption of the radiation which produces the continuous spectrum of the B star affected by the various elements in the atmosphere of the K star. From the changes noted, the relative numbers of atoms existing at different levels above the photosphere of the K star have been deduced.

No hypothesis thus far formulated accounts satisfactorily for the observed distribution of the elements. The measures of the hydrogen lines indicate that the shell of hydrogen surrounding the K-type star is of uniform density, but the distribution of the neutral metals apparently follows an exponential law.

NOVA HERCULIS 1934

Nearly 200 spectrograms of Nova Herculis 1934 were obtained with the cooperation of the various members of the observing staff. The first observations, made on the morning of December 15, showed bright bands of the expanding atmosphere which were flanked on the violet side by an α Cygni spectrum of absorption lines whose displacements corresponded to a velocity of —250 km./sec. This velocity decreased to —170 km./sec. on December 22, when the star reached its maximum apparent brightness of 1.3 mag. A few days later Wilson and Merrill discovered that the violet cyanogen bands, which had not previously been observed in novæ, were present in considerable strength. Measures by Sanford served to identify many cyanogen features in the red and yellow regions of the spectrum as well. The displacement of the cyanogen spectrum was the same as that of a second absorption spectrum which appeared at about the same time. After a few days the cyanogen disappeared, but the new spectrum, which resembled that of ζ Aurigæ, proved to be the chief absorption spectrum of the nova. The displacements of the sharp absorption components were accurately determined. The velocity given by the second component gradually increased from —265 km./sec. on December 23 to —390 km./sec. on March 26. Several additional components with greater displacements were also observed. About April 1 the bright-line spectrum of the nebular stage appeared.
Adams, Christie, Joy, Sanford and Wilson have made a preliminary examination of the spectrograms covering the blue and violet regions. On account of the high dispersion employed, the coudé plates, which were taken by Adams and Dunham, are especially valuable for the identification of lines and for velocity measures. Cassegrain grating spectrograms showing the region from λ5150 to λ6550 have been measured by Merrill. The chief dark lines within this region whose displacements have been studied in detail are those of Na I, O I, Si II, Sc II, Ti II, Fe II and Ba II. Bright lines of several elements, especially O I and Fe II, show progressive changes of structure of considerable interest.

**R AQUARI I**

A study of the anomalous features associated with the spectrum of the long-period variable R Aquarii and their behavior during the interval 1919-1934 has been completed by Merrill (Mount Wilson Contribution, No. 513). The star appears single, but the spectroscopic observations indicate three light-sources, all variable, *viz.* a red long-period variable, type M7e; a gaseous nebulosity, type P; and a blue “companion,” type Op or Bep. The features and cyclic changes of the M7e spectrum correspond in detail to some of the typical long-period variables. The nebular lines were sometimes conspicuous, at other times practically absent. On two occasions the “companion” spectrum resembled that of the nucleus of a planetary nebula; at other times it was entirely different, with either permitted or forbidden lines of ionized iron predominant. The spectroscopic data make possible a partial analysis of the light-curve into two curves: one for the Me star, the other for the “companion.” The behavior of the spectrum of R Aquarii is extraordinary and extremely puzzling, but remarkable similarities between some of its phases and the spectra of certain other variables suggest that phenomena of general astrophysical interest may lie back of the apparent anomalies.

The outer nebulosity surrounding R Aquarii is extremely faint, the brightest parts being at the intersections of two nebulous arcs approximately 40" preceding and following the variable. A single spectrogram obtained by Humason with the slit of the spectrograph extending through the intersection preceding the variable shows the following emission lines, with their intensities appended: Hδ(5), Hγ(2), Hδ(1). On the same date the intensities of these lines in the spectrum of R Aquarii itself were 2, 5 and 30, respectively.

**CEPHEID AND ECLIPSING VARIABLES**

Radial-velocity curves for RR Lyrae, FF Aquilae and Y Ophiuchi have been determined by Sanford (Mount Wilson Contributions, Nos. 508-510). The center-of-mass velocity of FF Aquilae evidently undergoes a long-period change somewhat resembling that of Polaris. The velocity-curve of Y Ophiuchi differs markedly from that found by Albrecht a quarter-century ago. The velocity range is greater and the eccentricity has increased. The curves of both stars differ from typical Cepheid velocity-curves in having rising branches that are steeper than the falling branches. The spectroscopic orbit and estimated dimensions of the eclipsing star W Ursæ Minoris have been determined by Joy and Professor O. L. Dustheimer of Baldwin-Wallace College (Mount Wilson Contribution, No. 521).
Spectroscopic observations of Cepheid variables in the southern Milky Way have been continued by Joy. The well-determined velocity-curves of the Cepheid program are now being prepared for publication.

A number of eclipsing stars are under observation by Joy and Sanford.

**ABNORMAL DISPLACEMENTS OF LINES IN STELLAR SPECTRA**

Adams and Miss MacCormack have published in *Mount Wilson Contribution*, No. 505, the results of measurement of certain lines on high-dispersion spectrograms of the very luminous stars β Orionis, α Cygni, α Orionis, α Scorpii, α Herculis, β Pegasi and ε Pegasi. The lines especially studied are D₁ and D₂ of Na I, H and K of Ca II, λ3944 and λ3961 of Al I, and certain strong lines of Si II. These lines agree in giving negative velocities which are systematically larger than those derived from the normal stellar lines. As the stars are relatively near, the effect of interstellar absorption should be small, and it seems likely that the dissymmetry and measured displacements are due to radial convection currents or to expanding gaseous envelopes surrounding the stars.

**INTERSTELLAR LINES**

Many spectrograms of O-, B- and A-type stars have been taken with the grating spectrograph in recent years by Merrill as a basis for study of the detached D lines of sodium, and with the prism spectrographs by Sanford for a similar study of the H and K lines of calcium. A detailed investigation of the displacements and intensities of these lines is under way. Of the new interstellar lines discovered by Merrill and reported last year, λ5780, 5796 and 6284 have been observed in the spectroscopic binary HD 224151 and found to remain stationary within the errors of measurement, while the stellar lines oscillate from −150 to +132 km./sec.

**R- AND N-TYPE STARS**

The program of radial-velocity determinations for stars of classes R and N has been closed, with only a few of those within reach still unobserved. The results have been compiled by Sanford and utilized to determine the solar motion, the galactic rotation and the direction of the galactic center (*Mount Wilson Contribution*, No. 525). The spectra of 17 N-type stars have been found to show exceptionally strong sodium lines, while for six others these lines are abnormally weak.

**c STARS OF CLASSES B AND A**

A list of 95 c stars of classes B and A has been compiled and published by Merrill in *Mount Wilson Contribution*, No. 512. The character of most of these stars has been either discovered or confirmed by observations made with slit spectrographs at Mount Wilson. The number having hydrogen emission is noteworthy. Because of their high luminosities (absolute magnitude about −5.0) and their great distances, c stars of early type should serve well for studies of galactic rotation, interstellar absorption and other important investigations. Preliminary experiments with the 10-inch telescope (exposures by Hendrix) indicate that such stars can be detected on objective-prism spectrograms by the anomalous intensities of the D lines.
RADIAL VELOCITIES OF GLOBULAR CLUSTERS

Humason has determined the radial velocities of three globular clusters by the measurement of their integrated spectra on low-dispersion spectrograms:

<table>
<thead>
<tr>
<th>NGC 6440</th>
<th>$-175$ km./sec.</th>
<th>G3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6981</td>
<td>$-180$</td>
<td>G5</td>
</tr>
<tr>
<td>7006</td>
<td>$-350$</td>
<td>G3</td>
</tr>
</tbody>
</table>

MISCELLANEOUS INVESTIGATIONS

Adams and Humason have observed the spectra of the white dwarfs AC $+70^\circ 8247$ and Wolf 1346. They show features similar to those found in the companion of Sirius.

Merrill has continued his investigations of long-period variables. Radial velocities have been obtained for several stars hitherto unobserved, and the spectra of others of type Me have been photographed at minimum with low dispersion. Merrill has also continued his study of forbidden lines in stellar spectra.

Several spectroscopic binaries are under investigation by Christie and Sanford, among them the companion of Rigel.

Humason has observed with the low-dispersion spectrograph a number of faint dwarf stars having large proper motions. He has also obtained additional spectra of the expanding nebulosity emitted by Nova Persei 1901, taken with the slit of the spectrograph extending across the faintest part of the shell. The emission lines from this region are weak, however, and longer exposures will be necessary before any definite interpretation of the spectrum of this part of the shell can be made.

Humason and Baade have studied the large gaseous nebula in Cygnus, NGC 6960 and 6992. Radial velocities from the outer edges and near the center show that if the nebula is expanding, as the proper motions suggest, the rate of expansion is small. Including measures by Sanford made in 1924 and 1925, the mean velocity from the preceding edge is $+14$ km./sec.; from the following edge, $+32$ km./sec.; and from a region near the center, $+50$ km./sec. But since the spectra were obtained with a dispersion of 500A per millimeter at H$_\gamma$ the uncertainty in the measures is of the same order as the differences observed. The result suggests that the parallax of the nebula is greater than 0.071.

The line $\lambda 4511$, which appears in emission in M- and S-type variables, was tentatively identified by Merrill and Joy in 1930 with a component of a resonance doublet of indium. Thackeray has studied the origin of this line and suggests that it is due to the coincidence of the other line of the indium doublet with H$_8$, the emission of H$_8$ stimulating the indium atoms to radiate $\lambda 4511$ in a manner similar to the excitation of O III radiation by ionized helium in nebulae (Mount Wilson Contribution, No. 517).

Wildt has studied theoretically the influence of a temperature gradient on the dissociation and ionization equilibrium in stellar atmospheres.
NEBULAR INVESTIGATIONS

SURVEYS OF NEBULÆ

Two surveys of extra-galactic nebulae have now been completed by Hubble which indicate the numbers of nebula per unit area brighter than magnitudes 18.5 and 21.0, respectively. Analysis of the five surveys now available gives the form of the relation between numbers of nebulae and limiting magnitudes. The empirical relation exhibits systematic deviations from that corresponding to an apparent uniform distribution of nebulae in space which are provisionally attributed to the effect of red-shift on apparent luminosity. The study of these results, which bear upon the interpretation of the red-shift, has led to an extensive review of all available data concerning the distances and velocities and the luminosity function of nebulae, and to revisions of the numerical quantities involved. Publication has been delayed pending the completion of a joint investigation by Hubble and Dr. R. C. Tolman of the California Institute of Technology on the bearing of these results on the theory of the expanding universe.

CLUSTER OF NEBULÆ IN CYGNIUS

A new cluster of nebulae in low latitude has been found by Baade on photographs of NGC 6992. The position for 1930 is R.A. 20° 55'7, Dec. +31°7; galactic longitude 43°, latitude —10°. The cluster consists of about 100 nebulae, 70 of which are situated within a circle of 16' diameter. The low surface brightness of the nebulae suggests that absorption affects the field.

COLORS AND INTEGRATED MAGNITUDES OF NEBULÆ

Integrated magnitudes of all extra-galactic systems in which supernovæ have appeared have been determined by Baade with the schraffierkassette at the 10-inch refractor or by means of intra-focal images with the 5-inch Ross camera. The results are in good agreement with those obtained photoelectrically by Stebbins and Whitford, who have derived magnitudes and colors for more than 100 of these objects. The photoelectric cell gives precise measurements of the integrated light, and hence is invaluable as a check on the photographic determinations of brightness and the inferred distances of nebulae. The dispersion of color in extra-galactic nebulae is greater than in globular clusters; nevertheless, the nebulae give additional evidence on the absorption of light in our own galaxy.

MASS OF THE VIRGO CLUSTER

From the radial velocities obtained by Humason and Smith and by Slipher of the Lowell Observatory for thirty members of the Virgo cluster, Smith has derived some of the physical characteristics of the cluster. Comparison of the velocities of faint and bright members of the cluster shows that the radial velocity of a nebula does not depend on its magnitude. Since difference in brightness implies a difference in mass, it follows that equipartition does not hold in the cluster. The distribution of the velocities in right ascension and in declination shows that the cluster is not in rotation and, further, that there is no central concentration of high velocities. This result is taken to
mean that the cluster is neither condensing nor breaking up, but is a fairly stable assemblage, more or less held together by its gravitational field.

From the observed distribution function for radial velocity, the distribution function of space velocities was derived. For an assumed distance of 2.2 \( \times 10^8 \) parsecs, this function leads to a mass for the cluster equal to 2 \( \times 10^{47} \) g. or 10\( ^{14} \) \( \odot \). On the supposition that the cluster includes 500 nebulæ, the mass per nebula is approximately 2 \( \times 10^{11} \) \( \odot \). While this value is far larger than Hubble's estimate of 10\( ^{6} \) \( \odot \) for an average nebula, the mean peculiar velocity of 500-600 km./sec. for nebulæ in the cluster, as against 150 km./sec. for isolated nebulæ, lends support to the high value here found. It is possible that both figures are correct, the difference representing a great mass of inter-nebular material within the cluster.

**AN INTENSIVE STUDY OF M 32**

An intensive study of M 32 has been undertaken by Smith as a beginning on the general problem of the structure of elliptical nebulæ. Thus far the following results have been obtained: (1) A series of photographs through a large Wollaston prism showed no detectable polarization within 75" of the nucleus. (2) The existence of a definite nucleus which can be treated as a separate entity was established from photometric data, and observations were made to determine its angular diameter. Direct photography proving inadequate, interference methods were tried, but these yielded only a lower limit. Finally the value 0\( ^{0} \) 38 \( \pm \) 0.71 was obtained visually with the aid of a micrometer at the Newtonian focus of the 100-inch telescope. (3) The spectral type as determined from a series of low-dispersion spectrograms shows no variation along the major axis.

If we assume that M 32 is a gigantic globular star-cluster, the foregoing results lead to a value of 1.9 \( \times 10^{7} \) for the number of stars in the cluster and a central density of 8.8 \( \times 10^{8} \) stars/parsec\(^3\). The spectral type is dG3.

**VARIABLE STARS IN NGC I 1613**

The investigation of the variable stars in NGC I 1613 has been continued by Baade, and sufficient material will be available by the end of the 1935 season. Reliable photometric sequences have been established by intercomparisons with S.A. 68. For practically all the brighter variables (periods between 14 and 42 days) light-curves have already been obtained. The resulting provisional modulus of the system is close to 22.2 mag. Since the total apparent magnitude of NGC I 1613 is about 11.0, it is without doubt a system of low luminosity.

**ANGULAR ROTATION OF SPIRAL NEBULÆ**

Measurements for the determination of angular rotations of four spiral nebulæ, M 33, 51, 81 and 101, have been made by Hubble on several pairs of 60-inch reflector plates taken at intervals ranging up to 23 years. The angular displacements to be expected on these plates on the basis of van Maanen's early measures of these objects on plate-pairs of relatively short interval are 15 to 20\( \mu \). The displacements actually found are of the order of the uncertainty of the data—about 1\( \mu \) on the average—and in the mean
for the four spirals are zero. A similar result is shown by measures of
one pair of plates for M 81 by Nicholson and of two pairs for M 51 by
Baade.
Recent measures by van Maanen of M 33 and M 74 on plates of excellent
quality taken with the 100-inch telescope (42 feet focus) with nine years
interval give a positive rotational displacement well in excess of the indi-
cated probable errors. The value for M 33 is, however, a third less than that
previously found by van Maanen. A few measures on 80-foot focus plates
of M 33 and M 101 also show positive displacements, but with values which
are also smaller than those obtained from early measures of 25-foot focus
plates. Although several sources of possible systematic error have always
been recognized, and in some cases certain kinds of systematic error are
known to be present, none of them explains satisfactorily the persistence of
the positive sign of the angular displacements shown by van Maanen’s
measures.
An independent analysis by Seares, involving reduction by a different
method of most of the data now available, reveals local systematic displace-
ments on some of the plates amounting to a few μ; but these displacements,
which seem to be of instrumental origin, are not rotational in character.
The analysis confirms the zero result found by Hubble, Nicholson and Baade
and shows that it can not be the consequence of a compensating systematic
error which has neutralized a real rotational displacement. Although the
anomaly of van Maanen’s results remains unexplained, these recent investiga-
tions apparently remove the one outstanding discrepancy in the field of
nebular research.

NEBULAR SPECTROSCOPY

Velocities of 19 extra-galactic nebulae have been obtained by Humason
during the year. Among them is a value of +42,000 km./sec. from a single
spectrogram of an object in the faint cluster Ursa Major 2. The velocities
of +39,000 km./sec. and +24,000 km./sec., derived from the Boötes cluster
and the cluster Gemini 1 and announced in last year’s report, have now
been confirmed by measures of additional spectrograms. The velocity from
the Boötes cluster and the new velocity from Ursa Major 2 indicate that
the velocity-distance relation is sensibly linear up to distances of the order
of those of these clusters, which Hubble and Baade estimate at 70 million
parsecs.
The velocities of 70 isolated nebulae brighter than apparent magnitude 13.0
are now known. When corrected for magnitude, solar motion and latitude
they show no dependence on position in the sky. The early-type nebulae, E0
to E9 of Hubble’s classification, are redder than the late-type spirals, Sc.
The mean spectral types for four groups are:

<table>
<thead>
<tr>
<th>Type</th>
<th>Spectrum</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>G4.1</td>
<td>20</td>
</tr>
<tr>
<td>Sa</td>
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</tr>
<tr>
<td>Sb</td>
<td>G2.8</td>
<td>16</td>
</tr>
<tr>
<td>Sc</td>
<td>G0.6</td>
<td>17</td>
</tr>
</tbody>
</table>

Preliminary observations by Humason for measurements of rotation in
NGC 3115 and NGC 4111 show inclined absorption lines, and with longer
exposures it should be possible to obtain spectra for both objects at a considerable distance from the nuclei.

A number of spectrograms of the elliptical nebulae NGC 3115, 4486, 4569 and 4648 extending into the violet to about 3100 Å have been obtained by Smith with the new quartz spectrograph and Schmidt camera. Each plate includes a series of spectra of a standard star as a means of comparing the energy distribution of the various objects. If these nebulae are assemblies of stars, the dominant spectral type would be expected to vary with the spectral region in which it is observed. Although the results are still incomplete, there is certainly no indication that the apparent spectral type becomes earlier as the region of shorter wave-lengths is approached; in fact the ultraviolet intensity, if anything, is lower than would be predicted from the usual classification of these objects. A certain amount of hydrogen absorption must be considered, however, and the final interpretation is not yet clear.

LABORATORY INVESTIGATIONS

ELECTRIC FURNACE SPECTRA

In continuing his study of rare-earth spectra, A. S. King has worked on the three elements in the middle of the group—samarium, europium and gadolinium—all three very rich in lines. The stronger lines of the ionized atom are in each case found in the solar spectrum; the absence from the sun of neutral lines of the rare earths, which are very strong in laboratory spectra, is, however, a remarkable feature. During the examination of samarium are spectra it was found that the relative intensities of the neutral and ionized lines could be varied at will by changing the amount of the substance being vaporized, low vapor density giving the solar lines. This result suggests that in the sun, as on the earth, the abundance of the rare earths is very low, and that the consequent rarity of recombinations of ionized atoms prevents the appearance of neutral lines.

The temperature classification of samarium lines, the main results of which were reported last year, has been extended to a total of 4474, of which about 450 are low-temperature lines. Further examination of the complex structure of many samarium lines, supplemented by measurements of their components and considered in the light of Aston’s recent discovery of seven isotopes for samarium, indicates that the complexities are probably a combined effect of isotope displacement and hyperfine structure in components belonging to the odd-numbered isotopes.

In preparation for the temperature classification of europium and gadolinium lines, suitable spectrograms were made for the range λ2800 to λ8000. Except for the ultra-violet section, the classification for europium, including more than 1200 lines, is complete, while from the gadolinium spectrum of nearly 3000 lines, those of low atomic levels, numbering 685, have been selected as a basis for the term analysis of neutral gadolinium.

Other work by King includes the selection of the low-temperature lines from furnace spectra of thulium for term analysis and the photography of furnace and arc spectra of titanium and vanadium in the infra-red as far as λ10000 for comparisons with the sun-spot spectrum.
ANALYSIS OF RARE-EARTH SPECTRA

The rare earths (atomic numbers 57-71) have the most complicated of all spectra. Hund's theory indicates, however, that those at the beginning and end of the group should have simpler spectra than the others, and that even the complicated spectra of elements close to the middle of the group should have relatively simple portions. These predictions have been confirmed by the complete analysis by Russell of the spectra of lanthanum (57) and a large part of those of ytterbium (70) and lutecium (71). King's work on temperature classification has been of vital importance in these analyses and in recent work on the middle of the group.

Dr. Walter E. Albertson of the Massachusetts Institute of Technology has analyzed the main part of the spark spectrum of europium (63). He has also grouped about 450 low-temperature lines of samarium (62) into multiplets involving 175 different levels (including the most important low terms) and made a similar beginning on gadolinium (64). Albertson's work will be continued at the Observatory under a National Research Council fellowship. Russell and A. S. King have classified the most important lines of the europium arc.

These spectra are of considerable theoretical interest. Terms of multiplicity 9 are found in Sm i and Eu II, and of multiplicity 10 in Eu i. The highest value previously known was 8, in Mn i and Re i; but 11 may be anticipated in Gd i. The normal electron configurations of the neutral atoms are: Sm, f^5s^2; Eu, f^7s^2; Gd, f^7s^2d; Yb, f^15s^2; Lu, f^13s^2d. Although the spectra are not yet completely analyzed, the temperature classification makes these results certain. Contrary to Bohr's original conjecture, three of the five configurations contain no d electrons; and the similarity of the chemical properties of these elements, despite the differences in atomic structure, presents an interesting problem. The ionization potential of europium was found to be 5.64 volts.

SPECTRUM OF COBALT

R. B. King has measured the Zeeman patterns of 160 lines of neutral cobalt in addition to those reported last year; the total number now measured is 958. With the aid of these data and of unpublished results generously communicated by Dr. W. F. Meggers and Dr. Keelin Burns, Russell is engaged in an analysis of the arc spectrum. The spectrum has already been analyzed by others, but many strong lines remained unclassified and numerous energy levels were not collected into terms. The Zeeman data enable this to be done with assurance, and many new levels and terms have been added.

PHOTOGRAPHIC PHOTOMETRY OF IRON MULTIPLES IN FURNACE ABSORPTION SPECTRA

A method of measuring the relative intensities of absorption lines in complex spectra has been developed by R. B. King and A. S. King. The element to be studied is vaporized in the vacuum furnace, the absorption lines being obtained by passing a parallel beam of light from a Philips tungsten lamp operated at about 3100° C. through the tube and onto the slit of the 15-foot concave-grating spectograph. With a small quantity of material in the furnace, the lines of the stronger class I multiplets appear faintly in absorp-
tion. The total absorption for very weak lines (below about 0.03 Å equivalent width for iron at 2100° C.) is dominated by the Doppler effect and is directly proportional to the number of atoms in the line of sight times the f-value for the line. Since for a given spectrogram the number of atoms enters as a constant, the measured total absorptions of lines on any one spectrogram having equivalent widths between 0.001 and 0.03 Å are proportional to their relative f-values when the latter have been corrected for the Boltzmann distribution which exists in the furnace. When the amount of absorbing vapor is increased, the stronger lines pass out of the part of the “curve of growth” dominated by the Doppler effect, and weaker lines then appear in this stage of development.

A large intensity range (about 3000 to 1 for iron at 2100° C.) is covered by the measurements made on lines appearing in the Doppler region for various amounts of absorbing vapor. Pressures of the order of 0.2 mm. of mercury are used in order to avoid the effects of collision broadening. Measurements of the relative f-values, with an average probable error less than 10 per cent, have been made on the lines of nine iron multiplets of classes I and II between λ3650 and λ4400.

**VACUUM SPECTROGRAPH**

Anderson has devoted the major part of his laboratory time to the vacuum spectrograph. The new aluminum casting has been found satisfactory, and a hypervac pump alone provides a vacuum sufficient for adjustments and tests of the spectrograph. Ordinary plates sensitized with oil have given usable spectrograms for zinc, copper and iron covering the region λ2200 to λ1300. For wave-lengths shorter than λ1300, the spectrograms are too weak to be of service. This circumstance probably indicates that the grating ceases to reflect at about this point. For future work it will be desirable to install a new grating ruled especially for the short wave-length region.

After the preliminary tests had been completed it was thought desirable to increase the pumping speed. A glass diffusion pump using apiezon oil was accordingly assembled by Smith. When backed with the laboratory megavac pump, the diffusion pump easily reaches and maintains a vacuum better than $10^{-3}$ mm. of mercury, thus releasing the hypervac pump for other laboratory purposes.

The vacuum spark appears to work so well that a separate vacuum spark chamber has been designed and constructed for use as a source with the 15-foot concave-grating spectrograph. The object is to increase our knowledge of the high-ionization spectra of the elements in the visual and near ultraviolet regions.

**RULING MACHINE**

Babcock has studied in detail the origin of the residual errors in the new ruling machine. An application of the Michelson interferometer has led to the rejection of an experimental feature introduced into this machine, and in consequence the diamond carriage and its supports have been completely redesigned. Prall, working from his own drawings, has spent several months on the reconstruction. Study of the performance of the machine in the light of evidence afforded by gratings of excellent quality indicates that the spacing system needs only minor improvements to render it fully satisfactory.
A NEW TELESCOPE DRIVE

Smith has experimented with the vibrations of a stretched wire as a means of generating an alternating current which was amplified until sufficient power became available to run a small synchronous motor suitable for driving a telescope. The advantage of such a system is that while the rate can be kept very constant it can also be varied over a wide range by changing the tension of the wire. This feature makes possible a drive having a wide range in rate and, moreover, one such that the rate can be constantly corrected by the guiding operations.

SCHMIDT CAMERAS

The development of cameras with spherical mirrors and correcting plates at the center of curvature, similar to the telescope invented by Schmidt, has been continued. The first experimental camera of this type (30 inches focal length), which was made by Dunham last year, has been provided with a metal mounting and a new correcting plate of ultra-violet transmitting glass made by Hendrix. A camera of the same type with a focal length of 73 inches is under construction for the coudé spectrograph. Both these cameras are designed to work off-axis so that the photographic plate is outside the incoming beam. A third camera, of 5 inches focal length and a focal ratio 1.75, has been made and tested with a temporary mounting in which a photographic plate 10 x 10 mm. is held centrally in the beam. Owing to the blind spot produced by the convex mirror at the top of the telescope tube, very little light is obstructed by the plate in the central position. The definition is very fine, and when the camera is used with the grating in the coudé spectrograph, the speed is such that the spectrum of Nova Herculis has been recorded to \( \lambda 8800 \) and that of Arcturus to \( \lambda 11000 \).

VELOCITY OF LIGHT

The discussion of the measurements of the velocity of light made by Michelson, Pease and Pearson with the mile-long vacuum tube has been finished and the results have been published as *Mount Wilson Contribution*, No. 522. The seasonal means, the final mean velocity and the average deviations for a single determination are indicated by the accompanying table.

<table>
<thead>
<tr>
<th>Series</th>
<th>Date</th>
<th>Number Determinations</th>
<th>Mean Velocity</th>
<th>Average Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–54</td>
<td>1931, Feb. 19–July 14.</td>
<td>493</td>
<td>km/sec.</td>
<td>299,770 ( \pm 12 )</td>
</tr>
<tr>
<td>55–110</td>
<td>1932, Mar. 3–May 13.</td>
<td>753.5</td>
<td>km/sec.</td>
<td>299,780</td>
</tr>
<tr>
<td>111–158</td>
<td>1932, May 14–Aug. 4.</td>
<td>742</td>
<td>km/sec.</td>
<td>299,771</td>
</tr>
<tr>
<td>159–233</td>
<td>1932, Dec. 3–1933, Feb. 27.</td>
<td>897</td>
<td>km/sec.</td>
<td>299,775</td>
</tr>
<tr>
<td>1–233</td>
<td></td>
<td>2885.5</td>
<td>km/sec.</td>
<td>299,774</td>
</tr>
</tbody>
</table>

CONSTRUCTION AND MAINTENANCE

The opening of the connecting road between Mount Wilson and the Angeles Crest Highway on April 19 provides a new route between the Ob-
servation and the Laboratories, Shops and Office in Pasadena. Although
the distance is 11 miles greater, the driving time remains the same; but
because of the width of the road and its easy grade the strain on motor equip-
ment and on the driver is much lessened. The availability of the road
during periods of heavy snowfall is still to be tested. The present ease of
communication has greatly increased the number of transient visitors to the
Observatory and raised questions as to the most effective method of handling
large numbers of people in the domes of the 60-inch and 100-inch telescopes
which are not yet satisfactorily answered.

No large construction has been undertaken during the year. The pier
and foundation for the new mounting of the 20-inch telescope, and concrete
steps, walk and retaining walls have been built on Mount Wilson; but the
greater part of the time of A. N. Beebe, superintendent of construction,
and of Sidney Jones, engineer on Mount Wilson, has been given to the main-
tenance of the buildings and equipment of the Observatory.

The instrument shop, under the direction of Alden F. Ayers, has met large
demands in the construction of apparatus. The work of instrument design
has remained in the charge of E. C. Nichols, assisted by H. S. Kinney. The
most important items are the new coudé spectrograph for the 100-inch
telescope with provision for the use of either prisms or a grating with several
cameras of different focal lengths; the new ruling machine; a thermoelectric
photometer of the type designed by Dr. F. E. Ross of the Yerkes Observa-
tory, which will greatly facilitate the measurement of photographs for the
determination of magnitudes; and the revision of Cassegrain spectrograph
No. VI. The repair and the modification of apparatus to meet the condi-
tions of special observations are matters which each year require a con-
siderable fraction of the time of the shop.

In the optical shop, John S. Dalton in charge, D. O. Hendrix, assistant, a
large amount of work has been done in the construction of mirrors and cor-
recting plates for Schmidt cameras. The largest of these are the two mirror
strips, 7 inches wide, with foci of 32 and 73 inches cut from a 22-inch spheri-
cal mirror having both surfaces concave, which will be used in the large
coudé spectrograph. The correcting plates are of ultra-violet glass, 17
inches in diameter. Other noteworthy items are a 10-inch, 9\degree objective
prism and the refiguring of the 12½-inch convex element of the Ross zero
corrector to obtain a better distribution of spherical aberration over the
field. In addition, the usual run of small optical parts passed through the
shop, including concave and plane mirrors, lenses, stellite slit jaws, interfer-
ometer plates, and parts for the ultra-violet quartz spectrograph.

An important undertaking was the very successful coating of the large
mirrors of the 60-inch and 100-inch telescopes with aluminum by Dr. John
Strong of the California Institute of Technology, assisted by Dalton of the
Observatory optical shop.

THE LIBRARY

During the year the library was increased by 194 volumes, 27 by gift, 82
by purchase, and 85 by binding; the total number is now 12,815, with
about 10,000 pamphlets. In 1935 the library is receiving regularly 130
serial publications; of these 39 are sent as gifts or exchanges, as are also
the publications of about 200 observatories and research institutions.
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HOGE, WENDELL P. See BABCOCK, HAROLD D.


See ADAMS, WALTER S.


See ADAMS, WALTER S.

JOYNER, MARY C. See Searles, FREDERICK H.


See KING, ROBERT B.; RUSSELL, HENRY NORRIS.


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Ross, Frank E. See Seares, Frederick H.


———. See Adams, Walter S.


Sternberg, Elizabeth E. See Nicholson, Seth B.


WHITFORD, ALBERT E. See STEBBINS, JOEL.


——— See WILSON, OLIN C.


——— See ADAMS, WALTER S.; CHRISTIE, WILLIAM H.
ORGANIZATION OF MOUNT WILSON OBSERVATORY, JULY 1, 1934
TO JUNE 30, 1935

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
FREDERICK H. SEARES, Assistant Director
ALFRED H. JOY, Secretary

Research Division


Stellar Interferometers: Francis G. Pease.

Trigonometric Parallaxes and Proper Motions: Adrian van Maanen, P. Th. Oosterhoff.


Research Associates

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Charles E. St. John, Pasadena; Joel Stebbins, University of Wisconsin.

Investigators Temporarily Associated with the Observatory

John C. Duncan, Wellesley College; O. L. Duschheimer, Baldwin-Wallace College; Caroline E. Furness, Vassar College; S. A. Mitchell, Leander McCormick Observatory; Charlotte E. Moore, University Observatory, Princeton; Frank E. Ross, Yerkes Observatory; Fred E. Wright, Geophysical Laboratory, Carnegie Institution of Washington; P. Th. Oosterhoff, International Research Fellow; A. D. Thackeray, Commonwealth Fellow; Albert E. Whitford, National Research Fellow; Rupert Wildt, Rockefeller Fellow; Rudolf Minkowski, Horace Babcock, William Humason.

Computing Division


Office and Design

E. C. Nichols, instrument design; H. S. Kinney, draftsman; Anne McConnell, bookkeeper; Alice S. Beach and F. Louise Gianetti, stenographers; Gladys Lincoln, stenographer and telephone operator.

Instrument Construction

Optical Shop: John S. Dalton, optician; D. O. Hendrix, assistant optician.

Instrument Shop: Alden F. Ayers, foreman; Elmer Prall, Albert McIntyre, M. C. Hurlbut, Fred Scherff, Oscar Swanson, L. R. Hitchcock, machinists; James Chapman, pattern maker; H. S. Fehr, cabinet maker; Albert Labrow, helper.

Operation and Erection

A. N. Beebe, superintendent of transportation and erection; Sidney A. Jones, engineer; Kenneth de Huff and Nelson G. White, assistant engineers; Thomas A. Nelson, Earl Karr, Glenn C. Moore, night assistants; Joseph Hickox, photographer and day assistant; A. K. Wright and Mrs. Wright, stewards; E. L. Aden, Frank Lavers, Kenneth Pitt, janitors; E. W. Hartong, truck driver.

Several of the individuals whose names are listed above have been associated with the Observatory only a part of the year.