remarkable changes in intensity of this helium line in various solar features.

Solar Infra-red Energy Distribution. The 24-inch reflector and Perkin-Elmer spectrometer are employed full time on the measurement, in absolute units, of the intensity of selected infra-red regions of the solar spectrum.

Solar Prominences. The velocities and accelerations in the eruptive prominence of August 7, 1950, were studied in detail. The prominence was shown to be associated with an active sunspot region that crossed the disc several days prior to the onset of a great geomagnetic storm. A series of solar radio noise bursts at 200 Mc/s took place when the eruptive prominence reached a height of 285,000 km. The forms and motions of eight prominence fields were analyzed for comparison with the prominence spectra taken with the McGregor spectrograph.

Solar Flares. Intensity measures of flares have been continued. Light curves for 21 flares photographed in 1949 showed intensities at maximum that ranged from 1.6 to 5 times the intensity of the undisturbed $H\alpha$ disc. Relationships between intensity, area, location on solar disc, and terrestrial effects were investigated.

The development of a flare at the limb of the sun was recorded on May 8, 1951. During the first minute of the activity the brilliant prominence rose with a velocity of the order of 700 km/sec and reached a height of 60,000 km. $H\alpha$ spectra taken during this period showed Doppler shifts indicating motion tangential to the sun's surface greater than 300 km/sec. $H\alpha$ was 8A to 10A wide. The flare-like prominence reached a maximum intensity four times that of the undisturbed $H\alpha$ disc. The occurrence of this bright limb object coincided with the onset of a burst of 200 Mc/s solar radio noise and a sudden ionospheric disturbance on the earth.

A solar flare was observed on May 19, 1951, in both the Fifty-foot Tower and in the McGregor Tower using the lead-sulfide cell. A complete record of this disturbance in the 10830 line of He I was obtained to accompany the $H\alpha$ spectroheliograms of the Fifty-foot Tower.

Solar Radio Noise. The comparison of 200 Mc/s solar radio noise records secured at Cornell with optical solar activity photographed at Lake Angelus continues. The relationships between the two aspects of solar activity have proved to be both interesting and complex and the results are being put in shape for publication.

Solar and Geomagnetic Data. A compilation has been made of solar features and events from 1948 to the present for comparison with concomitant ionospheric disturbances and geomagnetic effects.

Small Scale Features of the Solar Chromosphere. Studies have been and are being made of the smallest observable features in the solar chromosphere. Some of the data obtained from eclipse plates are being published.

Robert R. McMath, *Director*

Perkins Observatory. Ohio Wesleyan and Ohio State Universities, Delaware, Ohio.

McMillin Observatory. Ohio State University, Columbus, Ohio.

Wesleyan Student Observatory. Ohio Wesleyan University, Delaware, Ohio.

PERSONNEL

Perkins Observatory. Dr. Nicholas T. Bobrovnikoff returned to full duty as director of the Observatory on July 1, 1950. Dr. J. Allen Hynek was promoted to the rank of Professor and was appointed Assistant Dean of the Graduate School. He continues to spend part of his time at the Observatory. Dr. John E. Merrill joined the faculty of Ohio Wesleyan University as Associate Professor of Astronomy during September 1950. On October 1, 1950 Dr. Arne Slettebak was promoted to the rank of Assistant Professor, and became a permanent member of the staff. During September 1950 Miss Mary Beck resigned as Computer. This position was subsequently taken by Mrs. Mary L. Fenwick.

McMillin Observatory. The Observatory assistants were Mr. Philip Stanger and Mr. Leon Zechiel, graduate students in astronomy.

Wesleyan Student Observatory. Dr. John Merrill became director of the Observatory during September 1950.

EQUIPMENT

Perkins Observatory. The construction of an aluminization chamber for the 69-inch mirror under the direction of Dr. C. E. Hesthal is still in progress. Nearly all of the materials and equipment which are required are now on hand.

A low dispersion spectroscopic laboratory was established in the basement of the Observatory with the aid of a grant from the Office of Naval Research. The spectrograph of this laboratory was designed and constructed by W. B. Decker

in the Observatory shop. The arc and associated equipment were set up by Mr. Leon Schroeder, graduate student in astronomy.

A new amplifier was designed and built for use with the microphotometer by Mr. D. C. Livingston, a graduate student at Ohio State University. This has increased the sensitivity of the instrument so that we can now measure dense photographs which were beyond the reach of the old instrument.

A new direct-reading photometer was procured from the Ridell Scientific Instruments Co. under a grant of \$2500 from the Ohio State University Development Fund. It has been used to measure the strength of the bands of cyanogen in stellar spectra.

A new diffraction grating was made for the grating spectrograph by Dr. John Strong of the Johns Hopkins University. This has proved very satisfactory; with the same exposure times it is now possible to reach stars about one magnitude fainter.

The long-standing need of a precision lathe for the instrument shop was finally satisfied. A Rivett precision lathe has been purchased with funds provided by the Ohio State University College of Arts and Sciences.

The $f/1.0$ camera which has recently been put into use in connection with the spectrographs is described in an article by Abe Offner and W. B. Decker in the *Journal of the Optical Society of America*.

McMillin Observatory. All of the component parts for a photoelectric stellar photometer for use with the 12½-inch refractor were obtained. Assembly, incorporating the use of a double-slide photocell holder, should be completed during 1951.

RESEARCH

Comets. Bobrovnikoff has continued his work on the collection and systematization of recorded data on the spectra and brightness of comets. A very large amount of material has already been put into usable shape. The next step, the study of the motion of matter in comets, is about 80 per cent done.

Stellar spectroscopy. Keenan continued to work on the spectra of red stars. A preliminary scheme of classification of S-type stars according to their temperature was reported at the Bloomington meeting of the American Astronomical Society.

Aller and Keenan have been able to show that

the red system of CN bands is stronger in stars of types M and S than was generally recognized. Results have been published in the *Astrophysical Journal*.

The small spectrographic laboratory set up by Keenan with the support of a grant from the Office of Naval Research was operated by one of the graduate students, Mr. Leon Schroeder. A survey of the bands in the photographic infra-red was carried out for about 25 metallic monoxides of possible astrophysical interest. One new system of bands of VO has been found to account for the previously unidentified bands which appear in the $\lambda\lambda 7400-8000$ region of late M-type stars. A preliminary vibrational analysis of this system shows it to originate in the lowest level of the VO molecule.

Keenan and Keller have nearly completed a joint program on the classification of the brighter high-velocity stars. It was found that except for the well known scarcity of types earlier than F5, the non-variable high-velocity stars exhibit a main sequence and a red giant branch very similar to those of ordinary stars in the vicinity of the sun. A preliminary spectrum-luminosity diagram of 74 of these stars was presented at the Washington meeting of the A.A.S. One of the stars in this program, HD 26, has a unique spectrum showing some characteristics intermediate between CH stars and another group in which Ba II and Sr II are strong. A more complete description of this spectrum has been published as a note in the *Astrophysical Journal*.

Hynek continued his investigations of the spectra of some peculiar stars. At the Haverford meeting of the A.A.S. he reported on the star β Lyrae. In the photographic infra-red the Paschen lines behave very differently from the Balmer lines, making it necessary to revise the Kuiper-Struve theory of this star. Hynek is continuing work on parallaxes of giant double stars.

One of Hynek's students, Mr. W. C. White, published a note in the *Astrophysical Journal* in which the existence of six new spectroscopic binaries was established.

Slettebak continued his investigation of infra-red spectra of Be and peculiar A stars. On the basis of the material which he has obtained so far he has published three notes in the *Astrophysical Journal*. Most of his observing time has been devoted to obtaining spectra to be used for determining rotational velocities for the B8-A2 stars brighter than the fifth magnitude. There are about 150 stars on this program. Spectro-

grams have already been obtained for about 75 per cent of them, and computations are well advanced. The envisaged result is a catalogue of rotational velocities of the B8-A2 stars and a statistical study of the axial rotation of this group. An extension of this program to the B2-B5 stars and A3-F8 stars is planned.

Eclipsing binary stars. Merrill continued his work on the construction of tables and nomograms for use in the computation of the elements of eclipsing systems. The results of this work are currently appearing as *Contributions from the Princeton Observatory*.

The observations of Keller and Limber on the systems RS CVn and YY Sgr were published in the *Astrophysical Journal*. There appears to be strong evidence that the larger component of RS CVn is intrinsically variable, and it is quite possible that streams of gas are associated with the system. Keller and Mr. Leon Zechiel, a graduate student, are now collecting all the available material on apsidal motion of binary systems with the object of determining how the density distribution within a star depends on its mass, radius, and luminosity.

Theoretical astrophysics. An investigation of the motions of stars in elliptical galaxies was published in the *Astrophysical Journal* by Belzer, Gamow and Keller.

Keller and Dr. R. E. Meyerott, of the Argonne National Laboratory, undertook computations of the radiative opacity of stellar gas mixtures. Computations of the degree of ionization and of ionization potentials at various temperatures and pressures are well advanced, and will probably be published in a preliminary paper.

PUBLICATION

Hynek completed his task as editor of the book *Topics in Astrophysics*. It is being published by McGraw-Hill Co. and will be on the market by September 1951. Articles largely devoted to a review of progress in astrophysics during the last fifty years have been contributed by many eminent astronomers.

INSTRUCTION

A program of graduate instruction leading to a Ph.D. degree was inaugurated during the past year. Six new one-quarter courses were given for the first time.

The observatories will also be associated with the instruction and research programs of the

newly established Institute of Geodesy, Photogrammetry and Cartography, of the Graduate School, Ohio State University.

N. T. Bobrovnikoff, *Director*,
Perkins Observatory,
J. Allen Hynek, *Director*,
McMillin Observatory,
John E. Merrill, *Director*,
Wesleyan Student Observatory.

Princeton University Observatory, Princeton, N. J.

PERSONNEL

Visiting Professors during the spring term, 1951, were: G. P. Kuiper of the Yerkes and McDonald Observatories (March) and T. G. Cowling of the University of Leeds, England (March, April and May). Professor H. N. Russell visited Harvard for several weeks as Research Associate; in June he was awarded an honorary D.Sc. degree by Yale University at a special ceremony commemorating the 250th Anniversary of the founding of Yale. Professor L. Spitzer, Jr., was Guest Investigator at the Mount Wilson and Palomar Observatories from August through November, 1950. Professor J. E. Merrill of Hunter College spent the summer at the Observatory as Research Associate. Dr. Paul Ledoux of the Institute d'Astrophysique, Liège, spent the spring term of 1951 at Princeton as a Higgins Fellow.

M. Savedoff was the first recipient of the William Charles Peyton Advanced Fellowship, established last year. P. Routly was Thaw Fellow and also an Assistant in Research. Other Assistants in Research were J. Oke, I. Rabinowitz, and J. Schopp. Miss Rosemary Smith left the Observatory in September, 1950, after eight years of service. Her place as secretary was taken by Mrs. Marion Clohossey, who had been with the Observatory since 1944. Miss D. Ross served as stenographer during the period from July 1950 to June 1951. Miss Martha Roberts joined the office staff half-time for work with Professor J. Q. Stewart.

BUILDINGS AND FACILITIES

New aluminum sheeting was provided for the dome over the 23-inch telescope. The New Observatory was thoroughly water-proofed and redecorated throughout.

The pulse-counting photometer designed and constructed by the late Professor Newton L.

Pierce was acquired by the University of Pennsylvania, where it will be used under the supervision of Professor Bradshaw Wood. A smaller photoelectric photometer has been provided for routine photometric measurements; the mechanical parts were constructed by Eichner, the electronics by Sterling.

The Newton Lacy Pierce Junior Fellowship in Astronomy was established, with an endowment of approximately \$5,000. It is planned that this Fellowship will normally be given to a promising graduate student in astronomy, and will supplement income obtained from other sources.

RESEARCH PROGRAM

Stellar Photometry. Plates of Messier 15, taken by Schwarzschild with the 100-inch telescope at Mt. Wilson, were measured by Mrs. Knight with the iris photometer of the Warner and Swasey Observatory and reduced by Schopp. The magnitude scales were based on photoelectric measurements by H. L. Johnson at Mt. Wilson. The color-magnitude diagram obtained shows a sharp red giant sequence and a horizontal branch which turns downwards at the blue end.

Plates of Messier 3, taken by Schwarzschild with the 60-inch telescope at Mt. Wilson, were measured by Schopp to investigate whether the horizontal branch crosses the red giant sequence. The results did not substantiate a crossing.

Eclipsing Variable Stars. Merrill's nomographs, designed to provide a rapid determination of orbital elements from photometric observations, are now complete and in the hands of the printer. Work is nearly complete on the volume of auxiliary tables, designed to accompany the extensive tables already printed and distributed. Work has begun on the preparation of a number of illustrative examples, to show how the tables and nomographs can best be used. Several years will be required for the completion of this additional volume.

Russell continues to be actively engaged, in company with Merrill, in the preparation of a general theoretical discussion of the principles involved in these tables, and also of their practical use.

Stellar Atmospheres. Schwarzschild and Spitzer, in collaboration with Wildt of Yale, have investigated the spectroscopic differences between population I and II stars. They found that the observed differences may perhaps be explained by a general reduction of the abundances of the

heavier elements in stars of population type II. A reduction of this sort would be expected cosmogonically, if the type II stars formed from all types of atoms present in interstellar space, while type I stars formed in clouds with a higher abundance of grains, containing more heavier elements.

Savedoff has considered the formation of an absorption line in a stellar atmosphere on the assumption that the scattering is completely non-coherent. The transfer of radiation in the line is governed by an integral equation which has been solved numerically. This work should make it possible to predict the effects produced by non-coherent scattering under widely different conditions.

Stellar Interiors. Härm, Oke, Rabinowitz and Schwarzschild have undertaken an investigation of stellar models with inhomogeneities in the abundance of *H* and *He*. Two dozen particular solutions of the differential equations for the stellar interior were obtained by numerical integration. On the basis of these solutions three types of models have been constructed: models with convective cores and a jump of molecular weight in the radiative envelope, models with partially degenerate isothermal cores and a jump of the molecular weight at the edge of the core, and models with zones of continuously varying molecular weight. For all three types cases have been found with radii sufficiently large to represent red giants. However in all these cases the masses of the model stars are still somewhat smaller than those surmised from observations.

Interstellar Matter. Spitzer and Tukey have completed their analysis of interstellar polarization. They have explored the possibility that small grains of magnetic material may be aligned by an interstellar magnetic field, thus explaining the observations. With particles of the size usually assumed, the magnetic field required for this mechanism is roughly 2×10^{-3} gauss, which is unexpectedly large. There is some reason to expect that larger grains may be present, and these could be oriented by weaker fields. One result of this study is that a dense nucleus of iron and magnesium, or their oxides, is relatively difficult to destroy by collisions between grains, and a large fraction of the interstellar grains may contain dense nuclei of this refractory material.

Routly and Spitzer have compared the intensities of the faint displaced interstellar components in sodium and calcium. Results indicate

that the ratio of *Na* I to *Ca* II depends on the cloud velocity, with *Na* more abundant at low velocity, with ionized *Ca* more abundant at high velocity. This effect is apparently responsible for the difference previously observed in the curves of growth between these two elements. The physical reason for this observed effect is still not clear.

Spitzer and Greenstein have analyzed the role of two-photon emissions from hydrogen in planetary nebulae. The fraction of ultraviolet radiation converted into this two-photon continuum is relatively high, and in extreme cases all the Lyman α radiation may be so converted. This mechanism may explain the observed visual continua obtained from some planetaries.

Stellar Dynamics. Spitzer and Schwarzschild have investigated the dynamical consequences of gravitational encounters between stars and interstellar clouds. The relaxation time in the galaxy is found greatly shortened by this type of encounter. If one assumes the presence of vast cloud banks or cloud complexes, with masses of about 10^6 suns, and with velocity differences of 10 km/sec between neighboring cloud complexes, the velocity of an early-type main-sequence star will be doubled in roughly 3×10^9 years. It is suggested that the increase of stellar velocity observed with decreasing surface temperature along the main sequence may be the result simply of an age effect, since the stars of later spectral type are generally older than the earlier type stars. The rapidly moving type II stars would not be affected by this mechanism.

Social Physics. During the year increased attention was given to the idea of assigning "dimensions" in social studies, on the pattern of dimensions in physics; a tentative list of six dimensions of society include distance, time, social mass, number of people, level of living or "social temperature," and desire and satisfaction treated as electric charges. Research along these and similar lines has been supported by grants from the Rockefeller Foundation.

A number of conferences on social physics were organized, drawing in interested groups from widely different backgrounds and disciplines. In July a conference on the dimensions of society was held at Randolph, New Hampshire. In March a large conference was held at Princeton, including lawyers and philosophers as well as social and natural scientists. A session on social physics was held at the A.A.A.S. meeting in Cleveland in December, sponsored by Sections M (Engineering) and K (Social Scientists).

Electrical Conductivity. A number of computations have been made on the velocity distribution function in an ionized gas subject to a small electrical field. Since the earlier work failed to take into account one complicated term, the theory has now been extended and this term taken into account. The resultant values of electrical and thermal conductivity in an electron proton gas agree well with those obtained by the methods of Chapman and Cowling. Additional work is now planned on an ionized gas containing nuclei of higher ionic charge.

Lyman Spitzer, Jr., *Director*

Sproul Observatory. Swarthmore College, Swarthmore, Pa.

Dr. Binnendijk left in July for his new position at Carleton College. Dr. Roth continued as research associate until the end of the college year. Mr. Rubingh left in February. Mr. Conger continued as part-time observer and Miss Lippincott and Miss Damkoehler continued as assistants. John J. Davis, Jr. took part in the night work.

Mr. Pitman gave the one-semester course in Introductory Astronomy and Mr. van de Kamp gave the year course in Descriptive Astronomy, also a course in Stellar Astronomy. Dr. M. Schwarzschild and Dr. H. C. van de Hulst were visiting lecturers.

Mr. van de Kamp's Fulbright lectures, given in France in 1949, were published under the title "Long-Focus Photographic Astrometry," in four installments, in *Popular Astronomy*.

A fourfold increase in brightness of Krüger 60 B was found on plates taken July 26, 1939, making this star the sixth known flare star. Further information is given in the June issue of the *Publications of the Astronomical Society of the Pacific*.

Photographic observations with the twenty-four inch refractor were made on 115 nights, a total of 1529 plates were taken. Evening observations were made on 101 nights, morning observations on 46 nights; 32 nights included both evening and morning observations.

No night work was done over the interval 1950 Aug. 9–Sept. 17, during which steel plates were bolted onto the track of the dome to reinforce it. During the fall and winter the bearings in the dome wheels, and the wheels and bearings in the dome shutter were replaced, adjusted and aligned. The operation of both dome and shutter is markedly improved.

Peter van de Kamp, *Director*

United States Naval Observatory, Washington, D. C.

Captain George W. Welker, U.S.N., was detached on 27 April, 1951. Commander E. C. Long, U.S.N., served as Acting Superintendent for the remainder of the year.

Appointments to the staff were: Arthur A. Hoag, Joseph L. Gossner, Robert C. Cameron, Irving R. Greenbaum, Warren T. Toland, Vernon R. Hurley, Sara R. Lichtenstein, Simone D. Gossner, Doris A. Blake, Marie D. Prytulak, Elma K. Oehrtmann, James K. Gleim, Winifred Sawtell, and Don Monger. Losses by resignation or transfer were: Jeannette Reuning, E. G. Reuning, Mattie I. White, and Ruth Hayner.

The number of visitors during the year was 9419.

U. S. Naval Observatory Circulars Nos. 21-29 were issued. The contents of the individual circulars are noted in the following accounts of the work to which each relates.

During the year, 2157 star observations were made on 187 nights with the photographic zenith tube at Washington, and 4558 star observations were made on 310 nights with the photographic zenith tube at Richmond, Florida. The greater number of observations obtained at the latter station is largely due to better weather conditions at that place. The observations made at both stations were used for the determination of time and of the variation of latitude.

The zenith tube in use at Washington was originally designed for latitude work only, and was first installed at Gaithersburg, Md. It has been remodeled several times, to provide for the measurement of right ascensions, to make its operation more automatic, and to provide crystal control. Since it is still inferior to the newer instrument at Richmond, a new photographic zenith tube to take its place is now under construction in the Observatory shop.

New and improved frequency dividers were installed in all the quartz crystal-controlled clocks at the Observatory. A new photographic chronograph for the comparison of clocks and time signals is about 75 per cent completed.

Time signals based on Naval Observatory time determinations were broadcast throughout the year by the Naval Radio Stations NSS, NPG, NPM, and NBA, and by the standard frequency stations of the National Bureau of Standards, WWV and WWVH. The average error of the NSS transmissions on 9425 kilo-

cycles, as indicated by the time determinations at Washington and Richmond, was 0^o008.

The variation of latitude at Washington and Richmond during 1949 was published in *A. J.* 55, 258. The results for these stations during 1950 have been prepared for publication.

The *American Ephemeris and Nautical Almanac* for 1952 was issued February 5. The *American Nautical Almanac* for 1952 was issued June 11; and the three parts of the *American Air Almanac* for 1951 were issued August 4 and December 6, 1950, and March 14, 1951.

Extracts from the *American Ephemeris*, with a small amount of supplementary material, are now published separately under the title *Astronomical Phenomena*. The contents consist primarily of material of interest to the general public, which was formerly supplied in mimeographed form or by correspondence; the separate publication is primarily for economy, permitting the users instead of the Observatory to bear the cost of distribution. The first issue, for 1951, appeared January 18; and that for 1952 on April 16. It is hoped to publish the material for 1953 in September 1951, for 1954 in January 1952, and at yearly intervals thereafter.

U. S. Naval Observatory Circular No. 27 was devoted to the annular eclipse of September 1, 1951.

With the cooperation of the British Nautical Almanac Office, the preparation of extensive tables for air navigation was undertaken for the U. S. Navy Hydrographic Office. These tables, to be known as H. O. 249, will appear in three volumes, the first of which will give altitudes and azimuths of selected stars, while the other two will provide for reduction of sextant observations of the sun, moon, and planets.

As from 1953 the *American Air Almanac* and the British *Air Almanac* will become a single publication, under the title of the *Air Almanac*.

It will be produced jointly by the two Nautical Almanac Offices, to meet the general requirements for air navigation in the United States, the United Kingdom, and Canada. The *Air Almanac* will be printed and published separately in England and the United States; the two editions will be identical except for minor differences in paper and cover stock, binding, and title page. A more extended note on the subject is being published in *Navigation*.

The program of the 6-inch transit circle included the spaced list of 3087 stars between declinations +35° and +50°; the work on this list

is about one-third completed. Many of the computations attending this program are being transferred to the punched-card machines. It is believed that increased accuracy and considerable saving in time will be gained thereby. The usual observations of the sun, moon, planets, and FK3 and PZT stars brought the total number of observations to 6662. The discussion of the work of this instrument during the period 1941-1948 is approaching completion and the results should be ready for publication late in 1951. The greater part of this task has been carried out by Scott and Bestul with the aid of the punched-card machines. The publication will include the catalog of spaced stars between declination $+50^\circ$ and the pole. The observations of Ceres and Vesta, 1928-1935, given in *Publications of the U. S. Naval Observatory* 16, Part 1, are being compared by Scott with ephemerides computed from the rectangular coordinates prepared by Herget, Clemence, and Hertz (*Astronomical Papers of the American Ephemeris* 11, Part 4).

A description of the 6-inch transit circle appeared in *Publications of the U. S. Naval Observatory* 16, Part 2. The photoelectric measuring engine used with this instrument in connection with the circle microscope photographs has been considerably improved by Adams, who has revised a number of the circuits. It is now engaged in measuring a long series of division-error photographs.

The 7-inch transit circle is under construction in the Observatory shop. The micrometer, circles, and circle microscopes are still to be completed. New piers have been erected in the east transit house for the instrument.

The number of micrometer measures of visual binaries, made by Markowitz at the 26-inch equatorial, was 633. With few exceptions the separations of the pairs were less than one second of arc.

Reductions were completed for 113 asteroid positions as determined from plates secured in the years 1946-1949. These positions were forwarded for inclusion in the *Minor Planet Circulars*. Ninety-eight positions of asteroids, and positions of comets 1951a, 1951b, 1951f and Encke's comet, were determined during the year by Gossner from plates taken with the 15-inch telescope.

A 10 by 12 inch plate, kindly measured by Miss Barney at the Yale Observatory, was used by Gossner to determine the cubic distortion in the field of the 15-inch. This amounted to $2''.49$ at

100 mm ($2^\circ.51$) from the plate center; it is small enough to be neglected in nearly all measurements where the object is centered on the plate.

Photographs of the sun were obtained on 300 days. The positions, areas and counts of sunspots, found by Mrs. Day, were published bi-monthly in the *U. S. Naval Observatory Circulars*, Nos. 21, 22, 23, 24, 25, 26, 28, 29. Circular No. 30 consists of a paper by Markowitz on Sunspot Areas and Numbers as Indices of Solar Activity. Visual observations of the sun in the light of $H\alpha$ were made on 223 days. Beginning in October the birefringent filter was used instead of the spectrohelioscope for these observations.

Polarization observations were continued. At the 40-inch, photoelectric measures were made by Hall of the stars in Adams' list (*A. J.*, 109, 354, 1949) together with a number of other stars of special interest (*A. J.*, 56, 40, 1951). Measures of the Orion nebula indicate that most of the polarized light originates in HD 37022 and that polarization increases with distance from this star.

At the 26-inch, photographic polarization measurements were made by Markowitz of nebulae and stars in the Coma cluster, of southern stars and stars of special interest. The results were reported at the June meeting of the American Astronomical Society and are given elsewhere in this *Journal*.

Direct photoelectric microphotometry of the nebulae M 31 and M 81 and of the globular clusters M 13 and M 3 has been carried on by Hoag at the 40-inch reflector. Light intensities were recorded as these objects were allowed to drift across small apertures in the focal plane of the telescope. A sequence of stars is being observed photoelectrically within $2'$ of the center of M 13. Hoag is using similar techniques to determine limb darkening for Jupiter and Saturn in two colors.

Quantitative measurements of stellar scintillation have been continued. This project is partially supported by the Naval Bureau of Ordnance. Measurements of scintillation spectra under widely different conditions have been made, mostly by Mikesell, on 59 nights; on six of these nights the equipment was in operation at Flagstaff, Arizona. Motion pictures of shadow bands and Hartmann images were obtained. A survey of preliminary results was presented at the June meeting of the A.A.S.; an abstract will appear in this *Journal*. Efforts are being made to extend the spectral range to the subaudio region

and to measure the heights at which some of the observed disturbances occur.

A site for the 40-inch reflector near Flagstaff, Arizona, was selected. Although the transfer of this telescope has been authorized by Congress, no funds for carrying it out have yet been appropriated.

In the survey being made by Watts of the marginal zone of the moon 189 plates were measured during the year. About half of the 650 photographs on hand remain to be measured. Apparatus for the convenient application of several systematic corrections to the profiles drawn by the measuring engine is nearly completed. A group of 52 profiles, well distributed with respect to the librations, has been selected for use in establishing a preliminary datum surface; the computations relating to this operation are well advanced.

The status of the cooperative undertaking with the Yale University Observatory and the Watson Scientific Computing Laboratory, under the auspices of the Office of Naval Research, is as follows:

(a) Clemence's calculation of the second-order general perturbations of Mars is in progress.

(b) Morgan's new catalogue of the positions and proper motions of 5268 stars is complete, and copy for the printer is being prepared. The stars are well distributed over the entire sky. The positions at 1950.0 are based on 70 observational catalogues between the years 1915 and 1950, and the proper motions are obtained by comparing these new positions with positions from the *Albany General Catalogue*, at their mean epoch, 1900, after applying certain systematic corrections to the latter. The systematic differences between the new catalogue and the *General Catalogue* are being published in this *Journal*. The new proper motions have been discussed for precession, solar motion and rotation. They indicate a correction $+".75$ to Newcomb's centennial precession in longitude.

Observations have been kindly furnished, in advance of publication, by the Director of the Córdoba Observatory.

The meridian observations of Pallas since its discovery have been collected, and are being reduced on a uniform system preparatory to a comparison with theory.

(c) Hertz has continued his discussion of the meridian observations of Jupiter, with the primary object of improving our knowledge of the mass of Saturn. It is probable that Bessel's mass,

the reciprocal of 3501.6, requires a positive correction.

(d) Hollander completed the measurement of photographic plates of satellites of Saturn. The material consists of about 465 plates taken at Johannesburg and Allegheny in the years 1926–1947. The five satellites Tethys, Dione, Rhea, Titan, and Japetus usually appear on a plate, each with one to five exposures. Thus the total number of satellite images measured exceeds 7000. It is now possible to begin the study of the motions of these bodies.

(e) Numerical work on the theory of precession and nutation by Woolard is in progress.

(f) The numerical integrations at the Watson Scientific Computing Laboratory, giving the rectangular coordinates of Jupiter, Saturn, Uranus, Neptune, and Pluto at 40-day intervals from 1653 to 2060, are complete; and the coordinates will be published shortly as Volume 12 of *Astr. Papers Amer. Ephemeris*.

Further reference to this cooperative undertaking will be found in the report of the Yale Observatory.

Clemence's study of atmospheric refraction at large zenith distances was completed. The results, to be published in detail in *Navigation*, show that current theories of the refraction require no corrections large enough to be of importance in navigation, a conclusion contrary to the views heretofore held by some.

In addition to the publications already mentioned the following publications by members of the staff appeared during the year.

H. R. Morgan, "Primary Reference Stars for Pluto," *Astr. Papers Amer. Ephemeris*, **11**, Part III; "Report on Astronomical Constants," *Bulletin Astronomique*, **15**, no. 3, 1950.

G. M. Clemence and Hans G. Hertz (with Paul Herget), "Rectangular Coordinates of Ceres, Pallas, Juno, Vesta, 1920–1960," *Astr. Papers Amer. Ephemeris*, **11**, Part IV.

G. M. Clemence, "On Revising the Official System of Astronomical Constants," *Bulletin Astronomique*, **15**, no. 3, 1950; (with Dirk Brouwer) "The Motions of the Five Outer Planets," *Research Reviews*, Dec. 1950, and *Sky and Telescope*, Feb. 1951.

Glen H. Draper, "Elements and Ephemeris of (1566) Icarus," *Minor Planet Circular* 531.

R. L. Duncombe (with M. S. Davis), "General Perturbations and Orbit Correction of (185) Eunike," *A. J.* **55**, 133.

John S. Hall and A. H. Mikesell, "Polarization of Light in the Galaxy as Determined from Observations of 551 Early-type Stars," *Publ. of the U. S. Naval Observatory*, **17**, Part 1, 1950.

F. A. Graf, Captain U. S. Navy,
Superintendent

Warner and Swasey Observatory. Case Institute of Technology, East Cleveland, Ohio.

The activities of the Warner and Swasey Observatory for the year 1950-51 may be summarized as follows:

Galactic Structure. The investigation of changes in the luminosity function with galactic longitude and with distance in the galactic plane is proceeding. During the year region LF4 ($l = 70^\circ$, $b = -3^\circ$) has been completed and results published. In this area the variation of the luminosity function with distance was marked. An excess of stars with M between -1 and $+2$ was found, conforming to the pattern found in other LF regions thus far studied.

The spectral classification of stars in LF5 ($l = 97^\circ$, $b = -1^\circ$) and LF6 ($l = 114^\circ$, $b = +4^\circ$) has been completed as well as the determination of photographic magnitudes and colors. The completion of the study of these two regions will be made as soon as photoelectric measures are made to check the photographically determined sequences.

LF5 contains an unusually large number of main-sequence early-type stars and LF6 many stars of high luminosity of classes B and A.

Catalogues of the spectra, colors, magnitudes, etc., for regions LF 4, 7 and 8 are being prepared. The catalogue for LF2 has been completed during the year. Region LF9 ($l = 182^\circ$, $b = +2^\circ$) is being studied at present.

Intermediate Latitudes. The investigation on the stellar densities in intermediate latitudes is continued. The work on 1LF1 ($l = 45^\circ$, $b = 14^\circ$) is ready for publication and the work for 1LF3 ($l = 50^\circ$, $b = -19^\circ$) will be completed this summer.

Milky Way Survey. As reported last year this project is supported by an Office of Naval Research contract carried out jointly with the Yerkes Observatory with the cooperation of W. W. Morgan. The work for the early-type stars of high luminosity has been completed and a discussion of the material has been presented at the University of Michigan Symposium on Galactic Structure (June 1950). The survey for

supergiants of spectral classes F to M in the same galactic belt was completed this year.

A survey for faint OB stars near and around P Cygni to a limiting photographic magnitude about 12.0 has been completed. The area of 89 square degrees examined includes 135 OB stars already classified in our previous survey of bright stars and in addition 114 fainter OB stars. The determination of photoelectric magnitudes and colors is now in progress. Of the 40 faint stars situated in the Great Rift some have colors on the intermediate scale greater than one magnitude.

Infra-red Survey. The study of the distribution of stars of spectral classes later than M 4.5 in Cygnus and in intermediate galactic latitude at longitude about 40° is approaching completion. The number of such stars at $b = 2^\circ$ is 80 per square degree and at $b = 4^\circ$ is 28. The limiting infra-red magnitude of the survey is 14.

A similar study is being carried out in the Scutum Cloud. An area of 13 square degrees with center at $l = 354^\circ$ and $b = 3.8$ has been examined. Preliminary results show that the average number of stars later than M 4.5 to the limiting infra-red magnitude of about 13.0 is 145 per square degree. The surface distribution of these stars appears non-uniform with a number of regions having more than 300 such stars per square degree.

Instruments. A study of the accuracy of the determination of magnitudes on Schmidt plates with the Eichner iris photometer was made. The probable error of a single determination was found to be ± 0.060 mag. A similar study was made using plates taken with the 100-inch telescope. The probable error in this case was ± 0.032 mag.

During the year a photoelectric photometer of the Kron type was constructed. Mr. John Rogerson, a senior, built the electronic part and Mr. August Hruschka, of the Physics Department, made the mechanical part. It is adapted for use at the Newtonian focus of the Schmidt or with the $9\frac{1}{2}$ -inch equatorial. The performance of the photometer is highly satisfactory.

Publications. Reprints Nos. 42-44 and two notes have been published during the year. All appeared in the *Astrophysical Journal*.

Visitors. Among the visitors and other persons who are carrying on cooperative work with us and have stayed for a period of a few days or more during the year are: