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REPORT OF OBSERVATORIES 1949-1950

Yerkes Observatory. University of Chicago, Williams Bay, Wisconsin.

McDonald Observatory. University of Texas, Fort Davis, Texas.

In January 1950, Mr. Struve informed Chancellor Robert M. Hutchins that he had received an offer from the University of California at Berkeley, that he had decided to accept that offer, and that he therefore wished to resign his position with the University of Chicago as of July 1. The undersigned was appointed the Acting Chairman of the Department in March 1950 in order that the administration of the Department could be continued without interruption.

Personnel. Mr. Phillips resigned effective June 30 to accept a position at the University of California. Mr. Page resigned his position as the Secretary of the Department in December 1949; but he continues his research activities at the Yerkes and McDonald Observatories. Dr. A. B. Meinel was appointed an Instructor and Miss Roman was promoted to the position of a Research Associate. Dr. K. O. Kiepenheuer, Director of the Fraunhofer Institute of Freiburg, came to the Yerkes Observatory in December, 1949 on a contract with the Office of Naval Research to develop methods of measuring the general magnetic field of the sun with the 40-inch telescope. Dr. Meinel spent part of the year at the Yerkes Observatory on a contract with the Office of Naval Research held by the University of California. Dr. Archibald Brown spent his second year as a Commonwealth Fellow at the Yerkes Observatory; he returned to Great Britain at the end of this period. Dr. L. Rosino of the University of Bologna, Italy, held an Assistantship at the Yerkes Observatory; he also spent some time at the McDonald Observatory. Drs. V. Kourganoff and R. Canavaggia of the Institut

d'Astrophysique, Paris, spent some time both at the Yerkes and the McDonald Observatories. Dr. C. F. von Weizsacker, Alexander White Visiting Professor with the Committee on Social Thought at the University, made several visits to Yerkes during the winter of 1950 and gave a very stimulating series of lectures on cosmology. Lectures on related topics were also given by Dr. D. ter Haar during the summer of 1949. Mr. J. Kent from Texas A. and M. College worked as a volunteer assistant on the astrometric program during July and August of 1949. Messrs. C. Gasteyer of the Dearborn Observatory and A. Lukey of Antioch College also served as assistants on the astrometric program. Visitors to the Yerkes Observatory who gave colloquia during the year included Drs. C. T. Elvey, Y. Ohman, O. Heckmann, J. Neyman, V. Kourganoff, R. Canavaggia, W. Iwanowska, R. E. Williamson and C. J. Gorter. The Committee on Publications appointed by the American Astronomical Society met at the Yerkes Observatory in April. The visitors included Drs. Merrill, Mayall, Spitzer and Brouwer.

The following persons held assistantships during the year: Miss J. Ramsey and Messrs. R. Hardie, H. Horak, F. Edmonds, B. Stephenson, T. D. Lee, L. Rosino, W. Fitch and R. Becker. The following students were awarded Ph.D. degrees for graduate work done at the Observatories: K. N. Rao, A. D. Code, D. Harris, F. Edmonds and A. Slettebak; Miss Ramsey was awarded an M.A. degree.

At the invitation of the Belgian Government, Mr. van Biesbroeck spent six months, September 1, 1949-March 1, 1950, in the Belgian Congo exploring the possibilities of setting up an astronomical observatory near the equator. Mr. Struve spent some months at the Lick Observatory as a Morrison Research Associate; he also gave the

retiring Presidential Address to the American Astronomical Society and the George Darwin Lecture before the Royal Astronomical Society. Mr. Struve was awarded the Draper Medal of the National Academy of Sciences. Mr. Kuiper was elected to the National Academy of Sciences. Mr. Chandrasekhar was awarded an Adams Prize by Cambridge University, England.

Equipment. The installation of the 10 $\frac{1}{4}$ -inch Cook Observatory telescope at the McDonald Observatory was completed in 1949. An 800 foot road was built by the Observatory to give access to the site. A new crystal-controlled drive was added. The instrument was sheltered in a square, all metal observing structure provided with a sliding roof. This housing was financed by a grant from the Research Corporation. The 13-inch reflector mentioned in last year's report has been installed at the McDonald Observatory and was used extensively during the winter by several observers. Its quick-setting features make it an especially versatile instrument for photoelectric photometry. Hardie worked out and installed a frequency drive system.

The construction of the coudé spectrograph has been completed under Hiltner's supervision, in the Yerkes Observatory shops. The instrument is equipped with four cameras with focal lengths in the ratios 1, 2, 4 and 8. The dispersive unit is a grating ruled for first order at 8000Å; it will be used in the first order in the red and infra-red and in the second order in the blue and violet. The highest dispersion in the blue is 4.8Å/mm. The entire equipment was transferred to McDonald during the summer of 1950. Hardie assisted in the drafting of the instrument. Hiltner and Code have now published the results they have so far obtained by the photoelectric scanning device which compensates for seeing. Further developments are in progress and a new unit will be attached to the coudé spectrograph.

Strand, Code and Ridell designed a special plate carriage which will fit the parallax camera of the 40-inch telescope, intended for double-star photography. The instrument has automatic timing of exposures and shifts between exposures. The construction is being financed by a grant from the Research Corporation. Kiepenheuer has re-activated the solar laboratory in the attic of the Yerkes Observatory and has installed solar testing equipment in connection with his main program on the 40-inch telescope. Two coelostats feed a 6-inch objective of 63 feet focal length, the same as the 40-inch telescope. A

large solar spectrograph equipped with a 21-foot grating, rotating polarizing devices and a photoelectric photometer was attached to the 40-inch. This instrument will be used for the measurement of solar magnetic fields. Funds for the construction for this equipment were provided in part by the Research Corporation.

SOLAR SYSTEM

Planets and asteroids. Kuiper measured, with his disk meter attached to the 82-inch telescope, the diameters of Mars, Uranus and the asteroids (1), (9), (30) and (97). Through the courtesy of Dr. Bowen, Kuiper was enabled with the assistance of Mr. Humason to measure the diameter of Pluto with his disk meter attached to the 200-inch Hale telescope. Kuiper took an extensive series of photographs of Venus and Mars with the scale 1 mm = 2".

Stephenson made summaries of visual observations of Mercury for a popular publication and observed the lunar eclipse of October 6, 1949 in a search for lunar meteors.

The orbit of Nereid. Kuiper observed Nereid during its second opposition. These observations were extended by van Biesbroeck and gave a period of 364 days. Van Biesbroeck also found that the observations indicate a highly inclined orbit with eccentricity 0.3.

Spectra of planets and satellites. Kuiper took low dispersion ultraviolet spectra of Pluto, Triton, Titan, Mars and the moon in an effort to determine the total number of scattering molecules, or their upper limit, over the surfaces of these bodies. He also found that the CO₂ bands of Venus are strongly variable with phase and with position on the disk: from this Kuiper concludes that the cloud layer on Venus undergoes large changes with height.

At the invitation of the Physical Society of London, Kuiper prepared a report on the subject of "Planetary and Satellite Atmospheres" for publication in their Reports.

Infra-red color indices of rocks. Following Kuiper's comparison between the reddish areas of Mars and that of felsitic rhyolite, Page and Mrs. Page determined the infra-red color indices of 30 igneous rocks and pure minerals with Kuiper's PbS spectrometer. They found a wide range of infra-red color indices, the reflectivity at 1.8 μ being nearly twice that at 0.8 μ . Also, they found that several rocks of very different chemical and geological characteristics show similar colors.

Comet observations. Van Biesbroeck made observations on comets as in past years. In particular he made the first observation of the 1950 return of comet D'Arrest 48 days before perihelion when it was only of the 18th magnitude. With the B spectrograph, Page, Swings and Jose studied the infra-red spectrum of comet Bester.

The theory of the origin of the solar system. Kuiper developed new ideas on the origin of the solar system. A detailed account of Kuiper's theory will be found in a forthcoming book on *Astrophysics* edited by J. A. Hynek and to be published by the McGraw-Hill Book Company.

Solar physics: experimental. Kiepenheuer has built a concave grating spectrograph and photoelectric photometer for measuring small Zeeman displacements in the solar spectrum by transforming them into intensity changes. He accomplishes this by using a rotating $\lambda/2$ or $\lambda/4$ wave plate of mica. A null method can be applied which cancels the line displacement by a calibrated oscillating line shifter. The final spectrograph which will be attached to the 40-inch is nearly completed.

Night sky and aurorae. Meinel made observations with a fast grating spectrograph of the infra-red spectrum of the night sky and aurorae. These observations led him to the discovery and the identification of *OH*. He has shown that new band systems due to *OH* give rise to the most intense emissions in the night sky. Meinel has further determined a temperature of 258°K from an analysis of the rotational structure of the *OH* bands. He found that in some aurorae the λ 8446 *O*I line is enhanced.

STATISTICAL ASTRONOMY: SPECTRAL CLASSIFICATION

Survey of high luminosity stars. Morgan in collaboration with Dr. J. J. Nassau of the Warner and Swasey Observatory carried out a survey for stars of high luminosity. A belt 12° wide centered on the galactic equator was covered by means of objective prism plates for the northern sky between galactic longitudes 335° and 200° to a limiting photographic magnitude of 10. The survey resulted in a catalogue of around 900, O and B stars having absolute magnitudes brighter than -2.5 ; three regions of especial interest were indicated because of the large numbers of high luminosity stars as compared with average regions on the galactic equator; they are the small star cloud in Sagittarius, the region

between γ Cyg and η Cyg and an area centered on the double cluster in Perseus.

Morgan continued his program of the spectroscopic parallaxes of B stars with the 40-inch telescope. He has been able to derive a fairly definite preliminary arrangement in space of B stars in the neighborhood of the sun. He confirmed the existence of a "local cluster" for these objects and finds that this cluster has a diameter of the order of 500 pc. It is inclined to the plane of the galaxy by 20° and has its nodes near galactic longitudes 270° and 90° . Morgan includes the following clusters as its principal members: Scorpius-Centaurus, Orion, the cluster of B stars in Perseus, which have been described by Blaauw, and a probable cluster of B stars in Canis Major. All of these groups are within a limit of approximately 400 pc from the sun. Confirming the ideas of various investigators in this field, Morgan also finds that for the more distant high-luminosity stars there is no indication of a preference for this plane; he concludes that it is highly probable that the clustering is a relatively local one.

As a part of Morgan's program on the spectroscopic absolute magnitudes of the early-type stars, Miss Ramsey completed an investigation of the distances of 224 stars for which interstellar line data have been determined by Dr. W. S. Adams at the Mount Wilson Observatory.

Under Morgan's supervision, Duke observed 300 early-type stars with the 40-inch spectrograph to study the central intensities of the interstellar band at 4430Å. He examined the correlation of these central intensities with distance and with other interstellar parameters such as the color excess and the intensities of the D-lines.

Supergiant stars associated with galactic clusters. Bidelman found that three supergiant stars of types B, G and M are associated with the B-star galactic cluster NGC 2439. The brightest of these is R Pup, a Go Ia star; Bidelman estimates its absolute magnitude as -7.2 . His estimate of the absolute magnitude of the M-type star is -5.6 .

Spectra of RV Tauri and yellow semi-regular variables. Rosino obtained spectrograms of a number of variable stars of the RV Tau and semi-regular types with the 40-inch spectrograph and determined light curves for the same stars with the 6-inch UV camera. He found that two definite groups of stars can be distinguished from the behavior of the hydrogen lines and the presence of bands of *TiO* at minimum light. The star

AC Her is peculiar in that it appears to be a carbon star.

Rosino derived a period-luminosity relationship for the following types of variables: (1) W Virginis Cepheids, (2) RV Tauri variables and (3) semi-regular variables.

Spectral classification. Page obtained with the B spectrograph a fairly complete selection of standard spectral types covering a wide range of temperature and absolute magnitudes; the object of this investigation is to extend the Yerkes system of spectral classification to spectra of faint objects taken with this spectrograph.

Spectral types and space motions of late F and G-type stars. Miss Roman found that when the space motions of some late F- and G-type stars, which have lines which are systematically weaker than those in other stars of the same type and luminosity, are corrected for the usual solar motion, their velocity distribution is very different from that of the stars showing the lines with normal strength. More particularly, she found that the frequency distribution of the speeds of the stars with the stronger lines shows a definite maximum between 10 and 20 km/sec with a steady drop toward higher velocities and that no star in this group has a velocity higher than 70 km/sec. On the other hand, she found that the speeds of stars with the weaker lines show a broad frequency maximum between 20 and 50 km/sec as well as values exceeding 90 km/sec.

Stellar rotation. Under Morgan's supervision, Slettebak completed his investigation on the axial rotation of the brighter O and B stars. The principal result of this study is a catalogue of the rotational velocities of about 120 Be stars.

Moving cluster in Perseus. Morgan and Miss Roman investigated the reality of the Eddington moving cluster in Perseus and found definite evidence for the reality of the visible clustering of B stars in the neighborhood of α Per. They found that 25 stars of types B3-A2 including the supergiant α Per belong to this moving cluster which is estimated to be at a distance of 180 pc from the sun.

The colors and magnitudes of stars in globular clusters. Brown obtained material for a study of the colors and magnitudes of stars in the globular clusters M 13 and 15. The measurements were made on direct photographs with the Ross photometer at the Yerkes Observatory, the photometer readings having been calibrated with the photoelectric magnitudes he had determined for a sequence of stars in the field of each

cluster. With the proper motions determined from plates taken earlier with the 40-inch telescope, Brown was able to separate the foreground stars from the cluster members.

Variables in globular cluster. By blinking a few plates of the globular cluster M 15 taken by Archibald Brown, Rosino discovered 28 variables probably of the RR Lyrae-type and one long period Cepheid.

STATISTICAL ASTRONOMY: ASTROMETRY

Strand, Hall, Stephenson and Edmonds participated full time in the astrometric program. Duke, Gasteyer and Lukey participated part time. Strand was in charge of the program throughout the year.

Parallaxes. During the year 529 parallax plates were obtained mainly of late M dwarf-type stars and stars for which accurate absolute-magnitude criteria had not been established. Parallaxes have been measured for 25 stars and will be published soon.

Proper motions. There were 141 first epoch plates taken of stars with proper motions larger than $0''.30$ per annum and requiring more accurate determinations. This program also includes some U Gem stars.

Mass-ratios. On the mass-ratio program 197 plates were obtained. Kent measured the mass-ratio for 48 Cas and Duke completed the measurements of ζ Cnc.

Double stars. During the year 19 plates with approximately 70 exposures each were taken. The program consists mostly of pairs with separations between $2''$ and $3''.5$, requiring good seeing.

Double star measures. Van Biesbroeck continued his measures on double stars with the 40-inch and with the 82-inch telescopes.

Miscellaneous studies. Hall completed his investigation of the photographic blending of adjacent images from laboratory experiments in an effort to find the proper corrections in determinations of mass-ratios.

The determination of the convergent point of moving clusters. Brown developed a method based on Fisher's method of maximum likelihood for determining the convergent point of moving clusters. Brown's discussion departs from earlier heuristic approaches in that he bases his method on the true distribution of $\cot \theta$, where θ denotes the position angle of the proper motion.

OBSERVATIONAL ASTROPHYSICS

Eclipsing variables. Struve investigated the properties of eclipsing variables having short periods with a view to answering the question whether there exist binary systems of which one component is a normal B or A star, while the companion may be a very small and dense object somewhat related to the white dwarfs. For this purpose, while he was a Morrison Research Associate at the Lick Observatory, he studied particularly the work done by W. F. Meyer on β CMa. While a number of new facts came to light out of this study, it was not possible to identify this system and others like it, with the hypothetical binary system described.

With the assistance of Horak, Struve measured the radial velocities of several spectroscopic binaries including W UMa, YY Gem and RZ Cas.

Spectra of close binaries. Struve investigated the spectrum of U Sge in which the hydrogen lines are unsymmetrical to a very pronounced extent. He interprets this asymmetry as due to the combined effect of rotation and Stark effect.

Velocity curve of eclipsing binaries. Hiltner and Hardie obtained the velocity curve of RW Tau. They found asymmetries in H lines close to the eclipse similar to those found in U Cep.

Hardie also examined the spectra of U Cep with a view to learning the causes underlying the distortion of the velocity curve. He found that if the radial velocity measurements were adjusted to correspond to the position of the center of the wings of the H lines instead of the cores, the resulting velocity curves appeared to be better representations of the true binary motion.

Wolf-Rayet stars. Hiltner has studied the light curve of CQ Cep photoelectrically in the radiation of $He\ II\ \lambda\ 4686$ only. He found that the emission shows a variation of 0.3 mag. and that it is brightest at conjunctions. Hiltner also found a similar variation in the Wolf-Rayet binary HD 211853.

Münch made spectroscopic observations of the WR system V444 Cyg and established that the emission and the absorption features of the Wolf-Rayet spectrum are subject to periodic variations and also erratic fluctuations in intensity. He found that the violet absorption edges are in general stronger when the absorption component is in eclipse and, moreover, that at these phases some emission lines develop a violet displaced absorption not visible outside of eclipse.

These observations of the intensity changes of the emission lines have established definite departures from a pure recombination spectrum. Münch has further detected the effects of scattering of the radiation from the O star by free electrons in the WR envelope in the change suffered by the spectrum of the O star when it is eclipsed. He has also made an attempt to account for the observed features in terms of a model for the WR envelope, characterized essentially by the increasing state of ionization with increasing distance from the parent nucleus.

Peculiar stars. Bidelman discussed the shell spectrum of HR 7415 and published his study of the apparently hydrogen-poor star HD 30353. Bidelman found that the spectrum of KN Cas is similar to that of HR 2902 but with somewhat weaker lines of H and $Fe\ II$ in emission. He also found that the 7th magnitude star HD 106223 shows the spectroscopic characteristics of the A-type subdwarfs. Miss Roman found that HDE 227611 shows strong emission lines of $Fe\ II$. Struve found that the spectrum of Pleione was greatly changed since 1949 and that the lines produced in the shell have become much weaker while the state of ionization has increased. Bidelman studied the spectrum of the very cool star GP Ori; he suggests that this star, as well as other stars of class S, may have an intermediate carbon abundance.

Peculiar carbon stars. Bidelman discovered several K-type stars which appear to be intermediate in carbon content between ordinary stars and the carbon stars. He found that the spectra of these objects show bands of CH , CN and C_2 which are stronger than in normal K-type stars but considerably weaker than in the regular carbon stars. He also found that these stars show very strong resonance lines of $Ba\ II$. HR 774 is typical of these stars.

Planetary nebulae. Together with Wurm, Page has used the photometric data he had obtained on various planetary nebulae, to derive the nuclear temperatures from the Balmer continuum. With the polarimeter, Page tried to detect polarization in these objects; but the observation proved difficult and inconclusive. Page has also obtained calibrated spectra of various planetary nebulae, the Pleiades nebula and other nebulae of low surface brightness.

Spectra of extragalactic nebulae. Page continued his investigation of the spectra of extragalactic nebulae with his B spectrograph. This spectrograph gives excellent definition from

3600Å to 6700Å or over a 3000-Å interval in the infra-red, at a dispersion of approximately 330 Å/mm. During the current year he took the spectra of 37 additional faint nebulae making a total of over 100 spectra of 47 different objects. Page finds emission lines of OII (λ 3727) and/or $H\alpha$ (λ 6563) with intensities of the order of one to three per cent of the total integrated light of the nebula; they have an equivalent width corresponding to 90Å. From his measurements of the differential radial velocities in the double systems, Page estimates that the average mass of these systems must be less than 10^{10} solar masses.

Interstellar polarization. Hiltner has continued the observations on interstellar polarization the discovery of which was reported last year. In addition to collecting data on a large number of stars, Hiltner found that the degree of polarization is sensibly constant over the range 4100Å–8000Å.

Photoelectric photometry. Hiltner, Struve and Jose observed the light curve of UX Mon in November, 1949.

LABORATORY INVESTIGATIONS

Molecular spectroscopy: Phillips completed the rotational analysis of the TiO bands at λ 8859 and λ 5597 and found that the two bands have a lower electronic state in common and that they represent ${}^1\Pi - {}^1\Delta$ and ${}^1\Phi - {}^1\Delta$ transitions. The molecular constants for the two states were determined from the rotational analysis.

Phillips investigated the C_2 band at λ 3670 and showed that the lower state is the $v'' = 6$ vibrational level of the ${}^1\Pi_u$ state; this is the lower state of the ${}^1\Pi_g - {}^1\Pi_u$ Deslandres-d'Azambuja system. He concludes from his discussion that the ${}^1\Pi_g$ state must undergo a strong vibrational perturbation and that the dissociation energy derived by Herzberg for ${}^1\Pi_g$ state based on a Birge-Sponer extrapolation cannot be valid.

In order to make a rotational analysis of the γ -system (${}^3\Sigma - {}^3\Pi$) of the TiO molecule, Phillips photographed the spectrum in the regions λ 6651, λ 7054 and λ 7590 in the second order with the 21-foot grating spectrograph. All the lines, about 4600 in all, have been measured and the reduction and the analysis have been nearly completed.

With the aid of a contract with the Office of Naval Research, Phillips constructed an electric furnace on the design of Brewer, Gilles and Jenkins at the University of California. It was com-

pleted in February. By heating TiO_2 with this furnace, Phillips has taken emission spectra of TiO with the infra-red grating spectrograph in the first order. The entire spectrum from λ 4500 to λ 9000 was photographed in sections. Using three temperatures, 1900°C, 2100°C and 2300°C, Phillips has taken over 500 plates all of which are calibrated. Using the same apparatus, Phillips has also been able to obtain the spectrum of ZrO in emission at a temperature of 2400°C.

From a preliminary comparison of the laboratory spectrum of TiO in the region λ 7054 with that found in absorption in the M-type stars, Phillips finds that the two sources produce very different band structures.

THEORETICAL ASTROPHYSICS

Radiative transfer. Chandrasekhar's book *Radiative Transfer* was published by the Clarendon Press, Oxford, in the International Series of Monographs on Physics.

Edmonds studied the following problems in the theory of radiative transfer: (1) the diffusion of imprisoned resonance radiation and the interpretation of the experimental data on the mercury line at λ 2537, (2) the scattering by a moving electron atmosphere and its effect on spectral lines both under the conditions of Schuster's problem and under the conditions of the planetary nebula problem. In these latter investigations, Edmonds solved the first examples of a transfer problem in which the effects both of non-coherence and of differential expansion are taken into account.

Horak applied Chandrasekhar's theory of diffuse reflection to interpret the existing data on planetary illumination. He determined the albedos for single scattering in the atmospheres of the various planets from their total brightness, their dependence on phase. He also made comparisons between the observed and the predicted laws of limb darkening for various assumed phase functions.

The theory of turbulence. Chandrasekhar worked out a theory of axisymmetric turbulence and developed for this purpose a new theory of axisymmetric tensors and forms. The decay of axisymmetric turbulence was studied. He also investigated the nature of turbulence in a highly conducting medium with a view to examining the partition of energy between the kinetic and the magnetic energies.

By analyzing the data on the decay of vorticity, Lee determined the arbitrary constant κ