

SCIENCE

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THE UNITED STATES NAVAL OBSERVATORY.

ALTHOUGH much interest was shown by individuals in the science of astronomy in the early history of our country, this interest did not culminate in the founding of any astronomical observatories until the third and fourth decades of the present century. About 1835 Professors Olmsted and Loomis observed Halley's comet with a five-inch telescope placed in the steeple of one of the buildings of Yale College at New Haven, Connecticut, but the observatory erected by Professor Albert Hopkins of Williams College, in 1836, was probably the earliest establishment of the kind in the United States. It was 48 feet long by 20 in breadth, and consisted of a central apartment surmounted by a revolving dome and flanked by two wings. The dome contained an equatorially mounted Herschelian telescope of 10-feet focus, and a 3.5-inch transit instrument was set up in one of the wings. Only two years later Professor Loomis built a small observatory at Hudson, Ohio, and furnished it with a 4-inch equatorial telescope and a 2.7-inch transit circle. The longitude and latitude of this observatory was determined by Professor Loomis, and he observed five comets and sixteen occultations in the brief intervals of leisure left from his regular class work in the Western Reserve College. Another indication of the zeal of individuals in the advancement of science by actual astro-

nomical observation is shown by a paper published in the 'Transactions' of the American Philosophical Society, New Series, Vol. VII., pp. 165-213, detailing observations of nebulae made by H. L. Smith and E. P. Mason at New Haven, Connecticut, with a 12-inch reflector. This memoir contains carefully executed plates of several nebulae, on which the stars are accurately plotted.

Among those in our country who repeatedly urged the foundation of an astronomical observatory in the United States was John Quincy Adams. While Secretary of State, as early as 1823, he offered personally to contribute \$1,000 towards the establishment of an astronomical observatory in connection with Harvard College, provided the requisite amount for completing the work should be raised within two years, but this effort failed. In 1825, in his first message to Congress after becoming President of the United States, he made recommendations for the establishment of a national observatory, a uniform standard of weights and measures, a naval academy, a nautical almanac and a national university. Party rancor prevented the carrying-out of any of these far-reaching plans at that time, but all of them, except that of a national university, were executed by our government at a later date. It was some years after this notable message of President Adams before Emperor Nicholas, of Russia, entered upon the preliminary steps which culminated in the creation of the celebrated Pulkowa Observatory.

Even after leaving the Presidential chair, President Adams never once relaxed his efforts towards the founding of a national observatory. In 1838 our Minister to England announced that he had received the money bequeathed to the American people by James Smithson for the increase and diffusion of knowledge among men. Mr. Adams immediately urged that this fund should be devoted to the founding of an

astronomical observatory and a nautical almanac, and, as chairman of the select committee on the Smithson fund, he advocated that plan on three different occasions between 1838 and 1842. It is interesting to note that Senator Preston, of South Carolina, violently opposed these recommendations of Mr. Adams, but that in 1842 Mr. Preston gave the weight of his influence in favor of the bill which finally created a national observatory under the name of 'A Depot of Charts and Instruments of the Navy of the United States.' Let us trace the circumstances leading up to this event.

In 1830, under orders from the Navy Department, Lieutenant Goldsborough established a depot of charts and instruments in the western part of the City of Washington, in the square bounded by 24th and 25th Streets, Pennsylvania Avenue and K Street Northwest. Here, in a small circular building, on a brick pier with a foundation 20 feet below the surface, he mounted a 30-inch transit instrument made by R. Patten, of New York City. Goldsborough was succeeded in 1833 by Lieutenant Wilkes, who removed the depot to a site on Capitol Hill, on the west side of North Capitol Street, between B and C Streets north, about 1,200 feet, north, 5° west, from the center of the Capitol. The dimensions of the small observatory erected by Lieutenant Wilkes were 14 feet by 13 feet, and 10 feet from the floor to the eaves, and its outfit was as follows: A transit instrument of $3\frac{3}{4}$ inches' aperture and 63 inches' focal length, made by Troughton under Hassler's direction for the U. S. Coast Survey in 1815, which was loaned to the Navy Department and mounted on massive piers. A Borda's circle presented by Troughton to Mr. Hassler in 1815; a $3\frac{1}{2}$ -foot achromatic portable telescope by Jones; a portable transit instrument made by Richard Patten, and a sidereal clock. The Patten transit instrument had previously been

mounted by Lieutenant Goldsborough in the depot of charts and instruments established by him, and was now mounted near the south door of the observatory for the use of the assistants. The sidereal clock was bolted to the western pier of the Troughton transit instrument, but it never performed satisfactorily.

On assuming command of the United States Exploring Expedition, in 1838, Lieutenant Wilkes turned over the direction of this observatory to Lieutenant J. M. Gilliss. To perfect and complete the instrumental outfit Gilliss was permitted by the Navy Department to order the following instruments: From Parkinson and Frodsham, of London, a sidereal clock and a meantime clock; from Ertel and Son, of Munich, a meridian circle of 4.5 inches' aperture, furnished with circles 30 inches' in diameter, one of which was graduated to three minutes; from William Simms a portable achromatic telescope of $3\frac{1}{4}$ inches' aperture and 42 inches' focal length. On the parapet of the Capitol building a south meridian mark was made, which was viewed by reducing the aperture of the transit instrument to 0.9 inch, and at a distance of 2,302 yards a north mark was erected, which could be viewed with the full aperture of the transit instrument. The north mark consisted of an obelisk of sandstone 18 feet high and 14 inches square at the top, having painted on its south face five black lines, three inches apart.

Up to 1838 the work at the 'Depot of Charts and Instruments' consisted of such astronomical observations as were needed for the rating of chronometers. In the beginning of that year instructions, prepared by Lieutenant Charles Wilkes, were transmitted through the Navy Department to Lieutenant Gilliss, directing him to cooperate with the United States Exploring Expedition during the years 1838 to 1842 by systematically observing the following

named objects: (1) The Moon and moon-culminating stars. (2) Falling stars, particularly the periodic ones in November. (3) All eclipses of the Sun and Moon. (4) Eclipses of Jupiter's satellites. (5) Occultations of the larger stars. In addition to the work required by these instructions Lieutenant Gilliss determined the right ascensions of 1,248 stars, which were reduced to the epoch January 1, 1840, compared with the right ascensions of the British Association Catalogue and published in 1846 in an 8vo. volume of astronomical observations containing xxv+671 pages. During the years 1840 to 1842 Gilliss also made at the 'Depot of Charts and Instruments,' a fine series of magnetic observations, which were published in 1845 in an 8vo. volume of xxviii+648 pages.

The facilities for scientific work at the little observatory on Capitol Hill were very limited, but Gilliss used them most assiduously. He endeavored by actual achievement to demonstrate to the Navy Department and to Congress the desirability of providing an observatory especially equipped for executing the most refined astronomical work, and in this he was successful. On the 15th of March, 1842, the House Committee on Naval Affairs reported to the House of Representatives a bill 'to authorize the construction of a Depot for Charts and Instruments of the Navy of the United States,' together with a written report which stated at some length that the present 'Depot' and its observatory are inadequate for the purposes intended, and are unsafe for the protection of the valuable instruments; that we are indebted to other nations for the data which enable our vessels to cross the ocean; that an observatory is absolutely essential to the performance of the duties which devolve upon the 'Depot;' that the existing observatory was erected at private expense, and that facilities should be provided for the execution of magnetic

observations. The wording of the bill which accompanied the report and became a law August 31, 1842, was as follows:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled: That the Secretary of the Navy be and he is hereby authorized to contract for the building of a suitable house for a depot of charts and instruments of the Navy of the United States on a plan not exceeding in cost the sum of twenty-five thousand dollars.

"And be it further enacted: That the sum of ten thousand dollars be and is hereby appropriated of any money in the Treasury not otherwise appropriated towards carrying this law into effect.

"And be it further enacted: That the said establishment may be located on any portion of the public land in the District of Columbia which the President of the United States may deem suited to the purpose."

The Secretary of the Navy immediately placed the preparation of the plans for the new observatory in the hands of Lieutenant Gilliss, who, after consulting with astronomers in America, visited Europe to obtain the views of those competent to advise in these matters. In March, 1843, he returned home, having ordered the instruments under authority from the Secretary of the Navy. Only eighteen months were consumed in the erection of the buildings, the mounting of the instruments and the procuring of a library, and on the 7th of February, 1845, Gilliss presented a detailed report of his labors (Senate Document, No. 114, 28th Congress, 2d session, Vol. VII.) which contains a careful description of the buildings and instruments, illustrated by accurate drawings. The site selected for the building was a reservation between 23d and 25th Streets west, extending from E Street north to the Potomac river. The area of the plot was 17.85 acres. The elevation of the ground on the building site was about 100 feet above the Potomac. Gilliss stated that the new equipment was as follows: 1st, an achromatic equatorial telescope by Merz and Mahler, Munich, of 9.6 inches' aperture. 2d, a meridian transit instrument of 5½

inches' aperture by Ertel, of Munich. 3d, a prime vertical transit instrument of 4.9 inches' aperture by Pistor and Martins, Berlin. 4th, a mural circle by Troughton and Simms, London, with a telescope of 4.1 inches' aperture, and a circle 5 feet in diameter divided to 5' and read by six micrometer microscopes. 5th, a comet seeker of 4 inches' aperture by Utzschneider and Fraunhofer, Munich. 6th, magnetic instruments. 7th, meteorological instruments. 8th, books. In addition to those items purchased, there belonged to the 'Depot of Charts and Instruments' a portable transit and two clocks, purchased by Lieutenant Wilkes for the Exploring Expedition, and a 30-inch transit circle and two clocks ordered by Gilliss for the 'Depot.'

At the close of September, 1844, Gilliss reported the observatory completed, with the instruments mounted and ready for use. On the 1st of October, 1844, Lieutenant M. F. Maury was ordered to take charge of the institution, and directed to remove to it all the nautical books, charts and instruments of the then-existing depot.

In reviewing the history of the Naval Observatory during Maury's administration, we shall first notice the instrumental equipment, in the selection of which it is probable that Gilliss was principally influenced by English advisers. Instrumental construction was just then passing through a critical period. The Observatory of Pulkowa, which was completed in 1838, following the German school of construction, rejected the mural circle, and supplied its place with the celebrated Ertel vertical circle. An Ertel transit instrument and a Repsold meridian circle completed the outfit of Pulkowa for meridian work, and these instruments were amply provided with horizontal collimators and azimuth marks distant 550 feet, which were rendered visible by the interposition of lenses of corresponding focal length. In contrast with this, the Naval

Observatory followed English precedent, and was supplied with a mural circle which remained its principal declination instrument until 1865. The remaining equipment was the Ertel transit instrument, of first-class construction, but without horizontal collimators and azimuth marks; the small Ertel meridian circle, which had been ordered by Gilliss for the Observatory on Capitol Hill; the Pistor and Martins prime-vertical transit instrument, identical in design with the similar instrument at Pulkowa; and the Merz and Mahler equatorial refracting telescope. The Ertel meridian circle showed such serious defects of construction that it was subsequently sold, and the Merz and Mahler equatorial was much smaller than the refractors at Pulkowa and Harvard College Observatories, one of which was erected a little before and the other a little after that at the Naval Observatory. It may also be mentioned that instead of making the walls of its observing rooms of brick, the Naval Observatory might advantageously have followed the example of Pulkowa by making them of wood, the use of sheet metal for such purposes being then unknown.

Now, for a passing glance at the personnel of the astronomical corps, which was composed of three more or less distinct classes, namely, line officers and staff officers of the United States Navy and civilians. After years of persistent labor, Gilliss had created an astronomical observatory only to have it snatched from his grasp when it was ready for work. Lieutenant Matthew F. Maury, who was ordered to take charge of the new 'Depot of Charts and Instruments' as its Superintendent on October 1, 1844, was then thirty-eight years old. He was possessed of great energy, together with a high degree of native ability, and was well versed in naval affairs, but was very scantily informed in regard to the great advances in astronomical science

which had recently been made in Europe. From the line of the navy three lieutenants and six midshipmen were detailed as his assistants. These gentlemen entered upon their work with energy, but their tour of duty was so limited by the rules of the Navy Department that they were obliged to return to their nautical work when they had barely familiarized themselves with their astronomical duties. Among their names will be recognized many who at a later date attained distinction during the Civil War. To these line officers were added Professors of Mathematics Coffin, Keith and Hubbard, who were staff officers in the Navy. The corps of Professors of Mathematics in the United States Navy was originally created to supply instructors for midshipmen afloat and ashore, and all of them served in that capacity, until the founding of the Naval Academy in 1845 closed their seafaring career and gave the Navy Department an opportunity to utilize a part of the corps in other duties. Professor Coffin had instructed midshipmen on shipboard for some half dozen years before he was ordered to assist Lieutenant Gilliss in 1843 in fitting up the new Observatory. Hubbard, a recent graduate of Yale College, was appointed Professor of Mathematics, U. S. N., in 1845, and was immediately ordered to the Observatory. Keith, who had just graduated from Middlebury College, Vt., received his appointment as Professor of Mathematics, U. S. N., in 1847. These gentlemen were each possessed of a high degree of mathematical ability and were destined to leave a lasting impress on the work of the Observatory. At that time the only civil appointee attached to the Observatory was Mr. Sears Cook Walker, who was employed as a computer and observer. He was one of the ablest, and certainly the most experienced, of the corps of astronomers, but unfortunate differences with

Lieutenant Maury led to his resignation after a service of only fourteen months. In 1848 Mr. James Ferguson received the civilian appointment of Assistant Observer, and later that of Assistant Astronomer. He proved an indefatigable observer, and the records of the Observatory show a vast amount of valuable and painstaking work with the equatorial by him. In 1851 Professor Yarnall, U.S.N., was ordered to the Observatory, and in the most untiring and conscientious manner he made substantially all the observations obtained with the mural circle and the Ertel transit instrument during the decade from 1850 to 1860. Professor Keith withdrew from the Observatory in 1853, and Professor Coffin was obliged to give up astronomical observing in 1850 on account of an affection of his eyes.

The work of the Observatory as published during Maury's administration is contained in the following volumes: The Observations for 1845, published in 1846; the Observations for 1846, published in 1851; the observations for 1847, published in 1853; the observations for 1848, published in 1856; the observations for 1849-1850 (one volume), published in 1859. It is worth noting that in the published volumes from 1845 to 1848 inclusive the institution is designated as the National Observatory, but on December 12, 1854, the Hon. J. C. Dobbins, Secretary of the Navy, directed that its official designation should be 'The United States Naval Observatory and Hydrographical Office,' and accordingly all subsequent volumes have been issued as the work of the United States Naval Observatory.

The scheme of work arranged by Maury was as follows: To observe regularly in the meridian the positions of the Sun, Moon, planets and moon-culminating stars; to observe α Lyrae regularly with the prime vertical transit, to determine with that instrument the declinations of a catalogue of zenith stars, and to review the Dorpat

Catalogue of double stars with the equatorial telescope.

The meridian observations of the Sun, Moon and planets were commenced in 1845 with some degree of ardor, and kept up with decreasing persistency for several years, but after 1850 only a few scattering observations occur in the published records. The prime vertical transit was also employed for a few years, but soon after 1850 it fell into disuse.

The equatorial was used continuously during the entire period from 1845 to 1861. Assistant Astronomer Ferguson had charge of it during a large portion of this time, and the records show an unbroken series of carefully executed observations of comets, minor planets and occultations of stars by the Moon. The assiduity of Ferguson is attested by his discovery of three minor planets, viz: Euphrosyne, No. 31, on September 1, 1854; Virginia, No. 50, on October 4, 1857; Echo, No. 60, on September 14, 1860.

It would be an act of injustice to pass by unmentioned the numerous items of personal work which enrich the published records. In them we find Coffin's refraction tables founded on Bessel; tables for aiding in the reduction of the apparent places of stars to mean places, by Coffin, Keith and Hubbard; an investigation of the latitude of the observatory and a discussion of the errors of standard thermometers, by S. C. Walker; and last, but not least, we must mention S. C. Walker's discovery, on February 4, 1847, that certain stars observed by Lalande at Paris on May 8 and 10, 1795, were the recently discovered planet Neptune; thus extending the observations of that planet over an interval of fifty years, and thereby making the determination of its elements much more precise.

By far the most ambitious task which Maury set for the new observatory was detailed in his letter to George Bancroft, Sec-

retary of the Navy, July 28, 1846. Speaking of the regular work upon the Sun, Moon and planets, he adds: "A regular series of observations is continued on these objects and the time which is not occupied in the round with them has, with your approval, been devoted to cataloguing; to this end a regular and systematic exploration of the whole heavens from 45° south has been commenced, with the intention of penetrating with the telescope every point of space from that parallel of declination up to the north pole, and of assigning position to every star, down to the 10th magnitude, that shall pass through the field of view." The amount of labor involved in this colossal undertaking was entirely beyond the capacity of any one observatory to accomplish in a generation. Maury would never have undertaken it if he had possessed an intimate knowledge of the herculean labor in respect to observation and computation which its execution demanded. The result was that the observation of the zones was continued with some degree of energy through the years 1846, '47, '48 and '49 with the transit instrument, the mural circle and the meridian circle, by some eleven different observers, two of whom were experienced, and the remainder quite inexperienced. The number of observations accumulated un-reduced in these four years was fully 38,000. Maury did not publish any results until 1860, when he issued the meridian circle zones observed in 1846, containing about 4,000 observations. The publication of the remaining zone work was delayed until 1873, when it was printed under the supervision of Professor Asaph Hall, who remarks: "On account of the inexperience of some of the observers and the lack of good organization these observations contain many errors, and the whole work needs a careful revision." To furnish material for this revision, four hundred and fifteen zero stars were selected by Professor Hall from

the zones, and their places have since been determined, but as yet the revision has not been accomplished. In contrast with this we may recall that during the decade 1850 to 1860 Argelander, of the Bonn Observatory, in accordance with a carefully conceived plan, observed and published the approximate positions of more than 450,000 stars of the first nine magnitudes between 23° of south declination and the north pole of the heavens. Maury failed because his scheme was entirely too herculean to be accomplished with the means at his command, while Argelander achieved success by bringing the scope and precision of his work within the limits possible of execution.

A review of this period would be incomplete without a reference to the invention of the chronographic method of registering star transits and the general application of electro-magnetism to the transmission of time signals for the determination of differences of longitude. Soon after the invention of the telegraph several persons at about the same time conceived the idea of applying its fundamental principles to the transmission of clock signals and the registering of star transits. Among them were Walker, Bache, Bond, Mitchell, Saxton and Locke. Lieutenant Maury became interested in the labors of the last-named gentleman, and induced Congress to appropriate \$10,000 on March 3, 1849, to pay Dr. Locke, of Cincinnati, for the construction and use at the National Observatory of a magnetic clock, a fillet chronograph and a cylinder chronograph. These instruments, although not perfect in details, embraced the essential features of the chronographs in actual use at the present time.

We come now to the third period of the history of the Observatory—namely, from Maury's resignation to the removal to the new site. On April 20, 1861, Maury suddenly resigned his commission and went south to join the Rebellion, and on April

23 Commander J. M. Gilliss, who had built the Observatory some sixteen years before, was ordered to assume charge. For ten years previous to his withdrawal Maury had ceased to have an active interest in astronomical work, and had been wholly absorbed in hydrographic studies. Upon the accession of Gilliss new life was immediately infused into the institution. He resumed meridian observations of the Sun, Moon and planets, which had been practically suspended, and made it one of his first tasks to press the completion of all the unfinished work, which had been accumulating since 1852. At the same time he carried on with equal zeal the nautical work of the Observatory, which the Civil War, then just beginning, had very largely increased.

Until June 21, 1866, when the Hydrographic Office was created, an important part of the duties of the Naval Observatory had been to care for and issue to the Navy all charts, sailing directions, compasses, chronometers, sextants, spy-glasses and other nautical instruments. At the date above mentioned the care of all this material, except chronometers, was transferred from the Observatory, but most of it was returned in 1883, and since then the Observatory has had charge of all nautical instruments of the Navy, except charts and compasses. Since January 1, 1884, all chronometers have been regularly subjected to a temperature test ranging from 45° to 95° Fahrenheit.

* During the Civil War, from 1861 to 1865, the duties devolving on the Observatory, in connection with the inspection and issue of all varieties of nautical instruments, were especially arduous, and the constant attention of a number of officers was required to supply each of our several hundred war vessels with their needed outfits.

Since August, 1865, in accordance with a plan originated by Professor Harkness, the Naval Observatory has transmitted time

signals daily, except Sundays and holidays, over the telegraph lines running into the chronometer room. Up to the latter part of the year 1879 these signals were transmitted by hand, but since that date they have been sent by an automatic apparatus in connection with the transmitting clock devised by Professor J. R. Eastman. Time balls in a large number of the principal cities of the country are dropped by them.

In 1862 Congress authorized the appointment of three civilians, called aids, to assist in meeting the increased demands on the Observatory on account of the war. Some of the changes in the personnel during this period were as follows :

Simon Newcomb was appointed Professor of Mathematics, U. S. N., in 1861; Asaph Hall, William Harkness and J. R. Eastman received appointments as aids in 1862. Hall and Harkness were promoted in 1863, and Eastman in 1865, to be Professors of Mathematics, U. S. N. In 1863 the Observatory lost by death the gifted Professor Hubbard, whose labors had been restricted for years by a frail body.

The later additions to the personnel were as follows: Edgar Frisby was appointed Assistant Astronomer in 1868; A. N. Skinner in 1870 and H. M. Paul in 1875. Frisby was promoted to be Professor of Mathematics, U. S. N., in 1878, on the retirement of Professor Yarnall.

Soon after Gilliss' accession to the superintendency it became apparent that in order to meet the demands of science the Observatory needed a first-class meridian circle, and he took steps to remedy this defect in its equipment. The result was the sale of the small Ertel meridian circle, and the mounting in 1865 of a Pistor and Martins meridian circle 8.52 inches' aperture. The Ertel transit instrument was moved to the east wing and the new meridian circle took its place in the west wing.

In 1873 the Observatory received the

great 26-inch equatorial refractor by Alvan Clark & Sons, which was then the largest telescope in the world.

A continuous series of Sun, Moon and planet meridian observations was carried on from 1861 to 1865 with the mural circle and the transit instrument. In the beginning of 1866 the new Pistor and Martins meridian circle was put in service, and observations were made with it in the old west transit room until 1869, June 5. It was then removed to the new transit room, where it was used from February 2 to August 15, 1870, when observations were suspended for some repairs on the instrument. They were resumed in 1871, August 1, and then continued until 1891, June 28, when the instrument was dismounted for removal to the new Observatory. In connection with the Sun, Moon and planet observations, there were made on this instrument extensive determinations of the positions of the Ephemeris stars and of large numbers of miscellaneous stars. When the mural circle and transit instrument were relieved of the planet work, Professor Yarnall devoted them to the completion of the determination of the positions of all miscellaneous stars which had been observed with them since 1845. These collected observations form Yarnall's catalogue, which was published later. The equatorials were assiduously employed on the observation of asteroids, comets, occultations, double stars, satellites, and other work for which they were especially adapted.

The annual volumes of observations were published regularly from 1861 to 1890, and the principal memoirs and researches of greater or less extent appearing in them during this period are as follows:

The solar parallax; from equatorial observations of Mars, 8.8415'' by Professor Hall, Washington Observatory 1863, p. XI; from meridian observations of Mars, 8.8310'' by Assistant Astronomer Ferguson, Washington Observations, 1863, p. XI.

Discussion of the solar parallax by all known methods, 8.848'' by Professor Newcomb, Washington Observations, 1865, App. II.

A catalogue of the positions of 151 stars in Præsepe by Professor Hall, Washington Observations, 1867, App. IV.

Reports on the solar eclipse of 1869, August 7; Washington Observations, 1867, App. I.

Reports on the solar eclipse of 1870, December 22; Washington Observations, 1869, App. I.

Reports on the solar eclipse of 1873, July 29; Washington Observations, 1876, App. III.

Reports on the solar eclipse of 1880, January 11; Washington Observations, 1876, App. III.

The following embrace all of Hall's double-star work with the 26-inch equatorial; Washington Observations, 1876, App. IV., and Washington Observations, 1888, App. I.

The time of rotation of Saturn on its axis was determined by Professor Hall by means of an equatorial spot which was visible from 1876, December 7, to 1877, January 2. The period deduced was $10^h 14^m 23.8^s$ mean solar time. The paper may be found in the *Astronomische Nachrichten* No. 2146.

On the right ascensions of the equatorial fundamental stars, by Professor Newcomb, Washington Observations, 1870, App. III.

Researches on the motion of the Moon, by Professor Newcomb, Washington Observations, 1875, App. II.

The Uranian and Neptunian systems, Professor Newcomb, Washington Observations, 1873, App. I.

The central parts of the nebula of Orion, Professor Holden, Washington Observations, 1878, App. I.

A catalogue of 10,964 stars from observations on the mural circle and transit instrument, by Professor Yarnall, revised edition by Professor Frisby, Washington Observations, 1884, App. I.

A catalogue of 1963 stars observed by Gilliss, at Santiago, Chili, edited by Professor Harkness, 1868, App. I.

Observations and orbits of the satellites of Mars, Washington 1878. This memoir is bound with some copies of Washington Observations, 1875.

The two satellites of Mars were discovered by Professor Hall in August, 1877, with the 26-inch equatorial.

The six inner satellites of Saturn, by Professor Hall, Washington Observations, 1883, App. I.

Saturn and its rings, by Professor Hall, Washington Observations, 1885, App. I.

Observations for stellar parallax, by Professor Hall, Washington Observations, 1883, App. II.

The solar parallax and its related constants, by Professor Harkness, Washington Observations, 1885, App. III.

Reports on the observations of Encke's comet during its return in 1871, by Professors Hall and Harkness, Washington Observations, 1870, App. II.

Chronometer rates as effected by changes of temperature and other causes, by Commander C. H. Davis, Jr., Washington Observations, 1875, App. III.

The following differences of Longitude have been determined between Washington and

Havana, Cuba, Professor Harkness, Washington Observations, 1867, App. I.

St. Louis, Professor Harkness, Washington Observations, 1870, App. I.

Detroit, Mich. } Professor Eastman, Washington
Carlin, Nev. } Observations, 1872, App. II.
Austin, Nev. }

Ogden, Utah, Professor Eastman, Washington Observations, 1874, App. II.

Sayre Observatory, South Bethlehem, Pa.; Professor Eastman, Washington Observations, 1875, App. I.

Cincinnati Observatory, Professor Eastman; Washington Observations, 1876, App. IV.

Morrison Observatory, Glasgow, Mo.; Professor Eastman, Washington Observations, 1876, App. V.

Observatory Princeton, N. J.; Assistant Astronomer Paul, Washington Observations, 1878, App. II.

The zone observations made in 1846-1849 were published as follows:

Meridian circle zones observed in 1846 (a separate publication) contains 4,054 stars, 1860.

Mural circle zones 14,804 stars, Washington Observations, 1869, App. II.

Transit zones, 12,033 stars, Washington Observations, 1870, App. IV.

Meridian circle zones observed in 1847, '48, '49, 7,390 stars, Washington Observations, 1871, App. I.

Results of observations made with the transit instrument and mural circle, 1853 to 1860 inclusive, Washington Observations, 1871, App. II.

Report of Lieut. A. G. Winterhalter as delegate of the United States Naval Observatory to the Astrophotographic Congress held in Paris 1887; with a report on European observatories, Washington Observations, 1885, App. I.

Announcement of the discovery in April 1888, and the subsequent determination of the elements, of a new short-period variable star, S Antliae = No. 3407 of Chandler's catalogue; by Assistant Astronomer H. M. Paul, *Astronomical Journal* No. 215.

A magnetic observatory was arranged by Maury in 1845, but its construction was so faulty and inadequate that its use was soon discontinued. Nothing further was done

in reference to magnetic observations until 1887, when the Bureau of Navigation erected on the grounds of the Naval Observatory a complete magnetic outfit which was provided with facilities for obtaining continuous photographic records of declination, inclination and horizontal force. Instruments were also provided for the necessary absolute determinations of the magnetic elements. This magnetic outfit was turned over to the Observatory in July, 1887. Observations were commenced soon after that date, and continued until September, 1892, when the instruments were removed to the new site.

The preparations for the observations of the transits of Venus of 1874 and 1882, by the United States Transit of Venus Commission, were made at the Naval Observatory as the headquarters of the operations of the Commission, but although this work was done principally by Professors Newcomb and Harkness, it was entirely distinct from the work of the Observatory.

During the years 1885, 1886 and 1887 Professor S. J. Brown, U. S. N., was permitted by courtesy of the Superintendent of the Naval Academy to use its 4-inch Repsold meridian circle as an adjunct of the Naval Observatory in making a series of determinations of the positions of the 303 stars which had been selected to serve as the basis of the German Astronomical Society's southern zones.

When it became known that the work of the Naval Observatory would be interrupted by its removal to a new site the trustees of the Washburn Observatory, of Madison, Wis., very considerably offered the free use of the instruments of the Washburn Observatory to the staff of the Naval Observatory during that period. In acceptance of this invitation Professor S. J. Brown went to Madison on the conclusion of his Annapolis work, and from October, 1887, to October, 1890, conducted a series of

observations with the 4.8-inch Repsold meridian circle on the 'zusatz' stars Nos. 337 to 539 of the Berlin Jahrbuch.

Principally through the exertions of Rear Admiral John Rodgers, during his superintendency, Congress purchased a new site for the Naval Observatory on Georgetown Heights in 1881. Appropriations for the construction of new buildings on this site were made by Congress in 1886, plans for them were prepared by the celebrated New York architect, R. M. Hunt, and in the beginning of 1893 they were sufficiently complete to warrant the transfer of the establishment to the new site.

We come now to the fourth period in the history of the Observatory, namely, from its change of location to the present time.

The new site is distant about two miles in a northwesterly direction from the old Observatory, and occupies 69.78 acres on Georgetown Heights, the buildings being situated on ground elevated from 260 to 280 feet above the Potomac River. The shape of the tract is so irregular that its reentrant angles occasionally approach the buildings more closely than is desirable, and, to remedy this, Congress has enacted a law authorizing the laying out of a circle having a radius of one thousand feet about the center of the clock room, and the acquiring for the Observatory of all the land included therein which is not now owned by the government. This consists principally of two tracts, one of 1.70 acres and the other of 7.37 acres, and the area included in the proposed circle will closely equal that of the original irregular tract. The plans adopted for the new Observatory involved the erection of one building principally for offices, and a separate cluster of isolated buildings for the principal instruments. The main building has the library on its eastern end, and a tower for the smaller equatorial on its western end, with an adjoining meridian room still further west. About 410 feet

northwest of the center of the main building is the clock room, which occupies the center of the cluster of instrument buildings. It is flanked on the east and on the west by connecting observers' rooms, which the observers occupy in the intervals between observations; the chronographs being installed therein, and the rooms being heated by steam. Twenty-five feet to the east of the east observers' room is the entirely isolated East Transit House, and at the same distance west of the west observers' room is the similarly isolated West Transit House.

Fifty feet to the north of the center of the clock room is the entirely isolated Prime Vertical Transit House; and 175 feet to the south of the clock room is the dome of the 26-inch equatorial, with two connecting rooms for the use of the astronomer in charge. About 275 feet northwest of the center of the clock room is a circular wooden building 11.5 feet in diameter, surmounted by a revolving dome, for the altazimuth instrument. Four hundred feet to the southeast of the clock room is mounted the horizontal photoheliograph, and 250 feet south of this is the magnetic observatory. Six hundred and fifty feet north of the main building is the Superintendent's residence, and 250 feet southeast of the library are quarters occupied respectively by the professors of mathematics in charge of the 26-inch equatorial and the 9-inch meridian circle. About 200 feet northeast of the library is the boiler house, where steam is generated for heating most of the buildings on the grounds. The main building and the 26-inch equatorial building are constructed of white marble, but the four transit houses are built entirely of metal, having iron frames, with double walls and roofs of corrugated metallic plates, which have proved very effective in preserving an equality between the outside and inside temperatures. The carefully constructed

foundations for supporting the piers of the instruments are unusually massive and give unsurpassed stability. All the revolving domes and the shutter machinery of the transit houses were made by Warner and Swasey, of Cleveland, Ohio, and operate in the most satisfactory manner.

Passing now to the instrumental equipment, the 9.6-inch equatorial refractor is replaced by a telescope having a 12-inch object-glass made by Clark and equatorially mounted by Saegmüller. This instrument occupies a 26-foot dome on the tower at the west end of the main building. The 26-inch equatorial is provided with a new mounting by Warner and Swasey, and a powerful spectroscope by Brashear. Its dome is forty-five feet in diameter, and is provided with an hydraulic elevating floor having a range of motion of twelve feet. The Ertel transit instrument is remounted without change in the meridian room at the west end of the main building. The Pistor and Martins meridian circle has received the following modifications: The 8.5-inch object-glass of 12-feet focal length has been replaced by a 9.14-inch Clark object-glass of 107 inches focal length, and the tube has been shortened accordingly; the arms for supporting the microscopes have been replaced by a brass alidade, on the edge of which the microscopes may be clamped in any position; the old collimators of $2\frac{1}{2}$ inches aperture have been replaced by new ones of 4 inches aperture, for which new mountings have been provided, and the apertures in the cube of the instrument have been correspondingly enlarged. The shortening of the telescope made it necessary to reduce the height of the piers, and new marble piers have been provided for the collimators. A vertical collimator has also been added, together with a north meridian mark erected at a distance of 380 feet, which is viewed by means of a lens of the same focal length, having an aperture of six inches,

and mounted on the north collimator pier immediately below the collimator.

Two new instruments have been provided which were designed solely by Professor William Harkness, and built by Warner and Swasey, viz.: 1. A meridian circle, constructed entirely of steel, which is mounted in the west transit house. The object-glass has a clear aperture of six inches, and the instrument has two circles each 26 inches in diameter and each graduated to two minutes. It is provided with two horizontal collimators 3.5 inches in aperture, a vertical collimator, and a north meridian mark distant 380 feet. The latter is viewed through a lens of corresponding focal length, which is mounted on the north collimator pier immediately below the collimator. 2. The other new instrument designed by Professor Harkness, and built by Warner and Swasey, is the alt-azimuth. This, like the new six-inch meridian circle, is constructed entirely of steel. The aperture of its object-glass is five inches, and the diameters of its vertical and horizontal circles are 26 inches, each being graduated to two minutes.

One of the Transit of Venus 40-foot horizontal photoheliographs is mounted with all its accessories in the location previously indicated, and to the south of it a well designed magnetic observatory has been built, as mentioned above.

From its inception until July 22, 1863, the Naval Observatory was under the Bureau of Ordnance and Hydrography; from July 22, 1863, to July 1, 1889, it was under the Bureau of Navigation; from July 1, 1889, to the present time, it has been under the Bureau of Equipment and Recruiting, whose name was changed July 1, 1890, to the Bureau of Equipment.

Before considering the present organization of the Naval Observatory it will be convenient to give the following list of those who have held the office of Superintendent:

Lieutenant, later Commander, M. F. Maury, October 1, 1844, to his resignation April 20, 1861.

Commander, later Captain, J. M. Gilliss, April 23, 1861, to his death February 9, 1865.

Rear Admiral C. H. Davis, April 28, 1865, to May 8, 1867.

Commodore, later Rear Admiral, B. F. Sands, May 8, 1867, to his retirement February 11, 1874.

Rear Admiral C. H. Davis, February 16, 1874, to his death, February 18, 1877.

Rear Admiral John Rodgers, May 1, 1877, to his death May 5, 1882.

Vice Admiral S. C. Rowan, July 1, 1882, to May 1, 1883.

Rear Admiral R. W. Shufeldt, May 1, 1883, to February 21, 1884.

Commodore S. R. Franklin, February 21, 1884, to March 31, 1885.

Commodore George E. Belknap, June 1, 1885, to June 7, 1886.

Captain R. L. Phythian, November 15, 1886, to June 28, 1890.

Captain F. V. McNair, June 28, 1890, to November 21, 1894.

Commodore R. L. Phythian, November 21, 1894, to July 19, 1897.

Commander, later Captain, C. H. Davis, from July 19, 1897, the present incumbent.

From its foundation until 1894 the Superintendent was the sole head of the Observatory. On March 3, 1847, Congress enacted that he must be either a captain, a commander or a lieutenant in the Navy, but on March 3, 1865, that restriction was repealed, and it was enacted that: "The officer of the Navy employed as Superintendent shall receive as salary only the shore-duty pay of his grade."

The work of the Observatory is distributed under the following Heads of Departments: The Astronomical Director, the Heads of the Departments of Nautical Instruments, of Chronometers and Time Service, and of Magnetism and Meteorology. The duties of these Heads of Departments are as follows:

The Astronomical Director. This office was created by an order of the Secretary of the Navy, September 20, 1894, which defined the duties of the incumbent as fol-

lows: The Astronomical Director has charge of and is responsible for the direction, scope, character, quantity and preparation for publication of all work purely astronomical which is performed at the Naval Observatory. He has charge of the 26-inch and 12-inch equatorial telescopes, the 6-inch and 9-inch transit circles, the prime-vertical instrument, the photoheliograph, and all other instruments and accessories used in his department, together with the construction, remounting and repairing of all astronomical instruments placed in his charge. He personally inspects, both day and night, the methods of observation and computation in all the astronomical departments.

The Head of the Department of Nautical Instruments sees that all nautical instruments issued from the Observatory, except chronometers, are thoroughly inspected and tested before issue.

The Head of the Department of Chronometers and Time Service has charge of the chronometers deposited at the Naval Observatory; he inspects, tests, rates and prepares them for issue; he has charge of the transmission of the daily time signals and the apparatus pertaining to them; finally he makes all necessary determinations of local time for use in his department, and for this purpose has the use of the 5-inch Ertel transit instrument, which is mounted in the meridian room at the west end of the main building.

The Head of the Department of Magnetism and Meteorology has charge of all the magnetic and meteorological apparatus and observations.

The Superintendent as commanding officer is charged with the general superintendence and government of the Observatory. The heads of departments, naval officers, assistant astronomers, computers and employes performing duty at the Observatory are subject to him, and he is responsible for the disbursement of all moneys

appropriated by Congress to sustain the Observatory.

The present personnel is as follows: Superintendent, Captain C. H. Davis, U. S. N.; Lieutenant A. N. Mayer, U. S. N., in charge of the chronometers and time service, and also general storekeeper and inspector of nautical instruments; Professor H. M. Paul, U. S. N., in charge of magnetic and meteorological observations; Computer M. E. Porter; Instrument-maker William F. Gardner.

The Astronomical Director is Professor William Harkness, U. S. N., and immediately under him are Professor Edgar Frisby, U. S. N., in charge of the 12-inch equatorial refractor; Professor S. J. Brown, U. S. N., in charge of the 26-inch equatorial refractor; Professor A. N. Skinner, U. S. N., in charge of the 9-inch meridian circle; Assistant Astronomer G. A. Hill, in charge of the prime-vertical transit and the alt-azimuth; Assistant Astronomers T. I. King and F. B. Littell; Computers E. A. Boeger, G. K. Lawton, William M. Brown and F. H. Parsons; Photographer George H. Peters.

The 6-inch transit circle is not yet ready for use.

The work of the Observatory since its removal to the new site, in the beginning of 1893, has been as follows:

In 1888 the management of the Naval Observatory acceded to a request from the German Astronomical Society to determine, in accordance with its general program, the positions of the stars in the zone $-13^{\circ} 50'$ to $-18^{\circ} 10'$ of declination. Various difficulties prevented the execution of this work at the old Observatory, but as soon as the 9-inch transit circle was got into working order at the new site the Superintendent, Captain F. V. McNair, directed Assistant Astronomer A. N. Skinner to proceed with the observations, and gave him the assistance of Computers T. I. King and F. B. Littell for that purpose. The

first zone was observed January 13, 1894, and with the exception of a few scattering stars, the entire work was completed in 182 zones, the last of which was observed on May 26, 1897. The program involved the determination of the position of 8,689 stars, with at least two observations of each. The number of observations actually made was 19,762, of which 18,062 were zone stars and 1,700 were zero stars. The reduction of these observations is about three-fourths completed. In the course of the zone observations Assistant Astronomer Skinner discovered the variability of the following stars:

X Hydræ, announced in the *Astronomical Journal*, No. 332.

W Ceti, announced in the *Astronomical Journal*, No. 342.

RT Libræ, announced in the *Astronomical Journal*, No. 352.

Z Capricorni, announced in the *Astronomical Journal*, No. 358.

The meridian observations of the Sun, Moon and planets were necessarily interrupted by the removal to the new site. As stated above, these observations were suspended June 29, 1891, and it was not found expedient to resume them until after the appointment of the Astronomical Director in September, 1894. During the progress of the observations of the German zone, other meridian observations could not be pushed energetically, and until the zone reductions are completed they will be limited to the Sun, Moon and planets, the necessary ephemeris stars, and a few miscellaneous stars. The Sun and major planets are now observed on the meridian every day, except Sundays and holidays, and the Moon is observed at every visible transit. The reductions of these observations are nearly completed to within a few months of date.

The 12-inch equatorial has been continuously employed by Professor Frisby on observations of asteroids, comets, occultations

of stars by the Moon, and eclipses of Jupiter's satellites. Much of the current work of this instrument may be found in the *Astronomical Journal*.

The 26-inch equatorial has been continuously employed by Professor Brown on observations of the more difficult asteroids, on double stars, and on the satellites of Mars, Saturn, Uranus and Neptune. In recent months some spectroscopic work has been done.

Assistant Astronomer George A. Hill has charge of the Prime Vertical transit instrument and the alt-azimuth. With the Prime Vertical transit from July 24, 1893, to November 20, 1898, he has made 1,140 observations of α Lyræ, θ Aurigæ, α Canum Venaticorum, μ Andromedæ and γ Bootis. With the alt-azimuth instrument from February 24, 1898, to November 20, 1898, he has made 425 vertical-circle observations of American Ephemeris stars, and from November 22, 1894, to November 20, 1898, he has also made 599 zenith telescope observations of pairs of stars selected in groups as suggested by Küstner.

As at the old Observatory, meteorological observations are taken every three hours by the watchman on duty. After removal to the new site magnetic observations were resumed, but it was soon found that the influence of the suburban electric roads in the vicinity entirely vitiated the photographic records, and they were discontinued in the summer of 1898.

The annual volume of Observations for the year 1889 was published in 1893, and that for 1890 was published in 1895. The latter contained an important appendix entitled 'A catalogue of 16,748 stars, deduced by the Naval Observatory from zone observations made at Santiago de Chili by the United States Naval Astronomical Expedition to the Southern Hemisphere during the years 1849, '50, '51, '52, Lieut. J. M. Gilliss, U.S.N., Superintendent.' Advantage

was taken of the interruption of the work of the Observatory by reason of its removal to a new site, to complete the reduction of these zone observations. Among the many persons who have shared in the computations Professors Harkness, Frisby and Brown have performed the most important part.

In November, 1898, was published Appendix I to the Washington Observations for 1892, entitled 'The Second Washington Catalogue of Stars, together with the annual results upon which it is based; the whole derived from observations made at the United States Naval Observatory with the 8.5-inch Transit Circle during the years 1866 to 1891 and reduced to the epoch 1875.0, prepared under the direction of John R. Eastman, Professor of Mathematics, U.S.N.' This catalogue contains the positions of 5,151 stars which have been derived from 72,941 observations, being the entire series made while the Pistor and Martins transit circle was located at the old Observatory.

It will be noted that the Naval Observatory owes its existence primarily to an attempt on the part of naval officers to provide a depot for the care and issue of charts and nautical instruments. This naturally involved the equipment of the Depot with such astronomical instruments as are necessary for rating chronometers, but the needs of the Wilkes Exploring Expedition of 1838 to 1842, and the inception of the American Ephemeris and Nautical Almanac ten years later, soon showed the necessity for an instrumental equipment sufficient to cope with all astronomical problems, and that followed in due time. The principal aim of the Naval Observatory has always been to carry forward a continuous series of Meridian observations on the Sun, Moon and planets, such as can only be undertaken by great government observatories, like those of Greenwich and Paris. Since 1861 this work

has been kept up assiduously, and in recent years the number of meridian observations of the Moon has largely surpassed those made anywhere else.

In spite of this limitation in the scope of its operations, the Naval Observatory has not been unmindful of other lines of work. As instances of this may be cited the brilliant discovery of the moons of Mars by Professor Hall; the extensive work upon the satellites of the outer planets by Professors Hall, Newcomb and Brown; and finally the star catalogues of Professors Yarnall and Eastman and the contribution to the great star catalogue of the German Astronomical Society in the observation of the zone of stars from $13^{\circ} 50'$ to $18^{\circ} 10'$ of south declinations.

A. N. SKINNER.

U. S. NAVAL OBSERVATORY.

THE PSYCHOLOGY OF SOCIETY.

THE attempt to construct a science of society by means of biological analogies has been abandoned by all serious investigators of social phenomena. It was one of those misdirected efforts that must be looked upon as inevitable in the development of any branch of knowledge. The notion of a universal evolution compelled those who accepted it to try to find some other explanation of our social relations than that dogma of an original covenant which had come down to us from Hobbes and Locke. Biology supplied most of the facts and ideas of which the evolutionary thought was constructed; and naturally, therefore, biological conceptions were first made use of in formal Sociology. At present, however, all serious work in Sociology starts from psychological data, and proceeds by a combination of psychological with statistical and historical methods.

Psychology has had a development somewhat similar. Beginning with purely metaphysical terms and reasonings, it became a natural science with the advent of evolu-

tionary thought, and for a long time drew its best materials and its most fruitful hypotheses from physiological data. Physiological Psychology was the only psychology very well worth attention. George Henry Lewes was one of the first writers to argue, as he did with great force and brilliancy in the 'Problems of Life and Mind,' that the physiological explanations of mind must be supplemented by explanations drawn from the study of society. At the present time the social interpretation of mental development is an important part of psychological activity.

Psychological and sociological investigations have thus converged upon certain common problems, namely: The problem of the social nature of the individual mind, and the problem of the psychical nature of social relations. Any new contribution to either Psychology or Sociology is likely to be found also a contribution to the other, and we may look in the near future for a number of books of which it will be difficult to say whether they are primarily works on Psychology or on Sociology.

This is eminently true of Professor Baldwin's 'Social and Ethical Interpretations,' the second volume of his work on 'Mental Development.' The first volume, on 'Methods and Processes,' was definitely a study in Psychology. The problem dealt with was that of mental development through the interaction of physical and social causes, and the importance of social factors was emphasized throughout. In the volume on 'Social and Ethical Interpretations' we again find the same problem. The development of the individual mind through its social relations and activities is further considered. In this volume, however, the opposite problem also is introduced. The development of social relations and activities through the outgoing of the individual is discussed, and the nature of society is subjected to a critical examination.