

NATIONAL ACADEMY OF SCIENCES

JOHN AUGUST ANDERSON

1876—1959

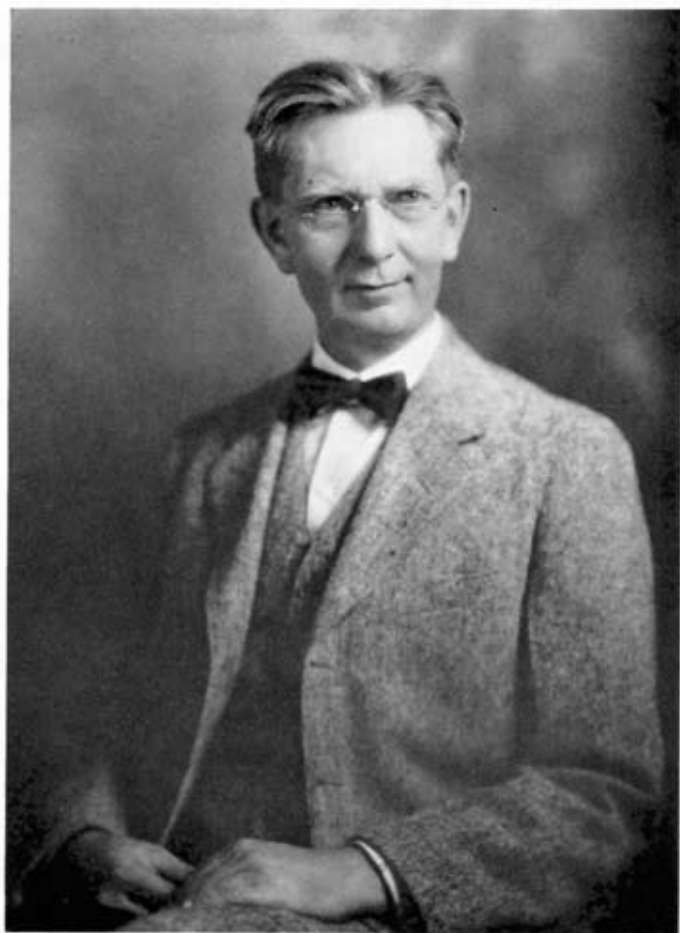
A Biographical Memoir by

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Biographical Memoir

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WASHINGTON D.C.



John August Anderson

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August 7, 1876-December 2, 1959

BY IRA S. BOWEN

DR. JOHN AUGUST ANDERSON was of Norwegian ancestry. His parents, Brede and Ellen Martha Berge, spent the early part of their lives in Namdalen Valley in the northern part of Trondheim Amth. In 1868 they left Bergen, Norway, on a sailing vessel and settled near Decorah, Iowa. Later they homesteaded a farm in Tansem township, Clay County, Minnesota. After moving to Minnesota, Brede Berge became a citizen of the United States, at which time he changed the family name to Anderson. Of their ten children two were born in Norway, two in Iowa, and the rest in Minnesota. John, the sixth child, was born on August 7, 1876, at Rollag, Minnesota.

After the usual elementary education in local schools John Anderson attended Concordia College at Moorhead, Minnesota from 1891 to 1893 and the State Normal School at Moorhead from 1893 to 1894. For the next four years he was employed at a hardware store and lumber yard in Hawley, Minnesota. In January, 1899, he entered Valparaiso College, Indiana, and was awarded the B.S. degree in August, 1900. Returning to Minnesota the following year he taught in District 77 in Clay County. He was then recalled to Valparaiso College where he taught courses in physics during the year 1902-3.

Anderson entered The Johns Hopkins University as a graduate student the following year and received the Ph.D. degree in 1907. His thesis, carried out under the direction of Professor J. S. Ames, was on the *Absorption and Emission Spectra of Neodymium and*

Erbium Compounds. The emission and absorption spectra of the oxides of these metals were observed through a wide range of temperatures and were compared with the spectra of other compounds of these metals and of their aqueous solutions. He concluded, "It seems reasonable therefore to assume that the three kinds of spectra defined above are due to the same vibrators," and further, "Let us assume that the vibrators in question are electrons located inside the metallic atom." This anticipated many of the current ideas in regard to the spectra of the rare earths.

Beginning in 1905, Dr. Harry C. Jones, Professor of Physical Chemistry at Johns Hopkins carried out a very extensive series of observations on the absorption spectra of solutions with the aid of grants from the Carnegie Institution of Washington. Anderson assisted on this project for the year 1907-8. Three joint monographs by Jones and Anderson resulted from this investigation, the most complete account being printed as Publication No. 110 of the Carnegie Institution. These investigations were carried out so far in advance of the development of atomic structure theory that no fundamental interpretations could be expected, although the observations became a part of the data on which later theories were based.

The summer of 1908 was spent at the Rouss Physical Laboratory of the University of Virginia. Here Anderson attempted to measure the rotational effect of plane polarized light on a crystal of tourmaline. From reasoning about the entropy of the system Anderson concluded that if plane polarized light were passed through a tourmaline crystal with the plane of polarization making an angle of 45° with the crystal axis, the crystal should be subject to a force tending to rotate it about an axis parallel to the beam of light. The observations seemed to confirm the prediction, but because of large radiometric effects were not conclusive.

On June 9, 1909, Anderson was married to Josephine Virginia Barron, who survives him. There were no children.

Anderson was recalled to The Johns Hopkins University in 1908 as Instructor in Astronomy. The following year he was advanced to

the rank of Associate and in 1911 to that of Associate Professor.

Henry Rowland, the great pioneer in spectroscopy in America, had carried out his classical experiments in this field at Johns Hopkins in the last two decades of the nineteenth century. Early in this period Rowland had constructed a ruling engine which, for the first time, produced gratings with the resolving power necessary for the detailed study of such complicated spectra as those of the sun and of many of the heavier elements. These gratings made possible Rowland's own work on the sun and, supplied to laboratories all over the world, led to a great expansion of high-dispersion spectroscopic studies at these institutions.

Rowland, however, died in April, 1901. Anderson, on taking up his position at Johns Hopkins, was asked to take charge of the ruling engine and continue the production of these gratings, which were in great demand by spectroscopists of all countries. He attacked this problem with his usual keen instrumental skill and insight. In the next few years he thoroughly rebuilt the engine and then ruled a substantial number of gratings with higher resolving power, less scattered light, and weaker "ghost" intensities than any produced before.

During this period he developed methods for making grating replicas, and with C. M. Sparrow studied theoretically the effect of groove form on the distribution of light in various orders. Their paper was one of the early studies which later led to the ruling of the blazed gratings that are of such great importance to present-day astronomical spectroscopy.

Because of the urgent need for larger and more perfect gratings for many of the programs at the Mount Wilson Solar Observatory, Dr. George E. Hale initiated a project for the construction of a large ruling engine. The plans for the engine were drawn by Dr. Francis G. Pease on the basis of the Rowland engine and many suggestions from Anderson. Arrangements were then made for Anderson to take a one-year leave of absence from Johns Hopkins starting in September, 1912. This year was spent in Pasadena supervising the construc-

tion of the ruling engine. The all-important master screw was cut, ground, and polished by Mr. Clement Jacomini, using new techniques suggested by Anderson, and experiments were made on new materials for the main thrust bearing.

Anderson returned to Baltimore in September, 1913, but was recalled to the Mount Wilson Observatory as a permanent member of the staff in July, 1916. For many years he spent a substantial portion of his time in supervising work on the ruling engine. Somewhat unfortunately this first ruling engine at the Mount Wilson Observatory had been designed to rule gratings very much larger than any hitherto attempted, and was theoretically capable of ruling an 18 × 24 inch surface. This of course required that the grating carriage be very heavy with correspondingly large starting friction in spite of partial mercury flotation. Furthermore, the great length of the screw increased the deformations caused by forces required to overcome this friction. All these factors added greatly to the difficulties of ruling gratings with the requisite accuracy. Several very fine small gratings were ruled under Anderson's supervision, but satisfactory gratings of a size approaching the capacity of the engine were never achieved. Some years after Anderson had given up supervision of the ruling engine to take charge of the 200-inch telescope, the conclusion was reached that a smaller engine would be more successful in ruling gratings of moderate size. This was constructed with the use of many ideas introduced by Anderson in the original large engine, and has been very successful.

On the basis of his experience with the Johns Hopkins and the original Mount Wilson engines Anderson wrote the paper "The Manufacture and Testing of Diffraction Gratings" in Glazebrook's *Dictionary of Applied Physics*. This still remains one of the best expositions of the problems and techniques of the ruling of gratings.

In planning the organization of the Mount Wilson Observatory, Hale wished to provide not only for astronomical observations but also for the interpretation of these observations in terms of physical conditions in the stars. For this purpose a physical laboratory was

organized to carry out investigations on the behavior of various chemical elements and their spectra under conditions of temperature, pressure, and magnetic and electrical fields similar to those present in the stars. A small group of physicists was added to the observatory staff for these investigations. These included Arthur King, who among other investigations carried out his classical studies of furnace spectra and the Zeeman effect, and Harold Babcock, who made determinations of the standards of wavelength and investigated the Zeeman effect and the spectrum of the night sky.

Anderson joined this group and immediately initiated studies of the Stark effect of several of the more infusible metals including Ti, V, Cr, Mn, Fe, and Ni. The original observations were made in the visual range with a grating spectrograph. Later these were extended to the ultraviolet with a quartz prism instrument.

These investigations were soon interrupted by the First World War, during which Anderson devoted much of his time to various military projects. He designed and later tested special micrometers which were constructed in the Observatory shops for the Bureau of Standards and for experimental researches in the Navy. Later he collaborated with Harold D. Babcock and Harris J. Ryan in the development of sonic submarine detection devices.

Soon after the war Anderson turned his attention to the application of the Michelson interferometer to the measurement of the separation of close double stars. With an adjustable pair of rotatable apertures close to the focus of the 100-inch telescope Anderson was able to make a precise measurement of the separation and position angle of the two components of Capella. Since the separations measured were only 0.04 to 0.05 seconds of arc, it had been impossible to resolve this object visually, although spectroscopic observations had shown it to be a double star. Later Dr. Paul Merrill made numerous measurements of Capella and a few of α Ursae Majoris with this equipment.

All interferometer measures of stellar diameters and of the separation of double stars depend on the effective wavelength of the light

used. This wavelength is a complicated function of the energy distribution curve of the source and the sensitivity curve of the eye. Anderson therefore carried out an extensive set of observations to fix this effective wavelength.

King had developed his electric tube furnace in the early days of the physical laboratory in order to study the spectra of various elements under conditions simulating those in the stars. His techniques, however, were limited to temperatures of less than 3000°C ., which is substantially lower than that of the majority of stars. To make possible investigations at temperatures approximating more nearly those of the hotter stars, Anderson started in 1919 a long series of experiments with exploding wires. To attain these very high temperatures, large amounts of energy must be concentrated in a small amount of matter in a very short period of time. To accomplish this, Anderson permitted a large capacity condenser charged to a high potential to discharge through a short length of fine wire weighing a few milligrams. This vaporized the wire in a few microseconds and raised the temperature of the vapor to $20,000^{\circ}\text{C}$. or more.

The first experiments were made with a condenser of 0.4 microfarad capacity, soon increased to 1 microfarad, charged to a potential of about 25,000 volts. Early in 1924 a new condenser and transformer were obtained capable of operating at potentials up to 60,000 volts and having a capacity of 0.6 microfarad. On discharge this yielded maximum currents of 40,000 amperes.

The successive stages of the explosion lasted for a few microseconds only, consequently various techniques had to be developed for separating the different stages and studying their characteristics. In the later phases of this investigation Anderson was assisted by Dr. Sinclair Smith. They designed rotating mirror cameras which enabled them to study the expansion of the exploding shell of gas with a resolution of about one microsecond. Later a spectrograph was combined with the rotating mirror camera to permit a similar time study of changes in the spectra. The rotating mirror camera was also used to measure the velocity of sound through the exploded gases,

thereby yielding a value for the temperature and ionization present in the gas at each stage. They also made use of the magneto-optical shutter and the electro-optical shutter to obtain very short exposure photographs of the early stages of the explosion. In other experiments they established the high opacity of the vaporized metals when near the peak temperature.

Anderson also used this high-voltage condenser to apply very high potentials and currents to other sources of spectra. These included the vacuum spark with which he investigated the spectra of C, Mg, Al, Si, Ca, Ti, Cr, Fe, Cu, Zn, Cd, and Pb in the visual and near ultraviolet range. These high-intensity discharges brought out many lines not found in the conventional arc or spark in air. In general these lines came from ions that had lost many electrons in the very high effective temperatures produced by this spark. Since the strongest lines of these high stages of ionization fall in the far ultraviolet, Anderson began the construction in 1931 of a 10-foot-focus vacuum spectrograph for investigations in this region. Unfortunately the vacuum techniques available before the Second World War were not adequate to produce the necessary vacuum in spectrographs of this size. Consequently, as in other long-focus vacuum spectrographs constructed during this period, observations were limited to the wavelength range above 1000 or 1200 Å.

The spectrum of a vacuum tube was also studied as the current density was increased up to several tens of thousands of amperes per square centimeter. Above 10,000 amp/cm² a strong continuous spectrum became conspicuous. Anderson studied the energy distribution curve of this continuous spectrum.

Anderson was always much interested in instruments and often assisted in the design of equipment for various projects at the Observatories. For example, shortly after the First World War it became desirable to study the effect of high temperatures and large magnetic fields on the spectra of a large number of elements. To make these observations properly it was necessary to produce a fairly uniform magnetic field of about 40,000 gauss throughout a volume of several

hundred cubic centimeters. Anderson made a careful analysis of the problem and came to the conclusion that this could be accomplished most effectively with a large, very high current liquid cooled solenoid without the use of iron. Such a solenoid was constructed under his supervision and was one of the very effective tools used by Dr. King in his studies of Zeeman effects.

During the 1920's the Carnegie Institution in collaboration with the California Institute initiated an intensive program for the study of earthquakes in the southern California area. Most of the seismographs then available were not suitable for the measurement of nearby shocks. Anderson made a careful analysis of the theory of seismographs and with Harry O. Wood developed a radically new torsion seismograph for this purpose. This has been widely used for this type of observation.

With Russell Porter he carried out an extensive investigation of the Ronchi test for optical surfaces. Anderson also investigated the use of a cylindrical lens to reduce the effect of photographic grain and thereby to improve the accuracy of the measurement of spectrograms. He collaborated with Harold D. Babcock in a measurement of the transmission of ultraviolet light through the air between Pasadena and Mount Wilson. They were able to show that this low-level air was much more transparent to the ultraviolet than a similar amount of air at high levels above Mount Wilson, presumably because of the larger amount of ozone present in the latter.

During his career Anderson participated in several eclipse expeditions. These included the Spanish eclipse in 1905, one in Wyoming in 1918, in California in 1923, and in Sumatra in 1926. In the Spanish eclipse expedition Anderson obtained satisfactory flash spectra with a dispersion of 5.21 Å/mm. In the last three of these expeditions Anderson played a major role in the design and construction of equipment, but in each the weather was unfavorable and the results were not as complete as had been hoped.

In 1928, largely due to the efforts of George E. Hale, the International Education Board made a grant of six million dollars to the

California Institute of Technology for the construction of a 200-inch telescope. As was necessary for any project of this size, a large organization was set up to handle the problems of the location, design, and construction of the new observatory. In general charge was the Observatory Council composed chiefly of Institute trustees with Dr. Hale and later Dr. Max Mason serving as Chairman.

Almost immediately after the formation of this Council Anderson was appointed as Executive Officer. One of the first problems undertaken by Anderson was the selection of a site for the new instrument. For the preliminary survey a dozen portable 4-inch telescopes with very high-power eyepieces were designed and constructed. These were used to observe Polaris at more than twenty sites in southern California and Arizona between 1929 and 1934. For these observations local observers were trained, and their observations were periodically checked by one of the astronomers from the Mount Wilson Observatory who moved from site to site. Later two 12-inch reflectors with very light equatorial mounts and driving clocks were constructed and were used to check in more detail a few of the most promising locations. On the basis of a study of meteorological records and these "seeing" tests, Palomar Mountain was finally selected.

Another problem undertaken early in the project was that of the design and the material of the 200-inch mirror. With previous smaller mirrors much observing time had been lost because of distortion in the mirror that occurred after the ambient temperature made a large shift. Simple calculations showed that in a mirror as large as the 200-inch such a thermal shift might render it ineffective for days after the temperature change. One obvious solution was the use of a material such as fused quartz whose coefficient of thermal expansion is about one-twentieth of that of glass. Dr. Elihu Thompson of the General Electric Company had experimented with this material and believed that, if a sufficient effort were made, it would be feasible to cast a 200-inch mirror blank. He was therefore authorized by the Observatory Council to proceed with the development of this material. However, after several years of effort and the ex-

penditure of about a half million dollars it had been possible to produce only a somewhat imperfect disk with a diameter of about 60 inches. It therefore became evident that the possibility of production of a satisfactory 200-inch disk of this material was very doubtful, and in any case would be prohibitively expensive.

The decision was then made to try Pyrex glass, whose coefficient of expansion is only about one-third of that of the ordinary glass used in previous telescope mirrors. Furthermore, it was decided to use a ribbed structure in which the maximum thickness of the ribs was only one-fourth to one-sixth of that of the more usual solid disk. This reduced the weight of the mirror to less than half of that of a solid disk as well as reducing by a large factor the time required to reach thermal equilibrium with the surroundings. The Corning Glass works undertook to cast the mirror of this material and after one unsuccessful attempt obtained a very satisfactory mirror blank on the second trial.

In the meantime a large optical shop was constructed in Pasadena for figuring the 200-inch blank and other smaller mirrors required for the telescope. Anderson was placed in direct charge of all the optical work. Since very few opticians experienced in large optical work were available he assembled a crew of untrained men and taught them the necessary techniques. The 200-inch Pyrex disk arrived at the optical shop in April, 1936, and this crew began the work of roughing out the disk to the paraboloid necessary for the final mirror. A total of about five tons of glass had to be slowly ground away to reach this shape.

The flexure of a mirror under its own weight increases very rapidly with its size. Because of this an entirely new type of support system had to be devised to hold the mirror without appreciable flexure in all the possible orientations it might assume while in the telescope. Furthermore it was necessary to have the mirror supported on this mechanism during optical tests in the optical shop. Previous tests of large paraboloidal mirrors had normally been made with the use of an auxiliary flat mirror nearly as large as the paraboloid. Because

of the very large cost of such a flat, Anderson, with the aid of Dr. Frank Ross, devised other methods of testing the 200-inch mirror. These worked very successfully.

For the design of the telescope tube, its drive and control, and the dome to house the instrument, a staff of engineers including Dr. Francis Pease, Captain Clyde McDowell, Russell Porter, Mark Serurier, Bruce Rule, and Edward Portras was assembled. In addition a large number of outside scientists and engineers were brought in as consultants. These included members of the staffs of companies such as the Corning Glass Company and the Westinghouse Manufacturing Company who were later to build major parts of the telescope. While many of the ideas that were finally used in the construction of the instrument came from these consultants, the responsibility for selecting the final designs and integrating them into a well-rounded instrument rested on Anderson and the project engineers working under his supervision.

In planning the 200-inch project it was realized that its ultimate success depended as much on having effective instrumentation to record and analyze the light as it did on an efficient telescope to collect it. A substantial item of the budget was accordingly set aside for the development of improved instrumentation and new auxiliary techniques. Anderson supervised and personally participated in this program. The design and construction of spectrographs of extreme speed using first the Rayton lens and later the thick-mirror Schmidt camera was an important development. These spectrographs were tried first on the 100-inch telescope and made possible many new fields of spectroscopic study including the observations which led to the concept of the expanding universe. Another project was the construction of a correcting lens to reduce the coma of a paraboloidal mirror thereby enlarging its useful field. This was designed by Dr. Frank E. Ross. These funds were also used to assist Dr. Joel Stebbins in the application of the photoelectric cell to precise magnitude measurements. Finally Dr. John Strong developed the method of evaporating thin aluminum films on astronomical mirrors. This

aluminum coat has almost completely replaced silver as a coat for telescope mirrors.

In any large project, such as the Palomar Observatory, in which dozens of scientists and engineers have participated and in which many of the ideas and designs have been reached through long discussions between groups of individuals, it is almost impossible to make an exact evaluation of the contributions of each participant. It is generally agreed, however, that on the instrumental side of the 200-inch project, the biggest single contributor was John Anderson. He was in general charge of carrying out the policies set by the Observatory Council. He had direct supervision of all optical work and personally participated in nearly all of the hundreds of tests of the 200-inch mirror made in the course of bringing it to its final figure. He also contributed directly to many of the solutions found for the innumerable mechanical and optical problems that had to be faced before the telescope could become an effective reality.

As the instrument reached completion and was given its final tests there were remarkably few changes and modifications that had to be introduced to make the 200-inch telescope the very successful instrument it has proved to be during its first decade of operation. The total expenditure for these modifications was less than one-half of one per cent of the cost of the project. This is a truly unusual record for an instrument that represents as big a step beyond anything attempted before as does the 200-inch. Much of the credit for this record should go to Anderson and the meticulous care and attention which he gave to all of the details of the design and construction of the instrument.

During the construction of the 200-inch telescope Anderson maintained a part-time connection with the Mount Wilson Observatory until his retirement on September 1, 1943. He continued as Executive Officer of the telescope project until the spring of 1948. By that time the mirror had been moved to the mountain and was undergoing its final tests and the Observatory was formally dedicated. He died suddenly on December 2, 1959.

John Anderson was a quiet, retiring man. In spite of his great ability and keen insight he was always modest and unassuming. He never rushed into print or offered a paper at a scientific meeting until he was thoroughly convinced of its validity. As a result he published relatively few papers, but each one is an important and lasting contribution to its field. He was always kindly and helpful to his associates and often assisted them in their instrumental problems. Many of his ingenious ideas bore fruit in their investigations and publications. He was greatly respected and beloved by all his colleagues.

Anderson was a member of the American Association for the Advancement of Science, the American Astronomical Society, the American Chemical Society, the American Physical Society, the Optical Society of America, and the Seismological Society. He was elected to the National Academy of Sciences in 1928.

KEY TO ABBREVIATIONS

- Am. Chem. J.=American Chemical Journal
 Astrophys. J.=Astrophysical Journal
 Bull. Nat. Research Council=Bulletin Series, National Research Council
 Bull. Seismological Soc. Am.=Bulletin of the Seismological Society of America
 Carnegie Inst. Wash. Pub.=Carnegie Institution of Washington Publication
 Elect. Eng.=Electrical Engineering
 Internat. Crit. Tables=International Critical Tables
 J. Elec.=Journal of Electricity
 J. Opt. Soc. Am.=Journal of the Optical Society of America
 J. Roy. Astron. Soc. Canada=The Journal of the Royal Astronomical Society of Canada
 Mt. Wilson Com.=Mt. Wilson Communications
 Mt. Wilson Contr.=Mt. Wilson Contributions
 Phys. Rev.=The Physical Review
 Phys. Z.=Physikalische Zeitschrift
 Proc. Am. Phil. Soc.=Proceedings of the American Philosophical Society
 Proc. Nat. Acad. Sci.=Proceedings of the National Academy of Sciences
 Pub. Am. Astron. Soc.=Publications of the American Astronomical Society
 Pub. Astron. Soc. Pac.=Publications of the Astronomical Society of the Pacific
 Pub. Astron. Soc. Pomona Coll.=Publication of the Astronomical Society of Pomona College
 Pub. U. S. Naval Obs.=Publication of the United States Naval Observatory
 Sci. Am.=Scientific American

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