without thanking you one and all for your presence here. I am well aware that it is no personal testimonial to me. Many of you I have met to-day for the first time and although I shall hope to have many opportunities of cultivating an acquaintance so pleasantly begun yet it is possible that many of us may never meet again.

Your presence here, however, is a testimony to the essential oneness in aim and in spirit of our American institutions of higher learning; it is an evidence of sympathy and good fellowship; it is earnest of cooperation and emulation for all good things.

We who are gathered together here as students, professors, trustees, benefactors, friends, of American colleges and universities may congratulate ourselves. We have surely followed Emerson's injunction and hitched our wagons to the stars. Every one of us may be glad that it has been permitted to him to take a part, however humble, in the great work of laying the foundation and erecting the superstructure for a series of institutions from the Atlantic to the Pacific, from the Great Lakes to the Gulf, which shall do for us and our civilization what the universities of the Old World have done for Europe.

Surely we may rejoice if we can help to win for our country the same proud position in education and science which our fathers and brothers have won for it in industry and commerce.

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*ON THE POSITIONS OF THE NORTHERN CIRCUMPOLAR STARS.**

THE importance of knowing the positions of the fixed stars has been recognized from the time of the early Greek astronomers, and the accuracy demanded has increased with the progress of the science. During the past two hundred years an enormous amount of labor has been expended in forming catalogues of the stars, and further progress in this direction is recognized to-day as one of the principal needs of astronomy. Not only ought a larger number of stars to have their places accurately measured, but the positions of many of the so-called fundamental stars should be more precisely determined.

Since the motions of the Sun, Moon and larger planets are confined to the region of the sky known as the Zodiac, the equatorial and zodiacal stars have been more frequently observed and their positions more accurately determined than is the case in general with the circumpolar stars. Comparison stars are needed near the pole only on those rare occasions when a comet crosses that region of the sky.

Beginning with the epoch-making observations of Bradley about one hundred and fifty years ago, the work of determining fundamentally, that is with reference to the equator and equinox, the places of a limited number of equatorial and circumpolar stars has been carried on continuously at Greenwich. Since its foundation about 1840, work of the highest value has been done by the National Observatory of Russia at Pulkowa, near St. Petersburg. Fundamental work of this kind has also been done at various other observatories, mostly European, and by professional astronomers, notably by Bessel and Struve.

Valuable differential work on the circumpolar stars has been done by amateur astronomers, whose work has been based on the positions of fundamental stars previously determined. Some of the noblest examples of devotion to science are found in the history of this subject.

Perhaps the most remarkable case is that of Stephen Groombridge, a linen draper of London, who about 1802 set up a transit circle by Troughton of three and one half

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inches aperture and five feet focal length at Greenwich, near the Royal Observatory. Groombridge labored for several years in observing the stars of the northern heavens. After his death in 1832, the reduction of these observations was superintended by Airy and a valuable catalogue of 4243 stars reduced to 1810.0 was formed. Airy pronounces the work 'one of the greatest which the long-deferred leisure of a private individual has ever produced.' This catalogue is not exclusively circumpolar, as many stars of forty or even fifty degrees of north polar distance are included. The Groombridge stars were reobserved by Johnson at the Radcliffe Observatory of Oxford University during the years 1840 to 1853 and the results form a part of the Radcliffe Catalogue of 6,317 stars for 1860.0. More than 85 per cent. of the Groombridge stars were observed at Greenwich during the years 1887 to 1896, and are contained in the second Greenwich 10-year Catalogue for 1890.0.

Another useful piece of amateur work is the Redhill Catalogue of 3,735 circumpolar stars for 1855.0 by R. C. Carrington, an astronomer otherwise well known for his work on the sun. His observatory was situated at Redhill in the southern suburbs of London, and his instrument, now at the Radcliffe Observatory, Oxford, was a transit circle by Sims of 5 inches aperture and 66 inches focal length. Carrington extended the zones of Bessel and Argelander from 80° north declination to the pole. It was his intention to observe all stars within this region down to the tenth magnitude. In the introduction to the catalogue Carrington states 'I will establish the rule that of the class of stars included in my plan, none shall be excepted from sufficiently repeated observation,' and this resolution seems to have been faithfully carried out.

Another work of importance is that of F. M. Schwerd, a professional astronomer of Speyer in Rhenish Bavaria, not far from Heidelberg. Schwerd observed, during the years 1826–8, 1,397 stars within fifteen degrees of the pole, with a small but '*vortreffliche*' meridian circle by Ertel of 1.7 inches aperture and 42 inches focal length. The divided circle was 20 inches in diameter and the power of eye-piece used was 126 diameters. Schwerd's observations reduced to 1828.0 were published by Wilhelm Oeltzen, of Vienna, in 1856.

The observations of circumpolar stars by Lalande at the Paris Observatory have been collected into a catalogue by Fedorenko, of Pulkowa, which, like the catalogue of Groombridge, contains many stars forty degrees or more from the pole. This catalogue contains 4673 stars for 1790.0.

A valuable recent work is the catalogue of 123 circumpolar stars for 1893.0 by M. Ditchenko, of Pulkowa. The stars of this catalogue are all within ten degrees of the pole and mostly of the 7.0 magnitude or brighter. The observations were made with the Repsold Meridian Circle of the Pulkowa Observatory and are differential, being based on the nine fundamental circumpolar stars of the *Berliner Jahrbuch*. The stars have been observed from four to six times each.

During the past twenty years good differential work on the circumpolar stars has been done in the United States with Repsold meridian circles at the Williams College Observatory, Williamstown, Mass.; at the Washburn Observatory, Madison, Wis.; and at the Lick Observatory. A few observations of circumpolar stars on a fundamental basis have within recent years been made at the Naval Observatory in Washington, but very little really fundamental work on the fixed stars seems to have been done in this country.

Dr. Auwers, of Berlin, published in 1897 (see *A. N. Nr.* 3440) a list of 21 circumpolar stars, with a request for observations

with a view to increase the number of well-determined stars near the pole. The great scheme of the *Astronomische Gesellschaft* of Leipzig for observing the stars of the northern heavens down to the ninth magnitude does not go beyond 80 degrees 20 minutes of north declination. The well-known need of additional work—especially fundamental work—in this part of the heavens has led me to outline a plan for fundamental observations of the circumpolar stars, which has not, as far as I know, been hitherto suggested or put into practice.

One of the chief difficulties in making fundamental determinations of the right ascensions of the stars at low declinations is in securing sufficiently accurate time keeping. This difficulty almost disappears near the pole, where an error in time means a much smaller error in space. The possibility of making observations at both upper and lower culminations is an important advantage in circumpolar work in both right ascension and declination. Those circumpolar stars which are bright enough to be seen in the daytime with meridian instruments are frequently observed by astronomers at both culminations at all times of the year. During the fall and winter months when in middle latitudes there are from twelve to fifteen hours of darkness daily, it is practicable to observe the fainter circumpolar stars at both upper and lower culminations. For six months of the year it is possible to work for an hour or two in the evening, between five and seven o'clock, observing a certain list of circumpolar stars as they come on the meridian at either upper or lower culmination. In the morning, twelve hours later, the same stars may be observed, each at the other culmination. In this way it is possible to observe with one instrument in a single year, at both upper and lower culmination, nearly all stars down to the seventh magnitude within ten degrees of the pole.

With a meridian circle provided with the usual accessories, including suitable meridian marks, the work may be made practically fundamental in both right ascension and declination. The right ascensions of ephemeris stars near the equator, used as clock stars, are known with sufficient accuracy so that the effect of their systematic errors may be neglected without serious error in observations of stars within 10 degrees of the pole.

Each pair of observations of the same star at both upper and lower culminations on the same day gives a fundamental determination of the azimuth of the meridian mark and the latitude of the place of observation, the observations in declination being made from the nadir. The observations of each night should be reduced with the azimuth of the mark and the latitude as found from the observations of that night, as in this way the effect of the recently discovered slight motion of the zenith-point is eliminated from the observed places. The more troublesome errors of personal equation will be eliminated from the final results of a year's work. In declination, the effect of errors of flexure of the instrument and of the refraction tables will be small. They will be somewhat smaller perhaps the higher the latitude of the place. Accidental errors of observation will be reduced to a minimum since the atmospheric conditions are usually best in the early morning and evening, and will be smaller at the higher latitudes. Observations made in this way will give the variation of the latitude as well as its mean value, and also the variation of the azimuth of the meridian mark. By observing, in addition to the circumpolar stars, stars which are selected for the purpose, corrections may be found to the refraction tables and to the constant of aberration.

The clock should be a good one, but need not be of unusual excellence. The instrument should be of the best quality, and its errors in both right ascension and declination should be investigated as completely and as rigorously as possible. The work should be done in both positions of the clamp of the instrument, and with the object glass and eye-end interchanged. All instrumental constants should be determined when the observations are made. In short all expedients should be resorted to to eliminate accidental and systematic errors —especially the latter—as it is only in this way that fundamental work can be made of value as such in the present state of astronomy.

The observations may be corrected for clock and instrumental error by either Mayer's or Bessel's formula. If the latter, which is perhaps the more convenient of the two, is used it may be put in the form,

$$a = T + \Delta T + m + (n + c)\tan\delta + c(\sec\delta - \tan\delta)$$

in which the quantity n is computed from values of the level constant found with the spirit level and a from observations on the meridian mark. The term c (sec δ — tan δ) may be used in the forms $c/(\sec\delta + \tan\delta)$ if more convenient. As is the case with all astronomical work, the value of the results will depend on the perfection and power of the instrumental outfit, and the skill with which the various processes are carried out. This plan of observation is of course applicable to the southern as well as to the northern circumpolar stars.

It may not be out of place to speak in this connection of the need of an extended series of fundamental observations of the brighter stars at all declinations, to supplement the work being done at Greenwich and Pulkowa. Astronomers who are interested in this subject feel the desirability of such an addition to the material at present available, from which to construct a general catalogue of several thousand stars whose places are based on an absolute system. The stars should be selected with reference to distribution, magnitude, color and other characteristics which affect their suitability to serve as standard points of reference. Such a catalogue is needed for a variety of purposes, among which may be mentioned:

1. As a basis for determining the positions of the fainter stars, by differential meridian circle observations or by photography.

2. For more convenient and accurate determination of longitude and latitude in geodetic work.

3. To make possible a more accurate and extensive determination of the proper motions of the stars in all parts of the heavens, which together with spectroscopic measurements of motions in the line of sight, likely to be greatly increased in the near future, will increase our knowledge of the proper motion of the solar system and also the motions and distribution of the stars in space.

4. To serve as a universal standard to which the great mass of existing star-catalogues, systems of star-places and series of observations may be reduced by the application of systematic corrections, thus harmonizing and making available for use a large amount of nonhomogeneous material.

There is perhaps no observatory in the world better located geographically for carrying out a series of observations of this kind than the Naval Observatory at Washington. While not an ideal climate for astronomical work in general, the climate of Washington is very good for work of this kind. The ground on which the observatory is situated was chosen with special reference to its suitability for the stable support of instruments and also with regard to freedom from unfavorable local conditions. As regards its latitude, 38 de-

grees 55 minutes, Washington is admirably situated for making observations intended to supplement the work of the European observatories and at the same time that of the observatories of the southern hemisphere. It is twelve and one half degrees south of Greenwich, twenty degrees south of Pulkowa and seven and one half degrees south of the new branch of the Pulkowa Observatory at Odessa. Stars of thirty degrees south declination are observed on the meridian at Washington at an altitude of twenty-one degrees and very near the zenith at Cordoba and the Cape of Good Hope. Being ten to fifteen degrees south of the observatories of central Europe, and yet far enough north for accurate observation of the circumpolar stars, perhaps no location better in this respect could be found for extending the accurate star places of the northern hemisphere thirty degrees or more south of the equator for comparison with the results of observations made in the southern hemisphere.

The value of the great work on the positions of the stars which has been carried on at Greenwich during the two hundred years which have elapsed since Flamsteed's time is recognized by every astronomer. As an example of continuous activity directed toward a definite end it is perhaps without a parallel in the history of science. Until 1850 a transit instrument of five inches aperture and a mural circle six feet in diameter, both by Troughton, were used. In that year the present Greenwich transit circle of eight inches aperture and twelve feet focal length was mounted by Airy. The axis is six feet long and the divided circle is six feet in diameter. While one of the most powerful instruments of its kind in the world, its construction is such as to make it liable to systematic error. No meridian mark is provided, although the north collimator was at one time used as such, and the spirit level is not used. Furthermore, the instrument cannot be reversed.

The great value of the fundamental work which the Pulkowa Observatory has done during the past sixty years is generally recognized. The instruments used have been of the best quality and their construction has been improved from time to time. The methods of observation are of the highest class and the systematic errors of the results have been found to be very small. But at the extreme north latitude of Pulkowa, the altitude of the sun on the meridian at the winter solstice is only seven degrees, and stars at the celestial equator are observed at an altitude of only thirty degrees. As a consequence the best work of that observatory is limited to stars of north declination. With the good judgment and enterprise which have from the first characterized the management of the Pulkowa Observatory, the branch observatory, mentioned above, was established in 1898 at Odessa, thirteen degrees further south, where valuable work is no doubt being done.

But all instruments and all methods of observing have their peculiar forms of error, and it seems clear that the establishment of a third center in the northern hemisphere for continuous fundamental observations of the stars is very desirable.

MILTON UPDEGRAFF.

U. S. NAVAL OBSERVATORY,
WASHINGTON, D. C.,
June 15, 1902.

THE CARNEGIE INSTITUTION.

THE provision for research constitutes a supremely important part of the intellectual organization of a great nation. A profound recognition of this fact has brought into existence the Carnegie Institution. I have elsewhere recorded (*The Dial,* February 16, 1902) my appreciation of the general aims and purposes of this