THE PRISMATIC ASTROLABE, A NEW INSTRUMENT FOR DETERMINING LATITUDE AND TIME BY EQUAL ALTITUDES.*

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The method of equal altitudes for the astronomic determination of the observer's position upon the earth's surface leads to results of such surprising accuracy that it has been termed incontestably superior to any other. As the name suggests, this method calls for the observation of celestial bodies in various portions of the heavens, but always at the same altitude, the observation consisting merely in noting the time when this altitude is attained.

As the altitude itself is entirely eliminated from the results in the course of the computation, its exact value, affected by constant errors of graduation, eccentricity, level, collimation, azimuth, flexure, etc., is of no consequence, provided only that it is the same for all stars observed. The local time and the latitude thus obtained, free from systematic error due to these sources, are remarkably precise.

The method itself was introduced by Gauss, who first pointed out its advantages a century ago. Employing a sextant and artificial horizon, this illustrious mathematician, even with such crude apparatus, and with only three stars, obtained a value for latitude, which excited wonder. After Gauss, others experimented with the sextant; but only the brighter stars can be observed with this little instrument. Very few of these can be found at a given altitude within a reasonably short period of time, and the small magnification necessarily employed to permit keeping the star in the field of view is not conducive to sharp observation. Sextant work cannot be relied upon for work of extreme precision.

Experiments were accordingly made with theodolites and other instruments rotatable around a stable vertical axis, and very good results were obtained by careful manipulation; but the artificial horizon was here replaced by some device like the spirit level, and this re-introduced the bugbear of systematic error. The method of equal altitudes, therefore, despite its advantages, though employed extensively at sea, was long neglected on land.

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Recently, the French took hold of the problem, and in their ingenious way solved it by inventing and improving a new instrument, "l' astrolabe à prisme," "the astrolabe with a prism," or the prismatic astrolabe. Of this there are several forms, but the principle in all is the same. Like the sextant, the astrolabe involves the use of an artificial horizon, but it replaces the two separate sextant mirrors by a single equilateral glass prism. The prism is mounted, edges horizontal, with rear face vertical, in front of the object glass of a horizontal telescope rotatable on a vertical axis in a horizontal plane, and the whole—prism, telescope, mercury basin and other appliances—is supported on a tripod like a theodolite.

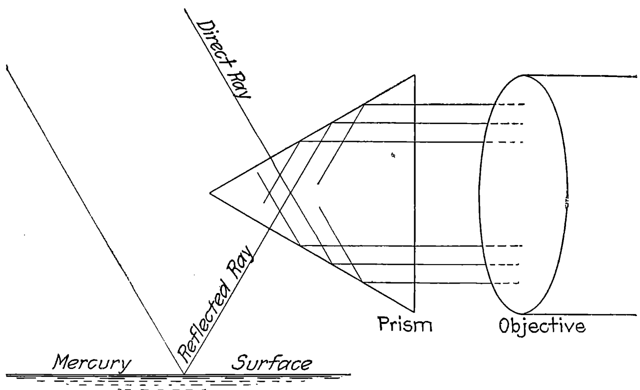

FIG. 1. ELEMENTS OF THE PRISMATIC ASTROLABE.

One face of the prism receives light directly from the star, another from the star's image reflected in the mercury, and the two light rays, after internal reflection, pass through the rear face of the prism to the object glass. Stars are thus observed at a constant altitude of 60°.

For time determination, observations are made in the neighborhood of the prime vertical, where the altitude changes most rapidly; for latitude, near the meridian. As it is easily possible without field illumination to observe stars as faint as the seventh magnitude, a skilful observer may secure 30 to 40 stars in less than an hour, and this number is sufficient to give very good values for both time and latitude. An interesting feature of the astrolabe is that, unlike other instruments, the results obtained, if the prism be well constructed and by employing reasonable care, are almost entirely independent of errors due to maladjustment. The telescope should be perfectly horizontal; so also should the prism edges; and the rear face of the prism should be vertical. If, however, the prism edges, for example, are not horizontal, the skilled observer will recognize this fact when he perceives the motion of the star in the field of view and a slight touch of a screw eliminates the inconvenience; indeed, this adjustment is generally effected on every star.

The one important adjustment—and even that is not absolutely essential—is the perpendicularity of the rear face of the prism to the axis of the telescope, which is easily affected by aid of a simple auxiliary device. If the adjustments are not perfect, the only error involved is in the observed altitude which, instead of being 60°, may be some larger or smaller quantity; but if care is taken to make all observations in the same portion of the field, and in the same way, this quantity will be the same in all positions of the instrument. All stars will be observed at the same altitude, and the resulting latitude and local time will be unaffected. With the newer type of prismatic astrolabe, per-

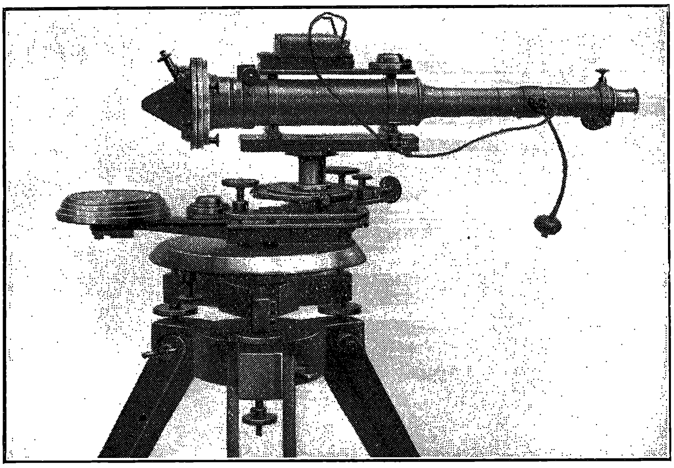

FIG. 2. PRISMATIC ASTROLABE FOR DETERMINING LATITUDE AND TIME BY THE METHOD OF EQUAL ALTITUDES.

mitting temporary field illumination, this condition is easily fulfilled.

There are no instrumental constants to be determined, and consequently there are no systematic errors introduced by such constants. There are no circle measures, with the danger of reading them incorrectly. There are no errors of nadir, pointing, thread inclination, pivots, etc., such as affect observations with other instruments. In fact, nearly all constant errors, affecting all observations alike, are eliminated. There is danger of systematic error introduced by the personal equation in noting the times of observation, but almost all other errors are of the accidental class, and may be eliminated by increasing sufficiently the number of observed stars.

The manipulation of the instrument is simple, rapid and easy. The French employ one or two assistants, but a single observer can work just as easily and quickly without aid. Guided by a previously prepared list of stars containing approximate times and azimuths, the observer first sets the telescope in azimuth, then seating himself at the eye end, watches the star and its reflected image enter the field of view from opposite directions. He touches a screw, perhaps, to cause the images to change slightly their relative positions, or to bring their vertical line nearer the center of the field. As the images draw closer in their approach toward each other, he concentrates his attention and at the moment of coincidence makes a record of the time, either by the eye and ear method, or by the chronograph and key. In this record is comprised the whole observation.

The computations, both preliminary to and succeeding the observations, are long and tedious. An hour's observing list requires many hours of preparation and subsequent computation. The labor of preparing the observing list may be considerably shortened by tables and other aids; and the final computations, too, may be made more easy by tables and graphic processes. The fact, nevertheless, remains that the computations are time consuming. In view of the high precision attainable, this objection should carry but little weight, particularly when it is remembered that the computations may be made at one's leisure, long after the observations have been completed.

The instrument is comparatively inexpensive, it is light and portable, and requires no previously established stable foundation, but may be set up in a few minutes. These considerations should recommend it particularly to geographers, explorers, surveyors and other travelers who seek accuracy, yet do not wish to encumber themselves with the comparatively heavy portable transit and accompanying chronograph. For the very finest kinds of longitude work, however, owing to the personal equation, the astrolabe should be looked upon with suspicion. Yet it should be remarked that it has been used side by side with portable astronomic transits of the best known types, and the results obtained by two different kinds of instrument have been wonderfully close.

The prismatic astrolabe has been employed by the French on boundary and other survey work in their colonies, in the measurement of a meridian arc in Ecuador, and more recently in important wireless longitude determinations. It was used in the spring of 1913 in the preliminary operations attending the determination of the difference of longitude between Washington and Paris.

The astrolabe may be employed for absolute longitudes by observing equal altitudes of stars and of the moon. It can advantageously replace the portable transit in much of the longitude work now carried on in this country, and would result in considerable saving. Among other applications, it may be employed at fixed observatories to determine star positions. Our astronomers and engineers should give it a trial.

For an exhaustive discussion, the reader is recommended to A. Claude et L. Duencourt, "Description et Usage de L' Astrolabe à Prisme."

REMARKS ON METEOR OBSERVING AND THE GEMINID METEORS OF DECEMBER 1914.

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A very interesting branch of astronomical work for amateurs is meteor observing. Under the able direction of Chas. P. Olivier, director of the American Meteor Society and as a member of the Society for Practical Astronomy, I have spent some time in this work and during the last two years have observed, recorded particulars and plotted paths, for about one thousand meteors. These and the work of other members of the A. M. S. are included in a recent publication of the Leander McCormick Observatory, University of Virginia, titled "126 Parabolic Orbits of Meteor Streams deduced from observations of over 2,800 meteors." It is the work of Mr. Olivier. I count my copy a very valuable addition to my library.

During my whole experience with meteors I found the conditions most favorable for observing during a stay of two months in the Cascade Mountains near Index, Washington. Here, while camping out on the mountains at elevations of from six to seven thousand feet, during nights when the hourly rate is usually from 8 to 12 per hour, I observed 20 and 30 meteors. The brilliant skies made visible a great number of low magnitude meteors that otherwise would have been lost. There are occasionally very clear skies along Puget Sound, Washington, but after midnight work is often interrupted by a haze that seems to drift inland from the waters. Here in southwestern California we have a great number of clear nights during the whole year and conditions for meteor observing as well as other astronomical work are very favorable.

I commend meteor observing to amateurs. Even though you may have a great interest in some other line or branch, such as variable star work, you will find it a pleasant relaxation from your other work. Try one night per month or when the maximum of some shower or radiant is at hand. Send the results to the director of the American Meteor Society.