formed there results, as the most probable value of the coordinates of the radiant,

$$A = 51° 10'$$
$$D = -35° 1'$$

In the present case there are two methods by which this result can be tested. First, it must satisfy the nine observations within reasonable limits; and secondly, when the right ascension and declination are converted into azimuth, the line indicated must pass thru the zenith of the place occupied by the *Castilian Prince*. On substituting in the equations from which the result is produced, very large residuals are found to exist for the last two stations. This is quite natural, considering their distance from the point of the meteor's first appearance. The azimuth derived from this radiant passes near Cape May, which is too far south. If the equations for these last two observations are abandoned, the position of the radiant is

$$A = 57° 17'$$
$$D = -15° 51'$$

and the meteor would have past thru the zenith of all places whose azimuth as seen from the end point was S. 72° 11′ E. The probable azimuth of the *Castilian Prince* was S. 73° 18′ E. From this agreement we may safely assume the above to represent the coordinates of the apparent radiant point.

The length of the path.—The most unsatisfactory data are those upon which depends our knowledge of the altitude at which the meteor began to glow. There are only two observations that one can use with any thing approaching certainty. These are Hanover, Pa., 61 miles; Orrstown, Pa., 70 miles, the average of which gives 65 miles as the most probable height above the surface. Fortunately the length of the path was so great that a considerable discrepancy in our knowledge of the altitude would have small effect on the resulting velocity. The probable length of the path approximates 385 miles.

The velocity thru the atmosphere.—The duration of visibility, when stated by the observer, is given in the last column of Table 1.

It is always a delicate question to decide which estimates are obvious errors and to which the law of probability can be safely applied. In the present instance, the Hanover observation has been rejected and the average of the remainder taken as the most probable value. Dividing the length of the path by the duration of visibility the velocity thru the atmosphere is 50 miles per second.

The path with regard to the sun.—From the Nautical Almanac it is found that the longitude of the sun was 191.7° and therefore the longitude of the apex of the motion of the earth was 102.6°. The angle between the true path of the meteor and that of the earth was 81.1° and the velocity thru the atmosphere was therefore greater then the velocity in space. The velocity in space before it fell under the attraction of the earth was 43.7 miles per second. The coordinates of the true radiant, or direction in space from which the meteor came, are celestial longitude, 24° 24′; celestial latitude, −40° 24′.

Making use of the known formulas of theoretical astronomy, the elements of the solar orbit [i. e. of the meteor's orbit about the sun] are easily deduced as follows: Longitude of ascending node, 11° 41′; inclination to ecliptic, 104° 14′; longitude of perihelion, 74° 38′; log. of perihelion distance, 9.7495; log. of eccentricity, 0.4790.

NOTE ON SOME METEOROLOGICAL USES OF THE POLARISCOPE.

By DR. LOUIS BELL. Dated January 27, 1908.

[Reprinted from the Proceedings of the American Academy of Arts and Sciences, March, 1908.]

This is merely a preliminary notice of certain facts regarding atmospheric polarization which may prove to have some prognostic value. They were incidental to a proposed study of the character of autumnal haze which the writer undertook last year at Mount Moosilauke, N. H. This peak, 4,811 feet high, has an almost uninterrupted sweep of horizon over a radius of 100 miles or so, and offers an excellent chance for investigating the distribution and nature of the haze that veils the landscape in early autumn. For instruments I took along a Savart polariscope, merely a Savart plate with a bit of tourmaline as analyzer, an extemporized double-image polarimeter of the type outlined in the early and valuable paper of Prof. E. C. Pickering,[1] a couple of carefully calibrated photographic wedges for determining opacities, and a direct vision spectroscope.

A prolonged easterly storm, about the only thing which could have defeated the program, cut short observations upon the summit, but a week of preliminary observations at Breezy Point (elevation 1,650 feet) at the base of the mountain yielded results which seem to be of sufficient interest to put upon record.

These were made mostly with the Savart polariscope, an instrument which, from its very wide field of view and great sensitiveness, showing even one or two per cent of polarization, enables sky conditions to be very readily investigated. The character of the sky polarization, with its general symmetry and maximum in a plane of 90° solar distance, is well known, but the nature and causes of its casual variations have not, perhaps, received the attention that is their due. Nearly everything in the landscape polarizes by reflection to a greater or less extent, the more as the specular component of reflection is the greater. For example, the glossy upper surface of a maple leaf polarizes strongly at fairly large angles of incidence, while the mat lower surface has only a trifling effect —which facts explain the old observation of Spottiswoode that ivy leaves polarize particularly well. Grass, trees, stones, especially if wetted, all produce their effect, which, when sky polarization is cut off by white cloud, is generally a maximum in the vertical plane.

I have several times observed this terrestrial polarization carried up by reflection into low-lying cloud as noted by Pickering (loc. cit.), or even into near-by dense fog otherwise neutral. A completely cloudy sky is otherwise practically free of polarization, but in a partially clear sky white cumuli commonly show some effects with the Savart plate, and light cirri often give bands almost as strongly as the clear sky. This may be due to the usually considerable height of cirri,—quite enough to allow noticeable polarization to have origin below them—or to their letting thru considerable polarized sky light from above—a phenomenon which I observed from the summit station in the case of rather thin layers of cloud in which it was immersed.

One of the most striking features of the sky polarization observed from Breezy Point was the extent to which it appeared while originating over short stretches of air. Mounts Kineo and Cushman, about three miles distant and dark with a heavy growth of conifers, repeatedly showed strong polarization effects from intervening haze, and at times slopes within a mile brought out the bands, altho less conspicuously. On several occasions the polarization on Kineo and Cushman was sensibly as considerable as on peaks at 10 or 15 miles distance. Similarly, in the brief observations on the summit, the Green Mountains, and the almost effaced Adirondacks, showed little if any more polarization than the peaks in the same direction in the middle distance, altho the former were 80 to 100 miles and the latter only 20 to 40 miles. These results follow from the exponential relation between distance and apparent absorption, but show clearly the magnitude of the effects due to comparatively short reaches of air.

At no time was I able to repeat the results obtained by Tyndall in the apparent clearing up of the haze by observation thru a crost Nicol. In this case the mountains remained

[1] Proceedings of the American Academy of Arts and Sciences, Vol 9, p. 1 et seq.

dim, Nicol or no Nicol, showing that the typical autumnal haze, often whitish blue near the horizon, acts mainly by general obstruction and diffusely reflecting a good deal of light, the polarized component being usually only moderately strong.

Haze in general is well known to be due simply to suspended particles of one sort or another, and haze which produces polarization, as well as the ordinary sky polarization, is well known to be due to particles, whether of dust or water, or of other nature, small compared with the wave-length of light. Lord Rayleigh[2] has given the theory of this action in considerable detail.

The polariscope integrates the effect of such particles along the line of sight, and this information may have considerable meteorological significance. The light-scattering particles which produce sky polarization are much finer than those which produce coronas and similar phenomena, with the beginnings of ordinary reflection. In artificial fogs the nuclei gradually grow from the polarizing dimensions to those which scatter white light and become visible. It is not easy to assign exact dimensions to the finer particles. They are quite certainly much less than a quarter wave-length in diameter, that is, say 100 $\mu\mu$, and probably run very much smaller. From the very exhaustive work of Barus[3] it appears that the diameter of the particles to which visible fog and coronas in a fog chamber of laboratory dimensions are due range from .0005 μ upwards, those near this limit showing as fog, while the coronas began to form as the diameters reached 10 μ and above. The fog particles to which lunar coronas are due often rise to greater dimensions, 20 or 30 μ.

Now such fog particles are the preliminary to rain, which forms by the accretion of these particles to a size that readily falls; and it is well known that water vapor, even when saturated as shown by the psychrometer, will not begin to condense to visible fog unless in the presence of nuclei about which aggregation takes place. These may be of very fine dust, or even of water particles electrically charged to an extent that resists the surface tension that would otherwise promote evaporation. Such charged aqueous nuclei may exist in unsaturated air at very small diameters, down to 1 or 2 $\mu\mu$, as has been shown by J. J. Thomson,[4] by Wilson,[5] and by others. Between these almost molecular dimensions and those indicated by coronas are the light scattering particles active in sky polarization. Their effect, that is, the amount of light scattered, varies, as Rayleigh[6] has shown, as the inverse fourth power of the wave-length of the light affected and directly as their volume, assumed to be small compared with a wave-length. Now plotting the resulting equation, $I = \frac{\kappa A}{\lambda^4}$, one obtains a group of curves shown in fig. 1 [omitted], which discloses the cause of the familiar intense blue of the scattered light. As larger particles grow during the process of nucleation or are present as dust, the blue gets weak and whitish from the scattering of white light. Near the horizon, where the light traverses a long reach of atmosphere and coarser dust is common, one gets the familiar weakening of the sky blue.

The process of increasing nucleation, which results in cloud formation and frequently in subsequent rain, can be followed very closely by the polariscope. A fall in polarization, particularly when the spectroscope shows the presence of much aqueous vapor, indicates the progress of nucleation.

On several occasions I noted this phenomenon in the Breezy Point observations. Starting with strong polarization on the distant hills to the southward and a strong rain band visible in the spectroscope, the next few hours showed a conspicuous weakening of the polarization, followed presently by the formation of visible clouds, and in at least two cases by precipitation. In short, if from change of temperature or other cause cloud is due to form in any particular direction, the nucleation which precedes visible fog formation is bound, other things being equal, to cut down the polarization. The prognostic value of this process depends largely upon the rate at which it progresses. In two instances which I noted, the decrease toward the south occupied most of an afternoon. Of course a drifting in of coarser dust particles would produce weakening of polarization, but the concurrence of weakening with a heavy rain band intimates very strongly that nucleation is progressing.

A detailed study of the changes would require the use of a sensitive polarimeter, by which variations from the theoretical polarization could be accurately measured. Observations of this kind, made where there is a wide sweep of horizon, should frequently disclose incipient cloud formation and the causes which produce it. The use of a spectro-polarimeter would be very desirable, as showing by the change in the quality of the scattered light the progress of events. The nature of the minute nuclei, whether dust or water particles, is not definitely known. After a heavy rainstorm the lower strata seemed to have been cleared pretty effectively of polarizing nuclei, while the upper sky remained much as before. On one occasion, more than twenty years ago, I was taking rain-band observations on Moosilauke and was favored with a day in which the distant peaks, even up to 100 miles, stood out almost as black as silhouettes, while the sky took on a deep hue almost startling in its unfamiliarity. A polarimeter would certainly have given extremely interesting results had it been at hand. It seems quite possible that one might get a fairly clear idea of the relative number and distribution of nuclei in the upper air by such means.

It would certainly be interesting also to find out whether the apparently very strong absorption of ultra-violet rays by the atmosphere is due to any genuine absorption or merely to a serious loss of light by lateral scattering, which Rayleigh has shown may perhaps be due to the air molecules themselves. In the lower strata my observations pointed rather to dust than to minute water nuclei, since a whitish haze showed powerful polarization on near-by peaks, making it clear that the haze was extremely heterogeneous. The conditions which would produce stable water nuclei of strongly polarizing size on a clear day would tend to reduce larger droplets to the similar order of magnitude instead of leaving them to superimpose specular reflection.

I am not disposed to suggest that in the polariscope we have a meteorological tool of vast importance, but my preliminary observations certainly show that it gives a most instructive view of the very early stages of atmospheric nucleation, and especially if combined with rain-band observations it should have material prognostic value as regards comparatively local conditions. There is also a chance for forming a clearer idea of the conditions of nucleation in the upper air, including the very high altitudes, since polarization is manifest after the sun is so far below the horizon as to illumine only the upper strata. I bring the preliminary facts to notice here in the hope that some one with a suitable location and opportunity for systematic observation may find them useful as a guide to further work along this line.

[2] Phil. Mag., 1871, p. 107 et seq.
[3] Smithsonian Cont., No. 1373.
[4] The Discharge of Electricity thru Gases. [5] Phil. Trans., 1897.
[6] Rayleigh, loc. cit.

NOTES FROM THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Librarian.

UPPER AIR RESEARCH IN GREAT BRITAIN.

The active part that British observers are now taking in the world-wide campaign of upper air research was reflected in the prominence given to this topic at the last Royal Society conversazione held at Burlington House, May 13, 1908. The sub-