Some Recent Work on the Light of the Night Sky.[1]

By LORD RAYLEIGH, F.R.S.

IT is now well known that the light of the night sky has little in common with the day sky. When the sun is 18° below the horizon, and the moon also below the horizon, night conditions may be considered to be established. A clear sky is of course necessary for the study of the luminosity. Unlike the day sky, it is found to exhibit very little polarisation. The intensity is considerably below the threshold of colour vision, and subjective impressions about its colour, which is sometimes described by imaginative writers as blue, have no basis in reality.

The chromatic constitution of the light of the night sky can be investigated by experiments with coloured glasses. We may select a red and a blue glass, and look through them at the night sky. The blue one will almost certainly be the brighter, owing to the Purkinje effect. We may superpose neutral glasses on the blue one until the intensities are matched, and we shall then have a test by means of which the night sky can be compared qualitatively with other sources as regards the blueness or redness of the light. It is only necessary to reduce the intensity below the threshold of colour vision, and to note which glass gives the brighter field.

It is found in this way that the day sky is much bluer than the night sky, which is nearly of the general colour of a piece of white paper illuminated by a half watt lamp at normal incandescence. In this comparison, the brightness of the paper may be suitably reduced by placing the lamp a long way off.

SPECTRUM OF THE NIGHT SKY.

Spectroscopy of the night sky is a difficult problem, and the most that can be made out by visual methods is that the green auroral line is present on a background of apparently continuous spectrum. Some writers have recorded that they can always see the green line. I myself can only see it when the brightness as revealed by the photometric method presently to be described is above the average. Many experienced spectroscopists have been unable to see it at all. The main instrumental condition is to use a wide slit and a high dispersion. Lenses may advantageously be dispensed with.

Photographic methods are necessary for a more detailed study of the spectrum. In a single night's exposure it is scarcely possible to do more than photograph the green line, using a one prism spectrograph with spectrum ratio not less than $f/2$ and an orthochromatic plate. I have constructed small spectrographs with an aperture ratio $f/0 \cdot 9$, and with these it has been possible with an exposure of many nights to photograph the apparently continuous background of the spectrum, along with two emission lines or bands at wavelengths very roughly estimated as 4210 A. and 4430 A. The broad absorption lines *G*, *H*, and *K* of the solar spectrum are seen in absorption. These are probably to be attributed to starlight, which is superposed on the light proper to the night sky. The relative amount of starlight has not been determined. I believe it is largest in the blue region of the spectrum, and relatively unimportant in the yellow and red regions.

An exposure of many nights on an Ilford panchromatic plate failed to show anything in the red region of the spectrum.

It is noteworthy that the negative bands of nitrogen, which are the most important feature in photographs of the auroral spectrum, are not present in the night sky.

PHOTOMETRIC METHODS OF OBSERVATION.

For some years past I have been making systematic photometric observations on the light of the night sky. As we have seen, the spectrum consists partly of the green auroral line, and partly of apparently continuous background. It is desirable to treat these separately. The light is, however, too feeble to allow of spectrophotometry in the ordinary sense. The method adopted in this work is to analyse the light with colour filters. Three filters were used, one designed to isolate the green auroral line as nearly as possible, and the others designed to transmit the region (*a*) on the red side, and (*b*) on the blue side of the line, excluding the line itself in each case. These are called the red, auroral, and blue filters.

The standard comparison light consists in each case of crystals of potassium-uranyl sulphate, which are self luminous, owing to the radioactivity of the contained uranium which stimulates the fluorescence of the salt. There is reason to believe that when in a sealed vessel the source may be regarded as independent of external conditions, and constant, at all events for very many years.

The type of photometer chiefly used consists of a Lummer cube, with the field divided into two vertical strips. The right hand (transparent) is backed by the uranium salt; the left-hand part, silvered, reflects the sky with a colour filter interposed. Choice from a series of neutral glasses allows the filtered sky light to be matched with the standard.

The densities ($\log_{10}$ opacity) of the set of neutral glasses had the values

0·1 0·2 0·3 . . . . 0·7, etc.

The scale used for recording and discussing the results is a magnitude scale, that is, one in which each step is a constant multiple of its predecessor. The zero reading is that which gives a match without one of the neutral glasses. For example, a reading of -3 means that the third neutral glass has to be used *over the sky*. A reading is recorded as -3 if the

[1] This paper was sent in for publication to Prof. S. Chapman, F.R.S., chairman of the Committee of the International Research Council on Solar and Terrestrial Relationships, and received by him (as he confirms to me) on Monday, June 18.

same glass has to be used *over the uranium source.* Intermediate interpolated values are entered; for example, 3·5. The zeros for the three separate regions of the spectrum, red, auroral, blue, are related in an arbitrary manner, though the factor involved in passing from one neutral glass to the next is, of course, the same for each, so far as the glasses deserve the same neutral. Within the practical limits of experimental error they do deserve it.

It is to be noticed that the comparisons are not at all prejudiced by a difference in colour between the two lights. At these low intensities the eye sees everything in monochrome, just as the photographic plate does at all intensities.

If the intensities are to be compared at different places and at the same time, it is necessary to duplicate the instruments and to adopt one as a master standard. The others can be compared with it by means of an 'artificial sky' consisting of a diffusing screen of which the brightness can be controlled and measured by varying the voltage across the terminals of a small electric lamp used to illuminate it. The details are here passed over. Each local observer takes the readings with his own instrument as described. They are reduced to the standard scale at headquarters by applying a subtractive correction, which gives the result which would be obtained under the same conditions on the master standard instrument, with the filters belonging to the latter. The scale numbers thus adopted are those of the neutral glasses, thus the intensity is multiplied by passing up one unit by the anti-logarithm of 0·1 or 1·259. Three steps on the scale are equivalent to a factor of $(1{\cdot}259)^3$, or to approximately a doubled intensity. This is a convenient rule to remember.

PHOTOMETRIC OBSERVERS AND RESULTS.

For observations in various parts of the world, I have been able to rely on the kindness of scientific friends who either undertook the work themselves or were able to find other capable observers who were so kind as to undertake it.

The stations and observers were as follow: Hawaii (United States Magnetic Observatory, Ewa, Oaku—Mr. H. E. McComb); Victoria, British Columbia (Dominion Observatory—Dr. J. S. Plaskett, Mr. Harper, Mr. H. H. Plaskett, Mr. Pearce); Mt. Wilson, California (Mr. Humason, as arranged for by Mr. H. D. Babcock); Pomona College, Claremont, California (Prof. Brackett); Pinehurst, N. California (Prof. J. C. McLennan); Kingston, Ontario (observations received through Prof. J. C. McLennan); Arequipa, Peru (Dr. J. S. Paraskevapoulos, as arranged by Prof. Harlow Shapley); Lerwick Observatory, Shetland Islands (Mr. A. W. Lee, arranged by Dr. G. C. Simpson); England (Terling, Essex, and near Hexham, Northumberland, during part of the autumn—Lord Rayleigh); Cape of Good Hope (Dr. H. Spencer Jones); Gilgil, Kenya Colony, E. Africa (Mrs. G. Cole); Kodaikanal Observatory, India (Dr. Royds, Mr. A. A. Narazana Ayer, Mr. P. R. Chidambara Ayer, Mr. S. S. Ramaswamy Ayyangar); Canberra, Australia (Commonwealth Solar Observatory—Dr. W. C. Duffield and Mr. A. L. Kennedy); Christ-

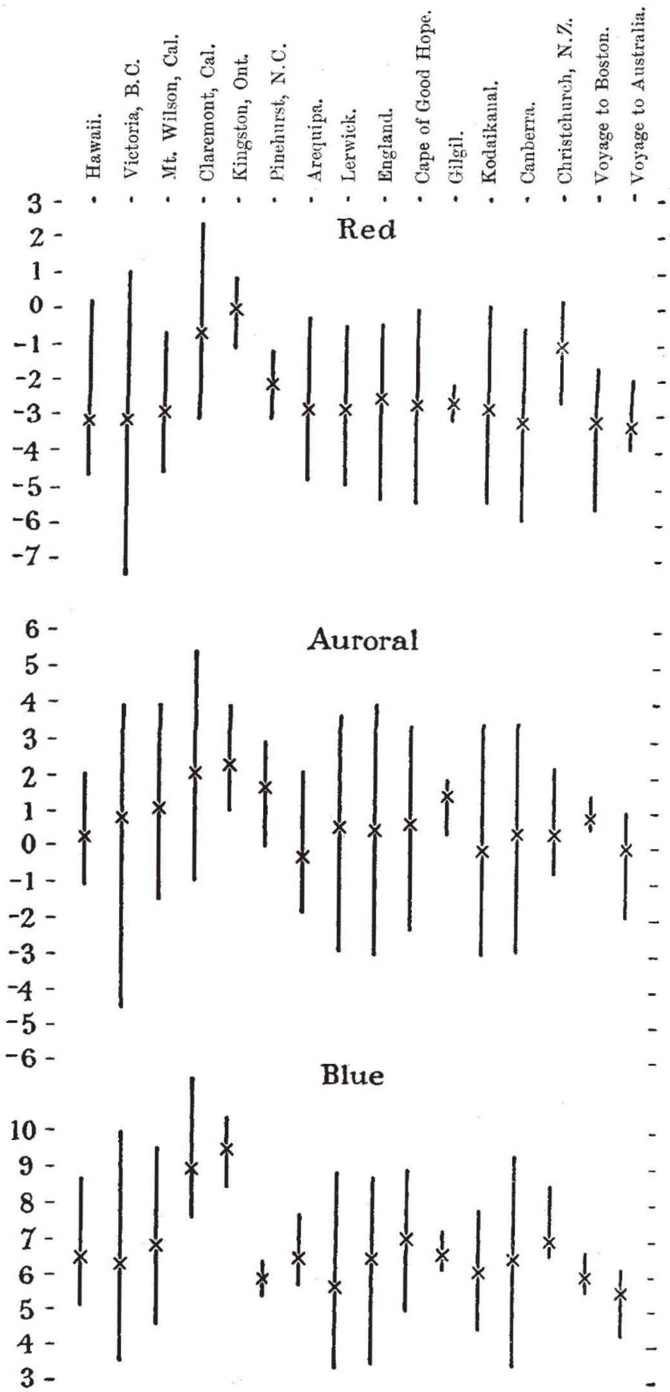

FIG. 1.

church, New Zealand (Mr. P. W. Glover); Voyage from Marseilles to Boston (Mr. H. D. Babcock); voyage from England to Melbourne (Miss Natalie Allen).

MEAN VALUES AND RANGE OF VARIATION.

The accompanying diagram (Fig. 1) gives the mean results in each component. It must be emphasised that though the red component, for example, is measured throughout on a consistent scale, this scale has an arbitrary difference (representing an arbitrary but constant intensity ratio to) from the scale used for either of the other components. The mean values are marked by crosses, and the extreme range in each component by the vertical lines.

The general conclusions to be drawn from this diagram appear to be as follows: First, fairly normal values can be stated for the intensity of each component at any part of the world. These values are somewhat as follows, on the various arbitrary scales:

Red	−2·5
Auroral . . .	+0·8
Blue	+6·5

The few cases which apparently lie outside these limits are believed to be due to observational causes. Full discussion is given in a paper presented to the Royal Society. The usual range of variation is from three to four fold in any given component. There is a strong correlation between the red and auroral intensities on any given occasions, and a rather less strong but still marked correlation between these and the blue. It is, however, definitely established that this correlation is not complete. A simple test for this is to match, for example, a red glass directly against a blue one by the addition of suitable neutral glasses, discarding the use of the self-luminous standard. It is found that this adjustment does not remain good for all succeeding nights, though it may be necessary to wait for some time before a marked change is observed.

ARE THE VARIATIONS AT DIFFERENT STATIONS CORRELATED ?

The variations of intensity which form the subject of this investigation do not occur uniformly all over the world. They are conditioned, in large part at any rate, by local circumstances. To illustrate this, some striking illustrative cases will be given before discussing the subject by statistical methods.

Date.	Place.	Red.	Auroral.	Blue.
Jan. 16, 1926	England	−4·4	−1·4	+5·8
	Cape	−1·9	+2·0	+9·0
Mar. 2, 1926 .	England	−3·6	−0·2	+6·4
	Cape	−0·4	+2·0	+7·7
April 15, 1926	England	−3·6	−0·8	+6·4
	Cape	−2·4	+2·4	+8·3
Sept. 19, 1925	England (Northumberland)	−3·6	+1·7	+6·4
	Shetland (Lerwick)	−4·4	−2·8	+3·4
June 7, 1926 .	Hawaii	−4·7	−0·9	+5·1
	Canberra	−2·4	+2·1	+7·9

These cases have been chosen to show contrast. The mean values at the two places are in each case very nearly the same. Yet we see that occasion may be found where the intensity at one is double or more than double that at the other.

On calculating the correlation coefficients for approximately simultaneous observations at the pairs of stations mentioned, no significant coefficients were found. It will be seen immediately that there probably are long period variations which imply a correlation, but these are swamped by local irregular variations.

(To be continued.)

The Centenary of James B. Neilson's Invention of Hot-Blast in Iron Smelting.

By Prof. WILLIAM A. BONE, F.R.S.

IT may be considered singularly fortunate and appropriate that the forthcoming meeting of the British Association in Glasgow exactly coincides with the centenary of James Beaumont Neilson's epoch-making invention of the use of hot-blast in iron smelting, which was first conceived and demonstrated in that city. For it inaugurated a century of continuous advance in scientific fuel economy, and may be said to have done for iron-smelting what Richard Arkwright's inventions had previously done for cotton-spinning.

In 'praising famous men,' it is well to appreciate their personalities and upbringings as well as their achievements; and in many ways the case of James B. Neilson is of peculiar interest. He was born on June 22, 1792, in the village of Shettleston, near Glasgow, the son of Walter Neilson, a colliery engine-wright; his mother has been described as "a woman of capacity and an excellent housewife." After a village-school education up to the age of fourteen years, he first helped his father for a while, and afterwards became apprenticed to his elder brother John, an engineman at Oakbank, near Glasgow, who is said to have designed and constructed the first iron steamer that put to sea.

In the year 1814, Neilson took employment as a colliery engine-wright at Irvine, where a year later he married Barbara Montgomerie; in 1817 the failure of the colliery compelled them to move into Glasgow, where Neilson was appointed foreman (and five years later, manager and engineer) to the newly established gas-works, where he remained for the next thirty years.

This proved to be the turning-point in Neilson's life; for, besides ensuring him steady and congenial employment, his settlement in Glasgow brought educational opportunities of which he fully availed himself at the Andersonian College, where he studied physics and chemistry with conspicuous zeal and success. Not only did he thus improve