Philosophical Magazine Series 5

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: <http://www.tandfonline.com/loi/tphm16>

L. On spectra of lightning

Arthur Schuster Ph.D. F.R.A.S.

To cite this article: Arthur Schuster Ph.D. F.R.A.S. (1879) L. On spectra of lightning , Philosophical Magazine Series 5, 7:44, 316-321, DOI: [10.1080/14786447908639613](https://doi.org/10.1080/14786447908639613)

To link to this article: <http://dx.doi.org/10.1080/14786447908639613>

Published online: 13 May 2009.

Submit your article to this journal [↗](#)

Article views: 3

View related articles [↗](#)

practically useless, as we can accomplish the same end in as many minutes by an indirect method as it would require hours by the direct method.

The following illustration will show how it can be accomplished. The top half of the slit is covered as before, and sunlight reflected onto it, and the spectrum is impressed on the photographic plate. The bottom half is next covered up, and a flame, in which the compound to be examined, is placed in front of the slit; the sunlight is then caused to traverse the flame, and a second spectrum is impressed on the plate through the top half of the slit.

New absorption-lines are thus formed in the solar spectrum, or *those already existent are intensified*, as is already well known. As an example, lithium chloride was heated in the flame, and the known line of lithium was found reversed between B and C, though absent in the spectrum of sunlight, and a faint line lying in the spectrum below the red was found intensified. By following out this plan we perhaps may eventually establish the existence of compounds in the solar photosphere. By using the light emanating from the white-hot carbon points of the magnetoelectric light to produce a continuous spectrum, and by burning the metallic compounds as before for one spectrum, and then by using sunlight to give the other spectrum, confirmatory evidence would be obtained. I may remark that I have photographed bright-line spectra of lithium, and got the same line in the ultra red as that obtained reversed. This method seems to promise to be a new weapon of attack in solar physics, more especially in this ultra-red portion.

L. On Spectra of Lightning.

By ARTHUR SCHUSTER, *Ph.D., F.R.A.S.**

ALL observers of lightning-spectra agree in having seen the line-spectrum of nitrogen; but most of them have seen, in addition to this, sometimes a continuous spectrum, sometimes a band spectrum, the chemical origin of which is unknown.

The following historical summary may give an idea of our knowledge on that point.

Prof. Kundt (*Pogg. Ann.* cxxxv. p. 315) observed a line spectrum consisting of one or two lines in the red, some very bright ones in the green, and some less bright ones in the blue. He mentions that the lines are not always seen together.

* Communicated by the Physical Society, having been read at the Meeting on February 22nd.

Lines which in one flash appeared especially bright were not seen in another flash. The greater number of flashes, however, gave a different spectrum altogether. In the place of bright lines a great number of bands were seen; and Prof. Kundt even distinguishes two different band spectra.

Mr. John Herschel (Proc. R. S. xvii. p. 61) observed a variable continuous spectrum crossed by bright lines, which also had a variable intensity. He gives the measurements of two lines, which agree very well with nitrogen-lines.

M. Laborde (*Les Mondes*, viii. p. 219) observed some lines, especially one near E, which sometimes appeared alone. He also saw a continuous spectrum.

Dr. H. Vogel (Pogg. *Ann.* cxliii. p. 653) describes lines only; but in his list I find two which do not coincide with any bright lines in the spectrum of the electric spark taken in atmospheric air; they do, however, coincide with two bands which I have observed in some flashes of lightning, as I shall show.

Mr. J. P. Joule ('*Nature*,' vol. xvi. p. 161) also observed some spectra of lightning. Frequently there was only one bright line visible, this being coincident with the brightest nitrogen-line. At other times there were several bright lines visible, sometimes with and sometimes without the green nitrogen-line. A continuous spectrum was also observed.

Mr. H. R. Proctor ('*Nature*,' vol. xvi. pp. 161 & 220) gives some measurements of lines which do not lay claim to any accuracy. He observed also a band spectrum, which he finds not to be the band spectrum of nitrogen.

From conversation with Prof. A. Young, I learned that he also had seen a line spectrum, a band spectrum, and a continuous spectrum.

During my stay in Colorado last summer, I had some good opportunities of studying the spectra of lightning. It was my intention to get some reliable measurements of the band spectrum which I, in common with most observers, have seen; and in order to have greater chance of succeeding, I confined myself to one part of the spectrum only. The part I chose extended from $\lambda = 5000$ to $\lambda = 5800$, and covered, therefore, most of the yellow and green. I used a direct-vision spectroscope, with a slit movable by means of a micrometer-screw. A bright line in the principal focus of the telescope formed a fiducial mark. Under ordinary circumstances, the slit is moved until the line to be measured forms a continuation of the bright line which reaches down into the centre of the field. I found, however, that the bands I wanted to measure were nearly as broad as the thin glass bar which carries the bright line; and I used the bar therefore simply as pointer.

The measurements were always made at night; and the spectroscope was left undisturbed until the following morning, when the Fraunhofer lines in the neighbourhood were measured, so that the wave-lengths of the measurements could be interpolated.

It is of course impossible to put a pointer on a band during the instantaneous flash; but a succession of flashes allows us to put the pointer successively nearer and nearer until we see it in coincidence with the band. In this way several readings of each band were obtained. The dispersive power of the spectroscopes was such that, with a higher-power eyepiece than the one used in this investigation, the nickel-line could be seen between the two sodium-lines. The distance between the two sodium-lines was such that the two readings of the slit differed by ten divisions of the micrometer, or one tenth of a whole revolution. With sunlight I can measure easily to the tenth part of the distance between the sodium-lines. I obtained measurements on three different nights. Unfortunately, the best nights for the work occurred before the Total Solar Eclipse, which had taken me out to Colorado. A desire to save my eyes prevented me from making as good use of these nights as I otherwise should have done.

July 25th, West Las Animas.—The whole horizon seemed to be almost constantly illuminated with lightning, generally sheet-lightning. I observed about thirty or forty different flashes. I often saw the bright nitrogen-lines 5002 and 5681. I did not take any measurements of these lines; but there can hardly be a doubt as to their position. I saw in the part of the spectrum which I was observing three bands, which, however, did not always appear together. The measurements reduced to wave-lengths will be given further on. Two measurements of the bands β and γ were obtained, but one only of the band α . The greatest difference between the two measurements amounts to three times the distance between the sodium-lines. This difference must be partly accounted for by the difficulty of the observation, partly by the fact that the spectroscope had only just been unpacked after the journey; and it was found next day that it was considerably out of adjustment. The micrometer-screw, also, owing to the heat and dust, had a considerable backlash; it was taken to pieces next day and cleaned, which greatly improved it.

August 3rd, Manitou.—Clouds were coming from the west over Pike's Peak; and strong flashes of lightning, partly sheet lightning, partly forked lightning, were observed. Only two measurements were secured. One of the bands measured was β . Prof. Arthur Wright, who was present, observed that one

spot of the sky was illuminated during some flashes with a strong blue light, looking like a fluorescent light. I pointed the spectroscope to that spot, and observed a single broad band in the green. I moved the pointer on it as well as I could; but not being able to get another flash to verify the measurement, I had to take the reading. The position of this band, which I call δ , is very doubtful.

August 18th, Salt-Lake City.—I only obtained one measurement of the band γ . The kind of lightning observed differed considerably from that of the preceding nights. The lightning was nearly all forked lightning; and the bright nitrogen-line came out very strongly. The bands were but seldom seen. In one flash I saw a series of lines in the green which I had never seen before. My impression is that they were at about equal distances from each other, decreasing in strength towards the red; so that the whole made an impression similar to that of a fluted band, such as those seen in the spectrum of aluminium oxide, but shading off towards the red.

In addition to the line and band spectra, I have on many occasions seen a continuous spectrum only.

The following Table contains all the measurements I have taken. I have added in the last column numbers contained in Dr. Vogel's list of lines. It will be seen that these coincide with two of the bands I have seen.

Band.	Date.	λ	Mean.	Vogel.
α .	July 25	5592	5592	
β .	July 25	5348	5334	5341
	July 25	5329		
	Aug. 3	5325		
γ .	July 25	5175	5182	5184
	July 25	5193		
	Aug. 18	5177		
δ .	Aug. 3	5260	5260	

In trying to identify these bands with known spectra we meet with an unexpected difficulty. Two of them unfortunately admit of two different interpretations. At first sight I was struck by the close agreement of α and γ with two bands of carbonic oxide. These bands fade away towards the blue; and their sharp edges have a wave-length of 5607 and 5197. Observing with the same spectroscope, and widening the slit as I did in observing the lightning, I can produce the same impression of an unshaded band; and taking a measurement of

the centres of the bands under these circumstances, I obtain $\lambda=5579$ and $\lambda=5180$, which agree within the limits of possible errors with the above values.

The ordinary spectrum of air, however, contains a band at 5178; so that, as far as mere position is concerned, one might well be taken for the other. I was, however, under the impression that I had sometimes seen this band without the chief nitrogen double line 5002-5; and as the yellow band of carbonic oxide was also apparently present, I stated with considerable confidence when I first wrote out this paper that I had observed the spectrum of carbonic oxide. It was only when I came to work out the position of the band δ that I began to have serious doubts as to the accuracy of this conclusion. The position of the band δ , as I have said, is very doubtful; I even thought it was possible that I had taken a very bad measurement of either β or γ , and felt at first inclined to reject it altogether. On working out its wave-length, however, I found that it was coincident with one of two strong bands, which are found at the negative pole of vacuum-tubes filled with oxygen. Now the second of the two bands is nearly coincident with the yellow band of carbonic oxide; so that, of the two bands which I at first thought belonged to that gas, one might be due to nitrogen, the other to oxygen, as seen at the negative pole.

The explanation of the band β is obvious. It is the brightest of the two green lines in the low-temperature spectrum of oxygen. Its wave-length, when seen under a pressure of about a millimetre, is 5329; but under higher pressures it widens more on the less-refrangible side than towards the blue, and may well appear as a band with its centre at 5334 or even 5341, as given by Vogel.

I have not been able to obtain this band from atmospheric air in vacuum-tubes, although I have tried the experiment under various pressures. If the so-called continuous discharge is allowed to pass, the band spectrum of nitrogen alone appears; if the disruptive discharge passes, the high-temperature spectrum of oxygen is superadded to the line spectrum of nitrogen. As regards the two bands α and γ , it does not seem to me to be possible at present to decide between the two interpretations which I have given. On the one hand, it seems improbable that the slight traces of carbonic acid known to exist in the atmosphere should reveal their presence in the spectrum; but, on the other hand, it is to be remarked that oxygen vacuum-tubes, which show the band β , always reveal the slightest trace of carbonic oxide. It is exceedingly difficult, though quite possible, to obtain the band β without the bands

α and γ . The measurement of δ , however uncertain, renders it probable that the spectrum of the negative pole in oxygen forms part of the spectrum of lightning; and on the whole I should feel inclined to attribute the band α to oxygen. I have shown in my paper on the spectrum of oxygen that this spectrum of the negative pole is due to an allotropic modification of oxygen (possibly ozone), and I have been able to obtain it, though only temporarily, in the positive part of the discharge. As regards the band γ , I have some difficulty in attributing it to nitrogen, and still think it probably due to carbonic oxide. During the observations I certainly felt convinced that it did not belong to the same spectrum as the chief lines of nitrogen, and I made a note that, on the contrary, it generally appeared together with β . It seemed sometimes to be present alone, and often to form the most prominent part of the whole spectrum. As the lines of the capillary part of an oxygen-tube are also present at the negative pole, together with the bands distinctive of that pole, I can best express my observations on the band spectrum of lightning by saying that it resembles in a remarkable way the spectrum which is found at the negative pole of a vacuum-tube filled with oxygen which is slightly contaminated with carbonic oxide.

LI. *On a Property of Vulgar Fractions.*
By J. W. L. GLAISHER, M.A., F.R.S.*

§ 1. **T**HE present paper relates principally to the following property of vulgar fractions:—If all the proper fractions in their lowest terms having numerators and denominators not exceeding a given number n , be written down in order of magnitude, then each of these fractions is equal to the fraction whose numerator and denominator are respectively equal to the sum of the numerators and denominators of the fractions on each side of it; for example, if $n=7$, the fractions are

$$\frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{2}{7}, \frac{2}{3}, \frac{3}{5}, \frac{3}{7}, \frac{4}{2}, \frac{4}{7}, \frac{5}{3}, \frac{5}{7}, \frac{6}{4}, \frac{6}{5}, \frac{7}{2}$$

and

$$\frac{1}{6} = \frac{1+1}{7+5}, \quad \frac{1}{5} = \frac{1+1}{6+4}, \quad \frac{1}{4} = \frac{1+2}{5+7}, \text{ \&c.}$$

This property was enunciated by Mr. John Farey in the Philosophical Magazine for May 1816 (vol. xlvii. pp. 385–386), and was shortly afterwards proved by Cauchy. There is an-

* Communicated by the Author.