

XIV.—*Note on Sir David Brewster's Line Y, in the infra-Red of the Solar Spectrum.* By C. PIAZZI SMYTH, Astronomer Royal for Scotland. (Plate XXXVII).

(Read 17th December 1883.)

Of all known examples in physical science, of simplifying, and at the same time "precisionising" some of its fundamental data, which might otherwise fall to be entangled in high numbers, none has been happier than FRAUNHOFER'S application of the letters of the alphabet to certain chief lines in the solar spectrum. Happy both in its conception by the inventor, and its universal acceptance since then by the world. Whence it comes to pass now, that in every country, whoever observes the solar spectrum at all, with whatever instrument, large or small, diffracting or refracting, and whether he holds to the undulatory, or any other theory of light, and catalogues spectral lines either in Wave-lengths or Wave-numbers, or merely in terms of the brass scale screwed to his instrument by a maker,—yet whenever he speaks of the line A, or B, or C, or any other so named by FRAUNHOFER, he singles out thereby from among thousands, exactly the same identical line which any and every other spectroscopist alludes to under the same simple letter.

Hardly less happy was the extension of the system made by our great specialist in optical physics, Sir DAVID BREWSTER, when, having discovered several lines in the infra-red of the solar spectrum, beyond or before FRAUNHOFER'S commencing line "great A"—he named them with the later letters of the alphabet, whose stock of symbols had not been more than half used up by FRAUNHOFER in reaching toward the further violet end of the spectrum. Hence, without disturbing any one of FRAUNHOFER'S lettered lines from red through green, to blue and violet, BREWSTER called his new line next beyond, or before great A in the "infra red," by the letter Z; the next before and outside that, Y; and the next before that again, X.

In so far, BREWSTER'S proceeding was quite as happy as FRAUNHOFER'S; and if his assigned letters have been lately misused or omitted in certain high quarters, that is not his fault, and perhaps not intentional on the part of those who have done so, but has arisen *firstly* from the difficulty that many observers have in seeing his lines in the ultra-red, on account of their exceeding faintness; and *secondly*, from some of them being Solar, and others Telluric, to a degree that even he himself had not fully anticipated. It would seem, therefore, to be high time, in BREWSTER'S own Society and Country, to come to a clearer understanding on the facts of his nomenclature, touching at least those three chief

lines X, Y, Z; and the case is all the more claimant just now, seeing that a very grand chemical identification has just been made out in France for one of them; but one, unhappily of late called after one letter by some persons, and another letter by others, a fruitful source of future trouble unless corrected speedily. I propose, therefore, to inquire here, by help of a few recent observations, and reference to many old ones, which is the right letter to employ for each of those three lines.

Sir DAVID BREWSTER'S activities in Solar-spectrum observation were in full force at his favourite Border seat of Allerly, in 1833, as evidenced by three spectroscopic papers in our volume of *Transactions* for that year; but the fullest and most authoritative publication on his new lines in the infra-red is that contained in his joint paper with Dr GLADSTONE in the *Philosophical Transactions of the Royal Society*, London, in 1860.

Of the longest spectrum-view contained in a plate accompanying that paper, I submit a portion copied by myself, as Strip No. 1 of my own plate now presented, with very little alteration, except slightly expanding it to suit my scale; and freely crossing and recrossing the lines representing both shade and the inevitable darkness at and about the very origin of spectrum light, which, beginning on the left-hand side of the picture, rapidly increases in intensity towards the right—FRAUNHOFER lines and bands therein always excepted.

As an observer, I like Sir DAVID'S drawing much, for its truthful representation of the real and necessary degree of darkness, in midst of, or antagonistically to, which the new lines had to be detected; a feature of Nature, this darkness at either end of the spectrum, so rarely introduced in modern spectrum drawings. And though the shade bands are rather too sharply defined on either edge, I recognise, in spite of the depreciatory comments of M. KIRCHOFF, that it is exceedingly like what appears at that end of the spectrum, when a spectroscope is under-prismed and over-telescoped. So too it must most eminently have been in Sir DAVID'S case, when he seems to have employed but one simple prism of not very heavy glass, and no less than a 5-foot achromatic telescope to look into it. But then it was BREWSTER'S eye that looked; so no wonder that he saw with it more than any of his predecessors, and most of his successors as well.

"The light less refrangible than A," say the conjoint authors at their page 150, "is red, but extremely faint, so faint indeed, that few observers of the spectrum have perhaps ever seen it; and the only drawing hitherto published of lines in it appears to be in a map of the solar spectrum by M. MATTHIESEN of Altona. He represents a few lines which, on comparison with fig. 1, may be identified as the band anterior to Y, Y itself, and the band Y¹. In order to map the lines and bands in this portion of the prismatic image, Sir DAVID BREWSTER was obliged to take extraordinary precautions. The telescope was lined with

black velvet, in order to exclude any reflected light; a low power was employed; the slit was made about the eighth, or tenth, of an inch wide,* and the eye of the observer was washed with water to cleanse the fluid that lubricates the cornea. The most prominent line in this space is that marked Y."

That last remark is quite to our purpose, and I trust the drawing-strip, No. 1, of the Plate now given, illustrates it perfectly, remembering that "great A" and "little a" are introduced merely to give milestone references to known parts of the spectrum, and a measuring test universally understood for scale.

Strip No. 2 represents some rude efforts of mine in 1871, with very unequal apparatus, to see something of this rare region of the ultra-red. The drawing is slightly altered from that in Vol. XIII. of the *Edinburgh Astronomical Observations*, inasmuch as the mere general appearances of many close, thin lines unmeasured, and of shading, improperly represented there by vertical lines, are here crossed diagonally and horizontally in such a manner that they cannot be understood to imply true, resolved spectral lines, or anything but shade only, symbolically expressed. And the chief result is thereby plainer than ever, *viz.*, that the Y line was better seen in a high summer, than a low winter, sun; a feature indicating it to be of Solar origin, and not of Earth's atmosphere, or "Telluric" intervention.

Strip No. 3 gives the two views of high and low sun, contained in the Royal Society's Himalaya spectrum, in their *Philosophical Transactions* for 1875. This drawing is on a smaller scale than their's; and their questionable shadings with vertical lines have been changed by me into diagonal lines; but otherwise it represents in exactly the same manner their very surprising negation of the visibility of Y in a high sun, but its abundant visibility, and that of BREWSTER'S Z also, in a low sun.

Strip No. 4 represents on a reduced scale my own observations (from Vol. XIV. of *Ed. Ast. Obs.*) made in Portugal in 1877, with a far more powerful spectroscope than I had ever possessed before, and which I had had constructed specially to look into this particular question of the visibility, or non-visibility, of the Y line in a very high, indeed almost Zenithal, sun. The result, as will be seen in the drawing, was to confirm the previous Edinburgh observation, and to show that Y was, with the sun near the zenith, most notably visible; BREWSTER'S X appearing next in strength; but Z only in the faintest manner possible, if at all.

Strip No. 5 is a very reduced copy of part of a magnificent work derived from photography by Captain ABNEY and Colonel FESTING, forming the Bakerian Lecture at the Royal Society for 1880.

* The distance of this slit is unfortunately not stated. It may have been at the other end of a long room, and was apparently unfurnished with any kind of collimator lens, in the improved manner introduced by Professor SWAN.

By dint of Captain ABNEY's really wonderful processes of changing the colour of silver for transmitted light, he was enabled to photograph not only all that part of the infra-red end of the solar spectrum discovered with so much pain and labour by BREWSTER, but to procure records of other lines, some of them very grand ones too, extending nearly three times as far away, and into what is, to the human eye, absolute, unmitigated darkness. There is, therefore, not the slightest intention here to compete with him in spectral range; and I have purposely left his spectrum strip bright and of full height up to the extreme left hand end of my paper, to indicate that his view extends very much further still in that same direction. The only point of difference in fact which I have with him and his distinguished fellow-labourer, or the Central Metropolitan Society which publishes their work, is,—that the very strong line, which from its place in the spectrum can be no other whatever than Y, he calls Z; and the letter Y he gives no place to.

Apparently Captain ABNEY and Colonel FESTING had not seen the real Z line at all; and with little doubt because they worked in a too high Sun for *it*, though excellent for their other, and chief, objects. For Strip 6 shows the result of three observations which I had the fortune to make during an unusually long, bright sun-shiny afternoon on the 30th of May last at the house No. 15 Royal Terrace, Edinburgh. The apparatus was moderate in power; there was no attempt to resolve bands into their very thin component lines; but only to note the main features of Y and Z, "Great A" being given in as a necessary mile-stone.

At 5^h 50^m P.M. then, of distinct lines, Y alone was visible outside Great A.

At 6^h 40^m P.M., with a lower Sun, besides Y, there was a suspicion of Z.
But

At 8^h 0^m P.M., with a very much lower Sun, there, besides Y nearly as before, stood out Z as quite a strong line, accompanied too with bands, and proving itself to be Telluric without a doubt.

Finally, Strip 7 represents what the ancient Greeks might have called the apotheosis of line Y, in its glorious identification at last by M. HENRI BECQUEREL, with a bright emission line of the same Solar Sodium (Na), which produces that grand turning-key to all the modern developments of Spectrum analysis, viz., the Solar lines D¹ and D².

The fullest account of this final confirmation of the Solar character of Y that I have yet seen is that contained in the *Comptes Rendus* for July 9, 1883, pp. 71-74, by M. HENRI BECQUEREL himself. He had been researching the infra-red spectrum of chemistry by his celebrated Father's method of the phenomena of Phosphorescence, and found two new distinct and widely separated salt lines to exist therein. He next proved the correspondence of both of them with two extra strong and equally widely separated lines at the same points of

the Solar spectrum. One, and the fainter of these two lines, was an immense distance further into visual darkness than any of the lines in my plate. It was even beyond Captain ABNEY's and Colonel FESTING's furthest photographic, being at 23 130 Wave Number. But the other, at 31 010 W.N.—to be freely taken as equivalent to our 30 860—is no less than BREWSTER'S Y, and is honourably mentioned by M. BECQUEREL as being such.

It is indeed so instructive, as well as encouraging, to find the line thus alluded to in Paris as "BREWSTER'S Y line," three years after that letter was expunged in London from the Solar spectrum, that I beg to conclude with M. HENRI BECQUEREL's own words thus :—

"La vapeur de sodium, qui est principalement caractérisée dans le spectre lumineux par la double raie D, présente dans l'infra-rouge deux très fortes raies caractéristiques dont les longueurs d'onde sont 819 (= W.N.Br. 31 010) et 1098 (= W.N.Br. 23 130). Ces raies sont les mêmes lorsqu'on volatilise dans l'arc, du sodium métallique ou du chlorure de sodium; elles coïncide avec deux fortes raies du spectre solaire.

"La raie λ 819 (W.N. 31 010) que l'on peut voir à l'œil nu avec un spectroscopie ordinaire, coïncide avec une des plus fortes raies du spectre infra-rouge du Soleil que BREWSTER avait vue, et désignée par la lettre Y.

"Dans les conditions où l'on dédouble les raies D, je n'ai pu dédoubler distinctement la raie Y."

POSTSCRIPT.

The above concluding remark of M. H. BECQUEREL is instructive to those who would desire to see for themselves this salt representative of BREWSTER'S Y line; for it shows that even in his "Arc" light, notwithstanding its necessary brilliance, that particular line must have been too faint for neat physical notation; and, indeed, unless an arc light can be prepared as bright as, or possibly still brighter intrinsically than, a high summer sun, such almost must be the result.

With the most powerful Bunsen gas burners, consuming any amount of Chloride of Sodium, the trial is quite hopeless; and even with 1-inch induction sparks, condensed by a half-gallon jar between platinum points, of which one rises through moistened salt, with the effect of making the D lines painfully bright, I have not succeeded in causing the same salt's Y line, or lines, to certainly appear.

I have, however, in the search found three air lines much further towards the infra-red than any of the standard list of air lines entered in Dr WATT's invaluable Index of Spectra, as compiled by him from the observations of the greater spectroscopists.

Though not quite so far to that end of the spectrum as certain two lines of Rubidium, yet being much more constant and more easily procured, these new lines may be useful to other researchers as references for spectrum place in that rather barren region. I give their approximate Wave-number readings therefore here, and have depicted their appearance in the last or "appended" spectrum strip of our table, desiring to remark only, in addition, that the middle line of the three is triple, the distance between its first and second components being rather greater, and between its second and third rather less, than the potassium $\alpha^{1 \text{ and } 2}$ pair, whose Wave-number places are 32 988 and 33 128, respectively; while all the three air lines appear fairly sharp, with a narrow slit, and under a dispersion of 12° A to H, combined with a magnifying power on the inspecting telescope of 15.

Air Line 1, Rel. Intensity=5, Wave-number place in Brit. Inch=32 693

Air Line 2,	{	Its "a" component, Intens.=5, W.N.Pl.	„	=33 944
		„ "b" „ „ =3, „ „	=34 071	
		„ "c" „ „ =2, „ „	=34 157	

Continuous spectrum begins soon after this, and goes on increasing towards the violet.

Air Line 3, Rel. Intensity=6, W.N.Pl. in Brit. Inch. =35 404

First Air Line in Dr WATTS' Index of Spectra, Intens=6, W.N.Pl.=38 470

NOTE ADDED ON MAY 30, 1884.

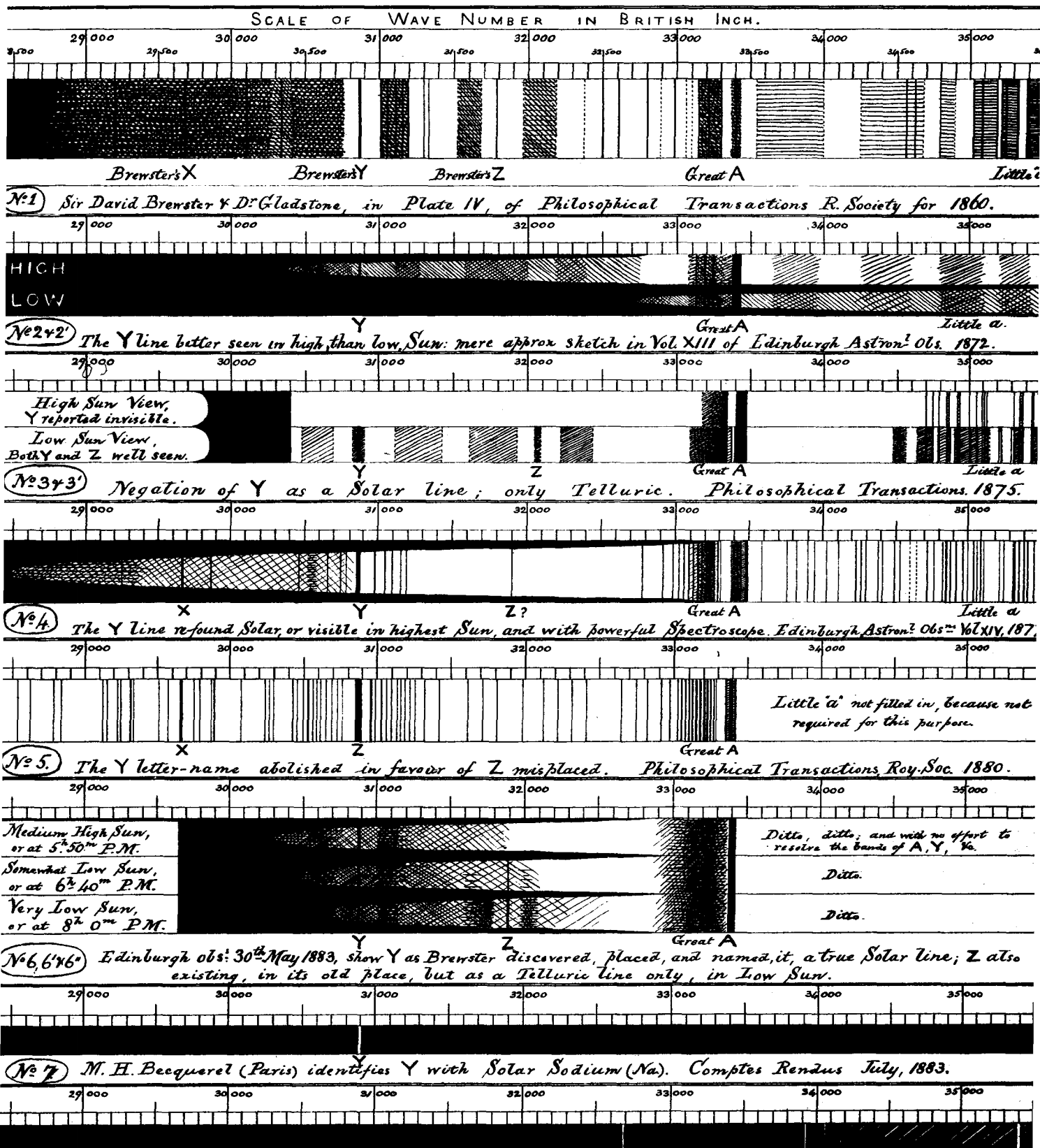
In the course of sundry spectroscopic experiments on vacuum tubes through the winter of 1883-4, and now communicated to Royal Society, Edinburgh, I have had abundant testimony that the first of the lines noted above, viz., at 32 693 Wave-number place, is an oxygen line; a very remarkable one too, for though like all other "tube," or simple-spark, oxygen lines, it is very faint,—yet it is well-defined, and is further towards the ultra red than any line or band I have yet come across in any of the other gases.

The triple line which follows I have equally proved to belong to nitrogen.

But to what gas, air line 3, at 35 404 Wave-number place belongs, I have obtained no indication as yet from vacuum tubes.

C. P. S.

APPROXIMATE SPECTRUM DRAWINGS FOR THE HISTORY OF SIR DAVID BREWSTER'S LINE Y IN THE INFRA-RED OF THE SOLAR SPECTRUM.



APPENDED. *New AIR LINES discovered in Edinburgh; November, 1883.*