

XXVI. "Report to the Committee on Solar Physics on the Basic Lines common to Spots and Prominences." By J. NORMAN LOCKYER, F.R.S. Communicated at the request of the Committee. Received June 19, 1879.

I have now for some time past been making efforts to bring together the various observations which have been recorded of the lines visible in solar disturbances at the sun's limb, and those observed to be widened, brightened or otherwise modified in the spectra of solar spots.

The result which stares us in the face when we examine the lists of the lines given by Young as representing his Sherman work is so striking, both with regard to the conclusions which we are justified in drawing from the old work, and the suggestions for future operations, that I have thought it desirable to call attention to it without waiting until the Italian observations have been discussed.

Although Young's observations of the chromospheric lines extend over the whole visible spectrum, the list of lines in the solar spots is limited to the region between B and *b*, I have therefore limited the discussion to this region.

As a basis for the discussion, I have used the lines given in Thalén's admirable tables, comparing these lists with the lines shown in Ångström's and Thalén's map, and indicating the intensities of the lines which are given in the tables, and which particular line occurs in the map only.

Further, as a discussion of the coincident lines shown in some sheets of Ångström's map, which I communicated to the Royal Society last March, had convinced me that the lines shown to be common to two or more substances by Thalén were not due to impurities ("Proceedings of the Royal Society," No. 194, 1879), I have shown these coincidences, where they occur, in a special column.

Having then Thalén's list for a basis, other columns showing us whether each line is seen in spots and prominences, and how it is affected, give us in one view, for each metallic substance, exactly what happens to the lines of that substance. We see at once, for instance, which lines are not touched, those again which are visibly affected both in spots and storms, or those recorded in one table and not in the other.

Taking all the lines included in the discussion, the following statistics will show how they are distributed :—

Total number of lines in Thalén's list and map included	
in the discussion.	345

s 2

Number of lines affected in spots.....	108
Number of lines bright in storms	122
Number of lines common to spots and storms	68
Number of lines seen in neither spots nor storms ...	183

So much for the list of lines as a whole : the following list shows the number of lines assigned to each metal, the number of lines which occur in both spots and storms, or only in one or the other, and the number of lines unaffected.

Metal.	Number of lines.	Number of lines common to spots and storms.	Number of lines due to		Unaffected.
			Spots.	Storms.	
Sodium	8	4	6	6	0
Magnesium.....	4	3	4	3	0
Barium	23	1	3	7	14
Calcium.....	25	7	15	10	7
Strontium.....	18	0	0	0	18
Nickel	12	1	3	2	8
Cobalt	19	3	3	3	16
Manganese	16	2	3	6	9
Cadmium	15	0	0	0	15
Chromium.....	14	3	3	5	9
Titanium.....	87	11	18	18	62
Iron.....	104	33	50	62	25
	345	68	108	122	183

It will be seen that the ratio between the affected and unaffected lines is very variable.

What strikes one indeed in regard to all these substances is the wonderful irregularity in the behaviour of the various lines; there is no relation for instance between the widening of the lines in the spots and their appearances in the prominences. As I have before shown, there is no relationship between the intensities of the lines and their appearances in the spots and storms.

Amongst the substances shown in the table I have included strontium, in order that the difference in its behaviour in comparison with calcium and barium may be seen.

But all these, however, are matters for subsequent discussion; what does come out in the strongest way is the following very remarkable fact.

Among the 345 lines given by Thalén are 18 with identical readings in two spectra. I have before given reasons to show that these are not due to mutual impurities, they therefore are the exact equivalents of those lines which I have termed basic in my communication of last December to the Royal Society.

If they be basic, then we should expect a considerable development of these lines in the spectrum of the sun's reversing layer, which spots and storms enable us to study apart from the absorption going on at higher levels.

These tables enable us to settle this question, and they settle it in the most conclusive way. The only constant thing about the tables is, that these basic lines are always widened in the spots. However badly the brighter lines of a chemical substance may be represented amongst the spot lines, the basic line, which is often of the second or third order of intensity and sometimes even of the fourth, is never absent.

The same fact holds almost equally true with regard to the storms.

The following table gives a comparison of these coincident lines of Thalén's with Young's tables.

Comparison of Thalén's coincident lines with those seen by Young
in solar spots and storms.

Thalén.			Young.		
Wave-length.	Common to	Intensity.	Spots.	Storms.	
			Widening.	Frequency.	Brightness.
5207·6	Fe Cr	3 1	4	10	6
5203·7	Fe Cr	3 1	4	10	6
5340·2	Fe Mn	2 3	2	1	2
6064·5	Fe Ti	2 2	3	5	2
5661·5	Fe Ti	3 1	4	15	2
5403·1	Fe Ti	2 3	4	5	3
5396·1	Fe Ti	2 2	7	4	2
5352·4	Fe Co	4 3	2	4	2
5265·8	Fe Co	2 3	2	10	4
5168·3	Fe Ni	3 5	4	40	30
5166·7	Fe Mg	2 1	2	30	20
5681·4	Fe Na	3 3	3	2	1
6121·2	Co Ca	1 3	4	5	3
5601·7	Ca Fe	4 1	2		
5597·2	Ca Fe	3 1	2		
5856·5	Ca Ni	3 4	2		
5425·0	Ba Ti	3 3	4		
6449·0	Ca Ba	2 3	2		

So far as my own knowledge of these matters goes, I can imagine no severer test to apply to the hypothesis which I have lately advanced, and to my mind the proof is conclusive that at the temperature of the sun's reversing layer, we have a mixed mass of vapours in which the base is more predominant than the chemical substances to which that base is common.

This result of the inquiry not only adds a new importance to the observations of spot and storm phenomena, but it suggests the precise work which should be done, both in the observatory and laboratory. Not only must special prominence be given to the brightening and thickening of these basic lines in spots and storms, but the existence or non-existence of them in other substances besides those indicated by Thalén, should be inquired into. This latter branch of work has indeed already been begun, since I have pointed out (in the "Proceedings," No. 194, 1879), in a table showing basic lines, that some lines in the blue and green seen many times by Young in storms, are common to many substances, the spectra of which were observed with a Rutherford's grating (second order, 17,000 lines).

In this work it will be well to include those lines which only differ by a tenth of Thalén's unit, although they have been rigorously rejected in the present discussion and tables. Young, indeed, included such lines, among his coincidences, the line at 5269·5 being a case in point which is widened in spots, and has been seen 50 times in storms.

Attention must also be directed to those lines which, like those shown in the following table, although seen both in spots and storms, have not yet been detected in the spectrum of any chemical substance.

List of lines seen more than ten times by Young in the storms, but which do not appear in Thalén's list or maps.

Wave-length.	Frequency.	Brightness.	Whether seen by Vogel in spots.	Whether seen in spots by Young.	Widening.
6515·5	15	4	Yes		
6453·8	10	6	Yes		
6429·9	20	4	Yes		
6346·1	10	4	Yes	Yes Ru. Ir.*	2
5990·0	10	4	Yes		
D ₃ 5874·9	100	90	Yes	Yes	2†
5275·0	30	15	..	Yes	2
5197·0	15	10			

* Ruthenium and iridium lines are not given in Thalén's list; the line in question is marked in the map without any remarks. In Ångström's map it is entered and marked as a line coincident with a line given by Ru, Ir.

† But sometimes reversed.

Iron.

Thalén.		Young.				Remarks.	
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.		
			If visible.	Widening.	If visible.		How many times.
6489·8	3	Seen by Vogel.	
6407·0	Map	..	..	Yes	5
6399·0	1	..	..	Yes	1
6392·6	Map	5	Vogel gives a line at 619·1.	
6357·7	Map	..	4	..	..
6300·3	3	..	..	Yes	8
6245·4	2	Yes	5	Vogel gives a line marked iron at 606·4, much thickened.	
6231·5	Map	..	..	Yes	2
6229·7	2	..	..	Yes	2
6199·6	Map	Yes	10	Vogel gives a line marked iron at 600·7.	
6190·5	2	..	2	Yes	3		
6148·1	Map	..	..	Yes	2
6135·6	2	..	3	Yes	5	Vogel gives a line marked iron at 600·7.	
6064·5	2	Ti	3	Yes	..		
6023·0	3	..	Double, nearly invisible in spot spectrum	Yes	..		
6019·1	4	..	Yes	..	..
6007·5	4	..	..	..	..
6002·1	4	..	..	..	..
5986·2	4	..	..	..	..

5574.9	2	..	Yes	2	Yes	40	5
5571.7	1	..	Yes	2	Yes	2	1
5568.5	2	..	Yes	2	Yes	2	1
5531.6	Map	..	..	..	..	1	1
5525.9	Map	..	..	..	..	10	4
5505.9	3	..	..	..	..	10	4
5500.5	3	..	..	..	..	8	3
5496.6	3	..	..	..	..	2	2
5486.8	4	..	..	..	..	2	2
5462.3	Map	..	..	..	..	2	2
5454.7	1	..	..	..	..	2	2
5445.9	1	..	..	..	..	2	2
5433.0	Map	..	..	..	..	2	2
5428.8	1	..	..	..	..	2	2
5423.6	Map	..	..	..	..	2	2
5414.5	Map	..	..	..	..	2	2
5410.0	Map	..	..	..	..	2	2
5404.8	2	..	..	..	..	2	2
5403.1	2	..	..	..	..	2	2
5396.1	2	Ti	Yes	4	Yes	2	1
5392.3	3	Ti	Yes	7	Yes	2	1
5392.2	Map	..	..	..	..	2	1
5382.3	3	..	..	..	..	2	1
5370.5	1	..	..	..	..	2	1
5369.0	3	..	..	..	..	2	1
5366.5	3	..	..	..	..	2	1
5364.0	3	..	..	..	..	2	1
5361.9	4	..	..	..	..	2	1
5352.4	4	Co	Yes	2	Yes	20	10
5348.6	4	..	..	..	..	4	2
5340.2	2	Mn	Yes	2	Yes	1	2
5339.2	2	..	Yes	2	Yes	1	2
5327.6	Map	..	..	..	..	5	2
5327.3	1	..	..	..	..	5	2
5327.1	Map	..	..	..	..	5	2
5323.4	2	..	..	..	..	5	2

Iron—continued.

Thalén.			Young.				Remarks.			
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.					
			If visible.	Widening.	If visible.	How many times.		Brightness.		
5315.9	2	..	Yes	Distinctly weakened and some-times re-versed	Yes	90	50	Thalén gives Ca line at 5269.4.		
5306.5	3		Yes			3	Yes		15	4
5301.5	3		Yes			3	Yes		12	3
5282.6	2		Yes			2	Yes		10	4
5280.9	3			..	Yes	1	2			
5269.5	1	..	..	..	Yes	3	1
5268.5	1	Co	..	..	Yes	4	2	
5265.8	2		Yes	2	Yes	1	3			
5262.4	4			2	Yes	10	3			
5254.1	Map	..	Yes	2	Yes	2	3			
5249.7	Map	..	Yes	2	Yes	10	3			
5246.3	Map	..	Yes	2	Yes	2	1			
5239.0	Map	..	Yes	2	Yes	3	2			
5232.1	1	..	Yes	2	Yes	3	2			
5229.0	Map	..	Yes	2	Yes	3	2			
5226.2	1	..	Yes	2	Yes	3	2			
5216.5	Map	..	Yes	2	Yes	3	2			
5215.5	Map	..	Yes	2	Yes	3	2			

Thalén gives Ca line at 5269.4.

Titanium—continued.

Thalén.		Young.				Remarks.
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.	
			If visible.	Widening.		
5978·0	1	..	Yes	4		
5977·1	Map		Yes	2		
5965·3	1	..				
5951·8	1					
5921·5	3					
5918·9	3					
5899·0	1					
5865·3	1	..	Yes	2		
5738·0	3					
5714·0	4					
5701·5	5					
5688·5	2					
5679·0	3					
5674·4	1					
5661·5	1	Fe	Yes	4	Yes	2
5647·0	4					15
5643·0	1					
5629·0	5					
5597·2	5					
5564·6	3					
5513·4	1	..	Yes	3		

5511.8	1	..	Yes	2	Yes	2	1	
5502.8	2							
5488.9	2							
5486.8	3							
5480.2	2				Yes	2	1	
5476.5	3							
5473.3	3							
5470.5	4							
5448.0	3							
5445.9	Map	..	Yes	4	Yes	10	4	Iron in tables.
5445.8	4							
5428.8	Map	..	Yes	3	Yes	8	3	Iron in tables.
5428.6	2							
5425.0	3	Ba	Yes	4				
5424.5	3	..	..	..	Yes	25	6	
5417.9	4	..	Yes	2	Yes	5	2	
5408.6	2							
5403.1	3	Fe	Yes	4	Yes	5	3	
5396.1	2	Fe	Yes	7	Yes	4	2	
5380.2	3	..	..	..	Yes	3	2	
5368.8	2							
5350.5	2							
5336.8	1							
5335.9	Map	..	..	..	Yes	5	2	
5298.5	3							
5296.7	1							
5295.5	3							
5287.8	4							
5282.8	1							
5271.5	4							
5267.2	4							
5265.0	2							
5262.9	4							
5259.6	4							
5255.0	4							

Titanium—*continued.*

Thalén.		Young.				Remarks.	
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.		
			If visible.	Widening.	If visible.		How many times.	Brightness.
5251.0	4						
5246.3	2						
5238.5	2						
5226.0	3				Yes	3	2
5224.3	Map	..	..	..
5223.0	1						
5217.5	4						
5209.5	1	..	Yes	4	Yes	1	2
5205.5	3						
5200.5	3						
5192.3	1						
5188.3	2						
5187.4	Map	..	Yes	3			
5187.3	Map	..	..	..	Yes	1	1
5185.1	3	..	..	..	Yes	5	2
5173.0	2						
5153.2	3						
5151.2	2						
5147.0	3						
5144.5	2						

Chromium.

5409.0	2	..	..	..	2	2
5342.5	5	..	..	Yes	2	
5341.0	5	..	..	Yes	1	1
5318.0	5	..	..	Yes	1	
5313.0	5	..	..	Yes	1	
5296.6	5	..	..	Yes	1	
5296.1	5	..	..	Yes	1	
5274.3	4	..	..	Yes	1	
5263.4	4	..	..	Yes	1	
5254.1	4	..	..	Yes	1	
5246.3	4	..	..	Yes	1	
5207.6	1	Fe	Yes	Yes	10	6
5205.2	1	..	Yes	Yes	10	6
5203.7	1	..	Yes	Yes	10	6

Cadmium.

6466.0	3	..	..	..	..	..
6438.1	Map	..	..	..	..	..
6438.0	1	..	..	..	..	..
6056.5	5	..	..	..	..	..
6003.5	5	..	..	..	..	..
5957.5	5	..	..	..	..	..
5913.0	5	..	..	..	..	..
5790.0	5	..	..	..	..	..
5687.0	4	..	..	..	..	..
5489.0	5	..	..	..	..	..
5471.0	4	..	..	..	..	..
5375.0	1	..	..	..	..	..
5335.7	1	..	..	..	..	..
5304.5	5	..	..	..	..	..
5153.0	4	..	..	..	..	..

Manganese.

Thalén.		Young.				Remarks.	
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.		
			If visible.	Widening.	If visible.		How many times.	Brightness.
6020·7	1						
6015·9	1						
6012·5	1						
5515·6	5						
5443·0	5						
5419·5	3						
5412·4	3	..	..	..	Yes	4	2
5406·5	5	..	Yes	4			
5399·6	4	..	..	..	Yes	2	1
5388·5	4						
5376·6	3						
5359·0	4						
5340·2	3	Fe	Yes	2	Yes	1	2
5254·1	4	..	Yes	2	Yes	1	2
5233·6	4	..	..	..	Yes	10	8
5195·2	4	..	..	..	Yes	1	1
Cobalt.							
6142·5	3						
6121·2	3	Ca	Yes	4	Yes	5	3
6003·5	2						
						Vogel gives Ca line, much thickened, at 612·1.	

5452.4	4					
5452.0	3					
5443.0	3					
5368.0	3					
5362.5	5					
5359.5	5					
5352.4	3	Fe	Yes	2	Yes	4
5351.2	3					
5342.6	5					
5342.1	5					
5279.6	3 double					
5267.2	5					
5265.8	3 double	Fe	Yes	2	Yes	10
5234.4	5					
5230.0	5					
5212.0	5					

Nickel.

3	6175.7	3	Yes	3	1	Vogel gives a calcium line at 585.6.
4	6115.3	4	Yes	2	Ca	..	1	
4	6107.5	4	Yes	..	..	Yes	40
1	5892.0	1	..	..	..	Yes	30
4	5856.5	4	..	..	Ca	..	1
3	5475.9	3	..	..	..	Yes	40
5	5175.6	5	Yes	4*	Fe	Yes	30	
5	5168.3	5	Yes	4*	Fe	Yes	30	
5	5155.1	5	Yes	4*	Fe	Yes	30	
5	5145.7	5	Yes	4*	Fe	Yes	30	
5	5142.0	5	Yes	4*	Fe	Yes	30	
5	5136.8	5	Yes	4*	Fe	Yes	30	

* But sometimes thinned, and even reversed.

Strontium.

Thalén.		Young.				Remarks.	
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.		
			If visible.	Widening.	If visible.		How many times.	Brightness.
6550·4	4	Seen by Vogel.*
6501·5	2						
6407·0	1						
6387·0	3						
6380·0	4						
5970·5	5						
5850·0	5						
5540·0	3						
5533·5	2						
5522·5	2						
5503·5	2						
5485·0	3*						
5480·0	1						
5256·0	2						
5238·5	1						
5228·5	3						
5225·3	3						
5223·5	3						

* The solar line here referred to is marked by Thalén in his map as due to iron, although in his tables he makes no mention of it. Kirchhoff gives the same solar line coincident with strontium, the wave-length of which, according to Thalén, is 6407, whilst the solar line is nearer 6407·2.

Calcium.

6498.0	2	..	Yes	3	Yes	5	2	Vogel gives a Ca line at 646.2. Seen by Vogel.
6492.1	1	..	..	..	Yes	..	..
6498.5	2	Ba	Yes	2	..	5	2	
6461.7	1	..	Yes	3	Yes	3	1	
6449.0	2	..	Yes	4 double	Yes	8	3	Vogel gives a Ca line at 616.1, very much thickened.
6438.1	1	..	Yes	4	Yes	5	3	Vogel gives a Ca line at 612.1, much thickened.
6168.3	2	..	Yes	4	Yes	3	2	Vogel gives a Ca line at 610.1, much thickened.
6161.2	1	Co	Yes	4	..	..	..	Vogel gives a Ca line at 585.6.
6121.2	1	..	Yes	4	Yes	..	..
6101.7	2	..	Yes	2	..	..	..
5856.5	3	Ni	Yes	2	..	..	..
5601.7	4	Fe	Yes	2	..	..	..
5600.2	3	..	Yes	2	..	..	..
5597.2	3	Fe	Yes	2	..	..	..
5593.4	2	..	Yes	2	..	..	..
5589.0	4	..	..	..	..	..	..
5587.6	1	..	..	..	..	..	..
5580.8	4	..	..	..	..	..	..
5348.6	2	..	Yes	3	..	..	..
5269.5	Map	..	Yes	3	..	..	..
5269.4	2	..	Yes	3	..	..	..
5264.5	3	..	Yes	2	..	..	..
5263.4	4	..	..	..	..	..	..
5263.3	Map	..	..	..	..	..	..
5261.2	5	..	..	..	..	..	..
5260.8	5	..	..	..	..	..	..
5188.2	3	..	Yes	3	..	..	..

Given as iron line in Thalén's list.

Barium.

Thalén.			Young.				Remarks.
Wave-lengths of lines.	Intensities.	Coincident with	Spots.		Prominences.		
			If visible.	Widening.	If visible.	How many times.		Brightness.
6526.6	3	..	..	..	Yes	18	5
6496.0	1	..	Yes	2	..	..	..
6483.0	3	Ca	..	..	Yes	25	10
6449.0	3	..	..	..	Yes	2	1
6343.0	1	..	..	..	Yes	2	1
6140.6	3	..	..	..	Yes	2	1
6109.9	3	..	..	..	Yes	2	1
6062.0	3	..	..	..	Yes	2	1
6018.0	3	..	..	..	Yes	2	1
5991.5	3	..	..	..	Yes	2	1
5971.0	3	..	..	..	Yes	2	1
5904.5	5	..	..	..	Yes	2	1
5852.7	Map	..	..	..	Yes	8	2
5852.5	1	..	..	..	Yes	8	2
5827.0	3	..	..	..	Yes	8	2
5808.5	5	..	..	..	Yes	8	2
5803.5	5	..	..	..	Yes	8	2
5779.5	3	..	..	..	Yes	8	2
5534.5	1	..	..	..	Yes	8	2
5534.1	Map	..	Yes	2	Yes	50	12
5521.5	3	..	..	..	Yes	15	2
5518.7	Map	..	..	..	Yes	15	2
5425.0	3	Ti	Yes	4	Yes	15	2

Seen by Vogel.

Magnesium.

5527.4	1	..	Yes	2	Yes	50	30	$\left. \begin{array}{l} b_1 \\ b_2 \\ b_3 \\ b_4 \end{array} \right\} \begin{array}{l} \text{Seen by Vogel.} \\ \text{Vogel marks this line at 516.7.} \end{array}$
5183.0	1	..	Yes	3*	Yes	50	35	
5172.0	1	..	Yes	3*	Yes	50	20	
5166.7	1	Fe	Yes	2	Yes	30		

* But sometimes thinned, and even reversed.

Sodium.

6160.0	2	..	Yes	4	Yes	50	30	$\left. \begin{array}{l} D_2 \\ D_1 \end{array} \right\} \begin{array}{l} \text{Seen by Vogel.} \\ \text{Seen by Vogel.} \end{array}$
6154.2	2	..	Yes	4	Yes	50	30	
5895.0	1	..	Yes	6*	Yes	50	1	
5889.0	1	..	Yes	6*	Yes	2	1	
5687.2	3	..	Yes	3	Yes	2	1	
5681.4	3	Fe	Yes	3	Yes	2	1	
5154.8	3	..	..	..	Yes	3	1	
5132.5	3	..	..	..	Yes	3	1	

* But sometimes reversed.