Suggested Mutual Repulsion of Fraunhofer Lines
By Charles E. St. John

THE correct interpretation of the results given by the spectroscope is so fundamental to progress in present day astronomy that every suggestion offering new points of view and avenues of approach to the problems furnished by the powerful instruments in commission deserves consideration. The spectrographs now used upon the sun yield spectra of such a scale and dispersion that minute changes in spectrum lines can be studied that were beyond the reach of the older instruments.

Changes in the relative position of spectrum lines are the phenomena most often under consideration. All astrophysicists recognize two conditions that produce displacements of the Fraunhofer lines, motion in the line of sight and differences in pressure, both capable of precise determination. Two others have been suggested, the gravitational effect of Einstein¹ and the anomalous dispersion hypothesis of Julius.² The former influence would displace all lines to a calculable amount and would, if found, add no serious difficulties to the solar problem. The effects of anomalous dispersion, however, would introduce an indeterminate factor into the spectroscopic problem. It becomes then a matter of prime importance to determine whether the relative positions of the Fraunhofer lines are measurably affected by this cause.

An accepted deduction from the theory is a mutual influence between neighboring lines, a quasi repulsion increasing with the proximity of the adjacent lines. The violet and red components of a close pair must then be displaced to the violet and red, respectively, in comparison with the displacement of the isolated lines of the same class. Displacements between the solar and arc lines give a direct and definite means of testing the question.

Iron, from its abundance of lines and the searching investigations given to them, furnishes the most reliable data. The wave lengths of the iron lines belonging to groups *a*, *b* and *c* of the Mount Wilson classification are independent of arc conditions.³ These lines therefore are capable of giving results of the highest possible precision. The mean sun-arc displacement for 213 lines of these groups is +0.0039 Å. Those who assign an important rôle to anomalous dispersion in the solar atmosphere assume that solar lines within 0.5 Å from each other are subject to mutual repulsion. The mean displacement for 30 lines with companions at an average distance of 0.314 Å to the red is +0.0042 Å; for 59 lines with companions at an average distance of 0.270 Å to the violet it is + 0.0040 Å. The displacements for the three cases are equal within the limits of accidental error, and, within such limits, the equality shows the absence of mutual influence.

Since a detectable mutual repulsion between adjacent solar lines should increase their separation over that determined from terrestrial sources, another approach to the question is found through such a comparison. It is usually assumed that repulsion occurs between all closely adjacent solar lines. For forty-five pairs, mean separation 0.29 Å, the differences $\Delta\lambda_{\text{Sun}} - \Delta\lambda_{\text{Arc}}$ are positive for seventeen, negative for twenty-one and zero for seven lines, the mean differences being zero. It has recently been suggested⁴ that repulsion is to be expected only if the line in the solar spectrum has a closely adjacent line due to another substance not present in the arc. The following data from re-

λ Rowland.		$\Delta\lambda$ Sun.	$\Delta\lambda$ Arc.	$\Delta\lambda_{\text{Sun}} - \Delta\lambda_{\text{Arc}}$
4058.915	Fe			
.081	Mn	.170	.173	—0.003
4226.904	Ca			
.606	Fe	.700	.710	—0.010
4315.138	Ti			
.262	Fe	.115	.115	0.000
4427.266	Ti			
.482	Fe	.215	.213	+0.002
4454.552	Fe			
.953	Ca	.399	.399	0.000
4489.911	Fe			
.253	Mn	.340	.340	0.000
5208.596	Cr			
.776	Fe	.169	.170	—0.001
5446.797	Ti			
.130	Fe	.332	.334	—0.002
Mean.....		.305	.307	—0.0018

cent determinations do not show the differences required by the theory, though the lines are due to different elements and originate in separate arcs.

¹Proceedings of the National Academy of Science.
²A. Einstein, *Leipzig, Ann. Phys.*, 35, 898 (1911).
³W. H. Julius, *Astrophys. J.*, 40, 1 (1914).
⁴*Trans. Internat. Union Co-op. Solar Res.*, 4, 74. Charles E. St. John and Harold D. Babcock, "A Study of the Pole Effect in the Iron Arc," *Mt. Wilson Contr.*, 106; *Astrophys. J.*, 46 (1915).
⁵Sir Joseph Larmor, *Observatory*, 497, 103 (1916).

Recently Albrecht⁵ found by comparing the Rowland and International wave-lengths of iron lines that the violet and red components of a solar pair showed apparent displacements to the violet and red of 0.007 and 0.005 Å, respectively. He interpreted these as effects of anomalous dispersion, an interpretation accepted by Julius, who says,⁶ "Only if the Fraunhofer lines are *mainly* due to anomalous dispersion will they be able to show a mutual influence of the observed kind and magnitude." The absence of mutual influence would, within the limits of error, remove any direct evidence that anomalous dispersion contributes to the production of the Fraunhofer lines.

As the Mount Wilson data for sun-arc displacements and for the comparative separation between close pairs of lines in solar and terrestrial spectra do not show the effect of mutual influence, it seems necessary to assume either that the Mount Wilson data are affected by systematic errors just sufficient to annihilate the effect of anomalous dispersion, or that the Rowland wave-lengths for lines in close pairs are systematically in error; a slight over-separation of such pairs would introduce an effect of the sign indicated by the theory. The results of an investigation upon "The Accuracy of the Measured Separations of Close Solar Pairs; Systematic Errors in the Rowland Table for such Lines" are given in a Contribution from this Observatory.⁷ For pairs consisting of lines of intensities 3 and 4, with mean separations of 0.274, 0.145 and 0.075 Å, the Rowland separations exceed the Mount Wilson values by 0.003, 0.008 and 0.013 Å, respectively. As errors of this sign and magnitude would account for the deviations found by Albrecht, an exhaustive examination of the cases included in Albrecht's list was undertaken; details of this investigation will appear in a Contribution from this Observatory.

The wave-lengths of the one hundred and four lines used by Albrecht have been referred to those of neighboring free-standing lines. The measurements have been made by two observers upon spectrograms of a scale and dispersion that previous experience had shown were best adapted to each case. The errors found in the Rowland values are systematic and of a sign and magnitude corresponding to the Albrecht deviations. This correspondence is marked, large and small values of the one being associated with large and small values of the other. The coefficient of correlation between the two sets of observations is $+0.55 \pm 0.05$, indicating that the correlation is a practical certainty. No explanation of this correlation seems possible other than that the errors in the Rowland wave-lengths and the Albrecht deviations are two phases of the same phenomenon, that in fact the deviations observed by Albrecht are a measurement of the Rowland errors.

Summary and Conclusion.—1. The violet and red components of close pairs of solar lines show the same displacement as isolated lines when compared with the spectrum of the arc.

2. The mean separation of close pairs in the solar spectrum is the same as that determined from terrestrial sources whether the component lines are due to the same or different elements.

3. The Rowland wave-lengths for close pairs of solar lines are systematically in error; the violet and red components being assigned values, respectively too small and too large.

4. The systematic deviations for lines with violet and red companions found by comparing the Rowland and International wave-lengths go *pari passu* with and are referable to the errors in Rowland wave-lengths. The coefficient of correlation is $+0.55 \pm 0.05$.

5. These systematic deviations, therefore, do not furnish evidence that the relative positions of the Fraunhofer lines are systematically displaced by mutual influence. On the other hand, the sun-arc displacements and the relative separation of the components of close pairs in solar and arc spectra indicate that, within the limits of error, evidence of mutual influence is absent from the solar spectrum, and, in so far as mutual influence is a necessary corollary of anomalous dispersion in the sun, evidence for it also is absent.

Gas From Peat

ACCORDING to a Friesland newspaper, the municipal gasworks at Akkrum in that province are extracting gas from peat mixed with coal. It is stated that if peat alone were used the retorts would become too hot, because of the steam created by the moisture always found in peat. Accordingly the retorts are filled with two parts in weight of coal to one of peat. The peat—as well as the coal—produces about 30 cubic meters of

⁵Sebastian Albrecht, *Astrophys. J.*, 41, 333 (1915).
⁶W. H. Julius, *Astrophys. J.*, 43, 53 (1916).
⁷Charles E. St. John and L. W. Ware, *Mt. Wilson Contr.*, *Astrophys. J.*—(1916).

gas per 100 kilogrammes (220 lb.), and, according to a report by the United States Consul at Amsterdam, the gas produced from this mixture is declared to be of excellent quality. The peat is entirely consumed in the process, and therefore yields no by-products, as coal does in tar and coke; but the use of peat is a great saving of coal, which is important in Holland now, where all coal, and particularly gas coal, is scarce, and has to be imported from a distance at heavy cost. Peat, on the other hand, is plentiful, particularly in Friesland, and is dug in the vicinity of the gasworks.

SCIENTIFIC AMERICAN
SUPPLEMENT
Founded 1876

NEW YORK, SATURDAY, OCTOBER 21st, 1916.
Published Weekly by Munn & Company, Incorporated
Charles Allen Munn, President; Frederick Converse Beach,
Secretary; Orson D. Munn, Treasurer;
all at 233 Broadway, New York
Entered at Post Office of New York, N. Y., as Second Class Matter
Copyright 1916 by Munn & Co., Inc.

The Scientific American Publications
Scientific American Supplement (established 1876) per year \$5.00
Scientific American (Established 1845) 4.00
The combined subscription rates and rates to foreign countries,
including Canada, will be furnished upon application
Remit by postal or express money order, bank draft or check
Munn & Co., Inc., 233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

Back Numbers of the Scientific American Supplement
SUPPLEMENTS bearing a date earlier than January 2nd, 1915, can be supplied by the H. W. Wilson Company, 39 Mamaroneck Avenue, White Plains, N. Y. Please order such back numbers from the Wilson Company. Supplements for January 2nd, 1915, and subsequent issues can be supplied at 10 cents each by Munn & Co., Inc., 233 Broadway, New York.

We wish to call attention to the fact that we are in a position to render competent services in every branch of patent or trade-mark work. Our staff is composed of mechanical, electrical and chemical experts, thoroughly trained to prepare and prosecute all patent applications, irrespective of the complex nature of the subject matter involved, or of the specialized, technical, or scientific knowledge required therefor.

We also have associates throughout the world, who assist in the prosecution of patent and trade-mark applications filed in all countries foreign to the United States.

MUNN & Co.,
Patent Solicitors,
Branch Office: 625 F Street, N. W.,
Washington, D. C. 233 Broadway,
New York, N. Y.

Table of Contents	
	PAGE
New Archaeological Lights.—I.—By Sir Arthur Evans....	258
Determining the Age of Blazes.—8 illustrations.....	260
Old Time Standard in Europe.....	260
A Fossil Nutmeg from the Tertiary of Texas.—By Edward W. Berry.....	261
The Dynamic Balance of Machines.—By Chas. L. Clarke.	262
Correspondence.—Bronze in Catskill Aqueduct.....	263
Locomotion and Behavior of Sea-Anemones.—By G. H. Parker	263
Healthy Animals Carry Diphtheria Germs.....	263
One of the Curious Trades of New York.—7 illustrations.	264
The Progress of Chemistry.—By Prof. G. G. Henderson..	264
Cocoon Products and Other Substitutes for Butter....	265
Hydrogen for Military Purposes.—By Edward M. Ardery.	266
Bacterized Peat.—The Problem in Relation to Plant Nutrition	267
Cactus Makes an Excellent Cattle Food.....	267
Optical Stress Analysis.—14 illustrations.....	268
Five Years' Progress in the Industrial Fellowship System	269
Armor Plate	270
Effect of Light on Solid Silver Chloride and Bromide....	271
Suggested Mutual Repulsion of Fraunhofer Lines.—By Charles E. St. John.....	272
Gas From Peat.....	272