June 6, 1872.

The Annual Meeting for the election of Fellows was held this day.

Mr. WILLIAM SPOTTISWOODE, M.A., Treasurer and Vice-President, in the Chair.

The Statutes relating to the election of Fellows having been read, Sir James Alderson and Prof. A. W. Williamson were, with the consent of the Society, nominated Scrutators to assist the Secretaries in examining the lists.

The votes of the Fellows present having been collected, the following Candidates were declared to be duly elected into the Society:—

Prof. William Grylls Adams, M.A.
Andrew Leith Adams, M.B.
Frederick Le Gros Clark, F.R.C.S.
Prof. John Cleland, M.D.
Prof. Michael Foster, M.D.
Prof. Wilson Fox, M.D.
Arthur Gamgee, M.D.
Rev. Thomas Hincks, B.A.
Prof. William Stanley Jevons, M.A.
Prof. George Johnson, M.D.
Prof. Thomas Rupert Jones.
Major Thomas George Montgomerie, R.E.
Edward Latham Ormerod, M.D.
Edward John Routh, M.A.
William James Russell, Ph.D.

Thanks were voted to the Scrutators.

June 13, 1872.

Sir JOHN LUBBOCK, Bart., Vice-President, in the Chair.

Mr. F. Le Gros Clark, Dr. Wilson Fox, Dr. George Johnson, Dr. E. Latham Ormerod, Mr. E. J. Routh, Dr. W. J. Russell, and Colonel Tennant were admitted into the Society.

The following communications were read:—

I. "On the Spectrum of the Great Nebula in Orion, and on the Motions of some Stars towards or from the Earth." By WILLIAM HUGGINS, LL.D., D.C.L., F.R.S. Received May 2, 1872.

In my early observations of the spectrum presented by the gaseous nebulæ, the spectroscope with which I determined the coincidence of two of the bright lines respectively with a line of nitrogen and a line of hydrogen was of insufficient dispersive power to show whether the brightest

nebular line was double, as is the case with the corresponding line of nitrogen.

Subsequently I took some pains to determine this important point by using a spectroscope of greater dispersive power. I found, however, that the light furnished by the telescope of eight inches aperture, to which the spectroscope was attached, was too feeble, even in the case of the brightest nebulæ, to give the line with sufficient distinctness when a narrow slit was used. The results of this later examination are given in a paper I had the honour of presenting to the Royal Society in 1868. I there say * :—"I expected that I might discover a duplicity in the line in the nebula corresponding to the two component lines of the line of nitrogen, but I was not able, after long and careful scrutiny, to see the line double. The line in the nebula was narrower than the double line of nitrogen; this latter line may have appeared broader in consequence of irradiation, as it was much brighter than the line in the nebula." When the spark was placed before the object-glass of the telescope, the light was so much weakened that one line only was visible in the spectroscope. "This line was the one which agrees in position with the line in the nebula, so that under these circumstances the spectrum of nitrogen appeared precisely similar to the spectra of those nebulæ of which the light is apparently monochromatic. This resemblance was made more complete by the faintness of the line; from which cause it appeared narrower, and the separate existence of its two components could no longer be detected. When the line was observed simultaneously with that in the nebula, it was found to appear but a very little broader than that line." I also remark:—"The double line in the nitrogen-spectrum does not consist of sharply defined lines, but each component is nebulous, and remains of a greater width than the image of the slit. The breadth of these lines appears to be connected with the conditions of tension and temperature of the gas. Plücker† states that when an induction-spark of great heating-power is employed, the lines expand so as to unite and form an undivided band. Even when the duplicity exists, the eye ceases to have the power to distinguish the component lines, if the intensity of the light be greatly diminished." I state further:—"I incline to the belief that it [the line in the nebula] is not double."

One of the first investigations which I proposed to myself when, by the kindness of the Royal Society, I had at my command a much more powerful telescope, was the determination of the true character of the bright line in the spectra of the nebulæ which is apparently coincident with that of nitrogen. From various circumstances, chiefly connected with the alterations and adjustments of new instruments, I was not able to accomplish this task satisfactorily until within the last few months.

Description of Apparatus.

It seems to me desirable to give a description of the spectroscopic

* Phil. Trans. 1868, pp. 542, 543.

† Phil. Trans. 1865, p. 13.

apparatus with which the observations in this paper were made. In the former paper, to which I have already referred, I gave some reasons* to show that the ordinary method of comparison, by reflecting light into the spectroscope by means of a small prism placed before one half of the slit, is not satisfactory for very delicate observations unless certain precautions are taken. I then describe an arrangement for this purpose, which, with one or two modifications, is adopted in the collimator constructed for use with the Royal Society's telescope. I give the description from that paper† :—

"The following arrangement for admitting the light from the spark appeared to me to be free from the objections which have been referred to, and to be in all respects adapted to meet the requirements of the case. In place of the small prism, two pieces of silvered glass were securely fixed before the slit at an angle of 45°. In a direction at right angles to that of the slit, an opening of about $\frac{1}{10}$ inch was left between the pieces of glass for the passage of the pencils from the object-glass. By means of this arrangement the spectrum of a star is seen accompanied by two spectra of comparison, one appearing above and the other below it. As the reflecting surfaces are about 0·5 inch from the slit, and the rays from the spark are divergent, the light reflected from the pieces of glass will have encroached upon the pencils from the object-glass by the time they reach the slit, and the upper and lower spectra of comparison will appear to overlap to a small extent the spectrum formed by the light from the object-glass. This condition of things is of great assistance to the eye in forming a judgment as to the absolute coincidence or otherwise of lines. For the purpose of avoiding some inconveniences which would arise from glass of the ordinary thickness, pieces of the thin glass used for the covers of microscopic objects were carefully selected, and these were silvered by floating them upon the surface of a silvering solution. In order to ensure that the induction-spark should always preserve the same position relatively to the mirror, a piece of sheet gutta percha was fixed above the silvered glass; in the plate of gutta percha, at the proper place, a small hole was made of about $\frac{1}{20}$ inch in diameter. The ebonite clamp containing the electrodes is so fixed as to permit the point of separation of these to be adjusted exactly over the small hole in the gutta percha. The adjustment of the parts of the apparatus was made by closing the end of the adapting-tube, by which the apparatus is attached to the telescope, with a diaphragm with a small central hole, before which a spirit-lamp was placed. When the lines from the induction-spark, in the two spectra of comparison, were seen to overlap exactly, for a short distance, the lines of sodium from the light of the lamp, the adjustment was considered perfect. The accuracy of adjustment has been confirmed by the exact coincidence of the three lines of magnesium with the component lines of *b* in the spectrum of the moon."

The modifications of this plan consist in the substitution of a thin silver

* Phil. Trans. 1868, pp. 537, 538. † *Ibid.* 1868, p. 538.

plate polished on both surfaces for the pieces of silvered glass. The opposite side of the silver plate to that from which the terrestrial light is reflected to the slit reflects the images formed by the object-glass to the side of the tube where a suitable eyepiece is fixed. This arrangement forms a very convenient finder, for it is easy to cause the image of the star to disappear in the hole in the silver plate. When this is the case, the line of light formed by the star falls on the slit, and its spectrum is visible in the spectroscope. This collimator is so constructed that, by means of a coupling-screw, any one of three spectroscopes can be conveniently attached to it.

This apparatus performs admirably; but it seemed to me desirable, for observations of great delicacy, to be able to dispense with reflection, and to place the source of the light for comparison directly before the slit. Formerly I accomplished this object by placing the spark or vacuum-tube before the object-glass of the telescope. The great length of the present telescope renders this method inconvenient; but a more important objection arises from the great diminution of the light when the spark is removed to a distance of 15 feet from the slit. I therefore resolved to place the spark or vacuum-tube within the telescope at a moderate distance from the slit. For this purpose holes were drilled in the tube opposite to each other, at a distance of 2 feet 6 inches within the principal focus. Before these holes short tubes were fixed with screws; in these tubes slide suitable holders for carrying electrodes or vacuum-tubes. The spark is thus brought at once nearly into the axis of the telescope. The final adjustment is made in the following manner:—A bright star is brought into the centre of the field of an ordinary eyepiece; the eyepiece is then pushed within the focus, when the wires or vacuum-tube can be seen across the circle of light formed by the star out of focus. The place of discharge between the electrodes, or the middle of the capillary part of the vacuum-tube, is then brought into the centre of the circle of light. The vacuum-tubes are covered with black paper, with the exception of a space about a $\frac{1}{4}$ inch long in the middle of the capillary part; through this small uncovered space the light passes to reach the slit.

The accuracy of both methods of comparison, that by reflection and that by the spark within the tube, was tested by the comparison of the three bright lines of magnesium and the double line of sodium with the Fraunhofer lines *b* and D in the spectrum of the moon. I greatly prefer the latter method, because it is free from several delicate adjustments which are necessary when the light is reflected and which are liable to be accidentally displaced.

Spectroscope A is furnished with a single prism of dense glass with a refracting angle of 59° 42′, giving 5° 6′ from A to H.

Spectroscope B has two compound prisms of Mr. Grubb's construction, which move automatically to positions of minimum deviation for the different parts of the spectrum. Each prism gives about 9° 6′ for minimum deviation from A to H.

Spectroscope C is furnished with four similar prisms.

The small telescopes of the three spectroscopes are of the same size: diameter of object-glass $1\frac{1}{4}$ inch; each is furnished with three eyepieces magnifying 5·5, 9·2, and 16·0 diameters.

Spectrum of the Nebula of Orion.

With spectroscopes A and B four* lines are seen; they are represented in the diagram which accompanies this note. The scale in the diagram gives wave-lengths.

First line.—With spectroscope B and eyepiece 1 and 2, the slit being made very narrow, this line was seen to be very narrow, of a width corresponding to the slit, and defined at both edges, and undoubtedly not double. The line of nitrogen when compared with it appeared double, and each component nebulous and broader than the line of the nebula. This latter line was seen on several nights to be apparently coincident with the middle of the less refrangible line of the double line of nitrogen. This observation was on one night confirmed by observation with the more powerful spectroscope C.

The question suggests itself whether, under any conditions of pressure and temperature, the double line of the nitrogen-spectrum becomes single; and further, if this should be found to be the case, whether the line becomes single by the fading out of its more refrangible component, or in what other way the single line of the nebula comes to occupy the position in the spectrum, not of the middle of the double line of nitrogen, but that of the less refangible of the lines.

I stated in my former paper that when for any reason the light from the luminous nitrogen is greatly reduced in intensity, the double line under consideration is the last to disappear, and consequently a state of things may be found in which the light of nitrogen is sensibly monochromatic when examined with a narrow slit†. Under these circumstances the line of nitrogen appears narrower, and the separate components can be detected with difficulty, if at all.

I stated also that the breadth of the component lines appears to be connected with the conditions of density and temperature of the gas. As was to be expected from theoretical considerations, the lines become narrower and less nebulous as the pressure is diminished. My observations of this change seemed to show that the diminution of the breadth of the lines takes place chiefly at the outer sides of the lines; so that in the light from very rarefied gas the double line is narrower, but the space of separation

* The fourth line was first seen in nebula 18 H. IV. (Phil. Trans. 1864, p. 441).

† Phil. Trans. 1868, pp. 540–546. Observations on this point were subsequently made by Frankland and Lockyer (Proc. Roy. Soc. vol. xvii. p. 453). It should be stated that the authors make no reference to this observation, though they refer to a purely hypothetical suggestion contained in the same paper.

between the components is not as much wider as would be the case if the lines had decreased equally in width on the sides towards each other.

When the pressure of the gas is reduced to about 15 inches of mercury, the line-spectrum fades out to give place to Plücker's spectrum of the first order. During this process a state of things occurs when, for reasons already stated, the spectrum becomes *sensibly* monochromatic when viewed with a narrow slit and a spectroscope of several prisms. The line is narrower but remains double, and has the characters described in the preceding paragraph.

As the pressure is diminished, the double line fades out entirely, and the spectrum of the second order gives place to the spectrum of the first order. When, however, the pressure becomes exceedingly small, from 0·1 inch to 0·05 inch, or less, of mercury, there is a condition of the discharge in which the line again appears, while the other lines remain very faint. Under these conditions I have always been able, though with some difficulty, on account of the faint light when the necessary dispersive power (spectroscope B with second or third eyepiece) and a narrow slit are used, to see the line to be double, but it is narrower than when the gas is more dense, and may be easily mistaken for a single line. I have not yet been able to find a condition of luminous nitrogen in which the line has the same characters as those presented by the line in the nebula, where it is single and of the width of the slit.

Upon the whole I am still inclined to regard the line in the nebula as probably due to nitrogen.

If this should be found to be the case, and that the nebular line has originally the refrangibility of the middle of the double line of nitrogen, then we should have evidence that the nebula is moving from the earth. The amount of displacement of the nebular line from the middle of the double line of nitrogen corresponds to a velocity of 55 miles per second from the earth. At the time of observation the part of the earth's orbital motion, which was from the nebula, was 14·9 miles per second. From the remaining 40 miles per second would have to be deducted the probable motion from the nebula due to the motion of the solar system in space. This estimation of the possible motion of the nebula can be regarded as only approximate.

If the want of accordance of the line in the nebula with the middle of the double line of nitrogen be due to a recession of the nebula in the line of sight, there should be a corresponding displacement of the third line as compared with that of hydrogen. For reasons which will be found in a subsequent paragraph, I have not been able to make this comparison with the necessary accuracy.

In my former paper* I gave reasons against supposing so large a motion in the nebula; these were based on the circumstance that the nebular line falls upon the double nitrogen line, which the present observations

* Phil. Trans. 1868, pp. 542, 543.

confirm. I was not then able to use a slit sufficiently narrow to show that the nebular line is single and not coincident with the middle of the double line of nitrogen.

I am still pursuing the investigation of the parts of this inquiry which remain unsettled.

Second line.—This line was found by my former comparisons to be a little less refrangible than a strong line in the spectrum of barium. Three sets of measures give for this line a wave-length of 4957 on Ångström's scale; this would show that the line agrees nearly in position with a strong line of iron. At present I am not able to suggest to what substance this line belongs.

This line is also narrow and defined. I suspect that the brightness of this line relatively to the first line varies in different nebulæ.

Third and fourth line.—My former observations show that these lines agree in position with two lines of the spectrum of hydrogen, that at F and the line near G.

These lines are very narrow and are defined; the hydrogen therefore must be at a low tension.

The brightness of these lines relatively to the first and second lines varies considerably in different nebulæ; and I suspect they may also vary in the same nebulæ at different times, and even in different parts of same nebula; but at present I have not sufficient evidence on these points*. I regret that, in consequence of a continuance of bad weather, I have not yet been able to obtain decisive observations as to the possible

* Since writing this sentence, I have seen a note by Prof. D'Arrest in the 'Astronomische Nachrichten,' No. 1885. Speaking of the nebula H. IV. 37, he says:—" Sein Spectrum ist ausser von Huggins bisher nur noch von Dr. H. Vogel untersucht worden. In No. 1864, Ast. Nachr. theilt Letzterer mit, dass er im Jahre 1871, im Widerspruch mit Huggins' Angabe, die Linie Neb. $(3)=(2)$, bisweilen sogar $(2)<(3)$ gefunden habe. Nach Huggins war dagegen im Jahre 1864 positiv $(2)>(3)$. Ist Vogel's Beobachtung, wie ich nicht bezweifle, zuverlässig, so wird seine Vermuthung einer Veränderung hier in der That begründet sein, denn diesen Winter, namentlich im Februar und März

motion of the nebula in the line of sight. With spectroscope B and eyepiece 2, the lines appear to be coincident with those of hydrogen. In consequence of the uncertainty of the character of the first line, which is single, while that of nitrogen is double, this determination can now only be made by means of the comparison of the third line with that of hydrogen. This third line becomes very faint from the great loss of light unavoidable in a spectroscope that gives a sufficient dispersive power, and the comparison can only be attempted when the sky is very clear and the nebula near the meridian.

(Received June 12, 1872.)

§ 2. *On the Motions of some Stars towards or from the Earth.*

In the early part of 1868 I had the honour of presenting to the Royal Society some observations on a small change of refrangibility which I had observed in a line in the spectrum of Sirius as compared with a line of hydrogen, from which it appeared that the star was moving from the earth with a velocity of about twenty-five miles per second, if the probable advance of the sun in space be taken into account *.

It is only within the last few months that I have found myself in possession of the necessary instrumental means to resume this inquiry, and since this time the prevalence of bad weather has left but few nights sufficiently fine for these delicate observations.

Some time was occupied in obtaining a perfectly trustworthy method of comparison of the spectra of stars with those of terrestrial substances, and it was not until I had arranged the spark within the tube, as described at the beginning of this note, that I felt confidence in the results of my observations.

It may be well to state some circumstances connected with these com-

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1872, fand ich wiederum, so wie es Huggins früher gesehen hat, unzweifelhaft (2) > (3). Die relative Intensität der drei Lichtarten habe ich mehrfach in Zahlen geschätzt und erhielt z. B. in den letzten Nächten:

	März 6.	März 13.
(1)	100	100
(2)	58	63
(3)	49	52"

* Phil. Trans. 1868, pp. 529–550. As a curious instance in which later methods of observation have been partially anticipated, a reference may be made to an ingenious paper in the Philosophical Transactions for 1783, vol. lxxiv., by the Rev. John Michell, entitled "On the means of discovering the Distance, Magnitude, &c. of the Fixed Stars, in consequence of the Diminution of the Velocity of their Light." The author suggests that by the use of a prism "we might be able to discover diminutions in the velocity of light as perhaps a hundredth, a two hundredth, a five hundredth, or even a thousandth part of the whole." But he then goes on to reason on the production of this diminished velocity by the attraction produced on the material particles of light by the matter of the stars, and that the diminutions stated above would be "occasioned by spheres whose diameter should be to the sun, provided they were of the same density, in the several proportions of 70, 50, 30, and 22 to 1 respectively."

parisons which necessarily make the numerical estimations given further on less accurate than I could wish. Even when spectroscope C, containing four compound prisms, and a magnifying-power of 16 diameters are used, the amount of the change of refrangibility to be observed appears very small. The probable error of these estimations is therefore large, as a shift corresponding to five miles per second (about $\frac{1}{40}$ of the distance of D^1 to D^2), or even a somewhat greater velocity, could not be certainly observed. The difficulty arising from the apparent smallness of the change of refrangibility is greatly increased by some other circumstances. The star's light is faint when a narrow slit is used, and the lines, except on very fine nights, cannot be steadily seen, in consequence of the movements in our atmosphere. Further, when the slit is narrow, the clock's motion is not uniform enough to keep the spectrum steadily in view; for these reasons I found it necessary to adopt the method of estimation by comparing the shift with a wire of known thickness, or with the interval between a pair of close lines. I found that, under the circumstances, the use of a micrometer would have given the appearance only of greater accuracy. I wish it, therefore, to be understood that I regard the following estimations as provisional only, as I hope, by means of apparatus now being constructed, to be able to get more accurate determinations of the velocity of the motions.

Sirius.—The comparison of the line at F with the corresponding line of hydrogen was made on several nights from January 18 to March 5. Spectroscope C and eyepieces 2 and 3 were used. These observations confirm the conclusion arrived at in my former paper, that the star is moving from the earth; but they ascribe to the star a velocity smaller than that which I then obtained.

These observations on different days show a change of refrangibility corresponding to a velocity of from 26 miles to 36 miles per second. The part of the earth's orbital motion from the star varied on these days from 10 miles to 14 miles per second. We may take, therefore, 18 to 22 miles per second as due to the star.

The difference of this estimate, which is probably below rather than in excess of the true amount, from that which I formerly made may be due in part or entirely to the less perfect instruments then at my command. At the same time, if Sirius be moving in an elliptic orbit, as suggested by Dr. Peters, that part of the star's proper motion which is in the direction of the visual ray would constantly vary*.

* Dr. H. Vogel at Bothkamp seems to have repeated my observations on Sirius with the necessary care. He says (Astron. Nachr. No. 1864):—"Mit der eben beschriebenen Anordnung gelang es Herrn Dr. Lohse und mir am 22. März (1871) bei ganz vorzüglicher Luft die Nichtcoincidenz der drei Wasserstofflinien H α, H β, und H γ, der Geissler'schen Röhre mit den entsprechenden Linien des Siriusspectrum zu sehen...... mit Berücksichtigung der Geschwindigkeit der Erde zur Zeit der Beobachtung berechnet sich die Geschwindigkeit mit welcher sich Sirius von der Erde bewegt zu 10·0 Meilen in der Secunde, wogegen Procyon sich 13·8 Meilen in der Secunde von unserer Erde entfernen würde."

Betelgeux (*α Orionis*).—In the early observations of Dr. Miller and myself on this star, we found that there are no strong lines coincident with the hydrogen lines at C and F. The line H α falls on the less refrangible side of a small group of strong lines, and H β occurs in the space between two groups of strong lines where the lines are faint. On one night of unusual steadiness of the air, when the finer lines in the star's spectrum were seen with more than ordinary distinctness, I was able with the more powerful instruments now at my command to see a narrow defined line in the red apparently coincident with H α, and a similar line at the position of H β. These lines are much less intense than the lines C and F in the solar spectrum; there are certainly no bright lines in the star's spectrum at these places.

The most suitable lines in this star for comparison with terrestrial substances for ascertaining the star's motion are the lines of sodium and of magnesium. The double character of the one line agreeing exactly with that of sodium, and the further circumstance that the more refrangible of the lines is the stronger one, as is the case in spectrum of sodium and in the solar spectrum, and the relative distances from each other and comparative brightness of the three lines, which correspond precisely to the triple group of magnesium, can allow of no doubt that these lines in the star are really produced by the vapours of these substances existing there, and that we may therefore safely take any small displacement of either set of lines to show a motion of the star towards or from the earth. The lines due to sodium are perhaps more intense, but are as narrow and defined as the lines D_1, D_2 in the solar spectrum: they fall, however, within a group of very fine lines; this circumstance may possibly account for the nebulous character which has been assigned to them by some observers.

The bright lines of sodium were compared with spectroscope B and eyepiece 3; they appeared to fall very slightly above the pair in the star, showing that the stellar lines had been degraded by the star's motion from the earth. The amount of displacement was estimated at about one fifth of the distance of D_1 from D_2, which is probably rather smaller than the true amount. This estimation would give a velocity of separation of 37 miles per second. At the time of observation the earth was moving from the star at about 15 miles per second, leaving 29 miles to be due to the star.

When magnesium was compared, a shift in the same direction, and corresponding in extent to about the same velocity of recession, was observed; but, in consequence of other lines in the star at this place, the former estimation, based on the displacement of the lines of sodium, was considered to be more satisfactory.

Rigel.—The lines of hydrogen are strong in the spectrum of this star, and are suitable for comparison.

The line H β is not so broad as it appears in the spectrum of Sirius, but is stronger than F in the solar spectrum: this line was compared by

means of spectroscope C and eyepieces 2 and 3. The line of terrestrial hydrogen falls above the middle of the line in the star; the star is therefore receding from the earth. The velocity of recession may be estimated as rather smaller than Sirius, probably about 30 miles per second, the earth at the time of observation moving from the star with a velocity of 15 miles, leaving about 15 miles as due to the star. This estimate is probably rather smaller than the true velocity of the star.

Castor.—The spectra of the two component stars of this double star blend in the spectroscope into one spectrum. The line H β is rather broad, nearly as much so as the same line in the spectrum of Sirius.

The narrow line of rarefied hydrogen was compared in spectroscope B with eyepiece 3; it appeared to fall on the more refrangible side of the middle of the line in the star, leaving more of the dark line on the side towards the red. The shift seemed to be rather greater than that in Sirius, and may probably be taken at from 40 to 45 miles per second; but the earth's orbital motion was nearly 17 miles from the star, thu sleaving about 25 miles for the apparent velocity of the star. This result rests at present on observations on one night only, but they seemed at the time to be satisfactory.

Regulus.—The line at F rather broad. The corresponding line of hydrogen falls on the more refrangible side of the middle of the dark line in the star. The air was unfavourable on all the evenings of comparison; a rough estimate gives a velocity of from 30 to 35 per second. The earth's motion was 18 miles, leaving from 12 to 17 miles for the velocity of recession between the star and the sun.

β and δ Leonis.—These stars were compared with hydrogen; they appear to be moving from the earth, but the want of steadiness in the air prevented me from making a satisfactory estimate of their velocity. I suspected their motion to be rather smaller than that of Regulus.

β, γ, δ, ε, ζ *Ursæ majoris.*—All these stars have similar spectra, in which the line F is strong, though there are small differences in the breadth of the line. They were compared with hydrogen, and appear to be moving from our system with about the same velocity. Probably their motion may be taken to be not far from 30 miles per second. The earth's motion at the time of observation was from 9 miles to 13 miles from these stars, leaving a probable velocity of recession of 17 to 29 miles per second. In the case of the double star ζ, the spectrum consisted of the light of both stars.

η *Ursæ majoris* was also compared with hydrogen. I believe it shows a motion from the earth, but the observations of this star are at present less satisfactory.

α Virginis and α Coronæ borealis.—These stars were compared with hydrogen. I suspect that they are receding, but I have not had nights sufficiently fine to enable me to make satisfactory observations of these stars.

In addition to these stars some observations (which are less satisfactory

on account of the unfavourable state of the weather at the time) appear to show that the stars Procyon, Capella, and possibly Aldebaran, are moving from the earth.

The stars which follow have a motion of approach.

Arcturus.—In the spectrum of this star the lines of hydrogen, of magnesium, and of sodium are sufficiently distinct for comparison. I found the comparison could be most satisfactorily made with magnesium.

The bright lines of magnesium fall on the less refrangible side of the corresponding dark lines in the star's spectrum, showing that the star is approaching the earth. I estimated the shift at about $\frac{1}{5}$ to $\frac{1}{4}$ of the interval between Mg_2 and Mg_3; this amount of displacement would indicate a velocity of approach of 50 miles per second. To this velocity must be added the earth's orbital motion from the star of 5·25 miles per second, increasing the star's motion to 55 miles per second.

When I can get favourable weather, I hope to obtain independent estimations from the lines of sodium and of hydrogen.

α Lyræ.—In the spectrum of Vega the line corresponding to $H\beta$ is strong and broad. Comparisons were made on several nights, but on one evening only was the air favourable. The observations are accordant in showing that the narrow bright line from a Geissler's tube falls on the less refrangible side of the middle of the line in the star, thus leaving more of the line on the side towards the violet. The estimations give a motion of approach between the earth and the star of from 40 to 50 miles per second, to which must be added 3·9 miles for the earth's motion from the star.

α Cygni.—The hydrogen line at F in the spectrum of this star is narrower than in the spectrum of Sirius and of *α* Lyræ, though probably rather broader than the same line in the solar spectrum. I have at present observations made on two evenings only, on both of which the state of the air was unfavourable for the comparison of this line with that of terrestrial hydrogen. They give to the star a motion of approach of about 30 miles per second, which would have to be increased by 9 miles, the velocity at the time of the earth from the star.

Pollux.—The lines of magnesium and those of sodium are very distinct in the spectrum of this star. As the air was not very steady at the time of my observations, I found it more satisfactory to use for comparison the lines of magnesium, which are rather stronger than those of sodium. The three lines of magnesium appeared to be less refrangible than the corresponding dark lines in the spectrum of the star by about one sixth of the interval from Mg_2 to Mg_3. This estimation would represent a velocity of approach equal to about 32 miles per second. The earth's motion from the star was 17·5 miles, which increases the apparent velocity of approach to 49 miles per second. On one evening only was the air favourable enough for a numerical estimate, but the observations were entered in my observatory-book as satisfactory.

α Ursæ majoris.—The spectrum of this star is different from the spectra of the other bright stars of this constellation. The line at F is not so strong, while the lines at *b* are more distinct, and are sufficiently strong for comparison with the bright lines of magnesium. The bright lines of this metal fall on the less refrangible side of the dark lines, and show a motion of approach of from 35 to 50 miles per second. The earth's motion of 11·8 miles from the star must be added.

γ Leonis and ε Boötis.—In both these double stars the compound spectrum due to the light of both component stars was observed. Both stars are most conveniently compared with magnesium. I do not consider my observations of these stars as quite satisfactory, but they seem to show a movement of approach; but further observations are desirable.

The stars *γ Cygni*, *α Pegasi*, *γ Pegasi*, and *α Andromedæ* were compared with hydrogen on one night only. It is probable that these stars are approaching the earth, but I wish to reobserve them before any numerical estimate is given of their motion.

γ Cassiopeiæ.—On two nights I compared the bright lines which are present in its spectrum at C and F with the bright lines of terrestrial hydrogen. The coincidence appeared nearly perfect in spectroscope C with eyepieces 2 and 3; but on the night of best definition I suspected a minute displacement of the bright line towards the red when compared with H β. As the earth's orbital motion from the star at the time was very small, about 3·25 miles per second, which corresponds to a shift that could not be detected in the spectroscope, it seems probable that γ Cassiopeiæ has a small motion of recession.

In the calculation of the estimated velocities the wave-lengths employed are those given by Ångström in his 'Recherches sur le spectre solaire' (Upsal, 1868). The velocity of light was taken at 185,000 miles per second.

The velocities of approach and of recession which have been assigned to the stars in this paper represent the whole of the motion in the line of sight which exists between them and the sun. As we know that the sun is moving in space, a certain part of these observed velocities must be due to the solar motion. I have not attempted to make this correction, because, though the direction of the sun's motion seems to be satisfactorily ascertained, any estimate that can be made at present of the actual velocity with which he is advancing must rest upon suppositions, more or less arbitrary, of the average distance of stars of different magnitudes. It seems not improbable that this part of the stars' motions may be larger than would result from Otto Struve's calculations, which give, on the supposition that the average parallax of a star of the first magnitude is equal to $0''\cdot209$, a velocity but little greater than one fourth of the earth's annual motion in its orbit.

It will be observed that, speaking generally, the stars which the spectro-

scope shows to be moving from the earth (Sirius, Betelgeux, Rigel, Procyon) are situated in a part of the heavens opposite to Hercules, towards which the sun is advancing, while the stars in the neighbourhood of this region, as Arcturus, Vega, α Cygni, show a motion of approach. There are in the stars already observed exceptions to this general statement; and there are some other considerations which appear to show that the sun's motion in space is not the only or even, in all cases, as it may be found, the chief cause of the observed proper motions of the stars*.

There can be little doubt but that in the observed stellar movements we have to do with two other independent motions—namely, a movement common to certain groups of stars, and also a motion peculiar to each star.

Mr. Proctor has brought to light strong evidence in favour of the drift of stars in groups having a community of motion by his graphical investigation of the proper motions of all the stars in the catalogues of Mr. Main and Mr. Stone†. The probability of the stars being collected into systems was early suggested by Michell and the elder Herschel‡. One of the most remarkable instances pointed out by Mr. Proctor are the stars β, γ, δ, ε, ζ of the Great Bear, which have a community of proper motions§, while α and η of the same constellation have a proper motion in the opposite direction. Now, the spectroscopic observations show that the stars β,

* As the velocities assigned to the stars are, for reasons already stated, provisional only, I feel some hesitation in drawing from them the obvious conclusions which they would suggest. The velocities given in the Tables for those stars which are moving in direction in accordance with the sun's motion towards Hercules do not bear to each other the relation which they should have if they were mainly produced by the sun's motion. Even for these stars, therefore, we must look elsewhere for the cause to which they are chiefly due.

† See "Preliminary Paper on certain Drifting Motions of the Stars," Proc. Roy. Soc. vol. xviii. p. 169.

‡ Sir William Herschel writes:—"Mr. Michell's admirable idea of the stars being collected into systems appears to be extremely well founded, and is every day more confirmed by observations, though this does not take away the probability of many stars being still as it were solitary, or, if I may use the expression, intersystematical ...... A star, or sun such as ours, may have a proper motion within its own system of stars, while at the same time the whole starry system to which it belongs may have another proper motion totally different in quantity and direction." Herschel further says, "And should there be found in any particular part of the heavens a concurrence of proper motions of quite a different direction, we shall then begin to form some conjectures which stars may possibly belong to ours, and which to other systems."—Phil. Trans. 1783, pp. 276, 277.

§ Mr. Proctor, speaking of these stars, says:—"Their drift is, I think, most significant. If, in truth, the parallelism and equality of motion are to be regarded as accidental, the coincidence is one of most remarkable character. But such an interpretation can hardly be looked upon as admissible when we remember that the peculiarity is only one of a series of instances, some of which are scarcely less striking."—Other Worlds than Ours, p. 269. See paper in Proc. Roy. Soc. vol. xviii. p. 170.

γ, δ, ϵ, ζ have also a common motion of recession, while the star α is approaching the earth. The star η, indeed, appears to be moving from us, but it is too far from α to be regarded as a companion to that star.

Although it was not to be expected that a concurrence would always be found between the proper motions which indicate the apparent motions at right angles to the line of sight and the radial motions as discovered by the spectroscope, still it is interesting to remark that in the case of the stars Castor and Pollux, one of which is approaching and the other receding, their proper motions also are different in direction and in amount; and further, that γ Leonis, which has an opposite radial motion to α and β of the same constellation, differs from these stars in the direction of its proper motion.

It scarcely needs remark that the difference in breadth of the line H β in different stars affords us information of the difference of density of the gas by which the lines of absorption are produced. A discussion of the observations in reference to this point, and other considerations on the physical condition of the stars and nebulæ, I prefer to reserve for the present.

Table I.—Stars moving from Sun.

Star.	Compared with	Apparent motion.	Earth's motion.	Motion from sun.
Sirius	H	26 to 36	−10 to 14	18 to 22
Betelgeux	Na	37	−15	22
Rigel	H	30	−15	15
Castor	H	40 to 45	−17	23 to 28
Regulus	H	30 to 35	−18	12 to 17
β Ursæ majoris	H }			
γ " "	H }			
δ " "	H }	30	− 9 to 13	17 to 21
ϵ " "	H }			
ζ " "	H }			
β Leonis	H			
δ Leonis	H			
η Ursæ majoris	H			
α Virginis	H			
α Coronæ borealis	H			
Procyon	H			
Capella	H			
Aldebaran ?	Mg			
γ Cassiopeiæ	H			

TABLE II.—Stars approaching the Sun.

Star.	Compared with	Apparent motion.	Earth's motion.	Motion towards sun.
Arcturus	Mg	50	+ 5	55
Vega	H	40 to 50	+ 3·9	44 to 54
α Cygni	H	30	+ 9	39
Pollux	Mg	32	+17	49
α Ursæ majoris	Mg	35 to 50	+11	46 to 60
γ Leonis	Mg			
ε Boötis	Mg			
γ Cygni	H			
α Pegasi	H			
γ Pegasi?	H			
α Andromedæ	H			

II. "On Blood-relationship." By FRANCIS GALTON, F.R.S.

Received May 7, 1872.

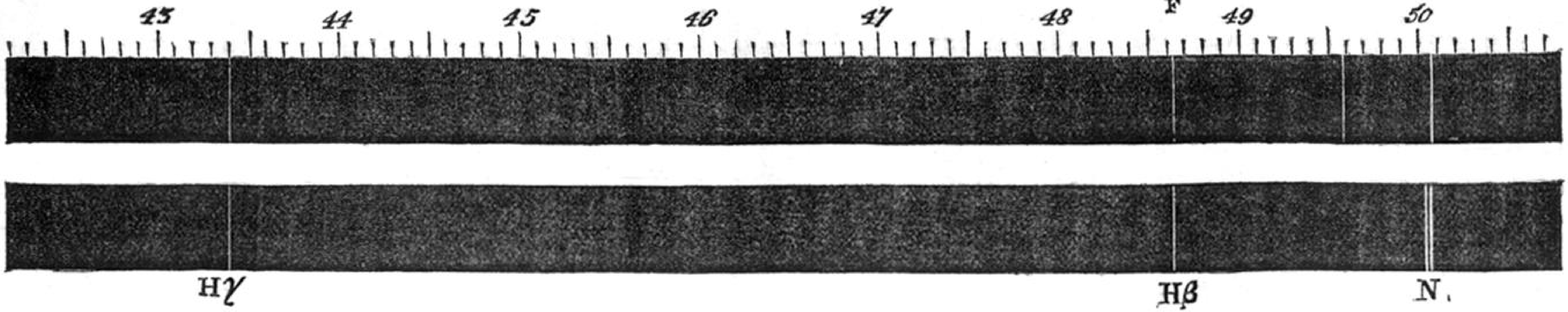
I propose in this memoir to deduce, by fair reasoning from acknowledged facts, a more definite notion than now exists of the meaning of the word "kinship." It is my aim to analyze and describe the complicated connexion that binds an individual, hereditarily, to his parents and to his brothers and sisters, and, therefore, by an extension of similar links, to his more distant kinsfolk. I hope by these means to set forth the doctrines of heredity in a more orderly and explicit manner than is otherwise practicable.

From the well-known circumstance that an individual may transmit to his descendants ancestral qualities which he does not himself possess, we are assured that they could not have been altogether destroyed in him, but must have maintained their existence in a latent form. Therefore each individual may properly be conceived as consisting of two parts, one of which is latent and only known to us by its effects on his posterity, while the other is patent, and constitutes the person manifest to our senses.

The adjacent and, in a broad sense, separate lines of growth in which the patent and latent elements are situated, diverge from a common group and converge to a common contribution, because they were both evolved out of elements contained in a structureless ovum, and they, jointly, contribute the elements which form the structureless ova of their offspring.

The annexed diagram illustrates my meaning, and serves to show clearly that the span of each of the links in the general chain of heredity extends from one structureless stage to another, and not from person to person:—

Structureless elements in Father	{ ....Adult Father .... } { ....Latent in Father........ }	Structureless elements in offspring.



43
44
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F
49
50
Hγ
Hβ
N.