These places were obtained thus:—

1st and 2nd are each the combination of two Windsor (N.S.W.) observations, which were in both cases checked by Cape of Good Hope observations.

3rd place is the mean of observations at Cape of Good Hope, Arcetri, and Nice.

4th place mean of two observations at Arcetri, one at Vienna, and one at Nice.

The following are the residuals (C−O) from comparisons of the elements with the above places.

(C−O).

	I.	II.	III.	IV.
	″	″	″	″
$\Delta\lambda$	0·2	0·0	0·0	0·1
$\Delta\beta$	0·0	+1·4	+4·2	0·0

The care with which the places have been selected and the computations made justifies the belief that the orbit will be very accurate.

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The Motions of Stars in the Line of Sight.

[Continued from p. 122.]

The proper adjustment of the spectroscope, though it may require a lengthened explanation to describe, is easy to effect, and the real difficulty of the work now lies in the character of the stellar spectra themselves. No two of these are precisely alike, but they may be grouped into two great classes—the blue stars, with spectra crossed only by a few broad ill-defined bands due to hydrogen, and the yellow stars, with many hundreds of fine lines. In observing stars of the first class there is the difficulty, in some cases almost the impossibility, of determining exactly where the centre of the broad ill-defined band is. As many of our brightest stars, Sirius, Vega, Procyon, belong to this class, a high dispersion can often be employed, but no advantage is thereby secured, since the band is made broader in just the same proportion as the dispersion is increased, and whether the dispersion be high or low, the uncertainty of the bisection is great as compared with any admissible displacement due to the motion of the star. Fig. 2 will render this more evident than any mere description could do. The spectrum selected, that of Sirius, is undoubtedly an extreme case, few stars showing quite so broad a line, but many have lines which are quite as ill-defined in character. Spectra of the second class are much more satisfactory to measure; the lines are narrow and sharp, and if they can be seen and held steadily there is no possibility of uncertainty about their bisection. But unfortunately

Star.	Miles per second. b_1.	F.	Nights. b_1.	F.
Aldebaran	+21	+28	17	18
Capella	+31	+22	12	19
Pollux	−25	−42	17	14
Arcturus	−47	−44	21	26
α Cygni	−33	−37	11	22

The F line in the spectrum of Pollux is faint and difficult to see.

In this and in the following tables, + denotes a motion away from our system, − a motion towards it.

Where the spectrum is too faint, or its lines too feeble for such a comparison, only the employment of more powerful instruments, and under more favourable conditions of atmosphere, can assure us that our observations have not been affected by this source of error.

As a check on the adjustment of the spectroscope, the lines in the spectra either of the Moon or of the sky are compared with the lines in the comparison-spectrum. It is true that neither the Moon nor the diffused daylight from the sky is observed under quite the same conditions as a star, since in both cases the light much more than fills the slit; still if care has been taken to have the slit narrow enough to cut off some of the light of the star, and it is found that no displacement can be detected between the lines of the Moon and the comparison-spectrum, it is fair to assume that a displacement observed in the spectrum of a star is real, and not fictitious.

On a few occasions Venus and Mars have been observed as a test of the accuracy of the star-measures. On every occasion the displacement observed has been in the right direction, but usually slightly, or, in the case of Venus, considerably too large in amount. The difficulty of measuring accurately a very small distance probably partly accounts for this discordance.

Perhaps the most satisfactory proof that the observations as a whole were affected by no serious instrumental error would be given by the observation of a change in the amount of displacement noticed in a star-line corresponding to the season of the year at which the star was observed. For the Earth, in its annual revolution round the Sun, is at one time approaching and at another receding from any particular star; and the measures of displacement must be cleared of the effect of this motion before the true motion of the star towards the solar system can be deduced. Unfortunately the observations have, as a rule, been made between sunset and midnight, and on stars near the meridian. The Earth was therefore usually approaching the star observed; and the measures made when it was receding have been few in number, and have frequently been obtained under disadvantageous circumstances. There is therefore but scanty material, and that not very satisfactory, for ascertaining if the observations show the effect of the Earth's motion as they should. Such material as there is seems, however, to indicate that there is a decided tendency to exaggerate the amount of displacement when the motion of the star is partly neutralized by that of the Earth, and the amount to be measured therefore small.

The following table gives the mean *observed* motions, uncorrected for the Earth's motion, for several stars which have been observed sufficiently frequently in opposite parts of the Earth's orbit:—

Star.	Earth and star moving the same way. Nights.	Earth and star moving the same way. Star's motion.	Earth and star moving different ways. Nights.	Earth and star moving different ways. Star's motion.	Difference in observed motion of star.	Difference in Earth's motion.
Aldebaran ...	25	+35·2	10	+25·5	+ 9·7	+21·7
α Lyræ	12	−34·4	44	−32·3	− 2·1	− 9·4
α Aquilæ......	11	−17·4	28	−14·6	− 2·8	−13·6
γ Cygni	8	−20·2	6	− 5·9	−14·3	−11·7
α Cygni	13	−34·0	19	−31·6	− 2·4	−11·4

The foregoing facts will give a tolerably correct impression both as to the difficulty of making these observations and of the degree of reliance which can be placed upon them. They are as yet far less exact than one might well wish them to be, but they contain a promise of greater accuracy when more adequate means are employed; and they already enable us to speak positively as to the *direction* of motion of a considerable number of stars, and in the case of not a few to fix the *speed* of motion with some approach to definiteness, some fifty stars in all having been observed a sufficient number of times for us to be able to deduce their speed to the nearest ten miles per second.

An interesting subject for inquiry now presents itself. Do these results afford any support to the theory which holds that the Sun with his attendant planets are travelling towards a point in the constellation Hercules? One or two attempts have already been made to answer this question, but a glance at the annexed diagram (fig. 3) will show at once that these attempts have been premature. A sufficient number of stars have not yet been observed, and those observed are not sufficiently equally distributed to render any inferences as to the direction and speed of the solar motion worthy of much confidence. So far as the observations go, however, they would seem to indicate a motion towards *α* Aquarii, rather than towards any point in Hercules. Still, if the Sun's speed be small as compared with the average speed of the stars observed, there would be nothing in the observed facts incompatible with the generally accepted direction. Or the suggestion thrown out by Mr. Proctor several years ago may have a foundation in fact, and the stars of Ursa Major may form a connected system having a common drift. Should the stars of Orion's belt, with *γ* and *κ* Orionis, form a similar system, the remainder of the stars observed would afford but very incomplete testimony as to the solar motion, but, so far as it went, it would be quite compatible with the usually assumed apex.

The case of the five stars in Orion just referred to is rather interesting, as they seem to be stationary with regard to the Earth, whilst their proper motions also are small. If, then, the spectroscopic results can be sufficiently relied upon, these stars must be

Fig. 3.

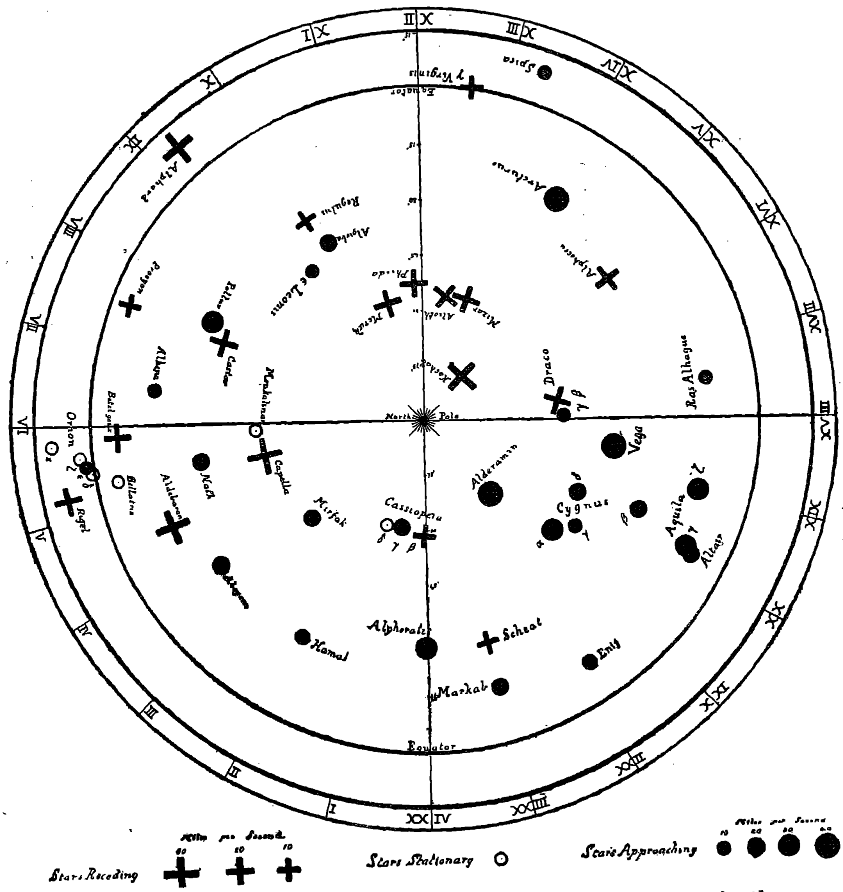


Chart showing distribution of Stars observed for motion in the line of sight.

travelling very nearly in the same direction and with the same speed as our Sun. This would suggest the possibility of their being much nearer to us than is commonly supposed, in which case they might have an appreciable parallax—a parallax, however, that might possibly escape detection if the comparisons were limited to neighbouring stars.

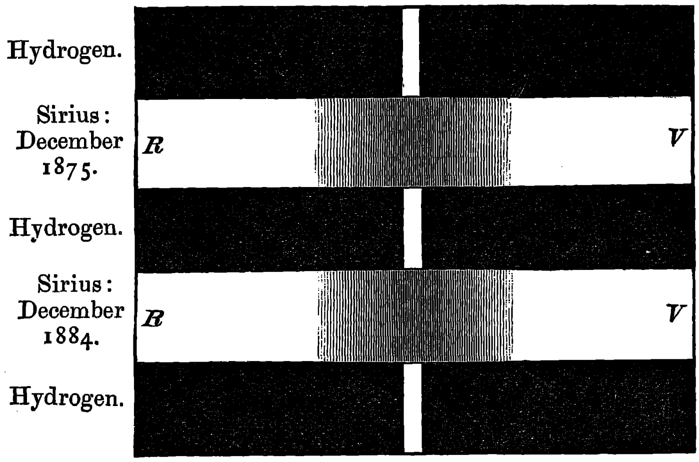
Two other stars than those shown in the little map have been observed at Greenwich a considerable number of times. One of these is Algol, the well-known variable. It will be remembered that Prof. Pickering has suggested that the variations in the light of this star are due to a large dark satellite, which periodically transits across it, producing a partial eclipse. Prof. Pickering has further pointed out that in this case Algol will have a rapid motion round the centre of gravity of the system, and will sometimes, therefore, be approaching us at a high speed, and sometimes receding from us equally rapidly. Up to the present time Algol has been observed on 15 nights. The results show very great discordances; but it is not possible at present to say whether these are due to a real change of motion in the star, or simply to a very unusual roughness in the observations.

The other star is Sirius. In the case of this star the spectroscopic method has brought out a most singular and unexpected result. Each season's observations has given a different value for the rate with which the star is moving, and the change has always been in the same direction. So that whilst in 1868 Dr. Huggins found the star to be receding from us at the rate of 29 miles per second, the observations obtained during the winter just past show it to be now approaching us with a speed of about 22 miles per second. The following table, which was quoted by the President of the Royal Astronomical Society in his address on awarding the Gold Medal of the Society to Dr. Huggins, exhibits the progress of the change very strikingly:—

Opposition of	Number of nights.	Number of measures.	Mean concluded motion.
1875–6 and 1876–77 ..	4	8	+21·1
1877–78	3	8	+23·0
1879–80	3	10	+15·1
1880–81	2	4	+11·3
1881–82	5	22	+ 2·1
1882–83	3	18	− 4·7
1883–84	13	43	−19·4
1884–85	2	8	−21·5

It has already been suggested by Dr. Peters and others, from a consideration of the movements of Sirius in R.A. and N.P.D., at right angles, that is, to the visual ray, that the star is moving in an elliptic orbit, and this would undoubtedly have the effect of making the part of the star's motion which was in the direction of the visual ray vary continually. But it is premature at present to attempt to combine the two different classes of observation into one harmonious whole. Certainly too much weight must not be given to the actual numerical results obtained by taking the mean of the observations of a season. Fig. 4 shows the apparent change in the position of the F line in the spectrum of Sirius, in the nine years between Dec. 1875 and Dec. 1884. It will be seen that it is little more than one-twentieth of the total breadth of the line, so that the mean annual change does not amount to the one-hundredth part of that breadth. And when the diffused and ill-defined character of the line to be measured is borne in mind, and the unsteadiness of the spectrum of Sirius in this latitude, except under the most unusually favourable circumstances, no wonder

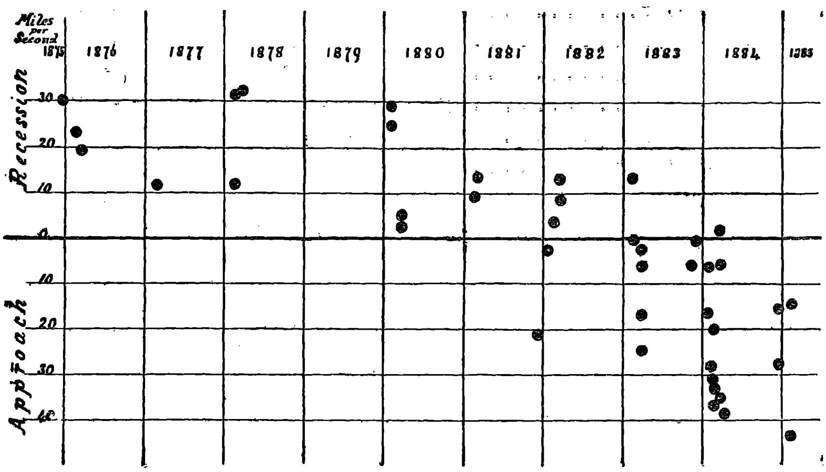
Fig. 4.



F line in Spectrum of Sirius in 1875 and in 1884, as compared with Hβ line of Hydrogen.

can be felt that the mean results do not readily fall into agreement with a given curve. A better idea of the real value of the evidence for the change will probably be afforded by fig. 5, in which each

Fig. 5.



Separate observations of the motion of Sirius in the line of sight, from Dec. 1875 to Feb. 1885.

evening's observation is shown separately. It will be observed that the early observations are but few in number—so few, that if they were not corroborated by Dr. Huggins's observations of 1868 and 1872, it would seem the most natural course to reject them, as possibly affected by some unknown source of error. But since they do possess that powerful confirmation, the fact of the change seems manifest, though the observations are evidently not accurate enough for us to infer the shape of the orbit in which the star is travelling, until the star has much more nearly completed a revolution than it has at present.

Some advance may probably be made in the mean time, either by a resort to larger telescopes, or by the use of some form of spectroscope specially designed for this particular research. The most promising form would seem to be that of a reversion spectroscope, in which half the spectrum is reversed end for end, so that the red of one half is seen immediately above the violet of the other. This has the advantages that the displacement to be measured is doubled in amount, and that the lines in the spectrum of the stars become their own measuring pointers, and all difficulties about the illumination of pointers or cross-wires are done away with. There is also the further advantage that in the case of stars of the first type, the broad diffused line has to be brought into coincidence with a line precisely similar instead of with a wire or pointer entirely unlike it.

The device of dividing the object-glass of the viewing telescope, making it, in fact, a miniature heliometer, would probably give satisfactory results, as the comparison or standard line could be used as a pointer for the bisection of the star-line.

There are several interesting side details which would be sure to attract the attention of any astronomer taking up this line of research. One is the varied character of the same lines in different stellar spectra. Thus Rigel, Cor Caroli, Procyon, and Sirius are all grouped as belonging to the first type of spectrum. Yet there is a well-marked difference in the characters of these lines. Thus the F line in Rigel is narrow and fairly well-defined, in Cor Caroli broad and intensely dark, in Procyon very broad but faint and with a faint narrow line in its centre, in Sirius very broad and very ill-defined, shading off gradually from the centre on either side, but with no trace of anything like a defined line in the centre.

There is a certain degree of similarity in the characters of the F line in the stars of certain districts. Thus the Orion stars except α resemble Rigel, and the principal stars of Ursa Major, except α, resemble the β of that constellation.

There is some slight reason to think that these lines may, in some cases, change their character a little. In two or three cases where the star is variable we know that this really occurs—that, as in the case of β Lyræ as observed by M. Gothard, a line may appear as dazzlingly bright at one time, and may then gradually fade away until it is finally replaced by a dark line not many days later. In the case of γ Cassiopeiæ the change is equally real, though less marked and taking place less quickly. With these instances of change, it seems at least a plausible theory that the character of the lines in other stellar spectra may change too. At all events it certainly is the case that the F line in the spectrum of Altair, which in the years 1874–78 proved exceptionally difficult to bisect, in 1884 seemed little harder than that in the spectrum of Vega, whilst Regulus, on the other hand, has become a somewhat more difficult object for measurement.

The present insufficiency of our means for dealing with the problem of the Sun's path, and the suggestive, but incomplete observations of Sirius, surely justify an appeal to the possessors of great telescopes, and especially to those in southern latitudes to co-operate in a research which promises so rich a reward. Discussions of proper motions and determinations of parallax are needed to increase our knowledge of the structure of the stellar universe; but the thorough application of the spectroscopic method would prove a most valuable additional weapon, and the combination of the three could not fail to secure the most important results. Yet with the one honourable exception of the Temple Observatory, Rugby, where the means are certainly inadequate to the task, the work has been for many years absolutely restricted to Greenwich Observatory, to a single telescope of only barely sufficient aperture, situated where the atmospheric conditions for good observation are rare indeed, and become rarer year by year. If the observatories of, say, Nice and Melbourne and those English amateurs who possess telescopes of apertures of 18 inches and upwards would but lend their aid, without doubt we should soon have results of a considerably greater accuracy than we have at present—results which could not fail to greatly advance our science and increase our knowledge of the sidereal system. E. W. Maunder.

Maxima and Minima of Variable Stars observed during the year 1884.

The observations from which the following results are derived were made with an equatoreally mounted achromatic of 6 inches aperture and powers of 80 and 125.

		Mag.
	R Arietis.	
Maximum	Aug. 3	8·1
	U Boötis.	
Minimum	April 22	13·3
Maximum	Aug. 1	9·5
	V Boötis.	
	1855·0 $14^h\ 17^m\ 18^s{\cdot}9\ +16^\circ\ 58{\cdot}8$.	
Maximum	June 26	9·4
Minimum	Aug. 7	10·0
	R Camelopardi.	
Maximum	May 30	7·9
	S Coronæ.	
Maximum	April 30	6·6