XIV. *Continuation of an Account of the Changes that have happened in the relative Situation of double Stars.* By William Herschel, *LL. D. F. R. S.*

Read June 7, 1804.

In my former Paper,* I have given the changes which have happened in the situation of six double stars. When the causes of these observed changes in the double star Castor were investigated, I had recourse to the most authentic observations I could find, of the motions in right-ascension and polar distance of this star. But the Tables which have been lately published, in the last volume of the observations made by the Astronomer Royal at Greenwich, give us now the proper motions of 36 principal stars, of which α Geminorum is one; and, as the motion of this star, especially in north polar distance, is very different from what it has been supposed in my former examination, it will be necessary to review the arguments which have been used, in order to ascertain what will be the result of this new motion. We shall here again follow the order of the paragraphs of the former Paper, and denote those which treat of the same motions, with the same letters, that they may be readily compared.

Single Motions.

(a) The small star x cannot be alone in motion, as we have now, in the new Tables I have mentioned, an evident proof that the large star α is not at rest.

* See Phil. Trans. for 1803, p. 339.

(*b*) As the observations of the Astronomer Royal have ascertained the motion of Castor, so it is no less evident, from the series of observations which has been given in my Paper, that its smaller companion has also changed, if not its real situation, at least its relative one with respect to the large star. Let us therefore examine, whether the motion of α can be the cause of the apparent change that has taken place in the relative situation of these two stars.

The annual proper motion of α Geminorum, in right ascension, by the new Tables, is $0'',15$; which, in $23\frac{1}{2}$ years, will amount to $3'',525$. The annual proper motion in polar distance, by the same Tables, is $0'',04$; which, in the same time, will amount to $0'',94$; the former motion being retrograde, and the latter towards the south. Let FP, in Figure 1, (Plate IX.) be the parallel of Castor, and make $\alpha\alpha'$ equal to 2978,5; which will be the quantity of its motion in right ascension in the parallel, when it is 3525 in the equator. At right angles to αP, make $\alpha'\alpha''$ equal to 940; and this will represent the motion of the star in polar distance towards the south. Draw the line αx so as to make an angle of $32° 47'$ with the parallel FαP on the north preceding side, and place x at the distance of 3765 from α. Then will α and x be the situation in which these two stars were observed in the year 1779; their apparent distance, estimated in diameters of the large star, being $1\frac{7}{8}$; and the angle of position, as has been stated, $32° 47'$ north-preceding.

If the star x had been at rest while α moved towards α'', the relative situation of the two stars in the year 1803 would have been represented by $\alpha'' x$; that is to say, the apparent disks of these two stars would have been hardly $1\frac{1}{3}$ diameter of the largest asunder, and the angle of position $x\alpha''$P$'$ must have

been 86° 25′ north-preceding. But this is quite inconsistent with the observations that have been given; according to which, the small star, in the year 1803, was situated at x'. It is therefore proved, that the motion of α alone cannot account for the change which has taken place.

(*c*) If the motion of Castor should be only an apparent one, arising from the motion of the solar system, then the proper motion of the sun must be just the reverse of that which the new Tables assign to α Geminorum. This being admitted, let us examine what will be the result with regard to the relative situation of the small star, which, since only the sun is supposed to be in motion, must now remain at rest, as well as α. The effect of the parallax, which we are now considering, is inversely as the distances of the stars which are affected by it. Hence arise the three cases which have been examined in my first Paper,

When a line from the sun to Castor, Oα,* is perpendicular to the line αx, joining the two stars, no change in their relative situation can take place, arising from parallax, which will act equally on both. For, let α, α'' and x, in Fig. 2, be placed as they were in Fig. 1; and the real motion of the sun from O to O′, will produce the parallactic motion of Castor from α to α''. It will also occasion an apparent motion of x, equal to that of α, and in a parallel direction with it. This star will therefore appear to have moved from x to x', in the same time that the large star has moved from α to α'', so that their relative situation will remain unchanged.

(*d*) If x be placed beyond α, the effect of parallax, exerted in the direction xx'', parallel to $\alpha\alpha''$, will be less upon this star than on Castor; and its apparent motion must fall short of the

* See Figure 1 of the former Paper.

situation x'. The consequence of this will be an increase of the angle of position; but, as we know, from the observations which have been given, that this angle has been decreasing, it follows, that the small star cannot be admitted to have been at rest, if we place it farther from us than α.

(*e*) When the smallest of the two stars of our double star is supposed to be much nearer than the largest, the effect of parallax will carry it beyond x'. Let its distance from us to that of α be, for instance, as 3123 to 6076. In this case, while α appears to move as far as α'', x will be seen to move to x''; where its angle of position $x''\ \alpha''\ P'$, will be just 10° 53′ north-preceding, as by observation it was found to be in the year 1803. But, according to this hypothesis, the distance $\alpha''\ x''$ of the two stars, ought now to be nearly double what it was in 1779; and, since this is contrary to observation, we must also give up this last supposition.

Double Motions.

(*f*) Let us now suppose α and x to be in motion, while the solar system remains at rest. Then, since there will be no parallax that can affect the appearance of these motions, they must be real, and proper to each of the stars. But the circumstances that must take place, in order to produce the phenomena which have been observed, are so particular, that we shall soon find the great improbability of such an accidental arrangement of them as would answer the end. It has already been shown, in the paragraph (*c*) of the former Paper, that we cannot place the two stars at an equal distance from us; and it would be the height of improbability to suppose them to move in parallel planes. But, whatever may be the directions and velocities of

the motions of the stars, or at whatsoever different distances we may place them, the effect which is to arise from these combined circumstances is positively determined; for the star α must appear to move at the rate of $3''{,}123$ of an arch of a great circle in $23\frac{1}{2}$ years, and in the direction of $17^\circ\ 31'$ south-preceding its parallel; while the star x, in the same time, must seem to move over an arch of $4''{,}179$, in a direction of $32^\circ\ 52'$ south-preceding the same parallel. When these quantities, resulting from the proper motions of our new Tables, are substituted for those which have been used in the paragraph (f) of my former Paper, the arguments which it contains will remain in full force, and need not be here repeated.

(g) The same argument which has been used in the first Paper, when the sun and the small star only were supposed to be in motion, will perfectly apply to the proper motion of Castor, as given in the new Tables. For, as this motion is now to be accounted for by the motion of the sun, we have only to substitute the velocity of $3''{,}123$, in a direction which makes an angle of $17^\circ\ 30'\ 56''$ north-following with the parallel of α Geminorum, for the quantity of the solar motion before used; and to assign a proper motion to the small star, having a direction of $68^\circ\ 10'$ south-preceding the parallel of α Geminorum, with a velocity which, if the star was at the distance of α from us, would carry it in $23\frac{1}{2}$ years through $1''{,}4303$.

(h) When the sun and Castor only are supposed to be in motion, the former statement of the case will in every respect remain conclusive.

Motion of the three Bodies.

(i) It remains now only to be shown, that the arguments which are contained in my first Paper, against the probability of

a supposition which ascribes all the observed phenomena to three real motions, will not be affected by the given alteration in the proper motion of Castor. Without repeating any part of the discussion of the former paragraph (*i*), it will be sufficient if I point out three motions, such as will answer the required purpose.

Let the solar motion, as before, be towards λ Herculis, with such a velocity as will in $23\frac{1}{2}$ years produce a parallactic motion, at the distance and situation of α Geminorum, amounting to 2″,2805, in a direction of 60° 36′ 57″ south-preceding the parallel of that star. Let Castor have a real motion, which in $23\frac{1}{2}$ years would carry it over an arch of 2″,1341, in a direction of 29° 23′ 3″ north-preceding its parallel; and let the real motion of the small star be such that in $23\frac{1}{2}$ years, at its distance from us, supposed to be to that of Castor as 3 to 2, it would describe an arch of 2″,9212, in a direction of 18° 50′ 13″ south preceding. Then would the parallactic motion of α,= 2″,2805, compounded with the real motion we have mentioned, give us an apparent annual motion equal to that which, in Dr. MASKELYNE's Table, is called the proper motion in right ascension and polar distance of this star. And the parallactic motion of x,= 1″,5203, compounded with the real motion we have assigned, would also produce an apparent annual motion which would correspond with my series of observed situations of this small star. But, for the high improbability of such an hypothesis, I refer to the paragraph (*i*) of my former Paper.

What has been said of Castor, will apply to every other double star of which the proper motion may hereafter be assigned; for, unless the parallactic motion arising from the motion of the solar system should completely explain the observed changes, the same arguments will still remain in full force.

I shall now proceed to a continuation of my account of the changes that have happened in the relative situation of double stars, either in their position or their mutual distance; and, in the following list of them, it will be seen that, of 50 changeable double stars which are given, 28 have undergone only moderate alterations, such as do not amount to an angle of 10 degrees. None of them however have been admitted, except where the change was at least so considerable, that the micrometer which was used on this occasion could ascertain the change with a proper degree of accuracy. Two of the stars, indeed, have hardly suffered any alteration in the angle of position; but, with them it will be found, that a change in their distance has been so ascertained as not to admit of any doubt. Thirteen of the stars have altered their situation above 10 degrees, but less than 20. Three stars have undergone a change in the angle of position, of more than 20, and as far as 30 degrees. The six remaining stars afford instances of a still greater change, which, in the angle of position of some of them, amounts to more than 30 degrees; in others, to near 40, 50, 60, and upwards, to 130 degrees.

α Herculis. II, 2.*

The two stars of this double star have undergone a considerable change in their angle of position. By a measure taken May 20, 1781, it was 21° 28′ south-following.† April 3, 1783, two measures gave 25° 29′. A mean of two measures, taken

* The numbers after the name of the star, refer to my Catalogues of double Stars, published in the Philosophical Transactions. For instance, II, 2, denotes that α Herculis is the 2d star in the 2d class.

† By mistake, the first angle of position in my Catalogue is given 30° 35′, instead of 21° 28′, and should be corrected. See Phil. Trans. Vol. LXXII. Part I. p. 122.

Feb. 21 and March 4, 1802, was 31° 38′. By five measures, taken in 1803 and the beginning of 1804, it was 31° 54′; and, June 3, 1804, by a very accurate measure, with an improved illumination of the wires, it was 32° 50′. This gives a change of 11° 22′, in 23 years and 14 days.

It does not appear that the distance has undergone any perceptible alteration.

As we have now the proper motion of this star in Dr. MASKELYNE'S new Tables, we are enabled to enter upon an examination of the cause of the observed change; but first it will be necessary to mention, that in this and all the following stars, I have no longer supposed the solar motion to be directed towards λ Herculis. A point at no very great distance from this star has been chosen, for reasons which it would lead us too far from our present subject to assign, and which are of no absolute consequence to it. The motion of the solar system, towards this assumed point, will produce an opposite parallactic motion, in every star that is not too far from us to be sensibly affected by it.

That change of place which astronomers have established by observation, and which is called the proper motion of a star, either may agree with this parallactic motion, (in which case it will be only an apparent one, the star being really at rest,) or it may be directed to another part of the heavens, so as to differ from our parallactic motion. Whenever this happens, the star will have the following three motions: a real, a parallactic, and an apparent one; the latter being a composition of the former two.

That α Herculis is one of those stars which has these three motions, will appear thus: the parallactic motion which this star, from its magnitude and consequent proximity, must be

allowed to have, will carry it, in an angle of about $58\frac{1}{2}$ degrees, towards the south-preceding part of the heavens; but the motion assigned to it in the new Tables, has a direction towards the north. Hence it follows, that α Herculis has also a real motion, which, by its composition with the parallactic one, produces the tabular apparent one.

We are now to examine the effect of these three motions, on the position of the two stars of our double star, in order to see how far they will account for the observed change. The two stars are sufficiently different in magnitude, for us to expect a difference of parallax, on a supposition that their distances from us are inversely as their apparent magnitudes. The change of the angle of position, arising from a superior parallactic motion of the large star, would have occasioned a retrograde motion of the small one; but this, by my observations, has moved according to the order of signs; its change of situation, therefore, will admit of no explanation from the effect of parallax.

The real motion of α Herculis, being such as, with the union of the parallactic one, will produce an apparent motion towards the north, is determined by the velocities and directions of the other two motions. It must however be towards the north-following part of the heavens, and of a velocity considerably greater than the proper motion given in the new Tables; but, since it is known to be compounded with the parallactic one, we are now only to consult the direction and velocity of that composition, which is such that the large star, in 23 years and 14 days, must have been carried $5''{,}299$ towards the north. If the stars are not connected, the most favourable case we can put, will be to suppose the small one at rest, and at such a distance from us as to be intirely free from sensible parallax.

This being admitted, the large star, by its motion, should now have left the small one so far behind, that the distance of the centres of the two stars, (which Sept. 25, 1781, by a measure with my lamp micrometer, was $4'' 34'''$,) should now be $7'',92$; while, at the same time, the angle of position ought to have increased to $52\frac{1}{2}$ degrees. My last observations, however, give so different a result, that this hypothesis cannot be admitted.

If the small star, which is not so much less than the large one that we can justly place it at the above mentioned distance, should partake of some parallactic motion, it will then increase the objections we have stated; for, if the effect of it should be only one quarter of what it is upon the large star, it will add to the magnitude of the angle of position, and increase the distance of the two stars.

Hence it follows, that, unless we should admit the supposition of three independent motions, the high improbability of which has been sufficiently shown, we have good reason to believe that the large star has, during the 23 last years, carried the small one along with itself, in the path it describes in space; both being equally affected by parallax and real motion. If this be admitted, a mutual revolution of the two stars will be the immediate consequence, when the laws of gravitation are taken into consideration; and the change of position they have undergone, will be a necessary consequence of it.

γ Arietis. III, 9.

This star being only of the 4th magnitude, and of the third class as a double star, we have no reason to expect a great change in the angle of position; and yet, with the assistance of a very distant observation, which we have in MAYER'S Zodiacal Catalogue, a considerable change may be proved to have taken place.

The position, Nov. 2, 1779, was 84° 0′ south-following.* Oct. 10, 1780, it was 86° 5′; and, Feb. 7, 1802, it was 89° 10′. The change, in 22 years and 97 days, is 5° 10′. From the given right ascension and declination of the two stars, in MAYER's Catalogue, we compute, that their position in 1756 was 78° 46′ south-following; which gives a change of 5° 14′, in 23 years and 306 days, up to the time of my first observation. The two periods, which are nearly equal, give a change of 10° 24′, for 46 years and 38 days. A motion of γ Arietis, arising from systematical parallax, by which we may admit the smallest of the two stars (on account of its supposed greater distance) not to be so much affected as the large one, will perfectly account for the change; unless, hereafter, the proper motion of this star, when known, should lead to a different conclusion.

ξ *Ursæ.* I, 2.

This double star has undergone a very extraordinary change in the angle of position. Dec. 19, 1781, the smallest of the two stars was 53° 47′ south-following. Feb. 4, 1802, it was 7° 31′; and, January 29, 1804, the position was only 2° 38′. This gives a motion of 51° 9′, for 22 years 41 days, and amounts to 2° 19′ *per* year. If an annual alteration to this amount should continue to take place for the future, a very few years would be sufficient to ascertain the cause of this change, as no motion but a revolving one could possibly explain the phenomenon. If, on the contrary, the parallactic motion of the largest star should have occasioned the change of situation, which is not impossible, it will soon be verified by an increased distance of the two stars.

* This position, for reasons explained in the note to p Serpentarii, page 374, has not been given in my Catalogue.

accompanied with very little angular change in their position. The little difference in the magnitude of the two stars, however, does not well agree with a supposition which gives a parallactic motion to one of them only.

γ Andromedæ. III, 5.

It has already been noticed, on a former occasion, that this double star is one of the most beautiful objects in the heavens. The striking difference in the colour of the two stars, suggests the idea of a sun and its planet, to which the contrast of their unequal size contributes not a little. The position of the small star, when we consider that this double star is one of the third class, has undergone a sufficient change to deserve notice. In the year 1781, Oct. 15, it was 19° 37′ north-following. Feb. 3, 1802, 26° 34′. Feb. 11, 1803, 26° 5′; and, Feb. 5, 1804, 27° 39′. The difference, in 22 years and 113 days, is 8° 2′. The distance of the two stars is too great to be accurately estimated by their apparent diameters; and measures taken with a micrometer, unless fractions of a second of space could be strictly ascertained, would be useless. If we suppose the small star sufficiently removed not to partake of the systematical parallax of the large one, the change of the angle of position may be accounted for, upon the principle of the solar motion. The stars, however, are hardly so different in magnitude as would be required for that purpose. We ought also to know, whether a proper motion has been observed in this star.

μ Draconis. II, 13.

The change in the relative situation of the two stars of this double star is pretty considerable. The position, Sept. 24, 1801,

was 37° 38′. This may stand either for south-preceding or north-following, because the stars were then regarded as being equal. March 4, 1802, a measure of the position gave 50° 32′. Feb. 5, 1804, position 49° 0′ south-preceding; and, Feb. 6, 1804, 50° 4′. A memorandum annexed to the observation says, that the preceding star is the smallest, but that the difference is so little as to require much attention to be perceived. The alteration, in 22 years and 135 days, is 12° 26′. The two stars being nearly of an equal magnitude, we can have no inducement to suppose them to be at very different distances from us. This makes it not probable that the difference of their parallactic motion should be the cause of the angle of position; otherwise, the direction of that motion would be sufficiently favourable.

δ Geminorum. II, 27.

The measures of the position of the two stars of this double star are attended with great difficulty, on account of the faintness of the smallest; a considerable disagreement will therefore be excuseable. The position, Nov. 18, 1781, was 85° 51′ south-preceding. Jan. 28, 1802, it was 76° 21′. Feb. 4, 1802, 73° 5′; and, Feb. 6, 1804, 69° 52′. The difference, in 22 years and 80 days, is 15° 59′. We can have no assistance from observations made on the distance of the two stars, which is too great for estimation. A parallactic motion, which, on account of the great difference in the magnitude of the stars, might be admitted, would lessen their distance, and make the angle of position retrograde, which, by my observation, has moved in a contrary direction. A connection between the two stars is also rendered improbable, on account of the great number of small ones that are scattered in this neighbourhood, of which our small star may be one;

so that we have good reason to ascribe the change which has happened in the situation of our two stars, to a proper motion of δ.

ε *Draconis.* I, 8.

In this star, we have to notice a great change of the angle of position, but none in the distance. In the year 1782, Sept. 4, with 460, I found the stars to be $1\frac{1}{2}$ diameter of L. asunder. May 22, 1804, they were still at the same distance of $1\frac{1}{2}$ diameter of L. Oct. 20, 1781, the position was 63° 14′ north-preceding; and, May 22, 1804, it was 84° 29′; which proves a change of 21° 15′, in 22 years and 214 days. This cannot be owing to a parallactic motion of the large star; for the effect arising from such a motion, would have been directly contrary to the change which has taken place: the angle of position would have undergone a direct, instead of a retrograde alteration. We are consequently assured that ε Draconis cannot be at rest. If future observations on the proper motion of the stars should furnish us with that of ε, and if this motion should also fail to explain my observed change of the angle of position, without a change of distance, we shall then have good reason to admit this star into the list of those that have a small one revolving about it. For, to ascribe an additional and independent motion to the small star, would be to have recourse to three separate motions, of given velocities, in given directions, and at given distances; the improbability of which has been sufficiently pointed out.

ζ *Aquarii.* II, 7.

The position, Nov. 26, 1779, was 71° 5′ north-following. Sept. 24, 1781, it was 71° 39′. June 19, 1782, 72° 7′. Jan. 3, 1802. 78° 3′. The change is 6° 58′, in 22 years and 38 days.

As the equality of the two stars gives little room for admitting a difference in their parallactic motions, we cannot reasonably ascribe the change of situation to that cause; though, otherwise, the direction of such a motion in the largest of the two, would be sufficiently favourable. The situation of the stars being much insulated, a connection between them may be admitted, with a high degree of probability.*

ξ Bootis. II, 18.

The change in the situation of the two stars of this double star is very remarkable. The small star, April 15, 1782, was 65° 53′ north-following the large one. In one of my *sweeps*, April 20, 1792, I perceived the small star in the 20-feet reflector; and estimated its position, as it passed the field of view, to be about 85° north-preceding. When the sweep was finished, I found that this star could not be in the situation I had just seen it, unless it had undergone a considerable change since the year 1782; and, that no mistake had been made in the estimation of this evening, appeared very clearly, by a measure taken of its position, which actually gave 85° 43′,5 north-preceding. This pointed out a retrograde motion of the small star. March 22, 1795, the position was 84° 56′. April 1, 1802, 82° 57′; and, April 2, 1804, I found it 83° 54′. A mean of the two last measures, will give the present situation 83° 26′ north-preceding; and the total change of the angle of position, in 21 years and 352 days, will be 30° 41′.

If it should be remarked, that the measure taken in 1795

* The calculation of the probability of a connection, which has been given in the Phil. Trans. for 1802, page 484, makes it above 75 millions to 1, that these two stars are not situated as they are, by a mere casual scattering of them in space.

appears to be inconsistent, it ought to be recollected, that the cause of this apparent motion remains to be investigated. If the largest of the two stars should pass closely by the smallest, which, on account of its supposed great distance from us, may appear fixed, a very great and quick alteration in the angle of position will take place; but, in a short time the change will become very moderate, and not long after insensible. The same appearances may also happen, although the small star should not be fixed, but revolve about the large one; for, if its orbit were in a plane with the line of sight, it would be seen to move with great velocity, about the opposition, and soon after appear to be almost stationary. That either one or the other of the stars has really had a motion approaching to a straight line, is ascertained from an alteration of the distance; for, in the year 1781, the vacancy between the two stars, with 460, was 3 diameters of the large one. But, April 2, 1804, with 527, their distance was greater than estimations by diameters can determine; and, comparing ξ with π Bootis, I found that the stars of ξ were farther asunder than those of π; notwithstanding, in the year 1782, the former was placed in the 2d class, and the latter in the 3d. The change of the angle of position, if it were owing to a parallactic motion, would have been direct, instead of retrograde.

ω Leonis. I, 26.

In a note added to this star, which is the 26th in my second Catalogue, a suspicion is expressed, that the two stars which compose this very minute double star, were receding from each other.* This has since been completely verified; for, having seen the two stars close upon one another, and afterwards by

* See Phil. Trans. Vol. LXXV. Part I. page 48.

degrees disengaged, as related in my second Catalogue, the separation between them kept on increasing, and, on the 21st of April, 1795, they were $\frac{1}{2}$ diameter of the small star asunder. Feb. 5, 1804, with a power of 527, the vacancy between them was nearly 1 diameter of the small one. The position has likewise undergone a sensible alteration. Nov. 13, 1782, it was 20° 54′ south-following. Feb. 4, 1802, 41° 28′. Feb. 5, 1804, 40° 17′. A mean of the two last measures, is 40° 53′ The change, therefore, amounts to 19° 59′, in 21 years and 84 days, and is probably owing to a real motion of ω Leonis; for the effect of a parallactic motion would have shown itself in a contrary alteration of the angle of position.

π *Arietis.* I, 64.

This star is marked as being treble; and the third star, as it happens, is now of use, in verifying the measures which have ascertained the relative change in the situation of the other two. The position of π and its adjacent star, Oct. 29, 1782, was 19° 9′ south-following; and the third star was in the same line of that angle continued. Oct. 17, 1802, the position was 34° 11′; and, Feb. 6, 1804, by a mean of two measures, 31° 15′; which gives a change of 12° 6′, in 21 years and 100 days.

That this change has taken place gradually, is confirmed by two observations of the third star. Jan. 15, 1795, the distant star was observed to have remained a little behind, while the near one had advanced; and, Oct. 17, 1802, it was again remarked, that the three stars were no longer in a line, and that the nearest small star had advanced according to the order of the signs, which had increased its angle of position.

The multitude of small stars in this neighbourhood, and the

minuteness of the two that have been observed with π, as well as the distance of the farthest, render a connection between the three stars very improbable; nor can the change of situation be owing to parallax, as this would have occasioned a retrograde motion of the small star, which, on the contrary, has been direct. From these considerations we may conclude, that π Arietis has a proper motion, to which we must look for the cause of the observed change.

η Coronæ. I, 16.

This very minute double star has undergone a great alteration in the relative situation of the two stars. Sept. 9, 1781, their position was 59° 19′ north-following; and, Sept. 6, 1802, by a mean of two very accurate measures, it was 89° 40′ north-preceding; which amounts to a change of 31° 1′, in 20 years and 362 days. The distance of the two stars has not been subject to any sensible alteration. Sept. 9, 1781, a very small division might be seen, with 460. August 30, 1794, they were so close that, with a 10-feet reflector, and power of 600, a very minute division could but just be perceived. April 15, 1803, with a 10-feet reflector, a very small division was also visible, with 400, though better with 600. And, May 15, 1803, I saw the separation between the two stars, with the same 7-feet reflector, and magnifying power of 460, with which I had seen it 22 years before. The stars differ very little in magnitude; so that we have no reason to expect any effect from a difference of parallax. Besides, if the small one were out of the reach of it, a parallactic motion of the largest alone, would have occasioned the small one to move apparently according to the order of the signs; but the motion has been retrograde.

Fl. 21 *Ursæ.* II, 73.

Nov. 17, 1782, the two stars were in the position of 36° 45′ north-preceding; and, May 20, 1802, I found them 47° 37′; which gives a change of 10° 52′, in 19 years and 184 days. A parallactic motion will account for it; unless, hereafter, a proper motion of the large star should be found to have a different tendency.

Fl. 4 *Aquarii,* I. 44.

The position of the two stars, July 23, 1783, was 81° 30′ north-preceding; and, by a mean of two observations, August 28 and 29, 1802, it was 61° 5′ north-following. Both the last measures are positive, with regard to the position being following, and not preceding, as it certainly was in the year 1783. This proves a change of 37° 25′, in 19 years and 37 days. The distance is perhaps a little increased. Sept. 5, 1782, it was $\frac{1}{6}$ diameter of S. August 29, 1802, less than $\frac{1}{2}$ diameter of S. A parallactic motion of the large star, would have brought on a retrograde motion of the small one, which, on the contrary, we find has been direct. This proves a real motion, the nature of which cannot remain many years unknown; its velocity, hitherto, having been at the rate of nearly 2 degrees *per* year, of angular change.

South-preceding π Serpentis. I, 81.*

The position, March 7, 1783, was 49° 48′ south-preceding. August 30, 1802, it was 59° 5′. The change is 9° 17′, in 19 years and 176 days. If the stars were a little more different in

* We now have the place of this double star in BODE's Catalogue, where it is called 112 Serpentis.

magnitude, a parallactic motion of the largest would account for the change of position.

Near μ *Bootis.* I, 17.

There is a considerable change in the relative situation of the two stars of this double star; and, by the assistance of μ Bootis, it is remarkably well ascertained. This star is so near, that it may be brought into the same field of view with our double star. Sept. 3, 1782, the position was 87° 14′ north-preceding; and, about a year before, the situation of μ Bootis had been determined, so that it appeared, from the two measures, that the three stars were almost in a line, the small star being, however, 6° 49′ on the *following* side. August 30, 1802, the position of the small star was 76° 14′ north-preceding; which, in 19 years and 361 days, gives a change of 11° 0′; and it was at the same time observed, that when all the three stars were seen together, the small one was on the *preceding* side of the line which joins this double star and μ Bootis. A parallactic motion of the large star, would have occasioned the small one to go in a direct order; but it has had a retrograde motion.

North-preceding Fl. 18 *Persei.* I, 38.*

The two stars, August 20, 1782, were situated in a direction 8° 24′ north-preceding; and, by a mean of two measures, taken March 7, 1804, the position was 20° 34′. This gives a change amounting to 12° 10′, in 21 years and 199 days. There is probably a little increase in the distance of the stars. The first observations, with 460, give $\frac{1}{2}$ diameter of either of them,

* The place of this star is now given in BODE's Catalogue, where it is the 85th Persei.

supposing the stars to be equal; and the last, with 527, make it a diameter of the smallest; the stars being then considered as pretty unequal. If the difference of the parallactic motion of the two stars should be sufficiently considerable, that motion would account, not only for the change of the angle of position, but also for a small increase of the distance of the two stars.

σ Coronæ. I, 3.

This star has undergone a great change. The position of the two stars, Oct. 15, 1781, was 77° 32′ north-preceding; but, Sept. 6, 1802, it was 78° 36′ north-following; which gives an alteration of 23° 52′, in 20 years and 326 days. The great number of small stars in this neighbourhood, is not favourable to a supposed connection between any of them and σ Coronæ. As the two stars are considerably unequal, we may suppose the large one to be affected by a parallactic motion, which will sufficiently account for the angular change.

ε Lyræ. II, 5 and 6.

This remarkable double-double star has undergone a change of situation in each double star separately, which is not very considerable, but deserves our notice, on account of a certain similarity in the directions of the alteration. The position of II, 5, Nov. 2, 1779, was 56° 5′ north-following; and, by a mean of three observations, taken Sept. 20, 1802, May 26, and 29, 1804, it was 59° 14′; which gives a change of 3° 9′; the motion of the angle being retrograde. The position of II, 6, on the same days, was 83° 28′, and 75° 35′, south-following. This gives a difference of 7° 53′; the motion being also retrograde. Now, from the position of the apex of the translation of the solar

system, it follows, that the parallax arising from this principle, cannot account for the motion of both the sets of double stars: it may explain the change of the preceding, but not of the following one. The situation of both, however, is in a part of the heavens which is so rich in scattered small stars, that a variety of casual, and merely apparent combinations may be expected.

p Serpentarii Fl. 70. II, 4.

The alteration of the angle of position, that has taken place in the situation of this double star, is very remarkable. Oct. 7, 1779, the stars were exactly in the parallel, the preceding star being the largest; the position therefore was 0° 0′ following.* Sept. 24, 1781, it was 9° 14′ north-following; and, May 29, 1804, it was 48° 1′ north-preceding; which gives a change of 131° 59′, in 24 years and 234 days. This cannot be owing to the effect of systematical parallax, which could never bring the small star to the preceding side of the large one.

λ *Ophiuchi*. I, 83.

The position, March 9, 1783, was 14° 30′ north-following. May 20, 1802, it was 20° 41′. The difference, in 19 years and 72 days, is 6° 11′. March 9, 1783, the distance, with 460, was $\frac{1}{4}$ or $\frac{1}{3}$ diameter of the small star. May 1 and 2, 1802, I could not perceive the small star, though the last of the two evenings was very fine. May 20, 1802, with 527, I saw it very well, but

* The first position was not given in my Catalogue, as I had no reason to suppose, at the time of its publication, that the positions of the stars were liable to any progressive change. It may be remembered, that my principal aim was, if possible, to find out some small annual variation, or libration of position, which might lead to a discovery of the parallax of the fixed stars.

with great difficulty. The object is uncommonly beautiful; but it requires a most excellent telescope to see it well, and the focus ought to be adjusted upon ε of the same constellation, so as to make that perfectly round. The appearance of the two stars is much like that of a planet with a large satellite or small companion, and strongly suggests the idea of a connection between the two bodies, especially as they are much insulated. The change of the angle of position, might be explained by a parallactic motion of the large star; but the observations on the distance of the two stars, can hardly agree with an increase of it, which would have been the consequence of that motion.

North-preceding Fl. 29 *Capricorni.* I, 47.

The position, July 23, 1783, was 84° 48′ north-preceding. Sept. 1, 1802, it was 66° 50′. This gives a change of 17° 58′, in 19 years and 40 days. The effect of a parallactic motion would fall chiefly on the distance; it will, however, account for the change of the angle.

Near Fl. 3 *Pegasi.* II, 62.

The position, May 3, 1783, was 88° 24′ north-preceding. August 31, 1802, it was 79° 38′ south-following. The change is 8° 46′, in 19 years and 120 days. The stars are so nearly equal, that in 1783 I supposed the preceding one to be the smallest, and in 1802 the following one; which occasions the different denomination of the angles of position. If the distance of the preceding star should be much greater than that of the following one, a parallactic motion would explain the change of the angle, but not otherwise.

Fl. 49 *Serpentis.* I, 82.

In the year 1783, March 7, the position of the two stars of this double star, was 21° 33′ north-preceding. May 20, 1802, 32° 52′; and, April 2, 1804, 35° 10′; which gives a change of 13° 37′, in 21 years and 26 days. The stars are now a little farther asunder than they were formerly. A parallactic motion would account for the change of the angle, but not for the increased distance.

Preceding Fl. 11 *Serpentarii.* II, 23.

The position of the stars, May 18, 1782, was 46° 24′ north-preceding. May 20, 1802, it was 66° 56′; which gives a change of 20° 32′, in 20 years and 2 days. A parallactic motion, if the small star should be sufficiently distant from us, will account for it.

Fl. 38 *Piscium.* II, 50.

The position, June 30, 1783, was 25° 3′ south-preceding, and, August 31, 1802, it was 34° 43′. The change is 9° 40′, in 19 years and 62 days. The small star has been retrograde. If the change had been owing to the systematical parallax, the motion would have been direct.

Near Fl. 64 *Aquarii.* III, 69.*

The position, August 21, 1783, was 20° 3′ north-following. Oct. 16, 1802, it was 31° 34′. The change, in 19 years and 56 days, is 11° 31′; and may be accounted for by a parallactic motion of the large star, especially as the stars are extremely unequal in apparent magnitude.

* In BODE'S Catalogue, it is now called 222 Aquarii.

Fl. 46 *Herculis.* I, 79.

There is a small change in the distance of the two stars of this double star. Feb. 5, 1783, the interval between them, with 227,* was nearly 1 diameter of L, and with 460, $1\frac{3}{4}$ diameter of L. Sept. 29, 1802, it was $2\frac{1}{2}$ or 3 diameters of L. The position, Feb. 5, 1783, was 66° 36′ south-following. Sept. 29, 1802, it was 76° 18′. The alteration is 9° 42′, in 19 years and 236 days; but cannot be owing to parallactic motion.

δ *Cygni.* I, 94.

This double star, I believe, has furnished us with a second instance of a conjunction, resembling that of ζ Herculis. The position, Sept. 22, 1783, was 18° 21′ north-following. Jan. 3, 10, and 11, 1802, I could no longer perceive the small star; which must have been at least so near the large one as to be lost in its brightness. Jan. 29, 1804, I examined this star with powers from 527 to 1500, and saw it as a lengthened star, but not with sufficient clearness to take a measure of its position. May 22, 1804, in a very clear evening, I tried 527 and 1500, with the 10-feet reflector, which acted remarkably well on other double stars, but I could not perceive the small star of δ Cygni. In hopes that the superior light of a 20-feet reflector would show it, I examined the star, May 29, 1804, with the powers 157 and 360, but could not perceive the small one. A parallactic motion of δ will perfectly account for this occultation; for the situation of the two stars, in 1783, was such, that this motion

* In my Catalogue, the power is called 460, instead of 227, as it should have been; and the rest of the observation, with 460, was by mistake omitted.

must have carried the large star, by this time, nearly upon the small one.

b Draconis. I, 7.

The position, Oct. 10, 1780, was 77° 19′ north-following; and, Oct. 30, 1802, it was 83° 41′. The change is 6° 22′, in 22 years and 20 days. The effect of a parallactic motion of the largest star, would have shown itself in a direction contrary to the observed one; a proper motion of one of the stars, at least, must be admitted.

South-preceding Fl. 30 *Orionis.* I, 75.

The position, Jan. 9, 1783, was 89° 36′ north-preceding; and, Jan. 22, 1802, it was 79° 12′ north-following; which gives a change of 11° 12′, in 19 years and 13 days. A parallactic motion of either of the stars, for they are nearly equal, would chiefly affect their distance; besides, the stars are so numerous in this part of the heavens, that we can only look upon this as a casual double star; a proper motion therefore must be recurred to.

η Cassiopeæ. III, 3.

The situation of the two stars of this beautiful double star, June 14, 1782, was 27° 56′ north-following; and, Feb. 11, 1803, it was 19° 14′; which gives a change of 8° 42′, in 20 years and 242 days. This arises probably from a real motion of η in space; for parallax would have had a contrary effect.

d Serpentis. I, 12.

This star has not altered its angle of position sufficiently to be certain of the change, which only amounts to 2° 8′; this

quantity being too small for the precision of the micrometer, when only two measures are taken; but the alteration in the distance of the two stars is well ascertained. Oct. 22, 1781, with 278, it was $1\frac{1}{3}$ diameter of L. April 28, 1783, with 460, it was $2\frac{1}{2}$ diameters; and, May 4, 1802, it was not less than 4 or 5 diameters of L. If this change had arisen from a parallactic motion, there must have been a considerable alteration in the angle of position, which cannot be admitted; it may, therefore, more properly be ascribed to a real motion of *d* Serpentis.

North of 105 *Herculis.* I, 86.

The alteration in the angle of position of this star is uncommonly great. April 27, 1783, it was 79° 24′ north-preceding; and, Sept. 29, 1802, it measured only 22° 27′; which denotes a change of 56° 57′, in 19 years and 155 days. The distance has undergone very little alteration, but is rather less now than it was formerly. A real motion of the largest star, in a north-following direction, may explain this change, which cannot be ascribed to a parallactic motion of the stars.

Rigel. II, 33.

This bright star has undergone a change of situation with regard to its distance from the small one, which is near it; but, in the angle of position, very little difference can be perceived. By eleven measures, taken between Jan. 1, 1802, and Feb. 18, 1803, the mean position is 69° 5′ south-preceding; which is but little more than 68° 12′, the measure of Oct. 1, 1781, given in my Catalogue.

The distance was estimated, Oct. 1, 1781, with 460, to be more than 3 diameters of Rigel; and, as I supposed it to be

one of those double stars of which I might ascertain the vacancy between the two stars, by estimating the number of diameters of the large one that would fill it up, I placed the star in the second class. However, by a measure taken with a micrometer, Oct. 22, 1781, the stars were found to be far enough asunder to come into the third class. By a mean of six measures, which were taken the first 18 months of my observing the star, their distance was $9'' 32'''$; and, by a repetition of estimations, it appeared, Dec. 22, 1781, that the vacancy between the two stars was not less than 4 diameters, and, when the air was tremulous, 4 or 5. After an interval of more than 21 years, having omitted estimations by the diameter, as not very proper to be used with these stars, I wished to compare their distance with the former estimations; and, with the same instrument and same magnifying power that had been used before, the vacancy, Feb. 22, 1803, amounted to 5 or 6 diameters of the large star; so that, certainly, an increase of distance must be admitted.

The number of scattered stars in this neighbourhood, and the smallness of the star to which the relative situation of Rigel has been referred, render it probable that there is only a casual proximity, and no real connection, between these two stars. Nor can the change of their relative situation be accounted for by a parallactic motion of Rigel, although we should admit the small star to be without the reach of solar parallax; for the effect arising from parallactic motion, would not only lessen the distance of the two stars, but would occasion a considerable diminution in the angle of position, neither of which have taken place.

As we have now the proper motion of Rigel, in Dr. MASKELYNE'S new Tables, we can no longer be at a loss for the cause of the change; for, by a composition of the tabular motions in

right ascension and polar distance, this star, in 21 years and 144 days, must have moved about 3″,481, in an angle of 79° 29′ 33″, towards the north-following part of the heavens. This would consequently remove it from the small star, which is placed almost in an opposite direction, and would occasion hardly any change in its angle of position; and these are the very phenomena which have been established by my observations.

ζ Cancri. III, 19.

The position of the stars, Nov. 21, 1781, was 88° 16′ south-preceding; and, Feb. 7, 1802, it was 81° 47′ south-following. The change is 9° 57′, in 20 years and 78 days; and may be ascribed to a parallactic motion of the large star, which is in favour of the observed alteration.

ϱ Capricorni. II, 51.

The position, July 4, 1783, was 84° 0′ south-following; and, August 29, 1802, it was 86° 55′ south-preceding. This gives a change of 9° 5′, in 19 years and 56 days; and a motion arising from parallax will sufficiently account for it.

North-preceding Fl. 56 *Andromedæ.* I, 89.*

The position, July 28, 1783, was 75° 30′ south-following; and; Sept. 19, 1802, it was 67° 4′. The change is 8° 26′, in 19 years and 53 days. A parallactic motion of the large star would have occasioned the change of the angle to be direct, instead of retrograde.

* The 241st Andromedæ of Bode's Catalogue, gives us now the place of this star.

Near 37 Aquilæ. I, 13.*

The position, Oct. 6, 1782, by a mean of two measures, was 37° 15′ north-preceding; and, Oct. 2, 1802, it was 44° 45′. The change is 7° 30′, in 19 years and 361 days; and may be owing to a parallactic motion.

α Ursæ minoris. IV, 1.

There has been a small alteration in the relative situation of the pole star; but, when we consider that this double star is of the fourth class, we cannot expect that any great change in the angle of position should have taken place, in the course of 20 years. The position, Dec. 19, 1781, was 66° 42′ south-preceding; and, June 17, 1782, it was 67° 23′. A mean of both measures, is 67° 3′. March 4, 1802, the position was 61° 43′; which gives a difference of 5° 20′, in 19 years and 350 days. A parallactic motion of the large star, which, considering the great difference of size between the two, may well be admitted, will account for the angular change; especially as the distance of the two stars exceeds the limits which probability points out for connected stars, when the large one is of the third magnitude.

North-preceding Fl. 62 *Aquilæ.* I, 93.

The position, Sept. 12, 1783, was 19° 9′ north-preceding; and, Oct. 2, 1802, it was 13° 21′. The change is 5° 48′, in 19 years and 20 days. A parallactic motion of the largest of the two stars, would have occasioned a contrary apparent motion of the small one.

* The place of this star is now given in BODE'S Catalogue, where it is 136 Aquilæ.

Preceding τ Orionis. I, 54.

The position, January 22, 1783, was 35° 42′ north-preceding; and, Jan. 25, 1802, it was 41° 27′. The change is 5° 45′, in 19 years and 3 days; and may be owing to the effect of parallax.

ζ Ursæ majoris. III, 2.

The position, Nov. 18, 1781, was 56° 46′ south-following; and, Oct. 3, 1802, it was 51° 14′. The change is 5° 32′, in 20 years and 319 days; but this cannot be accounted for by a parallactic motion of ζ, which would have occasioned a contrary change of the angle.

North-following φ Herculis. I, 37.

The position, Oct. 6, 1782, was 59° 48′ south-following; and, Sept. 20, 1802, it was 65° 0′; which gives a change of 5° 12′, in 19 years and 349 days. It cannot be ascribed to a parallactic motion of the largest star.

North-following ν Aquarii. I, 46.

The position, July 31, 1783, was 62° 27′ north-preceding; and, August 29, 1802, it was 67° 27′. The change is 5° 0′, in 19 years and 29 days. The distance of these stars is now greater than it was formerly July 31, 1783, with 460, they were rather more than 1 diameter asunder. August 29, 1802, I found them too far distant to be put into the first class. If any effect of parallax can reach such small stars, it is so far in favour, that it will account for an increase of the distance, but not for the change of the angle of position.

α Piscium. II, 12.

The position of the stars, Oct. 19, 1781, was 67° 23′ north-preceding; and, by a mean of three measures, taken Jan. 28 and Feb. 4, 1802, it was 63° 0′. This gives a change of 4° 23′, in 20 years and 105 days. The parallactic motion of α will account for the alteration, unless a proper motion should hereafter lead to a different conclusion, which, from the insulated situation of this double star, is r t improbable.

Fl. 11 *Monocerotis.* II, 17.

The position, Oct. 20, 1781, was 31° 38′ south-following; and, by a mean of two measures, taken Feb. 4, and March 4, 1802, it was 27° 12′. The change, which is 4° 26′, in 20 years and 121 days, may be accounted for by a parallactic motion.

North-preceding γ Aquilæ. I, 91.

The position, August 7, 1783, was 8° 18′ north-preceding; and, Sept. 20, 1802, it was 12° 23′. This gives a change of 4° 5′, in 19 years and 44 days; and may be accounted for upon the principles of parallax.

e Geminorum. III, 47.

The position, Oct. 2, 1782, was 89° 54′ south-following; and, April 6, 1802, it was 86° 6′ south-preceding; which gives a change of 4° 0′, in 19 years and 186 days. This cannot be ascribed to parallactic motion.

Fl. 32 *Eridani.* II, 36.

The position, Oct. 22, 1781, was 73° 23′ north-preceding; and, Feb. 6, 1804, it was 77° 19′. The change is 3° 56′, in 22 years and 107 days. It cannot be owing to a parallactic motion, which would have produced a different effect.

Fig. 1.

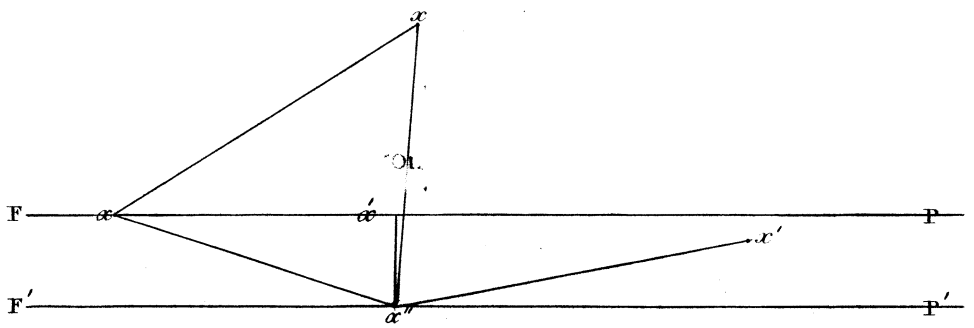

Fig. 2.