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Admiral MANNERS, President, in the Chair.

Rev. C. Gribble, British Embassy, Constantinople;
Dr. G. Neumeyer, 10 Gower Street; and
David Vines, Esq., Kingswood, Bristol,

were balloted for and duly elected Fellows of the Society.

On the Preparatory Arrangements which will be necessary for efficient Observation of the Transits of Venus in the years 1874 *and* 1882. By George Biddell Airy, Astronomer Royal.

On two occasions (*Monthly Notices*, 1857, May 8, and 1864, June 10) I have called the attention of the Society to the Transits of *Venus* across the Sun's disk, which will occur in the years 1874 and 1882; and have pointed out that, for determination of the difference between the Sun's parallax and the parallax of *Venus*, the method by observation of the interval in time between Ingress and Egress at each of two stations at least, on nearly opposite parts of the Earth (on which method, exclusively, reliance was placed in the treatment of the observations of the Transit of *Venus* in 1769), fails totally for the Transit of 1874, and is embarrassed in 1882 with the difficulty of finding a proper station on the almost unknown Southern Continent.

The publication of M. Le Verrier's new Tables of *Venus*, and

of Mr. Hind's inferences from them as to the points of the Sun's limb at which the Ingress and Egress will take place in each Transit (which inferences I have in part verified), has induced me again to examine the whole subject. And, without giving up the hope of using the observation of interval between Ingress and Egress at each of two stations in 1882, I have come to the conclusion (from all the information which has reached me) that it will be unsafe to trust exclusively to the chance of securing observations on the Southern Continent; and that, while observations are by all means to be attempted in that manner, it is also very desirable to combine with them observations of the same phenomenon (at one time the Ingress, at another time the Egress), made at nearly opposite stations whose longitudes are *accurately* known, and recorded in *accurate* local time. This principle being once admitted, the Transit of 1874 is, or may be, as good for observations of that class as the Transit of 1882; and the selection of localities for the observations must be made with equal care for the two Transits.

Mr. Hind's calculations for the points of Ingress and Egress are contained in a paper in the *Comptes Rendus* of the French Academy for 1861, July 22. My valued friend has been so much accustomed, in the admirable calculations issued from his office, to describe phenomena as seen in an inverting telescope (a method of exhibition which I could wish entirely to banish) that he has inadvertently given the elements of Ingress and Egress on that supposition, but without explanation of it. Correcting for this peculiarity, the elements to be used for discussion of observation-stations are, with sufficient approximation, the following:—

Transit of Venus, 1874, *Dec.* 8. *Sun's Declination* 22° 35′ *S.*
Ingress at $14^h\ 0^m$ Greenwich Mean Solar Time.
Position on Sun's Limb 131° from South through East towards North.
Egress at $18^h\ 12^m$ Greenwich Mean Solar Time.
Position on Sun's Limb 160° from South through West towards North.

Transit of Venus, 1882, *Dec.* 6. *Sun's Declination* 22° 44′ *S.*
Ingress at $2^h\ 5^m$ Greenwich Mean Solar Time.
Position on Sun's Limb 35° from South towards East.
Egress at $8^h\ 2^m$ Greenwich Mean Solar Time.
Position on Sun's Limb 66° from South towards West.

With these data, a common terrestrial globe can be adjusted for each place, on the supposition that the Sun is vertically above the globe, and therefore that the globe-horizon defines those parts of the earth to which the phase will be visible. If a point be taken on the globe-horizon corresponding to the "Position on Sun's Limb," the terrestrial station thus indicated is that at which Parallax has its maximum effect in apparently displacing

Venus towards the Sun's centre; and the opposite station is that where the maximum apparent displacement from the Sun's centre occurs. The effect at any other station is proportional to the cosine of its distance, in arc of great circle of the Earth, from the maximum station.

The Maps which I attach to this paper have been prepared by taking advantage of the principle which I have described. They do not profess any extreme accuracy, but they will, I trust, be found abundantly accurate for the purpose for which they are prepared. All are on the same scale except the first, whose scale is $\frac{3}{4}$ that of the others. It will be remarked that the local elements, which at any station are important, are, first, the "Factor of Parallax," or the cosine of angle above mentioned, on which depends the theoretical value of the observation; second, the "Sun's elevation above the horizon," on which the chance of good observation will greatly depend. These are defined upon the maps; for the first, by the station's place among the semicircular curves; and for the second, by the station's place among the parallel lines. A point surrounded by a circle, upon the horizon-line, indicates the place at which the effect of Parallax is maximum.

It will be remarked that, in this mode of observing the Transit, the Ingress is a phenomenon complete in itself, requiring to be observed at nearly opposite sides of the Earth; namely, at one side where it is apparently accelerated by Parallax, and at another side where it is apparently retarded by Parallax. The two maps corresponding to these two tracts of observation will be placed in the bound volume, face to face. In like manner, the Egress is a phenomenon complete in itself, also requiring two districts of observation on nearly opposite sides of the Earth, different from those used for the observation of Ingress, and therefore requiring two special maps, and these in like manner will be bound face to face.

I can now proceed to discuss the individual maps with reference to the selection of stations for the observation of the several phenomena.

Transit of Venus, 1874, Dec. 8.

Map No. 1.—*Stations for observing the Ingress as accelerated by Parallax.*

Owhyhee and the neighbouring islands are excellent. The factor of parallax is about 0·92, and the Sun is at nearly two hours' elevation. There is English society at Woahoo. These islands are just within the tropics. For use of this station the absolute longitude must be accurately determined.

At the Marquesas Islands the Factor of Parallax is 0·7, and the

Sun is nearly as high as at Woahoo. Our neighbours across the Channel have, from the time of Louis XIV., taken an honourable lead in scientific enterprise of every class. I trust that we may rely on them for accurate determination of longitude at Marquesas, and for accurate observation of the Ingress in 1874.

The desert Aleutian Islands can scarcely be recommended, although the factor 0·8 for the westernmost of them, where the Sun is highest, is favourable. But it is very probable that the Russians will soon have established telegraphic communication with the mouth of the Amoor, by which its absolute longitude will be accurately determined; and though the factor is only 0·57, the Sun is 15° high, and the station will be valuable.

On the whole, if the British Government will undertake the accurate determination of longitude of Woahoo, and the careful observation of Ingress there in 1874, we may consider that good provision is made for the Accelerated Ingress.

Map No. 2.—*Stations for observing the Ingress as retarded by Parallax.*

The best station, as referred to the test of numbers, is Kerguelen's Island, where the factor is 0·91, and the Sun is 25° high. This island is emphatically known as "The Island of Desolation." I know not whether its character is so repulsive, or its utility as a zero of longitude so small, as to make our nautical authorities unwilling to determine its longitude, and to station observers there in 1874. If these difficulties are not thought too great, it will be an excellent position. At Crozet's Islands the factor 0·98 is very favourable, but the Sun is rather low (10° altitude).

The next stations in order of merit are Rodriguez, Mauritius, and Bourbon. Mauritius possesses this claim, that it will be a fairly good station, though not so good as Bourbon, in 1882; in 1874, as well as in 1882, it has this disadvantage, that the Sun will be low. If only one longitude can be determined in this chain of islands, it ought to be that of Mauritius; if two can be determined, they ought to be those of Rodriguez (for 1874) and Bourbon (for 1882).

At Madras and Bombay the factors, 0·47 and 0·44, are small; but the value of either station does not depend entirely on its simple factor, but upon the sum of its factor with the factors at the stations in Map No. 1. These two Observatories, with well-known longitudes, will prove very useful stations.

With the assistance which we may hope to receive from the British Government, we may consider the observation of the Retarded Ingress as well secured.

Map. No. 3.—*Stations for observing the Egress as accelerated by Parallax.*

Excluding from consideration the Southern Continent, as not to be entertained in our thought without the most absolute

necessity, the stations in order of merit are the Auckland Islands, Canterbury, Wellington, and Auckland, in New Zealand (factors ranging from 0·83 to 0·77), Norfolk Island (0·66), Melbourne and Sydney (0·6). I omit Chatham Island, where the Sun is rather low. The existence of the Observatories at Melbourne and Sydney makes the observation of the Accelerated Egress almost secure, although, in confirmation, I should much desire to have one station at least on the New Zealand group.

Map No. 4.—*Stations for observing the Egress as retarded by Parallax.*

The stations which are favourable for this observation are almost entirely on Russian and Turkish territories. At none of them is the factor less than 0·84; and we have, therefore, only to consider the elevation of the Sun, leaving to the national governments to estimate the facilities or difficulties depending on the locality, the climate, or the season. Any station either to the east or to the west of the Lower Caspian will have the Sun well elevated. Omsk, Orsk (whose longitude has been determined with peculiar care), Astrakhan, Erzeroum, Aleppo, Smyrna, and Alexandria, have the Sun sufficiently high. At Tobolsk, Perm, Kazan, Kharkov, Odessa, Constantinople, and Athens, the Sun will be rather low, and at Moscow it will be on the horizon. We may with the utmost confidence leave the selection of the stations, the determination of longitude, and the observation of the phenomenon, to our Russian friends. One station, however, ought specially to be considered as being, for this purpose, in British hands, namely, Alexandria. It appears not improbable that we may soon have very direct telegraphic communication with Alexandria; but failing this, I trust that no efforts will be wanting to determine accurately its longitude; a longitude which was in the survey of Admiral Smyth, and which always must be, the zero of longitude in the Levant. This being ascertained, Alexandria would probably be the best of all the stations for observation of the Retarded Egress.

Transit of Venus, 1882, Dec. 6.

First, by the method of absolute Longitudes.

Map No. 5.—*Stations for observing the Ingress as accelerated by Parallax.*

Omitting for the present all allusion to the Southern Continent, it will be seen that the best station is Kerguelen's Island, its factor being 0·98, and the Sun's elevation (12°) probably sufficient. This circumstance, in addition to its value as explained in the discussion of Map No. 2, renders it well worthy of attention. At Crozet's Islands the factor is 0·9, and the Sun's elevation 23°; abstractedly it is preferable to Kerguelen's Island,

but not in quite so great a degree as that in which Kerguelen's Island is superior in Map No. 2. The next in value are Bourbon and Mauritius, with factor about 0·78, the Sun being higher at Bourbon. On comparing these qualifications with those remarked under Map No. 2, the reasons will be evident for my recommendation that either the longitude of Mauritius or the longitudes of Bourbon and Rodriguez should be determined.

At the Cape of Good Hope the factor is about 0·62, and the observation there will be valuable.

The satisfactory observation of the Accelerated Ingress requires, however, some longitude-determinations.

Map No. 6.—*Stations for observing the Ingress as retarded by Parallax.*

Every city near the seaboard of the United States of America, and every important city of Canada, commands this phenomenon most favourably. The lowest factor is 0·95, and the smallest elevation of the Sun is 12°. The utmost reliance may be placed on the zeal of our American brethren for observing the Ingress. As great facility exists for determining the absolute longitude of any place within the range of American telegraphs (Harvard having been accurately referred to Greenwich), it is unnecessary to look further. Otherwise it might be remarked that Bermuda, Jamaica, and the West Indian Islands, and both sides of Central America, are excellent stations, but requiring determinations of longitude.

Map No. 7.—*Stations for observing the Egress as accelerated by Parallax.*

All the American stations mentioned in the last paragraph, from Halifax to New Orleans, and Bermuda and the West Indian Islands, are well situated for this observation, the factors being near 0·85, and the Sun's altitude varying from 4° at Halifax to 32° at New Orleans and Jamaica. The coast of South America also is favourable, from its union with the Isthmus to the harbour of Rio de Janeiro. It is believed that efforts have been made for exact determination, in a nautical sense, of the longitude of Rio; it may now be desirable to give to that longitude the utmost accuracy.

Map No. 8.—*Stations for observing the Egress as retarded by Parallax.*

Omitting for the present the Southern Continent, this observation will be amply secured by the Observatories of Sydney and Melbourne, where the factor is 0·96, and the Sun's elevation 12° to 14°. If, however, the longitudes of the New Zealand stations can be ascertained, they, with factor 0·8 and Sun's elevation 32°, will form a valuable addition.

Second, by the Method of interval between Ingress and Egress.

On comparing Maps Nos. 6 and 7, it will be seen that the North American localities supply, in a manner which leaves nothing to be desired, the demand for stations, at which the Ingress is retarded and the Egress accelerated, or the whole interval is diminished, by Parallax.

With these, it is necessary to combine one or more stations, at which the Ingress is accelerated and the Egress retarded, or the whole Interval is increased, by Parallax. On examining Maps Nos. 5 and 8, it will be seen that the only possible method of responding to this demand is by the selection of stations on the Antarctic Continent, in which the observation will be made when the Sun is nearly below the Pole.

In so far as the coast of the Antarctic Continent follows nearly a parallel of latitude, the best position for a station is at 7^h east longitude. The factors would be, for Ingress and Egress, about 0·95 and 0·68. The Sun would be, at each station, about three hours from the sub-polar meridian. But its elevation above the horizon would scarcely exceed 4°, and any alteration of the longitude, with the view of increasing the elevation at one phenomenon, would diminish it at the other.

Advantage may, however, be taken of the deep southern inlet discovered by Sir James Ross, to the western side of which is given the name of South Victoria. If a station can be established in latitude exceeding 72° S., it will be preferable, for observation of Ingress, to the station in 7^h longitude, and if the expedition could be pushed on to an observing place in the neighbourhood of Mounts Erebus and Terror, that position would be greatly preferable. For observation of Egress, it is manifestly far superior ; the Sun's altitude being about 27°. The factors for the two observations are respectively about 0·78 and 0·58.

The decision on the choice to be made between these two stations, and the judgment on the facility, or even the possibility, of using either of them, must rest with persons who have had some familiarity with Polar, and if possible with South Polar voyages.

In partial correction of some small inaccuracies in these remarks, it may be observed that,—

The Ingress, as viewed from the Earth's centre, is always a few minutes earlier, and the Egress always a few minutes later, than is supposed in the maps.

As affected by Parallax, the phenomenon is always retarded with ascending Sun and accelerated with descending Sun.

As referred to Apparent Solar Time, the phenomena are slightly retarded.

The only phenomena which are critically affected by these corrections are those of Maps Nos. 4 and 5, and in both the circumstances of solar elevation are rendered more favourable.

There may be a cause of uncertainty, in the observation-elements on which M. Le Verrier's Tables of *Venus* are founded, arising from the unsatisfactory form in which the observations of the planet were recorded in Bradley's time. At a critical Inferior Conjunction, when *Venus* was apparently a very large body, very deeply hollowed, it is impossible to say whether the limb was observed or whether an attempt was made to observe the centre. In my reductions of the planetary observations I inclined to the former idea. Subsequently M. Le Verrier adopted the latter. The tables are, at this time, very accurate; and it may prove that M. Le Verrier's interpretation was correct. Any uncertainty, however, of this kind, makes it desirable to avoid observations of the Ingress or Egress very near to the horizon.

It appears, from this discussion, that the Absolute Longitudes required for the observation of the two Transits, the determination of which may be considered as a duty of the British nation, are the following:—

Alexandria.
Stations in New Zealand.
Woahoo, or some other point in the Sandwich Islands.
Kerguelen's Island, or Crozet's Islands (Kerguelen's being slightly preferable.)
Mauritius, or the two islands Rodriguez and Bourbon (which would be preferable).

I now proceed to remark on the methods by which these longitudes may be determined.

For Alexandria,—we may probably rely on the transmission of Greenwich Time, either by sending numerous chronometers in the steam ships which make regular voyages between the British ports and Alexandria, or by galvanic signals through the desired direct telegraph-communication. The saving of time and labour by the latter method would be so great that, if there is any reasonable prospect of soon forming that communication, it would be best to wait for it. The Local Time may be obtained by instruments sent for the purpose, either a Transit Instrument for meridian transits, or an Altazimuth for extra meridian zenith distances. Where the labour of computation, as for a limited object, is not worth taking into account, I prefer the Altazimuth. The largest portable instrument, with circles about sixteen inches in diameter, and with four microscopes for reading the vertical circle (two microscopes being insufficient for eliminating the effect of oval form) should be employed; an instrument of this class now forms

part of the equipment of the Royal Observatory of Greenwich. In every expedition, however, I would send instruments of both classes. It is unnecessary to particularise clocks and chronometers, &c.

For the New Zealand stations, I should trust that connexion by chronometers might be made with Sydney and Melbourne.

For Woahoo and Kerguelen's Island, the circumstances are different. The expense of sending special steamers with chronometers, even from San Francisco to Woahoo, and from the Cape of Good Hope to Kerguelen's Island, would be very great. Here, I think, we must make use of the motions of the Moon. If a hundred transits of the Moon be taken, equally divided between the first and second limb, the probable error of the resulting longitude will be about three times the probable error of a single transit of a star ; or, with liberal allowance for every source of error, it will be below 1^s of time : this accuracy would suffice. A hundred transits might be obtained in a year with the transit instrument, or perhaps in three months by vertical transits with the altazimuth. Through this time, a competent observer must be stationed at the one point. No transmission of chronometers would be required.

The same method, I think, must be adopted for Mauritius, or for Rodriguez and Bourbon.

It would be a question for the Naval Authorities whether the determinations of Absolute Longitude should be preliminary to the observation of the Transits of *Venus*, or whether they should be made about the same time, requiring only one visit of the observer or observers to the station.

For British observation of the Transit of *Venus* in 1874, the number of sets of instruments required (each set including a transit instrument, an altazimuth, a clock, several chronometers, several telescopes, one or two observing tents) would be five (Woahoo, Kerguelen's Island, Rodriguez or Mauritius, Auckland, Alexandria.) For the Transit in 1882, the number required would be three (Kerguelen's Island, Bourbon or Mauritius, Auckland). I suppose here that the Canadian observatories are already sufficiently equipped. The instruments of the 1874 Expedition, thus set free from two stations, would be required at that of which I next speak.

For selection of an observing station on the Southern Continent, I think that it will be best to examine carefully the accounts given by Sir James Ross, and Commodore Wilkes, and their officers, and to decide on the absolute and relative probability of gaining access to the coast on December 6, in the neighbourhood of the Antarctic Circle at 7^h east longitude, or at a much higher latitude on South Victoria ; and also to judge on the possible difference in the transparency of the atmosphere. The choice of station being made, I would not recommend any reconnaissance, but I would propose that an expedition should

go direct to the selected point, in good time for the observation of the phenomenon. The season is early for south polar expeditions, and any difficulties produced by ice would probably diminish every day. A station being gained, all that is necessary in the way of subsidiary observation is, a few days' observation to give clock rate; then the clock times only of the two phenomena will furnish all that is required.

The first action to be undertaken by the Government is, to procure the stock of instruments; and this ought to be done without delay. An observing plant like that above mentioned is not to be obtained in haste; and the proposed expedition might be entirely crippled by a small negligence on this point. The equipment of ships, and the selection of officers, would probably require much less time.

I have now to advert to the details of the instruments and the observations of the Ingress and Egress.

I trust that my friend Mr. Stone (First Assistant of the Royal Observatory), whose knowledge of the accounts of the Transits of *Venus* in the last century probably exceeds that of any other astronomer, and whose personal experience in the observation of the late Transit of *Mercury* is equal to that of any other, will be induced to attach to this notice his own remarks on the points to which the observer's attention ought specially to be called. We are undoubtingly of opinion that the telescopes ought to be nearly similar, with aperture perhaps of 4 to 5 inches, and used with power perhaps of 120 to 200. When there are several telescopes at one station, some variation among them may be actually advantageous. The protection of the eye from the Sun's bright light, and the neutralization of the atmospheric dispersion, require distinct consideration. From my own experience in the observation of total eclipses, and from my view of *Mercury* in the late transit, I can state positively that much is gained in clearness of outline by the use of an achromatised prismatic coloured glass, adjustible by the observer. The atmospheric dispersion enters very seriously into the question of accurate observation. The very nature of a phenomenon, which is to exhibit in the highest degree the effects of parallax, implies, that the planet must immerge or emerge near the highest or lowest part of the Sun's limb, and that the Sun must not be very high. No circumstances can be imagined in which atmospheric dispersion is more injurious. To meet this, coloured shades should be used which, as examined on a solar spectrum, absorb the ends of the spectrum, leaving the green predominant. I think it probable also that advantage would be gained by attaching to the eye-piece a dispersive prism with its acute angle upwards; on this, however, I propose to make some experiments.

I trust that Mr. De La Rue will be induced to publish, with