

THE COMING TRANSIT OF VENUS *

VI.

HAVING now discussed all the methods to be employed, and the chief difficulties to be encountered, it is time to examine what has actually been done. What method or methods ought to be chosen? What stations are most suitable, taking into account the chances of good or bad weather and good or bad anchorage? What preparations have been made by the various Governments and by private individuals? And are the arrangements satisfactory?

As to the choice of method, the observation of contacts was the only kind originally contemplated. The employment of photography and heliometers is a comparatively new idea, and will be spoken of later. The observation of contacts is applicable to three methods, for each one of which different stations must be chosen; these are Halley's method, the method of durations, and De l'Isle's method. We will consider these in order.

1. Halley's method fails totally in the transit of 1874, but *may* perhaps be applied in 1882, though not under good conditions. On referring to Fig. 13 in Article III., it will be noticed that Sabrina Land is a station where in 1882 the transit will commence just before sunset, and end just before sunrise. Hence during the transit this station and another placed in America will be moving in opposite directions, thus fulfilling the conditions required by Halley in his communications to the Royal Society. By referring to Fig. 12 it will be seen that no such stations exist in 1874.

2. The method of durations may be successfully applied, so far as mere geometrical position is concerned, in either of the two transits. This method is really combined of two parts, and includes Halley's as a particular case. The lessening of the duration of the transit depends partly upon the diminished motion of one of the stations, or upon the fact that it moves in the opposite direction to the other; and partly on the fact that in one case the planet seems to trace a path on the sun farther from his centre (and therefore shorter) than in the other. The difference in this last case is greatest when the path of Venus is far from the sun's centre. But in transits like the coming ones, where this is the case, the motion of Venus towards the sun's centre at the time of contact is very much slower than when she describes a large chord upon the sun. This has been well pointed out by Mr. Stone, † and from his paper we learn that the method of durations depending upon two such observations at each of the two stations will not be so satisfactory as we might otherwise have expected. But other very serious objections present themselves to a method like this requiring four observations of contact, when we carefully consider the circumstances. In applying this method, one station must be chosen in high southern latitudes. Now diligent inquiries have been made upon this subject, and it appears very improbable that the weather at any suitable station will be such as to give much hope of observing both the ingress and egress in a satisfactory manner. Hence if we depended upon this method there would be a great probability of the expedition proving a failure. The method of De l'Isle requires the observation of only one contact at each of the two stations. For these reasons hardly any expedition will use this method except as secondary to De l'Isle's, the photographic, or the heliometric method.

3. De l'Isle's method. The accuracy with which this method can be applied depends upon the certainty of longitude operations. From what was said in the last article, it will be seen that this is no easy matter; but it is

absolutely necessary that it must be done if this method is to be employed. Sir George Airy says that longitudes can be determined with an error of not more than one second by lunar observations; and observers will receive orders to remain at their stations until they have a sufficient number of observations to accomplish this. The lunar observations will be supported, where practicable, by telegraphic determinations of longitude, and also by the transport of chronometers. The Russians, whose stations lie mainly along the whole length of Siberia, will employ a telegraphic line over that region, with branch lines to the subsidiary stations. The English will probably fix the longitude of Alexandria by submarine cable. They will employ chronometers to group together all stations neighbouring each other. The station at Rodriguez will be thus connected with Lord Lindsay's station at Mauritius, and with the French station at Réunion. Lieut. Corbet, R.N., will connect by chronometers the various islands occupied by the Germans, Americans, and French in the neighbourhood of the two English stations on Kerguelen's Island. The three English stations on the Sandwich Islands will likewise be connected by chronometers; and it would be very desirable to connect these islands with San Francisco on the one hand, and Yokohama on the other. The longitudes of both these places will have been compared with Greenwich by telegraph. It would be a matter of the utmost interest to complete the chain round the world by the transport of chronometers across the Pacific. M. Struve says that with the aid of an uncompensated chronometer this might be done with great accuracy. The Germans have also made valuable suggestions for comparing the longitudes of the observing stations of all nations; and the French will also probably help in this matter. Thus it is likely that the longitudes of all the stations of different countries suitable for the application of De l'Isle's method will be very accurately known.

It will be noticed that the accuracy of De l'Isle's method depends upon two longitudes and two observations of contact; while that of durations depends upon four observations of contact. Neglecting all considerations of climate the two methods are, so nearly as the somewhat vague data at our command can tell us, very nearly equal. But the uncertain climate of southern seas renders the chance of many contact observations doubtful and throws the balance in favour of De l'Isle's method. Add to this that before long all the stations except the Kerguelen group will soon have their longitudes determined absolutely by telegraph, and recollecting that the coming observations are to serve astronomers until the next transit of Venus in 2004, by which time even the Kerguelen group may perhaps be chronometrically determined: recollecting all this, there is little doubt that astronomers have been wise in settling upon De l'Isle's method for the main observations of contacts.

It will be well, before going further, to mention the stations which have been chosen by different nations for the observation of the coming transit.

I.—The British, having selected for the reasons above mentioned the method of De l'Isle, originally fixed upon the following stations:—

Alexandria, Sandwich Islands, Rodriguez, Kerguelen's Island, and New Zealand. No alteration has been made in the choice of these stations. Supplementary ones have, however, been added. Thus at Kerguelen's Island there will be two expeditions: one at Christmas Harbour in the north, and the other in the south of the island. In the Sandwich Islands there will be three stations: one at Honolulu, a second on the island of Hawaii, and a third on the island of Kauai, sometimes called by English writers Atooi. The station at Alexandria will be supplemented by a second one at Cairo, and a private one by Col. Campbell, of Blythswood, under the Astronomer Royal's direction at Thebes. The New Zealand station

* Continued from p. 52.

† Monthly Notices of the R.A.S., vol. xxix. p. 250.

will be placed at Christchurch. Since the idea of photography has been introduced, two additional stations have been added by the Indian Government under the superintendence of Col. Tennant, R.E. These are very completely equipped, and will probably be situated the one near Peshawur, the other at Roorkee.

Besides these the observatories at Madras, Cape of Good Hope, Melbourne, and Sydney will be utilised so far as possible. The New South Wales Government have voted 1,000*l.* for other observations in Australia. The English Government have voted 15,000*l.* for all the expeditions, but a much larger sum than this will be actually required. It will be understood that the principal method of observation is De l'Isle's, aided everywhere when possible by all the other methods except the heliometric.

From the account that has been given of the difficulty of determining the longitudes of the different stations it will be seen that no little power of organisation is required for the execution of the foregoing programme. All preparations must be made for the observation of the moon culminators. Alt-azimuths must be made, and also actually invented for the express purpose. Nearly fifty chronometers must be provided, and negotiations must be completed with telegraph companies. The photographic operations have required the invention of a new photo-heliograph, and the Janssen method of a new application to it. The observations of contact have required the purchase of a large number of equatorials; for each station, besides having a 6-inch telescope, has also one or more smaller instruments. One of the larger ones, made by Simms, is shown in Fig. 18. The transit instruments have also been made expressly for this expedition. Besides this all the accessories of these instruments had to be provided. Huts for receiving them had to be made. Forms for entering and reducing the observations had to be prepared and printed. For some of the stations sleeping arrangements, cooking apparatus, washing utensils, and provisions had to be provided. Workmen, masons, and assistant photographers, besides twenty-two observers, had to be collected and trained to the work. When this is considered it will be seen that no ordinary man could fulfil all the duties. Fortunately we have in our Astronomer Royal a man who combines to an exceptional degree theoretical, mechanical, and organising powers; and we may safely say that the present expedition has been completed under a generalship quite unparalleled in the annals of Science. Sir George Airy has accomplished all that was required in a manner that has called forth the applause of those who have been connected with the preparations for this perhaps the most important astronomical event of the century. We must congratulate ourselves upon the fact that he has been most liberally supported on all points by the British Admiralty. If we cannot enter into the same details with regard to other nations, it is only because we have not had the opportunity of learning all their actions. But we cannot conclude this account of the British Government expedition without alluding to the valuable services which have been rendered to it by Capt. G. L. Tupman, R.M.A., who has spent the last three years in training himself and nearly all the other observers in the use of the instruments, seeing the instructions of the Astronomer Royal carried out, ordering the stores, and in the most disinterested manner looking after the expedition; so that (as the Astronomer Royal has lately pointed out) if the observations be successful their success will in a great measure be due to his exertions.

II. Besides the expeditions under the direction of the British Government, another has been prepared which is perhaps the most completely equipped one which has ever been undertaken by a private individual in the interests of astronomy. Lord Lindsay has made preparations to take up his position at Mauritius, provided with means for utilising all the different modes of observation.

He will combine his own results mainly with those of the Russians; and it is probable that no station could have been found more suitable for a single observer to occupy when so many different methods are employed. All the instruments are of the most perfect description and made by the best makers. The photographic method which he will employ has been already described. The siderostat has been made expressly for this purpose, and its surface has been tested and found to be truly plane. Lord Lindsay and his assistant Mr. Gill lay considerable stress on the employment of the heliometer, and have discussed its capabilities with great lucidity. They propose to make observations of the external contact by the aid of the spectroscopic method. The expedition will be provided with about 50 chronometers, including one uncompensated. These will be transmitted four times between Aden and Mauritius. It is probable that they will also connect the longitudes of the different stations on that group of islands by chronometers. The German expedition at Mauritius will probably be connected with Lord Lindsay's by a trigonometrical survey. Of these islands two can be connected by direct signals with a heliotrope reflecting the sun's light. From experiments made in Russia, it appears that a signal may thus be seen in a mountainous country with a clear atmosphere at a distance of 200 miles. There is little doubt then that the longitude of each station on this group of islands will be accurately known.

III.—The Germans are sending out five or six expeditions. At Cheefoo the accelerated ingress and retarded egress will be observed; at the Macdonald Islands the retarded ingress and the accelerated egress. The Auckland Islands will be favourable for accelerated egress; Mauritius for retarded ingress, and Ispahan for retarded egress.

They will probably employ all the four methods at most stations, viz. eye-observations of contact, heliometers, photo-heliographs for the distance of centres, and also for position-angles. There will be no photography at Mauritius. Here will be employed four heliometers by Fraunhofer, 3 in. aperture, 3½ ft. focus; four equatorially-mounted telescopes by Fraunhofer 4½ in. aperture, 6 ft. focus; two photo-heliographs by Steinheil, 5½ in. aperture, and two with quadruple object-glasses of 4 in. aperture. Besides these, instruments are required for determining the local time and the longitude; for the Germans lay great stress on De l'Isle's method. For this purpose transit instruments with diagonal telescopes on the Russian method of 2½ in. aperture will be supplied, and alt-azimuths with divided circles 12 in. to 14 in. diameter. The necessity of determining the longitudes accurately has led the German astronomers to consider carefully the best means by which this can be done. Dr. Auwers, to whom the direction of the arrangements has been entrusted, has discussed the matter in a very able manner. It appears from his inquiries that each group of stations will have their longitudes very accurately determined. Thus the stations in east Asia can be connected telegraphically. So also can those about Alexandria; also those about the Caspian Sea and New Zealand. The group of islands near Kerguelen's, the Sandwich Islands group, and the Mauritius group will be determined by chronometers. The only difficulty is to connect these different groups. Many of them will be compared with Greenwich indirectly by telegraph. It is probable that Honolulu will be compared by chronometers with San Francisco and Yokohama, thus completing, as already mentioned, the telegraph and chronometer connection round the world. In any case there is little doubt that before the transit of Venus in 2004 the longitude of Honolulu will be determined by telegraph. Since Lord Lindsay intends to compare the longitude of Mauritius with that of Aden by four chronometer expeditions, aided by an uncompensated chronometer, there is little doubt that the longitude of that group of islands will be

accurately known. The group of islands about Kerguelen's will depend very much upon the British observations of the moon; but it will be well if chronometers could be employed to connect it with the Cape. The Germans rely very much upon the heliometric method. It will be a matter of great interest to learn how these observations agree with other methods as a guide to the arrangements for 1882. The expense of this expedition is about 130,000 thalers, besides the expenses connected with chronometric determinations.

The organisation of the German expedition has been entrusted almost wholly to Dr. Auwers, as secretary of the commission. His contributions to the subject are of great value, and the zeal with which he has superintended the expeditions, even in the minutest details, cannot be overvalued.

IV. The Russians are mainly employed in utilising the Siberian stations. The actual places which have been chosen from which to observe the transit are given in the following list, in order from east to west. The numeral 1 appended to a station means that there are good ob-

servers, practised with the model, good equatorials, and a heliometer or photo-heliograph. The numeral 2 signifies the same without heliometers or photo-heliographs. When the numeral 3 is appended, the observer has not practised with the model, and employs a small telescope. The stations are:—

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| Yeddo 2 | Tachkent 1 |
| Port St. Alga 3 | Port Peroffski 1 |
| Nakhodka 2 | Fort Uralsk 1 |
| Wladivostock 1 | Orenburg 3 |
| Port Possiet 1 | Aschura-deh 1 |
| Lake Hanka 1 | Teheran 2 |
| Chabarovka 2 | Nachitzewan 2 |
| Peking 2 | Erivan 1 |
| Blagowvtschenska 2 | Tiflis 3 |
| Nertschinsk 1 | Taganrok 3 |
| Xhita 1 | Kertch 2 |
| Kiachta 1 | Ialta 2 |
| Tomsk 3 | Thebes 2 |

Besides these stations the following will be utilised, but the sun will be very low: at Kazan the sun's altitude will

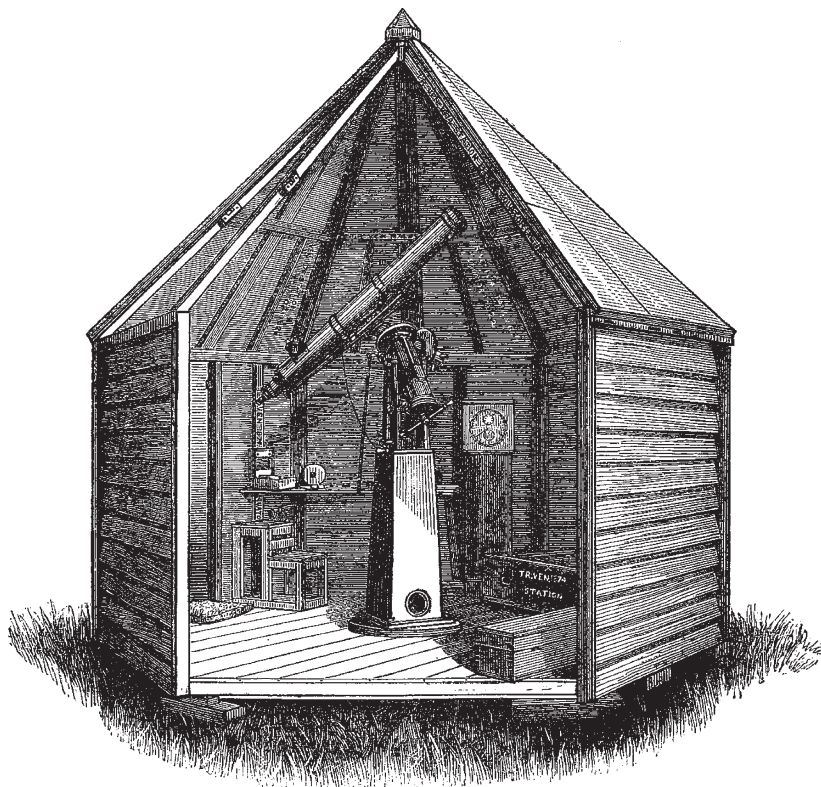


FIG. 18.—6-in. Equatorial of the British Expedition.

be 8° or 10° , at Nicolaïf it will be 6° , and at Charkof and Odessa 5° ; at Moscow it will be exactly on the horizon.

As to instruments, the Russians are employing 6-inch and 4-inch equatorials. Their heliometers are larger than those of the Germans, having 4 in. apertures. Their photo-heliographs are constructed on the English model by Mr. Dallmeyer. The telegraphic connections between the stations have been already discussed. The expense incurred will be defrayed by the Government. Besides this, the State contributes 45,000 roubles. This will be spent mainly on the transport and maintenance of observers and instruments. The different observatories in Russia have shared the expense of providing the different instruments. The whole expedition has been conducted under the superintendence of M. Otto Struve.

Some of the expeditions have already started provided with every means for resisting the cold of a Siberian winter. Great attention has been paid to the chances of good weather. The accelerated ingress and retarded egress will thus be admirably observed; and the comparison which M. Struve has made with observers of other countries in practising with the model will render comparisons possible. Moreover, many of the Russian stations are admirably situated for the employment of the method of durations; and if the two internal contacts be observed at any of the stations in the neighbourhood of Kerguelen's Island excellent results may be obtained.

GEORGE FORBES

(To be continued.)