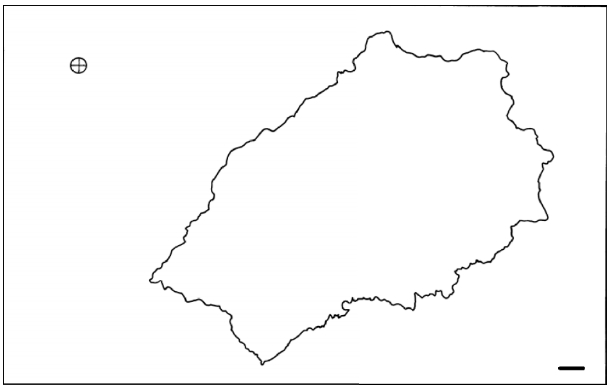

Fig. 8. The position estimated by Maskelyne and the real position.

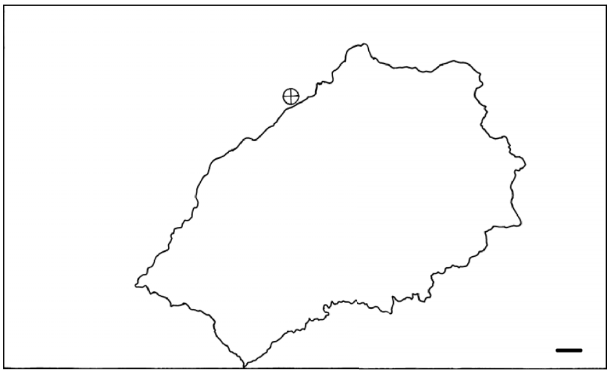

Fig. 9. The position estimated by Johnson and the real position.

1826. Johnson had made observations of the southern stars from November 1829 to April 1833. In 1833 he retired from the Artillery and went back to England. There in 1835 he published his work as the star catalogue [9], by which he received the Gold Medal from the Royal Astronomical Society. The year 1835 saw the return of Halley's Comet.

The lunar distance method is shortly to know the Moon's position in the celestial sphere. An astronomer or a navigator observes the culmination of the Moon and compare the data with the master data of the Sun or the fixed star predicted in 'Nautical Almanac [10].' After some algebra one gets the longitude of the observed place from Greenwich. There is the companion manual [11] that comprehensively describes how to handle data. The center of the Moon is merely conceptual, because the Moon waxes and wanes. The observation is made at the Moon's limbs. One calculates when the conceptual center of the Moon culminates. Johnson determined the longitude of the Ladder Hill observatory by the lunar distance method comparing his 1830–33 data with those at Greenwich, Cambridge and the Cape of Good Hope. The result is as follows:

The latitude: 15°55′26″S; the longitude: 5°43′39″W.

As shown in Fig. 9, the estimated position is in the ocean and several hundred metres away from the observatory site.

There was a solar eclipse on 27th July 1832. Jonson observed this solar eclipse at the Ladder Hill observatory. But the solar eclipse is not a global event, and he estimates timings of the conjunction [11] by using data observed at St Helena ($13^h39^m8.6^s$), St Fernando near Cadiz ($13^h37^m2.5^s$), Marseille ($14^h23^m19.4^s$), and Padua ($14^h49^m11.4^s$). Comparing differences of the conjunction timings, he arrives at the conclusion: by St Fernando near Cadiz 5°40′45″W; by Marseille 5°40′27″W; by Padua 5°38′24″W. Johnson is not satisfied with these longitude estimates.

Our exercise makes use of the true conjunction time at Greenwich. It is, however, unavailable, so we shall use NASA data base: $14^h01^m00^s$ (UT) with 6 seconds error.

*St Helena: $14^h01^m00^s - 13^h39^m8.6^s = 21^m51.4^s$.

This is very short, for the estimated longitude is only 5°27′51″W. Let us check out the other sites:

*St Fernando: $14^h01^m00^s - 13^h37^m2.5^s = 23^m57.5^s$; longitude at $24^m49.1^s$ by [10];

*Marseille: $14^h01^m00^s - 14^h23^m19.4^s = -22^m19.4^s$; longitude at $-21^m29.0^s$ by [10];

*Padua: $14^h01^m00^s - 14^h49^m11.4^s = -47^m11.4^s$; longitude at $-47^m29.2^s$ by [10].

The longitudes in [10] are quite correct, so the estimated timings of the conjunction is the source of the errors. The errors of these sites are 51.6^s (St Fernando), 50.4^s (Marseille), and 42.2^s (Padua). It is difficult to determine the longitude by the solar eclipse, because the observation depends on the location of the earth.

3. Conclusion

In the Age of Exploration the pressing problem is determination of the longitude at sea or on an unknown place. Before the marine chronometers became commodities among navigators, the astronomical observations are crucial clues to determination of the longitude. The process is the unification of space and time: to read the celestial situation and the local time; then to compare the local readings with those on the mother land.

In the first place we point out establishing local time with the connection to 'Equation of Time,' the phenomena geometrical as well as gravitational. The solar culmination must be corrected by 'Equation of Time.' The algorithm for 'Equation of Time' presented here is our novel and rigorous recipe.

The next step is observing the celestial events that would be timing-sensitive. Historically astronomers paid attention to eclipses of Jupiter's satellites. By mid-17th Century this became the most accurate method, but setbacks are inapplicability at sea, necessity of skills in observation, and sometimes unavailability.

The second best is the lunar distance method. This requires comparison between the lunar culmination and the solar culmination (or other star culmination). Less skilled navigators could observe the large Moon. But the Moon waxes and wanes. Therefore one must observe the Moon by its limbs, and this fact affects accuracy.

There are introduction of three other ways of determining the longitude and accompanying exercises about the island of St Helena.

(1) Edmond Halley's observation of 'the transit of Mercury:' the result points the place one island away from St Helena.

(2) Nevil Maskelyne's observation of the total lunar eclipse: the result points the place half an island away from St Helena.