From the seventeenth century on, problems in physics became the object of careful study. These were mainly related to astronomy and the shape of the Earth, which called for organized scientific expeditions to take measurements in different places. Here we present some of these problems and the solutions adopted at the time.

Keywords: eclipse, Meridian, weather, relativity, travel.

It is easy to understand why naturalists need to travel but the fact that physicists have to undertake expeditions to solve or study certain problems in depth may come as a surprise. You may think: «of course, they must meet with other scientists or visit specially equipped laboratories to perform certain experiments». Certainly this type of travel forms part of the work of any scientist, but that is not the issue dealt with here. Rather, we are talking about journeys undertaken to gather data – otherwise unobtainable – needed to study specific problems. There have been many expeditions, mainly dealing with issues relating to the size and shape of the Earth or other astronomical problems. But, as we will see, some journeys have proved useful to address theoretical problems such as the theory of relativity.

Johannes Kepler (1571-1630) was the first to calculate the transit of Venus between the Sun and Earth. His prediction, for 1631, had a margin of error of just a few hours. Newtonian mechanics allowed more accurate calculations and he realised that these transits occur only in twos and were a hundred years apart. Therefore, it was not possible to immediately verify Edmund Halley’s (1656-1742) proposal that the solar parallax and consequently the distance between the Sun and Earth could be calculated quite accurately from the observations of the transits of Venus (Halley, 1716) as it was necessary to wait for the first pair of transits to occur in 1761 and 1769.

Partly due to inexperience, the 1761 observations turned out to be somewhat unsuccessful. Nonetheless, the Russian physicist Mikhail Lomonosov (1711-1765) was able to conclude there was an atmosphere on Venus. But the errors provided a learning experience and served to make preparations for the 1769 sighting like never before. Institutions in many countries prepared observations each in their own territory, and expeditions to places with the best views (as it is a phenomenon that lasts just a few hours, it is good to find places where it can be seen around noon). Indeed, when the British Royal Society was preparing its expeditions in 1768, the first news arrived from Samuel Wallis about the island of Tahiti. It seemed like an ideal spot for observation, and so they organized an expedition under the command of James Cook (1728-1779). The observations were made
at a place still known as Venus Point (Cook and Mohr, 1771).

In addition to observing the transit of Venus, Cook had received orders to find and study the «Terra Australis Incognita», a continent that was supposed to be located in this part of the Earth. Although they did not find it then, they did collect a lot of new geographical and naturalistic data on New Zealand and Australia, virtually unknown at that point (Cook, 1922).

■ THE SHAPE OF THE EARTH

According to the gravitational theory put forward by Newton (1642-1727), the Earth could not be spherical, but ellipsoid instead – slightly flattened at the poles –, which is why the measurement of a degree of latitude should not be the same everywhere. However, the measurements taken by the astronomer G. D. Cassini (1625-1712), director of the Paris observatory, pointed to a flattened shape at the equator. Given the recognized quality of Cassini’s measurements, and both Cassini and Newton’s prestige, the French Académie des Sciences undertook an experiment to get to the bottom of the riddle. What they did was to measure the length of a meridian arc in two places where the supposed differences were greatest in order to minimize possible errors. They chose Lapland – as this land is accessible but close to the North Pole – and the Viceroyalty of Peru – then part of the Spanish empire – located on the equator itself. They then organized two expeditions to take measurements in both places simultaneously.

The northbound expedition was led by Pierre-Louis Maupertuis (1698-1759), and left Paris in April 1736 and returned in July 1737. Not only did they confirm Newton’s hypothesis with their measurements, but also took the opportunity to collect ethnographic and naturalistic samples. The southbound expedition to the Viceroyalty of Peru was led by Charles Marie de La Condamine.
Condamine (from 1701 to 1774). It comprised, among others, Pierre Bouguer (1698-1758) and Louis Godin (1704-1760) and was joined in America by two naval officers from Spain: the Valencian Jorge Juan (1713-1773) and Antonio de Ulloa from Seville (1716-1795). The work in America presented a greater challenge than in Lapland. The travellers had to make observations in tropical conditions on the coast and others in snow-covered mountains. If we add to these troubles, the quarrels that broke out between them (sometimes they went off separately), we understand why the expedition lasted until 1744. Indeed they each returned separately. For instance, instead of backtracking, La Condamine followed the course of the River Amazon to Pará and from there returned to Paris, where he arrived in February 1745 (Lafuente and Mazuecos, 1987).

Apart from the measurements that again confirmed Newton’s hypothesis, they took many others related to the force of gravity and, for the first time, of the gravitational anomaly detected near the mountains (known as the Bouguer anomaly). They also took many meteorological measurements and witnessed other phenomena and took naturalistic records (Juan and Ulloa, 1748).

This work later involved measuring the meridian arc from Paris to Barcelona to define the metre, which would last throughout the nineteenth century, extending the measurement of the meridian from the Shetland Islands to Laghouat in Algeria, 27 degrees in total. It was an undertaking full of adventures, many occurring in Spain, but we will not go into describing them here.

■ METEOROLOGY AND THE POLAR YEARS

The nineteenth century witnessed an explosion in the development of meteorology. Suffice to say that this was due to the invention and use of the telegraph rather than to great scientific progress. This invention made it possible to compare simultaneous data in almost real time and analyse the atmosphere over large areas, shedding light on the movement of cyclones. In the second half of the century, almost all major national meteorological services and data exchange networks were set up and by 1870, after several attempts, the International Meteorological Organization was established.

At that time, almost all weather stations were in the northern hemisphere, and they soon realised there was
a strong relationship between major winter depressions affecting Europe and the Polar regions. However, these regions did not have meteorological stations (nor telegraphs that could disseminate their data), therefore it is not surprising that when the Austrian Carl Weyprecht (1838-1881) proposed an expedition to make observations at the Poles, others rallied to the idea immediately. Thus, a number of weather observation expeditions to places with extreme climatic conditions were coordinated and organized internationally rather than nationally, as had been the case before (Batlló, 2008).

This took place between 1882 and 1883 with the participation of twelve countries. To carry out these expeditions, they had to coordinate many aspects, design homogeneous observation methodologies (then not yet fully standardized) and create new instruments (for instance, the commonly used alcohol thermometers froze, and so did the ordinary psychrometers). They defined an entire methodology to observe the northern lights. Indeed, these expeditions were packed with adventures! You can read the original reports of various expeditions, which have recently been digitized\(^\text{1}\). For example, the American expedition to Lady Franklin Bay had to be rescued two years later.

Although not remarkable, the results of the first Polar expedition were useful, and thus on the occasion of the 50th anniversary, the second International Polar Year was organized between 1932 and 1933, encompassing both hemispheres and with better means at its disposal. This was repeated in 1957 and 1958 but was designated as the International Year of Geophysics. In fact, regardless of the epic nature of the first project, the latter was the largest international scientific collaboration ever made up to that time, indeed, we should remember

\(^{1}\) They can be found at the following website: <http://www.arctic.noaa.gov/aro/ipy-1/index.htm>
that the Soviet Union launched the first artificial satellite, Sputnik, in collaboration with this project.

More recently, a new «Polar Year» was held in 2007-2009, although this event mainly intensified observations and experiments in existing observatories, rather than performing «adventurous» expeditions like the previous ones.

CONFIRMING THE THEORY OF RELATIVITY

By 1911, Albert Einstein had already postulated that the light from a star would be deflected by passing near the Sun. At that time, it was impossible to observe stars near the Sun (resolved 20 years later, when Bernard Lyot invented the Coronograph in 1931), thus the only chance to observe and measure the phenomenon was during minute-long eclipses. The first attempt to measure these deviations during the eclipse of 1914 was thwarted by the outbreak of the First World War. The Greenwich expedition was already in Russia, and although the astronomers managed to return to England they were unable to recover their apparatus until 1919.

The first total solar eclipse after the war occurred on 29 May 1919 in the equatorial Atlantic Ocean. The Royal Society prepared two expeditions: one to Sobral, on the coast of Brazil, led by Frank Watson (1868-1939), director of the Greenwich Observatory, and another to the island of Principe, off the West African coast, led by Arthur Eddington (1882-1944), director of the Cambridge Observatory. Unfortunately, bad weather and problematic instruments almost ruined the expeditions. Finally, however, the measurements were taken and confirmed Einstein’s postulates (Dyson et al., 1920).
Juan Olivares. Journey to the Centre of the Earth VI, 2013. Acrylic on paper, 21.5 × 28.5 cm.
EPILOGUE

On taking a closer look, we see certain characteristics that are specific to expeditions in physics. The first is that most journeys are coordinated, with various groups travelling to different places. The reason is obvious: one does not need one measurement, but to compare the same measurements from different places.

Also, given the size of the enterprise, it is also common to find they were organized by large scientific institutions rather than the personal interests of particular scientists. However, there are some noteworthy exceptions like, for example, the journey undertaken by Alexander von Humboldt (1769-1859), who took a host of magnetic and meteorological observations, revealing the wide scope of his interests.

REFERENCES


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