Highlights of Spanish Astrophysics VI, Proceedings of the IX Scientific Meeting of the Spanish Astronomical Society held on September 13 - 17, 2010, in Madrid, Spain. M. R. Zapatero Osorio et al. (eds.)

Teaching astronomical navigation at the university: an historical overview

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Abstract

Astronomy and navigation are two sciences whose historical evolution have been linked for centuries through relationships of mutual dependency, up to the point of leading to a new science: astronomical or celestial navigation. Currently, astronomy has a very important well defined area within all university nautical degrees. Knowledge of astronomical navigation is still mandatory for deck officers in merchant ships. In the GPS era, practicing astronomical navigation has been relegated to a mere control procedure, and the tendency is to falling into disuse. Nevertheless, it is still the only method through which seamen can depend on their own means and knowledge to keep a track in a safe way. The new syllabi of our majors contemplates a drastic reduction of the contents of this subject, whose importance in the seafarer's profession we want to highlight in this paper.

1 Introduction

For centuries, astronomy and maritime navigation have been two intimately linked sciences. Let's keep in mind that, up to the appearance of hyperbolic radionavigation systems and of first satellite positioning systems, around the second half of last century, seafarers only counted on the stars to obtain their position when they were out of sight of the coast. The following sections provide a brief historical overview recalling the major advances in the understanding of celestial dynamics and improvements in astronomical instruments that allowed the development of maritime navigation up to the current situation in which technology seems to have completely overcome traditional navigation methods.

2 Historical perspective from the XV to the XVIII century: the evolution of the "art of navigating"

The beginning of astronomical navigation is attributed, within Western Europe, to the sixteenth century's Portuguese and Spanish navigators [3]. Up to that moment, voyages were

Figure 1: Original project of the building of the "Official Nautical School" of La Coruña, dated 1948. This building still hosts the current nautical degrees in A Coruña University.

rarely away from the coast, and if they were, seafarers used basic rules of observation of natural phenomena, such as the direction of prevailing winds and currents, presence and behaviour of birds and fish and the colour of the water, not to obtain a position but to get an orientation during their trip. Some astronomical events were also used, such as movement of the sun, rising in the east and setting in the west, and the position of the stars during the night, especially the Pole star. Nevertheless, these astronomical navigations lacked a scientific methodology and were only used to determine the direction to be followed to reach the shore [3].

This situation changes dramatically throughout the fifteenth century. During the era of great discoveries, first the Portuguese and then the Spanish realized that more safety and accuracy in navigation was needed. Government's investment in these voyages and commercial exploitation of the new established routes led to promote research to use available resources in different sciences, especially astronomy, to solve problems and inaccuracies of navigation during that period.

This is how astronomers and cosmographers were put at the service of navigation, applying methods that had been already applied inland to measure geographic latitude and adapting the instruments for observation of altitude so that they could be used at sea.

The first procedure used on board to determine latitude was the observation of the altitude of the celestial pole over the horizon. However, this procedure could only be used at night and, in any case, it became unworkable for those expeditions that crossed the Equator. The solution was provided by the appearance of solar declination tables and of methods known as "regiment of the Sun", with which latitude was calculated by measuring its meridian

altitude.

In order to apply these methods, different instruments for measuring the altitude of the stars were developed [4]. These instruments were at first a mere adaptation of the ones already used in traditional astronomy. The first instrument for this purpose was the nautical quadrant, derived from the most complex astronomical quadrant, used on land since the time of Ptolemy. This instrument, due to the difficulty of its employment on board a ship that's moving, was soon displaced by the nautical astrolabe, derived equally from its equivalent on land but in a smaller size and with openings on its surface to provide less resistance to wind. However, astrolabes also seem not to be too useful when the sea was not calmed, falling into disuse when the cross staff appeared for the first time during the first half of the sixteenth century. This last instrument, derived from the Jacob's staff used in astronomy and topography, was the first practical solution to measure altitudes in the sea. From that moment, many tools were developed to that end, reaching the Davis quadrant, at the end of the sixteenth century, whose use would extend to the mid-XVIII century [3, 5].

Once in the sixteenth century, it was already possible to determine at sea the four classic terms in which navigation was divided: course, navigated distance, latitude and longitude, but still with very poor accuracy [3]. Course was established with the help of the compass, while the navigated distance was calculated with the chip log and the experience of the officer, latitude was obtained using observations of altitude of known stars and, finally, longitude was estimated over the chart based on the previous data. Errors were significant. The fact that the compass did not indicate the real north was still unknown. The chip log was a primitive instrument and did not consider the effect of ocean currents not mentioning when the calculation was left to the intuition of the officer. Navigation charts available were far from accurate. And the calculation of latitude, being the most reliable data that officers could get at sea, also induce to error due to the imperfection of the instruments used, the available data on the declination of the sun, and the lack of knowledge of the corrections to be applied to the observed altitudes.

This situation marks the detachment of nautical astronomy from its counterpart on land. While the first one was a mere appendix to the second one up to the moment, this relationship was reversed between the seventeenth and eighteenth centuries, the research in the field of astronomy becoming a subordinate to the needs imposed by the problems of navigation. Maths also played an important role in this aspect. While until the beginning of the seventeenth century the only method used to solve problems on navigation was basically geometry, from that moment on a new concept of spherical triangle of position was introduced and the treaties on navigation of that time began to implement trigonometry formulas to the problematic of obtaining the latitude.

But while the resources of science were sufficient to solve the problems and inaccuracies of navigation, with the exemption of the calculation of the geographic longitude, which still constituted a pending matter, it was obvious that a new and important source of errors required a prompt solution, this source was the lack of training of seafarers.

Throughout the sixteenth century, institutions for training and examination of seafarers were created in practically all countries with a nautical tradition. This way, in the early 1700s, it was possible to have seafarers instructed in the techniques of traditional navigation based

Figure 2: *Left*: Modern sextant for teaching astronomical navigation, in use at La Coruña University. *Right*: Measuring the solar azimuth with an alidade.

on the use of arithmetic, geometry and learning of rules that covered situations that were likely to occur. Nevertheless, the knowledge they acquired by was far from turning them into real scientists. As regards of celestial navigation, training consisted of no more than teaching the use of the different devices and the use of tables and certain rules that they had to memorize and which allowed them to obtain a position by using data such as course, navigated distance and observed altitude of one or several stars.

3 Modern history: from art to the science of navigating

This is how we got to the eighteenth century, which is when a revolution in navigation takes place. New tables of astronomical positions appear and the first nautical almanacs with the necessary ephemeris required for the positioning methods start being published. The concept of loxodrome (track followed by a ship keeping a constant course) is already familiar among seafarers. Reflecting instruments for observing altitudes appear (octants and quintantes), these being more comfortable to use and more accurate than the previous ones, and the application of the corrections of the observed altitudes of the stars is consolidated, reaching a great accuracy when measuring star angles. More sensitive compasses are manufactured and studies on geomagnetism allow knowing in a more accurate way the variations between the course given by the compass and the real one. Mercator projection is of common use when elaborating navigation charts, and these become more accurate thanks to the job performed by the hydrographic offices of each country. And, finally, the solution to one of the most important problems up to the moment on history, the calculation of geographic longitude, was found.

This solution came from two different sources. First, the presentation of the first accurate marine chronometers by John Harrison, which allowed the time in Greenwich to be known on board and, therefore, the coordinates of the stars to be observed (these last ones being extracted from the nautical almanac). Second, the appearance of reflecting instruments and new astronomical ephemeris, which encouraged the feasibility of the lunar distances method.

It was soon evident, due to this avalanche of innovations, that the training of the seafarers was outdated. A mere memorization of the rules to be applied in each case was not enough, for it was as well required its comprehension and understanding. Thus, governments in each country started imposing more and more qualified officers on board their vessels, creating official nautical schools in which seafarers received an extensive training in the fields of Mathematics and Astronomy, as well as in the use of the instruments and nautical publications as these emerged. This way, a transition between the traditional "art of navigating" to a just new born "science of navigation" took place, leaving room among other disciplines, and which study was required from all those who wished to become deck officers.

A new generation of deck officers and captains trained according to this new illustrated philosophy took over the astronomers and mathematicians in the subsequent revolution of this new science. It can be said that the most contemporary milestones in the new astronomical navigation come from the discoveries of seafarers. The invention of the sextant by Captain John Campbell in 1759 can be mentioned as an example of this [2]. Derived from former reflecting instruments, the sextant was an authentic revolution in the instruments used to measure altitudes in the sea and, still nowadays, with small improvements regarding its design and optics, constitutes part of the mandatory equipment in merchant ships. Another mentionable example is the discovery of the line of position, base of the current celestial navigation positioning methods, developed by Captain Thomas H. Sumner.

4 Current situation: navigation in the GPS era

Regarding the current situation of the celestial navigation, it could be said that it is stalled as regards of the development of new methods and instruments since mid twentieth century, with few exemptions. This fact doesn't mean that the astronomical navigation science is obsolete. On the other hand, it reflects the high degree of perfection reached regarding manufacturing of sextants and establishing a simple standard methodology, fully settled in the seafarer's routine and totally simplified in the last two decades thanks to the appearance of specialized software programs and programmable calculators [1].

Another factor that originates a strong tendency to consider astronomical navigation obsolete, this time as to the validity of its practical application, is the widespread deployment of the satellite navigation systems. Currently, all ships have installed at least one receiver of GNSS which allows them to know, with a high degree of accuracy, their position at every moment. Clearly, satellite positioning systems meant a revolution in maritime navigation and have displaced the astronomical observations as a primary system to obtain a position in the high seas. A GPS receiver does not depend on a clear sky, nor requires any effort from the seafarer to obtain the position of the ship, offers a better accuracy and is even cheaper than a good sextant. The advantages of these systems over the traditional methods of celestial navigation cannot be denied in any case. However, it should also be noted that the observation of the stars is the only technique on which the seafarer counts on that does not depend on external systems, only depends on his skills. This is how it has been considered by the International Maritime Organization, which, in its standards of training, certification and watchkeeping convention, establishes that seafarers must acquire during their training

the skills to determine the position of the ship using the stars and the errors of the magnetic compass and gyroscope by means of using astronomical methods.

5 University studies of nautical science in Spain: the UDC case

The teaching of celestial navigation in Nautical Science degrees of the University of A Coruña (UDC) is developed as part of the contents of three Navigation subjects, two of them imparted for obtaining the Degree and the last one to obtain the Master Degree.

Students are trained to know the sky, locating main stars and constellations, and the peculiarity of the movement of the moon and planets as well as the systems of celestial coordinates, the position triangle, the measurement of time, the use of the nautical almanac and some instruments such as the sextant or the alidade. Plus they are trained in all astronomical navigation methods that they may need in their majors.

We want to stress, to finish this paper, that all exposed here regarding the teaching of nautical astronomy may change radically the next academic year, due to the beginning of the new nautical degree (now Degree in Nautical Engineering) in the UDC, which has been adapted to the common European Space of Higher Education. In the new syllabus, the credits devoted to the teaching of navigation could be dramatically reduced.

In this new situation, it is likely that teachers will not have any option that limiting the contents on celestial navigation to what was back then in the sixteenth and seventeenth centuries, that is, to the simple aptitude to apply the rules, leaving behind the comprehension and understanding of them. Deck officers will no longer be considered the scientists inside the field of knowledge that belongs to them: celestial navigation.

In this situation, the science of nautical astronomy may be relegated to a simple hobby or pastime of those who still maintain that romantic spirit that accompanied the Spanish seafarers during a long part of our history.

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