# The Use of the Planetarium in Nautical and Field Astronomy Education

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## 1. Introduction

The universe of marine navigators and surveyors is basically a geocentric one. All calculations necessary for reducing celestial observations to obtain directional or positional information can be carried out within the pre- Copernican two sphere hypothesis. Some mature students on the degree courses have practical experience of navigation at sea but are not used to more abstract ways of thinking. However, most courses in navigation require students to understand the many corrections that have to be applied in astro-navigation. The planetarium can be used to illustrate the basic concepts of the two sphere hypothesis, although other methods are needed to understand the nautical almanac and the principles used in its calculation.

## 2. Coordinate Systems and the Planetarium

Obviously a planetarium is very useful to teach star identification, which all practical navigators should be able to do. Projected vertical circles, meridians, prime verticals, celestial equator and ecliptic, hour circles and projected protractors at zenith and pole are very helpful in teaching co-ordinate systems. These circles can also be used as an empirical introduction to the basic concepts of spherical trigonometry. Planetariums can also be used to demonstrate the effect of precession on right ascension and declination. However, since the planetarium emphasises the geocentric view point it cannot readily be used to explain the physics of precession.

## 3. Gyroscopes and Orreries

Many astronomy textbooks take the trouble to explain the dynamics of precession, using the spinning top analogy, but few explain the gyroscopic properties of a spinning body. Even physics students find rotary motion difficult at first, and most good physics textbooks go to great pains to explain and illustrate the concepts. On the other hand elementary astronomy texts, including those written for non-science majors, fail to explain the behaviour of a free spinning gyroscope in space. An orrery can be used to illustrate the parallel annual transport of Earths axis, but it is not obvious to some students, especially those not doing physics, what causes the axis to behave in this way. Marine navigation students have to understand the basic physics of the free-spinning gyroscope as an introduction to the dynamics of the gyroscopic compass, which is an important part of navigators training.

## 4. Geocentric Corrections

Some corrections which must be carried out by navigators and hydrographic surveys are geocentrically based. These are: dip of the sea horizon; refraction in the atmosphere; semi-diameter of the Sun; semi-diameter of the Moon (including augmentation of its semi-diameter); lunar parallax. Using slides and specially constructed teaching aids, it



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is possible to demonstrate some of these corrections in a planetarium, though in all cases the effect must be greatly exaggerated to be visible on the dome.

It is also possible to use the planetarium to illustrate the difference between the mean sun and the true sun, and the difference between solar and sidereal time. However, one has to step out of the pre-Copernican geocentric framework to explain the equation of time and the reasons for the difference between solar and sidereal time.

## 5. Heliocentric Corrections

Our courses on nautical astronomy go beyond the utilitarian aspects of celestial science and include some aspects of the history and philosophy of science. Since a great deal of navigation is now done via radio and satellite methods, the emphasis on astro-navigation has changed. Some students are committed sailors who want an understanding of more traditional methods of position fixing. Others are attracted by the educational value of classical positional astronomy and its applications.

The fact that the navigator can use an out-dated and limited model of the universe to obtain useful information comes as a surprise to many students. On the way to introducing Keplers Laws of Planetary Motion, it is possible to discuss the algebraic equivalence of the very different geometrical solar systems models of Copernicus and Tycho Brahe. In order to keep the advantages of the Copercican scheme, but still have a fixed Earth, Tycho had the Sun going around Earth, but all the other planets went around the Sun. The positions of the planets against the background stars can be obtained using either model.

Demonstration of the motion of the planets on the celestial sphere is of more than academic value to a navigator who wants to understand the nautical almanac. We can explain why the "v"correction has to be applied. Because the planets orbit the Sun they have a movement with respect to the Vernal Equinoxial Point which can be expressed as a change of sidereal hour angle. The SHA of the navigation planets lie between certain limits. This in turn gives rise to changes in the Greenwich Hour Angles. The *Nautical Almanac* adopts fixed values for the hourly differences of the various astronomical objects relevant to the marine navigator. These are: Sun and Planets 15°; Moon 14°19'.0; Aries 15°02'.46.

Interpolation tables give the increment to be added to the GHA at the tabulated hour, for every second of each minute for all these bodies. To allow for the discrepany between the adopted value of hourly difference and its true value at the time, a quantity, denoted by "v", is tabulated in the daily pages of the *Nautical Almanac*. This is equal to the excess of the actual hourly difference over the adopted one, and it embodies information on the vagaries in the motions of these celestial objects.

## 6. History of Nautical Astronomy

Students on our BSc Marine Studies degree may also take modules in maritime history, including history of nautical astronomy. More specifically, we cover the beginnings of navigation based on the stars, the latitude problem and the longitude problem. The application of astronomy to position fixing at sea and the impact this had on progress in astronomy offers students an insight into important aspects of the history and philosophy of science.

#### 6.1. *Finding latitude at sea*

A planetarium can demonstrate very clearly how to find latitude at sea, using Polaris and the Sun. Although Arab and Genoaese sailors could find latitude by Polaris by means of rather crude instruments, such as the Kamal, the Magic Kalabash and, possibly, the forestaff, the accuracy of their determinations was not very great. It was left to Portuguese captains, mathematicians and astronomers, who met at the court of Prince Henry the Navigator, to develop Pole Star and Solar Declination tables, which made a great improvement to finding latitude (Cotter, 1978). These improvements meant that the great voyages of discovery could be undertaken with more confidence.

#### 6.2. *The longitude problem*

The outstanding problem in marine navigation just over three hundred years ago was that of finding longitude. Since accurate timekeepers did not yet exist, it was not possible to 'transport' the time of some reference meridian to sea. Two other possibilities presented themselves at this time. The first, due to Galileo, used the Moons of Jupiter, the other due to Sieur de St Pierre, involved using our own Moon.

#### 6.3. *The Moons of Jupiter*

Paris Observatory, founded by Louis XIV in 1667, did much to develop the first method. Astronomers at Paris studied Jupiter's Galilean satellites to produce tables of their motions. Surveyors and geographers set up portable observatories along the coast and borders of France and by comparing their observations with the Paris tables could determine the longitude of places (Cotter, 1978). This procedure led to better maps of France, but the difficulties of using a telescope on board a ship made it useless at sea. Cassini's observations on Jupiter's moons led Roemer to discover the finite speed of light. We use a projection orrery, in our planetarium, to introduce students to the basic concepts of this method.

##### 6.3.1. *The Lunar Distance Method*

The Royal Observatory at Greenwich was founded in 1675 by Charles II, specifically to solve the longitude problem by the method of lunar distances (Forbes, 1975). Essentially the method consisted of using the Moon as a celestial clock to tell Greenwich Time and comparing this with local time based on the stars. Successive Astronomer Royals at Greenwich made greatly improved maps of the sky and meticulously studied the motions of the Moon against the background stars. However, in order to produce a set of tables on the Moon's motion of use to a marine navigator, it was necessary to produce these tables several months, or even a year, in advance. This required a reasonably accurate theory of lunar motion. It is well known that the dynamics of our Moon is an example of the three body problem. Newton's geometrical work on lunar theory was cumbersome and was not accurate enough to calculate such tables. The planetarium is a powerful visual aid for teaching students some of the complexities of lunar motion and the basic principles of the lunar distance method.

## 7. Conclusion

The planetarium enables introduction of a wide variety of concepts relevant to maritime honours degree level education. It may be used not only to illustrate the more practical aspects of astro-navigation, but may also be used as a starting point for more advanced positional astronomy concepts. History of science and mathematical concepts may not easily capture the imagination of all students, but when linked to planetarium illustrations, even relatively difficult concepts can be made exciting. The planetarium has a unique role to play in maritime education and in training navigators and hydrographic surveyors.

## REFERENCES

Cotter, C.H., 1978, *A History of Nautical Astronomy*, Hollis & Center.

Forbes, E.G., 1975, Greenwich Observatory, Vol. I, London, Taylor & Francis.