'Columbus's Method of Determining Longitude'

Keith A. Pickering *replies*:

I am pleased to see that, in light of my critical evaluation, Arne B. Molander[1] has re-evaluated a number of points in his analysis, and has revised his proposals of Columbus's alleged use of the Moon for determining his longitude. However, it is disappointing that these latest proposals again do not seem to have been thoroughly considered.

Since it is clear that Columbus's East–West position fixes are not correlated with visible lunar-planetary conjunctions,[2] Mr Molander's latest hypothesis is that Columbus observed a dark-horizon moonrise or moonset near each conjunction – which usually can be done whether or not the conjunction itself is visible. However, it is entirely unclear how such an observation can be converted into a longitude. Reading attentively, we can glean a few details of this process: only a single observation is required, since some positions are computed within a few hours of the purported observation; and Columbus apparently used the *Ephemerides* of Johann Müller, since errors in that ephemeris are alleged to have caused errors in the computed longitude. In his 1992 paper, Mr Molander asserted that timing of the conjunction is not required by this method, because Columbus somehow utilizes the Moon's daily topocentric motion.[3] But how this datum is utilized, and in fact all details of the longitude determination itself, are entirely obscure.

A useful illustration of the practical difficulties involved in converting such horizon geometries into longitudes can be found in figure 2 in Mr Molander's reply. The wide scatter of planetary positions relative to the Moon in this figure is impressive, especially when we consider that most of these simulated observations were made from the same mid-Atlantic position. In other words, Columbus's method (whatever it was) would have to have been sophisticated enough to reduce these scattered observations to the same longitude, yet simple enough so that the computations could be done by every pilot in the fleet within a few hours of the observation. Further, Columbus would have needed an instrument for measuring non-vertical angles, although there is no historical evidence that he carried such a tool on any of his voyages.

If we attempt to re-create such a longitude determination, we discover immediately that it is not possible to predict horizon geometries using the *Ephemerides*, because that ephemeris contains no predictions of ecliptic latitude for the planets. (Knowledge of ecliptic latitude is not required to predict conjunctions, because a conjunction occurs when the ecliptic longitudes of the Moon and planet are equal.) Even with the proper data, Columbus would have had to have made extensive use of spherical trigonometry in any such computations.

But there is circumstantial evidence that Columbus did not know spherical trigonometry. Ptolomey's *Geographia*, a book Columbus owned, gives the latitudes of cities by the length of daylight at the summer solstice. In many cases, Ptolomey converted these measurements into degrees of latitude. It is therefore highly significant that Columbus timed the length of the daylight in 13 December 1492 – the day after the winter solstice. But he does not then take the next logical step and convert this measurement into degrees of latitude. Considering that Columbus made several unsuccessful attempts at determining his latitude with a quadrant, the best explanation for this omission is that he lacked the mathematical knowledge to make the conversion.

In the face of such difficulties, is there any evidence that Columbus may have actually used the lunar distance method? Once again, the theory relies on statistical correlations as its principal support, and once again, these statistics are rendered invalid by data selection. Correlations can be 'found' in any set of random data, provided only that the statistician devises a method of systematically eliminating unwanted data from consideration. This is a form of bias known as data selection. In the present instance, the position fixes of 3 October, 2 November and 15 February, all correlation failures, have been excluded from the analysis. Grouping the positions fixes of 7 February and 10 February (both correlation failures) along with the success of 6 February is another example of data selection. These former positions were at times excluded from consideration because the pilots were allegedly having an argument at the time. Why this should affect celestial observation appears to be inexplicable.

A more subtle form of data selection can be found in the division of data into separate 'types' for analysis. In this case, the types are single-ship and multi-ship position fixes. Since data types can be invented according to any arbitrary criteria, the successes can be grouped together in one type and the failures can be grouped together in another type, skewing the results significantly. This is an example of the so-called Texas Sharpshooter fallacy: the Texas Sharpshooter fires a dozen shots wildly into the side of a barn, then finds the smallest random cluster of bullet holes and draws a bullseye around the cluster. The Sharpshooter believes he's a great shot. His error is in finding an arbitrary criterion *post hoc* that creates a cluster of successes that would not have occurred otherwise.

It is disappointing that Mr Molander has not corrected his evaluations of the time at which the position fixes were recorded. If the log entry of 25 September actually records events of that date and the following night, it must have been written after that date; that is, at about 0600 on 26 September. So the moonset at 1900 on 24 September occurred 35 hours before the position fix was recorded, not 11 hours as Mr Molander asserts. This time shift infects all horizon geometries in Mr Molander's table 1.

Mr Molander uses a value of 0·1 as the probability that any given day contains a horizon geometry, a value which is too low. In the 175 days in which Columbus was out of sight of known land on the first voyage, there were 23 lunar–planetary conjunctions occurring more than 30° from the Sun – that is, in which a horizon geometry should normally be visible near the conjunction. Each conjunction contains two dark-sky horizon geometries, one before the conjunction and one after, but of the two apparently only the closer alignment is used. This makes the single-day probability of success 0·131, assuming good weather throughout. But, as every backyard astronomer knows, even a sky that is mostly clear overhead can be completely obscured near the horizon. Columbus seldom recorded cloud cover in his log, but he did mention storms and rain when they occurred. If we allow for the effects of bad weather, four conjunctions are eliminated: 28 October, 8 December, 13 February and 27 February. The single-day probability of success becomes 0·109 after this correction.

After accounting for all these factors, we find one position fix (6 February) that was recorded within 24 hours of a visible horizon geometry, and eleven that were not (8 August, 19 September, 25 September, 1 October, 3 October, 2 November, 15 January, 7 February, 10 February, 15 February and 27 February). The probability of randomly getting a result this good or better is 76 percent, which is not statistically significant. I have argued that the position of 15 January is not a longitude determination and should be excluded from consideration. If we eliminate this date we have one success and ten failures, and the probability of randomly getting a result this good or better becomes 73 percent. This also is not statistically significant.

Amerigo Vespucci's alleged use of the conjunction of 23 August 1499 to determine his longitude is known to be fraudulent.[4] Mr. Molander has attempted to resurrect this observation based on the supposition that Vespucci's reported position of the Moon – 'a degree and some minutes east of Mars' – was measured in azimuth, rather than the conventional astronomical way, in ecliptic longitude. But this cannot be true, since Mars is east of the Moon when horizon based coordinates are used. In fact, every quantified observation reported by Vespucci turns out to be wrong, and in amounts that Vespucci would have been able to measure. Most incriminatingly, Vespucci wrote that the almanac of Müller predicted the conjunction to occur at midnight, although that ephemeris actually predicted the conjunction to occur four hours after midnight. So Vespucci never actually looked at the ephemeris: he simply fabricated the longitude story.

In his 1992 paper, Mr Molander proposed that Columbus predicted usable conjunctions in advance of his departure, and that these predictions were the principal reason he delayed his departure from Palos and later Gomera. Since Mr Molander's new method does not depend upon actually observing conjunctions, he has tried to revive this hypothesis by computing pre-conjunction horizon geometries visible during 1492. The flaw in this argument is again that Columbus could not have computed these geometries the way Mr Molander has (i.e., with a modern computer and modern theories of lunar and planetary motion). If Columbus had attempted to compute such a chart in 1492, he would have run up against that same critical omission of Müller's ephemeris: it does not contain ecliptic latitudes for the planets. Thus it is doubtful that Columbus could have predicted horizon geometries in advance at all.

Columbus often asserted that a degree of the Earth's circumference was $56\frac{2}{3}$ miles, or $14\frac{1}{6}$ leagues, and most now accept that Columbus's league was less than three nautical miles.[5] This means that Columbus had seriously underestimated the size of the Earth. Of course the true length of a degree is about 60 nautical miles, but it would be incorrect to compute Columbus's league length as $60 \div 14\frac{1}{6} = 4{\cdot}2$ nautical miles, since his idea of the Earth's size was so badly mistaken. Mr Molander claims that I have used a league of 4·22 nautical miles, but there is no such statement in my paper. He may have been misled by the results[6] given in table 2, which assumed that Columbus's logged positions were derived from lunar longitudes and computed the way Columbus would have, using his own adopted size of the Earth. So any inordinate league length derived from table 2 is a direct outcome of the lunar longitudes theory, and furnishes additional evidence that Columbus could not have used celestial observations to arrive at the positions recorded in his log. Thus the statistical analysis of table 2 remains sound: there is no correlation between Columbus's actual longitude errors and the errors expected from lunar observation, and this in itself refutes the lunar longitudes hypothesis for both conjunctions and horizon geometries.

In conclusion, there is no significant correlation between conjunctions and position dates when utilizing horizon geometries; Columbus could not have computed horizon geometries at sea, because of the absence of required data in the *Ephemerides* of Müller; and considering Columbus's mistaken idea of the Earth's size, there is still no clear procedure for accurately converting a longitude into its recorded unit of leagues. Given this lack of evidence, given the fraudulent claims by Vespucci, and given the lack of correlation between actual longitude errors and the errors expected from lunar observations, the suggestion that Columbus used lunar observations to determine his longitude must continue to be considered entirely conjectural.

REFERENCES

[1] Molander, Arne B. (1996). 'Columbus's method of determining longitude'. This *Journal*, **49**, 444.

[2] Pickering, Keith A. (1996). Columbus's method of determining longitude: an analytical view. This *Journal* **49**, 101–103.

[3] Molander, Arne B. (1992). Columbus and the method of lunar distance. *Terrae Incognitae* **24**, 68–69.

[4] Randles, W. G. L. (1995). Spanish and Portuguese attempts to determine longitude in the fifteenth and sixteenth centuries. *The Mariner's Mirror* **81**:4, 403.

[5] Kelley, James E. Jr (1983). In the wake of Columbus on a portolan chart. *Terrae Incognitae* **15**, 102–104.

[6] Pickering, Keith A. (1996) Columbus's method of determining longitude: an analytical view. This *Journal*, **49**, 109.

KEY WORDS

1. History. 2. Astronomical navigation.