Light Touch

Revisiting Columbus at 500 ... What If?

On the occasion of the Columbus Quincentennial, it is interesting to speculate on how simple optical observations, or the lack thereof, may have had a major impact on the course of world history. Standing on a pier overlooking Mobile Bay one night, we noticed a phenomenon illustrated in Figure 1. As the head of the observer descends, it reaches a height x above the water at which a string of causeway lights across the bay suddenly disappear. These lights, whose height above the water is y, drop below the horizon due to the earth's radius of curvature, R. One can apply the Pythagorean Theorem to the two right triangles in Figure 1, and use the approximation that x and y are small compared to R. Solving for R gives

$$R = \frac{(a + b)^2}{2 (\sqrt{x} + \sqrt{y})^2}$$

We measured x to be 2.6 m, and y to be 20 m. From a marine chart, we measured $(a+b)$ to be 12.6 statute miles. The formula then gives $R =$ 3430 miles, which differs from the correct value of 3960 miles by 13%.

Eratosthenes of Cyrene used an equally simple geometry to measure the Earth's radius around 200 B.C. His experiment required measuring the lengths of shadows in two cities 500 miles apart. By contrast, the longest distance that must be measured in Figure 1 is about 12 miles. Furthermore, since the Figure 1 experiment is purely terrestrial, there is no need for using solstices or the Tropic of Cancer.

Since no optical instruments are required, this experiment could have been performed on bays or lakes in Europe in the 15th century, using lanterns or fires, presumably with the same accuracy that we obtained. Yet Christopher Columbus believed[1] that an equatorial degree equalled 45, rather than 60, nautical miles. As a
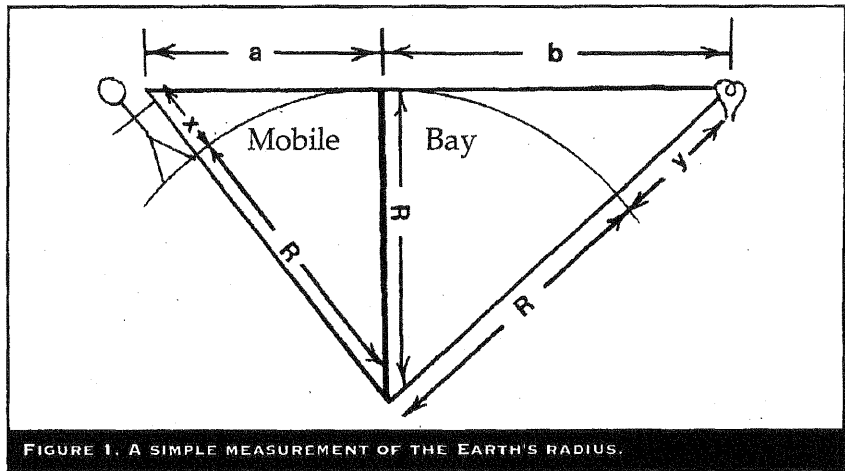

FIGURE 1. A SIMPLE MEASUREMENT OF THE EARTH'S RADIUS.

result, the Earth's circumference is 33% (or about 6200 statute miles) larger than Columbus thought it was. It was from the unexplored portion of the Western Hemisphere that the 6,200 miles were missing in 15th century maps. This led Columbus to believe[2] that the Orient was some 4,000 miles west of the Canary Islands, instead of its true distance (along the 30th parallel) of about 11,000 miles. Even after his voyages, he continued to believe that Cuba was part of the Asian mainland.

It is unclear how accurate Eratosthenes' measurement was, since we don't know what his unit of length, the stadion, was in modern units. But what if someone had done the experiment in Figure 1 prior to 1492, and in so doing, eliminated the 33% underestimate of the Earth's size? Would Columbus have embarked, knowing that his destination was 11,000 miles away? Cartographers of the time drew fictional islands in the Atlantic, but the lure of small islands could not match the lure of the Orient. Accurate knowledge of the Earth's size might have postponed European discovery of the New World by a century or more. If it had been postponed until after the defeat of the Spanish Armada in 1588, Spanish influence in Latin America might have been far less. Or, if the North American colonies had matured under Queen Victoria instead

of King George III, would there have been an American Revolution? And, if not, would the dominant powers in the world today be monarchies instead of democracies?

Although such speculation is interesting, about the only conclusion that can be drawn with confidence is that the accuracies of simple optical observations have already affected our lives in ways we will never know.

REFERENCES
1. R.A. Skelton, in an Appendix to the *Journal of Christopher Columbus*, Bramhall House, New York, N.Y., 1960, 218.
2. D. Castlereagh, *The Glorious Age of Exploration*, Doubleday, New York, N.Y., 1971, 403.

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higher output powers by increasing the pump powers used, they say.

The near bandwidth-limited pulses generated by this laser show less than 1% amplitude noise with continuous mode-locked operation for periods of several hours. The researchers say the results indicate that the Nd:LMA laser, when diode-pumped, will be an ideal source for seeding high power chirp pulse amplification systems based on amplification in Nd:phosphate glass.

—George Leopold

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