Tracking Polynesian Seafarers

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About 4000 years ago, Stone Age voyagers from Island Southeast Asia began to sail east into the Pacific, where they settled the previously uninhabited islands of Remote Oceania (Eastern Melanesia, Micronesia, and Polynesia). As Europeans began exploring the Pacific, they were surprised to find that mid-ocean islands were occupied by seemingly primitive seafarers, who had only slim canoes carved with stone adzes, powered by mat sails, and navigated without instruments. Some Europeans could not accept that such seemingly ill-equipped people had settled the islands on their own. They instead imagined such scenarios as storms or currents pushing coastal people far out to sea, the sinking of a great continent leaving only high peaks and surviving inhabitants above water, and the special creation of humans on the islands.

A few prehistorians still begrudge the Remote Oceanians only minimal seafaring skills, but more than two centuries of research have led to widespread appreciation of their nautical capabilities. On page 1907 of this issue, Collerson and Weisler (1) confirm the wide extent of Polynesian voyaging by chemically tracing basalt adzes found on coral atolls to specific volcanic sources.

Not until the late 1700s did foreign explorers consider seriously how canoe people could have actively settled the Pacific. Captain Cook and Joseph Banks judged Tahitian sailing canoes and navigation methods fit for long voyages. By comparing Tahitian words with those gathered from islands far to the west, they realized that Tahitian was related to languages of the “East Indies.” Upon hearing from the Tahitian savant Tupai'a how navigators waited for seasonal spells of westerly winds to sail east against the trade wind direction, Cook presciently suggested that their ancestors had used these westerlies to sail east into the ocean (2).

During the 1800s, amateur scholars collected oral Polynesian migration traditions. The histories they produced were highly suspect, because they cut and pasted together passages from various narratives and committed other scholarly sins. Nonetheless, the unedited traditions, and increasingly sophisticated linguistic comparisons, suggested migration paths.

During the past century, ethologists and archaeologists sought to trace these paths by comparing artifacts from various islands, but with mixed results. Canoe comparisons became mired in turgid debates over canoe typology, outrigger attachments, and migration waves. Stylistic comparisons of temples, adzes, and fishhooks fared better, but often foundered over whether features from different islands were similar because of a common origin or convergent adaptation.

The breakthrough came in the 1960s and 1970s, when the discovery of distinctively decorated Lapita pottery enabled archaeologists to track the rapid entry of the Polynesians’ ancestors into Remote Oceania. The many potsherds proved ideal for stylistic comparisons, and in some cases, geologists were able to source constituent temper sands to islands near and far. The wide range of Lapita voyaging was demonstrated even more dramatically by chemically tracing obsidian tools to volcanic sources scattered over hundreds and in some cases thousands of kilometers of the Western Pacific (3).

At about the same time, other researchers were reconstructing extinct Polynesian voyaging canoes and testing them over legendary long-distance sailing routes (see the figure) (4), studying traditional navigation on remote Micronesian and Melanesian islands where voyaging had not died out (5), and using computer simulations to elucidate strategies of ocean exploration and island colonization (6). These efforts supported the hypothesis that Remote Oceanians were capable of purposefully making long navigated voyages and settling distant islands.

Unfortunately, pottery making declined after Lapita voyagers reached the mid-Pacific, and was not spread farther east by their Polynesian descendants. Moreover, although obsidian occurs in New Zealand and Easter Island, tools made from this type of volcanic glass were apparently not widely spread from these peripheral islands.

In the 1980s and 1990s, archaeologists therefore turned again to stone adzes, particularly those made from fine-grained oceanic basalts of the “hot-spot archipelagos” of East Polynesia. This time they used major-element composition to trace each piece of basalt back to its geological source. This approach allowed intra- and interarchipelago connections to be traced over much of Polynesia, but did not always allow the precise sources of the basalts to be identified (7).

To more precisely source basalt adzes collected over 70 years ago among East Polynesia’s Tuamotu atolls, Collerson and Weisler turned to more discriminating analyses possible with trace elements and isotopes. The results indicate that the adzes came from five volcanic archipelagoes surrounding the Tuamotus, and to particular islands within these, such as Hawai’i’s Kaho’olawe (some 4000 km to the north-northwest). The authors do not hesitate to relate this connection to legends of canoe voyaging between Hawai’i and Tahiti via the Tuamotus, as well as the 1976 voyage over this route of the modern double canoe Hokule’a (see the figure) (8).
Quantum Weirdness in the Lab

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In ordinary arithmetic, multiplication obeys a commutative law. That is, for any two numbers \( n \) and \( m \), the product \( nm \) is always equal to \( mn \). In classical physics, measurements of physical properties also obey a commutative law. For example, if one first measures the position of a particle and then its momentum, one obtains the same result by first measuring the particle’s momentum and then its position. However, quantum mechanical quantities do not in general obey this commutation relation (1). In fact, the breakdown of the commutative law lies at the heart of many fundamental quantum properties, such as the Heisenberg uncertainty principle. In the example of position and momentum, the lack of commutativity is conventionally stated by means of the relation \( \Delta x \Delta p - \Delta p \Delta x = \hbar / 2 \pi \), where \( \Delta x \) and \( \Delta p \) are the quantum mechanical operators (2) associated with position and momentum, respectively, and where \( \hbar \) is Planck’s constant.

In an intriguing and illustrative report on page 1890 of this issue, Parigi et al. (3) present the results of a laboratory demonstration of what happens in the quantum mechanical operations of photon creation and annihilation, which lacks commutativity. These authors add a single photon to a light beam, which corresponds to the action of the standard quantum mechanical creation operator \( \hat{a}^\dagger \). They can also subtract a single photon from the light beam, which corresponds to the annihilation operator \( \hat{a} \).

Parigi et al. measure the quantum mechanical state of a thermal light field after performing these two operations on it, and they show that the final state depends on the order in which the operations are performed. This result is a striking confirmation of the lack of commutativity of quantum mechanical operators. Moreover, the authors present the strongly counterintuitive result that, under certain conditions, the removal of a photon from a light field can lead to an increase in the mean number of photons in that light field, as predicted earlier (4).

The basic idea of the experiment of Parigi et al. and some of their results are shown in the figure. In the top row, a laser beam passes through a rotating ground glass plate (th) to mimic the random fluctuations of a thermal source and is detected by a quantum state analyzer (QSA). The results of the measurement are shown on the right. Here, \( \rho(E) \) gives the probability distribution of the electric field amplitude \( E \). Rows B through E illustrate the consequences of acting on the input state by various quantum mechanical operations. Row B shows the result of removing a single photon from the field with a beam splitter. Counterintuitively, the mean number of photons \( \bar{n} \) in the output field is increased by this operation. Row C illustrates the consequence of adding a single photon to the input state with an optical parametric amplifier (a device that splits one photon into two, each with approximately half the energy of the original photon). Row D illustrates the consequence of first adding a photon to the field and then subtracting a photon, whereas row E illustrates the situation in which a photon is first subtracted and then a photon is added. One sees that the fields created in these two situations are markedly different.

Beyond the conceptual interest in the quantum arithmetic, Schematic experimental procedure of Parigi et al. and some of their laboratory results. The order in which photons are added and subtracted from a light field strongly influences the field’s properties.