graph offers an easy example of the ways that science and technology facilitated the colonial enterprise. Communication was slow in the early 19th century, and armies require information. A story told about the sepoys who rose up against British officers in the Indian Mutiny of 1857–59 is probably apocryphal, but it is nonetheless revealing of the power that the Crown ascribed to its technology. As one rebel was led to his death, he was supposed to have noted a telegraph wire and muttered, "The accursed string that strangles us!"

Certainly, the so-called lightning wire allowed communication at speeds hitherto unimaginable. Before the age of steam, sending a letter from Britain to India and then receiving a reply could take considerably more than a year, depending on the prevailing winds. With steamships and trains, that time had been cut to two or three months by the 1850s. In the 1870s, however, a telegraph message could get from Britain to India in a number of hours, and in 1924 King George V could send himself a message that traveled the globe on all-British lines in 80 seconds.

What telegraphy made easier, medicine made possible. One set of data may serve to illustrate a larger point. According to statistics published in 1840, out of 1685 white British troops that arrived in western Africa between 1822 and 1825, 77% died between 1823 and 1827; the remaining 23% were "invalided" (that is, removed from service due to infirmity). Of the latter group, 4% died on their journey home; only 9% of the survivors were found fit for service again.[4] Quinine prophylaxis against malaria was one of the main reasons that the "scramble for Africa" became thinkable. Where death rates for Europeans in West Africa had once been on the order of 25–75% per year, by the end of the century,[5] they were closer to 5–10%.

The history of science and colonialism is, relatively speaking, a fairly new area of research. Its most fundamental claim is, however, well established: Modern colonialism and modern science could not have been what they were—and what they are—without one another.

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LETTERS

Heliocentrism before Copernicus

In his interesting review of P. C. Deshmukh's *Foundations of Classical Mechanics* (Physics Today, December 2021, page 54), Robert Scott notes "that the 14th- to 16th-century Kerala school of astronomy and mathematics developed a heliocentric model of the solar system well before the Copernican revolution." But I believe that for historical completeness, that statement should be supplemented by a note that about 1600 years earlier, in the third century BCE, Aristarchus of Samos proposed a heliocentric model in which Earth revolved about the Sun in a circular orbit with the Sun at the center. However, the writings in which he proposed that idea have been lost, and the only reference to his work from that century is by Archimedes in a letter to King Gelon of Syracuse.[1]

Aristarchus of Samos is regrettably skipped over in many popular accounts of early astronomy—for example, in Stephen Hawking's well-known book *A*

Brief History of Time: From the Big Bang to Black Holes (1988). Thus, years ago, when I was teaching an introductory course on the history and philosophy of science, I would ask the students whether they had heard of Copernicus, and everyone would raise their hand, but when I asked about Aristarchus of Samos, usually no hands went up. If I were still teaching, in addition to my usual covering of Aristarchus and Copernicus, I would teach about the Kerala school as well, thanks to Deshmukh's book.

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Observing interstellar molecular hydrogen

Johanna Miller's Search and Discovery story "Ten billion years ago, galaxies were already running out of gas" (Physics Today, December 2021, page 20) describes evidence that some galaxies deplete their interstellar matter to fuel star formation. Particularly important are cold interstellar gas clouds, where the atomic-to-molecular transition is a key step in sustaining new star formation. The story highlights recent Atacama Large Millimeter/Submillimeter Array observations of molecular gas in carbon monoxide microwave emission and far-IR emission from dust grains.[1] But these two sentences were misleading: "Measuring the galaxies' H_2 content directly isn't an option because H_2 molecules themselves are essentially invisible. They're symmetric and lack electric dipole moments, so they don't absorb or emit radiation when they rotate and vibrate."

Rumors of H_2 invisibility have been greatly exaggerated. Although it's true that the H_2 ground electronic state has no dipole moment, two low-lying electronic states (molecular orbitals from 1*s*–2*s* and 1*s*–2*p*) do have dipole moments. Electronic absorption lines into those states lie in the far-UV and are known as the Lyman and Werner bands.[2] Widely observed in the interstellar medium by the *Copernicus* and *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) satellites, they provide diagnostics of the molecular fraction, gas temperature, and UV radiation field in diffuse and translucent interstellar clouds. *FUSE* also surveyed H_2 in two external galaxies, the Large and Small Magellanic Clouds orbiting the Milky Way.[3]

UV H_2 lines have also been seen in strong quasar absorption systems redshifted into the visible band.[4] For systems in the Milky Way and local galaxies, measuring those absorption lines requires finding a bright UV background source, such as a hot star or quasar, behind the absorbing gas. That makes dark molecular clouds hard to probe in the UV. But *FUSE* observed H_2 in a number of translucent clouds[5] with one to five magnitudes of visual extinction and molecular fractions up to 75%.

Thanks to cosmological redshifting of light, H_2 has now been observed in distant intervening galaxies in spectra of background quasars. The H_2 far-UV absorption lines are shifted into portions of the UV accessible to the *Hubble Space Telescope* for galaxy redshifts $z > 0.05$ (a distance of 680 million light-years). At redshifts $z > 1.8$, the H_2 lines can be observed by optical spectrographs. The European Southern Observatory's Very Large Telescope in Chile has detected H_2 in more than 22 distant galaxies (damped Lyman-alpha absorbers) at redshifts z between 1.96 and 4.22, corresponding to cosmological distances of 10.3 to 12.2 billion light-years. The recent Decadal Survey on Astronomy and Astrophysics supported plans for a 6 m optical, UV, and IR space telescope. With greatly enhanced sensitivity in the far-UV (90–200 nm), that facility would be a powerful tool for probing the atomic and molecular gas that fuels star formation in galaxies.

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