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to leave planet Earth

# Cosmic Humility

Studies of worlds beyond our solar system could reveal just how significant Earth and its denizens really are BY MARIO LIVIO

**W**HEN NICOLAUS Copernicus proposed in 1543 that the sun was the center of our solar system, he did more than resurrect the “heliocentric” model devised by Greek astronomer Aristarchus of Samos. He took humanity down a peg. The ensuing “Copernican principle” tells us that we are nothing special. Earth is just another ordinary world revolving around an ordinary star.

Scientific revelations in the centuries that followed have only underscored our mediocrity. In the mid-19th century Charles Darwin realized that rather than being the “crown of creation,” humans are simply a natural product of evolution by means of natural selection. Early in the 20th century Harlow Shapley showed that the entire solar system lives in the Milky Way’s sleepy outer suburbs rather than the comparatively bustling galactic center. A few years later Edwin Hubble demonstrated that even our galaxy is unexceptional—one of many bundles of stars, planets, gas and dust. Estimates put

the total number of galaxies in the observable universe at a staggering trillion or more.

Within the Milky Way, roughly 20 percent of sunlike or smaller stars harbor an Earth-size world orbiting in a “Goldilocks” region that is neither too hot nor too cold for liquid water to persist on a rocky planetary surface. At least a few hundred million planets in our galaxy may be habitable. With each advance in our knowledge, our existence is reduced to mere cosmic flotsam.

Increasing numbers of physicists have begun to suspect—often against their most fervent hopes—that our entire universe may be but one member of a mind-bogglingly huge ensemble of universes: a *multiverse*. Interestingly, though, if a multiverse truly exists, it suggests a limit to Copernican humility. Many researchers speculate that random chance rather than fundamental laws sets the values for some of the three dozen physical

constants that shape our reality. That is, the density of the “dark energy” that drives the universe’s accelerating expansion or the ratios of masses of subatomic particles can take drastically different values in different parts of the multiverse. Moreover, the so-called laws of nature may be no more than local bylaws governing our particular patch of the multiverse.

If the multiverse exists, odds are the laws and constants prevailing in any given universe would preclude life’s emergence.

If so, we inhabit a rare subclass of universes that allows for life. In other words, we—humans, our planet, our universe—may be special after all.

Our astronomical search for life beyond the solar system may tell us where the Copernican principle breaks down. Extrapolating from what we know about how stars are born, live

and die—and how a subset of them host potentially habitable Earth-size planets—one can estimate the relative likelihood of life’s emergence in the universe as a function of time.

Because low-mass stars are the most numerous and longest-lived, in the future life in the cosmos is much more likely to arise on a planet orbiting a low-mass star, such as a red dwarf, rather than on a planet orbiting a bulkier star akin to our sun. In other words, life on Earth appears to be very premature and rather special.

Many factors could inhibit the formation of the chemical building blocks of life. For instance, red dwarf stars tend to emit strong flares and stellar winds that could strip planets of their atmospheres, thwarting the environmental conditions and availability of precursors that life-creating chemistries need to percolate. Current and near-future astronomical searches for biosignatures in the atmospheres of exoplanets, which now focus on worlds around low-mass red dwarfs, offer valuable clues as to whether life can exist in such settings.

Each blow to the Copernican principle and our own perceived physical significance was a tremendous expansion in our knowledge. The Copernican principle teaches us humility, yes, but also reminds us to keep our curiosity and passion for exploration alive. ●

Is life common throughout the cosmos? Worlds orbiting red dwarf stars may offer vital clues.

