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The Dawn of a Mindful Universe: A Pathway towards a Biocentric Global Ethics

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This article presents arguments for a biocentric worldview based on the rarity and uniqueness of planet Earth as confronted with trillions of other worlds in our galaxy alone. This cosmic outlook comes from recent astronomical knowledge concerning the distribution of exoplanets and the growing understanding of the interconnectedness and codependence of all life on Earth, past and present. Confronting the uniqueness of Earth's biosphere and its current fragile state due to centuries of aggressive human presence, the biocentric worldview proposes an ethics of belonging that takes life center stage as humanity struggles to chart its path toward a sustainable future.

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Introduction

The story of who we are as cohabitants of a diverse and fragile biosphere needs to be retold. We need a new narrative of what it means to be human on planet Earth. Civilization is at a crossroads and time is running out. It is hard not to sound alarmist when one considers the current political and social fragmentation under the mounting threats of climate change and technological existential threats. Although our collective history is no stranger to crisis, the challenges we now face are unprecedented. What is different is the scale of the crisis, truly global in its reach. The remarkable industrial and economic growth of the past two centuries has come with an enormous environmental cost. Unless we redefine our relation to nature and realign our economy within a moral framework anchored on sustainable and regenerative practices, we may indeed come to experience some of the many dystopian scenarios seen in the news and in popular culture: droughts, floods, massive climate migration, and political and social unrest (Berry 1988). How we arrived at our current predicament and what could possibly be done to rescue our project of civilization is the focus of this article. The new narrative for humanity proposed here combines elements not often brought together: Indigenous wisdom, astrobiology and the search for life on exoplanets, and a post-Copernican approach to modern cosmology.

With the aid of technology and the success of agrarian practices, humans have moved away from the very essence of our evolutionary history: hunter-gathering groups well adapted to coexist with the planet and its resources gradually transitioned to concentrated populations in ever-growing cities. Anthropologists trace the origins of our species to some 300,000 years ago. For about 290,000 of those years, our ancestors developed strategies to function within nature, seeing themselves as an integral part of the life collective (Graeber and Wengrow 2022). The shift to agrarian civilization happened roughly within the past 10,000 years or so as people gathered in fertile regions, spurring the growth of cities with increased populations and accumulation of goods. Cities are, in a sense, unnatural conglomerates of humans, artificial constructions built out of processed materials designed to house as many people as possible within the smallest space possible. Built to leave nature mostly outside their boundaries, cities aggregate large numbers of humans to the exclusion of other living creatures, except for scattered trees and flowerbeds, or those species that thrive on our refuse, like cockroaches, rats, and a small number of birds. Of course, cities also offer great benefits (to those who can afford them), from cultural activities and diverse entertainment to sheltered housing, policed security, and easy access to food. They are an integral part of modern civilization and no realistic proposal considering our collective future would be taken seriously without them. (A recent study compared large cities and their suburban spread linked by rail lines to cancerous growths on the surface of the planet (Capel-Timms et al. 2024).) How to house, feed, educate, and care for

a population of eight billion humans, with over 55% currently living in urban areas, is an enormous challenge.[1]

Dystopian scenarios claim it is impossible for a living planet to support a dominant species so out of balance with the rest of the biosphere (Kolbert 2014), gloomily suggesting that sufficiently advanced civilizations—if they exist—sooner or later inevitably self-destruct (Frank 2018). At this pivoting point in our collective history, we must ask: Is this our inexorable destiny or are there other possible pathways forward? Although there are clearly no simple or unique answers to such a vastly complex question, we can try to isolate the root causes of our current predicament to then suggest a possible course correction.

Fermi's Paradox and Our Cosmic Loneliness

In 1950, physicist Enrico Fermi was having lunch with a few colleagues at the Los Alamos Laboratory cafeteria, apparently lost in thought. As the story goes, after scribbling some calculations on his napkin, he stopped suddenly and asked his colleagues: "Where is everybody?" (Webb [2002] 2015). "Everybody" referred to aliens. In particular, aliens capable of creating a technological, space-faring civilization. He reasoned that since the Milky Way galaxy is about 100,000 light years across and 10 billion years old, a civilization that had developed technologies for space exploration would have had plenty of time to colonize, or at least explore, the galaxy. Their forays should, Fermi believed, have included a visit to our home planet. The numbers do make sense. If aliens with a flair for technology and exploration flourished a few million years before we came about, they could have developed technologies for travelling at speeds close to the speed of light. If they reached, say, one-tenth of the speed of light, which is not unreasonable even by our current standards, it would have taken them "only" a million years or so to cross the galaxy. After a few million years of exploration, they could have planted outposts across countless stellar systems, including ours. And since it takes life to recognize life, they would have spotted our planet with some curiosity. How come, then, we have no indication of any such civilization in our galactic neighborhood? Hence was born the Fermi Paradox, a frequent topic in countless sci-fi movies and novels as well as popular and academic books and scientific papers.

Given Fermi's role in the development of controlled nuclear fission and the atomic bomb, and the subsequent threats of global annihilation during the Cold War, the paradox is often associated with what is sometimes called a civilizational bottleneck: any civilization that develops advanced technologies would, sooner or later, self-destruct (Leslie 1996; Rees 2021). According to this premise, aliens have not visited here simply because they did not survive long enough.

The Cold War is long gone, but the threat of nuclear annihilation remains very present. In a 2023 survey, the number of nuclear warheads was estimated to be around 12,500, with 90% belonging to the United States and Russia. A staggering 9,600 remain in military service, while the rest await dismantlement

(Arms Control Association 2025). For now, the polity of Mutual Assured Destruction has held. We cannot know, of course, what the future holds.

Nuclear obliteration is only one possible existential risk that haunts technological civilizations like ours. Dystopian scenarios abound where nanobots, AI, or bioengineered diseases get out of "control" and become an unstoppable threat to our collective future. Bombs, robots, crazed self-conscious computers, and bioengineered germs have a common source: scientific research serving the interests of the state and stockholders gets out of human control or is controlled by groups or leaders with destructive intent. Science's noble goal of alleviating human suffering is turned on itself to become the most efficient perpetrator of human suffering. Together, technological existential threats represent the tragedy of the modern human, the neglect of life in favor of power. Considering the current political climate and predictions for excessive global warming due to the rampant use of fossil fuels, we must add runaway climate change and its devastating consequences as the frontrunner existential risk for humanity (Mann 2022). We may indeed become another technological civilization unable to pass through the civilizational bottleneck.

The obvious difficulty with discussing alien life is the complete lack of data. We have no data pointing to life in any of the worlds of our solar system, despite a few false alarms with Mars, as with the famous ALH84001 meteorite.[2] Planned future missions to explore Europa, Enceladus, and Titan may change this general picture, but given the extreme conditions in these worlds, the chance they harbor life is quite small. Even if, say, subsurface water-based life exists on Europa or Enceladus, it will be very simple, most probably unicellular.[3]

It goes without saying that the discovery of any kind of alien life would be deeply transformative. Given that the laws of physics and chemistry are the same across the observable universe, if life is confirmed to exist in one world beyond ours, it will probably exist in many more, though inductive thinking is inadequate for biological speculation about the ubiquity of life in the cosmos (Gleiser 2023). Still, the discovery of simple alien life, certainly a spectacular find, would not directly impact our current need to solve the planetary crisis and safeguard Earth's biosphere, us included. Indeed, it would probably foster a conceptually mistaken inductive generalization of the Copernican principle into biology, that not only is Earth a common kind of world in the universe but so are worlds with biospheres. Inductive thinking works well for stellar systems because the process of stellar formation and gravitational dynamics follows well-understood physics laws. This is surely not the case with the origin and evolution of life here or (if applicable) elsewhere in the cosmos (Kauffman 2019).

The James Webb Space Telescope is now helping us uncover the atmospheric chemical composition of exoplanets (Ahrer et al. 2023a, 649; 2023b, 653). We search for biosignatures, that is, molecules or groups of molecules directly or indirectly associated with biological activity. As James Lovelock and Lynn Margulis argued in 1974, life changed Earth as a whole, in particular by keeping

the atmosphere out of thermal equilibrium, expressed here through the coexistence of both oxidizing (CO_2) and reducing (CH_4) carbon compounds (Lovelock and Margulis 1974). It is reasonable to suppose that similar principles apply for alien worlds with biospheres, although, of course, specific biospheres and their resulting biosignatures will depend on the details of alien biology. Climbing further in complexity, technosignatures would point to life capable of large-scale engineering works that could be observed from afar (Frank 2024; Lingam et al. 2023; Wilkinson 2013). It is interesting to consider that the first popular alien life craze in history was prompted by the presumed discovery of a technosignature, Percival Lowell's misinterpretation of Giovanni Schiaparreli's Mars *canali* as being channels dug by a dying civilization (Lane 2011).

Although we currently cannot be certain of the existence of life elsewhere, we can state with confidence that the difficulties of interstellar travel severely constrain the possibility that aliens visited here in the past or that we will be travelling to other stellar systems in the near or not-so-near future. For example, to travel to the star system closest to the sun, the Centauri triple-star system at 4.2 light years away, would take our fastest spaceship roughly 80,000 years. We are, for all practical purposes, alone to decide our collective future. Human civilization thus finds itself at the edge of Fermi's civilizational bottleneck, a pre-galaxy-faring technological civilization teetering on the brink of massive social and economic collapse prompted by its disregard for the existential risks of climate change.

Beyond Copernicus: Earth Is a Special World

In the past two decades or so, exoplanet finding techniques, in particular through the Doppler and Transit methods, have produced spectacular results, allowing us to have an approximate grasp of their astronomical properties, such as radius, mass, and distance from their parent star or stars (Scharf 2009). The results, which tend to favor large-mass planets in closer proximity to their stars, indicate that about 3.5% of the planets in the Milky Way galaxy are "terrestrial," that is, with a mass and radius similar to Earth's. Extrapolating this statistic, if there are about one trillion planets in our galaxy, about thirty billion (or 3%) have a mass and radius similar to Earth's. Of those, a smaller but substantial number orbit G-type stars like the sun: since about 7% of stars in the galaxy are sunlike, in simple numbers, that would mean there are about two billion terrestrial worlds orbiting sunlike stars. This may sound like a large number of potentially life-bearing, Earthlike planets. But as remarked earlier, we cannot use inductive thinking to conclude that all (or even any) of these worlds harbor life. When the focus is on finding life, having a mass and radius *like* Earth's, or orbiting a star *like* the sun, is a long way from *being a living planet like* Earth.

Our planet is much more than a rocky world with a certain mass and radius orbiting a G-type star once a year. To assess Earth's uniqueness, we must begin by disentangling astronomy from biology. In his *Commentariolus* of 1514, and later in his great 1543 book *On the Revolutions of the Heavenly Spheres*, Copernicus

famously suggested that Earth is just another planet orbiting the sun. Discounting Aristarchus of Samos's earlier speculations from about 250 BCE, Copernicus's thesis was the first in a series of astronomical steps that shifted Earth from its cosmic centrality to an ordinary world orbiting an ordinary star among billions of other stars, belonging to an ordinary galaxy among billions of other galaxies receding from each other in an expanding universe where stars, planets, clouds, and people are made of matter that makes up only 5% of the total stuff that fills space. (The other 95% are conjectured to be dark matter and dark energy, both still unidentified.) During the past four centuries, this ongoing shift in astronomical perspective, coupled with the fast pace of industrial growth fed by our voracious appetite for natural resources, led to a devastating objectification of nature. What was once a sacred realm became an increasingly desacralized material commodity, just another world wandering the vastness of cosmic space. In growing numbers, humans separated themselves from the natural world, congregating in cities and in artificially built working environments, believing to be above the natural order. The general sentiment is one of disregard: we own nature and its living inhabitants. This narrative has become unsustainable and needs to change. Perhaps a rereading of what the new astronomy of exoplanets is telling us could help.

What separates Earth from other known worlds is that it is a living world, unique in its biodiversity. "Living world" here means a world where life has spread over diverse environments and persisted long enough to become an ever-evolving biosphere. Some worlds may have been living worlds for part of their history (as many conjecture is the case with Mars (Sauterey et al. 2022)), while others may yet become living worlds. The essential point is that even if there are other living worlds in the galaxy and beyond, each will have its own particular biosphere—none will have the same type of life found here. This includes life as we know it, that is, carbon/water based, with RNA/DNA for genetic coding. Even within this terrestrial framework, evolution will always take a different turn due to variations in geophysical and geochemical conditions in alien worlds. As Lovelock and Margulis suggest, once life takes hold of a planet, planet and life become an inseparable, mutually interactive, and codependent whole. Life affects the planet's geochemical cycles, and the planet affects life's evolution, adaptability, and diversity. For example, cosmic cataclysms of global impact reset evolution in unpredictable ways. Consequently, with or without life, every single world in the observable universe— planets, moons, and asteroids—is by necessity unique. Each will have its own formation history and initial chemical composition, and each will evolve according to local variabilities, which are highly unlikely (I would argue impossible) to be duplicated elsewhere in the universe. Worlds may share similar astronomical and geochemical properties and characteristics, but no two worlds will be the same. When life is added to this picture, even two living worlds that are very similar will have very different biospheres.

From a physics perspective, Earth is remarkable for many reasons, including having a strong enough magnetic field and a dense enough atmosphere to shield the surface from different kinds of cosmic and solar radiation; having a single moon large enough to affect the precession of the equinoxes and sustain the seasons; having a large amount of surface area that allowed for life to eventually migrate to the surface and mutate into a hugely differentiated biodiversity; having a hot and active interior that spewed and keeps spewing materials onto the surface and into the atmosphere; being covered with tectonic plates that syphon CO_2 from the atmosphere into Earth's mantle, releasing it back upwards through volcanic activity and thus regulating long-term CO_2 levels; being in a peculiar solar system with very large planets in its outer regions that shield the interior (including Earth) from life-endangering collisions with comets; and so on. The conclusion is straightforward: there is no Earth 2.0 in the universe. Even if all the physical conditions listed are duplicated elsewhere, the unpredictability of cosmic cataclysms will have created unique conditions in each world. When life is added, the variability among worlds sharply increases, as does the unpredictability of how specific biospheres would have evolved. Starting with a prokaryotic cell three billion years ago, no one could have predicted the existence of a lobster. Or a human. Every living world will by necessity be different.

Living Worlds as Sacred Realms

As argued, a living world is not only rare but unique. We can thus conclude that we are the only humans in the universe. Any living creature has a certain level of cognition and agency, an ability to interact with the environment to maximize its viability, that is, the urge we share with bacteria to remain alive (Sowinski et al. 2023). On this planet, for better and for worse, humans are the dominant intelligent life-form, as our capacity for symbolic thinking enables us to expand our reach into imaginary and inaccessible realms, from writing poetry and composing symphonies to building radio telescopes, fMRI machines, and nuclear bombs. If there are intelligent life-forms in other stellar systems, "they" will not be like us, even if they share some of our physical traits, such as an approximate left-right symmetry. Furthermore, as remarked earlier, any existing alien life-form is so far away that, for all practical purposes, we are alone to decide our collective fate. Modern science has allowed us to describe how our planet transformed from a barren ball of molten rock to a thriving abode for life. Over the past seven decades, we have pushed the boundaries of this narrative to the very first moments after the origin of the universe itself, some 13.8 billion years ago (Swimme and Tucker 2014). Before our species came into existence about 300,000 years ago, the universe evolved in silence, as collisions between particles created ever more complex material structures, from atoms to stars to chemicals to planets and moons. If other species elsewhere also tell stories of creation, they will be particular to their physical and cognitive realities. Humans tell human stories of creation, each echoing in unique ways the realities of their originating cultures (Gleiser 1997).

The current scientific narrative of creation, the Big Bang model of cosmology, leaves life out. The evolutionary narrative of life on Earth leaves the universe out. Although physics and biology seem to be telling two separate stories, and that is how we study them in school, the stories are profoundly interwoven. The universe only has a story because we are here to tell it. This discipline-based separation—nonliving and living matter—took hold over the past two centuries as a consequence of a compartmentalization of knowledge that grew from the hyper-specialization of scientific research. Science's success created its own blind spots. Of central relevance to us here, one of the key blind spots is the objectification of nature as something separate from us, as an object of study detached from value (Frank, Gleiser, and Thompson 2024). It was this objectification, allied with the remarkable technological growth generated from the Newtonian mechanistic worldview, that propelled our immense material success, as witnessed through the industrial and now digital revolutions. Although there is no going back on this growth, there are options for how to go forward. The first obvious point is that an ideology of infinite material progress is inconsistent with a planet of finite resources. We have reached a point in our collective history where we need to make hard choices about how to coexist with a fragile biosphere.

The biocentric view discussed here and elsewhere (Gleiser 2023) proposes the sacrality of every living world. "Sacred" here should primarily be seen as secular, divested of specific creeds, although of course many religious traditions propose that the planet that allows us to exist is holy and should be venerated as such. Among countless examples, the Guarani Indigenous tradition of Brazil calls Earth *Nhandecy*, "Mother Earth."[4] When we call Earth our mother, we do so with humility and gratitude. We understand at the rational level that we could not survive on a sick planet, that what we receive from the skies and land are essential to our existence. We understand that we are not alone on this planet but profoundly codependent with the biosphere and its rich diversity, which we can call the life collective, of which we are an integral part. But more than understand, we also feel it in our hearts as we gaze in wonder at the beauty of our world and its mysteries. In the words of Thomas Berry (1999, xi), "Intimacy with the planet in its wonder and beauty and the full depth of its meaning is what enables us an integral human relationship with the planet to function . . . The fulfillment of the Earth community is to be caught up in the grandeur of existence itself and in admiration of those mysterious powers whence all this has emerged." We have forgotten that our very existence comes from a secret buried in Earth's distant past, the emergence of life itself. It is time we rekindle this memory of our distant origins based on the lens of a new scientific narrative that connects us to all forms of life and the cosmos itself.

Concluding Remarks

Earth may not be the only living world in the cosmos, but it is our living world, the one to which we belong. We may fly into outer space in search of other worlds, but as we do so, we must carry bits of our world with us—the water

we drink, the air we breathe, the food we eat—or else we will not survive. Technology allows us to extend our reach to the stars and beyond. It helps us extend our lives and redefine our lifestyle and the way we communicate. But it cannot solve all our problems. It may alleviate some of them—for example, we may capture energy from the sun and wind and sequester carbon dioxide from the atmosphere—but, in doing so, it will inevitably create new ones. No machine is 100% efficient, and every machine is built from and must use natural resources extracted from the environment at a cost. Nothing in the universe, not even the universe itself, escapes the inexorability of thermodynamics.

The reapproximating of humans with nature, which Thomas Berry so eloquently urged, inspired by a reevaluation of our role as partners rather than owners of the natural world, cannot be based only on rational decision-making. We have tried this for decades and failed, as the many violations and implementation failures of already-limited climate agreements continue to show. To be sure, governments and large corporations have an essential role to play in facilitating this reawakening, but it is at the level of the individual that this mindset change probably will unfold. Possible steps to achieve this mindset change have been suggested elsewhere (Gleiser 2023). In short, we need to reenchant the planet. This reenchanting can be inspired by an intense exposure to the wonders, beauty, and power of our home planet. This exposure to nature takes many shapes. In schools, at all levels, we must teach the post-Copernican modern scientific narrative of belonging briefly described here, tracing our roots to the deep past of cosmic history and to all forms of life on this planet. Consumers with sufficient purchasing power can choose to buy goods from corporations aligned with sustainable and bioethical practices, for example, in accordance with the rules of the B Corporation certification movement.[5] Schools, families, and communities can choose to organize trips to awe-inspiring landscapes as a study in re-belonging, with the goal of reconnecting with our evolutionary history. Biocentrism is the cornerstone of a bioethics profoundly engaged in preserving and celebrating life on this and any other living planet based on a confluence of Indigenous values and scientific discoveries that place life center stage in the cosmos.

Religions traditionally revere what is more powerful than humans, the unknowable forces that are responsible for our origins and allow us to exist. The ineffability of existence inspires the experience of the sacred. The creation myths of countless cultures past and present tell us of our origins and the origins of the sky and the Earth, the sun and the moon, the planets and animals. Our modern scientific narrative based on the Big Bang theory of cosmology and the evolutionary theory of biology tells us of our profound connection to both the cosmic history and all life on Earth, past and present. This remarkable convergence of narratives—if not in method, at least in meaning—should bond us in our shared humanity as we move forward toward an uncertain future.

Notes

[1] This number is expected to reach 68% by 2050, as reported by the United Nations in https://www.un.org/uk/desa/68-world-population-projected-live-urban-areas-2050-says-un.

[2] For research on the ALH84001 meteorite, see, e.g., https://curator.jsc.nasa.gov/antmet/mmc/alh84001.pdf.

[3] A contrasting argument is defended by British biologist Simon Conway Morris: that evolution towards complexity is a natural and probable outcome of life's adaptation and refinement over billions of years. See, e.g., Conway Morris (2004). That being the case, if we ever find life in another world, and this life has existed long enough, it would have evolved beyond unicellularity.

[4] See Sandra Benites (2025), where Nhandecy is explained as the Guarani term for "our mother."

[5] https://www.bcorporation.net/en-us/.

References

Ahrer, Eva-Maria, et al. 2023a. "Identification of Carbon Dioxide in an Exoplanet Atmosphere." *Nature* 614:649–52.

———. 2023b. "Early Release Science of the Exoplanet WASP-39b with JWST NIRCam." *Nature* 614:653–58.

Arms Control Association. 2025. "Nuclear Weapons: Who Has What at a Glance." https://www.armscontrol.org/factsheets/Nuclearweaponswhohaswhat.

Benites, Sandra. 2025. *Nhandereko, the Guarani Law*. Berkeley, CA: Center for Latin American and Caribbean Studies, University of California, Berkeley.

Berry, Thomas. 1988. *The Dream of the Earth*. San Francisco: Sierra Club.

———. 1999. *The Great Work: Our Way into the Future*. New York: Three Rivers Press.

Capel-Timms, Isabella, David Levinson, Bahman Lahoorpoor, Sara Bonetti, and Gabriele Manoli. 2024. "The Angiogenic Growth of Cities." *Journal of the Royal Society Interface* 21 (213): 20230657.

Conway Morris, Simon. 2004. *Life's Solution: Inevitable Humans in a Lonely Universe*. Cambridge: Cambridge University Press.

Frank, Adam. 2018. *Light of the Stars: Alien Worlds and the Fate of the Earth*. New York: W. W. Norton.

Frank, Adam. 2024. "Alien Life Is No Joke." *American Scientist* 112:216.

Frank, Adam, Marcelo Gleiser, and Evan Thompson. 2024. *The Blind Spot: Why Science Cannot Ignore Human Experience*. Cambridge, MA: MIT Press.

Gleiser, Marcelo. 1997. *The Dancing Universe: From Creation Myths to the Big Bang*. New York: Dutton.

———. 2023. *The Dawn of a Mindful Universe: A Manifesto for Humanity's Future*. New York: Harper One.

Graeber, David, and Wengrow David. 2022. *The Dawn of Everything: A New History of Humanity*. New York: Penguin Books.

Kauffman, Stuart A. 2019. *A World Beyond Physics: The Emergence and Evolution of Life*. New York: Oxford University Press.

Kolbert, Elizabeth 2014. *The Sixth Extinction: An Unnatural History*. New York: Henry Holt and Co.

Lane, K. Maria D. 2011. *Geographies of Mars: Seeing and Knowing the Red Planet*. Chicago: Chicago University Press.

Leslie, John. 1996. *The End of the World: The Science and Ethics of Human Extinction*. London: Routledge.

Lingam, Manasvi, Jacob Haqq-Misra, Jason T. Wright, Macy J. Huston, Adam Frank, and Ravi Kopparapu. 2023. "Technosignatures: Frameworks for Their Assessment". *The Astrophysical Journal* 943:27.

Lovelock, J. E., and L. Margulis. 1974. "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis." *Tellus A* 26 (1–2): 2–10.

Mann, Michael E. 2022. *Our Fragile Moment: How Lessons from Earth's Past Can Help Us Survive the Climate Crisis*. New York: Hachette.

Rees, Martin. 2021. *On The Future: Prospects for Humanity*. Princeton, NJ: Princeton University Press.

Sauterey, Boris, Benjamin Charnay, Antonin Affholder, Stéphane Mazevet, and Régis Ferrière. 2022. "Early Mars Habitability and Global Cooling by H_2-Based Methanogens." *Nature Astronomy* 6:1263–71.

Scharf, Caleb A. 2009. *Extrasolar Planets and Astrobiology*. Sausalito, CA: University Science Books.

Sowinski, Damian R., J. Carroll-Nellenback, R. N. Markwick, J. Piñero, M. Gleiser, A. Kolchinsky, G. Ghoshal, and A. Frank. 2023. "Semantic Information in a Model of Resource Gathering Agents." *Physical Review X* 1:023003.

Swimme, Brian Thomas, and Mary Evelyn Tucker. 2014. *Journey of the Universe*. New Haven, CT: Yale University Press.

Webb, Stephen. (2002) 2015. *If the Universe is Teeming with Aliens . . . Where Is Everybody? Seventy-Five Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life*. Heidelberg: Springer.

Wilkinson, David. 2013. *Science, Religion, and the Search for Extraterrestrial Intelligence*. Oxford: Oxford University Press.