Exoplanets and Astrotheology

with Andreas Losch, "Astrotheology: Exoplanets, Christian Concerns, and Human Hopes"; David Wilkinson, "Searching for Another Earth: The Recent History of the Discovery of Exoplanets"; Michael J. Crowe, "William Whewell, the Plurality of Worlds, and the Modern Solar System"; David Dunér, "Swedenborg and the Plurality of Worlds: Astrotheology in the Eighteenth Century"; Ted Peters, "Astrobiology and Astrochristology"; Howard Smith, "Alone in the Universe"; and Lucas John Mix, "Life-Value Narratives and the Impact of Astrobiology on Christian Ethics."

ALONE IN THE UNIVERSE

by Howard Smith

Abstract. We are probably alone in the universe—a conclusion based on observations of over 4,000 exoplanets and fundamental physical constraints. This article updates earlier arguments with the latest astrophysical results. Since the discovery of exoplanets, theologians have asked with renewed urgency what the presence of extraterrestrial intelligence (ETI) says about salvation and human purpose, but this is the wrong question. The more urgent question is what their absence says. The "Misanthropic Principle" is the observation that, in a universe fine-tuned for life ("Anthropic Principle"), the circumstances necessary for intelligence are rare.

Rabbis for 2,000 years discussed the existence of ETI using scriptural passages. We examine the traditional Jewish approaches to ETI, including insights on how ETI affects our perception of God, self, free-will, and responsibility. We explore the implications of our probable solitude, and offer a Jewish response to the ethical lessons to be drawn from the absence of ETI.

Keywords: astrobiology; astroethics; astrotheology; exoplanets; extraterrestrial life; Judaism; Kabbalah; Misanthropic Principle; Talmud

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We are alone in the universe, at least for all practical purposes. This is the most probable conclusion to be drawn from a host of fundamental physical constraints and new astrophysical observations, and in particular the discovery (at this writing) of 4,696 exoplanet candidates (http://kepler.nasa.gov/) including some Earth-sized planets in their habitable zones (Quintana et al. 2014). The implications of these discoveries, and their modern context, are radical.

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[*Zygon*, vol. 51, no. 2 (June 2016)]
ISSN 0591-2385

Since the discovery of first extrasolar planets in the last decade, theologians and philosophers have probed with renewed urgency the religious consequences of discovering intelligent species elsewhere in the cosmos and what their presence says about the human role in a cosmic plan (if any) and salvation (e.g., Peters 2010; 2014). The discussions about the religious implications of extraterrestrial intelligence (ETI) have almost entirely fallen into two categories. The dominant group believes, like Epicurus, that humanity is the result of the natural evolution of systems of atoms. It assumes that the same processes of nature produced ETI elsewhere in a boundless cosmos, with the result that humanity is entirely reduced in stature and is not only ordinary by virtue of not being at the center of the universe, but also because it is in no way special. A smaller group of theologians accepts that ETI is common, a result of God's grace and power, but asserts that the special redemptive quality of God's love of humanity is nevertheless present (e.g., Bonting 2003; Clayton 2014; Losch and Krebs 2015); in addition, mystical Jewish theologians elevate humanity further by adding a cosmic redemptive purpose to human activity. For all of these thinkers, whether ETI represents for them either chemistry or Divine potency, humanity is neither unique nor special, and the Earth is but one of many habitable planets. The evidence, however, currently indicates otherwise: we are probably alone, at least for all practical purposes. Thus, the question posed above—What does the presence of ETI say about the human role in a cosmic plan?—is the wrong question. The more relevant question is what their *absence,* which appears to contradict Copernican assumptions, says about humanity and its purpose. The answers to this question are likely to be disconcerting to a public that is comfortable thinking of itself as cosmically irrelevant and free of any grand responsibilities.

In this article, we update the scientific arguments for our solitude, and discuss the original and evolving Jewish attitudes toward ETI and the dilemma that their absence implies. The section of this article entitled "Is There Intelligent Life Elsewhere in the Universe?" summarizes the context for the discussion of ETI and reviews the scientific case for our solitude, including the Drake equation parameters. The most dramatic new scientific evidence derives from the measurements of exoplanets—planets around other stars (Smith 2011)—and the section "Recent Results from Exoplanet Studies" is devoted to the most recent exoplanet results, updating the statistics presented in earlier ETI papers. It concludes by introducing the "Misanthropic Principle," the observation that, in a universe whose physical parameters are spectacularly well suited for intelligent life (the "Anthropic Principle"), the environments and circumstances necessary for intelligence to develop are comparatively rare (Smith 2011). The section "Jewish Perspectives on ETI" reviews the primary scriptural allusion to ETI and the active rabbinic responses to that passage from Talmudic times through the discovery of intelligent beings in the New World until modern times.

IS THERE INTELLIGENT LIFE ELSEWHERE IN THE UNIVERSE?

Background. Life—specifically intelligent life, and not just viruses—might be ubiquitous in the cosmos. The attitude typical of scientists has traditionally been that in a universe as spacious and rich as ours, presumably with more than enough stellar systems to overwhelm "pessimistic" scenarios, there should be many stars with Earth-like planets hosting life because there is no reason to think that suitable planets or life are extraordinary. Typical of this traditional attitude was that of Percival Lowell, famous for his search for Pluto and for his studies of the canals of Mars from his observatory in Flagstaff. He wrote in his 1908 book, *Mars as the Abode of Life*: "From all we have learned of its constitution on the one hand or of its distribution on the other we know life to be as inevitable a phase of planetary evolution as is quartz or feldspar or nitrogenous soil. Each and all of them are only manifestations of chemical affinity" (Lowell 1908, 39). Lowell was by no means unique. Before him, in 1803, the eminent French astronomer Jerome Lalande had confidently written, "Is it rational to suppose the existence of living and thinking beings is confined to the earth? From what is such a privilege derived but from the groveling minds of persons who can never rise above the objects of their immediate sensations?" (Lalande, quoted in Fontenelle 1803, viii). More recently, Harlow Shapley (1985–1972), the distinguished director of my own institution, the Harvard College Observatory, wrote of "intimations of man's inconsequentiality" in a vast cosmos and of "our [firm] belief in the cosmos-wide occurrence of life" (Shapley 1963, 3, 77). Michael Crowe has reviewed how the assumption of the existence of cosmic aliens, perhaps originating with the Greeks, was pervasive by the seventeenth century among both scientists and theologians (Crowe 1997; 2008).Today we know that Mars has no artificial canals, and that Lowell's confident assumption and Lalande's rhetorical logic were unproven, and their arrogant assertions were just wishful thinking.

Those assumptions continue to this day. A recent issue of the *Philosophical Transactions of the Royal Society* entitled "The Detection of Extraterrestrial Life and Consequences for Science and Society" (Dominik and Zarnecki 2011) includes articles by scientists, philosophers, and theologians addressing this topic. Ted Peters summarizes the popular sentiment: "To date no message has been received. Yet, many among us hope that tomorrow, or the day after tomorrow, we will discover a Second Genesis of life elsewhere" (Peters 2014). He quotes Bishop Krister Stendahl's reaction to possible ETI: "It seems always great to me, when God's world gets a little bigger [that] *I get a somewhat more true view of my place and my smallness in that universe* [emphasis added]." Most of the respondents in the Royal Society volume, and in related publications like the recent book *Talking About Life* edited by Chris Impey (2010), echo similar sentiments about our cosmic smallness, or ordinariness, and wonder how the impact of first contact with ETI might change our view of ourselves or of God. Issues range from specific doctrinal beliefs on salvation or moral responsibility to whether or not such contact diminishes human dignity. The August 5, 2015 issue of *New Scientist* trumpets the headline: "What if . . . we are not alone? Those hunting for ET think it's just a matter of time—a finding that would strike the final blow to the idea that we're the center of the cosmos."

The idea carries the endorsement of the overwhelming majority of the public, perhaps because it seems like such a straightforward extrapolation of the Anthropic Principle, which recognizes the physical parameters of our universe are almost miraculously finely tuned so as to nurture intelligent life (for one of three possible reasons—in brief: either luck, a multiverse, or God; e.g., Barrow and Tipler 1986; Smith 2006; Davies 2010). If it is one the first two, life should be nurtured everywhere, and intelligent species would exist on many planets around many stars. The popular attitude probably also reflects confidence in a Copernican presumption of mediocrity: we on Earth are just typical of life forms throughout our galaxy and the universe. A 2008 Scripps Howard Poll (cited in A. A. Harrison 2011, 656–68) found 56 percent of respondents thought ETI was likely (31 percent thought they had already visited Earth). Harrison also offers another reason why the public endorse ETI: "[the belief] that ETI came from 'utopian societies which are free of war, death, disease, or any other . . . mid-twentieth century problems' and could 'help mankind overcome its problems'." As the alien Klaatu puts it in the movie *The Day the Earth Stood Still*, "Join us and live in peace, or pursue your present course and face obliteration . . . . The decision rests with you." Similar benevolent sentiments are echoed by the super-intelligent beings in the movie *Contact*, for example, or by the alien ET in *Close Encounters of the Third Kind*.

Alone "for all practical purposes." Two preliminary clarifications are essential before presenting the latest astrophysical results, in particular the discovery of exoplanets, and discussing their dramatic implications for ETI. First, only the existence of intelligent beings is relevant. Primitive life may yet be discovered on Mars; perhaps even multicellular animals will be found on a nearby extrasolar planet. These revolutionary discoveries would help us reconstruct how life on Earth evolved, but unless a species is capable of conscious, independent thought and has the ability to communicate, we will still be alone—with no one to teach or learn from, no one to save us from ourselves, or, in the fanciful extrapolations of Stephen Hawking (1988) (and endless filmmakers), no one to do battle with. ETI implies life able to communicate between stars (e.g., Shklovskii and Sagan 1966). This implies having radio or similar technology. Since our own society, by this definition, is only about 100 years old, if intelligent life is common in a universe that is 13.7 billion years old we are surely among its youngest forms. As the physicist Enrico Fermi famously observed, however, the fact that there are no other known intelligent life forms signals that the assumption is wrong—intelligent life is not very common (this is called "the Fermi Paradox").

The second important caveat derives from two features of the world that were unknown to Percival Lowell and all philosophers and scientists before the late twentieth century. The first is relativity—the fastest any signal can travel is the finite speed of light, which sets a practical limit on communication even between stars in our own Milky Way galaxy and its presumed billions of planets. It will take hundreds of thousands of years for any ETI on most of them to receive our signals, and that long again for us to get a reply.

The other feature is the expanding nature of the universe, the result of an inflationary "big bang" creation, with two relevant effects. The first might seem to bolster the chances for ETI: Beyond our cosmic horizon (the distance set by how far light can travel in the age of the universe) the universe may be extremely large. Even more fantastically, there are possibly an infinite number of universes (the so-called "multiverse"). Therefore, as Stephen Hawking (1988) and other physicists have speculated, even if ETI were infinitesimally rare, in an infinite universe all possible scenarios and life forms will exist in plenitude. While such possibilities may be philosophically amusing, they are irrelevant. We cannot communicate with, or even directly measure anything about, this unlimited vastness. The second relevant aspect of cosmology is the discovery that distant galaxies are actually receding from us at an *accelerating* rate (e.g., Riess et al. 1998). As a result, light signals sent from Earth today will *never* even catch up to galaxies whose light has taken only about 10 billion years to reach us (Loeb 2002). Although they are well within our cosmic horizon, such galaxies are now beyond our reach forever and receding quickly. Waiting longer times for signals will not help.

The SETI program (Search for Extraterrestrial Intelligence), which undertakes extensive searches for signals, fully acknowledges this science but argues that "we are unanimous in our conviction that the only significant test of the existence of extraterrestrial intelligence (ETI) is an experimental one" (Tarter 1983, 359). I support SETI in principle—if we don't look we won't find. But it is a risky endeavor, and nonprofessionals in particular need to be reminded of the enormous limitations imposed by the finite speed of light. Even if there were a network of advanced civilizations living on the other side of our galaxy, they much are too far away from Earth to converse with. Any signals of theirs that we happen to pick up will already be hundreds of thousands of years out of date, and to be "alone" is to be without anyone to talk to. By the way, indirect statistical evidence, as SETI scientists would agree, is also "experimental," including the absence of sought-for signals coupled with careful statistical analyses of geological, astronomical, and biological data sets.

Two possible ways out of these constraints have been proposed. It is possible that some distant alien civilization scans the galaxy's stars for juvenile Earths, predicts their evolution and optimistically sends out greetings eons ahead of time as signals or robotic probes timed to arrive just when intelligent species have evolved and are starting to listen. But it is very hard to imagine any such enterprise being practical either technically or economically (e.g., Goldsmith and Owen 1992, 446–50; Davies 2010). Another, tactical approach to exploring the cosmos given the limitations of relativity is for civilizations to colonize suitable nearby stellar systems locally, within an achievable volume, and then for each of these new settlements to similarly colonize a spherical volume around itself. As they independently "percolate" outward, civilizations will eventually span the galaxy. Cartin (2015) calculates the probability that spacefaring ETI has arisen in the Solar System's neighborhood (he uses 130 light-years) based on their *not* having reached here through this percolation approach. Using assumptions about distance and speed that he considers realistic, he concludes that their absence implies "at *most* [my emphasis] only one out of every 585 *habitable* [again, my emphasis] planets within the local Solar neighborhood could be the cradle of an interstellar civilization" (Cartin 2015, 573). He admits that the fraction of worlds on which life has arisen is "unknown." We show in the detailed discussions below that habitable by no means implies inhabited, and so "at most" is at best an understatement. No wonder there are no signals, nor even faint traces, despite decades of looking. As Fermi argued, they are not there.

The second way out of the Special Relativity constraint is the question I get most often: Perhaps some physics we think we understand will be overturned with future knowledge! Faster than light travel, in particular, will then turn science fiction into fact, and we will be able to warp-drive our way even to the most distant galaxies that have so far been excluded from our vision. Unfortunately, Fermi's Paradox—"If they are not uncommon, then where are they?"—implies that we cannot have it both ways. If life were common and if superluminal travel or communication were possible, then we face an insuperable contradiction: the billions of intelligent species in the universe (and we are surely one of the newest and least technologically advanced) should have already used this super-technology to visit us. That NONE have done so surely means that the basics of relativity as we know it will remain inviolable—leaving us alone. Alternatively, if relativity can some day be overcome, then there cannot be very many civilizations out there, and we are also alone. An interesting implication of this line of argument is that if our scientists were some day to discover a way to travel faster than light, it would put a nail into the coffin of all advanced alien societies. Fermi's observation therefore suggests that advanced beings are not only not living in our galaxy, but there are not many living anywhere in the universe!

To be alone for all practical purposes means to be without any communication—or even the knowledge that any signal is coming—for a very long time. How long before we feel such solitude? For the purposes of a quantitative discussion I choose 100 human generations, practically forever in a subjective sense. This is of course an arbitrary timescale. If we choose a smaller volume, say, that accessible within only one generation, the chances of success go down by a factor of a million (!) because the number of stars is proportional to the volume of space, and scales with time (distance) cubed—but we will have a yes-or-no answer one hundred times sooner. If instead we want to improve the probability of success by a factor of one million, we can extend the search volume, but then the wait time goes up correspondingly to ten thousand generations. I stick with 100 generations for now, and because one generation corresponds to 25 years (and at least one round trip of messaging is necessary), in the following Drake equation calculations I constrain estimates to stars closer to Earth than 100 × 25/2 or 1,250 light-years. We know a lot about the stars in this neighborhood.

Prejudices and expectations. The Drake equation is a set of multiplicative factors tracking the various phenomena thought to be necessary to yield intelligent life. It is not a mathematical formulation of a physical process, and every researcher who uses it breaks down the individual terms somewhat differently, but all estimate the same thing—the number of civilizations around today. At its simplest, the result is a product of five terms: (a) the number of suitable stars, (b) the number of suitable planets around such a star, (c) the probability of life developing on a suitable planet, (d) the probability that life evolves to be intelligent and (e) the typical lifetime of a civilization compared to the lifetime of its star (e.g., Smith 2011). The individual factors and their values have been hotly debated since Frank Drake introduced the formula in the 1950s because only the first variable could be reasonably estimated from physical evidence or extrapolated from a statistically meaningful sample, the number of solar-type stars (although the group of "suitable stars" might include more types). The new results from exoplanet searches impact the second term and provide the basis for the following discussion.

Modern astronomers, such as Lowell before them, have generally been outspokenly optimistic that Earth-like environments are common. Don Goldsmith and Tobias Owen, in their classic book *The Search for Life in the Universe* (1992), wrote: "Nothing in our theories for the origin and evolution of our sun is unique to the solar system. . . . We anticipate that all planetary systems will have a set of rocky inner planets, with atmospheres produced by outgassing, weathering, and escape, for the same reasons that our own rocky inner planets have atmospheres. Judging from our own example, the chances seem good that one of these inner planets will orbit its star at the right distance. . . . We say one in every two to be conservative" (Goldsmith and Owen 1992, 384).

The latest results of astronomy show otherwise, and stunningly so. The publication and confirmation so far of over 4,000 exoplanets and their orbital characteristics, and the more detailed analyses of the 366 exoplanets whose masses and radii have been measured, together with other lines of evidence, argue strongly against the assumption of mediocrity. The single most remarkable result from the discovery of extrasolar planets is their variety: some systems have extreme, elliptical orbits, other contain giant planets orbiting very close to their stars (called "hot Jupiters"), among other unexpected properties. It is important to stress again that technology is only just now able to detect Earth-sized planets, and those in the habitable zone of a Sun-like star (the range of distances where the temperatures allow surface water to be liquid) will take about a year to orbit, and thus will require several years of monitoring to confirm their repeat transits.

Calculating the odds. The first term in the Drake expression is the number of stars. The Sun lies in a cavity of interstellar gas, called the Local Bubble, which extends over roughly 600 light-years. It in turn is located in Gould's Belt, a spur of stars, star clusters and molecular clouds between two of the Milky Way galaxy's spiral arms, stretching from the Orion nebula to the Ophiuchus-Scorpius clouds and on to the Perseus clusters—a distance of about 1,200 light-years in its longest dimension. The approximate number of stars per cubic light-year here is 0.004, to within a factor of two, or about 30 million stars of all types in a volume of radius 1,250 light-years (Smith 2011). This result provides the first factor in the Drake equation.

Smith (2011) expands on the second criterion above—planetary suitability—and enumerates four essential conditions for life: stability, habitability (including the presence of water), planetary mass, and planetary composition. Stability requires a host star stable in size, age, and radiative output for the billions of years needed to nurture intelligent life. It also implies a system of planets which orbit in a stable, habitable, non-mutually disruptive mode for billions of years. The habitability criterion means that a suitable planet must reside in the habitable zone of its star or else have some other mechanism to maintain liquid water. Its orbit must be stable, and sufficiently circular or otherwise unchanging so that it remains hospitable for billions of years. The third condition, planetary mass, means that a suitable planet must be massive enough to hold an atmosphere, but not so massive that plate tectonics are inhibited, because that would reduce geological processing and its crucial consequences for life. Current estimates (e.g., Ward and Brownlee 2000) are that planets smaller than about

0.4 Earth masses are unsuited for long-term atmospheres; if a planet is bigger than about four Earth masses, assuming it is rocky, then planetologists estimate it will be unable to produce the plate tectonics thought necessary to refresh the atmosphere with volcanoes or other processes associated with the carbon cycle. Last is planetary composition. A suitable planet obviously must contain the elements needed for complex molecules (carbon, for example), but it also needs elements that are perhaps not necessary for making life itself but that are essential for an environment that can host intelligent life: silicon and iron, for example, to enable plate tectonics, and a magnetic field to shield the planet's surface from lethal charged winds from its star. The core of Earth remains liquid because of the presence of radioactive elements, whose heat keeps the iron molten and energizes Earth's internal temperature structure.

The last three terms in the Drake equation, (c)–(e), are biological. The probabilities associated with all these terms are very uncertain, and astronomy provides no new evidence to evaluate them. Traditional discussions tend to imagine either that intelligence is inevitable on any approximately suitable planet, or that it is unlikely. Spiegel and Turner (2012) recently used a Bayesian statistical analysis to estimate the likelihood that life can form from inanimate matter using priors based on the few known facts: the sample consists only of us, and life arose on Earth relatively quickly (perhaps in under a few hundred million years) once Earth became habitable about 3.5 billion years after forming. Their approach presumes, among other things, that the molecular structures of life originally assembled via stochastic chemical processes in an organic soup. All known life forms, however, even viruses, are chemically large and complex. Even if the basic alphabet blocks of life, amino acids, are easily formed (something that is not entirely obvious), the chances of large numbers of them finding each other and combining to form the simplest macromolecules capable of reproduction as required for Earth-based life forms, like ribosomes with tens of thousands of carbon atoms, are astronomically small. They conclude that "although terrestrial life's early emergence provides evidence that life might be common in the Universe if early-Earth–like conditions are, the evidence is inconclusive and indeed is consistent with an arbitrarily low intrinsic probability of abiogenesis [life forming from inanimate matter] for plausible uninformative priors. . . . Our conclusion that the early emergence of life on Earth is consistent with life being very rare in the Universe for plausible priors is robust against two of the more fundamental simplifications in our formal analysis" (Spiegel and Turner 2012, 1, 6). Other authors also have tackled a broad range of aspects of this question. Schulze-Makuch, Schulze-Makuch, and Houtkoopoer (2015) investigate the likelihood of the survival of primitive life forms in hostile environments given the abundance of extremophilic life forms on Earth. All known extremophiles, however, need liquid water, are carbon-based, and most significantly are *alive*. How they came to be alive is not discussed. Irwin et al. (2014) propose a biological complexity index for life forms, based on the astronomical and geological parameters of exoplanets, and rank the potential that some exoplanets or solar system bodies could host complex organisms, but the authors do not try to estimate the biological terms needed to get life started in the first place. Scharf and Cronin (2015) propose a Drake-like equation to estimate the probability of abiogenesis based on the availability of chemical building blocks and related parameters. They find that, given that there is life on Earth, the probability of an abiogenesis "event" happening in 100 million years on another Earth-*like* planet (but only Earth-*sized* planets have been found so far), is "poorly understood" but perhaps around 10^{-32} "when all other necessary conditions are met." All these discussions end up assuming that life-nurturing places like Earth are abundant in the vast cosmos and that life arises through straightforward chemical reactions, and therefore that even if life is very rare the universe is so large that even low statistics will yield many civilizations. The point of this current article is that truly suitable places for ETI might be rather uncommon, that something more than normal chemistry might be involved, and most crucially, that we are not likely to know one way or the other for a long time, perhaps forever.

Drake himself currently guesses that "only about 1 in 10 million stars has a detectable civilization" (Drake 2011) so in our 100-generation volume of space comprising 30 million stars, there might be two others. Readers can make their own estimates. There will be no civilization if a star is too large or too small, if a planet's orbit or obliquity is wrong, if its size or chemical composition is unsuited, if its surface is ill equipped, if its geologic and meteoritic history is too inauspicious, if the powerful chemistry needed to generate the first life forms is too intricate or too slow, if evolution from proteins to intelligence is too often aborted or directed into sterile tangents, or if civilizations die off easily. If we are to have company in our volume of the galaxy, the likelihood on average for each of these conditions has to be pretty high—better than 20 percent. If the probability of some, such as the chances for life to form, evolve or survive, is much smaller, then even if the others are 100 percent certain, it is unlikely there are any stars near us hosting intelligent beings (see Smith 2011, for additional details).

RECENT RESULTS FROM EXOPLANET STUDIES

Since the publication of Smith (2011), the exoplanet community and the Kepler mission in particular have announced the confirmation of another 1,521 exoplanets, bringing the total to 1,952 out of about 4,696 exoplanet candidates (i.e., likely, but not yet confirmed) so far (www.kepler.nasa.gov). Of these 1,952 confirmed objects, 366 have measured masses and radii, and hence densities and a perspective into their physical compositions. The field has exploded, and the upcoming launch of the transiting exoplanet survey satellite (TESS) in 2017 will add many more. How do the new objects influence earlier conclusions? In this section, I will discuss the main results, which are itemized here for convenience, but to summarize, the conclusion drawn in Smith (2011) and cited above is reinforced: The single most remarkable finding of the new research on extrasolar planets is that an enormous variety of systems exist—a diverse range of often-bizarre environments that is considerably broader than had usually been imagined before the first one was discovered. As the MIT exoplanet scientist Sara Seager puts it, "It seems that less than 10–20 percent of Sun-like stars could host solar system copies. Instead, astronomers have found that exoplanets and exoplanetary systems are incredibly varied, with planets of nearly all conceivable masses and sizes as well as orbital separations from their host star" (Seager 2014, 12634).

The first dramatic new result of the past four years is simply the large number of new detections, which provides a basis for firm statistical analyses of exoplanet probabilities under various conditions. The next is the firm detection of Earth-sized exoplanets, with a couple located within their "habitable zones." Earth-*sized*, of course, by no means implies it is "Earth-*like*"! Venus and Mars are Earth-sized. But the result both shows the power of technology and the ability of cosmic forces to make small as well as large planets with ease. Next are the exoplanets detected inside their habitable zones, meaning that water (if present) could be liquid. The last important, relevant development is the measurement of several exoplanetary atmospheres. So far atmospheres have been studied around hot-Jupiters, but others systems will be found and the first step in identifying an Earth-like exoplanet in its habitable zone will be to detect molecular biomarkers in its atmosphere. There are other interesting and important developments as well, but they don't greatly affect the ETI discussion: the indirect detection of exoplanets in systems via their gravitational perturbations of their sibling exoplanet orbits; the ability to infer exoplanets from rings in dusty disks as sweep out material as the exoplanets orbit in young systems; measurements of the spins of stars as influenced by interactions with their planets; improvements in direct imaging of exoplanets; and not least, improved computational and modeling abilities.

Statistics. One of the most important recent papers on exoplanet statistics is Burke et al.'s (2015) "Terrestrial Planet Occurrence Rates for the Kepler GK Dwarf Sample." (The Sun is a G Dwarf star.) The group's statistical analysis of the first four years of the Kepler mission predicts that probably 7.7 out of 10 of these stars host an exoplanet with radius between about 0.75 and 2.5 Earth-radii and with an orbital period of between about 50 and 300 days (that is, overlapping the habitable zones). Much progress has been made on stars smaller than the Sun as well. Smith (2011) notes that over 90 percent of stars are smaller than the Sun, many with less than one-tenth of the Sun's mass. The MEarth Project (Nutzman and Charbonneau 2008) focuses on these small M-dwarf stars which, because they are the most numerous, are possible host stars for the most numerous exoplanet populations. Berta, Irwin, and Charbonneau (2013) completed a statistical analysis of early MEarth results and report that warm (600–700 K), Neptune-sized exoplanets (about four Earth-radii) probably lie around about 15 percent of early M dwarfs stars. However, it may be hard for a planet around a small star to evolve intelligent life because small stars are cooler and their habitable zones lie closer to the star. When a planet is in this closer region, it tends to become gravitationally (tidally) locked to the star, with one side perpetually facing the star. (Tidal locking keeps one face of the Moon pointing toward Earth.) But then half of the planet will be in the dark and cold, and the other half at constant noon. A related issue is the lower mass of M-dwarf stars, which results in their interior circulation being almost entirely convective. Convective flows lead to surface magnetic fields and the production of coronal flares, X-ray emission, and stellar winds, all of which might be hazardous to nearby exoplanets. Studies suggest that any exoplanets in the habitable zones of M dwarfs with atmospheres will be adversely affected by solar winds (Cohen et al. 2014*)*. Lalitha et al. (2014) now estimate from a statistical analysis of the X-ray behaviors of M-dwarfs that they typically have tens of X-ray flares per day; the largest of these flares contain as much energy as about 10 percent of the Sun's total radiative output and can occur once every few hundred days (see also Kulow et al. 2014; Ehrenreich et al. 2015). In the Sun, energy transport in the inner region is dominated by radiative flow out to about 0.71 solar-radii, and only beyond that is it convective (and of course the Earth is farther away).

Among the many issues to consider when evaluating the suitability of exoplanets of any kind to host intelligent life, Smith (2011) uses as an example the case of eccentricity. The orbital eccentricity of a planet is a measure of its closest distance to the star compared to its largest distance—and thus determines the annual variations the planet receives in stellar illumination, as well as its susceptibility to gravitational orbital perturbations and disruption by other planets whose orbits might cross nearby. Thankfully, the Earth's elliptical orbit is nearly circular with an eccentricity of only about 0.017. The *Exoplanet Encyclopedia* (www.exoplanet.eu) now lists the eccentricities of 754 exoplanets, almost double the number at the time of Smith (2011), and the percent of exoplanets with eccentricities less than or equal to the Earth's is 5.3 percent, up from the 2.2 percent in the earlier paper though still a relatively small number. The point here is that continued research on exoplanets and exobiology is essential, and there is a lot more to be learned.

Earth-sized planets and their habitable zones. There about 391 exoplanets known with radii between about 1–2 Earth-radii, about 30 percent. However, 98 percent of these orbit closer to their star than does Mercury in our solar system. Of particular excitement is the exoplanet Kepler-186f which is both Earth-sized and in the habitable zone of its M-dwarf star (Quintana et al. 2014). Kepler-186f is the fifth exoplanet found around this star, and interestingly the other four, 186b-186e, are also Earth-sized although not in the habitable zone. Another interesting case is Kepler-296, a binary star of two M-dwarfs and five orbiting exoplanets, two of which seem to be Earth-sized and possibly in their habitable zone (Barclay et al. 2015).

Atmospheres. Any exoplanet hosting life would have to have some kind of an atmosphere, and detecting atmospheres has become an exciting sub-specialty of exoplanet research. One of the earliest detections of an exoplanetary atmosphere was made with infrared measurements by the Spitzer Space Telescope, by noticing asymmetric behavior in the lightcurve of the exoplanet HD189733b as it crossed the face of its star and then passed behind, inferring that an atmosphere was responsible. A more powerful technique is transmission spectroscopy—as the exoplanet passes across the face of the star, molecules in its atmosphere absorb some of the starlight and reveal their presence. Four exoplanets have so far had their atmospheres measured in this way, revealing that haze and/or clouds may cover the surfaces. Naturally, there is keen interest to see if any biomarkers can be spotted; these are molecules like oxygen, nitrous oxide, and methane; other important molecules (though not particularly indicative of the presence of life) are water, carbon dioxide, and nitrogen (e.g., Seager 2014). DeWit (2015) estimates that there are likely to be hundreds of Earth-sized exoplanets in habitable zones with atmospheres accessible to such spectroscopic measurement in the next decade. Heng and Showman (2015) review the atmospheres of hot-Jupiters, which as noted in Smith (2011) are easier to detect but perhaps less likely to host life. The results so far find atmospheres relatively free of clear molecular indicators, suggesting that scattering by clouds dominates.

In summary, the field of exoplanet research has exploded in the past few years, and is likely to continue to grow in drama as well as in important data. In this author's view, one unfortunate aspect of this recent progress, especially as typified in the popular reporting of Earth-sized planets or others in their "Goldilocks" habitable zones, is the nonsequitur hyperbole about ETI, as for example in the *New Scientist* headline: "What if . . . We are not alone?" (5 August 2015). As the new results reviewed in this section illustrate, the prospects of finding ETI remain (at best) low.

ETI in the future universe. Astrophysicist Avi Loeb has noted that about 10 million years after the creation of the universe in the Big Bang, the temperature in the cosmos cooled to room-temperature and was suitable for life in the same sense as the habitable zone requirement for temperature: water can be liquid (Loeb 2014). Loeb does not suggest, however, that intelligent life could exist in the early universe. Even people wary of presuming that all intelligent beings resemble us, for example in their atomic composition, and so on, generally agree that, at the very least, all intelligence requires complexity. This is the reason why almost certainly atomic carbon will be the building-bone of such beings, because of all the elements only carbon can form a wide array of extremely complex molecules, DNA being just one example. But however it is structured, complexity takes time to develop (in our own case it took a few billion years) and there is not enough time in the early universe for ETI to form. Allowing enough time for complexity to develop is precisely why a planet's long-term stability is such a critical requirement for ETI.

The universe is vast. The size of the universe that we can see (our cosmic horizon, set by the distance light could travel in the age of the universe, 13.8 billion years) is currently about 80 billion light-years (the universe has expanded significantly since the light left these distant regions headed toward us). If there is ETI scattered throughout the universe, we have shown above why we probably will not know one way or the other for a very long time. Indeed, for most of the universe—the part on the other side of our horizon—we will never know even if we wait forever because it is accelerating away from us. Moreover, the longer we do wait, the more of the universe accelerates across the horizon and is lost to us into the unknowable beyond. In the context of considering cosmic time, however, we can also consider (albeit in a very cursory fashion) the possibilities of ETI developing locally (for example, in the Milky Way) in the future. Our Sun and stars like it are slowly exhausting the hydrogen gas they burn. As has been well described in the literature (e.g., Sackmann, Boothroyd, and Kraemer 1993) the Sun will swell in size as it ages, eventually enveloping all the planets out to Mars, and in about 5 billion years will leave the so-called main-sequence and evolve rapidly towards its eventual death as a white dwarf star in another billion years or so. There is time, therefore, for new life to evolve elsewhere in the outer solar system, perhaps in subterranean water that might be located in the moons of Jupiter or Saturn. The rapid changes in illumination as the Sun ages, however, make the stability requirement for ETI very difficult to achieve. The situation is roughly the same for other Sun-like stars elsewhere in the Milky Way. Less massive stars will remain on the main-sequence for very much longer times, but also as noted above the closer-in habitable zones of these M-dwarfs pose risks of their own for ETI. New stars are being formed in the galaxy, currently at a rate of about one per year (the current stellar population is about 100 billion stars). In another few billion years, if current trends hold, there could be a few billion new stars and their planetary systems are possible hosts for ETI.

The Milky Way is part of a local group of galaxies, bound together by their gravity, with the most massive other member of the group being the Andromeda Galaxy. Our two galaxies appear to be gradually falling together in a humongous collision (Cox and Loeb 2008). Within the current lifetime of the Sun these two galaxies will merge—well before the Sun makes it to old age—and observations (and simulations) of other currently merging galaxies suggest the merger process is extremely disruptive, though not necessarily fatal. Individual stars are so widely spaced that they will practically never collide, but gravity will sling them out of their normal galactic orbits onto unfamiliar paths. Our own collision with Andromeda will cast the Sun out to the outer halo of the galaxy (Cox and Loeb 2008). Although our planetary system, and even some neighboring stars, might perhaps remain bound together, the long, stable era of steadily orbiting our spiral galaxy's center will be ended. Simulations show that after a few billion years more the merger settles down, and some new stars will continue to form, although as the hydrogen gas is used up or disbursed the rate of star formation drops steadily.

Complex elements are a requirement for life, as noted above. Several authors (e.g.,Ward and Brownlee 2000; Smith 2011) point out that these "metals" are not uniformly available across the galaxy, depending on the local star formation activity that makes them. A collision with Andromeda will enhance the star formation rate substantially for a few hundred million years and certainly will result in the production of more of these needed elements. After a few billion years more, however, the rate of making new stars drops substantially and then stays low. There is a catch to this initial enhanced production of elements: the Earth relies on radioactive elements to heat its interior, a key factor in the development of life here. Elements like uranium-238 and thorium-232 are made in supernovae, and supernovae are also a product of star formation. Fortunately one went off in the neighborhood of our Sun just before it formed. But unlike elements that accumulate, these radioactive elements decay and disappear; they are the result of the star formation *rate*, which drops dramatically after a merger. After 10 billion years or so, these isotopes will no longer be available to heat planetary interiors. Ultimately, after hundreds of billions more years, our galaxy and its neighbors will increasingly be made up of black holes and the cold ashes of dead stars, while meanwhile the expanding universe sweeps other systems even farther away or beyond our horizon altogether. In this cold and lonely future, ETI is not necessarily excluded from developing, at least for a while, and current ETI may even find ways to survive it, but the long-term future prospects for ETI are even less auspicious than the current ones.

The Misanthropic Principle. The cumulative results from exoplanet studies summarized above reinforce the basic conclusion reached in earlier analyses (Smith 2011): *we are most probably alone*—at least there is probably no other intelligent life within 100 generations reach to talk with. For all intents and purposes, we and our descendants for at least 100 generations are very likely living in solitude. I call this the Misanthropic Principle (Smith 2011). The Anthropic Principle expresses the observation that the physical constants in the cosmos are remarkably finely tuned to make it perfect for hosting intelligent life (e.g., Barrow and Tipler 1986; Davies 2010). The Misanthropic Principle expresses the idea that the multiplicity of possible environments in this suitable cosmos is so varied and uncooperative (or hostile) either always or at some time during the roughly 3–4 billion years intelligent life needs to emerge, that it is extremely *unlikely* for intelligent life to form and thrive.

I have only considered a volume of space that is 100 generations of light-travel-time across. As noted earlier, by expanding the volume of space by a factor of a thousand, or more, the chances for finding intelligent life are of course correspondingly higher, but then neither we nor our children are likely to know for even longer. In this sense the term Misanthropic Principle reflects not only the inhospitable nature of the universe to intelligence, but also the way it seems we must live, alone with our uncertainties, our doubts, and ourselves. However, opposite to the dour connotations of misanthropy, the Misanthropic Principle is joyous. We should rejoice in our good fortune. Atheists and religious people alike can also identify in it an expression of pride in humanity and (as I will argue later) even an acknowledgment of our cosmic competence.

It used to be thought, until science proved otherwise, that we were the center of the universe and everything orbited around us. This is no longer anyone's way of thinking, even metaphorically. From the Copernican revolution onward, people have gradually come to realize that in most ways we are utterly ordinary, neither at the center of the universe nor even of our solar system. Our bodies are made from the chemical detritus of stars, and we (like all life) evolved from simpler organisms through apparently contingent processes that in our case took billions of years. One consequence of this aspect of self-awareness has been the popular nonsequitur presumption (even hope!) that ETI exists, and *should* exist. The theologian and astronomer Thomas Dick succinctly expressed this logic in 1826 when, after presenting his theological reasoning, he summed up his logical argument: "There is an absurdity involved in the contrary supposition" (quoted in Crowe 2008, 261). The Misanthropic Principle, the result of current research and basic physical constraints, offers a new and more honest perspective: ETI is almost certainly nowhere nearby, and its possible existence elsewhere is for all practical purposes unknowable to us (at least for a very long time, if not forever). Speculation about its nature is consequently specious and irrelevant. Very likely we are alone.

The Misanthropic Principle raises three acute dilemmas that have not previously been carefully explored: epistemological, theological, and ethical. The *epistemological* dilemma is clear: Not knowing about the existence of something does not mean it does not exist. Until we hear a clear signal from beyond, or until our science has progressed far enough to provide some kind of all-embracing and conclusive answer (although the nature of such absolute evidence is hard to imagine), humanity is left in an existential quandary. Religion of course makes the point that we are not *spiritually* alone (although religion has its own ontological uncertainty). In this environment of necessary ignorance, how should scientists and theologians respond to the many people for whom the prospect of being "alone," without hope for salvation or comfort from a super-intelligent species abiding in heaven, is frightening?

The theological problem is particularly grave for scientific reductionists, but most people will share some of the angst. We moderns are nearly convinced by the Epicurean argument that we are a randomly evolved collection of atoms. But if we might be unique (at least as far we will know) then must we not reconsider the possibility that we are *not* an accident but were created by some kind of intent, even for some purpose? When the Anthropic Principle directly challenged the Epicurean approach, scientists responded by positing a multiverse. There has not yet been a scientific rejoinder to the Misanthropic Principle. I imagine that it will take the form of a wait-and-see attitude, even if it takes a few millennia of living with nagging doubt. The theological dilemma is also present for religious believers, who have spent centuries showing that Divine potency or grace should naturally imply many extraterrestrial civilizations, but who now must justify the need for the vast, excess cosmos beyond human reach (e.g., Crowe 2008). For both groups, the default explanation is that a vast universe is just the consequence of natural laws. Religious believers, like the Epicureans, might also decide that a wait-and-see attitude is the best response.

The *ethical* dilemma, however, cannot wait. The Earth itself is under stress, and humanity faces growing misery. If we are merely a collection of evolved atoms, then these issues are of no great concern: there is life elsewhere, distributed among the stars, along with many salubrious, Earth-like planets. Possibly some will survive; perhaps that is enough. We have no special status and no particular purpose. But if—as far as we are likely to know for eons—we are alone, then perhaps, just perhaps, the above is not true, and neither we nor our planet are products of common happenstance. The Earth and its life have value. The prospect brings great urgency to the cause of protecting this rare planet and all of its precious inhabitants.

JEWISH PERSPECTIVES ON ETI

"They fought from heaven; the stars in their courses fought against Sisera. . . . Curse ye Mroz, said the angel of the Lord, curse ye bitterly *the inhabitants thereof* because they came not to the help of the Lord" (Judges 5: 20–23). This excerpt is from the ancient Biblical poem, *The Song of Deborah*, dated by scholars to earlier than about 1100 BCE (McDaniel 2003), and provides the basis for the traditional Jewish attitude on ETI. The Talmud records the following comment of Rav Ulla, who lived in the latter half of the third century CE and who cited earlier, unnamed sources: "Rav Ulla said, 'Some say that Mroz was the name of a great personage, others say that it was the name of a star, as it is written, "They fought from heaven, the stars in their courses . . . ."'" (Babylonian Talmud, Mo'ed Katan 16a). The implication is that stars can host inhabitants. The comment has particular significance because Rav Ulla was familiar with astronomy and is known as one of the scholars involved in calculating the times of the new moon. The Hebrew word for stars can also mean planets, and in the context of "in their courses" perhaps obviously refers to a planet. (It therefore strikes me as remarkable that the name of this warrior planet, Mroz, is homophonic with the Roman name for the planet that the Greeks called Ares, namely, Mars.)

In the centuries following the Talmud, Rav Ulla's comment did not appear to raise any hackles. Writing around the year 1000, Rabban Hananel, in his running commentary printed in many modern editions of the Talmud, added the following clarification to his quote: "'Others say that it was the name of a star.' [And there are other examples:] for example, 'Can you bring forth the Constellations in their season? Or can you guide the Great Bear *with her sons*' [my emphasis]?" (Job 38:32). His implication is that other scriptural passages, like this one from Job about the constellation Ursa Major, also suggest extraterrestrial inhabitants. Somewhat later, the greatest of all Biblical commentators, Rashi (Rabbi Shlomo Yitzchaki, c.1040–1105), whose lucid explanations still appear in nearly all modern Jewish Biblical texts, cites Rav Ulla's explanation in his commentary to the above passage in the Book of Judges.

In the sixteenth and seventeenth centuries the *implications* of ETI for humanity and its self-image took on particular urgency, including for Jewish theologians, for at least two reasons. The first was the discovery of alien intelligent life in the New World by Columbus. Christian theologians wondered whether these natives were descended from Adam and therefore in need of salvation. Jewish theologians were curious about whether or not the natives were from the Ten Lost Tribes. At least one French Catholic writer, Isaac La Peyrere (1596–1676), the descendant of forced Portuguese Jewish converts, wrote extensively on the former topic, and concluded, No. In his *Praeadamitae* (*Men Before Adam*, 1661), he suggested that the Bible was not the history of all mankind, that the flood was only local, and posited other revolutionary notions. He discussed his radical ideas in person with Baruch Spinoza, and some scholars think he helped trigger the new field of Biblical criticism (Popkin 1987; Almond 1999). The second significant event was the publication of the *Zohar,* the classic text of Kabbalah and Jewish mysticism, in 1558, and its subsequent translation into Latin by Christian Knorr von Rosenroth (1636–1689) as *Kabbala Denudata.* Both Newton and Leibniz were influenced by Rosenroth's translation. The *Zohar* and other mystical Jewish works freely speculate about heavenly beings (nominally angelic, though they might be taken as ETI) and of course the *Zohar*'s theology opened up many new, dramatic, and perhaps heretical avenues of thought. Giordano Bruno was a Kabbalist and the author of several books on Kabbalah himself, including his intricate work *Cabala* (1584). His interest in other worlds and exoplanets was part of an overall worldview that eventually got him into serious trouble with the Church.

The issue for Jewish theologians was not one of salvation, because that is available to all creatures with moral choice. The defining problem was articulated by Rabbi Chasdai Crescas (c. 1340–1411), writing in his *Or Adonai* (cited in Lamm 1971*)*. As presented in the Bible and amplified by rabbinic teachings, we are partners with God to improve the world. Indeed, if this is the point of ethical conduct as presented in scripture, then are these other intelligent beings also involved in this task? If so, then they too must have received a revelation of divine commandments, and moreover their participation may minimize our role. If not, then it must be because they do not have free will, and in that case, what is their purpose? Rabbi Yosef Albo (1380–1444), writing in *Ikkarim*, concludes for these latter reasons that it would be superfluous for ETI to exist. (Note that in my own definition of intelligent life, following Shklovskii and Sagan [1966], I ignore the issue of free will—we don't really understand it—and base intelligence solely on an ability to communicate between the stars, something that perhaps does not require free will.) Rabbi Norman Lamm, in his book *Faith and Doubt* (2007), devotes a chapter to ETI, and summarizes some of these earlier considerations. Like other modern thinkers, however, he accepts at face value the likelihood that the Earth and its inhabitants have company elsewhere in the cosmos, even beings with moral free will and consciousness. His goal is to make the case that it does not really matter: contrary to Shapley, we *can* be "consequential" even if we are not unique.

What are we going to do? But we might be unique! And even if we are not unique in the universe, even if intelligent aliens thrive throughout the galaxy, there are probably none nearby and we are unique in our cosmic sphere of influence. We are unusual, and we are certainly blessed. Since Biblical times, added blessings or favors entail added responsibilities, with consequences when those responsibilities are shirked. In particular, responsibility includes the obligation to deal compassionately with other beings and to attend to the welfare of community and its environment.

The Jewish view of the state of being blessed (having gifts) or even of being chosen (having special gifts) offers some insights into the three dilemmas raised earlier. The epistemological issue has no practical implications and is not particularly problematic: Whether or not we know about others, we know about our own blessings. Indeed, says the prophet Amos, urging humility: "Are ye not as children of the Ethiopians unto me, O children of Israel? saith the Lord. Have not I brought up Israel out of the land of Egypt? And the Philistines from Caphtor, and the Syrians from Kir?" (Amos 9:7). There might be other intelligent beings, but our obligations are independent of theirs. The theological issues are similarly unproblematic. The absence of ETI in our sphere of influence only enhances our self-awareness of our peculiar status, and their possible presence does not diminish it.

The ethical dilemma is the one for which I think a Jewish perspective is the most helpful. Our exceptional status on Earth, and our new-found awareness of this probable good fortune, should make us more sensitive of our task "to serve the Earth and to protect it" (Genesis 2:15). "When you live in the land that flows with milk and honey . . . you shall therefore obey the voice of God and keep his commands" (Deuteronomy 27:3). The Jewish perspective not only asserts that we should try, it emphasizes that we have the skills to succeed. Our task is possible. Maimonides (1135–1204) presents the case in his *Guide for the Perplexed*: The very fact that a loving God has commanded us to behave ethically proves that we have been empowered to succeed if we so choose (Friedlander 1904, 386). The Kabbalists and Jewish mystics wove a deeper layer of meaning into this perspective, arguing that responsibility and caring were not only important to self and society, they were essential to the very welfare of the cosmos. Humanity actually plays a role in perfecting the world—called *tikkun olam* (e.g., Matt 1996). Quantum mechanics include the still incompletely understood implication that the world and its matter are composed of wave functions of probability that only become real entities upon being measured. Physicists have long speculated that measurement by a conscious observer is what leads to this "collapse of the wave function." Some, most famously John Wheeler, have suggested that the universe created conscious beings in order to observe it and thus bring it into reality (e.g., Smith 2006). It is in this quantum mechanical sense (even when considering the important process of decoherence) that our consciousness is much more than a mere chemical accident. If we are truly alone in the observable universe, then we play a crucial—not a peripheral—role in the cosmic order, and moreover in a Maimonidean sense the cosmos has empowered us to succeed in this task if we so choose. As for ETI, if intelligent extraterrestrials exist, they like the nations mentioned by Amos presumably have their own moral codes with intrinsic value. If their codes happen also to include, for example, an injunction about a Sabbath, that would certainly be a remarkable suggestion of universal ethics, implying that we are partners in a larger cause.

CONCLUSION

The message of modern research is not that we are ordinary, but the opposite: we appear to be quite extraordinary, even if we may not be unique. To be of flesh and blood is to be marvelous, and cosmically significant. At the same time, an awareness of our rare capabilities may hopefully generate a renewed appreciation coupled with deeper personal humility. Similarly the Earth, even if it is not unique, is for all intents and purposes a special place. Writing about the impact of the discovery of exoplanets, researchers Seager and Lissauer make the dramatic claim that "we will at last complete the Copernican Revolution. . . . We are on the verge of, if not in the very midst of, the greatest change in perspective of our place in the universe since the time of Copernicus" (Seager and Lissauer 2010, 11). Perhaps, but if honestly considered, that change of perspective is much more likely to be in the direction opposite to what these authors imagine: toward reclaiming our exceptional status.

The implication of the Misanthropic Principle is that we will have to care for one another and for our beautiful planet by ourselves, without help from alien insights or technologies. Moreover, the preservation of our planet and its inhabitants appears to have cosmic as well as local significance. But is the herculean task of caring for humanity, all life, and our fragile planet beyond our abilities? Perhaps an atheistic inclination would lead to pessimism: Things are what they are, and whether or not humanity perishes makes no particular difference to the cosmos—and so why bother? The first century Rabbi Tarfon offers a famous aphorism that provides a basis for positive motivation rather than despair. It is grounded in the religious notion that we are blessed and therefore obligated to assume responsibility: "You are not expected to complete the task," he writes, "but neither are you free to abstain from the effort" (Talmud Avot: 2, 15). And, if perchance we are not alone, then we share in the cosmic goals of *tikkun olam* with all other conscious beings with free will . . . although we may never know about them for sure.

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