On Living Alone in the Universe: New Indications of Our Probable Solitude

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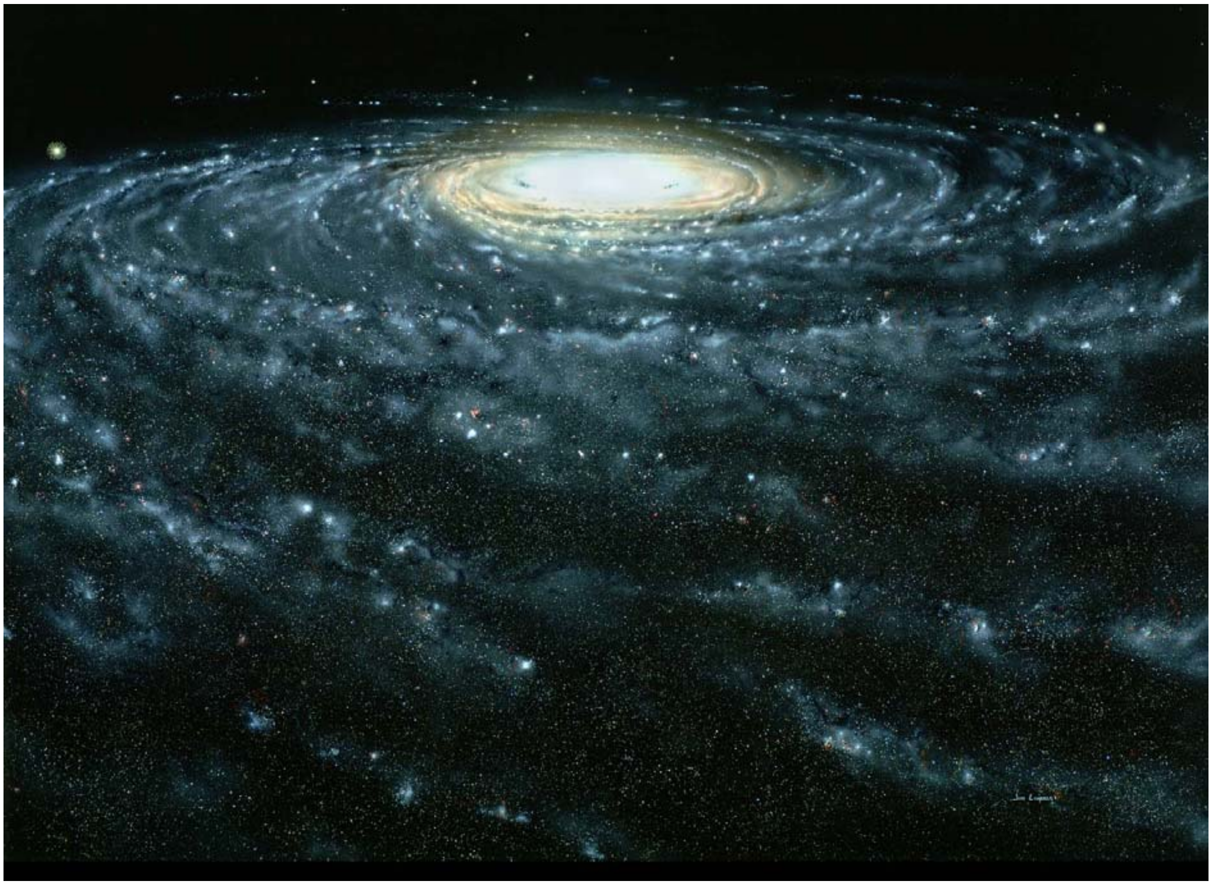

"Portrait of the Milky Way" by Jon Lomberg

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Abstract:

Recent results in extrasolar planet detection highlight the tremendous variety of planetary systems that can exist in nature – a diverse range of strange environments that is considerably broader than had been imagined before the first one was discovered only about fifteen years ago. Although Earth-*like* planets have so far fallen below the detection threshold, those planets we have discovered (including Earth-sized ones) make it possible to improve the estimates of how many might planets in our neighborhood might be suitable and stable enough to nurture life to evolve and become intelligent. The indication is: not many.

The results indicate that we are alone in the universe "for all practical purposes" -- that is, we are not likely to make contact with an alien intelligence, or even to know if one exists, for at least 100 human generations and perhaps for very much longer. This time frame defines a volume of the cosmos available for communication, the number of stellar systems within it, and the consequent probabilities. A smaller search volume shortens the wait but reduces the chances; a bigger volume improves the odds, but the wait time until we find out goes up as well.

The conclusion has fundamental implications for our self-perception, and for environmental, ethical, and religious behavior. Since the discovery of extrasolar planets in the last decade, theologians and philosophers have asked about the religious implications of discovering intelligent species elsewhere in the cosmos and what their presence says about salvation and the human role in a cosmic plan (if any). These are misleading questions. A more relevant question is what their *absence* says about humanity and our purpose. The answers to it may be disconcerting to a public that believes in a Copernican principle of mediocrity, and is comfortable in thinking of itself as cosmically irrelevant and free of any grand responsibility. But human beings are not an insignificant cosmic species! We are rare and precious, and the Earth is exceptional. We must rely on ourselves. The "Misanthropic Principle" is the observation that, in a universe whose physical parameters are amazingly well suited for intelligent life (the "Anthropic Principle"), the environments and situations necessary for intelligence to develop are extraordinarily rare. A Jewish perspective on the Misanthropic

Principle offers some insights into humility, accountability, the social / environmental imperative, and even a cosmic role for humanity.

I. Life in the Universe

Traditional Attitudes

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 either suitable planets or life are exceptionally difficult to produce. 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* (1908),

> "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. "

More recently Don Goldsmith and Tobias Owen, in their classic book, *The Search for Life in the Universe (1993* edition*)*, 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... (page 384)"

In the 1990 edition of their popular textbook, *Astronomy: The Cosmic Perspective*, Zeilik and Gaustad include a chapter on "The Galaxy as an Abode of Life." There they cautiously conclude from the evidence available at that time that "a few planets orbit at the magic ecosphere distance of a solar-mass star. So N_e [the number of planets in the habitable zone of a star] may range from 1 to 4 or so; we'll use 3…. If we survive as long as the sun shines, N_{ic} [the number of intelligent civilizations in the galaxy] is about ten billion (page 767)."

Non-specialists, including the general public, may be inclined to agree with this optimistic perspective. This might be in part because it seems like a straightforward extrapolation of the Anthropic Principle, which expresses the view that the physical parameters of our universe are finely tuned so as to nurture intelligent life (for one of three possible reasons - in brief: either luck, a multiverse, or God; e.g., Davies 2007; Barrow and Tipler 1998). If so, life should be nurtured everywhere, and intelligent species would exist on many planets around many stars. The popular attitude probably also reflects a Copernican presumption of mediocrity: we on Earth are just typical of life forms throughout our galaxy and the universe.

I argue that the latest results of astronomy suggest otherwise. The publication and confirmation so far of over 500 extra solar planets and their orbital characteristics, and the analysis of these planetary systems, together with other lines of evidence, argue strongly against the assumption of mediocrity. I call this the Misanthropic Principle. The Kepler satellite (Borucki et al., 2010) will soon provide thousands more important examples of new transiting planetary systems; its discoveries so far are consistent with these earlier results. We are special. *For all practical purposes* we are probably alone. In the rest of this paper I review the basis for reaching this conclusion, most significantly the surprising and large new set of data on extrasolar planets, and explore some implications of being alone from the perspective of religion, in particular traditional Jewish responses to being blessed.

Intelligence "for All Practical Purposes"

Two important clarifications are necessary. Only the existence of intelligent beings matters in this discussion. Primitive forms of life may be discovered on Mars; perhaps even multicellular plants or animals are someday found on a nearby extrasolar planet. These revolutionary discoveries would be extremely interesting and valuable, certainly helping us understand how life on Earth evolved. But unless one of these species is capable of conscious, independent thought and the ability to communicate with us, we would still be alone, with no one to teach us or learn from us, no one to share with -- or (in a pessimistic but more popular science fiction vein) no one to battle against. *Intelligent life, for the purposes of this discussion, therefore means a life form able to communicate between stars* -- for example, using radio telescopes, the practical definition promoted by Carl Sagan and Yosif Shklovskii, (1996). A species with the maximum techno-logical prowess we can imagine -- easy space travel -- will surely also have radio technology. At the other technical extreme, a species needs at least a minimum of communications technology for us to know of their existence. Our own society, by this definition, is only about 100 years old.

If intelligent life is *common* in a universe that has had 13.7 billion years to evolve, then surely we are among the youngest forms of intelligent life in existence. As Enrico Fermi famously observed, however, the fact that there *is no* other known intelligent life indicates that the assumption is wrong – it is not common.

The second important caveat derives from two features of the world that we understand today but that Percival Lowell did not know about. The first is Relativity – the fastest any signal can travel is at the finite speed of light. The second is the expanding nature of the universe (presumably the result of a "big bang" creation event, although the origin of the expansion is not critical to the conclusions) – distant galaxies are receding from us at an accelerating rate.

If the universe is infinite in size and extent, then even if intelligent life is infinitesimally rare, the cosmos will have every physically possible life-based scenario in it, however bizarre and unlikely. For example, there is certainly another solar system someplace with another Earth identical to ours except that your alter-ego on it is wealthier; see for example Davies 2008). Stephen Hawking and others who argue from anthropic principles for the existence of "many universes" inflate this notion of infinities even further (although it is worth remembering the caution of the great mathematical physicist David Hilbert that "the infinite is nowhere to be found in reality, no matter what experiences, observations and knowledge are appealed to; Carr, 2007)." In any case we cannot communicate with, or even directly measure anything about, this unlimited vastness because almost all of it lies beyond the "cosmic horizon," the distance set by how far light can travel in the time allotted by age of the universe, currently about 13.7 billion years. Waiting longer will not help either, since the universe and the horizon are not static but are expanding away from us. We can therefore never communicate with any region of the universe beyond the current horizon.

As a matter of fact, for purposes of communication (though not for measurement), the limit to our abilities are even stricter. The universe is not simply expanding – it is accelerating its outward expansion, and, as Avi Loeb has shown (2002), light sent from Earth today can *never even catch up to (!)* galaxies seen to be receding from us at a redshift velocity measure of about z~1.8, which is to say galaxies whose distance is such that their light has taken about ten billion years to reach us. Even though they are well within our cosmic horizon, they are forever beyond our reach and receding quickly, and even if the universe continues forever, they will never enjoy episodes of *I Love Lucy*.

The finite speed of light also sets a practical limit on cosmically closer galaxies, like the ones in the Milky Way's "local supercluster" of neighboring galaxies, whose distances from us are less than only about 100 million light-years. Even if there were intelligent beings on one of these neighboring galaxies, we will probably never know about each other (except through some wonderfully lucky coincidence) because it takes tens or hundreds of millions of years for them even to spot us in a SETI-like survey of theirs (SETI; the Search for Extra-Terrestrial Intelligence), and that long again to send us a message of greetings. Even within our own Milky Way galaxy most stars are hundreds of thousands of light-years away, and it takes hundreds of thousands of years for them to see our light signals, and that long again for us to receive their reply.

When I say, therefore, that we are alone *for all practical purposes*, I mean that we will probably be alone for at least 100 human generations – a very long time, practically forever. With one generation being 25 years, and with one round-trip necessary for a minimum exchange, *I therefore limit the following estimates to stars closer to Earth than 1250 light-years.* The qualification provides the added advantage that since we know quite a lot about the stars in this neighborhood volume of space, we can be quantitative. If we choose to examine a smaller volume of local space, say that available within one human lifetime, we will reduce our chances of success by a factor of about a million since the number of stars is proportional to the volume and scales like the time (distance) cubed, but we will have an answer sooner; if we expand the search volume, the probabilities increase but so does the wait. In short: although the visible universe probably has well over 10^{20} stars and may or may not have many worlds hosting intelligent life, *for all practical purposes* we are alone. Even after 100 generations we probably will not know for sure, and unless one is found we will always be looking … and always uncertain.

II Calculating the Chances

The Drake Equation

The Drake Equation in its various forms (e.g., Shklovskii and Sagan, 1996; Bennett, 2008) tracks the probabilities of each of the multiple phenomena or occurrences thought to be necessary to produce intelligent life. Its factors have been widely debated (e.g., Ward and Brownlee 2000). It is convenient here to group them into two broad terms. The first term consists of all those factors estimated from solid physical evidence or extrapolated from a statistically meaningful sample, for example, the number of solar-type stars. The second term includes those factors estimated from an example of one – life on Earth – which are perforce vastly more speculative. The biological considerations (for instance the probability of life developing from a suitable chemical stew) are among these highly speculative terms.

The most conspicuous feature of typical previous Drake Equation estimates for intelligent life is the high probability assigned to factors in the first term (whose factors are based on evidence or processes we think we understand). Astronomers today, like Percival Lowell before them, generally tend to be optimistic, estimating that all the non-biological probabilities of this equation, like the one for the existence of habitable planets, are so astronomically high that even if the second term - the likelihood of life developing - is small, intelligent life will nonetheless be plentiful. The earlier quote about suitable planets from Goldsmith and Owen is representative: "…about one in every two to be conservative." *But while it is impossible to increase the chances much over these early, optimistic estimates, it is easy indeed to make the chances very much smaller*. As we will see, the results from the past ten years of discovery do not improve the odds – they make things harder, even while adding a wonderful depth of possibility for modeling and for imagination.

Our Stellar Neighborhood

I will consider the two terms in order. The sun lies in a cavity of interstellar gas, the Local Bubble, that extends over roughly 600 light-years. The Local Bubble in turn is located in the "Gould's Belt," a spur of stars, star clusters, and molecular clouds between the Milky Way galaxy's spiral arm that stretches from the Orion nebula to the Ophiucus-Scorpius clouds and on to the Perseus clusters – a distance of about 1200 light-years in its longest dimension -- and which lies mostly within the Orion arm of the galaxy (e.g., Maiz-Apellaniz, 2001). Although there are obvious local variations in stellar densities and types, and some suggestions that our region of the Orion Arm may be a particularly suitable environment for hosting life-bearing planets (e.g., Scharf, 2009), a constant average stellar density at least out to 1250 light-years is not an unreasonable assumption for our purposes and provides an estimate of the number of stars in the earth's immediate ("for all practical purposes") vicinity. Bochanski et al. (2010; 2007), Shkolnik, Liu and Reid (2009), and numerous other papers including the foundational work by Kroupa (1993) try to estimate the local stellar density. With disagreement hovering at a level of about a factor of two, the approximate value is 0.14 stars per cubic parsec, or about *thirty million stars in a volume of radius 1250 light-years*.

Rare Earths: The Nature of Extrasolar Planets

There are so far approximately 500 known extra-solar planets whose confirmed, published parameters include estimates of masses, orbital parameters, and other details specific enough to examine the likelihood for life in a statistically useful way (e.g., Deeg et al., 2007; The Exoplanet Data Explorer at http://exoplanets.org). The "rare Earth" hypothesis expresses the idea that Earth-like planets suitable for intelligent life are few and far between, and proponents of this idea quantify their case by delineating a set of familiar conditions that planets need to satisfy for intelligence to prosper (e.g., Ward and Brownlee, 2007; Forgan and Rice, 2010). These can be bundled into four essential ones: (1) Stability: a suitable planet's orbit must be stable, that is, sufficiently circular or otherwise unchanging so that it remains suitable not only for one revolution around its star, but for the billions of years it takes for intelligence to evolve. The star it orbits must be stable in size and radiative output for this long too. (2) Habitability - Water: a suitable planet must reside in the "habitable zone" of the star, that is, at a distance from the star where the temperatures allow water to be liquid – or else have some other mechanism to maintain liquid water. (3) Planetary Mass: The planet must be massive enough that its gravity can hold an atmosphere, but not so massive that plate tectonics are inhibited, since geological processing and its important consequences will be reduced. (4) Composition: The planet must be rich in all the key elements needed to build complex molecules (carbon for example), but also including heavy elements like iron, silicon, etc., that are perhaps not needed for making life itself but that are essential for an environment that can host *intelligent* life. We consider each of these in turn.

<u>(1) Stability</u>: To nurture life, and especially intelligent life, a planet must provide a stable environment for long times with a stable star and a stable orbit. Our sun is by no means average. On the contrary, it is among the less common types of stars in the stellar community, with perhaps only a few hundredths of a percent of other stars being closely similar in mass and spectral type to the sun. The stellar Initial Mass Function (IMF) describes what kinds of stars – that is, what distribution of masses - comprise the population of a group, in our case the 30 million stars accessible to us for all practical purposes. The largest number of stars are smaller than one solar mass, but these smaller stars are the comparatively faint and hard to detect, and observations to confirm their numbers are more uncertain (although recent infrared surveys with 2MASS and other ground-based work, and with the infrared satellites ISO, *Spitzer* and WISE, have made dramatic progress in studying them). Nevertheless, various studies of the IMF reach wide general agreement, though with detailed differences or uncertainties depending on the physical nature of each star-forming region (turbulence, metal abundance, etc.).

The large majority of all stars, over 90% of them, are smaller than the sun, with many of them having less than one-tenth of the sun's mass. About half of all these stars have masses from the minimum possible for nuclear reactions, 0.08 solar-masses, to 0.8 solar-masses (e.g., Bochanski;

2010). About 42% of the approximately 500 stars with extra-solar planets considered here (and which were carefully selected to be good candidates) are smaller than the sun; 16% are smaller than 0.8 solar-masses. For most small stars it unlikely to find a suitable planet for intelligent life. The reason is this: because smaller stars are less luminous, their habitable zones lie closer to the star. When this happens the planet becomes gravitationally (tidally) locked to the star: it will always have one side facing the star and one side facing away. (Tidal locking is responsible for the moon always showing only one side to the earth.) Tidal locking in turn means that half of the planet will be perpetually in the dark and cold, and the other half in perpetual noon. We don't fully understand the weather patterns on such worlds, assuming they have atmospheres, but life there seems improbable. At least one recent paper (Tarter, 2009) argues that life could develop and prosper in the annular zone around the planet which experiences some intermediate climatic conditions. It is also the case that the width of the habitable zone is much narrower for a low-mass star, making orbital eccentricity a more severe constraint. At the other extreme, most stars more massive than the sun are also probably unsuitable for life because bigger stars burn hotter and live shorter lives. Stars with twice the mass of the sun live in a stable, hydrogen-burning "main-sequence" phase for only a few billion years, about 18% as long the sun's lifetime – but billions of years more than this were needed for evolution of life on Earth. Stars with more than about eight times the sun's mass will end their lives exploding as supernova in only a few millions of years; so far only 3.2% of stars with detected extra-solar planets are larger than 2 solar-masses (although one reason may be that pointed searches tended to prefer looking at lower mass stars). In summary, fewer than 10% of all stars are in a nominally acceptable range of masses, from about 0.7 to 1.7 solar-masses (main-sequence dwarf stars ranging from about types K5 to F0),

For a star in this size range, a further consideration is its age: stars that are too young will of course not have had time for life to develop or evolve; older ones are also problematic since a star's luminosity on the main sequence increases with time (the sun will be 40% more luminous in another 3.5 billion years), and the location of its habitable zone increases correspondingly (e.g., Juliana-Sackmann et al., 1993). Younger stars, and less massive stars, are also among the most variable stars, with variability potentially disrupting fragile biological systems.

A final stellar issue of concern is stellar multiplicity. Most stars have a companion star orbiting nearby; about two-thirds of solar-type stars are binaries. Their planets might either form between them, orbiting one or the other star, or form around the pair and orbit them both. But either of these situations is problematic. The periodic, changing gravitational influence of an orbiting companion star, even if regular (but depending on the eccentricity of the stellar companion) might disrupt or inhibit the formation of stable, near-circular orbits of its planets and possibly preclude the long residence of a planet in a habitable zone.

<u>(2) Habitability - Water</u>: Only a few of the so-far confirmed 500 extra-solar planets reside in their habitable zone. *Indeed, the single most remarkable result from the discovery of extra-solar planets is their variety: virtually every one so far is in an odd system with extreme elliptical orbits, giant planets ("hot Jupiters") or others very close to their star (almost three-quarters of them), or other unexpected properties.* A hot-Jupiter or other massive, inner planet by no means excludes the existence of an Earth-like planet farther away in the habitable zone. (Technology is only just now able to detect Earth-*sized* planets, and so-called "Earth-*like"* planets will take a bit more time to discover but are sure to be found.) However, models of planet formation find that it is difficult to make a planet close to its star. Much more likely is a scenario in which planets form far from a star by the gradual coalescence of dust grains in a protoplanetary disk into larger and larger bodies. Once formed, these planets will tend to migrate into much closer orbits as they slow down due to collisions with other material, grow, and loose angular momentum (e.g., Scarf, 2009). Depending on their initial masses this process can be faster ("Type I") or slower ("Type II"), but in either case after a few hundred thousand years the migration will have been accomplished. As they migrate inward, such planets would certainly disrupt any small Earth-like bodies that might have been forming in the habitable zone. The issue is whether there might be enough material left behind in the disk for an earth-like planet to form later, or perhaps for one that originally formed farther away to migrate into the habitable zone. Some recent simulations (e.g., Mandell, Raymond, and Sigurdsson, 2007; Raymond, Mandell and Sigurdsson,

2010) suggest that water-rich, Earth-like could indeed form from the surviving material. Other new work suggests that outward migration can sometimes occur (e.g., Spiegel et al., 2010)

The eccentricity of a planet's orbit measures the ratio of the closet distance of the planet to the star to its largest distance. For planets like the Earth in an elliptical orbit the eccentricity equals the difference of these values over their sum. The eccentricity of the Earth's orbit is 0.0167 – i.e., it is very nearly circular, and the Earth never varies much from its mean distance from the sun. In the solar system, Mercury is the planet with the largest eccentricity, 0.2056 (the minor planet Pluto has an eccentricity of 0.248). A large eccentricity not only subjects an extra-solar planet to larger annual variations in stellar illumination than a circular orbit, it also increases the likelihood that in a system of similar planets it might occasionally be chaotically disrupted by the gravitational influence of a giant planet passing much closer than average. Of the 500 extra-solar planets with confirmed and published orbital parameters, only eleven – 2.2% -- have values less than that of the Earth. Twenty percent have eccentricities larger than 0.33, meaning that their distances from the stars vary by a factor of two during their year. About half have stellar distances that vary by 20% or more during their year. Even if severe orbital variations do not preclude liquid water under some situations, it could very well inhibit the development of sophisticated biological systems (e.g., Spiegel et al, 2010; Dressing et al., 2010).

A related parameter of increasing interest to astronomers studying habitability is a planet's obliquity**:** the angle between its spin axis and the axis of its orbit around its star. The Earth's obliquity, 23.5 degrees, is the consequence of a massive collision it had with a giant object early in its life, and which created the moon. The stability of the Earth's obliquity is maintained by torque from the moon. This apparently ideal and stable value of the obliquity insures that the climate on the Earth's surface over the course of a year is neither too hot nor too cold (maximum variations across the Earth are less than about 150 degrees kelvin) as first one pole points slightly towards the sun providing more daylight in that hemisphere, and then the other (e.g., Heller, LeConte and Barnes 2011). It has been estimated that if the Earth's obliquity were as high as 90 degrees a substantial part of its surface would become uninhabitable (op. cit.) No other planet in our solar system has such a stable, much less congenial, obliquity; that of Mars seems to have varied chaotically between about 0 and 60 degrees. On the other hand, a high obliquity might help make habitable a planet that is otherwise too far from its star.

(3) Planetary Mass: Our third requirement relates to the planetary mass. The most popular current scenario for planet formation is by gradual accretion of material (the alternative of gravitational collapse seems to take too long). In this scheme even giant planets have metal cores, but they have continued to accumulate ices and gases in their outer layers. Earth-sized planets that form by accretion probably have solid compositions, although the relative abundances of these metals might vary considerably. Because a habitable planet must have an atmosphere, it needs to be massive enough for its gravity to retain one, but details depend also on the orbit since the surface is illuminated and the atmosphere is heated by its star; planets like Mercury in close orbits are too small. Current estimates are that planets smaller than about $0.4M_{Earth}$ are unsuited for long-term atmospheres (e.g., Raymond, Quinn, and Lunine ; 2007). On the other hand if the planet is too massive, more than about $4M_{Earth}$ assuming that it is rocky, then planetologists estimate it will be unable to produce the plate tectonics thought to be necessary to refresh the atmosphere with volcanoes or other processes associated with the CO_2 cycle (e.g., Scharf 2009; Korenaga 2011). The fraction of such planets is still not known; because they are small, technology is only now becoming able to spot them. One of the primary goals of Kepler is discovering Earth-sized planets in their habitable zones (Borucki 2010). The mission recently announced the discovery of Kepler 10b, a rocky planet of radius 1.4 Earth-radii and about 4.6 Earth-masses, but located well outside the habitable zone: its surface temperature is about 1600C. Discoveries of Earth-sized planets within their habitable zones should be forthcoming in the next few years.

(4) Planetary Composition: The last of the four general conditions relates to the chemical composition of the planet. As a preliminary comment, and one that may not be generally appreciated, is that the relative abundances of the elements – and in particular those needed for sophisticated biological life - are not uniform throughout the galaxy. Some places in the galaxy

are rich in these elements, while other places appear to be deficient in them. These elements are not only required for the building blocks of life – of whatever possibly strange type, even if non carbon-based. They are also needed so that the planet itself is conducive to life. Plate tectonics for example, enable the planet's surface to regenerate and on earth help drive the CO_2 cycle; iron generates a magnetic field that helps shield the planet's surface from charged winds from the sun. Both are the result of a geological structure rich in silicon, iron, and other minerals. Finally, the liquid core of the earth is due to the presence of radioactive elements whose heat keeps the iron molten and which energizes the earth's internal temperature structure (e.g., Scharf, 2009; Montmerle et al. 2006). All of these features demand that a solar system capable of hosting intelligent life must form in a region of the galaxy where elements are abundant. Furthermore, the need for radioactive elements means that a supernova, the primary source of radioactive elements, must have exploded in the vicinity relatively recently (but not too recently). Although there is good evidence of some variations in the element abundances even within the 1250 light-years of interest to us (e.g., Shkolnik, Liu and Reid, 2009), these are not yet well enough studied to warrant eliminating those systems from consideration, and I assume solar values prevail for the rest of the discussion. As for the essential radioactive elements, the sun, as noted earlier, is located in the Local Bubble caused by a sequence of supernova explosions, and it might very well be the case that these elements are deficient in other regions of the 1250 light-year zone.

This short summary completes the review of the main considerations about a planet's suitability for hosting and evolving life, the first group of factors in the Drake Equation assessment of probabilities. The take-away thought is that the possible range of planetary systems around these stars is dramatically larger than we had expected 15 years ago: planetary systems do not conform at all to the traditional notion as expressed by Goldsmith and Owen (1993) that nearly all have suitable rocky planets, with Earth-sized objects lying in a habitable zone half of the time. We find instead that planets are actually spread across a vastly wider range of situations than we had previously imagined.

We are only now beginning to piece together and model a comprehensive story of planet formation, and do not yet even know the whole story for each of the known planets - for example, we do not yet understand the extent to which giant planet migration will diminish the likelihood of an Earth-sized planet orbiting in a habitable zone, or how severe the effects of an eccentric orbit or oblique tilt can be on climate over the course of the few billion years needed for intelligence to develop. The models are still crude, and the discoveries of new cases will help clarify the importance of the many complex parameters. For my purpose here, I venture some optimistic, rough estimates with the understanding that future research could make the numbers a whole lot smaller … or little bit bigger. Perhaps 10% of all stars are in the right range of masses. About 10% of those have suitable ages, with either no companion or non-disruptive ones, and whose planets are in stable configurations; about 10% of these planets orbit in their habitable zones over billions of years (including cases where planet migration has disrupted that zone) with suitably non-eccentric orbits and satisfactory obliquities; perhaps as many as 10% of them have Earth-sized masses. Even if we assume for this group of planets that 100% have chemical compositions with the metals and radioactive species needed to make an Earth-*like* planet, only a few thousand stars in our volume might be potential hosts to nurture suitable life forms for the billions of years needed for them to evolve into self-conscious, technological beings.

Getting to Life

We have not yet considered the biological terms in the Drake Equation, the second broad category mentioned earlier. It could very well be the case that even under ideal situations life does not develop easily – we don't know. In fact, it seems to me that the fact that life has not yet been created in the laboratory – under ideal conditions! – means that it is not easily generated. Suppose that life were the inevitable outcome of chemical processes in any planetary environments that have liquid water -- still, there is no evidence that this happens quickly. Life on Earth, after all, took on the order of a billion years to form, and another few billion years were needed to produce us. If it happens that sometimes the chemistry runs a bit slower or evolution is sidetracked, with things taking things two or three times as long, well, by then the sun would have evolved into a red giant star, and swollen in size enough to fill the orbit of the Earth. It is too late.

For the sake of argument, suppose life is certain to take hold around a planet that is suitable. In that case there is very likely to be extra-solar life in our cosmic neighborhood. In considering the existence of *intelligent* life, however, much more than mere habitability is involved. Consider the unlikely accidents – perhaps essential? perhaps incidental? – that facilitated humanity's evolution. A gigantic collision with a Mars-sized planet was required early in the Earth's history to create the moon, an event able to knock the Earth's axis enough over to make the obliquity and salutary seasons we enjoy, but not quite enough to shatter the Earth entirely. Meanwhile the moon that was produced generates the Earth's tides and stabilizes the Earth's wobble. A few billion years later the dinosaurs, which had successfully ruled the planet for 100 million years, were fortuitously wiped out by another, smaller asteroid so powerful it destroyed them all … yet did not kill off the mammals. Ward and Brownlee (2000) among others note that there were roughly ten mass extinctions on Earth before humanity emerged on the scene, suggesting the complex, tumultuous, and perilous history of our evolution.

Many other contingent conditions on Earth enabled life to thrive. Water is essential, yes, but too much water could be disastrous; if the Earth had twice as much water in its oceans, there would be no land mass for complex life to walk upon (e.g., Ward and Brownlee, 2000). Moreover the route that evolution took toward intelligence was circuitous. S.J. Gould famously argues that our evolution was so random that it could probably *never* repeat (Gould, 1989). Conway Morris (2003, 2011) argues to the contrary: that the convergence of life on Earth towards humanity was inevitable, but only on Earth. In making that case he admits that the environmental perfection producing convergence does, by its very narrow constraints, severely restrict evolution in other situations. As he puts it, we are "inevitable humans in a lonely universe." These and other examples highlight the incredible good fortune that befell intelligent life on Earth as it evolved. Last, but not least, the main uncertainly in Drake's original formulation of probabilities was the

longevity of an intelligent civilization. Even if intelligence were common, if it typically survives for only a short time (recall that our own radio-based civilization is only about one hundred years old) then very few of them exist now for us to communicate with.

The probabilities associated with all these biological terms are highly uncertain; recent results from astronomy provide no new evidence to evaluate them. Traditional discussions either tend to think intelligence is inevitable on any approximately suitable planet (i.e., having a probability near 1), or else to be very small. I leave it to the reader to use his or her judgment. But the uncertainties in all the estimates almost don't matter. Of the roughly thirty million stars within 1250 light-years of earth, only a hundreds or thousands of them are likely under optimistic projections to have planets suitable for advanced life as based on the estimates in the previous section. If the chances for intelligent life to form and survive is smaller than one in a thousand, then almost certainly there are no stars in this volume with planets hosting intelligent beings: the stars are too small or the planets' orbits are wrong, the planetary sizes or chemical compositions are unsuited, their surfaces are ill equipped, or their geologic and meteoric histories are too inauspicious, the powerful chemistry needed to generate the first life forms is too intricate or slow, evolution from proteins to intelligence is too often aborted or directed into sterile tangents, or civilizations die off easily.

The indication from the past decade of research and discovery is this: *we are most probably alone* – at least there is probably no other intelligent life within one hundred generations reach to talk to. No wonder there are no signals, nor even faint traces, despite decades of looking. As Enrico Fermi argued, they are not there. To all intents and purposes, for us and for our descendants for at least 100 generations, we are living alone in the universe.

III Religion and The Misanthropic Principle

Are we back at the center?

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, Tipler and Wheeler, 2006; Davies, 2007). The *Misanthropic Principle* (my term) expresses the idea that the multiplicity of possible environments in this suitable cosmos are 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. 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 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: like hermits, alone with our thoughts and ourselves. Opposite to the dour connotations of misanthropy, however, 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 acknowledgement of our cosmic competence.

The Fermi paradox – “If civilizations are common, where are they?” - has only four reasonable answers. The first three are: they never existed, they arise frequently but are short-lived so that none are now around, or we are the first to make it to this stage. In these three cases we are alone. I am not the first person to call attention to the frightening consideration that if the second reason is correct - that they arise easily by die off quickly - then we need to be worried, since there is no evidence we differ from them. The fourth and last possibility is that they are not *common* but neither are we unique; intelligent life simply exists too far away for them to have found us yet - and/or there are a few peculiar, isolationist societies closer by. But this fourth possibility also leaves us alone, at least until some indefinite time in an indeterminate future when we possibly might hear from them.

There is one possible out: perhaps some physics we think we understand will be overturned with future knowledge –faster than light travel, in particular. If science fiction becomes fact, might not we be able to explore even the most distance galaxies that I had previously excluded from our vision? Unfortunately, Fermi's paradox implies that we cannot have it both ways. If life is common and if superluminal travel or communication were possible, then we really face an insuperable contradiction: the billions of intelligent species in the universe should have used this super-technology to visit us already. That they have not, surely means that the basics of relativity as we know it will remain inviolable – leaving us alone. Alternatively, if relativity can someday be overcome, then there cannot be very many super-civilizations, and we are also alone. The interesting implication of this line of argument is that if scientists were to discover some way to travel faster-than-light, it would put a nail into the coffin of all advanced alien societies.

Many atheists and others resolve the underlying puzzle posed by the Anthropic Principle – *why* is the universe so perfect for life? – by resorting to the multi-universe theory we mentioned earlier. This idea and its variants, grounded in solid (if still unfinished) physics, argues that the inflationary big bang theory, or quantum mechanics, implies that an infinite number of universes exist with varying conditions. Only in those universes like ours, with perfectly suitable physical laws and constants, does intelligent life arise. For these people, the fact we are alone for all practical purposes dramatically amplifies our special nature: the endless myriad of sterile universes highlights how fabulously precious we are!

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 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 contingent processes that in our case took billions of years.

One consequence of this aspect of self-awareness has been a popular expectation that extraterrestrial intelligence (ETI) exists. A 2008 Scripps Howard Poll (cited in A.A. Harrison, 2011) found 56% of respondents thought ETI was likely (31% thought they had already visited Earth). A recent issue of the Philosophical Transactions of the Royal Society entitled "The detection of extra-terrestrial life and consequences for science and society (2011)" includes articles by scientists, philosophers, and theologians addressing this topic. Ted Peters (op. cit.) 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." He then 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." 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.

A.A. Harrison in the same volume offers a reason why the public wants to believe in ETI, namely, "[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 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 ET, or in *Close Encounters of the Third Kind*.

The Royal Society volume asks what the detection of extra-terrestrial life means for science and society. A more relevant question, it seems to me, is: what does it mean that we are *alone in the* *cosmos* (at least for all practical purposes)? While it is true that we are not at the *spatial* center of the cosmos, I believe that recent results in extrasolar planet research and the limits imposed by relativity mean that we very well could be effectively the *spiritual center* of the universe by virtue of our effectively being alone. By "spiritual center" I mean to invoke the whole gamut of human self-conscious perception and awareness (perhaps related in some way to quantum mechanical notions of conscious observing, as continued below) – that religion addresses. We are not simply inert matter; we are somehow self-consciousness. This makes all the difference.

Jewish Views on Extraterrestrials

Jewish tradition has no difficulty coping with life existing beyond the Earth. The authoritative 12th century commentator, Rashi (Rabbi Shlomo Yitzchaki;) even remarks in his notes to Judges (5:23)[1] that life might exist around other stars, following an tradition voiced in rabbinic literature a thousand years earlier[2] about this text which dates from a millennium earlier still. There is in Judaism no notion of Adam's original sin that his descendants, other humans, and/or perhaps other intelligent life forms need redemption from; salvation is available to all creatures with moral choice. Thus, when new people were discovered by Columbus in the New World, Jewish theologians, unlike their Christian contemporaries, were not particularly perplexed, although it was certainly of interest to know whether or not the natives were actually from the Ten Lost Tribes. As one result, there has been comparatively little written about the topic of extraterrestrial life in Jewish sources.

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[1] Judges: *"20. They fought from heaven; the stars in their courses fought against Sis'era.… 23 Curse ye Meroz, said the angel of the LORD, curse ye bitterly the inhabitants thereof because they came not to the help of the LORD"*. This ancient poem is dated by scholars to earlier than about 1100 BCE. Meroz is taken by many Jewish sages to be the name of a star whose inhabitants are cursed. Since the Hebrew word for stars can also mean planets, which after all do stay "in their courses," I wonder whether the name Meroz might not be an early reference to the red, warrior planet: Mars.

[2] Talmud, Moed Katan 16a.

The above comment about “moral choice” needs further elucidation. For the few rabbinic authors who wondered about extraterrestrial life, the issue was not about their existence but about their free will. Does free will automatically come with intelligence, for example as we have defined it – the ability to communicate between the stars? The dominant view, first propounded by Rabbi Chasdai Crescas in the fifteenth century, is no. Indeed, he argues that these species could not have free will because God would then have had to reveal to them the moral code of the Torah, but there was no need for a second such revelation. In my own definition of intelligent life I ignored the issue of free will; we don’t really understand it. But perhaps it should be a criterion as well.

What Are We Going to Do?

The Jewish view on the more likely scenario – that we are alone – is more interesting and profound. Not least, religion makes the point that we are of course not spiritually alone. But if indeed we Earthlings are alone for all practical purposes, then how should we react? How should we respond to the many people for whom the prospect of being “alone,” at least without hope for salvation from a super-intelligent species, is frightening?

We are blessed – this is one certain conclusion. I think that the Jewish view of the state of being blessed offer some important insights. Since Biblical times, added blessings or favors carry with them added responsibilities. In particular, responsibility includes the obligation to deal compassionately with other people and to attend to the welfare of larger community and its environment. Blessings come with added expectations too, and with consequences when responsibilities are shirked. Hopefully, an awareness of our rare capabilities will also generate renewed appreciation and deeper personal humility. Indeed our exceptional status on Earth, and our awareness of this probable good fortune, should make us more sensitive to our task “to serve the Earth and to protect it (Gen 2:15).”

The Jewish perspective not only asserts that we should try: it emphasizes that we have the skills to succeed. Our task is possible. As Maimonides (1135-1204) emphasizes in his *Guide to 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.

The Kabbalists and other 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." I explore what this latter notion might mean in a modern, physical context in my book, *Let There Be Light: Modern Cosmology and the Kabbalah, a New Conversation Between Science and Religion.* Quantum mechanics includes the still incompletely understood implication that the world and its matter are composed of wavefunctions 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 wavefunction." Some, most notably John Wheeler, have suggested that the Universe created conscious beings in order to observe it and thus bring it into reality. It is in this quantum mechanical sense 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. If we are not alone, then we share in this purpose with all other conscious beings … but we may never know about them for sure.

> "It is not night when I do see your face,
> Therefore I think I am not in the night;
> Nor doth this wood lack worlds of company,
> For you in my respect are all the world:
> Then how can it be said I am alone,
> When all the world is here to look on me?"
>
> --- *A Midsummer's Night Dream*

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