Chapter 2
Space in the Background

The basic parameters for the continuing discussion involve three major sets of concepts. The first has to do with the basic question (which I admit is sidestepped throughout the rest of the book, but not in this chapter) of *whether* other intelligent beings exist anywhere else in the universe. Inseparable from that question are two others: talking about life on other worlds implies a necessity for understanding some of the basis of what is meant by “other worlds.” That is, how is the universe to be conceptualized? What are the bases upon which a discussion of ETI can take place? The third question is related to the first, but it has to do with another level of life (and of the universe). How is the universe made up? What elements in the universe need to be kept in mind in order to be able to make the assumptions that will be made here and later in this book? Because we are to deal with life only remotely related (if at all) to our own, we must start with the microcosmic universal basics, even with the laws that make the universe up, in order to understand why we should assume life would emerge, and, whether there are any fixed compass points that will help us understand *how* an intelligent species would behave.

To start, however, it is useful to recapitulate the efforts that have been made to confirm the existence of intelligent life elsewhere than on Earth, and to try and contact it. I am not concerned here with all such efforts, but only with general approaches and their principles. It is however necessary to emphasize that searches for extraterrestrial intelligence operate, as scientific endeavors, under a set of principles and limitations that do not necessarily limit the discussion here. The physical difficulties in reaching other stars do not concern me: I leave that to the physicists. It is the *consequences* and modes of contact that are my major concern.

M. Ashkenazi, *What We Know About Extraterrestrial Intelligence*,
Space and Society, DOI 10.1007/978-3-319-44456-7_2

2.1 The Search for Extraterrestrial Life

Humans have been discussing the possible existence of intelligent life forms on other stars or planets for centuries. The earliest such speculations recorded were those of Democritus, but they have persisted in many cultures since (Dick 1999; Crowe 1986). These speculations have been motivated by scientific interest (SETI efforts in the twentieth century), religious discourse (Renard 1986; Lamm 1978), political polemic (Bergerac 1923), intellectual discourse (Kant in Dick 2013). or for entertainment (Verne, Welles, and subsequent science fiction). It is only in the twentieth century that technology has provided the tools necessary to formulate some questions and at least partial answers, to many of the questions that the problem poses.

2.1.1 The Drake/Green Bank Equation

Insofar as we (the human species) know, there is only one intelligent life-form in the universe: us. This fact, known as Fact One (Hart and Zuckerman 1982) is almost unarguable. However, the statement as it stands includes a number of semantic traps we ought to be aware of, and sometimes are not.

In this particular instance, the 'we' embodies not a particular group of people, but a process, a particular way of 'knowing' that we call 'science'. Science implies a definite set of rules *about* knowing and about knowledge. When we say the human species 'knows' what we mean is that insofar as the process called science has been able to determine, using the methodology it uses, there is no evidence for the existence of any ETI. This does raise two questions: what about signs of ETI existence that are *not* amenable to our current scientific discourse? The manifold reports of UFO sightings would tend to support this methodological position (though I hasten to say this is not an argument for UFO existence, let alone that UFOs are ETI, as I shall show in Chap. 5). Another dimension is the rather short reach of our science. As Forgan and Elvis (2011) argue, a likely location of ETI *artifacts* may be in the asteroid belt. But even those objects, astronomically speaking practically a part of our planet, are currently way out of reach. So Fact One, important empirical evidence though it is, should not constrain nor end our search. It is also important, therefore, to understand the processes by which we go about 'knowing' whether or not there are ETI. Part of this process is a technical one: the construction of physical means for deciding the issue. A more important part of the process is the logical examination of the possibilities, the rationale for the scientific endeavor.

This rationalization is presented in abbreviated form as a set of relationships, generally known as the Drake equation (for its originator, Professor Frank Drake) or the Green Bank equation (where Drake first formally presented the equation). The

Drake equation proposes that the number N of intelligent communicating civilizations in the Galaxy can be expressed as

$$\mathbf{N = R * f_g * n_c * f_l * f_i * f_c * L}$$

where

N number of intelligent life forms
R rate of star formation
$\mathbf{f_g}$ fraction of stars with planets
$\mathbf{n_c}$ fraction of such planets within the 'habitable zone'
$\mathbf{f_l}$ fraction of such planets where life actually arises
$\mathbf{f_i}$ fraction of such planets where life gives rise to intelligence
$\mathbf{f_c}$ fraction of intelligent species that give rise to a technological civilization (detectable by us)
L Average lifespan of a technological culture

The precise details of the equation, its modifications, and the parameters of its variables are still being debated today (Drake 1967; Drake and Sobel 1992; Forgan 2009; Gleiser 2010; Maccone 2010). Note that the variables start from the physical sciences on the left, and move onto attempts to quantify biological, and later social unknowns on the right. Two points, however, are to be borne in mind.

First, as we proceed from physical science to the biological and then social sciences, the variables become more difficult to assess. Some of the independent variables have approximate solutions. The approximate rate of main sequence star formation in the Galaxy has been variously estimated at 0.68–1.45 solar masses/year (Robitaille and Whitney 2010). Other estimates are as high as 7 solar masses. These estimates are being updated as more information about the universe becomes available as the result of work by astronomers.

Some of the variables which had no data at the time the equation was stated, are currently being filled in: star systems with planets are apparently common, and as of the writing of this book, many planets have been discovered in the habitable zones (that is, the zone in which water can be found as a constant liquid 0C < $\mathbf{n_c}$ < 100C) around nearby stars. Though there is currently insufficient evidence to refine $\mathbf{f_g}$ to the point of making it a known variable, that is merely a matter of time, though it is currently estimated as quite high (Beckwith 2008; Beichman 2002).

In contrast, the rightmost end of the equation which contains biological and social variables is unknown. For all the variables f_l, f_i, f_c, we have only one example, ourselves and our planet, to generalize from. For L, the lifetime of a technological civilization (defined by SETI as a civilization capable of building and operating radio telescopes. Oliver 1976) we have a complete unknown: we have no knowledge beyond the fact that it *could* extend for more than a century.

Second, the various searches for ETI (SETI projects) by necessity, must have a very conservative definition of extraterrestrial intelligence, and of an ETI species. ETI must, for example, be a technologically advanced species, otherwise the effort is futile: there is no possibility of signal exchange across space. Moreover, an ETI species must also, to a great extent, think like humans and be interested in similar things, otherwise there will also be no likelihood of communication. Finally, because SETI projects must deal with current technological and scientific know-how, they must accept all basic physical implications of the known universe. The most prominent of those are the vast distances involved, and the fundamental universal velocity limit **C**.

Those limitations are not as rigid for this book. The variables of the Drake equation will here serve as a framework for discussion, because they are the currency of intellectual exchange in the SETI community. Yet it will also be necessary to consider exotic possibilities, as well as ignoring completely some issues arising from the physical limitations. In a later chapter, where I consider the consequences of contact, for instance, I will at times ignore the (current knowledge-based) absolute limitation on faster-than-C messaging and travel.

2.1.2 Arguments Pro- and Con-: The N = 1 Versus N > 1 Debate

Speculations about the existence of ETI fall generally into two opposing views. The first is that N (the number of intelligent, communicating, life forms in the galaxy) is greater than 1. We know of at least one ILF species: ourselves. The hypothesis on which ETI research is based is that there are more, thus N > 1 (Billingham 1981; Sagan and Drake 1975; Sagan and Shklovskii 1966). The opposite hypothesis (Hart 1982; Tipler 1981) N = 1, is, the idea that it is improbable that there are any more than one intelligent, communicating species in the galaxy.

So long as none of the independent variables in the Drake equation equal zero, the potential for number N is always greater than 1. There are some 300 to 600 *billion* stars in our Galaxy alone. It is sufficient that the product of the variables is a measurable fraction, for N > 1. Estimates of N have varied between highly optimistic, and probably unrealistic estimates of one million, to lower estimates on the order of one thousand to one hundred communicating civilizations in the galaxy. Keep in mind, however, that 2 is a theoretically sufficient number for purposes of contact.

There is an additional factor that must be considered. Its importance derives from the physical nature of the universe. As currently known (that is, to date unfalsified, and seemingly unfalsifiable) the limiting velocity of any object in the universe, light and other electromagnetic phenomena included, otherwise known as C, is 299,792 km/sec. Communication—by physical or radiation means—with any but the nearest stars, is measured therefore in centuries and millennia. The nearest stars are mere years away *at the speed of light*: a speed that is practically and theoretically impossible to achieve (Einstein 1955). What this means, among other things, is that two communicating civilizations must overlap in time for a considerable period, in order to carry on any sort of communication, making the variable L a crucial limiting number: *both* societies' L *must* overlap for there to be any contact.

Theoretically some complex ways of overcoming the C limitation, without violating the velocity and energetic requirements posed by the universe have been proposed (Hawking 1993; Wolf 1989). In practical terms no one has been able to suggest a way in which these (which have some severe limitations of their own) can be achieved. For the Drake equation, however, this means that the variable L is absolutely crucial: the longer the average lifespan of a communicating technological culture (assuming N > 1), in terms of *millennia at least*, the greater the odds such civilizations will overlap and thus indeed be able to communicate with others. If, for example, L averages one thousand years, the evolution of a technological species lasts one hundred million years, and of two species, one started evolving 1 % of that time before the other, no communication will occur.

2.1.3 The Fermi Paradox AKA the Great Silence

There is one aspect of the N = 1 party that *does* necessitate discussion here, though its full implications will be explored later. In 1950, the great physicist Enrico Fermi, during an evening discussing SETI, asked a simple question now known as the Fermi Paradox: "If there are advanced ETI in the universe, where are they?" In other words, why have they not contacted us? Why have we not even seen any sign of their presence?

This simple question (all great questions appear simple) represents a major problem for N > 1. For the N = 1 party it represents empirical demonstration of the N = 1 hypothesis. For the N > 1 it represents an even greater set of problems, highly relevant to the subject of this book, which David Brin has labelled "The Great Silence" (Brin 1983).

Let us assume, following Brin and others, that (a) there are contemporary ETI civilizations out in our galaxy; and that (b) they are avoiding contact with us. What then are the implications? Several such possibilities have occurred to SETI researchers, including the Zoo hypothesis (they wish to preserve us in our innocence, to allow us to develop at our own pace, cf. Ball 1973) to the Great Silence (they are hiding from some greater threat, Brin 1983), and the Transcendence theory (they have evolved so far ahead of us technologically (Bracewell 1981) that, to quote the Old Testament "We are as grasshoppers to them." Numbers 13:33).[1]

From the point of view of this book, these are all relevant but from a different perspective: all three theories constitute speculations on the nature of ETI civilization and culture. We shall address this core topic later on. For now, it is sufficient to say that the argument about the Fermi paradox by both the N = 1 and the

[1]This does beg the question of the two other N > 1 possibilities, that ETI are at our technological level, or behind us. *Most* SETI speculation, for obvious reasons, assumes that ETI are more advanced. Since we are principally discussing CETI in this book, however, we shall be ignoring the assumption of ETI technological superiority for the moment.

N > 1 parties are a side issue: we accept N > 1 as a given. And whether they are avoiding us deliberately or not, the principles to be discuss here remain the same.

2.1.4 SETI Programs

The possibility that other intelligent life may exist in the universe has led to a number of attempts to find ways of empirically demonstrating their existence. Establishment of organized searches for Extraterrestrial Life (known in the US as SETI and in the former Soviet Union as CETI) began in earnest in the late fifties. To sum up the results in terms of the final goal, they are zero so far. That is, there has been not so much as a hint of the existence of other intelligent life forms in the universe. This having been said, we must indicate that the 'zero' must be qualified. The searches *have* yielded a great deal of important information, not the least of which are the refinement of techniques for SETI. Given the universal realities discussed in the previous section, most searches have concentrated on using radio. Generation and detection of radio waves are both cheaper and more efficient than the transmission of physical artifacts.

The SETI Project (formerly the official NASA project searching for Extraterrestrial Intelligent life forms, currently a voluntary astronomical project run by the SETI Institute in Mountain View, California) defines an intelligent life form operatively as a life form able to construct large radio telescopes (Oliver 1986). This means a life form that we will be able to communicate with, given our own technological level. As an operative definition *for a SETI project* this is an admirable formulation, since it simplifies the discussion of what is intelligence, what is life, and so on. As a normative definition this does not do much good for the discussion here for two reasons. First, because the discussion is intended to examine as many possibilities as possible, and second, no less importantly, because the definition is ethnocentric: it assumes that all intelligence is roughly similar to human, which might not be the case.

It is useful to make a distinction between SETI efforts and SETI programs. A SETI program is a managed and organized project by some organization, to search for extraterrestrial life. Like all programs, any one of these might prove ephemeral for reasons of politics, financing, or technology. A SETI effort is the sum total of a species endeavor to search for intelligent life other than its own. This includes public opinion, intellectual debate, as well as SETI programs. A species with a SETI effort is different qualitatively from one that does not have one. Intelligent, even very intelligent lifeforms with advanced technology may well *not* engage in SETI efforts (Ashkenazi 1995). As we shall see subsequently, this will affect the SETI efforts of other species to some degree. No less importantly, reaching the position of "uninterested in SETI" is one that can be reached by several paths, many of them germane to the subject of this book. The absence of SETI programs or a specific program, on the other hand, merely means that a species has not gotten itself organized to engage in the enterprise. That might indicate shortsightedness, even stupidity by those responsible for organizing that particular species, but would still mean that the species is comparable, even comprehensible to us, at least in some fashion.

Organized SETI programs have been in operation world-wide for five decades (Tarter 1985; Drake and Sobel 1992). By and large these have been searches through the electromagnetic spectrum for indications either of intentional beacons or of leakage from broadcasts. There have also been searches for the possibility of physical arrival of ETI probes in the Solar System (Freitas 1980), known by the acronym of SETA (Search for Extraterrestrial Artifacts), and an ongoing search for signals in the visible spectrum: Optical SETI (Kingsley 2001). Other searches have been conducted for possible indications of ETI technology outside the Solar System (e.g. radiation leakage, stellar engineering. For some suggestions see Ćirković 2001).

The future of many of these programs depends on the will and enthusiasm of their various designers and proponents. These include private and philanthropic initiatives, ranging from the SETI Institute in California, to the 100 million dollar Breakthrough Listen project which started operation in 2016 (equivalent to the total budget of the government-sponsored NASA-SETI project). No less, it depends on the political and economic climate that exists in any country in which a SETI program takes place. These are not many, and with the impoverishment and demise of the Soviet Union, some of whose scientists and engineers were fervent supporters and maintainers of SETI program, some projects have disappeared (though the enthusiasm has not, as witness the Breakthrough Listen project, funded by Yuri Milner, a Russian businessman). We can only hope, if only for the sake of our remote descendants, that the SETI effort is sufficiently entrenched in the human species so that programs will be maintained and even strengthened by private or government funding.

2.2 The "ILF" Perspective

We start then by trying to picture and perhaps understand the relevant physical facts of the universe. Of those, the easier to grasp are those elements of the universe that have to do with size and dimension. We are a planet-bound species, though we have only begun to realize it in the past few centuries. Our planet is intimately tied to a star and the star is tied to still larger universal elements.

Understanding how these interrelate at some level, makes the following discussion easier. Understanding the implication in terms that make sense to an individual, even more so. We start therefore with a rough description of the major elements of the stage and the props. The obvious features within the universe that are of great interest to us are stars and their associations. We, the human species, exist as a consequence of factors inherent in physical activities at many levels. The most obvious, at least to the senses, is the star around which the Earth revolves. It is a reasonable supposition that *if* humanity came into being on a planet around a star, other species may do the same on other planets, around other stars. This not to prejudge the issue of what conditions need to occur for life or intelligent life to *occur*, but to suggest that similar conditions could bring about similar results. Given that the catalog of extra-solar planets in our near stellar neighborhood has swollen as of 1st July 2016 to 3443, partly due to the operation of the Kepler observatory (Exoplanet EU 2016) of which about 1/5 are in a habitable zone (Petigura et al. 2013), the odds of finding a habitable planet are growing daily. In other words, we can chalk up another victory for Drake's equation.

I must start by emphasizing that cosmology, as physicists understand it does not concern me here too much. Cosmological physics is a subject best comprehended by numbers and the relationship between them, not by humanizing the phenomena. But for our purposes, it is more important to humanize than to present an accurate mathematical description that a cosmologist would accept. The following description, wherever possible, humanizes the cosmos rather than abstracts it. Like all maps, it suffers therefore by being skewed. Accurate in some ways, it is misleading in others: if in making the universe comprehensible for human purposes it also makes it incomprehensible and unacceptable for the professional physicist and cosmologist. They have my apologies.[2]

2.2.1 Space and Time

The interrelationship of mass, time, and distance are complicated enough as physical phenomena. Our concern is however with ILF perspectives, which makes the issue more complicated still, because we need to add a *subjective* component to these issues: what, for instance, does time mean for an intelligent species? For example, the critical time-span for most people, over most of history, is one's own life span. Which is itself subjective: consider what 'life span' means to a ten year old and to a ninety year old. The same is obviously true for societies, and, we can extend that, for civilizations and species. Objectively (from a cosmological perspective) and subjectively (from an ILF perspective) time is a crucial dimension.

It is necessary to understand, first and foremost, that the universe is huge. Getting to our closest neighbor, Proxima Centauri, would take over 4.2 years traveling at the speed of light. To put it materially in ways that can (perhaps) be comprehended, if there were a highway stretching to Proxima Centauri., and you could drive at about 100 km/hr all the way, it would take you 34,560,000 *years* to make the trip (provided of course that you did not stop along the way for a snack or to relieve yourself). Most of that distance would be through 'empty' space.

[2]I could add, in consolation, that I find much of the discussion of social and cultural phenomena by my astronomer and cosmologist colleagues in SETI rather incomprehensible as well. Each to his knitting.

For a technologically developed civilization, the first stage of both space and time is its solar system: the cradle, and possibly the entire domain, of any non-exotic ILF. Since we presently adhere to the Principle of Mediocrity, we can assume, at least *pro tem* that ETI populated solar systems will be similar to our own in most ways.

2.2.2 The Solar System

The Solar System consists of a star, Sol, two torque-shaped planetary zones nestling one inside the other, a wide cometary belt of frozen ice and gas particles called the Oort cloud, and finally, a very diffuse solar atmosphere of charged particles which extends as far as the solar atmospheres of the nearer stars. Because of the rotation which initially formed them, most (well over 99 %) of the matter we are talking about is on the same plane, rather than existing as a sphere (with the exception of the charged particles which are emitted from the spherical surface of the sun).

Sol is a G2 V type star: mid-range, rather small, neither very hot nor very cool by stellar standards. This has implications for considerations of searching for extraterrestrial life. Life is an aspect of the cosmos, that is, a product of physical forces including energy and time. If Sol is an average solar system in physical-cosmic terms, then it is possible, for cosmic reasons and in the absence of another data point, to assume that it is average in all respects. This means in the existence of life on a planet surrounding it. If the Solar System is average, than on other stars that are close to the average we will find similar processes, and perhaps similar results. Other stars will also have life, other biospheres will also have intelligent life-forms. *If* the assumption of mediocrity holds true throughout.

Sol has a number of effects that are relevant to life *beyond* considerations of the evolution of life around it. First, and that is its most apparent characteristic to humans, it produces energy. All energy available to life on Earth is a product of the Sun. This has an implication as well: in a sense life on Earth is 'habituated' to certain types and ranges of energy from the sun. For example, we need liquid water, which implies a certain degree of insolation. Too much and water evaporates, too little, and it solidifies into ice. But is this a *universal* requirement for life?

Sol has mass, and effects on mass: the particles that stream away from it in the form of solar wind, and, more importantly, its gravity. It is the gravitational factor which accounts largely for the formation and continued existence of planets, and thus, directly and indirectly, to our continuation as a species: the speed of Earth's passage neatly counterbalances the effects of Sol's gravity: as neat and elegant a balancing act as one could ever expect to see, in fact, a marvel of engineering and architecture. Again, is this a feature in the emergence of life?

Finally, Sol, like any other star, has a temporal effect on its environment. This temporal effects starts from Sol's birth, some six billion years ago, extends through its lifetime as a nurturing star possessing a zone around it where life is possible, and continuing into the future to some final date when Sol most likely will go nova. So long as Sol exists in its current form, so do its dependents and immediate neighborhood. When it moves on to the next phase of its existence, as inevitably it must, this will affect its dependents. Lest one become complacent, it must be recalled that *we*, *Homo sapiens*, are one of Sol's dependents. We have, as presumably do all other stellar species, a "window" of existence. That is, from a certain time t_0 to a certain other time t_1 we can exist, in current form, as dependents of Sol. Before and after that window things may not be so simple. The lifetime of a star as it exists on the main sequence of stars is, effectively, the basic parameter for the existence of life on planets around that star.

Of greatest concern to us (because we live in it and it is most obviously accessible to our examination) is the planetary system. It consists of Mercury, Venus, Earth, Mars (the inner planets) Jupiter, Saturn, Uranus, Neptune, the recently demoted Pluto (the outer planets) and possibly another outer planet. Between them are the orbits of smaller objects generically (and often mistakenly) called the asteroid belt: the asteroid orbits are a "belt" to astronomers, but largely empty space (science fiction films to the contrary) for the rest of us (see Petit et al. 2001).

Insofar as we know, the only body capable of evolving and sustaining life in the solar system is Earth. There are some indications that other planets, e.g. Mars, may have had *some* of the conditions for life in the far past, and *may* still hold simple life today (Levin 2010; Yung et al. 2010), but there is no concrete evidence of the existence of life on Mars. One of the reasons for this consideration is the lack of flowing water. Water in liquid form may be a natural prerequisite for the evolution of life. Some recent studies (Battison 2011) indicate that other locations, notably some of the moons of Jupiter, may harbor free-flowing water. If that is the case, Ganymede, and possibly Europa which *may* have free standing water hidden under a crust (Keszthelyi 2011) are candidates for the existence of life.

There are some claims that life could originate in the methane clouds of a large gas giant such as Jupiter. The changing colors of Jupiter's bands and great spot have been suggested to mean that there is biological activity on Jupiter. If that is indeed the case, then necessary changes will have to be made in human calculations about the likelihood of life. So far, however, there is no real evidence that Jupiter possesses life.

The other planets—Saturn to Pluto—would seem to be too cold for the evolution of life. Outside their orbits there are belts of cometary material, largely ice, about which little is known from direct observation, perhaps other planets. No life would seem to be present there. Some suggestions have been made (e.g. by Shapiro and Feinberg 1982) that life may possibly emerge under conditions approaching zero absolute, but such life would be too strange for us to consider at this point.

Solar System Resources

Like a kid before a candy store, we can, at present, merely look at the material riches of the solar system, but not touch (the odd Lunar or asteroid rock notwithstanding). The solar system as a whole represents a bank of minerals, metals, and energy, as well as specific physical qualities that have major relevance to certain types of civilization, notably those that can overcome the gravity well. The human species is at the threshold of access to this cornucopia.[3] Other intelligent species may well have passed that threshold, a point worth keeping in mind.

2.2.3 Why Habitability Zones

Our life consists of a complicated chemical interaction between chemicals whose breakdown and reassembly provides us with our energy and the material of our bodies. There is good reason to suggest that a liquid is crucial for the emergence of life, since suspension in a liquid medium allows exchanges of chemicals, and later of cellular and genetic material which facilitates evolution. Not every liquid will do.

Empirically speaking, we have evidence that life evolved on Earth from, or within, a liquid or semi-liquid medium. This is true both for the emergence of very simple prokaryotic cells, and for the development of their more complex eukaryotic descendants into colonies of specialized multi-cellular beings, about a billion years later. Water has two relative advantages over other liquids as a cradle for life. First, both hydrogen and water are found in relative abundance in the universe, as they are extremely archaic and relatively light and they have a marked affinity for one another, creating H_2O molecules relatively commonly in cosmic terms. Second, water ice, peculiarly enough, floats *on top* of water. In our individual experience, most solids sink through liquids. Ice forms crystal-like structures whose volume is greater than the water the ice is formed from, and as a consequence, floats on top of the water. The same is not true for other potential liquids such as methane or sulphur, which have been suggested as candidates for a liquid medium for life. In those materials, the solid, ice form sinks to the bottom.

Why is this important? Ice forming as a crust on top of water serves as a shell allowing life to continue in the liquid that remains below. Lake Vostok, currently being explored in the Antarctic exemplifies that principle, which also raises hopes for the existence of life in the liquid under-ice oceans of Europa and Ganymede. Under normal weather conditions, atmospheric temperatures can drop below zero centigrade. This should not affect the existence, nor the exchanges of life processes necessary for life, so long as the bottom of the liquid body remains liquid. Any additional ice would accumulate on top, and eventually melt by solar insolation and heat, or crack, forming access corridors between the atmosphere and the liquid below. In contrast, methane ice is denser than methane liquid. The liquid, in effect, serves as a shield protecting the ice from heat and since the ice rests on the bottom of the liquid column, it is not subject to many stresses. Over time, the ice builds up, displacing liquid, and eliminating life processes.

[3] Whether the species turns out to be bright enough to access this wealth *sensibly* is another matter.

For many astrobiologists, the ‘zone of habitability’ is defined as the zone where water temperature never drops below 0 degrees Centigrade (at which stage it would be more or less a solid) or rises above 100 °C (in the form of steam or vapor). This *may* be ‘carbon-centric’ thinking (the Carbon-Oxygen exchange upon which our physiology is based works well with water), but may also be a universal truth. Very hot, very large (O, B, A types) stars suppress the chemical interactions by the sheer violence of their emission of heat and charged particles which destroy such interactions before they can start. The habitability zone—the distance from the star where water is liquid—is also for physical reasons very narrow, lessening the odds of a planet of suitable composition orbiting within the zone. Life *may* emerge in other chemical environments, and some thought has been given to that possibility as well, which changes somewhat the definition of ‘habitability zone’ (Shapiro and Feinberg 1982).

2.2.4 The Solar Neighborhood

There are some 14,000 stars within 100 light years of Earth, of which around 500 are spectral type G (similar to Sol in luminosity). There are in addition some 1300 F (yellowish) and K (reddish) stars within the same volume. Such stars—yellowish (hotter) to reddish (cooler) stars—seem to offer the best bet for the existence of life *as we know it*. The reasons for this have to do with the nature of stars.

As a general principle, the hotter the star and the larger, the newer it is, and the shorter its lifespan is likely to be. From the ILF perspective this provides serious obstacles to the emergence of life, let alone intelligence. On Earth, life took several billion years to emerge, and another billion to evolve into multicellular organisms that could devote enough energy to develop nerve tissue and brains. The evolution of culture—that is, for our purposes at the moment, the ability to develop artifacts to the point of being able to explore our speculations on the existence of other ILF (such as e.g. computers and radio-telescopes)—took several million years from the point at which our genetic ancestors first picked up a stone and shaped it to some purpose.

The other end of the spectrum—the M and N type stars—suffer from the reverse problem from a life perspective. The habitability zone is closer to the star, as it emits less energy. Planets are less likely to form or survive that close, as they may be ripped apart by solar tides. Nevertheless, life on planets around red dwarf M stars may be possible (Heath et al. 1999). M-class stars in the solar neighborhood, ignored until recently, are now (2016) being studied by the SETI Institute. For other reasons, other types of stars such as brown dwarfs and the fascinating array of exotic stars—quasars, neutron stars and the like—are even less likely to support planets, let alone those where ‘mediocre’ forms of life may have emerged.

2.2.5 *The Galaxy and Beyond*

The distances between stars within galaxies vary. Again, we can assume Sol is average in this regard, lying about two thirds of the way from the center to the rim along the Sagittarius arm of the galaxy we call the Milky Way. The Galaxy is composed of about 300 to 600 billion stars of varying sizes and temperatures. It is assumed to be about 1000 ly thick, and 100,000 ly in diameter. Gas and dust clouds veil most of its structure from our eyes, and much of the discussion of its structure relies on comparison with other, more distant galaxies that are visible. Some recent evidence suggests that the center of the Galaxy may be collapsing into a giant black hole (Genzel et al. 2010). In any case, the center of the Galaxy is the realm of closely packed stars. This too has implications for the existence of life. The closeness of stars in the galactic center may well increase radiation to the point that organic life may not be possible. Moreover, if as has been suggested, the center of the Galaxy is an enormous black hole, then the odds of life existing there go way down.

The Milky Way is not the only galaxy known. Two closer small galaxies, visible in the southern hemisphere of Earth are the Magellanic clouds. These two are much smaller than the Milky Way. Their structure is also more amorphous. The closest galaxy apparently similar to our own is the great Messier M31 Andromeda galaxy, composed of some one trillion stars. It too is a spiral galaxy like the Milky Way though twice as large. There are some thirty galaxies in our local cluster, and there are numerous clusters throughout the observed universe. In addition, space is rife with a multitude of observed physical material. Clouds of gas darken and shroud the light of stars and galaxies. There are large star clusters, too small to be considered galaxies on their own, which constitute nebulae. There are several types of hypothesized bodies, ranging from black holes (stars that have collapsed in on themselves to the point that the physical laws we know can no longer account for them), dark stars or protostars (large dark bodies that have not-yet ignited), brown stars, solitary wandering planets, neutron stars, and so on.

The point, again, is not to enumerate the wonders of the observable universe, but to indicate the ILF dimension: the universe, insofar as our understanding of physics goes, cannot be traversed, but it can be observed.

2.2.6 *Universe*

The universe is difficult to conceive of, let alone describe. For all ILF intents and purposes, the universe is infinitely large. That astronomers may *perhaps* be able to see to the limits of the universe means little to us or other ILFs, except insofar as it yields information regarding the universe itself. The ends of the universe are so far that they are out of reach, physically as well as conceptually.

What is important for us about the universe, is that it is the matrix for the operation of a set of physical laws. Whether those laws are inevitably supportive of life, as some (Margulis and Lovelock 1974; Gardner 2003) would argue, or whether other laws exist locally in the universe, is something to consider. But the truly important fact is that, insofar as we are able to tell, the physical laws under which the universe operates, are applicable throughout it. That is, the laws of gravity, light, atomic and subatomic interactions are as true on Earth as in Andromeda and far beyond.

In discussing universal rules an intriguing possibility must be mentioned. There is some theoretical evidence that other universes may also exist, in forms that appear inconceivable except to mathematical physicists (Wolf 1988). What this implies for ILFs is hard to conceptualize. The possibility is mentioned here merely to indicate that there may very well be *no* limit to the universe, if it is conceived of as a universe of universes: of possibilities that exist side-by-side without end.

2.3 Physical and Non-physical Contact

What the preceding discussion of space means, in terms of communication, is that there are a number of possibilities. Though interstellar physical contact is enormously—many astronomers and physicists would say "prohibitively,"—expensive, some cultural quirk, dire need, or driving urge might cause ETIs to contact us physically. This is rather far-fetched, but we must consider the possibility. In point of fact, STL contact, whatever conservative physicists say, is not prohibitive *provided* a civilization is prepared to pay the cost (Hodges 1985).

Still faster alternatives may exist. At constant 1 g acceleration, a vehicle would reach 99 % of light speed in 3,265,3061 s, or 9000 h: a bit over one year. The problem of providing power for such huge acceleration, and then deceleration is something we will not consider directly. The mass considerations *if a reaction motor is used* are horrendous. In practice, and notwithstanding time dilation for the passengers at that theoretical velocity, other stars are out of reach for immediate purposes.

The preceding very brief description of the physical universe must return us to my original point: the cosmic factors are important in this discussion only inasmuch as they fit ILF dimensions. The great distances between the stars, or between the galaxies, are only important (not 'interesting' which is a different kettle of fish) because of the value, or the difficulties, that they present to ILFs.

Now, interstellar distances may well be insurmountable—socially, economically, politically—for humans. But for an ILF with different motivations and a different economic persuasion, perhaps not so. Keep in mind too, that other human societies have indeed done things which are roughly comparable: Columbus is one example, Polynesian voyagers sailing to Easter Island another (Finney and Jones 1985). In each case a large amount of economic wealth were invested in an attempt to go someplace else. The economic return for the endeavor was always in doubt, but the motivation for the effort was not necessarily economic: while the Spaniards were anxious to be rewarded with the wealth of the Indies, they also wanted to spread religion. Polynesians had limited land resources and expanding populations, so long-distance travel was the only solution they could come up with. And though it can be demonstrated that energy considerations would be a major barrier for any given civilization from spreading into interstellar space, there is no reason to suppose that this is true for *all* species at *all* stages of technological development and knowledge.

For all ILFs anywhere in the universe, three factors are important: energy, matter, and distance. All three of these should be measured in ILF, not cosmic terms. Energy refers to those types of energy the ILF can use or enjoy: not to hot *for it*, not to cold *for it*; usable. Matter refers to solid points: star systems, planets, moons, dust clouds, providing both reference points and the very material of life, as well as fuel for exploration. Obviously this is related very closely to the issue of energy. The reasoning is the same for the discussion of energy: we are interested in the ILF, not the physics. Finally, distance is a factor that too is measured in ILF terms. Put very simply, the distance between Greenland and Africa is very different for an ant walking it, a man canoeing it, or a bird flying it on its yearly migration. Life span, other activities, energy needs, all conspire to define that elusive factor called “distance” for different life forms. Certain life forms (very simple ones, such as bacteria and viruses, and to a lesser extent, some more complex ones such as lungfish and cicadas) have the ability to aestivate (suspend their natural processes of anabolism and catabolism) for a period ranging from a season to several years. The technology of slower-than-light star travel is not too complex, theoretically, and given the desire to do so, we could probably send humans to the nearest stars. Yet we define that as ‘impossible’. Why is that? Because in human socio-cultural terms it is indeed impossible. Under some configurations, the trip to one of the nearest stars (Barnard’s star: 6 ly, the Centauris: 4.3 ly) would take only several years subjective. *Objectively* however, the time would be so great that few individuals would be willing to contemplate the trip. This is because in *our* terms, both social, psychological, and physiological, there are too many barriers. But what if we could, and did aestivate? Much of the cultural generational notions (i.e., I am younger than my parents’ generation and older than my children’s) would not exist. Moreover, we would not have the physiological limitations on life span (we actually would, but they would undoubtedly appear different to us) and therefore the two hundred years spent traveling would not be that much of a burden. Thus ‘distance’ for aestivators and for non-aestivators represent two subjectively different things even if physically they amount to the same distance in kilometers, light years, or inches.

The various arguments pro- and con- physical exploration and colonization of the universe are not provided here in order to enter into the debate of whether ‘we’ or ‘they’ can visit another star system. They do suggest that one must carefully examine the assumptions that are used to discuss CETI. We *cannot* assume, from the start, that ETI are likely to affect us in any particular way (see for example the

Zoo hypothesis, of which more subsequently). What we can do is suggest what the parameters and limitations of certain sorts of behaviors *might* be.

The major point of this chapter has been to describe very briefly the background against which the issue of xenology must be discussed. It is also important to reemphasize that the dimensions and background *must* be seen in ILF terms, not those of a physicist. That having been said, it is necessary to identify what 'ILF-terms' are. For that, it is necessary to attempt the construction of some parameters of ILFs, starting from the simplest building blocks and what we know about them, and progressing gradually, with ever-growing uncertainty, to some assumptions about the parameters of intelligent life under various circumstances.

2.4 The Microcosm

The stars and their dependents are the consequence of interactions between features at atomic and sub-atomic levels. These interactions have an effect on life as we know it, and certain features are obviously of interest if we are speaking of life elsewhere in the universe, insofar as those features are truly universal.

Stars are composed of elements, largely hydrogen and helium, and also are the furnaces in which heavier elements, including metals and the very heavy transuranics, are created by fusing lighter elements. The physical laws by which this activity takes place were determined, for reasons that are still debated, at the initial moment of the universe (cf. Hawking 1988).

These universal features affect us in a number of ways. First, they determine the form of the universe, and thus the forms we take and *can take*. Certain possibilities we could conceive of are simply not possible, given the laws of the universe as they are. This is important for the continuing discussion here, because these laws provide us with a boundary for considering the possibilities of life, and thus of ETI.

Second, the basic laws may well determine factors ranging from gross morphological features of a species, to the ways in which a species may or may not organize itself into intelligence. We need not consider the possible intelligence of a rock if it lacks certain organizing characteristics that are the result of truly universal rules.

Finally, the basic laws of the universe determine the possibilities, and the means by which we can communicate with ETI. For example, one derivative of the basic microcosmic laws of the universe is the limitation on velocity C. Grossly stated, a physical object cannot travel faster than 299,792 km per second. This is an absolute limit *insofar as we know*. It places limitations on communication, physical visits, travel in the universe and so on.

This final range of features will become less important as the discussion here progresses. "Insofar as we know" allows for an escape clause, one that will allow me to ignore the issue at some points. Nonetheless, the effect of these basic universal rules is profound and overall, unavoidable.

2.4.1 Evolution in the Universe

The universe—whether considering the entire cosmos or merely our part of it—is in constant movement and ferment. In essence, the universe is undergoing a persistent process of change at all levels. In fact, this process is often indistinguishable from a process of evolution. Evolution, in its grossest sense, means the development of more, complex forms, from fewer, simpler ones. This happens in the universe at the level of atoms, where complex hydrocarbons are formed through a random process like the one that affects biological evolution. It also happens at the levels of stars. Older population stars, formed "soon" after the Big Bang which initiated our universe, are giving way to younger stars, some of them complex and variable. Evolution is thus not only a biological rule. To the contrary. It would appear that biological evolution, the evolution of species that we normally think of when we consider the term, is but a special case. Under the proper circumstances, such as the hearts of stars, heavy elements are evolved from lighter (and simpler ones). Interactions between some of the molecules of these elements cause the creation of complex molecules in space. On Earth (and possibly elsewhere) elements stimulated by energy can create long molecule chains: amino acids that are the precursors of life as we know it.

This universality is crucial for ETI. If evolution is indeed the universal law it seems, then we have the basis for some comparisons that go beyond the Earth we know. We can speculate intelligently on possibilities elsewhere.

2.4.2 The Chemical Basis

The interaction of atoms, brought together in larger groups of molecules, constitutes what human science arbitrarily defines as a specific discipline: chemistry. The interaction of atoms requires energy, as does any other interaction, and certain inviolable laws of chemistry derive from the basic laws which compose the universe: certain elements interact better, or to a greater degree with some, and worse, or to a lesser degree with others. These differences determine the conceivable building blocks of organisms that can be termed living. Insofar as we know, these laws apply throughout the universe. That is, an oxygen atom and a carbon atom are the same throughout the universe, as are their features. Consequently, under the same circumstances, their interactions will be similar, whether on Earth or on a planet across the Galaxy. This is important for it allows us to predict what combinations are impossible, which are possible, even which are likely.

Life on Earth is based on the reaction and combination of several elements, the principle of those being oxygen and carbon. Other elements—sulphur, potassium and metals such as iron—are essential for our form of life, and may be essential for the energy exchanges that power all life. These interactions, in themselves, are sufficient for the creation of very varied life forms, as they have done on Earth. At the molecular and unicellular level, life could have risen through several distinct pathways which are not mutually incompatible (cf. Russell and Hall 1997; Lahav et al. 2001). This has significant implications. If life has arisen several times *and succeeded* on Earth, then given similar conditions, it may well arise elsewhere. Whether it becomes complex enough to form multicellular organisms, even intelligence, is a separate issue (Bainbridge 1983).

2.4.3 That Thing Called Life

Well, what then is life? Or, again, to use our particular lens of the ILF perspective, what can we identify as life? The question has, of course, many ramifications, ranging from the purely taxonomic and scientific, to the religious and theological, even artistic. The abstract question of 'what is life' is less critical for the issue of ETI, than the concrete issue of the *product* of life.

However. Roughly speaking, for biologists, life is identified by the presence of three characteristics:

- Self-reproduction (that is, some copying of the parent organism)—without which genetic information would be lost after each generation.
- Mutation—without which genetic information is 'unchangeable' and hence cannot even arise.
- Metabolism—without which the system would regress to equilibrium, from which no further change is possible (Murphy and O'Neill 1995).

We therefore come closer to accepting that evolution is a natural law for the universe: the development of complexity from simplicity.

2.4.4 Biological Basis and Biological Preconditions

Once life has arisen, it starts a process of interaction, with other life forms and with its environment. On Earth that interaction *apparently* has been one of competition for resources, and consequently of the evolution of more complex forms. This process, the Darwinian process, may or may not be universal. What is necessarily the case is that life will, wherever it emerge, start interacting with its environment in more-than-mechanical ways. On Earth, the competition for resources led to the evolution of eukaryotic cells. Unlike their predecessors, the prokaryotes, basic eukaryotes have a cellular membrane which protects the cell from its environment, and a cellular nucleus which contains genetic information. This means that eukaryotes are better able to survive environmental changes than prokaryotes, and that their survival strategies (e.g. the instruction 'develop a membrane') can be 'taught' to other eukaryotes *if* a method of exchanging genetic information can be developed as well. Which it has been. Once these principles—‘develop specialized cellular elements’, and ‘exchange information for survival’—have been implemented, one can also learn how to specialize, aggregating individual cells into simpler, then more complex colonies. The rest, as they say, is history.

Emergent Properties
A significant issue in the emergence of life is what is now being called “emergent properties” a concept formalized through the study of complexity. Roughly put, the properties of a complex body of any sort are not predictable from the properties of the components that make it up. Thus, while living things on Earth are made up of proteins carbohydrates and fats (all types of molecules) mediated by DNA and RNA (other types of molecule) the molecular interaction is insufficient to predict, let alone explain, the American Declaration of Independence, the Forbidden City in Beijing, or the works of Beethoven. The complex specialization-cooperation-competition of colonies of eukaryotes (you and I included) is insufficient to explain cultural products, or even social practices. From our perspective, the critical implication of emergent properties that needs to be kept in mind is that *it will be impossible to predict the complex features of ILFs—their social arrangements and culture—from elementary principles*. In other words, familiarity with an ETI’s molecular or cellular composition may tell us something about what that being is *not*, but very little about what it *is*, let alone what it thinks, produces, or communicates. On the plus side, however, knowing that ETI are most likely formed as we are—some arrangement of cooperating, specialized cells and elements—means that the evolution of complexity is a universal law. This principle is important, because *maybe* we can assume the same principle is true for more complex behaviors as well.

2.5 Conclusions to Chapter 2

One major important fact emerges from this chapter. *If* there exist intelligent life forms, they *can*, and perhaps will come into contact. This is the premise of this book: that indeed contact and communication will occur, and that initial steps must be taken to ensure that such contact is fruitful and successful.

All of the physical and cosmological issues discussed above are the stage for ETIs. They also point out some of the difficulties we are likely to face in the search for ETI. They do not, however, indicate with any convincing data that there are, or there are not ILFs beside us. The question is, and will remain for some time, a moot issue. In the final analysis it can only be decided empirically, and, in the absence of proof to the contrary, we are free to assume that the phenomenon exists. First, negative evidence do not prove the existence or absence of a phenomenon. The fact we are *unable* to find ETI is not the same, scientifically, as the fact of their nonexistence. Second, no less importantly, the SETI effort is in a sense an insurance against the positive case: that there are ETI somewhere in the universe. The potential benefits of searching for them far outweigh the possible risks. Finally, there is also the issue of serendipity. Whether SETI does or does not achieve its ultimate goal, along the way, as is the nature of scientific research, many other sets of valuable data, of techniques, of theories, are likely to emerge. These may well create undreamed of-as-yet technological spinoffs.

References

Ashkenazi, M. (1995). Will ETI be space explorers? Some cultural considerations. In G. S. Shostak (Ed.), *Progress in the search for extraterrestrial life*. San Francisco: Astronomical Society of the Pacific Conference series#74, pp. 507–20.

Bainbridge, W. S. (1983). Attitudes towards interstellar communication: An empirical study. *Journal of the British Interplanetary Society, 36*, 298–304.

Ball, J. A. (1973). The zoo hypothesis. *Icarus, 19*, 347–49.

Battison, L. (2011). Niche habitats for extra-terrestrial life: The potential for astrobiology on the moons of Saturn and Jupiter. *Journal of Cosmology, 13*, 3890–3903.

Beckwith, S. V. W. (2008). Detecting life-bearing extrasolar planets with space telescopes. *The Astrophysical Journal, 684*(2), 1404–1415.

Beichman, C. (2002). Captain cook, the terrestrial planet finder and the search for extraterrestrial intelligence. F - arXiv:astro-ph/0212336.

Finney, B. R., & Jones, E. M. (Eds.) (1985). *Interstellar migration and the human experience*. Berkeley CA: University of California Press.

Bergerac, C. de. 1923. (1662). *Voyages to the moon and the sun* (R. Aldington, Trans.). London/New York: Routledge & Sons Ltd/E.P. Dutton & Co.

Billingham, J. A. (Ed.). (1981). *Life in the universe*. Boston: MIT Press.

Bracewell, R. L. (1981). Manifestations of advanced civilizations. In J. Billingham (Ed.), *Life in the universe* (pp. 343–350). Boston: MIT Press.

Brin, G. D. (1983). The 'great silence': The controversy concerning extraterrestrial life. *Quarterly Journal of the Royal Astronomical Society, 24*, 283–309.

Ćirković, M. M. (2001). Is many likelier than few? A critical assessment of the self-indicating assumption. F - arXiv:gr-qc/0110002.

Crowe, M. J. (1986). *The extraterrestrial life debate 1750–1900*. Cambridge: Cambridge University Press.

Dick, S. J. (1999). *The biological universe: The twentieth century extraterrestrial life debate and the limits of science*. Cambridge: Cambridge University Press.

Dick, S. J. (2013). The societal impact of extraterrestrial life: The relevance of history and the social sciences. In D. A. Vakoch (Eds.), *Advances in Astrobiology and Biogeophysics* (pp. 227–57). Berlin, Heidelberg: Springer Berlin Heidelberg.

Drake, F. D. (1967). *Intelligent life in space*. New York: Macmillan.

Drake, F. D., & Sobel, D. (1992). *Is anyone out there? The scientific search for extraterrestrial intelligence*. New York: Delacorte Press.

Einstein, A. (1955). *The meaning of relativity*. Princeton: Princeton University Press.

Exoplanet.eu. (2016). *The extrasolar planet encyclopedia*. http://Exoplanet.eu. Accessed July 4, 2016.

Forgan, D. H. (2009). A numerical testbed for hypotheses of extraterrestrial life and intelligence. *International Journal of Astrobiology, 8*(02), 121–131.

Forgan, D. H., & Elvis, M. (2011). Extrasolar asteroid mining as forensic evidence for extraterrestrial intelligence. *International Journal of Astrobiology*, *10*(4), 307–313.

Freitas, R. A. (1980). A search for natural or artificial objects located at the earth-moon libration points. *Icarus, 42*, 442–447.

Gardner, J. (2003). *Biocosm: The new scientific theory of evolution: intelligent life is the architect of the universe*. Makawao Maui HI: Inner Ocean.

Genzel, R., Eisenhauer, F., & Gillessen, S. (2010). The galactic center massive black hole and nuclear star cluster. *Reviews of Modern Physics, 82*, 3121–3195.

Gleiser, M. (2010). Drake equation for the multiverse: From the string landscape to complex life. arXiv:1002.1651.

Hart, M. H. (1982). An explanation for the absence of extraterrestrials on Earth. In M. H. Hart & B. Zuckerman (Eds.), *Extraterrestrials: Where are they?* (pp. 1–8). New York: Pergamon.

Hart, M. H., & Zuckerman, B. (Eds.). (1982). *Extraterrestrials: Where are they?*. New York: Pergamon.

Hawking, S. (1988). *A brief history of time: From the big bang to black holes*. Toronto [u.a.]: Bantam Books.

Hawking, S. (1993). *Black holes and baby universes and other essays*. London: Bantam Press.

Heath, M. J., Doyle, L. R., et al. (1999). Habitability of planets around red dwarf stars. *Origins of Life and Evolution of the Biosphere, 29*(4), 405–424.

Hodges, W. (1985). The division of labor and interstellar migration: A response to ‘demographic contours. In B. R. Finney & E. M. Jones (Eds.), *Interstellar migration and the human experience*. Berkeley: University of California.

Keszthelyi, L. P. (2011). Planetary science: Europa awakening. *Nature, 479*(7374), 485–485.

Kingsley, S. A. (2001). *Optical SETI observatories in the new millennium: A review*. http://www.coseti.org/pdf/4273-06.pdf

Lamm, N. (1978). “The religious implication of extraterrestrial life. In A. Carmell & C. Domb (Eds.), *Challenge: Torah views on science and its problems* (2nd ed., pp. 354–398). New York: Feldheim Publishers.

Levin, G. V. (2010). Extant life on Mars: Resolving the issues. *Journal of Cosmology, 5*, 920–929.

Maccone, C. (2010). The statistical Drake equation. *Acta Astronautica, 67*(11-12), 1366–1383.

Margulis, L., & Lovelock, J. E. (1974). Biological modulation of the Earth’s atmosphere. *Icarus, 21*, 471–489.

Murphy, M. P., & O’Neill, L. eds. (1995). *What is life?: The next fifty years: Speculations on the future of biology*. Cambridge: Cambridge University Press.

Noam, L., Nir, S., & Avshalom Elitzur, C. (2001). The emergence of life on Earth. *Progress in Biophysics and Molecular Biology, 75*(1–2), 75–120.

Oliver, B. M. (1976). Proximity of galactic civilizations. *Icarus, 25*, 360–67.

Oliver, B. M. (1986). Technological civilizations. *Journal of the British Interplanetary Society, 39* (7), 327.

Petigura, E. A., Howard, A. W., & Marcy, G. W. (2013). Prevalence of earth-size planets orbiting sun-like stars. *Proceedings of the National Academy of Sciences, 110*(48), 19273–19278.

Petit, J. -M., Alessandro M., & John C. (2001) The primordial excitation and clearing of the asteroid belt. *Icarus*, *153*(2), 338–47.

Renard, J. B. (1986). La Croyance Aux Extraterrestres: Approche Lexicologique [Belief in Extraterrestrials: A Lexicological Approach]. *Revue francaise de Sociologie, 27*(2), 221–29.

Robitaille, T. P., & Barbara, W. A. (2010). The present-day star formation rate of the milky-way determined from Spitzer detected young stellar objects.” F - arXiv:1001.3672.

Russell, M. J., & Hall, A. (1997). The emergence of life from iron Monosulphide bubbles at a submarine hydrothermal redox and Ph Front. *Journal of the Geological Society, 154*(3), 377–402.

Sagan, C., & Drake, F. (1975). The search for extraterrestrial intelligence. *Scientific American, 232*, 80–89.

Sagan, C., & Shklovskii, I. S. (1966). *Intelligent life in the universe*. New York: Dell Books.

Shapiro, R., & Gerald, F. (1982). Possible forms of life in environments very different from the Earth. In M. Hart & B. Zuckerman (Ed.), *Extraterrestrials: Where are they?* (pp. 113–121). New York: Pergamon Press.

Tarter, J. (1985). Searching for extraterrestrials. In E. Regis (Ed.), *Extraterrestrials: Science and alien intelligence* (pp. 167–189). Cambridge: Cambridge University Press.

Tipler, F. J. (1981). Extraterrestrial intelligent beings do not exist. *Physics Today, 34*, 9–81.

Wolf, F. A. (1988). *Parallel universes: The search for other worlds*. New York: Simon and Schuster.

Wolf, F. A. (1989). *Taking the quantum leap: The new physics for nonscientists*. New York: Perennial Library.

Yung, Y. L., Russell, M. J., & Parkinson, C. D. (2010). The search for life on Mars. *Journal of Cosmology, 5*, 1121–1130.

http://www.springer.com/978-3-319-44455-0

What We Know About Extraterrestrial Intelligence
Foundations of Xenology
Ashkenazi, M.
2017, XVIII, 430 p., Hardcover
ISBN: 978-3-319-44455-0