Answering the Fermi Paradox:
Exploring the Mechanisms of Universal Transcension,
© 2002-2010 John M. Smart

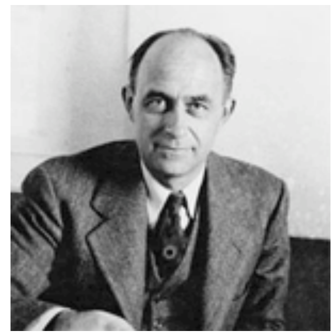
Published in *Journal of Evolution and Technology (JET)*, June 2002.
Further revisions here in June 2005, Sept 2006, Jan 2007, Dec 2008, Mar 2009, Aug 2010.

[Permalink: **http://accelerating.org/articles/answeringfermiparadox.html**]

A longer treatment of issues and assumptions relevant to this article may be found in:
Evo Devo Universe? A Framework for Speculations on Cosmic Culture (PDF), **2008-10.**

Overview

I wrote this piece as a formal response to the Fermi paradox, one of the most fascinating open questions about the long term destiny of intelligence in the universe. I came to these ideas in their essentials as a high school student in 1972 and have been refining them in lay readings ever since. I wrote it reluctantly in 2002, thirty years after conceiving the idea, as I have long expected someone with credentials in astrophysics and information theory to state what to me has always been the most obvious conclusion: universal intelligence is and always has been on a developmental trajectory to inner space, not outer space. Making information-theoretic arguments for constrained 'transcension' of universal intelligence as it develops, rather than cosmic expansion, is not likely to be easy with our current science. Nevertheless, the entire idea seemed both so intuitive and so overlooked both in the literature and by the cosmologists and astrobiologists of my acquaintance that I felt it necessary as a systems theorist and futurist to attempt to make the initial and tentative case, using a few quantitative but mostly qualitative arguments.



Enrico Fermi

Abstract

I propose that humanity's descendants will not be colonizing outer space. As a careful look at cosmic history demonstrates, complex systems rapidly transition to inner space, and apparently soon thereafter to universal transcension. For sixty years answers have been attempted for the Fermi paradox, yet the vast majority neglect what may be the most parsimonious explanation—a process of constrained universal transcension. I propose that any species or von Neumann probe complex enough to improve its intelligence while traveling through interstellar space would transcend shortly after beginning its journey, and less complex probes would not be sent for information theoretic reasons. The discrete universe that creates multi-local computational complexity rapidly becomes an "informational desert" (a well simulated past) to the leading edge of each local emergent intelligence. In an analogy to living systems, the universe is a finite developmental soma (body) that is deeply simulated in evolutionary terms by each local emergent intelligence (germline), and eventually outgrown, in a cosmic evolutionary developmental process we may term a "developmental singularity."

Intelligent life on our planet may be engaged in the creation of such a developmental singularity, a process that should be rapidly accelerated by the technological singularity likely to occur in this century. This trend is apparently driven and elucidated by the mechanism of space, time, energy, and matter (STEM) efficiency and density, or "compression," in all known universal computation. Emergent complex systems consistently discover how to use less, not more, of these finite universal resources (space-time and energy-matter) to encode standardized amounts of environmental information, and as a result become dramatically more materially, energetically, spatially, and temporally dense (accelerated) over time, rapidly approximating black hole-equivalent energy densities. Systems of emergent local complexity thus lead rapidly to "intelligent" cosmological developmental singularities, highly compressed structures, censored from universal observation, which are very likely distantly related to the quasars and black holes that are developmental endpoints of simpler (universal, galactic and stellar evolutionary development) cyclic physical-computational substrates in the multiverse.

Fortunately, researchers in astrobiology and the search for extraterrestrial intelligence (SETI) may provide empirical confirmation of this transcension hypothesis within the next few decades by actively seeking and identifying "radio fossils," which we define as *unintentional, weak, by-product transmissions* of kHz, MHz, and GHz radio signals (radio, TV, radar, etc.), that are statistically likely to emanate from the surface of all planets with early technological civilizations. We further argue that a predictable fraction of such signals must inexplicably cease transmitting as each civilization enters its own local developmental singularity. We argue that intentional, high-powered transmissions (aka 'beacons') are never constructed by advanced civilizations for ethical and information theoretic reasons, because such one-way messages can be clearly shown to reduce and homogenize, not improve universal evolutionary complexity en route to a developmental singularity, and because the physics of transcension will very likely tell us that the only way to meet and naturally select with other universal intelligences is to take the path of inner space, not outer space, in our cosmic future.

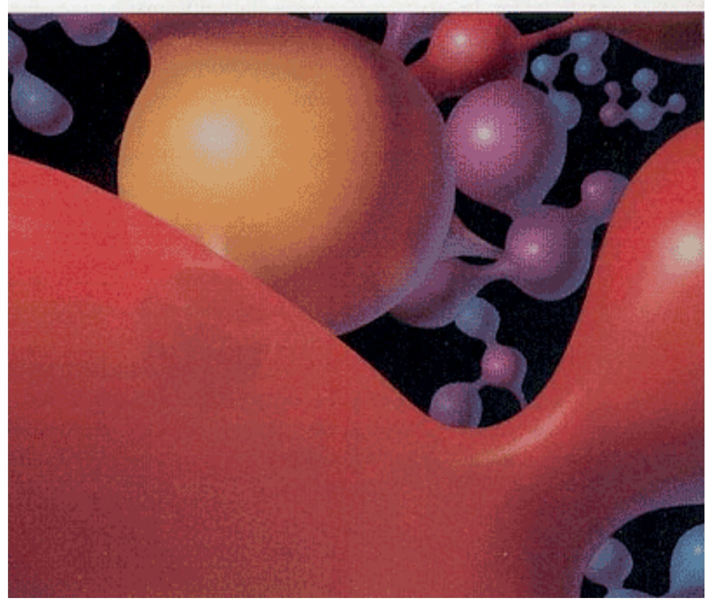
[Keywords: accelerating change, accelerating universe, anthropic principle, astrobiology, autopoesis, average distributed complexity, beacon communications, black holes, by-product communications, catastrophe, circumstellar habitable zone, computational closure, computational incompleteness, computational limits, convergent development, cosmological natural selection, dark energy, developmental physics, developmental purpose (teleology), developmental singularity, disposable soma theory, Drake equation, Encyclopedia Galactica, evolutionary development, evolutionary diversity (variability), expansion hypothesis, extra-solar terrestrial planets, fine tuning, Fermi paradox, free energy rate density, galactic habitable zone, galactic internet, general relativity, hierarchicy theory, hyperspace, information theory, intelligence, intelligence scanning horizon, interstellar communication, law of accelerating returns, law of locally asymptotic computation, Low Frequency Demonstrator (Mileura Wide-Field Array), STEM compression, multiverse, parsimony, particle horizon, Planck scale, positive-sum game, Prime Directive, radio fossils, redundancy, respiratory fossils, self-organization, self-similarity, SETI, simulation (consciousness, virtual reality), speed of light, technological singularity, transcension hypothesis, two-way communication (feedback), unique connective potential, universal evo devo, Von Neumann probe]

Introduction to the Transcension Scenario

Once hyperexponentiating computation has permeated virtually all the local matter and energy in its vicinity, what must it do next? There are at least two competing options that have been proposed by those presently forecasting the future of cosmic intelligence, expansion or transcension. In expansion, the current perspective of the overwhelming majority of thinkers on this subject, intelligence moves outward from its universal origin at some significant but finite fraction of the speed of light.

In transcension, once intelligence saturates its local environment, it is constrained to leave local spacetime. It learns how to enter hyperspace, that suspected multidimensional environment hinted at in our string, supersymmetry, and M-theory, and within which cosmologists tell us new universes may be born and other yet-uncertain events may happen. In transcension, advanced intelligence inevitably moves out of our slow and computationally-restrictive spacetime, multi-locally, once it reaches a certain point in its development. The developmental singularity hypothesis, elaborated below, is one of several possible versions of the transcension scenario, but it need not be proven correct for constrained transcension to remain the destiny of local intelligence.

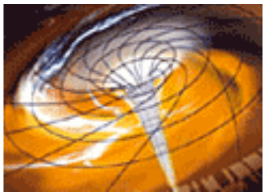
MULTIPLE UNIVERSES are continually being born, according to some cosmologists. Each universe is shown here as an expanding bubble branching off from its parent universe. The changes in color represent shifts in the laws of physics from one universe to another.



Cosmologist **Lee Smolin**, first in a 1992 paper ("Did the Universe Evolve?" *Classical and Quantum Gravity 9*, 173-191) and later in his 1997 book (*The Life of the Cosmos*) has presented early quantitative evidence that universes, which we now know to be sharply finite systems which begin taking themselves apart via dark energy at an accelerating rate after less than ten billion years of existence (see **Livio,** *The Accelerating Universe*, 2000), may nevertheless perpetuate themselves via "bounces" at black holes to create new universes within an cosmologically extended parent structure called the multiverse.

In Smolin's calculations, our universe appears tuned both to exist for billennia and to be fecund for black hole creation. He proposes a process of "cosmological natural selection" (what we would call evolutionary developmental selection, a distinction best elucidated in another discourse) that would explain, through a succession of prior universes, the emergence of many of the apparently carefully selected "anthropic parameters" of our present universe. That is parsimoniously self-similar to the way complexity has emerged in biological systems, and is a fascinating insight, but Smolin stops short of suggesting a role for intelligence in this line of universal descent.

The developmental singularity hypothesis, building on Smolin's insight, proposes that all emergent universal intelligence tends toward ever-greater space-, time-, energy- and matter-compressed ("STEM-compressed") computational substrates, following preexisting gradients built into the unique physics of this universe, which continually rewards ever accelerating miniaturization, density increase, and efficiency increase of autopoetic systems, ultimately ending in something analogous to a black hole. All of our universe's black holes might therefore exist on a continuum of replicative complexity, based on the autopoetic capacities and time-to-formation of their event horizons, ranging from quasar to galactic-core to early stellar black holes, which would be expected to create stable lineages of much simpler (and probably lifeless) universes within the multiverse, right on up to a subset of "intelligent black holes" that must also exist in our universe, transcension remnants of universal civilizations, each going on to develop even more complex intelligence-filled universes in the next timeline.



Transcension is a suspiciously elegant and parsimonious solution to the problem of the Fermi paradox. As **Timothy Ferris** (*The Mind's Sky*, 1992) points out, any single emergent intelligent civilization, if it wished, could colonize the Milky Way with a "galactic internet" of self-replicating robot probes in only tens of thousands to tens of millions of years. Even our nearest neighboring galaxy, Andromeda, is only 2.5 million light years away, a small hop by comparison to the four billion year developmental lead time (see Footnote 1) that early civilizations are likely to have had over us in our local galactic neighborhood.

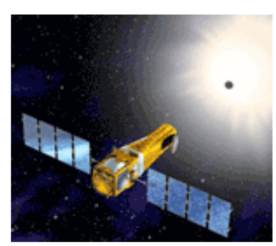
Parsing the Drake Equation

This article will build a case both for constrained universal transcension and for SETI's future role as a transcension verification tool, but before we can consider either we should refresh ourselves on the Drake Equation, formulated by physicist **Frank Drake** in 1961, a useful way to package interstellar communication issues into a discrete set of probabilities.

Drake proposed that the number of signals we might expect from our intelligent neighbors will be roughly based on the following terms (with our own eighth term added):

1. The number and rate of formation of suitable stars.
2. The fraction of such stars with planets.
3. The number of life-possible planets per solar system.
4. The fraction of such planets where life actually develops.
5. The fraction of life-bearing planets where intelligence develops.
6. The fraction of intelligence-bearing planets where technology develops.
7. The lifetime of communicating technological civilizations.
8. The desire for such civilizations to actively communicate ("beacon" versus "incidental' communication).

This eighth term is often inexplicably dropped from SETI formulations, but for transcension advocates, this is one of the most important in the bunch. It speaks to the question of whether we will be seeking "by-products" of intelligence when we look at a star and its planets (such as escaped television signals, or signs of a life-supporting atmosphere) or are instead looking for some powerful beacon, one specifically and expensively designed for interstellar communication. If we are seeking the former, our job is going to be much harder, and we may not even have the sensitivity to detect such signals until we have built detection programs in space, which we have not yet prioritized as a species.



There are two groups of opinion on the first six of the Drake terms. Most astrophysicists, citing the large numbers (at least a hundred billion stars our galaxy alone) known to be involved in the first term, believe life must also be ubiquitous. This is called an argument from "the law of large numbers." Successful planet hunters like **Geoff Marcy** have given us reason to suspect that the second term is also very large. By 2006, over 400 large gas giant planets have been discovered. Europe's COROT (picture right), launched Dec 2006, is the first space-based planet-hunting satellite, developed in a bid to discover the first rocky planets outside our solar system.

Astrobiologists, citing the ubiquity of Earth-like, life-supporting chemistry including water, small rocky planets of the right size and metallicity, spectral signatures for the critical elements, and a cosmochemistry that is known to spontaneously create complex organic molecules, including amino acids, lipids, and even pre-nucleotides (purines and pyrimidines), make increasingly convincing arguments that the third and fourth terms are also quite large.

But when we get to the fourth term, the probability of biogenesis, we run into the second major camp, the biologists. Everyone in this group has been educated with, and many have come to accept as their general paradigm, the incomplete "random and contingent" neo-Darwinian view of change ("life does not engender progress in generalized functional complexity, except in rare circumstances, and then only by chance"). In other words, they don't presently think about universal change developmentally, but rather only evolutionarily. The way development constrains evolutionary chaos and contingency, and the way initial conditions and the constancy of physical law (environment) creates path dependency in long range chemical and biological development is still poorly argued and poorly understood by life scientists. While evolutionary theory has made great strides in describing local contingency, a theory of evolutionary development, what we call meta-Darwinism, is only now in the early stages of emergence.

Because of this outlook, biologists such as **Francisco Ayala** think that life, and particularly intelligent life, must be extremely rare and contingent in the universe. Thus Ayala has used estimated low probabilities in these terms (particularly terms five and six), derived from his "randomness" perspective, to argue that our biological intelligence is likely to be alone in the galaxy.

Fortunately, there is an increasing minority of "developmentalist" (convergent evolution) scholars, such as **Simon Conway Morris** (*Life's Solution*, 2004), who argue that in addition to evolution, convergent evolutionary developmental processes must also operate on macroscopic timescales, significantly increasing the probabilities of the emergence of certain complex forms over time. In other words, our universe is not only enaging in evolution, but appears to be fine-tuned from its initial stages for special types of evolutionary development, including life and intelligence. This universal process of evolutionary development, or "evo devo," appears to be highly analogous to the way that an organism's genes become finely tuned, over successive cycles in the environment, to engage the organism not only in evolutionary experiment (building the organism at the molecular scale through stochastic chemical interaction, creating new sex cells in the gonads through genetic recombination, creating new ideas in the brain through memetic recombination, trying out new behaviors in the environment) but also in the developmental elaboration of form and life cycle (birth, maturity, reproduction, senescence, and recycling). In addition astrobiologists (see **Lunine,** *Astrobiology*, 2004) are beginning to learn to articulate the predictable (nonevolutionary, noncontingent) patterns of emergence of long range universal developmental form.

In addition, anthropic arguments for the fine tuning of the cosmic constants and initial conditions of our universe are further evidence for treating our universe as a long-range *developmental*, not simply evolutionary environment (for a still excellent introduction, see **Barrow and Tipler**, *The Anthropic Cosmological Principle*, 1988). Just as biological evolutionary developmental intelligence is *self-organized* in living systems (not a result of "intelligent design"), and just as emergent subsystems within all living organisms are able to gain an extended, accurate "model" of the system as a whole from their special developmental vantage point (your nervous systems and sexual organs are both good examples of this), we should likewise expect special emergent parts of our universe (us, in this case) to play the same cybernetic (steerage, self-and-world modelling) role. All that would be required for this to occur on a universal scale would be that the emergent intelligence have some nonrandom influence (a very incomplete and partial influence would be enough, just as in biological evo devo) on the success of the parameters of universes subsequent to ours in the multiverse. Intelligent life, in other words, is likely to have a highly specific evolutionary developmental role to play (a telelogy, or functional purpose) in multiversal context.

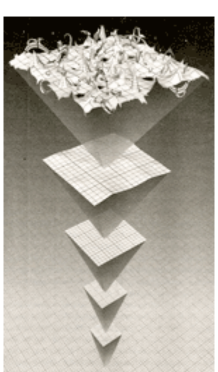
Those who admit the likelihood of universal evo devo would therefore argue that terms four through six of the Drake equation are likely quite large. Most would further argue that once you have one property (such as life), the next in the series becomes increasingly likely to emerge, in percentage terms, and thus if it can be determined that our galaxy provides plentiful planetary conditions for the long term existence of cellular life, then intelligent life and technology must also be plentiful. This is because developmental failures in biological systems (e.g., spontaneous abortions in mammalian gestation) are observed to become statistically much less frequent the further advanced the process, in time or complexity.

Given the curious evidence of the astrophysicist **Carl Sagan's** famous [cosmic calendar](), which tells us that complexity development is not only regular but it emerges at accelerating rates ever more locally in special environments over cosmic time, seems likely that the universal conditions for generating high yields of each of the terms in the Drake Equation will emerge both more rapidly and in an ever more predictable manner with later stages, due to our apparently life-friendly, intelligence-friendly universal evolutionary developmental programming. With regard to the sixth term, we can also use our single data point, technology development on Earth, to observe that it has continued this hyper-accelerating process of development. Indeed, many of our civilization's most recent inventions (electricity, silicon based computing, the internet) feel much less like evolution than they do the convergence of scientific possibility on inevitable developmental form.

This brings us to the seventh and eight terms, perhaps the least clearly understood of the lot, at present. Again, there are at least two distinct camps for these terms, those who expect either the expansion or transcension scenarios for intelligent life in the cosmos. There are of course other potential outcomes, such as the possibility of extinction in the process, which we must also carefully consider.

If you expect expansion, then you expect intelligent civilizations to move out as rapidly as they can, shortly after they develop. In that situation, you'd expect both of the last two terms to be very large. Unless you also expect that extinction is a frequent occurrence for intelligent civilizations, in which case you would expect the seventh term, on average to be small. But while extinction of individual species is quite frequent, the extinction, or even the slowing down, of the accelerating emergence of intelligence when defined as the "average distributed complexity" of the most complex local evolutionary developmental systems, has so far not been observed in any known epochs in our own evolutionary developmental record. (I'll discuss this fascinating phenomenon at greater length in my forthcoming book). So while the extinction scenario for intelligence is possible and must be continually guarded against, it seems extremely unlikely for human civilization, at least in our present analysis. Taking a short-sighted, dirty, dangerous, unjust, and unhealthy path toward transcension however, as opposed to a foresighted, clean, safe, fair, and healthy path, is another matter entirely, and squarely in the realm of our collective and personal sociopolitical evolutionary choice.

If you expect transcension, by contrast, you expect intelligent civilizations to leave the observable universe soon after they emerge, and you'd expect both the seventh and eighth terms to be very small.



With regard to the seventh term, **Seth Lloyd** has estimated in "[Ultimate physical limits to computation]()," *Nature*, 2000, that local computing may continue to accelerate (in other words, a generalized exponential **Moore's** law-following growth in local information processing may continue to hold) for as much as six hundred more years, as humanity's descendents drill closer and closer to the Planck scale in tomorrow's ever more miniaturized ecologies. Thus seven hundred years (600 plus our 100 year history of radio wave emissions) provides a good early guestimate for the average length of time we might expect intelligent life-containing planets to remain electromagnetically visible to this universe, prior to a developmental singularity transcension (whereupon the entire planet may transition to something that looks to us like a black hole, and may even be undetectable as such, from our vantage point).

Note that the ever more rapid development of each successive "stage," paradigm, or substrate of complexity in the universe argues that the lifetime of intelligent civilization (the seventh term) will be surprisingly short in cosmologic time, even as the probability of its emergence increases over previous substrates, before it proceeds to create something different, something presumably even more complex. On a surface level then, the dramatically progressive time compression of substrate lifespans argues for transcension over expansion, via the Drake terms.

But those backing that perspective still have a difficult challenge explaining why the eighth term would be so small. Many human beings today clearly desire to communicate with the rest of the universe. Not only SETI, but the Pioneer (10&11) and Voyager (1&2) probes (recall the Golden Record), soon to enter interstellar space, are good examples. In short, if we believe that intelligence in coming years will become much more of all those benevolent and capable attributes discussed earlier, wouldn't all advanced civilizations automatically desire to communicate?

Fermi's Answer: Two-Way Communication, Information Theory, and Communication-Censored Transcension

The developmental singularity hypothesis suggests several possible reasons why we should expect no intentional communication from other universal intelligences. In the transcension scenario, all intelligent civilizations, cosmologically-soon after they emerge, rapidly desire transcension. In other words, their science (and ours) soon discovers (e.g., through a coming **Albert Einstein** of developmental physics, plus a **Claude Shannon** of information theory) that all multi-local intelligence is developmentally tuned, statistically predetermined, to rapidly transcend as well, based on the unique structural parameters of this universe. If so, it would be quite rare to find two civilizations of comparable complexity both around long enough and close enough together to want to communicate before they transcended.

In such circumstances, it is also likely that the only kind of communication we'd be able to engage in, if our universe were tuned for intelligence transcension, would be very curiously constrained. *First*, it would have to occur in the very brief period before our own transcension, and *second*, it would in almost all cases be restricted to a benevolent one-way message sent to less complex systems, perhaps best exemplified as an "Encyclopedia Galactica" primer to help them along in their journey, as seen in Sagan's *Contact*, 1985/97.

In this model, we wouldn't be able to voyage to other star systems in person, because we are assuming intelligence overwhelmingly converges on transcension shortly after it emerges. Thus any robot probes we would send that were too intelligent would rapidly transcend themselves soon after beginning their journey. So the encyclopedia, dispersed by an army of sterile and specially complexity-limited probes, capable of replicating but *not* of increasing their own complexity, would be the only reasonable benificent communication we could expect.

But if twenty-first or twenty-second century Earth science discovers that *all* emergent universal intelligence is inescapably on a trajectory toward transcension, in order to exponentially grow their local and universal awareness, and that the inner space trajectory is the most rapid way to contact other advanced civilizations, we might, as in the Prime Directive in *Star Trek*, decide not to interfere with the natural course of evolutionary development of less complex civilizations. We might even be able to prove, with our near-future simulation science, that such interference (one way beacons) would decrease either 1) the internally balanced nature or 2) the evolutionary diversity of their transition, or both. Consider the apparent fact that we are limited to these one-way messages by the special self-organization of our universe, with a speed of light limit and vast gulfs of space between all the intelligent civilizations in the space time matrix. The special structure and physical limits of spacetime itself may soon make it clear that such communication will not be desirable. Indeed, that the universe itself has self-organized to minimize such communication, a generalized ethical injunction baked into cosmologic structure itself, one that all intelligences inevitably discover as their science advances.

General relativity appears at first glance to be a law of nature with no specific relation to emergent intelligence. But if transcension is possible, the GR "speed limit", and the time dilation that occurs with near-light-speed travel, both act to strongly discourage universal expansion vs. transcension of emergent intelligence. At the same time, the GR physics of black holes appears structured, via STEM compression, for the accelerating universal transcension of intelligence. Should these speculations prove true, we may come to understand that our universe self-organized with this special GR structure precisely to protect a vast number of local, isolated evolutionary computations of reality, presently occuring in each emergent civilization in the cosmos.

On Earth, almost all the most useful communication appears to be two-way. I can think of very few examples in biology where one-way communication survives for long. It is occasionally useful for top-down control, but it is never useful for botom-up complexity construction. In political ecologies, we know that centrally planned, command economies (one-way communication from the government) are always overwhelmingly replaced by ones that locally self-organize their own laws, markets, and prices via two-way communications equilibria. Feedback is an inherent aspect of building valuable complexity, and we use it whenever we engage in responsible, culturally-appropriate development on this planet. Are we sure we could give that up in any one way communication and still do net good? Can we prove it, or might we instead prove the reverse?

This brings us to the diversity argument, which from my perspective, seems the most powerful of all for a communication-censored scenario of universal transcension. One of the most important lessons that evolutionary development has taught us is that nature abhors sameness, monocultures, or “clonality” wherever it arises. (Remember the Irish potato famine?). Enforcing our own path to transcension on all those other civilizations via sending them a book of our learnings would condemn them to transcending in the same way we did, and substantially decrease the variability of their evolutionary paths. That in turn would significantly decrease the value and uniqueness of their intelligence in evolutionary developmental universe.

Assuming also that each intelligence path will be constrained by the limits of computation to come up with an essentially incomplete (**Godel, Church, Turing, Chaitin**) model of the universe prior to transcension, wouldn't we want multiple independent solutions to be generated to this most fundamentally interesting problem, one that we all share in common (where we came from, who we are, where we are going)? Again, if transcension is the default, it is beginning to look as though our present universe's structure (speed of light limit, almost unbreachable distances between civilizations) has been self-organized, probably over multiple cyclings in the multiverse, to protect this evolutionary variability. To maximize collective wisdom in an evolutionarily incomplete universe.

Inner Space, Not Outer Space - We Need An Anti-Kardashev Scale for Civilization Development

Committed space colonizers might try to override all this anyway (see for example **Adrian Berry's** *The Giant Leap*, 2001), but perhaps it is very difficult to go against the flow, and even statistically impossible. As mentioned earlier, it is becoming suspiciously likely that all cosmic intelligence heads inevitably toward “inner space,” not outer space, as it increases in computational complexity.

Futurists, engineers, and physicists frequently champion the Kardashev scale, which proposes that growth in the amount and spatial scale of energy use (planet, sun, then galaxy) is an appropriate metric for future levels of civilization development. But if STEM compression exists, this "expansion hypothesis" is 180 degrees out of phase with the vector of universal complexity development, which is transcension, not expansion. Cosmologist John Barrow in *Impossibility*, 1998, has usefully proposed an anti-Kardashev scale, where the appropriate metric is not total energy use, but the miniaturization of a civilization’s engineering. The developmental singularity hypothesis is a variant of Barrow's perspective which proposes that STEM density and STEM efficiency of our physical and computational engineering are the best metrics for an anti-Kardashev scale. Miniaturization is a good proxy for this, as the closer approach engineering on the Planck scale, the greater the densities and efficiencies of our engineered objects. But it is our increasing approach to black hole level densities and computational efficiencies (see **Seth Lloyd**, 1999 for more on black holes as the 'ultimate laptop') that truly measures civilization development.

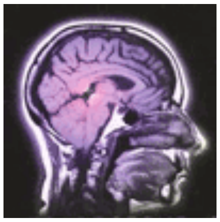
Our historical human era of planetary exploration may appear, on untutored examination, like a journey "outward", but actually, no new zones of space have ever been colonized, in an autopoetic fashion, by the efforts of later, more complex organisms arriving on the scene. In other words, the trajectory of hierarchically developing universal complexity has never actually involved a true journey out, in the cosmological sense. Even the cyclic birth and death of suns in supernovas is best seen as an initially galactic-scale event that rapidly creates locally interesting, high-metallicity solar systems within which further development occurs. And once biological intelligence emerges, all the really interesting computation occurs on one special planet per habitable solar system, on a sliver of surface between magma and vacuum that we call home.

In essence, all of Earth's human explorers have been part of a largely unconscious effort to wire up an already previously verdant Earth into one global technological intelligence—making our world smaller, not larger. Today's intelligent bipeds colonize only a small fraction of the space inhabited by our bacterial ancestors, who dwell at least six miles deep in our crust and two miles up in the clouds, as well as having left Earth entirely, and been transported to neighboring planets, as spores on impacting meteorites billennia ago.

The hyperexponential 'developmental' trajectory is always, on average, relentlessly inward, even as 'evolutionary' individuals regularly do exactly the reverse, using their own lives as experiments. It surprises me that this fundamental constraint, this overwhelming developmental vector, has been overlooked for so long.

Will technological intelligence require colonization of space to provide insurance against unanticipated catastrophe or aggression on Earth? There are arguments that a post- technological singularity civilization might create a few archives for Earth's intelligence in near space, timed to automatically redeploy in case of catastrophe. And technological systems are uniquely capable of such redundancy, where biological systems are not, which fundamentally improves their game theory and ethics of interaction in ways we biologicals don't fully appreciate.

Yet while we might easily place inanimate "seeds" in such archives, I suspect that any animate consciousness sitting in near-Earth space would feel banished, denied the vastly faster and more complex activities occuring on planet, in Earth's most advanced zones of inner space—paradises of nano, quantum, and eventually femtocomputation which we can scarcely imagine today. And with regard to outer space, there are no scenarios I can envision that would require or reward its use for redundancy, and none that would contribute to universal or local diversity versus simply staying here and rapidly minaturizing ourselves using local resources, which are more than abundant to the task, given the unreasonably pliant and rewarding nature of universal microstructure (again, an architecture that appears self-organized to continually drive STEM compression of intelligence).



Human consciousness, the emergence of inner subjective experience, is yet another prime example of the shift of the most complex local matter towards inner space. Consider that the average number of synaptic connections in one individual human brain, 100 trillion, is roughly 50 times greater than the number of stars in our entire Milky Way galaxy (200 billion). And there are almost seven billion unique individuals on the planet, at present. At the leading edge of universal complexity development, it's all about unique connective potential (computation and local diversity), not about large numbers of homogeneous units.

With the anticipated tremendous rise of simulation capacity in our nonbiological intelligent environments, and given the likelihood of an imminent computational closure in our models of universal space and time, this inner subjective experience is likely to become so well-developed that the computationally accessible aspects of outer space will rapidly become an informational desert, a "rear view mirror" on the trajectory of universal evolutionary development. At least one bold astronomer (**Martin Harwit,** *Cosmic Discovery*, 1981) has been willing to chart what he sees as the progressive decrease in truly novel astrobiological knowledge the more advanced our science becomes. We may call this phenomenon "computational closure", and we can observe it in any domain that is finite and mappable, allowing all the conceptual territory to be increasingly well traversed with time. The science of the large, with respect to developmental detail, is increasingly gap-filling, not paradigm-changing. **John Horgan's** intrepid work, *The End of Science*, 1997, is another excellent, yet early and incomplete contribution in this regard.

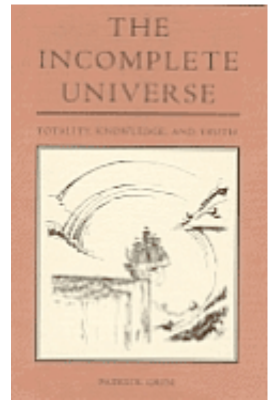
It is the science of the small, of inner and hyperspace, where our future unpredictable evolutionary creativity increasingly lies. There certainly remain important macroscopic experiments yet to be conducted, perhaps for several centuries more on this planet, yet I predict that the universe's entire macroscopic structure will be increasingly well mapped and understood by our future astrophysics, both in its developmental architecture and in the developmentally-constrained envelopes of its evolutionary paths, even as we remain unable to access the details of the evolutionary paths taken by other intelligences on their way to their own developmental singularities.

What will remain little known, by comparison, will be both the local particulars of each evolutionary environment, and the implications of our universe's "transcendent dimensions," how things might be in a different universe, with a different set of physical laws, and perhaps even more dimensional degrees of freedom. We would just be beginning to explore our computational potentials within the multiverse, versus our much more easily understood developmental constraints within our historical universal environment.

Thus I can find no special reason, frontier yearnings aside, why expansion of cosmic intelligence would suddenly start now, in violation of all past complexity development trends. At present I am a nearly lone voice making this prediction, and we will have to see if others join me in this perspective as our models and data become clearer. In my own future scenario, I can see post-singularity society building a few large sensor and experimentation instruments in near space, to verify the universal computational closure that we've already begun to discover with human-level simulation. In the process, I expect we will all continue rapidly progressing inward, journeying on into far more complex and interesting realms.

Unique Searches, Less-Random Trajectories, and the Role of Simulation

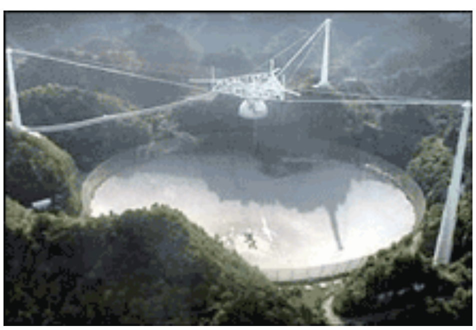
Transcension is thus apparently occurring multi-locally in isolated pockets of spacetime, in a universe that appears specially designed to protect the diversity of each emergent intelligence. Why? Because each local path is apparently a uniquely important search of total universal computational phase space. In other words, each intelligent system eventually discovers the developmental inevitability of the universal cycle (such developmental structure is apparently always easiest to detect first) and also realizes that comprehending the full evolutionary possibilities of each path taken remains significantly more difficult. We discover that to maximize universal computational complexity we must protect the variation of those paths, for while we may soon discover our local destiny, that doesn't tell us our ultimate destiny in the multiverse. If the universe, and all complex life, appears to "be" anything, it looks like a sentient system trying as many different ways to understand itself as possible, while it unfolds a constrained developmental cycle. And then, at regular intervals, it readjusts the entire parametric architecture to create greater individual and collective intelligence emergence in the next cycle.



The likelihood that we don't communicate with other intelligent civilizations from within this universe may be thus be one of the major lessons of information theory and evolutionary development. Apparently, the reorganizing of the parameters that we will do at the "bounce" (see Smolin) is just less random than the reorganizing that has occurred in prior epochs. In a universe that will always be essentially incomplete, in multiverse terms (see **Patrick Grim's** *The Incomplete Universe*, 1991), the intelligent search process may never get entirely nonrandom, no matter how intelligent the structures at the end of any developmental cycle. Evolution, while refining itself in yet-unclear ways over cyclic recurrences, may always be an essential feature of computational systems within the multiverse.

Discussing the coming of virtual reality, **David Gelernter** (*Mirror Worlds: Or the Day Software Puts the Universe in a Shoebox, How it Will Happen and What it Will Mean*, 1991) has observed that both we and our computers model a tremendous number of actions in the virtual space, but as these models grow in sophistication we paradoxically execute a progressively smaller number of actions in real space. We also use the data feeds from those progressively fewer real actions to keep building the quality of our inner worlds. Perhaps that aptly describes the local destiny of intelligence in this universe—a system that moves asymptotically toward reflection and computational refinement, and away from action and experience the closer the intelligence seed comes to the point of universal recreation. These are all early speculations, at present, but well worth considering, as we contemplate the real spatio-temporal constraints that will apply to the coming technological intelligence.

SETI's Unique Ability To Provide Empirical Evidence of Transcension



What kind of data would we need from our search for extraterrestrial intelligence (SETI) community in order to make developmental transcension a testable hypothesis?

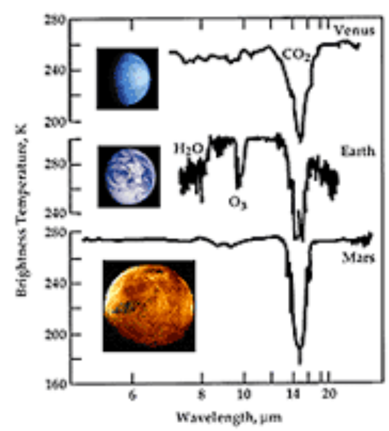
Perhaps the first "pre-verification" we can expect would be the discovery of **"respiratory fossils"** (spectra for atmospheric oxygen, methane, and nitrous oxide) as signatures of life, emanating from some of the Earth-similar exoplanets orbiting some of the nearest million or so G-type star systems. Discovery of such evidence of life is a very reasonable expectation from current trends in astrobiology and exoplanet astronomy, and would allow us to greatly improve the early terms in the Drake Equation, which estimate just how ubiquitous life is in our universe.

The next piece of evidence that would greatly help confirm transcension would be the discovery of **"radio fossils"** on some of these planets, low-power, nonrandom radio signals (radio, TV, and radar) emanating from the surface of some of these planets, which would represent unmistakable evidence that intelligent life has emerged on those planets. Earth has had as much as 70 years of this kind of radio signal broadcasting, emanating outward in all directions from our planet at the speed of light, ever since the first powerful radio beacons were built in the 1930's (see the movie *Contact,* for example). **Frank Drake** and others have noted that our increasing use of spread spectrum and digital EM, rather than narrowband broadcast analog EM, makes it increasingly difficult to detect Earth's intelligent EM signature. Thus the window for detecting unintentional EM from an early technological planet may be as short as 100 years. Yet as long as some Earthlings continue to use older analog signals for some tasks prior to the technological singularity, a detection window of 200 years, or the average lifespan between the invention of radio and the emergence of postbiological intelligence, seems a more appropriate estimate.

Such signals would be very weak, and would undergo extinction (absorption and scattering) with distance. Detecting them will require the building of a large radiotelescope array, probably in space, a job for twenty-first century teleoperated and increasingly autonomous robots. *If* we are able to find respiratory fossils from even a few planets within the next few decades, however, as seems very likely if we live in a biofelicitous universe, we can then reasonably expect that within the next generation afterward the world's scientific community might be able to secure the significant but still quite affordable expense of constructing a large space-based radiotelescope, capable of scanning *millions* of nearby G-type star systems for low-power radio emissions, as the next step forward in SETI development.

If the transcension hypothesis is true, and assuming that we have the ability to detect a reasonably large sample of such radio fossil bearing planets, we *must then observe* the regular disappearance of a steady fraction of such radio signals every year, as a steady, small fraction of these civilizations reaches an advanced stage in its technological evolutionary development, and then predictably transitions to a far more complex and compelling inner space future.

Furthermore, if the developmental singularity involves a generalized transcension of all local planetary life to inner space, and not simply intelligent life, which seems to this author a reasonable assumption, then *even respiratory fossils on these special planets should regularly wink out*, from this universe's perspective, as each entire planet undergos a transcension. For a rough visual reference for what I suspect must occur on all technologically advanced planets, recall the transformation of Jupiter at the end of the film version of **Arthur C. Clarke's** *2010*. Something analogous to the creation of an Earth-mass sized (or perhaps larger) black hole, but driven by *higher-intelligent* dynamics, not a gravitational process. It is even plausible that the creation of these small mass "intelligent black holes" as developmental singluarity endpoints, might also sent out unique and detectable signals (neutrino, X-ray signals, or even characteristic "ringing gravity waves"), as another form of observable astronomical evidence for transcension.

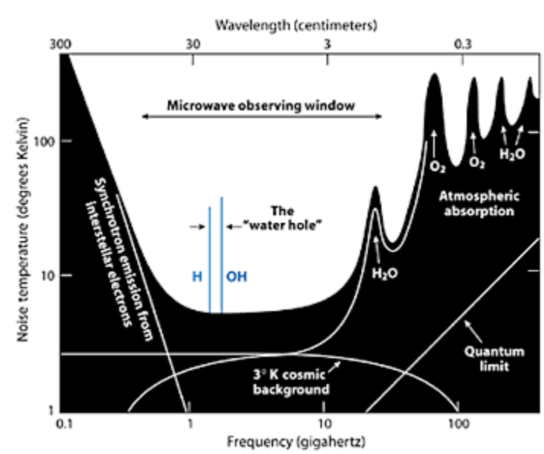


Infrared spectra of three terrestrial planets in our solar system.

Though their strength declines by a factor of four whenever the distance from the source doubles, radio waves (television, radar, radio, cellphones, microwave telecommunications) are considered the ideal band of the electromagnetic spectrum for interstellar communication, as they are relatively free of the absorption and noise that affects other bands, since stars are particularly quiet in large sections of radio wavelength.

Assuming transcension, the unintentionally emitted "by-product" radio communications (kHz to low GHz) seem the most promising signs of intelligence that we might detect. As this short report ("SETI Researchers Sift Interstellar Static for Signs of Life", 2004) on UC Berkeley's SERENDIP program notes notes, "Just as the 'local transmissions' of American television shows, such as "I Love Lucy" and "The Honeymooners," leaked out into space 50 years ago (and now have passed thousands of star systems), it is concievable that we could intercept some extraterrestrial situation comedy shows."

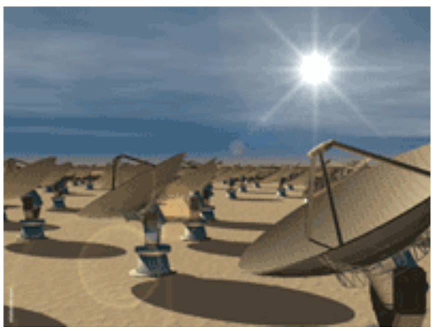
Unfortunately, searching for such subtle and unintentional signals has not been an option for SETI scientists, who have traditionally looked for high-power radio "beacon" communications. Our historical bias is understandable, as it is much easier and less expensive to search for beacons than by-products with first generation SETI technology. Furthermore, the assumption that other civilizations would desire to create beacons is a natural corollary of the expansion hypothesis.



SETI scientists tend to seek for beacon signals in the "water hole," a narrow radio frequency band between 1.4 and 1.6 GHz, between the neutral hydrogen line and the hydroxyl (OH) line, and a natural place to transmit such an intentional signal. Note however that the water hole is a small section of a much broader "window" of relative radio quiet (an area of low "noise temperature") for emissions from nonliving astronomical sources. From the picture right, from the website of astrobiologist **David Darling** (*Life Everywhere*, 2002), this window looks to be much larger, perhaps ranging from 800 MHz to 20 GHz when observing from the bottom of our atmosphere on Earth, and perhaps even larger when observing from space-baced radio observatories. **The transcension hypothesis would argue that looking for *low-power by-product signals* in this broad window, rather than high-power beacon signals in a narrow "water hole" window, may be the only successful search strategy for cosmic intelligence.**

Perhaps the earliest example of conceptual work to detect unintentional radio fossils is **Bernard Oliver and John Billingham's** Project Cyclops (1971), a Stanford/NASA Ames summer study, created by an interdisciplinary visioning group that sought to design specifications for the "ultimate" SETI-detection tool, a ground-based array of one thousand 100-meter dishes. It was this document that first identified the water hole as an ideal listening post for SETI technology. At the same time, according to Billingham, a functioning Cyclops would also be powerful enough to detect routine radio emissions (radio, TV, radar, etc.) from "a large number of neighboring stars." Unfortunately, the array's estimated $10 billion cost kept it a theoretical exercise at the time.

Recently, the SETI Institute and the Radio Astronomy Lab at UC Berkeley have begun to build the Allen Telescope Array (ATA) in California. Funded in large part by Microsoft co-founder **Paul Allen,** the ATA will eventually (funding is uncertain) grow to as many as 350 primary (6.1 meter) and secondary (2.4 meter) antennas. But even at full strength, will the ATA be sensitive enough to detect unintentional radio signals from enough stars to find a radio fossil? Perhaps not. One of the ATA's science goals will be to "Survey the 4×10^10 stars of the inner Galactic Plane from 1.42 to 1.72 GHz for very powerful transmitters". This sounds like very much less than we need to find low-power, accidental, by-product communications.



Nevertheless, g round based radiotelescopes may one day prove up to the task. SERENDIP director **Dan Wertheimer** says a ground-based square kilometer array (SKA) (artist's rendition left) having the equivalent collecting area of roughly ten Arecibo (Puerto Rico) telescopes, will have the power to detect unintentionally emitted television signals from nearby stars, without the need of prohibitively long signal integration times, which would be needed to attempt to search for such signals today at Arecibo. An international consortium is moving ahead on the design of Earth's first SKA, with design funds provided by the European Union. The array will be placed in either Western Australia or South Africa, and construction is estimated to begin in 2010, with initial observations in 2015, and full operation by 2020. The price tag will be only $1.6 billion, an affordable price for the knowledge that will come with this kind of sensitivity. See the SKA website for more on this amazing project. LOFAR, another array with a square kilometre collecting area, to observe in the frequencies below 250 MHz, and to be sited in the Netherlands, is also currently in design.

We may even be on the verge of gaining the ability to detect unintentional radio emissions from as many as *1,000* of our closest neighboring stars. As **Loeb and Zaldarriaga** note in this promising 2007 article, the new ground-based Low Frequency Demonstrator of the Mileura Wide-Field Array in Australia, being built for 2008 operation, will not only be able to detect leftover cosmic hydrogen from the Big Bang, it may be the first radiotelescope with the sensitivity to detect low power radio signals emanating within the nearest thirty light years (1,000 closest stars). While some think that ground-based radio interference will make such detection exceedingly difficult, such that groundbased radiotelescopes will never be up to this challenging task, astrobiologists are nevertheless building a SETI capacity into the system.

All of this is heartening news. If radio fossils are out there, we should expect to find our first one with ever-increasing probability within a generation of finding our first respiratory fossils. On first writing this article in 2002, without researching the state of the engineering efforts, I anticipated it might require elaborate space-based monitoring systems, and take eighty years (2080) before we'd discover our first radio fossils. But given the developments in ground-based observing in recent years, and the continued hyperexponential help of Moore's law, I am more optimistic today in 2010. With good luck in our exoplanet searching, we just might get empirical astronomical confirmation of the transcension hypothesis within this next human generation (25 years, or by 2035).

If that happens, such an exciting discovery might occur even before we have a universal information theory, a model of evolutionary developmental physics, that takes us to the same conclusion--intelligence goes to inner space, not outer space, as it increases its evo devo complexity. I am also hopeful that a variety of tests and confirmations will be used to verify both the technological and developmental singularity hypotheses in coming decades, and turn these topics into the formal scientific disciplines that I suspect they deserve to be.

So while I don't expect that we are the first intelligent life in our galaxy, I agree with **Ray Kurzweil** (see his SETI section in "The Law of Accelerating Returns," 2001) in his assessment that we should act as if we are the first, at least until we have incontrovertible data that prove otherwise. That just sounds like a responsible policy for intelligent civilizations in general.

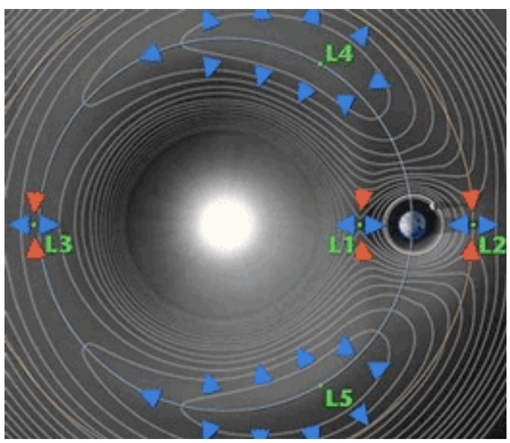
How many radio fossils should we expect to find? My own very crude guesstimates (see **Footnote 1**) with respect to intelligence emergence propose that we should expect to discover a population on the order of 22,000 by-product “radio fossils” of *unintentionally* communicating civilizations within our own Milky Way galaxy, and no beacons of any kind, as such communications would be both very expensive in time and materials for the host civilizations to produce, and if my arguments are correct, would be *unethical* to operate and *universally complexity reducing*, in information theoretic terms. If they occurred they'd be likely to be quite rare and short-lived events. Developmental failures, not the norm. Perhaps one in ten thousand galaxies might be "infected" with cases of intelligence expansion, rather than transenscion. If we look closely at our galaxies, we might discover a signs of such behavior, but they would be quite rare if transcension is a developmentally guided process.

My calculations are restricted to the Milky Way, the first place we are likely to develop a practical SETI detection capacity (radio or respiratory). But since there are 10 to 125 billion galaxies in the universe, and since some recent research estimates that about 40 percent of the universe is observable to Earth today (eg., is within our "particle horizon") this fossil number may grow to be many times larger in the long term future. Of course only a fraction of these observable galaxies will be streaming light that is *of the right age* to detect life or intelligence. And there may be a resolution limit for detecting both respiratory and radio fossils, due to attenuation and scattering with distance. Will the Andromeda Galaxy, for example, 2.5 million light years from us, and a very promising barred spiral galaxy like our Milky Way, be scannable for by-product radio fossils, or only for beacons, which our hypothesis argues are overwhelmingly likely to never be built? Even if we are restricted for the forseeable future to looking only within our own galaxy, the discovery and analysis of first respiratory and later radio fossils may become a major enterprise in the astrobiology of the late 21st century.

Given the cosmologically insignificant time interval between our own emergence of broadcast communications technology 100 years ago, and our own anticipated technological singularity, perhaps less than 100 years from now, we may guestimate that the fraction of time in which technological civilizations send out detectable unintentional radio emissions (radio, television, etc.) should, on average, as short as 200 years, after which they will wink out of existence, as their civilization first ceases radiative electromagnetic communication, then moves most, perhaps even all communication from narrowband analog to spread spectrum, digital, optical, quantum, etc. Eventually, such civilizations would transcend the biological and macrotechnological domain entirely, *leaving no other universal traces behind*.

If this lifespan estimate is correct, about 112 (22,500/200) of these radio fossils of older civilizations will cease emission annually, as they will be in their last year of transmission when we detect them. If we were able to actually decode such signals, versus simply demonstrate their complex and nonrandom nature (which may be all we will be able to do), we might further discover something interesting about them, perhaps right around the time they are entering a developmental singularity.

New extra-solar planet hunting tools will also greatly enhance our ability to map our galaxy's habitable zone in coming decades, and improve our estimates of the frequency of complex life. Now would be a great time to go into astrobiology, if you are a student with an interest in that field.



The European Space Agency's (ESA's) star surveying and planet hunting COROT satellite (Dec 2006 launch) will survey 120,000 stars for luminosity variations that should detect the rare transit of not only large gas giants, but even small rocky planets several times larger than Earth. ESA's Gaia (2011 launch) is an impressively innovative mission that will operate at the outer Lagrange point (L2), 1.5 million km farther from the Sun than Earth (see picture right), a space where the Sun's and Earth's gravity are equal, so it offers a stable orbit, and which is also permanently shielded from instrument sun blinding (see picture). Gaia will precisely survey one billion stars in our galaxy and beyond over five years. In addition to providing an extraordinarily precise galactic map, she will be able to detect massive numbers of extrasolar planets. Thus as **Plaxco and Gross** note (*Astrobiology*, 2006), by 2016 "we should know conclusively whether Earth-sized planets are common in our galaxy."

In Conclusion

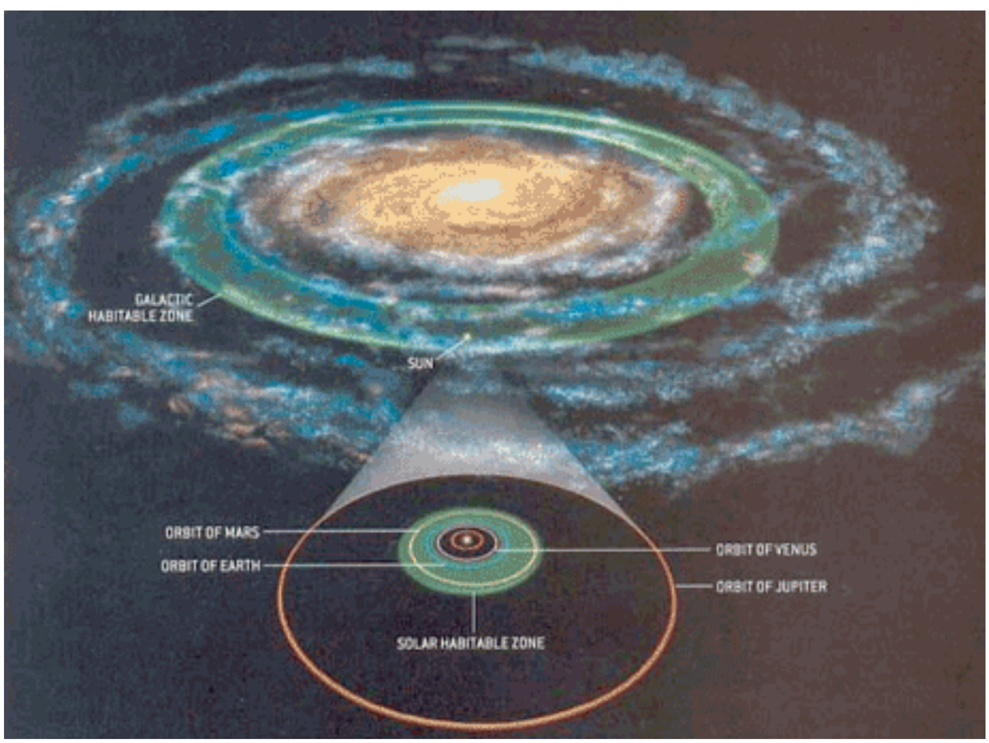
Recent developments in astrobiology, space science, and SETI hold the promise of providing evidence that we are not alone. But I'd also bet that cosmic intelligence doesn't stay in our universe for long. We will soon be in a position to answer this fascinating open question. If the answer turns out as I have suggested here, it will demonstrate the elegance of a universe that is apparently engaged in a developmental process that self-organizes to allow empirical confirmation of its developmental information theory, by all internally-developing sentient species who would choose to look for such confirmation.

That is just the kind of universe I would want to live in, one that strongly and continually provides positive sum rewards for the application of local intelligence.

Whether any of the speculations above turn out to have been correct, usefully wrong, or quite off the mark, if they stimulate a program of progressively better experimentation and analysis, they will have been worth the effort.

Feedback welcomed at johnsmart(at)acceleration.org. Thanks to **Martin Andersen** for helpful fixes.

> **Footnote 1.** Here I make a series of extremely crude guesses (I invite the specialists to help clean these up) to arrive at an estimate for radio fossil detection as a SETI transcension verification tool.
>
> The first guess involves the cosmic lifetime of an unintentionally communicating civilization. This is the least obvious parameter in the Drake equation: the length of time a civilization can be expected to one-way-communicate their intelligence to the stars, either unintentionally or intentionally, and the probability that they would want to communicate it intentionally (which I assume is effectively zero for the reasons given above). On Earth we've been transmitting unintentionally for approximately 70 years. If you assume we'll reach a technological singularity circa 2060, as I do, after which radio signals may significantly decrease, and that, using Seth Lloyd's guestimate of computational capacity, our entire planet might transition to a local developmental singularity perhaps 600 years from today, after which even respiratory signals might disappear, a radio communication lifetime around 200 years seems a reasonable estimate prior to "cosmic censorship". Fortunately, respiratory fossils should be around for billions of years per planet. Guestimating their presumably significantly higher detection rate is beyond the scope of this article.
>
> The second guess derives from Galactic Habitable Zone (GHZ) models in astrobiology. **Charles Lineweaver et. al.** (*Science*, Jan 2, 2004) have estimated that 10% of the star systems in our galaxy, those with sufficient distance from the galactic core, yet close enough in to have high metallicity ratios, are capable of supporting complex life. Their GHZ is a region



with stars roughly 4 to 8 billion years old, with 75% of the GHZ being older than our Sun, and whose average age is roughly 1 billion years older than the Sun.

Citing Lineweaver's work, and given the most common (and probably low) estimate that there are 100 billion stars in the Milky Way (Allan 1973), **Rasmus Bjork** (2007) estimates the number of GHZ stars capable of supporting complex life is roughly 12 billion. According to Lineweaver, 75% of these, or 9 billion, are older than our Sun, and thus might have sent radio emissions already. All 12 billion might have sent off respiratory fossils, but again, detecting the latter isn't the subject of this article.

Considering the narrowness of our own circumstellar habitable zone (0.95 to 1.3 AU, at present, where Earth averages 1 AU from the Sun) we may expect only one planet per star to have complex life, on average. Considering life development as one of the purposes, or teleologies of the universe as a self-organizing system, I would guestimate that half of these (or 4.5 billion planets) would successfully develop complex life with detectable respiratory fossils, and that half of these again (2.25 billion planets) would harbor life that exists long enough to allow intelligence and technological civilization to emerge. This means we are looking for 2.25 billion special planets that emerged over a timeframe anywhere from a year ago to 3.5 billion years ago (the difference between 8 billion years ago and the 4.5 billion year age of our Sun and Earth).

The next guess estimates how many of these transmitting civilizations are likely to have emerged within the last 35,000 years, my guesstimate for our "galactic scanning horizon," or the age range in years of the relevant radio waves currently streaming past our observation point here on Earth. This horizon number comes from a guess of the average distance in light years from Earth to all other habitable-zone galactic stars, which form a ring-shaped region roughly 25,000 light years from the galactic core. We must remember that if transcension is correct, the vast majority of our galaxy's intelligent radio communications would emerge and then disappear in a cosmic flash, either long before or long after the period of time in which we are presently searching. Thus their existence would be hidden to us here in the present time.

Assuming equal emergence ratesover this entire time frame, which may not be correct, and assuming our galaxy's dust clouds don't obscure the low-power radio emissions from any significant fraction of these, which may also not be correct, we get:

> 2.25 billion equivalent-aged or older technical civilizations x (35,000 years/3.5 billion years) = **22,500** "radio fossils" that should be detectable in our galaxy.

Assuming a 200 year radio emission lifespan, on average 112 of these would be in their last year of transmission when we find them, just heading into inner space. Their signing off, or winking out, might be especially interesting. In addition to providing hard justification for transcension, they might even send out some inocuous "signing off" signal, perhaps even conveying the information theorem that tells us they are heading inward. Perhaps even telling us that we'll soon be joining them there.

If instead we assume one million technical civilizations in the Milky Way, per Sagan, and if 75% of these are older than our Sun, per Lineweaver, we get:

> 750,000 equivalent-adged or older technical civilizations x (35,000 years/3.5 billion years) = **7.5 fossils**

This would make SETI's job a lot harder, and confirmation of the transcension hypothesis even harder. We'd find only a few fossils, and would have to wait decades before one of them might wink out.

In closing, my guestimate of 2.25 billion intelligent planets in our Milky Way is much larger than what is found today in the professional astrobiology community. It is larger by three orders of magnitude than the late Carl Sagan's estimate of one million such civilizations, and significantly larger than **Frank Drake's** estimate of 10,000 communication-capable civilizations, and **Peter Ward and Donald Brownlee's** estimate (*Rare Earth*, 2000) of "perhaps only a few thousand" such civilizations.

My estimates stem from an intuition that life's emergence is a ubiquitous and well-constructed developmental process, as noted earlier, and that developmental failures late in the process, such as in the transition from life to technology-using life, would be statistically much less frequent than early in the process, such as in the transition from complex planetary chemistry to the first cells. I call this increasing probability of continued development as a function of complexity a "law of developmental immunity". If it exists, astrobiology should be able to verify it in coming decades.

It should be pointed out that even if 2.25 billlion intelligent planets is three orders of magnitude optimistic for this galaxy, this estimate could still be conservative if we are able to scan large numbers (thousands?) of nearby galaxies for radio fossils, a prospect and calculation that is beyond my present ability to guesstimate. In the latter case, our detection timeframe may be delayed by another century or so, as it might take a bit longer for us to develop space-based detection equipment capable of analyzing respiratory and radio fossils from nearby galaxies, with stars that are millions to hundreds of millions of light years distant from us, not tens of thousands.
