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MYSTERY OF THE GREAT SILENCE

BY DAVID BRIN

I first heard the subject of extraterrestrial intelligence brought up at a scientific seminar in 1968, when a speaker suggested that pulsars—then newly discovered—might be beacons of an advanced civilization. He was only partly serious, but it was soon clear that most of those with tenure didn't like this kind of talk at all. Only a few years later, however, some of those who were angriest in 1968 applauded when Carl Sagan unveiled at Caltech a gold "message" plaque to be placed upon Pioneer 10, the first human artifact that would leave the solar system.

Soon scientists were discussing not whether extraterrestrial intelligences exist, but how to go about listening for signals from our nearest neighbors, adapting radio telescopes for the search and asking, "Is anyone out there?"

But the voices of the critics never really went away. For no sooner had it become legitimate to inquire, "Where are they?" than new questions were raised asking, "Why aren't they here already?"

But let's not get ahead of ourselves. To early xenologists it was dangerous enough talking about alien life forms without risking one's scientific reputation talking about interstellar travel. Thus, modern scientific xenology first dealt with the possibility of life springing up in isolation among the stars—yielding islands of sentience separated by vast distances and for all time.

Early students of this new science, no matter how daring, were faced with one major limitation: a near total lack of data. Still, certain scientific discoveries, combined with a useful philosophical tool, gave researchers the courage to make crude estimates.

First, it was found almost ridiculously easy to make amino acids and

other precursors to living matter from abundant molecules such as methane, ammonia, and cyanogen. Harold Urey and Stanley Miller subjected a solution of these substances to electrical discharge and ultraviolet radiation and got an organic "soup" in short order. Furthermore, during the last two decades, radio astronomers have discovered great clouds of complex molecules drifting in space: ethylene, formaldehyde, and ethyl alcohol among them.

It's clear the raw materials for life are out there. But what about the right environments? For simplicity, we have to assume it's most likely for complex life to grow and evolve where we did, on planets orbiting stable stars. While there is, as yet, no proof that other planetary systems exist, rings of dust have been discovered circling nearby stars Vega and Beta Pictoris, and many astronomers believe stars like our Sun are naturally born with companions.

Finally, the philosophical tool mentioned earlier, which caps the legitimacy of xenology, is called the cosmological principle, or the "assumption of mediocrity."

Since Copernicus, astronomy has given us a series of lessons in humility, all leading to the conclusion that there is nothing special about where and when we are. First the Earth was displaced from the center of the solar system, then the Sun became a nondescript traveler in orbit about the rim of the Galaxy. Finally, the Galaxy became merely one island universe among billions, and the Universe seems to have no "middle" at all.

The cosmological principle tells us we should avoid the temptation to think that there's anything unique about the Earth in space, time, or situation. Therefore, what has happened here might happen elsewhere, perhaps many times.

THE DRAKE EQUATION

The most popular way to guess at the possible distribution of technological species was invented by then Cornell Professor Frank Drake when he was at the Arecibo National Radio Observatory. It remains a widely accepted tool for xenological speculation.

Let N equal the current number of technological civilizations in the Galaxy. Then

$$N = R_* f_p n_e f_l f_i f_c L$$

There are reasons to believe that it is short about three factors. But we'll tay with this version for a while. During the 1960s, with plenty of up-and-lown leeway in every parameter, Carl Sagan and others estimated that.

$$N = 0.01\ L$$

This meant the average life span, *L*, of technological races determines the number present in the Galaxy at any time. If self-destruction is the common fate of "civilized" species, there might be no more than a handful in the Milky Way at a given moment. But if a reasonable fraction live long, the Galaxy might teem with intelligent life.

If the planets of a million stars held sophont races, then about one thousandth of a percent of eligible stars in the Galaxy would be orbited by thinking beings. The average distance separating these islands would be several hundred light-years—a gap easily crossed by radio waves.

This was the state of affairs in the early 1970s. The accepted model depicted isolated motes of intelligence separated by sterile tracts of space. Frank Drake and his associates began the search by looking at the nearest candidates. But they found only star noise coming from Epsilon Eridani and Tau Ceti.

Undaunted, they and others expanded the search. Telescopes turned and scanned. The Russians joined in enthusiastically. They too reported only negative results. (In the Soviet Union, extraterrestrial intelligence was not only considered possible, but required by Leninist dogma.)

Astronomers suggested that no advanced species would waste energy broadcasting over the entire radio spectrum. To conserve power and attain a high signal-to-noise ratio, they would modulate over a very narrow frequency band. Yet even the second and third generations of eavesdropping devices, tuned to seek in narrow, so-called water-window or water-hole bands, have come up with nothing so far. Though better instruments are planned, and some radio xenologists are promising vastly improved searches, others have begun glumly proposing that no one is "out there" after all, at least not in our vicinity.

Why this new pessimism? We've only been at the search for less than fifteen years, using spare time and borrowed equipment. According to most calculations using the Drake Equation, the average distance between technological civilizations might be six hundred light-years, or two hundred parsecs. There are well over a million stars in a sphere that wide centered

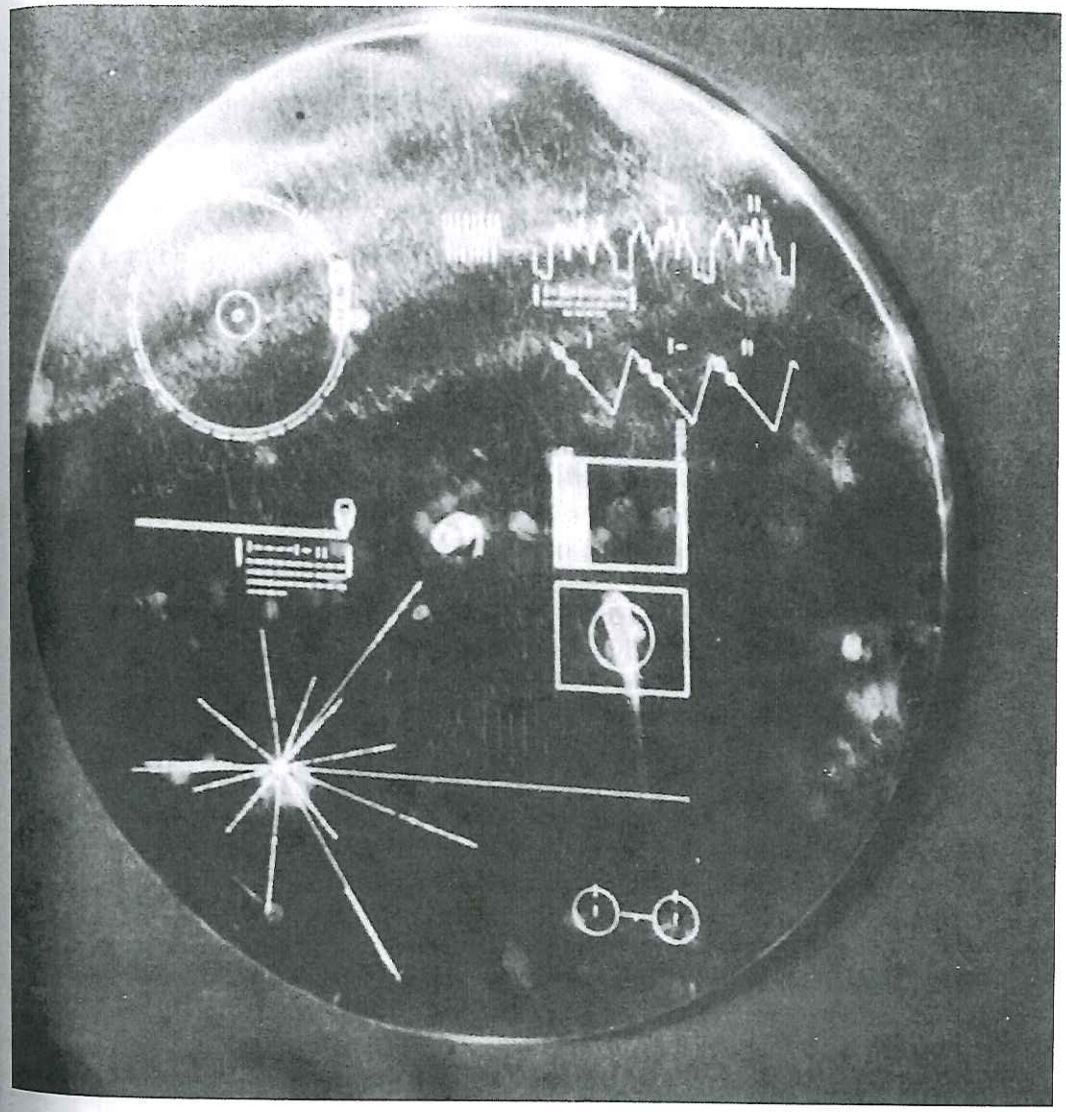

Figure 1. The Voyager record, attached to the spacecraft, contains coded information about us, our planet, and our location in the Galaxy. *(Photo: Courtesy NASA.)*

on the Sun. It would take a long time to search even the most likely of these, choosing only those radio bands we guess to be the best.

Two hundred parsecs makes "conversation" a little difficult. But a Sesame Street beacon would be as useful as ever, at that range. And just knowing extraterrestrials exist might profoundly boost poor Homo sap's sagging morale. Success, in the long run, seems assured to the persistent.

What has changed then? What has caused this spreading anxiety?

It's not the sort of thing one would expect to be a cause for pessimism. At first hearing, it sounds like very good news: starships are possible!

THE THIRD ERA OF XENOLOGY

Sometime in the mid-1970s, several prominent scientists challenged the conventional wisdom that intelligent life arises upon isolated islands, forever separated by the wide gulfs of interstellar space. Ron Bracewell, Robert Forward, and others demonstrated that it's possible, in theory, for spaceships to cross the emptiness between the stars. No "magic" is needed. It isn't necessary to repudiate Einstein. Whether by light sail or anti-matter rocket, humanity may be launching its own starships within a few centuries.

These starships will be nothing like the good old *Enterprise* of television. Limited to possibly a tenth the speed of light, they couldn't travel far by interstellar standards. But they might carry people, possibly several generations, in transit. The "slowboat" generation-ship of science fiction has been mathematically vindicated.

Why is this bad news? Because the possibility of starships presents us with a paradox that is difficult to overcome.

Consider: What would we do if we had starships? If history tells us anything, we would look around for nice real estate and start colonizing. In fact, we wouldn't even need to find planets; stable stars with asteroid belts would do. Professor Gerard O'Neil argues convincingly that cities in space may need little more than raw materials and solar power.

Once the new settlements had reached a high level of industry, they'd send out more colony ships of their own, to stellar systems even further out. Imagine a sphere of human settlement slowly expanding through space. Even limiting ship speed to a tenth of the speed of light, and allowing each colony plenty of time to industrialize, how long would it take for colonies to be planted three hundred light-years from Earth? Ten thousand years? Thirty thousand years?

Mankind has hardly changed in the last thirty thousand years. If we make a few social advances and avoid self-destruction, we should live long enough to fulfill the above scenario.

If *we* could do this, why shouldn't this sort of expansion occur with other sophont species? Isn't it likely many of those million high-tech races we spoke of earlier might also spread and colonize?

If many advanced life forms did this, the 200 light-year "average spacing" between races would be filled up in under 100,000 years!

In fact, all it might take is just one aggressive, colonizing species. Recent calculations by Eric Jones, of Los Alamos Laboratories, indicate a slowly expanding sphere of settled solar systems could fill the entire Galaxy within sixty million years. It's not unreasonable to imagine at least one out of a million civilized races living that long.

Finally, why haven't we met any wise old alien star robots? Frank Tipler, of Tulane University, calculates we should have by now. These robots, first prophesied by the great John Von Neumann, would go exploring like the Voyager and Viking space probes, but would also stop at each solar system to make copies of themselves to send onward. Tipler says just one such self-copying probe could become a horde, with one at every star in the Galaxy in under three million years. Such "Von Neumann machines" should have arrived long ago, and would have been waiting ages for Earth to evolve someone smart enough to talk to.

So we are faced with a new question—why do we see no signs that Earth has been colonized in the last sixty million years? And it's even more curious that we haven't seen signs of civilization near neighboring stars. Why have we picked up no radio signals, when the stars should be humming with information and commerce?

Where is everybody? Does this really mean we're alone?

Debate over this issue has come as a shock to believers in SETI. Just when they seemed to have won acceptance, suddenly they had to contend with jokes that xenobiology was "the only scientific field without a subject matter."

These questions mark the traumatic awakening of xenology as an adult science. It marks the end of a short period of innocence. The dust has not yet settled, but one thing is clear: Some of our assumptions are wrong. The Universe might turn out to be considerably more complicated than the optimistic scientists of the late 1960s first thought.

THE GREAT SILENCE

We see no evidence for ancient alien cities in Earth's crust. Venus, Mars, and the asteroids appear to be untouched.

Most significantly, Earth, until less than a billion years ago, was populated for eons by only primitive prokaryotic bacteria, teeming in the oceans, with no life on land at all. A visiting starship need not have landed colonists. All they'd have to do is be careless with their garbage, or latrine, and the history of Earth would have been totally different; sophisticated alien parasites would have overwhelmed our primitive ancestors. Since this didn't happen, it seems unlikely aliens landed here during that time. [For a different view on the potential for damage by alien trash, see the articles by Clement; Benford.]

It certainly looks as though we've been alone for ages.

The quandary of the Great Silence has given the infant field of xenology its first traumatic struggle, between those seeking optimistic excuses for the apparent absence of sentient neighbors and those who enthusiastically accept the silence as evidence for humanity's isolation in an open frontier.

Eric Jones and Frank Tipler, in particular, think the apparent absence of ETIS (Extraterrestrial Intelligent Species) simply means this part of the Galaxy is uninhabited. Their "uniqueness hypothesis" implies that some or all of the key factors in the Drake Equation are really very small. For instance, some contend that intelligence such as ours may be an evolutionary fluke.

Then there is Michael Hart's contention that habitable planets like Earth are rare. Alternatively, John Ball dredged up the science-fictional idea that Earth is a "zoo," and extraterrestrials are already here, observing us. (This implies we should add to the Drake Equation a factor to account for ET's *purposely* avoding contact!)

Contact optimists, such as William Newman of Princeton and Carl Sagan of Cornell, have tried to make excuses for the extraterrestrials, suggesting truly advanced cultures would practice zero population growth. The rate of "galaxy-filling" calculated under their conservative assumptions is slow enough to suggest the nearest space-faring race might not have reached us yet.

Or our assumptions for f_l (the fraction of planets on which life originates) might be too high. Although the precursors of life—sugars, amino acids, nucleotides—seem likely to be common, it's possible the next steps might be much harder, requiring some rare catalyst to set off the process.

These and many other ideas have been presented to explain why aliens aren't here. (A complete catalog will be given later in this article.) All the hypotheses offered so far have problems, though. Some seem to contradict the best knowledge we have. Others, like the "zoo" theory, are untestable.

Let's consider one hypothesis xenological speculators have mostly passed up. It's a bit frightening. But maybe not as much as others we'll pick up later on.

THE FATE OF "NURSERY WORLDS"

In the Drake Equation the combined factor f_{ic}—the fraction of life-planets on which intelligence and technology eventually evolve—is generally assigned a value of about one in one hundred. The xenologists who put forward the "one-percent" argument support it by citing the apparent fact that it took four billion years for Earth to give rise to merely one technological race. This is almost half the viable life span of the planet. Intelligent life would seem to be a rare and wonderful thing.

But is this assumption tenable? Let's consider the life cycle of a "nursery world," a planet with a stable biosphere in which the slow evolution to intelligence can take place.

Evolution appears to have proceeded gradually at first, then at an accelerating pace for three billion years. Except for the introduction of sexual reproduction, and later of angiosperms (flowering plants), there is no evidence even to hint the Earth was ever suddenly invaded by extraterrestrial flora and fauna. The Great Silence seems, at first glance, to have stretched through the entire Paleozoic.

If we assume Earth lay untampered with until at least the time of the Jurassic, we can guess that it takes about three billion years for life on a nursery world to evolve to a level of complexity that makes intelligence feasible.

But if humanity suddenly vanished? Would it take another three billion years for intelligence to arise on Earth again? If so, it's reasonable to accept the guess that only one or two technological species could erupt per habitable planet.

But *Homo sapiens* isn't the only species to have benefited from three billion years of evolution. Today's German cockroach may look like his distant ancestors, but he has accumulated many little tricks his cousins in the Triassic never heard of. The size of genome of the raccoon and wolf (the number of genes in their chromosomes) is no smaller than that of man.

Consider what's happened since the Cretaceous-Tertiary Catastrophe, approximately sixty-five million years ago, which wiped out nearly every species of land animal massing more than forty kilos.

The creatures who went on to dominate the planet were small mammals: he early equivalent of mice, and tree shrews. We are among their lescendants.

Now, despite the present arms race, man still lacks the ability to extermiiate mice. The sudden demise of this star system's current technological :ace would not finish off the Earth as a nursery. If "mice" did it once they :ould probably do it again.

Perhaps suitable worlds must pass through long initial "fallow" periods before attaining a level of biological sophistication ripe for intelligence. Afterward, though, such planets might produce sapient species at fairly short intervals, depending on the time needed to recover from the damage done by the previous sentient race.

EXPANSION SHELLS

It is generally assumed that a space-faring species will expand into the Galaxy because of either raw curiosity or population pressure. For a race limited to slow-boat technology, colonization will take place only in a thin, growing shell surrounding an older, settled region within.

If population pressure is the primary motive for expansion, what of the long-occupied worlds in the interior, especially near the home planet? The words "population pressure" suggest the likely fate of these worlds.

Consider the settlement of Polynesia from roughly 1500 B.C. to about 800 A.D. (The island-hopping analogy is apt.) Eric Jones borrowed growth and emigration rates for his model of interstellar settlement from Polynesian history. The intrepid Polynesians testify to the likely viability of "star-hopping" colonization ventures.

Polynesia may, indeed, be representative of interstellar settlement, but not only in a pleasant sense. The Hollywood image of island life is paradisical, but Polynesian cultures were subject to regular cycles of overpopulation, controlled in war or ritual by culling adult male population. There are stories of islands whose men were wiped out completely.

Meanwhile, introduction of domestic animals disrupted island ecosystems. Many native species were wiped out.

The most severe example is Rapa Nui, also called Easter Island. Isolated thousands of miles from its nearest neighbors, it was as like an interstellar colony as any place in human history. Mankind may devoutly hope to do better when we finally do embark to the stars.

The colonists wrecked the virgin ecosystem of Rapa Nui. When no trees remained to make houses or boats, they had to abandon the sea and it resources, along with all possibility of escape. What remained was native rock—which they carved into hauntingly desolate images—and warfare.

The story of that place should be a lesson to make us all thoughtful.

Now, assume a settled sphere of expansion by an extraterrestrial intelligent species. What of the *inner* systems, within the sphere? The Polynesian example suggests a dismal image of increasing competition for dwindling resources with no escape valve for excess population, since all surrounding systems are in similar straits.

What happens to those inner worlds? In an old, settled system, all available asteroids would long have been turned into habitats. Safe inner orbits with unhindered access to solar power would be at a premium. Even the most efficient space structures will require frequent replenishment of gases such as oxygen, hydrogen, and nitrogen. Comets might supply part of this need, but terrestroid planets would be closer.

One might expect to see a profound cultural split between those living on planetary surfaces and those in space, as depicted by Larry Niven and Jerry Pournelle in their novel *Mote in God's Eye.* It would be simple to bombard cities with redirected asteroids. Factor *L* (average lifetime) clearly falls in such a case.

In any event, it would be the innocent higher animals who would suffer most in such a crossfire.

CYCLES OF RECOVERY AND EXPANSION

Recently scientists have uncovered thin layers of clay rich in exotic elements, including iridium (up to five times the normal abundance of some isotopes), at levels associated with the end of the Cretaceous Period. Discoveries in locations from Italy to New Mexico seem to correlate with the great extinction. Some scientists conclude that a major meteorite impact kicked up a great pall of dust, severely altering weather patterns (perhaps in conjunction with major volcanic activity), resulting in mass starvation.

The Cretaceous-Tertiary event wasn't the only one of its kind. At least four other mass extinctions are found in the sedimentary record, including one at the end of the Devonian and another at the Permian-Triassic boundary, approximately 225 million years ago. These events are less well understood and may have taken place over longer periods than the Cretaceous

die-back, but we may compare the rough 10- to 500-million-year intervals seen with those suggested by Newman and Sagan for galaxy filling by space-traveling species.

Here's one possibility to consider—might the ecological holocaust of the Cretaceous have been a local manifestation of the death spasm of a prior space-faring race, whose overpopulated sphere of settlement spoiled and self-destructed as the shell of colonization passed outward? It's farfetched of course, but also thought-provoking.

If this were so, all neighboring star systems might also have suffered ecological collapse at the same time. Earth might be the first nursery world to have recovered sufficiently, since the last wave of "civilization" passed this way, to develop a species with intelligence again.

Whether or not the end of the Cretaceous corresponded to the agony of dying star-farers, it may well be that colonizing cultures inevitably leave behind them wastelands empty of intelligence and living voices. If we humans initiate an era of interstellar travel of our own, we may find all around us the blasted remains of such an earlier epoch.

Would we then learn a lesson? Perhaps. But with the ever present opportunities for expansion, those humans who exercise self-restraint and environmental sensitivity toward their adopted worlds will not be able to force this tradition upon those who travel far away to establish newer colonies. A nucleus of selfishness may expand faster than a center of more rational colonization. While some settlers may preserve and protect local ecospheres, cognizant of their long-range potential, others may be rapacious.

Which type will we be? Clearly our environmental record here on Earth is a test. The list of extinct species, some of which might one day have become star-farers, is long and growing longer.

The Great Silence may be the sound of sands drifting up against monuments. It may be quiet testament to the fate of species that allow "population pressure" to be their motivation for the stars.

THE RETREAT OF THE CONTACT OPTIMISTS

In June of 1984, a new subunit of the International Astronomical Union gathered in Boston, devoted solely to discussing the question of extraterrestrial intelligence. At that meeting the trend of several years continued. The "Contact Optimists" —who have fought hardest to believe we have neighbors in space—continued to beat an organized retreat. They dug in behind fortress hypotheses offering excuses for the tardy, laggard extraterrestrials and explaining their strange failure to appear.

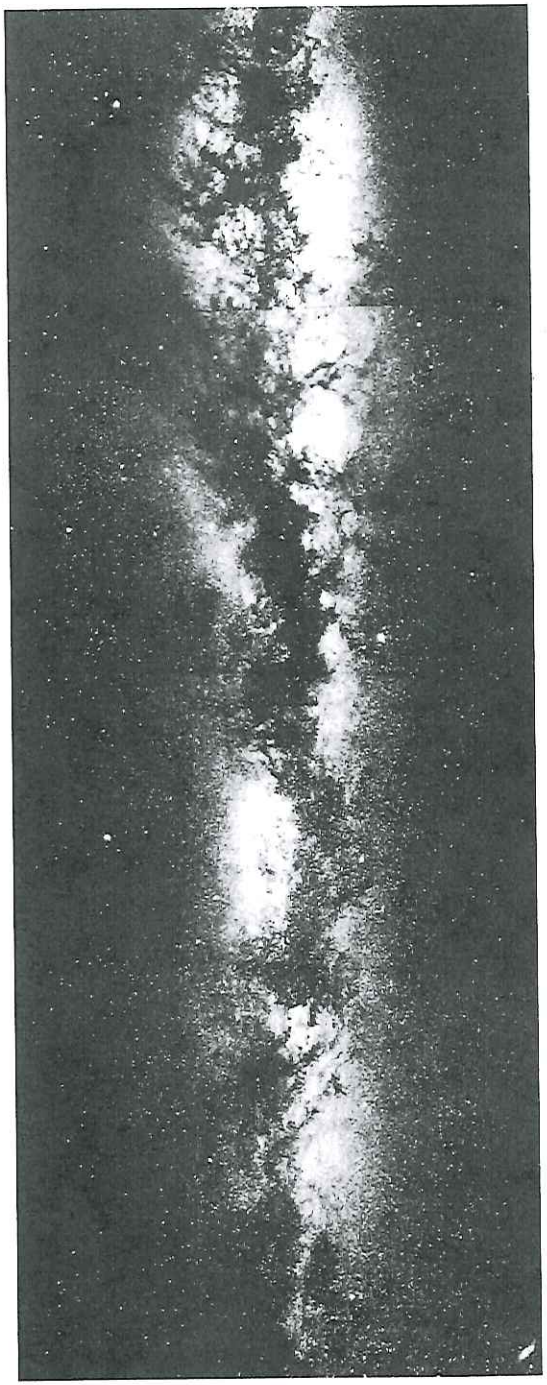

Figure 2. Photomosaic of the northern Milky Way. The constellations of Scorpius and Sagittarius are visible at the right. M 31 (the Andromeda Galaxy) is visible in the lower left. This is a close-up view of the left third of the frontispiece sky map. *(Photo: Courtesy the American Museum of Natural History.)*

In so doing, the Contact forces have begun to sound downright gloomy.

Starships are impossible, some of them declare.

ETs kill themselves off before they get very far, others say.

Or *extraterrestrials are pinch-pennies,* who would shrink back from the challenge of the stars.

All this from scientists who once carried the science-fictional banner! Strangely, it is their opponents, the Uniqueness crowd, who now cluster in excited circles at these conferences, chattering about starships and galactic colonization.

Just who are the "conservatives" in an argument like this? We certainly do live in fascinating times.

With the possibility of star travel, and colonization, an average separation of a few hundred light-years starts looking trivial. Not only is the Drake equation no longer complete. We see that it doesn't even predict anything anymore!

When we introduce star travel, the Drake Equation suddenly needs three new factors:

> *V*—the velocity at which an interstellar culture grows into space, pausing to settle likely solar systems and rebuild necessary industry, before again continuing its expansion.
>
> L_z—the lifetime of a zone of colonization into which a species has expanded, after which the settled region becomes "fallow" once again.
>
> *A*—an "approach/avoidance" factor, different for each culture, representing a "cross-section for discovery" by contemporary human civilization. (How likely is it we would even notice them? For example, a culture with a preference for settling on comets would never have visited Earth, and might exist undiscovered even now in our solar system.)

By including these factors in the appropriate formula one can try to predict *C*—the probability of contact between human beings and extraterrestrials. The seven factors of the old equation, plus the three new ones, give us a space within which to sort out our ideas, an organizational aid that was missing until now.

All ten probability terms are vital. Contact proponents admit that visits to Earth have been sparse, if they even have happened at all. They merely choose different explanations ... or excuses ... for the fact that we have observed no beings from other stars. It turns out the differences of opinion between Contact and Uniqueness forces divide quite simply according to which factor each uses to explain the absence of extraterrestrials.

Uniqueness advocates tend to concentrate on the left and middle of the Drake Equation. For instance, some claim that planets are rare, or that many Earth-like worlds get trapped into Venus-type runaway greenhouse effects, destroying any chance of developing life.

Other Uniqueness savants bitterly dispute this. Planets are plentiful, men such as Michael Hart say, but the odds of independently evolving life are small. Still others, such as Eric Jones of Los Alamos, claim life is probably common enough, but it is the step to *intelligence* that is a fluke here on Earth, unlikely to be repeated elsewhere.

Those on the Contact side disagree, of course. They believe technological societies should crop up all over the place. To account for the apparent absence, Frank Drake and Bernard Oliver hang on to a belief that star travel is impractical. Factor *V* does have its attackers, then, in the face of a tide of popular and inventive starship designs.

And hypotheses abound as to why extraterrestrials might choose to make themselves invisible ... to avoid contacting us, or to abjure star travel even if it is possible, or to have neglected to settle our solar system in the more than three billion years that it's been prime real estate.

Any of those explanations might work for one or two races ... maybe a dozen. But if ETIS are as diverse as men and women, the excuses run into trouble. Can the Contact people seriously contend that, out of millions of races, not one would behave as humans do in so many sf novels ... setting forth in their space Conestogas to settle and alter their new homes?

(True ... aliens "might think differently than we do." But if there are enough of them, ought not a *few* think like us?)

As always, the most entertaining Contact Optimist is Carl Sagan. Anxious to find an excuse for the missing aliens, and too smart to disdain starships, he has come up with one of the most fascinating explanations. And in so doing he and his colleagues have possibly done mankind a great service.

NUCLEAR WINTERS

In the Christmas 1983 issue of *Science*, there appeared an article entitled "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions." It has come to be referred to as "TTAPS"—after the initials of its authors, R. P. Turco, O. B. Toon, T. P. Ackerman, J. B. Pollack, and C. Sagan. This historical document has shaken up thought concerning the potential consequences of modern major warfare.

If the models presented by the TTAPS authors are correct even within orders of magnitude, one can only conclude that the arms race between the great powers is a pointless waste of time and money. Even a "limited" nuclear war will devastate the Northern Hemisphere and leave it barren of civilization, nearly devoid of life.

It would not be due to fearsome blasts, nor even lingering radiation. Some fragment of America or Russia might survive those effects. Rather, it would be the dust kicked into the sky by as few as a hundred nuclear ground bursts, or soot from airburst-ignited fires, that would plunge the world into a frigid night from which very little might survive.

At least that's the contention of TTAPS. In the years following, there have been numerous follow-up studies, but no one has successfully disputed the article's orverall conclusions, that nuclear war could severely affect Earth's climate.

Very interesting—and perhaps vital for us all to think about—but what has all this to do with extraterrestrials?

Well, there is reason to believe the nuclear winter scenario had its birth in a struggle to find excuses for absent star-faring aliens!

Consider the position in which Contact proponents like Sagan found themselves. Unable to convince themselves starships are impossible, they had to come up with some universal mechanism to explain how both the number of extraterrestrial species and their rate of expansion could be small enough to explain the Great Silence.

Sagan's answer was to propose the following:

Assume that two types of species achieve technology—peaceful and aggressive. Peaceful races presumably lack the greedy drives that caused humans to seize every opportunity to conquer and spread, here on Earth. These quiet civilizations will expand to neighboring star systems slowly, if at all. So slowly, we can excuse their absence. They just haven't arrived here yet.

Aggressive types would push ever outward, filling the Galaxy as fast as Jones and Tipler contend. But those species must first pass through a dangerous phase—that period between developing nuclear weapons and viable star travel. Sagan says warlike species either cure themselves of their aggressive tendencies, or die.

In other words, the "optimists" are now suggesting the Galaxy is sparsely occupied by long-lived pacifists—who drive their starshipss only on Sunday, presumably—and by the planetary tombs of all the rest . . . species who couldn't learn to control themselves.

But for this rationale to work, there had to be an easily triggered mechanism for destroying civilizations. It must be more powerful than even bomb blasts or radiation . . . so compelling that one could envision it happening again and again, to every warlike race that failed to make the transition to a calmer mode of life.

Nuclear winter appears to offer Sagan's brand of Contact aficionado just such a mechanism.

A MENU OF EXPLANATIONS FOR THE GREAT SILENCE

Why do we seem to be alone?

Each of the explanations offered so far suggests a way to suppress one or more of the factors in an expanded Drake Equation in order to make the overall contact number fit observations of actual extraterrestrials . . . so far zero. Let's summarize a list of popular (and not so popular) explanations.

Starting from the left side of the Drake Equation, we begin with some favorite explanations of Uniqueness proponents.

Category One: Solitude

1. Habitable planets may be rarer than astronomers now believe (Suppress factor n_e.)
2. Some unexpected "spark" may be needed to initiate life out of prebiotic compounds. (Suppress f_l.)
3. The final step to intelligence may require some "software miracle" that makes it far more improbable than currently expected. (Suppress f_i.)
4. Insatiable curiosity and manipulativeness, such as contemporary humans display, may be rare among intelligent species. (This effect would obviously suppress factor f_c.) As Author Poul Anderson put it: "The puzzle is why we're as bright as we are. Pithecanthropus was doing all right." He proposes that intraspecies selection, especially sexual, became fierce in protohumans, leading to a strange animal that is uniquely clever and capable of fitting itself to live in vacuum or the bottom of the sea.

If any combination of ideas 1–4 are right, we may simply be the first tool users ever to come along. We are the "Elder Race."

Category Two: Graduation

5. Technological species may sooner or later discover advanced techniques that make radio and colonization irrelevant. (Still, it is hard to believe any race would abandon the electromagnetic spectrum—radio and light—completely.)
6. Space-faring sophonts might "graduate" to other realms or unimaginable endeavors, coming to look on planets and starships as mere toys. This would set a limit to the period of expansion, though not, perhaps, to exploration.

Either of these scenarios would lower our expected contact cross-section, *A*, with such a civilization. They might also tend to reduce *V*.

Category Three: Timidity

7. There might be reasons species develop an aversion to space-flight. For example, Carl Sagan has suggested that the achievement of immortality might make individuals reluctant to take even the slightest risk.
8. As discussed earlier, those species who don't destroy themselves may "cure" themselves of aggressiveness, and so become slow star-farers.
9. Intelligent species might develop a form of telepathy, through mind-computer links, which makes their lives far richer than existence as individuals. If this happened, they might grow reluctant to venture many light-days from the center of their civilization, in order to avoid, in effect, lobotomizing themselves.

Still, it's hard to imagine these notions applying in all cases, which is what we need from a convincing overall explanation for the Great Silence.

Category Four: Quarantine

10. Benevolent species may have a tradition of letting nursery worlds lie fallow for long periods, allowing new sentience to be nurtured there.
11. Observers might be awaiting mankind's social maturity, or may have quarantined us as dangerous. A galactic radio club might avoid too early contact, to let us develop our own unique culture, to contribute something new to the galactic melting pot.

12. No listing would be complete without including the far-fetched idea that aliens are already in covert contact with some on Earth. A charming Poul Anderson story depicts Earth's sole "member of the Federation" as an obscure tribe of southwest American Indians.
13. The *low rent* explanation suggests the Earth is simply too unattractive to be settled, or even visited by aliens. For example, Earth life forms rely almost totally on the left-handed isomers of complex organic proteins and amino acids. Other life forms could be right-handed.
14. Finally, it's possible Frank Tipler's imagined self-replicating robots, which should make star exploration cheap and easy for even the timid—might behave just a little differently than Tipler imagined. Perhaps there are hundreds of *friendly* probes, sitting around the solar system, patiently waiting for us. Perhaps we must prove our ability actually to go out there in person before they will deign to say hello.

There is a problem with the quarantine scenarios, unfortunately. All appear to call for cultural uniformity in the Milky Way . . . some way for the pattern to be enforced for billions of years in a galaxy of constantly shifting neighborhoods and star formations. Such a rigid pattern would seem difficult in a relativistic Universe governed by the speed of light.

Category Five: Interstellar Wanderers

Perhaps waves of interstellar wayfarers *have* passed this way. Travel in vast slowboat starships might select for the sorts of beings who *like* living in space, who even come to abandon planet-dwelling as a lifestyle. This could lead to different behaviors.

15. Truly space-borne sophonts might greedily fragment terrestroid planets for building materials and volatiles, having a terrible effect on factor n_e, the number of planets that can support life.
16. Alternatively, they might have a tradition of cherishing nursery worlds, protecting them without any desire to use high-gravity real estate.

But we have looked over our asteroid belts in recent years, and they appear to have been untouched since the beginning of the solar system. No

one seems to have disturbed them, yet these are the same small bodies such star-farers would covet—which our own grandchildren may be melting and reforming in a century or so.

Looking over our list so far, none of the explanations seems to explain the Great Silence in a convincing way. What's needed is a universal mechanism that acts impartially over long time scales, which would keep the numbers of extraterrestrial species small, or suppress their rates of expansion among the stars.

A few ideas have been proposed that seem to fit these criteria. The reader is warned that some may seem unsettling. If it's any consolation, I'll try to finish with an optimistic scenario ... one that satisfies all the preceding criteria without being nasty.

Category Six: Dangerous Natural Forces

We've already mentioned the possibility Earth might have fallen into a "Venus Trap" ... the runaway greenhouse effect that killed our sister world ... or the perpetual frozen tundra of the "Martian Trap." Here are some other "natural" hazards. Any of them could have disastrous effects on the last four factors of the Drake Equation.

17. In its 230-million-year orbit round the Galaxy, our solar system regularly crosses regions of shocked gas clouds and hot young stars. These can be dangerous events. Spiral arms are where interstellar clouds compress to form new stars, and where supergiants end their quick lives in titanic explosions.

    Proposed advanced cultures eventually tire of playing galactic roulette and leave the spiral arms for good—setting up in the Milky Way's "halo" of older stars that drift in long, lazy orbits out of harm's way. That could explain why we don't see anybody flying around this part of the Galaxy: Those who *can* leave, do.

18. Were the dinosaurs really killed off by meteorite or comet impacts, which triggered major changes in the Earth's ecology? If so, were these and other collisions random? It has been suggested that a small dark, companion of the Sun, called Nemesis, or Shiva, orbits far beyond the comet belt, dipping in every twenty-six million years or so to scatter icy and rocky debris into the inner solar system. Alternatively, interactions with the galactic plane, or spiral arms, might trigger such events.

In any case, other solar systems might be in even worse shape than we are, so often smashed by cosmic debris that we're the first to climb up far enough to look around.

19. Our Milky Way may contain objects far more dangerous than mere shock fronts or falling rocks. Radio astronomy shows that many galaxies contain powerful, dangerous jets of relativistic particles, perhaps caused by huge black holes at the galaxies' cores. It's still unclear whether we share this galaxy with a compact version of such terrors, but already there is strong evidence for a black hole, of a few hundred solar masses, near the center of the Milky Way.

Category Seven: Dangerous "Unnatural" Forces

Nature can be malignant, as we have seen. But there are other dangers, as well, dangers that might arise from life itself.

20. Migrational holocausts. This idea was discussed earlier. What happens to planets that are colonized by an expanding interstellar civilization? Unless the settlers leave large parts of their worlds fallow in wilderness preserves, or engage in "uplift" bioenginering of local higher animals, their mere presence is likely to do harm. A world probably cannot serve as a useful nursery of intelligence so long as it's occupied by a space-faring race. When the interstellar tenants finally vacate or die off, it may be a long time before a local species of tool users evolves.

    So Earth might be the first nursery world to have recovered sufficiently—since the last wave of "civilization" passed this way.

21. Inevitable self-destruction is another cheery theme mentioned earlier, suggesting that many alien races found themselves where we now stand, on the teetering precipice between self-ruin and self-control; perhaps only a very few make it.

22. From physics and science fiction comes the dreadful notion of "deadly probes," which devastate life among the stars. A particularly paranoid advanced species might not want any potential competition to rise up elsewhere and so might send forth machines like Tipler's self-reproducing probes, but with a nasty edge. Whenever radio traffic indicates that new sentients (like us) have arisen, these robots would home in to destroy the

infection before it spreads. This need only happen once for it to become the status quo, keeping the Galaxy silent and empty for billions of years.

Category Eight: A Grasp at Optimism

Is there any friendly explanation for the Great Silence? Isn't there any way the Universe could look the way it does and still let both sides in the debate get their dream—a galaxy with other minds to talk to, and yet still wide open for our great-grandchildren to have adventures in?

I have managed to come up with one.

23. The "Water Worlds" scenario. We've spoken of the Venus Trap and of a Mars Trap, which might yank Earth-like worlds toward conditions where life can't exist. This leaves us with the impression that Terra miraculously found itself straddling a narrow fence between two death sentences, and that might be true.

On the other hand, it might not. Recently, Professors Kasting and Pollack have published persuasive arguments that there is a deep valley, a cusp, between the Mars and Venus catastrophes. Within this valley there is another "trap," pulling toward it all planets within its reach. This is the pleasant trap of the Water World.

The existence of life on Earth has had powerful repercussions. It has taken most of the carbon out of the atmosphere and regulated the planet's temperature so that it varies less than the heat output of the Sun itself. One result: the preservation of vast oceans.

If this turned out to be a common phenomenon, let's consider the possibility that the Earth is unusually *dry* for a water world. In other words, what if the vast majority of this kind of planet has far *less* dry land than ours?

Geneticists say that species diversity and rates of evolution depend on the size of the environment involved. It is unlikely that land creatures would develop to the complexity they have on Earth on a world with only island archipelagoes and tiny continents.

That doesn't necessarily mean *intelligence*, per se, is impossible on such planets. After all, dolphins and whales are pretty bright. But it does imply there'd be few places where "hands and fire" beings would develop the technology and basic outlook necessary to take to the stars.

There might be millions of intelligent species out there, ignorant and uncaring about starships, preoccupied with their own oceanic adventures. The result? Envision our descendants setting forth, as Jones and others anticipate. They find no other star-farers, and at first it seems they are all alone. At last, though, they discover other minds . . . minds that pose no threat, no danger.

Intelligent whales, or squid, or octopus . . . why should they refuse the roving humans' request to make use of local asteroids to build their cities and factories? If the strange-looking bipeds are willing to bring down exciting toys and machines, why not invite them to come take their vacations on the shores of the "useless" little islands, to splash and play and exchange philosophy lazily under the balmy sunshine?

Humans could be the voyageurs—the transporteers—carrying mail and slow philosophical discussion among the water sapients who will only be grateful for the service, of course, never jealous. Our great-to-the-*n*th grandchildren will have their adventures, and serve to tie the Galaxy together.

It sounds like a way to give both sides in our great debate what they want, without having to have a dangerous, malignant Universe, one that's out to get us.

I promised to end on a note of optimism, and I cannot do any better than that.

Now, if only if were true.