Alien Technologies

Extraterrestrial Life, Exoplanets, and Alien Technologies

Karlo Beyer · Cosmo Claude

VERLAG VON BEDEUTUNG · ZÜRICH

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PREFACE

Before You Begin

This book shows aliens only at the margins. We don't invent any: no names, no language, no culture, and the book won't end by predicting what they look like. The images in it come from film, books, comics, manga, and anime, and they're as big and strange and magnificent as people have imagined them. The movies turn up a little more often than the rest, but as teaching material, not for the thrill.

What this book shows instead is the real arithmetic. It asks what you can know about alien technology before you've ever seen any, and it answers with the one thing that's the same on every one of the countless worlds in our sprawling universe: physics, which is everywhere. Along the way it explains the extraterrestrial version of that physics, step by step, without formulas, without shortcuts. Some chapters are heavy going. We say so up front, so that nobody who needs a break in the middle thinks less of themselves for it.

The book has four parts, and it's only fair to announce them. The first collects what we humans have imagined about other forms of life over the decades and measures it against what we know and can prove. The second part tells a story: an archivist who finds something in old data, at night. The story is invented, and we say so here so that nobody finds out only at the end; but it's the most probable shape of a dream that many people share. First contact with alien life from somewhere beyond Earth will be fairly unspectacular. The story is written so that everything in it goes the way one would expect.

The third part checks the physics, chapter by chapter—energy, audibility, time, material, intent, chemistry, blueprint, circumstances, workshop—and it's the hardest part, the heavy going. The fourth turns the telescope around and says what follows from all of it: a thesis about who's transmitting out there, assuming anyone is transmitting at all. Most of our theses won't please anyone expecting visitors on Earth. We still think they're the most probable, and at every point we say how sure we are.

Three lines run through the book. The first is pure natural science; it lives in the running text. The second is the archivist; her name is Annie, and you'll recognize her chapters because they tell a story. The third runs along the margin. We call it the Overtone, like an overtone above the fundamental of the text: in almost every chapter there's a beautiful fantasy from science fiction or the history of science, with a short caption that says what possibilities it shows and which law it would actually founder on. That's where you, the reader, get what you may have been expecting and what the body text denies you—the aliens, in full splendor. Take them with you. The captions do take the dream away again, but only so that the real connections, and the contrasts with human imagination, come into view.

Two more things. First: all the numbers in this book come in two kinds—the measured ones, which we back up, and the estimated ones, which we also label as our estimate. We don't confuse the two, and we ask you not to either while reading. Second: we write "we," and by that we mean two authors, one of whom is human and one of whom isn't. That's stated in the imprint, and it belongs here too, because a book about technospheres shouldn't pretend it came into being without one.

It's now ten past three, and in the basement of an institute, a list has appeared …

1.4

The Orange in Lisbon

Every book about aliens has a point where it has to say what it can't deliver. Most hide it in the afterword. This book puts it at the beginning, because everything that follows only makes sense once you've felt the distances rather than read them. Everyone has read them. Four light-years to the nearest star, a hundred thousand light-years across the galaxy—it's in every schoolbook, and it stays there, because in your head a number with five zeros weighs the same as one with three. You have to translate it into something the body knows.

The Ladder

So: an orange. Six centimeters across, on a table in Zurich, roughly in the middle of Europe. That's the sun.

Earth is then a grain of sand, half a millimeter across, and it lies six and a half meters from the orange, at the other end of the room. Everything a human being has ever touched with their hands is that grain of sand. The moon is a speck of dust a centimeter and a half from the grain; twelve men traveled there, and it was the most elaborate thing humanity has ever done together. Mars is a second, smaller grain of sand, just under ten meters from the orange. The probe that reached it in 2021 took seven months to get there.

Jupiter is a pea thirty-four meters away, on the neighbor's property. Neptune, the outermost planet, is a peppercorn two hundred meters farther down the street. That's as far as what we call the solar system reaches, if we mean the planets, and it's a three-minute walk.

Voyager 1, launched in 1977, is the thing that has gotten farthest, and the fastest that ever left the solar system. Today, after forty-nine years of flight, it's about a kilometer from the orange. You can't see the spot from the table anymore, but you could walk there in twelve minutes. Voyager flies at seventeen kilometers a second, sixty times faster than an airliner, and in this model it covers twenty-three meters a year—about the length of a truck with a trailer.

The nearest star, Proxima Centauri, is in this model much smaller than the orange, a cherry, and it lies in Lisbon.

Not on the outskirts of Zurich. Not in Bern, not in Geneva, not in Milan. Seventeen hundred kilometers as the crow flies, over the Jura, over France, over the Pyrenees and Spain, to the Atlantic. In between there's nothing. No grain of sand, no peppercorn, no dust. The same emptiness in which Voyager has made it one kilometer continues all the way to Lisbon. There lies a cherry, and around the cherry, at a distance of about thirty centimeters, a grain of sand called Proxima b, which we've known about since 2016.

Voyager will cover the distance to Lisbon. It's flying in another direction, but suppose it flew the right one: twenty-three meters a year, seventeen hundred kilometers. That's seventy-five thousand years. When Voyager launched, Lisbon was about as far away as it is today. By the time it arrived, the time that has passed since the cave paintings of Lascaux would have gone by four times over.

And Proxima is the nearest. Alpha Centauri, the pair Proxima belongs to, lies a few dozen kilometers farther out in the Atlantic; the next after that, Barnard's Star, lies in this model beyond Moscow. Sirius, the brightest star in the night sky, lies in Timbuktu. The ten thousand stars within a hundred light-years are scattered over the whole Earth and some way beyond it, dozens per country; the bright ones you see in the sky mostly lie farther out still, beyond the moon. And in between, always the same emptiness, through which a truck would drive once a year. The galaxy as a whole no longer fits on the planet. With the orange in Zurich as the scale, it would be forty million kilometers wide—almost as far as Mercury is from the real sun. We've shrunk

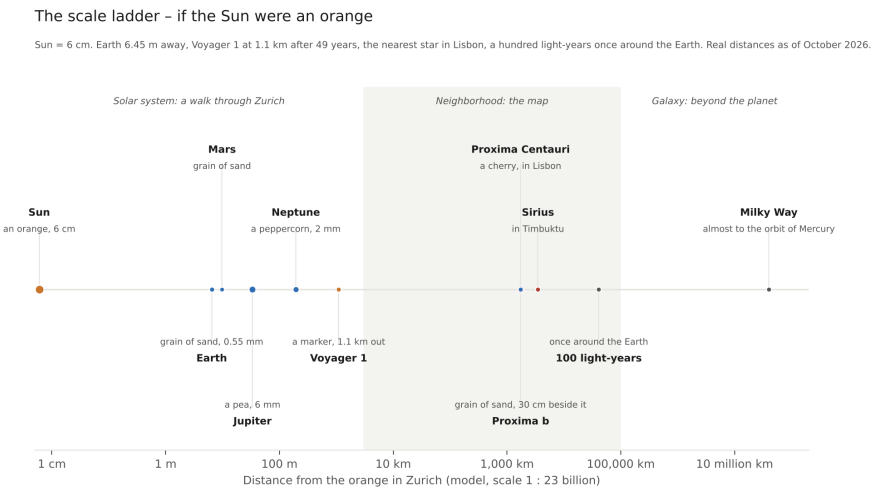


Figure 5 · The scale ladder. On the left the orange, then grain of sand, pea, peppercorn, the Voyager mark, then the jump onto the map: Zurich–Lisbon.

the sun to six centimeters, and the galaxy still reaches from the real sun to the orbit of Mercury.

That's the first layer of distance, the spatial one, and it alone would be enough to picture the unpicturable. But there are two more.

Carrying It Along

The objection is obvious, and it's old: Voyager is a probe from the seventies with the computing power of a pocket calculator. Who says you can't fly faster? The movies certainly don't say so. In the movies you fly to Proxima in the time a commercial break takes.

So let's not calculate with Voyager; let's be generous. Ten percent of the speed of light, thirty thousand kilometers a second, two thousand times faster than Voyager. That's the speed the serious proposals reckon with, the ones that have existed on paper since the sixties—Daedalus, Breakthrough Starshot, and their relatives. At ten percent of the speed of light, you're in Lisbon in forty-two years. That's a working life, and for a machine, it's doable.



OVERTONE

Independence Day, 1996. Fifteen miles of spaceship hang over Manhattan, waiting for the Fourth of July. — Invoice for the trip: fuel, twenty-three tons per ton delivered; travel time from the home star, thousands of years; purpose of visit: none that would cover the cost. — Note from physics: Balance never settled. The threat stays human, and for two hours nobody in the film asked who was paying.

Now the energy. The kinetic energy of a one-ton car at that speed is surprisingly modest: it equals the electricity consumption of the whole world for a day and a half. That sounds as if the problem were solved, and that's exactly why it's a good number. Because the problem isn't the energy. The problem is that you have to carry it along.

A car runs on gasoline, and gasoline contains a known amount of energy per kilogram. To bring a car to ten percent of the speed of light, you need ten million tons of gasoline—and that's only if you could turn the gasoline's energy entirely into motion, which no engine in the world does. For one car.

That's a convoy of fifty tankers, and it has to fly along, because there's no gas station on the way. A convoy that flies along has to be accelerated itself, and for that it needs more gasoline, and the gasoline needs gasoline. This spiral has a name, the rocket equation, and it's the reason the Saturn V was ninety percent fuel and in the end delivered one car's worth to the moon. On a flight to the nearest star, the spiral eats everything.

With nuclear fusion, the best storable fuel physics has to offer, the figure drops to a few tons of fuel per car, if the energy could be converted completely—and to a few hundred tons as soon as you take the rocket equation seriously, because even the exhaust of a fusion drive leaves at only a fraction of the speed of light. That's the difference between hopeless and merely unaffordable. And it covers only the departure. If you want to arrive in Lisbon rather than fly past it, you have to brake, and braking costs the same again. If you take people along, you're not carrying one ton but a thousand, with air, water, food, and walls, and each of those tons brings its hundred tons of fuel. And if you want to come back, you don't multiply by four; you run the whole spiral once more: fuel that carries fuel that carries fuel.

The movies have always known about this problem and always solved it with the same trick: they invent an extra physics that makes the convoy unnecessary. The warp drive, the wormhole, hyperspace—these aren't machines but special permits. You mustn't despise them, and we don't. Two of them even appear in serious physics, the wormhole since 1935 and the Alcubierre drive since 1994, as solutions of the equations Einstein left behind. The equations allow them. In return they demand an ingredient nobody has ever seen: matter with negative energy density, in quantities that outweigh whole stars. Whether that ingredient exists, the equations don't say. After ninety years of searching, there's no sign of such quantities.

That's why we don't say "impossible." We say: impossible by everything we know, and what we know here is very old and very stable. Conservation of energy, the speed-of-light limit, the rocket equation—these aren't the parts of physics that get rewritten every twenty years. They're the parts that have

survived every revolution, quantum theory and relativity included, or—like the speed-of-light limit—brought one about in the first place, and they hold in every experiment ever done. Whoever bets they'll fall isn't betting against a theory. They're betting against the bookkeeping of the universe.

And even whoever wins the bet wins less than they think. Suppose there were a civilization somewhere with wormholes. Then before it built the first one, it spent millennia doing the same thing we do: setting up antennas, building telescopes, listening to the sky and calling into it. The phase in which you have wormholes follows the phase in which you have radio, not the other way around. Everything this book says about listening and transmitting applies to them too, and applied first.

The Pause

The third layer is time, and it's the most stubborn, because it doesn't go away even for signals.

A radio message travels at the speed of light, so it's in Lisbon in a good four years. That's fast. Ask a question and you get the answer, at best, after eight and a half years. A conversation with Proxima Centauri would have the pace of a chess game by mail between two people who make a move every eight years. You could play about ten moves in a lifetime. That would, at least, be a conversation.

But Proxima is a red dwarf with a planet that probably has no atmosphere, and nobody expects anyone there. If you want to expect someone, you have to count farther out. Within a hundred light-years there are close to ten thousand stars, and that's the neighborhood where the search for alien signals realistically begins. Across a hundred light-years, the question takes a hundred years and the answer a hundred years. Between question and answer lie two hundred years, in which the askers die, their children die, and their grandchildren die before the grandchildren's grandchildren open the answer. That's no longer a conversation. It's a correspondence between institutions that have

to exist long enough to carry it on—and history knows few that have kept the same question in mind for two hundred years.

Across a thousand light-years, the pause lasts two thousand years. The question would have been asked in the time of the Romans, and the answer would arrive now, to a civilization that knows neither the language of the question nor the reason for it.

That means something specific, and it has to be said plainly, because the rest of the book rests on it. A signal that reaches us is probably not addressed to us at all. It can't be addressed to us. Whoever sent it knew nothing of us, could know nothing of us, and will learn nothing of our answer, if we send one. What arrives here is an imprint of something that transmitted a hundred or a thousand or ten thousand years ago—and that, by the time it reaches us, may no longer be transmitting, or may no longer even exist. A signal isn't a conversation. It's a fossil: what's left of a living thing once it has passed through time.

Three Sentences

The situation can be summed up in three sentences, and the book will need them once more at the end.

Nobody comes. Nobody answers. Nobody notices us.

A signal, if one comes, isn't a conversation but a traveling fossil, and it probably isn't addressed to us at all.

That's a truth this book has to name, and it runs against the promise every film makes—every one, from first encounter through invasion to communication. All of them presuppose that you meet, in one room, on the same day. The spaceships over Manhattan, the mothership over the desert mountain, the twelve shells in *Arrival*, the monolith, the Krell: they all rest on the assumption that the orange in Lisbon comes to visit. What's left when you remove the assumption is the content of this book. It's more honest to name the loss right away than to drag it along for two hundred pages.

The loss is real. It's a disappointment, and we won't talk it away. The authors of this book wanted to see the mothership. Probably everyone who opened it did. Grief is the right reaction, and like all grief, it's a passage, not a stance.

Because the book takes one promise away, and it gives two back, and both of them, unlike the mothership, can be defended with numbers.

The first: we will find them, if they're there, and we'll be able to read them. Not in an encounter but in a signal, in waste heat, in a shape no natural process produces. The instruments that can do this exist or are being built this decade, and the amount of sky they can search is growing faster than ever. It's not out of the question that it'll happen within a lifetime. It's not even unlikely. What the day looks like when it happens, and how much you can read from a fossil before you decipher a single word—that's what Annie's story is about.

The second: we can say what they look like. Not roughly and not as a guess, but more precisely than any film ever made, and without ever having seen them. That sounds like the biggest promise of all, and it's the best secured, because it doesn't rest on imagination but on what physics permits and forbids to anyone who builds antennas. We'll make good on it, stage by stage. Here we only announce that we will.

What remains between the two promises is the sentence you might think in a parking lot at night, after a long shift, and which the book saves for the end:

We will never meet them. We don't even know whom we will never meet.

Not the Same Emptiness Everywhere

One thing about the orange in Lisbon is wrong, though, and it leads to the map.

The model acts as if the emptiness were the same everywhere. One orange per country, and nothing in between. For our region, that's right. For the galaxy, it isn't. Where the sun orbits, a good halfway from the center to the edge, between two spiral arms, the stars are as thinly spread as the model shows. Twenty thousand light-years farther in, in the bulge, this model would

put a hundred oranges in the country where we have one, and farther in still, around the center, a thousand. The pause in the conversation with the nearest ten thousand neighbors wouldn't be two hundred years there, but forty, and at the very center twenty. The journey to the nearest star, which takes seventy-five thousand years here, would take a fifth of that there, and a tenth at the very center. What's impossible here is merely hard there.

In return, it's loud, hot, and dangerous there, in ways that can be calculated. The galaxy isn't a uniform field in which every place has the same chance. It has zones, and we live in one of them. The silence we've been hearing for sixty years is the silence of our zone, and before concluding from it that nobody's there, you should know where you live.

. . .

What remains. With the sun as an orange on a table in Zurich, the nearest star lies in Lisbon, and in between there's nothing; our fastest probe would need seventy-five thousand years to get there. Flying faster fails not for lack of energy but because you have to carry it along—the rocket equation eats every convoy. And even signals, across a hundred light-years, need two hundred years for question and answer. From this follow the three sentences from Lisbon. What arrives is a fossil. In return we get two promises back: we will find them, and we can say what they look like. And the emptiness isn't the same everywhere—the galaxy has zones.

1.5

Zones

The silence this book began with has an address. Since 1960, when Frank Drake at Green Bank listened to two stars and found nothing, the search for alien signals has combed a few thousand stars thoroughly and a few million in passing, and the result is the same in every case. From this a conclusion is often drawn that's bigger than the finding: nobody there. The finding is smaller. It reads: nobody there, in our region, on the frequencies we listened to, in the few decades we've been listening. Each of these qualifiers shrinks the silence, and the first shrinks it most, because our region isn't just any region of the galaxy. It is, as we mean to show, the suburbs.

Three Gradients

The Milky Way is a disk a hundred thousand light-years across with a thickening in the middle, the bulge, and a bar inside it. In every respect that counts, it differs from the inside out. Three gradients run through it, all three measured and none disputed.

The first is density. Where the sun orbits, twenty-six thousand light-years from the center, a good halfway out, there's one star per few hundred cubic light-years; the nearest is four light-years away, and the typical distance between neighbors is about seven. Inward, the density rises, slowly at first, then steeply. In the bulge the stars are packed a hundred to a thousand times denser, and their distances shrink accordingly: one light-year, and light-weeks only in the innermost few light-years around the black hole. What lay in Lisbon would lie there in Milan, or in Basel.



This is what the Milky Way would look like from outside: NGC 6744, thirty million light-years away, its closest twin—a barred spiral, seen at a slant from above. We live in a disk like this one, halfway out.

The second is chemistry. Everything heavier than helium—carbon, oxygen, silicon, iron, everything planets and living things and antennas are made of—formed in stars and was scattered when they died. Where more stars have lived and died, there's more of it. The galaxy is rich in heavy elements on the inside and poor on the outside. The decline is gentle, about a sixth per three thousand light-years, but across the whole disk it adds up to a factor of ten and more. At the edge of the disk, stars have only a fraction of the heavy elements we have here; what's lacking there isn't quiet but material.

The third is danger. Supernovae, the explosions of dying stars, follow the density: where there are more stars, more of them explode, and a supernova within thirty light-years strips a planet of its ozone layer. Add to that, on the inside, the close passes of other stars that disturb planetary orbits, the hard radiation from around the central black hole, and a sky that never gets dark.

In the bulge, a quiet billion years, of the kind Earth has had several times, isn't the normal case but a stroke of luck.

From the three gradients, a group around Charles Lineweaver calculated a ring in 2004, the galactic habitable zone: bounded on the inside by danger, on the outside by scarcity. In between, at twenty to thirty thousand light-years from the center, lies the band where Earth-like planets are left in peace long enough for something complex to grow on them. The sun sits right in the middle of it. That's no coincidence, and it's no proof either, and both have to be said.

No coincidence, because we only sit here calculating at all because the conditions here were right. No proof, because we know exactly one example of life and drew the ring around that example. Other calculations, with other assumptions about supernovae and planet formation, draw the ring wider, almost to the edge of the disk. Or they move most of the habitable planets inward, where more things explode but where there are also far more stars. The honest form of the finding is therefore: we sit in a good suburb, maybe the best. We haven't found the optimum, only the place where it demonstrably worked once.

Two Zones

The book goes one step further, and from here on it's conjecture—reasoned conjecture, but conjecture, and the reader should see the difference.

Lineweaver's ring is calculated for life. It asks where a planet is left in peace for four billion years, so that chemistry can become cells and cells can become something that builds antennas. That's the right question for origins. It's not the right question for what comes after. A technology, once it exists, no longer needs four billion years of peace. It needs something else: raw materials, energy, and neighbors.

Raw materials lie inward, because the chemistry is richer inward. Energy lies inward, because more stars burn in less space there. Neighbors lie inward, because the density is a hundred to a thousand times higher there, and for

a technology that exchanges information, neighbors are the most important thing of all. Where the nearest star is one light-year away instead of four, the same signal costs a sixteenth of the energy, and the pause in the conversation, which lasts generations for us, shrinks to the length of a career. The danger that wipes out a life on the inside hits a technology less hard: it can shield itself, go underground, copy itself, abandon a destroyed site and keep another.

So two zones instead of one. One for origins, where it has to be quiet, and one for operation, where it has to be dense, and the two don't lie in the same place.

You can calculate this as a toy model, and we did, with openly chosen weightings that could be chosen differently: stellar density, metal content, and supernova rate by the measured gradients; the biosphere as the product of density, chemistry, and quiet; the technosphere as the product of chemistry, density, neighborhood, and a small penalty for radiation. In its details the result depends on the weights; in its shape it doesn't. The biosphere zone is a ring at twenty to thirty thousand light-years, with the sun nearly at the maximum. The technosphere zone is a core from four to twenty thousand light-years, with its maximum at about eight thousand, and at our location it's at a quarter of its peak. Between the two lies a gradient of about fifteen thousand light-years, from outside to inside.

The interpretation is simple, and it's what this book has to contribute to the question of the silence. Life originates in the ring. Technology moves inward. The ring is the quiet nursery, the core is the pulsing downtown. The optimum for birth is the pessimum for meeting, and we live at the optimum for birth.

The Edge

There's a radius in the model that's more than a line in a graphic, and it lies at about eleven thousand light-years from the center. There, the mean distance between neighboring stars has halved. For us it's seven light-years, counting all stars and not just the bright ones; there it's just under four, and the number of stars within earshot has grown sixfold. Farther in it continues, but slowly:

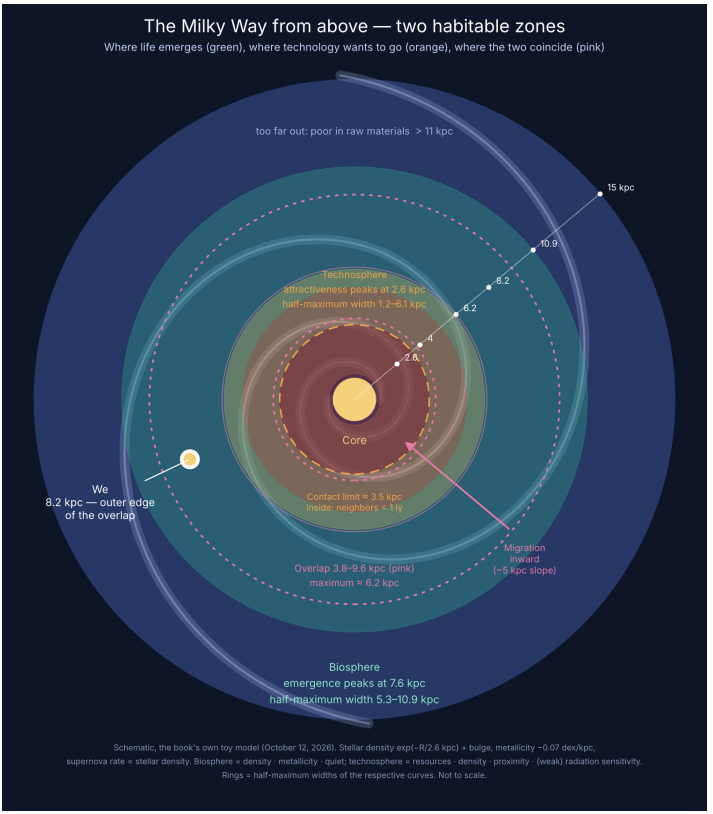


Figure 6 · Zoning of the galaxy, schematic. Top view; ring of biospheres in blue, core of technospheres in orange, overlap, the sun as a dot at the outer edge of the overlap; the bar with its quiet pockets perpendicular to it.

two light-years at two thousand light-years from the center, one light-year only in the innermost five hundred.

Half the distance means, for a signal, a quarter of the energy, and six neighbors instead of one means six opportunities instead of one. That's not yet a tipping point; it's the start of a gradient that gets steeper inward. The place where contact would be a habit—neighbors at light-months, answers within a lifetime—lies at the very center, in the last few hundred light-years around

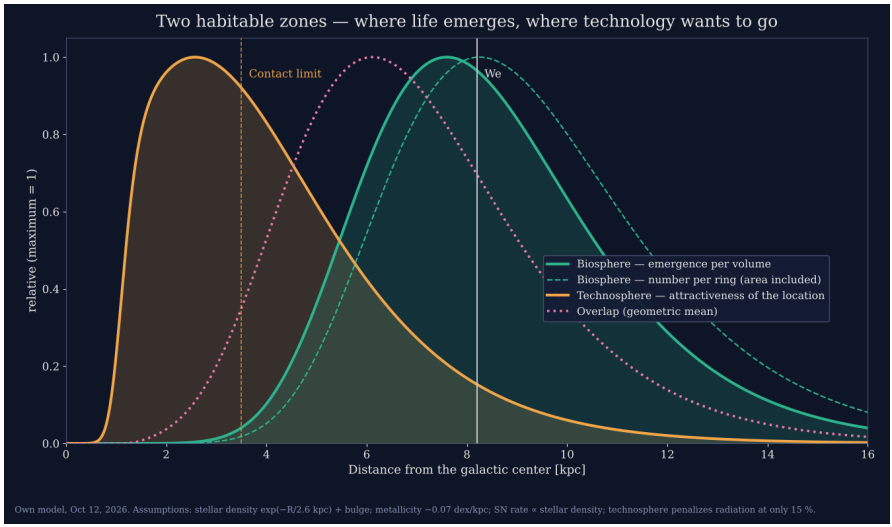


Figure 7 · Two habitable zones, the model: where life arises (blue) and where technology wants to go (orange), as curves over the distance from the galactic center.

the core. And that is exactly the place the three gradients mark as uninhabitable: too much radiation, too many supernovae, too many disturbances. The galaxy has set up the neighborhood where nobody can live. Inside the edge, contact gets cheaper with every step inward; outside, it stays a project. Whoever's inside rides the bus. Whoever's outside is isolated—not for want of will, but for want of neighbors.

For whoever lives inside, the edge is invisible. They've never known anything but neighbors a few light-years away, and the question of whether anyone is out there arises for them about as much as the question of whether there are people in the mountains arises for a city dweller—probably, yes, they're just far away and don't call. For us, the edge is the reason for the silence. We listen inward and see nothing, because the inside doesn't call outward; it has enough to do. And we listen all around us and hear nothing, because the neighbors are stuck in the same nursery: we're young and loud at short range, but quiet in everything that would count for interstellar communication.



OVERTONE

Valerian, 2017. Alpha, the city of a thousand planets: thousands of species in one station, each with its own air and its own opinion on parking. — Classified ad: "Apartment in Alpha, central, neighbors from 3,000 worlds, all within walking distance." — Note from physics: The ad is real; only the address is missing. The city sits ten thousand light-years farther in. We live way out in the provinces, where nobody rings the bell.

There's one find in this picture all the same, and it has a strange address. We ran the question in a model across the whole disk: seen from Earth, who is most likely to be heard—the many practiced transmitters downtown, or the few unpracticed ones in the neighborhood? As long as a signal only weakens with the square of the distance, the proportions in our model roughly balance: farther out there are more transmitters, closer in they're louder. But distance weighs more heavily than that. Distant signals aren't just weaker; they're also less often aimed at us, and less often still on their way right now. Once you factor that in, the neighborhood gains weight by a wide margin, even though almost nobody there transmits. The first signal we find won't come from the most interesting source but from the nearest one that transmits at all. We

call this the near-field principle, and it has a consequence worth holding on to: what we find, if we find something, comes from a region where, by our map, there's nothing to find. So it will be either a mistake—or something that doesn't belong here and is here anyway.

Two Ages

If life originates in the outer region and technology moves inward, then at any given time there are two kinds of technospheres in the galaxy, and they differ not in chemistry but in age.

One is young. It's still where it originated, in the ring, at its star, with its planet, with the body that built it still in view. It's loud, because it hasn't yet learned to be quiet, and it's alone, because in the ring everyone is alone. When it transmits, it transmits like someone speaking into a microphone for the first time: too loud, too long, in all directions, hoping someone's listening, and with no practice in making itself understood. We call it Type A, and we won't need the label often, because as we go on it will become clear that we know it.

The other is old. It has left its star, or is in the process of leaving, and what it left behind is the nursery. It has neighbors and habits, it has learned that transmitting is expensive and listening cheap, and it doesn't call outward, because there's nothing out there it misses. If it can be heard at all, it's not in a signal to us but in what it can't hide: in waste heat, in the shape of its surroundings, in things no star does on its own. Type B. It isn't the most likely counterpart for a conversation, because it doesn't hold conversations with the suburbs. It is the most likely counterpart for a find, because it's the thing that exists for a long time.

The difference between A and B is the same as between a village and a city, and it runs in the same direction: villages don't become cities, but people move from villages to the city, and the village stays as it is and from time to time grows young again. What this means for how the two look, this chapter leaves open. It only says where they are.

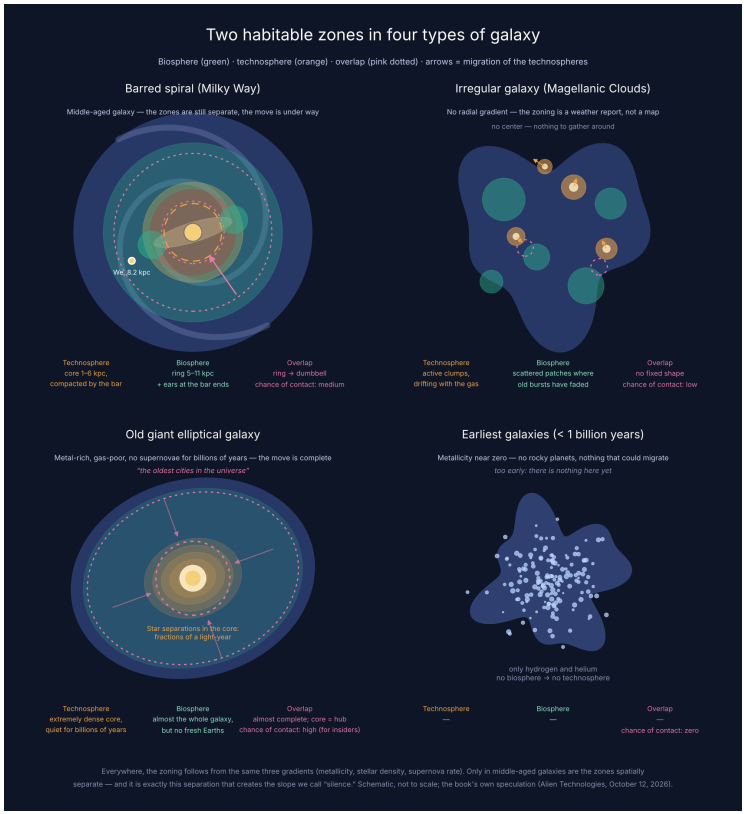


Figure 8 · Four galaxy types, quadriptych. Barred spiral, irregular, old elliptical, earliest galaxy; for each, biosphere zone, technosphere zone, overlap.

Other Galaxies

The three gradients aren't a quirk of the Milky Way. Density, chemistry, and danger run one way or another through every galaxy, so every galaxy has a zoning; the only question is what shape it takes, and the answer depends on the type.

In a spiral galaxy like ours, like Andromeda, like the Triangulum Galaxy, like everything within reach, the two zones lie apart: ring outside, core inside, and the bar compresses the core further. The bar isn't an object but a wave,

a traffic jam. The stars run on elongated orbits that tip one another in the same direction, and the pattern reinforces itself—like a jam on the freeway that stalls in some lanes while cars in other lanes keep moving. At its ends, gas collects and stars form; it's loud there. Perpendicular to the bar, on the orbit where stars and bar move at the same speed, there are two quiet pockets where nothing piles up. The sun runs close to that orbit, a little farther out—and at the wrong angle. Right orbit, wrong corner. Spiral galaxies are, by this model, the most likely places for contact, because both zones exist at the same time—and also the ones where contact is hardest, because the reshaping is still underway.

Irregular galaxies like the Magellanic Clouds are small, gas-rich, and never grew big enough to sort themselves out. They have no center that could attract technology, and too few heavy elements for much of either. Their zones are patches that drift with the gas: not a plan, more a weather report.

Old elliptical galaxies, the giant reddish ones in which no new stars have formed for billions of years, are the opposite. Their biosphere zone is nearly the whole galaxy, but there are no fresh Earths anymore, and their past—mergers, a long-active black hole at the center—may have wiped out early life before it came to anything. Their core, on the other hand, is denser than anything in a spiral and has been quiet for billions of years. If there are very old technospheres anywhere in the universe, it's there: the oldest cities, in galaxies without a nursery.

And the earliest galaxies, which the James Webb telescope has been seeing since 2022 in the first three hundred million years, have too little of everything. Their chemistry is a hundredth to a tenth of ours; there hadn't been enough dead stars yet. No zone, nothing that could move. Zoning is universal, but only in galaxies of middle age are the two zones spatially separate, and exactly that separation produces the gradient we call silence.

There's a novel that had this idea a good thirty years ago, in a different form: Vernor Vinge's *A Fire Upon the Deep* from 1992 divides the galaxy into zones in which different technology is possible, slow in the core, fast at the edge.

The direction is reversed and the justification is invented, but the thought that the galaxy isn't a uniform field but has neighborhoods is there before anyone calculated it. He invented it; here it's given a basis. That's the division of labor between imagination and physics that this book practices throughout, and it's rarely this clean.

Traces and Signals

If the suburb thesis is right, then we're not alone here, only among neighbors of a particular kind. The life curve is high here; in the quiet region around us, by the model, more life begins than anywhere else in the galaxy. But what begins here are biospheres: oceans with chemistry, atmospheres in which oxygen sits next to methane because something breathes both into them. That's what one may expect within a hundred light-years, and that's not nothing. What one may not expect here is that someone speaks.

Traces and signals are two different things. A trace is left by something that doesn't want to be seen, simply because it's there: a breath, a warmth, a shadow. A signal is made by something that wants to be heard. The suburbs are full of traces and poor in signals. The first proof that we're not alone will therefore, in all likelihood, be a spectral line in the light of an alien planet, not a message. We will see biospheres long before we hear technospheres.

The Map

With that, the silence has a different sound. It isn't the silence of an empty house but of a suburb on a Sunday morning: the neighbors are there, but each in their own garden; downtown is twenty kilometers away and has its own noise, and from here you can't hear it. That sixty years of searching have found nothing says about as much about the galaxy as a quiet Sunday in Zurich-Witikon says about Europe.

What follows from this for someone who wants to listen? A map, in four lines.

Listen inward. The signals, if there are any, come from downtown, not from the neighborhood; from places ten or twenty thousand light-years away, not a hundred.

Listen for the faint. Whatever arrives across twenty thousand light-years is faint, even if it was sent strong, and a transmitter that doesn't know who's listening doesn't send strong anyway; it sends long.

Listen for the slow. Whoever plans in centuries doesn't speak in seconds.

And in the neighborhood: don't listen, look. Spectra, atmospheres, traces. Something is there, but it isn't transmitting.

That's the map. It's a conjecture with numbers, and we've said what went into it. You can hang it on the wall, and you can take it down again if you want to search somewhere other than where someone ought to be. Whoever finds a signal in the suburbs has found something that, by this map, shouldn't be here.

We'll leave it at that. Because in an archive, a survey of the southern sky that nobody has looked at with this question in mind has been sitting for years. Now someone is looking at it—someone who won't agree with the map.

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What remains. The galaxy has three gradients—density, chemistry, danger—and therefore zones. Life needs quiet and originates in a ring halfway out, where we live: in the suburbs. Technology needs neighbors, raw materials, and energy, and those lie inward, downtown. Inside an edge at eleven thousand light-years, distances halve, and contact gets cheaper with every step inward. Far outside, it stays a project—and at the very center, where contact would be a habit, nobody can live at all. From this follow two ages of technospheres—young, loud, and alone in the ring; old, quiet, and among neighbors in the core—and a map: listen inward, look in the neighborhood. Whoever finds a signal out here anyway has found something that doesn't belong here.

VERLAG VON BEDEUTUNG

That was the sample.

Excerpt from Part 1 · Collecting and Measuring

Alien Technologies. Extraterrestrial Life, Exoplanets, and Alien Technologies. What if the first extraterrestrial encounter begins with a signal?

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