Gregory Benford - Life At Galactic Center

We're not in a lucky part of the galaxy, at least for views.

Our sun is tucked down in the disk's plane, though this took centuries to realize. In retrospect, perhaps it is puzzling that astronomers did not guess until the nineteenth century that the Milky Way is a disk, seen edge on.

Ancients used water analogies to describe it, images of rivers and streams. How much easier matters might have been if we could have seen the truly gaudy attraction in all the galaxy, the brilliant center.

Perhaps, thought, our ignorance is good luck. Dark dust clouds block our view in the constellation Sagittarius, so we cannot see in the optical frequencies beyond the edge of our local spiral arm. Beyond that are immense dark lanes, blotting out the next arm and the hub beyond.

One way to see the center would be to live much nearer. But that could be fatal.

The galactic center is about 25,000 light years away. We orbit about two thirds of the way out into the spiral disk, a benign, even boring neighborhood. The nearest star, Alpha Centauri, is 4.2 light years away, an average stellar separation for our region, where there is a star in roughly every fifty cubic light years.

Were we to approach the galactic hub, well past the dust clouds, we would find a halo of stars glowing brightly, growing ever denser. In 1932 Carl Jansky discovered that, to his shock, the galactic center was the brightest radio location in the sky, outshining even our sun. Something was going on.

In the core, within a few light years of the exact center, there are a million stars within a single light year. On average, the nearer stars are only a hundredth of a light year away. This is only ten thousand times the distance from the Earth to the sun. Imagine having several stars so close they outshine the moon.

As one might expect, this is bad news for solar systems around such stars. Close collisions between all these stars occur in about a hundred thousand years, scrambling up planetary orbits, raining down comets upon them as well.

The galactic center is the conspicuous Times Square of the galaxy -- and far more deadly than the comfortable suburbs like ours. Joel Davis's Journey to the Center of Our Galaxy details how horrific it is, points out that the survival time for an unshielded human within even a hundred light years of the core is probably hours.

I began studying the galactic center in the mid-1970s, out of curiosity. I did not guess that this mysterious region would intertwine two of my passions, physics and science fiction, though in part I was interested because I had begun writing a series of novels which seemed pointed in that direction.

The first was In the Ocean of Night, exploring the discovery that computer-based life seemed dominant throughout the galaxy. The action followed a British astronaut, Nigel Walmsley, cranky and opinionated. It detailed a few incidents in our solar system, in the late twentieth century and beyond, which uncovered the implication that "evolved adding machines," as Walmsley put it, had inherited the rains of earlier, naturally derived alien societies.

As I began work on the next volume, I realized that the galactic center was the obvious place for machines to seek. By the early 1980s we knew that there is a virulent gamma ray flux there, hot clouds, and enormously energetic processes. Most of this we gathered from the radio emissions, which penetrate dust clouds and revealed the crackling activity at the center for the first time. Infrared astronomy soon caught up, unmasking the hot, tangled regions.

By the time I finished Across the Sea of Suns, I realized that I could do some research myself on the galactic center. I had by that time written papers on pulsars and galactic jets, and had both expertise and curiosity. Our galaxy is a barred spiral, meaning that a straight segment runs through the center, connecting two bright spiral arms. The inner thousand light years is a turbulent zone of high velocity clouds, moving so fast that gravitation finds it difficult to force them to collapse into stars. Magnetic fields are also strong, making collapse still harder. Few new stars, so few later supernova explosions.

In the 1960s my friend Larry Niven had begun his Known Space stories, featuring a colossal explosion at galactic center, perhaps a chain reaction of supernovas. There was some evidence of greatly energetic processes there, but we know now that there was no such mammoth explosion, big enough to make alien races flee. However, within the inner hundred light years, there does seem to have been a great energy release a few million years ago. In the infrared we can see the outrushing gases.

More striking, though, are mysterious features appearing in the radio. In 1984 I was giving a talk on galactic jets at UC Los Angeles, and my host was Mark Morris, a radio astronomer. "Explain this," he challenged, slapping down a radio map he had just made at the Very Large Array in New Mexico.

"Good grief," was my first reaction. "Is this a joke?"

It showed a feature I called the Claw, but which Mark more learnedly termed the Arch: a bright, curved prominence made up of slender fibers. Though the Arch is over a hundred light years long these fibers are about a light year wide.

They curve upward from the galactic plane, like arcs of great circles which center near the galactic core, which is several hundred light years away. These intricate filaments shine by energetic (in fact, relativistic) electrons, radiating in strong magnetic fields, which are aligned along the filaments.

There was nothing remotely like them in astronomy. What process could make long, slightly curved paths, a light year wide?

I undertook the challenge, with some hesitation. The object was bizarre, which meant some new ideas were needed. I was aided by later discoveries in 1985, which spotted separate filaments within a few hundred light years of the core, single threads shining brightly. Above the Arch, some Japanese astronomers found what looks like a weak, fat jet.

How to explain thin filaments which glow by electron luminosity, a hundred times longer than they were wide? I thought of neon lights, which are glow discharges sustained by electric currents in slender tubes. What could contain the hot gas, or electrons? The magnetic fields, which mid-1980s measurements found to be at least a hundred times stronger than typical in the rest of the galaxy.

Astronomers began thinking of conceptual models for the phenomenon, mostly using magnetic loops which had been somehow expelled from the galactic center, and were striking distant gas clouds. These I didn't much believe; the Arch was too orderly. Others thought maybe the filaments were cosmic strings -immense fractures in space-time, made in the early universe -- lit up by their passage through the galactic inner regions. This model was disproved quickly, because strings should move at very nearly the speed of light; the Arch didn't.

By the time I got through with my calculations, building a mathematical model, I had decided that the entire network of Arch and threads might be a huge circuit. It had to be powered by some battery, and while most people thought the galactic center was the logical site, I kept noticing that it was hundreds of light years away. Instead, I studied the giant molecular clouds which were moving counter to the general galactic rotation. These were quite odd, dark and carrying millions of stellar masses of dust and gas in clumps light years wide.

I found that if they were even slightly ionized -- and how could they not be, with so much ultraviolet glare from nearby blue stars? -- these clouds would generate electric fields as they crossed the strong magnetic fields. The edges of these clouds could then act as batteries, applying voltages which accelerated electrons, sending them shooting along the magnetic field lines, lighting up the magnetic structures that already existed.

Since these discharges occurred because of momentary passage of clouds, they were essentially like weather -- changeable. Perhaps we could see some bright filaments weaken, others flare? I calculated the times required, and found that the best we could expect was a change within a decade or so, or longer.

Since these were circuits, they reminded me of lightning. Clouds on Earth discharge to ground along slightly ionized trails in the air. The stroke time is about a second, just a bit shorter than the time the lightning takes to begin snaking about itself, like a garden hose -- or the twisting snapping sparks from generators, a cliche overworked in films like Frankenstein.

Could these fibers be a sort of slow-motion lightning, taking perhaps hundreds of thousands of years to discharge? Then we might see filaments curling about themselves, or each other?

I asked these questions, sketched out solutions, and made a few predictions. In science any model, to win flavor, must paint an appealing picture and predict the outcome of future observations. I published the model in the Astrophysical Journal in 1988, "An Electrodynamic Model of the Galactic Center."

People seemed to find it plausible, if a bit strange. Electrodynamics isn't used much in astronomy, where gravity rules. I waited to see what observations would unmask.

Mark Morris kept making maps of the Arch region, but so far has seen no brightening or dimming, In 1990, though, some other radio astronomers found an odd thread they termed the Snake -- because it twisted, not once but twice,

I was pleased. The Snake seems attached to a giant molecular cloud at one end, and merges with the spherical rim of a supernova at the other. Is its cause the cloud, or the supernova? We don't know.

For now, mine seems the only theory left standing in the blizzard of data we're now getting about the galactic center. But my model depends on, without explaining, the strong smooth magnetic fields. How did they get there? Are they simply accumulated, as matter in falls? Or did some past explosion make them? We don't know.

And what about the jet? This points to the big unanswered question about the center: is there a black hole there? Certainly our experience with distant, active galactic nuclei leads us to suspect one, since the galactic jets I had already studied almost certainly come from the accretion disks around truly massive black holes, some ranging up to perhaps a billion stellar masses.

Measures of the orbital velocities of stars very close to the true galactic center, called Sagittarius A, suggest that a point mass of about a million stellar masses lurks there, giving off very little light.

Much controversy surrounds these observations, though, with some holding that the data could mean only a thousand stellar masses iS needed. All that is packed into a radio bright structure less than ten times as wide as the distance between the Earth and our sun. The region is hard to fathom, though, because the total luminosity within fifteen light years of this structure is about ten million stellar luminosities. Picture ten million or more bright, young stars orbiting a tiny dark spot, and you'll see the problem making out what's going on.

While I was mulling over data and jotting equations, I kept on writing novels. What came to be called the Galactic Series (by my publisher) pushed on with Great Sky River, a reference to the ancient Indian names for the Milky Way. I focused on the inner ten light years, for dramatic effects, even though I knew the sheer energy flux there made humans quite vulnerable. It seemed a good stage to act out my main theme, the superiority of machines in much of the galaxy.

The huge energetics of the center would draw machines, I felt. The black hole would intrigue any inquisitive life form. And the struggle between vastly different forms would surge across such a virulent territory. Humans would be part of it all, but certainly not the major players.

So I began envisioning what it might be like at stage center. Black holes draw matter in. Energetic arguments suggest that a black hole at the center should ingest about a thousandth of a star's mass in a year, already ground into dust from the giant molecular clouds -- with occasional burps if a whole sun gets swallowed. Indeed, the electrodynamic view I advanced suggested a mechanism to fuel the black hole: the discharges we see are in fact energy shed by slowing the clouds, a sort of electrodynamic brake.

The mass funnels into a disk, rotating about the hole. The disk gets hot from friction, its rotation perhaps shaping the jets which may focus intermittently above and below the disk. Here the diet of particles and photons is rich and varied. Only hard, tough machines could survive for long there. In the fourth novel, Tides of Light, I drew out these contrasts.

Machines which can reproduce themselves would, inevitably, fall under the laws of natural selection. Earlier forms which arrived from elsewhere would specialize to use local resources. The entire panoply of biology would recapitulate: parasites, predators, prey. Adaptation would shape machines, who would by their intelligence counter with their own clever moves, carrying out their long term agenda.

How to think of this? I prepare for novels by writing descriptive passages of places and characters. In spare moments I began working up snapshots of possible life forms and their survival styles. I wrote them in present tense, for a sense of immediacy, seeking the analogy to biology:

Above the disk nothing made of metal or ceramic can long survive.

The grinding down of stars goes on perpetually. Blobs of already incandescent matter spiral in at speeds higher than found anywhere else in the galaxy. The Eater holds eternally captive the gathered masses of a million dead suns. Its pull whirls the. doomed matter in a final frenzied gyre.

The blobs rub against each other. Magnetic fields mediate the friction and in turn grow. The fields twine and loop through the condemned kernels. In tight collisions fields themselves annihilate against each other and more energy releases.

Above such brutal furnaces skim the phase creatures. They had once been of the mechanicals. Now they exist not in hard circuits or ceramic lattice-intelligences. They have evolved out of self-directed necessity.

To drink more energy they have learned to dissolve.

As torrents of hard radiation lance through them, they are plasmas. This gathers in fluxes and stores them in long-range correlations.

When the flood ebbs the phase creatures change. In the cooler spots above the disk they can condense. Lacy filaments become gaseous discharges. The power so generated they broadcast outward, to lesser ranks who can store it.

The phase creatures themselves use these fluxes to organize themselves into free-floating networks. Circuits without wires. Electrons flowing only in their own self-consistently generated magnetic fields. Voltages and switches light-quick, gossamer thin.

Lively intelligences dance there. They enter the discussion which has been teeming above them, in the cooler realms. With silky elegance their thoughts merge with the hard beings who are the cruder, earlier forms of mechanicals.

But the phase creatures still know their origins. They share the thought patterns of the metallic forms. They converse.

My reading in evolutionary theory suggested that generally, the rate of development was faster where the contrast between energy levels was greatest. This explains why volcanic vents at the bottom of oceans proved a rich life site. Similarly, the tropics boast of myriad species, the poles few. The contrast between the black hole region and the surrounding sea of stars is similarly stark.

I worked out a crude model for setting up a current system which could link the disk of a black hole to the surroundings. The disk traps magnetic fields as in falling matter brings the field lines in. A rotating magnetic field can sling particles -probably electrons and positrons -out along the gradually opening field lines. The disk acts like an enormous rotating flywheel, driving currents and mass flow both up and down from the disk. This should yield two jets. One can calculate the energy yield -- actually, just an upper bound, which turns out to be considerable.

This part of any electrodynamic model is quite iffy, because we know nothing directly from the black hole environment. A gamma ray emission was seen several times through the 1980s from somewhere near galactic center, which corresponds to the annihilation of electrons and positrons. Perhaps it was from the black hole region, but certainly it's intermittent, for it vanished years ago and has not been seen since. Perhaps the weather there changed.

Worse, the calculated energy going into jets proved to be much higher than the rather weak, broad jet seen (in radio maps) emerging northward from the center. So perhaps the process is much weaker than we think. Further, there is no visible counter-jet, casting doubt on the whole assumed geometry of the black hole region.

It is easy to show that the present core region is accreting matter at a mild rate. If a star plunged in, there would be much more emission. Still, all this assumes that the radiation from matter plunging into the disk and then into the hole is simply streaming out.

What if something else intercepts this flow, uses it, and degrades it into lukewarm heat? Then all our calculations of spectra would be awry. What could such intervening agencies be... ?

Black holes have weather, of a sort.

Light streams from them. Blackness dwells at their cores, but friction heats the infalling gas and dust. These streams brim with forced radiation. Storms worry them. White-hot tornadoes whirl and suck.

For the immense hole at the exact center of the galaxy, a virulent glow hammers outward. It pushes incessantly at the crowded masses that circle it, jostling in their doomed orbits. Gravity's gullet forces the streams into a disk, churning ever inward. Suffering in the weather.

The press of hot photons is a wind, driving all before it. Except for the grazers. To these photovores, the great grinding disk is a source of food.

Fire-flowers blossom in the disk, sending up lashes of fierce ultraviolet. Storms of light.

Both above and below the accretion disk, in hovering clouds, these photons smash molecules to atoms, strip atoms into bare charge, whip particles into sleet. The clouds are debris, dust, grains. They are already doomed by gravity's rob, like nearly everything here.

Nearly. To the gossamer, floating herds this is a fountain. Their life source.

Sheets of them hang, billowing with the electromagnetic winds. Basking in the sting. Holding steady.

The photovores are patiently grazing Some are Infras, others Ultras - tuned to soak up particular slices of the electromagnetic spectrum.

Each species has a characteristic polish and shape. Each works within evolutionary necessity, deploying great flat receptor planes. Each has a song, used to maintain orbit and angle.

Against the wrathful weather here, information is at least a partial defense. Position-keeping telemetry flits between the herd sheets. They sing luminously to each other in the eternal brimming day.

Hovering on the pressure of light, great wings of high-gloss molysheet spread. Vectoring, skating on winds, magnetic torques in a complex dynamical sum. Ruling forces govern their perpetual, gliding dance. This is decreed by intelligences they scarcely sense, machines that prowl the darker lanes further out.

Those magisterial forms need the energies from this furnace, yet do not venture here. The wise and valuable run no risks.

At times the herds fail. Vast shimmering sheets peel away. Many are east into the shrouded masses of molecular clouds, which are themselves soon to boil away. Others follow a helpless descending gyre. Long before they could strike the brilliant disk, the hard glare dissolves their lattices. They burst open and flare with fatal energies.

Now a greater threat spirals lazily down. It descends from the shelter of thick, turbulent dust. It lets itself fall toward the governing mass, the black hole itself. Then it arrests its descent with out-stretched wings of mirrors. They bank gracefully on the photon breeze.

Its lenses swivel to select prey. There a pack of photovores has clumped, disregarding ageless programming, or perhaps caught in a magnetic flux tube. The cause does not matter. The predator eases down along the axis of the galaxy itself.

Here, navigation is simple. Far below, the rotational pole of the Eater of All Things is a pinprick of absolute black at the center of a slowly revolving, incandescent disk.

The clustered photovores sense a descending presence. Their vast sailing herds cleave, peeling back to reveal deeper planes of burnt-gold light seekers. They all live to ingest light and excrete microwave beams. Their internal world revolves around ingestion, considered digestion, and orderly excretion.

These placid conduits now flee. But those clumped near the axis have little angular momentum, and cannot pivot on a magnetic fulcrum. Dimly they sense their destiny. Their hissing microwaves waver.

Some plunge downward, hoping that the predator will not follow so close to the Eater. Others cluster ever more, as if numbers give safety. The opposite is true.

The metallovore folds its mirror wings. Now angular and swift, accelerating, it mashes a few of the herd on its carapace. It scoops them in with flux lines. Metal harvesters rip the photovores. Shreds rush down burnt-black tunnels. Electrostatic fields separate elements and alloys.

Fusion fires await the ruined carcasses. There the separation can be exquisitely tuned, yielding pure ingots of any alloy desired. In the last analysis, the ultimate resources here are mass and light. The photovores lived for light, and now they end as mass.

The sleek metallovore never deigns to notice the layers of multitudes peeling back, their gigshertz cries of panic. They are plankton. It ingests them without registering their songs, their pain, their mortal fears.

Yet the metallovore, too, is part of an intricate balance. If it and its kind were lost, the community orbiting the Eater would decay to a less diverse state, one of monotonous simplicity, unable to adjust to the Eater's vagaries. Less energy would be harnessed, less mass recovered.

The metallovore prunes less efficient photovores. Its ancient codes, sharpened over time by natural selection, prefer the weak. Those who have slipped into unproductive orbits are easier to catch. It also prefers the savor of those who have allowed their receptor planes to tarnish with succulent trace elements, spewed up by the hot accretion disk below. The metallovore spots these by their mottled, dusky hue.

Each frying instant, millions of such small deaths shape the mechsphere.

Predators abound, and parasites. Here and there on the metallovore's polished skin are limpets and barnacles. These lumps of orange-brown and soiled yellow feed on chance debris from the prey. They can lick at the passing winds of matter and light. They purge the metallovore of unwanted elements -- wreckage and dust which can jam even the most robust mechanisms, given time.

All this intricacy floats on the pressure of photons. Light is the fluid here, spilling up from the blistering storms far below in the great grinding disk. This rich harvest supports the mechsphere which stretches for hundreds of cubic light years, its sectors and spans like armatures of an unimaginable city.

All this, centered on a core of black oblivion, the dark font of vast wealth.

Inside the rim of the garish disk, oblivious to the weather here, whirls a curious blotchy distortion in the fabric of space and time. It is called by some the Wedge, for the way it is jammed in so close. Others term it the Labyrinth.

It seems to be a small refraction in the howling virulence. Sitting on the very brink of annihilation, it advertises its artificial insolence.

Yet it lives on. The mote orbits perpetually beside the most awful natural abyss in the galaxy: the Eater of All Things.

Intelligent machines would build atop this ferment a society we could scarcely fathom -- but we would try. Much of the next novel I wrote, Furious Gulf was about that -- the gulf around a Mack hole, and the gulf between intelligences born of different realms.

For years I had enjoyed long conversations with a friend, noted artificial intelligence theorist Marvin Minsky, about the possible lines of evolution of purely machine intelligence. Marvin views our concern with mortality and individualism as a feature of biological creatures, unnecessary among intelligences which never had to pass through our Darwin-nowing filter.

If we can copy ourselves indefinitely, why worry about a particular copy? What kind of society would emerge from such origins? What would it think of us -- we Naturals, still hobbled by biological destiny?

A slowly emerging theme in the novels, then, was how intelligence depended on the "substrate," the basic building blocks. Machines could embody intelligence, but their styles would be different.

Angular antennas reflect the bristling ultraviolet of the disk below. Shapes revolve. They live among clouds of infalling mass -- swarthy, shredding under a hail of radiation: infrared spikes, cutting gamma rays.

Among the dissolving clouds move silvery figures whose form alters to suit function. Liquid metal flows, firms. A new tool extrudes: matted titanium. It works at a deposit of rich indium. Chewing digesting,

The harvesters swoop in long ellipses, high above the hard brilliance of the disk. As they swarm they strike elaborate arrays, geometric matrices. Their volume-scavenging strategy is self-evolved, purely practical, a simple algorithm. Yet it generates intricate patterns which unfurl and perform and then cuff up again in artful, languorous beauty.

They have another, more profound function. Linked, they form a macro- antenna. In a single-voiced chorus they relay complex trains of digital thought. Never do they participate in the cross-lacing streams of careful deliberation, any more than molecules of air care for the sounds they transmit.

Across light-minutes the conversation billows and clashes and rings. A civilization blooms on the brink of the deepest abyss in Creation.

By the time I reached the last volume, in 1992, I had spent over twenty years slowly building up my ideas about machine intelligence, guided by friends like Marvin. I had also published several papers on the galactic center, am working on a further model for the Snake, and still eagerly read each issue of Astrophysical Journal for further clues.

Much remains to be found there. My nephew, now a doctoral student at Caltech, will make a thorough map of the center in 1995, using a detector he built to view light wavelengths shorter than a millimeter -he's caught the bug.

I finished the last novel, Sailing Bright Eternity, in summer 1994. It had been twenty-four years since I started on the series and our view of the galactic center had changed enormously. Some parts of the first two books, especially, are not representative of current thinking. Error goes with the territory.

I had taken many imaginative leaps in putting together a working "ecology" for the center, including truly outre ideas, such as constructions made by forcing space-time itself into compressed forms, which in turn act like mass itself: reversing Einstein's intuition, that matter curved space-time. All this was great fun, requiring a lot of time to think. I let my subconscious do most of the work, if possible. It's an easier way to write; but it stretches out projects, too. Occasionally I wanted to say to long-suffering readers, who wrote in asking when the next volume would appear, "Sorry; I'm writing as fast as I

Doubtless there are many more surprises ahead. We're extending our gaze into ever more distant frequencies, gaining better resolution, seeing liner detail. In peeling back the onion skins, we get closer to. how galaxies work, how the vast outbursts of their centers affect life, and how the truly bright galactic cores, quasars, work.

My own model is quite possibly completely wrong. It seems to explain some features (the filaments, the Snake) but has trouble with the jets. Eventually, comparing radio maps over time, we might see flareups and changes in the threads. Mine is strictly done in what I call the "cartoon approximation"--good enough for a first cut, maybe, but doomed to fail somewhere.

In any case, models are like matters of taste. Nobody expects a French impressionist painting to look much like a real cow; it suggests ways of looking at cows.

Is there life at the center? Nobody knows, but nobody can rule it out. Only by thinking about possibilities can we test them. My first intuition, seeing the radio map of the Arch, was, This looks artificial. Maybe it is -- you had probably thought of that explanation halfway through this piece. Astronomy reflexively assumes that everything in the night sky is natural. Someday, that may prove wrong.

One of the ways science fiction looks at the world is by pushing it to extremes, asking the questions that go beyond the bounds of what we can observe and check now. Imagination is no mere foot soldier; it wants to fly. That's why science fiction and science are forever linked.

The End

About this Title