

GLORY  
by Greg Egan

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1

An ingot of metallic hydrogen gleamed in the starlight, a narrow cylinder half a meter long with a mass of about a kilogram. To the naked eye it was a dense, solid object, but its lattice of tiny nuclei immersed in an insubstantial fog of electrons was one part matter to two hundred trillion parts empty space. A short distance away was a second ingot, apparently identical to the first, but composed of antihydrogen.

A sequence of finely tuned gamma rays flooded into both cylinders. The protons that absorbed them in the first ingot spat out positrons and were transformed into neutrons, breaking their bonds to the electron cloud that glued them in place. In the second ingot, antiprotons became antineutrons.

A further sequence of pulses herded the neutrons together and forged them into clusters; the antineutrons were similarly rearranged. Both kinds of cluster were unstable, but in order to fall apart they first had to pass through a quantum state that would have strongly absorbed a component of the gamma rays constantly raining down on them. Left to themselves, the probability of them being in this state would have increased rapidly, but each time they measurably failed to absorb the gamma rays, the probability fell back to zero. The quantum Zeno effect endlessly reset the clock, holding the decay in check.

The next series of pulses began shifting the clusters into the space that had separated the original ingots. First neutrons, then antineutrons, were sculpted together in alternating layers. Though the clusters were ultimately unstable, while they persisted they were inert, sequestering their constituents and preventing them from annihilating their counterparts. The end point of this process of nuclear sculpting was a sliver of compressed matter and antimatter, sandwiched together into a needle one micron wide.

The gamma ray lasers shut down, the Zeno effect withdrew its prohibitions. For the time it took a beam of light to cross a neutron, the needle sat motionless in space. Then it began to burn, and it began to move.

The needle was structured like a meticulously crafted firework, and its outer layers ignited first. No external casing could have channeled this blast, but the pattern of tensions woven into the needle's construction favored one direction for the debris to be expelled. Particles streamed backward; the needle moved forward. The shock of

acceleration could not have been borne by anything built from atomic-scale matter, but the pressure bearing down on the core of the needle prolonged its life, delaying the inevitable.

Layer after layer burned itself away, blasting the dwindling remnant forward ever faster. By the time the needle had shrunk to a tenth of its original size it was moving at ninety-eight per cent of light speed; to a bystander this could scarcely have been improved upon, but from the needle's perspective there was still room to slash its journey's duration by orders of magnitude.

When just one thousandth of the needle remained, its time, compared to the neighboring stars, was passing five hundred times more slowly. Still the layers kept burning, the protective clusters unraveling as the pressure on them was released. The needle could only reach close enough to light speed to slow down time as much as it required if it could sacrifice a large enough proportion of its remaining mass. The core of the needle could survive only for a few trillionths of a second, while its journey would take two hundred million seconds as judged by the stars. The proportions had been carefully matched, though: out of the two kilograms of matter and antimatter that had been woven together at the launch, only a few million neutrons were needed as the final payload.

By one measure, seven years passed. For the needle, its last trillionths of a second unwound, its final layers of fuel blew away, and at the moment its core was ready to explode it reached its destination, plunging from the near-vacuum of space straight into the heart of a star.

Even here, the density of matter was insufficient to stabilize the core, yet far too high to allow it to pass unhindered. The core was torn apart. But it did not go quietly, and the shock waves it carved through the fusing plasma endured for a million kilometers: all the way through to the cooler outer layers on the opposite side of the star. These shock waves were shaped by the payload that had formed them, and though the initial pattern imprinted on them by the disintegrating cluster of neutrons was enlarged and blurred by its journey, on an atomic scale it remained sharply defined. Like a mold stamped into the seething plasma it encouraged ionized molecular fragments to slip into the troughs and furrows that matched their shapes, and then brought them together to react in ways that the plasma's random collisions would never have allowed. In effect, the shock waves formed a web of catalysts, carefully laid out in both time and space, briefly transforming a small corner of the star into a chemical factory operating on a nanometer scale.

The products of this factory sprayed out of the star, riding the last traces of the shock wave's momentum: a few nanograms of elaborate, carbon-rich molecules, sheathed in a protective fullerene weave. Traveling at seven hundred kilometers per second, a fraction below the velocity needed to escape from the star completely, they climbed out of its gravity well, slowing as they ascended.

Four years passed, but the molecules were stable against the ravages of space.

By the time they'd traveled a billion kilometers they had almost come to a halt, and they would have fallen back to die in the fires of the star that had forged them if their journey had not been timed so that the star's third planet, a gas giant, was waiting to urge them forward. As they fell toward it, the giant's third moon moved across their path. Eleven years after the needle's launch, its molecular offspring rained down on to the methane snow.

The tiny heat of their impact was not enough to damage them, but it melted a microscopic puddle in the snow. Surrounded by food, the molecular seeds began to grow. Within hours, the area was teeming with nanomachines, some mining the snow and the minerals beneath it, others assembling the bounty into an intricate structure, a rectangular panel a couple of meters wide.

From across the light years, an elaborate sequence of gamma ray pulses fell upon the panel. These pulses were the needle's true payload, the passengers for whom it had merely prepared the way, transmitted in its wake four years after its launch. The panel decoded and stored the data, and the army of nanomachines set to work again, this time following a far more elaborate blueprint. The miners were forced to look further afield to find all the elements that were needed, while the assemblers labored to reach their goal through a sequence of intermediate stages, carefully designed to protect the final product from the vagaries of the local chemistry and climate.

After three months' work, two small fusion-powered spacecraft sat in the snow. Each one held a single occupant, waking for the first time in their freshly minted bodies, yet endowed with memories of an earlier life.

Joan switched on her communications console. Anne appeared on the screen, three short pairs of arms folded across her thorax in a posture of calm repose. They had both worn virtual bodies with the same anatomy before, but this was the first time they had become Noudah in the flesh.

"We're here. Everything worked," Joan marveled. The language she spoke was not her own, but the structure of her new brain and body made it second nature.

Anne said, "Now comes the hard part."

"Yes." Joan looked out from the spacecraft's cockpit. In the distance, a fissured blue-gray plateau of water ice rose above the snow. Nearby, the nanomachines were busy disassembling the gamma ray receiver. When they had erased all traces of their handiwork they would wander off into the snow and catalyze their own destruction.

Joan had visited dozens of planet-bound cultures in the past, taking on different bodies and languages as necessary, but those cultures had all been plugged in to the Amalgam, the meta-civilization that spanned the galactic disk. However far from home she'd been, the means to return to familiar places had always been close at hand. The Noudah had only just mastered interplanetary flight, and they had no idea that the Amalgam existed. The closest node in the Amalgam's network was seven light years away, and even that was out of bounds to her and Anne now: they had agreed not to risk disclosing its location to the Noudah, so any transmission they sent could only be

directed to a decoy node that they'd set up more than twenty light years away.

“It will be worth it,” Joan said.

Anne's Noudah face was immobile, but chromatophores sent a wave of violet and gold sweeping across her skin in an expression of cautious optimism. “We'll see.” She tipped her head to the left, a gesture preceding a friendly departure.

Joan tipped her own head in response, as if she'd been doing so all her life. “Be careful, my friend,” she said.

“You too.”

Anne's ship ascended so high on its chemical thrusters that it shrank to a speck before igniting its fusion engine and streaking away in a blaze of light. Joan felt a pang of loneliness; there was no predicting when they would be reunited.

Her ship's software was primitive; the whole machine had been scrupulously matched to the Noudah's level of technology. Joan knew how to fly it herself if necessary, and on a whim she switched off the autopilot and manually activated the ascent thrusters. The control panel was crowded, but having six hands helped.

## 2

The world the Noudah called home was the closest of the system's five planets to their sun. The average temperature was one hundred and twenty degrees Celsius, but the high atmospheric pressure allowed liquid water to exist across the entire surface. The chemistry and dynamics of the planet's crust had led to a relatively flat terrain, with a patchwork of dozens of disconnected seas but no globe-spanning ocean. From space, these seas appeared as silvery mirrors, bordered by a violet and brown tarnish of vegetation.

The Noudah were already leaving their most electromagnetically promiscuous phase of communications behind, but the short-lived oasis of Amalgam-level technology on Baneth, the gas giant's moon, had had no trouble eavesdropping on their chatter and preparing an updated cultural briefing which had been spliced into Joan's brain.

The planet was still divided into the same eleven political units as it had been fourteen years before, the time of the last broadcasts that had reached the node before Joan's departure. Tira and Ghahar, the two dominant nations in terms of territory, economic activity and military power, also occupied the vast majority of significant Niah archaeological sites.

Joan had expected that they'd be noticed as soon as they left Baneth — the exhaust from their fusion engines glowed like the sun — but their departure had triggered no obvious response, and now that they were coasting they'd be far harder to spot. As Anne drew closer to the home world, she sent a message to Tira's traffic control center. Joan tuned in to the exchange.

“I come in peace from another star,” Anne said. “I seek permission to land.”

There was a delay of several seconds more than the light-speed lag, then a terse

response. "Please identify yourself and state your location."

Anne transmitted her coordinates and flight plan.

"We confirm your location, please identify yourself."

"My name is Anne. I come from another star."

There was a long pause, then a different voice answered. "If you are from Ghahar, please explain your intentions."

"I am not from Ghahar."

"Why should I believe that? Show yourself."

"I've taken the same shape as your people, in the hope of living among you for a while." Anne opened a video channel and showed them her unremarkable Noudah face. "But there's a signal being transmitted from these coordinates that might persuade you that I'm telling the truth." She gave the location of the decoy node, twenty light years away, and specified a frequency. The signal coming from the node contained an image of the very same face.

This time, the silence stretched out for several minutes. It would take a while for the Tirans to confirm the true distance of the radio source.

"You do not have permission to land. Please enter this orbit, and we will rendezvous and board your ship."

Parameters for the orbit came through on the data channel. Anne said, "As you wish."

Minutes later, Joan's instruments picked up three fusion ships being launched from Tiran bases. When Anne reached the prescribed orbit, Joan listened anxiously to the instructions the Tirans issued. Their tone sounded wary, but they were entitled to treat this stranger with caution, all the more so if they believed Anne's claim.

Joan was accustomed to a very different kind of reception, but then the members of the Amalgam had spent hundreds of millennia establishing a framework of trust. They also benefited from a milieu in which most kinds of force had been rendered ineffectual; when everyone had backups of themselves scattered around the galaxy, it required a vastly disproportionate effort to inconvenience someone, let alone kill them. By any reasonable measure, honesty and cooperation yielded far richer rewards than subterfuge and slaughter.

Nonetheless, each individual culture had its roots in a biological heritage that gave rise to behavior governed more by ancient urges than contemporary realities, and even when they mastered the technology to choose their own nature, the precise set of traits they preserved was up to them. In the worst case, a species still saddled with inappropriate drives but empowered by advanced technology could wreak havoc. The Noudah deserved to be treated with courtesy and respect, but they did not yet belong in the Amalgam.

The Tirans' own exchanges were not on open channels, so once they had entered Anne's ship Joan could only guess what was happening. She waited until two of the ships had returned to the surface, then sent her own message to Ghahar's traffic control.

“I come in peace from another star. I seek permission to land.”

3

The Ghahari allowed Joan to fly her ship straight down to the surface. She wasn't sure if this was because they were more trusting, or if they were afraid that the Tirans might try to interfere if she lingered in orbit.

The landing site was a bare plain of chocolate colored sand. The air shimmered in the heat, the distortions intensified by the thickness of the atmosphere, making the horizon waver as if seen through molten glass. Joan waited in the cockpit as three trucks approached; they all came to a halt some twenty meters away. A voice over the radio instructed her to leave the ship; she complied, and after she'd stood in the open for a minute, a lone Noudah left one of the trucks and walked toward her.

“I'm Pirit,” she said. “Welcome to Ghahar.” Her gestures were courteous but restrained.

“I'm Joan. Thank you for your hospitality.”

“Your impersonation of our biology is impeccable.” There was a trace of skepticism in Pirit's tone; Joan had pointed the Ghahari to her own portrait being broadcast from the decoy node, but she had to admit that in the context her lack of exotic technology and traits would make it harder to accept the implications of that transmission.

“In my culture, it's a matter of courtesy to imitate one's hosts as closely as possible.”

Pirit hesitated, as if pondering whether to debate the merits of such a custom, but then rather than quibbling over the niceties of interspecies etiquette she chose to confront the real issue head on. “If you're a Tiran spy, or a defector, the sooner you admit that the better.”

“That's very sensible advice, but I'm neither.”

The Noudah wore no clothing as such, but Pirit had a belt with a number of pouches. She took a hand-held scanner from one and ran it over Joan's body. Joan's briefing suggested that it was probably only checking for metal, volatile explosives and radiation; the technology to image her body or search for pathogens would not be so portable. In any case, she was a healthy, unarmed Noudah down to the molecular level.

Pirit escorted her to one of the trucks, and invited her to recline in a section at the back. Another Noudah drove while Pirit watched over Joan. They soon arrived at a small complex of buildings a couple of kilometers from where the ship had touched down. The walls, roofs and floors of the buildings were all made from the local sand, cemented with an adhesive that the Noudah secreted from their own bodies.

Inside, Joan was given a thorough medical examination, including three kinds of full-body scan. The Noudah who examined her treated her with a kind of detached efficiency devoid of any pleasantries; she wasn't sure if that was their standard bedside manner, or a kind of glazed shock at having been told of her claimed origins.

Pirit took her to an adjoining room and offered her a couch. The Noudah anatomy did not allow for sitting, but they liked to recline.

Pirit remained standing. "How did you come here?" she asked.

"You've seen my ship. I flew it from Baneth."

"And how did you reach Baneth?"

"I'm not free to discuss that," Joan replied cheerfully.

"Not free?" Pirit's face clouded with silver, as if she was genuinely perplexed.

Joan said, "You understand me perfectly. Please don't tell me there's nothing *you're* not free to discuss with me."

"You certainly didn't fly that ship twenty light years."

"No, I certainly didn't."

Pirit hesitated. "Did you come through the Cataract?" The Cataract was a black hole, a remote partner to the Noudah's sun; they orbited each other at a distance of about eighty billion kilometers. The name came from its telescopic appearance: a dark circle ringed by a distortion in the background of stars, like some kind of visual aberration. The Tirans and Ghahari were in a race to be the first to visit this extraordinary neighbor, but as yet neither of them were quite up to the task.

"*Through* the Cataract? I think your scientists have already proven that black holes aren't shortcuts to anywhere."

"Our scientists aren't always right."

"Neither are ours," Joan admitted, "but all the evidence points in one direction: black holes aren't doorways, they're shredding machines."

"So you traveled the whole twenty light years?"

"More than that," Joan said truthfully, "from my original home. I've spent half my life traveling."

"Faster than light?" Pirit suggested hopefully.

"No. That's impossible."

They circled around the question a dozen more times, before Pirit finally changed her tune from *how* to *why*?

"I'm a xenomathematician," Joan said. "I've come here in the hope of collaborating with your archaeologists in their study of Niah artifacts."

Pirit was stunned. "What do you know about the Niah?"

"Not as much as I'd like to." Joan gestured at her Noudah body. "As I'm sure you've already surmised, we've listened to your broadcasts for some time, so we know pretty much what an ordinary Noudah knows. That includes the basic facts about the Niah. Historically they've been referred to as your ancestors, though the latest studies suggest that you and they really just have an earlier common ancestor. They died out about a million years ago, but there's evidence that they might have had a sophisticated culture for as long as three million years. There's no indication that they ever developed space flight. Basically, once they achieved material comfort, they seem to have devoted themselves to various artforms, including mathematics."

“So you've traveled twenty light years just to look at Niah tablets?” Pirit was incredulous.

“Any culture that spent three million years doing mathematics must have something to teach us.”

“Really?” Pirit's face became blue with disgust. “In the ten thousand years since we discovered the wheel, we've already reached halfway to the Cataract. They wasted their time on useless abstractions.”

Joan said, “I come from a culture of spacefarers myself, so I respect your achievements. But I don't think anyone really knows what the Niah achieved. I'd like to find out, with the help of your people.”

Pirit was silent for a while. “What if we say no?”

“Then I'll leave empty-handed.”

“What if we insist that you remain with us?”

“Then I'll die here, empty-handed.” On her command, this body would expire in an instant; she could not be held and tortured.

Pirit said angrily, “You must be willing to trade *something* for the privilege you're demanding!”

“Requesting, not demanding,” Joan insisted gently. “And what I'm willing to offer is my own culture's perspective on Niah mathematics. If you ask your archaeologists and mathematicians, I'm sure they'll tell you that there are many things written in the Niah tablets that they don't yet understand. My colleague and I -” neither of them had mentioned Anne before, but Joan was sure that Pirit knew all about her “— simply want to shed as much light as we can on this subject.”

Pirit said bitterly, “You won't even tell us how you came to our world. Why should we trust you to share whatever you discover about the Niah?”

“Interstellar travel is no great mystery,” Joan countered. “You know all the basic science already; making it work is just a matter of persistence. If you're left to develop your own technology, you might even come up with better methods than we have.”

“So we're expected to be patient, to discover these things for ourselves ... but you can't wait a few centuries for us to decipher the Niah artifacts?”

Joan said bluntly, “The present Noudah culture, both here and in Tira, seems to hold the Niah in contempt. Dozens of partially excavated sites containing Niah artifacts are under threat from irrigation projects and other developments. That's the reason we couldn't wait. We needed to come here and offer our assistance, before the last traces of the Niah disappeared forever.”

Pirit did not reply, but Joan hoped she knew what her interrogator was thinking: *Nobody would cross twenty light years for a few worthless scribbles. Perhaps we've underestimated the Niah. Perhaps our ancestors have left us a great secret, a great legacy. And perhaps the fastest — perhaps the only — way to uncover it is to give this impertinent, irritating alien exactly what she wants.*



The sun was rising ahead of them as they reached the top of the hill. Sandó turned to Joan, and his face became green with pleasure. “Look behind you,” he said.

Joan did as he asked. The valley below was hidden in fog, and it had settled so evenly that she could see their shadows in the dawn light, stretched out across the top of the fog layer. Around the shadow of her head was a circular halo like a small rainbow.

“We call it the Niah's light,” Sandó said. “In the old days, people used to say that the halo proved that the Niah blood was strong in you.”

Joan said, “The only trouble with that hypothesis being that *you* see it around *your* head ... and I see it around mine.” On Earth, the phenomenon was known as a “glory”. The particles of fog were scattering the sunlight back toward them, turning it one hundred and eighty degrees. To look at the shadow of your own head was to face directly away from the sun, so the halo always appeared around the observer's shadow.

“I suppose you're the final proof that Niah blood has nothing to do with it,” Sandó mused.

“That's assuming I'm telling you the truth, and I really can see it around my own head.”

“And assuming,” Sandó added, “that the Niah really did stay at home, and didn't wander around the galaxy spreading their progeny.”

They came over the top of the hill and looked down into the adjoining riverine valley. The sparse brown grass of the hillside gave way to a lush violet growth closer to the water. Joan's arrival had delayed the flooding of the valley, but even alien interest in the Niah had only bought the archaeologists an extra year. The dam was part of a long-planned agricultural development, and however tantalizing the possibility that Joan might reveal some priceless insight hidden among the Niah's “useless abstractions”, that vague promise could only compete with more tangible considerations for a limited time.

Part of the hill had fallen away in a landslide a few centuries before, revealing more than a dozen beautifully preserved strata. When Joan and Sandó reached the excavation site, Rali and Surat were already at work, clearing away soft sedimentary rock from a layer that Sandó had dated as belonging to the Niah's “twilight” period.

Pirit had insisted that only Sandó, the senior archaeologist, be told about Joan's true nature; Joan refused to lie to anyone, but had agreed to tell her colleagues only that she was a mathematician and that she was not permitted to discuss her past. At first this had made them guarded and resentful, no doubt because they assumed that she was some kind of spy sent by the authorities to watch over them. Later it had dawned on them that she was genuinely interested in their work, and that the absurd restrictions on her topics of conversation were not of her own choosing. Nothing about the Noudah's language or appearance correlated strongly with their recent division into nations — with no oceans to cross, and a long history of migration they were more or less geographically homogeneous — but Joan's odd name and occasional *faux pas* could still be ascribed to

some mysterious exoticism. Rali and Surat seemed content to assume that she was a defector from one of the smaller nations, and that her history could not be made explicit for obscure political reasons.

“There are more tablets here, very close to the surface,” Rali announced excitedly. “The acoustics are unmistakable.” Ideally they would have excavated the entire hillside, but they did not have the time or the labor, so they were using acoustic tomography to identify likely deposits of accessible Niah writing, and then concentrating their efforts on those spots.

The Niah had probably had several ephemeral forms of written communication, but when they found something worth publishing, it stayed published: they carved their symbols into a ceramic that made diamond seem like tissue paper. It was almost unheard of for the tablets to be broken, but they were small, and multi-tablet works were sometimes widely dispersed. Niah technology could probably have carved three million years' worth of knowledge on to the head of a pin — they seemed not to have invented nanomachines, but they were into high quality bulk materials and precision engineering — but for whatever reason they had chosen legibility to the naked eye above other considerations.

Joan made herself useful, taking acoustic readings further along the slope, while Sando watched over his students as they came closer to the buried Niah artifacts. She had learned not to hover around expectantly when a discovery was imminent; she was treated far more warmly if she waited to be summoned. The tomography unit was almost foolproof, using satellite navigation to track its position and software to analyze the signals it gathered; all it really needed was someone to drag it along the rock face at a suitable pace.

Through the corner of her eye, Joan noticed her shadow on the rocks flicker and grow complicated. She looked up to see three dazzling beads of light flying west out of the sun. She might have assumed that the fusion ships were doing something useful, but the media was full of talk of “military exercises”, which meant the Tirans and the Ghahari engaging in expensive, belligerent gestures in orbit, trying to convince each other of their superior skills, technology, or sheer strength of numbers. For people with no real differences apart from a few centuries of recent history, they could puff up their minor political disputes into matters of the utmost solemnity. It might almost have been funny, if the idiots hadn't incinerated hundreds of thousands of each other's citizens every few decades, not to mention playing callous and often deadly games with the lives of the inhabitants of smaller nations.

“Jown! Jown! Come and look at this!” Surat called to her. Joan switched off the tomography unit and jogged toward the archaeologists, suddenly conscious of her body's strangeness. Her legs were stumpy but strong, and her balance as she ran came not from arms and shoulders but from the swish of her muscular tail.

“It's a significant mathematical result,” Rali informed her proudly when she reached them. He'd pressure-washed the sandstone away from the near-indestructible

ceramic of the tablet, and it was only a matter of holding the surface at the right angle to the light to see the etched writing stand out as crisply and starkly as it would have a million years before.

Rali was not a mathematician, and he was not offering his own opinion on the theorem the tablet stated; the Niah themselves had a clear set of typographical conventions which they used to distinguish between everything from minor lemmas to the most celebrated theorems. The size and decorations of the symbols labelling the theorem attested to its value in the Niah's eyes.

Joan read the theorem carefully. The proof was not included on the same tablet, but the Niah had a way of expressing their results that made you believe them as soon as you read them; in this case the definitions of the terms needed to state the theorem were so beautifully chosen that the result seemed almost inevitable.

The theorem itself was expressed as a commuting hypercube, one of the Niah's favorite forms. You could think of a square with four different sets of mathematical objects associated with each of its corners, and a way of mapping one set into another associated with each edge of the square. If the maps commuted, then going across the top of the square, then down, had exactly the same effect as going down the left edge of the square, then across: either way, you mapped each element from the top-left set into the same element of the bottom-right set. A similar kind of result might hold for sets and maps that could naturally be placed at the corners and edges of a cube, or a hypercube of any dimension. It was also possible for the square faces in these structures to stand for relationships that held between the maps between sets, and for cubes to describe relationships between those relationships, and so on.

That a theorem took this form didn't guarantee its importance; it was easy to cook up trivial examples of sets and maps that commuted. The Niah didn't carve trivia into their timeless ceramic, though, and this theorem was no exception. The seven-dimensional commuting hypercube established a dazzlingly elegant correspondence between seven distinct, major branches of Niah mathematics, intertwining their most important concepts into a unified whole. It was a result Joan had never seen before: no mathematician anywhere in the Amalgam, or in any ancestral culture she had studied, had reached the same insight.

She explained as much of this as she could to the three archaeologists; they couldn't take in all the details, but their faces became orange with fascination when she sketched what she thought the result would have meant to the Niah themselves.

"This isn't quite the Big Crunch," she joked, "but it must have made them think they were getting closer." *The Big Crunch* was her nickname for the mythical result that the Niah had aspired to reach: a unification of every field of mathematics that they considered significant. To find such a thing would not have meant the end of mathematics — it would not have subsumed every last conceivable, interesting mathematical truth — but it would certainly have marked a point of closure for the Niah's own style of investigation.

“I'm sure they found it,” Surat insisted. “They reached the Big Crunch, then they had nothing more to live for.”

Rali was scathing. “So the whole culture committed collective suicide?”

“Not actively, no,” Surat replied. “But it was the search that had kept them going.”

“Entire cultures don't lose the will to live,” Rali said. “They get wiped out by external forces: disease, invasion, changes in climate.”

“The Niah survived for three million years,” Surat countered. “They had the means to weather all of those forces. Unless they were wiped out by alien invaders with vastly superior technology.” She turned to Joan. “What do you think?”

“About aliens destroying the Niah?”

“I was joking about the aliens. But what about the mathematics? What if they found the Big Crunch?”

“There's more to life than mathematics,” Joan said. “But not much more.”

Sando said, “And there's more to this find than one tablet. If we get back to work, we might have the proof in our hands before sunset.”

## 5

Joan briefed Halzoun by video link while Sando prepared the evening meal. Halzoun was the mathematician Pirit had appointed to supervise her, but apparently his day job was far too important to allow him to travel. Joan was grateful; Halzoun was the most tedious Noudah she had encountered. He could understand the Niah's work when she explained it to him, but he seemed to have no interest in it for its own sake. He spent most of their conversations trying to catch her out in some deception or contradiction, and the rest pressing her to imagine military or commercial applications of the Niah's gloriously useless insights. Sometimes she played along with this infantile fantasy, hinting at potential superweapons based on exotic physics that might come tumbling out of the vacuum, if only one possessed the right Niah theorems to coax them into existence.

Sando was her minder too, but at least he was more subtle about it. Pirit had insisted that she stay in his shelter, rather than sharing Rali and Surat's; Joan didn't mind, because with Sando she didn't have the stress of having to keep quiet about everything. Privacy and modesty were non-issues for the Noudah, and Joan had become Noudah enough not to care herself. Nor was there any danger of their proximity leading to a sexual bond; the Noudah had a complex system of biochemical cues that meant desire only arose in couples with a suitable mixture of genetic differences and similarities. She would have had to search a crowded Noudah city for a week to find someone to lust after, though at least it would have been guaranteed to be mutual.

After they'd eaten, Sando said, “You should be happy. That was our best find yet.”

“I am happy.” Joan made a conscious effort to exhibit a viridian tinge. “It was

the first new result I've seen on this planet. It was the reason I came here, the reason I traveled so far.”

“Something's wrong, though, I think.”

“I wish I could have shared the news with my friend,” Joan admitted. Pirit claimed to be negotiating with the Tirans to allow Anne to communicate with her, but Joan was not convinced that she was genuinely trying. She was sure that Pirit would have relished the thought of listening in on a conversation between the two of them — while forcing them to speak Noudah, of course — in the hope that they'd slip up and reveal something useful, but at the same time she would have had to face the fact that the Tirans would be listening too. What an excruciating dilemma.

“You should have brought a communications link with you,” Sando suggested. “A home-style one, I mean. Nothing we could eavesdrop on.”

“We couldn't do that,” Joan said.

He pondered this. “You really are afraid of us, aren't you? You think the smallest technological trinket will be enough to send us straight to the stars, and then you'll have a horde of rampaging barbarians to deal with.”

“We know how to deal with barbarians,” Joan said coolly.

Sando's face grew dark with mirth. “Now *I'm* afraid.”

“I just wish I knew what was happening to her,” Joan said. “What she was doing, how they were treating her.”

“Probably much the same as we're treating you,” Sando suggested. “We're really not that different.” He thought for a moment. “There was something I wanted to show you.” He brought over his portable console, and summoned up an article from a Tiran journal. “See what a borderless world we live in,” he joked.

The article was entitled “Seekers and Spreaders: What We Must Learn from the Niah”. Sando said, “This might give you some idea of how they're thinking over there. Jaqad is an academic archaeologist, but she's also very close to the people in power.”

Joan read from the console while Sando made repairs to their shelter, secreting a molasses-like substance from a gland at the tip of his tail and spreading it over the cracks in the walls.

There were two main routes a culture could take, Jaqad argued, once it satisfied its basic material needs. One was to think and study: to stand back and observe, to seek knowledge and insight from the world around it. The other was to invest its energy in entrenching its good fortune.

The Niah had learned a great deal in three million years, but in the end it had not been enough to save them. Exactly what had killed them was still a matter of speculation, but it was hard to believe that if they had colonized other worlds they would have vanished on all of them. “Had the Niah been Spreaders,” Jaqad wrote, “we might expect a visit from them, or them from us, sometime in the coming centuries.”

The Noudah, in contrast, were determined Spreaders. Once they had the means, they would plant colonies across the galaxy. They would, Jaqad was sure, create new

biospheres, re-engineer stars, and even alter space and time to guarantee their survival. The growth of their empire would come first; any knowledge that failed to serve that purpose would be a mere distraction. “In any competition between Seekers and Spreaders, it is a Law of History that the Spreaders must win out in the end. Seekers, such as the Niah, might hog resources and block the way, but in the long run their own nature will be their downfall.”

Joan stopped reading. “When you look out into the galaxy with your telescopes,” she asked Sando, “how many *re-engineered stars* do you see?”

“Would we recognize them?”

“Yes. Natural stellar processes aren't that complicated; your scientists already know everything there is to know about the subject.”

“I'll take your word for that. So ... you're saying Jaqad is wrong? The Niah themselves never left this world, but the galaxy already belongs to creatures more like them than like us?”

“It's not Noudah versus Niah,” Joan said. “It's a matter of how a culture's perspective changes with time. Once a species conquers disease, modifies their biology, and spreads even a short distance beyond their home world, they usually start to relax a bit. The territorial imperative isn't some timeless Law of History; it belongs to a certain phase.”

“What if it persists, though? Into a later phase?”

“That can cause friction,” Joan admitted.

“Nevertheless, no Spreaders have conquered the galaxy?”

“Not yet.”

Sando went back to his repairs; Joan read the rest of the article. She'd thought she'd already grasped the lesson demanded by the subtitle, but it turned out that Jaqad had something more specific in mind.

“Having argued this way, how can I defend my own field of study from the very same charges as I have brought against the Niah? Having grasped the essential character of this doomed race, why should we waste our time and resources studying them further?”

“The answer is simple. We still do not know exactly how and why the Niah died, but when we do, that could turn out to be the most important discovery in history. When we finally leave our world behind, we should not expect to find only other Spreaders to compete with us, as honorable opponents in battle. There will be Seekers as well, blocking the way: tired, old races squatting uselessly on their hoards of knowledge and wealth.

“Time will defeat them in the end, but we already waited three million years to be born; we should have no patience to wait again. If we can learn how the Niah died, that will be our key, that will be our weapon. If we know the Seekers' weakness, we can find a way to hasten their demise.”

The proof of the Niah's theorem turned out to be buried deep in the hillside, but over the following days they extracted it all.

It was as beautiful and satisfying as Joan could have wished, merging six earlier, simpler theorems while extending the techniques used in their proofs. She could even see hints at how the same methods might be stretched further to yield still stronger results. “The Big Crunch” had always been a slightly mocking, irreverent term, but now she was struck anew by how little justice it did to the real trend that had fascinated the Niah. It was not a matter of everything in mathematics collapsing in on itself, with one branch turning out to have been merely a recapitulation of another under a different guise. Rather, the principle was that every sufficiently beautiful mathematical system was rich enough to mirror *in part* — and sometimes in a complex and distorted fashion — every other sufficiently beautiful system. Nothing became sterile and redundant, nothing proved to have been a waste of time, but everything was shown to be magnificently intertwined.

After briefing Halzoun, Joan used the satellite dish to transmit the theorem and its proof to the decoy node. That had been the deal with Pirit: anything she learned from the Niah belonged to the whole galaxy, as long as she explained it to her hosts first.

The archaeologists moved across the hillside, hunting for more artifacts in the same layer of sediment. Joan was eager to see what else the same group of Niah might have published. One possible eight-dimensional hypercube was hovering in her mind; if she'd sat down and thought about it for a few decades she might have worked out the details herself, but the Niah did what they did so well that it would have seemed crass to try to follow clumsily in their footsteps when their own immaculately polished results might simply be lying in the ground, waiting to be uncovered.

A month after the discovery, Joan was woken by the sound of an intruder moving through the shelter. She knew it wasn't Sando; even as she slept an ancient part of her Noudah brain was listening to his heartbeat. The stranger's heart was too quiet to hear, which required great discipline, but the shelter's flexible adhesive made the floor emit a characteristic squeak beneath even the gentlest footsteps. As she rose from her couch she heard Sando waking, and she turned in his direction.

Bright torchlight on his face dazzled her for a moment. The intruder held two knives to Sando's respiratory membranes; a deep enough cut there would mean choking to death, in excruciating pain. The nanomachines that had built Joan's body had wired extensive skills in unarmed combat into her brain, and one scenario involving a feigned escape attempt followed by a sideways flick of her powerful tail was already playing out in the back of her mind, but as yet she could see no way to guarantee that Sando came through it all unharmed.

She said, “What do you want?”

The intruder remained in darkness. “Tell me about the ship that brought you to Baneth.”

“Why?”

“Because it would be a shame to shred your colleague here, just when his work was going so well.” Sando refused to show any emotion on his face, but the blank pallor itself was as stark an expression of fear as anything Joan could imagine.

She said, “There's a coherent state that can be prepared for a quark-gluon plasma in which virtual black holes catalyze baryon decay. In effect, you can turn all of your fuel's rest mass into photons, yielding the most efficient exhaust stream possible.” She recited a long list of technical details. The claimed baryon decay process didn't actually exist, but the pseudo-physics underpinning it was mathematically consistent, and could not be ruled out by anything the Noudah had yet observed. She and Anne had prepared an entire fictitious science and technology, and even a fictitious history of their culture, precisely for emergencies like this; they could spout red herrings for a decade if necessary, and never get caught out contradicting themselves.

“That wasn't so hard, was it?” the intruder gloated.

“What now?”

“You're going to take a trip with me. If you do this nicely, nobody needs to get hurt.”

Something moved in the shadows, and the intruder screamed in pain. Joan leaped forward and knocked one of the knives out of his hand with her tail; the other knife grazed Sando's membrane, but a second tail whipped out of the darkness and intervened. As the intruder fell backward, the beam of his torch revealed Surat and Rali tensed beside him, and a pick buried deep in his side.

Joan's rush of combat hormones suddenly faded, and she let out a long, deep wail of anguish. Sando was unscathed, but a stream of dark liquid was pumping out of the intruder's wound.

Surat was annoyed. “Stop blubbing, and help us tie up this Tiran cousin-fucker.”

“Tie him up? You've killed him!”

“Don't be stupid, that's just sheath fluid.” Joan recalled her Noudah anatomy; sheath fluid was like oil in a hydraulic machine. You could lose it all and it would cost you most of the strength in your limbs and tail, but you wouldn't die, and your body would make more eventually.

Rali found some cable and they trussed up the intruder. Sando was shaken, but he seemed to be recovering. He took Joan aside. “I'm going to have to call Pirit.”

“I understand. But what will she do to these two?” She wasn't sure exactly how much Rali and Surat had heard, but it was certain to have been more than Pirit wanted them to know.

“Don't worry about that, I can protect them.”

Just before dawn someone sent by Pirit arrived in a truck to take the intruder away. Sando declared a rest day, and Rali and Surat went back to their shelter to sleep. Joan went for a walk along the hillside; she didn't feel like sleeping.

Sando caught up with her. He said, “I told them you'd been working on a



military research project, and you were exiled here for some political misdemeanor.”

“And they believed you?”

“All they heard was half of a conversation full of incomprehensible physics. All they know is that someone thought you were worth kidnapping.”

Joan said, “I’m sorry about what happened.”

Sando hesitated. “What did you expect?”

Joan was stung. “One of us went to Tira, one of us came here. We thought that would keep everyone happy!”

“We’re Spreaders,” said Sando. “Give us one of anything, and we want two. Especially if our enemy has the other one. Did you really think you could come here, do a bit of fossicking, and then simply fly away without changing a thing?”

“Your culture has always believed there were other civilizations in the galaxy. Our existence hardly came as a shock.”

Sando’s face became yellow, an expression of almost parental reproach. “Believing in something in the abstract is not the same as having it dangled in front of you. We were never going to have an existential crisis at finding out that we’re not unique; the Niah might be related to us, but they were still alien enough to get us used to the idea. But did you really think we were just going to relax and accept your refusal to share your technology? That one of you went to the Tirans only makes it worse for the Ghahari, and vice versa. Both governments are going absolutely crazy, each one terrified that the other has found a way to make its alien talk.”

Joan stopped walking. “The war games, the border skirmishes? You’re blaming all of that on Anne and me?”

Sando’s body sagged wearily. “To be honest, I don’t know all the details. And if it’s any consolation, I’m sure we would have found another reason if you hadn’t come along.”

Joan said, “Maybe I should leave.” She was tired of these people, tired of her body, tired of being cut off from civilization. She had rescued one beautiful Niah theorem and sent it out into the Amalgam. Wasn’t that enough?

“It’s up to you,” Sando replied. “But you might as well stay until they flood the valley. Another year isn’t going to change anything. What you’ve done to this world has already been done. For us, there’s no going back.”

Joan stayed with the archaeologists as they moved across the hillside. They found tablets bearing Niah drawings and poetry, which no doubt had their virtues but to Joan seemed bland and opaque. Sando and his students relished these discoveries as much as the theorems; to them, the Niah culture was a vast jigsaw puzzle, and any clue that filled in the details of their history was as good as any other.

Sando would have told Pirit everything he’d heard from Joan the night the

intruder came, so she was surprised that she hadn't been summoned for a fresh interrogation to flesh out the details. Perhaps the Ghahari physicists were still digesting her elaborate gobbledygook, trying to decide if it made sense. In her more cynical moments she wondered if the intruder might have been Ghahari himself, sent by Pirit to exploit her friendship with Sando. Perhaps Sando had even been in on it, and Rali and Surat as well. The possibility made her feel as if she was living in a fabricated world, a scape in which nothing was real and nobody could be trusted. The only thing she was certain that the Ghaharis could not have faked was the Niah artifacts. The mathematics verified itself; everything else was subject to doubt and paranoia.

Summer came, burning away the morning fogs. The Noudah's idea of heat was very different from Joan's previous perceptions, but even the body she now wore found the midday sun oppressive. She willed herself to be patient. There was still a chance that the Niah had taken a few more steps toward their grand vision of a unified mathematics, and carved their final discoveries into the form that would outlive them by a million years.

When the lone fusion ship appeared high in the afternoon sky, Joan resolved to ignore it. She glanced up once, but she kept dragging the tomography unit across the ground. She was sick of thinking about Tiran-Ghahari politics. They had played their childish games for centuries; she would not take the blame for this latest outbreak of provocation.

Usually the ships flew by, disappearing within minutes, showing off their power and speed. This one lingered, weaving back and forth across the sky like some dazzling insect performing an elaborate mating dance. Joan's second shadow darted around her feet, hammering a strangely familiar rhythm into her brain.

She looked up, disbelieving. The motion of the ship was following the syntax of a gestural language she had learned on another planet, in another body, a dozen lifetimes ago. The only other person on this world who could know that language was Anne.

She glanced toward the archaeologists a hundred meters away, but they seemed to be paying no attention to the ship. She switched off the tomography unit and stared into the sky. *I'm listening, my friend. What's happening? Did they give you back your ship? Have you had enough of this world, and decided to go home?*

Anne told the story in shorthand, compressed and elliptic. The Tirans had found a tablet bearing a theorem: the last of the Niah's discoveries, the pinnacle of their achievements. Her minders had not let her study it, but they had contrived a situation making it easy for her to steal it, and to steal this ship. They had wanted her to take it and run, in the hope that she would lead them to something they valued far more than any ancient mathematics: an advanced spacecraft, or some magical stargate at the edge of the system.

But Anne wasn't fleeing anywhere. She was high above Ghahar, reading the tablet, and now she would paint what she read across the sky for Joan to see.

Sando approached. "We're in danger, we have to move."

“Danger? That's my friend up there! She's not going to shoot a missile at us!”

“Your friend?” Sando seemed confused. As he spoke, three more ships came into view, lower and brighter than the first. “I've been told that the Tirans are going to strike the valley, to bury the Niah sites. We need to get over the hill and indoors, to get some protection from the blast.”

“Why would the Tirans attack the Niah sites? That makes no sense to me.”

Sando said, “Nor me, but I don't have time to argue.”

The three ships were menacing Anne's, pursuing her, trying to drive her away. Joan had no idea if they were Ghahari defending their territory, or Tirans harassing her in the hope that she would flee and reveal the non-existent shortcut to the stars, but Anne was staying put, still weaving the same gestural language into her maneuvers even as she dodged her pursuers, spelling out the Niah's glorious finale.

Joan said, “You go. I have to see this.” She tensed, ready to fight him if necessary.

Sando took something from his tool belt and peppered her side with holes. Joan gasped with pain and crumpled to the ground as the sheath fluid poured out of her.

Rali and Surat helped carry her to the shelter. Joan caught glimpses of the fiery ballet in the sky, but not enough to make sense of it, let alone reconstruct it.

They put her on her couch inside the shelter. Sando bandaged her side and gave her water to sip. He said, “I'm sorry I had to do that, but if anything had happened to you I would have been held responsible.”

Surat kept ducking outside to check on the “battle”, then reporting excitedly on the state of play. “The Tiran's still up there, they can't get rid of it. I don't know why they haven't shot it down yet.”

*Because the Tirans were the ones pursuing Anne, and they didn't want her dead. But for how long would the Ghahari tolerate this violation?*

Anne's efforts could not be allowed to come to nothing. Joan struggled to recall the constellations she'd last seen in the night sky. At the node they'd departed from, powerful telescopes were constantly trained on the Noudah's home world. Anne's ship was easily bright enough, its gestures wide enough, to be resolved from seven light years away — if the planet itself wasn't blocking the view, if the node was above the horizon.

The shelter was windowless, but Joan saw the ground outside the doorway brighten for an instant. The flash was silent; no missile had struck the valley, the explosion had taken place high above the atmosphere.

Surat went outside. When she returned she said quietly, “All clear. They got it.”

Joan put all her effort into spitting out a handful of words. “I want to see what happened.”

Sando hesitated, then motioned to the others to help him pick up the couch and carry it outside.

A shell of glowing plasma was still visible, drifting across the sky as it expanded, a ring of light growing steadily fainter until it vanished into the afternoon glare.

Anne was dead in this embodiment, but her backup would wake and go on to new adventures. Joan could at least tell her the story of her local death: of virtuoso flying and a spectacular end.

She'd recovered her bearings now, and she recalled the position of the stars. The node was still hours away from rising. The Amalgam was full of powerful telescopes, but no others would be aimed at this obscure planet, and no plea to redirect them could outrace the light they would need to capture in order to bring the Niah's final theorem back to life.

8

Sando wanted to send her away for medical supervision, but Joan insisted on remaining at the site.

“The fewer officials who get to know about this incident, the fewer problems it makes for you,” she reasoned.

“As long as you don't get sick and die,” he replied.

“I'm not going to die.” Her wounds had not become infected, and her strength was returning rapidly.

They compromised. Sando hired someone to drive up from the nearest town to look after her while he was out at the excavation. Daya had basic medical training and didn't ask awkward questions; he seemed happy to tend to Joan's needs, and then lie outside daydreaming the rest of the time.

There was still a chance, Joan thought, that the Niah had carved the theorem on a multitude of tablets and scattered them all over the planet. There was also a chance that the Tirans had made copies of the tablet before letting Anne abscond with it. The question, though, was whether she had the slightest prospect of getting her hands on these duplicates.

Anne might have made some kind of copy herself, but she hadn't mentioned it in the prologue to her aerobic rendition of the theorem. If she'd had any time to spare, she wouldn't have limited herself to an audience of one: she would have waited until the node had risen over Ghahar.

On her second night as an invalid, Joan dreamed that she saw Anne standing on the hill looking back into the fog-shrouded valley, her shadow haloed by the Niah light.

When she woke, she knew what she had to do.

When Sando left, she asked Daya to bring her the console that controlled the satellite dish. She had enough strength in her arms now to operate it, and Daya showed no interest in what she did. That was naive, of course: whether or not Daya was spying on her, Pirit would know exactly where the signal was sent. So be it. Seven light years was still far beyond the Noudah's reach; the whole node could be disassembled and erased long before they came close.

No message could outrace light directly, but there were more ways for light to

reach the node than the direct path, the fastest one. Every black hole had its glory, twisting light around it in a tight, close orbit and flinging it back out again. Seventy-four hours after the original image was lost to them, the telescopes at the node could still turn to the Cataract and scour the distorted, compressed image of the sky at the rim of the hole's black disk to catch a replay of Anne's ballet.

Joan composed the message and entered the coordinates of the node. *You didn't die for nothing, my friend. When you wake and see this, you'll be proud of us both.*

She hesitated, her hand hovering above the send key. The Tirans had wanted Anne to flee, to show them the way to the stars, but had they really been indifferent to the loot they'd let her carry? The theorem had come at the end of the Niah's three-million-year reign. To witness this beautiful truth would not destroy the Amalgam, but might it not weaken it? If the Seekers' thirst for knowledge was slaked, their sense of purpose corroded, might not the most crucial strand of the culture fall into a twilight of its own? There was no shortcut to the stars, but the Noudah had been goaded by their alien visitors, and the technology would come to them soon enough.

The Amalgam had been goaded, too: the theorem she'd already transmitted would send a wave of excitement around the galaxy, strengthening the Seekers, encouraging them to complete the unification by their own efforts. The Big Crunch might be inevitable, but at least she could delay it, and hope that the robustness and diversity of the Amalgam would carry them through it, and beyond.

She erased the message and wrote a new one, addressed to her backup via the decoy node. It would have been nice to upload all her memories, but the Noudah were ruthless, and she wasn't prepared to stay any longer and risk being used by them. This sketch, this postcard, would have to be enough.

When the transmission was complete she left a note for Sando in the console's memory.

Daya called out to her, "Jown? Do you need anything?"

She said, "No. I'm going to sleep for a while."