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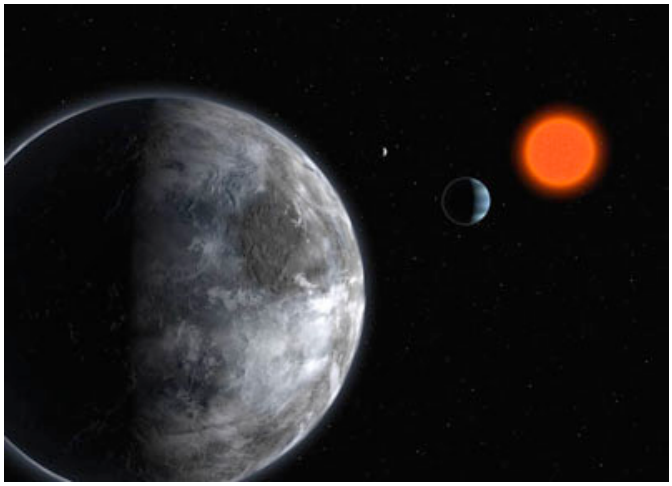
The Neighbor: Gliese 581c

Midday, Muspell Scablands, Gliese 581c (Planet Ymir)

A bloated sun hangs at high noon above a worn rockscape. Dark blemishes twist gradually across the sun's face, coiling out messages in magnetic ink like the handwriting of Apollo. Sunspots recede toward the solar east limb at unnatural speed, while similar blemishes rotate into view in the solar west, both clearly defining the sun as a sphere. The dark magnetic storms dot the sun's face like islands in some vast solar ocean of blood. The sunlit sky is a brilliant crimson at zenith, shading to a lurid claret horizon, the whole unmarked by a single cloud. A tiny amber coin slides out of the western solar limb, its shape rippling in the brutal atmospheric heat. In hours the disk is at half phase, already doubled in apparent size. In a few more hours it is a large crescent, then a wide black circle crossing the sun like a vast pupil from west to east. Electric arcs wind across the planet's outer face, stitches of incandescent sodium ten thousand kilometers long. In hours the nearby world will disappear once again, orbiting east behind the sun.



Below the gleaming sky is a dazzling, shadowless plain of rhyolite sand and lumpy granite cliffs. Fluted ventifacts decorate the rocky terrain. There are perched boulders shaped like gigantic horizontal teardrops, their scalloped ridges sweeping artfully toward leeward knife edges. Weird arches penetrate the beige granite, themselves pocked with thousands of meter-sized hollows once occupied by white feldspar blocks that weathered away to dust long ago. No birds nest in the sheltering hollows. No lizards burrow in the ashen sand. No sturdy lichens encroach the sunburnt cobbles. The scablands are lifeless.

And yet, nothing is still. A constant gale bellows across the beaten plateau. The heavy wind scrubs rock into sand, sand into dust, and dust into the burgundy horizon. Pounding updrafts howl constantly from the deeper canyons, driven by the endless noon heat, sending hot dry air into the stratosphere and out in all directions from the noon pole. The brutal gusts grind steadily at the granite hills, ablating the massif with fifteen atmospheres of carbon dioxide and nitrogen shrieking at three hundred kilometers per hour. Not a breathe of oxygen freshens the searing air, and there is only the thinnest trace of water vapor. Farther from the pole deep shadowed canyons hide briny lakes and bitter acid springs, but no moisture can survive the shadeless glare of the polar noon.

A low rumble travels from over the horizon. Mount Surtur, at 2,300 meters the tallest rocky peak on the planet, vents a burst of sulfur dioxide and water vapor into the barren hyperbaric winds. Mountains are modest on this world. Twice the gravity of Earth makes for a subdued topography. Volcanoes are commonplace, despite the planet's miserly portion of iron and heavy metals. A small core provides for only the weakest of geomagnetic fields, but what this world's mantle lacks in uranium heat is amply compensated for by its insulating bulk – five Earth masses – and generous supply of warm, radioactive potassium to drive mantle convection.

Time passes, and midday persists. The sun never moves in the ruby sky. Beneath the sculpted rock arches, permanent shadows form a fixed patchwork of light and murk. Slowly, almost imperceptibly, the shadows deepen. The ruby glare intensifies. This sun is a variable star, intermittently doubling in brightness, and doubling again, before eventually dimming back to its normal sullen glow. The cycles are random, and are the only seasons known to this massive, tidally-locked world.

As the torrent of solar photons reaches its peak, fresh waves of heat coil through the air. A diorite boulder shatters with a deafening report as its upper side expands in the quadrupled heat faster than its underside. Thermal drafts blaze skyward with renewed intensity, creating a vacuum pull. Cooler air masses rush in from the high latitudes, carrying dark cyclones thousands of kilometers wide to spiral in toward the noon pole, veering and skittering like droplets on a stove. Most of these storms evaporate before they reach the sunlit polar highlands. But today is special. One powerful cyclone, the first in many sun-cycles, has momentum enough to touch the pole before burning away. Its hurricane winds power across the hillsides, lifting sand and gravel that weigh twice what they would on Earth. The humid vortex lashes across the plateau, through arches, over ventifact cliffs, bringing rare moisture to work eroding alchemy on the parched minerals. A rippling staccato blast echoes over the dead scablands. Like bullets from the gods, billions of heavy drops impact the parched rock and flash instantly to steam. It is a rainstorm, the first and last in an epoch. Springtime has come to the sunward pole.

Midnight, Niflheim Expanse, Gliese 581c (Planet Ymir)

A spinning vault of stars glimmers above crystalline peaks. The constellations wheel across the heavens in a vertiginous rush. A

lone azure world coasts silently through the sky, at times large enough that its banded disk is plain, if there were eyes here to see it. Thin frozen clouds stream through the night sky at supernal speed, thinning further as they reach the midnight pole and dissolve into hurtling snow. Flakes like diamond caltrops impact the glaciers at lacerating velocity, forming squalls of snow that pound the icy heights. A chaotic vista of sundered glacial peaks recedes into the foggy distance. Toward the horizon in all directions, dark cloudbanks scud through the gelid night, spiraling toward the midnight pole and shedding weight on their approach. The polar mountains are composed entirely of ice, accumulated age upon age, building in weight and height with each new squall. Forty kilometers thick and eight thousand kilometers across, the polar cap buckles bedrock down to the mantle, where geothermal warmth lubricates the ice with meltwater. Hundreds of darkling lakes perforate the belly of the ice continent, deep saline lenses sealed below the frigid crust, some as large as seas. All are sterile and still.

The ice massif extends nearly to the equator. Its mass encompasses two thirds of the available water on this planet's surface, and near the pole the frozen peaks reach 5,000 meters above the datum, almost to the edge of the compressed troposphere. The polar heights are the ultimate moisture shadow; cold and tall, no cloudbank can pass over them. On this world ice is twice as heavy, and glaciers crawl twice as quickly. As the massif builds it spreads outwards under titanic pressure, creeping and flowing in slow rivers toward the equator, toward the dawn. The polar cap is a permanent conveyor belt, accumulating moisture driven in high altitude winds from the sunward pole, and dispensing it slowly into cool and misty seas at the edge of night.

Dawn, Ginnunga Ocean, Gliese 581c (Planet Ymir)

Hulking glacial cliffs calve loudly into a pellucid violet sea. The blast of each cracking stack of separating ice echoes across tens of kilometers. In one direction purple ice floes extend in a crevassed march between black rocky hills, back to the shadowy horizon. Behind each jagged vertical thrust of ice, fixed shadows a kilometer long shelter narrow frozen ridges straight as lasers. At the opposite horizon a lurid half-sun crouches like a livid dome at the edge of the world. Incandescent beams of ruby, coral and apricot coruscate through the claret sky above gaps in the pregnant cloud cover. In the middle distance, indigo rain squalls glide over wine-dark waters. A fresh breeze with the momentum of a locomotive pushes magenta icebergs lazily about. Vast chunks of rotten ice pile up onto a gravel beach between the glacial toes. The heavy air is laden with salt, and the sour stench of sulfur.

At the water's edge, among the granite pebbles and broken quartz boulders, there is slime. Stringy coal-black filaments permeate the slime. The filaments form a continuous tangle, like matte cobwebs dusted in soot, occupying every square millimeter of space on every particle of wet sediment exposed to the tenuous dawn light. There are no filaments on the shadowed sides of the rocks, only occasional gray flakes of dried stringy matter where a pebble once faced the sun, but was tumbled by some random flake of falling ice or windborne grit. Where water meets beach, dark viscous clots float in the wind-chopped foam. Millions of miniscule bubbles decorate the slimy filaments and floating clots. As each bubble pops a whiff of brimstone is released; hydrogen sulfide, exhaled from billions of tiny globules growing upon the glistening rafts of mucus. The slime is alive.

Eons ago, where ice met dawn warmth, a world-circling ocean formed here. A necklace of seas marks the equator of this world, in the temperate middle where cool moist airs flow sunward, pulled by the rising thermal gales of the noon pole. In return, high warm currents flow toward the terminator into night, where their thin moisture condenses to snow and adds to the vast polar cap. As the ice spreads sunward under its hypergravitic weight, it feeds the necklace of seas with melt, nutritious rock flour, and yellow volcanic sulfur from subglacial volcanoes. At the juncture of light and fertile waters, life has formed colonies. In some windless coves the steady sunlight fosters vast fields of knobby growth below the water line, where microbial slime catches silt to erect mineral fortresses with a living skin. Claret light is greedily devoured by the colonists, who use every precious erg to build their insulating ooze. The photosynthesizers feed on volcanic sulfur dioxide, and bitter hydrogen sulfide exhaled by other colonists who feed on their waste. It is a simple ecosystem, but a robust one.

At the boundary of land and sea, crude bacteria find linked cell membranes offer strength, and exploit that strength to weave bodies into cobwebs to catch every infrared joule. Clever proteins capture heat as well as light, driving cellular machinery to assemble and proliferate onto every sunlit surface. Lurking among the filaments are other colonists; manipulative eaters of the dead, who scavenge the webs for every molecule of discarded carbohydrate and hungrily drink from the bath of oceanic sulfate.

In the largest of the fibrous marine mats, away on the sunward coast, there is a novelty. A race of the microscopic sulfate-breathers has developed a new ploy. One of its proteins acts as a camouflage, allowing it to penetrate the membrane of a living light-gatherer, and continue to feed from within the unwary host. As it feeds it pumps out sulfide waste, which is greedily absorbed by the photosynthesizing host. New vigor galvanizes the host, for now nestled inside its own cellular sheath is a personal dynamo that absorbs its waste sugars and exudes precious sulfide into its plasm. Host and invader are now one hybrid, and their union gives them clout. The hybrid multiplies faster than its neighbors, and shadows them to death with new layers of growth. It begins to spread.

As it multiplies through the necklace of seas, it diversifies into a wealth of alternate forms and chemistries. Each seeks more light, more warmth. The bizarre hybrid reaches the furthest sunward edge of the world-sea, and can go no further. It is blocked by heat, and by desiccation, and by simplicity. But it continues to struggle, dividing and replacing its progenitors with ruthless efficiency at each new chemical innovation. Eventually, in a quiet backwater in a placid purple bay at the sunward edge of the girdling sea a stray neutron, coasting at half the speed of light from an exploding sun many light years away, ricochets through the genes of a hybrid host cell. There is damage. There is also a lucky accident. One of the neutron's blunders flips a gene fragment the wrong way, and ribosomes begin to manufacture a weird new light-gathering protein. This protein can contract in sunlight, coiling like a spring and then releasing in darkness. As the new protein infiltrates the microbe, the cell begins to *move*. Plasmic springs contract with each warming photon, pulling the cell with amoebic grace toward the distant dawn.

The hybrid microbes have a new future. As each replicating blob drags itself over each mountainous pebble, a myriad of futures are forged. It has taken the hybrid, and the other colonists, four billion years to get this far, to emerge from their source in stygian volcanic fountains at the bottom of the world-sea and diffuse to the colder surface. It will take many billions of years more to gather themselves into shapes and geometries capable of dominating their world. But there is ample time. Their world is in its infancy, and their sun will burn for a trillion years.

Afterward

The preceding work of fiction is dedicated to the discoverers of Gliese 581c (Udry et al., 2007), who announced last month their find of the first known terrestrial extrasolar planet within the habitable zone of its star, Gliese 581, a red dwarf only 20.4 light years away. The Gliese 581 system has three known planets, all of which are mentioned in this fictional narrative. Planet 'c', the middle planet between a massive inner neighbor that catapults around its star every 5.4 days and an outer Neptune-sized world with an 83.6 day orbit, is only five times as massive as the Earth and is likely to have a blackbody surface temperature somewhere

between -3 and +40° C, depending on its (unknown) albedo.

This planet, which I've taken the hubristic liberty of nicknaming "Ymir", after the old Norse god whose corpse formed the world, is probably about 1.5 times the diameter of the Earth and has about twice Earth's gravity at its surface. The diameter is educated guesswork, of course, and depends largely on its assumed bulk composition. I took place names on Ymir also from the Norse creation myth: in the old sagas Muspell was a hot southern region and Niflheim a chilly northern, and where they met at the Ginnunga Gap life was engendered.

In my imagining of this planet I've assumed a few things. First, I've assumed that Ymir is tidally locked to its star, as our Moon is toward the Earth. Gliese 581c is close enough for liquid water to exist at its surface, but its sunward side should be searing hot while its night side should be sheathed in ice. On Ymir, water ice would be almost twice as heavy, but would be no stronger mineralogically, and so the icecap should undergo continuous viscous relaxation toward the sunlit side. The resulting hydrologic cycle I've envisaged is speculative, but I think it is entirely plausible if one assumes an Earth-like supply of surface water (or perhaps a little more).

Second, I assumed that because Gliese 581 is a low-metallicity red dwarf, it ought to have condensed planets with somewhat lower metal contents but substantially higher volatile contents than the inner worlds of our own star system. Terrestrial planets orbiting Gliese 581 probably have small to negligible iron cores, and ought to have mantles and crusts composed of silicates that are richer in the lighter elements sodium and magnesium, but poorer in heavier elements such as iron and calcium, compared to our world. Thus my depiction of a quartz-rich, granitic and probably high albedo crust.

Third, I've assumed that because calcium would be scarce, planktonic bacteria probably wouldn't crystallize calcite, leaving most of the planet's original complement of carbon dioxide in its atmosphere through geologic time. This would help to warm the planet and distribute enough heat around the globe to prevent the atmosphere from completely freezing out on the permanent dark side.

As far as life is concerned, what I've imagined here is entirely speculative, of course. However, if life does exist on Ymir (and no, I don't seriously expect anyone else to start calling the planet that) it will have evolved in a very low energy environment constrained by a weak sun and a geographic range limited by where water can stay wet. My assumption of an ecology built around sulfide-oxidizing phototrophs and sulfate-reducing heterotrophs, with incipient motility evolving first in endosymbiotic phototrophic hosts, is based on analogy with the evolution of complex life on Earth, but leaving out the evolution of oxygenic photosynthesis. On Earth only one branch of the Eubacteria ever evolved the latter trick, and green plants exist today only because they endosymbiotized (or were invaded by) photosynthesizing Eubacteria. I created what I imagine to be a plausible route to complexity on a world without oxygen but with ample sulfur (there is little iron to lock it away) and plenty of time.

And time they do have. Gliese 581 is a slow-burning red dwarf with sufficient hydrogen fuel to last long into the distant geologic future. If the orbits of Gliese 581's planets are stable over such time scales, Ymir might really have around a trillion years in which to play out its evolutionary drama. That should be more than enough time for us to take a trip there and back again, to see what mischief our neighbor is really up to.

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