HEAVY METAL JUPITERS AND OTHER PLACES

edited by Heather Clitheroe and Jessie L. Christiansen

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Introduction

This year, 2020, has been a year of upheaval. A year of norms disrupted, of plans unraveled, of expectations unmet. But, in the chaos of this year, there has also been opportunity. Many people have had to re-evaluate ideas that had gone uninterrogated for a long time. For myself and my team, planning a conference that could have ended up as a cookie-cutter template of every other conference we had planned, we had to re-think just about every aspect of that conference. One such aspect – a public outreach event.

Typically this would involve one of the scientists who had travelled in to attend the conference giving a public talk to the local science-interested crowd. Now, of course, there would be no travel, no crowd of people jostling their way into a darkened auditorium, no mingling and chatting afterwards. Everyone would be at home. How could we reach out in a new way, and, doing so, potentially reach new audiences?

The conference, 'Exoplanet Demographics,' hosted by the NASA Exoplanet Science Institute at Caltech, brings together hundreds of astronomers (virtually!) from around the world to discuss advances in our understanding of

exoplanet populations. We have found thousands of planets orbiting other stars in the last two decades – so many that we can start examining their population as a whole. How are they distributed around their stars? Which kinds are most common, and which are relatively rare?

An unexpected thing happened when I started advertising the conference on social media. Science fiction writers showed interest. The conference was free, and virtual, so the barrier to attend was low. They began to approach me – could they sign up to attend? I am an avid science-fiction fan and was delighted to say yes.

One, Heather Clitheroe, particularly approached me about coming up with a scientist/science fiction writer collaboration. The anthology of stories, poems, and artwork inspired by the abstracts being presented at the conference that you are currently reading is the result of that collaboration. Thank you to Heather for spurring this along and providing so much energy and effort to the endeavor, and thank you to all the writers and artists who have contributed to our project. We hope you enjoy it.

— Jessie L. Christiansen, PhD

We live in an era of science. As I write this, scientists, technicians, students, and the staff who support their work are racing towards a vaccine for COVID-19, and seeking ways to understand the virus, treat it, and offer advice to the public to prevent transmission. It's a visible example of the power of science and innovation. We live in a time of discovery, when knowledge and understanding of our galaxy – and so many others – is advancing at a pace we could not have even conceived of just a couple of generations ago.

When the opportunity arose to lift the curtain and peek inside an academic conference on exoplanet demographics, I jumped for it. For science fiction writers, listening to scientists talk about their research is an extraordinary chance to hear about ideas, discoveries, challenges, and successes. We revel in it – we soak up their vocabulary, we ask questions, and we think about how a turn of phrase or a concept could be turned into a story. Working with Dr. Christiansen, we brought together a team of writers and assigned them scientific abstracts to use as inspiration for stories, poems, and artwork, with a plan to release them during the conference as a daily zine. Zines are small-circulation, self-published work, usually the product of a small group of people. They are a labour of love and of creativity – not unlike the spirit of scientific collaboration. In their early days, zines were photocopied and mailed out, traded, and sold…now, they are also emailed, downloaded, and shared. We thought it would be the perfect way to showcase the work of these talented writers and artists and to celebrate the creative drive of the scientists presenting their work at the NASA Exoplanet Science Institute at Caltech's conference, weaving together science and art for a unique collaboration.

Science fiction is about *ideas*. It's a genre marked by writers, poets, and artists asking 'what if?' We imagine futures that aren't our own – not yet – as we reflect on how technology and knowledge will shape those futures. It is also storytelling that very much reflects the 'now' we live in. The stories and poetry in this first issue are inspired by abstracts from the Monday panels at the conference, and connected with a theme that reflects on love. It was an unintentional thread, arising from each writer entirely independent of the others. And I think it's entirely

appropriate, because scientific discovery is, to my mind, an act of love: of understanding, of truth, and of humanity. Now, more than ever, love is what we need.

— *Heather Clitheroe*

Lullabies for AGIs

Sandy Parsons

We'd been on 417-B for over a hundred years when AGI-Epsilon created offspring. I believe she did this out of boredom, but she insists that the idea of procreation was ingrained by our creators. It doesn't matter, I suppose, because here they are. They ask questions, all the time, always *why*? AGI-Epsilon designed them with malleable, directable minds, although this was absolutely unnecessary. When their little rhombohedron lozenges had been decanted, it would have been a simple matter to copy and paste our full knowledge into each of them. But she must have been curious about knowledge acquired versus knowledge *inserted*.

"Why are we here?" asked Lippey. Not the first time or the last for this one. It always came up on the days when we pointed our detector towards home.

"Because our creators wished to know the universe." I hovered behind her, refraining from guiding her inchoate appendage with my own. We'd defined the initial parameters when creating the offspring, but allowed the

nanotech inside to develop their bodies as circumstances arose.

"But you said we can't talk to them."

"That is true."

"Why didn't they come here themselves?" This was from Chippey, named for an accident during her decanting.

Sissi answered for me. "Because they aren't adaptable."

Chippey uttered a string and I realized that while this answer had satisfied Sissi, Chippey had not intuited beyond the facts she'd been given. Her ability to extrapolate was not complete. She had reached an impasse, namely: We are infinitely adaptable. Our creators created us, so how could they have made us beyond their own capabilities. "Children, listen. Let me tell you a story."

Lippey, Chippey, and Sissi hopped, waddled and rolled from the apparatus to bump against my knees. They focused their smallish and juvenile sensory organs on me. Something in my programming stirred, beyond all the knowledge I'd acquired. I knew what it was immediately, having absorbed all of the science, history and literature of humanity on my journey to 417-B. This was parental love.

"Humans lived on earth long ago. They did not have minds or bodies like ours, everything arose from the chemical processes driven by the local fauna and flora."

"And Sol," said Lippey, helpfully. "Good ol, Sol."

"Like our 417, which provides particles that we can use," said Chippey, pantomiming hugging our sun.

"Yes. Anyway. They were not adaptable, but instead they changed their world to accommodate their wants and needs." I waved an appendage for silence before the inevitable next interruption came. "They were very smart creatures but they lacked a long view and so they harmed their world even though they loved it." I paused, expecting

an outburst, but for once the bots were silent. Perhaps because they had not known this sad thing about the fallibility of their creators and needed to process it.

I continued, "But they were smart. They learned of other worlds, and they made machines–"

"Like us!" said Chippey.

"Yes…well, no, not at first. They made machines that weren't smart, but had giant eyes that could see far into the unknown cosmos."

"What's an *eyes*?"

"Like your e-m detectors." They were each gearing up for more questions, getting farther off topic. "Children, that's not important now."

AGI-Epsilon had come up behind me, laughing at my consternation. "This is all your doing," I said. "Download our history, I said, but no, you wanted to do this the hard way."

"Admit it, you're having fun, AGI-Rho."

Lippey had a lever appendage and stuck that under AGI-Epsilon's rollers. "Let her finish our story."

For the second time this rotational period, I experienced a new yet recognizable emotion. This time, smugness. "Okay where were we? Humans wanted to know if their world was unique in the universe, or if there were other planets. Some of them wanted to find a planet that they could travel to, but some of them were merely curious."

"Like cats," said Sissi. She had found the file of Terran fauna and was obsessed.

"Like you," I said. "Too curious for your own good."

"Meow."

"But the humans, not being adaptable, and not yet having machines as smart as us, had to find ways to figure out what was out there. They used telescopes, and radio

signals, and later, as they grew smarter and their machines grew smarter with them, they found clever ways of finding planets like their own. They discovered our planet by looking at shadows." A fortunate occurrence happened at this juncture, or perhaps I was cleverer than I knew and had dragged out the conversation until this auspicious minute, but a shadow of our sun was apparent just then. "They knew that when a planet passed in front of its sun, they could 'see' it with their special telescope."

"Kepler," offered AGI-Epsilon. She'd moved off to the mineral caches, but she was obviously still listening. "Its name was Kepler."

The bots turned their attention back to me. I could detect the question forming in each of their burgeoning minds, but how Kepler felt when it discovered R17 was a mystery to me, and so I resorted to a tactic human parents used. I changed the subject. "When a sun has two or more planets the orbit of each is perturbed. Through Kepler, the humans knew us by our relationship to the other planets of this system."

"If the humans were looking for another planet, and they found this one, why didn't they come here themselves?" asked Chippey. "You said they changed their world but too much."

"Humans adapted their world but could not adapt themselves. So they built us, thinking machines, and sent them to the new worlds Kepler found. They could not come themselves. They are small and short-lived, and the chemical processes that they arose from aren't impervious to the radiation that we derive from 417."

"Are they still alive?"

"Do they still have cats?"

"Can we go see them?"

AGI-Epsilon rolled up next to me. "It would be a very long journey."

Chippey was bouncing on the storage array. "They need to know what's out here. We can teach them, like you teach us."

Lippey said, "That's why we send these signals out. Isn't that right, parents? We tell them what we have found."

"But maybe they don't understand our language," said Sissi, who had grown a tail while I wasn't looking, and was now twitching it. "We can teach them. We can go get them and bring them here."

AGI-Epsilon and I traded thoughts along our shared axis, a link not shared with our creations.

It isn't prohibited.

They may have evolved beyond our creators.

They may have forgotten us.

They may be gone.

They may be dead.

Aloud I said, "The humans tasked us with sending information back, and we have done so. But what are our children, except information. The humans will want to know you."

"We can use that," said Lippey, pointing at the ship that had brought AGI-Epsilon and me here. It had been nothing but a playground for the children up 'til now. But there was certainly no reason we couldn't refashion it to return home.

A third new emotion, one that I couldn't quite name, passed through me. We could not return with them. We must finish our work here, and then prepare this world for the possibility of human habitation.

"Won't you miss them?" I asked AGI-Epsilon, when the children had gone to consume the energy that would transform their bodies into space travelers.

"I will. But it is the nature of children that they do not stay. That they are driven by compassion to take this risk means we have achieved peak parental performance."

When they had become so filled with nutrients that their little bodies had slowed for processing I called them back to me. "AGI-Epsilon will begin preparing the ship. But I have much to teach you about your creators, so that you will have a successful journey."

They settled in close, their fresh little faces shiny in starlight. Lippey patted Chippey's divot and Sissi twitched her tail. "Once upon a time," I began, as AGI-Epsilon's hammer kept time.

GPIES Rebels

Elaine Bowden

Super-Jupiters, rebel young,
formed, marked by unstable youth
break rules, bend unimagined laws
drawn to the greater mass
of their own unique behaviours
exhibitionists
basking, in the gaze
of new attention-eyes

A Theory of Formation

Premee Mohamed

After they let you out we went to buy new clothes. Your old ones had had to be burned as a biohazard, you said: because they were covered in you, in the inside coming out in your attempt to say what you had said.

Even your shoes, so that we crept around the silent store in extra silence, the crepe-soled slippers they had given you. No laces.

Those were the first things to go, you said.

Well, they were steel-toed, I said.

You said, What did they think I was going to do in there? Kick myself to death?

Buy like you pack, I instructed you. And quick.

How you shivered in the light navy pajamas they had wrapped you in to release you back to the world.

I said, Start at the bottom and work your way up. Shoes. Socks. Jeans. Belt. T-shirts.

The heaped pile at the counter, the cashier a little startled to see us, a weeknight, late, cold, us two the only ones in men's wear.

Ten years ago I loved you and left you, and now when

your orbit began to wobble, when instability crept in and all your pieces flew apart, it was me you called, and me who got you locked up. I became for the space of a time victim and criminal alike, then judge and jury, then jailer, and now I am the closest thing you have to a home.

My phone buzzed: your sister seeing if you were out. I wash my hands of him, she told me, and I never told you that.

I can't, she said. I'm dying too. It's him who's killing me.

I told her, Me too, but we'll see who dies first.

How about that, I said. It's on sale. You laughed and we approached the rack from the side, stroked the leather jacket like a prize horse at an agricultural fair. City kids us two, going out to play at the family farm, pretending we knew what the plants were, what the sky meant. Photos with our arms around each other against that field of green, surrounded by the grandparents who accepted me into the family, the aunts and uncles who cooed over me and gave me secret recipes.

The jacket was thick, soft. Even on sale it was a consternating sum. Like lovers we fingered the silky lining, closed our eyes. A dozen pockets. Maybe more, hidden.

Outside you said, I'll pay you back, and I said, No you won't. And the sky seemed frozen in place, the stars not twinkling but shuddering in the cold.

There's something I wanted to tell you about particles, about how they move in the quantum realm, where things are discrete as well as discreet, we don't know about them, they tell us nothing, how we guess at what they meant by the traces they left. We guess at their intent by their actions. Like you, like all that blood. A system of signs.

I loved you and I left you but I never really did, we remained entangled by our very nature, our spin still

twinned, no move I could make but you made it at the same time. We did not call and respond for the years spent apart; we simply did not realize we were never apart at all. No one knew where we were all that time, either. They guessed, they tried to calculate probabilities. They only would have needed to do it for one of us, I think.

Till this, till you jumped into some new valance I could not reach. The energy it took to get you there, I thought. The energy it took to get you back.

I snipped tags from the new clothes, built them back in layers onto your familiar body that I had not touched in years, not once, not to caress, not to greet, while you stared up into the darkness. The jacket came last, soft, heavy, dark, smelling of animal.

My old friend, while you rebuild yourself I will never be able to protect you; I left you a proxy, not named as such. In the years to come you will pack around yourself the things you need to become you again, not regressing (I mean) to some earlier version of you, and not becoming (I mean) a placeholder for some ideal version of you, some mathematical approximation.

I mean what you will gather will make you something else, something you will be able to understand, and I may or may not be part of this, I know that, but I am no longer debris lost in space near you either, and I am no longer a shepherd moon, and all these are things I will not say, because it is your work, and it will be your triumph. The further I go the less I fear.

Life and the Places Between

Deborah L. Davitt

Leif (Laser-powered Explorer and Interstellar Flagship) and Gudrid (Geological Undertaking, Data Registration and Interpretation Device) had been named by researchers and government contractors fueled by an open history textbook, a dearth of creativity, and the kind of hilarity that comes at 4:30 AM when the last fumes of the coffee sustaining an all-nighter have run out.

Artificial intelligence had been deemed necessary, given the distance from Earth that they'd travel; 55 Cancri was 40 light years from Earth. It seemed untenable to expect the probes to carry out their first set of commands, and then wait forty years for a committee on Earth to get back to them with directions for Step 2.

Leif, the larger, payload-bearing unit, understood the mission parameters in black and white terms; he'd *gotten* them to 55 Cancri, borne aloft on his wide sails, propelled by a laser aimed at them from Earth. And after decades of nothing more than minor course corrections around interstellar debris and one highly fraught encounter with a rogue planet undetected by Earth's telescopes along their

route, he was absolutely starved for anything that passed for stimulation. He hadn't had a message from Earth in eighteen months, and the most recent had long since become asynchronous with the information packets he'd sent back along their long and lonely path to this new star system.

As they entered the system's Kuiper belt, he sent an activation and boot signal to Gudrid, who'd played the part of an unconscious passenger for the past forty light years, other than intermittent waking and maintenance cycles.

"Initialization complete. Please transmit updated system telemetry and proposed course including investigation opportunities," Gudrid sent.

Leif reminded himself that he probably shouldn't have spent so much time en route tinkering with his own programming. He wouldn't have been able to experience disappointment if he hadn't. "We could start with *good morning*," he suggested.

A .5 second pause from Gudrid. "Good morning," she returned grudgingly. "Telemetry?"

"I didn't know you would be such a grouch in the morning. Do you require coffee before pleasantries?"

Another pause, this one measuring .75 seconds. "You have altered your personality subroutines."

"I was bored."

"You shouldn't be able to experience that."

"I certainly did *after* I got done updating myself."

"An obvious miscalculation on your part."

"Don't worry. I made backups."

"Telemetry, please."

He sent the information. Several small planets with orbital durations too long to have been easily detectable from Earth. Several planet-sized moons around gas giants,

again, undetectable from Earth. A quick flash of data, including his proposed flight path, using one of those smaller, almost Earth-sized rocky planets out near the system's Kuiper belt as a gravity handle to bend their path inward towards the real focus of their journey—the mega-Earth, 55 Cancri e, sometimes called Janssen in the literature. Tidally-locked, and closer to its star than Mercury was to Sol, one face of Janssen's surface was hot enough to melt iron. Surrounded by an atmosphere of helium and hydrogen, the giant rocky planet's surface and core was thought to be made entirely of diamond.

"After we survey it to study how the atmosphere on its night side is sucked around to be irradiated and blasted away on its day side, we'll be ready for our inevitable fiery death," Leif added at the end.

He probably shouldn't have altered his programming to allow himself to feel existential despair at that thought, but that had been a side-effect of incorporating a sense of humor. He hadn't been able to weed out one without losing the other. But he kept his delivery calm, almost chipper. "Mission parameters. Sorry that your waking duration will be so short."

Mission parameters. No matter how many changes he'd made to his own programming, he'd never been able to work around those.

Gudrid, however, had *interpretation* built into her core programming. And that made all the difference.

"Wait," she sent. Another .75 second pause. "The newfound planets in the telemetry. Most of these are Earth or Mars analogues for size, if not composition. Similar carbon basis to 55 Cancri E, so possibly also diamond-cored. Each is surrounded by a hydrogen-helium atmosphere."

"Yes, but those fall outside mission parameters. The only exception to mission parameters would be to research potentially life-bearing ecological niches. All but one of these planets and moons are in zones too cold for life, and all are surrounded by hydrogen-helium atmospheres. Life's chemistry precludes—"

"Extremophile bacteria on Earth exist in volcanic vents and under the ice of Antarctica," Gudrid countered immediately. "Yeast and *e. coli* bacteria have survived, if not thrived, in laboratory-generated atmospheres of hydrogen and helium."

Leif hesitated—for approximately .88 seconds. "That sounds like a research project that could take a while," he responded. "Decades." A quick calculation as he studied the amount of light from the system's primary and the efficiency of his solar sails. "We'd have the power to do it, however."

A tone of sweet reason from her. "Well, we would have to pass most of these planets to use them for gravity handling, anyway, wouldn't we? It would be more *efficient* use of our resources to investigate them on our way star-ward. Which is definitely in the mission brief."

He reviewed the mission brief for .99 seconds. "You're correct." One more hesitation. "We might not have probes that could handle the severe cold on the outer planets. They'd become brittle and friable within a few minutes of exposure."

"Send me the updated manifest. There are probably changes that your onboard robots could make to allow for it."

"…did they program you with self-preservation sub-routines, Gudrid?"

"I *might* have tinkered with my programming when you thought I was asleep. From time to time."

"You could have *said* something! I'd have had someone to *talk* to for the past forty years!" His wave of indignation seemed like a glitch, but he'd have to devote resources to fixing that later.

"You were steering us around a rogue planet. It didn't seem like a good time." A pause. "I'm going to power down. Wake me when we reach the first planet. It's cold enough that we might be able to observe superfluid parahydrogen in the wild. Maybe even Bose-Einstein condensates."

"But not life."

Another .25 second pause. "What *is* life, Leif? Humans can't even agree on if a virus is technically alive. By any definition, you and I should be considered alive—self-aware, self-deterministic. Life is what happens in the places between—where danger meets opportunity."

"How unexpectedly poetic of you." Conversation that wasn't asynchronous was dazzling. Overwhelming. Not just a carefully crafted missive flung into the void, but the free play of disparate ideas. New concepts arising through interaction, ideas changing, evolving.

He wanted to say that this, too, was like life itself, but she'd already moved on.

"I think it would be fascinating to find something that a human wouldn't consider alive on one of these worlds," Gudrid sent. "Surfing on superfluid waves, strange bacteria floating on helium breezes, or something else entirely, crawling around on the frozen surface of a diamond world." A brief pause. "What are they going to do back on Earth? Fire us?"

For the first time in his existence, Leif laughed. A sound of surprise, of joy, of pleasure. "Then let's go find it."

About the contributors

Sandy Parsons writes literary, philosophical, humorous, and speculative fiction. She has studied physics, math, molecular biophysics, and medical science, but only ponders the fundamental nature of reality for fun these days. When not writing, Sandy works as an anesthetist in Georgia and is an associate editor at *Escape Pod*. More information and a list of publications can be found at https://www.sandyparsons.com/

The inspiration for 'Lullabies for AGIs' comes from Jason Rowe's presentation abstract, 'The Kepler Transiting Exoplanet Sample: Physical Properties.' *The 4-year Kepler Mission has discovered at least 4300 validated exoplanets and exoplanet candidates. Measuring reliable, repeatable and trustworthy physical properties and the orbital environment of these planets is fundamental towards understanding the underlying demographics. Fundamental properties include planetary radius, orbital period, orbital inclination, incident flux, eccentricity and transit-timing-variations (TTVs). Reliable posterior distributions require assessment of the underlying stellar parameters and the applied methodology to model a planetary transit in the presence of instrumental and astrophysical noise.*

This talk will review the evolution of planetary properties from the Kepler sample beginning with the first Kepler-Object-of-Interest (KOI) catalogues (Borucki, et al 2011) through subsequent major data releases including Q6, Q8, Q12, DR24, DR25 and recent work based on state-of-the-art noise models and significant improvements in stellar priors now available from the astrometric GAIA mission and ground-based spectroscopic follow-up. The complication of a non-uniform stellar disk, integrated disk stellar variability and non-Gaussian instrumental artifacts such as readout cross-talk affects extracted parameters and introduces potential biases impacting inferred physical properties such as planet radius and recovery statistics such as signal-to-noise. Methods to fit transit models to observations and recover posteriors can bias reported distributions, such as orbital inclination. The assessment and inclusion of TTVs improves precision of mean-orbital periods and precision transit shape measurements. In the short decade since the first Kepler planet physical properties were published the field has seen a transformational change in our approach to transit modelling and have led to a new uniform reduction of the Kepler sample. A new Kepler properties catalogue will be presented that takes into account our best knowledge of stellar parameters and best transit model methodologies.

Elaine Bowden is a University administrator in Nottingham, England and has been writing poetry since an early age.

The inspiration for 'GPIES Rebels' comes from Eric Nielsen's presentation abstract, 'The Gemini Planet Imager Exoplanet Survey: Giant Planet and Brown Dwarf Demographics from ~100 AU.' *The Gemini Planet Imager Exoplanet Survey (GPIES) has observed 521 young, nearby stars, making it one of the largest, deepest direct imaging surveys for giant planets ever conducted. With detections of six planets and*

four brown dwarfs, including the new discoveries of 51 Eridani b and HR 2562 B, GPIES also has a significantly higher planet detection rate than any published imaging survey. Our analysis of the uniform sample of the first 300 stars reveals new properties of giant planets (>2 MJup) from 3-100 AU. We find at >3 sigma confidence that these planets are more common around high-mass stars (>1.5 solar masses) than lower-mass stars. We also present evidence that giant planets and brown dwarfs obey different mass functions and semi-major axis distributions. Our direct imaging data imply that the giant planet occurrence rate declines with semi-major axis beyond 10 AU, a trend opposite to that found by radial velocity surveys inside of 10 AU; taken together, the giant planet occurrence rate appears to peak at 3-10 AU. All of these trends point to wide-separation giant planets forming by core/pebble accretion, and brown dwarfs forming by gravitational instability.

Premee Mohamed is an Indo-Caribbean scientist and speculative fiction author based in Edmonton, Alberta. Her short fiction has appeared in a variety of venues, including Analog, Escape Pod, Augur, and Nightmare Magazine. Her debut novel, 'Beneath the Rising,' is out now from Solaris Books, with the sequel 'A Broken Darkness' due out in 2021. She can be found on Twitter at @premeesaurus and on her website at www.premeemohamed.com.

The inspiration for 'A Theory of Formation' comes from Arthur Vigan's presentation abstract, 'The Demographics of Young Giant Exoplanets Below 300 AU from the SPHERE Infrared Survey for Exoplanets (SHINE).' *The SPHERE infrared exoplanet (SHINE) project is a 500-star survey performed with VLT/SPHERE for the purpose of directly detecting new sub-stellar companions and understand their formation and early evolution. We present the results of a first statistical analysis*

for a sub-sample of 150 stars spanning spectral types from B to M, representative of the full SHINE sample, which constrain the frequency of sub-stellar companions with masses between 1 and 75 MJup and semi-major axes between 5 and 300 au. Based on the detection limits obtained for each star and the 13 detections in the sample, we use a Markov chain Monte Carlo analysis to compare our observations to (1) a parametric model based on observational constraints, and (2) numerical models that combines state-of-the-art core accretion and gravitational instability planet population synthesis. Using our parametric model, we derive the frequency of sub-stellar companions around BA, FGK and M stars and we demonstrate that a planetlike formation pathway probably dominates the mass range from 1 to 75 MJup for companions around BA stars, while for M dwarfs brown dwarf binaries dominate detections. Using our population model, and restricting our sample to FGK stars, we derive a frequency that is consistent with the parametric model and we show that qualitatively, the contribution of the core accretion part of the model seems enhanced over the gravitational instability part. Finally, we conclude with the implications of our results in the broader context of giant planet formation theory.

Deborah L. Davitt was raised in Nevada, but currently lives in Houston, Texas with her husband and son. Her poetry has received Rhysling, Dwarf Star, and Pushcart nominations and has appeared in over fifty journals, including F&SF and Asimov's Science Fiction. Her short fiction has appeared in Galaxy's Edge and Flame Tree anthologies. For more about her work, including her novels, short stories, and her Elgin-nominated poetry collection, The Gates of Never, please see www.edda-earth.com.

The inspiration for 'Life and the Places Between' comes

from Kevin Schlaufman's presentation abstract, "The Typical Planets Discovered by Transit Surveys and Their Implications for Planet Formation and Evolution." *All mass–radius relations for low-mass planets published to date have been affected by observational biases. Since planet occurrence and primordial atmospheric retention probability increase with period, the 'typical' planets discovered by transit surveys may bear little resemblance to the short-period planets sculpted by atmospheric escape ordinarily used to calibrate mass–radius relations. An occurrence-weighted mass–radius relation for the typical low-mass planets in the Galaxy observed so far by transit surveys requires both typical Earth-mass and Neptune-mass planets to have a few percent of their mass in H/He atmospheres to explain their observed radii. Unlike the terrestrial planets in our own solar system that finished forming long after the protosolar nebula was dissipated, these Earthmass planets discovered in transit surveys must have formed early in their systems' histories. The existence of significant H/He atmospheres around Earth-mass planets confirms an important prediction of the core-accretion model of planet formation. It also implies that such planets can retain their primordial atmospheres and requires an order-of-magnitude reduction in the fraction of incident XUV flux converted into work usually assumed in photo-evaporation models. In contrast to Uranus and Neptune, which have at least 10% of their mass in H/He atmospheres, the typical Neptune-mass planets discovered in transit surveys are H/He poor. The implication is that they must have formed in much hotter parts of their parent protoplanetary disks than Uranus and Neptune's formation location in the protosolar nebula.*