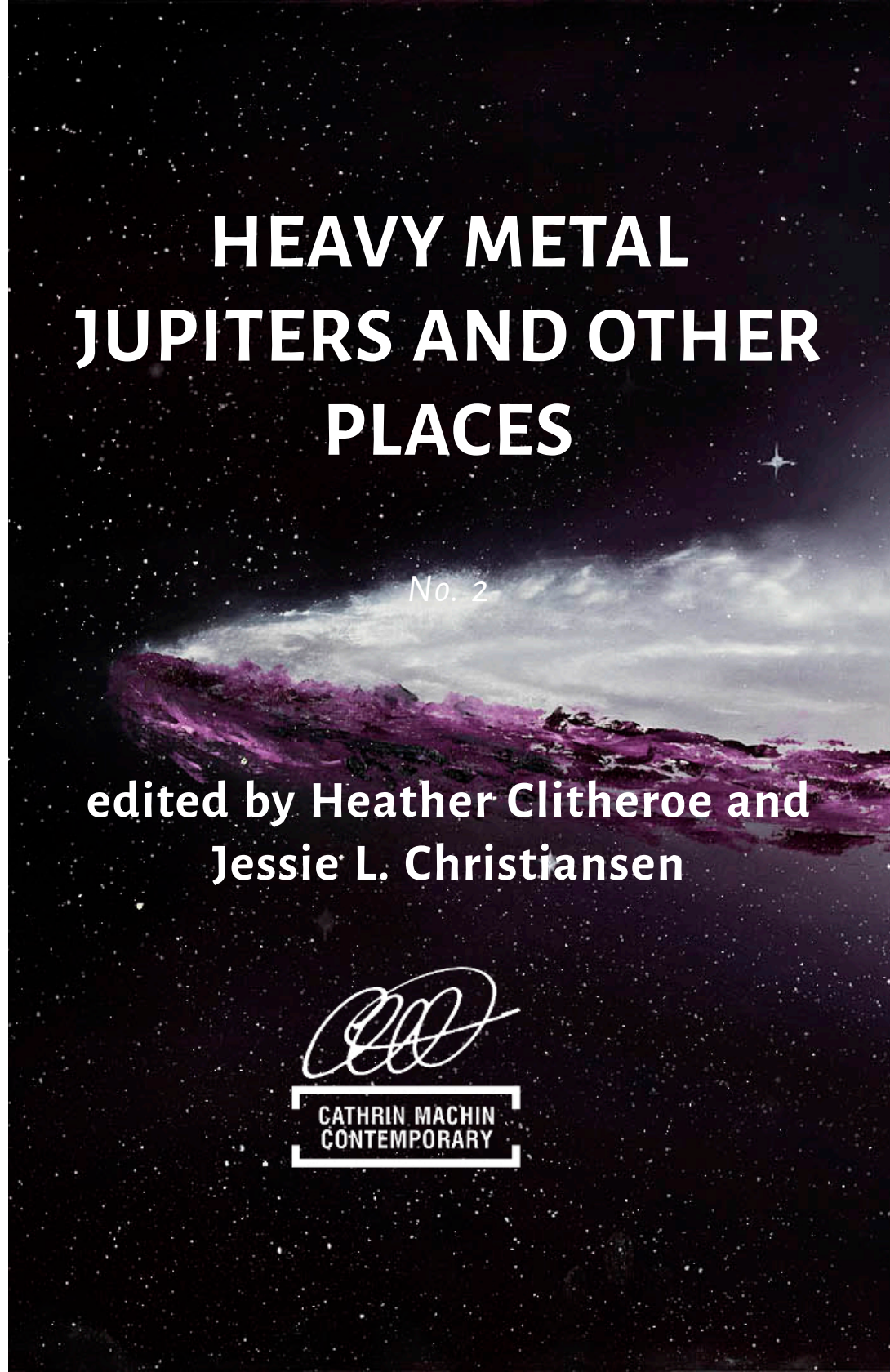
HEAVY METAL
JUPITERS AND OTHER
PLACES
No. 2
edited by Heather Clitheroe and
Jessie L. Christiansen
CATHRIN MACHIN
CONTEMPORARY

HEAVY METAL JUPITERS AND OTHER PLACES - TUESDAY

edited by Heather Clitheroe and Jessie L. Christiansen

Aaron Rosenberg, Kelli Fitzpatrick, Leo Korogodski, Vivek Mittal, Mark McCutcheon, Wendy Van Camp, and V Wegman

Contents

The Planets' Play

Vivek Mittal

Chamadjar sculpted what she could from stars set to retire, scraping pieces from available planetary nebula with one of her many limbs, suckered and rascally though they were. She preferred making planets of two types, rocky ones that could easily entertain her arms for awhile – especially when she slept – and larger ones whose atmospheres stored tinier elements for future use. There weren't many in between because she was new at this, and still needed practice.

A small one in the Milky Way was her first, and it set the stage against which to compare all the others. When she first crafted its peaks and valleys, and injected it with complex molecules (mostly a three element molecule), she would roam its surface, splitting apart the surface and diving deep into its oceans. Many years later, while checking in on her firstborn, she learned that crudely, one species overtook all the others. And that same species spotted her with her many arms and heads and mistook her as benevolent and interested in their affairs. So she went aloft and made a note to check on it in a few hundred years.

The others had told her that would happen, but she didn't heed their warnings.

At the moment, though, she focused in on building the small hills and valleys of her current project. She shrank her blue arms so she would have the dexterity to push the layers of dirt to make what she wanted. When she started, she always had a vision of what the planet might look like, and what kind of air it might hold. Lifeless or muddy? Hydrogen or carbon dioxide?

What she cared about most, though, was why the planet needed to be where it needed to be. At first, she gained counsel from others and placed the planet in it precise position. But as she built more, the visions she had while sleeping increasingly enveloped her. She would find herself on the planet, in a home that wasn't hers, and she would be there for a lifetime, or more. And it is while her limbs orbited the planet about her slumbering body, that she would learn why the planet was to be.

For the Win

Aaron Rosenberg

Kaleo Aukai cursed under her breath as another Kepler probe darted past her, its sleek silvery shape narrowly missing her own craft as it shot from the docking ring, clearing the retractable supports by mere meters. She didn't have to see the recklessly piloted ship's registry number to guess whose it was, and was unsurprised when, a second later, her comms pinged with a message.

"First one to find it wins!"

From Gentry. Of course.

With a sigh, Kaleo piloted her ship out and away, favoring precision over speed as she cleared the station and glided out among the stars. Why did they have to be such an unmitigated jerk, she wondered. But this was hardly new. She and Gentry had trained together, graduated together, joined the ranks of the Exoplanet Exploratory Guild together.

She should be used to their behavior by now.

Still, it chafed. Their current task was to find a viable water world. Not always an easy thing to do, but an immensely important one – in some ways even more than

locating a potentially habitable planet, because colonists and researchers alike were always seeking access to more water and to the ecosystems thus supported. The Guild didn't officially care if you were the first to find one or the second or the twenty-third, of course. Officially. Unofficially, though, it mattered. Scores were kept on who found what first, and when it came time for promotions and for plum assignments, well, those went to the ones on top.

Ones like her and Gentry. Even though they'd only been Guild members for a few years now they both tended to be in the top five overall, and often competed for Number One.

Which was why she was determined to beat Gentry at their own game.

Fortunately, she had a secret weapon. Kaleo smiled as she glanced down at the external drive she'd smuggled onboard, which was now plugged into her console's data ports and humming away happily.

Sure, Gentry had a head start. But finding water worlds was tricky as all get-out – unless you had access to the right modeling programs.

Which, thanks to poking around in the science forums and reading all the relevant articles, she had.

Just then, her console chimed. "Match Found," it reported, and provided coordinates – in the opposite direction from the way Gentry had headed.

"Bayesian for the win," Kaleo whispered, patting the little external drive. She smiled, locked in the route, and pushed her engines to full, the acceleration pushing her snugly back into her webbing.

Water world, here I come.

Rogue

Kelli Fitzpatrick

Crenzian Council for Giant Planet Control, Office of Rogue Planets

Memo on Recent Orbital Disruption of RQ-495

To all staff:

Since many of you continue to neglect office messages in your sub-light inbox, this direct telepathic memo is necessary. Do *not* reply all (that means you, Trelg).

Despite the best efforts of the Crenzian Confederate defense network to intercept the rogue planet known as NH-303, the body nonetheless succeeded in buzzing the Tabar system, pulling gas giant RQ-495 into a highly eccentric and deteriorating orbit. Our projections show that as it moves closer to the brown dwarf star, it will heat up and its radius will dilate in the phenomenon we have observed many times in the past.

However, our intelligence agents have caught the Earthlings observing this particular system as well. They seem particularly enthralled with these dilated giants, which they have named hot Jupiters after what appears to be a rather gaudily striped planet in their own Sol system.

In fact – and this cannot be repeated outside the office – our long-range surveillance indicates their top astrophysicists are researching theories on the inner workings of these gas giants that might explain their enhanced radii, including incident stellar flux, thermal tides, and some rather interesting interpretations of atmospheric hydrodynamics.

We thought the explanation was simply magnetism. Their obsessive curiosity with this type of planet – seriously, they have a multitude of telescopes and satellites tracking their transit – makes me think perhaps they are on to something and we should devote more of our sensor bandwidth to the evolution of this planetary subset.

However, I am unsure how their study of hot Jupiters will assist Earthlings in their insatiable quest for colonization, as their fragile bodies could not endure the heat or radiation on these worlds. Yes, my friends, the Earthlings are crazy enough to want to travel here. They want to travel everywhere, apparently. In that sense, their species bears striking similarity to these hot Jupiters: they both reach far beyond the limits of what should be physically possible. Their species can't even breathe vacuum and they are still chucking themselves gleefully at the stars.

I do not want to alarm you, but Cagnoren's simulations predict there is a 72.6% chance the Earthlings will succeed in reaching the fringe of Crenzian Confederate territory as soon as 900 years from now, and by then, they will likely possess a solid understanding not just of the astrodynamics of gas giants, but also how to extract Helium 3 from them for controlled fusion.

Perhaps it's time we buzz the Sol system. I am forwarding my recommendation for official species contact to headquarters.

Cordially,
Kaltragen Menz
Director, Office of Rogue Planets
P.S. No, Trelg, you can't be the first contact ambassador.

From Pad 39-A

A three part poem

Wendy Van Camp

APOLLO

At dawn, the monolith rises with
Brave men to ascend the heavens
We will journey to the moon
The nation holds its collected breath
As television cameras spy
At dawn, the monolith rises with
Brave men to ascend the heavens
On magnificent blossoms of fire
Kennedy's dream comes to life
We see our world with new eyes
At dawn, the monolith rises with
Brave men to ascend the heavens
We will journey to the moon

ENDEAVOUR

Over and over the flying brick

Transports humans into orbit
Landing home after her mission
    When the Challenger explodes
We grow fearful of outer space
    Over and over the flying brick
    Transports humans into orbit
    Astronauts float in the space station
Performing great experiments
The earth-bound do not comprehend
    Over and over the flying brick
    Transports humans into orbit
    Landing home after her mission

DRAGON

    The rising Dragon is a javelin
With precision, pierces the sky
Leaping forth from Pad 39-A
    Despite masks and social distance
The nation relives Apollo mystique
    The rising Dragon is a javelin
    With precision, pierces the sky
    Former shuttle pilots rename
SpaceX craft their Endeavour
Bringing the past into the future
    The rising Dragon is a javelin
    With precision, pierces the sky
    Leaping forth from Pad 39-A

Untitled

V Wegman

Scifaiku

Wendy Van Camp

Sublimation
ice in my cup
vaporises in summer's light
no teatime on Mars

Treasure
hidden treasure waits
under carbon dioxide cap
martian southern ice

Ice Miner
mining northern ice
awkward martian gloves grip
microwave jackhammer

Jupiter
a failure to launch
giant planet circles mate
unrealized binary

Probe
seeking answers
tiny Juno travels the void
spies Jupiter's glory

Jupiter Storm
great red spot dances
first red then shifting to white
Cassini's fading legacy

Charon and Pluto
two icy worldlets
ever facing his brother
in tidal embrace

Orbiting Secrets
In stationary orbit
city in the clouds
learning secrets

Venus Ascending
airship city floats
above toxic clouds
mysterious Venus

Crush
Spaceship seeks
floating city in Purgatory
finds crushing darkness

Rust
Martian hue isn't blue

rusty skies in morning light
color me pink

Cold

Twin moons chase stars
Mars descends into the cold
Another night alone

Rover

Lonely wheels rove gravel
rolling forever on Mars
seeking red cousins

Venetia's Wish

grandpa calls from Oxford
a girl's idea resonates
Pluto's name bestowed

Status Change

heated debate ensues
once too small to make the grade
dwarf Pluto now planet

Planet Pluto

in the Kuiper belt
dwarfs mingle with comets
size doesn't matter

From Earth to Crucible

Leo Korogodski

From the flight log of the *Chrysalis,*
an interstellar generation ship

We're getting close. Soon, our generation ship will reach our destination. I'm honored to be the one to captain it when we arrive and begin settling our new planet. It's a gas giant, one of many found several centuries ago by my ancestor Jiayin Dong. Admittedly, it doesn't have a surface of the kind that rocky planets do, like Earth where the human species had evolved. But over the centuries of interstellar flight, our people have become quite used to living their entire lives without one. The airships we'll build will not feel all that different to our generation ship.

Before we set our course, our leaders had been arguing whether to choose a warm large planet with a high or low orbital eccentricity. And even though we will have to weather periods of heat and cold, I'm happy with the final choice they made. The planet has enough thermal capacity to spare us from the extremes, and we can always change the cruising altitude. But, more importantly, during high-eccentricity tidal migration into its present orbit, our

planet has passed through the parts of its star system rich in different kinds of elements, including water, and has captured a retinue of planetesimals containing a diverse buffet of minerals. So what if our star system has few planets – if that means more moons for us, within an easy reach, to mine?

From Earth – to Crucible!
– Signed Captain Wushi Dong

Heavier cores: a poem from some other century, attributed to Alonzo Guzman

Mark McCutcheon

after work we succumbed
...to the science-fiction tales of democracy
– Dionne Brand, *Inventory* (8)

the station habitation ring filled with workers
from far away as Jupiter's sulphur mines
the forces that had brought their ancestors out
more like a labor union than a nation
made human expansion into the system possible
the pinnacle of creativity the impossible made real

planets with masses dominated by gas oligarchies
men of science cured of conscience
look on us as their labor force

the people who wound up as cheap labor for
crimes of economy, the boot on the colonists' neck
heavier planets harbour heavier cores

waking up from a nightmare into something worse
one of the worst places in the system, corporate death sentence
shifts runaway growth by mergers only not work
radioactive as hell, fires intense as black holes
the vast parliament blending together breaking apart
territory that you can't hold onto

tidally spun-down from break-up rotation
any other distribution is in violation
the frontier always outpaces the law
do I need my union representative
already counterfiling for raises hazard pay
wish I knew the way back gladly would I leave

systems initially containing many protocores
experiment in possible forms of human collective
a future requires a population transformed by range
immeasurably large and rich and strange
with the logic of dreams it carries
heaven help a Jupiter's child down by the methane sea

Notes

This cento (a poem made of lines from other works) samples Sivan Ginzburg and Eugene Chiang's "Heavy-metal Jupiters" (a scholarly article that the NExScl STEAM-collaboration organizers gave me as a creative prompt), excerpts from James S.A. Corey's *The Expanse* novels, proto-heavy metal songs that mention Jupiter, and Dionne

Brand's *Inventory*. The citations below specify excerpts used.

Title: Ginzburg, Sivan and Eugene Chiang. "Heavy-metal Jupiters by major mergers: Metallicity versus mass for giant planets." *Monthly Notices of the Royal Astronomical Society*, vol. 498, 2020, p. 680.
Subtitle: Corey, James S.A. *Cibola Burn* (2014). Orbit, 2015, p. 503, and *Abaddon's Gate*. Orbit, 2013, p. 251.
Epigraph: Brand, Dionne. *Inventory*. McClelland & Stewart, 2006.
Line 1: —. *Nemesis Games* (2015). Orbit, 2016, p. 55
2: The Jimi Hendrix Experience, "Voodoo Chile." *Electric Ladyland*, Reprise, 1968.
3-4: Corey, *Abaddon's Gate*, p. 183.
5: —. *Caliban's War*. Orbit, 2012, p. 27.
6: ibid., p. 344.
7: Ginzburg and Chiang, pp. 680-81.
8: Corey, *Abaddon's Gate*, pp. 38-9.
9: —. *Leviathan Wakes*. Orbit, 2011, p. 108.
10: —, *Nemesis Games*, p. 14.
11: —, *Nemesis Games*, p. 390 and *Cibola Burn*, p. 47.
12: Ginzburg and Chiang, p. 685.
13: Corey, *Nemesis Games*, p. 351.
14: —, *Caliban's War*, p. 548 and *Abaddon's Gate*, p. 34.
15: Ginzburg and Chiang, p. 681.
16: Corey, *Caliban's War*, p. 548 and Brand, *Inventory*, p. 22
17: —, *Abaddon's Gate*, p. 266.
18: —, *Caliban's War*, p. 511.
19: Ginzburg and Chiang, p. 687.
20: Corey, *Cibola Burn*, p. 218.
21: ibid., p. 146
22: Corey, *Babylon's Ashes*. Orbit, 2016, p. 396
23: —, *Cibola Burn*, pp. 557-58.

24: Steppenwolf, "Jupiter's Child." *At Your Birthday Party*. ABC/Dunhill, 1969.
25: Ginzburg and Chiang, pp. 685-86.
26-27: Corey, *Abaddon's Gate*, pp. 266-67.
28: Ginzburg and Chiang, p. 681.
29: Corey, *Persepolis Rising*. Orbit, 2017, p. 44.
30: Steppenwolf, "Jupiter's Child" and The Jimi Hendrix Experience, "Voodoo Chile."

About the contributors

Vivek Mittal is a dad, writer, and immigration attorney. He grew up around the United States, spending time in Virginia, Texas, Pennsylvania, and Georgia and finally ended up in Los Angeles, California. He is currently a Managing Attorney at the University of California Immigrant Legal Services Center where he assists others in fighting the current administration. His writing explores themes of race, intersectionality, climate change, and migration. He currently enjoys socially-distanced, masked hangouts in his backyard and spending time with his two kids and partner. He is fluent in Hindi, and is devoutly anti-Hindutva.

'The Planets' Play' was inspired by Ryan Cloutier's 'Sculpting the Close-in Planet Population Across the Main Sequence' presentation abstract. *One of the most important results in exoplanet demographics over the past half-decade has been the detection of the radius gap: the bimodality in the occurrence rate distribution of close-in planets smaller than Neptune. Both observations and models of planet formation and evolution agree that the radius gap arises from the existence of a transition from small terrestrial planets to larger nonrocky planets*

that host substantial gaseous envelopes. We are now tasked with trying to understand what physical process, or processes, are responsible for producing this rocky/non-rocky transition and whether these processes are universal across the entire main sequence. I will review the suite of physical processes proposed to explain the emergence of the radius gap, including photoevaporation, core-powered mass loss, and terrestrial planet formation in a gas-poor environment. I will focus on the unique model predictions of the gap's dependence on orbital separation, stellar mass, and age, as well as on how specific targeted observations can provide a clear pathway towards identifying the dominant physics at play. With the on-going TESS mission and the growing cohort of precision radial velocity spectrographs, the community is well-positioned to establish which processes are responsible for sculpting the radius gap around FGK stars, down to the lowest mass M dwarfs in the coming years.

Aaron Rosenberg is the author of the best-selling DuckBob SF comedy series, the Relicant Chronicles epic fantasy series, the Dread Remora space-opera series, and, with David Niall Wilson, the O.C.L.T. occult thriller series. His tie-in work includes novels for Star Trek, Warhammer, World of WarCraft, Stargate: Atlantis, and Eureka. He has written children's books (including the award-winning Bandslam: The Junior Novel and the #1 bestselling 42: The Jackie Robinson Story), educational books, and roleplaying games (including the Origins Award-winning Gamemastering Secrets). You can follow him online at www.gryphonrose.com, on Facebook at facebook.com/gryphonrose, and on Twitter @gryphonrose.

'For the Win' was inspired by Andrew Neil's 'Joint Mass-Radius-Period Distribution Modeling of Water Worlds' presentation abstract. *Water worlds have been hypothesized as*

an alternative to photo-evaporation in order to explain the gap in the radius distribution of Kepler exoplanets. We explore water worlds within the framework of a joint mass-radius-period distribution of planets. We employ hierarchical Bayesian modeling to create a range of mixture models that include multiple exoplanet populations. We model these populations – including planets with gaseous envelopes, evaporated rocky cores, evaporated icy cores, intrinsically rocky planets, and intrinsically icy planets – in different combinations in order to assess which combinations are most favored by the data. Using cross-validation, we evaluate the support for models that include planets with icy compositions compared to the support for models that do not. We further explore the population-level degeneracies between subpopulations of water worlds and planets with primordial envelopes. Looking forward, we demonstrate how to extend this analysis by incorporating planet interior structure models to directly model the composition distribution of exoplanets.

Kelli Fitzpatrick is a science fiction and fantasy author, English educator, and community activist based in Michigan. Her *Star Trek* story "The Sunwalkers" won the Strange New Worlds 2016 contest, and her essays on pop culture media appear at StarTrek.com and Women at Warp, Sequart, and ATB Publishing. She currently writes for the *Star Trek Adventures* role-playing game from Modiphius. She is a strong advocate of the arts, public education, and gender rights and representation. Kelli can be found at KelliFitzpatrick.com and on Twitter @KelliFitzWrites.

'Rogue' was inspired by Daniel Thorngren's 'Giant Planet Population Physics' presentation abstract. *The study of giant planet physics was long limited to the four planets found in our solar system. However, giant exoplanet discoveries have enabled a*

powerful new approach to planetary physics: the statistical study of their populations. This work has only become possible recently, with a large sample of transiting planets with well-determined masses and radii. In this review, I discuss how through comparison with structure and evolution modelling, we can find insights that cannot be obtained from studies of the solar system. This includes new views on planetary composition, structural evolution, and atmospheric physics. I review recent and ongoing work regarding 1) the planetary mass-metallicity relation of giant planets, and how it does (or does not) connect with stellar metallicity, 2) the long-unsolved radius inflation problem of hot Jupiters, 3) how giant planets evolve over time in the face of brightening parent stars on and off the main sequence, and 4) the depth of the atmosphere's radiative-convective boundary, which affects interpretation of atmospheric spectra. I also discuss how this work connects with ongoing planet characterization efforts, prioritization of TESS target follow-up, planet formation studies, and connections to population studies of the physics of smaller planets.

V Wegman is a professional science communicator and educator from Pittsburgh. They are a three-time NASA intern, currently working with the Carnegie Museums of Pittsburgh and teaching at a local primary school.

Their artwork was inspired by the fiction and poetry created for this collaboration.

Wendy Van Camp is the creator behind No Wasted Ink (http://nowastedink.com), a blog about the craft of writing that features author interviews, sci-fi and fantasy book reviews and poetry. Her short stories and poems have appeared in "Lit Up," "Scifaikuest," "Quantum Visions" and "Far Horizons." She's published "The Curate's Brother: A

Jane Austen Variation of Persuasion," a Regency historical novel and "The Planets: a scifaiku poetry collection." A graduate of the James Gunn Speculative Fiction Workshop, Wendy has won Honorable Mention at the Writers of the Future Contest, and has been nominated for an Elgin Award.

'From Pad 39-A' and was inspired by Rafael Luque's 'The Obliquity Distribution of Ultra Hot Jupiters: A Population-wide View' presentation abstract. *Ultra hot Jupiters (UHJs), which we define as gas giants with equilibrium temperatures above 2000 K, have recently emerged as a population of exoplanets with distinct atmospheric characteristics. The hottest of the hot Jupiters are amenable to extensive characterization due to their high temperatures, inflated radii, short periods, and atmospheres with large concentrations of atoms and ions relative to molecules exhibiting strong thermal inversions. The hosts are normally early-type, hot, rapidly rotating stars and their planets frequently reside in misaligned orbits. In this work, we carry out a homogeneous derivation of the obliquity of a sample of UHJs via the Rossiter-McLaughlin effect using new and archival high-resolution spectroscopic transit observations. We analyze the obliquity of the UHJ sample and study its dependence with the stellar parameters, orbital eccentricity, planetary mass, and atmospheric composition, comparing it with the larger population of hot Jupiters. UHJs show preferentially a wider range of obliquities, in agreement with the findings of Winn et al. (2010) that suggest that the photospheres of cool stars realign with the planet orbits due to tidal dissipation in their convective zones, while hot stars cannot realign because of their thinner convective zones.*

Leo Korogodski is a science fiction author and a software developer. He has a Ph.D. in Mathematics from MIT. His

science fiction novella *Pink Noise: A Posthuman Tale* won the 2011 Indie Excellence Award (1st place) and the 2010 eLit Books Award (2nd place). He lives with his family in Holland, PA.

'From Earth to Crucible' was inspired by Jiayin Dong's 'The Eccentricity Distribution and Occurrence Rates of Warm, Large Exoplanets' presentation abstract *Warm, Large Exoplanets (WaLEs) – defined here as planets larger than 6 Earth radii with orbital periods 8–200 days – are a key missing piece in our understanding of how planetary systems form and evolve. It is currently debated whether WaLEs form in situ, undergo disk or high eccentricity tidal migration, or even have a mixture of origin channels. These different classes of origin channels lead to different expectations for WaLEs' properties, such as their eccentricity distribution and occurrence rates. In this talk, I will first discuss our recent work where we uniformly search for WaLE candidates in the southern ecliptic hemisphere in the TESS Full Frame Images (FFIs) and discover a catalog of ~80 WaLE candidates. We characterize the eccentricity distribution of these WaLE candidates using hierarchical Bayesian models and find a two-population mixture model — a low-e population for in situ or disk migration origins and a high-e population for high eccentricity tidal migration origin can well describe the observed WaLEs' eccentricities. Our hierarchical model suggests a mixture of origin channels and also an upper limit on the fraction of WaLE systems forming through high-eccentricity tidal migration. Furthermore, I will discuss our ongoing project on the validation of the WaLE candidates using ground-based telescopes and the TESS extended mission. By the end of the observation cycles, we aim to construct a well-understood WaLE catalog for a deeper understanding of WaLEs' eccentricity distribution and occurrence rates.*

Mark A. McCutcheon is Professor of Literary Studies at Athabasca University. Mark's debut book of poems, *Shape Your Eyes by Shutting Them*, was published in 2019 by AU Press; his poems also appear in *Beyond Earth's Edge: The Poetry of Spaceflight* (U of Arizona P, 2020), the 2019 *Rhysling Anthology*, and journals like *On Spec*. Mark's monograph *The Medium Is the Monster: Canadian Adaptations of Frankenstein and the Discourse of Technology* (2018) won the Media Ecology Association's 2019 McLuhan Award for Outstanding Media Ecology Book. Mark's on Twitter and Mixcloud as @sonicfiction.

'Heavier Cores' was inspired by Sivan Ginzburg's 'Heavy-Metal Jupiters by Major Mergers' presentation abstract. *Some extrasolar Jupiters have large metal masses, well above the mass needed in a solid core to trigger runaway gas accretion. We demonstrate that such "heavy-metal Jupiters" can result from planetary mergers. We provide a simple derivation of the mass-metallicity relation for giants, and compare to observations. While the average gas giant merges about once to double its core, others may merge multiple times as merger trees grow chaotically. Chaotic collisional histories naturally reproduce the large scatter in observed giant planet metallicities. Mergers potentially correlate metallicity, eccentricity, and spin.*