Introduction

Familiarizing the Extraterrestrial / Making Our Planet Alien

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Abstract A growing number of researchers in the social sciences and the environmental humanities have begun to focus on the wider universe and how it is apprehended by modern cosmology. Today the extraterrestrial has become part of the remit of anthropologists, philosophers, historians, geographers, scholars in science and technology studies, and artistic researchers, among others. And there is an emerging consensus that astronomers and other natural scientists—contrary to a common prejudice—are never simply depicting or describing the cosmos "just as it is." Their research is always characterized by a specific aesthetic style and by a particular "cosmic imagination," as some have called it. Scientific knowledge of the universe is based on skilled judgments rather than on direct, unmediated perception. It is science, but it is also an art. This special section focuses on two at first sight contradictory aspects of this cosmic imagination. On the one hand, there is a distinctive move toward viewing the extraterrestrial in familiar terms and comprehending it by means of conceptual frameworks that we, earthlings, are accustomed to. On the other hand, there is a tendency to understand our own planet in unfamiliar terms, especially in astrobiology, where so-called analog sites and "extreme environments" provide clues about alien planets.

Keywords outer space, cosmic imagination, extremes of life, analog sites, humanities off Earth, science and art

Introduction

The initial idea for this special section goes back two years. In June 2015 one of us, Praet, organized an international workshop: "Frontiers of Life: Terrestrial and Extraterrestrial Prospections," at the University of Roehampton (London). In November 2015, Salazar organized a panel together with Jessica O'Reilly at the American Anthropological Association (AAA) Annual Meeting in Denver: "Extreme Horizons: Anthropology of Planetary and

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Post-planetary Frontiers."[1] Both events aimed to look at how the frontiers of life continue to shift and expand in remarkable ways. Biological organisms have been discovered in the world's driest deserts as well as in subglacial lakes and in hot springs, while airborne microbes have been captured in the stratosphere. Experiments conducted at the International Space Station have established that microscopic animals capable of suspended animation, such as tardigrades, are surprisingly tolerant of the conditions of outer space. Findings such as these have inspired researchers in the field known as astrobiology to reassess the notion of "habitable environment" and to rethink what it means to be "alive." These concerns have been met with a rising ethnographic interest in the reconfiguration of planetary and post-planetary imaginings.

In this special section we convey a particular interest in frontiers as borders of a very specific kind, and in the intricacies of novel ways to envisage life in the extremes. While borders are conventionally portrayed as spaces of profound, intimate, flowing interaction peopled on all sides, frontiers both recapitulate and challenge borders, such as those between nature and culture or between science and art. We propose to investigate such frontiers in two principal ways. On the one hand, this special section brings together research on outer space by means of ethnographic explorations of astrobiology, planetary science, and physical cosmology. On the other hand, it seeks to explore how Earth is being transformed into a "natural laboratory" of sorts, allowing scientists to experiment with and theorize about alien life; we pay specific attention to the various "extreme environments" that operate as analog sites for what happens on celestial bodies elsewhere.

Social Scientific Perspectives on Outer Space

Sixty years into the so-called space age, scientists continue to investigate our solar system and the farthest reaches of the cosmos. Traditionally, this exploration has been the business of astronomers, rocket builders, planetary scientists, aeronautic engineers, and astrophysicists. In recent years, however, there has been a turn of sorts: outer space is no longer the exclusive domain of what is usually designated as "hard" science. Today supposedly "messier" or "softer" sciences play an increasingly prominent role, exerting considerable influence on how the extraterrestrial is portrayed and understood. In the first place, one might think of the burgeoning field known as astrobiology—the scientific study of life in a cosmic context. What we wish to emphasize here, however, is that a growing number of researchers in the social sciences and the environmental humanities have begun to focus on the wider universe and how it is apprehended by modern cosmology. We observe how "sites of political, scientific, and economic engagement

1. Thom van Dooren, the coeditor of *Environmental Humanities*, was instrumental in bringing both projects together, and we are very grateful for this. His involvement in this special section has gone beyond what one would normally expect of a journal editor. We would also like to acknowledge the invaluable help of Astrida Neimanis and Jamie Lorimer.

that source specifically to the extraterrestrial" are emerging across disciplines. Today the extraterrestrial is part of the remit of anthropologists, philosophers, historians, geographers, psychologists, scholars in science and technology studies, experts in robotics, and artists, among others.[2] All these endeavors contribute to what Debbora Battaglia, David Valentine, and Valerie Olson have called an emerging "anthropology off the Earth."[3] What unites these fledgling efforts is a concern with the notion of the extreme. As these authors argue, the figure of the extreme "shapes an analytic of limits and ever-opening horizons—epistemological and physical—provoking new understandings of humanness, environment, temporality, and of inter-species life as we think we understand it, here on Earth."[4] What further unites these efforts is an intuition that the manifold surprises you may encounter "out there" also tell you something about "us," here on this planet.

In a piece that highlights the parallels between space science and molecular biology, the anthropologist Gísli Pálsson has suggested that the conventional, astronomical universe must be grasped in conjunction with "the universe within" our own bodies.[5] In a similar way, Sophie Houdart is interested in how particular ideas and images of the cosmos are stabilized and maintained.[6] She has described how the world's largest particle accelerator, CERN's Large Hadron Collider, connects physicists to the immensity of the universe—tellingly, this contemporary, underground "cathedral" also tends to be experienced as a kind of "spaceship." What fascinates Houdart is that the machine provides access to something that surpasses humanity and yet simultaneously contains it. Studies such as these do not only invite social scientists to reflect on the linkages between the infinitely large, the "human" scale, and the infinitely small; they also reveal something that is usually overlooked, namely, that "our" modern cosmology and the "standard" view of space-time and quantum physics that goes with it are the product of a very specific history. What is currently happening in all likelihood follows from this incipient realization; it is a move to historicize or indeed "anthropologize" the space sciences. At the same time, you could argue it is a move to "naturalize" or indeed "extremify" the social sciences and humanities (a point we will return to below). For some, all this may sound like a regressive step; some will no doubt dismiss it as a scandalous proposition. Is the defining feature of modern, scientific cosmology not precisely the fact that it systematically gets rid of such things as cultural ballast and historical error?

At this point, it is useful to stand back a little and to contemplate the long-term picture. In a study on seventeenth-century natural philosophy and early science fiction literature, the historian Frédérique Aït-Touati has shown that what we nowadays refer to as science and art used to be much more intertwined.[7] Not only did monumental

2. Valentine, Olson, and Battaglia, "Extreme: Limits and Horizons."
3. Battaglia, Valentine, and Olson, "Relational Space," 252.
4. Valentine, Olson, and Battaglia, "Extreme: Limits and Horizons," 1008.
5. Pálsson, "Celestial Bodies."
6. Houdart, *Incommensurables*.
7. Aït-Touati, *Fictions of the Cosmos*.

thinkers such as Johannes Kepler and Christiaan Huygens forge the great astronomical breakthroughs for which they are deservedly remembered today, but also their works exhibit a distinctive poetic genius. Aït-Touati underlines that in that period, "debates about cosmology, astronomy, and optics and other branches of natural philosophy are also poetic debates."[8] Figures like Kepler and Huygens did not just perfect the laws of planetary motion or discover the rings of Saturn, they also wrote with formidable speculative verve. In his *Somnium* (posthumously published in 1634), the former described a lunar voyage in which proto-astronauts are shot to the Moon like cannonballs. In *Cosmotheoros* (also posthumously published, in 1698) the latter brilliantly developed the idea that all planets in the solar system "are as beautiful and as well stock'd with Inhabitants as the Earth." Yet in canonical accounts of their cosmological achievements, this imaginative aspect has rather consistently been brushed under the carpet, seen as a bit of an embarrassment. In the present day and age, there is no place for frivolities such as lunar serpents or water that cannot freeze. In our current, supposedly disenchanted world, poetic license or, as Aït-Touati calls it, the "cosmic imagination" is deemed a capital vice: that we, moderns, have expelled it or have at least reduced it to a bare minimum is generally viewed as a mark of progress. But *have* we actually done away with it? Is it even possible to unequivocally separate fact from fiction, science from art, nature from imagination? Perhaps not, according to now well-established scholarship in the history and philosophy of science and science and technology studies.

In a study that shows how the digitally processed images taken by the Hubble Space Telescope are used in pursuit of an "astronomical sublime," Elizabeth A. Kessler has shown that telescope pictures never quite render the cosmos "just as it is" (whatever that may mean)—upon closer inspection, they always reveal a particular aesthetic style.[9] Some of the images produced by Hubble possess a striking affinity with certain forms of early nineteenth-century Romantic landscape painting, for example. In her ethnography of the planetary scientists and space engineers engaged in NASA's Mars Exploration Rover project, Janet Vertesi has presented similar arguments.[10] With reference to the robotic rovers and the digital cameras they used to explore the Martian surface, she notes that it would be all "too easy to assume that scientific images show exactly 'the things themselves as they appear' without paying attention to the considerable work it takes for scientists to produce such pictures."[11] Scientific seeing, Vertesi points out, is always skilled seeing—and scientific imaging is therefore skilled work as well. In other words, "seeing like a rover"—which is what the NASA mission team members must learn—is an art or a craft. In a similar vein, Charlotte Bigg has suggested that one of the most promising ways to enhance our understanding of scientific imagery is

8. Ibid., 7.
9. Kessler, *Picturing the Cosmos*.
10. Vertesi, *Seeing like a Rover*.
11. Ibid., 8.

to apply the methods of art history.[12] And this is precisely what unconventional art historians such as Martin Kemp, Barbara Stafford, and James Elkins have been doing, each in their own way. Bigg emphasizes that these authors have done more than simply demonstrate that the artistic and scientific spheres are not as compartmentalized as they are often supposed to be. Crucially, they have also identified "visual cultures" whose style and aesthetic characteristics evolve in accordance with the history of the scientific discipline in which they emerge.

To be sure, contemporary scientists and the wider public do not only relate to the wider universe by means of images. The visual may be exceedingly prominent—think of the famous Blue Marble image made from the Voyager 1 spacecraft and its subsequent impact on ecology and environmental science[13]—but we should not forget that alternative, nonvisual ways to connect to the cosmos have become increasingly important.[14] Because of rapid advances in detection and computing technologies, almost all data are digital in observational astronomy nowadays. As a result, its practitioners have become more akin to number crunchers than skywatchers. But this shift from the sensorial to the numerical, from the actual telescope to globally shared data sets, does not necessarily mean that scientists have finally found the road toward a more absolute or objective representation of the universe. In an ethnographic study of how astronomers combine the data obtained from a Chilean and a Spanish telescope to make novel claims about cosmic phenomena, Götz Hoeppe has shown that digital data are eminently malleable.[15] Among other things, this has to do with the removal of putative artifacts of the unsteady observing situation: pixel-to-pixel variations in detector sensitivity, dust on lenses and mirrors, clouds passing through the field of view, the moonlight shining into the telescope dome. This removal is performed according to specific protocols or "recipes" and is pervaded by unacknowledged, backgrounded assumptions. Hoeppe speaks of "an implicit cosmology," that is, a shared but negotiable characterization of what the universe looks like. His ethnography thus reveals a cosmos based on skilled judgments rather than on direct, unmediated perception.

All these connections have the merit of illustrating a more basic point: an aseptic cosmology free from any trace of human imagination is in fact unrealistic—it is itself a figment of the (modern) imagination. Any astrophysical theory of the universe includes poetic leaps; any scientific representation is based on some kind of artistic choice. But these leaps and choices typically remain unnoticed. They stay under the radar because we lack the appropriate tools to spot them. In this special section, we develop the idea that an anthropology taken beyond our own planet can provide such tools and can thus offer a more realistic picture of what is currently happening in the space sciences.

12. Bigg, "Études visuelles des sciences."
13. See, e.g., Cosgrove, *Apollo's Eye*.
14. Cf. Houdart and Jungen, "Cosmos Connections."
15. Hoeppe, "Working Data Together."

Of course, people across the world have always engaged with the wider cosmos. In long-established fields such as "cultural astronomy" there is an abundance of documentation on traditional skywatchers and their ingenious observatories, mythical kite flyers reaching the stars, pyramids and their astrological purposes, gravity-defying shamanic voyages, sacred landscapes that mirror the heavens, and so forth. Ancient Greeks and Babylonians were in all likelihood not the first astronomers. The celestial observations and reflections of people such as the Yolgnu of Arnhem Land in northern Australia may very well go back much further in time. Like many indigenous astronomical practices, and unlike Western astronomy, Yolgnu observations were not only concerned with stars and planets but also with the Milky Way and the dark areas separating stars.[16] Before the current spacefaring epoch started with the launch of the Sputnik satellite in 1957, humans were not exactly grounded, Battaglia, Valentine, and Olson note. Yet they also suggest there is something distinctive about the emerging "anthropology off Earth": "as some humans have increasingly used robotic and remote explorations of the solar system and universe . . . openings are emerging to imaginative engagements with radical new ways of world-making and a re-imagination of the planet as embedded in a wider space ecology."[17] And as Salazar shows in this special section, this also applies to "extreme environments" such as Antarctica, where remote sensing and satellite technologies have been instrumental in "seeing," imagining and sensing the Antarctic continent and Southern Ocean.[18]

Battaglia and her colleagues plead for "a space-inclusive anthropology" that does not assume that the relationship between the social and the ecological ends at our planet's upper atmosphere because it is a "natural" boundary for earthly forms of life.[19] By zooming in and out they propose to expose anthropological questions, concepts, and debates to the environments of outer space and "space-on-Earth" (a notion we will expound in the following section). Olson—who conducted ethnographic research at the Johnson Space Center in Houston, Texas—has shown that American astronautics connects to a larger historical genealogy of environmental sciences.[20] Consequently, she has advocated a shift in focus from space-as-frontier to space-as-environment. What we are currently witnessing, according to her, is the emergence of a solar system grasped in ecological terms, and the rise of a veritable astronautic environmentalism. In a similar vein, Lisa Messeri has illustrated how the cosmos and our solar system are being scaled down to the level of human experience.[21] In her ethnography of exoplanet astronomers and Mars scientists she emphasizes the importance of "place-making." As

16. E.g., Norris and Hamacher, "Australian Aboriginal Astronomy."

17. Battaglia, Valentine, and Olson, "Relational Space," 245.

18. See, e.g., Kathryn Yusoff's "Visualising Antarctica as a Place in Time"; and Salazar's article in this special section.

19. Battaglia, Valentine, and Olson, "Relational Space."

20. Olson, *American Extreme*, 7.

21. Messeri, *Placing Outer Space*.

numerical data produced by telescopes and satellites is transformed into representations of worlds that scientists can imagine visiting, place becomes a tool by means of which their objects of research can be thought of on a human scale. As she puts it: "Scientific practices of place-making turn the infinite geography of the cosmos into a theatre dotted with potentially meaningful places that are stages for imaginations and aspirations."[22] Echoing Aït-Taouti's "cosmic imagination," she writes of "the planetary imagination." Messeri even suggests, tantalizingly, that planetary science and anthropology are ultimately not that different, for isn't the work of creating planetary space similar to the anthropologist's desire to make the strange and alien familiar? We will return to this point in the next section.

The Quest for Alien Life and Extremophile Research

Today, the world's major space agencies—which include NASA, Roscosmos, European Space Agency (ESA), and China's National Space Administration—spend a growing proportion of their resources on the search for habitable worlds and, more ambitiously, on the quest for actual life beyond Earth. The astronomy of exoplanets and the field labeled as astrobiology have expanded rapidly in the past two decades. And while a range of startling discoveries have been announced, there is also an emerging consensus that some of the basic questions have been ill-formulated, or at least require more sophisticated conceptual groundwork. What it means to be "habitable" or to be "alive," it turns out, is not as straightforward as many overly optimistic scientists believed in the immediate aftermath of the confirmation, in 1995, of the first detection of an extrasolar planet orbiting a Sun-like star. It is crucial to realize that the space sciences are not merely observational sciences—for one thing, they also operate as conceptual laboratories. Astrobiology is not just premised on the findings acquired by high-tech telescopes or robotic spacecraft—it is also a hotbed of philosophical innovation, as Stefan Helmreich's seminal work on how space researchers and marine biologists conceive of and engage with "the limits of life" testifies.[23]

The concept of life—arguably one of the cornerstones of modern scientific thought and also something of a fetish concept in the space sciences—has become unsettled, Helmreich observes. We need to consider the possibility that "life itself" is an historical rather than a universal category, he suggests—that is, what happens if it turns out to be a parochial construct rather than an eternal, self-evident notion? Other anthropologists have developed concurring arguments. Tim Ingold, for one, thinks that it is a mistake to believe that the modern conception of "life" will be stuck forever in the neo-Darwinian template that remains—to his great grief—so dominant today.[24] Gísli Pálsson has demonstrated that the concept of life is always and inevitably hybrid, underpinned by social

22. Ibid., 3.

23. See, especially, Helmreich, *Alien Ocean*, and his latest monograph, *Sounding the Limits of Life*.

24. See, e.g., Ingold and Pálsson, *Biosocial Becomings*.

and cultural assumptions, even in such fields as genetics and molecular biology.[25] And of course notions of life also vary cross-culturally—anthropological work on non-Western societies and animisms highlights that biology does not have a monopoly on the idea of life and how it can be employed.[26] So it is not that life is becoming unsettled only because of what is happening in the space sciences. Yet for the purposes of this special section we focus almost exclusively on the nexus between life and outer space. What interests us here is that the instability of life is linked to the flourishing of astrobiology as a discipline in its own right. As Helmreich has phrased it: "If the definition of life has been a frustratingly evasive object for theory in biology, this elusiveness has been the foundation for astrobiology as a research program."[27] Indeed, what motivates many of those who engage in this endeavor is the realization that the search for extraterrestrial life is deeply constrained by how we understand life here on Earth.

In an article on "life as we don't yet know it," in which she examines how scientists theorize "weird life," Battaglia has made a similar point: the human mind, she underlines, finds it difficult to create ideas truly different from what it already knows.[28] In other words, our modern, scientific outlook may be inescapably "terra-centric." Now life's terrestrial origin is currently thought to go back at least 3.5 billion years, as indicated by fossilized microbial mats. Its spatial distribution is more extensive and its resilience is much greater than generally assumed until a few years ago: biological organisms have been discovered in undersea volcanoes, for example, and experiments in space have established that certain microscopic organisms, such as *Deinococcus radiodurans*, are remarkably tolerant to outer space conditions. As a result of such findings the so-called panspermia hypothesis, according to which interplanetary space is pervaded by organic seeds, has gained a new respectability in scientific circles. For example, the *Tanpopo*, or "dandelion," mission, conducted by a group of Japanese space scientists, is collecting cosmic dust and small meteorites in an attempt to establish whether hardy microorganisms are capable of traveling between planets. The geochemist Steven Benner has even proposed that *all* terrestrial life originated on Mars—there are good reasons to believe, he argues, that the "seeds of life" were catapulted toward our planet after a volcanic eruption (which used to occur frequently on our neighboring planet) or reached us on board a Martian meteorite.[29]

All of this illustrates a point that Helmreich has underlined: ushered by astrobiology, life's limits continue to shift and expand in unexpected ways.[30] Yet we know very little about how this ongoing shift actually unfolds; one of the aims of this special section

25. Pálsson, *Nature, Culture, and Society*.

26. Cf. Praet, *Animism and the Question of Life*; and Pitrou, "Vie, un objet pour l'anthropologie?"; as well as Pitrou, "Life as a Process of Making."

27. Helmreich, *Alien Ocean*, 265.

28. Battaglia, "Life as We Don't Yet Know It."

29. Benner and Kim, "Case for a Martian Origin for Earth Life."

30. See, especially, Helmreich, "What Was Life?"

is to document a few of these mutations ethnographically. To do this properly, we must, as Sophie Houdart and Christine Jungen have stressed, consider issues of scale and perspective.[31] It is necessary to improve our understanding of how scientists make the universe palpable and how they apprehend both the very large and the very small by means of a panoply of telescopes, spectroscopes, microscopes, and a variety of other instruments. At the same time, we need to come to terms with the fact that a field such as astrobiology is itself constituted by a considerable variety of disciplines and specialisms. Philosophers of science tell us that observatory techniques, and even objectivity itself, have a history.[32] Space researchers may claim that their observations and measurements are objective, yet their ideals of objectivity change over time and depend on the specific context (or subdiscipline) in which they are applied. An astrophysicist may have a slightly different standard of objectivity and a subtly distinctive definition of life than, for example, a geochemist or a microbiologist. The way in which planetary scientists frame their questions—whether they are about subsurface oceans, alternative biochemistries, ice volcanoes, extraterrestrial lightning storms, putative microfossils, or the analogy between Earth's hydrosphere, the sulfur cycle of Jupiter's volcanic moon Io, and the "methanosphere" of Saturn's biggest moon, Titan—is never neutral. The degree to which these respective entities or phenomena are considered to be "alien" or "familiar" always depends on specific but usually unacknowledged conventions. The challenge, which we take up in this special section, is to make some of those conventions explicit.

At first glance, one can roughly discern two seemingly contradictory, but interrelated, currents in the contemporary space sciences: one of familiarization and one of alienation. On the one hand, there is a pronounced move toward viewing the extraterrestrial in familiar terms and comprehending it by means of conceptual frameworks that we, earthlings, are accustomed to. Outer space, so to speak, is in the process of being "de-exoticized." Our planetary neighbor Venus, notwithstanding its extreme surface conditions that are routinely described as "hellishly hot," is said to be dotted with snow-capped mountains—yet that "snow" is metallic, composed of lead sulfide and bismuth sulfide, rather than being aquatic. The surface of the Saturnian moon Titan apparently consists of "rocks" and "lakes," even though these rocks are merely composed of ice that is so cold that it behaves like rock, and its lakes are made up of hydrocarbons that behave like liquid. Mars is no doubt the most prominent example of this ongoing "de-exotization." The red planet is commonly envisaged as "a dead world: freeze-dried, geologically static, and irradiated daily with lethal ultraviolet."[33] It is true that none of the landers or rovers have so far conclusively identified microfossils or

31. Houdart and Jungen, "Cosmos Connections."

32. See, e.g., Norton Wise, *Growing Explanations*; Daston and Galison, *Objectivity*; and Daston and Lunbeck, *Histories of Scientific Observation*.

33. Grinspoon, *Lonely Planets*, 179.

other traces of microbial life. Yet an increasing number of astrobiologists believe that this vision of Mars remains clouded by an Earth-centric bias. "We must strive to comprehend Mars in Martian terms," an astrobiologist told one of the editors (Praet) at a major planetary science conference in London, "only then can you see that it is not so different from Earth." What he alluded to is that we need to understand the red planet as a dune world rather than as an aquatic world. Once you realize that sand is not just a solid but can, if you look carefully, behave as a liquid or even as a cloud, Mars instantly becomes much more interesting and at the same time oddly familiar; it emerges as a planet with an active geology, an active hydrology, and a much more active weather cycle than previously understood.

In other words, Mars suddenly appears much more Earth-like than hitherto deemed possible. Where it used to be imagined as a dull and lifeless world, more and more researchers now envision it as a highly dynamic, lively dune world. It is no coincidence that the work of the twentieth-century desert explorer Ralph Bagnold has become so influential in astrobiology and planetary science (among other things, NASA researchers have applied his pioneering insights into the workings of terrestrial dunes to Martian ones). An intriguing possibility is that dunes are themselves a manifestation of life, albeit life of an unfamiliar ilk. Bagnold himself already suggested as much in his memoirs: "Here [in the deep desert], where there existed no animals, vegetation, or rain to interfere with sand movements, the dunes seemed to behave like living things. How was it that they kept their precise shape while marching interminably downwind? How was it that they insisted on repairing any damage to their individual shapes? How, in other regions of the same desert, were they able to breed 'babies just like themselves that proceeded to run ahead of their parents?' Why did they absorb nourishment and continue to grow instead of allowing the sand to spread out evenly over the desert as finer dust grains do?"[34] The convergence between this "zoo of dunes" and living organisms has also been highlighted by some of the latest results of NASA's Mars Reconnaissance Orbiter. More specifically, we refer to a recently released image of a large crater near one of Mars's oldest valleys where a group of barchans dunes appears to "fly" in a V-formation, just like migrating geese. So Mars is not just becoming more Earth-like in the geological sense. Depending on how far you stretch the concept of life, it might also be becoming more terrestrial in the "biological" sense.

On the other hand, there is a growing tendency to understand our own planet in unfamiliar terms. And this tendency is particularly prominent in astrobiology. Earth, you could say, is literally made alien. We refer, of course, to the manifold "analog sites," "extreme environments," and "natural laboratories" that have been identified across the globe and that have become the privileged places where space scientists conduct geochemical experiments and test the boundaries of "life as we know it." As Helmreich has put it: "Astrobiologists treat unusual environments on Earth, such as methane seeps

34. Bagnold, *Physics of Blown Sand and Desert Dunes*, 103–4.

and hydrothermal vents, as models for extraterrestrial ecologies. Framing these environments as surrogates for alternative worlds has made marine microbes like hyperthermophiles attractive understudies—what scientists call *analogues*—for aliens."[35] This approach, which combines elements of laboratory-controlled simulations, astronaut survival training, and field research in "space-on-Earth" sites, is not a fringe activity. As Olson has underlined: "More analogue space exploration missions 'launch' each year than flights into outer space, representing a new extremely situated iteration of lab-based experimental goals to make humans and things survive space."[36]

The Danakil Depression in Ethiopia—with its landscape of unlikely colors, beehive-shaped salt mounds, bubbling sulfur sources, and improbable rocks—is conceived of as an analogue to early Mars, which was volcanically active and may have harbored "extremophile" microbes similar to those found in its acidic hot springs. What is truly remarkable but little studied is that hundreds of these analog sites have sprung up in the past decade or so, all over the world, from the Atacama Desert to the Svalbard Islands, from Trinidad to Morocco. Extremophile research is a booming business—as Salazar's article in this special section illustrates, microbiologists are flocking to Antarctica to bioprospect, sample, cultivate, and sequence enzymes and proteins from an untapped cornucopia of genetic material. In the process, astrobiology is becoming a fieldwork-based science, not unlike anthropology. It is a strange kind of fieldwork to be sure—fieldwork by proxy, carried out by terrestrial astronauts without rockets or space suits.

In a sense, space exploration is being brought home. Some have even suggested that astronomy today is perhaps not so much restricted by the limitations of cutting-edge telescope technology as by something more basic, namely, the shortcomings of its own imagination. In an unjustly overlooked book, Doris and David Jonas write: "Probably the greatest surprises are to be found here on Earth, if we only discover how to look for them. . . . Perhaps we shall be able to understand what we may discover in other worlds by referring back to what is present in our own. The difficulty seems not to be in the getting there, but in imagining and therefore in preparing for what we shall find when we arrive. The greatest obstacle here is our usual way of thinking. . . . We have to give our imaginations some bending and stretching exercises."[37] That last sentence perfectly captures the spirit of this special section, for grasping what is currently happening in the space sciences, astrobiology, and fundamental research on the limits of life requires insight into a great deal of imaginative bending and stretching. And our overall aim could indeed be summarized as an inquiry into how those related domains are subverting "our usual way of thinking." Ultimately, our goal is to reflect on how the selective "alienation" of our home planet correlates with the (apparently) opposite trend to "familiarize" the extraterrestrial. We intend to reveal the "artistic choices" that

35. Helmreich, *Alien Ocean*, 255.

36. Olson, *American Extreme*, 32.

37. Jonas and Jonas, *Other Senses, Other Worlds*, 17.

are involved in those parallel scientific endeavors and thus offer a basic sketch of what the "cosmic imagination" looks like today. In this way, we hope to cast fresh light on the space sciences' swiftly and at times capriciously evolving understanding of the cosmos.

Overview of the Articles

In the wake of the launch of NASA's Kepler space telescope, Lisa Messeri investigates the narrative framework that astronomers use to explain their search for an Earth-like planet elsewhere. The discovery of a planet "just like our own" is nowadays envisaged as the holy grail of exoplanet astronomy. Messeri is particularly interested in how scientists stretch the concept of habitability beyond this planet, across the cosmos. The argument she develops is that outer space is by no means entirely removed from terrestrial matters—in fact, it offers a different scale and perspective to examine human, technocultural relations. The tales of cosmic relations that she documents illustrate that astronomy does not stand apart from terrestrial pursuits; it actually deeply informs understandings of Earth and the modes in which we, earthlings, inhabit it. A thought-provoking suggestion is that the most significant legacy of the Apollo missions was not so much a deeper scientific knowledge of the Moon, as a fresh view of Earth from space—a view that became totemic for the environmental movement. As with human space flight, Messeri contends that the quest for Earth's "twin" not only promises a better understanding of places elsewhere in our galaxy but also provides a mirror for examining terrestrial relations. At the same time, exoplanet astronomy turns out to be profoundly terra-centric—the contemporary "mythology" that surrounds the search for a terrestrial twin seems premised on rethinking the alien in familiar terms; the extraterrestrial is being domesticated, so to speak. For example, it is widely assumed that life beyond Earth—if it exists—must be water-based; that is why exoplanet astronomers concentrate their efforts on the so-called Goldilocks zone, the donut-shaped area around a star where liquid water can occur. Yet the notion that extraterrestrial life is necessarily aquatic or even liquid-based remains nothing more than a hypothesis based on the idea that life forms elsewhere will more or less resemble those we know here, on this planet.

Antonia Walford, a social anthropologist, and Donnacha Kirk, an astrophysicist, explore speculative entities at the fringes of contemporary physical cosmology, such as Boltzman brains, to rethink anthropological approaches to the question of life. The idea of Boltzman brains derives from the work of the nineteenth-century physicist Ludwig Boltzman. They are—so the hypothesis goes—self-conscious entities that emerge due to random fluctuations out of a state of chaos. Walford and Kirk start from the observation that physical cosmologists work with inanimate matter that lies at the frontier of existential possibility, positing scales and concepts that seem to negate common-sense notions of life and nonlife. When anthropologists are faced with such infinite, nonhuman, and abstract landscapes, they usually attempt to crowbar "everyday life" back in,

but Walford and Kirk argue that conceptual space needs to be made for another style of engagement between anthropology and physical cosmology. Taking the Boltzmann brain as an example of life not only beyond the human but beyond life as we know it, they aim to establish a different sort of speculative, transdisciplinary endeavor at the interface between anthropology, biology, and astrophysics.

Leah V. Aronowksy's contribution challenges dominant accounts of American spaceflight, according to which the space cabin is seen as the ultimate expression of humans' control over their environment. Instead, she foregrounds the crucial yet neglected role of system maintenance and basic but usually invisible practices of care. More specifically, she documents the history of the "bioregenerative life-support system," a system in which simple organisms like algae would populate the space cabin and, through a series of interspecies symbioses, maintain cabin conditions and sustain astronaut life. By considering the daily practices involved in maintaining such a system, Aronowsky unites recent scholarship in the history of science and multispecies studies. She identifies the affective and intimate relations these systems engender and considers the latent doctrines of "ecological faith" upon which they are engineered. Ultimately, her work reveals "a logic of care" embedded in an architecture of control.

Astrobiology, according to Istvan Praet, is not merely the scientific enterprise preoccupied with the quest for life beyond our home planet. It is also a conceptual laboratory and a hotbed of philosophical experimentation. His article investigates how astrobiologists link domains of knowledge that have, historically, grown up in isolation from each other. More specifically, he focuses on the unexpected relationships between four "subfields" of astrobiology: solar physics, atmospheric science, dermatology, and ophthalmology (eye biology). Relating these at first sight disparate fields may cast new light on the question of extraterrestrial life, but these relations are also a fascinating topic of study in their own right. This is illustrated by using the angle of ultraviolet—light that has a shorter wavelength than visible light. UV-sensitive instruments play a crucial role in the contemporary exploration of outer space. The ultraviolet spectrum, it turns out, offers us a good vantage point to examine how practitioners of astrobiology are currently rethinking celestial bodies, planetary atmospheres, the skin, and the eye.

Juan Francisco Salazar explores world-making processes through which extreme frontiers of life are made habitable. Examining how notions of life are enlarged, incorporated, and appropriated in complex geopolitical contexts, the article argues that microbial worlds are becoming part of worlding processes and projects that further these frontiers. The emphasis on "microbial ontologies" is designed to draw attention to the increasing expediency of conceptualizing extreme earthly ecologies as analogues for other planetary worlds, as a way of tracing the relational trajectories of Antarctica and outer space. This article is informed by short-term ethnographic fieldwork in the Antarctic Peninsula with Chilean microbiologists engaged in the bioprospecting of extremophiles, to account for how these extremophile organisms are made part of a market-driven search

for bioactive components in areas highly sensitive to geopolitics at the same time as they become meaningful as proxies for extraterrestrial life.

Jessica O'Reilly also provides an ethnographic study of Antarctic field-workers living in a polar research station. Antarctica, she underlines, is "an environment beyond the scope of most earthly experience." What piques her curiosity is the fact that daily tasks and risks are heavily managed and closely overseen at the station. O'Reilly focuses on the highly ritualized, militaristic, and exceedingly bureaucratic aspects of polar field training and on the obsession with all kinds of potential hazards, emergencies, and catastrophes. Intense preparation and ceaseless training are central to those who visit the Antarctic "frontier zone." She suggests that people living and working in Antarctica perform extreme and exaggerated bureaucratic practices as a counterpoint to tropes of wild danger and extremes. They simultaneously cultivate an intimacy with the otherworldly and display a firm commitment to procedural practices; the sublime Antarctic wildness, you could say, is tempered by paperwork. O'Reilly thus provides an analysis of the tension between "extreme nature" and "extreme bureaucracy." Bureaucracy, in this context, is not ridiculous or superfluous but productive. It operates as a means to downscale an "almost inexpressibly awesome nature into quotidian human life." Finally, she also links the rituals of risk management that Antarctic field-workers engage in to something bigger, namely, the question of the Anthropocene and the issue of a looming global climate disaster: can the policy and regulatory practices that mitigate danger *on* the ice, she asks, do the same *for* the ice? Does attuning yourself to risks at an immediate scale lead to a view of the Anthropocene as a phenomenon of our own making that can be steered to change course rather than as an inexorable catastrophe?

David Dunér's contribution may strike readers of this journal as slightly unusual, for it is not so much an exploration of the environmental humanities as an exercise in cognitive semiotics. The author, who defines himself as a historian of science, refers to his field of inquiry—in analogy to astrobiology—as "astrocognition." Even though neither of the editors has great affinity with cognitive research, we invited Dunér to contribute to this special section because his work is tackling an important issue that has been unjustly ignored by anthropologists, philosophers, cultural geographers, and STS researchers alike. The article investigates the Drake equation, one of the most debated equations in contemporary space research and a key feature of astrobiology. Dunér sets out to reveal some of the cultural underpinnings of Frank Drake's famous formula—as far as we are aware, this is something that no other social scientist has attempted to do. And he manages to unveil a profound irony: an equation that attempts to fathom nothing less than the entire universe—aiming to calculate how many habitable planets with intelligent civilizations we, earthlings, can expect to contact—turns out to be unexpectedly parochial. Focusing on some of the individual factors that constitute the formula, he indicates that they are premised on historically contingent and culturally specific conceptions of "civilization," "intelligence," and "advanced technology." Dunér thus offers a more reflective appreciation of the Drake equation and implicitly exposes

the naïveté of hard-nosed natural scientists, who often still believe that the formula is premised on absolute, eternally solid (i.e., ahistorical and acultural) foundations.

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