**Jussi Parikka**

**Bio:**

**Dr Jussi Parikka is Professor of Technological Culture and Aesthetics at University of Southampton and Visiting Professor at the Academy of Performing Arts, Prague where heads the project Operational Images and Visual Culture. His earlier work and books, such as the trilogy of books *Digital Contagions* (2007/2016) *Insect Media (*2010), and *A Geology of Media* (2015) various ecological implications of media culture and theory. His forthcoming books include *The Lab Book* (with Lori Emerson and Darren Wershler) and *Photography Off the Scale* (with Tomas Dvorak).**

**A Recursive Web of Models: Studio Tomás Saraceno’s Working Objects**

**Working Objects Across Art and Science**

This article addresses contemporary art and science collaborations with special attention paid to how artistic practices, in this case, the renowned contemporary artist-architect Tomás Saraceno and his large studio team, deal with questions of environmental formations and agency. As such many of the projects, including the On Air (2018-2019) exhibition discussed in this article, are already implicitly part of the field of environmental humanities, which has over the years incorporated approaches relating to “agency, cultural formations, social change and the entangled relations between human and nonhuman worlds.” (Rose et al. 2012: 2) From multispecies ethnographies to cultural theory of the posthuman, from environmental histories and deep times to conceptually rich work on non-human animals, the field also reaches out to art practices. Environmental arts have become increasingly practiced and widely researched (see, e.g., Greaves 2013; Ballard 2017; Kahn 2013; Randerson 2018), and in some cases, like Janine Randerson (2018: xix), suggesting links to the broader genealogy of “process-based ontologies and the environmental posthumanities.”[[1]](#endnote-2)

The challenge when dealing with Studio Tomás Saraceno’s work is that it is already heavily invested in ongoing debates and vocabularies of environmental humanities and arts, and speaks directly to themes of environmental agency and relational ontology while involving awareness of ecological collapse as well as occasional nods to the context of the planetary scale (cognitive) capitalism of technological culture. Theoretically, this poses a compelling dilemma in so far as Studio Tomás Saraceno becomes almost too obvious a case for a cultural analysis of contemporary Anthropocene entanglements and discourses of relationality, nature, and ecology. In other words, the work is already involved in the variety of discourses about the Anthropocene from work by Anna Tsing to Bruno Latour, Karen Barad to Stefan Helmreich. But more than a rhetorical figure of theory that carries academic discourse into art or produces illustrations of those themes, the Studio engages in material production that escapes a self-referential theory circle. And it is the Studio’s work that provides springboards–further layers of useful materials and objects–for a cascade of concepts and questions about logistics, infrastructure, and technology, each embedded within the fragile realities in which environmental arts and theory bounce off multiple institutional contexts, presenting themes of hybridity in action at multiple scales of artworks that also function as research objects.

Studio Tomás Saraceno’s work on spider webs as diagrammatic models moves across multiple institutional contexts, from curatorial objects in exhibitions to art-science studio collaborations. The webs are material, emerging as visualizations and abstractions. These images and installations are also mediations between technical knowledge and artistic expression, fulfilling the double role as both aesthetic and epistemic agents (see Werner 2015. Wulz 2010). The work with arachnoids is parallel to the studio’s work on the Aerocene (see, e.g., McCormack 2017; Philippopoulos-Mihalopoulos 2016; Randerson 2018: 176-180. Page 2020), both of which express an interest in natural materials in technological culture, economies of energy, and alternative architectures. The work of the Studio is explored through the multiple scales of webs to understand the operations that, while becoming visually tangible as sculptural works, also capture a range of discourses circulating in contemporary art, scientific models, visual diagrams, and speculative architecture. The sculptural projects function as diffractive (Barad 2007; Haraway 2018; Miyazaki 2015) materializations of webs, instead of mere reflective commentaries of theoretical stances. These sculptural diffractions lead to a discussion on how practice-based work operates and understands materials such as spider webs, and further, how this work contributes to environmental humanities and related fields. As diffractive, these models are productive of difference, not merely registering it, as the section below on Diffractive Models elaborates in relation to Saraceno’s projects.

Figure 1:

**Caption**: Tomás Saraceno, *Webs of At(tent)sion*, 2018. Installation view at ON AIR, carte blanche exhibition to Tomás Saraceno, Palais de Tokyo, Paris, 2018. Curated by Rebecca Lamarche-Vadel. Courtesy of the artist and Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2018.

A fundamental proposition of this article is to think of Saraceno’s sculptural works as working objects. A term employed originally by Lorraine Daston and Peter Galison (1992) in their take on the history of science, working objects are forms of digested nature that become employed in scientific discourses: “If working objects are not raw nature, they are not yet concepts, much less conjectures or theories; they are the materials from which concepts are formed and to which they are applied.” (1992: 85). The processes of supply and selection seem like one logistical part of the scientific practice in the historical sense, whereas the concept is useful to consider in the art-science collaborations contexts of Studio Tomás Saraceno, where the question is not merely about selection but also the multiscalar transformation of materials and images. Following Daston and Galison’s analysis, “[w]orking objects can be atlas images, type specimens, or laboratory processes—any manageable, communal representatives of the sector of nature under investigation” (Ibid.), I want to observe how this concept bears examination through the investigation of a contemporary art and science practice such as the Studio’s. I propose that Saraceno’s arachnoid models are working objects, curated for art exhibitions, part of collective studio work (Engelmann 2017b; 2019), and collaborations with various scientific groups, such as MIT material scientists. In other words, the sculptures and models, installations and operations–from stereophotogrammetry and laser scanning to the most analog of pencil on paper–are employed in these works as visual diagrams that do not merely describe but are actively circulating in something that might also be coined as an ecology of images singular to the Studio’s work (Engelmann 2019: 306) and as an expression of the very working objects through which particular outputs stabilize.

These operations are relevant to a broader set of discussions about materiality, the modelization of and through living beings, and various forms of imaginaries entering the studio and the exhibition–some from architecture, some from art. This practice-led work is an important contribution to environmental humanities in how it operates across different disciplinary teams and aesthetic and scientific registers, offering ways to incorporate material practices into theoretical developments. In this way, the artistic-architectural work becomes methodologically stimulating for the field of environmental humanities–if that field is understood to incorporate the multiple ecologies that brand the contemporary moment: technologies, mediations, political assemblages, environmental situations, and the various flows of materials and energy in which both art practice and environmental humanities do their work (see, e.g., Peters 2015; Parikka 2010; Parikka 2015; Engelmann and McCormack 2017).

Beginning with a discussion of Saraceno’s recent On Air exhibition, this article explores the multiple contexts of such art and science working objects in exhibition and studio situations, as well as in some of the scientific discourses that are at the core of the Studio’s work. Hence, the discussion will respond to webs as cognitive architectures, and how, for example, the field of biotremology is implied in the work and also where the artistic work feeds new inputs. We will follow how these spatial constructions and sculptures work as diffractive yet productive models between art, science, and the arachnoid intelligence of AI, before concluding with how these models engage with larger questions of environmental humanities and practice-based art methods.

**On Air**

Figure 2:

**Caption**: Tomás Saraceno, *Webs of At(tent)sion*, 2018. Installation view at ON AIR, carte blanche exhibition to Tomás Saraceno, Palais de Tokyo, Paris, 2018. Curated by Rebecca Lamarche-Vadel. Courtesy of the artist and Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2018.

Saraceno’s recent large-scale show, On Air, was exhibited at the Palais de Tokyo from October 2018 to January 2019. Curated by Rebecca Lamarche-Vadel, the exhibition was articulated through different scales of webs, themselves the central motif of many of the pieces on display–in addition to those on dust and, for example, on architectures of air and communities of the Aerocene project. The exhibition’s focus on spiders was exemplary of the Studio’s longer interest in setting up “experimental systems for interspecies communication” (Saraceno, Bisshop, Krell, and Mühlethaler 2019: 485). This framework was reflected further in the introductory text of the exhibition that was positioned as an “ecosystem in becoming, hosting emergent choreographies and polyphonies across human and non-human universes, where artworks reveal the common, fragile and ephemeral rhythms and trajectories between these worlds” (Saraceno 2018: np.). The poetic phrasing of On Air was accompanied by curatorial sections that threaded links from spider webs to the post-fossil fuel imaginaries of the Aerocene project, between the different media and materials of the installations, from natural materials to moving images, and different methods of visualization of the microscopic dimensions of both (cosmic) dust to spider worlds. Studio Tomás Saraceno’s work, including the series of collaborations with non-human animals such as spiders, has aptly already been approached as “other-than-human-aesthetics” (Engelman 2017b; see also Page 2020). The installation in Paris was placed within the contexts of multiple voices, collaborations, and perceptual registers activated both by scale and by the different visual and material manifestations of the thematics of webs and architectures, and air, framed as an object of artistic and curatorial investigation. The building itself was included in the original planning and curation of the web installations; Palais de Tokyo was mapped for existing spiders and webs with Holocnemus pluchei spiders brought back to the studio in Berlin, where they became part of a collaborative community of other spider species, producing the hybrid webs that would become part of the display. Here is where multispecies interactions took place, where spiders built their web styles in relation to existing web structures, leading to either the adaptation or modification of existing spider structures or the tearing down of earlier, species-specific webs built by another spider, starting their versions anew. All webs presented in the show were made by spiders, first hosted at the artist’s studio in Berlin, and then transported to Palais de Tokyo to be displayed.[[2]](#endnote-3)

In a vitrine layout recalling a natural history museum, Webs of At-tent(s)ion (2018, fig. 2) displays spider webs in a darkened room, lit only by an array of carefully positioned spotlights which allows visitors to move freely–if carefully–around and between the hybrid formations that are placed, for the most part, at human eye level. Appearing to be free-standing architectural forms, the elaborate details of the web structures emerge from the inky black space, compelling us closer, visually and literally highlighting the complex arrangements and links of threads and hybrid webs installed in their transparent frames. Illuminated, the seventy-six Cartesian cubes–for the wandering, measuring analytical gaze infused with the subtlety of the very liveness of the organic structures within–present as a kind of light installation that showcase a different set of architectural structures than ones of concrete and steel; the uplifted, breathing airiness of spider silks respond to the displacements of air within the room, hinting at the most gentle of audience interactions with the installed pieces, as one moves through the room.

After navigating through the layered structures of webs, the following room envelops visitors in a vibrating hum, shifting the register from visuals to soundscapes, even before the visitor’s human eyes can adjust to the dimmed lights, to see the slowly moving strings, themselves made from modified spider silk. Sounding the Air (2018) creates a slow rhythmical aural pattern with long strings, filling the space and the air, a softly moving sculpture, as the threads catch and release rays of light, and shift slowly in and out of view. The sound frames and fills the space with its presence in tandem with the subtly moving sculpture, this large-scale Aeolian harp. This musical instrument is situated within the lineage that, in Douglas Kahn’s (2013) words, could be called the media art of energies and earth magnitudes, with sounds produced by nature, it acts as an interface between technical media and natural formations of sound and electromagnetics. Besides the environmental surrounds of such electrosonic sounds, the threshold of perception of sound becomes a key epistemological category that introduces a broader focus of soundscapes, of perceptions and of vibrations–some of which also differentiate between humans and non-humans according to perceptual capacities.

In many of the projects, the notion of interspecies communication is framed as one of play between spiders and humans, and between spider species in the architectural constructs of hybrid webs like Webs of At-tent(s)ion. The acoustic worlds and soundscapes of interspecies communication were part of the Jam Sessions that synchronize and play together with both the web’s acoustics and their use for signaling; in the spirit of experimental music, this meant creating musical instruments with which to listen and communicate with spiders (Saraceno, Bisshop, Krell, and Mühlethaler 2019). Such interspecies “jamming” is also present in the Particular Matter(s) (2018) installation, where central elements of the On Air exhibition are presented together again: the interactions of air, spider webs, and dust with the audience movement affecting the microscopic dust in the space, which in turn interacts with the web that is both visually amplified in a spotlight beam and sonically amplified into a speaker: “The presence of visitors in the space generates new variations in this evolving ecology.”[[3]](#endnote-4)

Moving deeper into the building still, the webs grow to human size–and larger. Consuming an entire room, Algo-r(h)i(y)thms (2018, fig. 3) is a living sculpture that functions as an infrasoundscape, combining the visual rhizome with the possibilities of vibrating touch-based communication. Stepping into this interconnected ecology, the participant becomes part of the orchestration of space and enters the feedback systems functioning below the 20 Hz, the threshold of human audibility. Here, the acoustic interspecies network has grown in size to become visible and haptic. Continuing into other spaces of the exhibition, visitors find sonic and visual instruments and mechanisms that highlight the different scales of webs, dust, structures, and air. The constructions shift registers between the natural and the technical, narrated as experiments, as jam sessions, and other terms that nod at the legacy of avant-garde arts of the 20th century. The material and narrative formats of the curated exhibition incorporate Saraceno’s practice into the lineage of contemporary art practices that consider instability and dynamics of space and signals from Cold War period experimental media arts, such as Alvin Lucier (who also performed in the Jam Sessions[[4]](#endnote-5)), to more recent contemporaries of Saraceno, such as Olafur Eliasson. As we will see later, this link also relates to the theme of dynamic models that becomes central to understanding Saraceno’s ways of working with architectures, complex installations, and images.

 Figure 3:

**Caption**: Tomás Saraceno, *Algo-r(h)i(y)thms*, 2018. Installation view at *ON AIR*, carte blanche exhibition to Tomás Saraceno, Palais de Tokyo, Paris, 2018. Curated by Rebecca Lamarche-Vadel. Courtesy of the artist; Esther Schipper, Berlin; Pinksummer contemporary art, Genoa. © Photography by Studio Tomás Saraceno, 2018.

The On Air exhibition is both a useful summary of the long-term projects of the Studio and a provocation for addressing how installations and collaborative practices relate to contemporary methods in art-science research–that also speak to environmental humanities such as animal studies. The installation’s working objects are also objects working across multiple functions, from art to epistemological concerns. They are at the center of the various forms of collaborations–both interdisciplinary and interspecies. In Saraceno’s case, this hybrid set of concerns can be articulated by asking what sort of conceptual, visual, sculptural, energetic, and aural objects function in these circuits of art that work through large-scale teams and are constructed in collaborative settings with material engineering and sciences as well as climate science and meteorology, bioacoustics and biotremology? While collaborative labor has defined Studio Tomás Saraceno’s work as a collective of multiple simultaneous projects housed in a studio that fills a several stories large building block in Berlin, it is the combination of skill sets, institutional contexts, and the broader context of arts and engineering that become a way to discuss the working objects at play. To speak of “working objects” in the context of interspecies collaboration is not, however, meant to imply anthropocentric objectification–even if such a danger should always be kept in mind. Hence, to carefully address the interspecies performances (Cull Ó Maoilearca 2019) as such would imply a necessary, sensitive awareness toward understanding the specific forms and materialities of communication that emerge from the spiders’ world, and in many ways, the specific research contexts in which the Studio has worked has also facilitated this awareness. Besides ethical considerations of how the spiders are cared for in the studio environment, specialist knowledge about ethologies of non-human animals and how the long-term iterative sense of care (ibid.) should be part of the work. Interspecies working objects also mean specific job roles and labor, and in the case of the Studio Saraceno, for example, a spider carer; this is where environmental humanities and ethics meet discussions in the history of science, and science and technology studies.

Instead of focusing on the more citizen science-oriented Aerocene project[[5]](#endnote-6), I turn to questions of models, diagrams, and aesthetics-cum-material epistemology as articulated in experimental situations, stabilized into objects of scientific knowledge and objects of contemporary arts curation. In other words, I move to take up how the notion of the web functions as a central architectural and material object that articulates multiple contexts and scales while also becoming spatially located as a sculptural object. The recursive nature of the web itself allows for functions across art, nature, engineering, and modeling, as well as speculative architecture, from the techniques of laser scan 3D visualization (Su et al. 2018) to structural engineering.

**Webs as Diagrams**

The web has become relatively pervasive as a cultural metaphor since (at least) the middle of the 1990s and emergence of the world wide web; this only adds to the difficulty of how to address it as a relevant material figure. Studio Tomás Saraceno’s solution is not only to refer to the rhetorical attraction of the web as a relational model of sensation and knowledge but also to employ it as a material, even dynamic working object that enables formalizable knowledge. Hence, the scientific contexts of such works relate to material sciences and especially biomateriomics, bioacoustics, and biotremology, as well as animal social and collective behavior (Saraceno, Bisshop, Krell, and Mühlethaler 2019). There is a sense of hybrid agenda between the material instances of the webs as singularly interesting visual and material pieces and their mathematical and abstract qualities. Saraceno stages the webs as living sculptural diagrams, situated as objects of visual art. Yet, they are indicative of other worlds and potentials of abstraction and follow the definition of diagrams as put forth by Bender and Marrinan (2010).[[6]](#endnote-7) But unlike the genealogy of diagrams Bender and Marrinan track from the late eighteenth-century Encyclopaedia to nineteenth-century scientific visualizations, Saraceno’s works are articulated between dynamic sculptures and their complex ecology of images as scientific visualizations, which is why we can consider them diagrams, as such.

Of all the Studio’s work exhibited in On Air, Webs of At-tent(s)ion (figs. 1 and 2) frames spider webs as architecture and organic design solutions for complex structures. As volumetric diagrams, and as speculative design, the dozens of examples in the carbon fiber frames display arthropod architecture–a theme identifiable as part of late nineteenth and early twentieth-century architectural discourse already (Parikka 2010)–as well as the legacy of artistic anti-architecture ways of dealing with questions of construction, space, energy, and materiality. Mark Wigley (2018: 51) aptly characterizes Saraceno as part of the lineage of experimental anti-architecture from the 1920s to the 1980s, from Buckminster Fuller, Frei Otto, Konrad Wachsmann and Cedric Price to Constantinos Doxiadis, Superstudio and Archizoom, “who systematically dissolved the solidity of buildings into diaphanous webs, networks of almost nothing in which society would now suspend itself.” On the one hand, at the crossroads of multiple genealogies and contemporary contexts, the web is about (visual) models for speculative architectures. On the other hand, it is about the animal communication of invertebrate species. On the one hand, the web becomes articulated as signals and vibrations of acoustic ecologies, and on the other as extended cognition. Each articulation is a reminder and acts to highlight that the theme of hybrid conjunctions is regularly functioning across multiple scales of the Studio’s methods.

Switching between architecture and extended cognition, and signal and sonic communication, such themes are carried over, recursively repeated in different contexts and at different scales. Focusing on the sensory mapping of extended cognition, the room-sized web of Algo-r(h)i(y)thms (fig 3.) is an ongoing multi-iteration experiment, echoing Antonio Damasio and Andy Clark’s work on the embodied brain. But, this web can also be understood through N. Katherine Hayles’ (2017: 46) arguments about the cognitive nonconscious functioning in ways that are “embedded in highly complex systems that are both adaptive and recursive.” The installed web of infrasounds and vibrations is but one version of spatialized infrastructures of cognition. And while signal transmission is an integral part of current scientific research on local spider’s structures and vibrations as informational (Mortimer et al. 2019), the focus also allows for the discussion of broader implications of the connection between cognition and architecture, where the web becomes a model for this artistically driven research work. Material constructions are dynamic models of users and their environments (cf. Eliasson 2007), and this modeling echoes much in scientific research–outside contemporary art and architecture–that argues non-human animal cognition operates outside the central nervous system in surrounding habitats and structures: “spiders behave as if planning routes in advance, show a sense of numerosity, learn conditional tactics of aggressive mimicry, reverse previous learned associations, and adjust their behaviour to altered conditions in a variety of ways.” (Japyassú and Laland 2017: 378) In other words, spiders are treated as being and having advanced logistics systems, that are also then transformed into working objects for the multiscalar work of contemporary art-science projects.

Hence, it is essential to consider Saraceno’s work not as a reflection of theoretical work on extended cognition and the cognitive nonconscious, but as a more complex working with of the shared objects of research–and the staging and producing of working objects. These, too, can also unfold the question from the other way around, starting from the situated, material, spatial webs against and on which various theoretical objects attach. As a working object, the web is fine-tuned in relation to contemporary theoretical discourse but irreducible to it. It acts recursively in relation to forms of knowledge that are gathered across humanities discourse, animal communication research, and other fields mentioned already. In other words, besides the rhetorical figure of the web as one of connections and relations, the materials are dynamic components that demonstrate a sense of potentials of built and grown space that shift from animal communication to diagrammatic and spatial vocabularies. The “surfaces, envelopes and interstices” are also significant in how they “transmit sensory information between and among scalar registers,” as Sasha Engelman (2017a: 20) points out about the Studio’s work as modeling one form of an architectural dynamism. This position towards space corresponds closely to how Olafur Eliasson–with whom Saraceno worked before his own artistic career–has characterized contemporary sculptural work as models that map dynamics of space as temporal, changing, and co-produced, where “the user’s interaction with other people co-produces space which in turn is a co-producer of interaction. By focusing on our agency in this critical exchange, it is possible to bring our spatial responsibility to the fore.” (2007: 19).

In such critical exchanges, the space of extended cognition and communication in the interspecies and interdisciplinary context is mapped through spider webs and related constructs; spatial relations of dynamic sculptural diagrams can be addressed as surfaces and envelopes that redesign space and its dimensions, thus modeling the movement and relations that constitute it–whether that of animal cognition or other forms of agency that extend across architectural space. Algo-r(h)i(y)thms is laid out as a vibrational universe, troubling any focus on atomistic agency through its spatial modeling of relations as localized (Cf. Latour 2011). Its threads and webs embody a collective subject entangled in shared signal space. For Studio Tomás Saraceno, the rhetoric reaches out to even cosmic dimensions, demonstrating how, although the web might be a scalar device for artistic discourse, still, it hints at the function of the web as capture, an epistemological register of modalities of perception that escape the human sensorium.

 The signals that the participants rearrange come from different places and speak other idioms: polluting particles and temperature differentials, supernovas, and distant galaxies, shifting temperatures and weather patterns, local spiders’ vibrational communication. From infinitely small to infinitely large, these movements between nested scales cause the room to shift in response: the lights fade, echoes increase. And in the darkness, the room enlarges infinitely, much like the expanding universe, asking those present to listen, or else face the eternal silence of extinction. (Saraceno 2018: np).

The room-sized piece functions as a two-fold articulation of the methodological activities, of signal and registering, of trace and inscription, of capture and graphing. The focus on signal transmission gives way to recording and sensors as the central trope of capture: what sort of near-invisible signals or weak vibrations are recordable, and hence measurable? And in this manner, also open to being modeled?

To clarify the point about modeling and measurement, I want to pair Algo-r(h)i(y)thms with Aerographies (2018, fig. 4). Another piece by the Studio, it combines work on spiders and balloons to create living inscription systems, exemplifying the studio’s practice-based investigation into material epistemologies of inscription.

 Pens suspended to balloons draw with black carbon ink pollution from the air of Mumbai and reveal trajectories drawn by the air, enlarging the territories of our imagination. Spider’s webs laid out on paper produce strange new Spider maps, while the trajectories of balloons that float freely in the air without the help of fossil fuels trace out Aeroglyphs. Together these ‘Aerographies’ are letters, characters and signatures of a new language for the Aerocene era. Every gesture, every interaction and event leaves a trace. Drawing with the air, the movements of persons, sounds, and spider/webs translate as the potential language of earthly phenomena; an emergent cartography of the air. (Saraceno 2018: np)

Figure 4:

**Caption**: Tomás Saraceno, *Aerographies,* 2018. Installation view at ON AIR, carte blanche exhibition to Tomás Saraceno, Palais de Tokyo, Paris, 2018.Curated by Rebecca Lamarche-Vadel.Courtesy of the artist and Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2018.

While the poetic description of the sculpture might offer a generic atmosphere for the work, the science and media studies driven observations about the experimental set-up are compelling: the apparatus of inscription is installed as an element that measures which dynamic time-bound events move across scales. In addition to the piece’s mood and atmosphere, the various sculptural systems consists of graphs, traces and various levels of material links that move the discourse of “extended cognition” into experimental apparatuses. In this manner, the shift takes place from cognition to technique, from embodied forms of perception to technologies of measurement and experiment. When historian of science Hans-Jörg Rheinberger (2007) writes in another context of spider webs just like models for experimental systems, we can here, for the sake of argument and the materials at hand, remove the “just like”: these webs are experimental systems that both capture signals, traces, vibrations, and materials, and also model their own behavior in a recursive fashion. The webs are artistic–and sometimes animal–versions of experimental systems that also at the same time inscribe their own function in a chain of extended operations that deal with questions such as cognition and capture of signals.[[7]](#endnote-8)

**Diffractive Models**

The theme and concept of extended cognition speaks to the multiple operative chains of cognition: from human embodied cognition it shifts to address the environments of support that distribute cognition as a material, felt entity that is discussed at times as architecture, at times as spider communication, and at times as interspecies performative sonic “jamming” of attempts to artistically synchronize human and non-human signal worlds. Furthermore, cognition becomes understood as a large-scale system of measure and vibration, relations, and their feedback, and this is where Saraceno’s background in architecture comes again to the fore while connecting to the role of modeling. The webs, experimental systems of spatialized knowledge apparatuses, take place, at first, as material sculptures, and second, as models that establish iterative, recursive, diffractive series. This continues the discursive themes of decentering the human in animal studies, posthumanities, and new materialisms, while adding this artistic and practice-based sense of building and exhibiting other levels of cognition beyond the human to the mix of environmental humanities. While some of Saraceno’s work plays with themes of cosmic webs as hypothesized in astrophysics research and visualizations, I am interested in how webs and other works become models, diagrams, and objects that lend themselves both to (environmental) humanities theorization and scientific investigation. This interest is less about biomimetic design than it is about a focus on practices that speak to material instantiations of cross-disciplinary work, which is also how Engelmann (2019) frames Studio Tomás Saraceno’s work: the image-making of the studio works in interaction with and parallel to scientific visualizations, establishing transversal links from studio work with spider webs to astrophysical simulations. Engelmann’s (2019: 307) way of addressing the “ecology of images” in production and simulation as generative experimentation is the reference point for a lot of the projects that I address as diffractive modeling that can be seen as one version of the broader theme of working objects that began this article.

While the usual course is to think of the material, designed, spatial models as “crystallizations of scientific theory” (Miyazaki 2015), I am interested in how they work in slightly alternative ways, that is, as material epistemologies (Pickering 2010) in artistic and experimental systems. Practices of modeling connect arts and technoscience (Miyazaki 2015) in how they are fundamentally generative instead of merely reactive (see Burnett and Solomon 2007); they are reality-producing instead of reality-imitating, and artistic works can also be seen as influentially developing complexifying notions of that said reality (see Eliasson 2007: 19). As D. Graham Burnett observed, models, in history of science, are a way to understand scalar shifts that can happen through such practices: “The power of thinking with models lies in the occasions they occasion for rapid and obscure oscillation between ‘as thinking’ and ‘is thinking’” (Burnett and Solomon 2007: 49).

This is a way of rephrasing the function of working objects too. Hence, as working objects, models enable particular statements to emerge that are not mere illustrations of pre-existing theory. They can work in an assemblage that is not merely artistic nor scientific, but in the process of their making, shifts from the artistic studio to the scientific laboratory and back via the spaces of curation and exhibition. We can claim that models don’t crystallize theory, but precede, regulate, enable, effectuate, and channel them (cf. Daston and Galison 1992). This position also feeds into the developing argument about the role of material epistemologies of sculptural and architectural objects of Studio Tomás Saraceno in contexts outside art, including environmental humanities. This is emphasized even more so because much of the work deals with interspecies collaborations that need to be cared for as dynamic, living non-human worlds that do not merely perform already pre-existing expectations.

In this manner, I propose to think Studio Tomás Saraceno’s architectural and sculptural objects as diffractive models. As Shintaro Miyazaki argues, we can think of speculative design models as diffractive, borrowing the term from Donna Haraway and Karen Barad, but replacing it from cultural theory to “designerly work and aesthetic experimentation” (Miyazaki 2007: 3). In its complex and influential use in material feminism, the term diffraction has worked as a methodology of reading (van der Tuin 2018) and as an onto-epistemological stance (Barad 2007). Barad’s position extends Haraway’s, who already suggested diffraction as an alternative to the other optical concept used for thinking: reflection, “whereas reflection is about mirroring and sameness, diffraction attends to patterns of difference” (Barad 2007: 29). This suggestion establishes a scene where material interactions–or intra-actions and entanglements in Barad’s vocabulary–are not only a reproduction of reality but channel its transformation. While Barad establishes a route from the situations of material production of diffraction as observed in physics (including her field, quantum theory) to a methodology in cultural theory and new materialism, it travels even further, in ways that become useful to understand the work of material apparatuses in contemporary visual practices, such as that of Studio Tomás Saraceno. While for Barad, Haraway and some of the new materialist developments, diffraction has become a narrative and political technology (Haraway 2018; Barad 2007: 71), it also incorporates the potential as a “material-semiotic apparatus” visible in the dynamic sculptures, visualizations, and architectures discussed in this article.

Diffraction is a conceptual and a material-semiotic device that responds to the dilemma of how do we think complex matters in material ways; how do we approach artistic and designer work that does not reduce it to representational schemas or public communication of scientific facts; and how do we not merely reflect theories but participate in their production and transformative potential. Diffractive models are real-world agents that are “interfering, blurring, bending and transforming with the content under study” (Miyazaki 2015: 3), producing situations that exhibit dynamics of the model in question, and hence, produce active differentiation in the spaces where they function, be that in the studio, an exhibition, or situations of cross-disciplinary academic research work. As such models, Studio Tomás Saraceno’s objects cross boundaries between the contexts of nature–working with live arachnoids as collaborators–and different sciences, where the working object circulates in the ecology of images of studio situations and scientific visualizations (Engelmann 2019).

As Engelmann notes in her extensive ethnographic research on Saraceno’s collaborative projects in collaboration with arthropods such as the golden silk orb-weaver spider Nephila, the central claim is that the webs express a recursive feature of their status as architectures and as material epistemologies. While localizable as a studio practice–the Studio Tomás Saraceno has its own “spider room,” the webs themselves a nest of an ontology of relations. Engelmann (2017b: 162) writes about her fieldwork in the studio: “there is never only one web. These collaborative experiments are always already about the relations between webbed forms. They are about comparing webs to other webs, through analogy, metaphor, and metonymy, but more precisely about the meshing, layering and attracting of webbed forms to each other.” The web is diffractively employed as a situated, material, and embodied model that shifts across scales, and is itself enabled to shift scale. The webs are volumetric, and they are not merely exhibited in space but reform the very notions of space: they offer multiple situations where outsides and insides fold without a clear sense of hierarchy of which level sits inside what. In Latour’s (2011) characterization, the multiple localities organized by those webs in Saraceno’s work are heterarchic (in contrast to hierarchic), and the “visual experience is not situated in any fixed ontological domain, nor at any given scale.”

The visual experience shifts scale in institutional ways, from curated exhibition space to a synthetic image used in various scientific and computational operations. Webs are approached as volumetric, 3-dimensional structures and also as potentials of traits that are not immediately perceptible without particular analytical apparatuses or instruments. Besides metaphors, metonymies, and analogies, the works’ material presence is also diagrammatic: they point to the powers of abstraction that can be materialized even further, for example, as scientific images; they “summarize complex events and relations into synthetic images” (Bratton 2016) which then extend possible effects outside their original site and situation of emergence.

Figure 5:

**Caption**: Tomás Saraceno, *How to entangle the universe in a spider web?*, 2018. Laser, spider silk, carbon fibre. Installation view at ON AIR, carte blanche exhibition to Tomás Saraceno, Palais de Tokyo, Paris, 2018. Curated by Rebecca Lamarche-Vadel. Courtesy of the artist and Tanya Bonakdar Gallery, New York. © Photography by Studio Tomás Saraceno, 2018.

In the case of the Studio, the synthetic images include the development of visualization techniques for laser-scanned modeling of 3-dimensional objects such as funnels and sheet webs. The work in new visualization techniques was driven by Tomás Saraceno, leading into collaborations with the TU Darmstadt Photogrammetry institute in 2009 and later experiments, including those with Markus Buehler’s engineering and material science research team at MIT (see Su et al. 2018). The spider web is turned into a laser image, which then functions as the working object of research that is concerned with its structural and topological qualities. The images “precisely map the real web architecture to a meso-scale model,” with further potential for designing “innovative 3D spider web-inspired structures” (Su et al. 2018: 9). Exhibited inOn Air, these webs and images comprised How to entangle the universe in a spider web? (2018, Fig 5). They are already multiple (working) objects: objects of 3-dimensional architectures of vibrational signals; exemplary of silk fiber mechanics (Su and Buehler 2018); objects for speculative design interested in “translation of new materials into a new program for social and ecological organization” (Bratton 2016).

The studio’s MIT collaboration with Buehler focused on mapping the material qualities of webs within the contexts of holistic biomateriomic approaches and even machine learning, allowing for differently speculative but completely viable directions to emerge: spider webs as already existing optimal structural solutions and material affordances that could be used in engineering and construction.[[8]](#endnote-9) Shifting and abstracted from spatial situations, the web changes into a model for material variations and optimized structures. Various social insects, such as colony behavior, have already over the past decades been incorporated into this version of AI (Parikka 2010) as both artificial intelligence in digital machines and animal intelligence as a model for optimization patterns. So too, arachnoid materials and behavior for this sense of extended cognition speak to the pairing of art and science, as well as the interspecies trio of art-science-invertebrates that shift registers between mathematics and volumetrics, animal architecture and logistics, art objects and material modelization. Somewhere between a mathematical model, a visual image, a material sculpture, and a theoretically productive working object, the web captures a multitude of interests of knowledge and practices of knowledge creation across the aesthetic and scientific spectra.[[9]](#endnote-10)

**Conclusions**

Studio Tomás Saraceno’s On Air exhibition (Paris 2018-2019) and their studio practices offer an entry point to what practice-led environmental humanities are capable of doing differently beyond methods that deal primarily with text or theoretical and conceptual approaches alone. An assemblage of animal architectures, spider webs, scientific visualizations, and theoretical humanities, their work exemplifies an ecology of images that circulates between “mathematics and code, cosmological theories, arachnology, production networks, and cultural semiosis” (Engelmann 2019: 306) in ways that produce the semiotic-material diffraction patterns that are a central characteristic of the studio’s work. The ecology of images is fundamentally important due to the production of material models, volumetric diagrams, and working objects that connect a multitude of institutional situations and disciplinary contexts. In the context of environmental and meteorological arts, Randerson (2018: 49) argues: “[a]rtists, unlike scientists, have traditionally operated in the realm of the unmeasurable; sensations are created perceptually that cannot be described mathematically.” This separation between experiential and formalizable is not a sustainable division when it comes to projects such as Saraceno’s that operate in the collaborative settings of art and science. The sculptures, installations, and models are not merely experiential objects for curatorial situations, but in many cases, also function as scientific working objects, as demonstrated in several of their projects, from biotremology to material sciences, and artistic examples from Webs of At-tent(s)ion to Algo-r(h)i(y)thms.

I proposed to address the Studio’s material production as working objects, which relate both to their (art and architectural) studio practices and how too those studio practices relate to concepts in STS and history of science. Working objects are, to return to Daston and Galison (1992: 85), “materials from which concepts are formed and to which they are applied.” The models, scales, and objects that emerge in the collective studio situations are one way of thinking about the material environmental humanities works with, where aesthetic concepts, material objects, scientific modes of imagining, and multiple institutional investments are part of the conditions of theoretical work. The studio’s multispecies investigations and studio routines, scientific imaging, post-fossil fuel experiments with slow planetary balloon travel (Aerocene project, left out of this article’s focus) are expressions of the hybrid constellation of practice and concepts situated in the contemporary cultural and environmental context. This sort of artistic activity, sometimes coined speculative design–or even anti-architecture–becomes an entry point to environmental humanities. It also becomes a demonstration that visual and material methods offer more than an illustration of environmental issues or representational approaches to non-human animals. What I have presented in this article concerning the diffractive models, research insights, and visual methods that shift between epistemological significance and aesthetic attraction does not resolve all the questions that emerge in these collaborations. Though some of those questions have to remain outside the scope of this article, there remain possibilities for further engagement. While the question of interspecies collaboration is the primary driver of the spider and hybrid web projects, there is an interesting question, briefly raised, as to how this impacts our sense of the working object when this includes a non-human animal partner engaged in the work. Another issue of consequence is to develop further insights into questions of attention and care that are central to Studio Saraceno’s work, including discussions about ethics codes for work–including specifically artistic work–with invertebrate species.[[10]](#endnote-11) Such themes represent further aspects to on-going work in animal studies and environmental humanities, which in this case is also visual and sculptural arts as well as the speculative models that then allow other disciplines to continue the Studio’s work in still other epistemological contexts of research.

Acknowledgments

I want to thank Elise Misao Hunchuck for her expert guidance in formulating the arguments and the language in this article and Ally Bisshop for her generous help in elaborating on and explaining many of the details about the Studio’s work. A thank you also to Tomás Saraceno and the Studio staff for sharing images and thoughts. In addition, I am grateful to Sasha Engelmann, Ryan Bishop, Joanna Page, and the anonymous reviewer for their helpful feedback when writing and editing this text. This research has also been supported by Czech Science Foundation funded project 19-26865X “Operational Images and Visual Culture: Media Archaeological Investigations.” An earlier version was presented as an IKKM (Bauhaus University, Weimar) lecture.

Works cited

Ballard, Susan. 2017. “New Ecological Sympathies Thinking about Contemporary Art in the Age of Extinction.” Environmental Humanities 9 (2): 255-279.

Barad, Karen. 2007. Meeting the Universe Halfway. Durham: Duke University Press.

Bender, John and Marrinan, Michael. 2010 Culture of the Diagram. Stanford, CA: Stanford University Press.

Bratton, Benjamin. 2016. “On Speculative Design.” Dis magazine. Online at http://dismagazine.com/discussion/81971/on-speculative-design-benjamin-h-bratton/

Burnett, Graham D. and Solomon, Jonathan D. 2007. “Masters of the Universe” in Models, edited by Emily Abruzzo, Eric Ellingsen and Jonathan D. Solomon, 44-51. New York: 306090/Princeton Architectural Press.

Cull Ó Maoilearca, Laura (2019) “The Ethics of Interspecies Performance: Empathy beyond Analogy in Fevered Sleep’s Sheep Pig Goat.” Theatre Journal, vol. 71 (3), September 2019, pp. E1-E22.

Daston, Lorraine and Galison, Peter. 1992. “The Image of Objectivity.” Representations 40 (Autumn 1992): 81-128.

Eliasson, Olafur. 2007. “Models are Real” in Models, edited by Emily Abruzzo, Eric Ellingsen and Jonathan D. Solomon, 18-25. New York: 306090/Princeton Architectural Press.

Engelmann, Sasha. 2017a. The Cosmological Aesthetics of Tomás Saraceno’s Atmospheric Experiments. Doctoral thesis, University of Oxford. Online available at https://pure.royalholloway.ac.uk/portal/en/publications/the-cosmological-aesthetics-of-toms-saracenos-atmospheric-experiments(89b6fe2f-8f0d-4335-8143-139ecb95dbb0).html

Engelmann, Sasha. 2017b. “Social Spiders and Hybrid Webs at Studio Tomás Saraceno.” Cultural Geographies 24, no. 1 (January 2017): 161–69. doi:[10.1177/1474474016647371](https://doi.org/10.1177/1474474016647371)

Engelmann, Sasha. 2019. “Of Spiders and Simulations: artmachines at Studio Tomás Saraceno.” Cultural Geographies 26, no. 3 (July 2019): 305–22. doi: [10.1177/1474474019838310](https://doi.org/10.1177/1474474019838310)

Engelmann, Sasha and McCormack, Derek. 2018. “Elemental Aesthetics: On Artistic Experiments with Solar Energy.” Annals of the American Association of Geographers, 108:1, 241-259. doi: 10.1080/24694452.2017.1353901

Greaves, Tom. 2013. “Environmental Arts as First Philosophy: This Too a NeoPresocratic Manifesto.” Environmental Humanities 3 (1): 149-155.

Haraway, Donna. 2018. Modest Witness & Second\_Millenium. Femaleman Meets Oncomouse: Feminism and Technoscience. 2nd edition. New York: Routledge.

Hayles, N. Katherine (2017) Unthought. The Power of the Cognitive Nonconscious. Chicago and London: University of Chicago Press.

Japyassú, Hilton F. and Laland, Kevin N. ( 2017) Extended spider cognition Anim Cogn 20: 375–395. DOI 10.1007/s10071-017-1069-7

Kahn, Douglas. 2013. Earth Sound, Earth Signal. Energies and Earth Magnitude in the Arts. Berkeley, CA: University of California Press.

László Barabási, Alberto. 2002. Linked. New York: Plume/Penguin.

Latour, Bruno. 2011. “Some Experiments in Art and Politics.” E-Flux #23, March 2011, https://www.e-flux.com/journal/23/67790/some-experiments-in-art-and-politics/.

McCormack, Derek P. 2017. “Elemental Infrastructures for Atmospheric Media: On Stratospheric Variations, Value and the Commons.” Environment and Planning D: Society and Space 35, no. 3: 418–37. doi: 10.1177/0263775816677292

Miyazaki, Shintaro. 2015. “How to talk about serious matters of complexity with models as agents: A speculative essay on artistic and design-based research” Journal for Research Cultures 1(1): 1-5.

Mortimer, B.; Soler, A.; Wilkins, L., and Vollrath F. 2019. “Decoding the locational information in the orb-web vibrations of Araneus diadematus and Zygiella x-notata” J. R. Soc. Interface 16: 154. doi: [10.1098/rsif.2019.0201](https://doi.org/10.1098/rsif.2019.0201)

Page, Joanna (2020) “Tomás Saraceno and the Ethics of the Sublime in the Aerocene” in Latin American Culture and The Limits of the Human, edited by Lucy Bollington and Paul Merchant. University of Florida Press, forthcoming.

Parikka, Jussi. 2010. Insect Media. An Archaeology of Animals and Technology. Minneapolis: University of Minnesota Press.

Parikka, Jussi. 2015. A Geology of Media. Minneapolis: University of Minnesota Press.

Peters, John Durham. 2015. Marvelous Clouds. University of Chicago Press.

Philippopoulos-Mihalopoulos, Andreas. 2016. “Withdrawing from Atmosphere: An Ontology of Air Partitioning and Affective Engineering.” Environment and Planning D: Society and Space34, no. 1: 150–67. doi: [10.1177/0263775815600443](https://doi.org/10.1177/0263775815600443)

Randerson, Janine. 2018. Weather as Medium. Toward a Meteorological Art. Cambridge, MA: The MIT Press.

Rheinberger, Hans-Jörg (2007) “Man weiss nicht genau, was man nicht weiss"  Neue Zürcher Zeitung 5.5.2007, https://www.nzz.ch/articleELG88-1.354487

Rose, Deborah Bird; van Dooren, Thom; Chrulew, Matthew; Cooke, Stuart; Kearnes, Matthew, and O’Gorman, Emily. 2012. “Thinking Through the Environment, Unsettling the Humanities.” Environmental Humanities 1 (1): 1-5.

Saraceno, Tomás (2018) On Air exhibition press package. Studio Tomás Saraceno/Palais De Tokyo, Paris.

Saraceno, Tomás; Bisshop, Ally; Krell, Adrian; and Mühlethaler, Roland (2019) “Arachnid Orchestras: Artistic Research in Vibrational Interspecies Communication” In

Biotremology: Studying Vibrational Behavior, eds. P. S. M. Hill et al. (eds.), Springer Nature Switzerland AG 2019, 485-509.

Su, Isabelle and Buehler, Markus J. 2016 “Nanomechanics of silk: the fundamentals of a strong, tough and versatile material.” Nanotechnology 27, 30, 2001. doi: 10.1088/

0957-4484/27/30/302001

Su, Isabelle; Qin Zhao; Saraceno, Tomás; Krell, Adrian; Mühlethaler, Roland; Bisshop, Ally, and Buehler, Markus J. 2018. “Imaging and analysis of a three-dimensional spider web architecture” J. R. Soc. Interface 15: 20180193. doi: 10.1098/rsif.2018.0193

Van der Tuin, Iris. 2018. “Diffraction” in The Posthuman Glossary, edited by Rosi Braidotti and Maria Hlavajova. London: Bloomsbury, 99-101.

Werner, Gabriele (2015) “Discourses about Pictures: Considerations on the Particular Challenges Natural-Scientific Pictures Pose for the Theory of the Picture.” In The Technical Image. A History of Styles in Scientific Imagery, eds. Horst Bredekamp, Vera Dünkel and Birgit Schneider. Chicago and London: The University of Chicago Press, 8-13.

Wigley, Mark (2018) “Sticking to Saraceno: Anti-Architecture Air-play” On Air, Carte Blanche à Tomás Saraceno. Le magazine du Palais de Tokyo, issue 28, 2018, 50-52.

Wulz, Monika (2010) Erkenntnisagenten: Gaston Bachelard und die Reorganisation des Wissens. Berlin: Kadmos.

1. For existing research on environmental arts, I point the reader to the various issues of the Environmental Humanities journal (Duke University Press) as one example of past years of theoretical engagement with art practices. [↑](#endnote-ref-2)
2. A special thanks to Ally Bisshop from the Studio Tomás Saraceno for clarifying the details about the hybrid webs as a multispecies project and also the logistics and practices of working with spiders. For a list of which species participated in the hybrid webs, please see https://studiotomassaraceno.org/webs-of-at-tentsion/. [↑](#endnote-ref-3)
3. Particular Matter(s) Jam Sessions, online introduction with images, https://studiotomassaraceno.org/particular-matters/. [↑](#endnote-ref-4)
4. From Saraceno’s On Air online description of the performance: ”Alvin Lucier, historical figure of experimental music from the 1960’s until today imagines an unreleased work for ON AIR during which his heartbeat is picked up by a special sensor, routed through the silk strings of a Qin, ancient Chinese stringed instrument, and sent to the moon. In about two-and-a-half seconds each heartbeat will bounce back to Earth. The sound of the heartbeats will change according to reflection points from the Moon’s surface.” https://www.palaisdetokyo.com/en/event/voices-collide-day-aerocene [↑](#endnote-ref-5)
5. See the Aerocene project website at <https://aerocene.org/>. [↑](#endnote-ref-6)
6. Bender and Marrinan (2010: 7): “A diagram is a proliferation of manifestly selective packets of dissimilar data correlated in an explicitly process-oriented array that has some of the attributes of a representation but is situated in the world like an object.” [↑](#endnote-ref-7)
7. The technical side of the experimental setup has received less attention. The Studio’s expertise and contribution to both artistic and curatorial contexts and scientific research also relate to the use of technical instruments, including piezoelectric sensors for the registering of pressure, acceleration, vibration; custom made microphones, and the laser scanning of complex volumes (which are also contexts where the works shift from being a display at an art exhibition to being a model in and for scientific collaborations). As images, sculptures, and visual art, they become working objects for this collaborative enterprise that continues the theme of diagrams and models. [↑](#endnote-ref-8)
8. Tomás Saraceno and Ally Bisshop, private communication, JP studio visit May 21, 2019. [↑](#endnote-ref-9)
9. While the spider might be unthinkable outside the web (Wigley 2018: 51), the web is thinkable without the spider (cf. László Barabási 2002) as scale-free network theory demonstrates in its own version of mathematical formalization of such structures as part of the lineage of graph theory. The open cube frames of the exhibition space hint of this larger theme of modeling efficiency and optimization of natural entities that include webs. [↑](#endnote-ref-10)
10. Tomás Saraceno and Ally Bisshop, private communication, JP studio visit May 21, 2019. [↑](#endnote-ref-11)