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Emmy Noether, Maria Goeppert Mayer, and their Cyborgian Counterparts: Triangulating Mathematical-Theoretical Physics, Feminist Science Studies, and Feminist Science Fiction

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This essay contains a portmanteau of two strands of narratives from which the reader can choose his or her own critical engagement; either biographical or literary. The science fiction aspect of the narrative attempts a critique of queer feminist science taking place at an ontologically abstract level to force a re-reading of the mathematical sciences via a politically astute lens of feminist epistemology. At the same time, the essay participates in a close reading of the intellectual biographies of Emmy Noether and Maria Goeppert Mayer to demonstrate the importance and revolutionary nature of their respective contributions to fields that would later converge into the most cutting-edge physics of today, as well as that of computation. A part of the essay critiques what was at stake for these two women who contributed enormously to shaping the imaginary of the world of theoretical physics and, therefore, the imaginary that informs the foundations of hard science fiction focusing on speculative and novel ideas of physics. The imaginary of theoretical physics is rife with a multiplicity of interpretations that shape how we like to perceive our microworld, and how that, in itself, influences our connection to the macro-world. Another part discusses the critical, creative, and intellectual drive behind my production of a queer feminist hard science fiction, the Schrödinger's Notebook.

Accompanying Materials

Methodology & Intellectual Context
(https://adanewmedia.org/2013/11/issue3-lee/)

Biography of Noether
(https://adanewmedia.org/2013/11/issue3-lee-accomp1/)

Biography of Goeppert Mayer
(https://adanewmedia.org/2013/11/issue3-lee-accomp2/)

On Speculative Science Fiction
(https://adanewmedia.org/2013/11/issue3-lee-accomp3/)

Epilog
(https://adanewmedia.org/2013/11/issue3-lee-accomp4/)

Introduction

In the chapter "Why 'Physics' is a Bad Model for Physics," from the book *Whose Science? Whose Knowledge: Thinking from Women's Lives*, published in 1991 by Cornell University Press, Harding argues that most feminist critiques have failed to identify the fortresses that seemingly protect science from "critical, causal scientific

explanation that the natural sciences insist on for all other social phenomena (77)." Most physicists and philosophers of physics would dispute Harding's claim, because the problem of causality, at least of the foundational issues surrounding questions of determinacy, certainty, physical realism, and observations, are germane problems in physics and its philosophical disquisition. Read differently, Harding's criticism is a call to arms for feminist criticism to get involved with the epistemological interrogation of the theoretical fundamentals of abstract sciences such as physics, stemming from the misperception that the field is not open to discursivity or social maneuvers. The modest goal of this paper is to produce an interjection that has been lacking, while moving the goal post further forward, thus enlarging the intellectual interventions of feminist theory.

Many of the earliest feminist interventions into science, or technology, derived from the turns that took place in cultural anthropology, literary studies, and cultural theory in the 1970s and 1980s that reversed their lenses so as to look inward into the critical examination of western cultures and the intellectual products that are the outcome of these cultures (McNeil). Hence, given the background and direction from where much (though not all) of science and technology studies have originated, there tends to be more interest in social than epistemological questions, while the internalist-directed philosophical analyses of scientific epistemology and ontology (particularly in analytic philosophy) would evaluate these fields in isolation of the social. Nevertheless, the traditions of literary and cultural studies are crucial for informing my transhuman reading of the subjects examined here. [1]

There have been rare, if any, instances of interventions by queer and feminist theories into mathematical and theoretical physics. Such lack is exacerbated by the small number of women who are participants in these two fields due to a combination of social and educational disadvantages over the course of centuries. In the cases of female scientists and mathematicians, their lack of public visibility means that even the most stellar contributions do not lend themselves as readily to public acclaim as comparable contributions by male scientists and mathematicians; moreover, female scientists and mathematicians are less likely to receive credit for their scholarship.[2] Therefore, queer and feminist interventions are ever more needed in light of how scientific epistemology has been shaped by the social conditions of privilege (some more than others) of a majority of the practitioners in the field. Karen Barad, who has played an important role in comparing the indeterminate matter of quantum theory with queer entanglements, is a notable exception. Her work has made it possible to

think about queerness beyond the materiality of the gendered: to incorporate queerness into the corporeal matter of science. Barad's work illustrates how the inviolability of the ontological constitution of science does not render its epistemological position closed to political recuperation. One such example is her Derridean reading of Frayn's play *Copenhagen*, about the imaginary conversations between Werner Heisenberg, Niels Bohr, and Margrethe Bohr. The conversations are framed in a manner analogous to interpretations in quantum theory that advocate the thinking of justice through the ethics of science and agency in decision-making concerning life-and-death situations (Barad, "Quantum Entanglements").

Since their beginnings, feminist technocultures have taken a more innovative turn by including the study of performativity and multi-modal transgressions. Such transgressions include the presentation of non-linearity as models for arguments that are not continuous but contiguous.[3] Additionally, theories within feminist science studies become the go-to for making sense of the materiality of a fictionalized/constructed body laden with multiple cultural inscriptions and social immersions. The body (that could be corporeal or metaphysical), whether situated within the space of the actual or the virtual, is the container for the superposition and interplay of dominant and suppressed (recessive) cultural and biological values. Even when the body is able to exert and stake the claims of the marginal, there will always be different intersections of resistances: one might ask whether such resistances could themselves downplay the autonomy of a body pushing through the tension, including the gendered body that could or could not insist on its difference, thus impacting the latter's interactions with epistemology.

In her essay, "The Implications of the New Materialisms for Feminist Epistemology," Samantha Frost wonders whether an engagement with historical materialism can destabilize feminist epistemic readings of the essence of biological materiality in binary relation to cultural power relations.[4] Could epistemic standpoints stemming from particular engagement with the inertness of matter that is shaped by norms and social constructs be better dissected? Her arguments foreground certain troubling aspects of essentialist and social constructivist practices grounded in the dichotomy of culture and nature, with the expectation that one be led to a more straightforward understanding of the state of causation pertaining to the aforementioned dichotomy. Frost argues that new materialist readings aim to "counter the figuration of matter as an agent only in virtue of its receptivity to human agency. They try to specify and trace the distinctive agency of matter and biology, elucidate the reciprocal imbrication of flesh, culture, and

cognition, investigate the porosity of the body in relation to the environment in which it exists, and map the conditions and technologies that shape, constrain, and enhance the possibilities for knowledge and action." Hence, perspective, as a constructed narrative of experience, is a rhizomatic matter that precludes the uniqueness of any social or gendered perspective, as the focus on any particular perspective merely collapses the other factors from consideration, but does not exclude their already-there impact.

Hence, the essay aspires to make the connection between mathematics, theoretical physics, and feminist technoscience more evident even as the non-linearity of such connections must be emphasized. This means reading against the grain of the current philosophical and historical discourse. It also means making jumps between arguments that are not dissimilar to the 'quantum jumps' articulated by Whitehead in his *Science and the Modern World* as representations of categorical leaps. In his thinking, the move from classical to quantum modes of thinking represented an ontological jump, which we know to be untrue today given that the leap is purely epistemological; the ontology as embodied by the mathematics and mechanical worldview enables points of continuity between classical and quantum mechanics, even if some rules appear to have changed. However, I am aware that many of the substantive arguments I want to make regarding the politics of the scientific epistemology get occluded by the high level of technicality in these objects. I hope to somewhat alleviate this by limiting my technical account to an impressionistic level and focusing on the impact that politics internal to epistemology has on practices thought to be external to the scientific facts. This connects back to the argument made by Frost on the problem of untangling the different factors of causality.

Before continuing, I should explain what I mean here by speculative theories, especially the enactment of speculation that overlaps the theories of the physical sciences with science fiction. Speculative theories are theories that could not directly explain the relation between cause and effect, or provide a determinate explanation to an outcome. However, this does not mean that the theory has no basis in hard facts or empirical data: it merely means that the theory is open to further re-interpretation and reconstitution as new possibilities emerge. Speculative scientific theories, as epistemological imperfectness overlying an ontology that is always at that point of becoming complete, do not object to considering subjectivities and affectivity that are part of the knowledge production. Debates internal and external to science can then be illustrated through carefully constructed thought experiments that consider these debates separately and together. Subjective affectivity constitutes the social

construction surrounding theory predictions and thought-experimental narratives that have significant roles in the interpretive act. We must also consider the importance of experimental design for bringing theoretical predictions out of their under-determined stage (where cause and effect have no direct correlative).The consideration of the experimental in partnership with theory is vital to an expanding feminist epistemology and intrinsic to thinking about how one can then go about 'queering' one's interpretation of scientific theories and practices.

Were one to examine the official history of quantum mechanics, one gets the sense that it is a narrative of white-male dominance and female tokenism.[5] Even as an increasing number of women and minorities are majoring in physics, the physics they study appears pedagogically immune to other forms of interventions as its traditions of thought and knowledge transmissions are kept on a mostly 'straight' narrative promulgated by introductory and even advanced textbooks. But, were one to enter into a thorough examination of the development of quantum theories, one would soon find many segues and theories that never quite entered into the mainstream of discourse, since most of these were never included in the popular textbooks used by students.[6]

Historians of science like Frederick Gregory argue that the scientific revolution of western civilization, which reified the mechanistic conception of nature, ensured the continuation of patriarchal attitudes towards knowledge as had happened throughout the development of the theory of mechanics in physics. One such example is the inclination towards the anthropomorphization of the universe and a refusal to consider a universe that can exist outside the empirically determined. This is made possible because the same clerical institutions that had hitherto resisted the epistemic changes during the scientific revolution had appropriated the same mechanical (abstract) view of nature as a tool for resisting a more organic, or other possible, views of nature that the church would not be able to regulate as easily. As Gregory argues, "the view of nature as a self-developing autonomous organism was discredited and replaced with a nature controlled and ruled by God the giver of fixed mechanical law." The mechanical view of the universe, Gregory claims, is exemplified in how the male-dominated clerisy had decided what scientific questions were important and what approaches should therefore work, embodying again the classic privileging of the intellectual choices of male authority (Gregory 51-53).

While there might have been women who were contributing to the world of abstract ideations before the twentieth century, the perpetuation of masculine versus feminine

ways of knowing (which, while a gendered discourse, has the insidious propensity of over-reaching into literal differences of the biological sexes and ignoring sexual différance) ensures the continuous ignominy of that pronounced as feminized ways of thinking. Knowledge driven by the ontology of mechanics is thus seen as constituted within the privilege of the masculine, with interventions from women discouraged.[7]

Much of the work in feminist science studies and also feminist science fiction is usually centered on issues of biology and the medical sciences, which is to be expected given the profusely important stakes in these areas. But there has not been as much attention paid to how feminism can be active in the physical sciences; not merely in terms of pushing for greater accessibility and receptivity of these fields to women and girls, but how feminist epistemologies can shape the knowledge practices in the field. In fact, two trained women physical scientists, in their 2006 NWSA paper, "Interpretations of Feminist Philosophy by Feminist Physical Scientists," sounded the clarion call for greater attention with regard to knowledge practices in the physical sciences (Belcastro and Moran). It is easy to understand the reservations that most would have in dealing directly with modern physics theories, given the seemingly high level of esotericism of the subject (let alone the obtuse mathematics), where a single mis-step (or even an out-of-context misinterpretation by a reader) can subject one to a level of ridicule reminiscent of the Sokal hoax.[8]

But should one be interested in taking up the challenge of examining mathematical-physical theories in relation to politics, one might begin by taking a closer look at how the foundational concepts and philosophies embedded within quantum theory can be made amenable to a feminist re-reading, with the latter foregrounding powerful ontological revisions. Karen Barad illustrates such possibilities in her re-appropriation and re-presentation of Bohr's theories, such as his theory of complementarity, which is the reconciliation between classical and quantum mechanics (macro versus microphysics) in terms of how they could be measured, through the enaction of agential realism. She then applies agential realism to issues of interest in feminist theory and feminist activism, such as reproductive technologies and discourse on the body. However, it is not evident that she has applied agential realism, as a valuable material tool, for politicizing the interpretations she made in connection to the standard readings for producing more challenging interpretations of the Bohrian epistemology, thus opening the official reading to further interjection.[9]

Feminist scientific epistemologies have much to say about the specific assumptions of knowing that take place during the process of de-naturing and reconstruction (a cyclic process of breaking down current epistemic structures for new configurations to be produced). These epistemologies work well in complement with feminist technocultures to produce a set of critical methods that could provide deeper interventions into science by challenging the status quo in sociological and philosophical foundations. It is valuable to know what feminist scientific epistemologies can say with regard to forms of knowledge that rest uneasily on any discourse of gender politics, such as the mathematical sciences, even though such knowledge's survivability and re-formations are partly the result of knowledge ideals that arose from social specificities, such as institutional recognition and access to resources, networks, and collaborations. At the same time, feminist epistemology shares parallel critical baggage and motivation with that of postcolonial theory, through a common subaltern genealogy, and the inclusion of postcolonial studies into the discussion can further enrich queer feminist intervention.

However, before we proceed further, I would like to explain further the structure of this article. The writing in this article will always be in the form of a triptych, with particular paths that the reader can choose to follow. I begin with a core introductory overview of brief critical discussions on the epistemic fields inhabited by the two women physicist/mathematicians of interest here: Amalie Kauffman Noether/ Emmy Noether (whose contribution was in the mathematics of symmetries and invariance, both cornerstones to the development of quantum theory) and Maria Goeppert Mayer (whose work was on the theory of nuclear shells). These explications are meant to provide a foundation for evaluating feminist epistemology against women's positions as socially immersed subjects of the scientific community who then perform cognitive labors as an outcome of their immersions. While these women occupied marginal positions at the time of their labor, their contributions grew to become part of the dominant discourse. One might ask what maneuverings went into legitimizing and validating the importance of their contributions. The answer possibly, though not straightforwardly, exists in relation to the privilege these women experienced as tokenized subjects in their relation to their epistemic engagements.[10] At the same time, the margins of their differences were submerged under the dominant practices that they did not resist.

Thereafter, the reader can choose to explore further the individual works of the two women. In the more detailed discursive biographical-theoretical discourse, one gets to

read the socio-political bodies of the women against the intellectual work in which they were participants, with more technical details on their contributions delineated, and about the importance of their contributions in shaping the disciplinary features of current technoscience. This section is also where I attempt a preliminary engagement of theories in the abstract sciences (mathematics included) using more humanistic feminist epistemology as another mode of reading the biographies of these two women. Therefore, the discussions in this section are less descriptive than analytical, which include the propagation of arguments that are not always historical in nature.

On the other hand, the reader can jump directly to reading about the speculative science fiction project that I am working on. I will then explain the theorization and background that informs the postcolonial-feminist-queer hard science fiction I am writing. I argue that there are parallel epistemic strains in queer and postcolonial discourses, as both arose from the desire to theorize one's situatedness at the margins while also attempting to theorize oneself out of those same margins. The goal is to contribute to meta-narratives that can free one from dominant master narratives. Of course, how possible that contribution is depends on the number of risks we are willing to take. It is my intention to test the limits and durability of the theories I propose here before subjecting them to a fictionalization process. The method of fictionalization also enables the theoretical exploration of certain social experimentation in superimposing the material perspectives of the micro-worlds with that of the macro-worlds where hard and speculative scientific problems and histories are involved in continuous interactions. In light of that, I argue that the explication of the 'real' through a critical reading of the production of these two women can foreground the limits contained in the fictional while problematizing the existing conceptions of the scientific method. The point is to invoke the potential for physics, and particularly mathematical physics, to incorporate qualitative queer interpretations.

Or, one can choose to read everything available, to see the interplay between the actual and fictive without there being a linear correlation of the two. The article is laid out such that, regardless of the initial choice made, one always has the chance to go back to the path not taken.

Whose Knowledge and Whose Science, To Echo Sandra Harding

Echoing the sentiments of Harding, I read the works of Noether and Goeppert Mayer as liberatory attempts at epistemic subversions that involve the dismantling of the current scientific order from a position of precarity. For them to arrive at the conclusions they

did about their work, they had to move outside the dominant thought-styles of their respective fields (Noether more so than Goeppert-Mayer) so as to analyze the scientific problems they were faced with. Then they had to re-articulate their analyses in a language that would make sense even to the most stubborn members of the scientific community. They flipped the order of linearity in mainstream mathematical and physical thought of that time, through the advancement of an alternate logic (though one still within the constraints of scientific logic), by reconstituting the explanatory theories current at that time. Therefore, they challenged the 'normal' progression of the mathematics and physics they worked in by advocating other ways for thinking about the hard problems they faced. This is a form of inscrutable transgression that uses subtlety in its undermining of an environment that devalued the contributions of women scientists and mathematicians through the continuous denial of academic positions and honors.

At the same time, one cannot forget that these women occupied positions of privilege even if they had to work at the margins of the scientific institutions of their time. They had had influential male mentors: beginning with their fathers, then colleagues, and a husband in the case of Goeppert Mayer, each of whom supported their work and provided them with unfettered access that most women could only dream of having. While their work should not be read against the background of their token privilege, their privileged position, in social as well as political proximity to the male elites in their fields, must not be underestimated. When they managed to achieve recognition later in life, the achievement was premised on how well they had managed the external political operations while working through subtle internal subversions, with the latter being mainly hidden.

One might assume that the two women have a 'feeling' (invoking Evelyn Fox Keller's claim of Barbara McClintock in *A Feeling for the Organism*) for the scientific objects they work with in ways that have nothing to do with their gendered position, but everything to do with their creative contribution to the epistemic and institutional spaces they occupied. They indirectly contributed to an emergent scientific imaginary that shapes some of the popular themes in hard science fiction works focusing on the physical sciences, even if men rather than women produce most of these works. They overcame institutional and social hurdles through a combination of strategic alliances and dedication.

The practices of these two women scientists reconstitute notions of 'competition' and collaboration in their social milieu; they were responsible for contributing to the foundational ideas in physics and mathematics that facilitated the predictions and speculations of physics theories and objects that would later emerge in creative non-fiction and speculative science fiction. They also worked in collaboration with mostly male physicists and mathematicians through the exchange of ideas. However, that required political savvy and delicacy, since the women would have to find the best way to insist on the legitimacy of their ideas even when those ideas, however promising, could not yet be unequivocally demonstrated.[11]

Mothers and female mentors were invisible in the life stories of these two women, at least in the accounts I have been able to access. Yet one could speculate that their mothers, married to fathers who were eminent in the scientific world, would have been aware of some of the more profound advances going on even if their knowledge were only peripheral. Little is known of the hidden services these mothers performed for their scientifically inclined husbands and daughters. More work would have to be done to unearth the influence of (non-scientific or scientific, in the case of Marie Curie) mothers on female scientists and mathematicians, since this could provide a clearer explication on the limits of agency that women are able to negotiate. In the case of Noether, she did eventually go on to mentor women mathematicians during her truncated time at Bryn Mawr.

Their respective contributions challenged the technoscientific thinking of their time, and continue to do so thereafter. In the case of Noether, symposiums were held in her honor decades after her death. Papers, in both mathematics and applied mathematics, have been produced that demonstrate the refinement and extension of her original ideas and methods.[12] In the case of Maria Goeppert Mayer, the recognition came latterly in the form of a Nobel Prize in physics. She became the second woman to win it after Marie Curie, with the prize shared with two other male physicists, one of who later became her co-author.[13] The implications of their work in mathematics and quantum physics can be read as knowledge not demanding of a 'final control' or finiteness, allowing for subjectivity even in objective analyses.[14]

Final control, as invoked here, refers to the containment of an arbitrary value based on the assumption that there is an absolute standard of epistemology for objectivity to be situated. Instead, what is called for is the willingness to swim in the ocean of "dis-engagement" in a manner that is both mutual and unequal in the structuring of

nature/culture, acknowledging that an attempt to draw boundaries can fail. Therefore, it appears that the only way to proceed is to see nature as a coyote with ever evolving meanings in its embodiment (Haraway 201). However, I doubt that either Noether or Goeppert Mayer would think in such Harawayan terms in relation to what they do, being, as they were, women who were trying to work within the constraints of fields that they were also pushing forward. Their works, on the other hand, took their own course outside the control of any one individual or institution, and therefore the representations of nature, as embodied by the ever refined epistemics, are never stable. The process, sociality, and product of scientific labor can be thought of as occupying a trinity of ontological-epistemological relations: image (the conceptual shape the science is imagined to contain); object (the image-subject interrogated); and mediation (existing/new medium whereby arguments undergo apophantic evaluation prior to transmission). This other layer of a triptych is also representative of how my arguments are played out in the next three sections of the essay.

Both women are the embodiment of cyborgian, scientific, and cultural multiplicities: their ideas challenge the privilege of the masculine insistence of its epistemic superiority through nuanced and subtle transgression; the transgression comes in the form of inserting the self into the stages of becoming that are integral to enabling the paradigmatic shifts necessary for the production of a "new" paradigm in physics. In other words, they rocked the boat quietly through subtle forms of intervention, one of which was to use their solid scientific productions to stake their intellectual claims. Depending on how one sees it, such subtlety may be considered insufficient for encouraging more female participations in similar knowledge production, and does nothing for the elimination of tokenism taken for representation of female successes.

However, the exceptionalism that is pervasive in the aforementioned tokenism masks other less overt forms of institutional devaluation and marginalization. Such exceptionalism required women to have greater confidence in their abilities so that they could earn respect through their work. The stress of working in such marginal environments cannot be underestimated, and parallels the adjunctification of the academy in the US institutions of today. While the world of physics does not need to be reminded that the most profound mathematical contributions that enabled the beginnings of a mathematical field theory, which led to the theory of quantum fields, came through the labors of some exceptional and better-known women scientists, the vital but less dramatic contributions from other women physicists and mathematicians

get swept under the carpet and not paid the attention given to the same (or lesser) achievements of their male counterparts.

Therefore, the formal ontology underlying all physics theories across the classical and quantum spectrum is invariant to whatever social influences or conditions producing that ontology. In other words, the laws that determine the scientific theories proposed will not change regardless of the specific ideologies or institutional conditions of the scientists formulating them.[15] One can read formal ontology as an androgynous figure that does not subscribe to any determinate categories of ideologies (gendered or otherwise) and is a composite of a series of different categories that could combine and split to re-emerge as an entirely new epistemic category. This formal ontology then attempts to communicate the physical reality, where the process of communication undergoes re-interpretations, which are open to multiple interjections from the most subjective to the more objective, but never in a form that is 'detached.' The interjections range from the sociology of its research programs, to the interactions between the scientists, to the philosophy of proofs. The androgynous, considered through the mathematical sciences, and therefore dissociated from direct social entanglement, is situated outside the phenomenon of the dichotomously gendered epistemology.

The androgynous figure of the abstract-exact science and its products are not undifferentiated, but instead, represent a form of non-normative differentiation, where the epistemics (factual interpretive areas of knowledge also making truth-claims) are differentiated from the ontological (formal equations, socially invariant, with dollops of objective truths). But even in their differentiation, epistemology and ontology exist as a Harawayan knowledge-hybrid cyborg. I ask the reader to consider scientific production as a product of androgynous epistemology. The dissemination of such an epistemology enables the breaking of the first layer of exclusivity by moving away from strident binary thinking to encourage an explosion of pluralistic standpoints.

While knowledge accumulation and production appear apolitical at the point of their making, the readings of the knowledge, and thus of the mathematics, can still be politically reconstituted, particularly for understanding why certain interpretations are able to generate greater acceptances over others. I argue that the creation of an androgynous mental model for thinking through current and developing mathematical epistemologies can potentially make political engagement feasible even for highly esoteric mathematics. I do this not by insisting on any lack of solutions and objective explication in mathematics, but by being cognizant of the fact that what underlies the

objective is subjective social discursivity. As mathematics requires the mastery of specific knowledge genealogies, it and its ancillary epistemics can exist outside the context of institutional hierarchies once their bodies of knowledge are depoliticized. All participants in knowledge-making have equal access to making epistemological interventions, with the latter representing the decoupling of the condition of production from its final outcome.

Thinking about mathematics as an androgynous category enables the coupling of mathematical functions to real and imaginary numbers that could then be constituted as an entity to be read as containing social causality. It also allows the works of the two women to be read transgressively through the ejection of the subject from a fetishized gaze, and by refusing to subscribe to the exclusivity of relationships between modern mathematics and an alphabetized culture as the dominant causal argument for mathematical developments. The ancient mathematics of the Chinese and Indus Valley had demonstrated how highly sophisticated mathematics, particularly geometry, were generated alongside the development of pictographic forms of writings, and these mathematics were then applied as tools to mechanical arts and technology. What the ancient mathematics demonstrates rather simply is how the production of mathematics is not indifferent to cultural and social conditions.

To begin the process of transgressive reading, I will have to chip away at a Platonic idealization, an idealization that insists on mathematics being objectively detached and non-discursive. The Platonic idealization of mathematics represents mathematical solutions as inviolable and absolute. Instead, I want to advocate thinking about mathematics and the mathematical sciences as representative of the knowledge of constant becoming and re-invention. I intend for this process to return mathematics to a discourse that allows for more direct engagement with the why of physical materiality, instead of locating mathematics as distinct while still embodying the physical.

Therefore, I read mathematics outside the binary of determinism/indeterminism at the micro level, and determinacy/indeterminacy at the macro level.[16] Such a re-interrogation of mathematics becomes increasingly pertinent in the age of new media and the digital medium that emphasizes a more multi-faceted representation of nature's ontology. The Platonic ideal that infuses the method by which mathematics are thought about has located the latter in an abstractness that is no different from the written texts the humanists encounter regularly, a familiar yet unradical practice.

According to Brian Rotman in his *Mathematics as Sign*, there is a privileging of the code as opposed to the more affective metacode, the privileging of alphabetic prejudice that erases the acceptance of the diagram as a useful and effective tool for doing mathematics. Hence, we end up with literal strings of very long derivations of symbols that are prone to errors. While there are diagramming methods in physics and also mathematics that try to illustrate particular concepts or intricate calculations, such as the Venn diagram for set theory, and the Feynman diagram for particle-field measurements, they are among the rarer instances of the invocation of the diagrammatic method for modern mathematical thinking. While I am not saying that the diagrammatic method is the only way to go, we must still consider why we privilege a specific form of mathematics over other possibilities. A more thorough excavation into the social-political history of mathematics could prove enlightening in this regard.

The method at work in the production of mathematics is not as non-discursive and objective as one thinks, particularly not in its illustration of physics. In fact, the work of Noether particularly, which would have extensive implications in the development of particle physics, had first utilized visualization (thinking about algebra in geometrical terms constitutes a form of visualization) in the process of integrating abstract algebra into geometry. This integration led to subsequent modern developments of abstract algebra. Such subsequent developments were then further developed by Noether and successive generations of mathematicians thereafter, into algebraic notations. These latter algebraic notations in turn have become so complex that the algebra produced is no longer intuitively imaginable without the deployment of visualizing software such as Maple and Mathematica. Is this embodiment of a trend towards abstraction a manner of demonstrating one is competent enough to be part of the old boys' network of academic mathematics.

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Footnotes (returns to text)

1. The transhuman quality I refer to here is a mode of thinking about knowledge as located and dislocated from its production, of seeing the supposedly 'inhumane' characteristic of that knowledge as being capable of informing its human origins, even when the origins have been so hyper-mediated that the connection is no longer evident.
2. Other than Marie Curie, few female scientists, however paradigm-changing their contributions, ever reached the same level of prominence and imagination-provoking stature of some of the famous male scientists and mathematicians (excepting Einstein from this comparison), even if the work they did enabled the work of these same male figures and therefore could be considered of comparable value. Einstein is in a class of his own, though one might say that his first wife, Mileva Maric, a woman of known brilliance and ambitions, had she not been burdened with the work of household management and childcare while her husband was out doing his thing, could have possibly been another famous scientist. But one could only speculate upon how far she could have gone given that she never had the chance to go beyond being the early succorer and supporter of Einstein's endeavors. Scientific establishments have chafed at the idea of her making any substantial contribution to Einstein's work, but then, they were working from the position that Einstein's scientific production stands on its own merits with no regard for the social conditions that enabled that form of

production in the first place. See < http://www.pbs.org/opb/einsteinswife/milevastory/ (http://www.pbs.org/opb/einsteinswife/milevastory/) > for a brief overview and also for references to other works.

3. I am thinking here the works of Sadie Plant in *Zeros + Ones: Digital Women + The New Technoculture* (1998), Robyn Ferrell's *Copula: Sexual Technologies, Reproductive Powers* (2006) and Luciana Parisi's *Abstract Sex: Philosophy, Biology, and the Mutation of Desire*. (2004).In terms of anthologies, there are *Between Monsters, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace* (1996) edited by Nina Lykke and Rosi Braidotti, and *Cyberfeminism. Next Protocol* (2004) edited by Claudia Reiche and Verena Kuni.
4. For an ethnographical, biographical and mixed-methods (qualitative and quantitative) analysis of the role and condition of women in the sciences, I suggest looking at the articles in *Perspectives on Gender and Science* edited by Jan Harding. Many of the attempts to explain the particular positionality of women that influenced their interactions with scientific institutions have come up in multiple iterations, and thought written before 1986, has much relevance today. More recently, social media, specifically Twitter, have been replete with issues of overt and subtle discrimination and harassment that women in science had to face, and how those may have played a bigger role in undermining their work and making it harder for them to actually be different and unique when so many other battles had to be fought at the base level. See #RipplesofDoubt for conversations that highlight in more direct ways the philosophical issues surrounding passive and malleable matter Frost is trying to get at.
5. For an exhaustive history of the development of quantum theory, I would suggest *The Historical Development of Quantum Theory* by Jagdish Mehra and Helmut Rechenbach in six volumes, published by Springer-Verlag. For a thoroughgoing history of the developments of quantum field theory, which both Noether and Goeppert Mayer played important early roles in developing, one may check out Silvan S Schweber, *QED and the Men Who Made It* (1994). The other three useful references would be David Kaiser, *Drawing Theories Apart: the Dispersion of Feynman Diagrams in Postwar Physics (*2005*),* Arkady Plotnitsky, *Epistemology and Probability: Bohr, Heisenberg,*

Schrödinger, and the Nature of Quantum-Theoretical Thinking (2010) and Helge Kragh, *Quantum Generations: A History of Physics in the Twentieth-Century* (2002). The references cited here are not, by all means, the final word in the history of quantum theory, but they provide sufficient triangulating information to prove that quantum theory, for the first half of the century, was dominated by white men of the transatlantic continents, with the exception of some still-pivotal contributions from a small number of Japanese and American Chinese physicists during the post second world-war periods. In fact, Kragh states as much in his book. Schweber's book has a chapter dedicated to the role of Japan in postwar quantum field theory. On the American Chinese contribution, there is some mention (and contributing articles) in the anthology edited by Lillian Hoddeson, *The Rise of the Standard Model: A History of Particle Physics from 1964 to 1979. (*1997) and another by Laurie M Brown, who was herself a student of Richard Feynman, *Renormalization: From Lorentz to Landau and Beyond* (1993).

6. While there are many areas of interpretation of quantum mechanics that did not make their way into standard textbooks, one might still see them in more advanced or specialized books in foundational matters in quantum theory. However, even with the interpretational differences, the theories are derived from the same mathematical ontology. There exist, however, physicists from other cultures and nations who have tried to provide direct correlations between the intellectual histories of their cultures and what they observe to be happening in modern physics. One such example is *Maya in Physics* authored by N.C. Panda, who tries to bring the Hindu intellectual traditions contained in some Vedic texts into a re-reading of quantum theory, by suggesting that similar strains of thoughts in modern quantum theory had already exerted and manifested themselves in the Vedanta tradition that appears similar, in its explication, to the idea of unification in western modern physics. The book was published in India. See http://www.vedicbooks.net/maya-physics-p-799.html. There have also been similar recuperations done at a more academic historical level through the readings of the work and lives of colonial and immediately postcolonial Indian scientists, such as in past conference panels I have organized. Such existing interventions make it possible to contemplate

other forms of interventions into the grand narratives of quantum theory.

7. The American Physical Society periodically publishes statistics of women majoring in physics as well as reports on the status of women in physics. Such reports describe the climate that female physicists are working in, as well as reports on their achievements, grants, prizes, and also tips for navigating the workplace. See http://www.aps.org/programs/women/reports/gazette/index.cfm (http://www.aps.org/programs/women/reports/gazette/index.cfm) . Also not too recently, a debate was sparked on an internal physics mailing list with regard to tokenism and the role that privilege plays in helping some women in physics, rather than all participating women, to advance, all other things being equal. Previous to that, there were also complaints of there being insufficient women physicists nominated to become speakers at summer schools targeting international groups of undergraduate physics majors. Both these narratives are contained, though not directly reproduced, in the two very different stories of Noether and Goeppert Mayer.
8. That said, I want to bring the reader's attention to a 2007 article by Harry Collins on "Mathematical Understanding and the Physical Sciences," which points to the possibility of learning physics without necessarily having to master, to excruciating detail, all the intricate mathematics involved. He is not arguing that the mathematics is unimportant to learning physics, but rather, discussing how physical concepts can be made more accessible to the layperson, and seeking to find ways to foster greater understanding and literacy of the physical sciences by advocating for the teaching of physical sciences that does not drown the learner with details to the point of missing the forest for the trees. That way, the learner can spend more time dealing with the subtlety of conceptual arguments, rather than figuring out which mathematical operator or functional goes with what physical delimitations while still not getting the bigger picture. Nevertheless, there is some merit in working out some problems laid out in the textbooks, not for the reason of solving everything to absolute finality, but for getting a feel for the mental models and thinking processes involved. At the same time, the article also showcases a social experiment Collins performed where he did the Turing machine

equivalent of masquerading as a gravitational wave physicist without possessing much mathematical knowledge of the subject area, yet appeared to have been successful in his performance.

The Sokal Hoax was perpetuated by Alan Sokal, a mathematical physicist, who **submitted a spurious paper to *Social Text* in 1994** (http://www.physics.nyu.edu/sokal/transgress_v2/transgress_v2_singlefile.html) , resulting in what was called the "science wars" that both humanists and scientists have not ceased commenting upon for the past two decades. Sokal cashed in on the hoax by writing a book on it, *The Sokal Hoax: The Sham That Shook the Academy,* published by University of Nebraska Press in 2000. You can see the original paper, "Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity," at. He did make a brilliant move of picking a subject in physics that would have confounded some physicists, given the high level of mathematical and theoretical esotericism involved, so it was not as easy to discern, for the uninitiated, his true intentions unless they had subjected his piece to thorough scrutiny and used it to open discussions with other scientists. Of course, few physicists would appreciate his generous and random sprinkling of postmodern theory that seemed to border on the masturbatory rather than the advancement of actual arguments. There appears to be a level of hypocrisy involved when physicists trained in the tradition of "shut up and calculate" feel the need to inform non-physicists that the latter are wrong about ontological questions that the former are not necessarily better versed in. Additionally, not all physicists are clued in on the discussion of realism, objectivism, and materialism that had been engaged by highly respected philosophers of physics, though the latter do not engage in postmodern discourse for the most part, being more interested in discussing foundational questions in physics than extending into questions raised in literary/cultural theories. Also, you may be interested to read **Mara Beller's critique of how physicists themselves are more 'tolerant' of the 'founding fathers' of quantum theory's own predilection towards philosophical ruminations** (http://www.mathematik.uni-muenchen.de/~bohmmech/BohmHome/sokalhoax.html) that extend into psychology, politics, ideology, and religion, while remaining brutally derisive of the same moves made by the non-physicists theorists such as Derrida and Lacan. Beller was trained as theoretical physicist before becoming a historian of physics, and was known for her incisive and clear writing in the field of the history of quantum physics. She has since passed on.

9. See *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, (2007). Should one refer to the

argument of the previous footnote, one would be presented with a clue as to why Bohr's philosophical conceptualizations in the foundations of quantum theory appear amenable to cultural and political interventions.

10. Tokenism stems from the idea that representations of minority, underprivileged, and traditionally excluded social groups have been accounted for by extrapolating from the successes of a small number from such groups in breaking through barriers.
11. The mathematical and physics contributions that Noether and Goeppert Mayer made cannot directly be viewed in the actual works of physics I am referring to, but their work enabled discoveries and theorizations in quantum field theory, and therefore, in particle and nuclear physics, that were relatively popular subject matter in hard science fiction short stories and also in physics popularization, besides space and time travel, such as can be found in the likes of the serial *Analog Science Fiction and Fact*. Look particularly at issues published between 1960s and the late 1990s, which also coincided with the rise of the post-war big science of astrophysics and cosmology, as well as elementary particle physics.
12. Noether's theorem has becomes so ubiquitous in thinking about particle physics that what it stands for is taken as given in most introductory particle physics textbooks that I have had a chance to read through. See Griffiths's *Introduction to Elementary Particles* (2008) and Mann's *An Introduction to Particle Physics and the Standard Model* (2010). Also, see *Emmy Noether in Bryn Mawr: Proceedings of a Symposium Sponsored by the Association for Women in Mathematics in Honor of Emmy Noether's 100th Birthday*. Eds. Bhama Srinivasan and Judith Sally (1983). The contributors to the proceedings are male and female mathematicians, though one sees a greater number of contributions from female mathematicians than would have been found in most other proceedings.
13. See the Nobel Prize website for more information <http://www.nobelprize.org/nobel_prizes/physics/laureates/1963/mayer-bio.html>. I am sure most would have known that, outside the Nobel Prize in Literature, Nobel Prizes in the natural sciences and economics have a pretty dismal track-record when it comes to awarding women. While prizes have been created specifically to celebrate a woman

scientist/mathematician's achievement, it did not yet accomplish the task of having the female scientists' accomplishments recognized on a scale equivalent to that of male scientists, returning to the argument I made earlier in the essay about specific social politics that are at play.

14. As I have argued previously, such belated recognitions of their contributions are representative of the token successes rendered possible by the importance of their works, but in no way dilute the precarity of the positions from which they had produced their works. They were fortunate to have produced works that are, in pop-cultural parlance, 'hits,' which neither necessarily advance the conditions for all their other female colleagues nor eliminate tokenism. Here is where I would like to acknowledge Sherryl Vint's helpful reference to Fox Keller's work on McClintock and a novel by Gwyneth Jones that has a strong protagonist who happens to be a biologist trying to deal with the insidious politics of academia and the effects of sexism on her personal life and her work. I recognize the confusion that Jones's character had had with regard to social and sexual expectations that are less primary but not unimportant to my protagonists' developments. I suppose I imagine a condition where one of my female protagonists did not feel pressured to fit in and whose actions reflect her resistance to, and tension with, gendered identification.
15. Whether there are such things as the Laws of Nature has been debated enthusiastically in *Laws of Nature: Essays on the Philosophical, Scientific, and Historical Dimensions* (1995), edited by Friedel Weinert, who also provides a good comprehensive introduction to how one would classify laws, and what are real laws versus 'pseudo' laws, by demarcating what he considers 'lawful' as representing true natures of laws versus 'lawlike' that has the appearance of exemplifying the essence of nature but are merely manifesting certain 'accidental' qualities in a regular fashion, a sort of 'pseudo-law.' The laws available are constituted as causal laws, functional laws, and statistical laws. See "Introduction" pp 4-14.
16. In her 2008 article "Living in a Posthumanist Material World: Lessons from Schrödinger's Cat," Barad outlines very clearly, in item number 3 of her notes (pp 174-5), the difference between determinacy and determinism, by emphasizing that determinism has nothing to do with causality but all to do with levels of certainty and probability of

something being definite, while determinacy itself has to do with the larger causal effect that, as Deleuze and Guattari would put it, something that is becoming has neither an end nor a beginning, at least not in a way that our limited capabilities can apprehend.

PEER REVIEWED

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2 THOUGHTS ON "EMMY NOETHER, MARIA GOEPPERT MAYER, AND THEIR CYBORGIAN COUNTERPARTS: TRIANGULATING MATHEMATICAL-THEORETICAL PHYSICS, FEMINIST SCIENCE STUDIES, AND FEMINIST SCIENCE FICTION"

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