A Different Kind of Dark Energy:

Placing Race and Gender in Physics

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Table of Contents

I. Introduction

In December 2015, the Chief Justice of the United States Supreme Court John Roberts asked, "What unique perspective does a minority student bring to a physics classroom? …I'm just wondering what the benefits of diversity are in that situation?"[1] The subtle malice of this question, which implies (among many things) that students of color must justify their place in white-male-dominated physics classrooms, is a result of the past and present glorification of the field of physical sciences as a meritocratic bastion of objectivity: physics supposedly occurs independently of physicist. Why should the identity of the physicist matter? Indeed, science as a whole has long been heralded as an academic pursuit that is separate from or superior to the subjectivities of men. Famous novelist and physical chemist C.P. Snow stated in his 1959 work *The Two Cultures and the Scientific Revolution* that a scientist is "freer than most people from racial feeling,"[2] and this notion remains within many scientific creeds today.

Yet when one views the ideals of the physical sciences through the critical lens of ethnic studies, the entire notion of objectivity breaks down. A scientist, just like any individual, holds countless unconscious socialized biases and can just as easily subject others to tokenism, microaggressions, and other manifestations of deeply socialized '-isms.' Scientific knowledge is but a particular form of cultural knowledge, and thus any purported distinction between 'science' and 'culture,' or between 'science' and 'individual', deserves rigorous examination. With this project, I examine such distinctions between science and humanity, and investigate what applying the un-teachings of Critical Race Feminism to physics can reveal about the most 'objective' of disciplines.

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[1] Chief Justice John Roberts in *Fisher v. Texas*, 2015.
[2] C. P. Snow, *The Two Cultures and the Scientific Revolution* (Martino Fine Books, 2013).

A. Context: Underrepresentation of Women and People of Color in Physics

It is a well-known fact among scientists that women and racial minorities (with the exception of Asian Americans) are underrepresented in the fields of physics and astronomy. According to a survey conducted by the American Institute of Physics' Statistical Research Center in 2012, among the almost 10,000 physical science professors working in over 700 universities across the United States, fewer than 600 are Hispanic, Latinx, African American, or Native American, and fewer than 75 are Hispanic, Latina, African American, or Native American women. Indeed, over 83% of physics professors are men, and over 79% are white.[3] Especially when compared to the United States population (see Figure 1 at right), these numbers are grossly misrepresentative. Yet this phenomenon is not limited to the professional sphere. Between 2010 and 2012, just 19% of all physics doctoral degrees awarded in the United States were granted to women, and only 5% to Hispanic and Latino scholars combined.[4] The numbers are similarly misrepresentative of women and people of color in undergraduate institutions. This phenomenon is often referred to as the 'leaky pipeline;' many women and minority students are lost along the long and arduous academic path to ultimately becoming a professional physical scientist.

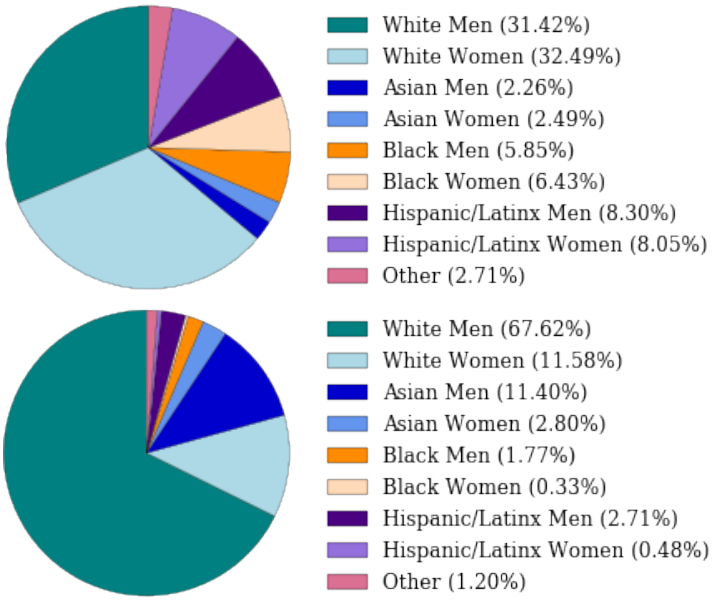

Figure 1. Populations of the United States (above) and the national physics professoriate (below) in 2012, broken down by racial and gender identifications. Note that the 'Other' category encompasses Native American, Pacific Islander, and non-Hispanic multiracial individuals. Data from the American Institute of Physics' Statistical Research Center and the US 2012

[3] Rachel Ivie, Garrett Anderson, and Susan White, "African Americans & Hispanics among Physics & Astronomy Faculty," *American Institute of Physics*, July 2014.

[4] Patrick J. Mulvey and Starr Nicholson, "Trends in Physics PhDs," American Institute of Physics, February 2014, https://www.aip.org/sites/default/files/statistics/graduate/trendsphds-p-12.2.pdf.

B. Critiques of Other Sciences

Thinking of interactions between physics and African American studies, few examples come to mind. Firstly, there is the handful of public figures like TV and radio star Neil Degrasse Tyson, TED fellow Jedidah Isler, or NASA scientist and movie inspiration Katherine Johnson. These scholars may not be at the epistemological intersection of astrophysics and African American studies, but they are African Americans in physics. Secondly, I think of analogies and rhetorical strategies, most likely scientific or quantitative lenses through which to view the social world, often used to explain social trends to scientifically-minded folks. How can vectors be useful for understanding identity? How is Planck's Law a metaphor for intersectionality?[5] I have personally used quantum physics to describe myself as a racial superposition, going so far as to describe the collapse of my racial identity wave function when I was labeled "white" at birth. Interestingly, these analogies are almost never flipped; race is never used to explain physical concepts. Third, the interplay between race and the physical sciences usually veers to questions of representation or equity: "why are there so few people of color in physics?" or "what are examples of racism in astronomy?" In my experience operating in both physics and African American studies communities, these three examples – Black celebrity-physicists, physical analogies, and physics demographics – are the extent of the connections that are made between studies of the physical world and studies of race and ethnicity.

If I were to consider instead a different realm of science, be it biology, medicine, or even chemistry, there are many more parallels with ethnic studies. Additionally, within these fields, the parallels become less superficial and more deeply tied to the ideology of the science itself. A community of scholars has already begun thinking about and critiquing the ways race, gender, racism, and sexism are built into biology and medicine as integral to the form of the knowledge

[5] Jedidah C. Isler, "On Planck's Law, Blackbodies and the Physics of Diversity," *STATUS: A Report on Women in Astronomy*, June 2014.

itself. Consider the studies of the history of phrenology, the Tuskegee Experiments, and the story of Henrietta Lax: all infamous examples of the deeply rooted and complex role race has to play in scientific fields. The same can be said even more emphatically for the social sciences of psychology, anthropology, sociology, and so on. Indeed, if one is looking for an intersection of African American studies and science, there is a copious archive to be found in the biological and social sciences.

Consider the work of Alondra Nelson, a professor of sociology and gender studies and the dean of social science at Columbia, whose book *The Social Life of DNA: Race, Reparations, and Reconciliation After the Genome* explores the interaction of the popular genetics boom that began in the 1970s with questions of race and reconciliation, specifically within the Black American community. Throughout the book, Nelson makes the case that the power of DNA is predominantly social; besides their scientific significance, genes have become symbols that "do not have inherent meaning outside a social and political context."[6] In addition to its rigorous examination of the relationship between race and genetics, *The Social Life of DNA* makes a striking case for the use of science as a new form of activism. Nelson is not alone in this quest; many scholars including Keith Wailoo, Emily Martin, Dorothy Roberts, and Peter Guarnaccia are producing monumental work that connects race, science, and social activism.[7]

However, this variety of scholarly work that connects and critiques the effects of race on scientific knowledge seems to disappear at the boundary of the physical sciences - a field that is supposedly more objective and removed from questions of humanity. Is it really true that the

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[6] Alondra Nelson, *The Social Life of DNA: Race, Reparations, and Reconciliation After the Genome*, 1 edition (Beacon Press, 2016), 16.

[7] See` Peter J. Guarnaccia and Lloyd H. Rogler, "Research on Culture-Bound Syndromes: New Directions," American Journal of Psychiatry 156, no. 9 (September 1, 1999): 1322–27.; Emily Martin, The Woman in the Body: A Cultural Analysis of Reproduction (Beacon Press, 2001).; Dorothy Roberts, Fatal Invention: How Science, Politics, and Big Business Re-Create Race in the Twenty-First Century (The New Press, 2011).; Keith Wailoo, Dying in the City of the Blues: Sickle Cell Anemia and the Politics of Race and Health, 1 edition (Chapel Hill: The University of North Carolina Press, 2001).

physical sciences are somehow so much more objective and empirical than other scientific fields that they have avoided incorporating effects of race and gender into their knowledge structures completely? That somehow, by avoiding dealing with humans in their objects of study, physicists across the centuries have sidestepped the social disasters that were (and are) slavery, Jim Crow, the Red Scare, the war on drugs? I am unconvinced. The question of race and physics must go deeper than a question of representation; race and gender have had an impact on ways of knowing in physics and astronomy. What are they?

C. Goals of this Project

In this thesis, I critically analyze the culture and theory of physics and astronomy through the perspective of Black women in an effort to understand the effects of a racist-sexist society upon scientific ways of knowing. I focus specifically on the stakes and implications of patriarchal white supremacy on the content of physics knowledge. The analysis I present draws upon interviews with five Black women who completed PhDs in physics or astronomy, as well as my own experiences and interpretations of the physical sciences. My analytic lens is formed within and shaped by the fields of science studies, feminist theory, and critical race theory. While this is, of course, a thesis in African American studies, I also draw upon my knowledge of astrophysical concepts as framing analogies for the work. Ultimately, I present evidence for a deeply sexist-racist physics epistemology. My framing questions are:

1. How do the ways in which we consider race, gender, and personhood inform the ways in which we understand the physical world, specifically the academic fields of physics and astronomy?
2. How do the fields of critical race theory, feminist theory, and science studies inform an analysis of race and gender in physics?
3. What kind of evidence exists for a racialized or gendered physics?
4. What unique insights does the intersectional Black female perspective bring to this question?

My ability to not only consider but to conceptualize these questions is a direct result of my specific positionality. Practically, I am an undergraduate at a well-endowed Ivy League university that has one of the oldest African American studies departments in the country, that not only encourages but also requires independent research, and that supports purely academic and 'basic' research in both its science and ethnic studies departments. Furthermore, my familiarity with boundary crossing as a woman of mixed race studying both astrophysics and African American studies informs every facet of this work. Of course, the questions I pose about race and gender in science, specifically Black womanhood in physics, are direct results of this positionality; they carry personal stakes for my own life and the lives of those (few may they be) occupying similar spaces.

Finally, throughout this thesis I strive to be aware of the radical, counter-normative, and unfamiliar nature of many of the arguments I present. I invite you, as a reader, to critically examine whatever pre-existing beliefs you might hold about physics and physicists and consider new understandings with me. Critical race theorist Derrick Bell often championed the power of imaginative narrative to suspend readers' belief: "To see things as they really are, you must imagine them for what they might be."[8] And so, heeding this call, I carefully present a short thought experiment:

What if physics was, and had always been, dominated by Black and brown women? If in 2017, only about 100 white men had ever received a physics PhD in the history of the United States? If Copernicus had been a woman studying during the Mamluk Sultanate in Cairo, if Galileo had been an Incan astronomer in Cusco? If Newton had been a Punjabi scholar from Lahore, if Einstein had been an Ethiopian refugee fleeing Mussolini's occupation of her home country, if Feynman had studied at Spelman? What if Supreme Court justices felt compelled to ask instead, "What benefits do white students bring to a physics classroom?" "What benefits do men bring to a physics classroom?"

[8] Derrick Bell, "Who's Afraid of Critical Race Theory?," *University of Illinois Law Review*, no. 1995 (n.d.): 893–910.

If men were assumed to just not be as interested in physics, or not biologically fit for quantitative analysis and objective thought? And if, in this world, white kids weren't thought to be missing from physics because of some systemic inequality, but because 'white culture' just didn't support careers in science (didn't inspire questions about what we're fundamentally made of, where we are, and what we come from)? What if white male neutrality wasn't presupposed? How would we view the roles of race, gender, and culture in influencing physics in this world? Of course, this world does not exist. But why not?

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II. The Black Female Voice

In the early stages of this project, I felt pressured to avoid exploration of the social and interpersonal realities of minority status in physics. After all, this thesis centers the knowledge structures and ideologies of physics – a subject around which I find little to no discussion of race or gender – rather than the social structures and communities of physics – a topic which has often come to incorporate race and gender in recent years. However, I quickly realized that if my central question is to understand how race and gender affect academic physical knowledge, then within this question lays a claim to the importance of the physicist to the physics. Put another way: if I hope to understand the physics, I must understand the physicist, and thus I must understand the environment within which the physicist exists.

The effects of a white male hegemony specifically, in physics culture and praxis as in many other institutions, may be often invisible, non-substantive, or even unreachable.[9] Thus, analyzing the field of physics through the unique lens of women of color becomes an invaluable and even necessary methodology for understanding the effects of society and culture on physics theory; knowledge is manifest within the marginalized experience. While centering the testimony of

[9] Maria Grahn-Farley, "An Open Letter to Pierre Schlag," in *Critical Race Feminism*, ed. Adrien Katherine Wing (New York: New York University Press, 2003).

minorities might feel uncomfortable in the context of physics, many legal scholars have demonstrated the power of storytelling to fight against a majority narrative, change the minds of those indoctrinated, and protect those oppressed. Critical race theorist Richard Delgado stresses the importance of learning about others' experiences through the communication of individual and collective experiences, and the power of narrative and story to disrupt power dynamics. Delgado explains how storytelling not only heals and strengthens the minoritized storyteller by vocalizing often-subdued truths about oppression, but also enlightens and instructs the majority listener by opening their eyes to realities they cannot personally experience. The sharing of stories is a process through which "we can overcome ethnocentrism and the unthinking conviction that our way of seeing the world is the only one – that the way things are is inevitable, natural, just, and best – when it is, for some, full of pain, exclusion, and both petty and major tyranny."[10] While Delgado is a law professor encouraging the use of stories in the legal realm, it is clear that his philosophies regarding the power of a vocal minority have direct applications to the physical sciences.

Black women, in particular, are in a powerful position to consider the effects of race, gender, and personhood in physics, as our intersectional identities afford us a unique perspective on the world. First presented by Kimberle Crenshaw in 1989, intersectionality theory recognizes the complex and non-commutative ways in which different aspects of an individual's identity interact and overlap. For instance, the experiences of a Black woman cannot be reduced to the added experiences of a white woman and a Black man; she experiences unique intersections of her Blackness and her womanhood.[11] Existing at the intersection of multiple marginalized identities, women of color possess an (unjustly) keen perception of both racism and sexism. In an expansion

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[10] Richard Delgado, "Storytelling for Oppositionists and Others: A Plea for Narrative," *Michigan Law Review* 87, no. 8 (1989): 2411–41, doi:10.2307/1289308.

[11] Kimberle Crenshaw, "Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics," *The University of Chicago Legal Forum* 140 (1989): 139–167.

of W.E.B. Du Bois' theory of the Black man's double consciousness, the Black female astrophysicist experiences something of a sextuple consciousness. She is Black, woman, and scientist, yet she must also understand what it is to be white, male, and non-scientist. By studying the experiences and words of Black women who have received doctoral degrees in physics, I aim to uncover the racialized and gendered realities of physics today.

Of course, both the categories of "Black" and "woman" can and should stand to be problematized. As I will address in subsequent sections, both the concept of Blackness and the concept of womanhood are social constructions that only imperfectly map onto reality. The term 'Black American' swallows not only the descendants of American slaves, but also any American with darker skin and perceived ties to Africa, whether their ancestry traces to Trinidad and Tobago, Ghana, or South Carolina (here not even addressing the complications of racial mixing). Similarly, while the term 'woman' is most commonly used to address a cis-gender female, it simplifies the complexities of gender and leaves in question the place of transgender and non-gender conforming folks. Of course, the experiences of Ghanaian Americans greatly differ from those of Black Americans descended from slaves, and the experiences of cis-gender women greatly differ from those of transgender women. Thus, even as I refer to 'Black women' throughout this thesis, I remind both myself and my readers to be mindful of the shortcomings and conflicts inherent to the term.

Though they are just 0.33% of the national physics professoriate,[12] Black women astrophysicists do, in fact, exist. According the African American Women in Physics website, which strives to track every Black woman in physics in the country, around 130 Black woman have received physics PhDs, with the first in 1972.[13] I interviewed five of these women – three post-docs

[12] Ivie et al., "African Americans & Hispanics among Physics & Astronomy Faculty," July 2014.

[13] Jami Valentine and Jessica Tucker, "The Physicists," *African American Women in Physics*, accessed March 27, 2017, http://aawip.com/aawip-members/.

and two research scientists – about their experiences in physics, their perceptions of objectivity, and their observations of sociocultural influence in physics. I asked each of my respondents some combination of the below questions, focusing especially on their responses to question six:

1. How has your identity as a Black woman interacted with your success in physics?
2. In December 2015, the Chief Justice of the United States Supreme Court John Roberts asked, "What unique perspective does a minority student bring to a physics classroom? …I'm just wondering what the benefits of diversity are in that situation?" How do you interpret this question? What is your answer to him?
3. How do you see the assignment of value within physics (what gets funded, who gets cited, who is awarded) affecting the physics that is ultimately produced?
4. Where do you see objectivity in physics? Where do you see subjectivity?
5. How do culture and society shape how physics is produced?
6. Throughout your career, where have you specifically seen race, gender, and identity inform and shape physics knowledge? (In lectures, textbooks, journal articles? Elsewhere? Anywhere?)

In addition to functioning as the data for my analysis, these interviews serve to elevate the voices of Black women in physics and accord them due focus – not solely for their biographies and phenotypes, which are often at the center of any published conversation with any woman of color in physics, but for their extraordinary intellect and experiential perspective. By communicating with Black women who have received doctoral degrees in physics, I tap into an archive of anecdotal evidence that goes far beyond what I have personally experienced as an undergraduate, and I collect a data set that does not currently exist.

The exceptional insights and observations shared by the five extraordinary women I interviewed were truly the foundation of this project, informing my thinking about every aspect. As such, the results of the five interviews are integrated throughout this work, though I use pseudonyms to maintain the women's anonymity. Erin, Maya, and Amber are all post-doctoral fellows at R1 research institutions studying astrophysics, having received their PhDs within the last 7 years. Kimberly and Ella are more senior researchers, working as a research scientist and an associate

professor, respectively. Both expanded their academic interests beyond the physical sciences after completing their PhDs, and are now spending their nomadic careers researching some combination of physics, physics education, science policy, and sociocultural studies of science.

Throughout their interviews, these women demonstrated the power of their particularly positioned perspectives to analyze race and gender in their lives, including in the realm of academic physics. Maya, for example, acknowledged that her minoritized identities accorded her a permanent critical awareness as she declared, "My lived experience does not allow me to pretend like race and gender and inequity don't exist!" Yet she was not alone; every single one of my respondents emphasized that their Black womanhood was present everywhere in their life, including in their work in physics. For these women, race is not an added variable or a special consideration tacked onto their experiences; it is deeply entangled to their very being. They are Black when they go to the grocery store, and they are Black when they sit in conference rooms - even if, as Maya observed, they are expected to be found in the former, and not so much in the latter. Their Blackness is omnipresent, and the effects of living with the constancy of race were at the forefront of these women's analyses of their worlds.

Furthermore, each woman that I spoke with testified that their subjugated identities accorded them a different way of seeing the world, one that is particularly attuned to seeing complexity and inequality. For instance, Erin expresses how her identity and perspective push her to think more critically about data and claims to objectivity, "I think that I am a better scientist because of it. I think that I am more focused on being discerning with data because I see how so many physicists abuse sociological data in ways that are harmful to Black women." Ella found that her intersectional identity accorded her greater comfort with complexity, especially in the face of reductionist physics:

> A lot of the training that you get in physics is reductionism. You take a complex system and you make it very simple...Whereas when you're African American and/or a woman, when you're intersectional, you have to deal with complexity all the time...Your identity and the way people perceive you is complex. And oftentimes you don't have control of your own image, so you have to develop strategies in order to get people to replace the image that they have of you with the image that you want them to have of you. We are complex, and our lives are very complex by virtue of our identity. And so that means that the way that I dealt with my dissertation, I looked at something that was complex and I tried not to reduce the complexity; I tried to weave the complexity together.

Maya's understanding of how her identity affected her perspective complemented both Erin's and Ella's. She expressed how her understandings of multiple different fields and lifestyles led to new contexts and insights, musing, "I don't know very many people who can write an article that combines diversity and [physical properties of light]. But it is because I am a Black woman, it is because I care about these things, because I don't have a choice to engage with them, that this new-ish, interesting, unique perspective emerges." This acute perception that Erin, Maya, and Ella possess and claim is a result of the unique perspective created by the occupation of conflicting spaces, of their non-normative and boundary-crossing positionalities. However, as Ella expressed, the in-between is not a comfortable place to be. As she reflected on her experience as an interdisciplinary physics scholar, Ella lamented frequent feelings of isolation and vagrancy:

> All my life I had been doing this stretching and combining and bending, doing all these things that are groundbreaking and pioneering and interdisciplinary, but it sucks! It really sucks because nobody's ready for you. And everyone thinks that you're lost. Everyone thinks that you belong somewhere else. Wherever you belong is not with them. So that's the way academia is, they have these silos, and it really sucks not having an intellectual home.

These women and I are interdisciplinary nomads and liminal thinkers because we have no choice but to be; we do not fit into classical demographic or disciplinary boxes. Nevertheless, the heightened perception that we possess, as a result of our complex identities and non-normative existences, forms the essential lens of my analysis. Kimberly perhaps best expressed the value of the often-

painful marginalized perspective: "Look around while you're down there. You will see things. You'll learn more compassion, and you will just learn to see the world from other perspectives."

The unique perspectives of Black women in physics were immediately evident, not just in these direct introspections, but in every observation about physics that my respondents shared. The creative, thoughtful, and critical ways in which these women view physics was obviously distinct from the perspectives presented to me by (white male) professors of quantum mechanics or electromagnetism. I found myself continuously awed by the ability of these women to simultaneously appreciate and contribute to the epistemological aims of physics, while also centering criticality in their interpretations of their own work and that of others.

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III. Syncretic Theoretical Foundations

This work builds upon foundational work produced by scholars of both critical race theory - critical race feminism, in particular - and science and technology studies - feminist science studies, in particular. While these disciplines do not frequently overlap, I choose to present some of their key implications for this project here together. The disciplines are not separated within my analysis, and the juxtaposition of the two fields has brought insights that would not arrive without cross-disciplinary thought.

Critical race feminism is a sub-discipline that grew out of legal traditions, such as critical legal studies, that "challenged orthodox ideas about the inviolability and objectivity of laws that had oppressed minorities and white women for centuries."[14] Specifically, critical race feminism is a progeny of the critical race theory pioneered by minoritized legal scholars such as Derrick Bell and Richard Delgado in the 1980s. Both disciplines are at their foundation critical, constantly encouraging examination of the subjective positionality, indoctrination, and privileges of its

[14] Adrien Katherine Wing, "Introduction," in *Critical Race Feminism: A Reader*, 2nd ed. edition (New York: NYU Press, 2003), 1–22.

scholars.[15] Yet by centering the experiences of women of color, critical race feminism took critical race theory and critical legal studies even further by embracing intersectionality and acknowledging the particular oppressions experienced by minoritized women.

Science and technology studies is an inherently interdisciplinary field of study that analyzes how the scientific and technological are affected by the cultural, social, historical, and political. An older discipline, science studies is often said to have originated with Ludwik Fleck's 1935 work, *Genesis and Development of a Scientific Fact,* that examines the institutional character of the sciences, the processes of scientific experimentation and truth-production, and the importance of scientific communities, among other questions.[16] Science studies has grown since Fleck to include investigations of technology (together called 'technoscience') and has widened to encompass philosophy, ethics, gender studies, anthropology, queer studies, and – to a limited extent – ethnic studies. Like critical race theory leading to critical race feminism, science studies ultimately led to the development of feminist science studies with new perspectives of (white) feminist scholars including Donna Haraway, Evelyn Fox Keller, Sandra Harding, and Karen Barad.

My project requires that I read feminist theory, critical race theory, and science studies not as separate but rather as intersecting disciplines whose relative tensions and resonances yield new perspectives. Indeed, I have gained insights into science while reading texts about race, and I have reciprocally gained insights into race while reading texts about science.

Consider Professor Hazel Carby's 1992 article "The Multicultural Wars," in which Carby critiques the exploitative nature in which 'diversity' is written into university curricula. Her observations about how to perceive whiteness resonate have informed how I perceive science.

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[15] Wing, *Critical Race Feminism: A Reader*, 16.

[16] Ludwik Fleck, *Genesis and Development of a Scientific Fact* (University of Chicago Press, 2012)

Carby criticizes the understanding of whiteness as "the normative state of existence...the white point in space from which we tend to identify difference."[17] She later questions:

> Do white women and men have no color? What does it mean, socially, politically, and culturally not to have color? Are those without color not implicated in a society structured in dominance by race? Are those without color outside of the hierarchy of social relations and not racialized? Are only the "colored" to be the subjects of a specialized discourse of difference? And, most importantly, do existing power relations remain intact and unchallenged by this discourse?[18]

What does it mean to conceive of science, and especially physical science, as "culture-less," as so objective that it is stands apart from lived humanity? As Carby probes the effects of leaving "whiteness" out of conversations about diversity, I probe the effects of leaving the scientific realm out of questions of identity and oppression. Thus I apply the critical perspective inherent to feminist theory and critical race theory to the physical sciences.

Conversely, consider Geoffrey Bowker and Susan Star's book *Sorting Things Out: Classification and Its Consequences (Inside Technology)*. In the first chapter, Star and Bowker examine epistemic infrastructure, or the social and historical paradigms that shape our knowledge and our means of knowledge production. This is no easy task, for as Star and Bowker point out, "Information infrastructure is a tricky thing to analyze. Good, usable systems disappear almost by definition. The easier they are to use, the harder they are to see."[19] Indeed, such infrastructures are omnipresent and are a challenge to analyze, as they express:

> Methodologically, we do not stand outside these systems, nor pronounce on their mapping to some otherworldly "real" or "constructed" nature. Rather, we are concerned with what they do, pragmatically speaking, as scaffolding in the context of modern life. Part of that analysis means understanding the coconstruction of classification systems with the means for data collection and validation.[20]

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[17] Hazel V. Carby, "The Multicultural Wars," *Radical History Review* 1992, no. 54 (September 21, 1992): 12.
[18] Carby, "The Multicultural Wars," 13.
[19] Geoffrey C. Bowker and Susan Leigh Star, "Some Tricks of the Trade in Analyzing Classification," in *Sorting Things Out: Classification and Its Consequences* (MIT Press, 2000), 33.
[20] Bowker and Star, *Sorting Things Out: Classification and Its Consequences*, 47-8.

Such a perspective on knowledge infrastructure reflects understandings of the nature of white supremacy and patriarchy. How is it possible to analyze, understand and critique the invisible infrastructures of white male supremacy when it is a system we cannot ourselves escape? As Star and Bowker investigate knowledge infrastructures and their effects on classification and data analysis in science and technology, I investigate white male hegemony and its effects on culture creation, classification, and data analysis in physics. Thus I apply the critical perspective inherent to science and technology studies to understandings of racialization and 'other'-ization.

These are just two of countless examples of the analytical benefits of syncretizing science studies and feminist critical race studies. Both critical race theory and science studies construct worldviews that are ideal for critiquing long-standing 'objective' institutions, like physics, and revealing the oppressive systems woven into them. Through familiarization with the foundational texts and destabilizing arguments of both disciplines in tandem, I seek to destabilize conceptions of what physics is, how it is produced, and what roles race and gender play in even the most 'objective' of physical theories.

A. What is Science? What is Race? What is Gender?

Before I can analyze race, gender, and science, I must characterize these very concepts. Perhaps most important for this characterization is the recognition that science, race, and gender are all social constructions. To be more specific, science, race, and gender are all subjectivities imposed upon objective realities. People who are called Black tend to have phenotypical differences – darker skin, curlier hair – from people who are called white. People who are called men and people who are called women tend to have different genitalia and body types. Celestial bodies tend to orbit one another with trajectories and velocities consistent with a relation, called gravity, between what is called mass and what is called distance. However, there are exceptions to each of these statements: consider light-skinned Black people, male-presenting or transgender women, and the extra-

gravitational velocities of stars in galactic rotation due to dark matter.[21] The classifying words we use to describe trends and phenomena - 'Black', 'white,' 'male,' 'female,' 'gravity,' 'dark matter' - are imperfect linguistic creations that, through ubiquitous use and cultural normalization, have come to be viewed, dangerously, as reflections of truth. Descriptions of phenotypical similarity shape our assumptions of what and who individuals truly *are*, just as descriptions of physical happenings shape our assumptions of what the universe truly *is*.

Though I will not delve too deeply into the origins of the concepts of race and gender, it is useful to recognize that they are not universal, nor have they existed forever. The first definitions of a Black race are thought to have originated in the 17th century, alongside the growth of Atlantic slavery and the need for moral justification of human subjugation. Cultural ideas of Blackness and whiteness have been used consistently since their conception to justify the enslavement, segregation, imprisonment, and general mistreatment of Black people.[22] Furthermore, efforts to define race biologically have been generally unsuccessful; there is no gene that all "white" people have that "Black" people do not, or vice versa, and it has been shown that there is actually more genetic difference within racial groups than there is between racial groups.[23] Racial divisions are social divisions. Modern understandings of gender are, too, social, and go back much further than the 17th century. One new theory connects modern gender roles to cultures that used the plough - a technology that was invented before the common era.[24] However, the social particularities of gender roles seem ubiquitous and natural in our world today, where social expectations of race and gender

[21] The phenomenon of dark matter is explained in greater detail in section IV, for those uninitiated with the concept.

[22] See Audrey Smedley, *Race in North America: Origin and Evolution of a Worldview* (Avalon Publishing, 1999).

[23] Lynn B. Jorde and Stephen P. Wooding, "Genetic Variation, Classification and 'Race,'" Nature Genetics 36 (October 26, 2004): S28–33, doi:10.1038/ng1435.; also see Ian Haney-López, "The Social Construction of Race: Some Observations on Illusion, Fabrication, and Choice," *Harvard Civil Rights-Civil Liberties Law Review*, January 1, 1994.

[24] Alberto Alesina, Paola Giuliano, and Nathan Nunn, "On the Origins of Gender Roles: Women and the Plough," *Quarterly Journal of Economics* 128, no. 2 (2013): 469–530.

are inevitable and inescapable; even the youngest of boys and girls are taught how to dress, behave, and even learn according to their perceived race and their gender as assigned at birth.[25]

The development of science as, broadly, a means for understanding the natural world has existed for the duration of human civilization. Unlike the origins of race, gender, or other distinctions between humans, the origins of science are perhaps more fundamental: a desire to understand the world in which we operate. Yet science, too, is constructed. What we call science today has been shaped by its long history, by the perspective of every decision, classification, description, abstraction, or theorization that came before. Indeed, Ludwik Fleck explains that all knowledge (scientific or otherwise) is a unique result of the "thought collectives," or communities of individuals exchanging ideas and observations, in which it is produced.[26] Thus, the long history of white supremacy in Western science and modern physics leaves genealogical effects on the theory that can be produced. This was not an unfamiliar idea to the Black women-physicists; Maya clearly expressed concerns about the effects of generations of preference on content: "If you predominantly cite white men, then not only are you implicitly saying that their ideas matter more, but it also sets the direction of what we're studying….[it] shapes what happens next."

Thomas Kuhn describes scientific disciplines as paradigms, or epistemic lenses, that are molded by generations of scientists, and the scientific revolutions that slowly resolved conflicting ideas into widely accepted theories. Once a disciplinary paradigm is established, a scientist within the discipline can build upon that paradigm, rather than reinventing the wheel, allowing for the specialization that characterizes modern science today.[27] Yet this system of paradigms, while enabling deep scientific advancement, serves to enhance science's subjectivity as well. As Bruno

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[25] Jeanne Marecek, Mary Crawford, and Danielle Popp, "On the Construction of Gender, Sex, and Sexualities," in *The Psychology of Gender*, ed. Alice Hendrickson Eagly, Anne E. Beall, and Robert J. Sternberg, 2nd ed (New York: Guilford Press, 2004), 192–216.

[26] Ludwik Fleck, *Genesis and Development of a Scientific Fact*, 38-9.

[27] Thomas S. Kuhn and Ian Hacking, *The Structure of Scientific Revolutions: 50th Anniversary Edition*, Fourth Edition edition (Chicago ; London: University Of Chicago Press, 2012), 10-22.

Latour describes in *Science in Action*, when technologies or theories become widely accepted they become 'blackboxes' that are no longer critically examined by those who use them, and are rather taken for granted. For example, consider a computer or the double-helix shape of DNA – concepts that were once disputed and that comprise generations worth of innovation and subjective decisions, yet that are today viewed as fundamental and unquestionable.[28] Taken together, these scholars characterize a science that is genealogical, contextual, institutional, and social by definition – though it is paradoxically blind to its own nature.

Because race, gender, and scientific knowledge are commonly viewed as concrete and rational truths, so declaring them each to be the results of social construction is a radical and often-rejected assertion. Interestingly, the Black women that I interviewed easily accepted the constructed nature of each. They were particularly adept at explaining the social nature of science, and the distinction between objective reality and the inherent subjectivity of science. For example, Maya exhibited little uncertainty as she described a theory of scientific objectivity that fit comfortably between often-conflicting ideas of realism and social constructivism:

> You can go out and measure something, and that measurement can stand alone and be a so-called truth. But the decision of what to measure and how to do it, all of that has a lot to do with the way you perceive the world and what you think is worthy of being measured, what you think will be a signifier of meaning or a signifier of truth. So the measurement itself can stand, but everything around it is socially and culturally constructed.

Though it may not be taught this way in physics textbooks and classrooms, physics as it stands is a subjective interpretation of an objective reality – an interpretation that is inseparable from the historical, social, political, and cultural contexts of the physicists who create it.

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[28] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Harvard University Press, 1987), 1-17.

B. The Perils of Social Constructivism

Just as soon as we consider the social constructivist mindset, it is important to note its shortcomings – with respect to both race and science. In the realm of racial politics, the abuse of social constructivism has resulted in the myth of colorblindness; individuals claim that, since they acknowledge that race is a construct, they no longer 'see' race. Yet this mindset leads to ignorance of the racial realities that still exist; race may be an immaterial social concept, but it has very material impact on those who are racially minoritized. Appropriate analysis and policy can only result from a combination of social constructivism (rejecting that race is real) and realism (accepting that racial constructions have real effects).[29]

A similar debate regarding the social constructivist nature of physics played out in past decades among scholars of science and technology studies. As described by French philosopher Bruno Latour, the Strong Programme is the notion that "the content of any science is social through and through."[30] In the past 40 years, rebuttals and defenses of the Strong Programme have constituted a fascinating, heated, and at times even scandalous discussion regarding not only the importance of society in physics, but also the very nature of truth.

I first came across the Strong Programme within Bruno Latour's close-reading of Einstein's popularized *Relativity, the Special and the General Theory,* "A Relativistic Account of Einstein's Relativity." In this work, Latour expresses a concern that I share with him: that for all of the consideration of the effects of society and psychology upon physicists, scholars have said little surrounding how physics "theory itself could be said to be social."[31] In order to understand the connections between science and society, Latour considers multiple literary techniques and semiotics

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[29] Eduardo Bonilla-Silva, *Racism Without Racists: Color-Blind Racism and the Persistence of Racial Inequality in America* (Rowman & Littlefield Publishers, Incorporated, 2014).

[30] Bruno Latour, "A Relativistic Account of Einstein's Relativity," *Social Studies of Science* 18, no. 1 (February 1, 1988): 3.

[31] Latour, "A Relativistic Account of Einstein's Relativity," 5.

present in Einstein's book: shifting in and out of subjectivities (across power, time, and space); the creation of internal referents to establish reality; the inscription, subscription, and transcription of documents and credibility within the text. At first read, I found "A Relativistic Account of Einstein's Relativity" to be exceptional for its apparently empirical analyses of physics as social, providing tangible and textual rather than just epistemological evidence. Then, I read John Huth's rebuttal.

In response to Latour's 'Relativity,' physics professor John Huth critiques that most of Latour's claims about a 'social relativity' are founded on faulty readings of the most popularized version of Einstein's theory. As Huth argues, Latour isn't organically expanding definitions of 'society' and 'abstraction' as he claims to, but rather "stretch[ing them] to fit his interpretation of relativity."[32] Indeed, Huth provides many examples in which Latour's fundamental arguments are built upon misreadings of the theory of relativity. And Huth is not alone in this opinion; other physicists including Alan Sokal and Jean Bricmont have also critiqued "A Relativistic Account" for its misinterpretation of Einstein's theory and logical fallacy.[33] These physicists' scathing critiques exemplify the vital role of scientists in science studies: science studies fails when it misunderstands the very science it studies (though there is certainly an argument to be made that the misunderstanding of natural science by social scientists is largely a result of natural scientists' disinterest and incompetence in effective science communication).

Huth's piece is one of many in a collection of scholarly work that was produced in opposition to a post-modern, social constructivist bent in science studies. This academic trend was exploded in 1996, by a scandal now known as the "Sokal Hoax." In 1996, physics professor Adam Sokal published an article in the journal *Social Text*, "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity," that claimed to present a social constructivist

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[32] John Huth, "Latour's Relativity," in *A House Built on Sand: Exposing Postmodernist Myths about Science*, ed. Noretta Koertge (New York: Oxford University Press, 1998), 185.

[33] Alan Sokal and J. Bricmont, *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science* (New York: Picador USA, 1998), 124-133.

perspective on quantum physics.[34] Little did the editors know that the article was a parody; in Sokal's own words, it was "structured around the silliest quotations I could find about mathematics and physics...from some of the most prominent French and American intellectuals; my only contribution was to invent a nonsensical argument linking these quotations together and praising them."[35] Sokal revealed his successful hoax via an article in *Lingua Franca* three weeks later, inciting a scandal while also stimulating conversation around the problems inherent to an extreme postmodern interpretation of science. In the works that followed, Sokal and many others were unrelenting in their criticisms of social constructivist science studies.

Yet Sokal's intentions were not as damning as they might originally seem. He vehemently denounces the academic trend, often based on faulty logic, in which social scientists study the natural sciences with a lack of expertise, failing to "distinguish clearly among ontology, epistemology, and sociology of knowledge" and thus simplifying all science to be a social construction of narratives and myths.[36] In broader strokes, he also decries the postmodern agenda, which, as described by philosopher Paul Boghossian, "views license, and typically insist[s] upon the substitution of political and ideological criteria for the historically more familiar assessment in terms of truth, evidence, and argument."[37] However, neither Sokal nor his colleagues dismiss the fundamental goals of science studies, or even the notion that science is fundamentally shaped by society – a notion that is still radical among physicists (consider famous quantum physicist Richard Feynman's comment that the philosophy of science is as useful to scientists as ornithology is to

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[34] Alan Sokal, "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity," *Social Text* 46/47 (1996): 217–52.

[35] Alan Sokal, "What the Social Text Affair Does and Does Not Prove," in *A House Built on Sand: Exposing Postmodernist Myths about Science*, ed. Noretta Koertge (New York: Oxford University Press, 1998), 11.

[36] Sokal, "What the Social Text Affair Does and Does Not Prove," 15-6.

[37] Paul A. Boghossian, "What the Sokal Hoax Ought to Teach Us," in *A House Built on Sand: Exposing Postmodernist Myths about Science*, ed. Noretta Koertge (New York: Oxford University Press, 1998), 26.

birds[38]). Rather, Sokal states that the work of postmodernists including Bruno Latour, Steve Woolgar, Michel Serres, and others "are a diversion from the important matters that motivated Science Studies in the first place: namely, the social, economic, and political roles of science and technology."[39]

Ultimately, I heed the *Social Text* hoax, the critiques of Latour's Relativity, and the robust anti-postmodernist arguments in *Fashionable Nonsense* and *A House Built on Sand* not as a condemnation of the work I am pursuing in this thesis, but rather as a clear and almost unsurprising warning against an uncritical evaluation of the social aspects of science. Science studies should not assume the field of physics to be wholly objective and unaffected by society; nor should it assume it to be wholly subjective and based in nothing but society. The 'real' answer lies somewhere in the middle. In my efforts to reveal the effects of race, gender, sexuality, and identity on the production of physical knowledge, I must reject binary answers, however tempting for their simplicity, and embrace the complexity inherent in such an epistemological question. Furthermore, as I place race and gender within physics and in some ways support the arguments of the Strong Programme, I must do so logically, mindfully, respectfully, and unambiguously, lest I make the same mistakes as Latour and others before me.

C. On Objectivity

In and around physics there persists today a myth of objectivity, or the ability to separate the doing of science from the biases and emotions of the scientist. One study of over 3,000 scientists and non-scientists found that scientists are viewed as more objective, rational, and open-minded than other highly-educated non-scientists.[40] This objectivity myth is tied to both the supposedly

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[38] Philip Kitcher, "A Plea for Science Studies," in *A House Built on Sand: Exposing Postmodernist Myths about Science*, ed. Noretta Koertge (New York: Oxford University Press, 1998), 32.

[39] Sokal, "What the Social Text Affair Does and Does Not Prove", 18.

[40] Coosje L. S. Veldkamp et al., "Who Believes in the Storybook Image of the Scientist?," *Accountability in Research* 24, no. 3 (April 3, 2017): 127–51.

neutral position of the white man and the elevated status accorded to the physical scientist. The myth of objectivity has been used to discredit women and racial minorities as inferior physicists due to their incapability of being truly objective.[41] Central to both science studies and critical race feminism is a refutation of the notion of objectivity. In the former, generally this serves as a rejection of the myth of the objective scientist, in the latter, of the objective white male – though, in physics especially, these two categories frequently overlap.

In perhaps the earliest work of science studies, Ludwik Fleck quite immediately rejects objective science. Fleck emphasizes the ways in which science is informed and shaped by inherited knowledges – "The bonds of history can never be cut"[42] – and in which scientists are shaped by the overlapping communities of thinkers, or "thought collectives" to which they belong. Thus in one rhetoric swoop, Fleck rejects both objectivity and individualism; in his view, "the greatest error of individualistic psychology is the assumption that a person thinks… What actually thinks within a person is not the individual [them]self but [their] social community."[43] The genealogical understanding of knowledge production is furthered by Kuhn and Latour, whose aforementioned arguments regarding the social nature of science dismiss the idea that any scientist could be truly objective.

Moving beyond a simple rejection of objectivity, there is much room to believe that an embrace of subjectivity produces better scholarship. Certainly, many scholars in both science studies and critical race theory have emphasized the importance of different perspectives, especially local and subjugated perspectives. In the first lecture of his "Society Must be Defended" lecture series, philosopher and social theorist Michel Foucault champions a new trend of 'offensive' knowledge that criticizes and undoes homogenous or simplifying theories through the inclusion of new

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[41] For a scholarly example claiming that women are naturally less objective than men, see Nancy Chodorow, "Feminism and Difference: Gender, Relation, and Difference in Psychoanalytic Perspective," *Socialist Review*, 1979.

[42] Fleck, *Genesis and Development of a Scientific Fact,* 22

[43] Fleck, *Genesis and Development of a Scientific Fact,* 47

knowledge that had previously been subjugated, be it disavowed or hidden.[44] Donna Haraway builds upon Foucault's work in perhaps the most celebrated theory of objectivity in feminist science studies, her 1988 article "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." Haraway criticizes and declares impossible the omniscience, impartiality, and universality claimed by so-called objective white male scientists, what she calls an illusion or "god-trick" that falsely purports a "direct, devouring, generative, and unrestricted vision."[45] In its place, Haraway proposes a feminist objectivity, termed 'situated knowledge,' that instead embraces locality, partiality, and relativity. For Haraway, true 'vision' comes from the ability of the seer to split the self, being simultaneously aware of what they see and of how their positionality affects what they see. She declares, "only partial perspective promises objective vision."[46] She, like Foucault, celebrates the subjugated who can "[see] from below"[47] for the unique perspectives they hold as they operate outside frames of power and normalcy. Yet it is important to note that these ideas of situated knowing, subjugated knowledge, and partial perspective are not present exclusively in academic social theory; they were also present in the experiential insights shared by my respondents. Kimberly, for instance, emphasized the importance of positionality and partiality when she commented, "you can't get to certain kinds of knowledge unless you are entangled, unless you are embedded, unless you're living in the space."

Finally, a discussion of objectivity in physics would not be complete without mention of the postulates of quantum mechanics and the hypocrisy they have come to epitomize. The field of quantum mechanics was developed in the 1920s by many now-famous physicists, including Bohr and Heisenberg, and it has been inciting physical and philosophical controversies ever since. One

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[44] Michel Foucault and François Ewald, *"Society Must Be Defended": Lectures at the Collège de France, 1975-1976* (Macmillan, 2003), 1-21.

[45] Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (1988): 575–99, 176.

[46] Haraway, "Situated Knowledges," 177.

[47] Haraway, "Situated Knowledges," 178.

consequence of quantum mechanics is that, until an observation takes place, a system can exist simultaneously in an almost infinite number of states. Upon observation, however, the observer can observe only one state. Thus the act of observation of a system changes the state of that system itself, making it 'choose' a state that is finally observed. And so with the introduction of quantum mechanics, the inescapability and influence of subjectivity is built into physics. The act of looking holds immense significance, itself subverting determinism.

The analogical application of quantum theory to physics praxis makes it immediately clear that bringing an individual's frame of reference (biases, experiences, expectations, understandings and lack thereof) to a physical observation must – in the most literal of ways – affect the observation itself. Why is it that physicists can accept the axiom of subjectivity inherent to quantum particles while so vehemently rejecting their own subjectivities? Why is it so radical to suggest that racism and sexism have an effect on physical theory? Many of my physicist-respondents expressed frustration with this contradiction. Kimberly voiced regret that, as scientific researchers, "it's okay for us to talk about quantum entanglement, but if you talk about the kind of entanglement you might have with your research subjects if you're a qualitative researcher, that's bad." Erin noted a similar contradiction: it is the same physicists who claim they are more objective because of their fluency in equations and statistics that also hold opinions about socioeconomics and culture that are often completely unfounded. She observed:

> People can feel confident in official documentation and in professional settings making strong statements about minoritized people without having to offer citations that, if they were making the same comments about weak gravitational lensing, we would expect them to offer a citation that backs up their claim. It's complex, because it's also entangled with a very serious disrespect for what the humanities and social sciences do and have to offer to the scientific community, which is like, 'oh, I can look out my office door into the hallway and do the same thing that all of the people in the sociology department did for their seven year dissertation.'

These inconsistencies that Kimberly and Erin expose ask: why can physicists accept subjectivity in the quantum realm, but not in the political, social or personal realms? Ultimately, the strongest renunciation of the myth of the objective physicist may be physics itself, and the mental gymnastics that physicists adopt to preserve their own individual objectivity in the face of irrefutable quantum subjectivity.

The strong refutation of the objectivity myth in science clears the way for analysis of racism and sexism in physics. As shown by scholars of science studies, critical race theory, and quantum mechanics, physics is not an untouchable city-on-a-hill that exists above and beyond the reaches of society. Physicists are individuals who have friends, read things on Facebook, are socialized in a racist-sexist world, and have opinions on what science is most interesting. They do not – cannot! – leave these experiences at the door of their laboratory. Numbers, equations, methodologies and theories, just like the scientists that wield (and are wielded by?) them, are products of their historical, social, and political contexts. In summary, the understanding of objectivity and subjectivity in physics that I have come to adopt is best phrased by Maya:

> The *universe* is objective, but the *constructs* that we've placed to understand it are not. Yes, atoms are atoms and they don't have a particular orientation or political stance. However, what their value is, the way we arrange them, how we use them as either healing or hurting - all of that is political! So, the questions we ask, the things that we privilege, the things that we award; *all of those things are cultural, sitting on top of something that is objective*. There is no way for us even to *investigate* if a question is objective. Because which question you investigate, how long you investigate, what the right answer becomes, all of those things are *subjective*. [emphasis added]

D. Feminist Physics Studies

In disciplinary terms, this project is most aptly situated within a specific sub-field that has arisen out of the syncretism of feminism and science studies: feminist science studies. As biologist and women's studies professor Banu Subramaniam describes the field, scholars of feminist science studies try to "understand the historical and contemporary role of science as well as exploring the

interconnections between science's constructions of race, gender, class, sexuality."[48] Unfortunately, within feminist science studies there are extremely few scholars examining physics, and even fewer Black scholars. Here I review their scattered work spanning epistemic philosophy, science studies, sociology, and anthropology.

The earliest and perhaps most influential of such scholars is Sharon Traweek. In her unprecedented ethnographic work, *Beamtimes and Lifetimes*, Traweek turns an anthropological lens to the spaces, tools, and daily lives of high-energy physicists in both the US – specifically the Stanford Linear Accelerator Facility – and Japan.[49] The ethnography is a successful demonstration of the impact of politics and bureaucracy on physics experiments, and Traweek illuminates the hierarchical, gendered, exclusive, and deeply socialized ways in which physicists interact with each other and 'outsiders.'[50] It is in the third chapter of her book, "Pilgrim's Process: Male Tales Told During a Life in Physics", that Traweek presents her strongest and most groundbreaking analyses regarding the social practices of physicists, describing the social, emotional, and professional evolution of a physicist, from undergraduate to graduate student, post-doc, group leader, statesman and genius. At the undergraduate level, students are indoctrinated by textbooks that idolize white male physics heroes as they learn the basics of physics but are denied "a full disclosure of truth."[51] As graduate students, separations arise by sub-field and students begin to learn how to react, judge, and feel like a physicist. Postdoctoral fellowships are the final sorting process, where theorists are distinguished from experimentalists, written exchanges of information are replaced by more exclusive oral exchanges, hard work goes largely unrewarded, and success only comes about from aggression and

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[48] Evelynn Hammonds and Banu Subramaniam, "A Conversation on Feminist Science Studies," *Signs* 28, no. 3 (2003): 923–44.

[49] Sharon Traweek, *Beamtimes and Lifetimes* (Cambridge, MA: Harvard University Press, 1988).

[50] However, Beamtimes and Lifetimes is a far from perfect text: generalizations abound, sexist and racist narratives are left uncontested, and marginalized communities remain marginalized while questions of race, class, and sexuality are absent. Indeed, the greater context in which these physicists exist and the positionality of both Traweek and her interlocutors remain unexamined.

[51] Traweek, *Beamtimes and Lifetimes,* 80.

risk-taking. Group leaders and statesmen are given a huge share of power to determine which and how physics is done, while geniuses are left to romanticize physics in heavily gendered terms. Traweek observes a trust in the (falsely) meritocratic system at the upper levels ("If they are good, they will get here")[52] despite a frequent sense of betrayal and unfairness among more junior physicists, who describe a double bind between the narrative of collaboration and the reality of competition in the workplace.[53] Overall, Traweek notes that women are excluded narratives of success at every step along the way.[54] While her work is certainly imperfect and only barely feminist, neglecting to examine racial dimensions of physics culture and often reifying faulty (and harmful) narratives of sexism and exceptionalism, *Beamtimes and Lifetimes* laid the foundation for all subsequent 'feminist' studies of physics.

A more recent sociological example is Maria Ong's 2005 study "Body Projects of Young Women of Color in Physics: Intersections of Gender, Race and Science",[55] a longitudinal study that followed 36 female and minority engineering and physical science undergraduates from 1996 to 2004. Ong calls upon Harvey Sacks' theory of "being ordinary", or "something a person does in order to claim the nature and benefits of membership in a particular community," to explain how women of color face pressure and contradiction in their parallel attempts to appear ordinary as women, as scientists, and as humans of color.[56] Indeed, Ong describes how 'ordinariness' in science often amounts to acting as masculine and hyper-confident as well as "objective, universal, and context-free" – requirements that are difficult if not impossible for women and racial minorities to meet.[57] In Ong's analysis of eight years worth of interviews and observations of women of color in physics, she describes two major strategies consciously adopted by these women in order to survive

[52] Traweek, *Beamtimes and Lifetimes,* 91.
[53] Traweek, *Beamtimes and Lifetimes,* 89.
[54] Traweek, *Beamtimes and Lifetimes,* 74-105.
[55] Maria Ong, "Body Projects of Young Women of Color in Physics: Intersections of Gender, Race, and Science." *Social Problems* 52, no. 4 (2005): 593–617. doi:10.1525/sp.2005.52.4.593.
[56] Ong, "Body Projects of Young Women of Color in Physics," 597.
[57] Ong, "Body Projects of Young Women of Color in Physics," 597.

and succeed within physics: fragmentation, or the "splitting [of] oneself to minimize cultural differences between oneself and other members of a community," and multiplicity, or when a student "displays all of her social, cultural, and professional identities at once, without apology."[58] These strategies reflect W.E.B. DuBois' theory of a double-consciousness, and they generally manifest in the women's bodies: their clothing, language, personality, body language, and self-presentation. Most pertinently to this thesis, these strategies were developed in response to a field that imposes and reinforces a masculine and culture-less standard for success.

In a similar work title "Narratives of the Double Bind: Intersectionality in Life Stories of Women of Color in Physics, Astrophysics, and Astronomy," Ong collaborates with Lily Ko, Rachel Kachchaf, and Apriel Hodari to analyze narratives from women of color in the physical sciences. The work presents two themes identified in 10 oral history interviews and 41 extant texts that discuss the experiences of African American, Asian American, Native American, and Latinx/Hispanic women in physics. The first theme is activism, which is found to be motivated by a desire for interpersonal work with other activists to improve the status of physics for those to follow. Activism exists in the form of diversity-focused research, committees, policy-crafting, and education, as well as via mentoring and active recruitment of underrepresented students by women of color in the field. This theme resonates with my own conversations with Black women in astrophysics. In her interview, Amber stressed the importance of sharing her science with her communities, and especially communities of color. She expressed, "For me, it's necessary to use my skills and my access as a scientist in struggles for justice, so I've been pretty involved in my community and community work since grad school. For me, that involvement has helped to sustain me on this path that I'm on, and it gives my science more value." However, activism does not come without sacrifice; Ko et al. found that many women shared that their activist passions might have

[58] Ong, "Body Projects of Young Women of Color in Physics," 600.

prevented them from taking opportunities or receiving promotions that other colleagues were free to benefit from. The second theme that was identified was the importance and challenge of work/life balance for women of color. The struggle of being both mother and scholar is somewhat universal across women in academia, but the researchers stress that little to no research exists exploring the unique work/life challenges faced by women of color.[59]

In a move towards epistemology, condensed matter physicist Amy Bug asks, "Has Feminism Changed Physics?" in her 2003 article in the feminist journal *Signs*. Bug acknowledges that, "to the uninitiated, demographics is the only issue relevant to women in physics."[60] Bug poses many strong questions about the state of physics that draw upon feminist ideologies. Why are there so few women and minorities in physics? Is 'physics-as-is,' gendered and hierarchical as it is, really the best physics that we can produce? Ultimately, Bug restricts her consideration of feminism to the realm of white feminism, and she makes few compelling claims about how physics theory could be concretely changed by even this brand of feminism in the future.[61]

Finally, as a professor of physics and feminist and gender studies at Colorado College, Barbara Whitten has considered the epistemological relationships between feminism and physics. In her article "(Baby) Steps Toward Feminist Physics," Whitten notices, as I have, how parallels between feminism and science are present in the life sciences but absent in the physical sciences. In the few cases she does find (including Bug's), she notes "no interest in, even hostility to, the idea that the content or methods of physics might be changed by feminism."[62] Thus, Whitten very clearly presents an article that, rather than addressing equity or diversity in physics, questions "how the *content* of physics might change if some physicists began to view their research through a feminist

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[59] Lily T. Ko, Rachel R. Kachchaf, Maria Ong, and Apriel K. Hodari, "Narratives of the Double Bind: Intersectionality in Life Stories of Women of Color in Physics, Astrophysics and Astronomy," *AIP Conference Proceedings*, 1513 (AIP Publishing, 2013):222–25.

[60] Amy Bug, "Has Feminism Changed Physics?," *Signs* 28, no. 3 (2003): 882.

[61] Amy Bug, "Has Feminism Changed Physics?"

[62] Barbara L. Whitten, "(Baby) Steps toward Feminist Physics," *Journal of Women and Minorities in Science and Engineering* 18, no. 2 (2012): 116.

lens."[63] Beyond this declaration, however, Whitten shies away from a truly direct confrontation, focusing on a contextual analysis of the 'softer' subfields of biophysics and environmental physics that are founded "not with a set of assumptions and theories," as particle physics or astrophysics might be, "but with a set of problems tied together by their context."[64] Whitten goes on to provide nine examples of intriguing physical projects that she views as feminist, including projects that problematize the distinction between subject and object, that push back against reductionism, that apply physics to human problems, and that restructure how physics is taught. However, her work leaves me still desiring a (Black) feminist analysis of the physics that *does* begin with assumptions and theories. What can feminism say to 'pure,' theoretical physics?

The review presented here of the limited existing literature within feminist physics studies, even incomplete due to my conscious omission of the significant contributions of Evelyn Fox Keller and Karen Barad, makes plain the necessity of this thesis. The feminist study of physics will benefit greatly from the introduction of ethnic studies and Black feminism to expand the white feminist analyses that currently exist. Furthermore, it is high time that feminist physics studies move beyond discussions of context and fully confront the question of content. What will a *Black* feminist analysis of physical *epistemologies* illuminate?

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IV. A Different Kind of Dark Energy

Frequently during the course of this project I have faltered and asked myself whether, in my search for the presence of race and gender in academic physical knowledge, I was searching for something that does not exist. Is it ridiculous to read race and gender into physics? Into theories of gravity, into the standard model, into simulations of supernovae and galaxy mergers? After all, in a strictly literal sense, these fields could not possibly be further from each other. Yet I found continual

[63] Whitten, "(Baby) Steps toward Feminist Physics," 115.
[64] Whitten, "(Baby) Steps toward Feminist Physics," 116.

encouragement in the work of critical race feminism and its usefulness in understanding how race and gender both affect systems and institutions. The words of Swedish law professor Maria Grahn-Farley resonated perhaps most strongly:

> To be able to understand a lack, a norm has to be understood… the norm against which women of color are measuring their arrival is the master norm of white male hegemony…. The master norm itself is invisible; the master norm is of nonsubstance; and the master norm is unreachable because it does not exist as a fixed entity. The master norm is visible only through its effects, through its function. The master norm operates out of a power relationship and its function is to uphold that relationship….Because reason itself is defined out of a power relationship, the relationship between the one who has the power to define reason and the one who does not...will determine what is and what is not reason.[65]

In the context of physics and astronomy, there is undeniably a master norm. The existence of that master norm is reflected not only in the phenotypic composition of every physics and astronomy department in the country, but in the manners of discourse and the assignment of academic value within conferences, presentations, papers, and even elevators. This norm is white male hegemony, and it is obvious in the culture of the physical sciences. Thus, though it may be invisible, nonsubstantive, malleable, and even unreachable, it must also be present among the theories and knowledge produced within these cultures of physics and astronomy. Not gravity, not the standard model, not even supernovae can be divorced from this master norm.

I propose that physics' master norm, in the words of Professor Grahn-Farley, can be understood and even illuminated through analogy with two astrophysical phenomena: dark matter and dark energy. Both of these theories describe physical realities that, by definition, can never be directly observed; rather, they can only be inferred from their effects on their surrounding environment.

First, dark matter was 'discovered' when astronomers realized that there was mass 'missing' across the universe. From many observations of distant galaxies, astronomers observed that stars

[65] Maria Grahn-Farley, "An Open Letter to Pierre Schlag," 146.

orbiting far away from the center of their galaxy were moving too fast; per Newton's law of gravitation, orbital velocity should *decrease* with increasing radius like $^1/r^2$ (where r represents the radius of orbit). Instead, stars were observed to have an *unchanging* velocity despite being further and further away from the galactic centers. One viable way to explain this unexpected velocity is to strengthen the force of gravity these stars experience by adding more mass to pull, mass that is not detectable with usual methods: 'dark matter.' Despite the fact that it is completely invisible to our telescopes and is only observable through its gravitational effects on normal matter, dark matter is a widely accepted theory among astrophysicists.

Secondly, dark energy (a completely independent theory from dark matter despite similar naming) is astrophysicists' current best guess to explain why the universe is expanding at an accelerating rate. In the 1990s, astronomers were observing a particularly well-understood variety of supernova, or stellar explosion, at different distances from Earth. Because the speed of light is constant ($3x10^8$ m/s), a light source's distance from Earth corresponds to the time when it was first produced (e.g. a star one light-year away will be observed on Earth as it appeared one year ago). Thus, astronomers in the 1990s who observed supernovae at different distances were also observing these supernovae at different times in the past. They found that older, more distant supernovae were moving away from Earth at a faster rate than younger, closer supernovae, suggesting that the universe is expanding *and accelerating*. This was not at all expected, as the prevailing theory predicted that the expansion of the universe was *decelerating* due to the attractive force of gravity. Yet dark energy, or a force that counters the attractive force of gravity and instead pushes the universe apart, was 'discovered' through the indirect measurement of supernovae.

Dark energy and dark matter, if they do exist, must exist all around us and even within us. We are surrounded by them and living within them without ever knowing it. Though they are impossible to directly detect, they are known to exist because of a discrepancy between

observational reality and theoretical expectation. Like dark matter and dark energy, the effects of white male hegemony on physics may not be directly observable. To read an equation or theory and understand what role race and gender played in its formation may be an impossible task. Yet through indirect observation of physics, perhaps the master norm can be revealed. Rather than searching for the dinosaur, one must search for the footprint.

How do we render a norm visible? How do we determine the effects of a norm on the reasoning of an academic discipline when that norm has the power to define and redefine even reasoning itself? My answer is twofold. First, center the most marginalized. Like revealing an invisible monster by dousing it with paint, rigorous analysis of the experiences of women of color operating at odds within the white-male dominated structure of physics can illuminate the characteristics of such an invisible culture, in relief. Second, think in the negative spaces. Look for what you cannot see but what you know must exist. Look at what is not there. Who fell through the cracks? What ideas are not being funded? Who is not being hired? What is missed in exclusion?

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V. Evidence for a Sexist-Racist Physics Epistemology

Armed with the unique positionality of the Black female astrophysicist; the theoretical underpinnings of science studies, feminist theory, and critical race theory; and the analytic lenses provided by dark energy and dark matter, I return to my primary research questions:

1. How do the ways in which we consider race, gender, and personhood inform the ways in which we understand the physical world, specifically the academic fields of physics and astronomy?
2. What kind of evidence exists for a racialized or gendered physics?
3. What unique insights does the intersectional Black female perspective bring to this question?

Before I present my answers to these questions, I feel compelled to reiterate a foundational implication of this thesis: the inseparability of physics content from physics culture. The lack of diversity among physicists is evident of a culture that promotes white masculinity, and such a culture

has deep and influential roots. It is not sufficient to observe that there are few Black physicists, declare it a problem of under-representation, and lament that physics does not have more diverse minds to shape its theories. Rather, one must realize that the underrepresentation of women and non-white folks in physics is evidence of a sexist-racist culture that not only excludes non-white non-males, but that also corresponds to a sexist-racist physics epistemology that pervades even physics theory. Culture, demographics, politics, and history mattered and continue to matter in the production of scientific knowledge. The three themes that emerged from my work and which I present here – histories of diverse innovation, colonial mindsets, and masculine mindsets – are direct evidence of the entanglements of physics content with the sexist and racist nature of physics culture.

A. Histories of Diverse Innovation

Perhaps some of the most compelling evidence for the effects that sexism and racism have had upon the physics canon is the trend across physics history in which (1) a minority succeeds in becoming a physicist, and (2) the field subsequently experiences a great advancement. While the dearth of demographic data about physicists until recent decades makes it difficult to definitively prove that innovations in physics coincide with demographic shifts, there is reason to believe that this has happened in physics multiple times. As information scientist Stephen Jackson claims in his article, "Rethinking Repair," it is precisely in moments of breakdown that we learn to see and engage our technologies in new and sometimes surprising ways.[66] How might breaking down or repairing cultures and ideologies in physics lead to new technological, logistical, methodological, epistemological, or social innovations? The histories I present here of Annie Jump Cannon, Albert Einstein, Subrahmanyan Chandrasekhar, and Katherine Johnson suggest that physics benefits from eras of demographic restructuring.

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[66] Steven J. Jackson, "Rethinking Repair," in *Media Technologies: Essays on Communication, Materiality, and Society*, ed. Tarleton Gillespie, Pablo J. Boczkowski, and Kirsten A. Foot (MIT Press Scholarship Online, 2014), 230.

During an era when women were involved in astronomy only as 'computers' that were assigned to supposedly menial and repetitive tasks such as measurement and classification of spectral photographs, Annie Jump Cannon claimed her place as an astronomer. At the Harvard Observatory in the 1890s, Cannon and her female colleagues developed a simplified system for classifying stars based on their spectral features that remains in use, with some modification, to this day. Cannon went on to become the first woman to receive an honorary doctoral degree from Oxford, and the first woman to become an officer of the American Astronomical Society.[67]

Albert Einstein, born to a Jewish family in Germany in 1879, became a physicist in an era shaped by anti-Semitism. In fact, in response to the success of Einstein's Theory of Relativity, Aryan physicists Philipp Lenard and Johannes Stark began to criticize what they called "Jewish Physics" and argued instead for the superiority of a German, "Aryan Physics."[68] Yet even before the rise of the National Socialist party in Germany, Jewish physicists were a rarity. It can be argued that before the 20th century, only three prominent physicists were Jewish: Carl G. J. Jacobi, Heinrich Hertz, and Albert A. Michelson.[69] Since the turn of the 20th century, however, many prominent physicists have been Jewish,[70] and Albert Einstein was one of the first. Einstein's reputation in the academic world precedes him; he completely transformed the ways both academic scientists and civilians interpret space, time, and motion. While of course rejecting the notion that a "Jewish Physics" would be inferior to any other physics, the theory of situated knowledges asserts the undeniably reality that Einstein's upbringing and Jewish culture shaped the theories that he produced.

In 1930 at the age of 19, Indian-born Subrahmanyan Chandrasekhar obtained a scholarship to pursue graduate studies at Cambridge; it was aboard the ship during his travels from India to

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[67] The Editors of Encyclopædia Britannica, "Annie Jump Cannon," *Encyclopedia Britannica*, 2014, https://www.britannica.com/biography/Annie-Jump-Cannon.

[68] See Steven Gimbel, *Einstein's Jewish Science: Physics at the Intersection of Politics and Religion* (JHU Press, 2012).

[69] See "Jews in Physics," *JInfo.org*, accessed April 17, 2017, http://www.jinfo.org/Physics.html.

[70] Intriguingly, the rise in Jewish immigrants to the United States in the 1930s has been found to correlate with a 31% increase in U.S. inventions. See Petra Moser, Alessandra Voena, and Fabian Waldinger, "German-Jewish Emigres and U.S. Invention," SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, December 21, 2013).

England that he derived what is now known as the Chandrasekhar limit, or the maximum mass a star can accumulate before collapsing onto itself and becoming either a superdense neutron star or a black hole. Though his research was controversial at the time for its suggestion of the existence of black holes, which were long considered a natural impossibility, the Chandrasekhar limit is now considered fundamental to astrophysics and is taught to students at almost every level.[71] However, Chandrasekhar was the very first Indian physicist to give astrophysics lectures, and he forged his successful career in the face of discrimination in the UK.[72]

Finally, consider the now-Hollywood-famous Katherine Johnson, a 'hidden figure' who worked at what is now NASA Langley during the post-WWII era. Johnson is the very first known Black woman to become a professional physicist.[73] She worked at NACA (now NASA) with a team of Black women who were, in the tradition of Annie Jump Cannon, labeled as "computers" and whose work was deemed inferior to that of the scientists and engineers. Yet because of her determination and mathematical talent in analytical geometry, Johnson became a key player in the space race. She calculated the orbital trajectory for Alan Shepard, the first American to reach space, and went on to calculate launch windows and trajectories for the later Apollo moon missions. While some might categorize Johnson's achievements as engineering rather than physics, they required a supreme understanding of aerodynamics and gravitational physics, and ultimately led to not only national but global technological feats that have shaped humans' relationship with space and space travel.[74]

These individuals, especially when considered together, exemplify the epistemological cost of excluding non-normative individuals from pursuing physics. Where would physics be today if Albert

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[71] Eugene N. Parker, "Subrahmanyan Chandrasekhar: 1910-1995," in *Biographical Memoirs* (National Academies Press, 1997), 29–50.

[72] Arthur I. Miller, "Creating the Measure of Chandrasekhar's Life," Physics Today 59, no. 9 (September 1, 2006): 10–12, doi:10.1063/1.4797423.

[73] Valentine and Tucker, "*African American Women in Physics*.

[74] Margot Lee Shetterly, *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race* (New York, NY: William Morrow, 2016).

Einstein had been rejected or discouraged to become a physicist because of his Jewish ancestry? Where would astronomy be if Annie Jump Cannon had never been allowed to publish her classification scheme, or if Chandrasekhar was never able to travel across the world and develop his theories? Without Katherine Johnson and NASA's Black computers, what would be the legacy of the United States in the space race? Or, conversely: where might the fields of physics, astronomy, or space travel be today if they had *never* systematically excluded and devalued women and people of color? What if women had been prominent in astronomy before 1890, if Indian physicists had been respected before the 20th century, or if Black women could have pursued graduate study in physics before 1970? Of course, it is impossible to know the answers to these questions. Yet the historical correlation between increased diversity and increased innovation hints at what might reside in the absence, what has been missed in exclusion, what effects racism and sexism have had upon physics.

B. Colonial Mindsets

All of Western science has been shaped by its roots in European colonization, and physics is no exception. The historical legacy of colonization in science is perhaps more obvious in the context of the lives of slaves and so-called Third World peoples that were historically exploited to create the wealth of Western countries, and thus the comfortable existence that enabled the academic European elite to produce knowledge between the 16th and 20th centuries (though this exploitation, in many ways, continues today). Beyond the material effects of colonization, however, ideological echoes of colonization exist within the physical sciences. The white/male physicist today, even while discussing purely physical phenomena, is often reifying their role as colonizer.

In the final chapter of his foundational work, *Science in Action*, Bruno Latour presents a theory for how scientific knowledge is created. He argues that knowledge creation occurs in 'centres of calculation,' to which knowledge is brought and accumulated from distant locations, and within which knowledge is processed and refined into theory. Central to Latour's theory of centers is a

power hierarchy between knowledges and the domination of one group over another. Within Latour's rhetoric is a disrespect for indigenous knowledge, which he casually mentions is so different from Western epistemologies as to "justify a deep distinction in cognitive abilities."[75] However this exists, too, within his theorization. In the anecdotal context of French mapmakers learning the geography of an island in the eastern Pacific from its native occupants, Latour frames the entire exchange as a battle for power. At first, the natives are 'stronger' than the researchers because of their geographic knowledge; when different explorers later return to the island with the map made by the first researchers, the natives are 'weaker' and are now susceptible to 'domestication.' This anecdote is then universalized to encompass all of scientific knowledge production. For Latour, the acts of collection and inscription become acts of technological domination. For example, he laments that "nothing dominates us more than the stars," and then celebrates how Tycho Brahe's creation of the telescope and the star-chart became a means for the man to reverse the power dynamic between the human and the celestial.[76]

Latour's philosophy regarding science, though articulated by someone who is by discipline a non-scientist, reflects observations that both my Black women respondents and I have recognized in physics today. The entire structure of modern science is attempting a sort of epistemological domination over the natural world. Modern Western scientific ideology seems to be centered on values of consumption; we desire to fully understand something simply so we can set it aside and turn our attention to the next thing. Basic science derives satisfaction from the possession of knowledge, from mastery over the natural.

Within astronomy, as the study of exoplanets has developed in the past decades, discussions of colonization have transitioned from the sociohistorical into the practical. The ways in which astronomers today discuss extraterrestrial life and planets around other stars is not only colonial in

[75] Latour, *Science in Action*, 216.
[76] Latour, *Science in Action*, 215-227.

nature; it is a colonizer's perspective. When considering the existence of extraterrestrial life, the chance of humans colonizing another planet is, for all we know, comparable to the chance of Earth being colonized by another planet. This possibility is not often reflected in research methods - take, for example, the 29 interstellar radio messages[77] that have been broadcast into space from Earth between 1974 and 2016, announcing our existence for anyone or anything that might be listening. My respondents and I argue that it is not simply a coincidence that the astronomers leading such missions are of the same people who historically viewed the Americas, the Caribbean, the Pacific, the entire African continent, etc. as ripe for their exploitation. Amber voiced insightful concern about the influence of colonial history and culture on modern astronomy:

> I think of the fascination with exoplanets - I suppose any culture or society has that question about who and what else is out there, is there other life out there - but I just wonder if we would be approaching the problem in the same way? ... People in the SETI [Search for Extraterrestrial Life] community often talk about colonizing other planets, or extracting resources, even, from other bodies in our solar system. I think that sort of mentality is very steeped in history and very steeped in, very reflective of, the main people who are practicing SETI: white men, like [in] the majority of sciences. And that comes with a lot of history and cultural baggage… My gut tells me that other cultures, other peoples, they approach science differently.

Indeed, science need not be colonial to be successful. The desire to understand the natural world need not be consumptive, exploitative, and possessive in nature. Modern science has become this way as a result of its saturation within Western cultures and Western values, but as Amber went on to imagine, there could be other alternatives:

> I don't think it's a foregone conclusion that every culture, equipped with the same knowledge of physics would have used it to the same ends, to send men to the moon or to create and drop bombs on people or to create iPhones or whatever… Many of the questions of science are often driven by the needs and the goals of a society in which the individual scientists exist, so that can't be divorced from the culture and the values and the history of the society.

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[77] As counted in the Wikipedia entry "Active SETI:" https://en.wikipedia.org/wiki/Active_SETI

In fact, the sciences of indigenous cultures are perfect examples of alternative sciences that often do not exhibit the consumptive and exploitative behavior that is seen among Western scientists. Hawaiian astronomers desire to understand the sky for the purpose of navigation,[78] and the Native Americans of the Great Plains explore botany for the purpose of food and medicine.[79] In these communities, science is another arm of a symbiotic and respectful relationship with the natural, rather than a quest for mastery of it.

I think of the Large Hadron Collider at CERN, a 17 mile-long particle accelerator buried deep beneath France and Switzerland and the largest machine ever built by humans:. I think of the Hubble Space Telescope, launched beyond the atmosphere atop a rocket and staring into deep space from low Earth orbit since 1990. I think of the IceCube Neutrino Observatory, an array of detectors drilled deep into a cubic kilometer of the Antarctic ice. Each of these facilities has been the result of international scientific collaborations, and has led to great discoveries and advances in their respective fields that are certainly worthy of celebration and appreciation. Yet each of these facilities has also been the result of colonialist cultures that value the collection of basic scientific knowledge about fundamental particles and distant galaxies over the consumption of environmental and human resources necessary for their creation and operation. Especially in the context of these feats of innovation, I do not attempt to make a value judgment; I rather hope to draw attention to the complex entanglement between colonialist values and modern science.

C. Masculine Mindsets

Even after the increased attention that has been given to increasing diversity in physics over the past decades, the field is still completely dominated by men. As noted in Section I.A, the United States physics professoriate in 2012 was over 83% men - and that number is certainly a historic low.

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[78] See David Lewis, *We, the Navigators: The Ancient Art of Landfinding in the Pacific*, ed. Derek Oulton, 2 edition (Honolulu: University of Hawaii Press, 1994).

[79] See Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants* (Milkweed Editions, 2015).

Centuries of exclusively male physics have affected the ways in which the physical sciences have developed. Indeed, women have observed masculinity to be inscribed into physical knowledge in the form of obsessions with power and size, with control, and with heroism.

Sharon Traweek's 1988 anthropology of Stanford physicists revealed not only the highly cultured and subjective nature of physics, but also its indoctrination of stereotypically masculine behaviors. Traweek documents a widespread gendering of language, including a universal depiction of scientists as male while nature, naturally beautiful and destined for scientists' domination, is female.[80] Her linguistic observations mirror my personal observations of the feminine gendering of mathematical theory, which in my experience are so often referred to as 'elegant' and 'beautiful,' fit for manipulation by the masculine master scientist.

Furthermore, by holding up the social trends of physicists to the anthropological light, Traweek revealed the truly dominant, sometimes surprisingly so, roles of emotion, relationships, and personality within physics. Especially as postdocs, personality becomes a make-or-break trait. Two workers at SLAC describe successful postdocs as confident and "aggressive" with a certain "son-of-a-bitchness;" "blunt, bright bastards" make it, while those who are "too nice" will fail.[81] Of course, this is not explicitly said to the postdocs; physicists portray themselves to others as collaborative team players, creating a double bind. One of my respondents, Erin, echoed this observation, speaking of her miserable experience with a widely disliked post-doc advisor that no one warned her of, leaving her alone to tough out an avoidable situation. Especially when compared to the more democratic, bottom-up structure of physics in Japan, the combative and aggressive nature of American physics is striking.

In her article, "Objectivity or Heroism? On the Invisibility of Women in Science," Naomi Oreskes exposes the overlap between masculine ideals, scientific ideals, and heroic ideals. She points

[80] Traweek, *Beamtimes and Lifetimes*.
[81] Traweek, *Beamtimes and Lifetimes*, 87-8.

out that heroism saturates the images of the scientist-explorer, the self-experimenter, the lone researcher staying late in the lab and risking it all for the sake of their data. Oreskes argues that it is this necessarily masculine ideal of the hero-scientist, more so than the more gender-fluid ideal of the objective scientist, that served to exclude women from scientific belonging; the "heroic ideology renders the female scientist invisible."[82] While Oreskes' analysis focused on the 1920s and 1930s, I still see heroic images today in conceptions of the ultra-dedicated laboratory researcher conducting dangerously supercooled or superheated experiments, the particle physicist daringly colliding hadrons at relativistic speeds, or the astronomer journeying to a telescope atop the summit of a remote mountain. How do these images shape the work that is ultimately conducted by hero-scientists? If such work invoked narratives of drudgery and tedium rather than the egoistic narratives of exceptionalism and bravery, would it be pursued at all?

Positivism, or the theory that experiment and observation are the sole means by which to produce knowledge, in the physical sciences also reflects masculinity in the preoccupation with control. As STS scholars Tine Kleif and Wendy Faulkner wrote, "technology is a gender-authentic and gender-available avenue for those men who particularly crave certainty because technology appears more certain, easier to understand, and easier to master than other worlds they inhabit."[83] One of my respondents, Ella, voiced the same observation of physicists:

> I think that [my colleagues are] really really attached to the positivist view that science can solve everything... one of the reasons that they got into the physical sciences is that they wanted things to have rules because the world is just too complex. People are too complex; their emotions are all over the place; they're unpredictable. And so they're actually attracted to the physical sciences because it seems to have more control.

The development of atomic, gravitational, radiative, or electromagnetic theory is, at its root, a desire to condense the complexities of the natural world to reduced and controlled concepts.

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[82] Naomi Oreskes, "Objectivity or Heroism? On the Invisibility of Women in Science," *Osiris* 11 (1996): 111.

[83] Tine Kleif and Wendy Faulkner, "'I'm No Athlete [but] I Can Make This Thing Dance!' Men's Pleasures in Technology," *Science, Technology, & Human Values* 28, no. 2 (2003): 296.

Finally, Amber shared a fascinating observation regarding the masculine nature of astronomical concepts, examining and exposing how deeply ingrained masculine values are in astronomical theory:

> Size and power are really important in our culture. In our lectures to students and in our 'Intro to Astronomy' textbooks, the power of celestial objects like the sun, other stars, quasars, supernovae, etc.… they're often described in really violent and destructive terms. Sometimes you'll hear people talk about black holes like monsters, or you'll describe the interior of stars as 'giant nuclear furnaces,' I've heard that phrase a number of times. And I think, 'why these comparisons?' When we teach intro to astronomy, we do order-of-magnitude exercises, right, and these are really useful to gain a sense of perspective about how vast the universe is. But this exercise often ends in a value judgment that says, 'because humans are so small and young compared to the rest of the universe, we are therefore puny and insignificant.' And I wonder if this is the white male way of looking at the world? I'm not sure, but how could it not influence how science is practiced, when the people practicing it think that the universe is this violent, monstrous place, and we're all really insignificant?

This observation pushed me to ask myself: how is a star different from a sunflower? They are alike in the labor of growth, the majesty of their maturity, and the genealogical gift they ultimately leave behind upon their death. Just as the flower bursts forth from the bud, a star is born from the marriage of matter. And just as a flower dies and leaves behind its seeds, it is the very death of the star, the supernova, that forges complex nuclei and creates the richness of the elements. In the famous words of Carl Sagan, "We are made of starstuff." So why is one viewed as gentle and the other as vicious? One blooms while the other explodes?

Indeed, the omnipresent correlation of size with power within astronomical rhetoric echoes an odd variety of phallocentrism. It is not an objective truth but rather a patriarchal construction that smallness correlates with powerlessness or insignificance. Furthermore, by framing the universe as a threatening and overpowering place, astronomers sets up a prerogative to, yes, dominate the cosmos as a matter of human self-preservation. Indeed, this language is not too different from the language of 'savagery' that was so frequently used to justify the conquering of Native Americans and Africans. But, like the native populations of the Americas, the fiery nature of stars and distant

celestial bodies poses no immediate threat to humans; on the contrary, it is the nuclear fusion that occurs within stars that is the energy source for all life on Earth. One could just as rationally study astrophysics while viewing the relationship between humans and the universe as symbiotic. How has astronomy's obsession with power and size affected the theories it has produced? Would astronomers be so preoccupied with Black holes and quasars if they were not presented as violent and powerful objects? What less sensational research topics might have been eclipsed?

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VI. Conclusions and Moving Forward

Where are race, gender, and identity in physics? They are everywhere: in the genealogy of physics theory, in the heroes the field worships, in the sub-fields and topics that are deemed interesting, in the politics of success, in our understandings of physical phenomena, in the very foundations of the scientific method. The Black women in physics that I interviewed demonstrated a profound understanding of this omnipresence, as Maya exemplifies:

> Race, gender, and identity inform the shaping of any knowledge. It's just a matter of which of those identities have to be named...It happens in basically anything that touches the work, the production of the work, the awarding of the work - all of it is informed by race, gender, and identity. It's just more pernicious because we never talk about it.

As I have shown in this thesis, the effects of a racist-sexist society and culture are particularly evident in the theoretical genealogies of white supremacy, colonialist ideologies, and masculine ideologies. However, this work presents only a preliminary analysis of the wide and deep influence of race, gender, and identity on physics knowledge. Much, much work remains to be done at the scholarly intersection of physics, science studies, feminist studies, and ethnic studies.

Following the example of Barbara Whitten, who presents nine feminist physics projects in her article "(Baby) Steps toward Feminist Physics,"[84] I propose the following five guidelines for

[84] Whitten, "(Baby) Steps toward Feminist Physics."

creating an anti-racist feminist physics. This list is not meant to be exhaustive, but rather to encourage creative imaginations of an anti-racist feminist future for physics, and of innovative means to achieve such futures.

1. *Teach science and technology studies alongside science and technology.* What if every aspiring physicist struggled to interpret Donna Haraway's theory of human subjectivity alongside Griffith's theory of quantum mechanical subjectivity? What if an entire generation of scientists learned to question claims of objectivity and value diverse perspectives? What if future scientists learned to value the contributions of sociologists, philosophers, and historians to understanding science, just as they learn to value the contributions of the scientists themselves?
2. *Build a physics professoriate that is fluent in social justice,* either by hiring socially aware scientists (of whom there are many, if you look), or by encouraging faculty to attend social justice education workshops. Teach scientists to see white supremacy and sexism in each other, just as they are taught to see statistical significance in data. Be aware of the influence of unconscious biases, and take steps to combat personal shortcomings - especially in admissions and hiring. Beyond creating more empathic and socially responsible physics departments, such a physics department would certainly enhance creative problem solving with the widened lens.
3. *Critically examine the origins and costs of scientific work.* Latour's theory of blackboxes of technoscience serves as a warning: do we, as scientists, truly understand the work we are doing? Too infrequently do we reexamine why machinery and methodologies are used; too frequently do we assume the accuracy of the work we build upon. Deepening critique of scientific origins might unearth forgotten alternative methods and theories, as well as unearthing forgotten scientific histories of inequality and exploitation. Furthermore, despite

popular belief, science is not intrinsically benign. Historically, science has been used to directly justify oppression (e.g. craniometry and eugenics). However, science has also been indirectly responsible for upholding and benefiting from oppressive systems, such as centuries of the slave economy and the use of disenfranchised populations as research subjects. As scientists we must ask, "At whose expense?"

4. *Embrace interdisciplinarity.* Work such as this thesis would not be possible if not for my mentors' encouragement for me to straddle apparently impenetrable disciplinary boundaries, bringing ethnic studies to the physical sciences. Yet this is true beyond ethnic studies; for instance, my respondent Amber lamented the separation of science from art and history. Both theorization and visualization would be enriched from understanding astronomy and physics in aesthetic and sociopolitical terms. What other disciplines are absent from the conversation?
5. *Encourage acknowledgement of positionality and subjectivity in physics.* The question of diversity in physics is so often framed as an expansion of what kinds of bodies are valued, while maintaining the ideology of physics as untouchable. If we, instead, expand what kinds of perspectives and ideologies are valued, we will open ourselves up to more diverse physicists and richer physics (and, secondarily, the variety of bodies that facilitate such diversity).

What does a Black feminist physics look like? Does it even exist? Many argue that the ultimate result of the anti-racist movement is the eventual eradication of capitalism, as the capitalist system inevitably reifies large-scale socioeconomic inequality. Is the ultimate result of an anti-racist movement in science the eventual eradication of basic physics and astronomy: hierarchical academic fields often without human application that consume resources and minds? Or less radically, perhaps an anti-racist science requires the gross deprioritization of physics and astronomy, in return for elevation of work that directly benefits humanity? I struggle to adopt a more optimistic view. What if

the study of the universe were to become truly universal? What if an anti-racist feminist physics came into existence, inspiring indiscriminately and uniting in curiosity? Perhaps astronomy and physics could truly become the universal intersection - the only fields in which all humans are connected by our innate desire to understand what we are made of and where we come from.

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