

A Different Kind of Dark Energy: *Evidence for Placing Race and Gender in Physics*

Lauren Marietta Chambers

Space Telescope Science Institute – | – lauren.m.chambers96@gmail.com

Astro2020 Decadal Survey

APC White Paper: Statement of the Profession Consideration*

July 2019

* This white paper is a modified version of my 2017 undergraduate thesis, advised by Prof. Hazel Carby and completed in fulfillment of the requirements for my Bachelor of Science in African American Studies from Yale University (while also completing a BS in Astrophysics). The thesis received the departmental William Pickens Prize, and is available in its entirety here:

https://laurenmarietta.github.io/pdfs/Chambers_ADifferentKindOfDarkEnergy.pdf.

I. Key Issue and Overview of Impact on the Field:

In 2015, the Chief Justice of the Supreme Court John Roberts asked, “What unique perspective does a minority student bring to a physics classroom? ... what [are] the benefits of diversity are in that situation?” 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 glorification of the physical sciences as a meritocratic bastion of objectivity: physics occurs independently of physicist. Yet when one views such ideals through the critical lens of ethnic studies, the entire notion of objectivity breaks down. 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. 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?

This white paper is a modified version of my 2017 undergraduate thesis in African American Studies.[†] This work critically analyzes 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. Ultimately, I present evidence for a sexist-racist physics epistemology, and I offer guidelines for moving towards an anti-racist feminist physics.

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

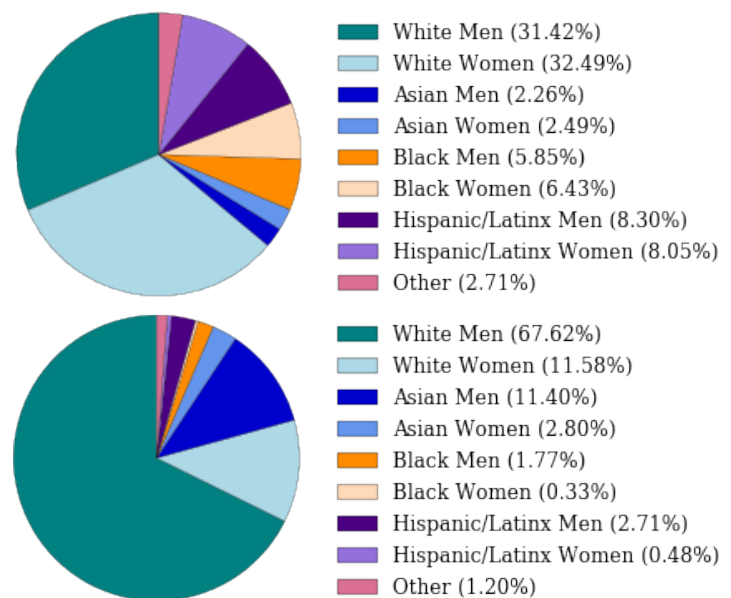


Figure 1. Populations of the United States (above) and the national physics professoriate (below) in 2012, broken down by racial and gender identifications. Note that the ‘Other’ category encompasses Native American, Pacific Islander, and non-Hispanic multiracial individuals. Data from the American Institute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

[†] The thesis is available in its entirety here:

https://laurenmarietta.github.io/pdfs/Chambers_ADifferentKindOfDarkEnergy.pdf.

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.¹ Especially when compared to the United States population (see Figure 1 above), 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.² 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.

B. Critiques of Other Sciences

Thinking of intersections between the fields of African American studies and astronomy or physics, few examples come to mind. In my experience operating in both astrophysics and African American studies communities, three examples – Black celebrity-physicists, physical analogies (e.g. Planck’s Law as a metaphor for intersectionality), 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. 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. 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.

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 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 and astronomers 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?

II. The Black Female Voice

Though I originally avoided the exploration of the social and interpersonal realities of minority status in physics, 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 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.³ 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 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 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."⁴ 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.⁵ Existing at the intersection of multiple marginalized identities, women of color possess an (unjustly) keen perception of both racism and sexism. In an expansion 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.

Though they are just 0.33% of the national physics professoriate,⁶ Black women astrophysicists do, in fact, exist. According to 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 1972.⁷ I interviewed five of these women – three postdocs and two research scientists – about their experiences in physics, their perceptions of objectivity, and their observations of sociocultural influence in physics. 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 work, informing my thinking about every aspect. As such, the results of the five interviews are referenced in this white paper, though I do not use names to maintain the women's anonymity.

III. A Different Kind of Dark Energy

Frequently during the course of this work, I 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, the standard model, simulations of supernovae and galaxy mergers? After all, the kinds of knowledge produced in each of these fields could not possibly be further from each other. Yet I found continual 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.⁸

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 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?

IV. Evidence for a Sexist-Racist Physics Epistemology

Equipped 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.⁹ 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.

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.¹⁰

Albert Einstein, born to a Jewish family in Germany in 1879, became a physicist in an era shaped by anti-Semitism and with few Jewish physicists.¹¹ 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.”¹² Of course, Einstein’s reputation precedes him; he completely transformed the

ways both academic scientists and civilians interpret space, time, and motion – and it is undeniable that Einstein’s upbringing and Jewish culture shaped the theories that he produced.

In 1930 at the age of 19, Indian-born Subrahmanyan Chandrasekhar 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 – a concept that is now considered fundamental to astrophysics and is taught to students at almost every level.¹³ 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.¹⁴

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.¹⁵ 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.¹⁶

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 Einstein had been rejected or discouraged to become a physicist because of his Jewish ancestry, if Annie Jump Cannon had never been allowed to publish her classification scheme? 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. This wealth in turn created 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. Central to Latour’s theory is a power hierarchy between knowledges and the domination of one group over another. 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 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 messages¹⁷ 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.

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. 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,¹⁸ and the Native Americans of the Great Plains explore botany for the purpose of food and medicine.¹⁹ 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 §I.A, the United States physics professoriate in 2012 was over 83% men - and that number is certainly a historic low. 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.²⁰ 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.²¹ Of course, this is not explicitly said to the postdocs; physicists portray themselves to others as collaborative team players, creating a double bind. Especially when compared to the more democratic, bottom-up structure of physics in Japan (another location where Traweek studied a high-energy physics lab), 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 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.”²² While Oreskes’ analysis focused on the 1920s and 1930s, I still see heroic images today in conceptions of 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?

Finally, one of my respondents 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?”

Her insight led me to an illuminating, if odd, analogy: 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 set 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?

V. Conclusions and Strategic Plan

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 one woman’s response 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,”²³ I propose the following five guidelines – a strategic plan – for 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 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 trends and 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 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, one of my respondents 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? 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."²⁴ And so, heeding this call, I conclude with a 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?" 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?

Endnotes

-
- ¹ Rachel Ivie, Garrett Anderson, and Susan White, “African Americans & Hispanics among Physics & Astronomy Faculty,” *American Institute of Physics*, July 2014.
- ² 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/trendspahds-p-12.2.pdf>.
- ³ Maria Grahn-Farley, “An Open Letter to Pierre Schlag,” in *Critical Race Feminism*, ed. Adrien Katherine Wing (New York: New York University Press, 2003).
- ⁴ Richard Delgado, “Storytelling for Oppositionists and Others: A Plea for Narrative,” *Michigan Law Review* 87, no. 8 (1989): 2411–41, doi:10.2307/1289308.
- ⁵ 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.
- ⁶ Ivie et al., “African Americans & Hispanics among Physics & Astronomy Faculty,” July 2014.
- ⁷ Jami Valentine and Jessica Tucker, “The Physicists,” *African American Women in Physics*, accessed March 27, 2017, <http://aawip.com/aawip-members/>.
- ⁸ Maria Grahn-Farley, “An Open Letter to Pierre Schlag,” 146.
- ⁹ 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.
- ¹⁰ The Editors of Encyclopædia Britannica, “Annie Jump Cannon,” *Encyclopedia Britannica*, 2014, <https://www.britannica.com/biography/Annie-Jump-Cannon>.
- ¹¹ See “Jews in Physics,” *JInfo.org*, accessed April 17, 2017, <http://www.jinfo.org/Physics.html>.
- ¹² See Steven Gimbel, *Einstein’s Jewish Science: Physics at the Intersection of Politics and Religion* (JHU Press, 2012).
- ¹³ Eugene N. Parker, “Subrahmanyan Chandrasekhar: 1910-1995,” in *Biographical Memoirs* (National Academies Press, 1997), 29–50.
- ¹⁴ 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.
- ¹⁵ Valentine and Tucker, “*African American Women in Physics*.”
- ¹⁶ 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).
- ¹⁷ As counted in the Wikipedia entry “Active SETI.” https://en.wikipedia.org/wiki/Active_SETI
- ¹⁸ 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).
- ¹⁹ See Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants* (Milkweed Editions, 2015).
- ²⁰ Traweck, *Beamtimes and Lifetimes*.
- ²¹ Traweck, *Beamtimes and Lifetimes*, 87-8.
- ²² Naomi Oreskes, “Objectivity or Heroism? On the Invisibility of Women in Science,” *Osiris* 11 (1996): 111.
- ²³ Whitten, “(Baby) Steps toward Feminist Physics.”
- ²⁴ Derrick Bell, “Who’s Afraid of Critical Race Theory?,” *University of Illinois Law Review*, no. 1995 (n.d.): 893–910.

 Bibliography

- Alesina, Alberto, 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.
- Bell, Derrick. "Who's Afraid of Critical Race Theory?" *University of Illinois Law Review*, no. 1995 (n.d.): 893–910.
- Boghossian, Paul A. "What the Sokal Hoax Ought to Teach Us." In *A House Built on Sand: Exposing Postmodernist Myths about Science*, edited by Noretta Koertge, 23–31. New York: Oxford University Press, 1998.
- Bonilla-Silva, Eduardo. *Racism Without Racists: Color-Blind Racism and the Persistence of Racial Inequality in America*. Rowman & Littlefield Publishers, Incorporated, 2014.
- Bowker, Geoffrey C., and Susan Leigh Star. "Some Tricks of the Trade in Analyzing Classification." In *Sorting Things Out: Classification and Its Consequences*, 33–50. MIT Press, 2000.
- Bug, Amy. "Has Feminism Changed Physics?" *Signs* 28, no. 3 (2003): 881–99. doi:10.1086/345323.
- Caplar, Neven, Sandro Tacchella, and Simon Birrer. "Quantitative Evaluation of Gender Bias in Astronomical Publications from Citation Counts." *arXiv:1610.08984 [Astro-Ph, Physics:physics]*, October 27, 2016.
- Carby, Hazel V. "The Multicultural Wars." *Radical History Review* 1992, no. 54 (September 21, 1992): 7–18. doi:10.1215/01636545-1992-54-7.
- Crenshaw, Kimberle. "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.
- Delgado, Richard. "Storytelling for Oppositionists and Others: A Plea for Narrative." *Michigan Law Review*, 87 (1989): 2411:2441.
- Elshakry, Marwa. "When Science Became Western: Historiographical Reflections." *Isis* 101, no. 1 (2010): 98–109. doi:10.1086/652691.
- Fisher v. University of Tex. at Austin*, 2015.
https://www.supremecourt.gov/oral_arguments/audio/2015/14-981.
- Fleck, Ludwik. *Genesis and Development of a Scientific Fact*. University of Chicago Press, 2012.
- Foucault, Michel, and François Ewald. "*Society Must Be Defended*": *Lectures at the Collège de France, 1975-1976*. Macmillan, 2003.
- Gimbel, Steven. *Einstein's Jewish Science: Physics at the Intersection of Politics and Religion*. JHU Press, 2012.
- Grahn-Farley, Maria. "An Open Letter to Pierre Schlag." In *Critical Race Feminism*, edited by Adrien Katherine Wing, 140–148. New York: New York University Press, 2003.
- Hammonds, Evelynn, and Banu Subramaniam. "A Conversation on Feminist Science Studies." *Signs* 28, no. 3 (2003): 923–44. doi:10.1086/345455.
- Haney-López, Ian. "Social Construction of Race: Some Observations on Illusion, Fabrication, and Choice, The." *Harvard Civil Rights-Civil Liberties Law Review*, January 1, 1994, 1.
- Haraway, Donna Jeanne. (1988) "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14: 575–99.
- Harding, Sandra G. *Is Science Multicultural?: Postcolonialisms, Feminisms, and Epistemologies*. Race, Gender, and Science. Bloomington, Ind: Indiana University Press, 1998.
- Huth, John. "Latour's Relativity." In *A House Built on Sand: Exposing Postmodernist Myths about Science*, edited by Noretta Koertge, 181–92. New York: Oxford University Press, 1998.

-
- Isler, Jedidah C. "On Planck's Law, Blackbodies and the Physics of Diversity." *STATUS: A Report on Women in Astronomy*, June 2014.
- _____. "The 'Benefits' of Black Physics Students." *The New York Times*, December 17, 2015. <http://www.nytimes.com/2015/12/17/opinion/the-benefits-of-black-physics-students.html>.
- Ivie, Rachel, Garrett Anderson, and Susan White. "African Americans & Hispanics among Physics & Astronomy Faculty." *American Institute of Physics*, July 2014. <https://www.aip.org/statistics/reports/african-americans-hispanics-among-physics-astronomy-faculty-0>.
- Ivie, Rachel, Susan White, Arnell Garrett, and Garrett Anderson. "Women Among Physics & Astronomy Faculty." *American Institute of Physics*, August 2013. <https://www.aip.org/sites/default/files/statistics/faculty/womenfac-pa-10.pdf>.
- Jackson, Steven J. "Rethinking Repair." In *Media Technologies: Essays on Communication, Materiality, and Society*, edited by Tarleton Gillespie, Pablo J. Boczkowski, and Kirsten A. Foot, 221–39. MIT Press Scholarship Online, 2014.
- Jorde, Lynn B., and Stephen P. Wooding. "Genetic Variation, Classification and 'Race.'" *Nature Genetics* 36 (October 26, 2004): S28–33. doi:10.1038/ng1435.
- Latour, Bruno. "A Relativistic Account of Einstein's Relativity." *Social Studies of Science* 18, no. 1 (February 1, 1988): 3–44. doi:10.1177/030631288018001001.
- _____. *Science in Action: How to Follow Scientists and Engineers Through Society*. Harvard University Press, 1987.
- Lawrence, Charles R. "The Id, the Ego, and Equal Protection: Reckoning with Unconscious Racism." *Stanford Law Review* 39, no. 2 (1987): 317–88. doi:10.2307/1228797.
- Kimmerer, Robin Wall. *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Milkweed Editions, 2015.
- Kitcher, Philip. "A Plea for Science Studies." In *A House Built on Sand: Exposing Postmodernist Myths about Science*, edited by Noretta Koertge, 32–56. New York: Oxford University Press, 1998.
- Kleif, Tine, 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): 296–325.
- Ko, Lily T., Rachel R. Kachchaf, Apriel K. Hodari, and Maria Ong. "Agency of Women of Color in Physics and Astronomy: Strategies for Persistence and Success." *Journal of Women and Minorities in Science and Engineering* 20 (2014): 171–95. doi:10.1615/JWomenMinorScienEng.2014008198.
- Ko, Lily T., 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." In *AIP Conference Proceedings*, 1513:222–25. AIP Publishing, 2013. doi:10.1063/1.4789692.
- Kuhn, Thomas S., and Ian Hacking. *The Structure of Scientific Revolutions: 50th Anniversary Edition*. Fourth Edition edition. Chicago ; London: University Of Chicago Press, 2012.
- Marecek, Jeanne, Mary Crawford, and Danielle Popp. "On the Construction of Gender, Sex, and Sexualities." In *The Psychology of Gender*, edited by Alice Hendrickson Eagly, Anne E. Beall, and Robert J. Sternberg, 2nd ed., 192–216. New York: Guilford Press, 2004.
- Miller, Arthur I. "Creating the Measure of Chandrasekhar's Life." *Physics Today* 59, no. 9 (September 1, 2006): 10–12. doi:10.1063/1.4797423.

-
- Moser, Petra, Alessandra Voena, and Fabian Waldinger. "German-Jewish Emigres and U.S. Invention." SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, December 21, 2013. <https://papers.ssrn.com/abstract=1910247>.
- Mulvey, Patrick J., and Starr Nicholson. "Trends in Physics PhDs." *American Institute of Physics*, February 2014. <https://www.aip.org/sites/default/files/statistics/graduate/trendspahds-p-12.2.pdf>.
- Nelson, Alondra. *The Social Life of DNA: Race, Reparations, and Reconciliation After the Genome*. 1 edition. Beacon Press, 2016.
- Ong, Maria. "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.
- Ong, Maria, Carol Wright, Lorelle L. Espinosa, and Gary Orfield. "Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering, and Mathematics." *Harvard Educational Review* 81, no. 2 (2011): 172–209.
- Oreskes, Naomi. (1996) "Objectivity or Heroism? On the Invisibility of Women in Science." *Osiris* 11: 87-113.
- Parker, Eugene N. "Subrahmanyan Chandrasekhar: 1910-1995." In *Biographical Memoirs*, 29–50. National Academies Press, 1997.
- Pitney, Nico. "Meet The 63rd Black Woman In American History With A Physics Ph.D." *The Huffington Post*, 48:05 400AD. http://www.huffingtonpost.com/2015/06/24/chanda-prescod-weinstein_n_7574020.html.
- Prescod-Weinstein, Chanda. "The Physics of Melanin: Science and the Chaotic Social Construct of Race." *Bitch Media*.
- Shetterly, Margot Lee. *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.
- Snow, C. P. *The Two Cultures and the Scientific Revolution*. Martino Fine Books, 2013.
- Sokal, Alan. "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity." *Social Text* 46/47 (1996): 217–52.
- . "What the Social Text Affair Does and Does Not Prove." In *A House Built on Sand: Exposing Postmodernist Myths about Science*, edited by Noretta Koertge, 9–22. New York: Oxford University Press, 1998.
- Sokal, Alan D., and J. Bricmont. *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science*. New York: Picador USA, 1998.
- U. S. Census Bureau. "Annual Estimates of the Resident Population by Sex, Race, and Hispanic Origin for the United States, States, and Counties: April 1, 2010 to July 1, 2012." Accessed November 13, 2016. <http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk>.
- Valentine, Jami, and Jessica Tucker. "The Physicists." *African American Women in Physics*. Accessed March 27, 2017. <http://aawip.com/aawip-members/>.
- Veldkamp, Coosje L. S., Chris H. J. Hartgerink, Marcel A. L. M. van Assen, and Jelte M. Wicherts. "Who Believes in the Storybook Image of the Scientist?" *Accountability in Research* 24, no. 3 (April 3, 2017): 127–51. doi:10.1080/08989621.2016.1268922.
- Wailoo, Keith. *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.

-
- White, Susan, Rachel Ivie, and Arnell Ephraim. "Number of Physics Faculty Members." *American Institute of Physics*, April 2012.
<https://www.aip.org/sites/default/files/statistics/faculty/num-facultymem-p-10.pdf>.
- Whitten, Barbara L. "(Baby) Steps toward Feminist Physics." *Journal of Women and Minorities in Science and Engineering* 18, no. 2 (2012): 115–34. doi:10.1615/JWomenMinorScienEng.2012003648.
- Wing, Adrien Katherine. "Introduction." In *Critical Race Feminism: A Reader*, 2nd ed. edition., 1–22. New York: NYU Press, 2003.