Indiscipline as Method: From Telescopes to Ventilators in Times of Covid

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Abstract
There is no unproblematic way to study things as "African", yet an epistemologically situated approach based on concrete technological projects situated in Africa and their social and political implications offers an important account of the intersection of the Fourth Industrial Revolution and African Studies. We explore this perspective through the notion of "indiscipline" using the Square Kilometre Array radio telescope project (SKA) based in South Africa as a case study through which to observe "indiscipline" as a methodological approach to technoscience at work. Indiscipline helps frame the socio-technical (by)products of astrophysics and engineering, and we present the production of ventilators for COVID-19 patients as an example of how the design of mega-science projects can become entangled with the dynamic concerns of society. Our conclusion elaborates on the politics of large technological systems, opening up a conversation on the intersection of science and society in the context of the Fourth Industrial Revolution in African settings, using the template of experiences with the SKA and the National Ventilator Project in South Africa.
Keywords: transdisciplinarity, interdisciplinarity, African Studies, SKA, 4IR, National Ventilator Project

Introduction

There is no unproblematic way to study things as "African" or in "an African way", least of all in terms of doing scholarship amid the epistemic and scientific crisis happening alongside the Fourth Industrial Revolution (4IR). Attempting to characterize Africa as a whole results in a hopeless reduction of the continent's multiple realities, histories, and ontologies into one neat narrative.[1] Taking a situated approach from postcolonial Science and Technology Studies (STS), and the notion of "co-production" (JASANOFF 2004) in particular, we frame technology and society as always located in a geographic place and in an epistemic frame; its industry-related variant has come to be called "inclusive innovation" in development discourse. The technological system we focus on is the Square Kilometre Array (SKA), a large-scale international radio telescope project which exemplifies methodological perspectives and analytical tools for framing technological advancement in Africa. In further developing co-production or inclusive innovation as useful notions, we add the idea of "indiscipline" as a method to observe and account for the context in which trans- and inter-disciplinary research unfolds. Indiscipline is seen as a decolonial update of transdisciplinary thinking, focusing on moments of rupture and puzzlement when leaving familiar epistemic terrain.

Conceived of as a deliberate method, indiscipline is a tool for making research objects visible. In our case, this entails the realization that digital technology is culturally situated in a Euro-American imposed hegemony, and, thus, socially charged by historic power relations. In addition, these technologies structure social behaviour and the lifeworlds of people outside these hegemonic set-ups in different ways. Indiscipline is employed as an analytical category that implies a deliberate methodological messiness (MITCHELL 1995), which has productive potential for researching the political, material, and epistemological entanglements at the intersection of 4IR and African Studies.

Our approach for eliciting the method of indiscipline is narrative eclecticism or "analytics as story" (MCKITTRICK 2020, 12) whereby 'story' is deployed as a tool and a unit of analysis. Storytelling is a common mode of co-production and indisciplined collaboration, which, on the one hand, tells us something about the "materiality of our analytical worlds" in demarcating the terrain and accounting for lived experience in the physical world, and on the other hand, allowing for explorative ways of enquiry (MCKITTRICK 2020, 12); stories create space for conceptual deviations from normative accounts of how research is conducted.

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[1] LAMOLA, John. 2021. African Studies and 4IR: In Search of an Appropriate Analytical Approach. Roundtable hosted by the University of Johannesburg

The Square Kilometer Array radio astronomy project and its involvement in the 'down to earth' concerns of providing technological solutions to a medical problem by producing autonomous ventilators is the empirical anchor we use to zoom in on the material products, and technological spin-offs transgressing the boundaries between basic and applied technoscience. Our story-telling of indiscipline in terms of the National Ventilator Project, which is a specific offshoot of the SKA in a time of crisis, elicits how this mega-science project has become 'grounded', situated, and effective (in the sense of co-production) in a political context, national interests and regional power structures. In speculating on the applicability of indiscipline to analyze the offshoots of large-scale science projects in Africa, we think about the politics of these technological systems in the Global South within wider debates on, for example, the need for more democratic, inclusive and relevant technical innovations in general and during the Coronavirus pandemic in particular (PARTHASARATHY 2017; 2020).

Our article is structured in four parts. We first define the concept of indiscipline, its provenance in the domain of interdisciplinarity and its promise for a decolonial application in Science and Technology Studies. The theoretical backdrop for relating indiscipline to STS will be explicated in a second step by drawing on Sheila Jasanoff's (2004) notion of co-production which locates knowledge production within the 4IR between the material, political and historical. Third is our core argument which is based on outlining William John Thomas Mitchell's (1995) five-step framework of indiscipline as a method for research, which we update alongside a discussion at the intersection of decolonial 4IR and the social sciences using two examples: first, a talk by Amanda Weltman about the methodologies behind radio astronomy and, second, the National Ventilators Project in South Africa, an unlikely offshoot of radio telescope engineering skills triggered by the Coronavirus pandemic. Based on these stories, we speculate on how indiscipline as an analytical framework and methodological procedure can breathe life into intersectional research in decolonial settings.

Defining indiscipline

Doing scholarship at the intersection of 4IR and African Studies, in particular, is like walking at the edge of the abyss where the ground upon which one stands is shaky (MACAMO 2018, 5). It involves exploring unlikely connections and disruptions by asking, *What Do Science, Technology, and Innovation Mean from Africa?* (MAVHUNGA 2017).

An interdisciplinary approach, we feel, is not sufficient for exploring and realizing science and technology in decolonial settings. Typically, interdisciplinary work involves comparison or the application of tried and tested methods to known problems that guarantee results, giving the impression that a scholar ought to be versed in more than one discipline (MITCHELL 1995, 540). In his proposition of indiscipline as an alternative, W.J.T. Mitchell (1995) targets visual culture, but we find the logic of his argument particularly compelling and productive for Science and Technology Studies in a decolonial setting. Indiscipline is an attempt to outgrow interdisciplinarity and to make scholarly work more "adventurous" and political, rather than simply "look professionally respectable and safe" (MITCHELL 1995, 540). We contend that an *indisciplined* approach reveals the inadequacies of theoretical and conceptual tools, not just in social science but in African Studies more specifically. To quote Mitchell:

> My real interest [is] in forms of 'indiscipline', of turbulence or incoherence at the inner and outer boundaries of disciplines. If a discipline is a way of ensuring the continuity of a set of collective practices (technical, social, professional, etc.), 'indiscipline' is a moment of breakage or rupture, when the continuity is broken and the practice comes into question. To be sure, this moment of rupture can itself become routinized… Nevertheless, there is that moment before the routine or ritual is reasserted, the moment of chaos or wonder when a discipline, a way of doing things, compulsively performs a revelation of its own inadequacy" (MITCHELL 1995, 541).

We expand on Mitchell, framing indiscipline as a method for opening up and reforming disciplinary routines that contributes to transdisciplinary research. While *Inter-* implies a reluctant lingering within the endogenous boundaries, *trans-* suggests a more forceful and sustained crossing of epistemes (MIGNOLO 2011b). Transdisciplinarity is therefore essentially an "act of liberating disciplinary boundaries" (TAKEUCHI ET AL. 2020, 6). *Trans-*gression is not only a "going between" structures and modalities, but also "going beyond" conventions (HUA & WEI 2020, 236). Indiscipline is then a subcategory of transdisciplinarity that focuses exactly on the moment of ruptured puzzlement.

Indiscipline as a way of enacting transdisciplinarity can be captured through storytelling. Disciplinary crossings enable the "deployment of fresh action, notably through narration" (GODART & WHITE 2010, 568). Storytelling is a central tool of indiscipline that enables mutual understanding and moments of innovation by recontextualizing the known and seeing them in a new light. Indiscipline, therefore, emerges through crossing the boundaries of standardised epistemic enquiry and opening up alternative ways of seeing and experiencing. While this formulation points to concerted efforts at disruption, one can, with a critical lens, observe ongoing acts of interdisciplinary collaboration as they already exist in the everyday lives of people. The work of description is absolutely critical in capturing these moments of disruption and disseminating them. Such has been the project of post-colonial scholars with a strong foundation in the humanities, philosophy and social sciences. Critical thinking about power and inequality[2] is underrepresented in the technical and natural sciences in Africa (BRAHIMA ET AL. 2020). To start to fill this gap, we offer an indisciplined perspective on events that are already in and of themselves, indisciplined.

[2] For pioneer work in this area see for instance Thomas-Emeagwali & Shiza (2016); Webb (2013); Leeuw (2014).

Indiscipline and co-production

The efforts of the African 4IR notwithstanding, and not to belittle the burgeoning interest in digital activities in and/or from Africa, techno-science in Africa, by and large, proceeds along networks of dependency and inequality that have been in place since the colonial period. Additionally, today, Google and Facebook are present in Africa's new tech hubs, where technology, innovation and capitalist entrepreneurism exist as islands that contrast starkly with the underdevelopment of surrounding neighbourhoods.[3] Interventions by social scientists that question the direction of development and technology in Africa will go largely unnoticed due to differences of power and inequalities in funding, as well as the value of knowledge produced between the soft and the hard sciences. That said, there is reason for some encouragement for staying with the "trouble", as Donna Haraway (HARAWAY 2016) says. Remaking the "troubled" world is to find approaches that disrupt nature/culture binaries as well as other dualisms obstructing human creativity, and potential relations, or entanglements with other-than-human kin (including the environment). While Haraway's aspirational stance envisions an ever more entangled future with the non-human, Sheila Jasanoff's notion of "co-production" sees technology, at least, as always, already imbricated in, and co-produced with societies. In both cases, these authors articulate a model of co-production and, thus, are opposed to positivism, which, as seen in development efforts, orients towards technoscience in its determinist sense. In Jasanoff's words:

> We gain explanatory power by thinking of natural and social orders as being produced together […] Briefly stated, co-production is shorthand for the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it […]. Scientific knowledge, in particular, is not a transcendent mirror of reality. It both embeds and

[3] See for example, Africa's new IT hubs including "Yabacon Valley" in Lagos, or Konza Technopolis in Kenya, or Ghana's Google AI centre, all of which are in part sponsored by Google or Facebook, as well as sites for African start-ups.

> is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions – in short, in all the building blocks of what we term the social. The same can be said even more forcefully of technology (JASANOFF 2004, 2-3).

This perspective comes from post-colonial approaches in STS that foreground technology's inherently political dimension (HARDING 2011; JASANOFF 2004) as being a product of a place, a time, and a set of interests. Technology does not exist above or outside of society, in difference to the tech hubs on digital islands such as Silicon Valley-derived sites, but is already fully immersed in society, inscribing, shaping and being shaped through human activities. To take a perhaps oversimplified example for the sake of illustration, consider this interaction that took place between one of the co-authors and an astrophysicist:

> A colleague of ours is an astrophysicist. After a long evening of working on his computer inside the Ghana Radio Astronomy Observatory, I [James] ask him to take me outside and show me what he is looking at. We walk out and the first thing is confusion: "Well, we cannot actually see it". He then asks me to find Orion and from there we can triangulate the position of the exploding star he was looking at earlier inside the observatory. We find it and he says: "There". It is invisible, we cannot see it, but it is there.

If the location of Orion in the sky is situated in that space in Ghana, and in that particular time in 2018, then it is, in essence, a co-production of the astrophysicist's training in science, and the social, physical and historical context of that knowledge of triangulating location. How it is seen becomes the problematic crux of the matter which involves applying a set of theoretical frameworks, conceptual categories and methodological procedures through which the object of research is contrived (Macamo 2018). In some sense, we should be asking in the social sciences "Where is Orion?" and then using that to triangulate how we make objects of research visible, particularly when those objects sit at intersections, for instance, of technology and society, 4IR and African Studies. What happens, therefore, when we look to astronomy with the interest in STS and - in particular - the Fourth Industrial Revolution? What sorts of topics emerge out of this constellation of disciplines? These questions can be addressed through a situated story, one that makes visible co-production at a particular time and place to better understand the co-production between a radio astronomy mega-science project and the demands placed on society by Coronavirus. Where is our Orion in this narrative? This is the question that takes us to through the next analytical steps.

As we have been arguing, indiscipline, as one way to nudge, encourage, or swing the lens onto moments of co-production at the interaction of technoscience and society through which we can tell stories about the mixing of material and social politics:

> When we tune into the rhythms of everyday life even at times of rapid technoscientific change [as in 4IR], we experience more often the steady hum of continuity than the sense of disequilibrium. In short, the ways in which we take note of new phenomena in the world are tied at all points – like the muscles on a skeleton or the springs on a cot frame – to the ways in which we have already chose to live in it (JASANOFF 2004, 16)

By inserting co-production into a theory of the 4IR in Africa, we avoid the problem of characterising something in terms of either social determinism or digital determinism – it is symmetrical and. Thus, a critique of the realist ideology that "separates the domains of nature, facts, objectivity, reason and policy from those of culture, values, subjectivity, emotion and politics" (JASANOFF 2014, 3). The research object is not technology *for* Africa, so much as the co-production of Africa *and* technologies, the representational modes and material outputs that index Africa, which are embedded in technology.

The political question is about how to capture the moments of crystallisation that speak for the interests of Africans, a question that will inevitably lead to different perspectives and conflicts, which can be struggled over in a democratic fashion. A practice-based study will train our attention to contested moments and normative stabilisation, which tell us what the stakes are and who stands to gain or lose. Therefore, what cultural or economic or political values are attached to this knowledge?

Applying indiscipline as a method

From co-production to collaboration

While an STS approach to collaboration emphasizes the agency of the material, i.e., "how the natural and the social are produced together" (JASANOFF 2014, 3), a conventional understanding of interdisciplinarity emphasizes the cognitive opening of humans to alternative ways of thinking. In both instances, the certainties of the self are unsettled by demanding a counter-intuitive, deliberate abandonment of epistemological and ontological stability. Both argue that instead of leading to fatalistic exasperation, doing collaborative post-colonial sciences and recognizing the implicit co-productive dimension respectively, is a necessary and fruitful next step in innovative research that tackles the problems of the 21st century (HARDING 2011, 22). Cosmologist Amanda Weltman provides an example of this kind of co-productive transdisciplinarity during her presentation on 'Fast Radio Bursts' at the *South African Astronomical Organization Conference* (SAAO) in 2020. In the following, we unpack her presentation through the lens of "indiscipline" and work up our level of analysis of the main case study, the National Ventilator Project.

Amanda Weltman at the South African Astronomical Organization Conference
In her SAAO presentation in October 2020, Amanda Weltman,[4] who holds the NRF South African research chair of Physical Cosmology at the University of Cape Town, presented her latest findings on Fast Radio Bursts, which were discovered, computed, and thus brought to life through SKA technology. Fast Radio Bursts are a sort of ultra-high regular energy signal that potentially hints at the collision of supernovas. The interdisciplinary set-up of the audience celebrating SAAO's 200-year anniversary and the many laypeople attending the conference inspired Weltman to also share some meta-reflection of the collaborative research process on Fast Radio Bursts. She stated that initially, Fast Radio Bursts were not found due to technical innovation but due to an "attitude shift to look for them" (WELTMAN 2020); i.e., by a different way of looking at reality and "finding Orion". Whether that shift was induced by an indisciplined encounter, as such, remains speculative. Weltman's accounts on Fast Radio Bursts, nevertheless, give some illustrative clues about the relevance of the five methodological steps suggested by Mitchell for indisciplined collaboration. We explore these in the following and signal how the framework helps to analyze the intersection of STS, 4IR and African Studies.

1. Disciplinary self-reflexivity pertains to an honest exploration of the power relations, the historicity of both the research object and the researchers' roles in the research process at the intersection of social and natural sciences.
Weltman starts her presentation with a reflexive definition of her field of cosmology contrasting it to and complementing it with the mothership, astronomy:

[4] Amanda Weltman is Professor for cosmology at the University of Cape Town and Director of the High Energy, Physics, cosmology and Astrophysics Group. She has been described as Africa's "next Einstein" (SIDDLE 2016).

> I think it's worth thinking about some of the history of what cosmology has meant in the past and to different societies at different times. So, the goal of cosmology is really building a system of understanding a way and have beliefs about the origin and structure of the universe…so space, the planets, celestial phenomena. Historically, this has been underlain by deep religious beliefs and ideologies and it's only really in modern times that cosmology has taken the step up from being a belief structure, a philosophy, a way of looking at the world. It's become something very scientific by building our ideas with astronomy as a way of measuring and mathematics, as a way of thinking through theories. And so, we try to answer the largest scale questions in the universe using very often very small-scale physics. …Advances in cosmology require advances in astronomy. And that's why I think it's so important to have these cosmology and astronomy discussions together. What do we need to do to build a theory of the universe and understand everything on the largest scales?

In providing a historical trajectory of her field, Weltman also implicitly alludes to the legitimation struggles of cosmology against and with astronomy. Weltman emphasized the need for collaboration in order to see the bigger picture and answer "large scale" questions.

An analysis of the social and historical situatedness of the production and reception of technological knowledge is a crucial part of innovation. Social sciences in this endeavour can help make these positionalities and power relations transparent by decentring positivist Eurocentric axioms and claims to universality. Politicizing the research in such a way might not always be welcome. Therefore, the intervention of social science should find a role that goes beyond the deconstructive armchair critique (or the moralizing compliance police) and towards an explicitly productive contribution, e.g., in highlighting the role of documenting the research through (self-)critical, complex, and contextualized narratives. While these roles can certainly be overlapping, partly obscure, and dynamic, it is important to be aware of these facets and respective power implications. Through "adamant self-reflexivity" (WIJNGAARDEN & IDAHOSA 2020) indiscipline foregrounds a proactive, productive, responsible and transparent engagement in the process.

2. Resistance to indifference through multiplicity. Traditionally, it is the post-colonial social researcher's main agenda to point out the context-specific constructedness and multiplicity of sciences and technologies. In line with taking on a responsible role in technological innovation, indisciplined co-production should, however, not be satisfied with stopping at, and being defeated by, these boundless pluriverses. What McKittrick (2020) claims for 'Black method' is equally applicable to indiscipline; viz. an assertion of our own normative underpinnings and a resistance against getting lost in, or being dragged down by, absolute relativity. Indiscipline is "not continuously and absolutely undisciplined (invariably without precision, invariably undone)" but instead strives to be "precise, detailed, coded, long, and forever" (MCKITTRICK 2020, 5f). Earnest indisciplined collaboration should – at least, within the horizon of the team – seek binding epistemological common ground axioms and norms (see ODOUR[5] this issue) from where to work. In Harding's words, these anti-relativistic "standpoints" are more than perspectives or views but "intellectual and political achievements in that a group has to work together to figure out how to arrive at them" (HARDING 2011, 19f).

Weltman affirms both the normative in stressing the data-driven ontology and logic-based methods, as well as the conceptual openness in highlighting the need to critically interrogate existing data-based certainties and conceptual correlations:

> When we have limited resources and limited data, we introduce bias into what we follow up. So, there's one very well understood FRB [Fast Radio Burst] and we keep studying it and if we delude ourselves into thinking it's typical, then we will miss out on a lot of new information. Just because we've convinced ourselves that magnetos are very likely progenitors, it doesn't rule out other mechanisms. … And so, we have to rule things out; either the data must rule it out or there must be a theoretical explanation for why it cannot happen.

Weltman's account can be read as the co-productive emergence of knowledge, i.e., a give and take between the materiality of data and an alternated social dimension, a change in attitude and viewpoint if you will:

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[5] Odour proposes Universal Design, Affordability, Cultural Identity, and Ethical Orientation as guiding norms for the Fourth Industrial Revolution in Africa (2020).

> There's a huge amount that we can learn from Fast Radio Bursts; not just scientifically but also how we do science. So, the fact that they were found originally with no technological innovation, just the fact that we thought to look in a different way at the existing data, is something that I think is really worth taking away. …. Yes, we need new tech advances now to see new results, but we should never forget the existing data may have a lot of science hidden up in it.

Crossing disciplinary boundaries involves a risky give and take, i.e., the readiness to genuinely invest in "foreign" ways of knowing and, in the process, being prepared to lose hard-earned certainties.

3. Co-producing instead of recycling concepts. Striving for a new language instead of simply importing or 'recycling' worn-out concepts that are safely used in the home disciplinary discourse is crucial in achieving common ground (MITCHELL 1995, 52). Central to creating mutual understanding as well as conceptual, affective learning is the creation of new polyvalent metaphors that enable the expansion of known attributes with new aspects; in other words, we can only understand new connections based on already familiar units. The collaborative construction of new metaphors goes beyond a creative communicative exercise but also opens ways of grasping and talking about previously unknown phenomena based on existing shared knowledge bytes. Metaphors are both an "(entwined material and imagined) future that has not arrived and the future we live and have already lived through" (MCKITTRICK 2020, 11). They describe scenarios of what might be with items we already know by assembling them anew. Through their semantic openness and ambiguity, metaphors "concretely" and simultaneously represent the problem and the solution. Through their aesthetic iconic dimension, they have the power to affectively "move" (MCKITTRICK 2020, 11) cognition. Metaphors, thus, not only describe a reality but also create and embody this reality, e.g., when classifying a specific radio signal as a "burst", this becomes a research object and sub-discipline of cosmology.

The negotiation about meaning can be achieved through dialogue and dialectics. The process of achieving mutual intelligibility involves the 'dumbing down' of acquired knowledges and might feel like a loss of complexity and advancement. But if it is for achieving commonality, in the literal sense of making knowledge accessible by employing less specialized language, it can go a long way in opening windows for collaborative innovation.

At the SAAO conference, Weltman had mastered this "dumbing down" exercise by adjusting her complex research results to a heterogeneous audience while fully retaining both her expert authority and respectful eye-level status towards the listeners. The materiality of the situation, i.e., a commemorative large scale public interest online conference, required utmost simplicity and brevity but also a measure of entertainment and awe. Instead of explaining the cumbersome theoretical axioms such as the Standard Model for Theory of Matter and Non-Gravitational Interactions, Weltman opted to show a photograph of her son wearing an imprint of the related formula on a T-Shirt. In doing so, she signalled that it is not so important to understand the formula itself but rather to understand its significance for the field, such that it warrants an iconic, star-like, branding on a T-Shirt. While often the 'dumbing down' only provides a unidirectional benefit, Weltman herself implied the possibility that a fresh look on data induced by interdisciplinarity might lead to genuine insights.

4. Analysis of the metaphysics of the object. The conceptualization and framing of the unknown — in particular the future of humanity — is an important part of 4IR that requires us to consider the "metaphysical consequences of the technological reconfiguration" (PIRC this issue). Furthermore, in focusing on co-production as the starting point for indiscipline, the method can "respond to people's deepest metaphysical concerns" (JASANOFF 2004, 21) by addressing the question of what we perceive as material and cognitive reality and how they relate to each other; i.e., how the human is connected to the world. In establishing this relationship, the nature and trajectory of humanity crystallizes. Weltman describes cosmology as "a framework that includes humanity", i.e., a discipline that also examines the relationship between the cosmos and humans.

An interesting example of that intersection is the work of Franco Vazza and Alberto Feletti (2020) who explore the neurological dimension of what can be grasped by humans. They quantitatively and structurally investigate the comparability of the human brain and the galaxy and find that "the self-organization of both complex systems is likely being shaped by similar principles of network dynamics" (VAZZA & FELETTI 2020). This suggests that how we perceive the cosmos is limited by the formatting of our brain's hard-drive, giving an indication of what is knowable in the first place, which is ultimately a metaphysical question.

Weltman addresses the anticipated metaphysical implications that cosmology triggers in the conference audience by admitting to being at the fringes of her discipline's knowledge: "Sometimes our cosmology is still built on beliefs and to really make progress we may have to question some of our beliefs and put them on firmer footing with evidence". Her statement highlights the overlapping of belief-structures with theoretical constructs requiring evidence to legitimize their existence. Theory can thus be understood as the material representation of metaphysic ontologies.[6] This illustrates that theory can be seen as "a form of storytelling" highlighting its "fictive", temporal and "speculative" aspects:

> Fact-finding, experimentation, analysis, study, are recognized as narrative, plot, tale, and incomplete inventions, rather than impartial treatises. As story, theory is cast as fictive knowledge …the act of teaching and telling the story is collaborative (I will share this with you, co-author this with you, and live this life with you, I will tell you my secret); the contents of the story are multifarious and interdisciplinary (characters, plots, twists, metaphors, unexplained codes, places, secrets, connotations, structure the lesson and telling). The lesson, the telling, the contents, are ways of life (ways of being) (MCKITTRICK 2020, 7f).

Thus, by focusing on the metaphysical groundings of research and the "fictional" nature of theory, indiscipline has the capacity to lay open conceptualisations of the unknown, the understandings of nature, origins and destiny of humanity and its relation to the cosmos, as well as the driving teleologies[7], ideologies, and agendas of science and technology.

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[6] Weltman anchors the metaphysical underpinnings of her work in four theoretical pillars: Einstein's Theory of General Relativity, the Theory of Matter and Non-Gravitational Interactions (Standard Model); as well as two categories for "choices that we make based on data", i.e., geometry and topology. That is − almost literally – science understanding of the cosmos in a nutshell: "Putting together these very simple theoretical ideas, we arrive at the sort of surprising result that the universe began in a hot dance state that we now observe as the CMB [Cosmic Microwave Background]" (WELTMAN 2020).

[7] These worldviews are based on axioms of evolution, progress, and development of humanity ultimately believing that growth of knowledge automatically leads to betterment of society.

5. Analysis of the political economy of the object. In acknowledging that every knowledge is situated, what can become knowledge is subject to the institutional norms and standards within which scientific knowledge is produced. The importance of this aspect becomes evident, when considering how Weltman routinely acknowledged the political/institutional enablers of her work by lauding the "international collaboration", and thanking her research funders, the National Research Foundation of South Africa, as well as the organizers of the conference SAAO. Beyond mere politeness, this acknowledgement is an assertion and transparent revelation of the political and economic set-up of the research. It tells something about the contextual expectations of how she can tell and produce her story.

McKittrick points out how a narrative analysis of the political economy dimension is especially relevant at the intersection of 4IR and African Studies:

> Stories think through how racism and other forms of oppression underpin the political economy of academic and non-academic disciplinary thinking (the demand to gather and live with seemingly transparent data, in a range of sectors; living with data [policies, reports, cards and carding] that ostensibly prove that those communities living outside normalcy are verifiably outside normalcy (MCKITTRICK 2020, 3).

A strategic analysis of the political and economic situatedness of research, as suggested by Mitchell (1995), affords a change of parameters that yield more desirable results: South-South collaborations in technical knowledge production (RASHIED & BHAMJEE 2020), corporate and political interests in research results (BIRHANE 2020), and origin and trajectory of knowledge and theory (HOUNTONDJI 1990), as well as technology suitable for African contexts.

For the latter, we propose the South African Ventilator Project as a site of applying and testing indiscipline within the parameters of a particular context or example. The project arose during a global crisis, i.e., was urgent and need-driven; it received a national mandate and funding as well as the explicit involvement of humanities in logistics, consulting and communicating; it was set in an African context geared towards finding Africanized solutions and was dependent on, and influenced by, the existing infrastructure and materials, i.e., a necessarily co-productive project.

Application: Crystalizing the 4IR through the National Ventilator Project in South Africa

In her presentation, Weltman suggested that in scientific practice - whether it be radio astronomy or sociology - new information comes through rupture, i.e., a disturbance of old certainties. Her account is based on looking at existing data in a new way that requires an "attitude shift to look for them [Fast Radio Bursts]" (WELTMAN 2020). It is, thus, actually epistemological uncertainty (not certainty) that advances a discipline and interdisciplinary networks, suggesting that interdisciplinary projects are most productive when they embrace uncertainty and epistemological rupture (rather than retreating to common assumptions and behaviours). In order to explore these points further - and to link this to issues around innovation, astronomy, society, and 4IR - we turn to the technological "spin-offs" emerging out of the SKA radio astronomy project in South Africa.

Spin-Offs from the SKA

South Africa hosts the world's largest radio telescope, the Square Kilometre Array (SKA), and the biggest science project in Africa with the potential for many technological spin-offs (DAVIDSON 2012), which have scope for application in the Fourth Industrial Revolution. These are mainly in the domain of big-data processing, but also societal demands that elicit the innovative potential of radio astronomy engineers and managers.

As Davidson (2012) has illustrated, large-technology based missions in other parts of the world have shown that technology spin-offs are serendipitous rather than planned, lending themselves to an indisciplined approach. For instance, the integrated circuit technology at the heart of modern electronic devices was driven by the US space and missile programs of the 1960s. The invention of the World Wide Web at CERN was initially designed for sharing the results of particle accelerator laboratories but eventually revolutionised commerce and communication in an entirely unplanned fashion. Advances in robotics are being made by NASA's Jet Propulsion Laboratory with dual-use applications for the exploration of other planets and for medical projects such as robot-assisted microsurgery. Research into nuclear physics in South Africa had contributed both to upholding white minority rule as well as to medical applications in the 1950s (BEINART & DUBOW 2021). In this frame, the SKA features in this larger history of innovation by driving - amongst other things - semiconductor chips for very large-scale computing.

The innovative potential of the SKA outside of radio astronomy has emerged from the challenges and innovations of the technological and engineering requirements of using an interferometric array of one million square meters[8] where data processing and timing has become a major challenge. While the present data rates can be handled with current technology, the SKA will require computation rates that exceed the capacity of existing computers. It is not clear, for example, whether an ExaFLOP — i.e., super computing speed — is technically feasible but research is underway that will spin-off into other fields where large data sets must be processed. The ROACH (Reconfigurable Open Architecture Computing Hardware), which was developed in South Africa in collaboration with international organisations and the University of Cape Town is at the center of this development in high-performance computing.[9]

The SKA is not just an engineering project. It also has a strong human capital development programme with hundreds of MA students, PhD students and post-doctoral fellows, as well as several national-level research chairs, made available. In addition, there are new initiatives in radio astronomy that are not directly linked to the SKA site in South Africa but have resulted in high-level activity such as the development of the African Very Long Baseline Interferometry (AVN) Network, which is based on recycling recently decommissioned telecommunications dishes across Africa. The first conversion was in Ghana in 2017, which has had a significant impact on the building of astrophysics and big data processing in West Africa.

These developments in space science provide a counterexample to what Paulin Hountondji (1990) had argued in terms of Africa's scientific dependence. While the training of African scientists has notoriously taken place at institutions in Europe and North America, the SKA/AVN offer an infrastructure for educating a new generation of astronomers and data scientists. Although the best-equipped laboratories, the top universities, the most powerful research centers, editorial teams and offices of the most prestigious scientific journals, as well as the most complete reference libraries and publishing houses and the major concentration of practicing scientists still remain outside of Africa, the SKA/AVN has the unique potential to be an infrastructure through which students on the African continent can do experiments and research on home ground.

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[8] The basic method of interferometric radio astronomy is connecting dishes over vast distances to create one massive virtual dish whose collecting area amounts to the space in between them.

[9] Its applications outside of astronomy include radar systems such as ground penetrating radars used for the detection of buried pipes during construction work, and collision avoidance radars under investigation for motor vehicles. Therefore ROACH-board technology may well be one of the first candidates for a new spin-off development.

Having mentioned some of the industry grade spin-offs from the SKA, we turn now to a particularly interesting case, and the most recent example of a spin-off that is unfolding through the story of the National Ventilator Project (NVP).

South Africa, Astronomy & Ventilators

In 2020 when the number of coronavirus cases began to increase in South Africa, the government called on companies and experts, engineers and scientists to develop innovative solutions to help combat the pandemic. Anticipating the demand for critical medical supplies, the Department of Trade, Industry and Competition invited companies and experts to express their interest in the design, development, production and procurement of equipment such as ventilators. Experts and companies registered their interest and relevance to the National Ventilator Project (NVP), an example of partnership and innovation toward a common objective to help patients get oxygen by pumping air into their lungs with no need for electricity. This is contextually relevant since South Africa has an ongoing problem of stabilising its electric grid, an obvious hamper to economic growth not to mention the reliable operation of medical services.[10] Within the space of four months, South Africa had gone from not producing any ventilators at all to having the first units in production, and identified that there was the industrial capacity to scale-up production for exporting ventilators to other African countries.

[10] For instance, see 1. https://www.opml.co.uk/blog/south-africa-s-crippling-electricity-problem and 2. https://www.bloomberg.com/news/articles/2021-01-17/eskom-extends-south-africa-power-cuts-due-to-lack-of-capacity

The astronomical community has been active, offering their skills to help address the challenges of COVID-19. On 9 April 2020, the Minister of Trade and Industry, Ebrahim Patel, mandated the South African Radio Astronomy Observatory (SARAO) with overseeing the development and manufacturing of ventilators based on the experience they have gained in developing the complex systems for the MeerKAT radio telescope, a precursor to the SKA (SARAO 2020). SKA project director Bernie Fanaroff asserted that, "if we have the skills that put the MeerKAT together, why can't we use them to put together medical capacity?" (WILD 2020). SARAO members, according to Fanaroff, "are amongst the best system engineers and system integrators in the country and the lessons they learned designing complex systems in a very efficient way [for MeerKAT] has allowed SARAO engineers to work through a large number of options and designs in a very short time" (WILD 2020). A network of astronomers, scientists and engineers were tasked with conceptualising a local ventilator design, and engineers at the South African Radio Astronomy Observatory had produced two mechanical ventilator prototypes, which provide a mixture of oxygen and air at a constant pressure to the patient with a non-invasive ventilation mask (which also prevents patients from infecting hospital staff and other patients). The alternative prototypes developed by SKA engineers provided a non-invasive ventilator system that does not require electricity to pump air into patients' lungs and were able to treat the majority of hospitalised cases. As they were simpler and locally manufactured, the new machines were significantly cheaper than imported ventilators.

The design is particularly innovative in terms of helping the patient recover from the virus without needing invasive ventilation. The very small overpressure of air ensures that the lungs remain inflated, promoting the efficient transfer of oxygen to the blood. For the critically ill, the standard medical response is tracheal intubation — the insertion of a flexible plastic tube via the mouth into the airway to move air in and out of the lungs. Khulu Phasiwe, a spokesperson for the Radio Astronomy Observatory, said about 75% of patients requiring hospitalisation for Covid-19 treatment only need low-level oxygen therapy and require non-invasive ventilator therapy. The aim is to ensure that ventilation, which is a painful, invasive and technical procedure, is the last option because putting foreign objects into the body introduces the possibility for infections and complications such as 'ventilator-associated pneumonia'.

Analysis

The production of ventilators facilitated by an astronomical organizational network makes visible the link between materials, systems, and political conditions in the context of an Africanized 4IR. As previously mentioned, the scope of spin-offs, of which the ventilator project is a part, also includes big data processing and high-performance computing, which opens up further examples of the need for a 'trading zone' (GALISON 1997) between engineers and scientists from a variety of disciplines. Indiscipline not only foregrounds the political power of technology but also the relevant criteria for clearing the way toward the creation of widely accountable and locally relevant "inclusive innovation". Inclusive innovation is a buzzword in international development and technology discourse that differs from the earlier focus on large infrastructure projects, tending to emphasize small low-tech devices, driven by local concerns and interests (see e.g., PARTHASARATHY 2017). Therefore, an important premise for indisciplined collaboration is a social context where research and innovation are need-driven and applied.

Mitchell calls the "bottom-up model" of interdisciplinarity that emerges from the "shop floor…in response to emergencies and opportunities" (MITCHELL 1995, 541). While much of the innovation during the COVID-19 pandemic has been driven by elite concerns, capitalist interests and exposed societies gaping inequalities (PARTHASARATHY 2020), it has also enabled pockets of inclusive innovation due to these now very visible differences. Contemporary research is changed because political and ecological parameters have changed. A useful point of departure in elaborating on this is 'cosmopolitics' (STENGERS 2010), a conservative form of radicalism that creates an awareness of the situations that mobilise scientists and technologists toward matters of mutual concern.

Slowing down politics is a way to turn attention to the situatedness of technological design. The National Ventilation Project shows how a team of scientists, managers and engineers who are normally concerned with receiving signals from stellar objects had mobilised to produce appropriate technologies on a massive scale. Even though these air pumps run without electricity, have a simple design and require little prior expertise, they still require expansive infrastructure to produce, transport, and distribute them widely (within and beyond South Africa's national borders). These ventilators will be on the move, transferred from sites of central production to remote areas where they are most needed. Being 'low tech', they have a flexibility to travel almost anywhere.

While we do not yet have data to justify claims about what happens when these ventilators arrive in particular places, we might be able to speculate that – like the Zimbabwe Bush Bump (DE LAET & MOL 2000) – the ventilators do not impose, they address a need, and are adaptable, flexible and responsive.

Conclusion

In the context of African Studies and 4IR, we proposed indiscipline as a method to foster the political dimension of Science and Technology Studies (HARDING 2011) and a pathway to the social and material co-production (JASANOFF 2004) of Africanised technology. The quest was driven by curiosity, "sustained by wonder (the desire to know)" and derived from a dissatisfaction with the kind of standardized questions "that result in descriptive-data-induced answers" (MCKITTRICK 2020, 3).

Indiscipline can narrow down the gap between the application of post-colonial theory in STS and post-colonial critics' lingering in the realm of literature (ANDERSON 2009, 390). It allows for a decolonial reading of STS, because it foregrounds disciplinary and cultural diversity, which advocates in Mignolo's sense for epistemological "disobedience" (MIGNOLO 2011a, 54). We believe that a foregrounding of technology's political implications is necessary for clearing the way towards the creation of widely accountable and relevant technological innovation (HARDING 2011).

In illustrating indiscipline as a method, we have drawn on several narrative examples that are grounded in South African astronomy: Orion, the Fast Radio Bursts and the 'unplugged' ventilators. Narratives, captured in various textual genres, can provide a new path for thinking about decolonial technology. Due to their eclectic incongruence, these texts can support the illustration of challenging "the primacy of evidentiary and insular normalcies" (MCKITTRICK 2020, 3):

> "In assembling ideas that are seemingly disconnected and uneven (the seabird and the epilogue, the song and the soil, the punch clock and the ecosystem …), the logic of knowing-to-prove is unsustainable because incongruity appears to be offering atypical thinking. Yet curiosity thrives. The industry punch clock calibrates and recalibrates the ecosystem" (MCKITTRICK 2020, 3).

Our examples of applied indiscipline at the intersection of African Studies and the 4IR have provided cues for thinking about interdisciplinarity in decolonial contexts. This invites further empirical analysis and story-telling around matters of mutual concern between the sciences and society, between the disciplines and amongst discrete groups of engineers, technologists, astrophysicists, managers and government officials whose engagement provoked moments of indiscipline, rupture and disruptive innovation.

While the gaze into outer-space is mediated from a position on (or near) earth, it is still emplaced within specific social, technological, economic and historical conditions. Relating the metaphysics and political economy of the object puts attention on the situatedness of research affording more desirable technologies that are suitable for particular contexts. Exploring indiscipline through narration and storytelling we account for the cosmopolitical intersections of exploding stars, supernovae, supercomputers, ventilators, people and viruses. This has opened up a methodology of indiscipline and moments of co-production, which yield innovation that is inclusive, representing a shift in focus - through narrative - to earth-bound concerns that are made visible during a pandemic crisis.

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