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Karoo Futures: Astronomy in Place and Space – Introduction

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Historians and social scientists of southern Africa have been slow to engage with what is undoubtedly the region's most ambitious investment in 'big science' in the new millennium: the radio astronomy project of the Square Kilometre Array (SKA), the core site of which is located in the semi-arid Karoo region of South Africa (see [Figure 1](#)). Yet this mega-project, the immediate origins of which date back to the intersecting millennial moments of intense globalisation and democratic transition in South Africa, should be of considerable interest for scholars in the social sciences and humanities. Intended to probe fundamental questions about the nature of the universe,¹ the SKA raises significant conceptual, theoretical, methodological and ethical challenges for those concerned with social and environmental dynamics on Earth, across different scales and registers of analysis. Issues include understanding the project's national and regional geo-political implications, its local social and environmental impacts and the contestations they are engendering, as well as its global importance on the frontiers of scientific knowledge; the project also raises profound questions about human agency and modes of knowing, meaning-making and representation.

That the core site of this endeavour is located in the Karoo, at once the historic heartland of the devastating encounter between white settlers and indigenous Khoisan groups in the colonial period and today one of the country's most marginal regions, adds a sharp political edge to critical engagements with the unfolding of this project in South Africa. Within the African continent more broadly, the SKA is tightly tied to South Africa's conception of itself as a modernising, developmental state and leading continental power. It is also core to wider ambitions to reshape Africa's relationship to global science. Once completed, the full Array is projected to reach into a further eight African countries, most but not all located in southern Africa: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia.² The difficult questions this project raises concerning radio astronomy as not

1 In the words of the SKA Organisation: 'From challenging Einstein's seminal theory of relativity to the limits, looking at how the very first stars and galaxies formed just after the big bang, ... helping scientists understand the nature of a mysterious force known as dark energy, ... through to understanding the vast magnetic fields which permeate the cosmos, and, ... are we alone in the Universe, the SKA will truly be at the forefront of scientific research'. See 'The SKA Project', available at <https://www.skatelescope.org/the-ska-project/>, retrieved 1 February 2019.

2 The Array works as a telescope by virtue of being a composite of, potentially, many thousands of individual antennae, ultimately extending over many countries, that are linked together through computer technology to act as a 'single' lens on the universe with a collecting area of approximately one square kilometre.

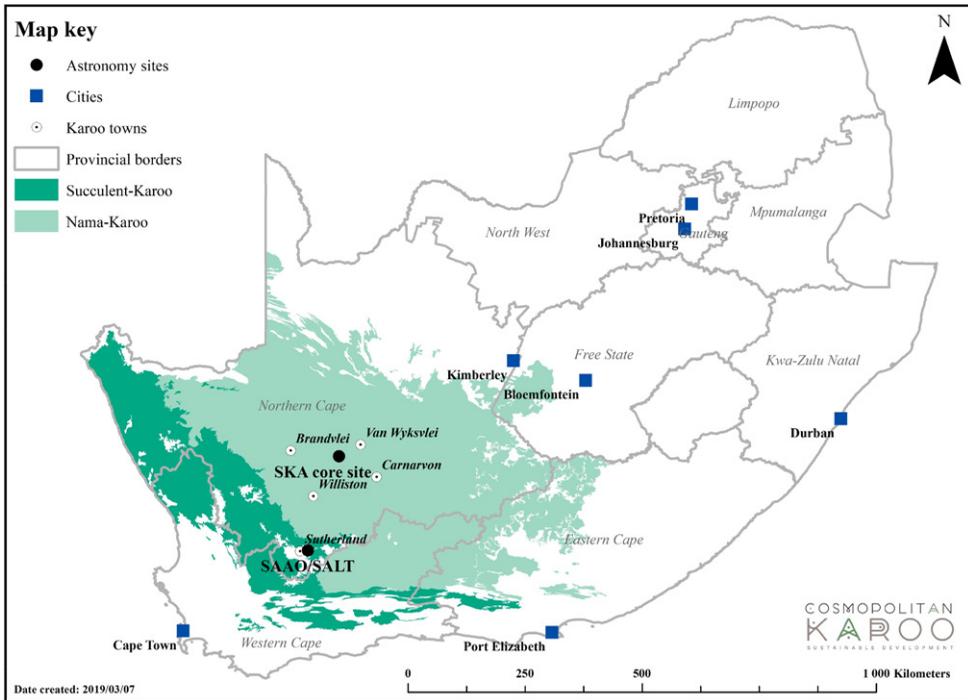


Figure 1. The Karoo biomes and Northern Cape astronomy sites in national context.

simply a ‘pure’, celestial science but also a globally networked industry, with the potential to affect local communities in profound ways on the ground, can thus be expected to play out in other African contexts in due course.

This Special Issue of *JSAS* brings together scholars from different disciplinary backgrounds to probe the history, meanings, contemporary conflicts and development claims swirling around the SKA in particular and astronomy in South Africa more generally. While the articles can all be read as stand-alone pieces, we hope that they will be read together as a set. We also hope that they will stimulate further research and debate on the history and sociology of astronomy as a field within African Studies and encourage comparative analysis with other countries and regions where astronomy is a significant growth industry.

This introduction offers general background on astronomy in South Africa, the SKA and the Karoo, followed by a brief overview of selected themes from the seven articles in this issue, along with pointers to issues for further work.

Astronomy in South Africa

As the discussion of the ‘intimate cosmology’ of the |Xam people of the Karoo by Parkington, Morris and De Prada-Samper in this issue makes clear, human engagement with the stars and the dark ‘empty’ spaces of southern Africa’s night skies stretches back into the very deep past; today this fragile cultural heritage is the subject of both re-imaginings and contestations as to ownership and authority, as several other authors in this issue (Parkington *et al.*; Davide Chinigò; Saul Dubow; Cherryl Walker) also discuss. There are, indeed, overlapping issues in the investigation of astronomical and palaeontological ‘deep time’,

both of which converge in the Karoo.³ The roots of the modern science of astronomy, however, lie in South Africa's much more recent colonial past. Saul Dubow observes that astronomy was 'the first scientific discipline to root itself institutionally' in southern Africa, with the establishment in the 1820s of the Royal Observatory at Cape Town after only a few years under British rule. The subsequent development of astronomy in the 19th century was deeply implicated in the project of British imperialism regionally and globally, with a primary function of the observatory to advance applied science related to maritime navigation, time-keeping and terrestrial surveying and mapping, all in the service of empire.

In the first half of the 20th century, astronomy was a somewhat fragmented discipline in the newly constituted Union of South Africa, with no defined base in the university system. What this period did see was the establishment of Johannesburg and Pretoria, by then the economic and political centre of the country, as a competing base for astronomical research, along with growing interest among northern astronomers in South Africa as a 'viewing platform' (in Dubow's words) from which to conduct their work – a phenomenon that continues today. However, from the 1960s, the apartheid state began to pay more serious attention to developing local capacity in astronomy, including radio astronomy, as part of its general investment in boosting national scientific expertise and countering the country's growing political and economic isolation internationally. This led to the conversion of the satellite-tracking facility at Hartebeesthoek, some 50 kilometres west of Johannesburg, into a state-sponsored radio astronomy observatory in the 1970s, after the USA's National Aeronautics and Space Agency (NASA) severed ties with South Africa. By this time, a flat hilltop outside the small southern Karoo town of Sutherland had also been identified as a superior site for optical observation in the then Cape Province, away from the growing light pollution of Cape Town, and this site was formally opened under the auspices of the South African Astronomical Observatory (SAAO) in 1973. At a time when Britain was reassessing its commitment to South African astronomy, but still keen to maintain scientific and diplomatic connections, 'the SAAO helped to reaffirm Anglo-South African scientific and cultural links', within a broader context of greater state control and centralisation (Dubow, this issue). Notably, 'international astronomical collaboration continued through and beyond the apartheid era', for the most part 'under the radar of the anti-apartheid movement' (as was also the case with Antarctic research and nuclear enrichment).

Intriguingly, in the light of current debates on decolonising knowledge, the post-apartheid state under, first, the Mandela presidency (1994–99) and then the Mbeki presidency (1999–2008) remodelled this ambiguous legacy to drive an equally strongly modernising, nationalist project, now with global ambitions. While committed to the economic and practical benefits to be derived from investing in science and technology, the political backers of astronomy also aimed to reposition post-apartheid South Africa as a progressive, fully equal, fully deserving member of the global knowledge community. Several articles in this Special Issue quote from a telling passage in South Africa's 1996 *White Paper on Science and Technology*, which strongly justified the national commitment to 'basic' science and has been regularly cited by official and other advocates of the case for astronomy ever since:

[s]cientific endeavour is not purely utilitarian in its objectives and has important associated cultural and social values. It is also important to maintain a basic competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to

3 On South Africa as a portal to explorations of the origins of both the universe and humankind, see S. Dubow, 'Frontiers of Scientific Knowledge in South Africa: Global Science, National Horizons', Smuts Professor of Commonwealth History inaugural lecture, Cambridge, 28 November 2018, available at <https://www.hist.cam.ac.uk/podcasts>, retrieved 8 August 2019.

take a negative view of our future – the view that we are a second class nation, chained forever to the treadmill of feeding and clothing ourselves.⁴

By 2002, astronomy was clearly positioned by the Department of Science and Technology (DST) as one of four fields of scientific research in which South Africa was seen to have a strongly competitive geographic advantage, the others being human palaeontology, biodiversity and Antarctic research.⁵ By then, initiatives were already well under way to develop a major optical telescope, the South African Large Telescope (SALT), at the SAAO site outside Sutherland, and to develop a bid to host the internationally backed SKA radio telescope; this bid was formally launched in 2003 under the auspices of South Africa's SKA Project office within the National Research Foundation (NRF).

Along with its contribution to boosting South African capacity in science, technology, engineering and mathematics – called the STEM fields – the fact that astronomy was selected as one of South Africa's 'big' science priorities in the 1990s can be linked, in part, to the Mandela government's desire to denuclearise the country and advance a less militaristic agenda after the bloody years of the national liberation struggle. Also significant was Mbeki's vision of an 'African Renaissance', in which South Africa was to play a leading role, which was linked to his and subsequent government commitments to the ideals, if not the practice, of South Africa as a strong 'development state' (see Dubow, Walker, and Atkinson in this issue). However, the elevation of astronomy in the post-apartheid era also owed much to the skilful advocacy of a cohort of visionary astrophysicists, some with impeccable 'struggle' as well as scientific credentials, who were appointed to leading positions within the presidency and department responsible for science and technology in the 'new' South Africa after 1994.⁶

The drive and creativity of these individuals have been well matched by their and other credible public figures' canny marketing of astronomy as a national 'feel-good' story, one that has dominated reporting on both the SALT and SKA projects from the start.⁷ In a sense, then, the imperial and colonial astronomy of the 19th century has been nationalised twice in South Africa, first by the apartheid state and then by the early post-apartheid state, still basking in the after-glow of the country's transition to democracy in the mid 1990s and bolstered by the ideology of an African renaissance in which South Africa was destined to play a leading role.

Yet, while state investment has played a key role in the history of astronomy in South Africa, it is not the only dimension to consider. As the articles by Dubow and Twidle in this issue show, the pioneering Victorian astronomers at the Cape and their 20th-century successors were animated by deep scientific curiosity and wonder at the immensity of the universe and the place of humanity within it; contemporary astrophysicists evince similar

4 Department of Arts, Culture, Science and Technology, 'White Paper on Science and Technology: Preparing for the 21st Century', 4 September 1996, available at <https://www.dst.gov.za/index.php/legal-statutory/white-papers/361-science-a-technology-white-paper>, retrieved 25 January 2019. The DST became a separate department of government in 2002, with a separate Ministry following in 2004.

5 See Government of South Africa, 'South Africa's National Research and Development Strategy' (Pretoria, Department of Science and Technology, August 2002), available at <http://eqdb.nrf.ac.za/sites/default/files/resources/R%26D%20Strategy.pdf>, retrieved 25 January 2019.

6 Significant here are Bernie Fanaroff, an astrophysicist who chose to work in the trade union movement in the 1980s, and Rob Adam, who undertook his doctorate in theoretical nuclear physics while a political prisoner. The former served as deputy director-general in the Office of President Nelson Mandela before becoming the first director of the SKA South Africa Project in 2002. He was succeeded by Rob Adam in January 2016, who then became Director of the South African Radio Astronomy Observatory (SARAO) in 2018.

7 On the early history of the SKA, see S. Wild, *Searching African Skies* (Johannesburg, Jacana, 2012); see also M. Gastrow, *The Stars in Our Eyes: Representations of the Square Kilometre Array Telescope in the South African Media*, (Cape Town, HSRC Press, 2017).

sentiments. In this respect, there are interesting but largely unexplored points of convergence to consider with the country's earlier Karoo cosmologists, among the Xam and other pre-colonial societies. How to do justice to the cultural significance of astronomy and the intellectual, philosophical and aesthetic motivations of its practitioners across time and place, while attending to the more overt, instrumentalist concerns of contemporary astronomy's state and corporate backers, constitutes a challenging terrain for the social sciences. Here, Twidle's insistence in this issue on the value of giving 'more of a hearing to the SKA's science case' is instructive, as is his plea for the need to 'combine scientific and socio-political narratives with the requisite intelligence and sensitivity'.

The SKA

Several articles in this issue review the history of South Africa's bid to host and develop the SKA core site some 90 kilometres from the small Karoo town of Carnarvon, but it is useful to summarise its main features here. The international consortium driving the project began to coalesce in the early 1990s, leading to the signing of a Memorandum of Agreement in 1997 involving, at that stage, eight institutions in six countries (Australia, Canada, China, India, the Netherlands and the USA).⁸ Subsequent negotiations led to the establishment of an international steering committee, which agreed to locate the project headquarters at the University of Manchester in the UK in 2007.⁹ This body also oversaw the shortlisting of South Africa and Australia as possible hosts of the Array infrastructure, in September 2006, and the signing of a new International Collaboration Agreement for the SKA Programme in 2007–8 (with South Africa's NRF one of the signatories). In 2011, the management of the international project was vested in a 'not-for-profit company', the SKA Organisation, which, at the beginning of 2019, had 12 formal member countries (Australia, Canada, China, France, India, Italy, New Zealand, South Africa, Spain, Sweden, the Netherlands and the UK),¹⁰ along with a much wider network of research institutions and other potentially interested national science bodies. In May 2018, negotiations were concluded among member states to constitute the SKA as an inter-governmental organisation (IGO).¹¹

By the time South Africa launched its formal bid to host the Array in 2003, the project's champions had already identified the Northern Cape Karoo as a favourable region for the core site, for reasons which included the region's aridity, elevation, clear skies, degree of basic transport and electricity infrastructure, and, not least, its perceived emptiness and lack of worthy development alternatives. On the SKA International website, the SKA sites in South Africa and Australia are described, collectively, as deserts, hence ideal locations 'for many scientific and technical reasons, from the atmospherics above the sites, through to the radio quietness, which comes from being some of the most remote locations on Earth'.¹² While the Australian site in Western Australia has only a handful of permanent residents, the two local municipalities in which the South African SKA core site is located had a

8 The following summary is based on 'The History of the SKA project', available at <https://www.skatelescope.org/history-of-the-skaproject/>, retrieved 25 January 2019.

9 'The History of the SKA Project'; a further inherently political contest between the UK and Italy to determine where the global headquarters would finally be located saw the UK confirmed, with the project headquarters relocating to the Jodrell Bank Observatory in late 2012.

10 'Participating Countries', available at <https://www.skatelescope.org/participating-countries/>, retrieved 2 February 2019.

11 'SKA Treaty Now Open for Initialling', available at <https://www.skatelescope.org/news/ska-treaty-now-open-for-initialling/>, retrieved on 2 February 2019.

12 'The SKA Organisation', available at <https://www.skatelescope.org/ska-organisation/>, retrieved 26 January 2019. For detailed accounts of the early period, see also Wild, *Searching African Skies*, and Gastrow, 'The Stars in Our Eyes'.

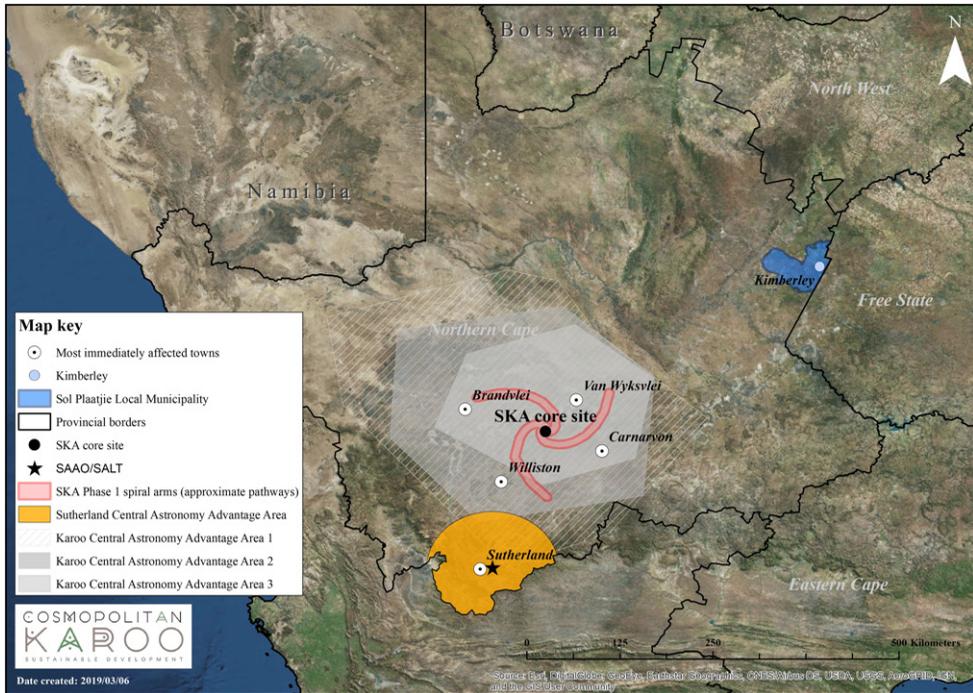


Figure 2. The Northern Cape Astronomy Advantage Areas (AAAs).

combined population of more than 23,000 people in 2011,¹³ and, as several articles in this issue describe, the perception of their land as empty desert is fiercely resented by local residents.

In 2008, the NRF bought two commercial sheep farms in the Kareeberg north-west of Carnarvon, on which to build its seven-unit Karoo Array Telescope (KAT-7);¹⁴ KAT was a South African prototype telescope that was intended to prove to the SKA bid committee that South Africa had the expertise, financial resources and political resolve to host the full array. In this early period, the South African government also took decisive steps to secure its investment in astronomy by enacting the Astronomy Geographic Advantage Act in 2007. This legislation gives far-reaching powers to the minister of science and technology ‘to protect areas ... that are of strategic national importance for astronomy and related scientific endeavours’,¹⁵ by declaring them astronomy advantage areas (AAAs) that can be subjected to further regulatory controls on communication, transport and any other technology (such as electric fencing, microwave ovens and petrol-driven vehicles) as the particular research environment requires.¹⁶ To date, the whole of the Northern Cape province, excluding the provincial capital of Kimberley, has been declared an AAA, while smaller, nested AAAs, each with their site-specific

13 On Australia, see <https://www.skatelescope.org/australia/>, retrieved 5 February 2019; on South Africa, see Statistics South Africa, ‘Provincial Profile: Northern Cape, Census 2011’, Report No. 03-01-72 (Pretoria, Statistics South Africa, 2011).

14 ‘Notes to Editors on the MeerKAT’s Regional Economic Impact’, available at <http://www.ska.ac.za/notes-to-the-editors-on-the-meerkat-regional-economic-impact/>, retrieved 2 February 2019.

15 See <https://www.ska.ac.za/about/astronomy-geographic-advantage-act/>, retrieved 5 February 2019.

16 Republic of South Africa (RSA), *Astronomy Geographic Advantage Act* (No. 21 of 2007, Government Gazette, Vol. 516, No. 31157, Cape Town).

regulation, have been gazetted around the SKA core site and the SAAO site outside Sutherland (see [Figure 2](#)).¹⁷

As several authors (Walker, Chinigò, Atkinson) in this issue point out, the astronomy reserve is significant not only because of its scale and potentially far-reaching consequences for other land users in the Northern Cape but also because of the way it builds on and further reinforces a dominant national discourse that represents the Karoo as essentially a wasteland, of little national significance and hence eminently suitable for development in the interests of the larger public good. Here it is also important to note the significant differences between optical and radio astronomy as land-based activities. Provided light pollution is managed, optical astronomy can co-exist reasonably amicably with other land uses and even encourage new ones, such as tourism, as has been seen in the town of Sutherland, where there was a surge in bed and breakfast establishments catering for star-gazing tourists in the early 2000s. Radio astronomy, however, is a very different proposition: its stringent requirements to reduce, as far as possible, radio-frequency interference from non-cosmic sources mean that a host of modern technologies, including cell phones and petrol-fuelled vehicles, cannot be allowed to operate without regulation in and around the SKA's core site. This makes it an extremely intrusive and inhospitable neighbour.

In 2012, the international bid process to host the Array was concluded with a strongly politically infused decision by the SKA Organisation to split the award between South Africa and Australia, with the larger share of the infrastructure (its high- and mid-frequency dish antennae) to be built in South Africa. Since then, the global project has been unfolding in phases, on the back of the national investments in infrastructure already made by South Africa and Australia. Phase one of the SKA proper, in which an additional 200 dish antennae will be built in South Africa's core site, is currently gearing up, with phase two projected to start in the late 2020s. This will see the building of dish antennae in the eight African partner countries that South Africa brought with it into the project as part of its initial bid.¹⁸

This award of hosting rights to South Africa in May 2012 ushered in a new and far more contentious period in the relationship between the SKA and local residents in the Karoo, as the consequences of the AAA for local sheep farmers became more apparent and the initially high expectations that many local townspeople held about jobs and other opportunities were disappointed (see Atkinson; Gastrow and Oppelt, this issue). Further aggravating these tensions was an acrimonious land-acquisition process by the NRF, involving the purchase of an additional 32 commercial sheep farms from their (white) owners on which the SKA proper (phase one) is to be built. This process was wrapped up in mid 2018, by which time a total of some 130,000 hectares had been transferred into state ownership to constitute the SKA's core site in South Africa. In this time, an additional 64 dish antennae, collectively dubbed 'MeerKAT', were constructed on the two farms originally bought by the NRF for KAT-7 in 2008.¹⁹ A further step towards securing the core site involves its proclamation as a 'special nature reserve' under South Africa's protected

17 RSA, *Declaration of the Karoo Central Astronomy Advantage Areas in terms of the Astronomy Advantage Act, 2007* (No. 141 of 2014, Government Gazette, No. 37397, Cape Town).

18 The eight countries are not full members of the international SKA consortium but have been identified as hosts for some of the infrastructure projected for phase two. While the rolling out of phase two remains uncertain, currently these eight partner countries are involved in the African Very Long Baseline Interferometry (VLBI) Network (AVN), a South African-funded body aiming to 'help to develop the skills, regulations and institutional capacity needed in SKA partner countries to optimise African participation in the SKA'. For more information, see <https://www.ska.ac.za/science-engineering/avn/>, retrieved 5 February 2019.

19 The name 'MeerKAT' is a play, in Afrikaans, on the original Karoo Array Telescope (KAT); it can be read to mean, literally, 'more KAT' while also invoking the meerkat mongoose found in the area, a cartoon drawing of which has been used in some promotional material on the SKA project in South Africa.

areas legislation, devoted to scientific research and thus off limits to ordinary members of the public (see Walker, this issue).²⁰

For local critics of the project, the SKA's campaign to control bandwidth frequency, access and technology in the Karoo has pitted not only the needs of global science against the needs of local residents but also very different understandings of where the power to define the future of this region should lie – with those working to transform it into an infrastructural hub for national and global science or with local residents, many of them mired in poverty and still grappling with an unresolved history of dispossession, discrimination and marginalisation. For those concerned with social justice and sustainable development, this raises difficult questions, engaged by all the articles in this issue more or less explicitly, about whose Karoo it is, who should benefit from the global project taking shape in this neglected part of the country, and what responsibilities lie with the SKA, now the biggest landowner and most powerful institutional player in the district, towards addressing local needs and expectations.

Whose Karoo?

'Karoo' derives from a Khoekhoe word meaning 'dry' or 'hard'.²¹ Today the term is incorporated into the names of two of South Africa's nine biomes – the Succulent Karoo, along much of the western coastline of South Africa, and the Nama Karoo, covering much of the western inland plateau, which is where the SKA and SAAO sites are both located (see Figure 1). What is not always realised is just how much of South Africa the Karoo encompasses: together these two biomes extend over almost one third (30 per cent) of South Africa's total land area.²² However, because of the aridity of the environment and its unsuitability for cultivation and dense settlement, the Karoo biomes account for less than 2 per cent of the national population, a disjuncture which, Walker argues, 'lies at the heart of contemporary disputes over what this land represents for different parties'.

At the same time, despite its significant ecological continuities, the Karoo is not a simple, homogeneous zone with clearly defined boundaries and neatly demarcated borders. Administratively, it falls across four provinces (Atkinson argues that this fact undermines its holistic management and makes it an interesting test-case for co-operative state and regional planning). As a biophysical space, it shades into its neighbouring biomes (fynbos in the south, savannah and grasslands to the north-east and east, ecological desert proper to the north), while ecologists recognise numerous environmental sub-zones, with shifting, porous boundaries, within it. For their part, historians, archaeologists and social scientists have also identified an overlapping but not strictly contiguous range of sub-zones within what may be called the 'social Karoo', each marked by particularities of history, micro-environments and economic opportunity.²³ In literature, 'the Karoo' has long been seen as a liminal space, allowing writers from contributors to the 19th-century *Cape Monthly* magazine through to Olive Schreiner, Pauline Smith, Guy Butler and J.M. Coetzee to imagine its landscape and people as the crucible of the country's deep history. By the early 20th century, the Karoo began to be appreciated by other constituencies as, variously, a distinct zone of aesthetic

20 The small number of dishes installed along three 'spiral arms' extending outwards from the core site over private land will be managed by means of servitude agreements with the landowners, still under negotiation at the time of writing. See Figure 2 for a depiction of the reach of these arms relative to the core site.

21 P.E. Raper, n.d., *Dictionary of Southern African Place Names*, available at https://archive.org/stream/DictionaryOfSouthernAfricanPlaceNames/SaPlaceNames_djvu.txt, retrieved 5 February 2019.

22 See C. Walker, S.J. Milton, T.G. O'Connor, J. Maguire and W.R.J. Dean, 'Drivers and Trajectories of Social and Ecological Change in the Karoo, South Africa', *African Journal of Range and Forage Science*, 35, 3–4 (2018), pp. 157–77.

23 *Ibid.*

value, a place suitable for recuperation (especially by tuberculosis sufferers) and an ancient fossil-rich geological zone of great scientific value.

As Parkington *et al.* (this issue) make clear, the Karoo has never been an empty space. Rather, it has been populated, traversed and claimed from the beginnings of human time. Its contemporary marginalisation within South Africa is a product of both its environment and its more recent past. In the colonial period, it was a site of often murderous conflict that saw indigenous Khoisan groups lose most of the land, with those who survived the onslaught incorporated into the lowest rungs of colonial society and reclassified as ‘coloured’ farm workers. In the first half of the 19th century, as Chinigò (this issue) describes, numerous groups, including Europeans, Khoekhoen, San, Basters, Griquas and Xhosa, competed for resources; however, in the course of the second half of that century, political authority was centralised under the colonial state and an era of settled, comparatively prosperous commercial agriculture initiated, centred on large, white-owned, primarily sheep farms (‘the merino revolution’).²⁴ The social hierarchy of a relatively wealthy elite of white farmers and town-based merchants above a majority of mostly impoverished ‘coloured’ people was further entrenched in the apartheid period and largely persists today.

As a consequence of this history, the socio-economic setting in which astronomy is being developed is, in the words of Gastrow and Oppelt (this issue), ‘one of marginalisation, impoverishment and a persistent racialised apartheid legacy’. This is why questions about identity, belonging and the proper locus of responsibility for local development and redress have been posed so very sharply in relation to the development of the SKA.

Major Themes

Understanding the conflicts and unequal power relations around the development of the SKA and exploring the very different meanings attached to land, place, identity, development and knowledge in and through the Karoo are core concerns of this special issue. However, while all seven articles share an interest in the Karoo as a complex spatio-social site, they draw on different disciplinary perspectives to cover a range of cross-cutting themes, several of which are briefly reviewed here.

A prominent theme, as the above discussion makes clear, concerns the relationship between space, place and time in the configuration of the locus and authority of astronomy in the Karoo. More or less explicitly, each of the articles engages with the analytical distinction between the Karoo as empty ‘desert’ space, ripe for external interventions and appropriation, and the Karoo as deeply social ‘place’, albeit one in which its contested history has produced very different understandings of identity and belonging among its residents. In introducing these concepts, Walker shows how the relationship between space and place is directly connected to questions of scale. Using the lens of critical cosmopolitanism, she discusses the SKA project in relation to its cosmic, global, national and local scales, highlighting the tensions this has produced among actors with very different stakes in the project and the ambiguous alliances that the national SKA organisation has had to forge as a result (involving organised agriculture, environmentalists and the San Council, a body claiming to represent the Karoo’s indigenous San people).

Scale is also an issue in the tension between metropolitan and local networks that has characterised the development of astronomy in South Africa – although, as Dubow points out, this must be read not only in relation to the global centres of power in ‘the north’, but also in relation to long-running south–south rivalries, as seen in the recent competition over

24 See also W. Beinart, ‘An Overview of Themes in the Agrarian and Environmental History of the Karoo since c.1800’, *African Journal of Range and Forage Science*, 35, 3–4 (2018), pp. 191–202.

SKA hosting rights between South Africa and Australia. This raises further questions about the role of nationalism and prestige in driving the investment in astronomy, both clearly evident in South Africa's commitment to expanding the SKA in Africa and recasting its role in the global knowledge economy. Such dynamics are also at play in the rivalries among other member states of the international consortium, for instance the competition between Italy and the UK to host the global headquarters.²⁵ A related theme concerns the significance of borders and boundaries in the ideological representation and the materialisation of the project, operating at very different levels of abstraction and scale. The SKA project is simultaneously boundless (probing the universe on behalf of all humankind) and bounded (a consortium of national states, regulated by an international treaty, working from specific terrestrial sites). In this regard, Twidle raises questions about the significance of the erasure of planetary boundaries as astronomers seek to humanise space, while Atkinson focuses on the relationship between astronomy and the political and administrative boundaries shaping the physical and political spaces in which the SKA is operating in post-apartheid South Africa.

As this last point indicates, the role of the state in the promotion of astronomy and how public authority is constituted in the Karoo are additional themes that this issue addresses, from different angles. Both Dubow and Chinigò point to the similarities in the modernising narratives advanced by the new nation state in South Africa in the Union era as well as 100 years later. In her account, Atkinson approaches the SKA as a case study of the failure of the participatory model of government envisaged in South Africa's 1996 Constitution, read alongside the post-apartheid state's more ambiguous record in relation to the ambitions of the ruling African National Congress to reconfigure South Africa as a successful developmental state – the SKA, she argues, can be seen as a positive example of success in this regard. This analysis helps to explain how a small team of scientists, bureaucrats and politicians, in the relatively minor ministry and departments of science and technology, was able to impose its centralist, top-down agenda for astronomy on the Northern Cape province and the local municipalities affected by the SKA.

Atkinson's account is complemented by the article by Gastrow and Oppelt, which looks more specifically at the national SKA office and its development mandate. This mandate was not, in the first instance, about local social development but about a national agenda aimed at building capacity in science and technology. Building on a normative analysis of the development mandate of the SKA, Gastrow and Oppelt draw on the literature on the development impact of big science projects to show how the SKA's understanding of its local development mandate has been tacit and (thus far) ill-equipped to deal with the social and economic marginality that it has had to confront in the small towns surrounding its core site, where very different understandings of 'development' reside. These different development logics point to a central finding of all the articles in this special issue, namely that the advance of astronomy in the Karoo embodies a notion of development in which the interests of the national 'many', encapsulated in the notion of the 'public good', self-evidently override the interests of the local 'few'.

A related theme raised by this issue concerns the politics of knowledge underpinning astronomy, including the tensions between global scientific knowledge and ideas of progress, on the one hand, and local knowledges and uncertainties about the future, on the other. All the articles in the collection attend to this theme, either explicitly or obliquely, as well as the calculation of and access to the benefits said to flow from astronomy. The politics of knowledge is also deeply entwined with issues around identity formation at

25 See 'UK Beats Italy to Host SKA Headquarters', 4 May 2015, available at <https://physicsworld.com/a/uk-beats-italy-to-host-ska-headquarters/>, retrieved 5 February 2019.

different levels and contrasting understandings of what the Karoo landscape means and for whom. Building on the distinction between place and space, Parkington *et al.* draw attention to profound differences between past and present understandings of this landscape when they contrast the intimate cosmology and being-in-the-world of the |Xam against the infinite cosmology of astronomy.

In reflecting on this encounter, they also address two persistent myths about the |Xam hunter-gatherers of the 19th century, the endorsement of which has been implicit in the way the SKA has attempted to deal with the pre-colonial history of its core site. The first of these myths is the ‘myth of extinction’ and the second the ‘myth of retreat’. Against the widely held view that settler violence led to the *de facto* extinction of the |Xam in the colonial period, the authors argue that |Xam descendants are still living in the farms and towns around the SKA core site today, although their relationship to their forebears is seldom acknowledged. This adds a further compelling argument to why local people should be actively involved in bottom-up planning of the local development opportunities that could result from current astronomy initiatives in the Karoo. Expanding on related points in Walker’s article, they are also critical of the SKA management’s use of snippets of the cultural heritage of San cosmology as, essentially, a decorative backdrop to embellish the political credentials of their project.

The politics of knowledge is also imbricated in complex ways with contemporary negotiations around identity in the Karoo. Contributions by Walker, Parkington *et al.*, and Chinigò refer to the re-emergence of Khoisan and Xhosa identities in the Karoo and how these are manifesting themselves in land claims that, if realised, have the potential to destabilise the current investment in astronomy in the region. At a time when the debate on the parameters of an equitable land reform programme has become a major focus of political contestation in South Africa, these claims are also taking on a broader significance in relation to how far back in time the country’s formal restitution programme should reach, which ‘first people’ narratives have the greatest authenticity, and over how much land in contemporary South Africa that authenticity should stretch. As Chinigò’s article shows, depending on how far back in the 19th century one goes, the descendants of both the |Xam and Xhosa people who previously occupied or formally owned land in the region where the SKA is now being built have serious claims to restitution; only the latter, however, qualify under South Africa’s Restitution of Land Rights Act of 1994, by virtue of a history of dispossession that extends up until 1913 and thereby meets the legal cut-off date requirements of that Act. Read together, the articles by Parkington *et al.* and Chinigò highlight the complex history of dispossession in the region where the SKA is being constructed, and its reverberations in contemporary identity claims. Ironically, the white beneficiaries of the history of dispossession that they describe, those whose farms were acquired by the SKA for its core site, have been compensated financially for their losses, while older, historically more pressing claims have not (yet) been recognised.

A further set of themes, raised most compellingly by Parkington *et al.* and Twidle, relate to understanding the cultural artefacts that have come from the study of the stars, whether in the form of |Xam stories about the origins of the Milky Way, Herschel’s 1847 pencil sketch of Orion’s Great Nebula, or the ‘sublime’ images of galactic phenomena produced by the Hubble Space Telescope, which circulate on the internet. Representations of the cosmos, Twidle notes, ‘can be seen simultaneously as a scientific object and a multi-dimensional archive of the humanities: a vast repository of narrative, picturing, pattern-recognition, myth and metaphor’. Twidle also uses a discussion of the differences between optical and radio astronomy in terms of the imagery (rather than the underlying data) that they produce as an entry point to ask how the SKA organisation might develop a more affective relationship between the publics whom it wants to convince (about the importance of its work) and the

imagery that its science is producing: a question that is particularly relevant in the context of the Karoo, where basic science literacy is extremely low.²⁶ He concludes that astronomers need a different form for telling their story – that ‘the extra-terrestrial ambitions of astronomy must be brought down to earth and understood within a distinctly worldly set of concerns and local contestations’. In this respect, his analysis, framed by the literatures of the environmental humanities, converges with the concerns of Gastrow and Oppelt, working from the perspective of Science Studies (and the sub-field of Science Communication within that).

Further Research

Given the exploratory nature of this special issue, many important topics are covered only in passing or not at all. In conclusion, we wish to highlight four broad issues for future research, without in any way suggesting that this list is definitive. The first concerns understanding the SKA as a global enterprise, one that is also unfolding in other national contexts. The second, which is linked to this, is about the need for more comparative perspectives, both in relation to other astronomy projects and in relation to other big infrastructure projects, in southern Africa and elsewhere, that raise similar or related concerns around development, place, space and scale. The third concerns the methodological and conceptual challenges around researching astronomy as a social as well as a cognitive practice, and the fourth is about taking forward the challenges that all the articles pose, asking what a more socially just, sustainable and participatory local development agenda might look like.

With regard to the first issue, there are important questions about geo-politics and the structure of the SKA’s funding that need more systematic research than has been undertaken to date. Key questions include how much this mega-science project is costing both globally and at national level, how it is being funded and who will end up paying for it. Part of the complexity here arises from the nature of the international collaborations constituting the consortium that has been funding the project, culminating in the IGO. Unlike ‘traditional’ big science projects funded through single-country national budgets, the SKA is taking shape at the intersection of a network of governments, research communities and industrial actors from different parts of the world.

In respect of comparative work, there are many compelling issues to take up, especially as the SKA extends its footprint into Africa in the coming decade, an expansion that may recapitulate earlier forms of sub-imperialism. Twidle references the history of astronomy in Chile’s Atacama Desert, where science, archaeology and international and local politics all come together in place-specific but provocatively comparable ways with developments in southern Africa. Another area for comparative work is in Hawaii, where first-nation people have protested forcefully against the erection of a giant optical telescope on their sacred site of Mauna Kea, in a striking instance of colliding global and indigenous cosmologies.²⁷ A comparison of the history of astronomy in colonial South Africa and Australia, pointed to by Dubow, is another fascinating area for more work, as is comparative work on the rollout of the SKA in Australia, including how issues around competing land uses and the project’s relationship to indigenous knowledge and aboriginal land claims are unfolding. Such work

26 See D. Atkinson, R. Wolpe and D. Kotze, ‘Socio-Economic Assessment of SKA Phase 1’, report prepared as part of the strategic environmental assessment (SEA) for the Phase 1 of the SKA radio telescope (Pretoria, CSIR, 2017), pp. 122–3.

27 See, for instance, M.B. van Dyke, ‘Dozens Arrested as Hawaiians Protest \$1.4bn Telescope on Sacred Mountain’, *Guardian*, London, 18 July 2019, available at https://www.theguardian.com/us-news/2019/jul/18/hawaii-mauna-key-protest-arrests-observatory?CMP=Share_iOSApp_Other, retrieved 18 July 2019.

would also be important for challenging the methodological nationalism and insularity that Walker (this issue) notes has so often characterised South African studies.

The third issue concerns the challenge of undertaking critical, inter-disciplinary work across the conceptual, methodological and institutional boundaries that separate social scientists (broadly understood) from astronomers and physical scientists. This challenge, which has taxed all the contributors to this Special Issue in various ways, has many different aspects, including how social scientists can engage productively with physicists who relegate the work of social scientists to the domain of ‘outreach’ and science education, and how they can present critical, socially grounded independent research without being seen as anti-science. At the same time, as Twidle points out, a major responsibility also lies with social scientists to understand what astronomers actually do, both as scientists and as significant producers of cultural artefacts and ways of knowing in the contemporary world.

Finally, more work is urgently needed on alternative development scenarios for the Karoo and what the more inclusive process of consultation and development that the contributors to this Special Issue would like to see would look like and how that process might be advanced. All the authors highlight the need for this, for both strategic and moral reasons, but they also agree that this is a major challenge. Given the nature of radio astronomy, are such objectives even possible in relation to the SKA? What are the responsibilities of global and national astronomy in relation to other agents tasked more directly with responsibility for local development? What would an effective and inclusive land restitution process look like and how could it contribute to breaking down, not reinforcing, the social and economic marginalisation of the Karoo? What are the prospects for astro-tourism, and who should drive and benefit from this? Can astronomy be combined with environmental conservation in ways that benefit local economies, rather than entrenching the sharp divisions between protected areas and neighbouring communities?

These and other difficult questions have exercised the contributors to this Special Issue in their individual work and in the debates at the workshop in February 2018, at which earlier iterations of these articles were discussed.²⁸ There are differences as to the degree of optimism or scepticism with which they approach the underlying issues, but all agree that these are important, open questions that need to be taken up across the different arenas of policy, governance, advocacy and research, as events unfold.

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28 Workshop titled ‘Karoo Futures? Global Science, Astronomy and the Square Kilometre Array (SKA)’, hosted by the DST/NRF SARChI Research Chair in the Sociology of Land, Environment and Sustainable Development, Stellenbosch University, South Africa, 22–23 February 2018.