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Impossible Images: Radio Astronomy, the Square Kilometre Array and the Art of Seeing

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In South Africa's arid central Karoo, astronomers and engineers are slowly building the biggest scientific instrument in the world. The Square Kilometre Array (SKA) will one day link radio telescopes across the southern hemisphere, turning much of the planet into a vast ear for picking up the faintest echoes from the early universe. This article explores the conceptual and representational challenges posed by radio astronomy in general and the SKA in particular. What kinds of cultural artefacts and images are likely to be produced by the SKA, and what kind of relationship will a non-specialist audience have with them? How can the Array's unprecedented power to look (or listen) back in time be related to the deep human past that has left traces all through the Karoo landscape? Working through a series of images, my enquiry moves from optical astronomy in Cape Town and Sutherland to the radio dishes near Carnarvon, tracing a history of picturing the cosmos and the southern skies. I explore how questions of visibility, imagination and aesthetics might be introduced to the languages of science, policy and public relations, in which this project is most often discussed, and argue that the project (in terms of a cultural response) asks for more than the journalistic, the literal or the merely informational. It challenges writers and artists to work at the limits of representation and to find ways of registering the incommensurate scales and meanings compacted into a Karoo landscape that has often been figured as 'empty' but now seems full of noise, data and politics.

Keywords: Square Kilometre Array; radio astronomy; astronomical imaging; Karoo; space and place; landscape; South Africa

'How strange these representations become when they are at their limits. Their dullness is fascinating in its own right, as if transcendence were secretly boring'.

James Elkins, *Six Stories from the Edge of Representation*¹

First Light

In July 2016, a press release from the Square Kilometre Array (SKA) announced: 'MeerKAT joins the ranks of the world's great scientific instruments through its First Light image'. Operating at a quarter of its eventual capacity, this precursor telescope to the full

¹ J. Elkins, *Six Stories from the Edge of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics 1980–2000* (Stanford, Stanford University Press, 2008), p. 115.

Array had been pointed at a patch of sky representing 0.01 per cent of the celestial sphere. In just this portion, the instrument had detected 1,300 galaxies where only 70 were known before. The scientists and engineers at SKA were, the *New York Times* reported, ‘showing off the first taste of the ultimate cosmic feast of what is to come’.²

In astronomy, the term ‘First Light’ denotes the initial use of a telescope to produce an image after the instrument has been constructed. Often it will be of little scientific interest or of poor quality; it serves mainly a symbolic function and signals a significant milestone in the history of the project. The SKA, when completed, will be the largest scientific instrument in the world: a radio telescope of unprecedented size and power. Yet, for a casual observer of these and other promotional materials released by SKA, there is likely to be something of a disjuncture between the knowledge of what is being perceived and the aesthetic force of the images, particularly when compared to the spectacular pictures generated from, say, the Hubble Space Telescope (HST). The same *New York Times* article on MeerKAT carried a link to a piece celebrating the 25th anniversary of the Hubble in 2015 and a gallery of its greatest hits: the gaseous spires of the Eagle Nebula, dubbed ‘The Pillars of Creation’ by NASA; the Helix Nebula, nicknamed the ‘Eye of God’; the 2004 Hubble Ultra Deep Field exposure.

Both the Hubble Deep Field and SKA’s First Light undertake a kind of deep core sample of a tiny patch of sky. But, while the former offers spirals that are visibly recognisable as galaxies and a depth of field that the mind’s eye can inhabit feelingly, the radio image seems to work in a different visual language. First Light is mainly a dark square against which the newly discovered phenomena show up as whitish, yellowish, reddish specks or particles of glitter (see Figure 1).³ Vast radio galaxies with black holes at their centre do not resolve into much more than pixellated blurs reminiscent (as with many radio astronomical images) of infrared or thermal mapping. Even when magnified, they have the feel of low-resolution graphics or pictures still being rendered.⁴ Yet, at the same time, radio astronomy is able to grant much richer images of more proximate parts of the cosmos that are invisible to optical telescopes. In July 2018, the completed MeerKAT array was trained on the supermassive black hole at the centre of our Milky Way galaxy, a region shrouded by dust, impenetrable to optical instruments. MeerKAT’s image was aglow with supernova remnants and gaseous filaments (see Figure 2), its exceptional resolution and detail showing this precursor radio telescope to be, already, one of the most powerful in the world.

Such tensions – between data and image; between what is cosmologically and visually arresting; between science, symbol and public perception – are my points of departure in exploring the representational challenges posed by radio astronomy in general and the SKA in particular. Reflecting on a history of picturing or figuring southern skies, I am interested in how questions of aesthetics and representation might be introduced into the discourse of science, policy and public relations, in which such a project is most often discussed.⁵ What kinds of cultural artefacts will be produced by the SKA, and what kind of affective

2 ‘South African Telescope Spots 1,300 Unknown Galaxies’, *New York Times*, 18 July 2016, available at <https://www.nytimes.com/2016/07/19/science/square-kilometer-array-south-africa-meerkat.html>, retrieved 1 May 2018. MeerKAT is the South African-built precursor to the SKA proper; on this background, see C. Walker, ‘Cosmopolitan Karoo: Land, Space and Place in the Shadow of the Square Kilometre Array’, elsewhere in this issue.

3 For a larger gallery of images and captions associated with this article, see H. Twidle, ‘Impossible Images’, 1 December 2018, available at <https://hedleytwidle.com/home/the-array?rq=impossible>, retrieved 10 June 2019.

4 For more examples of the visual ‘language’ of radio astronomy, see MeerKAT Gallery, available at the SKA South Africa website, <http://www.ska.ac.za/gallery/meerkat/>, retrieved 1 May 2018.

5 For a consideration of the SKA’s publicity and media messaging, see M. Gastrow, *The Stars in Our Eyes: Representations of the Square Kilometre Array Telescope in the South African Media* (Cape Town, HSRC Press, 2017).

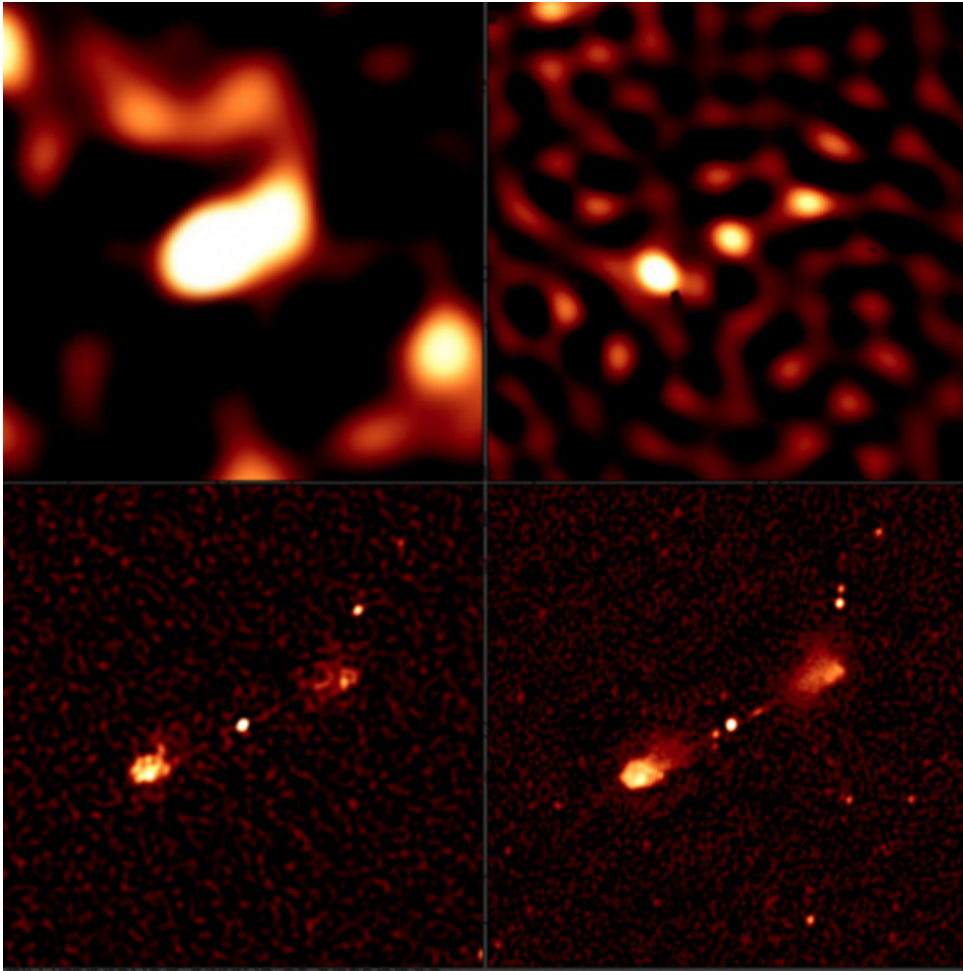


Figure 1. MeerKAT First Light (details). Courtesy of SKA South Africa/SARAO.

relationship might a non-specialist audience be able to have with them? How do the scientists and engineers involved understand their own practice, and in what terms do they discuss the project?

Following visits to both the core site near Carnarvon in the Northern Cape and the South African head offices in the Cape Town suburb of Pinelands, I have found the SKA a challenging subject to write about, poised as it is between the mind-boggling and the banal. It is a global scientific collaboration of immense ambition and complexity, which will transform scientific ideas across a range of topics: the nature of pulsars and dark matter, the formation of galaxies, the possibilities of detecting extra-terrestrial life, and the emergence of the first star-producing regions within the early universe during the Epoch of Re-ionisation (another meaning of the phrase ‘First Light’ within the lexicon of cosmology). Radio astronomy, remarks one former SKA systems scientist, is the technology poised to detect the oldest ‘light’ in the universe: waves and photons ‘that have been travelling for as long as it has been possible for them to travel’.⁶

⁶ Interview with former SKA senior systems scientist Charles Copley, Cape Town, 23 May 2018. All interviews for this article were conducted by the author.

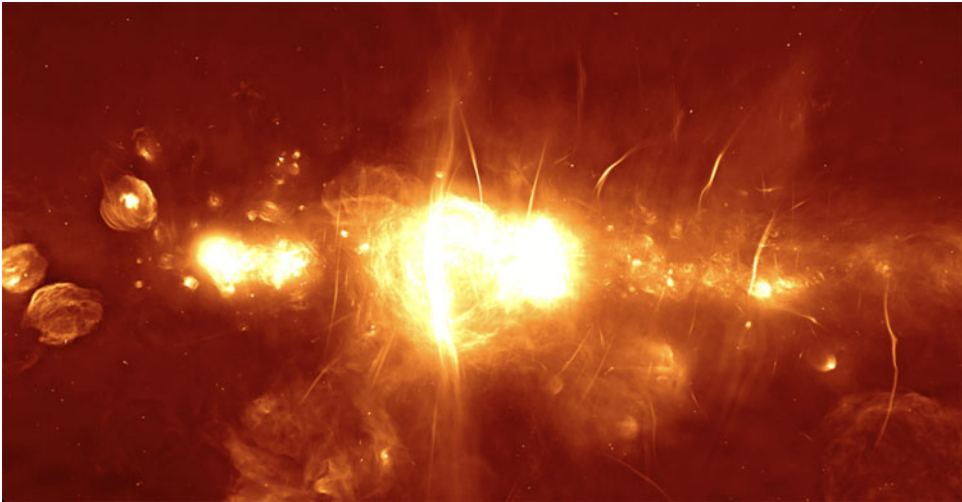


Figure 2. MeerkAT image of galactic centre. Courtesy of SKA South Africa/SARAO.

For such matters, wrote Primo Levi, ‘our language is inadequate and seems laughable, as if someone were trying to plough with a feather. It’s a language that was born with us, suitable for describing objects more or less as large and as long-lasting as we are; it has our dimensions, it’s human. It doesn’t go beyond what our senses tell us’.⁷ As one of the most thoughtful 20th-century writers operating at the interface of literature and the sciences, Levi goes on to remark that if this story (in his case, the death of a distant star) must be written, ‘we must have the courage to eliminate all adjectives that tend to excite wonder: they would achieve the opposite effect, of impoverishing the narrative’.⁸

In evoking domains of experience that confound and supersede human apprehension, while simultaneously re-affirming the reach and ingenuity of the human subject to think of the unthinkable, astronomy is a science that has often been understood in terms of the sublime. And yet there is something decidedly non-sublime – mundane, in fact – about the day-to-day workings of an organisation like the SKA: a large, globally dispersed project in which many of the major technical challenges are concerned with matters of data capture and digital processing architecture, in which the images produced will often be at the limits of resolution and representation – blurry, grainy, flat or colourless. They are patently artificial or impossible constructs, given that they are mapping phenomena that can never be ‘seen’ in the ordinary sense. Contrary to Neil deGrasse Tyson’s comments on the Hubble archive, they *do* need a caption in order to be appreciated.⁹ At first glance it is difficult for a non-scientist to have an affective relation to many of the images produced by radio astronomy, images that, as one MeerkAT researcher remarks, are ‘as close to a graph as you can get for a picture’.¹⁰

The early history of optical astronomy in southern Africa is shot through with romantic tropes and compelling visuals, from Nicolas Louis de Lacaille’s 1756 planisphere of the

7 Primo Levi, ‘A Tranquil Star’ (1981), trans. A. Goldstein, in Primo Levi, *Complete Works*, vol. 2 (New York, Liveright, 2015), p. 1419.

8 *Ibid.*

9 ‘Unforgettable Hubble Space Telescope Photos’, *New York Times*, 23 April 2015, available at <https://www.nytimes.com/interactive/2015/04/23/science/space/unforgettable-hubble-space-telescope-photos.html>, retrieved 1 May 2018.

10 Interview with Richard Armstrong, a postdoctoral researcher working at SKA on MeerkAT imaging, Cape Town, 23 May 2018.

‘austral’ stars to John Herschel’s sketches of nebulae in the 1830s. It is a story that lends itself readily to narrative presentation: lone mavericks struggling against physical and political impediments, observing all through the night, unlocking hitherto unknown domains of experience, tracing and retracing them by hand.¹¹ But the dispersed, disembodied and post-human nature of radio astronomy – a science intimately linked with massive data aggregation and 20th-century computing – presents more of a challenge to a non-specialist writer. It is not, as journalist Sarah Wild remarks in the first book-length account of the SKA, ‘an immediate science’.¹²

Moreover, if the sublime is an aesthetic mode that has often been implicated in a discourse of colonial expansion and spurious ‘discovery’, then the SKA’s attempt to represent astronomy as a transformative, post-apartheid project poses the second-order question of what socio-aesthetic register its own discoveries might best be expressed in. This comes into particular relief given that the large Astronomy Reserve decreed for the SKA in the Northern Cape quite literally overlays a space that carries an immense time-depth of human occupation, a rich record of indigenous cosmology and an often unspoken history of colonial dispossession and genocide.¹³ Are such stories – of contemporary astronomy and the Xam, of First Light and First Peoples – continuous or just contiguous? And how might they be placed into relation without being forced or falsified?

As the contributors to this special issue emphasise in different ways, the extra-terrestrial ambitions of astronomy must be brought down to earth and understood within a distinctly worldly set of concerns and local contestations. Several articles deal in detail with the local politics and conflicts around the ‘Astronomy Reserve’ (formally, the Astronomy Advantage Areas) in the Northern Cape.¹⁴ While bearing these dynamics in mind, I have felt the need to sketch in a ‘bigger picture’: to give more of a hearing to the SKA’s science case, to understand the project’s basic physics and logistics, and to deepen an understanding of 21st-century radio astronomy as a practice. I am intrigued by the very different scales, temporalities and histories that touch each other within the space of the SKA core site and how representations of even the most distant and non-human objects will inevitably be inflected with contemporary designs and desires. How can the telescope’s unprecedented power to look (or listen) back in time be related to the deep human past that has left traces all through this Karoo landscape, a space that has itself both invited and resisted the discourse of the sublime?

This region – a place of important archaeological and rock art sites now become portal to the early universe – emerges as a site of overlaid timescales that are difficult to hold within a single conceptual frame or to reduce to a simple narrative or political shape. In what follows, I trace a history of picturing space from southern Africa and reflect on the challenge of bringing the unseen, in both cosmological and historical terms, into view. The final section turns to Patricio Guzmán’s film *Nostalgia de la luz* (*Nostalgia for the Light*, 2010) – a

11 See S. Dubow, ‘200 Years of Astronomy in South Africa: From the Royal Observatory to the “Big Bang” of the Square Kilometre Array’, elsewhere in this issue; see also I.S. Glass, *Nicolas-Louis de la Caille: Astronomer and Geodesist* (Oxford, Oxford University Press, 2013) and *The Royal Observatory at the Cape of Good Hope: History and Heritage* (Cape Town, Mons Mensa, 2015); B. Warner, *Charles Piazzi Smyth. Astronomer-Artist. His Cape Years 1835–1845* (Cape Town, A.A Balkema, 1983) and *Royal Observatory, Cape of Good Hope, 1820-31: The Founding of a Colonial Observatory* (Dordrecht, Kluwer, 1995); D. Gill, *A History and Description of the Royal Observatory, Cape of Good Hope* (London, HMSO, 1913); S. Ruskin, *John Herschel’s Cape Voyage: Private Science, Public Imagination and the Ambitions of Empire* (Aldershot and Burlington, Ashgate, 2004).

12 S. Wild, *Searching African Skies* (Johannesburg, Jacana, 2012), p. 56.

13 See J. Parkington, D. Morris and J. de Prada-Samper, ‘Elusive Identities: Karoo Xam Descendants and the SKA’, elsewhere in this issue.

14 For background on the declaration and reach of the Astronomy Advantage Areas in the Northern Cape, see the Introduction to this special issue.

documentary meditation on astronomy in Chile's Atacama desert – for a model of how to combine scientific and socio-political narratives with the requisite intelligence and sensitivity.

Outer Space and Earthly Place

In *Picturing the Cosmos*, Elizabeth Kessler notes that astronomy is distinct as a science in that most of its objects cannot be manipulated, only observed – and so in many ways it is 'about the pleasure of looking'.¹⁵ In a close reading of the images collated by the Hubble Heritage Project, she explores them as graphics both otherworldly and commonplace: reproduced on calendars, desktop backgrounds and coffee mugs around the world. Positioned at an intersection of science and public relations (and with the US soft power of NASA's marketing arm behind it), the visual language of the Hubble project has come to inform everything from album covers to computer games. The HST's time in orbit (launched in 1990) has also coincided with the advent of the Internet as a tool for circulating images to an extent unprecedented in human history; and so the telescope's brilliant career has also been intimately linked to a global shift from analogue to digital image processing.¹⁶

Tracing a history of how optical astronomy has often been drawn to remote, arid and sparsely populated landscapes in search of darker, clearer skies, Kessler argues that the Hubble Heritage version of the astronomical sublime – towering spires of dust clouds, vertical orientations, high contrast, dramatic lighting, boundlessness – is strongly indebted to a tradition of romantic landscape painting that constructed the American West, and later informed the work of photographers like Ansel Adams: immensely detailed, high-contrast images of canyons and buttes that were often cropped to exclude signs of human presence.¹⁷ What she does not touch on, however, is how this vision of a wilderness denuded of any prior or indigenous habitation has often served an expansionist or extractive imaginary that makes claim to an empty landscape or *terra nullius*. The idea of the Karoo as a space void of human history and community – a 'dream topography' inflected by deep rather than historical time – is partly re-animated by the construction of the Northern Cape as a site 'empty' of radio interference and other signals of industrial modernity: a matter to which I will return.¹⁸

In their 'earthly ethnographies' of NASA missions, Mars exploration and equatorial launch sites, scholars such as Lisa Messeri and Peter Redfield show how outer space is inevitably reimagined as place: a geopolitical working out of Calvino's insight that human representation has evolved with (at most) planetary dimensions and frames of reference at its

15 E. Kessler, *Picturing the Cosmos: Hubble Space Telescope Images and the Astronomical Sublime* (Minneapolis and London, University of Minnesota Press, 2012), Kindle edition, loc. 156.

16 From its planning stages, the HST relied on charged-coupled devices (CCDs) rather than photographic plates or television receptors, producing numerically coded images that were relayed to earth (in the first instance) as greyscale digital images. As such, they are among the earliest examples of 'natively digital' photographs. K.K. Arcand *et al.*, 'Processing Colour in Astronomical Imagery', *Studies in Media and Communication*, 1, 2 (2013), p. 27.

17 R. Solnit, *Savage Dreams: A Journey into the Hidden Wars of the American West* (San Francisco, Sierra Club, 1994) reads Yosemite National Park and the Nevada Testing Range as linked spaces that were both constructed as empty of native American history within mainstream discourses of conservation and the Cold War, the former to create an American Eden (and one popularised by photographer Ansel Adams's images), the latter as a domestic Armageddon, 'national sacrifice zone' required for nuclear dominance.

18 The phrase 'dream topography' is from J.M. Coetzee, *White Writing: On the Culture of Letters in South Africa* (New Haven, Yale University Press, 1988), p. 7: 'South Africa as a vast, empty, silent space, older than man, older than the dinosaurs whose bones lie bedded in its rocks, and destined to be vast, empty, and unchanged long after man has passed from its face'. This metaphorical schema, Coetzee suggests, registers a failure or willed blindness of the settler-colonial imagination, in that it fails to imagine human community and fraternity in South Africa. Intriguingly, as other articles in this issue show, local farmers are among those who are now contesting the notion of the Karoo as empty landscape.

disposal.¹⁹ In a comparable way, within the popularised visual language of Hubble (a global astronomical lingua franca, if ever there was one), the radically distant and unfamiliar is remade via recognisable, even conventional aesthetic codes, using the immense array of image-processing tools available through software like Photoshop. In the light of such obtrusive aesthetic decisions, the Hubble pictures have always had their sceptics and detractors: those who regard such ‘false colour’ images as artificial, hyperbolic or even kitsch confections – ‘pretty pictures’ (in the dismissive phrase often used by astronomers) used to attract public support but of limited interest to scientists.²⁰

‘We must have images; we cannot have images’, writes Peter Galison in attempting to capture the uneasy relation between visual and mathematical ways of knowing in the history of science:

[w]e must have scientific images because only images can teach us. Only pictures can develop within us the intuition needed to proceed towards further abstraction. We are human, and as such, we depend on specificity to learn and understand.[...] And yet: we cannot have images because images deceive. Pictures create artifactual expectations, they incline us to reason on false premises. We are human, and as such are easily led astray by the siren call of material specificity. Logic, not imagery, is the acid test of truth that strips away the shoddy inferences that accompany the mis-seeing eye. Abstraction, rigorous abstraction, is exactly that which does not depend on pictures.²¹

Holding in mind this long-standing ambivalence around the image within scientific history – a tension between numerical data and visual models as ways of understanding – one can trace different but linked ways of conceiving what kind of instrument a telescope might be: an aid for greater seeing, but also an instrument for imaging the unseeable.

From Galileo’s *Sidereus Nuncius* (1610) onwards, such technologies have in one sense worked to extend and amplify human vision: the telescope as an ever more powerful or surrogate eye. Yet, equally, Galileo’s remarkably precise sketches of the rough, cratered surface of the moon (achieved through early modern techniques of shading and chiaroscuro) bring home how astronomical imaging has, from its inception, also depended on aesthetic mediation and available technologies of visual reproduction.

In Lacaille’s 1756 planisphere of the southern stars, one sees a diagram in which mythological picturing and Enlightenment technology quite literally exist on the same plane (see [Figure 3](#)). Following his observations at the Cape in 1751–52, this French apostle of Newton added to the Ptolemaic zodiac by naming 15 ‘new’ constellations after his own equipment, among them the Telescope, the Microscope, the Air Pump, the Compass, the Chisel, the Easel. As a visit to Cape Town’s planetarium will be sure to inform you, Lacaille gave modern astronomy the first constellation that takes its name from a terrestrial object: Mons Mensa (Table Mountain), so called because the adjoining Nubecula Major, or Large

19 L. Messeri, *Placing Outer Space: An Earthly Ethnography of Other Worlds* (Durham, Duke University Press, 2016); P. Redfield, ‘Beneath a Modern Sky: Space Technology and its Place on the Ground’, *Science, Technology, and Human Values*, 21, 3 (1996), pp. 251–74, and *Space in the Tropics: From Convicts to Rockets in French Guiana* (Berkeley and Los Angeles, University of California Press, 2000). Messeri quotes Redfield for the epigraph of her book: ‘Concentrating on space, one encounters place’.

20 See, for example, the discussion of ‘Astronomy’s Bad Reputation’ in Elkins, *Six Stories from the Edge of Representation*, pp. 87–8. Elkins remarks: ‘[o]utside the poison well of sentiment and sensationalism there is a truly lovely desert of astronomical images that do not try to be pretty [...] a far cry from the boisterous whirling galaxies that are presented in NASA press releases’ (p. 89). I am grateful to Elizabeth Kessler for drawing my attention to this passage.

21 P. Galison, ‘Images Scatter Into Data, Data Gather Into Images’, in B. Latour and P. Weibel (eds), *Iconoclasm: Beyond the Image Wars in Science, Religion and Art* (Cambridge, Mass., MIT Press, 2002), p. 300.

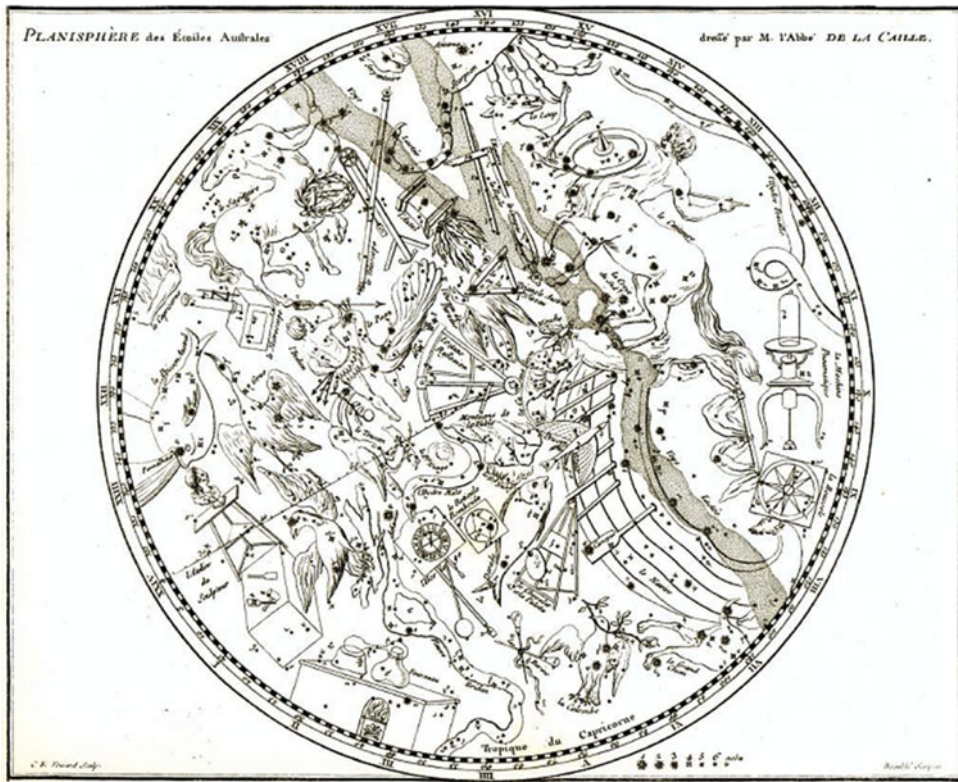


Figure 3. De Lacaille's 1756 Planisphere. Wikimedia Commons.

Magellanic Cloud, might be said to resemble the distinctive white 'table cloth' that forms over the mountain's cliffs when the south-easterly wind blows.

As a graphic that collapses technology, mythology (and earthly topography) into a single disc, Lacaille's Planisphere might serve as an emblem for how representations of the cosmos – or at least the 'shallow sky' of our Milky Way galaxy, visible to naked-eye astronomers – 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.

If the SKA First Light and Hubble Deep Field images offer a 'core sample' of a small patch of the celestial sphere, then the gaze, so to speak, can also be reversed and trained on the human past. That is: astronomical objects distinctive to the naked eye can be used as optics to undertake an archaeological cross-section through the human imagination, and to trace how conspicuous phenomena in a shared sky have been differently figured throughout human history. To take just this one example: the dwarf galaxies of the Magellanic Clouds were seen as cows (*al-Baqari*) by Muslim chroniclers of the heavens such as Ibn Qutaybah and Al-Sufi, as emu eggs by the ancestors of Yamaji and other Aboriginal communities living near the SKA site in Western Australia, and as a family of *steenbokke* (antelopes) by the |Xam people, whose heartland overlapped so closely with what is now the Astronomical Reserve in the Northern Cape.²² In the decades since 1994, the 19th-century testimonies and

22 See J.M. de Prada-Samper, '|Xam Star Lore', in J. Parkington, D. Morris and J. de Prada-Samper (eds), 'Karoo and the |Xam Cosmos', unpublished manuscript, p. 134. Orion's Belt, Lloyd recorded in an 1873 notebook, was seen by the |Xam as 'three she-tortoises living upon a stick'.

narrations of individuals like |A!kúnta (Klaas Stoffel), Diä!kwain (David Hoesar), |Han ≠kass'ō (Klein Jantje), ||Kabbo (Oud Jantje Tooren) and Kweiten-ta-||ken (Griet) have come, via the Bleek and Lloyd archive, to inform so much of the post-apartheid cultural imaginary (even appearing on the South African national crest itself).²³

This method of running together the immensely distant objects of contemporary astronomy with the 'intimate cosmology' of First Peoples across the global south formed the basis of the 2015 SKA-sponsored 'Shared Sky' exhibition, which sought to place southern African and Australasian star lore into dialogue.²⁴ In South Africa, a community art project based in the eastern Karoo town of Nieu Bethesda helped in creating artworks based on such well-known stories as 'The Girl Who Made Stars' and 'The Origin of Death'.²⁵ The result was an exhibition that then travelled round the world as a method of showcasing the SKA project, while also highlighting its political sensitivity and social responsiveness: 'Shared Sky stems from a vision by the Square Kilometre Array (SKA) to bring together under one sky Australian and South African artists in a collaborative exhibition celebrating humanity's ancient cultural wisdom'.²⁶ Within such commissioned projects, I would suggest, there is a risk of forcing scientific and indigenous knowledge systems into an uneasy alliance, or an unlikely narrative, in the service of public relations and transnational diplomacy. But, equally, a notion of the cosmos as, in the philologist Wilhelm Bleek's words, 'the theatre of numberless poetically conceived histories' is one that can be held in mind even when turning to scientific practice and exploring the questions of aesthetics and representation that have always inhered in astronomical imaging.²⁷

The Art of Seeing

'Seeing is in some respects an art that must be learnt', wrote William Herschel to a correspondent in 1782, fending off the scepticism of those who did not believe in the magnifying power of his instruments: '[m]any a night have I been practising to see, and it would be strange if one did not acquire a certain dexterity by such constant practice'.²⁸ Continuing his father's research into nebulae, clusters and binary stars, John Herschel travelled to Cape Town in 1834 and spent four years 'sweeping' the southern skies with a private 20-foot reflector telescope installed on his estate at Feldhausen in the shadow of Table Mountain (in the present-day Cape Town suburb of Claremont). Published in 1847, his *Cape Results* consists mainly of tables and figures charting the co-ordinates and magnitudes of celestial objects: a magisterial survey of the southern skies that caught the

23 For an account of the complex cultural mediations and contestations that produce this archive, and its 'rediscovery' after apartheid, see H. Twidle, '|Xam Narratives of the Bleek and Lloyd Collection', in D. Attwell and D. Attridge (eds), *The Cambridge History of South African Literature* (Cambridge, Cambridge University Press, 2012), pp. 19–41.

24 On |Xam cosmology as an 'intimate cosmology', see Parkington *et al.*, 'Elusive Identities'. On the Shared Sky exhibition, see also Walker, 'Cosmopolitan Karoo'.

25 Recorded in over 70 variants throughout southern Africa, the latter story of the moon giving a message about the immortality of humankind to the hare (who distorts the message and makes humans mortal) is one of the most compelling suggestions that a pan-Khoi-San myth complex once extended throughout the entire southern African region. It is also, at a stretch, a story about astronomical noise and signal.

26 See the brochure catalogue for the Shared Sky exhibition, which was held at the Iziko South African National Gallery, 13 February–26 May 2015: 'This vision embodies the spirit of the international science and engineering collaboration that is the SKA project itself, bringing together many nations around two sites in Australia and South Africa to study the same sky' (p. 2).

27 W.H. Bleek and L. Lloyd, 'Names of Stars and Stories Connected with Them', unpublished manuscript dated February 1873, Special Collections, University of Cape Town, BC 151 E4.2.2.

28 J.L.E. Dreyer (ed.), *The Scientific Papers of Sir William Herschel*, vol. 1 (London, Cambridge University Press, 1912), p. xxxiii.



Figure 4. The Great Nebula in Orion: pencil sketch by John Herschel in preparation for *Cape Results* (1847).

public imagination and in some ways worked to echo and reiterate British imperial ambitions, as exemplified by Herschel's close association with the Astronomer Royal, Thomas Maclear at the time, and the latter's project of creating the first survey maps of the Cape Colony. Both were projects that relied on geodetic techniques for mapping space, in the (respectively) cosmic and terrestrial senses of the word.²⁹

Interleaved with the forbidding columns of numbers and trigonometric calculations in the *Cape Results* are a remarkable series of etchings and lithographs worked up from Herschel's original pencil drawings (see Figure 4). These are asymmetrical, painstakingly shaded and stippled representations of nebulae that pull towards the cloudy, semi-abstract immensities of an artist like William Turner as they try to represent (in Herschel's words) the 'wisps', 'convolutions', 'branches' and 'appendages',³⁰ 'the endless and complicated fluctuations of our system'.³¹ Simultaneously, they employ cartographic and land-surveying techniques now transferred to the night sky, so preserving a metric accuracy and integrity that marked a new kind of image in astronomy – etchings that functioned as both pictorially and

29 See also Dubow, '200 Years of Astronomy in South Africa'.

30 John Herschel, *Results of Astronomical Observations Made During the Years 1834, 5, 6, 7, 8, at the Cape of Good Hope: Being the Completion of a Telescopic Survey of the Whole Surface of the Visible Heavens, Commenced in 1825* (London, Smith, Elder and Co., 1847), p. 40.

31 John Herschel, 'Address to the Royal Astronomical Society', 11 April 1827, in *Essays from the Edinburgh and Quarterly Reviews with Addresses and Other Pieces* (London, Longman, Brown, Green, Longmans, & Roberts, 1857), p. 469.

numerically rich.³² Crafted at the edge of 19th-century optical resolution and perception, such astronomical sketches are given a detailed reading by Omar Nasim as examples of drawing as a form of knowing: a visual and aesthetic attentiveness, even obsessiveness, likely to reveal and uncover relations through a form of applied epistemology.³³ As Herschel writes, classifying nebulae (as opposed to clusters that could be resolved into individual stars) took the mid 19th-century astronomer to the limits of both instrumentation and representation:

[t]he distinction between nebulae and clusters of stars, must depend on two very different considerations, viz., 1st, on the power of the instrument to distinguish the very minute individuals of which a resolvable cluster, or one entirely composed of stars, may consist, and 2ndly on the idea we attach to the word ‘nebulous’, that is to say, on the distinction which we conceive to exist between objects physically nebulous, and objects only optically so. As respects the idea conveyed by the word nebula, it seems not easy to draw any distinct and serviceable line of demarcation between objects optically and physically (i.e. apparently and really) nebulous.³⁴

The question of where to draw the line, in other words, was both a literal and conceptual problematic that informs the history of sketching indistinct celestial objects by hand: a zone where the art-historical concepts of ‘figure’ and ‘ground’ can no longer be reliably distinguished and where (following Calvino) language as a human-scaled sensing system begins to reach the limits of utility. In *Six Stories from the Edge of Representation*, James Elkins carries such insights much further forwards (and backwards) in time, finding himself drawn to the dark patches *between* the visible galaxies within the Hubble Deep Field images, and wondering whether the blurred pixels within them represent the limits of the telescope’s resolving power or the limits of visibility itself, as astronomical seeing approaches ‘the border of [...] the “dark age” of the universe, before it ionized and lit up with stars’.³⁵ In this sense, it is precisely those zones at the limits of resolution and the image domain that will be of great interest to cosmologists and historians of the universe.

John Herschel would go on to coin the word ‘photography’ (light-writing) in correspondence with William Henry Fox Talbot, both of them deeply involved in the evolving set of techniques for the chemical fixing of light that began to revolutionise astronomical research in the late 19th century, particularly following the invention of the dry plate method in the 1870s. In 1882, Royal Astronomer David Gill photographed the Great Comet from the Observatory in Cape Town (see [Figure 5](#)), a moment that proved a serendipitous breakthrough in the history of astronomical imaging. Gill noticed that, beyond and around the comet’s tail, the gelatin process had recorded extremely faint stars – a method that, he realised, could be enhanced with repeated and longer exposures. Astronomical photography could then be used to survey the sky with much greater accuracy, and in a way no longer reliant on human agency during the act of observation or hindered by the difficulty of recording in lamplight dim enough not to disturb the night adjustments. Instead, light-gathering glass plates covered with grid lines could be used to obtain images of large star fields (see [Figure 6](#)).

Between 1895 and 1900, some half a million stars were measured off such plates by hand and eye and then reduced to usable data by ‘computers’ – a term then referring to those

32 See O.W. Nasim, ‘The “Landmark” and “Groundwork” of Stars: John Herschel, Photography and the Drawing of Nebulae’, *Studies in History and Philosophy of Science*, Part A 42, 1 (2011), p. 72.

33 See, for example, the discussion of John Ruskin’s art criticism in the context of astronomical imaging, in O.W. Nasim, *Observing by Hand: Sketching the Nebulae in the Nineteenth Century* (Chicago, University of Chicago Press, 2013), p. 33.

34 Herschel, *Cape Results*, p. 137.

35 Elkins, *Six Stories from the Edge of Representation*, p. 110.



Figure 5. Great Comet of 1882, photographed by David Gill, Royal Observatory, Cape Town. Courtesy of SAAO.

individuals, most often women, who performed the tedious mathematical calculations needed to convert the raw x - y co-ordinates of the plates into the Right Ascensions and Declinations (celestial latitudes and longitudes) for each star. Gill's career at the Cape Town Observatory saw it emerge as a leading global institution in astrophotography and one involved in a project to create a comprehensive photographic catalogue of the entire night sky: the International *Carte du Ciel*, launched in 1887. The mapping of the 'Cape Astrographic Zone' occupied much of the early half of the 20th century, and, as Saul Dubow's article in this issue shows, this is just one chapter in a long story of international consortia looking to southern latitudes as a place of privileged access to the skies.³⁶ The development of South African radio astronomy at Hartebeesthoek in order to facilitate ground tracking of the Apollo missions for NASA during the 1960s extends this narrative into the geopolitics of apartheid and the Cold War.³⁷

The material legacy of the surveys directed by Gill is an archive of glass plates stippled with stars or lined with spectrometry, now in storage at the renamed South African Astronomical Observatory. As artefacts created largely for mapping the co-ordinates and

³⁶ Dubow, '200 Years of Astronomy in South Africa'.

³⁷ See Wild, *Searching African Skies*, and L. Ezell, *NASA Historical Data Book II: Programs and Projects 1958-1968* (Washington DC, NASA, 1988), available at <https://history.nasa.gov/SP-4012v2.pdf>, retrieved 1 May 2018.

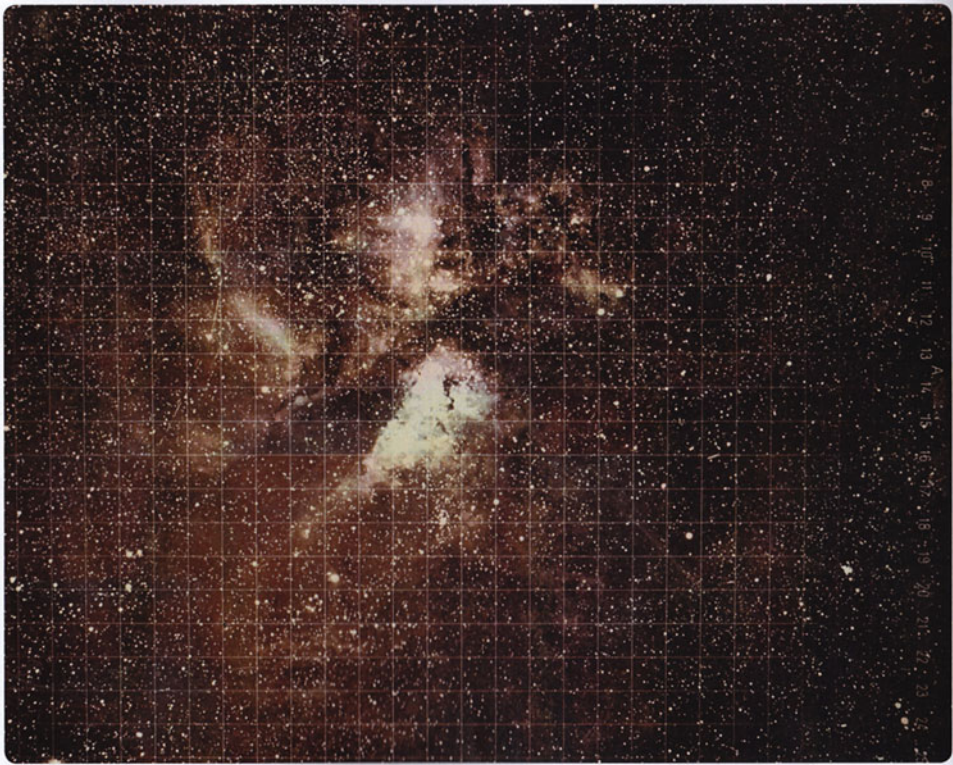


Figure 6. Eta Carina Nebula, 1892, Royal Observatory, Cape Town. Courtesy of SAAO.

magnitudes of celestial objects, these are often ‘unpretty’ images; but to look at a twelve-hour exposure of the Eta Carinae Nebula taken in March 1892 (one made on several successive nights without disturbing the plate) is to receive a powerful sense of astronomical imaging as the slow distillation and incremental layering of the faintest of sky signals (see [Figure 6](#)). ‘Its primary raw materials’, as John Berger wrote of photography, ‘are light and time’.³⁸ Or, to quote Roland Barthes in another classic meditation on the subject: ‘[t]he photograph is literally an emanation of the referent. From a real body, which was there, proceed radiations which ultimately touch me, who am here; the duration of the transmission is insignificant; the photograph of the missing being [...] will touch me like the delayed rays of a star’.³⁹

The telescope (and its camera) as giant, light-gathering eye reaches a national apotheosis at the Southern African Large Telescope (SALT) near the small Northern Cape town of Sutherland, a facility that was opened in 2005 and has served as an icon for the re-imagining of astronomy as a post-apartheid project, a science described as ‘transformative’ in both conceptual and political terms by its champion Khotso Mokhele, head of the National Research Foundation (NRF) at the time.⁴⁰ The books produced about SALT as ‘Africa’s Giant Eye’ also establish the kind of African Renaissance narrative that has in turn been

38 J. Berger, ‘Appearances’, in *Understanding a Photograph* (London, Penguin, 2013), p. 61.

39 Roland Barthes, *Camera Lucida*, trans. Richard Howard (London, Flamingo, 1984), p. 84.

40 ‘I was transformed by the transformative power of the astronomy discipline’: Khotso Mokhele, quoted in Bernie Fanaroff, ‘The SKA South Africa’, address at the Astronomical History Symposium, South African Astronomical Observatory (SAAO), 7 March 2018.

adopted by the SKA as an NRF-funded project.⁴¹ This presents South African astronomy as a ‘flagship’ science able to compete globally at the ‘frontiers’ of knowledge, yet also as a continuation and honouring of indigenous ways of understanding the southern skies. The result is a grand but rather strained narrative in which the technological advances of ‘modern’ humans (in the anatomical sense) as ‘early African engineers’ are retrospectively understood as predictive of projects like SALT and SKA, or at least in which the latter are in some sense a continuation of the former, as part of a narrative of humanity’s inexorable techno-scientific progress.⁴²

As the biggest optical instrument in the southern hemisphere, the SALT is sensitive enough (your guide might tell you) to detect a match being struck on the moon. Its hexagonal mirrors collect and collate as much light as possible from the Karoo night sky: a process that a non-specialist can easily understand and identify with. In this sense, optical astronomy has always attracted and rewarded both specialist and amateur interest, and, at the southern end of the Karoo’s proposed ‘astro-tourism’ belt, Sutherland is full of guest houses offering stargazing and backyard observatories.⁴³ Yet to move north from Sutherland to the SKA near Carnarvon requires a shift in one’s understanding of what a telescope is, and what astronomical ‘seeing’ might mean.

‘With a radio telescope there is no eyepiece’, as SKA cosmologist Roy Maartens puts it, and the dishes observe all day.⁴⁴ Operated remotely from a control room in the SKA headquarters in the Cape Town suburb of Pinelands, the MeerKAT antennae at the Losberg core site draw down signals from the cosmos, amassing ‘astronomical’ quantities of data that must then be transmitted, stored, cleaned and processed. In this office-block headquarters (so different to the classical facades and cupolas of the old Royal Observatory nearby), ‘Sleep Rooms’ allow for the telescope controllers to recover after sessions guiding the dishes, while other sections are devoted entirely to testing and calibrating the instruments. Those working on imaging use a mathematical operation known as the Fourier Transform to ‘translate’ the streams of data into visual renditions of immensely distant phenomena – pulsars, radio galaxies with energy spewing from supermassive black holes at their centre, ‘relic radiation’ of an early universe – that in no way correspond with what the human eye would be able to see.

When asked about the apparent difference in the aesthetic of optical and radio astronomical imaging, SKA scientists would patiently explain away my misapprehension, working from first principles. Light is the form of radiation in which our sun puts out much of its energy, to which (in the circular logic of organic evolution) the eyes of living creatures on earth have consequently become most sensitive. Yet what is visible to humans constitutes only a small portion of the electromagnetic spectrum. When defined as measurable energy, light is separated from vision by scientists, becoming instead ‘a series of numeric values that corresponds to wavelength or intensity, attributes that the naked eye may or may not discern and never with the precision of an instrument’.⁴⁵ Even within the Hubble images (many

41 D. Buckley *et al.*, *Africa’s Giant Eye: Building the Southern African Large Telescope* (Observatory, SALT Foundation, 2005).

42 See, for example, the SKA South Africa publication, *Journeys of Discovery: Stories of Human Innovation in Africa* (Pinelands, SKA South Africa, 2015), in which Bernie Fanaroff writes in the Foreword: ‘This book shows how the history of technology and science began here at least 120,000 years ago. We are simply continuing that tradition of innovation and discovery’, p. 5.

43 For an account of attempts to position the Karoo as a tourist destination in this way, see M. Ingle, ‘Making the Most of “Nothing”: Astro-Tourism, the Sublime and the Karoo as a “Space Destination”’, *Transformation*, 74 (2010), pp. 87–111. See also D. Atkinson, ‘When Stars Collide: Competing Development Paradigms in the Central Karoo’, elsewhere in this issue.

44 Interview with Roy Maartens, Cape Town, 21 April 2018.

45 E. Kessler, ‘Astronomical Seeing’, 4 November 2013, available at <http://photomediatiionsmachine.net/2013/11/04/astronomical-seeing/>, retrieved 1 May 2018.

scientists pointed out), radiation in the ultraviolet or infrared (those wavelengths lying on either side of the rainbow) has been read off via different filters and represented in a final product where realism is no longer defined by human vision.

In this sense, the common caption ‘false colour’ in popular astronomy publications is misleading, since the phenomena it signifies do not exist as colours at all. The palettes are visual codes assigned as representative of the physical properties underlying the properties in an image (intensity, energy or chemical composition, for example), which function as tools for making structure visible. Hydrogen, the most abundant element in the universe, is undetectable via optical telescopes but ‘shines’ in the radio telescope, as Maartens puts it. Observed via MeerKAT, the Southern Pinwheel galaxy (described by La Caille in 1753 at the Cape, classed as number 83 in the Messier catalogue) emerges as a much larger spiral than before, trailing immense arms of hydrogen – a structure that can in turn be superimposed on to existing optical images of M83.⁴⁶

Multi-wavelength astronomy – the layering of readings and imaging across the electromagnetic spectrum – entered a new phase with the inauguration of the MeerLICHT optical telescope at Sutherland in May 2018. This instrument ‘was designed to always co-stare with the MeerKAT radio telescope’, in the words of Patrick Woudt, head of Astronomy at the University of Cape Town.⁴⁷ That is: MeerLICHT (‘more light’ in Dutch) will operate in tandem with the MeerKAT array some 250 kilometres to the north, with each telescope trained on the same patch of the sky at the same time and from the same space: a unique innovation in global astronomy. To date, multi-wavelength observations have relied on scientists around the world contacting each other to co-ordinate different optical and radio instruments (the ‘phone a friend approach’, as Rob Fender at the University of Oxford puts it): a method suitable for lengthy observations but too slow for the thousands of fast radio bursts that the SKA project hopes to track and catch ‘in the act’.⁴⁸ The project will, for the first time, ‘provide optical multi-band observations of every night-time observation conducted by a radio telescope’, with MeerLICHT and MeerKAT as the ‘eyes and ears’ of the Karoo astro-region.⁴⁹

Given this much richer conception of astronomical ‘seeing’, long-standing public queries about whether pictures of the distant universe are real or fake operate in a false dichotomy, as does my initial impression of a stark binary between optical and radio imaging. As the historical narrative I have traced here suggests at each juncture, such graphics are better understood as a layered accretion of disparate and painstakingly derived registers of information, artefacts that (particularly when stripped of the scales and axes required in scientific publication) hover ambiguously between picture and data, metaphor and map.

The SKA may come to speak in a somewhat different visual language from that of Hubble or SALT. Yet, as Elkins remarks, perhaps the most intriguing visuals produced by contemporary astronomy (and, at the opposite end of the scale, particle physics) are not those that have been cropped and translated into the recognisable and over-worked register of the sublime (or pretty, or kitsch) but, rather, those that operate at ‘the ill-defined borders shared by abstraction, competing naturalisms, and conceptual art’.⁵⁰ I am receptive to his

46 R. Maartens, ‘Exploring the Cosmos with a Giant Radio Telescope’, public lecture at The Orbit, Braamfontein, Johannesburg, 24 April 2018.

47 K-L. Moore, ‘A New Window on the Universe’, 28 May 2018, available at <https://www.news.uct.ac.za/article/-2018-05-28-a-new-window-on-the-universe>, retrieved 1 June 2018.

48 T. Kahn, ‘MeerLicht: SA’s Newest Optical Telescope’, *Financial Mail*, Johannesburg, 1 June 2018, available at <https://www.businesslive.co.za/fm/features/2018-06-01-meerlicht-sas-newest-optical-telescope/>, retrieved 1 June 2018.

49 SKA Media Release, ‘MeerLICHT Telescope Inaugurated’, 1 June 2018, available at <http://www.ska.ac.za/media-releases/meerlicht-telescope-inaugurated/>, retrieved 1 June 2018. See also <http://www.meerlicht.uct.ac.za/>, retrieved 1 June 2018.

50 Elkins, *Six Stories from the End of Representation*, p. xvi.

call for observers from the humanities to become more literate in visual–scientific registers that are not narrowly referential or figurative, to extend the idea of what is interesting beyond conventional aesthetic categories and to develop a taste of images that are in some sense impossible:

[t]he images I am interested in show us things that we can't possibly be seeing: things so far away, so faint, so large or soft or bright that they couldn't possibly be contained in the rectangular frame of a picture – and yet they are. They are pictures of objects that literally don't exist – that couldn't exist as they are pictured – but somehow do. They are abstractions of abstractions, feeble symbols for objects that have no reality of their own. They are formless things, blurred until they are unrecognisable. They are images of almost nothing, of single sparks of light, of inexplicable blazing colour, of thin lines and dots that stand for objects that cannot be understood.⁵¹

A Small Place

Yet, if optical and radio images are better seen as complementary and differing more in degree than type, then the means used to detect and produce them entail very different technological footprints, and social atmospheres, on the ground. The South African Astronomical Observatory (SAAO) in the Karoo is a hilltop landmark that welcomes visitors from nearby Sutherland, but the SKA core site is set apart from other human business, shielded by hills to ward off radio interference. Access is restricted and getting permission for a visit takes time. As other contributors to this special issue explore, the need to locate this utopian but technologically exacting project in a place as free as possible from the electromagnetic noise of industrial modernity – cellphone signals, petrol engines, electric fencing – generates a space of paradoxes.

In building an instrument where performance is inversely correlated with human activities, the SKA constructs a future prospectus of national development and uplift, even as it is premised on a sparse local population and economic 'quietness'.⁵² The combination of unprecedented data flow and socio-economic stasis (often dire poverty) is striking for anyone visiting a region where unemployment runs at over 30 per cent. Many astronomers whom I interviewed mentioned the remarkable openness with information that is characteristic of their discipline and unusual within the sciences: an unprecedented level of international collaboration and open-source data enabled by digital sharing. But in Carnarvon, which seemed to lack even a wi-fi café when I visited, local residents were sceptical of the secretive goings on at Losberg, at least in the bars where farmers and businessmen railed against the broken promises, outside contractors and incomprehensible science of the SKA, whose scientists jetted in and out on their own private runway far removed from the town.

In *A Small Place*, Jamaica Kincaid wrote powerfully of a late capitalist, and racialised, dialectic of mobility and stuckness in her native Antigua.⁵³ The object of Kincaid's ire is mass tourism, but in Peter Redfield's *Space in the Tropics* (a historical and ethnographic study of a launch site in French Guiana) one sees some of the same dynamics in its portrait of a globalised, visiting elite and an excluded or resentful local population. The desire

51 *Ibid.*, p. xv.

52 See D. Chinigò, 'From the "Merino Revolution" to the "Astronomy Revolution"', and M. Gastrow and T. Oppelt, 'The Square Kilometre Array and the Local Development Mandates in the Karoo', elsewhere in this issue.

53 J. Kincaid, *A Small Place* (New York, Farrar, Straus and Giroux, 1988), p. 88: 'That the native does not like the tourist is not hard to explain. For every native of every place is a potential tourist, and every tourist is a native of somewhere'.

among European powers for shuttle launch sites close to the equator generates a dynamic not unlike that produced by SKA, as previously ‘marginal’ areas become central in planetary, astronomical and geopolitical terms.

Driving north to the core site, our tour party’s first sign of the project was the new fibre optic cabling strung up on old roadside electricity poles, leading us onward into the dry, shallow hills. Engineers must inspect this new–old infrastructure regularly, ensuring that colonies of sociable weavers do not make their enormous, haystack-like nests on the pylons in a way that might disrupt the crucial data pipeline.⁵⁴ Feral horses and sheep within the core site were also causing problems, apparently, and so too the jackal populations now able to move freely between adjoining farms and a space functioning as a *de facto* (soon to be formalised) nature reserve. The result is a curious superposition of cutting-edge technology and incipient wilderness, or even re-wilding: an emergent space that confounds the pastoral binaries – the country and the city, tradition and modernity – through which the Karoo has often been produced in the artistic imagination.

At the office near the Klerefontein entrance, we switched to a diesel vehicle (no spark plugs) and slowly the seven dishes of the initial Karoo Array telescope (KAT) and then MeerKAT came into view, spread across the landscape in a seemingly random array that our guide, systems technician André Walker, described as ‘a gaggle’. The former are symmetrical, the latter configured as a Gregorian offset, like a satellite television dish, structures that may (given the long lifetime of the SKA project) come to be as iconic of the central Karoo as the earlier revolutionary technology of the windmill. In being guided through the dish assembly shed and the subterranean Karoo Array processing building (KAPB), buried six metres underground to ward off its own radio frequency interference, there was the sense of an operation being run with skeleton staff. Not having the focal point of an optical instrument, and with most of the science being done in a distant Cape Town suburb, the core site had a diffuse, disembodied quality that is perhaps inherent to the basic physics of radio astronomy.

Because of their length and faintness, radio waves from the distant universe are much more difficult to collect, collate and resolve than visible light. A general idea of the resolving power or angular resolution of an optical device is given by a simple equation:

$$R = \frac{\text{Wavelength}}{D}$$

where the resolution R is the product of wavelength of the observed radiation divided by D , the diameter or (aperture) of the telescope’s objective (light-gathering) lens or mirror. The wavelength of visible light is 0.4–0.7 microns (or 0.0004–0.0007 millimetres) and can be resolved by the human eye with a retinal aperture of around 6 millimetres. Yet the wavelength of the mid-frequency microwaves and radio waves that the South African SKA will be listening for range between 1 and 10 metres. As such, the corresponding increase in aperture in order to attain a comparable resolving power is immense.⁵⁵ To build a radio telescope dish several kilometres in diameter is an engineering impossibility, and so the principle behind an array is to create a synthetic aperture where D becomes B , the baseline or maximum physical separation of individual antennae:

$$R = \frac{\text{Wavelength}}{B}$$

54 B. Peterson, ‘The Most Important Place in the Universe’, *Popular Mechanics South Africa*, March 2018, p. 45, available at <https://www.popularmechanics.co.za/science/important-place-universe/>, retrieved 8 March 2019.

55 B. Frank, ‘MeerKAT and Big Data’, talk at the SAAO, Cape Town, 12 May 2018; and interview with Bradley Frank, University of Cape Town, 12 June 2018.

At present, the MeerKAT precursor telescope offers a maximum baseline of eight kilometres, but the full Array is planned to extend this to some 3,000 kilometres, with perimeter installations as far away as Ghana, Madagascar and Mauritius. In very long baseline interferometry (VLBI) this idea can be taken to the maximum distance permitted by the dimensions of our planet (around 8,000 kilometres). This is what several radio astronomers who spoke to me describe as the ‘magic trick’ of constructive interference, or interferometry: the creation of an aperture vastly larger than an actual dish by combining, multiplying and averaging the signals from widely dispersed antennae. The grand idea behind a project like SKA, which will eventually link up antennae throughout the African continent and across the southern hemisphere, is then to turn much of the planet into an enormous receiver for the faintest of radio signals, using the rotation of the earth to fill in the celestial sphere gradually, with dishes at various latitudes and listening for different frequencies in the electromagnetic spectrum.

Crucial to this process is what former SKA systems scientist Charles Copley describes as the ‘heartbeat’ of radio astronomy: the exact time-stamping of each signal, enabled via atomic clocks. Given that the signals from each antenna will reach a data-processing centre at different times owing to their variable distances, precise correlation and ‘beam forming’ of the signals is necessary in order to make the array operate as one big receiver.⁵⁶ As the earth turns, the distance between antennae and astronomical radio sources (the projected baseline) also changes, and here the time-stamping must register the infinitesimal time differences that result, logging the kind of digital stereo delay needed to create a viable image of the cosmos. That is: the increasingly ambitious dispersal of radio receivers in (earthly) space requires a corresponding increase in the exactitude of time-keeping. If anything, it is the hydrogen maser (microwave amplification by stimulated emission of radiation) that might be the core of the SKA core site, an atomic clock kept in a specially regulated room and marking time to within a few nanoseconds (billionths of a second).

In his star chart of 1756, Lacaille quite literally saw his own telescopes embedded in the night sky. Yet, for contemporary radio astronomy, which deals with such faint radiation, much of the work is to identify and subtract the noise produced by the physical structures and properties of one’s own instruments. The Array will be attuned to celestial radio power that is ‘a million times fainter than a cellphone signal’ or, in another of the gimmicky metaphors that scientists must fall back on when speaking to someone unversed in the language of mathematics, ‘the equivalent of a smartphone on Pluto’. The total kinetic energy of all cosmic microwave background radiation that has ever reached earth is ‘less than that of a falling snowflake’. Or, in an endearingly dated attempt to be contemporary that appears on the South African Radio Astronomy Observatory (SARAO) website: ‘[d]ata collected by SKA in a single day would take two million years to play back on an iPod’.⁵⁷

The MeerKAT antennae and pedestal are cryogenically cooled to prevent the receivers being corrupted by their own noise signal, ‘so that the instruments don’t interfere with themselves’, as André Walker put it when showing my tour group around. For this reason, in another of the off-grid self-sufficiencies of the core site, a purpose-built power station ensures a constant supply of electricity. To work against seeing a map of the SKA in a map of the distant radio universe, the gaggle of dishes in the Karoo will form a layout of

56 If the SKA is altering the *mythos* of a quintessential South African space, the Karoo, it has also quite literally changed the national sense of time, now calculated to a degree 1,000 times more precise than before, via a 2015 memorandum of understanding with the National Metrology Institute of South Africa (NMISA); see NRF media release, ‘NMISA to provide accurate time reference signals to SKA’s MeerKAT’, 25 June 2015, available at <http://www.nrf.ac.za/media-room/news/nmisa-provide-accurate-time-reference-signals-skas-meerkat>, retrieved 1 June 2018.

57 ‘Frequently Asked Questions’, <https://www.ska.ac.za/about/faqs/>, retrieved 1 June 2018.

carefully planned irregularity. This is to avoid introducing a metric uniformity that would affect data collection by privileging one baseline length over another (and so select for one particular frequency over others). As such, the multi-armed spiral planned for the full Array represents a combination of calculated non-uniformity with engineering economy: it is a shape that will enable variable spacing of dishes while also allowing for fibre optic cables to be run along the arms of each spiral linking the dishes to the core.

Beyond all this, astronomers and engineers must contend with the barrage of unwanted electromagnetic radiation, both ‘natural’ and anthropogenic, that is always present, even in a radio quiet zone: the trace of the ionosphere; solar flares; ‘spill over’ radiation absorbed and then released by the earth; flights between Cape Town and Johannesburg passing overhead – such are the electromagnetic clouds, spikes and pings that must be filtered out. ‘Satellites are the bane of our existence’, says Bradley Frank of SARAQ, who spoke of the long processes of calibration required for each observation and the difficulty of ‘teasing out a scientific image’ from the terabytes of noisy data that result. Radio astronomy is ‘like trying to hear someone whispering to you in a club’, he suggested, and then added: ‘someone whispering the lottery numbers to you in a dub step club’.⁵⁸

It was the best radio astronomical metaphor yet, but I left the core site with a sense that the form in which to tell the story of this project in the public domain is still to be found, and may require a turn to less literal, less straightforwardly informational or documentary modes.

No Comparison

In his 2010 film *Nostalgia for the Light*, Patricio Guzmán travels to Chile’s Atacama desert, the driest on earth, to create a compelling meditation on astronomy and memory. During the revolutionary tide of Salvador Allende’s presidency (1970–73), ‘science fell in love with the Chilean sky’, as the filmmaker puts it in his voice-over narration. The five-kilometre-high Chajnantor plateau became the location for some of the biggest optical and radio telescopes in the world – among them the Atacama Large Millimetre Array (ALMA). ‘The past is the astronomer’s main tool’, remarks Gaspar Galaz, one of the scientists interviewed, who explains how every image entails sifting through light years of time: ‘we manipulate the past. We are used to living behind the times’.

As the film unfolds, this region is also revealed as a unique place to access other kinds of pastness. Archaeologists trace the engravings of pre-Columbian shepherds on the rocks and the mummified remains of those who used this desert as a transit route 10,000 years ago. The dry, salted earth and the absolute lack of humidity preserve such ancient bodies to a startling degree, their hair and blankets and personal effects still visible in museum storage rooms. The images of the Atacama plateau composed by the cinematography – faces, stick figures and llamas scratched on rocks in the same frame as the telescope domes beyond – are strikingly reminiscent of the Northern Cape Astronomy Reserve, where MeerKAT antennae can be juxtaposed with engraved dolerite boulders. Why are these cosmic and earthly investigators in the same place, asks Guzmán? ‘The translucency of the sky is, for the archaeologists of space, what the dry climate is for us’, remarks one of the excavators, Lautaro Núñez. The thin, dry air facilitates access to the minute clues used to reconstruct both earthly and celestial deep time: ‘it is a door that we know how to go through’.

And yet the documentary goes on to trace a paradox: that the public enthusiasm for astronomy and archaeology in Chile co-exists with a hiding away of ‘our nearest past’: not only the 19th-century exploitation of Indian populations, whose bodies lie in the cemeteries

58 Interview with Bradley Frank, University of Cape Town, 12 June 2018.

of abandoned mines, but also the legacy of Pinochet's dictatorship following the coup of 11 September 1973.⁵⁹ At this point, the film makes a remarkable pivot, switching its focus to the memories of political prisoners kept in desert concentration camps and the remarkable work of the women of Calama (a mining region that is the gateway to the Atacama). Walking across the landscape with small trowels in their hands, they are mothers, sisters, daughters who have been sifting the same desert sands for 25 years, looking for the human remains of relatives and loved ones 'disappeared' by the military dictatorship. They search for bodies hidden here or for bone fragments left by bulldozers as the regime dug up and relocated mass graves to conceal its crimes. When asked about the relations between these different quests and why the paths of the astronomers and the women of Calama have not crossed, one of the scientists remarks that the past that astronomers look into 'does not accuse us': 'our search doesn't disturb our sleep'. The film explores how such astronomical 'nostalgia' has gained far more public acceptance and visibility than the social task of re-animating recent and traumatic political memory (the latter often dismissed with the sentiment that 'what's past is past'). The astronomer Galaz imagines what it might be like to look for missing relatives in the vastness of the cosmos, much as the women sift the immensity of the desert for fragmentary remains, and then remarks: 'there is no comparison'.

Nostalgia for the Light is a resonant work to hold in mind when thinking of the different histories compacted into the Karoo landscape. It speaks to an aesthetic and scientific enthusiasm for deep or pre-colonial time in South Africa that also risks effacing or ignoring a more recent human past.⁶⁰ None the less, the meditative and often silent image-language of the film succeeds in holding in frame cosmological, archaeological and historical temporal scales without forcing the relation between them. They are, simply, superimposed, with many of the wider implications left to the viewer.

In a world in which radio quietness has become a scarce resource, the SKA core site was chosen for its distance from the petrol engines, mobile phones, lighting and countless other technologies that produce radio interference: a space 'empty' of the electromagnetic noise of modernity and yet full of petroglyphs and stone tool middens: remnants of a different kind of modernity, in the archaeological sense, and which testify to an enormous time-depth of human occupation. Around 100,000 years ago, anatomically 'modern' human beings were spread all through this landscape, with some shelters showing a continuous human occupation for millennia.⁶¹ The long human history in the region is distantly registered in the richness and beauty of the star lore related by |Xam individuals in the 19th century, and

59 Chilean playwright Ariel Dorfman, in a collection of essays and non-fiction – A. Dorfman, *Writing the Deep South: The Mandela Lecture and Other Mirrors for South Africa* (Johannesburg, Picador, 2011) – reflects on the Truth and Reconciliation Commission, exploring southern Africa and Latin America as 'mirrors' for each other, while simultaneously explaining how 'September 11' had resonated differently for Chileans long before the World Trade Centre attacks of 2001. Tuesday 11 September 1973 was the date of General Pinochet's coup (with covert support from the USA) against the socialist government of Salvador Allende: 'in 1976, the year of the Soweto massacre', he remarks in his 2010 Mandela Lecture, 'we were suffering a slow massacre of our own' (p. 4).

60 For post-apartheid meditations on the politics and poetics of archaeology and deep time, see, for example, J. Martin, *A Millimetre of Dust: Visiting Ancestral Sites* (Cape Town, Kwela, 2008), and N. Shepherd, *The Mirror in the Ground: Archaeology, Photography and the Making of a Disciplinary Archive* (Johannesburg, Jonathan Ball, 2015). The latter draws attention to 'an indifference towards the African present' as deeply ingrained in the local archaeological imaginary, in ways that echo the terms of Guzmán's film: 'In fact, in a broadly metaphorical way, but also in the most literal of ways, doing archaeology involved looking through present landscapes, with their clutter of political aspiration and cultural change, to find the traces of an imagined past lying below' (N. Shepherd, 'State of the Discipline: Science, Culture and Identity in South African Archaeology, 1870–2003', *Journal of Southern African Studies*, 29, 4 (2003), pp. 838–9).

61 See H.J. Deacon and J. Deacon, *Human Beginnings in South Africa: Uncovering the Secrets of the Stone Age* (Cape Town, David Philip, 1999).



Figure 7. Sivuyile Manxoyi, outreach manager at SAAO, Observatory, Cape Town, at the McClean Telescope. Photograph from ‘Hemelliggaam or The Attempt to Be Here Now’, courtesy of Tommaso Fisaletti and Nic Grobler, <https://www.hemelliggaam.com/>

an intimate relation with the night sky is still present throughout the Northern Cape, though now refracted through different languages and technologies.⁶² Honouring these different histories and expressive cultures without ‘resolving’ them too glibly or collapsing them into one another is a sensitive and difficult task.⁶³

62 In its focus on ‘the interplay between scientific astronomical activity and everyday awareness of space through a contemporary lens’, the photographic project *Hemelliggaam* (Afrikaans: Heavenly Body) or *The Attempt To Be Here Now* is creating a locally embedded archive of communities, landscapes and objects in the Northern and Western Cape (see Figures 7, 8 and 9). Partly inspired by the Afrikaans science fiction writings of Jan Rabie, collaborators Tommaso Fisaletti and Nic Grobler undertake ‘a visual exploration of the existential aspects of the human–environment–astronomy relationship’ in a way that registers both scientific and amateur interest. Shot on Kodak 120 film, the work introduces a welcome note of idiosyncrasy, everydayness and the unofficial in its portrait-interviews with both professional astronomers and the builders of backyard observatories. See <https://www.hemelliggaam.com/feature/>, retrieved 1 June 2018.

63 It is one that is not best served, I suggest, by the photograph (on the SKA website banner) of a man with bow and arrow juxtaposed with a MeerKAT antenna. ‘SKA SA and San Council of SA signs MoU’, 16 May 2017, available at <https://www.ska.ac.za/about/highlights/>, retrieved 1 June 2018.



Figure 8. Personal observatory, Clanwilliam, Northern Cape. Photograph from ‘Hemelliggaam or The Attempt to Be Here Now’, courtesy of Tommaso Fisaletti and Nic Grobler, <https://www.hemelliggaam.com/>

In the decades to come, as the Array is slowly completed and South Africa becomes an even more powerful scientific portal to the cosmos, accounts of the Karoo astro-region will need, I would suggest, a more textured, inter-disciplinary and historically frank account of what colonial and globalised modernity has meant in the Northern Cape, and where its silences might lie. If the sublime has often been in an uncomfortable proximity to imperial exploration, expansion and questionable ‘discovery’, if the discourse of wilderness and empty landscape has often served to make certain histories invisible, then the SKA’s attempt to re-present astronomy as a post-colonial, post-apartheid project begs the question of what socio-aesthetic register its own discoveries might best be expressed in.

What kind of space, finally, will the vast Astronomy Reserve of the Northern Cape become? Is it a kind of national or economic ‘sacrifice zone’, to be compared to the *sperrgebiet* (restricted diamond mining zone) of Namibia or the vast tracts of land given over to military testing and nuclear waste disposal in the USA? In the case of the SKA, the concept of a sacrificial zone seems misdirected for a venture that is non-polluting and non-extractive. If anything, given that its core site is set to become a protected area under South Africa’s National Parks agency, SANParks, it could enable ecological restoration rather than devastation of the Nama Karoo biome. The Astronomy Reserve might then become an area of national regeneration, particularly when thought about in conjunction with the large-scale wind and solar power plants under way in the Northern Cape, and one which may place limits on plans for uranium and natural gas extraction in this rapidly changing South African



Figure 9. Sansa, SA National Space Agency # 1, Hermanus, Cape Town. Photograph from ‘Hemelliggaam or The Attempt to Be Here Now’, courtesy of Tommaso Fiscaletti and Nic Grobler. <https://www.hemelliggaam.com/>

hinterland.⁶⁴ In any case, it is an uncommon, nebulous space and one that stretches the theoretical imagination.

The techno-utopian ethos of openness and universality underlying the SKA’s media messaging and the ‘Shared Sky’ exhibition co-exists with the necessarily closed nature of the site and the crisis of expectations produced by a major science project touching down in a region where the impress of a colonial and apartheid past is so highly visible. And yet the now familiar post-colonial critique of Kincaid’s ‘small place’ doesn’t quite seem to fit here either. The South African SKA is as much a product of the anti-apartheid struggle, Mbeki-era nationalism and the African Renaissance as it is of a neocolonial divide between global north and south; and its aims are far more ‘otherworldly’ than a competitive space race or quest for establishing satellite coverage. The collateral benefits of SKA science (data processing, digital innovation, ‘human capacity development’) are easily made visible in current socio-economic lexicons, the primary research objectives less so. They preserve an unresolvable curiosity and a non-applied, open-ended enquiry into cosmological origins that seems curiously outdated in the human-centred, planet-bound Anthropocene. ‘Because the objects and phenomena are just so distant, so faint, so difficult to detect’, remarks MeerKAT imaging researcher Richard Armstrong, ‘in a sense it really doesn’t matter if it’s one way or the other’.⁶⁵

64 On the SKA ‘special nature reserve’, and the politics of solar power in the Northern Cape, see Walker, ‘Cosmopolitan Karoo’, elsewhere in this issue.

65 Interview with Richard Armstrong, Cape Town, 23 May 2018.

In addressing the SKA, I have tried to recognise both the fascination of outer space and specificity of earthly place. Doing so has revealed to me a major difference of intellectual impetus between the sciences and the critical humanities, one that is perhaps suggestive of why they so often ‘miss’ each other in public conversation. The first seeks to isolate and decontextualise its object of knowledge: to filter out earthly noise; to minimise the signal of its own instruments; to avoid seeing its own structures in a distant, even unimaginable mathematical space. The second always feels the urgency of introducing contingency and context: to bring into frame the desperately poor environs of Carnarvon, to remember the imperial project that carries astronomy to the tip of Africa and to look for the history that hides in its brilliant and unearthly images.

If anything, I suggest that the SKA asks and needs something more than the modes of public relations, corporate governance, ‘outreach’ and nationalist boosterism that have so far enfolded it, something other than the model in which Big Science commissions an exhibition or subcontracts an artist to bolster its ethos. As it grows exponentially in resolving and computing power, the Array will surely be a phenomenon that asks for something other than the obvious, the merely visual, literal or notational. It will challenge writers and artists to work with the conceptual, to linger in the difficult and blurry zones at the limits of representation, to find ways of registering the incommensurate scales and meanings compacted into a Karoo landscape that has often been figured as ‘empty’ but now seems unaccountably full of noise, signal, data and politics.

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