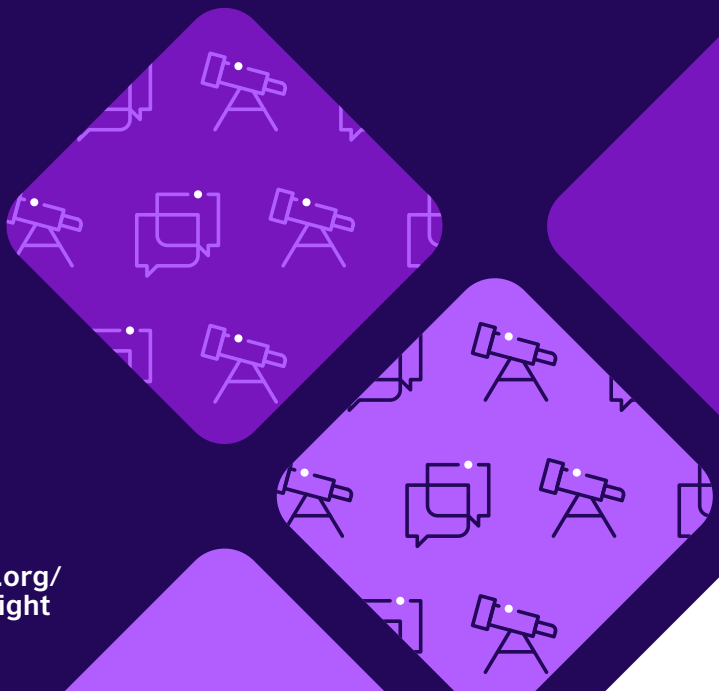
BRITISH COUNCIL

Research

Cultural Relations Collection

Under one sky: astronomy as a catalyst for cultural relations

Hannah Dalgleish



www.britishcouncil.org/research-policy-insight

Acknowledgements

Series editor
Christine Wilson

Series manager
James Perkins

Reviewers
Adrian Fenton
Anna Duenbier
Billie Lindsay
Caroline Meaby
Jen Bardsley
Mags Walsh
Rasheeda Nalumoso
Reece Waldron
Stephanie Renforth

The author
Dr Hannah Dalgleish obtained her PhD in Astrophysics from Liverpool John Moores University, where she studied the motions of stars within clusters. She is now a Postdoctoral Researcher in Astronomy for Development, based between the University of Oxford and University of Namibia, focusing on dark sky tourism and astronomy education. Hannah acknowledges support from the UKRI STFC Global Challenges Research Fund project ST/S002952/1 and Exeter College, Oxford.

Contributor
Dr Stephanie Renforth is Science Adviser at the British Council. She supports official development assistance (ODA) and non-ODA science programmes in the UK and globally.

The series editor

Christine Wilson has worked in the British Council since 2004. As Head of Research, she oversees a global portfolio, and is responsible for global standards and practice, ethics and networks. She directs the Next Generation research series, which aims to engage youth voices around the world and contribute to improved policymaking. She is an Advisory Board member at the Institute for Advanced Studies in the Humanities (IASH) at the University of Edinburgh, and is a Fellow of the Royal Society of Arts.

The British Council

The British Council builds connections, understanding and trust between people in the UK and other countries through arts and culture, education and the English language.

We help young people to gain the skills, confidence and connections they are looking for to realise their potential and to participate in strong and inclusive communities. We support them to learn English, to get a high-quality education and to gain internationally recognised qualifications. Our work in arts and culture stimulates creative expression and exchange and nurtures creative enterprise.

www.britishcouncil.org/research-policy-insight

Foreword

Over the past year we have come to understand more clearly than ever the value of cultural relations and connection generally. If the world is to face and overcome the challenges of the future in a co-operative and collaborative manner, then cultural relations has a vital role to play.

The British Council's responsibility is to create the person-to-person connections that build trust and enable collaboration across national borders. Coming at the same time as a global pandemic, the United Kingdom's new post-EU status means we have a particular responsibility to use all the tools of international engagement wisely. Last year, like everyone else, the British Council faced some very big challenges. We're now in the process of looking closely at ourselves to make sure we're fit for the future.

The pandemic has shown us how much cultural exchange can take place digitally, and the expansion of our digital services, already under way, will only accelerate. In everything that we do, our values and the values that the UK seeks to promote around the world will be paramount.

It is essential to underpin the many and various activities of the British Council with a body of academic thinking about and around the subject of cultural relations. This essay collection is a showcase of both the quality of that thinking and the breadth of activities that come under the heading of 'cultural relations' – everything from astronomy to the everyday encounters of street and marketplace. It's a rich and optimistic field.

For research into the power and purpose of cultural relations, a period of history when normal human encounters and gatherings are banned presents a special interest. Regardless of the range of subject matter, each essay was written in the context (or shadow) of Covid-19, which has reshaped the meaning of encounter. The pandemic has made some things impossible – or at least illegal – while expanding other channels of communication and connection beyond what we believed achievable just a few short months ago.

What remains both possible and inevitable is the need for human beings to create culture in all its forms, and to communicate their feelings and thoughts about it to others. This collection is a brief and welcome contribution to that endless, fascinating and ultimately human process.

Kate Ewart-Biggs
Interim Chief Executive, *British Council*

Preface to the Cultural Relations Collection

Welcome to the new series of essays from the British Council's Research and Policy Insight Team. This collection seeks to deepen understanding of cultural relations by inviting early-career researchers to examine both theory and practice. An important word in our open invitation for submissions was 'afresh,' with the aim to seek new voices to explore what has been the British Council's business – building connections, understanding and trust – for more than 80 years.

Under one sky. When first reading this submission from one of this collection's authors, I was struck by the aptness of the title, not just for her own work – a fascinating journey through cultural co-operation through astronomy – but for the situation we find ourselves in today.

Much has been said about whether or not we are, as some commentators claim, all 'in the same boat' when it comes to Covid-19. The statistics in the UK alone about infection and death falling disproportionately on black, Asian and minority ethnic communities suggest otherwise, as do concerns about the long-term impact on young people due to their extended time out of school. On the global stage, WHO Director-General Dr Tedros Adhanom Ghebreyesus warned in January 2021 of a 'catastrophic moral failure' if equitable access to vaccines is not achieved, with the poorest countries far behind the Global North when it comes to vaccinating their populations.

Yet while we are not all in that boat, we are all under one sky. That means that as well as the moral impetus to ensure vaccines are distributed around the world, there is a practical one – if the virus grows and mutates in countries where they cannot vaccinate populations, while at the same time wealthier countries are opening up borders and economies, we may find ourselves once more facing restrictions to halt that spread. Covid-19 is yet another common challenge that requires collective dialogue and action.

Through building connections, understanding and trust, the British Council's work in cultural relations seeks to create the conditions for dialogue and co-operation, whether it is around tackling a pandemic, addressing climate change or achieving the Sustainable Development Goals.

In this collection, our writers explore cultural relations through varied lenses – astronomy, science communication, arts festivals and urban public space – but all address the power of coming together, of interacting and collaborating. In his essay, Will Haynes suggests that cultural relations happen in the spaces immediately around us, in the way city dwellers negotiate the places around them, navigating through difference and challenge as they come. Hannah Dalgleish looks to the space above, in outlining the history of 'remarkable' intercultural openness and collaboration between astronomers.

The two remaining essays examine how Covid-19 has accelerated innovation in cultural relations activity. Gary Kerr explores the role of science diplomacy, and how a major international competition in science communication was rapidly forced online by the onset of Covid-19. Co-operation and innovation allowed for the move to digital. Poppy Spowage looks at how African arts festivals have led the way in delivering continued meaningful interactions between artists and audiences, despite the global pandemic. Both essays raise questions about how experiences are made, audiences are nurtured and connections developed and sustained in a virtual world.

At the time of writing, it seems likely that this shift to digital interaction will remain, if not as the new normal, then as a major part of our ways of living and working for some time to come. We will need to negotiate new ways of interacting with our neighbours, locally and globally, and to co-operate on the major challenges ahead. As Poppy Spowage notes in her essay, uncertainty itself is the catalyst for change. It is likely that uncertainty is here to stay. We hope that this collection offers some new insight into how cultural relations can help navigate the way ahead.

Christine Wilson
Head of Research
Research and Policy Insight, *British Council*

Editor's notes

This writer brings a genuinely new take to cultural relations by turning her eyes to the heavens. Starting with a journey through the history of astronomy – perhaps the most ancient science – this essay explores how scholars have collaborated across borders for hundreds of years, creating intercultural encounters along the way. The very nature of astronomy, the writer argues, is dependent on co-operation, as the skies have no borders, and observers need shared infrastructure and intelligence to understand the Universe's complexity.

This history of international collaboration, together with its ability to appeal to the imagination and its relatively neutral political situation, has led to astronomy emerging as a site for development co-operation. This essay explores in detail the implications for South Africa, and some of its most marginalised communities, of the Development in Africa with Radio Astronomy programme. This case study skilfully weaves together the strands of UK–South Africa history around astronomy, from its early days as an extractive colonial project to the current day, where young graduates are benefiting from new opportunities to enhance their skills in radio astronomy. Themes of power imbalance, exploitation and marginalisation continue to emerge, whether from the experiences of communities near a 'big science' project, to the stories from African students undertaking research in the UK, not all of whom felt included by their peers.

But it also includes stories of rich intercultural engagement and learning on the part of students. In addition, this essay reflects on the knowledge often locked into indigenous communities, many of whom have retained a deep relationship with the sky above them, inspiring astronomers and artists to collaborate to bring that insight about our shared sky to new audiences.

The story of the community living with restrictions imposed by scientists at the observatory in the Central Karoo reminded me of the similar situation in Green Bank, West Virginia, USA, where Wi-Fi and mobile phone signals are also non-existent due to the nearby radio telescope – a shared experience thousands of miles away.

And the observation from an interviewee speaking of the very 'personal experience to look at the night skies from a place of darkness and silence' brought to mind the trend observed in the UK during recent Covid-19 restrictions on movement, whereby people have taken up night walking to counter the lockdown slump. Those who do it speak of a powerful reconnection with the landscape and the sky. Again, these experiences are shared unknowingly across borders, across cultures, where we are under one sky.

In astronomy, as the essay notes, those who want to develop their knowledge need to take observations and develop analysis from multiple points of view across the world. This is also true for – indeed, is central to – cultural relations.

Introduction

Astronomy is regarded to be the oldest of sciences. For millennia, humankind has studied the stars – research then used for agriculture, navigation, and timekeeping. Astronomy is also a deeply cultural science; an evening spent under a dark, starry night sky can evoke feelings of awe, wonder, and of being a global citizen. Indigenous peoples continue to use and pass on their ancient astronomical heritage through storytelling; wisdom originating from countless generations ago. At the same time, as we seek to solve the deepest mysteries of the Universe, ever-larger and increasingly sophisticated observatories are constructed to aid us in our search.

The development of astronomy is thus driven by complex international collaborations, required to raise funds to construct the next generations of extremely large telescopes. These collaborations often bridge North–South nations, and pose enormous logistical, technical, political – and cultural – challenges (Young, 2020). In an academic sense, scientific relationships such as these have previously been studied in the context of diplomacy or sustainable development, but there is little-to-no research on the cultural relations of science collaboration.

This Cultural Relations Collection presents a unique opportunity to explore themes which have had little recognition but are of great relevance to the British Council. Using astronomy as an example, this essay introduces the idea of the culture of astronomers and their collaborations, and how these relationships have developed over the past few centuries. The essay then centres on two large-scale astronomy projects involving the UK and South Africa (the Square Kilometre Array [SKA] and Development in Africa with Radio Astronomy [DARA]).

South African astronomy has its roots in colonialism, but today, astronomy projects in Africa are typically celebrated as decolonisation endeavours – an opportunity to rectify wrongdoings through capacity building. Driven by a desire to become a global leader in science, technology and innovation, South Africa has embraced numerous astronomy projects in recent decades. Some of these programmes have been made possible through bilateral UK–South African funding, on the order of millions of pounds, through official development assistance (ODA).

What can this UK–South Africa relationship tell us about cultural relations, and how astronomy development differs on individual, local, national and international scales? Is it possible that astronomy as a subject in itself influences the culture of astronomy collaboration? This work looks to shed light on these questions, and is also informed by new data, collected through questionnaires of astronomy students and interviews of five staff working on relevant astronomy projects in the UK and South Africa.

The culture of astronomy as a globally inclusive scientific endeavour

Astronomers have been collaborating across cultures and nations for many centuries. As early as the 15th century, Islamic, Latin, Byzantine and Jewish scholars would travel and exchange ideas, at a time when travel was largely inaccessible (Feldhay & Ragep, 2017). It was this cross-cultural exchange that likely led to the Copernican Revolution, which placed the Sun at the centre of the then known universe and not the Earth. It is unlikely that this discovery, which in some ways marked the beginning of modern astronomy, occurred in isolation, as eurocentric views uphold today (Feldhay & Ragep, 2017).

After centuries of scientific and technological developments – through the creation and advancement of telescopes, and the more recent invention of the daguerreotype – international collaboration took on a new form. Beyond astronomers visiting one another and exchanging data to compare results, they began to join efforts to pursue ever-ambitious projects which would have been too time-consuming and cumbersome alone. In 1887 astronomers came together in Paris to launch the Carte du Ciel project, a sophisticated plan which sought to map the entirety of the night sky using photographic plates (Lamy, 2009). The scientific programme thus necessitated North–South co-operation – 18 observatories on almost every continent were involved. Although the project was never completed, this example marks a significant transformation in the operation of scientific activity – Carte du Ciel is possibly the first instance of planned, large-scale international scientific collaboration.

The international co-operation of scientific activities inevitably suffered during the wars of the 20th century, and astronomy was no exception. During the First and Second World Wars, academic conferences were cancelled, and it became difficult to receive letters and journals, making astronomy research difficult. Soon after the First World War, the International Research Council (IRC) was founded in 1919, under which the International Astronomical Union (IAU) was also formed. The IAU was the first union to be established, alongside the International Union of Geodesy and Geophysics. Lalli (2018) makes a strong case that these two unions were the first to be created because of their pre-established networks and intrinsically international outlook, lacking in other disciplines at the time.

The first decades of the IAU were turbulent, with significant stress and tension felt by the international astronomy community. The IRC prevented the membership of any former Central Power, which neutral countries and several astronomers from Allied Powers strongly opposed (Blaauw, 1994). One astronomer, Jacobus Kapteyn, boycotted the IRC and its unions altogether, for its lack of ‘truly international’ outlook (Anderson et al., 2019). Although German membership became possible in 1925, Germany did not become a member of the IAU until 1951 – for political, cultural, and financial reasons. It is apparent that there was some rivalry between the IAU and a German society formed much earlier, the Astronomische Gesellschaft (AG) (Wielen, 2019). The AG was set up in 1863 as an international astronomical society and has lived true to its function via the involvement of several foreign astronomers. This included the unusual case of Sir Arthur Eddington who served as vice-president for both the AG and IAU at different times.

The Cold War and other politically charged events like the Tiananmen Square protests and Yugoslav Wars posed further challenges for the IAU (Anderson et al,. 2019). Although conferences still took place and astronomers from all sides were always welcome, scientists could easily be denied permission to travel by their governments or refused visas (an issue faced by many Global South astronomers today; Nshemereirwe, 2018). These meetings were always politically neutral, however, and helped to facilitate relations between astronomers at times of extreme political conflict. More recently, links with astronomers from the Democratic Republic of North Korea have also been made (Anderson et al., 2019). These cases show that despite severe political differences, the astronomy community has always persevered in its internationally welcoming outlook.

This internationalism remains the norm in current times. Several studies have shown that astronomy has the highest multinational authorship compared to other scientific fields (Abt, 2007; Coccia & Wang, 2016; Wagner, 2016). With the construction of larger observatories and telescopes in space, cross-border co-operation has become even more enhanced. Before this current landscape, there were few astronomers, but most would have had access to a small, private observatory at their home institution. The scene is now very different; the astronomy community has grown significantly, and as observatories have grown in scale, sophistication and cost, it is essential for several partners – if not nations – to come together to fund these astronomically rich programmes.

What perhaps is most extraordinary is that several of the most advanced observatories in the world allow scientists from non-partner organisations or countries to apply for observing time. Instead of limiting access to those which have contributed funding in some way – typical of operations in other scientific fields – time is allocated purely on the merit and brilliance of a proposal (although of course, there are always biases within any awarding process, which committees are working hard to address, e.g. Johnson & Kirk, 2020).

Federally funded observatories in the USA have adopted Open Skies Policies, allowing anyone with a ground-breaking idea the chance to observe with an instrument like the Hubble Space Telescope (HST), one the most expensive observatories in history. Other countries and international organisations have adopted similar open access policies, like the European Space Agency (ESA), the Optical Infrared Coordination Network for Astronomy (OPTICON), the European Southern Observatory (ESO), the Atacama Large Millimeter/submillimeter Array (ALMA) and the Japanese Subaru telescope. India also allows open access on its Giant Metrewave Radio Telescope and has seen a demonstrable increase in local capacity. Co-operation between local and international researchers has been enhanced, while improving the country's exposure to top international scientists and bringing a newfound international research prestige (Mauduit, 2017).

Maintaining open access to these observatories is not easy, however. It goes against the desires of governments and other funders to restrict the use of an instrument among those who have contributed to its finances, construction, or other in-kind support (Williams & Mauduit, 2019). These challenges are additional to the struggle of obtaining funding in the first place: astronomy is a blue-skies science and its findings do not have an immediate return for society.[1] There is, however, evidence that astronomy projects lead to societal benefits through value creation, such as improvements in rural infrastructure, job and business creation, environmental protection, uptake in science, technology, engineering and maths (STEM) education, and more (Nalewaik & Williams, 2021). In the words of Sam Okoye, Nigeria's first radio astronomer:

> *The relevance of astronomy to the development of a modern national economy is less than apparent and many enlightened officials as well as politicians would in fact regard astronomy as an esoteric subject that is worthy neither of the investment of the lean resources of the developing countries nor of the tuition or time of their pupils* (Okoye, 1990).

Thus, the funding of large-scale infrastructure needs to be politically justified, and justified to the broader public as well as the local communities upon whom the observatory may be impinging. As one interviewee described, five-year election cycles and a lack of resources pose additional challenges – it is hard to convince a government to invest in astronomy when it takes decades to see a tangible outcome. Another interviewee mentioned the exceptional case of South Africa: the country strategically invested in a long-term vision for astronomy, and has reaped significant benefits as a result. For example, the nation has successfully upskilled the next generation of scientists and engineers – no easy feat – and is now seen on the international stage as a leader in science, technology, and innovation (Gastrow et al., 2016).

At the same time, investing in astronomy has significant political advantages – astronomy has no agenda, save its quest for universal knowledge. One interviewee recognised that no other science in South Africa has united policymakers as much as (radio) astronomy. At annual budget meetings policymakers would argue about every item on the budget, but they would always agree that the SKA project – having been identified as a strategic area for science, technology and innovation investment – should receive the resources needed to enable its success (see also Bhogal, 2018). The interviewees also identified several examples for how astronomy can foster trust and co-operation between nations, generating positive intergovernmental relations.

1. Science enables countries to communicate on topics outside of the traditional political sphere, fostering mutual understanding and trust.

1. Astronomy has, however, led to several, unplanned innovations, fundamental to today's society (RAS, 2016; IAU, 2019). In medicine, techniques developed through astronomical research are important components of magnetic resonance imaging (MRI) and computer-assisted tomography (CAT) scans. Other examples include Wi-Fi, a technique developed by radio astronomers to transfer their data wirelessly, as well as satellite navigation (GPS; Global Positioning System) and compact camera chips (CCDs; charge-coupled devices).

2. The SKA has enabled governments to increase science-related discussions, especially between the African countries where the SKA will be constructed. These countries have regular ministerial meetings regarding the SKA's progress, which often lead to discussions for other potential opportunities and collaborations.
3. Astronomy is an easy and accessible entry point for soft power through science diplomacy (see, for example, Nye, 1990; Royal Society, 2010; Rivera, 2015), where Global North nations like the UK want to portray a positive picture and increase attractiveness.

Another important aspect is the appeal of astronomy itself, especially to young people. Astronomy is a gateway science (Salimpour et al., 2020) – interviewees highlighted how the study of the Universe embraces the naturally inquisitive side of young people, drawing them to science and technology. Gratification is relatively easy, achieved through 'obtaining spectacular images and working with amazing instruments', which makes it an easy sell to students.

One interviewee commented on how the added data science aspects have led to increased appeal from a wider variety of students, who perhaps are less interested in pure astrophysics but more interested in the technical side. Another interviewee recognised the great appeal and draw of space-related missions, like the Apollo missions, the HST (which had inspired themselves) or the Curiosity rover, which have inspired many of today's scientists and engineers.

Likewise, astronomical observatories capture the hearts and imaginations of the general public; several photos released by the Space Telescope Science Institute have become cultural icons. When NASA planned to cancel the last service mission to the telescope after the Space Shuttle Columbia disaster in 2003, it had to reverse that decision due to overwhelming and severe public pressure (Dick, 2020). The public grief shared in reaction to the recent collapse of the Arecibo Observatory provides further testimony to the cultural significance of astronomical instruments. The Arecibo's end was a great 'blow to the people of Puerto Rico, who embraced hosting the technological marvel' (Clery, 2021).

The openness of the astronomy community is also reflected through other activities: citizen science, and open access of literature and data. Astronomers have been engaged in citizen science for centuries (Marshall et al., 2015) and astronomy projects on platforms like Zooniverse have produced 584 publications (Pelacho et al., 2021). Most astronomy papers are publicly available as preprints through the arXiv repository, and enormous quantities of astronomical data from many of the world's best telescopes are archived in online databases. These open access systems are beneficial for not only the advancement of science but also the scientists (Zhang et al., 2011). This attitude towards openness was reflected in the interviews. One described how being open is part of an astronomer's identity, an aspect similarly depicted in Bhogal (2018). The international community works hard to ensure that scientists working in countries with limited resources can gain access to telescope time, online data repositories and engage in world-class science.

Although this culture of open access enables anyone to participate, it remains challenging to create a system which is truly equitable. While researchers in less-advanced countries have free access to some of the best instruments and data in the world, they may lack the resources and training to compete at the same level as those from more scientifically advanced countries. There are growing efforts in place to try and mitigate this, such as the OPTICON training schools for early career researchers, but more research and access to time allocation data is needed in order to fully understand and address these issues.

Astronomy training has the added advantage that the skills learned are transferable and beneficial to society. As an educational subject, astronomy is low-cost to fund at school or undergraduate level, especially compared to other sciences dependent on lab equipment, while providing students with essential skills needed for STEM industries (Pompea & Russo, 2020). One interviewee said: 'Astronomers are waking up to the idea that if you study astrophysics you don't need to become an astronomer.' As observatories grow in size, so do the quantities of data; the famous first image of a black hole produced by the Event Horizon Telescope involved processing petabytes of raw data (one petabyte is equivalent to one million gigabytes). Learning to work with big data presents new opportunities for collaboration with other disciplines like computer science, and for many more scientists to be included overall. The astronomy community has already passed the point at which they have too much data to analyse, and so with proper support and training the pursuit of astronomical research can become more available and inclusive, especially for those with limited resources (Norman, 2018).

We also find that as access to instruments and data increases for all, the more diverse the astronomy community becomes, fostering new creativity and different ways of thinking to solve the Universe's greatest mysteries. This is exemplified by a recent study which found that the more diverse a collaboration, the more scientific impact their work generated – ethnic diversity showed the strongest correlation (AlShebli et al., 2018).

Other training schools include the Pan-African School for Emerging Astronomers (Strubbe et al., 2021) and the International Schools for Young Astronomers (ISYAs). The ISYAs are an IAU activity which began in 1967. The schools are usually held in the Global South and last up to eight weeks, with the aim to train the next generation of astronomers. So far, 41 schools have been organised in 27 countries and attended by more than 1,400 students (Aretxaga, 2018). Michèle Gerbaldi, Chair of the ISYAs between 1994 and 2007, perceives these schools as deeply cultural activities and a necessity for the global astronomy community:

> *Experiencing the surroundings of the host country and the discussions that arise between participants and lecturers from different cultures are as equally important to build long-term perspective among the School alumni and the lecturers [...] Indeed the ISYAs have contributed to building an international community. So, it was never 'simply' about teaching [...] we brought together young people who all shared a passion for astronomy, but had very different backgrounds. I remember a School in Egypt in 1994, where we had students from the Middle East Region who were orthodox, Catholic, Muslim and atheists, and yet thoroughly enjoying the gathering [...] For the participants these Schools were – and are – a cross-border initiative that transcends the political and cultural barriers through their common interest: astronomy* (Anderson et al., 2019).

The astronomy community has also shown a keen dedication for public engagement and outreach. Astronomers Without Borders, for example, brings the world together via our passion for astronomy and the wonders of the Universe (Simmons, 2018). GalileoMobile has organised especially ambitious programmes, supported in part by the IAU's Office of Astronomy for Development (OAD), such as the Columba-Hypatia and Amanar projects. In collaboration with the Association for Historical Dialogue and Research, the Columba-Hypatia project brought together children and educators from the divided Greek-Cypriot and Turkish-Cypriot communities (Fragkoudi, 2020). The project used astronomy as a tool to bring different cultures together under one sky, promoting meaningful communication and a culture of peace and non-violence, and won the 2018 Falling Walls Engage Science Engagement award. The Amanar project similarly inspired a sense of global citizenship through sharing astronomy with hundreds of Sahrawi refugees in the Western Sahara (Benítez Herrera et al., 2020).

The International Astronomical Youth Camp (IAYC) is another example of a scientific activity that embraces cultural exchange. The IAYC has been in operation since 1969 and has brought together thousands of young people of more than 80 different nationalities (Dalgleish & Veitch-Michaelis, 2019). The organising body behind the camp, the International Workshop for Astronomy, lists two aims:

1. promotion of international collaboration and agreement, particularly for astronomical youth work
2. to spread astronomical knowledge and to teach young people to work scientifically on their own.

To achieve these missions, the camp requires participants to undertake a three-week research project, and yet, 'the goal of the camp is not to produce novel scientific results, but to bridge cultural barriers while fostering curiosity and intuition for how research is carried out'.

The culture of astronomy collaboration has been illustrated through three main contexts:

1. a historical origin in cross-cultural exchange
2. an attitude of openness and providing open access to telescope time, papers and data
3. the engagement of marginalised communities and the training of the next generations of scientists, often through cultural exchange.

Based on these examples, could it be that the subject of astronomy in itself, namely, the search for answers pertaining to the nature and evolution of the Universe, is the glue that drives astronomers to bring all citizens together under one sky? Or is this inclusive nature borne out of the demands of scientific progress? These are questions that cannot perhaps be answered, but would certainly be interesting to pursue further.

On the one hand, one interviewee argued that it is not astronomy that fosters positive relations, but that the development of astronomy is by its nature dependent on it. Astronomers require observations of the whole sky, from both the Northern and Southern hemispheres, and as the field becomes more complex it becomes more dependent on science collaboration and multinational infrastructure. Thus, astronomy relies on positive international relations to progress, which has led to the creation of intergovernmental organisations like ESO and the SKA.

On the other hand, Higgins (2016) argues that 'the emergence of the natural sciences can be read as an unintended consequence of the deep human curiosity about the stars'. It is also remarkable that vast proportions of astronomers go out of their way to engage with the public, especially compared to other sciences (87 per cent of IAU astronomers reported engaging with the public; Entradas & Bauer, 2019). The existence of the IAU's Office of Astronomy for Development in itself is also notable, and plays an important part in reaching and bringing together some of the most marginalised communities. Such activities draw upon our innate feelings of awe and wonder, which acts as catalyst for peace and development. Perhaps this presents some indication that the Universe does play a role in inspiring the citizens of the world to work together.

UK–South African astronomy: a 200-year relationship

The remainder of this essay considers the complex historiographies behind North–South astronomical collaboration, especially in light of the Global North's colonial past. Using the example of the UK–South African scientific relationship, cultural aspects can be explored most prominently through the SKA and the DARA projects. These cultural relationships differ widely on individual, local, national, and international scales.

By the end of the 18th century, astronomical discoveries were stagnating in the UK, fostering a desire to find a new view of the night sky. A Southern observatory would offer new heavenly perspectives to Northern astronomers – revealing the Magellanic Clouds and the centre of the Milky Way. Of few southern territories to choose from, the Cape of Good Hope was found to be the best suited for its favourable weather and convenient location. Thus, the history of UK–South African astronomy is rooted in colonialism (McAleer, 2013). Astronomers travelled to South Africa to construct observatories (using slave labour to a large extent; Warner, 1995) and to conduct research for the development of Western astronomy, for which the latter continued long into the 19th century (Dubow, 2019).

Colonialism inevitably led to a skewed and unsustainable scientific system, built on the skills and intellectual capital of white South Africans while excluding the majority. Now, science and astronomy are undergoing a transitional process, away from the 'legacies of the apartheid past, with its ideologies and discriminatory practices, into a new democratic era with new or modified practices, institutions, values and beliefs that have societal legitimacy' (Pandor, 2018).

Slowly, the sector is evolving to become more inclusive and representative of South Africa's population. Astronomy in particular has been a crucial driver of development in the country across a number of national imperatives (Pandor, 2018). This vision is reinforced by South Africa's 1996 *White Paper on Science and Technology:*

> *Scientific 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 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.*

As such, South Africa's imperatives include the investment in science, technology, and innovation, which are recognised as powerful tools to further sustainable development and overcome economic, environmental and societal challenges (AAS, 2018). African nations can invest in science, technology and innovation to take advantage of the oncoming demographic dividend and, implemented appropriately, will upskill individuals from all backgrounds, reduce inequalities and prepare society for the Fourth Industrial Revolution. The continent is currently guided by three significant initiatives, which all recognise the value of science, technology and innovation as an integral element of sustainable and inclusive growth:

1. the Science, Technology and Innovation Strategy for Africa (STISA-2024)
2. the African Union's Agenda 2063
3. the United Nations' 2030 Agenda for Sustainable Development.

Science, technology and innovation are acknowledged as an important enabler by the Organisation for Economic Co-operation and Development (OECD). Through ODA, OECD countries have an important role to play in the implementation of the Sustainable Development Goals (SDGs) at home and abroad.

The Newton Fund[2] is one example of UK ODA. It is a £735 million fund which aims to promote prosperity and long-term sustainable growth through the development of science and innovation partnerships. More specifically, the Newton Fund supports projects that will positively impact the lives of people on low incomes, and contribute to the economic development and social welfare of the partner country. Delivery of Newton Fund projects is largely delegated to several partners, including the British Council, and the partner countries are required to match-fund any resources they receive:

> *The matched funding requirement is important [...] because it establishes a relationship wherein both the UK and its partner countries have an equal stake in the program and a responsibility for driving the strategic direction of the fund. This partnership of mutual respect and commitment is crucial for the long-term international relations aspect of the project [and is] centered on understanding the partner-country needs* (Grimes & McNulty, 2016).

The involvement of the British Council as a Newton Fund partner infers a relationship between scientific collaboration and cultural relations, for which sustainable development is also an important dimension (see the 2020 British Council publication *The Missing Pillar – Culture's Contribution to the UN Sustainable Development Goals*). Many Newton Fund projects involve activities like exchanges for students and researchers to share knowledge and acquire experience, whereby academics have to navigate and embrace cultural differences (Francisco, 2015).

In addition to the professional development of early-career researchers, UK ODA has led to many other advantages, namely:

- the establishment of cross-disciplinary research institutes and centres
- an increase in the number of co-authored publications in major international peer-reviewed journals
- the increased reputation and recognition of the UK as a world leader in addressing global challenges (UUKi, 2020) – which is especially agreeable to the British Council's mission.

As such, the benefits are found to be mutual for all parties involved – not only the recipient of the funding – which is a core principle of ODA. These shared benefits similarly align with the British Council's ethos and approach to cultural relations, especially with regard to reciprocity, and building trust and intercultural relations (Singh, 2020). It comes as no surprise that the recent announcement of a drastic reduction in UK ODA down from 0.7 per cent to 0.5 per cent of gross national income – amounting to £4.5 billion – came as a severe disappointment to many UK ministers and institutions. Meanwhile, other G7 countries (Germany, France, Italy and Japan) are instead increasing their ODA (Mitchell et al., 2021).

2. The Newton Fund is managed by the UK Department for Business, Energy and Industrial Strategy (BEIS) and delivered through seven UK delivery partners and 87 in-country funding partners.

The Newton Fund agreement between the UK and South Africa is one of 17 active partnerships with middle-income countries. The agreement was launched in 2014 and builds significantly on the 1995 UK–South African bilateral agreement on science and technology. To date, the UK has committed £40 million to the UK–South African Newton Fund programme, which has been match-funded by South Africa. As highlighted by one of the interviewees, match-funding is important as it helps to make science, technology and innovation projects more sustainable: when a country is required to invest in science, technology and innovation themselves, it reduces their dependence on development aid and helps to foster a sense of ownership. Yet it remains an enormous challenge for African governments to contribute at this level; resources on such large scales are in short supply (see also Uden & Fotheringham, 2018).

South Africa's successful bid to co-host the €1.9 billion SKA with Australia in 2012 reinforced astronomy's place as one of the seven development priorities of the UK–South African Newton Fund programme. The SKA is facilitated by the SKA Observatory (SKAO), a worldwide intergovernmental organisation officially launched on 4 February 2021. The SKAO is so far made up of 15 countries across Europe, North America, Africa, Asia and Australasia, and its headquarters are located at Jodrell Bank near Manchester, a UNESCO World Heritage site. Societal impact has been at the root of the SKA since its inception, and the observatory has already found several ways to support the SDGs (SKAO, 2021).

When built, the SKA will be the largest radio telescope in the world, made up of ~3000 dishes spanning Sub-Saharan Africa and Western Australia. The former includes eight African VLBI[3] Network (AVN) countries: Ghana, Kenya, Zambia, Namibia, Botswana, Madagascar, Mozambique and Mauritius. These AVN countries have little or no radio astronomy expertise, but it is hoped that by following the South African example, astronomy can be kick-started, leading to increased South–South co-operation, the promotion of STEM education and economic development, and thus, ultimately, furthering the 2030 and 2063 agendas. The SKA may well become 'the first international scientific infrastructure with education and outreach embedded in its development from the earliest stages' (Berry, 2020).

3. VLBI stands for very-long-baseline interferometry, an astronomical technique used in radio astronomy.

The DARA project and cultural impact on the individual

To help prepare for the construction of the SKA in the AVN countries, the Development in Africa with Radio Astronomy project was selected as one of the Newton Fund's main programmes. DARA is funded through the Science Technology and Facilities Council (STFC), and has so far received £4 million to help train the first generation of radio astronomers across the AVN partner countries. These resources are matched by South Africa and delivered as a joint bilateral project. DARA activities include the provision of basic radio astronomy training in the eight AVN countries, where more than 250 young graduates have taken part in four two-week training courses delivered by experts from the UK and South Africa.

DARA Big Data is another Newton–STFC-funded project, with a stronger focus on data science and machine learning, techniques that will be vital to translate the massive quantities of data produced not only by the SKA, but also in other sciences and industries such as agriculture and medicine. Alongside hackathons and intensive workshops (attended by more than 200 students), DARA Big Data includes science policy activities as a vital component.

DARA and DARA Big Data have been in close collaboration since the beginning, and have together brought 50 Africans to the UK to study at master's and PhD level. Twelve of the DARA Big Data graduates have already shared their lived experiences of being in the UK.[4] Further insights about the impact of the DARA programmes on the students have been explored through a survey for past and present African students.[5] The survey was completed by 17 DARA and DARA Big Data students, representing six countries: Botswana, Ghana, Kenya, Mauritius, Zambia and Madagascar. Questions relate to their lived experiences of the DARA programme in socio-cultural and socio-economic contexts.

Expectedly, the survey responses show that culture is a significant part of their experience of living and studying in the UK. Students noted excellent student–supervisor relationships and fewer formalities (which they said improved interactions), recognition and support for mental health, and opportunities to be more independent as reasons for an improved experience compared to their home country. Many students wrote that they enjoyed travelling across the UK, and how they 'made friends from all the continents and discovered different cultures, which have helped broaden my horizons and greatly contributed to my self-development'. These experiences often centred around food:

> *I cooked different African foods for my Colombian, Pakistan, British, Indian and other European and Asian friends. They did the same. We shared stories and felt like one big family.*

In terms of negative experiences, one student noted their segregated environment:

> *It's hard to share African culture with most British people because they have the preconceived notion that African culture is primitive.*

4. See www.darabigdata.com/dbd-student-profiles
5. The questionnaires were designed and delivered by the author, and conducted through an online form. The survey included 16 questions, some of which were open-ended, and was shared with DARA and DARA Big Data students in autumn 2020. The questionnaire divided into two sections, depending on if the student was still in the DARA programme or not. Three of the respondents had not yet spent any time living in the UK, due to Covid-19 travel restrictions.

Another expressed that international students (non-EU) were 'sort of excluded from the main activities and ignored during social events. I, therefore, mostly exchanged with other African/DARA students and other international students.' Another contrasted this view, sharing that their interaction with others on the DARA programme 'has been deeply transformative. I have met other African students from the continent and interacting with them has been formative to my understanding of the continent.'

Where capacity and sustainability building are important strategic requirements of the Newton Fund, it is too soon to see if the DARA programmes have fulfilled their goal: to successfully train the next generation of radio astronomers in the AVN countries. Of the eight former students who completed the survey, half are in further training or have secured positions in academia. One of the students in further training elaborated:

> *DARA was life-changing for me. Thanks to DARA, I was able to follow a dream of mine to study in the UK [...] Thanks to the skills I have acquired during my DARA training in the UK, having a degree from a well-known and respected UK-based university, and with recommendation letters from known experts, I was able to secure a PhD position at a European university, in one of the biggest research groups specialising in the topic that I am interested in. I would have not done it without DARA.*

The remaining former students found occupations in the private sector, data science or teaching, and one respondent is unemployed. One of the current students noted:

> *There are not so many opportunities back home when it comes to postdoctoral fellowships so I think here [UK] or any other country it will be easier for me to get that opportunity.*

This is important because it highlights brain drain as one of the greatest challenges that capacity-building programmes like DARA face, as illustrated by the life of Sam Okoye (Bowler, 2020). The risk of brain drain was further elaborated in some of interviews; astronomy provides an incubator environment for Africans to develop transferable and desirable skills for industry, but at the same time, these skills are very mobile internationally, and so they need to be retained. The lack of infrastructure, especially in the AVN countries, means that these nations struggle to accommodate the newly trained graduates when they return home. This inevitably leads to graduates struggling to implement their skills and find work in their home countries, and so they seek opportunities elsewhere.

Overall, the DARA programmes have clearly fostered a strong pan-African network between the students, and have had a significantly positive impact on the majority of respondents: ‘I think [DARA] has uplifted my life and placed me in a position to take on bigger challenges across the globe’, and ‘The DARA scholarship has been my greatest achievement so far in life and for that I am grateful. It has made a very significant impact in my life.’

At this early stage, it is also visible that the programmes are helping students to develop transferable skills. This relates to a view of one of the interviewees, in that decolonisation is about giving Africans the skills and enabling them to fulfil their potential via human capacity building, knowledge which can then be applied in different sectors. Programmes like DARA and DARA Big Data are enabling young people to take advantage of the extensive opportunities that radio astronomy will bring, leading to possible careers in other academic fields or roles in policy, outreach, banking and software development, for example.

South African astronomy and culture on local, national, and international scales

Looking more closely at the example of the SKA's construction in South Africa, cultural manifestations vary between local, national, and international levels. 'Big science' projects like the SKA are framed as being the harbingers of development, providing opportunities for all citizens. Through critical examination of the implementation of the SKA in the Karoo region, a special issue of seven articles in the *Journal of Southern African Studies* found a range of impacts upon the rural communities living there (Walker et al., 2019).

To set the scene, the Central Karoo is often depicted as being a remote and mostly empty space. This is in contradiction with the 23,000 people living in the region presently, alongside evidence that the area has been inhabited since the Stone Ages (Parkington et al., 2019). The local peoples living there today embody complex, multicultural histories, many of whom are subjects of abject poverty and 'grappling with an unresolved history of dispossession, discrimination and marginalisation' (Walker et al., 2019).

As Gastrow and Oppelt (2019) explain, this setting makes it extremely difficult for a national flagship project like the SKA to fulfil the needs of the local population, because it does not have the means or resources to do so. Perceptions are thus misaligned from the start; the SKA SA is stuck between a long-term national vision – which will elevate South Africa's position globally – and local expectations that the SKA SA is there to solve acute development issues like foetal alcohol syndrome.

Tensions have also emerged through a lack of transparency, leading to unintended repercussions during the land acquisition process (Gastrow & Oppelt, 2019). For example, sheep farmers in the area said they were unaware that the SKA would require such vast quantities of land and some have been displaced, bringing newfound colonial implications (Christie, 2020). These struggles are in addition to strict requirements in the SKA's vicinity, legislated by the Astronomy Geographic Advantage Act of 2007, which prevent the use of petrol-powered engines, mobile phones, microwave ovens and electric fences since they interfere with sensitive radio observations.

In anticipation of some of these issues, the SKA SA project carried out several capacity-building activities in the local area. Farmers affected by land requisition have received compensation and their workers have received training and rehousing. The project has also stimulated human capacity development in the form of newly recruited qualified maths and science teachers, provision of computational and other lab equipment for schools. Sustainability issues have arisen, however, where some of the equipment has been found to be inaccessible or cannot be fixed when it breaks (Christie, 2020). The SKA has also created more than 1,000 bursaries for children to attend high school or university, on local and national levels, through the Human Capital Development Programme (HCDP; SKAO, 2021).

It has also been important for SKA SA to recognise the colonial history and appropriation of the land in the 1800s. Through collaborations between astronomers and indigenous peoples in the local area, the project has invested in indigenous knowledge systems to preserve and recover cultural heritage (Binneman & Davis, 2020). Other activities have occurred on international scales, such as the travelling exhibition Shared Sky, a project between the San peoples in South Africa and the Yamaji in Western Australia. The astronomers and artists worked together to create art, celebrating ancient and modern stories about the cosmos (Mann, 2016). They produced a piece called *Ilgali Inyayimanha* (Shared Sky) which the artists described as the following:

> *It doesn't matter where we live on this barna (Earth). Nganha (we) are all sharing the same Ilgari (sky). Although we may see different Ilgarijiri (things belonging to the sky) we are looking up at the same stars and constellations.*

Interviews with astronomers in South Africa revealed similar insights on embracing the ethnological connection between the stars and African people. The respondents reflected on the importance of astronomy for Africans in a cultural context – how it connects us to the past and our origins. One interviewee went on to say that unlike in much of the West, Africans have retained their cultural heritage with the night sky – particularly those coming from rural areas. Oral histories and traditions are still an essential part of these communities, where indigenous star lore is passed on through storytelling. It is a very 'personal experience to look at the night skies from a place of darkness and silence', a deeply profound encounter typically not found in relation to other scientific disciplines. Therefore, astronomy provides an additional attraction as it can be 'something carried within us', alongside research.

The interviews revealed other examples of the benefits of investing in astronomy, particularly on national scales. Two of the participants mentioned the example of the South African Radio Astronomy Observatory (SARAO) and its involvement in helping to co-ordinate the South African response for Covid-19. When the SA government realised they lacked a national production of ventilators, and were in a weak position in the international market to buy them, the government fathomed that SARAO had the infrastructure needed to oversee the production of ventilators in South Africa. With access to project managers, system engineers, and electrical mechanics, SARAO was able to oversee the production of 20,000 ventilators within just a few months, and at a fraction of the cost compared to ventilators on the market. This example clearly shows how an investment in astronomy can tangibly benefit society, across completely different fields – the skills and infrastructure gained from large-scale astronomy projects are versatile.

On international scales, South Africa's successful bid to host the SKA has not only been significant politically, but culturally. As one of the interviewees discussed, astronomers they knew from the Global North did not believe that South Africa could win the bid, because Africa has access to less money and resources, which they inferred as corresponding to less excellence. South Africa's success has therefore cemented their place within the astronomical community and has meant that 'people who did not see Africa as a scientific continent are having to rethink'. The SKA has placed Africa on the map as a global scientific leader, and has helped create a shift away from Afro-pessimistic attitudes.

One interviewee went on to share how large-scale astronomy projects like the SKA have a fundamental role in protecting and promoting cultural heritage, which will hopefully be embedded in African societies as their scientific capacity increases. They further discussed how the way we think and learn has its roots in culture, which needs to be embraced and made relevant for the sciences across all societies.

Interviewees also noted that politically speaking, creating a knowledge economy, for example via data science, gives you negotiating power and a place at the table: Africa is becoming a global player in astronomy more than ever before. This is exemplified by South Africa's successful bid to host the IAU's General Assembly in 2024 – a first for the continent in the union's 100-year history, and celebrated by all (Buckley, 2019). This ties into the pan-African vision, along with the recent re-establishment of the African Astronomical Society (AfAS; Leeuw et al., 2019).

Overall, projects like the SKA and DARA help to transfer scientific ownership to the African continent. Astronomy in Africa has 'gained its own momentum and is now a movement that lives by itself'.

Conclusion

Through the exploration of astronomy, we have seen how culture can permeate the scientific field in a myriad of ways. Astronomers themselves are strongly associated with a culture of openness, and this internationally collaborative outlook is remarkable compared to other scientific disciplines. Astronomers are devoted to including everyone, regardless of politics, shown through their dedication to sharing astronomy with others through cultural exchange. More recently, astronomers have found a new drive to embrace and preserve indigenous knowledge, and to rectify the horrors of their colonial past.

These points are reflected through the words of Oddbjørn Engvold, IAU Secretary General (2003–06):

> *Astronomy is rather unique in the way that it connects many with scientific disciplines, it's more accessible to people than many other sciences and it has influenced human culture – our understanding of the physical world, but also religion and philosophy – more than perhaps any other human endeavour [...] To me, astronomy has had a much stronger and more positive impact on human society than we normally realise. It lets us appreciate the richness of the Universe while also fostering rational thinking, which I believe is a need for humanity to survive* (Anderson, 2019).

We have also seen that astronomy can serve the SDGs, supporting Global South countries who seek to invest in science, technology and innovation. Several examples have shown that astronomical collaborations can help to bring governments and nations together to foster trust, peace and prosperity.

But what is immediately apparent is that the introduction of large-scale infrastructure does not come without significant challenges, especially when trying to please a variety of stakeholders with differing needs. Care and caution are duly needed, as well as more co-operation with historians and social scientists, to truly bring all voices together under one sky. Big science projects are at risk of being overly top-down and North–South, while reinforcing hierarchies and perpetuating dependencies on foreign aid (Barandiaran, 2015). Although it is difficult for lower-income countries to match the resources coming from the Global North, it is important if Global South countries are to feel empowered and enjoy ownership of a project.

For development to be carried out holistically, the astronomy community needs to improve its engagement with local stakeholders and work harder to foster a sense of ownership between all parties from the very start. The local challenges of the SKA in South Africa are not unique – although much more extreme, astronomers are facing intense opposition against the construction of a new telescope on Mauna a Wākea (Mauna Kea) in Hawai'i. Protests began in 2014 and have continued ever since, and can be encapsulated as follows:

> *The struggle to protect Mauna a Wākea is emblematic of over a century of struggle against U.S. settler colonialism, its logic of elimination, and practices of replacement* (Casumbal-Salazar, 2017).

These instances of conflict contradict the previously described openness and inclusiveness of the astronomer's ethos. Taken too far, the astronomer's utmost desire to solve the Universe's greatest mysteries – and belief that this is the fundamental pursuit of all citizens – can become the astronomer's greatest flaw, especially when it comes at the expense of local communities who continue to suffer from the after-effects of colonial rule.

And this is why the understanding of the cultural implications of science – and how they may foster or hinder relationships – is so important. Science is carried out by people, and thus there are inherent cultural juxtapositions between the pursuit of science for the sake of development and communities being too easily misinformed or left behind.

This Cultural Relations Collection essay has presented a unique opportunity to explore themes which have had little recognition but are still very relevant to the British Council. Although the subject of astronomy rarely appears within the charity's work, the charter states that the British Council shall 'encourage cultural, scientific, technological and other educational cooperation between the United Kingdom and other countries'. The 2014 *Triennial Review of the British Council*, however, states that the arts, English language, and education have been the main focus and that 'Science and Technology should be given higher profile within the Organisation'. Astronomy – with its strong ties to culture, science, and technology – offers an avenue for the British Council to fulfil its charitable purpose more wholly while introducing a new path of thought.

Acknowledgements

This essay wouldn't have been possible without the guidance and input from many people. Thanks are especially due to Stephanie Renforth and James Perkins for their continued support and advice throughout the development of this work, in addition to the helpful comments from the reviewers. I am also very grateful to the interviewees, as well as the past and present DARA and DARA Big Data students, for their precious time.

References

AAS (2018) Africa Beyond 2030: *Leveraging Knowledge and Innovation to Secure Sustainable Development Goals.* African Academy of Sciences, Nairobi, Kenya.

Abt, HA (2007) The frequencies of multinational papers in various sciences. Scientometrics 72: pp. 105–115. Available online at: doi.org/10.1007/s11192-007-1686-z

African Union (2013) *Agenda 2063—the Africa We Want.* African Union Commission (AUC), Addis Ababa, Ethiopia.

African Union & NEPAD Agency (2014) *Science, Technology and Innovation Strategy for Africa 2024.* NEPAD Coordinating and Implementing Agency, Midrand, South Africa.

AlShebli, BK, Rahwan, T & Woon, WL (2018) The preeminence of ethnic diversity in scientific collaboration. *Nat Commun* 9/5163. Available online at: doi.org/10.1038/s41467-018-07634-8

Andersen, J, Baneke, DM, Madsen, C (2019) *The International Astronomical Union: Uniting the Community for 100 Years.* Springer International Publishing.

Aretxaga, I (2018) The future of the International Schools for Young Astronomers (ISYA). *Proceedings of the International Astronomical Union* 13/S349: pp. 452–458. DOI:10.1017/S1743921319000590

Barandiaran, J (2015) Reaching for the Stars? Astronomy and Growth in Chile. *Minerva* 53: pp. 141–164. Available online at: doi.org/10.1007/s11024-015-9272-7

Benítez Herrera, S, Rodríguez-Antón, A, Carrelli, FJ, Rodríguez Eugenio, N & Monfardini Penteado, E (2020) A Refuge in the Stars: Outcomes from the Amanar Project. *CAPjournal* 28. Available online at: www.capjournal.org/issues/28/index.php

Berry, ST (2021) 'The SKA Approach to Sustainable Research', in HP Beck & P Charitos (eds) *The Economics of Big Science.* Science Policy Reports. Springer, Cham. Available online at: doi.org/10.1007/978-3-030-52391-6_4

Bhogal, N (2018) The role of the Square Kilometre Array in South Africa's economic development strategy. *S Afr J Sci* 114(3/4) #2017-0297. Available online at: dx.doi.org/10.17159/sajs.2018/20170297

Binneman, A & Davis, C (2020) Star stories: using indigenous knowledge for stakeholder engagement. *Communitas* 25: pp. 1–17. Available online at: doi.org/10.18820/24150525/Comm.v25.1

Blaauw, A (1994) *History of the IAU: The birth and first half-century of the International Astronomical Union.* Springer Science & Business Media.

Bowler, S (2020) Nigeria's first radio astronomer. *Astronomy & Geophysics* 61/5: pp. 28–30. Available online at: doi.org/10.1093/astrogeo/ataa072

British Council (2020) *The missing pillar – culture's contribution to the UN Sustainable Development Goals.* British Council.

Buckley, DAH (2019) The changing landscape of South African astronomy. *Nat Astron 3:* pp. 369–373. Available online at: doi.org/10.1038/s41550-019-0771-6

Casumbal-Salazar, I (2017) A Fictive Kinship: Making 'Modernity,' 'Ancient Hawaiians,' and the Telescopes on Mauna Kea. *Native American and Indigenous Studies* 4/2: pp. 1–30.

Christie, P (2020) *Decolonising Schools in South Africa: The Impossible Dream?* (1st ed.). Routledge. Available online at: doi.org/10.4324/9780367853624

Clery, D (2021) Fallen giant. *Science* 371/6526: pp. 225–229. DOI: 10.1126/science.371.6526.225

Coccia, M & Wang, L (2016) Evolution and convergence of the patterns of international scientific collaboration. *Proceedings of the National Academy of Sciences* 113/8: pp. 2,057–2,061. DOI:10.1073/pnas.1510820113

Dalgleish, HS & Veitch-Michaelis, JL (2019) Assessing the influence of one astronomy camp over 50 years. *Nat Astron* 3: pp. 1,043–1,047. Available online at: doi.org/10.1038/s41550-019-0965-y

Dick, SJ (2020) 'The Decision to Cancel the Hubble Space Telescope Servicing Mission 4 (SM4) and Its Reversal', in *Space, Time, and Aliens.* Springer, Cham. Available online at: doi.org/10.1007/978-3-030-41614-0_21

Dubow, S (2019) 200 Years of Astronomy in South Africa: From the Royal Observatory to the 'Big Bang' of the Square Kilometre Array. *Journal of Southern African Studies* 45/4: pp. 663–687. DOI:10.1080/03057070.2018.1496700

Entradas, M & Bauer, MW (2019) Bustling public communication by astronomers around the world driven by personal and contextual factors. *Nat Astron* 3: pp. 183–187. Available online at: doi.org/10.1038/s41550-018-0633-7

Feldhay, R & Ragep, F (eds) (2017) Before Copernicus: The Cultures and Contexts of *Scientific Learning in the Fifteenth Century.* Montreal; Kingston; London; Chicago: McGill-Queen's University Press. Available online at: www.jstor.org/stable/j.ctt1q1xth3

Fragkoudi, F (2020) Astronomy as a Tool for Peace and Diplomacy: Experiences from the Columba-Hypatia Project. *CAPjournal* 27. Available online at: www.capjournal.org/issues/27/index.php

Francisco, JS (2015) International Scientific Collaborations: A Key to Scientific Success. *Angew Chem Int Ed* 54: pp. 14,984–14,985 DOI:10.1002/anie.201505267

Gastrow, M, Kruss, G & Petersen, I-H (2016) Connecting capabilities in highly unequal developing countries: The case of the Square Kilometre Array telescope in South Africa. *Development Southern Africa* 33/3: pp. 361–375. DOI: 10.1080/0376835X.2016.1153455

Gastrow, M & Oppelt, T (2019) The Square Kilometre Array and Local Development Mandates in the Karoo. *Journal of Southern African Studies* 45/4: pp. 711–728. DOI: 10.1080/03057070.2019.1642679

Govender, K (2009) Astronomy for African development. *Proceedings of the International Astronomical Union* 5/S260: pp. 577–586. DOI:10.1017/S1743921311002870

Grimes, RW & McNulty, C (2016) The Newton Fund: Science and Innovation for Development and Diplomacy. *Science & Diplomacy* 5/4.

Higgins, J (2016) ''The first philosophers were astronomers': Curiosity and innovation in higher education policy', in T Halvorsen & J Nossum (eds) *North–South Knowledge Networks: Towards equitable collaboration between academics, donors and universities.* Cape Town: African Minds.

IAU (2019) *From Medicine to Wi-Fi: Technical Applications of Astronomy to Society.* International Astronomical Union, Paris, France.

Johnson, SK & Kirk, JF (2020) Dual-anonymization Yields Promising Results for Reducing Gender Bias: A Naturalistic Field Experiment of Applications for Hubble Space Telescope Time *PASP* 132 034503. Available online at: https://doi.org/10.1088/1538-3873/ab6ce0

Lalli, R (2018) Patterns to scientific internationalism: What can a comparative history of IAU and IUPAP teach us? *Proceedings of the International Astronomical Union* 13/S349: pp. 189–196. DOI:10.1017/S1743921319000309

Lamy, J (2009) Adjusting Astronomical Practices: The "Carte du Ciel", the democratic rules and the circulation of opinions at the end 19th century. *Proceedings of the International Astronomical Union* 5/S260: pp. 195–201. DOI:10.1017/S1743921311002286

Leeuw, L, Govender, K, Takalana, C, Randriamanakoto, Z & Mamo, A (2019) Science strategy of the African Astronomical Society (AfAS): An outcome of the Science Business held in synergy with the IAUS 356. *Proceedings of the IAU 15*(S356): pp. 379–382. DOI:10.1017/S174392132000349X

Mann, A (2016) Looking at a shared sky, through the lens of art. *Proceedings of the National Academy of Sciences* 113/50: pp. 14,165–14,167. DOI: 10.1073/pnas.1616196113

Marshall PJ, Lintott, CJ & Fletcher LN (2015) Ideas for Citizen Science in Astronomy. *Annual Review of Astronomy and Astrophysics* 53/1: pp. 247–278.

Mauduit, J-C (2017) Open Skies Policies in Astronomy: The Growing Need for Diplomacy on the Final Frontier. *Science & Diplomacy* 6/2.

McAleer, J (2013) 'Stargazers at the world's end': Telescopes, observatories and 'views' of empire in the nineteenth-century British Empire. *The British Journal for the History of Science* 46/3: pp. 389–413. DOI:10.1017/S0007087411000616

Mitchell, I, Hughes, S & Ritchie, E (2021) *An Overview of the Impact of Proposed Cuts to UK Aid.* Center for Global Development.

Nalewaik, A & Williams, N (2021) *Emergent and Unexpected Sources of Value from Radio Astronomy Projects: A Narrative Approach to Value Co-Creation and Co-Destruction.* IEEE Technology & Engineering Management Summit.

Norman, D (2018) Can Big Data Lead an Inclusion Revolution? *AstroBeat* 162 (Astronomical Society of the Pacific).

Nshemereirwe, C (2018) Tear down visa barriers that block scholarship. *Nature* 563/7.

Nye, JS (1990) Soft Power. *Foreign Policy* 80: pp. 153–171. Available online at: www.jstor.org/stable/1148580

Okoye, S (1990) A Panel Discussion. *International Astronomical Union Colloquium* 105: pp. 417–419. DOI:10.1017/S0252921100087455

Pandor, N (2018) Minister Naledi Pandor: Receiving honorary professorship from University of Leiden. Available online at: www.gov.za/speeches/minister-naladi-pandor-astronomy-and-development-26-feb-2018-0000 Accessed on 13 December 2020.

Parkington, J, Morris, D & de Prada-Samper, JM, (2019) Elusive Identities: Karoo |Xam Descendants and the Square Kilometre Array. *Journal of Southern African Studies* 45/4: pp. 729–747. DOI:10.1080/03057070.2019.1647655

Pelacho, M, Ruiz, G & Sanz, F et al. (2021) Analysis of the evolution and collaboration networks of citizen science scientific publications. *Scientometrics* 126: pp. 225–257. Available online at: doi.org/10.1007/s11192-020-03724-x

Pompea, SM & Russo, P (2020) Astronomers Engaging with the Education Ecosystem: A Best-Evidence Synthesis. *Annual Review of Astronomy and Astrophysics* 58/1: pp. 313–361. Available online at: doi.org/10.1146/annurev-astro-032620-021943

RAS (2016) *Astronomy Means Business.* Royal Astronomical Society, London, UK.

Rivera, T (2015) *Distinguishing Cultural Relations from Cultural Diplomacy: The British Council's Relationship with Her Majesty's Government.* Figueroa Press, Los Angeles.

Royal Society (2010) *New Frontiers in Science Diplomacy.* The Royal Society, London, UK.

Salimpour, S, Bartlett, S & Fitzgerald, MT et al. (2020) The Gateway Science: a Review of Astronomy in the OECD School Curricula, Including China and South Africa. *Res Sci Educ.* Available online at: https://doi.org/10.1007/s11165-020-09922-0

Simmons, M (2018) Reaching Underserved Communities Worldwide through Astronomy. *AstroBeat* 163 (Astronomical Society of the Pacific).

Singh, JP (2020) *British Council and Cultural Relations: Betwixt Idealism and Instrumentality.* The British Council.

SKAO (2021) SKA Phase 1: Construction Proposal. Square Kilometre Array Observatory.

Strubbe, L, Okere, BI & Zhang, J et al. (2021) The Pan-African School for Emerging Astronomers. *Nat Astron.* Available online at: doi.org/10.1038/s41550-021-01301-7

Uden, R & Fotheringham, J (2018) *Thematic Impact Study Report – South Africa. Newton Fund Evaluation.* Coffey International Development; RSM-PACEC.

UUKi (2020) ODA funding and its impact on the UK higher education sector. Universities UK International. Available online at: www.universitiesuk.ac.uk/policy-and-analysis/reports/Documents/2020/Impact-of-ODA-funding.pdf Accessed on 13 December 2020.

Wagner, CS, Whetsell, TA & Leydesdorff, L (2017) Growth of international collaboration in science: revisiting six specialties. *Scientometrics* 110: pp. 1,633–1,652. Available online at: doi.org/10.1007/s11192-016-2230-9

Walker, C, Chinigò, D & Dubow, S (2019) Karoo Futures: Astronomy in Place and Space – Introduction. *Journal of Southern African Studies* 45/4: pp. 627–639. DOI:10.1080/03057070.2019.1654664

Warner, B (1995) *Royal Observatory, Cape of Good Hope, 1820-1831: the founding of a colonial observatory: incorporating a biography of Fearon Fallows.* Springer Netherlands. DOI:10.1007/978-94-011-0139-4

Wielen, R (2018) Germany's difficulties in becoming a member of the International Astronomical Union. *Proceedings of the International Astronomical Union* 13/S349: pp. 205–213. DOI:10.1017/S1743921319000322

Young, A (2020) *Negotiating an international astronomy treaty to help reveal the hidden Universe.* CSIROscope. Available online at: blog.csiro.au/negotiating-international-treaty/

Zhang, J, Vogeley, MS & Chen, C (2011) Scientometrics of big science: a case study of research in the Sloan Digital Sky Survey. *Scientometrics* 86: pp. 1–14. Available online at: doi.org/10.1007/s11192-010-0318-1

British Council 2021 / L073
The British Council is the United Kingdom's international organisation for cultural relations and educational opportunities.