

Astronomy for development

This is a year of anniversaries: for the Royal Astronomical Society and the South African Astronomical Observatory, both 200 years old this year, but also for the High Energy Stereoscopic System (20), Africa's first space agency (10) and the African Astronomical Society (10). And it is five years since the United Nations launched its 17 Sustainable Development Goals, setting targets with a 2030 deadline. Here I examine how and why astronomy supports these development goals.

The UN Sustainable Development Goals (SDGs) are a set of 17 targets addressing global challenges such as poverty, inequality and climate change (sdgs.un.org/goals). Despite the progress made since 2015, the Covid-19 pandemic has taken us backwards: for the first time since 1998, poverty rates will increase, with some 40–60 million additional people falling into extreme poverty (defined by the World Bank as living on less than \$1.90 a day). Before the coronavirus crisis began, ~258 million children did not attend school, but by April this had increased to 1.6 billion. Extreme weather events, such as storms and floods, are displacing greater numbers of people each year: at the end of 2019, ~5.1 million were living in displacement and it is anticipated that by 2050 climate change in sub-Saharan Africa, South Asia and Latin America could create more than 143 million refugees.

These statistics serve as a stark reminder to act now, to prevent these harrowing predictions from becoming reality. But how? One way is to embrace our connection with the stars and use astronomy to improve society and the environment. Over the years, people have found innovative ways to use astronomy for development; we can harness and build on these successes to the end of the SDGs and beyond. At first glance, astronomy and sustainable development have little in common, but beneath the surface there are many examples of how astronomy and space science work towards the SDGs, while bringing people together under one sky (McBride *et al.* 2018, Benítez Herrera & Rivero González 2020, Fragkoudi 2020). Three examples in particular highlight how astronomy has furthered the goals: human capacity-building in Africa; dark sky tourism that protects night skies and living beings; and astronomers working to mitigate global warming.

Human capacity

With vast areas of dry, remote and radio-quiet land, much of the African continent naturally provides rich opportunities for the study of the heavens, something recognized 200 years ago when the South African Astronomical Observatory was founded. More African observatories have been built in the past few decades and, today, operate in more than 10 countries, with more telescopes – in even more nations – on the way (Pović 2018). Some are highly regarded, world-leading astrophysical facilities (see box 1).

But if astronomy is to be truly sustainable, especially for development, the construction of an observatory is not enough. A telescope requires engineers to design, construct and operate it, as well as scientists to conduct research, and it is unsustainable to outsource these

Hannah Dalgleish examines ways in which astronomy can help to forge a sustainable future for life on Earth.

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people from the global North. Yet, without access to relevant training by nationals, it is a significant challenge to find qualified employees locally. Thus, education needs to be at the root of any development programme, investing in the scientists of the future, along with the local communities and industries.

In preparation for MeerKAT and the forthcoming Square Kilometre Array telescope, the South Africa Radio Astronomy Observatory (SARAO) initiated a capacity development programme in 2005. SARAO has since established a technical training centre, appointed maths and physics teachers in local schools, and provided more than 1250 bursaries in astronomy, engineering and computer science. As a result, MeerKAT and related telescopes have been able to generate 8800 jobs in the Northern Cape, as well as creating skilled graduates who go on to work in industry. This programme has been pivotal to the success of MeerKAT so far, demonstrating how a country with almost no radio astronomy expertise can reach the forefront of the field in only 15 years.

The remarkable transformation of South African astronomy has also begun to spread to other African countries. This is in large part due to capacity-building projects such as the National Astrophysics and Space Science Programme (NASSP; Buckley 2019), the SKA Human Capital Development Programme (HCDP) and Development in Africa with Radio Astronomy (DARA; Hoare 2018). These programmes extend to students across Africa: NASSP offers scholarships primarily for under-represented and disadvantaged peoples to study in South Africa, while the SKA HCDP and DARA projects have been training students in countries that are part of the African Very Long Baseline Interferometry Network (Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia).

DARA has also been supporting African students to study and undertake research in the UK. Thus far, these three projects combined have trained more than 1300 students, and another 4000 people have been reached via DARA's public engagement activities. Many graduates have gone on to secure further positions in astronomy, at home and abroad, enabling several countries to offer new astronomy courses or expand on pre-existing ones: for example, Ethiopia, Kenya, Morocco, Namibia, Rwanda, Uganda and Zambia.

Thanks to efforts like these, each year brings a new cause for celebration for African astronomy. Future progress shows no sign of abating, especially with upcoming telescopes such as the SKA and the Africa Millimetre Telescope. This year is particularly special, with the South African Astronomical Observatory celebrating its bicentenary on 20 October (Glass 2020). But 20 years ago this September, the groundwork for the High Energy Stereoscopic System (HESS) began (figure 4) and, 10 years ago in December, Africa's first national space agency (SANSa) was founded in South Africa. SANSa has since launched two satellites with a third on the way. On 16 December 2020 it will be 10 years since the founding of the African Astronomical Society (AfAS, relaunched in March 2019). The number of IAU members from African nations continues to increase annually, with 252 members from nine different countries by October 2020.

Africa has demonstrated to the rest of the world that astronomy has an extraordinary power to revitalize society while aiding the SDGs. New astronomy courses are inspiring new generations of scientists (SDG 4: Quality Education); capacity-building programmes are upskilling local workforces (SDG 8: Decent Work and Economic Growth); and astronomical facilities are spurring industrial activity and improving infrastructure for local, rural communities (SDG 9: Industry, Innovation and Infrastructure). At the

1 African observatories

The High Energy Stereoscopic System (HESS) is a gamma-ray telescope array located near the Gamsberg mountain in Namibia. Since beginning operations in 2002, the HESS Collaboration – spanning 13 countries – has published more than 120 refereed articles. HESS also lies at the centre of a newly secured development grant from the UK's Global Challenges Research Fund.

Further south, in the Karoo desert in South Africa, the 10m Southern African Large Telescope (SALT) is one of the largest single optical telescopes in the world. Local industry manufactured ~60% of the telescope's components. Initially, the majority of support astronomers were expatriates due to the lack of local qualified candidates. Now, however, the staff are mostly South Africans. Since SALT began full science operations in 2011, more than 265 peer-reviewed papers have been published.

Also in the Karoo is the MeerKAT radio telescope array, a pathfinder to the Square Kilometre Array. The instrument came online in 2018, and was designed by African engineers within South Africa along with most of the hardware and software. MeerKAT was also almost entirely constructed within the continent.

The Square Kilometre Array (SKA) will be the world's largest radio telescope, and is on track for completion within the next decade. Predominantly based between South Africa and Western Australia, the SKA will also work with radio dishes in eight other countries of the African VLBI Network.

1 HESS. (Sabine Gloaguen)

2 SALT. (SALT Consortium)

3 MeerKAT. (SARAO)



same time, thriving partnerships have been made, not only between African countries but also between the global North and South (SDG 17: Partnerships).

Dark sky tourism

Humans have long been inspired by the night skies. Indigenous cultures across the world have been influenced by the stars and their arrangements on the sky, and used their positions to make calculations for agriculture and navigation. Star-filled nightscapes have sparked the curiosity of artists and scientists alike: examples include Van Gogh's *Starry Night*, Walt Whitman's *Leaves of Grass*, and Caroline and William Herchel's catalogues of stars and nebulae. But what if we could no longer see the stars? What if the beauty of the night sky could no longer be admired?

Celestial objects are becoming harder and harder to see. Continuing urbanization and the increased use of white LEDs mean that more than 99% of people in Europe and North America live under light-polluted skies, and the Milky Way is entirely obscured for a third of people worldwide (Falchi 2016). At long last, partly prompted by global lockdowns, people living in urban areas are experiencing a new-found desire to reconnect with Nature – including the night sky.

Dark sky tourism uses unpolluted nightscapes as a free and infinite resource, while upholding the conservation of natural resources and cultural heritage. It can be implemented at minimal cost, requiring minimal infrastructure – or none at all if stargazing is carried out with the naked eye. Travellers visiting a dark sky oasis have a chance to experience something awe-inspiring; many may have never seen more than a handful of stars at any one time. Their visit also presents an opportunity to learn about a wide range of topics – such as indigenous knowledge, astrophysics and light pollution – enriching the tourist as well as the host communities.

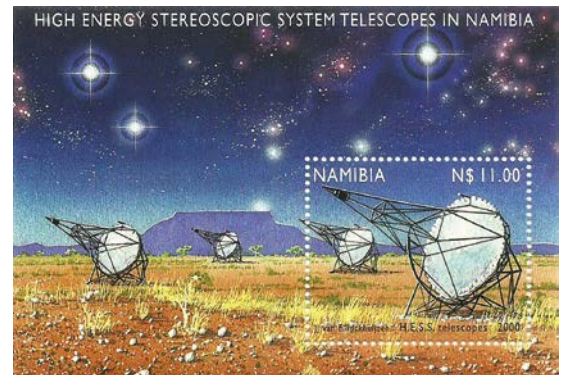
Where remote, dark areas are in abundance, from Namibia to Nepal for example, dark sky tourism is already supporting rural socioeconomic development via new opportunities for local people and diversification of the tourism industry (darkskytourism.com). In South Africa, the Southern African Large Telescope (SALT) has invigorated the local tourism scene immensely: within a year of opening, the number of annual visitors to the nearby town Sutherland increased from a few hundred to more than 13000. This sparked the appearance of numerous guest houses, coffee shops and other tourism-related businesses, and when SALT could no longer meet the demand for tours during the peak season, local groups began to hold star parties.

Dark sky tourism has an equally significant impact in the global North where dark skies are much more limited. Huge efforts are being made to conserve whatever darkness remains, and to motivate communities to engage in reducing their own artificial light at night. The largest international effort is led by the International Dark-Sky Association (IDA), which has been promoting “win-win solutions that allow people to appreciate dark, star-filled skies while enjoying the benefits of responsible outdoor lighting” since 1988.

In 2001, the IDA founded the International Dark Sky Places (IDSP) conservation programme as a way to encourage communities, parks and protected areas to use responsible lighting and educate the public. Dark sky status is difficult to attain and maintain, but can enhance visibility and foster increased tourism and local economic activity. There are more than 130 certified IDSPs in the world, and the UK and Ireland contain ~10% of them. Other organizations are running similar programmes, such as the Royal Astronomical Society of Canada, which

4 Namibia welcomed HESS with a stamp in 2000.

(J) [Koos] van Ellinckhuijzen



“Light pollution disrupts sleep-cycles, which can lead to depression, obesity and the progression of some cancers”

lists 19 Dark-Sky Preserves (pc.gc.ca/en/voyage-travel/experiences/ciel-sky), and the Starlight Foundation with its 14 Starlight Reserves (fundacionstarlight.org). The combined programmes feature dark sky oases across 27 countries, covering an area larger than 20million hectares.

But conserving darkness does more than providing jobs, education and supporting the tourism industry. The use of night-time lighting raises ecological and human health issues; light pollution interferes with biodiversity, harming ecosystems on local and global scales, and poses a significant threat to species on the edge of extinction. Artificial light adversely alters the nocturnal migrations of birds, as well as disorienting beetles, sea turtles and other creatures. Light pollution also disrupts human sleep-cycles and research has found that this can lead to sleep disorders, depression, obesity and the progression of some cancers (Davies & Smyth 2017).

Light pollution shows no signs of abating but rather is increasing at twice the rate of global population growth. This is especially troubling in the context of the ecological damage it poses, but also because of the tremendous waste of energy, money and unnecessary carbon emissions that artificial night lighting represents. In the USA, around 35% of light at night is wasted, amounting to \$3.3billion, or 21 million tonnes of carbon dioxide per year. We would need to plant 875million trees annually to offset the greenhouse gases produced by this superfluous light.

Dark sky tourism can help to mitigate these detrimental impacts and further serve the SDGs (see box 2). As well as saving energy and preserving biodiversity, dark skies can boost domestic tourism, avoiding flights, and can incite tourists to minimize light pollution in their communities when they return home. Furthermore, spending time in dark sky areas promotes health, well-being and connectedness with nature (Bell *et al.* 2014). Dark skies are also unique in that they can be recovered once they have been lost, unlike other marine and terrestrial resources.

Sustainable astronomy

Goal 13 of the SDGs requires urgent action to reverse anthropogenic climate change and mitigate its impacts. Academics emit more greenhouse gas emissions than the general public – and astronomers are no exception. If humanity is to survive the climate emergency, we are all obliged to play our part, whether through reducing our own emissions as astronomers or inciting the public to act via our outreach activities.

Astronomers have started to explore their place in the climate movement. Grassroots organizations and sustainability committees have come into fruition and astronomers are asking, “What can I do?” In the space of a year, Astronomers for Planet Earth (A4E; astronomersforplanet.earth) has brought together 650 astronomy students, educators and scientists, providing a much-needed space for discussion and spurring action. As A4E membership continues to grow on every continent,

2 How dark sky tourism and light pollution relate to the Sustainable Development Goals

 <p>3 GOOD HEALTH AND WELL-BEING</p>	 <p>4 QUALITY EDUCATION</p>	 <p>8 DECENT WORK AND ECONOMIC GROWTH</p>	 <p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p>	 <p>14 LIFE BELOW WATER</p>	 <p>15 LIFE ON LAND</p>
<p>Light pollution is detrimental to our health, while dark sky activities can promote good health and well-being</p>	<p>Dark sky tourism (DST) brings ample opportunity for astronomy and light pollution education, both for locals and tourists</p>	<p>DST creates jobs and opportunities for rural communities throughout the year</p>	<p>DST promotes investment in infrastructure in rural areas and fosters innovation for the sharing of astronomy knowledge</p>	<p>Studies have shown that anthropogenic light probably has a detrimental impact on seafloor ecosystems</p>	<p>Light pollution harms many ecosystems, from disrupting the migration of birds to the hatching of sea turtles</p>

astronomers who once felt isolated now have access to a strong network and can receive support to initiate climate action in their own departments.

If an institution wants to understand and reduce its reliance on fossil fuels, it first needs to understand its energy use. So far, four astronomy organizations have carried out carbon audits and calculated the carbon emissions made by their average astronomer, measured in tonnes of CO₂ per year (tCO₂y⁻¹). Organizations include the Max Planck Institute for Astronomy (18.1 tCO₂y⁻¹; Jahnke *et al.* 2020); the Canada–France–Hawaii Telescope (16.5 tCO₂y⁻¹; Flagey *et al.* 2020); and Australian astronomers (37.0 tCO₂y⁻¹; Stevens *et al.* 2020). To put these figures in context, astronomers are responsible for between 1.5 and 3.4 times the carbon emissions of academics in other fields – for example, professors at the Université de Montréal as a whole were found to emit 10.8 tCO₂y⁻¹ (Arsenault *et al.* 2019) – and far above the Paris Agreement goal of reaching 2.7 tCO₂y⁻¹ per person by 2030. The European Southern Observatory has also undergone a carbon audit and other organizations (including the RAS) are following suit.

There is much more to be done, however. Institutions also have a responsibility to set standards, for example for determining when flying is appropriate. The University of Ghent, for example, does not allow flights to destinations that can be reached in less than six hours by land ([ugent.be/en/ghentuniv/principles/sustainability/travelpolicy](https://www.ugent.be/en/ghentuniv/principles/sustainability/travelpolicy)). Other steps include publicly sharing the resulting policy changes, and developing systems to facilitate low-carbon-emitting methods for academics to work effectively and efficiently (Higham & Font 2020).

The Covid-19 pandemic has resulted in many conferences taking place online for the first time, including the European Astronomical Society's 2020 meeting. A silver lining appeared with the calculation of the conference's carbon footprint, some 3000 times smaller than the face-to-face meeting the year before (Burtscher *et al.* 2020). The EAS also hosted novel sessions dedicated to climate action, which were some of the best attended. Talks ranged from the carbon footprint of astronomical activities (e.g. travel, telescope operations and high-performance computing) to the impact of climate change on observations. The discussions resulted in a series of six articles published in *Nature Astronomy*, which received prominent attention in the press in several European countries. There were also other benefits for having the conference online: many more African astronomers were able to participate, who would otherwise have never been able to afford (or get the visas) to attend. Astronomers can also make the most of our role as communicators of a science that is greatly admired by the general public. We

"Astronomers can make the most of our role as communicators of a science that is greatly admired by the public"

are experts in both the scientific method and the fundamental physics behind climate science, and have or can develop links with climate scientists. We also have an acute understanding of the uniqueness of Earth: there is no Planet B. Astronomers are highly active in outreach: 87% of IAU astronomers engage with the public in some way (Entradas & Bauer 2018). This is significantly higher than other scientific fields and should be used to our advantage. If we incorporate our understanding of the facts and the need for climate action in our activities, together we can reach tens of thousands of people across the world.

What now?

Astronomy is international, transcending borders and cultural barriers, reminding us that we are one people, living beneath one sky. Astronomy transforms: the construction of observatories in rural areas provides employment, the upskilling of local communities and new opportunities for sustainable tourism. Astronomy enables: the scientific and engineering skills learned through the study of astronomy are in great demand from industry and business. Astronomy empowers: it is an opportunity for indigenous cultures to protect their heritage and share their experience and knowledge of the heavens. Astronomy inspires: it acts as a gateway science for children (Salimpour *et al.* 2020) and can spark the curiosity of people of all ages.

We are now at the end of the 200th anniversary year of the RAS – and who knows what the world will be like in another 200 years. One thing for certain is that astronomy is a wonderful tool for development – socially, economically and environmentally – and we can build upon these experiences to improve the lives of both people and planet. ●

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FURTHER READING

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Astronomy Means Business bit.ly/30Z6GF1