Physics in South Africa

South Africa is hunting for students in booming sectors of physics, including astronomy, optics, and nuclear physics.

By **Sarah Wild**

In October 2020, the South African Astronomical Observatory (SAAO) celebrated the 200-year anniversary of its establishment. Founded as the Royal Observatory at the Cape of Good Hope, it was the first astronomical observatory in the southern hemisphere. In these times of COVID-19, the observatory marked the milestone with a virtual symposium, allowing scientists, historians, and all of those with an interest in astronomy to touch base. An "Astrofest" accompanying the symposium also offered virtual stargazing and talks for the general public.

With talks ranging from indigenous astronomy to multiwavelength observations, the symposium showed that astronomy is blossoming in South Africa. In fact, it's doing so well that researchers in other fields complain that astronomy is "stealing" the country's students—the most precious commodity in South African physics right now. But the country's physics portfolio includes a diverse range of fields, from nuclear physics to photonics, which are strong in part as a result of South Africa's tumultuous political past.

The Southern African Large Telescope is one of the four telescopes operated by the South African Astronomical Observatory.
Credit: SAAO

A Rising Star in Astronomy

Since 1820, the fortunes of astronomy in South Africa have waxed and waned. But today you don't need to look hard for signs of its ascendancy. One of them is a forest of radio dishes rising out of the dusty Karoo in the Northern Cape province, where 20 years ago you would have found only sheep. Those dishes belong to the MeerKAT radio telescope, an instrument that will form part of the giant Square Kilometre Array (SKA) radio telescope. The SKA will be the world's largest and most sensitive radio telescope, and it will address questions on galaxy formation, dark energy, and the primordial Universe.

Facilities like MeerKAT and the **Southern African Large Telescope**—the largest optical telescope in the southern hemisphere—are "gravitational wells" for local and international funding, researchers, and students. "It was felt that having these flagship facilities was a way to motivate people into the sciences and physics in particular," says Justin Jonas, chief technologist at the South African Radio Astronomy Observatory and a physicist at Rhodes University. That expectation partly came true but missed a crucial detail: for historical reasons, finding enough skilled people to populate these facilities turned out to be challenging.

Legacies of Apartheid

Prior to the 1994 democratic transition, the country's physics landscape had been shaped by its apartheid regime, which invested in nuclear, materials, and space sciences, among others. During apartheid, the country became increasing isolated, and it used science, particularly physics, to bolster its

An array of 64 antennas makes up the MeerKAT radio telescope in the Northern Cape of South Africa.
Credit: MeerKAT

military and to circumvent international sanctions by, for example, reducing energy dependence and developing its own electronics industry.

But when apartheid fell, physics had to adapt. South Africa became the only country to have built nuclear weapons and then to have **willingly dismantled them**. The nuclear expertise and equipment were redirected into universities and other organizations. Facilities that used to build bombs turned to peaceful applications. For example, Safari-1, a 20-MW nuclear research reactor reconverted to run on low-enriched uranium, now produces radioisotopes used in medicine. This and other facilities, like **iThemba LABS**, Africa's largest accelerator, make the country one of the world's largest producers of such isotopes.

The country's strength in laser science also stems from laser equipment and expertise left over from its uranium-enrichment program. This legacy "accelerated photonics research in the country and has been responsible for almost all the growth in photonics," says **Andrew Forbes**, a photonics specialist at the University of the Witwatersrand in Johannesburg. His research focuses on using "structured" light for applications like secure quantum communications. Most universities in the country have at least a small photonics unit, with interests ranging from quantum optics to laser materials processing to renewable energy.

Building International Bridges

Physicists outside of astronomy, however, often need to travel overseas to access state-of-the-art expensive equipment. "Although most aspects of research can be dealt with at home institutions, one often has to travel abroad or to institutions with a larger collection of equipment to complement one's measurements," explains Makaiko Chithambo, a condensed-matter physicist at Rhodes University who studies point defects in solids using luminescence methods.

Linking to global research is a key pillar of the government's science strategy, through actions such as its support of international organizations including CERN and SKA. In 2016, more than 80% of physics papers produced in South Africa had foreign collaborators. Physics research is international by nature, and researchers who worked abroad will bring back their skills to South Africa, says Chithambo. The country's **extensive collaboration with CERN** is particularly focused on training students.

SOUTH AFRICAN RESEARCH FACTSHEET

R&D spending in 2017
$2.8 billion, or 0.83% of GDP
(US: $476 billion, or 2.7% of GDP)
Source: UNESCO

Researchers per million inhabitants
518 (US: 4217)
Source: NACI 2020 STI indicators

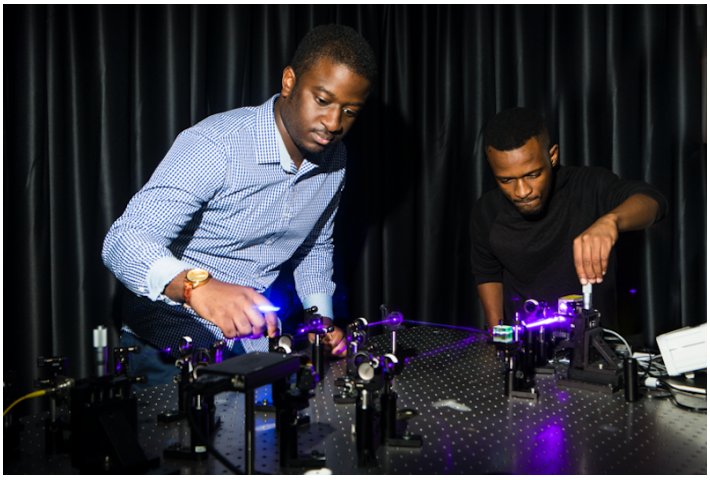
Number of physicists
500–600
Source: South African Institute of Physics

Number of physics PhDs per year
39 in 2015
Source: Government scientometric report

Credit: APS/**Alan Stonebraker**

"The last 20 years of South Africa's involvement at CERN have been phenomenal," says Zeblon Vilakazi, a particle physicist and incoming vice-chancellor of the University of the Witwatersrand. Several South African researchers were involved in the 2012 Higgs boson discovery. "From what was initially a group of two or three people at the University of Cape Town, the country's CERN program has grown to encompass more than five institutions."

Other research groups have established niches of their own, finding ways to make limited budgets go far. **Francesco Petruccione**, for example, has set up the Centre for Quantum Technology at the University of KwaZulu-Natal. "We don't have the resources to build our own quantum computer," he explains. With the present funding situation, building quantum hardware would be impossible, so his team turned to the much cheaper software side—developing algorithms for a quantum computer.



Isaac Nape and Bienvenu Ndagano align laser beams in a quantum photonics lab at the University of the Witwatersrand.
Credit: University of the Witwatersrand

Physics Students Wanted

Developing countries, such as South Africa, must funnel money toward health and social development, so the research budget is small, and it got even smaller after the government cut its science budget by about 16% because of the pandemic-linked economic downturn. However, a bigger issue is the lack of students. According to the physicists I interviewed, the low numbers of students is the greatest obstacle to physics research in the country.

Radio astronomy's Human Capital Development program is a success story in this context. Since its inception in 2005, the program has awarded over one thousand scholarships to students in the fields of science and engineering. But because these astronomy scholarships are substantially higher than those offered by funding agencies or by universities, they put other fields at a disadvantage. "[With] SKA scholarships, the students only study astrophysics. Quantum [physics], materials [science], and plasma physics—they struggle to find students," Petruccione says.

The government is also trying to transform the country's historically White academia, **introducing quotas** stating that 87% of students funded must be South African. Of those South African students, 80% must be Black, 55% female, and 4% disabled. While these quotas have improved academic diversity, they have posed barriers for students who wished to study physics but don't belong to these categories. "When we look at demographics, we're seeing an increase in women and Africans, but the bulk of the Africans [in physics] are not South Africans," says Phil Mwjara, the director-general of the Department of Science and Innovation, a physicist who previously headed the country's National Laser Centre.

The South African physics student shortage runs through the entire educational pipeline, starting in high school. The number of high-school students choosing physical science as a subject is declining and less than 50% of those students get grades that are good enough to attend university. "There is a systematic fundamental problem of poor physics education from the high-school level, which then impacts the whole physics value chain," Chithambo says. It is also difficult to retain those who do make it through the system, as academic salaries are far lower than those in industry.

What's more, African students coming from small villages often feel pressure to send money home to support their extended families. It's like a "Black tax" says **Azwinndini Muronga**, a particle physicist and dean of science at Nelson Mandela University. Muronga wonders why one should choose a Ph.D. in physics over a government or industry job paying 10 times more. In 2015, South Africa produced 39 Ph.D.s, of which only nine were Black. Muronga hopes the situation will change after the second or third generation have gone into administrative

jobs in government. “Their kids will have options,” he says.

Proving the Impact of Physics on the Society

With these social pressures, South African physics may be facing a reckoning of similar magnitude as when apartheid fell. In 2019, the government began focusing on innovation, rather than on research. “If we don’t make an impact on the lives of South Africans, then we don’t deserve to exist,” Mmamoloko Kubayi-Ngubane, the country’s then science minister, **said at the time**.

Some researchers, however, warn against halting funds for basic science. Vilakazi, one of the first South African students to complete his Ph.D. at CERN, hopes the government doesn’t just focus on quick returns. “Then we will be followers instead of equal partners [of] the developed North,” he says. And, without fundamental science, South Africa couldn’t have coped with the impact of the coronavirus, he says.

During the pandemic, many scientists applied their skills to fighting the virus. Bruce Mellado, a physicist at the University of the Witwatersrand and a senior scientist at iThemba LABS, helped in developing a **COVID-19 dashboard** that feeds into the government’s pandemic response. The South African Radio Astronomy Observatory was put in charge of the **National Ventilator Project**, which manufactured noninvasive ventilators and distributed them to hospitals. “The country saw the true value of having this expertise at home,” says Jonas.

Correction (10 December 2020) : An earlier version incorrectly stated that iThemba LABS was previously involved in the making of nuclear bombs.

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