FROM **HOPE** TO **ACTION** THROUGH **KNOWLEDGE**

The Renaissance of the
University of the Western Cape

2001 – 2014

Editors

Ramesh Bharuthram
and Larry Pokpas

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Faculty of Natural Sciences

Advances in Material and Nuclear Sciences, and in Astronomy and Astrophysics inspired by the leadership of Brian O'Connell

Professor Christopher Arendse

Professor Robert Lindsay

*Professor Roy Maartens**

Department of Physics and Astronomy

**DST/NRF/SKA SARChI Research Chair in Astronomy and Astrophysics*

Introduction

At its inception, the Department of Physics at UWC, like the rest of the University, was never set up to be more than an apartheid institution for 'Coloured' people, designed to produce graduates for the lower levels of the South African work force. The Department had a few academics who tried to get some research going, and managed to acquire two electron microscopes in the early 1980s. As such, the Department managed to do a fair amount of research during the 1990s, but this was a difficult time for the University with declining student numbers and financial challenges. The only equipment of significance was the hot-wire chemical vapour deposition system, which was purchased as part of the NRF multi-user equipment programme. Most research by staff was carried out in collaboration with iThemba LABS, the national research facility housing particle accelerators and related research equipment.

Postgraduate student numbers were low, with fewer than 10 students in the Department in 2000. The number of Honours students fluctuated between 2 and 5. The appointment of Prof Brian O'Connell did not immediately change the financial position of the University, but his positive attitude to the future and his emphasis on the need to build partnerships in order to succeed created an environment in which staff were motivated to respond proactively, for example, to engage with other institutions on collaboration and cooperation.

The MANUS/MatSci Programme

The new found vigour after the arrival of Prof O'Connell coupled to UWC's legacy of being an engaged university with a strong social conscience during the apartheid era, led to the establishment in 2004 of the master's in Accelerator and Nuclear Science (MANUS) / master's in Material Science (MatSci) Programme, a joint venture with the University of Zululand (UNIZUL) and iThemba LABS.

This collaborative Programme was beneficial to all three parties – for UWC a growth in postgraduate student enrolment, for UNIZUL the establishment of a postgraduate programme from the BSc Honours to the master's level in nuclear and material science, and for iThemba LABS a collaboration with two historically disadvantaged institutions with a significant increase in postgraduate students, in particular Black South Africans, researching at its experimental facilities.

The collaboration was financially supported by the DST/NRF as a novel research capacity development initiative, which fitted into South Africa's transformation and redress agenda, through which support, competitive scarce-skills bursaries were awarded to both honours and master's-level students. Figure 24.1 below shows the role-players at the launch ceremony of this novel partnership, at which the collaboration agreement was signed. Included in the picture are Prof O'Connell and the late Prof Rachel Gumbi, Rector and Vice-Chancellor of UNIZUL, and Prof Sharpey-Schafer, the then Director of iThemba LABS. At the ceremony and the accompanying discussions, the passion and commitment exuded by Prof O'Connell played a vital role in convincing the representatives from UNIZUL that UWC was sincere in working towards making this collaboration a mutual success, leading to trust on all sides.

This partnership was established at a time when, as a consequence of our past political dispensation, it was not uncommon for mistrust and scepticism to emerge when collaborative ventures between South African universities were discussed. In this particular case, the MANUS/MatSci Programme proved to be such a success that trust was maintained. Moreover, the Programme represented an attempt by one historically disadvantaged university (HDI), UWC, to build capacity in nuclear and material sciences at another HDI, (UNIZUL), in partnership with a national research facility. Consequently, the partnership was well received, including

by the Department of Science and Technology (DST) and the NRF. Moreover, it was in synergy with Prof O'Connell's vision that UWC must do good science that has high impact. Through its incredible success, the MANUS/MatSci Programme has been funded by the DST/NRF since its inception.

The MANUS/MatSci programme started with 13 honours students in 2004, of whom 12 are seen together with Prof O'Connell and Prof Gumbi at the launch in Figure 24.2, and this number grew to 30 in 2005. The jump in class size in 2005 resulted in major challenges, but also unexpected opportunities. There were not enough scholars in nuclear and material science at UWC, UNIZUL and iThemba LABS to supervise the research projects of all the students, which necessitated approaches to other research groups in South Africa. As a consequence, some of the students were placed at NECSA, MINTEK and the CSIR, which are national research and development facilities. It was indeed pleasing to find that these institutions had noticed the positive changes taking place at UWC; under the inspiring leadership of Prof O'Connell UWC had managed to train students to a level appropriate enough for them to be successfully placed as research students in their organisations.

The MANUS/MatSci programme indirectly led to a major growth in another research field in the Department of Physics. In 2005 Prof Danny Adams, the then Head of Department, had a discussion with Mr Tshepo Seekoe of the DST at a conference. When the latter heard of the success of the MANUS/MatSci programme in increasing the development of Black South African physicists, consistent with South Africa's transformation and redress agenda, he suggested that we meet with Dr Bernie Fanaroff, who was leading the development of South Africa's project proposal, in partnership with eight other African countries, to host the ambitious international Square Kilometre Array project, the largest radio telescope designed to study the universe and its origin.

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Figure 24.1 Photograph taken at the launch ceremony of the MANUS/MatSci Programme in 2004. From Left to Right: Prof R Lindsay (UWC, Head of Physics Department), Prof Muzi Ndwandwe (UNIZUL Physics Department), Prof John Sharpey-Schafer (Director, iThemba LABS), Mr Havilyn Michau (NRF), Prof Rachel Gumbi (Rector & VC, UNIZUL), Dr Terrence Marais (First Coordinator of the Manus/Matsci course), Prof Brian O'Connell (Rector & VC, UWC) and Dr Chris Theron (Head of the Material Science at iThemba LABS).

Figure 24.2 Students from the first MANUS/MatSci class, Prof Sharpey-Schafer, and the Vice-Chancellors of UWC and UNIZUL, Prof Rachel Gumbi and Prof Brian O'Connell.

The purpose of the meeting was to explore whether UWC could do something similar to the MANUS/MatSci Programme so as to increase the number of Black South African scholars in astronomy. This led to two initial meetings with Dr Fanaroff. South Africa had already committed to the Karoo Array Telescope (KAT), a demonstrator array of 7 observational dishes designed to show that the country had the capability to build and host the SKA. KAT's success laid the basis for the subsequent 64-dish MeerKAT radio telescope, a South African precursor to the SKA. The UWC proposal was well received by Dr Fanaroff. This led to a joint appointment of Dr Catherine Cress as the first lecturer in Astronomy at UWC in 2007. At that time Dr Fanaroff was in the process of establishing five SKA South African Research Chairs (SARChI Chairs) in partnership with the NRF to accelerate research in astronomy and astrophysics. He identified UWC as a potential applicant to strengthen the research programme that had been started by Dr Cress. The University's success in being awarded a SKA SARChI Research Chair is discussed below, where the further development of astronomy and astrophysics at UWC is explained.

Condensed Matter Physics

Prior to 1997, condensed matter physics research in the Department was conducted by UWC researchers as part of the Van de Graaff Accelerator Users Group at iThemba LABS (formerly the National Accelerator Centre). The research was focused on metal-silicides for application in integrated circuits. The electron-beam physical vapour deposition system and Van de Graaff accelerator at iThemba LABS were the major research instruments used. It is worth noting that this research programme produced the first PhD graduate as well the first research publication in condensed matter physics research (Marais et al., 1994) from the Physics Department at UWC – the late Dr Terrence K. Marais.

In 1994 Prof Dirk Knoesen of the Physics Department initiated a research collaboration with Prof Werner van der Weg of the Debye Institute at Utrecht University in the Netherlands, where he spent a year on sabbatical leave. The research was in the field of amorphous silicon thin films for solar-cell applications. In the following year Prof Knoesen secured NRF funding through (what is now known as) the National Equipment Programme (NEP) for the purchase of the MVSystems Inc. hot-wire chemical vapour deposition system, which was commissioned in 1996 (see Figure 24.3). Up to 2014 this deposition system had served as the research platform for several MSc and PhD graduates, of whom five are

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currently academic staff members in the Department. In parallel, as part of a strong collaborative programme with Utrecht University, three PhD students spent periods of up to 6 months at the Debye Institute in the Netherlands, where they were trained on similar deposition equipment and advanced analytical methods. These visits were funded by the NRF and a scholarship funding scheme established by Prof van der Weg.

Given the advancements made in the previous decade, the NRF approved the Materials Science and Applied Physics Group (including Applied Nuclear Physics) as a Research Niche Area (RNA) of UWC in 2004, which was funded under the Institutional Research Development Programme. Apart from building expertise, the research programme focused on (i) the preparation and characterisation of thin solid films, and (ii) advanced application of nuclear radiation. This funding allowed the condensed matter physics group an opportunity to develop into a leading national research group, which up to that point in time hosted the only hot-wire chemical vapour deposition capability on the continent. The MVSystems reactor allowed for the optimisation of device-quality nano-crystalline and amorphous silicon alloyed thin films for incorporation into solar cells (Arendse et al., 2006; Knoesen et al., 2008).

Figure 24.3 The MVSystems Inc. hot-wire chemical vapour deposition system with gas handling system, commissioned in 1996.

However, the major limitation of the reactor was that it did not have the capability to incorporate the absorber layers into complete solar cells, as two additional reactors connected in tandem to the existing reactor were required. With the imminent retirement of Prof Knoesen and the resignation of Prof Danny Adams to take up a position at the Department of Science and Technology, the Physics Department began a succession campaign that was successful in attracting Prof Christopher (Chris) Arendse, Dr Theo Muller and Dr Gerald Malgas (all PhD graduates of the Department) from ESKOM and the CSIR.

With the research area in condensed matter physics recognised as one of the emerging niche areas of UWC, with the support of the University, Prof Arendse was able to secure funding in 2015 through the NRF's National Nanotechnology Equipment Programme (NNEP) for the acquisition of a multi-process zone chemical vapour deposition system that will provide the necessary capability to manufacture multi-layered devices. This award was the first of its kind for the procurement of a state-of-the-art materials deposition system, uniquely designed by Prof Arendse, for the development of innovative nano-based devices (Figure 24.4 below).

Figure 24.4 The NNEP-funded ultra-high vacuum multi-purpose UWC-uniquely-designed zone chemical vapour deposition system, comprised of four chemical vapour deposition reactors, a thermal evaporator, central transport chamber and a load-lock. Also shown is the control unit in the far-right corner and the gas management system.

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At the time, a strategic partnership through a memorandum of understanding was already in place between UWC and the CSIR whereby nanotechnology and renewable energy were identified as areas of collaboration. Through this strategic partnership, our research endeavours into thin films evolved to include their applications in organic solar cells, gas sensors and metallurgy. As a result, several high-impact peer-reviewed publications and PhD and MSc graduates emanated, with the latest being the development of a hybrid perovskite-based solar cell produced in the new NNEP-funded CVD system with a power conversion efficiency of 11.7 % and improved air-stability (Ngqoloda et al., 2020). This work opens a path towards a low-cost, scalable CVD technique for the manufacturing of air-stable hybrid perovskite solar panels. Taking note of its humble beginnings with minimal resources, the UWC condensed matter physics research group can now contribute towards realising the societal benefits of nanoscience and nanotechnology through enabling access to low-cost renewable energy devices, especially for our fellow South African citizens living in the vast remote and rural areas where grid electricity connections are not possible. It was through this investment in condensed matter physics that the department dovetailed with the University's 34-year strategic partnership with the University of Missouri, USA to set up collaborative projects in the areas of nanophysics, condensed matter physics, renewable energy and physics education.

The Electron Microscope Unit

The Electron Microscope Unit (EMU) of UWC is one of the first research support units to have been established at UWC. The unit, set up by Prof Dirk Knoesen in the early 1980s, hosted Hitachi scanning (SEM) and transmission (TEM) electron microscopes that were acquired in 1983. Until 2007, these instruments served the research programmes of the Faculty of Natural Sciences at UWC. With the advent of nanotechnology and as part of the rollout of the South African Nanotechnology Strategy, the EMU at UWC, under the leadership of Prof O'Connell, was the first to secure funding from the NRF's NNEP for the acquisition of the first analytical high-resolution electron microscope (FEI Tecnai F20) in South Africa in 2007. This was followed by replacing the 30-year-old Hitachi SEM with the ZEISS Auriga field emission gun scanning electron microscope (FEG-SEM) in 2012. Figure 24.4 is a photograph of Prof O'Connell at the unveiling of the FEG-SEM. Furthermore, within UWC's strategic approach to the establishment of research niche areas, the new equipment was also

supported by the appointment of two academic staff members with the necessary expertise to advise and train the new cohort of nano-scientists in the faculty. Today these instruments and the expertise are utilised not only by researchers from a range of disciplines within the University, but also researchers from national and international institutions. The above-mentioned research equipment formed the basic building blocks for the establishment of UWC's Faculty of Natural Sciences as a leading institution on the international landscape in nanoscience and nanotechnology research. In doing so, it has produced highly skilled scientists and has contributed to enhancing the research publication output of the University.

Figure 24.1 Professor Brian O'Connell at the unveiling ceremony of the FEG-SEM.

Nuclear Science

There is a strong tradition of nuclear physics research in the Western Cape. The University of Cape Town (UCT) and Stellenbosch University started a joint research centre, the Southern Universities Nuclear Institute (SUNI) that opened in 1965. UWC was not included in any of these developments. This research centre was incorporated in 1988 into the new National Accelerator Centre (NAC) that was built on the same site at Faure. The name of NAC changed to iThemba LABS in 2001. UWC became more involved in research at NAC following the appointment of Prof Ieks van Heerden, former director of SUNI, in the Department of Physics in 1982. Alfred van Kent was the first nuclear physics student from UWC to obtain a master's degree through research conducted at this facility (Cowley et al., 1991). The involvement of UWC staff continued, but at a relatively low level. Once the MANUS/MatSci Programme started in

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2004, many more students registered for postgraduate degrees in nuclear science at UWC, with additional supervision provided by researchers from iThemba LABS. Apart from experimental nuclear science, the research programme included theoretical nuclear studies (Prof Lindsay) and later a strong collaboration grew in environmental nuclear science. These studies include measurements aimed at radiation protection studies linked to radon (Lindsay et al., 2008) and the use of gamma detectors in environment surveys (Lindsay et al., 2008).

The appointment of Prof Nico Orce in 2011 and Prof Smarajit Triambak as the DST/NRF SARChI Research Chair in Nuclear Science in 2013 led to a significant expansion in the involvement of UWC in fundamental experimental nuclear physics research. Prof Orce has pioneered Coulomb excitation studies at iThemba LABS, leading to publications on high spin-states (Dinoko et al., 2013) and on phonon states (Orce et al., 2016). In 2013 Dr Orce initiated a proposal to improve the instrumentation available at iThemba LABS. He is the principal investigator of project proposal by a consortium of four South African universities and iThemba LABs for the development of a state-of-the-art nuclear spectrometer to be housed at iThemba LABS. After a thorough review of the project – named the GAMKA nuclear spectrometer – the funding was approved by the DST/NRF as the first Strategic Research Equipment grant allocation and awarded R35 million in 2018 and is currently being assembled. Prof Triambak has established a new research initiative in South Africa in the field of fundamental symmetries and weak interaction studies using atomic nuclei. Simultaneously, he has also played a leading role in developing a nuclear astrophysics programme at iThemba LABS. He successfully directed the construction of an experimental facility that would enable researchers to make very short nuclear lifetime measurements. Such measurements allow a determination of important nuclear reaction rates in stellar environments. A crucial component of this state of the art facility is a 100% efficient high-purity n-type Germanium detector, which cost approximately 1.6 million ZAR. The detector was purchased by the University as part of a strategic approach to grow nuclear science as a research niche area. The increased collaboration with iThemba LABS has resulted in UWC becoming one of the major university partners of the facility.

These two researchers have significantly expanded UWC's involvement in nuclear science research on the international landscape. Through their collaborative programmes, UWC staff and students have now performed experiments at HIE-ISOLDE at CERN in Switzerland, at TRIUMF nuclear

facility in Vancouver, Canada, the Maier-Leibnitz Laboratory (MLL) in Garching, Germany and at the University of Washington in Seattle, USA. Collaborative partnerships have been established with the University of Guelph in Canada, University of Washington in Seattle, USA, Technische Universität and Ludwig Maximilian Universität in Munich, Germany and with the University of York in the UK.

Astronomy and Astrophysics

The University, with traditional strengths in materials science, nuclear physics and physics education, recognised that developments in astronomy in South Africa provided an opportunity to play a major role. In particular, the decision by the international Square Kilometre Array (SKA) project to build most of its giant radio telescope in South Africa was opening up historic opportunities for astronomy and data science in Africa (Maartens & Ellis, 2012).

As mentioned earlier, the venture into astronomy started with the appointment of Dr Catherine Cress as a senior lecturer in 2007, with support from the South African SKA Project. In addition, Dr Enrico Olivier was appointed as a joint postdoctoral researcher with the South African Astronomical Observatory (SAAO), and later joined UWC as a lecturer in 2012. Dr Cress began to build a group of postgraduate students and postdoctoral fellows, supported by the SKA and the NRF. She also developed undergraduate courses in astronomy. The research programme led by Dr Cress laid the foundation for UWC's emergence in the fields of astronomy and astrophysics.

Discussions with Dr Fanaroff were successfully continued with the arrival in January 2008 of the new Deputy Vice-Chancellor Academic, Prof Ramesh Bharuthram, who was instrumental in attracting Prof Roy Maartens back to South Africa in October 2010 as the DST/NRF/SKA SARChI Research Chair in Astronomy and Astrophysics from the University of Portsmouth in the United Kingdom, where he was the founding Director of the Institute of Cosmology and Gravitation. Prof Maartens was well known to the astronomy community in South Africa, since he had studied under Prof George Ellis at the University of Cape Town (UCT) and had lectured at the University of Witwatersrand (Wits) before moving to Portsmouth. By virtue of his high international standing in the field, he was not only a great asset to UWC but also to the astronomy programme in South Africa. Consequently, a welcoming function was arranged in the Department to

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celebrate this appointment. Many of the senior researchers and leaders in the fields of astronomy at the SKA, UCT and the South SAAO were in attendance. Prof O'Connell was also present, indicating how important he considered the appointment of Prof Maartens to his vision for UWC. He delivered a short but typically inspiring talk at the function. There is no doubt that all of the visitors were impressed by Prof O'Connell's message on the importance of knowledge-based research for the future of South Africa and Africa, and the important role that the researchers at UWC should play in this endeavour.

The rapid growth in astronomy and astrophysics research triggered by the arrival of Prof Roy Maartens consolidated the research programme as one of UWC's niche areas. Hence, a second SARCHI Chair in the field was part of UWC's submission to the DST/NRF call in 2012. To the University's pleasant surprise, when the awards were made after an evaluation process, UWC received the largest number of SARCHI Chairs of all universities in the country, a total of seven including in astronomy. At that time South Africa, together with its African partners, won the bid to host the major components of the SKA Project, leading to major celebrations across the country. Moreover, Prof Maartens became UWC's first NRF A-rated researcher, by definition a researcher who is considered by his international peers to be a world leader. These factors led to applications from outstanding international scholars when the second SARCHI Chair in Astronomy and Astrophysics was advertised by the University. After a very competitive selection process Prof Romeel Davé was appointed and took up the Chair in 2013, joining UWC from the University of Arizona in the USA. Prof Davé is one of the world's leading experts in computational galaxy formation, a field in which he built not only a research group at UWC, but through institutional support also established a mini-supercomputer for simulation of galaxy formation. In 2015 he received an NRF A-rating. In 2013 the research group was further strengthened by the appointment of Prof Mario Santos, following Prof Catherine Cress's move to the Centre for High-Performance Computing. Prof Santos is international leader in cosmology with radio telescopes. Consequently, today UWC researchers are playing leading roles in the SKA project. Prof Maartens was chairperson of the international SKA Cosmology Science Working Group from 2013 to 2015, while Prof Santos was appointed chairperson of the international SKA Cosmology Science Working Group in 2015. With the departure of Prof Davé for the University of Edinburgh in 2018, Prof Santos was

nominated by the University as his replacement as SARChI Chair, which was accepted by the NRF after an evaluation process. In 2020 Prof Santos was awarded an NRF A-rating.

In 2014 Prof Russ Taylor from Canada joined the Astronomy Research Group as a Research Chair. His position is held jointly with the University of Cape Town, and funded by both universities and the SKA project. Prof Taylor is an expert in large data science and one of the originators of the initial proposal to build the SKA, and he brings vast experience in radio astronomy. Soon after his arrival in South Africa, he led a major initiative to launch an inter-University Institute for Data Intensive Astronomy (IDIA), which is leading the South African effort to become internationally competitive in 'big data' science that is critical to successful exploitation of data generated by the South African MeerKAT project as well as the international SKA project. In 2015 Prof Taylor was awarded an NRF A-rating. The impressive expansion of the high-impact research programme in astronomy and astrophysics at UWC has not gone unnoticed. In 2018 Dr Ed Elson was appointed as a lecturer in astronomy, with significant funding provided by the SKA project.

With such an outstanding team of researchers, UWC's Astronomy and Astrophysics continues to play a high-profile role in the SKA Project, including leading roles in SKA Science Working Groups (with 3 chairperson positions in the last 5 years) and in SKA data science collaborations. Amongst South African institutions, UWC contributed the highest number of chapters, and the highest number of lead-author chapters, to the 2015 SKA science book, *Advancing Astrophysics with the Square Kilometre Array* (Bourke et al., 2015). In the period 2014-2019 UWC Astronomy and Astrophysics researchers have authored/co-authored over 500 articles in international journals with high-impact factors. Consequently, it was inevitable that at our request in November 2015, the University Senate approved the change in the name of the department from Department of Physics to the Department of Physics and Astronomy. In 2020 the research group was further strengthened with the appointment of Prof Lerothodi Leeuw, one of South Africa's leading scholars in astronomy.

Summary

The development of research in Physics and Astronomy at UWC has been significant under the leadership of Prof Brian O'Connell. One of UWC's greatest research achievements as an institution under the inspirational and innovative leadership of its Rector and Vice-Chancellor,

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Prof Brian O'Connell, was when UWC become the first historically disadvantaged institution to join the Tier 1 rank of research-intensive universities in South Africa in 2011. Following this, the Department of Physics and Astronomy, as part of Physical Sciences at UWC, was lauded for its achievements and excellence in research in several international platforms:

- o The Nature Index ranked UWC number 1 in Africa in Physical Science research output in top journals, covering the period 1 June 2015 to 31 May 2016;
- o The URAP World University Rankings placed UWC at 157 in the world in Astronomy & Astrophysics for 2018/2019, as such 3rd on the African continent; and
- o The URAP World University Rankings placed UWC at 470 in the world in Physical Science for 2018/2019.

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