The Square Kilometre Array and Radio Astronomy: What Does it Hold for Africa?

Nceba Mhlahlo

Radio astronomy has a long history of discovery. The discovery of pulsars, cosmic microwave background radiation and the first extra-solar planet, among others, benefited not only astronomy as a discipline, but also other areas of science such as cosmology, and marked the beginning of great advancement in this field, including innovations in technology. Yet for the past 27 years or more, radio astronomy has been using the same research facilities, whereas other areas of astronomy, such as high-energy astrophysics and optical astronomy, have been developing new facilities to push the frontiers of science to unprecedented levels. This, however, is about to change, as the radio astronomy renaissance is unfolding both in Africa and around the globe, with a plethora of radio telescopes being planned for the next 4 to 20, and some already under development. Arguably, the most exciting of these facilities is the Square Kilometre Array (SKA). This telescope and its precursor array, MeerKAT, are an epitome of what is probably the largest astronomy-based human capital development project in the world.

This brief will discuss radio astronomy activities in Africa, and the challenges. It will also cover the future of radio astronomy in the continent, with special focus on SKA and MeerKAT, and how the construction of these instruments will affect human capital development in our continent.

Introduction

Radio astronomy has been practised in very few institutions in Africa. In the past forty years, the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa has been the main activity centre for radio astronomy, and the only radio astronomy observatory in the continent. The fact that there are no radio astronomy facilities in other African countries, and that very few universities offer courses in the discipline, spells out a number of challenges for those countries, especially in the areas of Human Capital Development (HCD), skills transfer and technology development in radio astronomy.

Firstly, it means that students cannot be trained as electronic and mechanical engineering technicians to use telescopes and to ensure...
Radio astronomy has been practised in very few institutions in Africa

Radio astronomy practised in very few institutions. This is a barrier to the development of skills, human capital and technology in those countries. Secondly, in order for students in those countries to use research facilities and to study radio astronomy, they have to come to South Africa, or go overseas, only to end up as Physics teachers or to be absorbed into other fields when they return to their home countries. This fails to contribute towards the building of astronomy as a science in those countries, or towards HCD in the field.

South Africa, even though it is the only country in Africa with a radio astronomy facility, is still grappling with the issues of HCD and skills development. The National Astrophysics and Space Science Programme (NASSP) was introduced to deal with the challenge of HCD in astronomy in general in South Africa, and I have elsewhere criticised it for failing to achieve this goal. An analysis of NASSP student numbers since 2005 has revealed that the majority of students in the NASS programme have been from other African countries. Despite its good intentions towards those African countries, NASSP training does not particularly benefit radio astronomy in those countries, as they possess no radio astronomy facilities to do radio astronomy research; nor does it benefit radio astronomy in South Africa, as it fails to produce black radio astronomers, which are direly needed in this country, especially for future radio astronomy activities.

The advent of the Karoo Array Telescope (MeerKAT), however, and the possible construction of the Square Kilometre Array (SKA) in South Africa, will necessitate the building of SKA outstations in a number of African countries, in addition to the core and other outstations which will be located in South Africa. This will give a number of these countries an opportunity to host their ‘own telescopes’. The benefits of hosting these telescopes will include the training of students as technicians to use and maintain the telescopes. Students will also be trained as astronomers, and this will help develop astronomy and human capital in those countries.

Other benefits include the development of new technologies. The construction of SKA will necessitate the development of new software and hardware and subsequently innovation in the area of Information and Communications Technology (ICT), and in other areas such as renewable energy and optics.

MeerKAT and SKA will also promote the building of relationships, especially in Africa, and some relationships and partnerships have already been formed which are meant to establish SKA as a truly African telescope. SKA South Africa (hereafter SKA SA), for instance, has partnered with eight African countries to build an African effort to host the SKA. A number of SKA outstations will be built in these countries, thus benefiting those nations and their peoples.

This brief will discuss radio astronomy activities in Africa, together with the challenge of HCD facing radio astronomy in the continent. The future of radio astronomy is also discussed, focusing on the telescopes to be built and the benefits they will bring to African astronomy and the society at large.

Radio astronomy activities in Africa, and the status quo

South Africa is the only country in Africa with a radio astronomy facility – HartRAO – in which radio astronomy is active. Radio astronomy in South Africa is also active in a number of universities, namely the University of the Witwatersrand (Wits), Rhodes University, the University of South Africa (Unisa), the University of Cape Town (UCT), North-West University, the University of the Western Cape, and at the Radio Astronomy Centre in Rosebank, Johannesburg, which is a HartRAO/SKA initiative. South African universities offer most Radio Astronomy courses through NASSP, a programme aimed at training students at Honours, Masters and PhD levels in Astronomy and Astrophysics. In countries such as Tanzania, Malawi, Nigeria, Uganda and Morocco, Astronomy as a course is offered in quite a number of universities. The majority of universities (Table 3) offer courses that are related to astronomy or space physics as part of the Physics course (see discussion below).

Before highlighting challenges in these facilities and institutions, in the following sections I briefly discuss the facilities and their activities and the status quo regarding radio astronomy and HCD. It should be stated that there are many HCD efforts in Africa, but only two are relevant to this brief, and these are NASSP and the SKA Outreach Programme. These I also discuss below.

Hartebeeshoek Radio Astronomy Observatory (HartRAO)

HartRAO is a national facility for radio astronomy which operates the largest steerable radio
telescope in Africa, and the only 26-m class radio telescope in the continent.\textsuperscript{12} The facility is located 50 km west of Johannesburg, and is used to detect radio waves from various astronomical objects, using radio receivers operating at wavelengths from 1.3 cm up to 18 cm (~22 GHz down to 1.6 GHz).

Astronomy performed at HartRAO can be divided into two categories, the first being single-dish research, which entails measuring/mapping radio continuum emission by radiometry, spectroscopic observing of emission lines at radio frequencies from atoms and molecules, and pulsar timing, which is concerned with measuring the arrival times of pulses from rotating neutron stars. The second is Very Long Baseline Interferometry (VLBI), which entails high-angular resolution imaging networked with other radio telescopes around the world (Figure 1).\textsuperscript{13}

HartRAO employs six radio astronomers. There are three PhD students and one MSc astronomy student, and five technical students who are being trained as interns. Efforts are being made to recruit more staff. At HartRAO, HCD efforts include practicals which are carried out at the observatory by NASSP students at third- and fourth-year levels from a number of South African universities. Also, there are schools, public and group visits to the observatory and these are used to raise the awareness and understanding of astronomy, science and technology. In addition, as part of outreach, educator workshops are held.

They are specifically designed to assist educators in understanding and presenting astronomy and space-related topics to the learners. These workshops cover topics ranging from introduction to astronomy to satellites and space travel. All these activities contribute towards HCD efforts in this institution.

South African universities and the NASSP

Though radio astronomy is active in a number of universities in South Africa, only a few universities offer Radio Astronomy as a course. These are Wits University, Unisa and Rhodes. Wits offers an Honours course in Radio Astronomy and introduced a general Astronomy course in 2010. Unisa is the only university in South Africa which offers a BSc degree with a major in Radio Astronomy. This university also offers a BSc Honours degree in the subject. Rhodes also offers Radio Astronomy at Honours level. Most Radio Astronomy courses at these and other universities are offered through NASSP.

NASSP was established in order to address the problem of the shortage of researchers in South Africa, especially those from disadvantaged backgrounds.\textsuperscript{14} Between the years 2003 and 2010, NASSP supported more than 100 Honours students from a number of African countries. Out of those who graduated, 63 per cent were black students.
In South Africa, only a few universities offer Radio Astronomy as a course (Table 1). NASSP has been failing to increase the number of students in the programme, especially those who are from disadvantaged backgrounds, and also the graduation rates.

It is reassuring, however, to notice that the average number of all students per year, and that of black students graduating in the programme increased in 2009 and 2010, from 12 students overall (2003–2008) to 18 (2009–2010); and from 7 black students (2003–2008) to 12 (2009–2010). This slight increase could be due to the NASSP Extended Honours Programme, a pre-honours programme which was introduced in 2008 to increase the intake of black South Africans in Astronomy. It remains to be seen whether the number of students graduating in the programme will continue to increase.

For the MSc programme (Table 2), the number of all students per year, and that of black students enrolled in the programme, also increased in 2009 and 2010, from 12 (2003–2008) to 17 (2009–2010); and from 7 (2003–2008) to 11 (2009–2010), respectively. For the MSc, only records of enrolments were available during the time of the writing of this paper.

### Universities in other African countries

Table 3 summarises the state of affairs in other African nations as far as Astronomy and human capital are concerned; this shows some of the countries which responded to the International Year of Astronomy (IYA) survey. The survey was conducted in 2009 to evaluate the state of astronomy in Africa. The eight countries shown in Table 3 have been selected because they are South Africa’s partner countries in the SKA project.

As shown in Table 3, very few universities in the African partner countries offer Astronomy as a subject. Most of the astronomy at the universities is taught as part of the Physics course or as

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**Table 1: NASSP Honours students who graduated from the programme**

<table>
<thead>
<tr>
<th>Year</th>
<th>Black</th>
<th>White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>5</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>2004</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>2005</td>
<td>7</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>2007</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>2008</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>2010</td>
<td>15</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69</strong></td>
<td><strong>40</strong></td>
<td><strong>109</strong></td>
</tr>
</tbody>
</table>

*Source: Adapted from Whitelock (2006: 44); the table has been extended to year 2010.

Note: Black is defined here to mean African black people, which also includes black students from Madagascar.

**Table 2: NASSP Masters students who enrolled in the programme between 2003 and 2010.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Black students</th>
<th>White students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2004</td>
<td>6</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>2005</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>2007</td>
<td>11</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>2008</td>
<td>12</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>*2009</td>
<td>12</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>2010</td>
<td>11</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>66</strong></td>
<td><strong>33</strong></td>
<td><strong>99</strong></td>
</tr>
</tbody>
</table>

*One student is African-American.
Table 3: International Year of Astronomy (IYA) survey conducted in 2009 showing the number of universities in eight African SKA partner countries offering Astronomy and Physics courses.

<table>
<thead>
<tr>
<th>Country</th>
<th># of universities offering Astronomy course/s</th>
<th># of universities offering Physics course/s</th>
<th># of academics trained in Astronomy</th>
<th>Governmental astronomy/science outreach programmes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>Botswana</td>
<td>?</td>
<td>1</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Mozambique</td>
<td>2</td>
<td>2</td>
<td>0 (3 students)</td>
<td>Yes</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1</td>
<td>1</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Madagascar</td>
<td>2</td>
<td>8</td>
<td>30</td>
<td>None</td>
</tr>
<tr>
<td>Kenya</td>
<td>1</td>
<td>10</td>
<td>3 PhD+2 NASSP students</td>
<td>None</td>
</tr>
<tr>
<td>Ghana</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>Zambia</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>None</td>
</tr>
</tbody>
</table>


It seems South Africa is not doing enough to invest in HCD in science and research.

Table 3 shows the number of universities in eight African SKA partner countries offering Astronomy and Physics courses. The table indicates that there is a lack of universities offering Astronomy courses in most of the countries, with Namibia being the only country with no universities offering Astronomy courses. The number of universities offering Physics courses is higher, but still, the number of universities offering Astronomy courses is significantly lower. The number of academics trained in Astronomy is very low, with only Madagascar having a significant number of trained academics. The table also shows that there are no governmental Astronomy outreach programmes in at least half of these countries.

One of the modules of Physics is Astronomy, which constitutes a small section of the entire Physics course. Furthermore, universities in nearly half of these countries do not offer any kind of Astronomy at all, and there are no governmental Astronomy outreach programmes in at least half of these countries.

The number of academics who received training in Astronomy is very low in most of the universities. Even in Madagascar, where there seem to be many academics who have received some training in Astronomy, the majority are Physics teachers. Botswana and Mauritius did not respond to the IYA survey, and some of the information has been found from the websites of the universities of these countries. It is not clear how many academics are trained as radio astronomers, and whether there are any governmental astronomy/science outreach programmes in Botswana.

Challenges facing radio astronomy in Africa

In Africa, radio astronomy is faced with the challenge of the lack of research facilities. It is also faced with the challenge of developing human capital, both at the universities and the existing national research facility, and for the future radio astronomy facilities.

In the following sections I discuss these challenges, focusing on the only radio astronomy facility in Africa, on the NASSP programme, and on a number of African universities, particularly those in the SKA-Africa partner countries.

National facilities and funding: HartRAO

HartRAO has about 42 staff members, of whom only seven are radio astronomers, which can be considered too low for a 26-m class telescope and the type of research that can be done with this instrument. The Shanghai Astronomical Observatory in China (25-m telescope), for instance, has more than 200 staff, and this includes 155 scientific and technical personnel. In that facility there are 32 post-doctoral and visiting scientists working with staff, whereas at HartRAO there are only three. Does this have something to do with our past lack of commitment as a country to investing in HCD in science and research? The answer is possibly yes.

South Africa’s research and development (R&D) to gross domestic product (GDP) ratio was approximately 0,7 per cent in 1996/1997, and that of China was comparable, at 0,6 per cent. But China’s R&D:GDP ratio more than doubled, from 0,6 per cent in 1996 to 1,5 per cent in 2007, a period during which China’s GDP grew at 12 per cent annually, while South Africa’s R&D:GDP was lagging behind at 0,95 per cent in 2007. What went wrong? Even though our R&D:GDP ratio has been gradually increasing, it seems South Africa is not doing enough to invest in HCD in science and research.
This apparent lack of commitment was emphasised by the fact that in the 2008/2009 financial year, South Africa’s R&D spent shrank as a proportion of the country’s GDP for the second year running. It dropped down from 0,95 per cent in 2006/2007 to 0,92 per cent in 2008/2009. This drop meant the country had failed to reach its goal, adopted in 2004, of spending 1 per cent of GDP on R&D by 2008.

One of the important reasons given for the decline is the shortage of researchers. It seems that as long as the issue of HCD is not properly addressed, it is doubtful that the country will reach the 1 per cent target soon, or its more ambitious goal of spending 1,5 per cent of GDP on R&D by 2014. It is hoped that in the long term, plans and concerted efforts by the government, which include the National Space and Technology Strategy, which forms part of the Department of Science and Technology (DST) Ten-year plan for Science and Technology, and the National Research Foundation’s (NRF) Vision for 2015 will help avert this situation.

The lack of astronomical facilities in African countries inhibits the development of astronomy in the continent. In Rwanda, for instance, during 2008/2009 there was no radio astronomy observatory, no planetarium, no science centre and no telescope in the country. For young and enthusiastic students and researchers in Rwanda this means that they have to travel to South Africa and to overseas countries to receive training, and when they return to their countries they will no doubt be limited to Physics teaching at universities. This, however, is a temporary challenge and is about to change, for at least a significant number of African countries (see the section on benefits of SKA below).

Human Capital Development (HCD)

The NASSP Programme
The rates at which students are graduating from NASSP have been low and have averaged at 12 students per year between 2003 and 2008. The number of black South African Honours students graduating per year has been even lower. There were two black graduates in 2003, 2004 and 2005, and only one graduated in 2006.

However, as shown in the analysis in the previous section, the average number of students who graduated in the programme increased to 18 between 2009 and 2010. This is still, however, too low to produce the required number of radio astronomy PhD graduates to take full advantage of the future telescopes such as MeerKAT and SKA. It is estimated that 25 to 30 Radio Astronomy PhDs per year will have to be produced over the next three years in order to address the problem of HCD in radio astronomy. So even if, for instance, all Honours students graduating in NASSP were to end up as Radio Astronomy PhD graduates each year, the rate of graduation (assuming it remains at 18 students per year for the next three years) would still be much lower than that required to produce Radio Astronomy PhDs (25 to 30 per year).

The situation is even worse than this, because NASSP covers not only radio astronomy but also other areas such as optical, infrared and cosmology studies, narrowing still further the number of students who actually end up as Radio Astronomy PhD graduates, out of the 18 students who graduate per year.

Thus the real situation is that, according to the Decadal Strategy for Human Capacity Development in Astronomy and Astrophysics in South Africa report, our current rate of PhD production in Astronomy (covering all the above-mentioned areas of research), is four to five per year! Something more than the NASSP effort is required to address the HCD challenge in Africa, and this is discussed below.

African universities
As shown in Table 3, first of all, a number of universities in the SKA partner countries do not offer Astronomy as a subject. Secondly, the number of academics who have received training in Astronomy is very low in most of those countries.

Thirdly, the number of universities offering Astronomy is low compared with that of universities offering Physics, which is generally the case even in South Africa. These trends can also be seen in other African countries, as shown in Table 4. Nigeria and Morocco quote the highest number of universities offering Astronomy courses when compared to the other countries, but there is a possibility that the number of universities offering Astronomy proper is lower than that quoted. There is no indication that there is any Astronomy offered at some university departments of these two countries. Furthermore, it is hard to tell if the Astronomy courses offered by these institutions are Radio Astronomy courses, courses in other areas of astronomy such as Optical Astronomy,
Table 4: African countries randomly selected from the IYA survey.

<table>
<thead>
<tr>
<th>Country</th>
<th># of universities offering Astronomy course/s</th>
<th># of universities offering Physics course/s</th>
<th># of academics trained in Astronomy</th>
<th>Governmental astronomy/science outreach programmes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanzania</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>Malawi</td>
<td>None</td>
<td>2</td>
<td>Unknown</td>
<td>None</td>
</tr>
<tr>
<td>Uganda</td>
<td>1</td>
<td>8</td>
<td>7</td>
<td>None</td>
</tr>
<tr>
<td>Nigeria</td>
<td>6</td>
<td>&gt; 30</td>
<td>22</td>
<td>Yes</td>
</tr>
<tr>
<td>Morocco</td>
<td>6</td>
<td>6</td>
<td>13-20</td>
<td>Yes</td>
</tr>
<tr>
<td>Rwanda</td>
<td>None</td>
<td>7</td>
<td>4</td>
<td>None</td>
</tr>
</tbody>
</table>

or even courses in ‘general astronomy’. But the chances are that there were very few, if any Radio Astronomy courses offered by universities in Africa, at least at the time of the IYA survey.

The other challenge pertains to the number of staff working in, and to the whole question of HCD at African universities. Nigeria and Morocco appear to have more Astronomy academics than the other countries (Table 4). But the real picture is that in Nigeria, for instance, out of the more or less 22 academics trained as astronomers, about 13 were PhD astronomers, and there is a probability that fewer than half of these were radio astronomers. In South Africa, the total number of PhD astronomers is about 101, and a very small fraction of these are radio astronomers.

In other countries such as Uganda, all the Astronomy academics were students studying at South African universities during the IYA survey. The same is true of Rwanda. In the light of future radio astronomy events such as SKA, this paints a picture of how dire the situation really is regarding HCD in radio astronomy. Another related challenge is that, as we have seen, there are more universities offering Physics than Astronomy. In Uganda, for instance, Mbarara University of Science and Technology is the only university which offers an elaborate Astrophysics curriculum from first to third-year levels, compared with eight universities offering Physics. Even in South Africa, there are fewer universities (9) offering Astronomy than those offering Physics (16), and only three of these offer Radio Astronomy courses. The number of institutions offering Radio Astronomy may never equal that of institutions offering Physics, but it certainly has to increase if Africa is serious about developing astronomy in general, and radio astronomy in particular, and in addressing the challenge of HCD.

The present and future benefits of SKA and radio astronomy in Africa

SKA is an international project that is run by the SKA Programme Development Office (SPDO) at the Jodrell Bank Centre for Astrophysics in Manchester, UK. Nineteen countries and more than 50 institutions are involved in this project. The benefits of SKA will be many, and these will most notably be in the areas of science and research, technology and skills development and culture and society (see Figure 2). There are other anticipated benefits such as investment, tourism, relationships to be developed and other non-technology driven spin-offs.

It should be stated that it is not possible to discuss all the benefits of SKA in this brief. In this section, therefore, I discuss how the construction of MeerKAT and SKA will address the challenges mentioned in the previous section, which are the lack of research facilities, and HCD challenges at NASSP and at African universities. I also discuss the benefits in technology and skills development that these new facilities will bring, and the relationships to be developed in Africa out of the SKA bid. These are arguably more fundamental to Africa’s efforts to meet its developmental needs.

New facilities and technology

The MeerKAT

The construction of SKA in Africa will provide new facilities for radio astronomy research. Both South Africa and Australia are building demonstrator arrays for SKA, and MeerKAT. The South African pathfinder for SKA, will be the most sensitive and largest-centimetre wavelength instrument in the Southern Hemisphere. MeerKAT will be an array of 64 13.5-m diameter dishes, mostly in a compact
two-dimensional configuration, operating over a continuous frequency range of 0.6–14.5 GHz. Currently there is only one radio astronomy dish in operation in Africa. However, once the Karoo Array Telescope (KAT 7), which is made up of seven antennas and which is a test-bed for MeerKAT, starts operating, this instrument, together with the full MeerKAT array, will significantly increase the number of radio telescopes in the continent.

The Square Kilometre Array (SKA)

If the full SKA gets funded, a major component of the SKA telescope will be an array of approximately 3 000 10–15 m diameter dishes. The telescope will operate in the frequency range 70 MHz–25 GHz. SKA will benefit Africa in the sense that its telescopes will extend to nine African countries, with about three antenna stations in Namibia, four in Botswana and one each in Mozambique, Mauritius, Madagascar, Kenya, Ghana and Zambia. Each antenna station will consist of about 30 individual antennas. As discussed above, South Africa is the only African country that has a radio astronomy facility, and the above-mentioned arrangement will help in developing astronomy in Africa and in addressing the challenge of HCD cited earlier. Furthermore, as the most sensitive instruments, both MeerKAT and SKA will help improve the quality of research in Africa.

The African VLBI Network (VLBIN)

A new project has been initiated which is concerned with establishing networks of radio telescopes across Africa. It is a result of the cooperation between South Africa and SKA partner countries regarding the bid to host SKA in Africa. The idea is to convert large (up to 30 m in diameter) satellite telecommunications dishes, which are considered obsolete (because the undersea cables would take over the data that was formerly transported by these systems) and found in many African countries, into radio telescopes. A number of de-commissioned dishes in many African countries have already been identified. As a start, the SKA SA Project is planning to collaborate with Mozambique to acquire a 13-m satellite antenna, convert it for radio astronomy and re-erect it in Mozambique near Maputo. Large satellite antennas in other African countries may also become available for radio astronomy.
The African VLBIN project has been launched with SKA SA partner countries, but participation is not limited to these countries. Other countries in the northern part of Africa have been said to show interest. The VLBIN will be used for VLBI observations. Like MeerKAT and SKA, this project will serve to stimulate astronomy in the participating countries and to help develop skills in electronics and information and communications technologies.

Technology and skills development

New technologies will emerge out of the construction of the above-mentioned arrays, especially in the area of ICT. The question that needs to be asked, then, is how will that benefit the economies in Africa and address the challenges (particularly those related to the R&D:GDP ratio) mentioned in one of the previous sections? A 2009 World Bank report has directly connected wide-band connectivity with GDP. The research showed that every 10 per cent increase in wide-band connectivity boosts GDP by 1.38 per cent in developing countries. There is thus a direct link between ICT and economic growth, and in fact, ICT will be the backbone of SKA.

SKA will necessitate development of new software and hardware and subsequently innovation in the area of ICT, and in other areas such as renewable energy, optics, and the like. The requirements of SKA will necessitate very fast grid computing, very fast data transport, data storage, wireless engineering, digital electronics, and image processing and software development. It is anticipated that SKA will potentially set new global standards for ICT engineering and construction, and for innovation in hardware and software, making this telescope a model of the future global communications and information technology. It is also anticipated that benefits will include new innovations not only in hardware and software but also in signal processing, storage and computation.

Furthermore, ICT innovations and developments necessary for SKA will be useful for other activities which process large volumes of data from around the globe, such as the financial, commercial, communication and environmental monitoring industries. Some of the hardware and software packages necessary for SKA may even be adapted for commercial use or may produce new products. Optic fibres that extend for thousands of kilometres will be used and this will provide communication infrastructure that would possibly not have been considered otherwise.

Direct benefits to society will include training of technicians for development and operations and the attraction of new talent to ICT in general. Investing in broadband therefore is an investment in economic growth and development and this, together with increased human capital, will increase the R&D expenditure and GDP in Africa, and improve the economy of the continent.

There are other technology benefits in the arena of renewable energy production. There are also a number of indirect benefits that will be enjoyed from collaboration and linkages with science institutions, industry and other governments, which include producing new scientific information for novel commercial applications, training skilled graduates, producing new instrumentation, methodologies and techniques and creating new firms and jobs. All these linkages will offer benefits in terms of opportunities to apply research results to industrial problems.

HCD in radio astronomy

One of the important reasons given for the decline in South Africa’s R&D:GDP ratio in 2008 is the shortage of researchers. As shown in the analysis in one of the above sections, the lack of researchers is even worse in other African countries. Programmes such as NASSP become essential here to solve this problem, especially if efforts to increase enrolment and graduation rates are accelerated. As already discussed, however, it looks unlikely that in the next four to five years, which is the time frame when MeerKAT will start being operational, radio astronomy will benefit significantly from NASSP (see analysis in section on challenges), unless something dramatic occurs. More interventions are required urgently that deal head-on with the problem of HCD in radio astronomy.

SKA HCD programmes

It is estimated that 40 to 60 PhD graduates will be required in order to utilise the MeerKAT facility to its full potential, and even more PhD graduates will be required for SKA. For this reason SKA SA has initiated a number of programmes that seek to deal head-on with the problem of HCD in radio astronomy. One of them is the Youth into Science and Engineering
Programme, which seeks to develop highly skilled young scientists and engineers. This programme offers comprehensive bursaries to students in Engineering, Mathematics, Physics and Astronomy at undergraduate, postgraduate and postdoctoral levels. To date more than 400 postgraduate and undergraduate students and postdoctoral researchers (from South Africa and other African countries) have been awarded SKA grants. Seventy-two of these students are women, and 48 come from other African countries. This programme looks promising and has a potential to attract students to Radio Astronomy en masse.

As shown in Table 5, however, it seems there is still a problem attracting black students to Radio Astronomy. There are some reasons that are normally attributed to the failure to attract more black students to Astronomy, but with major projects such as MeerKAT and SKA under way, more efforts than reasons are needed to attract students from these groups, or else these big projects will become white elephants and benefit only the privileged few.

In an attempt to attract more black students to Science, Engineering and Technology, SKA SA has introduced an undergraduate bursary scheme. Sixteen undergraduates have already benefited from this programme. More, though, still needs to be done to change the demographics as shown in Table 5, and to increase the number of black students in the programme.

There are other programmes that have been initiated such as the African Technician Training Programme, in which students from Africa are supported to study and train as electronic and mechanical engineering technicians to ensure sufficient capacity for the maintenance of the telescope systems at the remote SKA stations in Africa. These students will have an opportunity to be part of the construction of MeerKAT and SKA stations and be part of the HCD effort in their own countries.

### HCD and African universities

As discussed earlier, there are major challenges at majority of African universities, and one of them is that few universities offer Radio Astronomy courses (tables 3 and 4). One of the ways of dealing with this challenge has been through the SKA Africa project, where in a few countries, namely Kenya, Mozambique, Madagascar and Mauritius, Astronomy undergraduate courses have been taught at the universities. A total of 114 undergraduate students have participated in these courses in 2010, and it is expected that this number will increase.

The other challenge has been the lack of researchers in the African countries. As mentioned in the preceding sections, most academic students in African countries who have received training in Astronomy have done so in South Africa. Some of these students are in NASSP while others in SKA programmes. Some have even done research through HartRAO. With the African array coming up, and the possibility of SKA later, once these students return to their own countries, instead of being absorbed in other fields due to the lack of radio astronomy facilities, they will have an opportunity to use these instruments and train other students, and by doing so help develop human capital and astronomy in their own countries.

### Relationships: SKA Africa and the SKA African Associate Countries

In order to make SKA a truly African telescope, SKA SA partnered with eight African countries (Table 3) to build an African effort to host the SKA. A number of SKA outstations will be built in these countries, in addition to the core and other outstations that will be located in South Africa. This is important in encouraging and fostering cooperation among the African countries.

Another category of cooperation is called the SKA African Associate Countries. This involves cooperation in training students to become global experts in Astronomy, Engineering and Information Technology. A few countries such as Botswana, Kenya, Mozambique and Mauritius, are members, and membership to become an SKA African Associate Country is open to all African countries.

As an effort to coordinate and ensure the success of Africa’s bid to host the SKA, the African SKA Working Group was officially established in 2008. It consists of the nine SKA SA countries.
partner countries. The purpose of the African SKA Working Group is to provide strategic direction for astronomy and associated HCD in the continent. These links and relationships are important both politically and in relation to development in Africa. So is the political role that can be played by the African Union (AU). The AU has, for instance, supported the bid to host the SKA in Africa, and has recognised the importance of the science, technology and innovation benefits emanating from the SKA project, and the important role that the SKA will play in driving programmes to develop human capital on the continent. This move by the AU will certainly encourage other member states to participate in SKA programmes, and be part of a bigger effort towards development in the continent.

Conclusion

The construction of MeerKAT, and possibly SKA in South Africa, will open doors for indigenous space activities and will create opportunities for many African citizens. Educated and trained citizens will be produced, leading to economic growth and the breaking of the vicious cycle of poverty. However, for maximum benefits to be enjoyed from these projects, more efforts are needed to develop human capital now, so that there would be enough user community for the telescopes when they are operational.

With rigorous efforts to develop human capital in place, the scientific and engineering goals of the SKA can be reached, and the SKA can bring about the required development in the continent.

Acknowledgements

I would like to thank Patricia Whitelock and Salle Alle for making available the NASSP data and information. I would also like to thank Mike Gaylard and Michael Bietenholz for their valuable comments and criticism. A special thanks goes to the anonymous referee for the comments which have helped improve the quality of this paper.

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