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COMMENTARY

# Towards an African Light Source

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## Introduction

An advanced light source (AdLS) presents itself as the most important scientific investment that Africa could construct at this point in its history. There is an urgent imperative to develop all the world's socioeconomic prowess more equitably across its diversity. There needs to be a more universal and regionally balanced participation in the global economy. This would reflect in science becoming a truly global enterprise. This is rather fundamental, as innovation is the most important factor that drives economic development (Romer 1986). The crystal ball indicates that Africa will soon be home to the bulk of the world's youth (United Nations, Department of Economic and Social Affairs, Population Division 2017). These young people will need to be engaged in the economy. Africa currently has a population of 1.2 billion, with 169 scientists per million people (UNESCO 2015a). This is a factor of 20 times less than the average of Europe. Africa therefore needs at least one million new scientists to drive its economic development through innovation. The vision of achieving sustainable and equitable development drives the logic of investment in science, technology, and innovation. All seventeen of the sustainable development goals of UNESCO must be progressed (UNESCO 2015b). The new large-scale scientific infrastructure must be both multi- and inter-disciplinary. The obvious candidate is the AdLS (LAAAMP 2018). Many have asked whether Africa is ready for such a technologically sophisticated large-scale scientific infrastructure. The answer is YES. Africa is long overdue for the acquisition of such an transformative instrument. Africa simply cannot afford to lag behind the rest of the world as now the only habitable continent without an AdLS. Some regions beyond Africa already have several generations of emerging career scientists trained to use this kind of premier tool for scientific enquiry. These second and later generations of scientists are now often active in industry, creating awareness and knowledge of the AdLS analytical and characterization prowess within the commercial world. With this impetus and also the outreach actions of AdLSs, many AdLSs worldwide now have dedicated industrial liaison or business development offices with the mission to engage with industry for exploitation of light source facilities and intellectual property). AdLSs have started to make the leap from academia to industry. They have progressed now to become a premier tool driving and supporting industrial innovation (biotechnology, nanotechnology, energy technology, and many more) through the advanced characterization of materials and living matter, going far beyond the capabilities of conventional X-ray sources. Several facilities, such as the

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APS (USA), SPring8 (Japan), and SLS (Switzerland) have beamlines wholly or partially owned by industry, and most light sources run significant commercial programmes with industry for proprietary access to the X-ray beamlines. Complementing this, it is important to note that engagement with industry is also significant through the public access programs where industry, usually in collaboration with academic teams, works on applied R&D with publishable results. This is an important engagement mechanism, supporting innovation via precompetitive research, and it is estimated that some 20–40% of public programs have industry relevance or engagement as part of the work being carried out.

Of course, we can have African suitcase scientists, who travel abroad when they need to use international research facilities, such as AdLSs. But then, ultimately, we lose many of the elite emerging African scientists to the African science diaspora. Africa misses out on the mega-science techno-industrial research and manufacturing parks that emerge around significant local research infrastructural capacity. An AdLS is not only just about good science but also about retaining innovators and seeding local competitive industry. Indeed though, an AdLS has stringent requirements on political stability, reliable electrical energy, travel connections, and Internet bandwidth. Indeed, it also requires an established user base of active scientists and also a strong local technological capacity (see Table 1). We have not said, indeed, that it requires financial capacity, since this aspect is simply about prioritization. An AdLS costs approximately half to one billion euros to construct, and a similar amount to operate, maintain, and upgrade every decade thereafter. Therefore, it is similar in cost to a football stadium, or a percentage of a large municipal railway system, or a large-scale power station. Thus, an AdLS is eminently affordable by the governments of Africa pooling their financial resources. Africa must just understand its contribution to transformation of continental socio-economics.

But what comes first, the chicken or the egg? There are several different precedents for the path to an AdLS. For Brazil's UVX and Sirius' AdLS, and for Spain's ALBA, many young and seasoned scientists were sent abroad for training. The return rate was quite high, with an estimated 80% invited and attracted back with the prospect of contributing to building an AdLS in their home countries. Local industries were invited to partner in localization through up-skilling and capacity-building programs. The growth of local technological and scientific capacity was significant and inspiring, allowing the AdLS constructed to be largely locally maintained and locally further developed. Through these efforts, a cohort of new competitive industries emerged. At the other end of the spectrum is the new AdLS in Poland called Solaris, which was ordered as a co-build with the Max IV machine in Sweden. In the former cases, the construction took a decade or more, while in the case of Solaris, a mere 2 years. While Africa is not yet at the stage of choosing its construction

**Table 1** Requirements to host a synchrotron

| Requirement | Applicability | Description |
|---|---|---|
| Stable power | AfLS site | Consider including onsite green power plant 50 MW in the TDR |
| Stable politics | AfLS country and region | For local and regional African governments |
| Good connections for travel | AfLS site | International, regional, and local |
| African government funding | Pan-African requirement | Assured for 80% of construction and operational costs (as stakeholders) |
| African users | Pan-African requirement | 300 established scientists in the AdLS user base from throughout Africa |
| Industry users | Pan-African requirement | More than five large companies with synchrotron user experience |
| Human capacity training program | Pan-African requirement | More than a hundred students per year, local and international in science and a good fraction of that in engineering |
| Sufficient site space | AfLS site | For hi-tech Mega-science and Industry industrial park to develop alongside the AdLS |
| African industry participation | Pan-African requirement) | Willing to up-skill and innovate across local and Africa-wide industry through procurement of AdLS components |
| High-bandwidth Internet connectivity | AfLS site | At least 10 GB/s capacity |
| Safe environment | AfLS site | Good policing, low criminal activity |
| Completed CDR and TDR phases | Pan-African requirement | Conceptual and technical design reports |

methodology, we do take home the message that the local scientific and technological capacity can be assembled within about 5 years. This capacity-building process in Africa must therefore urgently start. It can be done simultaneously with the process of developing the African Light Source (AfLS), both from the bottom-up and top-down, namely, developing the user base of AdLS researchers and the African scientific output inventory, as well as the Conceptual Design Report. Then, when we are ready politically, the human capacity will also be in place.

There is however a danger that if we develop capacity in young people but do not provide local positions in tertiary institutions where there is also appropriate local research infrastructure, then we will feed the African science diaspora and lose the value of that trained capacity within Africa. A look at some previous Nobel prizes in the chemical and biosciences illustrates this point. Those laureates were educated to their first postgraduate degree in Africa, but they did not remain there when they carried out their most innovative research.

1. Sir Aaron Klugg (1982 Nobel Prize in Chemistry: Educated in South Africa to MSc level)
2. Sydney Brenner (2002, Nobel Prize in Physiology/Medicine: Education in South Africa to MSc level)
3. Ahmed Zewail (1999 Nobel Prize in Chemistry: Educated in Egypt to MSc level)

The same trend will continue if there is not a significant improvement in the local research opportunities. The Roadmap towards the AfLS is designed to develop in a choreographed approach: the development of human capacity and of local and regional infrastructures, leading ultimately to the AfLS itself. This would be accomplished in a context where African governments ensure that there are also positions available on the continent, so that also in Africa's case, there will be at least 80% retention of the new highly skilled emerging researchers.

## History and progress

The AfLS project is coordinated by a Steering Committee (SC), now in its third year of operation. Its origins were an Interim Steering Committee (ISC), which was inaugurated electronically on 16 August 2014. This was the result of a process that formalized the decades-old conversation about an AdLS for Africa, which had been proceeding within the African continent and beyond. The ISC members were identified and drawn from those involved in the earlier conversations. The ISC took upon itself a very restricted mandate to initiate a transparent, inclusive, and democratic process that would lead to the first AfLS Conference and Workshop, which would have as one of its roles, to elect a fully representative and inclusive AfLS SC. The first AfLS Conference and Workshop was duly held at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, during 16–20 November 2015 (Connell et al. 2018). There were 98 delegates from 13 countries in Africa and 12 from the rest of the world. The fully mandated AfLS SC was formed, constituted as a broad partnership of scientists and institutions from both within Africa and beyond, in the common vision of an AdLS for Africa. The meeting also led to the AfLS Roadmap and the Grenoble Resolutions, which clearly defined *WHY* for an AfLS. These seminal documents expressed the extreme importance of an AdLS for Africa and developed a program of activities towards its realization. They can be accessed in more detail as Appendix 1 in the reference (Connell et al. 2018) as the "African Light Source Manifesto."

There were already significant milestones towards the AfLS in the period before the AfLS SC was formed.

For example, the first formal proposal for a Pan-African AdLS was written into the *2002 Strategy and Business Plan* of the African Laser Centre (ALC) (Mtingwa and Winick 2018). This development was strongly encouraged by the Edward Bouchet-Abdus Salam Institute (EBASI), an Institute promoting the growth of Science and Technology in Africa, supported by the Abdus Salam International Centre for Theoretical Physics (ICTP).

The Declaration and Action Plan of the 1st African Higher Education Summit on Revitalizing Higher Education for Africa's Future included a recommendation to establish a synchrotron as a centralized African scientific facility in Article 5.3.3 on page 22 (AUC 2019). This summit was held in Dakar, Senegal, from 10 to 12 March 2015 with the aim of establishing a shared Strategic Framework for inclusive growth and sustainable development and a global strategy to optimize the use of Africa's resources for the benefit of all Africans. The recommendation carries considerable weight, as the summit organizers included several key Pan-African organizations: the African Union Commission (AUC), TrustAfrica, the Council for the Development of Social Science Research in Africa (CODESRIA), the United Nations' Africa Institute for Development and Economic Planning (IDEP), the Association for the Development of Education in Africa (ADEA), the Association of African Universities (AAU), and the African Development Bank (AfDB), as well as other national and international partners.

In each of these two significant developments, some of the leaders of those early initiatives were soon to take leadership roles in the AfLS SC. The AfLS SC can be regarded as a community of individuals and organizations who work together coherently for the ultimate goal of the AfLS. As the AfLS is seen as a powerful engine for development, this goal is synonymous with the goals of sustainable global socioeconomic development with a focus on Africa. This goal has many intermediate goals, including human capacity building; the development of local and regional shared infrastructures; the development of scientific and technical networks, linkages, and collaborations within and beyond the continent; the involvement of industry in the research; and the marketing of the AdLS at National and Pan-African levels, in fact, all activities that promote the feasibility of a Pan-African AdLS. The AfLS is a legal entity registered as a Trust in the Masters Office of the High Court in South Africa with a constitution and an audited bank account. The name of the Trust is the African Light Source Foundation Trust. This AfLS Foundation enables formal partnerships to develop with other organizations whose missions have a strong overlap with the AfLS project.

An example mentioned here is the Lightsources for Africa, the Americas, Asia and Middle East Project (*LAAAMP*) whose aim is to enhance AdLS science and crystallography in Africa, the Caribbean, Mexico, Southeast Asia, and the Middle East. This is a project of the International Union of Pure and Applied Physics (IUPAP) and the International Union of Crystallography (IUCr) and is funded by the International Science Council (ISC). It has a partnership of 32 additional scientific organizations, including 16 AdLSs (LAAAMP 2019). The AfLS and LAAAMP do not compete but will partner on the aspects where they overlap. This includes deep training through medium- and long-term researcher-student working visits to AdLSs. A related example is the European Horizon 2020 Framework Programme support provided for building human capacity to fully exploit the SESAME synchrotron light source (SESAME 2019) hosted in Jordan and which includes Egypt as a Member. This project, called OPEN SESAME (Open SESAME 2019), has carried out a program of training actions for AdLS scientists, engineers, technicians, as well as researchers from the SESAME Member countries, such as a 2-week specialized Higher European Research Course for Users of Large Experimental Systems HERCULES (HERCULES 2019) training course and a workshop of structural biology and life science research using synchrotron light. Over 200 researchers have benefitted from training and mobility.

The HERCULES course is a world-renowned capacity building course targeting synchrotron and neutron sources. Since its inception in 1991, over 2000 young researchers have benefitted from the lectures and hands-on training provided by HERCULES, nurturing the next generation of users of such facilities. The main course is held annually over 4 weeks at European facilities, but the training now has a worldwide reach with targeted specialized courses held in Taiwan and Brazil with Jordan and Turkey planned (with light sources TPS, Sirius, SESAME, and TURKAY in mind, respectively). Africa so far has had only a few students attend the HERCULES course. The usage model involves extensive use of the local community as lecturers and access to hands-on training.

Another significant organization working towards the AfLS is the African Academy of Sciences (AAS). Both the AfLS and the AAS have been involved in conversations with the African Union (AU). The President of the AAS delivered a presentation on the Pan-African AdLS project to the 2nd Specialized Technical Committee on Education, Science and Technology (STC-EST) of the AU held in Egypt during 21–23 October 2017. The report of this meeting records the Call to the African Union Member States to support the Pan-African AfLS initiative. The AAS has also issued a general Call for Letters of Support and Endorsements, and it is hosting an online petition on its Web site. The Executive Council of the AU considered the reports of its Specialized Technical Committees (STCs) at its 32nd Ordinary Session during 23–24 January 2018 in Addis Ababa, Ethiopia. Its documentation on its decision calls upon Member States to support the Pan-African Synchrotron Initiative in section C.21 (AU-EC 2019), see Fig. 1.

The 2nd African Light Source Conference (AfLS2) convened as a Joint Conference with the Pan-African Conference on Crystallography (PCCr2) in Accra, Ghana, from 28 January to 2 February 2019. This was effectively two conferences held in parallel, with a one or more sessions of common interest per day. The AfLS2 component had 91 delegates participating with contributions, with some overlap of delegates with the PCCr2 conference. Figure 2 shows the participation was mostly from Africa, with strong support from the international community and also the African science diaspora.

The Conference gave profile to science conducted at AdLSs from a range of disciplines, including the Medical Sciences, Heritage Sciences, Geosciences, Environmental Sciences, Energy Sciences, Nano Sciences, Materials Sciences, Mineral Sciences, and Accelerator and Detector Sciences. There was an opportunity to give profile particularly to projects with African leadership or participation, and also research demonstrating the frontiers of a discipline, or a review of the contribution of AdLS-based research to that discipline. There were also sessions that focused on topics, such as the AdLS role in creating innovation and building competitive industries, capacity building for AdLSs, infrastructures that represented stepping stones towards an AdLS, and several talks illuminating the strategy and vision for the AfLS. Here, the experience from other AdLSs in their own journey from conceptualization to commissioning was of great interest. The AAS participated in the planning and leadership of the strategic planning sessions on the final day of deliberations.

The conference resolved to establish several African consortia. These include the following:

- Multinational consortia (distributed) to jointly access international synchrotrons
- Multinational consortia (regional) to jointly apply for large-scale funds and assemble regional funds to develop

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EXECUTIVE COUNCIL
Thirty-Second Ordinary Session
25 – 26 January 2018
Addis Ababa, ETHIOPIA

EX.CL/ Dec.986-1007(XXXII)

DECISIONS

**Fig. 1** The African Union Executive Council report of its 32nd Ordinary Session, 23–24 January 2018 in Addis Ababa, Ethiopia, calls upon Member States to support the Pan-African Synchrotron Initiative in section C.21 (AU-EC 2019)

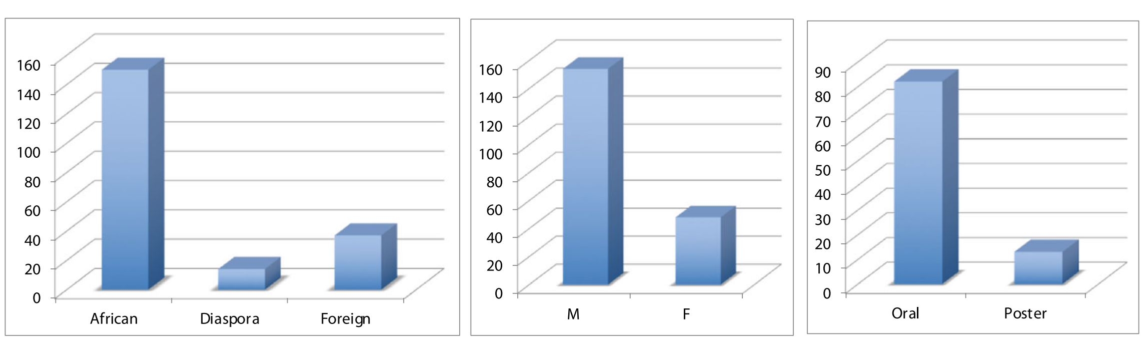


**Fig. 2** The second African Light Source Conference (AfLS2) was held in parallel with the Pan-African Conference on Crystallography (PCCr2) in Accra, Ghana, from 28 January to 2 February 2019. Some sessions of common interest were shared

regional feeder/training/research infrastructures towards building the AdLS user base
- Multi-national consortia (regional) for constructing and operating African beamlines at international facilities. Candidate research areas for these beamlines include tomography for palaeontology, crystallography for drug discovery, and material science for such studies as the environment, energy, and mineral beneficiation.

The AfLS will also coordinate funding applications in a multi-national manner to support the mobility and access for research visits, and longer-term access for training visits, as well as for schools, workshops, and specialist User Meetings. Furthermore, the AfLS will make high-level inputs into strategically important international meetings. The AfLS decided that in the near term, it will lay the groundwork for the preparation of the conceptual design report, which would examine the detailed scientific, business, and technical issues, developing the framework that answers the questions of what, why, how, and when. The questions of where and who funds the AfLS WILL come later, after the CDR process has matured considerably.

At the AfLS2 conference, the Ghanaian government came out strongly in support of the project, asserting that Ghana would act as a champion the AfLS and that it would seek to establish it as an official project of the AU and Economic Community of West African States (ECOWAS). This statement was made on behalf of President Nana Addo Dankwa Akufo-Addo by Kwabena Frimpong-Boatend, Ghana's Minister for the Environment, Science, Technology and Innovation, during the joint opening ceremony of the AfLS2 and PCCr2 conferences. Meetings to give effect to this statement are already underway and further meetings are planned.

The third African Light Source Conference (AfLS3) will convene in Kigali, Rwanda, during 16–21 November 2020. It will be hosted by the ICTP-affiliated East Africa Institute for Fundamental Research (EAIFR), located in the University of Rwanda's College of Science and Technology. It is anticipated that during the AfLS3, there will be focus sessions and roundtable discussions on the AfLS CDR and production of a pre-CDR document that will pave the way for a final CDR.

The database for the audit of African scientists participating in research programs at AdLSs has currently a footprint in Africa as shown in Fig. 3. More details on the AfLS program, its committees, projects, and details of the progress that Africa is making on the roadmap towards an AfLS is recorded in detail at AfLS Web site (AfLS 2019).

## AdLS-related bioscience in Africa

The biosciences represent a significant area of research at AdLSs, often contributing roughly half of the research that is conducted at AdLSs. It is therefore important to audit the development of research in the biosciences in the field of structural biology in Africa. In a current audit attempt, the structural biology carried out at lab-based facilities is also included, as these researchers are potential candidates to become AdLS users. Table 1 asserts that there should be a threshold of approximately 100 researchers active in the biosciences for a AdLS to be feasible in this field. It is notoriously difficult to audit a discipline on a continental scale, let alone on a country scale. At most, one can claim that such a process has been initiated and present the results so far. We are currently aware of 24 groups operating in the countries as shown in Fig. 4.

Some of the projects can be mentioned specifically.

The International Union of Crystallography (IUCr) has been actively promoting crystallography in developing countries since 2014. There has been a focus on Africa via the "Crystallography in Africa" project, which comprises a suite of activities, including lecture series and schools, equipment, bursaries, and support for attendance at IUCr Congresses. The IUCr-UNESCO-LAAAMP OpenLabs project is coupled to this and seeks to establish a network of operational crystallographic laboratories in carefully selected countries in Africa (LeCompte 2015; Zema et al. 2017). The crystallography here is inclusive of many fields, but it is mentioned as it usually includes structural biology, and even when it does not, it establishes an X-ray-based competency that then facilitates the growth of crystallography in biomedical applications. Considering the infrastructure developed through this project and also internal purchases within countries, we estimate that about 11 of the 54 African countries have local X-ray crystallography-based research instrumentation. An audit of this may be found in the AfLS Web pages mentioned previously.

Two examples of local and regional facilities that enable local research and training and also act as a springboard for the access of AdLS are mentioned in the audit. The first is the Aaron Klug Centre for Imaging and Analysis (AKC-IA 2019). This is a university facility based at the University of Cape Town; however, it is configured as a significant regional equipment resource, including the full pipeline of instruments necessary for structural biology studies. The second such facility is the new X-TechLab in Benin that launched recently. The local X-ray equipment is capable of sample analysis, phase identification, and crystalline structure resolution, as well as X-ray microtomography. In addition to research opportunities, there are training programs. X-TechLab is a national and a regional research facility. It does not have explicitly any structural biology program at the moment; however, it is explicitly part of the roadmap for the AfLS and facilitates access to AdLSs. In due course, it will acquire the capacity for structural biology. X-TechLab has declared that it also aims to contribute to the

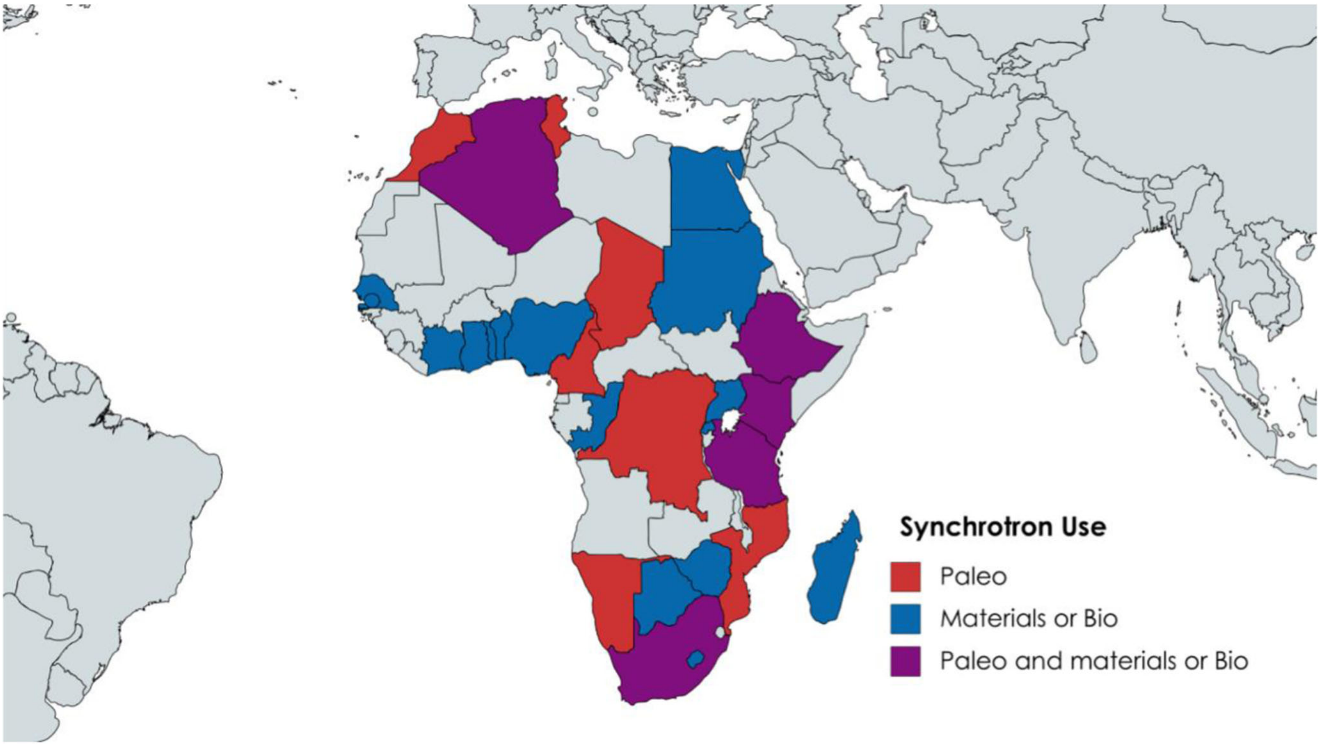


**Fig. 3** Countries in Africa that have research programs at an AdLS

emergence of a community of experts to constitute the active core of the users of the future African synchrotron and to define the main priorities (X-TechLab 2019).

Many synchrotrons have been involved in programs that support and encourage the development of users from Africa, using the mechanism of schools and conferences. In one case, this developed significantly, whereby South Africa became a Scientific Associate of the ESRF in Grenoble. This Associateship began during a signing ceremony at the ESRF on the 2 May 2013 and is current after one renewal at the 0.3% participation level (ESRF News 2013). This Associateship greatly facilitated access to the ESRF by South African bio scientists. It has been supplemented by the exchange/mobility France-South Africa PROTEA Scheme and the Grenoble Internship Programme.

Recently, the Synchrotron Techniques for African Research and Technology (START) program was launched on 27–28 March 2019, at the Diamond Synchrotron in the United Kingdom (UK) (START 2019; Goldsmith et al. 2019). It is funded by the UK's Science and Technology Facilities Council (STFC) from the Global Challenges Research Fund (GCRF). START has two pillars, in the biosciences and the material sciences. The former focuses on structural biology for understanding disease and developing drug targets. The aim is to develop international research collaborations and train emerging researchers. It has its African center of gravity in South Africa, but it is conceived as an African project, and Lesotho and Ethiopia are now also involved. It is considered to be a significant contribution within the roadmap of the AfLS.

The idea from structural biology is that structural information helps to elucidate protein function and, in particular, the mechanisms of enzymes, which inspires the design of new drugs. Africa should lead research of this nature as it would lead to the development of cures for diseases of particular relevance to Africa that may not otherwise be receiving sufficient research attention. Synchrotrons are extremely important facilities for the imaging of biomolecules. A recent paper explains that there has been the discovery and development of 210 new drugs that depended on protein structural information, derived from X-ray and other techniques (Westbrook 2019). The same point is made in the case of the development of drugs for treating HIV-AIDS, where the retroviral protease was identified as one potential target for structure-based drug design, leading to a host of treatments (Wlodawer and Vondrasek 1998). Of course, it is an ongoing process due to mutations in the HIV. There is a listing of nonconfidential information about drugs, their targets, and the companies developing them based on structural information maintained on the "Practical Fragments" Web site (Practical fragments 2018). Another article discusses the development of new treatments for tuberculosis using structure-guided


**Fig. 4** The countries in Africa where structural biology research programs are active. The current audit has 24 groups active. The supporting data for the map can be found at http://www.africanlightsource.org/audit-biosciences/

fragment-based drug design (Blundell 2017a). The progress in drug discovery via protein crystallography has best occurred historically based on a sophisticated and necessary interplay between academia and industry (Blundell 2017b). This characteristic would need to be encouraged at an AfLS. The factors relevant to improving the efficiency of pharmaceutical R&D are discussed by Scannell et al. (2012). There is clearly a strong case for structure-based drug design, and it is crucially important for Africa to be deeply engaged.

Programs and their motivations, such as those mentioned here, have a significant impact in acquiring local infrastructures, increasing training opportunities, building international networks, facilitating access to international facilities, and increasing academic output, leading to progress in understanding diseases and developing medical solutions.

## Conclusions

This paper has motivated the case for the AfLS and has looked at the development and some activities of the AfLS SC. There are many stakeholders in this endeavor, the multiplicity of which can work together in a coherent way, retaining their branding but cooperating towards a common goal. They should partner with each other within the umbrella of the AfLS. A new feature of the progress along the roadmap are examples where external funding sources partner well with local policy, and even more significantly, where African governments take responsibility for the development of local infrastructures.

The roadmap to the AfLS involves training in the advanced research techniques available at AdLSs. This is happening, although the throughput is still low. Unfortunately, even at the low throughput we currently have, the poor availability of appropriate positions and sufficiently well-equipped local laboratories mean that the training programs dominantly feed the African science diaspora.

The AfLS is becoming ever more firmly established on the agenda of the African Union. Benin's government firmly supports X-TechLAB as a contribution to the AfLS's feeder infrastructure, and the Ghanaian Government is positioning itself to champion the AfLS wherever it may ultimately be built.

There is much progress, and much remains to be done.

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## Compliance with ethical standards

**Conflict of interest** Simon H. Connell declares that he/she has no conflict of interest. Sekazi K. Mtingwa declares that he/she has no conflict of interest. Tabbetha Dobbins declares that he/she has no conflict of interest. Nkem Khumbah declares that he/she has no conflict of interest. Brian Masara declares that he/she has no conflict of interest. Edward P. Mitchell declares that he/she has no conflict of interest. Lawrence Norris declares that he/she has no conflict of interest. Prosper Ngabonziza declares that he/she has no conflict of interest. Tshepo Ntsoane declares that he/she has no conflict of interest. Herman Winick declares that he/she has no conflict of interest.

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