

ASTROPHYSICS IN AFRICA FOR DEVELOPMENT

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Abstract. Africa is probably the continent with the most assets for Astrophysics and Planetology: skies without light pollution, meteorites and meteorite impact craters, and geological records of the ancient Earth and of origin of life. Outside of South Africa, however, there are still few African scientists working in these fields. This situation can be explained by the dependence of African researchers on the priorities of external (international) funding together with structural weaknesses of national public funding. Aware of these assets and challenges, a community of African astronomers and planetary scientists is involved in increasingly ambitious projects and is distinguished by original scientific works that highlight the African scientific heritage. This article will highlight some of the recent activities carried out in collaboration between African and European scientists in astrophysics and planetary sciences: the on-going AFIPS network (African Initiative for Planetary and Space Science) and AWA project (Astrophysics and Planetary Science in West Africa), and the Africa-Europe RISE 5A (Astronomy and Astrophysics Arising Across Africa) proposal for staff mobility between the two continents. The focus will also be placed on specific achievements, such as the 2 stellar occultation campaigns in Senegal in connection with the NASA's space program in Senegal, and the launch of the first popular science magazine on astronomy in Francophone Africa. Through these achievements, we will show the impact of these activities on African youth and emphasize the role that African astronomers play in the scientific and cultural development of their countries.

Keywords: Africa, Development, Education

1 Introduction

Astronomy is not the first scientific discipline that naturally comes to mind when one evokes the African continent, which faces many challenges concerning health, agriculture, the consequences of climate change, the exploitation of resources and the environment. However, Astronomy is the oldest science, with its 5000 years of history, as evidenced by the "stone observatories" such as the great megalithic circles (Nabta Playa, in Egypt, Stonehenge in the United Kingdom). Astronomy has largely contributed to the development of humanity, to its knowledge, and to its technological development (Astronomy and Astrophysics Survey Committee et al. 2001; Fabian 2010; Pović et al. 2018; Valls-Gabaud & Boksenberg 2009). It is also the only science where amateurs play an active and very significant role, and where collaborations between professionals and amateurs are often at the forefront of the discipline (Mousis et al. 2014). Because of the universal subjects it deals with, it is a science that favors the links between the academic world and society. Astronomy questions our origins and our place in the universe, and, to address these questions, rely on mathematics, physics, and chemistry. Astronomy can be cited as an example of multi-, trans and inter-disciplinarity. It is also a science that arouses many vocations for scientific careers among young people. For all these reasons, astronomy must be considered as essential to the sustainable development of human societies. The existence of curricula in astronomy at various levels (from primary schools to universities) and the practice of research in astronomy shall not depend on the economic development of a country, under the pretext that its applications do not seem as immediate as in other fields.

Many young Africans are fascinated - as elsewhere in the world - by the observation of the sky during their childhood, and wonder about the origin of the stars and the functioning of the universe. Often isolated, and with few opportunities to feed this passion for science, their thirst for learning can dry up. In contrast with these

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unfavorable conditions, Africa is probably the continent with the most assets for astrophysics and planetary science: skies without light pollution (Netzel & Netzel 2018), meteorites and meteorite impact craters (Reimold & Koeberl 2014), geological records of the ancient Earth and of the origin of life. Outside of South Africa, which is the host of a major part of the Square Kilometre Array (SKA) project, there are still few African scientists working in astronomy or planetary sciences. This situation can be explained by the dependence of African researchers on international funding and the priorities of these funding bodies, and on the other hand, by the structural weakness of national public funding, which guarantees a certain academic freedom. Conscious of these assets, a community of astronomers and planetary scientists is involved in increasingly ambitious projects and is distinguished by original scientific works that highlight the African scientific heritage. Over the last few years, the extraordinary motivations of African astronomers and regular meetings with astronomers outside Africa, and in particular with European and American researchers, had indeed led to a number of new projects and initiatives that illustrate the growing dynamics of the continent in this field. In 2017, the launch of the "African Initiative for Planetary and Space Sciences" (Baratoux et al. 2017a,b), which can now be followed at <https://africapss.org>, contributed to break the isolation of some African astronomers and planetary scientists and brought more researchers from countries where astronomy is practiced at the highest level to engage with their African colleagues for the scientific development of their countries. The idea of this initiative was rooted in particular in the long-term collaboration between France and Morocco in the field of planetary science (Bouley et al. 2012; Ait Moulay Larbi et al. 2015; Chennaoui Aoudjehane et al. 2016). A few years later, the new projects and success stories mentioned below illustrate the growing interest for astronomy in Africa and the contributions of these initiatives to the sustainable Development of the continent.

2 Observations of occultations in Senegal in relations with missions of exploration of the Solar System

In 2018, Senegal enters the history of space exploration of the Solar System. For the first time, 21 Senegalese researchers, members of the Senegalese Association for the Promotion of Astronomy (ASPA), along with American and European researchers, participated in an astronomical observation campaign essential for the preparation of the flyby of the most distant object ever explored by a human-made spacecraft: Arrokoth (Buie et al. 2020), in the framework of the New Horizons NASA mission, and following the exploration of Pluto. The deployment of telescopes in Senegal, to record the last observable stellar occultation by Arrokoth before the flyby, was also the occasion to produce a scientific documentary entitled "A la poursuite d'Arrokoth", which is publicly available on the internet (Berger 2018). The impact of this observation campaign was beyond expectations, with several well-attended outreach events, exchanges between scientists and the public, and an audience of the entire team with the President of the Republic of Senegal (Fig. 1).

Two years later (September 2020), in the context of the Covid-19 pandemic, NASA decided to rely on the skills of the Senegalese astronomers, acquired during the deployment of telescopes in 2018, to pursue its occultation program. Maram KAIRE, president of ASPA, was appointed as the coordinator of a new campaign of astronomical observation. The necessary equipment was shipped by NASA to Senegal for a short period of time. The goal of this new deployment was to observe the stellar occultation by (15094) Polymele, an asteroid of Jupiter, which will be visited by the space probe Lucy (NASA), to be launched in October 2021. 14 telescopes were deployed in the region of Fatick (south-east of Dakar, Senegal) in order to attempt the recording of a few positive occultations. The telescopes were spatially distributed around the trajectory of the occultation. Good strategic decisions made by the team, taking in account the very difficult weather conditions in September 2020 (end of the rainy season), led to a successful observation of one chord.

To celebrate these achievements and the past activities of the president of ASPA, an asteroid, orbiting between Mars and Jupiter, now bears the name of Maram KAIRE - the first Senegalese scientist to receive this distinction. The Asteroid (35462) Maramkaire (by the WG Small Bodies Nomenclature 2021), a main belt asteroid, represents now a source of pride and of inspiration for the many students and young researchers in Senegal and beyond the borders of this country. A new observation campaign will take place in October 2021, in order to constrain the size and shape of the satellite of Jupiter Orus, again in preparation of its flyby by the Lucy spacecraft.

Through these missions, the participants had the opportunity to reinforce their skills in astronomy, but not only in astronomy. The preparation of the observation campaign was also an opportunity to approach notions of optics, mechanics, mathematics, physics. The instrumentation/software aspect is a key element of the training (Fig. 2). The success of these campaigns requires teamwork, with participants from different fields, with different positions (students, professors, engineers) who unite their motivations in the field during the training phases,



Fig. 1. The group of Senegalese, U.S.A and French astronomers in the front of the Presidential palace of Senegal, after an audience with the President of the Republic of Senegal, Macky Sall.

and during the final phase of night deployment of the telescopes on the Senegalese territory.



Fig. 2. Training session in the gardens of the Hôtel Royal Malango In Fatick. Participants are trained for telescope deployment and use of the software to record to the occultation using a GPS and camera. Credit : Senegalese Association for the Promotion of Astronomy.

3 Education and outreach

In parallel to these missions, the first Astronomy on-line magazine for French-speaking Africa, available at <https://lastronomieafrique.com/> has been launched, in the framework of a collaboration with ASPA, the Société Astronomique de France (SAF), and with other partners, including the SF2A. This on-line magazine presents astronomical phenomena that it is possible to observe from several capitals of African countries. It also connects African researchers with amateurs, and favors the dissemination of scientific knowledge in society.

A school has also been organized in May 2021 with the support of the Office of Astronomy for Development (OAD) of the International Astronomical Union. This school, entitled "Astronomy and Python" was an opportunity to train students with this programming language used in most scientific disciplines <https://astrosenegal.org/>. Here again, this experience illustrates how astronomy can be used to contribute to sustainable development. It is indeed unlikely that all of these students will become astronomers, but it is certain that most of them will now be able to use the Python language in their respective fundamental or applied research projects. The Python language is freely available, and used in many scientific and engineering fields. Learning Python through astronomy is an innovative educational experience that has given to the participants undeniable advantages for their future careers.

In the wake of the activities, the members of the AFIPS network have often contributed to the emergence of associations and events in several African countries, for instance, the launch of the Ivoirian Association for Astronomy (<https://lastronomieafrique.com/naissance-de-lassociation-ivoirienne-dastronomie-iaa/>), the Mauritanian Association for Astronomy (<https://www.facebook.com/nmauritanienastronomie.astronomie>), the Days for Introduction to Astronomy in Togo, organized by the Togolese Association for Astronomy (<https://www.facebook.com/AstronomieTogo/>). These events, and many others, that we cannot mention here, together with institutional efforts and projects of astronomical observatories in several African countries (Pović et al. 2018) indicate a growing maturity, and favorable conditions for the emergence of high level academic research in astronomy and planetary sciences in Africa.

4 Conclusion and perspectives for Africa - Europe collaborations in Astronomy and Planetary Sciences

In this context, it appears timely to strengthen Africa-Europe collaborations in the field of astronomy and planetary sciences. For 2021 – 2022, a group of scientists in France, Senegal, Burkina Faso and Côte d'Ivoire are funded by CNRS for a project entitled "Astrophysics and planetary Science in West Africa" (AWA) – this project focuses on astronomical observations of the solar systems (occultation campaigns), stellar and galactic physics, and search on existing and new meteorite impact craters in Africa (with a focus on the field of tectites in Côte d'Ivoire). A geophysical campaign of the potential meteoritic impact craters of Velingara will be organized by AWA in 2022. AWA will also strengthen existing collaborations between the University Ki-Zerbo of Ouagadougou and the Observatoire de la Côte d'Azur, which includes the co-supervision of PhD students between the two teams. AWA is co-funded by the French National Research Institute for Development (IRD) and the Agate project <https://agate-project.org/>. To implement the long-term vision for development of Astronomy on the continent, a group of African and European Astronomers are currently working on the preparation of large proposals, to be submitted to the Horizon Europe program in 2022. One of these proposals is entitled Astronomy and Astrophysics Arising Across Africa (RISE 5A) (Fig. 3). This proposal aims at offering new opportunities for staff and students exchanges between Europe and Africa. It is organized in 7 work packages, management (WP1), planetary sciences (WP2), stellar physics (WP3), Galactic and extragalactic science (WP4), instrumentation on and site testing (WP5), inclusion in astronomy (WP6), outreach dissemination on and communication (WP7).

This article of proceeding reports the efforts of large group of scientists including the members of the Africa Initiative for Planetary Science, the members of RISE 5A team, the members of the MATERNA (Mobility in Africa for Training, Education and Research: Network for Astrophysics) team, and the members of the different occultation campaigns in Senegal. The projects and achievements mentioned in this paper received funding from the French National Research Institute for Sustainable Development, the Centre National de la Recherche Scientifique (France), the Ministry of Research, Higher education and Innovation of Senegal, the French embassy in Dakar, the Organization of Women in Science, and the Agate Project. The University Cheikh Anta Diop (Sénégal), The Université Félix Houphouët-Boigny (Côte d'Ivoire), The University Joseph Ki-Zerbo (Burkina Faso), the University of Côte d'Azur, and the University of Toulouse III Paul Sabatier are particular acknowledged for constant institutional support. The support of the Hôtel Royal Malango in Fatick for the occultation campaigns in Senegal is greatly appreciated. Marc Buie, Anne Verbiscer and all the scientists of the New Horizon and Lucy teams (NASA) are acknowledge for exceptional support for the achievement of occultation campaigns in Senegal, which include in particular the shipment of the necessary equipment and necessary guidance.



Fig. 3. Flyer summarizing the goal and groups involved in the RISE 5A (Astronomy and Astrophysics Arising Across Africa) project. Bottom left panel photography: Salma SYLLA MBAYE, first Senegalese PhD student in Astronomy, with her supervisor François COLAS from the Paris Observatory, and Marie Teuw NIANE, former Ministry of Higher Education Research and Innovation of Senegal, during the 2018 occultation campaign in Senegal. Credit : The RISE 5A team.

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