Astronomy for development in Africa

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African School of Physics (virtual)
July 2021

Professional path:

 # In the past:

- Serbia
(old Yugoslavia, Bsc)
- Canary Islands
(Spain, MSc, PhD)
- South Africa
(first post-doc)
- Spain
(2 more post-docs)

 # Currently:

- Ethiopia
(assistant professor)
- Spain
(associate researcher)
- Uganda
(honorary lecturer)

Main interests:

 # Research:

- active galaxies
- morphological properties and classification in galaxies
- star formation in galaxies
- galaxy clusters
- galaxy formation and evolution

 # Education, astronomy, and science developments in Africa

A&SS

Astronomy and Space Science in ???

Extending our view from evident short-term toward long-term contributions for the benefit of our society

science

education

technology

To fight poverty in the long-term

Need for <u>long-term</u> planning and financial support

female participation, diversity, and inclusion

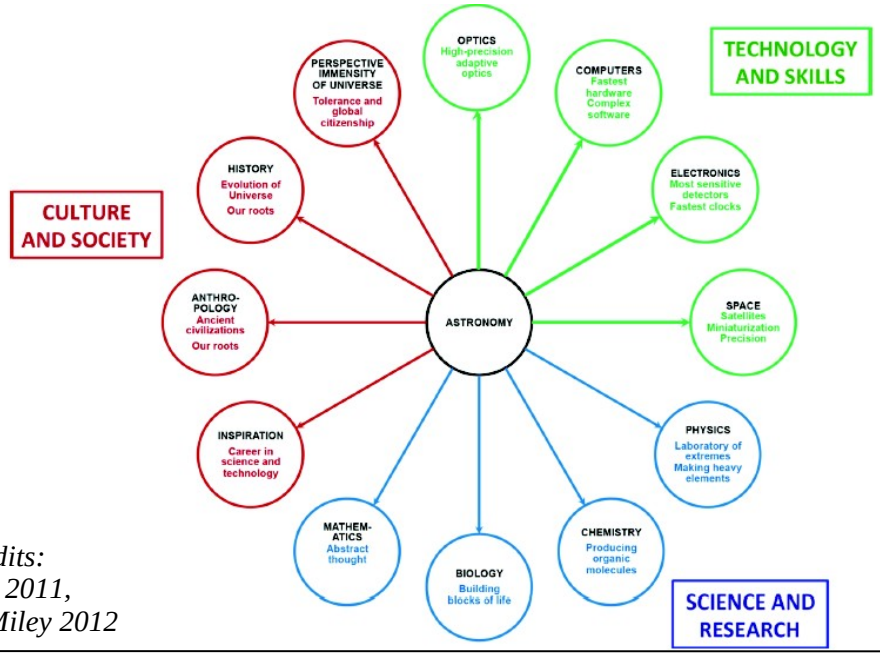
innovation

industrial development with manufacturing in Africa

Local (African) initiatives are fundamental, support of them and collaborations, instead of international programs planned fully from 'outside'.

ASTRONOMY is…

One of the most multidisciplinary sciences

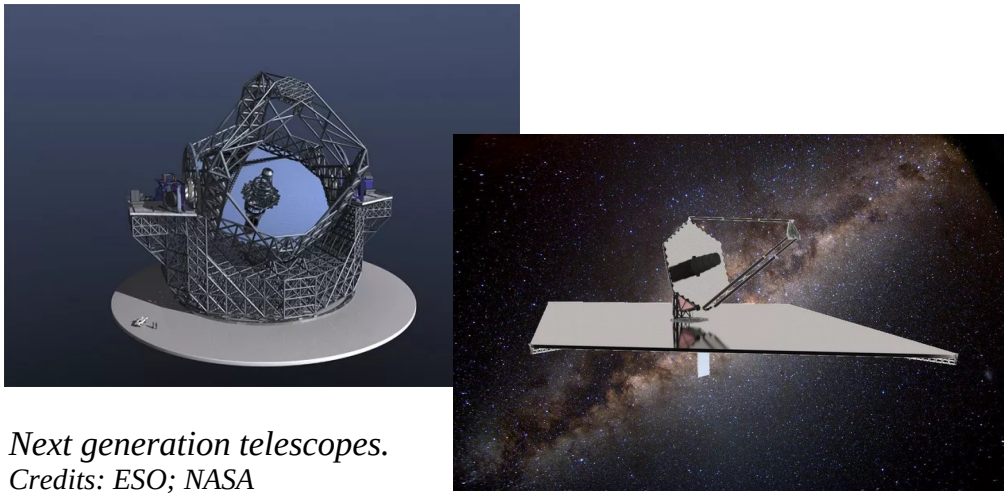


Credits:
IAU 2011,
G. Miley 2012

A powerful tool for promoting education and science, and for empowering girls and women in STEM

Outreach activities in Ethiopia and with street children in Ghana.
Credits: ESSTI/ESSS, E. Viñuales

One of the leading sciences for bringing strong technological developments and innovation



Next generation telescopes.
Credits: ESO; NASA

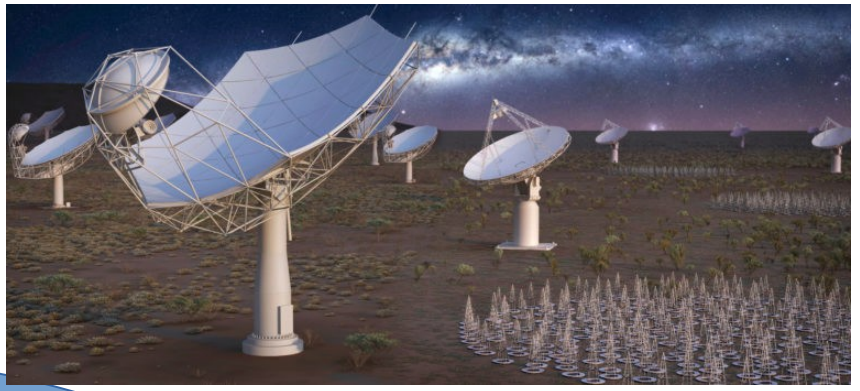
A powerful tool for diplomacy and for promoting peace

SKA AFRICA
SQUARE KILOMETRE ARRAY

Credits: SKA

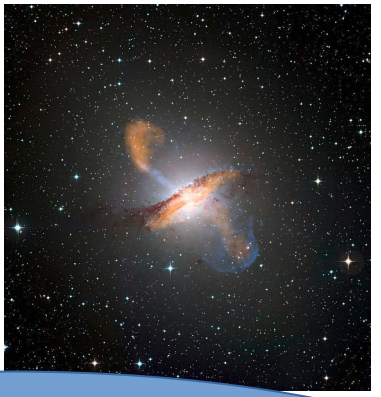
Digital revolution and astronomy

WIFI

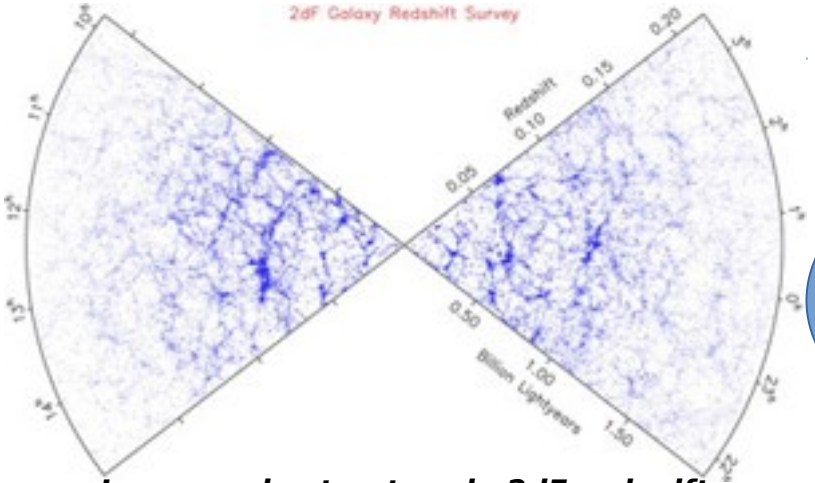


SKA artist's impression.
Credits: SKA

COMPUTING, COMMUNICATION, GPS, IMAGING
(e.g., grid computing, satellite communications, atomic clocks, CCDs, etc.)



Optical, X-rays, and radio view of Centaurus A active galaxy.
Credits: ESO/WFI, MPIfR/ESO/APEX/ A.Weiss et al.; NASA/CXC/CfA/R. Kraft et al.



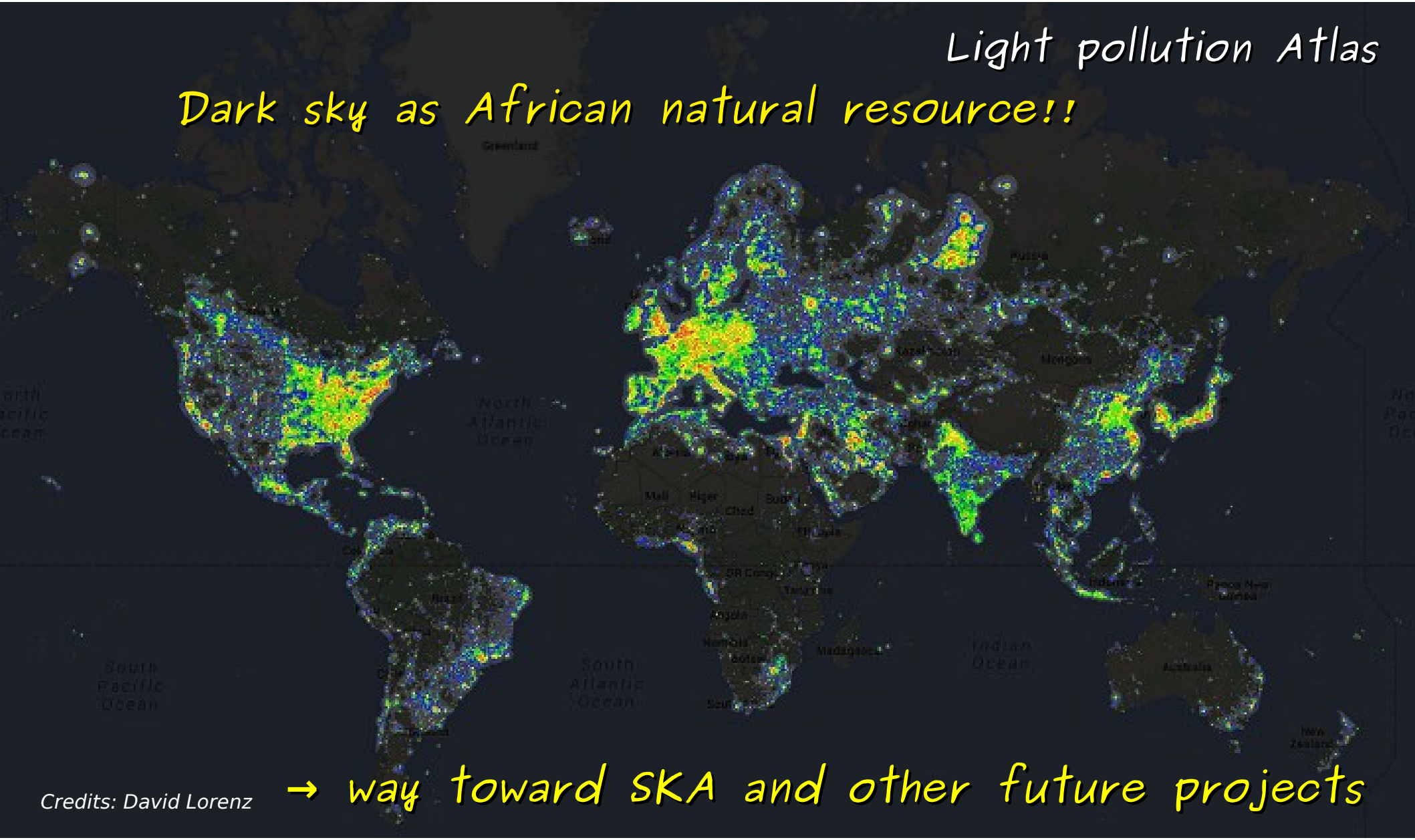
Large-scale structure in 2dF redsgift survey with hundreds of thousands of galaxies.
Credits: 2dF and M. Colles

BIG DATA and new technologies
(e.g., **SKA revolution** and **100,000 times faster data flow** then the current world one)

Check the IAU100 booklet 'From Medicine to Wi-Fi'

Background photo: Tanzania, Watoto Wa Africa children center, 2007. Credits: A. Marsal

Africa has huge potential for astronomy development!!



Chile, Canary Islands (Spain), and South Africa are great examples how dark skies and their conservation can contribute to socio-economical development

4 main astronomical observational sites

Example 1: Teide Observatory, Spain (since 1964)

- 6 solar telescopes (operated by: Germany (x 2), Italy/France, UK, USA, Spain)

- 9 nocturnal telescopes (operated by: UK, Belgium, Spain, ESA, Germany, USA, etc.)

- 5 radio telescopes (again different international collaborations)

Example 2: Roque de los Muchachos Observatory, Spain (since 1985)

> 15 telescopes, including:

- ***Gran telescopio Canarias (10.4m)***
- ***William Herschel Telescope (4.2m)***
- ***Galileo National Telescope (3.58m)***
- ***Isaac Newton Telescope (2.54m)***
- ***MAGIC telescopes***
- ***various experiments for extrasolar planets***

(international collaborations with Germany, UK, Italy, the Netherlands, etc.)

Example → some of the benefits for the Canary Islands and Spain due to astronomy and its dark skies:

- Support from > 20 countries

- Development of state-of-the-art technology

- Establishment of some of the best telescopes

- Access to the observational time and some of the best data for Spanish astronomers

- Strengthening of the Institute of Astrophysics of Canary Islands (IAC) and Spanish astronomy and science

- Development of Spanish science and technology through different national research centers and universities

- Development of high-tech private sector across the country

Example → some of the benefits for the Canary Islands and Spain due to astronomy and its dark skies:

- One of the most important sites for astrotourism

- Law on the Protection of the Astronomical Quality of Observatories, or "The Canarian Sky Act"

- Teide National Park and its peaks have been awarded the "Starlight" certificate as a Tourist Destination and as a Reserve → Mount Teide is the first location to have been declared both a UNESCO World Heritage Site and a "Starlight Tourist Destination".

- Development of the IACTEC center → dedicated to the R + D + i and the transfer of technology and public-private cooperation.

- Opportunity for the establishment of next-generation telescopes

- Astronomy as one of the principal sources of economical growth

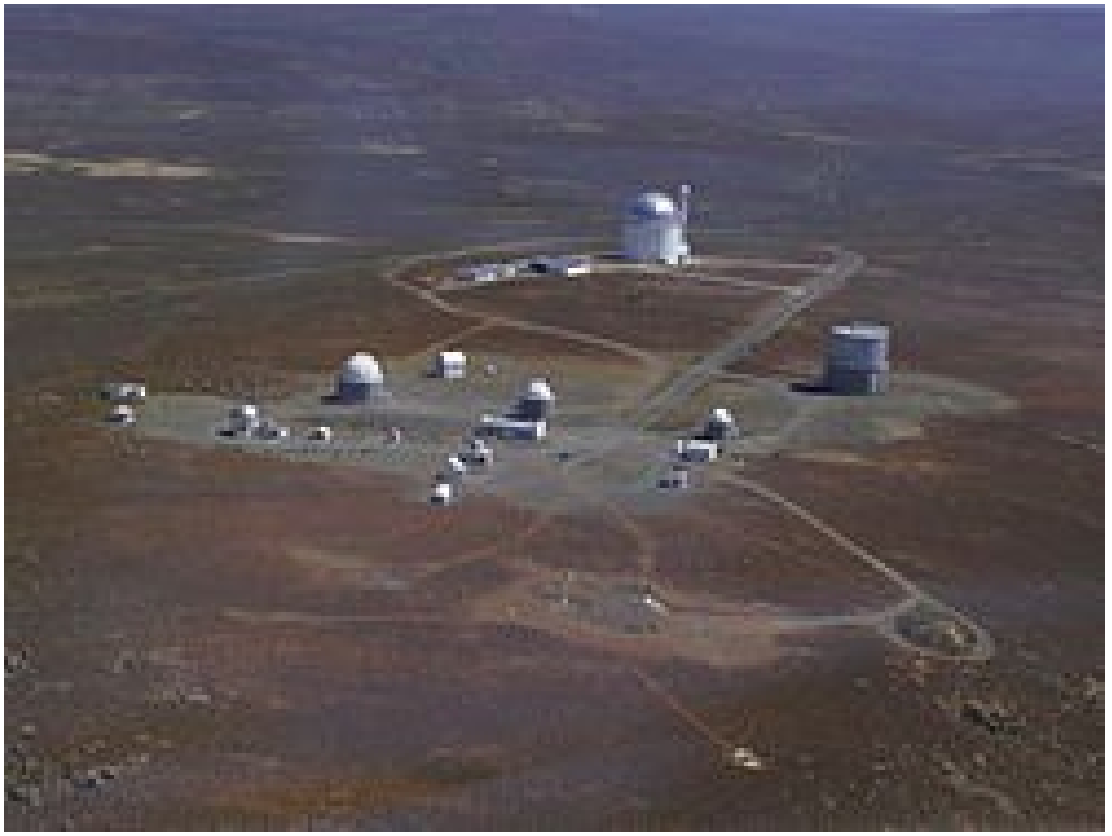
Another example → South African Astronomical Observatory (SAAO), South Africa (since 1972)

- 15 telescopes (different international collaborations, including UK, Japan, Germany, USA, South Korea, etc.)

- 2 geophysical observatories (international consortium)

Some of the benefits:

- Development of South African astronomy and science
- Strong technological development
- Opening the path toward governmental support
- Opening the path toward big projects such as MeerKAT/SKA, Hirax, etc.
- Strong contribution to socio-economical growth of the country

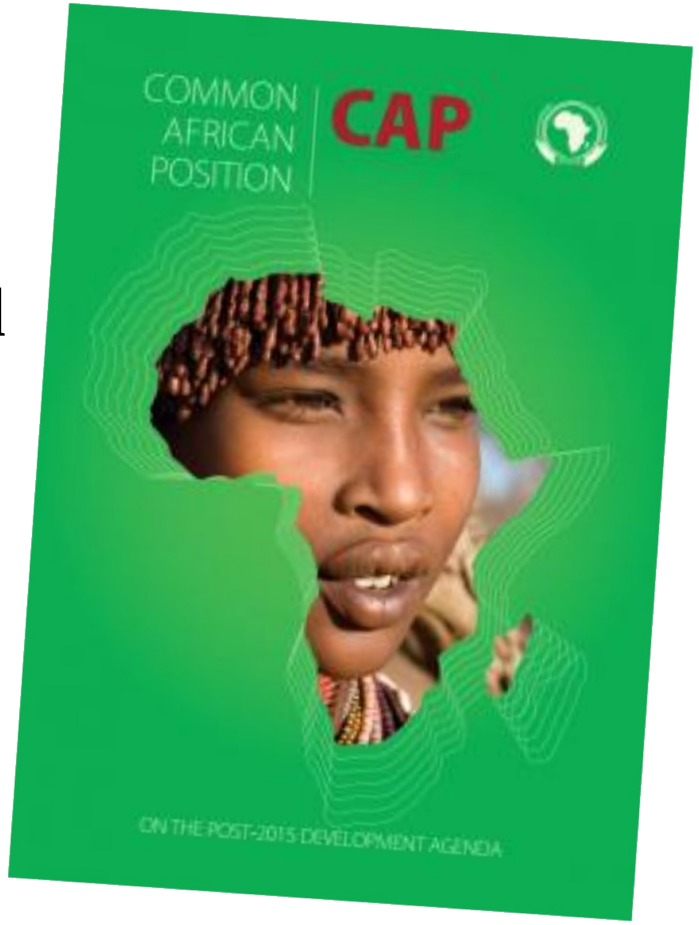


Background photo: Tanzania, Watoto Wa Africa children center, 2007. Credits: A. Marsal

Continental initiative

Common African Position on the Post-2015 Development Agenda

→ **pillar 2 (out of 6): science, technology, and innovation (through optimal utilisation of space and geo-spatial technologies)**

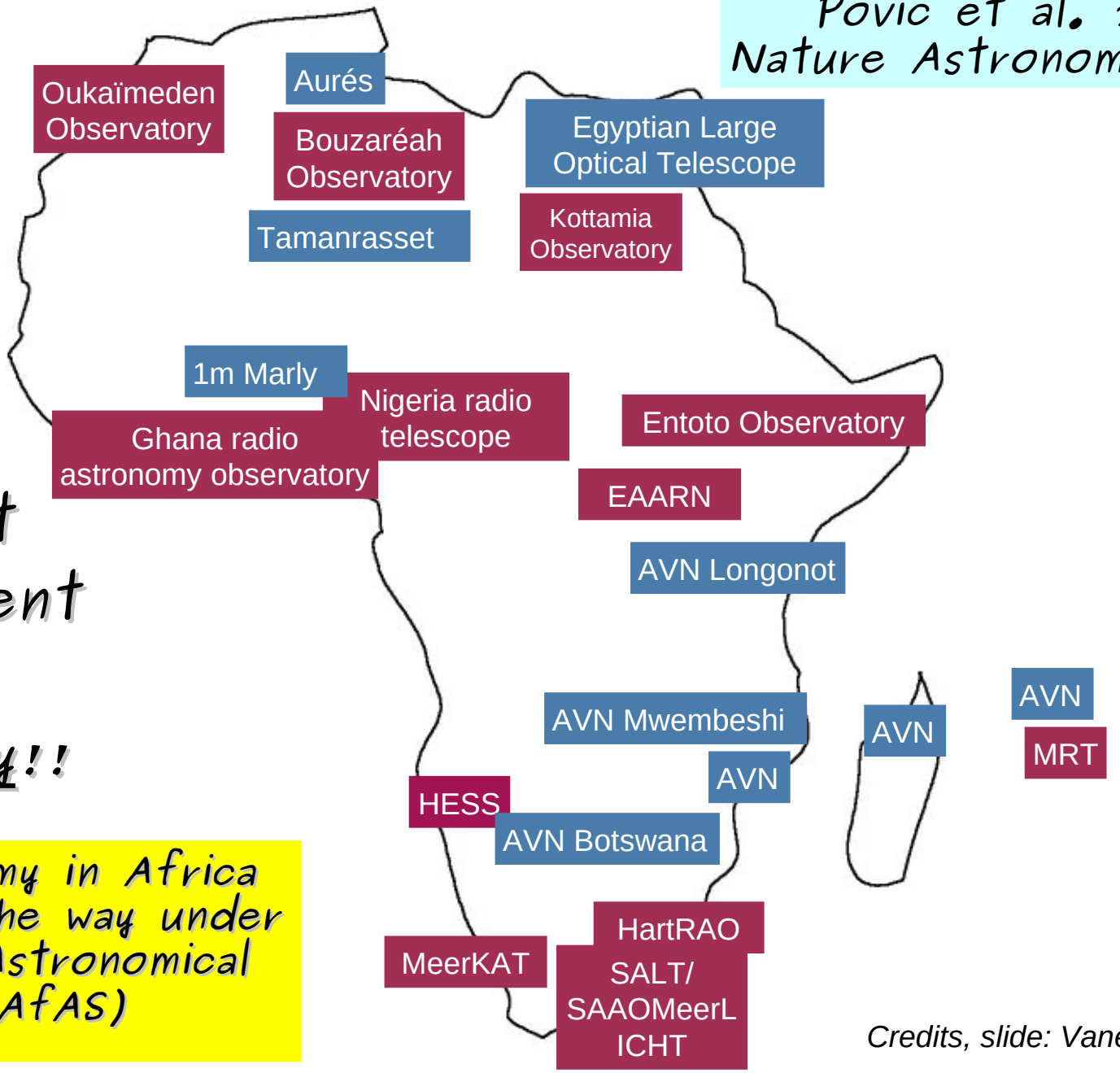


- **First African Space Strategy**

(selecting: Earth observations, navigation and positioning, satellite communications, and space science and astronomy)

- **Established African Space Agency in 2018 (based in Egypt)**

Pović et al. 2018, Nature Astronomy, 2, 507



Important development in astronomy!!

New 'Astronomy in Africa Survey' is on the way under the African Astronomical Society (AfAS)

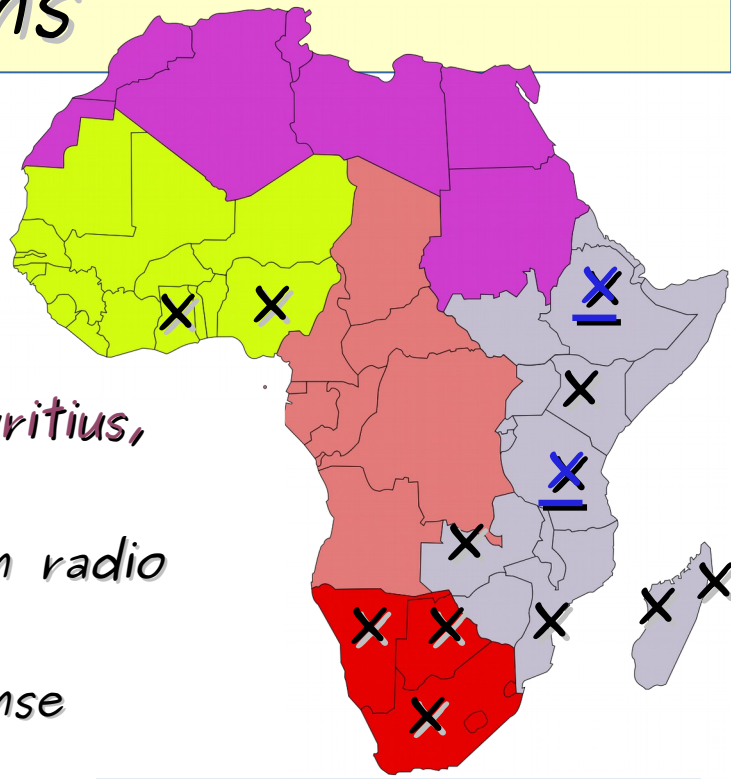
Credits, slide: Vanessa McBride

Some of the main achievements and future plans

In radio

SKA AFRICA
SQUARE KILOMETRE ARRAY

AVN
AFRICAN VLBI NETWORK



- including Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, South Africa, and Zambia

- MoU in 2017 between all members to collaborate on radio astronomy

- 32m Ghana Radio Astronomy Observatory in Kuntunse (since 2017)

Ghana Radio Astronomy Observatory

Credits: GSSTI

Credits: AVN

Starting from 2025 (SKA phase 2):
thousands of dishes planned
to be built in SA
and other African partner countries

Some of the main achievements and future plans

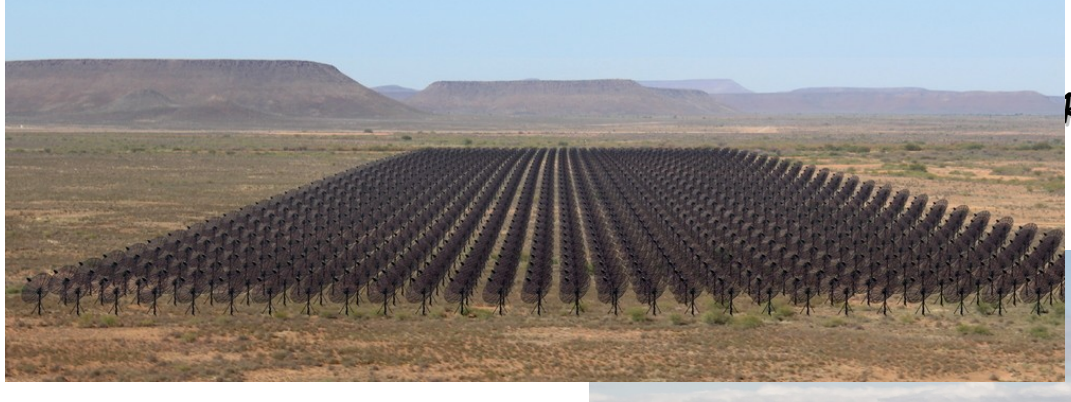
In radio

- **Nigeria** successfully assembled and installed 3m radio telescope (mainly for HCD)

- **Mauritius** (in collaboration with India) operated a radio telescope since 1992

- **Namibia** to build the first millimetre-wave radio telescope in Africa (together with Netherlands), site testing under preparation in **Tanzania**

- **South African Radio Astronomy Observatory – SARAO** (SKA-SA + HartRAO)



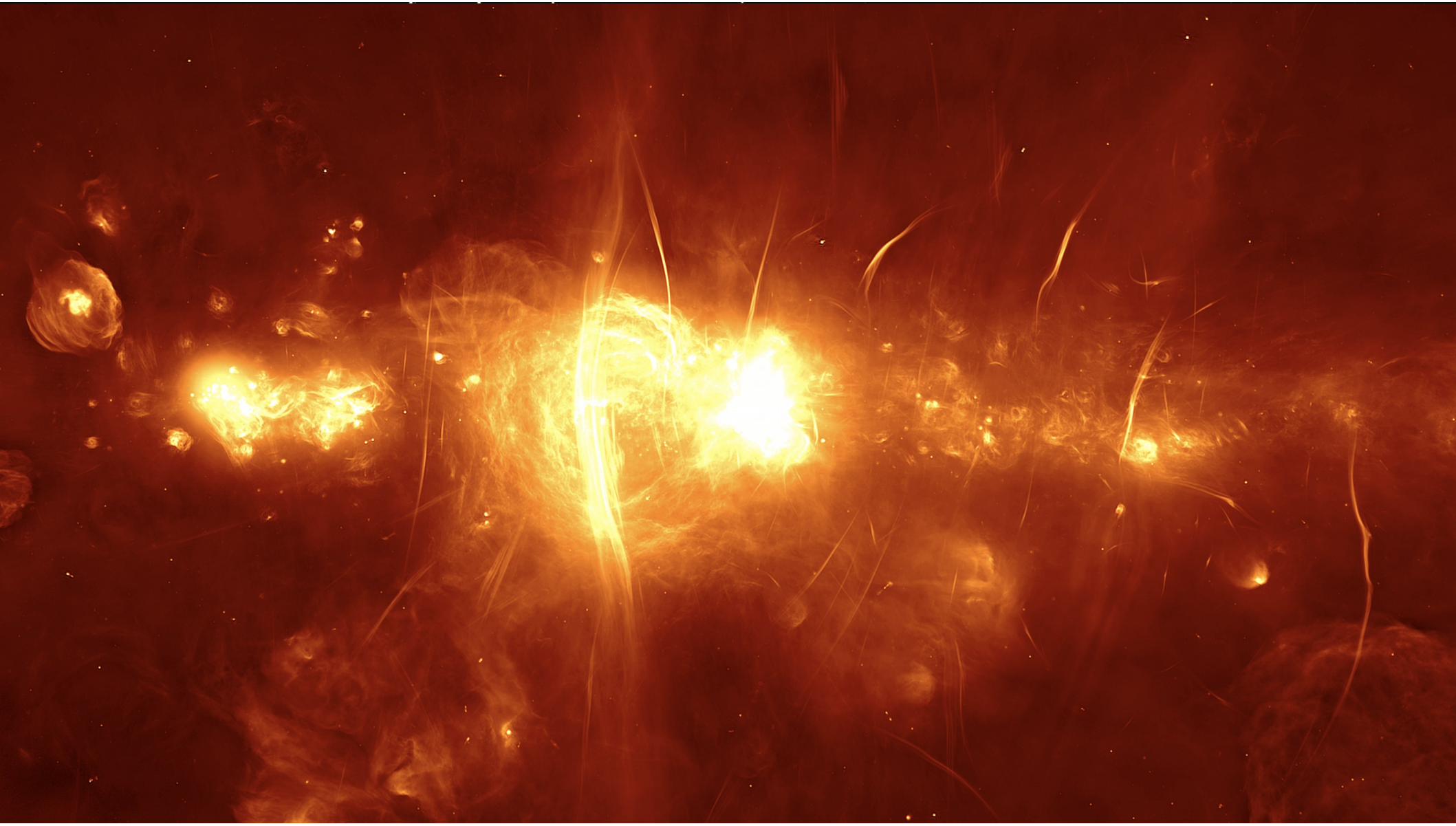
- HIRAX (Hydrogen Intensity and Real-time Analysis eXperiment) in South Africa (1000 6m dishes, 400-800 MHz)

Illustration of the final HIRAX array in the Karoo desert. Credits: HIRAX team

First phase of **MeerKAT** (13.5m 64-dish radio array) completed in 2018

Credits: MeerKAT

The most detailed view of MW centre - now coming from Africa



Credits: MeerKAT team

Giant elliptical galaxy in optical

Credits slide: F. Camilo

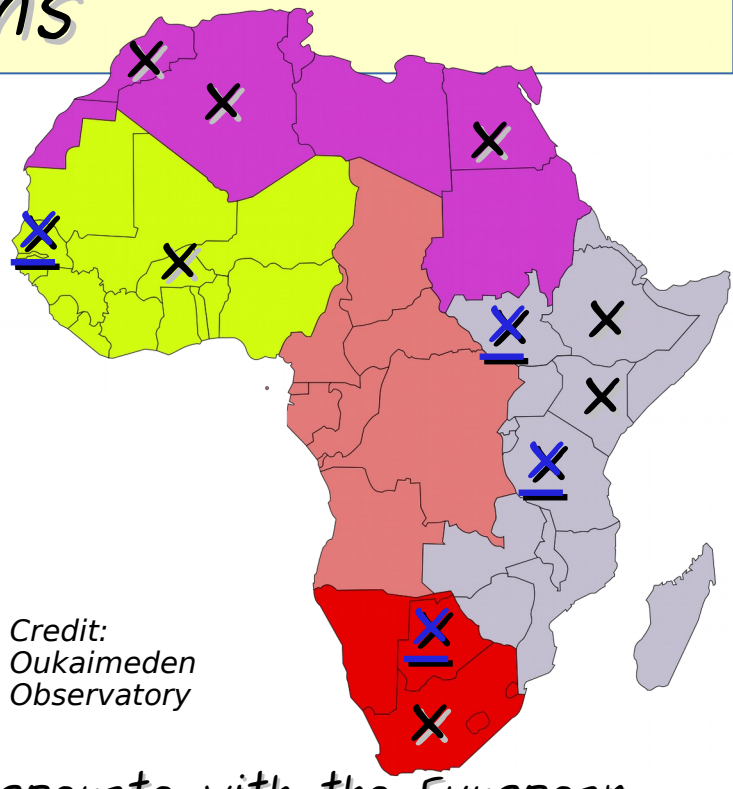
The same giant elliptical galaxy observed with MeerKAT, in radio

Credits: F. Camilo, and MeerKAT team

Some of the main achievements and future plans

In optical

- In **Morocco** strong development since inauguration of **Oukaimeden Observatory** in 2007 (including 60cm TRAPPIST-North)



Credit: Oukaimeden Observatory

- New **Observatoire National des Aurès** in **Algeria** to cooperate with the European Virgo and to optically follow up gravitational wave detections (under site testing)

- Plans to build ~ 6m **Egyptian Large Optical Telescope** (site testing)

- **Entoto Observatory** built in **Ethiopia** with two 1m telescopes

Credit: G. Gebreegziabher

Some of the main achievements and future plans

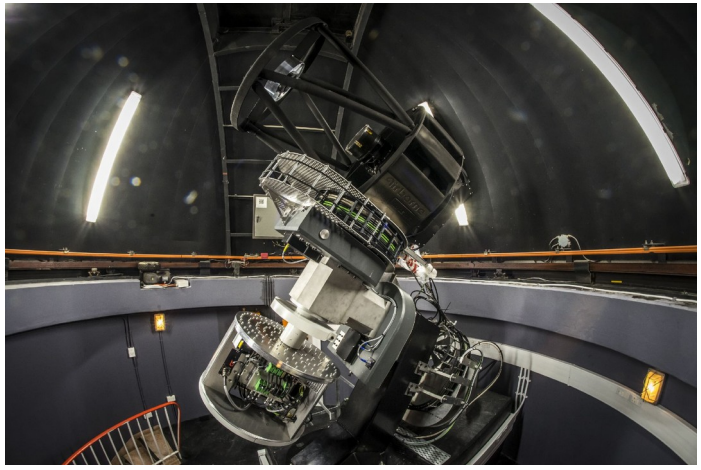
In optical

- Astronomical observatory under development in **Burkina Faso**, with 1m telescope (moved from La Silla)

Shipping of the MARLY telescope to Burkina Faso.

Credit: C. Carignan

- **Kenya** first optical observatory on the way in collaboration with UK (site testing)



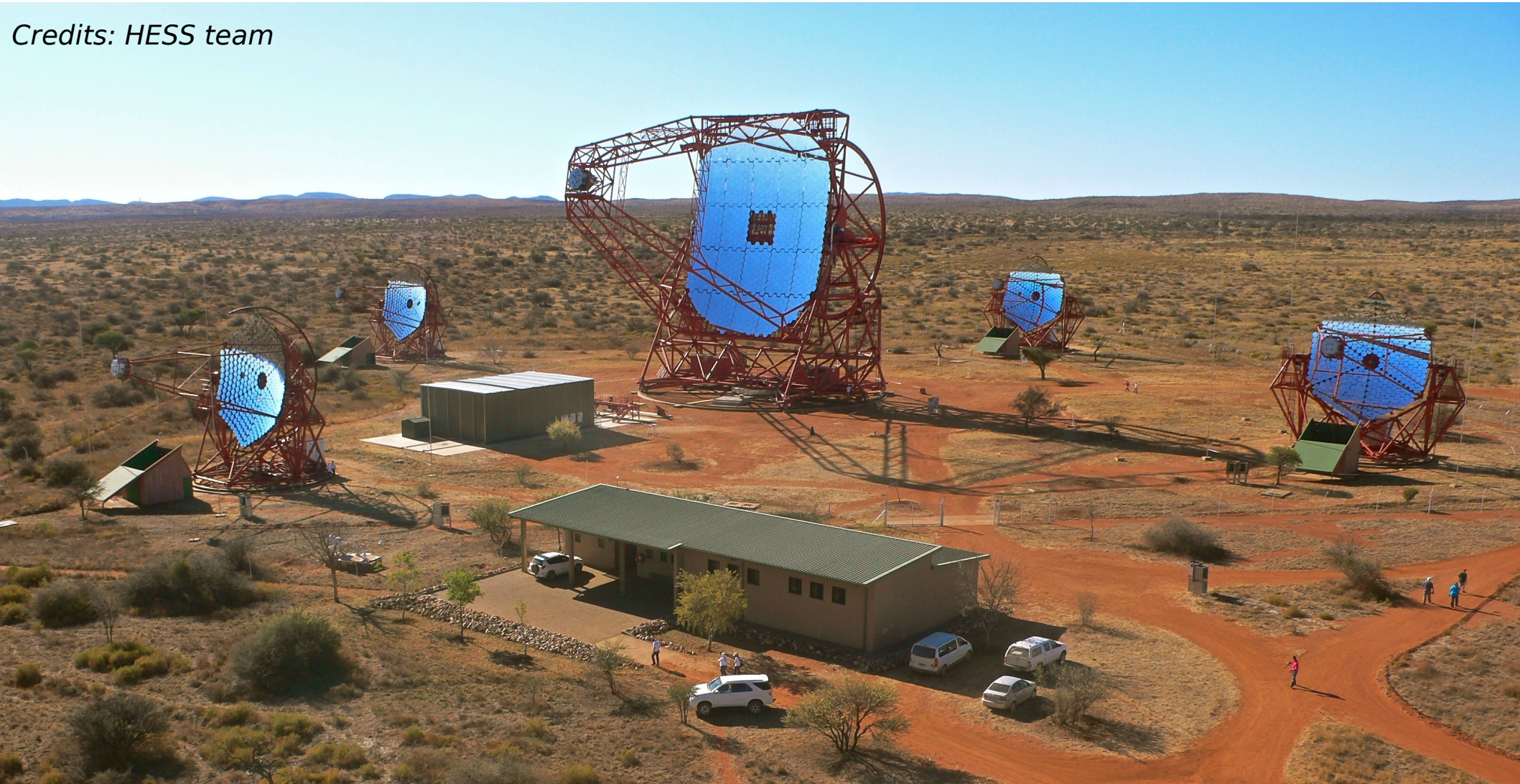
New **MeerLICHT** robotic 0.65m optical telescope synchronized with MeerKAT

- In **South Africa 11m SALT** + some 20 other **South African** and international telescopes under SAAO

Some of the main achievements and future plans

In γ-rays

H.E.S.S. in Namibia
– five Cherenkov telescopes
(Phase II since 2012)



Human Capacity Development

Remarkable progress!!

- New post-graduate programmes in A&SS (Uganda, Rwanda, Kenya, Ethiopia, Sudan, Namibia, Nigeria, SA, Egypt, Morocco, etc.)

- Public awareness and outreach increased everywhere

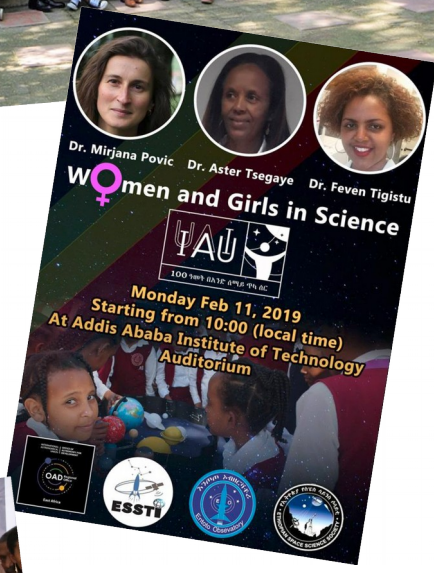
- IAU-OAD constant support (> 50 funded projects, > 250.000 EUR)

- Hundreds of MSc students trained through NASSP in South Africa

- AVN training: Development in Africa with Radio Astronomy (DARA) and SKA-HCD

- ISP long-term support (including East African Astronomy Research Network - EAARN)

DARA training



Feb 11 in Ethiopia

NASE teachers training

AfAS
African Astronomical Society

Astronomy Survey

To be the voice of astronomy in Africa and to contribute to addressing the challenges faced by Africa through the promotion and advancement of astronomy

Some of the committees:

- Science Committee
- Outreach Committee
- African Network of Women in Astronomy (AfNWA)

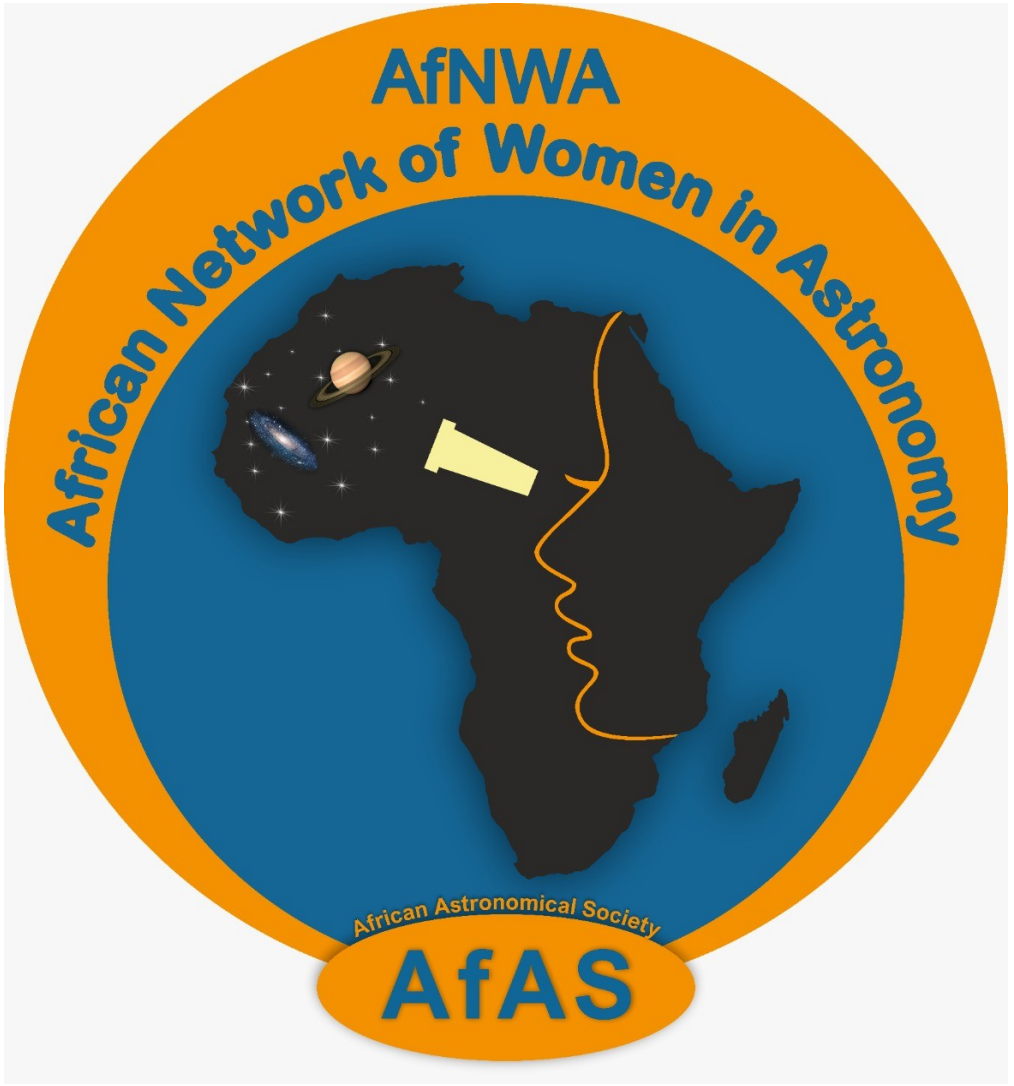
AfAS re-established

Cape Town, March 2019

Empowering women and girls through astronomy → need for AfNWA

The African Network of Women in Astronomy (AfNWA) is an initiative that aims to connect all women working in astronomy and related fields in Africa and to guarantee the participation of women in all astronomy and science developments.

Established under the African Astronomical Society (AfAS) as one of its sub-committees, to empower women and girls in science through astronomy.



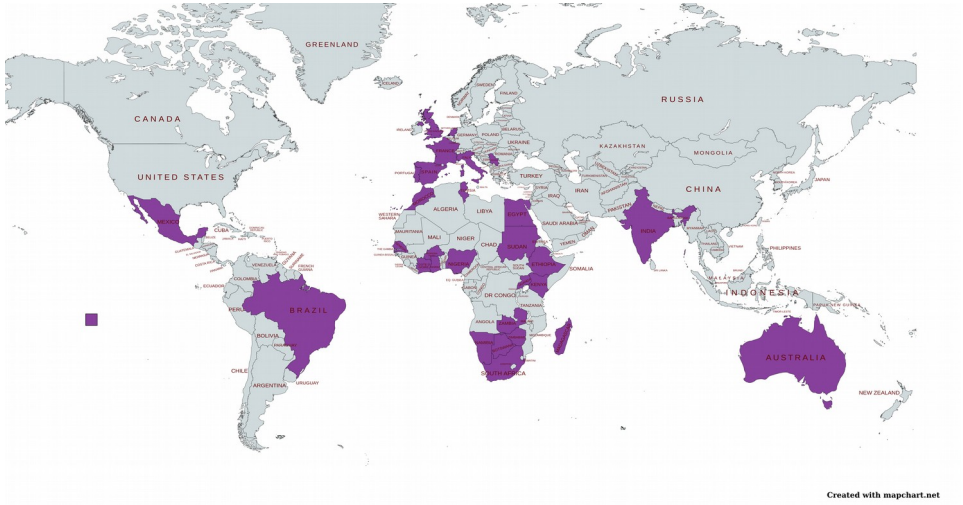
https://www.africanastronomicalsociety.org/afnwa/

Who is behind AfNWA and its current status?

Coordinating team:

Current status:

- Publicly launched in January 2021
- By now > 90 members from 30 countries (~ 80% women, ~20% men)
- Only 18% are senior/faculty members, > 80% are early-career researchers, PhD and MSc students

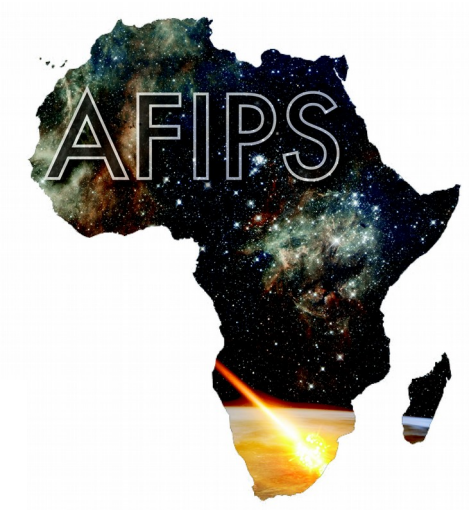


AfNWA is timing to:

- strengthen the links between female researchers, collaborations, support, and supervision
- strengthen professional and leadership skills
- attract girls to STEM through astronomy outreach and role modeling
- understand the main factors responsible for the lack of women in science and explore the ways to retain women in astronomy

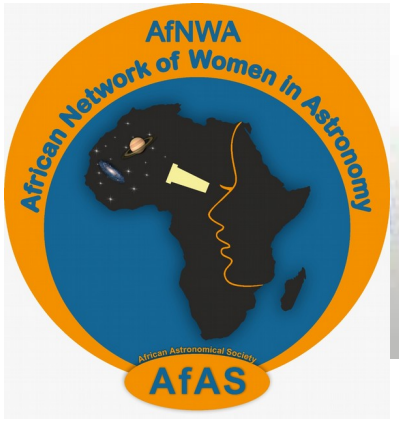
Some of the continental initiatives

ISP
International Science Programme



The African Initiative for Planetary and Space Science

HCD through SKA and AVN, NASSP and AIMS



AfAS
African Astronomical Society

DARA
DEVELOPMENT IN AFRICA WITH RADIO ASTRONOMY

OAD
OFFICE OF ASTRONOMY FOR DEVELOPMENT

EA-ROAD, SA-ROAD, WA-ROAD

europlanet SOCIETY

SEA for development

Ethiopia
as an example

ESSTI

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Ethiopian Space
Science & Technology
Institute

We explore the Universe for the benefit of our people!!

<u>Vision</u>: to use SS&T for improving the main challenges of Ethiopia, and its socio-economic and environmental status

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ESSTI offices in Addis Ababa

- **astronomy & astrophysics**
- **geodesy**
- **remote sensing**
- **space physics and applications**
- **space engineering**
- **satellite operations**
- **high performance computing and data administration**

Entoto Observatory (~ 10km out of Addis)

Astronomy for development: example of Ethiopia

Establishment of Entoto Observatory (2 x 1m telescopes)

→ ***possibilities to do both photometry and high-resolution spectroscopy***

→ ***possibilities to strengthen research***

→ ***possibility for human capacity development***

→ ***possibilities to strengthen international collaborations***

→ ***opens possibility for new projects and infrastructure development (example of recent collaboration with Russia)***

Main advantages:

→ ***good infrastructure***

→ ***close to equator***

→ ***lack of infrastructure at these latitudes in Africa***

Main problems:

→ ***light pollution and extension of cities***

→ ***lack of human resources and capacity***

Entoto Observatory, 2 x 1m telescopes, near Addis Ababa

Entoto 1m telescope, Ethiopia (ESSTI/EORC)

Azimuth-Altitude mount

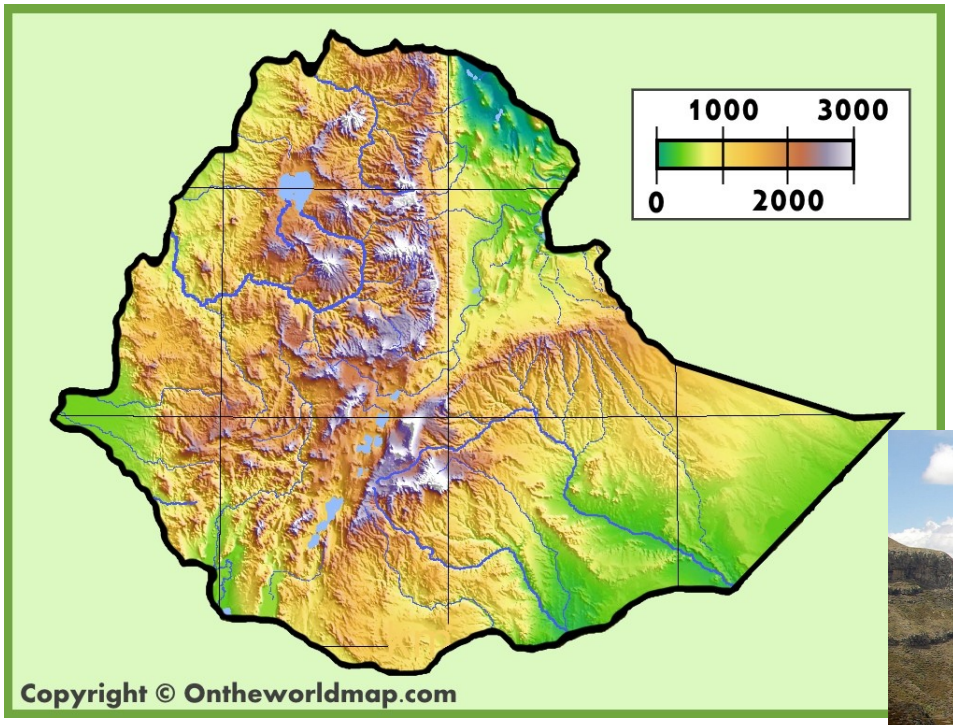
Hyperbolic M1 and M2

Image credits: ASTELCO, ESSTI/EORC

Astronomy for development: example of Ethiopia

Entoto observatory, Lalibela site testing

→ **infrastructure development**
→ **technological development**



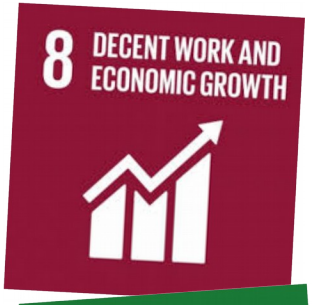
Entoto Observatory, 2 x 1m telescopes, near Addis Ababa

Abune Josef site testing, > 4000m, near Lalibela

Astronomy for development: example of Ethiopia

Important to have in mind (on the long-term):

→ ***best site selection (for finding the best site in terms of weather conditions, but also light pollution, available infrastructure, sustainability, etc…)*** → *higher chances for attracting international partners*



→ ***conservation and protection of selected site*** → *environmental benefits and potential touristic sites*

→ ***political stability*** → *stronger institutions*

→ ***long-term investment*** → *long-term benefits*

Astronomy for development: example of Ethiopia

Post-graduate program (MSc/PhD):
first MSc and PhD students in astronomy (attached to some of public universities);
6 PhD and 12 MSc graduates, 9PhD + 9 MSc currently

→ **improving the level of education in the country**

Some of our first Msc and PhD students

Training on Panchromatic Universe by Ignacio Garcia de la Rosa (IAC), 2017

Ghion Ashenafi, one of our engineers at Entoto

Human capacity building of our students and young staff members (numerous trainings, schools/workshops, research visits/trainings abroad)

→ **improving skills toward general socio-economic growth**

Astronomy for development: example of Ethiopia

Research: 3 groups in extragalactic, stellar, and cultural astronomy

Institutional development:
establishment of departments, structure, creation of committees, guidelines edition, etc.

Proposals development,
organisation of meetings/conferences, etc.

→ first publications, knowledge generation
→ science development
→ visibility given to the ESSTI and Ethiopia
→ HCB
→ strengthening international collaborations
→ stronger institutions
→ funds mobilisation
→ tourism, etc.

4th Middle East and Africa IAU Regional Meeting, 2017

8th African Space Leadership Conference, 2019

First EWASS SS on African-European collaborations, UK, 2018

It’s time for Africa!

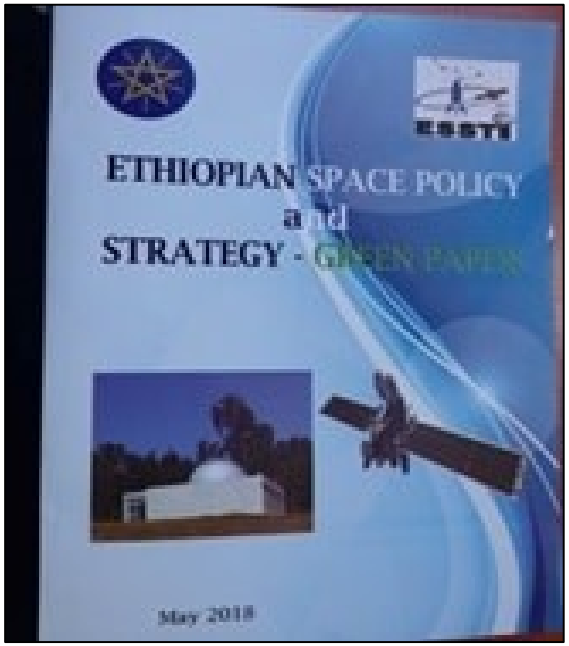
Keep in mind: The first IAU GA to be held in Africa in 2024!!

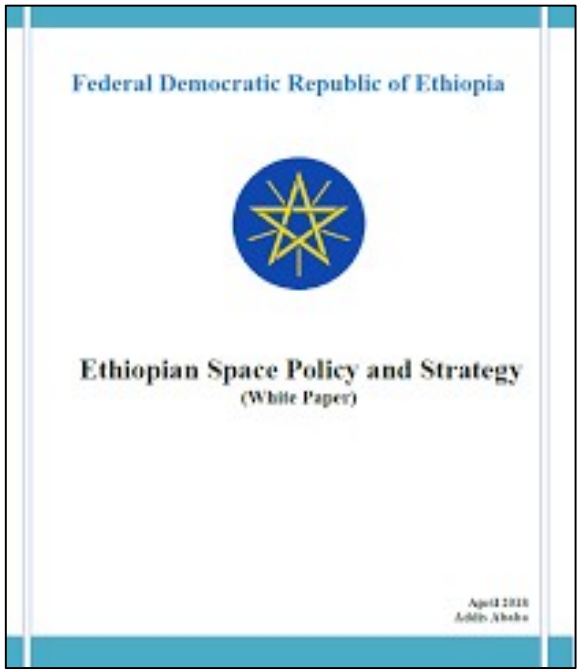
Astronomy for development: example of Ethiopia

Policy framework:

- **First Ethiopian Space Policy and Strategy: green and white papers (published)**
- **Ethiopian Space Science and Technology Road Map (2021-2050)**
  - **under development**

→ **political engagement**





Organised discussion on Space Policy and Strategy

Astronomy for development: example of Ethiopia

Teachers trainings

- teaching teachers astronomy, but also how to teach astronomy using practical approach

- Network for Astronomy School Education, Galileo Teachers Training Program, NUCLIO, GHOU

→ improving level of education

→ promoting STEM

→ road toward more equality

Astronomy for development: example of Ethiopia

Education, outreach, public awareness (in collaboration with ESSS):

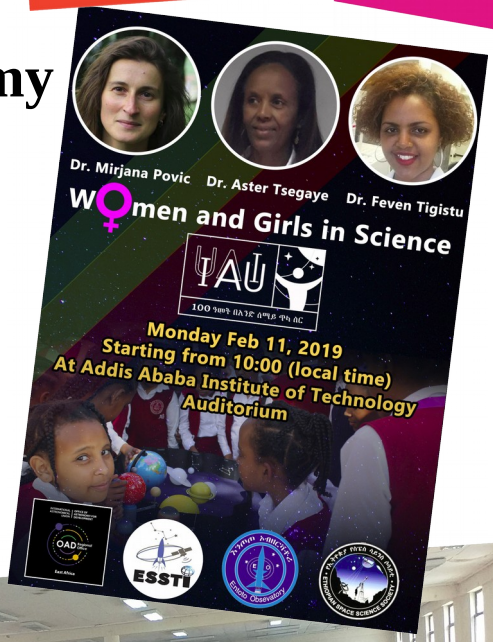
- schools visits
- public talks
- Entoto visits
- stargazing activities
- astrobus (in 2017 and 2019)
- 'Inspiring stars' - bringing astronomy to people with visual difficulties
- making national events out of astronomy (e.g., exoplanet naming, solar eclipse event)

Astronomy for development: example of Ethiopia

Girls and women in science:

- STEM for GIRLS in Ethiopia initiative, SEWiST (through Nature Research for Inspiring Science Award)

- Coming: The African Network of Women in Astronomy (AfAS-AfNWA)



Astronomy for development: example of Ethiopia

Support given from Ethiopia to East-African region and Africa

- with students supervision and research: 3 projects in collaboration with Rwanda, Uganda, and Tanzania (+ South Africa)

- with lecturing: in Uganda, Rwanda, and Kenya

- with teachers trainings (Uganda, Tanzania, Kenya, Ghana, Zambia)

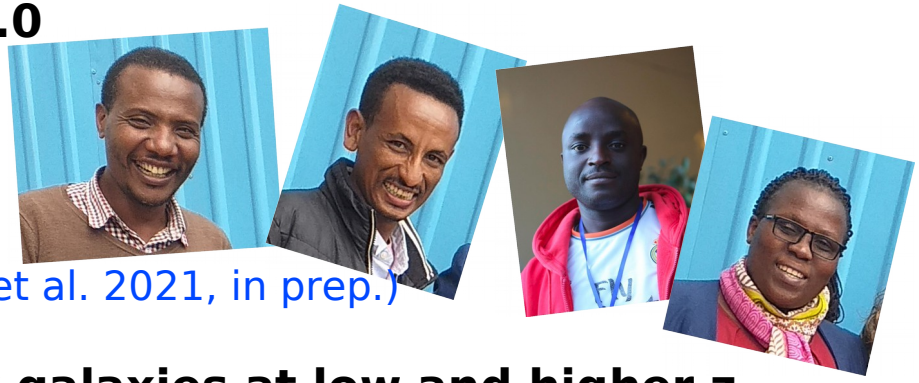
- with HCD through trainings/workshops/schools (e.g., ISYA, 1st Sub-Saharan School in Astronomy, 1st EA School in Astronomy in Tanzania, 6th EAAS workshop, etc.)

- with joint projects (e.g., MATERNA, 5A)

- with different activities through EA-ROAD based in Ethiopia

Projects under the extragalactic group in Ethiopia and East-Africa

- Properties of galaxies in clusters up to z ~ 1.0
(Beyoro-Amado et al. 2019, MNRAS, 485, 1528;
Beyoro-Amado et al. MNRAS, 2021, 501, 243)



- Morphological properties of active galaxies
(Getachew et al. 2021, MNRAS, under revision; Getachew et al. 2021, in prep.)

- Properties of AGN and non-AGN green valley galaxies at low and higher z
(Mahoro et al. 2017, MNRAS, 471, 3226; Mahoro et al. 2019, MNRAS, 485, 452; Nyirasengiyumva et al. 2021, MNRAS, in close submission; Mahoro et al. 2021, MNRAS, submitted; Mahoro et al. 2021b, in prep.)

- Dichotomy of radio-loud/radio-quiet quasars and the effect of radio jets on the gas (Terefe et al. 2021, in prep)

- AGN and Star-Formation Properties of Inside-out Assembled Galaxy (IOAG) Candidates at z < 0.1 (Zewdie et al. 2020, MNRAS, 498, 4345)

- Multiwavelength morphological study of ultra-hard X-ray AGN and their stellar populations in the BASS survey
(Bilata et al. 2021, MNRAS, in close submission; Pović et al., in prep.)

- Variability of nearby quasars (Tamirat et al. 2021, in prep.)

- Testing the alternative method to measure the accretion rate in Galaxies (Guelle et al. 2021, in prep)

- Characterisation of LINERs and retired galaxies at z < 0.1

How AGN research can contribute to development?

8 DECENT WORK AND ECONOMIC GROWTH

Human capacity building

10 REDUCED INEQUALITIES

Science development

Knowledge generation

17 PARTNERSHIPS FOR THE GOALS

Education development

4 QUALITY EDUCATION

Stronger international collaborations

5 GENDER EQUALITY

Support for technological development

Astronomy development

Outreach and public awareness

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Visibility given to the ESSTI

Institutional development

ILLUSTRATION: NASA, DANA BERRY / SKYWORKS DIGITAL

Credits image: Universe Today

Thank you very much for your attention

Outreach program during the IAU 356 symposium (2019), and 11 of Feb 2021

Solar eclipse observations in June 2020 at north of Ethiopia. Credits: ESSS and ESSTI