

Astronomy and development in Africa for the benefit of our society

(a journey of 20 years between two passions)

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Astronomy Site Testing and Training Workshop, Nairobi, Kenya
19–22 March 2025

Content of the talk:

- Astronomy in Africa

(brief introduction and summary of the current status)

- Astronomy to achieve UN Sustainable Development Goals (SDGs) in Africa
(through examples)

- Entoto Observatory in Ethiopia

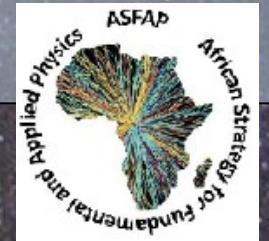


Astronomy in Africa

(brief introduction and summary of the current status)

Based on:

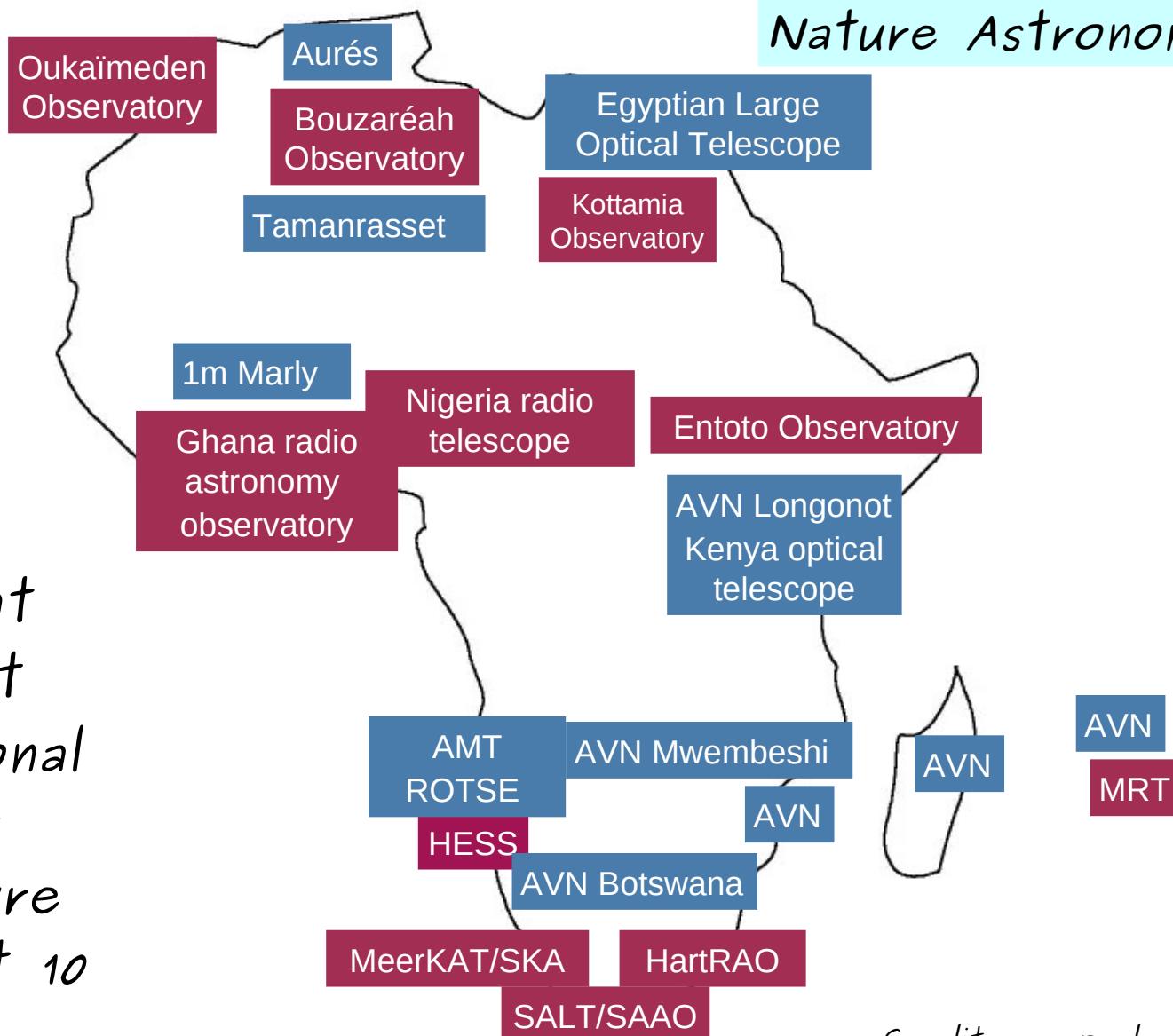
- Povic et al. 2018, Nature Astronomy, 2, 507
- Astronomy in Africa Survey
- ASFAP Astrophysics and Cosmology Final Report



Astronomy as an emerging science in Africa

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

Existing
Forthcoming



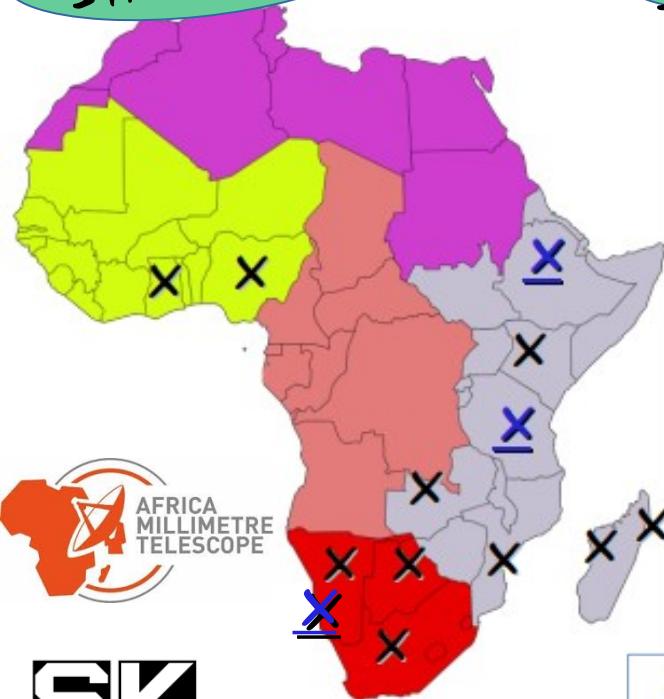
An important development in observational astronomy infrastructure over the last 10 years!!

Credits, map design:
Vanessa McBride



Main infrastructure developments

In radio



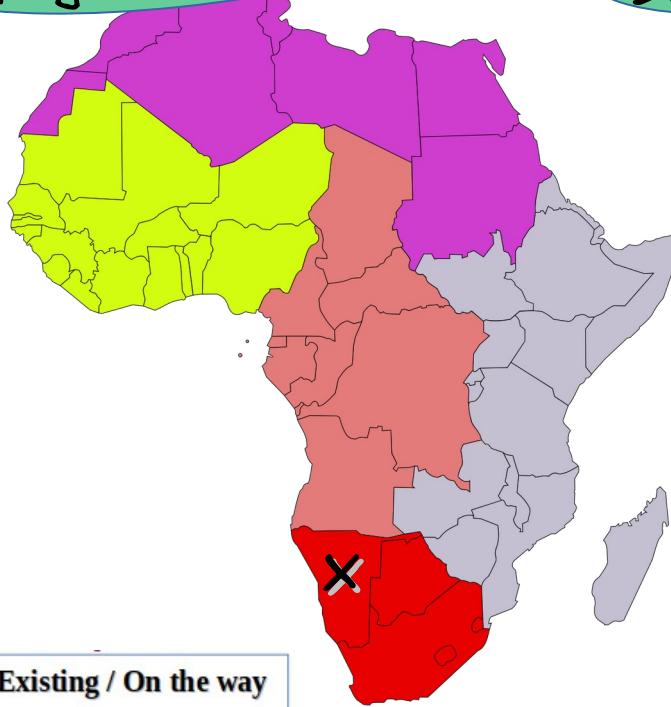
SKA AFRICA
SQUARE KILOMETRE ARRAY



Credits: MeerKAT

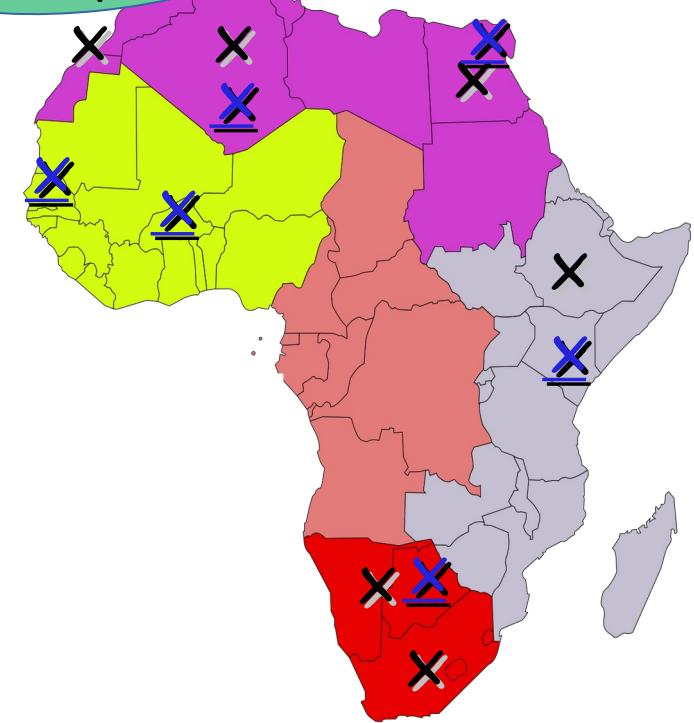


In gamma-rays



Credits: HESS team

In optical



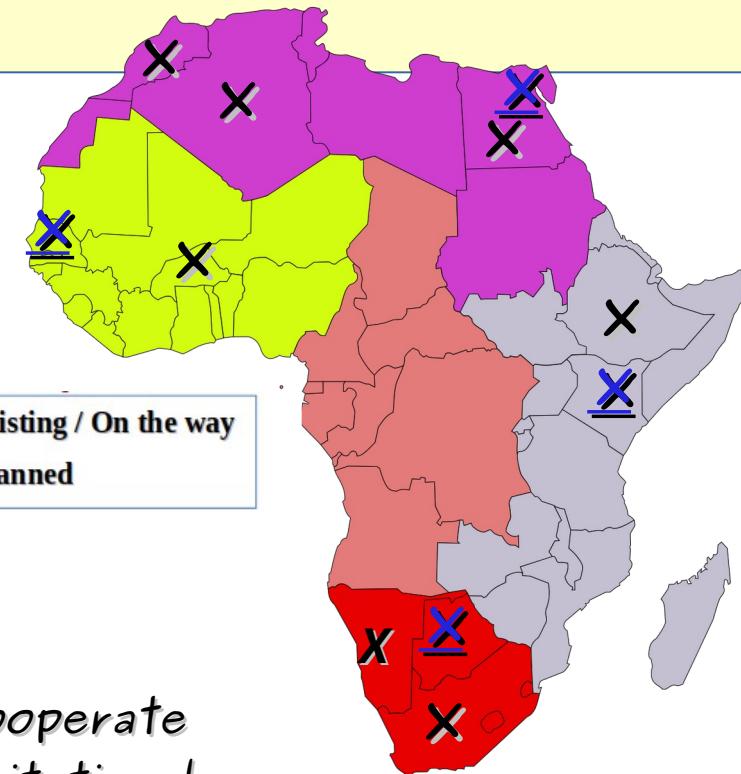
Credits: SAAO team

+ start of underground facilities



Main infrastructure developments in optical

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



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

- **Kottamia Observatory** in Egypt (1.88m),
plans to build ~ 6m **Egyptian Large Optical Telescope** (site testing)
→ Yosry Azzam's talk



- **Entoto Observatory** built in Ethiopia with two 1m telescopes, Lalibela site testing

Credit: G. Gebreegziabher



Main infrastructure developments in optical

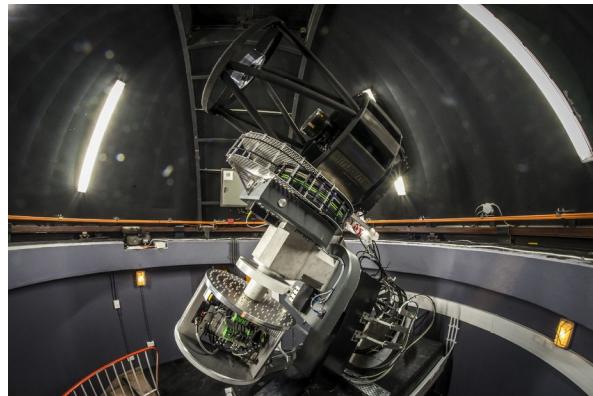
- Astronomical observatory under development in Burkina Faso, with 1m telescope (moved from La Silla)

Shipping of the MARLY telescope to Burkina Faso.

Credit: C. Carignan

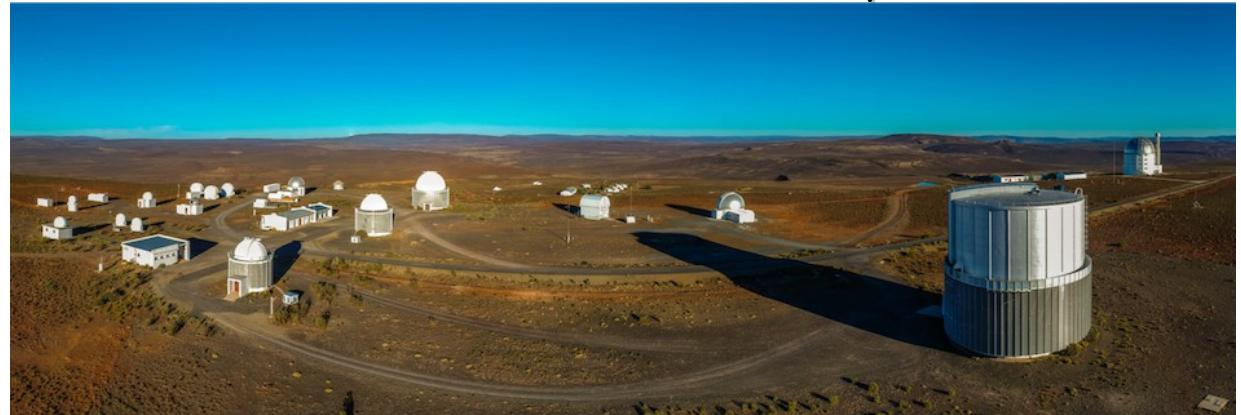


- Kenya first optical observatory planned in collaboration with UK (site testing)



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

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



- ROTSE telescope on the way in Namibia

Credit: SAAO

- Optical telescopes in Senegal and Botswana under planning

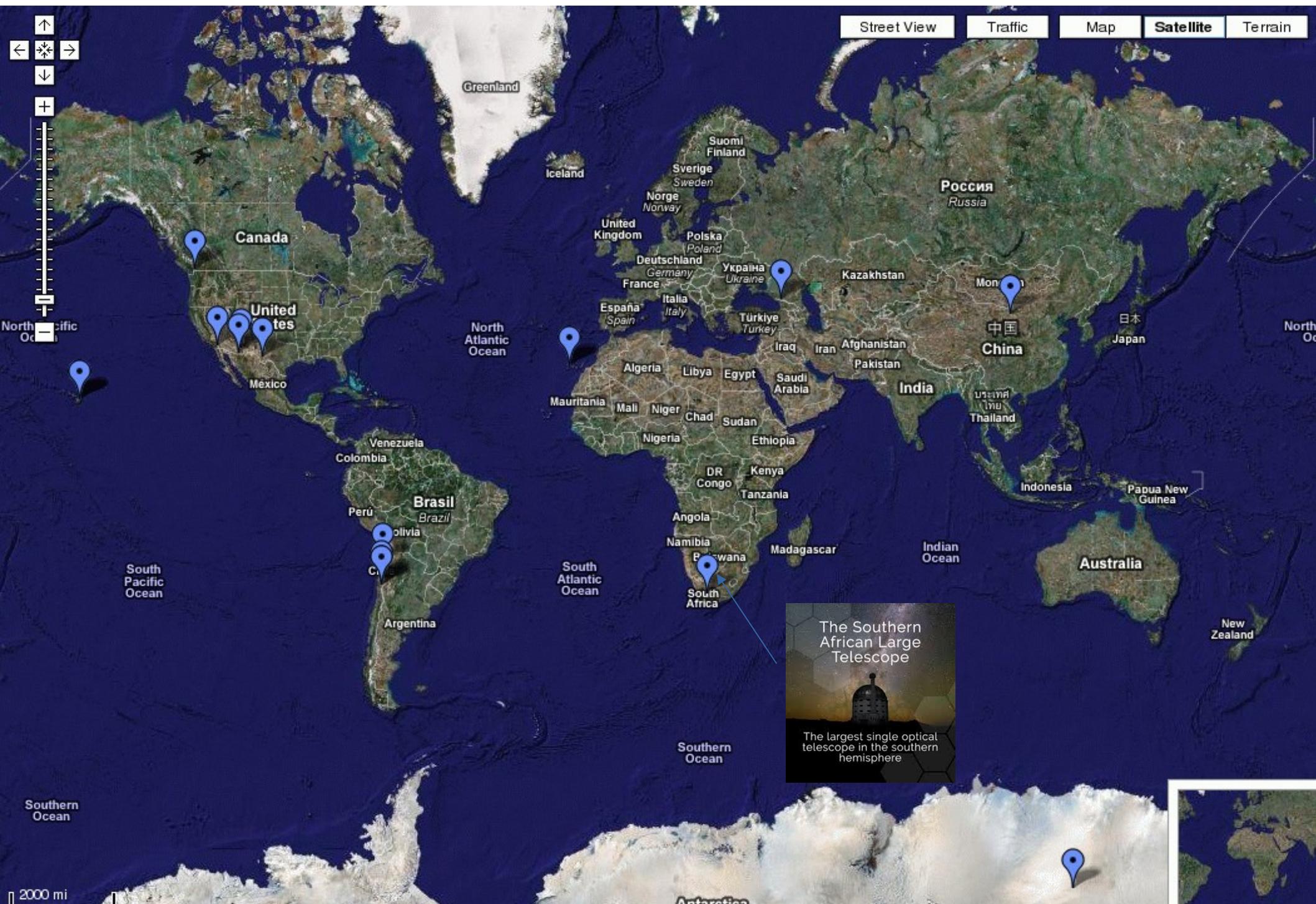
Main infrastructure developments in optical – future plans

African Integrated Observation System (AIOS)
→ David Buckley's talk



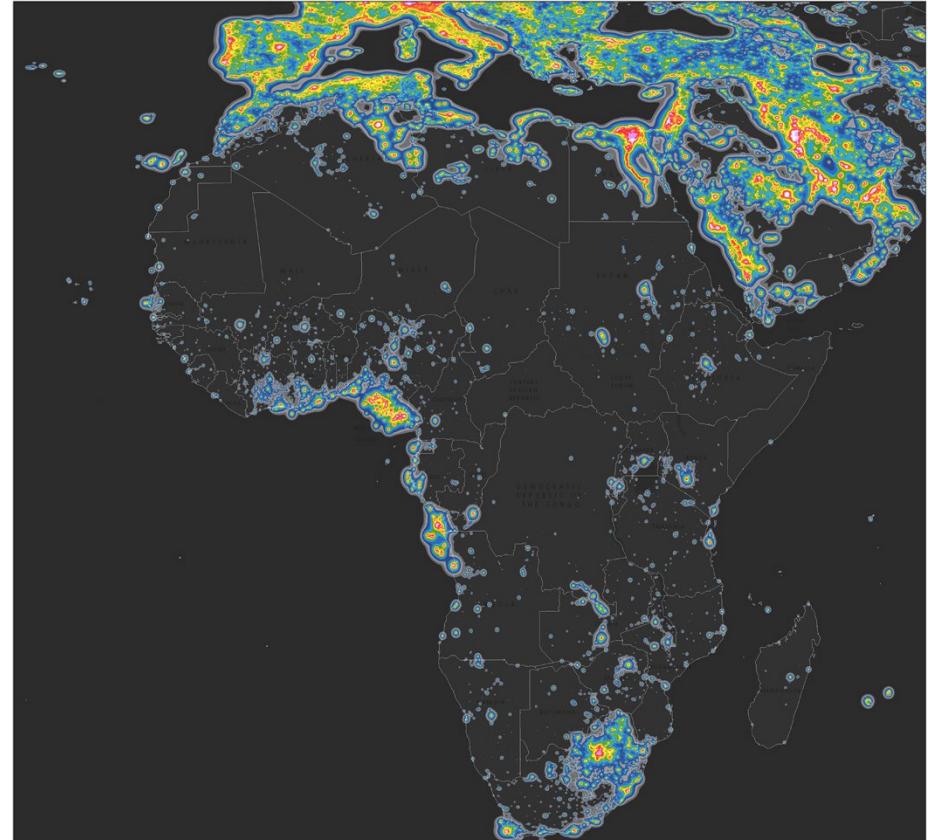
Image credits: AfAS

Location of the world largest 4m–11m optical telescopes

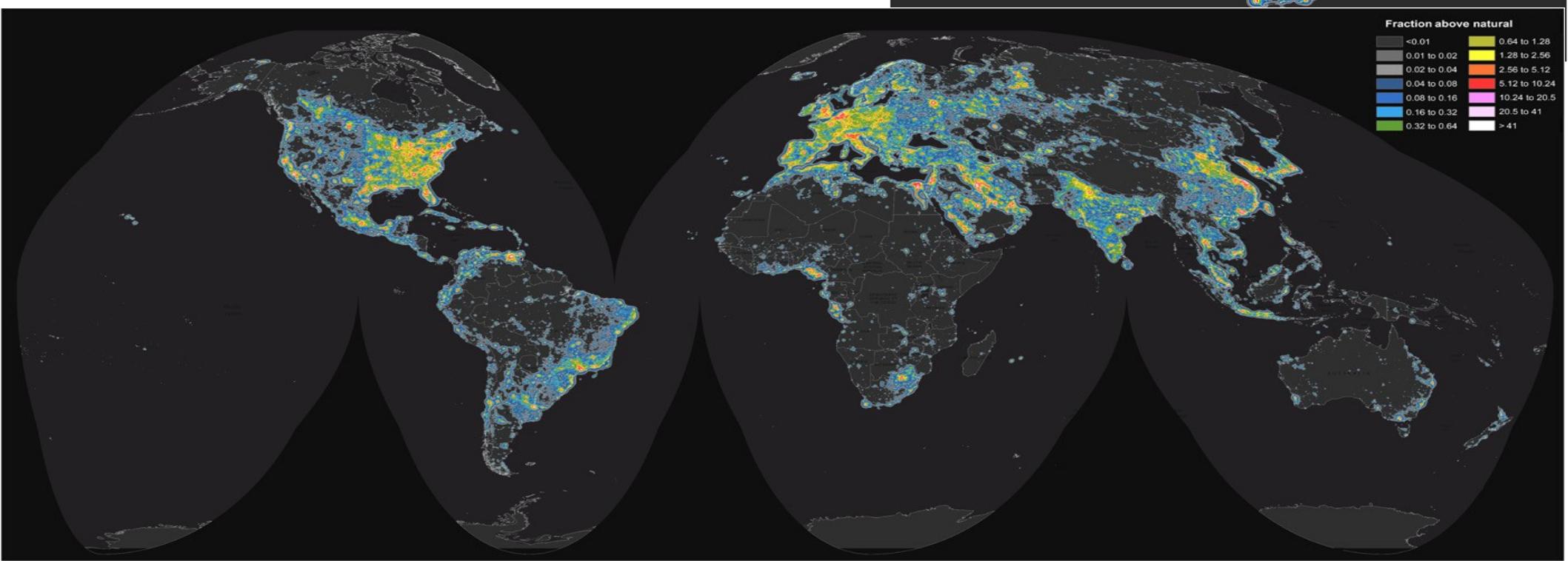


Map of artificial night sky brightness

→ Africa has a huge potential for the development of ground-based optical astronomy



Falchi et al. 2016, Science Advances



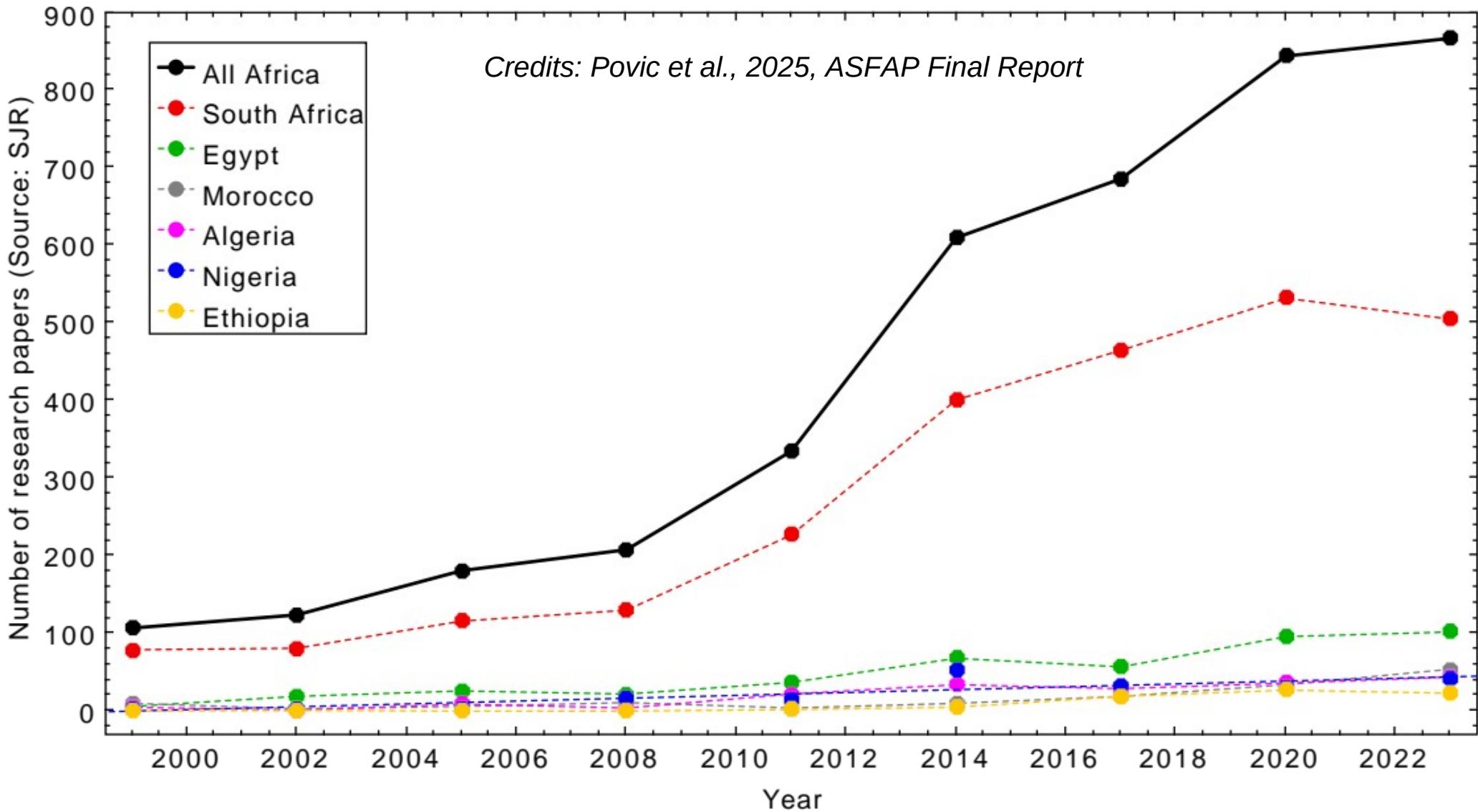
Astronomy in Africa: infrastructure, institutional development, human capacity building, site testing



Map of amateur astronomical societies.
Credits: Niruj M. Ramanujam/AfAS



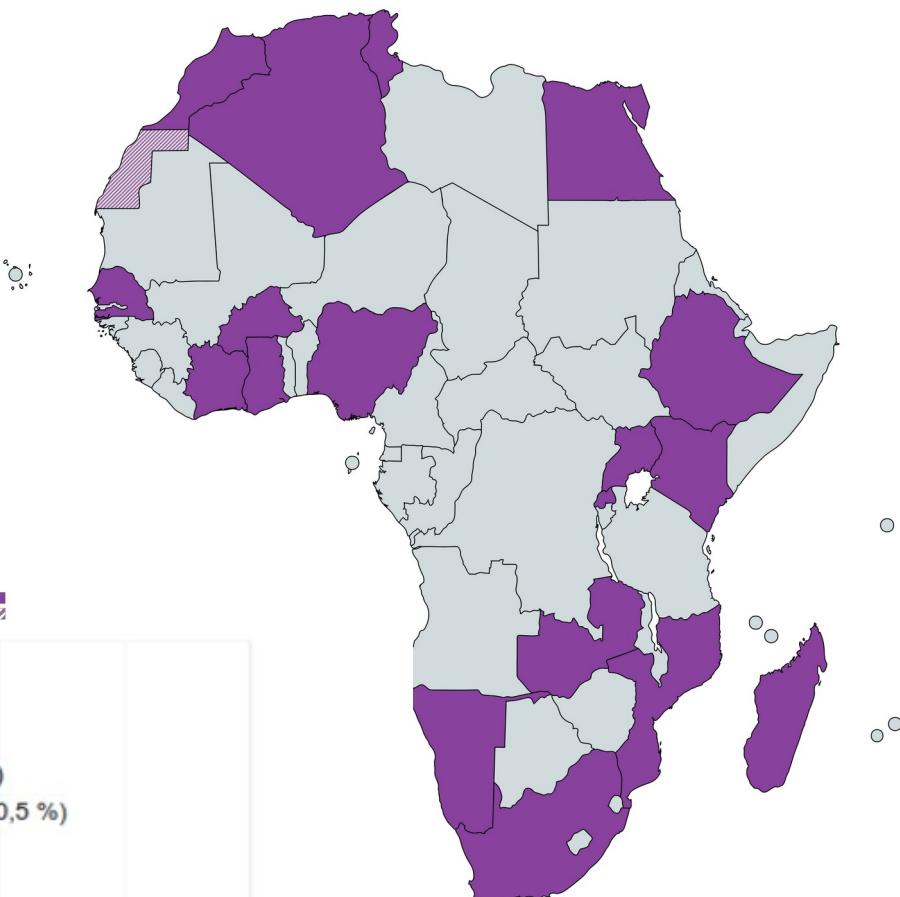
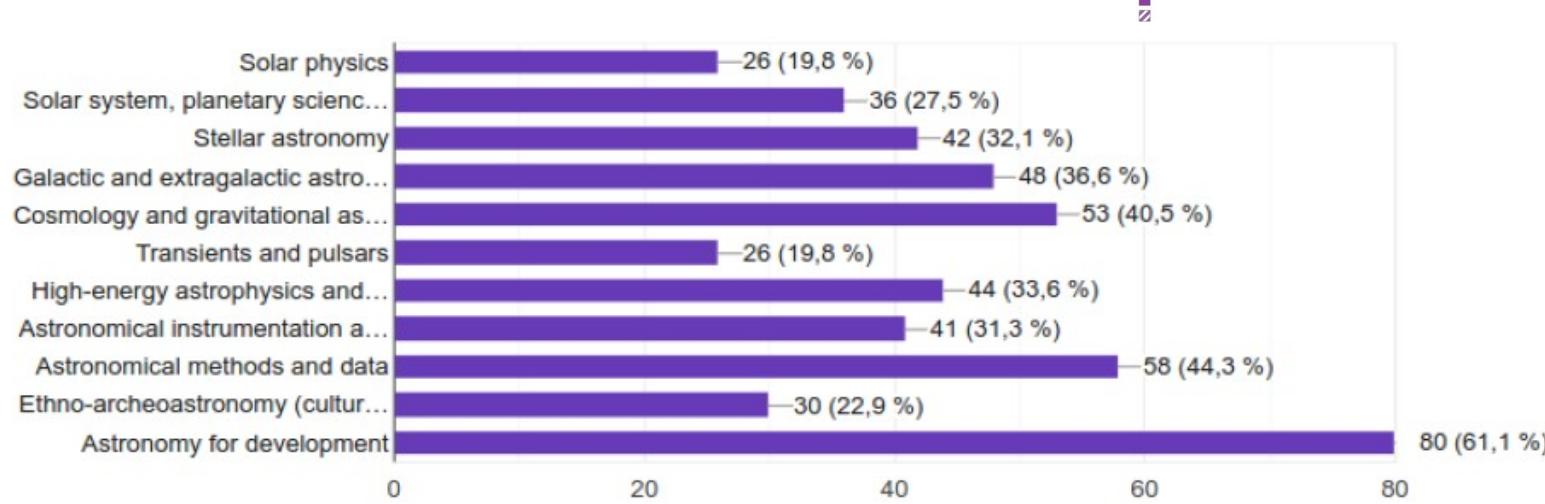
Status in research (peer-reviewed) papers (source: SJR)



The number of publications in Africa has tripled in the last 15 years
→ 3% and 1.8% of the top 10 countries and of world production, respectively

Astronomy in Africa survey

- ~ 60 feedbacks received
(senior researchers)
- from 18 countries



Signs of astronomy growth in Africa

- New post-graduate programs in A&A across the continent (e.g., Egypt, Ethiopia, Ghana, Kenya, Morocco, Namibia, Nigeria, Rwanda, South Africa, Sudan, Uganda, etc.)
- Strong increment in the number of professional astronomers and research (e.g., number of research papers tripled in 10 years - source SJR)
- Significant infrastructure development in observational astronomy and many site testings
 - strong institutional development (new research centers, space agencies, astronomy departments under the universities, etc.)
- Establishment of the African Astronomical Society (AfAS) with different committees (science, education/outreach, AfNWA, etc.)
- Public awareness and outreach increased everywhere,
 - > 70 amateur astronomical societies
 - Change in the political engagement (e.g. AU post-development agenda, African Space Agency, new policies and strategies, etc.)

Principal difficulties/challanges

- Astronomy development from scratch
- Limited number of human resources + limited qualified sector to meet all needs
- Lack of supportive infrastructure for scientific development
- Lack of funding (secured in the long-term) and support from local governments + many day-to-day difficulties (including uninterrupted power, internet...)
- Astronomy in Africa is still not accessible to all countries!!

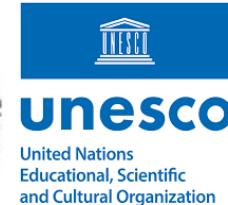
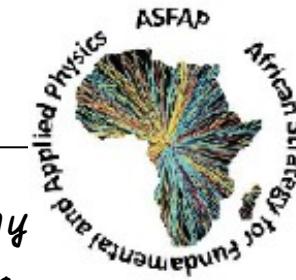
Principal difficulties/challanges

- Work **overload**, including **teaching**, and lack of time for research
- Lack of funding for contracting MSc and PhD students, or postdocs, for establishing a research group, for facilities including computers
- Attracting new students, how much students are prepared
- Uncertainty due to non-permanent positions
- Administration of higher institutions has grown exponentially in the last decades, taking away a lot of time that could be better used
- Limited telescope time available for African researchers

Principal difficulties/challanges

- Mobility of African researchers, visa problems even when the funding is secured
- Living far from the country of origin
- Low salaries
- High publishing rates of prestigious international journals, high subscription fees
- Need to raise awareness among the general public and policy- and decision-makers about the importance of astronomy and science for African growth and inclusion
- Political instability, conflicts

- Systemic inequalities (recommendations given in the strategy document)



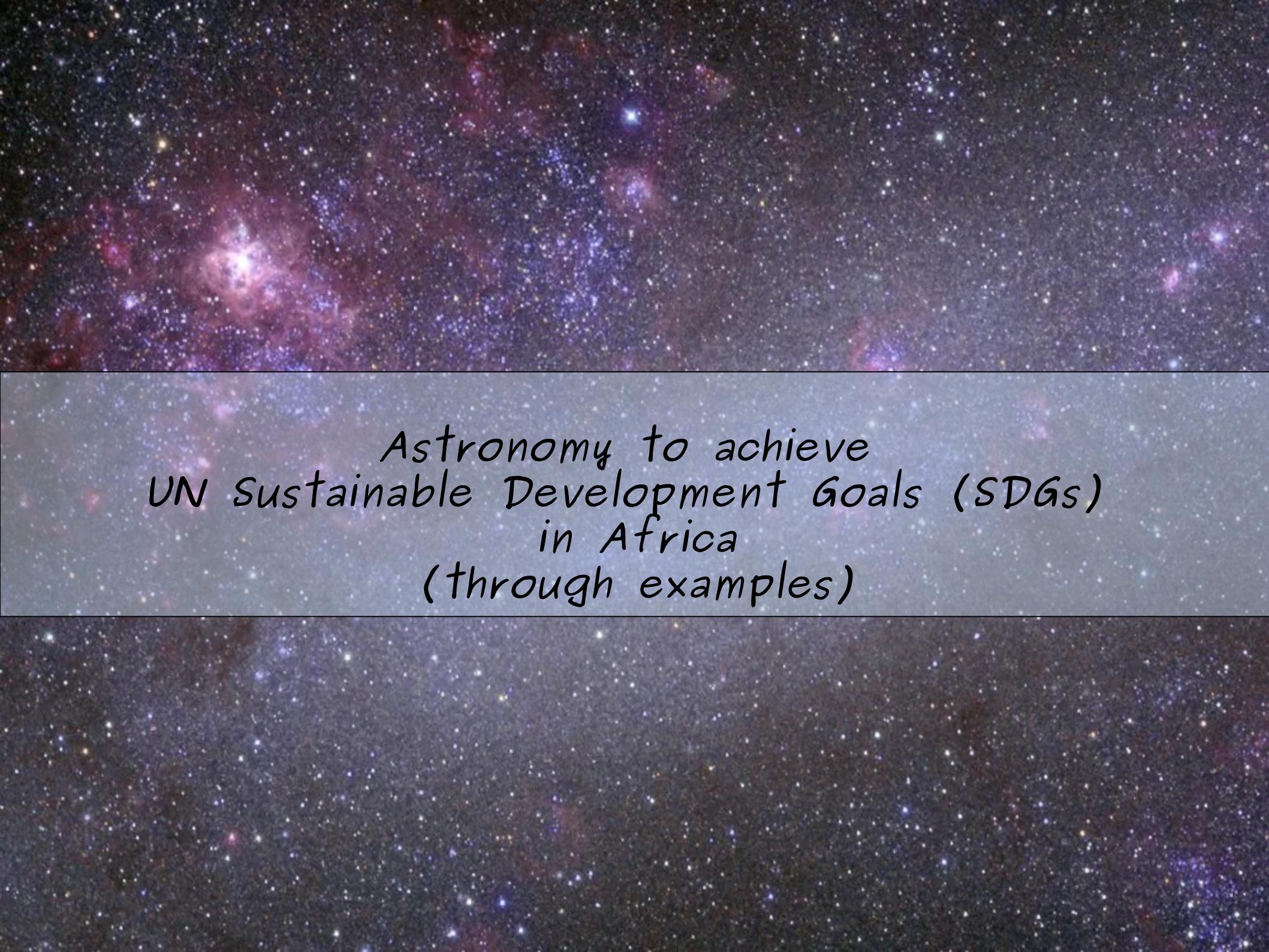
1. Global perception of importance of astronomy for development and for achieving the UN SDGs.
2. Systemic funding inequalities in astronomy at all levels between Africa and other continents, and more generally between the global south and north.
3. Systemic inequalities in human resources and number of qualified experts in the fields of astronomy and cosmology.
4. Systemic inequalities in the quality of the activities carried out, and in metrics used to measure the quality of work done in astronomy between Africa and the rest of the world.
5. Inequalities in the means of communicating astronomy (problems with publishing in Q1 journals).
6. Systemic inequalities in access to basic infrastructure (power cuts, internet connectivity, computers, etc.).
7. Systemic inequalities in access to world-class infrastructure and data.
8. Systemic inequalities in a fraction of under-represented groups such as women, minorities and the astronomical community in conflict- and crisis-affected areas.



Amazing development
in astronomy in
Africa + huge
potential!

still many challenges
are there in
astronomy
developments in
Africa.

Working together,
offering support to
each other, to
improve the
challenges!



Astronomy to achieve
UN Sustainable Development Goals (SDGs)
in Africa
(through examples)

"A blueprint to achieve a better and more sustainable future for all people and the world by 2030."

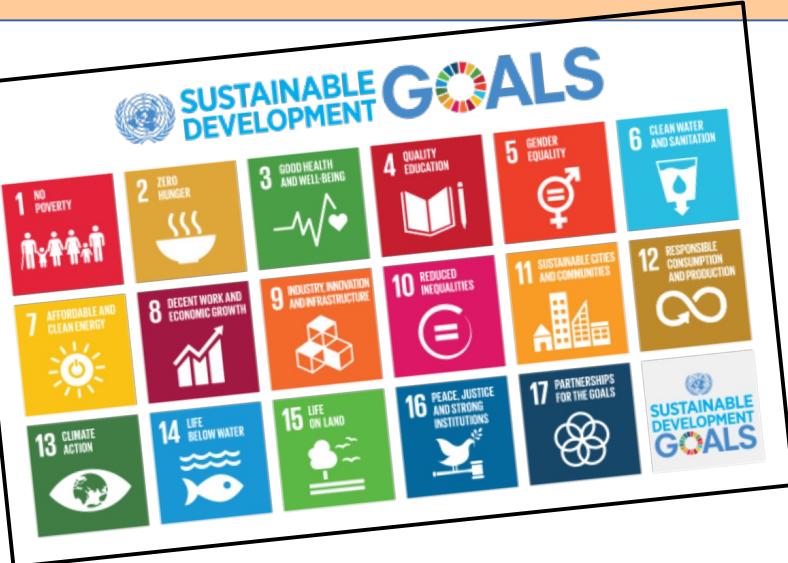
(Mission Statement)

Astronomy contributes to all SDGs!!



The SDGs 4, 5, 8, and 9 play a fundamental role in the world agenda.

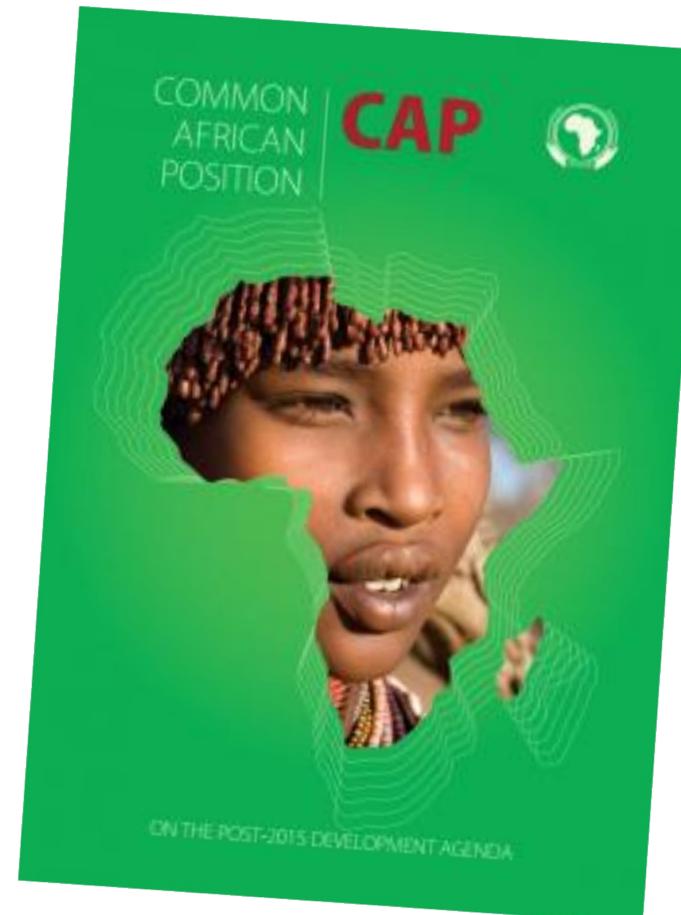
AU vision - continental initiative



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 also space science and astronomy)
- Established African Space Agency in 2018 (based in Egypt)
- Recent AU surveys on the importance of space and astronomy for Africa

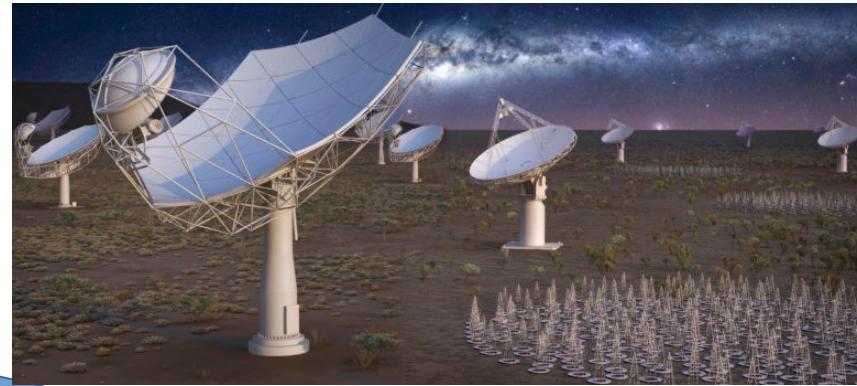


Astronomy is at the heart of digital and AI revolutions!!

WIFI



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

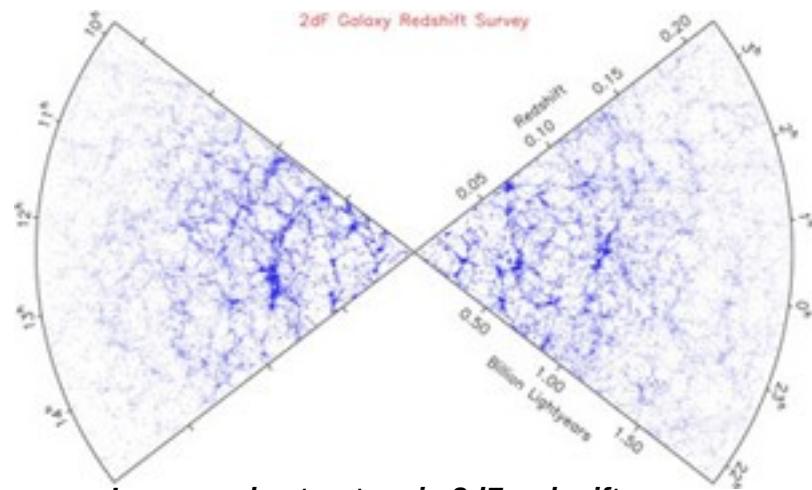


SKA artist's impression.
Credits: SKA



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 redshift 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)

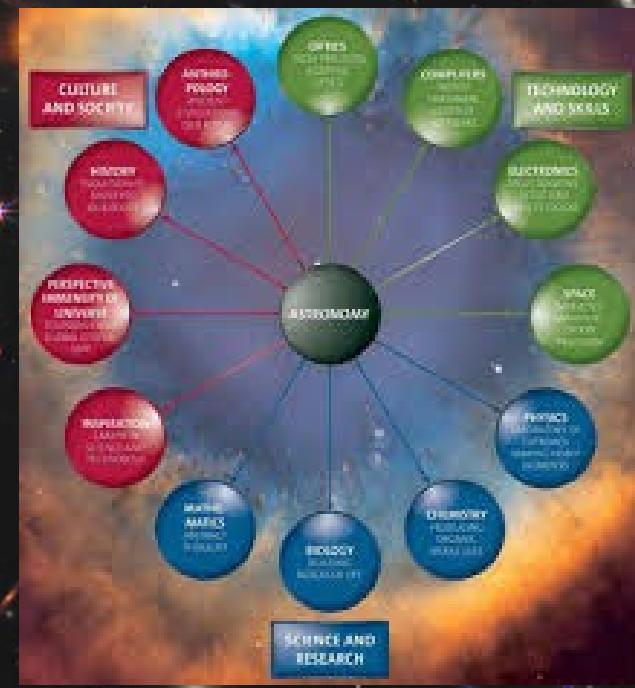
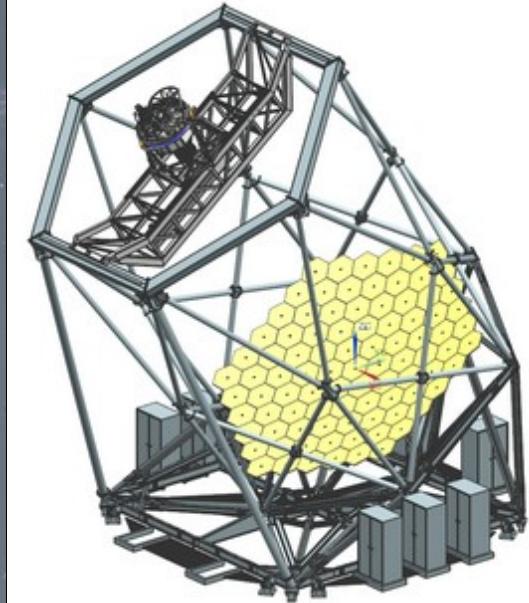
Check the IAU100 booklet 'From Medicine to Wi-Fi'

Astronomy, as a cutting-edge science (in addition to multidisciplinary), is a source of inspiration, challenge, and knowledge generation

→ contribution to the knowledge-based economy



Credits:
HST/NASA/ESA





Ensure inclusive and quality education for all and promote lifelong learning

Example: Improving the level of higher education in Ethiopia and East Africa through MSc and PhD in astronomy



Some of our first MSc and PhD students in A&A in Ethiopia and East-Africa doing their PhD in observational (optical) astronomy.

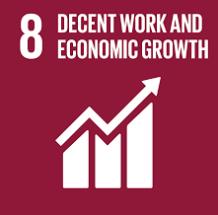
Credits: ESSTI, S. Abebe

Training some of the first master and PhD students in Ethiopia and East Africa (since 2016)

Properties and evolution of galaxies across cosmic time



How can fundamental research in galaxies contribute to long-term development?



Human capacity building

Education development

Support for technological development



Visibility given to the SSGI and Africa



Astronomy and science development

Entoto development



Institutional development

Outreach and public awareness



Knowledge generation

Stronger international collaborations





Promote sustained, inclusive and sustainable economic growth, ... , and decent work for all



Astronomy brings highly-qualified people!



Example of trained people in Ethiopia working currently all over the country



2023 training in astrotourism



> 40 organised workshops, schools, and trainings in the last 10 years
+ the 1st scientific meetings (e.g., IAUS, AfAS GA)



Example of Space Science and Geospatial Institute with currently ~ 400 employed people under 18 departments

Credits: ESSTI/SSGI, S. Abebe



Astronomy is a powerful tool for promoting education and science, and for empowering girls and women in STEM

4 QUALITY EDUCATION



5 GENDER EQUALITY



10 REDUCED INEQUALITIES



1 NO POVERTY



Example: Entoto Observatory as an important facility for trainings, education and outreach activities

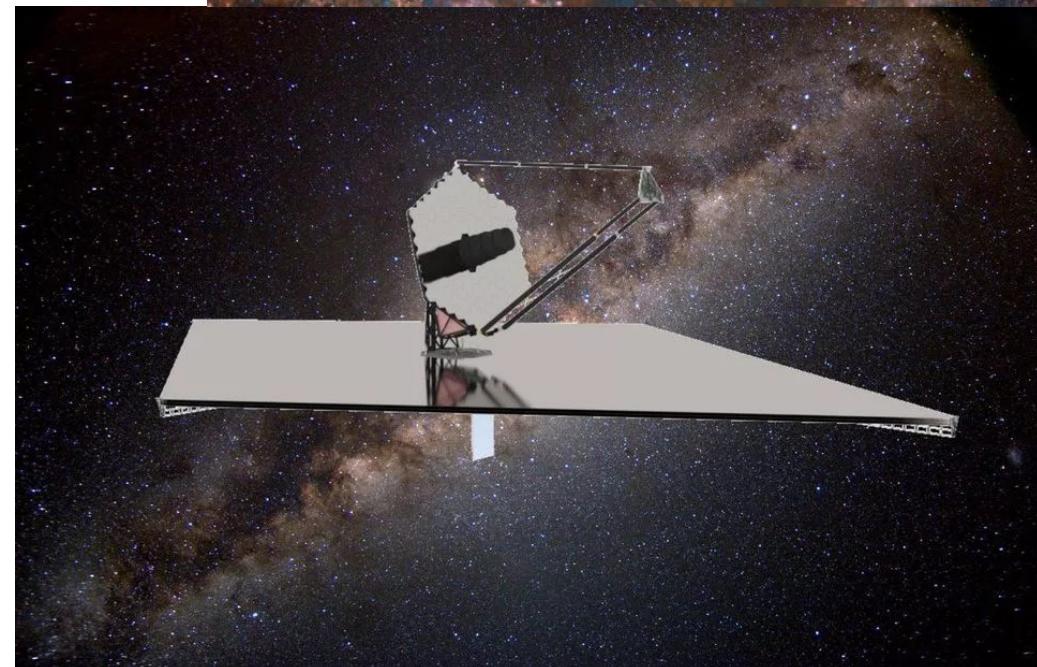
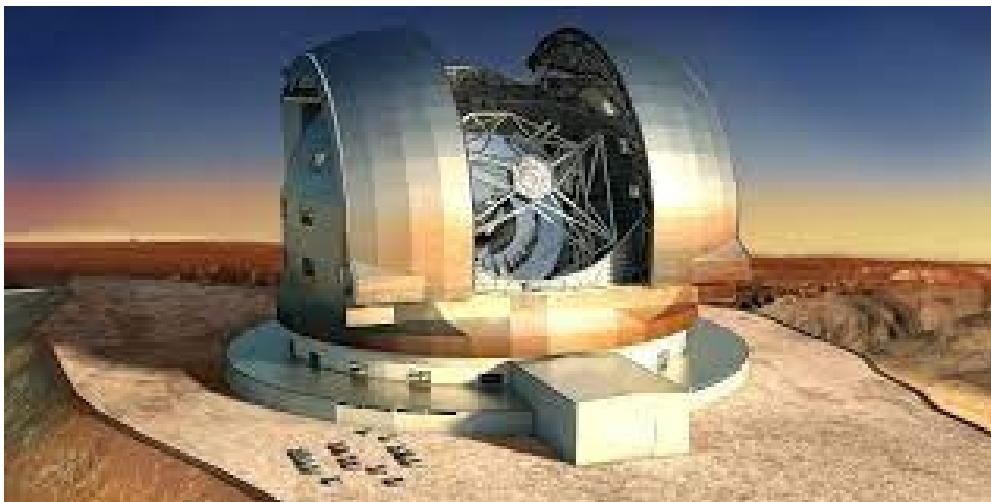
Credits: ESSTI/ESSS, A. Solomon, A. Mamo, M. Pović



Build resilient infrastructure... ..foster innovation

Astronomy is one of the leading sciences for bringing strong technological developments and innovation

→ opportunity for Africa and optical ground-based telescopes



E-ELT, MeerKAT, and James Webb telescopes.

Credits: ESO; SARAO; NASA

8 DECENT WORK AND ECONOMIC GROWTH



13 CLIMATE ACTION



Protection of dark skies as an African natural resource!!

Oukaimden



STARS4ALL
D. Padrón



IAU 386 SYMPOSIUM

DARK SKY AND ASTRONOMICAL HERITAGE
IN BOOSTING ASTRO-TOURISM AROUND THE GLOBE

DATE: 13 - 17 NOV 2023
PLACE: ADDIS ABABA, ETHIOPIA



18 SKY QUALITY
AND ACCESS
TO STARLIGHT



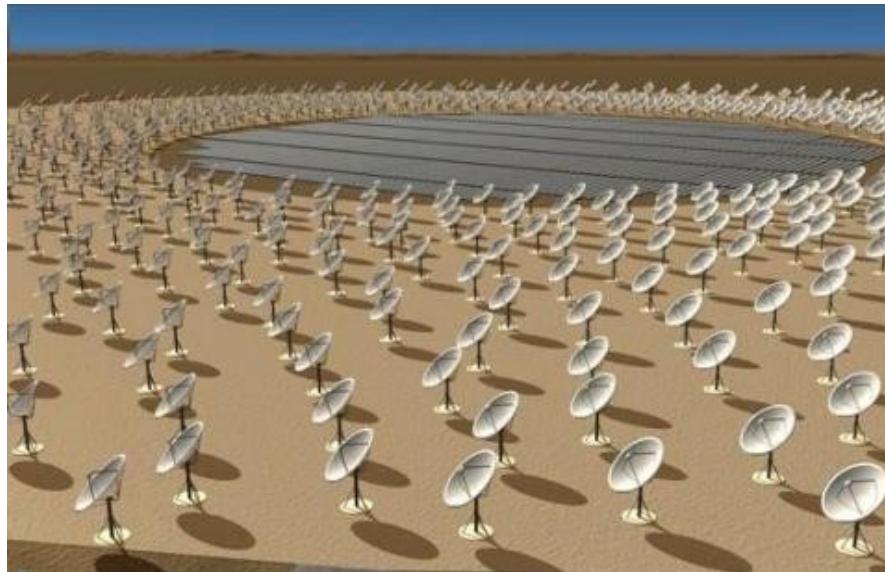
Examples of Morocco and South Africa, African dark skies strategy, IAU symposium in Ethiopia, etc.



Revitalise the global partnership for sustainable development

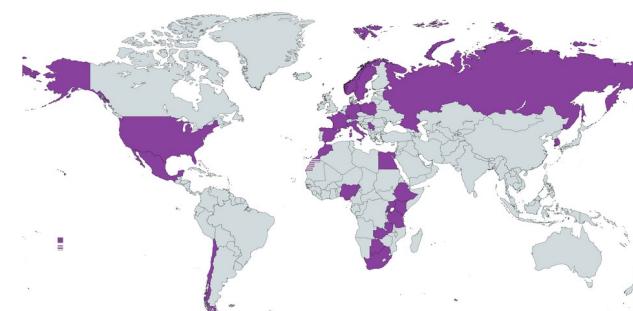
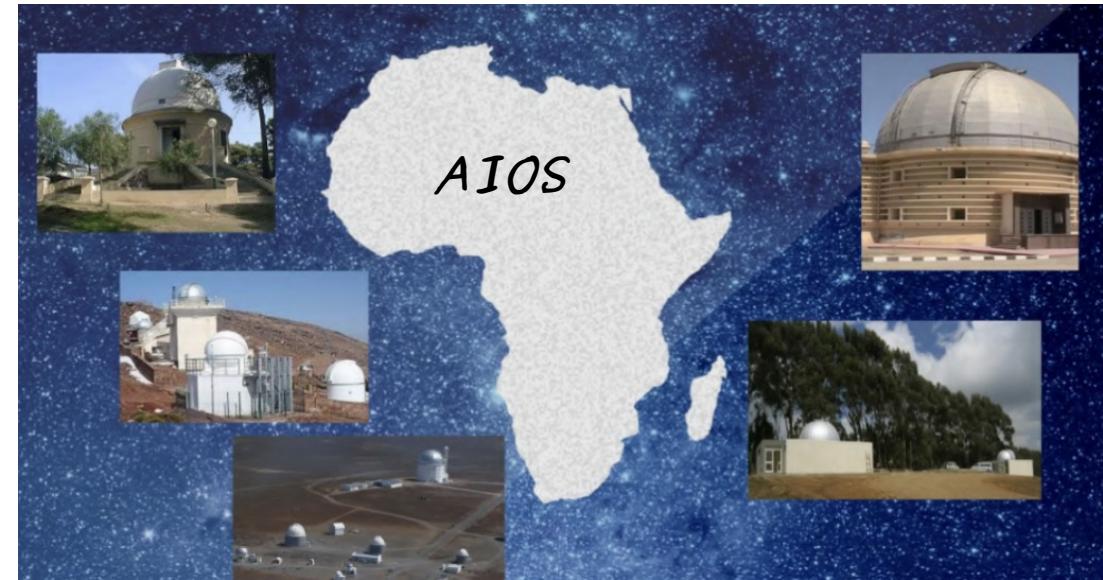
Astronomy is one of the leading sciences is fostering long-term partnerships

→ motivation for the development of ground-based optical telescopes



SKA as a great example in radio

Credits: SKA



Example of Ethiopian collaborations through optical astronomy

Example of HCB, collaborations, instrumentation and data development through research:

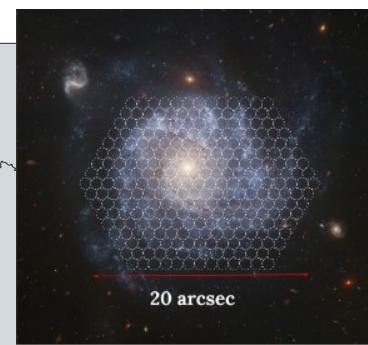
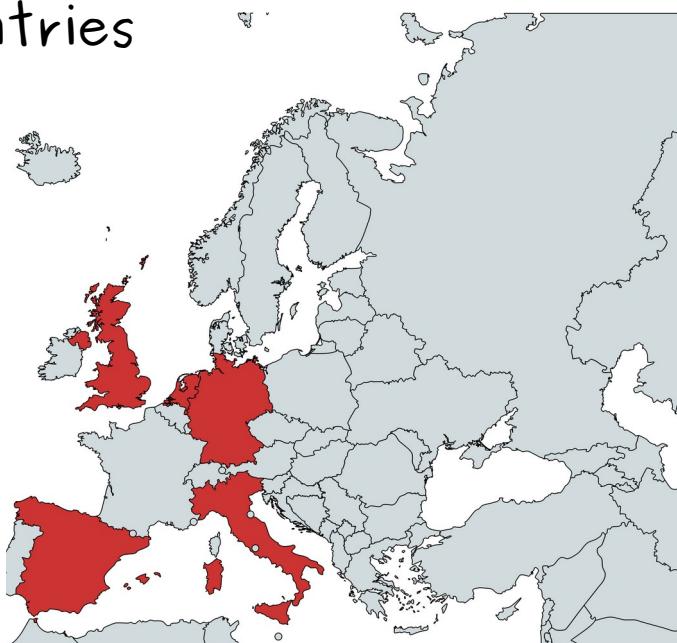
PanAfroAGN-SI (Pan-African AGN survey using SALT/IFS)

The PanAfroAGN-SI project aims to better understand the role of AGN in galaxy evolution through a detailed study of the properties of a large sample of active galaxies using for the first time the two new optical and NIR IFS instruments on SALT telescope.

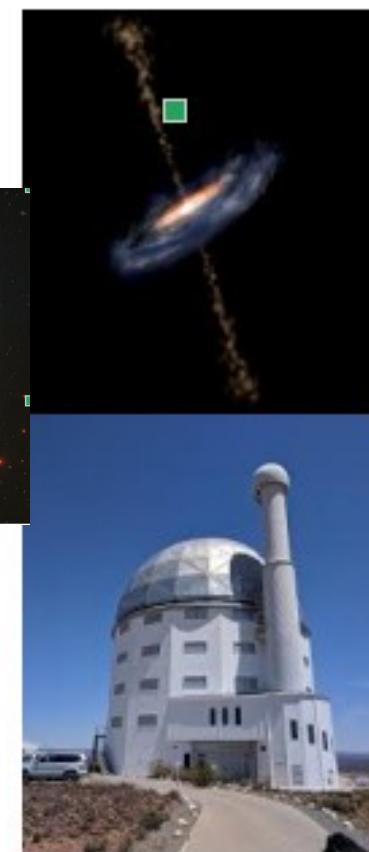


→ the largest AGN IFS survey

> 70 members, 14 African countries



SMI-200
&
NIRWALS



Postgraduate program (MSc & PhD)



- The East African Astrophysics Research Network (EAARN)



UNIVERSITY of
RWANDA



UPPSALA
UNIVERSITET

International Science Programme

MSc and PhD students supervisions in Africa



- Pan African Planetary and Space Network (PAPSSN) - Intra-Africa Academic Mobility Programme



PAPSSN



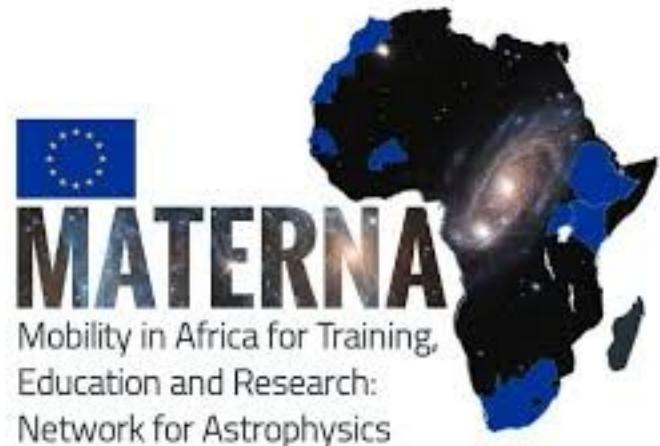
UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG



Other networks



- AFIPS - African Initiative for Planetary and Space Science → **funded**
- 5A - Astronomy and Astrophysics Arising Across Africa
(7 African, 4 EU countries)
- MATERNA
(7 African, 2 EU countries)
→ **to be resubmitted**
- AFROLINK - Astrophysics Frontier Research Opportunities for Learning and International Networking with Knowledge transfer
(7 African, 1 EU + ESO, 1 Asian countries)



One of the most sucessful examples:

DARA



Helping to drive
economic development
in Africa through high-
tech skills

- Basic training, advanced training, post-doc fellowships

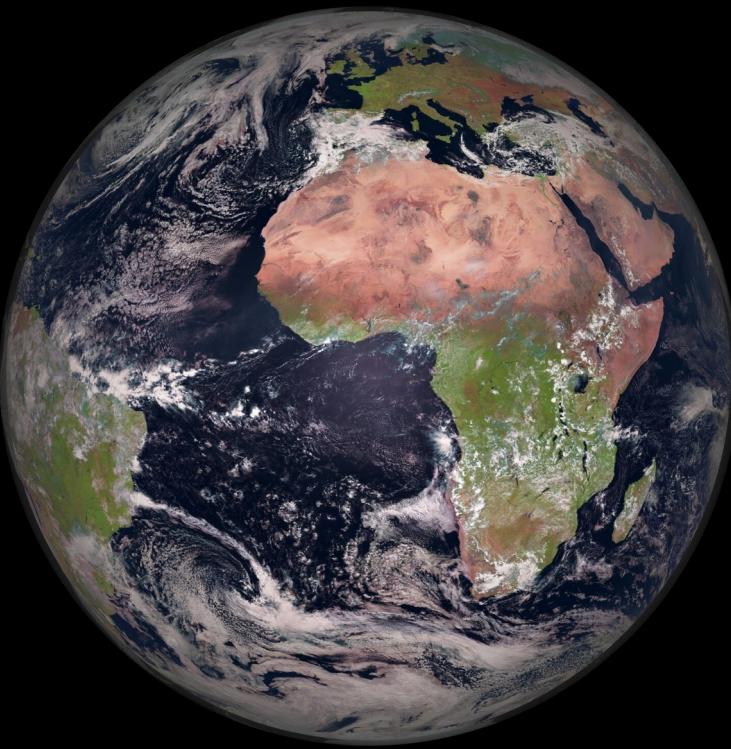
Credit images: DARA





Promote peaceful and inclusive societies for sustainable development

Astronomy is a powerful tool for diplomacy and peace-building.



Examples from Ethiopia, Nigeria, and Mali → use of astronomy to promote peace



Credits: M. Povic,
O. Fagbemiro,
J. Mimouni



We all live under the same sky!!

Example: South African Astronomical Observatory (SAAO), South Africa (since 1972)

- > 20 telescopes (different international collaborations, including UK, Japan, Germany, USA, South Korea, etc.)
- geophysical observatories (international consortium)

Some of the benefits:

- Development of South African astronomy and science, strong international collaborations
- strong technological development, employment, protection of dark skies
- Opening the path toward governmental support
- Opening the path towards big projects such as MeerkAT/SKA, Hirax, etc.
- strong contribution to socioeconomic growth of the country



All of the previous, in the long term can contribute to:

10 REDUCED INEQUALITIES



Reduce inequality within and among the countries

- By making Africa stronger and more independent through education, science, and technology.

1 NO POVERTY



End poverty in all its forms everywhere

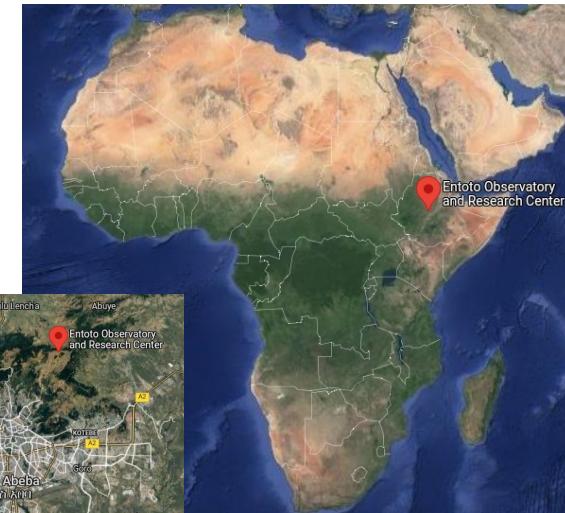
+ other SDGs.

The background of the image is a deep space photograph showing a dense field of stars of various colors (blue, white, yellow) and several red and purple nebulae or galaxy cores. A prominent red nebula is visible on the left side.

Entoto Observatory in Ethiopia
(since 2014)

Entoto Observatory

- established in 2014 under the ESSS
- ~ 10km from Addis, at 3160m
- establishment of ESSTI in 2016
- currently under the SSGI
- 2 x 1m Alt-Az optical telescopes
- Ritchey-Chretien-Nasmyth optical system (3 mirrors)
- photometry and high-resolution spectroscopy
- Good instrumentation: 4 CCD cameras (FLI, 2 SBIG, and Andor) with UBVRCIc filters, and 1 high-resolution Echelle spectrograph
- Davis weather station, 1 all-sky camera
- Suitable for planetary studies, near-Earth objects, stellar astronomy studies, transients, nearby galaxies, AGN variability, etc.



Entoto Observatory – site

- Fully dry period: mid Oct - Feb
Sporadic rains: March-June
Rainy season: July-Sep
(impossible to observe)
- Continuous seeing measurements not available
- Average seeing measured from observations 1–1.2 arcsec
- Light pollution is getting worst (expansion of Addis, but also Sululta and nearby villages)
- Advantage: easy access from Addis
- Has been used widely for outreach and education activities (until COVID in particular; e.g., > 10000 visitors in 2019)



Other infrastructure at Entoto



ETRSS-1 receiving station (4.2m antenna),



- Dec 2019, during the launching of the very first Ethiopian satellite



Multi-satellite receiving ground station (7.3m antenna)

Inaugurated in Dec 2020



Satellite data centre at Entoto, since Dec 2019

→ ETRSS-2 high-resolution satellite (up to 0.5m) under development

Faced challenges (constant interruptions since the first light)

- Spherical aberration of both primary mirrors (2014/2015)
- Software being blocked by Astelco for 1.5 years (until 2017)
- Strong lightning in 2016, destroyed many of the components not available on the local market (telescopes repaired only in Feb 2020)
- Interruption for several months in 2017 due to mirrors re-coating, many problems found after that as a consequence of lightning
- Long bureaucratic/administrative process from both ESSTI and Astelco sides since mid-2018 until 2019 for purchasing the burned spare parts
- Challenges with the design and installation of the new lightning system finding the material on the local market, took time and delayed the process of telescopes repair (finished in 2019) → fully done by our young engineers

Faced challenges

(constant interruptions since the first light)

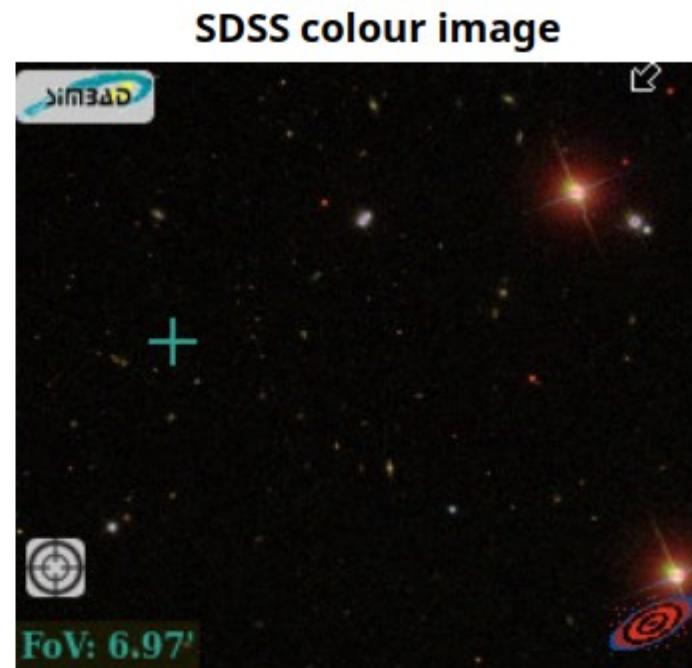
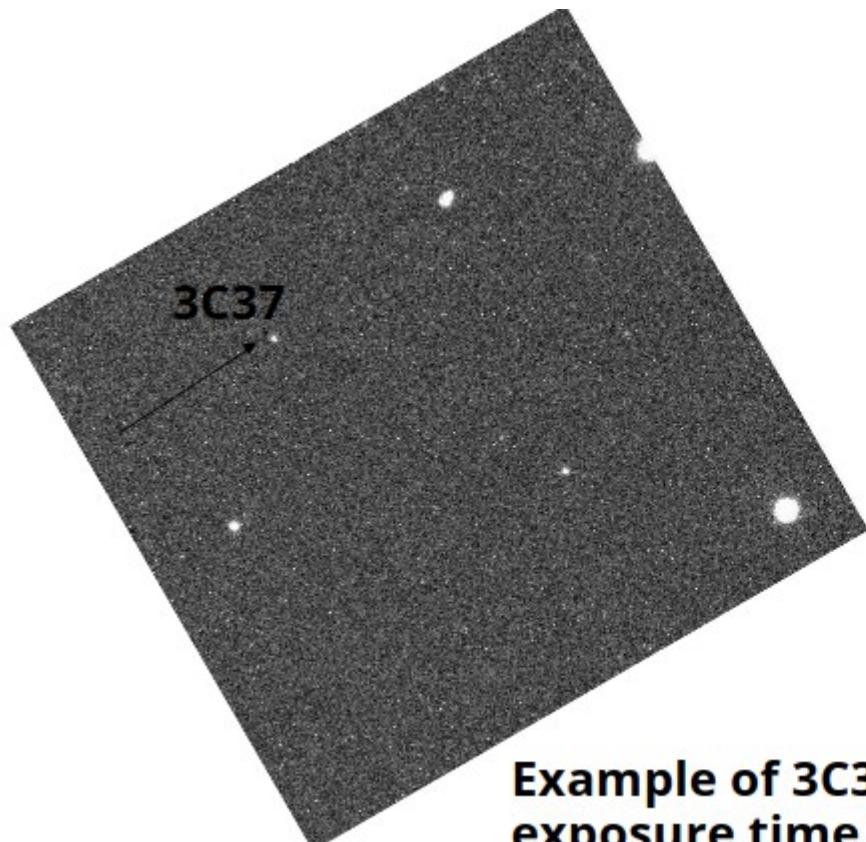
- COVID interruption in 2020 for several months, only one week after the telescopes have been repaired, followed by the rainy season
- The security situation at Entoto starting from Nov 2020, problems with uncontrolled light pollution inside the compound
- Challenges with uninterrupted power and internet
- Construction inside the EO, and road construction (for the last 3 years)
- Lack of human resources (and qualified sector, e.g., lack of sufficient number of observational astrophysicists)
- Lack of management EO body

Continuous progress at EO in the meantime

- Internet connection improved using optical fibre
- General maintenance, road and access to the observatory
- Installation of new, stronger, lightning protection ('home made')
- Repairing of telescopes
- Construction work on improving the 2 buildings
- Continuous work on water and power supplies
- Training of staff
- Society engagement (Friday's talk)

Scientific use of EO

- Trainings of MSc and PhD students in observations, data reduction, and calibration
- Observations in stellar astronomy (variable stars)
- Variability of nearby quasars

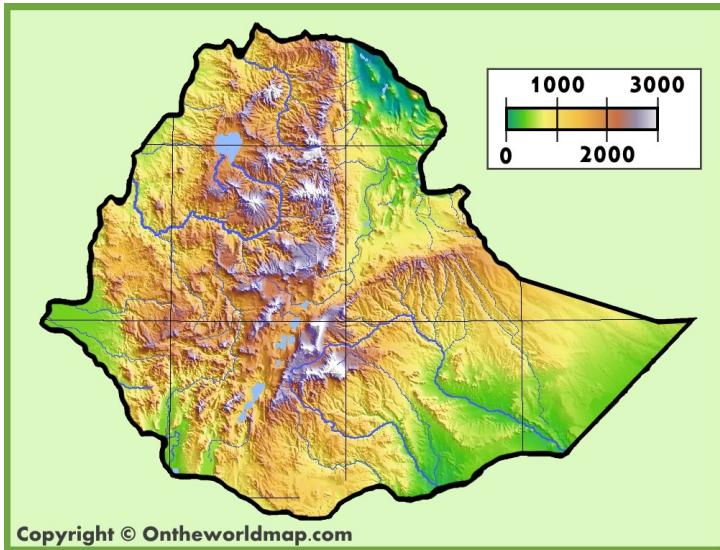


Example of 3C37 in V band (mag 17.5) with 600sec exposure time (SBIG STL 10000M camera)

Site testings out of Addis

Ethiopia has favourable conditions for the development of observational astronomy

→ pre-selection has been done of several possible sites



Abune Yoseph site testing, > 4000m, near Lalibela



Abohay Gara site testing, near Lalibela

→ destruction of sites during the conflict

Political stability is crucial for any infrastructure development in astronomy.

It's time for Africa!!

Investing in astronomy and in science is not a question of luxury, it is a fundamental need!



Thank you very much for your attention!