

IAU Symposium

356

7-11 October 2019  
Addis Ababa, Ethiopia

Proceedings of the International Astronomical Union

# Nuclear Activity in Galaxies Across Cosmic Time

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ISSN 1743-9213

International Astronomical Union



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NUCLEAR ACTIVITY IN GALAXIES ACROSS COSMIC TIME  
IAU SYMPOSIUM 356

*COVER ILLUSTRATION:*

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IAU SYMPOSIUM PROCEEDINGS SERIES

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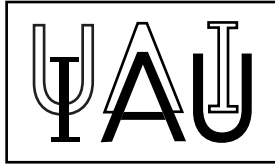
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INTERNATIONAL ASTRONOMICAL UNION  
UNION ASTRONOMIQUE INTERNATIONALE

International Astronomical Union



NUCLEAR ACTIVITY IN  
GALAXIES ACROSS  
COSMIC TIME

PROCEEDINGS OF THE 356th SYMPOSIUM OF  
THE INTERNATIONAL ASTRONOMICAL UNION  
HELD IN ADDIS ABABA, ETHIOPIA  
7–11 OCTOBER, 2019

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CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom  
1 Liberty Plaza, Floor 20, New York, NY 10006, USA  
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

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First published 2021

Printed in the UK by Bell & Bain, Glasgow, UK

Typeset in System L<sup>A</sup>T<sub>E</sub>X 2 $\epsilon$

*A catalogue record for this book is available from the British Library Library of Congress  
Cataloguing in Publication data*

This journal issue has been printed on FSC<sup>TM</sup>-certified paper and cover board. FSC is an  
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ISBN 9781108492010 hardback  
ISSN 1743-9213

*This book is dedicated to all of the people who in one way or another contributed to the development of astronomy and space science in Ethiopia and Africa, and to all of those who will continue doing so in the future.*



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## Preface

We are very pleased to introduce the proceedings of the 356th International Astronomical Union (IAU) Symposium titled “*Nuclear Activity in Galaxies Across Cosmic Time*” held in Addis Ababa, Ethiopia, from 7th to 11th of October, 2019. This was the third symposium organised in Africa in the past 100 years since the establishment of the IAU, and only the first one organised in Ethiopia and East-Africa. We hope that this meeting will inspire many of our colleagues, and that in future we will have more meetings organised in Africa. With this symposium we wanted to achieve two main goals.

First, we wanted to provide a general overview of recent findings and progress in observations, simulations, and theory of active galactic nuclei (AGN) from the local universe up to high redshifts. AGN play an important role in many aspects of modern cosmology. They are fundamental for understanding galaxy formation and evolution, black hole formation and growth, and the connection between the two. Multiwavelength studies by Herschel, ALMA, Planck, NuSTAR, HST and more, combined with larger and deeper AGN samples, resulted in better understanding of nuclear activity in galaxies and AGN physics across cosmic time. However, we are still far from understanding the full physics behind AGN activity and their role in galaxy formation and evolution. The timing of IAUS 356 was appropriate since we are now witnessing a rapid growth of results based on large data-sets at all wavelengths, and since we need to formulate the questions for several new missions such as eROSITA, JWST, Euclid, CTA, SKA, E-ELT, and Athena. The key topics highlighted in the symposium and covered in the proceedings encompass multiwavelength AGN surveys, AGN types and unification, AGN variability, active black holes and their host galaxies, triggering, feedback and shutting off AGN activity, jets and environment, highest redshift AGN and AGN evolution.

Second, we wanted to bring for the first time world experts in our field to the East-African region and contribute to the development of science in Ethiopia and Africa. We also wanted to call the attention of the international scientific community to the new activities and development of astrophysics in Sub-Saharan countries. For most of the international community South Africa is still the major player regarding scientific activities in astronomy and space science in Africa. However, over the past years many other countries (e.g., Egypt, Ghana, Kenya, Morocco, Namibia, Rwanda, Sudan, Uganda, etc.) have begun research activities, opened new MSc and PhD programs at their universities, and started developing new research centers and technological facilities for improving their socio-economical challenges. Many achievements have been realized, but still there are many difficulties, challenges, and needs. At the same time, the Ethiopian Space Science and Technology Institute (ESSTI) is a new research center established under the Ethiopian Ministry of Innovation and Technology in Nov 2016. It is the first center of this kind in Ethiopia and one of the first in all East-African region. Organizing this international conference in Ethiopia has shown to be an important contribution and a sign of international support to the new development of science in the country and Africa. We hope the conference provided important motivation for African scientists and students.

To take full advantage of the symposium and to benefit our society, different activities have been carried out for graduate students, young researchers, teachers, teachers trainers, school children, and general public, before, during, and after the symposium. Training for undergraduate, MSc and PhD students was organized before (5–6 Oct) and training for teachers after (12–13 Oct) the symposium. To promote science in general among the public and school children, one whole afternoon was dedicated to two public talks at Addis Ababa University and outreach activities that have been carried out

in 8 public schools. A lunch session about “*Development in astronomy and space science in Africa*” was organized in parallel to the science-business meeting of the African Astronomical Society (AfAS) that has been held at the same venue on 10 and 11 of Oct. Finally, NAO Data Lab training was also organised for interested participants. All education and outreach activities have been carried out voluntarily by our participants, both international and local. More details on all organised activities can be seen in section ‘IAUS356 for society’.

More than 160 people from 30 countries and 5 continents participated in IAUS 356. The papers presented in this proceedings are only part of the contributions that have been presented in the symposium (talks and posters). We were able to enjoy high level presentations and fruitful discussions that have been organised after each session. In total we had 7 invited talks (4 males and 3 females, from 7 countries and 5 continents), 60 contributed talks (53% male and 47% female speakers), and 33 poster presentations in the AGN field. We also wanted to motivate our students and young researchers in general to present their work and we had in addition 17 poster presentations out of AGN field. We put a lot of efforts to take care of geographical distribution and gender balance and to achieve approximately 50%–50% of male-female participation in different aspects of symposium organisation (as can be seen with selection of invited speakers, contributed talks speakers, or SOC members). Participants had a chance to learn more about Ethiopian history and culture, by visiting the National Museum, and by enjoying traditional food, music and cultural dance, and to learn more about establishment of the ESSTI by visiting Entoto Observatory out of Addis Ababa.

In summary, we hope that this conference will contribute to our better understanding of nuclear activity in galaxies across cosmic time. We aimed at clarifying the role of nuclear activity in the broader context of galaxy evolution, outlining major unsolved problems and observational and theoretical strategies to solve them. We also hope that it will help to strengthen the development of science in Ethiopia and Africa and open new space for collaborations between Africa and other parts of the globe for the benefit of all.

*This symposium and all organised activities would not be possible without huge support of the IAU and ESSTI, all SOC and LOC members, all our sponsors, invited speakers, all trainers and volunteers, and all IAUS 356 presenters and participants. Thank you everybody for all your contribution and support.*

*Mirjana Pović, Paola Marziani, Josefa Masegosa,  
Hagai Netzer, Seblu H. Negu, and Solomon B. Tessema*

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### *Organizing Committee*

#### **Scientific Organizing Committee**

|                       |   |
|-----------------------|---|
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| Hagai Netzer          | (Tel Aviv University, Israel) - co-chair        |
| Pheneas Nkundabakura  | (University of Rwanda, Rwanda) - co-chair       |
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| Mara Salvato          | (MPE, Germany)                                  |
| Miguel Sánchez Portal | (IRAM, Spain)                                   |
| Nebiha Shafi          | (HartRAO, South Africa)                         |
| Prajval Shastri       | (Indian Institute of Astrophysics, India)       |
| Sylvain Veilleux      | (University of Maryland, USA)                   |
| Jian-Min Wang         | (Institute of High Energy Physics - CAS, China) |

### Local Organizing Committee

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| Solomon Tessema Belay | (ESSTI) - co-chair                         |
| Feleke Zerihun        | (ESSTI) - co-chair                         |
| Jerusalem Tamirat     | (ESSTI) - co-chair                         |
| Josefa Masegosa       | (IAA-CSIC, Spain) - co-chair               |
| Biruk Abrham          | (ESSTI)                                    |
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| Zelege A. Beyoro      | (ESSTI and Kotebe Metropolitan University) |
| Tolu Biressa          | (Jimma University)                         |
| Solomon Cherie        | (ESSTI)                                    |
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| Getnet Geberegziabher | (ESSTI)                                    |
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| Getachew Mekonnen     | (ESSTI)                                    |
| Remudin R. Mekuria    | (Addis Ababa University)                   |
| Seblu H. Negu         | (ESSTI)                                    |
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| Mekbeb Tamrat         | (ESSTI)                                    |
| Getachew Wollel       | (ESSTI)                                    |
| Betelehem B. Woldeyes | (ESSTI)                                    |
| Tilahun G. Woreta     | (ESSTI and Bule Hora University)           |



**Figure 1.** IAUS 356 LOC and supportive staff. *Credits. A. Solomon*

## Acknowledgements

We highly appreciate the support of all institutions and people who in one way or another contributed to the realisation of this symposium, from the very initial stages of proposal writing to the final stage of all organisation. In particular, our gratitude goes to the IAU for giving us the opportunity and financial support to host for the very first time this symposium in Ethiopia and East-Africa. We also extend our thanks to the ESSTI and MInT for all the local support in terms of human and financial resources. This symposium would not be possible without huge support of SOC and LOC members, all our sponsors, invited speakers, all trainers and volunteers, and IAUS 356 participants. We hope that this symposium will contribute significantly to development of astronomy and science in Ethiopia and Africa.

The symposium is sponsored and supported by the IAU Divisions J (Galaxies and Cosmology), C (Education, Outreach and Heritage), and D (High Energy Phenomena and Fundamental Physics), by the IAU Commissions C.X1 (Inter-Division D-J Commission Supermassive Black Holes, Feedback and Galaxy Evolution), B2 (Data and Documentation), and C1 (Astronomy Education and Development), and by four African Regional Nodes of the Office of Astronomy for Development (IAU-OAD). We acknowledge the Cambridge University Press team for all the support offered during preparation and production of the IAU 356 book of proceedings.

The Local Organizing Committee operated under the auspices of the  
Ethiopian Space Science and Technology Institute (ESSTI).

### **Funding and support** by the

International Astronomical Union (IAU),  
Ethiopian Space Science and Technology Institute (ESSTI),  
Entoto Observatory and Research Centre (EORC),  
Ethiopian Ministry of Innovation and Technology (MInT),  
International Science Programme (ISP),  
Development in Africa with Radio Astronomy (DARA),  
Instituto de Astrofísica de Andalucía (IAA-CSIC) and its Severo Ochoa program  
SEV-2017-0709  
Spanish Astronomical Society (SEA),  
UK Science and Technology Facilities Council (STFC-UKRI),  
Ethiopian Space Science Society (ESSS),  
East-African Regional Office of Astronomy for Development (EA-ROAD),  
Addis Ababa University (AAU),  
and Nature Astronomy

**is gratefully acknowledged and much appreciated.**

**Thank you.**

## Opening Ceremony and Welcome Notes

### Address by the IAU 356 symposium chair and ESSTI Astronomy and Astrophysics Department Head, Dr. Mirjana Pović

His Excellency Dr. Ing. Getahun Mekuria State Minister of Ministry of Innovation and Technology, His Excellency Mr. Tefera Walwa Former Deputy Prime Minister and Patron of Ethiopian Space Science Society, Guests of Honor,

Dear Colleagues and Friends,

Welcome all to our symposium '*Nuclear Activity in Galaxies Across Cosmic Time*'. It is the 356th symposium of the International Astronomical Union (IAU), but only the third one to be organised in Africa in the past 100 years, and the first one in Ethiopia and East-Africa. We are very grateful to the IAU and all people who put their trust and confidence in us and gave us the opportunity to organise this symposium that is so important for recently established Ethiopian Space Science and Technology Institute (ESSTI) and our Astronomy and Astrophysics Department, astronomy in Ethiopia and Africa, and astronomy in general. With this meeting we hope to achieve some of the main proposed goals.

We hope that all together we will have very prospective and fruitful discussions and achieve better understanding of some of important points of AGN physics and observations, including: AGN multiwavelength surveys, AGN types and unification model, variability, properties of AGN host galaxies, triggering, feedback, and shutting off of AGN activity, jets and environment, and properties of youngest AGN and AGN evolution.

Beside that, this symposium goes much beyond a regular scientific meeting. Thanks to huge efforts of many of our African and international colleagues, many of African countries started with astronomy and space science developments over the past recent years, including Ethiopia. With this symposium we want to support those activities and contribute to these developments on national and continental level. We hope to give more visibility to the ESSTI, and astronomy and space science developments in Ethiopia and Africa, we want to inspire and motivate our first generation of MSc and PhD students by having all of you here, we want to benefit our society by organising in collaboration with all of you different education and outreach activities, and we wish to use this meeting for strengthening international collaborations on longer-term for the benefit of all.

All of this would not be possible without huge support of the IAU, ESSTI, Entoto Observatory and Research Center (EORC) and our Ministry of Innovation and Technology to whom we are very grateful. I want to thank all other institutions that supported organisation of this symposium, including the International Science Programme (ISP), Development in Africa with Radio Astronomy (DARA), Instituto de Astrofísica de Andalucía (IAA-CSIC) and its Severo Ochoa program SEV-2017-0709, Spanish Astronomical Society (SEA), UK Science and Technology Facilities Council (STFC-UKRI), Ethiopian Space Science Society (ESSS), East-African Regional Office of Astronomy for Development (EA-ROAD), Addis Ababa University (AAU), and Nature Astronomy. I would also like to acknowledge amazing efforts that LOC and SOC members made, together with all invited speakers, all outreach and education trainers and volunteers for making possible this meeting and all activities organised for society.

As a main organiser I have to say that I was touched with the level of humanity that I found and felt every time that I contacted somebody asking for support with organisation of IAUS 356. It clearly showed me that there are many of us who believe that together through education and science we can fight poverty on a long-term and hopefully make this world a better and more fair place in future for everybody. Thank you all very much for coming and for helping us in reaching the goals of this IAU symposium.

I wish you to have fruitful meeting, and happy and unforgettable stay in Addis and Ethiopia. Thank you!

*Mirjana Pović*  
*Addis Ababa, 7 October 2019*



**Address by the ESSTI General Director,  
Dr. Solomon B. Tessema**

His Excellency Dr. Ing. Getahun Mekuria State Minister of Ministry of Innovation and Technology and Guest of Honor, His Excellency Mr. Tefera Walwa Former Deputy Prime Minister and Patron of Ethiopian Space Science Society, SOC members, AfAS Executive Committee Members, LOC members, Dear colleagues,

As Director General of Ethiopian Space Science and Technology Institute (ESSTI), it is a great honor and pride to have the opportunity to say a few words before starting this symposium. First of all, on behalf of ESSTI, the government of Ethiopia and myself, I would like to express our great pleasure in welcoming all attendees of the International Astronomical Union (IAU) symposium 356 entitled 'Nuclear Activity in Galaxies Across Cosmic Time' to be held from 7th until 11th of October 2019 in Addis Ababa, Ethiopia, political capital of Africa and place of the origin of human being. I especially welcome those who traveled long distance to our lovely city. This is the third IAU symposium organized in Africa in the past 100 years, and the first one to be organized in Ethiopia and East- and Central-African region. It has been organised under the ESSTI Astronomy and Astrophysics Research and Development Department.

ESSTI was established by government of Ethiopia in 2016 by Regulation 393/2016. Since then some of the most important responsibilities and functions assigned to this Institute have been to promote, initiate, lead and coordinate basic and applied research activities in astronomy and astrophysics, space science, remote sensing, atmospheric and climate science, space geodesy, satellite development and operation, infrastructure development, capacity building in space science and technology, licensing, monitoring, controlling and authorizing space activities, strengthening international relations and collaborations, in collaboration with scientists, governmental and non-governmental organizations throughout our country as well as abroad. In view of the rapidly advancing frontiers of space science and technology, and the increasing importance of international collaborations, I strongly feel that our institute should play a leading role in promoting scientific activities in Africa as well as worldwide. This is not only a give-and-take information exchange, knowledge and technology transfer with the outside world, but also we intend to promote harmony between different scientific cultures in space science and technology through the establishment of different research and technology hubs at our institute.

Entoto Observatory and Research Center (EORC) has been established in 2013 and is currently one of the subordinates of ESSTI with two 1 meter telescopes able to connect Ethiopian astronomers with the rest of the world. In the past three years ESSTI has published more than 70 scientific papers in peer review journals. Presently, Ethiopia is hosting East African Office of Astronomy for Development and is working hard on the development of astronomy and astrophysics in the region. In addition to research and technology development, EORC has been giving trainings in both MSc and PhD in collaboration with Addis Ababa University in astronomy and astrophysics, space science, remote sensing, and space geodesy, including East-African students, with goal of being regional center of excellence in the above fields of study.

One activity among many is the global promotion of our research, technology and training, and hence we have decided to host different continental and international symposia on astronomy and space science in various topics in fields of our prioritized interest. The present IAU 356 symposium is one of the international conferences that have been conducted in past ten years. Since 2009, EORC and ESSTI have organized international and continental conferences and workshops, such as the two East African

Astronomical Society workshops, American Geophysical Union International Conference in Space Science, Middle East and Africa IAU Regional Meeting, annual ESSTI conference, and Africa Initiative for Planetary and Space Science workshop. The past conferences and the current symposium have been chosen based on the size, priority, national interest and knowledge and technology transfer mechanism. In addition to promoting exchange of expert insights, knowledge and technology transfer, we would like to encourage particularly young scientists to present papers in each symposium/ conference/ workshop on their new results from the astronomy, space science and technology areas and related fields, and to help them get an overview of fields they are involved in.

On behalf of ESSTI and myself, I assure you that such types of symposia, conferences and workshops are welcome and we are committed to support them at continental and international level. As the hosting country of African Union, Ethiopian government is committed to organize and lead research in astronomy and space science in both theoretical and observational aspects to support African development strategy through the ESSTI. In this symposium more than 120 papers and posters will be presented and known scientists as well as the youth, students and women will present their research findings, as well as panel discussions, invited talks, and public talks will be conducted. The current research development and future direction of extragalactic astronomy research will be forwarded and the next hosting countries will be proposed. Even though, Ethiopia is an emerging country in astronomy and space technology research, it has taken responsibility to support our African countries and widening to international level and strengthening scientific collaboration with the astronomical community in the world.

Finally, I would like to thank local and scientific organizing committees and ESSTI staff members for their hard work to organize this symposium. My thanks extend to IAU, Ministry of Innovation and Technology, International Science Programme (ISP), Development in Africa with Radio Astronomy (DARA), Instituto de Astrofísica de Andalucía (IAA-CSIC) and its Severo Ochoa program SEV-2017-0709, Spanish Astronomical Society (SEA), UK Science and Technology Facilities Council (STFC-UKRI), Ethiopian Space Science Society (ESSS), East-African Regional Office of Astronomy for Development (EA-ROAD), Addis Ababa University (AAU), and Nature Astronomy for all financial and organizational support.

We wish you all a very constructive and pleasant stay.

*Solomon B. Tessema*  
*Addis Ababa, 7 October 2019*

## Address by His Excellency Former Deputy Prime Minister and Patron of Ethiopian Space Science Society, Mr. Tefera Walwa

Dear colleagues,

My welcoming speech is not the usual welcome protocol. It is to present to you most serious points of mine as African. Main issues I want to raise are:

1. Is space science and technology important or imperative for development?
2. Should we limit to collaboration or should we come to unified efforts?
3. Who should be in charge?

### 1. Important or imperative?

Development is the result of imagination. What does space science and technology do? Its power of inspiration to release the power of imagination is its key role. Forget its being the first science. It is the center piece for all or I better say, it is gravity for all other sciences and technology. That is why it is imperative for development. Important makes optional. That is why I don't buy important. It is not me to talk to you on this. I better make world renowned scientists talk to you. For now, only one, out of very many.

*"All the progress of human civilization, from the invention of the first tools to our nascent quantum technologies, is the result of the disciplined application of the imagination. ... But if we hadn't descended from people who, hundreds of thousands of years ago, imagined ways to harness fire, we would still be prey."*

Time reborn, by Lee Smolin, p. 252

*"Imagination enabled us to turn change and surprise into opportunities to extend our domain across the planet. Some 12,000 years ago, we adapted our environments to ourselves, becoming farmers rather than opportunistic hunter-gatherers. Since then, our footprint has extended to the point where our impositions on the Earth's natural systems threaten to cause us great harm. Because imagination is our game, and imagination got us here, only imagination can provide the new ideas that will take us safely through the surprises to come."*

Ibid, p. 253

*"Our way is to aspire always to more than and other than what we have. To be human is to imagine what is not, to seek beyond the limits, to test the constraints, to explore and rush and tumble across the intimidating boundaries of our known world."*

Ibid, p. 254

### 2. To collaborate or unit?

Collaboration is the list option. It is duplication of effort and waste of many things (meager resources of the poor people of Africa, if not the whole humanity). Unity speeds up in all manner, by uniting the human resource of the field, the material wealth ..... etc. What not?! Unity means? One policy, strategy, organization, leadership and resource allocation, etc. means one school of thought leads and governs it. This is to the benefit of the whole humanity; it is not limited to Africa alone.

### 3. Who should be in charge?

The youth, if not the teenagers. The simple reason could be the next generation is better than the past and the current, undoubtedly. But many reasons more than this simple reason. Let's talk to Prof. Stephen Hawking and some other one.

*“But what lies ahead for those who are young now? I can say with confidence that their future will depend more on science and technology than any previous generation's has done. They need to know about science more than any before them because it is part of their daily lives in an unprecedented way.”*

Brief answers to the big questions, by Stephen Hawking, p.203

*“There is so much more to come and I hope that this prospect offers great inspiration to schoolchildren today. But we have a role to play in making sure this generation of children have not just the opportunity but the wish to engage fully with the study of science at an early level so that they can go on to fulfill their potential and create a better world for the whole human race. .... And I believe the future of learning and education is the Internet. People can answer back and interact. In a way, the Internet connects us all together like the neurons in a giant brain. And with such an IQ, what cannot we be capable of?”*

Ibid, pp. 207 - 208

Let me now take you to another one:

*“Apollo inspired generations, including people who are now the explorers working to take us back to the Moon, on to Mars and beyond. .... Their work is taking space exploration to new heights. But who will actually put new footprints on the Moon and take the first step on Mars? Who will take us beyond that goal? Who is responsible for the future of space exploration? Students. Today's students are that future-and it is our job to inspire them and help them see themselves as those leaders. .... To these students, this is not hard to imagine. It is not a dream world or something from a storybook. Setting foot on Mars, going back to the Moon and exploring beyond is not just an idea; it is their reality. Today's students have a ‘no limits, anything is possible’ mindset-the type needed for space exploration. .... While adults talk about technology as a thing, students simply experience it as part of their lives....., in your own way, you can inspire the next generation. Today's students have the mindset to transform the future of space exploration into something we cannot even imagine.....”*

Aviation Week and Space Technology, July 4 2019, by Lance Bush

Lance Bush is president and CEO of the Challenger Center, a non-profit formed by the families of the crew members who perished when the space shuttle Challenger broke apart.

*Tefera Walwa  
Addis Ababa, 7 October 2019*

**Address by East African Regional Office of Astronomy for Development Director, Mr. Alemiye Mamo**

Your Excellency Dr. Ing. Getahun Mekuria State Minister of Ministry of Innovation and Technology, His Excellency Mr. Tefera Walwa Former Deputy Prime Minister and Patron of Ethiopian Space Science Society, distinguished invited speakers and guests, symposium participants, ladies and gentlemen,

On behalf of the East African Regional Office of Astronomy for Development (EA-ROAD), as co-organizer of the symposium, I would like to pass my sincere gratitude and thanks for coming and to welcome you all to the symposium.

The International Astronomical Union (IAU) Office of Astronomy for Development (OAD) has 10 regional offices across the world. EA-ROAD is one of this offices opened in Ethiopia in 2014 as an East-Africa regional node. The office is hosted at ESSTI under the supervision of Ministry of Innovation and Technology.

The main objectives of EA-ROAD are to further use astronomy as a tool for development by mobilizing international collaborations, human and financial resources to realize the scientific, technological and cultural benefits to society, and by implementing the IAU strategic plan and missions of OAD.

For the past one decade the level of astronomy and space science development in East-African region has been gradually improved. The establishment of space agencies and institutes, formulation of space policies, introduction of astronomy education in the curriculum at both undergraduate and postgraduate levels, establishment of East-Africa Astrophysics Research Network (EAARN) and establishing of ROAD have contributed a lot to the development of astronomy and space science in the region. All this gradual development shows the existence of a promising and fertile landscape to flourish astronomy and space science in the region. In addition, there are green lights that encourage investment and commitment at all levels. However, there are also bottlenecks in coordinating and finding a synergy in the region to reach to the point where the development of astronomy should be.

Thus, it needs a collaborative approach that engages government and policy makers, science educators, advocates and professional societies to realize and advocate for the role of astronomy for development and to inspire and attract young people to the field. I, therefore, take this opportunity to pledge the respective authorities and scientific community to support and contribute for the development of astronomy in East-Africa as well as the whole Africa in terms of leadership, finance and scientific contributions and collaborations.

Finally, I wish you to have a fruitful deliberation and successful symposium.

Thank you!

*Alemiye Mamo*  
*Addis Ababa, 7 October 2019*

## Address by African Astronomical Society Vice-President, Dr. Lerothodi Leeuw

His Excellency the former Deputy Prime Minister of Ethiopia, his Excellency the Minister of Innovation and Technology of Ethiopia, honorable guests, invited speakers, presenters and participants at the International Astronomical Union (IAU) Symposium 356, good morning. Good morning.

I speak this morning on behalf of the very young and the very ancient. Who, you are welcome to ask is that. The young is the African Astronomical Society (Buckley *et al.* 2019, AfAS2019), that was just recently re-organized and re-launched; and, I come before you as its Vice-President. The ancient is the African continent, a continent that is the cradle of humanity and its development, and indeed where ancient humans distinguished themselves, mastering the science of making fire and using tools for their development and prosperity. I draw on this youthful African Astronomical Society and ancient history and wisdom of Africa to welcome you here this week, to the International Astronomical Union Symposium 356 titled ‘Nuclear Activity in Galaxies Across Cosmic Time’.

### *The Two Goals of the Symposium: Young and Ancient*

The symposium has two goals, and to be consistent with my opening, please allow me to cast them as young and ancient. The young goal, in the words of the organizers, is “strengthening the development of science in Ethiopia and Africa and opening new space for collaborations between Africa and other parts of the globe for the benefit of all.” Here the description young is especially relevant when having in mind the proposed new developments and collaborations, that it is hoped will come and grow from this symposium. The ancient goal is the deepening of “our understanding of nuclear activity in galaxies across cosmic time”, and for the cosmic objects that are the subject of this meeting, ancient indeed goes deeper and beyond the time of humans here in Africa and on Earth. These goals are deep, expansive and non-trivial, and rightfully ambitious and important; and, on behalf on the African Astronomical Society I proudly commend you in your efforts to be here and to tackle them. I do that with strong conviction that you will indeed make progress in advancing them.

### *The African Astronomical Society (AfAS) and the IAUS 356*

The African Astronomical Society (AfAS) will be running a two-day meeting on the 10th and 11th of October, parallel to this IAU Symposium. The goal of that meeting is to develop the science strategy of the society and deliberate its implementation. The society will welcome input from attendees of the symposium, in addition of the participants that will be gathering for that particular meeting. We hope that beyond the programs that have been formally organized for this IAU Symposium and the AfAS meeting, there will be opportunities for the respective participants to network and develop synergies to both tackle science and the development of Astronomy in Africa, that are the goals of this symposium. The AfAS Science Business Meeting is organized by the society together with the Ethiopian Space Science and Technology Institute (ESSTI) and partners; and, we are grateful to the amazing work that ESSTI has put in organizing these meetings.

The last time we were at this venue for an international astronomy meeting, it was two years ago for the Middle East and Africa Region IAU Meeting IV (MEARIM IV) of the IAU. In addition to the science discussed at that meeting, there was also a session dedicated to the revitalizing of the AfAS, that at the time was dormant. Rigorous debate

ensued in the meeting and following it, a resolution was taken to revitalize and give new life to the AfAS. I'm proud to say, that meeting led to the successful revival of the society; and, I stand here today as its vice-president as a result of the first steps from that meeting. In welcoming you here and opening this symposium officially, on behalf of our society, I hope that similar concrete and significant deliberations and actions will come from this meeting. On behalf of the African Astronomical Society, I welcome you all to Africa and to this meeting.

*Lerothodi Leeuw*  
*Addis Ababa, 7 October 2019*

**Acknowledgements:** Lerothodi Leeuw (LL) acknowledges funding from the South African National Foundation (NRF) and Department of Science and Innovation (DSI) to the African Astronomical Society (AfAS) and the Ethiopian Space Science and Technology Institute (ESSTI) and partners, to attend this meeting. Further, LL acknowledges the organizers of this symposium for the opportunity to present here.

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Plus the ESSTI and ESSS supportive staff members.

We would like to give our thanks to all participants for being a part of the IAUS 356.



**Figure 1.** Group photos from the opening session, National Museum visit, Entoto Observatory visit, and conference dinner. *Credits. A. Solomon and V. Oknyansky.*



Figure 2. IAUS 356 photos. Credits. A. Solomon

## Scientific program overview

IAUS 356 hosted in total 7 Sessions on different aspects of AGN physics and observations. Each Session consisted of one invited talk, number of contributed talks, and discussion. Each Session is related with one book Chapter and is briefly described here.

### **Session 1. Multiwavelength AGN surveys: past, present, and future**

This session focuses on photometric, spectroscopic and polarimetric observations of AGN over the entire electromagnetic spectrum including past and present multi-wavelength surveys. Expectations from future missions are also discussed.

### **Session 2. AGN types and unification**

Classification schemes in different wavelength bands with emphasis on new results from MIR, FIR and X-ray surveys and comparison between optical and radio classification are discussed. The session also includes new ideas about type 1, type 2 and type 1.9 AGN and discussion about torus observations and models.

### **Session 3. Variability**

This session includes broad band and spectroscopic studies of variable AGN. The discussion is focused on what we know about the duration and origin of variations in different parts of SED, and on new theoretical improvements. We will address the status of reverberation mapping and its use for determining black hole mass, and new observations and theoretical models regarding continuum variations and accretion disk properties. The session includes also a discussion about the role of large facilities (e.g., eROSITA, LSST, and SKA) in variability studies.

### **Session 4. Active black holes and their host galaxies**

New observational, theoretical, and numerical results about the connections between SMBHs and their host galaxies are presented. This includes models of SMBH growth, and stellar mass growth via star formation, at different epochs, and the various scaling relationships between the two. AGN morphology and types with regard to the growth scenarios, AGN in blue and red galaxies, and the role of environment, are also part of this session.

### **Session 5. Triggering, feedback and shutting off AGN activity**

The status of AGN theory and numerical simulations regarding triggering of AGN activity, and shutting-off black hole accretion and star formation via AGN feedback is discussed. This includes major and minor galaxy mergers, secular evolution and feeding from the halo. Special attention is given to differences in those mechanisms at different epochs.

### **Session 6. Jets and environment**

New observational, theoretical, and numerical results regarding relativistic and non-relativistic jets are presented. This includes modeling jet morphologies, propagation, and stability and the origin of AGN jets. We aim to understand better the evolution of astrophysical jets at different redshifts and the influence of jets on their environment.

**Session 7. The Highest redshift AGN and AGN evolution**

AGN evolution from the early seed black holes until the present time is discussed. Observations and modeling of the first AGN and plans to observe such objects at redshifts larger than 7.5 - the present record.

Invited and contributed talks were supported with significant number of poster presentations that in this book are presented under Chapter 8 (AGN posters). Finally, we had a significant number of poster presentations out of the field of AGN that are given in Chapter 9 (non-AGN posters).

## Summary of activities organised during the symposium

We are pleased to introduce here different outreach and education activities that have been carried out along the IAU 356 symposium for benefiting our society. These activities would not be possible without the IAU and ESSTI, all our sponsors, IAUS 356 participants who voluntarily did education and outreach activities, SOC and LOC members, ESSS members and volunteers, and active participants who directly benefited from all activities. Huge efforts have been made by all parties to organise all activities summarised below. We are very grateful for all received help and support, and we deeply believe in importance that such activities can have for science and education development and long-term benefits of our society.

### **Training for MSc/PhD students and young researchers (5–6 of October, 2019)**

This training was organised before the IAU 356 symposium, and was held in one of the halls of Addis Ababa University in collaboration with Physics Department. Its aim was to improve the skills of our MSc/PhD students and young researchers who are already attached to different universities and research centres. We had 45 participants in total, from different African countries, including Ethiopia (great majority of participants), Kenya, Nigeria, Rwanda, South Africa, Tanzania, and Uganda. In case of Ethiopian participants we supported colleagues coming from more than 10 different universities across the country. The training was planned for benefiting broader community, and not necessarily people involved in astronomy. Therefore, one part of the training (10 hours) was focused on '*Introduction to python*' programming given by Dr. Rubén García Benito (IAA-CSIC, Spain), while another one (6 hours) was related with tips on '*CV, motivation letter, proposals, and research papers writing*' given by Dr. Allison Man (University of Toronto, Canada) and Dr. Johan Knapen (IAC, Spain). Colleagues from astronomy, space physics, physics in general, and engineering attended the training. We got very positive feedback from both participants and trainers. Our appreciation goes to all facilitators, without whom this training would not be possible. Picture from training is shown in Fig. 1 (left plot).

### **Public talks and outreach activities at schools (8 of October, 2019)**

During one afternoon we organised in collaboration with the Ethiopian Space Science Society (ESSS) 2 public talks at Addis Ababa University, given by Prof. Christopher Impey (University of Arizona, USA) about '*Black holes and nuclear activity in galaxies*' and Prof. Petri Vaisanen (SAAO, South Africa) about '*South African astronomy in 2020s*'. In parallel, outreach activities were organised in 8 public schools where more than 40 symposium participants interacted with our primary and secondary school children and their teachers, and promoted during several hours astronomy and science. In total, with all activities we reached between 700 and 800 school children, students, and general public. We are grateful to all facilitators for their volunteer work done during all activities. Attached in Fig. 1 (right plot) and Fig. 2 are the poster announcing public talks and several pictures from the outreach events in schools.



**Figure 1.** Left: Group picture from MSc/PhD students and young researchers training. Credits: M. Pović. Right: Poster with announced public talks. Credits: ESSS.



**Figure 2.** Top left: Group picture from AAU during public talks. Credits: M. Pović. Top right and bottom: Outreach activities in schools. Credits: S. Ridgway, C. Harrison, and Z. Beyoro-Amado, respectively.



## The Astro Data Lab - An Open-Data, Open-Access Science Platform (10 of October, 2019)

During the afternoon of 10 of October, after all talks, practical session was organised for our MSc/PhD students and other IAUS participants on *'The NOAO Data Lab - An Open-Data, Open Access Science Platform'* given by Dr. Robert Nikutta (NOIRLab, USA). We are very thankful to Robert for his support and time.

### Lunch session on Astronomy in Africa (10 of October, 2019)

In parallel with the IAUS 356, there was a 2 days scientific-business meeting of recently re-established African Astronomical Society (AfAS), on 10–11 of Oct. We used this opportunity to organise a lunch session for presenting AfAS to our participants and for discussing about the status of astronomy in Africa. We had a very fruitful discussion with approximately 70 participants attending the session. Few pictures are attached in Fig. 3.



**Figure 3.** *Left:* NOAO data Lab training. *Credits:* M. Pović. *Middle:* Kevin Govender, Office of Astronomy for Development (IAU-OAD) Director chairing 'Astronomy in Africa' session. *Credits:* A. Solomon. *Right:* participants attending 'Astronomy in Africa session'. *Credits:* A. Solomon.

### Training in practical astronomy for teachers and teachers trainers (12–13 of October, 2019)

This training was carried out after the symposium at the ESSTI for 44 participants, who were public school teachers, teacher trainers, and ESSTI and ESSS staff members and

volunteers actively involved in astronomy/science outreach activities in Ethiopia. We also had 2 colleagues from Tanzania and Zambia as participants. On Saturday morning the training was given by 4 ESO colleagues who developed and brought different outreach materials that were used during the workshop. We are very much grateful to Dr. Chris Harrison, Ms. Miranda Jarvis, Dr. Gabriela Calistro Rivera, and Dr. Chiara Circosta for giving the training and for donating all their materials to the ESSTI. We are also grateful to Prof. Prajval Shastri who spent Saturday morning with us and shared with teachers some of her experiences.

Saturday afternoon and Sunday the training was done in collaboration with the Network for Astronomy School Education (NASE), where experiments have been constructed using recycled and easily accessible materials for showing different physical and astrophysical laws. Three workshops were given by Dr. Mirjana Pović (ESSTI), related with solar spectrum and light, stellar properties and stellar lives, and expansion of the universe. Introduction to the virtual planetarium software ‘Stellarium’ and stargazing was given by Mr. Alemiye Mamo (ESSTI). Few pictures from the training can be seen in Fig. 4.



**Figure 4.** Pictures from school teachers training. *Credits: A. Mamo and M. Pović.*