JUMPING JIVE

Project ID: 730884

Mid-term report on training visits to Africa

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Contents

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Executive Summary

This report (D9.2 '*Mid-term report on training visits to African countries*') focusses on the contributions of JUMPING JIVE work-package 9 on basic astronomy and astrophysics training for graduates within seven sub-Saharan African countries. This is a subset of the actions being undertaken under this work-package. In total 75 graduate students have been trained in the first two years of this programme. This includes a planned expansion from five to seven countries between years 1 and 2 reaching a steady number of 60 per year from 2018/19 onwards. Work-Package 9 has contributed substantial effort and resources to this training programme, which is run jointly between the UK-ZA funded 'Development in Africa with Radio Astronomy' project and the Horizon 2020 JUMPING JIVE. In particular, JUMPING JIVE training contributions have been essential in providing the additional capacity to increase the number of countries with access to this training from five to seven.

For completeness, the full scope of all of the activities of this work-package is outlined in this report. This included a description of the role of this work-package within the wider context of other related programmes and how these are directly collaborating to maximize the benefit and impact.

1. Introduction

Throughout the continent of Africa, a number of large research infrastructure projects are being developed. These include significant investment in radio astronomy and VLBI. The most notable of these are the development of an African VLBI Network (AVN), MeerKat and the SKA. For these large projects to be sustainable, as well as providing maximum benefit to the local economic regions, they require a skilled workforce of local scientists and technicians to both operate and use such facilities. However, many of these projects based in low to middle-income countries[1] where there is limited access to advanced training in science and technology education and training. This results in a lack of this skilled local workforce and highlights the need to provide graduate and postgraduate training opportunities which will both benefit these research facilities as well as act to stimulate economic growth in these countries. Education and sustained economic growth go hand in

[1] As defined by the Organisation for Economic co-operation and development: http://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/DAC_List_ODA_Recipients2014to2017_flows_En.pdf

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hand in lower to middle-income countries and form one of the key global challenges identified by the UN, EU and the UK's Overseas Development Agency.

Radio astronomy encompasses all of the science, technology, engineering and mathematics (STEM) skills that underpin the emergence of a strong developed economy. The modern astronomer needs knowledge in physics, mathematics, chemistry and computing. To develop, maintain and run the telescopes and instrumentation requires key skills in technology and engineering. Via a coordinated programme of training, we aim to inspire and train a new and diverse generation of young people to engage with these skills.

The training programme that this work-package contributes to aims to engender a research ethos as well as communication and diagnostic skills that are transferable to many aspects of a developing economy. The training team includes engineers, astronomers, and experienced entrepreneurs from the telecommunications and space industry who will impart their drive and enthusiasm to open the minds of the trainees to a world of possibilities in the academic, industrial, knowledge and commercial sectors.

This JUMPING JIVE work-package aims to help to address some these issues via multiple actions (see Section 3). At the core, the programme is a large and on-going basic training course in astronomy and astrophysics which introduces graduate students from seven (7) sub-Saharan African countries[2] to the subject area. This programme works in close collaboration with UK and ZA led initiatives (DARA –see below) to maximize the impact and reach of the training.

2. Associated and linked training programmes

JUMPING JIVE WP9 operates in close collaboration with a number of parallel research and development programmes, within Southern Africa, based around radio astronomy. This collaboration provides an essential framework within which the EU contributions can be cost-effectively channelled with maximal impact. Close coordination between JUMPING JIVE and these programmes is facilitated by the work-package leads, Beswick & Hoare, both of whom are leading contributors to, and executive management committee members of, the DARA project. Hoare is the overall PI of DARA, and Beswick leads the organization of Unit 4 (see Section 3) within the 'basic training' portion of DARA. These close connections between JUMPING JIVE and DARA ensure a full coordination of these two partner projects.

[2] Seven countries currently involved are: Zambia, Namibia, Kenya, Botswana, Ghana, Mozambique and Madagascar. Seed programmes and discussions with several further African countries (e.g. Egypt, Nigeria, Gabon etc) are underway with a view to future inclusion.

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2.1. Development via Radio Astronomy in Africa (DARA)

The DARA project (PI: Hoare) is a 4-year (2017-2021) jointly UK-ZA funded programme to enhance the human capital development in southern African countries which will be the host sites for future African VLBI Network telescopes. This is a two-tiered programme, providing (1) Basic training for graduate students in Astrophysics and Radio Astronomy via an annual training course open to graduates with a first degree in Physics or a related subject such as mathematics, engineering or Computing, and (2) provide advanced training opportunities for participants to qualify for a Masters or PhD in astrophysics. These two tiers of training, form a coherent human capital development project delivering a significantly inspired and up-skilled pool of young professionals to drive economic development. Initially, this training was made available to five countries (with the inclusion of Ghana via parallel Royal Society funding), through years 2-4, and with specific assistance from the JUMPING JIVE project, this programme has now expanded to include seven countries.

2.2. JUMPING JIVE WP9

The DARA project forms an essential framework for human capital development within southern African counties involved in radio astronomy and VLBI via the AVN. However, this programme has a number of limitations. In particular, it is only able to offer relatively small number of advanced training opportunities (~10 in total), limited technical and operational training, and has a limiting capacity in terms of the number of expert lecturers available to teach in Africa.

In order to complement and enhance this activity, work-package 9 of JUMPING JIVE has developed four specific action areas which expand and enhance the DARA programme by providing increased levels of technical and operational training, as well as intermediate training and up-skilling opportunities for students both before and after completion of higher-level degrees.

The four primary action areas of this WP provide new training and development opportunities which support the wider human capital development programme. These four areas are:

- Organize and support the participation of European radio astronomers as expert lecturers in the joint DARA/JUMPING JIVE basic training programme. The role of this work-package is particularly critical as it allows the broader expertise base within Europe to contribute thus enhancing the quality of the training provision, and expand the capacity of the existing scheme to include new countries. In particular, JUMPING

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JIVE participation is targeted at the technical and operational aspects of this programme.
    - **Target audience:** Physics & Science graduate students.
    - **This is a coordinated joint DARA-JUMPING JIVE activity**

- Facilitate and support European radio astronomers to travel to AVN and prospective AVN countries to deliver a range of seminars and lectures on astronomy and VLBI to major physics departments across the country. This programme reaches many hundreds to thousands of undergraduate and postgraduate students from multiple disciplines in each of these host countries, acting to both inspire and inform the future scientists, engineers and users of the prospects of VLBI and radio astronomy
    - **This is solely JUMPING JIVE activity.**

- Fund short-term training placements for African staff and students to develop their radio astronomy expertise in both scientific and technical/operational areas. These short training trips (<few months) are being hosted in a number of EU institutes.
    - **This is solely a JUMPING JIVE activity.**

- Support the development of an AVN technical & support network forum to remotely connect technical and operational staff within AVN countries. This activity aims to build an advanced community of scientists and install the framework for sustained operations.
    - **This is solely a JUMPING JIVE activity.**

Significant action has been undertaken on all of these four areas in the first half of the JUMPING JIVE programme – these are outlined in the project's first periodic report. This document (Deliverable 9.2: *'Mid-Term report on training visits to African Countries'*) is focused on the basic training action (first Bullet point above), which is run in close collaboration with the DARA project. The following sections describe in more details the structure and content of the 'Basic Training Programme', as well as outlining the specific JUMPING JIVE contributions.

3. Structure of the DARA-JUMPING JIVE Basic training programme

3.1. Countries & cohorts

The DARA/JUMPING JIVE basic training course is planned to run for four consecutive years between 2017 and 2021. During each year a cohort of ten trainees is selected from each partner country. In the initial year of this programme, five countries have been involved.

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From year 2 (2018), this has been expanded to a total of six cohorts, from seven countries, with Botswana and Namibia forming a combined cohort. Following the programme expansion, we aim to train a total of 60 students each year. At this mid-term point, 74 students have been trained as part of this programme.

Countries: *Ghana, Zambia, Mozambique, Madagascar and Botswana/Namibia* (combined cohort). All countries are classified as lower or lower-middle income countries on the OECD DACs list.

Students selection: Trainees/students selected to participate in the basic traineeship programme are competitively selected by the partner institutes within each of the host countries. These students come from a variety of age and socio-economic backgrounds but have all completed an undergraduate course in one of the STEM subjects. Throughout the selection process and the course, gender balance is monitored and appropriate measures are taken to maximize equality. The gender balance ratio of students who have been undertaking the course so far is 35:65 (female:male), this ratio varies by country and broadly follows to the underlying gender ratio of undergraduate science educated students in individual countries from which applicants are sought.

3.2. Course structure and syllabuses

Basic course structure and content: The basic training course comprises of five taught modules (plus a sixth English language course in Mozambique and Madagascar), along with an annual network meeting designed to bring all of the students together and provide training in 'soft skills' such as CV writing and presentations skills. The syllabus and course structure are detailed in the rest of this section.

- **UNIT 1: Astrophysics – Delivered by one or two lecturers within the host partner country.**

This is a series of lectures on introductory astrophysics, laying out the foundation to the whole training programme for the trainees. No previous experience of astrophysics is assumed, although knowledge of physics to first degree level or equivalent is required. This unit provides the relevant background that underpins the whole programme and highlights areas that inspire students to take up astronomy in the first place. Topics covered include the physics of stars, the birth of stars and planets including our own origins, stellar death and the lifecycle of interstellar material, galaxies including active galaxies in particular and the Universe as a whole.

The multi-wavelength nature of astronomy, which is an essential aspect of modern research, is introduced to the students during these lectures. There is a particular emphasis on the radio waveband and the theory of the various emission processes that give rise to radio

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emission and the objects responsible. This includes free-free emission from HII regions, synchrotron emission from magnetised jets, pulsars, atomic and molecular lines, masers, the Zeeman effect and polarization.

Unit duration: 2 weeks

Outcome: unit trainees have a solid foundation in astrophysics and are able to elucidate the role of radio astronomy in understanding key aspects

- **UNIT 2: Technical Training – Delivered by a team of lecturers at HartRAO (South Africa) or GSSTI (Ghana.) Two country cohorts combined per training camp.**

The technical training takes place either at Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa or at the first converted AVN dish at GSSTI in Ghana. Teams of 20 trainees from two of the participating countries are being flown in and trained together. In terms of the telescope technology and instrumentation, the trainees are taught about astronomical drive and tracking systems, encoders, limits, cable wraps, focus, stowing during high winds and lightning and use of backup generators for the telescopes. For the receiver system, the different components such as the feedhorn, low noise amplifier, filter, downconverter, local oscillator, IF amplifier and digital spectrometer are highlighted and discussed. For VLBI, the details of the local recording system are introduced and the concept of e-VLBI described. The importance of high accuracy timing and frequency standards is discussed and the role of hydrogen masers and GPS. The local radio frequency interference environment will be monitored and mitigations strategies discussed.

Throughout this unit, there are lectures on elements of radio telescopes and receiver systems, but the main emphasis will be more on hands-on training. The students learn in small groups by locating, testing and using the various components of the main antenna and receiver systems. A training receiver is made available that students can take apart and put back together. Health and safety training is strongly emphasised at every juncture as well as troubleshooting and maintenance of the equipment.

Unit duration: 1.5-2 weeks

Outcome: By the end of this unit trainees will be able to identify, test and maintain the main elements of the local telescope, receiver system and recording system in a safe manner.

- **UNIT 3: Radio Astronomy Observations – Delivered by a team of lecturers at HartRAO (South Africa) or GSSTI (Ghana). Two country cohorts combined per training camp.**

Training in observational radio astronomy is taught through a combination of lectures and hands-on experience. The unit 3 training follows-on immediately after the unit 2 training at the same location, either HartRAO or GSSTI. Lectures cover total power measurements before introducing the theory of interferometry including the two-element interferometer,

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synthesis arrays, VLBI and calibration. Astrometric VLBI measurements are covered to introduce the concept of parallax, proper motion determination, the International Celestial Reference Frame and geodetic VLBI.

At the local telescope, the basic techniques of observing are taught during hands-on sessions. Each student is taught how to select appropriate targets, slew, track and record data. Single dish techniques such as position and frequency switching are explored. Instruction is provided in flux calibration, polarization calibration, system temperature measurements and monitoring, and pointing corrections. Pulsar timing observations are also be covered if appropriate hardware is at the local telescope. At HartRAO a simple two-element interferometer is available to provide hands-on experience of the basic elements of interferometry. The DiFX software is available to demonstrate the correlation technique. If possible the execution of a coordinated VLBI run will be taught by an example between HartRAO and the Ghanaian dish to obtain fringes on strong calibrators. Monitoring of key diagnostic information is covered as well as coordination procedures with other nodes during interruptions to the observing sequence.

Trainees also learn and carry out exercises in the use of large survey datasets as an introduction to data mining in astronomy. They become familiar with some of the main multiwavelength databases available online and the Virtual Observatory infrastructure. They use the TOPCAT software package to cross-match catalogues and select sub-samples. Students will be set exercises to use data mining to search for particular types of object with an emphasis on those of relevance for radio observation. Students learn about window functions, selection effects and biases in sample selection as well as correlation techniques and statistical tests of the robustness in their results. Online bibliographic resources and multi-wavelength image servers are used to research a particular target and put together a written report and an oral presentation in order to develop the trainees' communication skills.

Unit duration: 1.5-2 weeks

Outcome: By the end of this unit trainees are familiar with the use of the local antenna for astronomical observations in both single dish and VLBI mode, to select samples from large multi-wavelength online databases and to research individual objects and present their results.

- **UNIT 4 – Radio Astronomy Data Reduction and Analysis - – Delivered by two lecturers within the host partner country.**

During this unit, trainees learn how to reduce and analyse VLBI data. The training takes place at computer clusters set up at the lead institution in each of the targeted AVN partner countries and supplied by either SARAO or the DARA project. The modern python-based CASA software (casa.nrao.edu) is used, which is well supported and freely available. Example datasets are provided from the European VLBI Network (EVN), including the HartRAO and

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Ghana dish when available. Students are guided through the reduction of raw data to produce a final reduced dataset (Figure 1). This includes flagging, fringe finding, flux calibration, phase calibration, polarization calibration, self-calibration and imaging. Each major step is preceded by a lecture explaining the theory and technique behind each. A combination of on-hand expert help and online tutorials guide the trainee through each step before they proceed to the next. Data analysis training follows a similar format. Students learn to measure flux densities and sizes of sources and examine missing flux considerations. Positional accuracy for astrometric measurements is covered that enables parallax and

Figure 1: JUMPING JIVE Lecture, Sarrvesh Sridhar (ASTRON) teaching Interferometric data reduction techniques in Mozambique, June 2018.

proper motion determination. Assessment of image fidelity and the identification of artefacts is an important skill that is examined in different example VLBI datasets. Students are given guidance on the writing of applications for observing time on telescopes such as the EVN and AVN.

Unit duration: 2 weeks

Outcome: By the end of this unit trainees will have gained experience of the theory and practice of the reduction and analysis of VLBI and single dish data. They will also be aware of good practice in applications for telescope time.

- **UNIT 5: Computer Skills - Delivered by the High-performance computer Group, South Africa.**

Running in parallel between Unit 1 and Unit 2/3 all students receive a 1-week long intensive course in computing. This course provides the necessary details of computer training in Linux and computer operating systems, as well as python programming. This is an important,

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transferable skills unit, that provides a foundation for the work undertaken in Unit 4 as well as future career options beyond astronomy for the students.

Unit duration: 1 week

Outcomes: By the end of this training the students have gained valuable computing skills in the use of Linux and Python for scientific research. Such skills are highly transferable into industry and commerce.

- **UNIT 6: English Language course - Delivered by the British Council/CNELA – *Mozambique and Madagascar cohorts only.***

The Mozambique and Madagascar cohorts have received their University education in Portuguese and French respectively, with English as usually their second language. To ensure the students will be able to follow the training programme that is delivered in English we will put the students through an intensive English course lasting 6-8 weeks prior to the start of the training programme. The DARA programme covers the cost of these courses which are delivered by well-established providers. In Mozambique, we use the British Council, whilst in Madagascar w use Le Centre National d'Enseignement de la Langue Anglaise (CNELA).

Unit duration: 6-8 weeks

Outcome: By the end of this training the students from Madagascar and Mozambique have improved English language skills that will enable them to establish and deepen scientific collaborations which are typically undertaken in English.

- **UNIT 7: Annual Network meeting – All Cohorts, and all partners**

Figure 2: 2018 Cohort at the DARA/JUMPING JIVE Annual Network Meeting, 2018, May 2-4.

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An annual network training meeting will be held to help build a training and research community across the countries participating in this programme. Figure 2 shows the group picture of the 2018 DARA/JUMPING JIVE meeting. The meetings take place at the Edukeni conference venue a short distance from HartRAO and follow on from one of the unit 2/3 training sessions to reduce travel costs. All the basic trainees from that year are expected to attend together with the Masters and PhD students and academic staff from the UK and ZA. The annual meetings include research talks from the Masters and PhD students to help them improve their communication skills and showcase their work. Academic staff gives overviews of the radio astronomy research taking place at each partner institution and advertise advanced training opportunities. Talks on the status of the dishes and developments in each of the AVN partner countries keeps participants informed on AVN progress. Related developments with the MeerKAT and SKA-mid arrays as well as the European VLBI Network (EVN) are also presented.

These meetings are an ideal networking opportunity for the basic trainees to meet the wider members of the training team and other trainees. The trainees are given advice on the next steps including Masters or PhD places or moving on to jobs in related high-tech industries. The attending academics and industrialists provide this advice and help to identify appropriate opportunities and funding schemes for each of the trainees. This advice utilizes the pooled experience of the academics, each of whom has extensive contacts and collaborations themselves.

At this time, guidance is also be given to the students on the writing of applications for PhD places including selecting suitable institutions, making contact, CV writing, research proposals, covering letters and funding schemes.

At each of the Annual Network Meetings, overview presentations regarding the role of the JUMPING JIVE project are given.

4. Summary of JUMPING JIVE Basic Training Activities (2017-18)

During the first two years of this programme, this JUMPING JIVE work-package has supported twelve trips of lecturers and trainers as part of the combined DARA/JUMPING JIVE basic programme. This training has utilized trainers from seven different EU institutes. A complete list of the training trips undertaken is listed in table 1.

Unit (Cohort)	Location	Dates	Trainer/Lecture
2 & 3 (Ghana/Kenya)	GSSTI, Ghana	18-27 April 2017	Jay Blanchard (JIVE)
2 & 3 (Ghana/Kenya)	GSSTI, Ghana	18-27 April 2017	Alasdair Gunn (Manchester)

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2 & 3 (Madagascar/Mozambique)	HartRAO, South Africa	16-20April 2018	Patrick Charlot (Bordeaux)
2 & 3 (Ghana/Kenya)	GSSTI, Ghana	16-25 April 2018	Ross Burns (JIVE)
2 & 3 (Ghana/Kenya)	GSSTI, Ghana	16-25 April 2018	Jay Blanchard (JIVE)
2 & 3 (Ghana/Kenya)	GSSTI, Ghana	16-25 April 2018	Eskil Varenius (Manchester)
5 network meeting (All cohorts)	Ekudeni, South Africa	29 April- 6 May 2018	Rob Beswick (Manchester)
4 (Kenya)	TUK, Kenya	28 May – 8 June 2018	Joe Callingham (ASTRON)
4 (Zambia)	UNZA, Zambia	4– 15 June 2018	Hannah Stacey (Groningen)
4 (Botswana/Namibia)	BIUST, Botswana	28 May – 8 June 2018	Nick Wrigley (Manchester)
4 (Mozambique)	UEM, Mozambique	18 - 29 June 2018	Sarrvesh Sridhar (ASTRON)
4 (Mozambique)	UEM, Mozambique	18– 29 June 2018	Dalmiro Jorge Filipe Maia (Porto)

Table 1: Summary list of JUMPING JIVE WP9 supported basic lecturing/training trips up to November 2018.

5. Specific actions and reports from JUMPING JIVE training

Beswick, supported via JUMPING JIVE and DARA, leads the organization of UNIT 4 curricular and coordinates the training schedule for all countries. He also leads the organization of the Unit 2/3 training in Ghana which is delivered to the Ghanaian and Kenyan cohorts. The course syllabus for unit 2 & 3 training is coordinated with academic leads in Oxford/HartRAO/Manchester.

JUMPING JIVE lecturers have been responsible for the design, writing and delivery of course elements in Ghana, Mozambique, Botswana/Namibia, Kenya, and Zambia through 2017/18. This contribution has been essential in providing the capacity to expand this programme to additional counties and in particular Mozambique and Madagascar. All lecture material is collated centrally for the use of future lecturers.

5.1. Unit 2/3 training: Ghana - 2017, 2018 & HartRAO -2018

In April 2017, two JUMPING JIVE sponsored lecturers (Blanchard and Gunn) delivered all VLBI and multiple observing training elements (unit 2/3) to the 2017 cohort Ghanaian and Kenyan

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cohorts at GSSTI in Ghana. In April 2018, Blanchard, Burns and Varenius delivered the Unit 2/3 training to the 2018 cohort of Ghanaian and Kenyan students (see Figure 3)

Figure 3: Blanchard/Burns/Varenius along with the 2018 Ghana/Kenya cohorts at the unit 2/3 training at GSSTI, Ghana (April 2018).

As part of the parallel Unit 2/3 training in HartRAO, South Africa for the 2018 Mozambican/Malagasy cohorts, JUMPING JIVE lecture Charlot provided expert lectures on VLBI, geodesy and astrometry. This was a particularly valuable contribution as Charlot was able to provide guidance to the Malagasy cohort in their native language and hence increasing the accessibility of the course to this cohort.

In total, the JUMPING JIVE contributions to this part of the basic training have reached over 60 individual students.

5.2. Unit 4 training: Kenya, Zambia, Botswana/Namibia & Mozambique – 2018

In total, ten weeks of face to face training have been undertaken by JUMPING JIVE lecturers and trainers as part of the 2018 UNIT 4 training. This has been held in four different countries. All training has been delivered to a very high standard with very positive feedback from all students who have undertaken this training. The contributions of the JUMPING JIVE lecturers have been critical to all courses, providing expertise and diversity within the project (see Figure and Figure).

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Figure 4: Lecturer Dalmiro Jorge Filipe Maia presenting a certificate of attendance to one of the 2018 Mozambique cohort.

Figure 5: Hannah Stacey (Groningen) - providing hands-on tuition help on VLBI data reduction in Zambia

Of particular note, the 2018 training in Kenya was led by Joe Callingham (ASTRON). As part of the overall action of the DARA/JUMPING JIVE programmes to build sustainability within the partner African countries Dr Callingham undertook this training alongside Willice Obonyo, a current DARA advanced studying for a PhD at the University of Leeds and originates from Kenya. This was a highly successful programme providing additional inspiration for the students involved.

6. Impact of JUMPING JIVE contributions to basic training programme at mid-term

In total, over 19 weeks of lecturing and training have been delivered as part of the JUMPING JIVE contributions to this programme. These training elements have over 70 students from seven different countries as part of the wider DARA/JUMPING JIVE programme. A number of these students have subsequently progressed to gain funded positions on postgraduate courses (MScR, or PhD) in multiple countries including the UK and ZA. Figure 6 shows Isaac Mutie, a DARA/JUMPING JIVE Basic training graduate, who with JUMPING JIVE support has now successfully secured funding to undertake a Master in Astronomy and Astrophysics at the

Figure 4: Isaac Mutie - DARA/JUMPING JIVE Basic training graduate

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University of Manchester. His story is documented in Nature Astronomy blogs[3]. Exit tracking of the student destinations is in progress and will be reported later in the project.

In conclusion, JUMPING JIVE impact to the Basic Training Programme in the first two years can be summarised as follow:

- Over 19 weeks of in-person teaching carried out by EU experts and lecturers within multiple African countries.
- Over 70 graduate students have been taught by JUMPING JIVE supported lecturers.
- JUMPING JIVE sponsored effort has supported the expansion of the DARA programme to include two new countries (Mozambique and Madagascar), a 30% expansion.
- Increased expertise in technical and operational activities from EU observatories. Experts have enhanced the quality and delivery of this portion of the course. This also helps to fill an expertise shortage within the partner DARA programme.
- New links and potential future collaborations between EU and African institutes have been established.

[3] http://blogs.nature.com/naturejobs/2018/02/28/african-astronomy-and-how-one-student-broke-into-the-field/

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